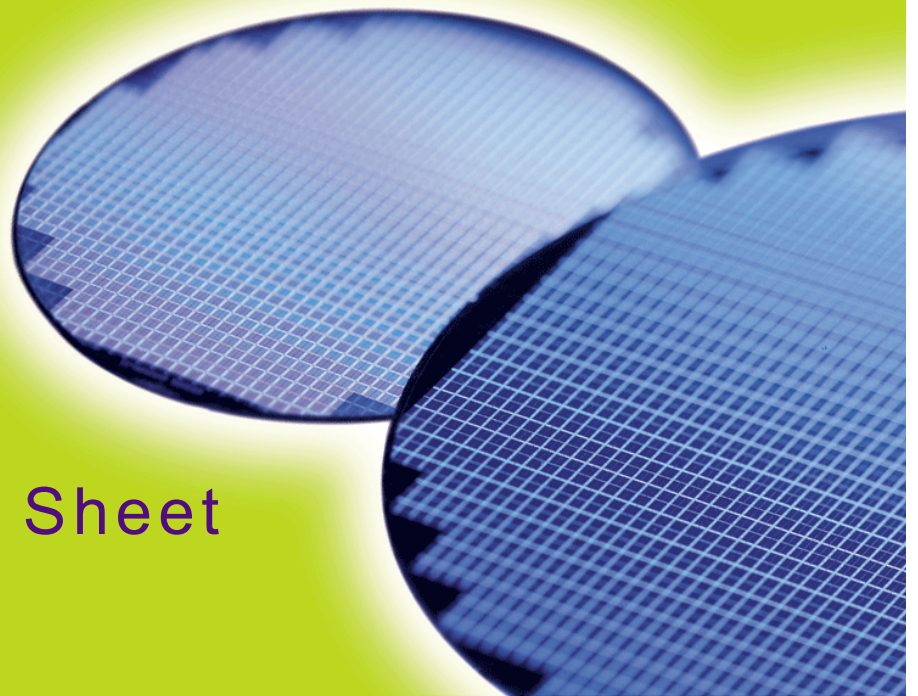


May 2007

**HYB18T512400B[C/F]**  
**HYB18T512800B[C/F]**  
**HYB18T512160B[C/F]**

*512-Mbit Double-Data-Rate-Two SDRAM  
DDR2 SDRAM  
RoHS Compliant Products*



**Internet Data Sheet**

*Rev. 1.1*

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512-Mbit Double-Data-Rate-Two SDRAM

|   |   |
|---|---|
| <b>HYB18T512400B[C/F], HYB18T512160B[C/F], HYB18T512800B[C/F]</b> |   |
| <b>Revision History: 2007-05, Rev. 1.1</b>                        |   |
| <b>Page</b>   | <b>Subjects (major changes since last revision)</b> |
| All   | Adapted internet edition                            |
| All   | Added more product types                            |
| <b>Previous Revision: 2007-01, Rev. 1.05</b>                      |   |
| All   | Qimonda template update                             |
| <b>Previous Revision: 2006-02, Rev. 1.04</b>                      |   |

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# 1 Overview

This chapter gives an overview of the 512-Mbit Double-Data-Rate-Two SDRAM product family and describes its main characteristics.

## 1.1 Features

The 512-Mbit Double-Data-Rate-Two SDRAM offers the following key features:

- 1.8 V  $\pm$  0.1 V Power Supply  
1.8 V  $\pm$  0.1 V (SSTL\_18) compatible I/O
- DRAM organizations with 4 and 8 data in/outputs
- Double-Data-Rate-Two architecture: two data transfers per clock cycle four internal banks for concurrent operation
- Programmable CAS Latency: 3, 4, 5 and 6
- Programmable Burst Length: 4 and 8
- Differential clock inputs (CK and  $\overline{\text{CK}}$ )
- Bi-directional, differential data strobes (DQS and  $\overline{\text{DQS}}$ ) are transmitted / received with data. Edge aligned with read data and center-aligned with write data.
- DLL aligns DQ and DQS transitions with clock
- $\overline{\text{DQS}}$  can be disabled for single-ended data strobe operation
- Commands entered on each positive clock edge, data and data mask are referenced to both edges of DQS
- Data masks (DM) for write data
- Posted CAS by programmable additive latency for better command and data bus efficiency
- Off-Chip-Driver impedance adjustment (OCD) and On-Die-Termination (ODT) for better signal quality
- Auto-Precharge operation for read and write bursts
- Auto-Refresh, Self-Refresh and power saving Power-Down modes
- Average Refresh Period 7.8  $\mu\text{s}$  at a  $T_{\text{CASE}}$  lower than 85 °C, 3.9  $\mu\text{s}$  between 85 °C and 95 °C
- Programmable self refresh rate via EMRS2 setting
- Programmable partial array refresh via EMRS2 settings
- DCC enabling via EMRS2 setting
- Full and reduced Strength Data-Output Drivers
- 1kB page size for  $\times 4$  &  $\times 8$ , 2kB page size for  $\times 16$
- Package: P(G)-TFBGA-60 and P(G)-TFBGA-84
- RoHS Compliant Products<sup>1)</sup>
- All Speed grades faster than DDR2-400 comply with DDR2-400 timing specifications when run at a clock rate of 200 MHz.

**TABLE 1**  
Performance Table for -25F and -2.5

| Product Type Speed Code |                  |                  | -25F            | -2.5            | Unit |
|-------------------------|------------------|------------------|-----------------|-----------------|------|
| Speed Grade             |                  |                  | DDR2-800D 5-5-5 | DDR2-800E 6-6-6 | —    |
| Max. Clock Frequency    | @CL6             | $f_{\text{CK6}}$ | 400             | 400             | MHz  |
|                         | @CL5             | $f_{\text{CK5}}$ | 400             | 333             | MHz  |
|                         | @CL4             | $f_{\text{CK4}}$ | 266             | 266             | MHz  |
|                         | @CL3             | $f_{\text{CK3}}$ | 200             | 200             | MHz  |
| Min. RAS-CAS-Delay      | $t_{\text{RCD}}$ | 12.5             | 15              | ns              |      |
| Min. Row Precharge Time | $t_{\text{RP}}$  | 12.5             | 15              | ns              |      |
| Min. Row Active Time    | $t_{\text{RAS}}$ | 45               | 45              | ns              |      |
| Min. Row Cycle Time     | $t_{\text{RC}}$  | 57.5             | 60              | ns              |      |

1) RoHS Compliant Product: Restriction of the use of certain hazardous substances (RoHS) in electrical and electronic equipment as defined in the directive 2002/95/EC issued by the European Parliament and of the Council of 27 January 2003. These substances include mercury, lead, cadmium, hexavalent chromium, polybrominated biphenyls and polybrominated biphenyl ethers.



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**TABLE 2**  
Performance table for -3(S)

| Product Type Speed Code |      |           | -3              | -3S             | Unit |
|-------------------------|------|-----------|-----------------|-----------------|------|
| Speed Grade             |      |           | DDR2-667C 4-4-4 | DDR2-667D 5-5-5 | —    |
| Max. Clock Frequency    | @CL5 | $f_{CK5}$ | 333             | 333             | MHz  |
|                         | @CL4 | $f_{CK4}$ | 333             | 266             | MHz  |
|                         | @CL3 | $f_{CK3}$ | 200             | 200             | MHz  |
| Min. RAS-CAS-Delay      |      | $t_{RCD}$ | 12              | 15              | ns   |
| Min. Row Precharge Time |      | $t_{RP}$  | 12              | 15              | ns   |
| Min. Row Active Time    |      | $t_{RAS}$ | 45              | 45              | ns   |
| Min. Row Cycle Time     |      | $t_{RC}$  | 57              | 60              | ns   |

**TABLE 3**  
Performance Table for -3.7(F)

| Product Type Speed Code |      |           | -37F            | -3.7            | Unit |
|-------------------------|------|-----------|-----------------|-----------------|------|
| Speed Grade             |      |           | DDR2-533B 3-3-3 | DDR2-533C 4-4-4 | —    |
| Max. Clock Frequency    | @CL5 | $f_{CK5}$ | 266             | 266             | MHz  |
|                         | @CL4 | $f_{CK4}$ | 266             | 266             | MHz  |
|                         | @CL3 | $f_{CK3}$ | 266             | 200             | MHz  |
| Min. RAS-CAS-Delay      |      | $t_{RCD}$ | 11.25           | 15              | ns   |
| Min. Row Precharge Time |      | $t_{RP}$  | 11.25           | 15              | ns   |
| Min. Row Active Time    |      | $t_{RAS}$ | 45              | 45              | ns   |
| Min. Row Cycle Time     |      | $t_{RC}$  | 56.25           | 60              | ns   |

**TABLE 4**  
Performance Table for -5

| Product Type Speed Code |      |           | -5              | Units |
|-------------------------|------|-----------|-----------------|-------|
| Speed Grade             |      |           | DDR2-400B 3-3-3 | —     |
| Max. Clock Frequency    | @CL5 | $f_{CK5}$ | 200             | MHz   |
|                         | @CL4 | $f_{CK4}$ | 200             | MHz   |
|                         | @CL3 | $f_{CK3}$ | 200             | MHz   |
| Min. RAS-CAS-Delay      |      | $t_{RCD}$ | 15              | ns    |
| Min. Row Precharge Time |      | $t_{RP}$  | 15              | ns    |
| Min. Row Active Time    |      | $t_{RAS}$ | 40              | ns    |
| Min. Row Cycle Time     |      | $t_{RC}$  | 55              | ns    |

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## 1.2 Description

The 512-Mb DDR2 DRAM is a high-speed Double-Data-Rate-Two CMOS DRAM device containing 536,870,912 bits and is internally configured as an quad-bank DRAM. The 512-Mb device is organized as either 32 Mbit  $\times$  4 I/O  $\times$  4 banks, 16 Mbit  $\times$  8 I/O  $\times$  4 banks or 8 Mbit  $\times$  16 I/O  $\times$  4 banks chip. These devices achieve high speed transfer rates starting at 400 Mb/sec/pin for general applications. See **Table 1** for performance figures.

The device is designed to comply with all DDR2 DRAM key features:

1. Posted  $\overline{\text{CAS}}$  with additive latency
2. Write latency = read latency - 1
3. Normal and weak strength data-output driver
4. Off-Chip Driver (OCD) impedance adjustment
5. On-Die Termination (ODT) function

All of the control and address inputs are synchronized with a pair of externally supplied differential clocks. Inputs are

latched at the cross point of differential clocks (CK rising and  $\overline{\text{CK}}$  falling). All I/Os are synchronized with a single ended DQS or differential DQS-DQS pair in a source synchronous fashion.

A 16-bit address bus for  $\times$ 4 and  $\times$ 8 organized components and a 15-bit address bus for  $\times$ 16 components is used to convey row, column and bank address information in a  $\overline{\text{RAS}}$ - $\overline{\text{CAS}}$  multiplexing style.

The DDR2 device operates with a 1.8 V  $\pm$  0.1 V power supply. An Auto-Refresh and Self-Refresh mode is provided along with various power-saving power-down modes.


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

The DDR2 SDRAM is available in FBGA package.



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**TABLE 5**  
Ordering Information for Lead-Free Products (RoHS Compliant)

| Product Type       | Org. | Speed     | CAS-RCD-RP Latencies <sup>1)2)3)</sup> | Clock (MHz) | Package     | Note   |
|--------------------|------|-----------|--|-------------|-------------|--|
| HYB18T512400BF-2.5 | ×4   | DDR2-800E | 6-6-6                                  | 400         | PG-TFBGA-60 | <sup>4)</sup><br> |
| HYB18T512800BF-2.5 | ×8   | DDR2-800E | 6-6-6                                  | 400         | PG-TFBGA-60 |  |
| HYB18T512160BF-2.5 | ×16  | DDR2-800E | 6-6-6                                  | 400         | PG-TFBGA-84 |  |
| HYB18T512400BF-25F | ×4   | DDR2-800D | 5-5-5                                  | 400         | PG-TFBGA-60 |  |
| HYB18T512800BF-25F | ×8   | DDR2-800D | 5-5-5                                  | 400         | PG-TFBGA-60 |  |
| HYB18T512160BF-25F | ×16  | DDR2-800D | 5-5-5                                  | 400         | PG-TFBGA-84 |  |
| HYB18T512400BF-3S  | ×4   | DDR2-667D | 5-5-5                                  | 333         | PG-TFBGA-60 |  |
| HYB18T512800BF-3S  | ×8   | DDR2-667D | 5-5-5                                  | 333         | PG-TFBGA-60 |  |
| HYB18T512160BF-3S  | ×16  | DDR2-667D | 5-5-5                                  | 333         | PG-TFBGA-84 |  |
| HYB18T512400BF-3   | ×4   | DDR2-667C | 4-4-4                                  | 333         | PG-TFBGA-60 |  |
| HYB18T512800BF-3   | ×8   | DDR2-667C | 4-4-4                                  | 333         | PG-TFBGA-60 |  |
| HYB18T512160BF-3   | ×16  | DDR2-667C | 4-4-4                                  | 333         | PG-TFBGA-84 |  |
| HYB18T512400BF-3.7 | ×4   | DDR2-533C | 4-4-4                                  | 266         | PG-TFBGA-60 |  |
| HYB18T512800BF-3.7 | ×8   | DDR2-533C | 4-4-4                                  | 266         | PG-TFBGA-60 |  |
| HYB18T512160BF-3.7 | ×16  | DDR2-533C | 4-4-4                                  | 266         | PG-TFBGA-84 |  |
| HYB18T512400BF-5   | ×4   | DDR2-400B | 3-3-3                                  | 200         | PG-TFBGA-60 |  |
| HYB18T512800BF-5   | ×8   | DDR2-400B | 3-3-3                                  | 200         | PG-TFBGA-60 |  |
| HYB18T512160BF-5   | ×16  | DDR2-400B | 3-3-3                                  | 200         | PG-TFBGA-84 |  |

1) CAS: Column Address Strobe

2) RCD: Row Column Delay

3) RP: Row Precharge

4) RoHS Compliant Product: Restriction of the use of certain hazardous substances (RoHS) in electrical and electronic equipment as defined in the directive 2002/95/EC issued by the European Parliament and of the Council of 27 January 2003. These substances include mercury, lead, cadmium, hexavalent chromium, polybrominated biphenyls and polybrominated biphenyl ethers.

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512-Mbit Double-Data-Rate-Two SDRAM**TABLE 6****Ordering Information for Lead-Containing Products**

| Product Type       | Org. | Speed     | CAS-RCD-RP Latencies <sup>1)2)3)</sup> | Clock (MHz) | Package    |
|--------------------|------|-----------|--|-------------|------------|
| HYB18T512800BC-3S  | ×8   | DDR2-667D | 5-5-5                                  | 333         | P-TFBGA-60 |
| HYB18T512160BC-3S  | ×16  | DDR2-667D | 5-5-5                                  | 333         | P-TFBGA-84 |
| HYB18T512800BC-3.7 | ×8   | DDR2-533C | 4-4-4                                  | 266         | P-TFBGA-60 |
| HYB18T512160BC-3.7 | ×16  | DDR2-533C | 4-4-4                                  | 266         | P-TFBGA-84 |

1) CAS: Column Address Strobe

2) RCD: Row Column Delay

3) RP: Row Precharge

*Note: For product nomenclature see **Chapter 9** of this data sheet*



## 2 Chip Configuration

This chapter contains the chip configuration and addressing.

### 2.1 Chip Configuration

The chip configuration of a DDR2 SDRAM is listed by function in **Table 7**. The abbreviations used in the Ball# and Buffer Type columns are explained in **Table 8** and **Table 9** respectively. The ball numbering for the FBGA package is depicted in **Figure 1** for  $\times 4$ , **Figure 2** for  $\times 8$  and **Figure 3** for  $\times 16$ .

**TABLE 7**  
Chip Configuration of DDR2 SDRAM

| Ball#   | Name                    | Ball Type | Buffer Type | Function  |
|---|-------------------------|-----------|-------------|---|
| <b>Clock Signals <math>\times 4/\times 8</math> organization</b>    |                         |           |             |   |
| E8  | CK                      | I         | SSTL        | <b>Clock Signal CK, Complementary Clock Signal CK</b>   |
| F8  | $\overline{\text{CK}}$  | I         | SSTL        |   |
| F2  | CKE                     | I         | SSTL        | <b>Clock Enable</b>   |
| <b>Clock Signals <math>\times 16</math> organization</b>            |                         |           |             |   |
| J8  | CK                      | I         | SSTL        | <b>Clock Signal CK, Complementary Clock Signal CK</b><br><i>Note: See functional description in <math>x4/x8</math> organization</i> |
| K8  | $\overline{\text{CK}}$  | I         | SSTL        |   |
| K2  | CKE                     | I         | SSTL        | <b>Clock Enable</b><br><i>Note: See functional description in <math>x4/x8</math> organization</i>                                   |
| <b>Control Signals <math>\times 4/\times 8</math> organizations</b> |                         |           |             |   |
| F7  | $\overline{\text{RAS}}$ | I         | SSTL        | <b>Row Address Strobe (RAS), Column Address Strobe (CAS), Write Enable (WE)</b>   |
| G7  | $\overline{\text{CAS}}$ | I         | SSTL        |   |
| F3  | $\overline{\text{WE}}$  | I         | SSTL        |   |
| G8  | $\overline{\text{CS}}$  | I         | SSTL        | <b>Chip Select</b>  |
| <b>Control Signals <math>\times 16</math> organization</b>          |                         |           |             |   |
| K7  | $\overline{\text{RAS}}$ | I         | SSTL        | <b>Row Address Strobe (RAS), Column Address Strobe (CAS), Write Enable (WE)</b>   |
| L7  | $\overline{\text{CAS}}$ | I         | SSTL        |   |
| K3  | $\overline{\text{WE}}$  | I         | SSTL        |   |
| L8  | $\overline{\text{CS}}$  | I         | SSTL        | <b>Chip Select</b>  |
| <b>Address Signals <math>\times 4/\times 8</math> organizations</b> |                         |           |             |   |
| G2  | BA0                     | I         | SSTL        | <b>Bank Address Bus 1:0</b>   |
| G3  | BA1                     | I         | SSTL        |   |





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| Ball#                                   | Name | Ball Type | Buffer Type | Function   |
|---|------|-----------|-------------|--|
| H8                                      | A0   | I         | SSTL        | <b>Address Signal 12:0, Address Signal 10/Autoprecharge</b>                        |
| H3                                      | A1   | I         | SSTL        |  |
| H7                                      | A2   | I         | SSTL        |  |
| J2                                      | A3   | I         | SSTL        |  |
| J8                                      | A4   | I         | SSTL        |  |
| J3                                      | A5   | I         | SSTL        |  |
| J7                                      | A6   | I         | SSTL        |  |
| K2                                      | A7   | I         | SSTL        |  |
| K8                                      | A8   | I         | SSTL        |  |
| K3                                      | A9   | I         | SSTL        |  |
| H2                                      | A10  | I         | SSTL        |  |
|   | AP   | I         | SSTL        |  |
| K7                                      | A11  | I         | SSTL        |  |
| L2                                      | A12  | I         | SSTL        |  |
| L8                                      | A13  | I         | SSTL        | <b>Address Signal 13</b>   |
|   | NC   | —         | —           | <i>Note: x4/x8 512 Mbit components</i><br><i>Note: and x16 512 Mbit components</i> |
| <b>Address Signals ×16 organization</b> |      |           |             |  |
| L2                                      | BA0  | I         | SSTL        | <b>Bank Address Bus 1:0</b>  |
| L3                                      | BA1  | I         | SSTL        |  |
| L1                                      | NC   | —         | —           |  |
| M8                                      | A0   | I         | SSTL        | <b>Address Signal 12:0, Address Signal 10/Autoprecharge</b>                        |
| M3                                      | A1   | I         | SSTL        |  |
| M7                                      | A2   | I         | SSTL        |  |
| N2                                      | A3   | I         | SSTL        |  |
| N8                                      | A4   | I         | SSTL        |  |
| N3                                      | A5   | I         | SSTL        |  |
| N7                                      | A6   | I         | SSTL        |  |
| P2                                      | A7   | I         | SSTL        |  |
| P8                                      | A8   | I         | SSTL        |  |
| P3                                      | A9   | I         | SSTL        |  |
| M2                                      | A10  | I         | SSTL        |  |
|   | AP   | I         | SSTL        |  |
| P7                                      | A11  | I         | SSTL        |  |
| R2                                      | A12  | I         | SSTL        |  |
| <b>Data Signals ×4/×8 organization</b>  |      |           |             |  |
| C8                                      | DQ0  | I/O       | SSTL        | <b>Data Signal 3:0</b>   |
| C2                                      | DQ1  | I/O       | SSTL        |  |
| D7                                      | DQ2  | I/O       | SSTL        |  |
| D3                                      | DQ3  | I/O       | SSTL        |  |



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| Ball#                                      | Name                     | Ball Type | Buffer Type | Function                          |
|--|--------------------------|-----------|-------------|-----------------------------------|
| D1   | DQ4                      | I/O       | SSTL        | <b>Data Signal 7:4</b>            |
| D9   | DQ5                      | I/O       | SSTL        |                                   |
| B1   | DQ6                      | I/O       | SSTL        |                                   |
| B9   | DQ7                      | I/O       | SSTL        |                                   |
| <b>Data Signals ×16 organization</b>       |                          |           |             |                                   |
| G8   | DQ0                      | I/O       | SSTL        | <b>Data Signal 15:0</b>           |
| G2   | DQ1                      | I/O       | SSTL        |                                   |
| H7   | DQ2                      | I/O       | SSTL        |                                   |
| H3   | DQ3                      | I/O       | SSTL        |                                   |
| H1   | DQ4                      | I/O       | SSTL        |                                   |
| H9   | DQ5                      | I/O       | SSTL        |                                   |
| F1   | DQ6                      | I/O       | SSTL        |                                   |
| F9   | DQ7                      | I/O       | SSTL        |                                   |
| C8   | DQ8                      | I/O       | SSTL        |                                   |
| C2   | DQ9                      | I/O       | SSTL        |                                   |
| D7   | DQ10                     | I/O       | SSTL        |                                   |
| D3   | DQ11                     | I/O       | SSTL        |                                   |
| D1   | DQ12                     | I/O       | SSTL        |                                   |
| D9   | DQ13                     | I/O       | SSTL        |                                   |
| B1   | DQ14                     | I/O       | SSTL        |                                   |
| B9   | DQ15                     | I/O       | SSTL        |                                   |
| <b>Data Strobe ×4/×8 organizations</b>     |                          |           |             |                                   |
| B7   | DQS                      | I/O       | SSTL        | <b>Data Strobe</b>                |
| A8   | $\overline{\text{DQS}}$  | I/O       | SSTL        |                                   |
| <b>Data Strobe ×8 organisation</b>         |                          |           |             |                                   |
| B3   | RDQS                     | O         | SSTL        | <b>Read Data Strobe</b>           |
| A2   | $\overline{\text{RDQS}}$ | O         | SSTL        |                                   |
| <b>Data Strobe ×16 organization</b>        |                          |           |             |                                   |
| B7   | UDQS                     | I/O       | SSTL        | <b>Data Strobe Upper Byte</b>     |
| A8   | $\overline{\text{UDQS}}$ | I/O       | SSTL        |                                   |
| F7   | LDQS                     | I/O       | SSTL        | <b>Data Strobe Lower Byte</b>     |
| E8   | $\overline{\text{LDQS}}$ | I/O       | SSTL        |                                   |
| <b>Data Mask ×4/×8 organizations</b>       |                          |           |             |                                   |
| B3   | DM                       | I         | SSTL        | <b>Data Mask</b>                  |
| <b>Data Mask ×16 organization</b>          |                          |           |             |                                   |
| B3   | UDM                      | I         | SSTL        | <b>Data Mask Upper/Lower Byte</b> |
| F3   | LDM                      | I         | SSTL        |                                   |
| <b>Power Supplies ×4×8×16 organization</b> |                          |           |             |                                   |
| A9, C1, C3, C7, C9                         | $V_{\text{DDQ}}$         | PWR       | —           | <b>I/O Driver Power Supply</b>    |


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| Ball#                                     | Name       | Ball Type | Buffer Type | Function                   |
|---|------------|-----------|-------------|----------------------------|
| A1  | $V_{DD}$   | PWR       | —           | Power Supply               |
| A7, B2, B8, D2, D8                        | $V_{SSQ}$  | PWR       | —           | I/O Driver Power Supply    |
| A3, E3                                    | $V_{SS}$   | PWR       | —           | Power Supply               |
| <b>Power Supplies ×4/×8 organizations</b> |            |           |             |                            |
| E2  | $V_{REF}$  | AI        | —           | I/O Reference Voltage      |
| E1  | $V_{DDL}$  | PWR       | —           | Power Supply               |
| E9, H9, L1                                | $V_{DD}$   | PWR       | —           | Power Supply               |
| E7  | $V_{SSDL}$ | PWR       | —           | Power Supply               |
| J1, K9                                    | $V_{SS}$   | PWR       | —           | Power Supply               |
| <b>Power Supplies ×16 organization</b>    |            |           |             |                            |
| J2  | $V_{REF}$  | AI        | —           | I/O Reference Voltage      |
| E9, G1, G3, G7, G9                        | $V_{DDQ}$  | PWR       | —           | I/O Driver Power Supply    |
| J1  | $V_{DDL}$  | PWR       | —           | Power Supply               |
| E1, J9, M9, R1                            | $V_{DD}$   | PWR       | —           | Power Supply               |
| E7, F2, F8, H2, H8                        | $V_{SSQ}$  | PWR       | —           | I/O Driver Power Supply    |
| J7  | $V_{SSDL}$ | PWR       | —           | Power Supply               |
| A3, E3, J3, N1, P9                        | $V_{SS}$   | PWR       | —           | Power Supply               |
| <b>Not Connected ×4/×8 organization</b>   |            |           |             |                            |
| G1, L3, L7, L8                            | NC         | NC        | —           | Not Connected              |
| <b>Not Connected ×4 organization</b>      |            |           |             |                            |
| A2, B1, B9, D1, D9                        | NC         | NC        | —           | Not Connected              |
| <b>Not Connected ×16 organization</b>     |            |           |             |                            |
| A2, E2, L1, R3, R7, R8                    | NC         | NC        | —           | Not Connected              |
| <b>Other Balls ×4/×8 organizations</b>    |            |           |             |                            |
| F9  | ODT        | I         | SSTL        | On-Die Termination Control |
| <b>Other Balls ×16 organization</b>       |            |           |             |                            |
| K9  | ODT        | I         | SSTL        | On-Die Termination Control |

HYB18T512[40/80/16]0B[C/F]  
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Abbreviations for Ball Type

| Abbreviation | Description                                 |
|--------------|---|
| I            | Standard input-only ball. Digital levels.   |
| O            | Output. Digital levels.                     |
| I/O          | I/O is a bidirectional input/output signal. |
| AI           | Input. Analog levels.                       |
| PWR          | Power                                       |
| GND          | Ground                                      |
| NC           | Not Connected                               |

**TABLE 9**  
Abbreviations for Buffer Type

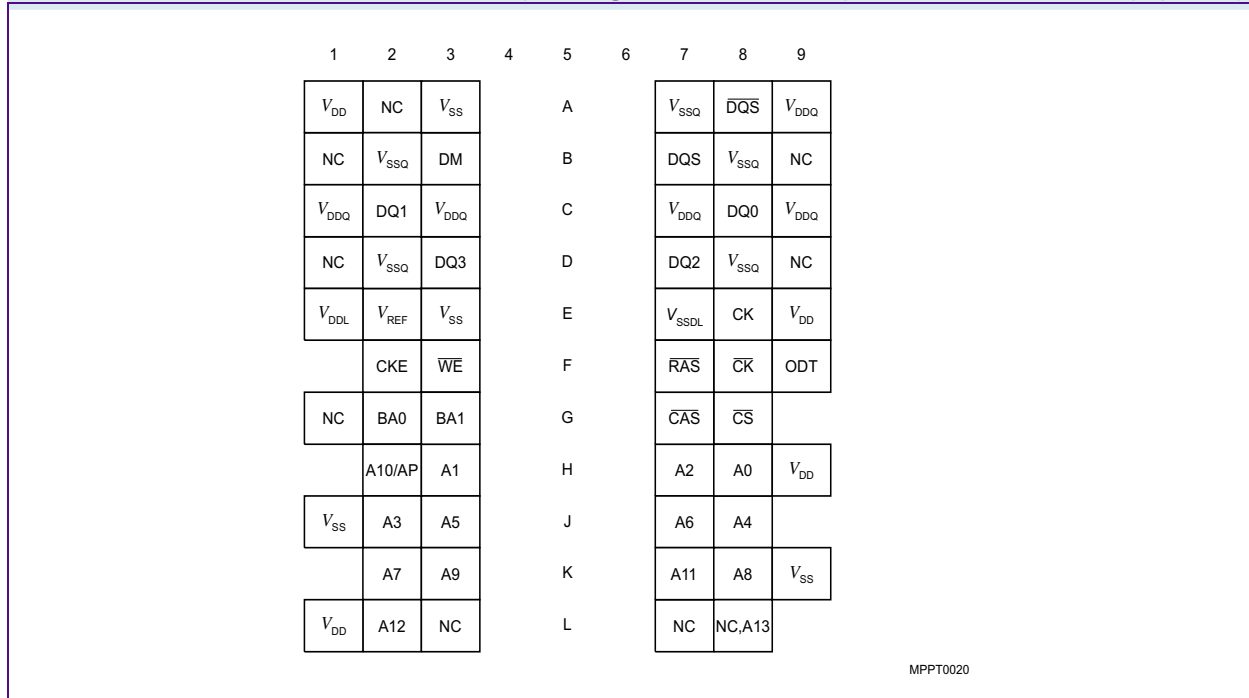
| Abbreviation | Description  |
|--------------|--|
| SSTL         | Serial Stub Terminated Logic (SSTL_18)   |
| LV-CMOS      | Low Voltage CMOS   |
| CMOS         | CMOS Levels  |
| OD           | Open Drain. The corresponding ball has 2 operational states, active low and tristate, and allows multiple devices to share as a wire-OR. |



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**FIGURE 1**

**Chip Configuration for ×4 components, PG-TFBGA-60 (top view)**



**Notes**

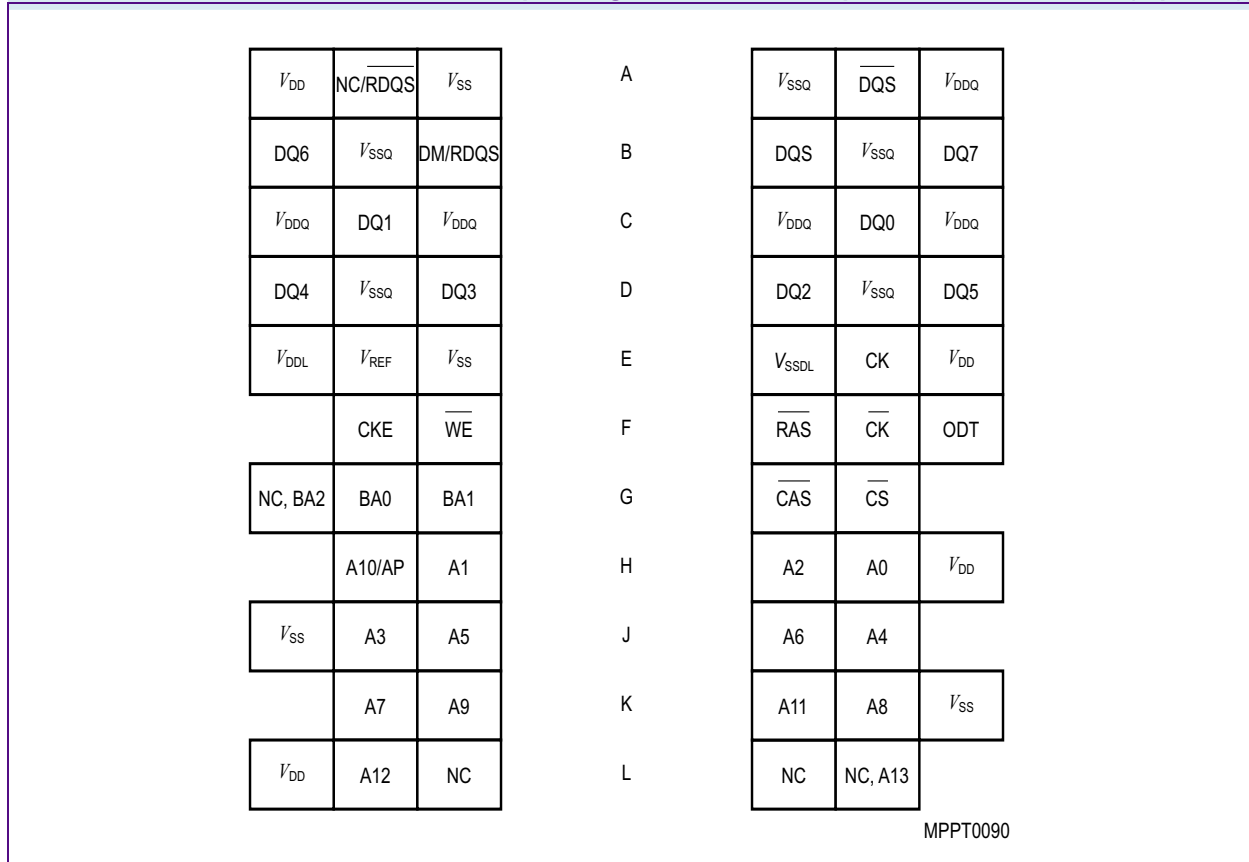
1.  $V_{DDL}$  and  $V_{SSDL}$  are power and ground for the DLL.  $V_{DDL}$  is connected to  $V_{DD}$  on the device.  $V_{DD}$ ,  $V_{DDQ}$ ,  $V_{SSDL}$ ,  $V_{SS}$ , and  $V_{SSQ}$  are isolated on the device.

2. Ball position L8 is A13 for 512-Mbit and is Not Connected on 256-Mbit



**FIGURE 2**

**Chip Configuration for ×8 components, PG-TFBGA-60 (top view)**



**Notes**

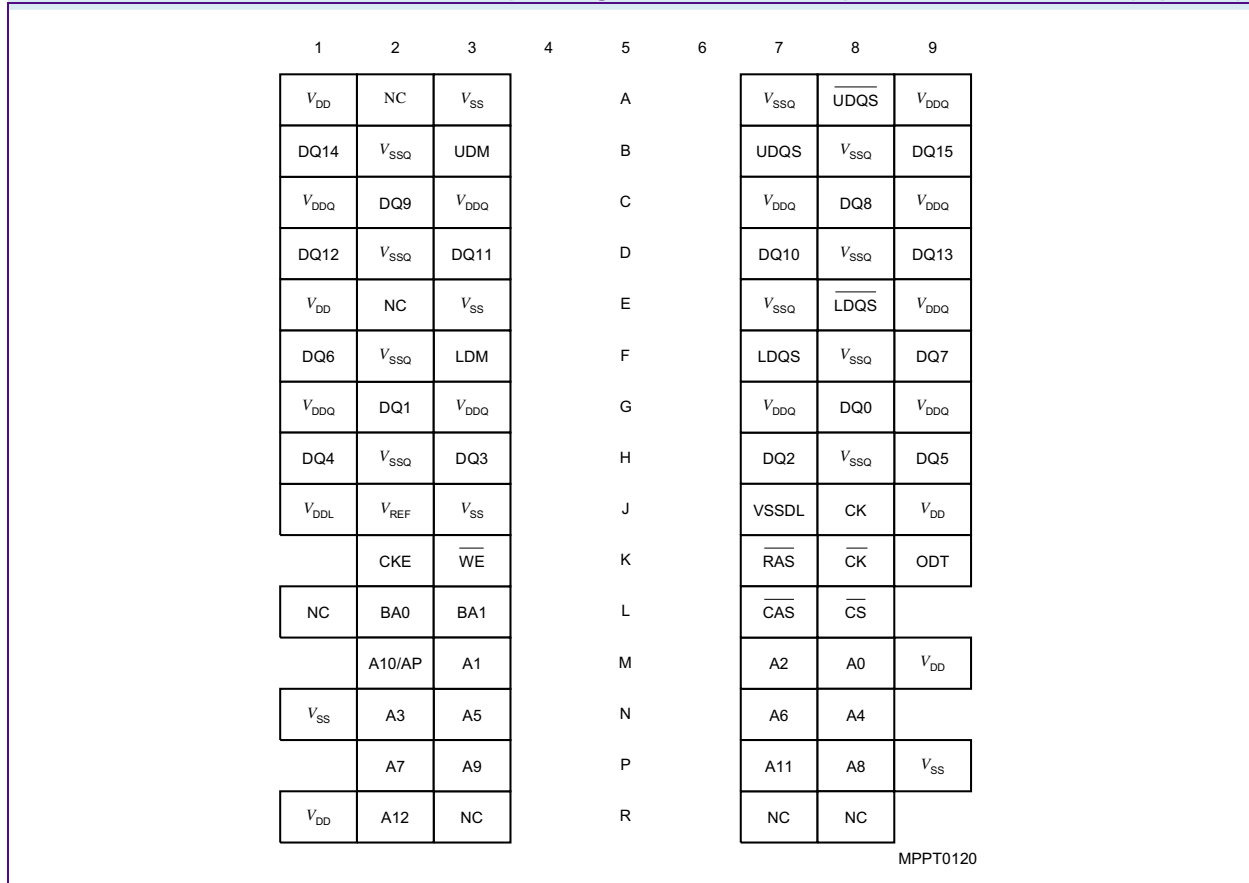
1.  $\overline{RDQS}$  /  $\overline{RDQS}$  are enabled by EMRS(1) command.
2. If  $\overline{RDQS}$  /  $\overline{RDQS}$  is enabled, the DM function is disabled
3. When enabled,  $\overline{RDQS}$  &  $\overline{RDQS}$  are used as strobe signals during reads.
4.  $V_{DDL}$  and  $V_{SSDL}$  are power and ground for the DLL.  $V_{DDL}$  is connected to  $V_{DD}$  on the device.  $V_{DD}$ ,  $V_{DDQ}$ ,  $V_{SSDL}$ ,  $V_{SS}$  and  $V_{SSQ}$  are isolated on the device.
5. Ball position L8 is A13 for 512-Mbit and is Not Connected on 256-Mbit.



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**FIGURE 3**

**Chip Configuration for ×16 components, PG-TFBGA-84 (top view)**



**Notes**

1.  $\overline{UDQS}/UDQS$  is data strobe for DQ[15:8],  $\overline{LDQS}/LDQS$  is data strobe for DQ[7:0]
2. LDM is the data mask signal for DQ[7:0], UDM is the data mask signal for DQ[15:8]
3.  $V_{DDL}$  and  $V_{SSDL}$  are power and ground for the DLL.  $V_{DDL}$  is connected to  $V_{DD}$  on the device.  $V_{DD}$ ,  $V_{DDQ}$ ,  $V_{SSDL}$ ,  $V_{SS}$ , and  $V_{SSQ}$  are isolated on the device.

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## 2.2 Addressing

This chapter describes the addressing.

**TABLE 10**  
DDR2 Addressing for ×4 Organization

| Configuration                 | ×128Mb × 4 <sup>1)</sup> | Note |
|-------------------------------|--------------------------|------|
| Bank Address                  | BA[1:0]                  |      |
| Number of Banks               | 4                        |      |
| Auto-Precharge                | A10 / AP                 |      |
| Row Address                   | A[13:0]                  |      |
| Column Address                | A11, A[9:0]              |      |
| Number of Column Address Bits | 11                       | 2)   |
| Number of I/Os                | 4                        |      |
| Page Size [Bytes]             | 1024 (1K)                | 3)   |

1) Referred to as 'org'

2) Referred to as 'colbits'

3) PageSize =  $2^{\text{colbits}} \times \text{org}/8$  [Bytes]

**TABLE 11**  
DDR2 Addressing for ×8 Organization

| Configuration                 | ×64Mb × 8 <sup>1)</sup> | Note |
|-------------------------------|-------------------------|------|
| Bank Address                  | BA[1:0]                 |      |
| Number of Banks               | 4                       |      |
| Auto-Precharge                | A10 / AP                |      |
| Row Address                   | A[13:0]                 |      |
| Column Address                | A[9:0]                  |      |
| Number of Column Address Bits | 10                      | 2)   |
| Number of I/Os                | 8                       |      |
| Page Size [Bytes]             | 1024 (1K)               | 3)   |

1) Referred to as 'org'

2) Referred to as 'colbits'

3) PageSize =  $2^{\text{colbits}} \times \text{org}/8$  [Bytes]





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**TABLE 12**  
**DDR2 Addressing for ×16 Organization**

| Configuration                 | ×32Mb × 16 <sup>1)</sup> | Note |
|-------------------------------|--------------------------|------|
| Bank Address                  | BA[1:0]                  |      |
| Number of Banks               | 4                        |      |
| Auto-Precharge                | A10 / AP                 |      |
| Row Address                   | A[12:0]                  |      |
| Column Address                | A[9:0]                   |      |
| Number of Column Address Bits | 10                       | 2)   |
| Number of I/Os                | 16                       |      |
| Page Size [Bytes]             | 2048 (2K)                | 3)   |

1) Referred to as 'org'

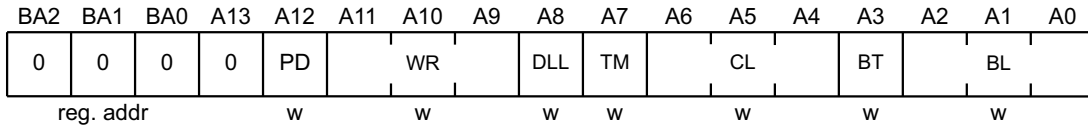
2) Referred to as 'colbits'

3) PageSize =  $2^{\text{colbits}} \times \text{org}/8$  [Bytes]



### 3 Functional Description

This chapter contains the functional description.



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**TABLE 13**  
Mode Register Definition (BA[2:0] = 000B)

| Field | Bits   | Type <sup>1)</sup> | Description  |
|-------|--------|--------------------|--|
| BA2   | 16     | reg. addr.         | <b>Bank Address [2]</b><br><i>Note: BA2 not available on 256 Mbit and 512 Mbit components</i><br>0 <sub>B</sub> <b>BA2</b> Bank Address  |
| BA1   | 15     |                    | <b>Bank Address [1]</b><br>0 <sub>B</sub> <b>BA1</b> Bank Address  |
| BA0   | 14     |                    | <b>Bank Address [0]</b><br>0 <sub>B</sub> <b>BA0</b> Bank Address  |
| A13   | 13     |                    | <b>Address Bus[13]</b><br><i>Note: A13 is not available for 256 Mbit and x16 512 Mbit configuration</i><br>0 <sub>B</sub> <b>A13</b> Address bit 13  |
| PD    | 12     | w                  | <b>Active Power-Down Mode Select</b><br>0 <sub>B</sub> <b>PD</b> Fast exit<br>1 <sub>B</sub> <b>PD</b> Slow exit   |
| WR    | [11:9] | w                  | <b>Write Recovery<sup>2)</sup></b><br><i>Note: All other bit combinations are illegal.</i><br>001 <sub>B</sub> <b>WR</b> 2<br>010 <sub>B</sub> <b>WR</b> 3<br>011 <sub>B</sub> <b>WR</b> 4<br>100 <sub>B</sub> <b>WR</b> 5<br>101 <sub>B</sub> <b>WR</b> 6 |
| DLL   | 8      | w                  | <b>DLL Reset</b><br>0 <sub>B</sub> <b>DLL</b> No<br>1 <sub>B</sub> <b>DLL</b> Yes  |
| TM    | 7      | w                  | <b>Test Mode</b><br>0 <sub>B</sub> <b>TM</b> Normal Mode<br>1 <sub>B</sub> <b>TM</b> Vendor specific test mode   |



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| Field | Bits  | Type <sup>1)</sup> | Description   |
|-------|-------|--------------------|---|
| CL    | [6:4] | w                  | <b>CAS Latency</b><br><i>Note: All other bit combinations are illegal.</i><br>011 <sub>B</sub> CL 3<br>100 <sub>B</sub> CL 4<br>101 <sub>B</sub> CL 5<br>110 <sub>B</sub> CL 6<br>111 <sub>B</sub> CL 7 |
| BT    | 3     | w                  | <b>Burst Type</b><br>0 <sub>B</sub> BT Sequential<br>1 <sub>B</sub> BT Interleaved  |
| BL    | [2:0] | w                  | <b>Burst Length</b><br><i>Note: All other bit combinations are illegal.</i><br>010 <sub>B</sub> BL 4<br>011 <sub>B</sub> BL 8   |

- 1) w = write only register bits
- 2) Number of clock cycles for write recovery during auto-precharge. WR in clock cycles is calculated by dividing  $t_{WR}$  (in ns) by  $t_{CK}$  (in ns) and rounding up to the next integer:  $WR [cycles] \geq t_{WR} (ns) / t_{CK} (ns)$ . The mode register must be programmed to fulfill the minimum requirement for the analogue  $t_{WR}$  timing  $WR_{MIN}$  is determined by  $t_{CK,MAX}$  and  $WR_{MAX}$  is determined by  $t_{CK,MIN}$ .

|           |     |     |     |                  |      |                  |             |    |    |                 |    |    |    |                 |     |     |
|-----------|-----|-----|-----|------------------|------|------------------|-------------|----|----|-----------------|----|----|----|-----------------|-----|-----|
| BA2       | BA1 | BA0 | A13 | A12              | A11  | A10              | A9          | A8 | A7 | A6              | A5 | A4 | A3 | A2              | A1  | A0  |
| 0         | 0   | 1   | 0   | Q <sub>off</sub> | RDQS | $\overline{DQS}$ | OCD Program |    |    | R <sub>tt</sub> |    | AL |    | R <sub>tt</sub> | DIC | DLL |
| reg. addr |     |     |     |                  | w    | w                | w           | w  |    | w               |    | w  |    | w               | w   | w   |

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**TABLE 14**  
Extended Mode Register Definition (BA[2:0] = 001<sub>B</sub>)

| Field | Bits | Type <sup>1)</sup> | Description   |
|-------|------|--------------------|---|
| BA2   | 16   | reg. addr.         | <b>Bank Address [2]</b><br><i>Note: BA2 not available on 256 Mbit and 512 Mbit components</i><br>0 <sub>B</sub> BA2 Bank Address              |
| BA1   | 15   |                    | <b>Bank Address [1]</b><br>0 <sub>B</sub> BA1 Bank Address  |
| BA0   | 14   |                    | <b>Bank Address [0]</b><br>1 <sub>B</sub> BA0 Bank Address  |
| A13   | 13   | w                  | <b>Address Bus [13]</b><br><i>Note: A13 is not available for 256 Mbit and x16 512 Mbit configuration</i><br>0 <sub>B</sub> A13 Address bit 13 |
| Qoff  | 12   | w                  | <b>Output Disable</b><br>0 <sub>B</sub> Qoff Output buffers enabled<br>1 <sub>B</sub> Qoff Output buffers disabled                            |
| RDQS  | 11   | w                  | <b>Read Data Strobe Output (RDQS, RDQS)</b><br>0 <sub>B</sub> RDQS Disable<br>1 <sub>B</sub> RDQS Enable                                      |



| Field                   | Bits  | Type <sup>1)</sup> | Description   |
|-------------------------|-------|--------------------|---|
| $\overline{\text{DQS}}$ | 10    | w                  | <b>Complement Data Strobe (DQS Output)</b><br>0 <sub>B</sub> $\overline{\text{DQS}}$ Enable<br>1 <sub>B</sub> $\overline{\text{DQS}}$ Disable   |
| OCD Program             | [9:7] | w                  | <b>Off-Chip Driver Calibration Program</b><br>000 <sub>B</sub> <b>OCD</b> OCD calibration mode exit, maintain setting<br>001 <sub>B</sub> <b>OCD</b> Drive (1)<br>010 <sub>B</sub> <b>OCD</b> Drive (0)<br>100 <sub>B</sub> <b>OCD</b> Adjust mode<br>111 <sub>B</sub> <b>OCD</b> OCD calibration default   |
| AL                      | [5:3] | w                  | <b>Additive Latency</b><br><i>Note: All other bit combinations are illegal.</i><br>000 <sub>B</sub> <b>AL</b> 0<br>001 <sub>B</sub> <b>AL</b> 1<br>010 <sub>B</sub> <b>AL</b> 2<br>011 <sub>B</sub> <b>AL</b> 3<br>100 <sub>B</sub> <b>AL</b> 4<br>101 <sub>B</sub> <b>AL</b> 5   |
| R <sub>TT</sub>         | 6,2   | w                  | <b>Nominal Termination Resistance of ODT</b><br><i>Note: See <a href="#">Table 25 "ODT DC Electrical Characteristics"</a> on Page 28</i><br>00 <sub>B</sub> <b>R<sub>TT</sub></b> ∞ (ODT disabled)<br>01 <sub>B</sub> <b>R<sub>TT</sub></b> 75 Ohm<br>10 <sub>B</sub> <b>R<sub>TT</sub></b> 150 Ohm<br>11 <sub>B</sub> <b>R<sub>TT</sub></b> 50 Ohm |
| DIC                     | 1     | w                  | <b>Off-chip Driver Impedance Control</b><br>0 <sub>B</sub> <b>DIC</b> Full (Driver Size = 100%)<br>1 <sub>B</sub> <b>DIC</b> Reduced  |
| DLL                     | 0     | w                  | <b>DLL Enable</b><br>0 <sub>B</sub> <b>DLL</b> Enable<br>1 <sub>B</sub> <b>DLL</b> Disable  |

1) w = write only register bits



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|     |     |     |     |     |     |     |    |    |     |    |    |    |     |    |      |    |
|-----|-----|-----|-----|-----|-----|-----|----|----|-----|----|----|----|-----|----|------|----|
| BA2 | BA1 | BA0 | A13 | A12 | A11 | A10 | A9 | A8 | A7  | A6 | A5 | A4 | A3  | A2 | A1   | A0 |
| 0   | 1   | 0   |     |     | 0   |     |    |    | SRF |    | 0  |    | DCC |    | PASR |    |

reg. addr

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**TABLE 15**

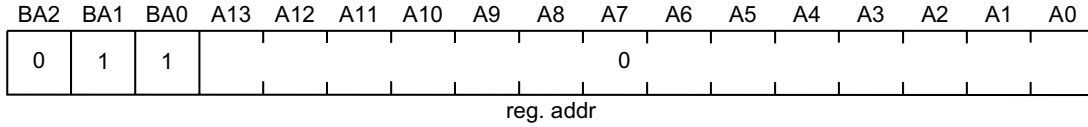
**EMRS(2) Programming Extended Mode Register Definition (BA[2:0]=010<sub>B</sub>)**

| Field                                   | Bits    | Type <sup>1)</sup> | Description  |
|---|---------|--------------------|--|
| BA                                      | [15:14] | w                  | <b>Bank Address</b><br>00 <sub>B</sub> <b>BA MRS</b><br>01 <sub>B</sub> <b>BA EMRS(1)</b><br>10 <sub>B</sub> <b>BA EMRS(2)</b><br>11 <sub>B</sub> <b>BA EMRS(3): Reserved</b>  |
| SRF                                     | 7       | w                  | <b>Address Bus, High Temperature Self Refresh Rate for <math>T_{CASE} &gt; 85^{\circ}C</math></b><br>0 <sub>B</sub> <b>A7 disable</b><br>1 <sub>B</sub> <b>A7 enable <sup>2)</sup></b>   |
| A                                       | [6:4]   | w                  | <b>Address Bus</b><br>000 <sub>B</sub> <b>A Address bits</b>   |
| DCC                                     | 3       | w                  | <b>Address Bus, Duty Cycle Correction (DCC)</b><br>0 <sub>B</sub> <b>A3 DCC disabled</b><br>1 <sub>B</sub> <b>A3 DCC enabled</b>   |
| <b>Partial Self Refresh for 4 banks</b> |         |                    |  |
| PASR                                    | [2:0]   | w                  | <b>Address Bus, Partial Array Self Refresh for 4 Banks<sup>3)</sup></b><br><i>Note: Only for 256 Mbit and 512 Mbit components</i><br>000 <sub>B</sub> <b>PASR0 Full Array</b><br>001 <sub>B</sub> <b>PASR1 Half Array (BA[1:0]=00, 01)</b><br>010 <sub>B</sub> <b>PASR2 Quarter Array (BA[1:0]=00)</b><br>011 <sub>B</sub> <b>PASR3 Not defined</b><br>100 <sub>B</sub> <b>PASR4 3/4 array (BA[1:0]=01, 10, 11)</b><br>101 <sub>B</sub> <b>PASR5 Half array (BA[1:0]=10, 11)</b><br>110 <sub>B</sub> <b>PASR6 Quarter array (BA[1:0]=11)</b><br>111 <sub>B</sub> <b>PASR7 Not defined</b>  |
| <b>Partial Self Refresh for 8 banks</b> |         |                    |  |
| PASR                                    | [2:0]   | w                  | <b>Address Bus, Partial Array Self Refresh for 8 Banks<sup>3)</sup></b><br><i>Note: Only for 1G and 2G components</i><br>000 <sub>B</sub> <b>PASR0 Full Array</b><br>001 <sub>B</sub> <b>PASR1 Half Array (BA[2:0]=000, 001, 010 &amp; 011)</b><br>010 <sub>B</sub> <b>PASR2 Quarter Array (BA[2:0]=000, 001)</b><br>011 <sub>B</sub> <b>PASR3 1/8 array (BA[2:0] = 000)</b><br>100 <sub>B</sub> <b>PASR4 3/4 array (BA[2:0]= 010, 011, 100, 101, 110 &amp; 111)</b><br>101 <sub>B</sub> <b>PASR5 Half array (BA[2:0]=100, 101, 110 &amp; 111)</b><br>110 <sub>B</sub> <b>PASR6 Quarter array (BA[2:0]= 110 &amp; 111)</b><br>111 <sub>B</sub> <b>PASR7 1/8 array(BA[2:0]=111)</b> |

- 1) w = write only
- 2) When DRAM is operated at  $85^{\circ}C \leq T_{Case} \leq 95^{\circ}C$  the extended self refresh rate must be enabled by setting bit A7 to "1" before the self refresh mode can be entered.
- 3) If PASR (Partial Array Self Refresh) is enabled, data located in areas of the array beyond the specified location will be lost if self refresh is entered. Data integrity will be maintained if  $t_{REF}$  conditions are met and no Self Refresh command is issued



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**TABLE 16**  
**EMR(3) Programming Extended Mode Register Definition(BA[2:0]=011<sub>B</sub>)**

| Field | Bits   | Type <sup>1)</sup> | Description   |
|-------|--------|--------------------|---|
| BA2   | 16     | reg.addr           | <b>Bank Address[2]</b><br><i>Note: BA2 is not available on 256 Mbit and 512 Mbit components</i><br>0 <sub>B</sub> <b>BA2</b> Bank Address                           |
| BA1   | 15     |                    | <b>Bank Address[1]</b><br>1 <sub>B</sub> <b>BA1</b> Bank Address  |
| BA0   | 14     |                    | <b>Bank Address[0]</b><br>1 <sub>B</sub> <b>BA0</b> Bank Address  |
| A     | [13:0] | w                  | <b>Address Bus[13:0]</b><br><i>Note: A13 is not available for 256 Mbit and x16 512 Mbit configuration</i><br>0000000000000 <sub>B</sub> <b>A[13:0]</b> Address bits |

1) w = write only



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**TABLE 17**  
ODT Truth Table

| Input Pin                | EMRS(1) Address Bit A10 | EMRS(1) Address Bit A11 |
|--------------------------|-------------------------|-------------------------|
| <b>×4 Components</b>     |                         |                         |
| DQ[3:0]                  | X                       |                         |
| DQS                      | X                       |                         |
| $\overline{\text{DQS}}$  | 0                       | X                       |
| DM                       | X                       |                         |
| <b>×8 Components</b>     |                         |                         |
| DQ[7:0]                  | X                       |                         |
| DQS                      | X                       |                         |
| $\overline{\text{DQS}}$  | 0                       | X                       |
| RDQS                     | X                       | 1                       |
| $\overline{\text{RDQS}}$ | 0                       | 1                       |
| DM                       | X                       | 0                       |
| <b>×16 Components</b>    |                         |                         |
| DQ[7:0]                  | X                       |                         |
| DQ[15:8]                 | X                       |                         |
| LDQS                     | X                       |                         |
| $\overline{\text{LDQS}}$ | 0                       | X                       |
| UDQS                     | X                       |                         |
| $\overline{\text{UDQS}}$ | 0                       | X                       |
| LDM                      | X                       |                         |
| UDM                      | X                       |                         |

Note: X = don't care; 0 = bit set to low; 1 = bit set to high

HYB18T512[40/80/16]0B[C/F]  
512-Mbit Double-Data-Rate-Two SDRAM**TABLE 18**  
**Burst Length and Sequence**

| Burst Length | Starting Address (A2 A1 A0) | Sequential Addressing (decimal) | Interleave Addressing (decimal) |
|--------------|-----------------------------|---------------------------------|---------------------------------|
| 4            | × 0 0                       | 0, 1, 2, 3                      | 0, 1, 2, 3                      |
|              | × 0 1                       | 1, 2, 3, 0                      | 1, 0, 3, 2                      |
|              | × 1 0                       | 2, 3, 0, 1                      | 2, 3, 0, 1                      |
|              | × 1 1                       | 3, 0, 1, 2                      | 3, 2, 1, 0                      |
| 8            | 0 0 0                       | 0, 1, 2, 3, 4, 5, 6, 7          | 0, 1, 2, 3, 4, 5, 6, 7          |
|              | 0 0 1                       | 1, 2, 3, 0, 5, 6, 7, 4          | 1, 0, 3, 2, 5, 4, 7, 6          |
|              | 0 1 0                       | 2, 3, 0, 1, 6, 7, 4, 5          | 2, 3, 0, 1, 6, 7, 4, 5          |
|              | 0 1 1                       | 3, 0, 1, 2, 7, 4, 5, 6          | 3, 2, 1, 0, 7, 6, 5, 4          |
|              | 1 0 0                       | 4, 5, 6, 7, 0, 1, 2, 3          | 4, 5, 6, 7, 0, 1, 2, 3          |
|              | 1 0 1                       | 5, 6, 7, 4, 1, 2, 3, 0          | 5, 4, 7, 6, 1, 0, 3, 2          |
|              | 1 1 0                       | 6, 7, 4, 5, 2, 3, 0, 1          | 6, 7, 4, 5, 2, 3, 0, 1          |
|              | 1 1 1                       | 7, 4, 5, 6, 3, 0, 1, 2          | 7, 6, 5, 4, 3, 2, 1, 0          |





# 4 Truth Tables

The truth tables in this chapter summarize the commands and there signal coding to control a standard Double-Data-Rate-Two SDRAM.

**TABLE 19**  
Command Truth Table

| Function                     | CKE            |               | $\overline{CS}$ | $\overline{RAS}$ | $\overline{CAS}$ | $\overline{WE}$ | BA0<br>BA1 | A[12:11]    | A10 | A[9:0] | Note <sup>1)2)3)</sup> |
|------------------------------|----------------|---------------|-----------------|------------------|------------------|-----------------|------------|-------------|-----|--------|------------------------|
|                              | Previous Cycle | Current Cycle |                 |                  |                  |                 |            |             |     |        |                        |
| (Extended) Mode Register Set | H              | H             | L               | L                | L                | L               | BA         | OP Code     |     |        | 4)5)                   |
| Auto-Refresh                 | H              | H             | L               | L                | L                | H               | X          | X           | X   | X      | 4)                     |
| Self-Refresh Entry           | H              | L             | L               | L                | L                | H               | X          | X           | X   | X      | 4)6)                   |
| Self-Refresh Exit            | L              | H             | H               | X                | X                | X               | X          | X           | X   | X      | 4)6)7)                 |
|                              |                |               | L               | H                | H                | H               |            |             |     |        |                        |
| Single Bank Precharge        | H              | H             | L               | L                | H                | L               | BA         | X           | L   | X      | 4)5)                   |
| Precharge all Banks          | H              | H             | L               | L                | H                | L               | X          | X           | H   | X      | 4)                     |
| Bank Activate                | H              | H             | L               | L                | H                | H               | BA         | Row Address |     |        | 4)5)                   |
| Write                        | H              | H             | L               | H                | L                | L               | BA         | Column      | L   | Column | 4)5)8)                 |
| Write with Auto-Precharge    | H              | H             | L               | H                | L                | L               | BA         | Column      | H   | Column | 4)5)8)                 |
| Read                         | H              | H             | L               | H                | L                | H               | BA         | Column      | L   | Column | 4)5)8)                 |
| Read with Auto-Precharge     | H              | H             | L               | H                | L                | H               | BA         | Column      | H   | Column | 4)5)8)                 |
| No Operation                 | H              | X             | L               | H                | H                | H               | X          | X           | X   | X      | 4)                     |
| Device Deselect              | H              | X             | H               | X                | X                | X               | X          | X           | X   | X      | 4)                     |
| Power Down Entry             | H              | L             | H               | X                | X                | X               | X          | X           | X   | X      | 4)9)                   |
|                              |                |               | L               | H                | H                | H               |            |             |     |        |                        |
| Power Down Exit              | L              | H             | H               | X                | X                | X               | X          | X           | X   | X      | 4)9)                   |
|                              |                |               | L               | H                | H                | H               |            |             |     |        |                        |

- 1) The state of ODT does not affect the states described in this table. The ODT function is not available during Self Refresh.
- 2) "X" means "H or L (but a defined logic level)".
- 3) Operation that is not specified is illegal and after such an event, in order to guarantee proper operation, the DRAM must be powered down and then restarted through the specified initialization sequence before normal operation can continue.
- 4) All DDR2 SDRAM commands are defined by states of  $\overline{CS}$ ,  $\overline{WE}$ ,  $\overline{RAS}$ ,  $\overline{CAS}$ , and CKE at the rising edge of the clock.
- 5) Bank addresses BA[1:0] determine which bank is to be operated upon. For (E)MRS BA[1:0] selects an (Extended) Mode Register.
- 6)  $V_{REF}$  must be maintained during Self Refresh operation.
- 7) Self Refresh Exit is asynchronous.
- 8) Burst reads or writes at BL = 4 cannot be terminated.
- 9) The Power Down Mode does not perform any refresh operations. The duration of Power Down is therefore limited by the refresh requirements.



**TABLE 20**  
**Clock Enable (CKE) Truth Table for Synchronous Transitions**

| Current State <sup>1)</sup>       | CKE                                   |                                    | Command (N) <sup>2) 3)</sup><br>RAS, CAS, WE | Action (N) <sup>2)</sup>   | Note <sup>4)5)</sup> |
|-----------------------------------|---------------------------------------|------------------------------------|--|----------------------------|----------------------|
|                                   | Previous Cycle <sup>6)</sup><br>(N-1) | Current Cycle <sup>6)</sup><br>(N) |  |                            |                      |
| Power-Down                        | L                                     | L                                  | X  | Maintain Power-Down        | 7)8)11)              |
|                                   | L                                     | H                                  | DESELECT or NOP                              | Power-Down Exit            | 7)9)10)11)           |
| Self Refresh                      | L                                     | L                                  | X  | Maintain Self Refresh      | 8)11)12)             |
|                                   | L                                     | H                                  | DESELECT or NOP                              | Self Refresh Exit          | 9)11)12)13)14)       |
| Bank(s) Active                    | H                                     | L                                  | DESELECT or NOP                              | Active Power-Down Entry    | 7)9)10)11)15)        |
| All Banks Idle                    | H                                     | L                                  | DESELECT or NOP                              | Precharge Power-Down Entry | 9)10)11)15)          |
|                                   | H                                     | L                                  | AUTOREFRESH                                  | Self Refresh Entry         | 7)11)14)16)          |
| Any State other than listed above | H                                     | H                                  | Refer to the Command Truth Table             |                            | 17)                  |

- 1) Current state is the state of the DDR2 SDRAM immediately prior to clock edge N.
- 2) Command (N) is the command registered at clock edge N, and Action (N) is a result of Command (N)
- 3) The state of ODT does not affect the states described in this table. The ODT function is not available during Self Refresh.
- 4) CKE must be maintained HIGH while the device is in OCD calibration mode.
- 5) Operation that is not specified is illegal and after such an event, in order to guarantee proper operation, the DRAM must be powered down and then restarted through the specified initialization sequence before normal operation can continue.
- 6) CKE (N) is the logic state of CKE at clock edge N; CKE (N-1) was the state of CKE at the previous clock edge.
- 7) The Power-Down Mode does not perform any refresh operations. The duration of Power-Down Mode is therefor limited by the refresh requirements
- 8) "X" means "don't care (including floating around  $V_{REF}$ )" in Self Refresh and Power Down. However ODT must be driven HIGH or LOW in Power Down if the ODT function is enabled (Bit A2 or A6 set to "1" in EMRS(1)).
- 9) All states and sequences not shown are illegal or reserved unless explicitly described elsewhere in this document.
- 10) Valid commands for Power-Down Entry and Exit are NOP and DESELECT only.
- 11)  $t_{CKE,MIN}$  of 3 clocks means CKE must be registered on three consecutive positive clock edges. CKE must remain at the valid input level the entire time it takes to achieve the 3 clocks of registration. Thus, after any CKE transition, CKE may not transition from its valid level during the time period of  $t_{IS} + 2 \times t_{CK} + t_{IH}$ .
- 12)  $V_{REF}$  must be maintained during Self Refresh operation.
- 13) On Self Refresh Exit DESELECT or NOP commands must be issued on every clock edge occurring during the  $t_{XSNR}$  period. Read commands may be issued only after  $t_{XSRD}$  (200 clocks) is satisfied.
- 14) Valid commands for Self Refresh Exit are NOP and DESELCT only.
- 15) Power-Down and Self Refresh can not be entered while Read or Write operations, (Extended) mode Register operations, Precharge or Refresh operations are in progress.
- 16) Self Refresh mode can only be entered from the All Banks Idle state.
- 17) Must be a legal command as defined in the Command Truth Table.

**TABLE 21**  
**Data Mask (DM) Truth Table**

| Name (Function) | DM | DQs   | Note |
|-----------------|----|-------|------|
| Write Enable    | L  | Valid | 1)   |
| Write Inhibit   | H  | X     | 1)   |

- 1) Used to mask write data; provided coincident with the corresponding data.



## 5 Electrical Characteristics

This chapter describes the electrical characteristics.

### 5.1 Absolute Maximum Ratings

Caution is needed not to exceed absolute maximum ratings of the DRAM device listed in **Table 22** at any time.

**TABLE 22**  
Absolute Maximum Ratings

| Symbol            | Parameter                                     | Rating |      | Unit | Note |
|-------------------|---|--------|------|------|------|
|                   |   | Min.   | Max. |      |      |
| $V_{DD}$          | Voltage on $V_{DD}$ pin relative to $V_{SS}$  | -1.0   | +2.3 | V    | 1)   |
| $V_{DDQ}$         | Voltage on $V_{DDQ}$ pin relative to $V_{SS}$ | -0.5   | +2.3 | V    | 1)2) |
| $V_{DDL}$         | Voltage on $V_{DDL}$ pin relative to $V_{SS}$ | -0.5   | +2.3 | V    | 1)2) |
| $V_{IN}, V_{OUT}$ | Voltage on any pin relative to $V_{SS}$       | -0.5   | +2.3 | V    | 1)   |
| $T_{STG}$         | Storage Temperature                           | -55    | +100 | °C   | 1)2) |

1) When  $V_{DD}$  and  $V_{DDQ}$  and  $V_{DDL}$  are less than 500 mV;  $V_{REF}$  may be equal to or less than 300 mV.

2) Storage Temperature is the case surface temperature on the center/top side of the DRAM.

**Attention: Stresses greater than those listed under “Absolute Maximum Ratings” may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect reliability.**

**TABLE 23**  
DRAM Component Operating Temperature Range

| Symbol     | Parameter             | Rating |      | Unit | Note     |
|------------|-----------------------|--------|------|------|----------|
|            |                       | Min.   | Max. |      |          |
| $T_{OPER}$ | Operating Temperature | 0      | 95   | °C   | 1)2)3)4) |

1) Operating Temperature is the case surface temperature on the center / top side of the DRAM.

2) The operating temperature range are the temperatures where all DRAM specification will be supported. During operation, the DRAM case temperature must be maintained between 0 - 95 °C under all other specification parameters.

3) Above 85 °C the Auto-Refresh command interval has to be reduced to  $t_{REFI} = 3.9 \mu s$

4) When operating this product in the 85 °C to 95 °C TCASE temperature range, the High Temperature Self Refresh has to be enabled by setting EMR(2) bit A7 to “1”. When the High Temperature Self Refresh is enabled there is an increase of  $I_{DD6}$  by approximately 50 %



## 5.2 DC Characteristics

**TABLE 24**  
Recommended DC Operating Conditions (SSTL\_18)

| Symbol     | Parameter                 | Rating                |                      |                       | Unit | Note |
|------------|---------------------------|-----------------------|----------------------|-----------------------|------|------|
|            |                           | Min.                  | Typ.                 | Max.                  |      |      |
| $V_{DD}$   | Supply Voltage            | 1.7                   | 1.8                  | 1.9                   | V    | 1)   |
| $V_{DDDL}$ | Supply Voltage for DLL    | 1.7                   | 1.8                  | 1.9                   | V    | 1)   |
| $V_{DDQ}$  | Supply Voltage for Output | 1.7                   | 1.8                  | 1.9                   | V    | 1)   |
| $V_{REF}$  | Input Reference Voltage   | $0.49 \times V_{DDQ}$ | $0.5 \times V_{DDQ}$ | $0.51 \times V_{DDQ}$ | V    | 2)3) |
| $V_{TT}$   | Termination Voltage       | $V_{REF} - 0.04$      | $V_{REF}$            | $V_{REF} + 0.04$      | V    | 4)   |

- $V_{DDQ}$  tracks with  $V_{DD}$ ,  $V_{DDDL}$  tracks with  $V_{DD}$ . AC parameters are measured with  $V_{DD}$ ,  $V_{DDQ}$  and  $V_{DDDL}$  tied together.
- The value of  $V_{REF}$  may be selected by the user to provide optimum noise margin in the system. Typically the value of  $V_{REF}$  is expected to be about  $0.5 \times V_{DDQ}$  of the transmitting device and  $V_{REF}$  is expected to track variations in  $V_{DDQ}$ .
- Peak to peak ac noise on  $V_{REF}$  may not exceed  $\pm 2\%$   $V_{REF}$  (dc)
- $V_{TT}$  is not applied directly to the device.  $V_{TT}$  is a system supply for signal termination resistors, is expected to be set equal to  $V_{REF}$ , and must track variations in die dc level of  $V_{REF}$ .

**TABLE 25**  
ODT DC Electrical Characteristics

| Parameter / Condition  | Symbol      | Min.  | Nom. | Max.   | Unit     | Note |
|--|-------------|-------|------|--------|----------|------|
| Termination resistor impedance value for EMRS(1)[A6,A2] = [0,1]; 75 Ohm  | Rtt1(eff)   | 60    | 75   | 90     | $\Omega$ | 1)   |
| Termination resistor impedance value for EMRS(1)[A6,A2] = [1,0]; 150 Ohm | Rtt2(eff)   | 120   | 150  | 180    | $\Omega$ | 1)   |
| Termination resistor impedance value for EMRS(1)(A6,A2)=[1,1]; 50 Ohm    | Rtt3(eff)   | 40    | 50   | 60     | $\Omega$ | 1)   |
| Deviation of $V_M$ with respect to $V_{DDQ} / 2$                         | delta $V_M$ | -6.00 | —    | + 6.00 | %        | 2)   |

- Measurement Definition for Rtt(eff): Apply  $V_{IH(ac)}$  and  $V_{IL(ac)}$  to test pin separately, then measure current  $I(V_{IH(ac)})$  and  $I(V_{IL(ac)})$  respectively.  
 $Rtt(eff) = (V_{IH(ac)} - V_{IL(ac)}) / (I(V_{IH(ac)}) - I(V_{IL(ac)}))$ .
- Measurement Definition for  $V_M$ : Turn ODT on and measure voltage ( $V_M$ ) at test pin (midpoint) with no load:  
 $delta V_M = ((2 \times V_M / V_{DDQ}) - 1) \times 100\%$

**TABLE 26**  
Input and Output Leakage Currents

| Symbol   | Parameter / Condition                                 | Min. | Max. | Unit    | Note |
|----------|---|------|------|---------|------|
| $I_{IL}$ | Input Leakage Current; any input $0V < I^1N < V_{DD}$ | -2   | +2   | $\mu A$ | 1)   |
| $I_{OL}$ | Output Leakage Current; $0V < V_{OUT} < V_{DDQ}$      | -5   | +5   | $\mu A$ | 2)   |

- All other pins not under test = 0 V
- DQ's, LDQS,  $\overline{LDQS}$ , UDQS,  $\overline{UDQS}$ , DQS,  $\overline{DQS}$ , RDQS,  $\overline{RDQS}$  are disabled and ODT is turned off.



### 5.3 DC & AC Characteristics

DDR2 SDRAM pin timing are specified for either single ended or differential mode depending on the setting of the EMRS(1) “Enable DQS” mode bit; timing advantages of differential mode are realized in system design. The method by which the DDR2 SDRAM pin timing are measured is mode dependent. In single ended mode, timing relationships are measured relative to the rising or falling edges of DQS crossing at  $V_{REF}$ .

In differential mode, these timing relationships are measured relative to the crosspoint of DQS and its complement,  $\overline{DQS}$ . This distinction in timing methods is verified by design and characterization but not subject to production test. In single ended mode, the  $\overline{DQS}$  (and  $\overline{RDQS}$ ) signals are internally disabled and don't care.

**TABLE 27**  
DC & AC Logic Input Levels for DDR2-667 and DDR2-800

| Symbol       | Parameter           | DDR2-667, DDR2-800 |                   | Units |
|--------------|---------------------|--------------------|-------------------|-------|
|              |                     | Min.               | Max.              |       |
| $V_{IH(dc)}$ | DC input logic high | $V_{REF} + 0.125$  | $V_{DDQ} + 0.3$   | V     |
| $V_{IL(dc)}$ | DC input low        | -0.3               | $V_{REF} - 0.125$ | V     |
| $V_{IH(ac)}$ | AC input logic high | $V_{REF} + 0.200$  | —                 | V     |
| $V_{IL(ac)}$ | AC input low        | —                  | $V_{REF} - 0.200$ | V     |

**TABLE 28**  
DC & AC Logic Input Levels for DDR2-533 and DDR2-400

| Symbol       | Parameter           | DDR2-533, DDR2-400 |                   | Units |
|--------------|---------------------|--------------------|-------------------|-------|
|              |                     | Min.               | Max.              |       |
| $V_{IH(dc)}$ | DC input logic high | $V_{REF} + 0.125$  | $V_{DDQ} + 0.3$   | V     |
| $V_{IL(dc)}$ | DC input low        | -0.3               | $V_{REF} - 0.125$ | V     |
| $V_{IH(ac)}$ | AC input logic high | $V_{REF} + 0.250$  | —                 | V     |
| $V_{IL(ac)}$ | AC input low        | —                  | $V_{REF} - 0.250$ | V     |

**TABLE 29**  
Single-ended AC Input Test Conditions

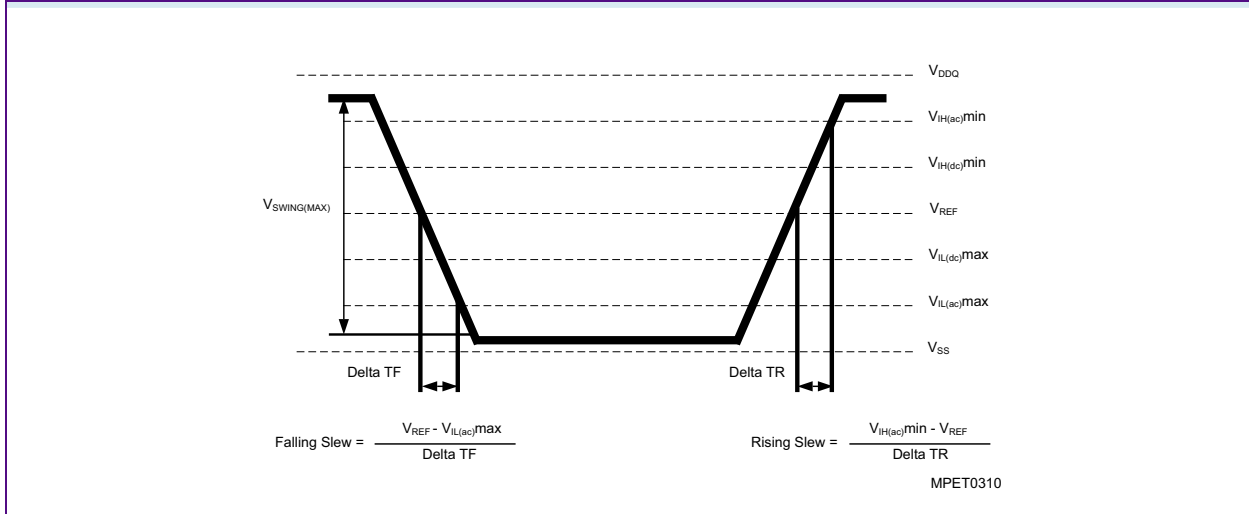
| Symbol          | Condition                               | Value                | Unit   | Note |
|-----------------|---|----------------------|--------|------|
| $V_{REF}$       | Input reference voltage                 | $0.5 \times V_{DDQ}$ | V      | 1)   |
| $V_{SWING,MAX}$ | Input signal maximum peak to peak swing | 1.0                  | V      | 1)   |
| SLEW            | Input signal minimum Slew Rate          | 1.0                  | V / ns | 2)3) |

- 1) Input waveform timing is referenced to the input signal crossing through the  $V_{REF}$  level applied to the device under test.
- 2) The input signal minimum Slew Rate is to be maintained over the range from  $V_{IH(ac),MIN}$  to  $V_{REF}$  for rising edges and the range from  $V_{REF}$  to  $V_{IL(ac),MAX}$  for falling edges as shown in **Figure 4**
- 3) AC timings are referenced with input waveforms switching from  $V_{IL(ac)}$  to  $V_{IH(ac)}$  on the positive transitions and  $V_{IH(ac)}$  to  $V_{IL(ac)}$  on the negative transitions.



**FIGURE 4**

**Single-ended AC Input Test Conditions Diagram**



**TABLE 30**

**Differential DC and AC Input and Output Logic Levels**

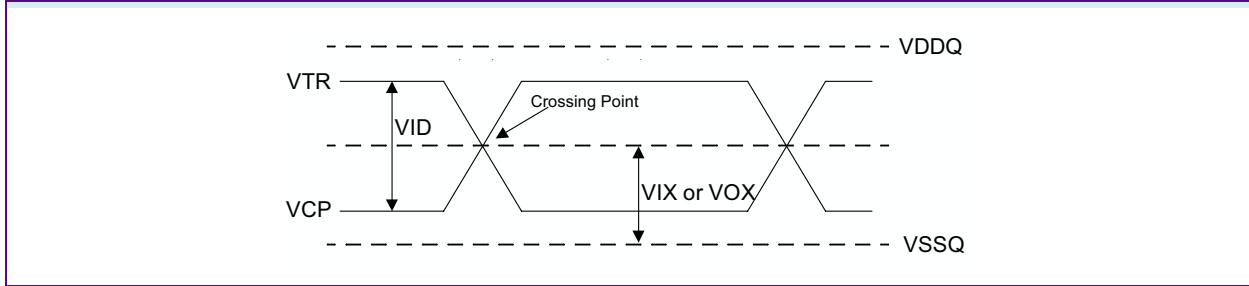
| Symbol       | Parameter                                  | Min.                         | Max.                         | Unit | Note |
|--------------|--|------------------------------|------------------------------|------|------|
| $V_{IN(dc)}$ | DC input signal voltage                    | -0.3                         | $V_{DDQ} + 0.3$              | —    | 1)   |
| $V_{ID(dc)}$ | DC differential input voltage              | 0.25                         | $V_{DDQ} + 0.6$              | —    | 2)   |
| $V_{ID(ac)}$ | AC differential input voltage              | 0.5                          | $V_{DDQ} + 0.6$              | V    | 3)   |
| $V_{IX(ac)}$ | AC differential cross point input voltage  | $0.5 \times V_{DDQ} - 0.175$ | $0.5 \times V_{DDQ} + 0.175$ | V    | 4)   |
| $V_{OX(ac)}$ | AC differential cross point output voltage | $0.5 \times V_{DDQ} - 0.125$ | $0.5 \times V_{DDQ} + 0.125$ | V    | 5)   |

- 1)  $V_{IN(dc)}$  specifies the allowable DC execution of each input of differential pair such as CK, CK, DQS, DQS etc.
- 2)  $V_{ID(dc)}$  specifies the input differential voltage  $V_{TR} - V_{CP}$  required for switching. The minimum value is equal to  $V_{IH(dc)} - V_{IL(dc)}$ .
- 3)  $V_{ID(ac)}$  specifies the input differential voltage  $V_{TR} - V_{CP}$  required for switching. The minimum value is equal to  $V_{IH(ac)} - V_{IL(ac)}$ .
- 4) The value of  $V_{IX(ac)}$  is expected to equal  $0.5 \times V_{DDQ}$  of the transmitting device and  $V_{IX(ac)}$  is expected to track variations in  $V_{DDQ}$ .  $V_{IX(ac)}$  indicates the voltage at which differential input signals must cross.
- 5) The value of  $V_{OX(ac)}$  is expected to equal  $0.5 \times V_{DDQ}$  of the transmitting device and  $V_{OX(ac)}$  is expected to track variations in  $V_{DDQ}$ .  $V_{OX(ac)}$  indicates the voltage at which differential input signals must cross.



**FIGURE 5**

**Differential DC and AC Input and Output Logic Levels Diagram**



## 5.4 Output Buffer Characteristics

This chapter describes the Output Buffer Characteristics.

**TABLE 31**

**SSTL\_18 Output DC Current Drive**

| Symbol   | Parameter                        | SSTL_18 | Unit | Note |
|----------|----------------------------------|---------|------|------|
| $I_{OH}$ | Output Minimum Source DC Current | -13.4   | mA   | 1)2) |
| $I_{OL}$ | Output Minimum Sink DC Current   | 13.4    | mA   | 2)3) |

- 1)  $V_{DDQ} = 1.7\text{ V}$ ;  $V_{OUT} = 1.42\text{ V}$ .  $(V_{OUT} - V_{DDQ}) / I_{OH}$  must be less than 21 Ohm for values of  $V_{OUT}$  between  $V_{DDQ}$  and  $V_{DDQ} - 280\text{ mV}$ .
- 2) The values of  $I_{OH(dc)}$  and  $I_{OL(dc)}$  are based on the conditions given in 1) and 3). They are used to test drive current capability to ensure  $V_{IH,MIN}$  plus a noise margin and  $V_{IL,MAX}$  minus a noise margin are delivered to an SSTL\_18 receiver. The actual current values are derived by shifting the desired driver operating points along 21 Ohm load line to define a convenient current for measurement.
- 3)  $V_{DDQ} = 1.7\text{ V}$ ;  $V_{OUT} = 280\text{ mV}$ .  $V_{OUT} / I_{OL}$  must be less than 21 Ohm for values of  $V_{OUT}$  between 0 V and 280 mV.

**TABLE 32**

**SSTL\_18 Output AC Test Conditions**

| Symbol    | Parameter                                 | SSTL_18              | Unit | Note |
|-----------|---|----------------------|------|------|
| $V_{OH}$  | Minimum Required Output Pull-up           | $V_{TT} + 0.603$     | V    | 1)   |
| $V_{OL}$  | Maximum Required Output Pull-down         | $V_{TT} - 0.603$     | V    | 1)   |
| $V_{OTR}$ | Output Timing Measurement Reference Level | $0.5 \times V_{DDQ}$ | V    |      |

- 1) SSTL\_18 test load for  $V_{OH}$  and  $V_{OL}$  is different from the referenced load. The SSTL\_18 test load has a 20 Ohm series resistor additionally to the 25 Ohm termination resistor into  $V_{TT}$ . The SSTL\_18 definition assumes that  $\pm 335\text{ mV}$  must be developed across the effectively 25 Ohm termination resistor ( $13.4\text{ mA} \times 25\text{ Ohm} = 335\text{ mV}$ ). With an additional series resistor of 20 Ohm this translates into a minimum requirement of 603 mV swing relative to  $V_{TT}$ , at the output device ( $13.4\text{ mA} \times 45\text{ Ohm} = 603\text{ mV}$ ).



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**TABLE 33**  
**OCD Default Characteristics**

| Symbol    | Description                                    | Min. | Nominal | Max. | Unit     | Note     |
|-----------|--|------|---------|------|----------|----------|
| —         | Output Impedance                               | —    | —       | —    | $\Omega$ | 1)2)     |
| —         | Pull-up / Pull down mismatch                   | 0    | —       | 4    | $\Omega$ | 1)2)3)   |
| —         | Output Impedance step size for OCD calibration | 0    | —       | 1.5  | $\Omega$ | 4)       |
| $S_{OUT}$ | Output Slew Rate                               | 1.5  | —       | 5.0  | V / ns   | 1)5)6)7) |

- 1)  $V_{DDQ} = 1.8\text{ V} \pm 0.1\text{ V}$ ;  $V_{DD} = 1.8\text{ V} \pm 0.1\text{ V}$
- 2) Impedance measurement condition for output source dc current:  $V_{DDQ} = 1.7\text{ V}$ ,  $V_{OUT} = 1420\text{ mV}$ ;  $(V_{OUT} - V_{DDQ}) / I_{OH}$  must be less than 23.4 Ohms for values of  $V_{OUT}$  between  $V_{DDQ}$  and  $V_{DDQ} - 280\text{ mV}$ . Impedance measurement condition for output sink dc current:  $V_{DDQ} = 1.7\text{ V}$ ;  $V_{OUT} = -280\text{ mV}$ ;  $V_{OUT} / I_{OL}$  must be less than 23.4 Ohms for values of  $V_{OUT}$  between 0 V and 280 mV.
- 3) Mismatch is absolute value between pull-up and pull-down, both measured at same temperature and voltage.
- 4) This represents the step size when the OCD is near 18 Ohms at nominal conditions across all process parameters and represents only the DRAM uncertainty. A 0 Ohm value (no calibration) can only be achieved if the OCD impedance is  $18 \pm 0.75\text{ Ohms}$  under nominal conditions.
- 5) The absolute value of the Slew Rate as measured from DC to DC is equal to or greater than the Slew Rate as measured from AC to AC. This is verified by design and characterization but not subject to production test.
- 6) Timing skew due to DRAM output Slew Rate mis-match between DQS /  $\overline{\text{DQS}}$  and associated DQ's is included in  $t_{DQSQ}$  and  $t_{QHS}$  specification.
- 7) DRAM output Slew Rate specification applies to 400, 533 and 667 MT/s speed bins.



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## 5.5 Input / Output Capacitance

This chapter contains the input / output capacitance.

**TABLE 34**  
Input / Output Capacitance for DDR2-800

| Symbol | Parameter  | DDR2-800 |      |      |
|--------|--|----------|------|------|
|        |  | Min.     | Max. | Unit |
| CCK    | Input capacitance, CK and $\overline{\text{CK}}$   | 1.0      | 2.0  | pF   |
| CDCK   | Input capacitance delta, CK and $\overline{\text{CK}}$   | —        | 0.25 | pF   |
| CI     | Input capacitance, all other input-only pins   | 1.0      | 1.75 | pF   |
| CDI    | Input capacitance delta, all other input-only pins   | —        | 0.25 | pF   |
| CIO    | Input/output capacitance,<br>DQ, DM, DQS, $\overline{\text{DQS}}$ , RDQS, $\overline{\text{RDQS}}$       | 2.5      | 3.5  | pF   |
| CDIO   | Input/output capacitance delta,<br>DQ, DM, DQS, $\overline{\text{DQS}}$ , RDQS, $\overline{\text{RDQS}}$ | —        | 0.5  | pF   |

**TABLE 35**  
Input / Output Capacitance for DDR2-667

| Symbol | Parameter  | DDR2-667 |      |      |
|--------|--|----------|------|------|
|        |  | Min.     | Max. | Unit |
| CCK    | Input capacitance, CK and $\overline{\text{CK}}$   | 1.0      | 2.0  | pF   |
| CDCK   | Input capacitance delta, CK and $\overline{\text{CK}}$   | —        | 0.25 | pF   |
| CI     | Input capacitance, all other input-only pins   | 1.0      | 2.0  | pF   |
| CDI    | Input capacitance delta, all other input-only pins   | —        | 0.25 | pF   |
| CIO    | Input/output capacitance,<br>DQ, DM, DQS, $\overline{\text{DQS}}$ , RDQS, $\overline{\text{RDQS}}$       | 2.5      | 3.5  | pF   |
| CDIO   | Input/output capacitance delta,<br>DQ, DM, DQS, $\overline{\text{DQS}}$ , RDQS, $\overline{\text{RDQS}}$ | —        | 0.5  | pF   |

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Input / Output Capacitance for DDR2-533

| Symbol | Parameter  | DDR2-533 |      |      |
|--------|--|----------|------|------|
|        |  | Min.     | Max. | Unit |
| CCK    | Input capacitance, CK and $\overline{\text{CK}}$   | 1.0      | 2.0  | pF   |
| CDCK   | Input capacitance delta, CK and $\overline{\text{CK}}$   | —        | 0.25 | pF   |
| CI     | Input capacitance, all other input-only pins   | 1.0      | 2.0  | pF   |
| CDI    | Input capacitance delta, all other input-only pins   | —        | 0.25 | pF   |
| CIO    | Input/output capacitance,<br>DQ, DM, DQS, $\overline{\text{DQS}}$ , RDQS, $\overline{\text{RDQS}}$       | 2.5      | 4.0  | pF   |
| CDIO   | Input/output capacitance delta,<br>DQ, DM, DQS, $\overline{\text{DQS}}$ , RDQS, $\overline{\text{RDQS}}$ | —        | 0.5  | pF   |

**TABLE 37**  
Input / Output Capacitance for DDR2-400

| Symbol | Parameter  | DDR2-400 |      |      |
|--------|--|----------|------|------|
|        |  | Min.     | Max. | Unit |
| CCK    | Input capacitance, CK and $\overline{\text{CK}}$   | 1.0      | 2.0  | pF   |
| CDCK   | Input capacitance delta, CK and $\overline{\text{CK}}$   | —        | 0.25 | pF   |
| CI     | Input capacitance, all other input-only pins   | 1.0      | 2.0  | pF   |
| CDI    | Input capacitance delta, all other input-only pins   | —        | 0.25 | pF   |
| CIO    | Input/output capacitance,<br>DQ, DM, DQS, $\overline{\text{DQS}}$ , RDQS, $\overline{\text{RDQS}}$       | 2.5      | 4.0  | pF   |
| CDIO   | Input/output capacitance delta,<br>DQ, DM, DQS, $\overline{\text{DQS}}$ , RDQS, $\overline{\text{RDQS}}$ | —        | 0.5  | pF   |



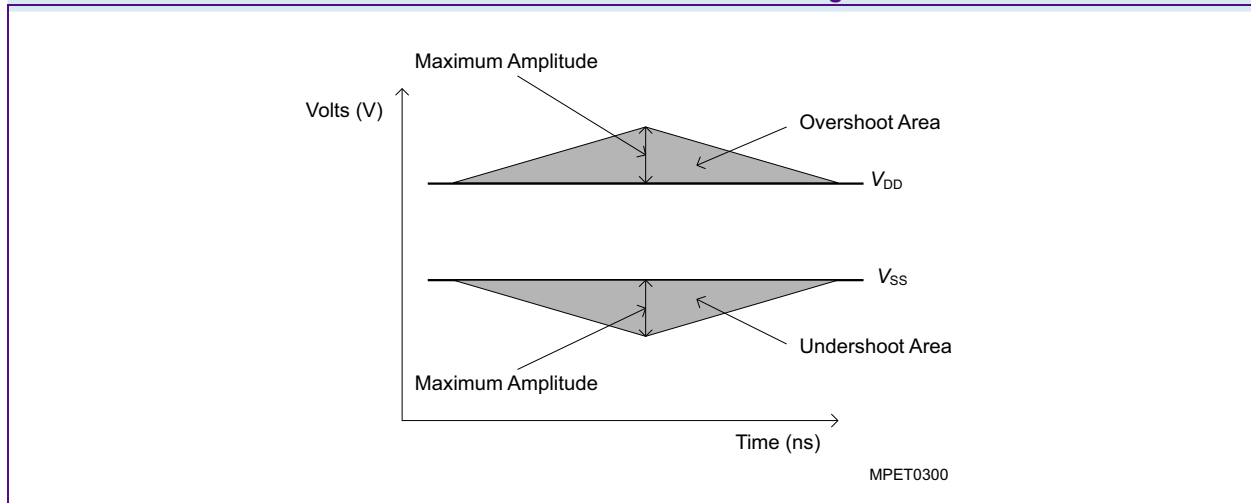
## 5.6 Overshoot and Undershoot Specification

This chapter contains overshoot and undershoot specification.

**TABLE 38**  
**AC Overshoot / Undershoot Specification for Address and Control Pins**

| Parameter  | DDR2-400 | DDR2-533 | DDR2-667 | DDR2-800 | Unit |
|--|----------|----------|----------|----------|------|
| Maximum peak amplitude allowed for overshoot area  | 0.9      | 0.9      | 0.9      | 0.9      | V    |
| Maximum peak amplitude allowed for undershoot area | 0.9      | 0.9      | 0.9      | 0.9      | V    |
| Maximum overshoot area above $V_{DD}$              | 1.33     | 1.00     | 0.80     | 0.66     | V.ns |
| Maximum undershoot area below $V_{SS}$             | 1.33     | 1.00     | 0.80     | 0.66     | V.ns |

**FIGURE 6**  
**AC Overshoot / Undershoot Diagram for Address and Control Pins**



**TABLE 39**  
**AC Overshoot / Undershoot Spec. for Clock, Data, Strobe and Mask Pins**

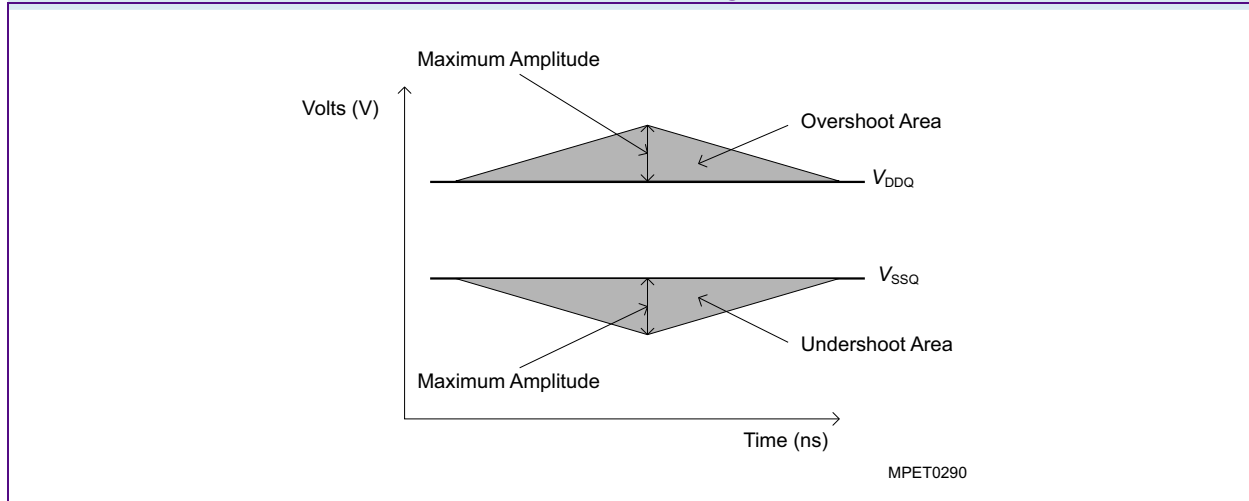
| Parameter  | DDR2-400 | DDR2-533 | DDR2-667 | DDR2-800 | Unit |
|--|----------|----------|----------|----------|------|
| Maximum peak amplitude allowed for overshoot area  | 0.9      | 0.9      | 0.9      | 0.9      | V    |
| Maximum peak amplitude allowed for undershoot area | 0.9      | 0.9      | 0.9      | 0.9      | V    |
| Maximum overshoot area above $V_{DDQ}$             | 0.38     | 0.28     | 0.23     | 0.23     | V.ns |
| Maximum undershoot area below $V_{SSQ}$            | 0.38     | 0.28     | 0.23     | 0.23     | V.ns |



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**FIGURE 7**

**AC Overshoot / Undershoot Diagram for Clock, Data, Strobe and Mask Pins**





## 6 Currents Measurement Conditions

This chapter describes the current measurement specifications and conditions.

**TABLE 40**  
 **$I_{DD}$  Measurement Conditions**

| Parameter  | Symbol        | Note       |
|--|---------------|------------|
| <b>Operating Current - One bank Active - Precharge</b><br>$t_{CK} = t_{CK(IDD)}$ , $t_{RC} = t_{RC(IDD)}$ , $t_{RAS} = t_{RAS.MIN(IDD)}$ ; CKE is HIGH, $\overline{CS}$ is HIGH between valid commands. Address and control inputs are switching; Databus inputs are switching.  | $I_{DD0}$     | 1)2)3)4)5) |
| <b>Operating Current - One bank Active - Read - Precharge</b><br>$I_{OUT} = 0$ mA, $BL = 4$ , $t_{CK} = t_{CK(IDD)}$ , $t_{RC} = t_{RC(IDD)}$ , $t_{RAS} = t_{RAS.MIN(IDD)}$ , $t_{RCD} = t_{RCD(IDD)}$ , $AL = 0$ , $CL = CL(IDD)$ ; CKE is HIGH, $\overline{CS}$ is HIGH between valid commands. Address and control inputs are switching; Databus inputs are switching. | $I_{DD1}$     | 1)2)3)4)5) |
| <b>Precharge Power-Down Current</b><br>All banks idle; CKE is LOW; $t_{CK} = t_{CK(IDD)}$ ; Other control and address inputs are stable; Data bus inputs are floating.   | $I_{DD2P}$    | 1)2)3)4)5) |
| <b>Precharge Standby Current</b><br>All banks idle; $\overline{CS}$ is HIGH; CKE is HIGH; $t_{CK} = t_{CK(IDD)}$ ; Other control and address inputs are switching, Data bus inputs are switching.  | $I_{DD2N}$    | 1)2)3)4)5) |
| <b>Precharge Quiet Standby Current</b><br>All banks idle; $\overline{CS}$ is HIGH; CKE is HIGH; $t_{CK} = t_{CK(IDD)}$ ; Other control and address inputs are stable, Data bus inputs are floating.  | $I_{DD2Q}$    | 1)2)3)4)5) |
| <b>Active Power-Down Current</b><br>All banks open; $t_{CK} = t_{CK(IDD)}$ , CKE is LOW; Other control and address inputs are stable; Data bus inputs are floating. MRS A12 bit is set to "0" (Fast Power-down Exit).  | $I_{DD3P(0)}$ | 1)2)3)4)5) |
| <b>Active Power-Down Current</b><br>All banks open; $t_{CK} = t_{CK(IDD)}$ , CKE is LOW; Other control and address inputs are stable, Data bus inputs are floating. MRS A12 bit is set to 1 (Slow Power-down Exit);  | $I_{DD3P(1)}$ | 1)2)3)4)5) |
| <b>Active Standby Current</b><br>All banks open; $t_{CK} = t_{CK(IDD)}$ ; $t_{RAS} = t_{RAS.MAX(IDD)}$ ; $t_{RP} = t_{RP(IDD)}$ ; CKE is HIGH, $\overline{CS}$ is HIGH between valid commands. Address inputs are switching; Data Bus inputs are switching;  | $I_{DD3N}$    | 1)2)3)4)5) |
| <b>Operating Current</b><br>Burst Read: All banks open; Continuous burst reads; $BL = 4$ ; $AL = 0$ , $CL = CL_{(IDD)}$ ; $t_{CK} = t_{CK(IDD)}$ ; $t_{RAS} = t_{RAS.MAX(IDD)}$ ; $t_{RP} = t_{RP(IDD)}$ ; CKE is HIGH, $\overline{CS}$ is HIGH between valid commands. Address inputs are switching; Data Bus inputs are switching; $I_{OUT} = 0$ mA.                     | $I_{DD4R}$    | 1)2)3)4)5) |
| <b>Operating Current</b><br>Burst Write: All banks open; Continuous burst writes; $BL = 4$ ; $AL = 0$ , $CL = CL_{(IDD)}$ ; $t_{CK} = t_{CK(IDD)}$ ; $t_{RAS} = t_{RAS.MAX(IDD)}$ ; $t_{RP} = t_{RP(IDD)}$ ; CKE is HIGH, $\overline{CS}$ is HIGH between valid commands. Address inputs are switching; Data Bus inputs are switching;                                     | $I_{DD4W}$    | 1)2)3)4)5) |
| <b>Burst Refresh Current</b><br>$t_{CK} = t_{CK(IDD)}$ , Refresh command every $t_{RFC} = t_{RFC(IDD)}$ interval, CKE is HIGH, $\overline{CS}$ is HIGH between valid commands, Other control and address inputs are switching, Data bus inputs are switching.  | $I_{DD5B}$    | 1)2)3)4)5) |
| <b>Distributed Refresh Current</b><br>$t_{CK} = t_{CK(IDD)}$ , Refresh command every $t_{REFI} = 7.8$ $\mu$ s interval, CKE is LOW and $\overline{CS}$ is HIGH between valid commands, Other control and address inputs are switching, Data bus inputs are switching.  | $I_{DD5D}$    | 1)2)3)4)5) |



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| Parameter  | Symbol           | Note         |
|--|------------------|--------------|
| <b>Self-Refresh Current</b><br>CKE $\leq$ 0.2 V; external clock off, CK and $\overline{\text{CK}}$ at 0 V; Other control and address inputs are floating, Data bus inputs are floating.  | $I_{\text{DD6}}$ | 1)2)3)4)5)   |
| <b>Operating Bank Interleave Read Current</b><br>1. All banks interleaving reads, $I_{\text{OUT}} = 0$ mA; BL = 4, CL = CL <sub>(IDD)</sub> , AL = $t_{\text{RCD(IDD)}} - 1 \times t_{\text{CK(IDD)}}$ ; $t_{\text{CK}} = t_{\text{CK(IDD)}}$ , $t_{\text{RC}} = t_{\text{RC(IDD)}}$ , $t_{\text{RRD}} = t_{\text{RRD(IDD)}}$ ; CKE is HIGH, $\overline{\text{CS}}$ is HIGH between valid commands. Address bus inputs are stable during deselects; Data bus is switching.<br>2. Timing pattern: | $I_{\text{DD7}}$ | 1)2)3)4)5)6) |
| DDR2-400-333: A0 RA0 A1 RA1 A2 RA2 A3 RA3 D D D (11 clocks)  |                  |              |
| DDR2-667-444: A0 RA0 D D A1 RA1 D D A2 RA2 D D A3 RA3 D D D D D (19 clocks)  |                  |              |
| DDR2-667-555: A0 RA0 D D A1 RA1 D D A2 RA2 D D A3 RA3 D D D D D (20 clocks)  |                  |              |
| DDR2-800-555: A0 RA0 D D D A1 RA1 D D D A2 RA2 D D D A3 RA3 D D D D D (22 clocks)  |                  |              |
| DDR2-800-666: A0 RA0 D D D A1 RA1 D D D A2 RA2 D D D A3 RA3 D D D D D (23 clocks)  |                  |              |

- 1)  $V_{\text{DDQ}} = 1.8 \text{ V} \pm 0.1 \text{ V}$ ;  $V_{\text{DD}} = 1.8 \text{ V} \pm 0.1 \text{ V}$
- 2)  $I_{\text{DD}}$  specifications are tested after the device is properly initialized.
- 3)  $I_{\text{DD}}$  parameter are specified with ODT disabled.
- 4) Data Bus consists of DQ, DM, DQS,  $\overline{\text{DQS}}$ , RDQS,  $\overline{\text{RDQS}}$ , LDQS,  $\overline{\text{LDQS}}$ , UDQS and  $\overline{\text{UDQS}}$ .
- 5) Definitions for  $I_{\text{DD}}$ : see **Table 41**
- 6) A = Activate, RA = Read with Auto-Precharge, D=DESELECT

**TABLE 41**  
Definition for  $I_{\text{DD}}$

| Parameter | Description  |
|-----------|--|
| LOW       | defined as $V_{\text{IN}} \leq V_{\text{IL(ac).MAX}}$  |
| HIGH      | defined as $V_{\text{IN}} \geq V_{\text{IH(ac).MIN}}$  |
| STABLE    | defined as inputs are stable at a HIGH or LOW level  |
| FLOATING  | defined as inputs are $V_{\text{REF}} = V_{\text{DDQ}} / 2$  |
| SWITCHING | defined as: Inputs are changing between high and low every other clock (once per two clocks) for address and control signals, and inputs changing between high and low every other clock (once per clock) for DQ signals not including mask or strobes |



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**TABLE 42**  
 **$I_{DD}$  Specification**

|        | -25F      | -2.5      | -3        | -3S       | -3.7      | -5        | Unit | Note          |
|--------|-----------|-----------|-----------|-----------|-----------|-----------|------|---------------|
|        | DDR2-800D | DDR2-800E | DDR2-667C | DDR2-667D | DDR2-533C | DDR2-400B |      |               |
| Symbol | Max.      | Max.      | Max.      | Max.      | Max.      | Max.      |      |               |
| IDD0   | 84        | 80        | 75        | 71        | 65        | 61        | mA   | ×4/×8         |
|        | 105       | 100       | 95        | 90        | 80        | 75        | mA   | ×16           |
| IDD1   | 100       | 95        | 90        | 85        | 75        | 70        | mA   | ×4/×8         |
|        | 120       | 115       | 105       | 100       | 90        | 83        | mA   | ×16           |
| IDD2P  | 7         | 7         | 7         | 7         | 7         | 7         | mA   |               |
| IDD2N  | 51        | 51        | 45        | 45        | 38        | 34        | mA   |               |
| IDD2Q  | 45        | 45        | 40        | 40        | 35        | 32        | mA   |               |
| IDD3P  | 39        | 39        | 33        | 33        | 28        | 24        | mA   | <sup>1)</sup> |
|        | 9         | 9         | 9         | 9         | 9         | 9         | mA   | <sup>2)</sup> |
| IDD3N  | 60        | 60        | 50        | 50        | 43        | 39        | mA   |               |
| IDD4R  | 155       | 155       | 130       | 130       | 110       | 95        | mA   | ×4/×8         |
|        | 180       | 180       | 155       | 155       | 130       | 115       | mA   | ×16           |
| IDD4W  | 155       | 155       | 130       | 130       | 110       | 95        | mA   | ×4/×8         |
|        | 200       | 200       | 170       | 170       | 145       | 130       | mA   | ×16           |
| IDD5B  | 145       | 145       | 140       | 140       | 130       | 125       | mA   |               |
| IDD5D  | 9         | 9         | 9         | 9         | 9         | 9         | mA   | <sup>3)</sup> |
| IDD6   | 7         | 7         | 7         | 7         | 7         | 7         | mA   | <sup>3)</sup> |
| IDD7   | 170       | 160       | 160       | 152       | 145       | 141       | mA   | ×4/×8         |
|        | 265       | 255       | 252       | 240       | 230       | 220       | mA   | ×16           |

1) MRS(12)=0

2) MRS(12)=1

3)  $0^\circ \leq T_{CASE} \leq 85^\circ C$ .



# 7 Timing Characteristics

This chapter contains speed grade definition, AC timing parameter and ODT tables.

## 7.1 Speed Grade Definitions

All Speed grades faster than DDR2-400B comply with DDR2-400B timing specifications ( $t_{CK} = 5\text{ns}$  with  $t_{RAS} = 40\text{ns}$ ).

**TABLE 43**  
Speed Grade Definition Speed Bins for DDR2-800

| Speed Grade          |           | DDR2-800D |       | DDR2-800E |       | Unit     | Note       |          |
|----------------------|-----------|-----------|-------|-----------|-------|----------|------------|----------|
| QAG Sort Name        |           | -25F      |       | -2.5      |       |          |            |          |
| CAS-RCD-RP latencies |           | 5-5-5     |       | 6-6-6     |       | $t_{CK}$ |            |          |
| Parameter            | Symbol    | Min.      | Max.  | Min.      | Max.  | —        |            |          |
| Clock Frequency      | @ CL = 3  | $t_{CK}$  | 5     | 8         | 5     | 8        | ns         | 1)2)3)4) |
|                      | @ CL = 4  | $t_{CK}$  | 3.75  | 8         | 3.75  | 8        | ns         | 1)2)3)4) |
|                      | @ CL = 5  | $t_{CK}$  | 2.5   | 8         | 3     | 8        | ns         | 1)2)3)4) |
|                      | @ CL = 6  | $t_{CK}$  | 2.5   | 8         | 2.5   | 8        | ns         | 1)2)3)4) |
| Row Active Time      | $t_{RAS}$ | 45        | 70000 | 45        | 70000 | ns       | 1)2)3)4)5) |          |
| Row Cycle Time       | $t_{RC}$  | 57.5      | —     | 60        | —     | ns       | 1)2)3)4)   |          |
| RAS-CAS-Delay        | $t_{RCD}$ | 12.5      | —     | 15        | —     | ns       | 1)2)3)4)   |          |
| Row Precharge Time   | $t_{RP}$  | 12.5      | —     | 15        | —     | ns       | 1)2)3)4)   |          |

- 1) Timings are guaranteed with  $\overline{CK}/\overline{CK}$  differential Slew Rate of 2.0 V/ns. For DQS signals timings are guaranteed with a differential Slew Rate of 2.0 V/ns in differential strobe mode and a Slew Rate of 1 V/ns in single ended mode. Timings are further guaranteed for normal OCD drive strength (EMRS(1) A1 = 0) under the "Reference Load for Timing Measurements".
- 2) The  $\overline{CK}/\overline{CK}$  input reference level (for timing reference to  $\overline{CK}/\overline{CK}$ ) is the point at which CK and  $\overline{CK}$  cross. The  $DQS / \overline{DQS}$ ,  $RDQS / \overline{RDQS}$ , input reference level is the crosspoint when in differential strobe mode; The input reference level for signals other than  $\overline{CK}/\overline{CK}$ ,  $DQS / \overline{DQS}$ ,  $RDQS / \overline{RDQS}$  is defined .
- 3) Inputs are not recognized as valid until  $V_{REF}$  stabilizes. During the period before  $V_{REF}$  stabilizes,  $CKE = 0.2 \times V_{DDQ}$  is recognized as low.
- 4) The output timing reference voltage level is  $V_{TT}$ .
- 5)  $t_{RAS,MAX}$  is calculated from the maximum amount of time a DDR2 device can operate without a refresh command which is equal to  $9 \times t_{REFI}$ .





**TABLE 44**  
Speed Grade Definition Speed Bins for DDR2-667

| Speed Grade          |           | DDR2-667C |       | DDR2-667D |       | Unit     | Note       |          |
|----------------------|-----------|-----------|-------|-----------|-------|----------|------------|----------|
| QAG Sort Name        |           | -3        |       | -3S       |       |          |            |          |
| CAS-RCD-RP latencies |           | 4-4-4     |       | 5-5-5     |       | $t_{CK}$ |            |          |
| Parameter            | Symbol    | Min.      | Max.  | Min.      | Max.  | —        |            |          |
| Clock Frequency      | @ CL = 3  | $t_{CK}$  | 5     | 8         | 5     | 8        | ns         | 1)2)3)4) |
|                      | @ CL = 4  | $t_{CK}$  | 3     | 8         | 3.75  | 8        | ns         | 1)2)3)4) |
|                      | @ CL = 5  | $t_{CK}$  | 3     | 8         | 3     | 8        | ns         | 1)2)3)4) |
| Row Active Time      | $t_{RAS}$ | 45        | 70000 | 45        | 70000 | ns       | 1)2)3)4)5) |          |
| Row Cycle Time       | $t_{RC}$  | 57        | —     | 60        | —     | ns       | 1)2)3)4)   |          |
| RAS-CAS-Delay        | $t_{RCD}$ | 12        | —     | 15        | —     | ns       | 1)2)3)4)   |          |
| Row Precharge Time   | $t_{RP}$  | 12        | —     | 15        | —     | ns       | 1)2)3)4)   |          |

- 1) Timings are guaranteed with CK/ $\overline{CK}$  differential Slew Rate of 2.0 V/ns. For DQS signals timings are guaranteed with a differential Slew Rate of 2.0 V/ns in differential strobe mode and a Slew Rate of 1 V/ns in single ended mode. Timings are further guaranteed for normal OCD drive strength (EMRS(1) A1 = 0) under the "Reference Load for Timing Measurements".
- 2) The CK/ $\overline{CK}$  input reference level (for timing reference to CK/ $\overline{CK}$ ) is the point at which CK and  $\overline{CK}$  cross. The DQS /  $\overline{DQS}$ , RDQS /  $\overline{RDQS}$ , input reference level is the crosspoint when in differential strobe mode; The input reference level for signals other than CK/CK, DQS /  $\overline{DQS}$ , RDQS /  $\overline{RDQS}$  is defined.
- 3) Inputs are not recognized as valid until  $V_{REF}$  stabilizes. During the period before  $V_{REF}$  stabilizes,  $CKE = 0.2 \times V_{DDQ}$  is recognized as low.
- 4) The output timing reference voltage level is  $V_{TT}$ .
- 5)  $t_{RAS,MAX}$  is calculated from the maximum amount of time a DDR2 device can operate without a refresh command which is equal to  $9 \times t_{REFI}$ .

**TABLE 45**  
Speed Grade Definition Speed Bins for DDR2-533

| Speed Grade          |           | DDR2-533C |       | DDR2-533B |       | Unit     | Note       |          |
|----------------------|-----------|-----------|-------|-----------|-------|----------|------------|----------|
| QAG Sort Name        |           | -3.7      |       | -37F      |       |          |            |          |
| CAS-RCD-RP latencies |           | 4-4-4     |       | 3-3-3     |       | $t_{CK}$ |            |          |
| Parameter            | Symbol    | Min.      | Max.  | Min.      | Max.  | —        |            |          |
| Clock Frequency      | @ CL = 3  | $t_{CK}$  | 5     | 8         | 3.75  | 8        | ns         | 1)2)3)4) |
|                      | @ CL = 4  | $t_{CK}$  | 3.75  | 8         | 3.75  | 8        | ns         | 1)2)3)4) |
|                      | @ CL = 5  | $t_{CK}$  | 3.75  | 8         | 3.75  | 8        | ns         | 1)2)3)4) |
| Row Active Time      | $t_{RAS}$ | 45        | 70000 | 45        | 70000 | ns       | 1)2)3)4)5) |          |
| Row Cycle Time       | $t_{RC}$  | 60        | —     | 56.25     | —     | ns       | 1)2)3)4)   |          |
| RAS-CAS-Delay        | $t_{RCD}$ | 15        | —     | 11.25     | —     | ns       | 1)2)3)4)   |          |
| Row Precharge Time   | $t_{RP}$  | 15        | —     | 11.25     | —     | ns       | 1)2)3)4)   |          |

- 1) Timings are guaranteed with CK/ $\overline{CK}$  differential Slew Rate of 2.0 V/ns. For DQS signals timings are guaranteed with a differential Slew Rate of 2.0 V/ns in differential strobe mode and a Slew Rate of 1 V/ns in single ended mode. Timings are further guaranteed for normal OCD drive strength (EMRS(1) A1 = 0) under the "Reference Load for Timing Measurements".
- 2) The CK/ $\overline{CK}$  input reference level (for timing reference to CK/ $\overline{CK}$ ) is the point at which CK and  $\overline{CK}$  cross. The DQS /  $\overline{DQS}$ , RDQS /  $\overline{RDQS}$ , input reference level is the crosspoint when in differential strobe mode; The input reference level for signals other than CK/CK, DQS /  $\overline{DQS}$ , RDQS /  $\overline{RDQS}$  is defined.



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- 3) Inputs are not recognized as valid until  $V_{REF}$  stabilizes. During the period before  $V_{REF}$  stabilizes,  $CKE = 0.2 \times V_{DDQ}$  is recognized as low.
- 4) The output timing reference voltage level is  $V_{TT}$ .
- 5)  $t_{RAS,MAX}$  is calculated from the maximum amount of time a DDR2 device can operate without a refresh command which is equal to  $9 \times t_{REFI}$ .

**TABLE 46**  
Speed Grade Definition Speed Bins for DDR2-400B

| Speed Grade          |           | DDR2-400B |       | Unit     | Note       |          |
|----------------------|-----------|-----------|-------|----------|------------|----------|
| QAG Sort Name        |           | -5        |       |          |            |          |
| CAS-RCD-RP latencies |           | 3-3-3     |       | $t_{CK}$ |            |          |
| Parameter            | Symbol    | Min.      | Max.  | —        | —          |          |
| Clock Frequency      | @ CL = 3  | $t_{CK}$  | 5     | 8        | ns         | 1)2)3)4) |
|                      | @ CL = 4  | $t_{CK}$  | 5     | 8        | ns         | 1)2)3)4) |
|                      | @ CL = 5  | $t_{CK}$  | 5     | 8        | ns         | 1)2)3)4) |
| Row Active Time      | $t_{RAS}$ | 40        | 70000 | ns       | 1)2)3)4)5) |          |
| Row Cycle Time       | $t_{RC}$  | 55        | —     | ns       | 1)2)3)4)   |          |
| RAS-CAS-Delay        | $t_{RCD}$ | 15        | —     | ns       | 1)2)3)4)   |          |
| Row Precharge Time   | $t_{RP}$  | 15        | —     | ns       | 1)2)3)4)   |          |

- 1) Timings are guaranteed with CK/CK differential Slew Rate of 2.0 V/ns. For DQS signals timings are guaranteed with a differential Slew Rate of 2.0 V/ns in differential strobe mode and a Slew Rate of 1 V/ns in single ended mode. Timings are further guaranteed for normal OCD drive strength (EMRS(1) A1 = 0).
- 2) The CK/CK input reference level (for timing reference to CK/CK) is the point at which CK and CK cross. The DQS / DQS, RDQS / RDQS, input reference level is the crosspoint when in differential strobe mode.
- 3) Inputs are not recognized as valid until  $V_{REF}$  stabilizes. During the period before  $V_{REF}$  stabilizes,  $CKE = 0.2 \times V_{DDQ}$  is recognized as low.
- 4) The output timing reference voltage level is  $V_{TT}$ . See section 8 for the reference load for timing measurements.
- 5)  $t_{RAS,MAX}$  is calculated from the maximum amount of time a DDR2 device can operate without a refresh command which is equal to  $9 \times t_{REFI}$ .



## 7.2 Component AC Timing Parameters

List of Timing Parameters Tables.

**TABLE 47**  
**DRAM Component Timing Parameter by Speed Grade - DDR2-800**

| Parameter  | Symbol        | DDR2-800                           |              | Unit         | Note<br>1)2)3)4)5)6)7) |
|--|---------------|------------------------------------|--------------|--------------|------------------------|
|  |               | Min.                               | Max.         |              |                        |
| DQ output access time from CK / $\overline{\text{CK}}$           | $t_{AC}$      | -400                               | +400         | ps           | 8)                     |
| CAS to CAS command delay   | $t_{CCD}$     | 2                                  | —            | $n_{CK}$     |                        |
| Average clock high pulse width                                   | $t_{CH.AVG}$  | 0.48                               | 0.52         | $t_{CK.AVG}$ | 9)10)                  |
| Average clock period   | $t_{CK.AVG}$  | 2500                               | 8000         | ps           | 9)10)                  |
| CKE minimum pulse width ( high and low pulse width)              | $t_{CKE}$     | 3                                  | —            | $n_{CK}$     | 11)                    |
| Average clock low pulse width                                    | $t_{CL.AVG}$  | 0.48                               | 0.52         | $t_{CK.AVG}$ | 9)10)                  |
| Auto-Precharge write recovery + precharge time                   | $t_{DAL}$     | WR + $t_{nRP}$                     | —            | $n_{CK}$     | 12)13)                 |
| Minimum time clocks remain ON after CKE asynchronously drops LOW | $t_{DELAY}$   | $t_{IS} + t_{CK.AVG} + t_{IH}$     | —            | ns           |                        |
| DQ and DM input hold time  | $t_{DH.BASE}$ | 125                                | —            | ps           | 18)19)14)              |
| DQ and DM input pulse width for each input                       | $t_{DIPW}$    | 0.35                               | —            | $t_{CK.AVG}$ |                        |
| DQS output access time from CK / $\overline{\text{CK}}$          | $t_{DQSCK}$   | -350                               | +350         | ps           | 8)                     |
| DQS input high pulse width                                       | $t_{DQSH}$    | 0.35                               | —            | $t_{CK.AVG}$ |                        |
| DQS input low pulse width  | $t_{DQSL}$    | 0.35                               | —            | $t_{CK.AVG}$ |                        |
| DQS-DQ skew for DQS & associated DQ signals                      | $t_{DQSQ}$    | —                                  | 200          | ps           | 15)                    |
| DQS latching rising transition to associated clock edges         | $t_{DQSS}$    | -0.25                              | +0.25        | $t_{CK.AVG}$ | 16)                    |
| DQ and DM input setup time                                       | $t_{DS.BASE}$ | 50                                 | —            | ps           | 17)18)19)              |
| DQS falling edge hold time from CK                               | $t_{DSH}$     | 0.2                                | —            | $t_{CK.AVG}$ | 16)                    |
| DQS falling edge to CK setup time                                | $t_{DSS}$     | 0.2                                | —            | $t_{CK.AVG}$ | 16)                    |
| CK half pulse width  | $t_{HP}$      | Min( $t_{CH.ABS}$ , $t_{CL.ABS}$ ) | —            | ps           | 20)                    |
| Data-out high-impedance time from CK / $\overline{\text{CK}}$    | $t_{HZ}$      | —                                  | $t_{AC.MAX}$ | ps           | 8)21)                  |
| Address and control input hold time                              | $t_{IH.BASE}$ | 250                                | —            | ps           | 22)24)                 |
| Control & address input pulse width for each input               | $t_{IPW}$     | 0.6                                | —            | $t_{CK.AVG}$ |                        |
| Address and control input setup time                             | $t_{IS.BASE}$ | 175                                | —            | ps           | 23)24)                 |
| DQ low impedance time from CK/ $\overline{\text{CK}}$            | $t_{LZ.DQ}$   | $2 \times t_{AC.MIN}$              | $t_{AC.MAX}$ | ps           | 8)21)                  |
| DQS/DQS low-impedance time from CK / $\overline{\text{CK}}$      | $t_{LZ.DQS}$  | $t_{AC.MIN}$                       | $t_{AC.MAX}$ | ps           | 8)21)                  |
| MRS command to ODT update delay                                  | $t_{MOD}$     | 0                                  | 12           | ns           | 34)                    |
| Mode register set command cycle time                             | $t_{MRD}$     | 2                                  | —            | $n_{CK}$     |                        |
| OCD drive mode output delay                                      | $t_{OIT}$     | 0                                  | 12           | ns           | 34)                    |
| DQ/DQS output hold time from DQS                                 | $t_{QH}$      | $t_{HP} - t_{QHS}$                 | —            | ps           | 25)                    |
| DQ hold skew factor  | $t_{QHS}$     | —                                  | 300          | ps           | 26)                    |



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| Parameter   | Symbol      | DDR2-800                   |      | Unit          | Note<br>1)2)3)4)5)6)7) |
|---|-------------|----------------------------|------|---------------|------------------------|
|   |             | Min.                       | Max. |               |                        |
| Average periodic refresh Interval   | $t_{REFI}$  | —                          | 7.8  | $\mu\text{s}$ | 27)28)                 |
|   |             | —                          | 3.9  | $\mu\text{s}$ | 28)29)                 |
| Auto-Refresh to Active/Auto-Refresh command period                          | $t_{RFC}$   | 105                        | —    | ns            | 30)                    |
| Precharge-All (4 banks) command period                                      | $t_{RP}$    | $t_{RP}$                   | —    | ns            |                        |
| Precharge-All (8 banks) command period                                      | $t_{RP}$    | $t_{RP} + 1 \times t_{CK}$ | —    | ns            |                        |
| Read preamble   | $t_{RPRE}$  | 0.9                        | 1.1  | $t_{CK,AVG}$  | 31)32)                 |
| Read postamble  | $t_{RPST}$  | 0.4                        | 0.6  | $t_{CK,AVG}$  | 31)33)                 |
| Internal Read to Precharge command delay                                    | $t_{RTP}$   | 7.5                        | —    | ns            | 34)                    |
| Write preamble  | $t_{WPRE}$  | 0.35                       | —    | $t_{CK,AVG}$  |                        |
| Write postamble   | $t_{WPST}$  | 0.4                        | 0.6  | $t_{CK,AVG}$  |                        |
| Write recovery time   | $t_{WR}$    | 15                         | —    | ns            | 34)                    |
| Internal write to read command delay  | $t_{WTR}$   | 7.5                        | —    | ns            | 34)35)                 |
| Exit power down to read command   | $t_{XARD}$  | 2                          | —    | $n_{CK}$      |                        |
| Exit active power-down mode to read command (slow exit, lower power)        | $t_{XARDS}$ | 8 – AL                     | —    | $n_{CK}$      |                        |
| Exit precharge power-down to any valid command (other than NOP or Deselect) | $t_{XP}$    | 2                          | —    | $n_{CK}$      |                        |
| Exit self-refresh to a non-read command                                     | $t_{XSNR}$  | $t_{RFC} + 10$             | —    | ns            | 34)                    |
| Exit self-refresh to read command   | $t_{XSRD}$  | 200                        | —    | $n_{CK}$      |                        |
| Write command to DQS associated clock edges                                 | WL          | RL – 1                     |      | $n_{CK}$      |                        |

- 1)  $V_{DDQ} = 1.8 \text{ V} \pm 0.1 \text{ V}$ ;  $V_{DD} = 1.8 \text{ V} \pm 0.1 \text{ V}$ .
- 2) Timing that is not specified is illegal and after such an event, in order to guarantee proper operation, the DRAM must be powered down and then restarted through the specified initialization sequence before normal operation can continue.
- 3) Timings are guaranteed with CK/CK differential Slew Rate of 2.0 V/ns. For DQS signals timings are guaranteed with a differential Slew Rate of 2.0 V/ns in differential strobe mode and a Slew Rate of 1 V/ns in single ended mode.
- 4) The CK /  $\overline{\text{CK}}$  input reference level (for timing reference to CK /  $\overline{\text{CK}}$ ) is the point at which CK and  $\overline{\text{CK}}$  cross. The DQS /  $\overline{\text{DQS}}$ , RDQS /  $\overline{\text{RDQS}}$ , input reference level is the crosspoint when in differential strobe mode.
- 5) Inputs are not recognized as valid until  $V_{REF}$  stabilizes. During the period before  $V_{REF}$  stabilizes,  $\text{CKE} = 0.2 \times V_{DDQ}$  is recognized as low.
- 6) The output timing reference voltage level is  $V_{TT}$ .
- 7) New units, ' $t_{CK,AVG}$ ' and ' $n_{CK}$ ', are introduced in DDR2-667 and DDR2-800. Unit ' $t_{CK,AVG}$ ' represents the actual  $t_{CK,AVG}$  of the input clock under operation. Unit ' $n_{CK}$ ' represents one clock cycle of the input clock, counting the actual clock edges. Note that in DDR2-400 and DDR2-533, ' $t_{CK}$ ' is used for both concepts. Example:  $t_{XP} = 2 [n_{CK}]$  means; if Power Down exit is registered at  $T_m$ , an Active command may be registered at  $T_m + 2$ , even if  $(T_m + 2 - T_m)$  is  $2 \times t_{CK,AVG} + t_{ERR,2PER(Min)}$ .
- 8) When the device is operated with input clock jitter, this parameter needs to be derated by the actual  $t_{ERR(6-10PER)}$  of the input clock. (output deratings are relative to the SDRAM input clock.) For example, if the measured jitter into a DDR2-667 SDRAM has  $t_{ERR(6-10PER),MIN} = -272 \text{ ps}$  and  $t_{ERR(6-10PER),MAX} = +293 \text{ ps}$ , then  $t_{DQSK,MIN(DERATED)} = t_{DQSK,MIN} - t_{ERR(6-10PER),MAX} = -400 \text{ ps} - 293 \text{ ps} = -693 \text{ ps}$  and  $t_{DQSK,MAX(DERATED)} = t_{DQSK,MAX} - t_{ERR(6-10PER),MIN} = 400 \text{ ps} + 272 \text{ ps} = +672 \text{ ps}$ . Similarly,  $t_{LZ,DQ}$  for DDR2-667 derates to  $t_{LZ,DQ,MIN(DERATED)} = -900 \text{ ps} - 293 \text{ ps} = -1193 \text{ ps}$  and  $t_{LZ,DQ,MAX(DERATED)} = 450 \text{ ps} + 272 \text{ ps} = +722 \text{ ps}$ . (Caution on the MIN/MAX usage!)
- 9) Input clock jitter spec parameter. These parameters and the ones in Chapter 7.3 are referred to as 'input clock jitter spec parameters' and these parameters apply to DDR2-667 and DDR2-800 only. The jitter specified is a random jitter meeting a Gaussian distribution.
- 10) These parameters are specified per their average values, however it is understood that the relationship as defined in Chapter 7.3 between the average timing and the absolute instantaneous timing holds all the times (min. and max of SPEC values are to be used for calculations of Chapter 7.3).
- 11)  $t_{CKE,MIN}$  of 3 clocks means CKE must be registered on three consecutive positive clock edges. CKE must remain at the valid input level the entire time it takes to achieve the 3 clocks of registration. Thus, after any CKE transition, CKE may not transition from its valid level during the time period of  $t_{IS} + 2 \times t_{CK} + t_{IH}$ .

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- 12)  $DAL = WR + RU\{t_{RP}(ns) / t_{CK}(ns)\}$ , where RU stands for round up. WR refers to the  $t_{WR}$  parameter stored in the MRS. For  $t_{RP}$ , if the result of the division is not already an integer, round up to the next highest integer.  $t_{CK}$  refers to the application clock period. Example: For DDR2-533 at  $t_{CK} = 3.75$  ns with  $t_{WR}$  programmed to 4 clocks.  $t_{DAL} = 4 + (15 \text{ ns} / 3.75 \text{ ns}) \text{ clocks} = 4 + (4) \text{ clocks} = 8 \text{ clocks}$ .
- 13)  $t_{DAL, nCK} = WR [nCK] + t_{nRP, nCK} = WR + RU\{t_{RP} [ps] / t_{CK, AVG} [ps]\}$ , where WR is the value programmed in the EMR.
- 14) Input waveform timing  $t_{DH}$  with differential data strobe enabled MR[bit10] = 0, is referenced from the differential data strobe crosspoint to the input signal crossing at the  $V_{IH, DC}$  level for a falling signal and from the differential data strobe crosspoint to the input signal crossing at the  $V_{IL, DC}$  level for a rising signal applied to the device under test. DQS, DQS signals must be monotonic between  $V_{IL, DC, MAX}$  and  $V_{IH, DC, MIN}$ . See **Figure 9**.
- 15)  $t_{DQSQ}$ : Consists of data pin skew and output pattern effects, and p-channel to n-channel variation of the output drivers as well as output slew rate mismatch between DQS /  $\overline{DQS}$  and associated DQ in any given cycle.
- 16) These parameters are measured from a data strobe signal ((L/U/R)DQS /  $\overline{DQS}$ ) crossing to its respective clock signal (CK /  $\overline{CK}$ ) crossing. The spec values are not affected by the amount of clock jitter applied (i.e.  $t_{JIT, PER}$ ,  $t_{JIT, CC}$ , etc.), as these are relative to the clock signal crossing. That is, these parameters should be met whether clock jitter is present or not.
- 17) Input waveform timing  $t_{DS}$  with differential data strobe enabled MR[bit10] = 0, is referenced from the input signal crossing at the  $V_{IH, AC}$  level to the differential data strobe crosspoint for a rising signal, and from the input signal crossing at the  $V_{IL, AC}$  level to the differential data strobe crosspoint for a falling signal applied to the device under test. DQS, DQS signals must be monotonic between  $V_{I(DC), MAX}$  and  $V_{I(DC), MIN}$ . See **Figure 9**.
- 18) If  $t_{DS}$  or  $t_{DH}$  is violated, data corruption may occur and the data must be re-written with valid data before a valid READ can be executed.
- 19) These parameters are measured from a data signal ((L/U)DM, (L/U)DQ0, (L/U)DQ1, etc.) transition edge to its respective data strobe signal ((L/U/R)DQS /  $\overline{DQS}$ ) crossing.
- 20)  $t_{HP}$  is the minimum of the absolute half period of the actual input clock.  $t_{HP}$  is an input parameter but not an input specification parameter. It is used in conjunction with  $t_{QHS}$  to derive the DRAM output timing  $t_{QH}$ . The value to be used for  $t_{QH}$  calculation is determined by the following equation;  $t_{HP} = \text{MIN}(t_{CH, ABS}, t_{CL, ABS})$ , where,  $t_{CH, ABS}$  is the minimum of the actual instantaneous clock high time;  $t_{CL, ABS}$  is the minimum of the actual instantaneous clock low time.
- 21)  $t_{HZ}$  and  $t_{LZ}$  transitions occur in the same access time as valid data transitions. These parameters are referenced to a specific voltage level which specifies when the device output is no longer driving ( $t_{HZ}$ ), or begins driving ( $t_{LZ}$ ).
- 22) Input waveform timing is referenced from the input signal crossing at the  $V_{IL, DC}$  level for a rising signal and  $V_{IH, DC}$  for a falling signal applied to the device under test. See **Figure 10**.
- 23) Input waveform timing is referenced from the input signal crossing at the  $V_{IH, AC}$  level for a rising signal and  $V_{IL, AC}$  for a falling signal applied to the device under test. See **Figure 10**.
- 24) 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 /  $\overline{CK}$ ) 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.
- 25)  $t_{QH} = t_{HP} - t_{QHS}$ , where:  $t_{HP}$  is the minimum of the absolute half period of the actual input clock; and  $t_{QHS}$  is the specification value under the max column. {The less half-pulse width distortion present, the larger the  $t_{QH}$  value is; and the larger the valid data eye will be.}  
Examples:  
1) If the system provides  $t_{HP}$  of 1315 ps into a DDR2-667 SDRAM, the DRAM provides  $t_{QH}$  of 975 ps minimum.  
2) If the system provides  $t_{HP}$  of 1420 ps into a DDR2-667 SDRAM, the DRAM provides  $t_{QH}$  of 1080 ps minimum.
- 26)  $t_{QHS}$  accounts for:  
1) The pulse duration distortion of on-chip clock circuits, which represents how well the actual  $t_{HP}$  at the input is transferred to the output; and  
2) The worst case push-out of DQS on one transition followed by the worst case pull-in of DQ on the next transition, both of which are independent of each other, due to data pin skew, output pattern effects, and pchannel to n-channel variation of the output drivers.
- 27) The Auto-Refresh command interval has been reduced to 3.9  $\mu$ s when operating the DDR2 DRAM in a temperature range between 85 °C and 95 °C.
- 28)  $0^\circ\text{C} \leq T_{CASE} \leq 85^\circ\text{C}$   
29)  $85^\circ\text{C} < T_{CASE} \leq 95^\circ\text{C}$
- 30) A maximum of eight Auto-Refresh commands can be posted to any given DDR2 SDRAM device.
- 31)  $t_{RPST}$  end point and  $t_{RPRE}$  begin point are not referenced to a specific voltage level but specify when the device output is no longer driving ( $t_{RPST}$ ), or begins driving ( $t_{RPRE}$ ). **Figure 8** shows a method to calculate these points when the device is no longer driving ( $t_{RPST}$ ), or begins driving ( $t_{RPRE}$ ) by measuring the signal at two different voltages. The actual voltage measurement points are not critical as long as the calculation is consistent.
- 32) When the device is operated with input clock jitter, this parameter needs to be derated by the actual  $t_{JIT, PER}$  of the input clock. (output deratings are relative to the SDRAM input clock.) For example, if the measured jitter into a DDR2-667 SDRAM has  $t_{JIT, PER, MIN} = -72$  ps and  $t_{JIT, PER, MAX} = +93$  ps, then  $t_{RPRE, MIN(DERATED)} = t_{RPRE, MIN} + t_{JIT, PER, MIN} = 0.9 \times t_{CK, AVG} - 72 \text{ ps} = +2178 \text{ ps}$  and  $t_{RPRE, MAX(DERATED)} = t_{RPRE, MAX} + t_{JIT, PER, MAX} = 1.1 \times t_{CK, AVG} + 93 \text{ ps} = +2843 \text{ ps}$ . (Caution on the MIN/MAX usage!).



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- 33) When the device is operated with input clock jitter, this parameter needs to be derated by the actual  $t_{JIT.DUTY}$  of the input clock. (output deratings are relative to the SDRAM input clock.) For example, if the measured jitter into a DDR2-667 SDRAM has  $t_{JIT.DUTY.MIN} = -72$  ps and  $t_{JIT.DUTY.MAX} = +93$  ps, then  $t_{RPST.MIN(DERATED)} = t_{RPST.MIN} + t_{JIT.DUTY.MIN} = 0.4 \times t_{CK.AVG} - 72$  ps = + 928 ps and  $t_{RPST.MAX(DERATED)} = t_{RPST.MAX} + t_{JIT.DUTY.MAX} = 0.6 \times t_{CK.AVG} + 93$  ps = + 1592 ps. (Caution on the MIN/MAX usage!).
- 34) For these parameters, the DDR2 SDRAM device is characterized and verified to support  $t_{nPARAM} = RU\{t_{PARAM} / t_{CK.AVG}\}$ , 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 DDR2-667 5-5-5, of which  $t_{RP} = 15$  ns, the device will support  $t_{nRP} = RU\{t_{RP} / t_{CK.AVG}\} = 5$ , i.e. as long as the input clock jitter specifications are met, Precharge command at  $Tm$  and Active command at  $Tm + 5$  is valid even if  $(Tm + 5 - Tm)$  is less than 15 ns due to input clock jitter.
- 35)  $t_{WTR}$  is at least two clocks ( $2 \times t_{CK}$ ) independent of operation frequency.

**TABLE 48**  
**DRAM Component Timing Parameter by Speed Grade - DDR2-667**

| Parameter  | Symbol        | DDR2-667                           |              | Unit         | Note<br>1)2)3)4)5)6)7) |
|--|---------------|------------------------------------|--------------|--------------|------------------------|
|  |               | Min.                               | Max.         |              |                        |
| DQ output access time from CK / $\overline{CK}$                  | $t_{AC}$      | -450                               | +450         | ps           | 8)                     |
| CAS to CAS command delay   | $t_{CCD}$     | 2                                  | —            | $n_{CK}$     |                        |
| Average clock high pulse width                                   | $t_{CH.AVG}$  | 0.48                               | 0.52         | $t_{CK.AVG}$ | 9)10)                  |
| Average clock period   | $t_{CK.AVG}$  | 3000                               | 8000         | ps           |                        |
| CKE minimum pulse width ( high and low pulse width)              | $t_{CKE}$     | 3                                  | —            | $n_{CK}$     | 11)                    |
| Average clock low pulse width                                    | $t_{CL.AVG}$  | 0.48                               | 0.52         | $t_{CK.AVG}$ | 9)10)                  |
| Auto-Precharge write recovery + precharge time                   | $t_{DAL}$     | WR + $t_{nRP}$                     | —            | $n_{CK}$     | 12)13)                 |
| Minimum time clocks remain ON after CKE asynchronously drops LOW | $t_{DELAY}$   | $t_{IS} + t_{CK.AVG} + t_{IH}$     | —            | ns           |                        |
| DQ and DM input hold time  | $t_{DH.BASE}$ | 175                                | —            | ps           | 18)19)14)              |
| DQ and DM input pulse width for each input                       | $t_{DIPW}$    | 0.35                               | —            | $t_{CK.AVG}$ |                        |
| DQS output access time from CK / $\overline{CK}$                 | $t_{DQSCK}$   | -400                               | +400         | ps           | 8)                     |
| DQS input high pulse width                                       | $t_{DQSH}$    | 0.35                               | —            | $t_{CK.AVG}$ |                        |
| DQS input low pulse width  | $t_{DQSL}$    | 0.35                               | —            | $t_{CK.AVG}$ |                        |
| DQS-DQ skew for DQS & associated DQ signals                      | $t_{DQSQ}$    | —                                  | 240          | ps           | 15)                    |
| DQS latching rising transition to associated clock edges         | $t_{DQSS}$    | -0.25                              | +0.25        | $t_{CK.AVG}$ | 16)                    |
| DQ and DM input setup time                                       | $t_{DS.BASE}$ | 100                                | —            | ps           | 17)18)19)              |
| DQS falling edge hold time from CK                               | $t_{DSH}$     | 0.2                                | —            | $t_{CK.AVG}$ | 16)                    |
| DQS falling edge to CK setup time                                | $t_{DSS}$     | 0.2                                | —            | $t_{CK.AVG}$ | 16)                    |
| CK half pulse width  | $t_{HP}$      | Min( $t_{CH.ABS}$ , $t_{CL.ABS}$ ) | —            | ps           | 20)                    |
| Data-out high-impedance time from CK / $\overline{CK}$           | $t_{HZ}$      | —                                  | $t_{AC.MAX}$ | ps           | 8)21)                  |
| Address and control input hold time                              | $t_{IH.BASE}$ | 275                                | —            | ps           | 24)22)                 |
| Control & address input pulse width for each input               | $t_{IPW}$     | 0.6                                | —            | $t_{CK.AVG}$ |                        |
| Address and control input setup time                             | $t_{IS.BASE}$ | 200                                | —            | ps           | 23)24)                 |
| DQ low impedance time from CK/ $\overline{CK}$                   | $t_{LZ.DQ}$   | $2 \times t_{AC.MIN}$              | $t_{AC.MAX}$ | ps           | 8)21)                  |
| DQS/DQS low-impedance time from CK / $\overline{CK}$             | $t_{LZ.DQS}$  | $t_{AC.MIN}$                       | $t_{AC.MAX}$ | ps           | 8)21)                  |
| MRS command to ODT update delay                                  | $t_{MOD}$     | 0                                  | 12           | ns           | 34)                    |



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| Parameter   | Symbol      | DDR2–667           |      | Unit         | Note<br>1)2)3)4)5)6)7) |
|---|-------------|--------------------|------|--------------|------------------------|
|   |             | Min.               | Max. |              |                        |
| Mode register set command cycle time  | $t_{MRD}$   | 2                  | —    | $n_{CK}$     |                        |
| OCD drive mode output delay   | $t_{OIT}$   | 0                  | 12   | ns           | 34)                    |
| DQ/DQS output hold time from DQS  | $t_{QH}$    | $t_{HP} - t_{QHS}$ | —    | ps           | 25)                    |
| DQ hold skew factor   | $t_{QHS}$   | —                  | 340  | ps           | 26)                    |
| Average periodic refresh Interval   | $t_{REFI}$  | —                  | 7.8  | $\mu s$      | 27)28)                 |
|   |             | —                  | 3.9  | $\mu s$      | 28)29)                 |
| Auto-Refresh to Active/Auto-Refresh command period                          | $t_{RFC}$   | 105                | —    | ns           | 30)                    |
| Precharge-All (4 banks) command period                                      | $t_{RP}$    | $t_{RP}$           | —    | ns           |                        |
| Read preamble   | $t_{RPRE}$  | 0.9                | 1.1  | $t_{CK,AVG}$ | 31)32)                 |
| Read postamble  | $t_{RPST}$  | 0.4                | 0.6  | $t_{CK,AVG}$ | 31)33)                 |
| Internal Read to Precharge command delay                                    | $t_{RTP}$   | 7.5                | —    | ns           | 34)                    |
| Write preamble  | $t_{WPRE}$  | 0.35               | —    | $t_{CK,AVG}$ |                        |
| Write postamble   | $t_{WPST}$  | 0.4                | 0.6  | $t_{CK,AVG}$ |                        |
| Write recovery time   | $t_{WR}$    | 15                 | —    | ns           | 34)                    |
| Internal write to read command delay  | $t_{WTR}$   | 7.5                | —    | ns           | 34)35)                 |
| Exit power down to read command   | $t_{XARD}$  | 2                  | —    | $n_{CK}$     |                        |
| Exit active power-down mode to read command (slow exit, lower power)        | $t_{XARDS}$ | 7 – AL             | —    | $n_{CK}$     |                        |
| Exit precharge power-down to any valid command (other than NOP or Deselect) | $t_{XP}$    | 2                  | —    | $n_{CK}$     |                        |
| Exit self-refresh to a non-read command                                     | $t_{XSNR}$  | $t_{RFC} + 10$     | —    | ns           | 34)                    |
| Exit self-refresh to read command   | $t_{XSRD}$  | 200                | —    | $n_{CK}$     |                        |
| Write command to DQS associated clock edges                                 | WL          | RL–1               |      | $n_{CK}$     |                        |

- 1)  $V_{DDQ} = 1.8 V \pm 0.1 V$ ;  $V_{DD} = 1.8 V \pm 0.1 V$ .
- 2) Timing that is not specified is illegal and after such an event, in order to guarantee proper operation, the DRAM must be powered down and then restarted through the specified initialization sequence before normal operation can continue.
- 3) Timings are guaranteed with  $CK/\overline{CK}$  differential Slew Rate of 2.0 V/ns. For DQS signals timings are guaranteed with a differential Slew Rate of 2.0 V/ns in differential strobe mode and a Slew Rate of 1 V/ns in single ended mode.
- 4) The  $CK/\overline{CK}$  input reference level (for timing reference to  $CK/\overline{CK}$ ) is the point at which  $CK$  and  $\overline{CK}$  cross. The  $DQS/\overline{DQS}$ ,  $RDQS/\overline{RDQS}$  input reference level is the crosspoint when in differential strobe mode.
- 5) Inputs are not recognized as valid until  $V_{REF}$  stabilizes. During the period before  $V_{REF}$  stabilizes,  $CKE = 0.2 \times V_{DDQ}$  is recognized as low.
- 6) The output timing reference voltage level is  $V_{TT}$ .
- 7) New units, ' $t_{CK,AVG}$ ' and ' $n_{CK}$ ', are introduced in DDR2–667 and DDR2–800. Unit ' $t_{CK,AVG}$ ' represents the actual  $t_{CK,AVG}$  of the input clock under operation. Unit ' $n_{CK}$ ' represents one clock cycle of the input clock, counting the actual clock edges. Note that in DDR2–400 and DDR2–533, ' $t_{CK}$ ' is used for both concepts. Example:  $t_{XP} = 2 [n_{CK}]$  means; if Power Down exit is registered at  $T_m$ , an Active command may be registered at  $T_m + 2$ , even if  $(T_m + 2 - T_m)$  is  $2 \times t_{CK,AVG} + t_{ERR,2PER(MIN)}$ .
- 8) When the device is operated with input clock jitter, this parameter needs to be derated by the actual  $t_{ERR(6-10PER)}$  of the input clock. (output deratings are relative to the SDRAM input clock.) For example, if the measured jitter into a DDR2–667 SDRAM has  $t_{ERR(6-10PER),MIN} = -272$  ps and  $t_{ERR(6-10PER),MAX} = +293$  ps, then  $t_{DQSCK(MIN(DERATED))} = t_{DQSCK(MIN)} - t_{ERR(6-10PER),MAX} = -400$  ps – 293 ps = – 693 ps and  $t_{DQSCK(MAX(DERATED))} = t_{DQSCK(MAX)} - t_{ERR(6-10PER),MIN} = 400$  ps + 272 ps = + 672 ps. Similarly,  $t_{LZ,DQ}$  for DDR2–667 derates to  $t_{LZ,DQ(MIN(DERATED))} = -900$  ps – 293 ps = – 1193 ps and  $t_{LZ,DQ(MAX(DERATED))} = 450$  ps + 272 ps = + 722 ps. (Caution on the MIN/MAX usage!)
- 9) Input clock jitter spec parameter. These parameters and the ones in **Chapter 7.3** are referred to as 'input clock jitter spec parameters' and these parameters apply to DDR2–667 and DDR2–800 only. The jitter specified is a random jitter meeting a Gaussian distribution.



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- 10) These parameters are specified per their average values, however it is understood that the relationship as defined in **Chapter 7.3** between the average timing and the absolute instantaneous timing holds all the times (min. and max of SPEC values are to be used for calculations of **Chapter 7.3**).
- 11)  $t_{CKE,MIN}$  of 3 clocks means CKE must be registered on three consecutive positive clock edges. CKE must remain at the valid input level the entire time it takes to achieve the 3 clocks of registration. Thus, after any CKE transition, CKE may not transition from its valid level during the time period of  $t_{IS} + 2 \times t_{CK} + t_{IH}$ .
- 12)  $DAL = WR + RU\{t_{RP}(ns) / t_{CK}(ns)\}$ , where RU stands for round up. WR refers to the tWR parameter stored in the MRS. For  $t_{RP}$ , if the result of the division is not already an integer, round up to the next highest integer.  $t_{CK}$  refers to the application clock period. Example: For DDR2-533 at  $t_{CK} = 3.75$  ns with  $t_{WR}$  programmed to 4 clocks.  $t_{DAL} = 4 + (15 \text{ ns} / 3.75 \text{ ns})$  clocks = 4 + (4) clocks = 8 clocks.
- 13)  $t_{DAL,nCK} = WR [nCK] + t_{nRP,nCK} = WR + RU\{t_{RP} [ps] / t_{CK,AVG}[ps]\}$ , where WR is the value programmed in the EMR.
- 14) Input waveform timing  $t_{DH}$  with differential data strobe enabled MR[bit10] = 0, is referenced from the differential data strobe crosspoint to the input signal crossing at the  $V_{IH,DC}$  level for a falling signal and from the differential data strobe crosspoint to the input signal crossing at the  $V_{IL,DC}$  level for a rising signal applied to the device under test. DQS, DQS signals must be monotonic between  $V_{IL,DC,MAX}$  and  $V_{IH,DC,MIN}$ . See **Figure 9**.
- 15)  $t_{DQSQ}$ : Consists of data pin skew and output pattern effects, and p-channel to n-channel variation of the output drivers as well as output slew rate mismatch between DQS /  $\overline{DQS}$  and associated DQ in any given cycle.
- 16) These parameters are measured from a data strobe signal ((L/U/R)DQS / DQS) crossing to its respective clock signal (CK /  $\overline{CK}$ ) crossing. The spec values are not affected by the amount of clock jitter applied (i.e.  $t_{JIT,PER}$ ,  $t_{JIT,CC}$ , etc.), as these are relative to the clock signal crossing. That is, these parameters should be met whether clock jitter is present or not.
- 17) Input waveform timing  $t_{DS}$  with differential data strobe enabled MR[bit10] = 0, is referenced from the input signal crossing at the  $V_{IH,AC}$  level to the differential data strobe crosspoint for a rising signal, and from the input signal crossing at the  $V_{IL,AC}$  level to the differential data strobe crosspoint for a falling signal applied to the device under test. DQS, DQS signals must be monotonic between  $V_{I(DC),MAX}$  and  $V_{I(DC),MIN}$ . See **Figure 9**.
- 18) If  $t_{DS}$  or  $t_{DH}$  is violated, data corruption may occur and the data must be re-written with valid data before a valid READ can be executed.
- 19) These parameters are measured from a data signal ((L/U)DM, (L/U)DQ0, (L/U)DQ1, etc.) transition edge to its respective data strobe signal ((L/U/R)DQS /  $\overline{DQS}$ ) crossing.
- 20)  $t_{HP}$  is the minimum of the absolute half period of the actual input clock.  $t_{HP}$  is an input parameter but not an input specification parameter. It is used in conjunction with  $t_{QHS}$  to derive the DRAM output timing  $t_{QH}$ . The value to be used for  $t_{QH}$  calculation is determined by the following equation;  $t_{HP} = \text{MIN}(t_{CH,ABS}, t_{CL,ABS})$ , where,  $t_{CH,ABS}$  is the minimum of the actual instantaneous clock high time;  $t_{CL,ABS}$  is the minimum of the actual instantaneous clock low time.
- 21)  $t_{HZ}$  and  $t_{LZ}$  transitions occur in the same access time as valid data transitions. These parameters are referenced to a specific voltage level which specifies when the device output is no longer driving ( $t_{HZ}$ ), or begins driving ( $t_{LZ}$ ).
- 22) Input waveform timing is referenced from the input signal crossing at the  $V_{IL,DC}$  level for a rising signal and  $V_{IH,DC}$  for a falling signal applied to the device under test. See **Figure 10**.
- 23) Input waveform timing is referenced from the input signal crossing at the  $V_{IH,AC}$  level for a rising signal and  $V_{IL,AC}$  for a falling signal applied to the device under test. See **Figure 10**.
- 24) 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 /  $\overline{CK}$ ) 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.
- 25)  $t_{QH} = t_{HP} - t_{QHS}$ , where:  $t_{HP}$  is the minimum of the absolute half period of the actual input clock; and  $t_{QHS}$  is the specification value under the max column. {The less half-pulse width distortion present, the larger the  $t_{QH}$  value is; and the larger the valid data eye will be.}  
Examples:  
1) If the system provides  $t_{HP}$  of 1315 ps into a DDR2-667 SDRAM, the DRAM provides  $t_{QH}$  of 975 ps minimum.  
2) If the system provides  $t_{HP}$  of 1420 ps into a DDR2-667 SDRAM, the DRAM provides  $t_{QH}$  of 1080 ps minimum.
- 26)  $t_{QHS}$  accounts for:  
1) The pulse duration distortion of on-chip clock circuits, which represents how well the actual  $t_{HP}$  at the input is transferred to the output; and  
2) The worst case push-out of DQS on one transition followed by the worst case pull-in of DQ on the next transition, both of which are independent of each other, due to data pin skew, output pattern effects, and pchannel to n-channel variation of the output drivers.
- 27) The Auto-Refresh command interval has been reduced to 3.9  $\mu$ s when operating the DDR2 DRAM in a temperature range between 85 °C and 95 °C.
- 28)  $0 \text{ }^\circ\text{C} \leq T_{CASE} \leq 85 \text{ }^\circ\text{C}$   
29)  $85 \text{ }^\circ\text{C} < T_{CASE} \leq 95 \text{ }^\circ\text{C}$
- 30) A maximum of eight Auto-Refresh commands can be posted to any given DDR2 SDRAM device.
- 31)  $t_{RPST}$  end point and  $t_{RPRE}$  begin point are not referenced to a specific voltage level but specify when the device output is no longer driving ( $t_{RPST}$ ), or begins driving ( $t_{RPRE}$ ). **Figure 8** shows a method to calculate these points when the device is no longer driving ( $t_{RPST}$ ), or begins driving ( $t_{RPRE}$ ) by measuring the signal at two different voltages. The actual voltage measurement points are not critical as long as the calculation is consistent.



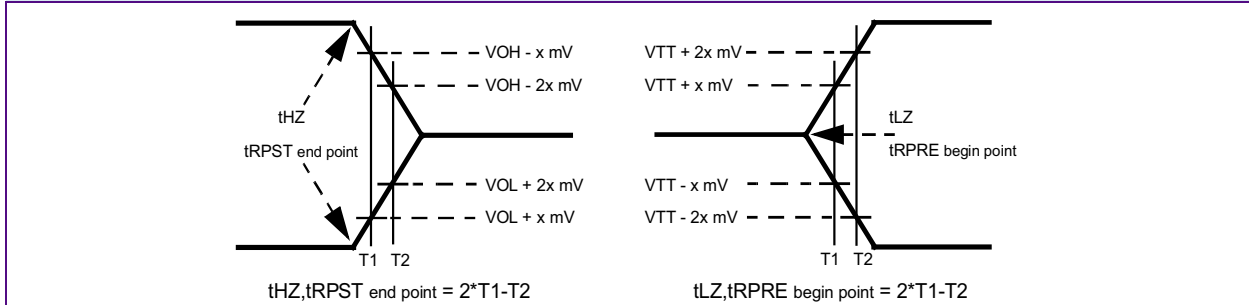
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- 32) When the device is operated with input clock jitter, this parameter needs to be derated by the actual  $t_{\text{JIT.PER}}$  of the input clock. (output deratings are relative to the SDRAM input clock.) For example, if the measured jitter into a DDR2-667 SDRAM has  $t_{\text{JIT.PER.MIN}} = -72$  ps and  $t_{\text{JIT.PER.MAX}} = +93$  ps, then  $t_{\text{RPRE.MIN(DERATED)}} = t_{\text{RPRE.MIN}} + t_{\text{JIT.PER.MIN}} = 0.9 \times t_{\text{CK.AVG}} - 72$  ps = + 2178 ps and  $t_{\text{RPRE.MAX(DERATED)}} = t_{\text{RPRE.MAX}} + t_{\text{JIT.PER.MAX}} = 1.1 \times t_{\text{CK.AVG}} + 93$  ps = + 2843 ps. (Caution on the MIN/MAX usage!).
- 33) When the device is operated with input clock jitter, this parameter needs to be derated by the actual  $t_{\text{JIT.DUTY}}$  of the input clock. (output deratings are relative to the SDRAM input clock.) For example, if the measured jitter into a DDR2-667 SDRAM has  $t_{\text{JIT.DUTY.MIN}} = -72$  ps and  $t_{\text{JIT.DUTY.MAX}} = +93$  ps, then  $t_{\text{RPST.MIN(DERATED)}} = t_{\text{RPST.MIN}} + t_{\text{JIT.DUTY.MIN}} = 0.4 \times t_{\text{CK.AVG}} - 72$  ps = + 928 ps and  $t_{\text{RPST.MAX(DERATED)}} = t_{\text{RPST.MAX}} + t_{\text{JIT.DUTY.MAX}} = 0.6 \times t_{\text{CK.AVG}} + 93$  ps = + 1592 ps. (Caution on the MIN/MAX usage!).
- 34) For these parameters, the DDR2 SDRAM device is characterized and verified to support  $t_{\text{rPARAM}} = \text{RU}\{t_{\text{PARAM}} / t_{\text{CK.AVG}}\}$ , which is in clock cycles, assuming all input clock jitter specifications are satisfied. For example, the device will support  $t_{\text{rRP}} = \text{RU}\{t_{\text{RP}} / t_{\text{CK.AVG}}\}$ , which is in clock cycles, if all input clock jitter specifications are met. This means: For DDR2-667 5-5-5, of which  $t_{\text{RP}} = 15$  ns, the device will support  $t_{\text{rRP}} = \text{RU}\{t_{\text{RP}} / t_{\text{CK.AVG}}\} = 5$ , i.e. as long as the input clock jitter specifications are met, Precharge command at  $T_m$  and Active command at  $T_m + 5$  is valid even if  $(T_m + 5 - T_m)$  is less than 15 ns due to input clock jitter.
- 35)  $t_{\text{WTR}}$  is at least two clocks ( $2 \times t_{\text{CK}}$ ) independent of operation frequency.



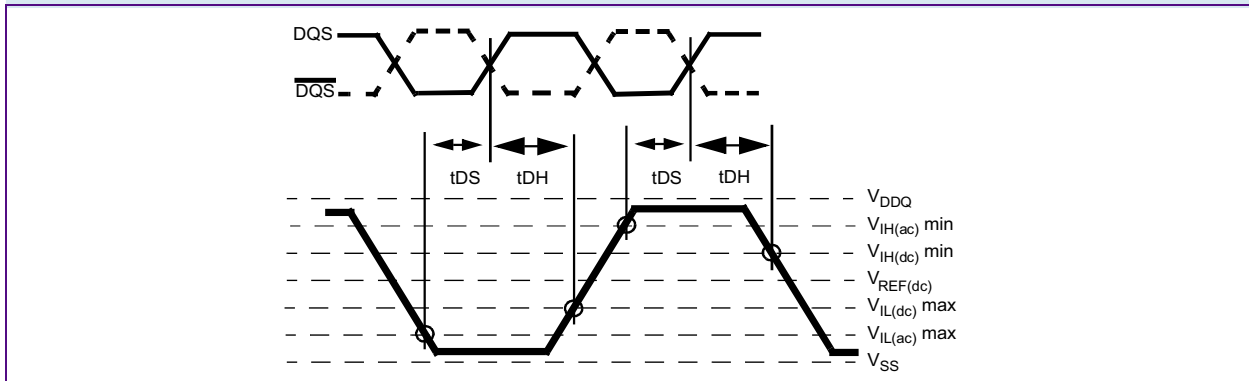
**FIGURE 8**

**Method for calculating transitions and endpoint**



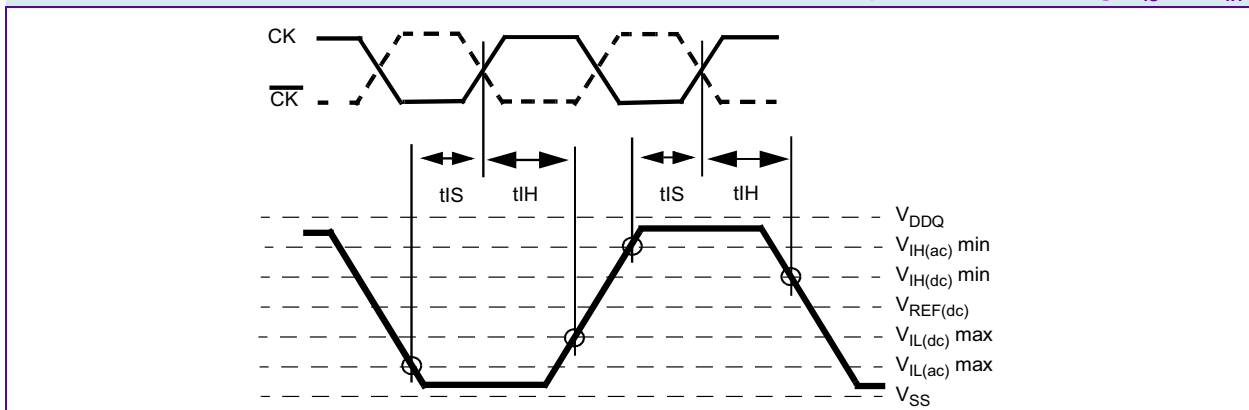
**FIGURE 9**

**Differential input waveform timing -  $t_{DS}$  and  $t_{DH}$**



**FIGURE 10**

**Differential input waveform timing -  $t_{IS}$  and  $t_{IH}$**





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**TABLE 49**  
**DRAM Component Timing Parameter by Speed Grade - DDR2-533**

| Parameter  | Symbol                 | DDR2-533                   |              | Unit          | Note<br>1)2)3)4)5)6) |
|--|------------------------|----------------------------|--------------|---------------|----------------------|
|  |                        | Min.                       | Max.         |               |                      |
| DQ output access time from CK / $\overline{\text{CK}}$           | $t_{AC}$               | -500                       | +500         | ps            |                      |
| CAS A to CAS B command period                                    | $t_{CCD}$              | 2                          | —            | $t_{CK}$      |                      |
| CK, $\overline{\text{CK}}$ high-level width                      | $t_{CH}$               | 0.45                       | 0.55         | $t_{CK}$      |                      |
| CKE minimum high and low pulse width                             | $t_{CKE}$              | 3                          | —            | $t_{CK}$      |                      |
| CK, $\overline{\text{CK}}$ low-level width                       | $t_{CL}$               | 0.45                       | 0.55         | $t_{CK}$      |                      |
| Auto-Precharge write recovery + precharge time                   | $t_{DAL}$              | WR + $t_{RP}$              | —            | $t_{CK}$      | 7)17)                |
| Minimum time clocks remain ON after CKE asynchronously drops LOW | $t_{DELAY}$            | $t_{IS} + t_{CK} + t_{IH}$ | —            | ns            | 8)                   |
| DQ and DM input hold time (differential data strobe)             | $t_{DH}(\text{base})$  | 225                        | —            | ps            | 9)                   |
| DQ and DM input hold time (single ended data strobe)             | $t_{DH1}(\text{base})$ | -25                        | —            | ps            | 10)                  |
| DQ and DM input pulse width (each input)                         | $t_{DIPW}$             | 0.35                       | —            | $t_{CK}$      |                      |
| DQS output access time from CK / $\overline{\text{CK}}$          | $t_{DQSQ}$             | -450                       | +450         | ps            |                      |
| DQS input low (high) pulse width (write cycle)                   | $t_{DQSL,H}$           | 0.35                       | —            | $t_{CK}$      |                      |
| DQS-DQ skew (for DQS & associated DQ signals)                    | $t_{DQSQ}$             | —                          | 300          | ps            | 10)                  |
| Write command to 1st DQS latching transition                     | $t_{DQSS}$             | -0.25                      | +0.25        | $t_{CK}$      |                      |
| DQ and DM input setup time (differential data strobe)            | $t_{DS}(\text{base})$  | 100                        | —            | ps            | 10)                  |
| DQ and DM input setup time (single ended data strobe)            | $t_{DS1}(\text{base})$ | -25                        | —            | ps            | 10)                  |
| DQS falling edge hold time from CK (write cycle)                 | $t_{DSH}$              | 0.2                        | —            | $t_{CK}$      |                      |
| DQS falling edge to CK setup time (write cycle)                  | $t_{DSS}$              | 0.2                        | —            | $t_{CK}$      |                      |
| Clock half period  | $t_{HP}$               | MIN. ( $t_{CL}, t_{CH}$ )  |              | —             | 11)                  |
| Data-out high-impedance time from CK / $\overline{\text{CK}}$    | $t_{HZ}$               | —                          | $t_{AC,MAX}$ | ps            | 12)                  |
| Address and control input hold time                              | $t_{IH}(\text{base})$  | 375                        | —            | ps            | 10)                  |
| Address and control input pulse width (each input)               | $t_{IPW}$              | 0.6                        | —            | $t_{CK}$      |                      |
| Address and control input setup time                             | $t_{IS}(\text{base})$  | 250                        | —            | ps            | 10)                  |
| DQ low-impedance time from CK / $\overline{\text{CK}}$           | $t_{LZ(DQ)}$           | $2 \times t_{AC,MIN}$      | $t_{AC,MAX}$ | ps            | 13)                  |
| DQS low-impedance from CK / $\overline{\text{CK}}$               | $t_{LZ(DQS)}$          | $t_{AC,MIN}$               | $t_{AC,MAX}$ | ps            | 13)                  |
| Mode register set command cycle time                             | $t_{MRD}$              | 2                          | —            | $t_{CK}$      |                      |
| OCD drive mode output delay                                      | $t_{OIT}$              | 0                          | 12           | ns            |                      |
| Data output hold time from DQS                                   | $t_{QH}$               | $t_{HP} - t_{QHS}$         | —            | —             |                      |
| Data hold skew factor  | $t_{QHS}$              | —                          | 400          | ps            |                      |
| Average periodic refresh Interval                                | $t_{REFI}$             | —                          | 7.8          | $\mu\text{s}$ | 13)14)               |



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| Parameter   | Symbol      | DDR2–533        |      | Unit          | Note<br>1)2)3)4)5)6) |
|---|-------------|-----------------|------|---------------|----------------------|
|   |             | Min.            | Max. |               |                      |
| Average periodic refresh Interval   | $t_{REFI}$  | —               | 3.9  | $\mu\text{s}$ | 15)17)               |
| Auto-Refresh to Active/Auto-Refresh command period                          | $t_{RFC}$   | 105             | —    | ns            | 16)                  |
| Precharge-All (4 banks) command period                                      | $t_{RP}$    | $t_{RP}$        | —    | ns            |                      |
| Read preamble   | $t_{RPRE}$  | 0.9             | 1.1  | $t_{CK}$      | 13)                  |
| Read postamble  | $t_{RPST}$  | 0.40            | 0.60 | $t_{CK}$      | 13)                  |
| Active bank A to Active bank B command period                               | $t_{RRD}$   | 7.5             | —    | ns            | 13)17)               |
| Active bank A to Active bank B command period                               | $t_{RRD}$   | 10              | —    | ns            | 15)21)               |
| Internal Read to Precharge command delay                                    | $t_{RTP}$   | 7.5             | —    | ns            |                      |
| Write preamble  | $t_{WPRE}$  | 0.25            | —    | $t_{CK}$      |                      |
| Write postamble   | $t_{WPST}$  | 0.40            | 0.60 | $t_{CK}$      | 18)                  |
| Write recovery time for write without Auto-Precharge                        | $t_{WR}$    | 15              | —    | ns            |                      |
| Internal Write to Read command delay  | $t_{WTR}$   | 7.5             | —    | ns            | 19)                  |
| Exit power down to any valid command (other than NOP or Deselect)           | $t_{XARD}$  | 2               | —    | $t_{CK}$      | 20)                  |
| Exit active power-down mode to Read command (slow exit, lower power)        | $t_{XARDS}$ | 6 – AL          | —    | $t_{CK}$      | 20)                  |
| Exit precharge power-down to any valid command (other than NOP or Deselect) | $t_{XP}$    | 2               | —    | $t_{CK}$      |                      |
| Exit Self-Refresh to non-Read command                                       | $t_{XSNR}$  | $t_{RFC} + 10$  | —    | ns            |                      |
| Exit Self-Refresh to Read command   | $t_{XSRD}$  | 200             | —    | $t_{CK}$      |                      |
| Write recovery time for write with Auto-Precharge                           | WR          | $t_{WR}/t_{CK}$ | —    | $t_{CK}$      | 21)                  |

- 1)  $V_{DDQ} = 1.8\text{ V} \pm 0.1\text{ V}$ ;  $V_{DD} = 1.8\text{ V} \pm 0.1\text{ V}$ .
- 2) Timing that is not specified is illegal and after such an event, in order to guarantee proper operation, the DRAM must be powered down and then restarted through the specified initialization sequence before normal operation can continue.
- 3) Timings are guaranteed with CK/CK differential Slew Rate of 2.0 V/ns. For DQS signals timings are guaranteed with a differential Slew Rate of 2.0 V/ns in differential strobe mode and a Slew Rate of 1 V/ns in single ended mode.
- 4) The CK /  $\overline{\text{CK}}$  input reference level (for timing reference to CK /  $\overline{\text{CK}}$ ) is the point at which CK and  $\overline{\text{CK}}$  cross. The DQS /  $\overline{\text{DQS}}$ , RDQS /  $\overline{\text{RDQS}}$ , input reference level is the crosspoint when in differential strobe mode.
- 5) Inputs are not recognized as valid until  $V_{REF}$  stabilizes. During the period before  $V_{REF}$  stabilizes,  $\text{CKE} = 0.2 \times V_{DDQ}$  is recognized as low.
- 6) The output timing reference voltage level is  $V_{TT}$ .
- 7) For each of the terms, if not already an integer, round to the next highest integer.  $t_{CK}$  refers to the application clock period. WR refers to the WR parameter stored in the MR.
- 8) The clock frequency is allowed to change during self-refresh mode or precharge power-down mode.
- 9) For timing definition, refer to the Component data sheet.
- 10) Consists of data pin skew and output pattern effects, and p-channel to n-channel variation of the output drivers as well as output Slew Rate mis-match between DQS /  $\overline{\text{DQS}}$  and associated DQ in any given cycle.
- 11) MIN ( $t_{CL}$ ,  $t_{CH}$ ) refers to the smaller of the actual clock low time and the actual clock high time as provided to the device (i.e. this value can be greater than the minimum specification limits for  $t_{CL}$  and  $t_{CH}$ ).
- 12) The  $t_{HZ}$ ,  $t_{RPST}$  and  $t_{LZ}$ ,  $t_{RPRE}$  parameters are referenced to a specific voltage level, which specify when the device output is no longer driving ( $t_{HZ}$ ,  $t_{RPST}$ ), or begins driving ( $t_{LZ}$ ,  $t_{RPRE}$ ).  $t_{HZ}$  and  $t_{LZ}$  transitions occur in the same access time windows as valid data transitions. These parameters are verified by design and characterization, but not subject to production test.



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- 13) The Auto-Refresh command interval has been reduced to 3.9  $\mu$ s when operating the DDR2 DRAM in a temperature range between 85 °C and 95 °C.
- 14)  $0\text{ }^{\circ}\text{C} \leq T_{\text{CASE}} \leq 85\text{ }^{\circ}\text{C}$
- 15)  $85\text{ }^{\circ}\text{C} < T_{\text{CASE}} \leq 95\text{ }^{\circ}\text{C}$
- 16) A maximum of eight Auto-Refresh commands can be posted to any given DDR2 SDRAM device.
- 17) The  $t_{\text{RRD}}$  timing parameter depends on the page size of the DRAM organization. See **Table 5 “Ordering Information for Lead-Free Products (RoHS Compliant)” on Page 6.**
- 18) The maximum limit for the  $t_{\text{WPST}}$  parameter is not a device limit. The device operates with a greater value for this parameter, but system performance (bus turnaround) degrades accordingly.
- 19) Minimum  $t_{\text{WTR}}$  is two clocks when operating the DDR2-SDRAM at frequencies  $\leq 200$  MHz.
- 20) User can choose two different active power-down modes for additional power saving via MRS address bit A12. In “standard active power-down mode” (MR, A12 = “0”) a fast power-down exit timing  $t_{\text{XARD}}$  can be used. In “low active power-down mode” (MR, A12 = “1”) a slow power-down exit timing  $t_{\text{XARDS}}$  has to be satisfied.
- 21) WR must be programmed to fulfill the minimum requirement for the  $t_{\text{WR}}$  timing parameter, where  $WR_{\text{MIN}}[\text{cycles}] = t_{\text{WR}}(\text{ns})/t_{\text{CK}}(\text{ns})$  rounded up to the next integer value.  $t_{\text{DAL}} = WR + (t_{\text{RP}}/t_{\text{CK}})$ . For each of the terms, if not already an integer, round to the next highest integer.  $t_{\text{CK}}$  refers to the application clock period. WR refers to the WR parameter stored in the MRS.

**TABLE 50**  
**DRAM Component Timing Parameter by Speed Grade - DDR2-400**

| Parameter  | Symbol                        | DDR2-400  |       | Unit            | Note<br>1)2)3)4)5)6) |
|--|-------------------------------|---|-------|-----------------|----------------------|
|  |                               | Min.  | Max.  |                 |                      |
| DQ output access time from CK / $\overline{\text{CK}}$           | $t_{\text{AC}}$               | -600  | +600  | ps              |                      |
| $\overline{\text{CAS}}$ A to CAS B command period                | $t_{\text{CCD}}$              | 2   | —     | $t_{\text{CK}}$ |                      |
| CK, $\overline{\text{CK}}$ high-level width                      | $t_{\text{CH}}$               | 0.45  | 0.55  | $t_{\text{CK}}$ |                      |
| CKE minimum high and low pulse width                             | $t_{\text{CKE}}$              | 3   | —     | $t_{\text{CK}}$ |                      |
| CK, $\overline{\text{CK}}$ low-level width                       | $t_{\text{CL}}$               | 0.45  | 0.55  | $t_{\text{CK}}$ |                      |
| Auto-Precharge write recovery + precharge time                   | $t_{\text{DAL}}$              | $WR + t_{\text{RP}}$                            | —     | $t_{\text{CK}}$ | 7)20)                |
| Minimum time clocks remain ON after CKE asynchronously drops LOW | $t_{\text{DELAY}}$            | $t_{\text{IS}} + t_{\text{CK}} + t_{\text{IH}}$ | —     | ns              | 8)                   |
| DQ and DM input hold time (differential data strobe)             | $t_{\text{DH}}(\text{base})$  | 275   | —     | ps              | 9)                   |
| DQ and DM input hold time (single ended data strobe)             | $t_{\text{DH1}}(\text{base})$ | -25   | —     | ps              | 10)                  |
| DQ and DM input pulse width (each input)                         | $t_{\text{DIPW}}$             | 0.35  | —     | $t_{\text{CK}}$ |                      |
| DQS output access time from CK / $\overline{\text{CK}}$          | $t_{\text{DQSCK}}$            | -500  | +500  | ps              |                      |
| DQS input low (high) pulse width (write cycle)                   | $t_{\text{DQSL,H}}$           | 0.35  | —     | $t_{\text{CK}}$ |                      |
| DQS-DQ skew (for DQS & associated DQ signals)                    | $t_{\text{DQSQ}}$             | —   | 350   | ps              | 10)                  |
| Write command to 1st DQS latching transition                     | $t_{\text{DQSS}}$             | -0.25   | +0.25 | $t_{\text{CK}}$ |                      |
| DQ and DM input setup time (differential data strobe)            | $t_{\text{DS}}(\text{base})$  | 150   | —     | ps              | 10)                  |
| DQ and DM input setup time (single ended data strobe)            | $t_{\text{DS1}}(\text{base})$ | -25   | —     | ps              | 10)                  |
| DQS falling edge hold time from CK (write cycle)                 | $t_{\text{DSH}}$              | 0.2   | —     | $t_{\text{CK}}$ |                      |
| DQS falling edge to CK setup time (write cycle)                  | $t_{\text{DSS}}$              | 0.2   | —     | $t_{\text{CK}}$ |                      |



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| Parameter   | Symbol         | DDR2-400                     |              | Unit     | Note<br>1)2)3)4)5)6) |
|---|----------------|------------------------------|--------------|----------|----------------------|
|   |                | Min.                         | Max.         |          |                      |
| Clock half period   | $t_{HP}$       | MIN. ( $t_{CL}$ , $t_{CH}$ ) |              | —        | 11)                  |
| Data-out high-impedance time from CK / $\overline{CK}$                      | $t_{HZ}$       | —                            | $t_{AC,MAX}$ | ps       | 12)                  |
| Address and control input hold time   | $t_{IH}(base)$ | 475                          | —            | ps       | 10)                  |
| Address and control input pulse width (each input)                          | $t_{IPW}$      | 0.6                          | —            | $t_{CK}$ |                      |
| Address and control input setup time  | $t_{IS}(base)$ | 350                          | —            | ps       | 10)                  |
| DQ low-impedance time from CK / $\overline{CK}$                             | $t_{LZ}(DQ)$   | $2 \times t_{AC,MIN}$        | $t_{AC,MAX}$ | ps       | 13)                  |
| DQS low-impedance from CK / $\overline{CK}$                                 | $t_{LZ}(DQS)$  | $t_{AC,MIN}$                 | $t_{AC,MAX}$ | ps       | 13)                  |
| Mode register set command cycle time  | $t_{MRD}$      | 2                            | —            | $t_{CK}$ |                      |
| OCD drive mode output delay   | $t_{OIT}$      | 0                            | 12           | ns       |                      |
| Data output hold time from DQS  | $t_{QH}$       | $t_{HP} - t_{QHS}$           | —            | —        |                      |
| Data hold skew factor   | $t_{QHS}$      | —                            | 450          | ps       |                      |
| Average periodic refresh Interval   | $t_{REFI}$     | —                            | 7.8          | $\mu s$  | 13)14)               |
| Average periodic refresh Interval   | $t_{REFI}$     | —                            | 3.9          | $\mu s$  | 15)17)               |
| Auto-Refresh to Active/Auto-Refresh command period                          | —              | 105                          | —            | ns       | 16)                  |
| Precharge-All (4 banks) command period                                      | $t_{RP}$       | $t_{RP}$                     | —            | ns       |                      |
| Read preamble   | $t_{RPRE}$     | 0.9                          | 1.1          | $t_{CK}$ | 13)                  |
| Read postamble  | $t_{RPST}$     | 0.40                         | 0.60         | $t_{CK}$ | 13)                  |
| Active bank A to Active bank B command period                               | $t_{RRD}$      | 7.5                          | —            | ns       | 13)17)               |
| Active bank A to Active bank B command period                               | $t_{RRD}$      | 10                           | —            | ns       | 15)21)               |
| Internal Read to Precharge command delay                                    | $t_{RTP}$      | 7.5                          | —            | ns       |                      |
| Write preamble  | $t_{WPRE}$     | 0.25                         | —            | $t_{CK}$ |                      |
| Write postamble   | $t_{WPST}$     | 0.40                         | 0.60         | $t_{CK}$ | 18)                  |
| Write recovery time for write without Auto-Precharge                        | $t_{WR}$       | 15                           | —            | ns       |                      |
| Internal Write to Read command delay  | $t_{WTR}$      | 10                           | —            | ns       | 19)                  |
| Exit power down to any valid command (other than NOP or Deselect)           | $t_{XARD}$     | 2                            | —            | $t_{CK}$ | 20)                  |
| Exit active power-down mode to Read command (slow exit, lower power)        | $t_{XARDS}$    | 6 – AL                       | —            | $t_{CK}$ | 20)                  |
| Exit precharge power-down to any valid command (other than NOP or Deselect) | $t_{XP}$       | 2                            | —            | $t_{CK}$ |                      |
| Exit Self-Refresh to non-Read command                                       | $t_{XSNR}$     | $t_{RFC} + 10$               | —            | ns       |                      |
| Exit Self-Refresh to Read command   | $t_{XSRD}$     | 200                          | —            | $t_{CK}$ |                      |
| Write recovery time for write with Auto-Precharge                           | WR             | $t_{WR}/t_{CK}$              | —            | $t_{CK}$ | 21)                  |

1)  $V_{DDQ} = 1.8 V \pm 0.1 V$ ;  $V_{DD} = 1.8 V \pm 0.1 V$ .

2) Timing that is not specified is illegal and after such an event, in order to guarantee proper operation, the DRAM must be powered down and then restarted through the specified initialization sequence before normal operation can continue.

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- 3) Timings are guaranteed with  $\overline{CK}/\overline{CK}$  differential Slew Rate of 2.0 V/ns. For DQS signals timings are guaranteed with a differential Slew Rate of 2.0 V/ns in differential strobe mode and a Slew Rate of 1 V/ns in single ended mode.
- 4) The  $\overline{CK}/\overline{CK}$  input reference level (for timing reference to  $\overline{CK}/\overline{CK}$ ) is the point at which  $\overline{CK}$  and  $\overline{CK}$  cross. The  $\overline{DQS}/\overline{DQS}$ ,  $\overline{RDQS}/\overline{RDQS}$ , input reference level is the crosspoint when in differential strobe mode.
- 5) Inputs are not recognized as valid until  $V_{REF}$  stabilizes. During the period before  $V_{REF}$  stabilizes,  $\overline{CKE} = 0.2 \times V_{DDQ}$  is recognized as low.
- 6) The output timing reference voltage level is  $V_{TT}$ .
- 7) For each of the terms, if not already an integer, round to the next highest integer.  $t_{CK}$  refers to the application clock period. WR refers to the WR parameter stored in the MR.
- 8) The clock frequency is allowed to change during self-refresh mode or precharge power-down mode.
- 9) For timing definition, refer to the Component data sheet.
- 10) Consists of data pin skew and output pattern effects, and p-channel to n-channel variation of the output drivers as well as output Slew Rate mis-match between  $\overline{DQS}/\overline{DQS}$  and associated DQ in any given cycle.
- 11) MIN ( $t_{CL}$ ,  $t_{CH}$ ) refers to the smaller of the actual clock low time and the actual clock high time as provided to the device (i.e. this value can be greater than the minimum specification limits for  $t_{CL}$  and  $t_{CH}$ ).
- 12) The  $t_{HZ}$ ,  $t_{RPST}$  and  $t_{LZ}$ ,  $t_{RPRE}$  parameters are referenced to a specific voltage level, which specify when the device output is no longer driving ( $t_{HZ}$ ,  $t_{RPST}$ ), or begins driving ( $t_{LZ}$ ,  $t_{RPRE}$ ).  $t_{HZ}$  and  $t_{LZ}$  transitions occur in the same access time windows as valid data transitions. These parameters are verified by design and characterization, but not subject to production test.
- 13) The Auto-Refresh command interval has been reduced to 3.9  $\mu$ s when operating the DDR2 DRAM in a temperature range between 85 °C and 95 °C.
- 14)  $0\text{ }^{\circ}\text{C} \leq T_{CASE} \leq 85\text{ }^{\circ}\text{C}$
- 15)  $85\text{ }^{\circ}\text{C} < T_{CASE} \leq 95\text{ }^{\circ}\text{C}$
- 16) A maximum of eight Auto-Refresh commands can be posted to any given DDR2 SDRAM device.
- 17) The  $t_{RRD}$  timing parameter depends on the page size of the DRAM organization. See **Table 5 "Ordering Information for Lead-Free Products (RoHS Compliant)" on Page 6**.
- 18) The maximum limit for the  $t_{WPST}$  parameter is not a device limit. The device operates with a greater value for this parameter, but system performance (bus turnaround) degrades accordingly.
- 19) Minimum  $t_{WTR}$  is two clocks when operating the DDR2-SDRAM at frequencies  $\leq 200$  MHz.
- 20) User can choose two different active power-down modes for additional power saving via MRS address bit A12. In "standard active power-down mode" (MR, A12 = "0") a fast power-down exit timing  $t_{XARD}$  can be used. In "low active power-down mode" (MR, A12 = "1") a slow power-down exit timing  $t_{XARDS}$  has to be satisfied.
- 21) WR must be programmed to fulfill the minimum requirement for the  $t_{WR}$  timing parameter, where  $WR_{MIN}[\text{cycles}] = t_{WR}(\text{ns})/t_{CK}(\text{ns})$  rounded up to the next integer value.  $t_{DAL} = WR + (t_{RP}/t_{CK})$ . For each of the terms, if not already an integer, round to the next highest integer.  $t_{CK}$  refers to the application clock period. WR refers to the WR parameter stored in the MRS.



### 7.3 Jitter Definition and Clock Jitter Specification

Generally, jitter is defined as “the short-term variation of a signal with respect to its ideal position in time”. The following table provides an overview of the terminology.

**TABLE 51**  
**Average Clock and Jitter Symbols and Definition**

| Symbol              | Parameter  | Description   | Units |
|---------------------|--|---|-------|
| $t_{CK.AVG}$        | Average clock period   | <p><math>t_{CK.AVG}</math> is calculated as the average clock period within any consecutive 200-cycle window:</p> $t_{CK.AVG} = \frac{1}{N} \cdot \left( \sum_{j=1}^N t_{CK_j} \right) \quad (1)$ <p><math>N = 200</math></p>   | ps    |
| $t_{JIT.PER}$       | Clock-period jitter  | <p><math>t_{JIT.PER}</math> is defined as the largest deviation of any single <math>t_{CK}</math> from <math>t_{CK.AVG}</math>:<br/> <math>t_{JIT.PER} = \text{Min/Max of } \{t_{CK_i} - t_{CK.AVG}\}</math> where <math>i = 1</math> to 200</p> <p><math>t_{JIT.PER}</math> defines the single-period jitter when the DLL is already locked.<br/> <math>t_{JIT.PER}</math> is not guaranteed through final production testing.</p> | ps    |
| $t_{JIT}(PER, LCK)$ | Clock-period jitter during DLL-locking period                | <p><math>t_{JIT}(PER,LCK)</math> uses the same definition as <math>t_{JIT.PER}</math>, during the DLL-locking period only.<br/> <math>t_{JIT}(PER,LCK)</math> is not guaranteed through final production testing.</p>   | ps    |
| $t_{JIT.CC}$        | Cycle-to-cycle clock period jitter                           | <p><math>t_{JIT.CC}</math> is defined as the absolute difference in clock period between two consecutive clock cycles:<br/> <math>t_{JIT.CC} = \text{Max of ABS}\{t_{CK_{i+1}} - t_{CK_i}\}</math></p> <p><math>t_{JIT.CC}</math> defines the cycle- to- cycle jitter when the DLL is already locked.<br/> <math>t_{JIT.CC}</math> is not guaranteed through final production testing.</p>  | ps    |
| $t_{JIT}(CC, LCK)$  | Cycle-to-cycle clock period jitter during DLL-locking period | <p><math>t_{JIT}(CC,LCK)</math> uses the same definition as <math>t_{JIT.CC}</math> during the DLL-locking period only.<br/> <math>t_{JIT}(CC,LCK)</math> is not guaranteed through final production testing.</p>   | ps    |
| $t_{ERR.2PER}$      | Cumulative error across 2 cycles                             | <p><math>t_{ERR.2PER}</math> is defined as the cumulative error across 2 consecutive cycles from <math>t_{CK.AVG}</math>:</p> $t_{ERR}(2per) = \left( \sum_{j=i}^{i+n-1} t_{CK_j} \right) - n \times t_{CK}(avg) \quad (2)$ <p><math>n = 2</math> for <math>t_{ERR}(2per)</math><br/> where <math>i = 1</math> to 200</p>   | ps    |





| Symbol         | Parameter                        | Description   | Units        |
|----------------|----------------------------------|---|--------------|
| $t_{ERR.nPER}$ | Cumulative error across n cycles | <p><math>t_{ERR.2PER}</math> is defined as the cumulative error across n consecutive cycles from <math>t_{CK.AVG}</math>:</p> $t_{ERR}(nper) = \left( \sum_{j=i}^{i+n-1} t_{CK_j} \right) - n \times t_{CK}(avg) \quad (3)$ <p>where, i = 1 to 200 and<br/>           n = 3 for <math>t_{ERR.3PER}</math><br/>           n = 4 for <math>t_{ERR.4PER}</math><br/>           n = 5 for <math>t_{ERR.5PER}</math><br/>           6 ≤ n ≤ 10 for <math>t_{ERR.6-10PER}</math><br/>           11 ≤ n ≤ 50 for <math>t_{ERR.11-50PER}</math></p> | ps           |
| $t_{CH.AVG}$   | Average high-pulse width         | <p><math>t_{CH.AVG}</math> is defined as the average high-pulse width, as calculated across any consecutive 200 high pulses:</p> $t_{CH}(avg) = \frac{1}{(N \times t_{CK}(avg))} \cdot \left( \sum_{j=1}^N t_{CH_j} \right) \quad (4)$ <p>N = 200</p>   | $t_{CK.AVG}$ |
| $t_{CL.AVG}$   | Average low-pulse width          | <p><math>t_{CL.AVG}</math> is defined as the average low-pulse width, as calculated across any consecutive 200 low pulses:</p> $t_{CL}(avg) = \frac{1}{(N \times t_{CK}(avg))} \cdot \left( \sum_{j=1}^N t_{CL_j} \right) \quad (5)$ <p>N = 200</p>   | $t_{CK.AVG}$ |
| $t_{JIT.DUTY}$ | Duty-cycle jitter                | <p><math>t_{JIT.DUTY} = \text{Min/Max of } \{t_{JIT.CH}, t_{JIT.CL}\}</math>, where:<br/> <math>t_{JIT.CH}</math> is the largest deviation of any single <math>t_{CH}</math> from <math>t_{CH.AVG}</math><br/> <math>t_{JIT.CL}</math> is the largest deviation of any single <math>t_{CL}</math> from <math>t_{CL.AVG}</math><br/> <math>t_{JIT.CH} = \{t_{CHi} - t_{CH.AVG} \times t_{CK.AVG}\}</math> where i=1 to 200<br/> <math>t_{JIT.CL} = \{t_{CLi} - t_{CL.AVG} \times t_{CK.AVG}\}</math> where i=1 to 200</p>                    | ps           |



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The following parameters are specified per their average values however, it is understood that the following relationship between the average timing and the absolute instantaneous timing holds all the time.

**TABLE 52**  
Absolute Jitter Value Definitions

| Symbol       | Parameter              | Min.   | Max.   | Unit |
|--------------|------------------------|--|--|------|
| $t_{CK.ABS}$ | Clock period           | $t_{CK.AVG(Min)} + t_{JIT.PER(Min)}$                         | $t_{CK.AVG(Max)} + t_{JIT.PER(Max)}$                         | ps   |
| $t_{CH.ABS}$ | Clock high-pulse width | $t_{CH.AVG(Min)} \times t_{CK.AVG(Min)} + t_{JIT.DUTY(Min)}$ | $t_{CH.AVG(Max)} \times t_{CK.AVG(Max)} + t_{JIT.DUTY(Max)}$ | ps   |
| $t_{CL.ABS}$ | Clock low-pulse width  | $t_{CL.AVG(Min)} \times t_{CK.AVG(Min)} + t_{JIT.DUTY(Min)}$ | $t_{CL.AVG(Max)} \times t_{CK.AVG(Max)} + t_{JIT.DUTY(Max)}$ | ps   |

Example: for DDR2-667,  $t_{CH.ABS(Min)} = (0.48 \times 3000ps) - 125 ps = 1315 ps = 0.438 \times 3000 ps$ .

Table 53 shows clock-jitter specifications.

**TABLE 53**  
Clock-Jitter Specifications for -667 and -800

| Symbol              | Parameter   | DDR2 -667 |      | DDR2 -800 |      | Unit         |
|---------------------|---|-----------|------|-----------|------|--------------|
|                     |   | Min.      | Max. | Min.      | Max. |              |
| $t_{CK.AVG}$        | Average clock period nominal w/o jitter                       | 3000      | 8000 | 2500      | 8000 | ps           |
| $t_{JIT.PER}$       | Clock-period jitter   | -125      | +125 | -100      | +100 | ps           |
| $t_{JIT(PEL,LCK)}$  | Clock-period jitter during DLL locking period                 | -100      | +100 | -80       | +80  | ps           |
| $t_{JIT.CC}$        | Cycle-to-cycle clock-period jitter                            | -250      | +250 | -200      | +200 | ps           |
| $t_{JIT(CC,LCK)}$   | Cycle-to-cycle clock-period jitter during DLL-locking period  | -200      | +200 | -160      | +160 | ps           |
| $t_{ERR.2PER}$      | Cumulative error across 2 cycles                              | -175      | +175 | -150      | +150 | ps           |
| $t_{ERR.3PER}$      | Cumulative error across 3 cycles                              | -225      | +225 | -175      | +175 | ps           |
| $t_{ERR.4PER}$      | Cumulative error across 4 cycles                              | -250      | +250 | -200      | +200 | ps           |
| $t_{ERR.5PER}$      | Cumulative error across 5 cycles                              | -250      | +250 | -200      | +200 | ps           |
| $t_{ERR(6-10PER)}$  | Cumulative error across n cycles with n = 6 .. 10, inclusive  | -350      | +350 | -300      | +300 | ps           |
| $t_{ERR(11-50PER)}$ | Cumulative error across n cycles with n = 11 .. 50, inclusive | -450      | +450 | -450      | +450 | ps           |
| $t_{CH.AVG}$        | Average high-pulse width                                      | 0.48      | 0.52 | 0.48      | 0.52 | $t_{CK.AVG}$ |
| $t_{CL.AVG}$        | Average low-pulse width                                       | 0.48      | 0.52 | 0.48      | 0.52 | $t_{CK.AVG}$ |
| $t_{JIT.DUTY}$      | Duty-cycle jitter   | -125      | +125 | -100      | +100 | ps           |



## 7.4 ODT AC Electrical Characteristics

This chapter describes the ODT AC electrical characteristics.

**TABLE 54**  
ODT AC Characteristics and Operating Conditions for DDR2-533 and DDR2-400

| Symbol      | Parameter / Condition                | Values                      |  | Unit     | Note |
|-------------|--------------------------------------|-----------------------------|--|----------|------|
|             |                                      | Min.                        | Max.                                     |          |      |
| $t_{AOND}$  | ODT turn-on delay                    | 2                           | 2  | $t_{CK}$ |      |
| $t_{AON}$   | ODT turn-on                          | $t_{AC,MIN}$                | $t_{AC,MAX} + 1 \text{ ns}$              | ns       | 1)   |
| $t_{AONPD}$ | ODT turn-on (Power-Down Modes)       | $t_{AC,MIN} + 2 \text{ ns}$ | $2 t_{CK} + t_{AC,MAX} + 1 \text{ ns}$   | ns       |      |
| $t_{AOFD}$  | ODT turn-off delay                   | 2.5                         | 2.5                                      | $t_{CK}$ |      |
| $t_{AOF}$   | ODT turn-off                         | $t_{AC,MIN}$                | $t_{AC,MAX} + 0.6 \text{ ns}$            | ns       | 2)   |
| $t_{AOFPD}$ | ODT turn-off (Power-Down Modes)      | $t_{AC,MIN} + 2 \text{ ns}$ | $2.5 t_{CK} + t_{AC,MAX} + 1 \text{ ns}$ | ns       |      |
| $t_{ANPD}$  | ODT to Power Down Mode Entry Latency | 3                           | —  | $t_{CK}$ |      |
| $t_{AXPD}$  | ODT Power Down Exit Latency          | 8                           | —  | $t_{CK}$ |      |

- 1) ODT turn on time min. is when the device leaves high impedance and ODT resistance begins to turn on. ODT turn on time max is when the ODT resistance is fully on. Both are measured from  $t_{AOND}$ , which is interpreted differently per speed bin. For DDR2-400/533,  $t_{AOND}$  is 10 ns (= 2 x 5 ns) after the clock edge that registered a first ODT HIGH if  $t_{CK} = 5 \text{ ns}$ .
- 2) ODT turn off time min. is when the device starts to turn off ODT resistance. ODT turn off time max is when the bus is in high impedance. Both are measured from  $t_{AOFD}$ . Both are measured from  $t_{AOFD}$ , which is interpreted differently per speed bin. For DDR2-400/533,  $t_{AOFD}$  is 12.5 ns (= 2.5 x 5 ns) after the clock edge that registered a first ODT HIGH if  $t_{CK} = 5 \text{ ns}$ .

**TABLE 55**  
ODT AC Characteristics and Operating Conditions for DDR2-667 and DDR2-800

| Symbol      | Parameter / Condition                | Values                      |  | Unit     | Note |
|-------------|--------------------------------------|-----------------------------|--|----------|------|
|             |                                      | Min.                        | Max.                                     |          |      |
| $t_{AOND}$  | ODT turn-on delay                    | 2                           | 2  | $n_{CK}$ | 1)   |
| $t_{AON}$   | ODT turn-on                          | $t_{AC,MIN}$                | $t_{AC,MAX} + 0.7 \text{ ns}$            | ns       | 1)2) |
| $t_{AONPD}$ | ODT turn-on (Power-Down Modes)       | $t_{AC,MIN} + 2 \text{ ns}$ | $2 t_{CK} + t_{AC,MAX} + 1 \text{ ns}$   | ns       | 1)   |
| $t_{AOFD}$  | ODT turn-off delay                   | 2.5                         | 2.5                                      | $n_{CK}$ | 1)   |
| $t_{AOF}$   | ODT turn-off                         | $t_{AC,MIN}$                | $t_{AC,MAX} + 0.6 \text{ ns}$            | ns       | 1)3) |
| $t_{AOFPD}$ | ODT turn-off (Power-Down Modes)      | $t_{AC,MIN} + 2 \text{ ns}$ | $2.5 t_{CK} + t_{AC,MAX} + 1 \text{ ns}$ | ns       | 1)   |
| $t_{ANPD}$  | ODT to Power Down Mode Entry Latency | 3                           | —  | $n_{CK}$ | 1)   |
| $t_{AXPD}$  | ODT Power Down Exit Latency          | 8                           | —  | $n_{CK}$ | 1)   |

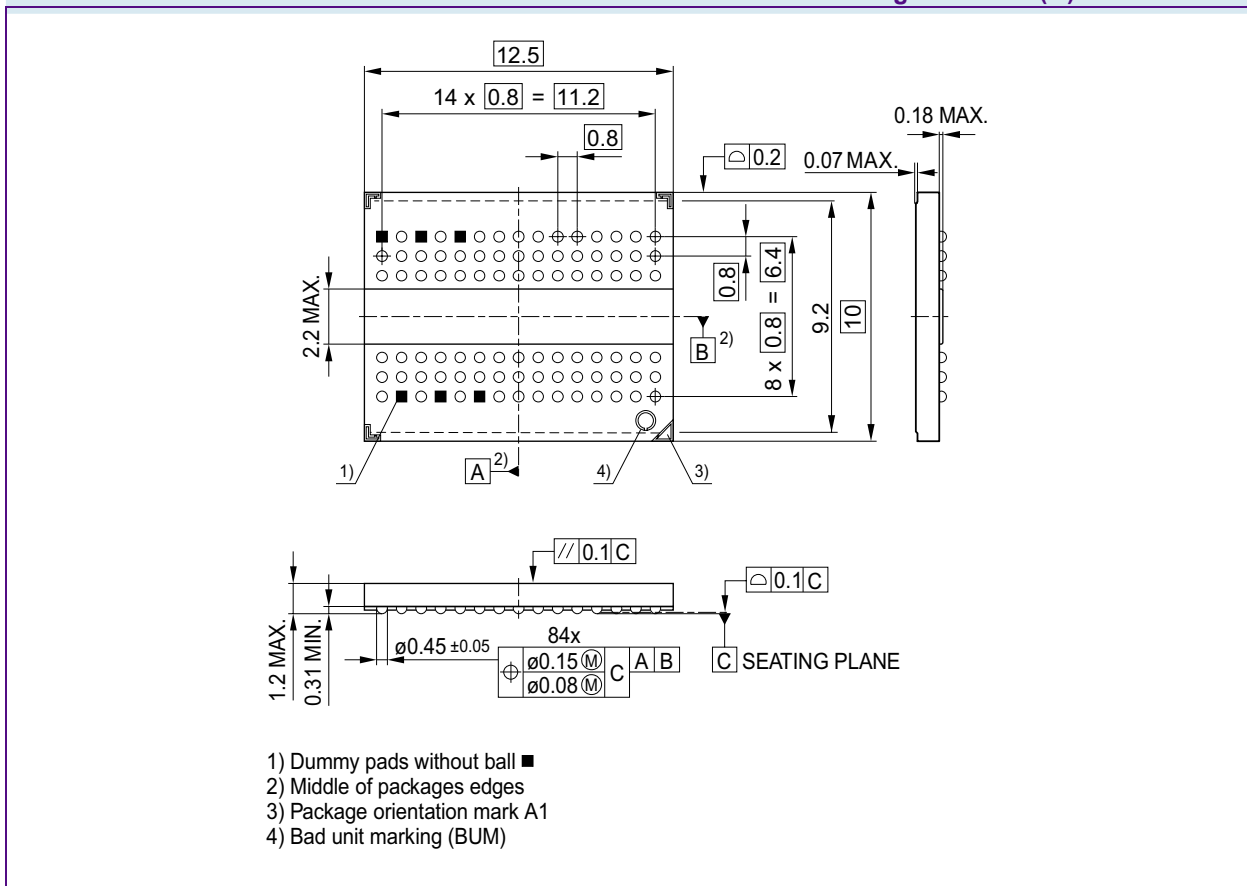
- 1) New units, " $t_{CK,AVG}$ " and " $n_{CK}$ ", are introduced in DDR2-667 and DDR2-800. Unit " $t_{CK,AVG}$ " represents the actual  $t_{CK,AVG}$  of the input clock under operation. Unit " $n_{CK}$ " represents one clock cycle of the input clock, counting the actual clock edges. Note that in DDR2-400 and DDR2-533, " $t_{CK}$ " is used for both concepts. Example:  $t_{XP} = 2 [n_{CK}]$  means; if Power Down exit is registered at  $T_m$ , an Active command may be registered at  $T_m + 2$ , even if  $(T_m + 2 - T_m)$  is  $2 \times t_{CK,AVG} + t_{ERR,2PER(MIN)}$ .
- 2) ODT turn on time min is when the device leaves high impedance and ODT resistance begins to turn on. ODT turn on time max is when the ODT resistance is fully on. Both are measured from  $t_{AOND}$ , which is interpreted differently per speed bin. For DDR2-667/800,  $t_{AOND}$  is 2 clock cycles after the clock edge that registered a first ODT HIGH counting the actual input clock edges.
- 3) ODT turn off time min is when the device starts to turn off ODT resistance. ODT turn off time max is when the bus is in high impedance. Both are measured from  $t_{AOFD}$ , which is interpreted differently per speed bin. For DDR2-667/800, if  $t_{CK(avg)} = 3 \text{ ns}$  is assumed,  $t_{AOFD}$  is 1.5 ns (= 0.5 x 3 ns) after the second trailing clock edge counting from the clock edge that registered a first ODT LOW and by counting the actual input clock edges.



# 8 Package Dimensions

This chapter describes the package dimensions.

**FIGURE 11**  
Package Outline P(G)-TFBGA-84-51



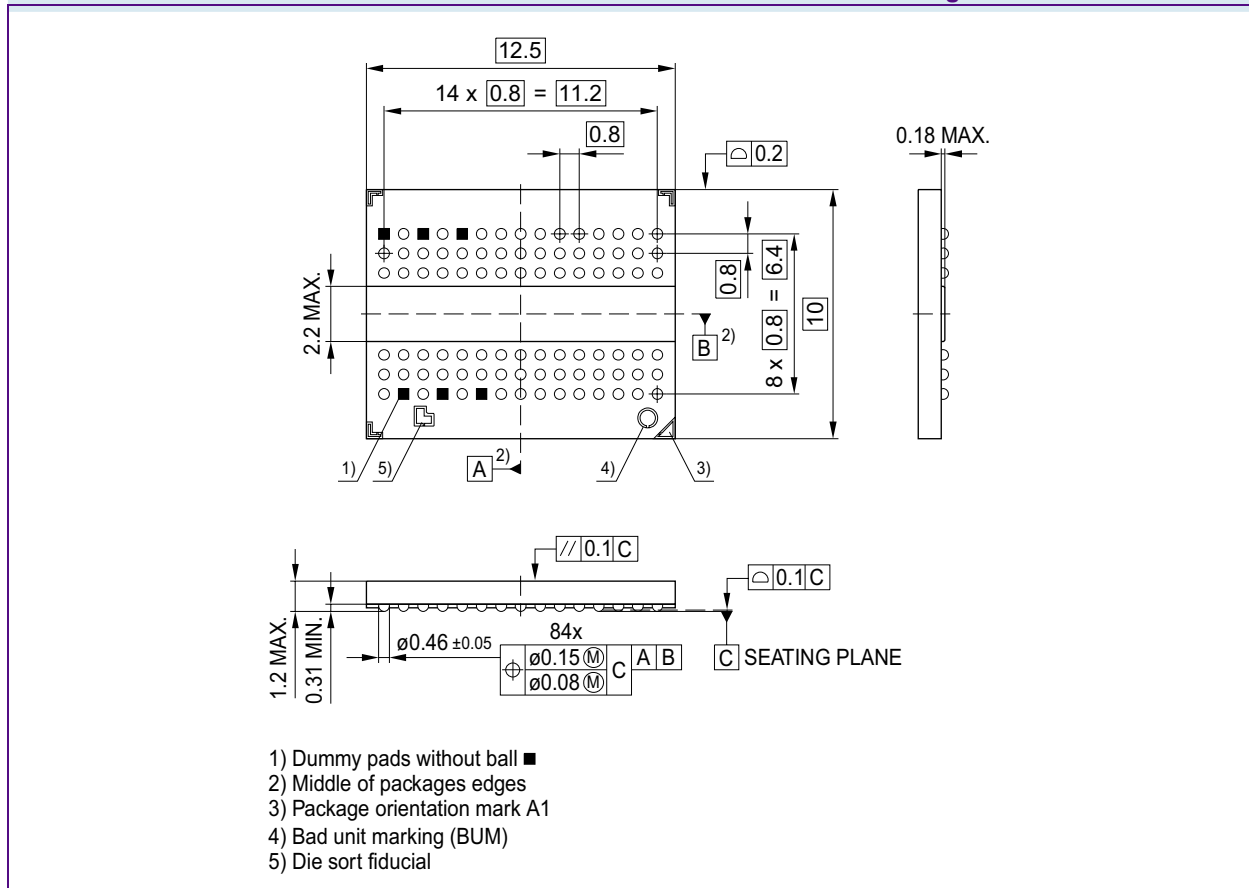
## Notes

1. Drawing according to ISO 8015
2. Dimensions in mm
3. General tolerances +/- 0.15



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**FIGURE 12**  
Package Outline P-TFBGA-84-1



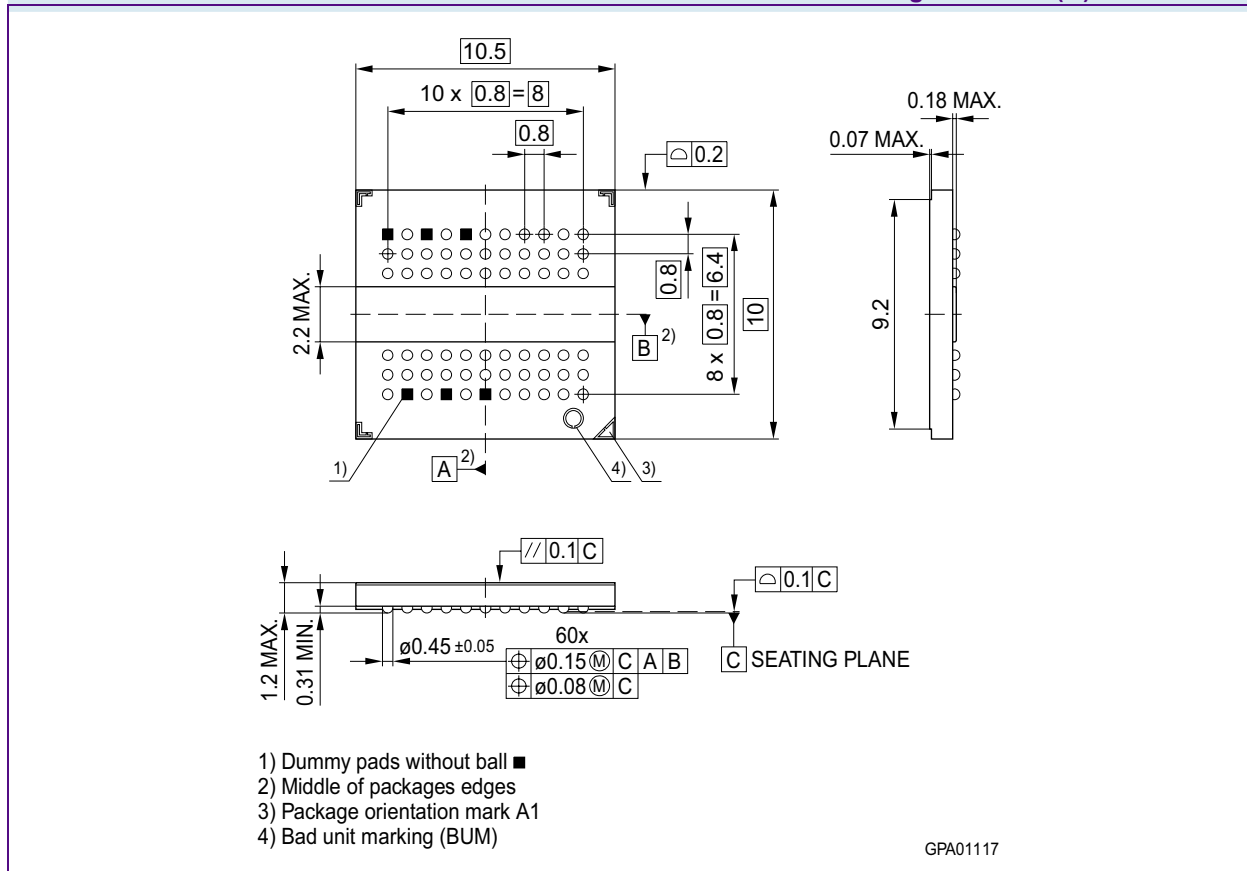
#### Notes

1. Drawing according to ISO 8015
2. Dimensions in mm
3. General tolerances +/- 0.15



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**FIGURE 13**  
Package Outline P(G)-TFBGA-60-6



#### Notes

1. Drawing according to ISO 8015
2. Dimensions in mm
3. General tolerances +/- 0.15



## 9 Product Nomenclature

For reference the Qimonda SDRAM component nomenclature is enclosed in this chapter.

**TABLE 56**  
Examples for Nomenclature Fields

| Example for | Field Number |    |   |     |    |   |   |   |   |    |      |
|-------------|--------------|----|---|-----|----|---|---|---|---|----|------|
|             | 1            | 2  | 3 | 4   | 5  | 6 | 7 | 8 | 9 | 10 | 11   |
| DDR2 SDRAM  | HYB          | 18 | T | 512 | 4  |   | 0 | A | F | —  | -3   |
| DDR2 SDRAM  | HYB          | 18 | T | 512 | 16 |   | 0 | B | F | L  | -3.7 |

**TABLE 57**  
DDR2 Memory Components

| Field | Description               | Values | Coding                 |
|-------|---------------------------|--------|------------------------|
| 1     | Qimonda Component Prefix  | HYB    | Constant               |
| 2     | Interface Voltage [V]     | 18     | SSTL_18                |
| 3     | DRAM Technology           | T      | DDR2                   |
| 4     | Component Density [Mbit]  | 256    | 256 Mbit               |
|       |                           | 512    | 512 Mbit               |
|       |                           | 1G     | 1 Gbit                 |
|       |                           | 2G     | 2 Gbit                 |
| 5+6   | Number of I/Os            | 40     | ×4                     |
|       |                           | 80     | ×8                     |
|       |                           | 16     | ×16                    |
| 7     | Product Variations        | 0 .. 9 | look up table          |
| 8     | Die Revision              | A      | First                  |
|       |                           | B      | Second                 |
|       |                           | C      | Third                  |
| 9     | Package, Lead-Free Status | C      | FBGA, lead-containing  |
|       |                           | F      | FBGA, lead-free        |
| 10    | Power                     | —      | Standard power product |
|       |                           | L      | Low power product      |
| 11    | Speed Grade               | -1.9   | DDR2-1066              |
|       |                           | -25F   | DDR2-800 5-5-5         |
|       |                           | -2.5   | DDR2-800 6-6-6         |
|       |                           | -3     | DDR2-667 4-4-4         |
|       |                           | -3S    | DDR2-667 5-5-5         |
|       |                           | -3.7   | DDR2-533 4-4-4         |
|       |                           | -5     | DDR2-400 3-3-3         |



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**Edition 2007-05**  
**Published by Qimonda AG**  
**Gustav-Heinemann-Ring 212**  
**D-81739 München, Germany**  
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