

	3	25A	25
	DDR2-667	DDR2-800	DDR2-800
Clock Cycle Time ( $t_{CK3}$ )	5ns	5ns	5ns
Clock Cycle Time ( $t_{CK4}$ )	3.75ns	3.75ns	3.75ns
Clock Cycle Time ( $t_{CK5}$ )	3ns	3ns	2.5ns
Clock Cycle Time ( $t_{CK6}$ )	3ns	2.5ns	2.5ns
Clock Cycle Time ( $t_{CK7}$ )	3ns	2.5ns	2.5ns
System Frequency ( $f_{CK\ max}$ )	333 MHz	400 MHz	400 MHz

## Features

The 2-Gbit 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 x8, x16 data in/outputs
- DDR2 SDRAM architecture:
  - Comply with JEDEC DDR2 SDRAM Standard
  - Eight internal banks for concurrent operation
- Programmable CAS Latency: 3, 4, 5, 6 and 7
- Programmable Burst Length: 4 and 8
- Differential clock inputs (CK and  $\overline{CK}$ )
- Bi-directional, differential data strobes (DQS and  $\overline{DQS}$ ) are transmitted / received with data. Edge aligned with read data and center-aligned with write data.
- DLL aligns DQ and DQS transitions with clock
- 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
- Support concurrent Auto Precharge function
- Auto-Refresh, Self-Refresh and power saving Power- Down modes
- Operating temperature range ( $T_{CASE}$ )
  - Commercial, (0 °C to 95 °C)
  - Industrial, I (-40 °C to 95 °C)
  - Automotive, A2 (-40 °C to 105 °C)
  - High-Rel, X (-55 °C to 125 °C)
- Average Refresh Period 7.8  $\mu$ s at a  $T_{CASE}$  lower than 85 °C, 3.9  $\mu$ s between 85 °C and 125 °C
- Programmable self refresh rate via EMRS2 setting
- Full and reduced Strength Data-Output Drivers
- 1KB page size for x8, 2KB page size for x16
- Packages: PG-TFBGA-60 for x8, PG-TFBGA-84 for x16

## Description

The 2-Gbit DDR2 SDRAM is a high-speed Double-Data-Rate- Two CMOS Synchronous DRAM device Containing 2,147,483,648 bits and internally configured as an octal bank DRAM.

The 2-Gbit device is organized as 16 Mbit x8 I/O x8 banks or 8 Mbit x16 I/O x8 banks chip. These synchronous devices achieve high speed transfer rates starting at 400mb/sec/pin for general applications. See [Table 1](#) for performance figures.

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

1. Posted  $\overline{CAS}$  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 CK falling). All I/Os are synchronized with a single ended

DQS or differential DQS- $\overline{DQS}$  pair in a source synchronous fashion.

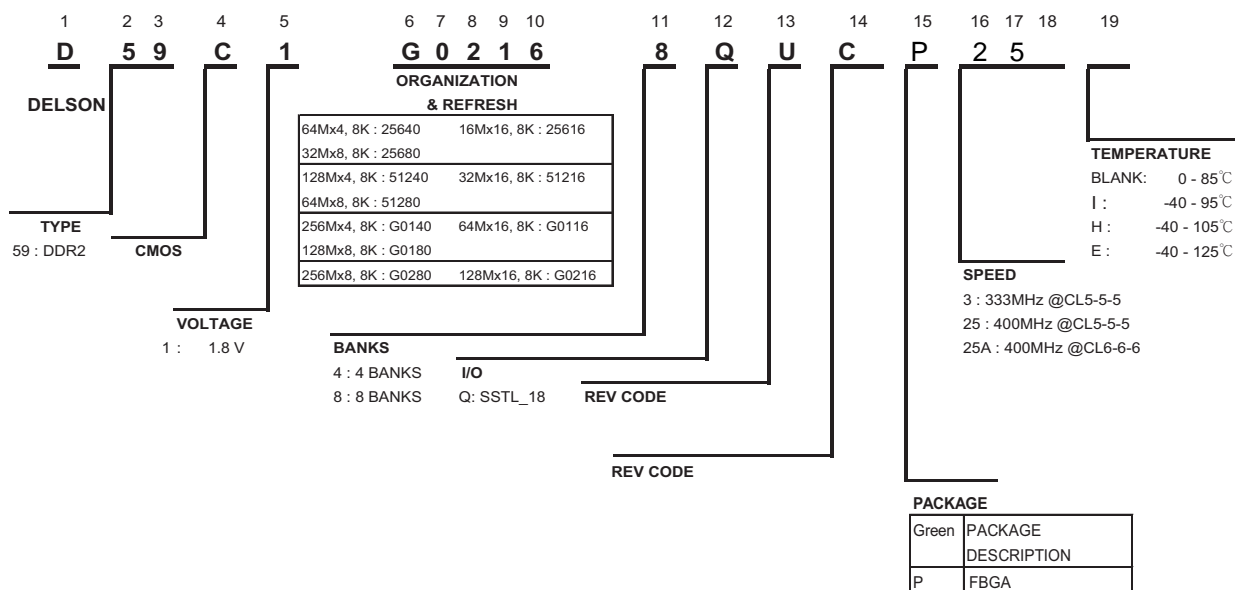
A 15 bit address bus for x8 organised components and a 14 bit address bus for x16 components is used to convey row, column and bank address information in a RAS- CAS multiplexing style.

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 TFBGA package.

# Part Number Information



## 2Gb DDR2 SDRAM Addressing

Configuration	128Mb x 16 / 256Mb x 8
# of Bank	8
Bank Address	BA0 ~ BA2
Auto precharge	A10/AP
Row Address	A0 ~ A13
Column Address	A0 ~ A9

Ball#	Name	Ball Type	Buffer Type	Function
H8	A0	I	SSTL	Address Signal 14:0, Address Signal 10/Auto precharge
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	
L3	A14	I	SSTL	
Data Signals x8 Organizations				
C8	DQ0	I/O	SSTL	Data Signal 3:0
C2	DQ1	I/O	SSTL	
D7	DQ2	I/O	SSTL	
D3	DQ3	I/O	SSTL	
D1	DQ4	I/O	SSTL	Data Signal 7:4
D9	DQ5	I/O	SSTL	
B1	DQ6	I/O	SSTL	
B9	DQ7	I/O	SSTL	
Data Strobe x8 Organizations				
B7	DQS	I/O	SSTL	Data Strobe
A8	DQS	I/O	SSTL	
Data Strobe x8 Organization				
B3	RDQS	O	SSTL	Read Data Strobe
A2	RDQS	O	SSTL	
Data Mask x8 Organizations				
B3	DM	I	SSTL	Data Mask

Ball#	Name	Ball Type	Buffer Type	Function
<b>Power Supplies x8 Organization</b>				
A9, C1, C3, C7, C9	$V_{DDQ}$	PWR	—	I/O Driver Power Supply
A1, E9, H9, L1	$V_{DD}$	PWR	—	Power Supply
A7, B2, B8, D2, D8	$V_{SSQ}$	PWR	—	I/O Driver Power Supply _Gnd
A3, J1, E3, K9	$V_{SS}$	PWR	—	Power Supply _Gnd
E2	$V_{REF}$	AI	—	I/O Reference Voltage
E1	$V_{DDL}$	PWR	—	Power Supply
E7	$V_{SSDL}$	PWR	—	Power Supply _Gnd
<b>Not Connected x8 Organization</b>				
L7	NC	NC	—	Not Connected
<b>Other Balls x8 Organizations</b>				
F9	ODT	I	SSTL	On-Die Termination Control

**TABLE 4**  
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 5**  
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.

FIGURE 1

Chip Configuration for ×8 Components, TFBGA-60 (Top view)

1	2	3	4	5	6	7	8	9
$V_{DD}$	$\overline{NU}/\overline{RDQS}$	$V_{SS}$		A		$V_{SSQ}$	$\overline{DQS}$	$V_{DDQ}$
DQ6	$V_{SSQ}$	DM/RDQS		B		DQS	$V_{SSQ}$	DQ7
$V_{DDQ}$	DQ1	$V_{DDQ}$		C		$V_{DDQ}$	DQ0	$V_{DDQ}$
DQ4	$V_{SSQ}$	DQ3		D		DQ2	$V_{SSQ}$	DQ5
$V_{DDL}$	$V_{REF}$	$V_{SS}$		E		$V_{SSDL}$	CK	$V_{DD}$
	CKE	$\overline{WE}$		F		$\overline{RAS}$	$\overline{CK}$	ODT
BA2	BA0	BA1		G		$\overline{CAS}$	$\overline{CS}$	
	A10/AP	A1		H		A2	A0	$V_{DD}$
$V_{SS}$	A3	A5		J		A6	A4	
	A7	A9		K		A11	A8	$V_{SS}$
$V_{DD}$	A12	A14		L		NC	A13	

#### 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.

## Configuration for TFBGA-84

The chip configuration of a DDR2 SDRAM is listed by function in **Table 6**. The abbreviations used in the Ball#/Buffer Type columns are explained in **Table 7** and **Table 8** respectively.

**TABLE 6**  
Chip Configuration for TFBGA-84

Ball#	Name	Ball Type	Buffer Type	Function
<b>Clock Signals ×16 Organization</b>				
J8	CK	I	SSTL	Clock Signal CK, /CK
K8	$\overline{\text{CK}}$	I	SSTL	
K2	CKE	I	SSTL	Clock Enable
<b>Control Signals ×16 Organization</b>				
K7	$\overline{\text{RAS}}$	I	SSTL	Row Address Strobe (/RAS), Column Address Strobe (/CAS), Write Enable (/WE)
L7	$\overline{\text{CAS}}$	I	SSTL	
K3	$\overline{\text{WE}}$	I	SSTL	
L8	$\overline{\text{CS}}$	I	SSTL	Chip Select
<b>Address Signals ×16 Organization</b>				
L2	BA0	I	SSTL	Bank Address Bus 2:0
L3	BA1	I	SSTL	
L1	BA2	I	SSTL	
M8	A0	I	SSTL	Address Signal 13:0, Address Signal 10/Autoprecharge
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	
R8	A13	I	SSTL	

Ball#	Name	Ball Type	Buffer Type	Function
Data Signals ×16 Organization				
G8	DQ0	I/O	SSTL	Data Signal Lower Byte 7:0
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	Data Signal Upper Byte 15:8
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	
Data Strobe ×16 Organization				
B7	UDQS	I/O	SSTL	Data Strobe Upper Byte
A8	$\overline{\text{UDQS}}$	I/O	SSTL	
F7	LDQS	I/O	SSTL	Data Strobe Lower Byte
E8	$\overline{\text{LDQS}}$	I/O	SSTL	
Data Mask ×16 Organization				
B3	UDM	I	SSTL	Data Mask Upper Byte
F3	LDM	I	SSTL	Data Mask Lower Byte
Power Supplies ×16 Organization				
J2	$V_{\text{REF}}$	AI	–	I/O Reference Voltage
A9, C1, C3, C7, C9, E9, G1, G3, G7,	$V_{\text{DDQ}}$	PWR	–	I/O Driver Power Supply
J1	$V_{\text{DDL}}$	PWR	–	Power Supply
A1, E1, J9, M9, R1	$V_{\text{DD}}$	PWR	–	Power Supply
A7,B2,B8, D2, D8, E7, F2, F8, H2,H8	$V_{\text{SSQ}}$	PWR	–	I/O Driver Power Supply _Gnd
J7	$V_{\text{SSDL}}$	PWR	–	Power Supply _Gnd
A3, E3, J3, N1, P9	$V_{\text{SS}}$	PWR	–	Power Supply _Gnd
Not Connected ×16 Organization				
A2, E2, R3, R7	NC	NC	–	Not Connected

Ball#	Name	Ball Type	Buffer Type	Function
<b>Other Balls ×16 Organization</b>				
K9	ODT	I	SSTL	On-Die Termination Control

**TABLE 7**  
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 8**  
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.



FIGURE 2

Chip Configuration for x16 Components, TFBGA-84 (Top view)

1	2	3	4	5	6	7	8	9
$V_{DD}$	NC	$V_{SS}$		A		$V_{SSQ}$	$\overline{UDQS}$	$V_{DDQ}$
DQ14	$V_{SSQ}$	UDM		B		$\overline{UDQS}$	$V_{SSQ}$	DQ15
$V_{DDQ}$	DQ9	$V_{DDQ}$		C		$V_{DDQ}$	DQ8	$V_{DDQ}$
DQ12	$V_{SSQ}$	DQ11		D		DQ10	$V_{SSQ}$	DQ13
$V_{DD}$	NC	$V_{SS}$		E		$V_{SSQ}$	$\overline{LDQS}$	$V_{DDQ}$
DQ6	$V_{SSQ}$	LDM		F		$\overline{LDQS}$	$V_{SSQ}$	DQ7
$V_{DDQ}$	DQ1	$V_{DDQ}$		G		$V_{DDQ}$	DQ0	$V_{DDQ}$
DQ4	$V_{SSQ}$	DQ3		H		DQ2	$V_{SSQ}$	DQ5
$V_{DDL}$	$V_{REF}$	$V_{SS}$		J		$V_{SSDL}$	CK	$V_{DD}$
	CKE	$\overline{WE}$		K		$\overline{RAS}$	$\overline{CK}$	ODT
BA2	BA0	BA1		L		$\overline{CAS}$	$\overline{CS}$	
	A10/AP	A1		M		A2	A0	$V_{DD}$
$V_{SS}$	A3	A5		N		A6	A4	
	A7	A9		P		A11	A8	$V_{SS}$
$V_{DD}$	A12	NC		R		NC	A13	

## 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.

## Addressing

This chapter describes the DDR2 SDRAM addressing.

**TABLE 9**  
Addressing

Configuration	256 Mb x 8 <sup>1)</sup>	128 Mb x 16 <sup>2)</sup>	Note
Bank Address	BA[2:0]	BA[2:0]	
Number of Banks	8	8	
Auto Precharge	A10 / AP	A10 / AP	
Row Address	A[14:0]	A[13:0]	
Column Address	A[9:0]	A[9:0]	
Number of Column Address Bits	10	10	3)
Number of I/Os	8	16	
Page Size [Bytes]	1024 (1 K)	2048 (2 K)	4)

1) Referred to as 'org'

2) Referred to as 'org'

3) Referred to as 'colbits'

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

# Functional Description

This chapter contains the functional description.

## Power-up and initialization sequence

The following sequence is required for Power-up and Initialization.

1) Either one of the following sequence is required for Power-up.

a1) While applying power, attempt to maintain CKE below  $0.2 \times VDDQ$  and  $ODT^{*1}$  at a LOW state (all other inputs may be undefined.) The VDD voltage ramp time must be no greater than 200 ms from when VDD ramps from 300 mV to VDD min; and during the VDD voltage ramp,  $|VDD - VDDQ| \leq 0.3$  volts. Once the ramping of the supply voltages is complete (when VDDQ crosses VDDQ min), the supply voltage specifications provided in section 5.2, table 20 Recommended DC operating conditions (SSTL\_1.8), prevail.

- VDD, VDDL and VDDQ are driven from a single power converter output, AND
- VTT is limited to 0.95 V max, AND
- Vref tracks  $VDDQ/2$ , VREF must be within  $\pm 300$  mV with respect to  $VDDQ/2$  during supply ramp time.
- $VDDQ \geq VREF$  must be met at all times.

a2) While applying power, attempt to maintain CKE below  $0.2 \times VDDQ$  and  $ODT^{*1}$  at a LOW state, all other inputs may be undefined, voltage levels at I/Os and outputs must be less than VDDQ during voltage ramp time to avoid DRAM latch-up. During the ramping of the supply voltages,  $VDD \geq VDDL \geq VDDQ$  must be maintained and is applicable to both AC and DC levels until the ramping of the supply voltages is complete, which is when VDDQ crosses VDDQ min. Once the ramping of the supply voltages is complete, the supply voltage specifications provided in section 5.2, table 20 Recommended DC operating conditions (SSTL\_1.8), prevail.

- Apply VDD/VDDL before or at the same time as VDDQ.
  - VDD/VDDL voltage ramp time must be no greater than 200 ms from when VDD ramps from 300 mV to VDD min
  - Apply VDDQ before or at the same time as VTT.
  - The VDDQ voltage ramp time from when VDD min is achieved on VDD to when VDDQ min is achieved on VDDQ must be no greater than 500 ms.
- (Note: While VDD is ramping, current may be supplied from VDD through the DRAM to VDDQ.)
- Vref must track  $VDDQ/2$ , Vref must be within  $\pm 300$  mV with respect to  $VDDQ/2$  during supply ramp time.
  - $VDDQ \geq VREF$  must be met at all times.
  - Apply VTT.
  - The VTT voltage ramp time from when VDDQ min is achieved on VDDQ to when VTT min is achieved on VTT must be no greater than 500 ms.

2) Start clock and maintain stable condition.

3) For the minimum of 200 us after stable power (VDD, VDDL, VDDQ, VREF and VTT are between their minimum and maximum values as stated in section 5.2, table 20 Recommended DC operating conditions (SSTL\_1.8)) and stable clock (CK, CK), then apply NOP or Deselect & take CKE HIGH.

4) Wait minimum of 400 ns then issue precharge all command. NOP or Deselect applied during 400 ns period.

5) Issue an EMRS command to EMR(2). (To issue EMRS command to EMR(2), provide LOW to BA0 and BA2, HIGH to BA1.)

6) Issue an EMRS command to EMR(3). (To issue EMRS command to EMR(3), provide LOW to BA2, HIGH to BA0 and BA1.)

7) Issue EMRS to enable DLL. (To issue DLL Enable command, provide LOW to A0, HIGH to BA0 and LOW to BA1-BA2 and A13-A15. And  $A9=A8=A7=LOW$  must be used when issuing this command.)

8) Issue a Mode Register Set command for DLL reset.

(To issue DLL Reset command, provide HIGH to A8 and LOW to BA0-BA2, and A13-A15.)

9) Issue a precharge all command.

10) Issue 2 or more auto-refresh commands.

11) Issue a MRS command with LOW to A8 to initialize device operation. (i.e. to program operating parameters

12) At least 200 clocks after step 8), execute OCD Calibration (Off Chip Driver impedance adjustment).

If OCD calibration is not used, EMRS to EMR(1) to set OCD Calibration Default ( $A9=A8=A7=HIGH$ ) followed by EMRS to EMR(1) to exit OCD Calibration Mode ( $A9=A8=A7=LOW$ ) must be issued with other operating parameters of EMR(1).

13) The DDR2 SDRAM is now ready for normal operation.

\*1: To guarantee ODT off, VREF must be valid and a LOW level must be applied to the ODT pin.

## Mode Register Set (MRS)

The mode register stores the data for controlling the various operating modes of DDR2 SDRAM.

BA2	BA1	BA0	A14 A13	A12	A11	A10	A9	A8	A7	A6	A5	A4	A3	A2	A1	A0
0 <sup>1)</sup>	0	0	0 <sup>1)</sup>	PD	WR			DLL	TM	CL			BT	BL		

**TABLE 10**  
Mode Register Definition, BA<sub>2:0</sub> = 000<sub>B</sub>

Field	Bits	Description
PD	12	<b>Active Power-Down Mode Select</b> 0 <sub>B</sub> PD Fast exit 1 <sub>B</sub> PD Slow exit
WR	[11:9]	<b>Write Recovery<sup>2)</sup></b> <i>Note: All other bit combinations are illegal.</i> 001 <sub>B</sub> WR 2 010 <sub>B</sub> WR 3 011 <sub>B</sub> WR 4 100 <sub>B</sub> WR 5 101 <sub>B</sub> WR 6 110 <sub>B</sub> WR 7 111 <sub>B</sub> WR 8
DLL	8	<b>DLL Reset</b> 0 <sub>B</sub> DLL No 1 <sub>B</sub> DLL Yes
TM	7	<b>Test Mode</b> 0 <sub>B</sub> TM Normal Mode 1 <sub>B</sub> TM Vendor specific test mode

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

- 1) BA2 and A14-A13 are reserved for future use and must be set to 0 when programming the MR.
- 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  $t_{CK,MIN}$ -3) speed bin determined.
- 3) speed bin determined.

## Extended Mode Register EMR(1)

The Extended Mode Register EMR(1) stores the data for enabling or disabling the DLL, output driver strength, additive

latency, OCD program, ODT,  $\overline{DQS}$  and output buffers disable, RDQS and RDQS enable.

BA2	BA1	BA0	A14 A13	A12	A11	A10	A9	A8	A7	A6	A5	A4	A3	A2	A1	A0
0 <sup>1)</sup>	0	1	0 <sup>1)</sup>	Qoff	RDQS	$\overline{DQS}$	OCD Program			Rtt	AL			Rtt	DIC	DLL

**TABLE 11**

Extended Mode Register Definition, BA<sub>2:0</sub> = 001<sub>B</sub>

Field	Bits	Description
Qoff	12	<b>Output Disable</b> <sup>5)</sup> 0 <sub>B</sub> <b>QOff</b> Output buffers enabled 1 <sub>B</sub> <b>QOff</b> Output buffers disabled
RDQS	11	<b>Read Data Strobe Output (RDQS, <math>\overline{RDQS}</math>)</b> <sup>6)</sup> 0 <sub>B</sub> <b>RDQS</b> Disable 1 <sub>B</sub> <b>RDQS</b> Enable
$\overline{DQS}$	10	<b>Complement Data Strobe (DQS Output)</b> 0 <sub>B</sub> $\overline{DQS}$ Enable 1 <sub>B</sub> $\overline{DQS}$ Disable
OCD Program	[9:7]	<b>Off-Chip Driver Calibration Program</b> 000 <sub>B</sub> <b>OCD</b> OCD calibration mode exit, maintain setting 001 <sub>B</sub> <b>OCD</b> Drive (1) 010 <sub>B</sub> <b>OCD</b> Drive (0) 100 <sub>B</sub> <b>OCD</b> Adjust mode <sup>3)</sup> 111 <sub>B</sub> <b>OCD</b> OCD calibration default <sup>4)</sup>
AL	[5:3]	<b>Additive Latency</b> <i>Note: All other bit combinations are illegal.</i> 000 <sub>B</sub> <b>AL</b> 0 001 <sub>B</sub> <b>AL</b> 1 010 <sub>B</sub> <b>AL</b> 2 011 <sub>B</sub> <b>AL</b> 3 100 <sub>B</sub> <b>AL</b> 4 101 <sub>B</sub> <b>AL</b> 5 110 <sub>B</sub> <b>AL</b> 6

Field	Bits	Description
R <sub>TT</sub>	6,2	<b>Nominal Termination Resistance of ODT</b> 00 <sub>B</sub> <b>RTT</b> ∞ (ODT disabled) 01 <sub>B</sub> <b>RTT</b> 75 Ohm 10 <sub>B</sub> <b>RTT</b> 150 Ohm 11 <sub>B</sub> <b>RTT</b> 50 Ohm <sup>2)</sup>
DIC	1	<b>Off-chip Driver Impedance Control</b> 0 <sub>B</sub> <b>DIC</b> Full (Driver Size = 100%) 1 <sub>B</sub> <b>DIC</b> Reduced
DLL	0	<b>DLL Enable</b> 0 <sub>B</sub> <b>DLL</b> Enable 1 <sub>B</sub> <b>DLL</b> Disable

- 1) BA2 and A14-A13 are reserved for future use and must be set to 0 when programming the EMR(1).
- 2) Optional for DDR2-400/533/667, mandatory for DDR2-800.
- 3) When Adjust mode is issued, AL from previously set value must be applied.
- 4) After setting to default, OCD calibration mode needs to be exited by setting A9-A7 to 000.
- 5) Output disabled - DQs, DQs<sub>s</sub>, DQSs, RDQS, RDQS. This feature is used in conjunction with DIMM IDD measurements when IDDQ is not desired to be included.
- 6) If RDQS is enabled, the DM function is disabled. RDQS is active for reads and don't care for writes.

## Extended Mode Register EMR(2)

The Extended Mode Registers EMR(2) control refresh related feature.

A14																
BA2	BA1	BA0	A13	A12	A11	A10	A9	A8	A7	A6	A5	A4	A3	A2	A1	A0
0 <sup>1)</sup>	1	0				0 <sup>1)</sup>			SRF		0 <sup>1)</sup>		0 <sup>1)</sup>		PASR	

**TABLE 12**

EMR(2) Programming Extended Mode Register Definition, BA<sub>2:0</sub>=010<sub>B</sub>

Field	Bits	Description
SRF	7	<b>Address Bus, High Temperature Self Refresh Rate for <math>T_{CASE} &gt; 85^{\circ}C</math></b> 0 <sub>B</sub> <b>A7</b> disable 1 <sub>B</sub> <b>A7</b> enable <sup>2)</sup>
PASR	[2:0]	<b>Partial Self Refresh for 8 banks<sup>3)</sup></b> 000 <sub>B</sub> Full array (Banks 000 <sub>B</sub> - 111 <sub>B</sub> ) 001 <sub>B</sub> Half Array(Banks 000 <sub>B</sub> - 011 <sub>B</sub> ) 010 <sub>B</sub> Quarter Array(Banks 000 <sub>B</sub> - 001 <sub>B</sub> ) 011 <sub>B</sub> 1/8th array (Banks 000 <sub>B</sub> ) 100 <sub>B</sub> 3/4 array(Banks 010 <sub>B</sub> - 111 <sub>B</sub> ) 101 <sub>B</sub> Half array(Banks 100 <sub>B</sub> - 111 <sub>B</sub> ) 110 <sub>B</sub> Quarter array(Banks 110 <sub>B</sub> - 111 <sub>B</sub> ) 111 <sub>B</sub> 1/8th array(Banks 111 <sub>B</sub> )

- 1) BA2 and A6-A3, A14-A8 are reserved for future use and must be set to 0 when programming the EMR(2).
- 2) When DRAM is operated at  $85^{\circ}C \leq T_{Case} \leq 125^{\circ}C$  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 self refresh location may get lost if self refresh is entered. During non-self-refresh operation, data integrity will be maintained if  $t_{REFI}$  conditions are met.



## Extended Mode Register EMR(3)

The Extended Mode Register EMR(3) is reserved for future use and all bits except BA0 and BA1 must be programmed to 0 when setting the mode register during initialization.

BA2	BA1	BA0	A14 A13	A12	A11	A10	A9	A8	A7	A6	A5	A4	A3	A2	A1	A0
0 <sup>1)</sup>	0	1	0 <sup>1)</sup>													

- 1) All bits in EMR(3) except BA0 and BA1 are reserved for future use and must be set to 0 when programming the EMR(3).

## 3.6 Burst Mode Operation

**TABLE 14**  
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

# Truth Tables

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

TABLE 15

Command Truth Table

Function	CKE		CS	RAS	CAS	WE	BA0 BA1 BA2	A[14:11]	A10	A[9:0]	Note <sup>1)2)3)</sup>
	Previous Cycle	Current Cycle									
(Extended) Mode Register	H	H	L	L	L	L	BA	OP Code			4)5)6)
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)7)
Self-Refresh Exit	L	H	H	X	X	X	X	X	X	X	4)7)8)
			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)5)
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)9)
Write with Auto-Precharge	H	H	L	H	L	L	BA	Column	H	Column	4)5)9)
Read	H	H	L	H	L	H	BA	Column	L	Column	4)5)9)
Read with Auto-Precharge	H	H	L	H	L	H	BA	Column	H	Column	4)5)9)
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)10)
			L	H	H	H					
Power Down Exit	L	H	H	X	X	X	X	X	X	X	4)10)
			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 CS, WE, RAS, CAS and CKE at the rising edge of the clock.

5) Bank addresses BA[2:0] determine which bank is to be operated upon. For (E)MRS BA[2:0] selects an (Extended) Mode Register.

6) All banks must be in a precharged idle state, CKE must be high at least for  $t_{XP}$  and all read/write bursts must be finished before the (Extended) Mode Register set Command is issued.

7)  $V_{REF}$  must be maintained during Self Refresh operation.

8) Self Refresh Exit is asynchronous.

9) Burst reads or writes at BL = 4 cannot be terminated.

10) The Power Down Mode does not perform any refresh operations. The duration of Power Down is therefore limited by the refresh requirements.

**TABLE 16**

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

Current State <sup>1)</sup>	CKE		Command (N) <sup>2)3)</sup> RAS, CAS, WE, CS	Action (N) <sup>2)</sup>	Note <sup>4)5)</sup>
	Previous Cycle <sup>6)</sup> (N-1)	Current Cycle <sup>6)</sup> (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	7)9)10)11)15)
All Banks Idle	H	L	DESELECT or NOP	Precharge Power-Down Entry	7)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 therefore 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 DESELECT 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 17**

**Data Mask (DM) Truth Table**

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

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

# Electrical Characteristics

This chapter describes the Electrical Characteristics.

## Absolute Maximum Ratings

Caution is needed not to exceed absolute maximum ratings of the DRAM device listed in **Table 18** at any time.

TABLE 18 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)3)
$T_{STG}$	Storage Temperature	-55	+150	°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. VDD and VDDQ must be within 300mV of each other at all times; and VREF must be not greater than 0.6 x VDDQ.

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

3) Voltage on any input or I/O may not exceed voltage on VDDQ.

**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 19 DRAM Component Operating Temperature Range					
Symbol	Parameter	Rating		Unit	Note <sup>1)-4)</sup>
		Min.	Max.		
$T_{OPER}$	Operating Temperature	0	+95	°C	Commercial Temperature
		-40	+95	°C	Industrial Temperature
		-40	+105	°C	Automotive A2 Temperature
		-55	+125	°C	High-Rel Temperature

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.

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 125 °C  $T_{CASE}$  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%.

## DC Characteristics

TABLE 20

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)5)
$V_{DDL}$	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)5)
$V_{REF}$	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)

- 1)  $V_{DDQ}$  tracks with  $V_{DD}$ ,  $V_{DDL}$  tracks with  $V_{DD}$ . AC parameters are measured with  $V_{DD}$ ,  $V_{DDQ}$  and  $V_{DDL}$  tied together.
- 2) 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  $V_{DDQ}$ .
- 3) Peak to peak ac noise on  $V_{REF}$  may not exceed  $\pm 2\% V_{REF}$  (dc)
- 4)  $V_{TT}$  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 the dc level of  $V_{REF}$ .
- 5) There is no specific device VDD supply voltage requirement for SSTL\_18 compliance. However under all conditions VDDQ must be less than or equal to VDD.

TABLE 21

ODT DC Electrical Characteristics

Parameter / Condition	Symbol	Min.	Nom.	Max.	Unit	Note
Termination resistor impedance value for EMRS(1)[A6,A2] = [0,1]; 75	Rtt1(eff)	60	75	90	$\Omega$	1)
Termination resistor impedance value for EMRS(1)[A6,A2] = [1,0]; 150	Rtt2(eff)	120	150	180	$\Omega$	1)
Termination resistor impedance value for EMRS(1)(A6,A2)=[1,1]; 50	Rtt3(eff)	40	50	60	$\Omega$	1)2)
Deviation of $V_M$ with respect to $V_{DDQ} / 2$	delta $V_M$	-6.00	—	+6.00	%	3)

- 1) 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.  

$$Rtt(eff) = (V_{IH(ac)} - V_{IL(ac)}) / (I(V_{IH(ac)}) - I(V_{IL(ac)}))$$
- 2) Optional for DDR2-667, mandatory for DDR2-800.
- 3) Measurement Definition for VM: Turn ODT on and measure voltage (VM) at test pin (midpoint) with no load:  $\text{delta } V_M = ((2 \times V_M / V_{DDQ}) - 1) \times 100\%$

TABLE 22

Input and Output Leakage Currents

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

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

## 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 23**  
DC & AC Logic Input Levels

Symbol	Parameter	DDR2-667, DDR2-800, DDR2-1066		Units
		Min.	Max.	
$V_{IH(dc)}$	DC input logic HIGH	$V_{REF} + 0.125$	$V_{DDQ} + 0.3$ <sup>1)</sup>	V
$V_{IL(dc)}$	DC input LOW	-0.3	$V_{REF} - 0.125$	V
$V_{IH(ac)}$	AC input logic HIGH	$V_{REF} + 0.200$	$V_{DDQ} + V_{PEAK}$ <sup>2)</sup>	V
$V_{IL(ac)}$	AC input LOW	$V_{SSQ} - V_{PEAK}$ <sup>2)</sup>	$V_{REF} - 0.200$	V

1)  $V_{DDQ} + 300mV$  allowed provided 1.9V is not exceeded.

2) Refer to Overshoot/undershoot specification. for  $V_{peak}$  value: maximum peak amplitude allowed for overshoot and undershoot.

**TABLE 24**  
Single-ended AC Input Test Conditions

Symbol	Condition	Value	Unit	Notes
$V_{REF}$	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 3**.

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 3

Single-ended AC Input Test Conditions Diagram

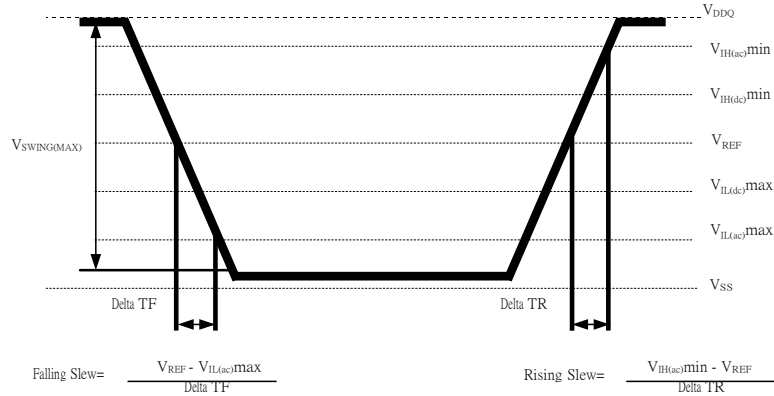


TABLE 25

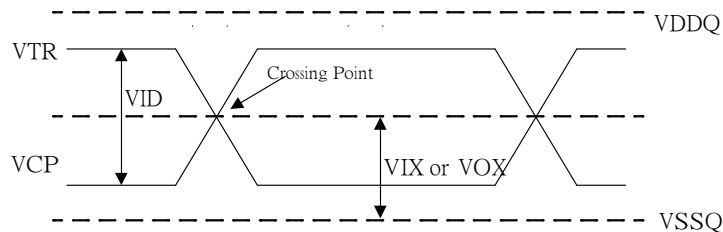
Differential DC and AC Input and Output Logic Levels

Symbol	Parameter	Min.	Max.	Unit	Notes
$V_{IN(dc)}$	DC input signal voltage	-0.3	$V_{DDQ} + 0.3$		1)6)
$V_{ID(dc)}$	DC differential input voltage	0.25	$V_{DDQ} + 0.3$		2)6)
$V_{ID(ac)}$	AC differential input voltage	0.5	$V_{DDQ} + V_{peak}$	V	3)7)
$V_{IX(ac)}$	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	$0.5 \times V_{DDQ} - 0.125$	$0.5 \times V_{DDQ} + 0.125$	V	5)

- 1)  $V_{IN(dc)}$  specifies the allowable DC execution of each input of differential pair such as CK,  $\overline{CK}$ , DQS,  $\overline{DQS}$  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  $VOX(ac)$  is expected to equal  $0.5 \times V_{DDQ}$  of the transmitting device and  $VOX(ac)$  is expected to track variations in  $V_{DDQ}$ .  $VOX(ac)$  indicates the voltage at which differential input signals must cross.
- 6)  $V_{DDQ} + 300mV$  allowed provided 1.9V is not exceeded.
- 7) Refer to Overshoot/undershoot specification. for  $V_{peak}$  value: maximum peak amplitude allowed for overshoot and undershoot.

FIGURE 4

Differential DC and AC Input and Output Logic Levels Diagram



## Output Buffer Characteristics

This chapter describes the Output Buffer Characteristics.

**TABLE 26**  
SSTL\_18 Output DC Current Drive

Symbol	Parameter	SSTL_18	Unit	Notes
$I_{OH}$	Output Minimum Source DC Current	-13.4	mA	1)2)4)
$I_{OL}$	Output Minimum Sink DC Current	13.4	mA	2)3)4)

- 1)  $V_{DDQ} = 1.7\text{ V}$ ;  $V_{OUT} = 1.42\text{ V}$ .  $(V_{OUT} - V_{DDQ}) / I_{OH}$  must be less than  $21\ \Omega$  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 <sup>1)</sup> and <sup>3)</sup>. 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  $21\ \Omega$  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  $21\ \Omega$  for values of  $V_{OUT}$  between  $0\text{ V}$  and  $280\text{ mV}$ .
- 4) The dc value of  $V_{REF}$  applied to the receiving device is set  $V_{TT}$ .

**TABLE 27**  
SSTL\_18 Output AC Test Conditions

Symbol	Parameter	SSTL_18	Unit	Note
$V_{OTR}$	Output Timing Measurement Reference Level	$0.5 \times V_{DDQ}$	V	

**TABLE 28**  
OCD Default Characteristics

Symbol	Description	Min.	Nominal	Max.	Unit	Notes
—	Output Impedance	See full strength default driver characteristics			$\Omega$	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)

- 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  $23.4\ \Omega$  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  $23.4\ \Omega$  for values of  $V_{OUT}$  between  $0\text{ V}$  and  $280\text{ mV}$ .
- 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  $18\ \Omega$  at nominal conditions across all process parameters and represents only the DRAM uncertainty. A  $0\ \Omega$  value (no calibration) can only be achieved if the OCD impedance is  $18 \pm 0.75\ \Omega$  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  $DQS / \overline{DQS}$  and associated  $DQ$ 's is included in  $t_{DQSQ}$  and  $t_{QHS}$  specification.



## Input / Output Capacitance

This chapter contains the Input / Output Capacitance.

**TABLE 29**

Input / Output Capacitance

Symbol	Parameter	DDR2-800		DDR2-667		DDR2-1066		Unit
		Min.	Max.	Min.	Max.	Min.	Max.	
CCK	Input capacitance, CK and $\overline{\text{CK}}$	1.0	2.0	1.0	2.0	1.0	2.0	pF
CDCK	Input capacitance delta, CK and $\overline{\text{CK}}$	—	0.25	—	0.25	—	0.25	pF
CI	Input capacitance, all other input-only pins	1.0	1.75	1.0	2.0	1.0	1.75	pF
CDI	Input capacitance delta, all other input-only pins	—	0.25	—	0.25	—	0.25	pF
CIO	Input/output capacitance, DQ, DM, DQS, $\overline{\text{DQS}}$	2.5	3.5	2.5	3.5	2.5	3.5	pF
CDIO	Input/output capacitance delta, DQ, DM, DQS, $\overline{\text{DQS}}$	—	0.5	—	0.5	—	0.5	pF

## Overshoot and Undershoot Specification

This chapter contains Overshoot and Undershoot Specification.

TABLE 30				
AC Overshoot / Undershoot Specification for Address and Control Pins				
Parameter	DDR2-667	DDR2-800	DDR2-1066	Unit
Maximum peak amplitude allowed for overshoot area	0.5	0.5	0.5	V
Maximum peak amplitude allowed for undershoot area	0.5	0.5	0.5	V
Maximum overshoot area above $V_{DD}$	0.8	0.66	0.5	V-ns
Maximum undershoot area below $V_{SS}$	0.8	0.66	0.5	V-ns

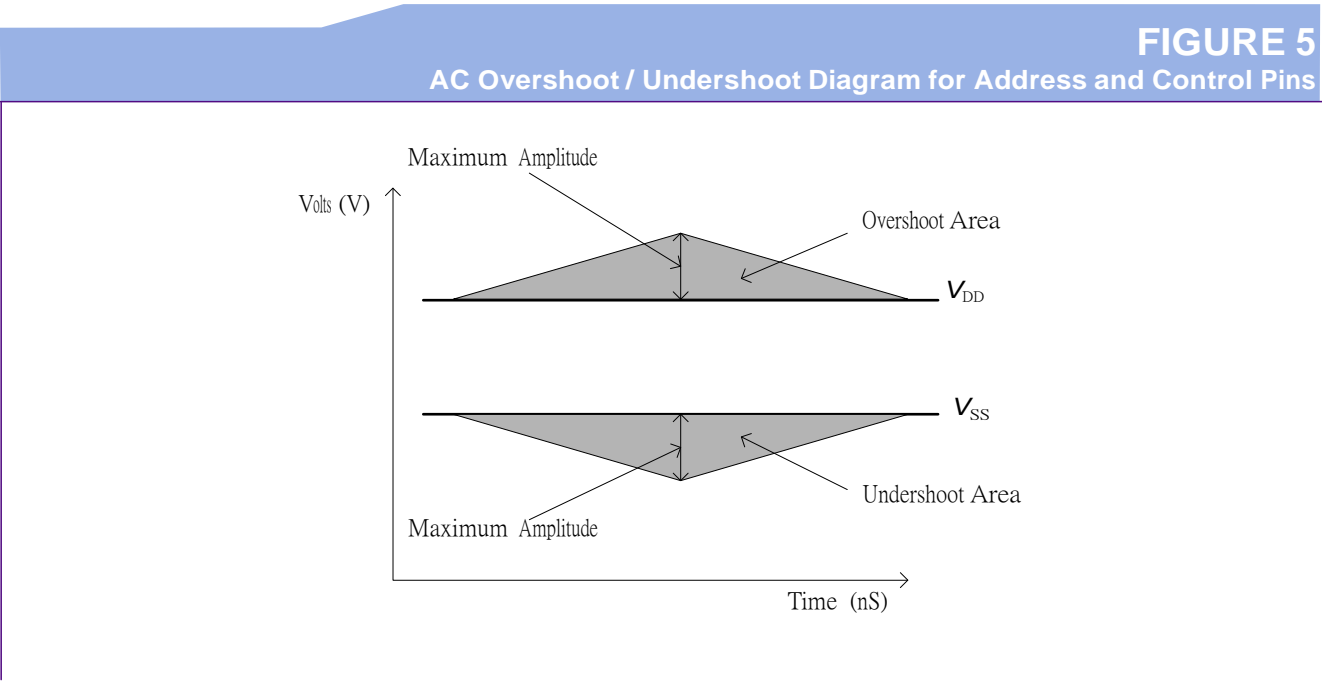


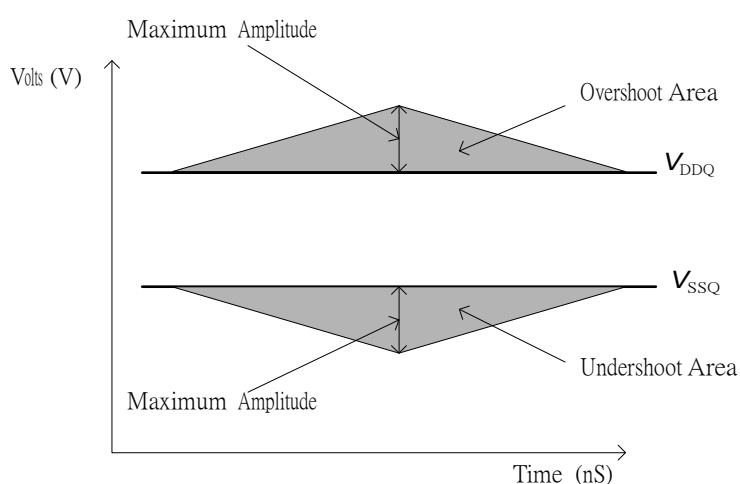
TABLE 31

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

Parameter	DDR2-667	DDR2-800	DDR2-1066	Unit
Maximum peak amplitude allowed for overshoot area	0.5	0.5	0.5	V
Maximum peak amplitude allowed for undershoot area	0.5	0.5	0.5	V
Maximum overshoot area above $V_{DDQ}$	0.23	0.23	0.19	V-ns
Maximum undershoot area below $V_{SSQ}$	0.23	0.23	0.19	V-ns

FIGURE 6

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



# Currents Measurement Conditions

This chapter describes the Current Measurement, Specifications and Conditions.

**TABLE 32**  
**I<sub>DD</sub> Measurement Conditions**

Parameter	Symbol	Note <sup>1)-7)</sup>
<b>Operating Current - One bank Active - Precharge</b> $t_{CK} = t_{CK(1DD)}$ , $t_{RC} = t_{RC(1DD)}$ , $t_{RAS} = t_{RAS.MIN(1DD)}$ , CKE is HIGH, $\overline{CS}$ is HIGH between valid commands. Address and control inputs are switching; Databus inputs are switching.	$I_{DD0}$	
<b>Operating Current - One bank Active - Read - Precharge</b> $I_{OUT} = 0$ mA, BL = 4, $t_{CK} = t_{CK(1DD)}$ , $t_{RC} = t_{RC(1DD)}$ , $t_{RAS} = t_{RAS.MIN(1DD)}$ , $t_{RCD} = t_{RCD(1DD)}$ , AL = 0, CL = CL(1DD); CKE is HIGH, $\overline{CS}$ is HIGH between valid commands. Address and control inputs are switching; Databus inputs are switching.	$I_{DD1}$	
<b>Precharge Power-Down Current</b> All banks idle; CKE is LOW; $t_{CK} = t_{CK(1DD)}$ ; Other control and address inputs are stable; Data bus inputs are floating.	$I_{DD2P}$	
<b>Precharge Standby Current</b> All banks idle; $\overline{CS}$ is HIGH; CKE is HIGH; $t_{CK} = t_{CK(1DD)}$ ; Other control and address inputs are switching, Data bus inputs are switching.	$I_{DD2N}$	
<b>Precharge Quiet Standby Current</b> All banks idle; $\overline{CS}$ is HIGH; CKE is HIGH; $t_{CK} = t_{CK(1DD)}$ ; Other control and address inputs are stable, Data bus inputs are floating.	$I_{DD2Q}$	
<b>Active Power-Down Current</b> All banks open; $t_{CK} = t_{CK(1DD)}$ , 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).	$I_{DD3P(0)}$	
<b>Active Power-Down Current</b> All banks open; $t_{CK} = t_{CK(1DD)}$ , 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);	$I_{DD3P(1)}$	
<b>Active Standby Current</b> All banks open; $t_{CK} = t_{CK(1DD)}$ ; $t_{RAS} = t_{RAS.MAX(1DD)}$ , $t_{RP} = t_{RP(1DD)}$ ; CKE is HIGH, $\overline{CS}$ is HIGH between valid commands. Address inputs are switching; Data Bus inputs are switching;	$I_{DD3N}$	
<b>Operating Current</b> Burst Read: All banks open; Continuous burst reads; BL = 4; AL = 0, CL = CL(1DD); $t_{CK} = t_{CK(1DD)}$ ; $t_{RAS} = t_{RAS.MAX(1DD)}$ , $t_{RP} = t_{RP(1DD)}$ ; CKE is HIGH, $\overline{CS}$ is HIGH between valid commands. Address inputs are switching; Data Bus inputs are switching; $I_{OUT} = 0$ mA.	$I_{DD4R}$	
<b>Operating Current</b> Burst Write: All banks open; Continuous burst writes; BL = 4; AL = 0, CL = CL(1DD); $t_{CK} = t_{CK(1DD)}$ ; $t_{RAS} = t_{RAS.MAX(1DD)}$ , $t_{RP} = t_{RP(1DD)}$ ; CKE is HIGH, $\overline{CS}$ is HIGH between valid commands. Address inputs are switching; Data Bus inputs are switching;	$I_{DD4W}$	
<b>Burst Refresh Current</b> $t_{CK} = t_{CK(1DD)}$ , Refresh command every $t_{RFC} = t_{RFC(1DD)}$ interval, CKE is HIGH, $\overline{CS}$ is HIGH between valid commands, Other control and address inputs are switching, Data bus inputs are	$I_{DD5B}$	
<b>Distributed Refresh Current</b> $t_{CK} = t_{CK(1DD)}$ , 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	$I_{DD5D}$	

Parameter	Symbol	Note
<b>Self-Refresh Current</b> 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.	$I_{\text{DD6}}$	
<b>Operating Bank Interleave Read Current</b> 1. All banks interleaving reads, $I_{\text{OUT}} = 0$ mA; BL = 4, CL = CL <sub>(IDD)</sub> , AL = $t_{\text{RCD(IDD)}} - 1 \times t_{\text{CK(IDD)}}$ ; $t_{\text{CK}} = t_{\text{CK(IDD)}}$ , $t_{\text{RC}} = t_{\text{RC(IDD)}}$ , $t_{\text{RRD}} = t_{\text{RRD(IDD)}}$ ; tFAW = tFAW(IDD), Trcd = 1 x tck(IDD); CKE is HIGH, CS is HIGH between valid commands. Address bus inputs are stable during deselects; Data bus is switching.	$I_{\text{DD7}}$	

- 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  $\overline{\text{UDQS}}$ . IDD values must be met with all combinations of EMRS bits 10 and 11.
- 5) Definitions for  $I_{\text{DD}}$ , see [Table 33](#).
- 6) Timing parameter minimum and maximum values for  $I_{\text{DD}}$  current measurements are defined in Chapter 7.
- 7) Input slew rate is specified by AC Parametric Test Condition.

#### Detailed $I_{\text{DD7}}$

The detailed timings are shown below for IDD7. Changes will be required if timing parameter changes are made to the specification. Legend: A = Active; RA = Read with Autoprecharge; D = Deselect.

#### $I_{\text{DD7}}$ : Operating Current: All Bank Interleave Read operation

All banks are being interleaved at minimum  $t_{\text{RC,IDD}}$  without violating  $t_{\text{RRD,IDD}}$  and  $t_{\text{FAW,IDD}}$  using a burst length of 4. Control and address bus inputs are STABLE during DESELECTs. IOUT = 0 mA.

#### Timing Patterns for devices with 1KB page size

DDR2-667: A0 RA0 D A1 RA1 D A2 RA2 D A3 RA3 D D A4 RA4 D A5 RA5 D A6 RA6 D A7 RA7 D

D DDR2-800: A0 RA0 D A1 RA1 D A2 RA2 D A3 RA3 D D D A4 RA4 D A5 RA5 D A6 RA6 D A7 RA7 D D D

DDR2-1066: A0 RA0 D D A1 RA1 D D A2 RA2 D D A3 RA3 D D D D D A4 RA4 D D A5 RA5 D D A6 RA6 D D A7 RA7 D D D D D

#### Timing Patterns for devices with 2KB page size

DDR2-667: A0 RA0 D D A1 RA1 D D A2 RA2 D D A3 RA3 D D D A4 RA4 D D A5 RA5 D D A6 RA6 D D A7 RA7 D

D D DDR2-800: A0 RA0 D D A1 RA1 D D A2 RA2 D D A3 RA3 D D D D A4 RA4 D D A5 RA5 D D A6 RA6 D D A7 RA7 D D D D

DDR2-1066: A0 RA0 D D D D A1 RA1 D D D D A2 RA2 D D D D A3 RA3 D D D D A4 RA4 D D D D A5 RA5 D D D D A6 RA6 D D D D A7 RA7 D D D D

**TABLE 33**  
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

TABLE 34

 $I_{DD}$  Specification

Symbol	-19F	-25D			-3D	Unit	Note
	DDR2 - 1066	DDR2 - 800			DDR2 - 667		
	Max.	Max.			Max.		
	95°C <sup>1)</sup>	95°C <sup>1)</sup>	105°C <sup>1)</sup>	125°C <sup>1)</sup>	95°C <sup>1)</sup>		
$I_{DD0}$	61	56	60	60	51	mA	×8
$I_{DD0}$	63	58	60	62	55	mA	×16
$I_{DD1}$	77	70	72	74	65	mA	×8
$I_{DD1}$	80	72	73	75	68	mA	×16
$I_{DD2P}$	12	12	12	12	12	mA	×8
$I_{DD2P}$	12	12	12	12	12	mA	×16
$I_{DD2N}$	39	37	39	41	36	mA	×8
$I_{DD2N}$	39	37	39	41	36	mA	×16
$I_{DD2Q}$	36	36	38	40	36	mA	×8
$I_{DD2Q}$	36	36	38	40	36	mA	×16
$I_{DD3P\_0}$ (fast)	19	17	21	23	17	mA	×8
$I_{DD3P\_0}$ (fast)	19	17	24	26	17	mA	×16
$I_{DD3P\_1}$ (slow)	34	32	21	23	32	mA	×8
$I_{DD3P\_1}$ (slow)	34	32	24	26	32	mA	×16
$I_{DD3N}$	63	58	47	49	55	mA	×8
$I_{DD3N}$	63	58	50	52	55	mA	×16
$I_{DD4R}$	135	130	121	124	125	mA	×8
$I_{DD4R}$	136	131	124	127	127	mA	×16
$I_{DD4W}$	136	132	123	126	128	mA	×8
$I_{DD4W}$	137	133	126	129	129	mA	×16
$I_{DD5B}$	150	145	147	150	140	mA	×8
$I_{DD5B}$	150	145	148	151	140	mA	×16
$I_{DD5D}$	18	18	19	21	18	mA	×8
$I_{DD5D}$	18	18	20	22	18	mA	×16
$I_{DD6}$	12	12	13	13	12	mA	×8
$I_{DD6}$	12	12	13	13	12	mA	×16
$I_{DD7}$	190	185	176	179	180	mA	×8
$I_{DD7}$	192	186	179	182	181	mA	×16

1) Tcase temperature.

## 7 Timing Characteristics

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

### 7.1 Speed Grade Definitions

**TABLE 35**  
Speed Grade Definition

Speed Grade			DDR2-1066		DDR2-800		Unit	Note
UniC Sort Name			-19F		-25D			
CAS-RCD-RP latencies			7-7-7		5-5-5		$t_{CK}$	
Parameter		Symbol	Min.	Max.	Min.	Max.	—	
Clock Period	@ CL = 4	$t_{CK}$	3.75	7.5	3.75	8	ns	
	@ CL = 5	$t_{CK}$	3	7.5	2.5	8	ns	
	@ CL = 6	$t_{CK}$	2.5	7.5	—	—	ns	
	@ CL = 7	$t_{CK}$	1.875	7.5	—	—	ns	
Row Active Time		$t_{RAS}$	45	70k	45	70k	ns	
Row Cycle Time		$t_{RC}$	58.125	—	57.5	—	ns	
RAS-CAS-Delay		$t_{RCD}$	13.125	—	12.5	—	ns	
Row Precharge Time		$t_{RP}$	13.125	—	12.5	—	ns	

**TABLE 36**  
Speed Grade Definition

Speed Grade			DDR2-800		DDR2-667		Unit	Note
UnifC Sort Name			-25E		-3D			
CAS-RCD-RP latencies			6-6-6		5-5-5		$t_{CK}$	
Parameter		Symbol	Min.	Max.	Min.	Max.	—	
Clock Period	@ CL = 4	$t_{CK}$	3.75	8	3.75	8	ns	
	@ CL = 5	$t_{CK}$	3	8	3	8	ns	
	@ CL = 6	$t_{CK}$	2.5	8	—	—	ns	
Row Active Time		$t_{RAS}$	45	70k	45	70k	ns	
Row Cycle Time		$t_{RC}$	60	—	60	—	ns	
RAS-CAS-Delay		$t_{RCD}$	15	—	15	—	ns	
Row Precharge Time		$t_{RP}^{(1)}$	15	—	15	—	ns	

- 1) 8 bank device Precharge All Allowance :  $t_{RPAll}$  for a Precharge All command for an 8 Bank device is equal to  $t_{RP} + 1 \times t_{CK}$ , where  $t_{RP}$  is the value for a single bank precharge, which are shown in this table.



## Component AC Timing Parameters

TABLE 37

DRAM Component Timing Parameter by Speed Grade - DDR2-800, DDR2-667, DDR3-1066

Parameter	Symbol	DDR2-1066		DDR2-800		DDR2-667		Unit	Note <sup>1)</sup> -7)
		Min.	Max.	Min.	Max.	Min.	Max.		
DQ output access time from CK / $\overline{\text{CK}}$	$t_{AC}$	-350	350	-400	+400	-450	+450	ps	8)
CAS to $\overline{\text{CAS}}$ command delay	$t_{CCD}$	2	—	2	—	2	—	nCK	
Average clock high pulse width	$t_{CH.AVG}$	0.48	0.52	0.48	0.52	0.48	0.52	$t_{CK.AVG}$	9)10)
Average clock period	$t_{CK.AVG}$	1875	7500	2500	8000	3000	8000	ps	9)10)
CKE minimum pulse width (high and low pulse width)	$t_{CKE}$	3	—	3	—	3	—	nCK	11)
Average clock low pulse width	$t_{CL.AVG}$	0.48	0.52	0.48	0.52	0.48	0.52	$t_{CK.AVG}$	9)10)
Auto-Precharge write recovery + precharge time	$t_{DAL}$	WR + $t_{nRP}$	—	WR + $t_{nRP}$	—	WR + $t_{nRP}$	—	nCK	13)
Minimum time clocks remain ON after CKE asynchronously drops LOW	$t_{DELAY}$	$t_{IS} + t_{CK.AVG} + t_{IH}$	—	$t_{IS} + t_{CK.AVG} + t_{IH}$	—	$t_{IS} + t_{CK.AVG} + t_{IH}$	—	ns	
DQ and DM input hold time	$t_{DH.BASE}$	75	—	125	—	175	—	ps	14)18)19)
DQ and DM input pulse width for each input	$t_{DIPW}$	0.35	—	0.35	—	0.35	—	$t_{CK.AVG}$	
DQS output access time from CK / $\overline{\text{CK}}$	$t_{DQSCK}$	-325	325	-350	+350	-400	+400	ps	8)
DQS input high pulse width	$t_{DQSH}$	0.35	—	0.35	—	0.35	—	$t_{CK.AVG}$	
DQS input low pulse width	$t_{DQSL}$	0.35	—	0.35	—	0.35	—	$t_{CK.AVG}$	
DQS-DQ skew for DQS & associated DQ signals	$t_{DQSQ}$	—	175	—	200	—	240	ps	15)
DQS latching rising transition to associated clock edges	$t_{DQSS}$	- 0.25	+ 0.25	- 0.25	+ 0.25	- 0.25	+ 0.25	$t_{CK.AVG}$	16)
DQ and DM input setup time	$t_{DS.BASE}$	0	—	50	—	100	—	ps	17)18)19)
DQS falling edge hold time from CK	$t_{DSH}$	0.2	—	0.2	—	0.2	—	$t_{CK.AVG}$	16)
DQS falling edge to CK setup time	$t_{DSS}$	0.2	—	0.2	—	0.2	—	$t_{CK.AVG}$	16)
Four Activate Window for 1KB page size products	$t_{FAW}$	35	—	35	—	37.5	—	ns	34)
Four Activate Window for 2KB page size products	$t_{FAW}$	45	—	45	—	50	—	ns	34)
CK half pulse width	$t_{HP}$	Min( $t_{CH.AB}$ $S_1$ )	—	Min( $t_{CH.AB}$ $S_1$ )	—	Min( $t_{CH.AB}$ $S_1$ )	—	ps	20)
Data-out high-impedance time from CK / $\overline{\text{CK}}$	$t_{HZ}$	—	$t_{AC.MAX}$	—	$t_{AC.MAX}$	—	$t_{AC.MAX}$	ps	8)21)
Address and control input hold time	$t_{IH.BASE}$	200	—	250	—	275	—	ps	22)24)
Control & address input pulse width for each input	$t_{IPW}$	0.6	—	0.6	—	0.6	—	$t_{CK.AVG}$	
Address and control input setup time	$t_{IS.BASE}$	125	—	175	—	200	—	ps	23)24)

Parameter	Symbol	DDR2–1066		DDR2–800		DDR2–667		Unit	Note <sup>1)</sup> 2)3 )4)5)6)7)
		Min.	Max.	Min.	Max.	Min.	Max.		
DQ low impedance time from CK/CK	$t_{LZ,DQ}$	$2 \times t_{AC,MIN}$	$t_{AC,MAX}$	$2 \times t_{AC,MIN}$	$t_{AC,MAX}$	$2 \times t_{AC,MIN}$	$t_{AC,MAX}$	ps	8)21)
DQS/DQS low-impedance time from CK / CK	$t_{LZ,DQS}$	$t_{AC,MIN}$	$t_{AC,MAX}$	$t_{AC,MIN}$	$t_{AC,MAX}$	$t_{AC,MIN}$	$t_{AC,MAX}$	ps	8)21)
MRS command to ODT update delay	$t_{MOD}$	0	12	0	12	0	12	ns	34)
Mode register set command cycle time	$t_{MRD}$	2	—	2	—	2	—	nCK	
OCD drive mode output delay	$t_{OIT}$	0	12	0	12	0	12	ns	34)
DQ/DQS output hold time from DQS	$t_{QH}$	$t_{HP} - t_{QHS}$	—	$t_{HP} - t_{QHS}$	—	$t_{HP} - t_{QHS}$	—	ps	25)
DQ hold skew factor	$t_{QHS}$	—	250	—	300	—	340	ps	26)
Average periodic refresh Interval	$t_{REFI}$	—	7.8	—	7.8	—	7.8	$\mu s$	27)28)
		—	3.9	—	3.9	—	3.9	$\mu s$	27)29)
Auto-Refresh to Active/Auto-Refresh	$t_{RFC}$	195	—	195	—	195	—	ns	30)
Read preamble	$t_{RPRE}$	0.9	1.1	0.9	1.1	0.9	1.1	$t_{CK,AVG}$	31)32)
Read postamble	$t_{RPST}$	0.4	0.6	0.4	0.6	0.4	0.6	$t_{CK,AVG}$	31)33)
Active to active command period for 1KB page size products	$t_{RRD}$	7.5	—	7.5	—	7.5	—	ns	34)
Active to active command period for 2KB page size products	$t_{RRD}$	10	—	10	—	10	—	ns	34)
Internal Read to Precharge command delay	$t_{RTP}$	7.5	—	7.5	—	7.5	—	ns	34)
Write preamble	$t_{WPRE}$	0.35	—	0.35	—	0.35	—	$t_{CK,AVG}$	
Write postamble	$t_{WPST}$	0.4	0.6	0.4	0.6	0.4	0.6	$t_{CK,AVG}$	36)
Write recovery time	$t_{WR}$	15	—	15	—	15	—	ns	34)
Internal write to read command delay	$t_{WTR}$	7.5	—	7.5	—	7.5	—	ns	34)35)
Exit active power down to read	$t_{XARD}$	3	—	2	—	2	—	nCK	37)
Exit active power down to read command (slow exit, lower power)	$t_{XARDS}$	10 – AL	—	8 – AL	—	7 – AL	—	nCK	
Exit precharge power-down to any command	$t_{XP}$	3	—	2	—	2	—	nCK	
Exit self-refresh to a non-read command	$t_{XSNR}$	$t_{RFC} + 10$	—	$t_{RFC} + 10$	—	$t_{RFC} + 10$	—	ns	34)
Exit self-refresh to read command	$t_{XSRD}$	200	—	200	—	200	—	nCK	
Write command to DQS associated clock edges	WL	RL – 1		RL – 1		RL–1		nCK	

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

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/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 / 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.

- 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 'nCK', are introduced in DDR2-667, DDR2-800 and DDR2-1066. Unit ' $t_{CK,AVG}$ ' represents the actual  $t_{CK,AVG}$  of the input clock under operation. Unit 'nCK' represents one clock cycle of the input clock, counting the actual clock edges. Note that in DDR2-400 and DDR2-533, ' $t_{CK}$ ' is used for both concepts. Example:  $t_{XP} = 2$  [nCK] 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  $t_{DQSK,MIN(DERATED)} = t_{DQSK,MIN} - t_{ERR(6-10PER),MAX} = -400$  ps - 293 ps = -693 ps and  $t_{DQSK,MAX(DERATED)} = t_{DQSK,MAX} - t_{ERR(6-10PER),MIN} = 400$  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. 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  $t_{IS} + 2 \times t_{CK} + t_{IH}$ .
- 12)  $t_{DAL,nCK} = WR$  [nCK] +  $t_{IRP,nCK} = WR + RU\{t_{RP}[ps] / t_{CK,AVG}[ps]\}$ , 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,  $\overline{DQS}$  signals must be monotonic between  $V_{IL,DC,MAX}$  and  $V_{IH,DC,MIN}$ . See Figure 8.
- 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,  $\overline{DQS}$  signals must be monotonic between  $V_{IH(DC),MAX}$  and  $V_{IH(DC),MIN}$ . See Figure 8.
- 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 9.
- 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 9.
- 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 125 °C.
- 28) -40 °C  $\leq T_{CASE} \leq$  85 °C.
- 29) 85 °C  $< T_{CASE} \leq$  125 °C.

- 30) A maximum of eight Refresh commands can be posted to any given DDR2 SDRAM, meaning that the maximum absolute interval between any Refresh command and the next Refresh command is  $9 \times t_{REFI}$ .
- 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 7** 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  $t_{RPRE.MIN(DERATED)} = t_{RPRE.MIN} + t_{JIT.PER.MIN} = 0.9 \times t_{CK.AVG} - 72$  ps = +2178 ps and  $t_{RPRE.MAX(DERATED)} = t_{RPRE.MAX} + t_{JIT.PER.MAX} = 1.1 \times t_{CK.AVG} + 93$  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  $t_{JIT.DUTY}$  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.
- 36) The maximum limit for this parameter is not a device limit. The device will operate with a greater value for this parameter, but system performance (bus turnaround) will degrade accordingly.
- 37) User can choose which active power down exit timing to use via MRS (bit 12). tXARD is expected to be used for fast active power down exit timing. tXARDS is expected to be used for slow active power down exit timing.

FIGURE 7

Method for Calculating Transitions and Endpoint

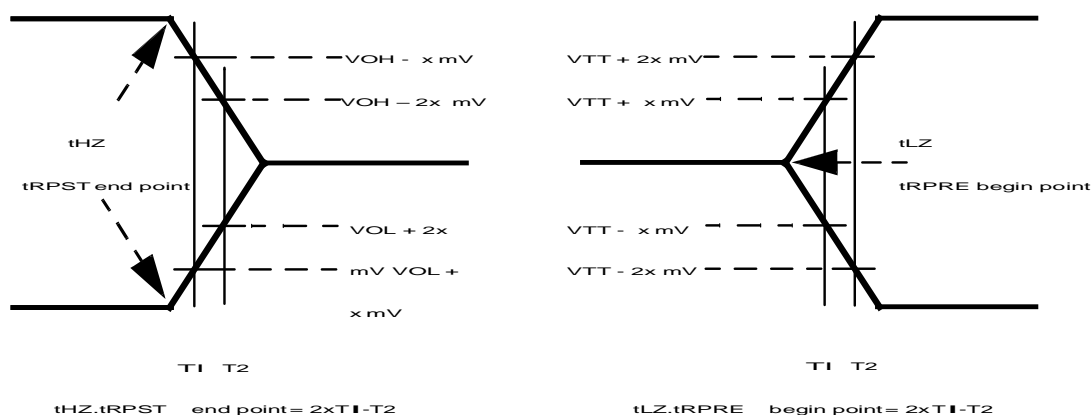


FIGURE 8

Differential Input Waveform Timing -  $t_{DS}$  and  $t_{DH}$

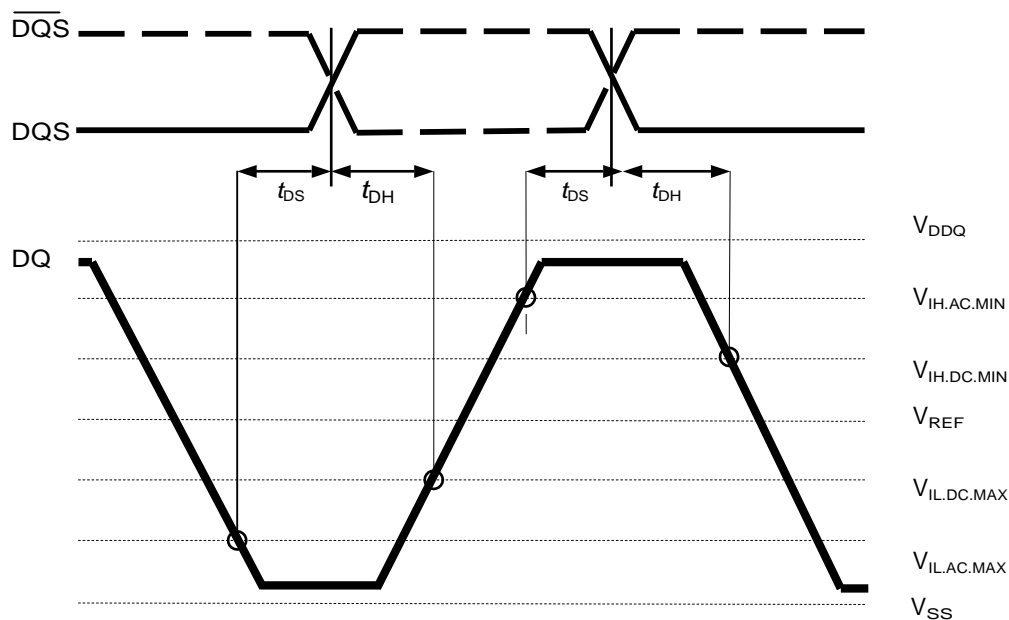
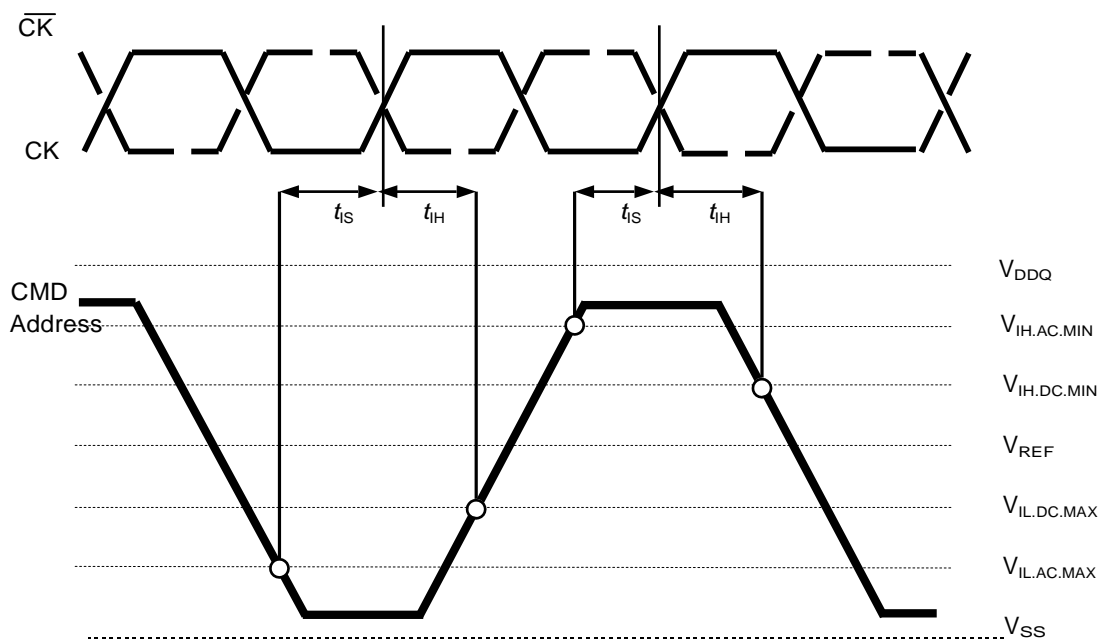


FIGURE 9

Differential Input Waveform Timing -  $t_{IS}$  and  $t_{IH}$



## 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 38**

**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> $t_{CK.AVG} = \frac{1}{N} \left( \sum_{j=1}^N t_{CKj} \right)$ <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>:</p> <p><math>t_{JIT.PER} = \text{Min/Max of } \{t_{CKi} - t_{CK.AVG}\} \text{ where } i = 1 \text{ to } 200</math></p> <p><math>t_{JIT.PER}</math> defines the single-period jitter when the DLL is already locked.</p> <p><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.</p> <p><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:</p> <p><math>t_{JIT.CC} = \text{Max of } \text{ABS}\{t_{CKi+1} - t_{CKi}\}</math></p> <p><math>t_{JIT.CC}</math> defines the cycle - to - cycle jitter when the DLL is already locked.</p> <p><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.</p> <p><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> $t_{ERR}(2per) = \left  \sum_{j=i}^{i+n-1} t_{CKj} \right  - n \times t_{CK}(avg)$ <p><math>n = 2</math> for <math>t_{ERR}(2per)</math> 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> $t_{ERR(nPER)} = \left( \sum_{j=i}^{i+n-1} t_{CK_j} \right) - n \times t_{CK(avg)}$ <p>where, i = 1 to 200            and n = 3 for <math>t_{ERR.3PER}</math>            n = 4 for <math>t_{ERR.4PER}</math>            n = 5 for <math>t_{ERR.5PER}</math>            6 ≤ n ≤ 10 for <math>t_{ERR.6-10PER}</math>            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> $t_{CH(avg)} = \frac{1}{(N \times t_{CK(avg)})} \cdot \left( \sum_{j=1}^N t_{CH_j} \right)$ <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> $t_{CL(avg)} = \frac{1}{(N \times t_{CK(avg)})} \cdot \left( \sum_{j=1}^N t_{CL_j} \right)$ <p>N = 200</p>	$t_{CK.AVG}$
$t_{JIT.DUTY}$	Duty-cycle jitter	<p><math>t_{JIT.DUTY}</math> = Min/Max of <math>\{t_{JIT.CH}, t_{JIT.CL}\}</math>, where:  <math>t_{JIT.CH}</math> is the largest deviation of any single <math>t_{CH}</math> from <math>t_{CH.AVG}</math>  <math>t_{JIT.CL}</math> is the largest deviation of any single <math>t_{CL}</math> from <math>t_{CL.AVG}</math>  <math>t_{JIT.CH} = \{t_{CHi} - t_{CH.AVG} \times t_{CK.AVG}\}</math> where i=1 to 200  <math>t_{JIT.CL} = \{t_{CLi} - t_{CL.AVG} \times t_{CK.AVG}\}</math> where i=1 to 200</p>	ps

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 39

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 40 shows clock-jitter specifications.

TABLE 40

Clock-Jitter Specifications for -667, -800, -1066

Symbol	Parameter	DDR2 -667		DDR2 -800		DDR-1066		Unit
		Min.	Max.	Min.	Max.	Min.	Max.	
$t_{CK.AVG}$	Average clock period nominal w/o jitter	3000	8000	2500	8000	1875	7500	ps
$t_{JIT.PER}$	Clock-period jitter	-125	125	-100	100	-90	90	ps
$t_{JIT(PEL,LCK)}$	Clock-period jitter during DLL locking period	-100	100	-80	80	-80	80	ps
$t_{JIT.CC}$	Cycle-to-cycle clock-period jitter	-250	250	-200	200	-180	180	ps
$t_{JIT(CC,LCK)}$	Cycle-to-cycle clock-period jitter during DLL-locking	-200	200	-160	160	-160	160	ps
$t_{ERR.2PER}$	Cumulative error across 2 cycles	-175	175	-150	150	-132	132	ps
$t_{ERR.3PER}$	Cumulative error across 3 cycles	-225	225	-175	175	-157	157	ps
$t_{ERR.4PER}$	Cumulative error across 4 cycles	-250	250	-200	200	-175	175	ps
$t_{ERR.5PER}$	Cumulative error across 5 cycles	-250	250	-200	200	-188	188	ps
$t_{ERR(6-10PER)}$	Cumulative error across n cycles with n = 6 .. 10,	-350	350	-300	300	-250	250	ps
$t_{ERR(11-50PER)}$	Cumulative error across n cycles with n = 11 .. 50,	-450	450	-450	450	-425	425	ps
$t_{CH.AVG}$	Average high-pulse width	0.48	0.52	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	0.48	0.52	$t_{CK.AVG}$
$t_{JIT.DUTY}$	Duty-cycle jitter	-125	125	-100	100	-75	75	ps



## ODT AC Electrical Characteristics

This chapter describes the ODT AC electrical characteristics.

**TABLE 41**

ODT AC Characteristics and Operating Conditions for DDR2-667, DDR2-800, DDR-1066

Symbol	Parameter / Condition	DDR-667, DDR-800		DDR-1066		Unit	Note
		Min.	Max.	Min.	Max.		
$t_{AOND}$	ODT turn-on delay	2	2	2	2	$n_{CK}$	1)
$t_{AON}$	ODT turn-on	$t_{AC.MIN}$	$t_{AC.MAX} + 0.7 \text{ ns}$	$t_{AC.MIN}$	$t_{AC.MAX} + 2.575$	ns	1)2)
$t_{AONPD}$	ODT turn-on (Power-Down Modes)	$t_{AC.MIN} + 2 \text{ ns}$	$2 t_{CK} + t_{AC.MAX} + 1 \text{ ns}$	$t_{AC.MIN} + 2 \text{ ns}$	$3 t_{CK} + t_{AC.MAX} + 1 \text{ ns}$	ns	1)
$t_{AOFD}$	ODT turn-off delay	2.5	2.5	2.5	2.5	$n_{CK}$	1)
$t_{AOF}$	ODT turn-off	$t_{AC.MIN}$	$t_{AC.MAX} + 0.6 \text{ ns}$	$t_{AC.MIN}$	$t_{AC.MAX} + 0.6$	ns	1)3)
$t_{AOFPD}$	ODT turn-off (Power-Down Modes)	$t_{AC.MIN} + 2 \text{ ns}$	$2.5 t_{CK} + t_{AC.MAX} + 1 \text{ ns}$	$t_{AC.MIN} + 2 \text{ ns}$	$2.5 t_{CK} + t_{AC.MAX} + 1 \text{ ns}$	ns	1)
$t_{ANPD}$	ODT to Power Down Mode Entry Latency	3	—	4	—	$n_{CK}$	1)
$t_{AXPD}$	ODT Power Down Exit Latency	8	—	11	—	$n_{CK}$	1)

- 1) New units, " $t_{CK.AVG}$ " and " $n_{CK}$ ", are introduced in DDR2-667, DDR2-800 and DDR2-1066. 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 ( $= 0.5 \times 3 \text{ ns}$ ) 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 Outline

This chapter contains the package dimension figures.

### Notes

1. Drawing according to ISO 8015
2. Dimensions in mm
3. General tolerances  $\pm 0.17$

**FIGURE 10**  
Package Outline PG-TFBGA-60

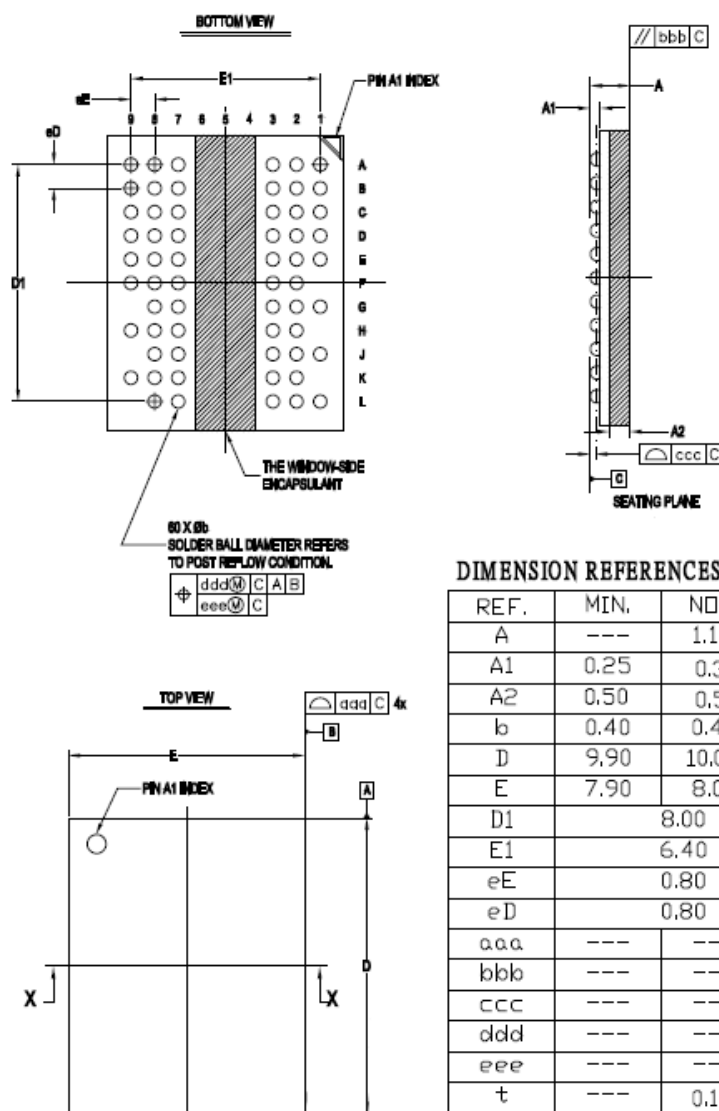
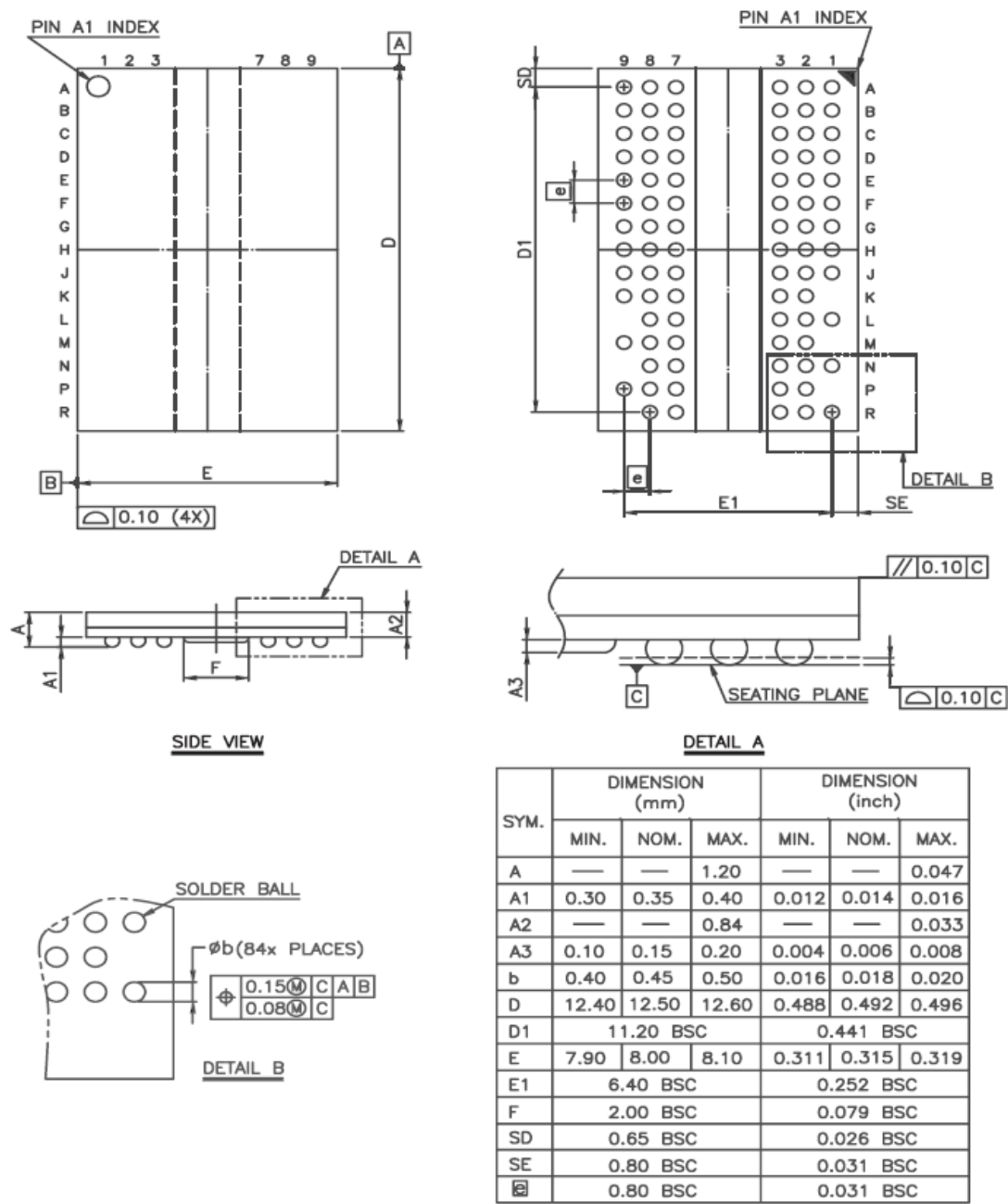


FIGURE 11  
Package Outline PG-TFBGA-84



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