

2Gb (x16) DDR2 SDRAM

NOVEMBER 2013

FEATURES

- Clock frequency up to 333MHz
- 8 internal banks for concurrent operation
- 4-bit prefetch architecture
- Programmable CAS Latency: 3, 4, 5, 6 and 7
- Programmable Additive Latency: 0, 1, 2, 3, 4, 5 and 6
- Write Latency = Read Latency-1
- Programmable Burst Sequence: Sequential or Interleave
- Programmable Burst Length: 4 and 8
- Automatic and Controlled Precharge Command
- Power Down Mode
- Auto Refresh and Self Refresh
- Refresh Interval: 7.8 μ s (8192 cycles/64 ms)
- ODT (On-Die Termination)
- Weak Strength Data-Output Driver Option
- Bidirectional differential Data Strobe (Single-ended data-strobe is an optional feature)
- On-Chip DLL aligns DQ and DQs transitions with CK transitions
- DQS# can be disabled for single-ended data strobe
- Differential clock inputs CK and CK#
- VDD and VDDQ = 1.8V \pm 0.1V
- PASR (Partial Array Self Refresh)
- SSTL_18 interface
- tRAS lockout supported
- Operating temperature:
Commercial (T_A = 0°C to 70°C ; T_C = 0°C to 85°C)
Industrial (T_A = -40°C to 85°C; T_C = -40°C to 95°C)
Automotive, A1 (T_A = -40°C to 85°C; T_C = -40°C to 95°C)
Automotive, A2 (T_A = -40°C to 105°C; T_C = -40°C to 105°C)

OPTIONS

- Configuration:
 - 128Mx16 (two-stacked 16M x 8 x 8 banks)
- Package:
 - 84-ball LF-BGA

ADDRESS TABLE

| Parameter | 128Mx16 |
|----------------------|---------|
| Row Addressing | A0-A13 |
| Column Addressing | A0-A9 |
| Bank Addressing | BA0-BA2 |
| Precharge Addressing | A10 |

Clock Cycle Timing

| | -3D | Units |
|-----------------|-----------|-------|
| Speed Grade | DDR2-667D | |
| CL-tRCD-tRP | 5-5-5 | tCK |
| tCK (CL=3) | 5 | ns |
| tCK (CL=4) | 3.75 | ns |
| tCK (CL=5) | 3 | ns |
| tCK (CL=6) | 3 | ns |
| tCK (CL=7) | 3 | ns |
| Frequency (max) | 333 | MHz |

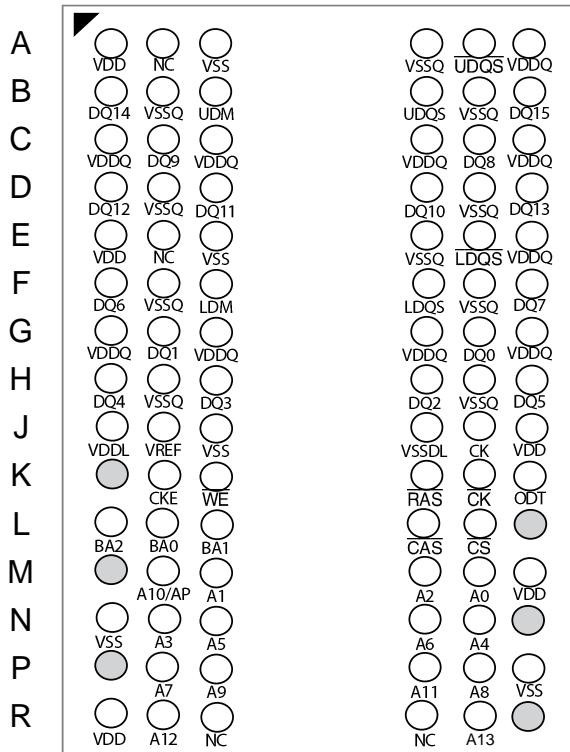
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DDR2 SDRAM (128Mx16) LF-BGA Ball-out (Top-View) (10.5mm x 13.5mm Body, 0.8mm pitch)

1 2 3 4 5 6 7 8 9


 Not populated

| Symbol | Description |
|-----------------|---------------------------|
| CK, CK# | Input clocks |
| CKE | Clock enable |
| CS# | Chip Select |
| RAS#, CAS#, WE# | Command control inputs |
| A[13:0] | Address |
| BA[2:0] | Bank Address |
| DQ[15:0] | I/O |
| UDQS, UDQS# | Upper Byte Data Strobe |
| LDQS, LDQS# | Lower Byte Data Strobe |
| UDM, LDM | Input data mask |
| VDD | Supply voltage |
| VSS | Ground |
| VDDQ | DQ power supply |
| VSSQ | DQ ground |
| VREF | Reference voltage |
| VDDL | DLL power supply |
| VSSDL | DLL ground |
| ODT | On Die Termination Enable |
| NC | No connect |

Note:
VDDL and VSSDL are power and ground for the DLL.

Functional Description

Power-up and Initialization

DDR2 SDRAMs must be powered up and initialized in a predefined manner. Operational procedures other than those specified may result in undefined operation.

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:

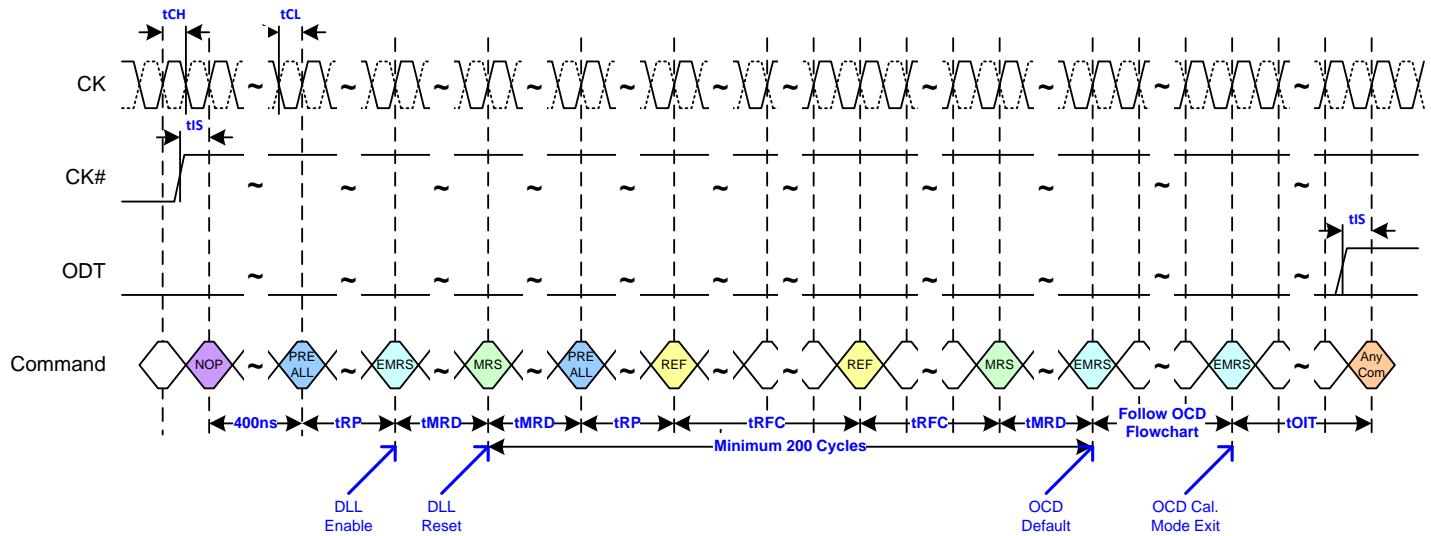
- A. While applying power, attempt to maintain CKE below $0.2 \times VDDQ$ and ODT¹ at a LOW state (all other inputs may be undefined.) The VDD voltage ramp time must be no greater than 200 ms from when VDD ramps from 300 mV to VDD(Min); and during the VDD voltage ramp, $|VDD-VDDQ| \geq 0.3$ V. Once the ramping of the supply voltages is complete (when VDDQ crosses VDDQ(Min)), the supply voltage specifications provided in the table *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 0.95V max, AND
 - VREF tracks VDDQ/2, VREF must be within ± 300 mV with respect to VDDQ/2 during supply ramp time.
 - $VDDQ \geq VREF$ must be met at all times
- B. While applying power, attempt to maintain CKE below $0.2 \times VDDQ$ and ODT¹ 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 the table *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 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 the VDDQ(Min) is achieved on VDDQ must be no greater than 500 ms.

- 2. Start clock and maintain stable condition.
- 3. For the minimum of 200 μ s after stable power (VDD, VDDL, VDDQ, VREF, and VTT values are in the range of the minimum and maximum values specified in the table *Recommended DC Operating Conditions (SSTL-1.8)*) and stable clock (CK, CK#), then apply NOP or Deselect and assert a logic HIGH to CKE.
- 4. Wait minimum of 400 ns then issue a precharge all command. During the 400 ns period, a NOP or Deselect command must be issued to the DRAM.
- 5. Issue an EMRS command to EMR(2).
- 6. Issue an EMRS command to EMR(3).
- 7. Issue EMRS to enable DLL.
- 8. Issue a Mode Register Set command for DLL reset.
- 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 without resetting the DLL.)
- 12. Wait at least 200 clock cycles after step 8 and then execute OCD Calibration. EMRS Default command (A9=A8=A7=HIGH) followed by EMRS OCD Calibration Mode Exit command (A9=A8=A7=LOW) must be issued with other operating parameters of EMR(1).
- 13. The DDR2 SDRAM is now ready for normal operation.

Note:

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

Initialization Sequence after Power-Up Diagram



Programming the Mode Register and Extended Mode Registers

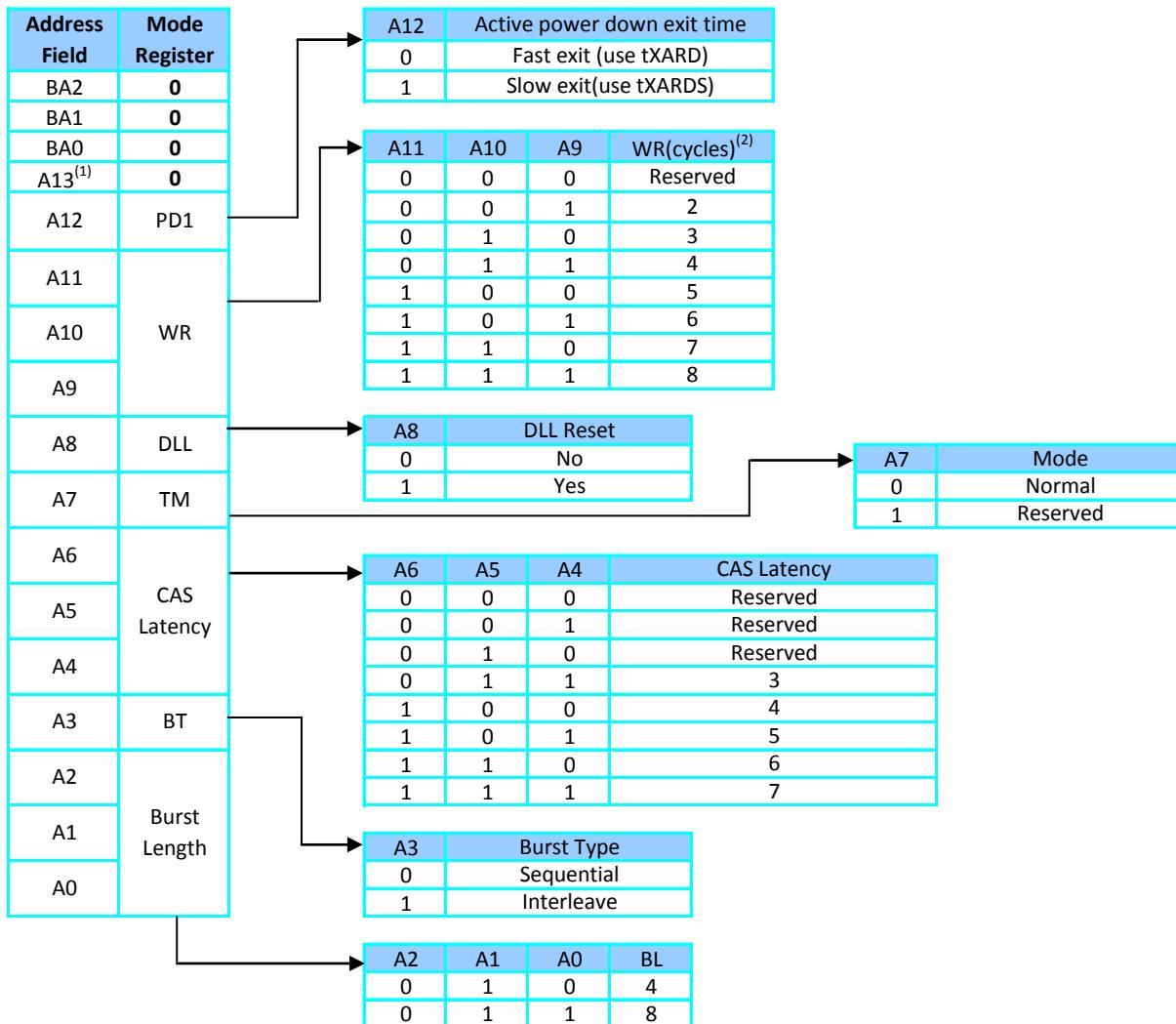
For application flexibility, burst length, burst type, CAS# latency, DLL reset function, write recovery time (WR) are user defined variables and must be programmed with a Mode Register Set (MRS) command. Additionally, DLL disable function, driver impedance, additive CAS latency, ODT (On Die Termination), single-ended strobe, and OCD (off chip driver impedance adjustment) are also user defined variables and must be programmed with an Extended Mode Register Set (EMRS) command. Contents of the Mode Register (MR) or Extended Mode Registers EMR[1] and EMR[2] can be altered by re-executing the MRS or EMRS Commands. Even if the user chooses to modify only a subset of the MR, EMR[1], or EMR[2] variables, all variables within the addressed register must be redefined when the MRS or EMRS commands are issued.

MRS, EMRS and Reset DLL do not affect memory array contents, which mean re-initialization including those can be executed at any time after power-up without affecting memory array contents.

DDR2 Mode Register (MR) Setting

The mode register stores the data for controlling the various operating modes of DDR2 SDRAM. It controls CAS# latency, burst length, burst sequence, DLL reset, tWR and active power down exit time to make DDR2 SDRAM useful for various applications. The default value of the mode register is not defined, therefore the mode register must be written after power-up for proper operation. The mode register is written by asserting LOW on CS#, RAS#, CAS#, WE#, BA0, BA1, and BA2 while controlling the state of address pins A0 - A13. The DDR2 SDRAM should be in all bank precharge with CKE already HIGH prior to writing into the mode register. The mode register set command cycle time (t_{MRD}) is required to complete the write operation to the mode register. The mode register contents can be changed using the same command and clock cycle requirements during normal operation as long as all banks are in the precharge state. The mode register is divided into various fields depending on functionality. Burst length is defined by A0 - A2 with options of 4 and 8 bit burst lengths. The burst length decodes are compatible with DDR SDRAM. Burst address sequence type is defined by A3; CAS latency is defined by A4 - A6. The DDR2 doesn't support half clock latency mode. A7 is used for test mode. A8 is used for DLL reset. A7 must be set to LOW for normal MRS operation. Write recovery time tWR is defined by A9 - A11. Refer to the table for specific codes.

Mode Register (MR) Diagram



Notes:

1. A13 is reserved for future use and must be set to 0 when programming the MR.
2. WR(write recovery for autorecharge) min is determined by tCK max and WR max is determined by tCK min. WR in clock cycles is calculated by dividing tWR (in ns) by tCK (in ns) and rounding up to the next integer ($WR[\text{cycles}] = tWR(\text{ns})/tCK(\text{ns})$). The mode register must be programmed to this value. This is also used with tRP to determine tDAL.

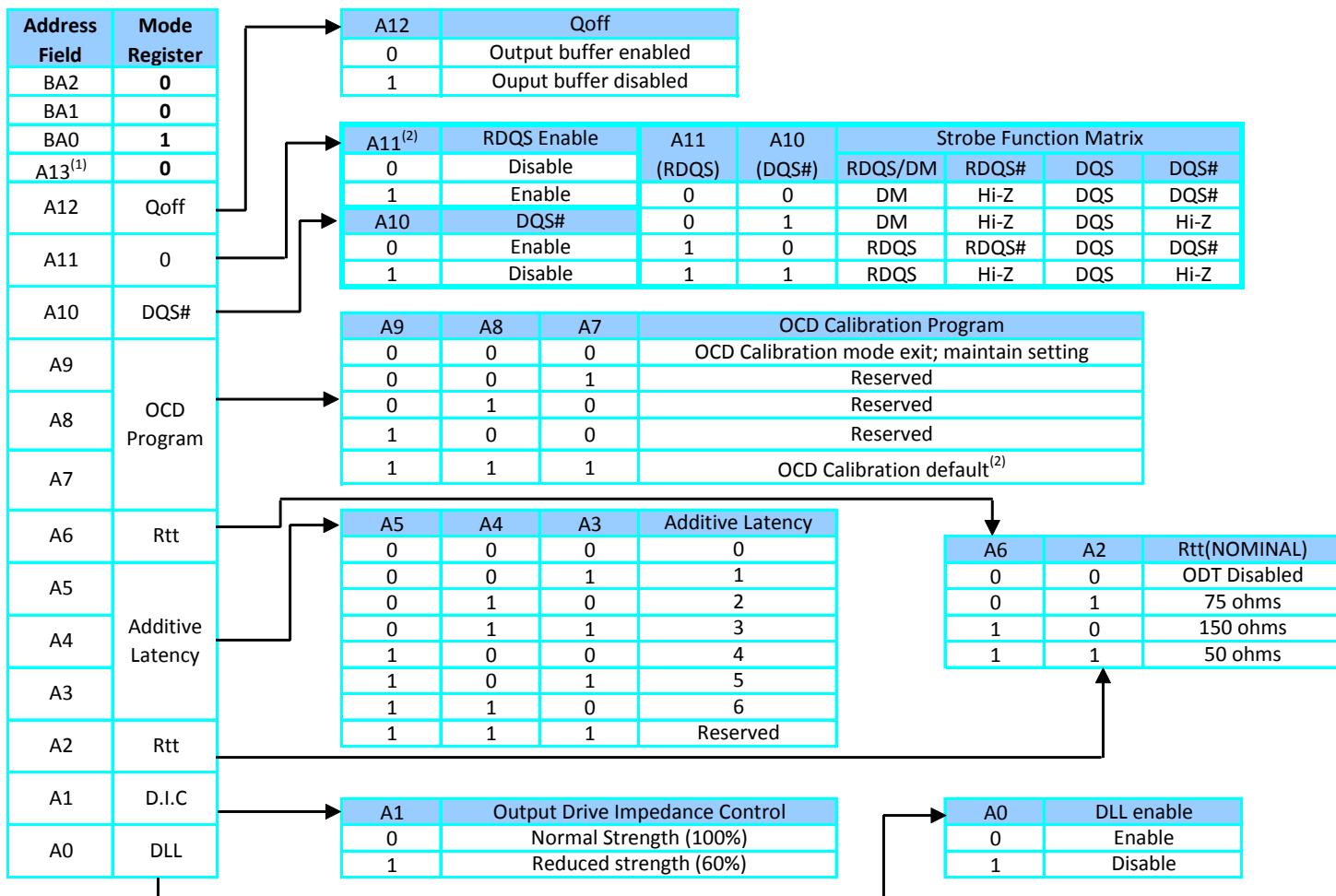
DDR2 Extended Mode Register 1 (EMR[1]) Setting

The extended mode register 1 stores the data for enabling or disabling the DLL, output driver strength, ODT value selection and additive latency. The default value of the extended mode register is not defined, therefore the extended mode register must be written after power-up for proper operation. Extended mode register 1 is written by asserting LOW on CS#, RAS#, CAS#, WE#, BA1, and BA2, and HIGH on BA0, and controlling pins A0 – A13. The DDR2 SDRAM should be in all bank precharge with CKE already HIGH prior to writing into the extended mode register. The mode register set command cycle time (tMRD) must be satisfied to complete the write operation to the extended mode register. Mode register contents can be changed using the same command and clock cycle requirements during normal operation as long as all banks are in the precharge state. A0 is used for DLL enable or disable. A1 is used for enabling reduced strength data-output driver. A3 - A5 determines the additive latency, A2 and A6 are used for ODT value selection, A7 - A9 are used for OCD control, A10 is used for DQS# disable and A11 is used for RDQS enable.

DLL Enable/Disable

The DLL must be enabled for normal operation. DLL enable is required during power up initialization, and upon returning to normal operation after having the DLL disabled. The DLL is automatically disabled when entering self refresh operation and is automatically re-enabled upon exit of self refresh operation. Any time the DLL is enabled (and subsequently reset), 200 clock cycles must occur before a Read command can be issued to allow time for the internal clock to be synchronized with the external clock. Failing to wait for synchronization to occur may result in a violation of the tAC or tDQSCK parameters.

Extended Mode Register 1(EMR[1]) Diagram



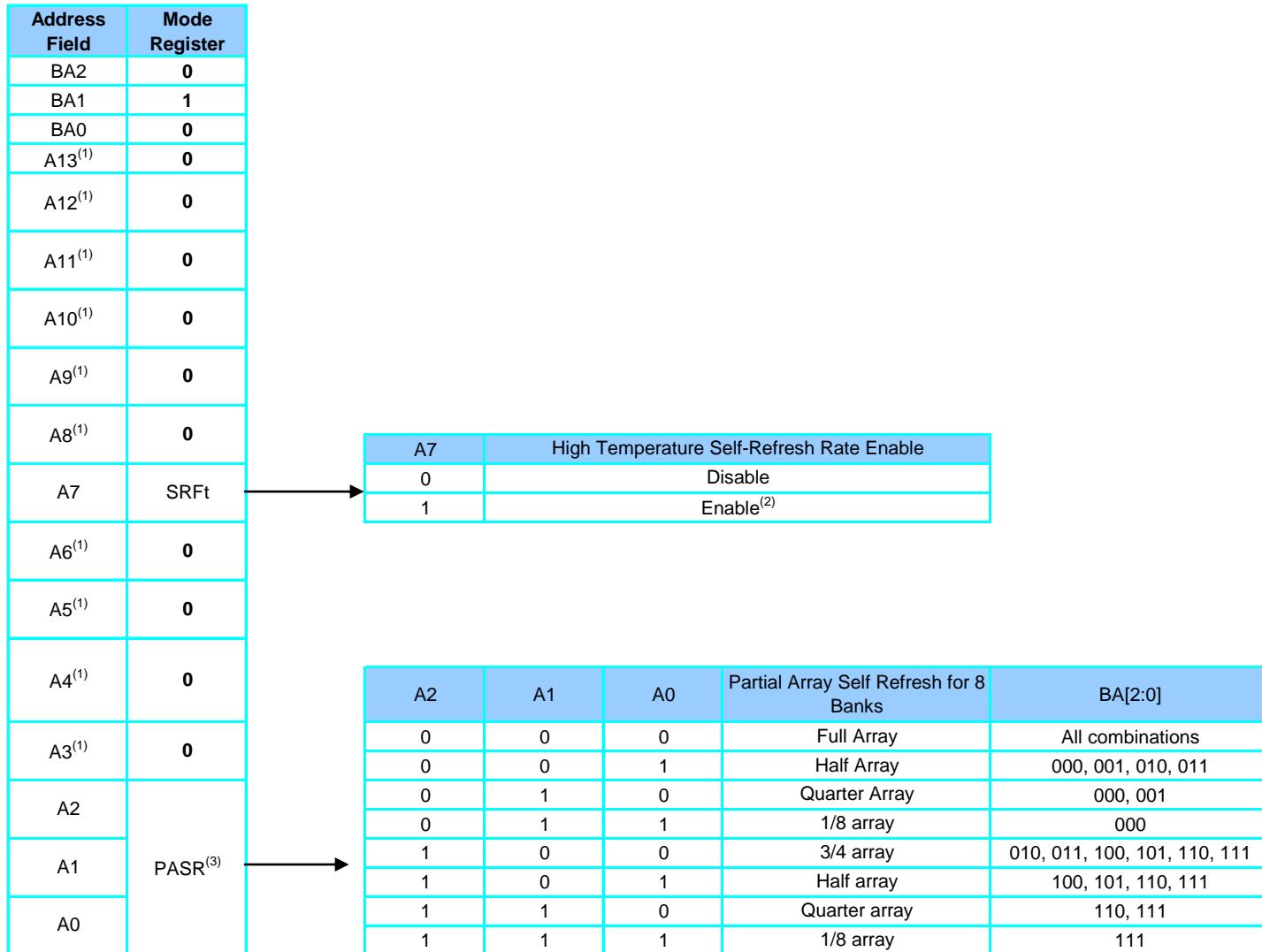
Notes:

1. A13 is reserved for future use and must be set to 0 when programming the EMR[1].
2. After setting to default, OCD calibration mode needs to be exited by setting A9-A7 to 000.

DDR2 Extended Mode Register 2 (EMR[2]) Setting

The extended mode register 2 controls refresh related features. The default value of the extended mode register 2 is not defined. Therefore, the extended mode register must be programmed during initialization for proper operation. The extended mode register 2 is written by asserting LOW on CS, RAS, CAS, WE, BA0, BA2, and HIGH on BA1, while controlling pins A0-A13. The DDR2 SDRAM should be in all bank precharge state with CKE already HIGH prior to writing into extended mode register 2. The mode register set command cycle time (tMRD) must be satisfied to complete the write operation to the extended mode register 2. Mode register contents can be changed using the same command and clock cycle requirements during normal operation as long as all banks are in precharge state.

Extended Mode Register 2 (EMR[2]) Diagram



Notes:

1. A3-A6, and A8-A13 are reserved for future use and must be set to 0 when programming the EMR[2].
2. Only Industrial and Automotive grade devices support the high temperature Self-Refresh Mode. The controller can set the EMR (2) [A7] bit to enable this self-refresh rate if $T_c > 85^\circ\text{C}$ while in self-refresh operation. TOPER may not be violated.
3. If PASR (Partial Array Self Refresh) is enabled, data located in areas of the array beyond the specified address range will be lost if self refresh is entered. Data integrity will be maintained if tREF conditions are met and no Self Refresh command is issued.

DDR2 Extended Mode Register 3 (EMR[3]) Setting

No function is defined in extended mode register 3. The default value of the extended mode register 3 is not defined. Therefore, the extended mode register 3 must be programmed during initialization for proper operation.

DDR2 Extended Mode Register 3 (EMR[3]) Diagram

| Address Field | BA2 | BA1 | BA0 | A13 | A12 | A11 | A10 | A9 | A8 | A7 | A6 | A5 | A4 | A3 | A2 | A1 | A0 |
|---------------|-----|-----|-----|-----|-----|-----|-----|----|----|----|----|----|----|----|----|----|----|
| Mode Register | 0* | 1 | 1 | 0* | 0* | 0* | 0* | 0* | 0* | 0* | 0* | 0* | 0* | 0* | 0* | 0* | |

Note: 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].

Truth Tables

Operation or 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.

Command Truth Table

| Function | CKE | | CS# | RAS# | CAS# | WE# | BA2-BA0 | An ⁽⁹⁾ -A11 | A10 | A9-A0 | Notes |
|---------------------------|----------------|---------------|-----|------|------|-----|---------|------------------------|-----|--------|-------------|
| | Previous Cycle | Current Cycle | | | | | | | | | |
| (Extended) Mode Register | H | H | L | L | L | L | BA | Opcode | | | 1, 2 |
| Refresh (REF) | H | H | L | L | L | H | X | X | X | X | 1 |
| Self Refresh Entry | H | L | L | L | L | H | X | X | X | X | 1, 8 |
| Sel Refresh Exit | L | H | H | X | X | X | X | X | X | X | 1, 7, 8 |
| | | | | L | H | H | | | | | |
| Single Bank Precharge | H | H | L | L | H | L | BA | X | L | X | 1, 2 |
| Precharge All Banks | H | H | L | L | H | L | X | X | H | X | 1 |
| Bank Activate | H | H | L | L | H | H | BA | Row Address | | | 1, 2 |
| Write | H | H | L | H | L | L | BA | X | L | Column | 1, 2, 3, 10 |
| Write with Auto Precharge | H | H | L | H | L | L | BA | X | H | Column | 1, 2, 3, 10 |
| Read | H | H | L | H | L | H | BA | X | L | Column | 1, 2, 3, 10 |
| Read with Auto Precharge | H | H | L | H | L | H | BA | X | H | Column | 1, 2, 3, 10 |
| No Operation (NOP) | H | X | L | H | H | H | X | X | X | X | 1 |
| Device Deselect | H | X | H | X | X | X | X | X | X | X | 1 |
| Power Down Entry | H | L | H | X | X | X | X | X | X | X | 1, 4 |
| | | | | L | H | H | | | | | |
| Power Down Exit | L | H | H | X | X | X | X | X | X | X | 1, 4 |
| | | | | L | H | H | | | | | |

Notes:

1. All DDR2 SDRAM commands are defined by states of CS#, RAS#, CAS#, WE# and CKE at the rising edge of the clock.
2. Bank addresses BA0, BA1, and BA2 (BA) determine which bank is to be operated upon. For (E)MRS BA selects an (Extended) Mode Register.
3. Burst reads or writes at BL=4 cannot be terminated or interrupted. See sections "Reads interrupted by a Read" and "Writes interrupted by a Write" for details.
4. The Power Down Mode does not perform any refresh operations. The duration of Power Down is therefore limited by the refresh requirements
5. The state of ODT does not affect the states described in this table. The ODT function is not available during Self Refresh.
6. "X" means "H or L (but a defined logic level)"
7. Self refresh exit is asynchronous.
8. VREF must be maintained during Self Refresh operation.
9. An refers to the MSBs of addresses, An=A13.

Clock Enable (CKE) Truth Table

| Current State ⁽²⁾ | CKE | | Command (N) ⁽³⁾ RAS#, CAS#, WE#, CS# | Action (N) ⁽³⁾ | Notes |
|------------------------------|-------------------------------------|----------------------------------|--|----------------------------|------------------|
| | Previous Cycle ⁽¹⁾ (N-1) | Current Cycle ⁽¹⁾ (N) | | | |
| Power Down | L | L | X | Maintain Power-Down | 11, 13, 15 |
| | L | H | Deselect or NOP | Power Down Exit | 4, 8, 11, 13 |
| Self Refresh | L | L | X | Maintain Self-Refresh | 11, 15, 16 |
| | L | H | Deselect or NOP | Self-Refresh Exit | 4, 5, 9, 16 |
| Bank(s) Active | H | L | Deselect or NOP | Active Power Down Entry | 4, 8, 10, 11, 13 |
| All Banks Idle | H | L | Deselect or NOP | Precharge Power Down Entry | 4, 8, 10, 11, 13 |
| | H | L | Refresh | Self-Refresh Entry | 6, 9, 11, 13 |
| | H | H | Refer to the Command Truth Table | | 7 |

Notes:

1. CKE (N) is the logic state of CKE at clock edge N; CKE (N-1) was the state of CKE at the previous clock edge.
2. Current state is the state of the DDR2 SDRAM immediately prior to clock edge N.
3. COMMAND (N) is the command registered at clock edge N, and ACTION (N) is a result of COMMAND (N).
4. All states and sequences not shown are illegal or reserved unless explicitly described elsewhere in this document.
5. On Self Refresh Exit, DESELECT or NOP commands must be issued on every clock edge occurring during the tXSNR period. Read commands may be issued only after tXSRD (200 clocks) is satisfied.
6. Self Refresh mode can only be entered from the All Banks Idle state.
7. Must be a legal command as defined in the Command Truth Table.
8. Valid commands for Power Down Entry and Exit are NOP and DESELECT only.
9. Valid commands for Self Refresh Exit are NOP and DESELECT only.
10. Power Down and Self Refresh cannot be entered while Read or Write operations, (Extended) Mode Register Set operations or Precharge operations are in progress.
11. tCKEmin 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 tIS + 2 x tCK + tIH.
12. The state of ODT does not affect the states described in this table. The ODT function is not available during Self Refresh.
13. The Power Down does not perform any refresh operations. The duration of Power Down Mode is therefore limited by the refresh requirements outlined in this datasheet.
14. CKE must be maintained HIGH while the DDRII SDRAM is in OCD calibration mode.
15. "X" means "Don't Care (including floating around VREF)" 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 EMR[1]).
16. VREF must be maintained during Self Refresh operation.

Data Mask (DM) Truth Table

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

Note:

1. Used to mask write data, provided coincident with the corresponding data.

Commands

DESELECT

The DESELECT function (CS# HIGH) prevents new commands from being executed by the DDR2 SDRAM. The DDR2 SDRAM is effectively deselected. Operations already in progress are not affected. DESELECT is also referred to as COMMAND INHIBIT.

NO OPERATION (NOP)

The NO OPERATION (NOP) command is used to instruct the selected DDR2 SDRAM to perform a NOP (CS# is LOW; RAS#, CAS#, and WE# are HIGH). This prevents unwanted commands from being registered during idle or wait states. Operations already in progress are not affected.

LOAD MODE (LM)

The mode registers are loaded via bank address and address inputs. The bank address balls determine which mode register will be programmed. See “Mode Register (MR)” in the next section. The LM command can only be issued when all banks are idle, and a subsequent executable command cannot be issued until tMRD is met.

ACTIVATE

The ACTIVATE command is used to open (or activate) a row in a particular bank for a subsequent access. The value on the bank address inputs determines the bank, and the address inputs select the row. This row will remain active (or open) for accesses until a PRECHARGE command is issued to that bank. A PRECHARGE command must be issued before opening a different row in the same bank.

READ

The READ command is used to initiate a burst read access to an active row. The value on the bank address inputs determine the bank, and the address provided on address inputs A0–A9 selects the starting column location. The value on input A10 determines whether or not auto precharge is used. If auto precharge is selected, the row being accessed will be precharged at the end of the READ burst; if auto precharge is not selected, the row will remain open for subsequent accesses. DDR2 SDRAM also supports the AL feature, which allows a READ or WRITE command to be issued prior to tRCD(Min) by delaying the actual registration of the READ/WRITE command to the internal device by AL clock cycles.

WRITE

The WRITE command is used to initiate a burst write access to an active row. The value on the bank select inputs selects the bank, and the address provided on inputs A0–A9 selects the starting column location. The value on input A10 determines whether or not auto precharge is used. If auto precharge is selected, the row being accessed will be precharged at the end of the WRITE burst; if auto precharge is not selected, the row will remain open for subsequent accesses.

DDR2 SDRAM also supports the AL feature, which allows a READ or WRITE command to be issued prior to tRCD(MIN) by delaying the actual registration of the READ/WRITE command to the internal device by AL clock cycles. Input data appearing on the DQ is written to the memory array subject to the DM input logic level appearing coincident with the data. If a given DM signal is registered LOW, the corresponding data will be written to memory; if the DM signal is registered HIGH, the corresponding data inputs will be ignored, and a WRITE will not be executed to that byte/column location.

PRECHARGE

The PRECHARGE command is used to deactivate the open row in a particular bank or the open row in all banks. The bank(s) will be available for a subsequent row activation a specified time (tRP) after the PRECHARGE command is issued, except in the case of concurrent auto precharge, where a READ or WRITE command to a different bank is allowed as long as it does not interrupt the data transfer in the current bank and does not violate any other timing parameters. After a bank has been precharged, it is in the idle state and must be activated prior to any READ or WRITE commands being issued to that bank. A PRECHARGE command is allowed if there is no open row in that bank (idle state) or if the previously open row is already in the process of precharging. However, the precharge period will be determined by the last PRECHARGE command issued to the bank.

REFRESH

REFRESH is used during normal operation of the DDR2 SDRAM and is analogous to CAS#-before-RAS# (CBR) REFRESH. All banks must be in the idle mode prior to issuing a REFRESH command. This command is nonpersistent, so it must be issued each time a refresh is

required. The addressing is generated by the internal refresh controller. This makes the address bits a “Don’t Care” during a REFRESH command.

SELF REFRESH

The SELF REFRESH command can be used to retain data in the DDR2 SDRAM, even if the rest of the system is powered down. When in the self refresh mode, the DDR2 SDRAM retains data without external clocking. All power supply inputs (including VREF) must be maintained at valid levels upon entry/exit and during SELF REFRESH operation.

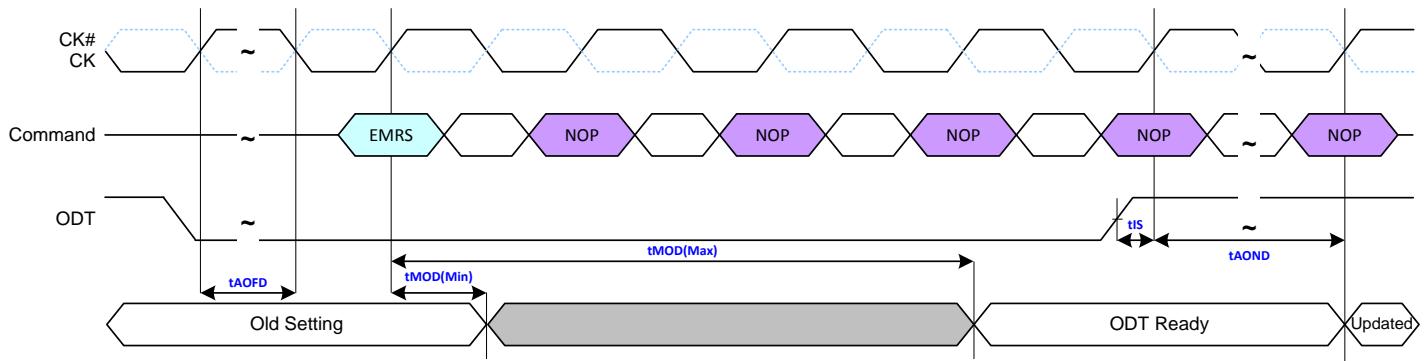
The SELF REFRESH command is initiated like a REFRESH command except CKE is LOW. The DLL is automatically disabled upon entering self refresh and is automatically enabled upon exiting self refresh.

ODT (On-Die Termination)

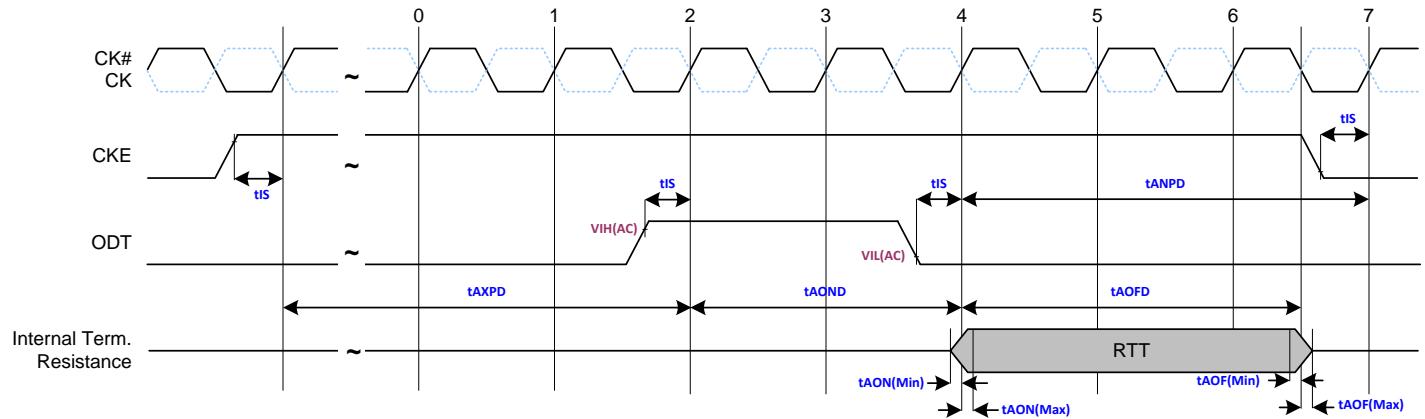
The On-Die Termination feature allows the DDR2 SDRAM to easily implement an internal termination resistance (Rtt). ODT can be configured for DQ[15:0], UDQS, LDQS, UDQS#, LDQS#, and UDM, and LDM signals. The ODT feature can be configured with the Extended Mode Register Set (EMRS) command, and turned on or off using the ODT input signal. Before and after the EMRS is issued, the ODT input must be received with respect to the timings of tAOFD, tMOD(max), tAOND; and the CKE input must be held HIGH throughout the duration of tMOD(max).

The DDR2 SDRAM supports the ODT on and off functionality in Active, Standby, and Power Down modes, but not in Self Refresh mode. ODT timing diagrams follow for Active/Standby mode and Power Down mode.

EMRS to ODT Update Delay



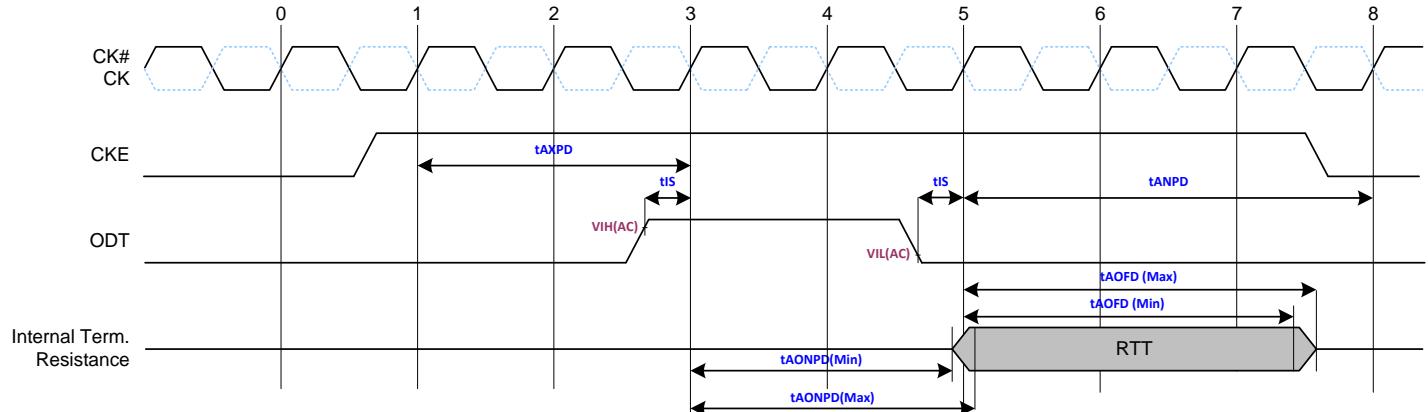
ODT Timing for Active/Standby (Idle) Mode and Standard Active Power-Down Mode



Notes:

- Both ODT to Power Down Entry and Exit Latency timing parameter tANPD and tAXPD are met, therefore Non-Power Down Mode timings have to be applied.
- ODT turn-on time, tAON(Min) is when the device leaves high impedance and ODT resistance begins to turn on. ODT turn on time max, tAON(Max) is when the ODT resistance is fully on. Both are measured from tAOND.
- ODT turn off time min, tAOF(Min), is when the device starts to turn off the ODT resistance. ODT turn off time max, tAOF(Max) is when the bus is in high impedance. Both are measured from tAOFD.

ODT Timing for Precharge Power-Down Mode



Note: Both ODT to Power Down Endtry and Exit Latencies tANPD and tAXPD are not met, therefore Power-Down Mode timings have to be applied.

Absolute Maximum DC Ratings

| Symbol | Parameter | Rating | Units | Notes |
|-------------------|-------------------------------------|-------------|-------|-------|
| VDD | Voltage on VDD pin relative to Vss | -1.0 to 2.3 | V | 1, 3 |
| VDDQ | Voltage on VDDQ pin relative to Vss | -0.5 to 2.3 | V | 1, 3 |
| VDDL | Voltage on VDDL pin relative to Vss | -0.5 to 2.3 | V | 1, 3 |
| Vin, Vout | Voltage on any pin relative to Vss | -0.5 to 2.3 | V | 1, 4 |
| Tstg | Storage Temperature | -55 to +150 | °C | 1, 2 |
| I _I | Input Leakage Current | -5 to 5 | uA | 4 |
| I _{oz} | Output Leakage Current | -5 to 5 | uA | 4 |
| I _{VREF} | V _{REF} Leakage Current | -2 to 2 | uA | 3 |

Notes:

1. Stresses greater than those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect reliability.
2. Storage Temperature is the case surface temperature on the center/top side of the DRAM.
3. VDD and VDDQ must be within 300mV of each other at all times; and VREF must be not greater than 0.6 x VDDQ. When VDD and VDDQ and VDDL are less than 500mV, VREF may be equal to or less than 300mV.
4. Voltage on any input or I/O may not exceed voltage on VDDQ.

AC and DC Operating Conditions

Recommended DC Operating Conditions (SSTL_1.8)

| Symbol | Parameter | Rating | | | Units | Notes |
|--------|---------------------------|-----------|-----------|-----------|-------|-------|
| | | Min. | Typ. | Max. | | |
| VDD | Supply Voltage | 1.7 | 1.8 | 1.9 | V | 1 |
| VDDL | Supply Voltage for DLL | 1.7 | 1.8 | 1.9 | V | 5 |
| VDDQ | Supply Voltage for Output | 1.7 | 1.8 | 1.9 | V | 1, 5 |
| VREF | Input Reference Voltage | 0.49*VDDQ | 0.50*VDDQ | 0.51*VDDQ | V | 2, 3 |
| VTT | Termination Voltage | VREF-0.04 | VREF | VREF+0.04 | V | 4 |

Notes:

1. There is no specific device VDD supply voltage requirement for SSTL_1.8 compliance. However, under all conditions VDDQ must be less than or equal to VDD.
2. The value of VREF may be selected by the user to provide optimum noise margin in the system. Typically the value of VREF is expected to be about 0.5 x VDDQ of the transmitting device and VREF is expected to track variations in VDDQ.
3. Peak to peak AC noise on VREF may not exceed +/-2% VREF(DC).
4. VTT of transmitting device must track VREF of receiving device.
5. AC parameters are measured with VDD, VDDQ and VDDL tied together.

Operating Temperature Condition ^(1, 2, 3)

| Symbol | Parameter | Rating | Units |
|--------|---|----------------------------------|-------|
| TOPER | Commercial Operating Temperature | Tc = 0 to 85, Ta = 0 to 70 | °C |
| TOPER | Industrial Operating Temperature, Automotive Operating Temperature (A1) | Tc = -40 to 95, Ta = -40 to 85 | °C |
| TOPER | Automotive Operating Temperature (A2) | Tc = -40 to 105, Ta = -40 to 105 | °C |

Notes:

1. Tc = Operating case temperature at center of package.
2. Ta = Operating ambient temperature immediately above package center.
3. Both temperature specifications must be met.

Thermal Resistance

| Package | Substrate | Theta-ja (Airflow = 0m/s) | Theta-ja (Airflow = 1m/s) | Theta-ja (Airflow = 2m/s) | Theta-jc | Units |
|---------|-----------|------------------------------|------------------------------|------------------------------|----------|-------|
| 84-ball | 4-layer | 29.8 | 27.2 | 25.1 | 5.8 | C/W |

AC and DC Logic Input Levels

Single-ended DC Input Logic Level

| Symbol | Parameter | Min. | Max. | Units | Notes |
|---------|---------------------|--------------|--------------|-------|-------|
| VIH(DC) | DC input logic HIGH | VREF + 0.125 | VDDQ + 0.3 V | V | |
| VIL(DC) | DC input logic LOW | - 0.3 | VREF - 0.125 | V | |

Single-ended AC Input logic level

| Symbol | Parameter | DDR2-533 | | DDR2-667 | | Units |
|---------|---------------------|--------------|--------------|--------------|--------------|-------|
| | | Min. | Max. | Min. | Max. | |
| VIH(AC) | AC input logic HIGH | VREF + 0.250 | VDDQ + Vpeak | VREF + 0.200 | VDDQ + Vpeak | V |
| VIL(AC) | AC input logic LOW | VSSQ - Vpeak | VREF - 0.250 | VSSQ - Vpeak | VREF - 0.200 | V |

Note: Refer to *Overshoot and Undershoot Specification* for Vpeak value: maximum peak amplitude allowed for overshoot and undershoot.

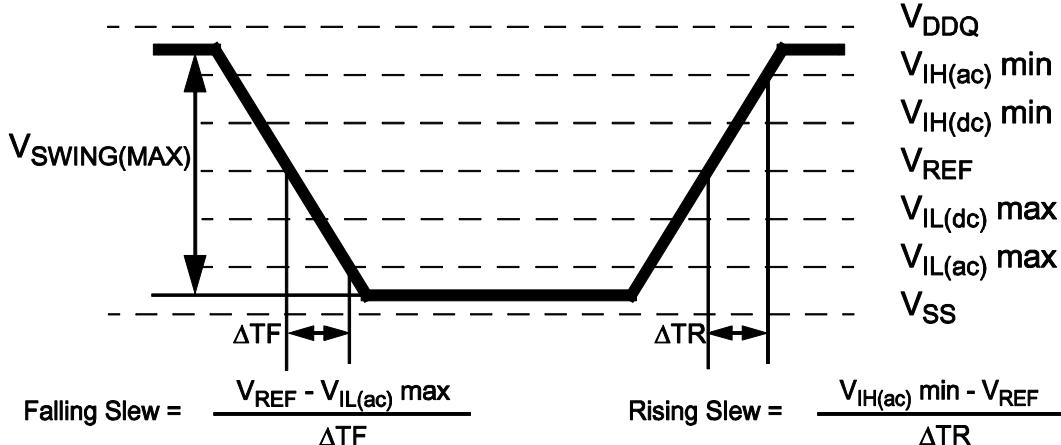
AC Input Test Conditions

| Symbol | Condition | Value | Units | Notes |
|--------|---|------------|-------|-------|
| VREF | Input reference voltage | 0.5 x VDDQ | V | 1 |
| VREF | Input signal maximum peak to peak swing | 1.0 | V | 1 |
| SLEW | Input signal minimum slew rate | 1.0 | V/ns | 2, 3 |

Notes:

1. Input waveform timing is referenced to the input signal crossing through the VIH/IL(AC) level applied to the device under test.
2. The input signal minimum slew rate is to be maintained over the range from VREF to VIH(AC) min for rising edges and the range from VREF to VIL(AC) max for falling edges as shown in the below figure.
3. AC timings are referenced with input waveforms switching from VIL(AC) to VIH(AC) on the positive transitions and VIH(AC) to VIL(AC) on the negative transitions.

AC Input Test Signal Waveform



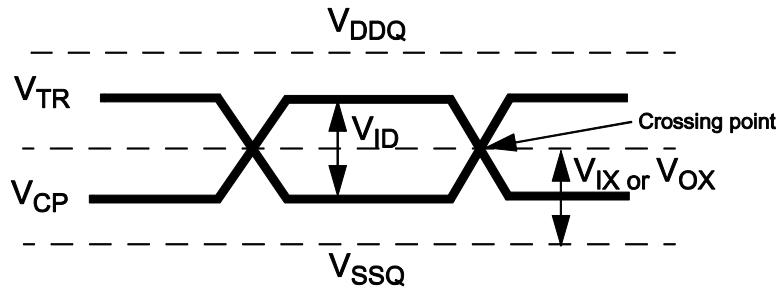
Differential Input AC logic level

| Symbol | Parameter | Min. | Max. | Units | Notes |
|---------|------------------------------------|----------------|----------------|-------|-------|
| VID(AC) | AC differential input voltage | 0.5 | VDDQ | V | 1, 3 |
| VIX(AC) | AC differential crosspoint voltage | 0.5*VDDQ-0.175 | 0.5*VDDQ+0.175 | V | 2 |

Notes:

1. VID(AC) specifies the input differential voltage $|VTR - VCP|$ required for switching, where VTR is the true input signal (such as CK, DQS, LDQS or UDQS) and VCP is the complementary input signal (such as CK#, DQS#, LDQS# or UDQS#). The minimum value is equal to $V_{IH(AC)} - V_{IL(AC)}$.
2. The typical value of VIX(AC) is expected to be about $0.5 \times VDDQ$ of the transmitting device and VIX(AC) is expected to track variations in VDDQ. VIX(AC) indicates the voltage at which differential input signals must cross.
3. Refer to *Overshoot and Undershoot Specifications* for Vpeak value: maximum peak amplitude allowed for overshoot and undershoot.

Differential Signal Level Waveform



Differential AC Output Parameters

| Symbol | Parameter | Min. | Max. | Units |
|-----------|------------------------------------|------------------|------------------|-------|
| $VOX(AC)$ | AC differential crosspoint voltage | 0.5 x VDDQ-0.125 | 0.5 x VDDQ+0.125 | V |

Note: The typical value of $VOX(AC)$ is expected to be about $0.5 \times VDDQ$ of the transmitting device and $VOX(AC)$ is expected to track variations in $VDDQ$. $VOX(AC)$ indicates the voltage at which differential output signals must cross.

Overshoot and Undershoot Specification

AC Overshoot and Undershoot Specification for Address and Control Pins

| Parameter | DDR2-533 | DDR2-667 | Unit |
|--|----------|----------|------|
| Maximum peak amplitude allowed for overshoot area | 0.5 | 0.5 | V |
| Maximum peak amplitude allowed for undershoot area | 0.5 | 0.5 | V |
| Maximum overshoot area above VDD^* | 0.8 | 0.8 | V-ns |
| Maximum undershoot area below VSS^* | 0.8 | 0.8 | V-ns |

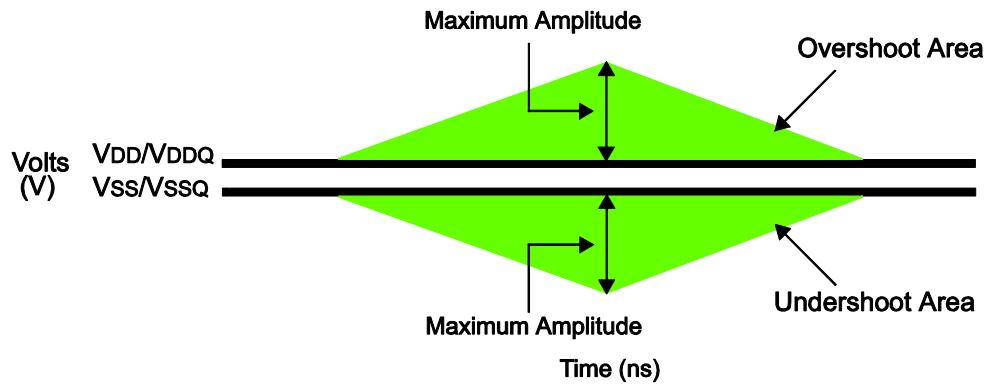
Note: Please refer to *AC Overshoot and Undershoot Definition Diagram*.

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

| Parameter | DDR2-533 | DDR2-667 | Unit |
|--|----------|----------|------|
| Maximum peak amplitude allowed for overshoot area | 0.5 | 0.5 | V |
| Maximum peak amplitude allowed for undershoot area | 0.5 | 0.5 | V |
| Maximum overshoot area above $VDDQ^*$ | 0.23 | 0.23 | V-ns |
| Maximum undershoot area below $VSSQ^*$ | 0.23 | 0.23 | V-ns |

Note: Please refer to *AC Overshoot and Undershoot Definition Diagram*.

AC Overshoot and Undershoot Definition Diagram



Output Buffer Characteristics

Output AC Test Conditions

| Symbol | Parameter | SSTL_18 | Units |
|--------|---|------------|-------|
| VOTR | Output Timing Measurement Reference Level | 0.5 x VDDQ | V |

Note: The VDDQ of the device under test is referenced.

Output DC Current Drive

| Symbol | Parameter | SSTL_18 | Units | Notes |
|---------|----------------------------------|---------|-------|---------|
| IOH(DC) | Output Minimum Source DC Current | 13.4 | mA | 1, 3, 4 |
| IOL(DC) | Output Minimum Sink DC Current | -13.4 | mA | 2, 3, 4 |

Notes:

1. VDDQ = 1.7 V; VOUT = 1420 mV. (VOUT - VDDQ)/IOH must be less than 21 Ω for values of VOUT between VDDQ and VDDQ - 280 mV.
2. VDDQ = 1.7 V; VOUT = 280 mV. VOUT/IOL must be less than 21 Ω for values of VOUT between 0 V and 280 mV.
3. The dc value of VREF applied to the receiving device is set to VTT
4. The values of IOH(DC) and IOL(DC) are based on the conditions given in Notes 1 and 2. They are used to test device drive current capability to ensure VIH min plus a noise margin and VIL max minus a noise margin are delivered to an SSTL_18 receiver. The actual current values are derived by shifting the desired driver operating point (see Section 3.3 of JESD8-15A) along a 21 Ω load line to define a convenient driver current for measurement.

Output Capacitance

| Paramater | Symbol | -37C (DDR2-533C) | | -3D (DDR2-667D) | | Units |
|---|--------|------------------|------|-----------------|------|-------|
| | | Min | Max | Min | Max | |
| Input Capacitance (CK and CK#) | CCK | 1.00 | 2.00 | 1.00 | 2.00 | pF |
| Input Capacitance Delta (CK and CK#) | CDCK | | 0.25 | | 0.25 | pF |
| Input Capacitance (all other input-only pins) | CI | 1.00 | 2.00 | 1.00 | 2.00 | pF |
| Input Capacitance Delta (all other input-only pins) | CDI | | 0.25 | | 0.25 | pF |
| I/O Capacitance (DQ, DM, DQS, DQS#) | CIO | 2.50 | 4.00 | 2.50 | 3.50 | pF |
| I/O Capacitance Delta (DQ, DM, DQS, DQS#) | CDIO | | 0.50 | | 0.50 | pF |

ODT DC Electrical Characteristics

| Parameter/Condition | Symbol | Min. | Nom. | Max. | Units | Notes |
|---|-----------|------|------|------|-------|-------|
| Rtt effective impedance value for EMRS(A6=0, A2=1); 75 ohm | Rtt1(eff) | 60 | 75 | 90 | ohms | 1 |
| Rtt effective impedance value for EMRS(A6=1, A2=0); 150 ohm | Rtt2(eff) | 120 | 150 | 180 | ohms | 1 |
| Rtt effective impedance value for EMRS(A6=A2=1); 50 ohm | Rtt3(eff) | 40 | 50 | 60 | ohms | 1 |
| Deviation of VM with respect to VDDQ/2 | Delta VM | -6 | | +6 | % | 2 |

Note:

1. Measurement Definition for Rtt(eff):
Apply VIHac and VILac to test pin separately, then measure current I(VIHac) and I(VILac) respectively

$$Rtt(eff) = \frac{VIH(AC) - VIL(AC)}{I(VIH(AC)) - I(VIL(AC))}$$

2. Measurement Definition for VM:

Measure voltage (VM) at test pin (midpoint) with no load:

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

ODT AC Electrical Characteristics and Operating Conditions

| Symbol | Parameter/Condition | Min. | Max. | Units | Notes |
|--------|--------------------------------------|--------------|-------------------|-------|-------|
| tAOND | ODT turn-on delay | 2 | 2 | tCK | |
| tAON | ODT turn-on | tAC(Min) | tAC(Max)+0.7ns | ns | 1 |
| tAONPD | ODT turn-on (Power-Down Mode) | tAC(Min)+2ns | 2tCK+tAC(Max)+1ns | ns | 3 |
| tAOFD | ODT turn-off delay | 2.5 | 2.5 | tCK | |
| tAOF | ODT turn-off | tAC(Min) | tAC(Max)+0.6ns | ns | 2 |
| tAOFPD | ODT turn-off (Power-Down Mode) | tAC(Min)+2ns | 2.5tCK+tAC+1ns | ns | 3 |
| tANPD | ODT to Power-Down Mode Entry Latency | 3 | | tCK | 4 |
| tAXPD | ODT Power Down Exit Latency | 8 | | tCK | 4 |

Notes:

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 tAOND.
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 tAOFD.
3. For Standard Active Power-Down (with MRS A12 = "0"), the non power-down timings (tAOND, tAON, tAOFD and tAOF) apply.
4. tANPD and tAXPD define the timing limit when either Power Down Mode Timings (tAONPD, tAOFPD) or Non-Power Down Mode Timings (tAOND, tAOFD) have to be applied

IDD Specifications and Conditions

IDD Measurement Conditions

| Symbol | Parameter/Condition |
|--------|---|
| IDD0 | Operating Current - One bank Active - Precharge: tCK = tCK(IDD), tRC = tRC(IDD), tRAS = tRASmin(IDD); CKE is HIGH, CS# is HIGH between valid commands; Address bus inputs are SWITCHING; Data bus inputs are SWITCHING. |
| IDD1 | Operating Current - One bank Active - Read - Precharge: IOUT = 0mA; BL = 4, CL = CL(IDD), AL = 0; tCK = tCK(IDD), tRC = tRC(IDD), tRAS = tRASmin(IDD), tRCD = tRCD(IDD); CKE is HIGH, CS# is HIGH between valid commands; Address bus inputs are SWITCHING; Data pattern is same as IDD4W |
| IDD2P | Precharge Power-Down Current: All banks idle; tCK = tCK(IDD); CKE is LOW; Other control and address bus inputs are STABLE; Data bus inputs are FLOATING |
| IDD2Q | Precharge Quiet Standby Current: All banks idle; tCK = tCK(IDD); CKE is HIGH, CS# is HIGH; Other control and address bus inputs are STABLE; Data bus inputs are FLOATING |
| IDD2N | Precharge Standby Current: All banks idle; tCK = tCK(IDD); CKE is HIGH, CS# is HIGH; Other control and address bus inputs are SWITCHING; Data bus inputs are SWITCHING |
| IDD3PF | Active Power-Down Current: All banks open; tCK = tCK(IDD); CKE is LOW; Other control and address bus inputs are STABLE; Data bus inputs are FLOATING. MRS A12 bit is set to "0"(Fast Power-down Exit). |
| IDD3Ps | Active Power-Down Current: All banks open; tCK = tCK(IDD); CKE is LOW; Other control and address bus inputs are STABLE; Data bus inputs are FLOATING. MRS A12 bit is set to "1"(Slow Power-down Exit). |
| IDD3N | Active Standby Current: All banks open; tCK = tCK(IDD), tRAS = tRASmax(IDD), tRP = tRP(IDD); CKE is HIGH, CS# is HIGH between valid commands; Other control and address bus inputs are SWITCHING; Data bus inputs are SWITCHING. |
| IDD4R | Operating Current - Burst Read: All banks open, Continuous burst reads, IOUT = 0 mA; BL = 4, CL = CL(IDD), AL = 0; tCK = tCK(IDD), tRAS = tRASmax(IDD), tRP = tRP(IDD); CKE is HIGH, CS# is HIGH between valid commands; Address bus inputs are SWITCHING; Data pattern is same as IDD4W |
| IDD4W | Operating Current - Burst Write: All banks open, Continuous burst writes; BL = 4, CL = CL(IDD), AL = 0; tCK = tCK(IDD), tRAS = tRASmax(IDD), tRP = tRP(IDD); CKE is HIGH, CS is HIGH between valid commands; Address bus inputs are SWITCHING; Data bus inputs are SWITCHING. |
| IDD5B | Burst Auto-Refresh Current: tCK = tCK(IDD); Refresh command at every tRFC(IDD) interval; CKE is HIGH, CS# is HIGH between valid commands; Other control and address bus inputs are SWITCHING; Data bus inputs are SWITCHING. |
| IDD5D | Distributed Refresh Current: tCK = tCK(IDD); Refresh command frequency satisfying tREFI; CKE is HIGH, CS# is HIGH between valid commands; Other control and address bus inputs are SWITCHING; Data bus inputs are SWITCHING. |
| IDD6 | Self-Refresh Current: CK and CK# at 0 V; CKE 0.2 V; Other control and address bus inputs are FLOATING; Data bus inputs are FLOATING. |
| IDD7 | Operating Bank Interleave Read Current: All bank interleaving reads, IOUT = 0mA; BL = 4, CL = CL(IDD), AL = tRCD(IDD) - 1 x tCK(IDD); tCK = tCK(IDD), tRC = tRC(IDD), tRRD = tRRD(IDD), tFAW = tFAW(IDD), tRCD = tRCD(IDD); CKE is HIGH, CS is HIGH between valid commands; Address bus inputs are STABLE during DESELECTS; Data pattern is same as IDD4R; |

Notes:

1. Data bus consists of DQ, DM, DQS, DQS#, RDQS, RDQS#, LDQS, LDQS#, UDQS, and UDQS#. IDD values must be met with all combinations of EMRS bits 10 and 11.
2. For DDR2-667/800 testing, tCK in the Conditions should be interpreted as tCK(avg).
3. Definitions for IDD:
 - a. LOW is defined as $VIN \leq VILAC(\max)$.
 - b. HIGH is defined as $VIN \geq VIHAC(\min)$.
 - c. STABLE = inputs stable at a HIGH or LOW level.
 - d. FLOATING = inputs at $VREF = VDDQ/2$.
 - e. SWITCHING = inputs changing between HIGH and LOW every other clock cycle (once per two clocks) for address and control signals, and inputs changing between HIGH and LOW every other data transfer (once per clock) for DQ signals not including masks or strobes.
4. Legend: A=Activate, RA=Read with Auto-Precharge, D=DESELECT.

IDD Specifications

| Symbol | -3D DDR2-667D | Units |
|--------|------------------|-------|
| IDD0 | 150 | mA |
| IDD1 | 175 | mA |
| IDD2P | 30 | mA |
| IDD2N | 90 | mA |
| IDD2Q | 70 | mA |
| IDD3Pf | 45 | mA |
| IDD3Ps | 35 | mA |
| IDD3N | 105 | mA |
| IDD4R | 350 | mA |
| IDD4W | 350 | mA |
| IDD5B | 400 | mA |
| IDD5D | 100 | mA |
| IDD6 | 12 | mA |
| IDD7 | 450 | mA |

Notes:

1. IDD specifications are tested after the device is properly initialized.
2. Input slew rate is specified by AC Parametric Test Condition.
3. IDD parameters are specified with ODT disabled.
4. For A2 temperature grade with $TA > 85^{\circ}\text{C}$: IDD values are derated to maximum values 10% above those shown.

AC Characteristics

(AC Operating Conditions Unless Otherwise Noted)

| Parameter | Symbol | -37C | | -3D | | Units | Notes |
|--|-------------|------------------------------------|-----------|-------|------|-------|-------|
| | | DDR2-533C | DDR2-667D | Min | Max | | |
| Row Cycle Time | tRC | 55 | | 55 | | ns | |
| Auto Refresh Row Cycle Time | tRFC | 197.5 | | 197.5 | | ns | 11 |
| Row Active Time | tRAS | 40 | 70K | 40 | 70K | ns | 21 |
| Row Active to Column Address Delay | tRCD | 15 | | 15 | | ns | 20 |
| Row Active to Row Active Delay | tRRD | 10 | | 10 | | ns | |
| Four Activate Window | tFAW | 50 | | 50 | | ns | |
| Column Address to Column Address Delay | tCCD | 2 | | 2 | | tCK | |
| Row Precharge Time | tRP | 15 | | 15 | | ns | |
| Write Recovery Time | tWR | 15 | | 15 | | ns | |
| Auto precharge Write recovery + Precharge Time | tDAL | Min = tWR+tRP, Max = n/a | | | | ns | 12 |
| Clock Cycle Time | tCK3 (CL=3) | 5 | 8 | 5 | 8 | ns | 2, 24 |
| | tCK4 (CL=4) | 3.75 | 8 | 3.75 | 8 | ns | 2, 24 |
| | tCK5 (CL=5) | | | 3 | 8 | ns | 2, 24 |
| | tCK6 (CL=6) | | | | | ns | 24 |
| Clock High Level Width | tCH | 0.45 | 0.55 | 0.48 | 0.52 | tCK | |
| Clock Low Level Width | tCL | 0.45 | 0.55 | 0.48 | 0.52 | tCK | |
| Cycle to cycle | tJITcc | 250 | | 250 | | ps | |
| Data-Out Edge to Clock Skew Edge | tAC | -0.5 | 0.5 | -0.45 | 0.45 | ns | |
| DQS-Out Edge to Clock Skew Edge | tDQSCK | -0.45 | 0.45 | -0.4 | 0.4 | ns | |
| DQS-Out Edge to Clock Skew Edge | tDQSQ | | 0.3 | | 0.24 | ns | |
| Data-Out Hold Time from DQS | tQH | Min = tHP(min)-tQHS, Max = n/a | | | | ns | |
| Data Hold Skew Factor | tQHS | | 400 | | 340 | ps | |
| Clock Half Period | tHP | Min = tCH(min)/tCL(min), Max = n/a | | | | ns | 5 |

AC Characteristics

(AC Operating Conditions Unless Otherwise Noted)

| Parameter | Symbol | -37C | | -3D | | Units | Notes |
|---|----------|-----------------------------------|-----------|------|-----|-------|----------|
| | | DDR2-533C | DDR2-667D | Min | Max | | |
| Input Setup Time (fast slew rate) | tIS | 250 | | 200 | | ps | 15,17 |
| Input Hold Time (fast slew rate) | tIH | 375 | | 275 | | ps | 15,17 |
| Input Pulse Width | tIPW | 0.6 | | 0.6 | | tCK | |
| Write DQS High Level Width | tDQSH | 0.35 | | 0.35 | | tCK | |
| Write DQS Low Level Width | tDQSL | 0.35 | | 0.35 | | tCK | |
| CLK to First Rising Edge of DQS-In | tDQSS | Min = -0.25tCK, Max = +0.25tCK | | | | tCK | |
| Data-In Setup Time to DQS-In (DQ, DM) | tDS | 100 | | 100 | | ps | 16,17,18 |
| Data-In Hold Time to DQS-In (DQ, DM) | tDH | 225 | | 175 | | ps | 16,17,18 |
| DQS falling edge from CLK rising Setup Time | tDSS | 0.2 | | 0.2 | | tCK | |
| DQS falling edge from CLK rising Hold Time | tDSH | 0.2 | | 0.2 | | tCK | |
| DQ & DM Pulse Width | tDIPW | 0.35 | | 0.35 | | tCK | |
| Read DQS Preamble Time | tRPRE | 0.9 | 1.1 | 0.9 | 1.1 | tCK | |
| Read DQS Postamble Time | tRPST | 0.4 | 0.6 | 0.4 | 0.6 | tCK | |
| Write DQS Preamble Setup Time | tWPRES | 0 | | 0 | | tCK | |
| Write DQS Preamble Hold Time | tWPREH | 0.25 | | 0.25 | | tCK | |
| Write DQS Preamble Time | tWPRE | 0.35 | | 0.35 | | tCK | |
| Write DQS Postamble Time | tWPST | 0.4 | 0.6 | 0.4 | 0.6 | tCK | 10 |
| Internal Read to Precharge Command Delay | tRTP | 7.5 | | 7.5 | | ns | |
| Internal Write to Read Command Delay | tWTR | 7.5 | | 7.5 | | ns | 13 |
| Data-Out to High Impedance from CK/CK# | tHZ | Min = n/a, Max = tAC(max) | | | | ns | 7 |
| DQS/DQS# Low Impedance from CK/CK# | tLZ(DQS) | Min = tAC(min), Max = tAC(max) | | | | ns | 7 |

AC Characteristics

(AC Operating Conditions Unless Otherwise Noted)

| Parameter | Symbol | -37C | | -3D | | Units | Notes |
|---|-----------------|---|-----------|------|-----|-----------------|--------|
| | | DDR2-533C | DDR2-667D | Min | Max | | |
| DQ to Low Impedance from CK/CK# | tLZ(DQ) | Min = 2 x tAC(min), Max = tAC(max) | | | ns | 7 | |
| Mode Register Set Delay | tMRD | 2 | | 2 | | t _{CK} | 9 |
| OCD Drive Mode Output Delay | tMOD | 0 | 12 | 0 | 12 | ns | |
| ODT Drive Mode Output Delay | tOIT | 0 | 12 | 0 | 12 | ns | |
| Exit Self refresh to Non-Read Command | tXSNR | Min = t _{RFC} + 10, Max = n/a | | | ns | 19 | |
| Exit Self refresh to Read Command | tXSRD | 200 | | 200 | | t _{CK} | |
| Exit Precharge Power Down to any Non-Read Command | tXP | 2 | | 2 | | t _{CK} | 14 |
| Exit Active Power Down to Read Command | tXARD | 2 | | 2 | | t _{CK} | |
| Exit Active Power Down to Read Command (slow exit, low power) | tAXRDS | 6-AL | | 7-AL | | t _{CK} | |
| Minimum time clocks remains ON after CKE asynchronously drops LOW | tDELAY | Min = t _{IS} +t _{CK} +t _{IH} , Max = n/a | | | ns | | |
| CKE minimum high and low pulse width | tCKE | 3 | | 3 | | t _{CK} | |
| Average Periodic Refresh Interval (-40°C ≤ T _C ≤ +85°C) | tREFI | | 7.8 | | 7.8 | μs | 18, 23 |
| Average Periodic Refresh Interval (+85°C < T _C ≤ +95°C) | tREFI | | 3.9 | | 3.9 | μs | 18, 23 |
| Average Periodic Refresh Interval (+95°C < T _C ≤ +105°C) | tREFI | | 3.9 | | 3.9 | μs | 18, 23 |
| Period Jitter | tJITPER | -125 | 125 | -125 | 125 | ps | 22 |
| Duty Cycle Jitter | tJITDTY | -125 | 125 | -125 | 125 | ps | 22 |
| Cycle to Cycle Jitter | tJITCC | -250 | 250 | -250 | 250 | ps | 22 |
| Cumulative error, 2 cycles | tERR(2PER) | -175 | 175 | -175 | 175 | ps | 22 |
| Cumulative error, 3 cycles | tERR(3PER) | -225 | 225 | -225 | 225 | ps | 22 |
| Cumulative error, 4 cycles | tERR(4PER) | -250 | 250 | -250 | 250 | ps | 22 |
| Cumulative error, 5 cycles | tERR(5PER) | -250 | 250 | -250 | 250 | ps | 22 |
| Cumulative error, 6-10 cycles | tERR (6-10PER) | -350 | 350 | -350 | 350 | ps | 22 |
| Cumulative error, 11-50 cycles | tERR (11-50PER) | -450 | 450 | -450 | 450 | ps | 22 |

Notes:

1. Input slew rate is 1 V/ns and AC timings are guaranteed for linear signal transitions.
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# input reference level is the cross point when in differential strobe mode; the input reference level for signals other than CK/CK#, or DQS/DQS# is VREF.

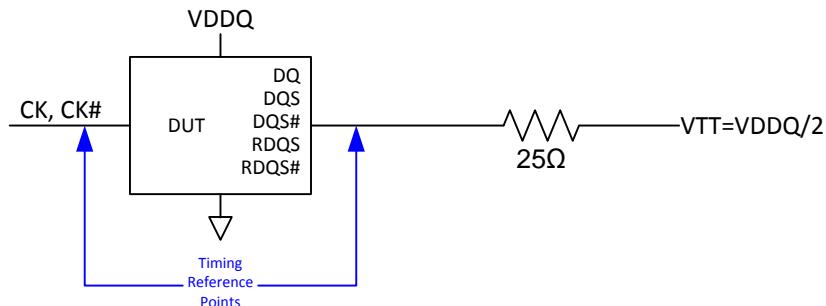
3. Inputs are not recognized as valid until VREF stabilizes. During the period before VREF stabilizes, CKE = 0.2 x VDDQ is recognized as LOW.
4. The output timing reference voltage level is VTT.
5. The values tCL(min) and tCH(min) refer to the smaller of the actual clock low time and the actual clock high time as provided to the device (i.e. this value can be greater than the minimum specification limits for tCL and tCH).
6. For input frequency change during DRAM operation.
7. Transitions for tHZ and tLZ occur in the same access time windows as valid data transitions. These parameters are not referred to a specific voltage level, but specify when the device is no longer driving (HZ), or begins driving (LZ).
8. These parameters guarantee device timing, but they are not necessarily tested on each device.
9. The specific requirement is that DQS and DQS# be valid (HIGH, LOW, or some point on a valid transition) on or before this CK edge. A valid transition is defined as monotonic and meeting the input slew rate specifications of the device. When no writes were previously in progress on the bus, DQS will be transitioning from Hi-Z to logic LOW. If a previous write was in progress, DQS could be HIGH, LOW, or transitioning from HIGH to LOW at this time, depending on tDQSS. When programmed in differential strobe mode, DQS is always the logic complement of DQS except when both are in high-Z.
10. The maximum limit for this parameter is not a device limit. The device operates with a greater value for this parameter, but system performance (bus turnaround) degrades accordingly.
11. A maximum of eight Auto-Refresh commands can be posted to any given DDR2 SDRAM device. (Note: tRFC depends on DRAM density)
12. For each of the terms, if not already an integer, round to the next highest integer. tCK refers to the application clock period. WR refers to the WR parameter stored in the MRS.
13. Parameter tWTR is at least two clocks independent of operation frequency.
14. User can choose two different active power-down modes for additional power saving via MRS address bit A12. In "standard active power-down mode" (MRS, A12 = "0") a fast power-down exit timing tXARD can be used. In "low active power-down mode" (MRS, A12 = "1") a slow power-down exit timing tXARDS has to be satisfied.
15. Timings are guaranteed with command / address input slew rate of 1.0 V/ns.
16. Timings are guaranteed with data / mask input slew rate of 1.0 V/ns.
17. Timings are guaranteed with CK/CK# differential slew rate 2.0 V/ns, and DQS/DQS# (and RDQS/RDQS#) differential slew rate 2.0 V/ns in differential strobe mode.
18. If refresh timing or tDS / tDH is violated, data corruption may occur and the data must be re-written with valid data before a valid READ can be executed.
19. In all circumstances, tXSNR can be satisfied using tXSNR = tRFC + 10 ns.
20. The tRCD timing parameter is valid for both activate command to read or write command with and without Auto-Precharge. Therefore a separate parameter tRAP for activate command to read or write command with Auto-Precharge is not necessary anymore.
21. tRAS(max) is calculated from the maximum amount of time a DDR2 device can operate without a Refresh command which is equal to 9 x tREFI.
22. Definitions:
 - a. tCK(avg): tCK(avg) is calculated as the average clock period across any consecutive 200 cycle window.
 - b. tCH(avg): tCH(avg) is defined as the average HIGH pulse width, as calculated across any consecutive 200 HIGH pulses.
 - c. tCL(avg): tCL(avg) is defined as the average LOW pulse width, as calculated across any consecutive 200 LOW pulses.
 - d. tJITDTY: tJITDTY is defined as the cumulative set of tCH jitter and tCL jitter. tCH jitter is the largest deviation of any single tCH from tCH(avg). tCL jitter is the largest deviation of any single tCL from tCL(avg)
 - e. tJITPER: tJITPER is defined as the largest deviation of any single tCK from tCK(avg).
 - f. tJITCC: tJITCC is defined as the difference in clock period between two consecutive clock cycles: tJITCC is not guaranteed through final production testing
 - g. tERR: tERR is defined as the cumulative error across multiple consecutive cycles from tCK (avg).
23. Applicable to certain temperature grades. Specified OPER (Tc and Ta) must not be violated for each temperature grade.
24. The Speed grade option -3D is backward compatible with all the timing specifications for slower grades, including -37C.

Reference Loads, Slew Rates and Slew Rate Derating

1. Reference Load for Timing Measurements

Figure AC *Timing Reference Load* represents the timing reference load used in defining the relevant timing parameters of the part. It is not intended to be either a precise representation of the typical system environment or a depiction of the actual load presented by a production tester. System designers will use IBIS or other simulation tools to correlate the timing reference load to a system environment. Manufacturers correlate to their production test conditions (generally a coaxial transmission line terminated at the tester electronics). This load circuit is also used for output slew rate measurements.

AC Timing Reference Load

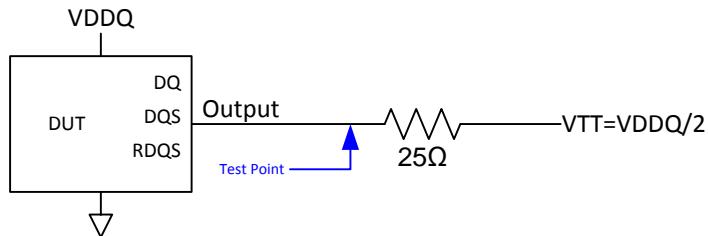


The output timing reference voltage level for single ended signals is the crosspoint with VTT. The output timing reference voltage level for differential signals is the crosspoint of the true (e.g. DQS) and the complement (e.g. DQS#) signal.

2. Slew Rate Measurements

a) Output Slew Rate

Output slew rate is characterized under the test conditions as shown in the figure below.



Output slew rate for falling and rising edges is measured between VTT - 250 mV and VTT + 250 mV for single ended signals. For differential signals (e.g. DQS - DQS#) output slew rate is measured between DQS - DQS# = - 500 mV and DQS - DQS# = + 500 mV. Output slew rate is guaranteed by design, but is not necessarily tested on each device.

b) Input Slew Rate

Input slew rate for single ended signals is measured from VREF(DC) to VIH(AC),min for rising edges and from VREF(DC) to VIL(AC),min for falling edges. For differential signals (e.g. CK - CK#) slew rate for rising edges is measured from CK - CK# = - 250 mV to CK - CK# = + 500 mV (+ 250 mV to - 500 mV for falling edges). Test conditions are the same as for timing measurements.

ORDERING INFORMATION

Commercial Range: $T_C = 0^\circ$ to $+85^\circ\text{C}$; $T_A = 0^\circ\text{C}$ to $+70^\circ\text{C}$

| Frequency | Speed Grade | CL-t _{RC} -t _{RP} | Order Part No. | Organization | Package |
|-----------|-------------|-------------------------------------|-------------------|--------------|---------------------------|
| 333 MHz | DDR2-667D | 5-5-5 | IS43DR16128A-3DBL | 128Mb x 16 | 84-ball TW-BGA, lead free |

Industrial Range: $T_C = -40^\circ$ to $+95^\circ\text{C}$; $T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$

| Frequency | Speed Grade | CL-t _{RC} -t _{RP} | Order Part No. | Organization | Package |
|-----------|-------------|-------------------------------------|--------------------|--------------|---------------------------|
| 333 MHz | DDR2-667D | 5-5-5 | IS43DR16128A-3DBLI | 128Mb x 16 | 84-ball TW-BGA, lead free |
| | | | IS43DR16128A-3DBI | 128Mb x 16 | 84-ball TW-BGA |

Automotive, A1 Range: $T_C = -40^\circ$ to $+95^\circ\text{C}$; $T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$

| Frequency | Speed Grade | CL-t _{RC} -t _{RP} | Order Part No. | Organization | Package |
|-----------|-------------|-------------------------------------|---------------------|--------------|---------------------------|
| 333 MHz | DDR2-667D | 5-5-5 | IS46DR16128A-3DBLA1 | 128Mb x 16 | 84-ball TW-BGA, lead free |

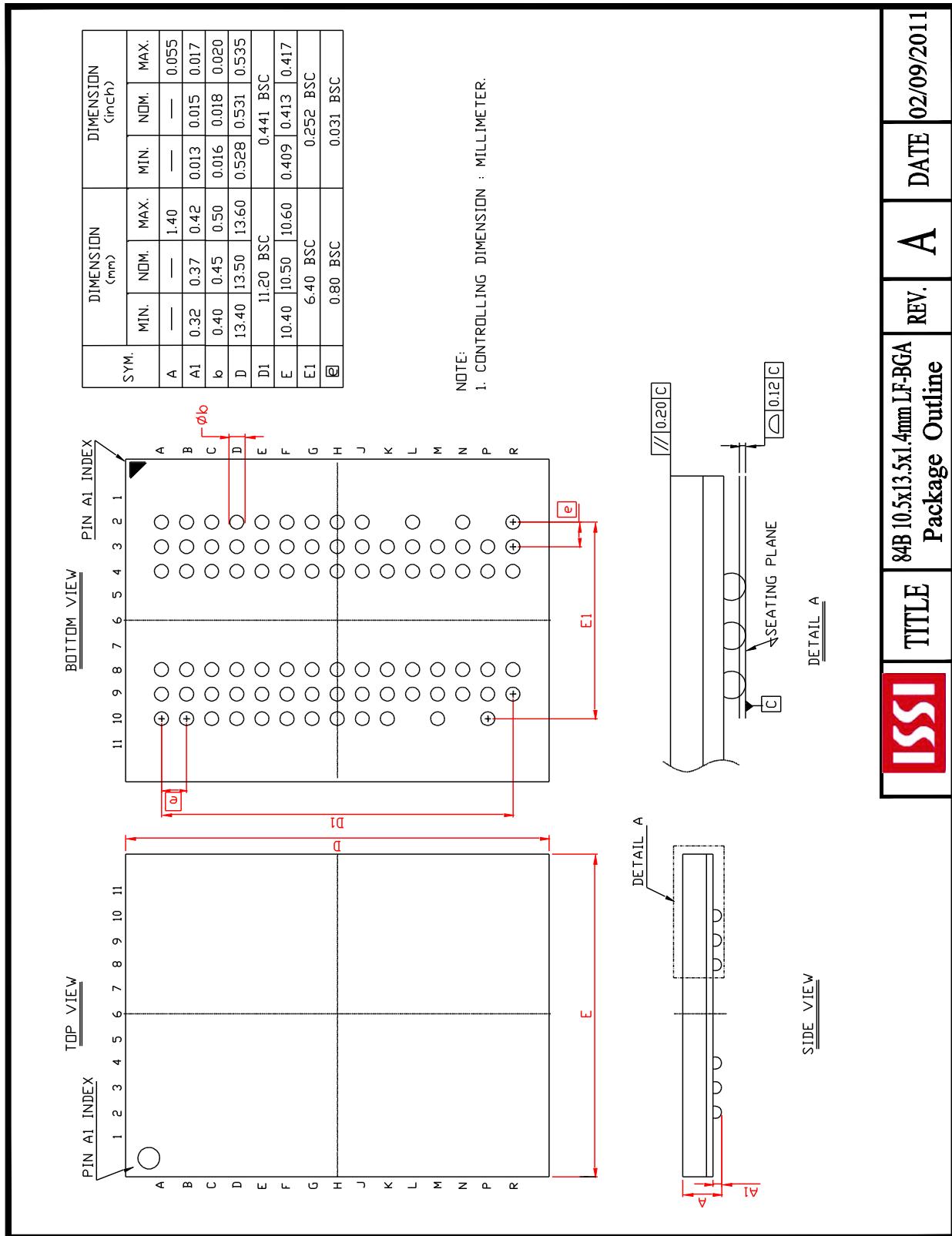
Automotive, A2 Range: $T_C = -40^\circ$ to $+105^\circ\text{C}$; $T_A = -40^\circ\text{C}$ to $+105^\circ\text{C}$

| Frequency | Speed Grade | CL-t _{RC} -t _{RP} | Order Part No. | Organization | Package |
|-----------|-------------|-------------------------------------|---------------------|--------------|---------------------------|
| 333 MHz | DDR2-667D | 5-5-5 | IS46DR16128A-3DBLA2 | 128Mb x 16 | 84-ball TW-BGA, lead free |

Notes:

1. Please contact ISSI for availability of leaded options.
2. The -3D speed option is backward compatible with all the timing specifications for slower grades, including -37C

84-ball TW-BGA: Fine Pitch Ball Grid Array Outline (x16)



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