

# Mobile SDRAM

**MT48LC16M32L2 – 4 Meg x 32 x 4 Banks**

**MT48V16M32L2 – 4 Meg x 32 x 4 Banks**

**MT48H16M32L2 – 4 Meg x 32 x 4 Banks**

## Features

- Low voltage power supply
- Partial array self refresh power-saving mode
- Temperature compensated self refresh (TCSR)
- Deep power-down mode
- Programmable output drive strength
- Fully synchronous; all signals registered on positive edge of system clock
- Internal pipelined operation; column address can be changed every clock cycle
- Internal banks for hiding row access/precharge
- Programmable burst lengths: 1, 2, 4, 8, or full page
- Auto precharge, includes concurrent auto precharge, and auto refresh modes
- Self refresh mode; standard and low power
- 64ms, 8,192-cycle refresh
- LVTTTL-compatible inputs and outputs
- Operating temperature range
- Industrial (-40°C to +85°C)
- Supports CAS latency of 1, 2, 3

## Options

- VDD/VDDQ  
3.3V/3.3V LC  
2.5V/2.5V V  
1.8V/1.8V H
- Configuration  
16M32 stacked die L2
- Package/ballout  
Plastic package 90-ball FBGA F5  
(8mm x 13mm) (standard)  
Plastic package 90-ball FBGA B5  
(8mm x 13mm) (lead-free)
- Timing (cycle time)  
8ns at CL3 (125 MHz) -8  
10ns at CL3 (100 MHz) -10
- Temperature  
Commercial (0°C to +70°C) No Marking  
Industrial (-40°C to +85°C) IT

## Marking

## Addendum Changes

The standard 256Mb SDRAM Mobile x32 data sheets should be referenced for a complete description of SDRAM functionality and operating modes. This addendum data sheet will concentrate on the key differences required to support the enhanced options of the TwinDie configuration.

The Micron 256Mb Mobile X32 data sheet provides full specifications and functionality unless specified herein.

**Table 1: Key Timing Parameters**

| Speed Grade | Clock Frequency | Access Time at CL = 3 | Access Time at CL = 2 |
|-------------|-----------------|-----------------------|-----------------------|
| -8          | 125 MHz         | 7.5ns                 | 8.5ns                 |
| -10         | 100 MHz         | 7.5ns                 | 8.5ns                 |

**Table 2: Configuration**

| Architecture      | 16 Meg x 32          |
|-------------------|----------------------|
| Configuration     | 4 Meg x 32 x 4 banks |
| Refresh Count     | 8K                   |
| Row Addressing    | 8K (A0–A12)          |
| Bank Addressing   | 4 (BA0, BA1)         |
| Column Addressing | 512 (A0–A8)          |

## General Description

The 512Mb SDRAM is a high-speed CMOS, dynamic random-access memory containing 536,870,912 bits. It is internally configured by stacking two 256Mb, 8 Meg x 32 devices. Each of these 256Mb devices is configured as a quad bank DRAM with a synchronous interface. They are organized with 32 DQs with 4 banks of 67,108,864 bits, comprising of 8,192 rows by 512 columns by 32 bits wide.

Read and write accesses to the SDRAM are burst oriented; accesses start at a selected location and continue for a programmed number of locations in a programmed sequence. Accesses begin with the registration of an ACTIVE command, which is then followed by a READ or WRITE command. The address bits registered coincident with the ACTIVE command are used to select the bank and row to be accessed (BA0, BA1 select the bank; A0-A12 select the row). The address bits registered coincident with the READ or WRITE command are used to select the starting column location for the burst access.

The SDRAM provides for programmable READ or WRITE burst lengths of 1, 2, 4, or 8 locations, or the full page, with a burst terminate option. An auto precharge function may be enabled to provide a self-timed row precharge that is initiated at the end of the burst sequence.

The 512Mb SDRAM uses an internal pipelined architecture to achieve high-speed operation. This architecture is compatible with the 2n rule of prefetch architectures, but it also allows the column address to be changed on every clock cycle to achieve a high-speed, fully random access. Precharging one bank while accessing one of the other three banks will hide the precharge cycles and provide seamless, high-speed, random-access operation.

The 512Mb SDRAM is designed to operate in 3.3V, 2.5V, and 1.8V memory systems. An auto refresh mode is provided, along with a power-saving, power-down mode. All inputs and outputs are LVTTTL-compatible.

SDRAMs offer substantial advances in DRAM operating performance, including the ability to synchronously burst data at a high data rate with automatic column-address generation, the ability to interleave between internal banks to hide precharge time, and the capability to randomly change column addresses on each clock cycle during a burst access.

Prior to normal operation, the SDRAM must be initialized. The following sections provide detailed information covering die initialization, register definition, command descriptions, and device operation on a per die basis unless otherwise noted.

This addendum documents any variances for the 512Mb: x32 Mobile SDRAM from the 256Mb: x32 Mobile SDRAM specification. Please refer to the 256Mb: x32 Mobile SDRAM data sheet on Micron's Web site for additional details on the part functionality.

## Commands

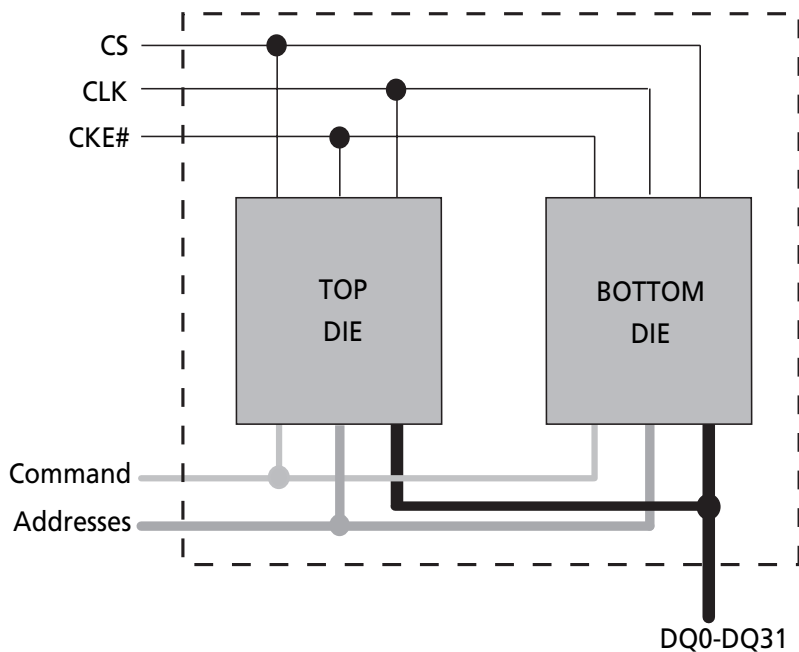
### AUTO REFRESH

AUTO REFRESH is used during normal operation of the SDRAM and is analogous to CAS#-BEFORE-RAS# (CBR) REFRESH in conventional DRAMs. This command is non-persistent, so it must be issued each time a refresh is required. All active banks must be PRECHARGED prior to issuing a AUTO REFRESH command. The AUTO REFRESH command should not be issued until the minimum <sup>t</sup>RP has been met after the PRECHARGE command as shown in the operations section.

The addressing is generated by the internal refresh controller. This makes the address bits "Don't Care" during an AUTO REFRESH command. The 512Mb TwinDie™ Mobile SDRAM requires 8,192 AUTO REFRESH cycles every 64ms (<sup>t</sup>REF). Providing a distributed

AUTO REFRESH command every  $7.81\mu\text{s}$  will meet the refresh requirement and ensure that each row is refreshed. Alternatively, 8,192 AUTO REFRESH commands can be issued in a burst at the minimum cycle rate ( $t^1\text{RC}$ ), once every 64ms.

**Figure 1: Functional Block Diagram**



## Ball Assignment

**Figure 2: 90-Ball FBGA Assignment**

|   | 1                                                                                        | 2                                                                                        | 3                                                                                        | 4 | 5 | 6 | 7                                                                                          | 8                                                                                          | 9                                                                                          |
|---|------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|---|---|---|--------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------|
| A |  DQ26   |  DQ24   |  Vss    |   |   |   |  VDD    |  DQ23   |  DQ21   |
| B |  DQ28   |  VDDQ   |  VssQ   |   |   |   |  VDDQ   |  VssQ   |  DQ19   |
| C |  VssQ   |  DQ27   |  DQ25   |   |   |   |  DQ22   |  DQ20   |  VDDQ   |
| D |  VssQ   |  DQ29   |  DQ30   |   |   |   |  DQ17   |  DQ18   |  VDDQ   |
| E |  VDDQ   |  DQ31   |  NC     |   |   |   |  NC     |  DQ16   |  VssQ   |
| F |  Vss    |  DQM3   |  A3     |   |   |   |  A2     |  DQM2   |  VDD    |
| G |  A4     |  A5     |  A6     |   |   |   |  A10    |  A0     |  A1     |
| H |  A7     |  A8     |  A12    |   |   |   |  NC     |  BA1    |  A11    |
| J |  CLK   |  CKE   |  A9    |   |   |   |  BA0   |  CS#   |  RAS#  |
| K |  DQM1 |  NC   |  NC   |   |   |   |  CAS# |  WE#  |  DQM0 |
| L |  VDDQ |  DQ8  |  Vss  |   |   |   |  VDD  |  DQ7  |  VssQ |
| M |  VssQ |  DQ10 |  DQ9  |   |   |   |  DQ6  |  DQ5  |  VDDQ |
| N |  VssQ |  DQ12 |  DQ14 |   |   |   |  DQ1  |  DQ3  |  VDDQ |
| P |  DQ11 |  VDDQ |  VssQ |   |   |   |  VDDQ |  VssQ |  DQ4  |
| R |  DQ13 |  DQ15 |  Vss  |   |   |   |  VDD  |  DQ0  |  DQ2  |

Ball and Array

## Electrical Specifications

**Table 3: DC Electrical Characteristics and Operating Conditions (LC version)**

V<sub>DD</sub>/V<sub>DDQ</sub> = +3.3V ±0.3V

Notes: 1, 5, 6; please refer to the 256Mb: x32 Mobile SDRAM data sheet for all notes.

| Parameter/Condition                                                                                                 | Symbol                            | MIN                    | MAX                   | Units | Notes |
|---------------------------------------------------------------------------------------------------------------------|-----------------------------------|------------------------|-----------------------|-------|-------|
| Supply Voltage                                                                                                      | V <sub>DD</sub> /V <sub>DDQ</sub> | 3                      | 3.6                   | V     |       |
| Input High Voltage: Logic 1; All inputs                                                                             | V <sub>IH</sub>                   | 0.8 x V <sub>DDQ</sub> | V <sub>DD</sub> + 0.3 | V     | 22    |
| Input Low Voltage: Logic 0; All inputs                                                                              | V <sub>IL</sub>                   | -0.3                   | 0.3                   | V     | 22    |
| Input Leakage Current:<br>Any input 0V ≤ V <sub>IN</sub> ≤ V <sub>DD</sub><br>(All other balls not under test = 0V) | I <sub>I</sub>                    | -5                     | 5                     | μA    |       |
| Output Leakage Current: DQs are disabled; 0V ≤ V <sub>OUT</sub> ≤ V <sub>DDQ</sub>                                  | I <sub>OZ</sub>                   | -5                     | 5                     | μA    |       |
| Output Levels:<br>Output High Voltage (I <sub>OUT</sub> = -4mA)                                                     | V <sub>OH</sub>                   | V <sub>DDQ</sub> - 0.2 | –                     | V     |       |
| Output Low Voltage (I <sub>OUT</sub> = 4mA)                                                                         | V <sub>OL</sub>                   | –                      | 0.2                   | V     |       |

**Table 4: DC Electrical Characteristics and Operating Conditions (V version)**

V<sub>DD</sub> = +2.5V ±0.2V V<sub>DDQ</sub> = +2.5V ±0.2V or V<sub>DDQ</sub> = +1.8V ±0.15V

Notes: 1, 5, 6; please refer to the 256Mb: x32 Mobile SDRAM data sheet for all notes.

| Parameter/Condition                                                                                                 | Symbol                            | MIN                    | MAX                    | Units | Notes |
|---------------------------------------------------------------------------------------------------------------------|-----------------------------------|------------------------|------------------------|-------|-------|
| Supply Voltage                                                                                                      | V <sub>DD</sub> /V <sub>DDQ</sub> | 2.3                    | 2.7                    | V     |       |
| Input High Voltage: Logic 1; All inputs                                                                             | V <sub>IH</sub>                   | 0.8 x V <sub>DDQ</sub> | V <sub>DDQ</sub> + 0.3 | V     | 22    |
| Input Low Voltage: Logic 0; All inputs                                                                              | V <sub>IL</sub>                   | -0.3                   | 0.3                    | V     | 22    |
| Input Leakage Current:<br>Any input 0V ≤ V <sub>IN</sub> ≤ V <sub>DD</sub><br>(All other balls not under test = 0V) | I <sub>I</sub>                    | -3.0                   | 3.0                    | μA    |       |
| Output Leakage Current: DQs are disabled; 0V ≤ V <sub>OUT</sub> ≤ V <sub>DDQ</sub>                                  | I <sub>OZ</sub>                   | -3.0                   | 3.0                    | μA    |       |
| Output Levels:<br>Output High Voltage (I <sub>OUT</sub> = -4mA)                                                     | V <sub>OH</sub>                   | 0.9 x V <sub>DDQ</sub> | –                      | V     |       |
| Output Low Voltage (I <sub>OUT</sub> = 4mA)                                                                         | V <sub>OL</sub>                   | –                      | 0.2                    | V     |       |

**Table 5: DC Electrical Characteristics and Operating Conditions (H version)**

VDD = +1.8V ±0.1V VDDQ = +1.8V ±0.1V

Notes: 1, 5, 6; please refer to the 256Mb: x32 Mobile SDRAM data sheet for all notes.

| Parameter/Condition                                                                         | Symbol   | MIN        | MAX        | Units | Notes |
|---------------------------------------------------------------------------------------------|----------|------------|------------|-------|-------|
| Supply Voltage                                                                              | VDD/VDDQ | 1.7        | 1.9        | V     |       |
| Input High Voltage: Logic 1; All inputs                                                     | VIH      | 0.8 x VDDQ | VDDQ + 0.3 | V     | 22    |
| Input Low Voltage: Logic 0; All inputs                                                      | VIL      | -0.3       | 0.3        | V     | 22    |
| Input Leakage Current:<br>Any input 0V ≤ VIN ≤ VDD<br>(All other balls not under test = 0V) | II       | -1.0       | 1.0        | μA    |       |
| Output Leakage Current: DQs are disabled; 0V ≤ VOUT ≤ VDDQ                                  | Ioz      | -1.5       | 1.55       | μA    |       |
| Output Levels:<br>Output High Voltage (IOUT = -4mA)                                         | VOH      | 0.9 x VDDQ | –          | V     |       |
| Output Low Voltage (IOUT = 4mA)                                                             | VOL      | –          | 0.2        | V     |       |

**Table 6: IDD Specifications and Conditions (LC version)**

VDD = +3.3V ±0.3V, VDDQ = +3.3V ±0.3V

Notes: 1, 5, 6, 11, 13; please refer to the 256Mb: x32 Mobile SDRAM data sheet for all notes.

|                                                                                                                            |                                           | MAX  |     |       |               |                       |
|----------------------------------------------------------------------------------------------------------------------------|-------------------------------------------|------|-----|-------|---------------|-----------------------|
| Parameter/Condition                                                                                                        | Symbol                                    | -8   | -10 | Units | Notes         |                       |
| Operating Current: Active Mode; Burst = 2; READ or WRITE;<br>t <sub>RC</sub> = t <sub>RC</sub> (MIN)                       | IDD1                                      | 210  | 185 | mA    | 3, 18, 19, 28 |                       |
| Standby Current: Power-Down Mode; All banks idle; CKE = LOW                                                                | IDD2N                                     | 800  | 800 | μA    | 32            |                       |
| Standby Current: Power-Down Mode; All banks idle; CKE = HIGH                                                               | IDD2NS                                    | 60   | 60  | mA    |               |                       |
| Standby Current: Active Mode; CKE = HIGH; CS# = HIGH; All banks active after t <sub>RCD</sub> met; No accesses in progress | IDD3NS                                    | 80   | 80  | mA    | 3, 12, 19, 28 |                       |
| Standby Current: Active Mode; CKE = LOW; CS# = HIGH; All banks active; No accesses in progress                             | IDD3N                                     | 60   | 60  | mA    |               |                       |
| Operating Current: Burst Mode; Continuous burst; READ or WRITE; All banks active, half DQs toggling every cycle.           | IDD4                                      | 165  | 140 | mA    | 3, 18, 19, 28 |                       |
| Auto Refresh Current<br>CKE = HIGH; CS# = HIGH                                                                             | t <sub>RFC</sub> = t <sub>RFC</sub> (MIN) | IDD5 | 300 | 250   | mA            | 3, 12, 18, 19, 28, 29 |
|                                                                                                                            | t <sub>RFC</sub> = 7.8μs                  | IDD6 | 5.0 | 5.0   |               |                       |
| Deep power down                                                                                                            | I <sub>ZZ</sub>                           | 20   | 20  | μA    |               |                       |

**Table 7: IDD Specifications and Conditions (V version)**

VDD = +2.5 ±0.2V, VDDQ = +2.5 ±0.2V

Notes: 1, 5, 6, 11, 13; please refer to the 256Mb: x32 Mobile SDRAM data sheet for all notes.

| Parameter/Condition                                                                                                    | Symbol                            | MAX |     | Units | Notes                 |
|------------------------------------------------------------------------------------------------------------------------|-----------------------------------|-----|-----|-------|-----------------------|
|                                                                                                                        |                                   | -8  | -10 |       |                       |
| Operating Current: Active Mode; Burst = 2; READ or WRITE;<br>$t_{RC} = t_{RC} \text{ (MIN)}$                           | IDD1                              | 210 | 185 | mA    | 3, 18, 19, 28         |
| Standby Current: Power-Down Mode; All banks idle;<br>CKE = LOW                                                         | IDD2N                             | 800 | 800 | μA    | 32                    |
| Standby Current: Power-Down Mode; All banks idle;<br>CKE = HIGH                                                        | IDD2NS                            | 60  | 60  | mA    |                       |
| Standby Current: Active Mode; CKE = HIGH; CS# = HIGH;<br>All banks active after $t_{RCD}$ met; No accesses in progress | IDD3NS                            | 80  | 80  | mA    | 3, 12, 19, 28         |
| Standby Current: Active Mode; CKE = LOW; CS# = HIGH;<br>All banks active; No accesses in progress                      | IDD3N                             | 60  | 60  | mA    |                       |
| Operating Current: Burst Mode; Continuous burst;<br>READ or WRITE; All banks active, half DQs toggling every cycle.    | IDD4                              | 165 | 140 | mA    | 3, 18, 19, 28         |
| Auto Refresh Current<br>CKE = HIGH; CS# = HIGH                                                                         | $t_{RFC} = t_{RFC} \text{ (MIN)}$ | 300 | 250 | mA    | 3, 12, 18, 19, 28, 29 |
|                                                                                                                        | $t_{RFC} = 7.8\mu s$              | 5.0 | 5.0 | mA    |                       |
| Deep power down                                                                                                        | Izz                               | 20  | 20  | μA    |                       |

**Table 8: IDD Specifications and Conditions (H version)**

VDD = 1.8 ±0.1V, VDDQ = 1.8V ±0.1V

Notes: 1, 5, 6, 11, 13; please refer to the 256Mb: x32 Mobile SDRAM data sheet for all notes.

| Parameter/Condition                                                                                                    | Symbol                            | MAX |     | Units | Notes                 |
|------------------------------------------------------------------------------------------------------------------------|-----------------------------------|-----|-----|-------|-----------------------|
|                                                                                                                        |                                   | -8  | -10 |       |                       |
| Operating Current: Active Mode; Burst = 2; READ or WRITE;<br>$t_{RC} = t_{RC} \text{ (MIN)}$                           | IDD1                              | 155 | 130 | mA    | 3, 18, 19, 28         |
| Standby Current: Power-Down Mode; All banks idle;<br>CKE = LOW                                                         | IDD2N                             | 600 | 600 | μA    | 32                    |
| Standby Current: Power-Down Mode; All banks idle;<br>CKE = HIGH                                                        | IDD2NS                            | 40  | 40  | mA    |                       |
| Standby Current: Active Mode; CKE = HIGH; CS# = HIGH;<br>All banks active after $t_{RCD}$ met; No accesses in progress | IDD3NS                            | 60  | 60  | mA    | 3, 12, 19, 28         |
| Standby Current: Active Mode; CKE = LOW; CS# = HIGH;<br>All banks active; No accesses in progress                      | IDD3N                             | 40  | 40  | mA    |                       |
| Operating Current: Burst Mode; Continuous burst;<br>READ or WRITE; All banks active, half DQs toggling every cycle.    | IDD4                              | 115 | 95  | mA    | 3, 18, 19, 28         |
| Auto Refresh Current<br>CKE = HIGH; CS# = HIGH                                                                         | $t_{RFC} = t_{RFC} \text{ (MIN)}$ | 245 | 205 | mA    | 3, 12, 18, 19, 28, 29 |
|                                                                                                                        | $t_{RFC} = 7.8\mu s$              | 5.0 | 5.0 | mA    |                       |
| Deep power down                                                                                                        | Izz                               | 20  | 20  | μA    |                       |

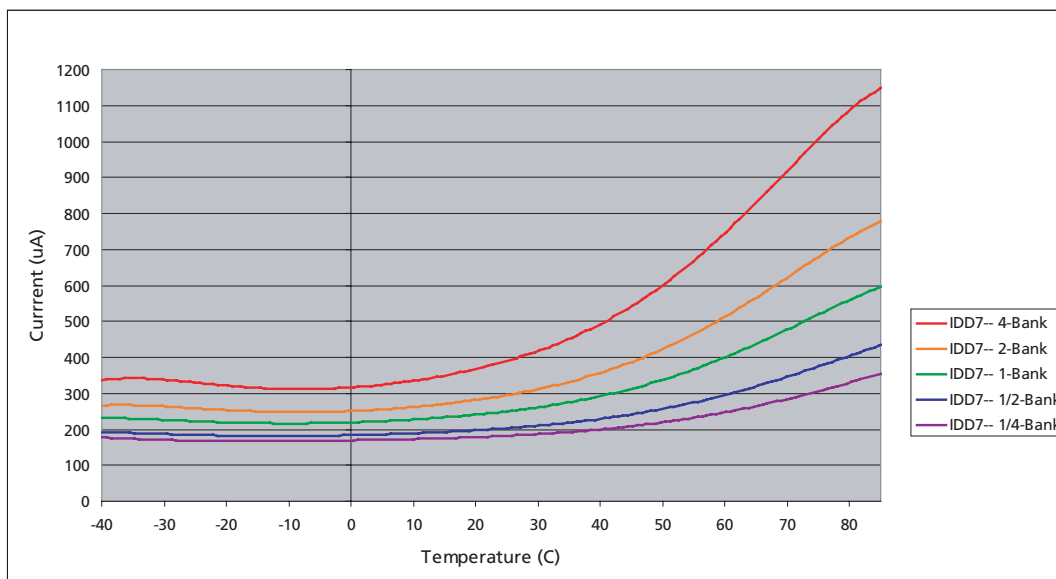
**Table 9: IDD7 - Self Refresh Current Options**

Note: 4; please refer to the 256Mb: x32 Mobile SDRAM data sheet for all notes. Values for IDD7 for 85°C are 100 percent tested. Values for 70°C, 45°C, and 15°C are sampled only.

| Temperature Compensated Self Refresh Parameter/Condition  | MAX Temperature | VDD = 3.3 | VDD = 2.5 | VDD = 1.8 | Units | Notes |
|-----------------------------------------------------------|-----------------|-----------|-----------|-----------|-------|-------|
| Self Refresh Current:<br>CKE = LOW – 4 Bank Refresh       | 85°C            | 1600      | 1600      | 1200      | μA    | 4     |
|                                                           | 70°C            | 1300      | 1300      | 960       | μA    | 4     |
|                                                           | 45°C            | 1000      | 1000      | 740       | μA    | 4     |
|                                                           | 15°C            | 864       | 864       | 630       | μA    | 4     |
| Self Refresh Current:<br>CKE = LOW – 2 Bank Refresh       | 85°C            | 1200      | 1200      | 900       | μA    | 4     |
|                                                           | 70°C            | 1025      | 1025      | 760       | μA    | 4     |
|                                                           | 45°C            | 875       | 875       | 640       | μA    | 4     |
|                                                           | 15°C            | 800       | 800       | 580       | μA    | 4     |
| Self Refresh Current:<br>CKE = LOW – 1 Bank Refresh       | 85°C            | 1000      | 1000      | 750       | μA    | 4     |
|                                                           | 70°C            | 900       | 900       | 660       | μA    | 4     |
|                                                           | 45°C            | 800       | 800       | 590       | μA    | 4     |
|                                                           | 15°C            | 760       | 760       | 560       | μA    | 4     |
| Self Refresh Current:<br>CKE = LOW – Half Bank Refresh    | 85°C            | 900       | 900       | 680       | μA    | 4     |
|                                                           | 70°C            | 825       | 825       | 610       | μA    | 4     |
|                                                           | 45°C            | 780       | 780       | 566       | μA    | 4     |
|                                                           | 15°C            | 750       | 750       | 540       | μA    | 4     |
| Self Refresh Current:<br>CKE = LOW – Quarter Bank Refresh | 85°C            | 850       | 850       | 640       | μA    | 4     |
|                                                           | 70°C            | 800       | 800       | 590       | μA    | 4     |
|                                                           | 45°C            | 760       | 760       | 550       | μA    | 4     |
|                                                           | 15°C            | 740       | 740       | 536       | μA    | 4     |

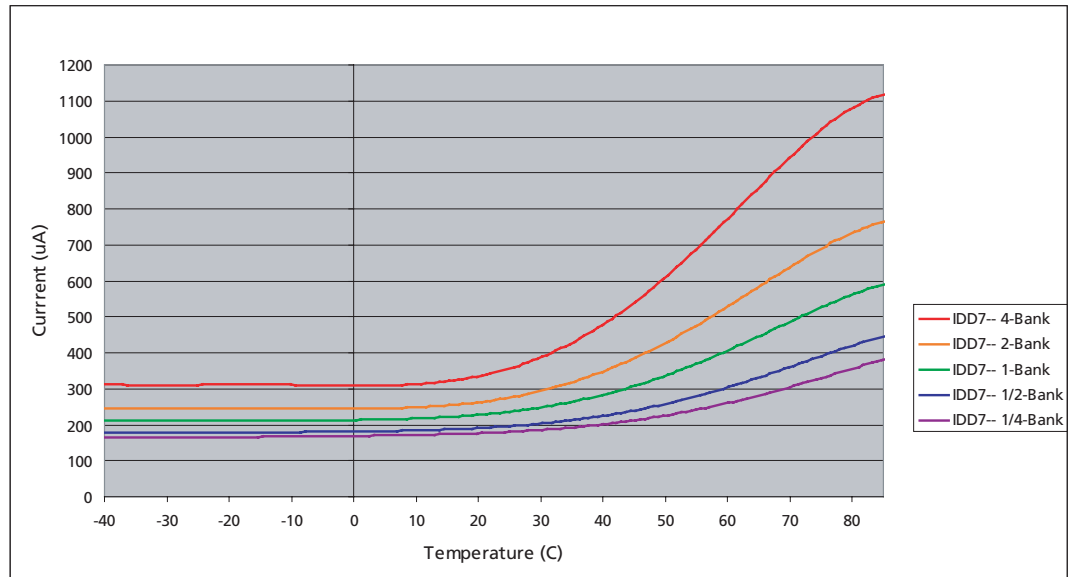
## IDD7 Curves

**Figure 3: Typical Self Refresh Current vs. Temperature – 3.3V Part**

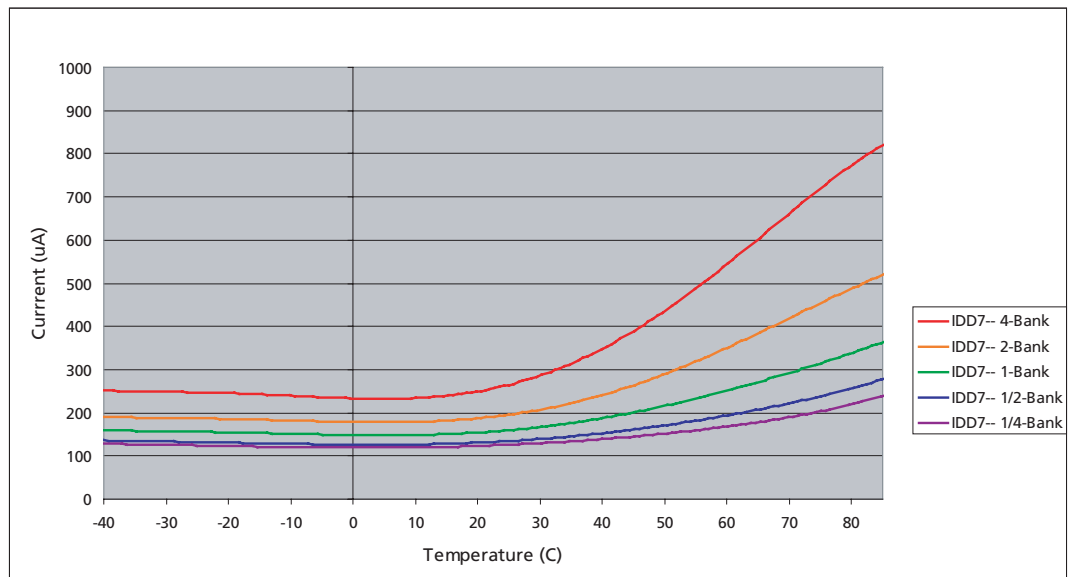




**Figure 4: Typical Self Refresh Current vs. Temperature – 2.5V Part**



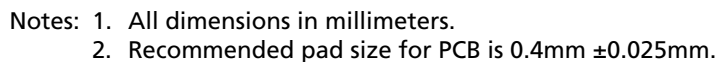
**Figure 5: Typical Self Refresh Current vs. Temperature – 1.8V Part**



**Table 10: Capacitance**

| Parameter – FBGA "S2" Package                 | Symbol          | MIN | MAX | Units |
|-----------------------------------------------|-----------------|-----|-----|-------|
| Input Capacitance: CLK                        | C <sub>I1</sub> | 5   | 8   | pF    |
| Input Capacitance: All other input-only balls | C <sub>I2</sub> | 5   | 8   | pF    |
| Input/Output Capacitance: DQs                 | C <sub>I0</sub> | 8   | 12  | pF    |

**Figure 6: 90-Ball FBGA (8mm x 13mm)**



**This data sheet contains minimum and maximum limits specified over the complete power supply and temperature range for production devices. Although considered final, these specifications are subject to change, as further product development and data characterization sometimes occur.**