DDR3 Thermals

Thermal Limits, Operating Temperatures, Tools, and System Development

4/12/2007
Agenda

- DDR3 Thermal Limits
- Estimated DDR3 DRAM Operating Temperatures
- Possible Thermal Solutions
- Micron Thermal Tools and System Development
DDR3 Thermal Limits

- DDR3 is specified to operate at the standard 85°C case or an extended temperature range of 95°C with 2X the refresh rate
  - 1X (standard) refresh rate = 64ms
  - 2X (high temp) refresh rate = 32ms

- Support optional $T_{CASE}$ range of 0°C to 95°C
  - Refresh period = 64ms when 0°C to 85°C
  - Refresh period = 32ms when >85°C to 95°C
Running at the higher temperature also requires the Extended Mode register to be set.

This ensures the DRAM will perform a 2X (32ms) refresh while the part is in Self-Refresh mode.
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DRAM Temperatures

• Simulation was performed to evaluate the thermal performance of several DDR3 RDIMMs
  ▪ SR x4, DR x8, DR x4 (planar) and DR x4 (stacked)
• The simulation was done for two worst case operating conditions
  ▪ 100% DRAM bandwidth from a single Rank
  ▪ ~65% DRAM utilization equally split between all Ranks
• Each condition was repeated for the three key DDR3 speed grades
  ▪ DDR3–800, DDR3–1067, DDR3–1333
DRAM Temperatures

• General System Module

  • Duct width is set to maintain the same air speed between 1 DIMM/ch and 2 DIMMs/ch

  • With FMHS the duct area and inlet air speed are the same, so the air speed and pressure differential through the DIMMs increase due to reduced area cross-section
DRAM Temperatures

• Raw Cards Simulated

R/C B (DR x8)

R/C C (SR x4)

R/C D (DR x4) – Stacked

R/C J (DR x4) – Planar
Requirements to Keep DRAM At/Below 85°C

How to read the chart...
For a single DR x8 (2GB) RDIMM running at DDR3-1066 speeds with a 65% DRAM utilization, closed page policy... the hottest DRAM case temperature is 85°C when the inlet air is about 42°C and there is a constant 1 m/s of air flow.

DR x8 (2GB) - Max DRAM temp = 85°C with 0.4" pitch

- 100% Bandwidth is from a single Rank, open page with continuous READs
- 65% Bandwidth reflects a sustained channel bandwidth of 65% of the maximum DRAM BW, 2x READs to WRITEs distributed evenly through all available ranks, closed page, PLL/Register package included
What does this show?
With high DRAM utilization, the (DR x8) runs cooler with open pages as compared to running with closed pages – about 6°C cooler.

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Requirements to Keep DRAM At/Below 85°C

• The simulations were then repeated with a full module heat spreader (FMHS) attached to each module

• The FMHS used was:
  ‣ A clamshell style heat spreader similar to FBDIMM
  ‣ Anodized 1mm 1050 aluminum alloy
  ‣ 15mil to 20mil gap pad TIM (1W/mK)
  ‣ Used two (2) clips to fasten to the module
DRx4 (4G) Planar Max DRAM Temperatures with 40C inlet

- Single Slot, DDR3-1333, 65% BW
- Single Slot - With Heat Sink, DDR3-1333, 65% BW
- Two Slots Populated, DDR3-1333, 65% BW
- Two Slots Populated - With Heat Sink, DDR3-1333, 65% BW

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DDR3 RDIMM Thermals – Including Heat Sink

DRx4 (4GB) - Stacked, Max DRAM Temperatures with 40(C) Inlet

- Without Heat Sink
  - Delta is about 3C

- With Heat Sink
  - Delta is about 6C

- Pitch = 0.4 inch

100% Bandwidth is from a single Rank, open page with continuous READs
65% Bandwidth reflects a sustained channel bandwidth of 65% of the maximum DRAM BW, 2x READs to WRITEs distributed evenly through all available ranks, closed page, PLL/Register package included

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Conclusion of Simulations

- At the slower speeds, DDR3 RDIMMs run cooler than comparable DDR2 RDIMM modules
- At the higher DDR3 clock rates and with minimal air flow, DRAM will approach or exceed the 85°C level
- A module heat sink provides cooling benefits and may be required for high speed, high density modules
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Possible Thermal Solutions

• System designs that utilize DDR3 must be proactive and consider the thermal aspects
  ‣ Will modules need heat sinks?
  ‣ Will there need to be an increased air flow?
  ‣ Will the inlet air temperature need to be cooler?
  ‣ Will socket spacing need to be increased?
  ‣ Will the controller need to consider throttling?
Possible Thermal Solutions

• Cooling the DDR3 RDIMM is different than cooling the FBDIMM
  ‣ On the FBDIMM, it is the AMB that needs cooling and the heat sink actually dissipates heat from the AMB into the DRAM
  ‣ The DDR3 RDIMM may need a heat sink to cool the DRAM
• A full module heat spreader decreases the DRAM and register temperatures; but to get the full benefits of the heat sink, increased air flows are required

Comparing the RDIMM (with) and (without) a heat sink shows even a greater difference between the DRAM temperature at higher airflow

- 3C delta at 1m/s
- 6C delta at +2.5m/s
Possible Thermal Solutions

• We may want to have the DDR3 modules updated to accept industry standard heat spreaders?
  › The PCBs may need to have notches added to accommodate the heat sink and mounting hardware (like on the FBDIMM)
Possible Thermal Solutions

• When adding heat sinks, system designers will need to account for the increased pressure drop through the DIMMs with fan selection and DIMM layout

• May need a higher pressure fan
• May need a greater DIMM pitch
Possible Thermal Solutions

- An example of 0.4” DIMM pitch, without heat sinks

About a 50% reduction
Possible Thermal Solutions

- An example of 0.4” DIMM pitch, with heat sinks

About a 70–80% reduction
Possible Thermal Solutions

- The affects of increasing the socket pitch to 0.45”

A decrease of about 5–6°C is realized just by increasing the socket pitch to 0.45 inch.
Possible Thermal Solutions

- The DDR3 RDIMMs are designed to include an “optional” thermal sensor
  - Thermal sensor datasheets are available for one at least the vendor
  - The sensor may be a discrete near the PLL/Register device, or included within the SPD on the back side
Possible Thermal Solutions

• The thermal sensor provides real time feedback through the module event pin, and/or the SMbus
• This allows the memory controller to monitor the temperature of the module and “throttle” back if critical thermal limits are approaching
• This is much like the thermal sensor on the AMB for the FBDIMM
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• Possible Solutions

• Micron Thermal Tools and System Development
Micron has many resources to help make your design a success

- For example, one of our wind tunnels
Micron Thermal Tools and System Development

• We offer thermal models of our components and some modules
• We do custom heat sink designs for many high bandwidth applications
• We can help to estimate your memory power budget using the Micron DDR3 Power Calculator