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<th>Date</th>
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<th>Description</th>
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<tr>
<td>June 2011</td>
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<td>February 2011</td>
<td>002</td>
<td>Table 3, &quot;Thermal Specifications&quot; on page 12</td>
</tr>
<tr>
<td>September 2010</td>
<td>001</td>
<td>Initial release.</td>
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June 2011
Reference Number: 324210-003

Intel® Atom™ Processor E6xx Series
TMDG
5
1.0 Introduction

This document describes thermal and mechanical design guidelines for the Intel® Atom™ Processor E6xx Series in the micro Flip Chip Ball Grid Array (micro-FCBGA) package.

In the embedded market, electronic components, system motherboard form factor and chassis design space are becoming smaller and more complex. To ensure that quality, reliability, and performance goals are met over the product’s life cycle, the heat generated by the device must be properly dissipated. Heat can be dissipated through the use of forced, free, or mixed airflow, and/or the use of heatsinks.

The goals of this document are to:

- Specify the thermal and mechanical specifications for the device
- Describe a reference thermal solution that meets the specifications

A properly designed thermal solution will adequately cool the device at or below the thermal specification. Operation outside the functional limits can degrade system performance and may cause permanent changes in the operating characteristics of the component.

The information provided in this document is for reference only and additional validation must be performed prior to implementing the designs into final production. The intent of this document is to assist each original equipment manufacturer (OEM) with the development of thermal solutions for their individual designs. The final heatsink solution, including the heatsink, attachment method, and thermal interface material (TIM) must comply with the mechanical design, environmental, and reliability requirements delineated in the Intel® Atom™ Processor E6xx Series Datasheet. It is the responsibility of OEMs to validate the thermal solution design with their specific applications.

This document addresses thermal and mechanical design specifications for the processor only. For thermal design information on other Intel components, please refer to the component’s datasheet.

1.1 Design Flow

Several tools are available from Intel to assist in the development of a reliable, cost-effective thermal solution. Figure 1 illustrates a typical thermal solution design process with available tools noted. The tools are available through your local Intel field sales representative.
1.2 Terminology

Table 1. Definition of Terms (Sheet 1 of 2)

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>°C</td>
<td>Degrees in Celsius</td>
</tr>
<tr>
<td>CFD</td>
<td>Computational Fluid Dynamics</td>
</tr>
<tr>
<td>FCBGA</td>
<td>Flip Chip Ball Grid Array. A ball grid array packaging technology where the die is exposed on the package substrate.</td>
</tr>
<tr>
<td>in.</td>
<td>Inches</td>
</tr>
<tr>
<td>MSR</td>
<td>Model Specific Register</td>
</tr>
<tr>
<td>OEM</td>
<td>Original Equipment Manufacturer</td>
</tr>
<tr>
<td>PCB</td>
<td>Printed circuit board</td>
</tr>
<tr>
<td>TDP</td>
<td>Thermal Design Power. Thermal solutions should be designed to dissipate this target power level.</td>
</tr>
<tr>
<td>TIM/TIM2</td>
<td>Thermal Interface Material. The thermally conductive compound between the heatsink and processor case. This material fills air gaps and voids and enhances spreading of the heat from the case to the heatsink.</td>
</tr>
<tr>
<td>T_JUNCTION-MAX</td>
<td>Maximum allowed component (junction) temperature. Also referred to as T_J-MAX</td>
</tr>
<tr>
<td>T_LA</td>
<td>Local ambient temperature. This is the temperature measured inside the chassis, approximately 1” upstream of a component heatsink. Also referred to as T_A.</td>
</tr>
<tr>
<td>T_S</td>
<td>Heatsink temperature measured on the underside of the heatsink base.</td>
</tr>
<tr>
<td>TTV</td>
<td>Thermal Test Vehicle</td>
</tr>
<tr>
<td>U</td>
<td>A unit of measure used to define server rack spacing height. 1U is equal to 1.75 inches, 2U equals 3.50 inches, etc.</td>
</tr>
<tr>
<td>W</td>
<td>Watt</td>
</tr>
</tbody>
</table>
Table 1. Definition of Terms (Sheet 2 of 2)

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\psi_{JA}$</td>
<td>Junction-to-ambient thermal characterization parameter. A measure of heatsink thermal performance using the total package power. Defined as $(T_{JUNCTION} - T_{LA}) / \text{Total Package Power}$</td>
</tr>
<tr>
<td>$\psi_{SA}$</td>
<td>Sink-to-ambient thermal characterization parameter. A measure of heatsink thermal performance using total package power. Defined as $(T_{SINK} - T_{JUNCTION}) / \text{Total Package Power}$.</td>
</tr>
<tr>
<td>$\psi_{TIM}$</td>
<td>Thermal interface material thermal characterization parameter. A measure of thermal interface material performance using total package power. Defined as $(T_{CASE} - T_{JUNCTION}) / \text{Total Package Power}$.</td>
</tr>
</tbody>
</table>

1.3 Related Documents and Utilities

In addition to the collateral available from the Intel® Developer Center, the Intel® Electronic Design Kit (EDK) provides online, real-time collateral updates. The following link takes you to the EDK for the Intel® Atom™ Processor E6xx Series and requires you to log into the Intel® Business Link (IBL):

Embedded Platform Code Named Queens Bay including Intel® Atom™ Processor E6xx Series

Readers of this document should also be familiar with material and concepts presented in the documents listed in Table 2.

Table 2. Related Documents and Utilities

<table>
<thead>
<tr>
<th>Document</th>
<th>Document Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intel® Atom™ Processor E6xx Series Datasheet</td>
<td>324208-001</td>
</tr>
<tr>
<td>Intel® Atom™ Processor E6xx Series Thermal Model User Guide</td>
<td>CDI #: 420336 Note 1</td>
</tr>
<tr>
<td>Intel® Atom™ Processor E6xx Series – Thermal Test Vehicle Hardware User Guide</td>
<td>CDI #: 450259 Note 1</td>
</tr>
</tbody>
</table>

Notes:
1. Contact your Intel sales representative. Some documents/utilities may not be available at this time.

1.4 Thermal Design Tool Availability

Intel provides thermal simulation models of the device and the Intel® Atom™ Processor E6xx Series Thermal Model User Guide to aid system designers in simulating, analyzing, and optimizing thermal solutions in a discrete, component level environment and in an integrated, system-level environment. The models are for use with commercially available computational fluid dynamics (CFD)-based thermal analysis tools including FloTHERM* by Mentor Graphics*, Inc. or Icepak* by Ansys*, Inc. Contact your Intel representative to order the thermal models and associated user’s guides.

Intel provides a Thermal Test Board (TTB) of the device and the Intel® Atom™ Processor E6xx Series – Thermal Test Vehicle Hardware User Guide to aid system designers in validating, analyzing, and testing thermal solutions designed in a discrete, component-level environment. Contact your Intel representative to order the TTB and associated user’s guides.
2.0 Package Information

The processor utilizes a 22 x 22 mm, 676-ball micro-FCBGA package. Please see Figure 2 (provided for reference only). Please refer to the device’s most recent datasheet for up-to-date information. In the event of conflict, the device’s datasheet supersedes data shown in these figures.

The micro-FCBGA package incorporates land-side capacitors, which are electrically conductive. Care should be taken to avoid contacting the capacitors with other electrically conductive materials on the motherboard. Doing so may short the capacitors and possibly damage the device or render it inactive.

The silicon die processor package has a mechanical load limit applied normal to surface of 100 psi or 14.88 lbf. This load limit should not be exceeded during heatsink installation, removal, mechanical stress testing, or standard shipping conditions. It is not recommended to use any portion of the processor substrate as a mechanical reference or load bearing surface in either static or dynamic compressive load conditions.
Figure 2. Micro-FCBGA Package
3.0 Thermal Specifications

3.1 Thermal Design Power

The Thermal Design Power (TDP)\(^1\) specification for the package with different SKUs are listed in Table 3. TDP is the highest attainable power at steady state if thermal monitor features are installed and enabled in the processor. Use the TDP value to design a component level thermal solution to account for the worst-case scenario. TDP is not suitable for system-level power budgeting and cannot be used to predict overall system-level power consumption.

3.2 Maximum Allowed Component Temperature

The device must maintain a maximum temperature at or below the value specified in Table 3. The thermal solution is required to meet the temperature specification while dissipating the TDP. Section 7.0 includes guidelines for accurately measuring the device temperature.

<table>
<thead>
<tr>
<th>CPU SKU</th>
<th># of Cores</th>
<th>Frequency (GHz)</th>
<th>TDP (W)</th>
<th>(T_{J-\text{MAX}}) (°C)</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultra Low Power (Extended Temperature)</td>
<td>1</td>
<td>0.6</td>
<td>3.3</td>
<td>110</td>
<td>1</td>
</tr>
<tr>
<td>Entry (Extended Temperature)</td>
<td>1</td>
<td>1.0</td>
<td>3.6</td>
<td>110</td>
<td></td>
</tr>
<tr>
<td>Mainstream (Extended Temperature)</td>
<td>1</td>
<td>1.3</td>
<td>3.6</td>
<td>110</td>
<td></td>
</tr>
<tr>
<td>Premium (Extended Temperature)</td>
<td>1</td>
<td>1.6</td>
<td>4.5</td>
<td>110</td>
<td>1</td>
</tr>
<tr>
<td>Ultra Low Power (Commercial Temperature)</td>
<td>1</td>
<td>0.6</td>
<td>3.3</td>
<td>90</td>
<td>1</td>
</tr>
<tr>
<td>Entry (Commercial Temperature)</td>
<td>1</td>
<td>1.0</td>
<td>3.6</td>
<td>90</td>
<td></td>
</tr>
</tbody>
</table>

---

1. TDP is defined as Intel’s recommended design point for thermal solutions. This specification is not indicative of the maximum power the processor can dissipate under worst case conditions. TDP offers an optimal end-user design point without unwarranted conservatism while accounting for the full range of possible end-user applications.
### Table 3. Thermal Specifications (Sheet 2 of 2)

<table>
<thead>
<tr>
<th>CPU SKU</th>
<th># of Cores</th>
<th>Frequency (GHz)</th>
<th>TDP (W)</th>
<th>T\textsubscript{J-MAX} (°C)</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mainstream (Commercial Temperature)</td>
<td>1</td>
<td>1.3</td>
<td>3.6</td>
<td>90</td>
<td></td>
</tr>
<tr>
<td>Premium (Commercial Temperature)</td>
<td>1</td>
<td>1.6</td>
<td>4.5</td>
<td>90</td>
<td>1</td>
</tr>
</tbody>
</table>

**Note:**
1. TDP for E620, E620T, E680 and E680T are estimates.
4.0 Mechanical Specifications

4.1 Package Mechanical Requirements

Package-level requirements are detailed in Section 2.0. Heatsink fastening must conform to package-specified allowable loading limits.

4.2 Package Keep-out Zones Requirements

The heatsink must not touch the hatched area on the package in Figure 2, which is the die-side capacitor placement keep-in zone for package design. The heatsink should include a means to prevent the heatsink from forming an electrical short with the capacitors placed on the top side of the package. The reference thermal solutions include z-stops machined into the base of the heatsink. The z-stops prevent the heatsink from inadvertently tilting when installed. Other methods are suitable including using electrically insulated gasket material at the base of the heatsink.

4.3 Board-Level Keep-out Zone Requirements

A general description of the keep-out zones and mounting hole pattern for the reference thermal solutions are shown in Figure 3 and Figure 4.
Figure 3.  Primary-Side Keep-out Zone Requirements — Micro-FCBGA

Notes:
1. Dimension in millimeters.
Figure 4. Secondary-Side Keep-out Zone Requirements — Micro-FCBGA

Notes:
1. Dimension in millimeters.
5.0 Thermal Solution Requirements

5.1 Characterizing the Package Thermal Impedance

Thermal impedance parameter, Theta ("θ") is the characterization of a package's temperature rise per watt. This value dictates whether a thermal solution is needed for cooling the package, and if needed, what type of thermal solution to use or design.

The thermal resistance, θJA, is defined by:

\[ \theta_{JA} = \frac{T_J - T_{LA}}{TDP} \]

The following illustrates how to determine the appropriate thermal resistance targets.

- Obtain a target component temperature \( T_{\text{JUNCTION}} \) and corresponding TDP from Table 3.
- Define a target local ambient temperature, \( T_{\text{LA}} \) based on specified application.

For the entry level SKU, if we assume:
- \( T_{\text{D P}} = 3.3 \text{ W} \)
- \( T_{\text{JUNCTION}} = 110^\circ \text{C} \)
- Local processor ambient temperature, \( T_{\text{LA}} = 40^\circ \text{C} \).

Then the following could be calculated for the given processor frequency depicted in Table 3:

\[ \theta_{JA} = \frac{T_J - T_{LA}}{TDP} = \frac{110 - 40}{3.3} = 21.2^\circ \text{C/W} \]

Table 4 summarizes the thermal impedance of the processor for a given local ambient temperature range.

<table>
<thead>
<tr>
<th>SKU</th>
<th>( \theta_{JA} ) (°C/W) at ( T_{\text{LA}} = 40^\circ \text{C} )</th>
<th>( \theta_{JA} ) (°C/W) at ( T_{\text{LA}} = 50^\circ \text{C} )</th>
<th>( \theta_{JA} ) (°C/W) at ( T_{\text{LA}} = 60^\circ \text{C} )</th>
<th>( \theta_{JA} ) (°C/W) at ( T_{\text{LA}} = 70^\circ \text{C} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>600 MHz</td>
<td>25.9</td>
<td>22.2</td>
<td>18.5</td>
<td>14.8</td>
</tr>
<tr>
<td>1.0 GHz</td>
<td>21.2</td>
<td>18.1</td>
<td>15.1</td>
<td>12.1</td>
</tr>
<tr>
<td>1.3 GHz</td>
<td>21.2</td>
<td>18.1</td>
<td>15.1</td>
<td>12.1</td>
</tr>
<tr>
<td>1.6 GHz</td>
<td>17.9</td>
<td>15.4</td>
<td>12.8</td>
<td>10.3</td>
</tr>
</tbody>
</table>

Notes:
1. \( T_{\text{LA}} \) is defined as the local (internal) ambient temperature measured approximately 1” upstream from the device.
2. \( \theta_{JA} \) is determined by \( (T_{\text{JUNCTION}} - T_{\text{LA}})/TDP \), so this value will change if any parameter changes.
5.2 Characterizing the Thermal Solution Requirement

Thermal characterization parameter, $\Psi$ ("psi"), is an industrial standard to characterize the performance for the thermal solution and to compare thermal solutions in identical situations (i.e., heating source, local ambient conditions, etc.). The junction-to-local ambient thermal characterization parameter ($\Psi_{JA}$) is used as a measure of the thermal performance of the overall thermal solution. It is defined by the following equation, and measured in units of °C/W:

**Equation 1. Junction-to-Local Ambient Thermal Characterization Parameter ($\Psi_{JA}$)**

$$\Psi_{JA} = \frac{(T_{JUNCTION\text{ MAX}} - T_{LA})}{TDP}$$

Where:

- $\Psi_{JA}$ = Junction-to-local ambient thermal characterization parameter (°C/W)
- $T_{JUNCTION\text{ MAX}}$ = Maximum allowed device temperature (°C)
- $T_{LA}$ = Local ambient temperature near the device (°C) (see Section 7.0 for measurement guidelines)
- TDP = Thermal Design Power (W), assumes all power dissipates through the top surface of the device

The junction-to-local ambient thermal characterization parameter, $\Psi_{JA}$, is comprised of $\Psi_{JS}$, which includes the thermal interface material thermal characterization parameter, and of $\Psi_{SA}$, the sink-to-local ambient thermal characterization parameter:

**Equation 2. Junction-to-Local Ambient Thermal Characterization Parameter**

$$\Psi_{JS} = \Psi_{JS} + \Psi_{SA}$$

Where:

- $\Psi_{JS}$ = Thermal characterization parameter of the thermal interface material and silicon die package (°C/W)
- $\Psi_{SA}$ = Thermal characterization parameter from sink-to-local ambient (°C/W)

TIM2 is strongly dependent on the thermal conductivity and bond line thickness between the heatsink and the processor. Bond line thickness is dependent on contact pressure between heatsink and processor. Design engineers must design heatsink fastening with the sufficient pressure for TIM2 while not exceeding package load limit requirement.

$\Psi_{SA}$ is a measure of the thermal characterization parameter from the bottom of the heatsink to the local ambient air. $\Psi_{SA}$ is dependent on the heatsink material, thermal conductivity, and geometry. It is also strongly dependent on the air velocity through the fins of the heatsink. Figure 5 illustrates the combination of the different thermal characterization parameters.
Whether adopting or designing a thermal solution, its thermal characterization parameter, \( \Psi \) ("psi"), must be an equal or smaller value than the thermal impedance, \( \Theta \) ("\( \Theta \)"), of the processor requiring cooling. Failing to do so may directly or indirectly affect overall performance of the processor and/or cause permanent damage to the processor due to overheating.
6.0 Reference Thermal Solution

Intel has developed reference thermal solutions designed to meet the cooling needs of embedded, form-factor applications. This section describes the overall requirements for the reference thermal solution, including critical-to-function dimensions, operating environment, and verification criteria. This document details a solution that is compatible with the 1U form factor.

The heatsinks are attached to the board using a screw, spring, and backplate assembly. The heatsink uses the fastener assembly (please refer to Section 6.4) to mount to the PCB. Detailed drawings of this heatsink are provided in Appendix B, "Mechanical Drawings."

Figure 6 illustrates an example of the thermal solution assembly. Full mechanical drawings of the thermal solutions and the corresponding heatsink clip are provided in Appendix B, "Mechanical Drawings." Appendix A, "Thermal Solution Component Suppliers" contains vendor information for each thermal solution component.

6.1 1U Reference Heatsink

The reference thermal solution compatible with the 1U form factor is designed and optimized for natural convection. Assuming these boundary conditions are met, the reference thermal solutions should meet the thermal specifications for the processor.

Figure 6. 1U Reference Natural Convection Heatsink

6.2 Mechanical Design

The 1U reference thermal solution is shown in Figure 6. The maximum heatsink height is constrained to 30 mm. The heatsink uses the fastener assembly to mount to the PCB (please see Section 6.4). Detailed drawings of this heatsink are provided in Figure 10.
6.3 Keep-out Zone Requirements

The PCB’s keep-out zone requirements for this heatsink are detailed in Figure 3 and Figure 4. Because it extends beyond the footprint of the device, it is critical for board designers to allocate space for the heatsink.

6.4 Heatsink Fastener Assembly

The reference solution uses screws, springs, and a back plate assembly to attach the heatsink to the PCB. The fastener assembly used on the reference heatsink must apply the load conditions described in Section 4.1. The fastener assembly must comply with all of the keep-out zone requirements described in this document, and should not degrade the thermal performance of the reference heatsinks. Finally the fastener assembly should be designed to meet the reliability guidelines described in Section 8.0.

6.5 Thermal Interface Material

The thermal interface material provides improved conductivity between the die and heatsink. It is important to understand and consider the impact of the interface between the die and heatsink base to the overall thermal solution. Specifically, the bond line thickness, interface material area, and interface material thermal conductivity must be selected to optimize the thermal solution.

It is important to minimize the thickness of the thermal interface material (TIM), commonly referred to as the bond line thickness. A large gap between the heatsink base and the die yields a greater thermal resistance. The thickness of the gap is determined by the flatness of both the heatsink base and the die, plus the thickness of the thermal interface material, and the clamping force applied by the heatsink attachment method. To ensure proper and consistent thermal performance, the TIM and application process must be properly designed.

Thermal interface materials have thermal impedance (resistance) that will increase over time as the material degrades. It is important for thermal solution designers to take this increase in impedance into consideration when designing a thermal solution. It is recommended that system integrators work with TIM suppliers to determine the performance of the desired thermal interface material. If system integrators wish to maintain maximum thermal solution performance, the TIM could be replaced during standard maintenance cycles.

The reference thermal solution uses Honeywell* PCM45F. Alternative materials can be used at the user’s discretion. Regardless, the entire heatsink assembly, including the heatsink, and TIM (including the attachment method), must be validated together for specific applications.

6.6 Heatsink Orientation

All of the heatsinks were designed to maximize the available space within the volumetric keep-out zone and their respective form-factor limitations. These heatsinks must be oriented in a specific direction relative to the processor keep-out zone and airflow. In order to use these designs, the processor must be placed on the PCB in an orientation so the heatsink fins will be parallel to the airflow and or gravity.
7.0 Thermal Metrology

The system designer must make temperature measurements to accurately determine the performance of the thermal solution. Validation of the processor’s thermal solution should be done using a thermal test vehicle (TTV). The TTV allows for an accurate junction temperature measurement as well as input power control. For more information on using the processor TTV, please refer to the Intel® Atom™ Processor E6xx Series – Thermal Test Vehicle Hardware User Guide, which can be obtained from your Intel field sales representative.

In addition, the processor’s heatsink should be verified in a system environment. Intel has established guidelines for techniques to measure the component temperature. Section 7.1 provides guidelines on how to accurately measure the component temperature. Section 7.2 contains information on running an application program that will emulate anticipated maximum thermal design power.

7.1 Die Temperature Measurements

The component $T_{JUNCTION}$ must be maintained at or below the maximum temperature specification as noted in Section 3.2. The best way to measure die temperature is to use the Digital Thermal Sensor as described in the Intel® Atom™ Processor E6xx Series Datasheet. Note that the Digital Thermal Sensor can only be read through a model specific register (MSR) of the processor, and cannot be accessed through an external I/O.

The on-board thermal diode is not recommended for performing heatsink validation. The thermal diode is suitable for long-term trending data, but is not a reliable indicator of the processor’s temperature.

7.2 Power Simulation Software

Power simulation software (PSS) is designed to dissipate the thermal design power (TDP) on a processor. To assess the thermal performance of the processor thermal solution under “worst-case realistic application” conditions, the utility operates the processor at near worst-case power dissipation.

Power simulation software should only be used to test customer thermal solutions at or near the thermal design power. For power supply current, please refer to each component’s datasheet for the $I_{CC}$ (Max Power Supply Current) specification.

Contact your Intel sales representative for availability of power simulation software for the Intel® Atom™ Processor E6xx Series.

7.3 Using Thermal Test Vehicles

Thermal Test Vehicle (TTV) is a DC-powered dummy processor built to generate desirable heat dissipation of a real processor. A TTV is used to validate a designed/directly adopted thermal solution in a predefined boundary condition — typically the application model.
For information on using the processor TTV, please see the Intel® Atom™ Processor E6xx Series – Thermal Test Vehicle Hardware User Guide. The TTB and user guide are available via the Intel Tools Loaner Program and your Intel representative.

7.4 Additional Thermal Features

The processor supports other thermal features including the Intel Thermal Monitor, PROCHOT_B, FORCPR_B, and THERMTRIP_B signal pins. Details for using these features are contained in the processor datasheet.

7.5 Local Ambient Temperature Measurement Guidelines

The local ambient temperature (T_LA) is the temperature of the ambient air surrounding the processor. For a passive heatsink, T_LA is defined as the heatsink approaches air temperature; for an actively cooled heatsink, it is the temperature of inlet air to the active cooling fan; for natural convection cooled heatsink, please refer to the JEDEC51-2 standard.

It is worthwhile to determine the local ambient temperature in the chassis around the processor to understand the effect it may have on the case temperature. T_LA is best measured by averaging temperature measurements at multiple locations in the heatsink inlet airflow. This method helps reduce error and eliminate minor spatial variations in temperature.

7.5.1 Active Heatsink Measurements

- It is important to avoid taking measurements in the dead flow zone that usually develops above the fan hub and hub spokes. Measurements should be taken at four different locations uniformly placed at the center of the annulus formed by the fan hub and the fan housing to evaluate the uniformity of the air temperature at the fan inlet. The thermocouples should be placed approximately 3 mm to 8 mm [0.1 to 0.3 in.] above the fan hub vertically and halfway between the fan hub and the fan housing horizontally (avoiding the hub spokes), as shown in Figure 7.

- Using an open bench to characterize an active heatsink can be useful, and usually ensures more uniform temperatures at the fan inlet. However, additional tests that include a solid barrier above the test motherboard surface can help evaluate the potential impact of the chassis. This barrier is typically clear Plexiglas*, extending at least 100 mm [4 in.] in all directions beyond the edge of the thermal solution. Typical distance from the motherboard to the barrier is 81 mm [3.2 in.]. If a barrier is used, the thermocouple can be taped directly to the barrier with clear tape at the horizontal location as previously described, halfway between the fan hub and the fan housing.

- For even more realistic airflow, the motherboard should be populated with significant elements like memory cards, graphic card, and chipset heatsink. If a variable speed fan is used, it may be useful to add a thermocouple taped to the barrier above the location of the temperature sensor used by the fan to check its speed setting against air temperature. When measuring T_LA in a chassis with a live motherboard, add-in cards, and other system components, it is likely that the T_LA measurements will reveal a highly non-uniform temperature distribution across the inlet fan section.

Note: Testing an active heatsink with a variable-speed fan can be done in a thermal chamber to capture the worst-case thermal environment scenarios. Otherwise, when doing a bench-top test at room temperature, the fan regulation prevents the heatsink from operating at its maximum capability. To characterize the heatsink capability in the worst-case environment in these conditions, it is then necessary to disable the fan regulation and power the fan directly, based on guidance from the fan supplier.
7.5.2 Passive Heatsink Measurements

- Thermocouples should be placed at least 13 mm [0.5 in.] away from processor and heatsink, as shown in Figure 8.
- For a horizontally oriented heatsink, the thermocouples should be placed approximately 1/3 of heatsink height, measured from the heatsink base. For a vertically oriented heatsink, the thermocouples should be placed approximately ½ of heatsink height, measured from the heatsink base. This placement guideline is meant to minimize the effect of localized hot spots from baseboard components.

Figure 7. Measuring $T_{LA}$ with an Active Heatsink

Note: Drawing not to scale.
7.5.3 Natural Convection Heatsink Measurements

Use JEDEC51-2 Integrated Circuits Thermal Test Method Environment Conditions – Natural Convection (Still Air) as reference.
Figure 9. Measuring $T_{LA}$ with a Natural Convection Heatsink

Note: Airflow shown in the figure is due to buoyancy force; no external force airflow.
8.0 Reliability Guidelines

Each motherboard, heatsink, and attachment combination may vary the mechanical loading of the component. The user should carefully evaluate the reliability of the completed assembly prior to use in high volume. Some general recommendations are shown in Table 5.

Table 5. Reliability Requirements

<table>
<thead>
<tr>
<th>Test</th>
<th>Requirement</th>
<th>Pass/Fail Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical Shock</td>
<td>50 g, board level, 11 msec, 3 shocks/axis</td>
<td>Visual Check and Electrical Functional Test</td>
</tr>
<tr>
<td>Random Vibration</td>
<td>7.3 g, board level, 45 min./axis, 50 Hz to 2000 Hz</td>
<td>Visual Check and Electrical Functional Test</td>
</tr>
<tr>
<td>Temperature Life</td>
<td>85° C, 2000 hours total, checkpoints at 168, 500, 1000, and 2000 hours</td>
<td>Visual Check</td>
</tr>
<tr>
<td>Thermal Cycling</td>
<td>-5° C to +70° C, 500 cycles</td>
<td>Visual Check</td>
</tr>
<tr>
<td>Humidity</td>
<td>85% relative humidity, 55 °C, 1000 hours</td>
<td>Visual Check</td>
</tr>
</tbody>
</table>

Notes:
1. The above tests should be performed on a sample size of at least 12 assemblies from 3 lots of material.
2. Additional pass/fail criteria may be added at the discretion of the user.
Appendix A Thermal Solution Component Suppliers

The vendors and devices listed in Table 6 are provided as a convenience. Intel does not make any representations or warranties whatsoever regarding quality, reliability, functionality, or compatibility of these devices. This list and/or these devices may be subject to change without notice.

Note: The enabled components may not be currently available from all suppliers. Contact the supplier directly to verify availability.

Table 6. Reference Heatsink

<table>
<thead>
<tr>
<th>Part</th>
<th>Part Number</th>
<th>Contact Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling solution set</td>
<td>EECC-00906-01-GP906-01-GP</td>
<td>Cooler Master Co. Ltd.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TEL: +886 (2) 32340050</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FAX: +886 (2) 32340051</td>
</tr>
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</table>
Appendix B Mechanical Drawings

Table 7 lists mechanical drawings included in this appendix.

<table>
<thead>
<tr>
<th>Description</th>
<th>Figure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1U Natural Convection Heatsink Mechanical Drawing</td>
<td>Figure 10</td>
</tr>
<tr>
<td>3.72 lbf Compression Spring for Silicon Die</td>
<td>Figure 11</td>
</tr>
<tr>
<td>Backplate Assembly for 1U Natural Convection Heatsink</td>
<td>Figure 12</td>
</tr>
<tr>
<td>M2.5 Rod Carbon Steel Screw</td>
<td>Figure 13</td>
</tr>
</tbody>
</table>

**Figure 10.** 1U Natural Convection Heatsink Mechanical Drawing
Figure 11.  3.72 lbf Compression Spring for Silicon Die

General Dimension Tolerances (Unit: mm)

<p>| | | |</p>
<table>
<thead>
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<th></th>
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</thead>
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<tr>
<td>0</td>
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</tr>
<tr>
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<td>100</td>
<td>± 0.2</td>
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<tr>
<td>101</td>
<td>Over</td>
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<tr>
<td>Angles</td>
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<td>± 1</td>
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</tbody>
</table>
Figure 12. Backplate Assembly for 1U Natural Convection Heatsink
Figure 13. M2.5 Rod Carbon Steel Screw

General Dimension Tolerances (Unit: mm)

<table>
<thead>
<tr>
<th>Length</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
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<tr>
<td>100 or over</td>
<td>±0.25</td>
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</table>

Angles ±1