Intel® G45, G41, Q45, Q35 and Q965 Chipsets for Embedded Applications

Thermal Design Guide

February 2009

Revision 1.5
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<th>Description</th>
<th>Revision Date</th>
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<tr>
<td>1.0</td>
<td>Initial release</td>
<td>September 2008</td>
</tr>
<tr>
<td>1.5</td>
<td>Added Intel® G45, G41, Q35 and Q965 chipsets to document.</td>
<td>February 2009</td>
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§
1 Introduction

1.1 Overview
This document describes thermal design guidelines for using embedded Intel® G45, G41, Q45, Q35 and Q965 Express Chipsets (GMCH) in 1U and PICMG 1.3 form factors. The objective of designing the thermal solution is to maintain the case temperature of the GMCH below the maximum allowable case temperature as specified in datasheet. For details of the form factors, please refer to the respective form factor websites for the full specifications.

The information provided in this document is for reference only; additional validation must be performed prior to implementing the thermal designs into final production. The intent of this document is to assist embedded OEMs with the development of thermal solutions for their individual designs. It is the responsibility of each OEM to validate the thermal solution design, including the heatsink, attachment method, and thermal interface material (TIM) with their specific applications.

1.2 Document Goals
This document describes the thermal characteristics and reference solution for the Intel® G45, G41, Q45, Q35 and Q965 chipsets in 1U and PICMG 1.3 form factors.

1.3 Document Scope
This document includes techniques and consideration for thermal solution design in using the Intel® G45, G41, Q45, Q35 and Q965 chipsets in an embedded application for the 1U and PICMG 1.3 form factors. Reference solutions are shared later in the document. Please refer to the product datasheet for the product dimensions, thermal power dissipation, and maximum case temperature. In case of conflict, the data in the product datasheet supersedes any data in this document.

In this document, the use of the term GMCH refers to any of the following chipsets listed below:

- Intel® G45 Chipset GMCH
- Intel® G41 Chipset GMCH
- Intel® Q45 Chipset GMCH
- Intel® Q35 Chipset GMCH
- Intel® Q965 Chipset GMCH

1.4 References
Material and concepts available in the following documents may be beneficial when reading this document.
<table>
<thead>
<tr>
<th>Document</th>
<th>Source/Reference Number</th>
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<tr>
<td>Intel® 4 Series Chipset Family Datasheet</td>
<td>319970</td>
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<tr>
<td>Intel® 4 Series Express Chipset, Thermal and Mechanical Design Guidelines</td>
<td>319972</td>
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<tr>
<td>Intel® 3 Series Chipset Datasheet</td>
<td>Available electronically</td>
</tr>
<tr>
<td>Intel® Q35/Q33/G33/P33 Express Chipsets Thermal and Mechanical Design Guidelines</td>
<td>Available electronically</td>
</tr>
<tr>
<td>Intel® 965 Express Chipset Datasheet</td>
<td>313053</td>
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<tr>
<td>Intel® 965 Express Chipset Family Thermal Mechanical Design Guidelines</td>
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<td>Intel® I/O Controller Hub 7 (ICH7) Thermal Design Guidelines</td>
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<td>Intel® I/O Controller Hub 8 (ICH8) Thermal Design Guidelines</td>
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<td>Intel® I/O Controller Hub 9 (ICH9) Thermal Design Guidelines</td>
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<tr>
<td>Intel® I/O Controller Hub 10 (ICH10) Thermal Design Guidelines</td>
<td>319975</td>
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<tr>
<td>PICMG1.3 Specification</td>
<td><a href="http://www.picmg.org/SHB_Express.stm">http://www.picmg.org/SHB_Express.stm</a></td>
</tr>
</tbody>
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**Note:** Contact your Intel field sales representative for the latest revision and order number of this document.

### 1.5 Definition of Terms

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CFM</td>
<td>Cubic feet per minute</td>
</tr>
<tr>
<td>LFM</td>
<td>Linear feet per minute</td>
</tr>
<tr>
<td>PCB</td>
<td>Printed circuit board</td>
</tr>
<tr>
<td>( T_A )</td>
<td>The measured ambient temperature locally surrounding the component. The ambient temperature should be measured just upstream of a passive heatsink or at the fan inlet for an active heatsink. Also referred to as ( T_{\text{Amb}} )</td>
</tr>
<tr>
<td>( T_C )</td>
<td>The case temperature of the GMCH, measured at the geometric center of the topside of the GMCH silicon die.</td>
</tr>
<tr>
<td>( T_E )</td>
<td>The ambient air temperature external to a system chassis. This temperature is usually measured at the chassis air inlets.</td>
</tr>
<tr>
<td>Term</td>
<td>Description</td>
</tr>
<tr>
<td>------</td>
<td>-------------</td>
</tr>
<tr>
<td>$T_S$</td>
<td>Heatsink temperature measured on the underside of the heatsink base, at a location corresponding to $T_C$.</td>
</tr>
<tr>
<td>$T_{C\text{-MAX}}$</td>
<td>The maximum case temperature as specified in a component specification.</td>
</tr>
</tbody>
</table>
| $\psi_{JA}$ | Junction-to-ambient thermal characterization parameter (psi). A measure of thermal solution performance using total package power. Defined as $(T_J - T_A) / \text{TDP}$.  
**Note:** Heat source must be specified for $\psi$ measurements. |
| $\psi_{JS}$ | Junction-to-sink thermal characterization parameter. A measure of thermal interface material performance using total package power. Defined as $(T_J - T_S) / \text{TDP}$.  
**Note:** Heat source must be specified for $\psi$ measurements. |
| $\psi_{SA}$ | Sink-to-ambient thermal characterization parameter. A measure of heatsink thermal performance using total package power. Defined as $(T_S - T_A) / \text{TDP}$.  
**Note:** Heat source must be specified for $\psi$ measurements. |
| TIM | Thermal Interface Material: The thermally conductive compound between the heatsink and the processor case. This material fills the air gaps and voids, and enhances the transfer of the heat from the processor case to the heatsink. |
| $P_{\text{MAX}}$ | The maximum power dissipated by a semiconductor component. |
| TDP | Thermal Design Power: a power dissipation target based on worst-case applications. Thermal solutions should be designed to dissipate the thermal design power. |
| Bypass | Bypass is the area between a passive heatsink and any object that can act to form a duct. For this example, it can be expressed as a dimension away from the outside dimension of the fins to the nearest surface. |
| Thermal Monitor | A feature on the Intel® processor that attempts to keep the processor’s die temperature within factory specifications. |
| TCC | Thermal Control Circuit: Thermal Monitor uses the TCC to reduce die temperature by lowering effective processor frequency when the die temperature is very near its operating limits. |
| $T_{\text{DIODE}}$ | Temperature reported from the on-die thermal diode. |
| U | A unit of measure used to define server rack spacing height. 1U is equal to 1.75 inches, 2U equals 3.50 inches, etc. |


# 2 Product Specifications

The reference solution presented in this document is targeted for providing cooling solution of chipset (GMCH) in 1U and PICMG1.3 form factors. For ATX form factors, refer to respective thermal mechanical design guidelines as shown in Section 1.4. Therefore, the thermal solution will have to fit into the solution space as defined in various form factor specifications. The reference solutions could be adopted into other form factors, however, individual assessment and verification should be done.

Performance results provided by the reference solution should be taken as reference only. In addition, the data implies no statistical significance. Therefore, final verification should be based on end user configuration at system integrator or customer area.

## 2.1 Package Description

FCBGA package for all GMCH in this document is measured at 34 mm x 34 mm footprint, but with different number of solder balls, die size as well as package stack-up thickness. Refer to Appendix B for the mechanical drawing of the respective chipset package. The GMCH package also uses the “ball anywhere”, where board designer should refer to the respective datasheet for exact ball locations relative to the package. For reference, Figure 1 shows the solder joint layout for the Intel® Q45 GMCH.
2.2 Package Loading Specifications

The mechanical maximum loading should not exceed the list as specified at Table 1 during heatsink assembly, shipping condition or normal use condition. The package substrate should not be used as a mechanical reference or loading-bearing surface for the thermal and mechanical solution. The post reflow package height should be utilized for heatsink clip preload calculation.
### Table 1. Package Loading Specification

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Maximum</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Static</td>
<td>15 lbf</td>
<td>1,2,3</td>
</tr>
</tbody>
</table>

Notes:
1. Uniform compressive loading applied normal to the package
2. Maximum allowed load from the heatsink retention clip. Minimum load must also be achieved to ensure adequate force from the heatsink to the package for heat transfer
3. These specifications are based on limited testing for design characterization. Loading limits are for the package only.

### 2.3 Thermal Specifications

The purpose of the thermal management is to ensure the case temperature of the GMCH is at or below the $T_{c\text{-}\text{max}}$ as defined in Table 2 in order to achieve product reliability target and proper operation. GMCH should also be operating above $T_{c\text{-}\text{min}}$ as stated in Table 2.

#### 2.3.1 Definition

Thermal Design Power (TDP) is the estimated power dissipation of the GMCH based on normal operating conditions, including Vcc and $T_{c\text{-}\text{max}}$, while executing real worst-case power intensive applications. This value is based on expected worst-case data traffic patterns and usage of the chipset and does not represent a specific software application. TDP attempts to account for the expected increases in power due to variation in GMCH current consumption due to silicon process variation, processor speed, DRAM capacitive bus loading, and temperature. However, since these variations are subject to change, it cannot be guaranteed that all applications will not exceed the TDP value.

The system designer must design a thermal solution for the GMCH such that it maintains $T_c$ below $T_{c\text{-}\text{max}}$ for the sustained power level equal to the TDP. $T_{c\text{-}\text{max}}$ specification is a requirement for a sustained power level equal to TDP, and case temperature must be maintained at less than $T_{c\text{-}\text{max}}$ when operating at power less than TDP. The TDP can be used for thermal design if thermal protection mechanisms are enabled. The GMCH incorporates a hardware-base failsafe mechanism to keep the product temperature in specification in the event of unusually strenuous usage above the TDP power.
Table 2. Thermal Design Power

<table>
<thead>
<tr>
<th>Component</th>
<th>System Bus Speed</th>
<th>Memory Frequency</th>
<th>Max Idle Power</th>
<th>Max Idle Power (C3/C4 Enabled)</th>
<th>TDP</th>
<th>Tc-min</th>
<th>Tc-max</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intel® G45 chipset</td>
<td>1333 MT/s</td>
<td>1333 MT/s</td>
<td>9W</td>
<td>7.7W</td>
<td>24W</td>
<td>0°C</td>
<td>103°C</td>
<td>1,2</td>
</tr>
<tr>
<td>Intel® G41 chipset</td>
<td>1333 MT/s</td>
<td>1067 MT/s</td>
<td>11.5W</td>
<td>N/A</td>
<td>25W</td>
<td>0°C</td>
<td>102°C</td>
<td>1,2</td>
</tr>
<tr>
<td>Intel® Q45 chipset</td>
<td>1333 MT/s</td>
<td>1067 MT/s</td>
<td>6W</td>
<td>4.7W</td>
<td>17W</td>
<td>0°C</td>
<td>105°C</td>
<td>1,2</td>
</tr>
<tr>
<td>Intel® Q45 chipset</td>
<td>1333 MT/s</td>
<td>800 MT/s</td>
<td>6W</td>
<td>4.7W</td>
<td>17W</td>
<td>0°C</td>
<td>105°C</td>
<td>1,2</td>
</tr>
<tr>
<td>Intel® Q35 chipset</td>
<td>1333 MT/s</td>
<td>800 MT/s</td>
<td>6.5W</td>
<td>N/A</td>
<td>15W</td>
<td>0°C</td>
<td>106°C</td>
<td>1,2</td>
</tr>
<tr>
<td>Intel® Q965 chipset</td>
<td>1066 MT/s</td>
<td>800 MT/s</td>
<td>13W</td>
<td>N/A</td>
<td>28W</td>
<td>0°C</td>
<td>97°C</td>
<td>1,2</td>
</tr>
</tbody>
</table>

Note:
1. Thermal specifications assume an attached heatsink is present.
2. Idle Power is referred to as a typical part of system booted to Microsoft Windows without background application.
3. This value indicates the max idle power with C1/C2 enabled.
4. Idle data is measured for Energy Start with C23/ASPM enabled.

2.3.2 $T_{control}$ Limit

Intel® Quiet System Technology (Intel® QST) can monitor an embedded thermal sensor. The maximum operating limit when monitoring with this thermal sensor is $T_{control}$. For the Intel® G45, G41 and Q45 chipsets, this value has been defined as 99°C. These values are set as 93°C and 95°C respectively for Intel® Q35 and Q965 chipsets. This value should be programmed into the appropriate register of Intel® Quiet System Technology (Intel® QST) as the maximum sensor temperature for the operation of the GMCH.
3 Thermal Management

The system designer must measure temperatures in order to accurately determine the thermal performance of the system. Intel has established guideline for the proper techniques for measuring GMCH component case temperatures.

3.1.1 Case Temperature Measurements

To ensure functionality and reliability of the GMCH the Tc must be maintained at or below the maximum temperature listed in Table 2. The surface temperature measured at the geometric center of the die corresponds to Tc. Measuring Tc requires special care to ensure an accurate temperature reading.

Temperature differences between the temperature of a surface and the surrounding local ambient air can introduce error in the measurements. The measurement errors could be due to a poor thermal contact between the thermocouple bead and the surface of the package, heat loss by radiation and/or convection, conduction through thermocouple leads, or contact between the thermocouple cement and the heatsink base (if a heatsink is used). To minimize these measurement errors a thermocouple attach with a zero-degree methodology is recommended.

3.1.2 Thermocouple Attach Methodology

1. Mill a 3.3 mm diameter hole centered on bottom of the heatsink base. The milled hole should be approximately 1.5 mm deep.

2. Mill a 1.3 mm wide slot, 0.5 mm deep, from the centered hole to one edge of the heatsink. The slot should be in the direction parallel to the heatsink fins. See Figure 3.

3. Attach thermal interface material (TIM) to the bottom of the heatsink base.

4. Cut out portions of the TIM to make room for the thermocouple wire and bead. The cut-out should match the slot and hole milled into the heatsink base.

5. Attach a 36-gauge or smaller type-K thermocouple bead to the center of the top surface of the die using cement with high thermal conductivity. During this step, make sure no contact is present between the thermocouple cement and the heatsink based because any contact will affect the thermocouple reading. It is critical that the thermocouple bead makes contact with the die. See Figure 2.

6. Attach heatsink assembly to the GMCH, and route thermocouple wires out through the milled slot.
3.2 Air Flow Characterization

The recommended air temperature measurement location is described in Figure 4, measured relative to the component. For a more accurate measurement of the...
average approach air temperature, it is recommended that you take the average reading from two thermocouples spaced about 25 mm apart. Locations for single and paired thermocouples are shown in Figure 4.

Figure 4. Air Flow and Temperature Measurement Locations

Air flow velocity can be measured using sensors that combine air velocity and temperature measurements. Typical airflow sensor technology may include hot wire anemometers. Figure 4 provides guidance for airflow velocity measurement locations, which should be the same as used for temperature measurement. These locations are for a typical JEDEC test setup and may not be compatible with chassis layouts due to the proximity of the processor to the GMCH. It may be necessary to adjust the locations for a specific chassis. Be aware that sensors may need to be aligned perpendicular to the airflow velocity vector or an inaccurate measurement may result. Measurements should be taken with the chassis fully sealed in its operational configuration to achieve a representative air flow profile within the chassis.

3.3 Thermal Management Guidelines

Thermal performance of thermal solution depends on many parameters, including the following product characteristics:

1. Thermal Design Power
2. Maximum case temperature (Tc-max)
3. Operating ambient temperature
4. Air flow
5. Interface between thermal solution and silicon die of package (TIM, pressure, flatness, etc.)
It is strongly recommended that the design team validate the reference thermal solution designed and developed with the end use condition to ensure all environmental variables are considered and reliability of the solution is tested.

### 3.3.1 Heatsink Orientation Relative to Airflow

The heatsinks are designed to maximize the available space within the volumetric constraint zone. These heatsinks must be oriented in a specific direction relative to the processor volumetric constraint zone and airflow. In order to use this design, the processor must be placed on the PCB in an orientation such that the heatsink fins are parallel to the airflow. Figure 5 illustrates this orientation by showing a top view of the heatsink assembly.

**Figure 5. Air Flow Direction and Heatsink Fin Orientation**

![Air Flow Direction and Heatsink Fin Orientation](image)

### 3.3.2 Thermal Interface Material (TIM)

The interface between the processor and heatsink base has a significant impact on 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, commonly referred to as the bond line thickness. A large gap between the heatsink base and processor 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.
Another important aspect of Thermal Interface Materials is the degradation of the thermal impedance over the life of the material. The impedance of the TIM increases over the life of the material; this must be taken into account when designing a thermal solution.

The resistance of the thermal solution increases considerably at the End of Life due to the TIM degradation. End of Line for a TIM material is when the TIM is first installed on the heatsink.

End-of-Life is defined as a time in the future at which the material is deemed to be at the end of its useful life. The End-of-Life time varies for TIM material. It is recommended that thermal solution designers work with TIM manufacturers to determine the performance of the thermal interface material and its expected End-of-Life time length. System integrators might wish to replace the TIM during regularly scheduled maintenance periods in order to maintain End of Life performance of the thermal solution.

The heatsink solution was optimized using a high-performance phase-change material (PCM) Thermal Interface Material (TIM) with low thermal impedance, e.g. Honeywell* PCM45 thermal phase-change material. Vendor information for this material is provided in Appendix A. Alternative materials may also be used. The entire heatsink assemblies, including the heatsink attach method, and thermal interface material, must be validated together for specific applications.

### 3.3.3 Solder-Down Anchors

For platforms that have very limited board space, a clip retention solder-down anchor has been developed to minimize the impact of clip retention on the board. It is based on a standard three-pin jumper and is soldered to the board like any through-hole header. A new anchor design is available with 45° bent leads to increase the anchor attach reliability over time. The part number and vendor information is contained in Appendix A.
4 Reference Thermal Solution

Note: The reference thermal mechanical solution information shown in this document represents the current state of the data and may be subject to modification. The information represents design targets, not commitments by Intel.

The reference thermal solution described will be targeted for specific form factors: 1U and PICMG 1.3. The keep out zone on the motherboard will remain identical to Intel® G965 keep out zone for 1U and PICMG1.3.

For ATX and BTX form factors thermal solution, please refer to Intel® 4 Series Chipset Thermal Mechanical Design Guideline.

This chapter provides detailed information on operating environment assumptions, heatsink manufacturing, and mechanical reliability requirements for the GMCH.

4.1 1U and PICMG 1.3 Form Factor Operating Environment

The reference thermal solution compatible with the 1U form factor was designed assuming a maximum local ambient air temperature, \( T_{LA} \), of 40° C with a minimum airflow velocity of 200 lfm [1.02 m/s] present 25 mm [1 in.] directly in front of the heatsink air inlet side. The system integrator should note that board layout may be such that there will not be 25 mm [1 in.] between the processor heatsink and the GMCH. The potential for increased airflow speeds may be realized by ensuring that airflow from the processor thermal solution exhaust are in the direction of the GMCH heatsink. In addition, GMCH board placement should ensure that the GMCH heatsink is within the air exhaust area of the processor heatsink. An example of typical 1U server layout is shown in Figure 6. This layout is based on the Thin Electronics Bay specification located at http://www.ssiforum.org. As an added advantage, the GMCH can be located in an area that has a direct fresh air flow. Refer to Figure 6 dotted box location.

Assuming these boundary conditions are met, the reference thermal solutions will meet the thermal specifications for the GMCH. Table 3 shows the required thermal performance for the Intel® GMCH thermal solution. The thermal solution designer must carefully select the location to measure airflow to get a representative sampling. These environmental assumptions are based on a system at sea level.

The 1U reference heatsink solution can also be implemented into a PICMG 1.3 SHB which is having a 1U to adjacent board or card. See details shown at Figure 7.
Figure 6. Mechanical Layout of 1U System

ADD ON CARDS

ICH
Memory
GMCH
CPU & Heatsink Assembly

FANS MODULE
The thermal performance required for the heatsink is determined by calculating the case-to-ambient thermal characterization parameter, $\Psi_{CA}$. This is a basic thermal engineering parameter that may be used to evaluate and compare different thermal solutions in similar boundary conditions. An example of how $\Psi_{CA}$ is calculated for the Intel® G41 chipset at $T_{LA}=40$ °C is shown below:

$$
\Psi_{CA} = \frac{T_{C\max} - T_{LA}}{TDP} = \frac{102^\circ C - 40^\circ C}{25W} = 2.48^\circ C/W
$$

In this calculation, $T_{C\max}$ and TDP are taken from the thermal profile specification in the chipset datasheet. It is important to note that in this calculation, the $T_{C\max}$ and TDP are constant, while $\Psi_{CA}$ will vary according to the local ambient temperature. Table 5 shows an example of required thermal characterization parameters for the thermal solution at various $T_{LA}$'s. These numbers are subject to change, and in case of conflict, the specifications in the GMCH datasheet supersede the $T_{C\max}$ and TDP specification stated in this document.
In order to maintain the GMCH case temperature below its maximum case temperature, the reference thermal solution should provide the necessary cooling capacity so that the calculated thermal characterization parameter is below the specified value shown in Table 5.

### Table 3. Thermal Characterization Parameters at Various TLA’s

<table>
<thead>
<tr>
<th>Chipsets</th>
<th>TDP(W)</th>
<th>Tc-MAX(°C)</th>
<th>35</th>
<th>40</th>
<th>45</th>
<th>50</th>
</tr>
</thead>
<tbody>
<tr>
<td>G45</td>
<td>24</td>
<td>103</td>
<td>2.83</td>
<td>2.63</td>
<td>2.42</td>
<td>2.21</td>
</tr>
<tr>
<td>G41</td>
<td>25</td>
<td>102</td>
<td>2.68</td>
<td>2.48</td>
<td>2.28</td>
<td>2.08</td>
</tr>
<tr>
<td>Q45</td>
<td>17</td>
<td>105</td>
<td>4.12</td>
<td>3.82</td>
<td>3.53</td>
<td>3.24</td>
</tr>
<tr>
<td>Q35</td>
<td>15</td>
<td>106</td>
<td>4.73</td>
<td>4.40</td>
<td>4.07</td>
<td>3.73</td>
</tr>
<tr>
<td>Q965</td>
<td>28</td>
<td>97</td>
<td>2.21</td>
<td>2.04</td>
<td>1.86</td>
<td>1.68</td>
</tr>
</tbody>
</table>

**Notes:**
1. Thermal Design Power (TDP) should be used for processor thermal solution design targets. The TDP is not the maximum power that the processor can dissipate.
2. Tc-MAX and TDP values provided in this table are for reference only. Please contact your Intel field representative for any updates that could occur in the GMCH datasheet prior to the next revision of this document.
3. In case of conflict, the GMCH thermal specification in datasheet supersedes the thermal specification provided in this document.

### 4.3 Thermal Performance of 1U and PICMG 1.3 Reference Solution

For environment at TLA of 40°C and 55°C, the required minimum thermal resistance for the Intel® Q45 will be 3.82 °C/W and 2.94 °C/W respectively. Based on the performance curve shown in Figure 8, it will require 90 LFM and 125 LFM airflow to cool the Intel® Q45 chipset within its Tc-max specification at TLA of 40 °C and 55 °C respectively. As for the Intel® Q965 chipset, it will require about 200 LFM airflow at TLA of 50 °C in order to cool it within Tc-max specification. Hence, it is recommended to position the chipset at higher air flow location as shown in Figure 6 for better thermal performance.

As for the Intel® G41 chipset, the required minimum thermal resistance is 2.08 °C/W at TLA of 50°C. From Figure 9, the required airflow is at about 130 LFM. Since the thermal requirement for the Intel® G45 at TLA of 50 °C is slightly less than for the Intel® G41, the required airflow is about 125 LFM. In order to meet TLA of 55 °C, the required airflow is 170 LFM based on the result shown in Figure 9.
4.4 Reference Design Mechanical Envelope

The motherboard component keep-out zone for the chipset in 1U and PICMG 1.3 form factors are included in Appendix B.
4.5 Thermal Solution Assembly

The 1U/PICMG 1.3 reference thermal solutions for the chipsets discussed in this document are shown in Figure 10 and Figure 11 respectively. For 1U form factor, the heatsink will be mounted horizontally in plane with chassis, whereas for PICMG 1.3 SHB, the heatsink will be mounted vertically with respect to the chassis, where retention mechanism should be considered to ensure the heatsink stay intact with the SHB.

**Figure 10. Reference Heatsink Assembly for Intel® Q45, Q35 and Q965 Chipsets**

![Figure 10](image_url)

**Figure 11. Reference Heatsink Assembly for Intel® G45 and G41 Chipsets**

![Figure 11](image_url)

4.6 Environment Reliability Requirements

For the environmental reliability requirements for the reference thermal solution, refer to the respective thermal/mechanical design guide for ATX form factor.
Appendix A: Enabled Suppliers

These vendors and devices are listed as a convenience to the embedded customer base, but Intel does not make any representation or warranty whatsoever regarding quality, reliability, functionality, or compatibility of these devices. The list and/or these devices may be subject to change without notice.

Table 4. 1U/PICMG 1.3 Reference Heatsink Suppliers for Intel® Q45, Q35 and Q965 Chipsets

<table>
<thead>
<tr>
<th>Component</th>
<th>Supplier</th>
<th>Intel Part Number</th>
<th>Vendor Part Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1U Copper Heatsink gasket, and pre-applied Honeywell PCM45F TIM</td>
<td>Cooler Master</td>
<td>N/A</td>
<td>ECB-00265-01-GP</td>
</tr>
<tr>
<td>Thermal Interface Material</td>
<td>Honeywell</td>
<td>N/A</td>
<td>PCM45F</td>
</tr>
<tr>
<td>Heatsink Attach Clip</td>
<td>CCI/ACK</td>
<td>A69230-001</td>
<td>N/A</td>
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<tr>
<td></td>
<td>Foxconn</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solder-down Anchor</td>
<td>Foxconn</td>
<td>A13494-005</td>
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Table 5. 1U/PICMG 1.3 Reference Heatsink Suppliers for Intel® G45 and G41 Chipsets

<table>
<thead>
<tr>
<th>Component</th>
<th>Supplier</th>
<th>Intel Part Number</th>
<th>Vendor Part Number</th>
</tr>
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<tbody>
<tr>
<td>1U Reference Heatsink</td>
<td>Cooler Master</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Thermal Interface Material</td>
<td>Honeywell</td>
<td>N/A</td>
<td>PCM45F</td>
</tr>
<tr>
<td>Fastener</td>
<td>Cooler Master</td>
<td>N/A</td>
<td>N/A</td>
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Table 6. Supplier Contacts

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<tr>
<th>Supplier</th>
<th>Contacts</th>
<th>Phone</th>
<th>Email</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCI (Chaun Choung Technology)</td>
<td>Monica Chih</td>
<td>+886-2-2995-2666</td>
<td><a href="mailto:Monica_chih@ccic.com.tw">Monica_chih@ccic.com.tw</a></td>
</tr>
<tr>
<td></td>
<td>Harry Lin</td>
<td>+1(714) 739-5797</td>
<td><a href="mailto:hlinack@aol.com">hlinack@aol.com</a></td>
</tr>
<tr>
<td>Cooler Master</td>
<td>Stella Liao</td>
<td>+886(2)3234-0050 ext: 11328</td>
<td><a href="mailto:STELLA_LIAO@coolermaster.com">STELLA_LIAO@coolermaster.com</a></td>
</tr>
<tr>
<td></td>
<td>Debby</td>
<td>+886-2-3234-0050</td>
<td><a href="mailto:debby@coolermaster.com.tw">debby@coolermaster.com.tw</a></td>
</tr>
<tr>
<td>Foxconn</td>
<td>Jack Chen</td>
<td>+1(714) 626-1233</td>
<td><a href="mailto:Jack.chen@foxconn.com">Jack.chen@foxconn.com</a></td>
</tr>
<tr>
<td></td>
<td>Wanchi Chen</td>
<td>+1(714) 626-1376</td>
<td><a href="mailto:Wanchi.chen@foxconn.com">Wanchi.chen@foxconn.com</a></td>
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Appendix B: Mechanical Drawings

The following table lists the mechanical drawings available in this document.

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<thead>
<tr>
<th>Drawing Name</th>
<th>Page Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 12. Intel® G45, G41 and Q45 Chipset Package Drawing</td>
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</tr>
<tr>
<td>Figure 13. Intel® Q35 Chipset Package Drawing</td>
<td>27</td>
</tr>
<tr>
<td>Figure 14. Intel® Q965 Chipset Package Drawing</td>
<td>28</td>
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<tr>
<td>Figure 15. 1U/PICMG 1.3 Keep-Out Zone for Intel® Q45, Q35 and Q965 Chipsets</td>
<td>29</td>
</tr>
<tr>
<td>Figure 16. 1U/PICMG 1.3 Heatsink Assembly for Intel® Q45, Q35 and Q965 Chipsets</td>
<td>30</td>
</tr>
<tr>
<td>Figure 17. 1U/PICMG 1.3 Reference Heatsink for Intel® Q45, Q35 and Q965 Chipsets</td>
<td>31</td>
</tr>
<tr>
<td>Figure 18. 1U/PICMG 1.3 Reference Heatsink Gasket for Intel® Q45, Q35 and Q965 Chipsets</td>
<td>32</td>
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<tr>
<td>Figure 19. 1U/PICMG 1.3 Reference Heatsink Clip for Intel® Q45, Q35 and Q965 Chipsets</td>
<td>33</td>
</tr>
<tr>
<td>Figure 20. 1U/PICMG 1.3 Keep-out Zone for Intel® G45 and G41 Chipsets</td>
<td>34</td>
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<tr>
<td>Figure 21. 1U/PICMG 1.3 Reference Heatsink for Intel® G45 and G41 Chipsets</td>
<td>35</td>
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</tbody>
</table>
Figure 12. Intel® G45, G41 and Q45 Chipset Package Drawing
Figure 13. Intel® Q35 Chipset Package Drawing
Figure 14. Intel® Q965 Chipset Package Drawing
Figure 15. 1U/PICMG 1.3 Keep-Out Zone for Intel® Q45, Q35 and Q965 Chipsets
Figure 16. 1U/PICMG 1.3 Heatsink Assembly for Intel® Q45, Q35 and Q965 Chipsets

1. Copper Heatsink
2. Heatsink clip
3. TIM
4. Gasket
5. GMCH package
6. Anchor
Figure 17. 1U/PICMG 1.3 Reference Heatsink for Intel® Q45, Q35 and Q965 Chipsets
Figure 18. 1U/PICMG 1.3 Reference Heatsink Gasket for Intel® Q45, Q35 and Q965 Chipsets
Figure 19. 1U/PC/CMG 1.3 Reference Heatsink Clip for Intel® Q45, Q35 and Q965 Chipsets
Figure 20. 1U/PICMG 1.3 Keep-out Zone for Intel® G45 and G41 Chipsets
Figure 21. 1U/PICMG 1.3 Reference Heatsink for Intel® G45 and G41 Chipsets