Intel® 82575EB Gigabit Ethernet Controller Thermal Design Considerations Specification

LAN Access Division

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Revision 2.1

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Legal

Revisions

Date	Revision	Notes
12/3/2010	2.0	Released to developer. Reformatted and edited.
1/28/2011	2.1	Updated title to match brand string.

Contents

1. Product Package Thermal Specification

Table 1. Package Thermal Characteristics in Standard Environment

Package Type	Measured Power (Thermal Design Power*)	ΘJA	ΨJT
25mm 576FCBGA5-4L No thermal solution	2.8 W	18.4°C/W	1.7°C/W
25mm 576FCBGA5-4L With thermal solution	2.8 W	13.5°C/W	0.6°C/W

* See section 2 for a detailed definition of this parameter.

The thermal parameters defined above are for reference only and based on a combination of empirical/simulated results of packages assembled on standard 4s4p 1.0-oz Cu signal layer, 1.0-oz Cu power/ground layer board in a natural convection environment. ΘJA is the package junction-to-air thermal resistance. ΨJT is the junction-to-package top thermal characterization parameter. Your system design may vary considerably from the typical JEDEC board environment used.

NOTE: Package thermal models are available upon request (Flotherm 2-Resistor, Delphi or Detailed and Icepak format).

2. Introduction

This document describes the thermal characteristics for the 82575EB. Use this document to properly design a thermal solution for systems implementing the device.

Properly designed solutions provide adequate cooling to maintain the case temperature (Tcase) at or below those listed. Ideally, this is accomplished by providing a low local ambient temperature and creating a minimal thermal resistance to that local ambient temperature. Heat sinks may be required if case temperatures exceed those listed. Any attempt to operate outside of these operating limits may result in improper functionality or permanent damage to the Intel component and potentially other components within the system. Maintaining the proper thermal environment is essential to reliable, long-term component/system operation.

2.1 Measuring the Thermal Conditions

This document provides a method for determining the operating temperature of the device in a specific system based on case temperature. Case temperature is a function of the local ambient and internal temperatures of the component. This document specifies a maximum allowable Tcase for the device.

2.2 Thermal Considerations

In a system environment, the temperature of a component is a function of both the system and component thermal characteristics. System-level thermal constraints consist of the local ambient temperature at the component, the airflow over the component and surrounding board, and the physical constraints at, above, and surrounding the component that may limit the size of a thermal enhancement (heat sink).

The component's case/die temperature depends on:

- component power dissipation
- size
- packaging materials (effective thermal conductivity)
- type of interconnection to the substrate and motherboard
- presence of a thermal cooling solution
- power density of the substrate, nearby components, and motherboard

All of these parameters are pushed by the continued trend of technology to increase performance levels (higher operating speeds, MHz) and power density (more transistors). As operating frequencies increase and packaging size decreases, the power density increases and the thermal cooling solution space and airflow become more constrained. The result is an increased emphasis on system design to ensure that thermal design requirements are met for each component in the system.

2.3 Importance of Thermal Management

The thermal management objective is to ensure that all system component temperatures are maintained within functional limits. The functional temperature limit is the range in which the electrical circuits are expected to meet specified performance requirements.

Operation outside the functional limit can degrade system performance, cause logic errors, or cause component and/or system damage. Temperatures exceeding the maximum operating limits may result in irreversible changes in the component operating characteristics.

Note that sustained operation at component maximum temperature limit may affect long-term device reliability.

3. Packaging Terminology

The following is a list of packaging terminology used in this document:

- **FCBGA Flip Chip Ball Grid Array**: A surface mount package using a combination of flip chip and BGA structure whose PCB-interconnect method consists of eutectic solder ball array on the interconnect side of the package. The die is flipped and connected to an organic build-up substrate with C4 bumps. An integrated heat spreader (IHS) may be present for larger FCBGA packages for enhanced thermal performance.
- **Junction**: Refers to a P-N junction on the silicon. In this document, it is used as a temperature reference point (for example, $Theta_{\_JA}$ refers to the “junction” to “ambient” thermal resistance).
- **Ambient**: Refers to local ambient temperature of the bulk air approaching the component. It can be measured by placing a thermocouple approximately 1” upstream from the component edge.
- **Lands**: The pads on the PCB to which BGA Balls are soldered.
- **PCB**: Printed Circuit Board.
- Printed Circuit Assembly (PCA): An assembled PCB.
- **Thermal Design Power (TDP)**: The estimated maximum possible/expected power generated in a component by a realistic application. Use Maximum power requirement numbers listed.
- **LFM:** Linear Feet per Minute (airflow).

4. Thermal Specifications

To ensure proper operation and reliability of the device, the thermal solution must maintain a case temperature at or below the values specified in Table 2. System-level or component-level thermal enhancements are required to dissipate the generated heat if the case temperature exceeds the maximum temperatures.

Analysis indicates that real applications are unlikely to cause the device to be at Tcase-max for sustained periods of time. Given that Tcase should reasonably be expected to be a distribution of temperatures, sustained operation at Tcase-max may be indicative that the given thermal solution will also result in situations where Tcase exceeds the specified maximum value. Such thermal designs may affect long-term reliability of the device and the system, and sustained performance at Tcase-max should be evaluated during the thermal design process and steps taken to further reduce the Tcase temperature.

Good system airflow is critical to dissipate the highest possible thermal power. The size and number of fans, vents, and/or ducts, and, their placement in relation to components and airflow channels within the system determine airflow. Acoustic noise constraints may limit the size and types of fans, vents and ducts that can be used in a particular design.

To develop a reliable, cost-effective thermal solution, all of the system variables must be considered. Use system-level thermal characteristics and simulations to account for individual component thermal requirements.

Table 2. Thermal Absolute Maximum Rating

Parameter	Maximum
Tcase-hs[1]	113°C
Tcase-no hs[2]	110°C
(1). Tcase-hs is defined as the maximum case temperature with the default enhanced thermal solution attached. (2). Tcase-no hs is defined as the maximum case temperature without any thermal enhancement to the package.	

5. Thermal Attributes

5.1 Designing for Thermal Performance

The appendices of this document give the PCB and system design recommendations required to achieve the thermal performance.

5.2 Typical System Definitions

The following system example is used to generate thermal characteristics data:

- The heat sink case assumes the default enhanced thermal solution.
- The evaluation board is a standard multilayer 4s4p 1.0-oz Cu signal layer, 1.0-oz power/ground layer PCB.
- Data at 50LFM and 150LFM is validated against physical samples.

Your system design may be significantly different.

A larger board size with more than six Cu layers may increase thermal performance.

5.3 82575EB Thermal Attributes

5.3.1 Package Thermal Characteristics

Figure 1 shows the required local ambient temperature versus airflow for a typical system (see Section 4.2 for a typical system definition)

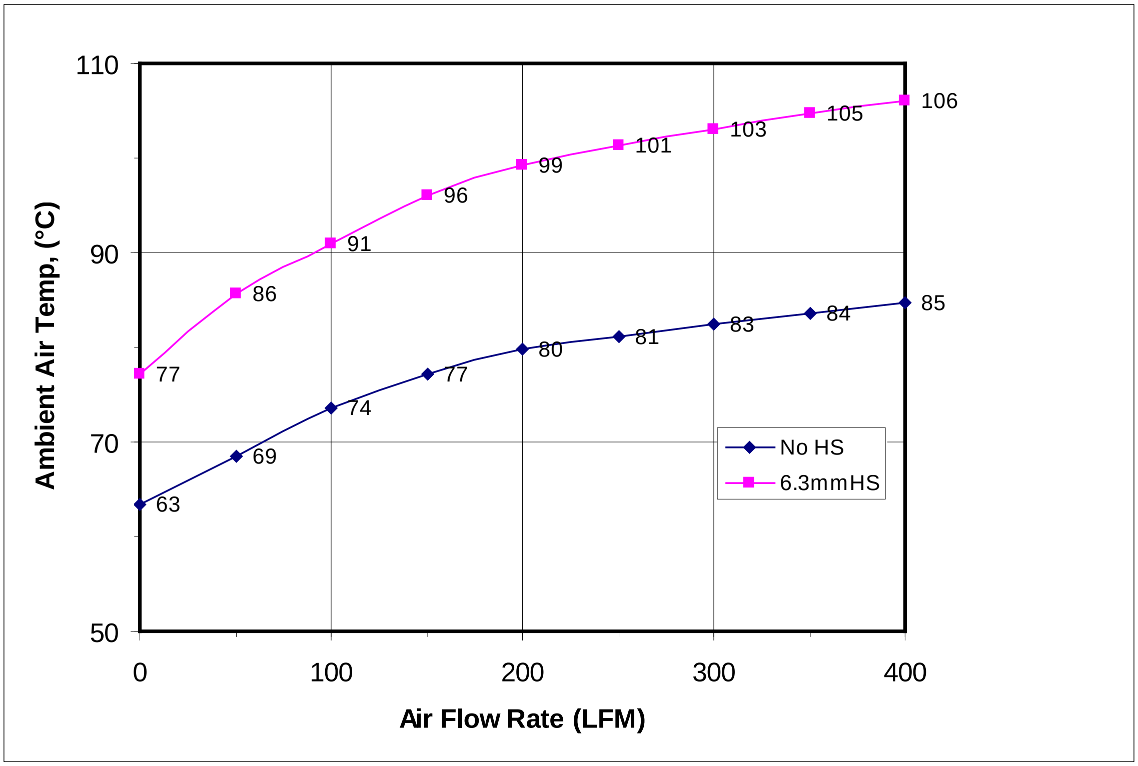

Figure 1. Max. Allowable Ambient Temperature vs. Air Flow

NOTE: Your system design may vary from the typical system board environment used to generate this table. Thermal models are available upon request (Flotherm: 2-Resistor, Delphi, or Detailed and Icepak: Detailed or 2-Resistor). Contact Intel for thermal models.

Table 3 shows Tcase as a function of airflow and ambient temperature at the TDP for a typical system and aids in determining the optimum airflow and heat sink combination for the device.

Table 3. Expected Tcase (°C) for Heat Sink Attached at TDP

Heat Sink Attached								Tcase Max =	113C
85 C amb.	<u>121</u>	<u>113</u>	107	102	99	97	95	94	92
80 C amb.	<u>116</u>	108	102	97	94	92	90	89	87
75 C amb.	111	103	97	92	89	87	85	84	82
70 C amb.	106	98	92	87	84	82	80	79	77
65 C amb.	101	93	87	82	79	77	75	74	72
60 C amb.	96	88	82	77	74	72	70	69	67
55 C amb.	91	83	77	72	69	67	65	64	62
50 C amb.	86	78	72	67	64	62	60	59	57
45 C amb.	81	73	67	62	59	57	55	54	52
Air Flow LFM	**0**	**50**	**100**	**150**	**200**	**250**	**300**	**350**	**400**

NOTE: The underlined value(s) indicate airflow/local ambient combinations that exceed the allowable case temperature.

Thermal enhancements (if required) are a method frequently used to improve thermal performance by increasing the component's surface area by attaching a metallic heat sink to the component top. Increasing the surface area of the heat sink reduces the thermal resistance from the heat sink to the air increasing heat transfer.

Table 4 shows Tcase as a function of airflow and ambient temperature at the TDP for a typical system and aids in determining the optimum airflow for the device.

Table 4. Expected Tcase (°C) for No Heat Sink Attached at TDP

No Heat Sink								Tcase Max =	110C
85 C amb.	132	127	122	118	115	114	113	112	110
80 C amb.	127	122	117	113	110	109	108	107	105
75 C amb.	122	117	112	108	105	104	103	102	100
70 C amb.	117	112	107	103	100	99	98	97	95
65 C amb.	112	107	102	98	95	94	93	92	90
60 C amb.	107	102	97	93	90	89	88	87	85
55 C amb.	102	97	92	88	85	84	83	82	80
50 C amb.	97	92	87	83	80	79	78	77	75
45 C amb.	92	87	82	78	75	74	73	72	70
Air Flow LFM	**0**	**50**	**100**	**150**	**200**	**250**	**300**	**350**	**400**

NOTE: The underlined value(s) indicate airflow/local ambient combinations that exceed the allowable case temperature for t.

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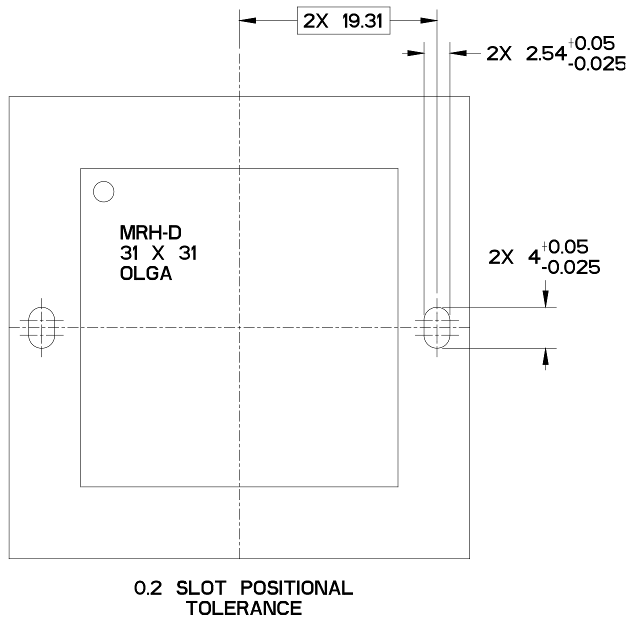
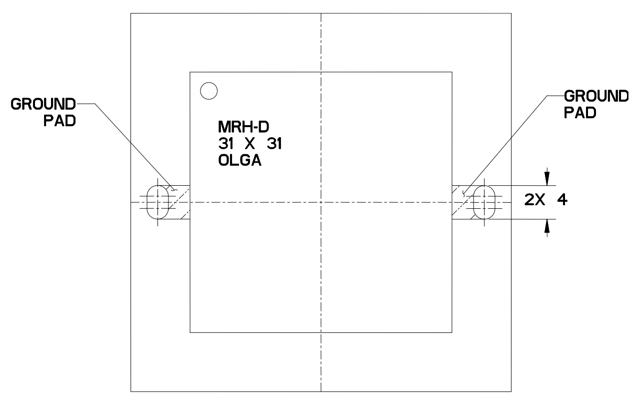
5.4 Clearances

To be effective, a heat sink requires a pocket of air around it free of obstructions. Though each design may have unique mechanical restrictions, the recommended clearance zones for a heat sink used are shown in Figure 2.



Primary Side



Secondary Side

Figure 2. Heat Sink Volume Restrictions

5.5 Default Enhanced Thermal Solution

If you have no control over the end-user's thermal environment or if you wish to bypass the thermal modeling and evaluation process, use the Default Enhanced Thermal Solution.

If the case temperature continues to exceed the appropriate value after implementing the Default Enhanced Thermal Solution, additional cooling is needed. Thermal performance gain may be achieved by improving airflow to the component and/or adding additional thermal enhancements.

5.6 Extruded Heat sinks

If required, the following extruded heat sink is suggested. Figure 3 shows the heat sink drawing. Equivalent heat sinks and sources are provided in Appendix A.

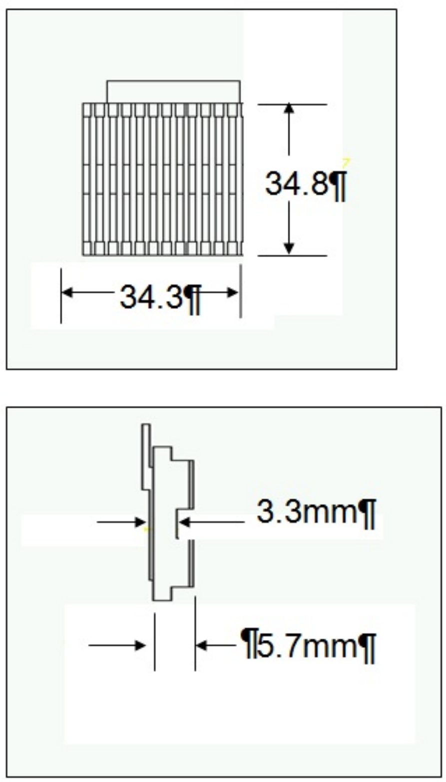


Figure 3. Heat Sink

5.7 Attaching the Extruded Heat sink

The extruded heat sink may be attached using clips with a phase change thermal interface material.

5.7.1 Clips

A well-designed clip, in conjunction with a thermal interface material (tape, grease, etc.) often offers the best combination of mechanical stability and rework-ability. Use of a clip requires significant advance planning as mounting holes are required in the PCB.

Use non-plated mounting with a grounded annular ring on the solder side of the board surrounding the hole. For a typical low-cost clip, set the annular ring inner diameter to 150 mils and an outer diameter to 300 mils. Define the ring to have at least eight ground connections. Set the solder mask opening for these holes with a radius of 300 mils.

5.7.2 Thermal Interface Material (PCM45F)

The recommended thermal interface is PCM45F from Honeywell. The PCM45F thermal interface pads are phase change materials formulated for use in high performance devices requiring minimum thermal resistance for maximum heat sink performance and component reliability. These pads consist of an electrically non-conductive, dry film that softens at device operating temperatures resulting in “grease-like” performance.

An altermative TIM is PCM45F from Honeywell. However, Intel has not fully validated the PCM45F TIM.

Follow the manufacturers recommended attach procedure:

1. Ensure that the component surface and heat sink are free from contamination. Using proper safety precaution, clean the package top with a lint-free wipe and Isopropyl Alcohol.
2. Pre heat the heat sink to 50 C. Remove the Honeywell PCM45F from the carrier. For best result, Peel the TIM off of the carrier by peeling back the carrier at 180 degrees.
3. Carefully align the pad, and place it on the heat sink.
4. Apply 10 PSI pressure to the PCM45F pad and let the heat sink cool to room temperature (25C).
5. Remove top liner. Peel back at 180 degrees to prevent voids and achieve best results.
6. Dents and minor scratches in the material will not affect performance since the material is designed to flow at typical operating temperatures. Honeywell pads can be removed for rework using a single-edged razor and then cleaning the surface with isopropyl (IPA) solvent.

NOTE: Each PCA, system and heat sink combination varies in attach strength. Carefully evaluate the reliability of tape attaches prior to high-volume use (See “Reliability”).

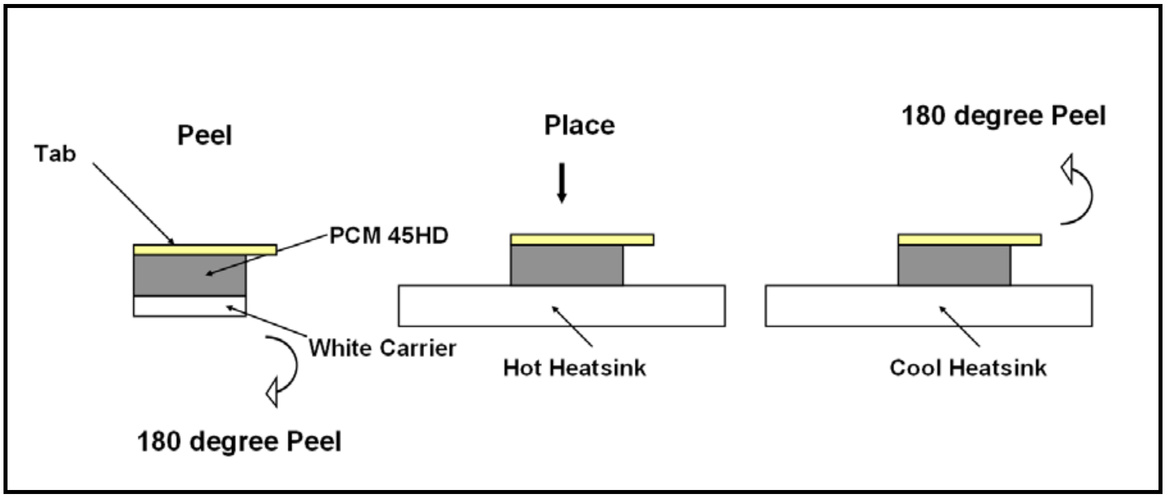


Figure 4. PCM45F Attach Process (in roll form)

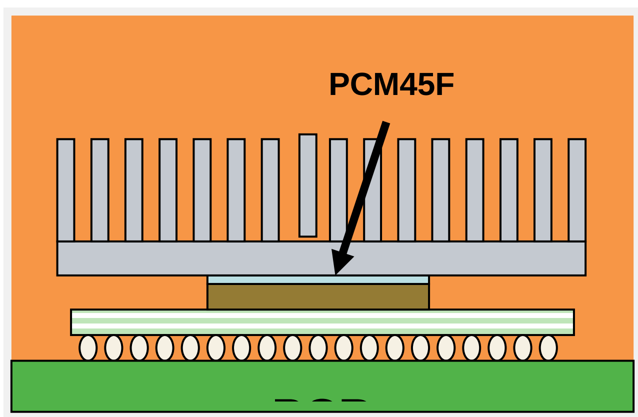


Figure 5. Completing Attach Process

5.8 Reliability

Each PCA, system and heat sink combination varies in attach strength and long-term adhesive performance. Carefully evaluate the reliability of the completed assembly prior to high-volume use. Some reliability recommendations are shown in Table 5.

Table 5. Reliability Validation

Test [1]	Requirement	Pass/Fail Criteria [2]
Mechanical Shock	50G, board level 11 ms trapezoidal pulse, 3 shocks/axis	Visual & Electrical Check
Random Vibration	7.3G, board level 45 minutes/axis, 50 to 2000 Hz	Visual & Electrical Check
High-Temperature Life	85 °C 2000 hours total Checkpoints occur at 168, 500, 1000, and 2000 hours	Visual & Mechanical Check
Thermal Cycling	Per-Target Environment (for example: -40 °C to +85 °C) 500 Cycles	Visual & Mechanical Check
Humidity	85% relative humidity 85 °C, 1000 hours	Visual & Mechanical Check

1. Perform the above tests on a sample size of at least 12 assemblies from 3 lots of material (total = 36 assemblies).

2. Additional Pass/Fail Criteria can be added at your discretion.

5.9 Thermal Interface Management for Heat-Sink Solutions

To optimize the 82575EB heat sink design, it is important to understand the interface between the exposed die and the heat sink base. Specifically, thermal conductivity depends on:

- Bond line thickness
- Interface material area
- Interface material thermal conductivity

5.9.1 Bond Line Management

The gap between the exposed die and the heat sink base impacts the heat-sink solution performance. The larger the gap between the two surfaces, the greater the thermal resistance. The thickness of the gap is determined by the flatness of both the heat sink base and the exposed die, plus the thickness of the thermal interface material (for example, PSA, thermal grease, epoxy) used to join the two surfaces.

The planarity of the 82575EB package is 8 mils in accordance to JEDEC specifications.

5.9.2 Interface Material Performance

The following two factors impact the performance of the interface material between the exposed die and the heat sink base:

- Thermal resistance of the material
- Wetting/filling characteristics of the material

5.9.2.1 Thermal Resistance of the Material

Thermal resistance describes the ability of the thermal interface material to transfer heat from one surface to another. The higher the thermal resistance, the less efficient is the heat transfer. The thermal resistance of the interface material has a significant impact on the thermal performance of the overall thermal solution. With a higher thermal resistance, there will be a larger temperature drop across the interface.

5.9.2.2 Wetting/Filling Characteristics of the Material

The wetting/filling characteristic of the thermal interface material is its ability to fill the gap between the exposed die top surface and the heat sink. Since air is an extremely poor thermal conductor, the more completely the interface material fills the gaps, the lower the temperature-drop across the interface, increasing the efficiency of the thermal solution.

6. Measurements for Thermal Specifications

6.1 Case Temperature Measurements

Maintain Tcase at or below the maximum case temperatures listed in Table 2 to ensure functionality and reliability. Use the following guidelines when making case measurements:

- Measure the surface temperature of the case in the geometric center of the case top.
- Calibrate the thermocouples used to measure Tcase before making temperature measurements.
- Use 36-gauge (maximum) K-type thermocouples.

Care must be taken to avoid introducing errors into the measurements when measuring a surface temperature that is a different temperature from the surrounding local ambient air. Measurement errors may be due to a poor thermal contact between the thermocouple junction and the surface of the package, heat loss by radiation, convection, conduction through thermocouple leads, and/or contact between the thermocouple cement and the heat-sink base (if used).

6.1.1 Attaching the Thermocouple (No Heat Sink)

The following approach is recommended to minimize measurement errors for attaching the thermocouple with no heat sink:

- Use 36 gauge or smaller diameter K type thermocouples.
- Ensure that the thermocouple has been properly calibrated.
- Attach the thermocouple bead or junction to the top surface of the package (case) in the center of the silicon die using high thermal conductivity cement.
- It is critical that the entire thermocouple lead be butted tightly to the exposed die.
- Attach the thermocouple at a 0° angle if there is no interference with the thermocouple attach location or leads (see Figure 6). This is the preferred method and is recommended for use with non-enhanced packages.

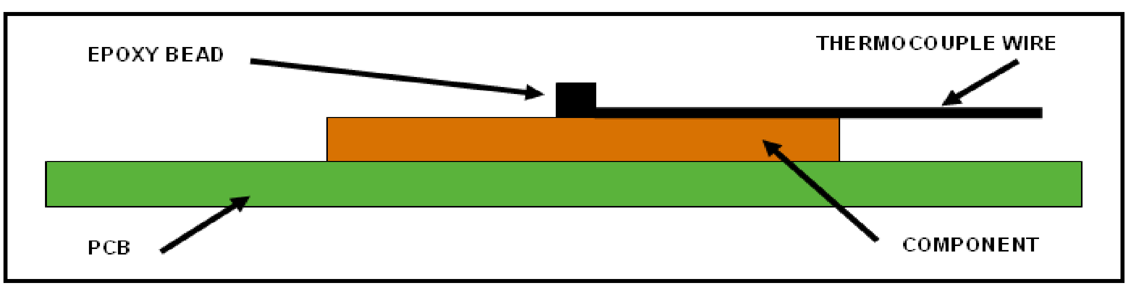


Figure 6. Technique for Measuring Tcase with 0° Angle Attachment, No Heat Sink

6.1.2 Attaching the Thermocouple (Heat Sink)

The following approach is recommended to minimize measurement errors for attaching the thermocouple with heat sink:

- Use 36 gauge or smaller diameter K-type thermocouples.
- Ensure that the thermocouple is properly calibrated.
- Attach the thermocouple bead or junction to the case's top surface in the geometric center using high thermal conductivity cement.

NOTE: The thermocouple lead must be butted tightly against the case.

- Attach the thermocouple at a 90° angle if there is no interference with the thermocouple attach location or leads. This is the preferred method and is recommended for use with packages with heat sinks.
- For testing purposes, a hole (no larger than 0.150" in diameter) must be drilled vertically through the center of the heat sink to route the thermocouple wires out.
- Ensure there is no contact between the thermocouple cement and heat sink base. Any contact affects the thermocouple reading.

See Figure 7.

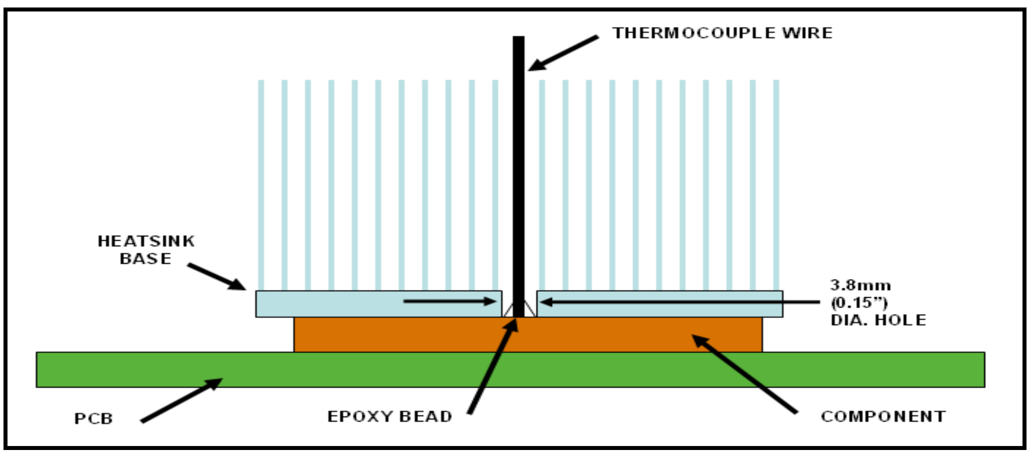


Figure 7. Technique for Measuring Tcase with 90° Angle Attachment

Appendix A. Suppliers

Table 6. Suppliers

Part	Part number	Supplier
Heatsink	728443-001	Foxconn
Retention Mechanism	C63585-0C1	CCI
Thermal interface	PCM45F included with heatsink size = $20mm^2$	Honeywell

Appendix B. PCB Guidelines

The following general PCB design guidelines are recommended to maximize the thermal performance of FCBGA packages:

1. When connecting ground (thermal) vias to the ground planes, do not use thermal-relief patterns.
2. Thermal-relief patterns are designed to limit heat transfer between the vias and the copper planes, thus constricting the heat flow path from the component to the ground planes in the PCB.
3. As board temperature also has an effect on the thermal performance of the package, avoid placing the device adjacent to high power dissipation devices.
4. If airflow exists, locate the components in the mainstream of the airflow path for maximum thermal performance. Avoid placing the components downstream, behind larger devices or devices with heat sinks that obstruct the air flow or supply excessively heated air.
5. The above guidelines are not all inclusive and are defined to give you known, good design practices to maximize the thermal performance of the components.

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