Intel® Pentium® III Processor – Low Power Thermal Design Guide

Application Note

May 2000

Order Number: 273285-003

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Revision History

Revision	Date	Notes
003	May 2000	Added 500 MHz information.
002	February 2000	Reorganized document and added additional reference material.
001	January 2000	First release of this document.

1.0 Introduction

This document provides thermal performance information for the Intel® Pentium® III processor – Low Power with an integrated 256-Kbyte L2 cache. The Pentium III processor – Low Power is available at 400 and 500 MHz with a processor side bus speed of 100 MHz. The Pentium III processor is packaged in a PBGA-B495 package (also known as BGA2), with the backside of the silicon die exposed to enable more efficient heat transfer. The thermal solution focus is on heatsinks and fans to meet the performance requirements of the Pentium III processor – Low Power.

This application note:

- Introduces the specifications for the Pentium III Processor – Low Power
- Defines target thermal parameters and clarifies terminology
- Identifies the concepts and airflow calculations used to design thermal solutions. Sample calculations are also provided.
- Identifies the z-height constraints of a thermal solution for single-slot and double-slot CompactPCI (CPCI) designs
- Discusses interface material and attachment methods for thermal solutions
- Provides a list of thermal solution vendors

This document provides supplemental thermal design information. Complete mechanical and thermal specifications are provided in the *Mobile Pentium® III Processor in BGA2 and Micro-PGA2 Packages at 400 MHz, 450 MHz, and 500 MHz* datasheet (order number 245302). Updates or changes to the specifications in the datasheet are listed in the *Mobile Pentium® III Processor Specification Update* (order number 245306).

2.0 Importance of Thermal Management

The objective of thermal management is to ensure that the temperature of each component is maintained within specified functional limits. The functional limit is the temperature range within which the electrical circuits can be expected to meet their specified performance requirements. Operation outside the functional limit can degrade system performance and cause reliability problems.

The junction temperature is the surface temperature of the package at its hottest point, typically at the geographical center of the chip. Over time, temperatures exceeding the junction temperature limit can cause physical destruction or may result in irreversible changes in operating characteristics.

3.0 Pentium® III Processor — Low Power Thermal Specifications

The power dissipation and junction temperature specifications for the Pentium III Processor — Low Power are shown in Table 1. To ensure functionality and reliability of the Pentium III processor – Low Power, the maximum device junction temperature must remain below 100° C.

A thermal solution should be designed to ensure the junction temperature never exceeds the specifications. If no closed loop thermal fail-safe mechanism (processor throttling) is present to maintain T_J within specification, the thermal solution should be designed to cool the maximum power condition (TDP_{MAX}). If a thermal fail-safe mechanism is present, the thermal solution could possibly be designed to a typical Thermal Design Power (TDP_{TYP}). TDP_{TYP} is a thermal design power recommendation based on the power dissipation of the processor while executing publicly available software under normal operating conditions at nominal voltages. TDP_{TYP} power is lower than TDP_{MAX}. Contact your Intel Field Sales Representative for further information.

Table 1. Pentium® III Processor — Low Power Power Dissipation and Junction Temperature

Frequency (MHz)	Package Type	Total Pins	Package Size (LxWxH in mm)	Ball Array	Maximum Power (W)[1, 2]	Max Junction Temp (°C)
400	PBGA	495	27.35 x 31.15	21 x 24	10.1	100
500	PBGA	495	27.35 x 31.15	21 x 24	12.2	100

NOTES:

1. Maximum Power is a specification of the total power dissipation of the processor while executing a worst-case instruction mix under normal operating conditions at nominal voltages. It includes the power dissipated by all of the components within the processor. Not 100% tested. Specified by design/characterization.
2. Not 100% tested or guaranteed. These power specifications are determined by characterization of the processor currents at higher temperatures.

3.1 Thermal Diode

The Pentium III Processor – Low Power incorporates an on-die thermal diode that can be used to monitor the die temperature (T_J). A thermal sensor located on the motherboard may monitor the die temperature of the processor for thermal management or instrumentation purposes. Table 3 and Table 2 provide the diode parameter and interface specifications.

Note: The reading of the thermal sensor connected to the thermal diode will not necessarily reflect the temperature of the hottest location on the die. This is due to inaccuracies in the thermal sensor, on-die temperature gradients between the location of the thermal diode and the hottest location on the die at a given point in time, and time based variations in the die temperature measurement. Time based variations can occur when the sampling rate of the thermal diode (by the thermal sensor) is slower than the rate at which the T_J temperature can change.

Table 2. Thermal Diode Interface

Signal Name	Ball Number	Pin Description
THERMDA	AA15	Thermal diode anode
THERMDC	AB16	Thermal diode cathode

Table 3. Thermal Diode Parameters

Symbol	Parameter	Min	Typ	Max	Unit	Notes
I_{FW}	Forward Bias Current	5		500	µA	1
n	Diode Ideality Factor	1.0057	1.0080	1.0125		2, 3, 4

NOTES:
1. Intel does not support or recommend operation of the thermal diode under reverse bias. Intel does not support or recommend operation of the thermal diode when the processor power supplies are not within their specified tolerance range.
2. Characterized at 100° C.
3. Not 100% tested. Specified by design characterization.
4. The ideality factor, n, represents the deviation from ideal diode behavior as exemplified by the diode equation:

$$I_{FW} = I_S \bullet \left(e^{qV_D / nkT} - 1\right)$$

where I_S = saturation current, q = electronic charge, V_D = voltage across the diode, k = Boltzmann Constant, and T = absolute temperature (Kelvin).

4.0 Thermal Characterization Data

Thermal solutions vendors have developed reference designs for the Pentium III Processor – Low Power. Refer to Table 9, “Vendor List” on page 18 for a list of vendors for each type of solution. Two types of thermal solutions are available to accommodate various system design requirements:

- Heatsink
- Fan heatsink

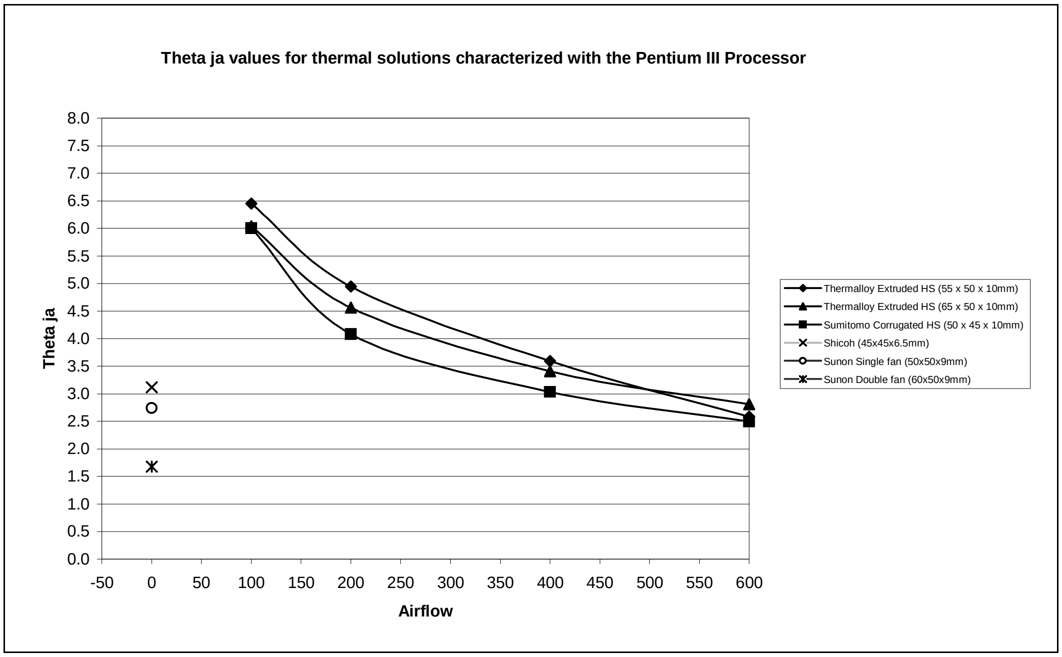
The thermal characterization data described in Table 4 illustrates that a thermal solution may be needed depending on the system’s operating ambient temperature and the system airflow that can be provided. The size of the heatsink and the amount of airflow are interrelated and can be optimized for a given system. For example, an increase in heatsink size decreases the amount of airflow required. In a typical system, heatsink size is limited by board layout, spacing, and component placement. Airflow is limited by the size and number of system fans and their placement in relation to the components and the airflow channels. Acoustic noise and life-expectancy constraints may also limit the size or types of fans used in the system.

Note: The inclusion of these reference designs by third-party thermal solution vendors should not be considered a recommendation or product endorsement by Intel Corporation.

Table 4. Pentium® III Processor — Low Power Thermal Characterization Data

Heatsink	Dimensions (LxWxH in mm)	θ_{ca} or θ_{ja} (°C/W) vs. Airflow (LFM)				
		0	100	200	400	600
Sumitomo Corrugated HS	50 X 45 X 10		6.0	4.1	3.0	2.5
Thermalloy HS1	55 X 50 X 10		6.5	4.9	3.6	2.6
Thermalloy HS2	65 X 50 X 10		6.0	4.6	3.4	2.8
Shicoh Single Fan	45 X 45 X 7	3.1				
Sunonwealth Single Fan HS	50 X 50 X 9	2.7				
Sunonwealth Double Fan HS	60 X 50 X 9	1.7				

Figure 1. Pentium® III Processor — Low Power Thermal Resistance vs. Airflow



5.0 Determining Thermal Solution Design Parameters

5.1 Measuring Ambient Temperature

Ambient temperature (T_A) is the temperature of the undistributed air surrounding the component. Ambient temperature is usually measured at a specified distance from the component. In a system environment, ambient temperature is the temperature of the air upstream to the component and in its close vicinity. In a typical laboratory test environment, the ambient temperature for passive solutions is measured one hydro-dynamic diameter (one hydro-dynamic diameter is typically the length of the heatsink) upstream from the component to represent the ambient temperature with air flowing past the system. When natural convection is used in a system, the ambient temperature is measured directly underneath the board near the component. In an active cooling system, the ambient temperature is the inlet air to the active cooling device.

The fan heatsink needs a boundary wall which is one inch above the fan and three and one half times the fan area.

5.2 Measuring Junction Temperature

Warning: Do not attempt to measure the junction temperature by attaching a thermocouple to the die. This process is mechanically difficult and will not result in correct temperature readings. Attaching a thermocouple to the die may cause the die to crack and invalidates any warranty that may exist on the device.

5.3 Calculating Junction-to-Ambient Thermal Resistance

The junction-to-ambient thermal resistance determines the performance of the thermal solution and can be calculated using the following equation:

Equation 1. $$\theta_{JA} = (T_J - T_A)/P$$

where:

θ_{JA} = junction-to-ambient thermal resistance (°C/W)
T_A = ambient temperature (°C)
T_J (= $T_{DIODE} + T_{JOFFSET}$) = junction temperature (°C)
P = device power dissipation (Watts)

The lower the thermal resistance between the junction and the ambient air, the more efficient the thermal solution will be.

The thermal resistance values depend on the heatsink material, thermal conductivity, thermal interface material, and geometry of the thermal cooling solution and airflow rates.

5.4 Estimating Required Airflow

Assuming *worst-case* conditions at 400 MHz (1.35 V):

- The junction temperature at the processor die surface is 100° C
- The ambient temperature is 50° C
- The TDP max dissipated by the Pentium III Processor — Low Power is 10.1 W
- The junction-to-ambient thermal resistance (θ_{JA}, calculated using Equation 1 above) is 4.95° C/W

Knowing the θ_{JA} value allows the system designer to estimate the airflow required to keep the junction temperature at 100° C. As indicated in Figure 1, the fan solutions would require no additional system airflow. The heatsink solutions would require about 200 LFM of airflow depending on the heatsink chosen.

Assuming *worst-case* conditions at 500 MHz (1.35 V):

- The case temperature at the processor die surface is 100° C
- The ambient temperature is 50° C
- The TDP max dissipated by the Pentium III Processor — Low Power is 12.2 W
- The case-to-ambient thermal resistance (θ_{CA}, calculated using Equation 1 above) is 4.1° C/W

Knowing the θ_{CA} value allows the system designer to estimate the airflow required to keep the case temperature at 100° C. As indicated in Figure 1, the fan solutions would require no additional system airflow. The heatsink solutions would require about 200 - 325 LFM of airflow depending on the heatsink chosen.

5.5 Measuring Airflow

The airflow, or air velocity flowing across the components, can be measured using a portable air velocity meter (anemometer). The meter contains two temperature sensing elements. One element is used to track the air stream temperature and the second element is heated by an electrical current to maintain a constant temperature above the air stream temperature. As the air stream takes heat energy away from the heated element, more current is required to maintain the temperature differential. The required electrical current is proportional to the air mass velocity displayed on the meter. This meter is available from Kurz Instruments. Refer to Table 9, “Vendor List” on page 18 for vendor information.

6.0 Thermal Solution Design Considerations

6.1 CompactPCI Component Height Requirements

The reference heatsink and fan solutions were designed to meet a single-slot or double-slot CompactPCI (CPCI) z-height constraints. Standard heatsinks or fans may be used for designs that do not need to meet the CPCI requirement. The z-height requirement for the single-slot CPCI heatsink is 13.71 mm - (2.54 mm + 0.25 mm) (PBGA height plus tolerance) - (0.25) (interface material thickness) (0.25 mm) = 10.66 mm (see Figure 2). For a double-slot heatsink solution, the maximum z-height allowed is 29.47 mm (see Figure 3).

Refer to Table 9, “Vendor List” on page 18 for information on obtaining CompactPCI Specification.

Figure 2. Single-Slot CompactPCI Z-Height Specification

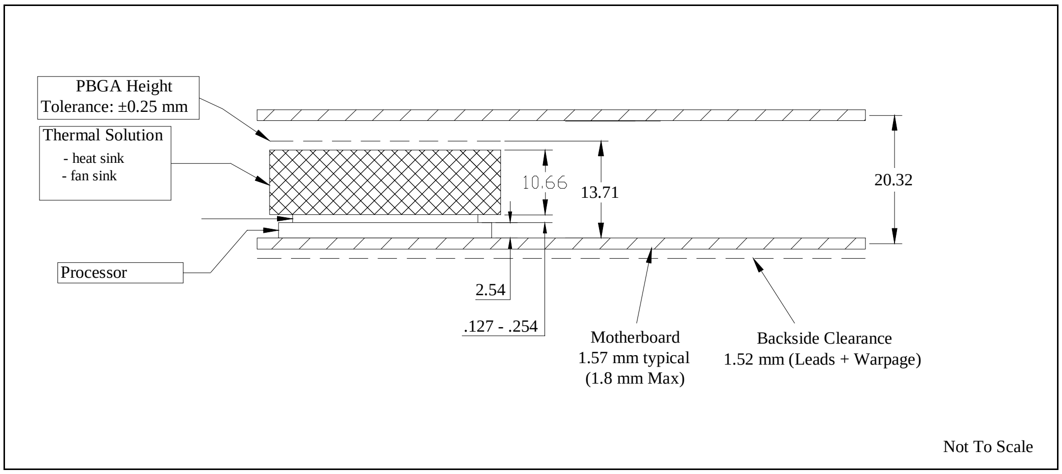
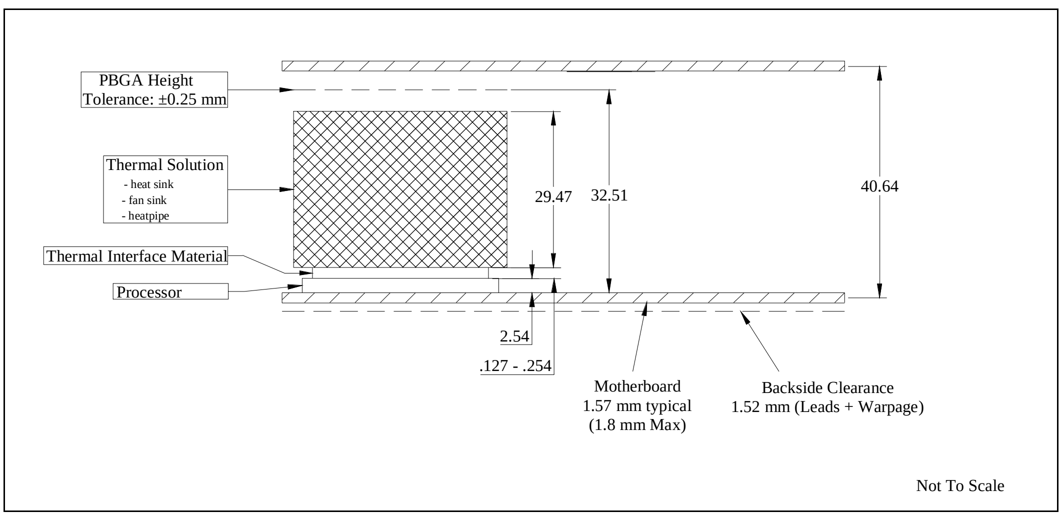


Figure 3. Double-Slot CompactPCI Z-Height Specification



6.2 Heatsink Solutions

6.2.1 Theory of Heatsink Operation

A heatsink is simply a metal surface with pins or fins rising up off the surface. Heatsinks are used to cool electronic devices by expanding the surface area of the part to which it is attached, increasing the amount of heat that can be cooled by the ambient air. A main characteristic of heatsinks is thermal resistance (θ), measured in °C/W. For example, if a component has a heatsink with a thermal resistance $\theta = 2°$ C/W, then for every Watt of heat it dissipates its temperature increases by 2° C. The larger the heatsink, the more surface area it has, and the better its thermal resistance.

6.2.2 Considerations for Implementing a Heatsink Thermal Solution

The following points should be considered when evaluating heatsink thermal solutions:

- **Cost.** Heatsink solutions typically are cheaper than the fan solutions. Extruded heatsinks typically cost less than corrugated, folded or bonded heatsinks.
- **Flexibility in x, y and z dimensions.** Based on the amount of airflow available in the system, a design may require a larger heatsink to dissipate a specified amount of heat. System designers may need to be flexible in at least one or two dimensions.
- **System airflow.** It is desirable to have some system airflow to allow heat to be removed from the heatsink.

Note: High fin density thermal solutions are only efficient if the area approaching and surrounding the heat sink is ducted. In addition, high fin density solutions will have higher airflow pressure drop through the heat sink; therefore, higher performance fans are often required. High fin heatsink solutions include corrugated, bonded fin and skived heatsink technology.

- **Extruded vs. Corrugated (Folded Fin).** An extruded heatsink has a lower cost but the folded fin heatsink typically provides better performance because of the extra surface area of the fins. Folded fin heatsinks are typically recommended for systems with minimal system airflow.
- **Extruded vs. Bonded Fin.** Extruded heatsinks fin height to fin spacing ratios are typically greater than 6:1 but less than 10:1. A bonded fin offers fin ratios greater than 30:1. Bonded fins expose more surface area to the cooling air, which transfers more heat away from the electronics.
- **Extruded vs. Skived.** Skive technology represents a process of shaping materials to produce lightweight, “high-fin-density” thermal solutions at high-volume with relatively low-costs as compared to performance-comparable high-fin density thermal technologies. In general, high-fin-density technologies such as skive, provide optimal thermal performance when coupled with by-pass air control features such as a shroud or system duct. Skived heatsinks can be made with fin pitch as narrow as 1.5 mm and fin thickness of 0.5 mm or thinner. Because skiving is a mechanical process with minimal temperature increase, the joint between fin and base is continuous aluminum. This property is shared with extrusions but not corrugated or bonded fin methods. Fin heights to 50 mm and aspect ratios to 25:1 are possible.

6.3 Fan Solutions

Passive-active fan heatsink solutions provide airflow and require little or no system airflow. Active fan heatsink solutions incorporate a fan that is attached to the solution.

6.3.1 Theory of Fan Operation

The typical fan involves a motor and a propeller. The motor can be either an AC induction motor or a brushless DC motor. The air flow that a fan produces blows parallel to the fan's blade axis. These fans can be made to blow a significant amount of air. Fans can be:

- Used alone to ventilate cool intake air through the processor (pushing warm air out)
- Used in passive thermal solutions to blow hot air off of heatsinks
- Assembled with a passive thermal solution to blow hot air off the component heatsink.

6.3.2 Considerations for Implementing a Fan Thermal Solution

The following points should be considered when evaluating fan thermal solutions:

- **Performance at a moderate cost.** Fan solutions typically cost more than heatsink solutions.
- **System airflow.** When there is no system airflow, a dedicated fan attached above the component provides an excellent source of airflow, which can ensure prompt removal of heat from the heat source.
- **Flexibility in x, y or z dimensions.** The size of the required fan solution can vary according to the amount of heat that must be dissipated, the availability of system airflow, and other factors. To achieve certain thermal requirements, a system designer may need to be flexible with one or more dimensions of the design.
- **Reliability.** Fans are reliable and typically have a life of 100,000 hours depending on the fan design and the manufacturer's standards.
- **Recirculation.** The customer must ensure that the heated system air does not re-enter the fan.

6.4 Interface Material

Air ranks low in terms of thermal conductivity, and if trapped between thermal joints, reduces the junction-to-sink thermal resistance and the overall thermal resistance of the system. Thermal interface materials address this problem by providing a buffer between mating surfaces to increase actual points of contact between the junction and the sink.

Thermal interface material must be applied between the processor die and the heat sink to ensure thermal conduction. Thermal interface material also serves as a mechanical load element during mechanical stress testing (i.e., mechanical shock). Many thermal interface materials can be pre-applied to the heat sink base prior to shipment from the heat sink supplier and allow direct heat sink attach, without the need for a separate thermal interface material dispense or attach process in the final assembly factory.

Caution: Do not attempt to make direct contact to the die without using an interface material. Concentrated forces applied directly to the die surface will crack the silicon and cause the device to be non-functional.

The optimal material to use as the interface material between the silicon die surface and the heatsink must be determined for each application. Procedures for storage, handling, application of material, and removal for rework purposes are available from the vendor. These procedures should be followed to ensure performance and reliability, and to avoid silicon die cracking or delamination issues.

The selection of the optimum thermal interface material between the device and heat sink must take into consideration the thermal performance, cost, ease of use, installation pressures, and long term stability. The following factors should be considered when selecting the interface material:

- Bulk thermal conductivity of the material: Materials with high thermal conductivity (low thermal resistance) are required. Determination of the bulk thermal conductivity of a material is governed by ASTM E 1530.
- Wetting/filling property of the material: The contact resistance of the interface contributes significantly to the overall interface resistance. Soft materials such as grease and low-durometer elastomers tend to deform readily to fill the contours of the die surface and heatsink base surface.
- Integrity of the material: The material must maintain its physical properties throughout the life of the product. Some materials are more sensitive than others to extended exposure to high-temperature or high-humidity environments. Accelerated life testing should be conducted to ensure that the thermal resistivity remains below the target value from the die to the thermal solution for the expected life of the product.
- Attach/Removal Process: Some thermal interface materials have high viscous and adhesive properties at room temperature and may transfer high tensile stresses directly to the processor die as the thermal solution is pulled away from the processor motherboard. Heat may have to be applied to the thermal solution and interface material prior to disassembly to “soften” the material for removal. If a pre-applied thermal interface material is specified, it may have a protective application tape. This tape must be removed prior to heat sink attach.
- Size and Position: All thermal interface materials must be sized and positioned on the heat sink base in a way that ensures the entire processor die area is covered. It will be important to compensate for heat sink-to-processor attach positional alignment when selecting the proper thermal interface material size.

Typical interface materials are greases, phase change materials, and elastomers. Grease may not be an ideal thermal interface material in this case due to its propensity to being squeezed out of the thermal gap by the thermal solution compression load. The resulting die-to-thermal solution contact may result in damage to the fragile silicon die.

6.4.1 Phase Change Materials

Phase change materials, at typical processor operating temperatures, behave very much like grease and flow to relieve any residual stresses and to fill the thermal gap, resulting in negligible interface pressure on the die. At room temperature, these materials are in a pliable, clay-like state that allows them to be pre-formed and placed onto the thermal solution in the same way as elastomers. The thermal solution should be a die-reference design that applies continuous pressure to the interface material. The phase change material may be squeezed out of the thermal gap and needs to be validated before using the material.

Caution: Phase change thermal interface materials are a class of material often selected due to their ease of use. In an evaluation of the mechanical behavior of thermal interface materials, Intel has determined that phase change materials which have an epoxy element can induce processor damage during heat sink removal. The epoxy materials used in some types of thermal interface materials do not cross-link, resulting in a polar compound. This polar compound is attracted to the polar oxide on the die and forms a strong bond between the heat sink base and the processor silicon surface, making the two surfaces extremely difficult to separate after the thermal interface material has cured. The force required can lead to processor damage; this damage may not always be visible. It may be important to consult with the thermal interface material supplier to determine its cross-linking characteristics.

6.4.2 Elastomeric Materials

Thermal elastomers provide an ideal interface material to complement the die-reference design requirement. The elastomer can be pre-cut by the supplier to adequately cover the die (a 1 mm overhang should be allowed for) and resist expansion ("pump-out") under compression. In general, better thermal performance will be obtained with the thinnest elastomer possible. The appropriate elastomer type and thickness must be selected to ensure the elastomer is always within the optimal compression range (typically greater than 207 kPa or 30 psi) so that the elastomer exerts no more than 689 kPa (100 psi) on the processor die surface during compression.

Caution: Phase change thermal interface materials are a class of material often selected due to their ease of use. In an evaluation of the mechanical behavior of thermal interface materials, Intel has determined that phase change materials which have an epoxy element can induce processor damage during heat sink removal. The epoxy materials used in some types of thermal interface materials do not cross-link, resulting in a polar compound. This polar compound is attracted to the polar oxide on the die and forms a strong bond between the heat sink base and the processor silicon surface, making the two surfaces extremely difficult to separate after the thermal interface material has cured. The force required can lead to processor damage; this damage may not always be visible. It may be important to consult with the thermal interface material supplier to determine its cross-linking characteristics.

6.4.2.1 Thermal Grease

Thermal grease forms a conductive film between the junction and the sink that enhances heat transfers. Because microscopic air voids exist on solid surfaces regardless of mechanical precision, thermal grease fills these gaps with thermally conductive substances. This ensures maximum contact between the junction and sink and reduces the temperature greatly for better thermal performance.

6.4.2.2 Thermal Tapes and Adhesives

Thermal tapes and adhesives are flexible and conform to the gaps on the surfaces under initial applied pressure. Although they generally provide lower conductivity, thermal adhesives do not require mechanical fasteners and are simple to mount without the mess of a grease or compound.

6.4.2.3 Thermal Compound

Thermal compounds behave much like grease, since they melt during operation to permanently smooth surface irregularities. They are often injected with ceramic fillers and/or other thermally conductive compounds for improved performance. Application involves less mess than grease, and the material will not dry out.

6.4.2.4 Thermal Foils

Thermal foils integrate the advantages of thermal compounds and thermal tape. They fill voids in junction and sink surfaces, provide electrical isolation without completely compromising thermal conductivity, and are easily applied.

6.4.3 Choosing an Interface Material

Available interface materials include:

- Chomerics XTS454* Low Thermal Resistance Pads - Phase Change Material

Table 5. Chomerics XTS454* Phase Change Material Properties

Property	XTS454* Specification
Carrier:	None
Specific Gravity:	1.1
Thickness:	0.14 mm
Phase Change Temperature:	45° C
Thermal Impedance (at 50° C, 50 psi):	0.04 °C-in^2/W
Thermal Conductivity (50 psi):	0.6 W/m-K
Volume Resistivity:	1 x 1015 Ω-cm

- Thermagon T-pli* 205 and 210 Elastomer

Table 6. Thermagon T-pli* 205 and 210 Elastomer Properties

Property	T-pli* 205 Specification	T-pli* 210 Specification
Thickness	5 mils	10 mils
Tolerance	1 mil	1 mil
Hardness (Shore A)	10	10
Density	1.3 g/cc	1.3 g/cc
Thermal Conductivity	6.0 W/m-°C	6.0 W/m-°C
Thermal Resistance (at 10 psi)	0.07 °C-in^2/W	0.12 °C-in^2/W
Minimum Dielectric Strength	1000	2000
Fiberglass Reinforcement	Yes	Yes
Color	Peach	Rose

- Shin-Etsu Chemical Co., Ltd. G-750* Thermal Interface Material

Table 7. Shin-Etsu G-750* Thermal Interface Material

Property	G-750
Viscosity	2700 Poise Avg.
Appearance	Gray
Bleed (150° C/24 hr)	0
Volatile Content	< 1.0%
Specific Gravity	2.81
Thermal Conductivity	3.6 W/m-°K

Refer to Table 9, “Vendor List” on page 18 for vendor information.

Note: Mention of specific brand-name interface materials should not be considered a recommendation or product endorsement by Intel Corporation.

6.5 Attach Methods

The heatsink attachment mechanism secures the heatsink to the board, provides adequate pressure to the heatsink for optimum thermal performance, and protects the backside of the die surface. The attachment mechanism should not interfere with the thermal ability of the package or inhibit the performance of the processor in the application.

Several types of attachment mechanisms are available. The first type consists of pins that pass through the heatsink and printed-circuit board (PCB) mounting holes. This can be done with a flange on the heatsink or by holes within the heatsink itself. A second type consists of a clip that wraps around, or attaches to, the heatsink and attaches to the PCB through specified mounting holes. A third type consists of screws passing from the top or bottom of the board into the heatsink assembly.

The thermal solution attachment should provide the following:

- Compression of the interface material: 30-60 psi (206-413 kPa); max pressure 100 psi (689 kPa).
- Flexibility to absorb die height variance.
- Support to the motherboard to prevent board warpage.

For pins and clips, the insertion and extraction forces are recommended to be less than 15 lbf. The attachment mechanism should be supplied by the heatsink vendor.

Note: For surface mount height considerations, keep in mind that the PBGA package is reflowed to the board. The ball height collapses approximately 20%-30%, or 0.11 mm to 0.16 mm. To compensate for surface mount height variation, springs may be used in conjunction with the pins to maintain a compressive force (5-10 lbf) on the thermal interface material.

7.0 Related Documents

These documents are available for download from Intel's World Wide Web site at http://developer.intel.com.

Table 8. Related Documents

Document	Order Number
Mobile Pentium® III Processor in BGA2 and Micro-PGA2 Packages	245302
Mobile Pentium® III Processor Specification Update	245306
AP-905 Pentium® III Processor Thermal Design Guidelines	245087
Intel Packaging Handbook	240800
Thermal Considerations for the Pentium® III processor at 550 MHz Heatsinks & Airflow in ATX Chassis	245184

8.0 Vendor List

Table 7 provides a vendor list as a service to our customers for reference only. The inclusion of this list should not be considered a recommendation or product endorsement by Intel Corporation.

Table 9. Vendor List (Sheet 1 of 2)

HeatSink and Fan Vendors	
AAVID One Kool Path P.O. Box 400 Laconia, New Hampshire 03247-0400 Email: chapman@aavid.com Phone: (603) 528-3400 Fax: (603) 528-1478 **Europe**: Tel: 44 1494474747 Fax: 44 1494474748 **Japan** Tel: 886 279 35677 Fax: 886 279 33460 Web site: http://www.aavid.com	**Sumitomo Precision Products Co., Ltd.** c/o Sumitomo Corporation of America 2900 Patrick Henry Dr. Santa Clara, CA 95054-1813 Phone: 408-980-0681 Fax: 408-980-1409 JAPAN: Email: heatsink@spp.co.jp Phone: 81-6-6489-5832 Fax: 81-6-6489-5879 Web site: http://www.sumitomocorp.com
Shicoh Engineering Co. Ltd. 3854-1 Shimotsuruma Yamato City, Kanagawa-Ken 242-0001 Japan Phone: 81-462-78-3570 Fax: 81-462-78-3576 Web site: http://www.evox-rifa.com	**Sunonwealth** 25501 Arctic Ocean Blvd. Lake Forest, CA 92630 Email: sunon@gus.net Phone: 949-583-9802 Fax: 949-583-9785 Web site: http://www.tradeserv.com/sunon/
Thermalloy, Inc. 2021 W. Valley View Lane Dallas Texas 75234-8993 Email:sales@thermalloyusa.com Phone: (972) 243-4321 Fax: (972) 241-4656 Web site: http://www.thermalloy.com	
Interface Material Vendors	
Chomerics 77 Dragon Court Woburn, MA 01888-4014 Phone: 781-939-4486 Fax: 781-938-6131 Email: jkefeyan@parker.com Web site: http://www.chomerics.com	**Thermagon, Inc.** 3256 W. 25th St. Cleveland, OH 44109-1668 Phone: 888-246-9050 Fax: 216-741-3943 Email: gblair@thermagon.com Web site: http://www.thermagon.com
Shin-Etsu MicroSi 10028 South 51st Street Phoenix, Arizona 85044 Phone: (888) - MICROSI (642-7674) Fax: (480) 893-8637 Web site:www.microsi.com	

Table 9. Vendor List (Sheet 2 of 2)

Air Velocity Meter Supplier	
Kurz Instruments, Inc. 2411 Garden Road Monterey, CA 93940 Phone: 800-424-7356 Fax: 831/646-8901 Email: sales@kurz-instruments.com Web site: http://www.kurz-instruments.com	
Temperature Measurement Supplier	
Omega Engineering, Inc. One Omega Drive P.O. Box 4047 Stamford, CT 06906 Phone: 1-800-622-2378 Email: temp@omega.com Web site: http://www.omega.com	
CompactPCI Specification	
Rogers Communications, Inc. 401 Edgewater Place, Suite 500 Wakefield, MA 01880 Phone: 781-224-1100 Fax: 781-224-1239 Web site: http://www.rogerscom.com	