AP-905 Pentium® III Processor Thermal Design Guidelines

Application Note

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The Pentium® III processor may contain design defects or errors known as errata which may cause the product to deviate from published specifications. Current characterized errata are available on request.

Contact your local Intel sales office or your distributor to obtain the latest specifications and before placing your product order.

Copies of documents which have an ordering number and are referenced in this document, or other Intel literature, may be obtained from:

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1.0 Introduction

In a system environment, the processor's temperature is a function of both the system and component thermal characteristics. The system level thermal constraints consist of the local ambient temperature at the processor and the airflow over the processor(s) as well as the physical constraints at and above the processor(s). The processor temperature, measured at various points, depends on the component power dissipation, size and material (effective thermal conductivity) of the cartridge, the type of interconnection to the substrate/processor die, the presence of a thermal cooling solution, the thermal conductivity and the power density of the substrate/processor die.

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

The Single Edge Contact Cartridge (S.E.C.C.), Single Edge Contact Cartridge 2 (S.E.C.C.2) and FC-PGA (Flip Chip Pin Grid Array) packaged processors introduce new temperature constraints and new thermal parameters to manage. Depending on the type of system and the chassis characteristics, new designs are required to provide adequate cooling for the processor. The goal of this document is to provide an understanding of these new thermal characteristics and discuss guidelines for meeting the thermal requirements imposed on single and multiple processor systems.

Note: This document discusses techniques in thermal management only for S.E.C.C., S.E.C.C.2 and FC-PGA processors primarily intended for the performance desktop. The Single Edge Plastic Package (S.E.P.P.) is not covered.

1.1 Related Documents

The following related documents are available from the Intel web site at http://developer.intel.com. Non-Intel documents are available from their respective websites.

Table 1. Related Resources

Document Title	Order Number
Pentium III Processor for the SC242 at 450 MHz to 1.13 Ghz	244452-008
Pentium III Processor for the PGA370 Socket at 500 MHz to 1.0B Ghz	245264-006
SC242 Connector Design Guidelines	243397-002
Single Edge Contact Connector 2 (S.E.C.C. 2) Thermal Interface Material Functional Requirements	244458-001
Coppermine Flip Chip Pin Grid Array (FC-PGA) Package Thermal / Mechanical Solution Functional Specifications, Rev 4.0	Contact your local Intel Field Sales Representative
Performance ATX Desktop System Thermal Design Suggestions v1.0	http://www.teleport.com/~ffsupprt/
Performance MicroATX Desktop System Thermal Design Suggestions v1.0	http://www.teleport.com/~ffsupprt/
Analog Devices EVAL-ADM1021 kit datasheet	http://www.analog.com
Maxim Integrated Products MAX1617EV Kit datasheet	http://www.maxim-ic.com

1.2 Terms Used In This Document

Table 2 contains definitions for terms used throughout this document.

Table 2. Definition of Terms

Term	Definition
$T_{\text{ambient-local}}$	The measured ambient temperature locally surrounding the processor. The ambient temperature should be measured just “upstream” of a passive heat sink or at the fan inlet for an active heat sink.
$T_{\text{ambient-OEM}}$	The target worst-case ambient temperature at a given **external** system location as defined by the system designer (OEM).
$T_{\text{ambient-external}}$	The measured ambient temperature at the OEM defined **external** system location defined by the system designer (OEM).
$T_{\text{ambient-max}}$	The target worst-case local ambient temperature. This can be determined by placing the system in maximum external temperature conditions and measuring the ambient temperature locally surrounding the processor. Under these conditions $T_{\text{ambient-local}} = T_{\text{ambient-Max}}$. This can also be determined by simultaneously measuring the $T_{\text{ambient-external}}$, $T_{\text{ambient-local}}$ and $T_{\text{Junction\_HIPWR30}}$ with the following equation: $T_{\text{ambient-max}} = T_{\text{ambient-OEM}} - T_{\text{ambient-external}} + T_{\text{ambient-local}}$.(This equation assumes a thermally linear system; i.e. No temperature controlled fans).
$T_{\text{junction-max}}$	The maximum core junction temperature of the processor, as specified in the processor datasheet.
$T_{\text{junction-HIPWR30}}$	The measured core junction temperature of the processor while running the High Power Application software (“HIPWR30.EXE”).
$T_{\text{junction-proj}}$	The projected thermal junction temperature at the maximum processor power dissipation for the system under analysis.
$T_{\text{junction-offset}}$	The worst-case difference between the thermal reading from the on-die thermal diode and the hottest location in the processor’s core, as specified in the processor datasheet.
$T_{\text{junction-error}}$	The measurement error for a diode connected to a thermal measure device as specified in the appropriate device datasheet.
$T_{\text{case-BSRAM}}$	The measured case temperature of the L2 cache BSRAM, while running the HIPWR30.EXE /L utility.
T_{cover}	The maximum cover temperature of the SECC2 cartridge, as specified in the processor datasheet.
$\Theta_{\text{junction-ambient}}$	The thermal resistance between the processor’s core junction and the ambient air. This is defined and controlled by the system thermal solution.
P_{max}	The maximum processor power, as specified in the processor’s datasheet.
P_{HIPWR30}	The processor power running the High Power Application software (“HIPWR30.EXE”).
Intel SC242	Slot Connector 242 (242 contacts) Formally referred to as "Slot 1". The connector on a baseboard where an Intel SC242 processor is installed.
Intel SC242 processor	Any Intel processor which plugs into the Intel SC242 including the Pentium® III and Pentium II processors.
PGA370	370 pin socket connector that is installed on a baseboard where an Intel FC-PGA processor is installed.

2.0 Importance of Thermal Management

The objective of thermal management is to ensure that the temperature of all components in a system is maintained within functional limits. The functional temperature limit is the range within which the electrical circuits can be expected to meet their 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 operating characteristics of the component.

3.0 S.E.C.C., S.E.C.C.2, And FC-PGA Processor Packaging Technology

This processor is delivered in a variety of packaging technologies. The following sections provide an overview of each type.

3.1 Single Edge Contact Cartridge

The Intel® Pentium® II processor introduced a new packaging technology known as a Single Edge Contact cartridge (S.E.C. cartridge, or S.E.C.C.). The S.E.C. cartridge contains the microprocessor silicon and the second level L2 cache. The cartridge consists of a plastic cover and an aluminum thermal plate. The thermal plate is designed for attaching a heatsink using the techniques described in the application note, AP-588 *Mechanical Assembly and Customer Manufacturing Technology for S.E.C. Cartridge Processors*. The S.E.C. cartridge connects to the motherboard through an edge connector referred to as the Intel SC242 (Slot Connector 242).

3.2 Single Edge Contact Cartridge 2

Further developments have produced a second generation of S.E.C. cartridge simply referred to as the S.E.C.C.2. This cartridge no longer requires the aluminum thermal plate.

The substrate used in this cartridge uses the Organic Land Grid Array (OLGA) packaged processor core and up to two BSRAM components for the L2 cache. This processor type is referred to in this document as S.E.C.C.2-OLGA. The S.E.C.C.2 also connects to the motherboard through a SC242 edge connector.

3.3 Flip Chip Pin Grid Array

Additional developments in packaging technology lead to the introduction of the Flip Chip Pin Grid Array package (FC-PGA). The FC-PGA package consists of the microprocessor silicon core with integrated L2 cache mounted on a pinned substrate. The processor core is mounted with the back of the die facing up, hence the term “flip chip.” The processor package connects to the motherboard by plugging into a 370 pin ZIF socket (PGA370). Mechanical package specifications are available in the processor datasheet, *Pentium III Processor for the PGA370 Socket at 500 MHz to 1.0B GHz.*

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4.0 Thermal Specifications

The processor power dissipation is described in the applicable Pentium III processor datasheet. Refer to this document to verify the actual thermal specifications for a particular processor. While the processor core dissipates the majority of the thermal power, the system designer should also be aware of the thermal power dissipated by the second level cache. System designers should design for the highest possible thermal power, even if a processor with a lower power requirement is planned, to allow the design to accept either processor interchangeably.

4.1 Assumptions

For the purposes of this application note, the following assumptions have been made about the requirements for proper operation and reliability of the processor:

1. Considering the power dissipation levels and typical system ambient environments of 35°C to 45°C, the processor component temperatures cannot be maintained at or below the specified guidelines without additional thermal enhancement to dissipate the heat generated.

2. The thermal characterization data described in later sections indicates that both a thermal-cooling device and system airflow is needed. The size and type (passive or active) of thermal cooling device and the amount of system airflow are interrelated and can be traded off against each other to meet specific system design constraints. In typical systems, board layout, spacing, and component placement limit the thermal solution size. Airflow is determined by the size and number of fans along with their placement in relation to the components and the airflow channels within the system. In addition, acoustic noise constraints may limit the size and/or types of fans that can be used in a particular design.

To develop a reliable, cost-effective thermal solution, all of the above variables must be considered. Thermal characterization and simulation should be carried out at the entire system level to account for the thermal requirements of each component.

4.2 S.E.C. Cartridge Cover Temperature

The S.E.C. cartridge cover temperature is a function of the local ambient temperature, the internal temperature of the processor, and the various components internal to the processor. The local ambient temperature is the temperature found within the system chassis surrounding the cartridge. This is discussed in the temperature measurement process found in “Local Ambient Temperature Measurement Guidelines” on page 35. “Cartridge Cover Measurement Guidelines”, also on page 35, discusses proper guidelines for measuring the cover temperature.

4.3 S.E.C. Cartridge Thermal Plate Temperature

The S.E.C. cartridge thermal plate is intended to provide a common interface for multiple types of thermal solutions and is the attach location for all thermal solutions onto an S.E.C. cartridge. These solutions can be active or passive. Active solutions incorporate a fan in the heatsink and may be smaller than a passive heatsink. Considerations in heatsink design include:

- Local ambient temperature at the heatsink
- Surface area of the heatsink
- Volume of airflow over the surface area
- Power being dissipated by the processor
- Other physical volume constraints placed by the system.

Note: Processors packaged in the S.E.C.C.2 and FC-PGA packages do not have a thermal plate. Techniques for measuring thermal plate temperatures are provided in “Thermal Plate Measurements” on page 37.

4.4 Thermal Junction Temperature

4.4.1 S.E.C.C.2 Packaging

The introduction of the S.E.C.C.2 package with OLGA core eliminates the thermal plate, which in turn requires a new technique for measuring a thermal solution's effectiveness. The core thermal junction temperature reading is used to evaluate the system's thermal solution performance. The measurement of the core junction temperature of a live processor using S.E.C.C.2 packaging technology is critical to validate an OEM chassis and heatsink thermal design. A thermal diode is independently routed off the processor core to the SC242 connector to assist in evaluating the junction temperature. This is the same diode that has been used by DMI client software to monitor processor temperature since the introduction of the Intel SC242 processor. For more information on the thermal diode, refer to the processor datasheet. Techniques for measuring thermal junction temperatures are provided in “Junction Temperature Measurement Procedure” on page 41.

4.4.2 FC-PGA Packaging

The FC-PGA package does not require the use of a thermal plate. Like the S.E.C.C.2 package, the measurement of the junction temperature for an FC-PGA package is facilitated through the use of a thermal diode. The diode is routed to the pins of the PGA370 socket, and can be connected to thermal monitoring hardware by soldering signal wires directly to the pins. Refer to the processor datasheet for more information on the thermal diode. Specific techniques on measuring junction temperatures can be found in “Junction Temperature Measurement Procedure” on page 41.

4.5 Thermal Case Temperature

S.E.C.C.2 packaged processors also require a measurement of thermal case temperature. The L2 cache (BSRAM) components are probed with this method in the S.E.C.C.2-OLGA package.

4.5.1 BSRAM Case Temperature

The introduction of the S.E.C.C.2 package eliminates the thermal plate, which in requires the system designer to test the core processor temperature and the L2 cache BSRAM components. The BSRAM case temperature reading is used to evaluate the effectiveness of the system thermal solution. This parameter should be tested in the S.E.C.C.2-OLGA solution when BSRAMs are present. Techniques for measuring BSRAM temperatures are provided in "BSRAM Case Temperature Measurement Procedure" on page 47.

4.6 Power

The processor core dissipates the majority of the thermal power. The system designer should also be aware of the thermal power dissipated by the second level cache. Systems should design for the highest possible thermal power. The combination of the processor core and the second level cache dissipating heat through the thermal plate is the thermal plate power in S.E.C.C. packaged processors. In S.E.C.C.2 packages, this heat is dissipated through the component case (processor, BSRAM, resistors). The processor power is the total of heat dissipated through all paths. In FC-PGA packages the L2 cache and processor core are integrated into a single die where all the heat is dissipated.

Note: The overall system thermal design must comprehend the processor power. The cooling solution should be designed to dissipate the processor core and L2 cache power.

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5.0 Designing For Thermal Performance

In designing for thermal performance, the goal is to keep the processor(s) within the operational thermal specifications. The inability to do so will shorten the life of the processor(s). It is the goal and requirement of the thermal design to ensure these operational thermal specifications are maintained. The heat generated by the components within the chassis must be removed to provide an adequate operating environment for both the processor and other system components. To do so requires moving air through the chassis to transport the heat generated by the processor for both the processor and other system components. ATX and MicroATX chassis specific thermal design guidelines can be found in *Performance ATX Desktop System Thermal Design Suggestions v1.0* and *Performance MicroATX Desktop System Thermal Design Suggestions v1.0.* These two documents can be of assistance when performing system level thermal design for these specific chassis form factors.

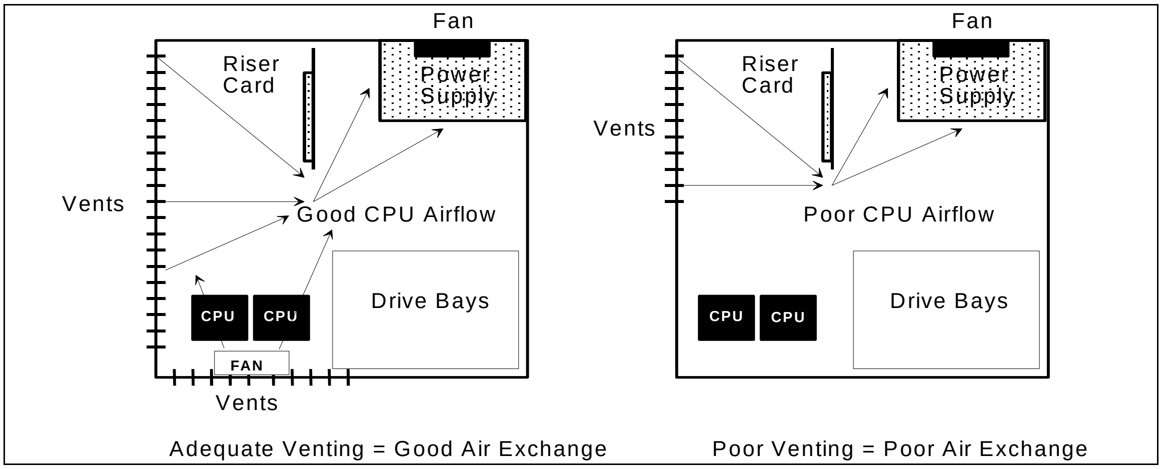
5.1 Airflow Management

It is important to manage the velocity, quantity and direction of air that flows within the system (and how it flows) to maximize the volume of air that flows over the processor. System airflow can be increased by adding one or more fans to the system or by increasing the output (faster speed) of an existing system's fan(s). Local air flow can also be increased by managing the local flow direction using baffles or ducts. An important consideration in airflow management is the temperature of the air flowing over the processor(s). Heating effects from add-in boards, DRAM, and disk drives greatly reduce the cooling efficiency of this air, as does re-circulation of warm interior air through the system fan. Care must be taken to minimize the heating effects of other system components, and to eliminate warm air circulation.

For example, a clear air path from the external system vents to the system fan(s) will enable the warm air from the processors to be efficiently pulled out of the system. If no air path exists across the processors, the warm air from the processors will not be removed from the system, resulting in localized heating ("hot spots") around the processors. Heatsink fin designs should be aligned with the direction of the airflow. If the airflow is horizontal the fins should be horizontally extruded, and when the airflow is vertical, the fins should be vertically extruded.

Figure 5-1 shows two examples of air exchange through a PC style chassis. The system on the left is an example of good air exchange. The thermal design incorporates the power supply fan and an additional system fan. The system on the right shows a poorly vented system. This design uses only the power supply fan to move the air, resulting in inadequate airflow. Re-circulation of warm air is most common between the system fan and chassis, and between the system fan intake and the drive bays behind the front bezel. These paths may be eliminated by mounting the fan flush to the chassis, thereby obstructing the flow between the drive bays and fan inlet, and by providing generous intake vents in both the chassis and the front bezel.

Figure 5-1. Example of Air Exchange Through a PC Chassis



5.2 Extruded Heatsink Solutions

One method used to improve thermal performance is to increase the surface area of the device by attaching a metallic heatsink. Heatsinks are generally extruded from blocks of metal, usually aluminum (due to its low price/performance ratio). To maximize the heat transfer, the thermal resistance from the heatsink to the air can be reduced by maximizing the airflow through the heatsink fins and by maximizing the surface area of the heatsink itself. Passive heatsinks rely on system fans for airflow while active heatsink that have a dedicated fan attached directly to the heatsink. A retention mechanism such as a clip provides the force necessary to mount the heatsink to the processor and to compress the thermal interface material. Note that active solutions may still require one or more system fans to maintain $T_{\text{ambient-local}}$ within system requirements.

5.2.1 Heatsink Design

Though each designer may have mechanical volume restrictions or implementation requirements, the following diagrams illustrate "generic" system form factors that are likely to be compatible with a given type of chassis design.

5.2.2 Example ATX Compatible S.E.C.C. and S.E.C.C.2 Heatsinks

Figure 5-2 and Figure 5-3 (thermal plate and side view respectively) indicate the space available for the physical outline for a S.E.C.C. or S.E.C.C.2 heatsink in an ATX style chassis.

Figure 5-2. Front View of Example ATX Style S.E.C.C. or S.E.C.C.2 Heatsink

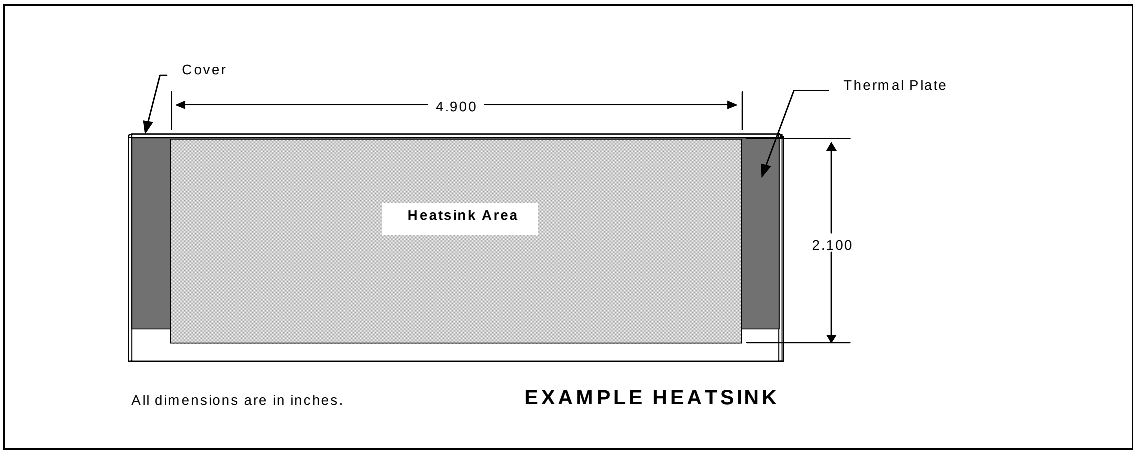
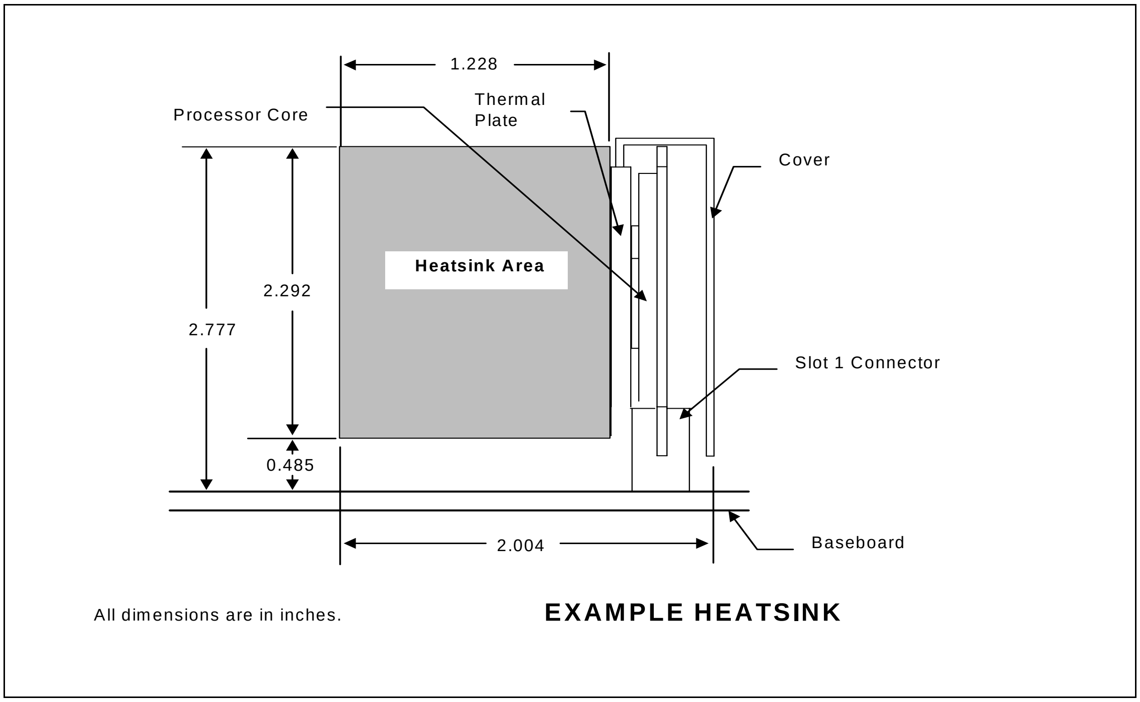


Figure 5-3. Side View of Example ATX Style S.E.C.C. or S.E.C.C.2 Heatsink



5.2.3 Example Low Profile (LPX) Compatible S.E.C.C. and S.E.C.C.2 Heatsinks

Figure 5-4 and Figure 5-5 shows the front and side view respectively indicating the space available for the physical outline for a S.E.C.C. or S.E.C.C.2 heatsink in a low profile (LPX) style chassis.

Figure 5-4. Front View of Example LPX Style S.E.C.C. or S.E.C.C.2 Heatsink

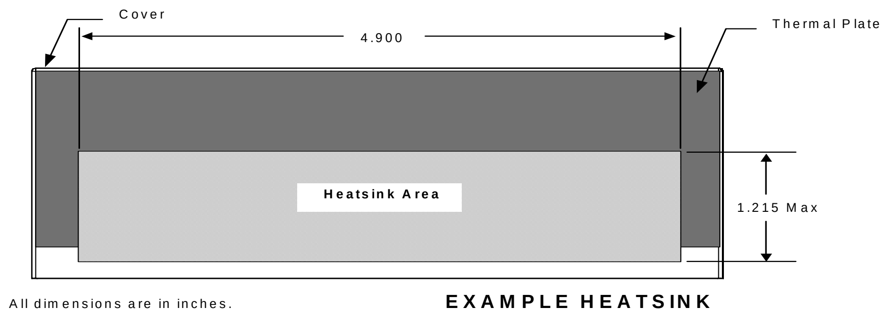
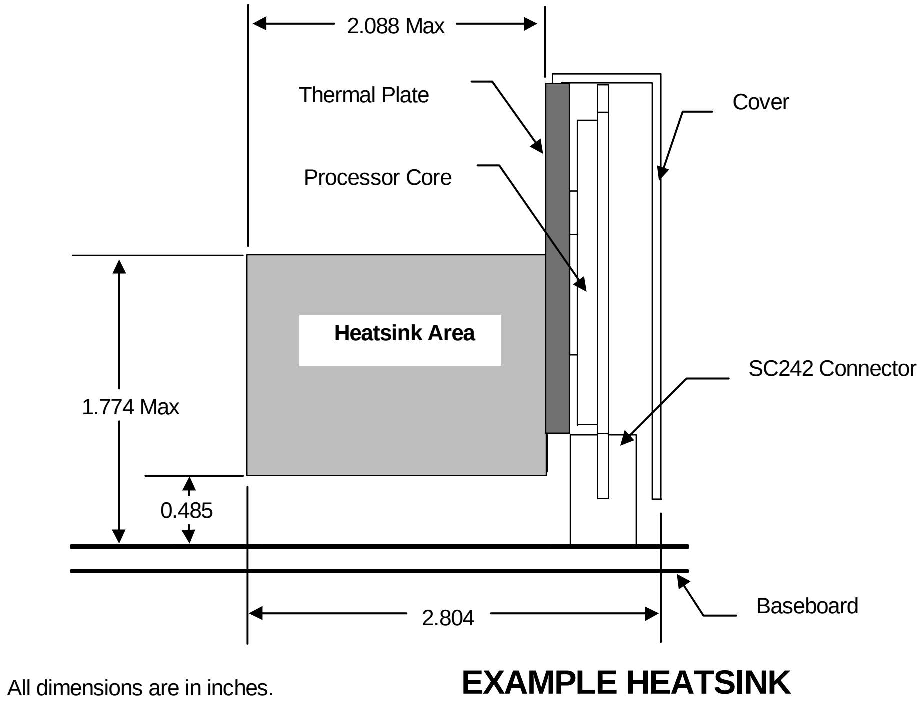


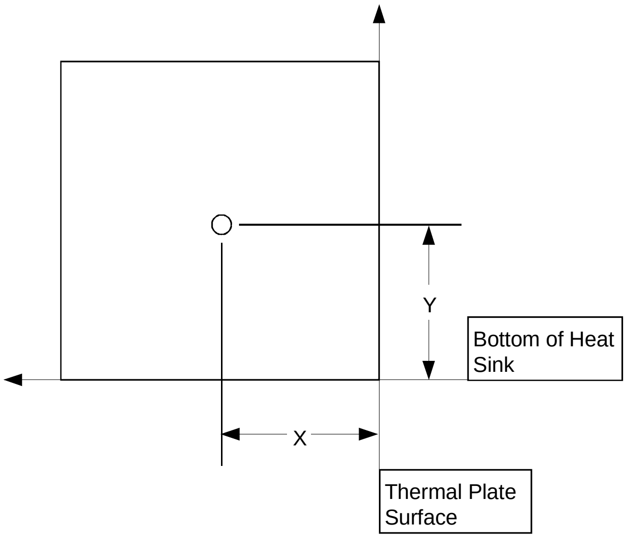
Figure 5-5. Side View of Example LPX Style S.E.C.C. or S.E.C.C.2 Heatsink



5.2.4 Heatsink Weight

The maximum weight of the heatsink and attachment mechanisms should not exceed 250 grams for S.E.C.C. and S.E.C.C.2 processors. This limit is based on the ability of the processor retention mechanism and heatsink support to withstand mechanical shock and vibration as a full assembly with heatsink attached. Figure 5-6 provides the maximum distances for the center of gravity for a heatsink to be used with the S.E.C.C. and S.E.C.C.2 processors. Heatsink design should try to maintain the center of mass within the "safe" area. This is the shaded area shown in the figures below.

Figure 5-6. Maximum Distances for Center of Gravity for Heatsink Types



Chassis Type	X Cg	Y Cg
ATX	1.2"	1.0"
LPX	1.4"	0.7"

5.2.4.1 Center of Gravity Calculations for S.E.C.C. and S.E.C.C.2 processor heat sinks

Although commonly calculated through solid modeling programs, the center of gravity can be calculated through straightforward computations described in this section. The center of gravity of an object with a uniform density is the geometrical center of volume of the object. The center of gravity can most easily be determined by dividing the object into smaller objects and averaging each individual centroid with respect to the volumes as shown in the following equations:

$$\sum_{n=1}^{n=m} Xcg_n * volume_n / total\,volume$$

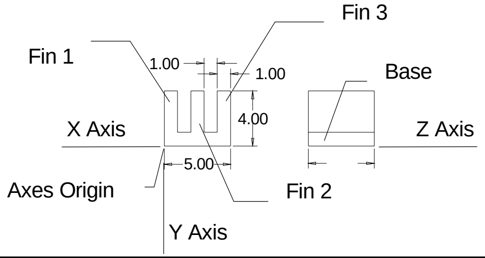
$$\sum_{n=1}^{n=m} Ycg_n * volume_n / total\,volume$$

$$\sum_{n=1}^{n=m} Zcg_n * volume_n / total\,volume$$

Where m = number of smaller objects

Each individual center of gravity (cg) must be related to a single point of origin. Once the individual cgs are calculated, multiply the individual cg by the individual volume and sum up each of these individual products. A computational example is shown in Figure 5-7.

Figure 5-7. Center of Gravity Calculation Example



The heatsink has a fin thickness of 1 and a square base of 5 by 5. First the heatsink must be split into four different volumes: three fin blocks (1X3X5 each) and one base block (5X1X5). The individual center of gravity with respect to the axis origin is:

Individual Block Centroid and Volume:
Fin 1: Xcg1 = 0.5, Ycg = 2.5, Zcg = 2.5
Fin 1 Volume = 15
Fin 2: Xcg2 = 2.5, Ycg = 2.5, Zcg = 2.5
Fin 2 Volume = 15
Fin 3: Xcg3 = 4.5, Ycg = 2.5, Zcg = 2.5
Fin 3 Volume = 15
Base: Xcgb = 2.5, Ycg = 0.5, Zcg = 2.5
Base Volume = 25
Total Volume = 70

Now that the individual block centroids have been calculated, the average of the centroids with respect to the volumes as described earlier is:

Xcg = ((0.5*15)+(2.5*15)+(4.5*15)+(2.5*25)/70
Xcg = 2.5

Ycg = ((2.5*15)+(2.5*15)+(2.5*15)+(0.5*25)/70
Ycg = 1.8

Zcg = ((2.5*15)+(2.5*15)+(2.5*15)+(2.5*25)/70
Zcg = 2.5

5.2.5 Example S.E.C.C.2 Passive Heatsink

Intel has designed and enabled a passive heatsink for the S.E.C.C.2 package. This heatsink was designed assuming a $T_{ambient}$ of 45ºC, 200 Linear Feet per Minute (LFM) airflow, and a maximum processor power of 28 watts. Information on this device can be found on Intel's web site at http://developer.intel.com/ (search for “SECC2 packaging”).

5.2.6 FC-PGA Reference Thermal Solution Heatsinks

Intel has enabled a passive heatsink and an active heatsink for use with the FC-PGA processor. Please refer to the Intel reference thermal solution functional specifications for details regarding thermal performance requirements, mass requirements, chassis volumetric keep out zones, motherboard component keep out zones, and mechanical design requirements. Contact your local Intel Field Sales representative to obtain a copy.

5.3 Thermal Interface Management

To optimize the heatsink design for the Pentium III processor, it is important to understand the impact of factors related to the interface between the processor and the heatsink base. Specifically, the bond line thickness, interface material area, and interface material thermal conductivity should be managed to realize the most effective thermal solution. For more information on this subject refer to the *Single Edge Contact Connector 2 (S.E.C.C. 2) Thermal Interface Material Functional Requirements* (order number 244458).

5.3.1 Bond Line Management

The gap between the processor and the heatsink base impacts thermal solution performance. The larger the gap between the two surfaces, the greater the thermal resistance.

For the S.E.C.C., the thickness of the gap is determined by the flatness of both the heatsink base and the thermal plate, plus the thickness of the thermal interface material (e.g., thermal grease) used between these two surfaces. The worst case flatness of the thermal plate will be 0.005" over the entire thermal plate surface. The attach area on the thermal plate will have the flatness specified as no greater than 0.001" per inch. For the S.E.C.C.2 without a thermal plate, the heatsink area that attaches to the OLGA core should maintain a similar flatness. The flatter the heatsink base, the thinner the resultant bond line that can be achieved. In addition, the attachment mechanism for the heatsink needs to be able to supply sufficient clamping force to spread the interface material out to form the thinnest film possible.

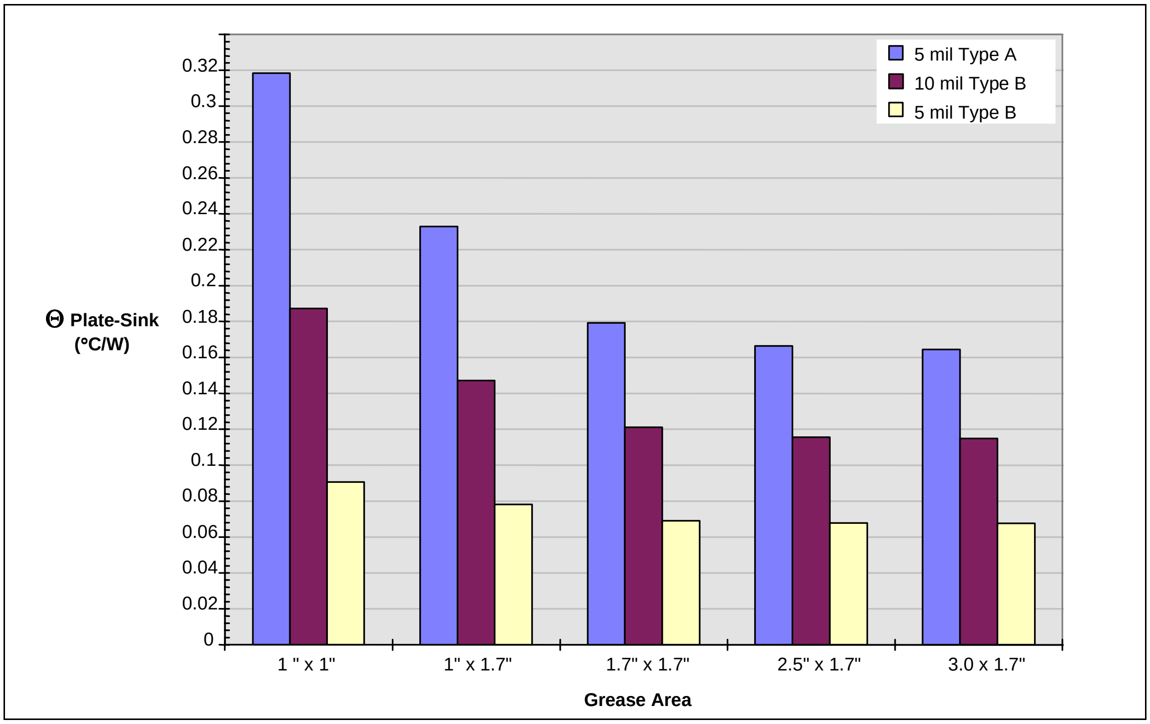
The FC-PGA processor core (bare die) also attaches directly to the heatsink base and relies on the flatness of the heatsink base and the retention mechanism clamping force to preserve an adequate bond line. A heatsink base flatness of 0.002 in/in is recommended for the area in contact with the die. Intel’s reference solutions adhere to this flatness requirement.

Heatsink tilt is an important factor in maintaining an adequate bond line for the FC-PGA package. Since the bare die is small in area, the heatsink is susceptible to tilt while attached to the processor/socket assembly. Tilt can cause a gap on one or more edges of the die and cause unacceptable increases in bond line thickness. The system designer should use a retention mechanism which applies all the clamping force at a single point on the heatsink directly above the package die.

5.3.2 Interface Material Area

The size of the contact area between the processor and the heatsink base will impact the thermal resistance. There is, however, a point of diminishing returns. Unrestrained incremental increases in thermal grease area do not translate to a measurable improvement in thermal performance. Figure 5-8 illustrates the results of empirical measurements of two different types of grease based on thermal conductivity. The bulk thermal conductivity of type A grease is 0.5 to 1.5 W/m-K and type B grease is 2 to 3 W/m-K. In addition to the diminishing returns seen with larger grease areas, the overall flatness that can be achieved tends to decrease. The decrease in flatness would have a negative impact of potentially increasing the resistance across the interface between the processor and the heatsink.

Figure 5-8. Impact of Contact Area and Thermal Interface Properties of the Interface Material



5.3.3 Interface Material Performance

Two factors impact the performance of the interface material between the processor and the heatsink base:

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

Thermal resistance is a description of the ability of the thermal interface material to transfer heat from one surface to another. The higher the thermal resistance, the less efficient an interface is at transferring heat. The thermal resistance of the interface material has a significant impact on the thermal performance of the overall thermal solution. The higher the thermal resistance, the higher the temperature drop across the interface and the more efficient the thermal solution must be to compensate.

The wetting/filling of the thermal interface material is its ability, under the load applied by the heatsink attach mechanism, to spread and fill the gap between the processor and the heatsink. 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. In this case, grease area size also becomes significant, as the larger the desired grease area size, the higher the force required to spread the thermal interface material.

Thermal pads are available from various vendors and may provide an adequate thermal interface solution. Also, some vendors can supply their heatsinks with pre-applied thermal interface material to reduce the handling, assembly time and assembly steps to attach a thermal solution.

5.4 Fans

Fans are needed to move the air through the chassis. The airflow rate of a fan is usually directly related to the acoustic noise level of the fan and system. Maximum acceptable noise levels may limit the fan output or the number of fans selected for a system. Fan/heatsink assemblies are one type of advanced solution that can be used to cool the processor. Intel has worked with fan/heatsink vendors and computer manufacturers to make fan/heatsink cooling solutions available in the industry. Please consult such a vendor to acquire the proper solution for your needs.

5.4.1 Placement

Proper placement of the fans can ensure that the processor is being properly cooled. Because of the difficulty in building, measuring and modifying a mechanical assembly, models are typically developed and used to simulate a proposed prototype for thermal effectiveness, and to determine the optimum location for fans and vents within a chassis. Prototype assemblies can also be built and tested to verify that the system components and processor thermal specifications are met.

An intake air fan ideally is centered vertically and placed along one axis with respect to the Intel SC242 processor with a passive heatsink. The fan should also be placed at least two (2) inches from the leading edge. Figure 5-9 and Figure 5-10 show the recommended fan placement for an ATX form factor layout and a LPX form factor for S.E.C.C., respectively.

Figure 5-9. Fan Placement and Layout of an ATX Form Factor Chassis – Top View

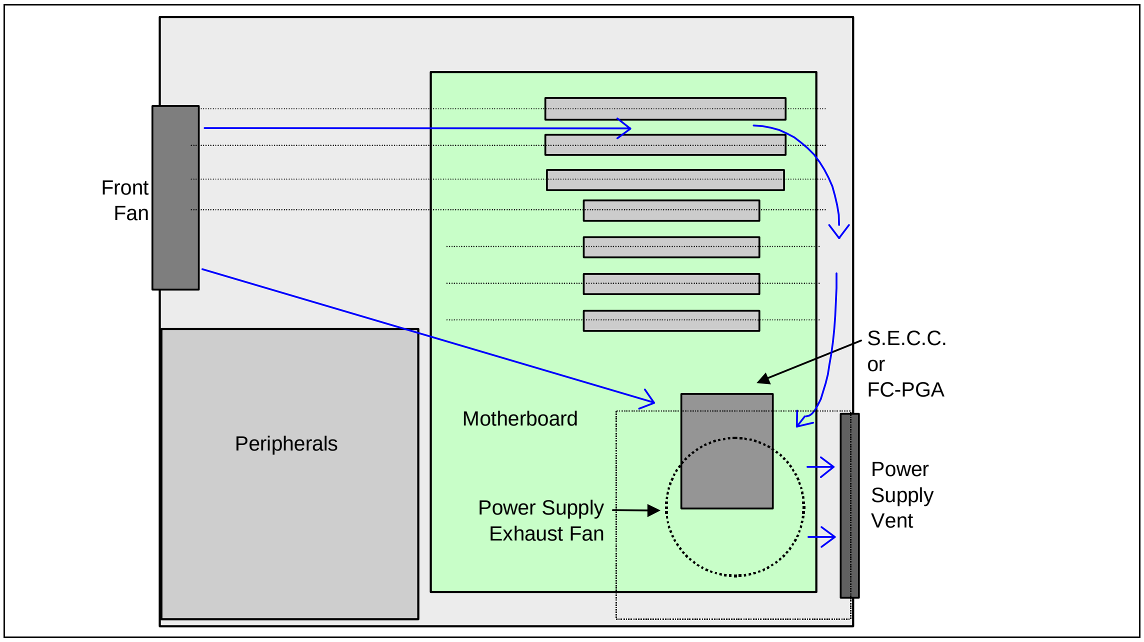
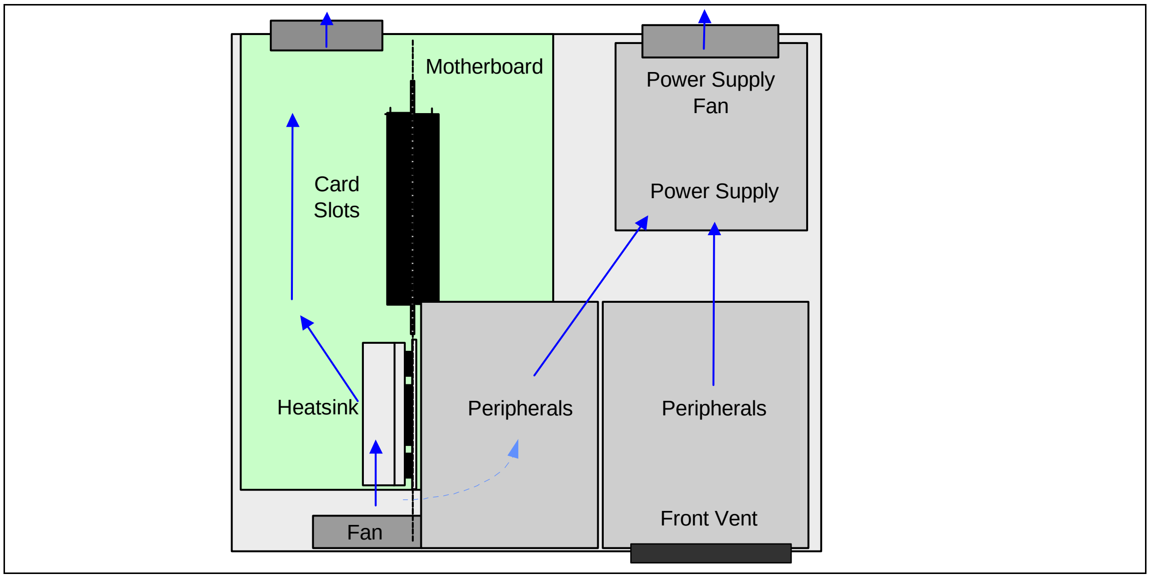


Figure 5-10. Fan Placement and Layout of a LPX Form Factor Chassis – Top View



5.4.2 Direction

If the fan(s) are not moving air across the heatsink, little cooling can occur. This may cause the processor to operate well above the recommended specification values. Two possibilities exist for blowing air across a passive heatsink. Air can be blown down vertically or horizontally across the heatsink. This may depend on the layout of other components on the board and/or within the chassis. The intake fan should blow through a passive heatsink parallel to the fins if possible. Both of these factors are considerations when laying out components on the board and in the chassis.

The direction of the air flow can be modified with baffles or ducts to direct the air flow over the processor. This will increase the local flow over the processor and may eliminate the need for a second fan, a larger fan, or a higher speed fan. For an actively cooled heatsink, the system airflow direction may not be as critical for proper thermal performance.

5.4.3 Size and Quantity

It does not necessarily hold true that the larger the fan the more air it blows. A small blower using ducting might direct more air over the heatsink than a large fan blowing non-directed air over the heatsink. The following provide some guidelines for size and quantity of the fan(s).

The fan should be a minimum of 80 mm (3.150") square, with a minimum airflow of approximately 200 LFM (linear feet per minute). Ideally two (2) fans should be used. The intake air fan should blow directly onto the processor heatsink, while a second fan (most likely in the power supply) would exhaust the air out of the system.

5.4.4 Venting

Intake venting should be placed at the front (user side) of the system. They should be located to optimize cooling of processor and peripherals (drives and add-in cards). A good starting point would be the lower 50% of the front panel (bezel). Intake vents directly in front of the intake fan is the optimal location. The ideal design will provide airflow directly over the processor heatsink.

5.4.4.1 Placement

In most cases, an exhaust fan and vent located at the power supply is sufficient. However, depending on the number, location, and types of add-in cards, exhaust venting may be necessary near the cards. This should be modeled or prototyped for the optimum thermal potential. A system should be modeled for the worst case, i.e., all expansion slots should be occupied with typical add-in options.

5.4.4.2 Area and Size

The area and size of the intake vents should be designed with the size and shape of the fan(s) in mind. Adequate air volume requires appropriately sized vents. Intake vents should be located in front of the intake fan(s) and adjacent to the drive bays. Vents should be approximately 50% to 60% open in the EMI containment area due to EMI constraints. Outside the EMI containment area, the open percentage can be greater if needed for aesthetic appeal (i.e., bezel/cosmetics). For more information concerning EMI constraints and Intel SC242 processor based system design, see the *Slot 1 Processor EMI Overview* application note (order number 243334).

5.4.4.3 Vent Shape

Round, staggered pattern openings are best for EMI containment, acoustics, and airflow balance.

6.0 Alternative Cooling Solutions

In addition to extruded heatsink and system fans, other solutions exist for cooling integrated circuit devices. For example, ducted blowers, heat pipes and liquid cooling are all capable of dissipating heat. Due to their varying attributes, each of these solutions may be appropriate for a particular system implementation. More information on this topic can be located on Intel's web site at http://developer.intel.com/.

6.1 Ducting

Ducts can be designed to isolate the processor(s) from the effects of system heating (such as add-in cards), and to maximize the processor cooling temperature budget. Air provided by a fan or blower can be channeled directly over the processor and heatsink, or split into multiple paths to cool multiple processors. This method can also be employed to provide some level of redundancy in a system requiring redundant capabilities for fault tolerance. This is accomplished by channeling air from two or more fans through the same path across a processor. Each fan, or each set of fans, must be designed to provide sufficient cooling in the event that the other has failed.

6.1.1 Ducting Placement

When ducting is to be used, it should direct the airflow evenly from the fan through the length of the heatsink. This should be accomplished, if possible, with smooth, gradual turns as this will enhance the airflow characteristics. Sharp turns in ducting should be avoided. Sharp turns increase friction and drag and will greatly reduce the volume of air reaching the processor heatsink.

6.2 Fan Heatsink

An active fan heatsink can be employed as an alternative mechanism for cooling the Intel SC242 and FC-PGA processor. This is the acceptable solution for most chassis. Adequate clearance must be provided around the fan heatsink to ensure unimpeded air flow for proper cooling. The Intel boxed SC242 processor uses this implementation and is shown here as an example of a fan heatsink implementation. The space requirements and dimensions for the fan heatsink on the Intel boxed SC242 processor are shown in Figure 6-1 (front view), Figure 6-2 (side view), and Figure 6-3 (top view). All dimensions are in inches. The Intel FC-PGA boxed processor with an active thermal solution is described in the processor datasheet titled *Pentium III Processor for the PGA370 Socket at 500 MHz to 1.0B GHz.*

Figure 6-1. Front View Space Requirements for the SC242 Processor Fan Heatsink

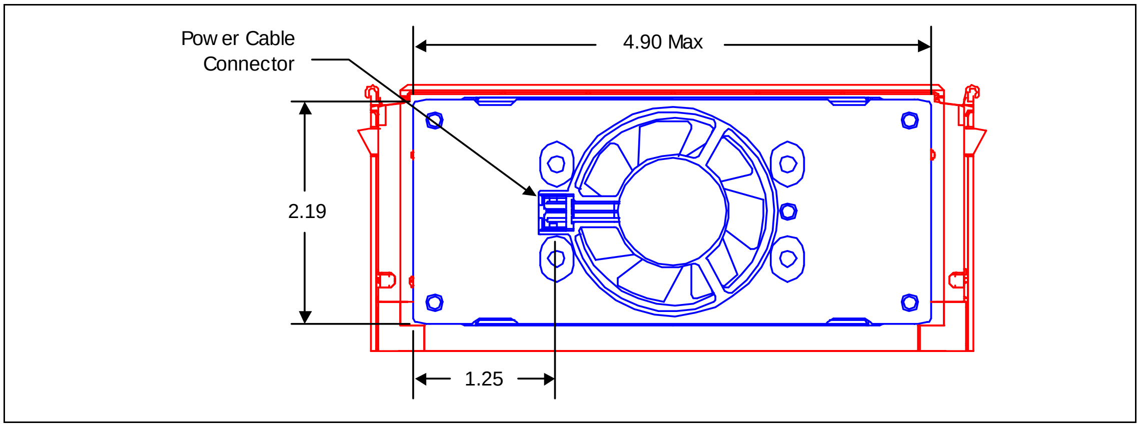


Figure 6-2. Side View Space Requirements for the SC242 Fan Heatsink (Supports not shown).

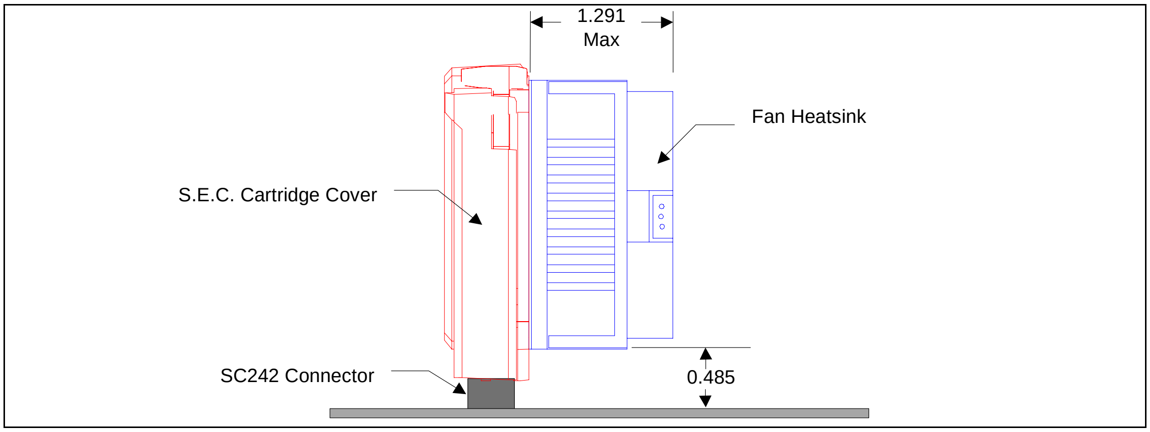
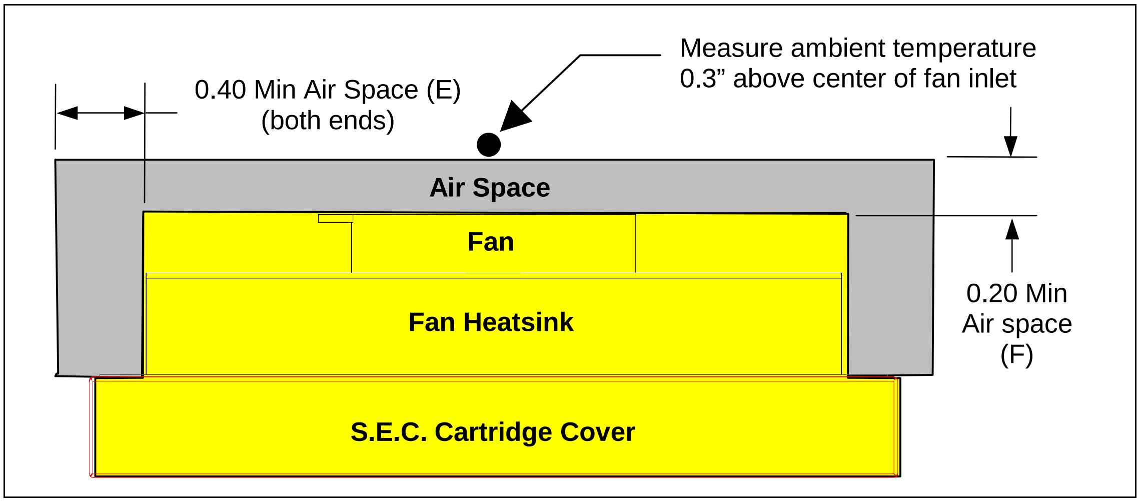


Figure 6-3. Top View Space Requirements for the SC242 Processor Fan Heatsink



6.3 Fan Heatsink Measurements

A fan heatsink must be able to keep the processor temperature, T_{plate} or $T_{junction}$, within the specifications. This will require that the airflow through the fan heatsink be unimpeded and the air temperature entering the fan is below 45°C, see Figure 7-4 for the measurement location for a SC242 processor. Figure 7-5 shows the measurement location for an FC-PGA processor. Airspace is required around the fan to ensure that the airflow through the fan heatsink is not blocked. Blocking the airflow to the fan heatsink reduces the cooling efficiency and decreases fan life. Figure 6-3 illustrates an acceptable airspace clearance for the SC242 processor fan heatsink.

6.4 System Components

6.4.1 Placement

Peripherals such as CD-ROMs, floppy drives, and hard drives can be placed to take advantage of the fan's movement of ambient air (i.e., near intake or exhaust fans or venting). Some add-in cards often have a low tolerance for temperature rise. These components should be placed near additional vents if they are downstream of the processor to minimize temperature rise.

6.4.2 Power

Some types of drives, such as a floppy drive, do not dissipate much heat, while others (read/write CD-ROMs, hard drives) dissipate a great deal of heat. These hotter components should be placed near fans or vents whenever possible. The same can be said for some types of add-in cards. Some PCI cards are very low wattage (5W) while others can be as high as 25 watts, per PCI specification. Great care should be taken to ensure that these cards have sufficient cooling.

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7.0 Thermal Metrology

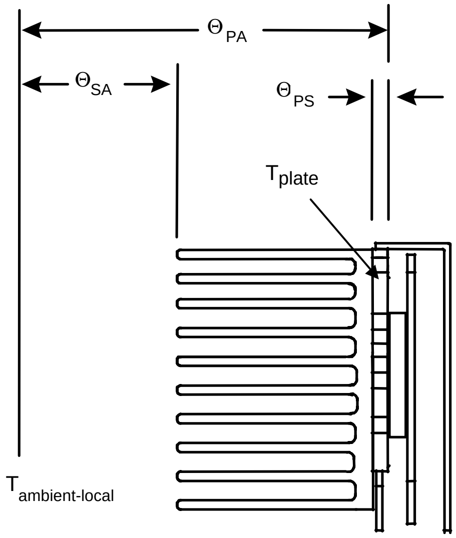
The following sections will discuss the techniques for testing thermal solutions under three package types: S.E.C.C., S.E.C.C.2, and FC-PGA. It should be noted that determining if a processor is sufficiently cooled is not as simple as it may seem. Carefully read the following instructions and interpretation steps to validate your cooling solution. "S.E.C.C. Metrology" on page 37 covers the steps necessary to test S.E.C. cartridge thermal plate temperature. "S.E.C.C.2 and FC-PGA Metrology" on page 39 covers the steps for testing S.E.C.C.2-OLGA and FC-PGA processor temperatures. "Common Metrology For S.E.C.C., S.E.C.C.2, and FC-PGA Processors" on page 31 covers the steps common to all packages.

7.1 Common Metrology For S.E.C.C., S.E.C.C.2, and FC-PGA Processors

7.1.1 Thermal Resistance

The plate-to-ambient thermal resistance value (Θ_{PA}) for the in S.E.C.C. packages is used as a measure of the thermal solution's thermal performance. For S.E.C.C.2 and FC-PGA packages, junction-to-ambient thermal resistance (Θ_{JA} or $\Theta_{junction\text{-}ambient}$) is used. Thermal resistance is measured in units of °C/W. The plate-to-local ambient thermal resistance, Θ_{PA}, includes the plate-to-sink thermal resistance (Θ_{PS}) and the sink-to-local ambient thermal resistance (Θ_{SA}). Θ_{PS} is a measure of the thermal resistance along the heat flow path from the top of the processor cartridge to the bottom of the heatsink. The junction-to-ambient thermal resistance, Θ_{JA}, includes the junction to heatsink base thermal resistance (Θ_{JS}) and the sink-to-local ambient thermal resistance (Θ_{SA}). The Θ_{JS} value is strongly dependent on the thermal conductivity and thickness of the thermal interface material (T.I.M.) between the heatsink and die surface. Θ_{SA} is a measure of the thermal resistance from the bottom of the heatsink to the local ambient air. Θ_{SA} is dependent on the heatsink's thermal conductivity and geometry, and is strongly dependent on the air velocity through the heatsink fins.

Figure 7-1. Thermal Resistance Relationships – S.E.C.C.



The thermal parameters for the S.E.C.C. are related by the following equations (Figure 7-1):

$$\Theta_{PA} = (T_{plate} - T_{ambient\text{-}local}) / P_D$$

$$\Theta_{PA} = \Theta_{PS} + \Theta_{SA}$$

Where:

Θ_{PA} = Thermal resistance from plate-to-local ambient (°C/W)

T_{plate} = Processor thermal plate temperature (°C)

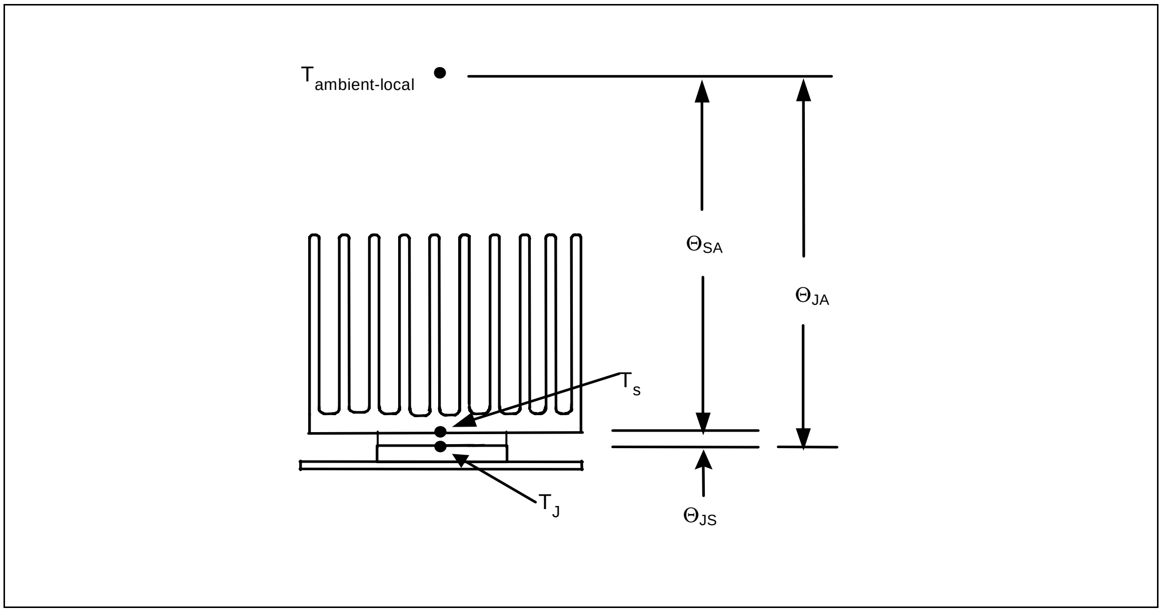
$T_{ambient\text{-}local}$ = Local ambient temperature in chassis around processor (°C)

P_D = Device power dissipation (W) (assuming no heat is dissipated through substrate)

Θ_{PS} = Thermal resistance from plate-to-sink (°C/W)

Θ_{SA} = Thermal resistance from heatsink-to-local ambient (°C/W)

Figure 7-2. Thermal Resistance Relationships – FC-PGA



The thermal parameters for S.E.C.C.2 and FC-PGA (Figure 7-2) are related by the following equations:

$$\Theta_{JA} = (T_{junction} - T_{ambient\text{-}local}) / P_D$$

$$\Theta_{JA} = \Theta_{JS} + \Theta_{SA}$$

Where:

Θ_{JA} = Thermal resistance from junction-to-local ambient (°C/W)

$T_{junction}$ = Processor junction temperature (°C)

$T_{ambient\text{-}local}$ = Local ambient temperature in chassis around processor (°C)

P_D = Device power dissipation (W) (assuming no heat is dissipated through substrate)

Θ_{JS} = Thermal resistance from junction-to-sink (°C/W)

Θ_{SA} = Thermal resistance from heatsink-to-local ambient (°C/W)

7.1.2 S.E.C.C. and S.E.C.C.2 Thermal Solution Performance

For S.E.C.C. and S.E.C.C.2 packages, all processor thermal solutions should attach to the processor cartridge. The thermal solution must adequately control the thermal resistance between the processor junction or plate and the local ambient air around the processor (Θ_{JA}or Θ_{PA}). The lower the thermal resistance between the processor junction (or plate) and the local ambient air, the more efficient the thermal solution. The required S.E.C.C. Θ_{PA} is dependent upon the maximum allowable processor temperature ($T_{cartridge}$), the local ambient temperature ($T_{ambient\text{-}local}$), and the processor power ($P_{cartridge}$). This can be expressed as follows:

$$\Theta_{PA} = (T_{cartridge} - T_{ambient\text{-}local}) / P_{cartridge}$$

The required S.E.C.C.2 Θ_{JA} is dependent on the maximum allowable junction temperature (Tj), the local ambient temperature ($T_{ambient\text{-}local}$), and the processor core power (P_{core}):

$$\Theta_{JA} = (T_{junction} - T_{ambient\text{-}local}) / P_{core}$$

$T_{ambient\text{-}local}$ is a function of the system design. Table 3 and Table 4 provide the resultant thermal solution performance requirements for Intel SC242 processor at different local ambient air temperatures and cartridge power values.

Table 3. Example Thermal Solution Performance Requirements for S.E.C.C. Packaged Processors

$T_{ambient\text{-}local}$	**Intel SC242 Processor Θ_{PA} (°C/W)**	
	Thermal Plate power of 41.4 Watts	**Thermal Plate Power of 26.4 Watts**
35°C	0.85	1.33
40°C	0.99	1.52
45°C	1.11	1.70

Note: See applicable processor datasheet for required power specifications

Table 4. Example Thermal Solution Performance Requirements for S.E.C.C.2 Packaged Processor with Processor Core Power of 28.0 Watts

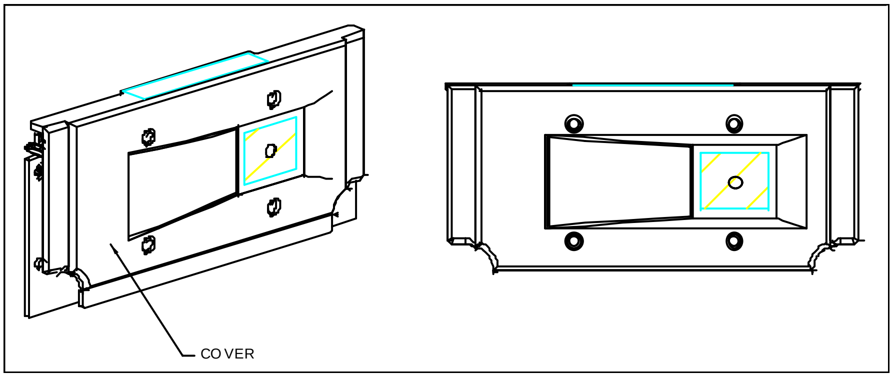
$T_{ambient\text{-}local}$	**Intel SC242 Processor Θ_{JA} (°C/W) at 28 W Processor Core Power**
35°C	1.25
40°C	1.42
45°C	1.61

The thermal resistance values Θ_{JA} and Θ_{PA} are made up of two primary components: the thermal resistance between the processor and heatsink (Θ_{JS} or Θ_{PS}) and the thermal resistance between the heatsink and local ambient air around the processor (Θ_{SA}). By minimizing one or both of these thermal resistance pathways, the overall processor junction (or plate) to ambient thermal resistance can be minimized. Θ_{JS} or Θ_{PS} can be reduced by optimizing the thermal interface material and bond line. Θ_{SA} can be reduced by optimizing the heatsink parameters, such as fin area, base thickness, and material conductivity.

7.1.3 Cartridge Cover Measurement Guidelines

The cartridge cover temperature specification is a maximum of 75°C for S.E.C.C. packages and 70-75°C for S.E.C.C.2 packages. The most up to date specifications can be found in the processor datasheet. There are several components on the substrate that comprise the Intel SC242 processor. Each of these components generates heat and since some components may reside on the opposite side of the substrate from the processor core, the cover must also meet a specified temperature for proper operation. Similar techniques presented in “Thermal Plate Measurements” on page 37 for measuring thermal plate temperature can be used for the cover measurements. The HIPWR30.EXE application should be running when the T_{cover} measurement is made. Refer to “About the HIPOWER Application” on page 49 for information on the HIPWR30.EXE application. Please contact your local Intel Field Sales representative to receive a copy.

Figure 7-3. Example processor cover



7.1.4 Local Ambient Temperature Measurement Guidelines

Local ambient temperature, $T_{ambient\text{-}local}$, is the temperature of the ambient air surrounding the cartridge or FC-PGA. In a system environment, ambient temperature is the temperature of the air upstream of the processor and in its close vicinity. In an active cooling system, it is the inlet air to the active cooling device.

Note: An ambient temperature is not specified for the S.E.C.C. processor. The only restriction is that T_{cover} (cover temperature) and T_{plate} (thermal plate temperature) requirements be met.

It is worthwhile to determine the local ambient temperature in the chassis around the processor to better understand the effect it may have on the S.E.C.C. thermal plate and cover temperature and on the S.E.C.C.2/FC-PGA junction temperature.

The following guidelines are meant to alleviate the non-uniform measurements found in typical systems. The local ambient temperature is best measured as an average of the localized air surrounding the processor. The following guidelines are meant to enable accurate determination of the localized air temperature around the processor during system thermal testing. These guidelines are meant as a reasonable expectation to ensure the product specifications are met.

- During system thermal testing of an S.E.C.C. or S.E.C.C.2 processor, a minimum of two thermocouples should be placed approximately 0.5" away from the cartridge cover and heatsink as shown in the Figure 7-4. For a system with an FC-PGA processor, the thermocouples should be placed approximately 0.5 to 1.0 inches away from the processor heatsink or fan as shown in Figure 7-5. These placement guidelines are meant to minimize localized hot spots due to the processor, heatsink, or other system components.
- The thermocouples should be placed approximately 2 inches above the baseboard. This placement guideline is meant to minimize localized hot spots from baseboard components.
- The $T_{ambient\text{-}local}$ should be the average of the thermocouple measurements during system thermal testing.

Figure 7-4. Guideline Locations for Cartridge Local Ambient Temperature Measurements

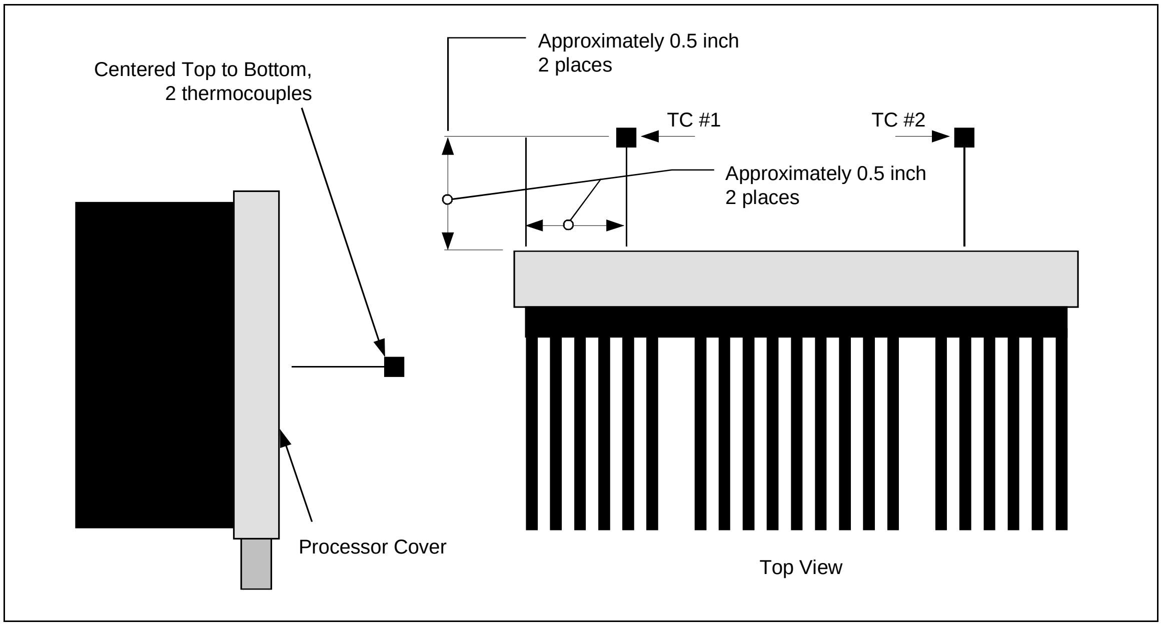
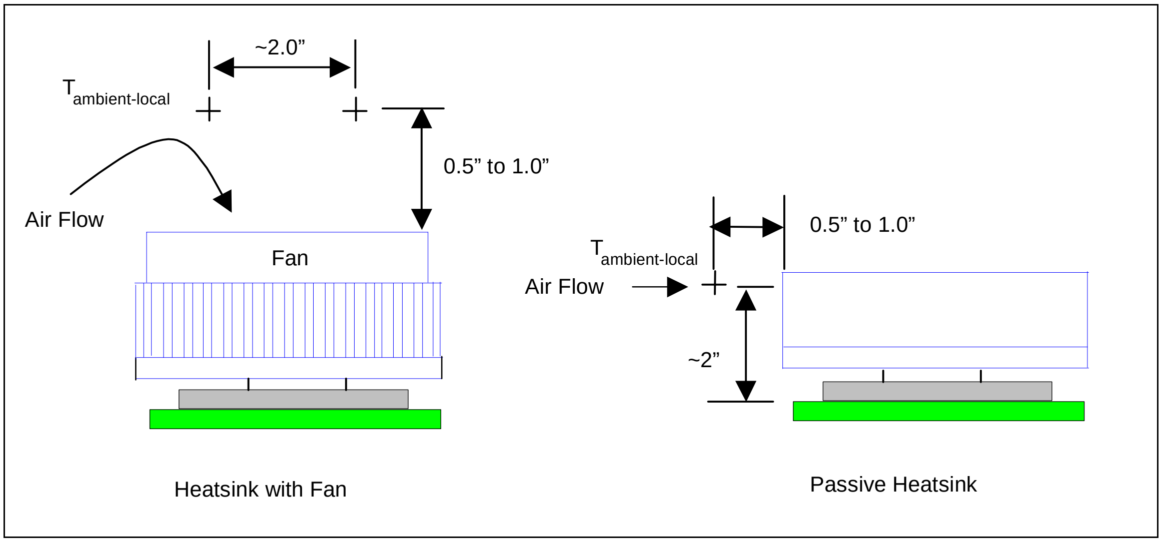


Figure 7-5. Guideline Locations for FC-PGA Local Ambient Temperature Measurements



7.2 S.E.C.C. Metrology

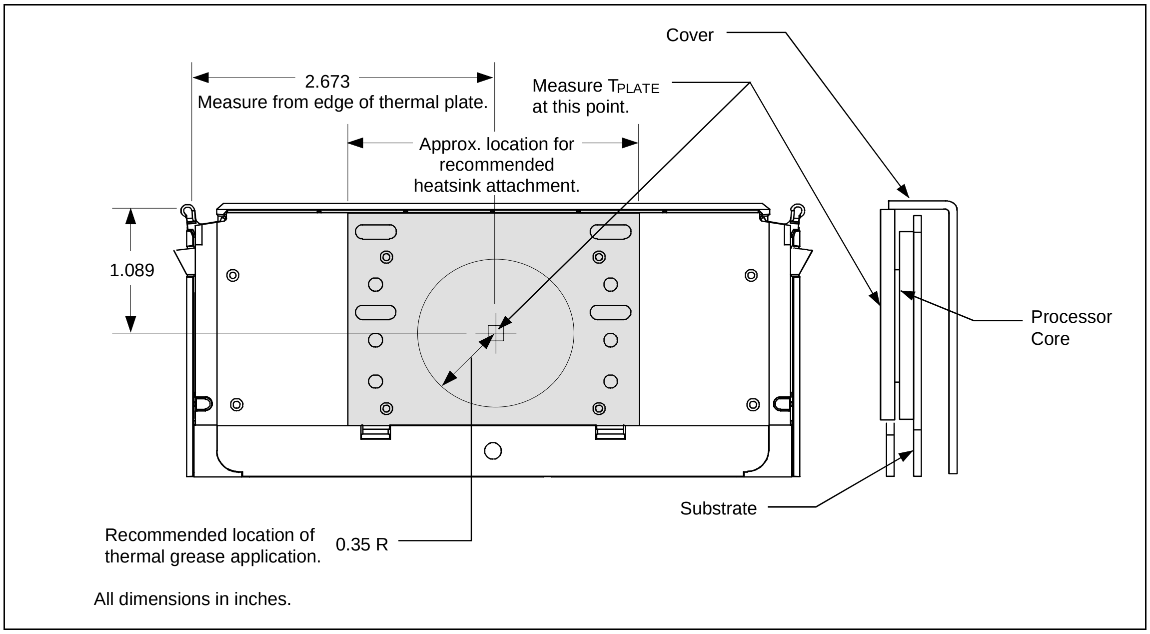
7.2.1 Measurements for Thermal Specifications

To appropriately determine the thermal properties of the system, measurements must be made. Guidelines have been established for proper techniques for measuring processor temperatures. The following sections describe these guidelines for measurement.

7.2.1.1 Thermal Plate Measurements

To ensure functionality and reliability, the S.E.C.C. processor is specified for proper operation when T_{plate} (thermal plate temperature) is maintained at or below 70°C. The surface temperature of the thermal plate directly above the center of the processor core is measured. Figure 7-6 shows the location for T_{plate} measurement.

Figure 7-6. Processor Thermal Plate Temperature Measurement Location



Special care is required when measuring the T_{plate} temperature to ensure an accurate temperature measurement. Thermocouples are often used to measure T_{plate}. Before any temperature measurements are made, the thermocouples must be calibrated. When measuring the temperature of a surface which is at a different temperature from the surrounding local ambient air, errors could be introduced in the measurements. The measurement errors could be due to having a poor thermal contact between the thermocouple junction and the surface of the thermal plate. Errors can also occur from heat loss by radiation, convection, and/or conduction through thermocouple leads or heat loss through contact between the thermocouple cement and the heatsink base. To minimize these measurement errors, the following approach is recommended:

- Use 36 gauge or finer diameter K, T, or J type thermocouples.
- Ensure that the thermocouple has been properly calibrated.
- Attach the thermocouple bead or junction to the top surface of the thermal plate at the location specified in Figure 7-6 using high thermal conductivity cements.
- The thermocouple should be attached at a 0° angle if there is no heatsink interference with the thermocouple attach location or leads.
- The thermocouple should be attached at a 90° angle if a heatsink is attached to the thermal plate and the heatsink covers the location specified for T_{plate} measurement.
- The hole size through the heatsink base to route the thermocouple wires out should be smaller than 0.150" in diameter.
- Make sure there is no contact between the thermocouple cement and heatsink base. Contact will affect the thermocouple reading.

7.3 S.E.C.C.2 and FC-PGA Metrology

This section describes the procedure for measuring the core junction temperature for Pentium® III processors in the S.E.C.C.2 and FC-PGA package. The metrology involves use of the High Power Application software ("HIPWR30.EXE") to perform system level analysis of cooling solutions. Using the methodologies described in this section, a system designer will be able to validate system cooling solutions for compatibility with the specified processor worst-case power consumption. Two specific measurements are involved, the processor core temperature utilizing the on-die thermal diode and the L2 cache BSRAM (if applicable) using a temperature probe on the BSRAM case (see "BSRAM Case Temperature Measurement Procedure" on page 47).

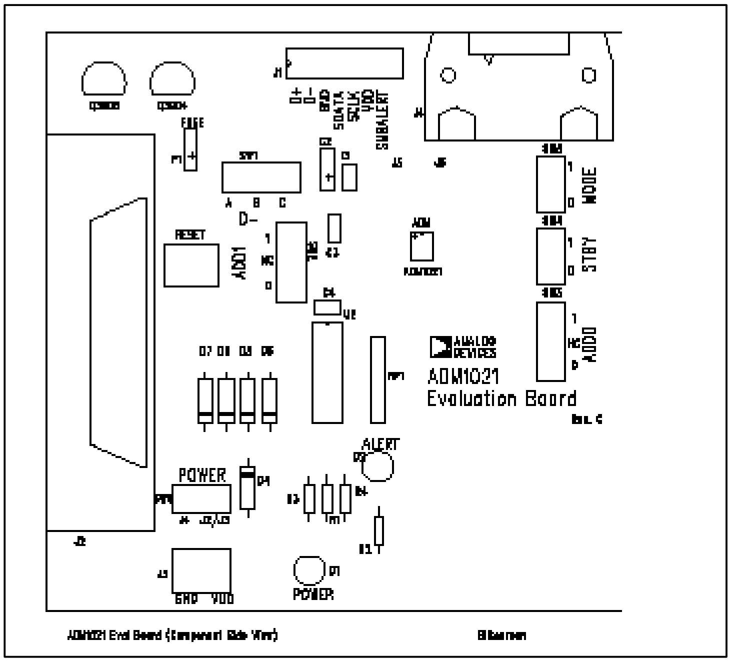
Note: While it is tempting to place a measurement device on the top of the S.E.C.C.2-OLGA package, the results can not be correlated to $T_{junction}$. Extensive experiments conducted by Intel using a top of the OLGA package measurement method proved the results were very erratic.

7.3.1 Junction Temperature Measurement Kit Description

The measurement of the junction temperature of a live processor using S.E.C.C.2 or FC-PGA packaging technology is critical for validating an OEM chassis and heat sink thermal design. A thermal diode is independently routed off the processor core to the SC242 connector or PGA370 Socket to assist in evaluating the junction temperature. The Analog Devices EVAL-ADM1021 kit is available to measure the temperature using the thermal diode. The kit is easy to use and requires no diode calibration. An alternate kit could be used in place of the Analog Devices kit, however, it is the responsibility of the user to ensure the correct offsets are determined. An alternate kit is available from Maxim Integrated Products with model number MAX1617EV. See Appendix A on page 57 for details on electrical hookup and operation procedures for this kit.

The Analog Devices EVAL-ADM1021 Kit is a tool provided by Analog Devices that includes the ADM1021 temperature sensor IC and all the additional circuitry and software needed to take temperature measurements with the ADM1021 and a typical PC (see Figure 7-7 for the layout of the kit board). The ADM1021 is essentially an 8 bit A/D converter and integrated controller which measures the difference between the voltage drop across a diode using 2 exciting currents to derive a junction temperature. The 8 bit temperature data is accessed by external applications via the 2-wire SMBus. The kit conditions the output from the ADM1021 to be read by a standard 25 pin parallel port terminal on a PC. Software is included with the kit to display temperature measurements on a PC running Windows 3.1 or Windows 95/98 OS. See the ADM1021 and Analog Devices EVAL-ADM1021 kit datasheets for more detailed information on the measurement tools.

Figure 7-7. Layout of the Analog Devices ADM1021 Test Board



Equipment Needed:

- 1 Analog Devices EVAL-ADM1021 Kit from Analog Devices Products[1] (software included)
- 1 Pentium class PC with available parallel port and Windows 3.1 or Windows 95/98 OS to take temperature measurements (measuring PC)
- 1 standard printer cable
- 1 twisted, shielded pair cable, up to 56” long, 24 gauge stranded copper
- 1 insulated wire, 24 gauge stranded copper, same length as the shielded pair cable (up to 56” long)
- 1 soldering iron
- HIPWR30.EXE application (available from your local Intel field sales representative)

---

[1] Analog Devices
One Technology Way
P.O. Box 9106
Norwood, MA 02062-9106, USA
Tel. 781-329-4700
Fax. 781-326-8703
http://www.analog.com

7.3.2 Junction Temperature Measurement Procedure

The exact procedure used to perform a test may vary slightly depending on the measurement kit used and whether the software has already been installed on a test/host system. Please vary the procedure as appropriate.

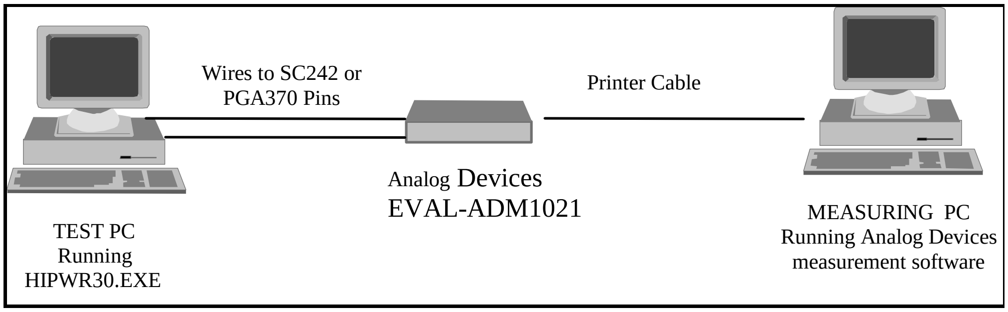
The recommended procedure for using an Analog Devices test kit for the first time is as follows:

1. Establish electrical connections.
2. Install the measurement software on the test PC.
3. Perform a no-power test.
4. Perform a power test.
5. Perform a validation test.
6. Complete calculation to determine if thermal solution is keeping the processor within specified $T_{junction}$.

7.3.2.1 Electrical Hookups for S.E.C.C. and S.E.C.C.2 Processors

This section outlines the electrical connectivity for the Analog Devices EVAL-ADM1021 Kit to measure the on-die diode. Figure 7-8 is a diagram of the test setup.

Figure 7-8. Test Measurement Setup



The following steps detail the electrical connection procedure:

1. Remove motherboard from test PC.

2. Strip insulation off ends of insulated wire and twisted, shielded pairs, and tin wire tips.

3. Solder the 56” insulated wire (this wire can be shorter) to the SC242 connector ground pin A10 (Vss).

4. **Ensure that any motherboard thermal sensor is disconnected from the processor. If the motherboard provides zero ohm resistors for this purpose, remove them, otherwise cut the traces going to pin B14 and B15. Measurement errors may result if this step is omitted.**

5. Solder 1 wire of 56” twisted, shielded pair to SC242 connector pin B14/THERMDP (diode anode).

6. Solder the other wire of 56” twisted, shielded pair to SC242 connector pin B15/THERMDN (diode cathode). See Figure 7-9 and Figure 7-10.

Figure 7-9. SC242 Connector pins

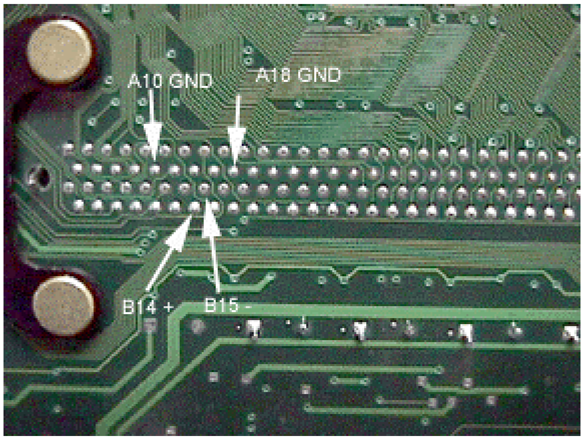
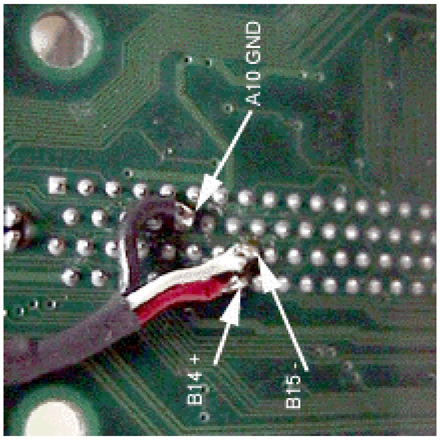


Figure 7-10. Connecting insulated wires to SC242 connector



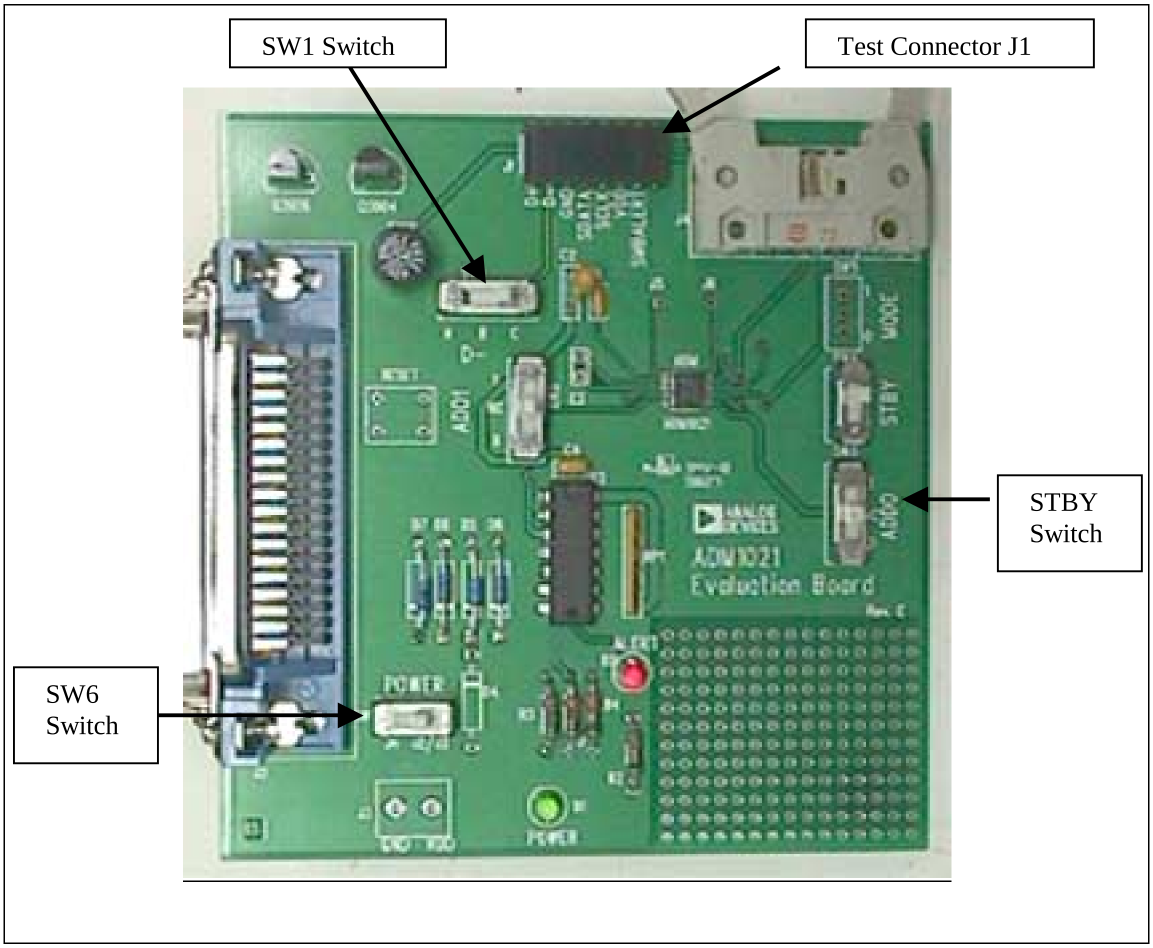
7. For reduced noise conditions it is recommended to solder the shield of the twisted pair to ground on the processor side. An alternate Vss pin on the SC242 connector, such as A18, can be used.

8. Tape the ground wire and twisted, shielded pair wires to the backside of the motherboard to relieve stress on the solder joints. Route wires out to edge of motherboard where there is sufficient clearance to allow wires to pass through.

9. Replace motherboard in chassis (you may wish to take room temperature measurements on processor before replacing all chassis components to verify solder joints).

10. Route the wires out of the chassis through a PCI slot (or other convenient hole in chassis. Make sure the wires do not obstruct any critical airflow paths.
11. Verify that the switch #1, SW1, (See Figure 7-10) in the ADM1021 is in the “C” position for remote monitoring of temperature.

Figure 7-11. ADM1021 Test Board Switches



12. Switch # 6 (SW6 or POWER) must be in the “J2/J3” position for printer cable power. See Figure 7-11.

13. Switch # 3 (SW3 or STBY) must be in the “1” position. See Figure 7-11.

14. Solder a Three-pin jumper connector to J1. See Figure 7-12 and Figure 7-13.

Figure 7-12. Test board with jumper connections. Top side view

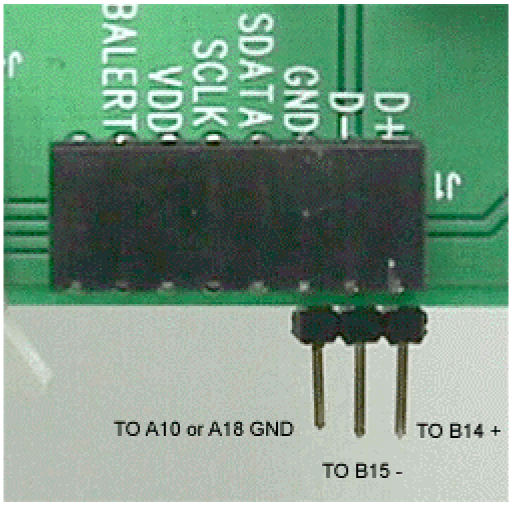
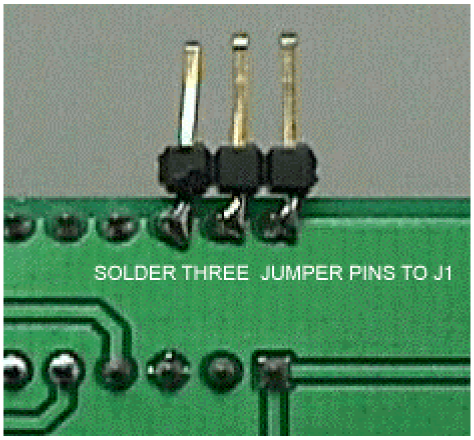


Figure 7-13. Test board with jumper connections. Bottom side view



15. Connect the other end of the twisted pair cable to the three jumper pins on J1on the ADM1021 card. The positive lead (coming from B14) to D+, the negative lead (coming from B15) to D- and the shield to GND. See Figure 7-12 and Figure 7-13.

16. Using the parallel port cable, connect measuring PC to kit.

17. Proceed to software installation.

7.3.2.2 Electrical Hookups for FC-PGA Processors

Use the following procedure for connecting an FC-PGA processor in a PGA370 socket to the kit. Remove motherboard from test PC.

1. Strip insulation off ends of insulated wire and twisted, shielded pairs, and tin wire tips.
2. **Ensure that any motherboard thermal sensor is disconnected from the processor. If the motherboard provides zero ohm resistors for this purpose, remove them, otherwise cut the traces going to AL31 and AL29. Measurement errors may result if this step is omitted.**
3. Solder a shielded twisted pair cable to the PGA370 socket on the target motherboard. AL31 (+), AL29 (-) and the shield to AM30 (ground). See Figure 7-14 and Figure 7-15.

Figure 7-14. Electrical Connections for an FC-PGA processor in a PGA370 socket

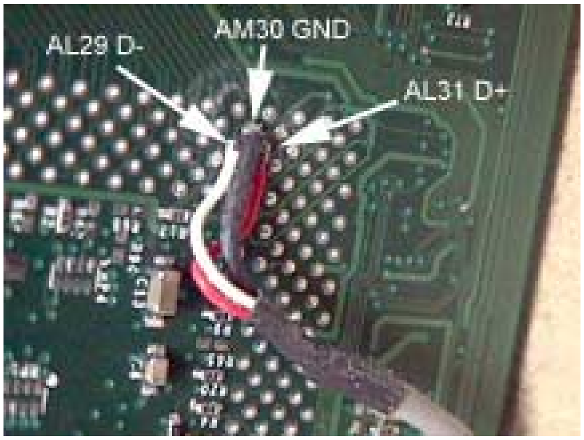
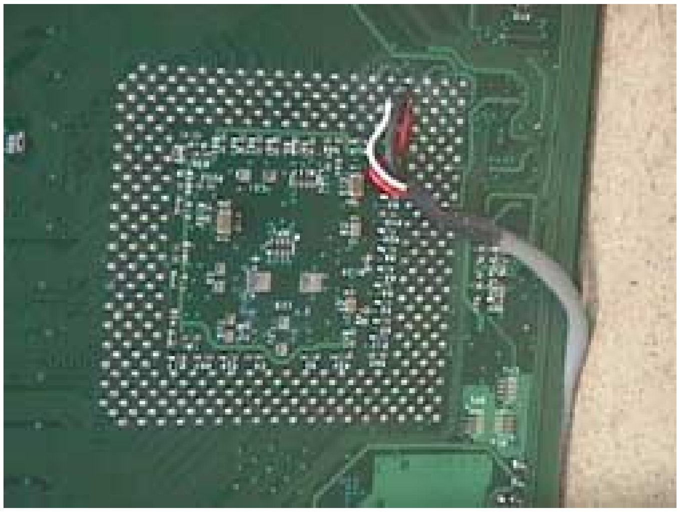


Figure 7-15. Back side of motherboard with PGA370 connections



4. Tape the ground wire and twisted, shielded pair wires to the backside of the motherboard to relieve stress on the solder joints. Route wires out to an edge of motherboard with enough clearance to allow wires to pass through.

5. Replace motherboard in chassis (you may wish to take room temperature measurements on processor before replacing all chassis components to verify good solder joints).

6. Route the wires out of the chassis through a PCI slot (or other convenient hole in chassis). Make sure the wires do not obstruct any critical airflow paths.

7. Connect the other end of the twisted pair cable to the three jumper pins on connector “J1” on the ADM1021 card. The positive lead (coming from AL31) to “D+”, the negative lead (coming from AL29) to “D-“, and the shield to “GND”. See Figure 7-12 and Figure 7-13.

8. Using the parallel port cable, connect measuring PC to the ADM1021 test board.

9. Proceed to software installation.

7.3.2.3 Software Installation

1. Install the software for the Analog Devices EVAL-AD1021 Kit according to the directions that come with the kit. The document is titled Evaluation Board for Microprocessor System Temperature Monitor or EVAL-ADM1021. This documentation should come in the box with the test kit. Please contact Analog Devices for additional copies of the documentation.

2. Proceed to no-power (to test PC) measurement.

7.3.2.4 No-Power (To Test PC) Measurement

This section is optional and describes how to take no-power (on the test PC) temperature measurements on the processor diode. Measuring a no-power processor temperature is useful in verifying the diode electrical connections and proper kit operation.

1. Start the test program from the floppy or hard drive by starting the Analog Devices application.
2. Follow the directions supplied by Analog Devices in the document titled *Evaluation Board for Microprocessor System Temperature Monitor or EVAL-ADM1021*.
3. If there are no addressing problems, a window containing the temperature measurement and data collection control features will start up. If there are slave addressing problems, check to make sure that all electrical connections are properly made and electrical switches are in their correct positions. If that does not solve the addressing problem, please refer to the Analog Devices EVAL-ADM1021 data sheet to resolve the problem.
4. Select a measurement rate of 1 Hz.
5. The temperatures displayed should read ambient temperature (provided the test processor is not warm from recent power-on).
6. Proceed to power-on temperature measurement.

7.3.2.5 Power-On (To Test PC) Temperature Measurement

This process outlines how to use the processor diode to take junction temperature measurements while the processor is powered on. This is the procedure that should be used to validate chassis and heat sink thermal designs while running the high power application software.

1. Turn on the test PC and run the high power application software.
2. Allow the High Power Application software to run for at least 1 hour to allow all chassis components to reach thermal equilibrium.
3. Note temperature displayed in the "remote" box. This is the test processor $T_{\text{junction-HIPWR30}}$ temperature.
4. The test setup is ready for performing a thermal solution validation test.

7.3.3 BSRAM Case Temperature Measurement Procedure

To ensure functional and reliable operation, the L2 Cache BSRAM case temperature ($T_{\text{case-BSRAM}}$) should be maintained at or below the maximum $T_{\text{case-BSRAM}}$ and at or above the minimum $T_{\text{case-BSRAM}}$ specified in the processor datasheet. Figure 7-16 shows the location for the $T_{\text{case-BSRAM}}$ measurement, assuming no external heating factors that cause other areas of the BSRAM case to reach higher temperatures. Before taking the $T_{\text{case-BSRAM}}$ measurement, execute the HIPWR30.EXE utility for approximately one (1) hour to maximize power dissipation of the BSRAM devices and allow for a steady-state reading. To select the L2 cache power portion of the utility execute with the "/L" switch from a DOS command window: "HIPWR30 /L".

Thermocouples are used to measure $T_{case\text{-}BSRAM}$. Special care is required to ensure an accurate temperature measurement. Before taking any temperature measurements, the thermocouples must be calibrated. When measuring the temperature of a surface, errors can be introduced in the measurement if not handled properly. Such measurement errors can be due to a poor thermal contact between the thermocouple junction and the surface of the case, conduction through thermocouple leads, heat loss by radiation and convection, or contact between the thermocouple cement and the heatsink base. To minimize these errors, the following approach is recommended:

1. Use 36 gauge or finer diameter K, T, or J type thermocouples.
2. Attach the thermocouple bead or junction using high thermal conductivity cements at the center of the top of the BSRAM package. See Figure 7-16.
3. Ensure the thermocouple is attached at a 0° angle if no heat sink makes contact with the BSRAM case. If a heat sink makes contact with the BSRAM case, but the heat sink does not cover the location specified for $T_{case\text{-}BSRAM}$ measurement, the thermocouple should be attached at a 0° angle. The thermocouple should be attached at a 90° angle if a heat sink makes contact with the BSRAM case and the heat sink covers the location specified for $T_{case\text{-}BSRAM}$ measurement (refer to Figure 7-17).
4. Drill a hole through the heat sink base to route the thermocouple wires out. Ensure this hole is smaller than 0.150" in diameter.
5. Make sure there is no contact between the thermocouple cement and heat sink base. This contact will affect the thermocouple reading.

Figure 7-16. BSRAM Case Temperature (Tcase-BSRAM) Measurement Location

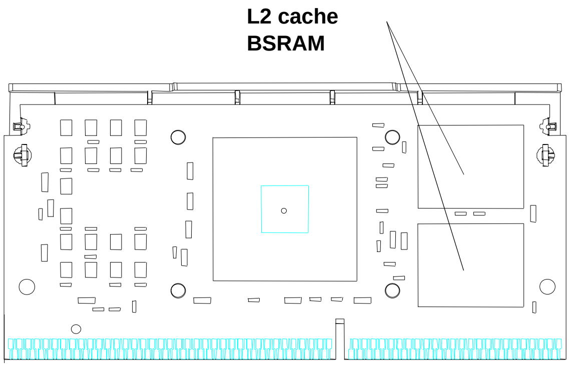
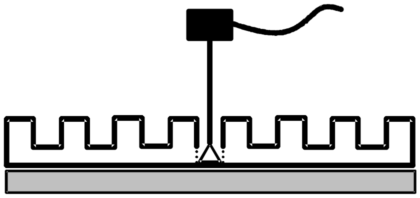


Figure 7-17. Technique for Measuring with 90° Angle Attachment



7.3.4 About the HIPOWER Application

The High Power Application software (a.k.a. “HIPWR30.EXE”) is intended for thermal evaluation purposes only. This software is not a general-purpose application. The software does not generate the absolute worst-case thermal power dissipation as defined in the processor’s datasheet. Differences between the observed thermal power measurements and the maximum power dissipation indicated in the datasheet can be attributed to process variation, manufacturing tester guard-bands, system configuration differences, and potential High Power Application software optimizations. This software does provide system designers with an application nearing worst-case power consumption for the analysis and validation of system cooling solutions.

All systems should be designed with the ability to dissipate the worst case thermal power indicated in the datasheet. The High Power Application software, utilizing the methodologies presented in this document, can enable system designers to design and validate robust cooling solutions that can adequately cool the processor at the maximum specifications.

The High Power Application software maximizes the current consumption of the processor core. All execution stages and various functional units of the core and L1 cache are fully utilized. The software performs minimal system bus accesses, with minimal L2 cache utilization. This mode of operation produces a large amount of thermal power from the processor.

A newer High Power Application (“HIPWR30.EXE”) incorporates the functionality of the “HIPWR30.EXE” utility and a L2 cache exerciser. “HIPWR30.EXE” can be run in 2 modes, one in which it only exercises the processor’s core power and another where it only runs L2 cache utilization code. The mode that concentrates on the processor’s core is the same application as HIPWR30.EXE and can be run by executing “HIPWR30 **/P**” at the DOS command window. For the purpose of this document and the procedures that involve the use of a High Power Application, “HIPWR30.EXE” is equivalent to using “HIPWR30 /P”. For all references to “HIPWR30.EXE”, “HIPWR30 /P” can be used alternatively.

The “HIPWR30.EXE” utility also has a mode for L2 cache utilization that can be used to produce a large amount of thermal power from the L2 cache BSRAMS. To execute this utility in the L2 cache mode execute “HIPWR30 **/L**” at the DOS command window.

7.3.5 Executing the High Power Application Software

The High Power Application software is a 32 bit Windows* NT[*]or Windows* 95/98 application. The application should be executed from a DOS window command prompt from within the Windows NT or Windows 95/98 environment, and not from a DOS only environment. The High Power Application software puts the processor into an infinite loop and locks the command prompt environment. The “HIPWR30.EXE” utility has an on-screen message with version number information and usage help. To halt execution of the application, use the Windows NT Task Manager* or Windows 95/98 Task Bar* to stop execution of the command prompt environment. For maximum processor power consumption, the software should be the only application executing on the system under evaluation. It is recommended that the Windows NT or Windows 95/98 operating environment be configured to the default OS settings.

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[*] Third-party brands and names are the property of their respective owners.

7.4 Thermal Validation Methodology

The High Power Application software can be used to design and validate processor cooling solutions compatible with the maximum power dissipation values specified in the processor's datasheet. Two methodologies are presented for validating worst-case processor compliance using this software combined with processor junction temperature measurements. Section 7.4.1 presents a simplified approach that system designers can use to check for worst-case processor power dissipation compatibility. For those designs that do not prove compatible or appear to be marginal using the simplified approach, Section 7.4.2 provides a more detailed, accurate methodology for validating worst-case power compliance. The detailed approach does require a significant increase in effort over the simplified approach, but provides a more accurate measurement method using specific characteristics of the processor under analysis. Section 7.4.3 describes a method for BSRAM case temperature validation.

7.4.1 Simplified Validation Method

The technique described here can be used to verify a system under test from $T_{ambient}$ to $T_{ambient\text{-}max}$. Performing a simplified validation of the cooling solution on the junction temperature for maximum specified processor power dissipation values requires the measurement of $T_{junction\text{-}HIPWR30}$ and $T_{ambient\text{-}local}$ temperatures while executing the High Power Application software. The following steps detail the validation method:

1. The system and processor under analysis should be prepared to measure both $T_{junction\text{-}HIPWR30}$ as described in Section 7.3 and $T_{ambient\text{-}local}$ in Section 7.1.4.

2. Once the system is ready for data collection, the "HIPWR30.EXE" High Power Application software should be executed.

3. With "HIPWR30.EXE" executing, after the temperatures have stabilized, gather the $T_{junction\text{-}HIPWR30}$ and $T_{ambient\text{-}local}$ temperature measurements.

4. Calculate the projected junction temperature at max power, $T_{junction\text{-}proj}$, using Equation 1and compare it to the datasheet maximum allowable junction temperature specification ($T_{junction\text{-}max}$). $T_{junction\text{-}offset}$ characterizes the temperature difference between the sensor diode and the hottest part of the die and is available in the processor datasheet. The measurement error, $T_{junction\text{-}error}$, is the estimated measurement error found in the diode temperature measurement kit. It is usually available in the diode kit datasheet.

Equation 1. Simplified Validation Junction Temperature

$$T_{junction\text{-}proj} = T_{junction\text{-}HIPWR30} + (T_{ambient\text{-}max} - T_{ambient\text{-}local}) + T_{junction\text{-}offset} + T_{junction\text{-}error}$$

A properly cooled processor should have a final validation junction temperature less than or equal to the datasheet maximum junction temperature specification, $T_{junction\text{-}max}$. If the final validation junction temperature result is marginal, i.e. slightly above the specification, the detailed validation method may be necessary to provide a more accurate result based on actual processor power measurements.

Note: For systems with non-linear thermal behavior, like those with thermally controlled fan(s), the system designer should exercise caution to ensure that the processor temperature specifications are met given the dependencies on airflow and different fan activation patterns. The change in airflow effectively changes the $\Theta_{\text{junction-ambient}}$ of the processor's thermal solution. Therefore, the various system conditions should be evaluated when determining the worst-case target $T_{\text{ambient-max}}$, $T_{\text{ambient-local}}$, and $T_{\text{junction-HIPWR30}}$.

If the measured $T_{\text{junction-HIPWR30}}$ temperature for the measured $T_{\text{ambient-local}}$ exceeds the value specified in the graph, then the detailed measurement approach presented in Section 7.4.2 should be used. The detailed approach incorporates the actual power consumed by the processor while executing the High Power Application software and the effectiveness of the particular cooling solution to eliminate guard-banding added to account for "HIPWR30.EXE" power dissipation variances across processors.

Example Simple Validation Calculation:

Determine whether a 600MHz processor is within maximum junction temperature specifications using the following specifications (always check the current datasheet for the most up to date specifications):

$T_{\text{junction-max}} = 82°C$ (from the appropriate Intel processor datasheet)

$T_{\text{junction-offset}} = 2.9°C$ (also from the datasheet)

$T_{\text{ambient-max}} = 45°C$ (the target worst case local ambient temperature)

$T_{\text{junction-error}} = 1°C$ (from the EVAL-ADM1021measurement kit datasheet)

If the following results were obtained from a validation test measurement:

$T_{\text{junction-HIPWR30}} = 68°C$

$T_{\text{ambient-local}} = 35°C$

Using Equation 1, the following $T_{\text{junction-proj}}$ is calculated:

$T_{\text{junction-proj}} = 68°C + (45°C - 35°C) + 2.9°C + 1°C = 81.9°C <= 82°C$ ($T_{\text{junction-max}}$)

Based on the result, this example processor's thermal solution is adequate in maintaining processor junction temperatures below the maximum allowable specifications.

7.4.2 Detailed Validation Method

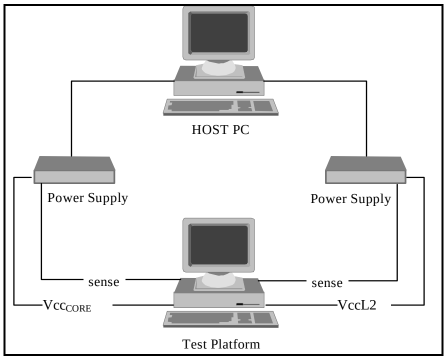
The detailed validation method uses the actual power dissipation values of the processor under test while running the High Power Application software combined with the effectiveness of the cooling solution to determine a projected $T_{\text{junction-proj}}$ temperature at the worst-case specifications. This projected temperature can then be used to determine junction temperature specification compliance.

7.4.2.1 Determining the High Power Application Software Power Consumption

Gathering valid processor power consumption and dissipation data requires the isolation of the processor power source from the power source of other system components. This isolation requires the use of external supplies to provide power to the processor. Isolation of the processor's power systems can be accomplished by masking the power source edge fingers of the processor from the baseboard power delivery paths. This isolation may be attained via modifications to either the system baseboard or the SC242/FC-PGA connector/baseboard connection.

The external supplies used to source the processor power should be able to provide voltage and current readings at regular intervals during system operation. This data may then be stored and analyzed for maximum and average power consumption figures. Figure 7-18 illustrates a test setup that may be used to collect power consumption data. External power supplies should be used to source both the Vcc_{CORE} and Vcc_{L2} power to gather data for the processor power consumption measurements. An isolated V_{TT} power supply is not required due to minimal activity of the system bus during execution of the High Power Application software. V_{TT} should be provided to the processor from the system V_{TT} supply.

Figure 7-18. Test Setup for Power Consumption Measurements



Current and voltage data should be sampled from the external power supplies several times per second over a span of several seconds. Increasing the number of data collection points will improve the precision of test results. While it is impossible to determine the absolute maximum power consumed by the processor using a periodic sampling methodology, average power consumption data can be derived. For the High Power Application software, this maximum power consumption value is an adequate approximation of the maximum thermal power dissipation of the processor.

7.4.2.2 Detailed Validation Approach

Detailed evaluation of the cooling solution's effectiveness in maintaining $T_{junction}$ requires the power dissipation data along with actual $T_{ambient\text{-}local}$ and $T_{junction\text{-}HIPWR30}$ temperatures while running the High Power Application software. This effectiveness is characterized by the junction to ambient thermal resistance ($\Theta_{junction\text{-}ambient}$) and should be calculated using the measured system $T_{ambient\text{-}local}$, $T_{junction\text{-}HIPWR30}$, and $P_{HIPWR30}$, as shown in Equation 2.

Equation 2. Thermal Junction to Ambient Thermal Resistance

$$\Theta_{\text{junction-ambient}} = (T_{\text{junction-HIPWR30}} + T_{\text{junction-offset}} + T_{\text{junction-error}} - T_{\text{ambient-local}}) \,/\, P_{\text{HIPWR30}}$$

The following example shows $\Theta_{\text{junction-ambient}}$ for an example system. $\Theta_{\text{junction-ambient}}$ should be calculated using actual system measurements and processor specifications:

Example Detailed Validation Calculation:

Determine whether a 500MHz processor is within maximum junction temperature specifications using the following specifications (always check the current datasheet for the most up to date specifications):

$T_{\text{junction-max}}$ = 90°C (from the appropriate Intel processor datasheet)

$T_{\text{junction-offset}}$ = 4.8°C (also from the datasheet)

$T_{\text{ambient-max}}$ = 45°C (the target worst case local ambient temperature)

$T_{\text{junction-error}}$ = 1°C (from the EVAL-ADM1021measurement kit datasheet)

P_{max} = 28 W (from datasheet)

If the following results were obtained from a detailed validation test measurement:

$T_{\text{junction-HIPWR30}}$ = 70°C

$T_{\text{ambient-local}}$ = 40°C

P_{HIPWR30} = 25 W (measured power)

Using Equation 3, the following $\Theta_{\text{junction-ambient}}$ is calculated:

$$\Theta_{\text{junction-ambient}} = (70.0\ ^\circ\text{C} + 4.8\ ^\circ\text{C} + 1.0\ ^\circ\text{C} - 40.0\ ^\circ\text{C}) \,/\, 25.0\ \text{W} = 1.432\ ^\circ\text{C/W}$$

Using the calculated $\Theta_{\text{junction-ambient}}$ and measured system $T_{\text{ambient-local}}$, it is now possible to determine the projected processor junction temperature at the maximum specified processor junction power. This is accomplished using Equation 3.

Equation 3. Projected Junction Temperature at Maximum Power

$$T_{\text{junction-proj}} = (\Theta_{\text{junction-ambient}} * P_{\text{max}}) + T_{\text{ambient-max}}$$

If the calculated $T_{\text{junction-proj}}$ is lower than the specified maximum processor junction temperature, $T_{\text{junction-max}}$, then the system cooling solution is compatible with the maximum processor power specifications for a given core frequency.

Continuing the previous example to determine worst case processor compatibility:

Stated Conditions:

$T_{ambient\text{-}max}$ = 45 °C (maximum target local ambient temperature from system designer)

$T_{junction\text{-}proj} = (1.432\ °C/W * 28.0\ W) + 45.0\ °C = 85.1°C$

Since 85.1 °C is less than the specified maximum junction temperature of 90°C, the example cooling solution is in compliance with the processor thermal specifications.

7.4.3 BSRAM Case Temperature Validation Method

Once the $T_{case\text{-}BSRAM}$ has been measured for processors using BSRAM components, a simple equation can be used to determine compliance to the maximum BSRAM case temperature specifications. Equation 4 relates the measured case temperature running the High Power Application software for the L2 cache with the measured ambient temperature for a given target maximum ambient temperature and processor frequency. Equation 4 is valid for determining compliance to the maximum BSRAM case temperature requirements for processors using the S.E.C.C.2-OLGA package.

Equation 4. BSRAM Case Temperature Limit at Maximum Power

$$T_{case\text{-}BSRAM} \le 105.56 - 0.0392 * \text{frequency} - (T_{ambient\text{-}max} - T_{ambient\text{-}local})$$

Where frequency is the processor's operating frequency in MHz. Equation 4 was developed to accommodate different frequencies. The 105.56 in the equation is from empirical data and has nothing to do with the BSRAM case specified maximum temperature.

In determining compliance of a 450MHz processor to the $T_{case\text{-}BSRAM}$ specification the following example illustrates the use of the simplified equation:

Stated Conditions:

Processor Core Freq. = 450 MHz

$T_{ambient\text{-}local}$ = 47.1 °C (measured temperature)

$T_{case\text{-}BSRAM}$ = 80.6 °C (measured temperature running HIPWR30 /L)

$T_{ambient\text{-}max}$ = 45.0 °C (maximum target ambient temperature from system designer)

Using Equation 4, we have:

$$T_{case\text{-}BSRAM} \le 105.56 - 0.0392 * \text{frequency} - (T_{ambient\text{-}max} - T_{ambient\text{-}local})$$

$$T_{case\text{-}BSRAM} \le 105.56 - 0.0392 * 450 - (45.0 - 47.1)$$

$$T_{case\text{-}BSRAM} \le 90.02$$

Since the measured $T_{case\text{-}BSRAM}$ 80.6 °C is less than 90°C, the calculated maximum case temperature from Equation 4, the example cooling solution is compliant with the example processor using the S.E.C.C.2 package.

8.0 Conclusion

As the complexity of today's microprocessors continues to increase, so do the power dissipation requirements. Care must be taken to ensure that the additional power is properly dissipated. Heat can be dissipated using passive heatsinks, fans and/or active cooling devices. Further thermal solutions can be achieved through the use of ducting.

The simplest and most cost effective method is to use an extruded heatsink and a system fan. The size of the heatsink and the output of the fan can be varied to balance size and space constraints with acoustic noise. This document has presented the conditions and requirements for properly designing a heatsink solution for an Intel Pentium III processor based system. Properly designed solutions provide adequate cooling to maintain the processor within thermal specifications. This is accomplished by providing a low local ambient temperature and creating a minimal thermal resistance between the processor core and the local ambient airflow. Active fan heatsinks or ducting can be used to cool the processor(s) if proper cover and package temperatures cannot be maintained otherwise. By maintaining the processor's cover temperature and processor core temperature at the values specified in the processor datasheet, a system can guarantee proper functionality and reliability of these processors.

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9.0 Appendix A – Using The Maxim 1617EV Junction Temperature Measurement Kit (S.E.C.C.2 only)

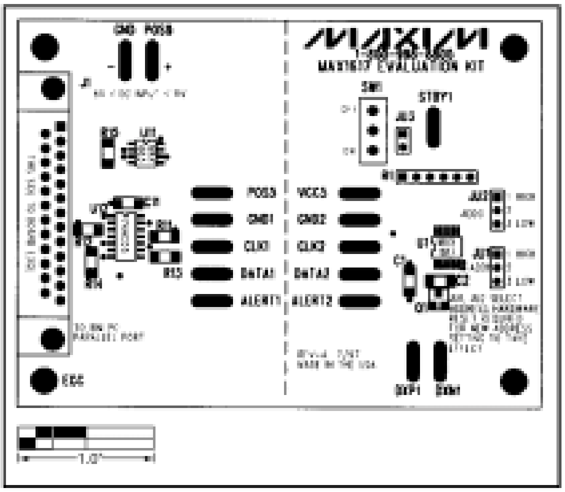
The purpose of this procedure is to explain how to take junction (die) level temperature measurements on live Intel SC242 processors in the SECC2 package technology with an OLGA processor core package using the Max1617EV kit. All electrical connections and software keystrokes needed to take no-power and power-on temperature measurements are included.

9.1 Kit Background

The measurement of the junction temperature of a live processor using SECC2 packaging technology and OLGA processor core is critical to validate an OEM chassis and heat sink thermal design. A thermal diode is independently routed off the processor core to the SC242 connector to assist in evaluating the junction temperature. In order to simplify the measurement of the diode temperature, it is recommended to use the Max1617EV kit. The advantage of using the EV kit is that it requires no calibration of the diode.

The Max1617EV kit is a tool provided by Maxim Integrated Products which includes the Max1617 temperature sensor IC and all the additional circuitry and software needed to take temperature measurements with the Max1617 and a typical PC (see Figure 9-1 for layout of the EV kit). The Max1617 is essentially an 8 bit A/D converter and integrated controller which measures the difference between the voltage drop across a diode using 2 exciting currents to derive a junction temperature. The 8 bit temperature data is accessed by external applications via the 2-wire SMBus. The EV kit conditions the output from the Max1617 to be read by a standard 25 pin parallel port terminal on a PC. Software is included with the EV kit to display temperature measurements on a PC running Windows 3.1 or Windows 95/98 OS. See the Max1617 and Max1617EV kit datasheets for more detailed information on the measurement tools.

Figure 9-1. Layout of Max1617EV Kit



Equipment Needed:

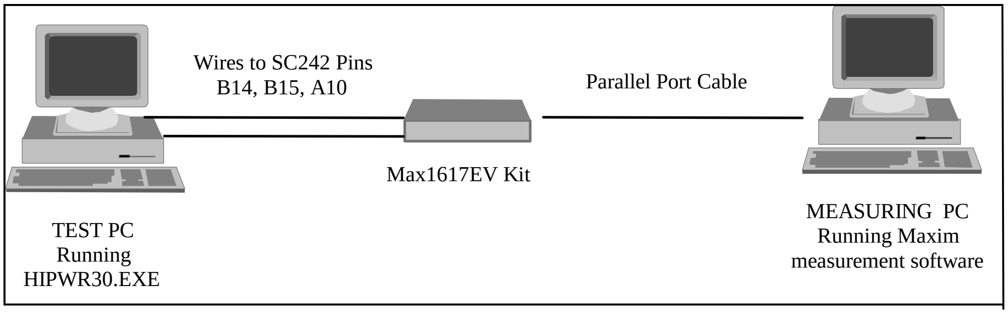
- 1 Max1617EV Kit from Maxim Integrated Products[2] (software included)
- 1 9V off-the-shelf battery
- 1 9V battery connector with extension wires
- 1 Pentium class PC with available parallel port and Windows 3.1 or Windows 95/98 OS to take temperature measurements (measuring PC)
- 1 parallel port cable with straight-through 25 pin connector, male-to-female type
- 1 twisted, shielded pair cable, up to 56” long, 24 gauge stranded copper
- 1 insulated wire, 24 gauge stranded copper, same length as the shielded pair cable (up to 56” long)
- 1 alligator clip wire (only to make room temperature measurements)
- 1 soldering iron
- 1 live chassis with processor diode to be evaluated (test PC)

9.2 Temperature Measurement Procedure

9.2.1 Electrical Hookups

This section outlines the electrical connectivity for the Max1617EV kit to measure the on-die diode. Figure 9-2 is a diagram of the test setup. For details on locating SC242 pins refer to Figure 8 of the SC242 Connector Design Guidelines, available at: http://developer.intel.com/.

Figure 9-2. Measurement Setup



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[2] Maxim Integrated Products
120 San Gabriel Drive
Sunnyvale, CA 94086
http://www.maxim-ic.com
1-800-998-8800

1. Remove motherboard from test PC.

2. Strip insulation off ends of insulated wire and twisted, shielded pairs, and tin wire tips.

3. Solder the 56” insulated wire to the SC242 connector ground pin A10 (Vss).

4. **Ensure that any motherboard thermal sensor is disconnected from the processor. If the motherboard provides zero ohm resistors for this purpose, remove them, otherwise cut the traces going to pin B14 and B15. Measurement errors may result if this step is omitted.**

5. Solder 1 wire of 56” twisted, shielded pair to SC242 connector pin B14/THERMDP (diode anode).

6. Solder the other wire of 56” twisted, shielded pair to SC242 connector pin B15/THERMDN (diode cathode).

7. For reduced noise conditions it is recommended to solder the shield of the twisted pair to ground on the processor side. An alternate V_{ss} pin on the SC242 connector, such as A18, can be chosen.

8. Tape the ground wire and twisted, shielded pair wires to the backside of the motherboard to relieve stress on the solder joints. Route wires out to edge of motherboard which has enough clearance to allow wires to pass through

9. Replace motherboard in chassis (you may wish to take room temperature measurements on processor before replacing all chassis components to verify good solder joints).

10. Route the wires out of the chassis through a PCI slot (or other convenient hole in chassis). Make sure the wires do not obstruct any critical airflow paths.

11. Solder the ground wire (pin A10) to GND1 pad on the Max1617EV kit substrate (see Figure 9-1).

12. Solder the diode anode wire (pinB14) to DXP1 pad on the Max1617EV kit substrate (see Figure 9-1).

13. Solder the diode cathode wire (pin B15) to DXN1 pad on the Max1617EV kit substrate (see Figure 9-1).

14. Solder 9V battery connector wires to GND and POS9 pads on the Max1617EV kit substrate, taking care to ensure correct polarity.

15. Use a soldering iron to remove the transistor component Q1 on the Max1617EV kit (just north of DXP1 and DXN1 pads in Figure 9-1).

16. Using the parallel port cable, connect measuring PC to Max1617EV kit.

9.2.2 Software Installation

This section describes how to install the temperature measurement software.

17. Insert the software disk which comes with the Max1617EV kit into floppy drive.

18. Start the Windows* Program manager application.

19. Select the A:\ drive.

20. To install the software on the hard drive, run the INSTALL.EXE application. This will automatically set up a program group containing the test software, a help document, and a un-install application. The test software may be run from a floppy disk.

9.2.3 No-Power (test PC) Measurement

This section is optional and describes how to take no-power (on the test PC) temperature measurements on the processor diode. It is useful to gain confidence in the Max1617EV kit accuracy, however, it requires an extra electrical hookup.

21. Plug 9V battery into battery connector
22. Slide switch, SW1 on EV kit, from “off” to “on”
23. Using wire with alligator clips ends, short together the wires connected to GND1 (Vss) and DXN1 (diode cathode) on the EV kit. This step is needed for room temperature measurements only, as the diode is not properly biased when the test processor is not running.
24. Start the test program from the floppy or hard drive by starting the MAX1617.EXE application. A dialog box will appear listing three possible parallel port addresses.
25. If the auto-detect routine was successful in finding the EV kit, one of the addresses will automatically be selected. Select “OK”.
26. A window containing the temperature measurement and data collection control features will start up. (If there are slave addressing problems, check to make sure that all electrical connections are properly made and that the switch is in the “on” position. If that does not solve the addressing problem, please refer to the Max1617 data sheet to resolve the problem.) If none of the addresses are selected, there is probably a problem with the parallel port connection with the EV kit. Close the application and check the connections.
27. Select a measurement rate of 1 Hz. Temperature measurements from the processor diode will automatically update in the box labeled “Remote”. The temperatures displayed in the “local” box are measurements taken using the Max1617 on die temperature sensor. The temperatures displayed should read ambient temperature (provided the test processor has not been heated up). This is typically around 25 °C.

9.2.4 Power-On (test PC) Temperature Measurement

This process outlines how to use the processor diode to take temperature measurements while the processor is powered on. This is the procedure that should be used to validate chassis and heat sink thermal designs while running the High Power Application software.

28. Plug 9V battery into battery connector.
29. Slide switch, SW1 on EV kit, from “off” to “on”.
30. *Important:* Remove alligator clips from between GND1 and DXN1 if used for no-power measurement.
31. Start the test program from the floppy or hard drive by starting the MAX1617.EXE application. A dialog box will appear listing 3 possible parallel port addresses.

32. If the auto-detect routine was successful in finding the EV kit, one of the addresses will automatically be selected. Select “OK”. A window containing the temperature measurement and data collection control features will start up. (If there are slave addressing problems, check to make sure that all electrical connections are properly made and that the switch is in the “on” position. If that does not solve the addressing problem, please refer to the Max1617 data sheet to resolve the problem.) If none of the addresses are selected, there is probably a problem with the parallel port connection with the EV kit. Close the application and check the connections.

33. Select a measurement rate of 1 Hz.

34. Temperature measurements from the processor diode will automatically update in the box labeled “Remote”. The temperatures displayed in the “local” box are measurements taken using the Max1617 on die temperature sensor. Temperatures will be unpredictable at this time as the diode is not properly biased until the test PC is powered up.

35. Turn on the test PC and run the high power application software.

36. Allow the High Power Application software to run for at least 1 hour to allow all chassis components to come to thermal equilibrium.

37. Note temperature displayed in “remote” box. This is the test processor $T_{junction\text{-}HIPWR30}$ temperature.