



# Intel<sup>®</sup> Pentium<sup>®</sup> 4 Processor and Intel<sup>®</sup> Celeron<sup>®</sup> Processor in the 478-Pin Package

Thermal Design Guide for Embedded Applications

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*January 2004*





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# Contents

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<b>1.0</b>	<b>Introduction</b> .....	7
1.1	Document Purpose .....	7
1.2	Document Scope .....	7
1.3	Related Documents .....	7
1.4	Definition of Terms.....	8
1.5	Design Guidelines.....	9
<b>2.0</b>	<b>Mechanical Guidelines</b> .....	10
2.1	Processor Package.....	10
2.2	System Board Keep-Out/Keep-In Requirements .....	13
2.3	Interface to the System Board: Clip and Retention Mechanism .....	18
2.3.1	Retention Mechanism .....	18
2.3.2	Clip.....	18
2.3.2.1	Heatsink Attach Clip Usage .....	18
2.3.2.2	Clip Structural Considerations .....	18
2.3.2.3	Additional Clip Mechanical Design Guidelines.....	19
2.3.2.4	Additional Requirements for Solutions Using Reference Heatsink and Reference Clip.....	19
2.4	Acoustic Performance.....	21
2.5	Fan Requirements .....	22
2.5.1	Electrical Requirements.....	22
2.5.2	Variable Speed Fan .....	22
2.6	Wire/Fan Power Connector .....	22
2.6.1	Reliability Requirements .....	23
2.7	Mechanical Performance Requirements.....	23
2.7.1	Structural Requirements .....	23
2.7.1.1	Platform Support.....	24
2.7.1.2	Random Vibration .....	24
2.7.1.3	Shock Test.....	24
2.8	Miscellaneous Requirements.....	25
2.8.1	Material and Recycling Requirements .....	25
2.8.2	Safety Requirements .....	25
<b>3.0</b>	<b>Thermal Design Guidelines</b> .....	26
3.1	Processor Case Temperature.....	26
3.2	Processor Power .....	27
3.3	Thermal Solution Requirements .....	27
3.4	Recommended Thermal Solutions .....	28
3.4.1	Desktop/ATX Form Factor .....	28
3.4.1.1	Intel RPG Enabled Active Heatsink Design .....	28
3.4.2	1U and Double-Slot Compact-PCI Thermal Solutions.....	29
3.5	Interface to Package Requirements .....	30
3.6	Thermal Interface Material Requirements .....	31
3.7	Package and Socket Load Specifications.....	32
<b>4.0</b>	<b>Intel® 845 Chipset MCH Thermal Solution</b> .....	33
4.1	Package Thermal Design Requirements .....	33

4.2	Thermal Interface Material.....	33
4.3	Thermal Solution Attachment .....	33
<b>5.0</b>	<b>Characterizing Cooling Performance Requirements .....</b>	<b>37</b>
5.1	Example.....	38
5.2	Looking at the Entire Thermal Solution.....	39
<b>6.0</b>	<b>Thermal Metrology for the Intel® Pentium® 4 and Celeron® Processors for Embedded Applications.....</b>	<b>40</b>
6.1	Local Ambient Temperature Measurement Guidelines .....	40
6.2	Processor Case Temperature Measurement Guidelines.....	41
6.2.1	Thermocouple Attachment.....	42
6.2.2	Heatsink Preparation – Rectangular (Cartesian) Geometry .....	44
6.2.3	Heatsink Preparation – Radial (Cylindrical) Geometry .....	45
6.2.4	Thermal Measurement.....	46
<b>7.0</b>	<b>Thermal Test Vehicle Information.....</b>	<b>47</b>
7.1	Thermal Test Die .....	47
<b>8.0</b>	<b>Mechanical Validation .....</b>	<b>48</b>
8.1	Test Sequence.....	48
8.2	Post-Test Pass Criteria.....	48
8.3	Recommended BIOS/CPU/Memory Test Procedures.....	49
<b>9.0</b>	<b>Retention Mechanism .....</b>	<b>50</b>
<b>10.0</b>	<b>Vendor List.....</b>	<b>53</b>

## Figures

1	Processor Package Specification .....	11
2	FC-PGA2 Package Mechanical Drawing.....	12
3	System Board Keep-Out Footprint Definition and Height Restrictions – Page 1 of 2.....	14
4	System Board Keep-Out Footprint Definition and Height Restrictions – Page 2 of 2.....	15
5	Volumetric Keep-In for ATX/Desktop Form Factor Enabling Components.....	16
6	Volumetric Keep-In for 1U and Double Slot CompactPCI Form Factor Enabling Components .....	17
7	Heatsink, Fan, and Shroud Assembly Volumetric Keep-In, ATX Form Factor .....	20
8	Heatsink, Fan, and Shroud Assembly Volumetric Keep-In, 1U and Double-Slot Compact-PCI Form Factor.....	21
9	Fan Connector Electrical Pin Sequence .....	23
10	Random Vibration PSD .....	24
11	Shock Acceleration Curve .....	25
12	Processor IHS Temperature Measurement Location .....	26
13	Thermal Resistance Values for Various Operating Temperatures of the Intel® Pentium® 4 Processor at 2.0 GHz .....	28
14	Intel RPG Enabled Thermal Solution.....	29
15	Double-Slot Compact-PCI Thermal Solution Z-Height Constraints .....	30
16	1U Thermal Solution Z-Height Constraints.....	30
17	Board Keep-Out and Anchor Placement Position for MCH .....	34

18	Intel® Recommended Enabled Thermal Solution for MCH.....	35
19	Processor Thermal Resistance Relationships .....	38
20	Guideline Locations for Measuring Local Ambient Temperature.....	41
21	Desired Thermocouple Location.....	42
22	Location of Kapton* Tape for Temporary Bond .....	43
23	Thermocouple Bead Covered with Epoxy .....	43
24	Grooved Heatsink Bottom.....	44
25	Heatsink Bottom Groove Dimensions.....	44
26	Radial Heatsink Geometry.....	45
27	Suggested Structural Test Sequence.....	48
28	Retention Mechanism.....	50
29	Retention Mechanism Final Assembly.....	51

## Tables

1	Fan Performance Recommendation.....	23
2	Processor Thermal Specifications .....	27
3	Intel RPG Enabled Active Heatsink Part Numbers .....	29
4	Package Static and Dynamic Load Specifications.....	32
5	Thermal Design Requirements .....	33
6	Intel Part Number A67916-001 Included Components .....	36
7	Vendor List.....	53

## Revision History

Date	Revision	Description
January 2004	003	Added information about the Intel® Pentium® 4 at 2.8 GHz and Intel® Celeron® at 2.5 GHz processors. Changed cooling characteristics nomenclature from $\theta$ (theta) to $\Psi$ (psi).
November 2002	002	Updated product name to include Intel® Celeron® processor and 478-pin package
May 2002	001	Initial release

## 1.0 Introduction

This document describes thermal design guidelines for the Intel® Pentium® 4 processor in the 478-pin Micro-Flip Chip Pin Grid Array 2 package (μFC-PGA2) with 512-Kbyte L2 Cache and the Intel® Celeron® processor in the 478-pin μFC-PGA2 package with 128Kbytes L2 cache on the 0.13 micron process. Detailed mechanical and thermal specifications for these processors can be found in the *Intel® Pentium® 4 Processor with 512-KB L2 Cache on 0.13 Micron Process Datasheet* (order number 298643) and the *Intel® Celeron® Processor on 0.13 Micron Process in the 478-Pin Package Datasheet* (order number 251748).

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

### 1.1 Document Purpose

This document describes the thermal characteristics of the Intel Pentium 4 and Celeron processors for embedded applications and provides guidelines for meeting the thermal requirements imposed on single processor systems for embedded applications. The thermal solutions presented in this document are designed for embedded computing applications that use ATX, 1U Server, and double slot CompactPCI\* form factors.

### 1.2 Document Scope

This document presents thermal management techniques for the Intel Pentium 4 and Celeron processors in embedded computing applications. The physical dimensions and power numbers used in this document are for reference purposes only. Please refer to the processor datasheet for product dimensions, thermal power dissipation, and maximum case temperature. In case of conflict, the specifications in the datasheet supersede information in this document.

### 1.3 Related Documents

- *Intel® Pentium® 4 Processor with 512-KB L2 Cache on 0.13 Micron Process Datasheet* (order number 298643)
- *Intel® Pentium® 4 Processor in the 478-pin package Thermal Design Guide* (order number 252161)
- *Intel® Pentium® 4 Processor 478-pin Socket (μPGA478) Design Guidelines* (order number 249890)
- *Mechanical Enabling for the Intel® Pentium® 4 Processor in the 478-pin Package* (order number 290728)
- *Intel® Celeron® Processor on 0.13 μ Process in the 478-Pin Package Datasheet* (order number 251748)

## 1.4 Definition of Terms

$T_{LA}$  ( $T_{Local-Ambient}$ ) – the measured ambient temperature that locally surrounds the processor. The ambient temperature should be measured just upstream of a passive heatsink, or at the fan inlet for an active heatsink.

$T_{Ambient-OEM}$  – the target worst-case ambient temperature at a given external system location as defined by the system designer (OEM).

$T_{ambient-external}$  – the measured ambient temperature at the OEM defined external system location.

$T_{ambient-max}$  – the target worst case local ambient temperature. To determine this, place the system in a maximum external temperature environment, and measure the ambient temperature surrounding the processor. Under these conditions,  $T_{LA} = T_{Ambient-Max}$ .

$T_{case-max}$  ( $T_{cmax}$ ) – the maximum case temperature of the processor, as specified in the processor datasheet.

$T_{case}$  ( $T_c$ ) – the measured case temperature of the processor.

TIM – Thermal Interface Material – the thermally conductive compound between the heatsink and processor case. This material fills the air gaps and voids, and enhances the spreading of the heat from the case to the heatsink.

$\Psi_{CS}$  – the case to sink thermal resistance, which is dependent on the thermal interface material. Also referred to as  $\Psi_{TIM}$ .

$\Psi_{CA}$  – the thermal resistance between the processor's case and the ambient air. This is defined and controlled by the system thermal solution.

$P_{Max}$  – the maximum processor power (theoretical maximum power).

478-Pin Socket – the surface mount Zero Insertion Force (ZIF) socket designed to accept the Intel Pentium 4 and Celeron processors.

Bypass/no-bypass – Bypass is the area between a heatsink and any object that can act to form a duct. For this example it can be expressed as a dimension away from the outside dimension of the fins to the nearest surface.

Thermal Design Power (TDP) – a design point for the processor. OEMs must design thermal solutions that meet or exceed the TDP and  $T_{case}$  specifications per the processor's datasheet.

U – a unit of measure used to define server rack spacing height. 1U is equal to 1.75 inches, 2U equals 3.50 inches, etc.

LFM – linear feet per minute.

CFM – cubic feet per minute.





## **1.5 Design Guidelines**

The thermal solutions presented in this document were designed to fit within the maximum component height allowed by embedded form factor specifications, including ATX, the 1U server, and double-slot CompactPCI\* form factors. The thermal solutions may be valid for other form factors. However, individual applications must be modeled, prototyped, and verified.

In some cases, prototype parts have been fabricated for verification tests. It is important to note that the thermal verification information described in this document is not adequate for statistical purposes. The intent of testing was only to verify that the thermal components were performing within reasonable expectations, based on computer modeling and component specifications.

## 2.0 Mechanical Guidelines

### 2.1 Processor Package

The Intel Pentium 4 and Celeron processors are packaged in a Micro Flip-Chip Pin Grid Array 2 ( $\mu$ FC-PGA2) package technology. Refer to the processor datasheet for detailed mechanical specifications of the 478-pin package. [Figure 1](#) and [Figure 2](#) are provided for reference.

The package includes an integrated heat spreader (IHS). The IHS spreads the non-uniform heat from the die to the top of the IHS, out of which the heat flux is more uniform and on a larger surface area. This allows more efficient heat transfer out of the package to an attached cooling device.

**Note:** It is not correct to assume that the processor power is dissipated uniformly on the IHS. In particular, when validating a thermal solution, an Intel Pentium 4 and Celeron processors thermal test vehicle should be used, and a correlation to real parts applied to the results. Refer to [Section 6.0](#) and [Section 7.0](#) for further information.

The IHS is designed to be the interface for mounting a heatsink. Details can be found in the processor datasheet.

The processor connects to the system board through a ZIF surface mount socket. A description of the socket can be found in the *Intel® Pentium® 4 Processor 478-Pin Socket ( $\mu$ PGA478B) Design Guidelines* (Intel order number 249890).

To facilitate assembly by the customer and to ensure proper alignment and cooling performance, the heatsink base must be designed for symmetrical assembly. Refer to [Section 2.3](#) for more information.

It is not recommended to use any portion of the interposer as a mechanical reference or load-bearing surface in either static or dynamic compressive load conditions.

Figure 1. Processor Package Specification

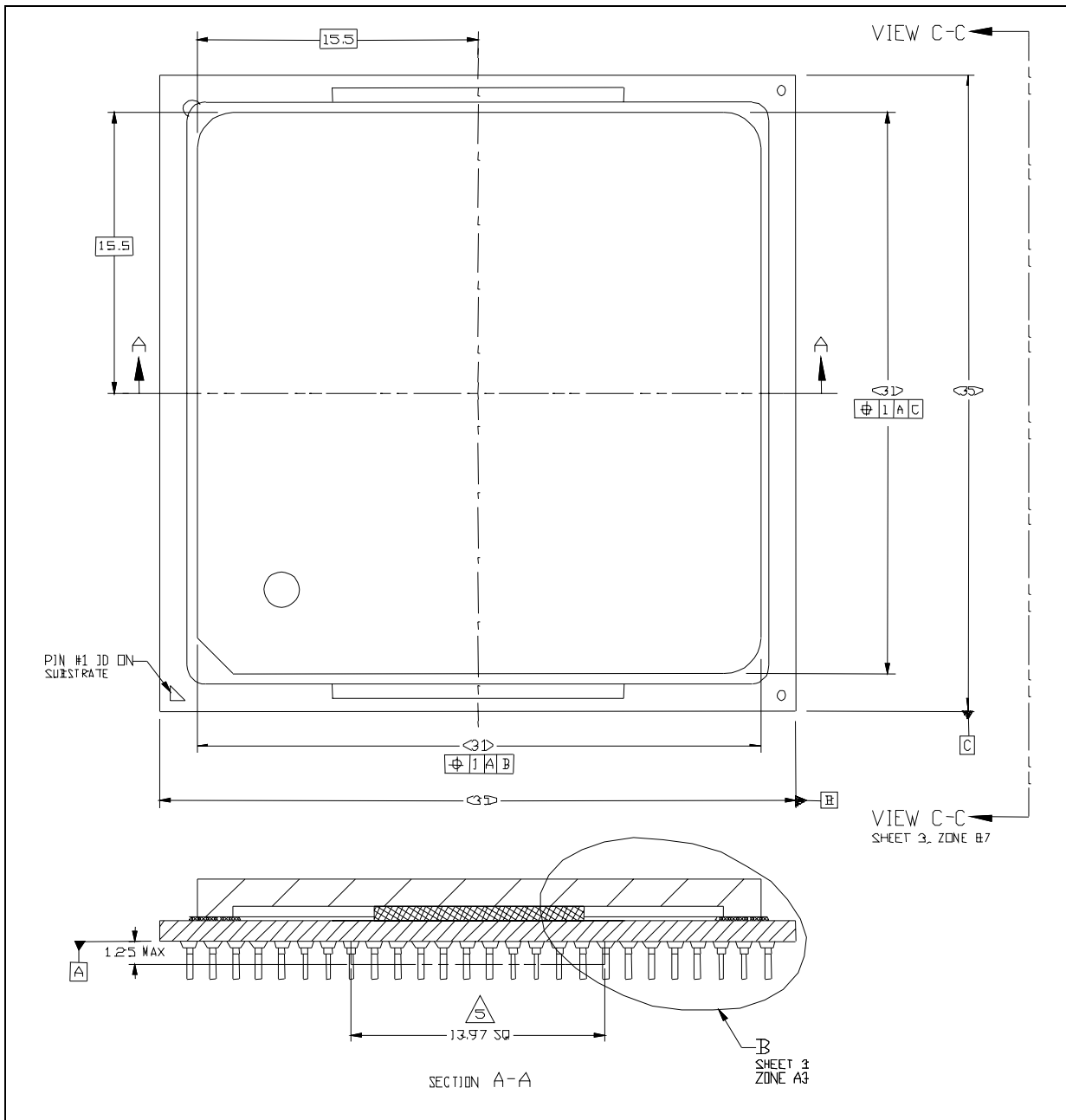
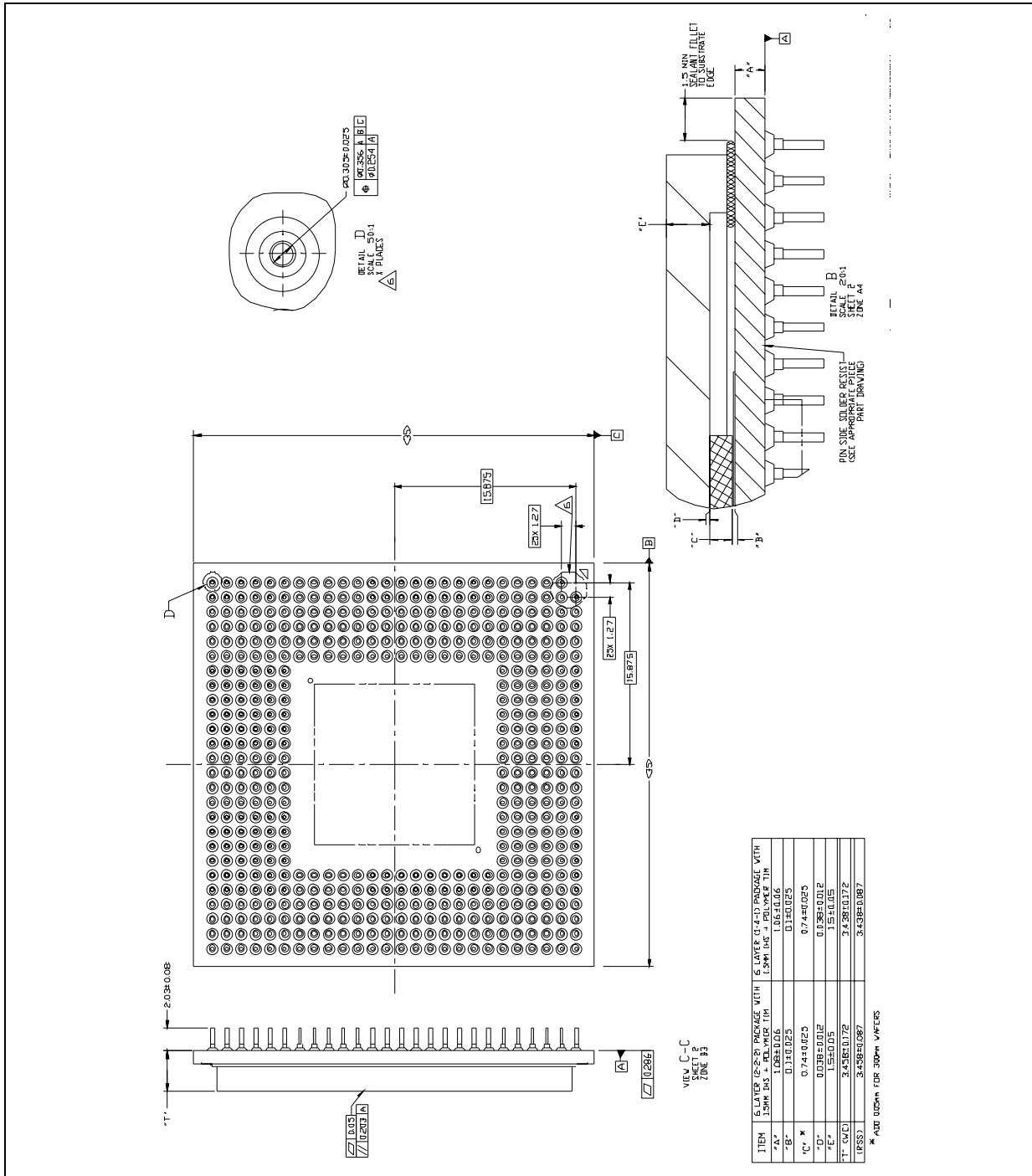


Figure 2. FC-PGA2 Package Mechanical Drawing



## 2.2 System Board Keep-Out/Keep-In Requirements

The keep-out/keep-in zone reserved for the processor package, heatsink, and heatsink attachment method for the baseboard is shown in [Figure 3](#) through [Figure 6](#). These are the typical keep-out/keep-in zones for the  $\mu$ FC-PGA2 package and 478-Pin socket. Please refer to the processor datasheets for detailed information.

Figure 3. System Board Keep-Out Footprint Definition and Height Restrictions – Page 1 of 2

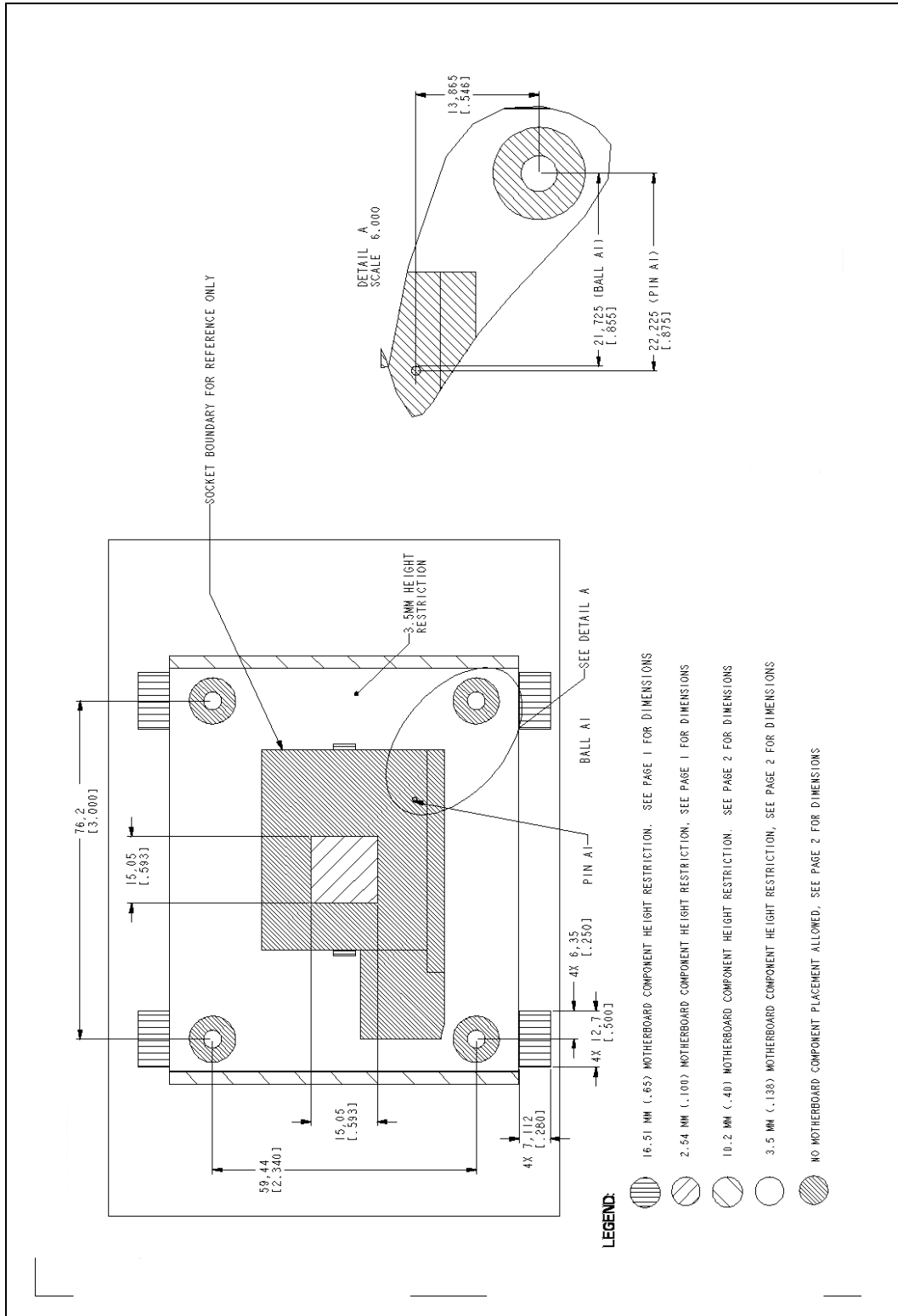


Figure 4. System Board Keep-Out Footprint Definition and Height Restrictions – Page 2 of 2

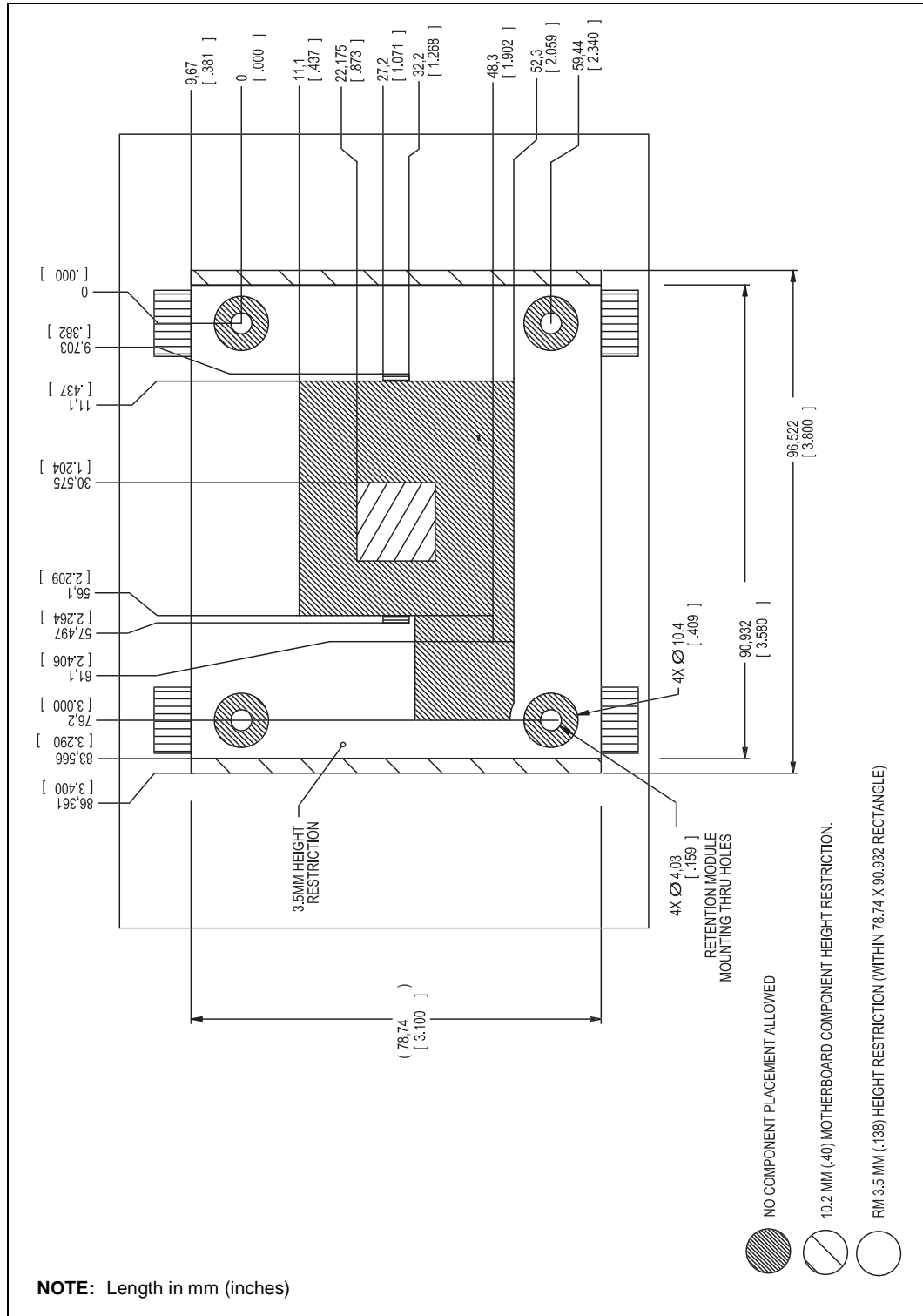


Figure 5. Volumetric Keep-In for ATX/Desktop Form Factor Enabling Components

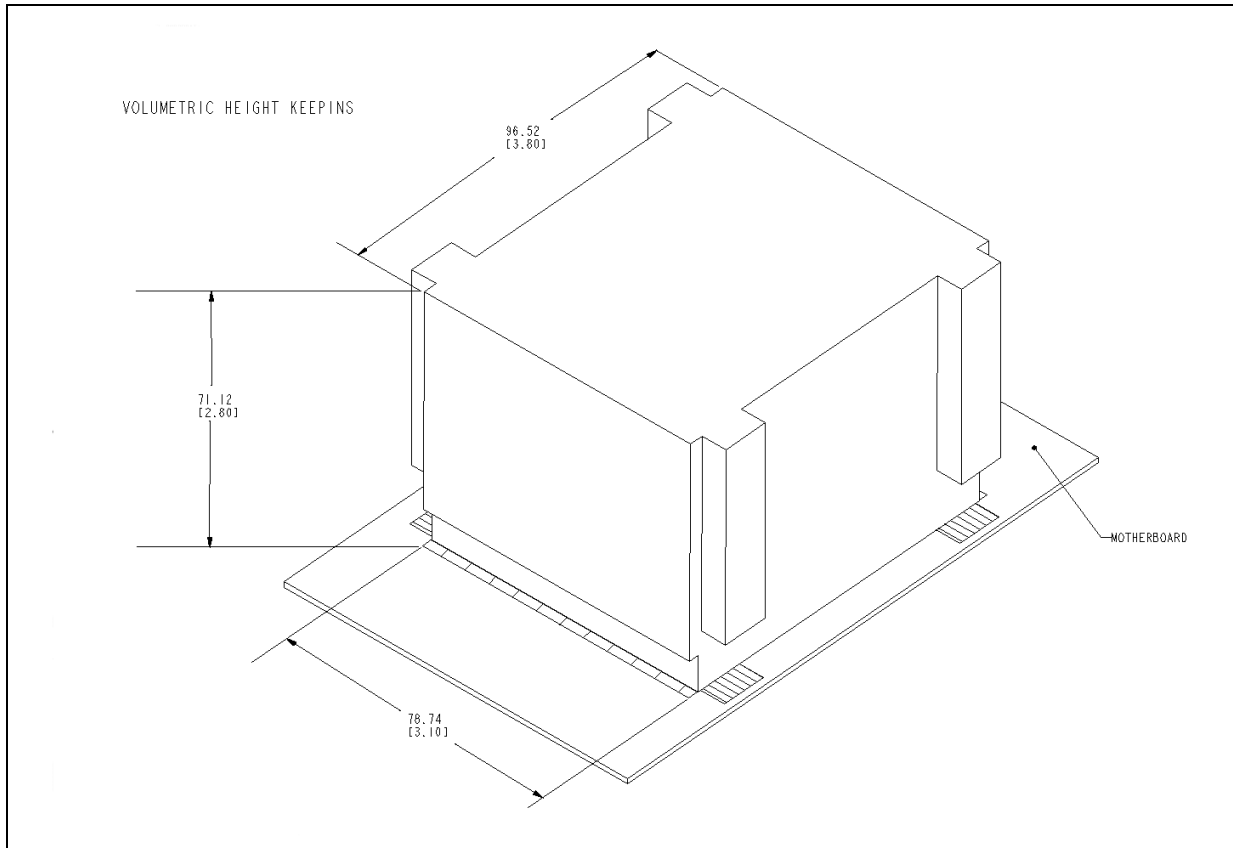
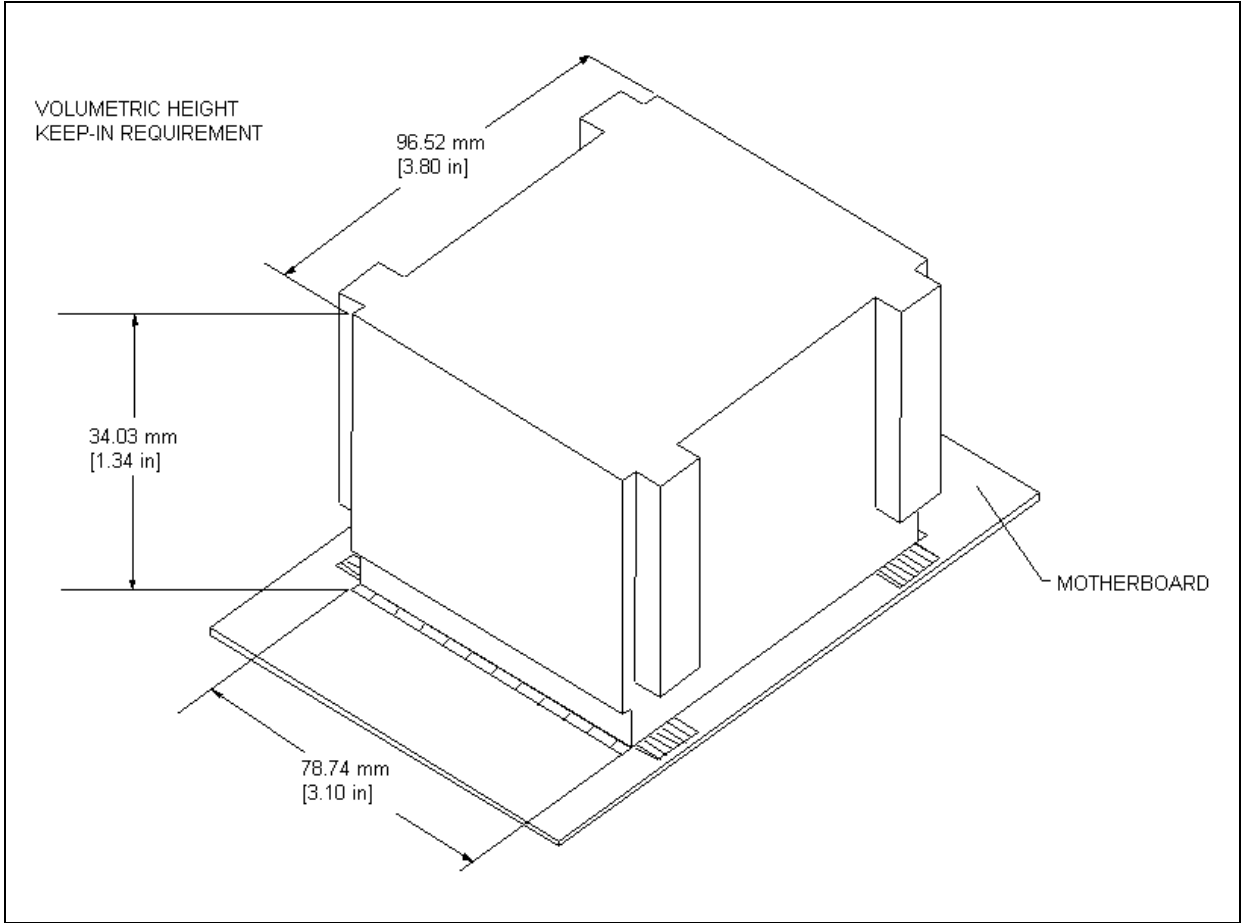




Figure 6. Volumetric Keep-In for 1U and Double Slot CompactPCI Form Factor Enabling Components



## 2.3 Interface to the System Board: Clip and Retention Mechanism

### 2.3.1 Retention Mechanism

The thermal mechanical solution must be compatible with the Intel reference retention mechanism. Refer to [Figure 28](#) for the mechanical drawing of the reference retention mechanism.

If another type of retention mechanism is developed, it should comply with the following guidelines:

- No tools required for assembly, installation on the system board, and removal from the system board
- Symmetrical design to allow installation in either orientation
- Installation force on the system board less than 10 lbs.
- System board interface compliant with system board keepouts, as defined in [Figure 3](#) through [Figure 6](#). This includes:
  - Hole pattern information
  - Hole size
  - Board thickness: 0.062 – 0.093 inches (design specific)

### 2.3.2 Clip

#### 2.3.2.1 Heatsink Attach Clip Usage

A heatsink attach clip holds the heatsink in place under dynamic loading, and applies force to the heatsink base:

- To maintain desired pressure on the thermal interface material for thermal performance
- To ensure that the package does not disengage from the socket during mechanical shock and vibration events (also known as package pullout)
- To protect solder joints from surface mount component damage during mechanical shock events, if no other system board stiffening device is used (preload concept used for the Intel reference design for the Intel Pentium 4 and Celeron processors. Refer to [Section 2.3.2.4](#).)

The heatsink clip is latched to the retention tab features at each corner of the retention mechanism (see reference retention mechanism tab features in [Section 9.0](#)).

#### 2.3.2.2 Clip Structural Considerations

The heatsink attach clip should be able to support the mass of its corresponding heatsink during mechanical stress testing (see [Section 2.6](#)). For the thermal interface material to perform as expected, the clip must remain engaged with the retention mechanism tab features and continue to provide adequate force to the heatsink base after mechanical stress testing. Maximum load is constrained by the package load capability, as described in [Section 3.7](#).

The clip should be designed in a way that makes it easy and ergonomic to engage with the retention mechanism tabs without the use of special tools. The force required to install the clip (during clip engagement to the retention mechanism tabs) should not exceed 15 lbf. Clips that take more than 15 lbf to install may require a tool to make installation ergonomically possible.

### 2.3.2.3 Additional Clip Mechanical Design Guidelines

The heatsink clip should be designed in a way that minimizes contact with the system board surface during clip attach to the retention mechanism tab features; the clip should not scratch the system board. All surfaces of the clip should be free of sharp edges to prevent injury to any system component or to the person performing the installation.

### 2.3.2.4 Additional Requirements for Solutions Using Reference Heatsink and Reference Clip

This section defines the mechanical requirements for the interface between a processor heatsink/fan/shroud assembly and the reference retention mechanism. These requirements are intended to support interface control in the design of a custom thermal solution.

**Requirement 1:** Heatsink/fan/shroud assembly must stay within the volumetric keep-in defined in [Section 2.2](#) and attach to the Intel reference retention mechanism defined in [Figure 28](#).

*Guideline:* Rectangular heatsink base dimensions and tolerances (shown in [Figure 7](#) and [Figure 8](#)):

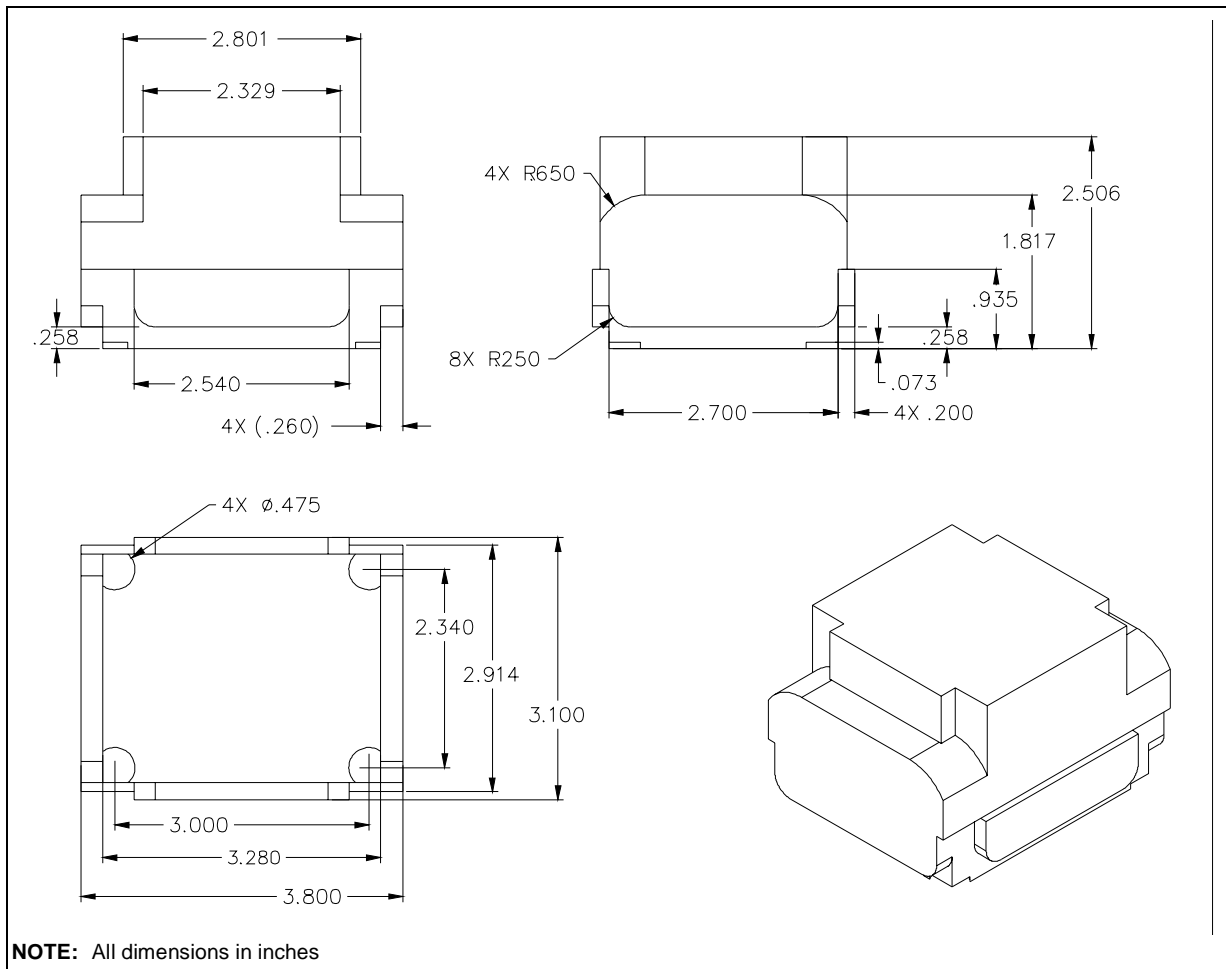
- X-dimension =  $2.70 \pm 0.010$  inch
- Y-dimension =  $3.28 \pm 0.010$  inch
- Z-dimension: Inset in bottom surface of heatsink base in each of the four corners should hold a z-dimension of  $0.073 \pm 0.010$  inch.

These dimensions are recommended to limit heatsink movement (rocking and sliding) during lateral shock (x and y directions).

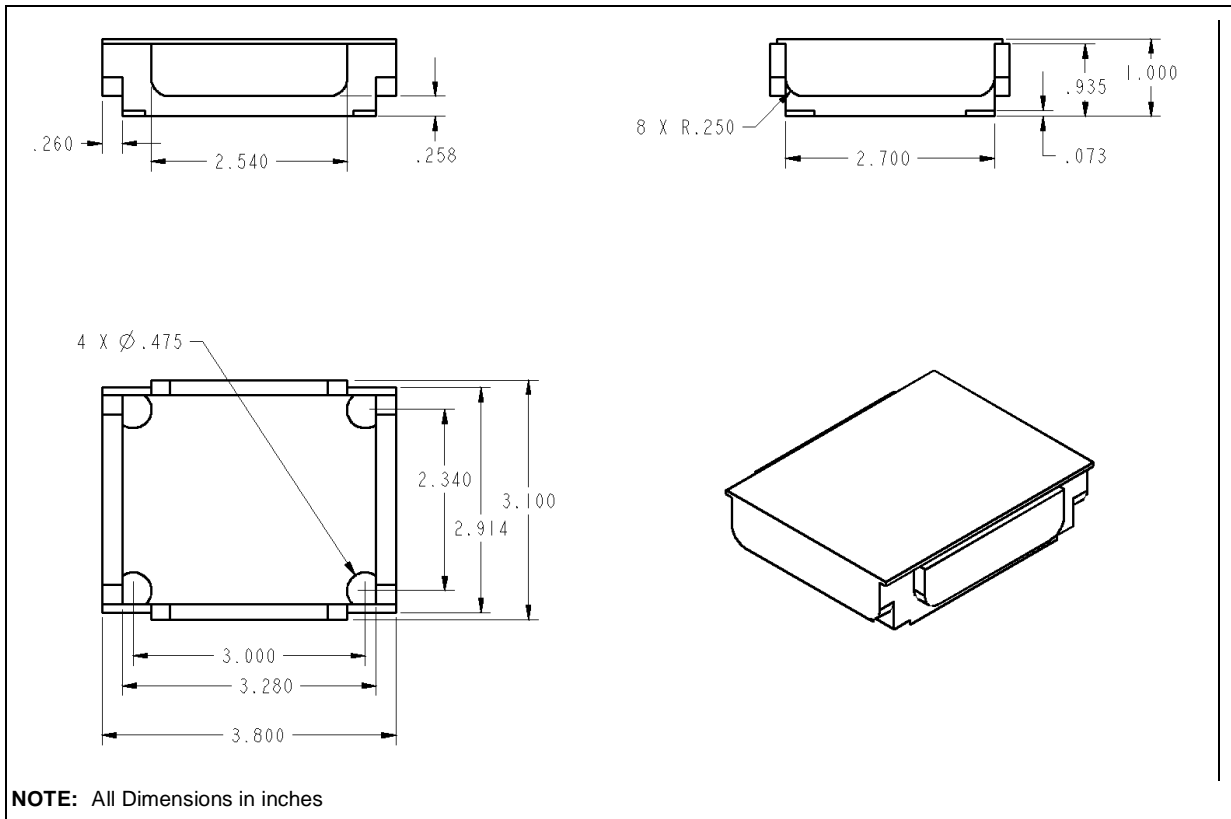
**Requirement 2:** Maximum mass and center of gravity (CG)

The maximum combined mass of the heatsink/fan/shroud assembly is 370 g. The combined center of gravity of the heatsink/fan/shroud assembly must be no greater than 0.85 inches above the system board.

Figure 7. Heatsink, Fan, and Shroud Assembly Volumetric Keep-In, ATX Form Factor



**Figure 8. Heatsink, Fan, and Shroud Assembly Volumetric Keep-In, 1U and Double-Slot Compact-PCI Form Factor**



## 2.4 Acoustic Performance

Acoustic performance is defined in terms of declared sound power (LwAd), as defined in the ISO 9296 standard.

To optimize acoustic emission by the fan heatsink, use a variable speed fan; a variable speed fan enables the attainment of thermal performance requirements at higher fan inlet temperatures ( $T_A$ ), and lower noise at lower fan inlet temperatures. The required fan speed that is necessary to meet thermal specifications can be controlled by the fan inlet temperature and must not exceed the following noise requirements:

- LwAd should not exceed 5.8 BA at the high set point temperature.
- LwAd should not exceed 4.4 BA at the low set point temperature.

High and low set points are defined in [Section 2.5.2](#).

## 2.5 Fan Requirements

### 2.5.1 Electrical Requirements

- Minimum: 9 V
- Typical: 12 V
- Maximum: 13.8 V
- Maximum startup and steady state fan current draw (IC): 740 mA
- The fan must start and operate at the minimum rated voltage and operating temperature
- The motor must be:
  - Polarity protected - fan must not be damaged if the power and ground connections are switched
  - Locked rotor protected - fan must not be damaged if the fan is stopped during operation
  - Sense frequency – two pulses per revolution
  - Open collector – system board must pull this pin up to VCC 5.0 V with a 10 K $\Omega$  resistor

### 2.5.2 Variable Speed Fan

A thermistor will be used to monitor the fan temperature with the inlet temperature  $T_A$ . The following is a summary of thermistor requirements.

- Maximum thermal performance, achieved at fan maximum speed (RPM) set point temperature is 45° C (refer to [Section 3.2](#) for further information).
- Minimum set point temperature (minimum fan speed) should be set at 32° C. The fan speed will be sufficient for the fan heatsink to meet processor thermal specifications at this  $T_A$ . This minimizes noise at lower ambient temperatures.
- The transition from minimum to maximum RPM must be linear.
- Fail-safe: The fan must run at the high set point RPM if the thermistor becomes damaged, sheared off or otherwise disabled.

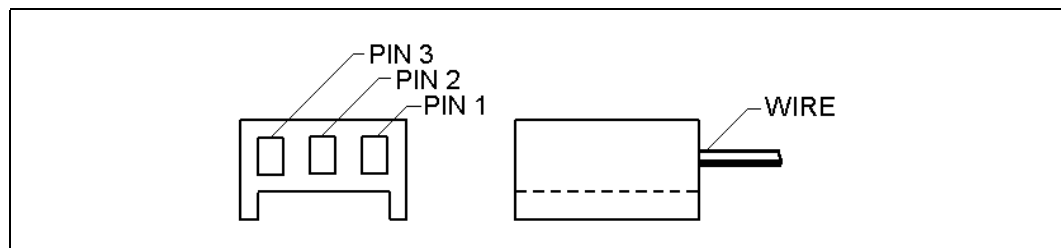
## 2.6 Wire/Fan Power Connector

The Fan Heatsink (FHS) assembly must be delivered to Intel with an integrated (attached) three wire fan cable and connector. [Figure 9](#) illustrates the fan connector pin out location. The following is a summary of the fan electrical connector and wire specifications:

- The fan connector must be a straight square pin, three pin terminal housing with polarizing ribs and friction locking ramp and match with a straight pin, friction lock header on the system board. The manufacturers and part numbers (or equivalent) are as follows:
  - AMP\*: fan connector: 643815-3, header: 640456-3
  - Walden\*/Molex\*: fan connector: 22-01-3037, header: 22-23-2031
- The wire must meet regulatory requirements outlined in [Section 2.6.1](#)

- Number of wires and connections: three
  - Pin 1: Ground; black wire
  - Pin 2: Power, +12 V; yellow wire
  - Pin 3: Signal, Open collector tachometer output signal requirement: two pulses per revolution; green wire.
- Orientation of wire and connector is required to not interfere with the RM Clip assembly
- Fan cable length:
  - The fan cable connector must reach a mating system board connector at any point within a radius of 110 mm (4.33”) measured from the central datum planes of the enabled assembly.

Figure 9. Fan Connector Electrical Pin Sequence



## 2.6.1 Reliability Requirements

For active thermal solutions, the fan must demonstrate a functional lifetime of 40,000 hours. In addition, the fan should demonstrate performance to the reliability criteria outlined in [Table 1](#).

Table 1. Fan Performance Recommendation

Test	Requirement	Pass/Fail Criteria
Thermal Cycling	-5° C to +70° C, 500 cycles	visual check <sup>1</sup> RPM check <sup>2</sup>
Humidity	85% relative humidity / 55° C, 1000 hours	visual check <sup>1</sup> RPM check <sup>2</sup>
Power Cycling	7,500 on/off cycles with each cycle specified as 3 minutes on, 2 minutes off 70° C	visual check <sup>1</sup> RPM check <sup>2</sup>

**NOTES:**

1. Visual check: Labels, housing and connections are all intact.
2. RPM check: No fan RPM changes of greater than 20%, following test.

## 2.7 Mechanical Performance Requirements

### 2.7.1 Structural Requirements

Structural reliability tests consist of unpackaged, board-level vibration and shock tests of a given thermal solution in assembled state. The thermal solution should be capable of sustaining thermal performance after these tests are conducted; however, the conditions of the tests outlined here may differ from your own system requirements.

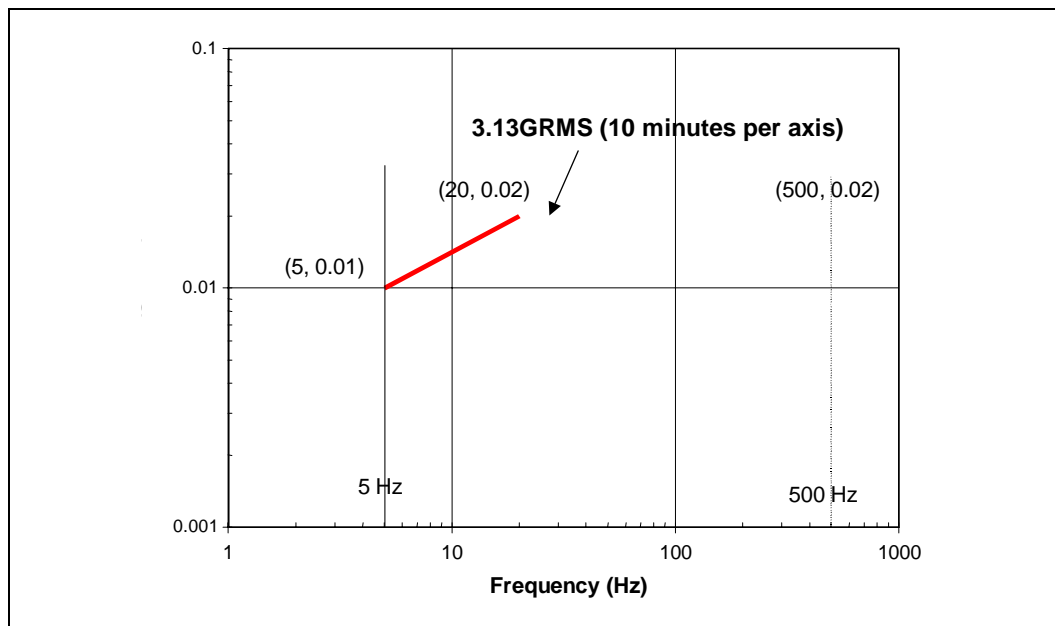
### 2.7.1.1 Platform Support

The thermal solution developed for the Intel Pentium 4 and Celeron processors for embedded applications must support the structural requirements for the Intel® 845 chipset. Refer to the thermal design guidelines of this chipset for further information.

### 2.7.1.2 Random Vibration

- Duration: 10 min/axis, three axes
- Frequency Range: 5 to 500 Hz
- Power Spectral Density (PSD) Profile: 3.13 g rms

Figure 10. Random Vibration PSD



### 2.7.1.3 Shock Test

Recommended performance requirement for a system board:

Quantity:	Three drops for + and - directions in each of three perpendicular axes (i.e., total 18 drops)
Profile:	50 G trapezoidal waveform, 11 ms duration, 170 inch/s minimum velocity change
Setup:	Mount sample board on test fixture



Figure 11. Shock Acceleration Curve



## 2.8 Miscellaneous Requirements

### 2.8.1 Material and Recycling Requirements

The material must be resistant to fungal growth. Examples of non-resistant materials include cellulose materials, animal and vegetable based adhesives, grease, oils, and many hydrocarbons. Synthetic materials such as PVC formulations, certain polyurethane compositions (e.g., polyester and some polyethers), plastics which contain organic fillers of laminating materials, paints, and varnishes also are susceptible to fungal growth. If materials are not fungal growth resistant, then MIL-STD-810E, Method 508.4 must be performed to determine material performance.

The material used must not have deformation or degradation in a temperature life test.

Any plastic component exceeding 25 grams must be recyclable per the European Blue Angel recycling standards.

### 2.8.2 Safety Requirements

Heatsink and attachment assemblies must be consistent with the manufacture of units that meet the safety standards:

- UL Recognition-approved for flammability at the system level. All mechanical and thermal enabling components must be a minimum UL94V-2 approved.
- CSA Certification: All mechanical and thermal enabling components must have CSA certification.
- Heatsink fins must meet the test requirements of UL1439 for sharp edges.

### 3.0 Thermal Design Guidelines

This document presents thermal solution design guidelines for the Intel Pentium 4 and Celeron processors in two different form factors: desktop/ATX and 1U server/Double-Slot CompactPCI\*. The required performance of the thermal solution is dependent on many parameters, including the processor's thermal design power (TDP), maximum case temperature ( $T_c$  max), the operating ambient temperature, and system airflow. The guidelines and recommendations presented in this document are based on specific parameters. It is the responsibility of each product design team to verify that thermal solutions are suitable for their specific use.

The thermal metrology for the Intel Pentium 4 and Celeron processors should be followed to evaluate the thermal performance of proposed cooling solutions. The thermal metrology is contained in the *Intel® Pentium® 4 Processor in the 478-Pin Package Thermal Design Guide* (order number 252161), as well as in [Section 6.0](#) of this guide.

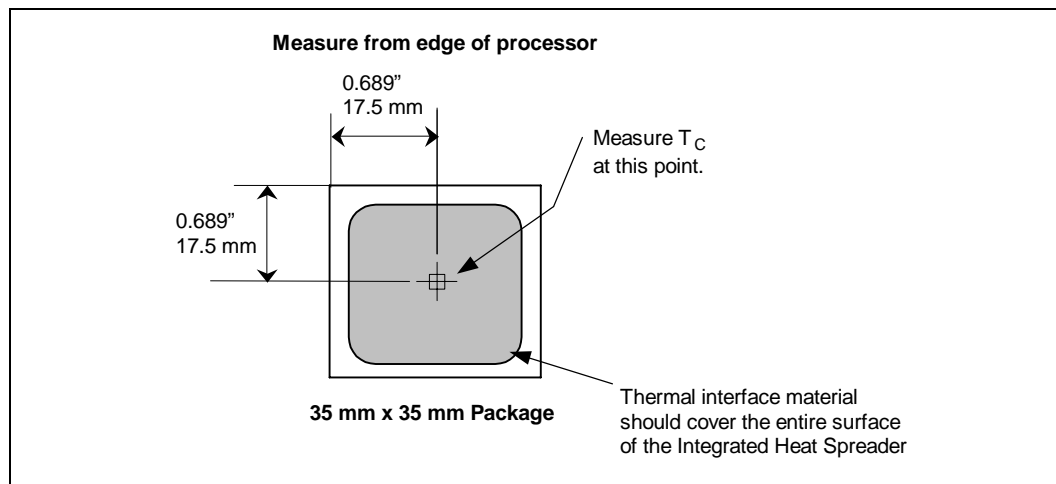
To develop a reliable thermal solution, all of the appropriate variables must be considered. Thermal simulations and characterizations must be carried out with all system parameters accounted for. The solutions presented in this document must be validated as specified in their final intended system.

#### 3.1 Processor Case Temperature

The case temperature is defined as the temperature measured at the center of the top surface of the IHS. For illustration, the measurement location for a 35 mm x 35 mm  $\mu$ FC-PGA2 package is shown in [Figure 12](#).

Techniques for measuring the case temperature are detailed in [Section 6.0](#).

**Figure 12. Processor IHS Temperature Measurement Location**



### 3.2 Processor Power

The processor power, as listed in the datasheet, is the total thermal design power that is dissipated through the IHS.

### 3.3 Thermal Solution Requirements

The thermal performance required for the heatsink is determined by calculating the case-to-ambient thermal resistance,  $\Psi_{CA}$ . This is a basic thermal engineering parameter that can be used to evaluate and compare different thermal solutions. Equation 1 shows an example of how  $\Psi_{CA}$  is calculated for the Intel Pentium 4 processor at 2.0 GHz.

Equation 1. Case-to-Ambient Thermal Resistance

$$\Psi_{CA} = \frac{T_{CMAX} \text{ } ^\circ\text{C} - T_{LA} \text{ } ^\circ\text{C}}{TDP \text{ (W)}} = \frac{69^\circ\text{C} - 45^\circ\text{C}}{54.3\text{W}} = 0.442 \frac{^\circ\text{C}}{\text{W}}$$

In these specifications,  $T_{CMAX}$  and TDP are constant, while  $\Psi_{CA}$  may vary according to  $T_{LA}$ . Table 2 gives the recommended values for  $T_{LA}$ , and shows that it is expected that chassis thermal performance will improve over time. However, Intel recommends that heatsink designers work with chassis manufacturers and system integrators to ensure that the processor requirements (i.e., power and  $T_C$ ) are met.

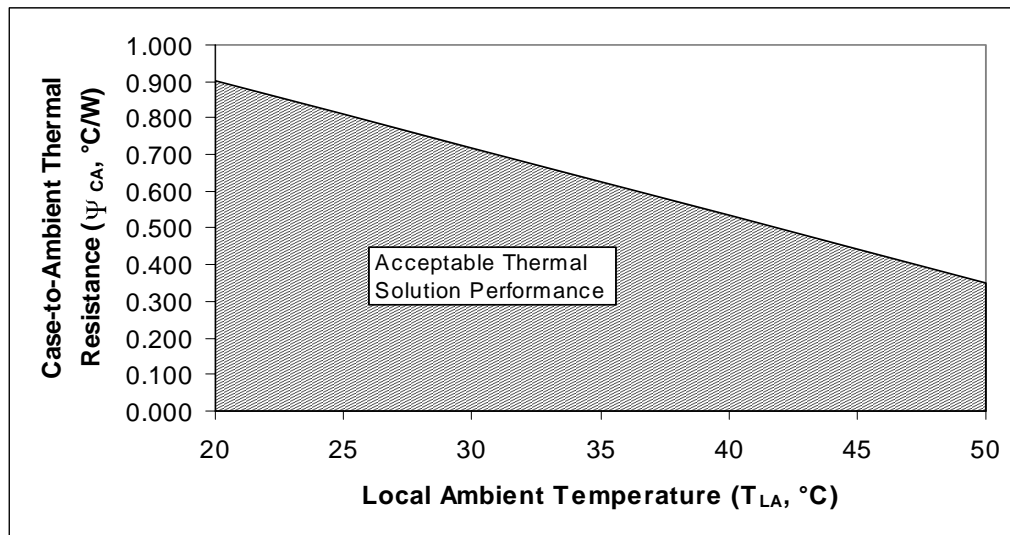
Table 2. Processor Thermal Specifications

Processor	Frequency	TDP (W)	Tcase max	Required $\Psi_{CA}$ ( $^\circ\text{C}/\text{W}$ ) of Thermal Solution at $T_{LA} = (^\circ\text{C})$		
				45	40	35
Intel® Pentium® 4 Processor in the 478-Pin Package	2.0	54.3	69	0.442	0.534	0.626
	2.4	59.8	71	0.435	0.518	0.602
	2.6	62.6	72	0.431	0.511	0.591
	2.8	68.4	75	0.438	0.512	0.585
Intel® Celeron® Processor in the 478-Pin Package	2.0	52.8	68	0.436	0.530	0.625
	2.5	61.0	72	0.443	0.525	0.607

**Note:** The  $\Psi_{CA}$  performance given above refers to sea level conditions, and does not take into account altitude effects like different air density and overall heat capacity. This often leads to some degradation in thermal solution performance compared to what is obtained at sea level, with lower fan performance and higher surface temperatures. Companies designing products that must function reliably at high altitude, typically 1,500 m (5,000 ft) or more must adapt the thermal performance targets accordingly. The system designer must account for this altitude effects in the overall system thermal design to make sure that the requirement for the processor is met at the targeted altitude.

Figure 13 further illustrates the required thermal performance for the Intel Pentium 4 processor at 2.0 GHz at different operating ambient temperatures. The thermal solution used to cool the processor must have a case-to-ambient thermal resistance less than the values shown for the given local ambient temperature.

**Figure 13. Thermal Resistance Values for Various Operating Temperatures of the Intel® Pentium® 4 Processor at 2.0 GHz**



## 3.4 Recommended Thermal Solutions

### 3.4.1 Desktop/ATX Form Factor

Intel recommends the following thermal solutions for the Intel Pentium 4 and Celeron processors for embedded applications in the ATX form factor:

- The boxed processor Intel Reseller's Product Group (Intel RPG) designed active heatsink, referenced below.
- An active 1U heatsink has been developed by Intel RPG.

No passive heatsink designs will be enabled by Intel for this processor for embedded applications.

#### 3.4.1.1 Intel RPG Enabled Active Heatsink Design

The Intel RPG enabled active heatsink currently in production has been validated for the Intel Pentium 4 and Celeron processors at speeds up to 2.8 GHz non-hyperthreading at a slightly reduced maximum ambient temperature of  $T_A = 42^\circ\text{C}$ .

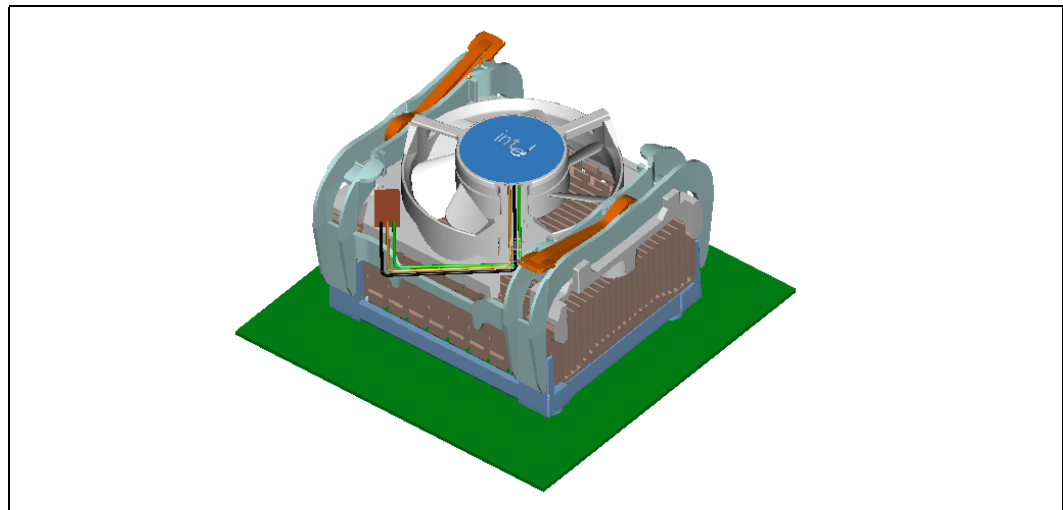
Relevant part numbers are listed in [Table 3](#):

**Table 3. Intel RPG Enabled Active Heatsink Part Numbers**

Heatsink Version	Intel® Part Number
Nidec Corporation	A80856-002
Sanyo-Denki	A38001-003
Fujikura America, Inc.	A57855-001

The standard RPG solution is 2.8” tall. Thus it may not be applicable for all embedded applications.

**Figure 14. Intel RPG Enabled Thermal Solution**



### 3.4.2 1U and Double-Slot Compact-PCI Thermal Solutions

Currently there are no thermal solutions developed in the double-slot compact-PCI form factors. Intel’s Reseller’s Products Group has developed a 1U active heatsink. The Intel part number for this solution is A76646-001. A clip kit is needed with this heatsink and the part number is A93123-001. Both products are available from Sanyo-Denki.

Developers who wish to design thermal solutions for the Intel Pentium 4 and Celeron processors in the 1U and Double-slot Compact-PCI form factors need to ensure that it meets the thermal requirement stated in [Section 3.3](#). They also have to adhere to the standard mechanical keep-outs as stated in [Section 2.2](#).

Below are figures that illustrate the Z-height constraints of these form factors.

Figure 15. Double-Slot Compact-PCI Thermal Solution Z-Height Constraints

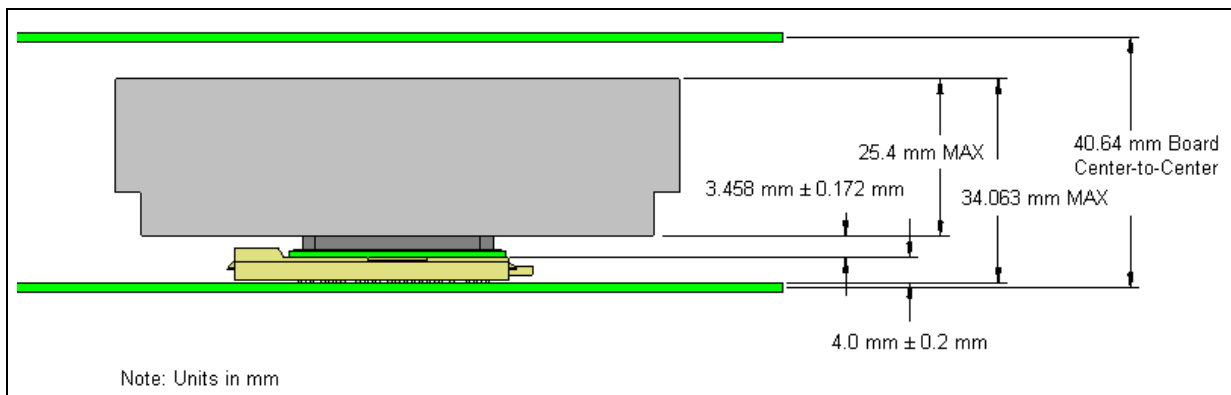
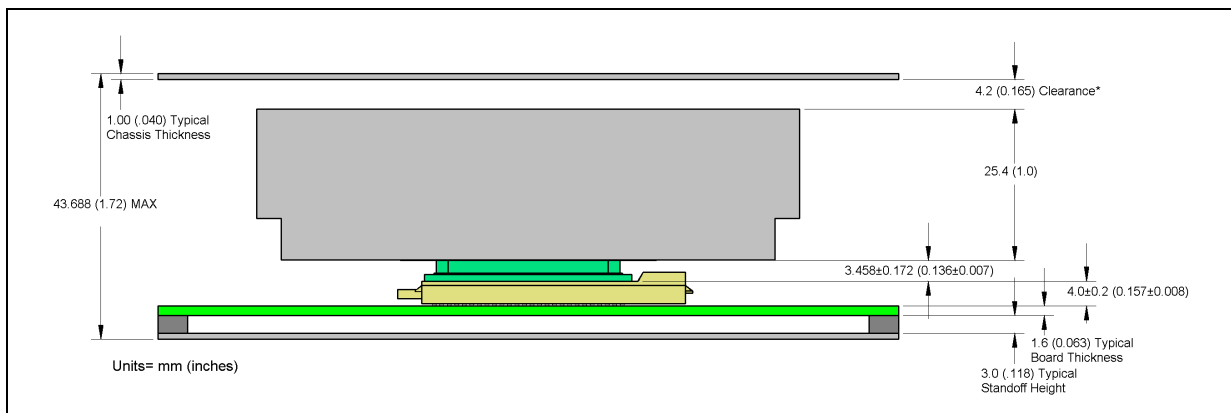


Figure 16. 1U Thermal Solution Z-Height Constraints



**NOTES:**

1. Chassis Thickness, Standoff height, and system board thickness can all vary depending on the design.
2. Minimum clearance is 1.27 mm (0.050 in.) for passive solutions. For active fan sinks the clearance must follow minimum recommended clearance of the fan manufacturer.
3. All of the above factors affect the height of the thermal solution.

### 3.5 Interface to Package Requirements

The Intel Pentium 4 and Celeron processors is packaged in a Micro Flip-Chip Pin Grid Array 2 (μFC-PGA2) package technology. Refer to the processor datasheet for detailed mechanical specifications of the 478-pin package.

The package includes an integrated heat spreader (IHS). The IHS spreads the non-uniform heat from the die to the top of the IHS, out of which the heat flux is more uniform and on a larger surface area. This allows more efficient heat transfer out of the package to an attached cooling device.

**Note:** It is not correct to assume that the processor power is dissipated uniformly on the IHS. In particular, when validating a thermal solution, an Intel Pentium 4 and Celeron processors thermal

test vehicle should be used, and a correlation to real parts applied to the results. Refer to [Section 7.0](#) and [Section 8.0](#) for further information.

The IHS is designed to be the interface for mounting a heatsink. Details can be found in the processor datasheet.

The processor connects to the system board through a ZIF surface-mount socket. A description of the socket can be found in the *Intel<sup>®</sup> Pentium<sup>®</sup> 4 Processor 478-Pin Socket (mPGA478B) Design Guidelines* (Intel order number 249890).

In order to facilitate customer assembly and ensure proper alignment and cooling performance, the heatsink base must be designed for symmetrical assembly. Refer to [Section 2.3](#) for further information on the interface to the system board.

It is not recommended to use any portion of the interposer as a mechanical reference or load-bearing surface in either static or dynamic compressive load conditions.

### 3.6 Thermal Interface Material Requirements

All thermal interface materials should be sized and positioned on the heatsink base so that the entire processor IHS area is covered. It is important to compensate for heatsink-to-processor attachment positional alignment when selecting the proper thermal interface material size.

If a pre-applied thermal interface material is specified, it may have a protective application tape. This tape must be removed prior to heatsink attachment.

As overall performance of the processor cooling solution becomes more and more demanding, thermal interface material performance contribution must be carefully looked at. The designer must consider the following when choosing a TIM:

- Compatibility with high-volume manufacturing and assembly for installation.
- Adhesion of the TIM can create a strong bond between the heatsink and the package; excessive adhesion can cause these problems:
  - Package pullout from the actuated socket when removing the heatsink from the processor for rework and servicing.
  - Increased risk of package pullout from socket during shock and vibration events.
- Load needed on the heatsink/processor/socket assembly to ensure TIM performance (see the next section for package load specifications).

## 3.7 Package and Socket Load Specifications

The following specifications come from the processor datasheet. Refer to this datasheet for additional information.

**Table 4. Package Static and Dynamic Load Specifications**

Parameter	Max	Unit	Notes
Static	100	lbf	1, 2
Dynamic	200	lbf	1

**NOTES:**

1. This specification applies to a uniform compressive load.
2. This is the maximum static force that can be applied by the heatsink and clip to maintain the heatsink and processor interface.

These load limits should not be exceeded during heatsink installation, removal, mechanical stress testing, or standard shipping conditions. For example, when a compressive static load is necessary to ensure thermal performance of the thermal interface material between the heatsink base and the IHS (see [Section 5.0](#) for more information regarding bond line management), this compressive static load cannot exceed 100 lbf.

The heatsink mass can also add additional dynamic compressive load to the package during a shock. Amplification factors due to the impact force during shock have to be taken into account in dynamic load calculations. The total combination of dynamic and static compressive load should not then exceed 200 lbf during a vertical shock. For example, with a 1 lb heatsink, an acceleration of 50 g during an 11 ms shock results in approximately a 100 lbf dynamic load on the processor package. If in addition a 100 lbf static load is applied on the heatsink for thermal performance of the thermal interface material (or for mechanical reasons), the processor/heatsink assembly then reaches the 200 lbf limit for the package.



## 4.0 Intel® 845 Chipset MCH Thermal Solution

### 4.1 Package Thermal Design Requirements

Table 5. Thermal Design Requirements

Package Description	FCBGA Bare Die
Thermal design power, (TDP <sub>typ</sub> )	5.8 W with DDR 266
T <sub>J</sub> Max (°C)	97° C
Heatsink Approach Air Temperature (T <sub>LA</sub> )	55° C Max
Ψ <sub>JA</sub>	7.24° C/W
Required Airflow for Thermal Solution	50 LFM

### 4.2 Thermal Interface Material

The recommended thermal interface material is a phase change material, Chomerics\* T710\*. It is included with the Intel thermal solution enabling assembly.

### 4.3 Thermal Solution Attachment

The thermal solution requires an attachment with anchors on the board. [Figure 17](#) shows board keep-outs and anchor placement position.

Figure 17. Board Keep-Out and Anchor Placement Position for MCH

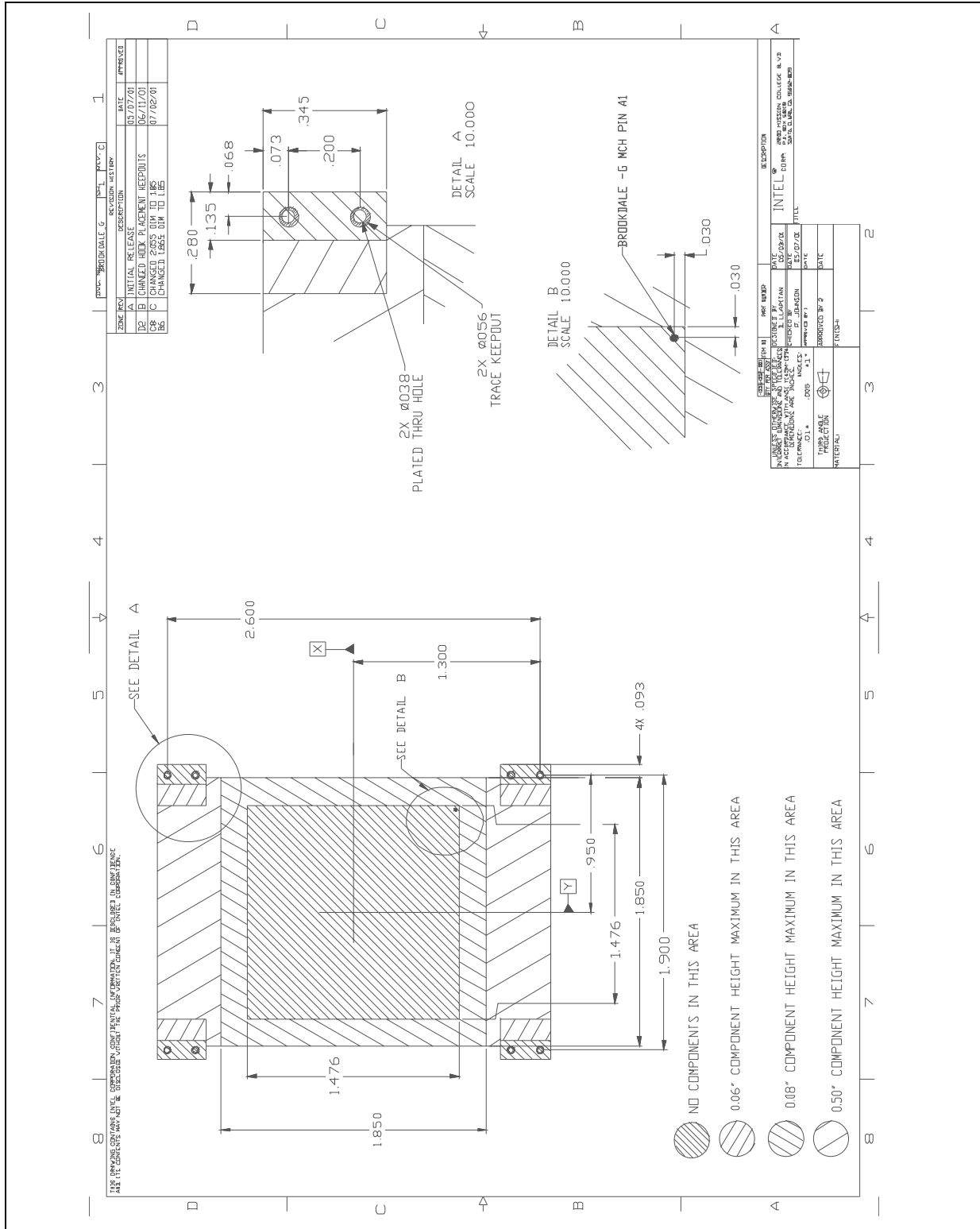
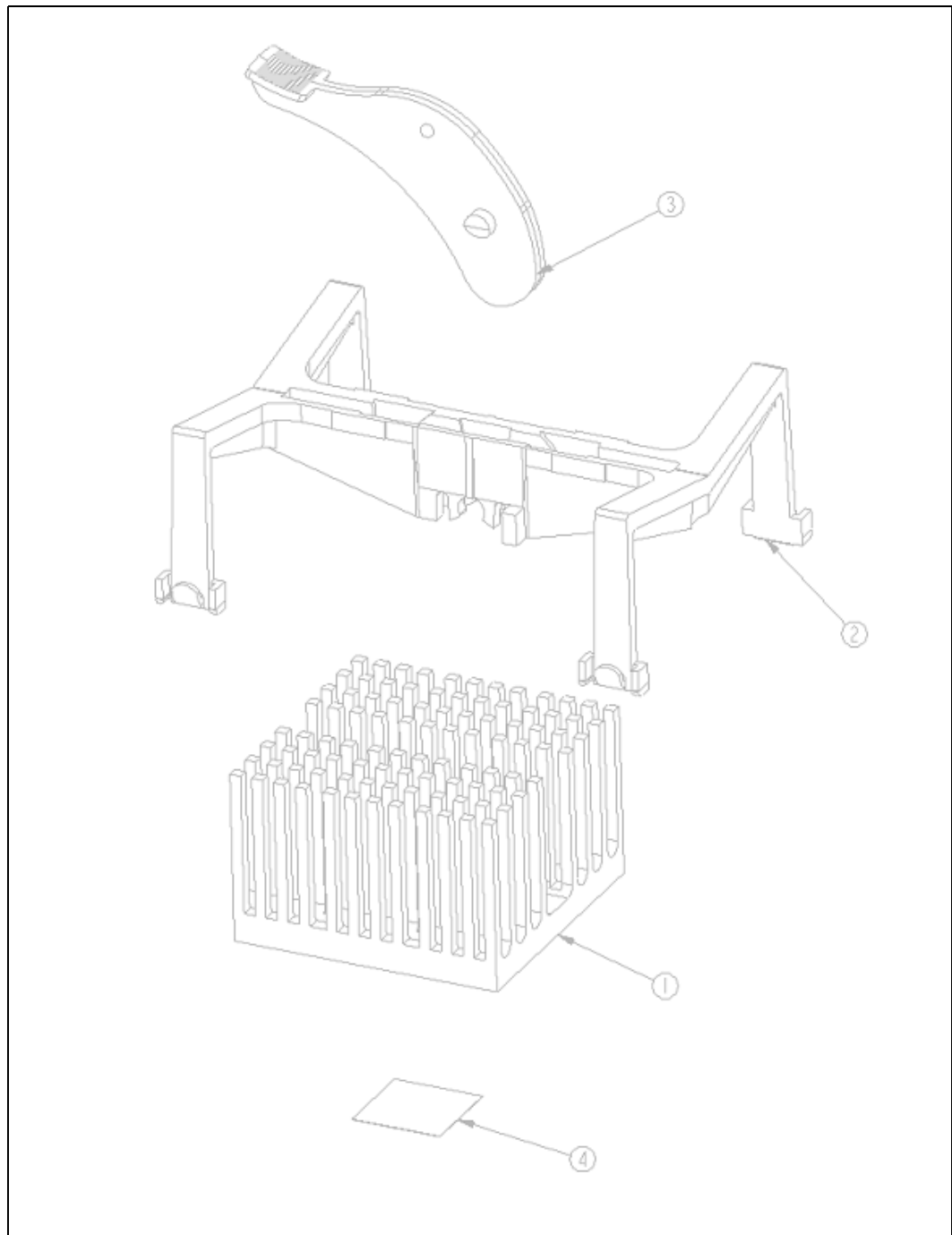


Figure 18. Intel® Recommended Enabled Thermal Solution for MCH



**Table 6. Intel Part Number A67916-001 Included Components**

Figure Reference	Intel Part Number
Heatsink	A54515-001
Clip Frame	A65066-001
Clip Lever	A67031-001
Thermal Interface Material – Chomerics T710	

*Note:* The Intel recommended thermal solution also requires four board-mount anchors, Intel part number A13494-005. For more detailed information, see [Figure 17](#).

## 5.0 Characterizing Cooling Performance Requirements

The idea of a “thermal characterization parameter,”  $\Psi$  (psi), is a convenient way to characterize the performance needed for the thermal solution and to compare thermal solutions in identical situations (heating source, local ambient conditions). A thermal characterization parameter is convenient in that it is calculated using total package power, whereas actual thermal resistance,  $\theta$  (theta), is calculated using actual power dissipated between two points. Measuring actual power dissipated into the heatsink is difficult, since some of the power is dissipated via heat transfer into the socket and board. Be aware, however, of the limitations of lumped parameters such as  $\Psi$  when it comes to a real design. Heat transfer is a three-dimensional phenomenon that can rarely be accurately and easily modeled by lump values.

The case-to-local ambient thermal characterization parameter value ( $\Psi_{CA}$ ) is used as a measure of the thermal performance of the overall thermal solution that is attached to the processor package. It is defined in [Equation 2](#) and measured in units of °C/W.

### Equation 2. Case-to-Local Ambient Thermal Resistance (Equation 1 of 2)

$$\Psi_{CA} = (T_C - T_A) / P_D$$

Where:

- $\Psi_{CA}$  = Case-to-local ambient thermal characterization parameter (°C/W)
- $T_C$  = Processor case temperature (°C)
- $T_A$  = Local ambient temperature ( $T_{LA}$ ) in chassis around processor (°C)
- $P_D$  = Processor total power dissipation (W) (assume all power goes through the IHS)

The thermal resistance of the processor case-to-local ambient,  $\Psi_{CA}$ , comprises  $\Psi_{CS}$ , the thermal interface material thermal resistance, and  $\Psi_{SA}$ , the sink-to-local ambient thermal resistance.

### Equation 3. Case-to-Local Ambient Thermal Resistance (Equation 2 of 2)

$$\Psi_{CA} = \theta_{CS} + \theta_{SA}$$

Where:

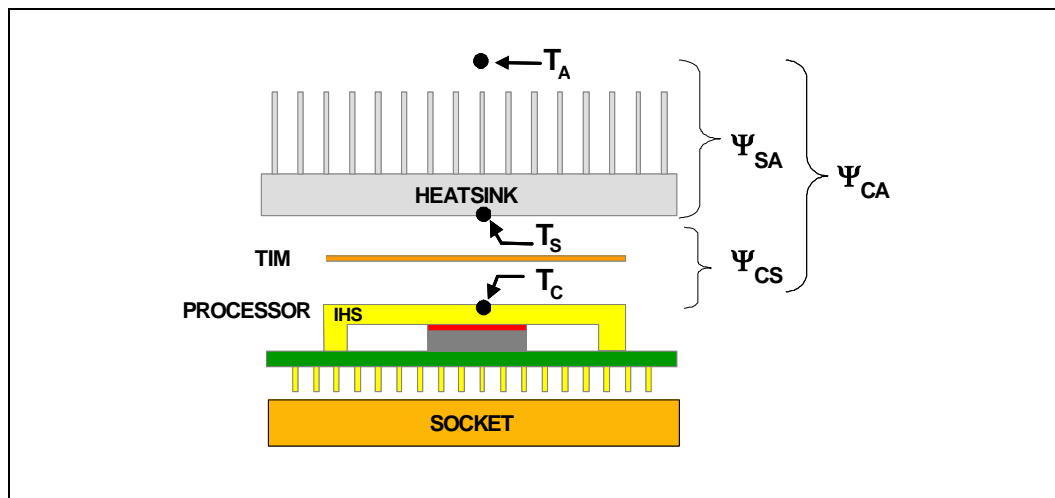
- $\Psi_{CS}$  = Thermal characterization parameter of the thermal interface material (°C/W)
- $\Psi_{SA}$  = Thermal characterization parameter from heatsink-to-local ambient (°C/W)

$\Psi_{CS}$  is strongly dependent on the thermal conductivity and thickness of the TIM between the heatsink and IHS.

$\Psi_{SA}$  is a measure of the thermal characterization parameter from the bottom of the heatsink to the local ambient air.  $\Psi_{SA}$  is dependent on the heatsink material, thermal conductivity, and geometry. It is also strongly dependent on the air velocity through the fins of the heatsink.

[Figure 19](#) illustrates the combination of the different thermal resistances.

Figure 19. Processor Thermal Resistance Relationships



## 5.1 Example

The cooling performance  $\Psi_{CA}$  is defined using the thermal characterization parameter described above:

- Define a target case temperature ( $T_{C_{MAX}}$ ) and corresponding thermal design power (TDP) at a target frequency given in the processor datasheet.
- Define a target local ambient temperature around the processor,  $T_A$ .

Since the processor thermal specifications ( $T_C$  and TDP) can vary with the processor frequency, it may be important to identify the worse case (smallest  $\Psi_{CA}$ ) for a targeted chassis (characterized by  $T_A$ ) to establish a design strategy such that a given heatsink can cover a given range of processor frequencies.

The following provides an illustration of how a designer can determine the appropriate performance targets. The power and temperature numbers used here are not related to any Intel processor thermal specifications, and are just given to carry out the example.

Assume the datasheet TDP is 55 W and the case temperature specification is 70° C. Assume as well that the system airflow has been designed such that the local ambient temperature is 45° C. Then the following could be calculated using [Equation 1](#) from above:

$$\Psi_{CA} = (T_C - T_A) / \text{TDP} = (70 - 45) / 55 = 0.45^\circ \text{ C/W}$$

To determine the required heatsink performance, a heatsink solution provider would need to determine  $\Psi_{CS}$  performance for the selected TIM and mechanical load configuration. If the heatsink solution were designed in such a way as to be compatible with the Intel TIM material and mechanical reference design, then  $\Psi_{CS}$  will be  $\leq 0.15^\circ \text{ C/W}$ . In which case, solving for [Equation 2](#), from above, the performance of the heatsink has to be:

$$\Psi_{SA} = \Psi_{CA} - \Psi_{CS} = 0.45 - 0.15 = 0.30^\circ \text{ C/W}$$

## 5.2 Looking at the Entire Thermal Solution

The heat generated by components within the chassis must be removed to provide an adequate operating environment for both the processor and other system components. Moving air through the chassis brings in air from the external ambient environment and transports the heat generated by the processor and other system components out of the system. The number, size and relative position of fans and vents have a decisive impact on the chassis thermal performance, and therefore on the ambient temperature around the processor. The size and type (passive or active) of the thermal cooling device and the amount of system airflow are related and can be compared to each other to meet specific system design constraints. Additional constraints are board layout, spacing, component placement, and structural considerations that limit the thermal solution size. For more information, refer to the *Performance ATX Desktop System Thermal Design Suggestions* or *Performance microATX Desktop System Thermal Design Suggestions* documents available at:

<http://www.formfactors.org/>

In addition to passive heatsinks, fan heatsinks 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 additional heat. Due to their varying attributes, each of these solutions may be appropriate for a particular system implementation.

To develop a reliable, cost-effective thermal solution, thermal characterization and simulation should be carried out at the entire system level, accounting for the thermal requirements of each component. In addition, acoustic noise constraints may limit the size, number, placement, and types of fans that can be used in a particular design.

To ease the burden on cooling solutions the Thermal Monitor feature and associated logic have been integrated into the silicon of the Intel Pentium 4 and Celeron processors. By taking advantage of the thermal monitor feature, system designers may reduce the cooling system cost while maintaining the processor reliability and performance goals.

## 6.0 Thermal Metrology for the Intel® Pentium® 4 and Celeron® Processors for Embedded Applications

The following sections discuss the techniques for testing thermal solutions. Note that determining if a processor is sufficiently cooled is not as simple as it may seem. Carefully read the following instructions to validate the thermal properties of the system. In all cases, measurements must be made. Guidelines have been established for proper techniques for measuring processor temperatures. The following sections describe these measurement guidelines.

The reference heatsink performance target for the Intel Pentium 4 and Celeron processors is provided. The Intel reference heatsink is validated within specific boundary conditions. Testing is done on bench top test boards at ambient lab temperatures.

Assuming a  $T_A$  at the processor fan heatsink inlet of 42° C, the performance target given below supports published frequencies for the Intel Pentium 4 and Celeron processors in the 478-pin package up to 2.8 GHz. Refer to the processor datasheet for additional information.

### 6.1 Local Ambient Temperature Measurement Guidelines

The local ambient temperature  $T_A$  ( $T_{LA}$ ) is the temperature of the ambient air surrounding the processor. For a passive heatsink,  $T_A$  is defined as the heatsink approach air temperature; for an actively cooled heatsink, it is the temperature of inlet air to the active cooling fan.

It is worthwhile to determine the local ambient temperature in the chassis around the processor to understand the effect it may have on the case temperature.

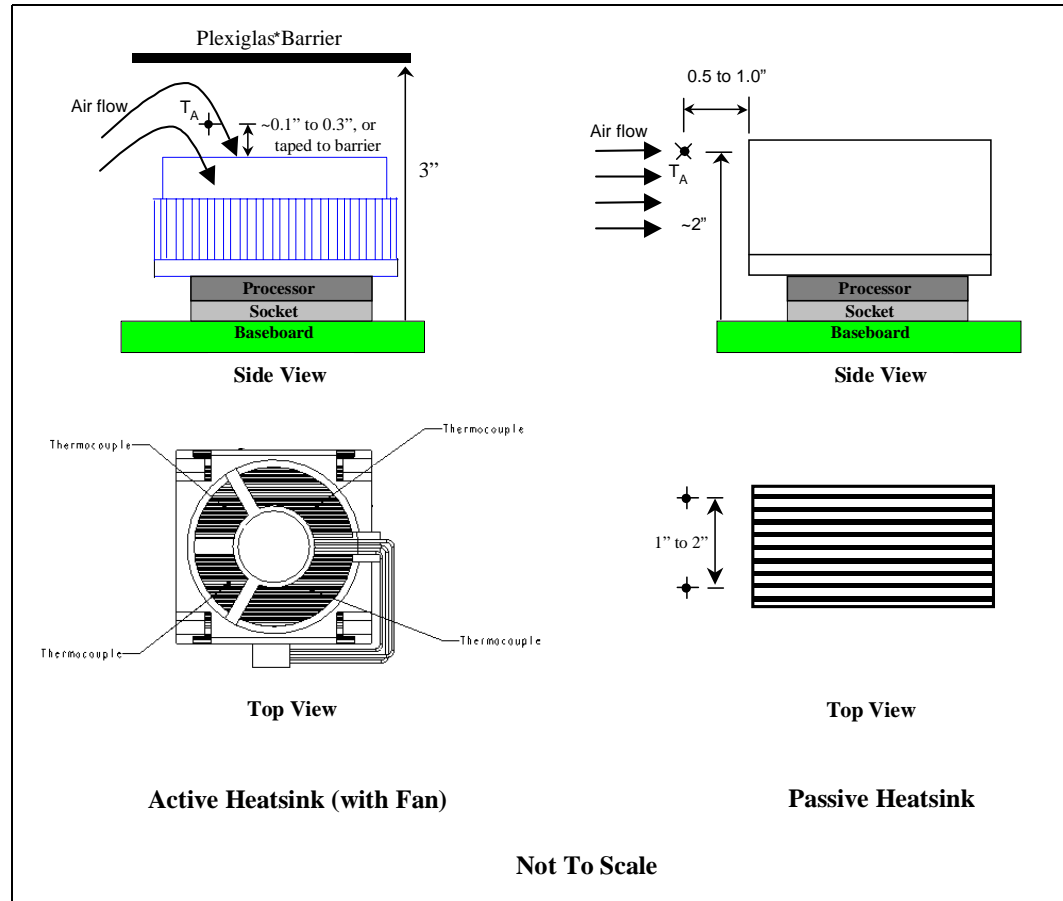
$T_A$  is best measured by averaging temperature measurements at multiple locations in the heatsink inlet airflow. This method reduces errors and eliminates minor spatial variations in temperature. The following guidelines are meant to enable accurate determination of the localized air temperature around the processor during system thermal testing.

For active heatsinks, the thermocouples should be placed approximately 0.1 to 0.3 inch (2.54 mm to 7.62 mm) above the fan hub vertically, and halfway between the fan hub and the fan housing horizontally, as shown in [Figure 20](#). This is to avoid taking measurement in the dead flow zone that usually develops above the hub. It may be useful to take measurements at four different locations, uniformly placed at the center of the annulus, formed by the fan hub and the fan housing, to evaluate the uniformity of the air temperature at the fan inlet. Using an open bench to characterize an active heatsink can be useful, and usually ensures more uniform temperatures at the fan inlet. However, additional tests that include a barrier three inches (76.2 mm) above the test system board surface can help evaluate the potential impact of the chassis. This barrier is typically clear Plexiglas\*, extending at least four inches in all directions beyond the edge of the thermal solution. It simulates the microATX specification for a solid barrier three inches (76.2 mm) from the surface of the system board. If a barrier is used, the thermocouple can be taped directly to the barrier with a clear tape, with the horizontal location as previously described half way between the fan hub and the fan diameter. If a variable speed fan is used, it may be useful to add a thermocouple taped to the barrier above the location of the temperature sensor used by the fan to check its speed setting against air temperature. When measuring  $T_A$  directly in a chassis with a live system board, add-in cards, and the other system components, it is likely that  $T_A$  shows as highly non-uniform across the inlet fan section.



For passive heatsinks, thermocouples should be placed approximately 0.5 to 1.0 inches (12.7 mm to 25.4 mm) away from processor and heatsink, as shown in Figure 20. The thermocouples should be placed approximately two inches (50.8 mm) above the baseboard. This placement guideline is meant to minimize the effect of localized hot spots from baseboard components.

**Figure 20. Guideline Locations for Measuring Local Ambient Temperature**



## 6.2 Processor Case Temperature Measurement Guidelines

To ensure functionality and reliability, the Intel Pentium 4 and Celeron processors is specified for proper operation when  $T_C$  is maintained at or below the value listed in the processor datasheet. The measurement location for  $T_C$  is the geometric center of the IHS. Figure 21 shows the location for  $T_C$  measurement.

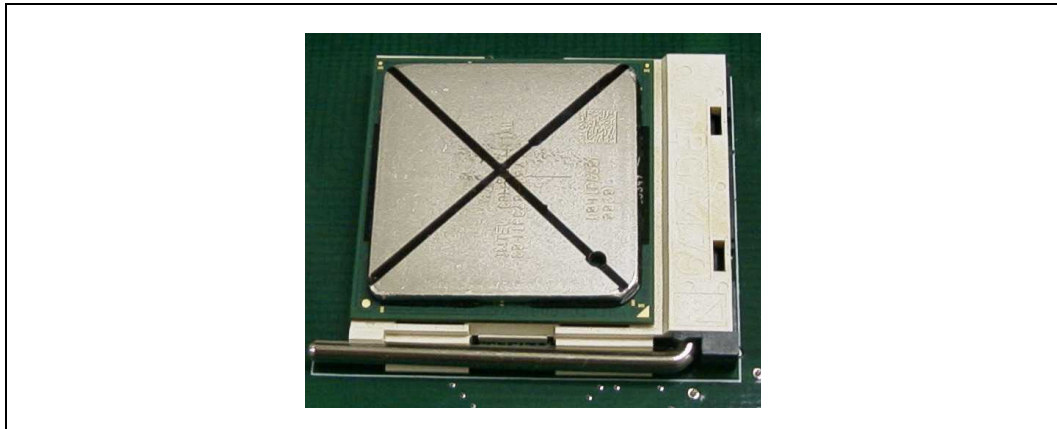
Special care is required when measuring the  $T_C$  to ensure an accurate temperature measurement. Thermocouples are often used to measure  $T_C$ . Before any temperature measurements are made, the thermocouples must be calibrated. When measuring the temperature of a surface that is at a different temperature from the surrounding local ambient air, errors could be introduced in the measurements. The measurement errors could be caused by poor thermal contact between the thermocouple junction and the surface of the integrated heat spreader, heat loss by radiation, convection, by conduction through thermocouple leads, or by contact between the thermocouple cement and the heatsink base. To minimize these measurement errors, Intel recommends the approach outlined in the next section.

## 6.2.1 Thermocouple Attachment

This section describes the procedure for attaching a thermocouple to the IHS for the case temperature ( $T_C$ ) measurement.

1. Obtain the necessary items needed for the quantity of thermocouple attaches desired:
  - Fine point tweezers
  - Exacto\* knife (#11 blade)
  - Thermocouples (Type K, 36 gauge, 36 inch, Teflon\* insulation). Ensure that the thermocouple has been properly calibrated
  - 3M\* Kapton\* tape (or equivalent) cut into strips (1/8 inch  $\times$  1/2 inch)
  - Epoxy (Omegabond\* 101 or equivalent)
  - Curing oven or equivalent
2. Use a scribe to mark at the center of the package (IHS side) where the bead of the thermocouple will be placed. Determine the center of the package by drawing two diagonal lines across the length of the package. The intersection of the two lines is the package center. (See [Figure 21](#)).

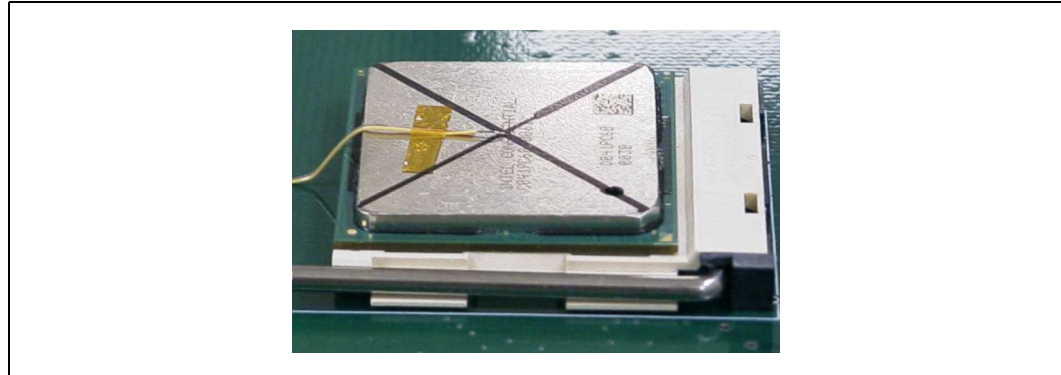
**Figure 21. Desired Thermocouple Location**



3. After the marks are scribed, clean the desired thermocouple attach location with a mild solvent and a lint-free wipe or cloth. Alcohol or acetone should suffice. Cleanliness of the part is critical for a strong epoxy bond after curing.
4. With thermocouple in hand, locate the junction and straighten the wire by hand so that the first 4-6 inches are reasonably straight. Use the fine point tweezers to ensure that the bead and the two protruding wires are straight and untwisted. Ensure the second layer of thermocouple insulation, sometimes clear, is not covering the bead.
5. Place a slight downward bend in the protruding wires approximately 1/16 inch from junction using the tweezers. This aids the user in ensuring the thermocouple junction contacts the heat spreader surface.
6. Place the thermocouple on the surface of the part so the bead is contacting the IHS at the desired location. Hold the thermocouple with one hand and use a pair of tweezers to apply a cut piece of Kapton tape across the wire approximately about 1/4 inch back from the bead. Apply pressure to the tape to ensure a good bond. Apply additional Kapton tape along the length of the wire to ensure a good temporary bond to the part. (See [Figure 22](#)). **Check for**

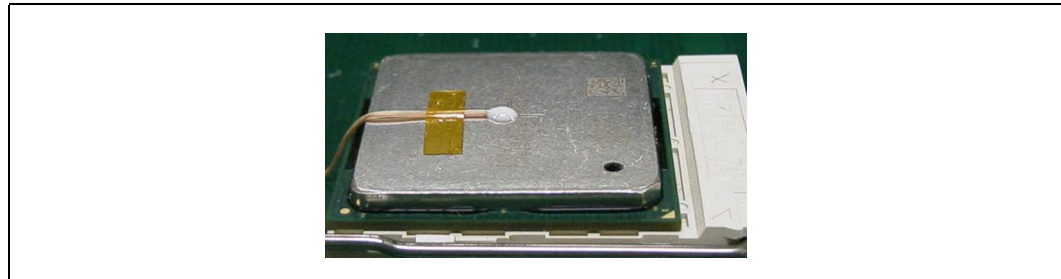
**electrical continuity between the thermocouple and the IHS using a multimeter.** If there is no electrical continuity between the thermocouple and the IHS, repeat Steps 4-6.

**Figure 22. Location of Kapton\* Tape for Temporary Bond**



7. With the thermocouple temporarily held to the part, apply epoxy to the thermocouple bead for a permanent bond. If applying Omegabond 101 epoxy, a small piece of paper works well for mixing. Follow the manufacturer's instructions for mixing.
8. Use the Exacto knife or similar to apply the epoxy to the thermocouple bead. Dab glue on the bead and the exposed wires. Use only the appropriate amount of epoxy to cement the thermocouple to the IHS. Excess epoxy will prevent the heatsink from mating flush with the IHS. The entire bead should be submerged and it is best to have insulated wires protruding from the epoxy. (See Figure 23).

**Figure 23. Thermocouple Bead Covered with Epoxy**



9. Add other tack-downs of epoxy along the length of wire to provide strain relief for the thermocouple wire. Remove any small epoxy dots or lines that have been accidentally added after the epoxy cures.
10. Follow the epoxy manufacturer's instructions for curing the epoxy. If an oven is used for curing the epoxy, ensure the vibration in the oven is minimal to prevent the thermocouple bead from moving and losing immediate contact with the IHS.
11. Once the epoxy has cured, remove all tape and check for any epoxy residual outside the thermocouple attach area. Run the tip of your finger around the IHS surface to find any small epoxy dots. Remove the non-necessary epoxy residual completely so it does not impact heatsink to IHS mating surface. Clean the IHS surface after conducting this finger test.
12. **Check for electrical continuity between the thermocouple and the IHS again.** If there is no electrical continuity between the thermocouple and the IHS, repeat Steps 4-12.

## 6.2.2 Heatsink Preparation – Rectangular (Cartesian) Geometry

To measure the case temperature, a heatsink must be mounted on the processor to dissipate the heat to the environment. The heatsink base must be grooved to allow a thermocouple to be routed from the center of the heatsink without altering the IHS for heatsink attachment. The groove in the heatsink has two features. The first is a 0.180 inch diameter relief for the thermocouple bead and surrounding epoxy. The second feature is a 0.040 inch-wide groove that allows the thermocouple wire to be routed to the edge of the IHS/heatsink assembly. The depth of the relief and wire routing groove is 0.025 inches. Notice the center of the thermocouple bead relief is located 0.050 inches from the centerline of the heatsink. An example of a grooved heatsink base is shown in Figure 24. The depth for the entire groove including the circle area is 0.025 inches (Figure 25). It must be noted that the center of the circle area needs to be located 0.05 inches off center from the location corresponding to the thermocouple bead at the center of the IHS. This offset accommodates the bead of epoxy that covers both the thermocouple and thermocouple wires.

Figure 24. Grooved Heatsink Bottom

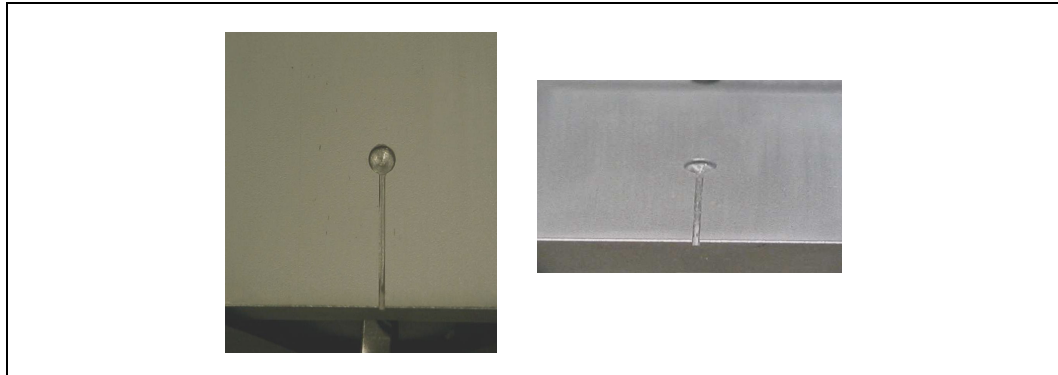
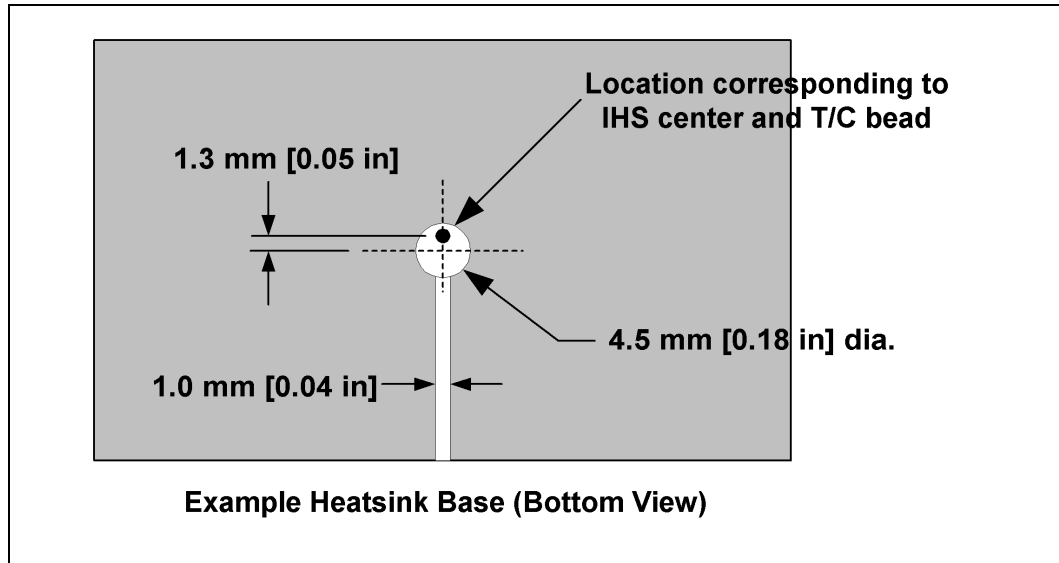


Figure 25. Heatsink Bottom Groove Dimensions



**NOTES:**

1. Applies to rectangular or cylindrical heatsink base
2. All units are in inches. The groove (including the circle area) depth is 0.025 inches

### 6.2.3 Heatsink Preparation – Radial (Cylindrical) Geometry

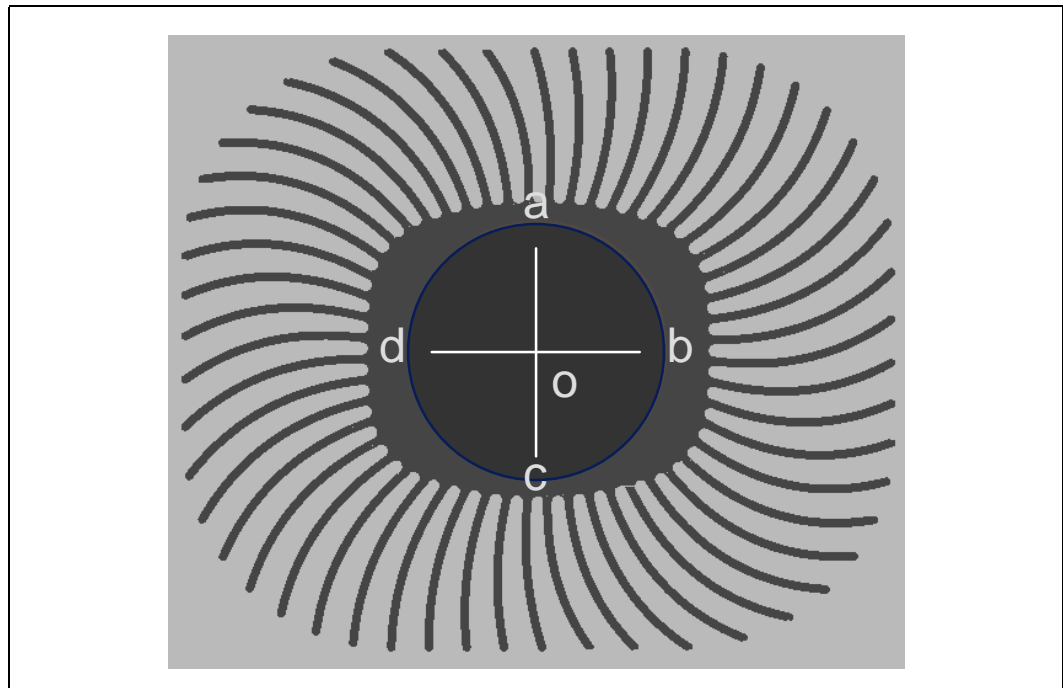
For some heatsinks that have a radial geometry (see Figure 26), it may be necessary to locate the center of the heatsink using features in the fin pattern.

For example, the 52-fin radial heatsink of the Intel reference design described in the note below, requires the following procedure:

1. Identify fin gap (a) as shown in Figure 26.
2. Count 13 fin gaps in clockwise direction; identify fin gap (b).
3. Repeat for fin gap (c) and fin gap (d).
4. Scribe lines (a-c) and (b-d) across the core area of the radial heatsink.
5. Locate heatsink center at the intersection of lines (a-c) and (b-d).
6. Machine a groove 0.040 inches wide, 0.025 inches deep along line (o-a).
7. Locate the center for the circle area 0.050 inches off the heatsink centerline, along line (o-a).
8. Machine the circle area 0.180 inches diameter, 0.025 inches deep to accommodate the thermocouple and epoxy bead.

**Note:** This procedure takes into account the fact that the center of the IHS and the center of the heatsink coincide for this particular design.

Figure 26. Radial Heatsink Geometry



## 6.2.4 Thermal Measurement

1. Attach a thermocouple at the center of the package (IHS-side) using the proper thermocouple attach procedure (refer to [Section 6.2.1](#)).
2. Connect the thermocouple to a thermocouple meter.
3. Mill groove on heatsink base (refer to [Section 6.2.2](#) or to [Section 6.2.3](#)).
4. Apply thermal interface material to either IHS top surface or on the surface of heatsink base.
5. Mount the heatsink to the processor package with the intended heatsink attach clip and all relevant mechanical interface components (e.g., retention mechanism, processor EMI attenuation solutions, etc.).

**Note:** This methodology requires special care when assembling the grooved heatsink on top of the IHS with the thermocouple attached. Mismatch between the heatsink groove and the thermocouple wires and bead may lead to inaccurate measurements, and even thermocouple damage, in particular when compressive load is required to get better performance out of the thermal interface material.



## **7.0 Thermal Test Vehicle Information**

The Intel Pentium 4 and Celeron processors Thermal Test Vehicle (TTV) is a  $\mu$ FC-PGA2 package assembled with a thermal test die. The cooling capability of a specific system thermal solution can be assessed by using the thermal tool in a system environment and powering the test die to the Intel Pentium 4 and Celeron processors operating conditions. The TTV is designed for use in Intel Pentium 4 and Celeron processors platforms.

### **7.1 Thermal Test Die**

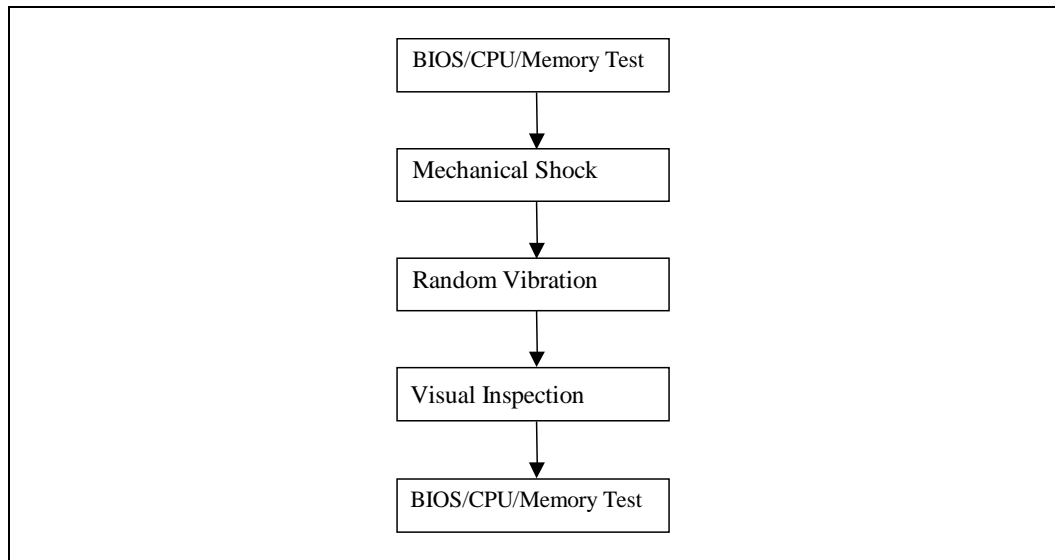
For complete information on the Intel Pentium 4 Thermal Test Vehicle, see the *Intel® Pentium® 4 Processor in the 478-Pin Package Thermal Design Guide* (order number 252151).

## 8.0 Mechanical Validation

### 8.1 Test Sequence

Figure 27 shows a recommended sequence of testing events.

**Figure 27. Suggested Structural Test Sequence**



### 8.2 Post-Test Pass Criteria

The post-test pass criteria are:

1. No significant physical damage to the retention mechanism windows, including any indication of shearing, cracks in the retention mechanism body, or evidence of significant clip lever penetration into the fan shroud.
2. Clip must remain latched to retention mechanism windows.
3. Heatsink remains seated and its bottom remains mated flatly against processor die surface. No visible gap between the heatsink base and processor IHS. No visible tilt of the heatsink with respect to the retention mechanism.
4. No signs of physical damage on system board surface due to impact of heatsink or heatsink attach clip.
5. No visible physical damage to the processor package.
6. Successful BIOS/Processor/memory test of post-test samples.
7. Thermal compliance testing to demonstrate that the case temperature specification can be met.



### 8.3 Recommended BIOS/CPU/Memory Test Procedures

This test is to ensure proper operation of the product before and after environmental stresses, with the thermal mechanical enabling components assembled. The test shall be conducted on a fully operational system board that has NOT been exposed to any battery of tests prior to the test being considered.

Testing setup should include the following components, properly assembled and/or connected:

- Appropriate system board
- Processor
- All enabling components, including socket and thermal solution parts
- Power supply
- Disk drive
- Video card
- DIMM
- Keyboard
- Monitor

The pass criterion is that the system under test shall successfully complete the checking of BIOS, basic processor functions and memory, without any errors. Intel PC Diags is an example of software that can be utilized for this test.

## 9.0 Retention Mechanism

Figure 28. Retention Mechanism

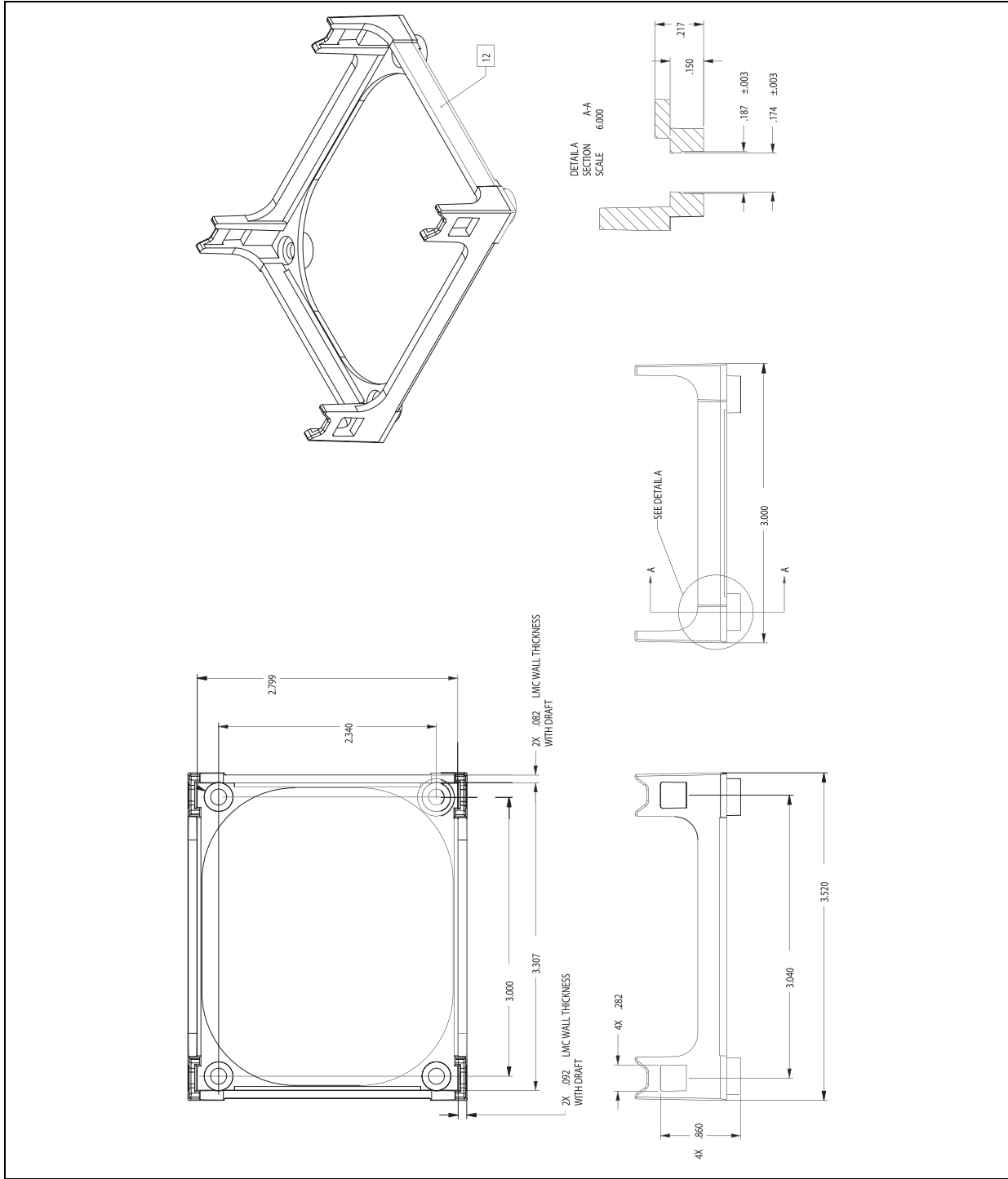
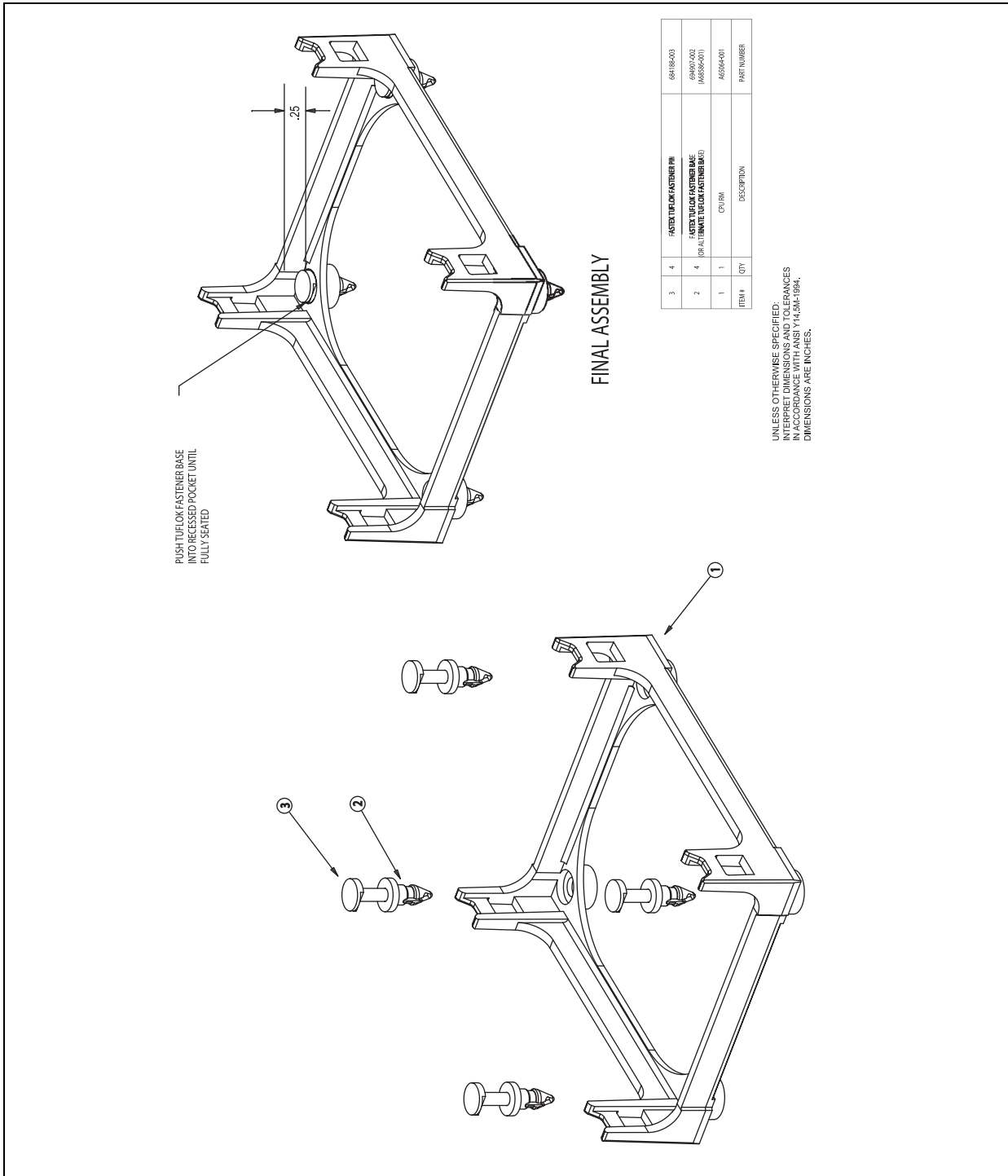


Figure 29. Retention Mechanism Final Assembly



**NOTES:**

1. Interpret dimensions and tolerances in accordance with ANSI Y14.5M-1994.
2. This drawing to be used in correlation with supplied 3D database file. All dimensions and tolerances on this drawing take precedence over supplied file.
3. Material:
  - A) Type: General Electric Corp. Lexan\* 3412R
  - B) Color: Blk GE Ref 7101
  - C) Regrind: 25% permissible
4. Flammability: Finished part shall have a minimum UL Flammability Rating of 94V2.
5. Degate: +0.000/-0.015
6. Flash: 0.005 max.
7. Sink: 0.005 max.
8. Ejector Marks: Flush to -0.015
9. Parting line mismatch not to exceed 0.002.
10. All dimensions shown are critical to function dimensions. All other dimensions for part construction should be taken from supplied 3D CAD model and held to  $\pm 0.01$ "
11. Tool design to be submitted to and approved by Intel Engineering prior to construction of the tools.

## 10.0 Vendor List

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

**Table 7. Vendor List**

Component	Supplier	Contact	Phone	E-mail Address
478-Pin Socket	Foxconn*	Julia Jiang	(408) 919-6178	juliaj@foxconn.com
	TYCO*/AMP* Inc.	Ralph Spayd	(717) 592-7653	respayd@tycoelectronics.com
Heatsinks	Sanyo-Denki*	Mamoru Yasui	(301) 783-5423	mamoru@sanyo-denki.com
	Nidec*	Mike Kulik	(781) 830-1107	mkulik@nidecpg.com
	Fujikura America, Inc.	Ash Ooe	(408) 748-6991	a_ooe@fujikura.com
Thermal Interface Materials	Shin-Etsu* Micro Si, Inc.		(480) 893-8898	www.microsi.com
CPU Retention Mechanism	Foxconn*	Julia Jiang	(408) 919-6178	juliaj@foxconn.com
	Nextron*	Johnson Lee	(886) 2-8691-8238 ext. 248	Johns@nextron.com.tw
	Wieson*	Rick Lin	(886) 2-2647-1896	rick@wieson.com
	CCI	Monica Chih	886-2-29952666ext. 8	monica_chih@ccic.com.tw
Heatsink Attach Clip	Foxconn	Julia Jiang	(408) 919-6178	juliaj@foxconn.com
	TecStar Manufacturing*	Christine Withers	(262) 255-5790	christine.withers@mgstech.com

