



Thermal Design Guideline for the Intel[®] Pentium[®] III Processor with 512 Kbytes L2 Cache at 1.26 GHz

Design Guide

November 2001

Order Number: 273625-001





Information in this document is provided in connection with Intel® products. No license, express or implied, by estoppel or otherwise, to any intellectual property rights is granted by this document. Except as provided in Intel's Terms and Conditions of Sale for such products, Intel assumes no liability whatsoever, and Intel disclaims any express or implied warranty, relating to sale and/or use of Intel products including liability or warranties relating to fitness for a particular purpose, merchantability, or infringement of any patent, copyright or other intellectual property right. Intel products are not intended for use in medical, life saving, or life sustaining applications.

Intel may make changes to specifications and product descriptions at any time, without notice.

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 by calling 1-800-548-4725 or by visiting Intel's website at <http://www.intel.com>.

AlertVIEW, i960, AnyPoint, AppChoice, BoardWatch, BunnyPeople, CablePort, Celeron, Chips, Commerce Cart, CT Connect, CT Media, Dialogic, DM3, EtherExpress, ETOX, FlashFile, GatherRound, i386, i486, iCat, iCOMP, Insight960, InstantIP, Intel, Intel logo, Intel386, Intel486, Intel740, IntelDX2, IntelDX4, IntelSX2, Intel ChatPad, Intel Create&Share, Intel Dot.Station, Intel GigaBlade, Intel InBusiness, Intel Inside, Intel Inside logo, Intel NetBurst, Intel NetStructure, Intel Play, Intel Play logo, Intel Pocket Concert, Intel SingleDriver, Intel SpeedStep, Intel StrataFlash, Intel TeamStation, Intel WebOutfitter, Intel Xeon, Intel XScale, Itanium, JobAnalyst, LANDesk, LanRover, MCS, MMX, MMX logo, NetPort, NetportExpress, Optimizer logo, OverDrive, Paragon, PC Dads, PC Parents, Pentium, Pentium II Xeon, Pentium III Xeon, Performance at Your Command, ProShare, RemoteExpress, Screamline, Shiva, SmartDie, Solutions960, Sound Mark, StorageExpress, The Computer Inside, The Journey Inside, This Way In, TokenExpress, Trillium, Vivonic, and VTune are trademarks or registered trademarks of Intel Corporation or its subsidiaries in the United States and other countries.

*Other names and brands may be claimed as the property of others.

Contents

1.0 Introduction	5
1.1 Nomenclature	5
2.0 Design Guideline	6
2.1 Mechanical Guidelines.....	6
2.1.1 Keep Out Zone	8
2.2 Thermal Guidelines.....	8
2.2.1 Thermal Solution Requirements	9
2.2.2 Recommended Heat Sink Design.....	10
2.2.2.1 Heat Sink Orientation Relative to Airflow	11
2.2.3 Alternative Heat Sink Designs	12
2.2.3.1 Aluminum Crimped Fin Heat Sink.....	12
2.2.3.2 1U Fan Heat Sink.....	13
2.2.4 Recommended Thermal Interface Material.....	14
2.2.5 Recommended Heat Sink Attachment Method.....	14
2.2.6 Dual Processor Considerations	14
3.0 Related Documents	15
4.0 Vendor List	16

Figures

1 FC-PGA2 Package Geometry	7
2 Volumetric Keep Out Zone for the FC-PGA2 Package.....	8
3 Thermal Resistance Values for Various Operating Temperatures	9
4 Heat Sink Design.....	10
5 Performance Comparison of Ducted Versus Non-Ducted Airflow	11
6 Heat Sink Orientation to the Processor and Airflow.....	12
7 Aluminum Crimped Fin Heat Sink.....	13
8 1U Fan Heat Sink	13
9 Optimum Orientation in Dual Processor Configurations	15

Tables

- 1 FC-PGA2 Mechanical Dimensions 7
- 2 Low-Profile Metal Clip Suppliers..... 14
- 3 Related Documents 15
- 4 Vendor List 16

Revision History

Date	Revision	Description
November 2001	001	First release of document.



1.0 Introduction

This document describes the thermal design guidelines for Intel processors in the FC-PGA2 package, including the Pentium® III with 512 Kbytes L2 Cache at 1.26 GHz and the Celeron® with 256 Kbytes L2 Cache at 1.2 GHz. Detailed mechanical and thermal specifications for these processors can be found in the *Pentium® III Processor with 512 KB L2 Cache at 1.13 to 1.26 GHz Datasheet* and the *Celeron® Processor for the PGA370 Socket at 1.2 GHz on 0.13 Micron Process Datasheet*.

The thermal solutions presented in this document are specifically designed for embedded computing applications, including the 1U Server and double slot compact PCI form factors.

1.1 Nomenclature

Δ	delta, difference, change between two states
θ	thermal resistance
θ_{max}	maximum allowable thermal resistance
°C	degrees in Celsius
CFD	computational fluid dynamics
CFM	cubic feet per minute
DP	dual processor
EMTS	electrical, mechanical, and thermal specifications
FC-PGA	flip chip pin grid array
in.	inch
lbf	pounds force
LFM	liner feet per minute
LP	low power
PCB	printed circuit board
PGA	pin grid array
Ta	ambient temperature of air at the leading edge of the PCB
TDPmax	maximum thermal design power
TIM	thermal interface material
Tc	case temperature
Tc max	maximum allowable case temperature
W	Watt

2.0 Design Guideline

The thermal solutions presented in this document were designed to fit within the maximum component height allowed by certain embedded form factor specifications, specifically the 1U server and double-slot compact PCI 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.

The information provided in this document is for reference only and additional validation must be performed prior to implementing the designs into final production. The final heat sink design, including the heat sink, attachment method, and thermal interface material (TIM) must comply with the mechanical design, environmental, and reliability requirements delineated in the *Pentium® III FCPGA2 Package, 1U Server Form Factor, Thermal Solution Functional Specification*.

2.1 Mechanical Guidelines

The processor uses a FC-PGA2 package technology that includes an integrated heat spreader (IHS) mounted directly over the bare die. Mechanical specifications for the processor can be obtained from the processor datasheets. The processors utilize a PGA370 socket for installation into the baseboard. Details for the socket are available in the *370 Pin Socket (PGA370) Design Guidelines*.

Figure 1 illustrates the geometry of the FC-PGA2 package with dimensions provided in Table 1. Please refer to *Pentium® III Processor with 512 KB L2 Cache at 1.13 to 1.26 GHz Datasheet* for detailed information.

Figure 1. FC-PGA2 Package Geometry

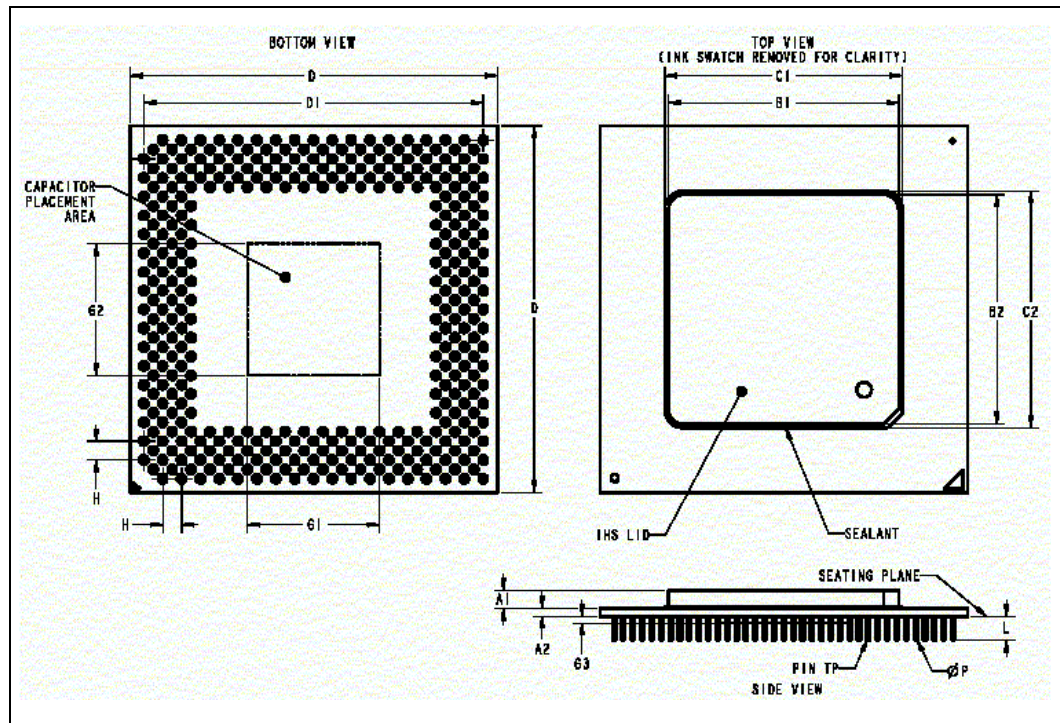


Table 1. FC-PGA2 Mechanical Dimensions

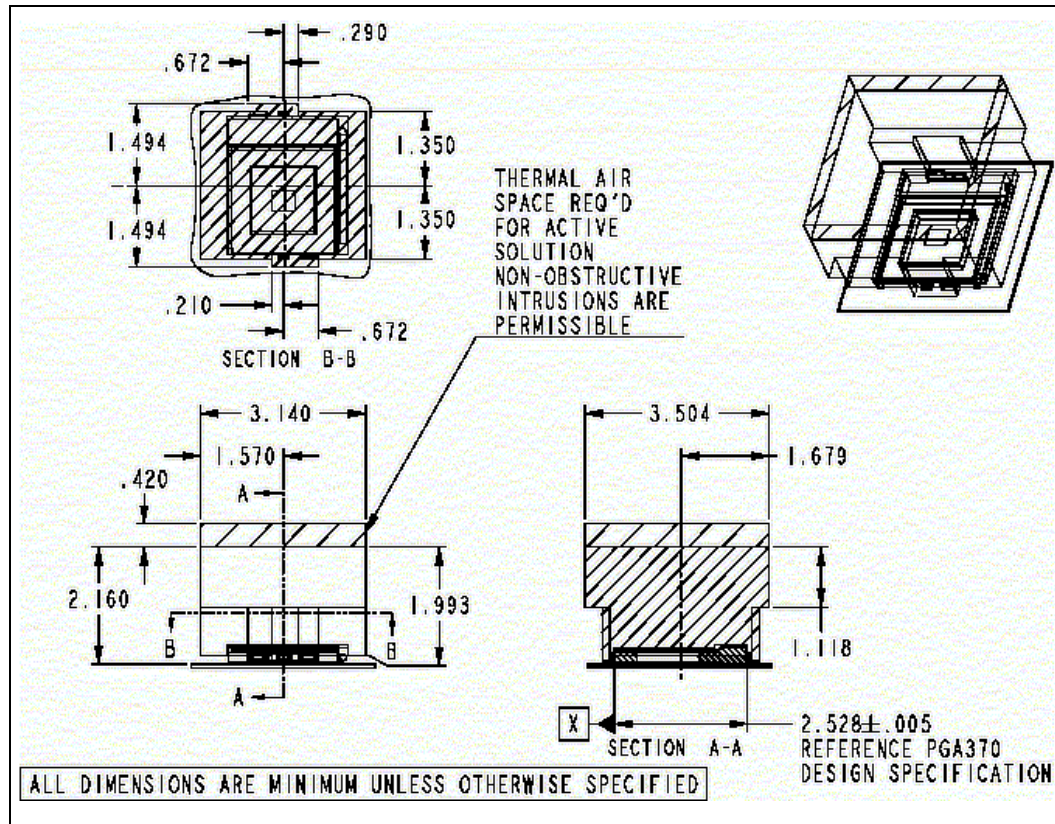
Symbol	Min	Max	Unit	Symbol	Min	Max	Unit
A1	2.266	2.690	mm	G1	0.000	17.780	mm
A2	0.980	1.180	mm	G2	0.000	17.780	mm
B1	30.800	31.200	mm	G3	0.000	0.889	mm
B2	30.800	31.200	mm	H		2.540 Nominal	mm
C1	-	33.000	mm	L	3.048	3.302	mm
C2	-	33.000	mm	ØP	0.431	0.483	mm
D	49.428	49.632	mm	Pin TP	0.508 Diametric True Position		mm
D1	45.466	45.974	mm				

1. Capacitors will be placed on the pin side of the FC-PGA2 package in the area defined by G1, G2, and G3. This area is a keep out zone for motherboard designers.
2. All dimensions are subject to change.
3. All dimensions are in millimeters.
4. Values shown are for reference only

2.1.1 Keep Out Zone

The keep out zone reserved for the processor package, heat sink, and heat sink attachment method for the baseboard is shown in Figure 2. This is the typical keep out zone for the FC-PGA2 package. Please refer to processor datasheets for detailed information.

Figure 2. Volumetric Keep Out Zone for the FC-PGA2 Package



2.2 Thermal Guidelines

This document presents a thermal solution for the Intel® Pentium® III Processor with 512 Kbytes L2 Cache at 1.26 GHz and the Celeron® Processor with 256 Kbytes L2 Cache at 1.2 GHz. The required performance of the thermal solution is dependant on many parameters including the processor's thermal design power (TDP), maximum case temperature (Tc max), 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® III processor in the FC-PGA2 package should be followed to evaluate the thermal performance of proposed cooling solutions. This metrology is contained in the *Intel® Pentium® III processors in the FC-PGA2 Package Thermal Design Guide*.

2.2.1 Thermal Solution Requirements

The thermal solutions recommended in this document were designed based on the processor thermal specifications as outlined in the datasheets listed in Section 3.0. In addition, the processor local ambient temperature was specified as 45 °C with minimum system airflow of 500 LFM. The ambient temperature and airflow are based on a measurement approximately 1 inch upstream from the processor.

The thermal requirement of the heat sink is determined by calculating the case-to-ambient thermal resistance, θ_{ca} . This is a basic thermal engineering parameter that can be used to evaluate and compare different thermal solutions. For this particular processor, θ_{ca} is calculated as shown in equation 1.

Equation 1. Case-to-Ambient Thermal Resistance

$$\theta_{CA_{max}} \rightarrow \theta_{max} = \frac{T_{c_{max}} (^{\circ}C) - T_a (^{\circ}C)}{TDP_{max} (W)} = \frac{69^{\circ}C - 45^{\circ}C}{29.9W} = 0.78 \frac{^{\circ}C}{W}$$

Figure 3 further illustrates the required thermal performance for these processors at different operating ambient temperatures. The thermal solution that is used to cool the processor must have a case-to-ambient thermal resistance less than the values shown for the given ambient temperature.

2.2.2 Recommended Heat Sink Design

The heat sink was designed to meet the required thermal performance for a maximum ambient temperature of 45 °C. This design is Intel intellectual property and intended for customer use with appropriate consent. The heat sink shown in Figure 4 was optimized using computational fluid dynamic (CFD) software. The heat sink is optimized for a non-ducted airflow of 500 LFM, as measured 1 inch upstream from the processor.

The same heat sink can be used in a ducted airflow environment to achieve improved performance. Based on computer modeling, an optimum duct will have a bypass less than 0.2 inch on both sides and no bypass at the top of the heat sink. Figure 5 illustrates the improvement gained by using a duct with a 0.2 inch bypass when compared to the same heat sink without a duct. It is important to note that the duct must be connected directly to the fan or blower supplying the airflow. Simply providing 250 LFM from system airflow and placing a duct over the heat sink will not improve the heat sink's performance.

The geometry of the heat sink is optimized for high volume manufacturing including extrusion, folded fin, and other heat sink manufacturing technologies. A list of enabled vendors is provided in Section 4.0.

Figure 4. Heat Sink Design

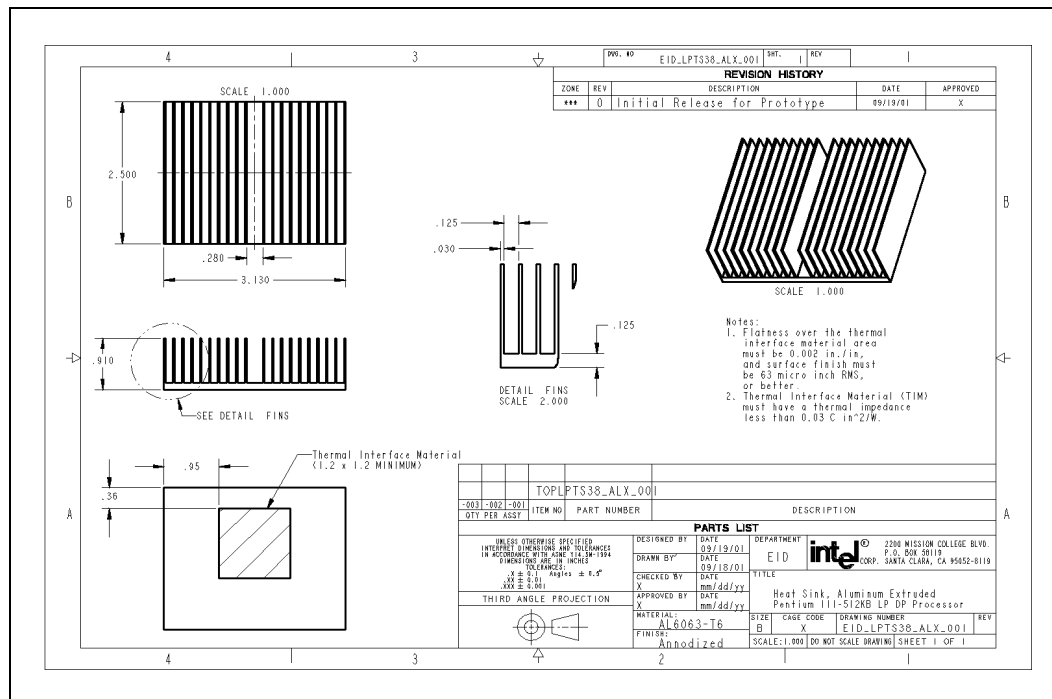
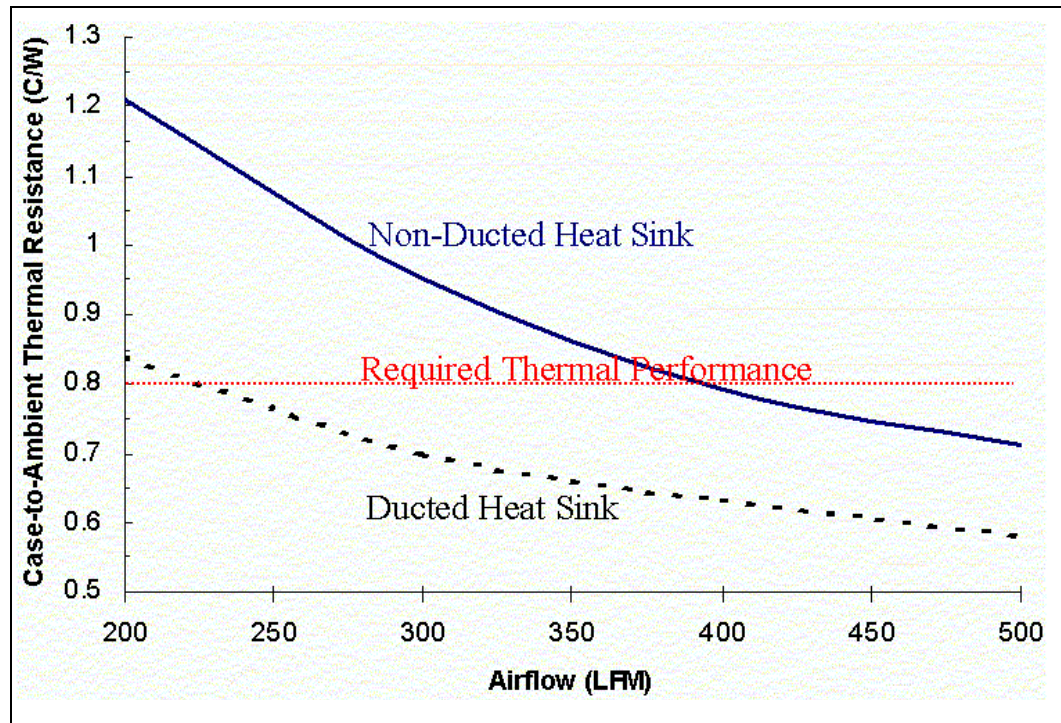


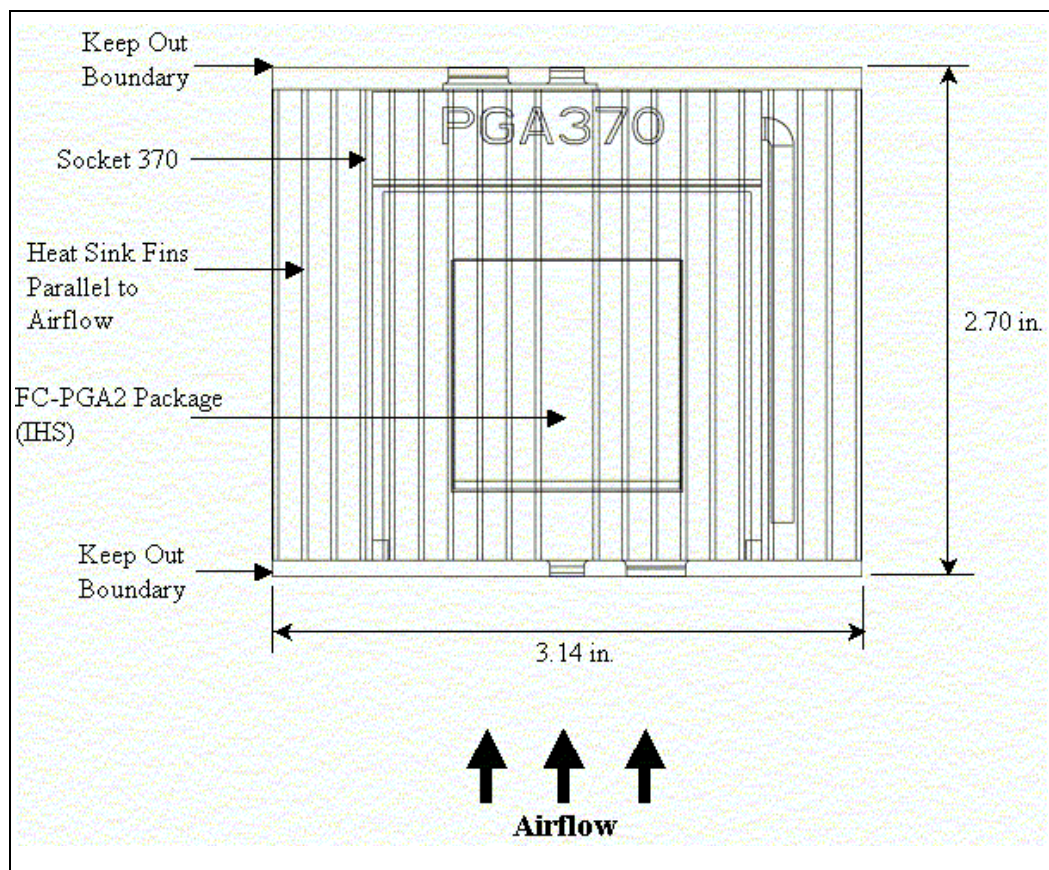
Figure 5. Performance Comparison of Ducted Versus Non-Ducted Airflow



2.2.2.1 Heat Sink Orientation Relative to Airflow

The heat sink was designed to maximize the available space within the volumetric keep out zone. Thermal modeling and verification tests indicate that this heat sink has a case-to-ambient thermal resistance of 0.71 °C/W at 500 LFM without the duct. With the duct, the same heat sink has a case-to-ambient thermal resistance of 0.58 °C/W at 500 LFM and 0.70 °C/W at 300 LFM. This heat sink must be oriented in a specific direction relative to the processor keep out zone and airflow. In order to use this design, the processor must be placed on the PCB in an orientation so the heat sink fins will be parallel to the airflow. Figure 6 illustrates the orientation of the heat sink relative to the processor, keep out zone, and airflow. A top view of the heat sink on the processor assembly is shown.

Figure 6. Heat Sink Orientation to the Processor and Airflow



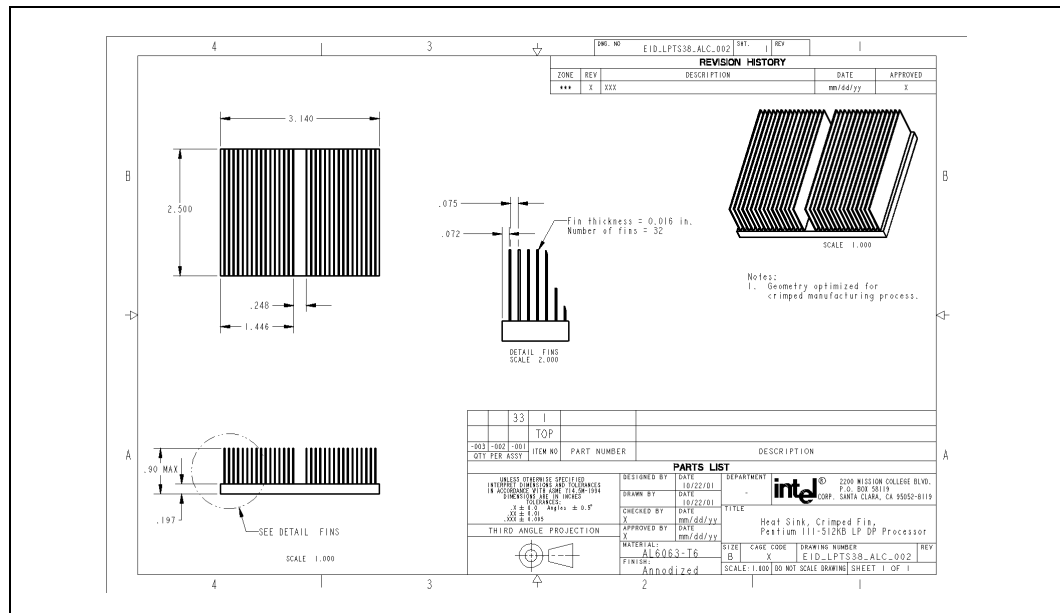
2.2.3 Alternative Heat Sink Designs

The following heat sink designs were developed by various Intel divisions for the Pentium® III Processors in the FC-PGA2 package in the 1U server form factor. These designs are provided as a reference only. Please refer to the appropriate documentation for details on the heat sink designs and intended applications.

2.2.3.1 Aluminum Crimped Fin Heat Sink

This heat sink was developed by the Embedded Intel Architecture division and has been subjected to preliminary verification tests. The geometry of the heat sink has been optimized to provide the required thermal performance and be manufactured using the crimped (a.k.a. pressed) fin manufacturing process. The critical dimensions of this heat sink design are shown in Figure 7. Preliminary test data indicate that this heat sink can be used to cool the Pentium® III Processor with 512 Kbytes L2 Cache at 1.26 GHz at local ambient temperatures up to 45 °C with a non-ducted airflow rate of 450 LFM.

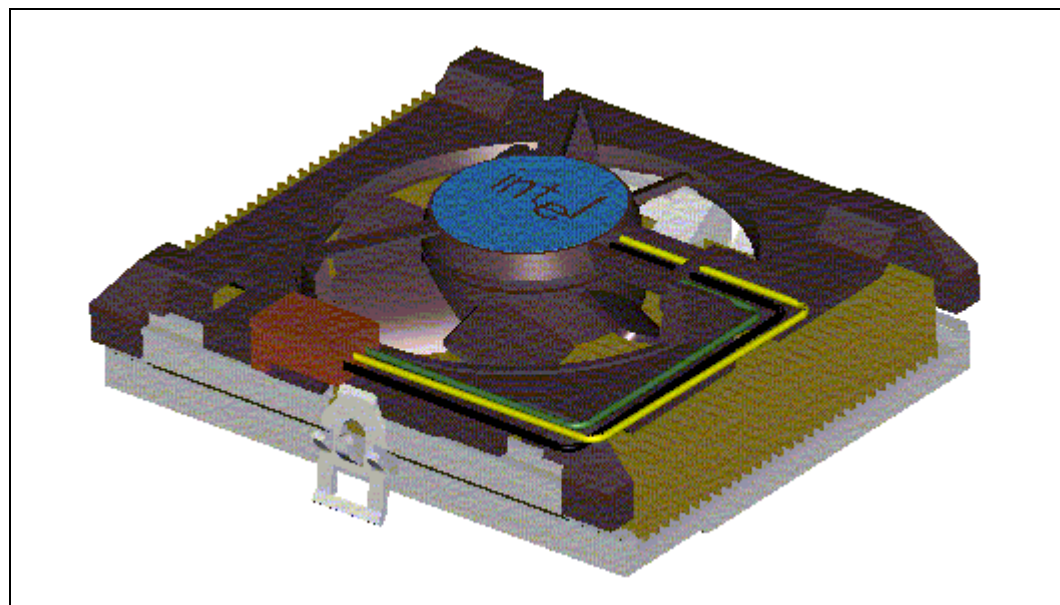
Figure 7. Aluminum Crimped Fin Heat Sink



2.2.3.2 1U Fan Heat Sink

The Intel Reseller Products Group developed this heat sink for use when adequate system airflow is not available. The fan sink has been validated by Intel and can be used with the Pentium® III Processor with 512 Kbytes L2 Cache at 1.26 GHz at local ambient temperatures up to 45 °C. The fan sink is shown in Figure 8. Please contact a local Intel field service engineer for details on this heat sink.

Figure 8. 1U Fan Heat Sink



2.2.4 Recommended Thermal Interface Material

The heat sink solution was optimized using a high performance phase change thermal interface material (TIM) with a thermal impedance of 0.03 °C-in²/W.

The heat sink was prototyped and verified using Chomerics* T725 phase change interface pads. Vendor information for this material is provided in Section 4. Alternative materials can be used at the user's discretion. The entire heat sink assembly must be validated together for specific applications, including the heat sink, clip, and thermal interface material.

2.2.5 Recommended Heat Sink Attachment Method

The heat sink is designed to secure to the PGA370 socket with a pressure-loaded clip. The clip needs to apply a maximum of 65 lbf to the surface of the processor IHS. To optimize the contact pressure between the IHS and heat sink, the maximum possible contact pressure is recommended. However, ergonomic factors must be considered. The clip should not require special tools to engage it to the socket tabs. The required force to engage the clip to the socket tabs should not exceed 15 lbf.

Table 2 lists several low-profile metal clips that meet the constraints mentioned in this document. Vendor information for these clips is provided in Section 4.0.

The use of these clips may require modifications to the heat sink. The channel width in the fins may need to be widened to accommodate the clips. Also, the thickness of the heat sink base plate may have to be increased at the location where the clip engages to the heat sink. However, it is not necessary to change thickness of the entire base; instead the thickness should be changed only at the location where the clip interfaces with the heat sink base.

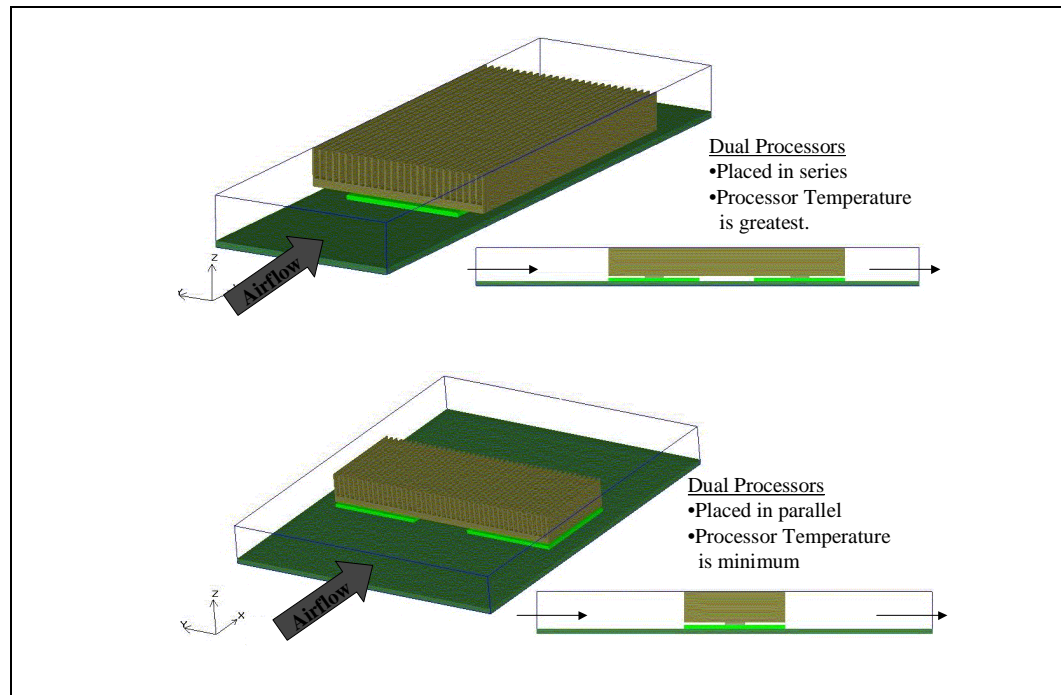
Table 2. Low-Profile Metal Clip Suppliers

Supplier	Part Number	Channel Width (in.)	Base Thickness (in.)
Foxconn*	PW26834-02	0.270 ± 0.10	0.210
Thermshield*	55024-KV	0.270 ± 0.10	0.210
Sanyo Denki*	A59980	0.220 ± 0.10	0.125

2.2.6 Dual Processor Considerations

These presented heat sink designs are suitable for use in a dual processor configuration. However, additional precautions must be taken with the orientation of the processors on the baseboard. Computer modeling indicates that two processors placed in series, one processor placed directly behind the other relative to the airflow, will have higher junction temperatures when compared to processors placed in parallel (side-by-side relative to the airflow). As a result, it is strongly recommended that the processors be placed in the parallel orientation for optimized thermal performance. For a better understanding, Figure 9 illustrates the two orientations and modeling results.

Figure 9. Optimum Orientation in Dual Processor Configurations



3.0 Related Documents

Table 3. Related Documents

Document	Order Number
Pentium® III Processor with 512 KB L2 Cache at 1.13 to 1.26 GHz Datasheet	249657
Celeron® Processor for the PGA370 Socket at 1.2 GHz on 0.13 Micron Process Datasheet	298596
370 Pin Socket (PGA370) Design Guidelines	244410
Intel® Pentium® III processors in the FC-PGA2 Package Thermal Design Guide	249660
Pentium® III FCPGA2 Package, 1U Server Form Factor, Thermal Solution Functional Specification	N/A



4.0 Vendor List

Table 4 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 4. Vendor List

Aluminum Extruded Heat Sink	
Peninsula Components (PENCOM) 1300 Pioneer Street, Suite E Brea, CA 92821	Contact: Steve Blank (562) 964-4477
Thermshield P.O. Box 1641 Laconia, NH 03246	Contact: Tom Garrity (603) 524-3714
Aluminum Crimped Fin Heat Sink	
Computer Memory Disk (FITEL) 2380 Qume Dr. Unit D San Jose, CA 95131	Contact: Katsu Mizushima (408) 232-9300
1U Fan Heat Sink	
Sanyo Denki 468 Amapola Ave. Torrance, CA 90501	Contact: Mamoru Yasui (301) 783-5423
Heat Sink Mounting Clips	
Thermshield P.O. Box 1641 Laconia, NH 03246	Contact: Tom Garrity (603) 524-3714
Foxconn 1699 Richard Ave. Santa Clara, CA 95050	Contact: Julia Jiang (408) 916-6178
Sanyo Denki 468 Amapola Ave. Torrance, CA 90501	Contact: Mamoru Yasui (301) 783-5423
Thermal Interface Material (Chomerics Material No. Thermflow* T725)	
Parker Hannifin Corporation (Chomerics Division) 842 E. Fairway Drive Orange, CA 92866	Contact: John Kefeyan (714) 639-6079