



INFORMATION IN THIS DOCUMENT IS PROVIDED IN CONNECTION WITH INTEL® PRODUCTS. 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 Corporation may have patents or pending patent applications, trademarks, copyrights, or other intellectual property rights that relate to the presented subject matter. The furnishing of documents and other materials and information does not provide any license, express or implied, by estoppel or otherwise, to any such patents, trademarks, copyrights, or other intellectual property rights.

Intel products are not intended for use in medical, life saving, life sustaining, critical control or safety systems, or in nuclear facility applications.

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

Designers must not rely on the absence or characteristics of any features or instructions marked "reserved" or "undefined." Intel reserves these for future definition and shall have no responsibility whatsoever for conflicts or incompatibilities arising from future changes to them.

The Intel® 80331 I/O 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 by calling 1-800-548-4725 or by visiting Intel's website at <http://www.intel.com>.

AnyPoint, AppChoice, BoardWatch, BunnyPeople, CablePort, Celeron, Chips, CT Media, Dialogic, DM3, EtherExpress, ETOX, FlashFile, i386, i486, i960, iCOMP, InstantIP, Intel, Intel Centrino, Intel logo, Intel386, Intel486, Intel740, IntelDX2, IntelDX4, IntelSX2, Intel Create & Share, Intel GigaBlade, Intel InBusiness, Intel Inside, Intel Inside logo, Intel NetBurst, Intel NetMerge, Intel NetStructure, Intel Play, Intel Play logo, Intel SingleDriver, Intel SpeedStep, Intel StrataFlash, Intel TeamStation, Intel Xeon, Intel XScale, IPLink, Itanium, MCS, MMX, MMX logo, Optimizer logo, OverDrive, Paragon, PC Dads, PC Parents, PDCharm, Pentium, Pentium II Xeon, Pentium III Xeon, Performance at Your Command, RemoteExpress, SmartDie, Solutions960, Sound Mark, StorageExpress, The Computer Inside., The Journey Inside, TokenExpress, VoiceBrick, VTune, and Xircom are trademarks or registered trademarks of Intel Corporation or its subsidiaries in the United States and other countries.

| The ARM* and ARM Powered logo marks (the ARM marks) are trademarks of ARM, Ltd., and Intel uses these marks under license from ARM, Ltd.

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

Copyright © 2005, Intel Corporation

Contents

1.0	Introduction	7
1.1	Definition of Terms.....	7
1.2	Reference Documents	8
2.0	Packaging Technology	9
3.0	Thermal Simulations	11
4.0	Thermal Specifications	11
4.1	Power.....	11
4.2	Die Temperature.....	11
5.0	Thermal Metrology	12
5.1	Die Temperature Measurements	12
5.1.1	Zero-Degree Angle Attach Methodology	12
6.0	Reference Thermal Solution	14
6.1	Operating Environment.....	14
6.2	Heat Sink Performance.....	14
6.3	Mechanical Design Envelope	15
6.4	Keep-Out Dimensions of the Board-Level Components.....	15
6.5	Heat Sink Clip Thermal Solution Assembly	16
6.5.1	Heat Sink Orientation.....	18
6.5.2	Extruded Heat Sink Profiles	18
6.5.3	Mechanical Interface Material.....	18
6.5.4	Thermal Interface Material.....	19
6.5.4.1	Effect of Pressure on TIM Performance.....	19
6.5.5	Heat Sink Clip	19
6.5.6	Heat Sink Clip Assembly	20
6.6	Reliability Guidelines	22
A	Thermal Solution Component Suppliers	23
A.1	Reference Thermal Solution Component Suppliers	23
B	Mechanical Drawings	24
C	Design Validation (DV)	36
C.1	TIM Degradation Shock and Vibration Validation Strategy.....	36
C.1.1	TIM Degradation	36
C.1.2	Metrology	36
C.1.3	TIM Thermal Resistance.....	36
C.1.4	Test Set-up	36
C.1.5	DV Result Summary	37
D	Manufacturing Validation (MV)	38

Figures

1	Intel® 80331 I/O Processor Package Dimensions (Top View).....	9
2	Package Dimensions (Side View)	9
3	Package Dimensions (Bottom View)	10
4	Zero-Degree Angle Attach Heat Sink Modifications	13
5	Zero-Degree Angle Attach Methodology (Top View).....	13
6	Intel® 80331 I/O Processor Heat Sink Clip Volumetric Envelope for the Component	15
7	Intel® 80331 I/O Processor Heat Sink Clip Board Component Keep-Out Zones	16
8	Intel® 80331 I/O Processor Retention Mechanism Component Keep-Out Zones	17
9	Intel® 80331 I/O Processor Heat Sink Clip Assembly	18
10	Intel® 80331 I/O Processor Heat Sink Extrusion Profile	18
11	Hand-Tool Design.....	20
12	Hand-Tool on Heat-Sink Clip Assembly	21
13	Intel® 80331 I/O Processor Reference Thermal Solution Assembly Drawing	24
14	Heat Sink Schematic 1	26
15	Heat Sink Schematic 2	27
16	Clip Schematic 1.....	29
17	Clip Schematic 2.....	30
18	Clip Schematic 3.....	31
19	Assembly Schematic 1	33
20	Assembly Schematic 2	34
21	Assembly Schematic 3	35
22	Test Fixture.....	36
23	Variability Chart for Rjs.....	37

Tables

1	Intel® 80331 I/O Processor Thermal Specifications	11
2	Heat Sink Performance Data.....	14
3	Reliability Guidelines	22
4	Reference Thermal Solution Component Suppliers	23
5	Mechanical Drawing List.....	24
6	Intel® 80331 I/O Processor Clip MV Result Summary.....	38

Revision History

Date	Revision	Description
May 2005	004	Added ARM disclaimer to Legal page. Revised Table 1 , Tcase value from 105 to 95. Added Table 2 , Note 1.
September 2004	003	Updated with version 2 heat sink. Rails were added to prevent heat sink from tipping.
March 2004	002	Added PCM45F alternate thermal solution sentence.
January 2004	001	Initial Release.



THIS PAGE INTENTIONALLY LEFT BLANK

1.0 Introduction

As the complexity of computer systems increases, so do the power dissipation requirements. Care must be taken to ensure that the additional power is properly dissipated. Typical methods to improve heat dissipation include selective use of ducting, and/or passive heat sinks.

The purpose of this document is as follows:

- To specify the operating limits of the Intel® 80331 I/O processor¹ (80331) component.
- To describe a reference thermal solution meeting thermal specifications for the 80331 component.

Properly designed thermal solutions provide adequate cooling to maintain the component die temperatures at or below thermal specifications. This is accomplished by providing a low local ambient temperature, ensuring adequate local airflow, and minimizing the die-to-local-ambient thermal resistance. By maintaining the component die temperature at or below the specified limits, a system designer can ensure the proper functionality, performance, and reliability of the chipset. Operation outside the functional limits can degrade system performance and can cause permanent changes in the operating characteristics of the component. The simplest and most cost-effective method is to improve the inherent system cooling characteristics through careful chassis design and placement of fans, vents, and ducts. When additional cooling is required, component thermal solutions can be implemented in conjunction with system thermal solutions. The size of the fan or heat sink can be varied to balance size and space constraints with acoustic noise.

This document addresses thermal design and specifications for the components only. For thermal design information on other chipset components, refer to the datasheet of the respective component.

1.1 Definition of Terms

BGA	Ball Grid Array. A package type, defined by a resin-fiber substrate, onto which a die is mounted, bonded, and encapsulated in molding compound. The primary electrical interface is an array of solder balls attached to the substrate opposite the die and molding compound.
T _{case}	Maximum die temperature allowed. This temperature is measured at the geometric center of the top of the package die.
TDP	Thermal Design Power. Thermal solutions must be designed to dissipate this target power level while keeping the die temperature under the maximum allowed.
T _J	Junction temperature
T _A	Ambient temperature
T _S	Sink temperature

1. Compliant with ARM* architecture



1.2 Reference Documents

The reader of this specification must also be familiar with the material and concepts presented in the following documents:

- *BGA/OLGA Assembly Development Guide*
- Various system thermal design suggestions located at <http://www.formfactors.org>.

Note: Unless otherwise specified, these documents are available through your Intel field sales representative. Some documents might not be available at this time.

2.0 Packaging Technology

The component uses a 37.5 mm × 37.5 mm, 10-layer FC-BGA package (Figure 1, Figure 2, and Figure 3).

Figure 1. Intel® 80331 I/O Processor Package Dimensions (Top View)

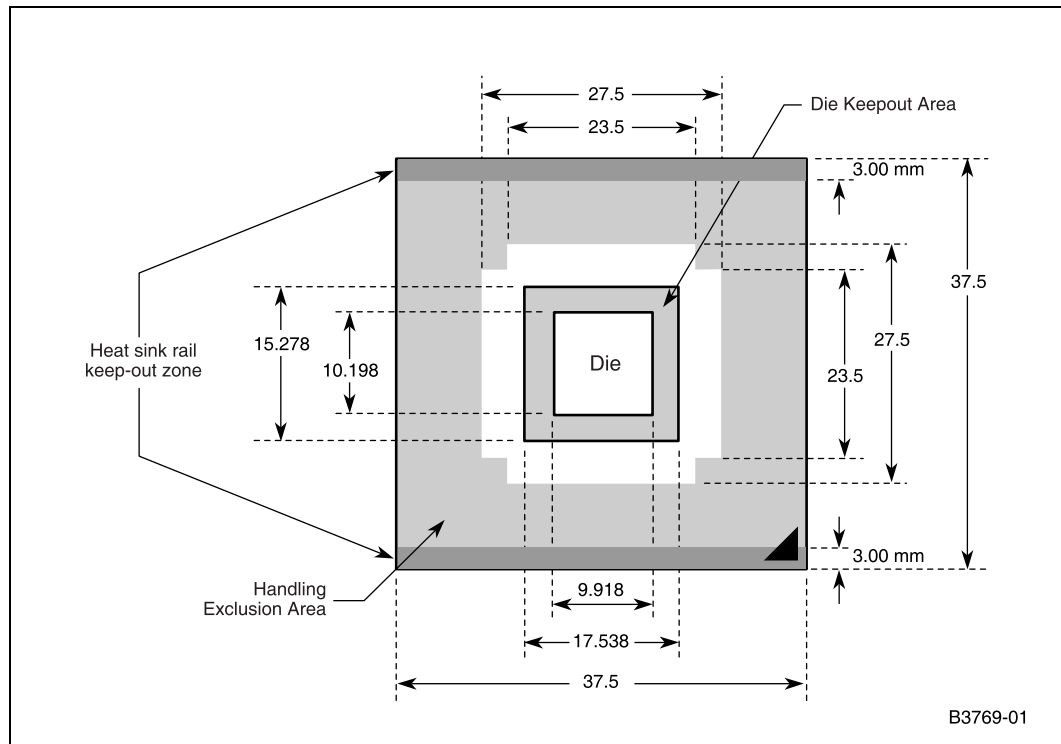


Figure 2. Package Dimensions (Side View)

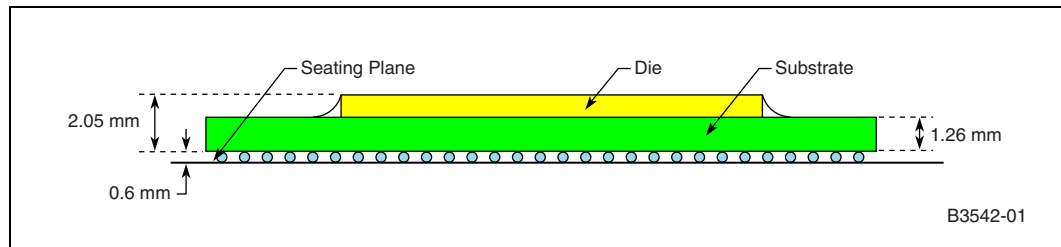
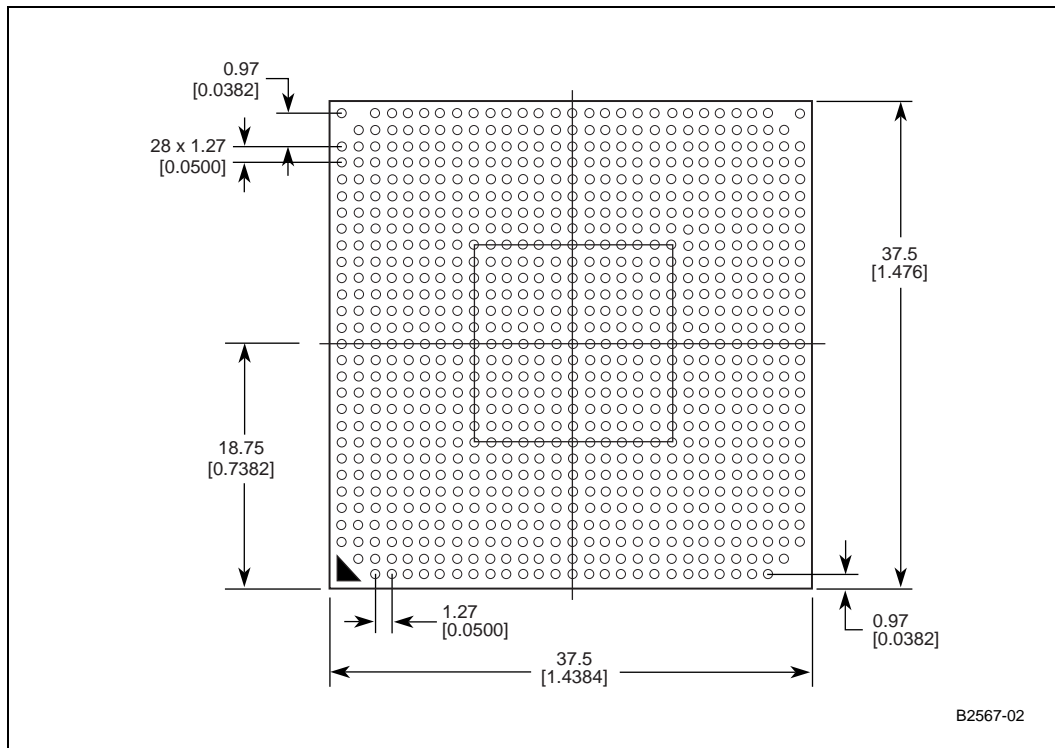


Figure 3. Package Dimensions (Bottom View)



3.0 Thermal Simulations

Intel provides thermal simulation models of the component and associated guides to aid system designers in simulating, analyzing, and optimizing their thermal solutions in an integrated, system-level environment. The models are for use with the commercially available Computational Fluid Dynamics (CFD)-based thermal analysis tool “ICEPAK*” (version 4.0 or higher) by Fluent*. Contact your Intel field sales representative to order the thermal models and user’s guides.

4.0 Thermal Specifications

4.1 Power

Flip Chip Ball Grid Array (FC-BGA) packages have poor heat-transfer capability into the board and have minimal thermal capability without thermal solutions. Intel recommends that system designers plan for a heat sink when using this component. For Intel® 80331 I/O processor power estimates, contact your local Intel sales representative.

4.2 Die Temperature

To ensure proper operation and reliability of the component, the die temperatures must be at or below the values specified in [Table 1](#). System- and/or component-level thermal solutions are required to maintain die temperatures below the maximum temperature specifications. Refer to [Section 5.0, “Thermal Metrology”](#) on page 12 for guidelines on accurately measuring package die temperatures.

Table 1. Intel® 80331 I/O Processor Thermal Specifications

Device	T _{case} (°C)	T _J max (°C)	P _{THERMAL} (W)
Intel® 80331 I/O Processor	95	110	8.69 ¹

NOTE:

1. This is the expected worst-case power used to calculate reference thermal solution.

5.0 Thermal Metrology

The system designer must make temperature measurements to accurately determine the thermal performance of the system. Intel has established guidelines for proper techniques to measure the die temperatures. [Section 5.1](#) provides guidelines on how to accurately measure the die temperatures.

5.1 Die Temperature Measurements

To ensure functionality and reliability, the T_{case} of the Intel® 80331 I/O processor must be maintained at or below the maximum temperature specification as noted in [Table 1](#). The surface temperature at the geometric center of the die corresponds to T_{case} . Measuring T_{case} requires special care to ensure an accurate temperature measurement.

Temperature differences between the temperature of a surface and the surrounding local ambient air can introduce errors in the measurements. The measurement errors can be due to a poor thermal contact between the thermocouple junction and the surface of the package, heat loss by radiation and/or convection, conduction through thermocouple leads, or contact between the thermocouple cement and the heat sink base (when a heat sink is used). To maximize measurement accuracy, only the 0° thermocouple attach approach is recommended.

5.1.1 Zero-Degree Angle Attach Methodology

1. Mill a hole 3.3 mm (0.13 in.) in diameter and 1.5 mm (0.06 in.) deep, centered on the bottom of the heat sink base.
2. Mill a slot 1.3 mm (0.05 in.) wide and 0.5 mm (0.02 in.) deep from the centered hole to one edge of the heat sink. The slot must be parallel to the heat sink fins ([Figure 4](#)).
3. Attach thermal interface material (TIM) to the bottom of the heat sink base.
4. Cut out portions of the TIM to make room for the thermocouple wire and bead. The cutouts must match the slot and hole milled into the heat sink base.
5. Attach a 36 gauge or smaller calibrated K-type thermocouple bead or junction to the center of the top surface of the die using a high thermal conductivity cement. During this step, ensure no contact is present between the thermocouple cement and the heat sink base, because any contact will affect the thermocouple reading. It is critical that the thermocouple bead makes contact with the die ([Figure 5](#)).
6. Attach heat sink assembly to the 80331 and route thermocouple wires out through the milled slot.

Figure 4. Zero-Degree Angle Attach Heat Sink Modifications

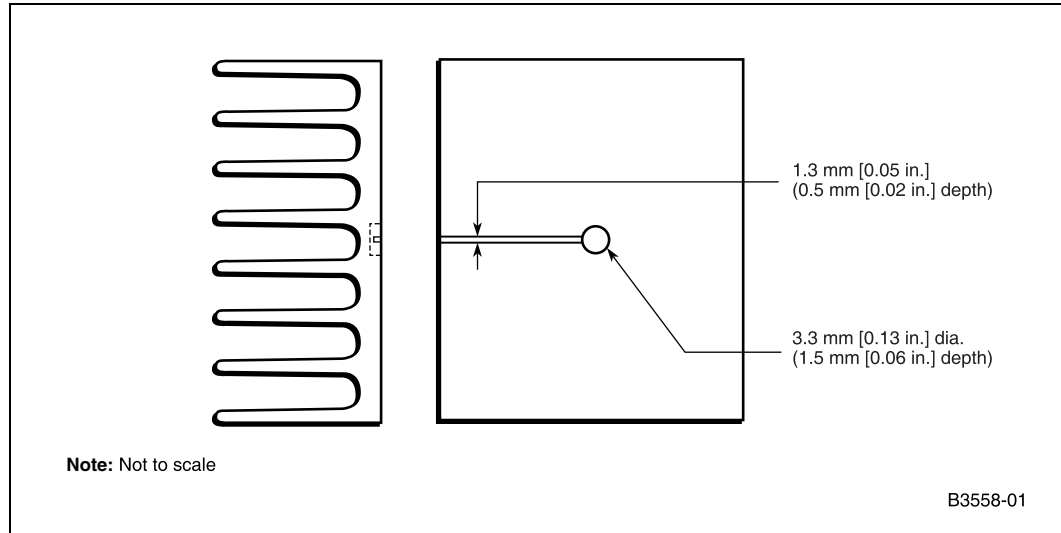
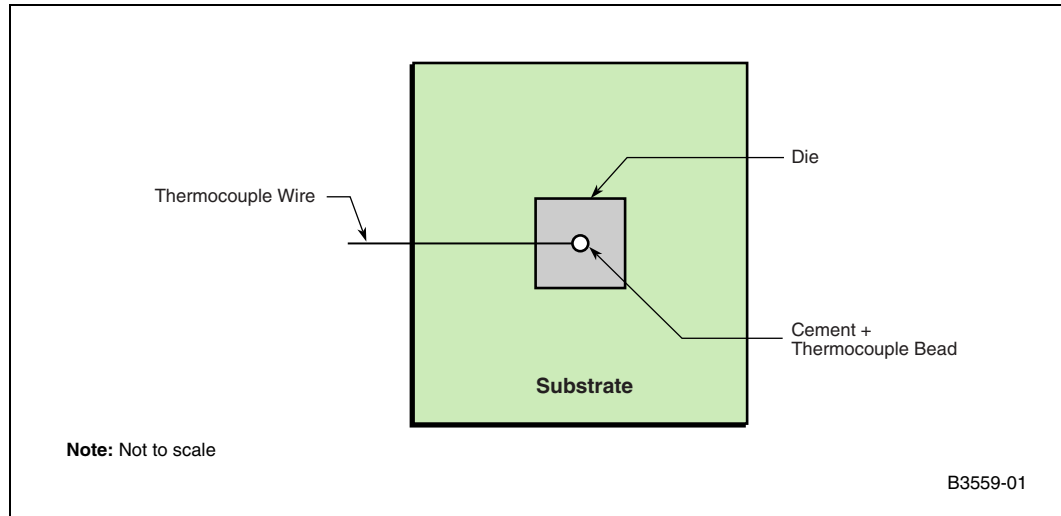


Figure 5. Zero-Degree Angle Attach Methodology (Top View)



6.0 Reference Thermal Solution

Intel has developed a reference thermal solutions designed to meet the cooling needs of the component under worst-case conditions. This section describes the overall requirements for the reference thermal solution including critical-to-function dimensions, operating environment, and validation criteria. Other chipset components might or might not need attached thermal solutions, depending on your specific system local-ambient operating conditions.

6.1 Operating Environment

The reference thermal solution was designed assuming a maximum local-ambient temperature of 50 °C at an elevation of 1800 m. The minimum recommended airflow velocity at the heat sink is 200 linear feet per minute (LFM) measured from the heat sink center. The approaching airflow temperature is assumed to be equal to the local-ambient temperature. The thermal designer must carefully select the location to measure airflow to obtain an accurate estimate.

6.2 Heat Sink Performance

This section is supplied with a measured thermal performance of the heat sink solution versus airflow rate.

Table 2. Heat Sink Performance Data

Air Flow (LFM)	Ψ_{SA} (18 °C @ Sea Level)	Ψ_{SA} (50 °C @ 1800 m)	Θ_{JS} EOLine (°C/W)	Θ_{JA} EOLine (°C/W)
100 ¹	4.69	5.72	0.67	6.39
200	3.80	4.63	0.67	5.30
300	3.29	4.02	0.67	4.68

1. The minimum recommended airflow is 200 LFM, as stated in [Section 6.1](#). This table includes 100 LFM only as a reference point.

Equation 1. Heat Sink Performance Equations

$$\Psi_{SA} = \frac{T_S - T_A}{P} \quad \Theta_{JS} = \frac{T_J - T_S}{P} \quad \Theta_{JA} = \Psi_{SA} + \Theta_{JS}$$

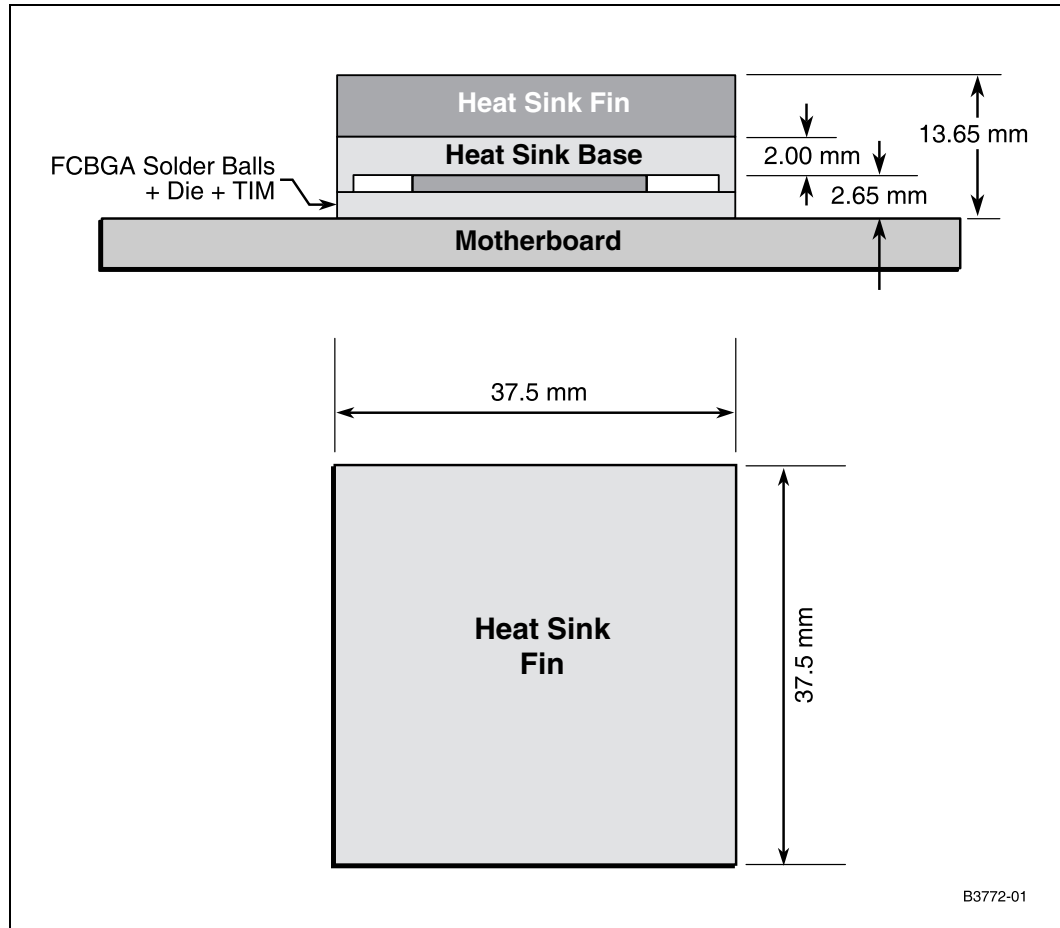
NOTES:

1. T_S = Heat sink temperature
2. T_A = Ambient temperature
3. P = Die power
4. Θ_{JS} = TIM thermal resistance denotes the TIM performance
5. Ψ_{SA} = Heat sink to ambient thermal resistance denotes the heat sink performance
6. Θ_{JA} = Package to ambient thermal resistance

6.3 Mechanical Design Envelope

Although each design can have unique mechanical volume and height restrictions or implementation requirements, the height, width, and depth constraints typically placed on the thermal solution are shown in Figure 6. When using heat sinks that extend beyond the reference heat sink envelope shown in Figure 6, any motherboard components placed between the heat sink and motherboard cannot exceed 2.65 mm (0.110 in.) in height.

Figure 6. Intel® 80331 I/O Processor Heat Sink Clip Volumetric Envelope for the Component



6.4 Keep-Out Dimensions of the Board-Level Components

The locations of hole patterns and keep-out zones for the reference thermal solution are shown in Figure 7 and Figure 8.

6.5 Heat Sink Clip Thermal Solution Assembly

The reference thermal solution for the component is a passive extruded heat sink with thermal interface. It is attached using a four-leg clip with four hooks directly penetrating through board holes and firmly engaged to the secondary side of the board. Figure 9 shows the reference thermal solution assembly and associated components. Full mechanical drawings of the thermal solution assembly and the heat sink clip are provided in Appendix B. Appendix A contains vendor information for each thermal solution component.

Figure 7. Intel® 80331 I/O Processor Heat Sink Clip Board Component Keep-Out Zones

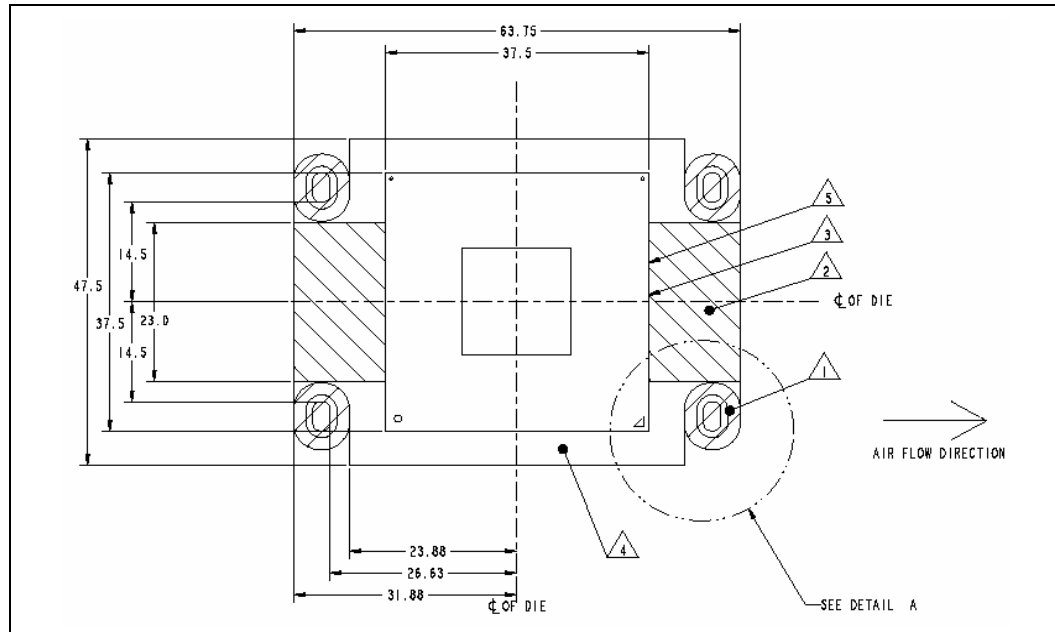
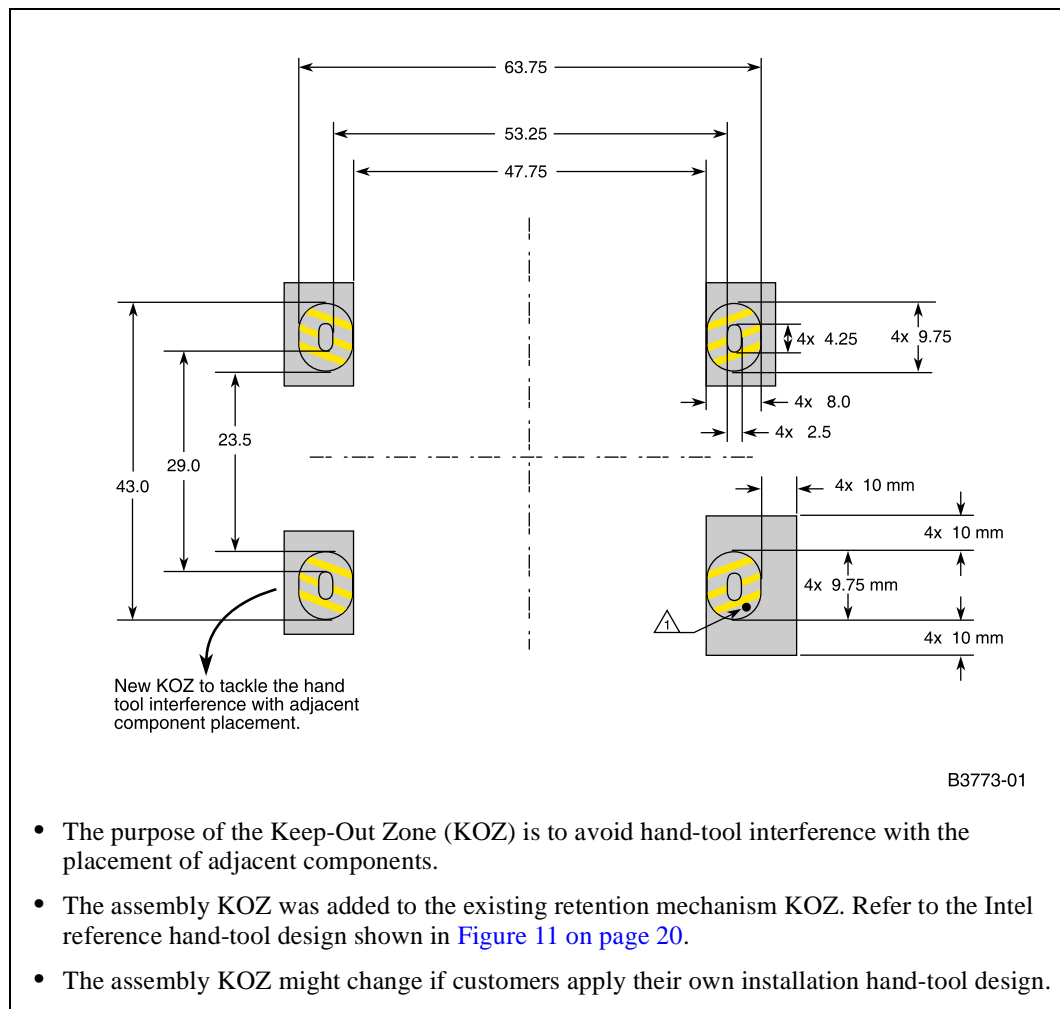


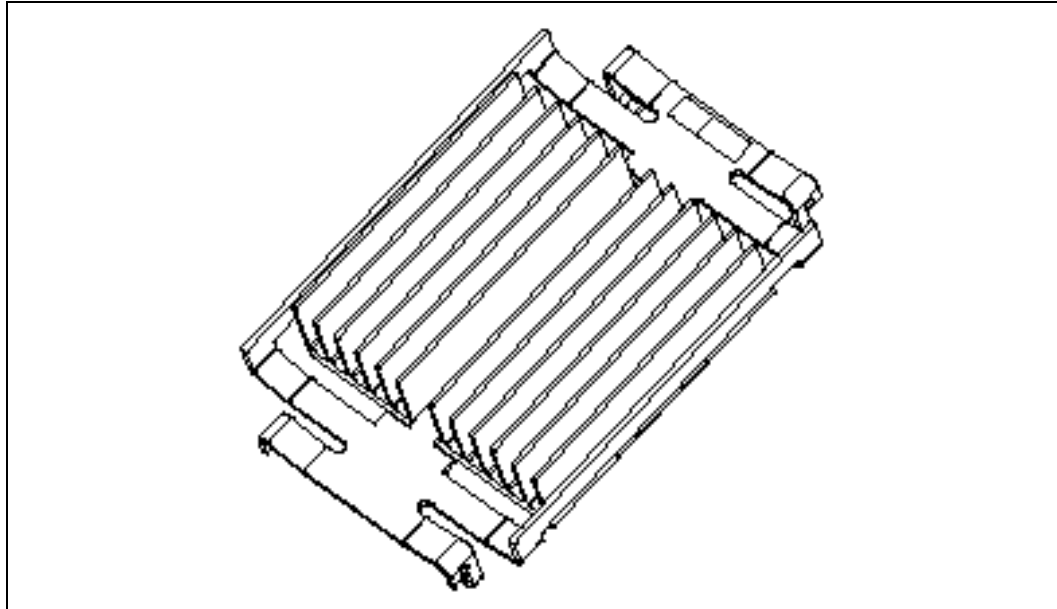
Figure 8. Intel® 80331 I/O Processor Retention Mechanism Component Keep-Out Zones



6.5.1 Heat Sink Orientation

Since this solution is based on a unidirectional heat sink, the mean airflow direction must be aligned with the direction of the fins of the heat sink.

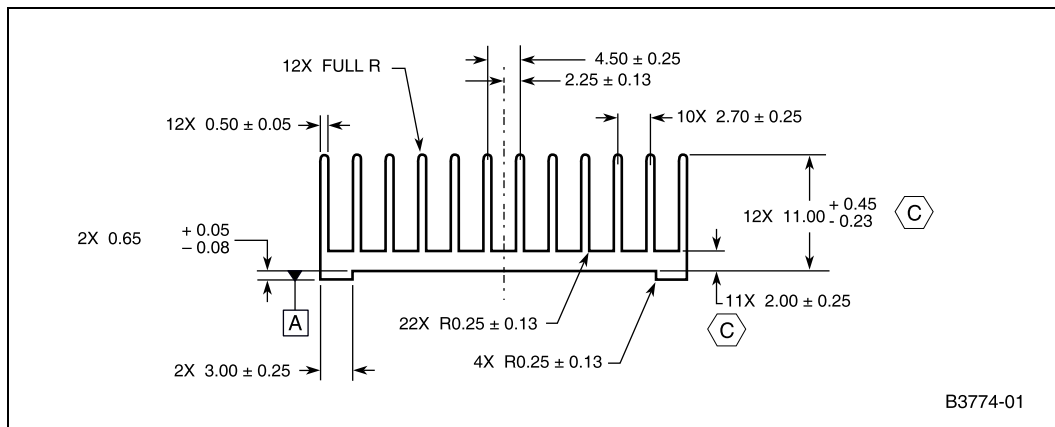
Figure 9. Intel® 80331 I/O Processor Heat Sink Clip Assembly



6.5.2 Extruded Heat Sink Profiles

The reference heat sink clip uses an extruded heat sink for cooling the component. Figure 10 shows the heat sink profile. Appendix A lists a supplier for this extruded heat sink. Other heat sinks with similar dimensions and increased thermal performance might be available. Full mechanical drawing of this heat sink is provided in Appendix B.

Figure 10. Intel® 80331 I/O Processor Heat Sink Extrusion Profile



6.5.3 Mechanical Interface Material

There is no mechanical interface material associated with this reference solution.

6.5.4 Thermal Interface Material

A thermal interface material provides improved conductivity between the die and the heat sink. The reference thermal solution uses Honeywell* PCM45HD, 0.0508 mm (0.002 in.) thick, 20 mm × 20 mm (0.7874016 in. × 0.7874016 in.) square.

Alternate reference thermal solution recommended is PCM45F.

6.5.4.1 Effect of Pressure on TIM Performance

As mechanical pressure increases on the TIM, the thermal resistance of the TIM decreases. This phenomenon is due to the decrease of the bond line thickness (BLT). The effect of pressure on the thermal resistance of the Honeywell* PCM45HD TIM can be found at the following URL:

<http://www.honeywell.com/sites/sm/em/interpack.htm>

The heat sink clip provides enough pressure for the TIM to achieve a thermal conductivity of $0.2 \times C \text{ cm}^2/\text{W}$ ($5.0 \text{ W/m} \times C$).

6.5.5 Heat Sink Clip

The reference solution uses a clip with hooked ends. The hooks penetrate through the board holes and are firmly engaged to the secondary side of the board. See [Appendix B](#) for a mechanical drawing of the clip.

6.5.6 Heat Sink Clip Assembly

It is recommended to use a hand tool to ease the heat sink clip assembly, with support fixture, beneath the package to be assembled. The support fixture is used to provide support to the package, in order to reduce the board deflection on the BGA solder ball. Figure 11 shows the recommended hand-tool design. The hand tool consist of the handle and metal groove. The groove is designed in the metal, in order to be inserted into the leg of the clip, so as to ease the bending and pressing process of the heat sink clip assembly. Figure 12 shows the heat sink clip assembly with groove inserted into the leg of the clip.

It is also recommended that the die on the package is cleaned with isopropyl alcohol (IPA) prior to the heat sink clip assembly. This is to ensure the thermal interface material (TIM) functions per the specification.

Figure 11. Hand-Tool Design

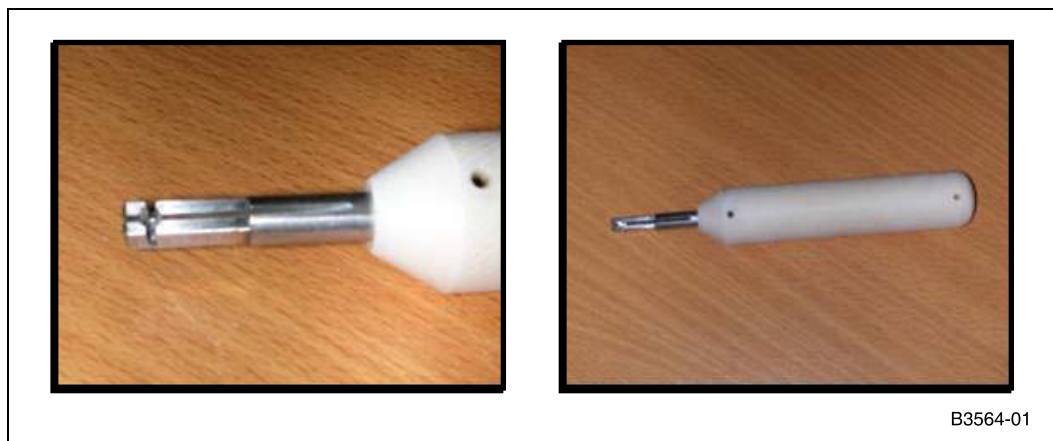


Figure 12. Hand-Tool on Heat-Sink Clip Assembly



6.6 Reliability Guidelines

Each motherboard, heat sink and attach combination may vary the mechanical loading of the component. Based on the end user environment, the user should define the appropriate reliability test criteria and carefully evaluate the completed assembly prior to use in high volume. Some general recommendations are shown in [Table 3](#).

Table 3. Reliability Guidelines

Test	Requirements	Reference	Pass/Fail Criteria
Mechanical Shock	50G 6 axis shock 3 shock/axis	Unpackaged System Level	Visual Check, Electrical Continuity Test (with cross section information), Thermal Resistance Testing
Random Vibration	3.12 gRMS, 5 Hz @ 0.01 g ² /Hz to 20 Hz @ 0.02 g ² /Hz (slop up) 20 to 500 Hz @ 0.02 g ² /Hz (flat) 10 min/axis	Unpackaged System Level	Visual Check, Electrical Continuity Test (with cross section information), Thermal Resistance Testing
High Operating Temperature	125 °C for 1000 hours	Board-Level Legacy	Visual Check and Electrical Continuity Test
Temperature Cyclic	-40 °C to +85 °C for 1300 cycles	Board-Level Use Condition	Visual Check and Electrical Continuity Test
Humidity	85 °C with 85% RH for 1000 hours	Board-Level Legacy	Visual Check

