Desktop 4th Generation Intel® Core™ Processor Family, Desktop Intel® Pentium® Processor Family, Desktop Intel® Celeron® Processor Family, and Intel® Xeon® Processor E3-1200 v3 Product Family

Thermal Mechanical Design Guidelines (TMDG)

December 2013

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Revision History

Revison Number	Description	Revision Date
001	• Initial release	June 2013
002	• Added Desktop Intel® Pentium® processor family	September 2013
003	• Added Desktop Intel® Celeron® processor family	December 2013

1.0 Introduction

This document contains thermal and mechanical design guidance for the Desktop 4th Generation Intel® Core™ processor family, Desktop Intel® Pentium® processor family, Desktop Intel® Celeron® processor family, and Intel® Xeon® processor E3-1200 v3 product family.

The components described in this document include:

- Thermal and mechanical design guidance for:
  — Desktop 4th Generation Intel® Core™ processor family with 4 cores and integrated graphics
  — Desktop 4th Generation Intel® Core™ processor family with 2 cores and integrated graphics
  — Desktop Intel® Pentium® processor family with 4 cores and integrated graphics
  — Desktop Intel® Pentium® processor family with 2 cores and integrated graphics
  — Desktop Intel® Celeron® processor family with 4 cores and integrated graphics
  — Desktop Intel® Celeron® processor family with 2 cores and integrated graphics
  — Intel® Xeon® processor E3-1200 v3 product family with 4 cores and integrated graphics
  — Intel® Xeon® processor E3-1200 v3 product family with 2 cores and integrated graphics

- A reference design thermal solution (heatsink) for the processors and associated retention hardware.

The processor has four SKUs. When required for clarity, this document will use:

- Desktop 4th Generation Intel® Core™ processor (PCG 2013D)
- Desktop 4th Generation Intel® Core™ processor (PCG 2013C)
- Desktop 4th Generation Intel® Core™ processor (PCG 2013B)
- Desktop 4th Generation Intel® Core™ processor (PCG 2013A)
- Desktop Intel® Pentium® processor (PCG 2013D)
- Desktop Intel® Pentium® processor (PCG 2013C)
- Desktop Intel® Pentium® processor (PCG 2013B)
- Desktop Intel® Pentium® processor (PCG 2013A)
- Desktop Intel® Celeron® processor (PCG 2013D)
- Desktop Intel® Celeron® processor (PCG 2013B)
- Desktop Intel® Celeron® processor (PCG 2013B)
- Desktop Intel® Celeron® processor (PCG 2013A)

- Intel® Xeon® processor E3-1200 v3 product family (PCG 2013D)
- Intel® Xeon® processor E3-1200 v3 product family (PCG 2013C)
- Intel® Xeon® processor E3-1200 v3 product family (PCG 2013B)
- Intel® Xeon® processor E3-1200 v3 product family (PCG 2013A)

Note: When the information is applicable to all products this document will use "processor" or "processors" to simplify the document.

1.1 Key Changes

The processors introduce thermal and mechanical changes that will be highlighted in this document and related documentation identified in Related Documents on page 9:

- A new fan speed control implementation scheme is introduced, DTS 2.0.
- A mechanical keying change has been made to differentiate the processor from previous generation processors shown in Figure 1 on page 8.
- The pin out count has been reduced to 1150 in the processors, down from 1155 in the previous generation.

Figure 1.   Keying and Pin Out Array Comparison
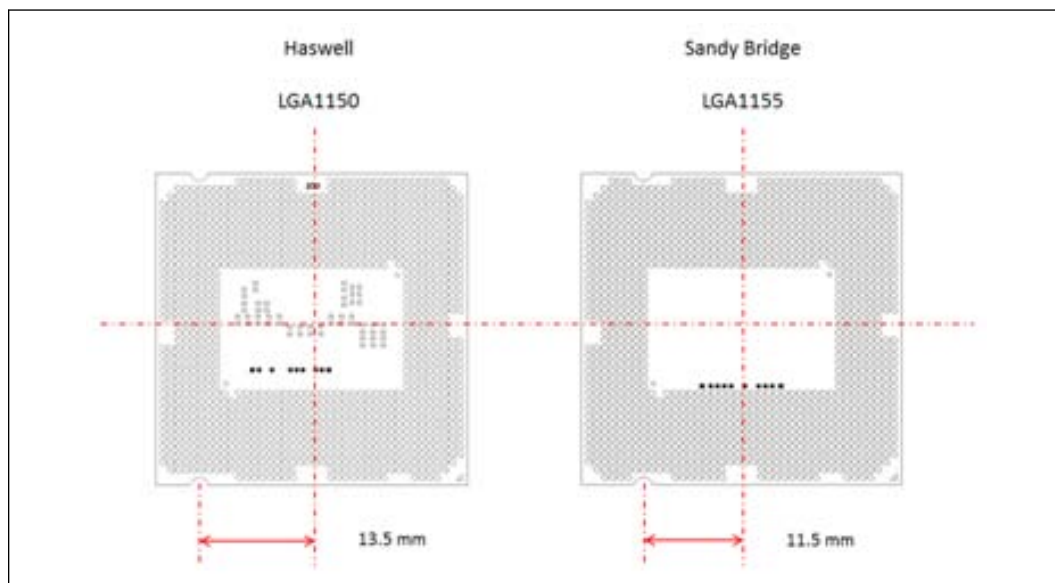
Despite the thermal and mechanical changes, the processor will allow for the reuse of the Socket Contact, Independent Loading Mechanism (ILM), Heatsink Keep-in Zone, ILM Cover, and Solder Joint Reliability (SJR) Recommendations.

The *Desktop 4th Generation Intel® Core™ Processor Family, Desktop Intel® Pentium® Processor Family and Intel® Xeon® Processor E3-1200 v3 Product Family - Thermal Mechanical Design Guidelines (TMDG)* also includes changes from the previous generation Thermal Mechanical Specifications and Design Guidelines (TMSDG). The two most significant changes include:

1. The Thermal Specifications chapter has been relocated to documents *Desktop 4th Generation Intel® Core™ Processor Family, Intel® Pentium® Processor Family, and Intel® Celeron® Processor Family Datasheet - Volume 1 of 2* and *Intel® Xeon® Processor E3-1200 v3 Product Family Datasheet - Volume 1 of 2*.

2. The *LGA1150 Socket Application Guide* will now contain the chapters discussing the Socket, the Independent Loading mechanism (ILM), their respective Electrical, Mechanical, and Environmental Specifications, and related Appendices.

Note: Refer to Related Documents on page 9 for details on acquiring these documents.

1.2 Related Documents

Material and concepts available in the following documents may be beneficial when reading this document.

Table 1. Related Documents

Title	Document Number / Location
Desktop 4th Generation Intel® Core™ Processor Family, Intel® Pentium® Processor Family, and Intel® Celeron® Processor Family Datasheet - Volume 1 of 2	328897
Desktop 4th Generation Intel® Core™ Processor Family, Intel® Pentium® Processor Family, and Intel® Celeron® Processor Family Datasheet - Volume 2 of 2	328898
Intel® Xeon® Processor E3-1200 v3 Product Family Datasheet - Volume 1 of 2	328907
Intel® Xeon® Processor E3-1200 v3 Product Family Datasheet - Volume 2 of 2	329000
Intel® Xeon® Processor E3-1200 v3 Product Family Specification Update	328908
LGA1150 Socket Application Guide	328999
Thermally Advantaged Chassis (TAC)	http://www.formfactors.org/
4-Wire Pulse Width Modulation (PWM) Controlled Fans	http://www.formfactors.org/
Various system thermal design suggestions	http://www.formfactors.org/

1.3 Definition of Terms

Table 2. Terms and Descriptions

Term	Description
ATX	Advanced Technology eXtended is a motherboard form factor specification developed by Intel in 1995.
Bypass	Bypass is the area between a passive 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.
CAG	Chassis Air Guide
CTE	Coefficient of Thermal Expansion. The relative rate a material expands during a thermal event.

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Term	Description
DTS	Digital Thermal Sensor reports a relative die temperature as an offset from TCC activation temperature.
FSC	Fan Speed Control
IHS	Integrated Heat Spreader: a component of the processor package used to enhance the thermal performance of the package. Component thermal solutions interface with the processor at the IHS surface.
ILM	Independent Loading Mechanism provides the force needed to seat the 1150-LGA land package onto the socket contacts.
MD	Metal Defined pad is one where a pad is individually etched into the PCB with a minimum width trace exiting it.
PCG	Platform Compatibility Guide (PCG) (previously known as FMB) provides a design target for meeting all planned processor frequency requirements.
PCH	Platform Controller Hub. The PCH is connected to the processor using the Direct Media Interface (DMI) and Intel Flexible Display Interface (Intel FDI).
LGA1150 socket	The processor mates with the system board through this surface mount, 1150-land socket.
PECI	The Platform Environment Control Interface (PECI) is a one-wire interface that provides a communication channel between Intel processor and chipset components to external monitoring devices.
PWM	Pulse Width Modulation
Ψ_{ca}	Case-to-ambient thermal characterization parameter (psi). A measure of thermal solution performance using total package power. Defined as $(T_{CASE} - T_{LA}) /$ Total Package Power. The heat source should always be specified for Y measurements.
Ψ_{CS}	Case-to-sink thermal characterization parameter. A measure of thermal interface material performance using total package power. Defined as $(T_{CASE} - T_S) /$ Total Package Power.
Ψ_{sa}	Sink-to-ambient thermal characterization parameter. A measure of heatsink thermal performance using total package power. Defined as $(T_S - T_{LA}) /$ Total Package Power.
SMD	The Solder Mask Defined pad is typically a pad in a flood plane where the solder mask opening defines the pad size for soldering to the component to the printed circuit board.
T_{CASE} or T_C	The case temperature of the processor, measured at the geometric center of the top-side of the TTV IHS.
T_{CASE_MAX}	The maximum case temperature as specified in a component specification.
TAC	Thermal Advantaged Chassis
TCC	Thermal Control Circuit: Thermal monitor uses the TCC to reduce the die temperature by using clock modulation and/or operating frequency and input voltage adjustment when the die temperature is very near its operating limits.
$T_{CONTROL}$	$T_{CONTROL}$ is a static value that is below the TCC activation temperature and used as a trigger point for fan speed control. When DTS > $T_{CONTROL}$, the processor must comply to the TTV thermal profile.
TDP	Thermal Design Power: Thermal solution should be designed to dissipate this target power level. TDP is not the maximum power that the processor can dissipate.
Thermal Monitor	A power reduction feature designed to decrease temperature after the processor has reached its maximum operating temperature.
Thermal Profile	Line that defines case temperature specification of the TTV at a given power level.
TIM	Thermal Interface Material: The thermally conductive compound between the heatsink and the processor case. This material fills the air gaps and voids, and enhances the transfer of the heat from the processor case to the heatsink.

continued...

Term	Description
TTV	Thermal Test Vehicle. A mechanically equivalent package that contains a resistive heater in the die to evaluate thermal solutions.
T_{LA}	The measured ambient temperature locally surrounding the processor. The ambient temperature should be measured just upstream of a passive heatsink or at the fan inlet for an active heatsink.
T_{SA}	The system ambient air temperature external to a system chassis. This temperature is usually measured at the chassis air inlets.

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2.0 Platform Environment Control Interface (PECI)

PECI uses a single wire for self-clocking and data transfer. The bus requires no additional control lines. The physical layer is a self-clocked one-wire bus that begins each bit with a driven, rising edge from an idle level near zero volts. The duration of the signal driven high depends on whether the bit value is a logic '0' or logic '1'. PECI also includes variable data transfer rate established with every message. In this way, it is highly flexible even though underlying logic is simple.

The interface design was optimized for interfacing to Intel processors in both single processor and multiple processor environments. The single wire interface provides low board routing overhead for the multiple load connections in the congested routing area near the processor and chipset components. Bus speed, error checking, and low protocol overhead provides adequate link bandwidth and reliability to transfer critical device operating conditions and configuration information.

The PECI bus offers:

- A wide speed range from 2 Kbps to 2 Mbps
- CRC check byte used to efficiently and atomically confirm accurate data delivery
- Synchronization at the beginning of every message minimizes device timing accuracy requirements

For temperature monitoring and fan speed control management purpose, the PECI 3.0 commands that are commonly implemented includes Ping(), GetDIB(), GetTemp(), $T_{CONTROL}$ and Tj_{MAX}(TCC) read. The $T_{CONTROL}$ and TCC read command can be implemented by utilizing the RdPkgConfig() command.

2.1 Fan Speed Control with Digital Thermal Sensor (DTS)

Processor fan speed control is managed by comparing DTS temperature data against the processor-specific value stored in the static variable, $T_{CONTROL}$. When the DTS temperature data is less than $T_{CONTROL}$, the fan speed control algorithm can reduce the speed of the thermal solution fan. This remains the same as with the previous guidance for fan speed control. Refer to Volume 1 of the processor Datasheet (see Related Documents section) for guidance where the DTS temperature data exceeds $T_{CONTROL}$.

The DTS temperature data is delivered over PECI, in response to a GetTemp() command, and reported as a relative value to TCC activation target. The temperature data reported over PECI is always a negative value and represents a delta below the onset of thermal control circuit (TCC) activation, as indicated by the PROCHOT# signal. Therefore, as the temperature approaches TCC activation, the value approaches zero degrees.

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3.0 Thermal Solution Design Process

Thermal solution design guidance for the processors is the same as with previous generation desktop processors. The initial design needs to take into account the target market and overall product requirements for the system. This can be broken down into several steps:

- Boundary Condition Definition on page 13
- Thermal Design and Modeling on page 13
- Thermal Solution Validation on page 14

3.1 Boundary Condition Definition

Using the knowledge of the system boundary conditions – such as, inlet air temperature, acoustic requirements, cost, design for manufacturing, package and socket mechanical specifications and chassis environmental test limits – the designer can make informed thermal solution design decisions.

For the PCG 2013D and PCG 2013C, the thermal boundary conditions for an ATX tower system are as follows:

- $T_{EXTERNAL}$ = 35 °C. This is typical of a maximum system operating environment or room temperature
- T_{RISE} = 5 °C. This is typical of a chassis compliant to CAG 1.1 or TAC 2.0
- $T_{AMBIENT}$ = 40 °C ($T_{AMBIENT} = T_{EXTERNAL} + T_{RISE}$)

Based on the system boundary conditions the designer can select a $T_{AMBIENT}$ and Ψ_{CA} to use in thermal modeling. The assumption of a $T_{AMBIENT}$ has a significant impact on the required Ψ_{CA} needed to meet TTV T_{CASE_MAX} at TDP. A system that can deliver a lower assumed $T_{AMBIENT}$ can use a design with a higher Ψ_{CA}, which can have a lower cost.

If the assumed $T_{AMBIENT}$ is inappropriate for the intended system environment, the thermal solution performance may not be sufficient to meet the product requirements. The results may be excessive noise from fans having to operate at a speed higher than intended. In the worst case this can lead to performance loss with excessive activation of the Thermal Control Circuit (TCC).

3.2 Thermal Design and Modeling

Based on the boundary conditions, the designer can now make the design selection of the thermal solution components. The major components that can be mixed are the fan, fin geometry, heat pipe or air cooled solid core design. There are cost and acoustic trade-offs the customer can make.

To aide in the design process, Intel provides Thermal Test Vehicle (TTV) thermal models. Consult your Intel Field Sales Engineer for these tools.

3.3 Thermal Solution Validation

Test for Compliance to the TTV Thermal Profile

This step is the same as previously suggested for prior products. The thermal solution is mounted on a test fixture with the TTV and tested at the following conditions:

- TTV is powered to the TDP condition

- Thermal solution fan is operating at full speed

- $T_{AMBIENT}$ is at the boundary condition from Boundary Condition Definition on page 13

The following data points are collected: TTV power, TTV T_{CASE} and $T_{AMBIENT}$. These are used to calculate Ψ_{CA} which is defined as:

$$\Psi_{CA} = (TTV\ T_{CASE} - T_{AMBIENT})\ /\ TTV\ Power$$

Ψ_{CA} must be lower than the specification listed in the specifications provided in Volume 1 of the processor Datasheet (see Related Documents section) for a given processor power and $T_{AMBIENT}$.

This testing is best conducted on a bench to eliminate as many variables as possible when assessing the thermal solution performance. The boundary condition analysis as described in Boundary Condition Definition on page 13 should help in making the bench test simpler to perform.

Thermal Solution Characterization for Fan Speed Control

The final step in thermal solution validation is to establish the thermal solution performance, Ψ_{CA} and acoustics as a function of fan speed. This data is necessary to allow the fan speed control algorithm developer to program the device. It also is needed to assess the expected acoustic impact of the processor thermal solution in the system.

For the characterization of a fan, data should be taken over the full operation range. As an example, data was collected at several points of operation to fit a curve for the RCBF7-1156 (DHA-A) which has an operation range from 900 to 3150 RPM shown in Figure 2 on page 15. Taking data at 6 evenly distributed fan speeds over the operating range provides enough data to establish an equation. By using the equation from the curve fit a complete set of required fan speeds as a function of Ψ_{CA} can be developed.

The fan speed control device may modulate the thermal solution fan speed (RPM) by one of two methods. The first and preferred is pulse width modulation (PWM) signal compliant to the 4-Wire Pulse Width Modulation (PWM) Controlled Fans specification. The alternative is varying the input voltage to the fan. As a result, the characterization data needs to also correlate the RPM to PWM or voltage to the thermal solution fan. The fan speed algorithm developer needs to associate the output command from the fan speed control device with the required thermal solution performance. Regardless of which control method is used, the term RPM will be used to indicate required fan speed in the rest of this document.

Note: When selecting a thermal solution from a thermal vendor, the characterization data should be requested directly from them as a part of their thermal solution collateral.

Figure 2.   Thermal Solution Performance versus Fan Speed
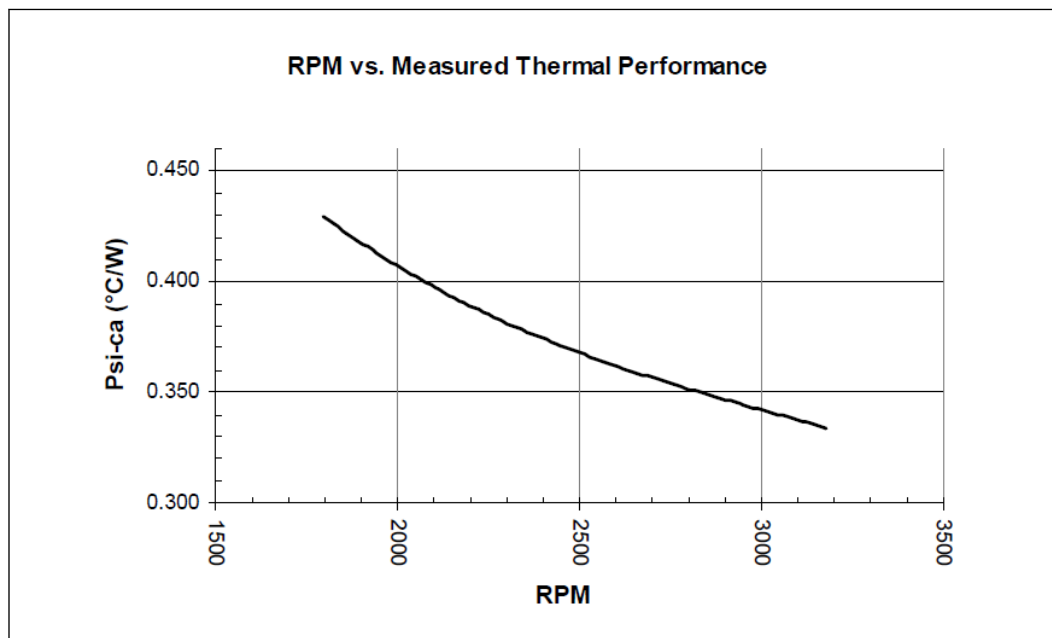
Note: This data is from the evaluation of the validation of the RCBF7-1156 (DHA-A) reference processor thermal solution.

4.0   Digital Thermal Sensor Design Guidance

The Digital Thermal Sensor Design Guide presents opportunities for the system designer to optimize the acoustics and simplify thermal validation. The digital thermal sensor design guidance uses the Digital Thermal Sensor information accessed using the PECI interface. The digital thermal sensor guidance assumes that the thermal solution meets the thermal solution requirements outlined in Thermal Solution Design Process on page 13.

Note: A new fan speed control implementation scheme is introduced for the processor identified as DTS 2.0. Please refer to Fan Speed Control Scheme with Digital Thermal Sensor 2.0 on page 19 for details.

4.1   Sensor Based Thermal Specification

The sensor based thermal specification consists of two parts. The first is a thermal profile that defines the maximum TTV T_{CASE} as a function of TTV power dissipation. The thermal profile defines the boundary conditions for validation of the thermal solution.

The second part is a defined thermal solution performance (Ψ_{CA}) as a function of the DTS value as reported over the PECI bus when DTS is greater than $T_{CONTROL}$. This defines the operational limits for the processor using the TTV validated thermal solution.

TTV Thermal Profile

For the sensor based specification, the only reference made to a case temperature measurement is on the TTV. Functional thermal validation will not require the user to apply a thermocouple to the processor package or measure processor power.

Note: All functional compliance testing will be based on fan speed response to the reported DTS values above $T_{CONTROL}$. As a result, no conversion of the TTV T_{CASE} to processor T_{CASE} will be necessary.

A knowledge of the system boundary conditions is necessary to perform the heatsink validation. More detail on defining the boundary conditions is provided in Boundary Condition Definition on page 13. The TTV is placed in the socket and powered to the recommended value to simulate the TDP condition.

Figure 3.   PCG 2013D Thermal Profile
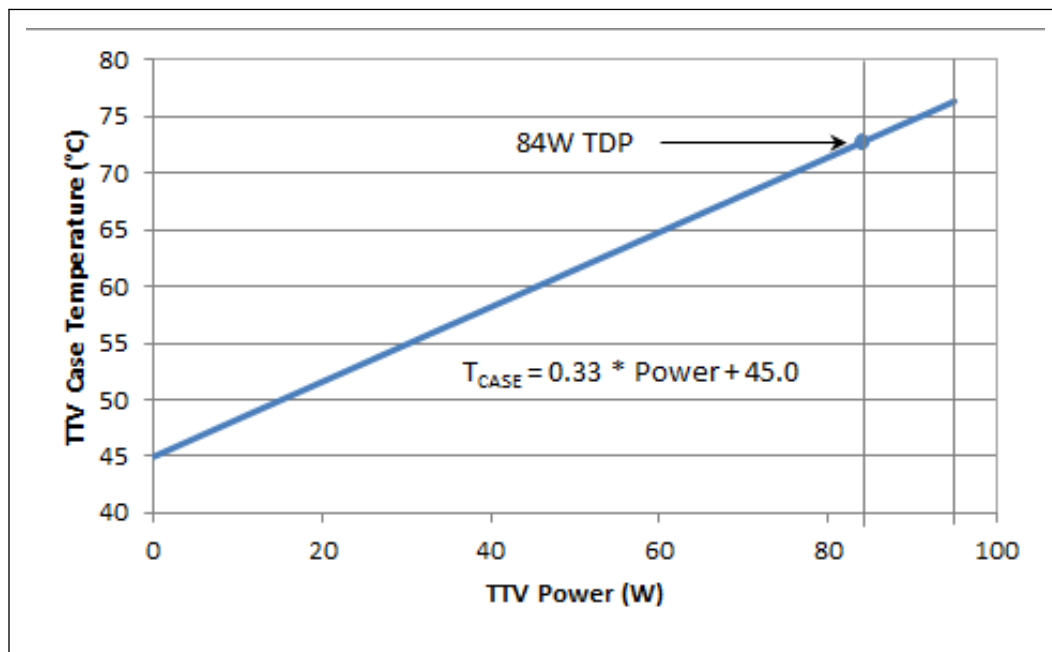
Note: This thermal profile is provided as a reference only; for the current thermal specifications see Volume 1 of the processor Datasheet (see Related Documents section).

4.2   Fan Speed Control (FSC) Guidance

Due to the effect of fan speed on acoustics, even small decreases in fan speed can result in large benefits to acoustics. In this design guide, the main area of focus will be the temperature regime between $T_{CONTROL}$ and DTS = -1. Below $T_{CONTROL}$, there is no required Ψ_{CA}. For FSC at temperature regimes between $T_{CONTROL}$ and DTS = -1, there are minimum Ψ_{CA} requirements that are provided in Volume 1 of the processor Datasheet (see Related Documents section).

The processor supports legacy FSC, DTS 1.1, and DTS 2.0, but the processor will no longer support DTS 1.0. DTS 1.1 and DTS 2.0 offer a better thermal solution, with better acoustics, than legacy FSC. DTS 1.1 and DTS 2.0 also eliminate the need for an ambient temperature sensor, which is a requirement of DTS 1.0(b). Table 3 on page 17 tabulates the differences between legacy FSC, DTS 1.1, and DTS 2.0.

Table 3.   Fan Speed Control (FSC) Scheme Comparison

FSC Scheme	Micro-Controller	Ψ_{CA} to RPM or PWM characterization	Relative acoustics
Legacy FSC	No	No	Satisfactory
DTS 1.1	No	Yes	Better
DTS 2.0	Yes	No	Best

4.3 Legacy Fan Speed Control

Legacy FSC is the simplest fan control scheme and yields satisfactory acoustics. With this scheme, the FSC begins ramping up the fan speed, based on the processor T_{CASE} thermal profile, while the processor temperature is below $T_{CONTROL}$ and reaches maximum fan speed at DTS = $T_{CONTROL}$. The following figure shows an example implementation of legacy FSC. The FSC begins ramp-up at DTS < $T_{CONTROL}$ (for this example, ramp-up begins when DTS = $T_{CONTROL}$ - 10) and reaches maximum fan speed at DTS = $T_{CONTROL}$.

Figure 4.   Example Fan PWM Profile using Legacy FSC
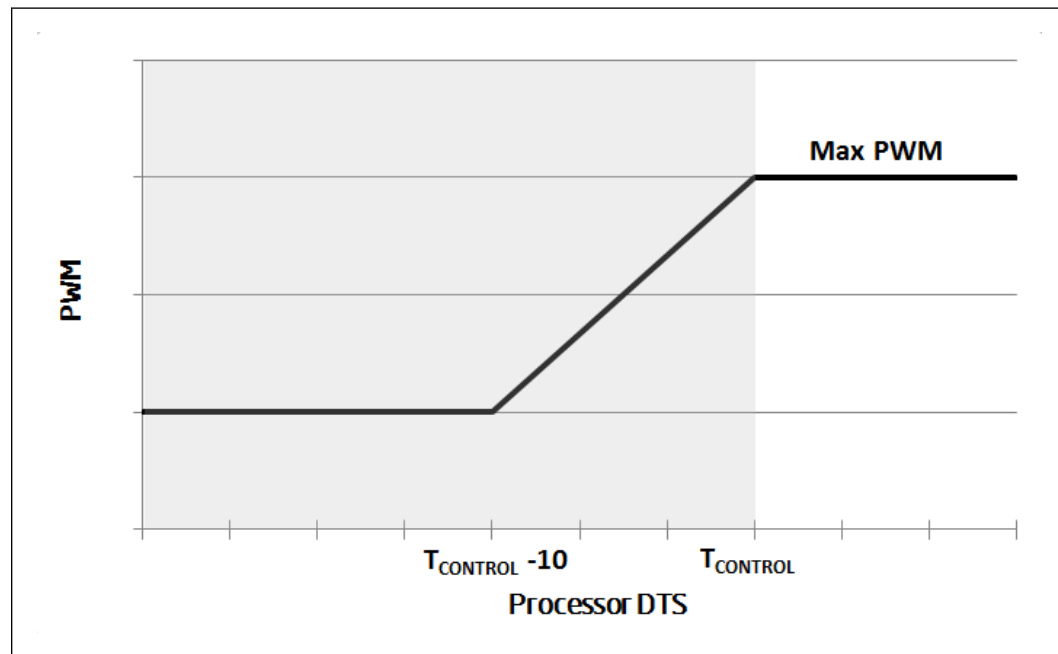
4.4 Fan Speed Control Scheme with Digital Thermal Sensor 1.1

FSC using DTS 1.1 eliminates the need for processor inlet ambient temperature data and allows for better acoustics through a change in the fan speed control scheme. Rather than force the fan speed controller to its maximum speed at DTS = $T_{CONTROL}$, the system designer can specify a fan speed at $T_{CONTROL}$ that meets or exceeds the Intel specified Ψ_{CA}. The fan speed will then follow a linear ramp up to the fan's maximum speed at DTS = -1 as demonstrated in Figure 5 on page 19.

To correctly utilize DTS 1.1, the designer must first select a worst case scenario $T_{AMBIENT}$, and ensure that the FSC can provide a Ψ_{CA} that is equivalent or greater than the specifications provided in the Thermal Specifications section of Volume 1 of the processor Datasheet (see Related Documents section).

The DTS 1.1 implementation consists of two points: a Ψ_{CA} at $T_{CONTROL}$ and a Ψ_{CA} at DTS = -1.

The Ψ_{CA} point at DTS = -1 defines the minimum Ψ_{CA} required at TDP considering the worst case system design $T_{AMBIENT}$ design point:

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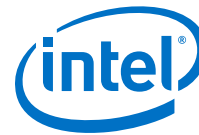
$$\Psi_{CA} = (T_{CASE\_MAX} - T_{AMBIENT\_TARGET}) / TDP$$

For example, for a 95 W TDP part, the T_{case} maximum is 72.6 ºC and at a worst case design point of 40 ºC local ambient this will result in:

$$\Psi_{CA} = (72.6 - 40) / 95 = 0.34 \text{ ºC/W}$$

Similarly for a system with a design target of 45 ºC ambient the Ψ_{CA} at DTS = -1 needed will be 0.29 ºC/W.

The second point defines the thermal solution performance (Ψ_{CA}) at $T_{CONTROL}$. The processor Datasheet (see Related Documents section) lists the required Ψ_{CA} for the various TDP processors.

These two points define the operational limits of the processor is DTS 1.1 FSC. At $T_{CONTROL}$ the fan speed must be programmed such that the resulting Ψ_{CA} is better than or equivalent to the required Ψ_{CA} listed in the Datasheet. Similarly, the fan speed should be set at DTS = -1 such that the thermal solution performance is better than or equivalent to the required Ψ_{CA} listed in the Datasheet. The fan speed controller must linearly ramp the fan speed from processor DTS = $T_{CONTROL}$ to processor DTS = -1.

Figure 5.   DTS 1.1 Definition Points
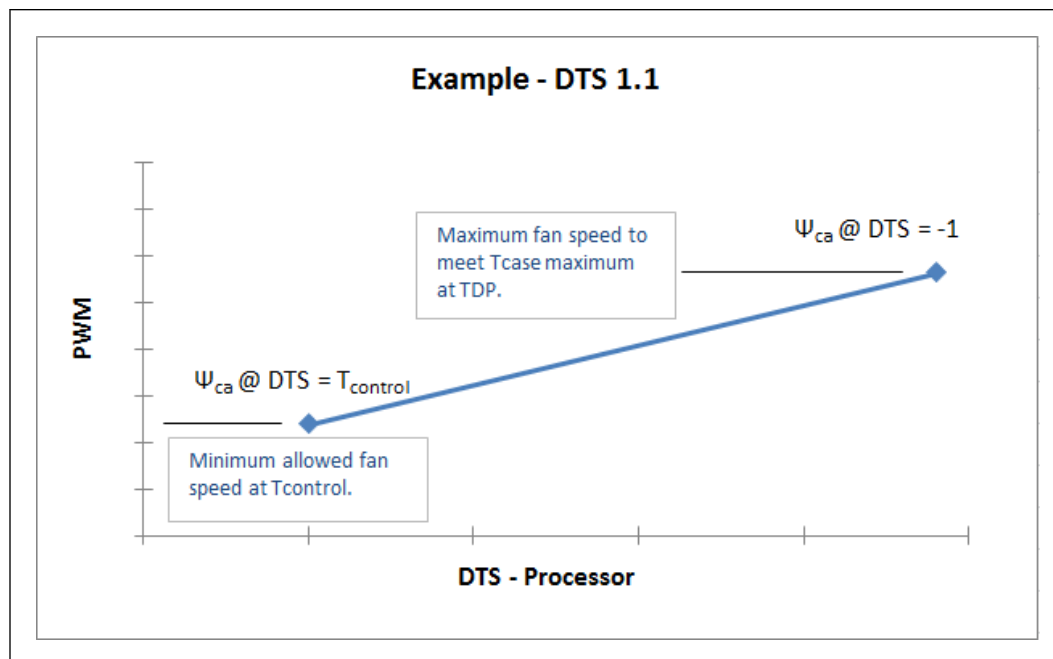
4.5   Fan Speed Control Scheme with Digital Thermal Sensor 2.0

For fan speed control using DTS 2.0, the processor heatsink design must still comply with the T_{CASE} thermal profile provided in Volume 1 of the processor Datasheet (see Related Documents section). Heatsink design compliance can be determined with thermocouples and TTVs as with previous processors.

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Thermal Margin

To simplify processor thermal specification compliance, the processor reports the thermal margin, the temperature difference of the processor from the DTS thermal profile (identified in the following figure), which is supported by the following model specific registers (MSR):

1. Temperature Control ($T_{CONTROL}$) Offset: MSR (1A2h) TEMPERATURE_TARGET[15:8]

2. TCC Activation Temperature: MSR (1A2h) TEMPERATURE_TARGET[23:16]

3. THERM Margin: MSR (1A1h) PACKAGE_THERM_MARGIN[15:0]

The processor calculates the DTS Thermal Profile from the $T_{CONTROL}$ Offset, TCC Activation Temperature, TDP, and the Thermal Margin Slope, provided in the processor Datasheet Volume 1 of 2 (see Related Documents section). Using the DTS Thermal Profile the processor can then calculate the Thermal Margin, where a value less than 0 indicates that the processor needs additional cooling, while a thermal margin greater than 0 indicates that the processor is sufficiently cooled.

Figure 6.   DTS 2.0 Thermal Specification
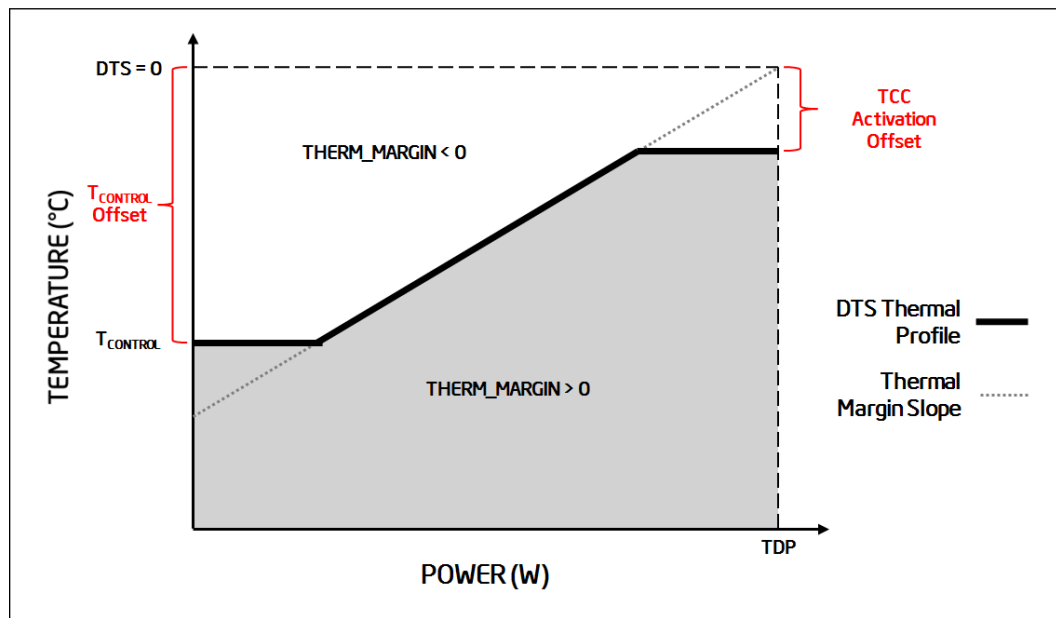
DTS 2.0 Implementation

A closed-loop controller is necessary to enable the FSC to adjust fan speed based solely on the thermal margin. Specifically, a PID-type controller is necessary in order to respond to a changing thermal margin. Thermal margin is obtained from reading MSR values or PECI, and is inputted into the closed-loop controller. The controller then increases or decreases the fan speed in order to minimize the thermal margin. Figure 7 on page 21 is a visual representation of the controller's interaction with the processor and FSC.

Note: DTS 2.0 does not require Ψ_{CA} versus RPM information. However, close power monitoring capability is required.

Figure 7.   Diagram of DTS 2.0 implementation
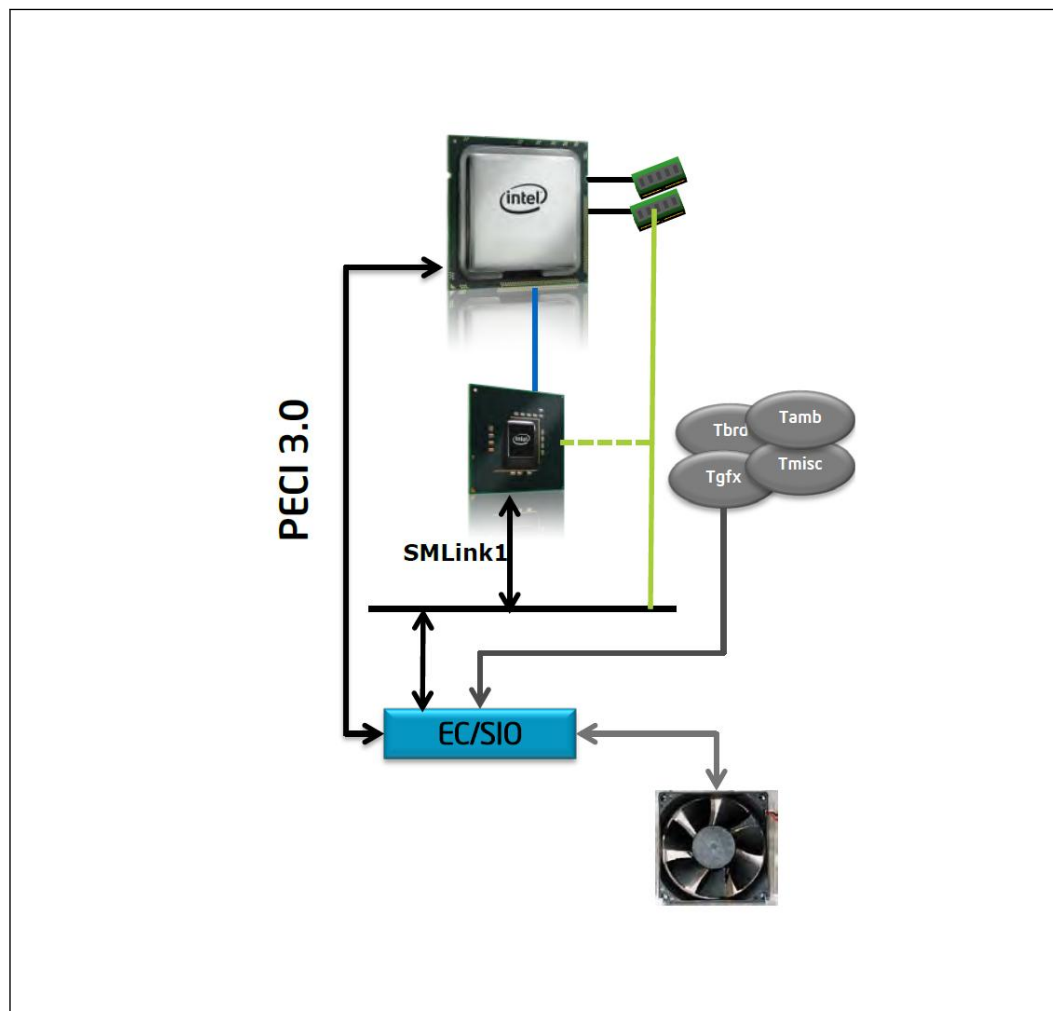
Note: This diagram shows the fan and processor as separate entities for ease of viewing. Actually, the fan and associated thermal solution are located on top of the processor as in previous generations.

5.0 Advanced Technology eXtended (ATX) Reference Thermal Solution

Note: The reference thermal mechanical solution information shown in this document represents the current state of the data and may be subject to modification. The information represents design targets, not commitments by Intel.

The design strategy is to use the design concepts from the prior Intel® Radial Curved Bifurcated Fin Heatsink Reference Design (Intel® RCBFH Reference Design) designed originally for the Intel® Pentium® 4 processors.

This chapter describes the overall requirements for the ATX heatsink reference thermal solution supporting the processors including critical-to-function dimensions, operating environment, and validation criteria.

5.1 Heatsink Thermal Solution

The reference thermal solutions are active fan solutions, same to the prior designs for the Desktop 2nd and 3rd Generation Intel® Core™ processor families, Desktop Intel® Pentium® and Desktop Intel® Celeron® processor families, and Intel® Xeon® processor E3-1200 v3 product family. There are three designs being enabled that support the Desktop 4th Generation Intel® Core™, Desktop Intel® Pentium®, Desktop Intel® Celeron® processor families, and Intel® Xeon® processor E3-1200 v3 product family. The first is called RCFH7-1156 (DHA-A) that is a universal design (PCG 2013D). The second is called the RCFH6-1156 (DHA-B) (PCG 2013C, PCG 2013B, and PCG 2013A). The third is called the DHA-D (PCG 2013B and PCG 2013A).

Table 4. **Reference Thermal Solutions**

Thermal Solution Name	PCG
RCFH7-1156 (DHA-A)	2011D
RCFH6-1156 (DHA-B)	2011C
DHA-D	2011A & 2011B

The three solutions are very similar. They all use an aluminum extrusion, integrated fan and molded plastic housing. The notable difference is the RCFH7-1156 has copper core to support the higher TDP as compared to the aluminum core of the RCFH6-1156. The difference of DHA-D is the shorter z-height heatsink to support the lower TDP as compared to the RCFH6-1156. These designs integrate the metal clip used in prior reference designs into a molded assembly that includes the fan motor housing and wire guard. Figure 8 on page 23 shows the reference thermal solution assembly. The heatsink attaches to the motherboard with the push pin fastener design from previous reference designs, see the *LGA1150 Socket Application Guide* for details on the push pin fastener design.

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Figure 8. **ATX Heatsink Reference Design Assembly**
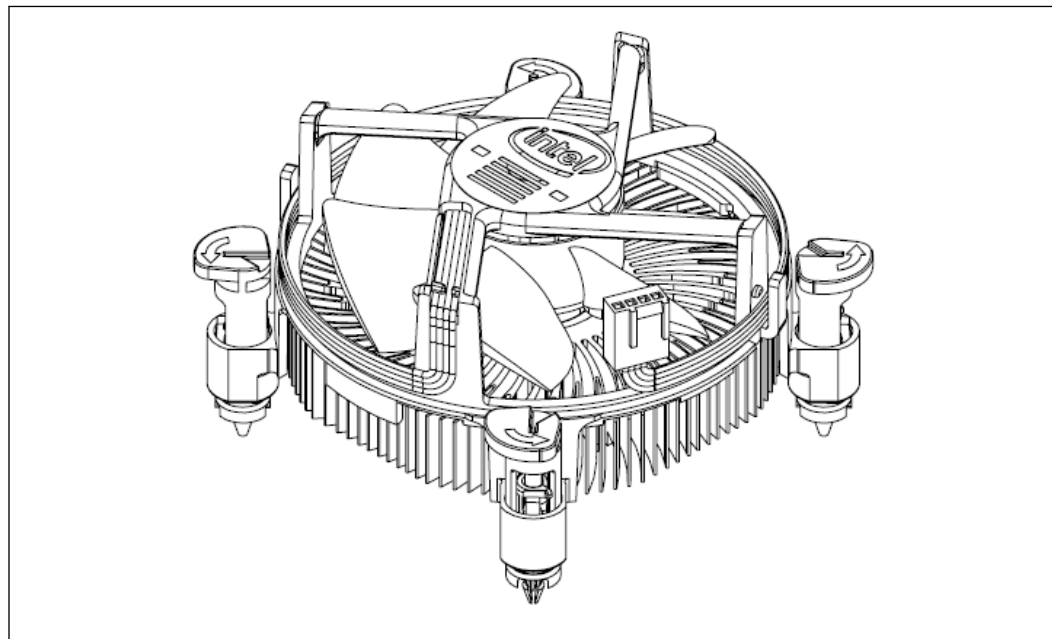
5.2 Geometric Envelope for the Intel® Reference ATX Thermal Mechanical Design

Figure 9 on page 24 shows a 3-D representation of the board component keep-out for the reference ATX thermal solution. A fully dimensioned drawing of the keep-out information is available in the *LGA1150 Socket Application Guide*. A PDF version of these drawings is available as well as a 3-D IGES model of the board level keep-out zone is available. Contact your field sales representative for these documents.

Figure 9. **ATX KOZ 3-D Model Primary (Top) Side**
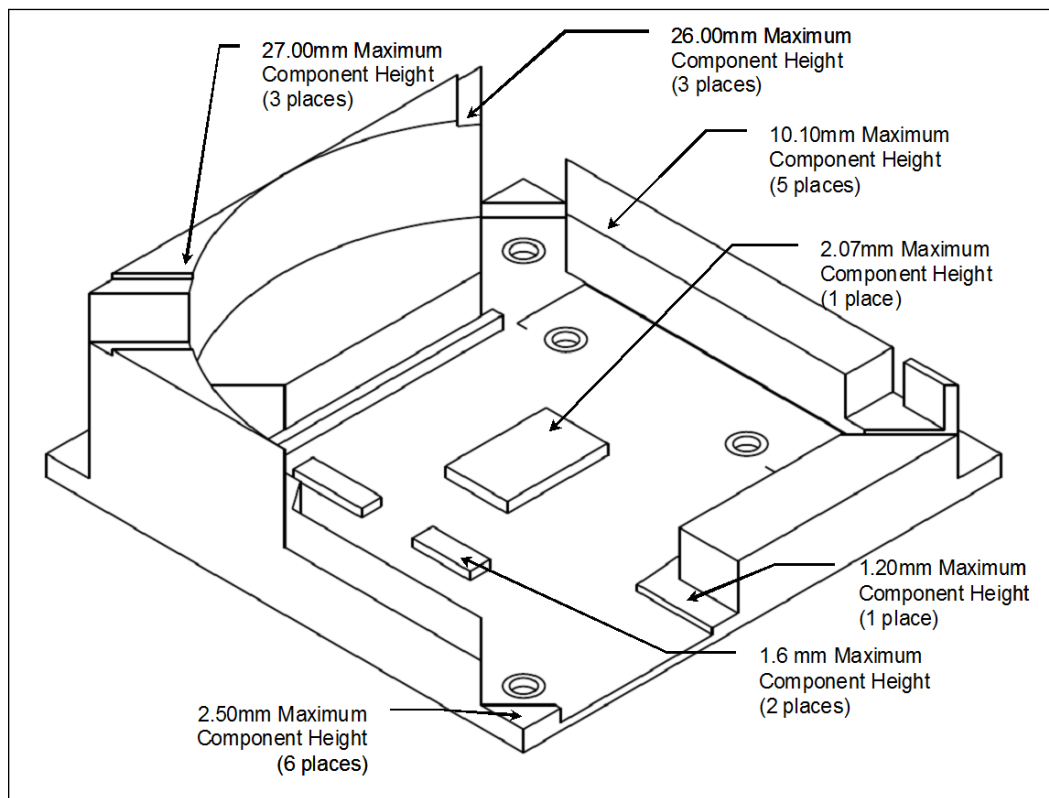
Note: All Maximum Component Heights are post reflow / assembly.

Note: The maximum height of the reference thermal solution (see Figure 9 on page 24) above the motherboard is 46.00 mm [1.81 inches], and is compliant with the motherboard primary side height constraints defined in the ATX Specification and the microATX Motherboard Interface Specification found at http://www.formfactors.org.

The reference solution requires a chassis obstruction height of at least 81.30 mm [3.20 inches], measured from the top of the motherboard. This allows for appropriate fan inlet airflow to ensure fan performance, and therefore overall cooling solution performance. This is compliant with the recommendations found in both ATX Specification and microATX Motherboard Interface Specification documents.

5.3   Reference Design Components

Extrusion

The aluminum extrusion design is similar to what is shown in Figure 10 on page 25. To facilitate reuse of the core design, the center cylinder ID and wall thickness are the same as RCBFH3.

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Figure 10.   RCBFH Extrusion
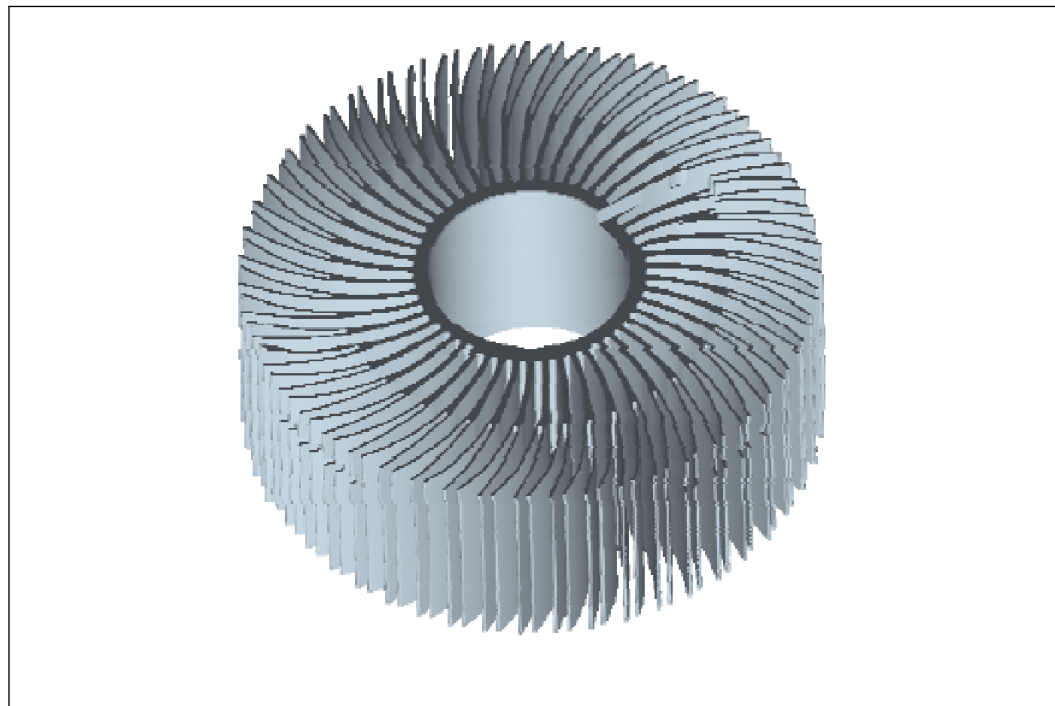
Clip

This clip design is intended to adapt previous thermal solutions such as the RCBFH3 to comply with the mechanical and structural requirements for the LGA1150 socket. Structural design strategy for the clip is to provide sufficient load for the Thermal Interface Material (TIM). The clip does not have to provide additional load for socket solder joint protect.

The clip is formed from 1.6 mm carbon steel, the same material as used in previous clip designs. The target metal clip nominal stiffness is 493 N/mm [2813 lb/in]. The combined target for reference clip and fasteners nominal stiffness is 311 N/mm [1778 lb/in]. The nominal preload provided by the reference design is 175.7 ± 46.7 N [39.5 lb ±10.5 lbf].

Note: Intel reserves the right to make changes and modifications to the design as necessary to the reference design, in particular the clip.

Figure 11.   Clip for Existing Solutions to straddle LGA1150 Socket
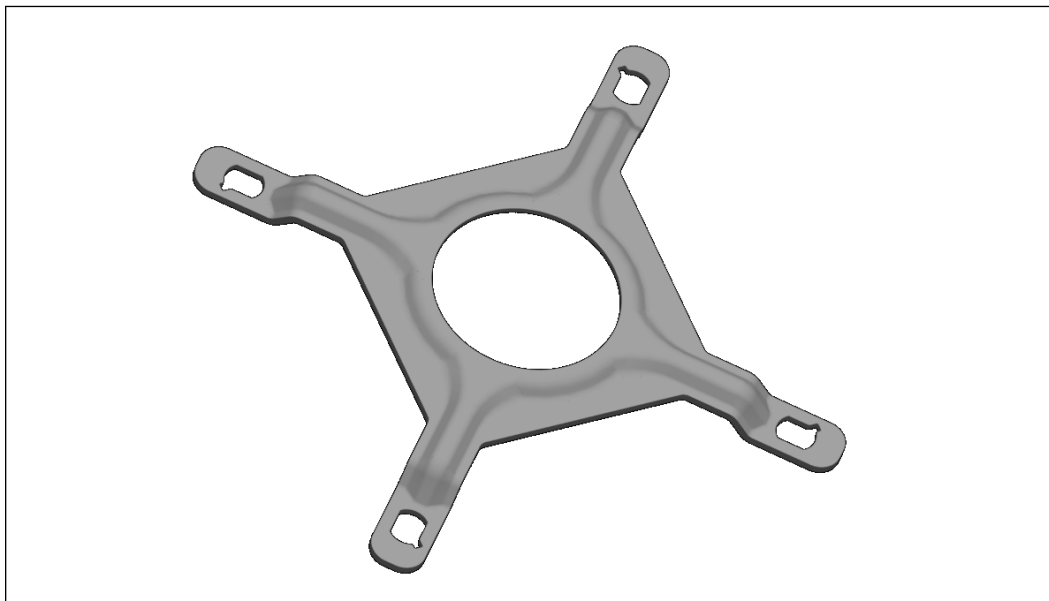
Core

The core is the same forged design used in previous reference designs. This allows the reuse of the fan attach and if desired the same extrusion from existing designs. The machined flange height will be determined in the design review to match the IHS height for the processors when installed in the LGA1150 socket. The final height of the flange will be an output of the design validation and could be varied to adjust the preload. See Mechanical Interface to the Reference Attach Mechanism on page 27 for additional information on the critical to function interfaces between the core and clip.

Figure 12.   Core

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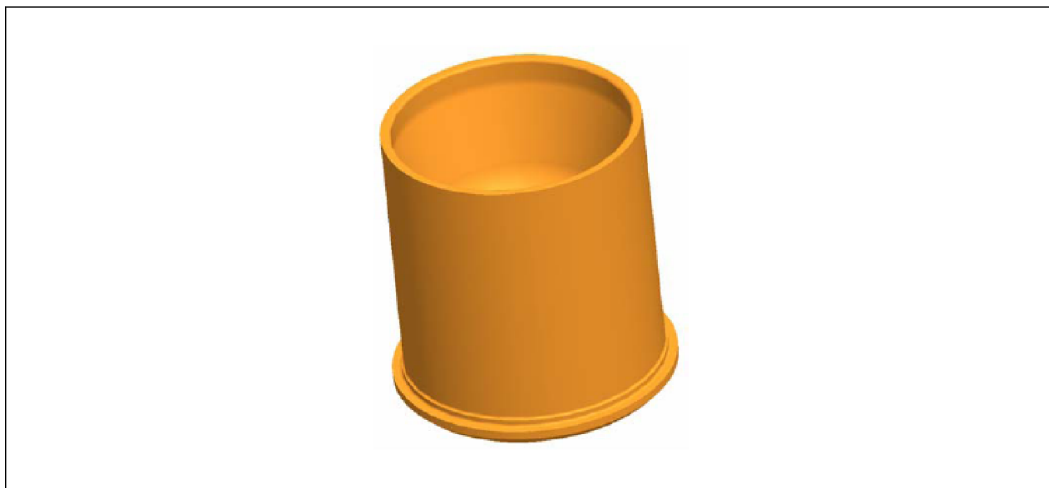
5.4 Mechanical Interface to the Reference Attach Mechanism

The attach mechanism component from the Intel Reference Design can be used by other 3rd party cooling solutions. The attach mechanism consists of:

- A metal attach clip that interfaces with the heatsink core.

- Four plastic fasteners.

Note: See the *LGA1150 Socket Application Guide* for detailed clip and plastic fastener drawings.

Note: For Intel RCFH6, RCFH7 and DHA-D Reference Designs, the metal attach clip is not used by the solutions as shown in Figure 8 on page 23. This metal attach clip design is only intended to adapt previous thermal solutions (such as the Intel RCBFH3 Reference Design) to comply with the mechanical and structural requirements for the LGA1150 socket.

If 3rd party cooling solutions adopt a previous thermal solutions (such as the Intel RCBFH3 Reference Design), the reference attach mechanism (clip, core, and extrusion) portion is shown in Figure 13 on page 27. The clip is assembled to heatsink during copper core insertion, and is meant to be trapped between the core shoulder and the extrusion as shown in Figure 14 on page 28.

The critical to function mechanical interface dimensions are shown in Figure 14 on page 28 and Figure 15 on page 28. Complying with the mechanical interface parameters is critical to generating a heatsink preload compliant with the minimum preload requirement for the selected TIM and to not exceed the socket design limits.

Figure 13. Clip Core and Extrusion Assembly
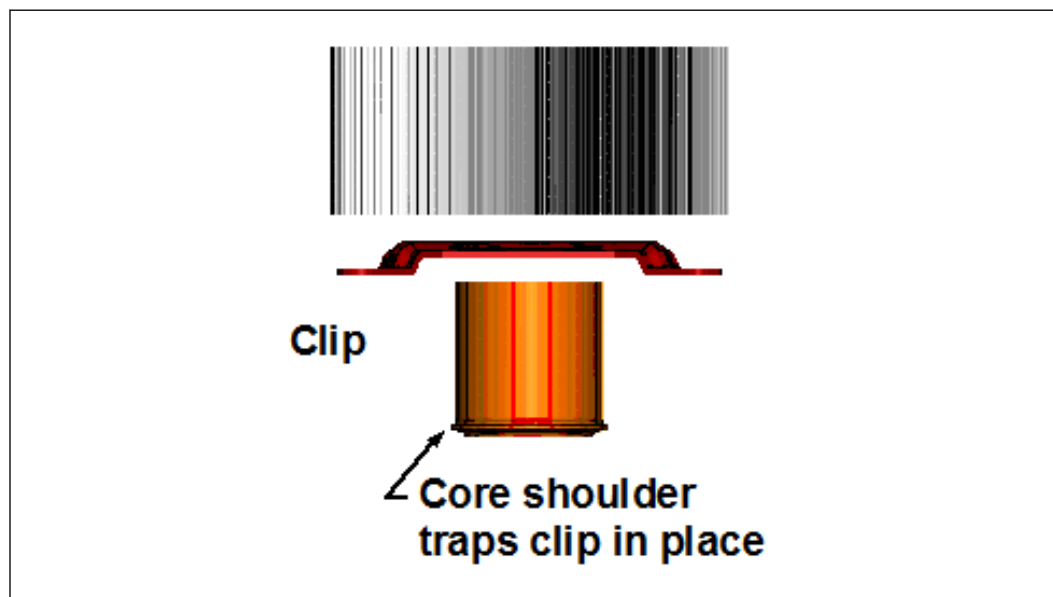
Figure 14.   Critical Parameters for Interface to the Reference Clip
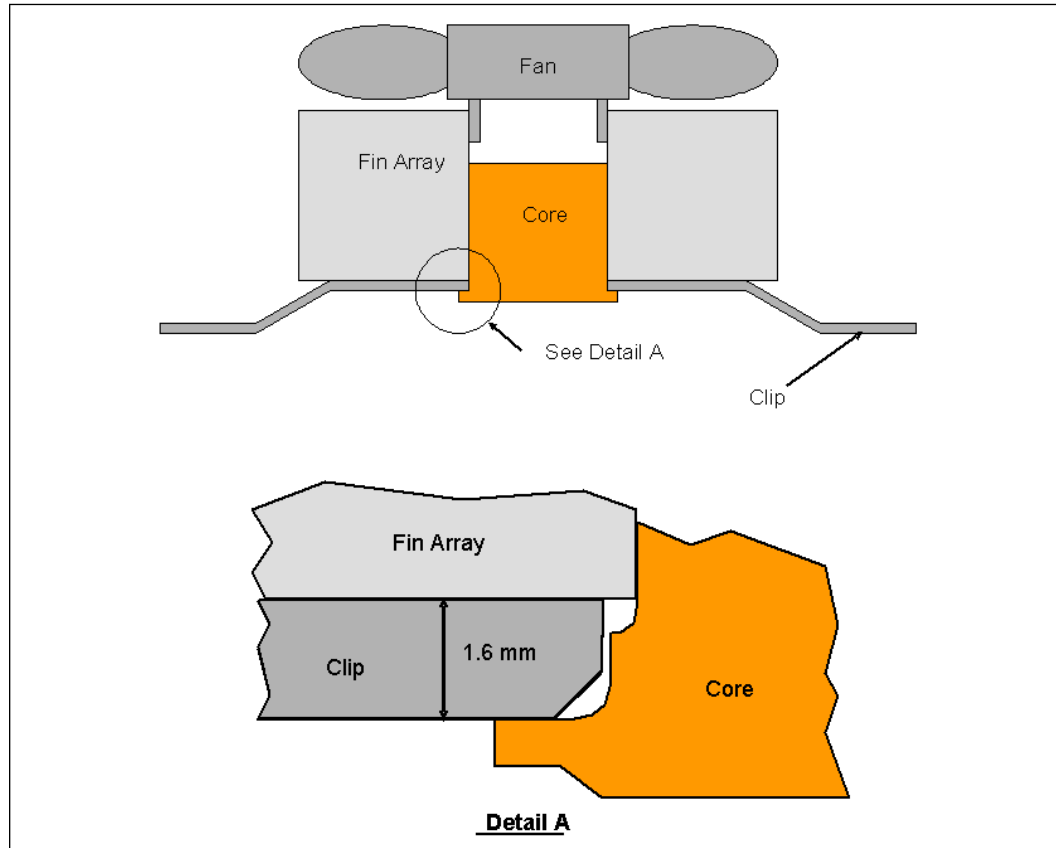
Figure 15.   Critical Core Dimensions
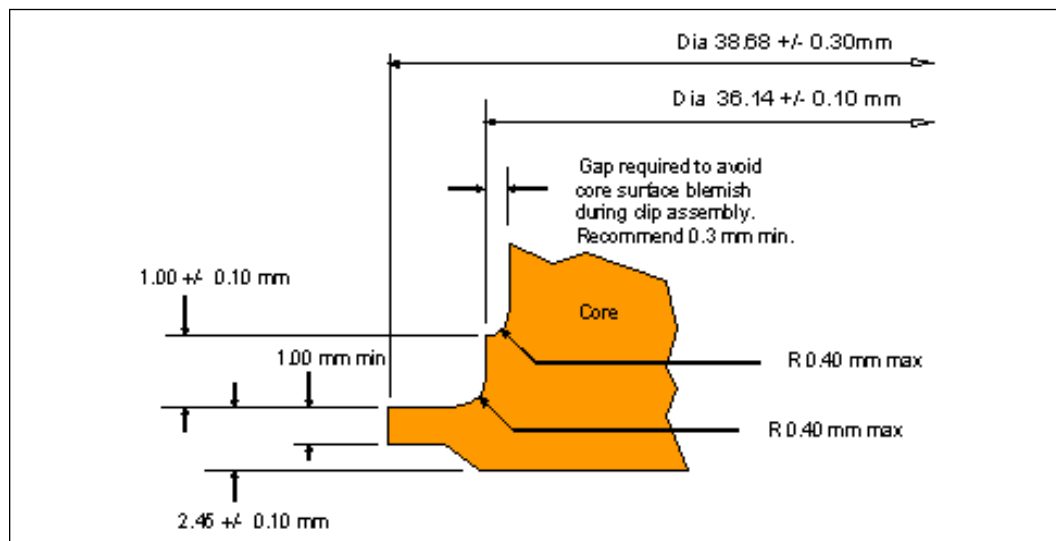
5.5 Heatsink Mass and Center of Gravity

- Total mass including plastic fan housing and fasteners <500 g.
- Assembly center of gravity ≤ 25.4 mm, measured from the top of the IHS.

5.6 Thermal Interface Material

A thermal interface material (TIM) provides conductivity between the IHS and heatsink. The designs use Dow Corning TC-1996. The TIM application is 0.14 g, which will be a nominal 20 mm diameter (~0.79 inches).

5.7 Heat Pipe Thermal Considerations

The following drawing shows the orientation and position of the 1150-land LGA Package TTV die. This package layout differs from the 1155-land LGA Package TTV and 1156-land LGA Package TTV. The TTV die is sized and positioned similar to the production die.

Figure 16.   1150 TTV Die Size and Orientation
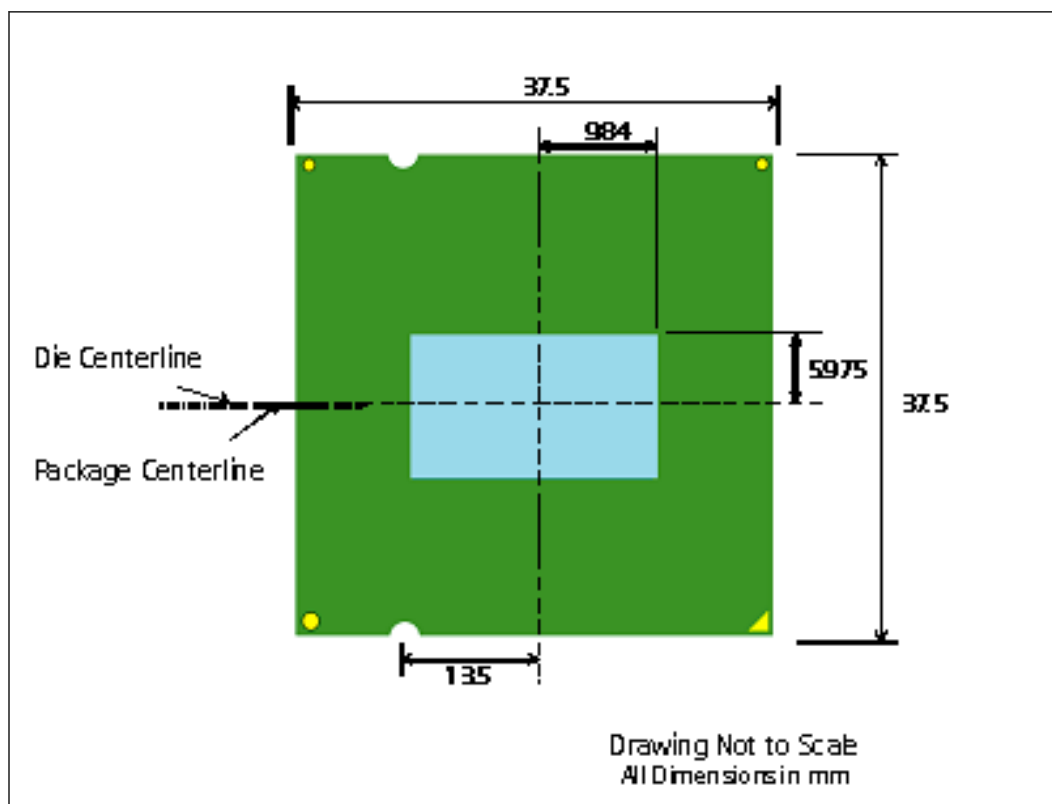
6.0 Thermal Solution Quality and Reliability Requirements

6.1 Reference Heatsink Thermal Verification

Each motherboard, heatsink 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. The Intel reference thermal solution will be evaluated to the boundary conditions provided in Volume 1 of the processor Datasheet (see Related Documents section).

The test results, for a number of samples, are reported in terms of a worst-case mean + 3s value for thermal characterization parameter using the TTV.

6.2 Mechanical Environmental Testing

Each motherboard, heatsink 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 5 on page 30.

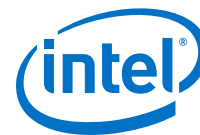The Intel reference heatsinks will be tested in an assembled to the LGA1150 socket and mechanical test package. Details of the Environmental Requirements, and associated stress tests, can be found in Table 5 on page 30 are based on speculative use condition assumptions, and are provided as examples only.

Table 5.   Use Conditions (Board Level)

Test [1]	Requirement	Pass/Fail Criteria [2]
Mechanical Shock	3 drops each for + and - directions in each of 3 perpendicular axes (that is, total 18 drops) Profile: 50 g, Trapezoidal waveform, 4.3 m/s [170 in/s] minimum velocity change	Visual Check and Electrical Functional Test
Random Vibration	Duration: 10 min/axis, 3 axes Frequency Range: 5 Hz to 500 Hz 5 Hz @ 0.01 g^2/Hz to 20 Hz @ 0.02 g^2/Hz (slope up) 20 Hz to 500 Hz @ 0.02 g^2/Hz (flat) Power Spectral Density (PSD) Profile: 3.13 g RMS	Visual Check and Electrical Functional Test

Notes:
1. Intel recommends that the above tests be performed on a sample size of at least ten assemblies from multiple lots of material.
2. Additional pass/fail criteria may be added at the discretion of the user.

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Recommended Test Sequence

Each test sequence should start with components (that is, baseboard, heatsink assembly, and so on) that have not been previously submitted to any reliability testing.

Prior to the mechanical shock & vibration test, the units under test should be preconditioned for 72 hours at 45 ºC. The purpose is to account for load relaxation during burn-in stage.

The test sequence should always start with a visual inspection after assembly, and BIOS/Processor/memory test. The stress test should be then followed by a visual inspection and then BIOS/Processor/memory test.

Post-Test Pass Criteria

The post-test pass criteria are:

1. No significant physical damage to the heatsink and retention hardware.

2. Heatsink remains seated and its bottom remains mated flatly against the IHS surface. No visible gap between the heatsink base and processor IHS. No visible tilt of the heatsink with respect to the retention hardware.

3. No signs of physical damage on baseboard surface due to impact of heatsink.

4. No visible physical damage to the processor package.

5. Successful BIOS/Processor/memory test of post-test samples.

6. Thermal compliance testing to demonstrate that the case temperature specification can be met.

Recommended BIOS/Processor/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 baseboard 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 baseboard.

*   Processor and memory.

*   All enabling components, including socket and thermal solution parts.

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.

6.3 Material and Recycling Requirements

Material shall 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 (such as, 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.

Material used shall not have deformation or degradation in a temperature life test.

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

The following definitions apply to the use of the terms lead-free, Pb-free, and RoHS compliant.

Lead-free and Pb-free: Lead has not been intentionally added, but lead may still exist as an impurity below 1000 ppm.

RoHS compliant: Lead and other materials banned in RoHS Directive are either (1) below all applicable substance thresholds as proposed by the EU or (2) an approved/pending exemption applies.

Note: RoHS implementation details are not fully defined and may change.

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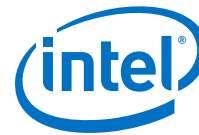
7.0 Boxed Processor Specifications

The processors will also be offered as Intel boxed processors. Intel boxed processors are intended for system integrators who build systems from baseboards and standard components. The boxed processor will be supplied with a thermal solution. This chapter documents baseboard and system requirements for the thermal solution that will be supplied with the boxed processor. This chapter is particularly important for OEMs that manufacture baseboards for system integrators.

Note: Unless otherwise noted, all figures in this chapter are dimensioned in millimeters and inches [in brackets]. Figure 17 on page 34 shows a mechanical representation of a boxed processor.

Note: The thermal solution that is supplied with the boxed processor will be halogen free compliant.

Note: Drawings in this chapter reflect only the specifications on the Intel boxed processor product. These dimensions should not be used as a generic keep-out zone for all cooling solutions. It is the system designers' responsibility to consider their proprietary cooling solution when designing to the required keep-out zone on their system platforms and chassis. Refer to the *LGA1150 Socket Application Guide* for further guidance on keep-in and keep-out zones.

Figure 17.   Mechanical Representation of the Boxed Processor Thermal Solution
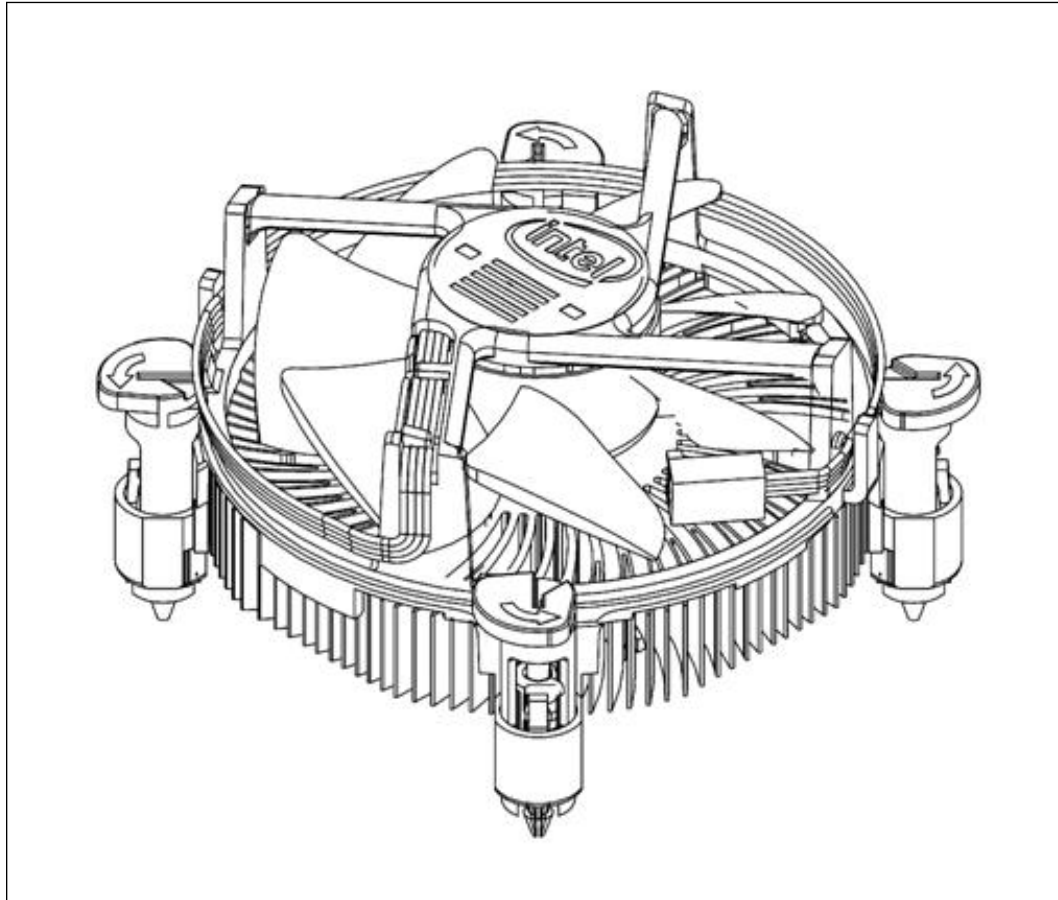

Note: The airflow of the fan heatsink is into the center and out of the sides of the fan heatsink.

7.1   Mechanical Specifications

Thermal Solution Keep-Out Zone

This section documents the mechanical specifications of the boxed processor thermal solution and the volumetric specifications of the thermal solution's keep-out zone. The keep-out zone specifications remain unchanged since their introduction with LGA1156. The boxed processor will be shipped with an unattached fan heatsink represented in Figure 17 on page 34.

Clearance is required around the fan heatsink to ensure unimpeded airflow for proper cooling. The volumetric space requirements and dimensions for the boxed processor and assembled fan heatsink are shown in Figure 18 on page 35, and Figure 19 on page 35. The airspace requirements for the boxed processor fan heatsink must also be incorporated into new baseboard and system designs. Airspace requirements are shown in Figure 23 on page 39 and Figure 24 on page 39. Some figures have centerlines shown (marked with alphabetic designations) to clarify relative dimensioning.

Figure 18. Space Requirements for the Boxed Processor (side view)
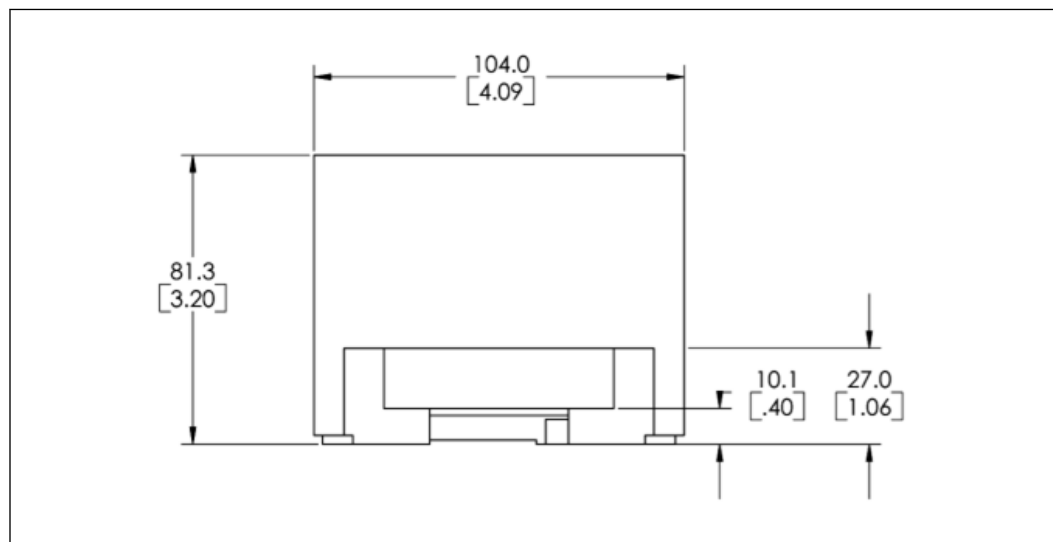
Figure 19. Space Requirements for the Boxed Processor (top view)
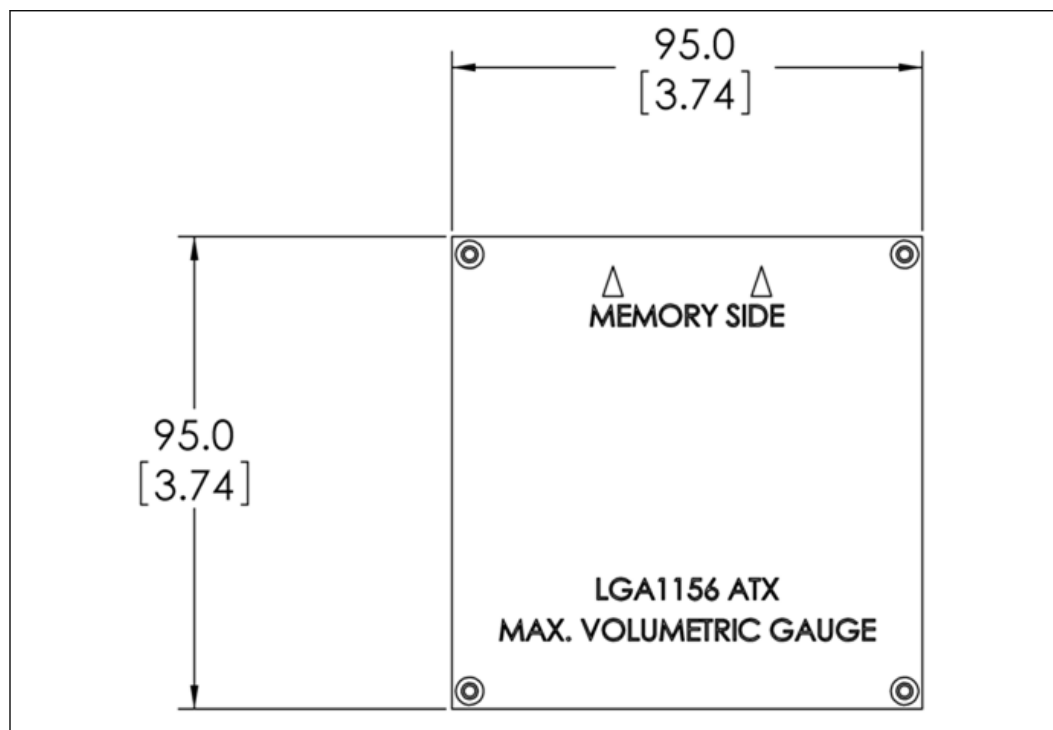
Note: Diagram does not show the attached hardware for the clip design and is provided only as a mechanical representation.

Figure 20. Space Requirements for the Boxed Processor (overall view)
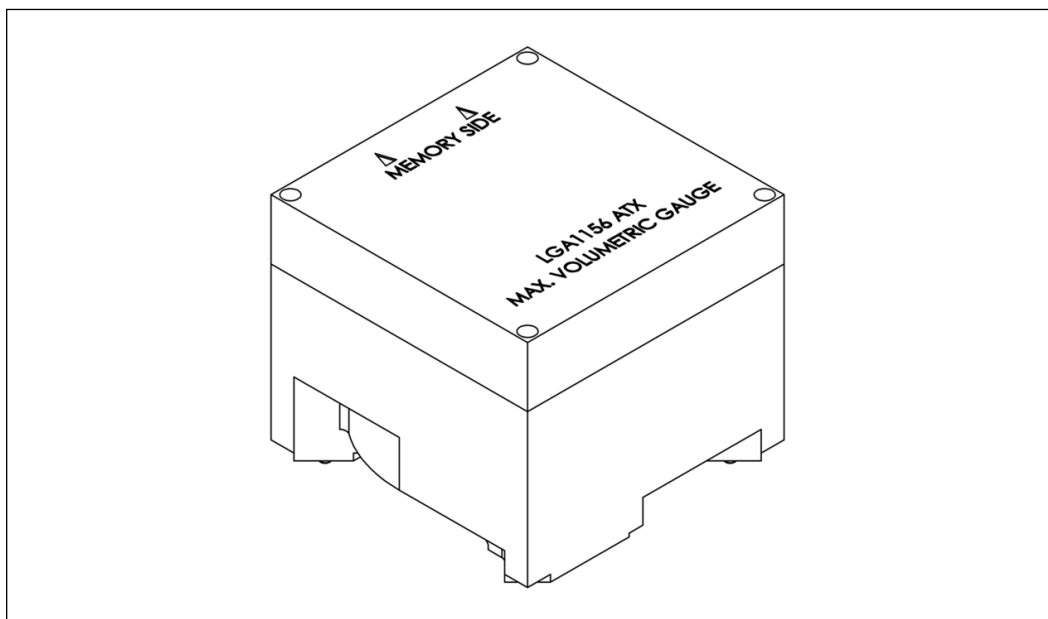
Boxed Processor Fan Heatsink Weight

The boxed processor fan heatsink will not weigh more than 450 grams.

Boxed Processor Retention Mechanism and Heatsink Attach Clip Assembly

The boxed processor thermal solution requires a heatsink attach clip assembly, to secure the processor and fan heatsink in the baseboard socket. The boxed processor will ship with the heatsink attach clip assembly.

7.2 Electrical Requirements

Fan Heatsink Power Supply

The boxed processor's fan heatsink requires a +12 V power supply. A fan power cable will be shipped with the boxed processor to draw power from a power header on the baseboard. The power cable connector and pinout are shown in Figure 21 on page 37. Baseboards must provide a matched power header to support the boxed processor. Table 6 on page 37 contains specifications for the input and output signals at the fan heatsink connector.

The fan heatsink outputs a SENSE signal, which is an open-collector output that pulses at a rate of 2 pulses per fan revolution. A baseboard pull-up resistor provides V_{OH} to match the system board-mounted fan speed monitor requirements, if applicable. Use of the SENSE signal is optional. If the SENSE signal is not used, pin 3 of the connector should be tied to GND.

The fan heatsink receives a PWM signal from the motherboard from the 4th pin of the connector labeled as CONTROL.

The boxed processor's fan heatsink requires a constant +12 V supplied to pin 2 and does not support variable voltage control or 3-pin PWM control.

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The power header on the baseboard must be positioned to allow the fan heatsink power cable to reach it. The power header identification and location should be documented in the platform documentation, or on the system board itself. Figure 22 on page 38 shows the location of the fan power connector relative to the processor socket. The baseboard power header should be positioned within 110 mm [4.33 inches] from the center of the processor socket.

Figure 21. **Boxed Processor Fan Heatsink Power Cable Connector Description**
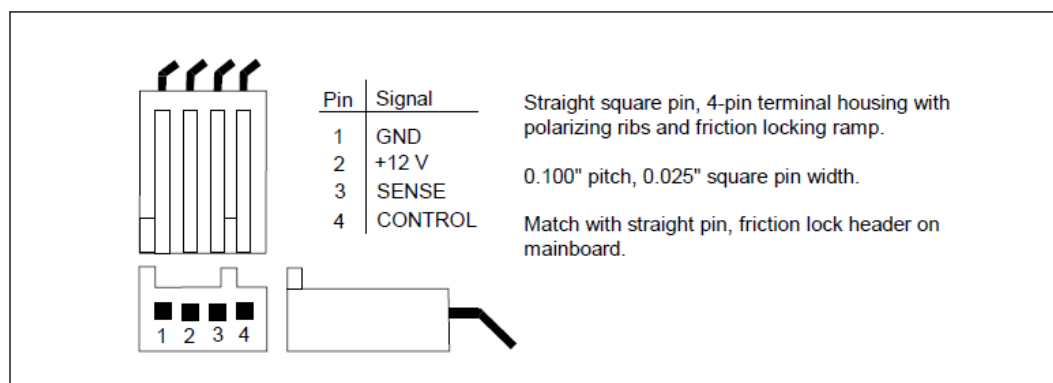
Table 6. **Fan Heatsink Power and Signal Specifications**

Description	Min	Typ	Max	Unit	Notes
+12V: 12 volt fan power supply	11.4	12.0	12.6	V	–
IC:					
• Maximum fan steady-state current draw	–	1.2	–	A	–
• Average steady-state fan current draw	–	0.5	–	A	–
• Maximum fan start-up current draw	–	2.2	–	A	–
• Fan start-up current draw maximum duration	–	1.0	–	Second	–
SENSE: SENSE frequency	–	2	–	pulses per fan revolution	1
CONTROL	21	25	28	kHz	2, 3
Notes: 1. Baseboard should pull this pin up to 5 V with a resistor. 2. Open drain type, pulse width modulated. 3. Fan will have pull-up resistor for this signal to maximum of 5.25 V.					

Figure 22.   Baseboard Power Header Placement Relative to Processor Socket
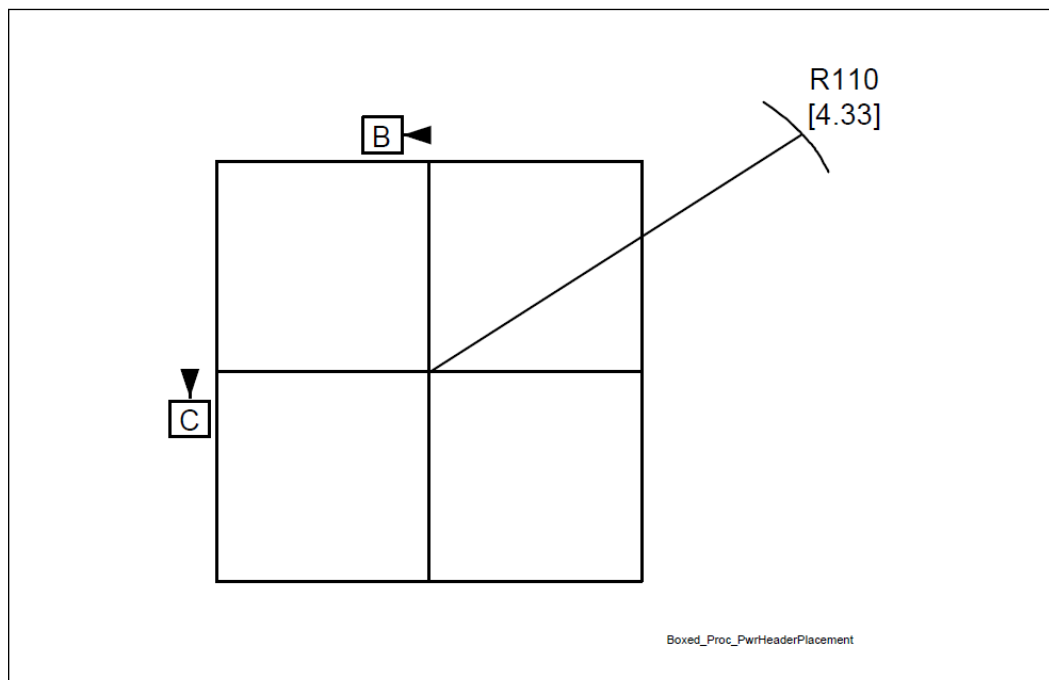

7.3   Thermal Specifications

This section describes the cooling requirements of the fan heatsink solution utilized by the boxed processor.

Boxed Processor Cooling Requirements

The boxed processor may be directly cooled with a fan heatsink. However, meeting the processor's temperature specification is also a function of the thermal design of the entire system, and ultimately the responsibility of the system integrator. The processor temperature specification can be found in Volume 1 of the processor Datasheet (see Related Documents section). The boxed processor fan heatsink is able to keep the processor temperature within the specifications in chassis that provide good thermal management. For the boxed processor fan heatsink to operate properly, it is critical that the airflow provided to the fan heatsink is unimpeded. Airflow of the fan heatsink is into the center and out of the sides of the fan heatsink. Airspace is required around the fan to ensure that the airflow through the fan heatsink is not blocked. Blocking the airflow to the fan heatsink reduces the cooling efficiency and decreases fan life. Figure 23 on page 39 and Figure 24 on page 39 illustrate an acceptable airspace clearance for the fan heatsink. The air temperature entering the fan should be kept below 40 ºC. Again, meeting the processor's temperature specification is the responsibility of the system integrator.

Figure 23. Boxed Processor Fan Heatsink Airspace Keep-Out Requirements (top view)
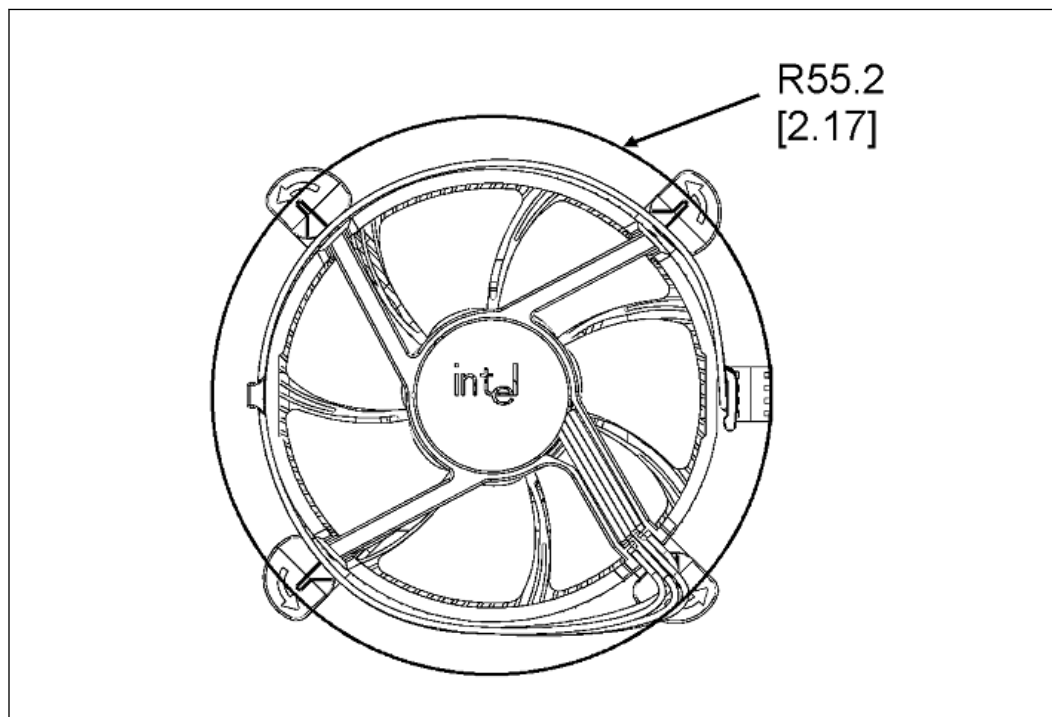
Figure 24. Boxed Processor Fan Heatsink Airspace Keep-Out Requirements (side view)
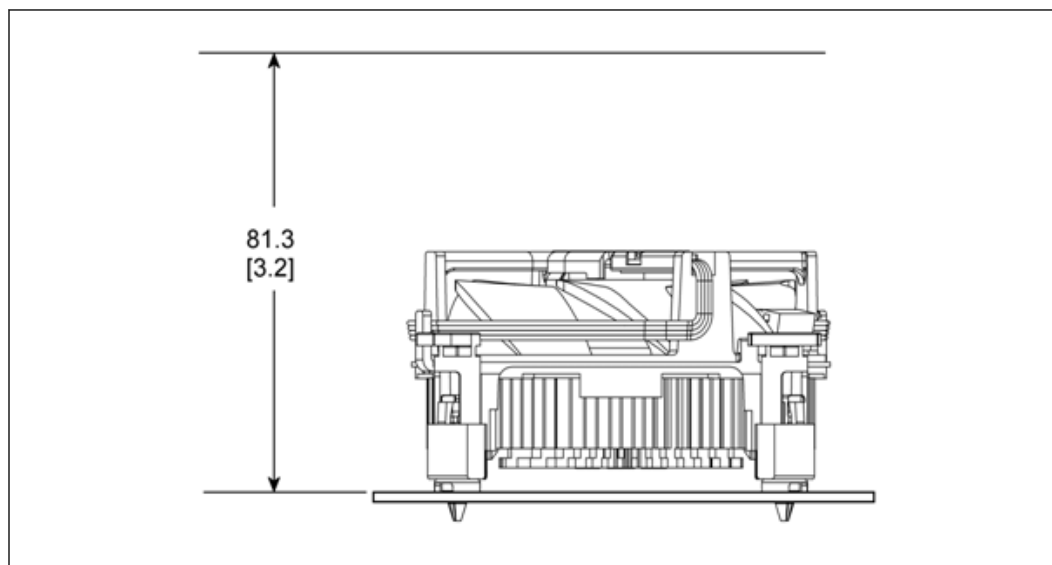

Variable Speed Fan

If the boxed processor fan heatsink 4-pin connector is connected to a 3-pin motherboard header, it will operate as follows:

The boxed processor fan will operate at different speeds over a short range of internal chassis temperatures. This allows the processor fan to operate at a lower speed and noise level, while internal chassis temperatures are low. If internal chassis temperature increases beyond a lower set point, the fan speed will rise linearly with the internal temperature until the higher set point is reached. At that point, the fan speed is at its maximum. As fan speed increases, so does fan noise levels. Systems should be designed to provide adequate air around the boxed processor fan heatsink that remains cooler then lower set point. These set points, represented in Figure 25 on page 40 and Table 7 on page 41, can vary by a few degrees from fan heatsink to fan heatsink. The internal chassis temperature should be kept below 40 ºC. Meeting the processor's temperature specification (see Volume 1 of the processor Datasheet (see Related Documents section)) is the responsibility of the system integrator.

The motherboard must supply a constant +12 V to the processor's power header to ensure proper operation of the variable speed fan for the boxed processor. Refer to for the specific requirements.

Figure 25.   Boxed Processor Fan Heatsink Set Points
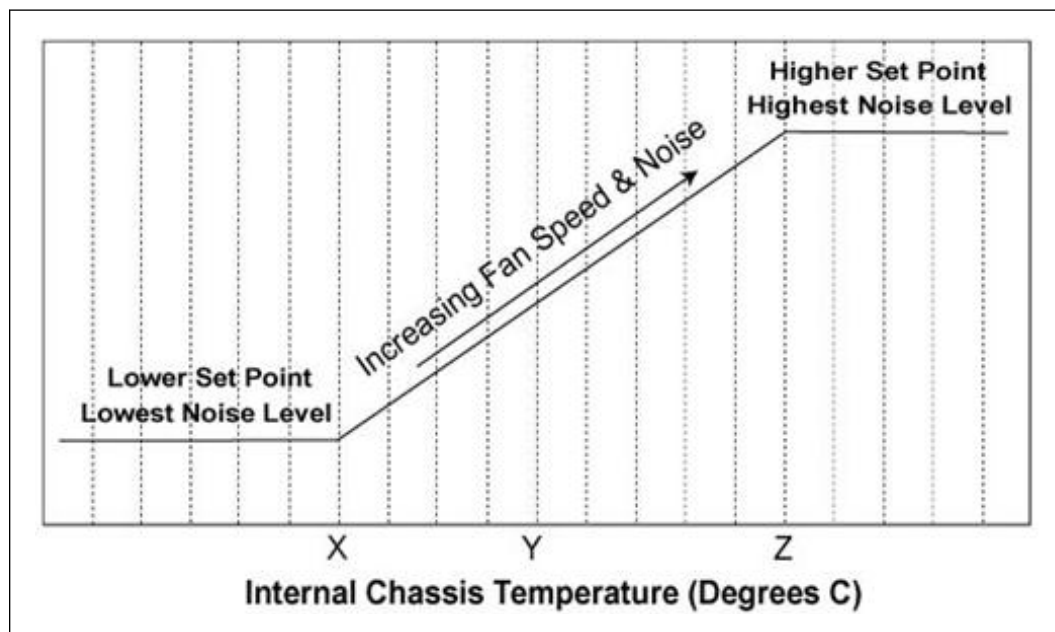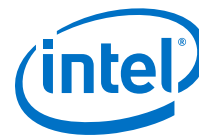
Table 7.   Fan Heatsink Power and Signal Specifications

Boxed Processor Fan Heatsink Set Point (ºC)	Boxed Processor Fan Speed	Notes
X ≤ 30	When the internal chassis temperature is below or equal to this set point, the fan operates at its lowest speed. Recommended maximum internal chassis temperature for nominal operating environment.	1
Y = 35	When the internal chassis temperature is at this point, the fan operates between its lowest and highest speeds. Recommended maximum internal chassis temperature for worst-case operating environment.	
Z ≥ 40	When the internal chassis temperature is above or equal to this set point, the fan operates at its highest speed.	
Note: 1. Set point variance is approximately ± 1 °C from fan heatsink to fan heatsink.		

If the boxed processor fan heatsink 4-pin connector is connected to a 4-pin motherboard header and the motherboard is designed with a fan speed controller with PWM output (CONTROL see Table 7 on page 41) and remote thermal diode measurement capability the boxed processor will operate as follows:

As processor power has increased the required thermal solutions have generated increasingly more noise. Intel has added an option to the boxed processor that allows system integrators to have a quieter system in the most common usage.

The 4th wire PWM solution provides better control over chassis acoustics. This is achieved by more accurate measurement of processor die temperature through the processor's Digital Thermal Sensors (DTS) and PECI. Fan RPM is modulated through the use of an ASIC located on the motherboard that sends out a PWM control signal to the 4th pin of the connector labeled as CONTROL. The fan speed is based on actual processor temperature instead of internal ambient chassis temperatures.

If the new 4-pin active fan heatsink solution is connected to an older 3-pin baseboard processor fan header it will default back to a thermistor controlled mode, allowing compatibility with existing 3-pin baseboard designs. Under thermistor controlled mode, the fan RPM is automatically varied based on the inlet temperature measured by a thermistor located at the fan inlet.

Appendix A Component Suppliers

Note: The part numbers listed below identifies the reference components. End-users are responsible for the verification of the Intel enabled component offerings with the supplier. These vendors and devices are listed by Intel as a convenience to Intel's general customer base, but Intel does not make any representations or warranties whatsoever regarding quality, reliability, functionality, or compatibility of these devices. Customers are responsible for thermal, mechanical, and environmental validation of these solutions. This list and/or these devices may be subject to change without notice.

Table 8.   Reference Heatsink

Item	Intel PN	Delta	Foxconn	Nidec
2011D PCG Heatsink Assembly RCFH7-1156 (DHA-A)	E41759-002	DTC-DAA07	1A01C7T00-DHA_XA02	F90T12MS1Z7-64A01A1
2011C PCG Heatsink Assembly RCFH6-1156 (DHA-B)	E41997-002	DTC-DAB03	1A01C7T00-DHB_XA02	F90T12MS1Z7-64A01B1
2011A and 2011B PCG Heatsink Assembly (DHA-D)	E98290-001	DTC-DAD03	1A01K3100-HAD	N/A

Table 9.   Reference Heatsink Components

Item	Intel PN	AVC	ITW
Clip	E36830-001	A208000389	N/A
Fastener	Base: C33389 Cap: C33390	N/A	Base: C33389 Cap: C33390

Table 10.   Supplier Contact Information

Supplier	Contact	Phone	Email
AVC (Asia Vital Components Co., Ltd.)	Kai Chang	+86 755 3366 8888 x63588	kai_chang@avc.com.tw
Delta	Jason Tsai	+1 503 533-8444 x111 +1 503 539-3547	jtsai@delta-corp.com
Foxconn	Cary Huang	+1 512 681 1120	cary.huang@foxconn.com
ITW Fastex	Chak Chakir	+1 512 989 7771	Chak.chakir@itweba.com
Nidec	Karl Mattson	+1 360 666 2445	karl.mattson@nidec.com

Note: The enabled components may not be currently available from all suppliers. Contact the supplier directly to verify time of component availability.