Intel® Atom™ Processor 300$^{\Delta}$ Series

Thermal and Mechanical Design Guidelines

— Supporting Nettop Platform for '08

September 2008

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Revision History

Revision Number	Description	Date
-001	Initial release.	September 2008

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1 Introduction

1.1 Document Goals and Scope

1.1.1 Importance of Thermal Management

The objective of thermal management is to ensure that the temperatures of all components in a system are maintained within their functional temperature range. Within this temperature range, a component is expected to meet its specified performance. Operation outside the functional temperature range can degrade system performance, cause logic errors or cause component and/or system damage. Temperatures exceeding the maximum operating limit of a component may result in irreversible changes in the operating characteristics of this component.

In a system environment, the processor temperature is a function of both system and component thermal characteristics. The system level thermal constraints consist of the local ambient air temperature and airflow over the processor as well as the physical constraints at and above the processor. The processor temperature depends in particular on the component power dissipation, the processor package thermal characteristics, and the processor thermal solution.

All of these parameters are affected by the continued push of technology to increase processor performance levels and packaging density (more transistors). As operating frequencies increase and packaging size decreases, the power density increases while the thermal solution space and airflow typically become more constrained or remains the same within the system. The result is an increased importance on system design to ensure that thermal design requirements are met for each component, including the processor, in the system.

1.1.2 Document Goals

Depending on the type of system and the chassis characteristics, new system and component designs may be required to provide adequate cooling for the processor. The goal of this document is to provide an understanding of these thermal characteristics and discuss guidelines for meeting the thermal requirements imposed on single processor systems using the Intel® Atom™ processor 300 series.

The concepts given in this document are applicable to any system form factor. Specific examples used will be the Intel enabled reference solution for a system.

1.1.3 Document Scope

This design guide supports the following processors:

- Intel® Atom™ processor 300 series applies to the Intel® Atom™ processor 330.

The Intel® Atom™ processor 300 series with Intel® chipset family-based systems support nettop platform for 2008.

In this document the Intel® Atom™ processor 300 series will be referred to as “the processor” with 533-MHz FSB. Intel® Atom™ processor 300 series with Intel® chipsets (Intel® 945GC GMCH and Intel® ICH7) supporting nettop platform for 2008 shall be referred as “the Intel® Atom™ processor 300 series / Intel chipset platform”.

In this document when a reference is made to “the processor” it is intended that this includes all the processors supported by this document. If needed for clarity, the specific processor will be listed.

In this document, when a reference is made to “datasheet”, the reader should refer to the *Intel® Atom™ Processor 300 Series Datasheet*. If needed for clarity, the specific processor datasheet will be referenced.

In this document, when a reference is made to the “the reference design” it is intended that this includes all reference designs supported by this document. If needed for clarify, the specific reference design will be listed.

Chapter 2 of this document discusses package thermal mechanical requirements to design a thermal solution for the Intel® Atom™ processor 300 series in the context of personal computer applications. Chapter 3 discusses the thermal solution considerations and metrology recommendations to validate a processor thermal solution. Chapter 4 gives information on the Intel reference thermal solution for the processor in a system application.

The physical dimensions and thermal specifications of the processor that are used in this document are for illustration only. Refer to the datasheet for the product dimensions, thermal power dissipation, and maximum junction temperature. In case of conflict, the data in the datasheet supersedes any data in this document.

1.2 Reference Documents

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

Document	Document No./Location
Intel® Atom™ Processor 300 Series Datasheet	http://download.intel.com/design/processor/datashts/320528.pdf
Thermally Advantaged Chassis (TAC) Design Guide	http://www.intel.com/go/chassis/
Power Supply Design Guide for Desktop Platform Form Factors (Rev 1.1)	http://www.formfactors.org/
Intel® I/O Controller Hub 7 (ICH7) Thermal Design Guide	http://www.intel.com/assets/pdf/datasheet/307013.pdf
Intel® 945G/945GZ/945GC/945P/945PL Express Chipset Family Thermal and Mechanical Design Guidelines (TMDG)	http://www.intel.com/assets/pdf/designguide /319970.pdf
Intel® Atom™ processor VR – Validation Methodology Guide	Available electronically

1.3 Definition of Terms

Term	Description
T_A	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_J	Processor junction temperature.
T_{CASE}	The measured case temperature of a component with an attached heatsink. This temperature is measured at the geometric center of the top of the package case/die.
$T_{S\text{-}TOP}$	Heatsink temperature measured at vicinity to center on the top surface of heatsink base.
T_S	Heatsink temperature measured at center on bottom surface of heatsink base.
Ψ_{JA}	Junction-to-ambient thermal characterization parameter (psi). A measure of thermal solution performance using total package power. Defined as (T_J – T_A) / Total Package Power. **Note:** Heat source must be specified for Ψ measurements.
Ψ_{JS}	Junction-to-sink thermal characterization parameter. A measure of thermal interface material performance using total package power. Defined as (T_J – T_S) / Total Package Power. **Note:** Heat source must be specified for Ψ measurements.

Term	Description
Ψ_{SA}	Sink-to-ambient thermal characterization parameter. A measure of heatsink thermal performance using total package power. Defined as (T_S – T_A) / Total Package Power. **Note:** Heat source must be specified for Ψ measurements.
TIM	Thermal Interface Material: The thermally conductive compound between the heatsink and the processor die surface. This material fills the air gaps and voids, and enhances the transfer of the heat from the processor die surface to the heatsink.
TDP	Thermal Design Power: a power dissipation target based on worst-case applications. Thermal solutions should be designed to dissipate the thermal design power.
P_{USAGE}	Maximum usage power of processor.
$P_{D\text{-}UP}$	Amount of processor power dissipation through TIM and heatsink, which is certain percentage of TDP. Normally the value is determined by thermal simulation results.
$P_{D\text{-}DOWN}$	Amount of processor power dissipation through package substrate, solder joints and motherboard, which is certain percentage of TDP. Normally the value is determined by thermal simulation results.

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2 Processor Thermal/Mechanical Information

2.1 Mechanical Requirements

2.1.1 Processor Package

The Intel® Atom™ processor 300 series is available in a 437-pins FCBGA8 package, as shown in Figure 1. The processor uses a Flip-Chip Ball Grid Array (FC-BGA8) package technology that directly solder down to a 437-pins footprint on PCB surface.

Mechanical specifications of the package are listed in Table 1. Refer to the datasheet for detailed mechanical specifications. In case of conflict, the package dimensions in the datasheet supersedes dimensions provided in this document.

The processor package has mechanical load limits that are specified in the processor datasheet. The specified maximum static and dynamic load limits should not be exceeded during their respective stress conditions. These include heatsink installation, removal, mechanical stress testing, and standard shipping conditions.

- When a compressive static load is necessary to ensure thermal performance of the thermal interface material between the heatsink base and the processor die, it should not exceed the corresponding specification given in the processor datasheet.
- When a compressive static load is necessary to ensure mechanical performance, it should remain in the minimum/maximum range specified in the processor datasheet.

No portion of the substrate should be used as a mechanical reference or load-bearing surface for the thermal or mechanical solution.

The processor datasheet provides package handling guidelines in terms of maximum recommended loads for the processor substrate. These recommendations should be followed in particular for heatsink removal operations.

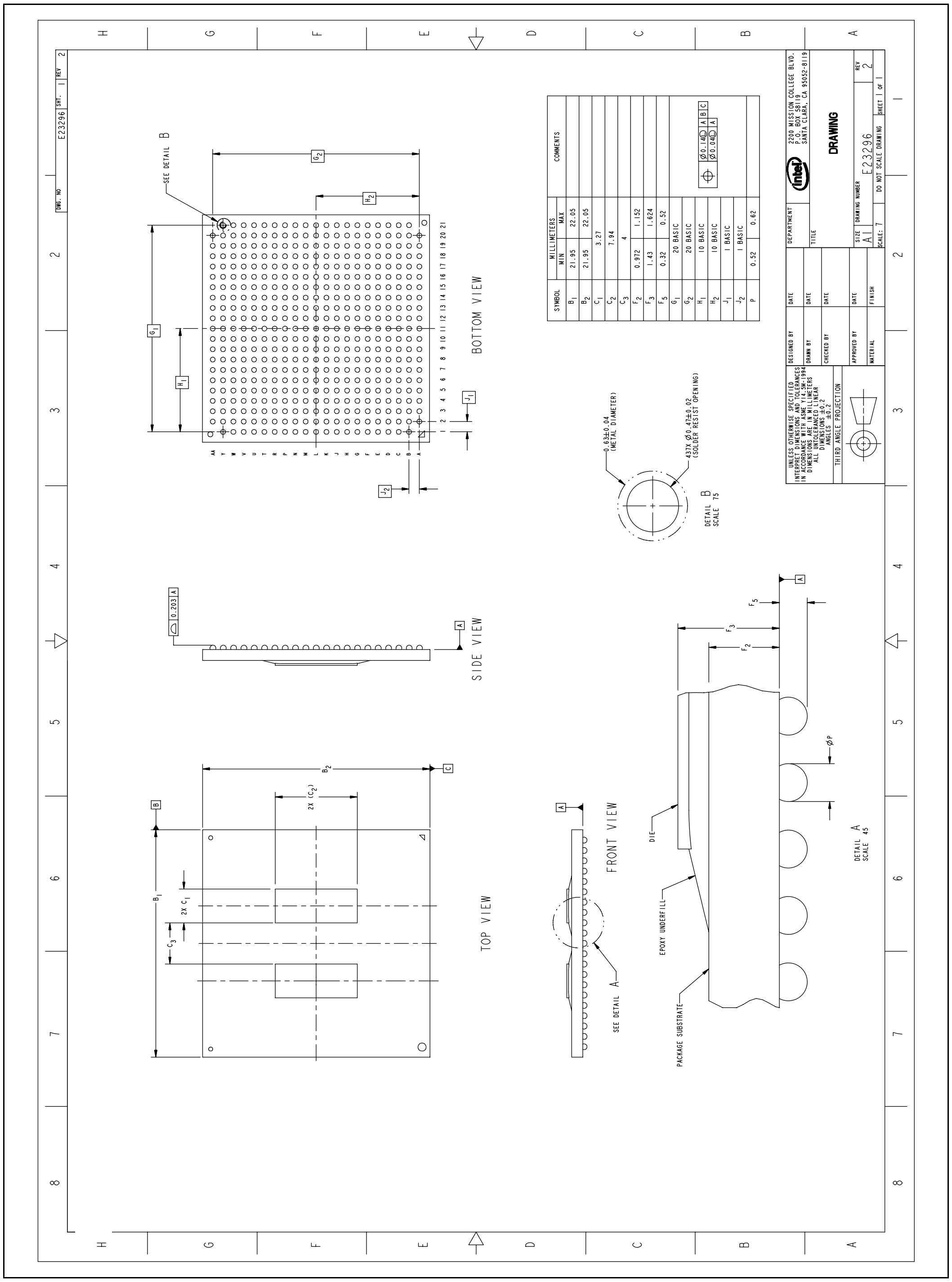
Table 1. FCBGA8 Package Mechanical Specifications

Symbol	Parameter	Min	Max	Unit	Figure
B1	Package substrate width	21.95	22.05	mm	Figure 1
B2	Package substrate length	21.95	22.05	mm	Figure 1
F2	Substrate thickness	0.972	1.152	mm	Figure 1
F3	Package overall height (package substrate to die)	1.430	1.624	mm	Figure 1
F5	Ball height	0.32	0.52	mm	
C1	Die width	3.27		mm	Figure 1
C2	Die length	7.94		mm	Figure 1
G1	Width (first ball center to last ball center)	20 Basic		mm	Figure 1
G2	Length (first ball center to last ball center)	20 Basic		mm	Figure 1
J1	Ball pitch (horizontal)	1 Basic		mm	Figure 1
J2	Ball pitch (vertical)	1 Basic		mm	Figure 1
P_{die}	Allowable pressure on the die for thermal solution	827.37		kPa	
W	Die mass	1.4		grams per die	

NOTE:

1. All dimensions are subject to change.
2. Overall height as delivered. Values were based on design specifications and tolerances. Final height after surface mount depends on OEM motherboard design and SMT process.

Figure 1. FCBGA8 Processor Package Drawing



NOTE: All dimensions in millimeters. Values shown are for reference only. See Table 1 for specific details.

2.1.2 Heatsink Attach

2.1.2.1 General Guidelines

A thermal and mechanical solution design must not intrude into the required keep-out zones as specified in the datasheet.

There are no features on the 437-pins FCBGA8 package for direct heatsink attachment: a mechanism must be designed to attach the heatsink directly to the motherboard. In addition to holding the heatsink in place on top of the processor die, this mechanism plays a significant role in the robustness of the system in which it is implemented, in particular:

- Ensuring thermal performance of the thermal interface material (TIM) applied between the processor die and the heatsink. TIMs based on phase change materials are very sensitive to applied pressure: the higher the pressure, the better the initial performance. Designs should incorporate a possible decrease in applied pressure over time due to potential structural relaxation in retention components (creep effect causing clip to lose its preload and causing anchor pull-out). It is not recommended to utilize TIMs such as thermal greases onto small bare die package, due to the TIM “pump-out” concern after heatsink is assembled.
- Ensuring system electrical, thermal, and structural integrity under shock and vibration events. The mechanical requirements of the heatsink attach mechanism depend on the mass of the heatsink and the level of shock and vibration that the system must support. The overall structural design of the motherboard and the system should be considered in designing the heatsink attach mechanism. The design should provide a means for protecting the solder joints.

2.1.2.2 Heatsink Clip Load Requirement

The attach mechanism for the heatsink developed to support the processor creates a nominal static compressive preload on the package of 4.1 lbf ±0.85 lbf throughout the life of the product for designs compliant with the Intel reference design assumptions:

- Utilizing TIM Honeywell* PCM45F (pad version).
- 55.88 mm x 43.72 mm attach pattern. Refer to Figure 11 for heatsink keep-out zone.
- And no board stiffening device (backing plate, chassis attach, etc.).

The minimum load is required to thermal performance while protecting solder joint` against fatigue failure in temperature cycling.

Notes the load range above is required to ensure a minimum load of 3.2 lbf at end-of-life. The tolerance and nominal load is based on reference design and will slightly differ on alternate thermal solution provided by third party.

It is important to take into account potential load degradation from creep over time when designing the clip or fastener to the required minimum load. This means that, depending on clip stiffness, the initial preload at beginning of life of the product may be significantly higher than the minimum preload that must be met throughout the life of the product.

Refer to Appendix B for clip load metrology guidelines.

2.1.2.3 Heatsink Attach Mechanism Design Considerations

In addition to the general guidelines given above, the heatsink attach mechanism for the processor should be designed to the following guidelines:

- *Solder joint reliability compliant with INTEL quality specification before & after reliability test such as shock & vibration*. The Critical-To-Function (CTF) corner solder joints of processor package might experience high stress concentration during shock and vibration test, therefore the "vertical lock-down" alignment feature is integrated into z-clip design to prevent solder joints failures (crack and pad crater). Table 2 summarizes success criteria of CTF joints at pre & post reliability test, to ensure no electrical defect to processor package during operation. Refer to the datasheet for CTF and NCTF locations.

Table 2. CTF Joints Success Criteria for pre & post reliability test.

Process	Inspection	CTF Joints Success Criteria
Pre Reliability Test		
Heatsink Assembly	Solder Joint Crack	0% crack area in BGA Dye & Pry results
	Pad Crater	0% crack length in cross-section results
Post Reliability Test		
Shock & Vibration	Solder Joint Crack	<40% crack area in BGA Dye & Pry results
	Pad Crater	<25% crack length in cross-section results

- Vertical Lock-Down Alignment Feature. Generic z-clip solution should include this feature to improve structural performance during shock and vibration test. The vertical lock-down feature is basically an additional feature (bends, etc.) that is incorporated into the z-clip to better constraint the heatsink. The reference thermal solution adds a vertical bend that contacts the heatsink after preload application. This in turn provides a 4 contact constraint as opposed to the 2 contact constraint as shown in Figure 2 (thru z-clip center indentation). Note that the vertical lock feature sizing must be determined thru FOC (First Order Calculation) or FEA (Finite Element Analysis) to ensure it touches the heatsink base just enough to provide the required restraint without causing the center indent feature losing contact. Refer to Figure 2 for further illustration.
- Figure 3 illustrates solder crack types.
- Heatsink should be held in place under mechanical shock and vibration events and applies force to the heatsink base to maintain desired pressure on the thermal interface material. Note that the load applied by the heatsink attach mechanism must comply with the package specifications described in the processor datasheet. One of the key design parameters is the height of the top surface of the processor die above the motherboard, is expected in the range of 2.73 mm ± 0.125 mm. This data is provided for information only, and should be derived from:
  - — The height of the package, from the package seating plane to the top of the die, and accounting for its nominal variation and tolerances that are given in the corresponding processor datasheet.
- Engages easily, and if possible, without the use of special tools. In general, the heatsink is assumed to be installed after the motherboard has been installed into the chassis. Ergo force requirement states that assembly force shall not exceed 15 lbf (target is 10 lbf).
- Minimizes contact with the motherboard surface during installation and actuation to avoid scratching/damaging the motherboard.

Figure 2. Vertical Lock-Down Alignment Feature

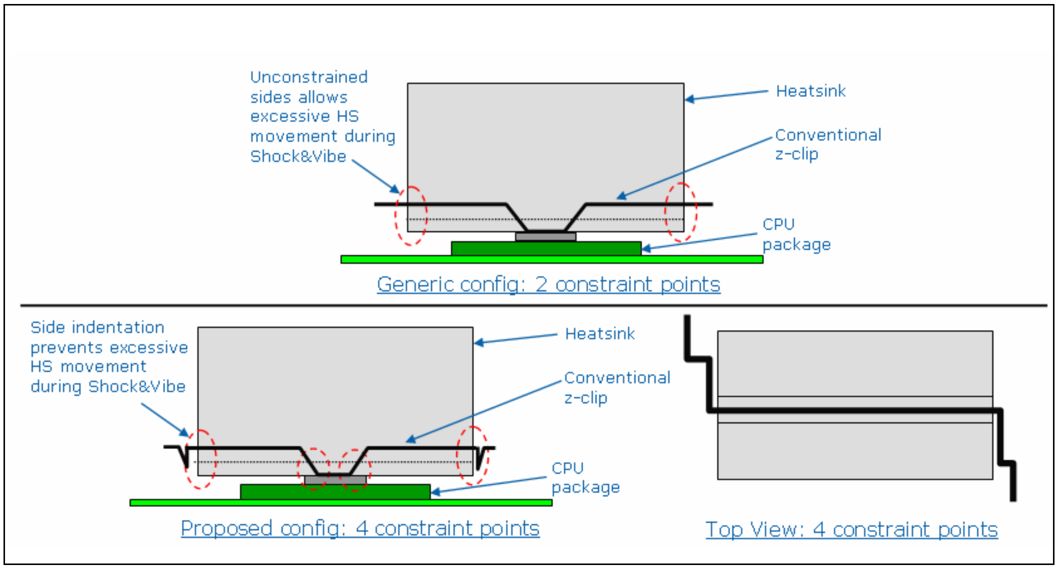
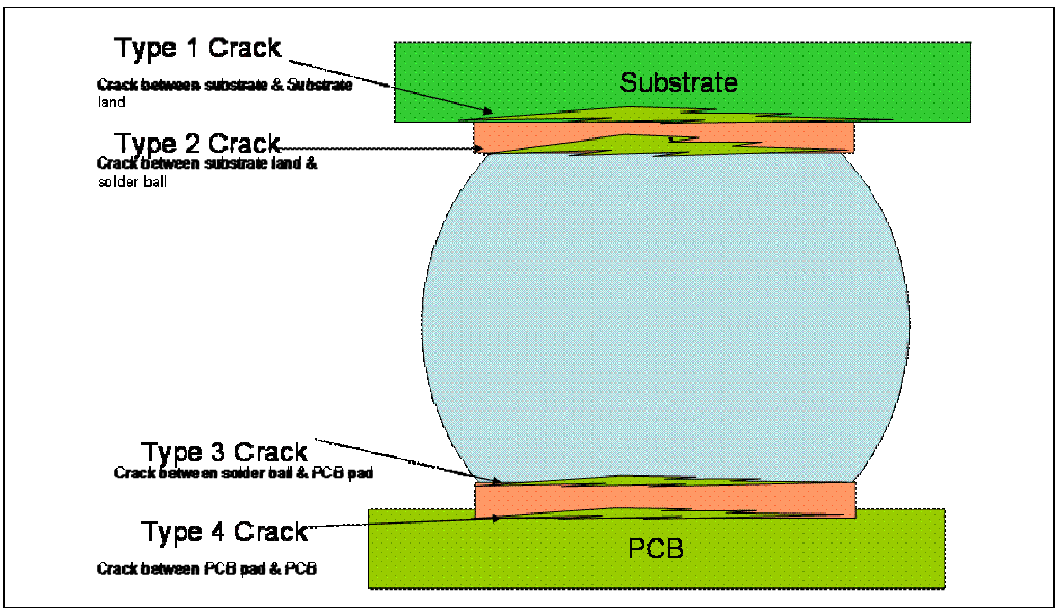


Figure 3. Various Types of Solder Crack



2.2 Thermal Requirements

The processor requires a thermal solution to maintain temperatures within operating limits. Refer to the datasheet for the processor thermal specifications. Any attempt to operate the processor outside these operating limits may result in permanent damage to the processor and potentially other components in the system. As processor technology changes, thermal management becomes increasingly crucial when building computer systems. Maintaining the proper thermal environment is crucial to reliable, long term system operation.

To allow for the optimal operation and long-term reliability of Intel processor-based systems, the system/processor thermal solution should remain within the minimum and maximum case temperature ($T_{CASE-MAX}$) specifications at corresponding thermal design power (TDP) as listed in datasheet. Designing to this specification allows optimization of thermal designs for processor performance.

The thermal limits for the processor are the case temperature (T_{CASE}). The case temperature is defined at the geometric top center of the processor. Analysis indicates that real applications are unlikely to cause the processor to consume the theoretical maximum power dissipation for sustained time periods. Intel recommends that complete thermal solution designs target the TDP indicated in Table 3, instead of the maximum processor power consumption. The Intel® Thermal Monitor feature is designed to help protect the processor in the unlikely event that an application exceeds the TDP recommendation for a sustained period of time, refer to datasheet for more details on the usage of this feature. In all cases the Intel® Thermal Monitor feature must be enabled for the processor to remain within specification as specified in the datasheet.

2.2.1 Processor Case Temperature

Table 3. Thermal Specifications for Intel® Atom™ Processor 300 Series

Symbol	Processor Number	Core Frequency and Voltage	Cache	Thermal Design Power (W)	
TDP	330	1.60 GHz	512 KB	8	
Symbol	**Parameter**			**Min**	**Max**
$T_{CASE-MAX}$ (°C)	Maximum Case Temperature			0 °C	85.2 °C

NOTE:

1. Thermal Design Power (TDP) should be used for processor thermal solution design targets. The TDP is not the maximum theoretical power the processor can generate.
2. Not 100% tested. These power specifications are determined by characterization of the processor currents at higher temperatures and extrapolating the values for the temperature indicated.
3. As measured by the activation of the on-die Intel® Thermal Monitor. The Intel® Thermal Monitor’s automatic mode is used to indicate that the maximum processor operating has been reached. Refer to datasheet for more details.
4. The Intel® Thermal Monitor automatic mode must be enabled for the processor to operate within specifications.
5. T_C and TDP values provided in this table are for reference only. Contact your Intel field representative for any updates that could occur in the processor datasheet prior to the next revision of this document.

2.3 Heatsink Design Considerations

To remove the heat from the processor, three basic parameters should be considered:

- **The area of the surface on which the heat transfer takes place**. Without any enhancements, this is the surface of the processor die. One method used to improve thermal performance is by attaching a heatsink to the die. A heatsink can increase the effective heat transfer surface area by conducting heat out of the die and into the surrounding air through fins attached to the heatsink base.
- **The conduction path from the heat source to the heatsink fins**. Providing a direct conduction path from the heat source to the heatsink fins and selecting materials with higher thermal conductivity typically improves heatsink performance. The length, thickness, and conductivity of the conduction path from the heat source to the fins directly impact the thermal performance of the heatsink. In particular, the quality of the contact between the package die and the heatsink base has a higher impact on the overall thermal solution performance as processor cooling requirements become stricter. Thermal interface material (TIM) is used to fill in the gap between the die and the bottom surface of the heatsink, and thereby improve the overall performance of the stack-up (die-TIM-Heatsink). With extremely poor heatsink interface flatness or roughness, TIM may not adequately fill the gap. The TIM thermal performance depends on its thermal conductivity as well as the pressure applied to it. Refer to Section 2.3.3 for further information.
- **The heat transfer conditions on the surface on which heat transfer takes place**. Convective heat transfer occurs between the airflow and the surface exposed to the flow. It is characterized by the local ambient temperature of the air, T_A, and the local air velocity over the surface. The higher the air velocity over the surface, and the cooler the air, the more efficient is the resulting cooling. The nature of the airflow can also enhance heat transfer via convection. Turbulent flow can provide improvement over laminar flow. In the case of a heatsink, the surface exposed to the flow includes in particular the fin faces and the heatsink base.

Active heatsinks typically incorporate a fan that helps manage the airflow through the heatsink.

Passive heatsink solutions require in-depth knowledge of the airflow in the chassis. Typically, passive heatsinks see lower air speed. These heatsinks are therefore typically larger (and heavier) than active heatsinks due to the increase in fin surface required to meet a required performance. As the heatsink fin density (the number of fins in a given cross-section) increases, the resistance to the airflow increases: it is more likely that the air travels around the heatsink instead of through it, unless air bypass is carefully managed. Using air-ducting techniques to manage bypass area can be an effective method for controlling airflow through the heatsink.

2.3.1 Heatsink Size

The size of the heatsink is dictated by height restrictions for installation in a system and by the real estate available on the motherboard and other considerations for component height and placement in the area potentially impacted by the processor heatsink. The height of the heatsink must comply with the requirements and recommendations published for the motherboard form factor of interest. Designing a heatsink to the recommendations may preclude using it in system adhering strictly to the form factor requirements, while still in compliance with the form factor documentation.

For the ATX/microATX compatible form factor, it is recommended to use:

- The ATX motherboard keep-out footprint definition and height restrictions for enabling components, defined for the platforms designed with the FCBGA8 of this design guide.
- The motherboard primary side height constraints defined in the *ATX Specification V2.2* and the *microATX Motherboard Interface Specification V1.2* found at http://www.formfactors.org/.

The resulting space available above the motherboard is generally not entirely available for the heatsink. The target height of the heatsink must take into account airflow considerations (for fan performance for example) as well as other design considerations (air duct, etc.).

2.3.2 Heatsink Mass

With the need to push air cooling to better performance, heatsink solutions tend to grow larger (increase in fin surface) resulting in increased mass. The insertion of highly thermally conductive materials like copper to increase heatsink thermal conduction performance results in even heavier solutions. As mentioned in Section 2.1.2, the heatsink mass must take into consideration the package load limits, the heatsink attach mechanical capabilities, and the mechanical shock and vibration profile targets. Beyond a certain heatsink mass, the cost of developing and implementing a heatsink attach mechanism that can ensure the system integrity under the mechanical shock and vibration profile targets may become prohibitive.

The recommended maximum heatsink mass for the Intel® Atom™ processor 300 series reference thermal solution is:

1. 26.0 grams, with recommended maximum fan heatsink mass 59.0 grams on Intel® 945GC GMCH, for Intel® Atom™ processor 300 / Intel chipsets platform.

Note: This mass includes the mass if the reference heatsink only. The attach mechanism (clip, fasteners, etc.) are not included.

Note: The mass limit for current solution is based on the capabilities of reference design components that retain the heatsink to the board and apply the necessary preload. Any reuse of the clip and fastener in alternate or derivative designs should not exceed the recommended mass limit. Designs that have a mass of greater than recommended mass should analyze the preload and retention limits of the fastener.

2.3.3 Thermal Interface Material

Thermal interface material application between the processor die and the heatsink base is generally required to improve thermal conduction from the die to the heatsink. Many thermal interface materials can be pre-applied to the heatsink base prior to shipment from the heatsink supplier and allow direct heatsink attach, without the need for a separate thermal interface material dispense or attach process in the final assembly factory.

All thermal interface materials should be sized and positioned on the heatsink base in a way that ensures the entire processor die area is covered. It is important to compensate for heatsink-to-processor attach positional alignment when selecting the proper thermal interface material size.

When pre-applied material is used, it is recommended to have a protective film applied. This film must be removed prior to heatsink installation.

The recommended TIM for the Intel® Atom™ processor 300 series reference thermal solution is Honeywell PCM45F (pad version). It is not recommended to utilize TIMs such as thermal greases onto small bare die package as specified in Section 2.1.2.1.

2.4 System Thermal Solution Considerations

2.4.1 Chassis Thermal Design Capabilities

The thermal solution for Intel® Atom™ processor 300 series is a passive heatsink design on the processor, which requires chassis to deliver sufficient airflow cooling to ensure stability and reliability of processor. The **maximum case temperature** (**$T_{CASE-MAX}$**) is set to **85.2 °C** for the processor to ensure the capability of a chassis in providing sufficient airflow for processor cooling. $T_{CASE-MAX}$ is the maximum limit value for a thermal solution to ensure stability and reliability of processor.

On a **Intel® Atom™ processor 300 series / Intel chipset platform** using a Intel reference thermal solution provided in Figure 15, the **maximum allowable heatsink temperature** (**$T_{S-TOP-MAX}$**) is set to **73.6 °C** for the processor with a GMCH reference active thermal solution (Figure 19) on the 945CG GMCH that is providing sufficient airflow for processor.

Note: $T_{S-TOP-MAX}$ is the maximum limit value for reference thermal solution which is calibrated to $T_{CASE-MAX}$ of the processor.

The TDP of Intel® Atom™ processor 300 series was quantified at maximum of 8.0 W. The reference thermal solution for processor is designed at TDP for performance & cost optimal considerations.

Table 4. System Thermal Solution Design Requirement

Platform	System Thermal Solution Design Requirement	Note
Intel® Atom™ processor 300 series / Intel Chipset Platform	$T_{S\text{-}TOP\text{-}MAX} \le 73.6°C$	1, 2
	$T_{CASE\text{-}MAX} \le 85.2°C$	1, 3, 4

NOTE:

1. Based on processor maximum Usage Power Consumption (P_{USAGE}) of 8 W.
2. For the implementation of Intel reference thermal solution on the processor, $T_{S\text{-}TOP\text{-}MAX}$ provided herein is calibrated to $T_{CASE\text{-}MAX}$ to ensure stability and reliability of processor.
3. For the implementation of any customized thermal solution in the processor, $T_{CASE\text{-}MAX}$ is thermal design criteria to ensure stability and reliability of processor.
4. For the implementation of any customized thermal solution using either thermal interface material, or clip, or heatsink design that is different from the Intel reference thermal solution as mentioned in this document.

To evaluate the system thermal capability of a given chassis, the system designer is recommended to conduct in-chassis system thermal test.

The data to be collected are both processor power consumption (P_{CPU}) and heatsink temperature ($T_{S\text{-}TOP}$) with Maximum Power Application of 100% processor load at 35 °C external ambient condition. See *Intel® Atom™ Processor VR – Validation Methodology Guide* for specific details on power measurement.

In a system using Intel reference thermal solution on the processor, the thermal pass requirement for a given chassis can be met, if

Equation 1 $T_{S\text{-}TOP} \le T_{S\text{-}TOP\text{-}MAX}$

In a system using customized thermal solution on the processor, the thermal pass requirement for a given chassis can be met, if

Equation 2 $T_{CASE} \le T_{CASE\text{-}MAX}$

2.4.2 Improving Chassis Thermal Performance

The heat generated by components within the chassis must be removed to provide an adequate operating environment for the processor and all other components in the system. Moving airflow through the chassis brings in fresh cool air from the external ambient environment and transports the heat generated by the processor and other system components out of the system. Therefore, the number, size and relative position of fans and vents determine the chassis thermal performance, and the resulting ambient temperature around the processor.

It is particularly important to choose a thermally advantaged chassis for the reference thermal solution for Intel® Atom™ processor 300 series that might be a passive heatsink design.

For more detail reference information about improving chassis thermal performance, contact your Intel field sales representative for the latest revision of *Nettop '08 System Design* White Paper. Note that the white paper may not be released as of the publication of this document.

2.4.3 Summary

In summary, heatsink design considerations for Intel® Atom™ processor 300 series include:

- The case temperature $T_{CASE-MAX}$ for the processor, which is a function of overall system thermal performance, must be compliant in order to ensure processor reliability.
- For the implementation of any customized thermal solution using either a thermal interface material, or clip, or heatsink design that is different from the Intel® reference thermal solution as mentioned in this document, the case temperature $T_{CASE-MAX}$ for the processor must be compliant in order to ensure processor reliability.
- The heatsink temperature $T_{S-TOP-MAX}$ for the processor must be compliant in order to ensure processor reliability for a system that using the Intel® reference thermal solution.
- Heatsink interface to die surface characteristics, including flatness and roughness.
- The performance of the thermal interface material used between the heatsink and the die.
- The required heatsink clip static load, throughout the life of the product (Please refer to Section 2.1.2.2 for further information).
- Surface area of the heatsink.
- Heatsink material and technology.
- Volume of airflow over the heatsink surface area.
- Development of airflow entering and within the heatsink area.
- Physical volumetric constraints placed by the system.

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3 Thermal Metrology

This chapter discusses guidelines for testing thermal solutions, including measuring processor temperatures. In all cases, the thermal engineer must measure power dissipation and temperature to validate a thermal solution.

3.1 Characterizing Cooling Performance Requirements ($T_{S\text{-}TOP\text{-}MAX}$ Methodology)

The idea of a "thermal characterization parameter", Ψ ("psi"), is a convenient way to characterize the performance needed for the thermal solution and to compare thermal solutions in identical situations (same heat source and local ambient conditions). The thermal characterization parameter is calculated using total package power. To define the performance of a thermal solution the "thermal characterization parameter", Ψ ("psi") will be used.

Note: Heat transfer is a three-dimensional phenomenon that can rarely be accurately and easily modeled by a single resistance parameter like Ψ.

The junction-to-local ambient thermal characterization parameter value (Ψ_{JA}) is used as a measure of the thermal performance of the overall thermal solution that is attached to the processor package. It is defined by the following equation, and measured in units of °C/W:

Equation 3 $\Psi_{JA} = (T_J - T_A) / TDP$

Where:

Ψ_{JA}	=	Junction-to-local ambient thermal characterization parameter (°C/W)
T_J	=	Processor junction temperature (°C)
T_A	=	Local ambient temperature in chassis at processor (°C)
TDP	=	Processor total power dissipation (W) (assumes all power dissipates through the processor die)

For the reference thermal solution of Intel® Atom™ processor 200 series, there are primary 2 heat flow paths for heat to be dissipated away from die to ambient. One of the paths is that heat flows from die though TIM and heatsink subsequently dissipates to ambient, which could be defined as $\Psi_{JA\text{-}UP}$. The other heat flow path is from die through substrate and solders joints of processor package then to motherboard and subsequently dissipation to ambient, which could be defined as $\Psi_{JA\text{-}DOWN}$.

Relationship of these 2 thermal resistances is defined as follow.

Equation 4 $1/\Psi_{JA} = 1/\Psi_{JA\text{-}UP} + 1/\Psi_{JA\text{-}DOWN}$

The $\Psi_{JA\text{-}TOP}$, is comprised of Ψ_{JS}, the thermal interface material thermal characterization parameter, $\Psi_{HS\text{-}BASE}$ the thermal characterization parameter of the heatsink base from bottom center of heatsink base to top center of heatsink base surface, and of $\Psi_{S\text{-}TOP\text{-}A}$, the sink-to-local ambient thermal characterization parameter:

Equation 5 $\Psi_{JA\text{-}TOP} = \Psi_{JS} + \Psi_{HS\text{-}BASE} + \Psi_{S\text{-}TOP\text{-}A} = (T_J - T_A) / P_{D\text{-}TOP}$

Equation 6 $\Psi_{S\text{-}TOP\text{-}A} = (T_{S\text{-}TOP} - T_A) / P_{D\text{-}TOP}$

Where:

$\Psi_{JA\text{-}TOP}$ = Thermal characterization parameter of thermal flow path from die through TIM, heatsink and subsequently dissipation to ambient (°C/W)

Ψ_{JS} = Thermal characterization parameter of the thermal interface material (°C/W)

$\Psi_{HS\text{-}BASE}$ = Thermal characterization parameter of the heatsink base (°C/W)

$\Psi_{S\text{-}TOP\text{-}A}$ = Thermal characterization parameter from heatsink top to local ambient (°C/W)

$P_{D\text{-}TOP}$ is the amount of processor power dissipation (W) dissipates through TIM, heatsink and subsequently to ambient. Normally this value is certain percentage of total power dissipation TDP, and it is determined from thermal simulation results.

Ψ_{JS} is strongly dependent on the thermal conductivity, thickness and performance degradation across time of the TIM between the heatsink and processor die.

$\Psi_{HS\text{-}BASE}$ is a measure of the thermal characterization parameter of the heatsink base. It is dependent on the heatsink base material, thermal conductivity, thickness and geometry. This value could be determined from thermal simulation results.

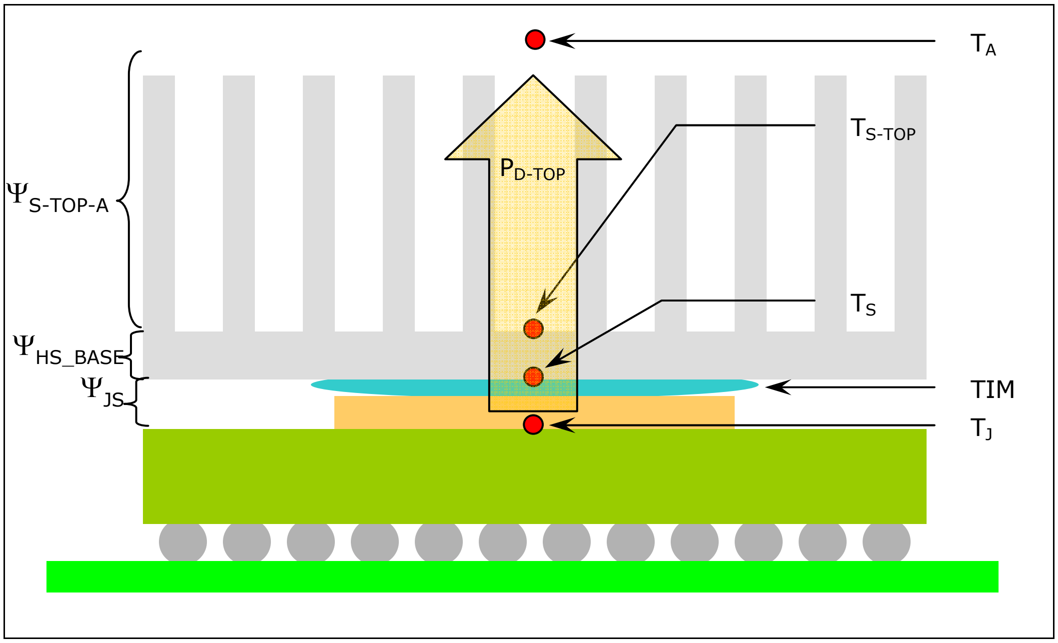
$\Psi_{S\text{-}TOP\text{-}A}$ is a measure of the thermal characterization parameter from the top center point of the heatsink base to the local ambient air. $\Psi_{S\text{-}TOP\text{-}A}$ is dependent on the heatsink material, thermal conductivity, and geometry. It is also strongly dependent on the air flow through the fins of the heatsink.

Equation 7 $(\Psi_{JA\text{-}TOP} - \Psi_{JS} - \Psi_{HS\text{-}BASE}) \times P_{D\text{-}TOP} + T_A = T_{S\text{-}TOP\text{-}MAX}$

With a given processor junction-to-local ambient requirement (Ψ_{JA}) and TIM performance (Ψ_{JS}) and processor power consumption ($P_{D\text{-}TOP}$), the processor's heatsink requirement ($T_{S\text{-}TOP\text{-}MAX}$) could be defined by Equation 7.

Figure 4 illustrates the combination of the different thermal characterization parameters.

Figure 4. Processor Thermal Characterization Parameter Relationships



3.1.1 Example

The cooling performance, $\Psi_{JA,}$ is then defined using the principle of thermal characterization parameter described above:

- The junction temperature $_{TJ\text{-}MAX}$ and thermal design power TDP given in the processor datasheet.
- Define the allowable heatsink temperature for processor, $T_{S\text{-}TOP\text{-}MAX}$.

The following provides an illustration of how one might determine the appropriate not related to any specific Intel processor thermal specifications, and are for illustrative purposes only.

Assume the TDP, as listed in the datasheet, is 20 W and the maximum junction temperature 20 W is 90 °C. Assume as well that the system airflow has been designed such that the local ambient temperature is 42 °C, and Ψ_{HS_BASE} = 0.30 C/W, $P_{D\text{-}TOP}$ = 90% of TDP = 18 W. Then the following could be calculated using Equation 3:

$$\Psi_{JA\text{-}TOP} = (T_J - T_A) / P_{D\text{-}TOP} = (90 - 42) / 18 = 2.67\ °C/W$$

To determine the required heatsink performance, a heatsink solution provider would need to determine Ψ_{JS} performance for the selected TIM and mechanical load configuration. If the heatsink solution were designed to work with a TIM material performing at $\Psi_{JS} \leq 0.50$ °C/W, The heatsink temperature requirement can be obtained from Equation 7.

$$T_{S\text{-}TOP\text{-}MAX} = (\Psi_{JA\text{-}TOP} - \Psi_{JS} - \Psi_{HS\_BASE}) \times P_{D\text{-}TOP} + T_A$$
$$= (2.67 - 0.50 - 0.30) \times 18 + 42$$
$$= 75.7\ °C$$

3.2 Case Temperature Measurement ($T_{CASE-MAX}$ Methodology)

The system designer that uses a customized heatsink design on Intel® Atom™ processor 300 series must measure the case temperature (T_{CASE}) in order to accurately determine the thermal performance of the system. Intel has established guidelines for proper techniques of measuring case temperature.

Note: A customized thermal solution using either a thermal interface material, or clip, or heatsink design that is different from the Intel reference thermal solution as mentioned in this document, the case temperature $T_{CASE-MAX}$ for the processor must be compliant in order to ensure processor reliability.

To ensure functionality and reliability, the processor is specified for proper operation when T_{CASE} is maintained at or below the maximum temperature listed in Table 3. The surface temperature at the geometric center of the die corresponds to case temperature. Measuring T_{CASE} requires special care to ensure an accurate temperature reading.

Temperature differences between the temperature of a surface and the surrounding local ambient air can introduce error in the measurements. The measurement errors could 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 heatsink base (if a heatsink is used). To minimize these measurement errors a thermocouple attach with a zero-degree methodology is recommended.

3.3 Thermocouple Attach Methodology

1. Mill a 3.3 mm [0.13 in] diameter hole centered on bottom of the heatsink base. The milled hole should be approximately 1.5 mm [0.06 in] deep.
2. Mill a 1.3 mm [0.05 in] wide slot, 0.5 mm [0.02 in] deep, from the centered hole to one edge of the heatsink. The slot should be in the direction parallel to the heatsink fins (see Figure 6).
3. Attach thermal interface material (TIM) to the bottom of the heatsink base.
4. Cut out portions of the TIM to make room for the thermocouple wire and bead. The cutouts should match the slot and hole milled into the heatsink 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, make sure no contact is present between the thermocouple cement and the heatsink base because any contact will affect the thermocouple reading. It is critical that the thermocouple bead makes contact with the die (see Figure 5).
6. Attach heatsink assembly to the component, and route thermocouple wires out through the milled slot.

Figure 5. 0° Angle Attach Methodology (top view, not to scale)

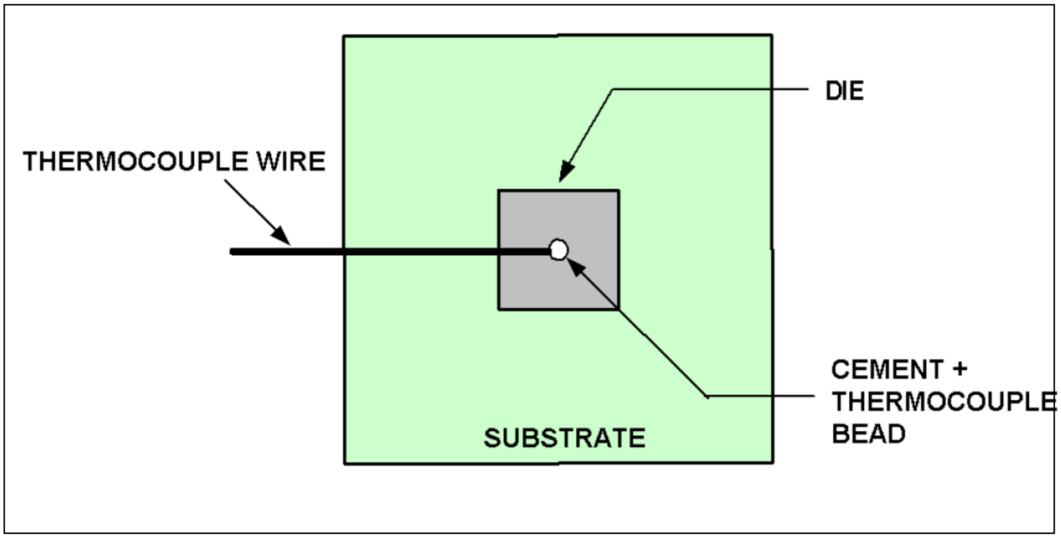
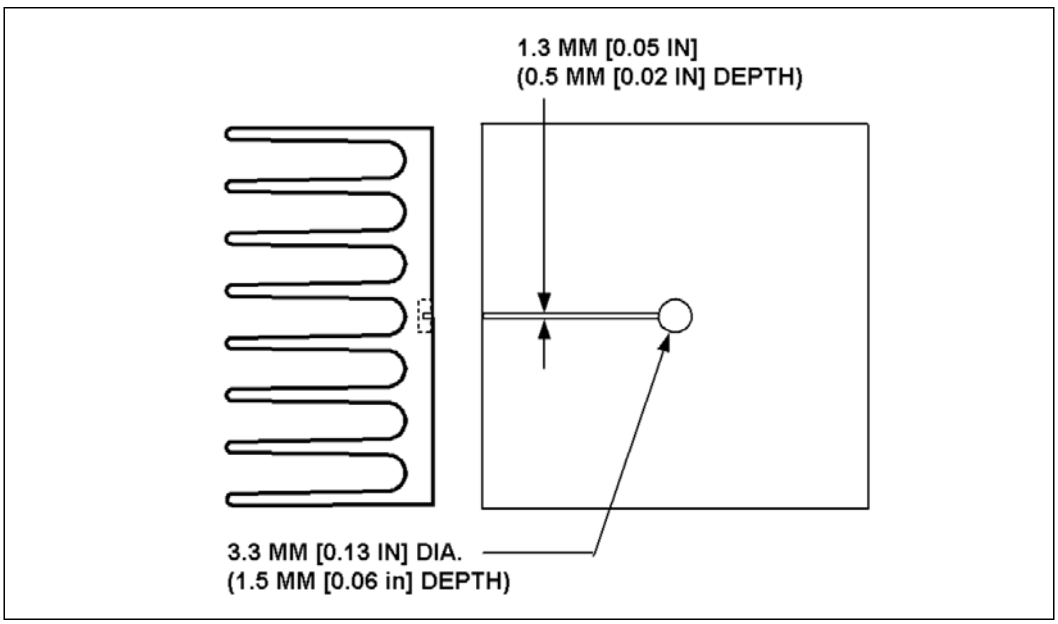


Figure 6. 0° Angle Attach Heatsink Modifications (generic heatsink side and bottom view shown, not to scale)



3.4 Local Ambient Temperature Measurement Guidelines

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

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

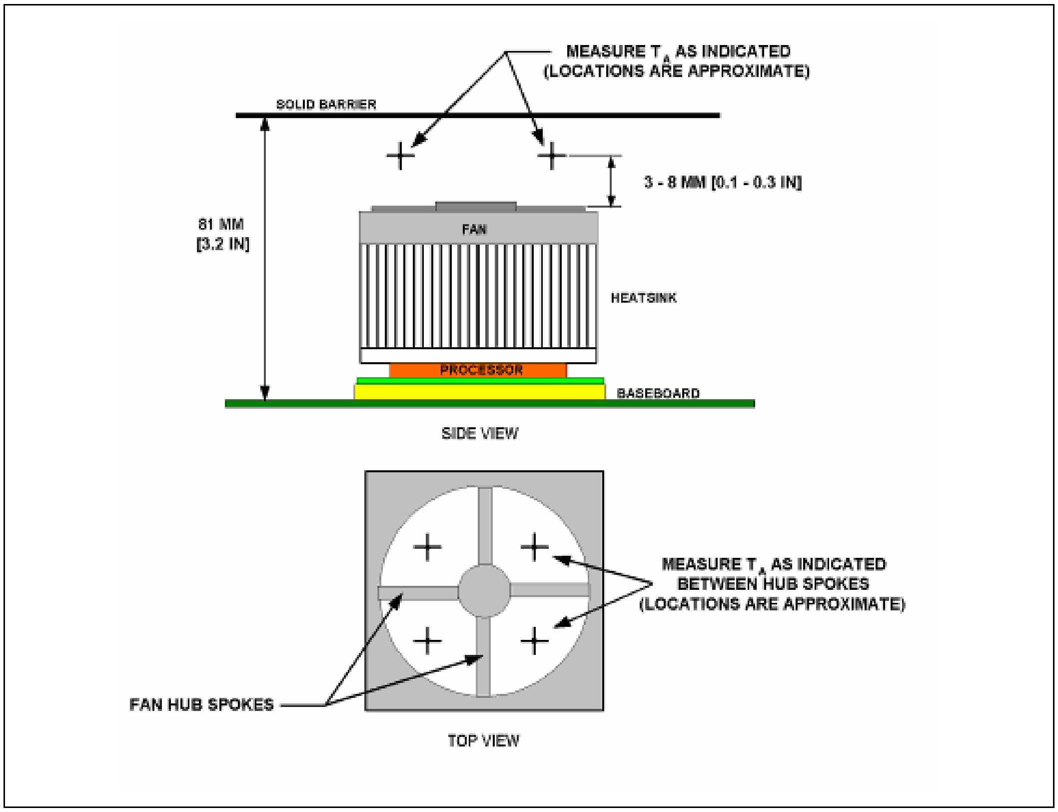
T_A is best measured by averaging temperature measurements at multiple locations in the heatsink inlet airflow. This method helps reduce error and eliminate minor spatial variations in temperature. The following guidelines are meant to enable accurate determination of the localized air temperature around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

For **active heatsinks**, it is important to avoid taking measurement in the dead flow zone that usually develops above the fan hub and hub spokes. Measurements should be taken at four different locations uniformly placed at the center of the annulus formed by the fan hub and the fan housing to evaluate the uniformity of the air temperature at the fan inlet. The thermocouples should be placed approximately 3 mm to 8 mm [0.1 to 0.3 in] above the fan hub vertically and halfway between the fan hub and the fan housing horizontally as shown in Figure 7 (avoiding the hub spokes). Using an open bench to characterize an active heatsink can be useful, and usually ensures more uniform temperatures at the fan inlet. However, additional tests that include a solid barrier above the test motherboard surface can help evaluate the potential impact of the chassis. This barrier is typically clear Plexiglas*, extending at least 100 mm [4 in] in all directions beyond the edge of the thermal solution. Typical distance from the motherboard to the barrier is 81 mm [3.2 in]. For even more realistic airflow, the motherboard should be populated with significant elements like memory cards, graphic card, and chipset heatsink. If a barrier is used, the thermocouple can be taped directly to the barrier with a clear tape at the horizontal location as previously described, half way between the fan hub and the fan housing. If a variable speed fan is used, it may be useful to add a thermocouple taped to the barrier above the location of the temperature sensor used by the fan to check its speed setting against air temperature. When measuring T_A in a chassis with a live motherboard, add-in cards, and other system components, it is likely that the T_A measurements will reveal a highly non-uniform temperature distribution across the inlet fan section.

For **passive heatsinks**, thermocouples should be placed approximately 13 mm to 25 mm [0.5 to 1.0 in] away from processor and heatsink as shown in Figure 8. The thermocouples should be placed approximately 51 mm [2.0 in] above the baseboard. This placement guideline is meant to minimize the effect of localized hot spots from baseboard components.

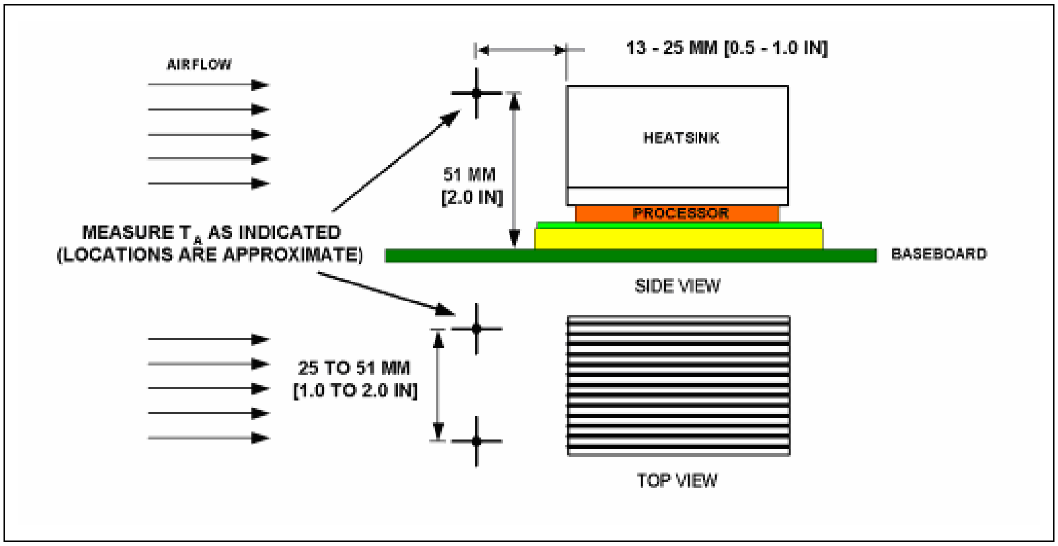
Note: Testing an active heatsink with a variable speed fan can be done in a thermal chamber to capture the worst-case thermal environment scenarios. Otherwise, when doing a bench top test at room temperature, the fan regulation prevents the heatsink from operating at its maximum capability. To characterize the heatsink capability in the worst-case environment in these conditions, it is then necessary to disable the fan regulation and power the fan directly, based on guidance from the fan supplier.

Figure 7. Locations for Measuring Local Ambient Temperature, Active Heatsink



NOTE: Drawing Not to Scale

Figure 8. Locations for Measuring Local Ambient Temperature, Passive Heatsink



NOTE: Drawing Not to Scale

It is recommended that full and routine calibration of temperature measurement equipment be performed before attempting to perform temperature measurement. Intel recommends checking the meter probe set against known standards. This should be done at 0º C (using ice bath or other stable temperature source) and at an elevated temperature, around 80º C (using an appropriate temperature source).

Wire gauge and length also should be considered as some less expensive measurement systems are heavily impacted by impedance. There are numerous resources available throughout the industry to assist with implementation of proper controls for thermal measurements.

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4 System Thermal/Mechanical Design Information

4.1 Overview of the Reference Design

This chapter will document the requirements for designing a passive heatsink that meets the maximum usage power consumption that mentioned in Section 2.4. The Intel® Atom™ processor 300 series reference thermal solution (E40825-001) satisfies the specified thermal requirements for Intel® Atom™ processor 300 series with Intel chipsets platform.

Note: The part numbers provided in this document is for reference only. The revision number -001 may be subject to change without notice. OEMs and System Integrators are responsible for thermal, mechanical and environmental validation of this solution on their platform (refer to Sections 4.1.2 and 4.2).

The Intel® Atom™ processor 300 series reference thermal solutions, E40825-001 for Intel® Atom™ processor 300 / Intel chipsets platform, take advantage of cost savings. The thermal solution supports the unique and smaller desktop PCs including small and ultra small form factors, down to a 5L system size.

The motherboard keep-out recommendations shown in Section 2.1 remain the same for a thermal solution for all Intel® Atom™ processors 300 series in the FCBGA8 package.

4.1.1 Altitude

Many companies design products that must function reliably at high altitude, typically 1,500 m [5,000 ft] or more. Air-cooled temperature calculations and measurements at the test site elevation must be adjusted to take into account altitude effects like variation in air density and overall heat capacity. This often leads to some degradation in thermal solution performance compared to what is obtained at sea level, with lower fan performance and higher surface temperatures. The system designer needs to account for altitude effects in the overall system thermal design to make sure that $T_{S\text{-}TOP\text{-}MAX}$ requirement for the processor is met at the targeted altitude for Intel® Atom™ processor 300 series reference thermal solution.

For a customized thermal solution, the system designer needs to account for altitude effects in the overall system thermal design to make sure that $T_{CASE\text{-}MAX}$ requirement for the processor is met at the targeted altitude.

4.1.2 Heatsink Thermal Validation

Intel recommends evaluation of the heatsink within the specific boundary conditions based on the methodology described in Chapter 3.

Testing is done on bench top test boards at ambient laboratory temperature.

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

4.2 Environmental Reliability Testing

4.2.1 Structural Reliability Testing

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

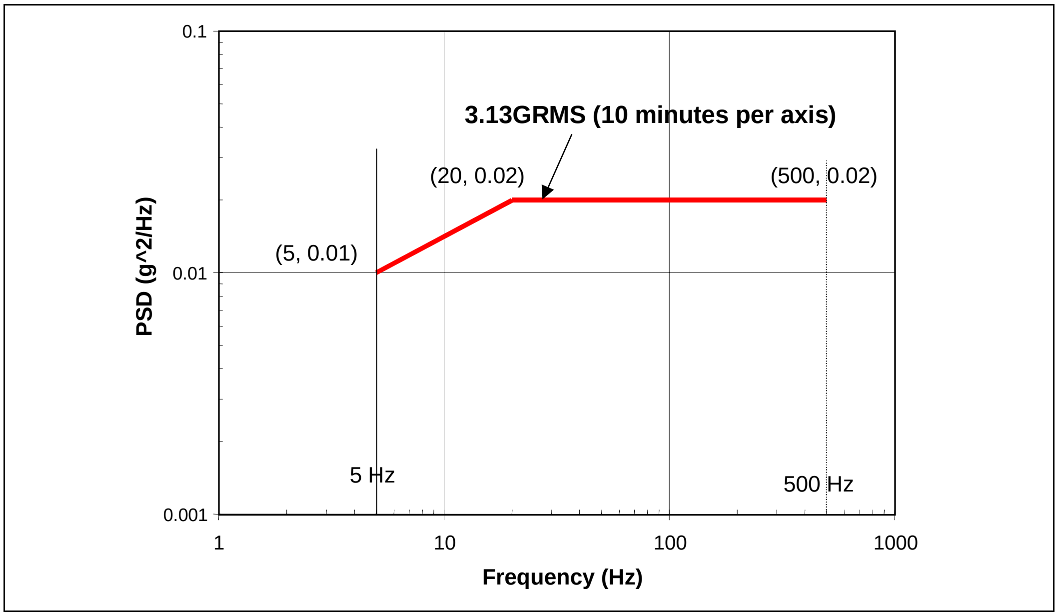
4.2.1.1 Random Vibration Test Procedure

Duration: 10 min/axis, 3 axes

Frequency Range: 5 Hz to 500 Hz

Power Spectral Density (PSD) Profile: 3.13 G RMS

Figure 9. Random Vibration PSD

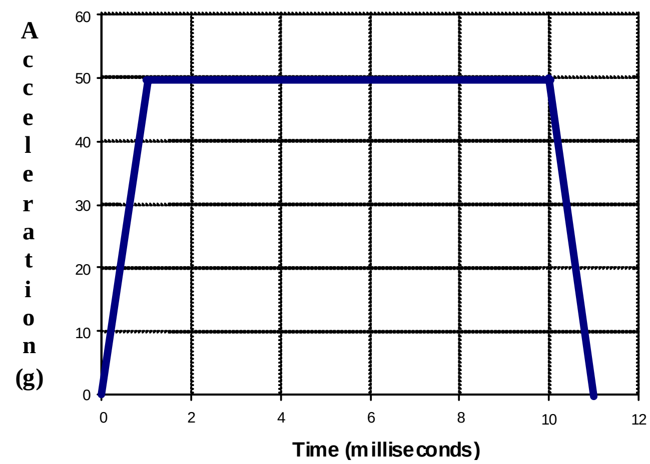


4.2.1.2 Shock Test Procedure

Recommended performance requirement for a motherboard:

- Quantity: 3 drops for + and - directions in each of 3 perpendicular axes (i.e., total 18 drops).
- Profile: 50 G trapezoidal waveform, 170 in/sec minimum velocity change.
- Setup: Mount sample board on test fixture.

Figure 10. Shock Acceleration Curve



4.2.1.2.1 Recommended Test Sequence

Each test sequence should start with components (i.e., motherboard, heatsink assembly, etc.) that have never been previously submitted to any reliability testing.

The test sequence should always start with a visual inspection after assembly, and BIOS/CPU/Memory test (refer to Section 4.2.1.2.2).

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 stress test should be followed by a visual inspection and then BIOS/CPU/Memory test.

4.2.1.2.2 Post-Test Pass Criteria

The post-test pass criteria are:

1. No significant physical damage to the heatsink attach mechanism (including such items as clip and motherboard fasteners).
2. Heatsink must remain attached to the motherboard.
3. Heatsink remains seated and its bottom remains mated flatly against die surface. No visible gap between the heatsink base and processor die. No visible tilt of the heatsink with respect to its attach mechanism.
4. No signs of physical damage on motherboard surface due to impact of heatsink or heatsink attach mechanism.
5. No visible physical damage to the processor package.
6. Successful BIOS/Processor/memory test of post-test samples.
7. Thermal compliance testing to demonstrate that the case temperature specification can be met.

4.2.2 Recommended BIOS/CPU/Memory Test Procedures

This test is to ensure proper operation of the product before and after environmental stresses, with the thermal mechanical enabling components assembled. The test shall be conducted on a fully operational motherboard 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 motherboard
- Processor
- All enabling components, including thermal solution parts
- Power supply
- Disk drive
- Add-in card
- DIMM
- Keyboard
- Monitor

The pass criterion is that the system under test shall successfully complete the checking of BIOS, basic processor functions and memory, without any errors.

4.3 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 (e.g., polyester and some polyethers), plastics which contain organic fillers of laminating materials, paints, and varnishes also are susceptible to fungal growth. If materials are not fungal growth resistant, then MIL-STD-810E, Method 508.4 must be performed to determine material performance.

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

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

4.4 Safety Requirements

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

- UL Recognition-approved for flammability at the system level. All mechanical and thermal enabling components must be a minimum UL94V-2 approved.
- CSA Certification. All mechanical and thermal enabling components must have CSA certification.
- All components (in particular the heatsink fins) must meet the test requirements of UL1439 for sharp edges.
- If the International Accessibility Probe specified in IEC 950 can access the moving parts of the fan, consider adding safety feature so that there is no risk of personal injury.

4.5 Reference Attach Mechanism

4.5.1 Structural Design Strategy

Structural design strategy for the Intel reference thermal solution to minimize upward board deflection during shock.

The design uses a high clip stiffness that resists local board curvature under the heatsink, and minimizes, in particular, upward board deflection.

4.5.2 Mechanical Interface to the Reference Attach Mechanism

The attach mechanism component from the Intel® Atom™ processor 300 series reference thermal solution can be used by other 3rd party cooling solutions. The attach mechanism consists of:

1. A metal clip that interfaces with the heatsink
2. Heatsink/fan mass ≤ 26.0 grams for metal clip E40824-001

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Appendix A Mechanical Drawings

The following table lists the mechanical drawings included in this appendix. These drawings refer to the reference thermal mechanical enabling components for the processor, and (G)MCH chipset.

Note: Intel reserves the right to make changes and modifications to the design as necessary.

Drawing Description	Page Number
Keep-out Footprint	
Intel® Atom™ Processor 300 Series Motherboard Keep-out Footprint Definition and Height Restrictions for Enabling Components	38
. Intel® 945GC GMCH Motherboard Keep-out Footprint Definition and Height Restrictions for Enabling Components on Intel® Atom™ Processor 300 Series/ Intel Chipset Platforms	39
For the Intel® Atom™ processor 300 Series/ Intel Chipset Platform	
. Intel® Atom™ Processor 300 series Reference Clip for Intel® Atom™ 300 Series / Intel Chipset Platform (E40824-001)	40
. Intel® Atom™ Processor 300 series Reference Heatsink for Intel® Atom™ 300 Series / Intel Chipset Platform (E20724-001)	41
. Intel® Atom™ Processor 300 Series Reference Thermal Solution for the Intel® Atom™ Processor 300 Series / Intel Chipset Platform (E40825-001)	42
. Intel® 945GC GMCH Reference Clip for Intel® Atom™ processor 300 Series / Intel Chipset Platform (E37585-001)	43
. Intel® 945GC GMCH Reference Heatsink for Intel® Atom™ Processor 300 Series / Intel Chipset Platform (E40145-001)	44
. Intel® 945GC GMCH Reference Heatsink Assembly for Intel® Atom™ Processor 300 Series / Intel Chipset Platform (E40144-001)	45
. Intel® 945GC GMCH Reference Thermal Solution for Intel® Atom™ Processor 300 Series / Intel Chipset Platform	46

Figure 11. Intel® Atom™ Processor 300 Series Motherboard Keep-out Footprint Definition and Height Restrictions for Enabling Components

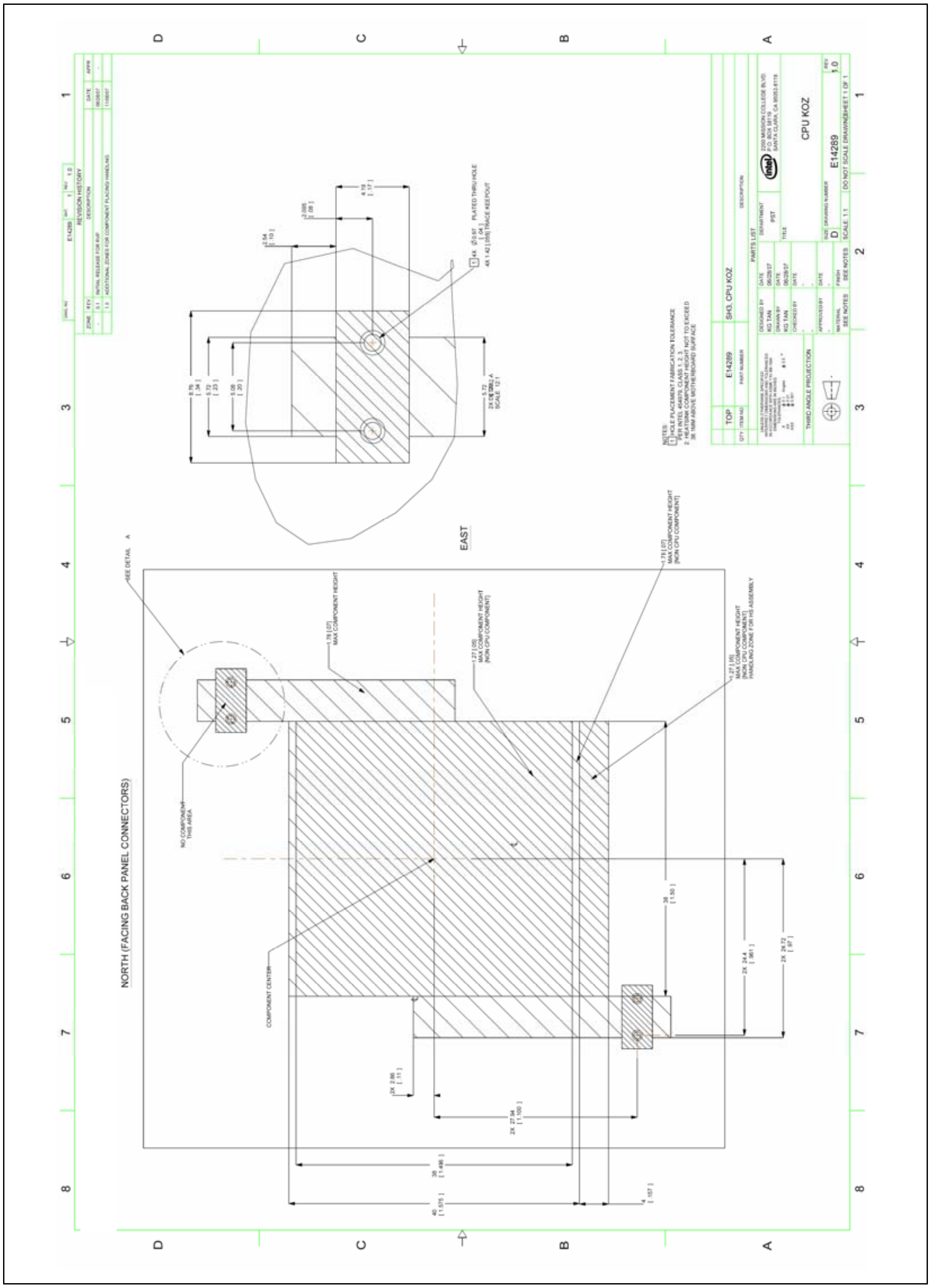


Figure 12. Intel® 945GC GMCH Motherboard Keep-out Footprint Definition and Height Restrictions for Enabling Components on Intel® Atom™ Processor 300 Series/ Intel Chipset Platforms

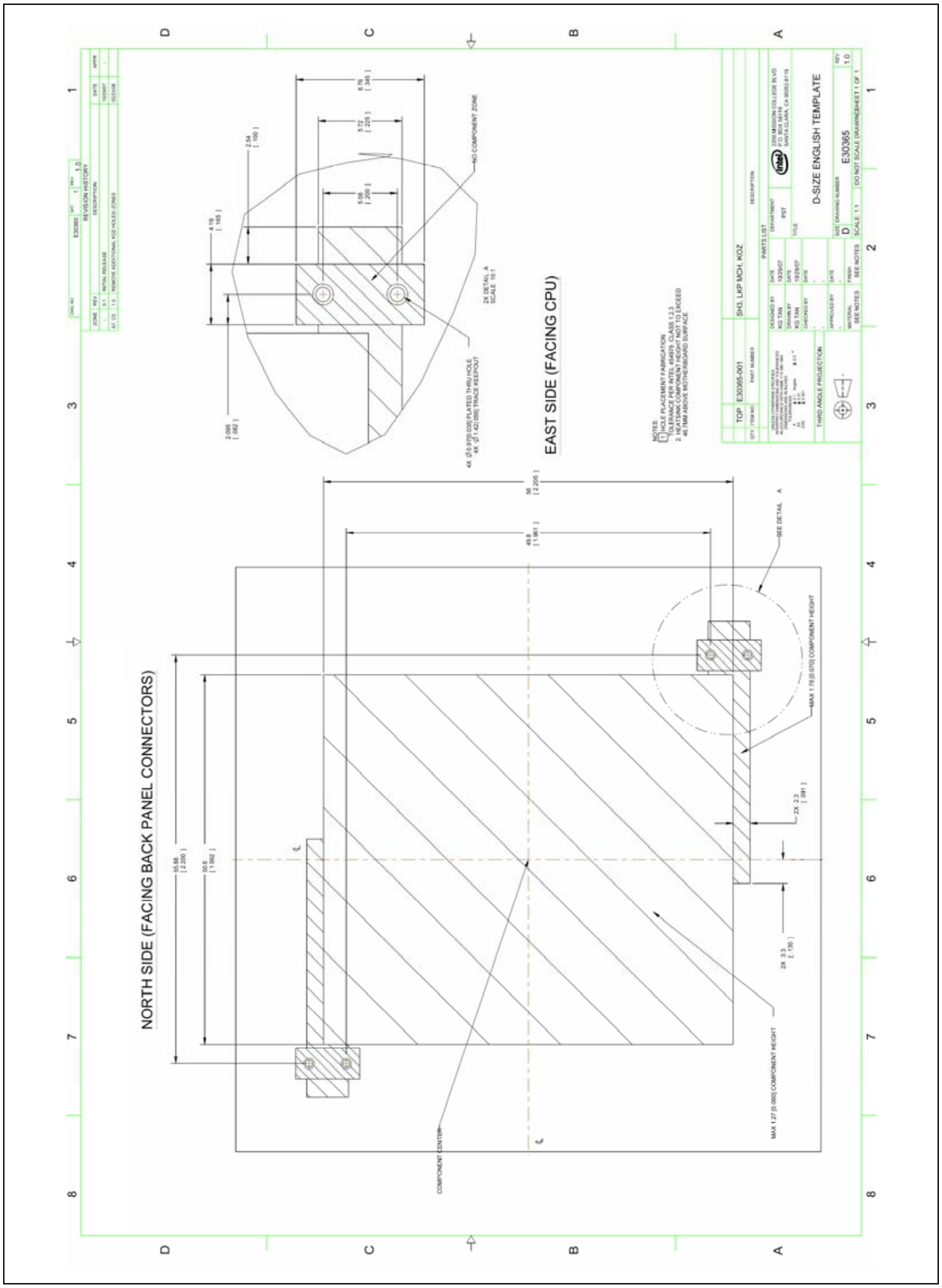


Figure 13. Intel® Atom™ Processor 300 series Reference Clip for Intel® Atom™ 300 Series / Intel Chipset Platform (E40824-001)

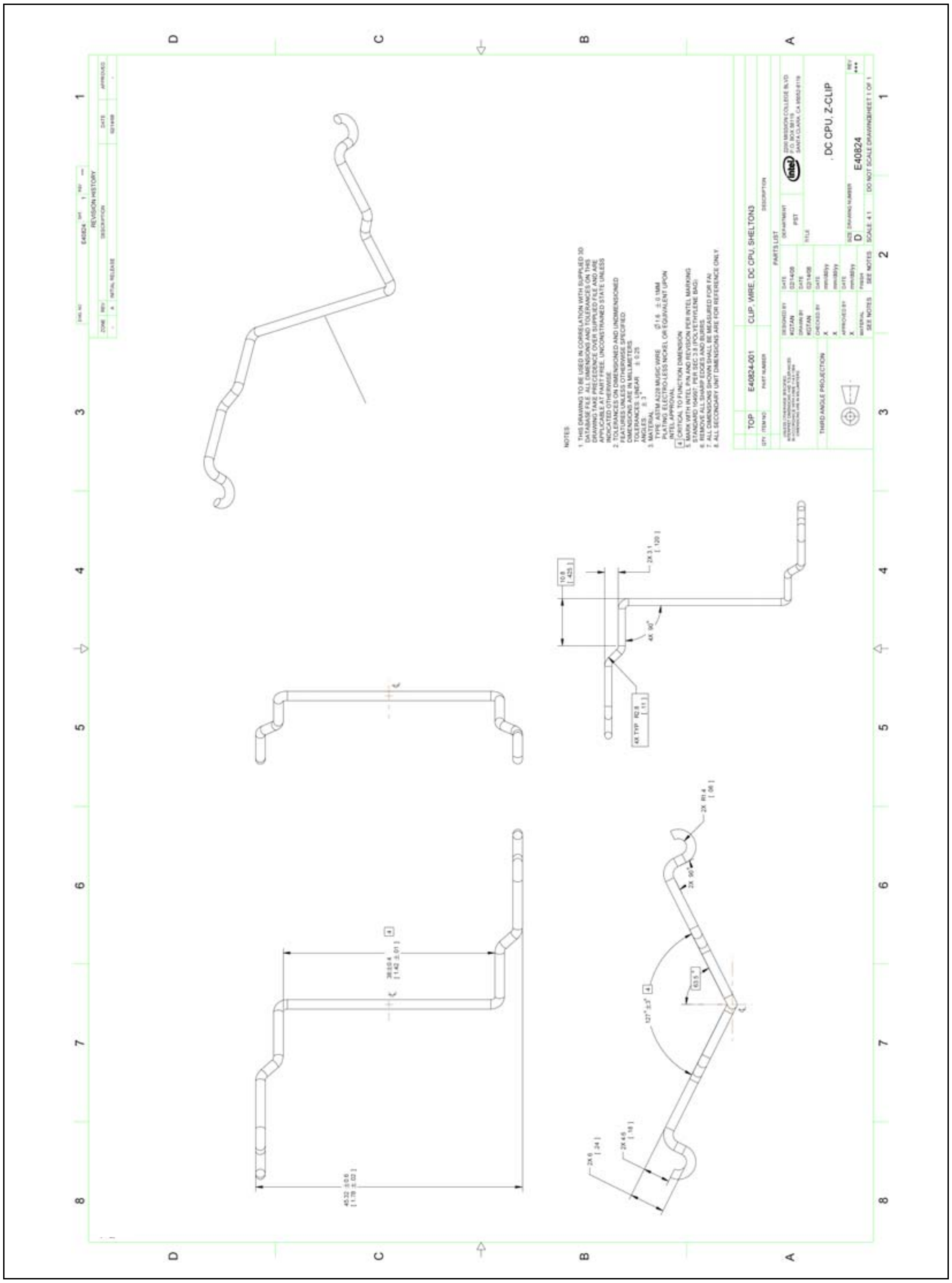


Figure 14. Intel® Atom™ Processor 300 series Reference Heatsink for Intel® Atom™ 300 Series / Intel Chipset Platform (E20724-001)

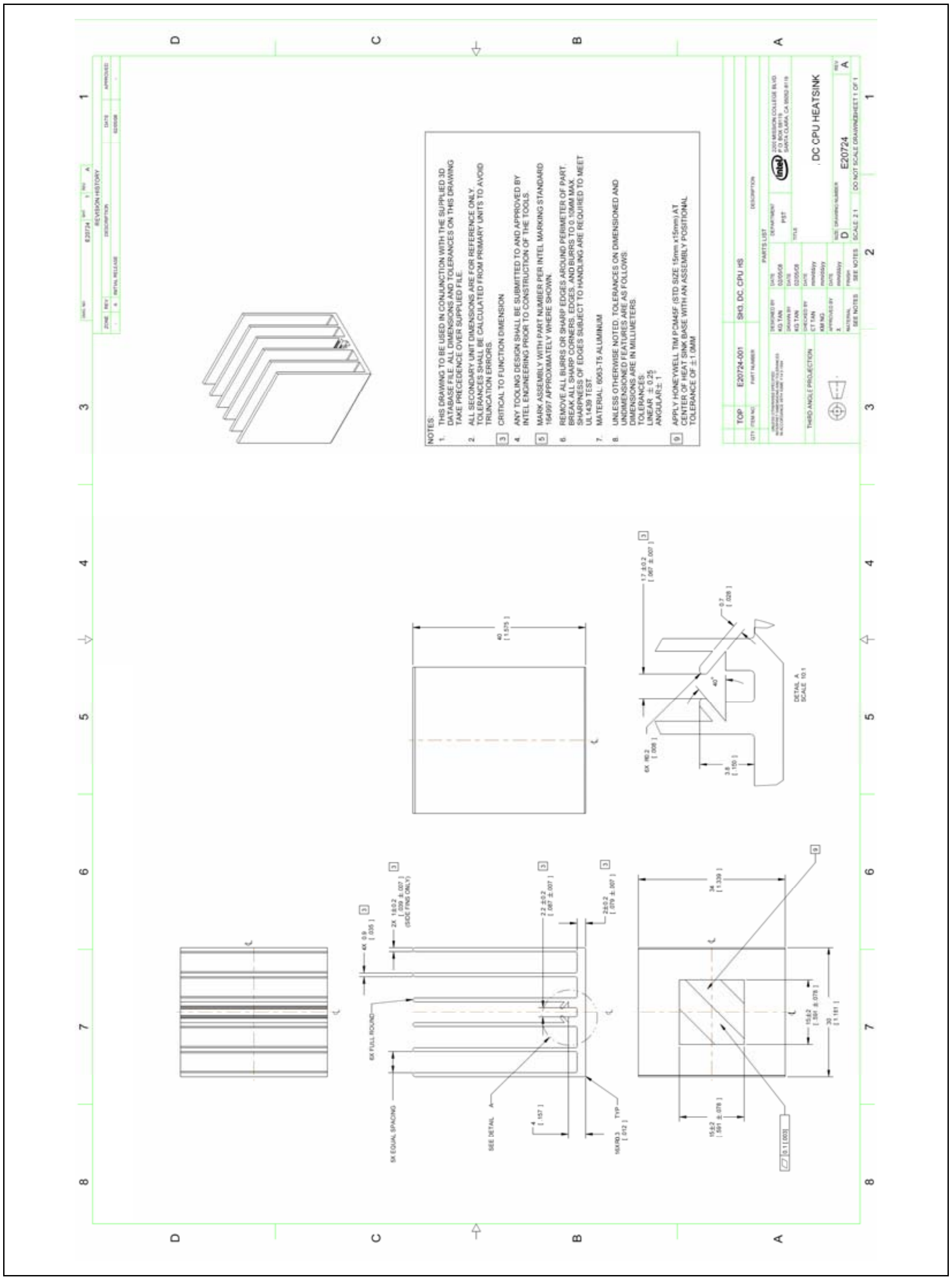


Figure 15. Intel® Atom™ Processor 300 Series Reference Thermal Solution for the Intel® Atom™ Processor 300 Series / Intel Chipset Platform (E40825-001)

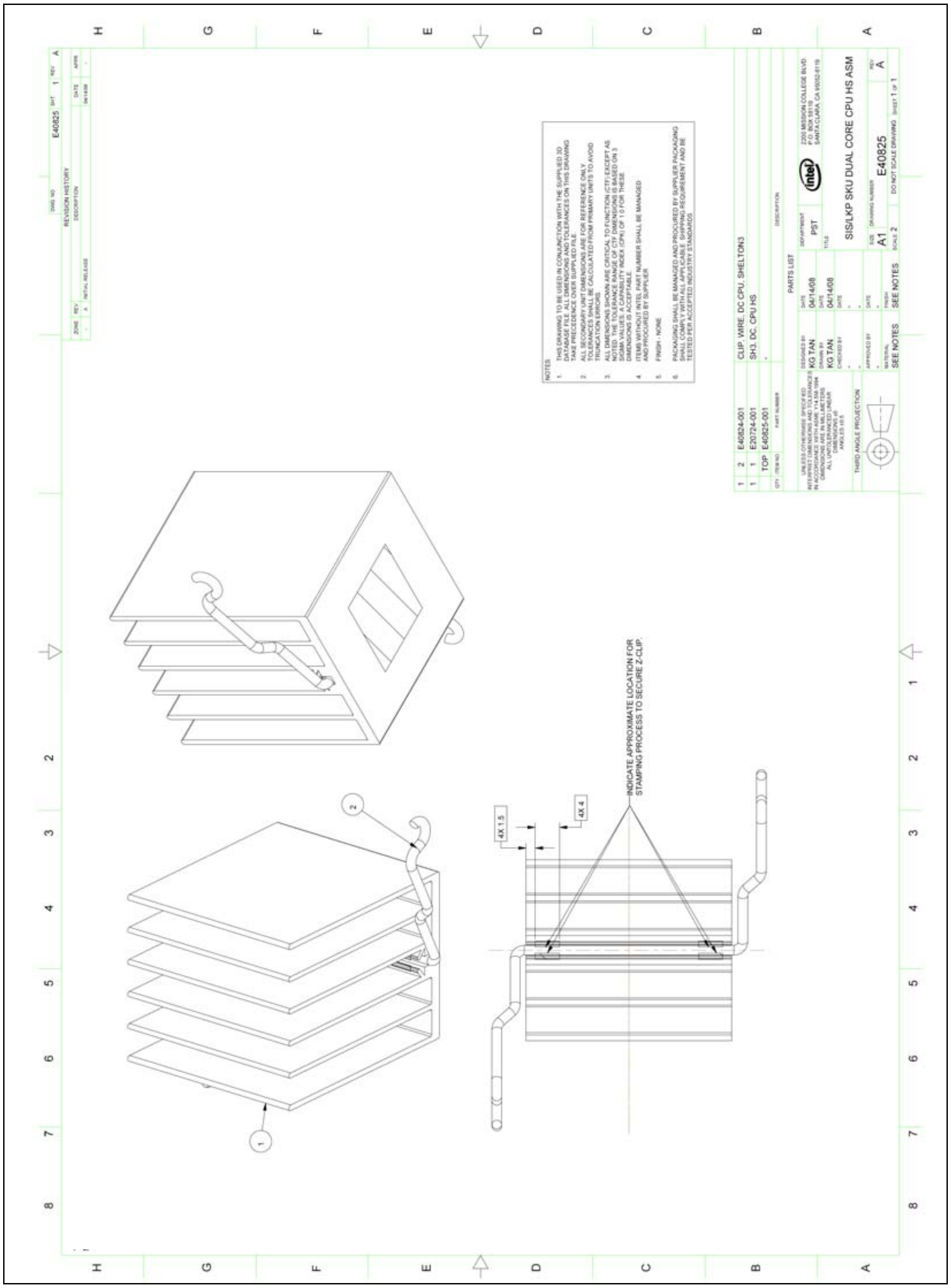


Figure 16. Intel® 945GC GMCH Reference Clip for Intel® Atom™ processor 300 Series / Intel Chipset Platform (E37585-001)

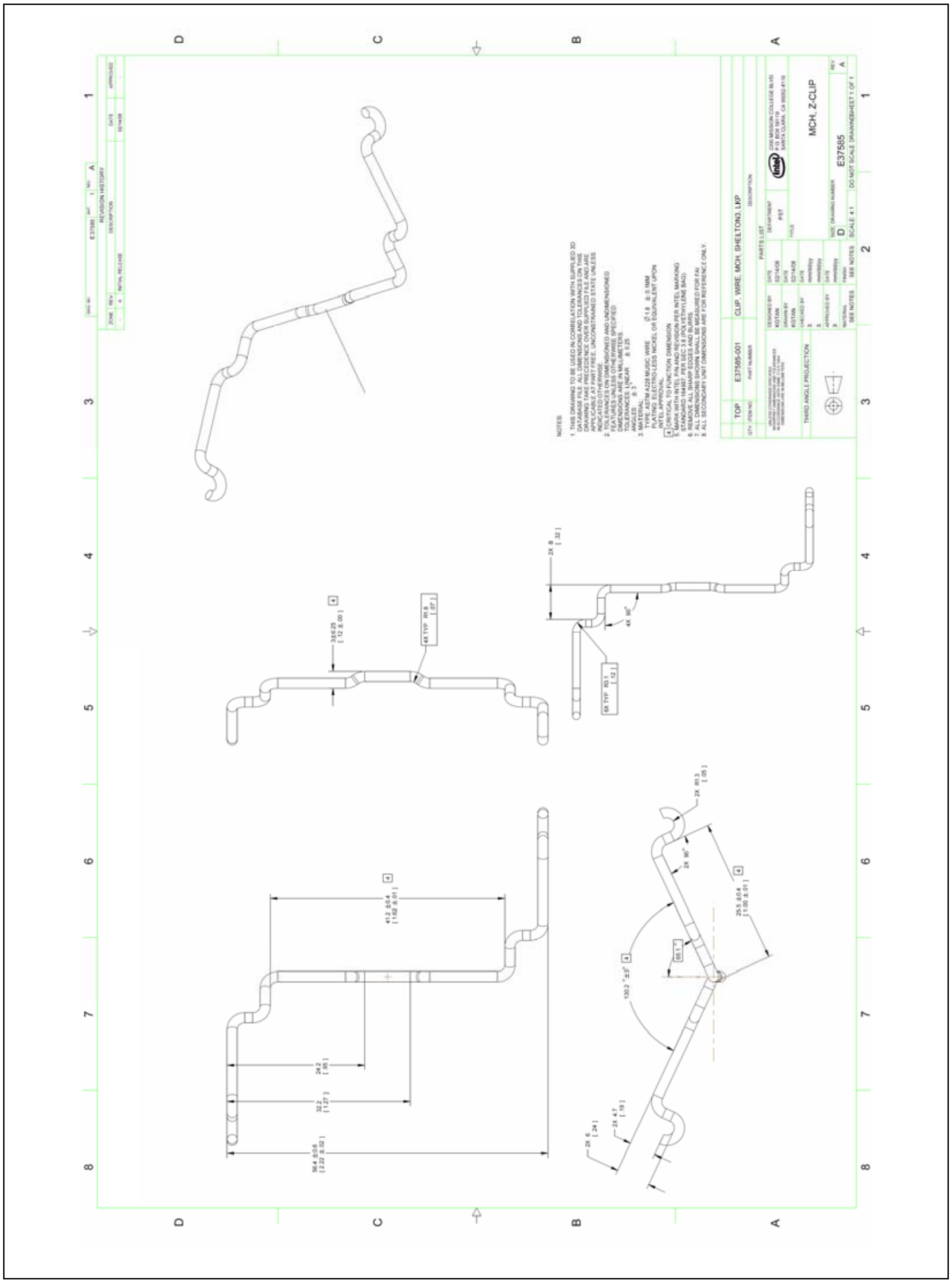


Figure 17. Intel® 945GC GMCH Reference Heatsink for Intel® Atom™ Processor 300 Series / Intel Chipset Platform (E40145-001)

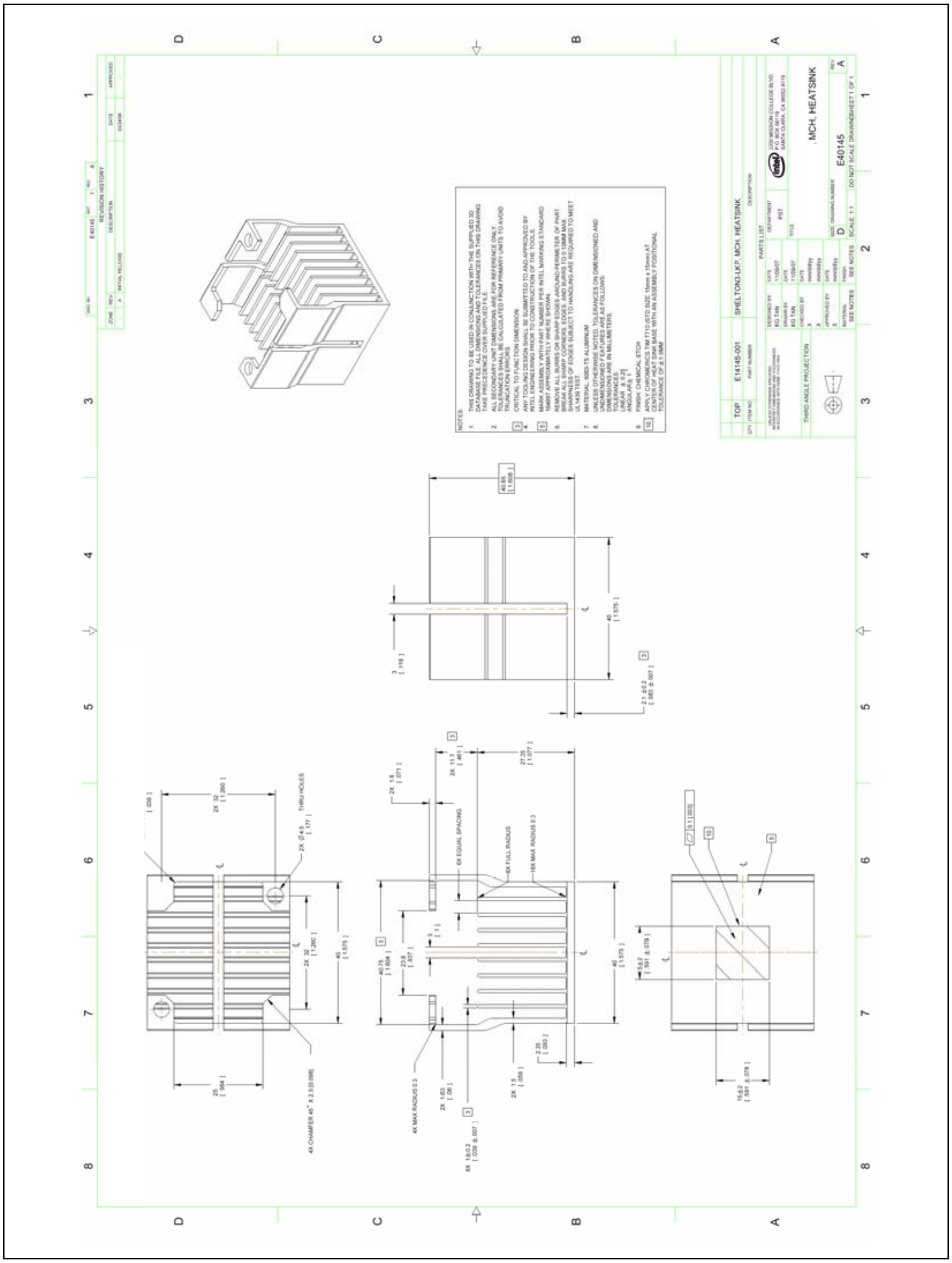


Figure 18. Intel® 945GC GMCH Reference Heatsink Assembly for Intel® Atom™ Processor 300 Series / Intel Chipset Platform (E40144-001)

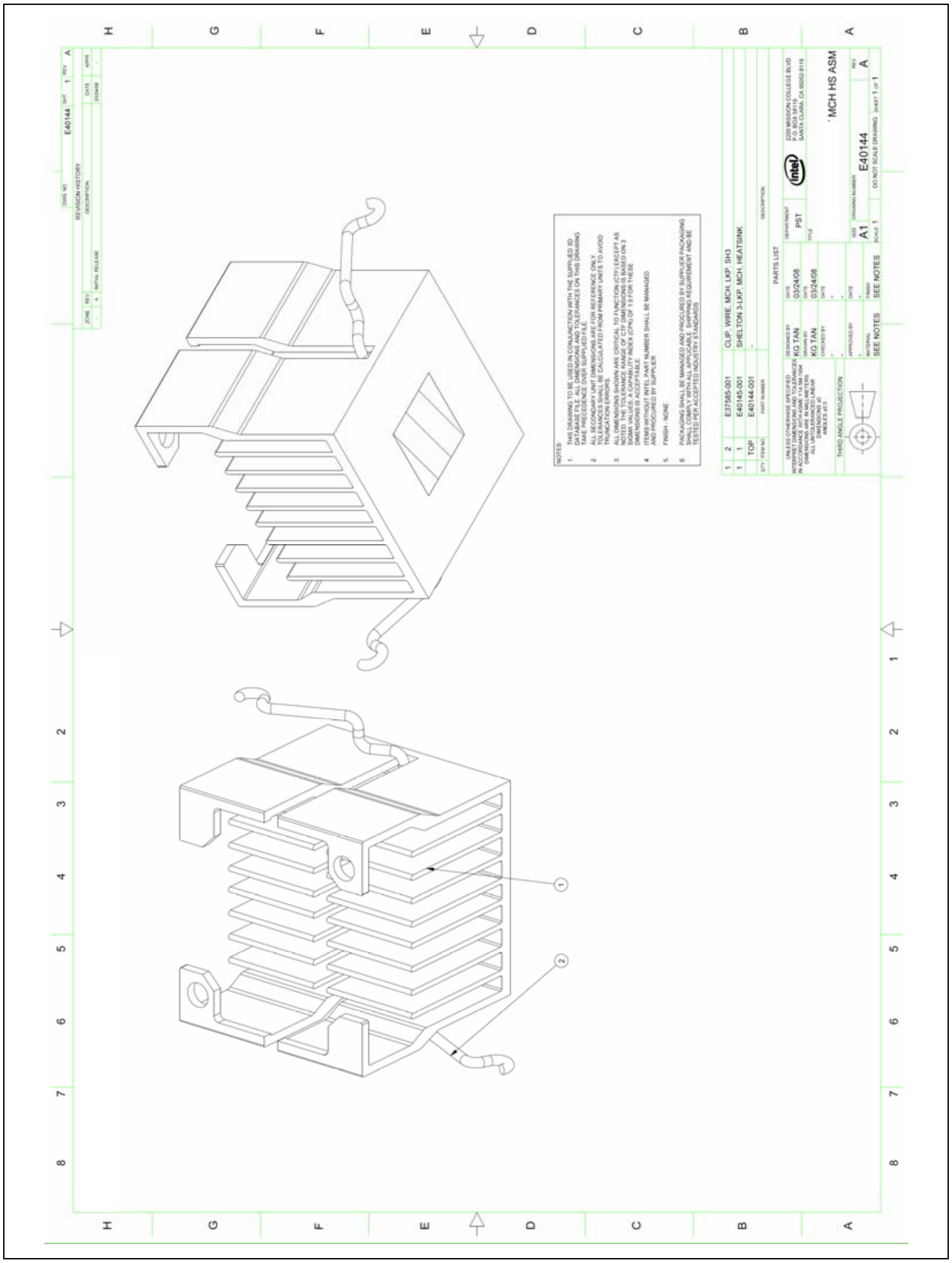
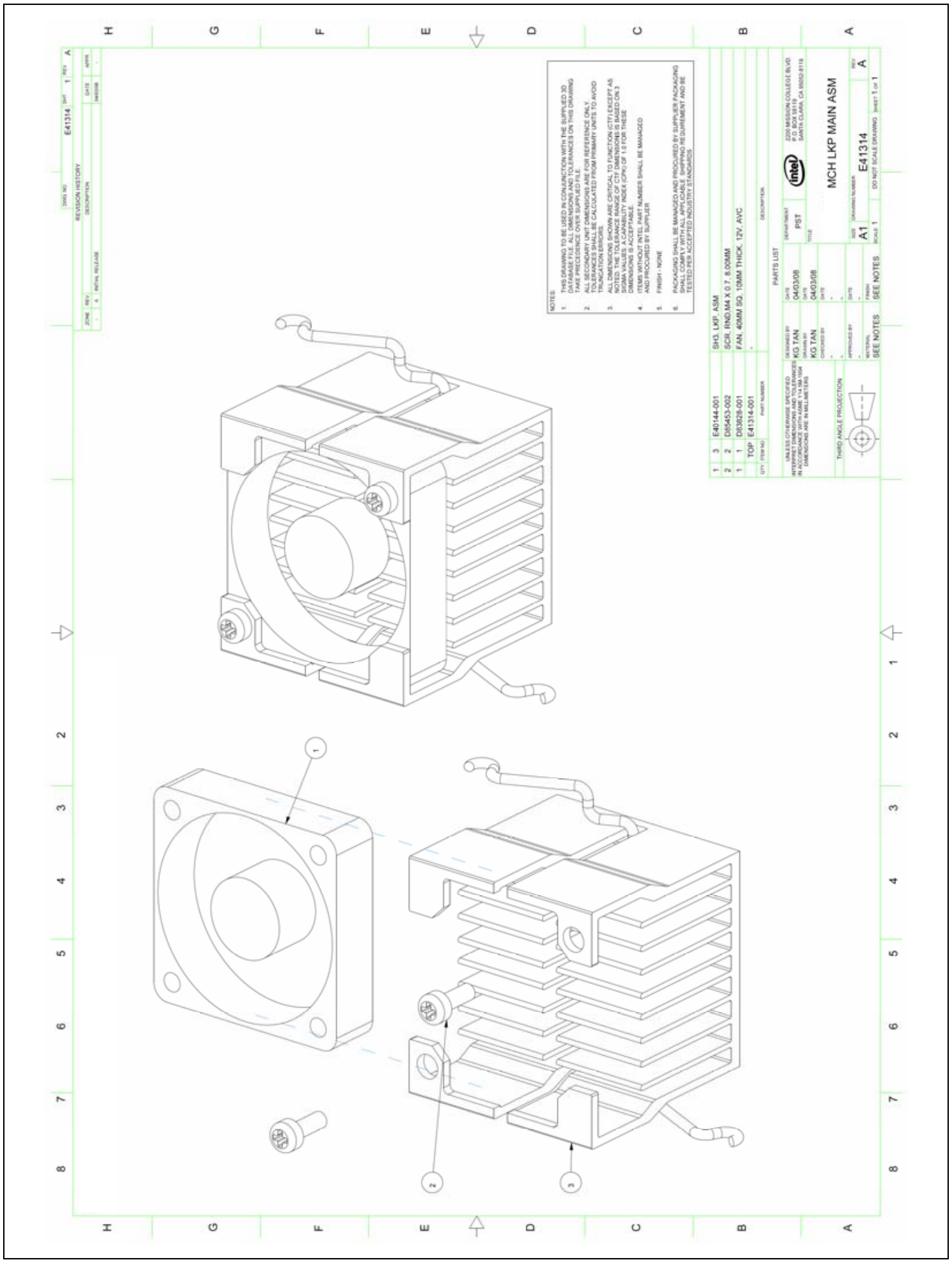


Figure 19. Intel® 945GC GMCH Reference Thermal Solution for Intel® Atom™ Processor 300 Series / Intel Chipset Platform (E41314-001)



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Appendix B Heatsink Clip Load Metrology

B.1 Overview

The primary objective of the preload measurement is to ensure the preload designed into the retention mechanism is able to meet minimum and does not violate the maximum specifications of the package (Refer to Section 2.1.2.2).

B.2 Test Preparation

B.2.1 Heatsink Preparation

The following components are required to validate a generic z-clip solution:

1. Thermal solution heatsink (for example, PN: E20724-001 for Intel® Atom™ processor 300 series)
2. Z-clip (for example, PN: E40824-001 for Intel® Atom™ processor 300 series)
3. 2X Anchors (IPN: A13494-008 if using Intel's part)
4. Customized top plate to allow anchor attachment and package simulator

B.2.2 Typical Test Equipment

For the heatsink clip load measurement, use equivalent test equipment to the one listed Table 5.

Table 5. Typical Test Equipment

Item	Description	Part Number (Model)
Load cell Notes: 1, 5	Honeywell*-Sensotec* Model 13 subminiature load cells, compression only Select a load range depending on load level being tested. www.sensotec.com	AL322BL
Data Logger (or scanner) Notes: 2, 3, 4	Vishay* Measurements Group Model 6100 scanner with a 6010A strain card (one card required per channel).	Model 6100

Item	Description	Part Number (Model)
Clip Force Measurement machine Notes: 4, 6, 8	Customized machine that houses load cell for force measurement. Top side plate can be modified to accommodate various attach pattern	CFM-001 (Cool Star Technology)

NOTES:

1. Select load range depending on expected load level. It is usually better, whenever possible, to operate in the high end of the load cell capability. Check with your load cell vendor for further information.
2. Since the load cells are calibrated in terms of mV/V, a data logger or scanner is required to supply 5 volts DC excitation and read the mV response. An automated model will take the sensitivity calibration of the load cells and convert the mV output into pounds.
3. With the test equipment listed above, it is possible to automate data recording and control with a 6101-PCI card (GPIB) added to the scanner, allowing it to be connected to a PC running LabVIEW* or Vishay's StrainSmart* software.
4. **IMPORTANT**: In addition to just a zeroing of the force reading at no applied load, it is important to calibrate the load cells against known loads. Load cells tend to drift. Contact your load cell vendor for calibration tools and procedure information.
5. When measuring loads under thermal stress (bake for example), load cell thermal capability must be checked, and the test setup must integrate any hardware used along with the load cell. For example, the Model 13 load cells are temperature compensated up to 71°C, as long as the compensation package (spliced into the load cell's wiring) is also placed in the temperature chamber. The load cells can handle up to 121°C (operating), but their uncertainty increases according to 0.02% rdg/°F.
6. Clip force measurement machine is recommended to be calibrated before usage. Standard weights should be used to check for preload cell accuracy and consistency.

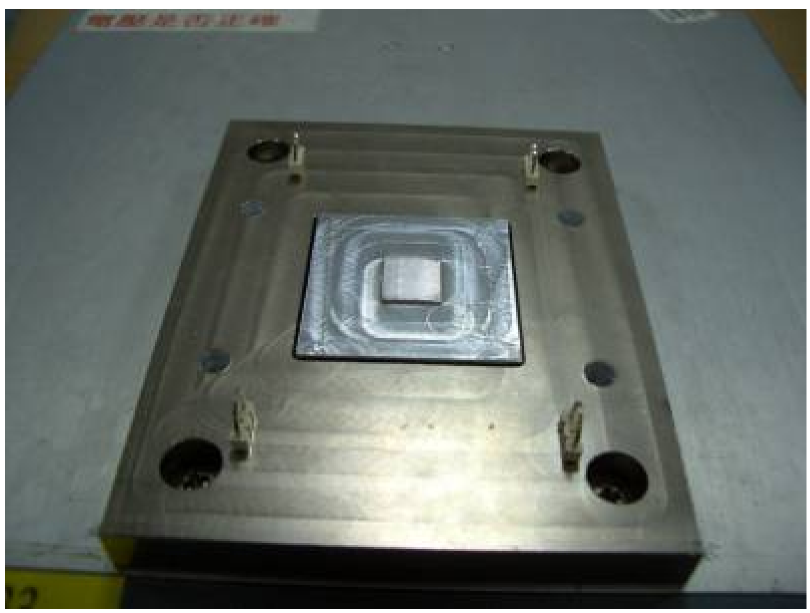
B.3 Test Procedure Examples

The following procedure is for a generic z-clip solution using the clip force time0 measurement machine at room temperature:

1. Install anchors onto top plate. Anchor can be secured using epoxy or glue.
2. Fasten top plate onto the clip force measurement machine. Place package simulator on top of the preload cell as well.
3. Place the heatsink (remove any TIM material) on top of the package simulator. Power on the clip force measurement machine.
4. Install the z-clip and record down the measured preload. Make sure measurement is taken after the reading stabilized. Remove the z-clip and repeat 2 times (in total 3 times) to ensure consistency.
5. Repeat step4 for remaining clip samples. Recommended minimum samples are 10 z-clip samples.

Figure 20. Top Plate And Package Simulator Fasten Onto Clip Force Measurement Machine

Figure 21. Anchors Installed and Glued Down BTX Base Plate – For Reference Only



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Appendix C Intel® Enabled Boxed Processor Thermal Solution Information

This appendix includes supplier information for Intel enabled vendors.

Table 6 lists suppliers that produce Intel® Atom™ processor reference thermal solution components. The part numbers listed in the table identify these reference components. End-users are responsible for the verification of the Intel enabled component offerings with the supplier. OEMs and System Integrators are responsible for thermal, mechanical, and environmental validation of these solutions.

Table 6. Intel® Atom™ Processor 300 Series Reference Thermal Solution Providers

Supplier	Part Description	Intel Part Number	Contact	Phone	Email
AVC	For Intel® Atom™ 200 series / Intel Chipset Platform		David Chao	+886 2 2299 6930 etx. 7619	david_chao@avc.com.tw
	Fan for Intel 945GC GMCH Fan Heatsink	D83828-001	Rachel Hsi	+886 2 2299 6930 etx. 7630	raichel_hsi@avc.com.tw
Bossard	For Intel® Atom™ 200 series / Intel Chipset Platform		Eddie Teoh	+604 642 4293 ext. 113	MPOT@bossard.com.sg
	Screws for Fan on Intel 945GC GMCH Fan Heatsink	D85453-001			
Foxconn	For Intel® Atom™ 200 series / Intel Chipset Platform		Wanchi Chen	+ 1 408 919 6135	Wanchi.Chen@Foxconn.com
	Intel 945GC GMCH Fan Heatsink Assembly	E41314-001			
	Intel 945GC GMCH Heatsink Assembly	E 40144-001			
	Intel 945GC GMCH Heatsink	E40145-001			

Supplier	Part Description	Intel Part Number	Contact	Phone	Email
CCI	For Intel® Atom™ 200 series / Intel Chipset Platform		Monica Chih	+886-2-2995-2666 ext. 1131	monica_chih@cci c.com.tw
	CPU Z-Clip	E40824-001	Cindy Zhang	+886-2-2995-2666 ext. 1140	cindy_zhang@cci c.com.tw
	CPU Heatsink	E20724-001			
	CPU Heatsink Assembly	E40825-001			
	Intel 945GC GMCH Z-Clip	E37585-001			

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