Intel® 82915GV Express Chipset

Thermal Design Guide for Embedded Applications

September 2004

Revision 1.0

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Revision History

Date	Revision	Description
August 2004	1.0	Initial Public Release.

1.0 Introduction

The objective of thermal management is to ensure that the temperatures of all components in a system are maintained within functional limits. The functional temperature limit is the range within which the electrical circuits can be expected to meet specified performance requirements. Operation outside the functional limit can degrade system performance, cause logic errors, or cause component and/or system damage. Temperatures exceeding the maximum operating limits may result in irreversible changes in the operating characteristics of the component. The goal of this document is to provide an understanding of the operating limits of the Intel® 82915GV Express Chipset GMCH and discuss a reference thermal solution.

The simplest and most cost-effective method to improve the inherent system cooling characteristics of the GMCH is through careful design and placement of fans, vents, and ducts. When additional cooling is required, component thermal solutions may be implemented in conjunction with system thermal solutions. The Intel 915GV GMCH will require a heatsink to maintain the component temperature specifications.

1.1 Scope

This document presents conditions and requirements to properly design a cooling solution for systems that implement the Intel® 82915GV Express Chipset GMCH. Specifically it applies to implementation in embedded applications and form factors (e.g., 1U/2U server form factor). Properly designed thermal solutions provide adequate cooling to maintain the GMCH case temperature at or below thermal specifications. This is accomplished by providing a low local-ambient temperature, ensuring adequate airflow, and minimizing case-to-local-ambient thermal resistance. By maintaining the GMCH case temperature at of below the specifications, a system designer can ensure the proper functionality, performance, and reliability of the chipset.

1.2 Terms and Definitions

Table 1. Terms and Definitions (Sheet 1 of 2)

Term	Definition
BGA	Ball Grid Array. A package type defined by a resin-fiber substrate where a die is mounted and bonded. The primary electrical interface is an array of solder balls attached to the substrate opposite the die and molding compound.
FC-BGA	Flip Chip Ball Grid Array. A package type defined by a plastic substrate where a die is mounted using an underfill Controlled Collapse Chip Connection (C4) attach style. The primary electrical interface is an array of solder balls attached to the substrate opposite the die. Note that the device arrives to the customer with solder balls attached.
Intel® ICH6	Intel® I/O Controller Hub 6. The chipset component that contains the primary PCI interface, LPC interface, USB, ATA, and/or other legacy functions.
mBGA	Mini Ball Grid Array. A smaller version of the BGA.
GMCH	Graphic Memory Controller Hub. The chipset component that contains the processor and memory interface and integrated graphics core.
T_A	The measured ambient temperature locally to the component of interest. The ambient temperature should be measured just upstream of airflow for a passive heatsink or at the fan inlet for an active heatsink. Also referred to as T_{LA}.

Table 1. Terms and Definitions (Sheet 2 of 2)

Term	Definition
T_C	The measured case temperature of a component. For processors, it is measured at the geometric center of the integrated heat spreader (IHS). For other component types, it is generally measured at the geometric center of the die or case.
$T_{C\text{-}MAX}$	The maximum case/die temperature with an attached heatsink. This temperature is measured at the geometric center of the top of the package case/die.
$T_{C\text{-}MIN}$	The minimum case/die temperature with an attached heatsink. This temperature is measured at the geometric center of the top of the package case/die.
TDP	Thermal Design Power is specified as the highest sustainable power level of most or all of the real applications expected to be run on the given product, based on extrapolations in both hardware and software technology over the life of the component. Thermal solutions should be designed to dissipate this target power level.
TIM	Thermal Interface Material: thermally conductive material installed between two surfaces to improve heat transfer and reduce interface contact resistance.
lfm	Linear Feet per Minute. Unit of airflow speed.
Ψ_{CA}	Case-to-ambient thermal characterization parameter (Psi). A measure of thermal solution performance using total package power. Defined as (T_C – T_A)/Total Package Power. Heat source size should always be specified for Ψ measurements.
WSHS	Wave Solder Heatsink. A heatsink that is installed to a board via wave solder process. Pins are fixed to the heatsink base and are held in place on the board by solder. There are no associated retention clips or retention anchors.

1.3 Reference Documents

The table below lists documents to be used as references with the Intel 915GV Express Chipset GMCH Thermal Design Guide for Embedded Applications. Contact your Intel field sales representative for more information.

Table 2. Reference Documents

Document	Intel Document Number
Intel® 915G/915GV/915P Express Chipset Datasheet	301467
Intel® 915G/915GV Express Chipset Thermal Design Guide	301469
Intel® I/O Controller Hub 6 (ICH6) Family Thermal Design Guide	302362
Intel® Pentium® 4 Processors 560, 550, 540, 530, and 520 on 90nm Process in the 775-Land LGA Package Supporting Hyper-Threading Technology Datasheet	302351
Intel® Pentium® 4 Processor in the 775-Land LGA Package on the 90nm Process Thermal Design Guide	302553
Intel® Pentium® 4 Processor in the 775-Land LGA Package on the 90nm Process for Embedded Applications Thermal Design Guide	302822

2.0 Product Specifications

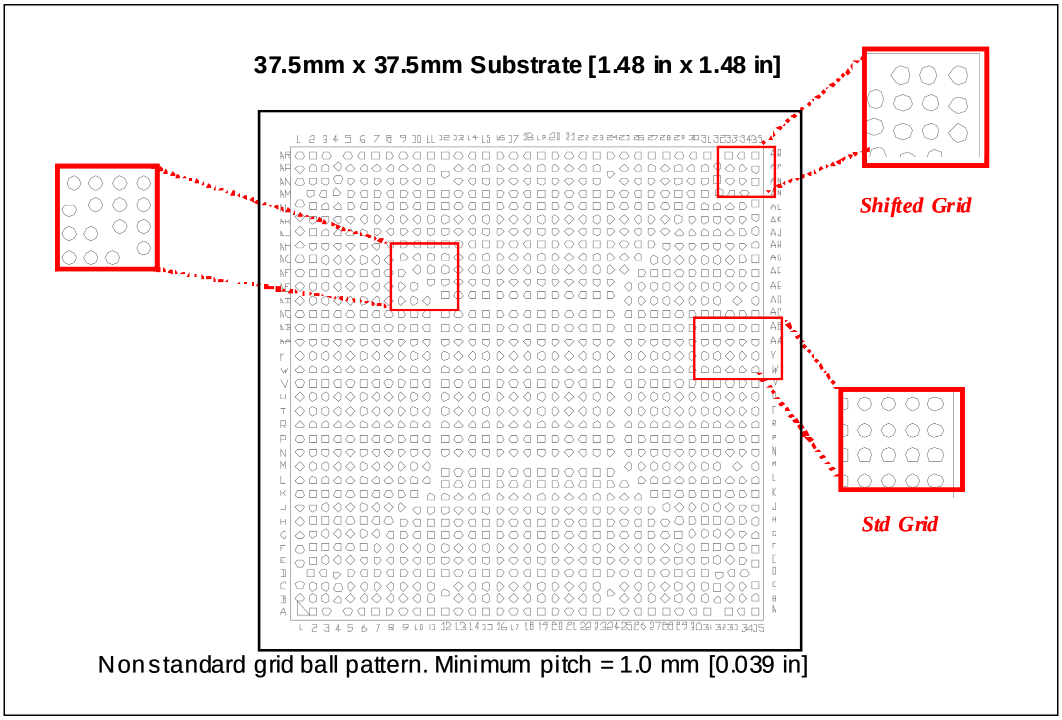
2.1 Package Description

The Intel® 915GV GMCH is available in a 37.5 mm [1.48 in] x 37.5 mm [1.48 in] Flip Chip Ball Grid Array (FC-BGA) package with 1210 solder balls. The die size is 12.29 mm [0.484 in] x 8.72 mm [0.343 in] and is subject to change. A mechanical drawing of the package is shown in Figure 1.

2.1.1 Non-Grid Array Package Ball Placement

The Intel 915GV GMCH package uses a "balls anywhere" concept. Minimum ball pitch is 1.0 mm [0.039 in], but ball ordering does not follow a 1 mm grid. Board designers should ensure correct ball placement when designing for the non-grid array pattern. For exact ball locations relative to the package, refer to the *Intel® 915G/915GV/915P Express Chipset Datasheet.*

Figure 1. Intel® 915GV GMCH Non-Grid Array



2.2 Thermal Specifications

To ensure proper operation and reliability of the Intel 915GVchipset GMCH, the temperature must be at or below the maximum value specified in Table 3. System and component level thermal enhancements are required to dissipate the heat generated and maintain the GMCH within specifications. Section 3.0, "Thermal Metrology" on page 9 provides the thermal metrology guidelines for case temperature measurements. The GMCH should also operate above the minimum case temperature specification listed in Table 3.

Table 3. GMCH Case Temperature Specifications

Parameter	Value
$T_{C\text{-}MAX}$	99 °C
$T_{C\text{-}MIN}$	0 °C

NOTE: Thermal specifications assume an attached heatsink is present.

2.3 Thermal Design Power (TDP)

Thermal design power (TDP) is the estimated power dissipation of the GMCH based on normal operating conditions including V_{CC} and $T_{C\text{-}MAX}$ while executing real worst-case power intensive applications. This value is based on expected worst-case data traffic patterns and usage of the chipset and does not represent a specific software application. TDP attempts to account for expected increases in power due to variation in chipset current consumption due to silicon process variation, processor speed, DRAM capacitive bus loading and temperature. However, since these values are subject to change, the TDP cannot guarantee that all applications will not exceed the TDP value.

The system designer must design a thermal solution for the GMCH such that it maintains T_C below $T_{C\text{-}MAX}$ for a sustained power level equal to TDP. The TDP value can be used for thermal design if the chipset thermal protection mechanisms are enabled. Intel chipsets incorporate a hardware-based, fail-safe mechanism to keep product temperature in spec in the event of unusually strenuous usage above the TDP power.

2.3.1 Application Power

Designing to the TDP can ensure a particular thermal solution can meet the cooling needs of future applications. Testing with currently available commercial applications has shown they may dissipate power levels below the published TDP specification in Section Specifications. Intel strongly recommends that thermal engineers design to the published TDP specification to develop a robust thermal solution that will meet the needs of current and future applications.

2.3.2 Specifications

The GMCH is estimated to dissipate the TDP values in Table 4 when using two DIMMs of 533 MHz dual-channel DDR2 and four DIMMs of 400 MHz dual-channel DDR1 with an 800 MHz processor system bus speed. The graphics core runs at 333 MHz. FC-BGA packages have poor heat transfer capability into the board and have minimal thermal capability without thermal solutions. Intel requires that system designers plan for an attached heatsink when using the Intel 915GV GMCH.

Table 4. GMCH TDP Specifications

Parameter	System Bus Speed	Memory Frequency	TDP Value
TDP (DDR2)	800 MHz	533 MHz	16.8 W
TDP (DDR1)	800 MHz	400 MHz	18.7 W

3.0 Thermal Metrology

The system designer must measure temperatures in order to accurately determine the thermal performance of the system. Intel has established guidelines for proper techniques of measuring chipset component case temperatures.

3.1 Case Temperature Measurements

To ensure functionality and reliability, the chipset GMCH is specified for proper operation when T_C is maintained at or below the maximum temperature listed in Table 3, “GMCH Case Temperature Specifications” on page 8. The surface temperature at the geometric center of the die corresponds to T_C. Measuring T_C 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 errors 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.

Although the basic metrology is the same for a clip-attached heatsink and a Wave Solder Heatsink (WSHS), the removal and replacement of the WSHS requires additional guidelines for accurate thermal measurements. Refer to the WSHS rework procedure found in the *Intel® 915G/915GV Express Chipset Thermal Design Guide* for guidelines on installing a WSHS modified for a zero-degree attach. Physical modifications to a WSHS are identical to modifications for a clip-attached heatsink. Section 3.1.1 details the modifications required to measure package case temperature using both clip-attached heatsinks and WSHS. The reference thermal solutions presented in this document use a clip-attach mechanism.

3.1.1 Thermocouple Attach Methodology

1. Mill a 3.3 mm [0.13 in] diameter hole centered on the 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 2.
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 3.
6. Attach heatsink assembly to the GMCH, and route thermocouple wires out through the milled slot. Following the guidelines is critical to ensuring an accurate and repeatable metrology.

Figure 2. 0° Angle Attach Heatsink Modifications (generic heatsink shown, not to scale)

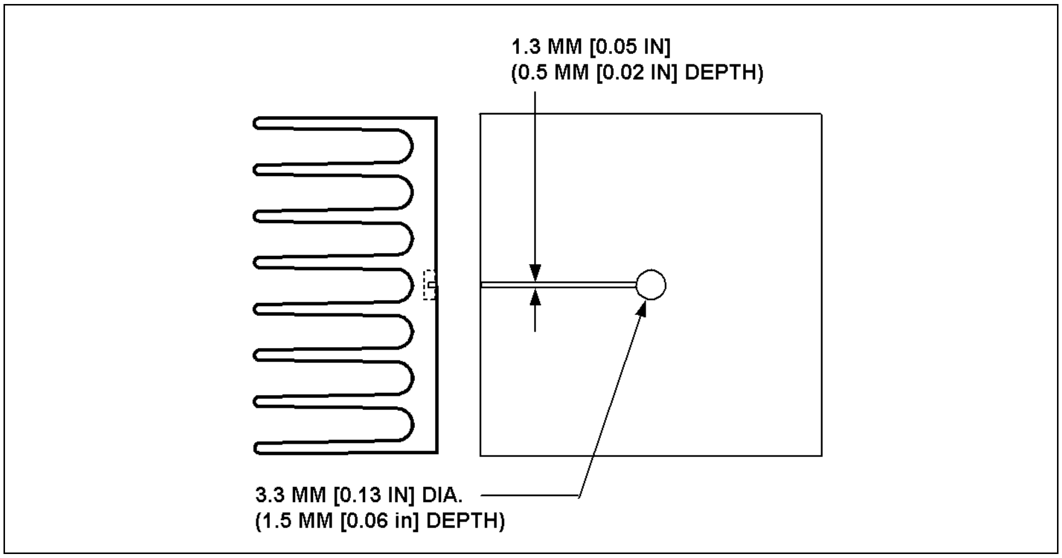
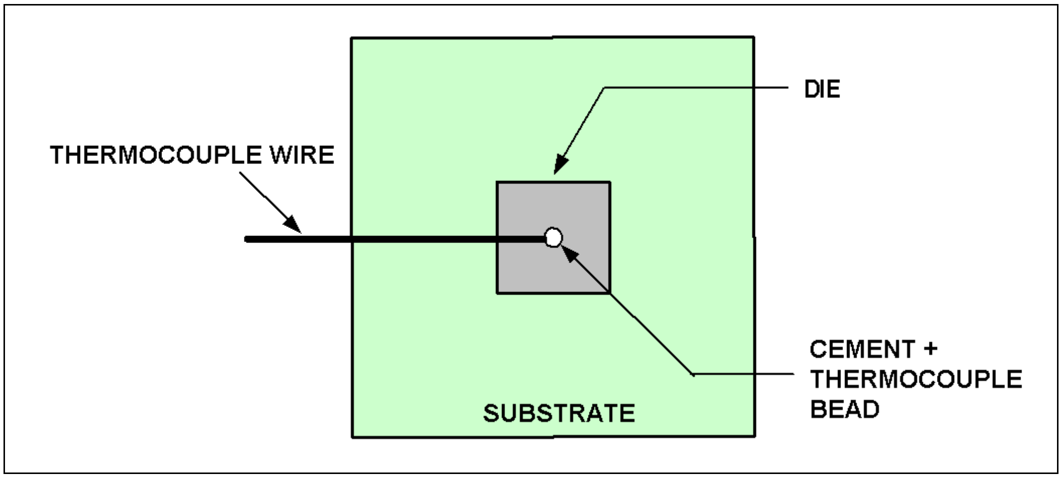


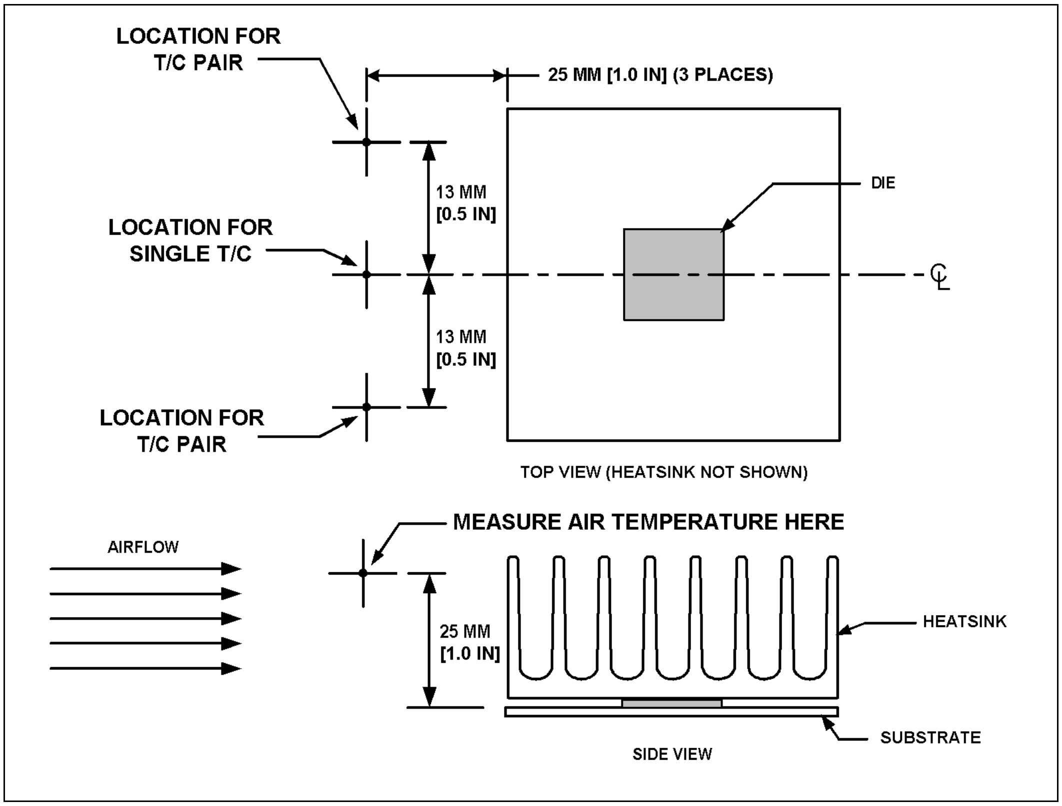
Figure 3. 0° Angle Attach Methodology (top view, not to scale)



3.2 Airflow Characterization

Figure 4 describes the recommended location for air temperature measurements measured relative to the component. For a more accurate measurement of the average approach air temperature, Intel recommends averaging temperatures recorded from two thermocouples spaced about 25 mm [1.0 in] apart. Locations for both a single thermocouple and a pair of thermocouples are presented.

Figure 4. Airflow Temperature Measurement Locations



Airflow velocity should be measured using industry standard air velocity sensors. Typical airflow sensor technology may include hot wire anemometers. Figure 4 provides guidance for airflow velocity measurement locations. These locations are for a typical JEDEC test setup and may not be compatible with chassis layouts due to the proximity of the processor to the GMCH. The user may have to adjust the locations for a specific chassis. Be aware that sensors may need to be aligned perpendicular to the airflow velocity vector or an inaccurate measurement may result. Measurements should be taken with the chassis fully sealed in its operational configuration to achieve a representative airflow profile within the chassis.

4.0 Reference Thermal Solution

Intel has developed an embedded reference thermal solution to meet the cooling needs of the Intel® 915GV Express Chipset GMCH. This chapter describes the overall requirements for the reference thermal solution, including critical-to-function dimensions, operating environment, and validation criteria. The other components of the chipset may or may not need attached thermal solutions, depending on your specific system local-ambient operating conditions. For more information on the Intel® I/O Controller Hub 6 (ICH6), refer to the *Intel® I/O Controller Hub 6 (ICH6) Family Thermal Design Guide*.

4.1 Operating Environment and Thermal Performance

This document describes the reference heatsink for the Intel 915GV GMCH for the 1U/2U server form factor. The Wave Solder Heatsink (WSHS) is the reference component thermal solution for the Intel 915GV GMCH in the ATX/µATX form factor. For more information on the WSHS refer to the *Intel® 915G/915GV Express Chipset Thermal Design Guide*.

The reference thermal solution compatible with the 1U/2U server form factor was designed assuming a maximum local ambient air temperature, T_{LA}, of 55° C with a minimum airflow velocity directly upstream of the heatsink of 275 LFM. Assuming these boundary conditions are met, the reference thermal solutions will meet the thermal specifications for the Intel 915GV GMCH in configurations that use DDR2 memory. Systems that use DDR1 memory must provide more airflow to meet the target. Table 5 shows the required thermal performance for the Intel 915GV Express Chipset GMCH.

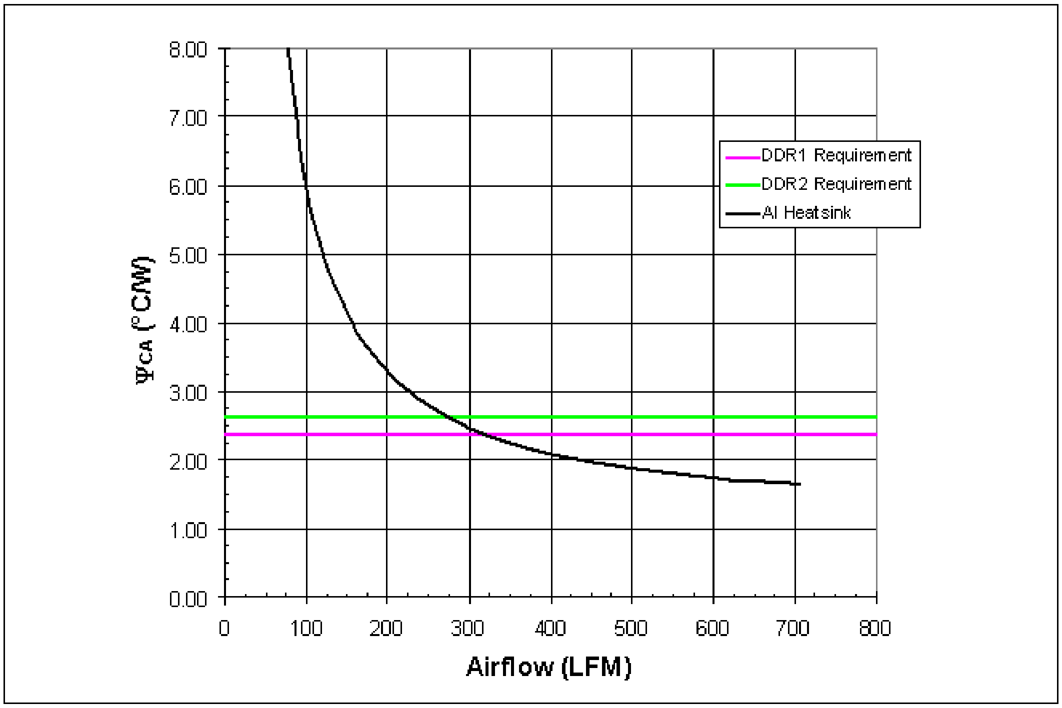
Table 5. Intel® 915GV Express Chipset GMCH Thermal Requirements

TDP	Required Ψ_{CA} at T_{LA}[1] = 55 °C
16.8 (DDR1)	2.62 °C/W
18.7 (DDR2)	2.35 °C/W

1. T_{LA} is defined as the local (internal) ambient temperature measured directly upstream of the chipset.

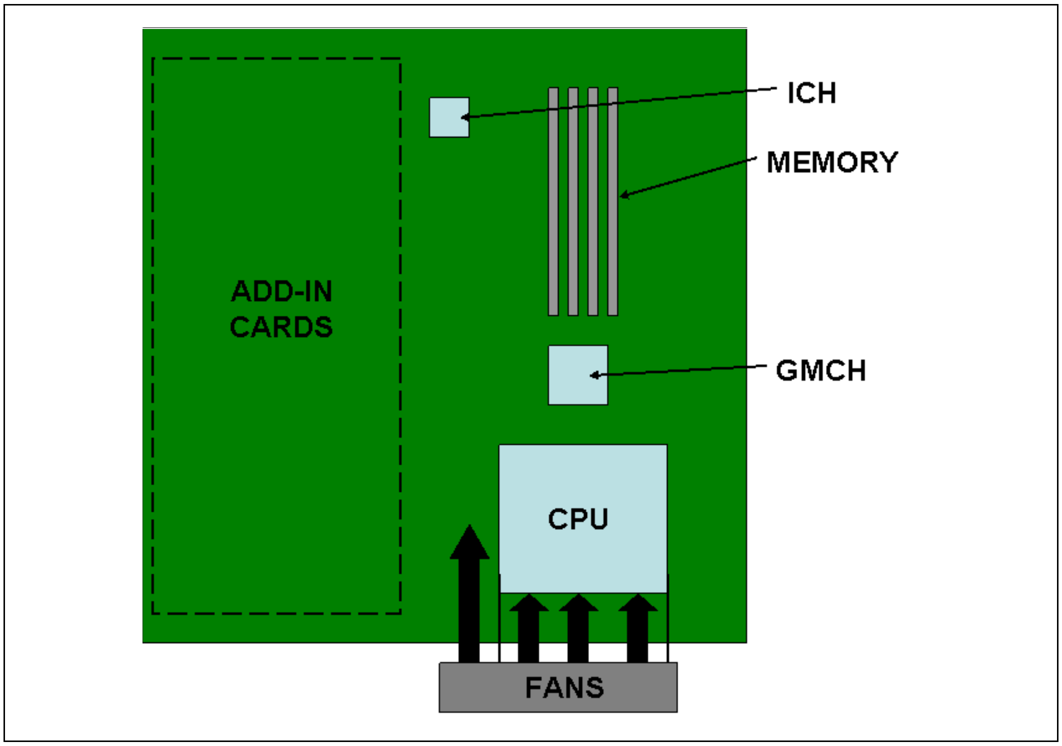
The thermal performance of the reference thermal solution for the Intel 915GV Express Chipset GMCH for the 1U/2U server form factor is show in Figure 5. This figure shows the estimated performance of the reference thermal solution at sea level based on thermal modeling with commonly available thermal modeling software.

Figure 5. Intel® 915GV GMCH Aluminum Heatsink Thermal Performance



The amount of airflow needed to meet the required performance for the GMCH is significantly higher than the amount of airflow needed in a standard desktop computer application. Although the amount of airflow is higher, it is usually not difficult to achieve this amount due to the layout and placement of components in a 1U/2U server system. The Intel® Pentium® 4 processor in the 775-Land LGA package requires a large volume of airflow through the heatsink fins to meet its thermal requirements. This airflow must be 100% ducted through the processor heatsink. This requirement for the processor benefits the airflow for the GMCH thermal solution. In most cases, the amount of airflow will be much higher than the minimum amount of 275 LFM. Figure 6 shows a typical component layout for a 1U/2U server system. This layout is based on the *Thin Electronics Bay* specification located at http://www.ssiforum.com.

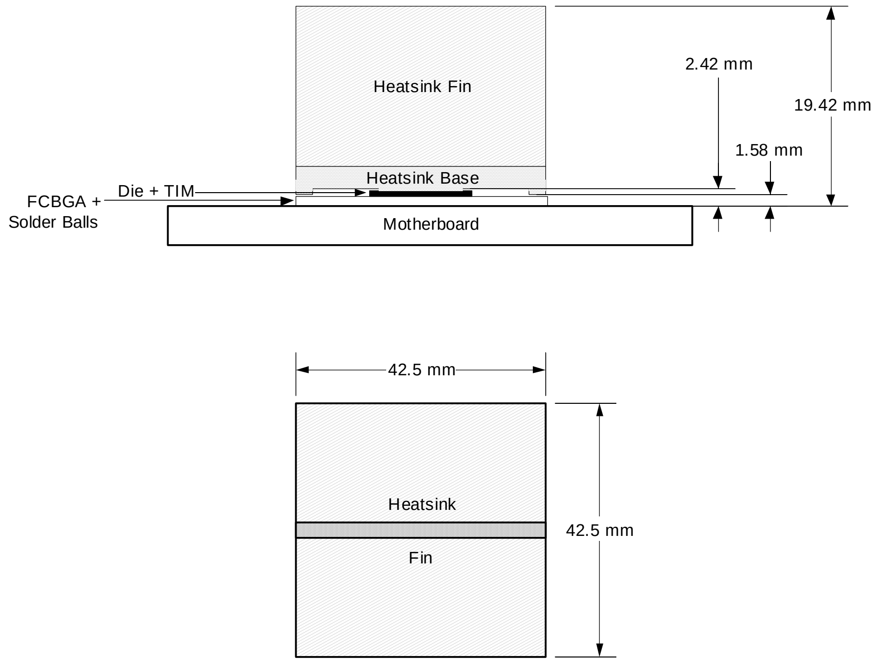
Figure 6. Typical Component Layout for 1U/2U Server Form Factor



4.2 Mechanical Design Envelope

The board component keep-out restrictions for the 1U/2U thermal solution are included in Section 4.4. Figure 7 shows the 1U/2U reference heatsink volumetric constraints. This heatsink extends 19.42 mm [0.675 in] nominally above the board when mounted. System integrators should ensure no board or chassis components would intrude into the volume occupied by the heatsink. This solution does not occupy the maximum allowed space above the board for the 1U and 2U server form factors. The maximum component height above the board is delineated in the *Thin Electronics Bay* specification located at http://www.ssiforum.com.

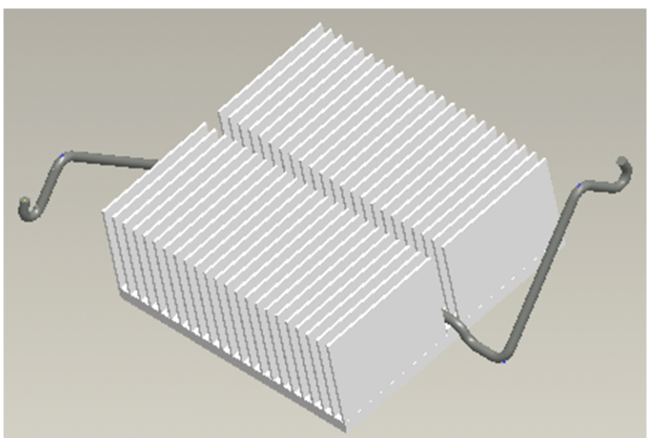
Figure 7. 1U/2U Reference Heatsink Volumetric Height



4.3 Thermal Solution Assembly

The reference thermal solution consists of a passively cooled aluminum heatsink. The heatsink is composed of an extruded or skived aluminum heatsink attached to the board by a torsional clip and anchors soldered to the board. The TIM for this heatsink, Honeywell* PCM45F, is preapplied to the heatsink bottom over an area in contact with the package die. The heatsink assembly is shown in Figure 8.

Figure 8. 1U/2U Reference Thermal Solution Assembly



4.3.1 Heatsink Orientation

The GMCH heatsink is a uni-directional fin heatsink. This type of heatsink design requires that the fins must be aligned with the direction of the airflow.

4.3.2 Heatsink Clip

The reference thermal solution uses a wire clip with hooked ends. The hooks attach to wire anchors to fasten the heatsink to the board. The mechanical drawing of the clip is located in the Appendix.

4.3.3 Solder-Down Anchors

For platforms that have very limited board space, a clip retention solder-down anchor has been developed to minimize the impact of clip retention on the board. It is based on a standard three-pin jumper and is soldered to the board like any common through-hole header. A new anchor design is available with 45° bent leads to increase the anchor attach reliability over time. The part number and vendor information is found in the Appendix.

4.3.4 Thermal Interface Material (TIM)

TIM provides improved conductivity between the die and heatsink. It is important to understand and consider the impact of the interface between the die and heatsink base on the overall thermal solution. Specifically, the bond line thickness, interface material area, and interface material thermal conductivity must be selected to optimize the thermal solution.

It is important to minimize the thickness of the TIM, commonly referred to as the bond line thickness. A large gap between the heatsink base and the die yields a greater thermal resistance. The thickness of the gap is determined by the flatness of both the heatsink base and the die, plus the thickness of the TIM, and the clamping force applied by the heatsink attachment method. To ensure proper and consistent thermal performance, the TIM and application process must be properly designed.

The Intel 915GV Express Chipset GMCH reference thermal solution uses Honeywell* PCM45F. Alternative materials can be used at the user’s discretion. Regardless, the entire heatsink assembly, including the heatsink, TIM, and attach method, must be validated for specific applications.

4.4 Board-Level Component Keep-outs

The locations of the hole patterns and board component keep-outs for the Intel 915GV GMCH can be seen in Figures 9 and 10. Dimensions are in inches.

Figure 9. Intel® 915GV GMCH Torsional Clip Heatsink Board Component Keep-out

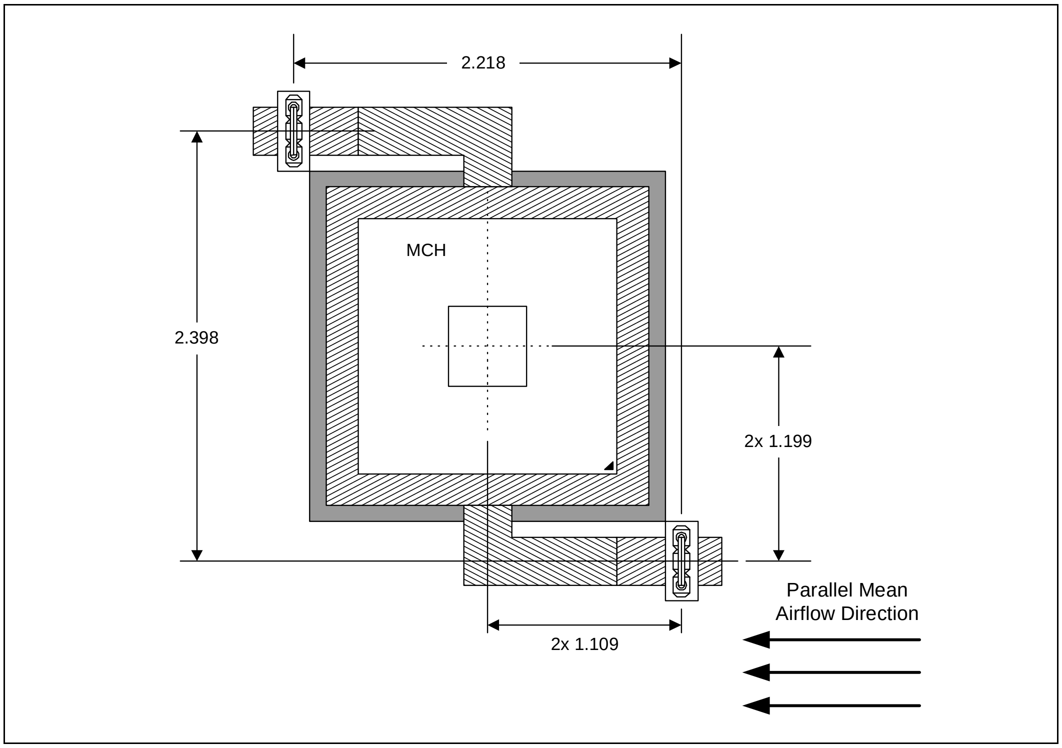
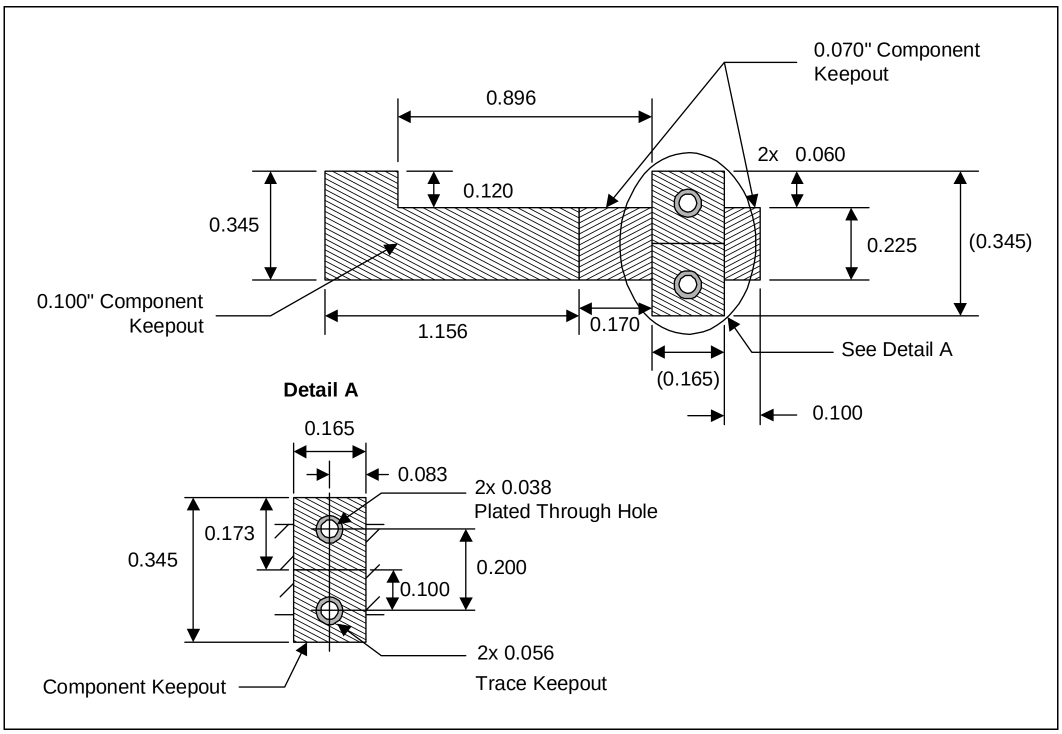


Figure 10. Intel® 915GV GMCH Retention Mechanism Component Keep-out Zones



4.5 Environmental Reliability Requirements

The environmental reliability requirements for the reference thermal solution are shown in Table 6. These should be considered as general guidelines. Validation test plans should be defined by the user based on anticipated use conditions and resulting reliability requirements.

Table 6. Reference Thermal Solution Environmental Reliability Requirements

Test[1]	Requirement	Pass/Fail Criteria[2]
Mechanical Shock	• 3 drops for + and - directions in each of 3 perpendicular axes (i.e., total 18 drops). • Profile: 50 G trapezoidal waveform, 11 ms duration, 4.3 m/s [170 in/s] minimum velocity change. • Setup: Mount sample board on test fixture. Include 450 g processor heatsink.	Visual\Electrical Check
Random Vibration	• Duration: 10 min/axis, 3 axes • Frequency Range: 5 Hz to 500 Hz • Power Spectral Density (PSD) Profile: 3.13 g RMS	Visual/Electrical Check
Thermal Cycling	-40 °C to +85 °C, 1000 cycles	Visual Check
Temperature Life	85 °C, 1000 hours total	Visual/Electrical Check
Unbiased Humidity	85 % relative humidity / 55 °C, 1000 hours	Visual Check

NOTES:
1. The above tests should be performed on a sample size of at least 12 assemblies from three different lots of material.
2. Additional Pass/Fail Criteria may be added at the discretion of the user.

5.0 Conclusion

As the complexity of computer systems increases, so do power dissipation requirements. The additional power of next-generation systems must be properly dissipated. Heat can be dissipated using improved system cooling, selective use of ducting, and/or passive heatsinks.

The simplest and most cost-effective method to improve the inherent system cooling characteristics of the GMCH is through careful design and placement of fans, vents, and ducts. When additional cooling is required, component thermal solutions may be implemented in conjunction with system thermal solutions. The size of the fan or heatsink can be varied to balance size and space constraints with acoustic noise.

This document has presented the conditions and requirements to properly design a cooling solution for systems that implement the Intel® 915GV Express chipset GMCH. Properly designed solutions provide adequate cooling to maintain the Intel 915GV Express chipset GMCH case temperature at or below thermal specifications. This is accomplished by providing a low local-ambient temperature, ensuring adequate local airflow, and minimizing the case to local-ambient thermal resistance. By maintaining the Intel 915GV Express chipset GMCH case temperature at or below those recommended in this document, a system designer can ensure the proper functionality, performance, and reliability of this chipset.

Appendix A Enabled Suppliers

Enabled suppliers for the Intel® 82915GV Express Chipset GMCH 1U/2U reference thermal solution are listed in Table 7.

Table 7. Intel® 915GV GMCH Intel Reference Design Heatsink Enabled Suppliers

Part	Part Number	Supplier	Contact Information
Aluminum Heatsink †	CoolerMaster* part # ECB-00168-01	CoolerMaster	Wendy Lin (USA) 908-252-9400 wendy@coolermaster.com
Thermal Interface	Honeywell part # PCM45F	Honeywell*	Paula Knoll 858-279-2956 Paula_knoll@honeywell.com
Heatsink Attach Clip	Intel part #: A69230-001	CCI/ACK*	Harry Lin (USA) 714-739-5797 hlinack@aol.com Monica Chih (Taiwan) 866-2-29952666, x131 Monica_chih@ccic.com.tw
		Foxconn*	Bob Hall (USA) 503-693-3509, x235 bhall@foxconn.com
Solder-Down Anchor	Intel part #: A13494-005	Foxconn*	Julia Jiang (USA) 408-919-6178 juliaj@foxconn.com

† Drawings may be delivered to any heatsink manufacturer for piece parts.

Note: 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. This list and/or these devices may be subject to change without notice.

Appendix B Mechanical Drawings

The following table lists the mechanical drawings in this appendix:

Table 8. Mechanical Drawings

Figure 11. Intel® 915GV GMCH Package

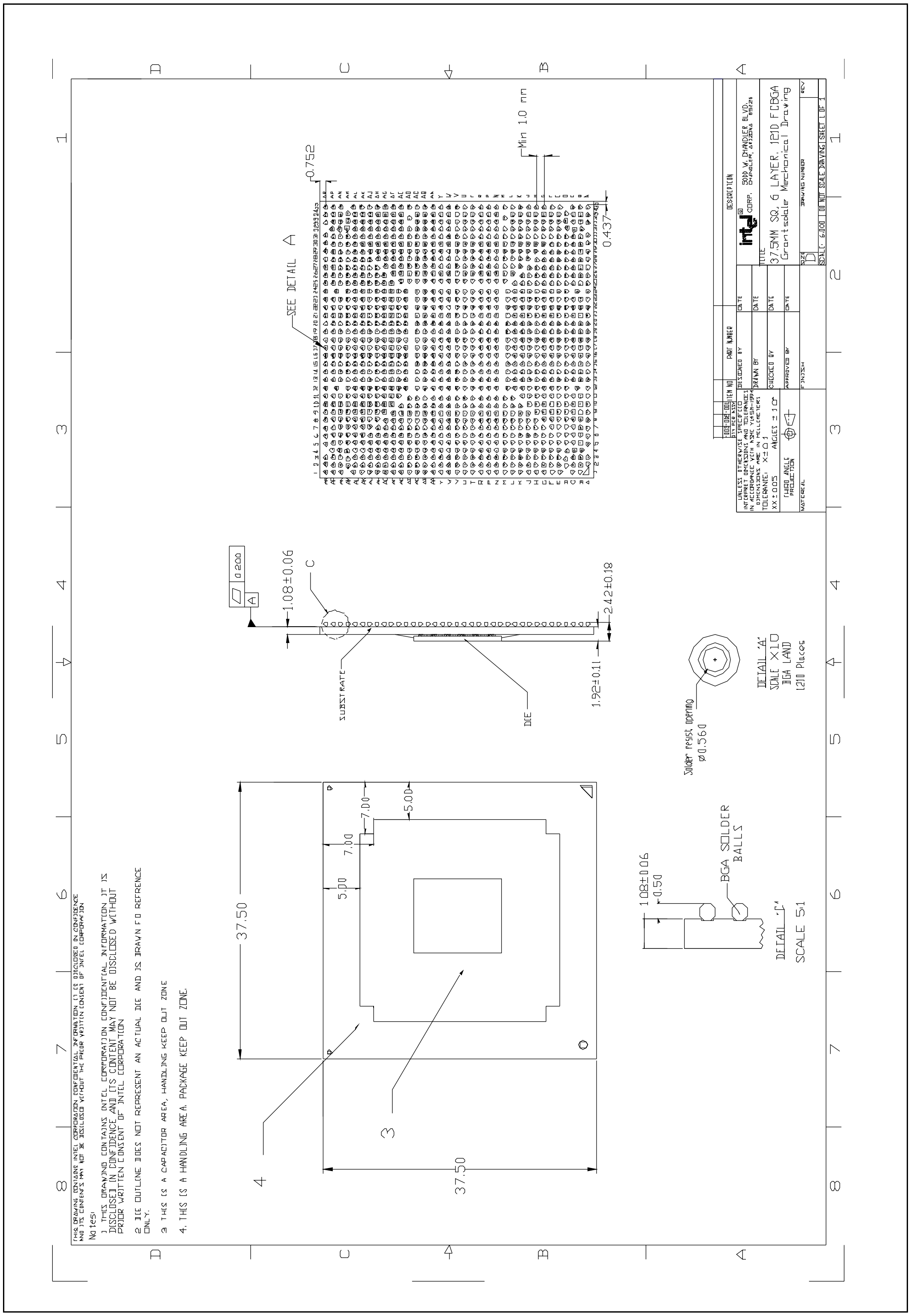


Figure 12. Intel® 915GV GMCH Heatsink Assembly

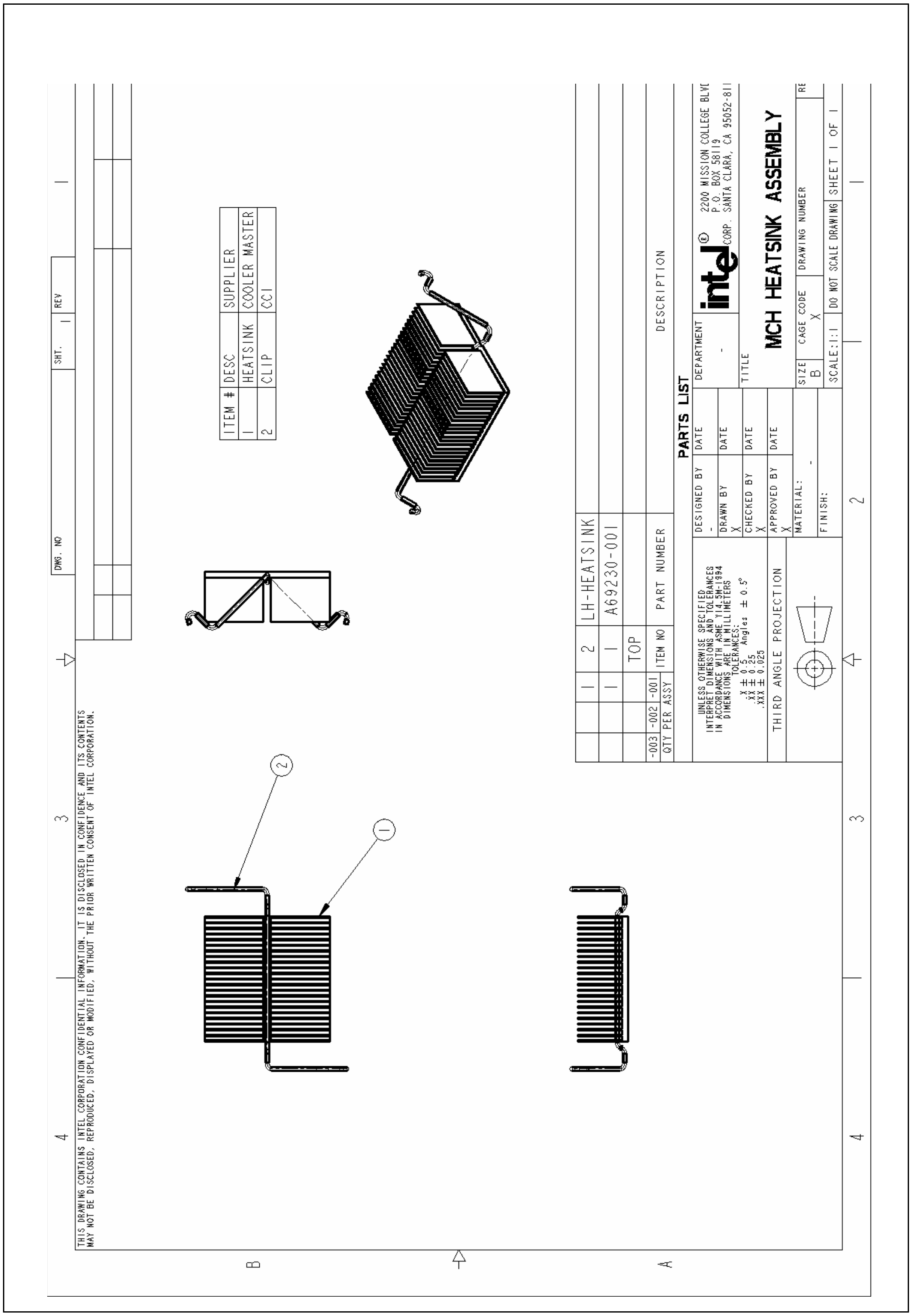


Figure 13. Intel® 915GV GMCH Aluminum Heatsink

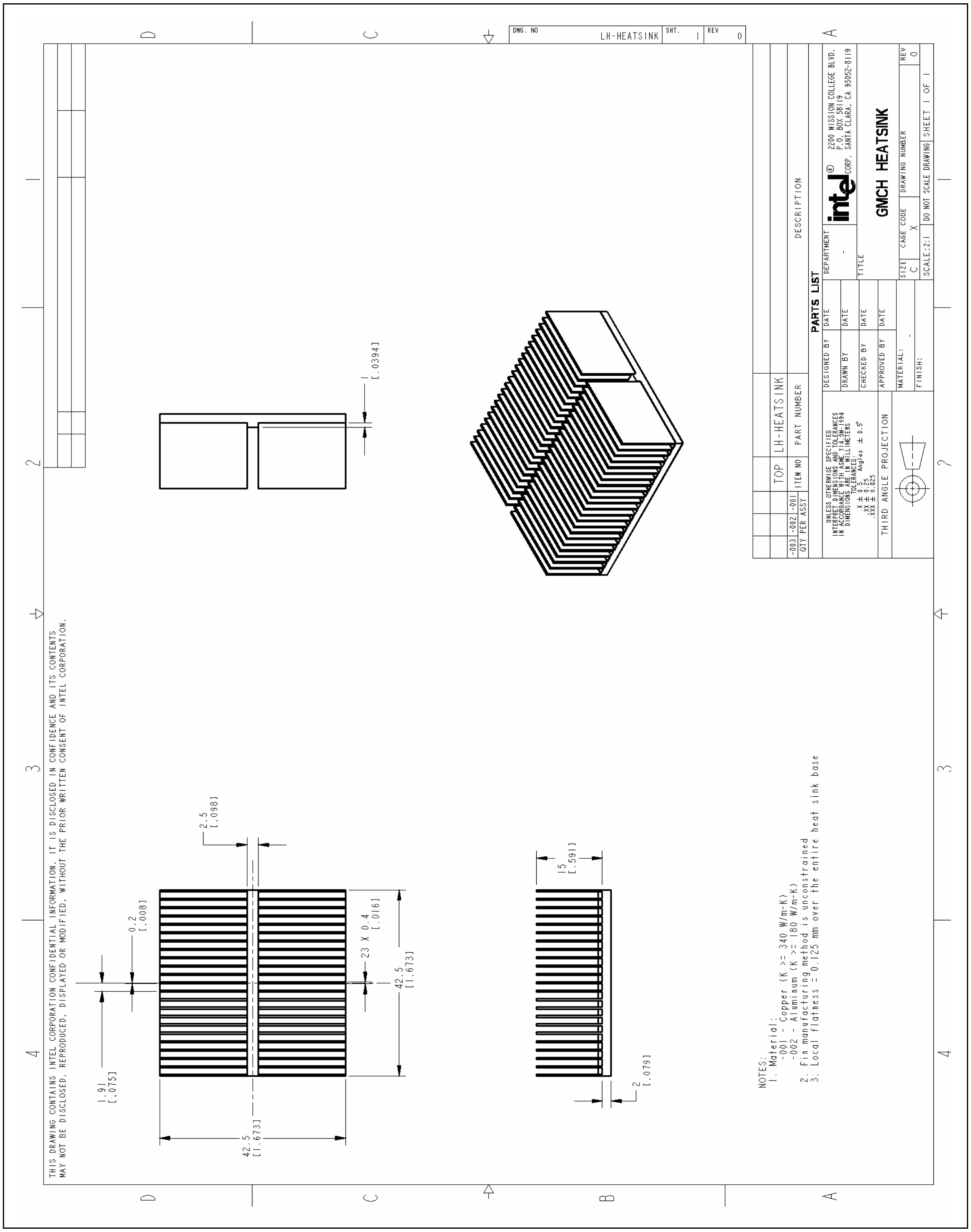
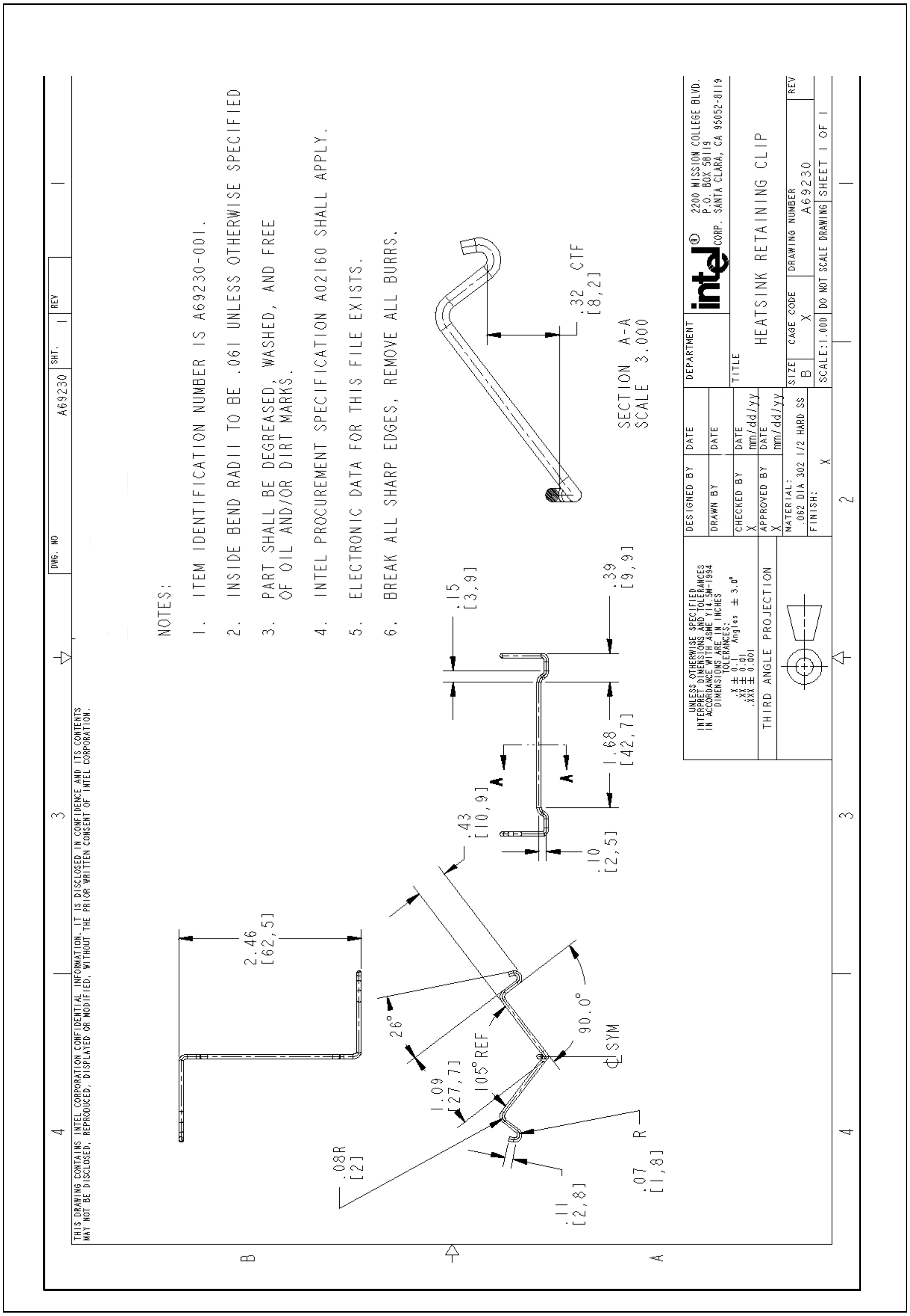


Figure 14. Intel® 915GV Torsional Clip



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