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Intel[®] 946 Express Chipset Family

Thermal and Mechanical Design Guidelines

– For the Intel[®] 82946GZ Graphics and Memory Controller Hub (GMCH) and Intel[®] 82946PL Memory Controller Hub (MCH)

June 2006



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Revision History

Revision Number	Description	Revision Date
-001	Initial release	June 2006

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1 Introduction

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 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.

Note: Unless otherwise specified the information in this document applies to Intel® 946 Express Chipset Family. The Intel® 946 Express chipsets will be available with integrated graphics and associated SDVO and analog display ports. In this document the integrated graphics component may be referred to as the GMCH. In addition a version will be offered using discrete graphics and may be referred to as the MCH. The term (G)MCH will be used in this document to refer to both components.

The devices covered by this document are:

- Intel® 82946GZ Graphics and Memory Controller Hub (GMCH)
- Intel® 82946PL Memory Controller Hub (MCH)

Note: In this document the use of the term chipset refers to the combination of the (G)MCH and the Intel® ICH7.

This document presents the conditions and requirements to properly design a cooling solution for systems that implement the (G)MCH. Properly designed solutions provide adequate cooling to maintain the (G)MCH 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 (G)MCH case temperature at or below those recommended in this document, a system designer can ensure the proper functionality, performance, and reliability of this component.



1.1 Terminology

Term	Description
FC-BGA	Flip Chip Ball Grid Array. A package type defined by a plastic substrate where a die is mounted using an underfill C4 (Controlled Collapse Chip Connection) attach style. The primary electrical interface is an array of solder balls attached to the substrate opposite the die. Note that the device arrives at the customer with solder balls attached.
Intel® ICH7	Intel® I/O Controller Hub 7. The chipset component that contains the primary PCI interface, LPC interface, USB, ATA, and/or other legacy functions.
GMCH	Graphic Memory Controller Hub. The chipset component that contains the processor and memory interface and integrated graphics core.
MCH	Memory Controller Hub. The chipset component that contains the processor and memory interface. This component is used with a discrete graphics card in the system.
T_A	The local ambient air temperature at 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.
T_C	The case temperature of the (G)MCH component. The measurement is made at the geometric center of the die.
T_{C-MAX}	The maximum value of T_C .
T_{C-MIN}	The minimum value of T_C .
TDP	Thermal Design Power is specified as the maximum sustainable power to be dissipated by the (G)MCH. This is based on extrapolations in both hardware and software technology. Thermal solutions should be designed to TDP.
TIM	Thermal Interface Material: thermally conductive material installed between two surfaces to improve heat transfer and reduce interface contact resistance.
Ψ_{CA}	Case-to-ambient thermal solution characterization parameter (Psi). A measure of thermal solution performance using total package power. Defined as $(T_C - T_A) / \text{Total Package Power}$. Heat source size should always be specified for Ψ measurements.



1.2 Reference Documents

Document	Location
<i>Intel® 946 Express Chipset Family Datasheet</i>	http://developer.intel.com/design/chipsets/datashts/313083.htm
<i>Intel® I/O Controller Hub 7 (ICH7) Thermal Design Guidelines</i>	http://developer.intel.com/design/chipsets/designex/307015.htm
<i>Intel® Pentium® D Processor, Intel® Pentium® Processor Extreme Edition, and Intel® Pentium® 4 Processor Thermal and Mechanical Design Guidelines</i>	http://www.intel.com/design/pentiumXE/designex/306830.htm
<i>Balanced Technology Extended (BTX) System Design Guide</i>	www.formfactors.org
<i>Intel® Pentium® D Processor 840, 830 and 820 Datasheet</i>	http://developer.intel.com/design/PentiumD//datashts/307506.htm
<i>Various System Thermal Design Suggestions</i>	http://www.formfactors.org

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2 Product Specifications

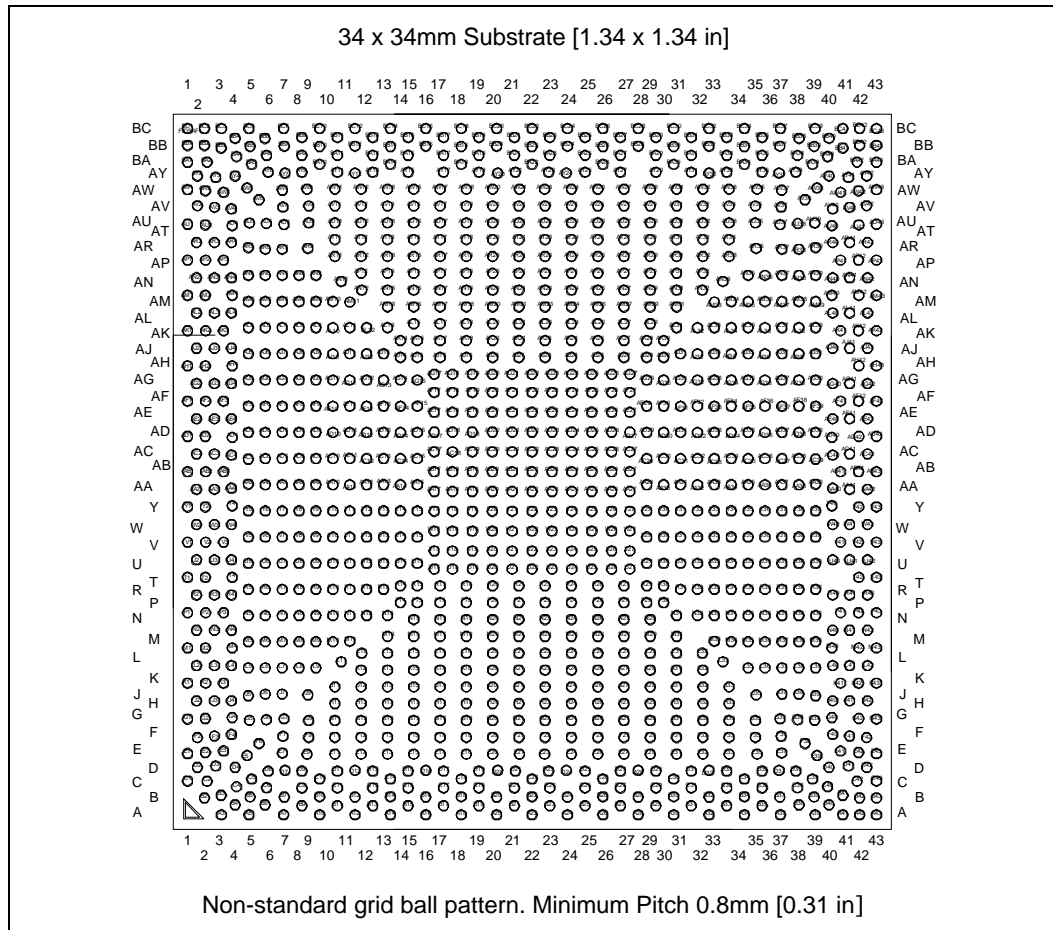
2.1 Package Description

The (G)MCH is available in a 34 mm [1.34 in] x 34 mm [1.34 in] Flip Chip Ball Grid Array (FC-BGA) package with 1226 solder balls. The die size is currently 11.9 mm [0.469in] x 10.9 mm [0.429in]. A mechanical drawing of the package is shown in Figure 9, 0.

2.1.1 Non-Grid Array Package Ball Placement

The (G)MCH package uses a “balls anywhere” concept. Minimum ball pitch is 0.8 mm [0.031 in], but ball ordering does not follow a 0.8-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® 946 Express Chipset Family Datasheet.

Figure 1. (G)MCH Non-Grid Array



2.2 Package Loading Specifications

Table 1 provides static load specifications for the (G)MCH package. This mechanical maximum load limit should not be exceeded during heatsink assembly, shipping conditions, or regular use conditions. Also, any mechanical system or component testing should not exceed the maximum limit. The package substrate should not be used as a mechanical reference or load-bearing surface for the thermal and mechanical solution.

Table 1. Package Loading Specifications

Parameter	Maximum	Notes
Static	15 lbf	1,2,3

NOTES:

1. These specifications apply to uniform compressive loading in a direction normal to the package.
2. This is the maximum force that can be applied by a heatsink retention clip. The clip must also provide the minimum specified load on the package.
3. These specifications are based on limited testing for design characterization. Loading limits are for the package only.



2.3 Thermal Specifications

To ensure proper operation and reliability of the (G)MCH, the temperature must be at or below the maximum case temperature specified in Table 2 when operating at the Thermal Design Power (TDP). System and component level thermal enhancements are required to dissipate the heat generated and maintain the (G)MCH within specifications. Section 3 provides the thermal metrology guidelines for case temperature measurements.

The (G)MCH should also operate above the minimum case temperature specification listed in Table 2.

2.4 Thermal Design Power (TDP)

2.4.1 Definition

Thermal design power (TDP) is the estimated power dissipation of the (G)MCH based on normal operating conditions including V_{CC} and T_{C-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 caused by variations in (G)MCH current consumption due to silicon process variation, processor speed, DRAM capacitive bus loading and temperature. However, since these variations are subject to change, the TDP cannot ensure that all applications will not exceed the TDP value.

The system designer must design a thermal solution for the (G)MCH such that it maintains T_C below T_{C-MAX} for a sustained power level equal to TDP. Note that the T_{C-MAX} specification is a requirement for a sustained power level equal to TDP, and that the case temperature must be maintained at temperatures less than T_{C-MAX} when operating at power levels less than TDP. This temperature compliance is to ensure component reliability over its useful life. The TDP value can be used for thermal design if the thermal protection mechanisms are enabled. The (G)MCH incorporates a hardware-based fail-safe mechanism to keep the product temperature within specification in the event of unusually strenuous usage above the TDP power.

2.4.2 Methodology

2.4.2.1 Pre-Silicon

In order to determine TDP for pre-silicon products in development, it is necessary to make estimates based on analytical models. These models rely on knowledge of the past (G)MCH power dissipation behavior along with knowledge of planned architectural and process changes that may affect TDP. Knowledge of applications available today and their ability to stress various aspects of the (G)MCH is also included in the model. The projection for TDP assumes (G)MCH operation at T_{C-MAX} . The TDP estimate also accounts for normal manufacturing process variation.

2.4.2.2 Post-Silicon

Once the product silicon is available, post-silicon validation is performed to assess the validity of pre-silicon projections. Testing is performed on both commercially available and synthetic high power applications and power data is compared to pre-silicon estimates. Post-silicon validation may result in a small adjustment to pre-silicon TDP estimates.



2.4.3 Specifications

The data in Table 2 is based on post-silicon power measurements of initial (G)MCH silicon. The system configuration is two (2) DIMMs per channel, DDR2, FSB operating at the top speed allowed by the chipset with an 800 MHz processor system bus speed. 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 (G)MCH.

Table 2. Thermal Specification

Component	System Bus Speed	Memory Frequency	T _{C-MIN}	T _{C-MAX}	Idle Power	TDP Value
Intel® 946GZ GMCH	800 MT/s	667 MT/s	0 °C	98°C	9.1 W	26 W
Intel® 946PL MCH	800 MT/s	667 MT/s	0 °C	103°C	7.8 W	16 W

NOTES:

1. Thermal specifications assume an attached heatsink is present.
2. Idle Power is based on a typical part in system booted to Windows* with no background applications running.

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3 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 (G)MCH component case temperatures.

3.1 Case Temperature Measurements

To ensure functionality and reliability of the (G)MCH the T_C must be maintained at or below the maximum temperature listed in Table 2. The surface temperature measured 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 error in the measurements. The measurement errors could be due to a poor thermal contact between the thermocouple bead 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.

3.1.1 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 3).
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 K-type thermocouple bead to the center of the top surface of the die using a cement with high thermal conductivity. 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 2).
6. Attach heatsink assembly to the (G)MCH, and route thermocouple wires out through the milled slot.

Figure 2. 0° Angle Attach Methodology (top view, not to scale)

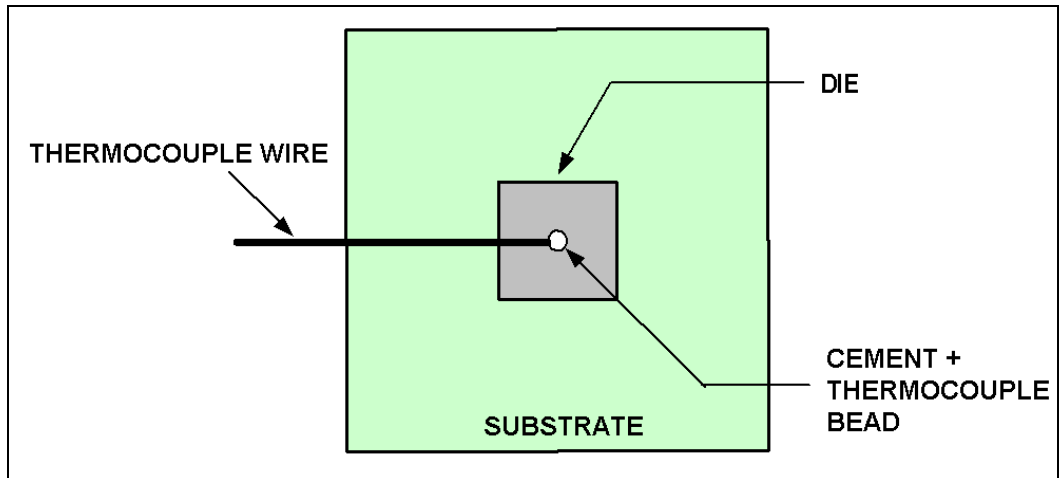
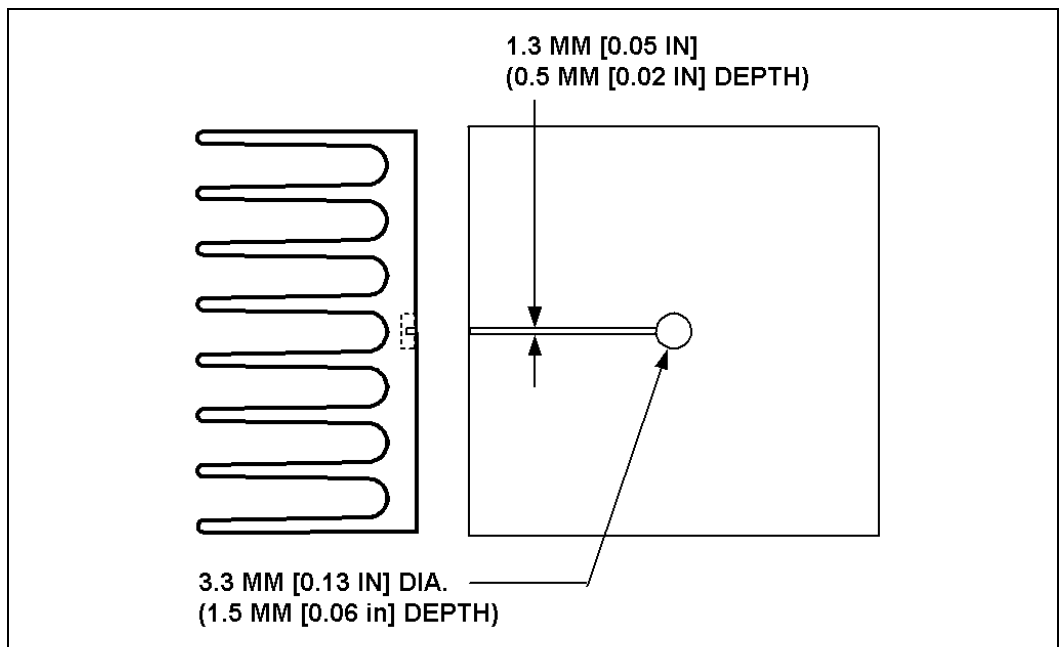


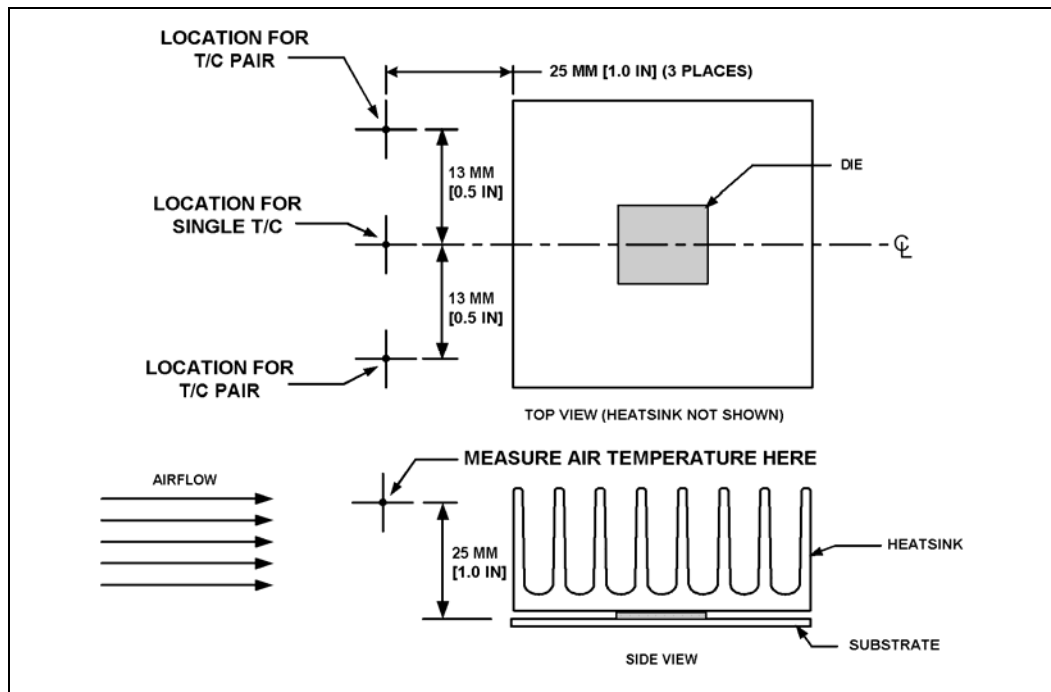
Figure 3. 0° Angle Attach Heatsink Modifications (generic heatsink side and bottom view shown, not to scale)



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 can be measured using sensors that combine air velocity and temperature measurements. Typical airflow sensor technology may include hot wire anemometers. Figure 4 provides guidance for airflow velocity measurement locations which should be the same as used for temperature measurement. 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 (G)MCH. 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.

3.3 Thermal Mechanical Test Vehicle

A Thermal Mechanical Test Vehicle (TMTV) is available for early thermal testing prior to the availability of actual silicon. The TMTV contains a heater die and can be powered up to a desired power level to simulate the heating of a (G)MCH package. The TMTV also contains daisy chain functionality and can be used for mechanical testing. The TMTV needs to be surface mounted to a custom board designed to provide connectivity to the die heater and/or daisy chain depending on the needs of the user. The package ball connections are provided so the user may design and build a board to interface with the TMTV. Note that although the TMTV is designed to closely match the (G)MCH package mechanical form and fit, it is recommended that final validation be performed with actual production silicon. The TMTV mechanical features, including die size, ball count, etc., may not reflect those of the final production package.

Please contact your Intel Field Sales Representative on the availability of the TMTV for your development needs.



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4 Reference Thermal Solution

The design strategy for the reference component thermal solution for the (G)MCH for ATX platforms reuses the ramp retainer, extrusion design and MB anchors from the Intel® 945G Express chipset thermal solution. The thermal interface material and a wire preload clip are being redesigned to meet the Intel® 946 Express chipset family thermal requirements.

The Balanced Technology Extended (BTX) reference design for the Intel 946 Express chipset family will include a new extrusion, clip with higher preload, and a new thermal interface material. A slightly larger motherboard keep out zone than used by the Intel 945G Express chipset thermal solution has been defined, see Figure 11.

This chapter provides detailed information on operating environment assumptions, heatsink manufacturing, and mechanical reliability requirements for the (G)MCH.

4.1 Operating Environment

The operating environment of the (G)MCH will differ depending on system configuration and motherboard layout. This section defines operating environment boundary conditions that are typical for ATX and BTX form factors. The system designer should perform analysis on platform operating environment to assess impact to thermal solution selection.

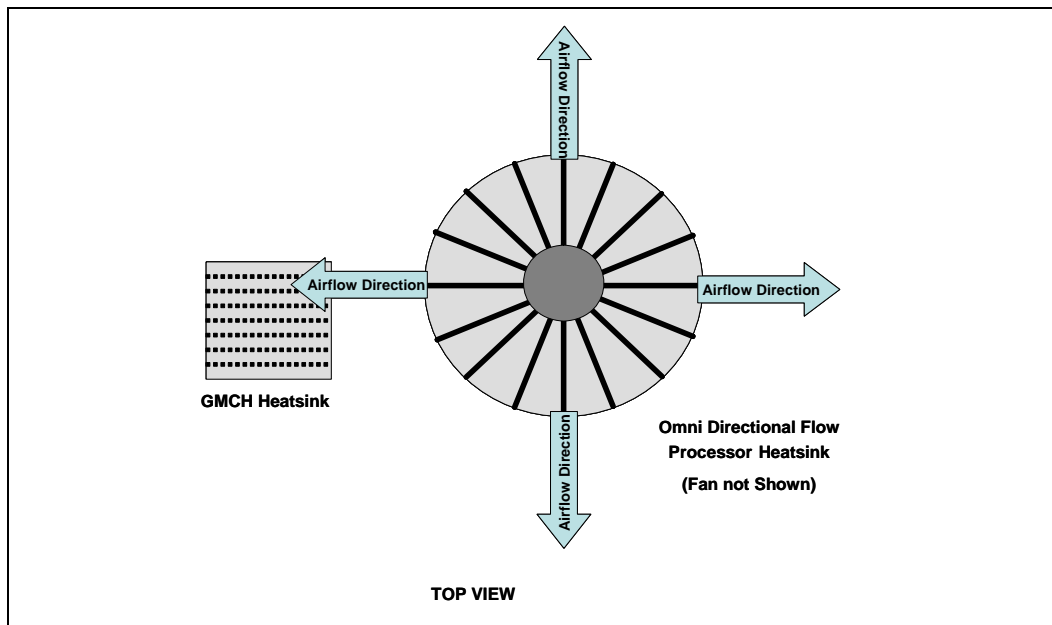
4.1.1 ATX Form Factor Operating Environment

In ATX platforms, an airflow speed of 0.76 m/s [150 lfm] is assumed to be present 25 mm [1 in] in front of the heatsink air inlet side of the attached reference thermal solution. The local ambient air temperature, T_A , at the (G)MCH heatsink in an ATX platform is assumed to be 47 °C. The system integrator should note that board layout may be such that there will not be 25 mm [1 in] between the processor heatsink and the (G)MCH. The potential for increased airflow speeds may be realized by ensuring that airflow from the processor heatsink fan exhausts in the direction of the (G)MCH heatsink. This can be achieved by using a heatsink providing multi-directional airflow, such as a radial fin or "X" pattern heatsink. Such heatsink can deliver airflow to both the (G)MCH and other areas like the voltage regulator, as shown in Figure 5. In addition, (G)MCH board placement should ensure that the (G)MCH heatsink is within the air exhaust area of the processor heatsink.

Note that heatsink orientation alone does not ensure that 0.76 m/s [150 lfm] airflow speed will be achieved. The system integrator should use analytical or experimental means to determine whether a system design provides adequate airflow speed for a particular (G)MCH heatsink.

The thermal designer must carefully select the location to measure airflow to get a representative sampling. These environmental assumptions are based on a 35 °C system external temperature measured at sea level.

Figure 5. Processor Heatsink Orientation to Provide Airflow to (G)MCH Heatsink on an ATX Platform



Other methods exist for providing airflow to the (G)MCH heatsink, including the use of system fans and/or ducting, or the use of an attached fan (active heatsink).

4.1.2 Balanced Technology Extended (BTX) Form Factor Operating Environment

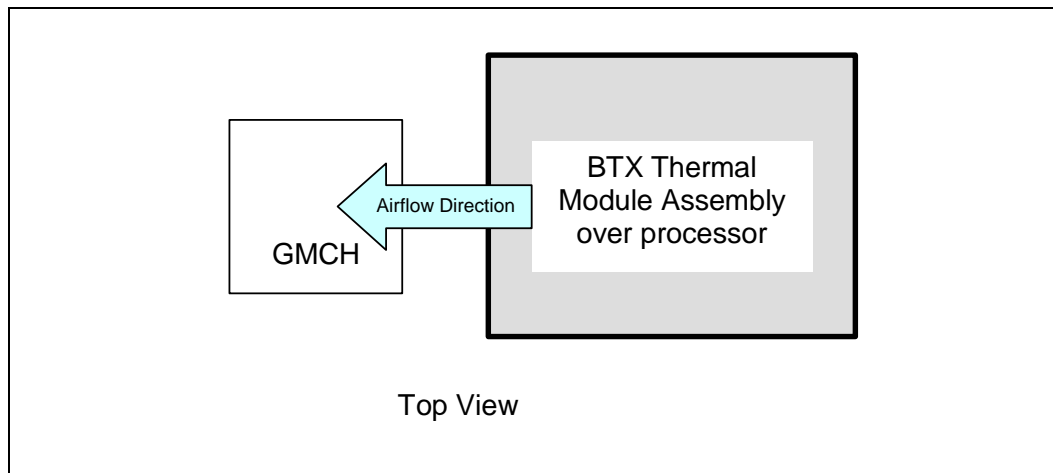
This section provides operating environment conditions based on what has been exhibited on the Intel micro-BTX reference design. On a BTX platform, the (G)MCH obtains in-line airflow directly from the processor thermal module. Since the processor thermal module provides lower inlet temperature airflow to the processor, reduced inlet ambient temperatures are also often seen at the (G)MCH as compared to ATX. An example of how airflow is delivered to the (G)MCH on a BTX platform is shown in Figure 6.

The local ambient air temperature, T_A , at the (G)MCH heatsink in the Intel micro-BTX reference design is predicted to be $\sim 45^\circ\text{C}$. The thermal designer must carefully select the location to measure airflow to get a representative sampling. These environmental assumptions are based on a 35°C system external temperature measured at sea level.

Note that the local ambient air temperature is a projection based on the power for a 2005 platform with processor TDP up to 130 W.



Figure 6. Processor Heatsink Orientation to Provide Airflow to (G)MCH Heatsink on a Balanced Technology Extended (BTX) Platform



4.2 Reference Design Mechanical Envelope

The motherboard component keep-out restrictions for the (G)MCH on an ATX platform are included in Figure 10. The motherboard component keep-out restrictions for the (G)MCH on a BTX platform are included in Appendix B, Figure 11.

4.3 Thermal Solution Assembly

The reference thermal solution for the (G)MCH for an ATX chassis is shown in Figure 7 and is an aluminum extruded heatsink that utilizes two ramp retainers, a wire preload clip, and four motherboard anchors. Refer to Appendix B for the mechanical drawings. The heatsink is attached to the motherboard by assembling the anchors into the board, placing the heatsink over the (G)MCH and anchors at each of the corners, and securing the plastic ramp retainers through the anchor loops before snapping each retainer into the fin gap. The assembly is then sent through the wave process. Post wave, the wire preload clip is assembled using the hooks on each of the ramp retainers. The clip provides the mechanical preload to the package. A thermal interface material (Honeywell* PCM45F) is pre-applied to the heatsink bottom over an area which contacts the package die.

Note: The ATX design is similar in appearance to the Intel® 945G Express Chipset thermal solution, but two critical items have been changed.

- A higher performance TIM
- A clip with a higher preload to meet the TIM preload requirements.

The combination of the two new items provides the performance increase to meet the Intel® 946 Express chipset family thermal requirements.

The reference thermal solution for the (G)MCH in a BTX chassis is shown in Figure 8. The heatsink is aluminum extruded and utilizes a Z-clip for attach. The clip is secured to the system motherboard via two solder down anchors around the (G)MCH. The clip helps to provide a mechanical preload to the package via the heatsink. A thermal

interface material (Honeywell* PCM45F) is pre-applied to the heatsink bottom over an area in contact with the package die.

Figure 7. ATX MCH Heatsink – Installed on Board

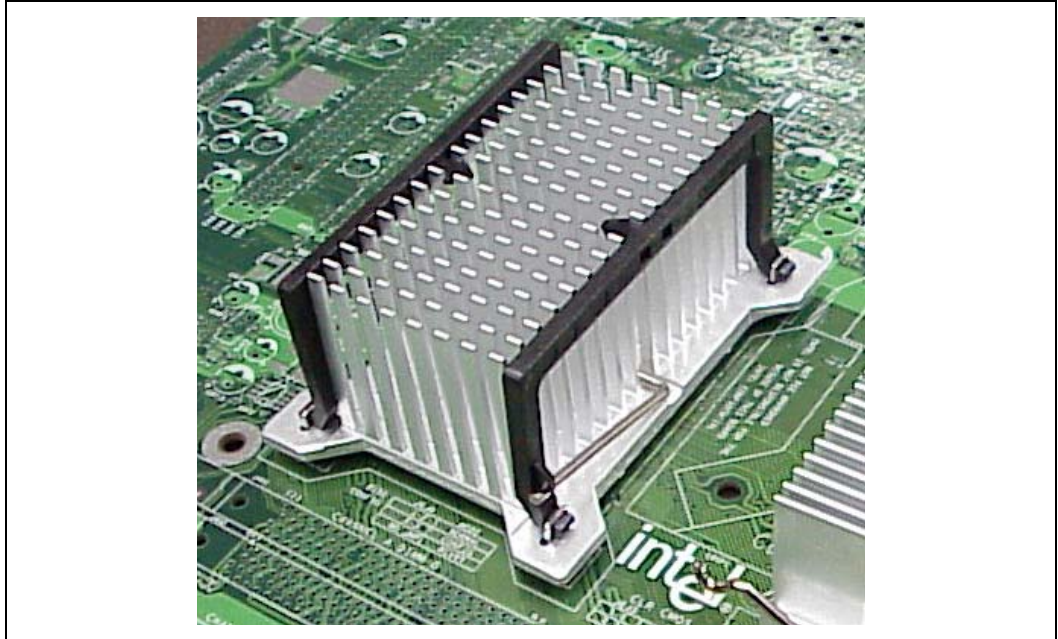
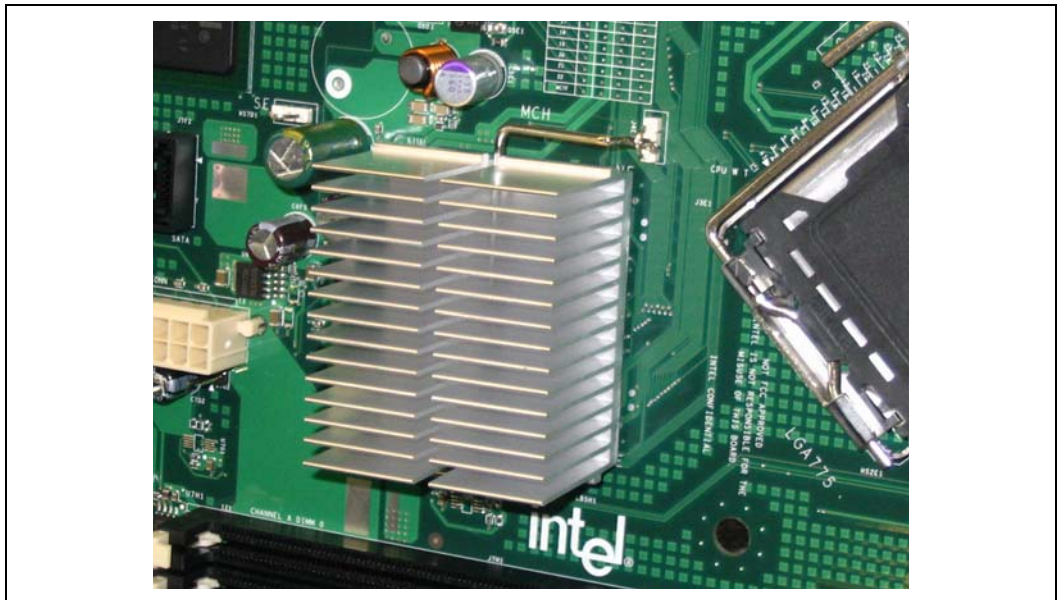


Figure 8. Balanced Technology Extended (BTX) MCH Heatsink Design – Installed on Board





4.4 Environmental Reliability Requirements

The environmental reliability requirements for the reference thermal solution are shown in Table 3 and Table 4. 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.

The ATX testing will be performed with the sample board mounted on a test fixture and includes a processor heatsink with a maximum mass of 550 g. The test profiles are unpackaged board level limits.

Table 3. ATX Reference Thermal Solution Environmental Reliability Requirements (Board Level)

Test ¹	Requirement	Pass/Fail Criteria ²
Mechanical Shock	<ul style="list-style-type: none"> 3 drops for + and - directions in each of 3 perpendicular axes (i.e., total 18 drops). Profile: 50 G, Trapezoidal waveform, 4.3 m/s [170 in/s] minimum velocity change 	Visual\Electrical Check \ Thermal Performance
Random Vibration	<ul style="list-style-type: none"> 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 Performance
Unbiased Humidity	<ul style="list-style-type: none"> 85 % relative humidity / 85 °C, 576 hours 	Visual Check

NOTES:

1. The above tests should be performed on a sample size of at least 12 assemblies from 3 different lots of material.
2. Additional Pass/Fail Criteria may be added at the discretion of the user.

The current plan for BTX reference solution testing is to mount the sample board mounted in a BTX chassis with a thermal module assembly having a maximum mass of 900 g. The test profiles are unpackaged system level limits.



Table 4. Balanced Technology Extended (BTX) Reference Thermal Solution Environmental Reliability Requirements (System Level)

Test ¹	Requirement	Pass/Fail Criteria ²
Mechanical Shock ⁵	<ul style="list-style-type: none"> • 2 drops for + and - directions in each of 3 perpendicular axes (i.e., total 12 drops). • Profile: 25g, Trapezoidal waveform, 5.7 m/s [225 in/sec] minimum velocity change. 	Visual\Electrical Check \ Thermal Performance
Random Vibration ⁵	<ul style="list-style-type: none"> • Duration: 10 min/axis, 3 axes • Frequency Range: .001 g²/Hz @ 5Hz, ramping to .01 g²/Hz @20 Hz, .01 g²/Hz @ 20 Hz to 500 Hz • Power Spectral Density (PSD) Profile: 2.20 g RMS 	Visual/Electrical Check \ Thermal Performance
Power Cycling	<ul style="list-style-type: none"> • 7500 cycles (on/off) of minimum temperature min 27 / max 96. • 1400 cycles (on/standby) min 35 / max 96. • A 15 second dwell at high / low temperature for both cycles. 	Thermal Performance - TIM degradation
Unbiased Humidity	<ul style="list-style-type: none"> • 85 % relative humidity / 85 °C, 576 hours 	Visual Check

NOTES:

1. The above tests should be performed on a sample size of at least 12 assemblies from 3 different lots of material.
2. Additional Pass/Fail Criteria may be added at the discretion of the user.
3. Mechanical Shock minimum velocity change is based on a system weight of 20 lbs to 29 lbs [9.08 kg to 13.166 kg].
4. For the chassis level testing, the system will include: 1 HD, 1 ODD, 1 PSU, 2 DIMMs and the I/O shield.
5. BTX reference solution testing for shock and vibration is to mount the sample board mounted in a BTX chassis with a thermal module assembly having a maximum mass of 900 g. The test profiles are unpackaged system level limits.

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Appendix A: Currently Enabled Suppliers

Currently enabled suppliers for the MCH reference thermal solution are listed in Table 5 through Table 7.

Table 5. ATX Intel® Reference Heatsink Enabled Suppliers for Intel® 946 Express Chipset Family

ATX items	Intel Part Number	AVC	CCI	Foxconn	Wieson
heatsink & TIM	D31682-001	S902Y10001	335I833301A	2Z802-032	—
plastic clip	C85370-001	P109000024	334C863501A	3EE77-002	—
wire clip	D29082-001	A208000233	334I833301A	3KS02-155	—
anchor	C85376-001	—	—	2Z802-015	G2100C8 88-143

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.

Table 6. Balanced Technology Extended (BTX) Intel Reference Heatsink Enabled Suppliers for Intel® 946 Express Chipset Family

BTX items	Intel PN	AVC	CCI	Foxconn	Wieson
heatsink assembly (HS, wire clip & TIM)	D34258-001	S905Y00001	00I833201A	2ZQ99-066	—
anchor, LF	A13494-008	—	—	HB9703E-DW	G2100C8 88-064H



Table 7. Supplier Contacts

Supplier	Contacts	Phone	email
AVC (Asia Vital Components)	David Chao	+886-2-2299-6930 ext. 7619	david_chao@avc.com.tw
	Raichel Hsu	+886-2-2299-6930 ext. 7630	raichel_hsi@avc.com.tw
CCI (Chaun Choung Technology)	Monica Chih	+886-2-2995-2666	monica_chih@ccic.com.tw
	Harry Lin	(714) 739-5797	hlinack@aol.com
Foxconn	Jack Chen	(714) 626-1233	jack.chen@foxconn.com
	Wanchi Chen	(714) 626-1376	wanchi.chen@foxconn.com
Wieson Technologies	Andrea Lai	+886-2-2647-1896 ext. 6684	andrea24@wieson.com
	Edwina Chu	+886-2-2647-1896 ext. 6390	edwina@wieson.com

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Appendix B: Mechanical Drawings

The following table lists the mechanical drawings available in this document:

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(G)MCH Package Drawing	28
(G)MCH Component Keep-Out Restrictions for ATX Platforms	29
(G)MCH Component Keep-Out Restrictions for Balanced Technology Extended (BTX) Platforms	30
(G)MCH Reference Heatsink for ATX Platforms – Sheet 1	31
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NOTE: Unless otherwise specified, all figures in this appendix are dimensioned in millimeters. Dimensions shown in brackets are in inches.



Appendix B: Mechanical Drawings

Figure 10. (G)MCH Component Keep-Out Restrictions for ATX Platforms

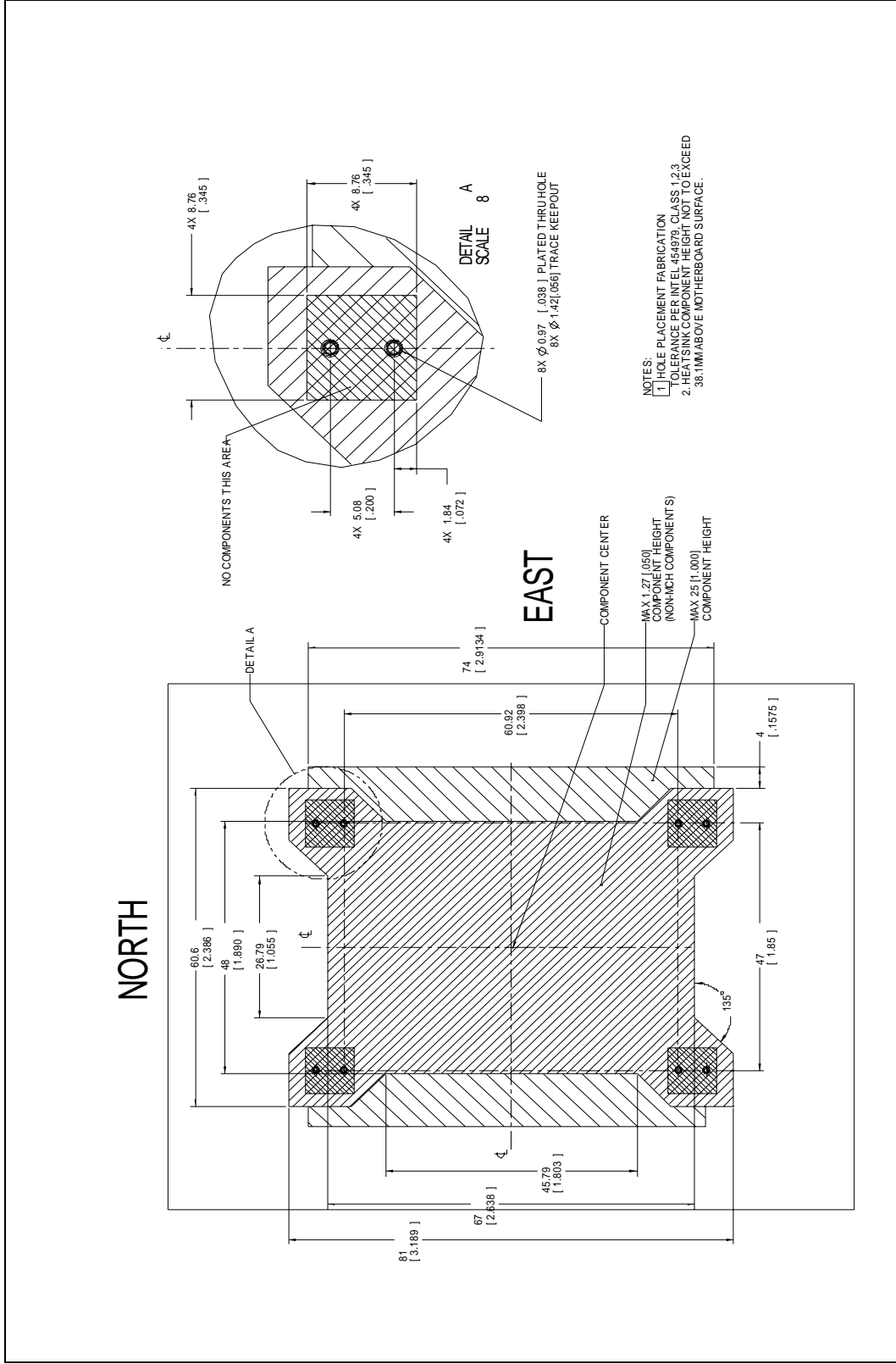
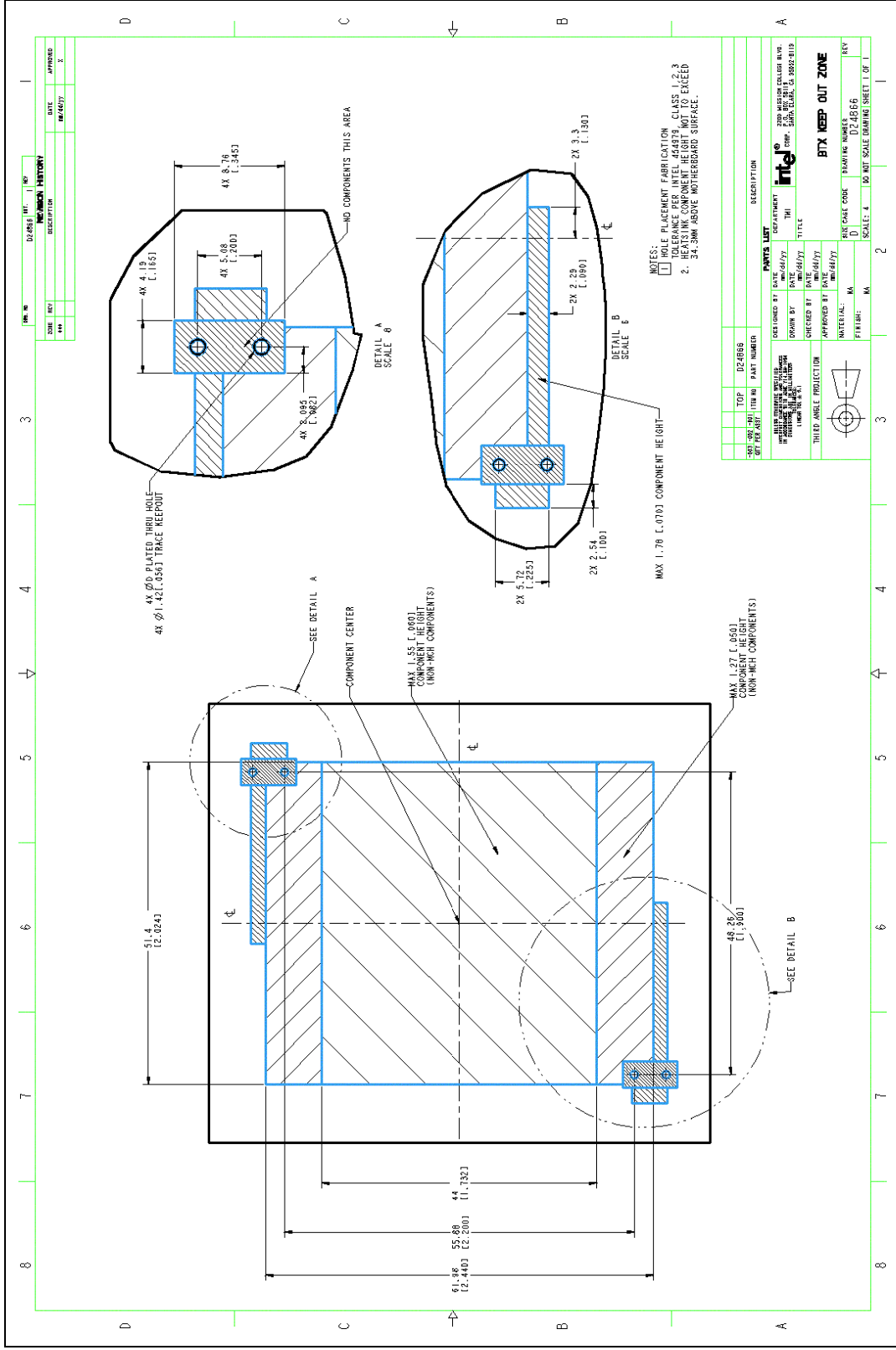




Figure 11. (G)MCH Component Keep-Out Restrictions for Balanced Technology Extended (BTX) Platforms





Appendix B: Mechanical Drawings

Figure 14. (G)MCH Reference Heatsink for ATX Platforms – Anchor

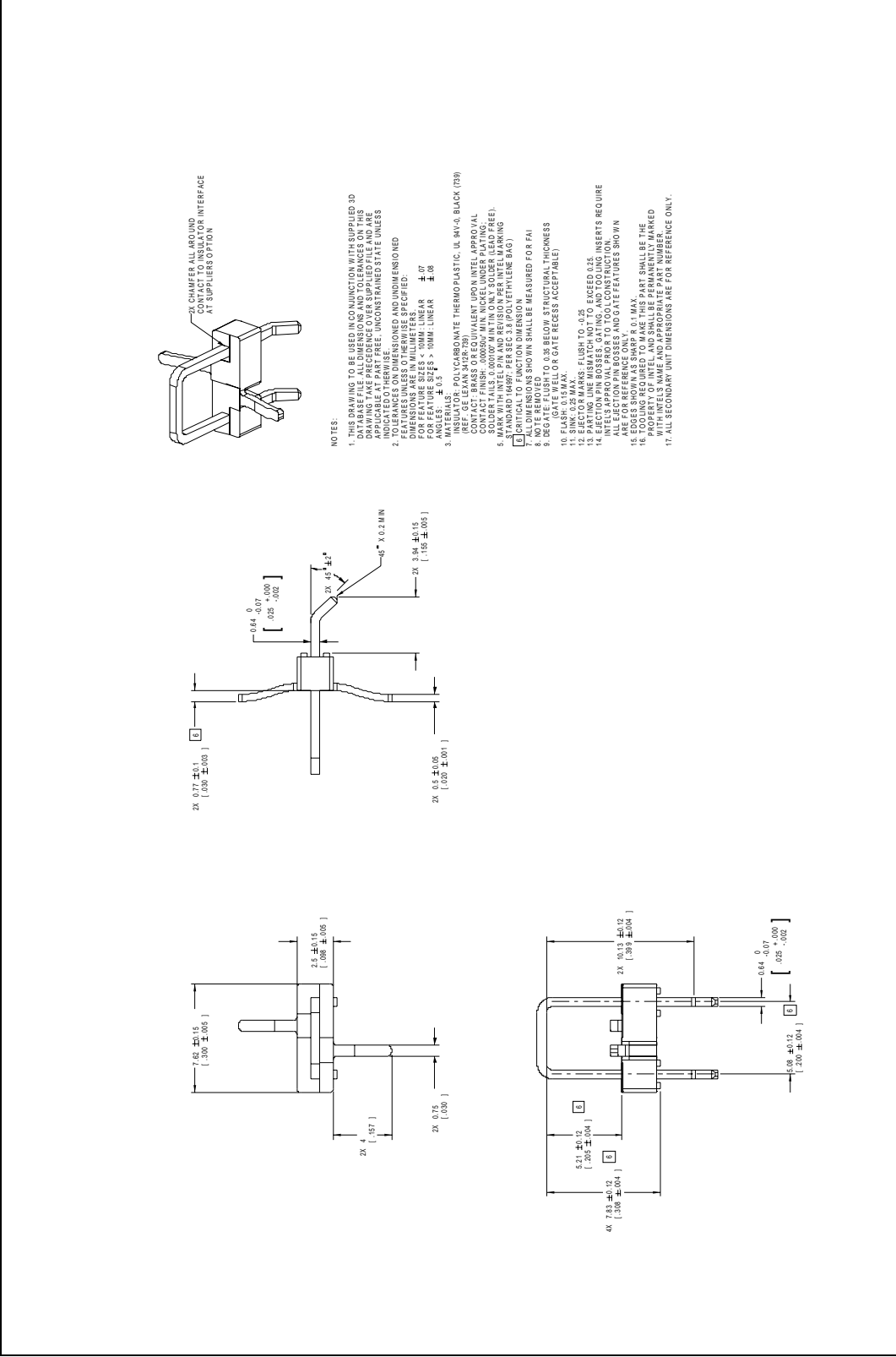




Figure 15. (G)MCH Reference Heatsink for ATX Platforms – Ramp Retainer Sheet 1

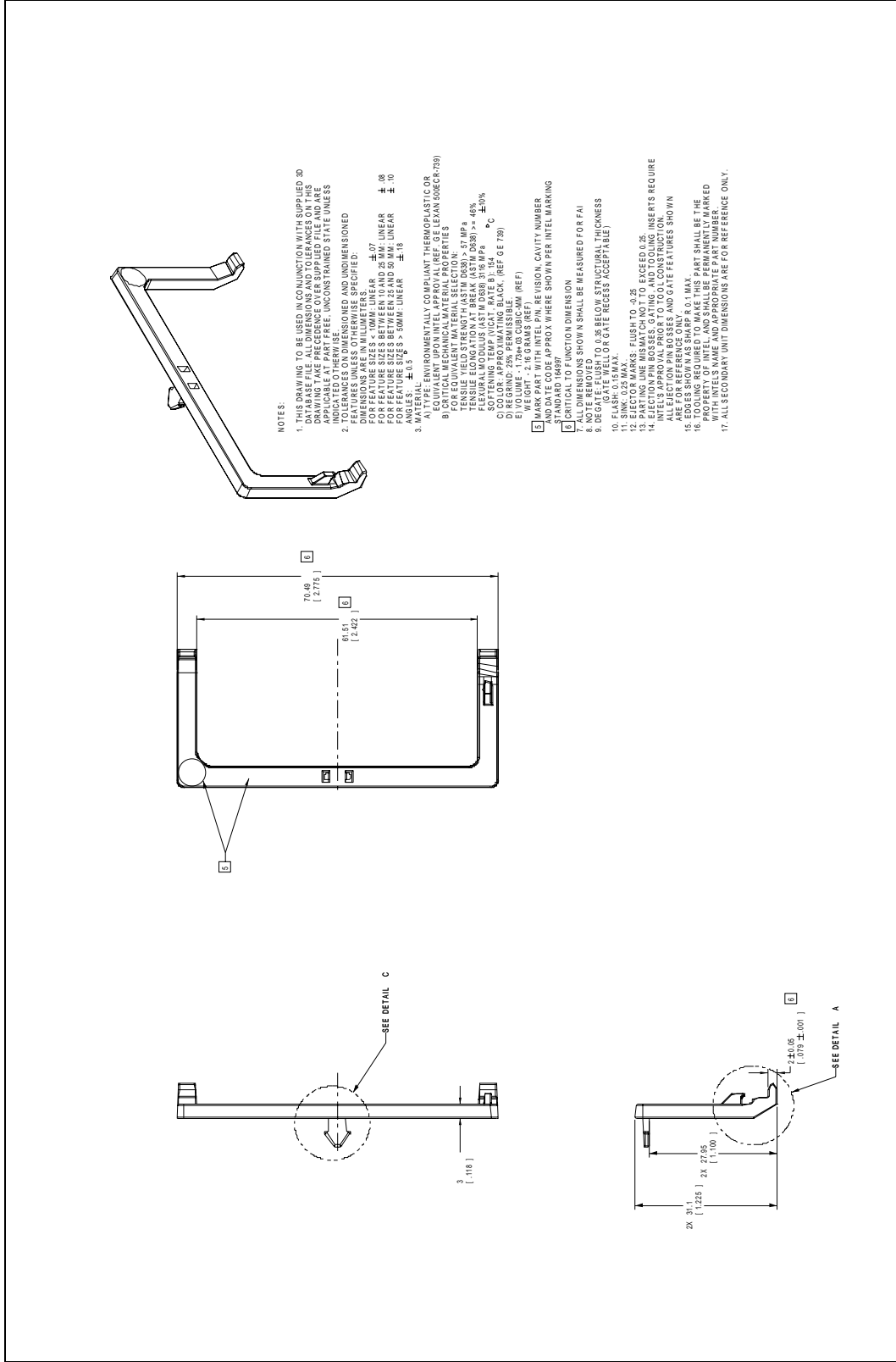




Figure 16. (G)MCH Reference Heatsink for ATX Platforms – Ramp Retainer Sheet 2

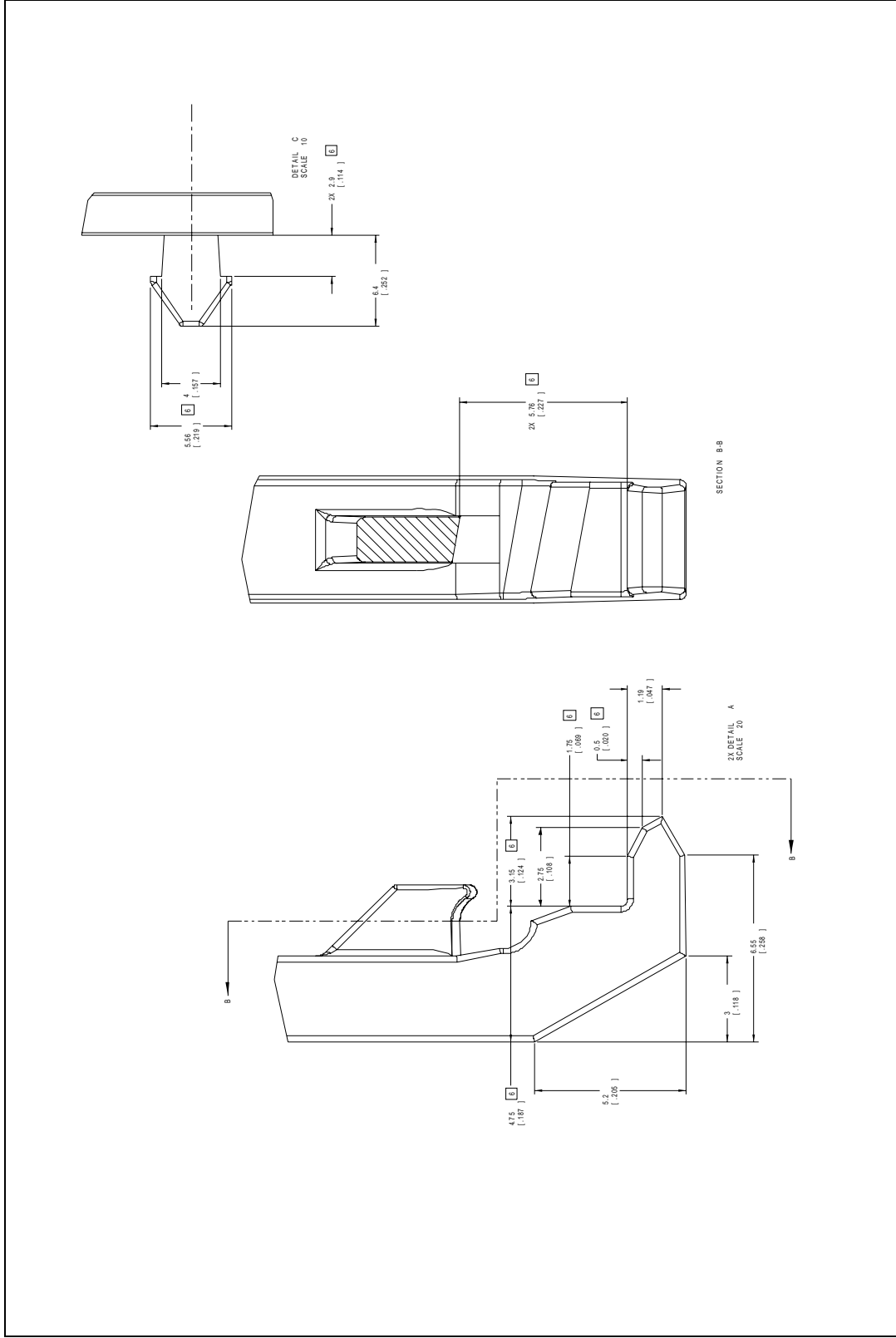




Figure 17. (G)MCH Reference Heatsink for ATX Platforms – Wire Preload Clip

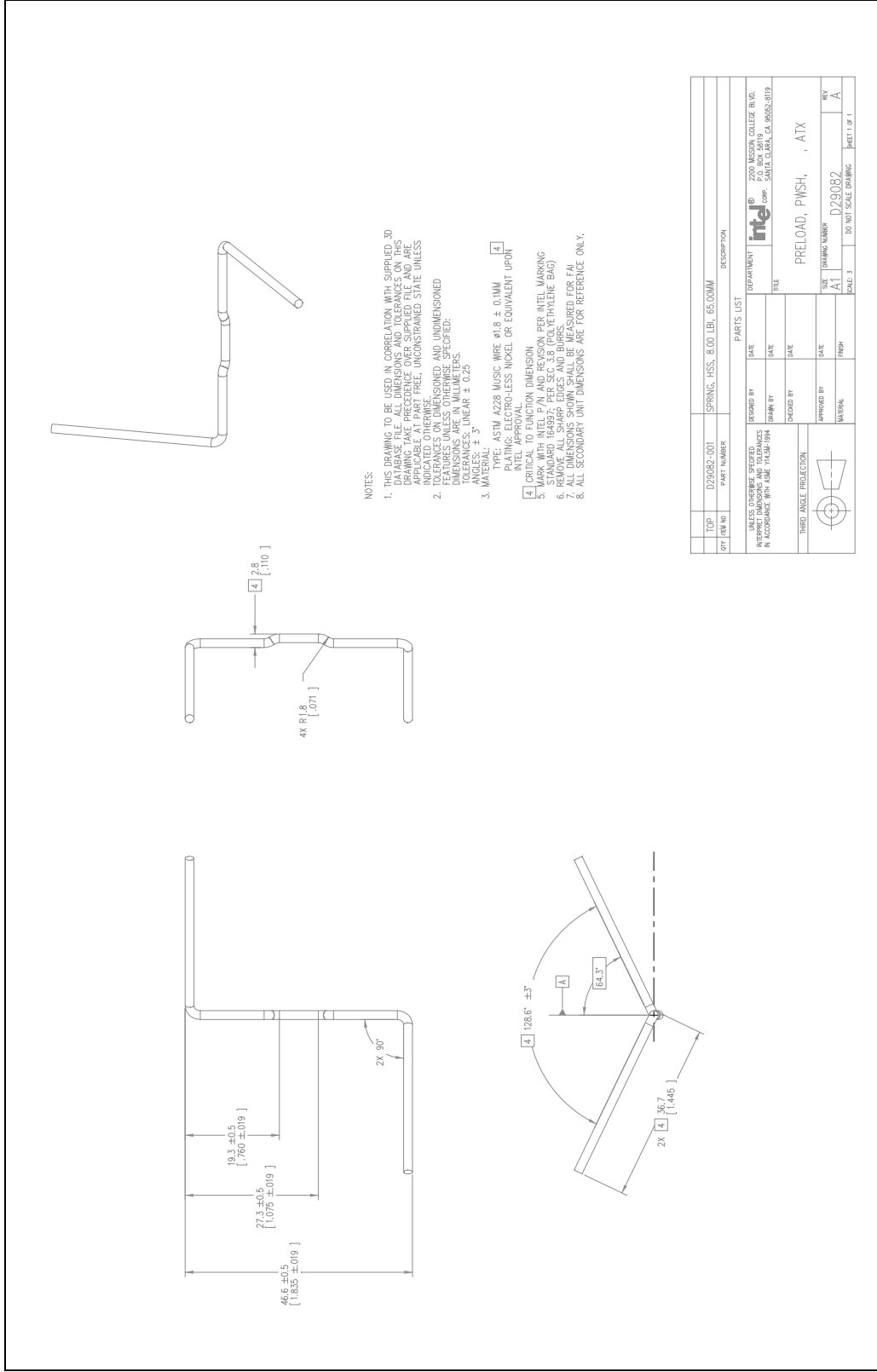




Figure 18. (G)MCH Reference Heatsink for Balanced Technology Extended (BTX) Platforms

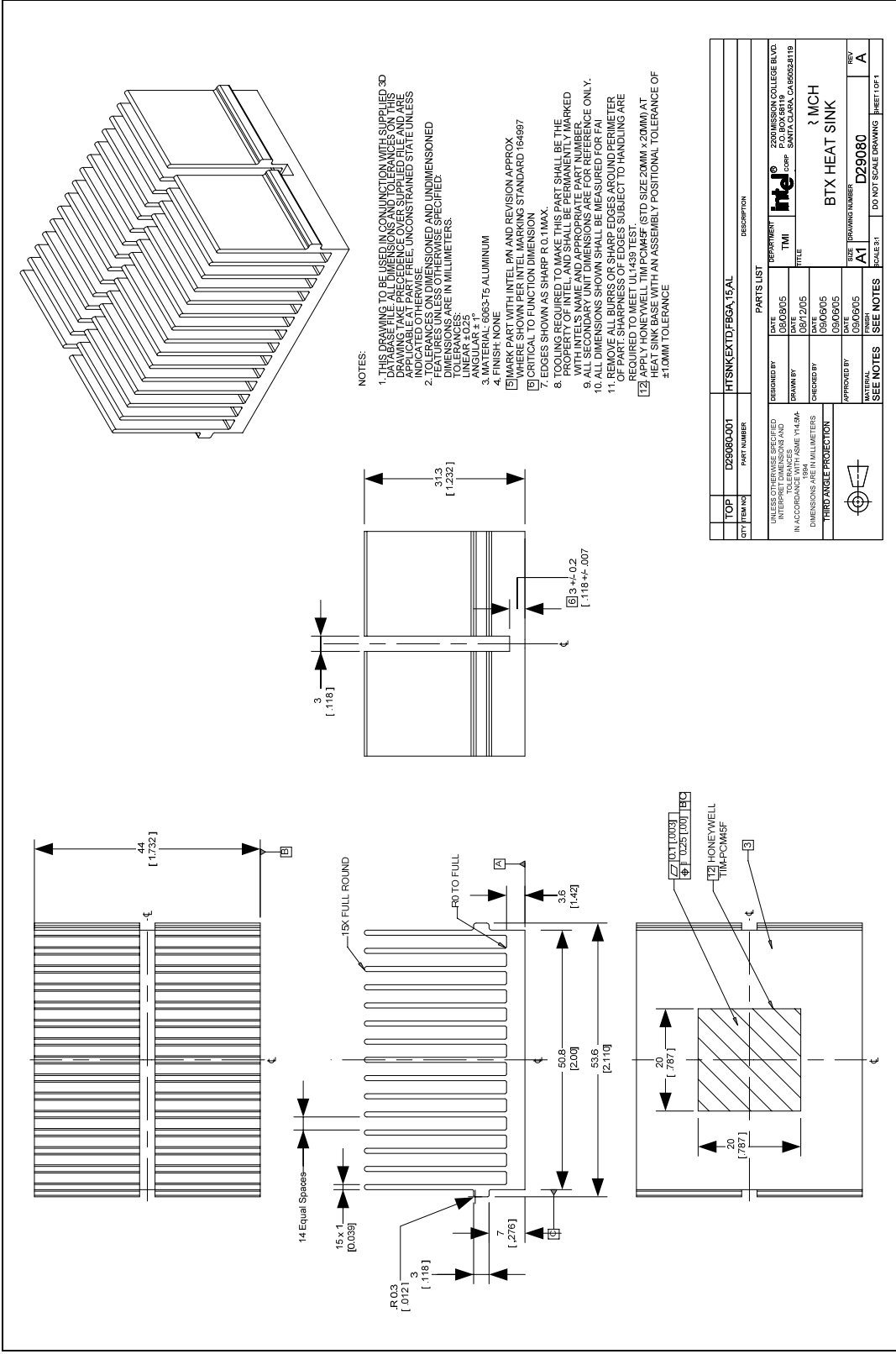
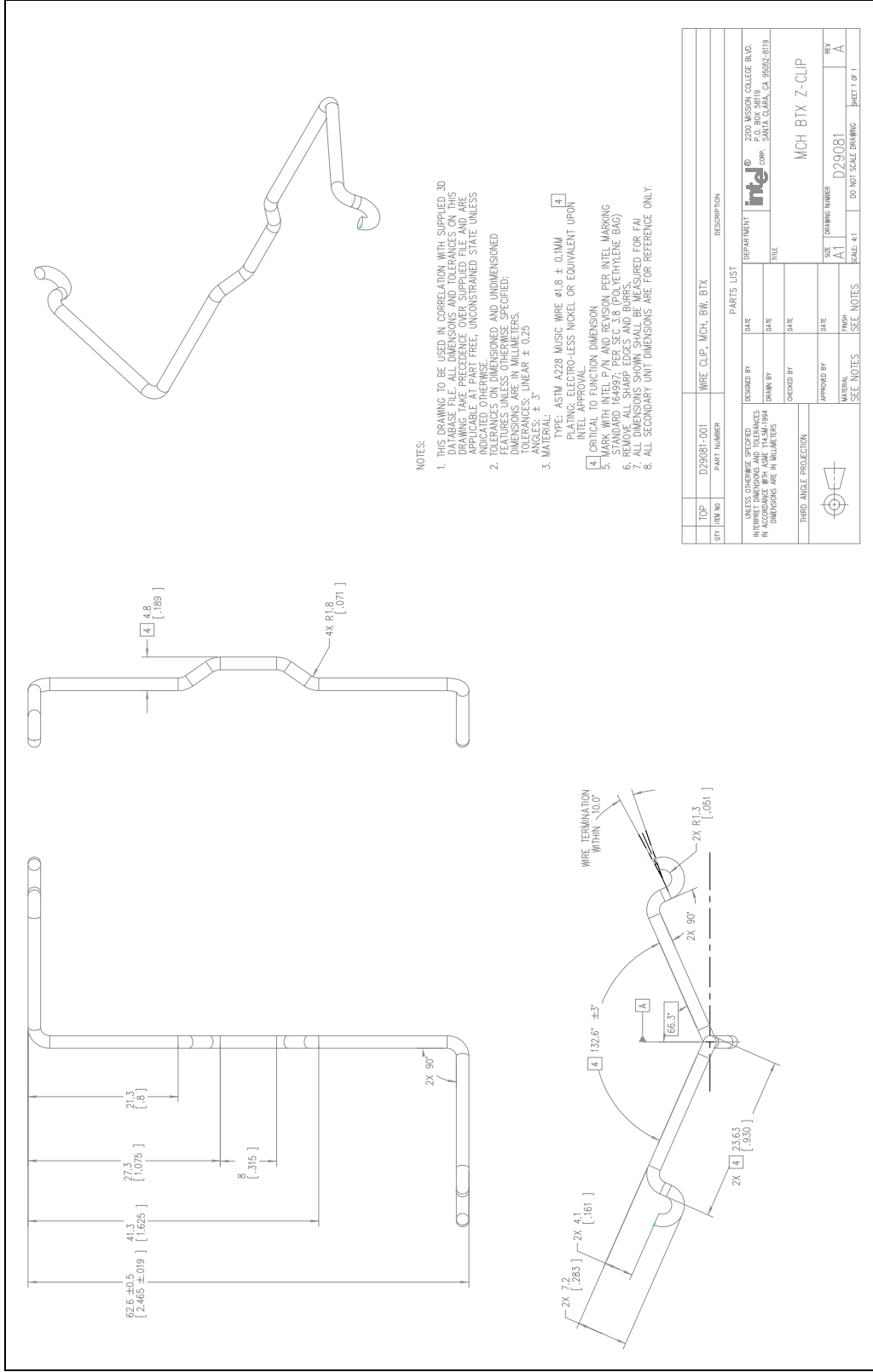




Figure 19. (G)MCH Reference Heatsink for Balanced Technology Extended (BTX) Platforms – Clip



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