



Intel[®] I/O Controller Hub 7 (ICH7)

Thermal Design Guidelines

— *For the Intel[®] 82801GB ICH7 and 82801GR ICH7R I/O
Controller Hubs*

April 2005



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Revision History

Rev. No.	Description	Date
-001	• Initial Release.	April 2005

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1 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® 82801GB ICH7 and 82801GR ICH7R I/O Controller Hubs.

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 is to improve the inherent system cooling characteristics of the ICH7 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 presents the conditions and requirements to properly design a cooling solution for systems that implement the ICH7 component. Properly designed solutions provide adequate cooling to maintain the ICH7 component 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 ICH7 component case temperature at or below maximum specifications, a system designer can ensure the proper functionality, performance, and reliability of this component.

Note: This document only applies to the desktop implementation of the Intel® ICH7 component.

Note: Unless otherwise specified, the term ICH7 refers to the Intel® 82801GB ICH7 and 82801GR ICH7R I/O Controller Hubs.

1.1 Terminology

Term	Description
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.
mBGA	Mini Ball Grid Array. mBGA is a smaller version of the BGA with a ball pitch of 1.07 mm. Wirebonded package with die encased with a mold encapsulant.
T _C	The measured case temperature of a component. It is generally measured at the geometric center of the die or case, as specified in the component documentation.
T _{C-MAX}	The maximum case/die temperature.
T _{C-MIN}	The minimum case/die temperature.
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. Units of airflow velocity.
PTC	Package Thermal Capability. The power level at which at or below its value, the component does not require a heatsink under the reference boundary condition assumptions.
Theta_CA	Thermal Resistance described using power dissipated between two points. Here, theta_ca is defined as: $(T_C - T_{ambient}) / (Power_{CA})$

1.2 Reference Documents

Document	Doc Number/ Location
<i>Intel® Pentium D Processor Thermal Mechanical Design Guidelines</i>	http://developer.intel.com/design/hipsets/designex/306830.htm
<i>Intel I/O Controller Hub 7 (ICH7) Family Datasheet</i>	http://developer.intel.com/design/hipsets/datashts/307013.htm
<i>Various System Thermal Design Suggestions</i>	http://www.formfactors.org

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2 Product Specifications

2.1 Package Description

The ICH7 component is available in a 652 ball, 31mm square mBGA package shown in Figure 9 in Appendix B.

2.2 Thermal Specifications

To ensure proper operation and reliability of the ICH7 component, the case temperature T_C must be at or below the maximum value T_{C_Max} specified in Table 1. If the temperature of the component exceeds the maximum temperature listed, system or component level thermal enhancements are required to dissipate the heat generated. The system designer must design a thermal solution for the ICH7 such that it maintains T_C below T_{C_Max} for sustained power level equal to the Thermal Design power (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 chipset reliability over its useful life. Chapter 3 provides the thermal metrology guidelines for case temperature measurements. Chapter 5 provides information on the reference cooling solution for ATX systems.

Intel's reference boundary conditions for ICH7 in an ATX system are 60 °C inlet ambient temperature and 0.25m/s [50 lfm] of airflow. The ICH7 package will not require a heatsink when power dissipation is at or below 3.1 W. This value is referred to as the Package Thermal Capability, or PTC. Note that the power level at which a heatsink is required will also change depending on system local operating ambient conditions and system configuration. For example, the local inlet ambient air for the ICH7 component in a BTX system is projected to be approximately 55°C. For BTX platforms that have similar boundary conditions to what is stated above, ICH7 does not require a heatsink.

Note: The local ambient air temperature for BTX is a projection based on anticipated power increases on a 2005 platform and are subject to change in the next revision of this document.

It is important to note, however, that since the ICH7 package has a molded plastic encapsulant, and because plastic is such a poor heat conductor, the relative importance of the motherboard heat transfer characteristics increases. The heat transfer capability of the motherboard in the area of the ICH7 should be characterized. Knowledge of these heat transfer paths can be used to determine if an ICH7 heatsink is required.

A future revision of this document will include characterized ICH7 θ_{ja} data on a BTX platform with under and above board airflow sensitivity studies. Note that our current thermal specifications account for the heat transfer characteristics of a typical motherboard.

In addition, high power PCI Express* graphic cards may alter the local ambient temperature as well as the airflow patterns in the vicinity of the chipset. Systems that have interface utilization less than that of the TDP configuration may be at power levels that may not require a heatsink.



Thermal validation should be performed in the anticipated system environment, in particular measuring the ICH7 case temperature to ensure it does not exceed its maximum case temperature specification. To evaluate the capability of the system for cooling the ICH7, the following system level tests are suggested to assess ICH7 case temperature compliancy:

1. Shipping configuration(s) with expected end user add-in cards and I/O peripherals installed.
2. All available slots on the board populated (only worst case if all I/O is fully populated including SATA, USB, etc.).

For completeness, both room ambient conditions (approximately 23 °C, to simulate impact of fan speed control) and worse case maximum external temperature (35 °C) conditions should be considered in the validation test suite. If the ICH7 case temperature is above the published T_{C-MAX} in any test scenario, a heatsink is required.

If it is determined that the ICH7 package requires a heatsink in the system configuration, refer to Appendix A for the reference ICH7 heatsink vendor information.

The component should be operated above the minimum case temperature specification listed in Table 1.

Table 1. Intel® ICH7 Component Case Temperature Specifications

Parameter	Value
T_{C-MAX} (Note 1 below) for TDP condition of 3.3 W	See Table 2 for additional configuration No Heatsink Attached: 108 °C
	See Table 2 for additional configuration Heatsink Attached: 99 °C
T_{C-MIN}	0 °C
Storage Temperature	-10 °C to +45 °C

NOTES:

1. Without a heatsink, most of the heat dissipated by the ICH7 goes through the PCB, acting as a heat spreader, and then into the ambient air. When a heatsink is installed on the package, more power is now being pulled through the case. As a result the maximum case temperature must be maintained at lower level than without a heatsink to maintain the junction within specification.

2.3 Power Specifications

The ICH7 component is estimated to dissipate the Thermal Design Power (TDP) value provided in Table 2. This TDP value is estimated based on various factors including: system configuration, industry stress applications, die temperature, and part-to-part variance.

Note: Table 2 reflects post-silicon validated power numbers.

Table 2. Intel® ICH7 Thermal Design Power Guidelines

Configuration		Config1:TDP	Config2	Config3	Config4
Devices	USB (HS/FS) ¹	6/2	6/2	6/2	8
	PCI Express	4	2	1	4
	SATA	3	4	4	4
	PATA	2 ²	2 ²	1 ²	2 ²
	PCI	3	3	3	3
Configuration Based Power ³		3.3 W	3 W	2.9 W	3.3 W
T _{C-MAX}	No Heatsink	108 °C	109 °C	109 °C	108 °C
	With Heatsink	99 °C	100 °C	100 °C	99 °C

NOTES:

1. USB HS = USB 2.0 High Speed Device (480 Mb/s), USB FS = USB 2.0 Full Speed Device (12 Mb/s)
2. The controller is used with up to two drives connected.
3. Refers to the power of each listed configuration. Configuration 1 is the typical configuration for Thermal Design Power.

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3 Thermal Metrology

The system designer must make temperature measurements to accurately determine the thermal performance of the system. Intel has established guidelines measuring chipset component case temperatures.

3.1 Case Temperature Measurements

To ensure functionality and reliability, the chipset component is specified for proper operation when T_C is maintained at or below the maximum temperature listed in Table 1. The surface temperature at the geometric center of the mold encapsulant corresponds to T_C . Measuring T_C requires special care to ensure an accurate temperature measurement.

Temperature differences between the temperature of a surface and the surrounding local ambient air can introduce 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, and/or conduction through thermocouple leads. To minimize these measurement errors, the approach described in Section 3.2 is recommended for thermocouple attach.

3.2 0° Angle 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 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 case 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 case (see Figure 1).
6. Attach heatsink assembly to the (G)MCH, and route thermocouple wires out through the milled slot.

Figure 1. 0° Angle Attach Methodology (Top View, Not to Scale)

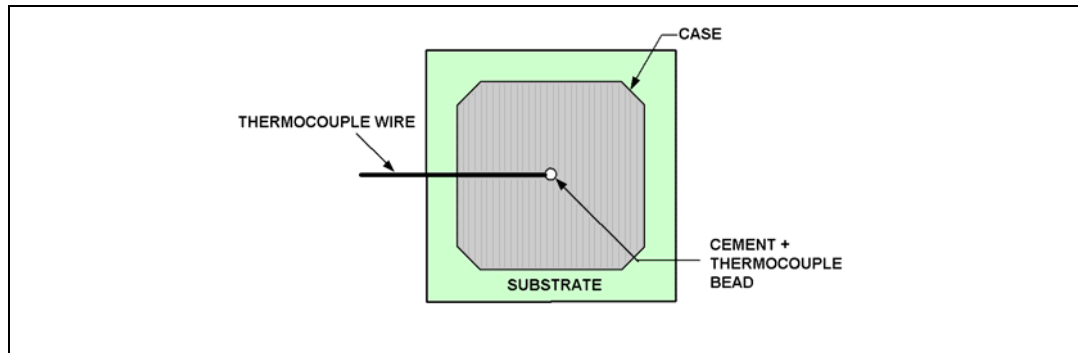
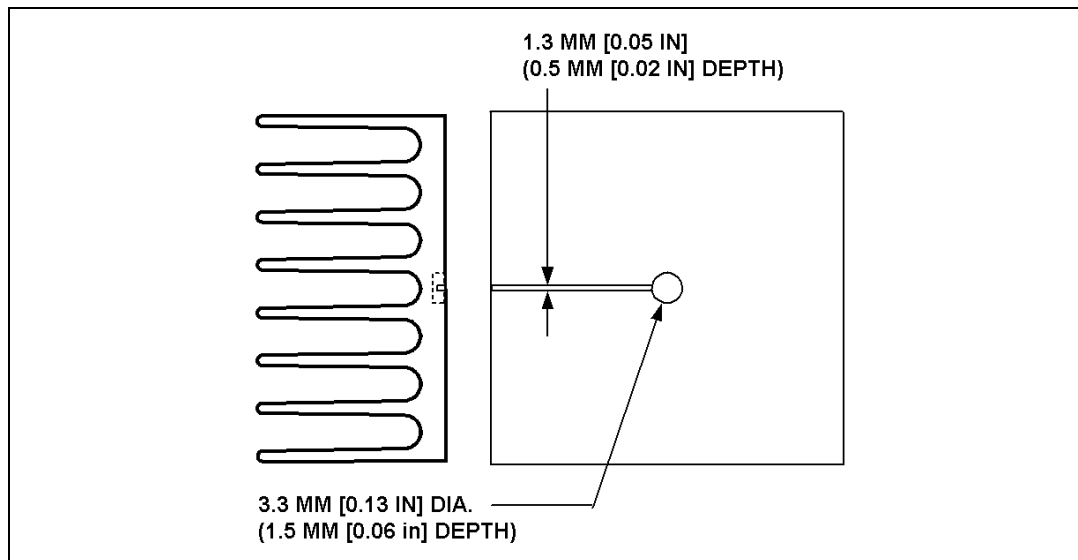


Figure 2. 0° Angle Attach Heatsink Modifications (Generic Heatsink Shown, Not to Scale)



3.3 Ambient Temperature and Airflow Measurement

Figure 3 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.

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 all chassis layouts due to the proximity of the processor to the (G)MCH, PCI and PCI-Express* add-in cards. 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.

Figure 3. Recommended Temperature Measurement Placement (Top View)

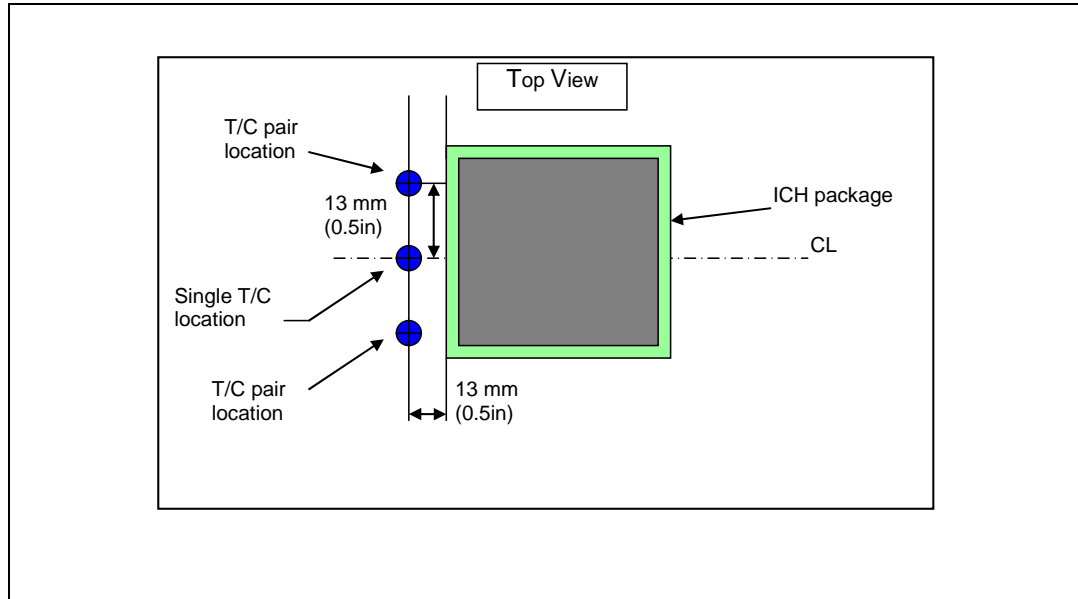
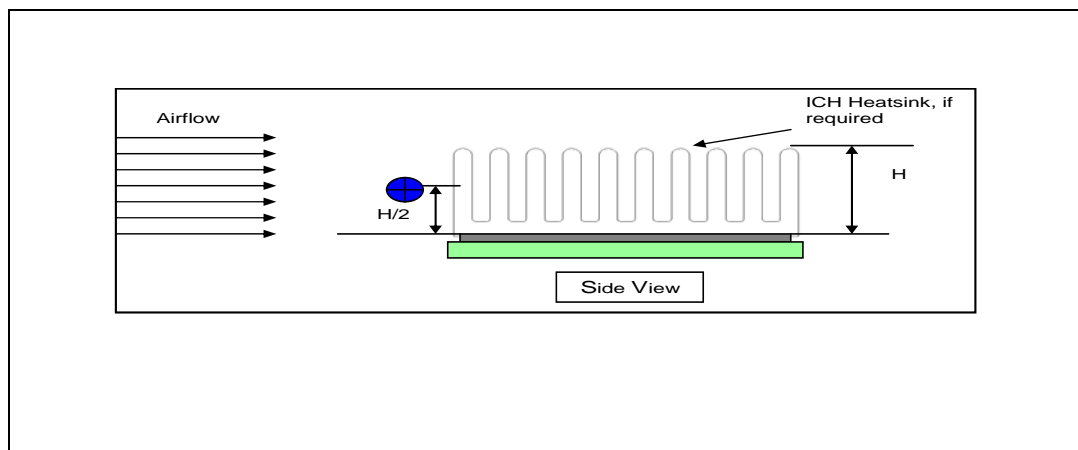


Figure 4. Recommended Airflow and Temperature Placement (Side View)



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4 Alternative Heatsink Determination Guidance

Often the system integrator will have a system environment that differs from the reference boundary conditions as listed in Section 2.2. This chapter provides additional guidance on:

- 1) Making a heatsink decision (Section 4.3), and 2) Determining if a pre-selected heatsink is adequate (Section 4.4) in meeting Intel® ICH7 specifications based on the boundary conditions as measured in your specific system.

Note that the guidance methodology in this section is meant to supplement the specifications listed in Chapter 2, and use of the information in this section is optional. Chapter 2 provides the case temperature specifications for the TDP configuration as well as other configurations of interest while operating under the Intel reference boundary conditions as stated in Section 2.2. If the system integrator believes that Intel’s reference boundary conditions correctly reflect the conditions in their own system, the guidance in this chapter does not need to be used.

4.1 Configurations Supported in this Methodology

The heatsink determination methodology presented below requires configuring your system to one of the configurations listed in Table 3 and then measuring the ICH7 case temperature and comparing it to the charts in Figure 5 and Figure 6 for each configuration.

Table 3. Intel® ICH7 Configurations with Associated Configuration Power and Devices Connected

Configuration	Power (W)	Devices(s)				
		USB (HS/FS) ¹	PCI Express*	SATA	PATA	PCI
Config 1:TDP	3.3	6/2	4	3	2	3
Config 2	3.0	6/2	2	4	2	3
Config 3	2.9	6/2	1	4	1	3
Config 4	3.3	8	4	4	2	3

NOTES:

- 1. USB HS = USB 2.0 High Speed Device (480 Mb/s), USB FS = USB 2.0 Full Speed Device (12 Mb/s)

4.2 System Configuration for T_C Analysis

System peripherals such as add-in cards and cables can effect the system environment, thereby changing the effective cooling capability of the system. As a result, the IDLE T_C measurement must be taken with the system populated as it is intended to ship to end customers. Examples of system peripherals that will be included (but are not limited to) are the following:

- PCI-Express* Graphics add-in card
- Other various PCI Cards
- IDE/ SATA Storage Drives
- Thermal solution assembly components (heatsink, fan, duct)
- Note that nothing specific needs to be done with the following:
- LAN Connect Interface
- AC'97/HD Audio

4.3 Heatsink Determination Procedure

The following information details how a system integrator can assess whether or not they require a heatsink on their platforms. Refer to Section 4.4 if you have already selected a heatsink and need to assess whether or not it is adequate.

Note: The ICH7 case temperature, ambient temperature, and airflow should be measured according to the guidance provided in Chapter 3: Thermal Metrology.

4.3.1 Procedure Description

To determine if a heatsink is needed on ICH7, follow the following steps:

1. Configure system to match one of the configurations listed in Table 3.
2. Boot system and allow system to reach steady state temperature.
3. Measure ICH7 case temperature (°C), ambient temperature (°C), and airflow (LFM) during test. Refer to Chapter 3 for thermal metrology for ambient temperature and airflow.
4. Use associated configuration plot in Figure 5 (Configurations 1 or 4) or Figure 6 (Configurations 2 or 3). Then plot the measured ICH7 case temperature with the measured airflow (LFM) on the chart.
5. Compare the final measurement data point to Intel's T_{C_max} specification line (as a function of ambient temperature) as indicated by the plot.
6. If data point is above the T_{C_max} specification line, additional cooling is required. If your data point is below the T_{C_max} specification line, additional cooling is not required (See following charts for a usage example).

Figure 5. Heatsink Determination Chart (Configuration 1 and 4)

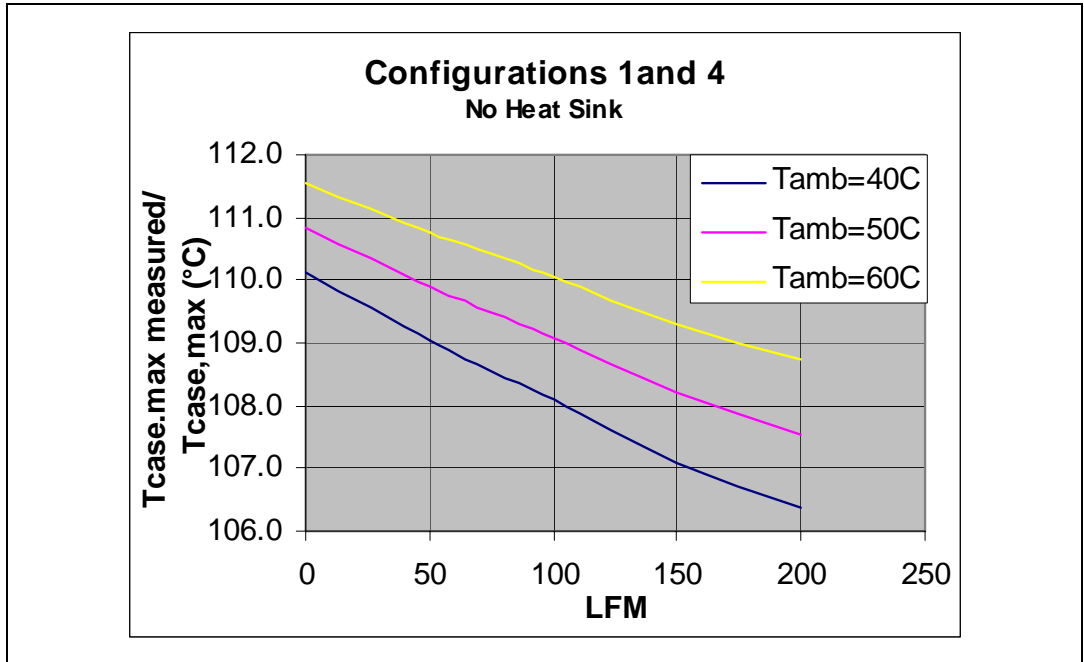
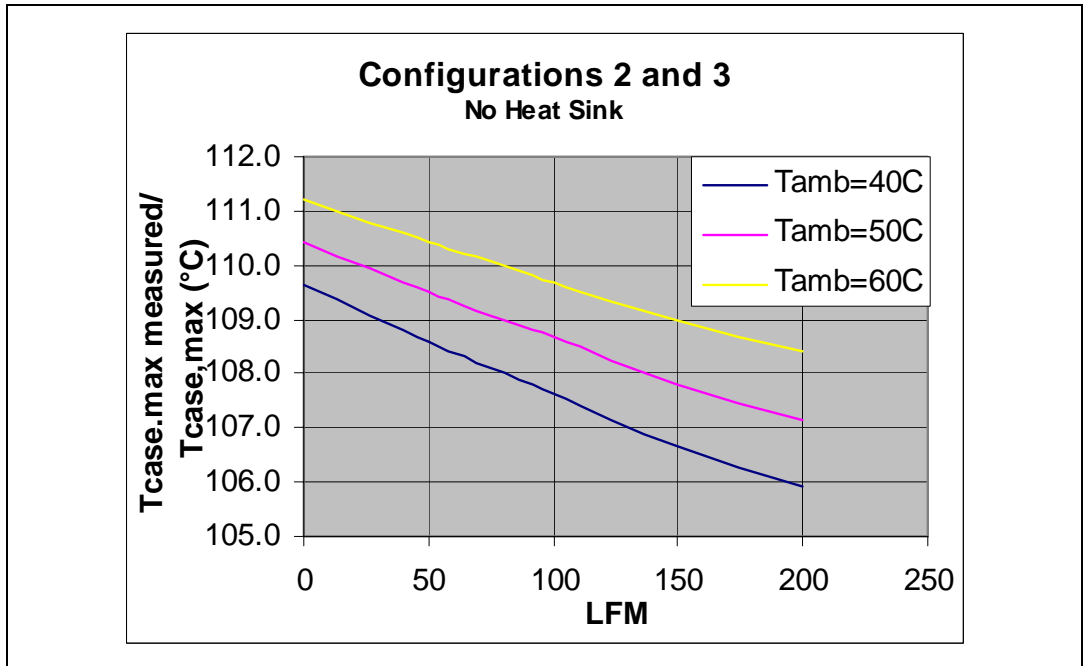


Figure 6. Heatsink Determination Chart (Configuration 2 and 3)

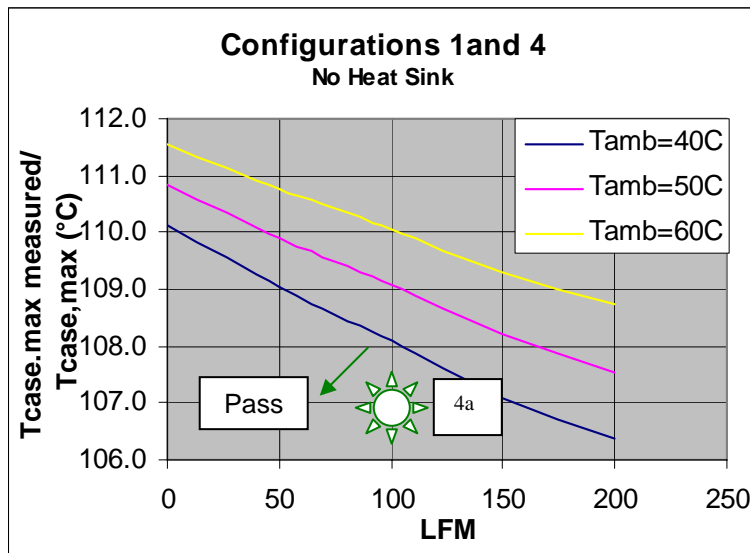


4.3.2 Application

Assume system configured to match Configuration 1 (TDP configuration) with no heatsink on ICH7:

1. Boot system
2. Measured maximum ICH7 case temperature at steady state = 107 °C, ambient temperature = 40 °C, measured airflow = 100 LFM.
3. Use chart in Figure 5 to plot measured case temperature and airflow (LFM).

Thus, 107 °C T_C temperature, 100 LFM was measured. See green star for measurement location on chart.



Compare the final measurement data point to Intel’s $T_{C,max}$ specification line (as a function of your measured ambient temperature = 40 °C) as indicated by the dark blue line “ $T_{amb} = 40C$ ”.

Our green star measurement location is below the ambient temperature line of 40 °C; therefore, additional cooling is not required.

4.4 Heatsink Adequacy Determination Procedure

The following section details how a system integrator can assess whether or not the selected heatsink meets Intel specifications for ICH7. Refer to Section 4.3 if you do not have a heatsink and need to assess whether one is required.

Note: The ICH7 case temperature, ambient temperature, and airflow should be measured according to the guidance provided in Chapter 3.

4.4.1 Procedure Description

To determine if the heatsink meets Intel specifications for ICH7, follow the following steps:

1. Configure system to match one of the configurations listed in Table 3.
2. Boot system and allow system to reach steady state temperature.
3. Measure ICH7 case temperature ($^{\circ}\text{C}$), ambient temperature ($^{\circ}\text{C}$), and airflow (LFM) during test. Refer to Chapter 3 for ambient temperature and airflow thermal metrology.
4. Use associated configuration plot in Figure 7 (Configurations 1 or 4) or Figure 8 (Configurations 2 or 3). Then plot the measured ICH7 case temperature with the predictive (or validated) heatsink θ_{ca} ($^{\circ}\text{C}/\text{W}$) on the chart.
5. Compare the final measurement data point to Intel's $T_{C_{\text{max}}}$ specification line (as a function of ambient temperature) as indicated by the plot.
6. If the data point is above the $T_{C_{\text{max}}}$ specification line, additional cooling is required. If your data point is below the $T_{C_{\text{max}}}$ specification line, additional cooling is not required (see following usage example).

Figure 7. Heatsink Adequacy Determination Chart (Configurations 1 and 4)

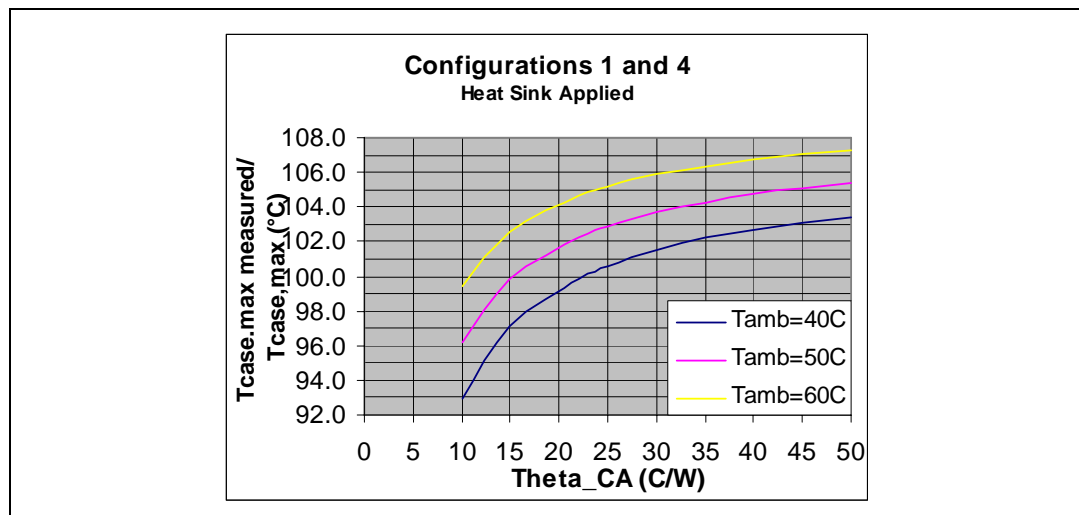
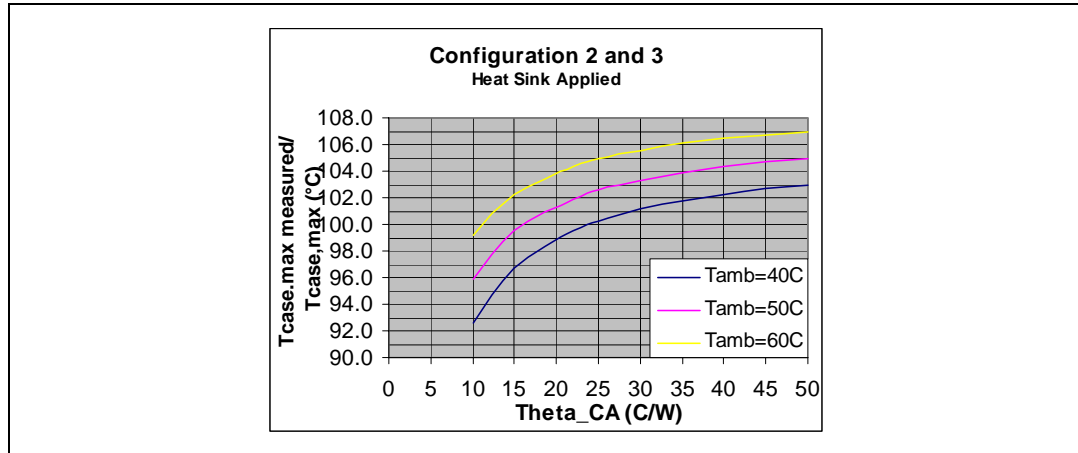


Figure 8. Heatsink Adequacy Determination Chart (Configurations 2 and 3)

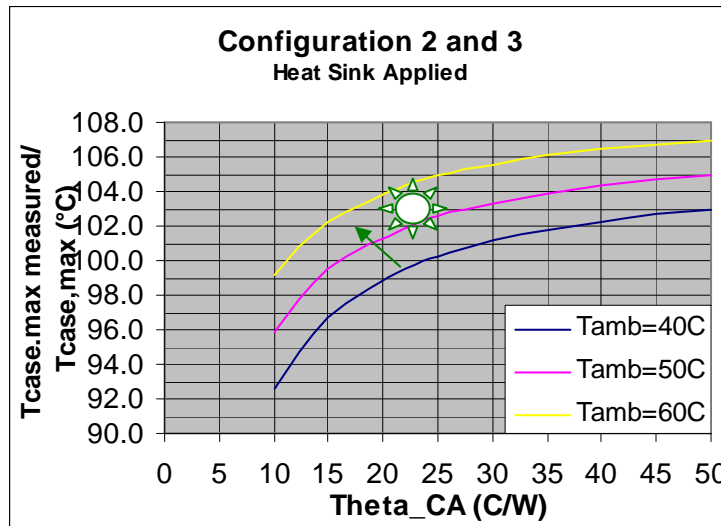


4.4.2 Application

System configured to match Configuration 2 with system integrator’s selected heatsink on ICH7:

1. Boot system
2. Measured maximum ICH7 case temperature at steady state = 103 °C, ambient temperature = 40 °C, measured theta_ca = 22 °C/W.
3. Use chart in Figure 8 to plot measured case temperature and theta_ca (°C/W).

Thus, 103 °C T_C temperature, theta_ca = 22 °C/W was measured. See green star for measurement location on chart.



Compare the final measurement data point to Intel’s T_{C_max} specification line (as a function of your measured ambient temperature = 40 °C) as indicated by the dark blue line (“Tamb=40C”).

Our green star measurement location is above the ambient temperature line of 40 °C; therefore, the selected heatsink is inadequate, and additional cooling is required.

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5 Reference Thermal Solution

The ICH7 reference solution on an ATX platform assumes a component local operating environment with a maximum local-ambient temperature of 60 °C and airflow of 0.25 m/s [50 lfm]. In these conditions, with the TDP projection given in Table 2, the ICH7 component requires an attached heatsink to meet thermal specifications. The local-ambient conditions are based on a 35 °C external-ambient temperature at sea level, where external-ambient refers to the environment external to the system. Refer to Appendix A for enabled suppliers for the ICH7 reference thermal solution and Appendix B for reference thermal solution mechanical drawings. Note that the reference heatsink for ICH7 is identical to the reference heatsink for the Intel® ICH6. Refer to Figure 10 for reference ATX/µATX motherboard keep-out information. The heatsink can be tape-attached, or attached with a Z-clip. This motherboard keep-out allows a Z-clip heatsink attach.

5.1 Environmental Reliability Requirements

If an attached heatsink is implemented due to a severe component local operating environment, the reliability requirements in Table 4 are recommended. The mechanical loading of the component may vary depending on the heatsink, and attach method used. The user should define validation test based on anticipated use conditions and resulting reliability requirements.

Table 4. Reference Thermal Solution Environmental Reliability Requirements

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, 11 ms duration, 170 inches/sec minimum velocity change. Setup: Mount sample board on test fixture. 	Visual/Electrical Check
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 Cycling	<ul style="list-style-type: none"> -40 °C to +85 °C, 1000 cycles 	Visual Check
Temperature Life	<ul style="list-style-type: none"> 85 °C, 1000 hours total 	Visual/Electrical Check
Unbiased Humidity	<ul style="list-style-type: none"> 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 3 different lots of material.
2. Additional Pass/Fail Criteria may be added at the discretion of the user.

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Appendix A Enabled Suppliers

Enabled suppliers for the ICH7 Reference thermal solution are listed in Table 5.

Table 5. Enabled Suppliers for the Intel® ICH7 Reference Heatsink

Supplier	Intel Part Number	Vendor Part Number	Contact Information
CCI* (Chaun-Choung Technology Corp.)	C46655-001	00C855802B	Taiwan: Monica Chi — Email: monica_chih@ccic.com.tw — Tel: +886 - 2 2-995-2666 Ext 131 USA: Harry Lin — Email: HLINACK@aol.com — Tel: (714) 739-5797
Foxconn	C46655-001	2Z802-009	USA: Jack Chen, PH.D — Email: rongchechen@foxconn.com — Tel: (714) 626-1233

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.

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Appendix B Mechanical Drawings

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

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Figure 9. Intel® ICH7 Component Package Drawing

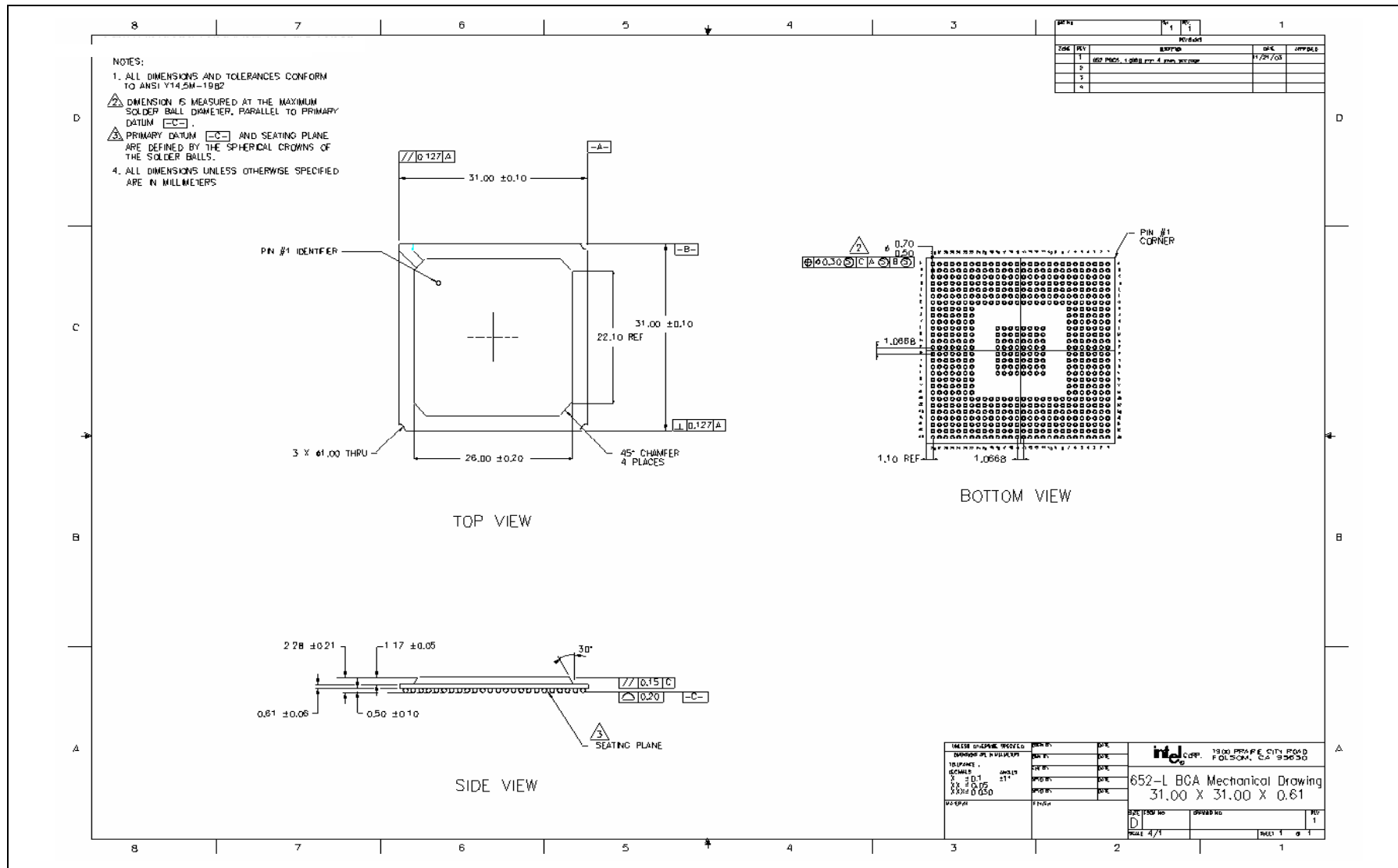


Figure 10. Intel® ICH7 Motherboard Reference Keep-Out

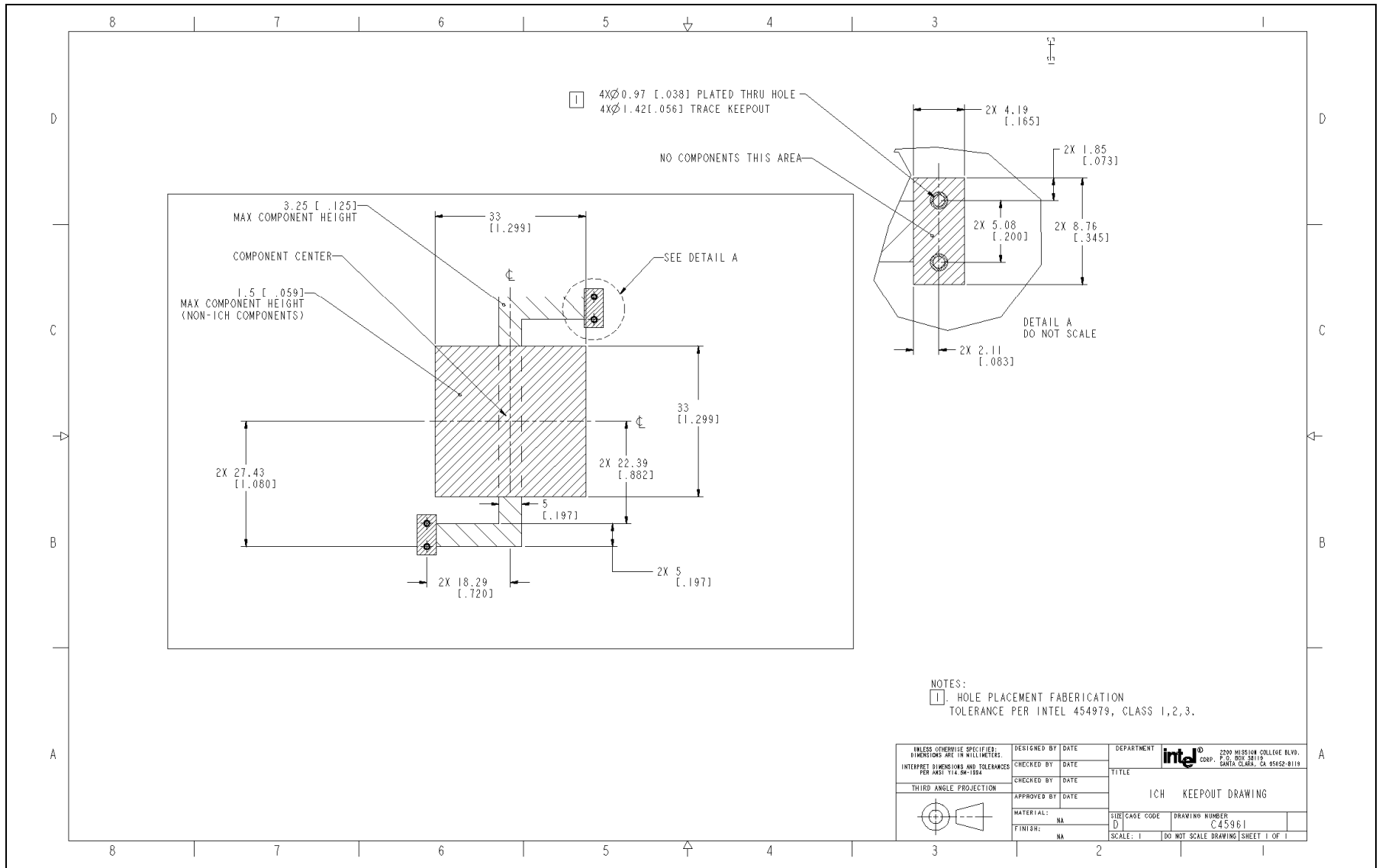


Figure 11. Intel® ICH7 Reference Heatsink Extrusion

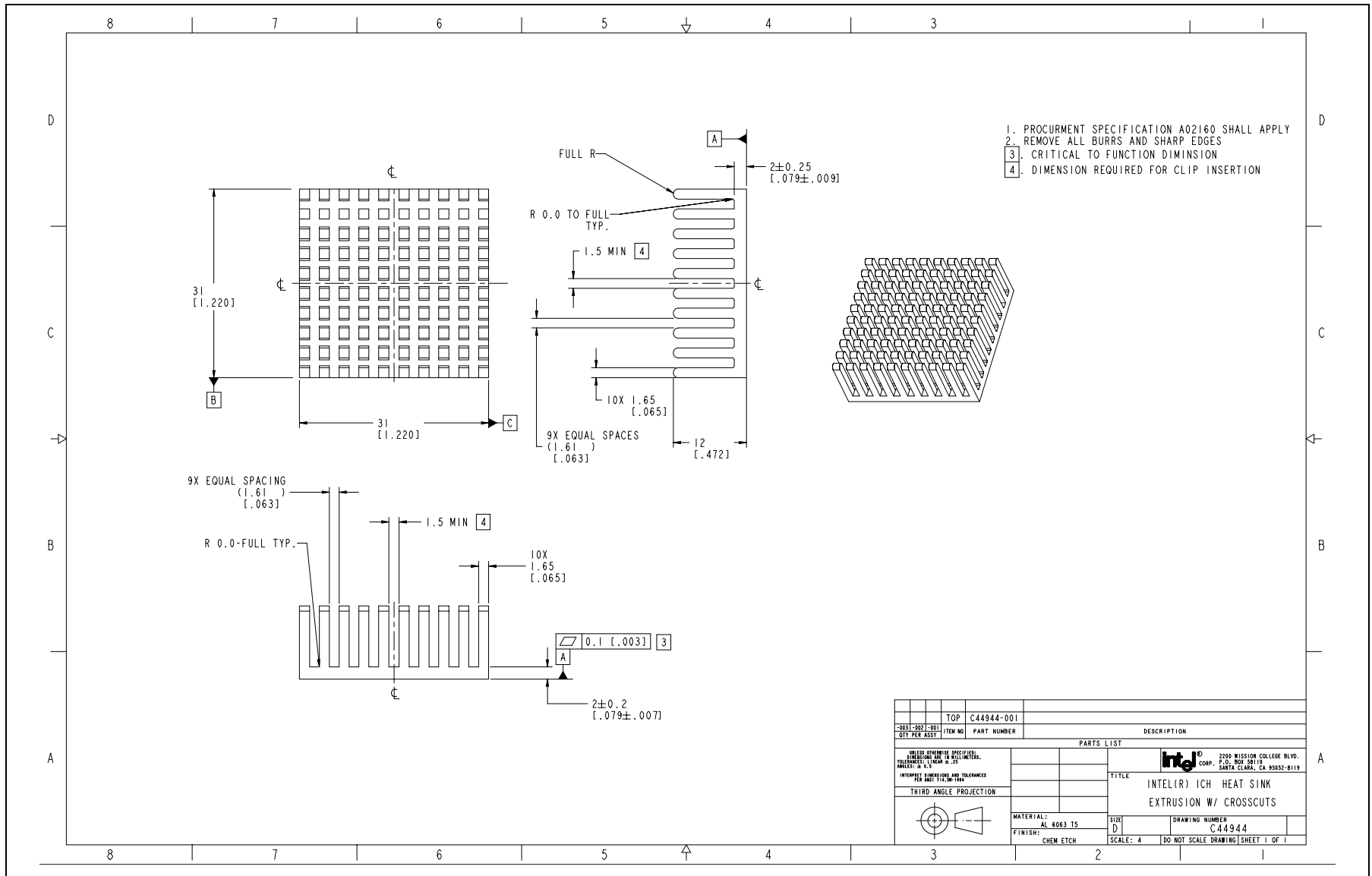


Figure 12. Intel® ICH7 Reference Heatsink Clip

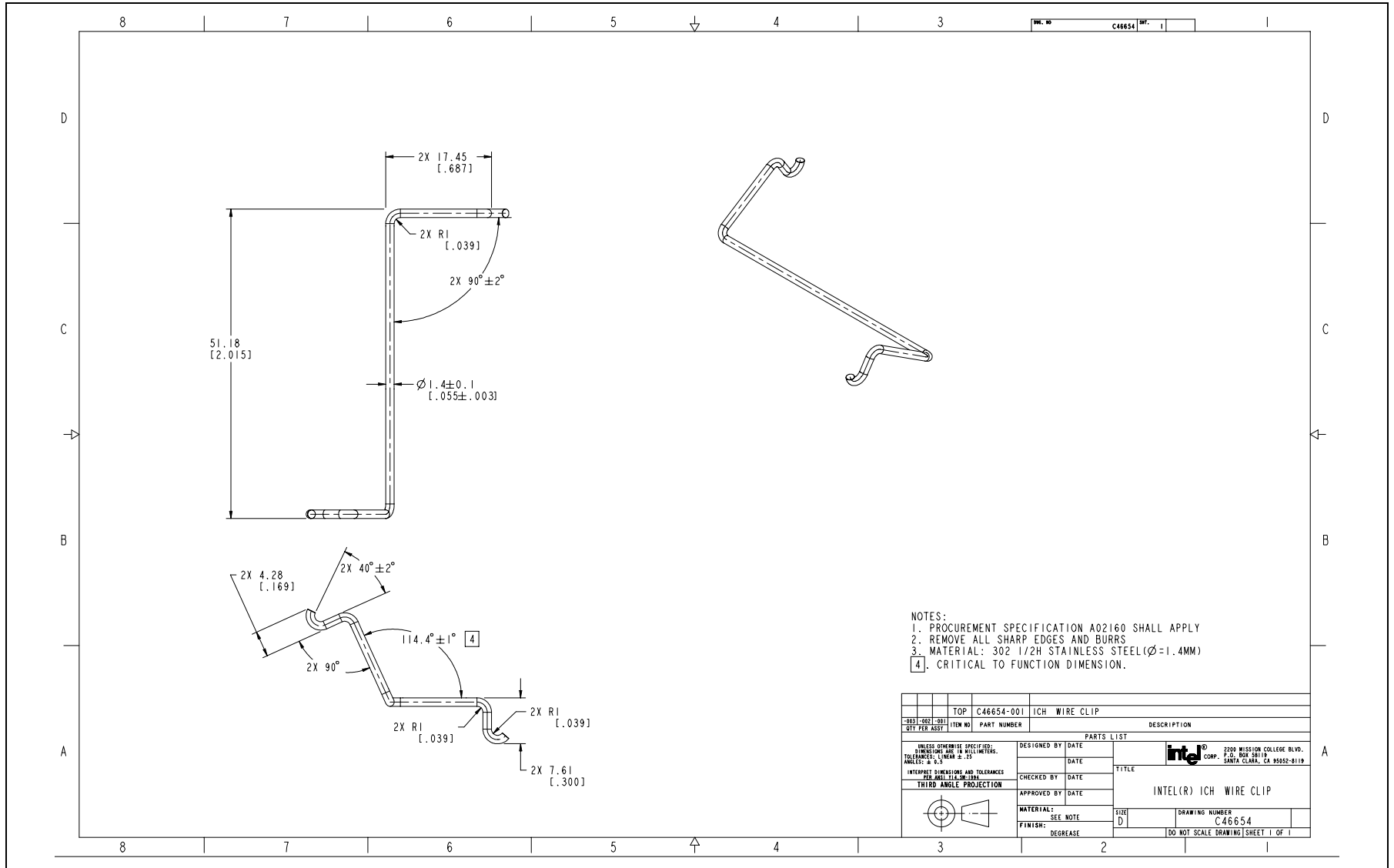


Figure 13. Intel® ICH7 Reference Heatsink Assembly

