Intel® 82854 Graphics Memory Controller Hub (GMCH) for Fanless Set Top Box Applications

Thermal Design Guide

March 2005

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Revision History

Date	Revision	Reference #	Description
March 2005	1.0	D14844-001	First release.

1 Introduction

1.1 Document Objective

This document is intended to aid system designers to properly implement a thermal management solution to ensure reliable and efficient operation of the Intel® 82854 Graphics Memory Controller Hub (GMCH). The objective of thermal management is to ensure that the temperature of the device while operating in a set top box system is maintained within functional limits. The functional temperature limit is the range within which the electrical circuits in the silicon 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 components. This document will provide an understanding of the operating limits of the Intel® 82854 GMCH and suggest proper thermal design techniques based on a particular configuration and system boundary conditions.

1.2 Related Documents

Table 1. Document References

Title	Number	Location
Intel® 854 Chipset GMCH Product Preview Datasheet	17064	See your local Intel field representative
ULV Intel® Celeron® M Processor at 600 MHz for Fanless Set Top Box Applications – Thermal Design Guide, Rev 1.0	17531	See your local Intel field representative
Intel® 855GME and Intel® 852GME Chipset Memory Controller Hub (MCH) – Thermal Design Guide for Embedded Applications, Rev 1.0	273838	http://developer.intel.com/
Thermal Considerations for Passive Set Top Box Design Guide, Rev 1.0	17114	See your local Intel field representative

1.3 Terminology

Table 2. Definitions of Terms

Term	Definition
DDR	Double Data Rate
FCBGA	Flip Chip Ball Grid Array. A package type defined by a plastic substrate on to which 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.
LFM	Linear Feet per Minute
GMCH	Graphics Memory Controller Hub
Natural Convection Cooling (free convection)	The transferring of heat from a surface to a fluid (i.e., air or liquid) where the convection flow is generated only by fluid buoyancy. No airflow devices (i.e., fans) are used in the system.
OEM	Original Equipment Manufacturer
PCB	Printed Circuit Board
TIM	Thermal Interface Material: the thermally conductive compound placed in between the heat sink and die to improve the heat transfer from the die to the heat sink.
TDP	Thermal Design Power: a design point for the component. OEMs must design thermal solutions that meet TDP and $T_{junction}$ specifications as specified in the component datasheet.
$T_{junction}$, T_j	The maximum junction temperature of the die, as measured or specified in the component datasheet.
T_{case}, T_c	The temperature at the geometric center of the top surface of the package. For bare die package, this is the temperature at the center of the back surface of the die.
T_{sink}, T_s	The temperature of the heat sink base plate at the center location of the package or die.
T_{amb}	The ambient temperature locally surrounding the component. The ambient temperature should be measured approximately one inch (25.4 mm) upstream of a passive heat sink or at the fan inlet of an active heat sink.
T_{amb_max}	Maximum allowable T_{amb} that can be supported by a thermal solution.
T_{air}	The air temperature external to the chassis enclosure. Also, referred to as the external ambient temperature, or the chassis ambient temperature.
T_{rise}	The temperature rise of the air as it enters from the chassis till it reaches the region of the component: defined as (T_{amb} - T_{air})
Ψ_{ja}	The thermal resistance between the junction and the ambient air. A measure of global thermal performance of a component thermal solution module using total package thermal design power: (T_j - T_{amb})/TDP.
Ψ_{jc} , $\Psi_{package}$	The thermal resistance between the junction and the package case. Also represents the package resistance. A measure of package thermal performance using total package thermal design power: (T_j – T_c)/TDP.
Ψ_{cs} , Ψ_{TIM}	The case to sink thermal resistance, which is dependent on the thermal interface material (TIM). Also referred to as Ψ_{TIM}. A measure of TIM thermal performance using total package thermal design power: (T_c – T_s)/TDP.
Ψ_{sa} , $\Psi_{heatsink}$	The sink-to-ambient thermal resistance. A measure of heat sink thermal performance using total package thermal design power: (T_s – T_{amb})/TDP.

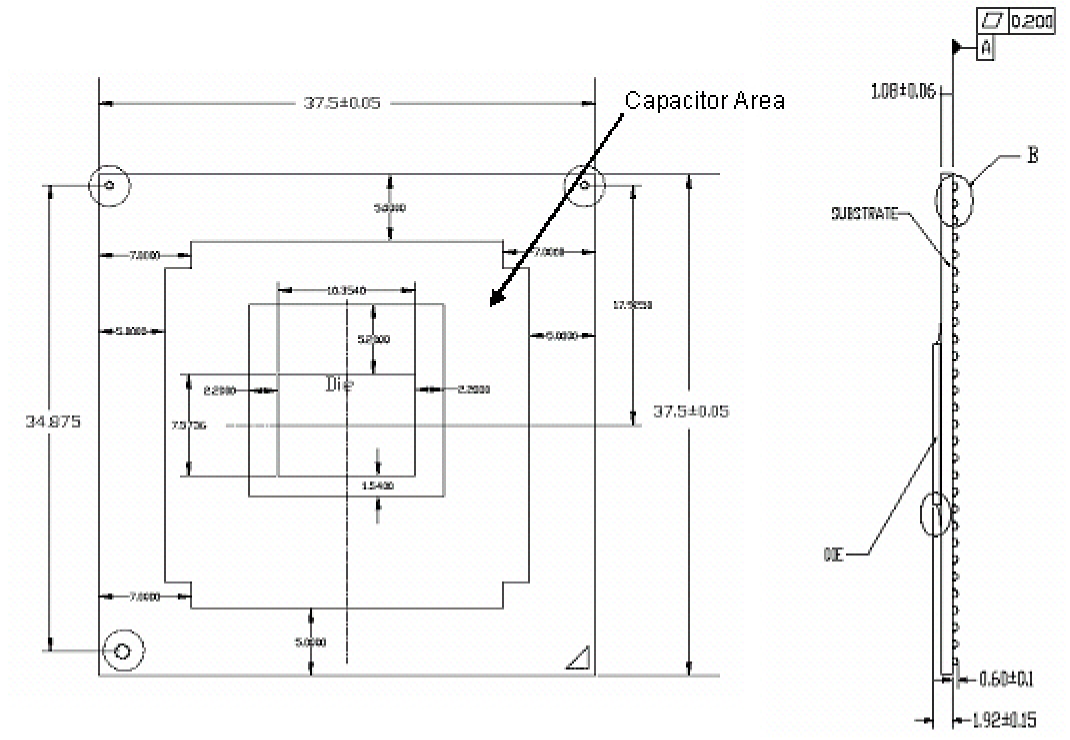
2 Mechanical Guidelines

2.1 Intel® 82854 GMCH Package

The Intel® 82854 GMCH is constructed with a Flip Chip Ball Grid Array (FCBGA) package with a size of 37.5 mm x 37.5 mm. It includes 732 solder ball lands with a ball pitch of 1.27 mm.

Figure 1 provides details of the package dimensions of the Intel® 82854 GMCH. The drawing is not drawn to scale and the units shown are in millimeters. The package consists of a silicon die mounted face down on a plastic substrate populated with solder balls on the bottom side. The Intel® 82854 GMCH also includes capacitors mounted on the top of the package in the area surrounding the die, as outlined in the top view. Because the die-side capacitors are electrically conductive, and only slightly shorter than the die thickness, care should be taken when applying a thermal solution onto the die in order to avoid any accidental electrical shorts.

Figure 1. Intel 82854 GMCH micro-FCBGA package dimensions (mm)

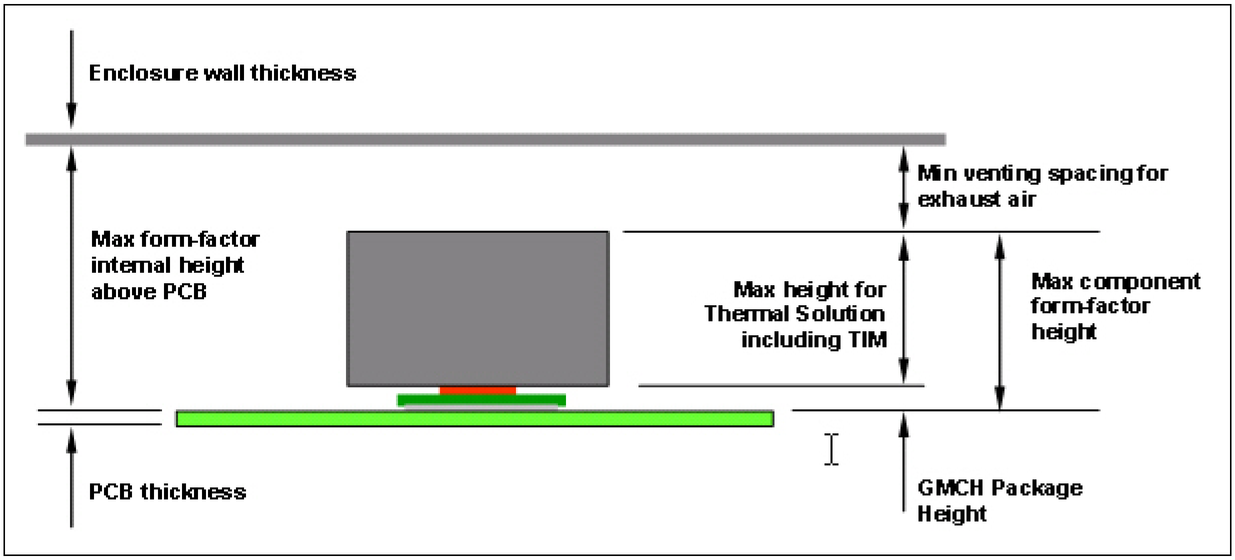


2.2 Thermal Solution Volumetric Constraint Zones

The thermal solutions enabled for the Intel® 82854 GMCH for set top box applications may have volumetric constraint zones that will allow for the thermal solution to be assembled to a system board. System designers must take these zones into account so that the thermal solution will be properly assembled to the board and not interfere with any other components. An example of such volumetric constraint zones for the reference natural convection thermal solutions is shown in "Appendix A Mechanical Drawings".

The maximum allowable height for a thermal solution is very important in the overall thermal performance and is a factor in the volumetric constraint for a thermal solution. This height is determined by the form factor in which the computer system is placed. For the third party reference thermal solutions presented herein, the maximum allowable height was based on a form factor requirement that is assumed to have the height limitation of 1.5" for the heat sink. These solutions may apply for other form factors, but it is up to the system integrator to ensure that all thermal and mechanical requirements are validated in the final intended configuration. Figure 2 shows a generic mechanical stack-up for the Intel® 82854 GMCH and the geometric parameters that need to be accounted for when determining the maximum allowable height for a thermal solution.

Figure 2. Typical Mechanical Stack-up



3 Thermal Guidelines

The overall performance requirement of a component thermal solution depends on the following three parameters:

- Thermal Design Power (TDP)
- Maximum junction temperature (T_j)
- Operating ambient temperature (T_{amb})

The guidelines and recommendations presented in this document are based on specific parameters that are relevant to designing a natural convection thermal solution. The overall heat dissipation capability of a thermal solution depends on many parameters, including:

- Package thermal performance or resistance (Ψ_{jc}, $\Psi_{package}$)
- Thermal performance or resistance of Thermal Interface Material, TIM (Ψ_{cs}, Ψ_{TIM})
- Heat sink performance or resistance (Ψ_{ca}, $\Psi_{heatsink}$)
- Maximum junction temperature, as specified in the datasheet (T_j)
- Operating local ambient temperature to the component (T_{amb})

To develop a reliable thermal solution all of the appropriate variables must be considered. Thermal simulations and characterizations must be performed. The solutions presented in this document must be validated in their final intended system.

3.1 Heat Sink Design Considerations

There are three fundamental modes of heat transfer to be considered:

1. The conduction from the heat source to the heat sink fins. Providing a direct conduction path from the heat source to the heat sink fins and selecting materials with higher thermal conductivity improve the heat sink performance. The cross-sectional area, thickness, and conductivity of the conduction path from the heat source to the fins directly impact the thermal performance of the heat sink. In particular, the quality of the contact between the package die and the heat sink base has a greater impact on the overall thermal solution performance as the cooling requirements become more difficult to satisfy. Thermal Interface Material (TIM) is used to fill in the gap between the die and the bottom surface of the heat sink which would have been filled otherwise with a layer of air and microscopic voids. High performance TIMs with good surface wetting characteristics will thereby improve the overall performance of the stack-up (die-TIM-heat sink). With poor heat sink interface flatness and/or roughness, TIM may not adequately fill the gap. The TIM thermal performance depends on its thermal conductivity, surface wetting characteristics, and the pressure applied to it.
2. The convection from the exposed surfaces to the air stream. After conduction carries the heat from the heat source to the surfaces exposed to air flow, such as the surface of the heat sink fins, the heat is dissipated from the heat sink by means of either convection or radiation heat transfer. Convection heat transfer occurs to the airflow from the surfaces exposed to the flow. Convection heat transfer is characterized by the temperature difference between the exposed surface and the local ambient air and the total area of the exposed surfaces. A thermal solution with a greater temperature difference and larger exposed area will have better cooling capability. In convection, the faster the air velocity over the surface and cooler the air, the more efficient the resulting cooling. In the case of natural convection with no externally driven induced or forced airflow, the convection flow is created by the buoyancy force acting on the heated hot air, and its velocity depends solely on the surface geometry and the surface-to-air temperature difference.
3. The radiation from the component to surrounding surfaces. Radiation heat transfer takes place between any two surfaces facing each other and having different temperatures. In a fanless system, the amount of radiation from a hot component like a heat sink to the cooler surrounding surfaces like the interior wall of the chassis enclosure can be a significant portion of the overall heat sink thermal dissipation. It is strongly recommended that the chassis layout designer take advantage of this naturally existing heat dissipation mechanism by comprehending the radiation phenomenon and promoting this radiation heat transfer. A bare aluminum heat sink can be simply anodized or painted to improve the radiation characteristics of the heat sink surface, resulting in a substantial thermal performance improvement.

3.1.1 Heat Sink Size

The size of the heat sink is dictated by height restrictions in a system and by the foot-print area available on the motherboard. The height and the base plate size of the heat sink must comply with the requirements and recommendations published for the motherboard and chassis form factors of interest.

3.1.2 Heat Sink Weight

With the need to push air cooling toward better performance, heat sink solutions tend to grow larger, resulting in increased weight. The insertion of highly thermally conductive materials like copper to increase heat sink thermal conduction performance results in even heavier solutions. The heat sink weight must take into consideration the package and socket load limits, the mechanical capability of the heat sink retention mechanism, and the mechanical shock and vibration profile targets.

3.1.3 Thermal Interface Material

A thermal interface material between the die and the heat sink base is generally required to improve thermal conduction from the die to the heat sink. Many thermal interface materials can be pre-applied to the heat sink base prior to shipment from the heat sink supplier and allow direct heat sink attach, without the need for a separate thermal interface material dispense or attach process during final assembly. Common types of interface materials include elastomers (i.e., Chomerics* T710) and phase change materials (i.e., Thermagon Tpcm). These types of materials can easily conform to fill small air gaps that are left between the two mating surfaces. These air gaps can act as insulators and will increase the thermal resistance. An interface material can assist in filling these voids and reduce the thermal resistance at the interface.

All thermal interface materials should be sized and positioned on the heat sink base in a way that ensures the entire die area is covered. It is important to compensate for heat sink-to-die attach positional alignment when selecting the proper thermal interface material size. When pre-applied material is used, it is recommended to have a protective cover over it prior to shipping. This cover must be removed prior to heat sink installation.

The thickness of the bond line between the heat sink and die is critical to the thermal performance of the TIM. The bond line thickness is dependent on the pressure between the heat sink and the die. It is imperative that the heat sink is applied to the die with adequate force. For more information on force required and other important documentation, refer to the Chomerics website at http://www.chomerics.com.

The thermal resistance of a material can be estimated by using the following expression which is applicable for one-dimensional conduction heat flow across any conducting materials, such as TIM.

$$\theta_{TIM} = \frac{L}{kA} \tag{1}$$

where θ_{TIM} = Thermal Resistance through the material (ºC/W)
L = thickness of the material (m)
k = effective thermal conductivity of material (W/m-ºC)
A = cross sectional area of the material (m^2)

3.1.4 Mechanical Loading

The pressure applied to the surface of the Intel® 82854 package should not exceed 100 psi, equivalent of 12 lbf.

If the pressure on the surface of the package is exceeded, problems may arise. The solder ball joints between the package and the motherboard may be subjected to fractures that could result in a loss or degradation of electrical signals from the device. Also, the die may be exposed to warpage or, at unusually high levels of stress, cracking.

If a large compressive load is applied to the die surface precautions should be taken to help alleviate some of the load. One manner of doing this is to provide some backing support for the motherboard directly underneath the package. Standoffs can be used between the motherboard and the chassis to add rigidity to the motherboard under the package and reduce the amount of board flexure under large loads.

The generic clip design may also provide mechanical preload on the package to protect the solder joint against damage under mechanical shock. The preload within the specified maximum contact pressure serves to compress the solder ball array between the package and the motherboard. The compression in the solder balls delays the onset of the tensile load under critical shock conditions, and the magnitude of the maximum tensile load is thereby reduced. In this manner, the critical solder balls are protected from tensile loading that may cause damage to the solder joint.

3.1.5 Thermal and Mechanical Reliability

Recommendations for thermal mechanical reliability testing are shown in Table 3. These should be considered as general guidelines. The user should define validation testing requirements based on anticipated use conditions.

Table 3. Reliability Validation

Test[1]	Requirement	Pass/Fail Criteria[2]
Mechanical Shock	• Quantity: three drops for + and – directions in each of three perpendicular axes (i.e., total of 18 drops). • Profile: 50 G trapezoidal waveform, 11 ms duration, 170 in/s minimum velocity change. • Setup: Mount sample board on test fixture	Visual Check and Electrical Functional Test
Random Vibration	• Duration: 10 min/axis, three axes • Frequency Range: 5 Hz to 500 Hz Power Spectral Density (PSD) Profile: 3.13 G RMS	Visual Check and Electrical Functional Test
Power Cycling (for active solutions)	• 7500 on/off cycles with each cycle specified as 3 minutes on, 2 minutes off at 70 °C	Visual Check and Electrical Functional Test
Thermal Cycling	• -5 °C to +70 °C, 500 cycles	Visual Check and Electrical Functional Test
Humidity	• 85% relative humidity, 55 °C, 1000 hours	Visual Check and Electrical Functional Test

Notes:

[1] The above tests are recommended to 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.

3.2 Natural Convection Cooling Considerations

Many factors play an important role in the ability to design a natural convection thermal solution that will keep the die within its maximum operating temperature. Both component attributes (i.e., $T_{junction}$, TDP, etc.) and the system attributes need to be considered. These include:

- Operating local ambient temperature (T_{amb})
- Heat-generating component placement and system orientation
- Location and size of venting
- Available volume for thermal solution

It is very challenging to design one thermal solution that will apply for multiple form factors. Thermal modeling and analysis needs to be performed in order to optimize the thermal solution for the intended form factor and environment. This in essence makes most natural convection thermal solutions custom designs.

3.2.1 Intel® 82854 GMCH Thermal Specifications

Thermal data for the Intel® 82854 GMCH for set top box applications is presented in Table 4. The data is provided for informational purposes only. Please refer to the Intel® 82854 GMCH datasheet for the most up to date information. In the event of conflict, the datasheet supersedes information provided in this document.

Table 4. Thermal Specifications

SKU	Core Vcc (V)	TDP (W)	T_j (°C)
Intel® 82854 GMCH	1.5	5.7	110

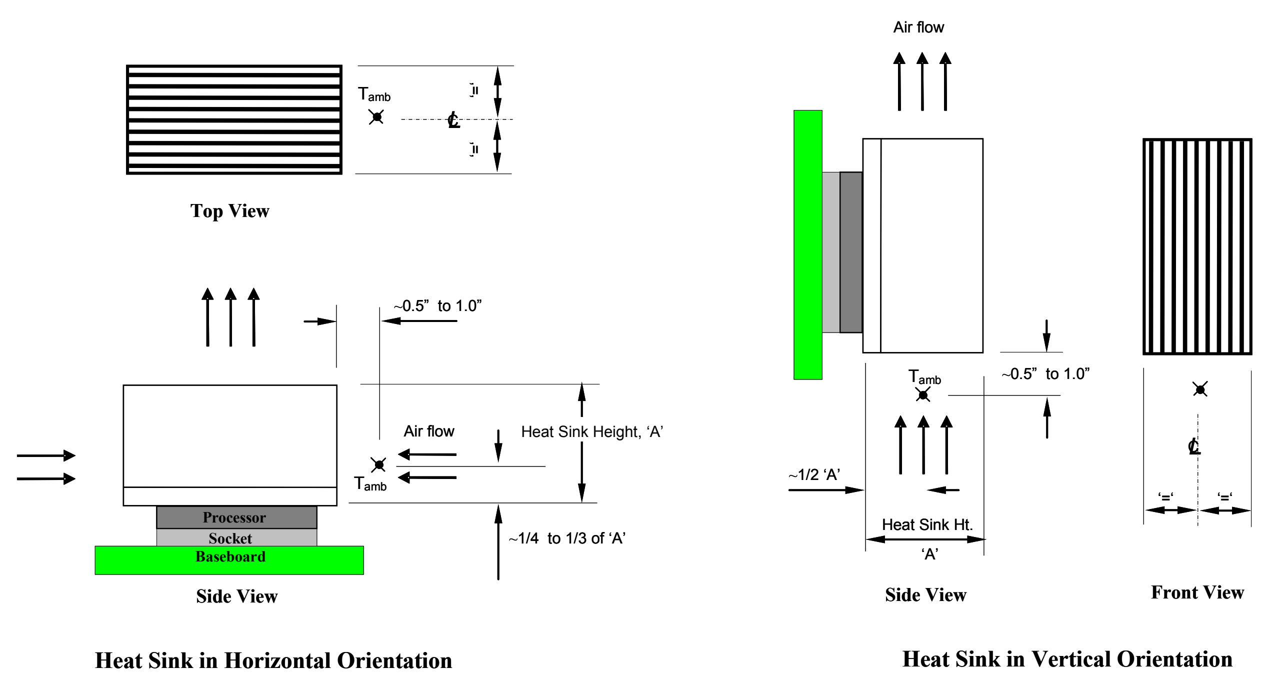
3.2.2 Thermal Design Power

Thermal Design Power (TDP) is defined as the worst-case power dissipated by the component while executing publicly available software under normal operating conditions, at nominal voltages that meet the load line specifications. The TDP definition is synonymous with the Thermal Design Power (typical) specification referred to in previous Intel data sheets. The Intel TDP specification is a recommended design point and is not representative of the absolute maximum power the component may dissipate under worst case conditions. For any excursions beyond TDP, the Thermal Management features, described in Section 5 of this document, are available to maintain the component thermal specifications.

3.2.3 Local Ambient Temperature (T_{amb})

The local ambient temperature (T_{amb}) has a significant influence when developing a thermal solution. The T_{amb} is defined as the local temperature at the location approximately one inch upstream of the thermal solution in a passive system or directly upstream of the fan intake of an active solution. For a natural convection system the T_{amb} is measured at the same point as a passive system, but the exact relative location to the heat sink depends on the orientation of the heat sink with respect to the local geometry. This location should be chosen so that the measured temperature is not affected by the air that is exhausting away from the heat sink. In a horizontal configuration, the measurement should be taken at the sides of the heat sink. In vertical orientation, the measurement should be taken about one inch below the leading edge. The local ambient temperature includes the external air temperature outside the enclosure plus any temperature rise due to other components in the system. The recommended measurement locations for T_{amb} are shown in Figure 3.

Figure 3. Local Ambient Temperature Locations for Passive Heat Sink



3.2.4 Thermal Resistance of a Heat Sink

The thermal characterization parameter or Ψ (Psi) is calculated for a given thermal system so that it may be compared to other thermal systems. In any computer system it is necessary to calculate the required thermal characterization parameter needed in order to keep the die within its operating temperatures. The thermal solution must maintain the die at or below the specified junction temperature. The equation for calculating the junction-to-ambient thermal characterization parameter is shown in Equation 2.

$$\psi_{ja} = \frac{T_j - T_{amb}}{TDP} \tag{2}$$

where Ψ_{ja} = junction-to-ambient thermal resistance in °C/W
T_j = maximum junction temperature of die as specified in Table 4
T_{amb} = local ambient air temperature in °C
TDP = Thermal Design Power in W

When calculating the required Ψ, it is important to determine the allowable temperature rise from the maximum operating environment to the component's maximum specification. It is important to know that lower Ψ_{ja} values require better thermal solutions and vice versa.

Typical T_{amb} values for natural convection systems depend linearly on T_{rise} which in turn depends largely on specific chassis design and the relative location of the component of interest with respect to other heat generating components within the system. For typical set top box chasses with good venting designs incorporated at thermally critical locations, this rise ranges from approximately 10 to 20°C. Considering a typical value for the external air temperature in set-top-box applications at T_{air} = 35-45°C, T_{amb} may become as high as 60-65°C. In some worst cases with thermally challenging circumstances, such as a compact small form-factor box placed in a confined or enclosed environment, it may be necessary to anticipate T_{amb} value of as high as 70°C. As an example, the thermal solution needed to cool an Intel® 82854 GMCH with a T_j of 110 °C and a TDP of 5.7W in a system with a T_{amb} = 70 °C, would need to have a junction-to-ambient thermal resistance of:

$$\psi_{ja} = \frac{110^o C - 70^o C}{5.7W} = 7.02^o C / W \tag{3}$$

The above case requires a thermal solution with a thermal characterization parameter less than or equal to 7.02°C/W to keep the component temperatures at or below the specifications.

Table 5 shows the required thermal performance at various local ambient temperatures for the Intel® 82854 GMCH. Figure 4, which is essentially a graphical version of Table 5, shows the thermal solution requirements for the Intel® 82854 GMCH at TDP = 5.7W as a function of increasing T_{amb}.

Note: Note that as the T_{amb} increases, a better Thermal Solution is needed (e.g., Ψ_{ja} must decrease).

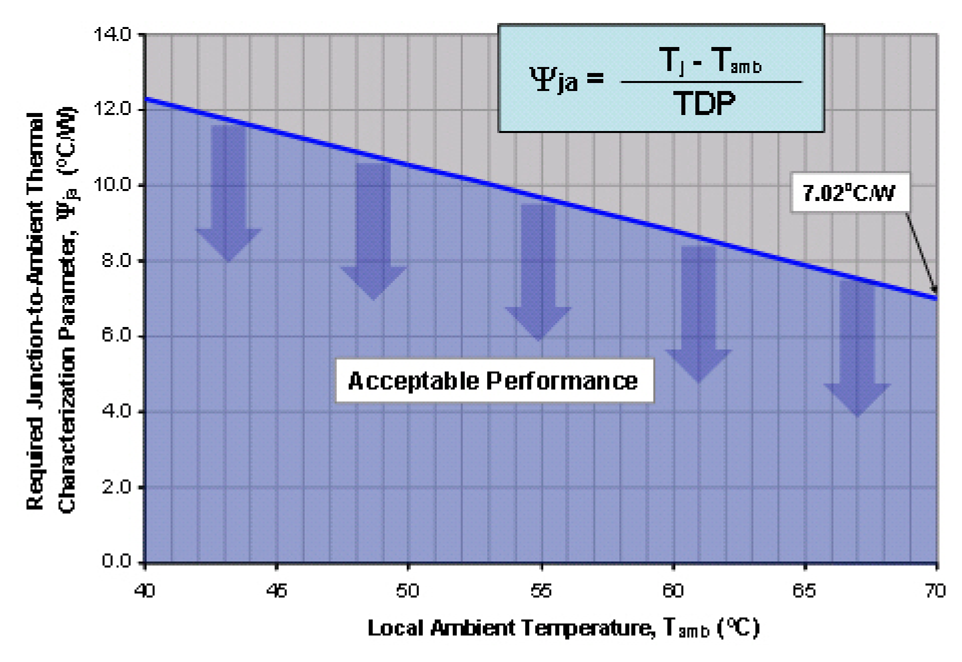
Table 5. Intel® 82854 GMCH Ψja Thermal Performance Requirements

Intel® 82854 GMCH		Required Thermal Solution Performance at Various Ambient						
		40°C	4 °C	5 °C	55°C	6 °C	6 °C	7 °C
TDP Max (W)	T_j Max (°C	Ψ_{ja} (°C/W)	Ψ_{ja} (°C/W)	Ψ_{ja} (°C/W)	Ψ_{ja} (°C/W)	Ψ_{ja} (°C/W)	Ψ_{ja} (°C/W)	Ψ_{ja} (°C/W)
5.	11	12.2	11.4	10.53	9.6	8.7	7.8	7.02

Note: Specifications (TDP, Tj) provided for reference only. Refer to the latest datasheet for the most recent data.

$\Psi_{ja} = (T_{junction} - T_{amb}) / TDP$: junction-to-ambient thermal resistance for the thermal solution.

Figure 4. Required Thermal Performance as a Function of Ambient Temperature for Intel® 82854 GMCH at Tj = 110oC and TDP = 5.7W



3.2.5 Component Placement, System Orientation and Venting

The placement of heat generating components in a system has an influence in the ability to develop a natural convection thermal solution. The component placement should be optimized for a number of reasons, these include:

- Location of venting in the chassis: the vents in the chassis will allow for external air that is at a lower temperature to enter the chassis and for the heated air to escape the system. For critical components with the highest amount of power generation (usually the CPU and GMCH), it is necessary to place both the inlet and outlet vents as close to them as possible in the chassis. This will facilitate the movement of air caused by buoyancy effects hence minimizing the internal temperature rise, T_{rise}, caused by the recirculation of the hot air rising from the component but unable to exhaust out of the chassis.
- Orientation of the system: the orientation of the system influences where the components should be placed and the ability to develop a natural convection solution. If the system is in a vertical configuration, the component should be placed at the bottom of the motherboard. This will allow for the air to rise and prevent any unnecessary pre-heating of the air surrounding the component. When the system is in a horizontal configuration, the component should be placed on the topside of the motherboard in order to avoid trapping the air underneath the board. The main goal of the component placement in regards to system orientation is to minimize the local ambient temperature and avoid placing the component and other critical components in unfavorable boundary conditions.
- Maximize the effects of radiation from hot components while minimizing the effect of irradiation to the components: the proximity of the power generating components to each other will affect not only the local ambient temperature but will reduce the radiation heat dissipation from the components. High power dissipating parts should be placed as far from each other as motherboard size and electrical routing constraints allow.

The component placement, location of the vents, and the orientation of the motherboard directly influence the value of T_{amb} hence the ability to develop and optimize natural convection thermal solution. A well designed chassis that provides lower T_{amb} will in turn allow smaller and more cost effective thermal solutions to the critical components. It is highly recommended that thermal simulations and analysis be performed on a system level. A Computational Fluid Dynamics (CFD) program may be used to study multiple tradeoff scenarios, and system configurations can be modeled to optimize the thermal solution to meet component's thermal requirements. Proper system level thermal modeling allows the thermal solution designer to optimize thermal solutions and be confident in their performance prior to fabricating hardware. This results in better solutions, lower design time, and faster integration. More in-depth discussions and guidelines on the system level considerations are provided in the *Thermal Considerations for Passive Set Top Box Design Guide.*

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3.3 Thermal Validations

The performance of a thermal solution is dependent on many parameters including the component’s maximum junction temperature, T_j, the operating ambient temperature, T_{amb}, the specific heat sink design, component materials, and the amount of airflow. In this document the designs are targeted for a natural convection environment, so there is no induced airflow. The guidelines and recommendations presented in this document are referenced to the parameter, T_{amb}, which relates the performance of a local heat sink solution to the local boundary conditions determined and provided by a given system. It is the responsibility of each product design team to ensure the target T_{amb} is achieved in a given chassis design and to verify that thermal solutions are suitable for their specific use.

4 Temperature Measurement Metrology

4.1 Case Temperature Measurements

Intel has established guidelines for the proper techniques to be used when measuring case temperature. Section 5 contains information on running an application program that emulates anticipated TDP.

The top surface temperature at the geometric center of the die corresponds to the maximum Tcase.

4.2 Zero-Degree Angle Attach Methodology

1. Mill a 3.3 mm (0.13”) diameter hole centered on bottom of the heat sink base (see Figure 5). The milled hole should be approximately 1.5 mm (0.06”) deep.
2. Mill a 1.3 mm (0.05”) wide slot, 0.5 mm (0.02”) deep, from the centered hole to one edge of the heat sink. The slot should be in the direction parallel to the heat sink fins (see Figure 5 and Figure 6).
3. Attach thermal interface material (TIM) to the bottom of the heat sink 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 heat sink 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 there is no contact between the thermocouple cement and the heat sink base because any contact will affect the thermocouple reading. It is critical that the thermocouple bead makes contact with the die (see Figure 6).
6. Attach heat sink assembly to the GMCH and route the thermocouple wires out through the milled slot.

Figure 5. Zero-Degree Angle Attach Heatsink Modifications (not to scale)

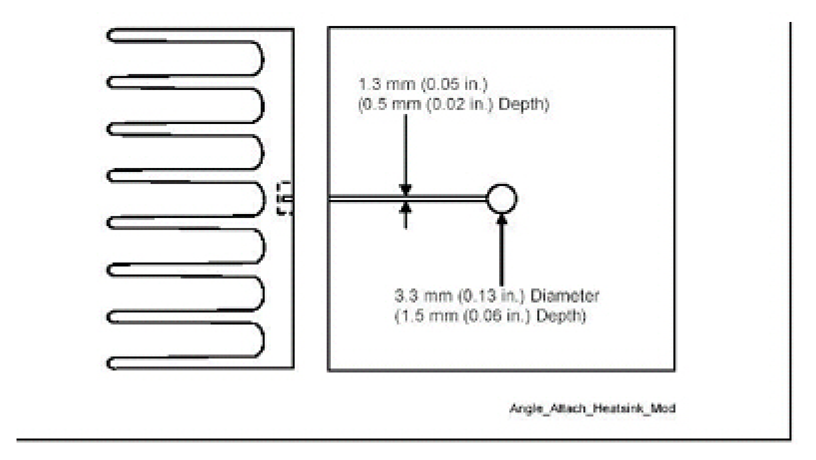
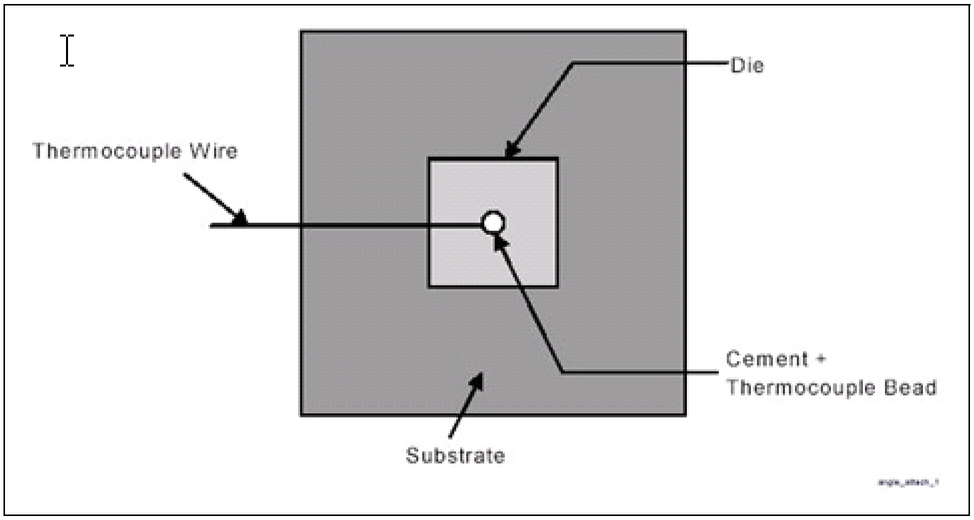


Figure 6. Zero-Degree Angle Attach Methodology (not to scale)



4.3 Maximum Case Temperature Specification

Use Table 6 to determine the maximum temperature value when performing thermal laboratory testing with the Intel® 82854 GMCH using the metrology described in this chapter and the TDP Stress Application. More information about the TDP stress application may be found in Section 5.

Table 6. Intel® 82854 GMCH Maximum Case Temperature Value

Tcase,max (°C)
105

5 Thermal Management Features and Tools

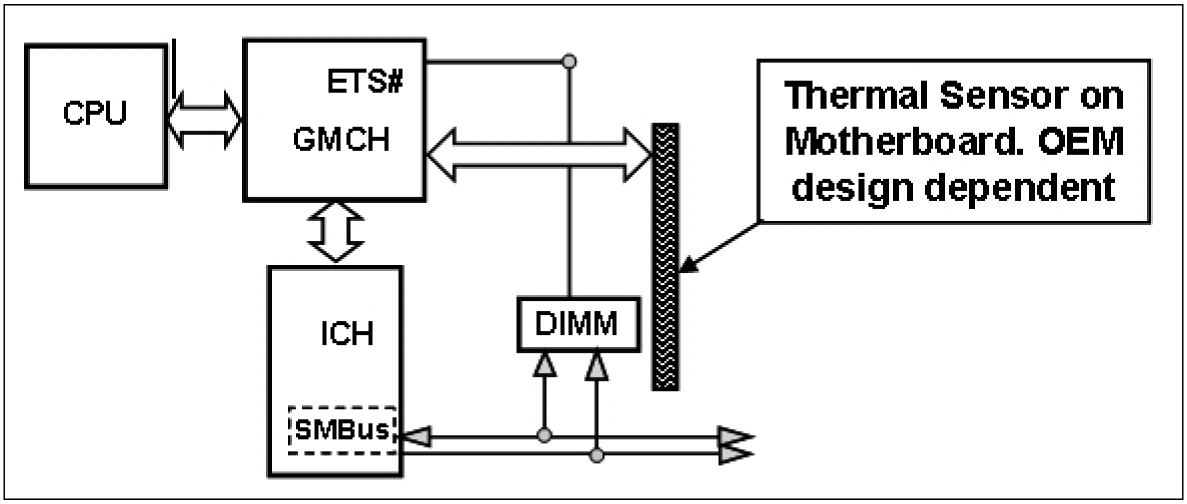
5.1 Internal Temperature Sensor

The Intel® 82854 GMCH will include an on-die temperature sensor that can be used to protect the die from exceeding the Tj max specification. Upon detection that the sensor has reached Tj max the Intel® 82854 GMCH will be capable of initiating a bandwidth throttling event that will reduce the device power and temperature. The sensor will also prove to be useful in optimizing the thermal design for the package by being able to provide junction temperature during testing and evaluation of the thermal solution.

5.2 External Temperature Sensor

The Intel® 82854 GMCH is designed to accept an input signal from an external temperature sensor. The external sensor can be placed in a location close to the DDR memory and upon detecting a "hot" condition the device would throttle the READ bandwidth. Proper placement of the sensor would have to be determined by the OEM. The OEM would have to characterize the temperature difference between the sensor and the DDR memory devices to determine the best placement for the sensor. On detection of a "hot" condition a signal is communicated directly from the thermal sensor to the device via the ETS# pin as shown in Figure 7. The external thermal sensor can be programmed via the SMBus.

Figure 7. External Temperature Sensor



5.3 Thermal Throttling

The Intel 82854 GMCH is available with throttling functionality to protect the device from power virus conditions that can cause junction temperatures to increase beyond maximum allowable junction temperatures. Two different methods of thermal throttling are available on the Intel® 82854 GMCH: bandwidth triggered and temperature based throttling.

There are three important things to remember about throttling:

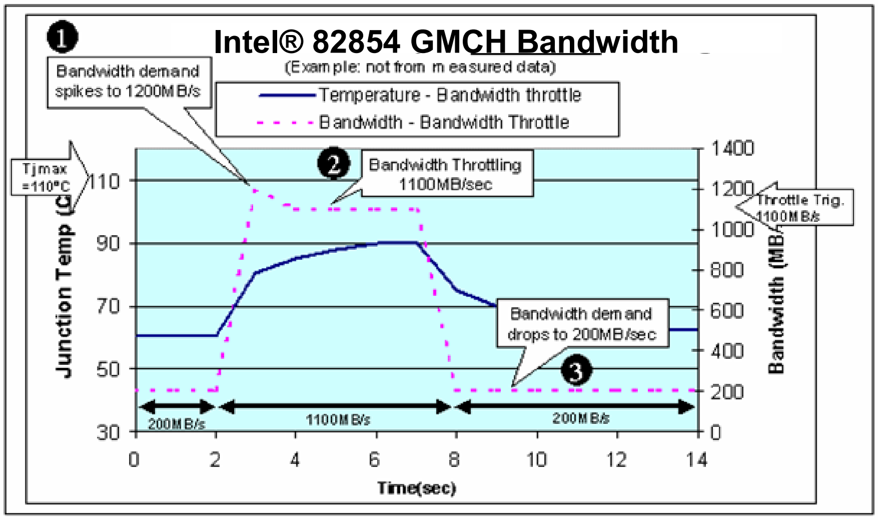
1. It is only intended to be a safeguard to ensure that junction temperatures do not exceed maximum specified junction temperatures.
2. The component thermal solutions must still be designed to TDP. Throttling is not recommended as a method of designing the device cooling capability to levels below TDP.
3. This mechanism was carefully designed to have minimal impact on real applications, while safeguarding against harmful synthetic applications. However, throttling may affect performance of the device. Performance of the Intel® 82854 GMCH should be verified by testing with benchmarks.

5.3.1 Bandwidth Triggered Throttling

Bandwidth triggered throttling will limit the maximum bandwidth that can be sustained over long periods as a safeguard against a thermal virus. This method of thermal management will temporarily decrease bandwidth performance of the Intel® 82854 GMCH when an application demands large, sustained bandwidth levels that could cause the device to exceed its maximum junction temperature. However, in order to trigger bandwidth throttling, the Intel® 82854 GMCH bandwidth must exceed the threshold over an entire sampling window. Most applications use high bandwidths only in short bursts, and through application analysis, this sampling window has been set large enough so that these applications that create short bursts in bandwidth will not see any throttling. Only a sustained high bandwidth for a period longer than the sampling window has the potential of exceeding thermal limits, and the throttle mechanism is designed to protect the chip against those potentially harmful applications.

Figure 8 provides a theoretical example of how bandwidth throttling would work. In this example, the bandwidth is set to throttle at 1100 MB/sec. The throttling value would be determined based on the worst case operating conditions. This throttle setting is enabled upon system boot and only one value can be set for the WRITE operations of the device. To determine bandwidth, the read/write operations are being monitored continuously by hardware inside the Intel® 82854 GMCH within a one second window.

Figure 8. Intel® 82854 GMCH Bandwidth Throttling



1. The system is operating at an idle workload until an application that requires a large amount of bandwidth is initiated. The above example shows a case where the peak bandwidth is 1200 MB/sec. for an entire sampling window interval, and it will be reduced to the bandwidth throttle setting limit of 1100 MB/sec. The throttle setting of 1100 MB/sec. effectively places a cap on the allowable bandwidth. The peak bandwidth is dependent on memory populated and can reach up to 1600 MB/sec. The bandwidth throttling limit can be configured via BIOS or configuration registers.

Note

Applications are still allowed to exceed the bandwidth throttling limit in short bursts that last less than the sampling window period.

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2. The Intel® 82854 GMCH will continue to operate at the throttled amount of 1100 MB/sec. until the application no longer requires this level of sustained bandwidth. In this case the junction temperature has not increased to a temperature that is close to the maximum junction temperature limit of 110º C. So it appears that for the brief period that the large bandwidth level was required the device was unnecessarily throttled. A drawback of using bandwidth triggered throttling is that under certain conditions when the system is not operating under worse case conditions the device will be throttled regardless of the junction temperature.
3. Once the application stops the system workload will return to a lower workload.

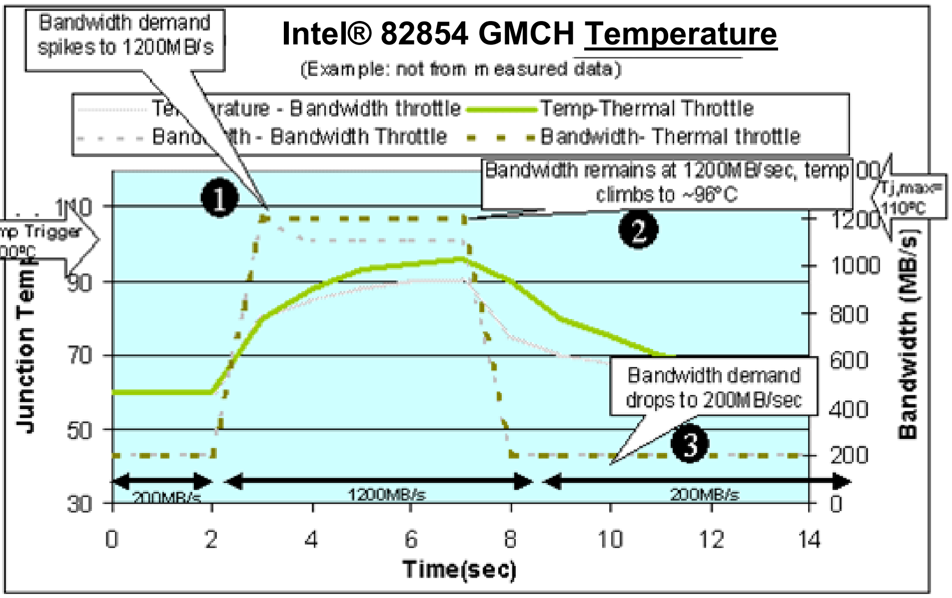
5.3.2 Temperature Triggered Throttling

Temperature triggered throttling will limit the maximum achievable bandwidth as a safeguard against a thermal virus only when the junction temperature reaches a specified trip point temperature. This method of thermal throttling is an improvement over the bandwidth triggered throttling method because the Intel® 82854 GMCH will only reduce bandwidth performance when it is absolutely necessary under a preset condition.

The temperature throttle trip point is programmed into the Intel® 82854 GMCH at boot. If the temperature of the device goes beyond the trip point limit, the device will be throttled to a predetermined maximum throttling amount until the temperature drops below the same temperature limit.

Figure 9 provides an example of how temperature triggered throttling would optimize throttling under conditions similar to the scenario that was described in Section 5.3.1. In this scenario the hot trip temperature is set at 100 ºC. Keep in mind that the Tj,max specification for the Intel® 82854 GMCH is 110 ºC, and the example described in the section is only intended to illustrate the behavior. The hot trip temperature represents the temperature setpoint at which the device will initiate throttling.

Figure 9. Intel® 82854 GMCH Temperature Throttling



1. The system is operating at an idle workload until an application that requires a large amount of bandwidth is initiated. The application demands a peak bandwidth of 1200 MB/sec. and the device will sustain this bandwidth level until the temperature climbs above the hot trip setting of 100ºC.
2. During this test the device operates at a 1200 MB/sec. bandwidth level for a period longer than the sampling window because the junction temperature has not increased above the hot trip point setting. In this case the Intel® 82854 GMCH is demonstrating better bandwidth performance while operating under the same application as in the bandwidth triggering case. This is clearly a preferred method of throttling the device only when it is absolutely necessary.
3. Once the application stops the system workload will return to its idle level of 200 MB/sec. In this example, the Intel® 82854 GMCH never required any thermal throttling. The method will potentially allow for large, brief bursts of bandwidth loading without impeding the performance.

6 Third Party Enabled Solutions

A number of natural convection thermal solutions were analyzed, and a set of baseline heat sink designs optimized for the Intel® 82854 GMCH in natural convection applications were established for a typical set top box form factor. As stated in Section 3.2 it is very important to consider all system and component boundary conditions when designing a natural convection thermal solution.

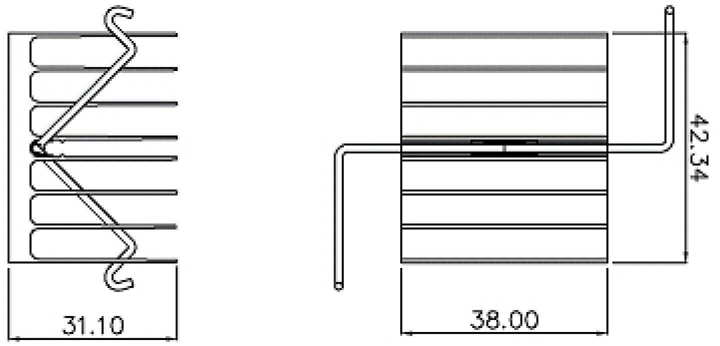
Based on the optimum heat sink parameters implemented in the baseline heat sink design, a number of passive heat sinks have been proposed by different suppliers for delivering the thermal performance required to cool the Intel® 82854 GMCH over a range of T_{amb} variations as illustrated in Section 3.2.4. These heat sinks are a good fit for platforms requiring a passive thermal solution if the z-height allowed is similar to the heights typically allowed for ATX family form factor solutions. The following sections provide details on the different passive heat sink designs provided by a number of suppliers. A list of heat-sink suppliers who also provide the total thermal solution set, including TIM and retention mechanisms, is provided in Section 7.1.

The performance predictions of the thermal solutions provided herein are for reference purposes only. These values were predicted based on a thermal solution stack-up commonly employed for cooling FCBGA packages in a typical set top box environment. As such, they do not include any variations that may be introduced by employing different set of solution stack-up with respect to TIM and the retention mechanism, nor do they imply any statistical significance. It is up to the system integrator to perform validation in the final intended system, including the heat sink, attachment method, and thermal interface material.

6.1 Aavid Passive Heat Sink

The Aavid heat sink is a black anodized aluminum extrusion, delivered with a low cost spring clip and pre-applied thermal interface material. Aavid recommends Thermagon T-pcm or T-mate2905 for TIM. These are phase change materials (PCMs) that are naturally tacky at room temperatures, requiring no adhesives or preheating. PCM means the material will change properties at elevated temperatures to increase thermal performance. An assembled part view is provided below. Dimensions are in mm.

Figure 10. Front and top views of Aavid passive heat sink



The passive heat sink is made of 6063-T5 aluminum extrusion alloy and has been optimized for natural convection applications while meeting the form factor and retention mechanism constraints of a typical set-top-box system. A complete set of engineering drawings for the heat sink and the clip is provided in Figure 15 in "Appendix A Mechanical Drawings".

Thermal performance, Ψ_{sa}, of this heat sink in natural convection cooling is provided in Table 7. Anodizing the heat sink surface enhances the radiation performance at an incrementally added cost. Typically it would increase the heat sink part cost by approximately 10%, but the performance gain of anodized heat sink is typically 10-20% over non-anodized parts. In natural convection applications, anodization or even thin surface painting often is a cost effective performance enhancement method. Using the predicted heat sink performance characteristics, the corresponding overall thermal performance of the component, Ψ_{ja}, is determined using a thermal network analysis. These parameters are tabulated below:

Table 7. Thermal performance of Aavid passive heat sink

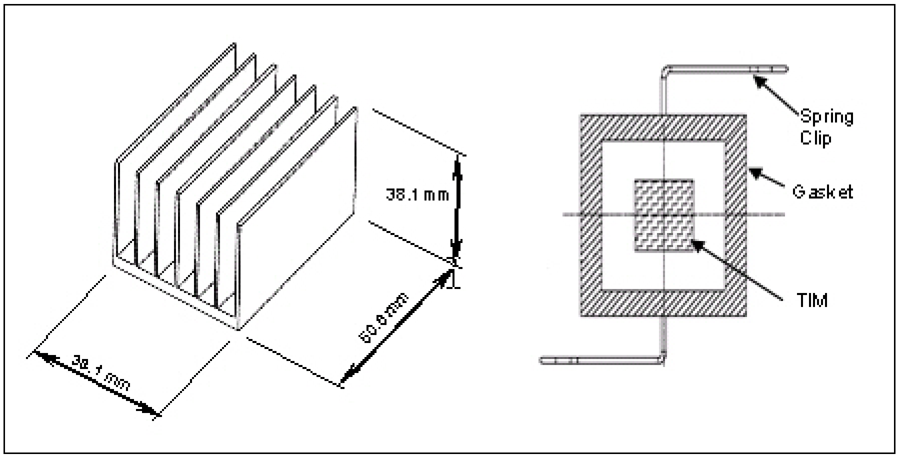
	Non-anodized	Black Anodized
Ψ_{sa} (°C/W)	7.5	6.3
Ψ_{ja} (°C/W)	6.7	6.0
T_{amb_max} (°C)	71	76

The corresponding local maximum ambient air temperature, T_{amb_max} , that can be supported by the heat sink solution is also included in the table. For example, the black anodized heat sink is capable of cooling an Intel® 82854 GMCH at TDP=5.7W with local ambient temperatures up to T_{amb} = 76°C without breaking the thermal specification of T_j =110°C.

6.2 CCI Passive Heat Sink

The CCI Technology's heat sink is an aluminum extrusion, delivered with pre-applied thermal interface material, Powerstrate 51-SA AF-S-10H-07B or Shinetsu 7762 Thermal Grease, a gasket, and a low cost spring clip. An isometric and the bottom views are provided below showing the TIM at the center and the peripheral gasket. A complete set of mechanical drawing of the parts is provided in Figure 16 in the "Appendix A Mechanical Drawings". CCI Technology also recommends a spring loaded nylon fastener as an alternative retention mechanism which may also be used with the heat sinks provided by other suppliers (see Figure 17 in the appendix for details).

Figure 11. Isometric and bottom views of CCI passive heat sink



This passive heat sink is also made of 6063-T5 aluminum extrusion alloy and has been optimized for natural convection applications while meeting the form factor and retention mechanism constraints of a typical set-top-box system. Thermal performance, Ψ_{sa}, of this heat sink in natural convection cooling is provided in Table 8. Anodizing the heat sink surface enhances the radiation performance at an incrementally added cost. Typically it would increase the heat sink part cost by approximately 10%, but the performance gain of anodized heat sink is typically 10-20% over non-anodized parts. In natural convection applications, it is often the situation that anodization or even thin surface painting is a cost effective performance enhancement method. Using the predicted heat sink performance characteristics, the corresponding overall thermal performance of the component, Ψ_{ja}, is determined using a thermal network analysis. These parameters are tabulated below:

Table 8. Thermal performance of CCI passive heat sink

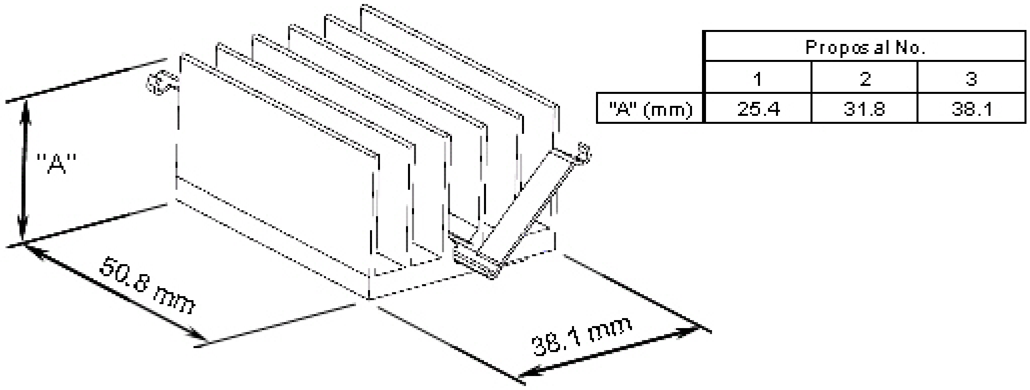
	Non-anodized	**Black Anodized**
Ψ_{sa} (°C/W)	6.3	5.3
Ψ_{ja} (°C/W)	6.0	5.3
T_{amb_max} (°C)	76	80

The corresponding local maximum ambient air temperature, T_{amb_max} , that can be supported by the heat sink solution is also included in the table. For example, the non-anodized heat sink is capable of cooling an Intel® 82854 GMCH at TDP=5.7W with local ambient temperatures up to T_{amb} = 76°C without breaking the thermal specification of T_j =110°C.

6.3 Cooler Master Passive Heat Sinks

The Cooler Master heat sinks are delivered with pre-applied thermal interface material and a nickel plated high strength steel clip. This TIM, Powerstrate* 51, manufactured by Power Devices, Inc., is a phase-change thermal interface material. This means the material will change properties at elevated temperatures to increase thermal performance. These phase change characteristics must be accounted for when testing the Cooler Master heat sinks. At low temperatures, the heat sink performance will be significantly degraded, but at elevated junction temperatures, the material will undergo a change phase and improve in performance. For more information, see the Power Devices website at: http://www.powerdevices.com. An isometric view of Cooler Master heat sinks with the clip inserted in place is provided in Figure 12.

Figure 12. Isometric view of Cooler Master passive heat sinks



	Proposal No.		
	1	2	3
"A" (mm)	25.4	31.8	38.1

These passive heat sinks are made of 6063-T5 aluminum extrusion alloy and have been optimized for natural convection applications while meeting the form factor and retention mechanism constraints of a typical set-top-box system. A complete set of engineering drawings for the heat sinks, retention clip, and TIM is provided in Figure 18 in "Appendix A Mechanical Drawings".

Thermal performances, Ψ_{sa}, of this family of heat sinks in natural convection cooling with and without anodization are provided inTable 9. Anodizing the heat sink surface enhances the radiation performance at an incrementally added cost. Typically it would increase the heat sink part cost by approximately 10%, but as can be seen from the table the performance gain of anodized heat sinks are well over 20% over non-anodized parts. In natural convection applications, it is often the situation that anodization or even thin surface painting is a cost effective performance enhancement method. Using the predicted heat sink performance characteristics, the corresponding overall thermal performance of the component, Ψ_{ja}, is determined using a thermal network analysis. These parameters are tabulated below:

Table 9. Thermal performance of Cooler Master passive heat sinks.

Surface Treatment	**Clear Chromated**			**Black Anodized**		
Proposal No.	**1**	**2**	**3**	**1**	**2**	**3**
Ψ_{sa} (°C/W)	8.8	7.5	6.6	7.1	6.1	5.4
Ψ_{ja} (°C/W)	7.5	6.7	6.1	6.5	5.8	5.4
T_{amb_max} (°C)	67	72	75	73	77	80

The corresponding local maximum ambient air temperature, T_{amb_max} , that can be supported by the heat sink solution is also included in the table. For example, the clear chromated No. 1 heat sink is capable of cooling the Intel® 82854 GMCH at TDP=5.7W with local ambient temperatures up to T_{amb} = 67°C without breaking the thermal specification of T_j =110°C.

6.4 Recommended Thermal Interface Materials

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

The heat sink solutions analyzed in this document are assumed to be using a high compliant, low cost thermal interface materials, such as Chmerics T710, Powerstrate 51-SA AF-S-10H-07B, or Shinetsu 7762 thermal grease. Alternative materials may be used at user's discretion. Although heat suppliers provide various TIMs as a part of total solutions, a list of vendors who specialize in TIM is provided in Section 7.2. The entire heat sink assembly, including the heat sink, attachment method, and thermal interface material, must be validated together in its final intended use.

6.5 Recommended Attachment Methods

The thermal solution can be attached to the motherboard in a number of ways. The thermal solutions may be designed with mounting holes in the heat sink base for a through-hole type of fastening mechanism, or a groove in between the fins for a spring clip-like retention mechanism. A typical through-hole retention mechanism uses a set of 4 spring-loaded fasteners to apply an even load on the die. For a spring-clip type mechanism, a set of mating hooks need to be placed on the motherboard at corresponding locations, as shown in Figure 15 for the Aavid heat sink. Different dimensions may be employed provided that there are enough clearances with other components on the motherboard, as well as with the heat sink and a sufficient contact pressure to the TIM can be applied. For more details and design specific modifications, consult with heat sink suppliers.

7 Vendor Contact Information

7.1 Heat Sink Suppliers

Aavid Thermalloy LCC
80 Commercial Street
Concord, NH 03301 USA
Tel: 603-224-9988
e-mail: info@aavid.com
web: www.aavidthermalloy.com

CCI – Chaun Choung Technology Corp.
US: 2204 Forbes Drive, Suite 104
Austin, TX 78754
e-mail: eunice_chen@ccic.com.tw
APAC: F12, No. 123-1, Hsing-De Road
Sanchung City, Taipei, Taiwan
Tel: 886-2-29952666~8
e-mail: monica_chih@ccic.com.tw
Web: www.ccic.com.tw

Cooler Master Co., Ltd.
9F, No. 786, Chung Cheng Road,
Chung Ho city, Taipei, Taiwan, R.O.C.
Tel: +886-(0)2-32340050
Fax: +886-(0)2-32340051
e-mail: sales@coolermaster.com.tw
Web: www.coolermaster.com

ThermaFlo Inc.
3817 Old Conejo Road
Newbury Park, CA 91320 USA
Tel: 805-498-9991
e-mail: info@thermaflo.com
Web: www.thermaflo.com

Tyco Electronics Corporation
464 N. Halsted Court
Chandler, AZ 85225-4032
Tel: 480-857-0011
Web: www.tycoelectronics.com

7.2 Thermal Interface Material Suppliers

Berquist Company
18930 W. 78th Street
Chanhassen, MN 55317 USA
Tel: 800-347-4572
Web: www.berquistcompany.com

Chomerics
77 Dragon Court
Woburn, MA 01888 USA
Tel: 781-935-4850
E-mail: chomailbox@parker.com
Web: www.chomerics.com

Honeywell International Inc.
101 Columbia Road
Morristown, NJ 07962 USA
Tel: 973-455-2000
Web: www.honeywell.com

Power Devices Inc.
26941 Cabot Road, Bldg 124
Laguna Hills, CA 92653 USA
Tel: 949-582-6712
e-mail: power.devices@loctite.com
Web: www.powerdevices.com

Shin-Etsu Micro Si. Inc.
10028 S. 51st St.
Phoenix, AZ 85044
(480) 893-8898
Web: www.microsi.com

Thermagon, Inc.
4707 Detroit Avenue
Cleveland, OH 44102 USA
Tel: 216-939-2300
e-mail: info@thermagon.com
Web: www.thermagon.com

Appendix A Mechanical Drawings

Table 10. Mechanical Drawing List (shown on the following pages).

Figure No.	Title
13	Natural Convection Small Form Factor Heat Sink Volumetric Constraint Zone (Primary Side).
14	Natural Convection Small Form Factor Heat Sink Volumetric Constraint Zone (Secondary Side).
15	Aavid Thermal Solution.
16	CCI Thermal Solution.
17	CCI’s Alternative Retention Mechanism.
18	Cooler Master Thermal Solution.

Figure 13. Natural Convection Small Form Factor Heat Sink Volumetric Constraint Zone (Primary Side)

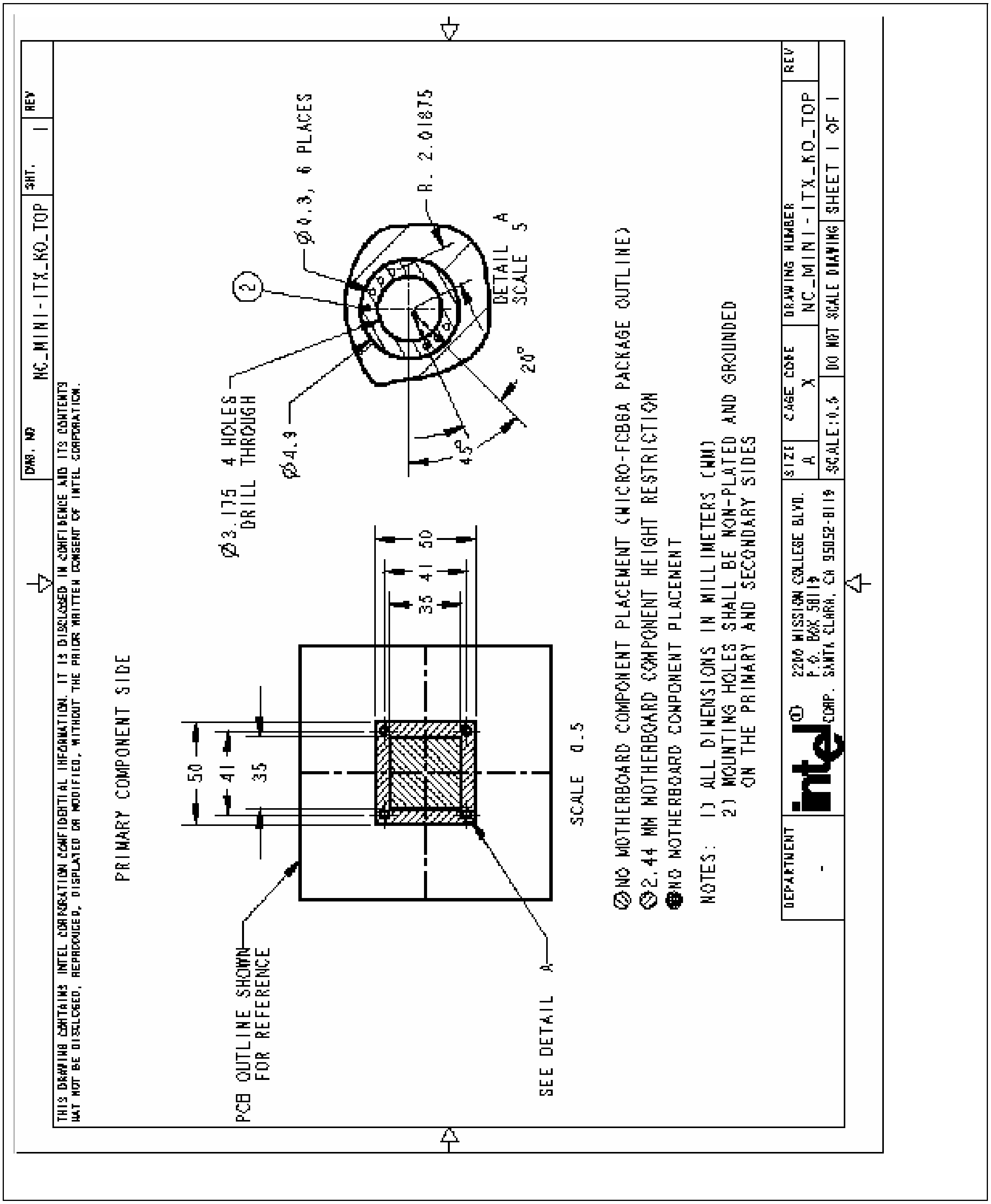


Figure 14. Natural Convection Small Form Factor Heat Sink Volumetric Constraint Zone (Secondary Side).

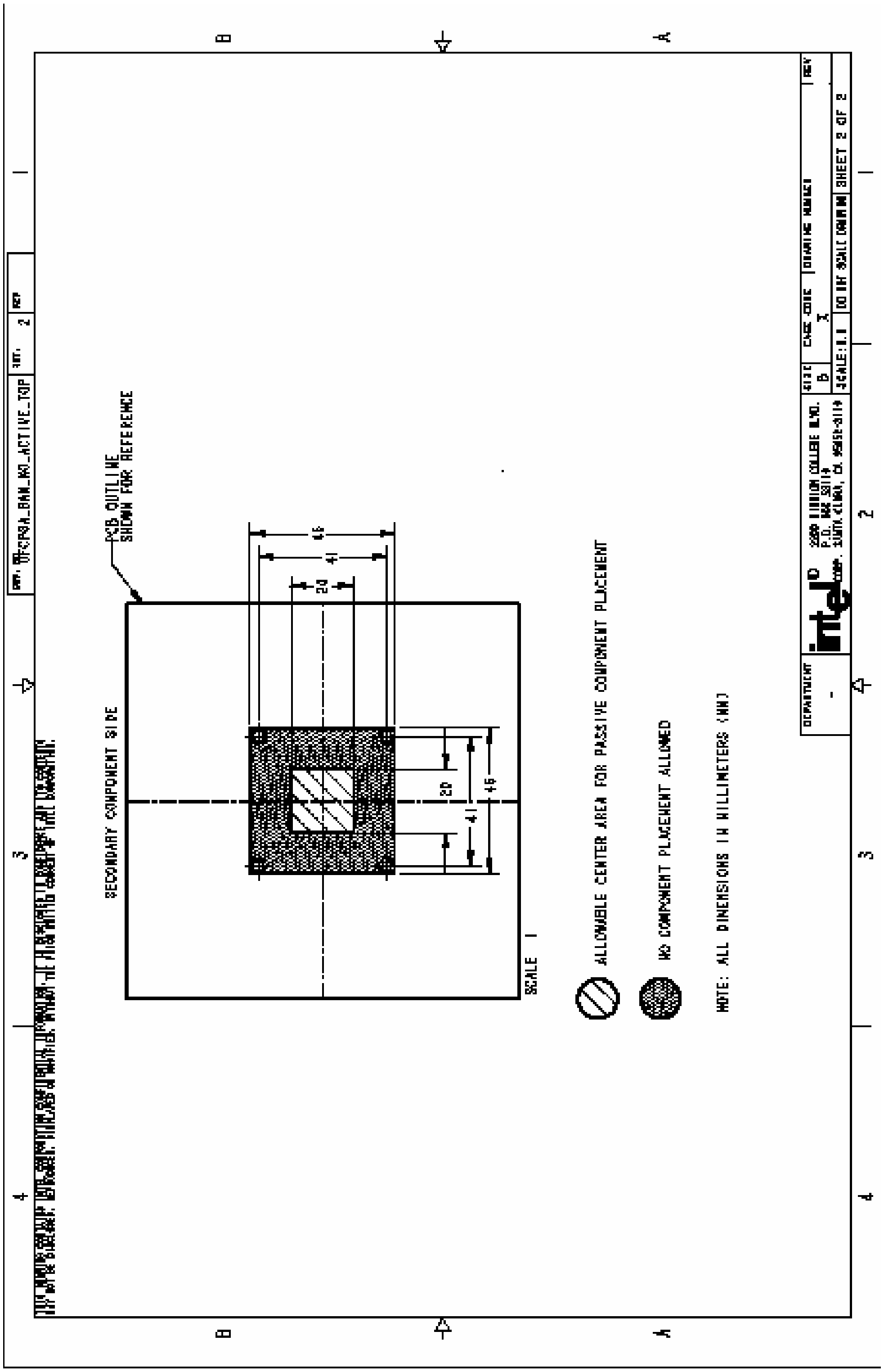
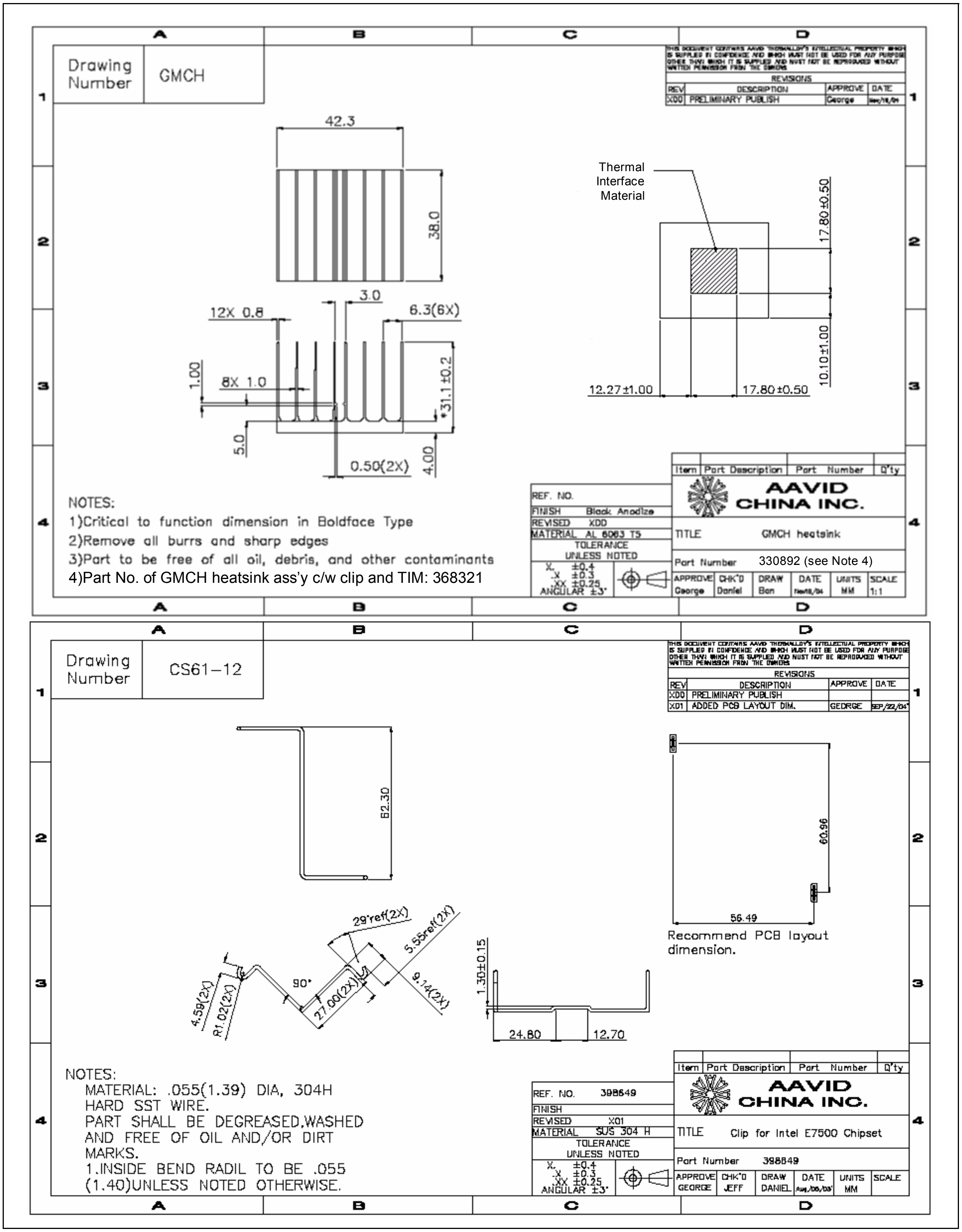


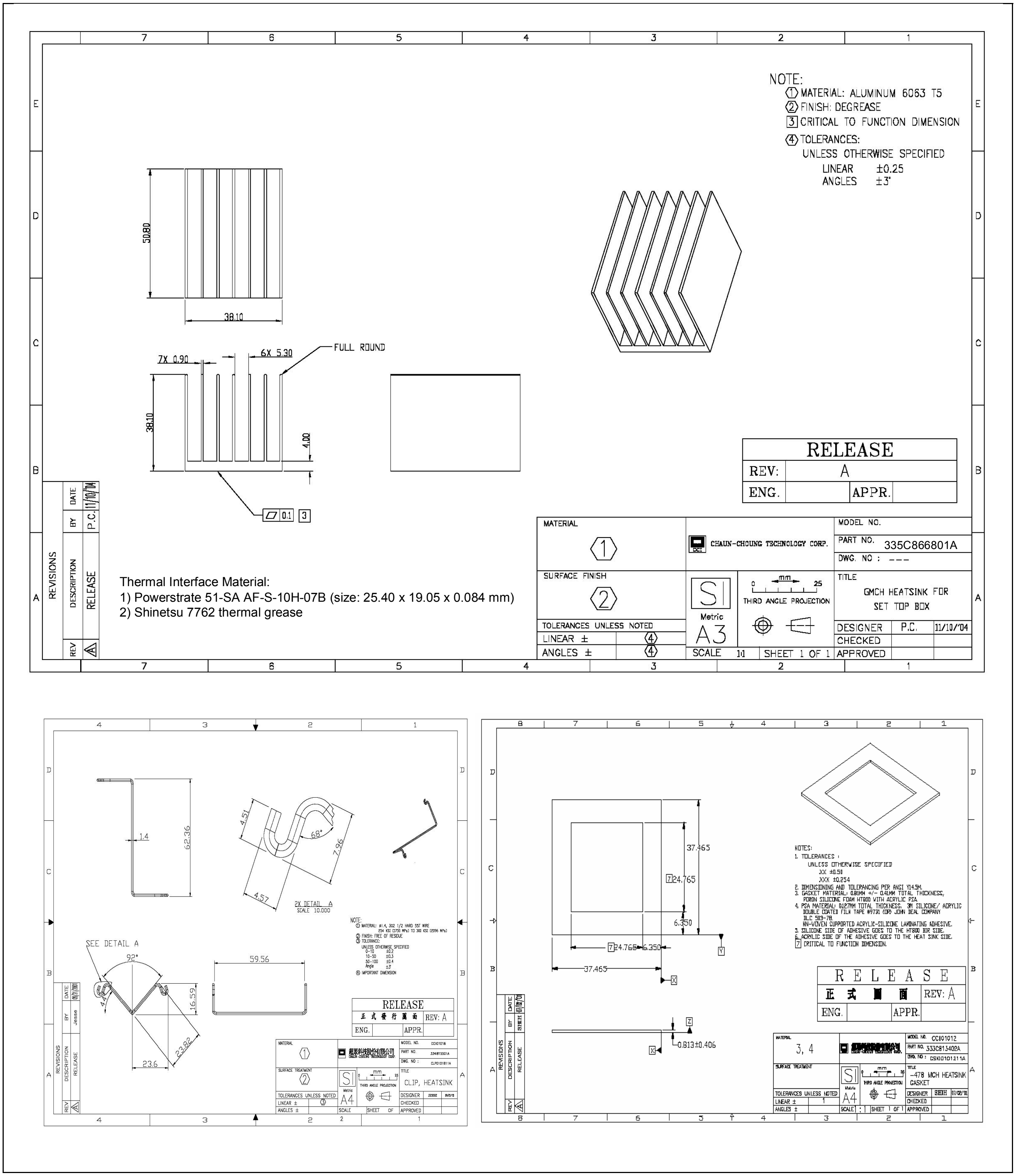
Figure 15. Aavid Thermal Solution.



NOTES:
1)Critical to function dimension in Boldface Type
2)Remove all burrs and sharp edges
3)Part to be free of all oil, debris, and other contaminants
4)Part No. of GMCH heatsink ass'y c/w clip and TIM: 368321

NOTES:
MATERIAL: .055(1.39) DIA, 304H
HARD SST WIRE.
PART SHALL BE DEGREASED,WASHED
AND FREE OF OIL AND/OR DIRT
MARKS.
1.INSIDE BEND RADIL TO BE .055
(1.40)UNLESS NOTED OTHERWISE.

Figure 16. CCI Thermal Solution.

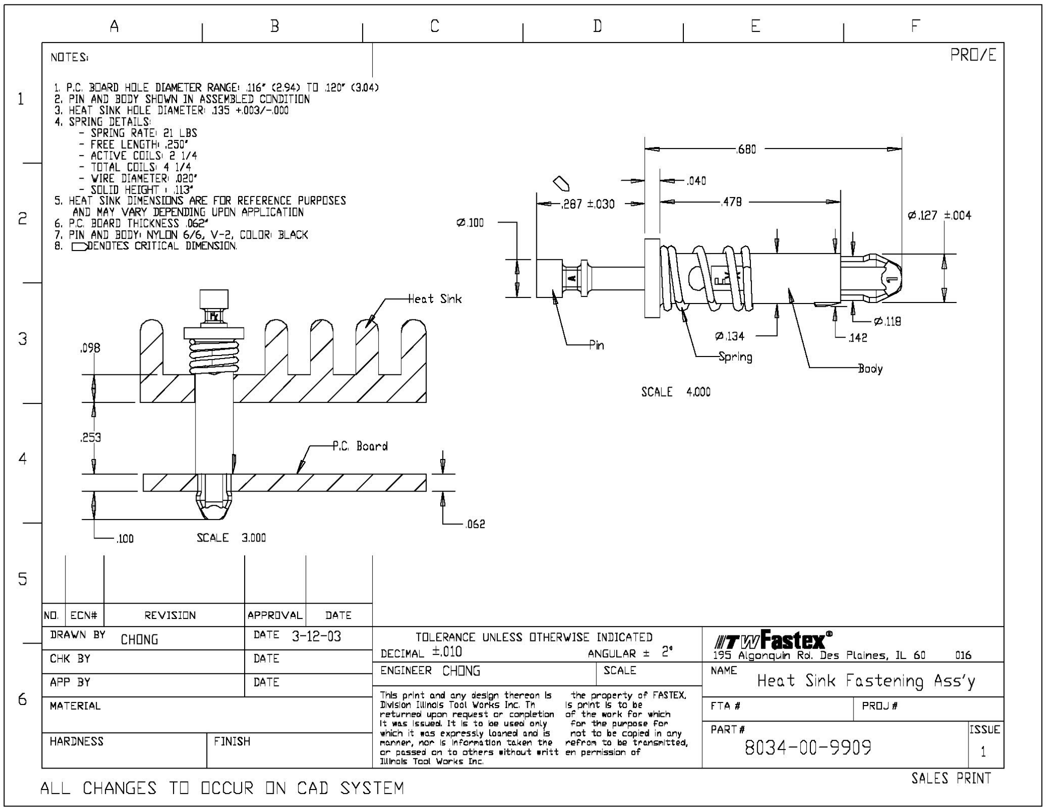


NOTE:
① MATERIAL: ALUMINUM 6063 T5
② FINISH: DEGREASE
3 CRITICAL TO FUNCTION DIMENSION
④ TOLERANCES:
UNLESS OTHERWISE SPECIFIED
LINEAR ±0.25
ANGLES ±3°

Thermal Interface Material:
1) Powerstrate 51-SA AF-S-10H-07B (size: 25.40 x 19.05 x 0.084 mm)
2) Shinetsu 7762 thermal grease

NOTES:
1. TOLERANCES :
UNLESS OTHERWISE SPECIFIED
XX ±0.50
XXX ±0.254
2. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M.
3. GASKET MATERIAL: 0.81MM +/- 0.41MM TOTAL THICKNESS, PORON SILICONE FOAM HT800 WITH ACRYLIC PSA
4. PSA MATERIAL: 0.127MM TOTAL THICKNESS, 3M SILICONE/ ACRYLIC DOUBLE COATED FILM TAPE #9731 (OR) JOHN DEAL COMPANY DLC 503-78.
NN-WOVEN SUPPORTED ACRYLIC-SILICONE LAMINATING ADHESIVE.
5. SILICONE SIDE OF ADHESIVE GOES TO THE HT800 BIR SIDE.
6. ACRYLIC SIDE OF THE ADHESIVE GOES TO THE HEAT SINK SIDE.
7 CRITICAL TO FUNCTION DIMENSION.

Figure 17. CCI's Alternative Retention Mechanism.



NOTES:

1. P.C. BOARD HOLE DIAMETER RANGE: .116" (2.94) TO .120" (3.04)
2. PIN AND BODY SHOWN IN ASSEMBLED CONDITION
3. HEAT SINK HOLE DIAMETER: .135 +.003/-.000
4. SPRING DETAILS:
   - SPRING RATE: 21 LBS
   - FREE LENGTH: .250"
   - ACTIVE COILS: 2 1/4
   - TOTAL COILS: 4 1/4
   - WIRE DIAMETER: .020"
   - SOLID HEIGHT : .113"
5. HEAT SINK DIMENSIONS ARE FOR REFERENCE PURPOSES AND MAY VARY DEPENDING UPON APPLICATION
6. P.C. BOARD THICKNESS .062"
7. PIN AND BODY: NYLON 6/6, V-2, COLOR: BLACK
8. ▭ DENOTES CRITICAL DIMENSION.

NO.	ECN#	REVISION	APPROVAL	DATE

DRAWN BY CHONG
DATE 3-12-03
CHK BY
DATE
APP BY
DATE
MATERIAL
HARDNESS
FINISH

TOLERANCE UNLESS OTHERWISE INDICATED
DECIMAL ±.010
ANGULAR ± 2°
ENGINEER CHONG
SCALE

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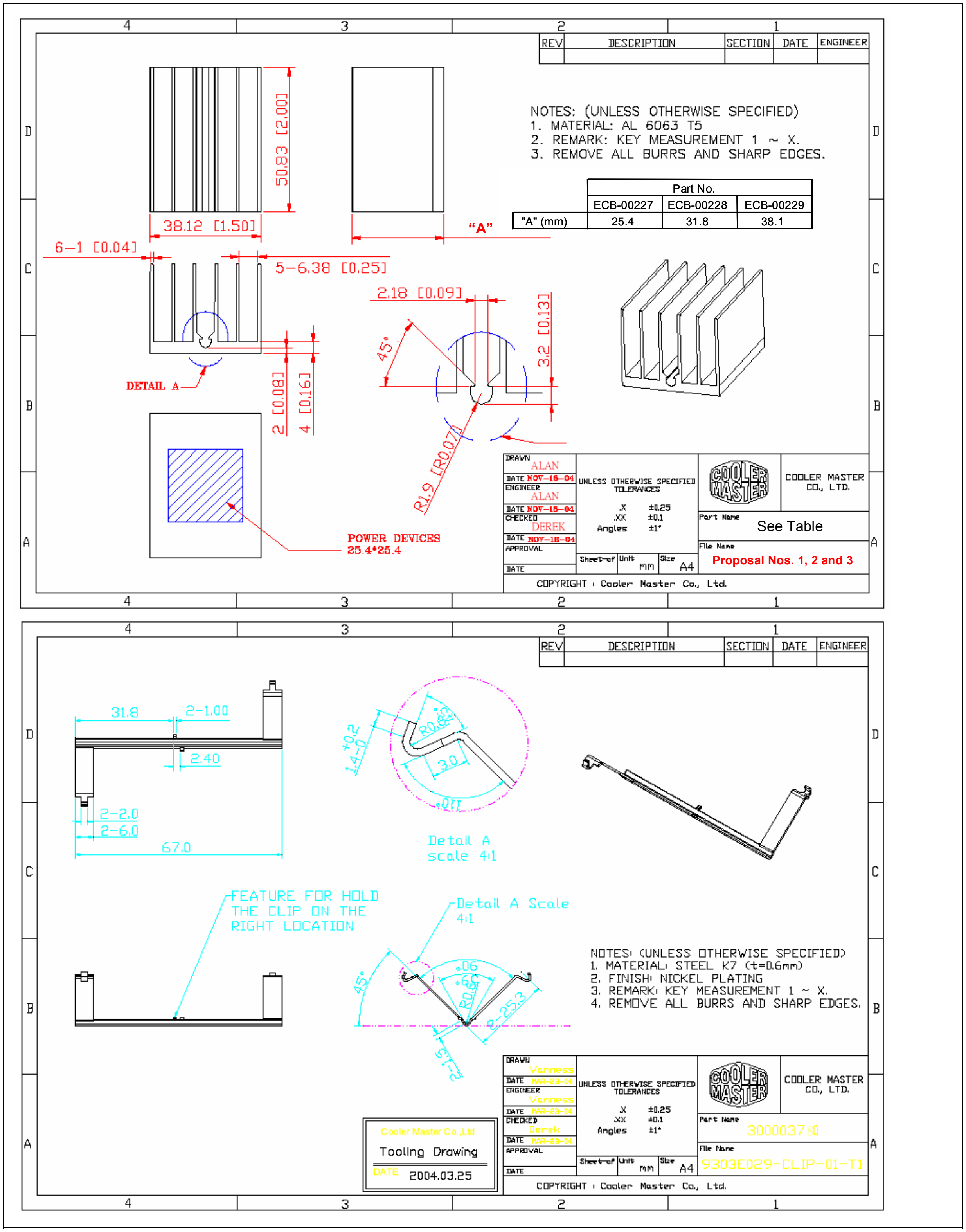
ITW Fastex®
195 Algonquin Rd. Des Plaines, IL 60016

NAME Heat Sink Fastening Ass'y
FTA #
PROJ #
PART # 8034-00-9909
ISSUE 1

ALL CHANGES TO OCCUR ON CAD SYSTEM

SALES PRINT

Figure 18. Cooler Master Thermal Solution.



NOTES: (UNLESS OTHERWISE SPECIFIED)
1. MATERIAL: AL 6063 T5
2. REMARK: KEY MEASUREMENT 1 ~ X.
3. REMOVE ALL BURRS AND SHARP EDGES.

	Part No.		
	ECB-00227	ECB-00228	ECB-00229
"A" (mm)	25.4	31.8	38.1

DRAWN	ALAN
DATE	NOV-18-04
ENGINEER	ALAN
DATE	NOV-18-04
CHECKED	DEREK
DATE	NOV-18-04
APPROVAL	
DATE	

UNLESS OTHERWISE SPECIFIED TOLERANCES
.X ±0.25
.XX ±0.1
Angles ±1°

COOLER MASTER CO., LTD.

Part Name: See Table

File Name: Proposal Nos. 1, 2 and 3

Sheet-of | Unit: mm | Size: A4

COPYRIGHT : Cooler Master Co., Ltd.

NOTES: (UNLESS OTHERWISE SPECIFIED)
1. MATERIAL: STEEL K7 (t=0.6mm)
2. FINISH: NICKEL PLATING
3. REMARK: KEY MEASUREMENT 1 ~ X.
4. REMOVE ALL BURRS AND SHARP EDGES.

DRAWN	Vanness
DATE	MAR-23-04
ENGINEER	Vanness
DATE	MAR-23-04
CHECKED	Derek
DATE	MAR-23-04
APPROVAL	
DATE	

UNLESS OTHERWISE SPECIFIED TOLERANCES
.X ±0.25
.XX ±0.1
Angles ±1°

COOLER MASTER CO., LTD.

Part Name: 30000378O

File Name: 9303E029-CLIP-01-T1

Sheet-of | Unit: mm | Size: A4

COPYRIGHT : Cooler Master Co., Ltd.

Cooler Master Co.,Ltd
Tooling Drawing
DATE 2004.03.25