Intel® 810 Chipset: Thermal Design Considerations

Application Note AP-670

June 1999

Order Number: 292228-001

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Revision History

Revision	Description	Date
-001	Initial Release	June 1999

1.0 Introduction

This document provides an understanding of the thermal characteristics of the Intel® 810 chipset and discusses guidelines for meeting the thermal requirements imposed on platforms. Some previous generations of Intel® Celeron™ processor PCIsets did not require a significant platform design effort to meet the component case temperature specifications. As the market transitions to higher-speeds and higher bandwidths with enhanced features, devices will generate more heat. Consequently, this introduces new thermal challenges for system designers. Depending on the type of system and the chassis characteristics, new designs may be required to provide better cooling solutions for these devices.

Elements of Thermal Design

In a system environment, the temperature of a component is a function of both the system and component thermal characteristics. The system level thermal constraints consist of the local ambient temperature at the component, the airflow over the component and surrounding board as well as the physical constraints at, above, and surrounding the component which may limit the size of a thermal enhancement (heat sink). The component's case temperature depends on the component power dissipation, size, packaging materials (effective thermal conductivity), the type of interconnection to the substrate and motherboard, the presence of a thermal cooling solution, the thermal conductivity and the power density of the substrate, nearby components, and motherboard.

All of these parameters are pushed by the continued trend of technology to increase performance levels (higher operating speeds, MHz) and power density (more transistors). As operating frequencies increase and packaging size decreases, the power density increases and the thermal cooling solution space and airflow become more constrained. The result is an increased emphasis on system design to ensure that thermal design requirements are met for each component in the system.

Importance of Thermal Management

The objective of thermal management is to ensure that the temperature of all components in a system is 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.

1.1 Intel® 810 Chipset Packaging Terminology

BGA	Ball Grid Array. A package type defined by a resin-fiber substrate on to which a die is mounted, bonded and encapsulated in molding compound. The primary electrical interface is an array of solder balls attached to the substrate opposite the die and molding compound.
Junction	Refers to a P-N junction on the silicon itself. In his document it is used as a temperature reference point.
MBGA	Mini Ball Grid Array. Defined as an Intel® BGA with 1.27mm ball pitch.
Lands	The pads on the PCB to which the BGA Balls are soldered.
Mold-Cap	The black encapsulating molding compound. The top of this is where maximum case temperatures are taken and where heat sinks are attached.
PCB	Printed Circuit Board.
TDP	Thermal Design Power. This is the estimated maximum possible expected power generated in a component by a realistic application. It is based on extrapolations in both hardware and software technology over the life of the product. It does not represent the expected power generated by a power virus.
Thermal Balls	Typically, this refers to an array of balls in the center of the larger array of balls which serve to channel heat into the PCB as well as ground connections.

1.2 References

- *Intel® 810 Chipset Design Guide* (Order Number: 290657)
- *Intel® 810 Chipset: Intel® 82810 and 82810-DC100 Graphics and Memory Controller Hub (GMCH)* Datasheet (Order Number: 290656)
- *Intel® 82801AA (ICH) and Intel® 82801AB (ICH0) I/O Controller Hub* Datasheet (Order Number: 290655)
- *Intel® Celeron ™ Processor Thermal Design Guidelines* Application Note (Order Number: 243331)
- *Design For EMI* Application Note AP-589 (Order Number: 243334)
- Integrated Circuit Thermal Measurement Method-Electrical Test Method (EIA/JESD51-1)
- Integrated Circuits Thermal Test Method Environmental Conditions - Natural Convection (Still Air) (EIAJESD51-2)

2.0 Thermal Specifications

Thermal Design Power (TDP) for the Intel® 810 chipset can be found either in the *Intel® 810 Chipset Design Guide* or *Design Guide Updates*. Refer to these documents to verify the thermal and power specifications for the Intel® 810 chipset. In general, systems should be designed to dissipate the highest possible thermal power.

To ensure proper operation and reliability of the Intel® 810 chipset, the thermal solution must maintain the case temperature at or below the values specified in Table 1 and Table 2. Considering the power dissipation levels and typical system ambient environments of 45°C to 55°C, if the case temperature exceeds the maximum case temperature listed in Table 1, system or component level thermal enhancements will be required to dissipate the heat generated.

To dissipate the highest possible thermal power good system airflow is critical. Airflow is determined by the size and number of fans, vents and ducts along with their placement in relation to the components and the airflow channels within the system. In addition, acoustic noise constraints may limit the size and/or types of fans, vents and ducts that can be used in a particular design.

To develop a reliable, cost-effective thermal solution, all of the above variables must be considered. Thermal characterization and simulation should be carried out at the entire system level accounting for the thermal requirements of each component.

Table 1. Intel® 810 Chipset Preliminary Thermal Absolute Maximum Rating

Parameter	Maximum	Notes
$T_{case\text{-}nhs}$	114 °C	1
$T_{case\text{-}hs}$	97 °C	2

NOTES:
1. $T_{case\text{-}nhs}$ is defined as the maximum case temperature without any thermal enhancement to the package.
2. $T_{case\text{-}hs}$ is defined as the maximum case temperature with the default thermal solution attached (see Section A).

Table 2. ICH Preliminary Thermal Absolute Maximum Rating

Parameter	Maximum	Notes
$T_{case\text{-}nhs}$	100°C	1

NOTES:
1. $T_{case\text{-}nhs}$ is defined as the maximum case temperature without any thermal enhancement to the package.

2.1 Case Temperature

The case temperature is a function of the local ambient temperature and the internal temperature of the component under evaluation. As a local ambient temperature is not specified for the components in an Intel® 810 chipset, the only restriction is that the maximum case temperature (Tcase) is not exceeded. Section 5.1 discusses proper guidelines for measuring the case temperature. Note that increasing the heat flow through the case (moldcap) increases the difference in temperature between the junction and case, reducing the maximum allowable case temperature. For the default thermal solution, see the adjusted values listed in Table 1.

2.2 Power

In previous generations of chipsets where Quad Flat Pack (QFP) packages may have been the primary package type, the majority of power dissipation has been through the plastic case of the package into the surrounding air. With the advent of Ball Grid Array (BGA) packaging for chipsets, the majority of the thermal power dissipated by the chipset typically flows into the motherboard to which it is mounted (when thermal or center balls are present). The remaining thermal power is dissipated into the ambient environment by the package itself. The MBGA packages used in the Intel® 810 chipset continues this trend.

The amount of thermal power dissipated, either into the board or by the package, varies depending on how well the motherboard conducts heat away from the package and whether the package uses thermal enhancements. While package thermal enhancements typically serve to improve heat flow through the case via a heat sink, how well the motherboard conducts heat away from the package is strictly a function of motherboard design:

The following are recommendations to ensure good thermal conductivity between the thermal balls and the inner planes of the motherboard:

- Good mechanical connection
- One via per ground ball be used (min).
- Minimum width of the trace connecting motherboard ground pads to their respective vias be 10 mil.
- Plated Via Size for ground balls be 14 to 16mil in diameter on a 24 mil to 27 mil pad. A larger via is more efficient in channeling heat.
- Do not use Thermal Relief Patterns to connect the via to the inner power and ground planes.

The following are recommendations to ensure that the motherboard inner planes effectively conduct heat away from the area beneath the package:

- Good ground paths to areas of the board away from the BGA will distribute heat more efficiently.
- The size of the motherboard, number of copper layers and the thickness of those layers. In some cases, the use of “2-ounce copper” on the ground plane has been successful in improving the thermal conduction by reducing case temperatures.

All points should be taken into account by system and board designers when developing new systems.

3.0 Designing for Thermal Performance

This section discusses general design consideration for all chassis. Specific design considerations for uATX, ATX and NLX chassis may be found at the following URLs:

http://www.teleport.com/~nlx/

http://www.teleport.com/~atx/

http://www.teleport.com/~microatx/

3.1 System Cooling

The first step in defining an acceptable cooling solution is to estimate the total airflow required to cool the entire system (not just the processor). Using the ideas from the 1st Law of Thermodynamics (Conservation of Energy) for a steady state steady flow process, the relationship between volumetric airflow, heat load (measured DC power), and the temperature rise of the system can be studied. To reach this simplified model, it is assumed that the change in kinetic and potential energy of the airflow is zero and no work is performed by the system.

For a zero airflow restriction inside the computer, the relationships are as follows:

$$V = f(\text{Power / Temperature rise})$$

Where **V** is the volumetric airflow, **Power** is the actual power dissipated by the power supply (DC power), and **Temperature rise** is the temperature rise of the system.

Note: For NO change in system temperature, as DC power increase, airflow must increase

Thus, more volumetric airflow is needed to keep the temperature rise of the system at a minimum. Note that these are under ideal conditions. In reality, there is between 30% to 50% restriction of airflow. For a well-designed chassis, an airflow increase of approximately 25% is typical to account for the system impedance. If possible, use the measured DC power of the system for the Power variable. The AC power can be used as an approximation; however, the inefficiency of the power supply makes this measurement larger than the actual power dissipated.

3.2 System Fans

Fans implement the forced convection approach to cooling. Stated simply, the greater the air velocity over the surface of a component, the greater the heat transfer from that component. Fans can be used to blow air into (pressurize) or out of (evacuate) the chassis depending on which direction they are installed.

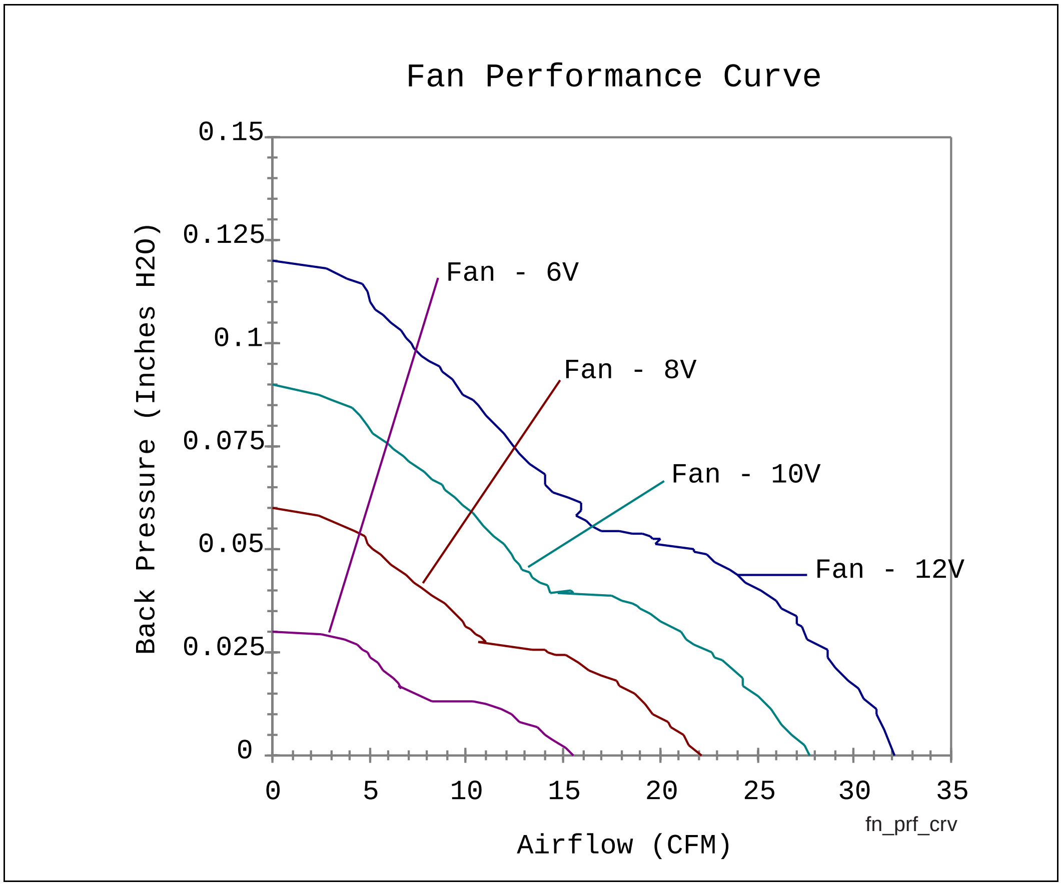
- **Pressurizing** the chassis with a fan delivers cool, room-temperature ambient air onto any location where it is needed to enhance heat transfer.
- **Evacuating** induces a negative pressure (relative to room ambient) inside the chassis, which draws air in through the vents. This inflow of air from the vents is pulled through the chassis across hot components and is exhausted out the fan. Fans may differ in their characteristics, and, therefore, a prudent choice of fans can optimize both airflow and acoustics.

3.2.1 Fan Types

Although there are several types of fans to consider for system cooling, this chapter focuses on two types; Tube Axial and Radial.

Tube axial is the most commonly used type throughout the computer industry. Axial fans typically cost less and generally push more air at a given back pressure. Radial fans, however, are much less susceptible to variations in back pressure and often have restricted openings which can focus needed cooling air directly at hot components. When power dissipation is highly concentrated, a blower may be a reasonable option. Figure 1 shows a typical axial fan characteristic curve and the effect of running the fan at different speeds (or voltage levels).

Figure 1. Typical Fan Characteristic Curve (for Various Voltages)



fn_prf_crv

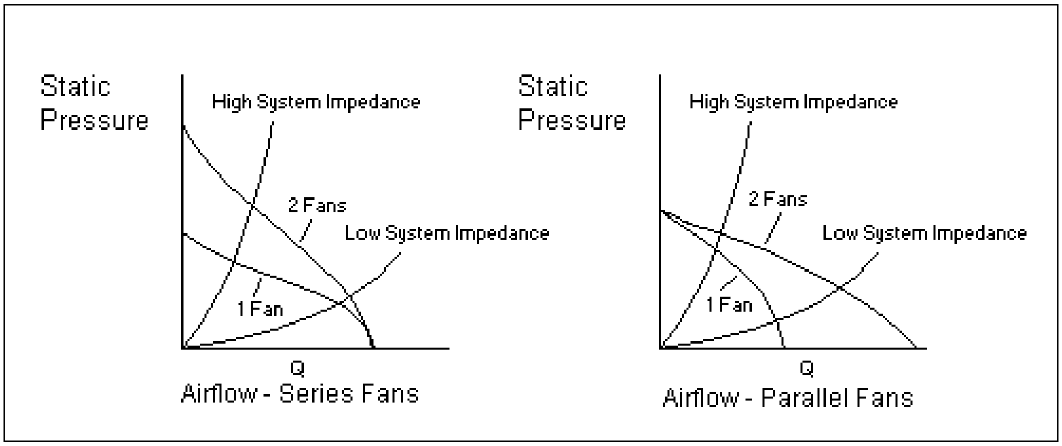
3.2.2 Parallel and Series Fan Combinations

Multiple fans can be utilized in two combinations, parallel and series.

- Two identical fans in parallel double the airflow, total airflow equals the airflow of fan 1 + airflow of fan 2 at zero back pressure, An example of a parallel fan combination is a system fan and a power supply fan both either pressurizing or evacuating a chassis.
- Two identical fans in series doubles the system's ability to overcome back pressure; total pressure is equal to the pressure of fan 1 + the pressure of fan 2 at zero airflow, An example of a series fan combination is a system fan blowing air into the chassis and a power supply fan exhausting air from the chassis.

Generally, due to venting, leakage and design compromises, when multiple fans are employed, a combination series/parallel configuration is often implemented. The effect of employing series/parallel fan configurations is shown in Figure 2.

Figure 2. Performance Curves for Series and Parallel Fan Combinations



Employing multiple (identical) fans in a system provides some marginal increase in airflow. The exact amount depends on many factors including fan speed and configuration, as well as chassis airflow impedance. If the fans are not identical, the figures will change slightly, but the trends will be the similar. **The general rule is: If the chassis has high impedance, place the fans in series. If the chassis has low impedance, place the fans in parallel.**

3.2.3 Fan Relationships

Fan variables such as airflow, pressure, R.P.M., and power can be generalized for a tube axial two fan combination of constant diameter.

- Airflow increases linearly with speed
- Pressure increases with the square of the speed
- Power increases with the cube of the speed

Understand that increasing the fan speed to increase airflow results in a much larger increase in pressure. If increased airflow is desired, consider increasing the fan diameter from 80 mm to 92 mm instead of increasing the speed. Cost must be considered because generally 92 mm fans are more expensive than 80 mm fans; however, a 92 mm fan operating at the same flow rate as an 80 mm fan is approximately 6 dBA quieter.

3.2.4 Fan Speed Control

Fan speed control circuit ideas have been around for some time but were generally avoided because of adding unnecessary cost and system complexity. Computers are now incorporating hotter processors and peripherals requiring greater airflow while, at the same time, customers are requesting quieter systems. These competing design constraints have led to a resurgence of fan speed control options. Fan speed control allows a system to vary its airflow as changes in load and/or temperature occur. Fan noise increases with fan speed and is a major contributor to total system noise. For systems that incorporate fan speed control, proper speed regulation is important since it is desirable to achieve low acoustic levels without overheating components. The fan speed control circuit should be designed such that it monitors temperature at a component (or several components) and adjusts fan speed as necessary to maintain the required thermal margin. Three distinct design options should be considered.

- **Discrete Digital Switches.** If airflow requirements can be confined to a discrete number of fan speeds, this option is the cheapest and easiest to implement.
- **Analog Linear Control between Two Guard Bands.** For fans used in most systems, speed control can usually be accomplished by varying the voltage level at the fan's power terminals (many power supplies/fans come equipped with this feature). An operating voltage range example for an 80 mm, 30 CFM, 0.14 amp fan might be 8 V to 12 V DC, corresponding to 1650 rpm and 2500 rpm, respectively.
- **Pulse Width Modulation Schemes.** This is a digital variation on the second option. Consider this option if the fan needs to be varied from some minimum speed (presumably set for the system sleep state) to some maximum speed (needed for a fully loaded active state).

Summary

Independent of which fan speed control method is chosen, the following issues should also be noted:

- The location where temperature is monitored is important (sensing critical component case temperatures is recommended).
- A driver circuit for the fan must be included.
- Some fans need a minimum starting voltage (see fan specification).
- Fan noise increases with fan speed (operating voltage). Minimum fan noise occurs at maximum fan power efficiency (see fan specification).
- If the fan is not speed controlled, at what speed (voltage level) is it operating? In this case since it is not possible to vary fan speed, choose the lowest rated fan speed that will cool the system under worst-case loading/temperature conditions.

If fan speed control is implemented, the thermal design should account for various load and temperature combinations. Component temperatures should be verified to ensure the thermal design meets specification under these load and temperature combinations.

4.0 System Airflow

4.1 Chassis and Bezel Venting

Proper venting is a key element in any good thermal design. A balanced vent configuration is a critical factor in this design. Implementing an insufficient amount of venting does not allow enough air into the system for adequate cooling. Implementing too much venting can decrease the air velocity across system components, resulting in less heat transfer through forced convection. To increase airflow through the system, all system accessory components (cables, wires, sheet metal, etc.) should present the lowest possible air impedance. To eliminate possible electromagnetic compliance issues, both the maximum vertical and maximum horizontal dimensions of ventilation apertures, I/O ports, and open areas along chassis seams must be less than 1/20th of a wavelength of the highest harmonic frequency of interest.

Key Considerations

- **Power Supply.** The air flow from the power supply fan is less of an importance when the front system fan delivers the majority of the airflow.
- **Front bezel venting.** The bezel vent area should be as large as possible because it serves as the main air inlet for the system. It also provides the main airflow source for the core logic components. **Ensure the plastic bezel vent pattern allows air to enter freely so it does not overly restrict airflow into the system.**
- **Riser card.** Some venting at the front and back of any riser cards is necessary to allow for the evacuation of the chassis and airflow over the add-in cards.
- **Side chassis venting.** This is desirable if there are any cards with components which require cooling nearby.
- **Rear chassis venting.** This adds to the airflow capability of the chassis.
- **Peripheral bay venting.** Cools peripherals. Minimal venting, if any, should produce adequate results. Implementing too much venting may cause lower airflow in other areas of the chassis.

4.2 Airflow Impedance

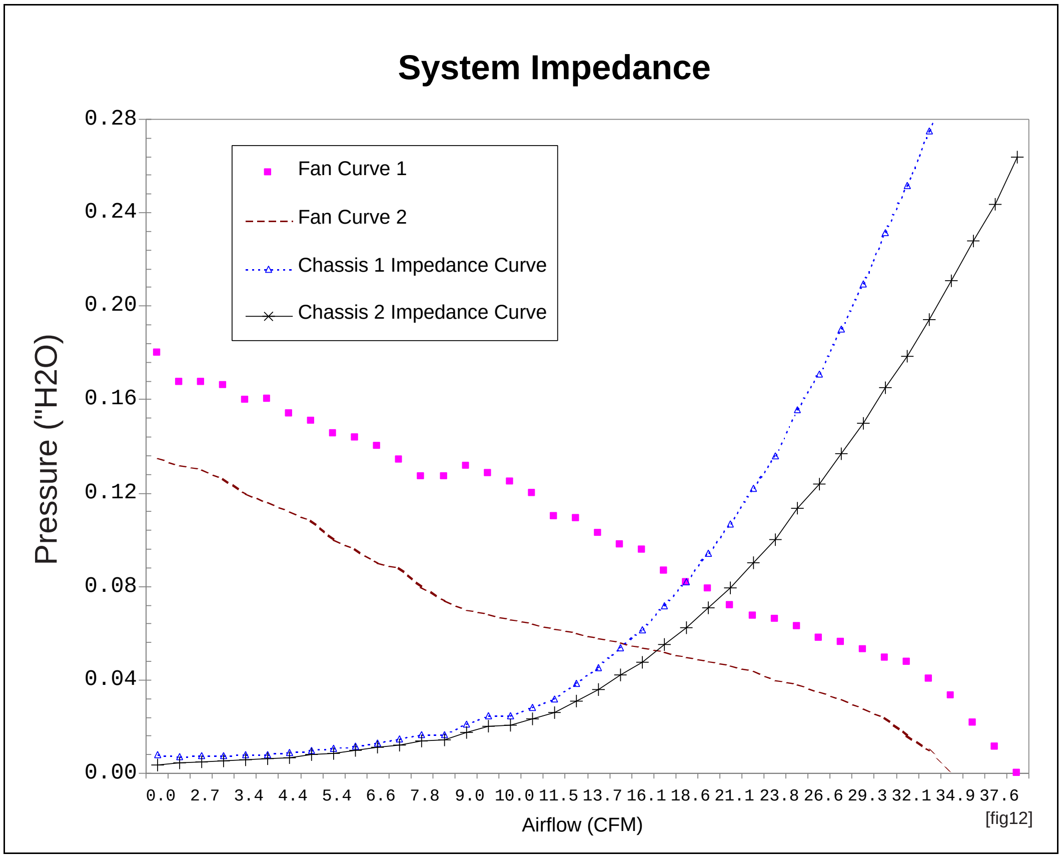
Air flowing through a computer chassis encounters frictional resistance, known as airflow impedance. This impedance creates a pressure drop in the chassis. The pressure drop will vary with the square of the velocity. Plotting pressure loss versus volumetric flow rate, which results in the system characteristic curve, can show the relationship. The point about this behavior is that if one data point on the curve is known, the system's overall performance can be predicted. When the system characteristic curve is superimposed on the fan performance curve, the operating point of the system is specified explicitly. The concept is demonstrated in Figure 3 where different power supplies are compared with different chassis.

The following lists additional guidelines to consider when assessing system airflow issues:

- To avoid pressure and volume fluctuations, the operating point should be chosen just right of the intersection between the fan curve and the chassis impedance curve.
- Choose a fan with a steep characteristic curve to maintain constant volumetric flow even with variable system impedance.
- Avoid obstructions near the inlet and exhaust of the fans as these tend to decrease airflow and increase system noise. Objects near the inlet can contribute to system noise.

- Use fan speed control whenever possible. This yields adequate thermal margin and provides a significant acoustic advantage.
- Power supply cables and drive signal cables should be kept short and properly folded.

Figure 3. System Characteristic Curve



4.3 Power Supply Airflow Characteristics

The power supply is the most influential component in the cooling system design. The chassis venting scheme may be well designed; however, if the correct power supply is not selected, the system will not cool the processor, chipset, memory, and/or the peripherals. The power supply and any system fans must provide enough airflow to cool the system heat load as outlined by the Equation in Section 2.1.

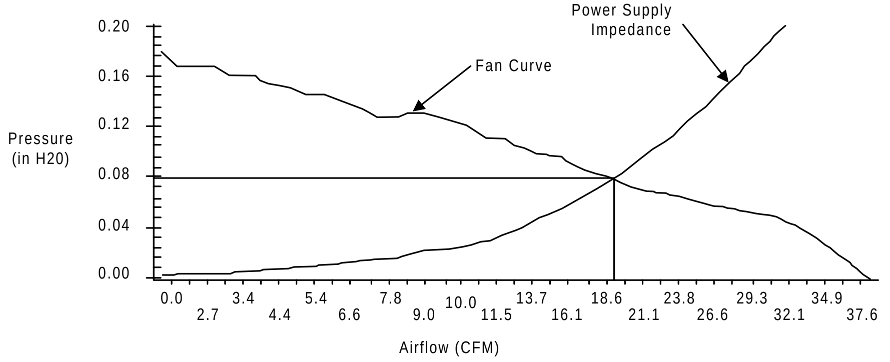
Key considerations when selecting/designing a power supply:

- Evacuate the chassis (rather than pressurize it) with the power supply fan. The advantage of evacuating the chassis is that cool room ambient air can be delivered (via vents) to any location where it is needed to enhance heat transfer. Evaluation has shown evacuating produces greater cooling than pressurizing using the same fan with proper implementation.
- All vents should have a minimum free area ratio of 60%. Consult the EMI design guidelines to ensure vent designs comply with all applicable regulations.
- Implement a wire fan grille rather than the common stamped sheet metal designs because the airflow impedance is reduced.
- When designing a power supply, minimize the component height to keep their profile low and streamlined. This reduces the overall airflow impedance while still maintaining effective power supply cooling.
- Keep power supply cables short to reduce their airflow obstruction.
- Select a power supply with the highest airflow possible. A well-designed power supply has low airflow impedance, allowing a smaller, quieter fan for cooling. The poorly designed supply requires a larger, louder fan to maintain the same airflow due to its greater airflow impedance.

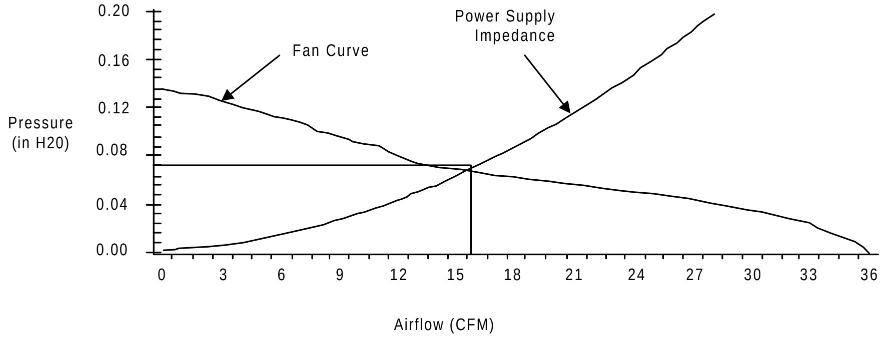
Figure 4 depicts the power supply impedance curve and the associated fan curve of three different power supplies. The point where the fan curve intersects the power supply impedance curve defines the operating point. Power supplies 1 and 2 (ATX and PS2 style, respectively) flow approximately twice as much as power supply 3 (ATX style). Note power supply 3 has a smaller fan and higher airflow impedance resulting in the lower airflow.

Figure 4. Power Supply Performance Comparison

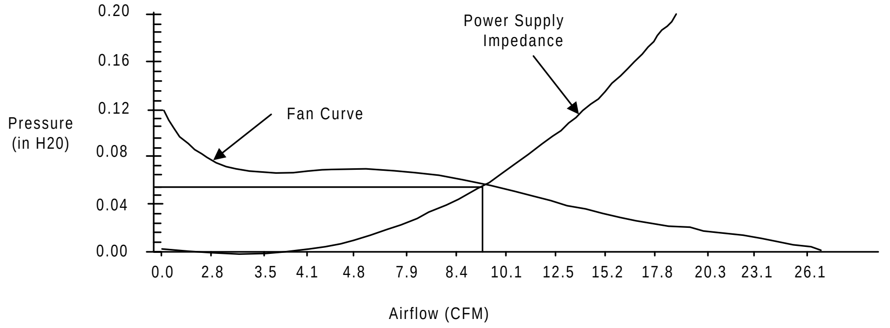
a) Power Supply 1 (ATX)



b) Power Supply 1 (PS2)



c) Power Supply 3 (ATX)



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4.4 Ducting

Ducts can be designed to isolate components from the effects of system heating and to maximize the thermal budget. Air provided by a fan or blower can be channeled directly over the components to be cooled or split into multiple paths to cool multiple components.

Ducting Placement

When ducting is to be used, it should direct the airflow evenly from the fan across the entire target area and surrounding motherboard. The ducting should be accomplished, if possible, with smooth, gradual turns as this will enhance the airflow characteristics. Sharp turns in ducting should be avoided. Sharp turns increase friction and drag and will greatly reduce the volume of air reaching the target.

While there are many ducting options, an excellent source of ducting alternatives can be found at the following URL:

http://developer.intel.com/ial/sdt/fanduct.htm

4.5 Intel® 810 Chipset GMCH Thermal Attributes

4.5.1 Physical Package Information

The GMCH (Intel 82810 and 82810-DC100) is packaged in a 31 mm, 4-layer MBGA. As a reference, the mechanical drawings are shown in Figure 5 and Figure 6.

Figure 5. GMCH Package Dimensions (421 BGA)–Top and Side View

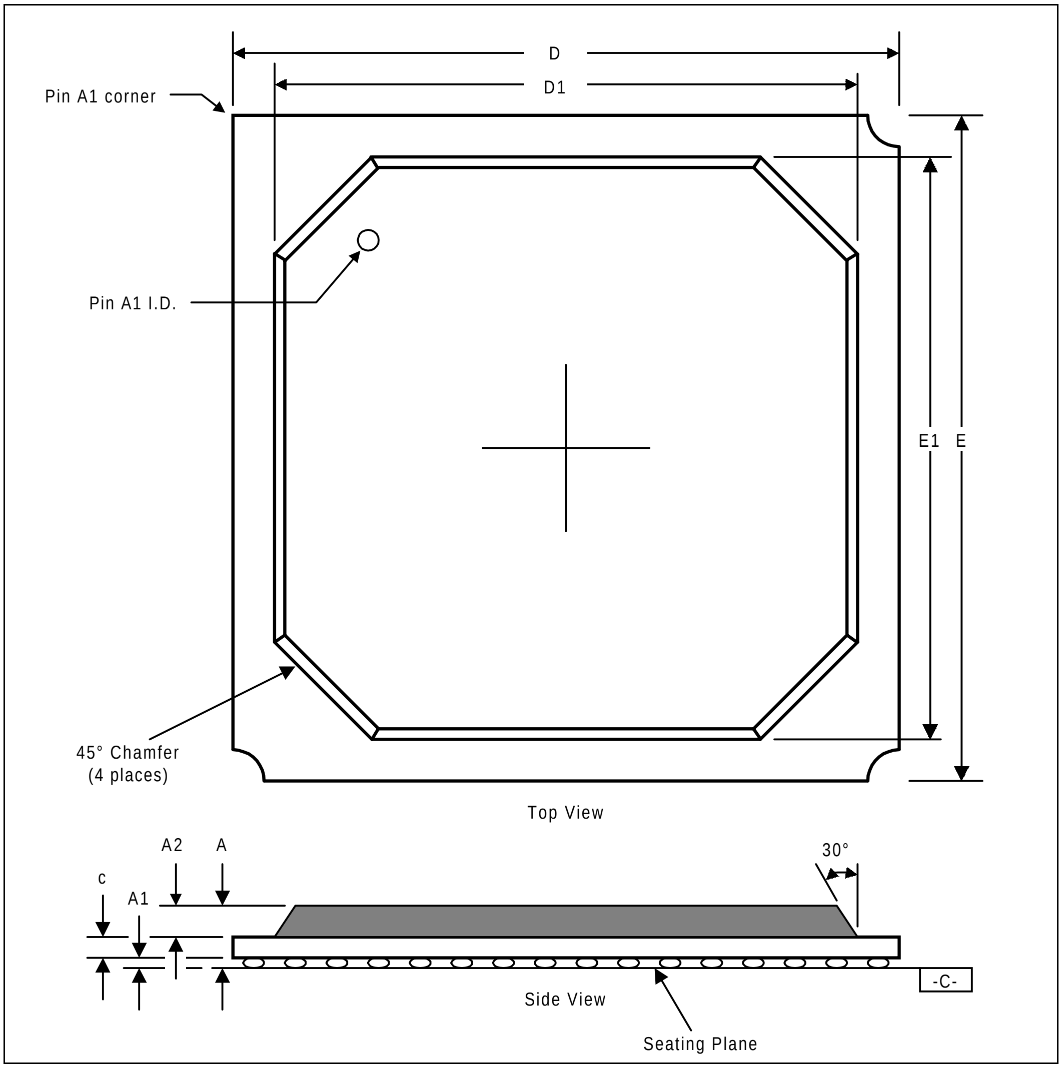


Figure 6. GMCH Package Dimensions (421 BGA)–Bottom View

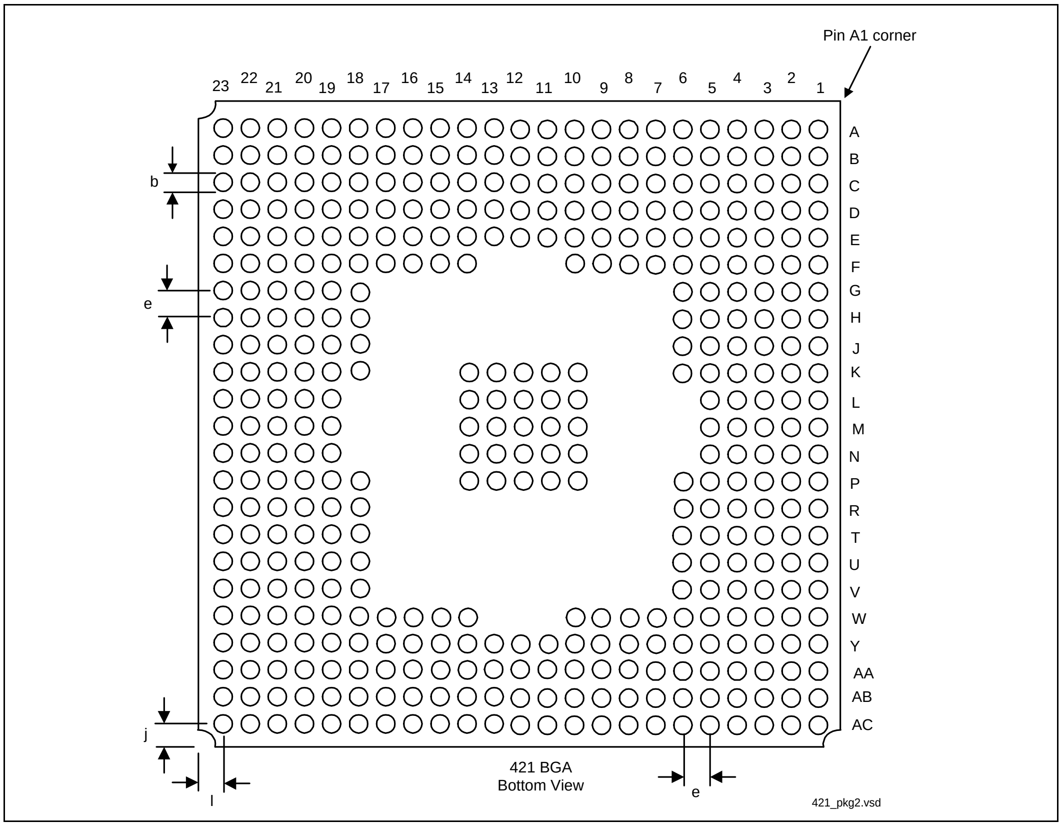


Table 3. GMCH Package Dimensions (421 BGA)

Symbol	Min	Nominal	Max	Units	Note
A	2.17	2.38	2.59	mm	
A1	0.50	0.60	0.70	mm	
A2	1.12	1.17	1.22	mm	
D	30.80	31.00	31.20	mm	
D1	25.80	26.00	26.20	mm	
E	30.90	31.00	31.10	mm	
E1	25.80	26.00	26.20	mm	
e	1.27 (solder ball pitch)			mm	
I	1.53 REF.			mm	
J	1.53 REF.			mm	
M	23 x 23 Matrix			mm	
b^2	0.60	0.75	0.90	mm	
c	0.55	0.61	0.67	mm	

NOTES:

1. All dimensions and tolerances conform to ANSI Y14.5-1982
2. Dimension is measured at maximum solder ball diameter parallel to primary datum (-C-)
3. Primary Datum (-C-) and seating plane are defined by the spherical crowns of the solder balls.

4.5.2 GMCH Package Thermal Characteristics

As an aid in determining the optimum airflow and heat sink combination for GMCH, Table 4 and Table 5 have been provided. The tables show Tcase as a function of airflow and ambient at the Thermal Design Power. These tables can be used to evaluate the system solution.

Table 4. No Heat Sink Attached (Tcase Specification = 114 °C)

Ambient (°C)	Heat Sink Tcase at TDP (°C)						
60	126	122	118	115	112	110	107
55	121	117	113	110	107	105	102
50	116	112	108	105	102	100	97
45	111	107	103	100	97	95	92
40	106	102	98	95	92	90	87
35	101	97	93	90	87	85	82
LFM	0	50	100	150	200	250	300

NOTES:
1. The values indicated in unshaded cells are combinations that will exceed the allowable case temperature for GMCH with default thermal solution. The values in shaded cells do not.
2. Heat Sink case assumes the default thermal solution, see Section A.3.
3. Tcase max with no heat sink is 114 °C, Tcase max with a heat sink is 97 °C.
4. Data collected is from Flotherm* simulations based on a motherboard environment, see Section C.
5. Zero LFM environment assumes natural convection.

Table 5. Heat Sink Attached (Tcase Specification = 97 °C)

Ambient (°C)	Heat Sink Tcase at TDP (°C)						
60	106	102	98	93	89	86	84
55	101	97	93	88	84	81	79
50	96	92	88	83	79	76	74
45	91	87	83	78	74	71	69
40	86	82	78	73	69	66	64
35	81	77	73	68	64	61	59
LFM	0	50	100	150	200	250	300

NOTES:
1. The values indicated in unshaded cells are combinations that will exceed the allowable case temperature for GMCH with default thermal solution. The values in shaded cells do not.
2. Heat Sink case assumes the default thermal solution, see Section A.3.
3. Tcase max with no heat sink is 114 °C, Tcase max with a heat sink is 97 °C.
4. Data collected is from Flotherm* simulations based on a motherboard environment, see Section C.
5. Zero LFM environment assumes natural convection.

5.0 Measurements for Thermal Specifications

To appropriately determine the thermal properties of the system, measurements must be made. Guidelines have been established for the proper techniques to be used when measuring the Intel® 810 chipset case temperatures. Section 5.1 provides guidelines on how to accurately measure the case temperature of the Intel® 810 chipset. Section 5.2 contains information on running an application program that emulates anticipated maximum thermal design power. The flowchart in Figure 9, as well as Appendix A offer useful guidelines for performance and evaluation.

5.1 Case Temperature Measurements

To ensure functionality and reliability, the Intel® 810 chipset is specified for proper operation when Tcase (case temperature) is maintained at or below the maximum case temperatures listed in Table 1. The surface temperature of the case in the geometric center of the mold cap is measured. Special care is required when measuring the Tcase temperature to ensure an accurate temperature measurement.

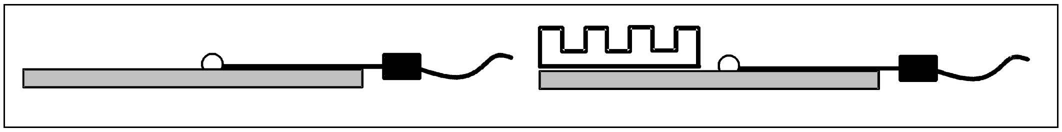
Thermocouples are often used to measure Tcase. Before any temperature measurements are made, the thermocouples must be calibrated.

When measuring the temperature of a surface which is at a different temperature from the surrounding local ambient air, errors could be introduced in the measurements. The measurement errors could be due to having a poor thermal contact between the thermocouple junction and the surface of the package, heat loss by radiation, convection, by conduction through thermocouple leads, or by contact between the thermocouple cement and the heat-sink base for those solutions which implement a heat-sink. To minimize these measurement errors the following approach is recommended:

Attaching the Thermocouple

- Use 36 gauge or smaller diameter K type thermocouples.
- Ensure that the thermocouple has been properly calibrated.
- Attach the thermocouple bead or junction to the top surface of the package (case) in the center of the mold-cap using high thermal conductivity cements. An alternative for tape attach users is to use the tape itself to mount the thermocouple. **It is critical that the thermocouple lead be butted tightly against the entire moldcap.**
- The thermocouple should be attached at a 0° angle if there is no interference with the thermocouple attach location or leads (refer to Figure 7). This is the preferred method and is recommended for use with both unenhanced packages as well as packages employing Thermal Enhancements.

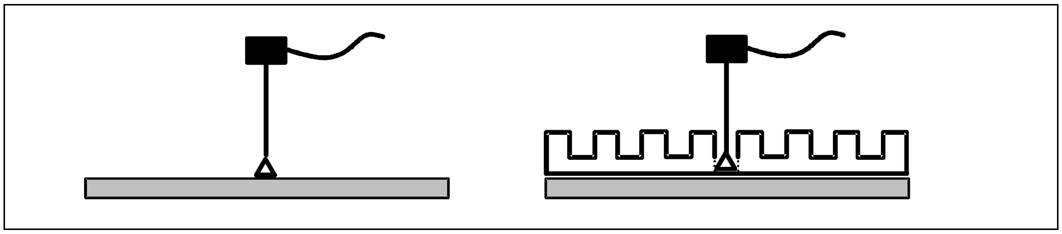
Figure 7. Technique for Measuring Tcase with 0° Angle Attachment



- If the thermocouple cannot be attached as previously shown, the thermocouple may be attached at a 90° angle. (refer to Figure 8).
- The hole size through the heat sink base to route the thermocouple wires out should be smaller than 0.150” in diameter.

- Make sure there is no contact between the thermocouple cement and heat sink base. This contact will affect the thermocouple reading.

Figure 8. Technique for Measuring Tcase with 90° Angle Attachment

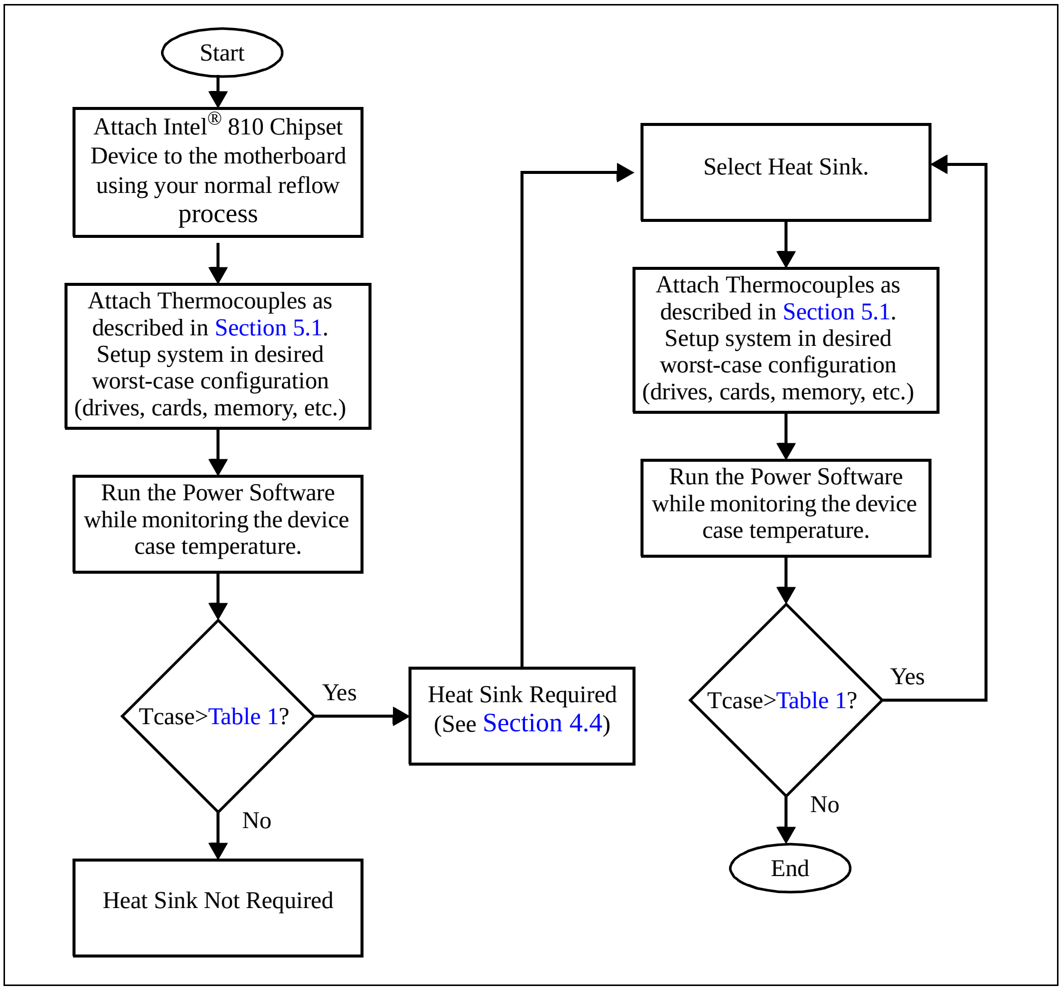


5.2 Power Simulation Program

The Power Simulation Software is a utility designed to test the thermal design power for an Intel® 810 chipset when used in conjunction with a Intel® Celeron™ processor. The combination of the Intel® Celeron™ processor and the higher bandwidth capability of the Intel® 810 chipset enables new levels of system performance. To ensure the thermal performance of the Intel® 810 chipset under “worst-case realistic application” conditions, Intel has developed a software utility that emulates this anticipated power dissipation.

The Power Simulation Software has been developed solely for testing Thermal Design Power and customer thermal solutions (Figure 9). Real future applications may exceed the Thermal Design Power limit for transient time periods.

Figure 9. Thermal Enhancement Decision Flowchart



6.0 Conclusion

As the complexity of today's systems continues to increase, so do the power dissipation requirements. Care must be taken to ensure that the additional power is properly dissipated. Heat can be dissipated using improved system cooling, selective use of ducting and/or passive heat sinks.

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

This document has presented the conditions and requirements to properly design a cooling solution for systems implementing the Intel® 810 chipset. Properly designed solutions provide adequate cooling to maintain the chipset case temperatures at or below those listed in Table 1 and. This is accomplished by providing a low local ambient temperature and creating a minimal thermal resistance to that local ambient temperature. By maintaining the Intel® 810 chipset case temperature at or below those recommended in this document, a system will function properly and reliably.

Appendix A Thermal Enhancements

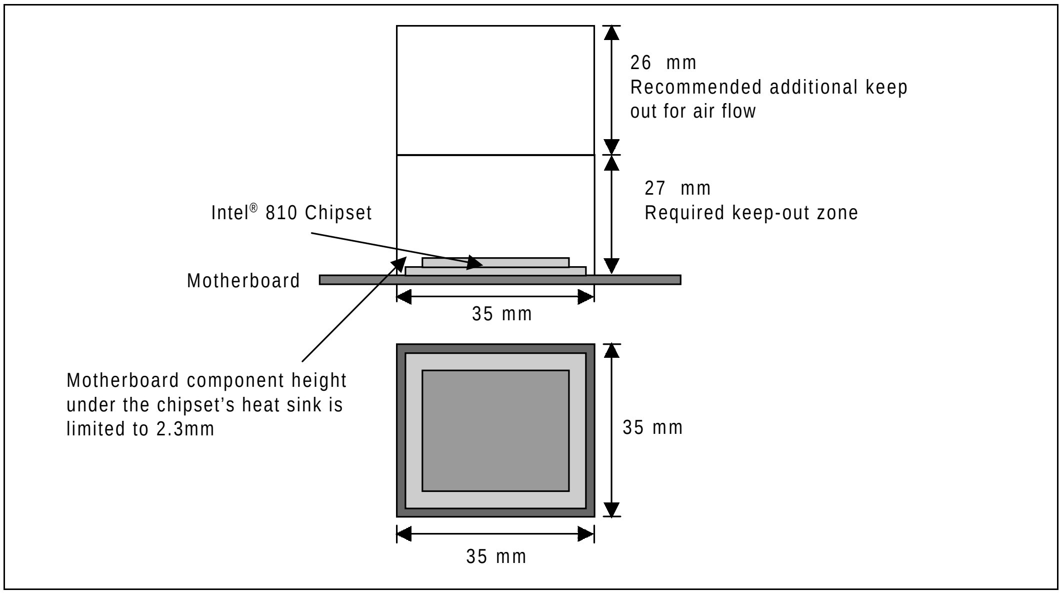
If sufficient airflow cannot be supplied to the component and motherboard, one method used to improve thermal performance is to increase the surface area of the component by attaching a metallic heat sink to the mold cap. To maximize the heat transfer, maximizing the surface area of the heat sink itself can reduce the thermal resistance from the heat sink to the air.

Note: Increasing the heat flow through the case increases the difference in temperature between the junction and case, reducing the maximum allowable case temperature.

A.1 Clearances

Though each design may have unique mechanical volume and height restrictions or implementation requirements, the height, width and depth constraints typically placed on the Intel® 810 chipset components are shown in Figure 10.

Figure 0-1. Extruded Heat Sink Drawing for GMCH With Socketed Processors



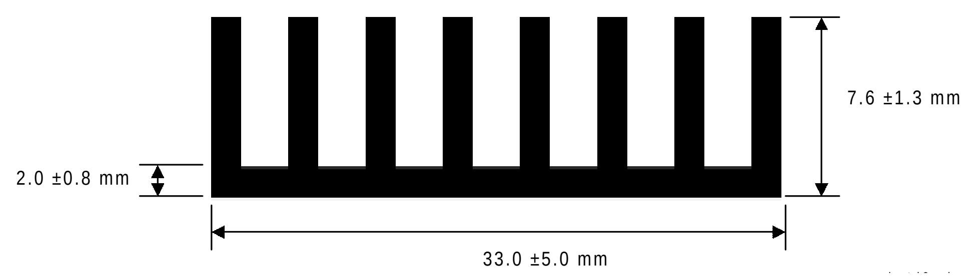
A.2 Default Thermal Solutions

For users having no control over the end-user's thermal environment or for users wanting to bypass the thermal modeling and evaluation process, Intel has developed a default thermal solution for the GMCH (discussed in the following section). The Default Thermal Solutions are designed to replicate the component thermal performance as shown in Figure 3 and Figure 4. **If, after implementing the Default Thermal Solution, the case temperature continues to exceed the appropriate value listed in** Table 1**, additional cooling will be required. This can typically be accomplished by improving airflow to the component or to the motherboard surrounding the component.**

A.3 Extruded Heat Sinks

An extruded heat sink is the default thermal solutions for the Intel® 810 chipset if T_{case} is exceeded and airflow improvements are not implemented. The drawing for this heat sink is shown in Figure 11. Recommended sources for the extruded heat sink are discussed in Appendix B. The weight of any of the extruded heat sinks should not exceed 25 gm.

Figure 10. Extruded Heat Sink Drawing for the GMCH



A.3.1 Attaching the Extruded Heat Sink

The extruded heat sink may be attached using clips and thermal interface (tape, grease, phase-change, etc.), epoxy or tape adhesives.

Clips

A well designed clip in conjunction with a thermal interface material (tape, grease, etc.) solution may offer the best combination of mechanical stability and reworkability. Use of a clip requires significant advance planning as mounting holes are required in the PCB. The mounting holes should be non-plated, but each must have a grounded annular ring on the solder side of the board surrounding the hole. For a typical low-cost clip, this annular ring should have an inner diameter of 150 mils and an outer diameter of 300 mils. It is recommended that this ring contain at least 8 ground connections. The solder mask opening for these holes should have a radius of 300 mils.

As clip designs are generally unique to a specific system and board layout, no procedural comments are provided.

Epoxy

Some users may prefer to implement epoxy attaches for their thermal solution. For these users, products known to be compatible with the mold cap material are listed in Appendix B. Epoxy users should plan their process carefully as once attached, the heat sink may be difficult or impossible to remove without damaging the component

For the epoxies described in Appendix B, the manufacturer's recommended attach procedure is as follows:

1. Ensure that the surface of the component and heat sink are free from contamination. Use a clean, lint-free wipe, proper safety precautions and isopropyl alcohol to ensure cleanliness.
2. Use the applicator provided by the epoxy manufacturer to apply the epoxy-activator to the mold-cap.
3. After the activator-solvent evaporates, the active ingredients will appear "wet" and will remain active for a maximum of two hours after application. **Contamination of the surface during this time prior to bonding must be avoided.**

4. Apply the adhesive to the heat sink. The amount of adhesive applied to the heat sink should be limited to the amount necessary to fill the bond and provide a small fillet.
5. Join and secure the assembly centering the heat sink on the component using a maximum pressure of 30 psi. Wait for the adhesive to set (approximately 5 minutes) before any further handling. Full cure occurs in 4–24 hours. **When applying pressure during attach, care should be taken to ensure that the motherboard is kept flat, bending or flexing the motherboard during application of the thermal solution may damage the solder joints of the Intel® 810 chipset. Excessive bending/flexing will create open joints.**

Note: The successful application of this product depends on accurate dispensing on to the parts being bonded. The manufacturer (Appendix B) offers equipment engineers to assist customers in selecting and implementing the appropriate dispensing equipment for various applications.

To remove the heat sink after the epoxy has set, the manufacturer recommends applying heat (70°C – 93°C) to the assembly. When in this temperature range, the heat sink can safely be removed from the component without damaging it.

Tape

For users who prefer to attach via tape, refer to Appendix B for the suggested manufacturer and part number. To maximize the bond line contact area and improve adhesion we recommend using two pieces of tape, one attached to the heat sink and one attached to the moldcap as shown in Figure 12, Figure 13, and Figure 14. The recommended attach procedure is at the end of this section.

Figure 11.Tape Layers (exploded diagram)

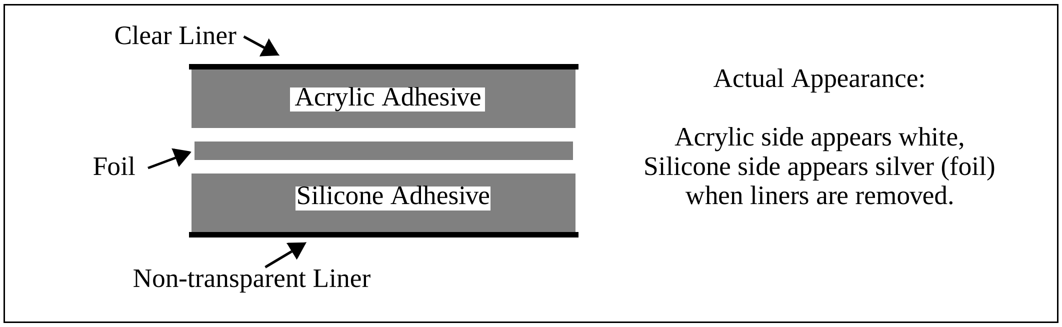


Figure 12.Attaching the Tape to the Package and Heat Sink

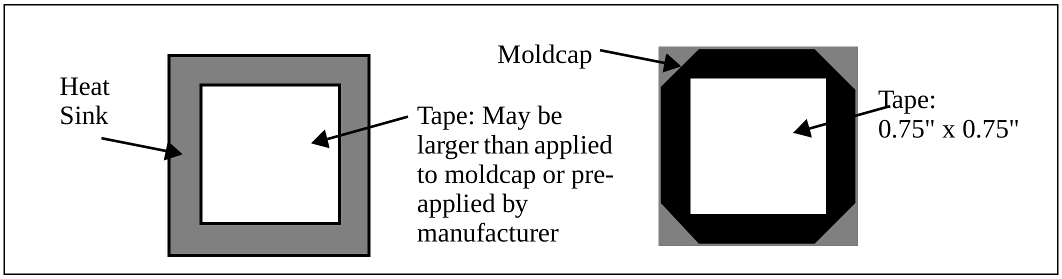
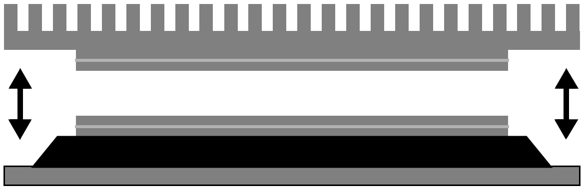


Figure 13.Completing the Attach Process



Note: Silicone adhesive always joins to either the heat sink or the mold cap, the acrylic adhesive sides must join to each other (Figure 12).

Note: As every motherboard, system and heat sink combination may introduce variance in attach strength, it is generally recommended that the user carefully evaluate the reliability of tape attaches prior to using in high volume.

For the Tape described in Appendix B the recommended two-piece attach procedure is as follows:

1. Ensure that the surface of the component and heat sink are free from contamination. Use a clean, lint-free wipe, proper safety precautions and Isopropyl Alcohol to ensure cleanliness.
2. Cut tape to size. Suggestions for the appropriate size can be seen in Figure 13.
3. Heat sink side: Remove the non-transparent liner. You will see foil underneath (Figure 12). Apply the tape to the center of the heat sink and smooth over the entire surface using moderate pressure. **There should be no air bubbles under the tape.**
4. Component side: Remove the non-transparent liner. You will see foil underneath (Figure 12). Apply the tape to the center of the mold cap and smooth over the entire surface using moderate pressure. **There should be no air bubbles under the tape.**
5. Both sides: Remove the clear liners from each side, center the heat sink over the component and apply using any one of the manufacturer's recommended temperature/pressure options shown in Table 6. **When applying pressure during attach, care should be taken to ensure that the motherboard is kept flat, bending or flexing the motherboard during application of the thermal solution may damage the solder joints of the Intel® 810 chipset. Excessive bending/flexing will create open joints.**

Table 6. Tape Attach Application Temperature/Pressure Options (Not To Be Exceeded)

Pressure	Temperature	Time
10 psi (0.069 mPa)	22°C	15 seconds
30 psi (0.207 mPa)	22°C	5 seconds
10 psi (0.069 mPa)	50-65°C	5 seconds
30 psi (0.207 mPa)	50-65°C	3 seconds

Note: Approximately 70% of the ultimate adhesion bond strength is achieved with initial application, 80%–90% of the ultimate adhesion bond is achieved within 15 minutes and ultimate adhesion strength is achieved within 36 hours.

Reliability

As every motherboard, system, heat sink and attach-process combination may introduce variance in attach strength, it is generally recommended that the user carefully evaluate the reliability of the completed assembly prior to use in high volume. Some test recommendations can be seen in Table 7.

Table 7. Reliability Validation

Test[1]	Requirement	Pass/Fail Criteria[2]
Mechanical Shock	50G, board level 11 msec, 3 shocks/direction	Visual Check
Random Vibration	7.3 G, board level 45 minutes/axis, 50 to 2000 Hz	Visual Check
Temperature Life	85°C, 2000 hours total, checkpoints occur at 168, 500, 1000 and 2000 hours	Visual Check
Thermal Cycling	-5°C to +70°C 500 Cycles	Visual Check
Humidity	85% relative humidity 55°C, 1000 hours	Visual Check

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

A.4 Thermal Interface Management for Heat-Sink Solutions

For solutions where a heat sink is preferred, to optimize the heat sink design for the Intel® 810 chipset, it is important to understand the impact of factors related to the interface between the mold-cap and the heat sink base. Specifically, the bond line thickness, interface material area and interface material thermal conductivity should be managed to realize the most effective heat-sink solution.

A.4.2 Bond Line Management

The gap between the mold-cap and the heat sink base will impact heat-sink solution performance. The larger the gap between the two surfaces, the greater the thermal resistance. The thickness of the gap is determined by the flatness of both the heat sink base and the mold-cap, plus the thickness of the thermal interface material (e.g., PSA, thermal grease, epoxy) used between these two surfaces.

The Intel® 810 chipset mold cap planarity is specified as 0.006 inches maximum.

A.4.3 Interface Material Performance

Two factors impact the performance of the interface material between the thermal plate and the heat sink base:

- Thermal resistance of the material
- Wetting/filling characteristics of the material

Thermal resistance describes the ability and ease of the thermal interface material to transfer heat from one surface to another. The higher the thermal resistance, the less efficient an interface is at transferring heat. The thermal resistance of the interface material has a significant impact on the thermal performance of the overall thermal solution. A high thermal resistance requires a larger temperature drop across the interface; thus, the thermal solution needs to be more efficient.

The wetting/filling characteristics of the thermal interface material is its ability to fill the gap between the case and the heat-sink. Since air is an extremely poor thermal conductor, the more completely the interface material fills the gaps, the lower the temperature drop across the interface.

Appendix B Heatsink and Attach Suppliers

Table 8. Extruded Heat Sink Sales Locations

Supplier	Part Number	Comment
Thermalloy*	22372B	http://www.thermalloy.com/catalog/htm/eprof13b.htm#19044
Aavid*	634553 B 01299	http://www.aavid.com/html/atp.html

Table 9. Attach Sales Locations

Supplier	Part Number	Comment
Epoxy*	383 or 384	http://www.loctite.com Select the country of your choice and Select “Products for the Electronics Industry”.
Chomerics Tape	T-410	For Tape, please go to: http://www.chomerics.com/locate

Appendix C System Based Thermal Assumptions

As mentioned in earlier sections, the majority of the thermal power dissipated by the chipset typically flows into the motherboard to which it is mounted (when thermal or center balls are present). The size of the board is a key factor in determining the amount of heat which the package may dissipate. In the course of comparing JESD/JEDEC derived data to data derived from system-level testing, the effect of the larger board used for a typical motherboard was profound. To reconcile the differences and provide more realistic data to the customer, Intel has adopted a system-based thermal simulation and test methodology. Figure 15 and Figure 16 depict the system based model for the Intel® 810 chipset.

The assumptions in the system-based model shown in Figure 15 and Figure 16 are:

- 4L 1oz. Board (6X6") Thermal Dissipation Area
- Processor does not dissipate any heat to MB
- Airflow is parallel to the MB
- Airflow and ambient are measured at 1" above the MB and 1" upstream from the GMCH center
- Processor HS modeled for airflow restriction only.

Figure 14. Airflow/Ambient Reference Point—Front View

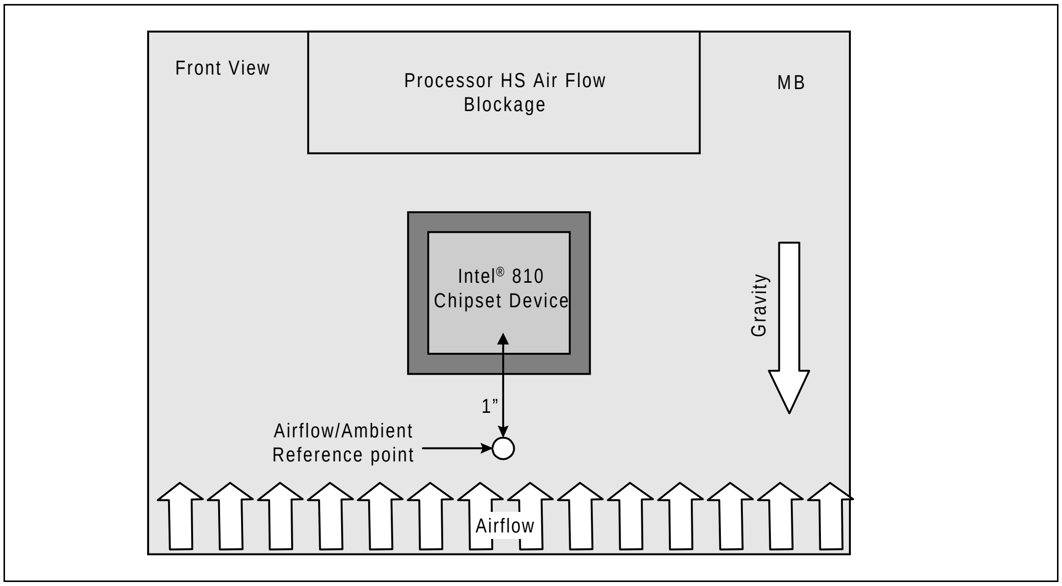
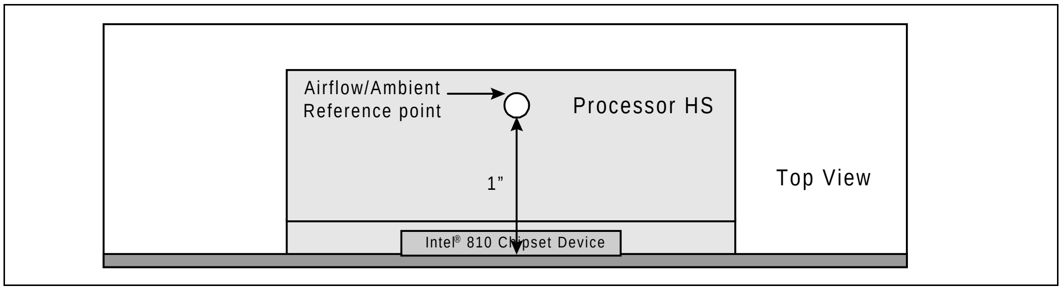


Figure 15. Airflow/Ambient Reference Point—Top View



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