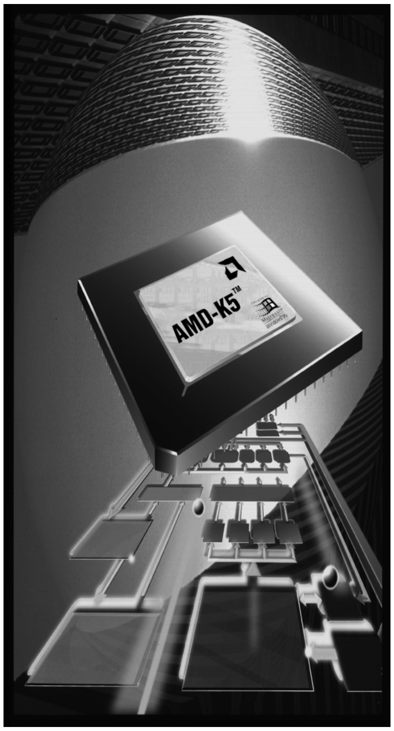

AMD-K5™

PROCESSOR

Thermal Considerations

Application Note

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Contents

List of Tables

List of Figures

AMD-K5™ Processor Thermal Considerations

Introduction

All semiconductor devices dissipate heat as a byproduct of normal operation. Prior to fourth-generation processors, these devices were able to dissipate heat via the integrated circuit package in most personal computer applications. Fifth-generation processors use sub-micron, CMOS VLSI integrated circuit technology to support superscalar processor architecture like the AMD-K5™ processor, which has integrated more than 3 million transistors on a single semiconductor die. Fifth-generation processors generally operate at a reduced supply voltage to minimize power consumption. Reducing V_{cc} from +5 V to +3.3 V decreases the power consumption by approximately 43 percent. Even with this power savings, fifth-generation processors can still exceed the maximum case temperature specification when operating at maximum clock frequency. External integrated cooling solutions such as heat sinks, heat spreaders, and heat sink/fan modules are required to maintain safe thermal margins for the processor junction temperature.

This application note discusses integrated circuit cooling solutions, thermal terms, and explains the thermal equations. This information allows designers to select the best processor cooling solution for personal computer applications. These solutions should have the following attributes: maintain safe processor thermal margins, be a non-custom solution that is readily available, be easy to attach to personal computer motherboards, have adequate mechanical attachment to withstand personal computer shock and vibration specifications, and be cost effective.

Definition of Thermal Terms

This section defines the thermal-related terms used in this document.

Temperature (T) is the degree of hotness or coldness of a material. The temperature abbreviation, T, is used in the following terms:

- $\mathbf{T_{junction}}$ is the junction temperature of the processor die
- $\mathbf{T_{case}}$ is the temperature of the processor case
- $\mathbf{T_s}$ is the temperature of the heat sink
- $\mathbf{T_a}$ is the ambient temperature. Ambient temperature is the average or mean temperature of the surrounding air that comes in contact with the unit under test. For personal computer applications, ambient temperature is the average temperature inside the personal computer that comes in contact with the heat sink and processor case.

Thermal Resistance (θ) is the opposition offered by a medium to the passage of thermal energy and is expressed in units of ^{o}C / watts. The thermal resistance abbreviation, θ, is used in the following terms:

- θ_{jc} is the thermal resistance from junction to processor case
- θ_{cs} is the thermal resistance from case to heat sink
- θ_{sa} is the thermal resistance from heat sink to ambient air

Heat Transfer is the process of thermal energy flowing from a body of higher temperature to a body of lower temperature. The means of transfer are conduction, convection, and radiation.

Natural Convection is the movement of ambient air over, around, and through a heat sink that is induced by temperature differences generated as a byproduct of processor power dissipation, also known as buoyancy effects. When air is heated around the processor, warm air rises and cool air sinks, causing air circulation around the processor package.

Forced Air Convection is caused by an active power element (e.g., a fan or a blower) that forces air to circulate around and through the heat sink channels (extruded and pin fin heat sinks). Heat sink/fan modules use impingement airflow to force air into the top of the heat sink. A hot wire anemometer can be used in wind tunnels to characterize heat sinks and heat spreaders. The anemometer is generally located in front of the heat sink (e.g., 2 inches) to minimize the effect of the air turbulence caused by the heat sink.

Heat Sinks are devices designed to transfer heat generated by an electronic component to a gas or a liquid. They are usually made of heat-conductive metal that has the ability to rapidly transmit heat from the generating source to the ambient air.

Heat Conduction is the transmission of heat by random molecular motion or vibration from a hotter region to a cooler region in the conducting media.

Convection is the transmission of thermal energy by random molecular motion or vibration and gross bulk motion of a fluid from a hotter region to a cooler region through a moving medium, such as air or water.

Radiation is the process of emission, transmission, and absorption of thermal energy by electromagnetic waves between bodies separated by empty space.

Thermocouples are sensing devices constructed of two dissimilar metals with a junction point. A thermocouple develops a voltage proportional to the difference in temperature between the hot junction and the lead wires. These devices are used to measure the temperature of materials.

Heat Sinks

A heat sink is thermally connected to the AMD-K5 processor to dissipate the heat it generates as a byproduct of its normal operation. If this heat is not removed, the processor would exceed its maximum operating temperature and fail. The junction temperature of the processor is a function of the thermal resistance between the junction and the ambient air, the amount of heat being dissipated, and the ambient air temperature.

Heat Sink Equations

The total thermal resistance from junction to ambient air, θ_{ja}, is equal to the sum of the following: thermal resistance from junction to case, thermal resistance from case to heat sink, and thermal resistance from heat sink to ambient air (see Equation 1 and Figure 1 for more information).

Equation 1 $\theta_{ja} = \theta_{jc} + \theta_{cs} + \theta_{sa}$

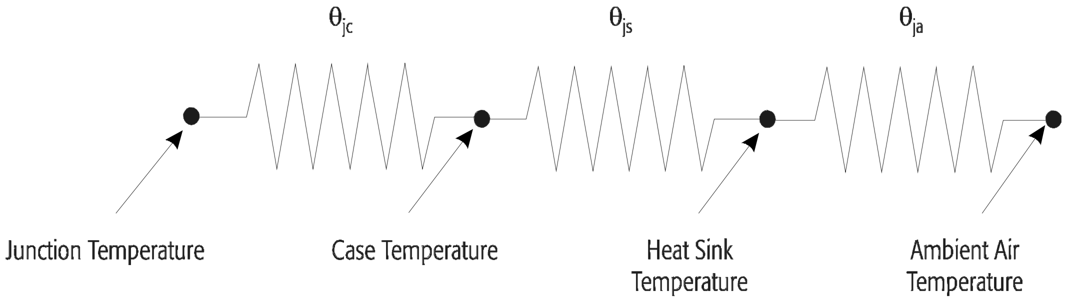


Figure 1. Series Resistance Representation of the Thermal Resistance Path

When the processor dissipates heat via the thermal interface layer, the relationship of the temperatures at the different thermal boundaries is found by using Equation 2:

Equation 2 $P_{max} = (T_j - T_a) / (\theta_{jc} + \theta_{cs} + \theta_{sa})$

where

- P_{max} is the maximum power consumption (in watts) of the AMD-K5 processor
- T_j is the operating junction temperature of the processor die
- T_a is the average ambient temperature inside the personal computer enclosure

- θ_{jc} is the thermal resistance from junction to case
- θ_{cs} is the thermal resistance from case to heat sink
- θ_{sa} is the thermal resistance from heat sink to ambient air

The above relationship can also be stated in the following forms:

Equation 3 $$\mathbf{P_{max} = (T_c - T_a) \;/\; (\theta_{cs} + \theta_{sa})}$$

Equation 4 $$\mathbf{P_{max} = (T_s - T_a) \;/\; (\theta_{sa})}$$

where

- T_c is the case temperature of the AMD-K5 processor
- T_s is the heat sink temperature

The heat sink selection process requires knowledge of the following system variables:

- Available volume of space to be occupied without interference of other system components (e.g., personal computer expansion cards, side walls of enclosure, peripherals, cables, etc.)
- The maximum allowable device junction temperature of the processor die
- The maximum power dissipation of the processor
- The device configuration (package size and orientation of the package)
- Ambient conditions (temperature, air velocity, and airflow direction)

Types of Heat Sinks

The most frequently used heat sinks for processor cooling applications are discussed in the following sections. These heat sinks are designed to transfer heat from the processor into the air inside a personal computer case. Several manufacturers offer standard, cost effective, aluminum products (e.g., extruded, pin fin, die cast), composition products, and custom products. Each heat sink should have the following items specified: thermal resistance (i.e., natural and forced air), size (length, width, and height), and weight. Many heat sink product families have one standard shape and varying heights (e.g., 0.25 in, 0.5 in, 0.75 in, 1.00 in, 1.25 in, etc.) to handle different processor speed grades. The speed of an AMD-K5 processor is directly proportional to its power consumption (see *The AMD-K5 Processor Thermal and Power Specifications* on page 17 for more information). Larger heat sinks usually cost more and can have reduced internal airflow. Airflow is a function of the friction coefficient, channel size, surface conditions, and heat sink shape. Closely examine the geometry of the heat sink to determine the best heat sink orientation for reducing airflow resistance.

Heat sink thermal performance is expressed for both natural and forced airflow. A typical heat sink performance curve (see Figure 2) is shown with two curves. Natural convection is represented by the positive slope curve. This curve is read from the left axis (heat sink temperature) and bottom axis (heat dissipation). Forced convection is represented by the negative slope curve. This curve is read from the upper axis (air velocity) and the right axis (thermal resistance from sink to ambient). Airflow is often the biggest uncertainty for processor designs and it is the most important variable on heat sink thermal performance.

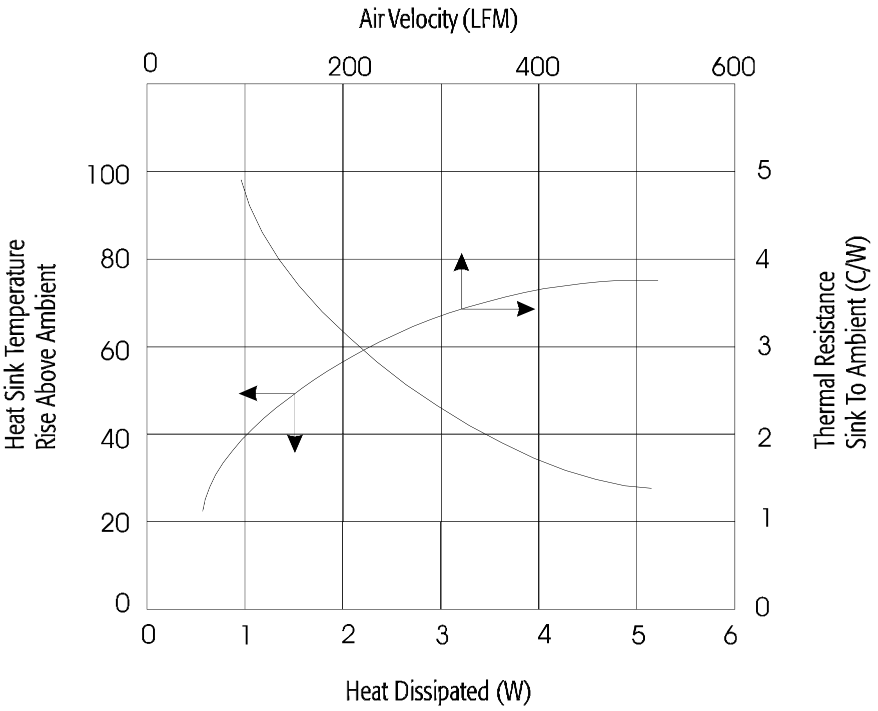


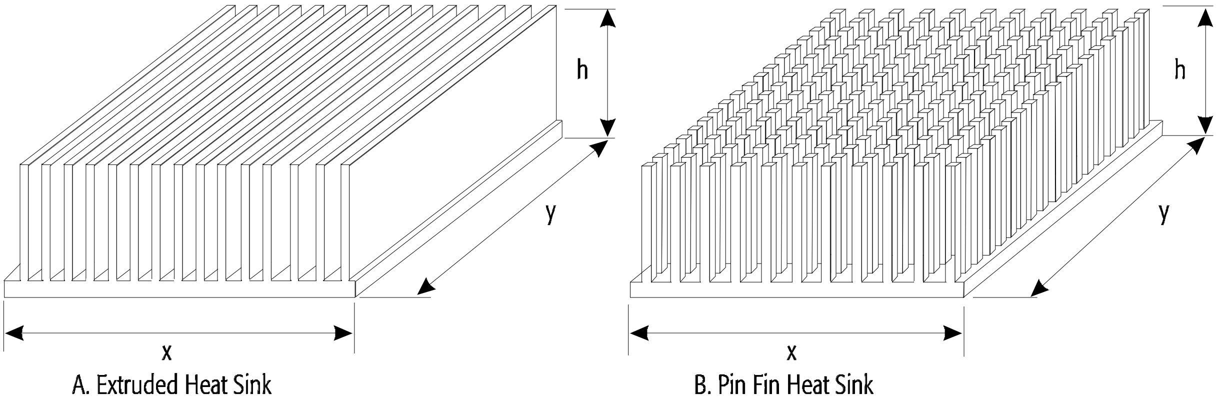
Figure 2. Natural and Forced Convection Curves for a Typical Heat Sink

Extruded Aluminum Heat Sinks

The extruded aluminum heat sink is the least expensive processor cooling solution, but it must be aligned with an airflow or have an attached fan. Many of the least expensive heat sink/ fan modules use aluminum extruded heat sinks.

If the extruded aluminum heat sink is not used with an attached fan module, the forced airflow must be generated by the personal computer power supply fan or system fan. The power supply fan usually blows warm air out of the system enclosure. Personal computer airflow can be obstructed by any of the following items: expansion cards, ribbon cables, internal peripherals, power cables, and brackets. Extruded aluminum heat sinks are specified usually with airflow entering the heat sink from one of two open ends. Using the extruded aluminum heat sink requires an in-depth knowledge of the airflow velocity and direction. To optimize heat sink efficiency, the airflow should be aligned with the extruded length of the heat sink.

Extruded aluminum heat sinks for the AMD-K5 processor are available with the following configuration variables: number of fins, location and thickness of fins, fin heights, and thickness of the base plate. For an example of an extruded aluminum heat sink, see Figure 3A.



A. Extruded Heat Sink

B. Pin Fin Heat Sink

Figure 3. Extruded and Pin Fin Heat Sinks

The example in Figure 3A has a base plate and 15 fins. The base plate would have a layer of thermal interface material applied to it (e.g., thermal grease) and then be mounted against the top of the AMD-K5 processor ceramic case top. The dimensions of the heat sinks in Figure 3 are represented by x and y for the base and h for the height.

Pin Fin Aluminum Heat Sinks

The pin fin aluminum heat sink is cost effective (e.g., approximately 1.2 times the cost of the extruded aluminum heat sink) and has the advantage of omnidirectional airflow. This means that airflow can efficiently enter the heat sink from any side. The airflow is maximized if it is in line with the row of pins. In personal computer cases, airflow moves in many directions because of mechanical restrictions. *Therefore, pin fin heat sinks are generally recommended.* For an example of a pin fin heat sink, see Figure 3B.

The pin fin aluminum heat sink can also be manufactured with an attached fan module. If a fan is attached, the height of the module is the combination of the heat sink height and the fan height.

Heat Sink/Fan Modules (Pin Fin Heat Sinks with Attached Fan)

In this type of module the following items are supplied: heat sink, DC brushless fan, and fan cable with four-pin power connector. These modules may be purchased in a retail store without any instructions or specifications. It is a gamble for personal computer system designers to select these modules by appearance and cost only. The least expensive modules generally come with sleeve bearings in the fan. Such fans are not noted for their reliability and durability, and are, therefore, *not* recommended. Better heat sink/fan modules have ball bearing fan motors and the following specifications:

Table 1. Heat Sink/Fan Module Specifications

Electrical Fan Specification	Recommended Specification for AMD-K5 Processors
1) Type of DC motor	Brushless DC motor, power supply voltage: +12 V or +5 V
2) Rated motor power consumption	Application dependent (e.g., approximately 1 watt)
3) Fan motor should have	With cable and standard 4-pin power supply connector
4) Optional alarm available if fan fails	When fan speed drops to less than 70% of rated speed
Mechanical Specification	
1) Heat sink type	Pin fin, extruded, or die cast aluminum
2) Rated airflow	Application dependent (e.g., 9 cubic feet per minute)
3) Noise	Application dependent (e.g., 27 dB)
4) Size x, y, h	Base plate approximately 2-inch square, and height dependent on application. See Figure 3 for more information.
5) Attachment means	Heat sink clip
6) Head clearance fan	Clearance height above fan air intake (e.g., 0.5 in to 1 in minimum)
7) Fan bearings	Sealed ball bearing
Thermal Performance	
Thermal resistance	Application dependent: thermal specification of the personal computer operating temperatures, power specification of AMD-K5 processor, airflow and flow direction of the processor

Sleeve bearing fans are less expensive but have as little as 1/10 the expected fan life as the more expensive sealed ball bearing fan (cost increase for a fan with sealed ball bearing is less than a $1.00). It is strongly recommended that sealed ball bearing fan motors be used for heat sink/fan modules. A fan failure is defined as a fan decreasing to less than 70 percent of its initial rotational speed. Evox Rifa has a technical note on fan operating life. See *Heat Sink Fan Motor Manufacturer* on page 35 for more information.

The heat sink/fan module uses an attached fan that generates airflow into the heat sink. This is referred to as *impingement airflow.* (see Figure 4 for more information.)

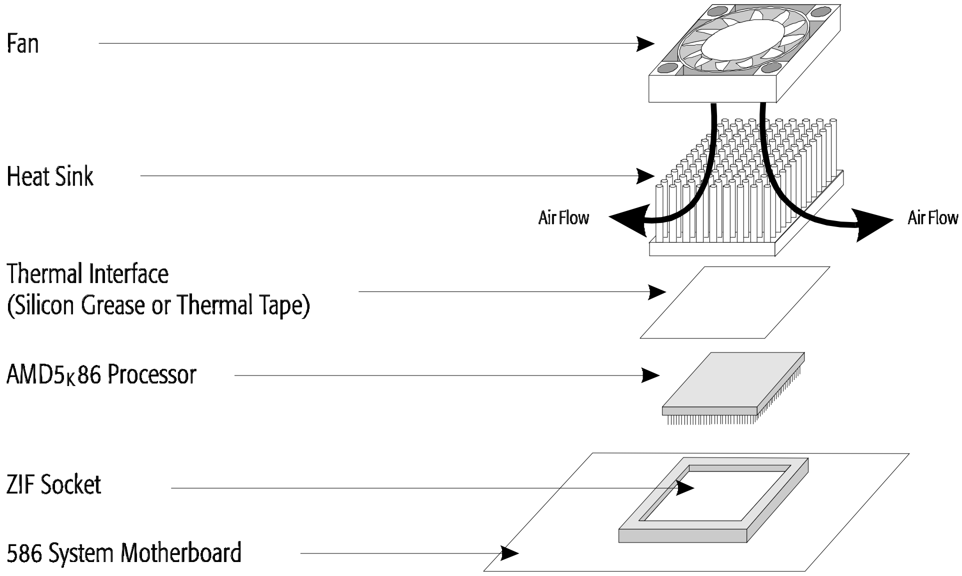


Figure 4. Heat Sink Impingement Airflow

Heat Sink Mechanical Interface

The heat sink mechanical interface (e.g., heat sink clips) is designed to withstand shock and vibration during shipping and normal operation. These heat sink clips assert pressure against the thermal interface and secure the heat sink to one of the following: the AMD-K5 processor, the AMD-K5 processor socket, or the personal computer motherboard. Different options for securing mechanical interfaces to the AMD-K5 processor are shown in Figure 5 and Figure 6. In both figures, options 3 and 4 are recommended. The first two options are not recommended because the processor can be dislodged from its socket due to shock and vibration.

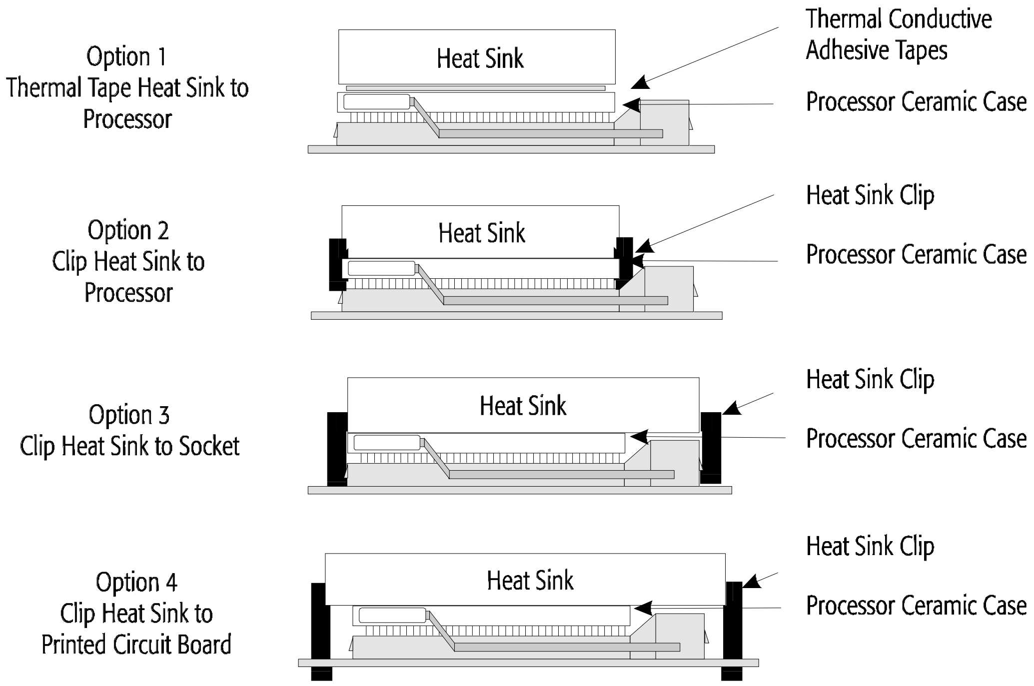


Figure 5. Mechanical Interface from AMD-K5 Processor to Heat Sink Options (Personal Computer Power System Fan Generates Airflow)

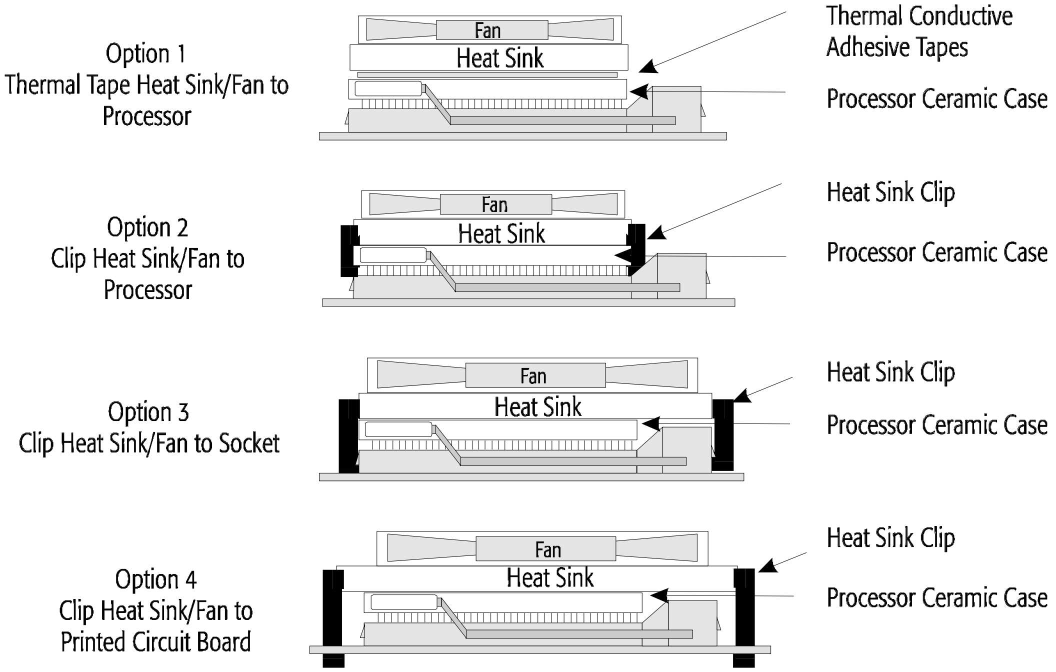


Figure 6. Mechanical Interface from AMD-K5 Processor to Heat Sink/Fan Module Options (Airflow Generated by Fan on Module)

Thermal Interfaces

Thermal interface between the case and heat sink is controlled in a variety of ways using different heat conducting materials. The interface resistance between the case and the heat sink is dependent on three variables: p (the thermal resistance of the interface material in units of (^{o}C · inch^{2}) / (watts · thickness in inches)), t (the average material thickness in inches), and A (the area of contact in square inches). These variables are related in the following equation:

Equation 5 $$\theta_{cs} = (p \cdot t) / A$$

Table 2 contains typical thermal resistance values for materials used in cooling solutions for semiconductors.

Table 2. Thermal Conductivity Values for Materials Used In Cooling Solutions

Thermal Interface Materials	Thermal Conductivity (Watts / (Meter · ^{o}C)
Copper (pure)	389
Aluminum (1100 series)	200
Aluminum (6000 series)	220
Beryllia	240
Carbon Steel	60.5
Alumina	21
Anodized Finish	0.5-1.0
Silicone RTV	0.2
Polyimide	0.15
Silicone Grease	0.5-1.0
Dead Air	0.026

The thermal interface material is placed between the top of the AMD-K5 processor case and the bottom plate of the heat sink. It is recommended that the heat sink plate have a flatness tolerance of 0.002″ to 0.003″ per inch. The thickness of the thermal interface material should be minimized to obtain the lowest possible thermal resistance. The thermal grease compounds are the best materials for the thermal interface, followed by thermal compounds, and then thermal adhesive tapes. (The latter is the least desirable from a thermal standpoint, but the most desirable from a user installation standpoint.)

Thermal Grease

Thermal grease is a compound composed of a carrier, conductor, and binder. The carrier is used to support the conductive material. The conductor is a material of relatively low thermal resistance and is added to the carrier as a filter. The binder is a material that controls the viscosity of the compound. Thermal grease is applied to both the heat sink and processor case to fill air gaps between the two surfaces. When using thermal grease, a heat sink clip is required. An example of thermal grease is the Thermalcoate I manufactured by Thermalloy, Inc. The thermal resistance of this material is p, expressed in units of ($^oC \cdot inch^2$) / watts.

Thermal Compounds

An alternative to silicone-based thermal greases (e.g., Sil-Free by Aavid) is silicone-free thermal joint compound, which is filled with metal oxide filler. These compounds were developed as an alternative to silicone grease and they do not exhibit the deterioration or contamination associated with silicone-based products. This material efficiently fills the air gaps between the top of the processor case and the bottom of the heat sink. When using these compounds, a heat sink clip is required.

Thermal Grease with Aluminum Carrier

These products use an aluminum carrier with a typical thickness of 0.004 inches and have uniform droplets of silicone grease applied to both sides of the aluminum carrier. Both sides have a protective paper coating that is removed prior to installation. An example of this product is Conducta-Cote by Thermalloy, Inc.

Thermal Adhesive Tape

Thermal tapes consist of the following: thermally conductive carrier, adhesive material coated on both sides, and a clear release liner used to protect the adhesive surface during shipping and handling. These tapes provide a thermal interface between the processor case and the heat sink. The adhesive material provides the mechanical attachment between the heat sink and processor case. This interface is prone to mechanical failures if one or more of the following conditions exist:

- Foreign material on the heat sink, processor case, or thermal interface tape
- Incorrect thickness of thermal interface tape. If the tape is too thin, air pockets may form. If the tape is too thick, the thermal resistance increases.
- Insufficient pressure applied during installation of tape.
- Failure to prepare the surface of the processor case with ceramic sealer.

For these reasons, thermal tapes are not recommended. But, if the personal computer design requires the use of thermal tape, the materials and procedures described below should be used.

Table 3. Thermal Conductive Adhesive Tapes

Typical Properties	Chomerics T405	Chomerics T412	Test Method
Carrier	Aluminum	Expanded Aluminum	n/a
Color	White	Gray	n/a
Thermal Resistance, $(^{o}C \cdot inch^{2})$ / Watt	0.5	1.40	MIL-I-49456A
Thermal Conductivity, Watt / (Meters · ^{o}C)	0.5	0.25	MIL-I-49456A
Thickness (in inches)	0.006	0.009	n/a
Shear Adhesion, psi @ $25^{o}C$	125	135	Chomerics T.P. 54
Shear Adhesion, psi @ $150^{o}C$	55	25	Chomerics T.P. 54

When using thermal conductive adhesive tape it is important to select one tape that fills the gap between the two surfaces (tolerance of both processor case top and heat sink is worst case of 0.003 inch). Therefore, tape thickness of a minimum of 0.006 inch should be used to fill the microscopic holes in the surfaces.

When ceramic packages are used, some manufacturers recommend using a primer (e.g., 1088 Primer by Chomerics) on the ceramic package before the adhesive tape is applied. The primer fills the porous ceramic surface to allow the adhesive tape to obtain a greater bond surface.

The procedure for applying thermal tape to the AMD-K5 processor and the heat sink is:

1. Cut the tape to a size that can cover the entire area between the AMD-K5 processor and the heat sink.
2. Make sure that all oils and dust are removed from the AMD-K5 processor case top and the bottom of the heat sink to ensure maximum adhesion. This is done by using a lint-free cloth with an industrial cleaner (e.g., toluene, acetone, or isopropyl alcohol) and rubbing both surfaces.
3. Peel away the clear release liner from the non-embossed side of the thermal adhesive tape.
4. Apply tape to the AMD-K5 processor case top.
5. Smooth over the entire surface of the tape with moderate pressure, using the applicator provided.
6. Remove the blue liner from the embossed side of the tape.
7. Align both the AMD-K5 processor and the heat sink and apply pressure (e.g., 10 psi).

   Note: *Improved surface contact can be achieved by heating the tape with a conventional heat gun, not to exceed 100^{o}C, prior to applying pressure.*
8. Approximately 70% of the ultimate adhesion is achieved at initial contact. At least 36 hours is required before ultimate adhesive strength is achieved.

The AMD-K5 Processor Thermal and Power Specifications

Table 4 contains target data believed to be accurate, but consult the AMD-K5 processor data sheet for the latest specifications.

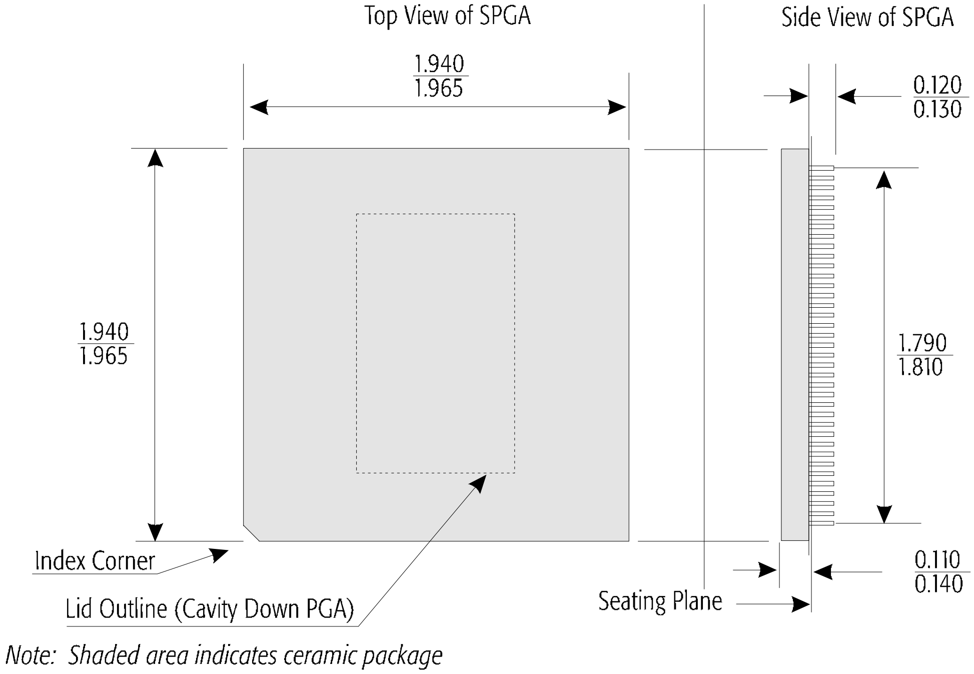
Table 4. Operating Range of the AMD-K5 Processor

Symbol	Parameter Description	Min.	Typical	Max.	Comments
T_{case}	Case Temperature	0^oC		70^oC	Temperature measured at the top center of case
V_{CC}	Power Supply Voltage	3.135 V		3.465 V	V_{CC} = 3.3 V +/- 5%
I_{CC}	Power Supply Current			44 mA / MHz	V_{CC} = 3.6 V
I_{CC}	Power Supply Current		36 mA / MHz		V_{CC} = 3.3 V

Physical Dimensions of the AMD-K5 Processor

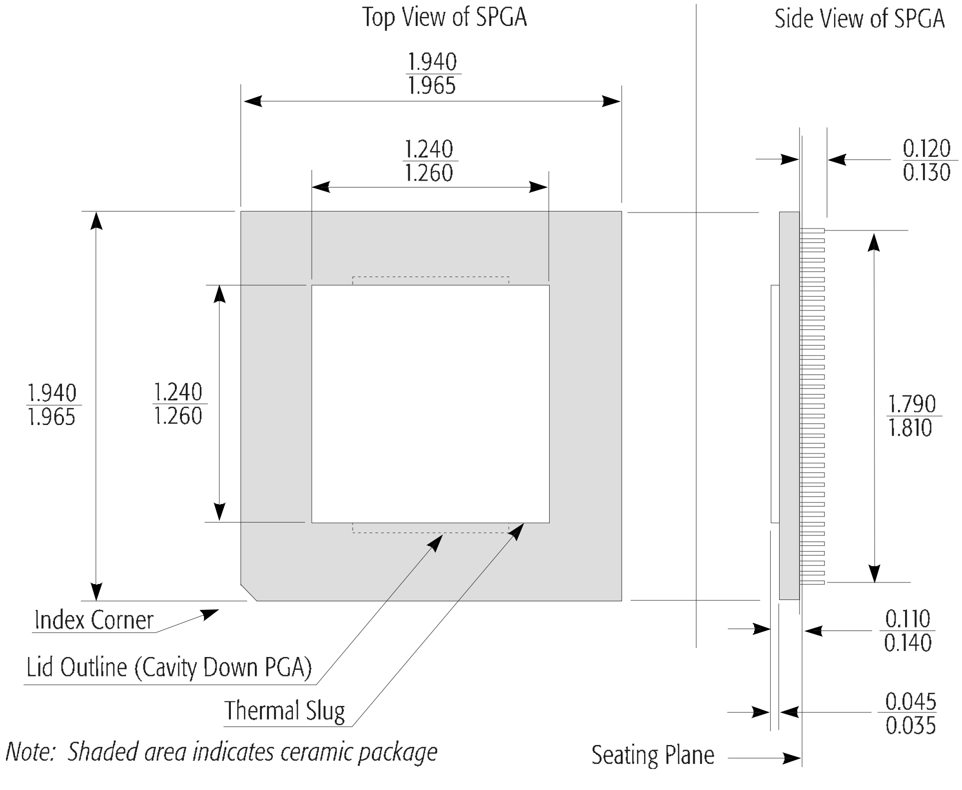
This section defines the mechanical specification for the AMD-K5 processor case, shown in Figure 7A and Figure 7B. The top of the ceramic package, approximately 4 square inches in area, is where the primary heat transfer occurs. Very little heat transfers from the bottom or sides of the package. The thermal interface is applied to the top of the package and care should be taken not to get foreign material on the interface or the heat sink surface.

Note: *Use the information in Figure 7A and Figure 7B for thermal reference only.*



Note: Shaded area indicates ceramic package

Figure 7A. 296-Pin Ceramic Staggered Pin Grid Array



Note: Shaded area indicates ceramic package

Figure 7B. 296-Pin Ceramic Staggered Pin Grid Array With Thermal Slug

Both the ceramic and the ceramic thermal slug PGA packages have the same overall dimensions (see Figure 7A and Figure 7B). Thus, the same cooling solution can be used for both processor packages. The heat sink clip that mechanically attaches the heat sink and processor to the processor ZIF socket is not affected by the package. The thermal interface layer (i.e., the silicon grease) has a cross sectional area of 3.8 square inches (1.95 inch squared) for the ceramic package, and 1.56 square inches (1.25 inch squared) for the ceramic thermal slug package. The copper slug has greater thermal conductivity than the ceramic package, allowing the processor junction to operate at a lower temperature for the same power levels. Vibration and shock testing have shown that the same heat sink clips perform equally for both processor packages.

Personal Computer System

To ensure good airflow in the personal computer, air vents should be inserted into the chassis. These vents bring in cooler ambient air from outside the chassis and cool the AMD-K5 processor inside the chassis. Refer to Figure 8 for more information.

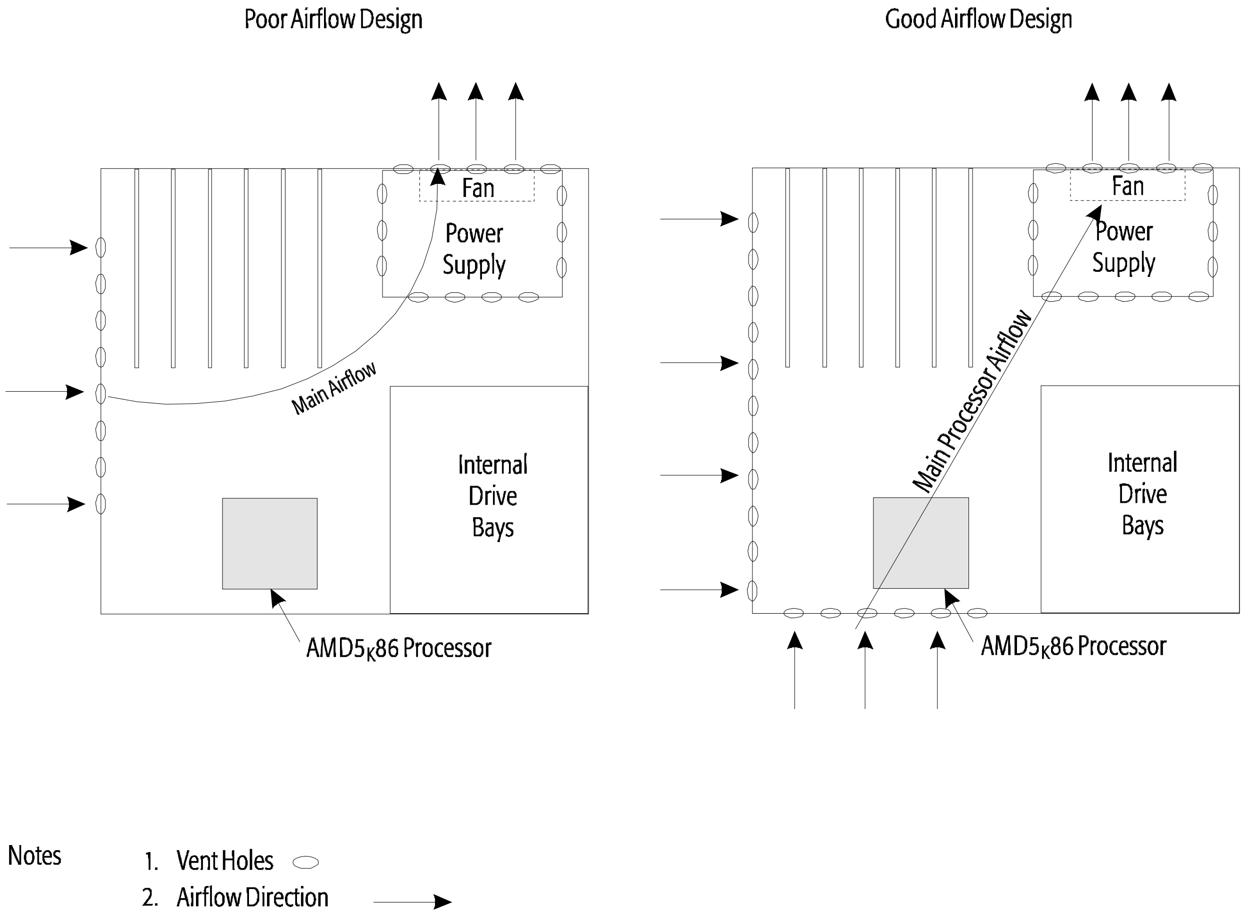


Figure 8. Airflow Through the Personal Computer Chassis

Thermal Measurement Procedure

The operating temperature range for the AMD-K5 processor case temperature is typically 0°C to 70°C. (Check the OPN and data sheet for the exact temperature range.) This temperature should be measured on the top of the case in the middle of the package (see Figure 9). In order to measure this temperature, a hole must be drilled into the heat sink and a thermocouple placed in contact with the case. Recommended thermocouple types include J, K, and T manufactured by Omega Engineering, Inc. Thermal epoxy is usually used to secure the thermocouple to the heat sink. Only the thermal bead at the end of the thermocouple should make contact with the AMD-K5 processor case. The leads of the thermocouple should be kept at a 90° angle to the processor case top. The thermocouple leads should not be allowed to short out against the metal heat sinks.

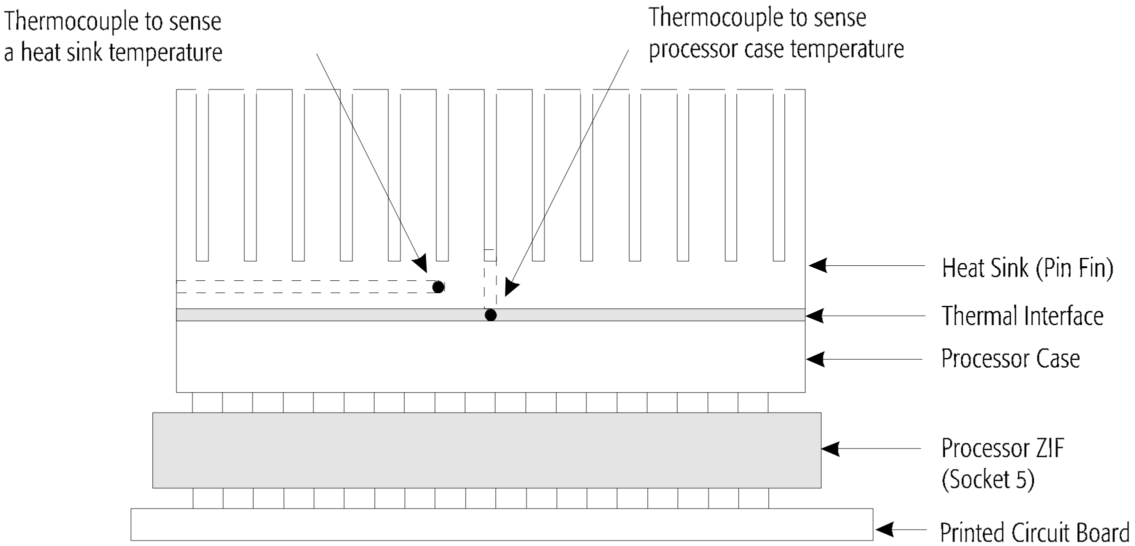


Figure 9. Test Setup to Measure AMD-K5 Processor Case and Heat Sink Temperature

Thermal Characterization of the AMD-K5 Processor 296-Pin Ceramic PGA Package

A thermal study was conducted to determine the thermal resistance of the AMD-K5 processor 296-pin grid array ceramic package. Three heat sinks were evaluated (i.e., heat sinks A, B, and C). All heat sinks were of the extruded aluminum pin fin design and were attached with a single clip to the AMD-K5 processor socket (AMP Socket 5). The socket was soldered to a six-layer printed circuit board.

Thermal test dies were mounted inside the processor ceramic package and were used as the source of the heat dissipation, simulating heat from the processor. These thermal dies have power resistors and PN junctions that are used to sense the junction temperature. The PN junctions were calibrated at the beginning of the test by accurately measuring voltage drops at different temperatures.

Type K (alumel/chromel) 40 AWG thermocouples were used to sense the case, heat sink, and ambient temperatures. Ambient temperatures were measured away from the processor to avoid local heating errors. Results of the measurements include calculations of steady state thermal resistance (see Table 6 for more information).

The heat sinks used in this study were supplied by manufacturers and are representative of fifth-generation pin fin designs. See Table 5 for heat sink characteristics.

Table 5. Test Heat Sink Characteristics for Fifth-Generation Processors

	Dimensions (inches)	Manufacturer	Part Number	Comments
Heat Sink A	Base = 1.96 x 2.67 Height = 0.45	Aavid	022694	124 pin fins
Heat Sink B	Base = 1.96 x 2.675 Height = 0.7	Aavid	363324B	132 pin fins
Heat Sink C	Base = 2.1 x 2.1 Height = 1	Wakefield	698-100AB	Penguin Cooler with 132 pin fins

Three types of thermal interface material were used in this test. The first material was standard silicon oil-based thermal grease. The second material was fiberglass-reinforced silicone interface material (ADUX White Pad by Thermagon, Inc.). The third material was thermally conductive elastomer (AS-210 Rose Pad by Thermagon, Inc.).

The steady state test results are detailed in Tables 7 through 16. Each table is accompanied by a figure that represents the test results graphically. Thermal grease is clearly the best thermal interface material. The variation in thermal interface resistance was caused by the heat sink flatness. Having a heat sink improved thermal resistance over not having a heat sink. Heat sinks B and C show similar performance. Heat sink B has a greater area in contact with the processor case, but heat sink C is taller. The volume of heat sink B is 3.7 cubic inches and the volume of heat sink C is 3.8 cubic inches.

Table 6. Table of Thermal Measurements

Parameter	Symbol	Units
Junction to Air	θ_{ja}	^oC / Watt
Junction to Airflow	θ_{ja} @ 200 linear feet/min (lfpm)	^oC / Watt
Junction to Airflow	θ_{ja} @ 400 lfpm	^oC / Watt
Junction to Case	θ_{jc}	^oC / Watt
Case to Ambient	θ_{ca}	^oC / Watt
Heat Sink to Ambient	θ_{sa}	^oC / Watt
Case to Heat Sink	θ_{cs}	^oC / Watt

Thermal Resistance Calculations with No Heat Sink

Table 7. Thermal Resistance Calculations with No Heat Sink

Airflow (lfpm)	θ_{ca}
0	12.6
200	9.3
400	8.5

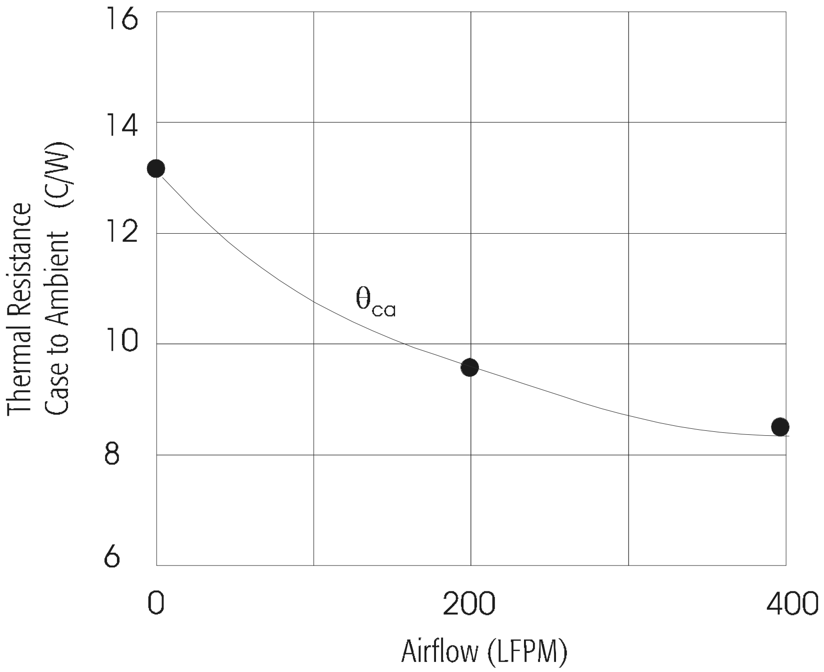


Figure 10. AMD-K5 Processor With No Heat Sink

Note: *The AMD-K5 processor requires a heat sink in most personal computer applications. The thermal data with no heat sink provides a point of reference for comparing the reduction of thermal resistance from case to ambient when a heat sink is used.*

Thermal Resistance Calculations with Pin Fin Heat Sink A

Table 8. Heat Sink A with Thermal Grease

Airflow (lfpm)	θ_{ca}	θ_{sa}	θ_{cs}
0	6.10	5.58	0.52
200	3.60	3.40	0.20
400	2.80	2.58	0.22

Table 9. Heat Sink A with White Pad

Airflow (lfpm)	θ_{ca}	θ_{sa}	θ_{cs}
0	7.60	5.48	2.12
200	5.30	3.27	2.04
400	4.50	2.42	2.08

Table 10. Heat Sink A with Rose Pad

Airflow (lfpm)	θ_{ca}	θ_{sa}	θ_{cs}
0	7.60	5.48	2.13
200	5.20	3.22	1.98
400	4.40	2.44	1.90

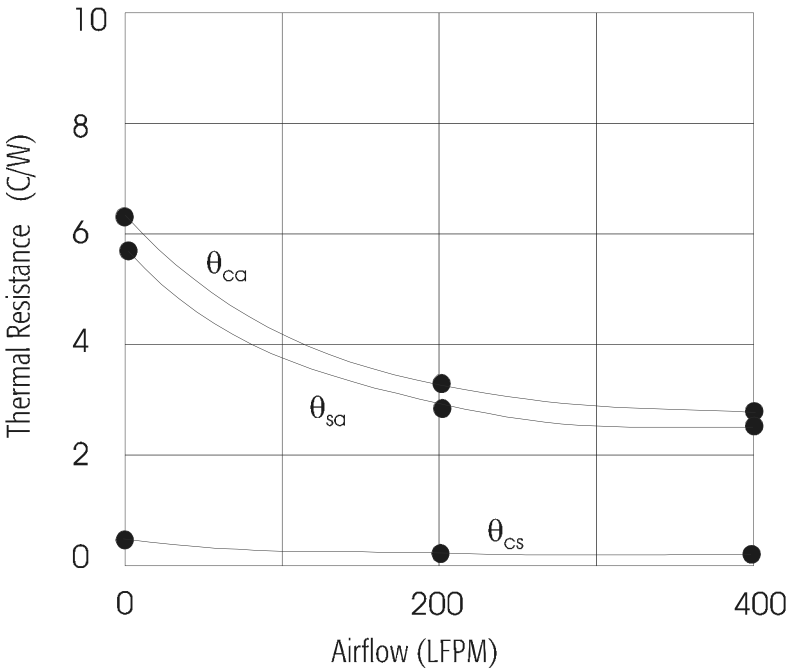


Figure 11. Heat Sink A with Thermal Grease

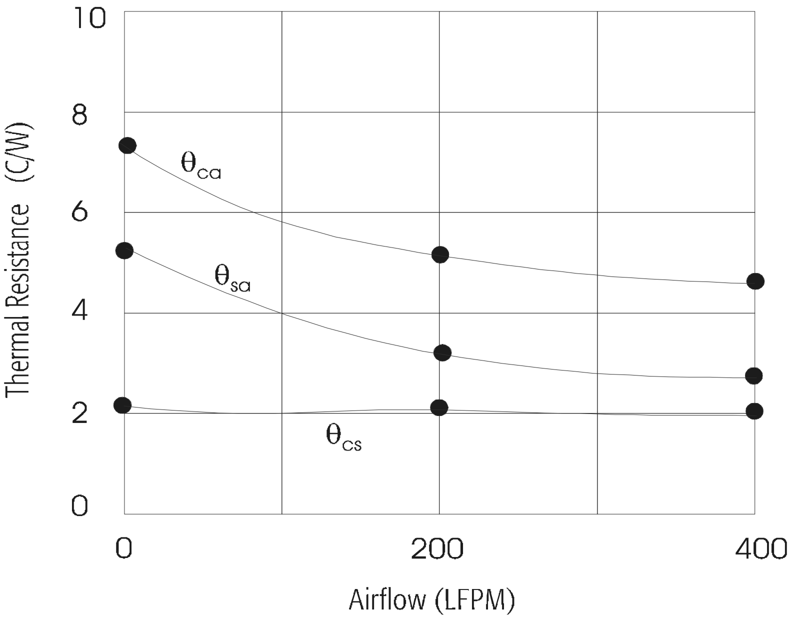


Figure 12. Heat Sink A with White Pad

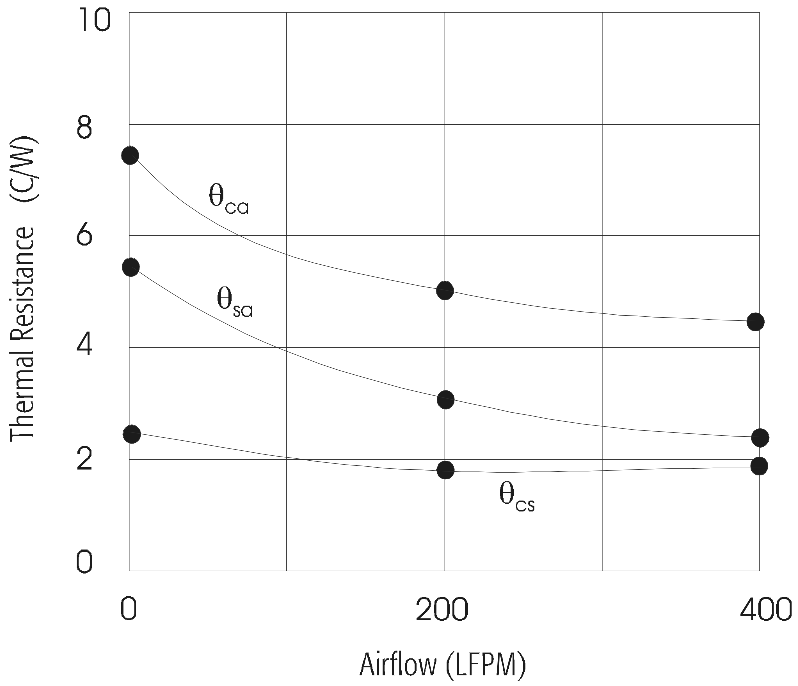


Figure 13. Heat Sink A with Rose Pad

Thermal Resistance Calculations with Pin Fin Heat Sink B

Table 11. Heat Sink B with Thermal Grease

Airflow (lfpm)	θca	θsa	θcs
0	5.00	4.44	0.56
200	3.10	2.72	0.38
400	2.20	1.90	0.30

Table 12. Heat Sink B with White Pad

Airflow (lfpm)	θca	θsa	θcs
0	7.30	4.52	2.78
200	6.00	2.49	3.51
400	5.20	1.69	3.51

Table 13. Heat Sink B with Rose Pad

Airflow (lfpm)	θca	θsa	θcs
0	7.30	4.40	2.90
200	5.10	2.63	2.47
400	4.30	1.82	2.48

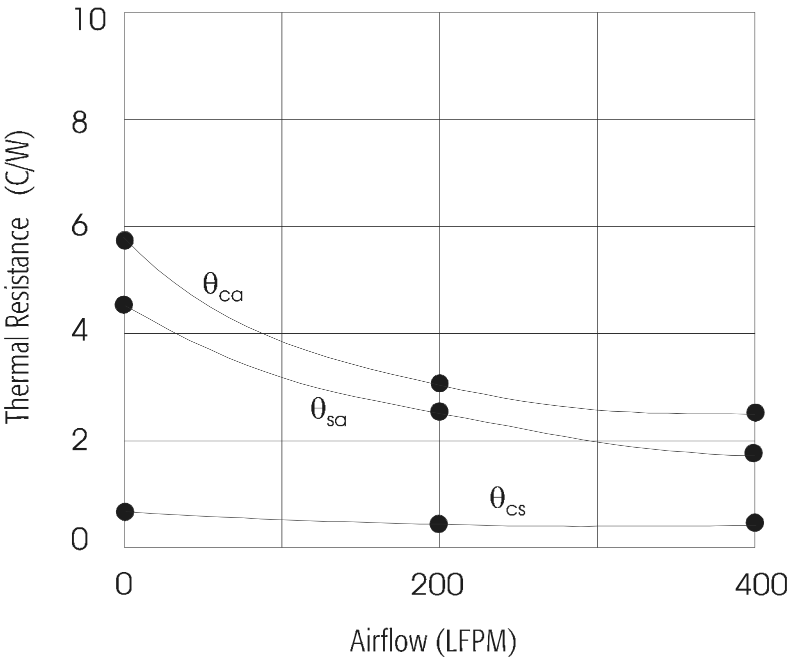


Figure 14. Heat Sink B with Thermal Grease

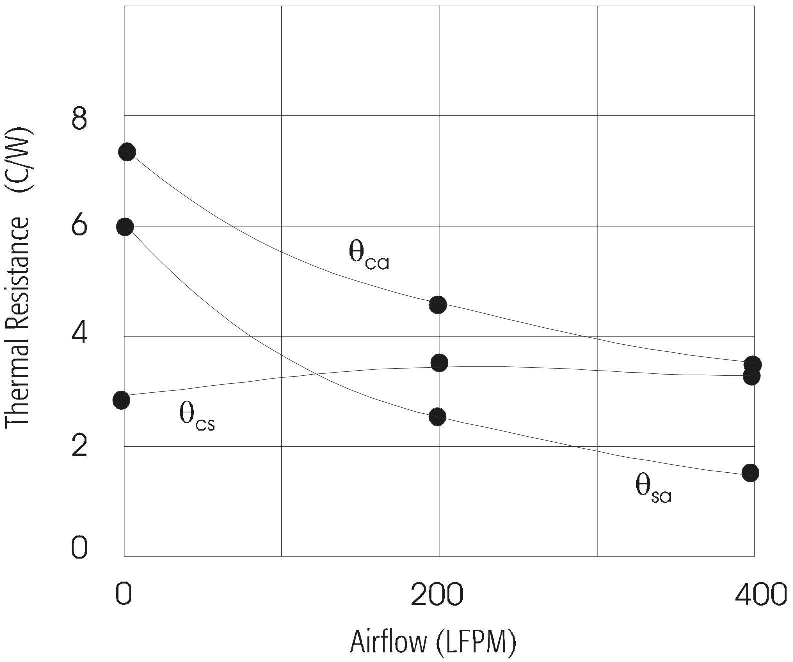


Figure 15. Heat Sink B with White Pad

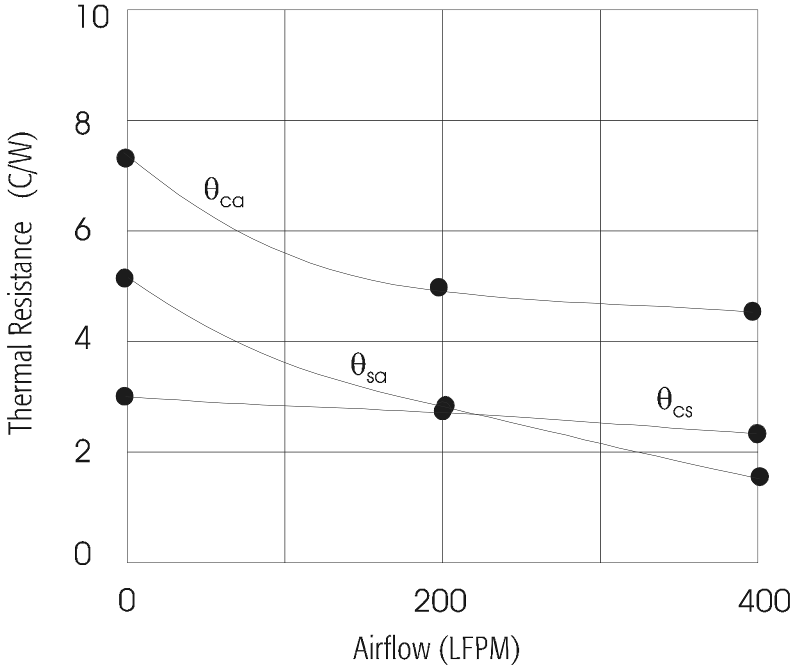


Figure 16. Heat Sink B with Rose Pad

Thermal Resistance Calculations with Pin Fin Heat Sink C

Table 14. Heat Sink C with Thermal Grease

Airflow (lfpm)	θca	θsa	θcs
0	4.80	4.08	0.71
200	3.00	2.65	0.35
400	2.10	1.76	0.34

Table 15. Heat Sink C with White Pad

Airflow (lfpm)	θca	θsa	θcs
0	7.60	4.15	3.45
200	5.80	2.49	3.31
400	4.80	1.55	3.25

Table 16. Heat Sink C with Rose Pad

Airflow (lfpm)	θca	θsa	θcs
0	7.40	4.23	3.17
200	5.50	2.47	3.03
400	4.60	1.55	3.05

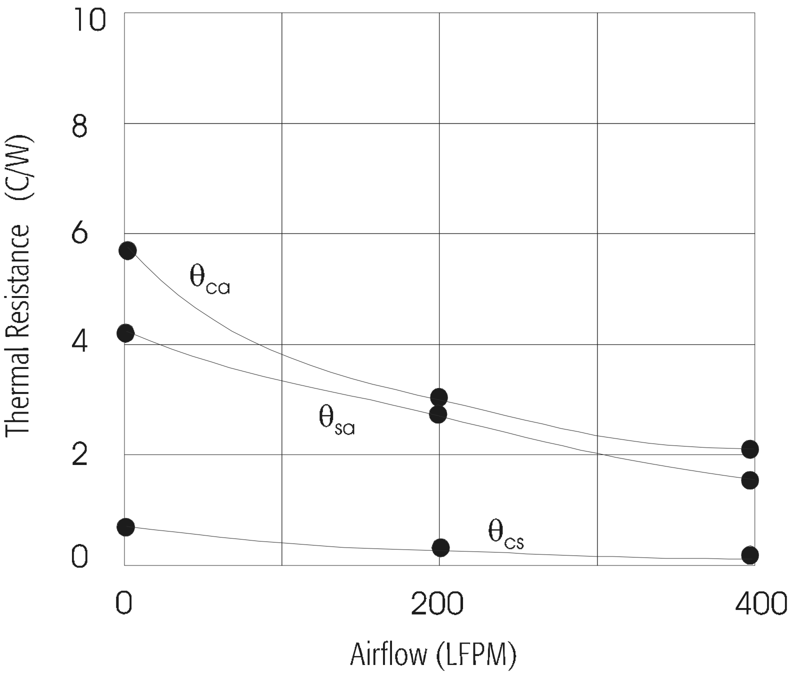


Figure 17. Heat Sink C with Thermal Grease

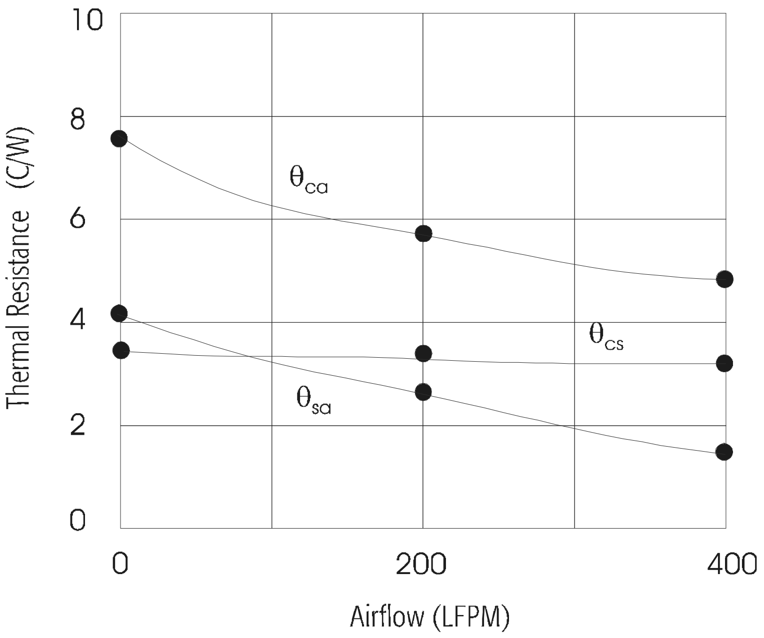


Figure 18. Heat Sink C with White Pad

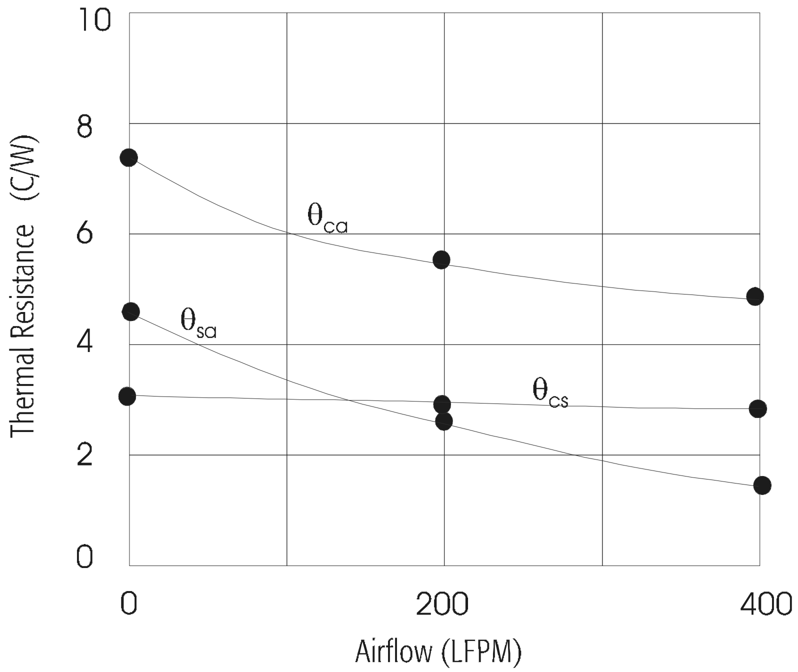


Figure 19. Heat Sink C with Rose Pad

Conclusion (Final Checklist)

When selecting a cooling solution for the AMD-K5 processor it is important to know the following:

1. Maximum operating clock frequency and maximum case temperature for the processor. Check the OPN and data sheet for the latest information.
2. Thermal specification of the desktop personal computer for both the maximum case inside temperature (e.g., 30^{o}C) and the airflow above the processor socket on the motherboard (200 lfpm).
3. Select a heat sink or heat sink/fan module that assures a safe thermal margin (see *Heat Sink Equations* on page 4) and that fits within the maximum size requirements with a secure mechanical attachment (e.g., heat sink clip or thermal adhesive tape) to withstand the vibration and shock requirements of a personal computer system.
4. Select fans that have sealed ball bearings to ensure long life (e.g., greater than 5 years).
5. Make sure that there are no mechanical restrictions above a fan heat sink module (e.g., 0.5 in or more).
6. If thermal adhesive tape is used, the following items should be specified: the tape should be approximately 0.006 and the top of the ceramic case should be primed to ensure maximum bond strength (see *Thermal Adhesive Tape* on page 15).
7. Thermal system measurements are required to ensure that the processor case doesn’t exceed the maximum case temperature specification (lower case temperatures ensure safe thermal margins).

Vendors and Manufacturers for the AMD-K5 Processor

Heat Sink Vendors

Aavid Thermal Technologies, Inc.
One Kool Path
P.O. Box 400
Laconia, NH 03247-0400
603-528-3400

IERC
135 W. Magnolia Blvd.
Burbank, CA 91502
818-842-7277

PC Power & Cooling, Inc.
5995 Avenida Encinas
Carlsbad, CA 92008
800-722-6555

Thermalloy, Inc.
2021 W. Valley View Lane
Dallas, TX 75234-0839
214-243-4321

Wakefield Engineering
60 Audubon Rd.
Wakefield, MA 01880
617-245-5900

Other Manufacturers

Heat Sink Fan Motor Manufacturer

Evox Rifa
708-948-9511

Processor Socket Manufacturer

AMP
2800 Fulling Mill Road
Middleton, PA 17057-3198
1-800-522-6752

Thermal Interface Material Manufacturers

Chomerics, Inc.
77 Dragon Court
Woburn, MA 01888-4014
617-935-4850

Thermagon, Inc.
3256 W. 25th Street
Cleveland, OH 44109-1668
216-741-7659

Aavid Thermal Technologies, Inc.
One Kool Path
P.O. Box 400
Laconia, NH 03247-0400
603-528-3400

Thermalloy, Inc.
2021 W. Valley View Lane
Dallas, TX 75234-0839
214-243-4321

Thermocouple Manufacturer

Omega Engineering, Inc.
One Omega Drive
Stamford, CT 06907
1-800-826-6342