AMD Thermal, Mechanical, and Chassis Cooling Design Guide

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Revision History

Date	Rev	Description
January 2002	F	Updated Figure 5, "Motherboard Keepout Area for a Socket A AMD Athlon™ Processor Heatsink," on page 12, removing the four mounting holes.
November 2001	E	Added Bergquist, Honeywell, Power Devices, and ShinEtsu to the list of Vendors in Table 5, "Suggested Thermal Interface Materials," on page 7.
March 2001	D	Corrected Athlon™ and Duron™ processor die sizes in tables 1 and 2 on page 4.
February 2001	C	Corrected Max. Length for heatsink from blank to 60mm, and corrected Min. Length for heatsink from 60mm to blank in Table 3 and in Table 4.
October 2000	B	■ Added mention of AMD Duron processor in the text and added the following tables and figures with AMD Duron information: Table 2 on page 4, Table 4 on page 6, and Figure 6 on page 13. ■ Revised "Suggested Interface Materials" on page 7, and Table 5 on page 7. ■ Added Section, "Thermocouple Installation for Temperature Testing" on page 14, and added Figure 7 through Figure 11.
May 2000	A	Initial release based on AMD Athlon Processor Family Thermal Cooling Requirements Version 2.1.

AMD Thermal, Mechanical, and Chassis Cooling Design Guide

This document specifies performance requirements for the design of thermal, mechanical, and chassis cooling solutions for the AMD Athlon™ and AMD Duron™ processors. In addition to providing design targets, drawings are provided from an AMD-designed solution meeting the requirements of the AMD Athlon and AMD Duron processors.

Summary of Requirements

To allow the optimal reliability for AMD Athlon and AMD Duron processor-based systems, the thermal design solution should dissipate heat from a theoretical processor running at a given maximum thermal power. The following sections specify recommended values for these optimal thermal parameters. By setting a high-power target, the engineer may avoid redesigning a point solution heatsink/fansink, thus increasing the life of the particular thermal solution.

PGA Socket A-Based Processor Thermal Requirements

Socket Description

Socket A is a new PGA socket designed for socketed AMD Athlon and AMD Duron processors. Figure 1 shows the new socket.

Note: *The figure socket is labeled SOCKET 462, which is synonymous with the Socket A.*

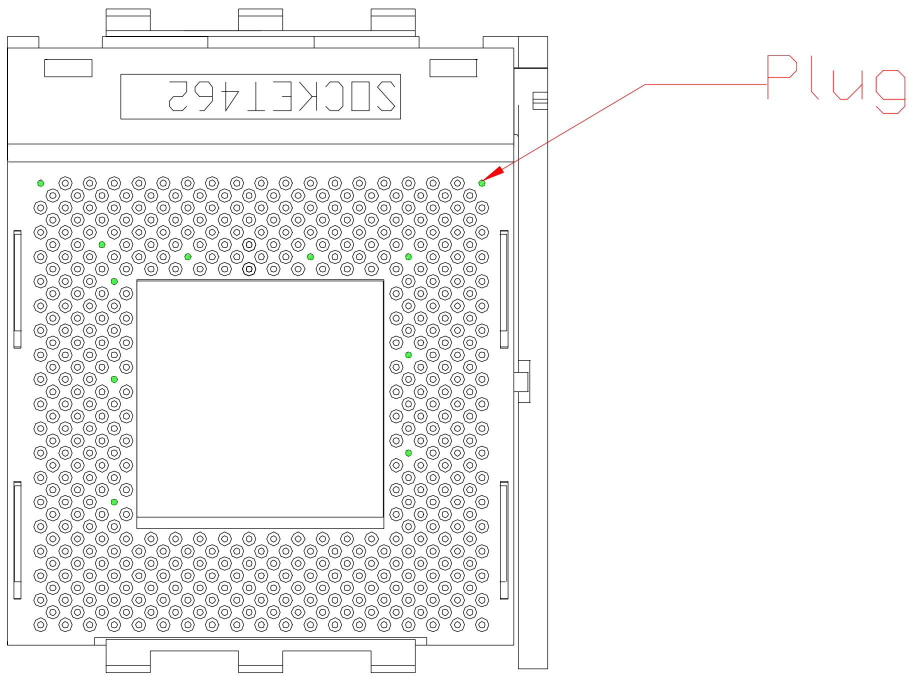


Figure 1. Socket A

Socket A is very similar in form factor to previous sockets, such as Socket 7. Socket A incorporates additional pins in the inner portion of the socket. Thus, a thermal solution for Socket A can leverage preexisting design efforts.

Figure 2 details the physical dimensions of Socket A.

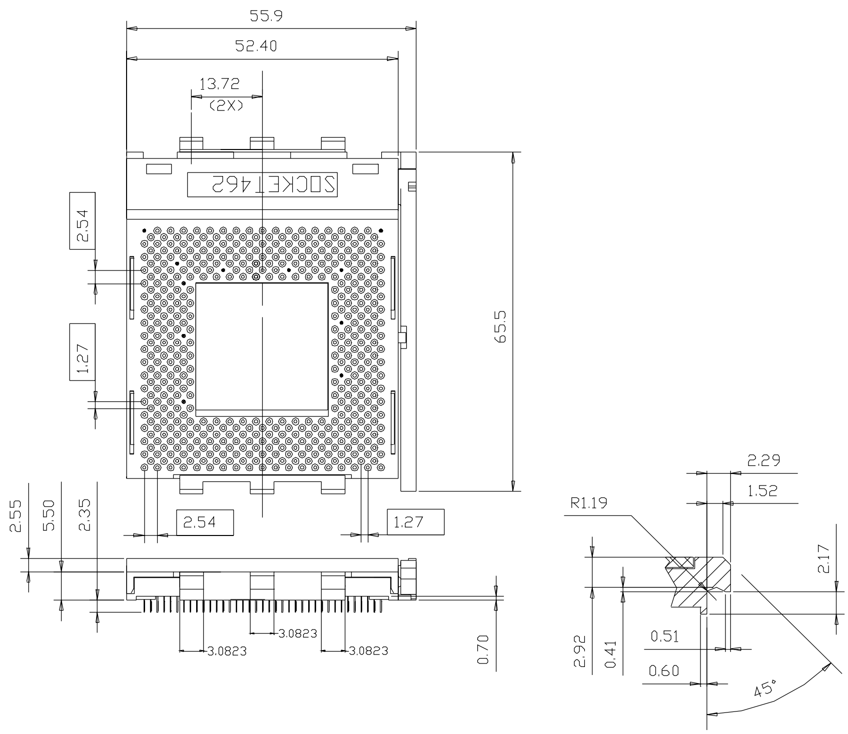


Figure 2. Dimensions of Socket A

Socket A-Based Processor Specifications

Table 1 and Table 2 list the thermal specifications of the AMD Athlon and AMD Duron socketed processors.

Table 1. Socketed Processor Specifications for the AMD Athlon™ Processor

Symbol	Description	Max Value	Notes
T_{die}	Maximum die temperature	90°C for under 1100 MHz	
		95°C for 1100 MHz and higher	
Total die size	Die size	119.77mm^2	Includes L2 cache
A_{core}	Core area	114.16mm^2	Die size not including L2 cache
Form factor	Heatsink form factor	PGA	PGA Socket A form factor
$P_{thermal}$	Max processor thermal power	55W	Required minimum supported power
		76W	Recommended supported power

Table 2. Socketed Processor Specifications for the AMD Duron™ Processor

Symbol	Description	Max Value	Notes
T_{die}	Maximum die temperature	90°C	
Total die size	Die size	99.72mm^2	Includes L2 cache
A_{core}	Core area	96.53mm^2	Die size not including L2 cache
Form factor	Heatsink form factor	PGA	PGA Socket A form factor
$P_{thermal}$	Max processor thermal power	38W	Required supported power

General Socketed Design Targets

To maintain the die temperature of the processor below the maximum T_{die} value, certain heatsink design points must be considered. Table 3 details additional specifications that must be met for the AMD Athlon processor to reliable operate.

Table 3. General Socketed Thermal Solution Design Target for the AMD Athlon™ Processor

Symbol	Description	Min	Max	Notes
L	Length of heatsink		60mm	Measurements are for the entire assembly, including attached fan.
W	Width of heatsink	60mm	80mm	
H	Height of heatsink		60mm	
θ_{SA}	**Sink-to-ambient thermal resistance:**			
	For 55W processor at 90°C		0.44° C/W	For under 1100 MHz
	For 55W processor at 95°C		0.48° C/W	For 1100 MHz and over
	For 76W processor at 90°C		0.32° C/W	For under 1100 MHz
	For 76W processor at 95°C		0.35° C/W	For 1100 MHz and over
θ_{JS}	**Interface material thermal resistance:**			Based on core area
	For 55W processor at 90°C		0.44° C/W	For under 1100 MHz
	For 55W processor at 95°C		0.48° C/W	For 1100 MHz and over
	For 76W processor at 90°C		0.32° C/W	For under 1100 MHz
	For 76W processor at 95°C		0.35° C/W	For 1100 MHz and over
CFM	Fan airflow	16 cfm		Minimum 16 cfm airflow
m_{HS}	Mass of heatsink		300 g	
F_{clip}	Clip force	12 lbs	24 lbs	Typical F: 14 lbs$\leq$ F $\leq$18 lbs Nominal F = 16 lbs.
T_A	Inside the box local ambient temperature		42° C	

Table 4 shows the thermal solution design target for the AMD Duron processor.

Table 4. General Socketed Thermal Solution Design Target for the AMD Duron™ Processor

Symbol	Description	Min	Max	Notes
L	Length of heatsink		60mm	Measurements are for the entire assembly, including attached fan.
W	Width of heatsink	60mm	80mm	
H	Height of heatsink		60mm	
θ_{SA}	**Sink-to-ambient thermal resistance:**			
	For 38W processor at 90ºC		0.63º C/W	
θ_{JS}	**Interface material thermal resistance:**			Based on core area
	For 38W processor at 90ºC		0.63º C/W	
CFM	Fan airflow	16 cfm		Minimum 16 cfm airflow
m_{HS}	Mass of heatsink		300 g	
F_{clip}	Clip force	12 lbs	24 lbs	Typical F: 14 lbs≤ F ≤18 lbs Nominal F = 16 lbs.
T_A	Inside the box local ambient temperature		42º C	

Suggested Interface Materials

AMD evaluates thermal interface materials for socketed designs. A list of suggested materials tested by AMD is provided in Table 5 . If the heatsink needs to be removed, the phase change material must be replaced on the heatsink before re-installing the heatsink. Use a plastic scraper to gently remove the old phase change material from the heatsink.

Table 5. Suggested Thermal Interface Materials

Vendor	Interface Material	Material Type
Bergquist	HF225UT	Phase Change
Chomerics	T725	Phase Change
Honeywell	PCM45	Phase Change
Power Devices	Powerfilm	Phase Change
ShinEtsu	PCS-TC-11T-13	Phase Change
Thermagon	T-pcm905C	Phase Change

Sample Socket A Heatsink Drawings

Figure 3 provides a reference drawing of a heatsink AMD has designed to work with Socket A processors.

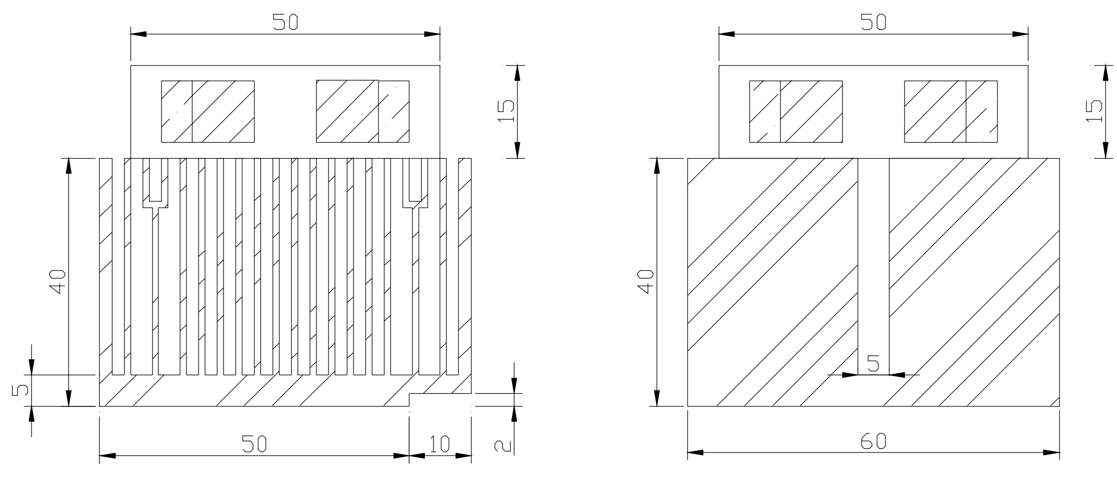


Figure 3. Sample Drawing of Socket A Heatsink

Socket A Heatsink Design Considerations

Heatsink Considerations

Flat Base to Contact Support Pads. The PGA processor is housed in a 50 x 50mm ceramic package. The heatsink makes direct contact with the flip-chip die. While the die dimensions are considerably less than the 50 x 50mm package footprint, the heatsink base must maintain a minimum flat surface of 46 x 46mm centered on the package and 48 x 48mm at a maximum. This positioning is required for the heatsink to make contact with compliant load support pads. The pads protect the die from mechanical damage during heatsink installation, as well from shock and vibration. Figure 4 on page 9 details the ceramic package and compliant load support pads.

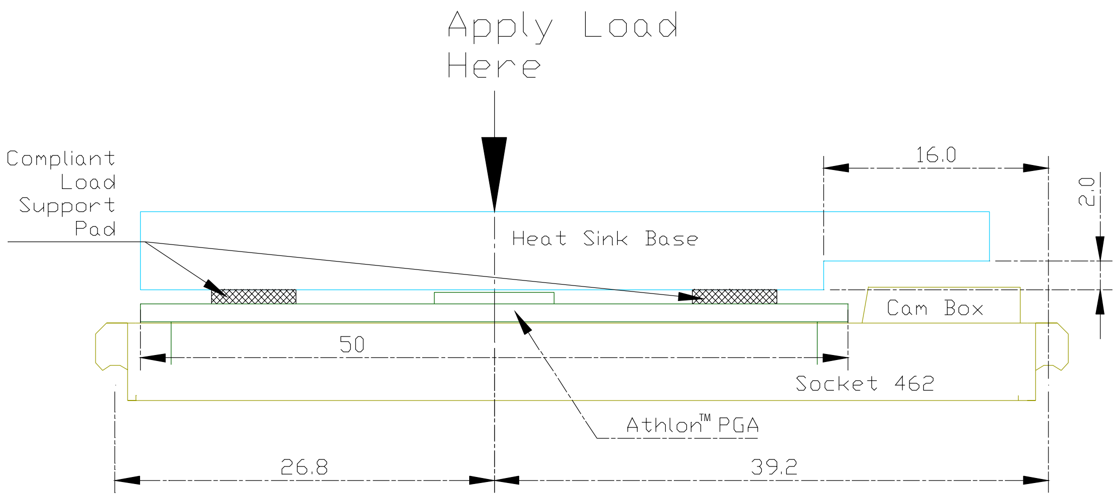


Figure 4. Heatsink and Load Pads

Maximum Base Footprint of 60 X 80mm. The maximum base footprint for socket heatsinks is 60 x 80mm (as detailed in Figure 3 on page 8). Not all processor speeds require the full 60 x 80mm footprint. Heatsinks with approximately 60 x 60mm footprints have proven to be adequate for low to moderate clock frequencies.

Clearance in Heatsink Base for Socket Cam Box. The heatsink base must have enough clearance so that it does not contact the cam box on the socket. The clearance zone is defined in the example shown in the Figure 3 on page 8 and Figure 4 on page 9.

Clip Considerations

Load Target Of 16 lb with Range of 12–24 lbs. The clip load is greater than that allowed for previous processors with similar mechanical form factors. Table 3 on page 5 details the clip force requirements.

Load Applied Directly over Center of Die (Asymmetric Design). To ensure adequate thermal interface performance between the flip-chip die and the heatsink, the clip must apply its load to the heatsink along a single contact axis. The load should be applied 26.8 mm from the front (non-cam side) socket tab load point (see Figure 4 on page 9). The acceptable tolerance for off-center clip load is +/– 1.5 mm.

Feature to Lock Relative Position of Heatsink, Clip, and Socket. A locking feature is needed to avoid incorrect placement of the heatsink on the package. Such a lock can be constructed with small tabs that project from the sides of the clip and fit into a heatsink channel.

Installation Features Designed to Minimize Operator Fatigue. With the increased clip load requirements of the socketed processor, emphasis should be focused on providing a clip design that is easily installed. While clips that do not require tools for installation offer some advantages, designs that accept a flat-head screwdriver (or nutdriver) near the clip hook have certain advantages. Such advantages include the ability to pry the clip hook over the socket tab during installation and the ability to install the clips onto the tabs in areas that are tightly confined by motherboard components surrounding the socket.

Interface Considerations

Pre-applied Pad Size and Location. Many customers have indicated a preference for pre-applied thermal interface materials. A heatsink vendor that chooses to offer pre-applied interface materials should apply a 25 x 25 mm pad centered 25 mm from the front edge of the heatsink.

Socketed Motherboard Restrictions

The motherboard design and layout must meet certain restrictions to ensure that the socketed thermal solution does not impede the performance of components on the motherboard. To maintain adequate airflow around the microprocessor, certain areas on the motherboard must be free of projecting components. Figure 5 on page 12 shows these ‘keepout’ areas on the motherboard for an AMD Athlon processor, and Figure 6 on page 13 shows the motherboard keepout area for an AMD Duron processor.

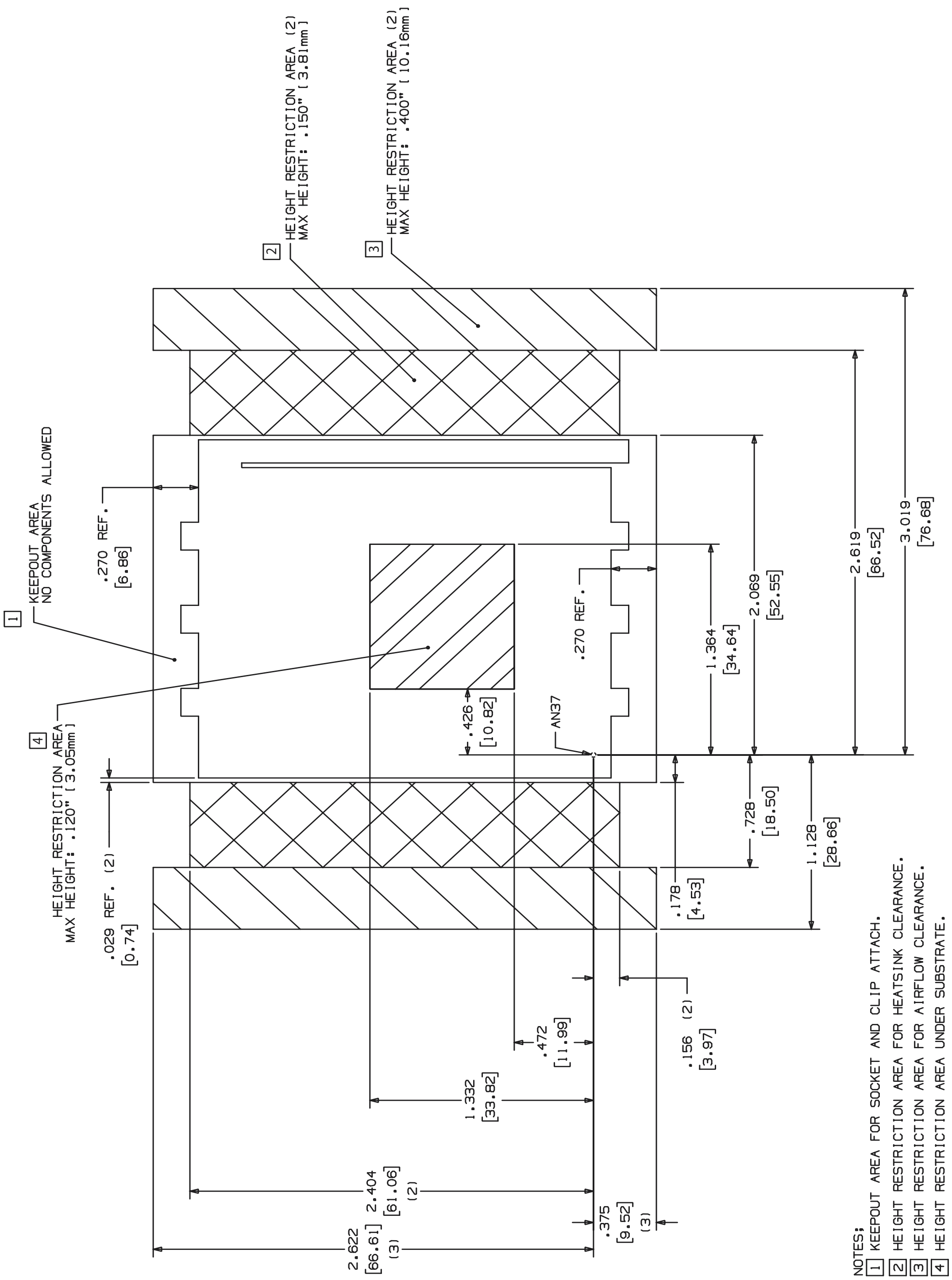


Figure 5. Motherboard Keepout Area for a Socket A AMD Athlon™ Processor Heatsink

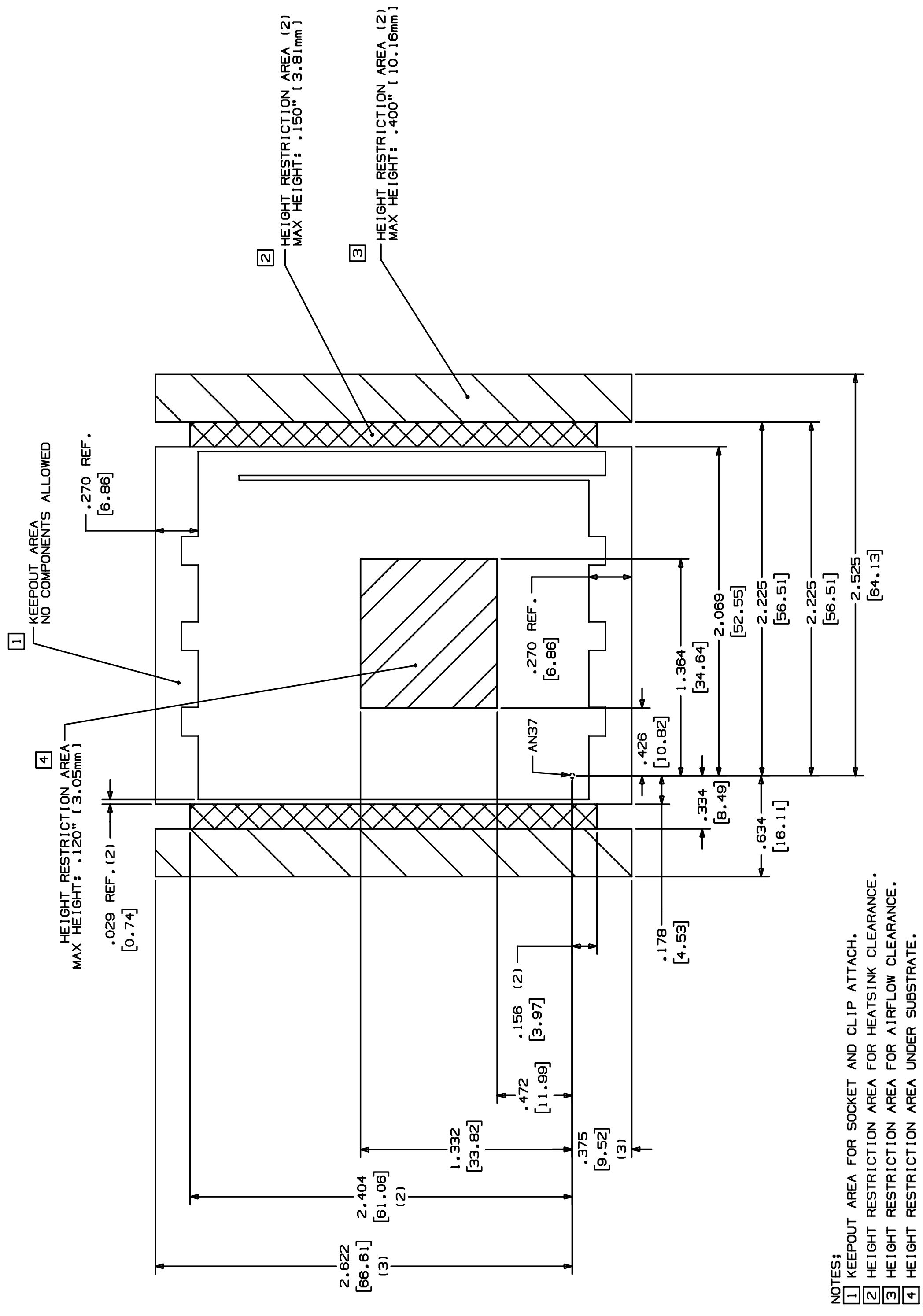


Figure 6. Motherboard Keepout Area for a Socket A AMD Duron™ Processor Heatsink

Thermocouple Installation for Temperature Testing

Thermocouple Positioning

To make accurate thermal measurements, drill a hole into the heatsink to obtain the heatsink base temperature.

Center the heatsink base thermocouple directly over the die and 2 mm above the die as shown in Figure 7.

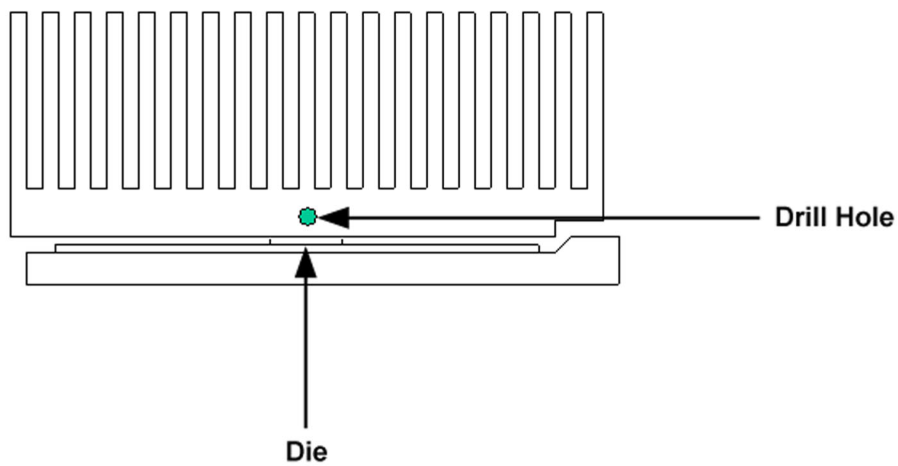


Figure 7. Drilling for Proper Thermocouple Position

Measuring the Thermocouple Position

Figure 8 shows the terms used in positioning the thermocouple. Determine the thermocouple position by using the following measurements:

- a = 24.765mm
- b = caliper measurement
- If the heatsink extends over the PGA processor (as it is diagrammed), then x = a + b
- If the heatsink does not extend over the PGA processor, then x = a – b
- y = 2mm

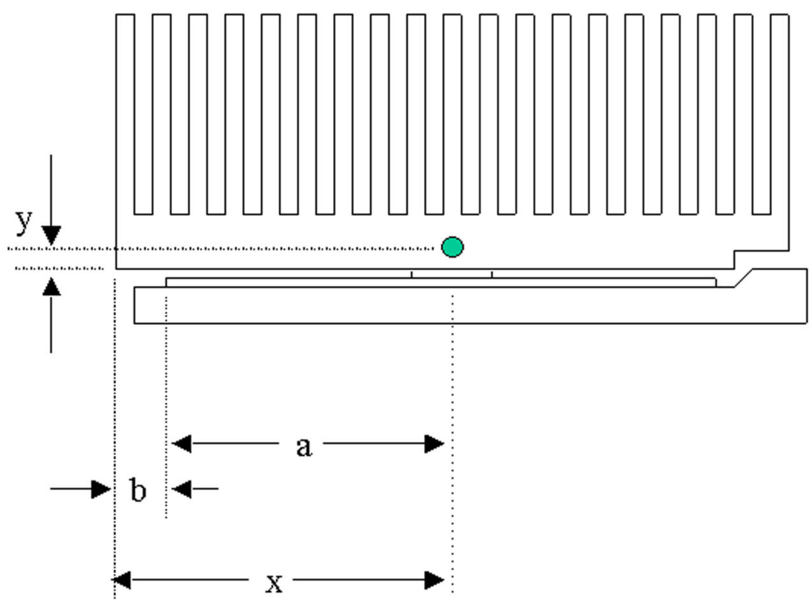


Figure 8. Measuring Thermocouple Position

Drilling Depth

Drill in the location as determined by x and y in Figure 8 on page 15. If the heatsink is symmetric in relation to the processor, drill to a depth of half the heatsink's width. If it is not symmetrical to the processor, drill to a depth that is directly over the center of the die, as shown in Figure 9.

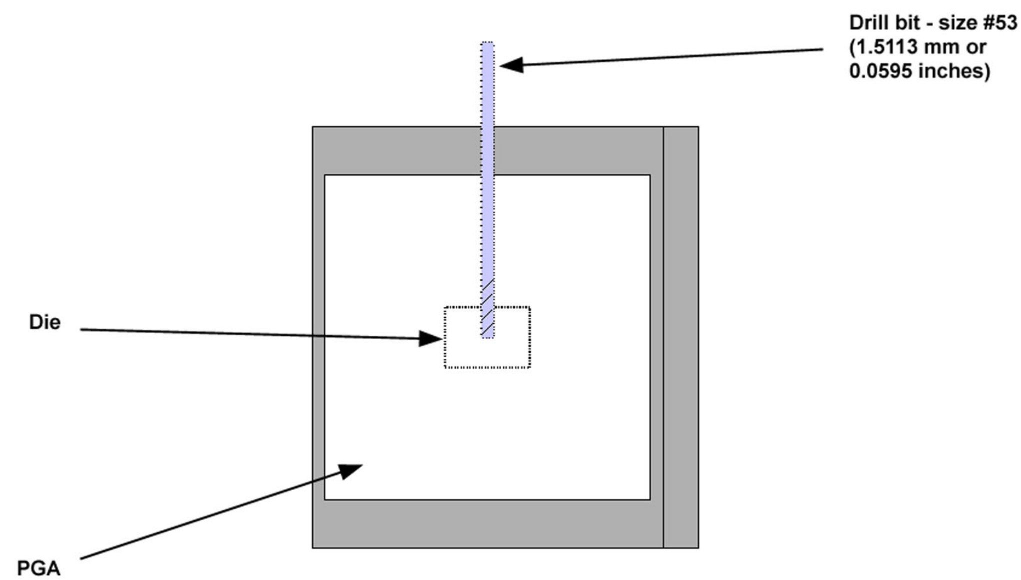


Figure 9. Bottom View of Heatsink and Drill Depth

Installing the Thermocouple

Injecting Thermal Grease

Inject thermal grease into the newly drilled hole with a syringe as shown in Figure 10. Dow Corning 340 white thermal grease may be used.

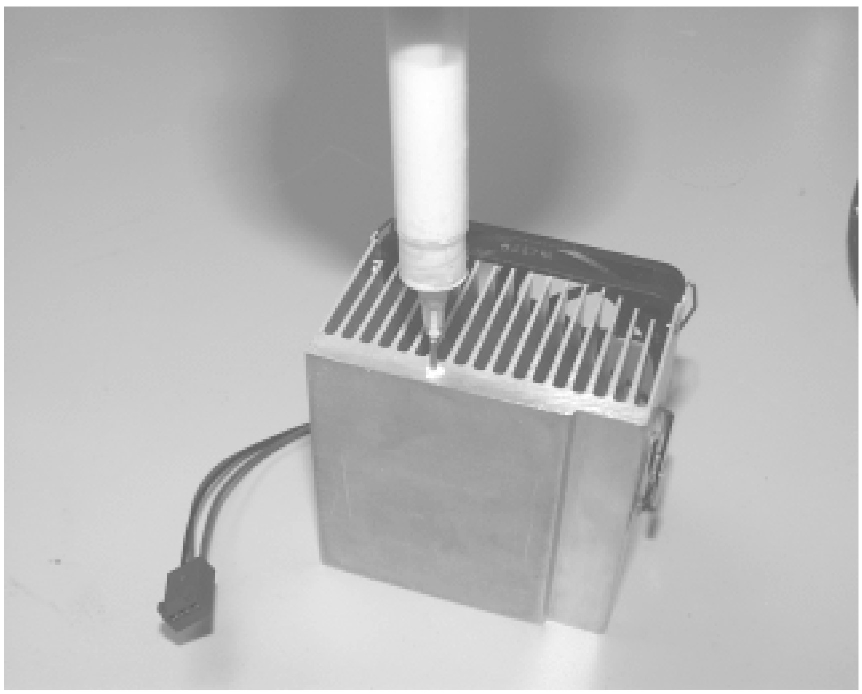


Figure 10. Injecting Thermal Grease into Drilled Hole

Installation of Thermocouple

Gently insert the thermocouple into the hole until it bottoms out, and tape it down with Kapton tape, making sure not to kink the thermocouple. Figure 11 shows an example of an installed thermocouple.

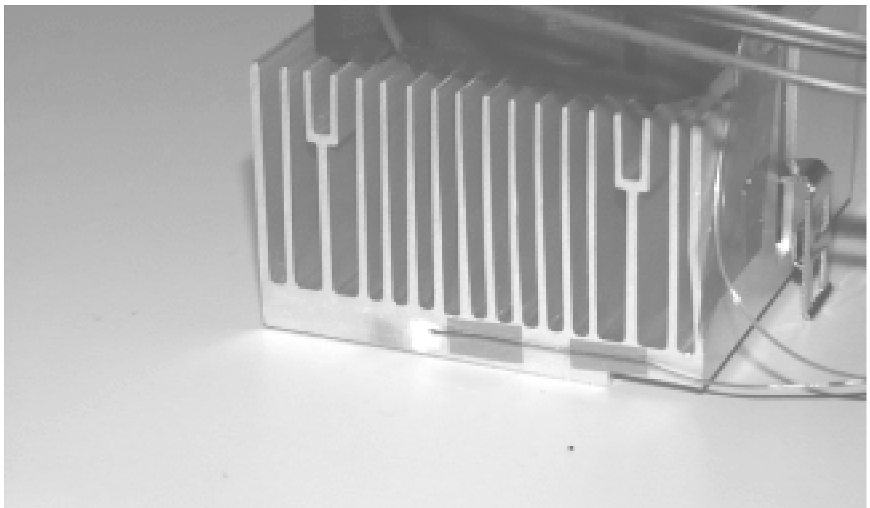


Figure 11. Installed Thermocouple

Slot A-Based Processor Specifications

Table 6 contains a list of the thermal specifications of the slotted processor. These values and additional information can be found in the *AMD Athlon™ Processor Module Data Sheet*, order# 21016.

Table 6. Slot A Processor Specifications

Symbol	Description	Max Value	Notes
T_{plate}	Maximum plate temperature	70°C	
Form Factor	Heatsink form factor	SECC1	SECC1 form factor
$P_{thermal}$	Max processor thermal power	50W	Required minimum supported power
		65W	Targeted theoretical maximum supported power

General Slot A Design Targets

To maintain the processor plate temperature below the maximum T_{plate} value, a heatsink must dissipate the heat produced by the processor. Table 7 on page 20 details additional information that should be met in order for the system to reliably operate.

Table 7. General Slot A Thermal Solution Design Targets

Symbol	Description	Min	Max	Notes
θ_{SA}	Sink-to-ambient thermal resistance		0.35ºC/W	
θ_{PS}	Interface material thermal resistance		0.15ºC/W	
CFM	Fan airflow	16 cfm		Minimum 16 cfm airflow
P_{fan}	Fan pressure	0.25 in. H_2O		Inches of water
P_{max}	Maximum theoretical thermal power		64W	Power target for future processors
m_{HS}	Mass of heatsink		250g	
T_A	Inside the box local ambient temperature	45ºC		

Sample Slot A Heatsink Drawings

Figure 13 on page 22 shows a heatsink that AMD designed and tested to work with the AMD Athlon processor. This design provides the heat dissipation necessary for optimal processor performance. Figure 12 on page 21 is a drawing of the mechanical module of the AMD Athlon processor.

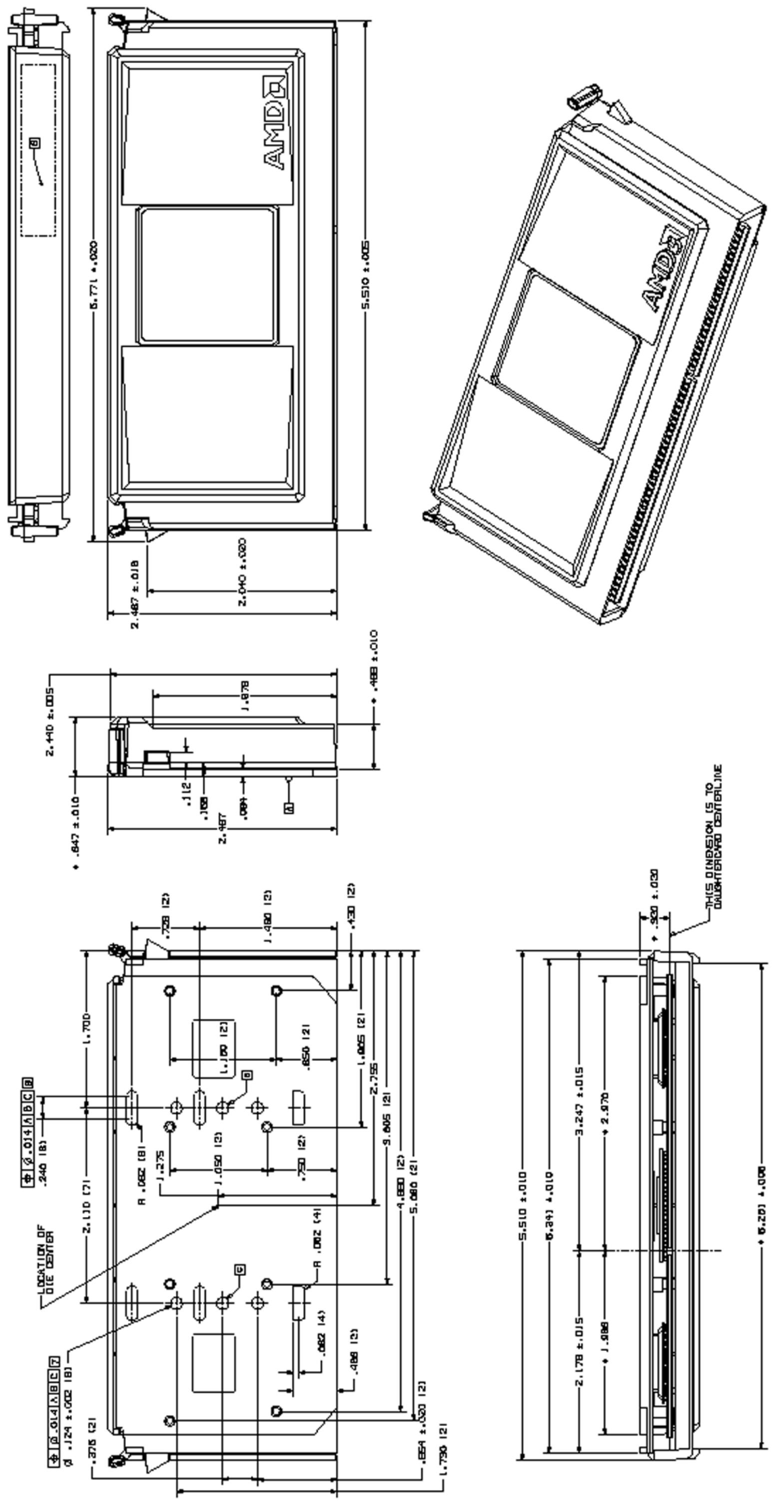


Figure 12. AMD Athlon™ Processor Module Package

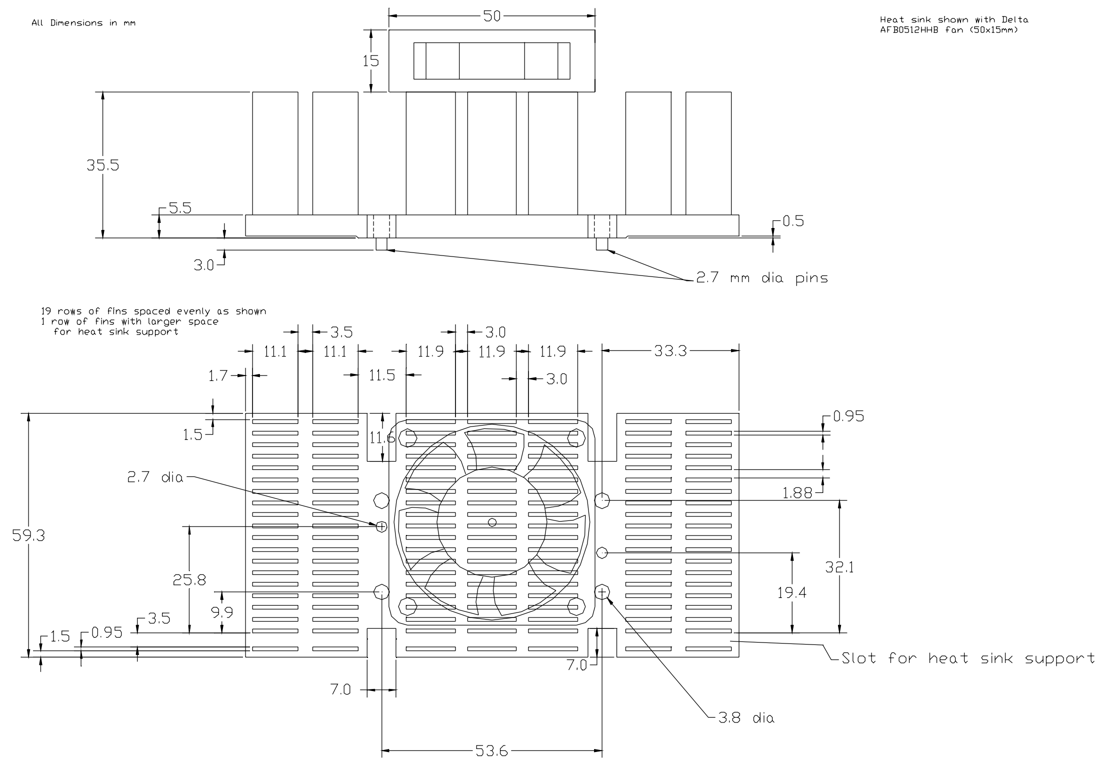


Figure 13. Impact Extrusion for Clip Attachment

Heatsink Performance Measurements for Slot A-Based Solutions

AMD gauges the performance of thermal design solutions by performing thermal measurements on heatsinks. Temperature measurements are taken at the module heat plate, at the heatsink base, and in the open air near the fan inlet. To facilitate quicker turnaround on thermal measurements, AMD requires that a 0.0595 inch diameter hole be drilled into the base of heatsinks that are submitted for thermal testing. The hole depth is determined by the size of the heatsink and its position relative to the AMD Athlon processor module. Tested hole depths have ranged from 25mm to 35mm. The typical depth has been around 30mm. A long #53 drill bit should be used to drill the hole.

Figure 14 on page 23 shows an AMD Athlon processor module from the heat plate side. The holes and slots for the heatsink alignment pins are indicated in the figure. Whether the heatsink base thermocouple hole is drilled from the top or bottom of the heatsink, the hole depth must be to the edge of the alignment hole.

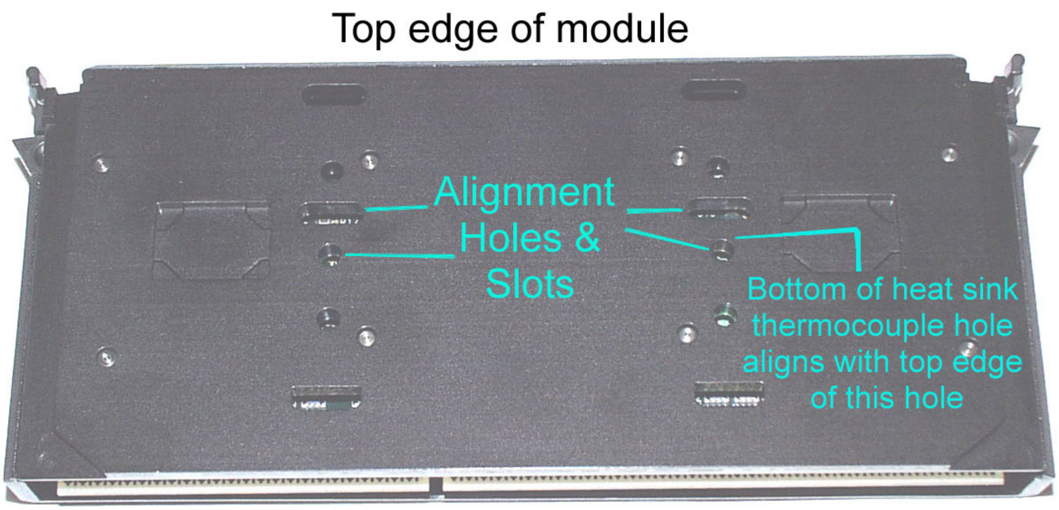


Figure 14. Module Heat Plate

Figure 15 displays a heatsink with the lower alignment pin used as the reference for the thermocouple hole depth.

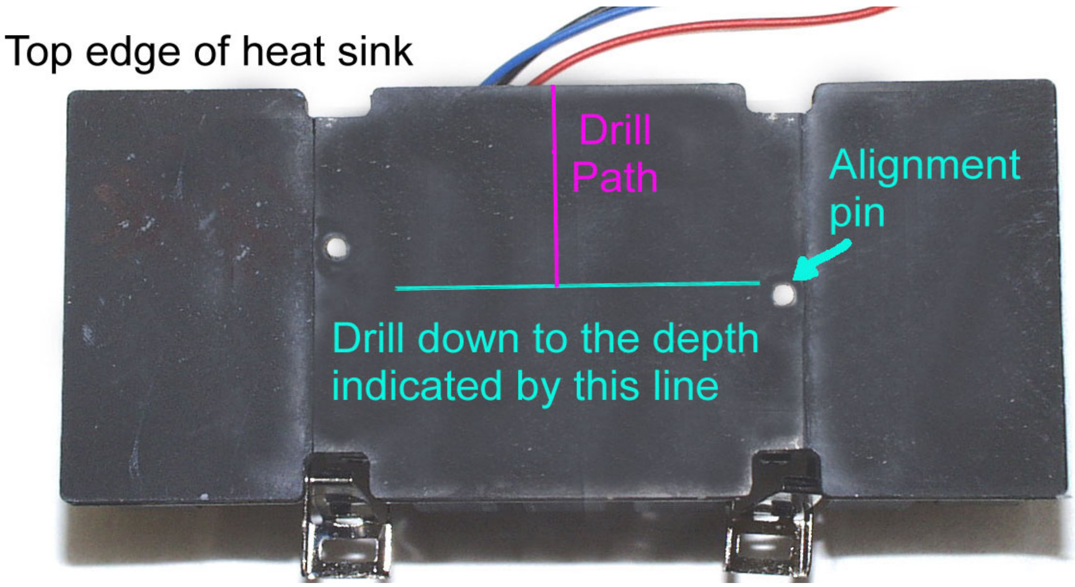


Figure 15. Drill Location

Figure 16 on page 25 and Figure 17 on page 26 show the hole from the top edge of the heatsink. The hole is centered along the length of the heatsink. The center of the hole is approximately 2 mm from the edge of the heatsink that is in contact with the module.

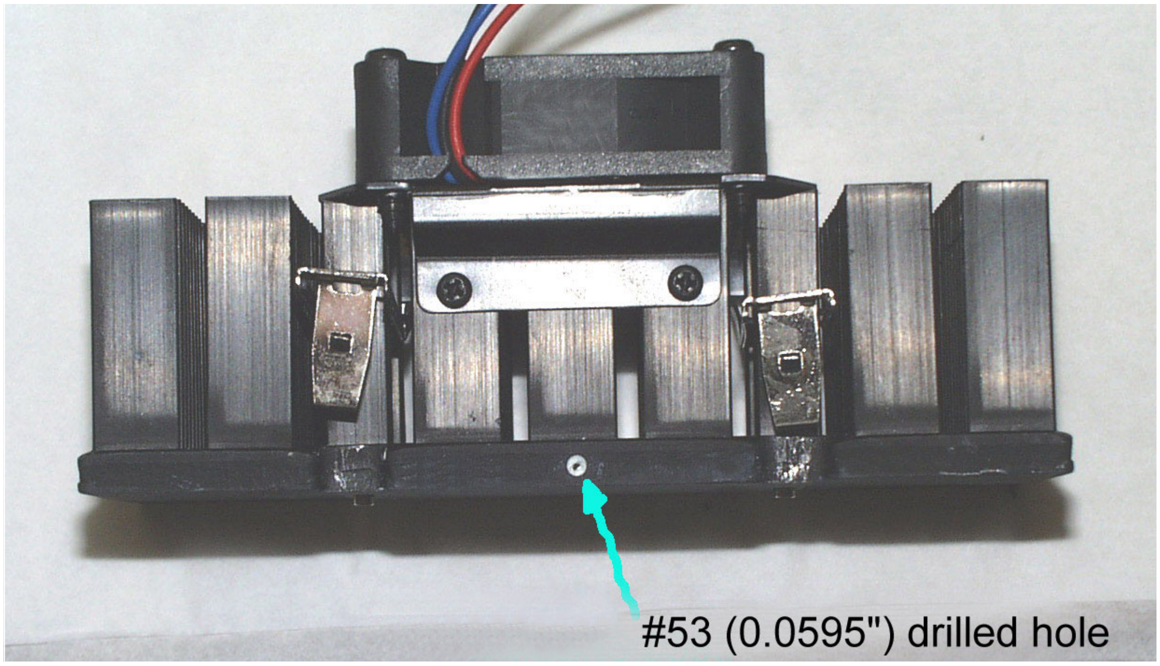


Figure 16. Drilled Hole Location

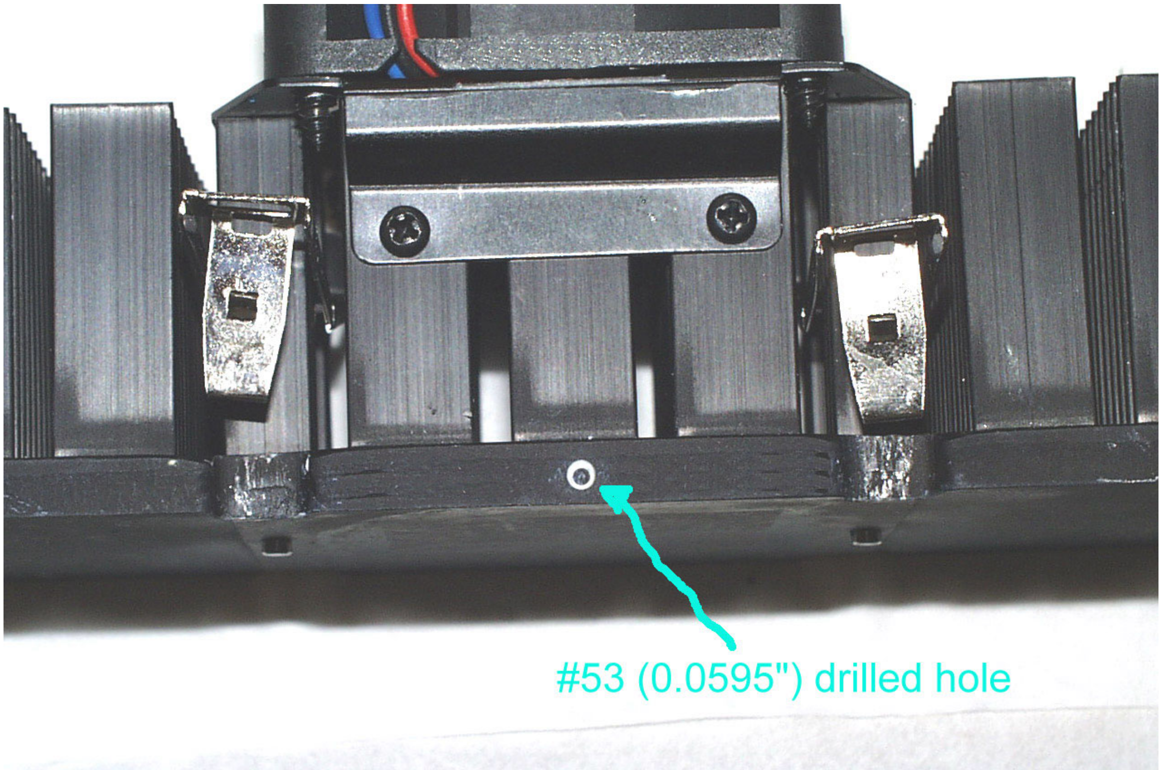


Figure 17. Close-Up of Drilled Hole Location

Chassis Cooling Guidelines

As high-performing systems continue to evolve, the power consumption of system components such as the processor, hard disks, and video cards continues to increase. The associated rise in power consumption can cause the system operating temperature specifications to be exceeded. The correct operating temperature of each system device can be controlled by providing proper airflow through the overall system.

Chassis Airflow

System cooling is dependent on several essential and related factors. Figure 18 shows a typical mid-tower chassis with the internal physical characteristics and recommended airflow.

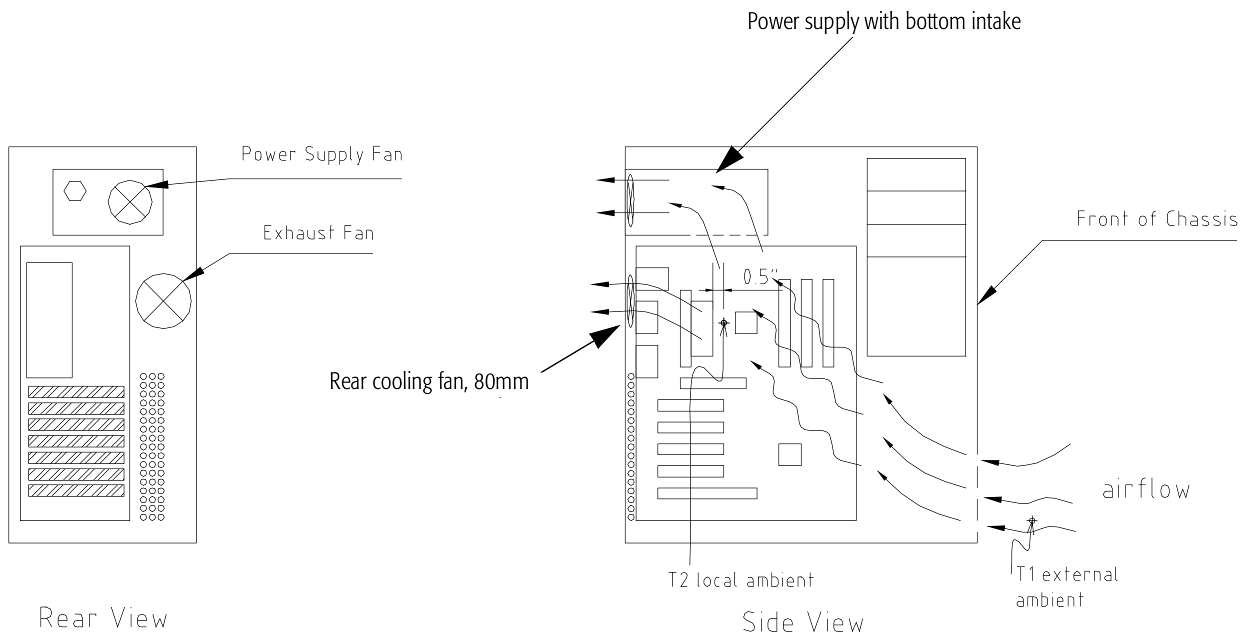


Figure 18. Airflow through the Chassis

Using thermal couples (type K or T, 36 gauge) in the locations shown in Figure 18, temperatures T1 and T2 can be measured. T1 represents the external ambient air temperature. T2, which is located approximately 0.5 inch to 1.0 inch away from the processor fan (centered on the hub), represents the internal local ambient air temperature. **It is highly recommended that T2 not exceed 40°C**. The following equation shows how to derive the proper overall system operating temperature:

$\Delta T = T2 - T1$

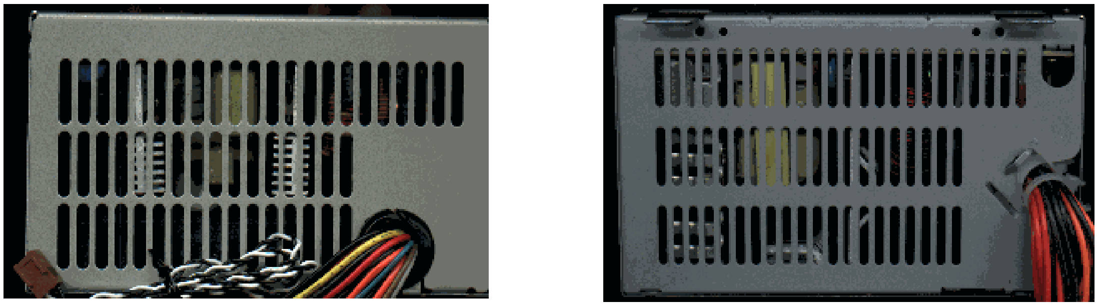
$\Delta T \leq 7°C$ to ensure proper cooling

Power Supply as Part of the Cooling Solution

For full-tower or mid-tower cases, it is important for system designers to be aware of the characteristics of the power supply used. Designers should only use a power supply recommended for the AMD Athlon or AMD Duron processors. For the recommended power supply lists, see www.amd.com. For best results, use a power supply with venting in the processor region, which means that the primary air intake is on the bottom of the power supply, not the front of the power supply. For the purposes of this chapter, such a power supply is referred to as 'ATX-style'. Some power supplies have 'NLX-style' venting (the primary air intake is at the front of the power supply) and does not pull air from the processor area. Figure 19 on page 29 compares desirable power supply venting designs with designs that are less desirable. The front and rear designs for the desirable and less desirable versions are very similar (the differences depend on the brand). However, the bottoms of the most effective power supply designs incorporate an air intake. Power supply having bottom air intakes cool the processor more effectively. Bottom air intakes with fans provide even more effective cooling.

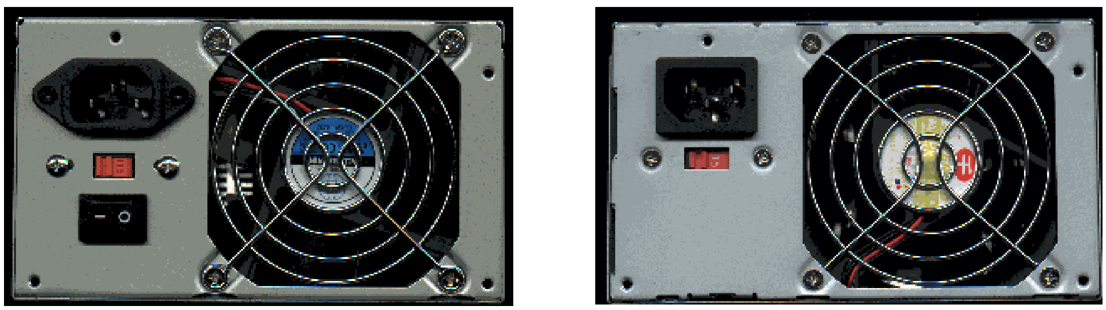
	Desirable Version	**Less Desirable Version**

Front—



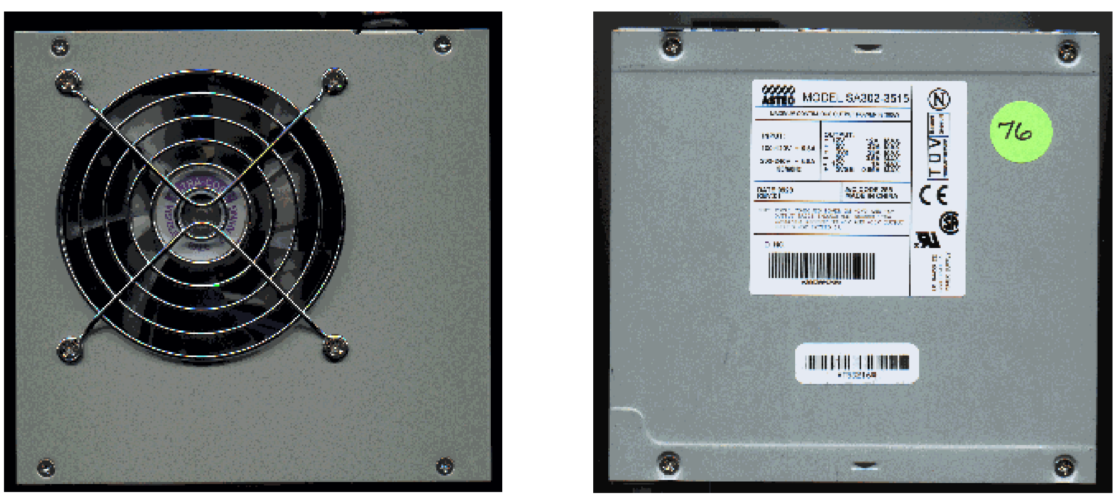
For the front air intake, the desirable and less desirable versions are very similar. The differences depend on the brand.

Rear—



For the rear air intake, the desirable and less desirable versions are very similar. The differences depend on the brand.

Bottom—



On the bottom, the desirable version has an air intake. A bottom air intake cools the processor more effectively. If the bottom air intake has a fan, cooling is enhanced.

Figure 19. Power Supply Venting

Rules for Proper Cooling

The following basic rules for chassis cooling can provide adequate airflow and system temperatures:

- Use the proper heatsink size for the processor speed used in the system. Make sure that the heatsink has appropriate sized fan(s). See the *AMD-K7 Processor Thermal Solutions* page or the *AMD Duron™ Processor Recommended Cooling Solutions* page at www.amd.com for more information.
- Use only the AMD-recommended thermal interface materials listed in Table 5 on page 7. Typically, AMD-recommended heatsinks include a validated thermal compound. If you are replacing the heatsink's packaged compound, use only AMD-recommended thermal interface materials.
- Use an auxiliary exhaust rear chassis fan. The suggested size is 80 millimeters or larger. The fan intake should be near the location of the processor.
- For best results, use an ATX power supply with air intake venting in the processor region, which means that the primary air intake is on the bottom of the power supply, not at the front of the power supply. Supplies with NLX-style venting (the primary air intake is at the front of the power supply) do not pull air from the processor area.
- Make sure all the internal wires and cables are routed carefully so airflow through the case is not blocked or hindered. Tie-wraps can help.
- Many cards, such as AGP cards, generate a lot of heat. Either leave the slot next to these cards open, or use a shorter card in these slots to allow airflow around heat producing cards (typically those cards with many electrical components).
- High-speed hard drives, especially 10,000 RPM SCSI hard drives, produce a great deal of heat. Mount these drives in 5.25 inch frames and install them in the larger drive bays. This mounting allows greater airflow around them for better cooling.
- A front cooling fan is not essential. In some extreme situations, testing showed that these fans recirculate hot air rather than introducing cool air.
- Maintain a $\Delta T \leq 7^{\circ}C$.

Conclusion

Thermal, mechanical, and chassis cooling solutions that meet the criteria described in the previous pages have been successful for applications incorporating AMD processors. AMD encourages vendors to innovate and propose other designs. If different heatsink production technologies, whether extrusion, folded fin, bonded fin, or cold forged, produce similar or better results than the solutions suggested in this guide, then designers are encouraged to incorporate them into new thermal solution designs. Any design, however, must meet the overall goal of dissipating the heat produced by the processor at a given ambient temperature.