Thermal Interface Material Comparison:

Thermal Pads vs. Thermal Grease

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Revision History

Date	Revision	Description
April 2004	3.00	Initial public release.

Chapter 1 Introduction

This document compares the different materials used as a thermal interface between the processor and the heatsink.

When installing heatsinks for AMD Athlon™ 64, AMD Athlon MP, AMD Athlon XP, AMD Duron™, and AMD Opteron™ processors, a suitable thermal interface material must be used. This thermal material significantly aids the transfer of heat from the processor to the heatsink. For optimum heat transfer, AMD recommends the use of high-performance thermal interface materials only.

For lidless processors, such as the AMD Athlon MP, AMD Athlon XP, and AMD Duron processors, the surface of the silicon chip contacts the bottom of the heatsink. For lidded processors, such as the AMD Athlon 64 and AMD Opteron processors, the lid contacts the heatsink. The surfaces of the two types of processors, lidless and lidded, are of different sizes, and AMD recommends a different type of thermal material for long-term use with each type of processor.

Processor-in-a-Box solutions include heatsinks with pre-applied, high-performance thermal interface materials.

High-performance thermal interface material is needed because even the largest heatsink and fan cannot effectively cool a processor unless there is good physical contact between the base of the heatsink and the top of the processor. The surfaces of both the heatsink and the processor are not absolutely smooth. This surface roughness can be observed when examined at a microscopic level. Because this surface roughness reduces the effective contact area, attaching a heatsink without a thermal interface material is not sufficient due to inadequate surface contact.

As shown (in exaggerated form) in Figure 1 on page 8 and in Figure 2 on page 8, tiny gaps exist between the two nearly flat surfaces. A thermal compound such as phase-change material or thermal grease fills these gaps and allows effective heat transference between the processor die and the heatsink.

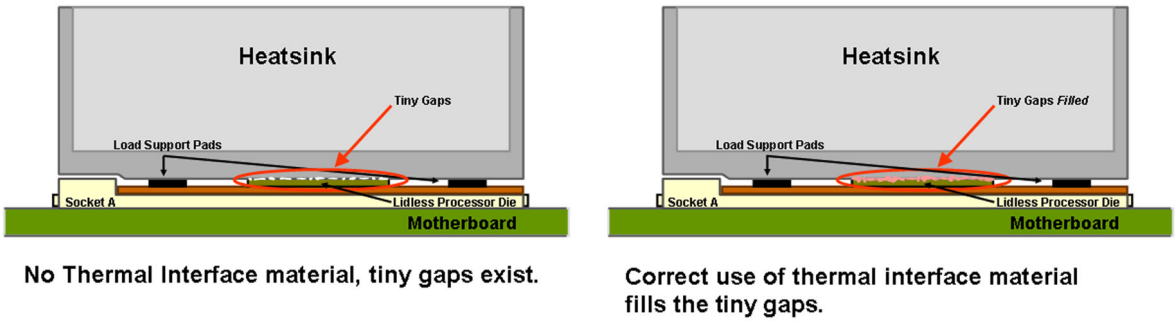

Figure 1. Thermal Interface Material Comparison for AMD Athlon™ MP, AMD Athlon XP, and AMD Duron™ Processors

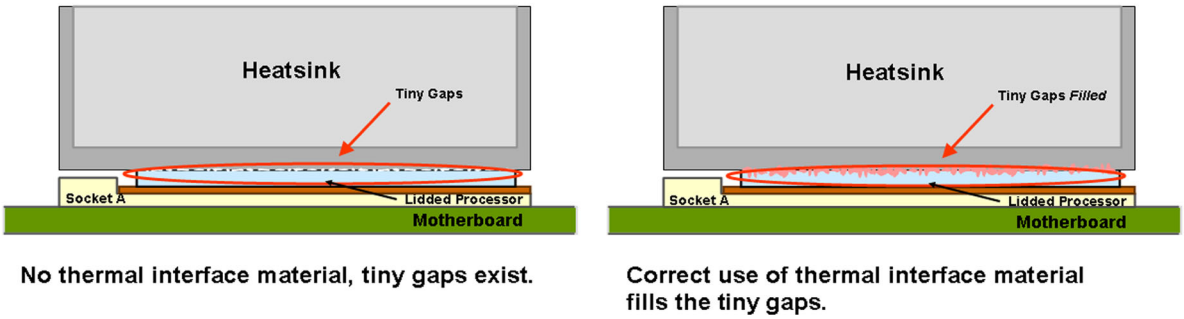

Figure 2. Thermal Interface Material Comparison for AMD Athlon™ 64 and AMD Opteron™ Processors

Chapter 2 Interface Materials

Two types of thermal interface material (TIM) are commonly used in the computer industry:

- Thermal pads, also called *phase-change* materials.
- Thermal grease, also called thermal paste.

Phase-change materials are usually thin pads approximately 1 in x 1 in (2.5 cm x 2.5 cm) in size and have protective films attached on both surfaces. The color is vendor-specific but is usually gray or pink. Thermal grease usually comes in a syringe, a tube, or a small plastic sachet. Thermal grease is similar in consistency to ordinary toothpaste and is typically gray or white.

2.1 Guidelines for Thermal Interface Materials

Five factors affect the choice, use, and performance of the interface material used between the processor and the heatsink.

- Thermal conductivity of the material
- Electrical conductivity of the material
- Spreading characteristics of the material
- Long-term stability and reliability of the material
- Ease of application

2.1.1 Thermal Conductivity of the Material

Thermal conductivity is the quantified ability of any material to transfer heat. The thermal conductivity of the interface material has a significant impact on its thermal performance. The higher the thermal conductivity, the more efficient the material is at transferring heat. Materials that have a lower thermal conductivity are less efficient at transferring heat, causing a higher temperature differential to exist across the interface. To overcome this less efficient heat transfer, a better cooling solution (typically, a more costly solution) must be used to achieve the desired heat dissipation.

2.1.2 Electrical Conductivity of the Material

Some metal-based TIM compounds are electrically conductive, whereas ceramic-based compounds are typically not. Manufacturers produce metal-based compounds with low electrical conductivity, but some of these materials are not completely electrically inert. Metal-based thermal compounds are not hazardous to the processor die itself, but other elements on the

processor or motherboard can be at risk if they become contaminated by the compound. For this reason, AMD does not recommend the use of electrically conductive thermal interface material.

2.1.3 Spreading Characteristics of the Material

The spreading characteristics of the thermal interface material determine its ability, under the pressure of the mounted heatsink, to spread and fill in or eliminate the air gaps between the processor and the heatsink. Because air is a very poor thermal conductor, the more completely the interface material fills the gaps, the greater the heat transference.

2.1.4 Long-Term Stability and Reliability of the Material

The long-term stability and reliability of the thermal interface material is its ability to provide a sufficient thermal conductance even after an extended time or extensive use of the computer (for example, servers or personal computers that work 24 hours a day, 7 days a week). Low-quality compounds may harden or leak out over time (the *pump-out* effect), leading to overheating or premature failure of the processor. High-quality compounds provide a stable and reliable thermal interface material throughout the lifetime of the processor. Thermal greases with higher viscosities are typically more resistant to pump out effects on lidless processors.

2.1.5 Ease of Application

A spreadable thermal grease requires the installer to carefully use the appropriate amount of material. Too much or too little material can cause problems. The PCM is a fixed size and is therefore easier to apply in a consistent manner.

2.2 Comparing the Types of Interface Materials

The two types of thermal interface materials share many characteristics, yet they can also be quite different.

2.2.1 Thermal Pads (Phase-Change Materials)

The key feature of thermal pads is their ability to change their physical characteristics. At room temperature these materials are firm and easy to handle. This allows more control when applying the solid pads to a heatsink surface. The thermal material softens as it reaches component-operating temperatures. With the heat from the operating processor and a light clamping pressure, the phase-change material readily conforms to both surfaces. This ability to completely fill the interfacial air gaps and surface voids that are typical between component packages and heatsinks allows performance comparable to thermal grease. For a list of recommended thermal pads, see the *AMD Thermal, Mechanical, and Chassis Cooling Design Guide*, order# 23794.

Thermal pads are the solution AMD recommends for AMD Athlon™ MP, AMD Athlon XP and AMD Duron processors. The advantages of thermal pads for these processors include:

- They can be handled more easily than thermal grease.
- The thermal pad interface material is less likely to be pumped out of the space between the processor die and the heatsink surface.
- The thermal compound is distributed in a uniform manner on the thermal interface pads.
- The pads contain the appropriate dosage needed to achieve optimal heat dissipation to the heatsink.

After installation, some phase-change pads create a strong adhesive bond between the processor and the heatsink. Exercise care when removing the heatsink from the processor. A slight twisting or rotating movement should help to remove the heatsink. Using strong force to remove the heatsink can damage the processor.

Note: *Thermal Pads are not recommended for use with lidded AMD processors.*

2.2.2 Thermal Grease

Thermal grease normally is packaged in a syringe, a tube, or a small plastic sachet (pouch or package). The correct amount of material must be applied to the designated area. The most important point to remember is that because heat transfer is inversely proportional to the thickness of the interface material layer, better heat transfer is achieved with a thinner TIM layer.

It is important to ensure that the proper amount of paste or grease is dispensed only to the top of the die or the lid prior to the installation of the heatsink. Too little material may leave gaps between the heatsink and processor; too much material may cause some of the material to leak outside the designated area, causing a mess and possibly contaminating other components on the processor.

High-performance thermal greases and pastes are the recommended solution for lidded processors, such as the AMD Athlon 64 and AMD Opteron™ processors. For a list of recommended greases for lidded parts, see the *AMD Athlon 64 and AMD Opteron Processors Thermal Design Guide*, order# 26633. These greases are also suitable for lab testing or short-term use on lidless processors, such as the AMD Athlon MP, AMD Athlon XP, AMD Duron, and Mobile AMD Athlon 64 processors. For long-term use on lidless processors, AMD recommends phase-change materials as a thermal solution.

The quality of the TIM compound is also very important. Manufacturers of thermal grease or paste use various components to achieve good thermal conductivity and proper spreading characteristics. These components have a direct effect on the consistency and durability of the compound. The following should be noted:

- Ensure that the proper amount of compound is used.

  Too little thermal compound reduces the thermal conductivity. The compound can dry out and prevent adequate heat transference to the heatsink. This can cause damage to the processor.

  An excessive amount of thermal compound can cause some of the material to leak out at operational temperatures, potentially causing contamination or failure of other components on the motherboard.
- Low-quality compounds often harden and dry out too quickly.

  When they dry out, they are no longer adequate thermal conductors.
- Low-quality compounds can become fluid and leak at the operating temperatures of a system.

  AMD Does not currently recommend using thermal compounds that are electrically conductive. Electrically conductive thermal compounds include most silver and gold pastes. These types of thermal compounds can leak out and contact vulnerable elements of the processor or motherboard (such as capacitors, resistors, pins, etc.), which may cause short-circuits or damage the processor or other components.
- Before use, ensure that the thermal compound has not reached its expiration date.

2.3 Thermal Material Handling Guidelines

The heatsink for your AMD processor should:

- Include the appropriate thermal interface material.
- Be recommended on the AMD Web site (*http://www.amd.com/systemconfig*).
- Be recommended for the processor you wish to use.
- Be included in the Processor-in-a-Box solution available in retail shops.

If one is not familiar with installing the heatsink on the processor, seek the assistance of a professional system builder. Incorrect handling or assembling of computer components may damage parts, void the warranty, and lead to disappointing results.

If the heatsink does not include the thermal interface material, inexperienced users should request assistance or help from the electronics supplier or computer product supplier where the heatsink was purchased.

Before applying any interface material, always make sure that the surfaces are clean and free of any foreign materials. If the surface of the heatsink or processor becomes soiled or greasy, use a lint-free wipe or cloth and a mild solvent such as denatured alcohol to clean it.

Use the AMD System Configuration Information at *http://www.amd.com/systemconfig* for more guidance.

Note: *Never reuse a thermal interface material. In case you want to reuse your heatsink, remove any residue of the previously used thermal material with a nonmetallic object like a plastic spatula and then use a lint-free wipe or cloth and a mild solvent such as denatured alcohol to fully cleanse the surface. Reapply a new thermal interface material.*

2.4 Heatsink Installation Guidelines

Follow the installation guidelines for either thermal pads (see Section 2.4.1) or thermal grease (see Section 2.4.2).

Before reusing a heatsink, remove the previously applied thermal interface material and apply a fresh layer of thermal interface material.

Caution: *Never use both a thermal pad and thermal grease at the same time!*

2.4.1 Installation with Thermal Pads (Phase-Change Material)

Follow these guidelines to install a heatsink on a processor, using a thermal pad as the thermal interface material. Thermal pads should be used with AMD Athlon MP, AMD Athlon XP and AMD Duron processors only. These processors are lidless, that is, the processor die comes into direct contact with the heatsink.

1. Verify that the heatsink has a thermal pad attached.

   If the heatsink does not have a thermal pad attached, locate the area of the heatsink that will directly contact the processor, and apply the thermal pad to this area only.

2. Remove the protective film(s) from the thermal pad.

3. Mount the heatsink onto the processor.

   Always follow the AMD-recommended procedures to install a heatsink onto a processor to avoid damaging the processor or motherboard. See the *Socket A AMD Processor and Heatsink Installation Guide*, order# 23986

Do not re-use thermal pads. Before re-using the heatsink remove the thermal interface material and reapply a new thermal pad.

Caution: *Do not use a thermal pad for AMD Athlon 64 or AMD Opteron processors!*

2.4.2 Installation with Thermal Grease

Follow these guidelines to install a heatsink on a processor, using thermal grease as the thermal interface material. Thermal grease is recommended for long-term usage on lidded parts, such as AMD Athlon 64 or AMD Opteron processors. These processors are *lidded*, that is, the processor die is covered with a lid, and it is the lid, not the processor die, that comes into direct contact with the heatsink.

1. Verify that the heatsink does not have a thermal pad attached.

2. Spread a thin layer of thermal compound on the processor die only.

   As a guideline, the quantity required for AMD Athlon MP, AMD Athlon XP, and AMD Duron processors is about the same volume as two small grains of rice placed at the center of the processor die. The quantity required for AMD Athlon 64 and AMD Opteron processors is about the same volume as five small grains of rice placed at the center of the lid. In either case, make sure that the entire processor die or lid surface is covered in an evenly spread, thin layer of thermal material.

3. Verify that the thermal grease covers the processor die or lid only, and no other components.

4. Mount the heatsink onto the processor.

   Always follow the AMD-recommended procedures to install a heatsink onto a processor to avoid damaging the processor or motherboard.

Caution: *For lidless processors, such as AMD Athlon MP, AMD Athlon XP, and AMD Duron processors, thermal grease is recommended only for short-term use; for long-term use AMD recommends thermal pads.*

2.5 Additional Information

The *Socket A AMD Processor and Heatsink Installation Guide*, order# 23986 describes the procedure for installing heatsinks with either thermal pads, thermal grease, or thermal paste and can be found under the Build and Installation Guides on the AMD System Configuration Information screen at *http://www.amd.com/systemconfig*.

Several videos are available to guide you through the phases of the installation. There are available at *http://www.amd.com/hs-installationvideo*.