White Paper

The Selection and Use of Thermal Interface Material for Solid State Relay Applications

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ABSTRACT

Solid State Relays generate thermal energy during their on state conduction at approximately the rate of 1.0 to 1.5 watts per ampere of load current depending upon their design. For reliable operation of the Solid State Relay, this energy must be dissipated into the surrounding air in order to maintain a safe operating temperature. The most common method to accomplish this dissipation to the air is through the use of a heat sink.

However, the proper sizing of the heat sink is not the only consideration when creating an SSR assembly. Another critical consideration if the proper mounting of the Solid State Relay to the heat sink itself, which can greatly effect the efficiency of the "thermal system" and therefore the operation and reliability of the assembly. This paper discusses the use of thermal interface materials that are placed between the SSR and the Heat Sink to improve thermal performance and the proper mounting techniques to ensure reliable operation of the Solid State relay.

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INTRODUCTION

The base plate of a solid state Relay and the surface of the heat sink where the relay is mounted are generally considered “flat”. However, upon closer examination, these two surfaces are generally not flat enough, coplanar or sufficiently parallel to maximize contact area and provide the lowest possible thermal impedance.

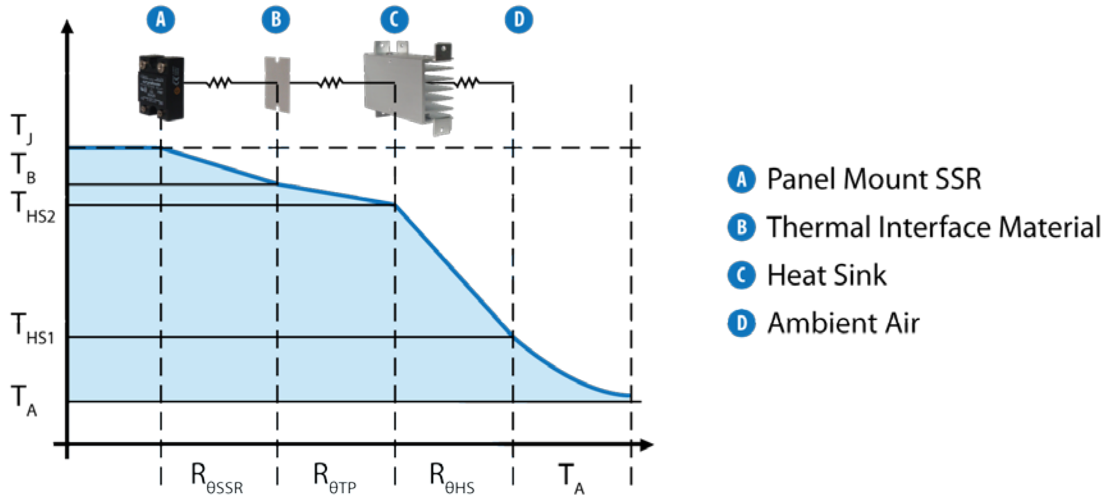
Thermal Interface Materials by definition are thermally conductive materials specifically designed to fill any voids or irregularities that may exist between the Heat Sink and SSR base plate mounting surfaces. This increases the contact area between the SSR and heat sink, effectively reducing the thermal impedance between them and allowing for the efficient transfer of heat.

To be effective, these materials must have very low bulk thermal resistivity and a viscosity low enough to allow them to flow away from points of contact towards any voids that may exist between the mating surfaces. The interface material must also stay in place once it flows and remain flexible during temperature changes. If the viscosity is too low, the interface material may flow out from between the mating surfaces leaving voids and resulting in higher thermal impedance.

In addition to thermal resistivity and viscosity, thickness and clamping pressure are also critical to achieving the lowest possible thermal impedance at the mating surfaces. If the thermal interface material is applied too thinly, then voids may remain between the surfaces no matter the clamping force. Applied too thickly and the interface material itself may actually raise resistivity rather than lower thermal resistance as intended.

Proper clamping pressure between the mating surfaces is also critical. Too much force and the mating surfaces may be distorted, worsening the thermal impedance of the joint. Too little force and the thermal material may not flow to fill all the voids. Generally for most commercially available panel mount SSRs, 15 to 20 inch pounds (1.7 to 2.2 Nm) of torque on the SSRs mounting screws will provide the proper clamping pressure to insure the lowest possible thermal impedance at the interface. Significantly higher torques may actually distort the SSRs base plate resulting in higher thermal impedance of the joint or damage to the SSR itself.

The following illustration models the structure and thermal system of an SSR mounted to a heat sink. The SSR, thermal interface material and heat sink are identified along with the assembly's thermal path and each component's relative thermal impedance.



Solid State Relay - Heat Sink Assembly Thermal Model

TYPES OF THERMAL INTERFACE MATERIALS AND WHY USE THEM WITH SSRS

There are two common types of thermal interface materials used with Solid State Relays:

A) Thermal compounds, a.k.a. thermal paste or grease.
B) Phase change materials, with or without substrates.

Thermal compounds have been available for a number of years and are commonly used, widely available and relatively inexpensive per application. They are typically shipped in "squeeze" tubes for manual application or plastic cylinders for pressure deposition systems, but in either case have very good thermal characteristics when properly applied. Thermal impedances for surface areas typical of standard "puck" type SSRs (2.2" x 1.7"/ 55 x 43 mm) typically vary from .04 to .10 ˚C/watt for .002" to .005" /.051 to .127 mm deposition thicknesses. Thermal compound viscosity is chosen for easy application and it remains flexible across a wide operating temperature range providing excellent performance for an extended length of time.

The main limitation to the use of any thermal compound is its initial application to the mounting surface. The best process is to screen print the paste on the SSRs base plate and then mount the SSR onto the heat sink. Screen printing permits a controlled and consistent deposition thickness (ideally .002" to .005"/.051 to .127 mm for SSRs) and therefore results in the lowest thermal impedance.

However, screen printing requires access to the correct equipment and screens which are often not available to many SSR installers. The result is that most thermal compounds are applied with knives, wood or plastic spatulas or similar tools. The results with these tools are often less than ideal due to the lack of control over the thermal compound deposition thickness. Thermal impedances thus may vary widely, possibly affecting the SSRs reliability in severe cases.

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Phase change thermal interface materials are a newer class of materials available from a number of manufacturers. They are supplied in solid but flexible sheets of varying thickness, size and shape and may or may not have an embedded substrate carrier. Sheets with substrates are made with phase change material placed on either or both sides of a substrate material such as aluminum, or the phase change material may be impregnated in a porous substrate material such as fiber glass. Phase change materials supplied with out a substrate often have a supporting cover such as plastic sheet which must be removed prior to installation.

Thermal impedances for surface areas equal to the standard “puck” type SSRs base plate area and .005”/.127 mm phase change material sheet thickness are roughly .03 ˚C/W, somewhat lower than for an equivalent thickness of thermal compound. Additionally, these sheets can be stamped to match the shape of the SSRs base plate including notches for the mounting screw holes, making their installation quite simple.

Note: Phase change material sheets with and without substrates may have slightly different flow characteristics and thermal impedances depending upon substrate resistivity and phase change material thickness. These characteristics must be considered when selecting a phase change “thermal pad” for a given application.

Phase change sheets are also available with and without an adhesive that allows the phase change “thermal pads” to be attached to the SSRs base plate prior to mounting on the heat sink if so desired. Care should be taken to insure not only proper centering of the pad on the SSR, but that there are no wrinkles in the phase change material after attaching it to the SSRs base plate. Such adhesive backed pads can also be pre-installed on the SSRs at the factory prior to shipment for convenience to the user. Either way, any protective backing cover placed on the thermal pad’s adhesive side during shipment must be removed prior to installation of the SSR or damage to the SSR may result.

Phase change thermal pads with out adhesive are simply placed between the SSR and heat sink as the relay is mounted to its heat sink. Other than making sure that the SSR and heat sink surfaces are clean prior to thermal pad installation, correct placement of the pad between the SSRs base plate and heat sink is the only process step needing attention.

Phase change materials by design have a transition temperature which is the point at which the material transitions from a flexible solid state to a moldable plastic state. This phase change temperature varies among manufacturers, but is typically in the range of 50 to 60 ˚ C. The phase change permits the material to flow from the points of highest pressure (closest contact points), to areas of lower pressure (voids) allowing equalization of pressure across the mating surface. This process fills the voids between the mating surfaces and lowers thermal impedance accordingly.

Note: The thermal impedance of the phase change material and the interface it fills is somewhat higher prior to the first thermal cycle and subsequent “phase change”. As a result, the SSR may operate at a slightly higher temperature than normal until the phase change occurs, at which point the SSR temperature will drop to the normal range due to the reduced thermal impedance of the interface material subsequent to its phase change.

Therefore, phase change temperatures must be coordinated with anticipated operating conditions. In order for the phase change material to provide the most favorable thermal impedance, it must be subjected to an operating temperature exceeding its specified phase change temperature during the first operational cycle.

CONCLUSION

Thermal interface materials are inexpensive and readily available. They serve to reduce the thermal impedance of the joint between the SSR and heat sink, thereby reducing the SSRs temperature and improving its reliability. The most common interface materials, “Compounds” and “Pads”, perform well with each offering certain advantages depending upon user application.

Crydom offers assistance through its Applications Engineering Department to select SSRs, heat sinks and accessories including thermal pads for any given SSR application. Visit www.crydom.com for contact information.

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