

## *Heat Sink Selection* **For Solid State Relay Applications**

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### *ABSTRACT*

Heat Sinks are required to insure the proper operation and long term reliability of Solid State Relays because they provide a means to dissipate the power that is normally developed by the SSR into the surrounding ambient air and maintain a safe operating temperature. Selecting the correct Heat Sink for any given SSR application involves coordinating form factor, size, mounting and thermal impedance rating. This paper discusses “Why Heat Sinks are Required for Reliable Solid State Relay Operation”, how the minimum required Heat Sink thermal impedance rating is calculated based upon application operating conditions, and includes an example calculation.



### *INTRODUCTION*

All SSRs in their conduction state create thermal energy in the output semiconductor at the rate of approximately 1 to 1.5 watts per ampere of load current for AC output SSRs, and 0.2 to 1.5 watts per ampere of load current for DC output SSRs depending upon their design. This power dissipation raises the Solid State Relay's operating temperature above the surrounding ambient.

Solid State Relays can operate reliably without heat sinks up to approximately 5 amps of load current depending upon model, duty cycle and ambient temperature. Free air ratings of traditional panel mount SSRs may be as high as 8 to 10 amps, but this rating relies on the SSRs exposed metal base plate acting as a heat sink, meaning that it must be exposed to ambient air.



Heat Sinks are made of high thermal conductive material such as aluminum. Not only is aluminum's thermal conductivity high, its cost is relatively low. Although other materials such as steel may provide a limited measure of heat sinking, thermal conductivity of these materials are relatively low compared to aluminum and therefore far less effective as a Heat Sink. Coatings also tend to diminish the thermal dissipation effectiveness of most materials and except anodizing, should be avoided.

Heat Sink performance is rated by thermal impedance, measured in °C per watt (°C/W) (thermal impedance is the inverse of thermal conductivity). Thermal impedance represents the resistance to the transfer of thermal energy, therefore lower numerical thermal impedance ratings mean more efficient heat transfer.

Thermal Impedance ratings of Heat Sinks are based upon natural convection air flow. To achieve this performance, the Heat Sink must be oriented such that air flow over its finned surface is maximized. Generally this means the fins should be orientated vertically.

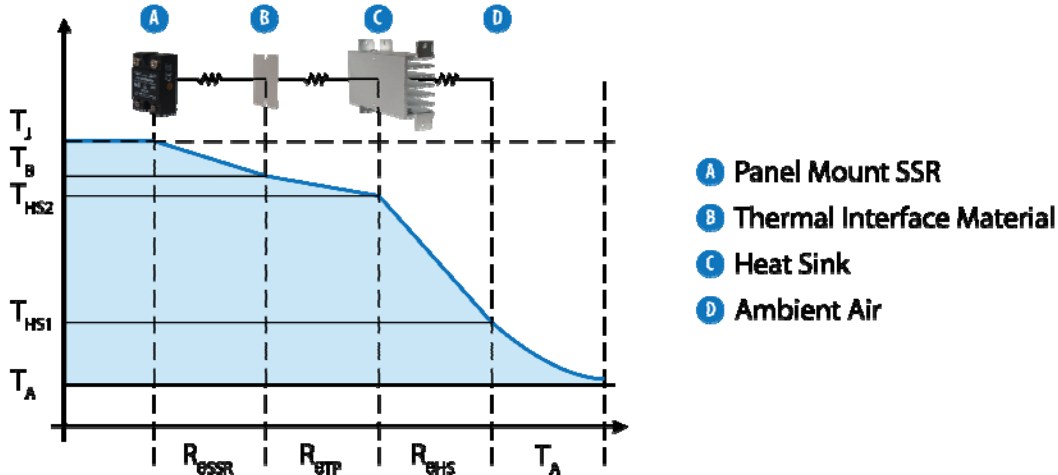
Significant improvement in Heat Sink performance can be achieved by providing forced air flow over the Heat Sink's surface area. Fans delivering relatively small volumes of air can reduce the Heat Sink's thermal impedance substantially, thereby improving its efficiency and consequently the SSRs reliability.

## *HOW TO CALCULATE AND SELECT A HEAT SINK FOR A GIVEN SOLID STATE RELAY APPLICATION*

The basic structure of a Solid State Relay includes an internal power semiconductor mounted to an electrical insulator which in turn is mounted to the Solid State Relay's base plate. To form an assembly, the SSR with an accompanying thermal interface material placed on its base plate is then torque mounted to the Heat Sink.

The thermal model representing the above configuration includes the following elements:

- A. The selected SSR with specified thermal impedance ( $R_{\Theta \text{ ssr}}$ ), forward voltage drop ( $V_f$ ), and maximum allowed internal operating temperature ( $T_j$ ).
- B. The thermal interface material placed between the SSR and the Heat Sink and its specified thermal impedance ( $R_{\Theta \text{ tp}}$ ).
- C. The calculated minimum Heat Sink thermal impedance rating ( $R_{\Theta \text{ hs}}$ ) required for proper SSR operation.
- D. The operating environment's max ambient air temperature in °C ( $T_A$ ).



**Solid State Relay - Heat Sink Assembly Thermal Model**

To determine the minimum Heat Sink rating ( $R_{\Theta HS}$ ) required for a particular application, the SSRs internal power dissipation must first be calculated. The power developed in the SSR will be the product of the actual load current in amps times the SSRs specified on state voltage drop at that current ( $P_d = I_f \times V_f$ ). Note: Manufacturers generally specify 'maximum forward voltage drop' in their data sheets. Typical voltage drops are often much lower.

For this example, assume that a 25 amp AC output SSR is selected to switch an AC load current of 18 amps with forward voltage drop specified to be 1.25 volts. Therefore the power generated in the SSR is 18 amps times 1.25 volts = 22.5 watts.

Next, determine the Solid State Relay's specified thermal impedance and allowed maximum internal temperature (if the max internal temperature is not specified by the manufacturer, assume 125 °C as this is a common value for many AC power semiconductors). For this example, assume  $R_{\Theta SSR}$  of 0.3 °C/W and  $T_J$  of 125 °C.

The next step is to determine the maximum operating ambient temperature ( $T_A$ ) in °C that the SSR will be expected to operate in its application. The ambient value should be the ambient air temperature of the local environment such as the interior of a control cabinet where the SSR and Heat Sink are to be mounted. In this example, assume  $T_A$  of 55 °C.

Finally, the thermal impedance of the interface material ( $R_{\Theta tp}$ ) must be determined. These materials will vary from 0.02 to 0.1 °C per watt depending upon the type and thickness selected. For this example, assume that the thermal impedance of the selected interface material  $R_{\Theta tp}$  is 0.05 °C/W.



The first calculation is to determine the temperature span ( $\Delta t$ ) that the SSRs power must be dissipated into in order to maintain its proper operation. This will be the difference between the SSRs maximum allowed internal temperature and the local ambient temperature.  $\Delta t = T_j \text{ max} - T_A$ . In this example the result would be:  $\Delta t = 125 - 55 = 70 \text{ }^\circ\text{C}$ .

The maximum allowed temperature rise noted above,  $\Delta t$ , must then be less than or equal to the combined sum of temperature rises across the three impedances times the power being developed in the SSR.  $\Delta t < (R_{\Theta \text{ ssr}} + R_{\Theta \text{ tp}} + R_{\Theta \text{ hs}}) \text{ times } P_d$ . For this example it would be  $70 < (0.3 + 0.05 + R_{\Theta \text{ hs}}) \times 22.5$ . Therefore the Heat Sink thermal impedance is  $R_{\Theta \text{ hs}} < (\Delta t / P_d) - (R_{\Theta \text{ ssr}} + R_{\Theta \text{ tp}})$  or  $70/22.5 - 0.35$ , equaling  $2.76 \text{ }^\circ\text{C/W}$ .

Therefore in this example, a  $2.75 \text{ }^\circ\text{C/W}$  or larger (lower numerical value) Heat Sink should be used with the Solid State Relay in the application as described above.

## *CONCLUSIONS*

Solid State Relays controlling loads rated at more than 5 amps require a heat sink for reliable operation. The size and thermal rating of the heat sink increases as the load current carried by the SSR increases, or as the operational ambient temperature increases. The Heat Sink thermal impedance rating necessary to maintain a safe SSR operating temperature can be calculated by knowing several SSR and operational parameters and using the formulas noted in the text above.

Note: Crydom offers technical assistance selecting a heat sink for any given SSR application through its Applications Engineering Department and on its web site. A selection "tool" to calculate a heat sink rating based upon load current and ambient temperature is available at [www.crydom.com](http://www.crydom.com).

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