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Solid Statements: Unraveling the Complexity of Heat Sinks

Many engineers with experience in solid-state relays have at least one (usually not-so-pleasant…) story to tell about adventures in attempted thermal management with various heat sinks. Most of these stories contain very colorful language to vividly describe overheated sub-systems, lost efficiency and cost, and wasted time and / or resources. Regardless of the nature of the story, nearly all revolve around one simple subject: the proper use of some form of heat sink to adequately manage thermal requirements.

Much to the dismay of many SSR manufacturers (including ourselves), these concerns over heat sink selection are at times directly responsible for preventing engineers from changing from electromechanical switching devices to solid-state switching devices. The list of advantages that SSRs have over EMRs is quite extensive, but power dissipation is tops amongst the disadvantages. The selection of an appropriate heat sink can be daunting at times as too little can result in failure, and too much will result in lost panel space and £$€! Hopefully we can shed a bit of light on the subject and minimize the complexity of heat sink selection.

What is a heat sink?

A heat sink is nothing more than an object that absorbs or dissipates heat. Basically, it's just a piece of aluminium. It can be anything from a complex profile of many angles and shapes, to the smooth metallic (unpainted) surface of an electrical panel. In either form (or anything in between) a heat sink does nothing more than transfer the heat from a source (solid-state relay) into the surrounding ambient air. How well it transfers heat is determined, for the most part, by the amount of surface area in contact with ambient air and is specified as "thermal resistance" (Commonly denoted as "Rs-a"). A heat sink with a large surface area will have more contact with ambient air. Therefore, its thermal resistance, or thermal "impedance", will be lower than a heat sink with less surface area. The impedance of a heat sink is measured in ºC/W (or ºK/W), which specifies the temperature rise of the heat source (SSR) for each Watt of power dissipated.

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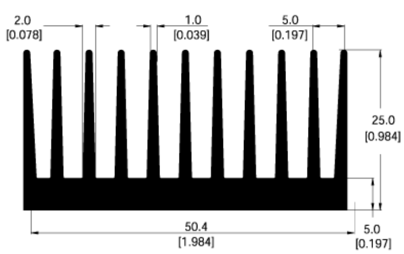
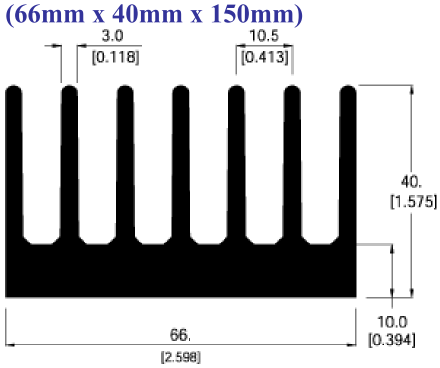
To simplify a bit… The example below shows two heat sinks of similar design. Both are aluminium extrusions (fancy word for "pieces of metal pushed through a die") cut to a length of 150mm. The profile of the first example is 50mm x 20mm and has a thermal impedance of 2.37ºC/W. The profile of the second heat sink is much larger (66mm x 40mm) so it has a lower thermal impedance (1.33ºC/W).

Typical Heat Sink Extrusion:
Example 1;
Rs-a = 2.37ºC/W
(50mm x 25mm x 150mm)



Example 2;
Rs-a = 1.33ºC/W
(66mm x 40mm x 150mm)



And this all means…. what?

Let's consider for a minute the ultimate objective of understanding this information; to manage the base plate temperature of a solid-state relay within the application. If we can do that, then we are well in control of the situation. So, let's look at the math involved in obtaining such control…

Tbp = Tamb + (Power x Rs-a)

* Tbp = max allowable base plate temp
* Tamb = ambient temperature
* Power = SSR dissipation (Watts – Vf x load current)
* Rs-a = heat sink impedance

Let's take the previous examples and apply them to a typical Crydom solid-state relay to see how the surface area of the heat sink affects base plate temperature of the relay. For this edition we will only concern ourselves with base plate temperature and leave SCR die temperature for a later discussion. We'll get creative and make up a few application specifications to complete the formula. In the "real world", this information should be readily available from the customer.

Let's assume that we want to hold the base plate temperature of a CWD2450 SSR to a relatively low 80ºC in an application with an ambient temperature of 40ºC (we can run the base plate of an SSR much hotter, but we're being cool here!!). The load is a resistive heating element inside a

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laboratory oven drawing 20 amps at 240Vac (4.8kW). The typical forward-voltage drop of a 50A CW series SSR is 0.9Vrms. Plugging this information into the formula above using the first heat sink example gives us

Example 1

1) **Tbp = 40ºC + ((0.9Vrms x 20A) x 2.37ºC/W)**
2) **Tbp = 40ºC + (42.66ºC)**
3) **Tbp = 82.66ºC**

As can be seen above, using the first heat sink with our SSR gives us a base plate temperature that slightly warmer than the desired 80ºC specified for our oven. Therefore, we need to evaluate an alternative heat sink with more surface area.

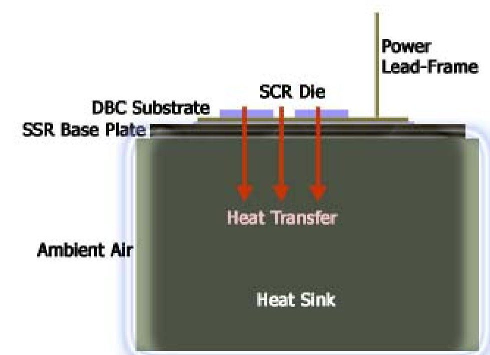
Example 2

1) **Tbp = 40ºC + ((0.9Vrms x 20A) x 1.33ºC/W)**
2) **Tbp = 40ºC + (23.94ºC)**
3) **Tbp = 63.94ºC**

The second heat sink puts us well under our target base plate temperature of 80ºC. Therefore, we have successfully identified 1.33ºC/W as a suitable impedance rating for our heat sink. Anything more than that puts us closer to the 80ºC limit (above it, if increased too much). Anything less than 1.33ºC/W will have more surface area, which will cost more and consume more panel space.

In Conclusion;

The example above gives us a basic understanding of how to calculate base plate temperature for a given application with given specifications. Obviously there is more to the puzzle, including SCR die temperature, thermal interface material, convection vs. forced airflow, etc... But let's digest what we can for now and we will consume a bit more in the next edition.



Heat Transfer Path from the SCR Die into the Heat Sink, Which is Cooled by Ambient Air

Regardless, what we've learned here will allow you to determine the desired thermal impedance within your application. From there you can begin the process of selecting an appropriate heat sink. They come in a variety of shapes, sizes and mounting styles, so selecting the heat sink may be as difficult as determining the rating you need. However, that's why we're here… we can help you throughout this

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process. More information on heat sinks and thermal management can be found on our website at www.crydom.com. Or, simply send us an e-mail with all of your application information and we will gladly help you select the appropriate heat sink for your application. If, that is, a heat sink is even necessary….

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