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TELEDYNE
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Unit of Teledyne Electronic Technologies
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Thermal Management of Solid-State Relays

When specifying a solid-state relay (SSR), engineers face a daunting problem: Keep the junction temperature within operating limits or face catastrophic results.

An SSR with very high current capabilities may need to dissipate as much as 210 watts. Multipole relays pose greater problems because power dissipation is multiplied by the number of poles.

Typical SSRs incorporate a silicon-controlled rectifier (SCR), triac or field-effect transistor (FET) as the output switching element. These components typically are in die form and placed on a copper lead frame, which is laid down on a substrate.

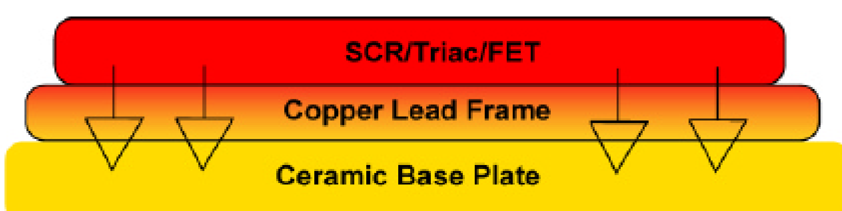
Each layer and connection introduces a thermal barrier of specific thermal resistance. When the relay is on, current flowing through the output device creates a voltage drop across it. Power dissipates in the form of heat:

$$V_{Drop}\text{ (Volts) x Current (Amps) = Heat (Watts)}$$

Heat can be transferred by conduction, convection and, to a lesser degree, radiation. In conduction, heat transfer takes place through a solid medium. In convection, heat is transferred by gas or fluid due to temperature differences.

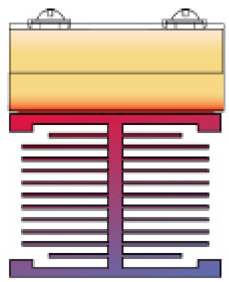
The dissipation of heat through convection depends upon the amount of surface area exposed to the cooler ambient. The amount of circulating air available to cool the surface also plays a role.

An SSR tends to retain heat because of the limited size of its substrate and because the substrate is the mounting surface. (See Figure 1.)



Layered thermal view of active Solid State Relay.
Heat is generated by the output device and flows down to the ceramic base substrate.
Figure 1

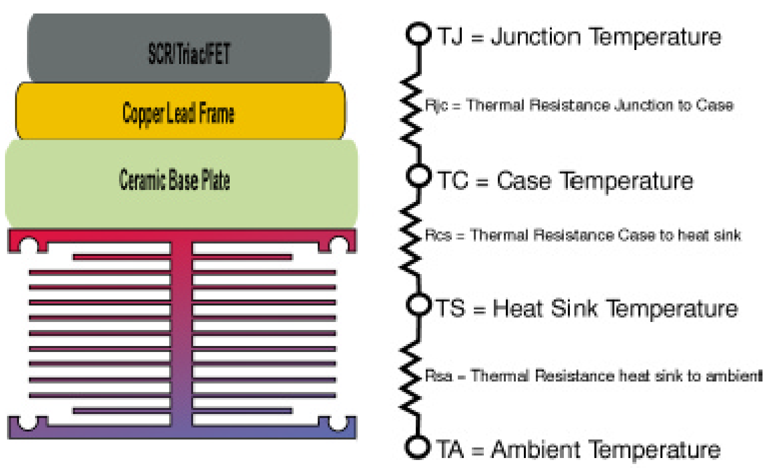
A heat sink facilitates cooling. It removes and dissipates heat through convection, thereby maintaining the relay's temperature within operating range. Heat sinks generally are aluminum alloy extrusions, often with fins that increase surface area and allow airflow. (See Figure 2.)



Heat spread through out the heat sink
Figure 2

Heat sinks are rated by their thermal resistance and measured in degrees Celsius per watt (°C/W). The lower the thermal resistance, the better the heat sink will transfer heat. Thermal resistance values of junctions along the transferred heat path assist in calculating important parameters for proper thermal design.

The configuration of the SSR and heat sink can be compared with a circuit. (See Figure 3.) The heat sink's thermal rating is labeled Rsa. The case to heat sink thermal rating (Rcs) depends on the effectiveness of interfacing the relay to the heat sink. This value is assumed to be 0.1°C/W.



Relay Heat Sink setup viewed as a circuit
Figure 3

The thermal circuit is comparable to an electrical circuit and may be analyzed using Ohm's law:

V (Voltage) = I (Current) x R (Resistance)

To calculate the resistance:

R = V/I, where V is the voltage across the resistor

In the thermal circuit, I is analogous to heat dissipation (watts), voltage to temperature, and electrical resistance (ohms) to thermal resistance (°C/W). This analogy transforms Ohm's law into:

Temperature = Heat Dissipation x Thermal Resistance

To calculate the thermal resistance:

Thermal Resistance = Temperature/Heat Dissipation

To calculate all the thermal resistances in the circuit (Rjc, Rcs, and Rsa), use Ohm's law. To calculate the thermal resistance of a heat sink:

$$Rsa = Temperature/ Heat Dissipation$$
$$Rsa = (TS - TA)/(V_{Drop} \times I)$$

Most SSR manufacturers provide Rcs, Rjc and V_{Drop}. It's important to be aware of the maximum ambient temperature and maximum current to be used.

To select the proper heat sink, Figure 3 must be analyzed as a total system, from the output device to the ambient. Using Ohm's law and the fact that resistances Rjc, Rcs and Rsa are in series, the equation for selecting a heat sink becomes:

$$TJ-TA = Heat Dissipation \times (Rjc + Rcs + Rsa)$$

Rearranging this equation to calculate Rsa, the equation for selecting a heat sink becomes:

$$\mathbf{Rsa = (TJ - TA)/(V_{Drop} \times I) - (Rjc + Rcs)}$$

All parameters needed to solve heat sink rating Rsa are either given by the relay manufacturer or are user defined.

After choosing the right heat sink, it's vital to mount the relay properly. The surfaces of the heat sink and base are lined with microscopic grooves that decrease the surface area in contact with the base, forming hot pockets and preventing heat transfer.

Two solutions assure proper heat transfer. One is thermal grease, which fills the grooves. A cleaner alternative is Teledyne Relays' thermally conductive pad.

Relays should be attached using the recommended hardware, quantities and torquing specifications. Follow these steps and the results will be very cool.