Mounting Guidelines for RCD Heat Sinkable Resistors

RESISTORS · CAPACITORS · COILS · DELAY LINES

Impressive gains in resistor power density have been achieved via the development of heat sinkable resistors that efficiently transfer heat from the resistive element out into the surrounding medium (heat sink). The technology was originally developed for the power semiconductor industry in the form of TO packages (TO-126, TO-220, TO-247, etc.). The increases in power density enable reduced costs and less PCB area.

The power capability of heat sinkable resistors depends largely on the mounting arrangement and therefore as power density increases, greater consideration to the thermal aspects of the layout becomes necessary.

Thermal Resistance

The thermal resistance (Rth $_{(junction-ambient)}$) of a mounted resistor is comprised of various component parts as shown in Fig. 1. The illustration depicts a molded TO220 package screwed down to a heat sink, but the same principal applies to other packages and mounting techniques. In order to increase power, reduce temperature rise, and/or improve reliability, it is necessary to minimize thermal resistance.

The circuit designer has influence over most of the component parts that make up the overall thermal resistance of his design:

Rth $_{(case-sink)}$ – determined by the size and quality of the contact areas between the resistor package and heat sink, the use of intermediate materials (thermal pads, grease, etc.), and contact pressure.

Rth (sink) – determined by heatsink design (material, size, and shape).

Rth (sink-ambient) – determined by heatsink design, air convection, water cooling, etc.

Contact Force

Package cases and heatsink surfaces are never perfectly smooth or flat. As a result, contact between the two (without use of interface material) would occur at a relatively small percentage of the surface area, resulting in microsopic air gaps between the surfaces. Since air is a thermal insulator it greatly impedes the transfer of heat out of the resistor package into the heat sink. With increased contact force (pushing of the two surfaces together), the amount of surface area in contact with each other also increases, thereby reducing contact thermal resistance. The minimum force required for good thermal contact varies from package to package. A force of 100 to 250 pounds is generally recommended for most applications, higher for increased heat transfer and larger package sizes. It is important that the pressure be applied evenly without distorting the component or heat sink surface. Belleville (compression) washers are recommended. On HDP Series, neither the screwhead nor washer should extend onto the resistive film (unless a fiber or other flexible washer).

Contact Conditions

Contact conditions encompass a number of factors including: surface roughness, surface cleanliness, and intermediate materials. The surface flatness should be less than .003in/in and surface finish should be 50μinch or less over the area where the device is to be mounted. For improved performance, it is generally recommended to polish or lightly sand both surfaces to minimize slight imperfections (such as burrs, mold flash, dirt particles, dents, scratches, etc.). Surface cleanliness is imperative, even if a thermal grease or other interface material is utilized. An air gap of only .001" (.025mm), which equates to ¼ the thickness of a typical sheet of paper, can result in a temperature rise of 10°C per watt or greater.

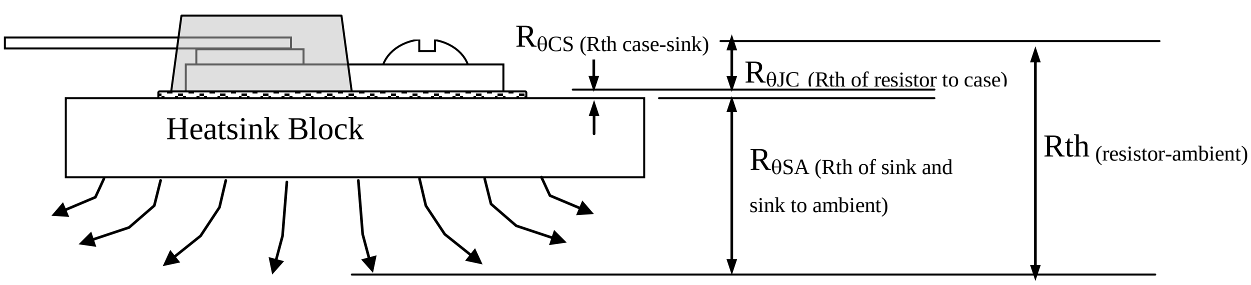

Figure 1 - Build-up of Thermal Resistance (Rth)

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Interface Materials (Heatsink Compounds)

Heatsink compounds, namely thermal grease, pads, phase change maerials, and adhesives, can greatly assist the transfer of heat into the heatsink, and are therefore strongly recommended on all RCD heatsinkable resistors. A variety of options are available from various manufacturers, each with a wide assortment of thermal conductivity grades. A material should be chosen that optimizes both the thermal and cost requirements of the system. Since RCD's standard resistor models are electrically isolated from the mounting plate, the thermal interface material does not have to be an isolator.

Thermal Grease

A number of companies offer suitable thermal greases, including Dow Corning and Thermagon. These usually consist of a silicone lubricant filled with a high thermal conductivity material such as zinc or aluminum oxide (Al_2O_3). Thinly applied, the grease does an excellent job filling air gaps without increasing the distance between the two surfaces. It is important to evenly spread the material over the entire mounting area. Silicone grease degrades/evaporates when subjected to elevated temperatures for extended periods so be sure to utilize material that is suitably rated.

Thermal Pads

Thermal pads offer thermal transfer levels approaching that of grease in a more convenient format. These usually consist of a silicone rubber filled with a high thermal conductivity material such as aluminum oxide, magnesium oxide, and Boron Nitride. When properly compressed, the pads fill the air gaps between the two surfaces. If not compressed enough, or compressed uniformly, the pad can act as an insulator actually impeding thermal transfer. Suppliers include Berquist, Thermagon, Chomerics, Aavid, and Thermalloy.

Phase Change Materials

The main problem associated with thermal pads is that the forces required for good thermal contact are quite high. Another option is to utilize a phase change material that is solid at low temperatures (typically 65°C or below), but becomes a gel at higher temperatures thereby filling gaps and voids. Upon cool down the material solidifies in place, filling the gaps. Suppliers of phase change materials include Chomerics, Berquist and Orcus Inc.

Adhesives

Another viable mounting approach is to glue a heat sink to the component package utilizing special high-temp thermally conductive adhesives. Silicone adhesives are recommended for extreme temperature cycling, and epoxy adhesives for less demanding applications. Two suppliers are Loctite and Thermagon.

Power Rating

RCD's heatsinkable resistors are rated at full power based on 25°C case temperature and require derating at temperatures above this level in order to ensure proper operation and high reliability. To determine the maximum power level for a particular device, utilize the following formula…

$$P_D = (T_J - T_A)/(R_{\theta JC} + R_{\theta CS} + R_{\theta SA})$$

where:

P_D = max. power that can be dissipated by the resistor
T_J = the maximum junction temperature rating of the internal resistance element (°C)
T_A = ambient temperature (°C)

For RCD resistors, the following design parameters are applicable. The following list includes a sampling of RCD's more popular heat sinkable resistor models. In some instances the catalog power rating is less than the theoretical power capability due to standardization with military specifications, employment of safety factor, etc. Parts should not be used above the catalog power rating, and in fact, a liberal derating factor should be employed to ensure utmost stability and reliability.

RCD Resistor Type	T_J Max.	Apprx. $R_{\theta JC}$
MP126, 20W, TO-126, Film	155°C	5.9°C/W
MP126, 20W, SM TO-126, Film	155°C	5.9°C/W
MP220, 35W, TO-220, Film	155°C	3.5°C/W
MP220G, 25W, SM TO220, Film	155°C	3.5°C/W
MPD220, 30W, SM TO263, Film	155°C	3.3°C/W
MP220B, 50W, TO220, Film	155°C	2.3°C/W
MP220GB, 50W, SM TO220, Film	155°C	2.3°C/W
MP247, 100W, TO247, Film	155°C	1.3°C/W
MP247B, 140W, TO247, Film	155°C	0.9°C/W
HDP126, 25W, TO-126, Film	200°C	5.5°C/W
HDP220, 50W, TO-220, Film	200°C	2.9°C/W
HDP247, 100W, TO-247, Film	200°C	1.5°C/W
605, 7.5W, Wirewound	250°C	9°C/W
605B, 15W, Wirewound	250°C	6°C/W
610, 12.5W, Wirewound	250°C	7°C/W
610B, 20W, Wirewound	250°C	4.5°C/W
615, 25W, Wirewound	250°C	5°C/W
615B, 35W, Wirewound	250°C	4°C/W
620, 50W, Wirewound	250°C	3°C/W
620B, 60W, Wirewound	250°C	2.3°C/W
625, 75W, Wirewound	250°C	2.0°C/W
625B, 100W, Wirewound	250°C	1.5°C/W
630, 100W, Wirewound	250°C	1.2°C/W
635, 100W, Wirewound	250°C	1.0°C/W
635B, 150W, Wirewound	250°C	0.75°C/W
640, 250W, Wirewound	250°C	0.7°C/W
640B, 300W, Wirewound	250°C	0.6°C/W

Power Rating Examples

The power rating of type HDP220 at 25°C ambient using thermal grease with a thermal resistance of 1°C/W and a heat sink with a thermal resistance of 3°C/W, would be calculated as follows…

$P_D = (T_J - T_A)/(R_{\theta JC} + R_{\theta CS} + R_{\theta SA})$

$P_D = (200°C - 25°C)/(2.9+1+3) = 175°C/6.9 = 25$ Watts

The same part with 0.5°C R_{TH} grease and 1°C R_{TH} heat sink would be capable of 175°C/4.4 = 40 Watts

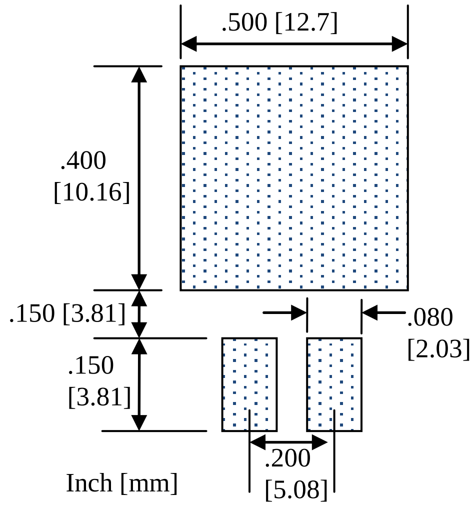
Heat Sink Selection

The heat sink and thermal interface material play a critical role in the temperature rise and power capability of the resistor. A large variety of heat sinks are available from different manufacturers. Air or water-cooling greatly enhance their thermal transfer capabilities. For instance a small clip-on heat sink designed for TO220 packages may have R_{TH} as high as 50°C under natural convection conditions, but only 4°C with forced air convection. Clip-on heat sinks are only recommended for low power applications and require careful selection and testing to ensure proper mating and contact pressure with RCD's product.

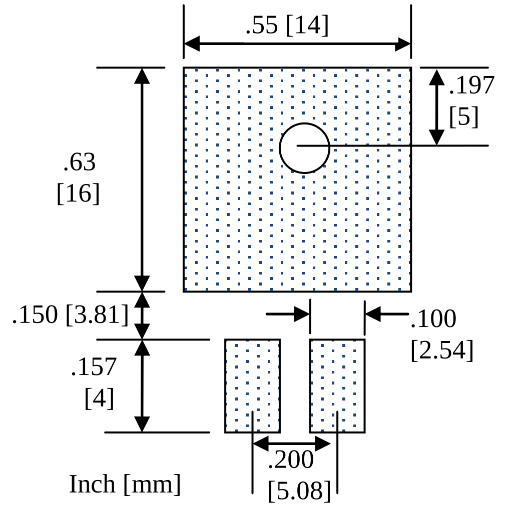
A chassis will also provide effective heat sinking, and therefore is often referenced in Military specifications. The standard chassis for 10W and smaller aluminum encased wirewound resistors is 4" x 6" x 2" x .040" thick aluminum which provides an approximate thermal resistance of 2.5°C/W. The standard chassis for similar 25W resistors is 5" x 7" x 2" x .040" which has 2°C R_{TH}.

Printed circuit boards can be utilized as heat sinks by including a large copper pad or tieing the component to a ground plane. Typical double sided FR4 PCB's provide a thermal resistance of 30 - 40°C/W depending on the degree of metallization, but with proper layout, levels of 10°C/W or less can be achieved.

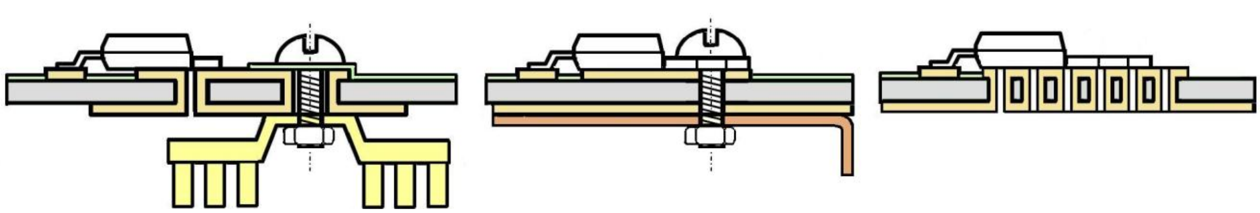
RCD MPD220 SM Heat Sink Resistor
Suggested Soldering Pads



RCD MP220G, MP220GB Heat Sink Resistor
Suggested Soldering Pads



RCD MPD220 & MP220G Suggested Mounting Configurations:
Tie to suitable heat sink or ground plane to limit hot spot case temperature to 155ºC



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