RESISTORS·CAPACITORS·COILS·DELAY LINES

Thermal Considerations and Temperature Rise of RCD Resistors

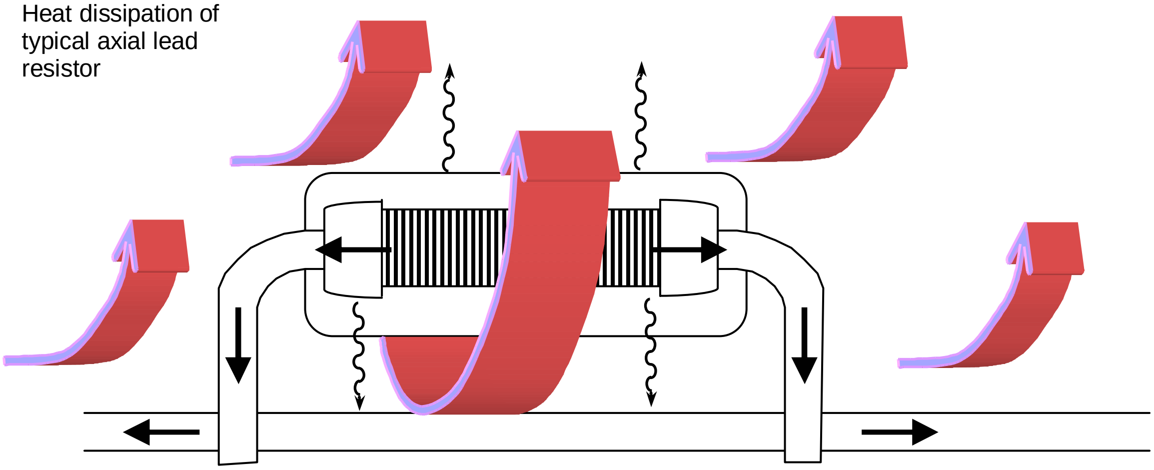
Application Guide R-35

Associated Documents:

- *Mounting Guidelines for RCD Heat Sinkable Resistors, App. Guide R-34*
- *Forced Air Convection Across Power Resistors, App. Guide R-33*
- *Thermal EMF Application Guide R-32*

Improper heat dissipation is a major cause of resistor failure, and it is therefore recommended that product be selected to ensure reasonably low temperature rise levels. Temperature rise can be significantly impacted by external conditions. Heat is transferred from regions of high temperature to regions of low temperature via radiation, conduction, and convection.

Heat dissipation of typical axial lead resistor



Radiation: electromagnetic transfer of heat between masses at different temperatures

Conduction: transfer of heat through a solid medium

Convection: transfer of heat through air or liquid

Radiation: The radiation impact is minor, and often ignored, in surface mount and small leaded resistors (2 watts and below), as well as some heat sink resistors, but quite significant in higher power resistors. Large power resistors typically operate at very high surface temperatures (275ºC to 350°C). At this level, radiation often accounts for 50% or more of the total power transferred.

Conduction:

The conduction of heat through leads and terminations typically accounts for 50% or more of heat transfer on SM and small leaded resistors, and as much as 90% on heat-sink resistors. The heatsink selection and mounting can therefore have a huge impact on resistor temperature rise and power capability. Refer to Application Guide R-34 *Mounting Guidelines for RCD Heat Sinkable Resistors* for more information. For optimum cooling without a heat sink, keep leads short and terminate to points of sufficient mass to act as heat sinks. If available, specify heavy gauge lead wires.

Convection:

Natural convection is the process of allowing the air or liquid medium surrounding a component or heat sink to remove heat without applying force. For instance, as a result of self-heating in a resistor body, the heat rises creating its own natural velocity. To take advantage of this natural convection, it is important to mount resistors in such a way that the air flow isn't impeded. When mounted, resistors should not come in contact with heat-insulating surfaces. When coating or potting circuits, the use of high thermal conductivity materials may help reduce body temperature whereas low thermal conductivity materials may impede the transfer of heat, resulting in an "oven effect".

Forced air or liquid convection can make a tremendous difference in cooling effectiveness. Improvements by an order of magnitude are achievable. Refer to Application Guide R-33 *Forced Air Convection Across Power Resistors.*

Thermal EMF:

Whenever there is a junction between dissimilar metals, a small voltage is produced. The level of voltage varies with temperature. As such it is called a thermal EMF (electro-motive force) or "thermocouple" effect, since in fact it is the same principal which enables thermocouples to act as temperature sensors. Since resistor leads are generally made from a material which is different than that the resistance material, thermal EMF's result from a heat source, either external and/or internal (self heating). Consideration should be given to component placement to ensure uniform body temperature (i.e. don't position heat generating component at one end of resistor, don't tie one lead to cool ground plane, etc). Thermal EMF's have polarity and so, for example, one end of a resistor might be a +20uV/º generator and the other end a -20uV/º generator. In the ideal situation of both ends of the resistor being at the same temperature, the thermal EMFs are self-cancelling, resulting in an actual in-circuit thermal EMF near zero. Circuits sensitive to thermal EMF require consideration to optimize layout to achieve uniform temperatures at each end of resistor body. Refer to Thermal EMF Application Guide #R-32 for additional information.

Temperature Rise:

Estimated temperature rise for a sampling of RCD's standard resistors is listed in following table. Contact factory for information on non-standard/modified versions and on items not listed. Temperature rise can vary depending on resistance value, coating material, coating thickness, lead wire material and diameter, etc. Customers are to utilize the following information as a rough guide in component selection but should verify product by evaluating samples under actual-use conditions. Since temperature rise can vary depending on raw material sources, etc., standard resistors should not be used as "heaters" (RCD offers controlled designs at little or no extra cost for these applications). Information is based on a free air/ natural convection environment, with resistors horizontally mounted (except those with radial leads which are specifically designed to be vertically mounted).

Estimated Temperature Rise

RCD Type	Temp Rise
125	130ºC/W
130	110ºC/W
133	90ºC/W
135	64ºC/W
155	58ºC/W
160	44ºC/W
170	36ºC/W
175	25ºC/W
202	130ºC/W
210	105ºC/W
232	75ºC/W
235	43ºC/W
255	36ºC/W
272	27ºC/W
605	9ºC/W[5]
605B	6ºC/W[5]
610	7ºC/W[5]
610B	4.5ºC/W[5]
615	5ºC/W[5]
615B	4ºC/W[5]
620	3ºC/W[5]
620B	2.3ºC/W[5]
625	2ºC/W[5]
625B	1.5ºC/W[5]
630	1.2ºC/W[5]
635	1ºC/W[5]
635B	.75ºC/W[5]
640	.7ºC/W[5]
640B	.6ºC/W[5]
ATS Series	See Attachment 1
BLU0402	380ºC/W[1]
BLU0603	320ºC/W[1]
BLU0805	260ºC/W[1]
BLU1206	180ºC/W[1]
BLU1210	140ºC/W[1]
CC1/4	140ºC/W
CC1/2	100ºC/W
CC1	50ºC/W
CF std	35-90ºC[7]
CF opt.S	60-90ºC[7]
EW	275-375ºC[2]
FW	250-325ºC[2]
FWE	275-375ºC[2]
GP std	40-60ºC[6]
GP opt.S	60-90ºC[6]
HDP126	5.5ºC/W[5]

RCD Type	Temp Rise
HDP220	2.9ºC/W[5]
HDP247	1.5ºC/W[5]
MC0402	380ºC/W[1]
MC0603	320ºC/W[1]
MC0805	260ºC/W[1]
MC1206	180ºC/W[1]
MC1210	140ºC/W[1]
MC2010	115ºC/W[1]
MC2512	75ºC/W[1]
MC2040	35ºC/W[1]
MCF std	40-60ºC[7]
MCF25S	160ºC/W
MGP std	40-60ºC[6]
MGP opt.S	60-90ºC[6]
MP220	5ºC/W[5]
MPF1	100ºC/W[3]
MPF2	50º/W[3]
MPF2S	75º/W[4]
MPF3	33º/W[3]
MPF3S	50º/W[4]
MWM1/2	180ºC/W[1]
MWM1/2L	170ºC/W[1]
MWM1	100ºC/W[1]
MWM1L	95ºC/W[1]
MWM2	60ºC/W[1]
MWM2L	65ºC/W[1]
MWM2S	75ºC/W[1]
MWM3	40ºC/W[1]
MWM3S	45ºC/W[1]
MWM5	30ºC/W[1]
MW1/2	125ºC/W[1]
MW1	98ºC/W[3]
MW2	65ºC/W[3]
MW25	54ºC/W[3]
MW35	46ºC/W[4]
MW3	50ºC/W[3]
MW5	40ºC/W[4]
PW2	60ºC/W
PW3	45ºC/W
PW5	35ºC/W
PW7	25ºC/W
PW10	19ºC/W
PW15	15ºC/W
PW20	11ºC/W
PW22	11ºC/W
PW25	10ºC/W

RCD Type	Temp Rise
RMF1/2	140ºC/W
RMF1	100ºC/W
RMF2	75ºC/W
RMF3	50ºC/W
RMF5	30ºC/W
RMF5S	40ºC/W
RMF7	27ºC/W
RSF1A	110ºC/W
RSF1B	90ºC/W
RSF2B	60ºC/W
RSF3B	44ºC/W
RSF5B	32ºC/W
RSF7B	25ºC/W
RW1	110ºC/W
RW2	90ºC/W
RW3	60ºC/W
SF1	88ºC/W[1]
SFG2	70ºC/W[1]
T Series	250-325ºC[2]

[1] The temperature rise of surface mount resistors is highly dependent on the PC board material, termination pad geometry, and component mounting density. Temp rise is approximate and based on DIN44050 board material, single component or low mounting density, and conventional pad sizes with 2oz copper traces (trace width equal to component width). Temp rise when mounted on alumina ceramic substrate is typically 25% to 40% less

[2] Temperature rise at full rated power

[3] The temperature rise of surface mount resistors is highly dependent on the substrate material, termination pad geometry, and component mounting density. Temperature rise is approximate and based on DIN44050 PCB materials with 500 sq.mil circuit traces

[4] The temperature rise of surface mount resistors is highly dependent on the substrate material, termination pad geometry, and component mounting density. Temperature rise is approximate and based on DIN44050 PCB materials with 1000 sq.mil circuit traces

[5] Approximate thermal resistance ($R_{\theta JC}$)

[6] Temperature rise at full rated power, rrefer to Engr Report R-8 Series GP, MGP for detailed temperature rise chart

[7] Temperature rise at full rated power, rrefer to Engr Report R-14 Series CF, MCF for detailed temperature rise chart

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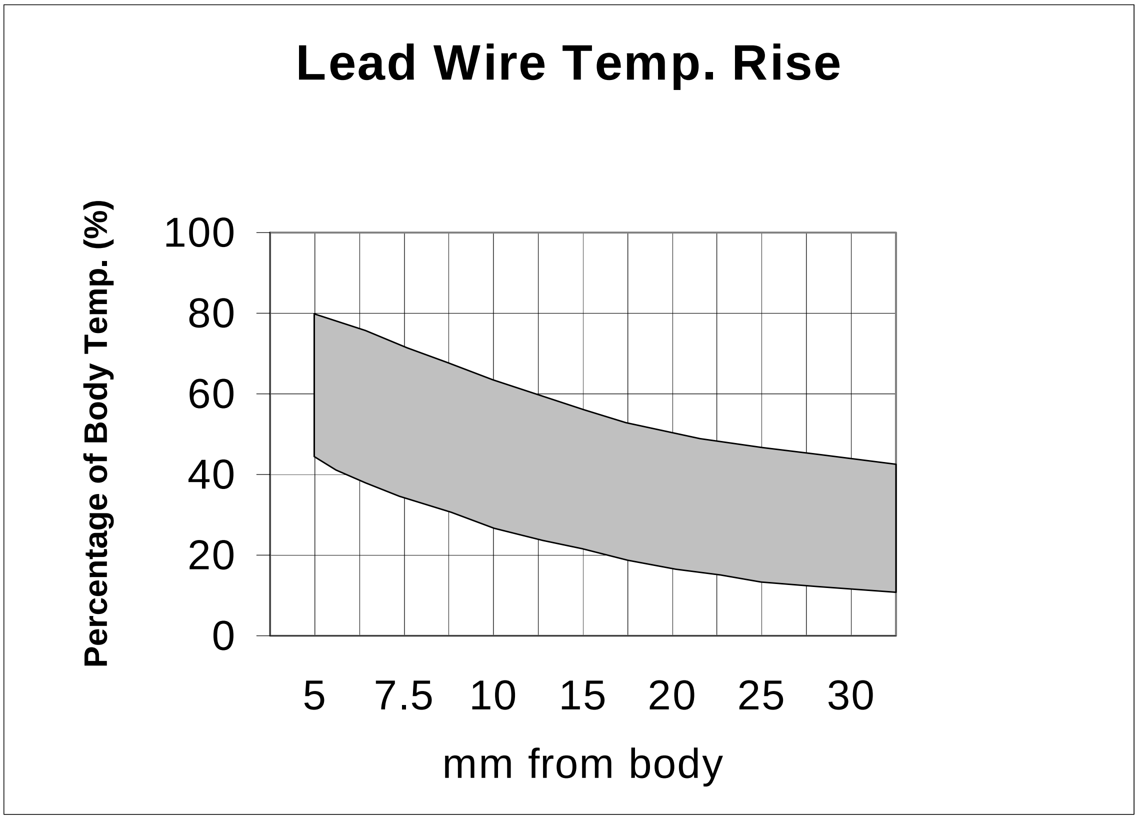

APPLICATION NOTE:
The above chart can be utilized as rough estimate of expected lead wire/solder joint temperature resulting from self-heating effect of leaded resistors under load. Eg. if a resistor is expected to have 200ºC hot-spot temperature rise (above ambient), the temperature rise of the lead wires will be roughly 50% that of the body, or 100ºC. Lead wire temperature varies due to material composition, diameter, resistor construction, PCB geometry, etc.

Leadwire composition: copperweld (copper plated steel) leads offer lower thermal conductivity than copper. As a result, copperweld leads typically exhibit lower temperature rise (bottom half of above curve). Copperweld leads are available on most products by specifying Option 'CW'. Copperweld leads have higher resistivity than copper and therefore will have a greater impact on in-circuit resistance and TCR of low value resistors.

Leadwire diameter: heavier gauge leads should be specified when it is important to reduce solder joint temperature. The heavier gauge leads are more effective at conducting the heat to the solder joint (which acts as a heat sink). This results in lower temperature of the resistor and the solder joint.

Resistor construction: RCD's use of specialty high-thermal conductivity cores to increase power ratings results in greater transfer of heat to the ends of the body and subsequently into the lead wires. These higher power versions (such as RCD option "B", Series 200, etc) would generally have lead wire temperatures in the top half of the above curve.

PCB geometry: designs which utilize heavy copper traces, ground planes, etc., act as heat sinks thereby reducing the temperature rise of the lead wires and solder joint. The above chart was developed based on typical PCB layouts and therefore by increasing the heat sink mass, customers can often reduce temperature levels significantly (often below the low range on the above chart).

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Attachment 2

RCD Series ATS Temperature Rise

The self-heating characteristic of a temperature sensitive resistor is not as straightforward is it is with other resistors. The reason for this is due to the fact that as the resistor increases in temperature due to the wattage dissipated, the resistance value increases, thereby resulting in a lower wattage level. Example: RCD type 135 100Ω 3W resistor will exhibit a temperature rise of approximately 200°C when 17.3V is applied. Note: 17.3V equates to 3W as determined by Ohm's Law... $W = E^2/R = (17.3)^2 \div 100 =$ 3 watts. The same resistor wound with +6000 ppm TCR wire, will exhibit a temperature rise of only 140°C, even though the voltage level applied is the same. The temperature rise vs. TCR can't be extrapolated linearly due to the fact that part of the resistance windings towards the ends of the body are heat sinked by the caps and leads and therefore do not exhibit the same temperature rise as the center windings. Use the following chart as guideline for ATS Series.

RCD Type	**Temp. Rise with TCR of 0 ppm (°C/W)**	**Temp. Rise with TCR of +1000 ppm (°C/W)**	**Temp. Rise with TCR of +3500 ppm (°C/W)**	**Temp. Rise with TCR of +6000 ppm (°C/W)**
ATS110	170°C	156	130	117
ATS125	125°C	115	95	86
ATS135	70°C	64	53	48
ATS145	65°C	60	50	45
ATS150	65°C	60	50	45
ATS155	57°C	52	43	39
ATS160	44°C	40	34	30
ATS170	35°C	32	27	24
ATS175	24°C	22	18	17

Series ATS temperature rise can vary significantly due to variations in coating thickness, mounting layout, PCB materials, resistor body size, leadwire material, etc., therefore the above information is intended as a rough guide to assist in the general selection of parts. Users should test and verify units in actual use conditions to determine final suitability. Customized versions are available (consult factory).