Considerations for Effective Thermal Management for High Power Resistors

APPLICATION NOTE

Introduction

During typical operation, high-power resistors are known to generate significant heat. If not properly managed, this can exceed material and application specification limits, reduce performance, or shorten component life.

The common solution is for power resistors to be mounted on a properly-sized heat sink enabling them to safely dissipate large amounts of power. This application note provides helpful calculations for determining the best heat sink thermal management approach using the basic thermal resistance of a resistor and how that resistance affects system operations. A heat sink example is included along with cautionary information about rated power.

Thermal Resistance of the Resistor

Thermal resistance (Rθr) defines the relationship between internal resistor temperature and dissipated power:

$$R\theta r = (T_r - T_c) / P$$

Where:
- T_r: Internal resistive element temperature (°C)
- T_c: Case or backplate temperature (°C)
- P: Power dissipated (W)

The nominal power rating of the resistor specified at 25°C case temperature with proper cooling system. As the power derating shows, higher ambient temperature reduces the power rating. Above 25 °C case temperature resistor can operate at reduced power level. When case temperature reach 150 °C, power is derated to zero, which means the resistor is not allowed to be stressed electrically.

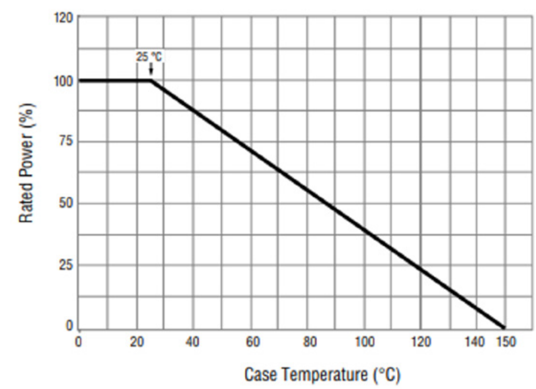

Figure 1. | Thermal Resistance

Thermal Resistance in a System

In practical designs, total thermal resistance is the sum of three components:

$$R\theta total = R\theta r + R\theta i + R\theta h$$

- Rθr: Resistor element to case (datasheet value).
- Rθi: Interface material (thermal pad/grease), typically 0.1–1 °C/W.
- Rθh: Heat sink to ambient, determined by heat sink size, airflow, and orientation.

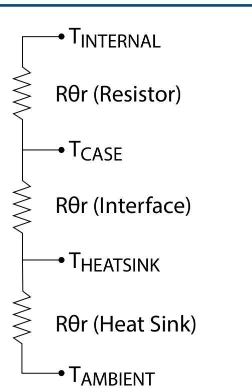

Figure 2. | Thermal Resistance Components

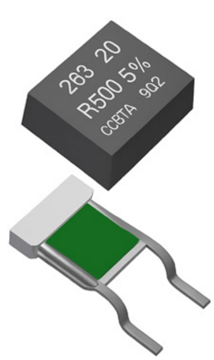

Figure 3. | Rθr = Resistive Element to Backplate

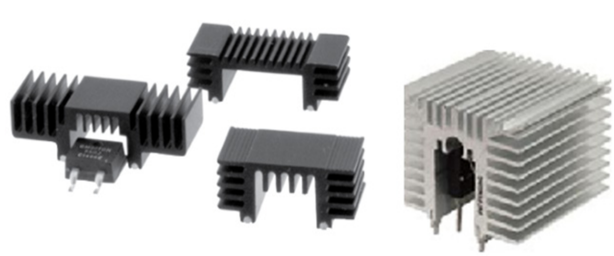

Figure 4. | Rθh = Heat Sink to Ambient

Thermal Resistance in a System (Continued)

In resistors in surface-mount packaging (DPAK, D2PAK), the PCB copper area acts as part of the cooling system. Heat transfer improves with:

- Larger copper areas
- Thicker copper layers (e.g., 70 µm)
- Thermal vias connecting to opposite PCB layers

A useful design tip for resistor thermal management is that forced air cooling can dramatically improve performance. For example, airflow of 3 m/s across a properly oriented heat sink can nearly double power dissipation capacity.

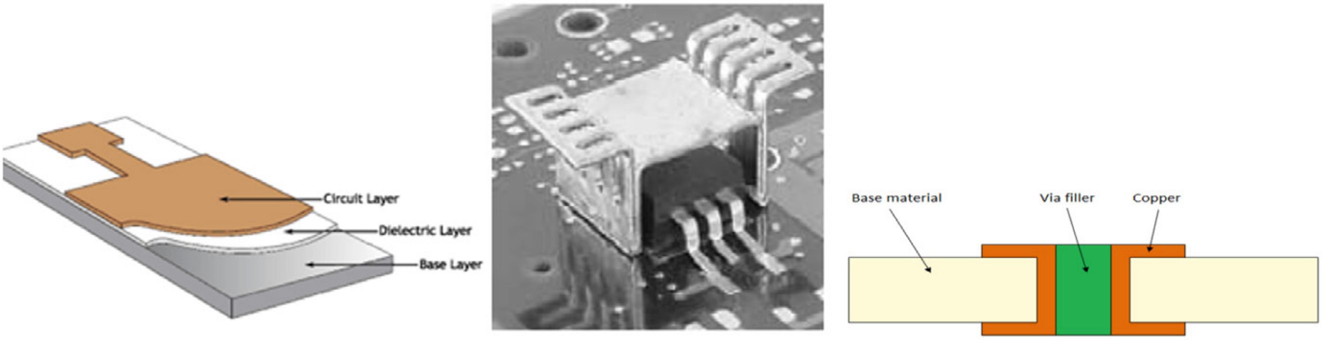

Figure 5. | *Upon request, Bourns can support a customer's thermal management concept with pre-bended terminals for through hole and reversed terminals for SMD mounting.*

Figure 6. | *For example, Bourns® Model PWR220 and Model PWR221 thick film resistors are offered with pre-bent terminals in through hole packaging and Model PWR163 resistors are available with reversed terminals in SMD packages.*

Bourns® Thick Film Resistors

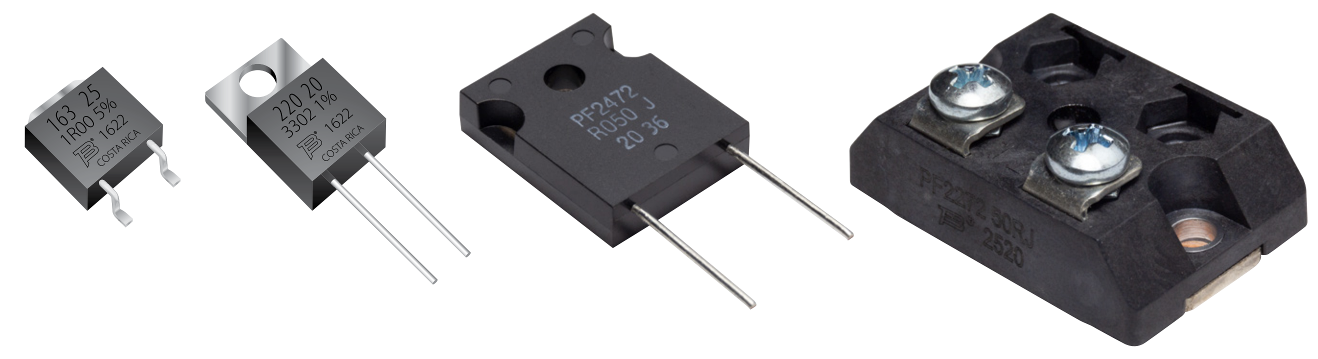

Figure 7. Bourns® Thick Film Resistors

Bourns offers a wide range of high-power thick-film resistors in the PWR and PF Series. These resistors are available in industry-standard packages such as:

- Surface-mount: TO-163, TO-263 (DPAK, D2PAK)
- Through-hole: TO-220, TO-247
- Planar: TO-227

These compact and widely used packages enable space savings and compatibility with off-the-shelf mounting and thermal management accessories.

The resistors are based on a thick-film resistive element on an alumina ceramic substrate, offering key advantages:

- High power rating from 20 to 300 W
- High energy absorption and power dissipation when used with an appropriate cooling system (PCB copper area, heat sink, and/or forced air).
- Low inductance (typically 0.1 μH) – suitable for switching circuits up to ~50 kHz.

The Bourns® PWR and PF Series cover a resistance range from 20 mΩ to 1 MΩ, with tolerance options of 1 % and 5 %. The PWR Series is AEC-Q200 qualified, making it suitable for demanding industrial, telecom, and automotive applications.

Typical uses include:

- Limiting inrush current in MOSFET and IGBT circuits.
- RC snubber circuits
- Absorbing capacitor precharge/discharge pulses.
- Shunt resistors for current measurement and control.
- Resistive heating elements for localized thermal management.

High power thick-film resistors are well-suited as snubber resistors in high-frequency applications. Their low inductance minimizes phase shift and switching losses when semiconductors operate in the Megahertz (MHz) range. They are also effective choices due to their ability to handle higher power, provide stable performance, and their cost-effectiveness.

Note:
Resistors achieve their rated power only with an adequate cooling system. In free air, their dissipation capability is significantly reduced.

Example Ratings

Model Number	Package	Power Rating @ 25 °C Case Temperature with Proper Cooling System	Power Rating on Free Air (without Heat Sink)	Thermal Resistance of The Resistor (R_{thj} (Rθr)	Operating Temperature Range	Maximum Operating Voltage
PWR163S-25	DPAK	25 W	2.8 W	5.2 °C/W	-55 °C to +155 °C	250 V
PWR263S-20	D2PAK	20 W	2.8 W	6.5 °C/W	-55 °C to +155 °C	250 V
PWR263S-35	D2PAK	35 W	2.8 W	3.7 °C/W	-55 °C to +155 °C	250 V
PWR220T-20	TO-220	20 W	2.8 W	6.5 °C/W	-55 °C to +155 °C	250 V
PWR220T-35	TO-220	35 W	2.8 W	3.7 °C/W	-55 °C to +155 °C	250 V
PWR221T-30	TO-220	30 W	2.8 W	4.2 °C/W	-55 °C to +150 °C	250 V
PF2203	TO-220	35 W	1 W	3.3 °C/W	-55 °C to +175 °C	500 V
PFS35	D2PAK	35 W	2 W	3.3 °C/W	-55 °C to +175 °C	500 V
PF2472	TO-247	100 W	3 W	1.3 °C/W	-55 °C to +175 °C	700 V
PF2270	TO-227	200 - 300 W	5 W	0.35/0.23 °C/W	-55 °C to +175 °C	250 V

Heat Sink Calculation Example

Goal: Dissipate 10 W with Bourns® Model PWR220T-30 resistor.

$R\theta h + R\theta i = (T_r - T_a) / P - R\theta r$

Substitute values:

- T_r: Max resistor element temperature = 155 °C
- T_a: Ambient = 25 °C
- P: Dissipated power = 10 W
- Rθr: From datasheet = 3.7 °C/W

Calculation:

$R\theta h + R\theta i = (155 - 25) / 10 - 3.7 = 9.3$ °C/W

Result:

The combined heat sink and interface resistance must be ≤ 9.3 °C/W.

Heat Sink Considerations

Below are best-practices considerations when designing in and selecting a heat sink for a thick film resistor:

- Always use thermal grease or pads to minimize Rθi.
- Increase surface area or add forced air cooling to reduce Rθh.
- Select a heat sink with sufficient margin below calculated requirements.
- Ensure proper mechanical mounting pressure for consistent thermal transfer.

Conclusion

Offering optimized current limiting and voltage regulation, Bourns® PWR and PF Series thick-film resistors are robust solutions for high-power applications. Developers do, however, need to carefully consider including thermal management in their design.

By understanding the thermal resistance chain and selecting suitable heat sinks, designers can minimize the effects of heat to help create a balanced design with reliable operation even in today's high-frequency applications.