Technical Note

Surface-Mount Power Resistors

QA Department, Nikkohm Co., Ltd. April 1, 2016

1. Heat releasing generated by surface-mount power resistors

While a plate-type resistive element power resistor (power film resistor, referred to as a "SMD power resistor" in this document) is designed in, the heat generated by the resistor is released from the base metal, the bottom of the resistor (referred to as "the flange" or “the base” in this document), to the ambient air through copper foil of the printed circuit board (PCB) on which the resistor is mounted, and the heat releases to the metal chassis that carries the PCB, or the metal box.

Types of surface-mount power resistor and the thermal resistances are listed in Table 1. Photos of the appearance of individual resistors are shown in figures 1, figure 2, and figure 3.

Shape	Rated power	Thermal resistance of resistor
DPAK	45 W	3.0°C/W
D2PAK, TO263	35 W	3.3°C/W
TO220 screw mount	35 W	3.3°C/W
TO220 screw mount	50 W	2.3°C/W

Table 1. SMD power resistors, rated powers, and thermal resistances between resistive film and the base

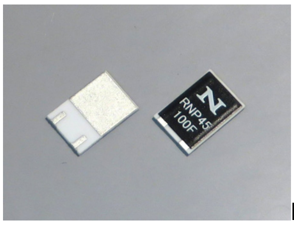

Figure 1. Similar as DPAK

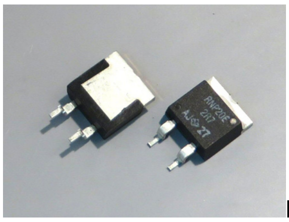
Figure 2. D2PAK

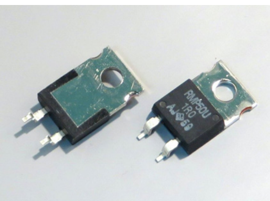
Figure 3. TO220

2. Soldering SMD power resistors on PCB directly

As shown in Figure 4, a SMD resistor is designed to be soldered to a printed circuit board. The flange of the resistor is insulated from the resistor terminals, and can be directly soldered to the copper foil of the printed circuit board. The capacity of the printed circuit board to release heat to air is, however, such that only the surface area of copper foil plays a role in the thermal conduction, and only the surface area of the surface of copper foil is cooled by the surrounding air. And thickness of the copper is very thin as 35um. Thus, the heat - conduction performance is very low, at about 20°C/W per 50 mm square, such that if 5 W of power is applied to a resistor when the surrounding air temperature is 50°C, the temperature of the resistance film inside the resistor will reach 166.5°C = 50°C + 5 W x (20 + 3.3)°C/W. This temperature exceeds the maximum operating temperature of the resistor, which means that this cooling system fails to release the 5 W of heat appropriately. Needless to say, even if a double-sided printed circuit board is used, resin with a thickness of 1.5 mm contributes very little to the heat release.

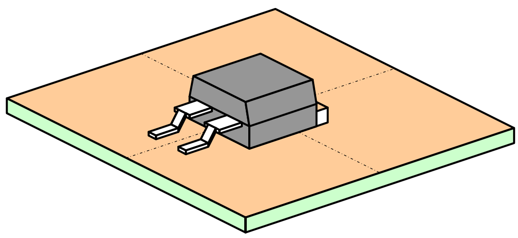
Figure 4. In air cooling of D2PAK and circuit board, 50mm square FR4 circuit board cannot release 5W power.

3. Methods of releasing heat from SMD power resistors

One way to release heat from DPAK and D2PAK surface-mount power resistors mounted on a printed circuit board is to rely on the thermal conduction of the surface copper foil, as shown in Figure 5. If heat is transferred from the end of width 10.1-mm flange of the D2PAK resistor to a thermally conductive bar, 5 mm distant via a 35-um copper foil, the thermal resistance of the copper foil will be about 35°C/W, such that it cannot contribute to the cooling of the

resistor.
Figure 6 shows a method whereby thermal vias are formed on the portion on which a D2PAK resistor is mounted, thereby releasing heat to not only the surface but also the copper foil on the reverse side.

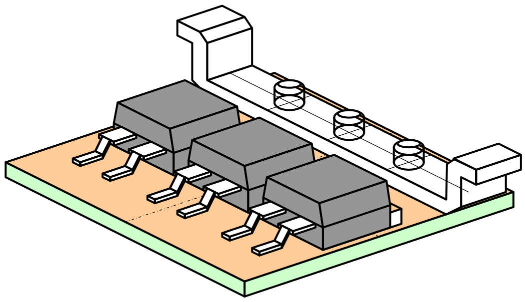

Figure 5. In D2PAK, circuit board and heat sink, heat resistance will be only 35 ° C/W when distance between flange and heat sink bar is 5mm.

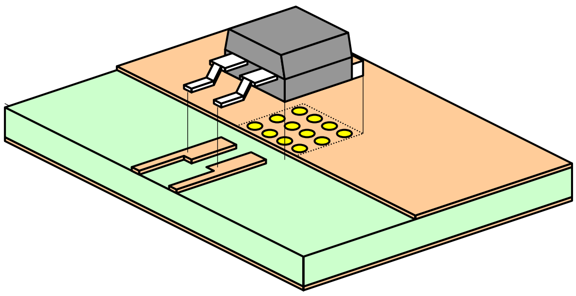

Figure 6. In D2PAK and circuit board with 12 pieces thermal via, the heat resistance from front side to back side will be 8.8°C/W. heat resistance of a thermal via of 0.5mmdiameter is around 106° C/W.

Structures for releasing heat from the copper foil of a printed circuit board to the air, as shown in Figures 5 and 6, incur some disadvantages such as it being undesirable to heat the printed circuit board itself. One possible way of releasing heat to the metal chassis more freely is to embed a copper or brass cylinder with a diameter of about 8 mm into the printed circuit board, as shown in Figure 7.

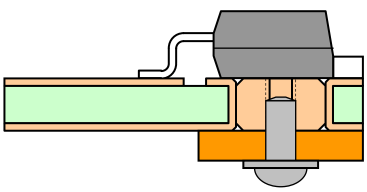

Figure 7. Releasing the heat to the back side of circuit board and the heat conduction bus - bar by a thermally conductive cylinder of 8mm diameter from D2PAK to heated heat transfer to the metal housing is effective. The thermal resistance of the copper cylinder of 8mm diameter is less than or equal to 0.1 ° C / W.

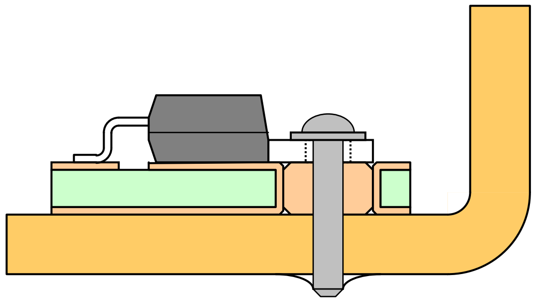

Figure 8. From the flange of the TO220, a thermal conductive cylinder of 8mm diameter escapes the heat to the metal housing or the heat conduction bar.

Another way of releasing heat more effectively is to transfer heat directly from a TO220 SMD power resistor (RMP20S or RMP50U) to a thermally conductive bar via an 8-mm diameter copper cylinder, ultimately releasing the heat to the metal chassis, as shown in Figure 8. The thermal resistance of the resistor is 2.3°C/W (for the RMP50U), the thermal resistance of the flange is 0.2°C/W, and the thermal resistance of the cylinder is 0.1°C/W, giving a total of 2.6°C/W. Assuming that the temperature of the metal chassis is 50°C and the upper limit of the operating temperature range is 155°C,
P (W) = (155°C - 50°C)/2.6°C/W = 40 W. Thus, it is possible to consume up to 40 W of power in the resistor and release the heat to the surrounding air.
It can be said that, if a resistor is to be SMD on a printed circuit board, and then several tens of W are applied, it is better to use a TO220 surface-mount resistor and release the heat through the screw used for securing the flange, rather than using a D2PAK resistor.

4. Metal insulated circuit board
Another recommended means of releasing heat from the flange of a D2PAK resistor more effectively is to adopt a metal insulating printed circuit board. The structure of a metal insulating printed circuit board features an aluminum plate and a circuit copper foil which are bonded together with an insulating adhesive material with a high thermal conductivity, as shown in Figure 9. In this way, heat is transferred from the heat-generating electronic parts, power resistors, and so on that are mounted on the surface of the circuit copper foil, and then released.
The thermal conductivity of such a printed circuit board is governed by the insulating material, but is usually 1.0 or 1.2 W/mK. Supposing that the flange dimensions of a D2PAK resistor are about 10 mm x 10 mm, the thermal resistance is
$R\theta = 0.06 \times 0.001/(10 \times 10 \times 10^{(-6)} \times 1.0) \cdots °C/W$
$R\theta = 0.6$ °C/W
Thus, if the aluminum plate on the reverse side can be maintained below the upper limit on the internal temperature of 60°C, the thermal resistance from

the resistance film to the aluminum plate is 3.3°C/W + 0.6°C/W = 3.9°C/W. For a power of 20 W, the temperature is 60°C + (3.9 x 20) = 138°C, which does not exceed the maximum operating temperature of +155°C, with the result being that the application of 20 W of power is possible. It is, however, necessary to fully consider the cooling capacity of the aluminum plate, the temperature fluctuations, and the impact of other heat-generating devices mounted on the printed circuit board.

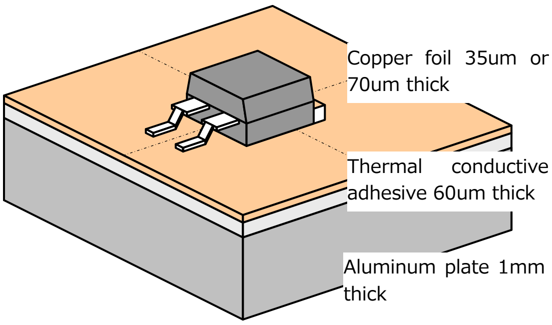

Figure 9. Typical insulated aluminum circuit board shows 0.6°C/W of 10mm x 10mm area.

5. Reference, thermal conductivity

Thermal conductivity is a physical constant indicating the ease with which heat can be transferred. It is the value of the heat quantity (W) for creating a temperature difference of 1°C between the two sides of a 1 m x 1 m x 1 m cube, with the symbol K and units of W/m・°C. The thermal conductivities of typical substances are listed in Table 2. A high thermal conductivity means that the substance transfers heat easily.

Material	Thermal conductivity, K (W/m °C)
Copper	403
Brass	119
Aluminum	236
Iron	83
Stainless steel	15
Solder	39
Alumina substrate	27
Glass epoxy	0.25

Table 2. Thermal conductivities of metals

6. Reference, thermal resistance

Thermal resistance is a value that represents the effect whereby the transfer of heat is prevented, with the material and the shape being taken into consideration, and is a convenient value from which the temperature difference between the entrance and exit through which a heat quantity (W) passes can be calculated instantly. Needless to say, thermal resistance is directly related to thermal conductivity, which is the ease with which heat can be transferred. If the thermal resistance is Rθ, the cross-section of the thermal conduction path is S, and the length of the thermal conduction path is L, then the following holds:

$$R\theta = \frac{L}{K \times S}(°C/W)$$

If the dimensions and shape of a thermal conductor are defined, thermal resistance can be easily determined through calculation and used as a rough guide.

End

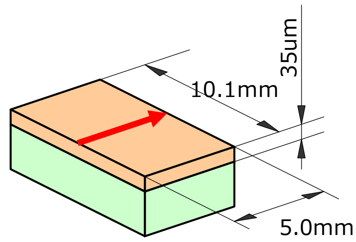

Figure 10. Thermal resistance of 10.1mm x 5.0mm x 35umcopper foil

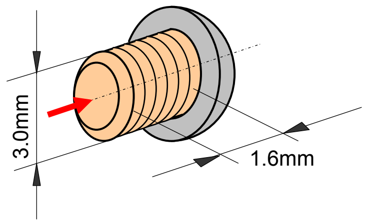

Figure 11. Thermal resistance of M3 screw – 1.6mm length

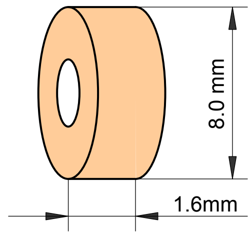

Figure 12. Thermal resistance of copper cylinder of 8.0mmΦ-1.6mm length

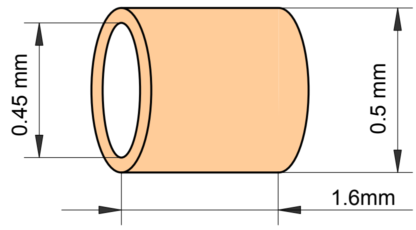

Figure 13. Thermal resistance of a thermal via

Material	Thermal conductivity	Cross-sectional area	Length	Thermal resistance
	W/m°C	mm^2	mm	°C/W
10-mm-wide copper foil	403	0.35	5.0	35.97
M 3 Cu screw	403	7.06	1.6	0.56
8-mm Cu cylinder	403	50.3	1.6	0.08
0.5-mmϕ via	403	0.037	1.6	106.42

Table 3. Results of calculating the thermal resistances of materials with different shapes and dimensions