THERMAL CONSIDERATIONS - DIODES

Thermal resistance

Circuit performance and long-term reliability are affected by the temperature of the die. Normally, both are improved by keeping the die temperature (junction temperature) low.

Electrical power dissipated in any semiconductor device is a source of heat. This increases the temperature of the die about some reference point, normally an ambient temperature of 25 °C in still air. The extent of increase in temperature depends on the amount of power dissipated in the device and the net thermal resistance between the heat source and the reference point. This can be expressed with the following formula:

$\Delta T_j = P_{tot} \times R_{th(j\text{-}a)}$

where:

ΔT_j is the increase in junction temperature

P_{tot} is the total power generated in the device

$R_{th(j\text{-}a)}$ is the thermal resistance from junction to ambient.

Surface mount devices

Heat transfer can occur by radiation, conduction and convection. Surface mount devices lose most of their heat by conduction when mounted on a substrate. Referring to Fig.1, heat conducts from its source (the junction) via the package leads and soldered connections to the substrate. Some heat radiates from the package into the surrounding air, where it is dispersed by convection or by forced cooling air. Heat that radiates from the substrate is dispersed in the same way.

The thermal resistance for surface mounted devices therefore, can be expressed as:

$R_{th(j\text{-}a)} = R_{th(j\text{-}tp)} + R_{th(tp\text{-}a)}$ (see Fig.2)

where:

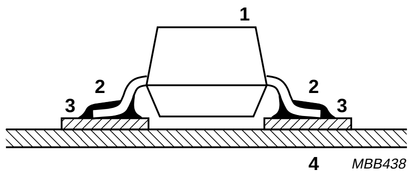
$R_{th(j\text{-}a)}$ is the thermal resistance from junction to ambient

$R_{th(j\text{-}tp)}$ is the thermal resistance from junction to tie-point

$R_{th(tp\text{-}a)}$ is the thermal resistance from tie-point to ambient.

The $R_{th(j\text{-}tp)}$ value is essentially independent of external mounting method and cooling air, but is sensitive to the materials used in the package construction, the die bonding method and the die area, all of which are fixed.

The $R_{th(tp\text{-}a)}$ value depends on the shape and material of the tracks and substrate. For all package types these values are given in Table 1 for mounting on (FR4) printed-circuit board with small pad area. For other pad areas and printed-circuit board configurations see Fig.3.



Heat radiates from the package (1) to ambient.
Heat conducts via leads (2), solder joints (3) to the substrate (4).

Fig.1 Heat losses.

The maximum power handling capability ($P_{tot(max)}$) is given by:

$$P_{tot(max)} = \frac{(T_{j(max)} - T_{amb})}{R_{th(j\text{-}a)}}$$

where:

$T_{j(max)}$ is the maximum junction temperature

T_{amb} is the ambient temperature.

Calculating this maximum power handling capability we have to take into account the maximum junction temperature of the particular device, the maximum temperature of the solder joints (110 °C for long time reliability) and the ambient temperature. Dependent on the ratio of the component parts of the thermal resistance, it will be possible that the junction temperature or the temperature of the solder joints (T_{tp}) will be the limiting factor. This can be shown in the following example for the SOT23 package mounted on FR4 printed-circuit board.

EXAMPLE FOR THE SOT23 PACKAGE

$$P_{tot(max)} = \frac{(T_{j(max)} - T_{amb})}{R_{th(j\text{-}a)}}$$

$$= \frac{(150\,°C - 25\,°C)}{500\ K/W} = 0.25\ W$$

$$T_{tp} = T_{amb} + P_{tot(max)} \times R_{th(tp\text{-}a)}$$

$$= 25\,°C + 0.25\ W \times 150\ K/W = 62.5\,°C$$

This is below 110 °C, so $T_{j\,max}$ is the limiting factor.

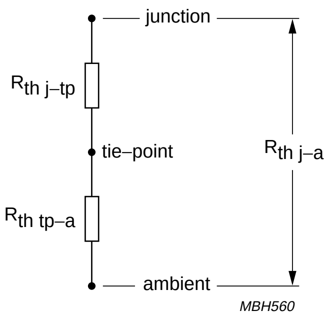


Fig.2 Representation of thermal resistance paths for a surface mounted diode.

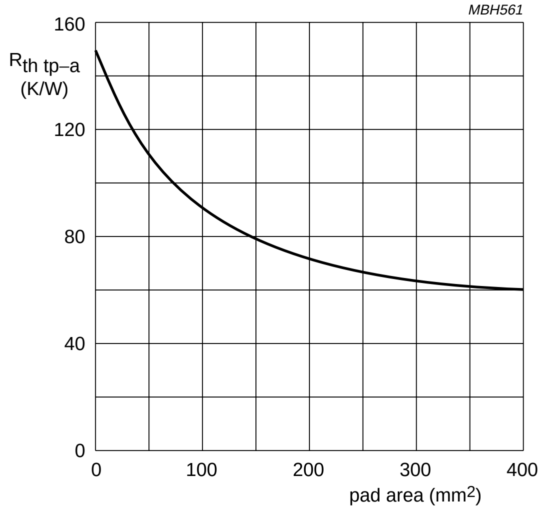


Fig.3 Thermal resistance ($R_{th(tp-a)}$) as a function of FR4 printed-circuit board pad area.

Table 1 Thermal resistance values and maximum power handling capability of surface mount packages

PACKAGE	$R_{th(j-a)}$ (K/W)	$R_{th(j-tp)}$ (K/W)	$R_{th(tp-a)}$ (K/W)	$P_{tot(max)}$ (W)
SOD110	315	165	150	0.40
SOD323	625	475	150	0.20
SOT23	500	350	150	0.25
SOT143	500	350	150	0.25