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AN204

Thermal Design

Application Note

AN204 - 1.0 August 1995

The temperature of any semiconductor device has an important effect upon its long term reliability. For this reason, it is important to minimise the chip temperature; and in any case, the maximum junction temperature should not be exceeded.

Electrical power dissipation in any device is a source of heat. How quickly this heat can be dissipated is directly related to the rise in chip temperature: if the heat can only escape slowly, then the chip temperature will rise further than if the heat can escape quickly. To use an electrical analogy: energy from a constant voltage source can be dawn much faster by using a low resistance load than by using a high resistance load.

The thermal resistance to the flow of heat from the semiconductor junction to the ambient temperature air surrounding the package is made up of several elements.

These are the thermal resistance of the junction–to–case, case–to–heatsink and heatsink–to–ambient interfaces. Of course, where no heatsink is used, the case–to–ambient thermal resistance is used.

These thermal resistances may be represented as

$\theta_{JA} = \theta_{JC} + \theta_{CH} + \theta_{HA}$
where θ_{JA} is thermal resistance junction–to–ambient °C/W
θ_{JC} is thermal resistance junction–to–case °C/W
θ_{CH} is thermal resistance case–to–heatsink °C/W
θ_{HA} is thermal resistance heatsink–to–ambient °C/W

The temperature of the junction is also dependent upon the amount of power dissipation in the device – so the greater the power, the greater the temperature.

Just as Ohm's Law is applied in an electrical circuit, a similar relationship is applied to heatsinks.

$T_j = T_{amb} + P_D (\theta_{JA})$,
where T_J = junction temperature
T_{amb} = ambient temperature
P_D = dissipation power

From this equation, junction temperature may be calculated, as in the following examples.

Example 1: A 1mm sq die placed in a DG16 package that must operate in ambient temperature of +50°C. Maximum junction temperature is +175°C. Let P_D = 598mW and θ_{JA} = 110°C/W.

$$\begin{aligned} T_J &= T_{amb} + P_D\,\theta_{JA} \\ &= 50 + (0.598 \times 110) \\ &= 115.8°\text{C} \end{aligned}$$

Where operation in a higher ambient temperature is necessary, the maximum junction temperature can easily be exceeded unless suitable measures are taken.

Example 2: The same device to be used at an ambient temperature of +120°C.

$$\begin{aligned} T_j &= 120 + (0.598 \times 110) \\ &= +185.8°\text{C} \end{aligned}$$

This clearly exceeds the maximum permissible junction temperature and therefore some means of decreasing the junction–to–ambient thermal resistance is required.

As stated earlier, θ_{JA} is the sum of the individual thermal resistances; of these, θ_{JC} is fixed by the design of device and package and so only the case–to–ambient thermal resistance, θ_{CA}, can be reduced.

If θ_{CA}, and therefore θ_{JA}, is reduced by the use of a suitable heatsink, then the maximum T_{amb} can be increased:

Example 3: Assume that an IERC LIC14A2U dissipator and DC000080B retainer are used. This device is rated as providing a θ_{JA} of 55°C/W for the DG16 package. Using this heatsink the above example would result in a junction temperature given by:

$$\begin{aligned} T_j &= 120 + (0.598 \times 55) \\ &= +\ 153°\text{C} \end{aligned}$$

Nevertheless, it should be noted that these calculations are not necessarily exact. This is because factors such as θ_{JC} may vary from device type to device type, and the efficacy of the heatsink may vary according to the air movement in the equipment.

It is possible to improve the dissipation capability of the package by the use of heat dissipating bars under the package, and various proprietary items exist for this purpose.

Under certain circumstances, forced air cooling can become necessary, and although the simple approach outlined above is useful, more factors must be taken into account.

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