Thermal Management of Electronics Devices

Most electronic such as power transistors, CPUs and power diodes produce a significant amount of heat and measures may be necessary to take account of this in order to prolong their working life and increase reliability.

If we consider a heat producing electronic component in isolation then, during operation, its temperature will rise until the heat produced within the device becomes equal to the heat lost to the surroundings and the device has reached equilibrium. The rate of loss of heat from a hot object is governed approximately by Newton's Law of Cooling. This states that the rate of loss of heat is proportional to the temperature difference between the body and the surroundings. As the temperature of the component rises the heat loss increases. When the heat loss per second equates to the heat produced per second within the component, the device will have achieved its equilibrium temperature. This temperature may be high enough to significantly shorten the life of the component or even cause the device to fail. It is in such cases that thermal management measures need to be taken.

The same considerations can be applied to a complete circuit or device which incorporates heat producing individual components. The rate of loss of heat will be higher in a forced draught than still air, so one way of controlling the temperature of a device or circuit is to incorporate a fan or fans to increase the air flow. Even ensuring adequate general ventilation will result in a lower operating temperature than if the circuit is in a confined space with no ventilation slots. One point which can be overlooked is that reduced atmospheric density at high altitudes leads to less effective heat transfer to the surroundings and consequent higher device operating temperatures.

Heat is lost from a component to its surroundings at the surface of the component. The rate of loss of heat will increase with the surface area of the component so that a small device producing 10 watts will reach a higher temperature than a similar powered device with a larger surface area. One way of limiting the operating temperature will therefore be to artificially increase the surface area. This is done by attaching a metal heat sink to the device. Heat sinks can be made by stamping, extrusion or casting and are generally fabricated from copper or aluminium or their alloys. The heat sink needs to be a good conductor of heat. Often heat sinks have a finned structure to maximise the available area for heat dissipation to the surroundings. Where heat sinks are being used, they will be more effective if the whole unit is well ventilated or, even better,forced air flow is applied by use of one or more fans. It is impossible to make heat sinks or components with perfectly flat mating surfaces, so, when the two come into contact, the high spots contact one another and there will be a small air gap between the two over a large part of the surface.

Air is a poor conductor of heat and so the interface will provide a thermal barrier which limits the efficiency of heat loss from the device. It is to overcome this effect that heat transfer compounds are used.
Heat transfer compounds are designed to fill the gap between the device and the heat sink and thus reduce the thermal resistance at the boundary between the two. This leads to faster heat loss to the heat sink and a lower operating temperature for the device. Heat transfer compounds can be of various types.

It is important to note that the higher the thermally conductivity transfer medium the lower will be the thermal resistance, and hence the lower the operating temperature.
The thermally conductive heat transfer compound will have a lower thermal conductivity than the heat sink material, so keeping the thickness of the film at the interface as low as possible will decrease the thermal resistance and again lower the operating temperature. It is important however to ensure that the lower film thickness does not result in air gaps in the film.

It is possible, knowing the thermal conductivity of the heat transfer compound, the thickness of the film of heat sink compound and the contact area of the heat sink, to calculate the thermal resistance across the boundary and hence the equilibrium operating temperature of the device. However, t-Global Technology always recommend testing of components in real-life situations as this always provides more accurate results.

Other very specialist methods of thermal control are the use of liquid cooling and also Peltier effect devices. Normal liquid cooling involves the circulation of a coolant fluid in close proximity to the device: liquids are more effective for heat transfer than air.
A refinement of liquid cooling is the use of heat pipes. With heat pipes a coolant fluid is vaporised at the hot component and the vapour then flows to a cold area where it is condensed. The latent heat of evaporation of the fluid gives very effective component cooling. This principle is used very effectively in refrigerators.

The Peltier effect is observed when a direct current is passed through the junction of two dissimilar metals. If current flows in one direction the junction heats up, but with flow in the reverse direction it cools down. Semiconductors have now been found which show this effect and an array of these can be used for cooling. All of these cooling devices will require the use of thermally conductive materials at the interface with the component being cooled, to exclude thermally insulating air and increase the efficiency of heat transfer to the cooling system. Also the hot end of the cooling device may involve the use of heat sinks to dissipate the heat.

Increasing miniaturisation in electronics means that heat dissipation problems are becoming increasingly important. More effective thermal management will often lead to enhanced reliability and life expectancy of devices.