# Role of the heat sink in thermal management of active devices.

## 1.0 Introduction:

All active devices dissipate power which gets converted into heat / light if not used to do useful work. In semiconductor devices a classic situation is a power device ( or a device dissipating power) encapsulated in a package placed on a PCB among other components dissipating power which gets converted to heat and must be cooled down if the thermal resistances are too large.

Radiation, conduction and convection are the three mechanisms of heat dissipation. In PCBs, heat sinks are used to increase the heat transfer from the hot device to the ambient ( or air ). Heat sinks have small thermal resistances between themselves and the ambient.

Thermal resistance is the measure of the heat dissipation capability of a surface. i.e how efficiently heat is transferred across a boundary or interface between different media.

A heat sink's function is to keep a device at a temperature that is below its maximum temperature limits. To determine whether a device needs a heat sink for thermal management, calculate its thermal resistance through the use of thermal circuit models and equations. These thermal circuit models are analogous to resistor circuits, which follow Ohm's law. With a heat sink, heat from a device flows from the junction to the case, then from the case to the heat sink, and finally from heat sink to ambient air.

Dissipated power within the device is analogous to current in electrical circuits while the temperature rise is analogous to voltage rise in electrical circuits. The thermal resistance is analogous to electrical resistance and can be stated as temperature/power in degrees centigrade ( or K) /Watts ( or kW).

In order to illustrate these concepts, consider Figure 1.0 below. This is a schematic diagram in terms of power, thermal resistance and heat flow.

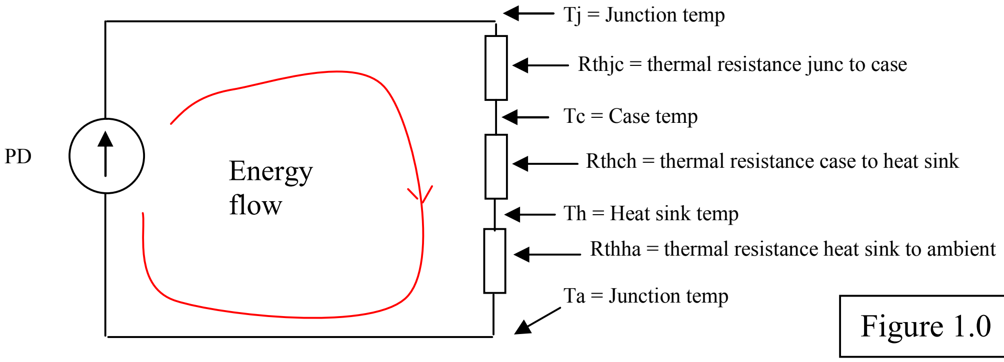

Figure 1.0

If we then consider the thermal analog model then the following equation can be written:

$$PD(Rthjc+Rthch+Rthha) = Tj - Ta \qquad (1)$$

If the heat sink is absent then,

$$PD(Rthjc+Rthca) = Tj - Ta \qquad (2)$$

Lets take a look at some numbers to clear up the concepts.

A IRF730 in a TO-220 package with a metallic tab is rated at :

$Rthja = 60$ Deg/W
$Rthjc = 1.7$ Deg/W

Thus if the power dissipation is assumed to be 2.5 Watt for a particular application then Using the Rthja resistance we get

$Tj = 60 * 2.5 = 150$ Deg C + 85 Deg C = 235 Deg C.

<u>This is an unsafe junction temperature</u>. To be safe we should use 125 Deg C as a safer junction temperature. However, to continue with the example,

$Tc = 1.7 * 2.5 = 4.25 + 85 = 89.25$ Deg C.

This is what would be measured by a laser infrared thermometer at the case of the IRF730.

Note in this example the maximum ambient temperature was chosen to be 85 Deg C. The same considerations apply to other higher or lower ambient temperatures ( obviously).

A way to reduce this high junction temperature is by the use of heat sinks. Note a typical heat sink for a TO-220 package has a thermal resistance of about 14 – 15 Deg C/Watt.

If a heat sink is used the picture changes considerably.

Now let us see what happens.

The following are the new numbers:

$Rthjc = 1.7$ Deg C/Watt
$Rthch = 0.5$ Deg C / Watt*
$Rthha = 14$ Deg/Watt

* The adhesive compound, used for sticking the heat sink on to the IRF730 has a thermal resistance that runs between 0.15 and 0.8°C/W.

Then, using the same expressions as before, we get:

Tj = 125.5 Deg C.

A much safer temperature than before! The heat sink has reduced the thermal resistance sufficiently to reduce the junction temperature and thereby allow the device to operate in a much safer mode.

A number of websites have good heat sink data and off-the-shelf heat sinks for purchase. In case of a problem with these off – the – shelf parts some manufacturers will do a custom heat sink.

In addition a number of CAD tools are now available to allow fairly decent simulations of thermal effects and allow the design engineer to develop a thermally safe package.