

## DETERMINING THE JUNCTION TEMPERATURE FROM DEVICE THERMAL RESISTANCE FOR PACKAGED SEMICONDUCTOR DEVICES

To illustrate the thermal resistance of a packaged power semiconductor device, the analogy of an electrical resistor network will be used. In the electrical resistor model the electrical resistance is defined by the potential difference (voltage) across the resistor divided by the current through that resistor. In a thermal resistance the thermal potential difference (temperature) divided by the thermal current (heat) through the thermal resistor defines the thermal resistance,  $R_{Th}$ .

Figure 1 will be used to illustrate the electrical resistor equivalent circuit for a semiconductor device. Starting from the heat source (transistor junction), heat may transport through two paths. In the first path heat transfers from the transistor junction, through the molding compound by conduction, and then to the air surrounding the device by convection. In the second path, which is parallel with the first, heat flows from the junction of the device through the lead, through the PCB, into the chassis by conduction and finally to the air surrounding by convection. The second path is the primary focus of calculating the junction temperature since the majority of heat generated in the device transports through this path. The following example illustrates how to calculate the junction temperature of a device given its thermal resistance.

The first consideration involves how the device will be used in operation. If a significant amount of power is output as RF energy, that energy is not being dissipated in the device and needs to be subtracted from the dissipated power in the calculation of junction temperature. To account for this, the effective power ( $P_{eff}$ ) dissipated is calculated by adding the DC and RF input powers ( $P_{DC}$  &  $P_{RFIn}$ ) and subtracting the RF output power ( $P_{RFOut}$ ).

$$P_{eff} = P_{DC} + P_{RFIn} - P_{RFOut}$$

If the input and the output RF power are very small compare to the DC power,  $P_{eff}$  can be simplified to:

$$P_{eff} = P_{DC}$$

The remaining steps are illustrated in the following example of determining the junction temperature of a device, given its operating parameters and thermal resistance.

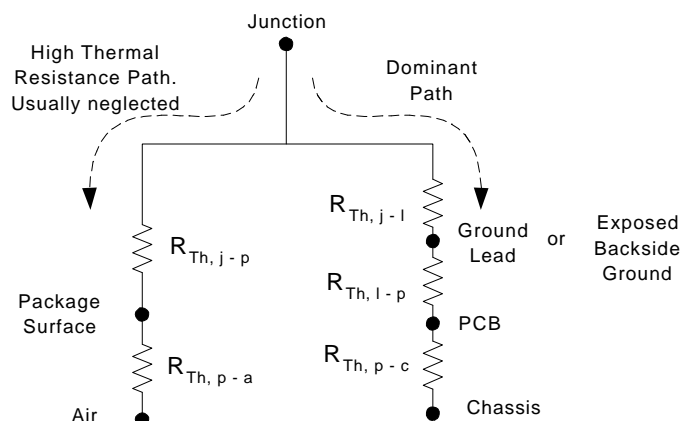


Figure 1: Thermal Resistance Equivalent Circuit

## Calculating Junction Temperature from Thermal Resistance

### Example 1

Given the following information, calculate the junction temperature of a NGA-589 device.

$T_{chassis} = 70^{\circ}\text{C}$  where  $T_{chassis}$  is the temperature of the chassis that the PCB is attached to

$$P_{RFIn} = 1\text{mW} \quad P_{RFout} = 50\text{mW}$$

$$V_{dev} = 5.0\text{V} \quad I_{dev} = 80\text{mA}$$

$R_{Th,j-l} = 100^{\circ}\text{C/W}$  where  $R_{Th,j-l}$  is the thermal resistance from the junction to the lead of the device

$\Delta T_{Lead-PCB} = 10^{\circ}\text{C}$  where  $\Delta T_{Lead-PCB}$  is the temperature difference between the lead of the device and the PCB

$\Delta T_{PCB-Chassis} = 5^{\circ}\text{C}$  where  $\Delta T_{PCB-Chassis}$  is the temperature difference between PCB and the Chassis

### Solution:

#### Step 1: Calculate Effective Dissipated Power

$$P_{eff} = P_{DC} + P_{RFIn} - P_{RFout} \quad (1)$$

$$P_{eff} = [(5.0\text{V}) * (0.080\text{A})] + (0.001\text{W}) - (0.050\text{W})$$

$$P_{eff} = 0.351\text{W}$$

#### Step 2: Setup Junction Temperature Equation

$$T_{Junction} = \Delta T_{Junct-Chassis} + T_{Chassis} \quad (2)$$

$$\Delta T_{Junct-Chassis} = \sum_i \Delta T_i = \sum_i (R_{Th,i}) * (P_{eff}) \quad (3)$$

where  $i$  is each thermal resistance from Fig. 1

#### Step 3: Calculate each $\Delta T_i$ from Fig. 1

$$\Delta T_{Junct-Lead} = (R_{Th,j-l}) * (P_{eff}) \quad \text{from } (3)$$

$$\Delta T_{Junct-Lead} = (100^{\circ}\text{C/W}) * (0.351\text{W})$$

$$\Delta T_{Junct-Lead} = 35.1^{\circ}\text{C}$$

#### Step 4: Solve Equation (3)

$$\Delta T_{Junct-Chassis} = \Delta T_{Junct-Lead} + \Delta T_{Lead-PCB} + \Delta T_{PCB-Chassis}$$

$$\Delta T_{Junct-Chassis} = (35.1 + 10 + 5)^{\circ}\text{C}$$

$$\Delta T_{Junct-Chassis} = 50.1^{\circ}\text{C}$$

#### Step 5: Solve Equation (2)

$$T_{Junction} = \Delta T_{Junct-Chassis} + T_{Chassis}$$

$$T_{Junction} = 50.1^{\circ}\text{C} + 70^{\circ}\text{C}$$

$$T_{Junction} = 120.1^{\circ}\text{C}$$

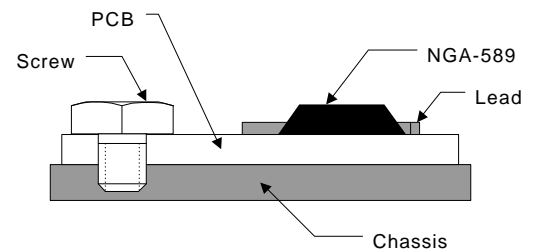


Figure 2: Cross Section of a PCB Assembly