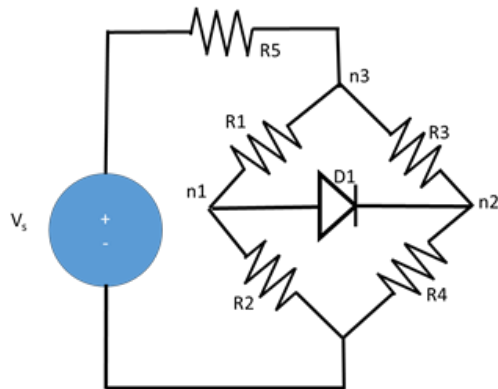# Circuit Thermal Solution

This is the scenario: Your organization makes a Silicon-based integrated circuit.
This circuit contains a diode in this resistive circuit.

Since this particular diode is created by your semiconductor process and has never been characterized, you have no model to simulate it's behavior. Testing has indicated that the integrated circuit does not work properly, and the technical team has decided the problem is that the diode is not behaving as expected.

The technical team as asked you to determine why. The theory is that it's too hot.

Use these parameters R1 = 3k, R2 = 4k, R3 = 2k, R4 = 1k, R5 = 1k ohms for the resistors. Use source voltages from 1V to 10V. For diode D1 use these parameters:

Io = 3e-9, q = 1.6e-19, kB = 1.38e-23, n = 2.0

This device is broad and we know that, as is typical in power devices, we can assume all heat is conducted down through the device into the metal flag of the package and into the printed circuit board. That is, we can assume that heat transfer by radiation and convection are negligible. Also because it is a wide device we can assume the temperature profile is essentially one dimensional. The diode structure is a stack described as follows:

A Si active region 12 mils thick, silicon has a thermal coefficient of 1.3 W/cmC

A Si bulk bulk region 16 mils thick also with a thermal coefficient of 1.3 W/cmC

A Cu back metal 5 mils thick with 3.86 W/cmC

A thermal paste holding the die in the package 40 mils thick with a thermal coefficient of 0.5 W/cmC

A Metal flag 160 mils thick with a thermal coefficient of 5 W/cmC

Assume the die area is 10 microns square, and the base of the die is at 25 degrees C above room temperature or 325 degrees K. (The diode equations expects temperature in K!)

You should approach this analysis by breaking the problem into steps.

Step 1) Create a function to calculate the temperature of the diode given a voltage and current. You'll have to calculate how the temperature changes through the vertical stack of layers. The temperature change through a layer is calculated as follows:

heat_flow = power_dissipated = current * voltage

thermal_resistance = d/(K*A)
        where d is thickness, K is the thermal coefficient, and A is the area

temperature_at_top = temperature_at_bottom + heat_flow * thermal_resistance

Step 2) Create a function that calculates the diode current and temperature error given a voltage and temperature guess. (Use the function created in Step 1 to calculate the temperature so you can find the difference between that and the guess.)

Step 3) Create a function to be called by fsolve. This function should take voltage guesses for each node and the temperature of the diode and calculate the current equation at each node. That is, the sum of all currents entering and exiting the node should be 0. Likewise, using the above functions, return the temperature difference which is also to be minimized. (Note that this is similar to problem 6.17 in Newman.) The deliverable is an error function that allows you to solve for the node voltages and temperature.

Step 4) Sweep source voltage from 1 to 10 volts, and generate the following plots:

One plot showing the node voltage at n1, the node voltage at n2, and the node voltage at n3, all as a function of swept source voltage;

Another plot which shows the diode temperature as a function of swept source voltage;

And a plot of the log of the diode current as a function of swept source voltage.

Turn in a Python script called hw6.py.