Department of Electrical and Computer Engineering
University of California, Santa Barbara
ECE 2B, Lab 1b

USING DIODES AS TEMPERATURE SENSORS

OBJECTIVE

To incorporate a diode within a circuit so that we can measure temperature differences.

INTRODUCTION

In class, we discussed the temperature sensitivity of the diode. In general, for a circuit, this is not such a great feature: you don't want your electrical performance and output to change as the temperature changes. However, sometimes you can take advantage of sensitive behavior. A temperature-sensitive device might itself be used to measure temperature. This lab will explore that application of diodes.

PROCEDURE

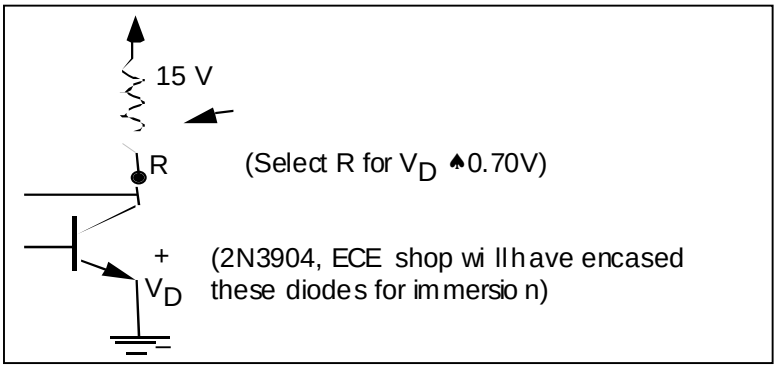
In ECE 2A, you carried out a lab that used an op-amp in a circuit. An op-amp can be used to compare two input signals and generate an output that is proportional to the differences of the inputs. You might want to read Section 5.6 in *Nilsson and Riedel* on the "Difference Amplifier Circuit". The idea behind the circuit is that a "reference diode' is kept at room temperature, while a 'temperature probe diode' is used to *probe* the temperature of a different environment. The different environment will be provided by a beaker of water that can be heated with an immersion heater.

Your diode will actually be a *three-terminal* device (a bipolar transistor – the next device we will study in ECE 2B) with *two of the terminals shorted* together (there is a practical reason, for this lab, that we are doing this). Your 'diodes' will be 2 NPN (2N3904) transistors. The *base* and *collector* terminals are shorted together for one terminal of your diode, and the *emitter* is used for the other terminal.

1. Measure the I-V Characteristics of the 'diode', under constant current conditions.

Materials Required: 1 encased 2N3904 transistor, 1 resistor, R, <u>two</u> Multi-meters for I-V measurements, a beaker of water and immersion heater.

Begin by measuring the I-V characteristics of this 'diode' to convince yourself that it actually looks like a diode. In order to make a *temperature comparison* between two diodes, we have either keep the *current constant* for both diodes and look at the differences in voltage, or we



have to keep the *voltage constant* and look at the differences in current.
We'll choose to keep the current constant, by using the circuit to the left. We want to operate at a value of current that will give us 0.7V *across the diode,* at room temperature. We need to choose a resistor, R that will give us the right current.

(a) Use Figure 1.24 in Boylestad and Nashalsky to help you *estimate what value of R* you would need.
(b) At room temperature, make the measurements of current and voltage the same way as you did for the diodes in your first lab.
(c) Now, using the same circuit, immerse the diode into the beaker of water, and turn on the immersion heater. Note the change in voltage across the diode as the water heats up. Measure the I-V characteristics at a temperature higher than room temperature.
(d) Compare the two I-Vs, taken at the two temperatures. For example, at a given value of current through the diode, what are the corresponding voltages at room temperature, and at a higher temperature?

2. Building a Temperature Probe Circuit.
Materials Required: 1 encased 2N3904 transistor, 1 non-encased 2N3904 transistor (reference), 2 resistor, R, 2 resistors, R_f, one offset resistor, R_{offset}, 1 operational amplifier, LF351 a beaker of water and immersion heater.

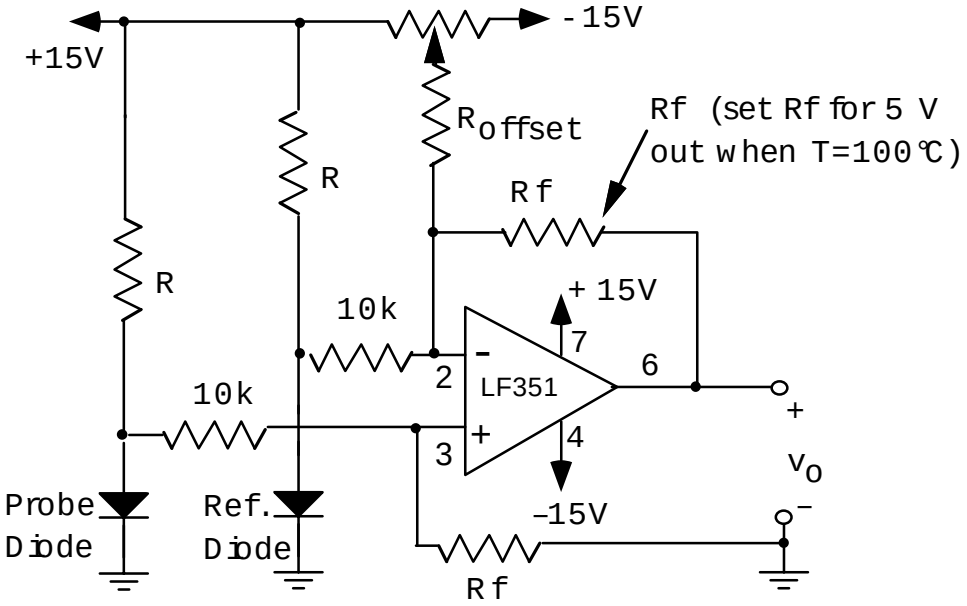


Fig. 2. Diode temperature probe circuit.

Build an op-amp circuit to measure the difference in the diode voltage between a "reference diode" and the "temperature probe diode" as shown in Fig. 2. You might want to refresh your knowledge of op-amps, and refer back to your ECE 2A lab. The numbers 2,3,4,6,7 refer to the pins on the 'dual in-line package' (DIP) encasing the op-amp. Use the value of R that you found to be best in Part 1. Select a feedback resistor, R_f so that you can get a *reasonable output voltage*, v_o.

The output voltage should be equal to R/R_f ($v_{\text{reference diode}} - v_{\text{probe diode}}$). R_{offset} is used to fine-tune the measurement: you may not need to use it.

(a) Measure values of v_o as the probe diode is gradually heated up from room temperature, up to the boiling point of water.

(b) Make a plot of v_o as a function of temperature.

(c) Discuss the value of R_f you wanted for this circuit and why.