5. Designing a Temperature Switch

MTVW 5-Feb-13

Objective

You somehow managed to get a job as an engineering summer student with a local contractor this summer. He's been having trouble with a piece of machinery overheating and, as a result, requiring constant repair. It is a known issue with the equipment but, unfortunately, the unit has just run out of warranty. The company has offered to retrofit the equipment for $20,000 with a temperature unit that will notify the equipment operator of unsafe operating temperatures. Your boss, of course, is quite upset about this, but he remembers that you took an Electricity and Magnetism course in your first year at University and wants you to design the temperature switch for "a lot less than $20,000".

Equipment

1. 1 – LM335 temperature sensor
2. 1 – TL081 Operational Amplified (to be used as a comparator)
3. 1 – breadboard
4. 1 – digital multimeter
5. 2 – alligator to banana cable (red and black)
6. 1 – LED
7. Lengths of red, black, and "other" coloured wire and various resistor values.

Preparation

You'll be using two new devices in this lab that you've probably never heard of before today. An LM335 temperature sensor and a TL081 Operational Amplifier (Op Amp) configured as a comparator. Let us first discuss how the temperature sensor of Figure 1 works.

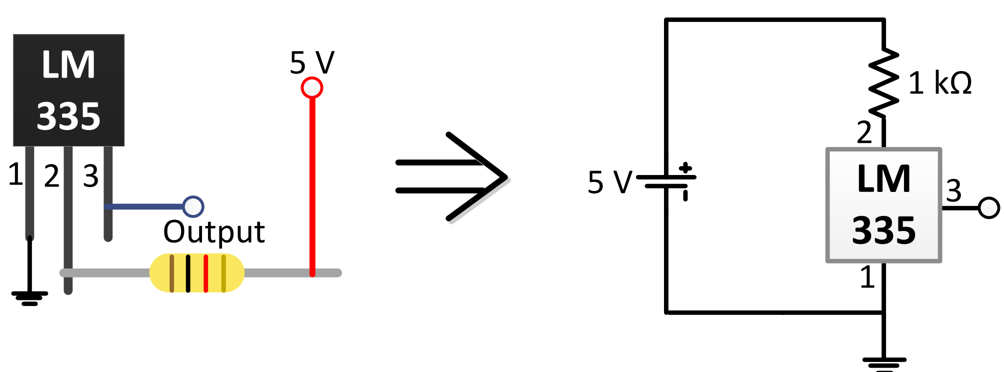

Figure 1: Temperature sensor physical connections versus its schematic representation

Figure 1 shows us how this temperature sensor is wired up and how it is schematically represented. The LM335 has an output that is linearly dependent upon the ambient temperature. This means that the output is a straight line relationship between voltage and temperature (Kelvin), as shown in Figure 2.

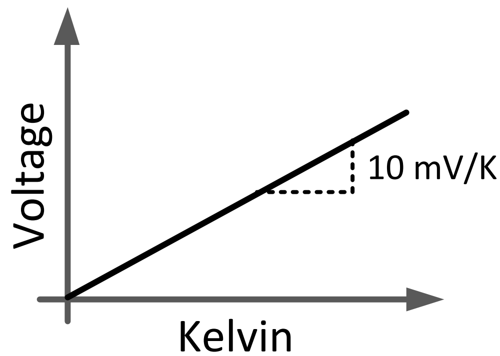

Figure 2: Voltage-Kelvin relationship for the LM335.

Note, the slope of this device's response is 10 mV/K. This means that the output voltage increases by 10 mV for every increase of 1 Kelvin.

The second device we will be using is a comparator, which quite simply compares two input signals and produces either an output signal that is either "true" or "false". The device shown in Figure 3 is a simple comparator. When $V_1 > V_2$ the output is "true" or 5 Volts, and when $V_1 < V_2$ the output is "false" or 0 Volts.

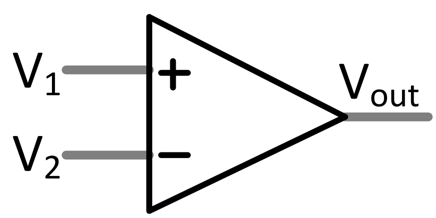

Figure 3: A comparator.

Design

1. Do not apply power to your circuits until either the Lab Instructor or a Teaching Assistant has verified your circuit.
2. Locate your LM335 temperature sensor and wire it up based on Figure 4. The resistor is 1 kΩ.

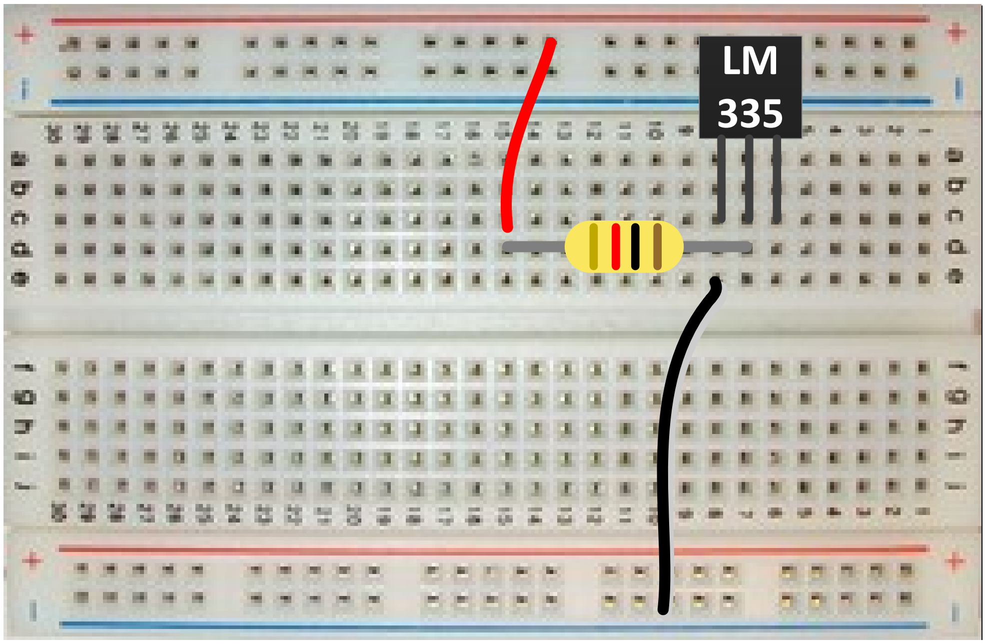

Figure 4: Wiring an LM335 temperature sensor.

3. Call a TA or lab Instructor to inspect your circuit.
4. Power up the circuit with a 5 V power supply.
5. Use your digital multimeter to measure the output voltage:
   a. Set it to Volts,
   b. Connect the COM terminal to the ground of the power supply
   c. Use the red probe to measure the voltage at the output of the LM335.
6. Use the voltage you measured to determine what the output voltage would be at 57°C (use a reference temperature of 22°C or the room temperature). The equation relating voltage to temperature is:

$$V_{OUT@T} = V_{OUT@T_0}\left[\frac{T}{T_0}\right]$$

where $V_{OUT@T}$ is the voltage output at temperature T, $V_{OUT@T0}$ is the voltage output at temperature T_0, T is the temperature you are interested in, and T_0 is the reference temperature.

7. Add the comparator circuit and indicator LED to the breadboard as shown in Figure 5. Note, no values have been given for R_1, R_2, and R_3. This is the part where you design the circuit values.

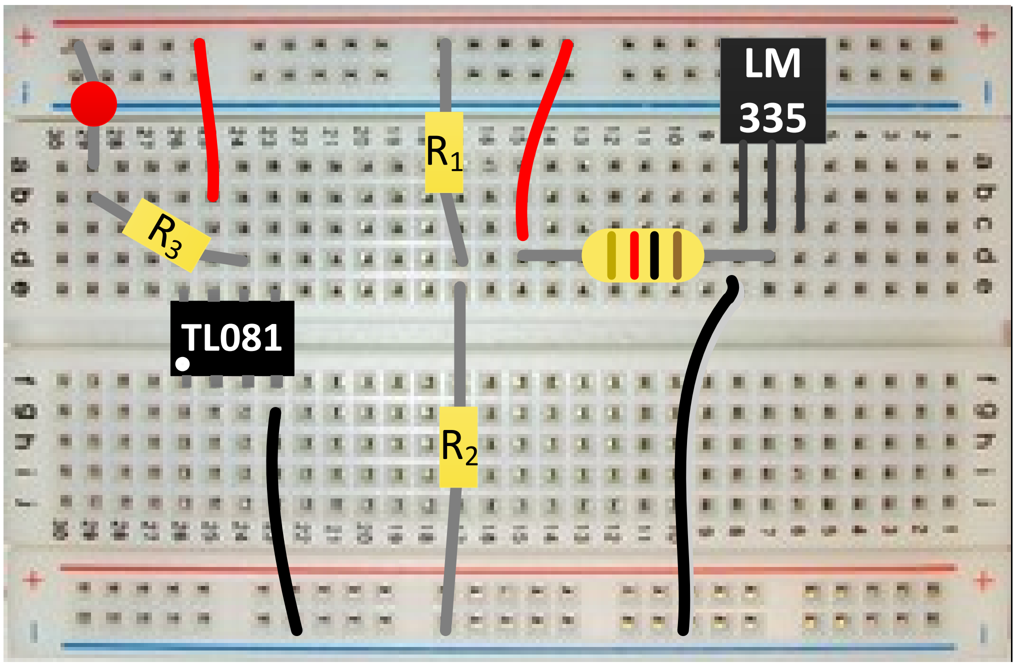

Figure 5: Temperature sensor with comparator circuit added.

a) First we'll design the resistor that limits current through the LED. Figure 6 shows the circuit we will use. Use Ohm' Law and Kirchoff's Voltage Law to determine what value of R3 will produce a current of 10 mA if the voltage drop across the LED is 1.8 Volts.

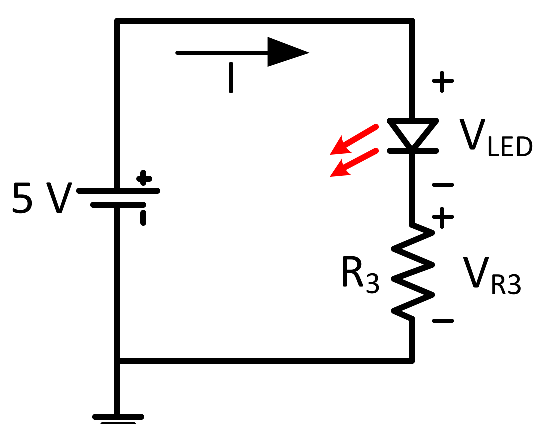

Figure 6: Current limiting circuit for an LED.

b) Next, we need to design the comparator circuit. The circuit of Figure 7 is going to produce the voltage that we compare to the LM335's voltage. So, take the value of the LM335's output voltage at 57˚C and let it be V_{R2}. Now, let R2 = 1.2 kΩ and determine what R1 must be.

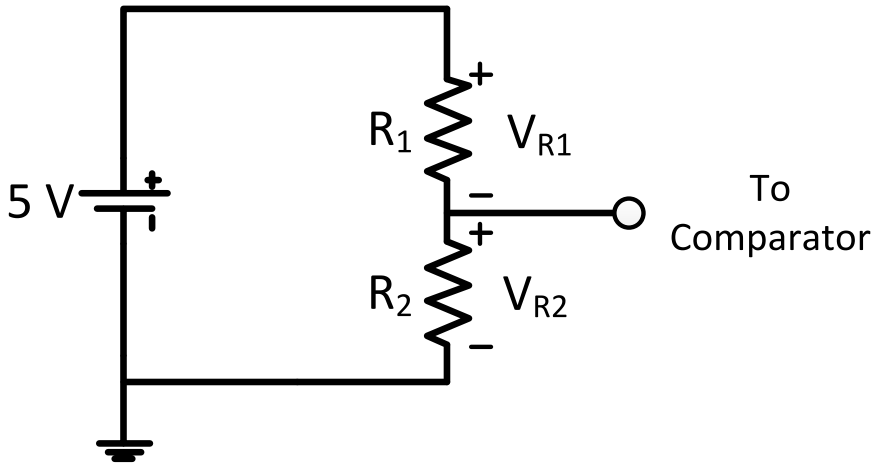

Figure 7: Reference voltage for 57°C.

c) You have two connections left to make, which are shown as purple wires in Figure 8.

Have a TA or Lab Instructor double check your circuit before powering it.

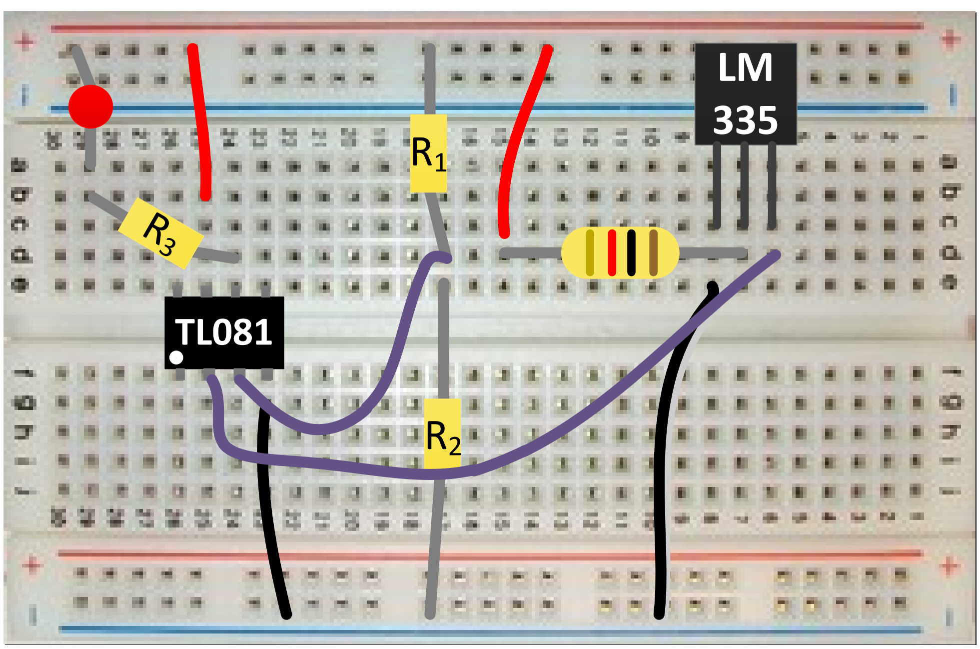

Figure 8: Final temperature switch circuit.

WORKSHEET

1. The slope of the LM335 response is ________________________.

2. The output voltage from the LM335 at room temperature is _________________.

3. Calculate the output voltage from the LM335 AT 57°C.

4. Calculate the value of the current limiting resistor.

5. Determine the value of R_1.

Have a TA or lab instructor sign your sheet when you have demonstrated its successful operation.

Signature ______________________________________