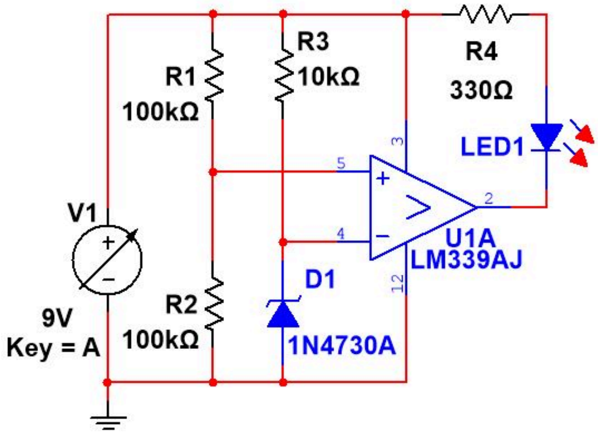
As we saw in the introduction to comparators, we can compare an input signal to any voltage -- not just ground. The following circuit is a "Battery Low" indicator.



Build this circuit in Multisim. V1 is a DC_INTERACTIVE_VOLTAGE source. Make sure you select the "LED_red" from "LED" under "Diodes".

Start with V1 set to 9 V, to simulate a 9 V battery. Also set its "increment" to 1% for finer adjustment.

Run the simulator, and slowly decrease the "Battery" voltage until the LED lights. Record the voltage here. 7.8 V_{DC}

At this voltage, a 9 V battery would be considered "Dead".

Now to analyze this circuit to see why it works.

First, look up the 1N4730A Zener diode to see what its reverse breakdown voltage is. 3.9 V

Since the Zener diode is connected between the inverting terminal and ground, when the circuit is working, the voltage at the inverting terminal will be 3.9 V

When the battery is "good", i.e. 9.0 V_{DC}, what voltage will appear at the non-inverting terminal? 4.5 V_{DC}

(That's because of the voltage divider created by R_1 and R_2, since no current can flow into the input.)

When the battery is "good", the output will be HIGH

In this condition, no current can flow through the LED, so it will be OFF.

What would the battery voltage need to be to produce a voltage at the non-inverting input that matches the inverting input voltage?

7.8 V_{DC}

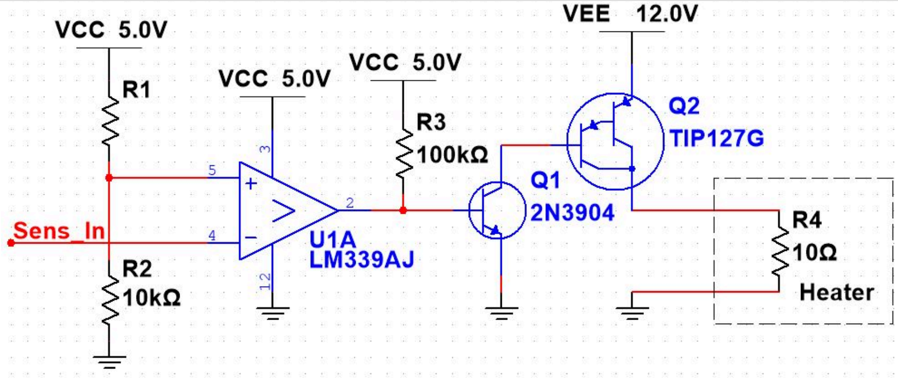
When the battery voltage is too low, the output will be LOW

Recall that the LM339 is an Open Collector device -- its output is the collector of an internal transistor. The output goes LOW when this transistor is turned ON, allowing current to flow through the LED.

Note that in this circuit the Zener diode provides a constant reference voltage regardless of the condition of the battery, as long as the battery voltage is high enough to put the Zener into reverse breakdown.

Worked Example

The following circuit receives an input voltage from a temperature sensor. When the temperature is too low (i.e. when the sensor voltage drops below 1.25 V), the Heater turns on.



First, let's analyze this circuit:

- The Sensor signal connects to the inverting input, so when the temperature is high, the output of U1A will be LOW, with its internal transistor turned on; when the temperature is too low, the output of U1A will be pulled up to +5.0 V. No current will flow into U1A's output, but R3 will act as the Base resistor for Q1.
- Q1 will be turned on, with a Base current of (5.0 V - 0.7 V)/100k = 43 μA. This means that the Collector of Q1 could draw up to βI_B = 100*43 μA = 4.3 mA from the Base of Q2.
- Q2 is a Darlington Pair PNP Power Transistor, which you'll learn more about in a subsequent course. Suffice it to say that it has a β of about 1200. The maximum Collector current that could be drawn through the heater is I=V_{EE}/R4 = 12 V/10 Ω = 1.2 A. Q2's Base current therefore would be 1.2 A/1200 = 1 mA, so Q1's Collector current is sufficient to turn Q2 on.
- So, when the Sensor voltage is lower than the Threshold voltage at the non-inverting input of U1A, the output of U1A goes high, allowing Q1 to conduct which draws Base current from Q2 which will turn it on and run about 1.2 A through the heater.
- When the Sensor voltage is higher than the Threshold voltage at the non-inverting input of U1A, the output of U1A goes low, turning off Q1 so no Base current is available to Q2, and Q2 will be off -- no current through the heater.

So, back to the original problem. The heater is supposed to come on if the Sensor voltage drops below 1.25 V. That means the Threshold voltage at the non-inverting input has to be set to 1.25 V. Reworking the voltage divider formula gives us the following:

$$V_{TH} = V_{CC}\left(\frac{R_2}{R_1+R_2}\right)$$

so

$$R_1 = R_2\left(\frac{V_{CC}-V_{TH}}{V_{TH}}\right) = 10\ k\Omega\left(\frac{5\ V-1.25\ V}{1.25\ V}\right) = 30\ k\Omega$$

In this case, we'll assume that the 1.25 V is critical, so we'll come up with a way to make 30 kΩ; and since we're doing that, we might as well make it adjustable! If we pick a standard potentiometer (with only 1, 2, and 5 available as multipliers) and a fixed resistor that's between 2x and 5x its size, it looks like we could use a 10 kΩ potentiometer and a 27 kΩ fixed resistor to provide a range of resistances from 27 kΩ to 37 kΩ.