UC San Diego, ECE65

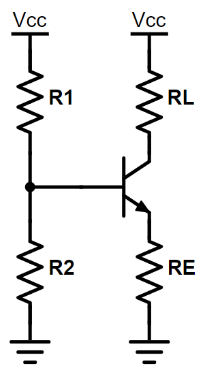
Lab 5, BJT Circuits

In this lab, we use 2N3904 Si BJT, 1N4148 diodes, and LM741 op-amp for the experiments. Assume $\beta = 200$, $V_{D0} = 0.7\ V$ and $V_{sat} = 0.2\ V$ for BJT in the circuit analysis. Use the Q2N3904 BJT model and LM741/NS op-amp model in the PSpice libraries for simulations. If you use LTspice for simulations, you can refer to the **Helpful Tips for LTspice** section of this document.

Experiment 1: BJT as a Current Source

Part a

Consider the circuit below with a 2N3904 Si BJT transistor, $V_{CC} = 10\ V$, $R1 = R2 = 4.7\ k\Omega$ and $RE = 1\ k\Omega$. In this experiment, you will find out the range of RL, load resistor, for which BJT will act as a current source, i.e., constant current will flow through RL.



<u>Prelab:</u>

Circuit Analysis

1. Find the state of the transistor, I_B, I_C, I_E, V_{BE} and V_{CE} for RL = $0.5\ k\Omega$, $1\ k\Omega$ and $2.5\ k\Omega$.

2. How does the change in load resistor value affect the collector current and the mode of operation of the transistor?

3. To what value can RL be increased while the collector current remains unchanged? Note: BJT operates as a current source when the current through the load doesn't change while changing the load resistor value.

Simulation

Simulate the circuit and generate a plot of I(RL) as a function of RL for RL ranging from 0.1 Ω to 3 $k\Omega$ (choose the increment in RL such that you have a meaningful plot, i.e., the curve looks nice and smooth). Is your plot consistent with the circuit analysis?

Lab Exercise:

1. Assemble the circuit. Use a 1 $k\Omega$ potentiometer in place of RL.

2. Vary the potentiometer resistance from the lowest value (0Ω) to the highest value (1 $k\Omega$) and measure load currents along with the corresponding resistances. Record the data for at least four different resistances in this step. Use a multimeter to measure the resistance.

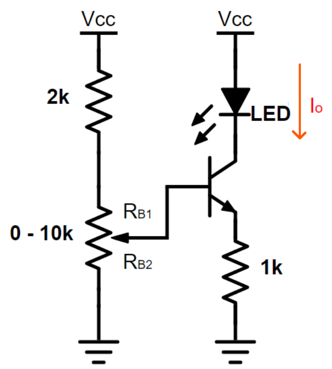
3. Disconnect the 10V power supply. Replace the potentiometer with a 1.2 $k\Omega$ resistor. Reconnect the power supply and measure the load current.

4. Repeat step 3 for 1.8 $k\Omega$, 2.4 $k\Omega$ and 3 $k\Omega$ resistors.

5. Plot load current vs. RL (use measured values in the previous steps). Compare the plot with your circuit analysis and simulation and explain any discrepancies.

Part b

In part b, you will use a 351-3230-RC LED as a load instead of the RL resistor in the BJT circuit of part a. You will explore how the brightness of LED can be controlled by varying the collector current of the transistor. The BJT will act like a variable current source. Consider the circuit below with a 2N3904 Si BJT transistor, a 351-3230-RC LED, a 10 $k\Omega$ potentiometer ($R_{B1} + R_{B2} = 10\ k\Omega$), a 1 $k\Omega$ resistor, a 2 $k\Omega$ resistor, and $V_{CC} = 10\ V$.



Prelab:

Circuit Analysis

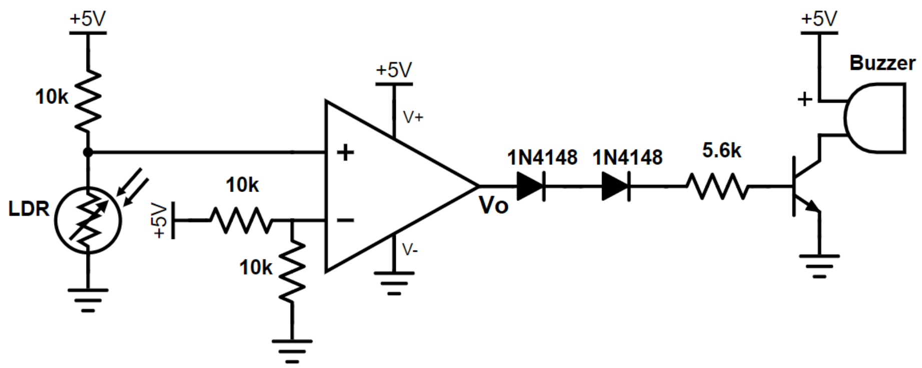
Compute the value of R_{B2} and the corresponding V_B that turns the LED on (assume that the LED will light as soon as the transistor comes out of the cut-off region). Plot I_o as a function of R_{B2}. You can assume $I_C \approx I_E$ for an active mode BJT.

Lab Exercise:

1. Assemble the circuit such that $R_{B2} = 0$. Measure V_B and I_o.
2. Slowly rotate the knob of the potentiometer(increase R_{B2}) until LED turns ON. Measure V_B and I_o of this point. From the measured V_B calculate R_{B2}. Does it match the circuit analysis?
3. Starting from the R_{B2} value at which the LED just turns ON, slowly increase R_{B2} while monitoring the value of I_o. For $I_o = 1mA$, $3mA$, $5mA$, and $7mA$, measure V_B and calculate R_{B2}. Explain your observations about LED's brightness.
4. Now, set R_{B2} at the highest possible value. What happens to the brightness of LED? Measure V_B and I_o of this point.
5. Plot I_o vs. R_{B2} (use measured values in the previous steps). Compare the plot with your circuit analysis and explain any discrepancies. What are your conclusions?

Experiment 2: BJT as a switch

Consider the circuit below with an LM741 op-amp, a 2N3904 Si BJT transistor, a light-dependent resistor (LDR) and a buzzer. Generally, LDR has a very high resistance ($M\Omega$) in the dark and a very low resistance ($\approx$ 100 Ω) in bright light. Notice that, here, the op-amp is powered only by a single supply voltage (i.e., the V+ terminal is connected to a 5V source, and V- terminal is grounded) instead of a differential supply used in previous labs.



Prelab:

The above circuit can be used as a dark and light indicator. Assume the resistance of the LDR is 50 $k\Omega$ in the dark and 1 $k\Omega$ in room light. Use a 200 Ω resistor to model the buzzer for circuit analysis and simulation. Turn on voltage for the buzzer is 1.4V, i.e., the buzzer works when the voltage drop across the buzzer is more than 1.4V.

Circuit Analysis

1. Calculate the output voltage, V_o, of the op-amp for both conditions (dark and light). For LM741, $V_{sat+} = V_+ - 1$ and $V_{sat-} = V_- + 1$.
2. Find out the state of the transistor (cut-off/active/saturation) and I_C for both conditions. When will you hear the sound from the buzzer (dark/light)? Show your calculation.
3. Remove the diodes and repeat step 2. Can the circuit work as a dark and light indicator without the diodes? Explain your conclusions.

Simulation

Simulate the circuit and attach the circuit with bias-point details for both dark and light conditions. Clearly show the value of V_o and I_C. Compare simulation results with the circuit analysis.

Lab Exercise:

1. Assemble the circuit in a way such that you can measure the collector current of the transistor.
2. Use your finger or any object to darken the surroundings of the LDR. Measure I_C and V_o. Explain your observation.
3. Move your finger/object away from the LDR and measure I_C and V_o again. Explain your observation.
4. Repeat step 2 and 3 without the diodes. What are your conclusions?

Helpful Tips for LTspice:

- Add an "npn" to your schematic. Then, right-click on the BJT to pick a new transistor. Choose '2N3904'.
- Use the steps described in lab 1 to use LM741 op-amp in your simulation. The model file LM741.txt is uploaded on Canvas.
- Check out the instructions from lab 3 for simulating circuits with a parametric sweep.