ECE 65 – Components and Circuits Lab

Lab 4 Report – Circuit Simulations

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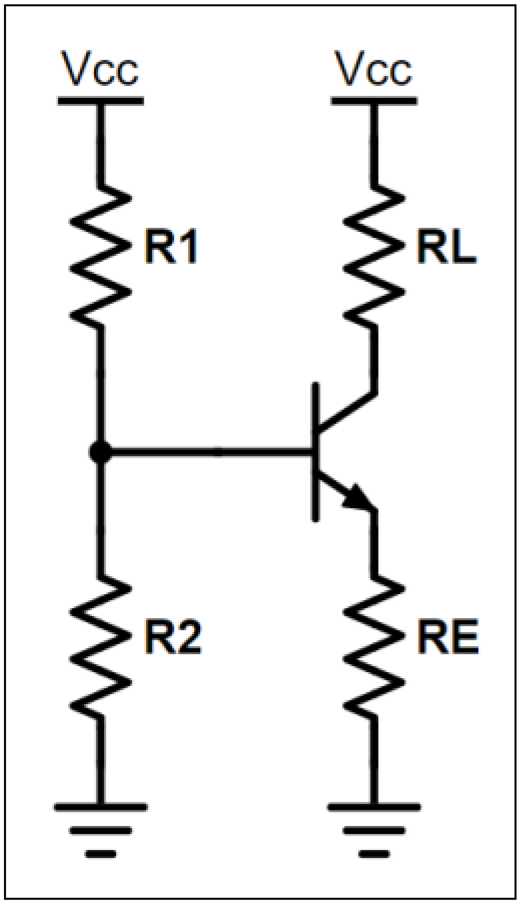
Abstract

This lab investigates the behavior of Bipolar Junction Transistors (BJTs) in various circuit configurations, including their application as a current source and a switch. Using the 2N3904 BJT, 1N4148 diodes, and the LM741 operational amplifier, we analyze and characterize transistor operation through theoretical calculations, circuit simulations, and practical measurements. In experiment one we utilize the BJT as a current source and examine the effect the load resistor has on the collector currents. In part two of this experiment we further tested this by attaching a LED to the circuit instead of the load resistor and see how the BJT can control the current to adjust the brightness of the LED. In Experiment 2, we implement a BJT-based switching circuit utilizing an LM741 op-amp and a light-dependent resistor (LDR) to design a dark-light indicator. Both of these experiments gave us a better understanding of how BJTs worked in different circuit configurations and strengthened our knowledge of how different circuit elements work with the BJT.

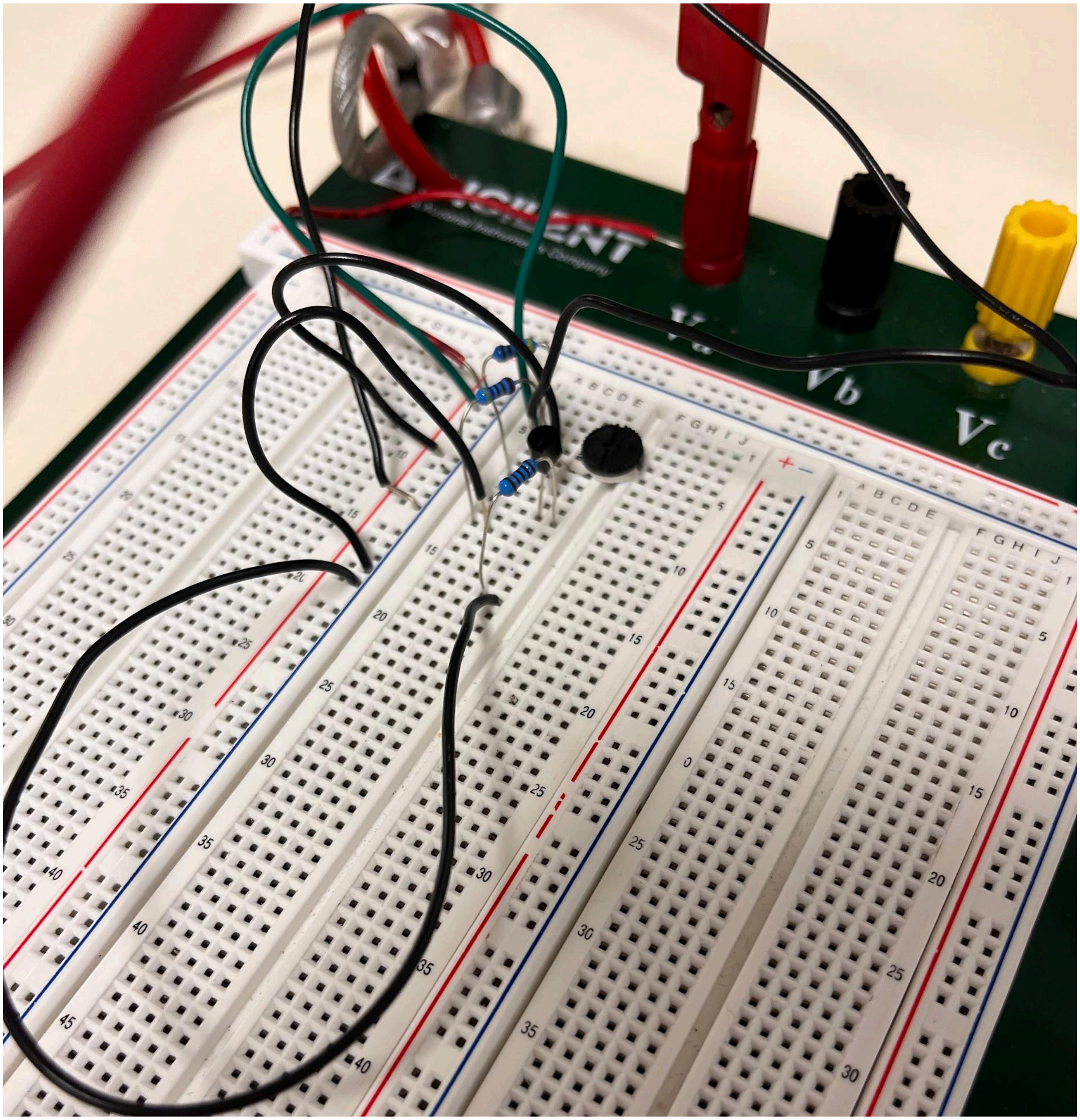
Experiment 1: BJT as a Current Source

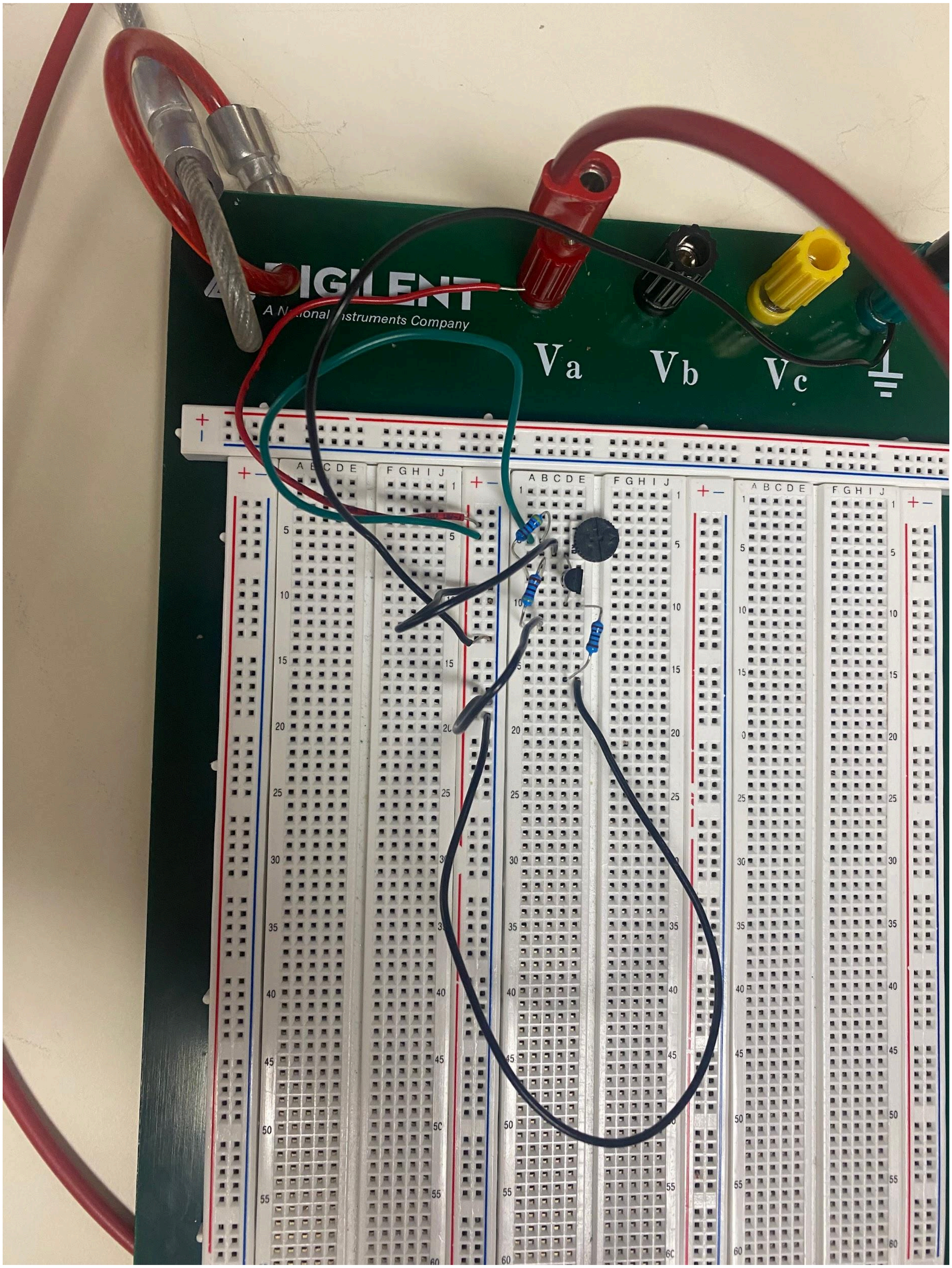
Part a

Consider the circuit below with a 2N3904 Si BJT transistor, VCC = 10 V , R1 = R2 = 4.7 kΩ and RE = 1 kΩ. 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.



1. Assemble the circuit. Use a 1 kΩ potentiometer in place of RL.




DIGILENT
A National Instruments Company
Va
Vb
Vc

2. Vary the potentiometer resistance from the lowest value (0Ω) to the highest value (1 kΩ) 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.

Resistance = [250 500 750 1000]

Current = [4.2, 4.2, 4.2 4.2]

3. Disconnect the 10V power supply. Replace the potentiometer with a 1.2 kΩ resistor. Reconnect the power supply and measure the load current.

The load current is 4.188 mA, which is very close to the original value of 4.19 mA.

4. Repeat step 3 for 1.8 kΩ, 2.4 kΩ and 3 kΩ resistors.

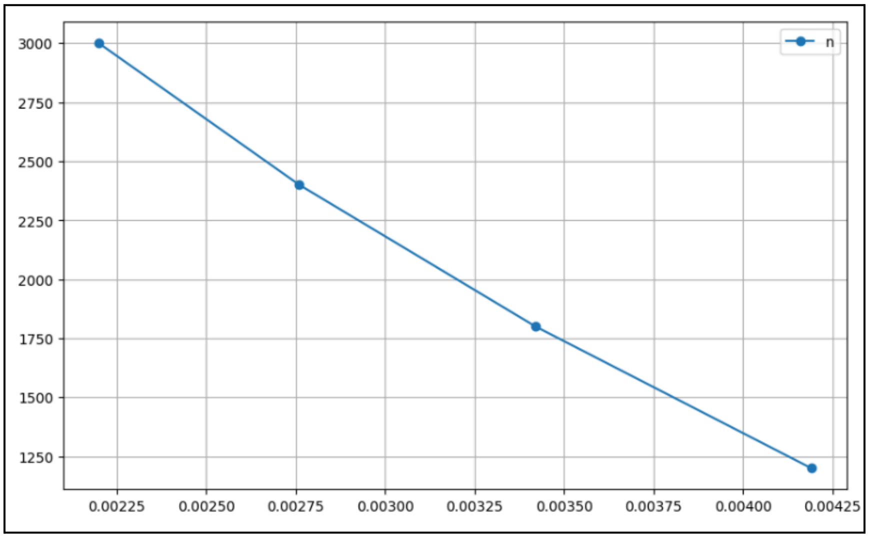
The load current of the circuit when we replace the potentiometer with the 1.8kΩ is 3.42mA.

The load current of the circuit when we replace the potentiometer with the 2.4kΩ is 2.76mA.

The load current of the circuit when we replace the potentiometer with the 3kΩ is 2.2mA.

As the resistance gets bigger than 1.2kΩ, the current decreases. This lines up with what we saw in our

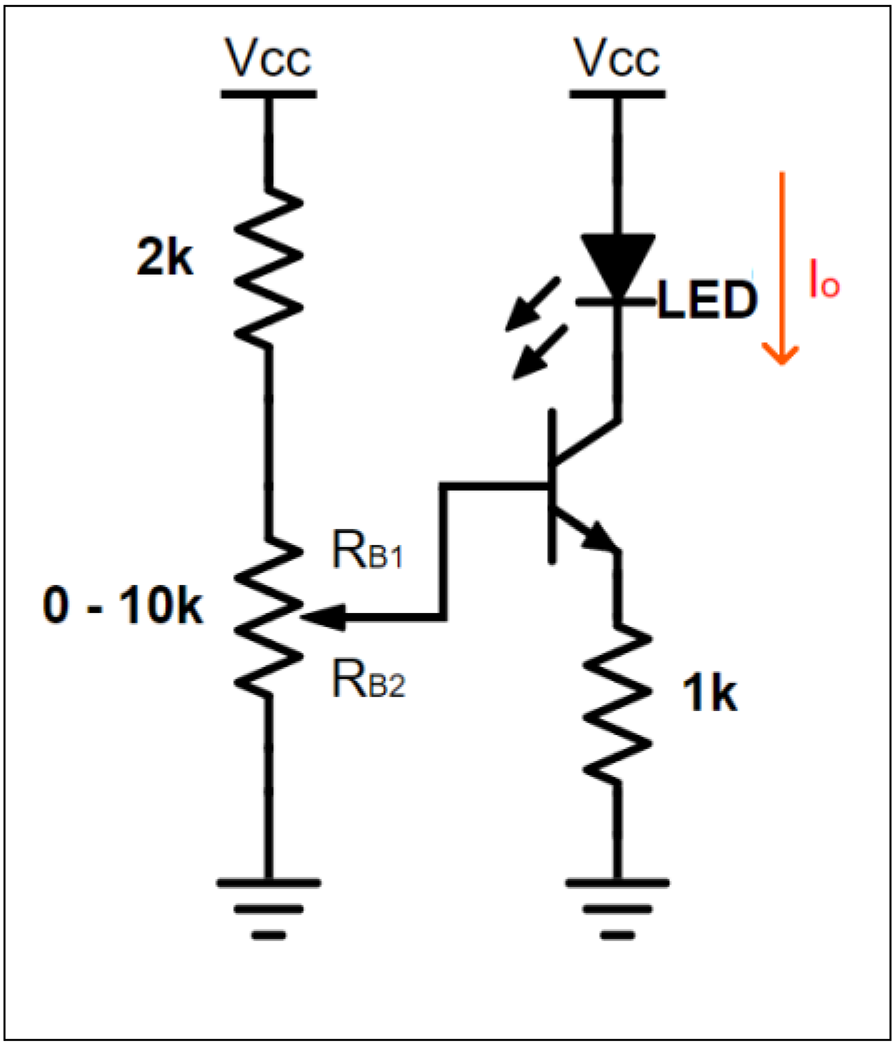
5. Plot load current vs. RL (use measured values in the previous steps). Compare the plot with your circuit analysis and simulation and explain any discrepancies.



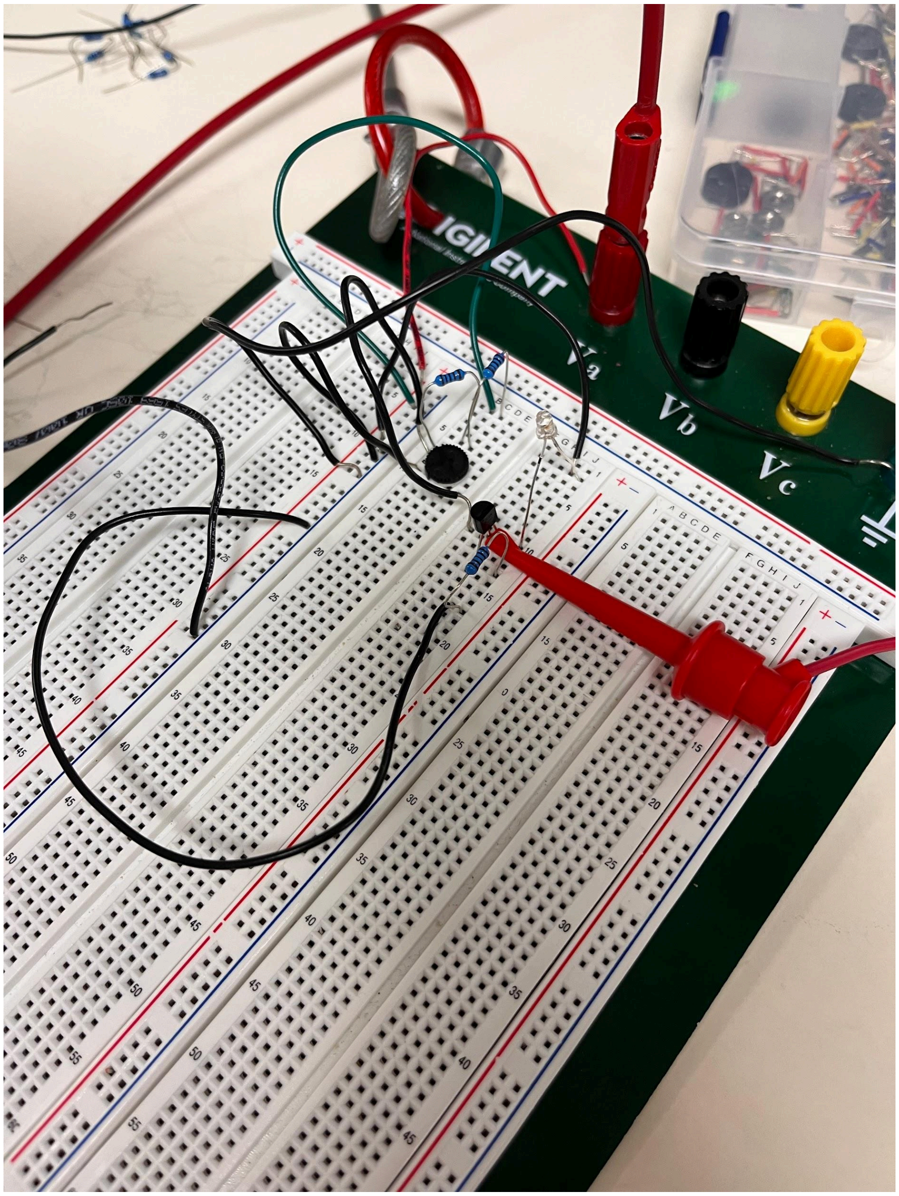
Experiment 1: BJT as a Current Source

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 kΩ potentiometer (RB1+RB2 = 10 kΩ), a 1 kΩ resistor, a 2 kΩ resistor, and VCC = 10 V .



1. Assemble the circuit such that RB2 = 0. Measure VB and Io.



RB2 will be zero, when we turn the potentiometer .

VB is also close to zero, 0.068mV.

Io is 0.0003mA.

2. Slowly rotate the knob of the potentiometer(increase RB2) until LED turns ON. Measure VB and Io of this point. From the measured VB calculate RB2. Does it match the circuit analysis?

The LED light turns on when VB=0.7V and Io= 0.128mA. This matches our circuit analysis where

The base voltage needed to turn on the transistor is 0.7V since

$$V_B = V_{BE} - V_E = 0.7 + 0 = 0.7V$$

$$I_C = \frac{V_{CC} - V_{LED} - V_E}{1k\Omega}$$

3. Starting from the RB2 value at which the LED just turns ON, slowly increase RB2 while monitoring the value of Io. For Io = 1mA, 3mA, 5mA, and 7mA, measure VB and calculate RB2. Explain your observations about LED's brightness.

Io = [1mA, 3mA, 5mA, 7mA]

Vb = [1.735V, 3.610V, 5.724V, 7.75V]

V/I = R

RB2 = [1.735V/1mA, 3.610V/3mA, 5.724V/5mA, 7.75V/7mA]

RB2 = [1735Ω, 1203.3Ω, 1144.8Ω, 1107Ω]

As resistance decreases, current will increase as well as voltage. This will cause the LED to increase in its brightness.

4. Now, set RB2 at the highest possible value. What happens to the brightness of LED? Measure VB and Io of this point.

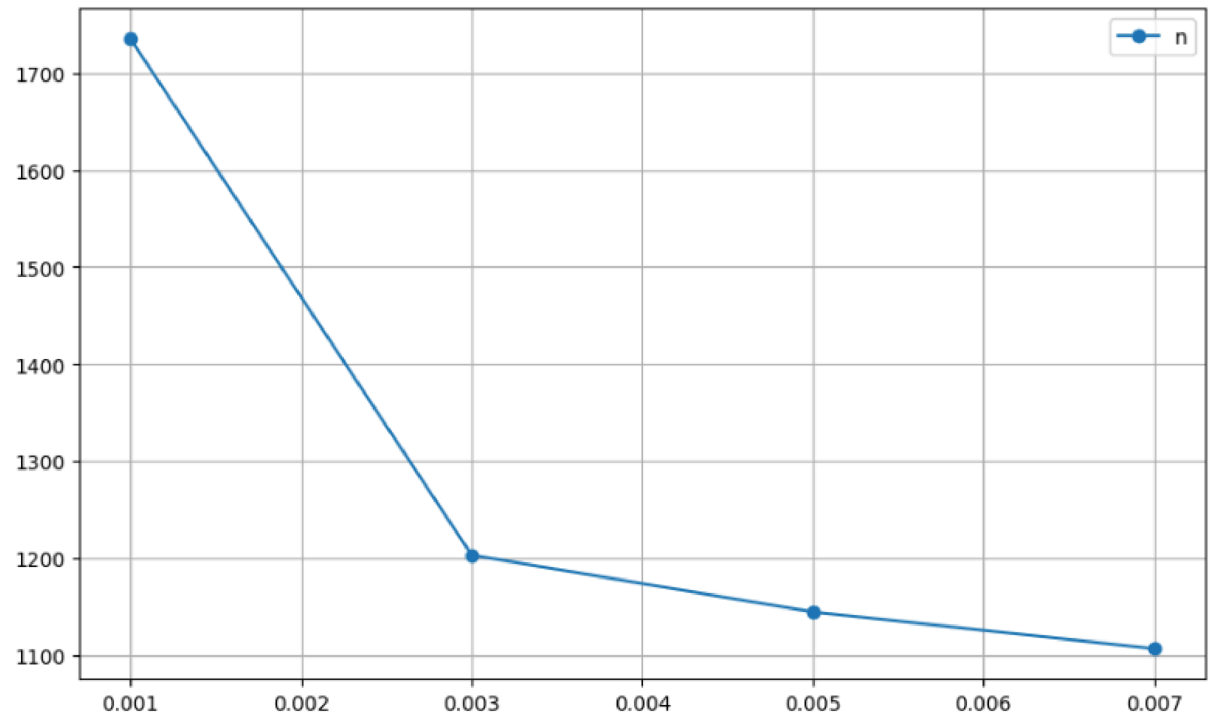
When the LED

VB=8.135V

Io=7.4mA

The brightness caps

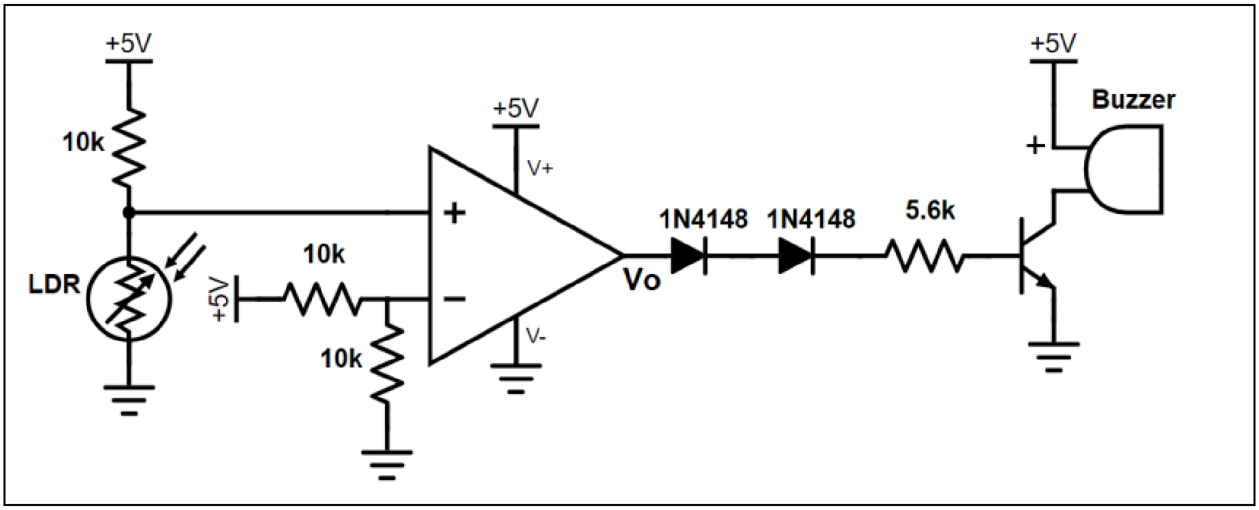
5. Plot Io vs. RB2 (use measured values in the previous steps). Compare the plot with your circuit analysis and explain any discrepancies. What are your conclusions?



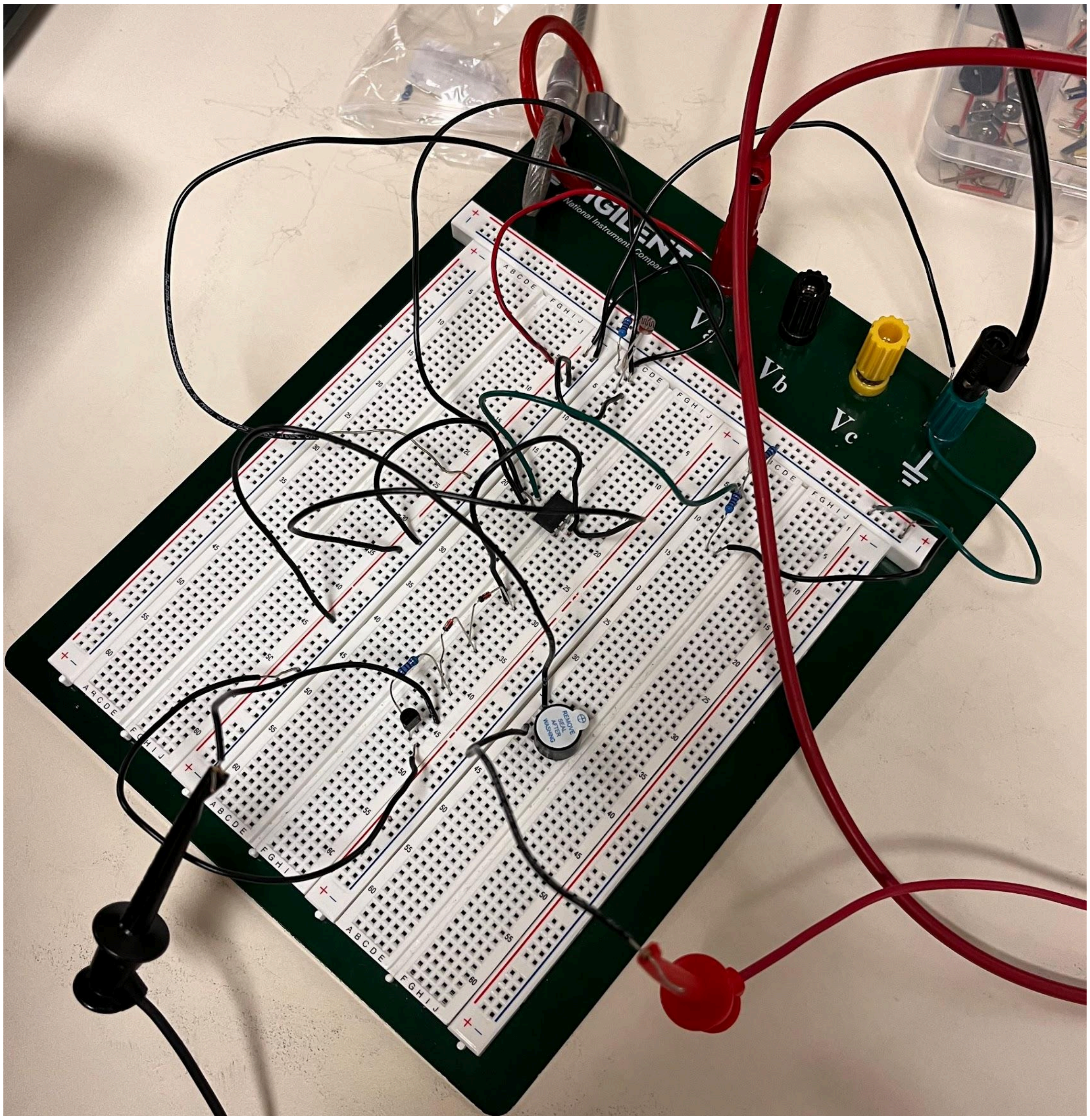
This connects to our circuit analysis because it shows that there is a relationship between Io and RB2 and it is a linear one. However, there is a big jump at points rather than smooth curves which is something to think about. But overall Io increases as Rb2 decreases.

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 (MΩ) in the dark and a very low resistance (≈ 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.



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 IC and Vo.

Explain your observation.

IC = 19 mA

Vo = 4.245V

We noticed that when we darkened the surroundings of the LDR, Vo and IC increased.

3. Move your finger/object away from the LDR and measure IC and Vo again. Explain your

Observation.

IC = 0.268mA

Vo = 1.24V

We noticed that when we moved our finger away from the surroundings of the LDR, Vo and IC decreased.

4. Repeat step 2 and 3 without the diodes. What are your conclusions?

Finger off:

Ic=7.39mA

Vo = 1.3 v

Finger on:

IC = 21.7mA

Vo = 4.2V

Conclusion

In this lab, we analyzed the functionality of BJTs and analyzed their interactions with various circuit elements such as op-amps, diodes, potentiometers, and buzzers.

The first experiment involved creating a circuit with a BJT and examining its collector current based on a changing load resistor. Through this experiment we found that as the load resistor increases the state of the BJT changes from active to saturation. Along with this, the collector current also decreases as RL increases. In the second part of this experiment we replaced the resistor with a LED and added a 10k potentiometer for the Base of the BJT. With this experiment we were able to slowly increase the potentiometer and observe how the output current changes. Likewise, as the resistance decreases for the potentiometer, the LED turns brighter. This experiment gave us a better understanding on how BJT can act as a current source.

In the second experiment, we created a circuit with a BJT, diodes, an op-amp, a buzzer, and an LDR (light dependent resistor) such that depending on the environment lighting, dark or light, current and voltage will alter. In a light setting, we observed that the collector current and the voltage output of the op-amp had values near to zero with the diodes in, and without the diodes. These results matched our expectation as the LDR has a resistance of 1kΩ when there in a light setting. Whereas, in a dark setting, voltage output and the collector amplitude would be greatly amplified because the LDR acts as a 50kΩ resistor. We also noticed that when we took out the diodes, the buzzer would be constantly on, indicating that there is enough voltage to power on the buzzer. The buzzer rang louder especially in a dark setting. This experiment ultimately helped us further understand how voltage and current function in a BJT.