

LAB 3 Bipolar Junction Transistor – Prelab

None.

LAB 3 Bipolar Junction Transistor

1 Objective

The BJT was invented in 1948 by Bardeen, Brattain, and Shockley at Bell Labs (for which they got the Nobel prize in physics), and became the first mass-produced transistor. Having a good grasp of the physics of the BJT is key to understanding its operation and applications. In this lab, we will explore the BJT's four operation regions and determine its characteristic values: DC current gain, β , and Early voltage V_A . The transistor we will use is the 2N3904, an NPN device.

It is strongly suggested that you read and understand the book sections on BJT physics before beginning this experiment.

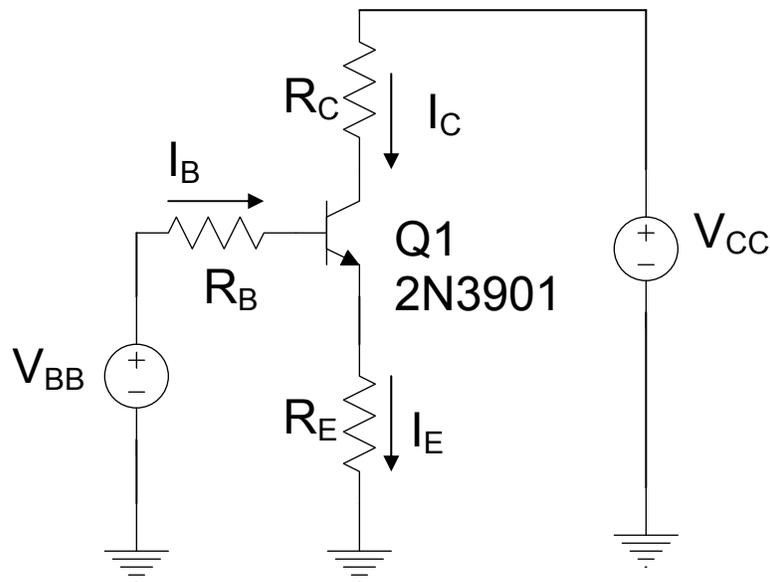


Figure 1 Circuit for part 2.

2 Region of Operation

1. Set up the circuit shown in Figure 1, with $R_B = 1\text{ M}$, $R_C = 5\text{ k}$, and $R_E = 100$. Set V_{CC} to 5 V.
2. Increase V_{BB} until $I_C = 0.5\text{ mA}$. Measure V_{BE} and V_{BC} . What is the region of operation of the transistor?

Warning: Never set V_{BE} higher than 2 V for any of the transistors we use. Doing so can permanently damage the transistor.

3. Now measure I_B . What is the value of β ?
4. From the value found above, calculate α . Use α to calculate I_E , then measure I_E and check if the values agree.
5. Let's examine the temperature dependence of collector current. Put two fingers around Q1 to heat it, then measure I_B and I_C (have your partner heat the BJT while you measure the currents if you're having trouble doing both at the same time). How does I_C compare to the value you measured before you heated the transistor?

6. Explain, using the equation you know for collector current, how you'd expect I_C to vary with temperature. Does this agree with your experimental results? If not, explain why this might be the case.

Hint: I_S depends on the intrinsic carrier concentration n_i and the diffusion coefficients D_n and D_p . Intuitively, how would n_i , D_n , and D_p change with temperature? How would I_S change with temperature as a result?

7. Look at the datasheet for the 2N3906. Does the β that you measured (called h_{FE} in the datasheet) agree with the values given in the datasheet? (Hint: A plot of h_{FE} versus I_C is given under "Typical Characteristics")

If the values do not agree, explain why you might see discrepancies.

7B. Measure I_C at several different values of V_{CC} . Estimate r_o and V_A .

8. Set V_{BB} to 4 V and V_{CC} to 2 V. Measure I_B , I_C , V_{BE} , and V_{BC} . What is the region of operation of the BJT?

9. Set V_{BB} to -3 V and V_{CC} to 5 V. Measure I_B , I_C , V_{BE} , and V_{BC} . What is the region of operation of the BJT?

10. Swap the emitter and the collector of the BJT in the circuit (you can do this by physically turning the device to face the opposite direction). Set V_{BB} to 4 V and keep V_{CC} at 5 V. Measure I_B , I_C , V_{BE} , and V_{BC} . What is the region of operation of the BJT?

3 Analog Amplifier, Digital Inverter

The common emitter can be used as an analog amplifier and a digital inverter. For this part of the lab, build your circuit on your portable prototyping board so that you can do part 3Bii easily.

3A) Using $V_{CC}=5V$, modify the circuit in Figure 1 to achieve the maximum voltage gain that you can.

You might want to use your SPICE deck from the prelab to help design this amplifier. **5% extra credit** for the group in each lab section that demonstrates the highest gain to the TA during the lab. Drive the input of your circuit with a small, low frequency sine wave to show the gain. Make sure that you record the bias conditions, and capture an image that shows the input and output waveforms to prove your claim.

3B) Using the amplifier that you built for part 3A, measure the DC transfer function from V_{IN} to V_{OUT} .

- i) Estimate the maximum slope of the transfer function. How well does it correspond to your gain from part 3A?
- ii) Hook your inverter up with some of the other lab groups' to form a ring oscillator. You need an odd number (3 or more) of inverters in series to make a ring oscillator. Measure the frequency of oscillation, and record the details of the waveform.

LAB 3 Bipolar Junction Transistor - Report

Using powerpoint (or equivalent) show what you did in each part of this lab, showing clearly what you measured, and how you answered the questions.