Pedro Cabrera

Experiment 6

Bipolar Junction Transistors

Collector and Base Biasing

Introduction:

The primary objective of this laboratory exercise is to delve into the operational characteristics and biasing techniques of Bipolar Junction Transistors (BJT). BJTs are fundamental components in the realm of electronics, serving as the building blocks for amplifiers and switching circuits. Through the course of this lab, we aim to understand the principles of collector and base biasing – two pivotal methods to ensure the BJT operates within its active region, a necessity for amplification applications. By constructing a transistor circuit and varying the base and collector voltages, we anticipate to empirically deduce the relationship between input and output currents, henceforth examining the transistor's response to these changes. This hands-on experience will enable us to comprehend the influence of biasing on a transistor's DC operating point and to compare the stability of different biasing methods against variations in transistor beta values. Theoretical underpinnings from electronic circuit theory will be reinforced as we test the hypotheses drawn from semiconductor physics, specifically the behavior of doped P-N junctions under different biasing conditions.

Bench Parts and Equipment List:

Components:

1. BJT Transistor (2N3904)
2. Resistors:
    - $1k\Omega$ resistor
    - $100k\Omega$ resistor
    - 500kΩ Potentiometer. (For 129kΩ R_B)

Equipment:

1. Power Supply
2. Multimeter

3. Breadboard

Discussion:

The data collected from the bench experiments and Multisim simulations provide insightful trends that align with theoretical expectations for the operation of Bipolar Junction Transistors (BJT). For instance, as the base current (I_B) was incrementally increased, a corresponding rise in the collector current (I_C) was observed, which supports the theory that BJTs exhibit current amplification characteristics. This is exemplified by the DC current gain (β) calculations, which were consistent across different measurements, underscoring the BJT's capability to amplify small base currents into larger collector currents.

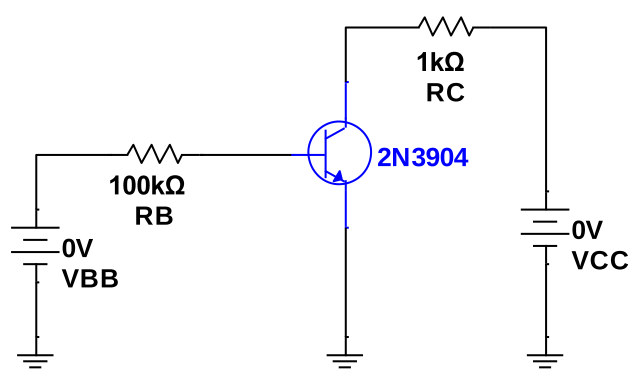

Figure 1- Multisim Transistor Circuit

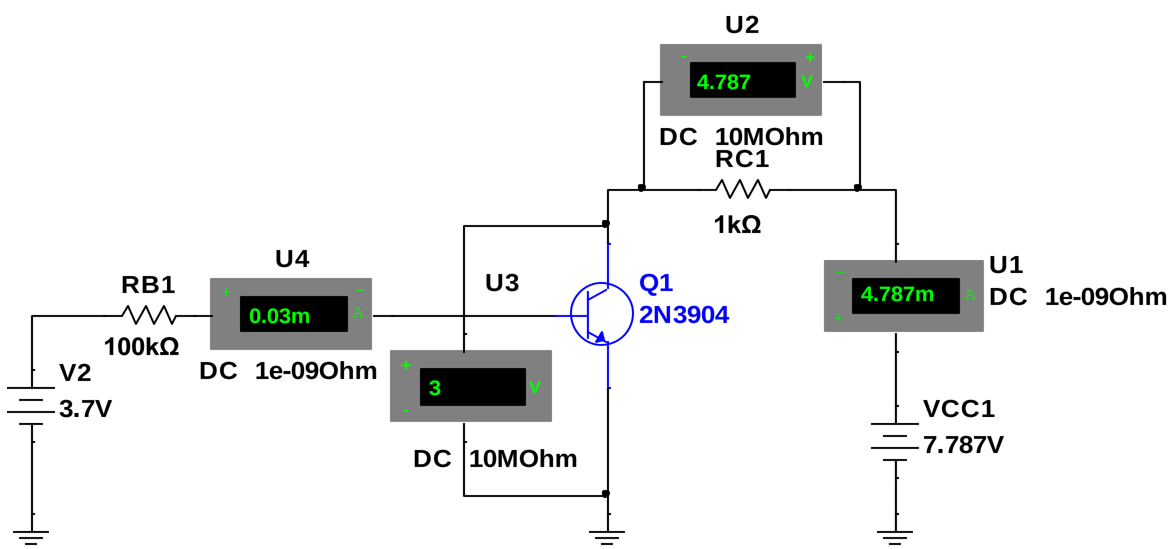

Figure 2 - Multisim sample.

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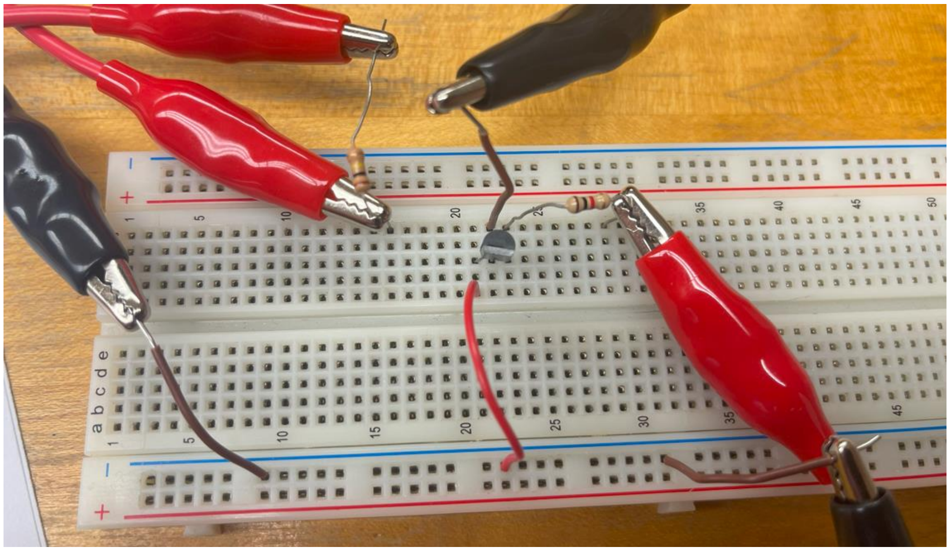

Figure 3- Bench Transistor Circuit Testing I_B

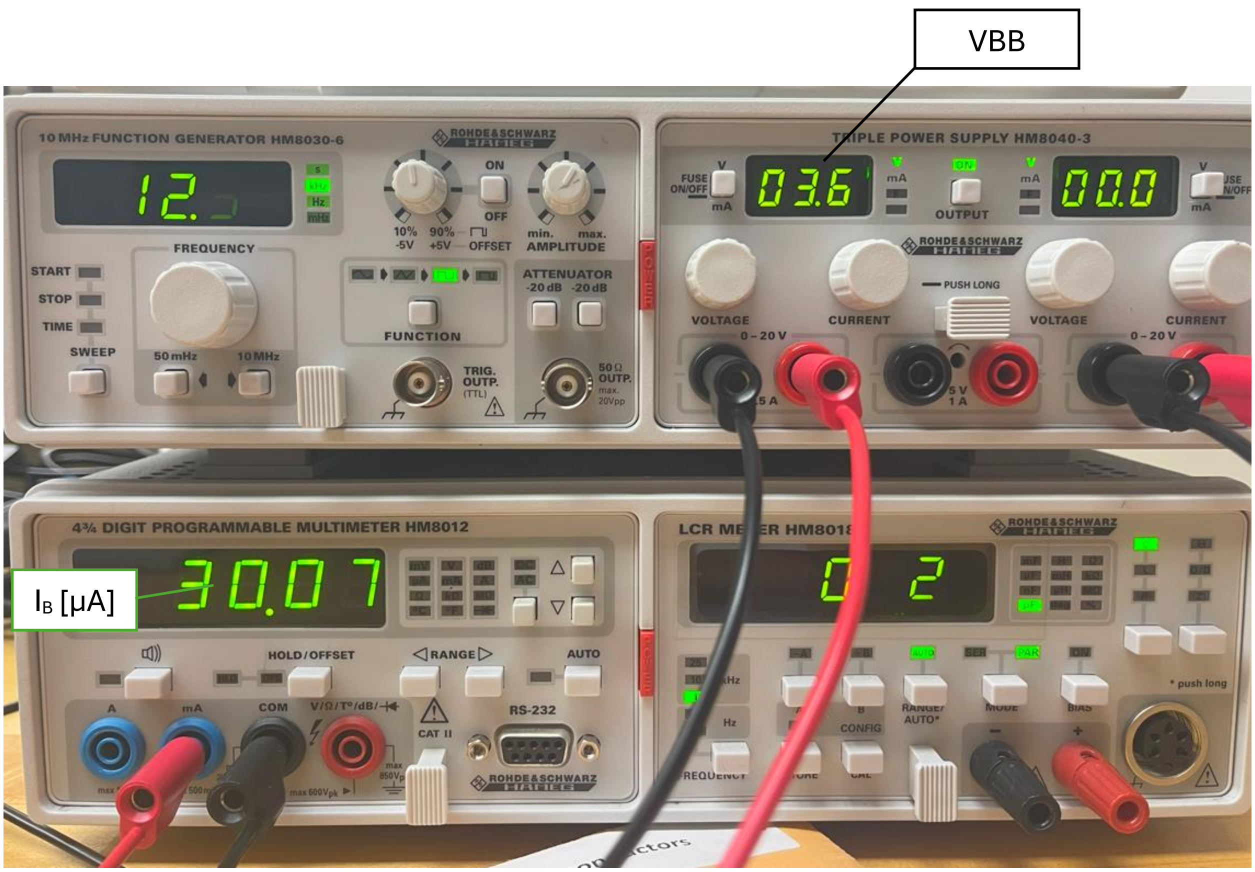

Figure 4

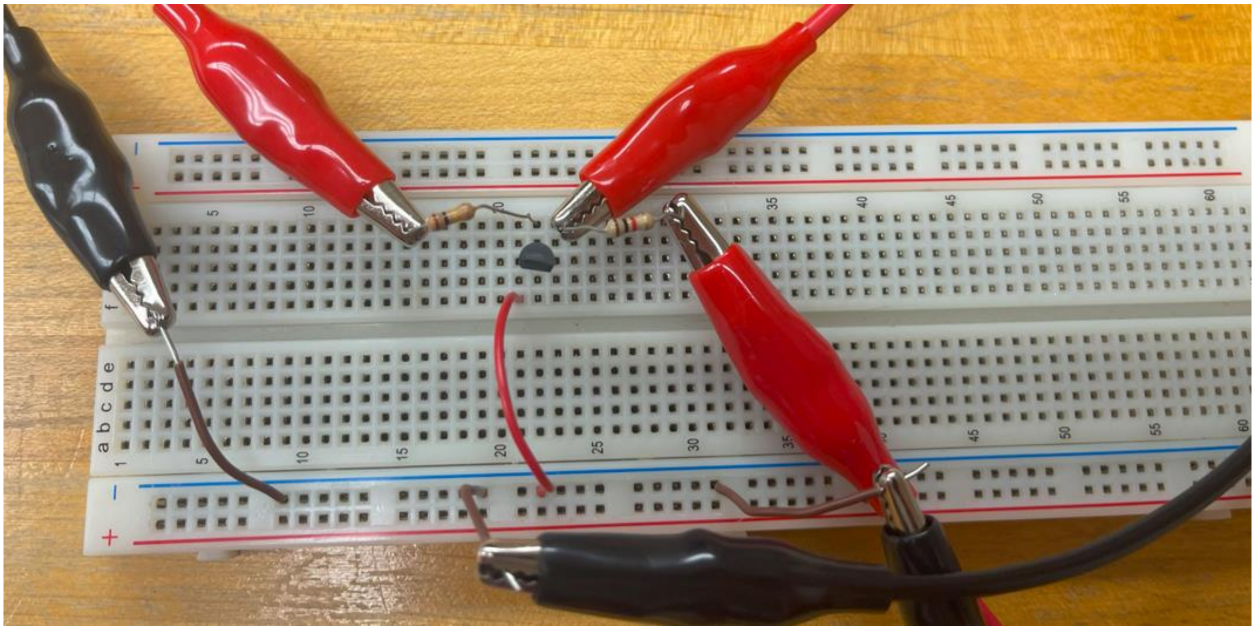

Figure 5 – Testing V_{CE} to make sure it matches 3V-9V.

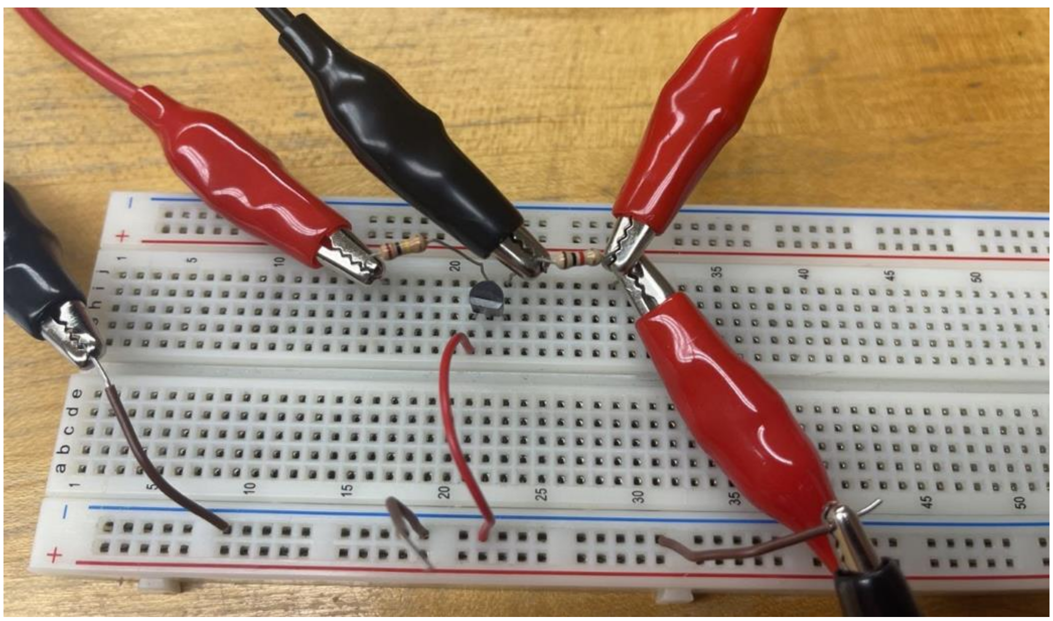

Figure 6 – Measuring V_{RC}.

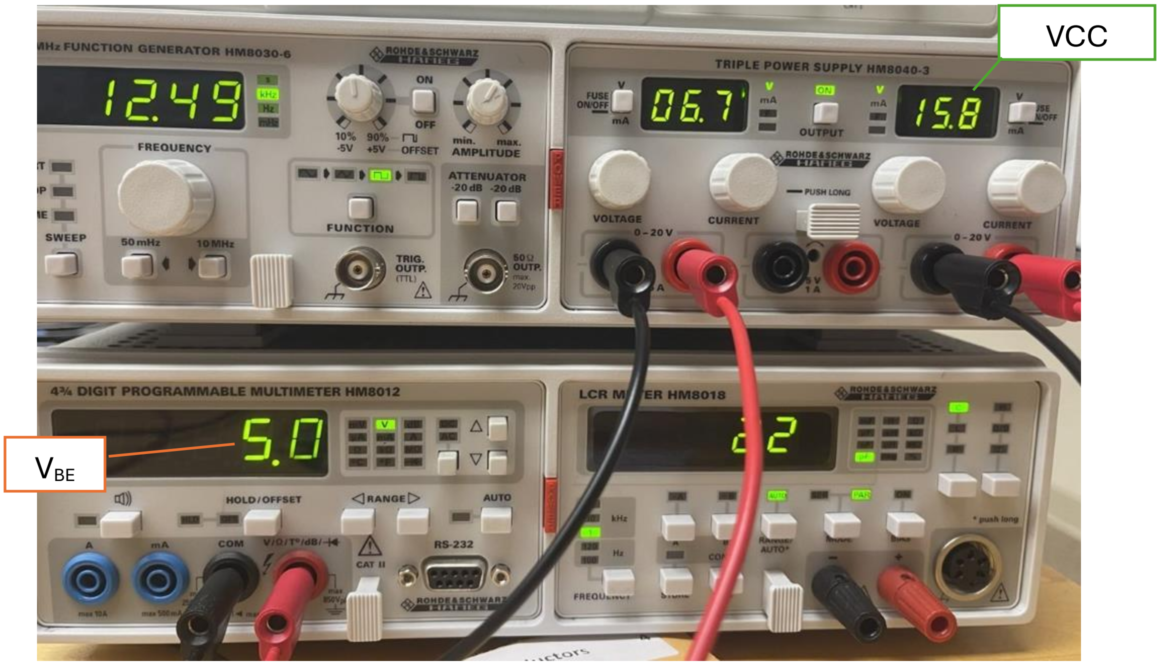

Figure 7 – V_{CE} Voltage validation at 5V, Giving a V_{CC} of 15.8V.

Table 1

Collector-to Emitter Voltage	Portion A Base current = 30 μA			Portion B Base current = 60 μA		
	VCC [V]	Voltage across R_C [V]	Current across R_C [mA]	VCC [V]	Voltage across R_C [V]	Current across R_C [mA]
3V	8.2	5.18	5.13	13.4	10.47	10.35
5V	10.2	5.29	5.20	15.8	10.85	10.65
7V	12.3	5.43	5.33	18	11.06	10.99
9V	14.5	5.48				

$$\beta_{30\mu A} = \frac{I_C}{I_B} = \frac{5.35\ mA}{30\mu A} = 178.16$$

$$\beta_{60\mu A} = \frac{I_C}{I_B} = \frac{10.79\ mA}{60\mu A} = 179.89$$

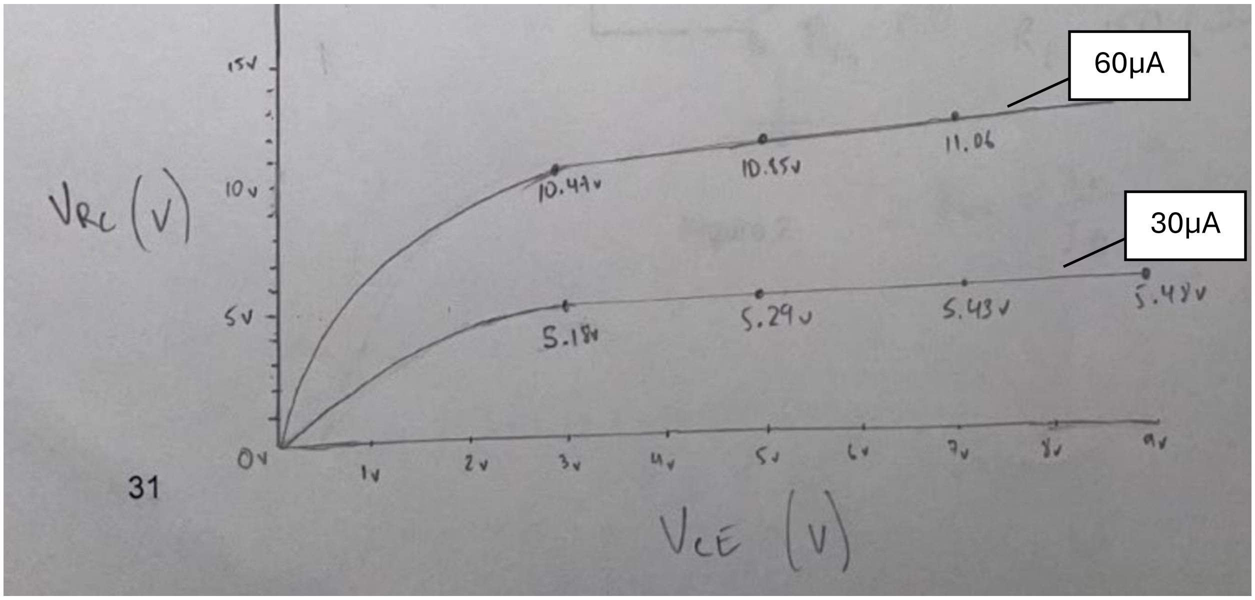

Figure 8 – Characteristic Graphs for base currents.

Furthermore, the output characteristics graph plotted for the base currents of 30 µA and 60 µA depicted the expected increase in collector current with the increase in collector-to-emitter voltage (V_CE) until saturation was reached. This behavior is in line with the active region operation of a BJT, where the collector current remains relatively constant despite increases in V_CE, after reaching saturation. [Figure 7]

Collector Bias:

This section of the lab focuses on the collector bias method, which is another technique to set up the DC operating point for an amplifier circuit. The purpose of the collector bias method is to improve the stability of the transistor's operation with respect to changes in beta (β), which is the current gain of the transistor. The lab work involved calculating the necessary resistor values to establish the desired biasing conditions and then constructing a circuit based on those calculations.

Calculating R_B:

$$VBB = VC = 5V$$

$$I_C = \frac{V_C}{R_C} = \frac{5V}{1k\Omega} = 5mA$$

$$R_B = \beta_{DC}\left(\frac{V_C - V_{BE}}{I_C}\right) = 150\left(\frac{5V - 0.7V}{5mA}\right) = 129k\Omega$$

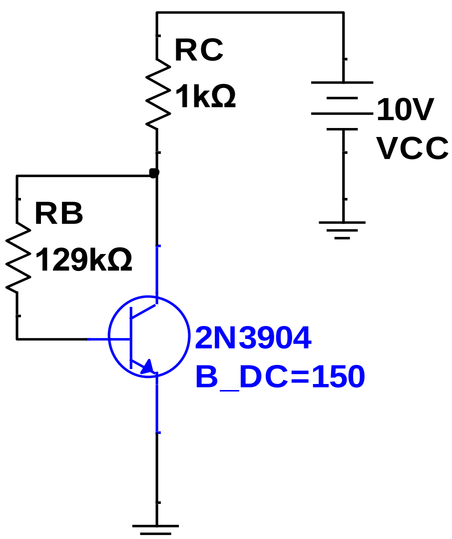

Figure 9 – Multisim Collector Bias Circuit.

Figure 10 – Potentiometer being set to the closest possible to 129kΩ.

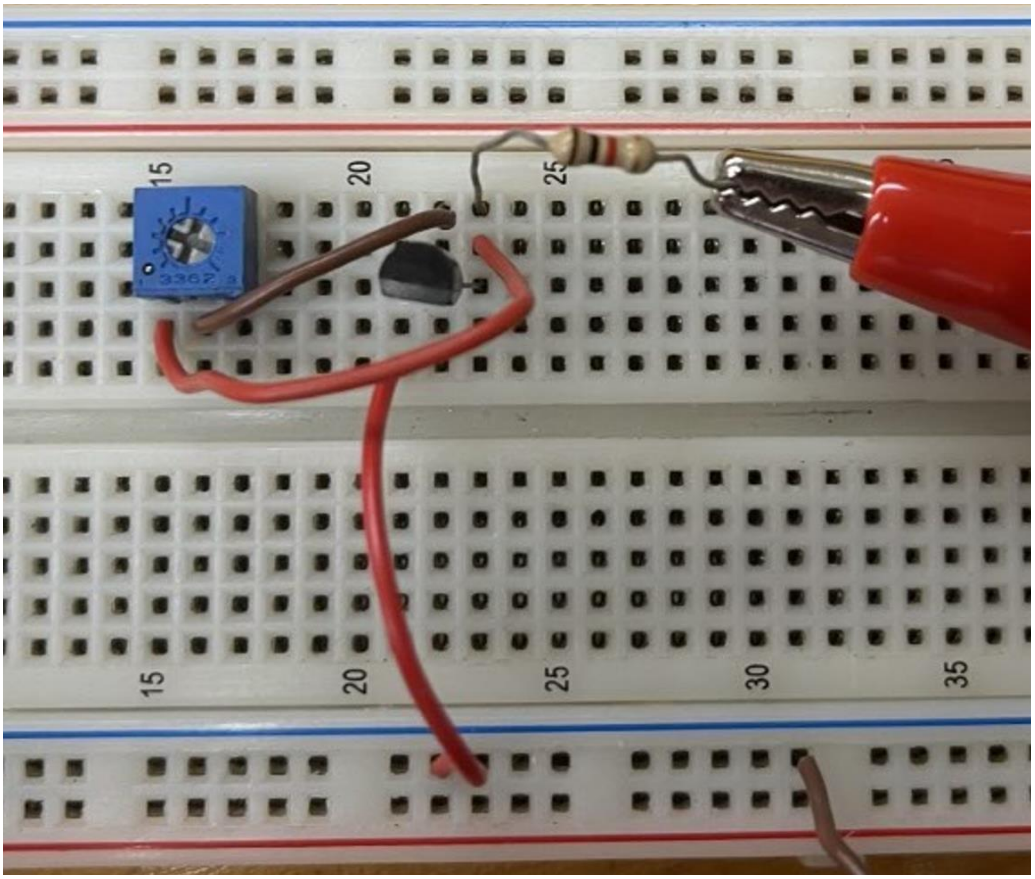

Figure 11 - Collector Bias Circuit Bench

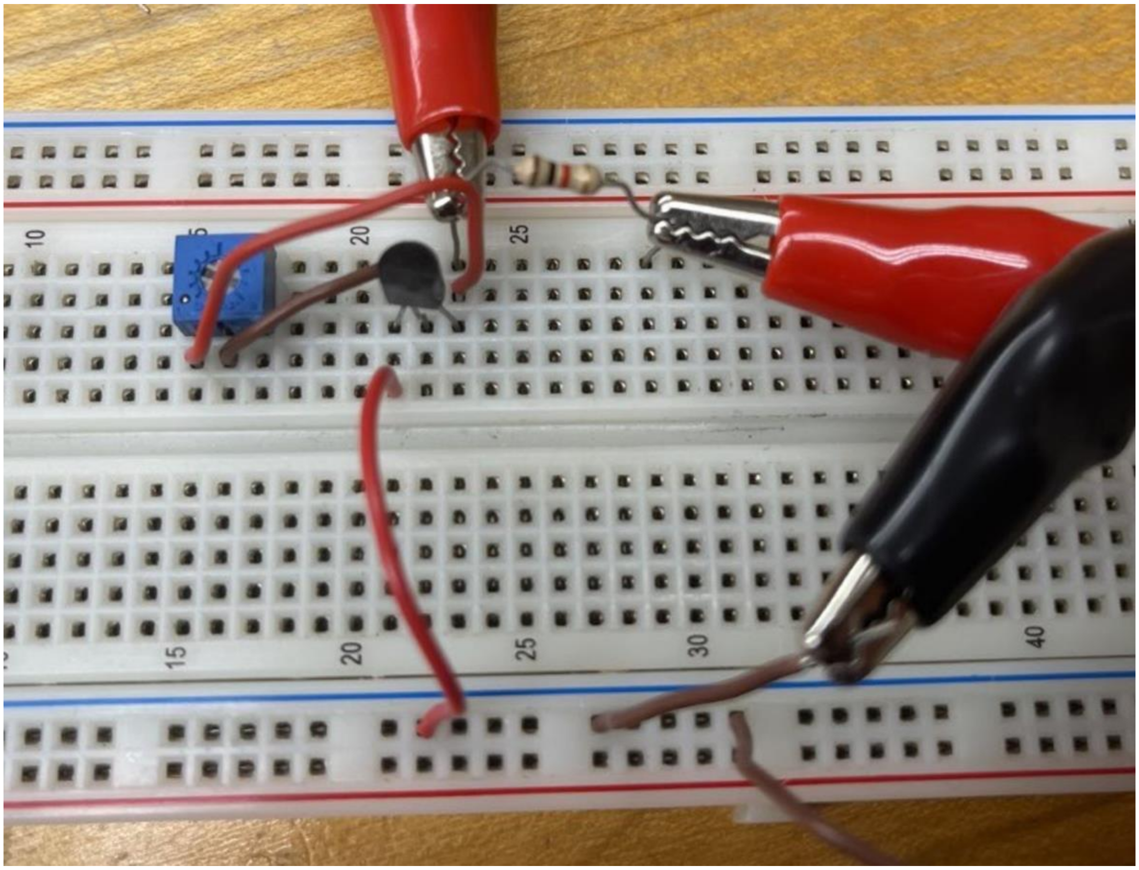

Figure 12 – Measuring V_{CE} Bench.

Figure 13

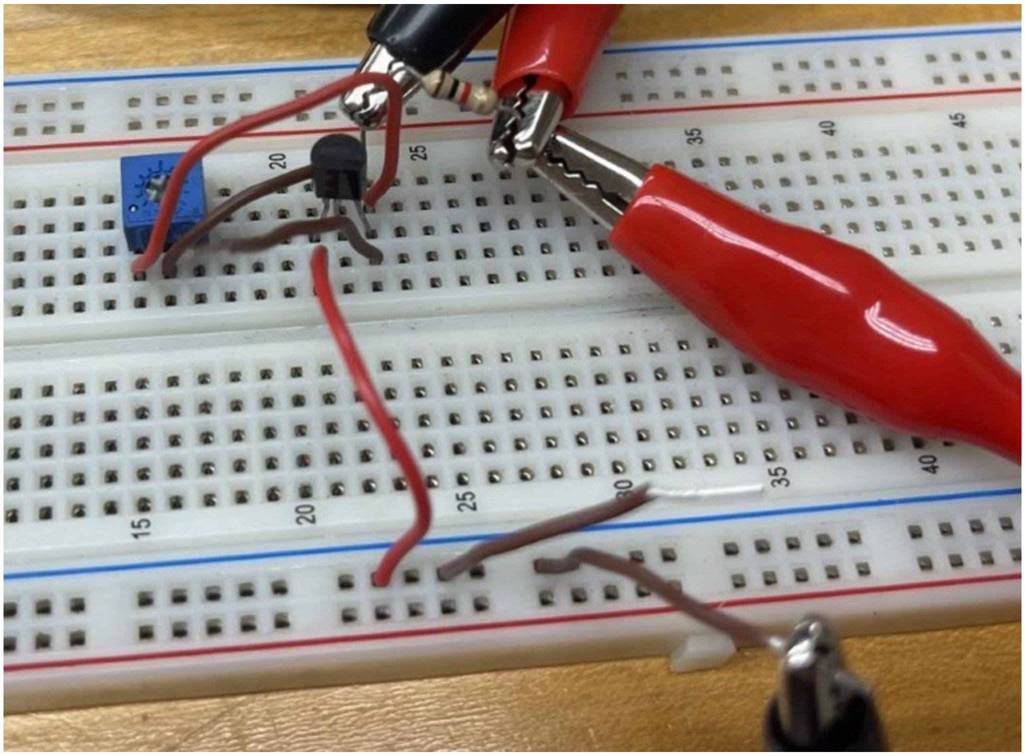

Figure 14 – Measuring V_{RC}

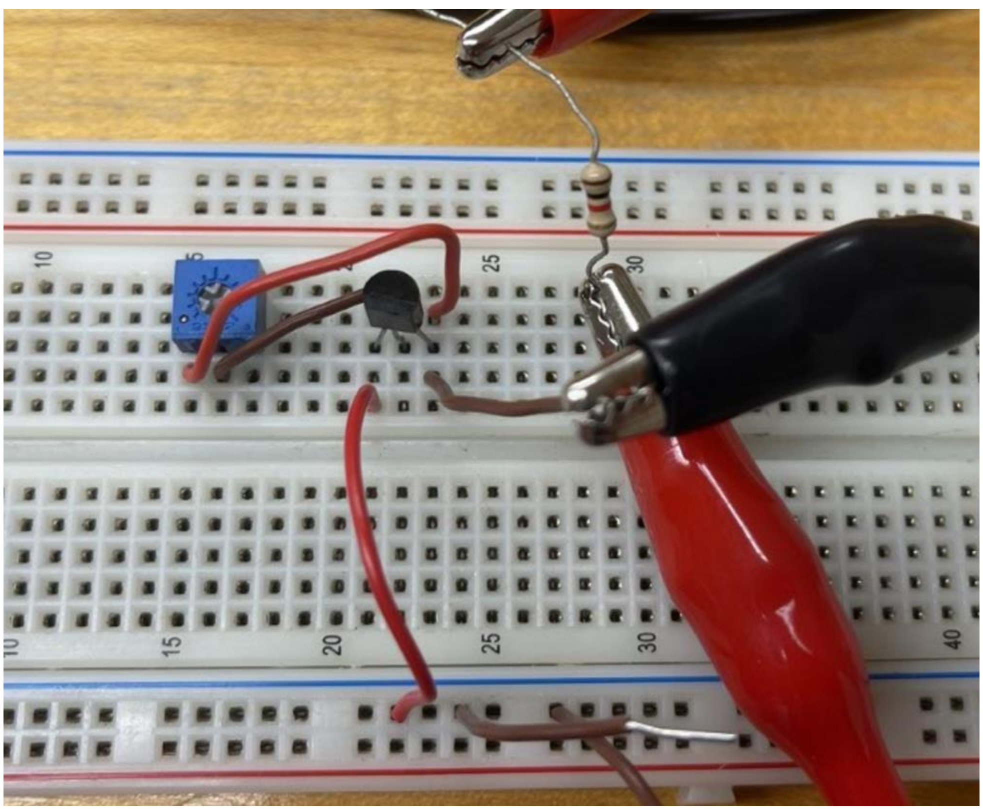

Figure 15 - Measuring I_{RC}

Figure 16 - I_{RC} Measured value, slightly off as DMM was adjusting.

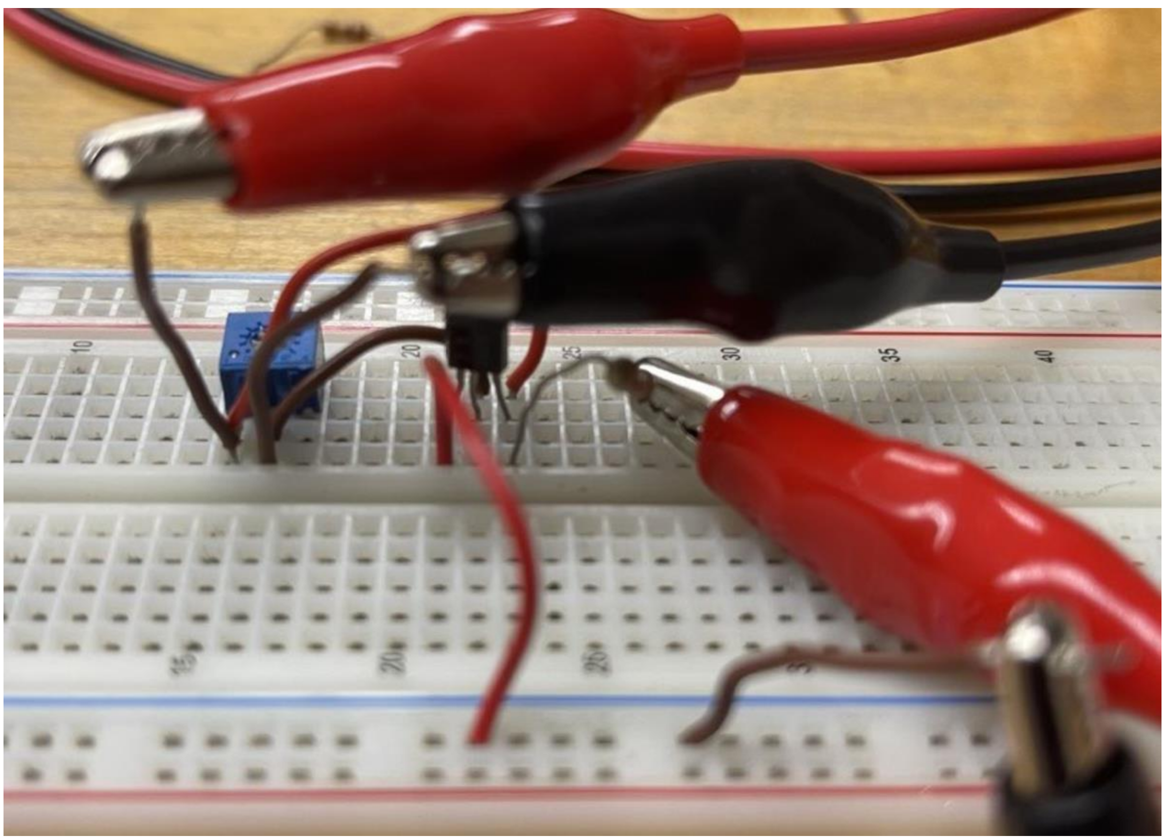

Figure 17 - Measuring I_{RB}

Calculations:

$$V_C = \boldsymbol{V_{CE}}\ by\ applying\ KVL = 5V$$

$$\boldsymbol{V_{RC}} = V_{CC} - V_C = 5V$$

$$\boldsymbol{I_{RC}} = \frac{V_{RC}}{R_C} = \frac{5V}{1k\Omega} = 5mA$$

$$\boldsymbol{V_{RB}} = V_{BB} - V_{BC} = 5V - 0.7V = 4.3V$$

$$\boldsymbol{I_B} = \frac{V_{BB} - V_{BC}}{R_B} = \frac{5V - 0.7V}{128k\Omega} = 33.33\mu A$$

$$\boldsymbol{\beta_{DC}} = \frac{I_C}{I_B} = \frac{5.04mA}{30.02}\mu A = 179.88$$

Table 2

Collector- to Emitter Voltage (V_{CE})		Voltage across R_c [V]		Current across R_C [mA]		Voltage across R_B [V]		Current across R_B [μA]	
M	C	M	C	M	C	M	C	M	C
4.63V	5V	5.39	5	5.04	5	4.64	4.3	30.02	33.33

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Experiment 6

Bipolar Junction Transistors

Collector and Base Biasing

Bipolar Junction Transistor (BJT) is semiconductor device consists of three differently doped regions called Base, Collector, and Emitter. BJT is a current amplifier designed to produce a large collector current from a small base current.

Transistor Biasing
In amplifier application the circuit must be biased to establish the transistor's operating point. To operate as an amplifier the base-to-emitter junction must be configured in forward bias and base-to-collector junction in reversed-bias. This experiment demonstrates how to bias a transistor.

Base Biasing Objective: To investigate the operation and characteristics of a base biased circuit.

Materials

- Power Supply
- BJT Transistor (2N3904)
- 1 kΩ and 100 kΩ Resistors

Input: Power supply
Output: Multimeter

1- Build the transistor circuit shown in figure 1. Set both V_{BB} and V_{CC} at zero volts.

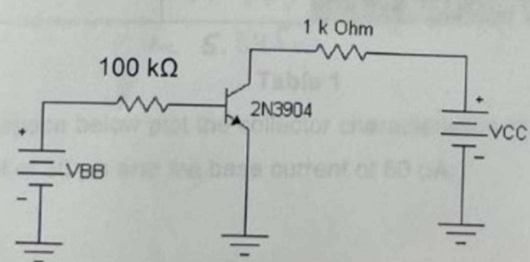


Figure 1

2- Measure and record the actual values for the base and collector resistance. 1.01 kΩ 100.36 kΩ

3- Increase the value of the power supply (VBB) from zero till a base current of 30 μA is established.

30

4- Connect a voltmeter across the collector-to-emitter junction to measure the voltage between the collector and emitter junctions (VCE).

5- Increase the power supply (VCC) from zero to establish the VCE voltages listed in table 1. Complete portion A of the table 1.

6- Increase the VBB voltage to establish a base current of 60 μA.

7- Change the value of the power supply (VCC) to establish the VCE voltages listed in table 1 to complete portion B of the table.

8- From the recorded data determine the DC gain **ß** for the base current of 30 μA and base current of 60 μA.

$\beta_{DC} = \frac{I_C}{I_B}$

$\beta_{30\,\mu A}$ = 178.16 $\beta_{60\,\mu A}$ = 179.89

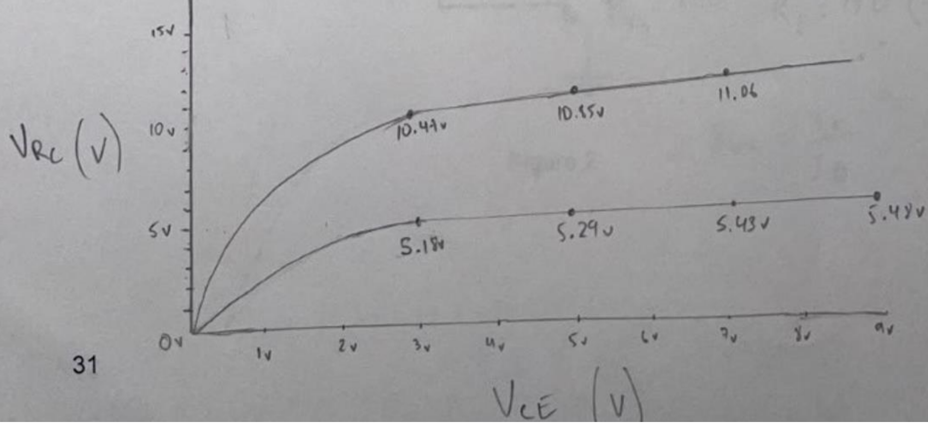
VBB = 3.6 V V BB = 6.7

	Collector-to Emitter Voltage (V_{CE})	Portion A Base current = 30 μA		Portion B Base current = 60 μA		
Vcc		Voltage across Rc	Current through Rc	Voltage across Rc	Current through Rc	Vcc
8.2V	3 V	5.18V	5.13 mA	10.47V	10.35 mA	13.4V
10.2	5 V	5.29V	5.20 mA	10.85V	10.65mA	15.8V
12.3	7 V	5.43V	5.33 mA	11.06V	10.99mA	18V
14.5	9 V	5.48V				

Ave 5.345v Ave 10.793v LD 03/05/24

Table 1

9- In the space below plot the collector characteristics graph for the base current of 30 μA and the base current of 60 μA.



31

Collector Bias

Collector bias is another technique used to setup the DC operating point for an amplifier circuit. The purpose is to determine if this biasing method provides better stability with respect to the change in beta.

1- Use the necessary equations to calculate the required value for the base resistor. In your calculation use a collector resistance R_C of 1kΩ, DC supply of 10 volt, current gain ß of 150, and a Vc of 5V for midpoint biasing.

2- Use the calculated value for base resistor to construct the circuit diagram shown in figure 2.

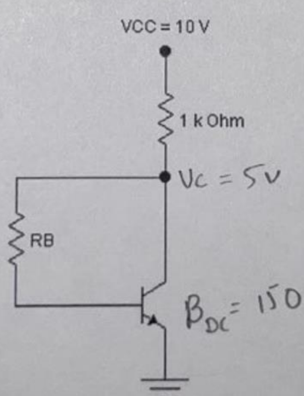
3- Explain below the stability of this collector feedback bias with respect to base biasing.

The collector feedback provides a form of negative feedback that stabilizes the operating point by minimizing the effects of β variation and temperature changes on the circuit performance

4- Complete table 2.

5- From the data in table 2 calculate the transistor's Beta. ß= 179.88

$$I_B = \frac{V_C - V_{BE}}{R_B} = \frac{4.3}{129k\Omega}$$



$$R_B = B_{DC}\left(\frac{V_C - V_{BE}}{I_C}\right)$$

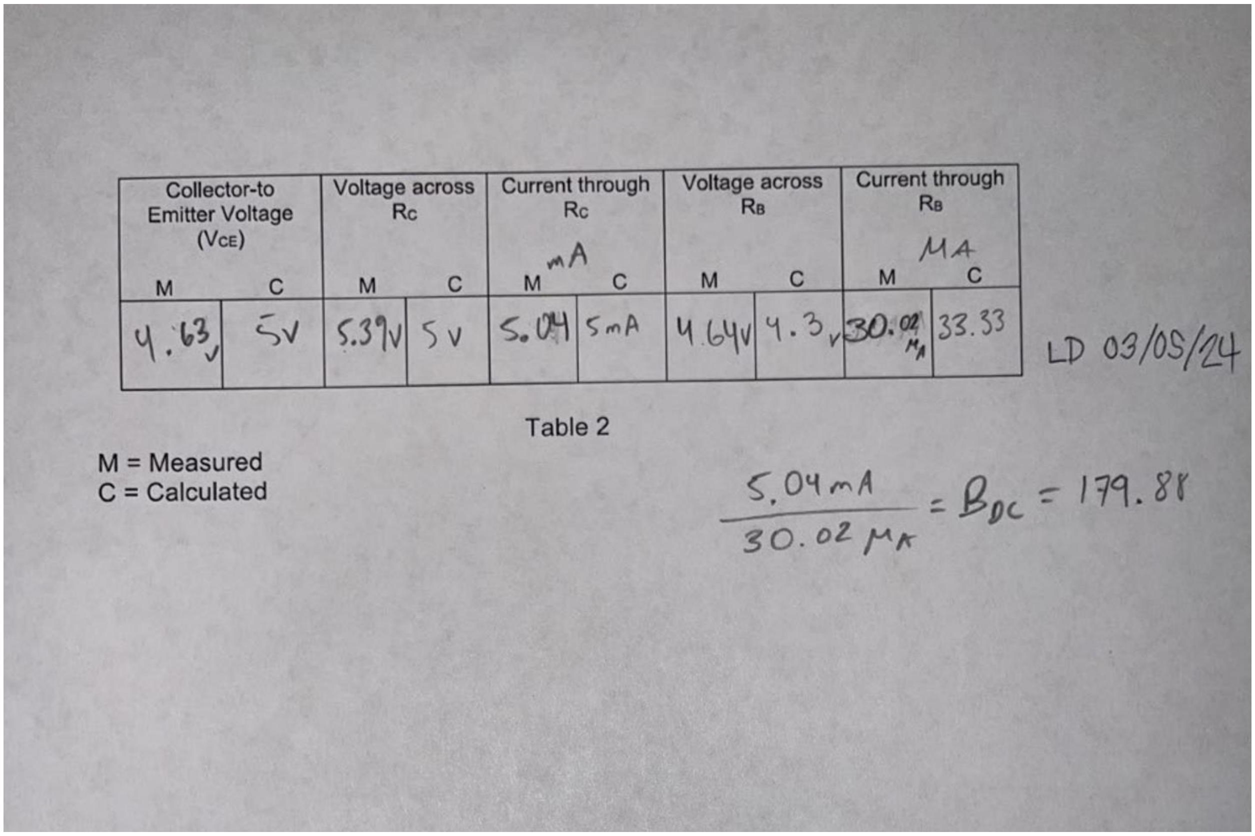
$$I_C = \frac{V_C}{R_C} = \frac{5V}{1000\Omega} = 5mA$$

$$R_B = 150\left(\frac{5 - 0.7}{.005}\right) = 129k\Omega$$

$$B_{DC} = \frac{I_C}{I_B}$$

Figure 2

32



Collector-to Emitter Voltage (V_{CE})		Voltage across R_C		Current through R_C mA		Voltage across R_B		Current through R_B μA	
M	C	M	C	M	C	M	C	M	C
4.63 v	5v	5.39v	5 v	5.04	5 mA	4.64v	4.3 v	30.02 μA	33.33

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Table 2

M = Measured
C = Calculated

$$\frac{5.04\,mA}{30.02\,\mu A} = \beta_{DC} = 179.88$$

Overall, the experimental data trends reinforce the semiconductor theory and electronic principles addressed in the lab manual. The practical results not only support the theoretical framework of BJT operation but also provide tangible evidence of the principles of transistor biasing and the impact of circuit configuration on transistor characteristics.

Conclusion:

The objectives of this lab were to investigate the operation and characteristics of base biased circuits and to understand the stabilization benefits of collector feedback biasing in Bipolar Junction Transistors (BJT). These goals were successfully met as evidenced by the data collected and analyzed, which corroborated the theoretical behavior of BJTs under different biasing schemes. The lab facilitated a deeper comprehension of how BJTs amplify currents and the significance of biasing in determining the operating point of a transistor.

I learned the practical aspects of transistor biasing, including how to set up a circuit for collector and base biasing and how to measure the resulting currents and voltages. Through the construction of the circuit and the empirical data collection, I gained insight into the relationship between the base and collector currents and the effect of biasing on a transistor's operation. The lab also reinforced the concept that the stability of an amplifier circuit can be significantly affected by the biasing method employed, with collector feedback providing an effective means of stabilization against beta variation and temperature changes.

In conclusion, the lab was successful in meeting its educational objectives, providing hands-on experience that linked theoretical principles with real-world electronics applications.