Pedro Cabrera

Experiment 8

Bipolar Junction Transistors

Common Emitter Amplifier

Introduction:

In this laboratory experiment, our primary objective is to understand and analyze the workings of a Bipolar Junction Transistor (BJT) configured as a common emitter amplifier. This configuration is integral to electronic devices due to its amplification properties, which are essential in the operations of radios, computers, and other electronic systems. By applying a small alternating current (AC) input signal and observing the resultant larger AC signal at the collector, we aim to learn about signal amplification. The focus will be on determining the maximum AC swing within the transistor's operation, which occurs when the transistor is biased at its operating point (Q) on the load line. Additionally, we will investigate the influence of different load resistances on the amplifier's gain. Through this exercise, we seek to grasp the practical aspects of theoretical concepts such as the DC operating point, AC signal behavior, and the impact of component variations on the amplifier's performance. This experiment builds on the foundations laid out in Experiment 7 and is designed to reinforce our understanding of electronic amplification.

Bench Parts and Equipment List:

1. Components:
    - BJT Transistor (2N3904)
    - Resistors: 1kΩ, 2.2kΩ, 3.6kΩ, 10kΩ
    - Capacitors: 1.0μF (C1), 47μF (C2), 1μF (C3)
    - Breadboard for constructing the circuit
2. Equipment:
    - Power Supply
    - Function Generator
    - Oscilloscope

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- Digital Multimeter (for measuring DC and AC parameters)
- Potentiometer (for determining input resistance)
- Wires and connectors for establishing connections on the breadboard

Discussion:

During the DC analysis portion of the experiment, our focus was on establishing the biasing conditions of the BJT (Bipolar Junction Transistor). Here, we carefully measured the base, emitter, and collector voltages and currents, aiming to set the transistor in its active region, where it can function as an amplifier. The measured DC parameters showed a good agreement with the computed ones, suggesting that our biasing strategy was effective. These parameters were critical in defining the operation point (Q) on the DC load line, which predicts the transistor's behavior for any given input.

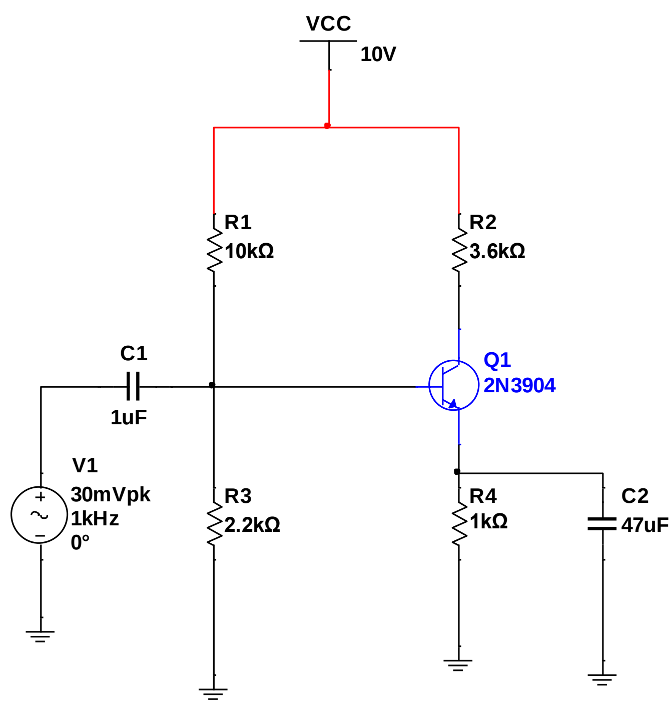

Figure 1

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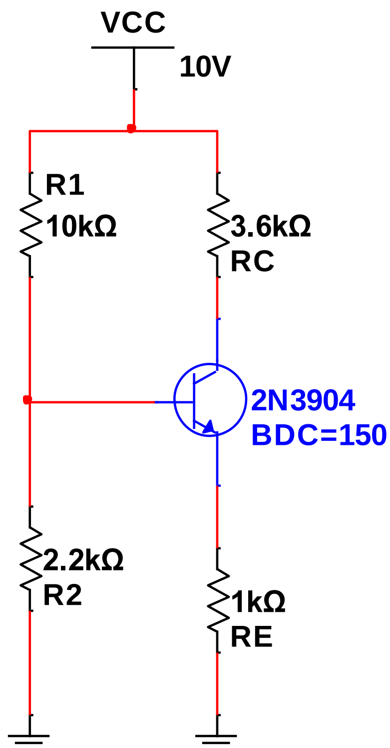

Figure 2

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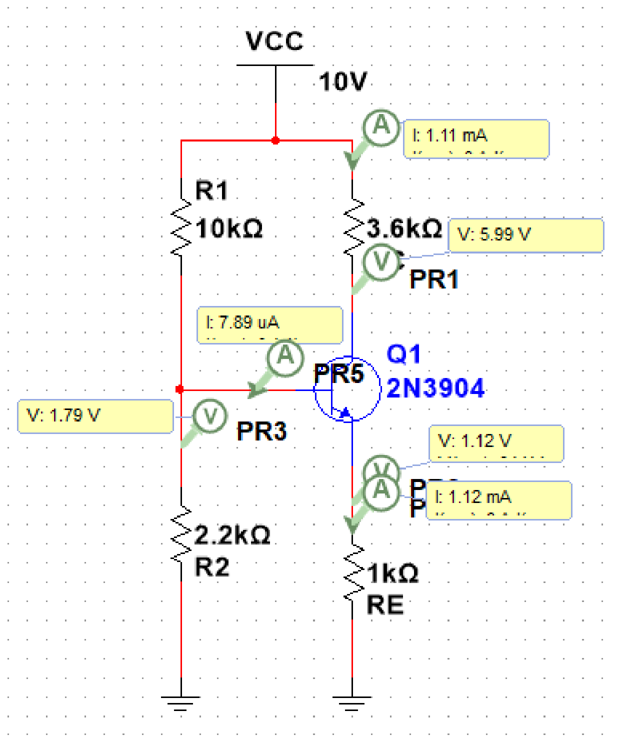

Figure 3

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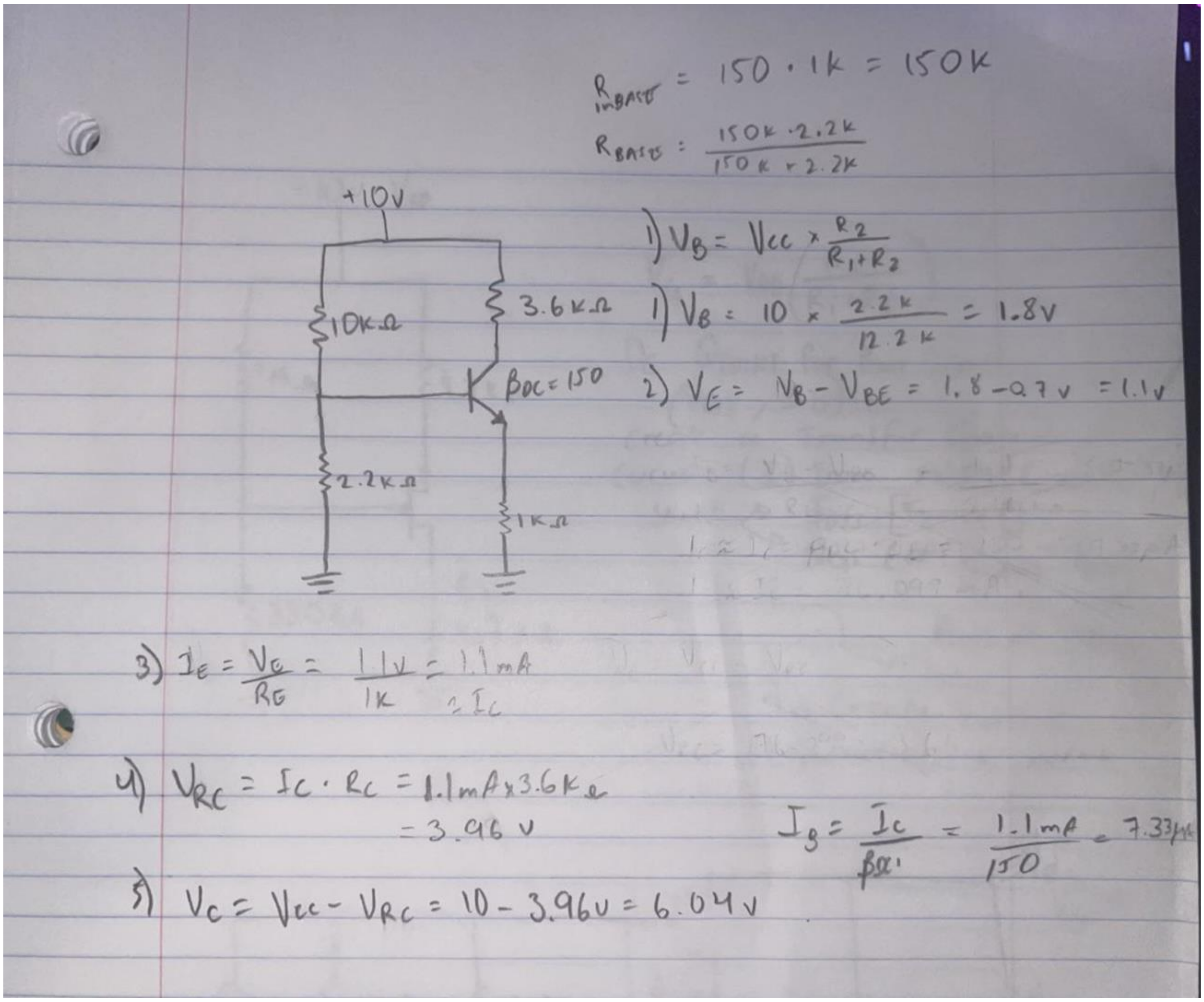

Figure 4

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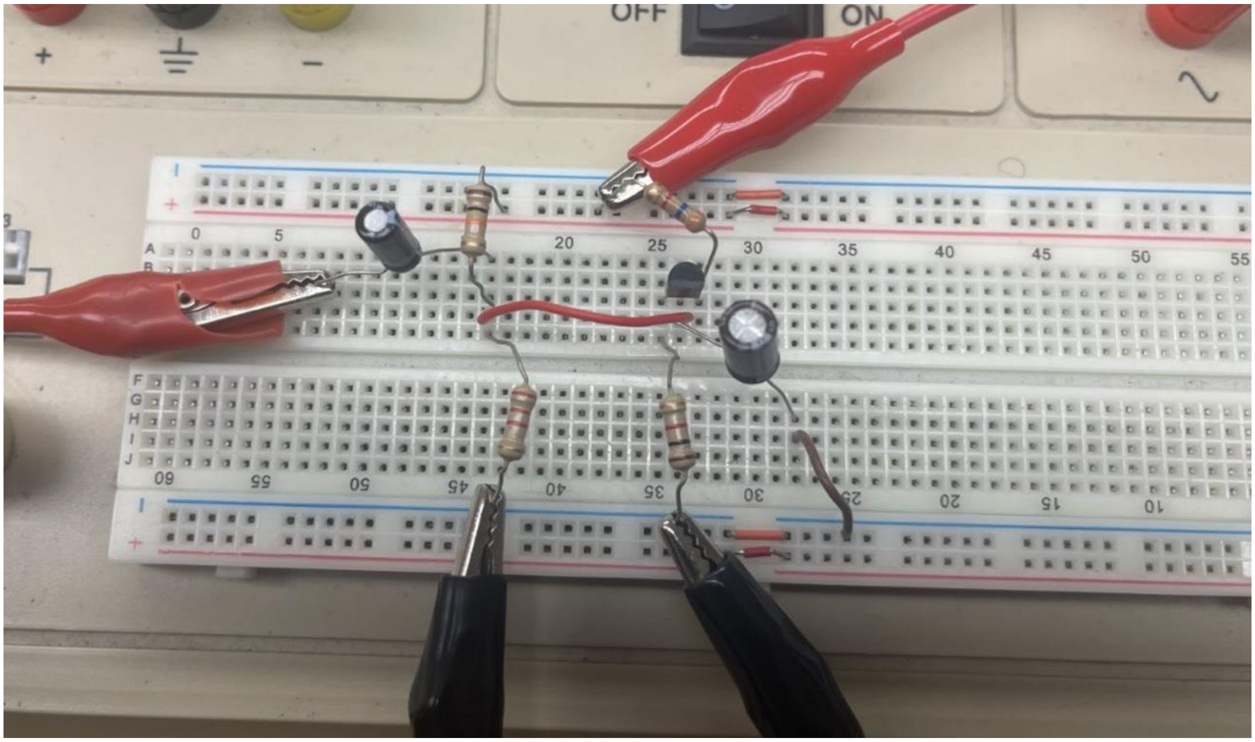

Figure 5

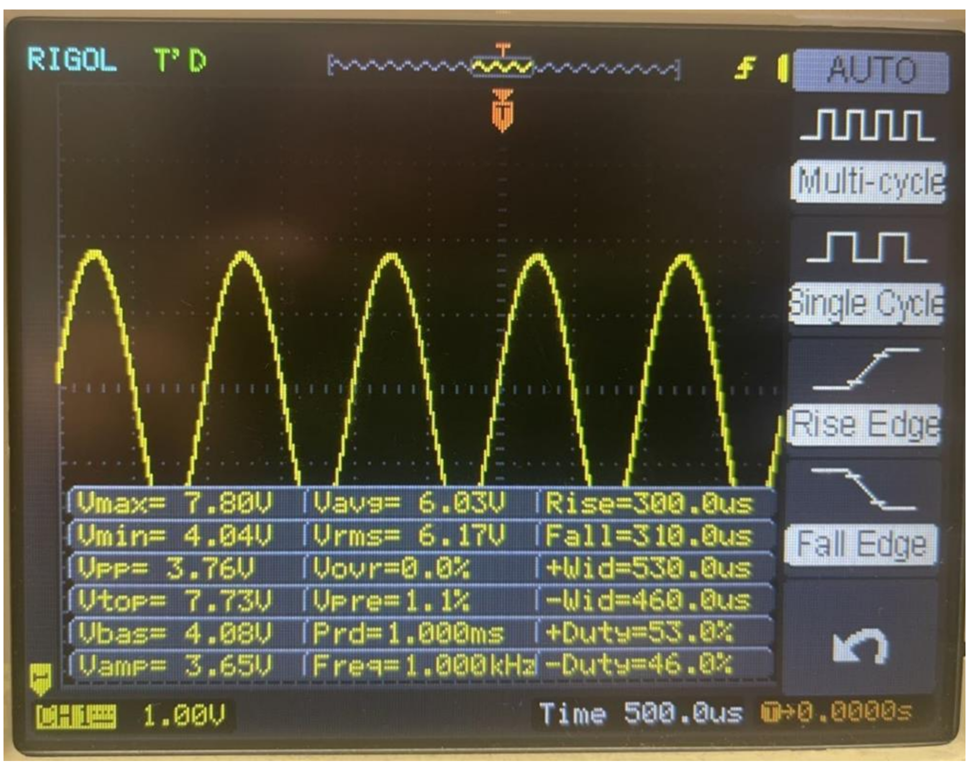

Figure 6

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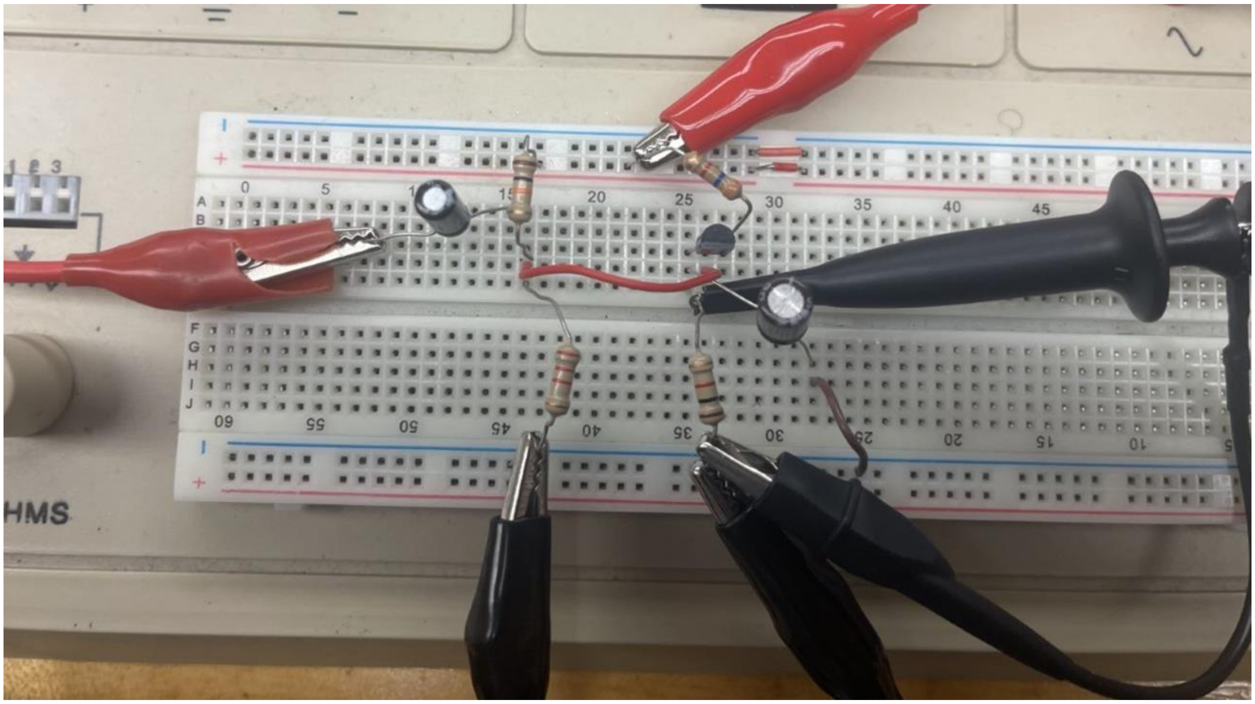

Figure 7

Figure 8

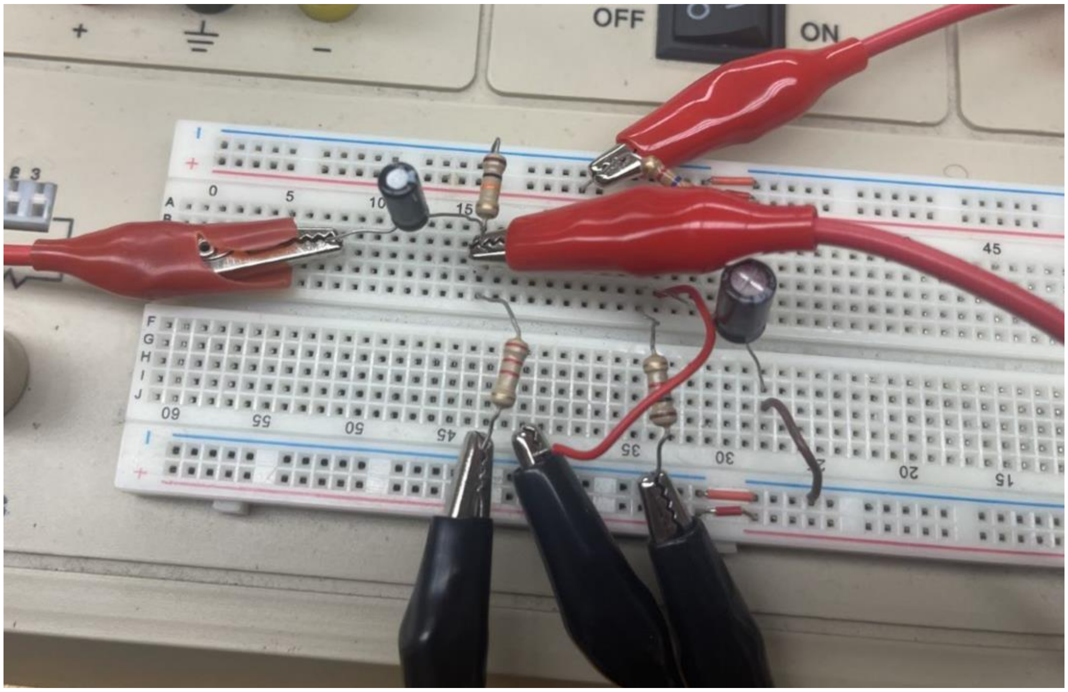

Figure 9

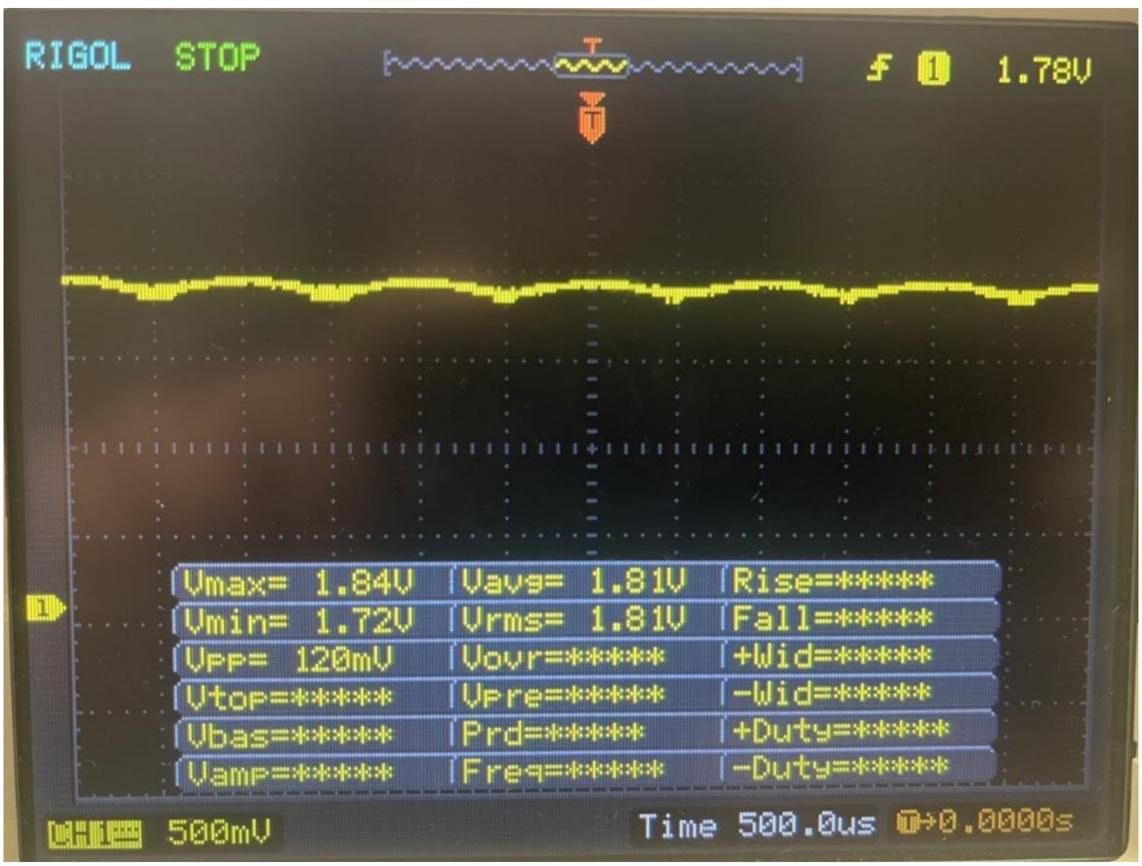

Figure 10

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Figure 11

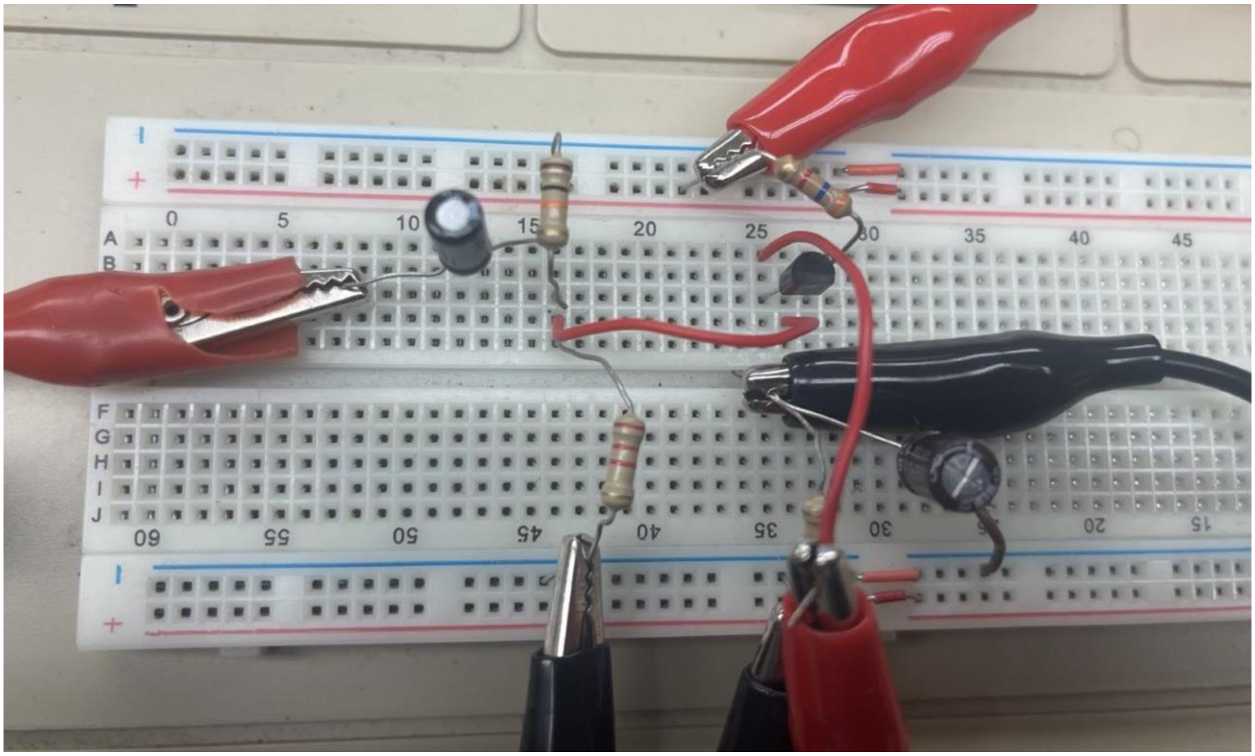

Figure 12

Figure 13

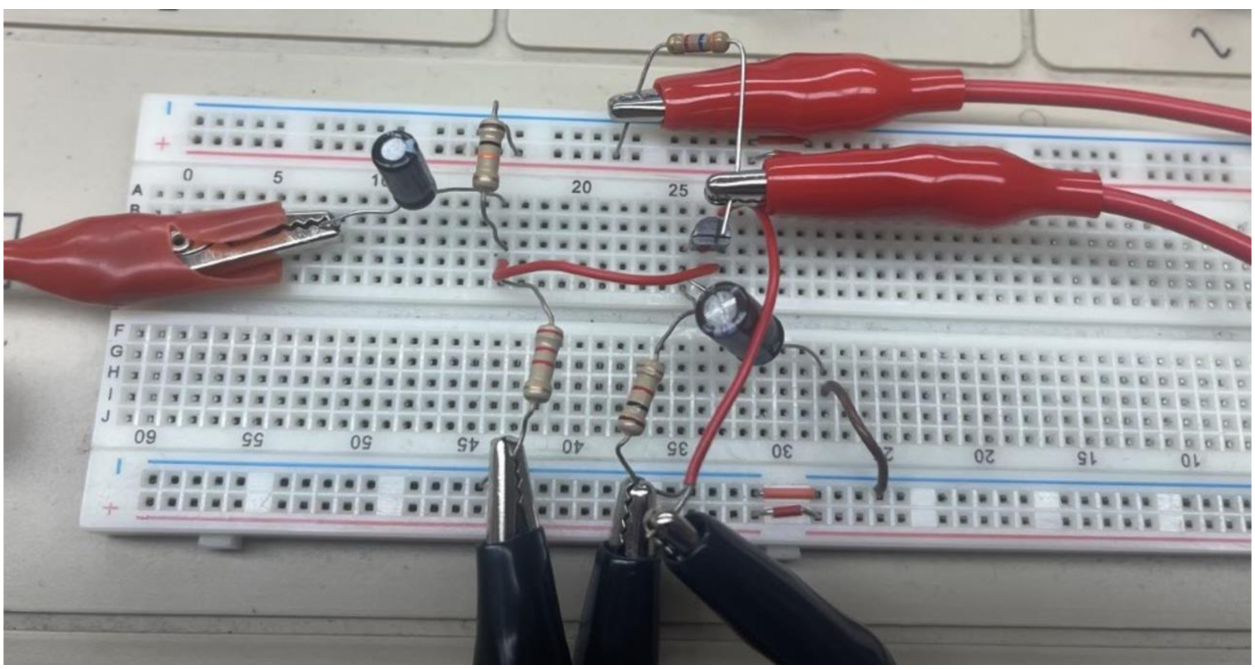

Figure 14

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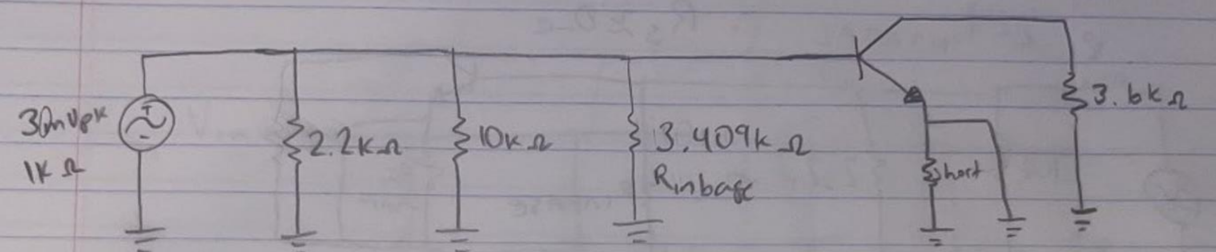
Figure 15

Shifting to the AC analysis, we observed the behavior of the transistor when a 30mV peak AC signal at 1kHz was introduced. This was superimposed on the DC biasing established earlier, and the role of C1 as the coupling capacitor was crucial here; it allowed the AC signal to pass to the base while blocking DC. The AC parameters were then recorded, which included the voltage gain and the phase shift of the signal.

$$R_{inbase} = \beta_{ac}(r'_e) = 150\left(\frac{25mV}{1.1mA}\right) = 3.409k\Omega$$



$$V_b = V_{in} = 30mVp$$

$$I_e = \frac{V_b}{r'_e} = \frac{30mVp}{\left(\frac{25mV}{1.1mA}\right)} = 1.32mA$$

$$I_b = \frac{I_e}{\beta_{ac}} = \frac{1.32mA}{150} = 8.8\mu A$$

$$I_c = I_b \cdot \beta_{ac} = 1.32mA \approx I_e$$

$$V_c = I_c \cdot R_c = 1.32mA \cdot 3.6K = 4.752\ Vp$$

Figure 16

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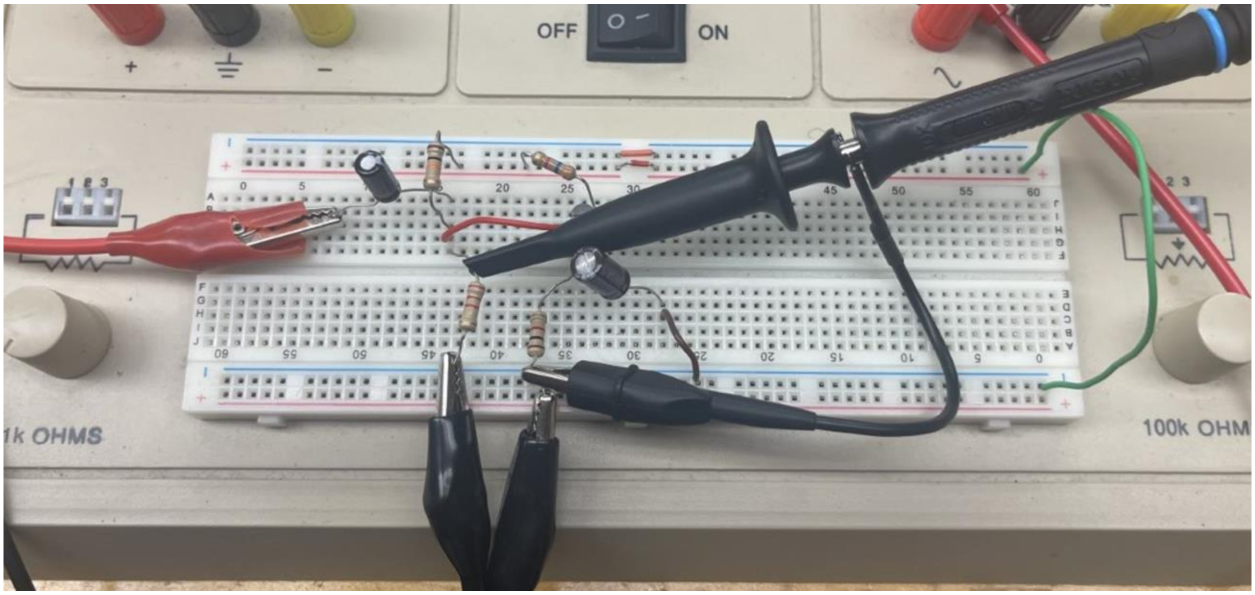

Figure 17

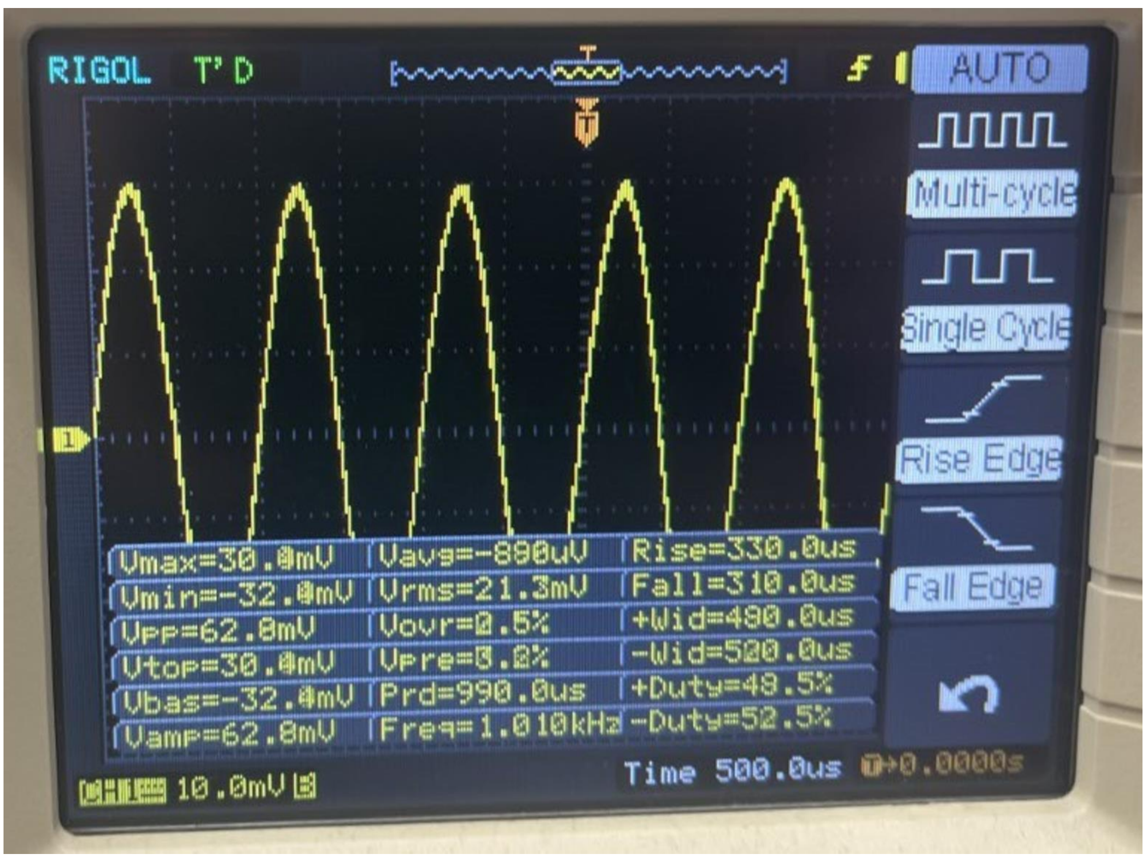

Figure 18

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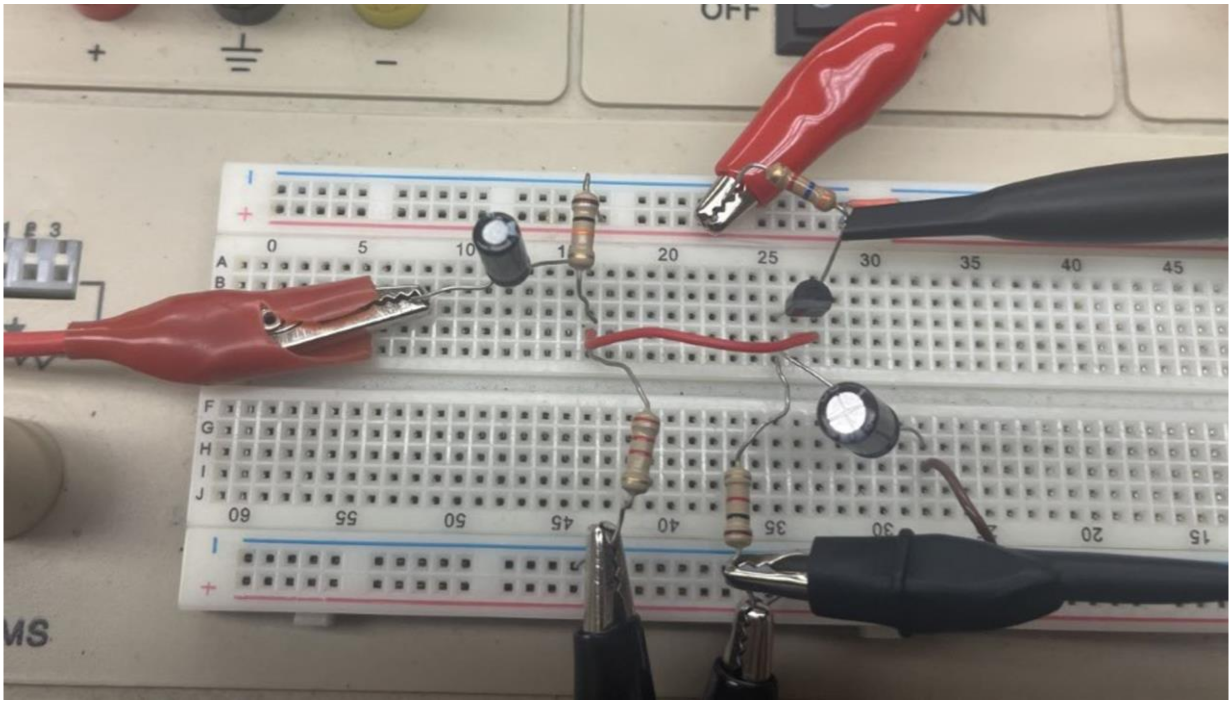

Figure 19

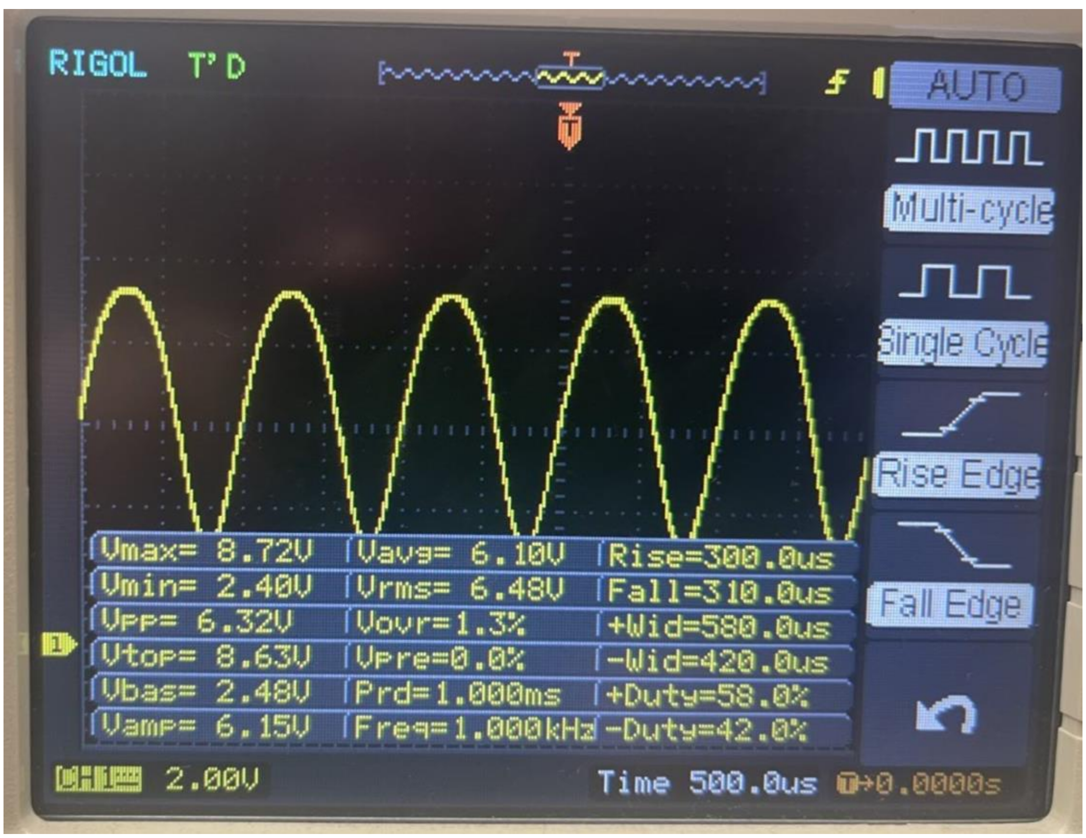

Figure 20

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	DC parameter Computed	DC parameter Measured	AC parameter Computed	AC parameter Measured
Base Voltage	1.8 V	1.81 V	30 mVp	30m Vp
Emitter Voltage	1.1 V	1.13 V	0 V	0 V
Collector Voltage	6.04 V	6.03	4.752 Vp	6.10 V
Base Current	7.33 μA	6.13 μA	8.8 μA	
Emitter Current	1.1 mA	1.12 mA	1.32 mA	
Collector Current	1.1 mA	1.13 mA	1.32 mA	

Table 1

The concept of load lines was explored by plotting the DC and AC load lines based on the data from Table 1. The DC load line, drawn from the IC and VCE values, allowed us to visualize the range of operation and helped confirm if the transistor was operating in the desired region. The AC load line provided insight into the dynamic behavior of the transistor with the applied AC signal and helped us understand the relation between the output voltage and current through the load.

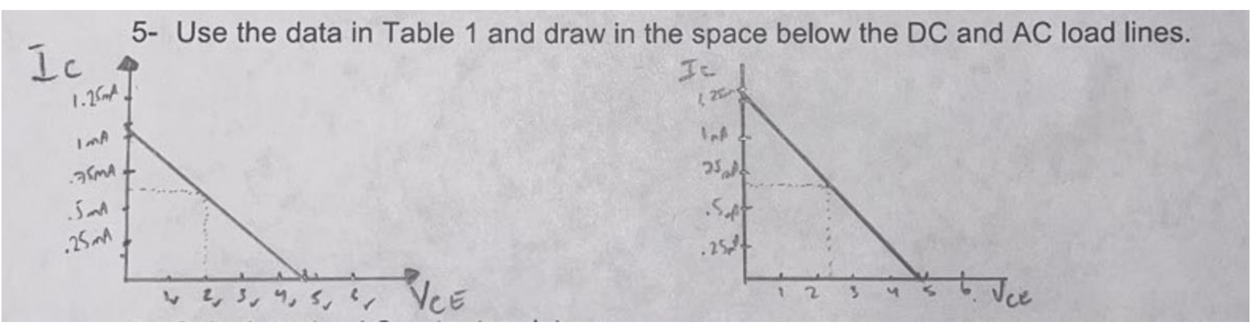

Figure 21

The concept of load lines was explored by plotting the DC and AC load lines based on the data from Table 1. The DC load line, drawn from the IC and VCE values, allowed us to visualize the range of operation and helped confirm if the transistor was operating in the desired region. The AC load line provided insight into the dynamic behavior of the transistor with the applied AC signal and helped us understand the relation between the output voltage and current through the load.

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Capacitors played a vital role in the functionality of our circuit. C2, the bypass capacitor, significantly affected the voltage gain. Its purpose was to provide a low impedance path to ground for the AC signals, bypassing the emitter resistor RE and therefore maximizing the AC gain. By removing C2, we observed a decrease in voltage gain, which emphasized its role in the amplifier's frequency response.

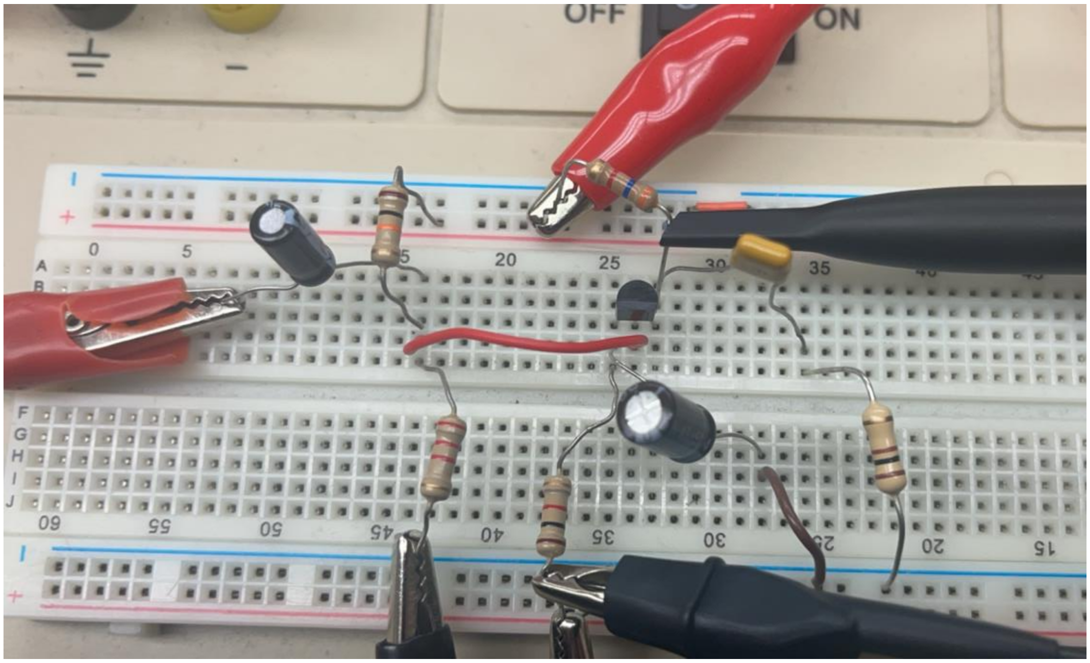

Figure 22

Lastly, we considered the effect of adding a load resistor and capacitor C3 in the circuit. The capacitor C3 functioned as an output coupling capacitor, blocking DC from reaching the load but allowing the AC component of the signal to pass. The inclusion of the load resistor demonstrated the concept of loaded gain and provided a practical demonstration of how the voltage gain of the amplifier is affected by the load attached to it. This step was essential for understanding how the amplifier would perform in a real-world application where it has to drive external components.

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Experiment 8

Bipolar Junction Transistors

Common Emitter Amplifier

Signal Amplification is a process critical to the electronics evolution giving birth to radio, television, computers, and etc… In this experiment the student will observe that applying a small ac signal into the base will result in much higher amplitude ac signal at the collector. The maximum ac swing will take place when the transistor is biased with the operating point (Q) almost at the middle of the load line. The bias parameters are the same as experiment 7.

Objective: To investigate the operation of a common emitter amplifier.

Materials

- Power Supply, Function Generator
- BJT Transistor (2N3904)
- 1kΩ,2.2kΩ, 3.6kΩ, and 10kΩ Resistors

Input: Function Generator
Output: Oscilloscope

NOTE: Use 1.0uF for capacitor C_1 and 47uF for capacitor C_2.
Assume $ß_{ac} = ß_{DC} = 150$

1- Build the amplifier circuit shown in Figure 1.
2- Use an input voltage of 30mv peak @1KHz sine wave signal.

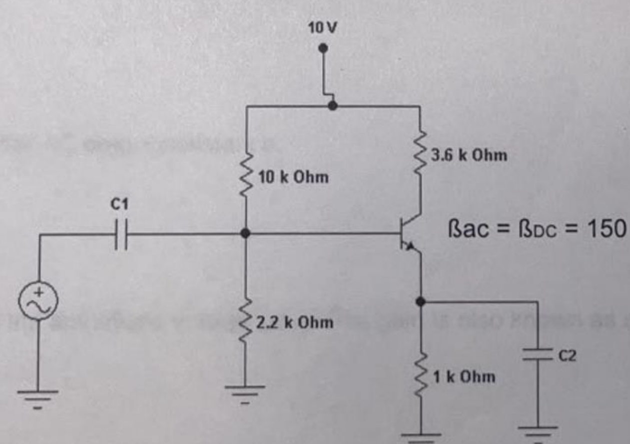

Figure 1

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3- Determine the input resistance (use a potentiometer).

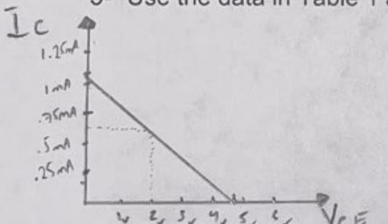
4- Complete Table 1.

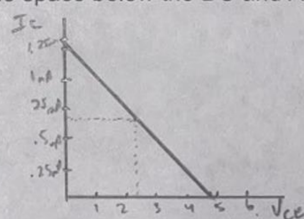
	DC parameter Computed	DC parameter Measured	AC parameter Computed	AC parameter Measured
Base Voltage	1.8 V	1.81 V	30mVp	30mVp
Emitter Voltage	1.1 V	1.13 v	0 v	0 v
Collector Voltage	6.04 v	6.03	4.752 Vp	6.10 v
Base Current	7.33 μA	6.13 μA	8.8 μA	
Emitter Current	1.1 mA	1.12 mA	1.32 mA	
Collector Current	1.1 mA	1.13 mA	1.32 mA	

3.27

Table 1

5- Use the data in Table 1 and draw in the space below the DC and AC load lines.





6- Calculate the AC output resistance.

R_C would be the output

3.6 kΩ

$V_{out} = I_C \times R_C = 1.32\,mA \times 3600$

7- Determine the amplifier's voltage gain. This gain is also known as unloaded gain.

$$A_V = \frac{V_{out}}{V_{in}} = \frac{3.05\,v}{30\,mV} = 101.67 \text{ gain}$$

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8- Add a 100 ohm load resistor and the capacitor C_3. See the transistor's output in Figure 2. Determine the resulting voltage gain. This gain is also known as loaded gain.

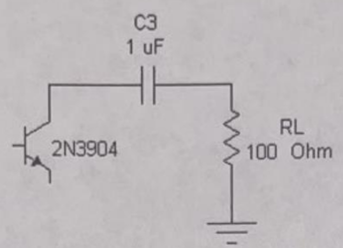

Figure 2

9- Describe below the effect of the load resistance on the amplifier gain.

The load Resistance on the Amplifier gain determines the amount of the signal's voltage that is dropped across the load, with a higher load Resistance will lead to higer Voltage gain.

10- Remove the capacitor C_2 from the circuit and measure the voltage gain. What affect a change in emitter resistance would have on the output voltage and the amplifier's voltage gain?

Results in a decrease in the voltage gain, because C_2 serves as a bypass to RE.

11-What is the function of C_2 capacitor?

It serves as a bypass to RE

12-Why is it important to select the proper values for the voltage divider resistors R_1 and R_2?

This is crucial to insure the correct biasing of the transistor and stable operation of the Amplifier.

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Conclusion:

The primary objective of this lab was to investigate the operation of a Bipolar Junction Transistor (BJT) configured as a common emitter amplifier, focusing on understanding the DC biasing, the effects of AC signal amplification, and the impact of various components, including load resistors and capacitors, on the amplifier's performance. This lab successfully met its objectives. We established the DC biasing conditions, superimposed an AC signal, and measured the resulting changes to validate our theoretical understanding. We also learned how the coupling and bypass capacitors influence the signal and how load resistance affects the amplifier’s gain.

Through hands-on experimentation, I gained a deeper appreciation for the precision required in setting up electronic circuits. Not only did I learn how to measure and analyze the DC and AC parameters of a BJT amplifier, but I also understood the significance of the operating point and load lines in predicting the transistor's behavior. Observing the changes in voltage gain with the removal of the bypass capacitor C2, and the introduction of a load resistor, concretized the theory behind impedance and its effects on an amplifier’s performance.

In conclusion, the lab was a practical embodiment of the principles of electronic amplification and reinforced the theoretical knowledge with empirical evidence. It bridged the gap between textbook circuit analysis and real-world electronic applications, providing a comprehensive understanding of the common emitter amplifier circuit.