Faculty of Engineering and Technology

Electrical and Computer Engineering Department

ENEE2103

Circuits and Electronics Lab

Experiment No.7

BJT Transistor as an Amplifier

Report No.8

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Abstract

The aim of this experiment is to examine the effect of applying sinusoidal signal to a transistor connected emitter, measure and calculate the AC parameters such as voltage gain, current gain, and input and output impedance. In addition, to find the properties of the transistor amplifier in common emitter, common collector, and common base connection and compare their parameters such as voltage gain together.

The methods used in this experiment is that all the specified circuits were connected in the board using the elements BJT transistor, potentiometer to adjust the voltage value, resistors, capacitors. In addition, the Function Generator was used to generate different types of electrical waveforms over specified frequencies values, DC voltage to provide a fixed voltage, the Oscilloscope was used to test and display the signals, and the Digital Multimeter (DMM) was used to measure the voltage and the current.

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1. Theory

1.1 Transistors:

A transistor is a type of a semiconductor device that can be used to both conduct and insulate electric current or voltage. A transistor basically acts as a switch and an amplifier. In other words, it is a miniature device that is used to control or regulate the flow of electronic signals.

A typical transistor is composed of three layers of semiconductor materials or more specifically terminals which helps to make a connection to an external circuit and carry the current. A voltage or current that is applied to any one pair of the terminals of a transistor controls the current through the other pair of terminals. There are three terminals for a transistor:

- **Base:** This is used to activate the transistor.
- **Collector:** It is the positive lead of the transistor.
- **Emitter:** It is the negative lead of the transistor.

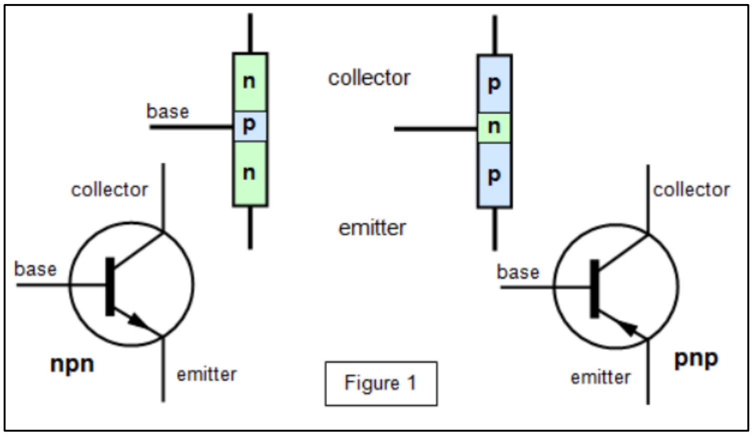


Figure 1 terminals of a transistor.

The transistor can be operated in three modes:

- **Saturation mode:** The transistor acts like a **short circuit**. Current freely flows from collector to emitter.
- **Cut-off mode:** The transistor acts like an **open circuit**. No current flows from collector to emitter.
- **Active mode:** The current from collector to emitter is **proportional** to the current flowing into the base.

To determine which mode a transistor is in, we need to look at the voltages on each of the three pins, and how they relate to each other. The voltages from base to emitter (V_{BE}), and from base to collector (V_{BC}) set the transistor's mode:

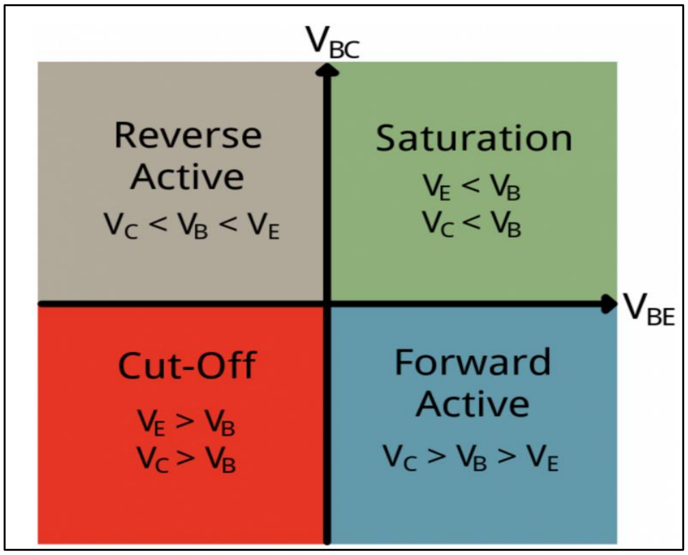
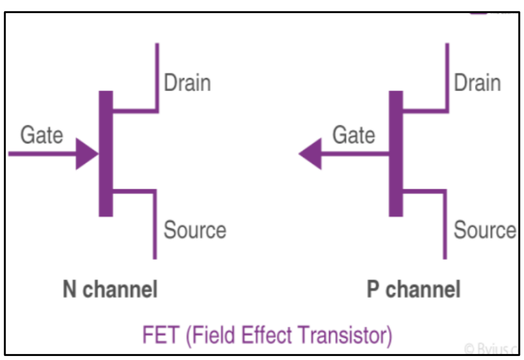


Figure 2 Transistor operational modes.

Based on how they are used in a circuit there are mainly two types of transistors.

- **Bipolar Junction Transistor (BJT):** That's what we will focus on in this experiment, and it contains the three terminals of BJT are base, emitter and collector. A very small current flowing between base and emitter can control a larger flow of current between the collector and emitter terminal.

- **Field Effect Transistor (FET):** For FET, the three terminals are Gate, Source and Drain. The voltage at the gate terminal can control a current between source and drain. FET is a unipolar transistor in which N channel FET or P channel FET are used for conduction. The main applications of FETs are in low noise amplifier, buffer amplifier and an analogue switch.



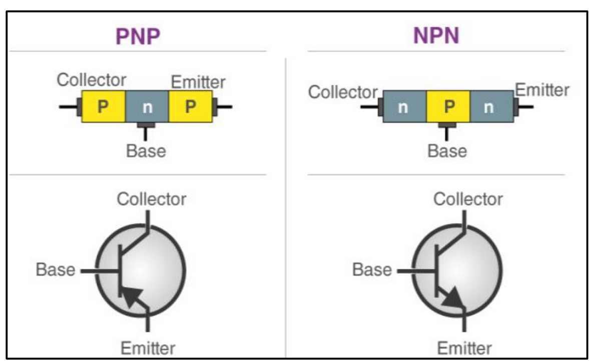


Figure 3 FET and BJT transistors.

1.2 Common Emitter Amplifier:

The common emitter amplifier is a three basic single-stage bipolar junction transistor (BJT) and is used as a voltage amplifier. The input of this amplifier is taken from the base terminal, the output is collected from the collector terminal and the emitter terminal is common for both the terminals.

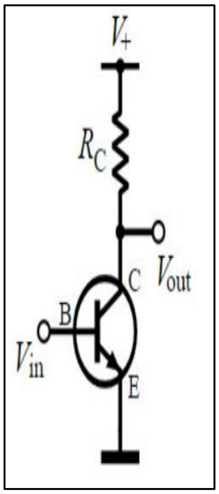


Figure 4 Common Emitter amplifier.

When a signal is applied across the emitter-base junction, the forward bias across this junction increases during the upper half cycle. This leads to an increase in the flow of electrons from the emitter to a collector through the base, hence increases the collector current. The increasing collector current makes more voltage drops across the collector load resistor RC.

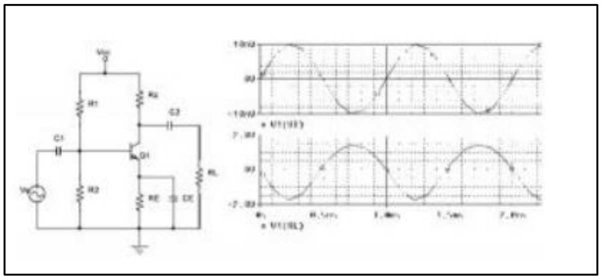


Figure 5 Operational Common Emitter.

The current gain of the common emitter amplifier is defined as the ratio of change in collector current to the change in base current. The voltage gain is defined as the product of the current gain and the ratio of the output resistance of the collector to the input resistance of the base circuits. The following equations show the mathematical expression of the voltage gain and the current gain.

$$\beta = \frac{IC}{IB}$$

$$Av = \beta \frac{Rc}{Rb}$$

1.3 Common Collector Amplifier:

The Common Collector Amplifier is another type of bipolar junction transistor, (BJT) configuration where the input signal is applied to the base terminal and the output signal taken from the emitter terminal. Thus the collector terminal is common to both the input and output circuits. This type of configuration is called Common Collector, (CC) because the collector terminal is effectively “grounded” or “earthed” through the power supply.

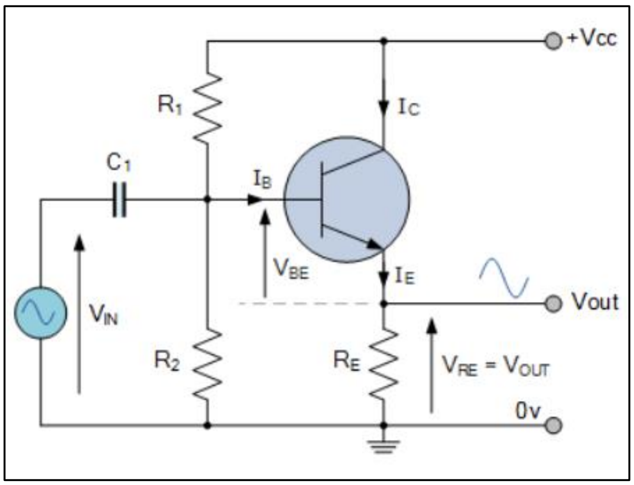


Figure 6 Common Collector Amplifier.

The common collector or grounded collector configuration is generally used where a high impedance input source needs to be connected to a low impedance output load requiring a high current gain. The voltage gain of the CC amplifier is almost 1, while the current gain is as the following:

$$A_I = \frac{I_{emitter}}{I_{base}}$$

$$A_I = \frac{I_{collector} + I_{base}}{I_{base}}$$

$$A_I = \frac{I_{collector}}{I_{base}} + 1$$

$$A_I = \beta + 1$$

Figure 7 Current gain of CC amplifier.

1.4 Common Base Amplifier:

The Common Base Amplifier is another type of bipolar junction transistor, (BJT) configuration where the base terminal of the transistor is a common terminal to both the input and output signals, hence its name common base (CB). The common base configuration is less common as an amplifier than compared to the more popular common emitter, (CE) or common collector, (CC) configurations but is still used due to its unique input/output characteristics.

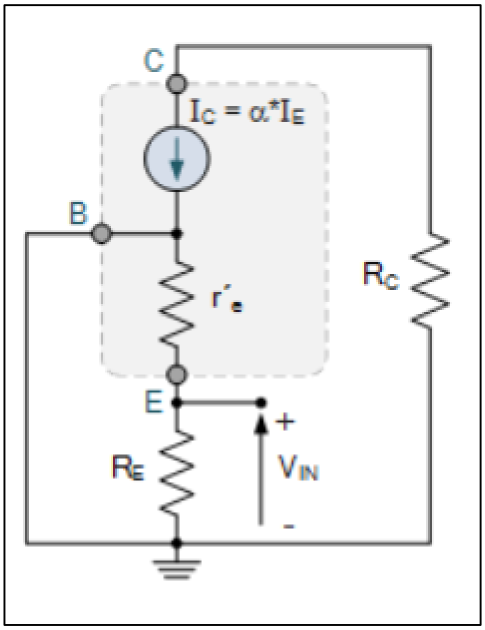


Figure 8 Common Base amplifier.

For the common base configuration to operate as an amplifier, the input signal is applied to the emitter terminal and the output is taken from the collector terminal. Thus the emitter current is also the input current, and the collector current is also the output current, but as the transistor is a three layer, two pn-junction device, it must be correctly biased for it to work as a common base amplifier. That is the base-emitter junction is forward-biased.

- The common base current gain for this type is as the following:

$$A_i = \frac{i_{OUT}}{i_{IN}} = \frac{\beta}{\beta + 1} \cong 1$$

- While the voltage gain is:

$$A_V = \frac{V_{OUT}}{V_{IN}} = \frac{V_C}{V_E} \cong \frac{I_C \times R_C}{I_E \times R_E}$$

2. Procedure and Data Analysis

2.1 Common Emitter Transistor Amplifier:

In this part, the first step was to connect the following circuit in the board, and the power supply was switched and the function generator was set with 1 kHz sine wave and zero amplitude, and finally the base bias potentiometer was adjusted for a DC collector voltage (Vc) of 8 Volts.

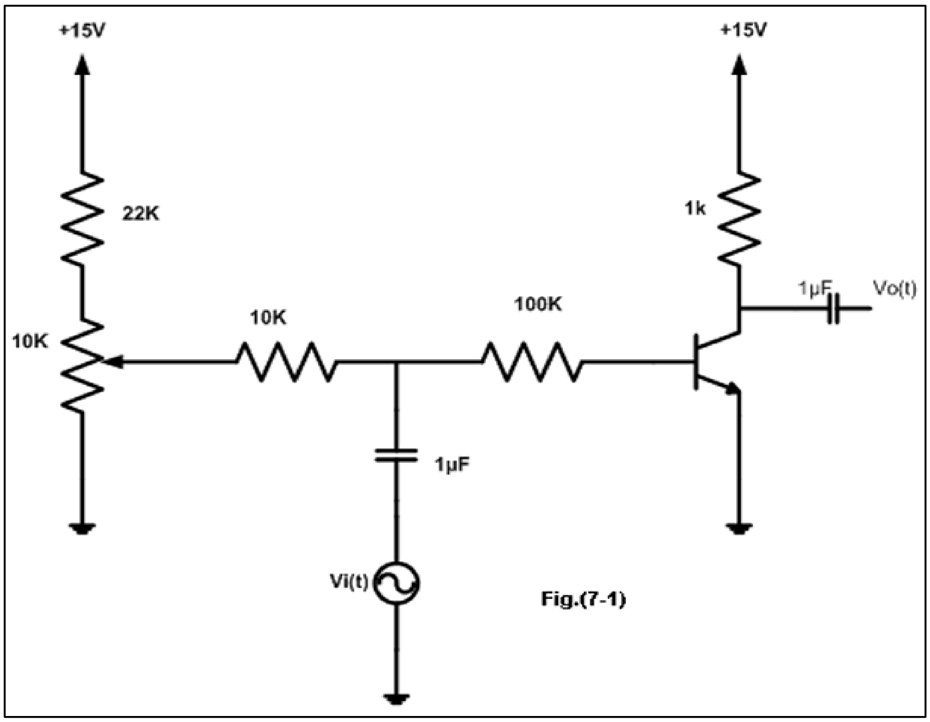


Figure 9 Common Emitter circuit.

Then, the following values were collected as the following values:

- Ic = 7.411 mA.
- Ib = 34.85 uA.
- Vce = 7.7 V.
- Vbe = 0.656 V.
- Vbc = 7.18 V.

Then, the oscilloscope was switched and connected to the base and the output of the previous circuit, and the function generator was turned up until the AC output of the circuit is 8 V peak-to-peak. In addition, the input signal **Vi(t)**, output signal **Vo(t)** the base voltage **Vb(t)** were recorded. From the previous figure, it is shown that the input voltage with, the base voltage, and the output voltage as the following:

Vi(t) = 4.16 V. **Vo(t) = 8.16 V.**

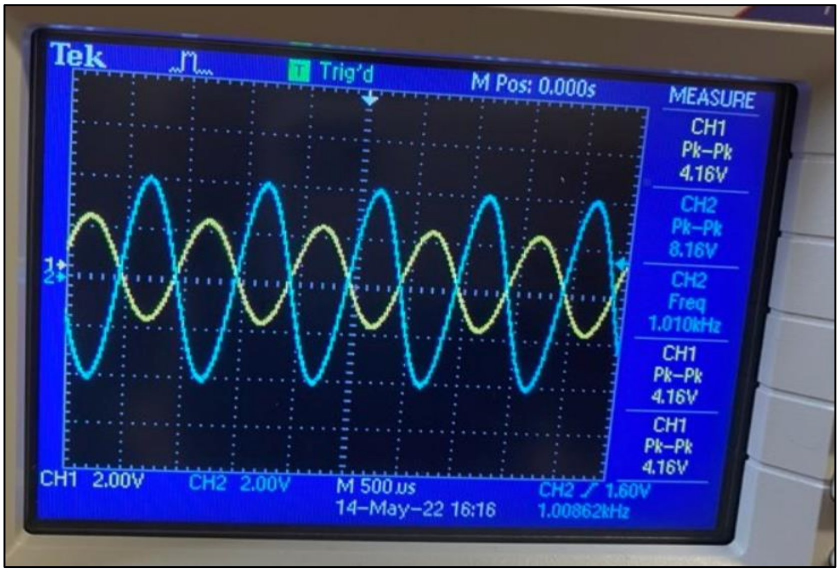


Figure 10 The input and output voltage signals.

And then the base voltage Vb(t) signal was measured **Vb(t)= 46 mV** as the following figure,

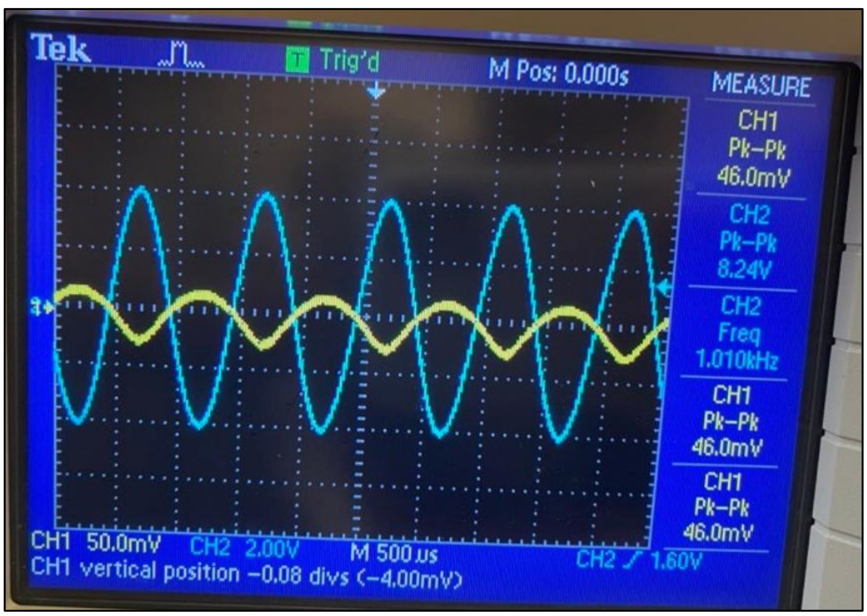


Figure 11 The base voltage signal.

Now, all the required values to find both the voltage gain Av and Av1 were found:

- $\boldsymbol{Av} = \frac{\boldsymbol{Voutput}}{\boldsymbol{Vinput}} = \frac{\mathbf{8.16}}{\mathbf{4.16}} = 1.96\,Volt.$
- $\boldsymbol{Av1} = \frac{\boldsymbol{Voutput}}{\boldsymbol{Vbase}} = \frac{\mathbf{8.16}}{\mathbf{46\ m}} = 177.39\,Volt.$

Using DMM, the AC current for both the base (Ib) and the collector (Ic) of the transistor was measured as the following:

- AC current for the base (Ib) = 32.63 uA.
- AC current for the collector (Ic) = 6.697 mA.

And the next step, the current gain which is the ration of the input current and the output current was calculated, the **output current** considered as the **sum of the Ib and Ic**, while the input current considered as the current of the base **Ib**:

- **Current gain** $= \frac{Ioutput}{Iinput} = \frac{6.70963\ mA}{32.63\ uA} = 205.62\ A.$
- **Input impedance** $= \frac{Vinput}{Iinput} = \frac{4.16}{32.63\ uA} = 127.49\ Kohm.$

Note: Unfortunately, we have forgotten to measure the output current and the input current using DMM, so I have used the relation of **(Ie= Ib+Ic)** to calculate the output current, while the input current considered as the same value of the current base **(Ib).**

Finally, to find the effect of the 100 Kohm resistor, it has been shorted and the following figure is the result of it, it is noticed that the voltage gain will be increased.

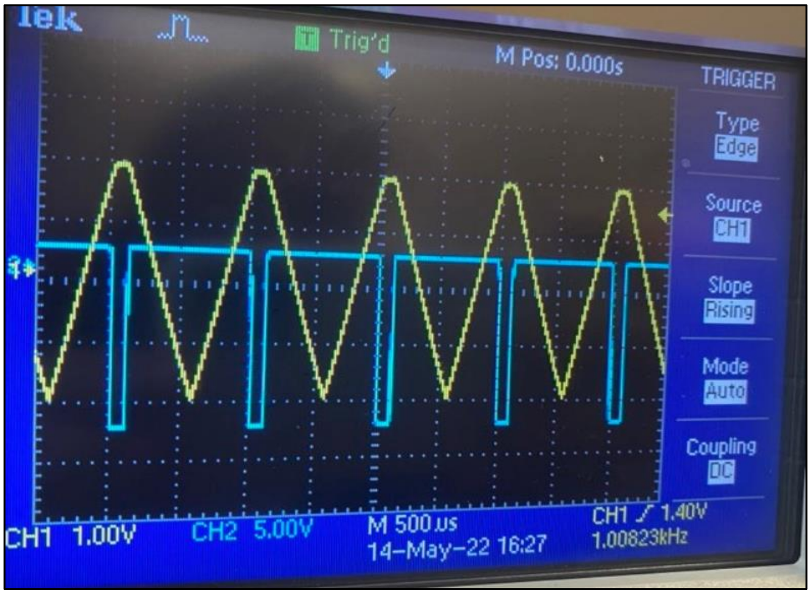


Figure 12 The effect of 100 Kohm resistor.

2.2 Common Collector Transistor Amplifier:

The first step in this part is that the following circuit with its elements was connected in the board, and the power supply was switched to 10 Volt. In addition, the generator was used to generate a frequency with 1 kHz, ,but either disconnecting its output ,or turn its output amplitude to zero, so there is no signal input to the circuit.

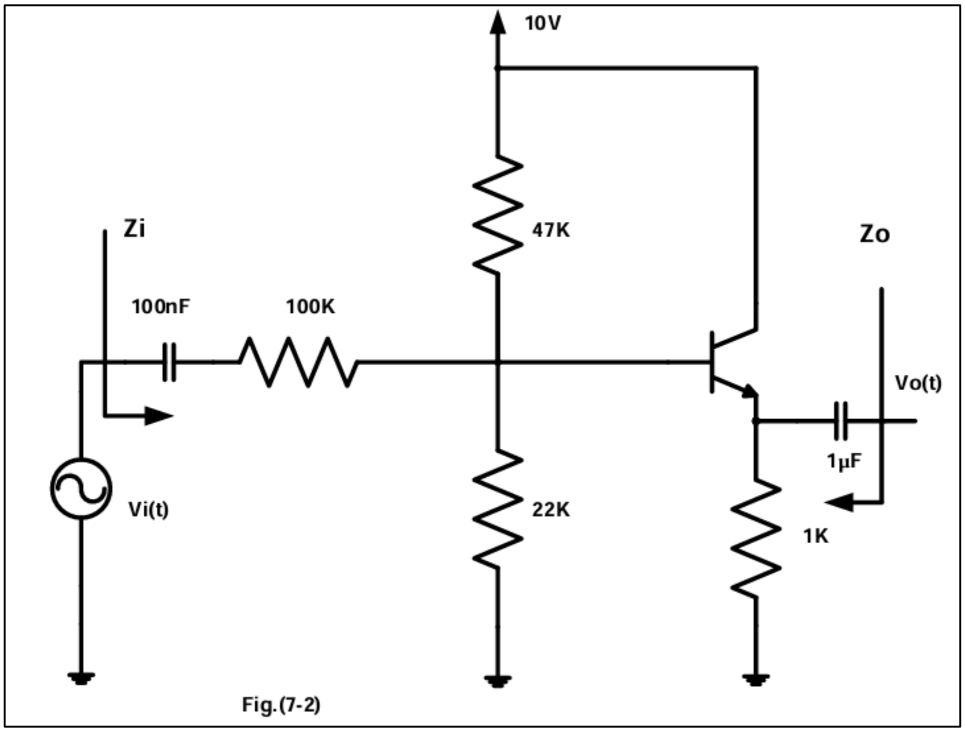


Figure 13 Common Collector Circuit.

Then, the quiescent bias voltages of the circuit VE and VB was measured using the DVM, and the results were as the following:

- **VB** = 3.007 V.
- **VE** = 2.356 V.

Figure 14 The base voltage in the common collector circuit.

The next step was to increase the amplitude of the sine wave generator until an output amplitude from the amplifier Vo(t) is about **2 Volts peak-to-peak** , as shown in the following figure. And from it is noticed that the amplitude of the amplitude of the input voltage which required to have a **2 Volts peak-to-peak output voltage** is:

Vi(t)= 16.8 V.

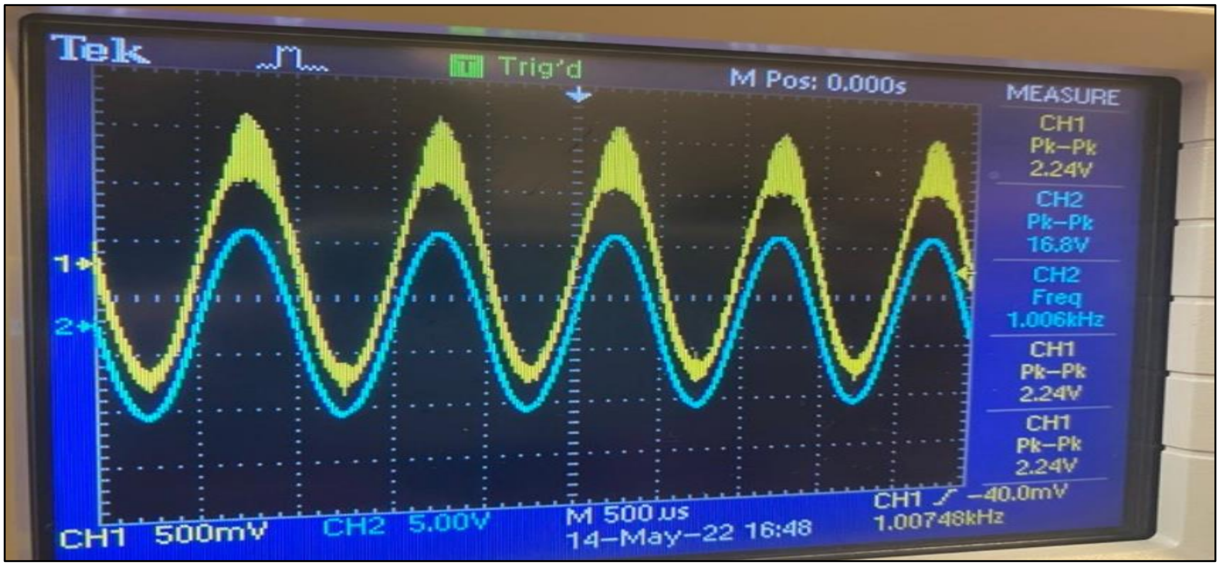


Figure 15 The input and output voltages sine wave.

Now, all the required values to calculate the voltage gain Av was found:

$$Av = \frac{Voutput}{Vinput} = \frac{2.24}{16.8} = 0.13333\,Volt.$$

The AC voltage across the 100 Kohm was also measured, the result was:

V100k_RMS = 5.048 V.

Figure 16 The voltage across the 100 Kohm resistor.

- ✓ **To calculate the current across the 100 Kohm resistor m the Ohms low was used as the following:**

$$Iin\_100k = \frac{V}{R} = \frac{5.048}{100\ k} = 5.048 * \ 10^{-5}.$$

- ✓ **From the output voltage and the load resistor value , the ac output current was calculated as the following:**

$$Iout = \frac{V}{R} = \frac{2.24}{1\ k} = 2.24\ mA$$

- ✓ **Now, all the required values to calculate the current gain Ai was found:**

$$Ai = \frac{Aoutput}{Ainput} = \frac{2.24m}{0.5048 * \ 10^{-5}} = 44.37$$

- ✓ **To find the input impedance Zin, the input and output voltage were used:**

$$Zin = \frac{Vin}{Iin} = \frac{16.8}{5.048 * \ 10^{-5}} = 3.328 * \ 10^{5}\ Ohm$$

Note: To find the output impedance of the amplifier, the input sine wave generator has to be removed with short circuit, and the generator to the output (emitter) has to be connected via a capacitor, but unfortunately, we have forgotten to do this step in order to find the output impedance.

- ✓ **The following table summarizes the measured and calculated results:**

Table 1 The results of common collector circuit.

Quantity	Measured Values
Vin	16.8 V
Vout	2.24 V
V100kohm	5.048 V
Iout	2.24 mA
	Calculated Values
Av=Vout/Vin	0.13333 V
Iin=V100k/100k	$5.048 * \ 10^{-5}$ A
Ai=Iout/Iin	44.37 A
Zin=Vin/Iin	$3.328 * \ 10^{5}$ Ohm

Note: To compare the parameters in the CC circuit with CE circuit, it is noticed that the voltage gain in the CC is less than 1, while in the CE is greater than 1.

2.3 Common Base Transistor Amplifier:

As previous steps, the first step in this part is to connect the following circuit in the board. In addition, the power supply was switched, and the variable dc voltage was set to 10 Volts, and the sine wave generator was set to a frequency of 1 Kohm.

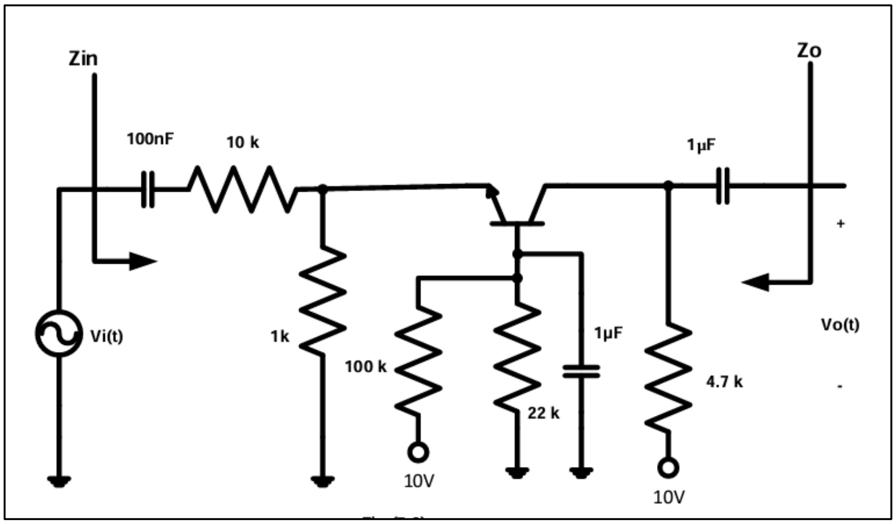


Figure 17 Common Base Circuit.

Using DMM, the values of the quiescent bias voltages and currents were recorded as the following:

- IB = 84.39 uA.
- IC = 1.09 mA.
- VBC = 3.247 V.
- VCE = 3.911 V.
- VBE = 0.637 V.

Figure 18 VBE in common emitter circuit.

The next step was to increase the amplitude of the input sine wave until the output sine signal has a 2 V peak-to-peak as the following:

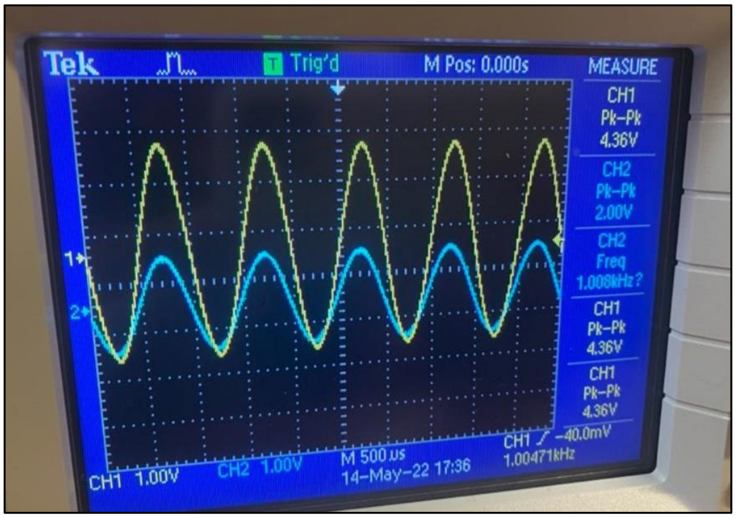


Figure 19 Vin and Vout in common emitter circuit.

- ✓ **From the previous figure, it is noticed that to get an output voltage with 2 V peak-to-peak, the input voltage with 4.36 V was required.**

Vi(t)= 4.36 V.

- ✓ **Now, all the required values to calculate the voltage gain Av was found:**

$$\boldsymbol{Av} = \frac{Voutput}{Vinput} = \frac{2.00}{4.36} = 0.4587\,Volt.$$

- ✓ **The AC voltage across the 10 Kohm was also measured, the result was:**

V10k= 1.491 V.

Figure 21 The AC voltage across 10 Kohm resistor.

- ✓ **We can calculate the input current across the input resistor as the following:**

$$Iin_{10k} = \frac{V}{R} = \frac{1.491}{10k} = 1.49 * 10^{-4}\,A$$

- ✓ **The output current can be calculated using the output voltage and the 4.7Kohm resistor as the following:**

$$Iout = \frac{V}{R} = \frac{2.00}{4.7k} = 4.2 * 10^{-4}\,A$$

- ✓ **Now, we have the input and output current, so the current gain can be calculated as the following:**

$$Ai = \frac{Ioutput}{Iinput} = \frac{4.2 * 10^{-4}}{1.49 * 10^{-4}} = 2.8187\,A$$

- ✓ **Calculating the input impedance Zin:**

$$Zin = \frac{Vin}{Iin} = \frac{4.36}{1.49 * 10^{-4}} = 29.26\,Kohm$$

- ✓ **To find the output impedance of the amplifier, the input sine wave generator was removed with short circuit, and the generator to the output (emitter) was connected via a capacitor:**

I=0.3117 mA and V=1.49 V.

Thus, $Zin = \frac{Vin}{Iin} = \frac{1.49}{0.3117 * 10^{-3}} = 4.78\,Kohm$

- ✓ **The following table summarizes the measured and calculated results:**

Table 2 The measured and calculated results in Common Base circuit.

Quantity	**Measured Values**
Vin	4.36 V
Vout	2.00 V
V10kohm	1.491 V
	Calculated Values
Av=Vout/Vin	0.4587 V
Iout=Vout/4.7k	$\mathbf{4.2 * 10^{-4}\,A}$
Iin=Vin/10k	$\mathbf{1.49 * 10^{-4}\,A}$
Ai=Iout/Iin	$\mathbf{2.8187\,A}$
Zin=Vin/Iin	$\mathbf{29.26\,Kohm}$
Zout=Vout/Iout	$\mathbf{4.78\,Kohm}$

3. Conclusion

This experiment has covered many concepts and applications for the BJT transistor amplifier in common emitter, common collector, and common base connection circuits. And many AC parameters were measured and calculated such as input and output impedance, voltage gain, and the current gain. Most measured and calculated values were in the accepted range such as voltage gains and current gains.

4. References

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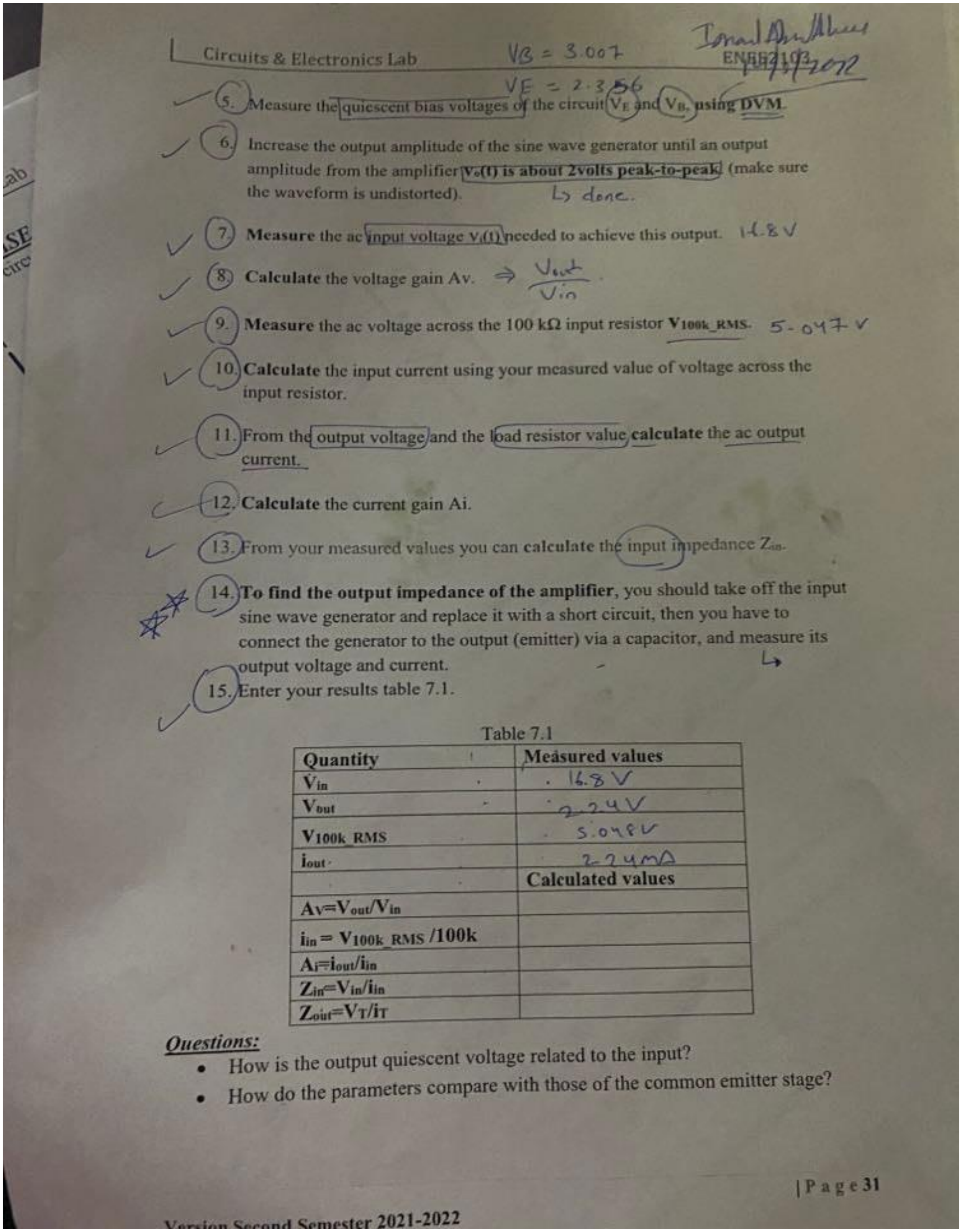
5. Appendixes



Circuits & Electronics Lab $V_B = 3.007$ ENEE2103

$V_E = 2.356$

5. Measure the quiescent bias voltages of the circuit V_E and V_B, using **DVM**.

6. Increase the output amplitude of the sine wave generator until an output amplitude from the amplifier **$V_o(t)$ is about 2volts peak-to-peak** (make sure the waveform is undistorted).
↳ done.

7. **Measure** the ac input voltage $V_i(t)$ needed to achieve this output. 16.8 V

8. **Calculate** the voltage gain Av. $\Rightarrow \frac{V_{out}}{V_{in}}$

9. **Measure** the ac voltage across the 100 kΩ input resistor $\mathbf{V_{100k\_RMS}}$. 5.047 V

10. **Calculate** the input current using your measured value of voltage across the input resistor.

11. From the output voltage and the load resistor value **calculate** the ac output current.

12. **Calculate** the current gain Ai.

13. From your measured values you can **calculate** the input impedance Z_{in}.

14. **To find the output impedance of the amplifier**, you should take off the input sine wave generator and replace it with a short circuit, then you have to connect the generator to the output (emitter) via a capacitor, and measure its output voltage and current.

15. Enter your results table 7.1.

Table 7.1

Quantity	Measured values
V_{in}	16.8 V
V_{out}	2.24 V
V_{100k_RMS}	5.048 V
i_{out}	2.24 mA
	Calculated values
$A_V = V_{out}/V_{in}$	
$i_{in} = V_{100k\_RMS}/100k$	
$A_i = i_{out}/i_{in}$	
$Z_{in} = V_{in}/i_{in}$	
$Z_{out} = V_T/i_T$	

Questions:

- How is the output quiescent voltage related to the input?
- How do the parameters compare with those of the common emitter stage?

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III. COMMON BASE TRANSISTOR AMPLIFIER

1. Connect the circuit of Fig. (7.3).

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14/5/2022

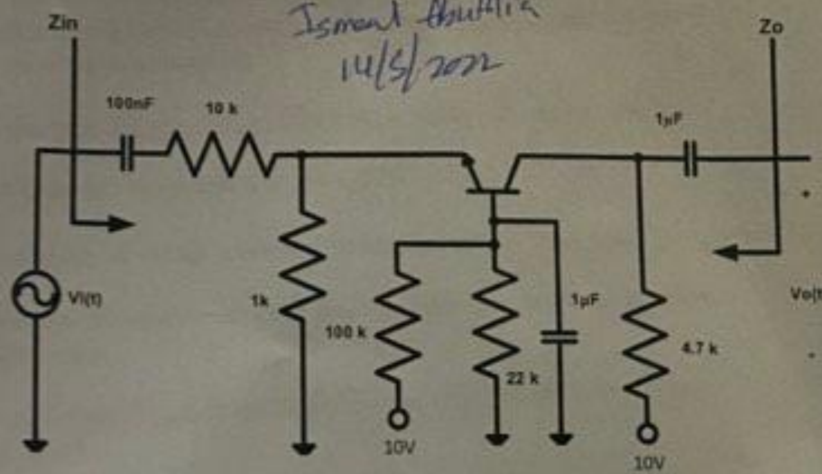

Fig.(7-3)

2. Ensure that the variable dc control is at min.

3. Switch on the power supply and adjust the variable dc voltage to give a Vcc of +10 volts.

4. Set the sine wave generator to a frequency of 1 kHz ,but either disconnect its output ,or turn its output amplitude to zero, so there is no ac signal input to the circuit.

5. Measure and record the quiescent bias voltages and currents I_B, I_C, V_{BE} , V_{BC} and V_{CE}.
,using DVM.
$I_c = 1.09mA$ $V_{CE} = 3.911$ $I_B =$
$V_{BC} = 3.247$ $V_{BE} = 0.837$

6. Increase the output amplitude of the sine wave generator until an output amplitude from the amplifier is about $\boxed{\text{2volts peak-to-peak}}$ → done

7. Measure the ac input voltage needed to achieve this output. What happens if the ac input is increased further? → $\boxed{4.36V}$

8. Calculate the voltage gain Av.

9. Measure the ac voltage across the 10 kΩ input resistor. $V_{10k\Omega} = 1.461\ V$

10. Calculate the input current using your measured value of voltage across the input resistor.

15. From the output voltage and the load resistor value (4.7k) calculate the ac output current io(t).

16. Calculate the current gain.

Ismail AbuAli
14/6/2022

17. From your measured values, you can calculate the input impedance Z_{in}.

18. To find the output impedance of the amplifier, you should take off the input sine wave generator and replace it with a short circuit, then you have to connect the generator to the output (collector) via a capacitor, and measure its output voltage and current.

$V = 1.51V$
$V_{DM} = 1.491$
$I_{RMS} = 0.3117m$

19. Enter your results in a table 7.2.

Table 7.2

Quantity	Measured values
V_{in}	4.36 V
V_{out}	1.00V
V_{10k_RMS}	1.491V
	Calculated values
$A_V=V_{out}/V_{in}$	
$i_{out}= V_{out}/4.7k$	
$i_{in} = V_{10k\_RMS}/10k$	
$A_I=i_{out}/i_{in}$	
$Z_{in}=V_{in}/i_{in}$	
$Z_{out}=V_T/I_T$	

Questions:

- How is the output quiescent voltage related to the input?
- How do the parameters compare with those of the common emitter stage?