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BIRZEIT UNIVERSITY

Faculty of Engineering and Technology

Electrical and Computer Engineering Department

ENEE2103 - Circuits and Electronics Laboratory

Exp7: BJT Transistor as An Amplifier, CE, CC, CB Connection

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1. Abstract

The purpose of the experiment was to be familiar with a transistor as an amplifier and its various circuit configuration including common base, common collector and common emitter, to distinguish between AC and DC analysis to establish the regarded voltages and current and find the maximum current and voltages requires before distortion happen , we used AC analysis to find some parameters for example the voltage gain , current gain , input resistance , output resistance .

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2. Theory

Transistor

It is an electrical device with three layers (NPN –PNP), used widely in integrated circuits, mainly as amplification, also as a switching. From the figure 1 we can see the three terminals of the transistor (C-collector, E-emitter, B- base).

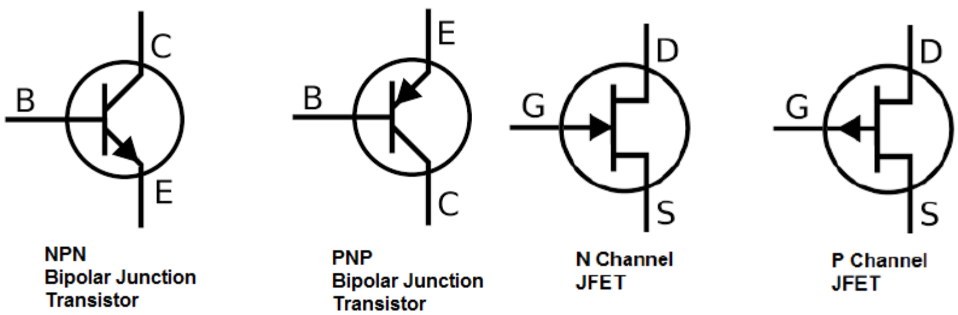

Figure 1: Transistors [1]

There are two types of transistor which are field effect transistor (FET) and bipolar junction transistor (BJT).

They operate in three different regions which are active region, cut-off region and saturation.

There are three basic configurations of the terminal of the transistor with different voltage gain and current gain which are Common Base (CB) with voltage gain, nor current gain, Common Collector (CC) with current gain nor voltage gain and Common Emitter (CE) with voltage and current gain.

Because the common element is often grounded, these configurations are frequently referred to as grounded emitter, grounded base, and grounded collector.

- ## Common Emitter

In this connection the input is connected to the emitter and the output is from the collector, it gives a negative voltage gain also a current gain, thus is works as an inventor circuit and the output will be anti-phase of the input (180°). see figure3.

It has a high voltage from the base part that will increase the base current as well as the collector current because of the relation IC=β IB, a load resistance is usually connected in this circuit its voltage increase as the collector current increase, so the voltage gain is affected by the value of the load resistance (Vout), it increases as the resistance increased. See figure 2.

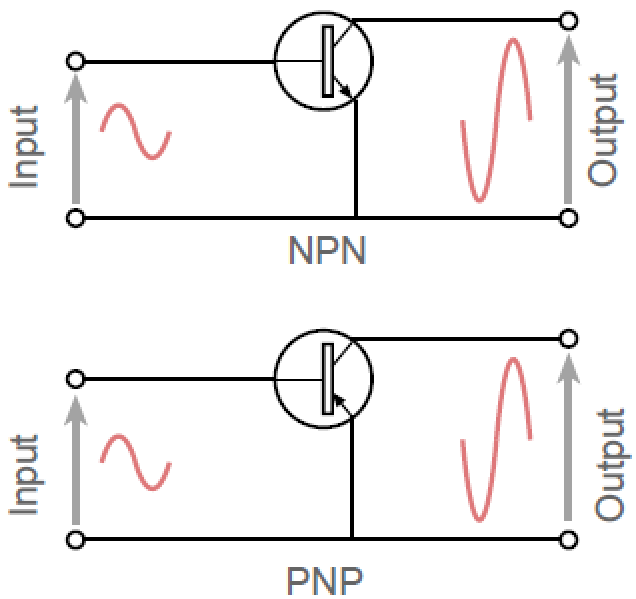

Figure 2: common emitter [2]

The ratio of Ic/Ib is β, while Ic/Ie is α

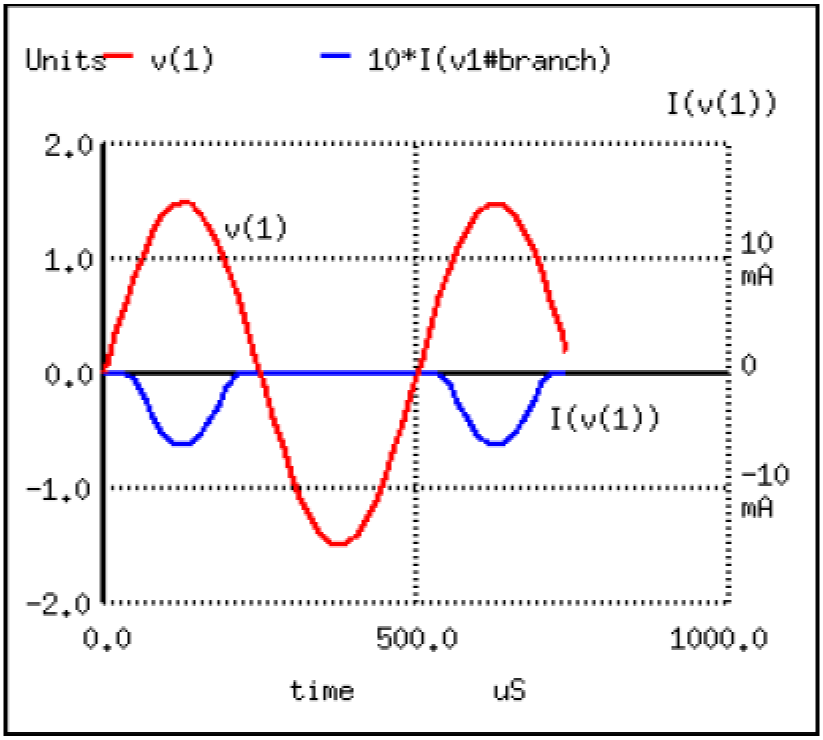

Figure 3: Common Emitter input –output voltages [3]

- **Common Collector**

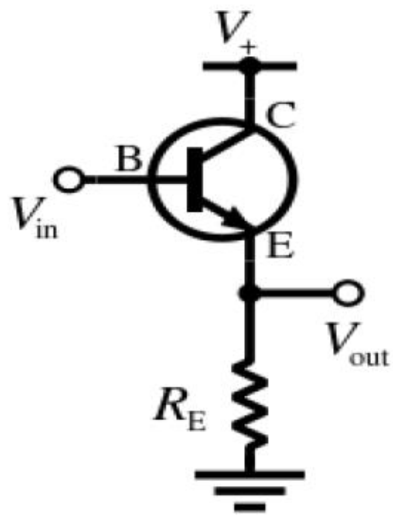

Figure 4: Common Collector [4]

In this configuration the input is connected to the base, and the output from the emitter, while the collector is common to both, and it's often called an emitter follower since its output is taken from the emitter.See figure 4

Its input impedance is much higher than its Output impedance, and it has a voltage gain of almost

$$A_v = \frac{v_{out}}{v_{in}} \approx 1 \qquad \text{unity:}$$

The load resistance in the common _collector receives

the base and the collector, since the emitter is the sum of the base and collector current it will be reasonable that this circuit will produce a large current gain.

When applying an AC signal to the input with the presence of the Dc voltage to keep the transistor in an active mode, the result is a non-inverting amplifier.

As seen from figure 5 the input and output signals are the same peak to peak amplitude

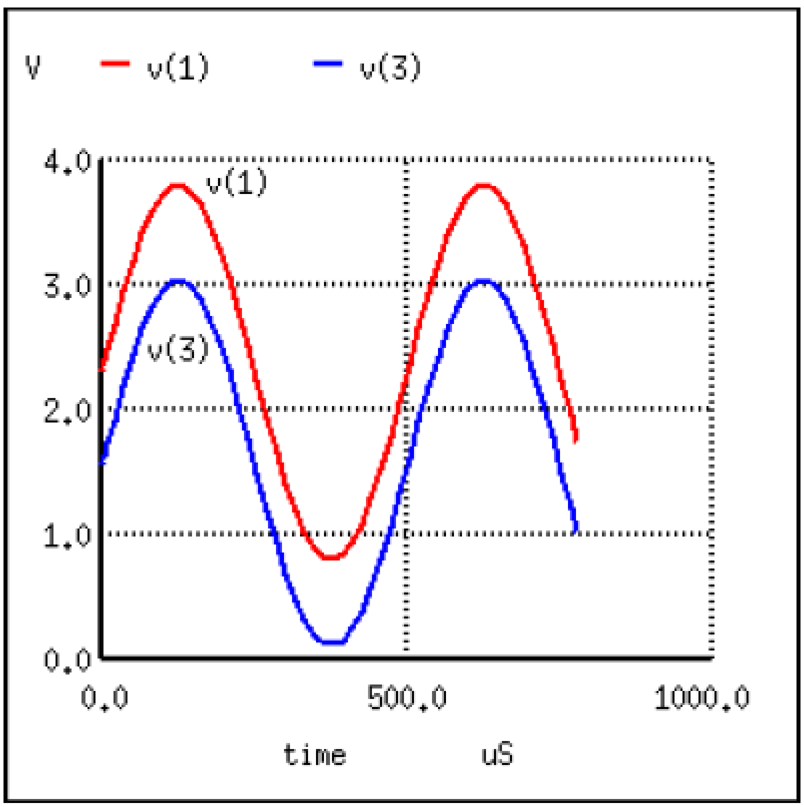

Figure 5: input and output voltage [5]

The load is situated in series with the emitter, and thus the current flowing through it is the emitter current, with the emitter carrying base and collector the load has all collector current running through it plus the base, this implies a current gain of β +1:

Ai=I emitter/I base

= (I collector + I base)/I base

= (I collector/I base) +1

= β+1

- **Common Base**

The input signal is applied to the emitter, and the output from the collector while the base common to both. See figure 6.

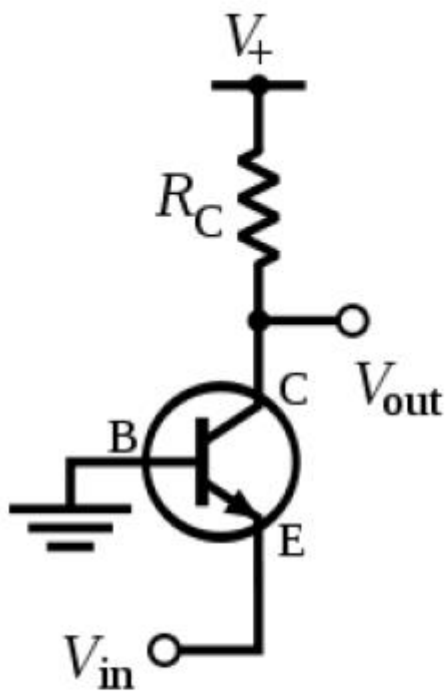

Figure 6: Common Base [6]

Since the input is applied to the emitter, it causes the emitter-base junction to react in the same manner as it did in the common-emitter circuit. For example, an input that aids the bias will increase transistor current, and one that opposes the bias will decrease transistor current.

It is mainly used for impedance matching, since it has a low input resistance and a high output resistance. However, two factors limit its usefulness in some circuit applications its low input resistance and its current gain of less than 1.

The current gain in the common-base circuit is calculated in a method similar to that of the common emitter except that the input current is I E not IB and the term ALPHA is used in place of beta for gain.

The voltage gain and the current gain amplifier equal

$$A_v = V_{out}/V_{in}, \quad A_i = I_C/I_B.$$

3. Procedure and Discussion

3.1 Common Emitter Transistor Amplifier.

After the circuit was connected as shown in figure 7:

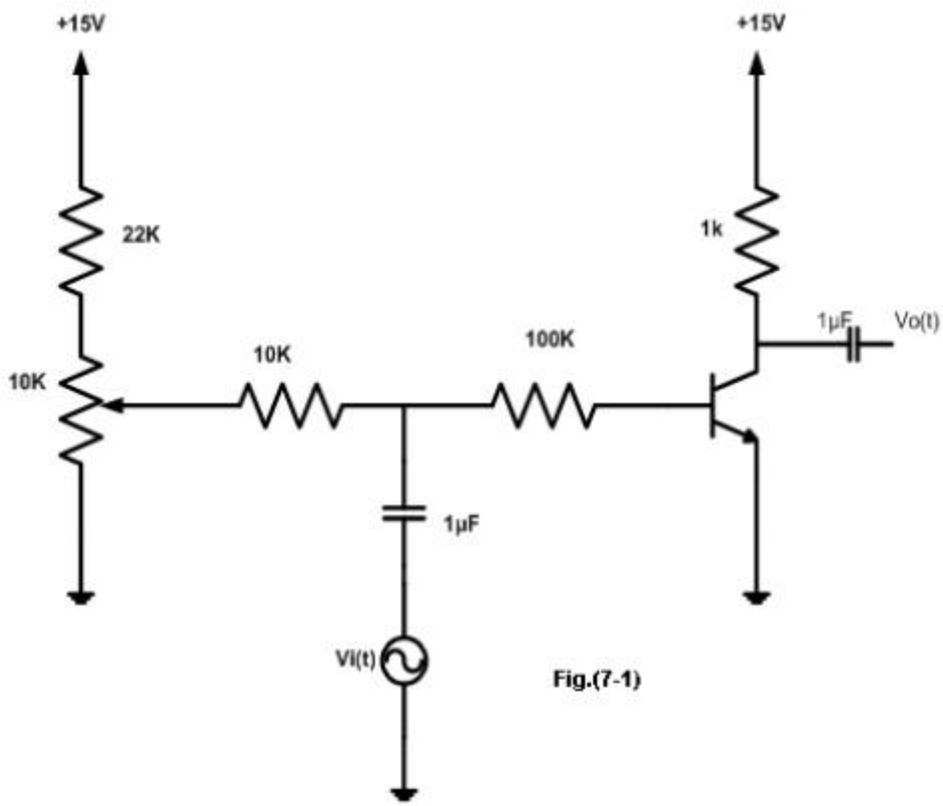

Figure 7: CE amplifier with voltage divider – bias

Function generator set there frequency to 1 kHz sine wave and amplitude to zero.

Then the base bias potentiometer was adjusted for a DC collector voltage (Vc) of 8 volts.

The measurements were:

Table 1

Current		Voltage		
Ic	**Ib**	**V_{CE}**	**V_{BC}**	**V_{BE}**
6.9mA	21.46uA	8.2v	10.8v	0.66v

As DC Analysis was made, the function generator output was turned up until the output of the circuit is 8 volts peak-to-peak, the input voltage was equal 2.68V, the figure below shown the voltages of the input which connected to channel 1 and the output which connected to channel 2.

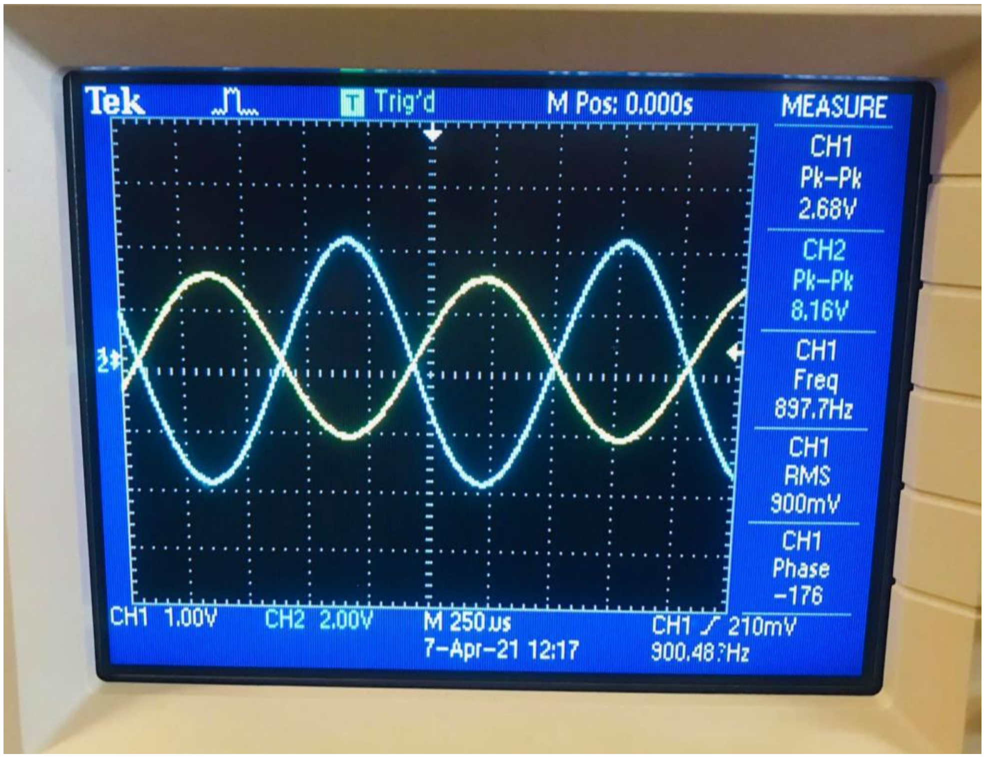

Figure 8: input wave form

Then the oscilloscope connected to the base and the output of the circuit, as shown in figure below channel 1 connected to show VB which is equal 13.8mV and channel 2 to the input voltage:

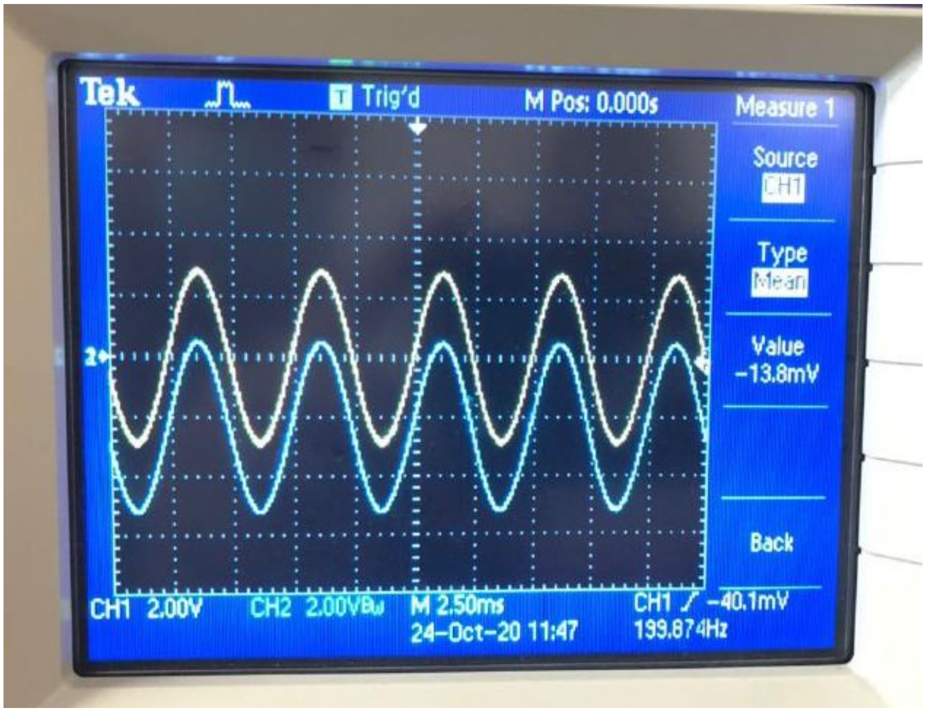

Figure 9: Vb

Voltage gain of the transistor (Av) = $\frac{Vo}{Vin} = \frac{4}{1.35} = 2.9629$v Eq.1

$$Av1 = \frac{Vo}{VB} = \frac{4v}{0.66v} = 6.06$$ Eq.2

After that DMM was used to measure the AC currents for both the base and the collector of the transistor

The results were:

Table 2

Ic	Ib
2.83mA	**11.43µA**

$Current\ gain\ of\ the\ amplifier = \frac{Iout}{Iin} = 247.59$ Eq.3

The input impedance Zi = $\frac{Vin}{Iin} = 118.11K\Omega$ Eq.4

Noticed that the effect of 100KΩ resistor in voltage gain was nothing, Av wasn't changed when remove this resistor, but Av1 was decreased as a result of increased in Vb.

3.2 Common Collector Transistor Amplifier

After the circuit was connected as shown in figure 10 below:

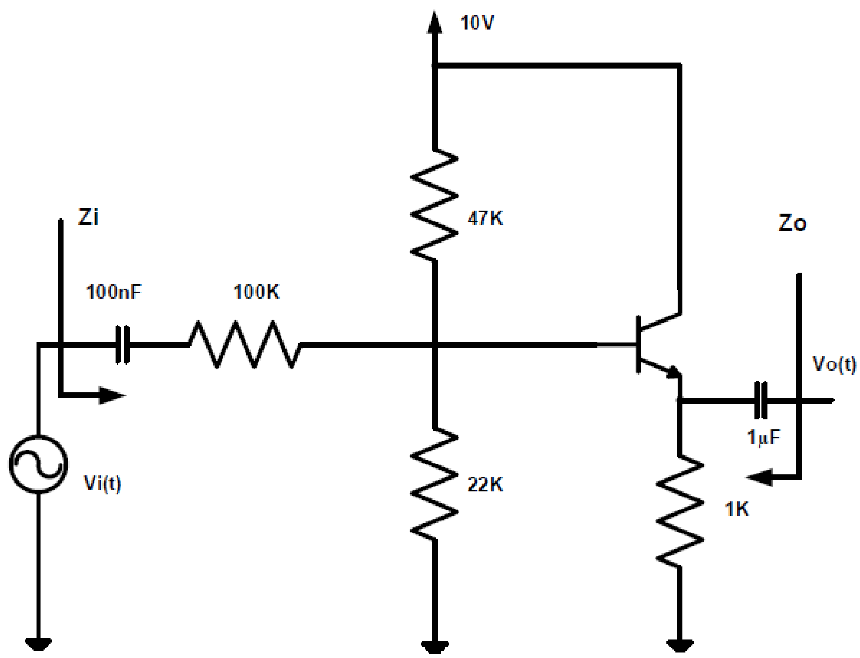

Figure 10: Common Collector Transistor Amplifier

Function generator was set to 1KHz and amplitude to zero, and Vcc to 10 Volt.

Using the DVM, the quiescent bias voltages of the circuit V_E and V_B was:

$VE = 1.67V$, $VB = 2.48V$ and Vc=10.03V

Amplitude of the input sinusoidal wave was increased until 19.2V peak-peak to get Vout with 2V peak-peak, and ac input was 6.45V RMS as shown in figure 11:

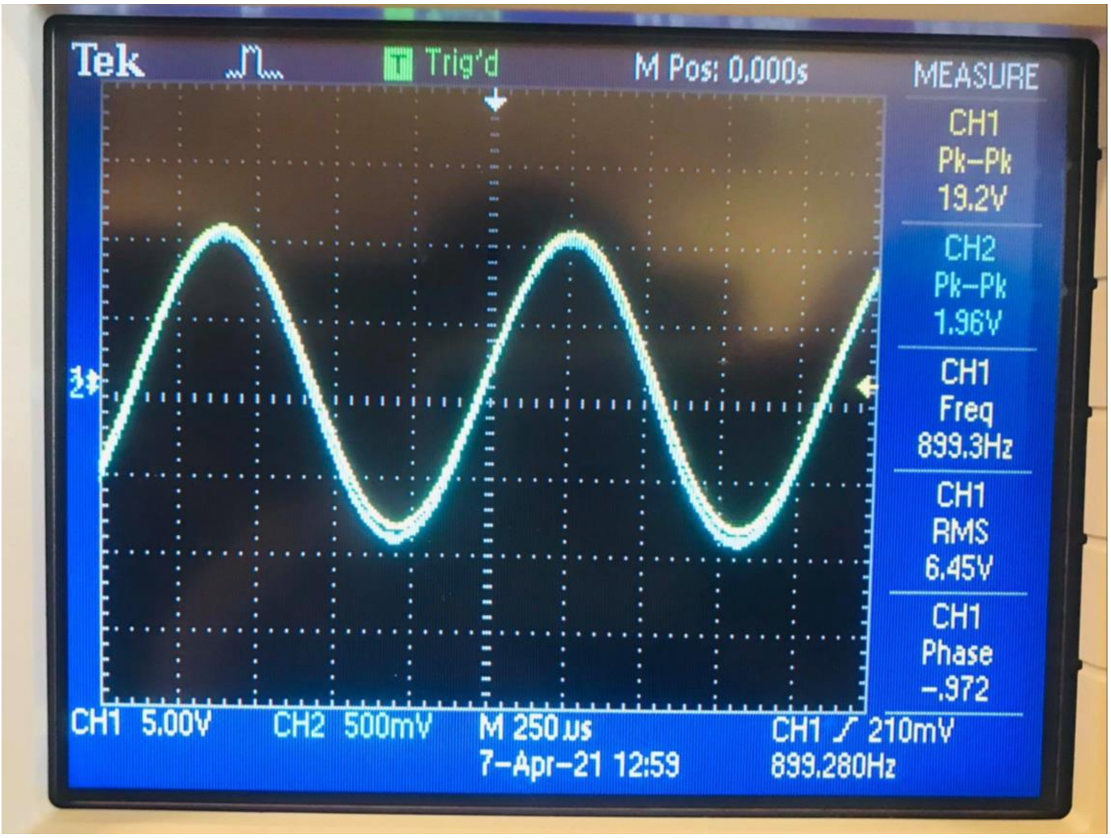

Figure 11: Peak_to_Peak value of Vin and Vout

$$Av = \frac{Vo}{Vi} = \frac{0.708Vrms}{6.45rms} = 0.1044$$

Ac voltage across the 100kohm input resistor was:

$$Vri = 5.026\ volt\ rms$$

So the current across the resistor is:

$$Ii = \frac{Vri}{Ri} = \frac{5.026}{100k} = 5.026\mu A\ rms$$

Ac output current: $$Io = \frac{Vo}{RL} = \frac{0.708}{1K} = 708\mu A\ rms$$

Current gain: $Ai = \frac{Io}{Ii} = \frac{708\mu A}{140.8uA} = 140.8$

Input Impedance: $(Zi) = \frac{Vi}{Ii} = \frac{6.78}{140.8uA} = 182.883\ k\Omega$

Finding the output impedance of the amplifier was done by that the input sine wave generator was removed and replaced with a wire to make it short circuit and connected to the emitter via capacitor, and its output and current were measured.

V_T = 1 rms, I_T= 4.236mA rms

So, $Zo = \frac{Vt}{I_T} = 236.07\Omega$

Result of this part was put in the table below:

Table 3

Quantity	**Measured values**
V_{in}	**9.5v**
V_{out}	**1v**
i_{in}	**140uA**
i_{out}	**3.3mA**
	Calculated values
$A_V=V_{out}/V_{in}$	**0.104**
$A_i=i_{out}/i_{in}$	**$0.024 * 10^3$**
$Z_{in}=V_{in}/i_{in}$	**0.183MΩ**
Z_{out}	**0.236kΩ**

After our calculation it can be noticed that:

- Voltage gain is too small and less than 1 so there is Attenuation, where as in common emitter circuit the voltage gain is more than 1 so there is Amplification.
- The input impedance in common collector is too high and in common emitter is in middle.

3.3 Common Base Transistor Amplifier

After the circuit was connected as shown in figure 10 below:

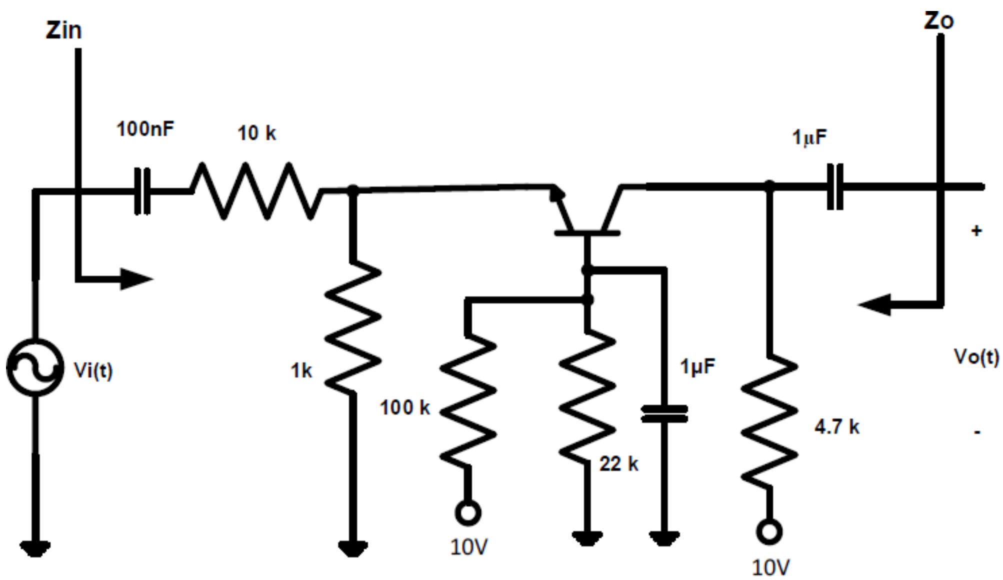

Figure 12: Common Base Transistor Amplifier

Function generator was set to 1kHz and amplitude to zero, and Vcc to 10 Volt.

Using the DVM, the quiescent bias voltages and currents of the circuit was:

Table 4

I_B	I_C	V_{BE}	V_{BC}	V_{CE}
75.51mA	**1.6mA**	**0.7v**	**6.3v**	**7.1v**

Amplitude of the input sinusoidal wave was increased until 4.72V peak-peak to get Vout with 2V peak-peak, and ac input was 1.59V RMS as shown in figure 13:

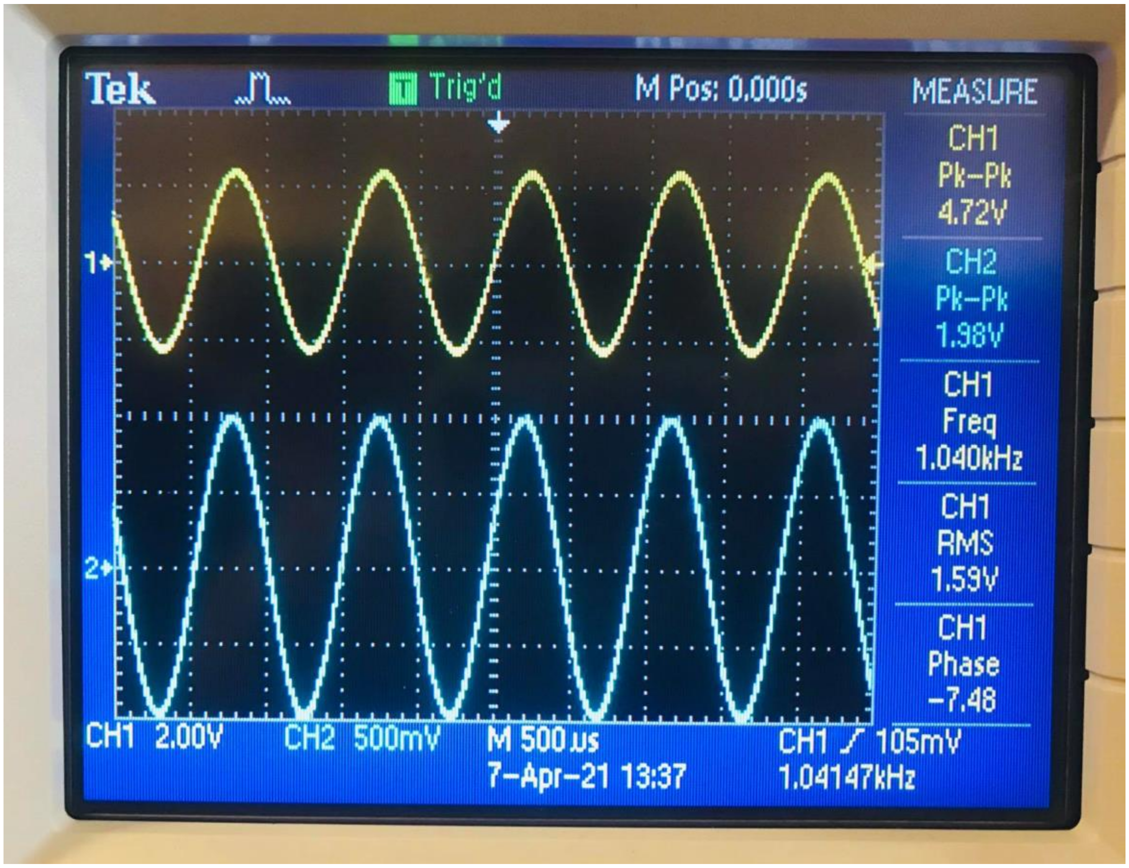

Figure 13: Inout and output waveform

$$Av = \frac{Vo}{Vi} = \frac{1V}{2.36V} = 0.4237$$

Ac voltage across the 10kΩ input resistor was:

$$Vri = 1.4285Vrms$$

The input current used measured value of voltage across the input resistor:

$$Iin = \frac{4p\_p}{R_{10k}} = 0.4mA$$

The output current used value of output voltage and load resistor:

$$Iout = \frac{2p\_p}{R_{4.7k}} = 0.21mA$$

Current gain: $$Ai = \frac{Io}{Ii} = \frac{0.21mA}{0.4mA} = 0.525$$

Input Impedance: $$(Zi) = \frac{Vi}{Ii} = \frac{2.36v}{0.4mA} = 5.9\ k\Omega$$

Finding the output impedance of the amplifier was done by that the input sine wave generator was removed and replaced with a wire to make it short circuit and connected to the emitter via capacitor, and its output and current were measured.

$V_T = 2v$, $I_T = 0.4mA$

So, $$Zo = \frac{Vt}{I_T} = 5k\Omega$$

Result of this part was put in the table below:

Table 4

Quantity	Measured values
V_{in}	4.72v
V_{out}	1v
i_{in}	0.4mA
i_{out}	0.21mA
	Calculated values
$A_V=V_{out}/V_{in}$	0.4237
$A_i=i_{out}/i_{in}$	0.525
$Z_{in}=V_{in}/i_{in}$	5.9kΩ
Z_{out}	5kΩ

Note: all calculation during the lab is attached in appendix A.

4. Conclusion

In this experiment we learned about BJT and especially about configurations of BJT circuits and how to connect circuit's components and how to measure the DC and AC quantities and find the characteristics of each configuration which are voltage gain, current gain, input impedance, output impedance.

We had some problems with the tools however in end we solved these problems and the results we got practically are generally accepted with the theoretically values.

5. References

[1] http://www.learningaboutelectronics.com/Articles/Electronic-schematic-symbols.php

[2] https://www.electronics-notes.com/articles/analogue_circuits/transistor/transistor-common-emitter-configuration.php

[3]http://www.learningelectronics.net/vol_3/chpt_4/5.html

[4] https://fr.wikipedia.org/wiki/Transistor_bipolaire

[5] http://www.vias.org/feee/bjt_07.html

[6] https://commons.wikimedia.org/wiki/File:NPN_common_base.svg

Appendix A

ENEE2103 — Circuits & Electronics Lab

BJT Transistor As An Amplifier, CE, CC, CB Connection

Objectives:

1. To investigate the effect of applying sinusoidal signal to a transistor connected in common emitter.
2. To investigate the properties of the transistor amplifier in common emitter, common collector, and common base connection.

Pre-lab Work

1. Simulate the circuits in the procedure section and determine the required values (set the parameters that must be assigned by the instructor in the procedure to proper values).
2. Verify if Simulation Results match the expected results

Procedure:

I. ***COMMON EMITTER TRANSISTOR AMPLIFIER.***

A.CE amplifier with voltage divider - bias

1. Connect the circuit of Fig. (7.1).

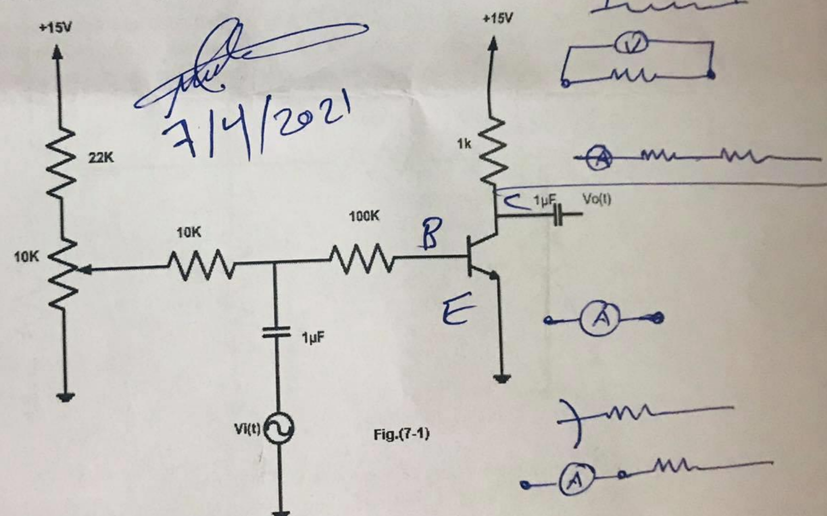

Fig.(7-1)

2. Switch on the power supply and the function generator.
3. Set the function generator frequency to 1 kHz sine wave and amplitude to zero.
4. Adjust the base bias potentiometer for a DC collector voltage (V_C) of 8 volts or as close as possible to it. Measure and record I_C, I_B, V_{CE}, V_{BE} and V_{BC}
5. Switch on the oscilloscope and connect its channels to the base and the output of the circuit.

$I_C = 6.9mA$ $V_{CE} = 8.2V$
$I_B = 21.46 \mu A$ $V_{BC} = 10.8V$
$V_{BE} = 0.6V$

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6. Turn up the function generator output until the output of the circuit is 8 volts peak-to – peak.(make sure there is no distortion due to saturation or cut-off)
7. Use oscilloscope to measure and record the input signal $v_i(t)$, the base voltage $V_B(t)$ and the output signal $V_o(t)$. 4 / 1.4
8. Calculate the voltage gain of the transistor $Av = Vo\ (t) / Vi\ (t)$ and $Av_1 = Vo\ (t) / V_B\ (t)$ → 4/0.66
9. Using DMM measure the AC currents for both the base and the collector of the transistor.
10. Calculate the current gain of the amplifier and the input impedance of the transistor amplifier.
11. What is the effect of the 100 kΩ resistor on the voltage gain? Zi

II. COMMON COLLECTER TRANSISTOR AMPLIFIER.

1. Connect the circuit of Fig. (7.2).

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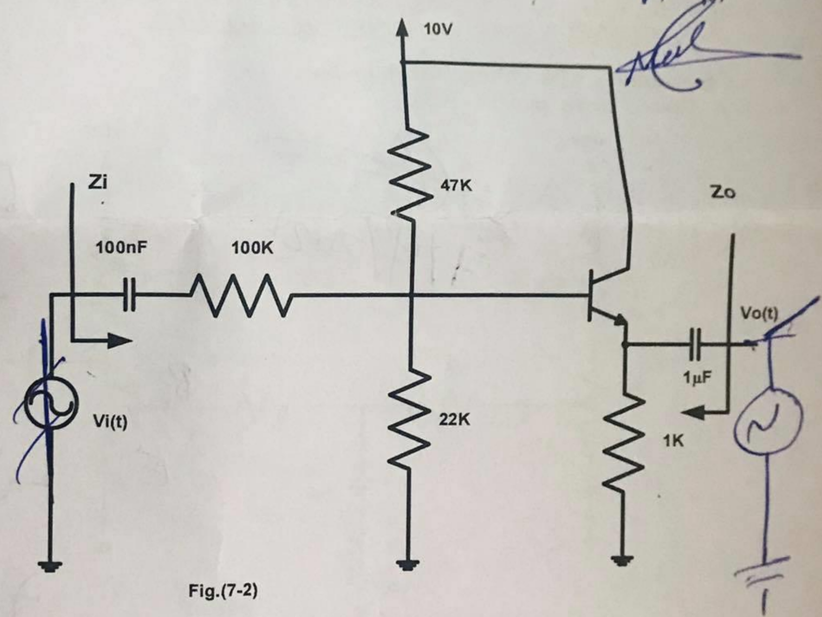

Fig.(7-2)

2. Ensure that the variable dc control knob is at minimum.
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 signal input to the circuit.
5. Measure the quiescent bias voltages of the circuit V_E and V_B, using DVM.
   1.6V 2.4V

6. Increase the output amplitude of the sine wave generator until an output amplitude from the amplifier is about 2volts peak-to-peak. (make sure the waveform is undistorted).
   V_{in} = 19 Pk-Pk / V_{out} = 2 Pk-Pk
7. Measure the ac input voltage needed to achieve this output.
8. Calculate the voltage gain Av.
9. Measure the ac voltage across the 100 kΩ input resistor. V_r = 5.026V rms
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}.

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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.

Quantity	Measured values
V_{in}	9.5V
V_{out}	1V
i_{in}	140 uA
i_{out}	3.3 mA
	Calculated values
$A_V=V_{out}/V_{in}$	0.104
$A_i=i_{out}/i_{in}$	0.024 x10³
$Z_{in}=V_{in}/i_{in}$	0.183 x10⁶ Ω
Z_{out}	0.236 KΩ

Table 7.1

Questions:

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

III. COMMON BASE TRANSISTOR AMPLIFIER

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

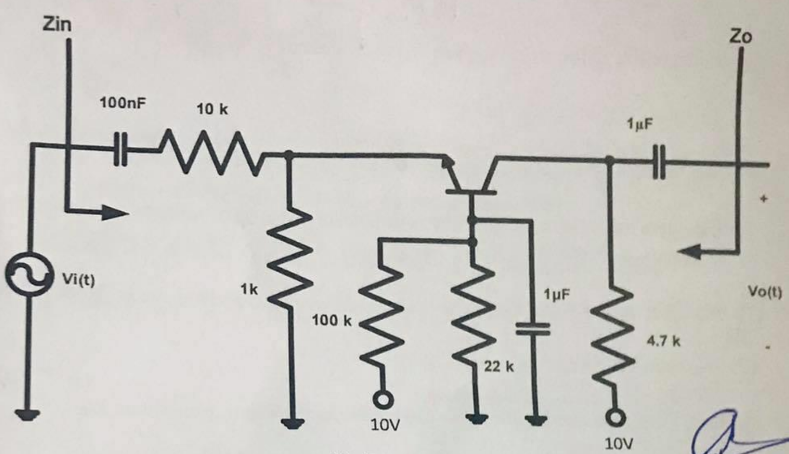

Fig.(7-3)

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.
6. Increase the output amplitude of the sine wave generator until an output amplitude from the amplifier is about 2volts peak-to-peak.
7. Measure the ac input voltage needed to achieve this output. What happens if the ac input is increased further?
8. Calculate the voltage gain Av.
9. Measure the ac voltage across the 10 kΩ input resistor.
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.
16. Calculate the current gain.