BIRZEIT UNIVERSITY

Faculty of Engineering & Technology – Electrical & Computer Engineering Department

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Circuits and electronics lab

ENEE2103

Report EXP.7

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

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1. Abstract

In this experiment, we will investigate the effect of applying sinusoidal signal to a transistor connected. In addition, we will understand the properties of the transistor as an amplifier in different common circuits' types. Finally, we will get to all concepts about transistor and his importance in circuits.

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2. Theory

▪ BJT Construction and Operation

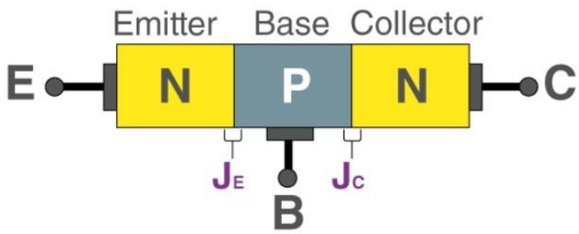

Figure 2.1 Symbol of NPN BJT

BJT is a semiconductor device that is constructed with 3 doped semiconductor Regions i.e. Base, Collector & Emitter separated by 2 p-n Junctions as shown in figure 2.1. Bipolar transistors are manufactured in two types, PNP and NPN, and are available as separate components, usually in large quantities.[1]

▪ Transistor Biasing

As we learned before, the BJT has 4 regions of biasing junction biases. They are: active region, saturation region, cut off region, reverse-active region. As shown in the table 2-1.

Junction type	Applied voltages	BE junction	BC junction	Mode
PNP	E < B <C	Forward	Reverse	Active region
	E < B > C	Forward	Forward	Saturation
	E > B <C	Reverse	Reverse	Cut-off
	E > B >C	Reverse	Forward	Reverse-active
NPN	E < B <C	Reverse	Forward	Reverse-active
	E < B > C	Reverse	Reverse	Cut-off
	E > B <C	Forward	Forward	Saturation
	E > B >C	Forward	Reverse	Active

Table 2-1 regions of operations

[1] https://byjus.com/physics/bipolar-junctionhttps://byjus.com/physics/bipolar-junction-transistor/ - :~:text=BJT%20is%20a%20semiconductor%20device,components%2C%20usually%20in %20large%20quantitiestransistor/#:~:text=BJT%20is%20a%20semiconductor%20device,components %2C%20usually%20in%20l arge%20quantities. In 9/12/2022 at 4:00 pm

- ✓ The active mode is that region in which the emitter-base junction is forward bias while the collector-base junction is reverse bias.
- ✓ Saturation Mode is the on mode of a transistor. A transistor in saturation mode acts like a short circuit between collector and emitter.
- ✓ Cutoff mode is the opposite of saturation. A transistor in cutoff mode is off -- there is no collector current, and therefore no emitter current. It almost looks like an open circuit.
- ✓ Reverse active is like active mode, the current is proportional to the base current, but it flows in reverse. Current flows from emitter to collector.[2] Important formulas:
- ✓ $I_c = \beta I_b$
- ✓ $I_c = (\beta+1) I_e$
- ✓ $I_c = \alpha I_e$
- ✓ $\alpha = \frac{\beta}{\beta+1}$
- ✓ $\beta = \frac{\alpha}{1-\alpha}$

▪ BJT configurations

As the Bipolar Transistor is a three terminal device, there are three possible ways to connect it within an electronic circuit with one terminal being common to both the input and output signals. Each method of connection responding differently to its input signal within a circuit as the static characteristics of the transistor vary with each circuit arrangement, as shown in table 2-2 and figure 2.2.[3]

Parameters	CE	CC	CB
Zin	Medium	High	Low
Zout	High	Low	Very high
Av	Medium	Low	High
Ai	Medium	High	Low
Cut-off Freq	Low	Medium	High

2 https://learn.sparkfun.com/tutorials/transistors/operationhttps://learn.sparkfun.com/tutorials/transistors/operation-modes - :~:text=A%20transistor%20in%20reverse%20active,direction%2C%20from%20emitter%20to%20collectormodes#:~:text=A%20transistor%20in%20reverse%20active,direction%2C%20from%20emitter%20to%20 collector. In 9/12/2022 at 4:25 pm

3 https://www.electronics-tutorials.ws/transistor/tran_1.html in 9/12/2022 at 4:42 pm

Voltage phase shift	180	0	0

Table 2-2 properties of configurations

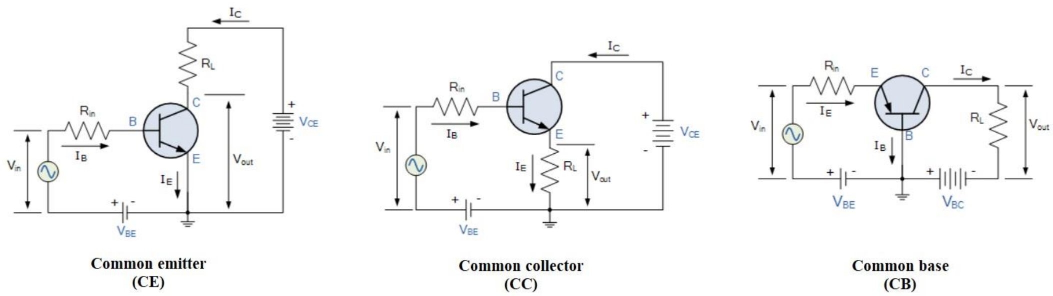

Figure 2.2 BJT configuration types

- **The Common Base Transistor Circuit (CB)**

This type of amplifier configuration is a non-inverting voltage amplifier circuit, in that the signal voltages Vin and Vout are "in-phase". This type of transistor arrangement is not very common due to its unusually high voltage gain characteristics. this type of bipolar transistor configuration has a high ratio of output to input resistance or more importantly "load" resistance (RL) to "input" resistance (Rin) giving it a value of "Resistance Gain". Then the voltage gain (Av) for a common base configuration is therefore given as: Av=$\frac{Vout}{Vin} = \frac{IcRl}{IeRin}$

- **The Common Emitter (CE) Configuration**

The input signal is applied between the base and the emitter, while the output is taken from between the collector and the emitter as shown. This type of configuration is the most commonly used circuit for transistor based amplifiers and which represents the "normal" method of bipolar transistor connection. The CE amplifier configuration produces the highest current and power gain of all the three bipolar transistor configurations. This is mainly because the input impedance is LOW as it is connected to a forward biased PN-junction, while the output impedance is HIGH as it is taken from a reverse biased PN-junction. The current is given as: Ie=Ic+Ib

- **The Common Collector (CC) Configuration**

The collector is connected to ground through the supply, thus the collector terminal is common to both the input and the output. The input signal is connected directly to the base terminal, while the output signal is taken from across the emitter load resistor as shown. This type of configuration is commonly known as a Voltage Follower or Emitter Follower circuit. It is very useful for impedance matching applications because of its very high input impedance, in the region of hundreds of thousands of Ohms while having a relatively low output impedance. The current gain can be given as: Ai=$\beta + 1$. [4]

[4] https://www.electronics-tutorials.ws/transistor/tran_1.html in 9/12/2022 at 5:00 pm

3. Procedure

I. Common Emitter Transistor Amplifier

▪ CE amplifier with voltage divider-bias.

The circuit here was connected as shown in figure 3.1. The function generator frequency was set to 1kHz sine wave with 0 amplitude. The base bias potentiometer was adjusted for a DC collector voltage of 8 volts and measures were taken.

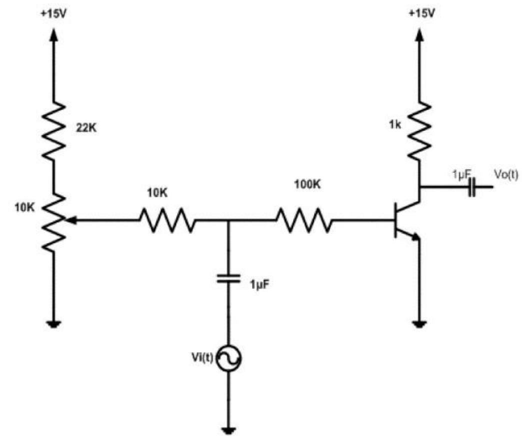

Figure 3.1 CE amplifier circuit

II. Common Collector Transistor Amplifier

The circuit here was connected as shown in figure 3.2. It was ensured that the dc control is at minimum. The sine wave generator frequency was set to 1 kHz, but it was disconnected at first to set the output amplitude to 0 and measures were taken. The generator was returned to its place and the output amplitude was set to 2V p-p. To measure Zin and Zout, the input sine wave was taken from its original place and was connected with the output (emmiter), it was replaced with short circuit.

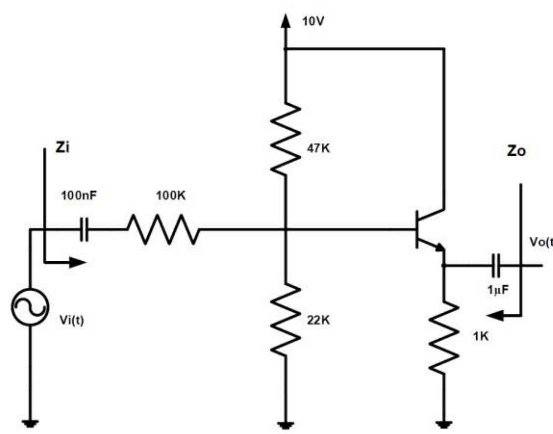

Figure 3.2 common collector circuit

III. Common Base Transistor Amplifier

The circuit was connected as shown in figure 3.3. It was ensured that the variable dc is at minimum. The sine wave generator frequency was set to 1 kHz, but it was disconnected at first to set the output amplitude to 0 and measures were taken. The generator was returned to its place and the output amplitude was set to 2V p-p. To measure Zin and Zout, the input sine wave was taken from its original place and was connected with the output (collector), it was replaced with short circuit.

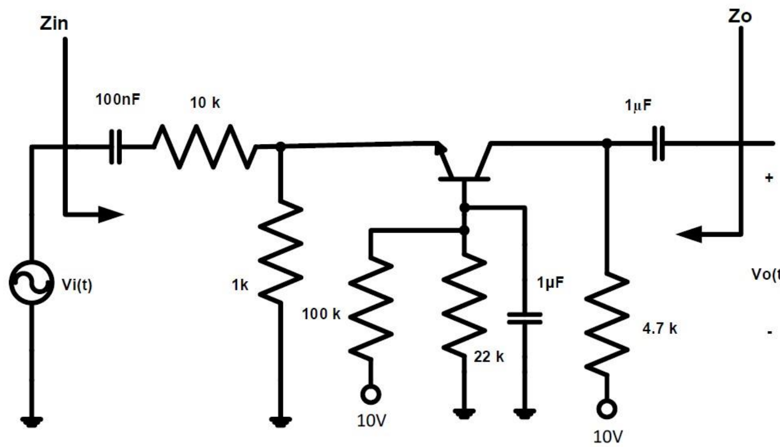

Figure 3.3 common base circuit

4. Data calculation and results

I. Common Emitter Transistor Amplifier

The results of this part is shown in figures 4.1 and 4.2.

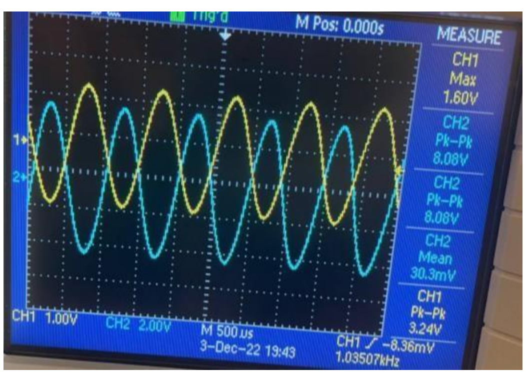

Figure 4.1 the Vin and Vout of circuit in fig.3.1

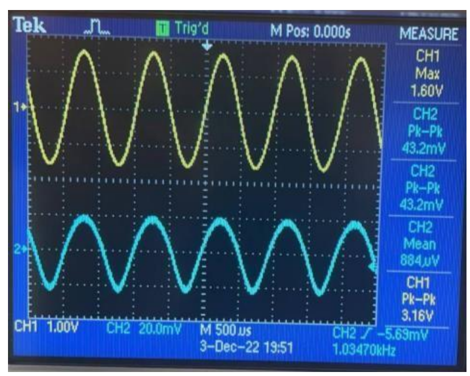

Figure 4.2 VB (CH2)

The measures was taken as shown in table 4-1 using DMM and DVM.

Ic	7.12mA
Ib	27.64μA
Vce	7.8V
Vbe	0.7V

Vbc	9.523V

Table 4-1 results part 1

The measures of Vin and Vout (on the collector) where its graph is figure 4.1, and VB where its graph is figure 4.2. All shown in table 4-2.

Vout	8.08V
Vin	3.24V
VB	43.2mV

Table 4-2 results part 2

Voltage gain Av= $\frac{Vo}{Vin} = \frac{8.08}{3.24} = 2.494$

Av1= $\frac{8.08}{43.2m}$ =187.04

The table 4-3 shows the results of Ic and Ib.

Ic	7.33mA
Ib	$27.8\mu A$

Table 4-3 results part 3

Current gain Iv= $\frac{Io}{Ii} = \frac{Ic}{Ib} = \frac{7.33m}{0.0278m}$ =263.67

Discussion:

After removing the 100k resistor, it was noticed that Vin=1.18V and Vo=5.14 (both decreased), in the other hand, the voltage gain was Av=4.58 (increased).

II. Common Collector Transistor Amplifier

The graph result of this part is shown in figure 4.3.

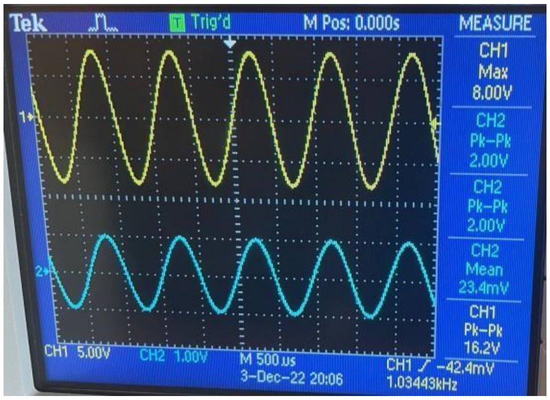

Figure 4.3 result of common collector

Quantity	Value
VE	2.33V
VB	3V
Vin	16.2V
Vout	2V
V(100k_rms)	4.86Vrms=6.87V
VT (for Zout)	8.82V
IT (for Zout)	14.08mA
Calculated values	
Io=Vo/Re	2/1k=2mA
Av=Vout/Vin	2/16.2=0.123
Ii=V(100k)/100k	6.87/100k=0.0687m
Ai=Io/Ii	2m/0.0687m=29.11
Zin=Vi/Ii	16.2/0.0687m=235.8k
Zout=VT/IT	8.82/14.028m=628.7k

Table 4-4 measurements and calculations of common collector circuit All measured data and calculations of this part are shown in table 4-4.

Discussion:

The voltage gain for this circuit is less than 1 (Attenuation), while in common emitter circuit the voltage gain > 1 (Amplification). Input impedance in common collector is very high, while it is medium in common emitter. Both CC and CE have a current gain more than 1.

III. Common Base Transistor Amplifier

The graph result of this part is shown in figure 4.4.

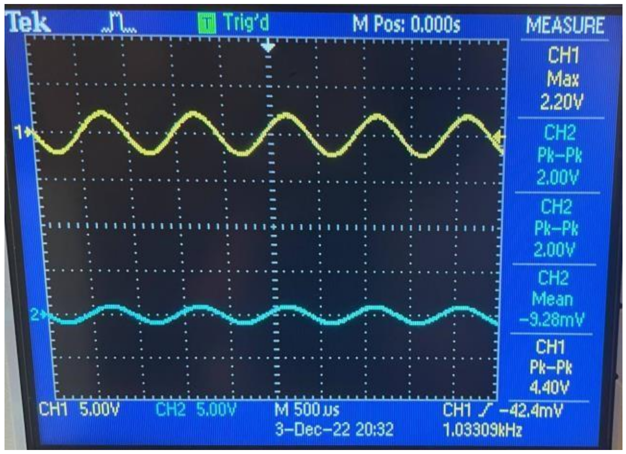

Figure 4.4 result of common base

Quantity	Measured Value	Quantity	Calculated Value
Vin	4.4V	Av=Vo/Vi	2/4.4=0.45V
Vout	2V	Io=Vo/4.7k	2/4.7k=0.425mA
V(10k_rms)	1.41Vrms	Ii=V10k_rms/10k	1.41/10k=0.141mA
VT (for Zout)	1.42V	Ai=Io/Ii	0.425m/0.141m=3
IT (for Zout)	0.29mA	Zin=Vi/Ii	4.4/0.141m=31.2k
Vbc	3.29V	Zo=VT/IT	1.42/0.29m=4.9k
Vbe	0.67V		
Vce	3.95V		
Ib	4.66μA		
Ic	1.04mA		

Figure 4.5 measurements and calculations of common base

Discussion:

The voltage gain for this circuit is more than 1 (Amplification) and it is more amplifier than the common emitter circuit's voltage gain (2.494). The current gain in CB is very low unlike the CE circuit (>1).

5. Conclusion

In this experiment, we have gained knowledge and learnt better about the effect of applying sinusoidal signal to a transistor connected. In addition, we had understood the properties of the transistor as an amplifier in different common circuits' types. We also saw the difference between common amplifiers by seeing and varying the results of each type.