> Common-Emitter Bipolar Junction Transistor Amplifier <

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Abstract—The bipolar junction transistor (BJT) is a non-linear electronic device which can be used for amplification and switching. Several experiments are presented that describe the various characteristics of the BJT. The gain, small-signal gain, input resistance, output resistance, saturation and cutoff are experimentally found for this device. Finally, two practical applications of the BJT are presented. In this experiment we use a function generator, a dual trace oscilloscope, a digital multi meter, and a dc power supply. First of all, we measure the frequency dependence of a signal, adjust the function generator to produce a 1 Khz sine wave with peak-to-peak amplitude of 1V. We also collect the input and output data to save screen image as .bmp from oscilloscope and we measure BJT values by digital multimedia. During this experiment, we will be working with BJT which are dependency of current at collector, emitter and base. This experiment investigates the various properties and characteristics of the BJT. First, the output characteristics of the transistor are discussed when operating with a constant base-to-emitter voltage. Second, the BJT's ability to amplify an AC signal is investigated. Third, the BJT's limitations are discussed and the saturation and cutoff are found. Finally, two practical applications of the BJT are presented. We need designing, construction, and characterizing a bipolar junction transistor amplifier in the common emitter configuration. BJT are used in many different aspects of design and implementation. During this experiment, we can know the transistor condition by measuring resistance and designing the BJT amplifier circuit to get the waveform and bode plot. We need to increase either the collector resistance or decrease the emitter resistance to increase the gain in the amplifier. We find that the output impedance by reducing the load resistance. The gain dependence on the collector current. The term common-emitter comes from the notion that the signal source and the load share the emitter as a common connection.
Keywords-BJT(bipolar junction transistor, amplifier, transistor condition, Fourier transform, Harmonic content, and output impedance

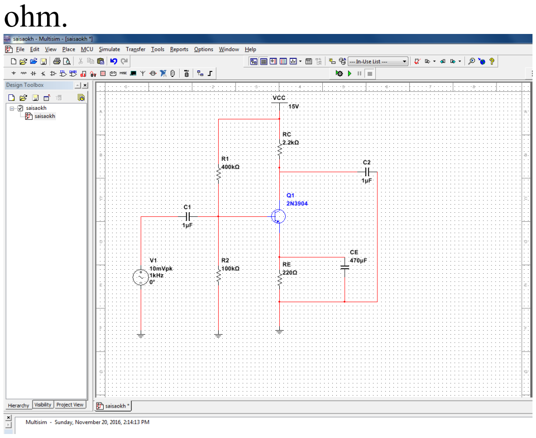
I. INTRODUCTION

Bipolar junction transistor (transistor) is a three terminal device consisting of a base, a collector, and an emitter. The primary characteristic of this device is that the current flowing across one junction affects the current flowing in the other junctions. In this experiment, we are going to build BJT, FET, as BJTs are basic building blocks of electronic amplifiers. BJT able to provide high gain and some of them can handle high power. BJTs are current-controlled devices. By applying an input current from base to emitter, the current flowing from collector to emitter can be controlled. Since the base-emitter junction is forward biased during normal operation, the input impedance of a BJT is low. In order for BJT operate well, it need to be in active mode. The current between collector and emitter is carried by the minority carriers of the base. In an npn BJT, for example, electrons flow from the emitter through base to the collector. Most electrons reach the collector. Only a small fraction, i.e., 0.5%, recombines with holes while passing through the base region. Holes in the base region are provided by the input base current. A 50-μA base current can, therefore, control the flow of a large, e.g., 10 mA, emitter current. The basic operational principle of all BJT amplifiers are as follow.

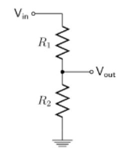
II. Guidelines For Manuscript Preparation

Preparation by collecting necessary components for the experimental such as browsing and searching the web for BJT. Follow the lab manual provided by Dr. Liu. Knowing the exact input and output of components i.e. 2N3904 BJT, electrolytic capacitors, 1-μF to 1000μF , resistors from 100Ω to 1 MΩ.

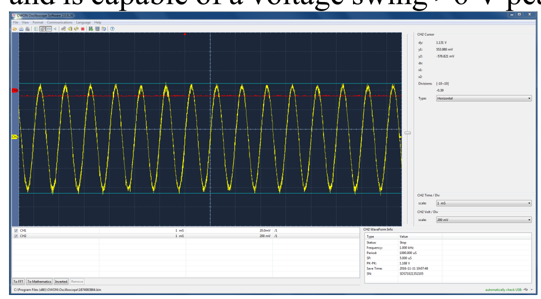
1. Using the multi-meter to measure the resistance between the base and the emitter to determine the transistor condition. We also repeated these measurements for the base-collector junction and the collector-emitter junction respectively.
2.we designed the circuit on the breadboard. In this part, we do not attach any load resistor. We adjust the bias resistance to obtain the voltage value at V_{CE} which is approximately half of the power supply voltage. In this step, we using the R1 equal to 400K ohm.



3. We need add voltage divider on the input to reduce the put-put of the function generator to a level of 10mV or smaller. Since the expected voltage gain is larger.



we using the 47ohm for R2 and1000ohm for R1.we can get a smaller input than 10mv.
4.we increase the amplitude of the function generator until we get a distorted waveform for output I of the amplifier. the amplifier operates with a gain of 260 and is capable of a voltage swing >6 V peak-to-peak.



We record the circuit diagram showing values of all components, power supply voltage, and dc voltages at the base, collection, and emitter. Record input and output waveforms with large voltage swing but without clipping. The recorded waveform data should contain at least 10 sinusoidal cycles. We also need to calculate the gain.
5. This part deals with the frequency response principles learned in previous labs in which we were asked to find both the high and low -3 dB frequencies. In this part, we need to measure and record the gain as a function of frequency from 1Hz to as high as the function generator can go .determine the low frequency -3db point and the high frequency -3db point.

6. Setting the function generator to 1K Hz. We need to connect via the output coupling capacitor, μF, a 100-kΩ load resistor. Verify the polarity of the coupling capacitor. Reduce the load resistance until the gain is reduced by a factor of two. The load resistance is equal to the output impedance.

7. according to the function 3, the voltage gain is current dependent. Measure the AC voltage gain at 1 K Hz as a function of the collector current. Collector

current can be calculated from the dc voltage drop across Rc and its resistance. Measure and compare the high frequency -3db points for low gain and high gain amplifiers.

Current gain

$$\beta_{ac} = g_m r_\pi$$

Trans conductance

$$g_m = \frac{I_C e}{kT}$$

Voltage gain

$$A_v = g_m R_C$$

Emitter voltage

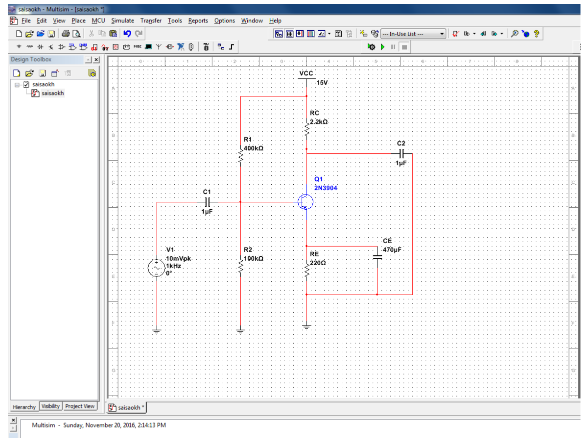
$$V_E = I_C R_E$$

III. Results and Data Analysis

Transistor Condition Based on Measured Resistances

Red Lead	Black Lead	Resistance
Base	Emitter	2.5MΩ
Emitter	Base	Infinity
Base	Collector	2.0MΩ
Collector	Base	Infinity
Emitter	Collector	Infinity
Collector	Emitter	Infinity

Circuit Diagram of Amplifier Designed



Using R1=400K ohm
Vce=7.78
Do not attach any load resistor at this time.

Waveforms and Bode Plot Generated by Simulation

Frequency (Hz)	Voltage in (V)	Voltage out	Gain (V/V)
1	0.78	0.46	0.589744
10	0.78	3.68	4.717949
50	0.78	11.2	14.35897
100	0.78	13.8	17.69231
150	0.78	14.2	18.20513
200	0.78	14.2	18.20513
250	0.78	14.2	18.20513
300	0.78	14.2	18.20513
350	0.78	14.2	18.20513
400	0.78	14.2	18.20513
500	0.78	14.2	18.20513
700	0.78	14.2	18.20513
900	0.78	14.2	18.20513
1000	0.78	14.2	18.20513
5000	0.78	14.2	18.20513
10000	0.78	14.2	18.20513
50000	0.78	14.4	18.46154
100000	0.78	14.4	18.46154
200000	0.78	13.8	17.69231
300000	0.78	13.4	17.17949
400000	0.78	12.6	16.15385
500000	0.78	11.4	14.61538

650000	0.78	9.4	12.05128
750000	0.78	8.4	10.76923
1000000	0.78	6.4	8.205128
5000000	0.78	1.76	2.25641
15000000	0.78	0.64	0.820513

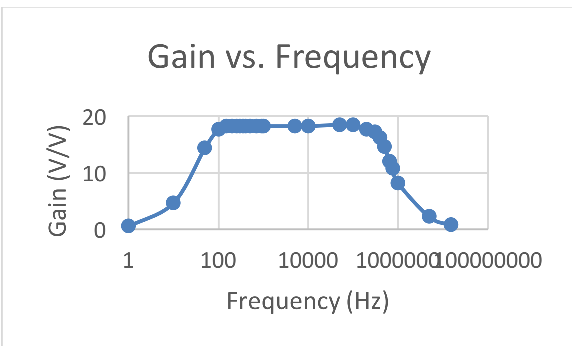
$V_C = V_{CC} - R_C \cdot I_C = 15 - 2.2\,k \cdot 3.04\,mA = 8.32\,V$

high

Bode Plot with -3d

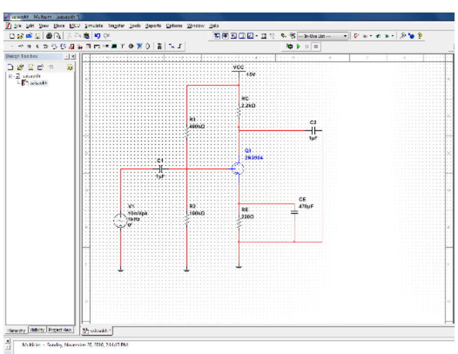
vin	vout	gain	frequency
42	649	15.4524	10
42	1440	34.2857	30
42	2160	51.4286	50
42	3280	78.0952	70
42	4400	104.762	90
42	5360	127.619	110
42	6320	150.476	120
42	6640	158.095	130
42	7120	169.524	150
42	8000	190.476	200
42	8640	205.714	300
42	8880	211.429	500
42	9520	226.667	1000
42	9840	234.286	2000
42	10000	238.095	5000
42	10000	238.095	10000
42	10000	238.095	30000
42	10000	238.095	50000
42	10000	238.095	70000
42	10000	238.095	120000
42	9450	225	270000
42	9120	217.143	390000
42	8640	205.714	500000
42	7200	171.429	850000
42	6400	152.381	1050000
42	4160	99.0476	2050000
42	2960	70.4762	3050000

We start off with the frequency response of the amplifier by simulating the circuit in Multisim. In doing so, we arrive at the following waveform:



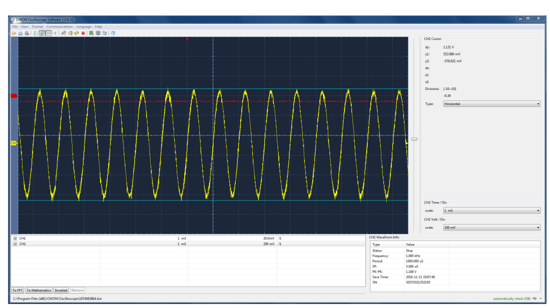
Low-pass -3db point (50, 14.35879)
High-pass -3db point (650000, 12.05128)

Circuit Diagram of Amplifier Built



Without LR

b Frequency



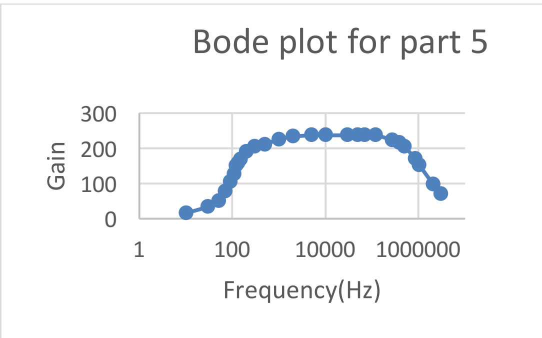
DC Operating Conditions

$I_c = (\frac{Av}{38.9}) / R_C = (\frac{260}{38.9})/2.2K = 3.04mA$

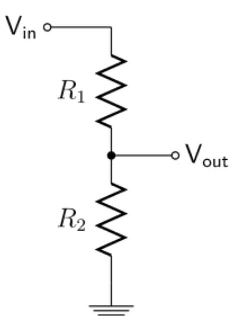
$V_E = I_C \cdot R_E = (3.04\,mA)(220) = 668\,mV$

$V_B = V_E + 0.65 = (668\,mV) + (0.65) = 1.32\,V$

Waveform of output



For this part, we using the voltage voltage divider to reduce the output the function generator to a lower level of peak-to-peak.

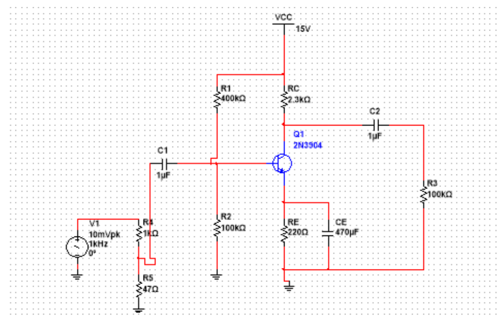


$$V_{out} = \frac{V_s \times R_2}{(R_1 + R_2)}$$

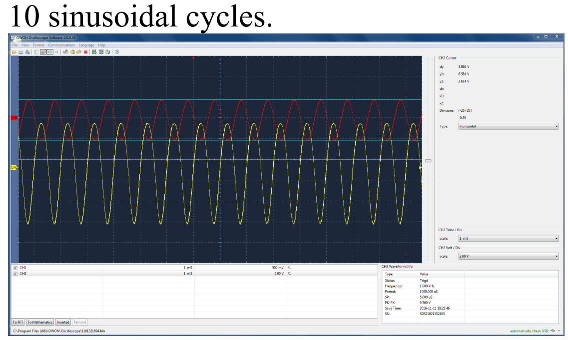
Using the R1=1000ohm and R2=47ohm. Our input Vpp=1.63*$\sqrt{2}$*2=4.6mv
The in put =7.5V and the output =30mV, the waveform of out put start have the clipping.
Gain Av the maximum gain is 250 V/V. -3 dB means 70.7% of the maximum voltage gain is 176V/V
Low -3db frequency is at 150Hz when the gain is 169.524.

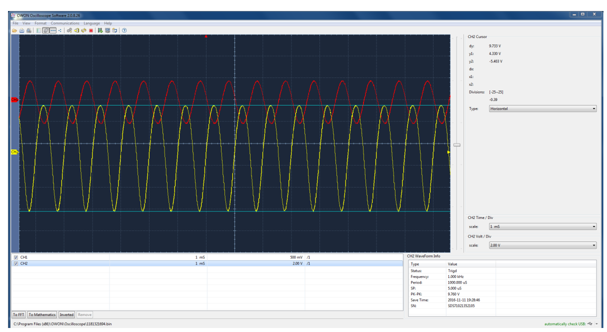
Error :((176-169.524)/176)*100%=3.67%
High -3db frequency is at 850000Hz when the gain is 171.429
Error: :((176-171.429)/176)*100%=2.6%

Input and Output Waveforms Showing Voltage Swing without Clipping
Circuit with voltage divider



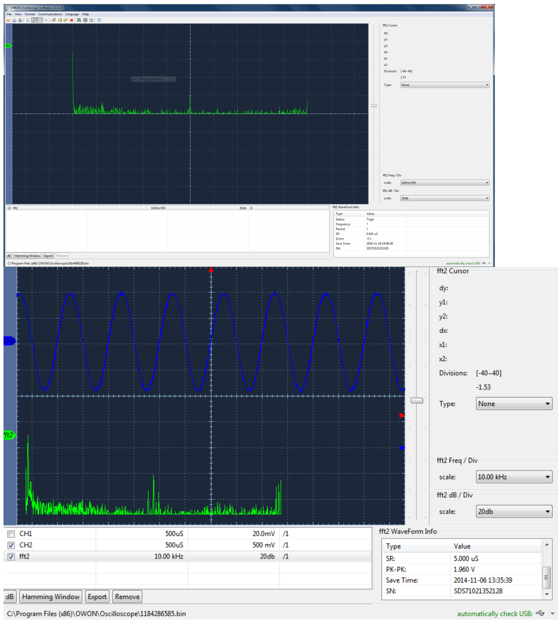
the recorded waveform data should contain at least 10 sinusoidal cycles.





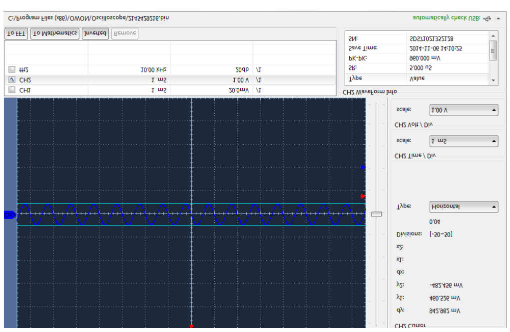
The power supply voltage=15V
The dc voltages at the base=1.471V.
At the collector=3.5V.
At the emitter=0.581V
The in put =7.5V and the output =30mV, the waveform of out put start have the clipping.
Gain Av = 7500/30=250 V/V
(260-250)/260=0.038=3.8%

Fourier Transform and Harmonic Content



The peak of the image in the left is the 0 Hz. The next peak have 5 horizontal units form the first peak. One horizontal scale means 10K Hz. The second is at 50K Hz. The final peak is at 100K Hz.it means -4db frequency below the fundamental peak.

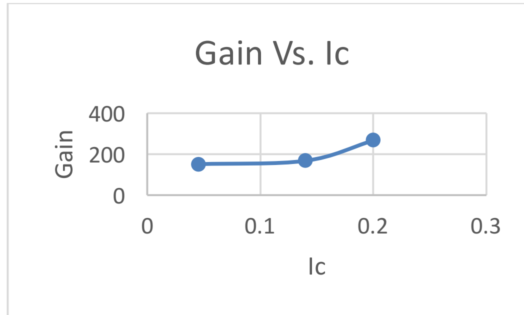
Output impedance



The resistance value at the load that reduces the gain by a factor of two is called the output impedance. We try to reduce the value of the load resistance in this step, we notice that the output impedance is 1K ohm because the waveform above was concentrated by a factor of two which was aspired.

Gain dependence on collector current

output	gain	Ic
1600	266.6667	0.2
1000	166.6667	0.14
900	150	0.045



From these data, we know that the gain dependence the collector current. When the Ic increasing ,the gain will be increasing.

IV. Discussions

- Bipolar transistors work as current-controlled current regulators. In other words, transistors restrict the amount of current passed according to a smaller, controlling current. The main current that is controlled goes from collector to emitter, or from emitter to collector, depending on the type of transistor it is (PNP or NPN, respectively). The small current that *controls* the main current goes from base to emitter, or from emitter to base, once again depending on the kind of transistor it is (PNP or NPN, respectively). According to the standards of semiconductor semiology, the arrow always points against the direction of electron flow. Bipolar transistors are called *bi*polar because the main flow of electrons through them takes place in *two* types of semiconductor material: P and N, as the main current goes from emitter to collector (or vice versa). In other words, two types of charge carriers—electrons and holes—comprise this main current through the transistor. No current through the base of the transistor, shuts it off like an open switch and prevents current through the collector. A base current, turns the transistor on like a closed switch and allows a proportional amount of current through the collector. Collector current is primarily limited by the base current, regardless of the amount of voltage available to push it. The next section will explore in more detail the use of bipolar transistors as switching elements. Transistors function as current regulators by allowing a small current to *control* a larger current. The amount of current allowed between collector and emitter is primarily determined by the amount of current moving between base and emitter.

In order for a transistor to properly function as a current regulator, the controlling (base) current and the controlled (collector) currents must be going in the proper directions: meshing additively at the emitter and going *against* the emitter arrow symbol.

V. Conclusion

When a transistor is in the fully-off state (like an open switch), it is said to be cutoff. Conversely, when it is fully conductive between emitter and collector (passing as much current through the collector as the collector power supply and load will allow), it is said to be saturated. These are the two modes of operation explored thus far in using the transistor as a switch. Frequency Response of an electric or electronics circuit allows us to see exactly how the output gain (known as the magnitude response) and the phase (known as the phase response) changes at a particular single frequency, or over a whole range of different frequencies from 0Hz, (d.c.) to many thousands of mega-hertz, (MHz) depending upon the design characteristics of the circuit. Generally, the frequency response analysis of a circuit or system is shown by plotting its gain, that is the size of its output signal to its input signal, Output/Input against a frequency scale over which the circuit or system is expected to operate. Then by knowing the circuits gain, (or loss) at each frequency point helps us to understand how well (or badly) the circuit can distinguish between signals of different frequencies. There are two types of BJT, NPN and PNP. The basic function of a BJT is to amplify current. This allows BJTs to be used as amplifiers or switches, giving them wide applicability in electronic equipment, including computers, televisions, mobile phones, audio amplifiers, industrial control, and radio transmitters. Bipolar junction transistor (bipolar transistor or BJT) is a type of transistor that uses both electron and whole charge carriers. In contrast, unipolar transistors, such as field-effect transistors, only use one kind of charge carrier. For their operation, BJTs use two junctions between two semiconductors. The collector–base junction is reverse biased in normal operation.

Furthermore, we will be able to build, design and implement an amplifier if we follow the description exactly provided by the instructors. It will also give us the opportunity to construct anything which are similar to BJT by doing this experiments.

VI. Reference

[1] SEDRA. SMITH, "Microelectronic Circuit," in *Title of His Published Book, 7t*h ed. New York.
[2] Dr. Liu Experimental 8 lab manual.
[3] Dr. Liu Experimental 8 lecture power point.

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