EEE109 Lab 2 – Transistors

Student Name: *Xuhui Gong*

Student IDs:*1718128*

Group ID: *28*

Submission Date: *12/12/2018*

Abstract

This experiment is mainly composed of BJT's understanding and amplification circuit. The experiment first tested the 2N3904BJT, including the measurement of the specific position of the three ports and the measurement of the turn-on voltage. Later, the input and output of BJT were plotted. Finally, the analysis of the entire amplifying circuit, by analyzing AV, we can derive the characteristics of the amplifying circuit.

1.Background

1.1 Background of transistor

This experiment uses transistor which called BJT (bipolar junction transistor). Transistor has a lot of type such as Bipolar Junction Transistor, Field Effect Transistor and MOSFET. BJT(Bipolar Junction Transistor) is the most common transistor. It has two types of BJT which is n-type and p-type[1]. The BJT has two PN junction, one terminal is emitter part, one terminal is collector part and the part in the middle is base part. For BJT, it has NPN type and PNP type. This experiment uses 2N3904, it is a NPN type. For BJT, it is be used in amplifying circuit, in common case, if one signal input from the base, a larger current will through emitter by BJT's circuit. It is a simple NPN's model in Figure 1. From this transistor, electronic through emitter from base, this is the reason for the current I, and if we give a V_{BE}, the hole will move base to emitter.

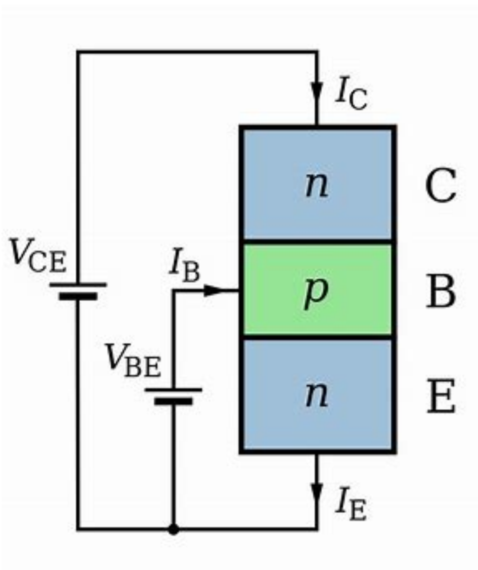

Figure 1: NPN type of BJT[2]

1.2 Background of circuit

The experiment circuit is shown in Figure 2. By using this circuit, a small signal could be amplified. However, how the small signal small, it is this experiment needs to explore.

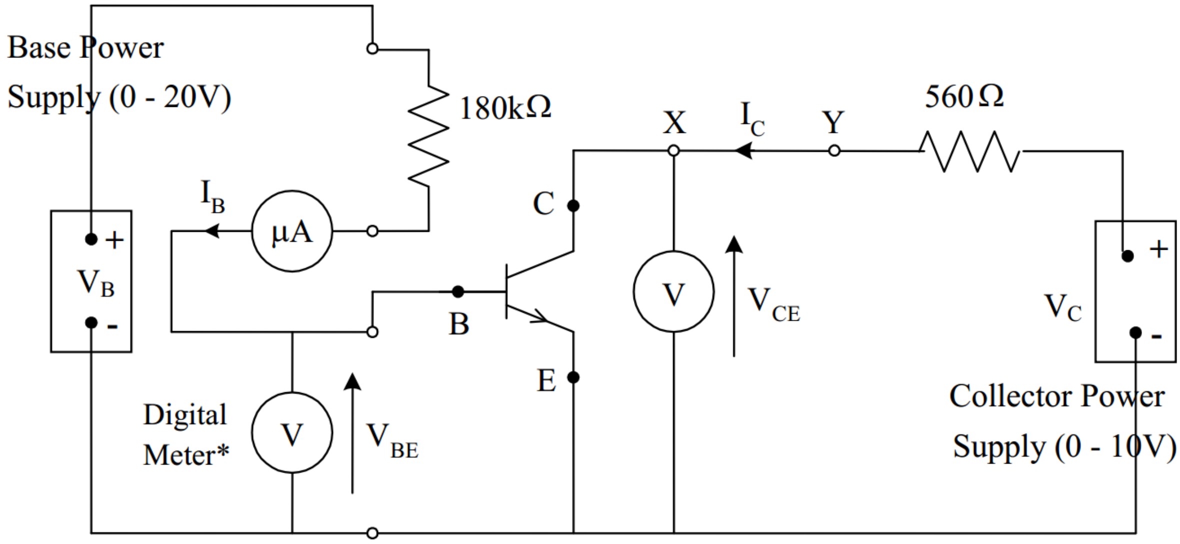

Figure 2: Experiment circuit

2. Aims and Objectives

The aim of this experiment is following the list:

1) Explores the basic characteristics of BJT, and find the BJT's type. Using multimeter to find the opening voltages in each P-N junction.

2) The input and output character build in circuit will be covered.

3) Understand how to build a simply common-emitter amplifier.

3. Experiment and Methodology:

3.1 Equipment:

The experiment equipment is listing here:

1) the Oscilloscope

2) D.C power supplies

3) The digital multimeter

4) Bench multimeter

5) Function generator

6) Capacitors

7) BJT 2N3904

8) Resistors

3.2 Transistor measurement :

Before the experiment, the BJT 2N3904 needs to be measured. The symbol of BJT is shown in Figure 2. Firstly, use DMM to check the connections of this 2N3904. It is simply to find the type of BJT. Use resistance measurement mode or diode mode to measure each sides, for example, like base and collect port, if B to C is N to P, the current cannot through this P-N junction, so the resistance in DMM is overload. As the same as B to E, we can find this easily. Secondly, the turn on voltage can be measured by DMM's Diode mode. Its principle is actually give the circuit a little current, then calculate the voltage through the P-N junction.

However, how to find the collector and emitter it is hard to use DMM to distinguish. We could use our finger to instead of resistance to find which part is C and E, however, they types are the same P or N. Firstly, use resistance measurement mode to measure C and E part, use one finger to connect N to P, the resistance will be lower, secondly, exchange multimeter table pen and connect to the other N snd P, compared which resistance is lower, which is collector port.

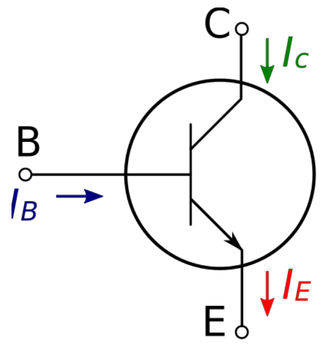

Figure 2 :BJT symbol

3.3 Input Characteristics:

First, we need to prepare this circuit. At first, the experimental description is not accurate, so we think that every time V_{CE} changes, it must be calibrated to 5 volts. The truth is that if we change the base power supply each times, the V_{CE} will change from 5 volts to others. This is a big waste of our time, after confirming with the teaching assistant, our party V_{CE} is 0 volts and starts to change the voltage. We only need to measure the I_B and V_{BE}. At the time, we thought that the mobile multimeter was not accurate enough, so we used an oscilloscope to display the voltage. It turns out that the oscilloscope must first fit the voltage when displaying the voltage, so the voltage is not accurate. Later, we used two multimeters to carry out this experiment.

3.4 Output Characteristics:

In this experiment, we have to explore different base voltage which could give different V_{CE}, this requires us to control the variables. By controlling one base voltage and control the V_{CE} to find the V_{CE} between I_C. Since the voltage source control is not very stable, we need to control it little by little.

3.5 Common-Emitter Amplifier:

This circuit will help us amplify input signal. At first, we need to set up this circuit which is shown in Figure 3. Then we need to find which signal is small.

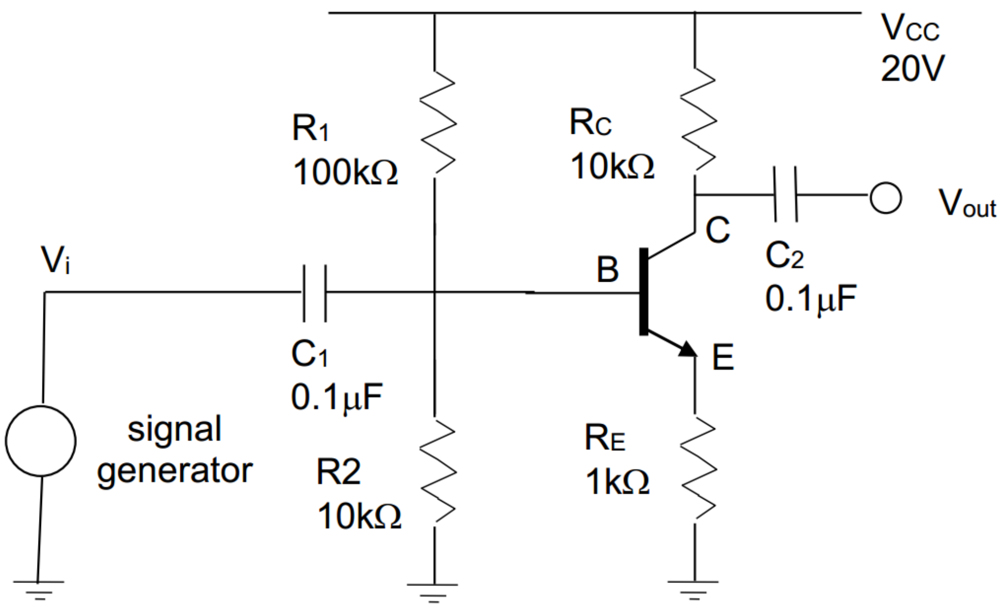

Figure 3: Common-Emitter Amplifier

4. Results:

4.1 Transistor diagrams and connections:

We find that this 2N3904 is NPN, and find each parts. It is shown in Figure 4. The turn on voltage is 0.660 V for E to B and 0.652 V for B to C.

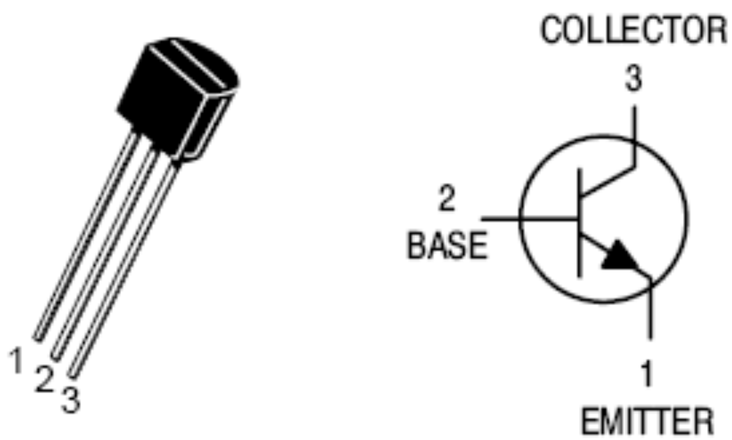

Figure 4: NPN

4.2 Input Characteristics:

When V_{CE} to 5 volts, the relationship between V_{BE} and I_B is shown in Table 1 and Figure 5.

0.628	0.667	0.683	0.697	0.705	0.717	0.73	0.737	0.74	0.743	0.744	0.745	0.746	V_{BE} V
2.23	6.65	10.61	15.71	19.4	25.32	31.93	36.2	40.32	50.59	60.61	70.3	81.69	I_B μA

Table 1: Relationship between V_{BE} and I_B in 5 V

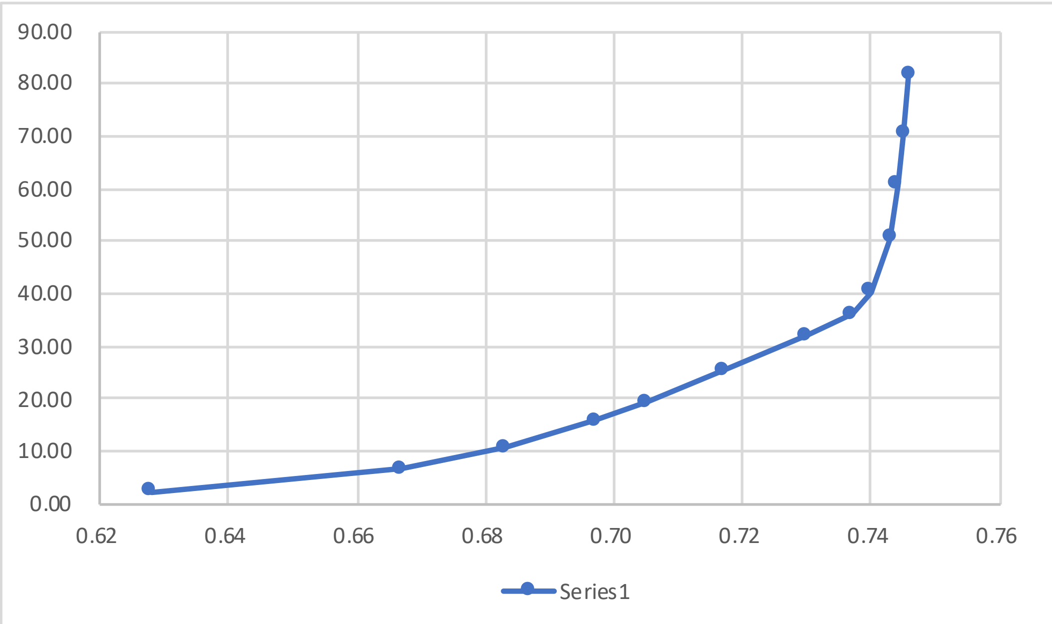

Figure 5: Relationship between V_{BE} and I_B in 5 V

When V_{CE} to 5 volts, the relationship between V_{BE} and I_B is shown in Table 2 and Figure 6.

0.628	0.667	0.683	0.697	0.705	0.717	0.73	0.74	0.743	0.744	0.749	0.765	V_{BE} V
2.47	8.23	15.3	26.27	34.18	45.29	53.23	60.38	62.9	63.79	70.67	90.73	I_B μA

Table 2: Relationship between V_{BE} and I_B in 10 V

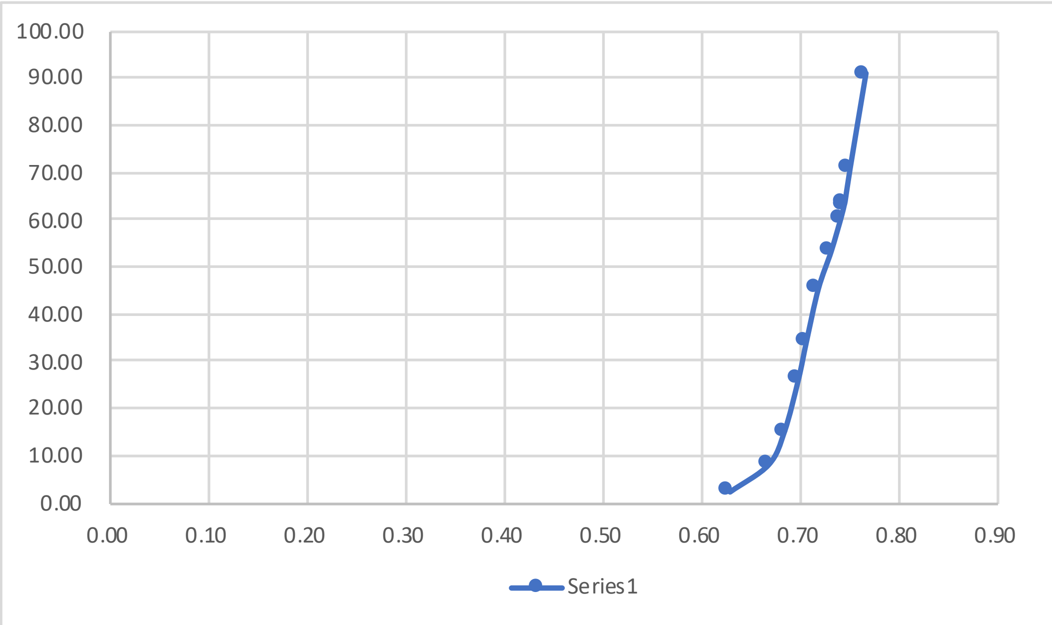

Figure 6: Relationship between V_{BE} and I_B in 10 V

4.3 Output Characteristics:

In this experiment, we control the variables and control IB to 0, 20, 40, and 70 volts. Subsequently, V_{CE} becomes an independent variable by gradually increasing the voltage, and I_C becomes a dependent variable. You can see the test results as shown below. It is shown in Table 3, 4, 5, 6.

Integrated image is shown in Figure 7.

$I_B = 0\mu A$									
V_{CE}(V)	0.053	0.108	0.211	0.396	0.807	1.60	3.21	6.40	10.00
$I_C(\mu A)$	0.1	0.3	0.7	6.9	11.8	13.3	15.8	17.0	18.5

Table 3: Output Characteristics for $I_B = 0\mu A$

$I_B = 20\mu A$									
V_{CE}(V)	0.047	0.109	0.22	0.41	0.801	1.608	3.22	6.44	10.00
$I_C(mA)$	0.10	0.52	1.97	3.43	4.25	4.61	4.77	4.93	5.18

Table 4: Output Characteristics for $I_B = 20\mu A$

$I_B = 40\mu A$									
$V_{CE}(\mathbf{V})$	0.052	0.102	0.200	0.402	0.802	1.605	3.22	6.39	10.02
$I_C(mA)$	0.37	1.73	5.53	7.89	8.77	9.27	9.64	10.13	10.88

Table 5: Output Characteristics for $I_B = 40\mu A$

$I_B = 70\mu A$									
$V_{CE}(\mathbf{V})$	0.048	0.103	0.203	0.401	0.802	1.602	3.23	6.41	10.02
$I_C(mA)$	0.69	3.78	10.62	13.43	14.99	16.17	17.17	18.24	20.73

Table 6: Output Characteristics for $I_B = 70\mu A$

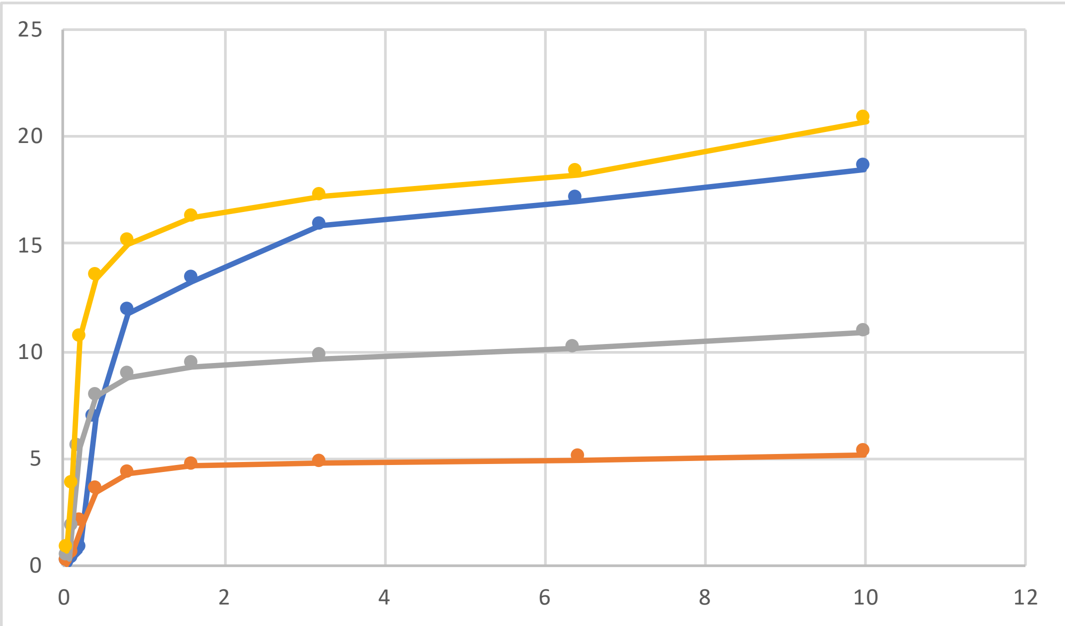

Figure 7: Output Characteristics

4.4 Common-Emitter Amplifier:

Firstly, we input the sine 5 kHZ and V peak to peak is 0.5 volt's signal. It's Av is -10. After actual measurement, we used an oscilloscope to make accurate measurements and found that this signal was amplified ten times. The actual measurement results are shown in the Figure 8. We found that the experimental results were in line with expectations and the phase difference was 180 degrees.

When we remove the AC input signal the results are $V_C = 9.26V$, $V_B = 1.76V$, $V_E = 1.10V$, $V_{BE} = 0.64V$ and $V_{CE} = 8.17V$. When the signal is changed, the signal is not displayed normally.

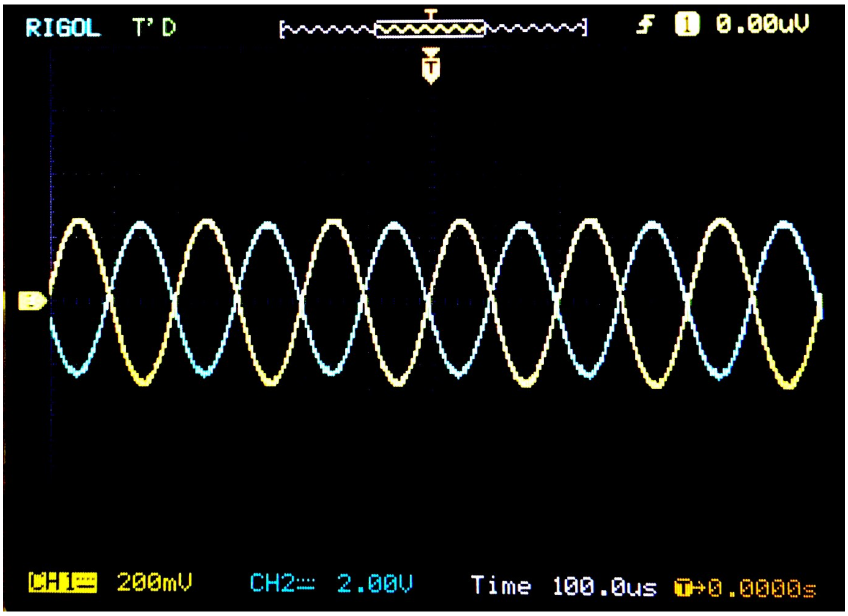

Figure 8: Common-Emitter Amplifier

5. Result Discussion:

5.1 Error Analysis

The experimental error mainly comes from the systematic error. At first we tried to use the oscilloscope to measure the voltage, but found that the voltage data and the multimeter measurement data obviously do not match. Later, after research, it was found that the oscilloscope grounding method would affect the measurement results. After repeated verification and comparison, we finally abandoned the oscilloscope to measure the voltage, which was measured with two multimeters. However, the accuracy of the multimeter is also differentiated. The precision of the seated multimeter is significantly higher than that of the handheld multimeter. In the experimental measurement, we also found a strange phenomenon, the current size will gradually become larger as the measurement time increases. Later, after analysis, it is possible that this is caused by the heat released by the circuit. In order to make the value of this measurement more accurate, we should read the reading accurately immediately.

5.2 Experiment analysis

The experiment 5.2 shows that the base's voltage influence the whole BJT. It's like a dam, the base is the dam, Its effect on current is exponential. This is also the basic feature of BJT. Other than this, It also has a saturation-like characteristic, that is, when the base current is given, no matter how the voltage of the C to E port becomes larger, the current does not change substantially.

For the last experiment, the result is that when we increase V_{in}'s amplitude, at 0.7V, V_{out} become clipped.

$$V_{R1} = \frac{20R1}{(R1+R2)}$$

$$V_{R2} = \frac{20R2}{(R1+R2)}$$

6. Conclusions:

These experiments help us to understand the nature of BJT, for example, the turn-on voltage of NPN is about 0.6 volts. And we also understand that different base voltages can be a substantial increase in base current, and an understanding of the output curve. Finally, the entire amplifier circuit has recorded a decisive role in the experiment. We know that the input of the small signal has a certain limit, and in the future, the specific value can be calculated by calculation.

7. Reference:

[1]C. Hu, Modern semiconductor devices for integrated circuits. Upper Saddle River [etc.]: Prentice Hall, 2010.Chenming Calvin Hu (2010). Modern Semiconductor Devices for Integrated Circuits.

[2]"Bipolar junction transistor", *En.wikipedia.org*, 2018. [Online]. Available: https://en.wikipedia.org/wiki/Bipolar_junction_transistor. [Accessed: 14- Dec- 2018].