EEE109 Lab 2 – Transistors

Group members: *Kai-Yu Lu*

Student IDs: *1614649*

Group ID: *72*

Submission date: *26/11/2017*

Abstract

Transistor is a significant electronic component in modern electronics. Currently, "the most common application of transistor is for computer memory chips" [1]. Therefore, it is meaningful to understand the working principle of transistors via studying its basic characteristics. In industry, the transistor is usually used to amplify and provide the signal. A common transistor usually has three parts which are base, collector and emitter. This report will cover the part of introduction of every task first. Then corresponding results and discussions which contain certain tables, graphs and figures. Through these results, we could understand the basic characteristics of the characteristics.

1. Introduction

1.1 Transistor diagrams and connections

A transistor has three pins which are the collector, the emitter and the base. Due to one transistor is a component that unites two PN junctions, a transistor could be divided into two groups, one is PNP, the other one is NPN. Therefore, this task required students to distinguish the type of the provided transistor and the types of its pins. In later corresponding sections, it will provide certain experiment procedures, results and discussions.

1.2 Input Characteristics

After finding the type of the transistor, to further study its characteristics, we need to find its input characteristics first. This task intends to test the input characteristics of a transistor through the relation between the current (I_B) and the voltage (V_{BE}) on the base. Normally, the input characteristics of a transistor is shaped like an exponential curve. Certain experiment procedures, results and discussions will be also provided in later corresponding sections.

1.3 Output Characteristics

Having found the input characteristics of the transistor, next task was to study its output characteristics. By learning the output characteristics of the transistor, we could understand how does a transistor amplify the current and the voltage. This task aims to determine the output characteristics of the transistor via the relation between collector current (I_C) and the collector-to-emitter voltage drop (V_{CE}). After this experiment, certain experiment procedures, results and discussions will be provided.

1.4 Common-Emitter Amplifier

The common-emitter circuit is a wide application in microelectronics. The input signal of the common emitter is from the base and the emitter, and the output. In addition, the output signal of the common emitter is from the collector and the emitter. During this experiment, certain parameters will be mentioned to find the characteristics of the common emitter, such as β and A_V.

2. Aims ang objectives

1. Measure and find the input and output characteristics of the transistor.
2. By designing and constructing a common-emitter amplifier and test its characteristics roughly.

3. Experiment Methodology

3.1 The procedure of transistor diagrams and connections

1. Check the connections on the transistor which is given in lab by a digital multimeter.
2. Switch the multimeter into DC voltage mode and sketch a diagram of the pins of the given transistor.

3. Switch the multimeter into the diode mode to exam the pins of the transistor. According to the test, determine the type of the transistor, is it NPN or PNP? Find the turn-on voltage for the two junctions.

3.2 The procedure of input characteristics

(1) Construct the circuit as shown in Figure 1.

(2) Connect the DC power supply V_B to the base with a 180 kΩ resistor parallel.

(3) Set the power supply on the collector to 5V which is called V_{CE}.

(4) Change base current to 20, 40 and 70μA respectively by varying the value of V_B.

(5) Record every V_{BE} and plot the graph of I_B against V_{BE}.

(6) Set V_{CE} to 10V and repeat the procedure (4) and (5).

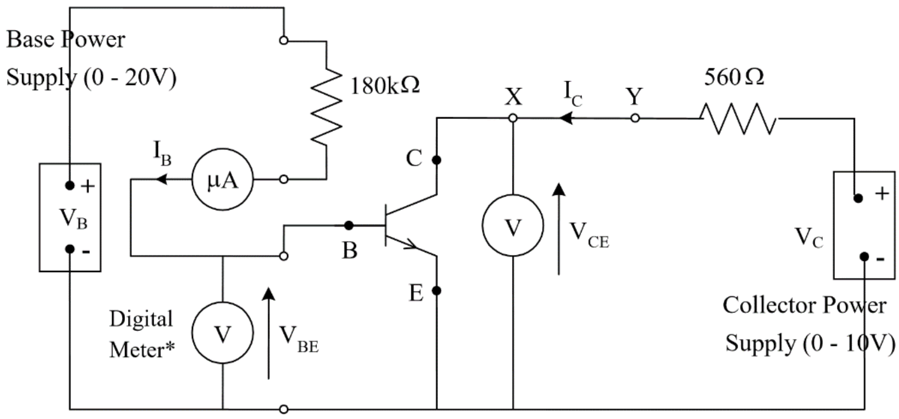


Figure 1: Circuit diagram to measure the transistor characteristics [2]

3.3 The procedure of output characteristics

(1) Move the digital multimeter to the collector to measure I_C.

(2) Move the digital multimeter to the collector to measure I_C.

(3) Measure every I_C and when V_{CE} changed in a doubling sequence to 10 V.

(4) Every time change base current to 0, 20, 40 and repeat procedure (2).

(5) Draw a graph of I_C against V_{CE} to create a family of I_C vs. V_{CE} for different I_B.

3.4 The procedure of common-emitter amplifier

(1) Construct the circuit as shown in Figure 2.

(2) Add the 20 V DC power supply on the collector.

(3) Add a sinusoidal V_{in} whose frequency is 5kHz and the amplitude to 0.5V.

(4) After adjusting the oscilloscope, observe their shapes of waveforms.

(5) Record the results and draw the essential graphs.

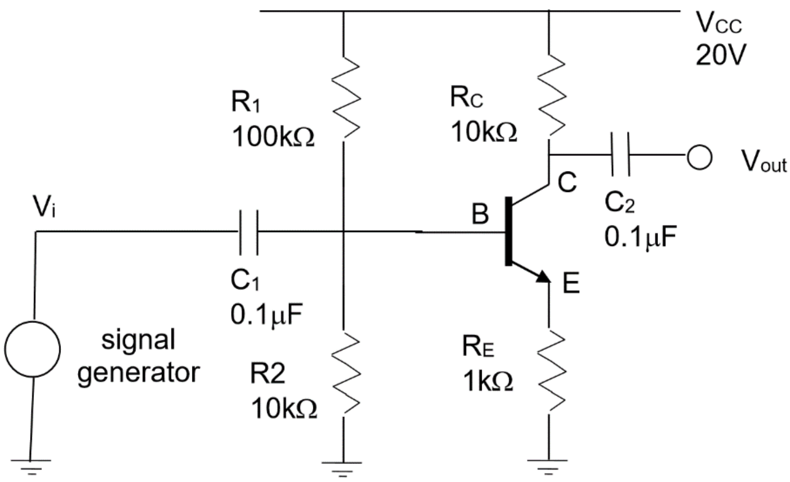


Figure 2: Common emitter amplifier using a single voltage supply [2]

4. Result and discussion

4.1 Transistor diagrams and connections

Due to the transistor given in the lab was 2N3904 (silicon NPN transistor), we do not need to use the multimeter to determine the types of pins. Subsequently, the diagram for selected transistor with the pins labeled is shown in Figure 3.

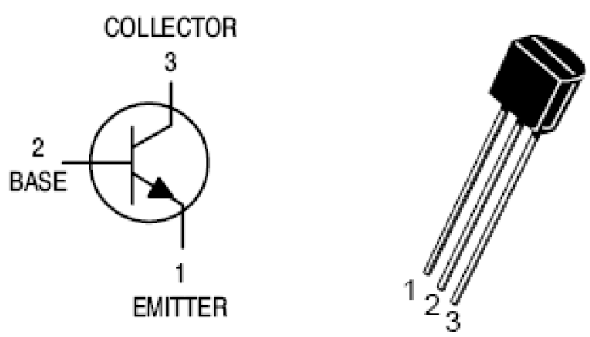


Figure 3: Bipolar junction transistor [2]

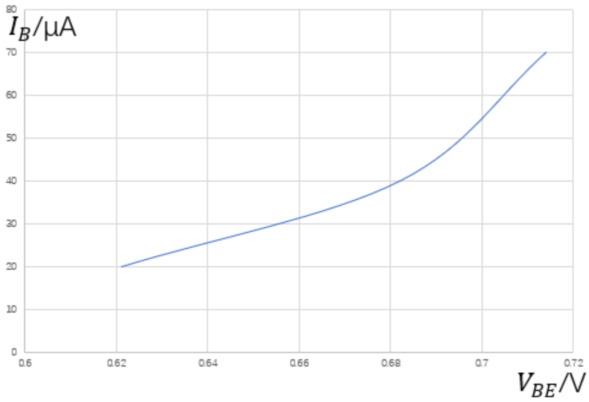
During the experiment, we attached the red test pen of the multimeter to the middle of the transistor and attached the black test pen to one of the rest pins, consequently, the result for both condition that the component was conductive. Therefore, it could be concluded that this transistor was NPN.

4.2 Input Characteristics

When V_{CE} was 5 volts, the result of the task can be seen in Table 1 and the relation between I_B against V_{BE} can be viewed in Graph 1.

I_B/μA	20	40	70
V_{BE}/V	0.621	0.682	0.714

Table 1: The measured V_{BE} when V_{CE} = 5 volts



Graph 1: The input characteristic of the transistor

From the Table 1, we could observe that V_{BE} was approximately equal to 0.7 volts which is the turn-on voltage of a normal diode. Due to the experimental errors, the value of V_{BE} did not need to be equal to 0.7 volts. Furthermore, we could confirm again that this transistor was a NPN type. In brief, this task was successfully completed.

4.3 Output Characteristics

Having obtained the result of the input characteristics, we need to continue studying the output characteristics of the transistor. The relation between I_C and V_{CE} with varied I_B can be arranged from Table 2 to Table 5.

I_C/μA	0.002	0.002	0.003	0.003	0.003	0.003	0.003	0.003
V_{CE}/V	0.1	0.2	0.4	0.8	1.6	3.2	6.4	10

Table 2: The relation between I_C and V_{CE} when I_B = 0 μA

I_C/μA	0.820	1.578	2.748	3.841	4.002	4.014	4.181	4.382
V_{CE}/V	0.1	0.2	0.4	0.8	1.6	3.2	6.4	10

Table 3: The relation between I_C and V_{CE} when I_B = 20 μA

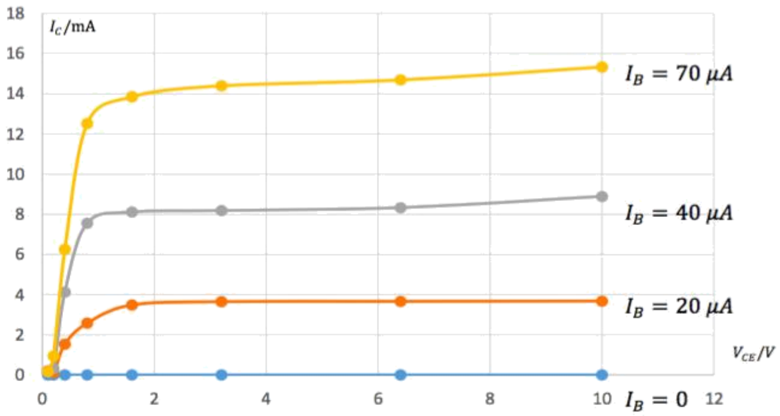
I_C/μA	0.157	4.462	7.691	8.109	8.728	9.208	9.534	9.846
V_{CE}/V	0.1	0.2	0.4	0.8	1.6	3.2	6.4	10

Table 4: The relation between I_C and V_{CE} when I_B = 40 μA

I_C/μA	0.325	6.356	11.358	11.592	12.374	12.793	13.048	13.106
V_{CE}/V	0.1	0.2	0.4	0.8	1.6	3.2	6.4	10

Table 5: The relation between I_C and V_{CE} when I_B = 70 μA

For convenience, we could arrange the date in tables in a graph as it can be indicated in Graph 2.



Graph 2: Output characteristics of the transistor

From Graph 2 and data in the tables, we could observe that, at the beginning, I_C increased rapidly with the increase of V_{CE}. When V_{CE} reached to 0.8 volts, the curve of I_C started levelling off to a specific value. Moreover, this specific value varied with the change of I_B. For the left of Graph 2, it is called the saturation region and the right part is called cut off region. Having discovered that I_C relies on I_B, thus we should find the relation between them. Subsequently, we found β which is the multiple relation between I_C and I_B. The relation between I_C and I_B can be expressed by the equation:

$$I_C = \beta \times I_B \tag{1}$$

The method to calculate β was to obtain different β in different I_C and I_B, then take the average value.

4.4 Common-Emitter Amplifier

After calculating A_V whose formula is:

$$A_V = -\frac{R_C}{R_E} \tag{2}$$

The magnitude of A_V was the same as to the predicted amplification with the consideration of the experimental errors. After connecting the oscilloscope on the input and output, wo could get the waveform as shown in Figure 4. In addition, the measured V_C, V_B and V_E can be indicated in Table 6.

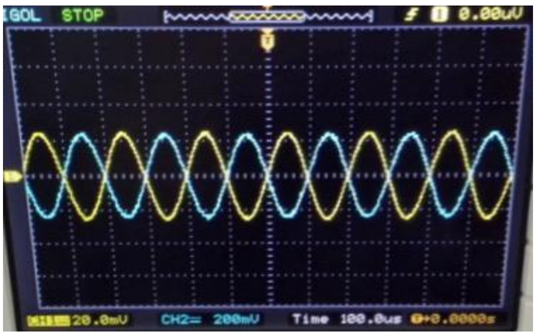


Figure 4: The waveform for V_{in} and V_{out}

V_C	V_B	V_E
7.967	1.739	1.168

Table 6: The value of V_C, V_B and V_E

From Table 6, we could calculate V_{BE} and V_{CE}.

$$V_{BE} = V_B - V_E = 1.739 - 1.168 = 0.571 \tag{4}$$

$$V_{CE} = V_C - V_E = 17.967 - 1.168 = 6.799 \tag{5}$$

The next step of analysis is to use Thevenin Theorem to simplify input resistors which is

$$R_{TH} = \frac{R_1 R_2}{R_1 + R_2} = 9.09 \text{ k}\Omega \tag{6}$$

$$V_{TH} = \frac{R_2}{R_1 + R_2} \times V_{CC} = 1.82 \text{ V} \tag{7}$$

Then we apply KVL (Kirchhoff Voltage Laws) to the input circuit, we get

$$V_{TH} = I_B R_{TH} + V_{BE(on)} + I_E R_E \tag{8}$$

Considering β equation which is one of the output characteristics of the transistor and apply KCL at the transistor

$$I_C = \beta \times I_B \tag{9}$$

$$I_E = I_B + I_C = I_B + \beta I_B = (1 + \beta) I_B \tag{10}$$

Then we substitute the equation (10) to the equation (8), Subsequently, we got the value of β which was about 168. I_B could be written by

$$I_B = \frac{V_{TH} - V_{BE(on)}}{R_{TH} + (1+\beta) R_E} = 6.3 \times 10^{-6} \text{ A} \tag{11}$$

Consequently, we could calculate V_C, V_B, V_E and V_{CE} and their values were very closed to the data in Table 6. Subsequently, we could conclude that this experiment was successful.

In conclusion, we could use β, V_C, V_B, V_E and values of corresponding resistors to calculate I_E so that we could test the characteristics of the common-emitter amplifier.

5. Conclusion

From this experiment, we have learned more details about the characteristics of the transistor, such as its input and output characteristics and basic characteristics of the common-emitter amplifier. With respect to the input characteristics, when the base-emitter voltage reaches to the turn-on voltage, the increment of I_B grows rapidly. Regarding the output characteristics, the shape or the value of I_C is mostly depend on I_B. As for the common-emitter amplifier, it shows how to amplify the input signal. Furthermore, its principle is quite similar to the circuit whose base input signal is DC, it would be more practical in real life due to the widely use of AC signal.

6. Reference

[1] R. Michael. (2004). *Transistor* [Online]. Available: https://www.britannica.com/technology/transistor

[2] *EEE109 Lab 2 Transistors (Semester 1)*. Department of Electrical and Electronic Engineering, XJTLU.