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EEE109 Lab 2 Transistors (Semester 1)

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1. Objectives

1) Measure the input and output characteristics of a transistor.
2) Design and build a simple common-emitter amplifier.

2. Equipment

Oscilloscope
d.c. power supplies
Digital multimeter (DMM)
Bench multimeter
Function generator

3. Electronic Components

Bipolar transistor 2N3904 (silicon NPN transistor).
Resistors: 560 Ω, 1k Ω, 10 kΩ × 2, 100 kΩ, 180 kΩ
Capacitors: 0.1 μF × 2

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4. Introduction

The most essential semiconductor device in modern electronics is the transistor, the first active component that we will study. Unlike the previous passive components that we've seen, the transistor can amplify and provide an output signal with more power than the input signal. The most common type of transistor is the bipolar junction transistor (BJT), consisting of an npn or pnp semiconductor structure. Although there are numerous details involved in designing an amplifier, keep in mind that the objective of this lab is to gain a basic (but solid!) understanding of the characteristics of a transistor.

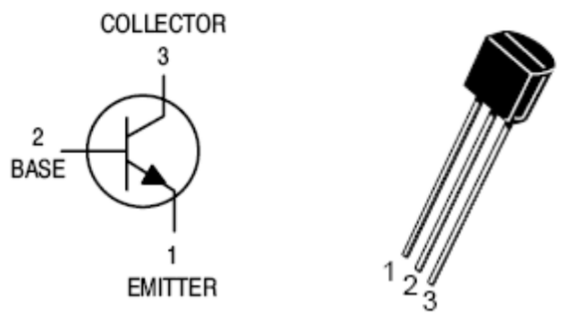

Figure 1 Bipolar junction transistor

5. Experiments

5.1 Transistor diagrams and connections

Use a DMM to check the connections on the given transistor.
(a) Which pin is the collector? emitter? base? Sketch a diagram of the transistor with the pins labeled.
(b) Use the DMM's diode mode to check the transistor pins. Is this an npn or a pnp transistor? What are the turn-on voltages for the two junctions?

5.2 Input Characteristics

Build the circuit as shown in Fig. 2. Ensure that the d.c. power supply is connected to the base via a 180 kΩ resistor. Adjust the base and collector power supply to set $V_B = 0$ and $V_{CE} = 5$ V.

Adjust V_B to perform a quick scan of V_{BE} values to determine the area of significant changes (see Fig. 2). Concentrate your measurements at V_{BE} values where I_B increases rapidly. Note the base voltage required to get a base current of **20, 40 and 70 µA**.

- **Question 1:** Plot the input characteristic, I_B against V_{BE}. Plot the graph as you take the measurements so you can see where you need measurement points to produce a well defined graph. (Use linear paper)

- Repeat a few of the measurements with V_{CE} set to 10 V. Are the values significantly different?

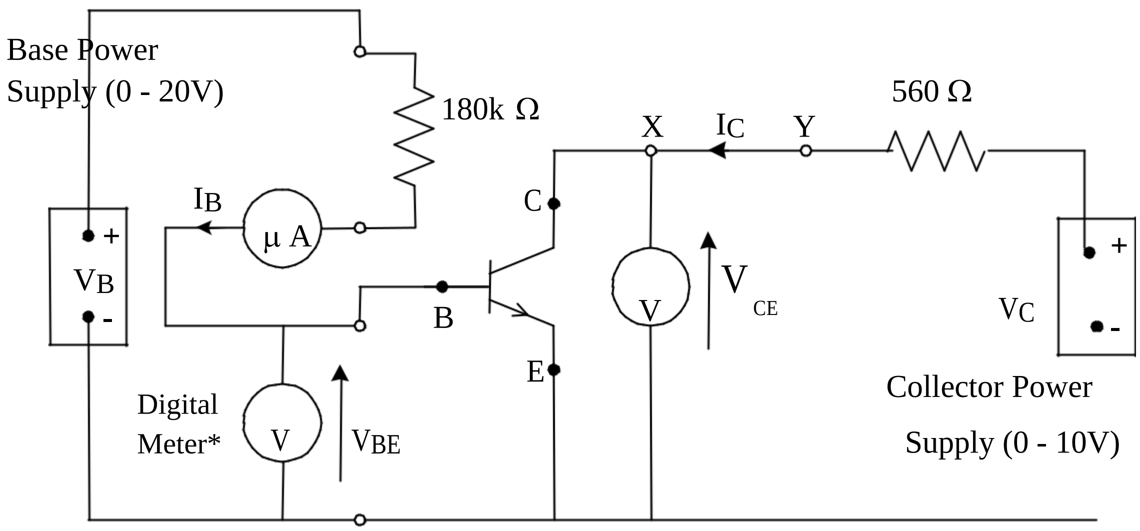

Figure 2 Circuit diagram to measure the transistor characteristics

Notes: Bipolar Transistor Input Characteristics

A typical input characteristic (I_B plotted against V_{BE}) for a small-signal general purpose NPN transistor operating in the common-emitter mode (See later) is shown in Fig. 3. This characteristic shows that very little base current flows until the base-emitter voltage (V_{BE}) exceeds 0.6 V. Thereafter, the base current increases rapidly (this characteristic bears a very close resemblance to a forward biased silicon diode).

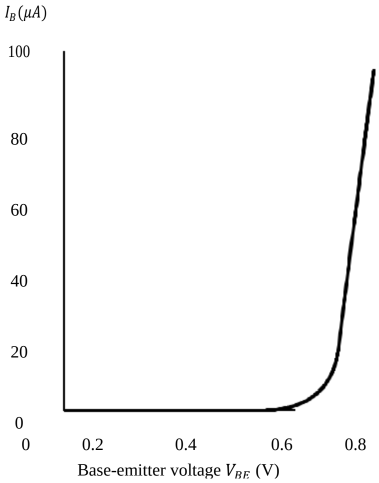

Figure 3 Typical input characteristic

5.3 Output Characteristics

Fig. 4 shows a typical set of output characteristics (I_C plotted against V_{CE}) general purpose NPN silicon transistor operating in the common-emitter mode. The characteristics are a family of curves, each curve for a different value of base current (I_B). Note that the curves are flattened above the "knee" (which occurs at values of V_{CE} of about 2V) with the collector current (I_C) not changing by a significant amount for a comparatively large change in collector-emitter voltage (V_{CE}). The flattened sections are almost parallel and are equally spaced for equal changes in I_B.

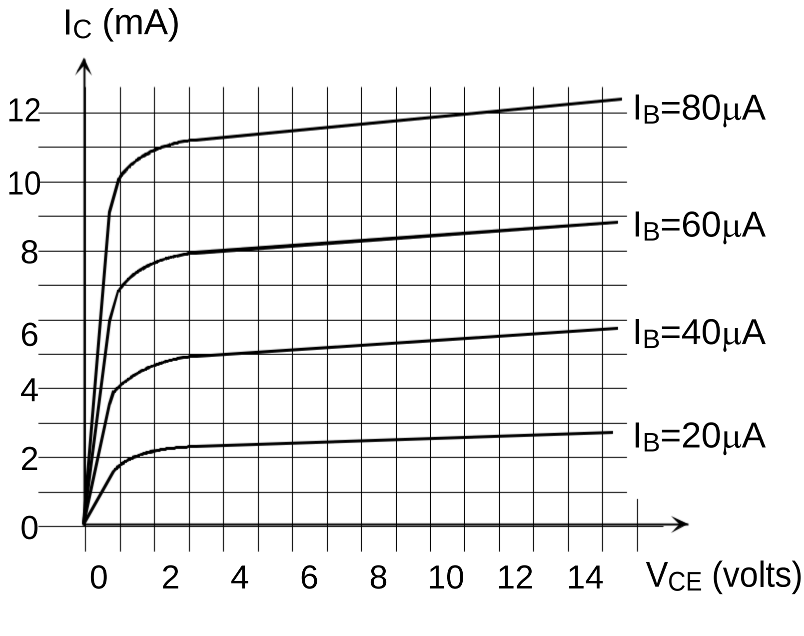

Figure 4 Typical output characteristics

Use the same circuit **but move** the digital ammeter from the base to the collector (between X and Y in Fig. 2). Set it to measure d.c. current. Measure the collector current, I_C, as a function of the collector-emitter voltage, V_{CE}, for I_B=0, 20, 40, 70 μA.

Use Fig. 4 to judge for which range of V_{CE} values you need to take more measurements. Appropriate values of V_{CE} are 0.05V, 0.1V, 0.2V etc., in a doubling sequence up to 10V.

Question 2: Plot I_C against V_{CE} to produce a family of I_C vs. V_{CE} curves for different values of base current **on the same graph**. These are the output characteristics. Again plot the graph as you take the measurements.

5.4 Common-Emitter Amplifier

We look at the common emitter amplifier's typical role as an amplifier for small a.c. voltages. Construct the circuit shown in Fig. 5.

(a) Test to see if the circuit works.

- Monitor input and output signals, Vin and Vout, on an oscilloscope.
- **Questions 3:** Use a sinusoidal Vin of about 5kHz and an amplitude of about 0.5V. This amplifier should have an amplification $A_v = -10$. Make a rough (but useful!) sketch of the waveforms. You should be able to get an idea of the amplitudes, periods, relative phases and zeroes from the sketch.
- Compare your gain to the predicted amplification, $A_v = -R_C/R_E$. . Do the magnitude and phase agree?

(b) Some analysis

- Remove the a.c. input signal and measure V_C, V_B and V_E with the DMM.
- **Questions 4:** Verify that R_2 and R_1 act like a voltage divider for V_{CC}. What V_B is expected for this divider? What is the measured value? What is V_{BE}? Is this expected? Explain. What is V_{CE}?
- Introduce an ac input signal again (0.5V amplitude, 5 kHz). Increase Vin's amplitude. At some point, Vout becomes clipped or distorted. At what amplitude does this correspond to? Why does this happen?

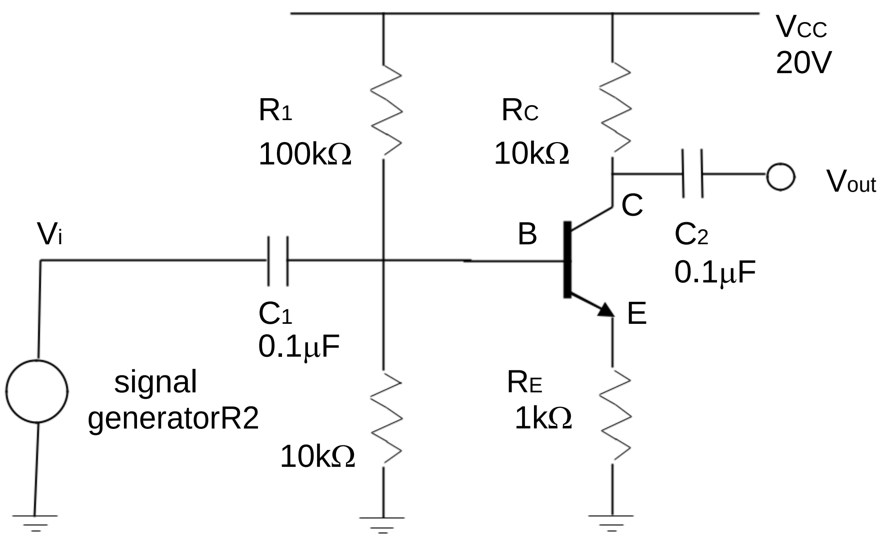

Figure 5 Common emitter amplifier using a single voltage supply

6. Important Notice on Lab Arrangement

1. Please obey the **lab rule** and **safety regulations** when working in the lab.

2. Please read the lab script before the lab.

3. Please follow the **same** team arrangement (same partner) as in Lab #1 and sit at the **same** Lab Desk as registered in Lab #1.

4. Every student writes his/her **own** report, and submit the **PDF** on Learning Mall. Teamwork is encouraged during lab session, NOT in report writing.

5. Please use the **template** provided for your lab report (attached along with the lab script on Learning Mall).