

## **EEE109 Lab 2 Transistors (Semester 1)**

---

### **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:  $560\Omega$ ,  $1k\Omega$ ,  $10k\Omega \times 2$ ,  $100k\Omega$ ,  $180k\Omega$   
Capacitors:  $0.1\mu F \times 2$

---

### **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.

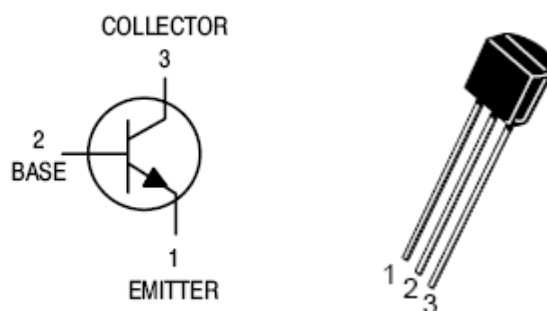


Figure 1. Bipolar junction transistor

## 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 Figure 2. Ensure that the d.c. supply is connected to the base via a  $180\text{k}\Omega$  resistor. Adjust the collector power supply to set  $V_{CE}$  to  $5\text{V}$ . Measure the base-emitter voltage,  $V_{BE}$ , as a function of the base current  $I_B$ , up to a maximum base current of  $100\text{ }\mu\text{A}$ .

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  $70\text{ }\mu\text{A}$** . (**HINTS:** Calibrate the oscilloscope by putting the same signal into both channels of the oscilloscope and overlaying the two screenshots using the controls.)

- **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  $10\text{V}$ . Are the values significantly different?

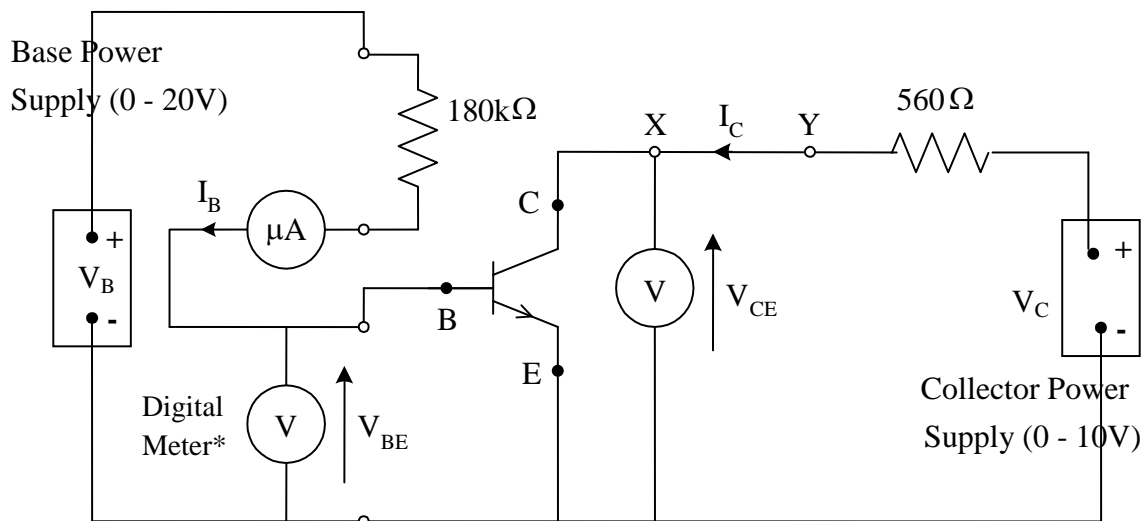


Fig . 2 - Circuit diagram to measure the transistor characteristics

### 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 0.6V. Thereafter, the base current increases rapidly (this characteristic bears a very close resemblance to a forward biased silicon diode).

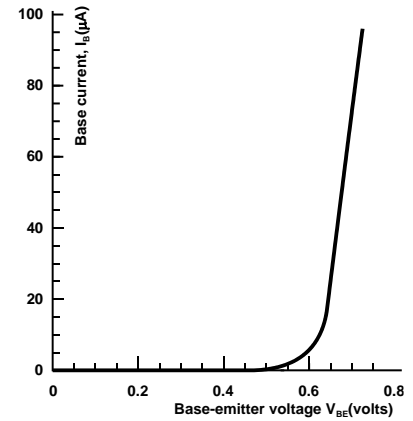


Fig. 3 Typical input characteristic

### 5.3 Output Characteristics

Figure 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  $I_B$ .

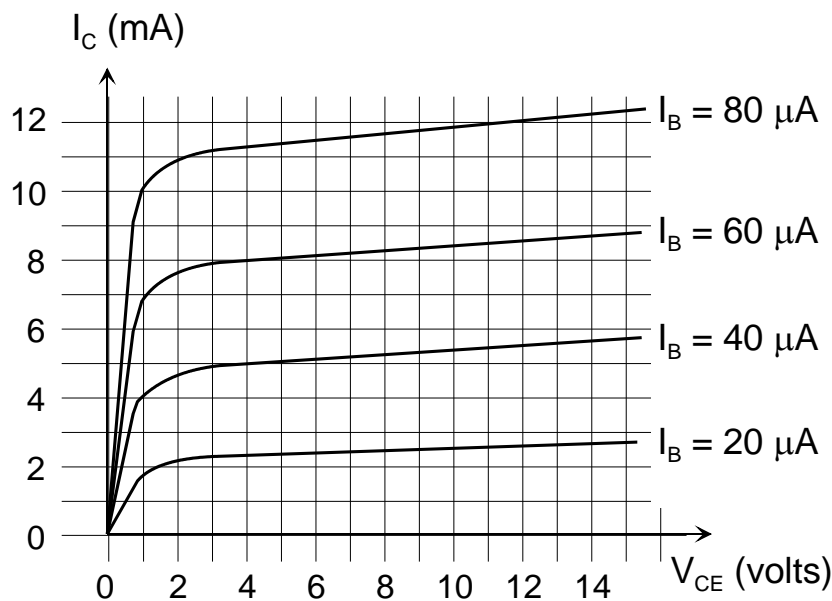


Figure 4 Typical output characteristics

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  $I_B=0, 20, 40, 70 \mu A$ .

Use Figure 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,  $V_{in}$  and  $V_{out}$ , on an oscilloscope.
- Use a sinusoidal  $V_{in}$  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.
- 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, 5kHz). Increase  $V_{in}$ 's amplitude. At some point,  $V_{out}$  becomes clipped or distorted. At what amplitude does this correspond to? Why does this happen?

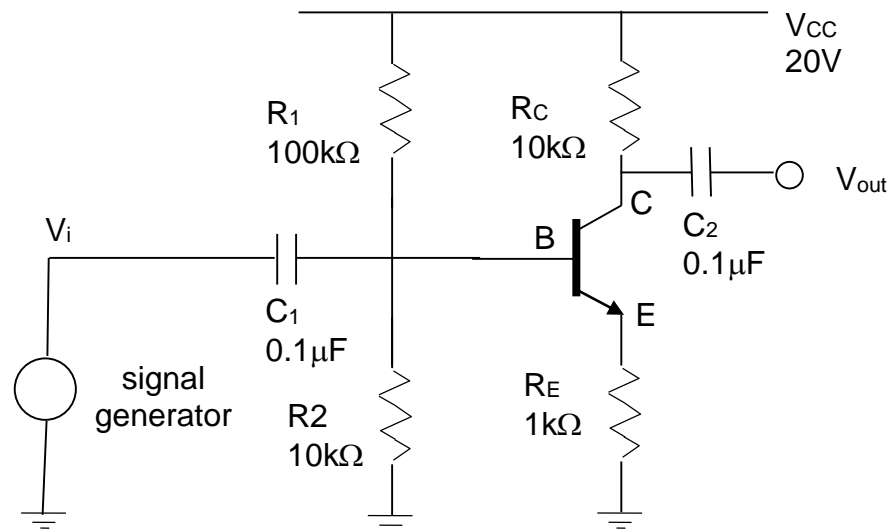


Figure 5 Common emitter amplifier using a single voltage supply

## 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. The lab is scheduled on **Week 8-11**
4. Please follow the **same** team arrangement (same partner) as in Lab #1 and sit at the **same** Lab Desk **according to your group ID** as registered in Lab #1.
5. Only **ONE report** is required **per group**. DO NOT submit twice on ICE - *Nominate one student to submit on ICE.*
6. Please use the **template** provided for your lab report (attached along with the lab script on ICE).