Electronics 1 Lab (CME 2410)

School of Informatics & Computing
German Jordanian University

Laboratory Experiment (5)

The Bipolar Junction Transistor (BJT)
Characteristics & DC Operation

1. Objective:

1. To be familiar with BJT transistors and to learn how they work.
2. To study the concept of biasing a Bipolar Junction Transistor (BJT).

2. Theory:

The transistor is a three-terminal device. The transistor consists of two n-type materials separated by a p-type material (npn transistor) or two p-type materials separated by an n-type material (pnp transistor). Figure 10.1 below shows a schematic representation of a transistor.

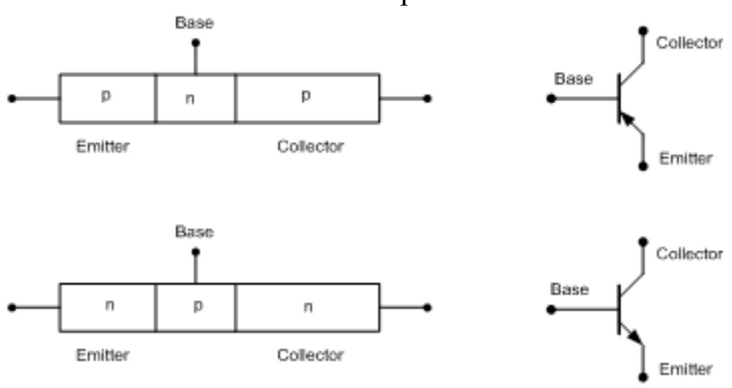


Fig. 10.1: The bipolar transistor

Because there are three terminals and the operations of the two p-n junctions are coupled, one single voltage-current characteristic (as was possible for the diode) is no longer valid for the BJT. Therefore, a set of curves is necessary.

Input characteristics: The input characteristic is a plot of the input base current I_B as a function of the controlling base-emitter voltage V_{BE} while the collector-emitter voltage V_{CE} is constant:

$$I_B = f(V_{BE})\big|_{V_{CE}=const}$$

Output characteristics: a plot of the output collector current I_C versus the output collector-emitter voltage V_{CE} with the input base current I_B as a parameter:

$$I_C = f(V_{CE})\big|_{I_B=const}$$

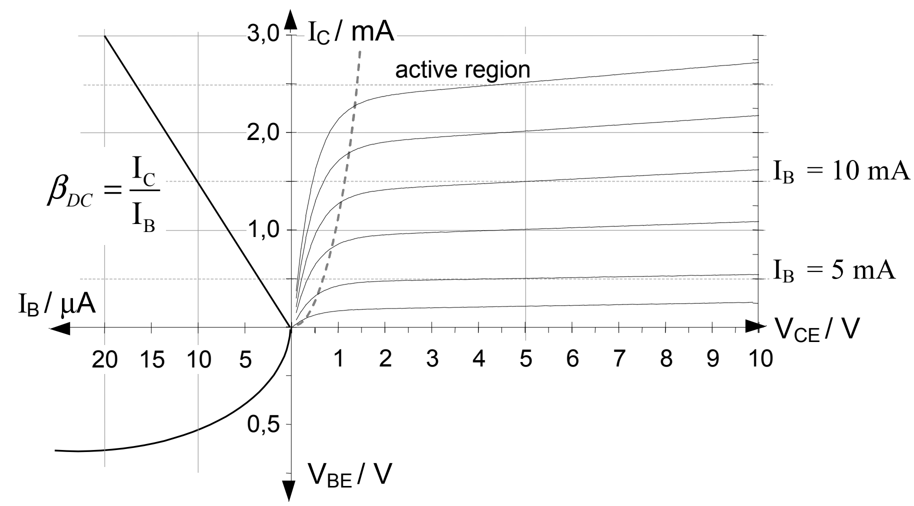


Fig. 10.2: Input and output characteristic curves

The transistor has different modes of operation. Out of these modes is

(a) the ACTIVE mode where the transistor operates linearly over a specified range as a controlled current source. In this mode of operation, the output collector current I_C is approximately directly proportional to the base current I_B with the proportionality constant being the *DC-current gain* β_{DC}:

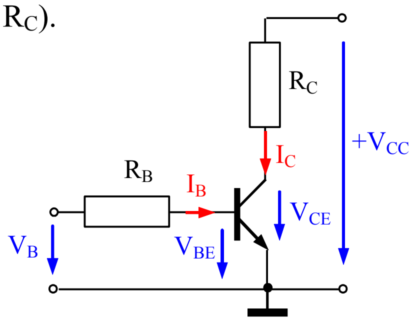
$$\beta_{DC} = \frac{I_C}{I_B} \quad \text{......................................} (1)$$

Our mission in this experiment is to carefully bias the BJT such that it is operating in the linear active mode. The chosen operating point depends on the bias voltage V_{BE}, the current gain β_{DC}, and the collector circuit resistance.

(b) A BJT can be made to act as a simple ON/OFF switch. In such an application, the transistor is operated in the saturation region to simulate the ON (closed) switch condition (with minmal voltage drop) and in the cut-off region to simulate the OFF (open) switch condition (with no current flowing). These conditions are dependent on the input applied to the base of the transistor. When the transistor switch is ON, $V_{CE} = V_{CE\,sat}$ and when the transistor switch is OFF, $V_{CE} = V_{CC}$.

BJT Circuit Examples:

A BJT circuit is shown in Fig. 10.3. The operating point of the BJT is described by the two quantities I_C and V_{CE}. We find them by analyzing the input loop (with R_B) and the output loop (with R_C).



Vcc source reverse bias the collector-base diode

VB source forward bias the base-emitter diode with RB as a current limiting resistor.

Fig. 10.3: Example of a BJT circuit

To find the collector current I_C we first have to calculate the base current I_B. To find its value we apply KVL to the left loop:

$$R_B \cdot I_B + V_{BE} - V_B = 0$$

$$I_B = \frac{V_B - V_{BE}}{R_B} \qquad \text{..................................} (2)$$

Then, using the DC-current gain β_{DC} to calculate I_C with equation (1)

$$I_C = \beta_{DC} \cdot I_B \qquad \text{..} (3)$$

The collector-emitter voltage V_{CE} we get by applying KVL to the right loop:

$$R_C \cdot I_C + V_{CE} - V_{CC} = 0$$

$$V_{CE} = V_{CC} - R_C \cdot I_C \qquad \text{................................} (4)$$

3. Equipment & Instruments

Module No. : DL 3155E14

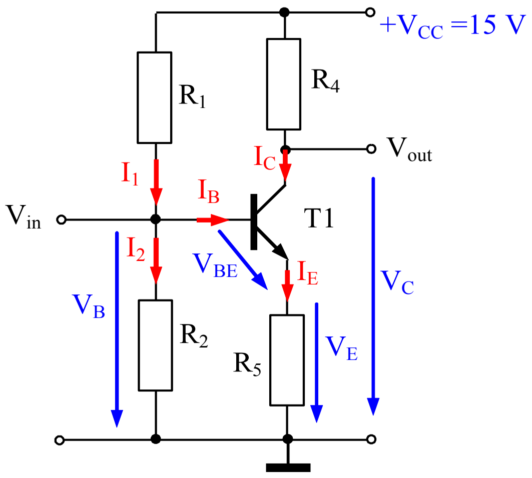
Multimeter

4. Components List:

R1 = 120 kΩ, R2 = 10 kΩ, R4 = 15 kΩ, R5 = 1 kΩ

5. Procedure

1) ➯ connect the circuit as shown in Fig. 10.4 ;



V_{in} is the input voltage,
V_{out} is the output voltage.
Both are not used in this experiment.

Fig. 10.4: Common emitter circuit

2) ➯ measure the voltages V_B, V_E and V_C, determine the emitter current $I_E = {}^{V_E}\!/_{R_5}$ by using the measured value of V_E ;
create a table like Tab. 10.1 and put these value in;
name these values of step (2) the "measured" values ;

3) ➯ calculate the voltages V_B, V_E and V_C,
considering the voltage $V_{BE} = 0.6V$; name other assumptions you used for the calculation;
calculate the value of the emitter current I_E by using the calculated value of V_E;
put them all as "calculated" values in a second row of Tab. 10.1;

4) ➯ measure the voltages between the 3 terminals of the transistor and write these 3 values in a new Tab. 10.2 ;

5) ➯ measure the voltage drops on R1 and R2 and write them in further columns of Tab. 10.2 ;

6) ➯ calculate the base current I_B and the DC-current gain β_{DC} and write them in further columns of Tab. 10.2 ;

7) ➯ observe and comment the carried out measures (transistor currents and bias voltage) and verify that the transistor works in the **active** zone.

Tab. 10.1

V_B /V	V_E /V	V_C /V	I_E /mA= I_C /mA	
				Measured Values
				Calculated Values

Tab. 10.2

V_{BE} /V	V_{BC} /V	V_{CE} /V	V_{R1} /V	V_{R2} /V	I_B /mA	$\beta_{DC} = I_C/I_B$
Measured Values					Calculated Values	

Modification insertion

Modification M1

1) remove the cover of the Modifications/Faults simulator and set the first dip-switch M1 to ON position (covered dot);
2) measure and record in Tab. 10.3 the collector, base and emitter voltages with reference to ground;
3) **determine if the transistor T1 works:**
   a. at the saturation point
   b. in the active region
   c. at the cut-off point
4) set the dip-switch M1 back to the initial upwards position;

Modification M2

5) set the dip-switch M2 to ON position (covered dot);
6) measure and record in Tab. 10.3 the collector, base and emitter voltages with reference to ground;
7) **determine if the transistor T1 works**:
   a. at the saturation point
   b. at the cut-off point
   c. in the active region
   d. at an optimum collector voltage (V_C)
8) set the dip-switch M2 back to the initial upwards position;

Modification M3

9) set the dip-switch M3 to ON position (covered dot);
10) measure and record in Tab. 10.3 the collector, base and emitter voltages with reference to ground;
11) **determine if the transistor T1 works**:
   a. at the cut-off point
   b. at the saturation point
   c. in the active region
12) set the dip-switch M3 back to the initial upwards position;

Tab. 10.3

	V_C / V	V_B / V	V_E / V
Modification M1			
Modification M2			
Modification M3			