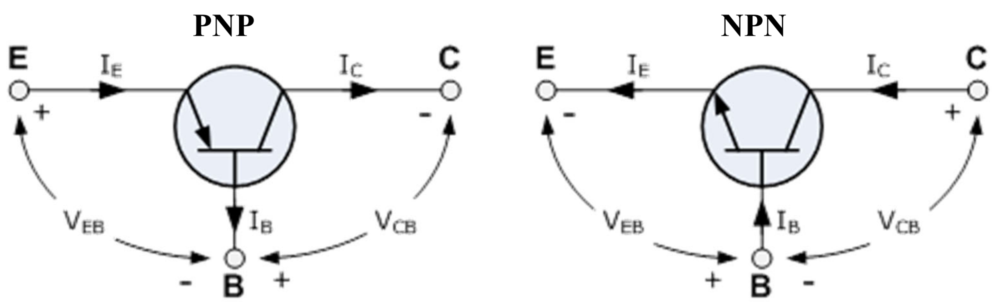
Bipolar Junction Transistor Static Characteristics

Objective:

(i) To study the input and output characteristics of a transistor in Common Emitter mode and determine transistor parameters.

Overview:

A **Bipolar Junction Transistor**, or **BJT** is a three terminal device having two PN-junctions connected together in series. Each terminal is given a name to identify it and these are known as the Emitter (E), Base (B) and Collector (C). There are two basic types of bipolar transistor construction, NPN and PNP, which basically describes the physical arrangement of the P-type and N-type semiconductor materials from which they are made. Bipolar Transistors are "CURRENT" Amplifying or current regulating devices that control the amount of current flowing through them in proportion to the amount of biasing current applied to their base terminal. The principle of operation of the two transistor types NPN and PNP, is exactly the same the only difference being in the biasing (base current) and the polarity of the power supply for each type.



The symbols for both the NPN and PNP bipolar transistor are shown above along with the direction of conventional current flow. The direction of the arrow in the symbol shows current flow between the base and emitter terminal, pointing from the positive P-type region to the negative N-type region, exactly the same as for the standard diode symbol. For normal operation, the emitter-base junction is forward-biased and the collector-base junction is reverse-biased.

Transistor Configurations

There are three possible configurations possible when a transistor is connected in a circuit: (a) Common base, (b) Common emitter (c) Common collector. We will be focusing on the first two configurations in this experiment. The behaviour of a transistor can be represented by d.c. current-voltage (I-V) curves, called the static characteristic curves of the device. The three important characteristics of a transistor are: (i) Input characteristics, (ii) Output characteristics and (iii) Transfer Characteristics. These characteristics give information about various transistor parameters, e.g. input and out dynamic resistance, current amplification factors, etc.

Common Emitter Transistor Characteristics

In a common emitter configuration, emitter is common to both input and output as shown in its circuit diagram.

(1) ***Input Characteristics:*** The variation of the base current I_B with the base-emitter voltage V_{BE} keeping the collector-emitter voltage V_{CE} fixed, gives the input characteristic in CE mode.

Input Dynamic Resistance (r_i): This is defined as the ratio of change in base emitter voltage (ΔV_{BE}) to the resulting change in base current (ΔI_B) at constant collector-emitter voltage (V_{CE}). This is dynamic and it can be seen from the input characteristic, its value varies with the operating current in the transistor:

$$r_i = \left.\frac{\Delta V_{BE}}{\Delta I_B}\right|_{V_{CE}}$$

The value of r_i can be anything from a few hundreds to a few thousand ohms.

(2) ***Output Characteristics:*** The variation of the collector current I_C with the collector-emitter voltage V_{CE} is called the output characteristic. The plot of I_C versus V_{CE} for different fixed values of I_B gives one output characteristic. Since the collector current changes with the base current, there will be different output characteristics corresponding to different values of I_B.

Output Dynamic Resistance (r_o): This is defined as the ratio of change in collector-emitter voltage (ΔV_{CE}) to the change in collector current (ΔI_C) at a constant base current I_B.

$$r_o = \left.\frac{\Delta V_{CE}}{\Delta I_C}\right|_{I_B}$$

The high magnitude of the output resistance (of the order of 100 kW) is due to the reverse-biased state of this diode.

(3) ***Transfer Characteristics**:* The transfer characteristics are plotted between the input and output currents (I_B versus I_C). Both I_B and I_C increase proportionately.

Current amplification factor (β)

This is defined as the ratio of the change in collector current to the change in base current at a constant collector-emitter voltage (V_{CE}) when the transistor is in active state.

$$\beta_{ac} = \left.\frac{\Delta I_C}{\Delta I_B}\right|_{V_{CE}}$$

This is also known as small signal current gain and its value is very large. The ratio of I_C and I_B we get what is called β_{dc} of the transistor. Hence,

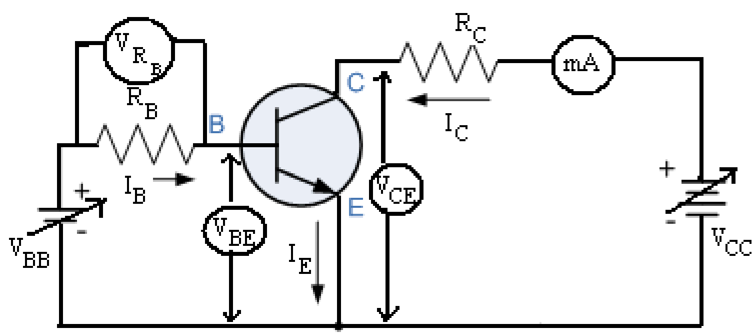
$$\beta_{dc} = \left.\frac{I_C}{I_B}\right|_{V_{CE}}$$

Since I_C increases with I_B almost linearly, the values of both β_{dc} and β_{ac} are nearly equal.

Circuit components/Equipment:

(i) Transistor (a) NPN (CL100 or equivalent)), (ii) Resistors (2 Nos.) (iii) Multimeters (3 Nos.), (iv) D.C. power supply, (v) Connecting wires and (vi) Breadboard.

Circuit Diagrams:



<u>NPN transistor in CE configuration</u>

Procedure:

1. Note down the type and code number of the transistor.
2. Identify different terminals (E, B and C) the transistor. For any specific information refer the data sheet of the transistors.

(I) NPN Common Emitter (CE) characteristics:

1. Now configure CE circuit using the NPN transistor as per the circuit diagram. Use $R_B = 100k\Omega$ and $R_C = 1\ k\Omega$.
2. For input characteristics, first fix the voltage V_{CE} by adjusting V_{CC} to the minimum possible position. Now vary the voltage V_{BE} slowly (say, in steps of 0.05V) by varying V_{BB}. Measure V_{BE} using a multimeter. If V_{CE} varies during measurement bring it back to the set value to determine I_B, measure V_{RB} across the resistor R_B and use the relation $I_B = V_{RB}/R_B$.
3. Repeat the above step for another value of V_{CE} say, 2V.
4. For output characteristics, first fix $I_B = 0$, i.e. $V_{RB} = 0$. By adjusting V_{CC}, vary the collector voltage V_{CE} in steps of say 1V and measure V_{CE} and the corresponding I_C using multimeter. If needed vary V_{CE} in negative direction like CB configuration and measure both V_{CE} and I_C, till you get 0 current.
5. Repeat the above step for at least 5 different values of I_B by adjusting V_{BB}. You may need to adjust V_{BB} continuously during measurement in order to maintain a constant I_B.
6. Plot the input and output characteristics by using the readings taken above and determine the input and output dynamic resistance.
7. Plot the transfer characteristics between I_C and I_B as described for CB configuration for a suitable voltage of V_{CE} on the output characteristics. Determine β_{ac} from the slope of this graph.

Observations:

CE configuration:

Transistor code: ________, Transistor type: ______

R_B = _____, R_C = ________.

Table (1): Input Characteristics

Sl. No.	V_{CE} = ___V			V_{CE} = ___V		
	V_{EB} (V)	V_{RB} (V)	I_B (μA)	V_{EB} (V)	V_{RB} (V)	I_E (μA)
1						
2						
..						
..						
10						

Table (2): Output Characteristics

Sl. No.	$I_B = 0$		$I_B =$ __		$I_B =$ __		$I_B =$ __		$I_B =$ __	
	V_{CE} (V)	I_C (mA)	V_{CE} (V)	I_C (mA)	V_{CE} (V)	I_C (mA)	V_{CE} (V)	I_C (mA)	V_{CE} (V)	I_C (mA)
1										
2										
..										
..										
10										

Table (3): Transfer Characteristics:

V_{CE} = _______ V

Sl. No.	I_B (μA)	I_C (mA)
1		
2		
3		
4		
5		

Graph

Plot the input, output and transfer characteristics for CE configuration.

CE configuration:

(1) Input characteristics: Plot $V_{BE} \sim I_B$, for different V_{CE} and determine the input dynamic resistance in each case at suitable operating points.
(2) Output characteristics: Plot $V_{CE} \sim I_C$, for different I_B and determine the output dynamic resistance in each case at suitable operating points in the active region.
(3) Transfer characteristics: Plot $I_B \sim I_C$, for a fixed V_{CE} and determine β_{ac}.

Results/Discussions: