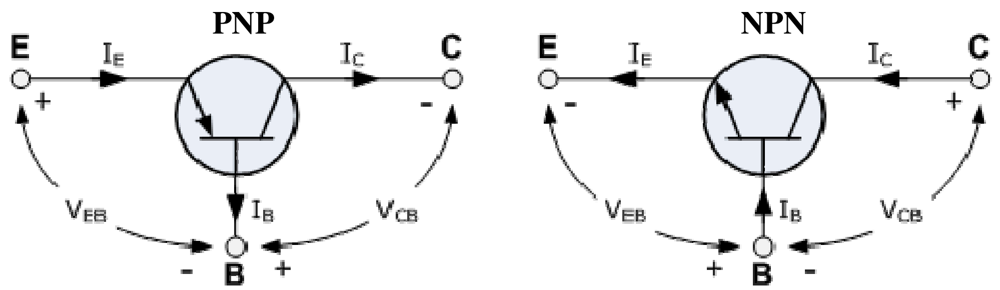
Bipolar Junction Transistor Static Characteristics

Objective:

(i) To study the input and output characteristics of a PNP transistor in Common Base mode and determine transistor parameters.
(ii) To study the input and output characteristics of an NPN 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 Base Transistor Characteristics

In common base configuration, the base is made common to both input and output as shown in its circuit diagram.

(1) ***Input Characteristics:*** The input characteristics is obtained by plotting a curve between I_E and V_{EB} keeping voltage V_{CB} constant. This is very similar to that of a forward-biased diode and the slope of the plot at a given operating point gives information about its input dynamic resistance.

Input Dynamic Resistance (r_i) This is defined as the ratio of change in base emitter voltage (ΔV_{EB}) to the resulting change in emitter current (ΔI_E) at constant collector-emitter voltage (V_{CB}). This is dynamic as its value varies with the operating current in the transistor.

$$r_i = \left.\frac{\Delta V_{EB}}{\Delta I_E}\right|_{V_{CB}}$$

(2) ***Output Characteristics:*** The output characteristic curves are plotted between I_C and V_{CB}, keeping I_E constant. The output characteristics are controlled by the input characteristics. Since I_C changes with I_E, there will be different output characteristics corresponding to different values of I_E. These curves are almost horizontal. This shows that the output dynamic resistance, defined below, is very high.

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

$$r_o = \left.\frac{\Delta V_{CB}}{\Delta I_C}\right|_{I_E}$$

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

Current amplification factor (α)

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

$$\alpha_{ac} = \left.\frac{\Delta I_C}{\Delta I_E}\right|_{V_{CB}}$$

This is also known as small signal current gain and its value is very large. The ratio of I_C and I_E is called α_{dc} of the transistor. Hence,

$$\alpha_{dc} = \left.\frac{I_C}{I_E}\right|_{V_{CB}}$$

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

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,

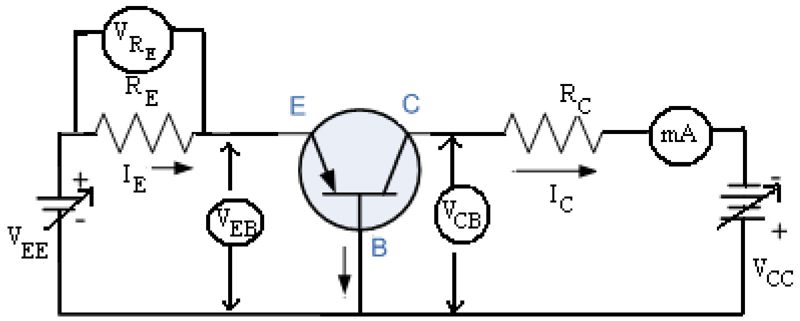
$$\beta_{dc} = \left.\frac{I_C}{I_B}\right|_{V_{CE}}$$

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

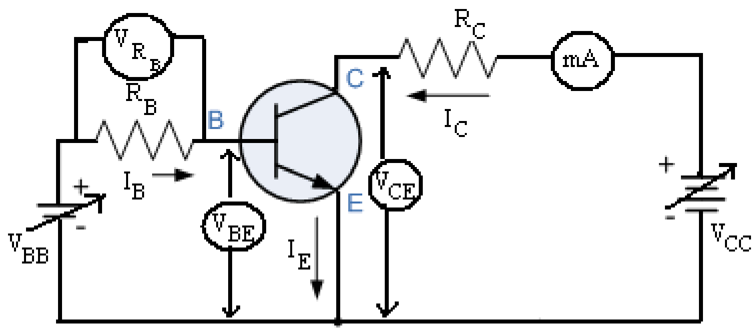
Circuit components/Equipments:

(i) Transistors (2 Nos: 1 PNP (CK 100 or equivalent) and 1 NPN (BC 107 or equivalent)), (ii) Resistors (4 Nos.) (iii) Multimeters (3 Nos.), (iv) D.C. power supply, (v) Connecting wires and (vi) Breadboard.

Circuit Diagrams:



PNP transistor in CB configuration



NPN transistor in CE configuration

Procedure:

1. Note down the type number of both the transistors.
2. Identify different terminals (E, B and C) and the type (PNP/NPN) of the transistors. For any specific information refer the datasheet of the transistors.

(I) PNP Common Base (CB) characteristics

1. Configure CB circuit using the PNP transistor as per the circuit diagram. Use $R_E = R_C = 150\ \Omega$.
2. For input characteristics, first fix the voltage V_{CB} by adjusting V_{CC} to the minimum possible position. Now vary the voltage V_{EB} slowly (say, in steps of 0.05V) by varying V_{EE}. Measure V_{EB} using a multimeter. If V_{CB} varies during measurement bring it back to the initial set value To determine I_E, measure V_{RE} across the resistor R_E and use the relation $I_E = V_{RE}/R_E$.
3. Repeat the above step for another value of V_{CB} say, 2V.
4. Take out the multimeter measuring V_{EB} and connect in series with the output circuit to measure I_C. For output characteristics, first fix $I_E = 0$, i.e. $V_{RE} = 0$. By adjusting V_{CC}, vary the collector voltage V_{CB} in steps of say 1V and measure V_{CB} and the corresponding I_C using multimeters. After acquiring sufficient readings, bring back V_{CB} to 0 and reduce it further to get negative values. Vary V_{CB} in negative direction and measure both V_{CB} and I_C, till you get 0 current.
5. Repeat the above step for at least 5 different values of I_E by adjusting V_{EE}. You may need to adjust V_{EE} continuously during measurement in order to maintain a constant I_E.
6. Plot the input and output characteristics by using the readings taken above and determine the input and output dynamic resistance.
7. To plot transfer characteristics, select a suitable voltage V_{CB} well within the active region of the output characteristics, which you have tabulated already. Plot a graph between I_C and the corresponding I_E at the chosen voltage V_{CB}. Determine α_{ac} from the slope of this graph.

(II) 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 multimeters. If needed vary V_{CE} in negative direction as described for 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:

CB configuration:

Transistor code: ________, Transistor type: ______ (PNP/NPN)
R_E = _____, R_C = ________.

Table (1): Input Characteristics

Sl. No.	V_{CB} = ___V			V_{CB} = ___V		
	V_{EB} (V)	V_{RE} (V)	I_E (mA)	V_{EB} (V)	V_{RE} (V)	I_E (mA)
1						
2						
..						
..						
10						

Table (2): Output Characteristics

Sl. No.	I_{E1} = 0		I_{E2} = __		I_{E3} = __		I_{E4} = __		I_{E5} = __	
	V_{CB} (V)	I_C (mA)	V_{CB} (V)	I_C (mA)	V_{CB} (V)	I_C (mA)	V_{CB} (V)	I_C (mA)	V_{CB} (V)	I_C (mA)
1										
2										
..										
..										
10										

Table (3): Transfer Characteristics **V_{CB} = _______ V**

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

CE configuration: Transistor code: ________, Transistor type: ______ (PNP/NPN)
R_B = _____, R_C = ________.

Table (5): Input Characteristics

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

Table (4): Output Characteristics

Sl. No.	I_{B1} = 0		I_{B2} = __		I_{B3} = __		I_{B4} = __		I_{B5} = __	
	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 (6): Transfer Characteristics **V_{CE} = _______ V**

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

Graphs:

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

CB configuration:

(1) Input characteristics: Plot V_{EB} ~ I_E, for different V_{CB} and determine the input dynamic resistance in each case at suitable operating points.
(2) Output characteristics: Plot V_{CB} ~ I_C, for different I_E and determine the output dynamic resistance in each case at suitable operating points in the active region.
(3) Transfer characteristics: Plot I_E ~ I_C, for a fixed V_{CB} and determine α_{ac}.

CE configuration:

(1) Input characteristics: Plot V_{BE} ~ 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} ~ 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 ~ I_C, for a fixed V_{CE} and determine β_{ac}.

Results/Discussions:

Precautions: