UNIT III Bipolar Junction Transistor (BJT):

Principle of Operation, Common Emitter, Common Base and Common Collector Configurations, Transistor as a switch, switching times.

3.1 Introduction

- Transistor is a three terminal device namely Base, emitter and collector, can be operated in three configurations common base, common emitter and common collector.
- According to configuration it can be used for voltage as well as current amplification.
- The input signal of small amplitude is applied at the base to get the magnified output signal at the collector.
- The amplification in the transistor is achieved by passing input current signal from a region of low resistance to a region of high resistance.
- This concept of transfer of resistance has given the name TRANSfer-resISTOR (TRANSISTOR).

3.1.1 Types of transistors

- There are two types of transistors namely unipolar junction transistor and bipolar junction transistor.
- In unipolar transistor the current conduction is only due to one type of carriers, majority carriers.
- In bipolar transistor the current conduction is due to both the types of charge carriers, namely holes and electrons. Hence this is called Bipolar Junction Transistor (BJT).
- In BJT output current is controlled by input current and hence it is a current controlled device.

3.1.2 Types of BJT

- npn type
- pnp type

3.1.3 Advantages of BJT

- Low operating voltage.
- Higher efficiency.
- Small size and ruggedness.
- Does not require any filament power.

3.2 Construction of Bipolar Junction Transistor (BJT)

- When a transistor is formed by sandwiching a single p-region between two n-regions, as shown in the Fig. 3.1 (a), it is an n-p-n type transistor.

- The p-n-p type transistor has a single n-region between two p-regions, as shown in Fig. 3.1 (b).

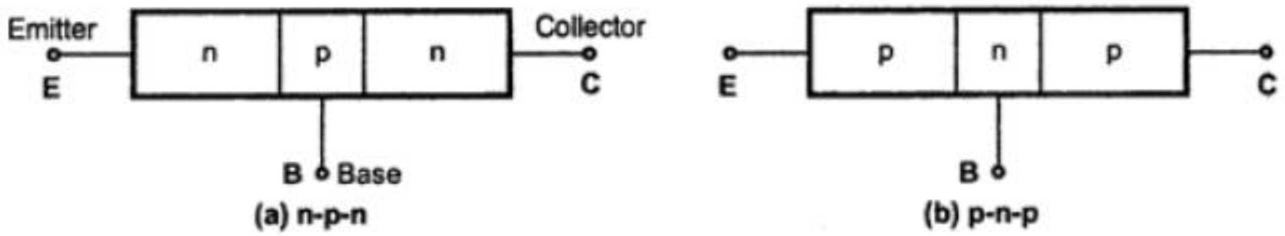

Fig. 3.1 Bipolar Junction transistor construction

- The middle region of each transistor type is called the base of the transistor. This region is very thin and lightly doped.
- The remaining two regions are called emitter and collector. The emitter is heavily doped and collector is moderately doped.
- The collector region area is slightly more than that of emitter.

3.2.1 Biased Transistor

- In order to operate transistor properly as an amplifier, it is necessary to correctly bias the two p-n junctions with external voltages.
- Depending upon external bias voltage polarities used, the transistor works in one of the three regions, Active region, Cut-off region and Saturation region

Region	Emitter base junction	Collector base junction
Active	Forward biased	Reverse biased
Cut-off	Reverse biased	Reverse biased
Saturation	Forward biased	Forward biased

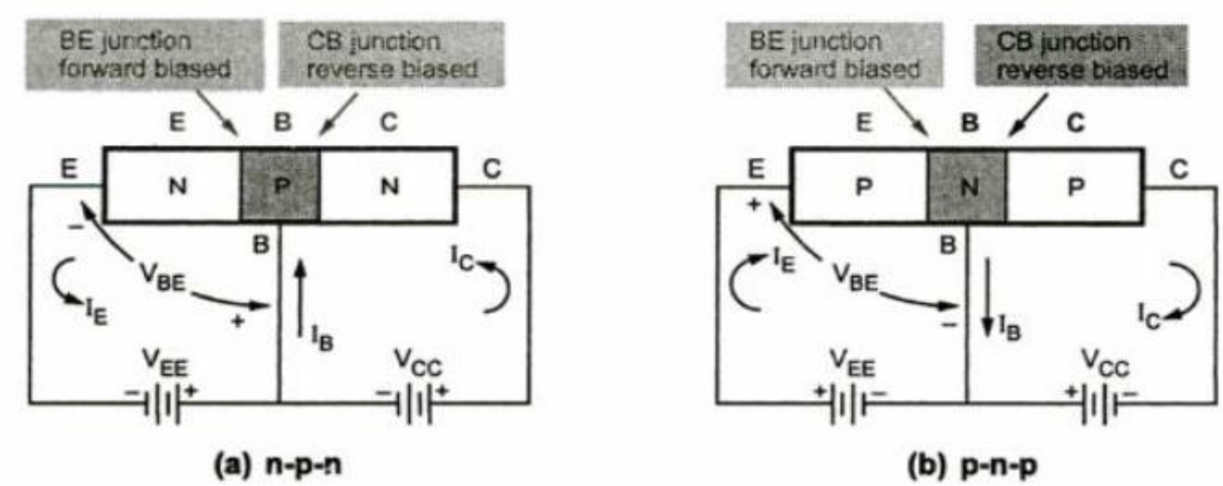

Fig. 3.2 Transistor forward-reverse bias

- To bias the transistor in its active region, the emitter base junction is forward biased while the collector base junction is reverse biased as shown in Fig. 3.2.

- The externally applied bias voltages are V_{EE} and V_{CC}, as shown in Fig. 3.2, which bias the transistor in its active region.

3.3 Operation of BJT

- The operation of the n-p-n is the same as for the p-n-p except that the roles of the electrons and holes, the bias voltage polarities, and the current directions are all reversed.

3.3.1 Operation of npn transistor

- The base to emitter junction is forward biased by the d.c source V_{EE}. Thus, the depletion region at this junction is reduced.
- The collector to base junction is reverse biased, increasing depletion region at collector to base junction as shown in Fig. 3.3.

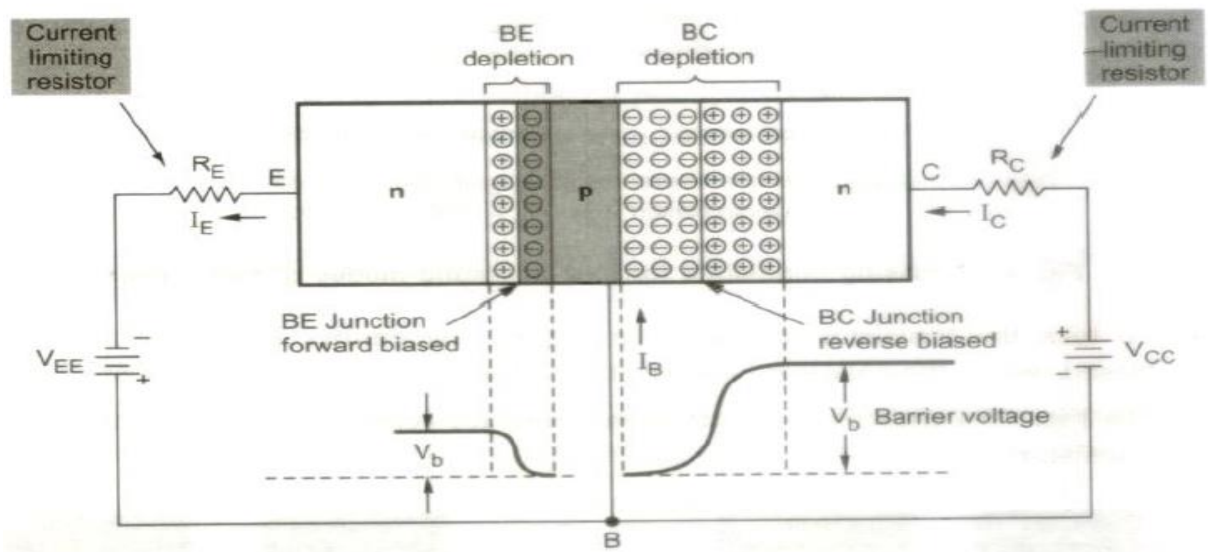

Fig. 3.3 Operation of npn transistor

- The forward biased EB junction causes the electrons in the n-type emitter to flow towards the base. This constitutes the emitter current I_E.
- *As* these electrons flow through the p-type base, they tend to combine with holes in p-region (base).
- Due to light doping, very few of the electrons injected into the base from the emitter recombine with holes to constitute base current, I_B and the remaining large number of electrons cross the base region and move through the collector region to the positive terminal of the external d.c source.
- This constitutes collector current I_C. Thus, the electron flow constitutes the dominant current in an n-p-n transistor.
- Since, most of the electrons from emitter flow in the collector circuit and very few combine with holes in the base.
- Thus, the collector current is larger than the base current.

$$I_E = I_B + I_C$$

3.3.2 Operation of pnp transistor

- The p-n-p transistor has its bias voltages V_{EE} and V_{CC} reversed from those in the n-p-n transistor as shown in Fig. 3.4.

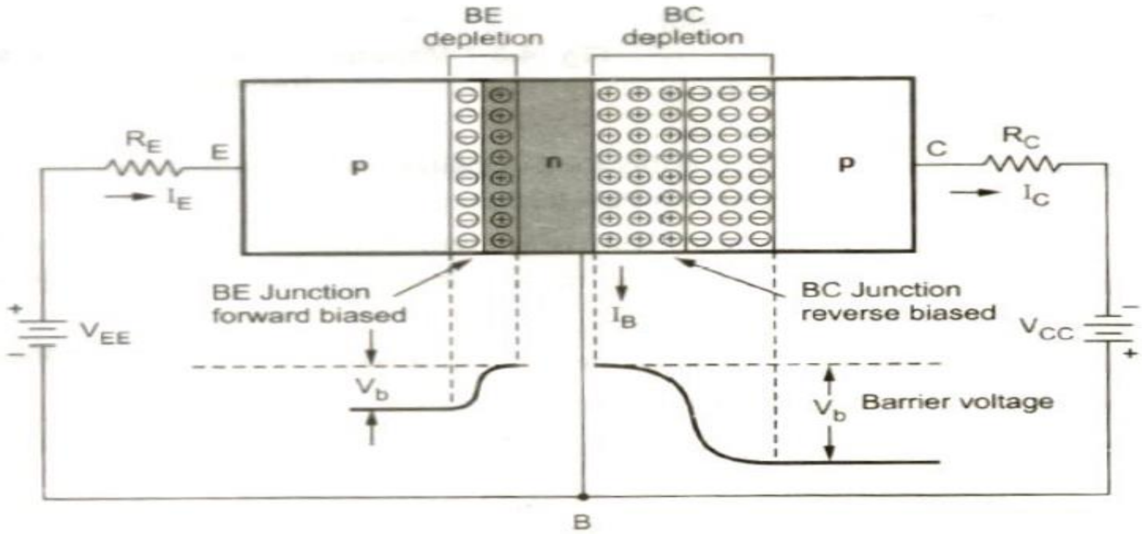

Fig. 3.4 Operation of pnp transistor

- This is necessary to forward bias the emitter base junction and reverse bias the collector base junction.
- The forward biased EB junction causes the holes in the p-type emitter to flow towards the base. This constitutes the emitter current I_E.
- As these holes flow through the n-type base, they tend to combine with electrons in n-region (base).
- As the base is very thin and lightly doped, very few of the holes injected into the base from the emitter recombine with electrons to constitute base current, I_B.
- The remaining large number of holes crosses the depletion region and move through the collector region to the negative terminal of the external d.c source.
- This constitutes collector current I_C.
- Thus, the hole flow constitutes the dominant current in an p-n-p transistor.
- Since, most of the holes from emitter flow in the collector circuit and very few combine with electrons in the base.
- Thus, the collector current is larger than the base current.

$$I_E=I_B+I_C$$

3.4 Transistor Circuit Configurations

- A transistor has three terminals or leads namely emitter (E), base (B) and collector (C).
- However, when a transistor is connected in a circuit, we require four terminals i.e., two terminals for input and two for output.
- This difficulty is overcome by using one of the three terminals as a common terminal to the input and output terminals.

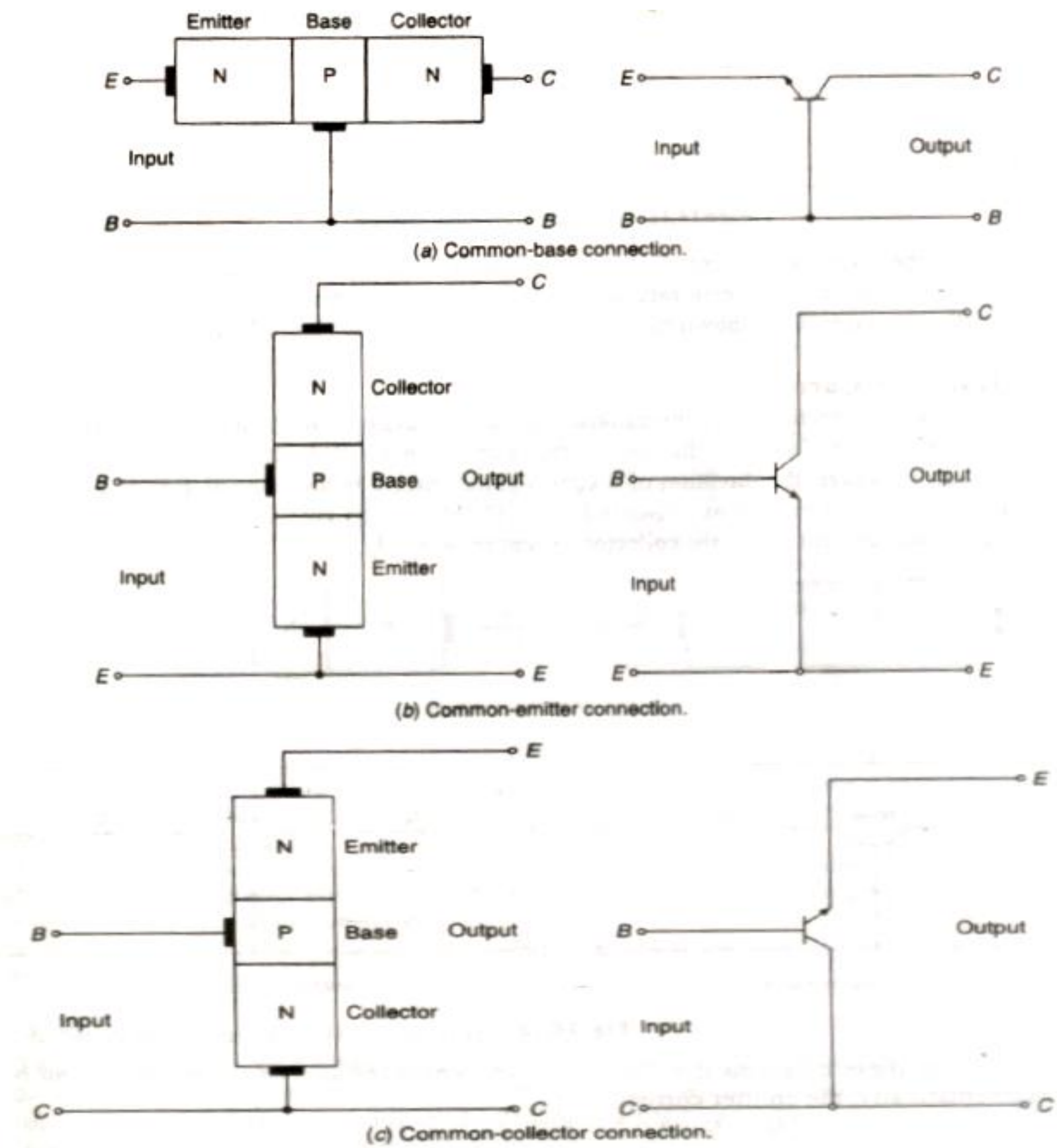

Fig. 3.5 Transistor Circuit Configurations

- Depending upon the terminals, which are used as a common terminal, the transistors can be connected in the following three different connections or configurations.
  - Common Base (CB) connection.
  - Common Emitter (CE) connection
  - Common Collector (CC) connection

Note:

- Regardless of circuit configuration, the base emitter junction is always forward biased while the collector base is always reverse biased to operate the transistor in active region.

3.5 Common Base Configuration

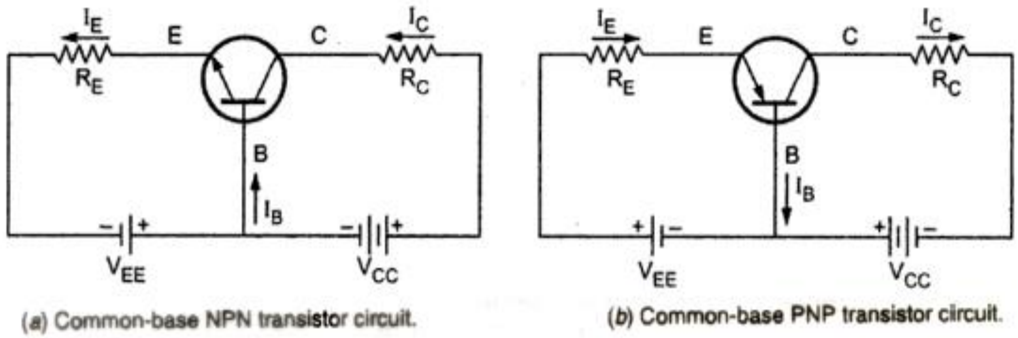

Fig. 3.6 Common Base Configuration

- Consider a transistor (either NPN or PNP) in a common base configuration as shown in Fig. 3.6 (a) or (b).
- Here the emitter current is the input current and collector current is the output current.
- The ratio of the transistor output current to the input current is called current gain of a transistor.
- Since the input current and output current may be either direct current or alternating current.
- Therefore, we define two types of current gains namely d.c current gain and a.c current gain.

3.5.1 Common base d.c current gain (α)

- It is defined as the ratio of collector current (I_C) to emitter current (I_E) and is usually designated by α, α_{DC} or h_{FB}
- Mathematically, the common base d.c current gain,

$$\boxed{\alpha = \frac{I_C}{I_E}}$$

- In a transistor, the collector current is always less than the emitter current.
- Therefore, current gain of a transistor in common base configuration is always less than unity.

3.5.2 Common base a.c current gain (α_0)

- It is defined as the ratio of small change in collector current (ΔI_C) to a small change in emitter current (ΔI_E) for a constant collector to base voltage (V_{CB}).
- It is designated by α_0, α_{ac} or h_{fb}.
- Mathematically, the common base a.c current gain

$$\boxed{\alpha_0 = \frac{\Delta I_C}{\Delta I_E}}$$

3.5.3 Current relations in Common Base configuration

- Hence the total collector current,

$$I_C = \alpha \, I_E + I_{CO}$$

Example *In a common-base connection, the emitter current is 6.28 mA and the collector current is 6.20 mA. Determine the common-base d.c. current gain.*

Solution. Given: $I_E = 6.28$ mA and $I_C = 6.20$ mA.

We know that common-base d.c. current gain,

$$\alpha = \frac{I_C}{I_E} = \frac{6.20}{6.28} = 0.987 \textbf{ Ans.}$$

Example *The common-base d.c. current gain of a transistor is 0.967. If the emitter current is 10 mA, what is the value of base current?*

Solution. Given: $\alpha = 0.967$ and $I_E = 10$ mA.

We know that common-base d.c. current gain (α),

$$0.967 = \frac{I_C}{I_E} = \frac{I_C}{10}$$

$$\therefore \quad I_C = 0.967 \times 10 = 9.67 \text{ mA}$$

We also know that emitter current (I_E),

$$10 = I_B + I_C = I_B + 9.67$$

$$\therefore \quad I_B = 10 - 9.67 = 0.33 \text{ mA } \textbf{Ans.}$$

3.5.4 Input and Output Characteristics of a Transistor in a Common Base Configuration

- Following are two important characteristics of a transistor in a common base (CB) configuration.
  - **Input characteristics**
    - These curves give the relationship between the emitter current (I_E) and the emitter to base voltage (V_{EB}) for a constant collector to base voltage (V_{CB}).
  - **Output characteristics.**
    - These curves give the relationship between the collector current (I_C) and the collector to base voltage (V_{CB}) for a constant emitter current (I_E).

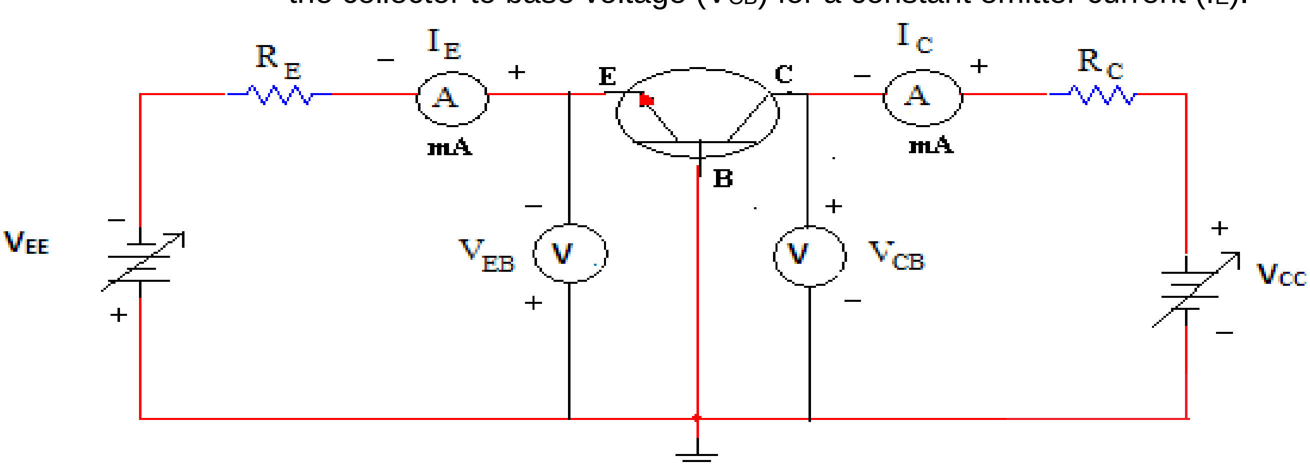

Fig. 3.7 Circuit arrangement for determining common base transistor characteristics

- In this circuit, the NPN transistor is connected in a common-base configuration.

- The d.c milli ammeters and d.c voltmeters are connected in the emitter and collector circuits of a transistor to measure the currents and voltages.

3.5.4.1 Input Characteristics of a Transistor in Common Base Configuration

- These curves may be obtained by using the circuit arrangement as shown in Fig. 3.7.
- First of all, vary the collector to base voltage (V_{CB}) to 1 V.

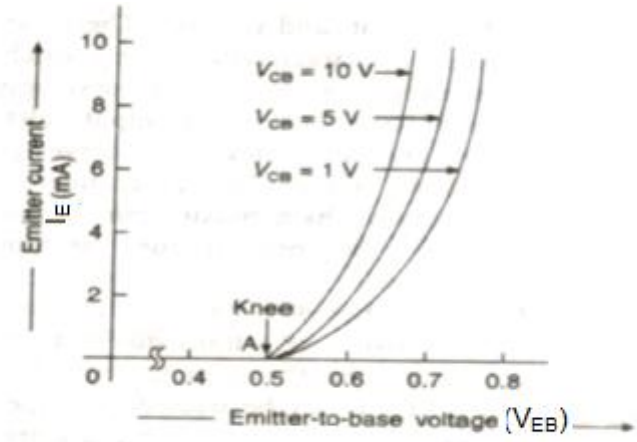

Fig. 3.8 Input characteristics of a common base transistor

- Then increase the emitter to base voltage (V_{EB}) in small suitable steps (i e., of the order of 0.1 V) and record the corresponding values of emitter current (I_E) at each step.
- Now, if we plot a graph with emitter to base voltage (V_{EB}) along the horizontal axis and the emitter current (I_E) along the vertical axis, we shall obtain a curve marked V_{CB} = 1 V as shown in Fig.3.8.
- A similar procedure may be used to obtain curves at different collector to base voltage 5 V and 10 V as shown in the figure 3.8.
- From the input characteristics the following important points are derived.
  - Up to region OA, the emitter current is negligibly small.
  - Beyond the point A, for a fixed collector to base voltage the emitter current (I_E) increases rapidly with a small increase in emitter to base voltage (V_{EB}).
  - The input characteristic may be used to determine the value of a.c input resistance.
  - Its value at any point on the curve is given by the ratio of a change in emitter to base voltage (ΔV_{EB}) to the resulting change in emitter current (ΔI_E) for a constant collector to base voltage (V_{CB}).
  - Mathematically the a.c input resistance,

$$R_i = \frac{\Delta V_{EB}}{\Delta I_E}$$

3.5.4.1.1 Base Width Modulation (or) Early Effect

- When reverse bias voltage V_{CB} increases, the width of depletion region also increases, which reduces the electrical base width.

3.5.4.2 Output Characteristics of a Transistor in Common Base Configuration

- These characteristics may be obtained by using the circuit shown in Fig. 3.7.

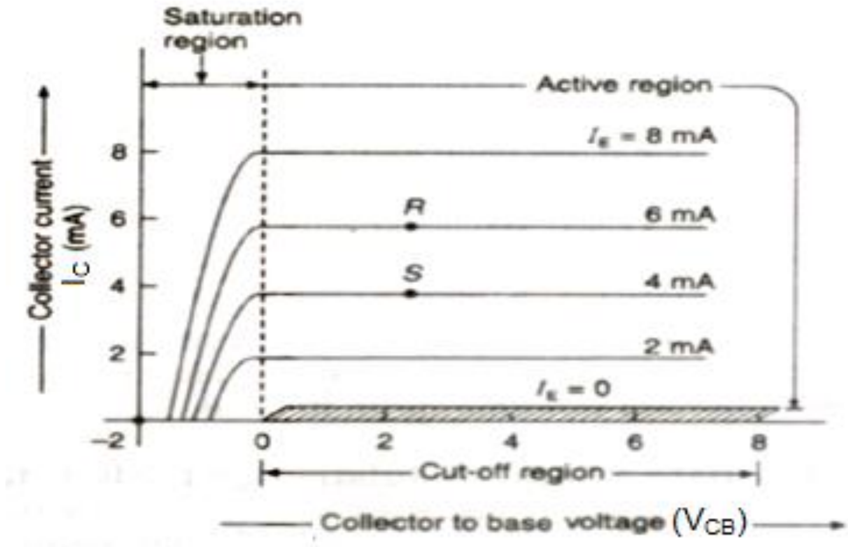

Fig. 3.9 Output characteristics of a common base transistor

- First of all, vary the emitter to base voltage (V_{EB}) to get a suitable value of emitter current (I_E) say 2 mA.
- Keeping the emitter current (I_E)constant, we increase the collector to base voltage (V_{CB}) from zero in a number of suitable steps and record the corresponding values of the collector current (I_C) at each Step.
- If we plot a graph with collector to base voltage (V_{CB}) along the horizontal axis and the collector current (I_C) along the vertical axis, we shall obtain a curve marked I_E = 2 mA as shown in Fig. 3.9.
- A similar procedure may be used to obtain the characteristics at different values of emitter current *i.e.,* I_E = 4, 6, and 8 mA.
- From the output characteristics the following important points are derived.
  - The curve may be divided into three important regions namely saturation region, active region and cut off region.

  Saturation Region

    - The saturation region is the region to the left of the vertical dashed line.
    - It may be noted that in this region, collector to base voltage (V_{CB}) is negative for a NPN transistor.
    - In this region, a small change in V_{CB} results in a large value of collector current.

  Active Region

    - The active region is the region between the vertical dashed line and the horizontal axis.
    - In the active region, the collector current is constant and is equal to the emitter current.

Cut off Region

- The cut off region is the region along the horizontal axis as shown by a shaded region in the figure. It corresponds to the curve marked $I_E = 0$.
- The collector current flows even when the collector to base voltage (V_{CB}) is zero.
- A small collector current flows even when emitter current (I_E) is zero.

- The collector current is practically independent of collector to base voltage (V_{CB}) in the active region.
- The output characteristic may be used to determine the value of a.c. output resistance.
- Its value at any point is given by the ratio of a change in collector to base voltage (ΔV_{CB}) to the resulting change in collector current (ΔI_C) for a constant emitter current (I_E)
- Mathematically, the a.c output resistance,

$$R_o = \frac{\Delta V_{CB}}{\Delta I_C}$$

3.6 Common Emitter Configuration

- Consider a transistor (either NPN or PNP) in a common emitter configuration as shown in Figure 3.10 (a) and (b).

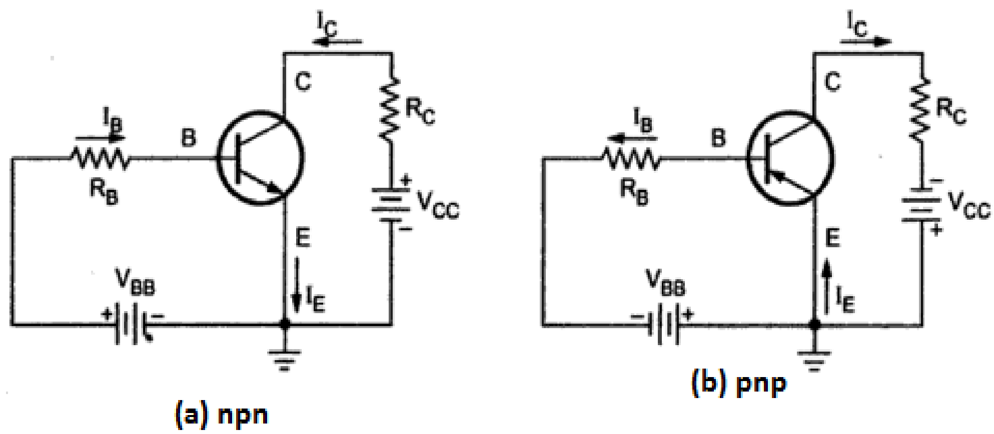

Fig. 3.10 Common Emitter Configuration

- Here, the base current is the input current and the collector current is the output current.
- The current gain is the ratio of collector current to the base current.
- Since the base current and collector current may be direct or alternating current.
- Therefore, we define two types of current gains namely d.c current gain and a.c current gains.

3.6.1 Common emitter d.c current gain (β)

- It is defined as the ratio of collector current (I_C) to base current (I_B) and is usually designated by β, β_{DC} or h_{FE}
- Mathematically, the common base d.c current gain,

$$\beta = \frac{I_C}{I_B}$$

- Collector current of a transistor is much larger than the base current.
- Therefore, current gain β is always greater than unity.

3.6.2 Common emitter a.c current gain (β_0)

- It is defined as the ratio of small change in collector current (ΔI_C) to a small change in base current (ΔI_B) for a constant collector to emitter voltage (V_{CE}).
- It is designated by β, β_{ac} or h_{fe}.
- Mathematically, the common emitter a.c current gain

$$\beta_0 = \frac{\Delta I_C}{\Delta I_B}$$

3.6.3 Relation between current gain α and β

- We know that emitter current (I_E) of a transistor is the sum of its base current (I_B) and collector current (I_C).

$$I_E = I_B + I_C$$

- Dividing the above equation on both sides by I_C,

$$\frac{I_E}{I_C} = \frac{I_B}{I_C} + 1$$

- We have $I_C / I_E = \alpha$, $I_C / I_B = \beta$ and apply it in above equation

$$\frac{1}{\alpha} = \frac{1}{\beta} + 1 = \frac{1+\beta}{\beta}$$

$$\alpha = \frac{\beta}{\beta + 1}$$

- The above expression may be written as

$$\alpha(\beta + 1) = \beta$$
$$\alpha \cdot \beta + \alpha = \beta$$
$$\alpha = \beta - \alpha \cdot \beta$$
$$= \beta(1 - \alpha)$$
$$\beta = \frac{\alpha}{1 - \alpha}$$

3.6.4 Current relations in Common emitter configuration

- The total leakage current flowing through the transistor with base open is given by

$$I_{CEO} = I_{CO} + \beta . I_{CO} = (1 + \beta)\, I_{CO}$$

- The total collector current in a transistor consists of the injected current (βI_B) and the leakage current (I_{CEO}).
- Thus, the total collector current is given by

$$I_C = \beta I_B + I_{CEO} = \beta I_B + (1 + \beta)\, I_{CO}$$

Example *(a) A transistor has an α of 0.975. What is the value of β; (b) if β = 200, what is the value of α?*

Solution. Given: α = 0.975 and β = 200

Value of β when α is 0.975

We know that

$$\beta = \frac{\alpha}{1-\alpha} = \frac{0.975}{1-0.975} = 39 \text{ Ans.}$$

Value of α when β is 200

We also know that

$$\alpha = \frac{\beta}{\beta+1} = \frac{200}{200+1} = 0.995 \text{ Ans.}$$

Example *A transistor has a typical β of 100. If the collector is 40 mA, what is the value of emitter current?*

Solution. Given: β = 100 and I_C = 40 mA.

We know that (β),
$$100 = \frac{I_C}{I_B} = \frac{40}{I_B}$$

$$\therefore \quad I_B = 40/100 = 0.4 \text{ mA}$$

and the emitter current,

$$I_E = I_B + I_C = 0.4 + 40 = 40.4 \text{ mA Ans.}$$

3.6.5 Input and Output Characteristics of a Transistor in a Common Emitter Configuration

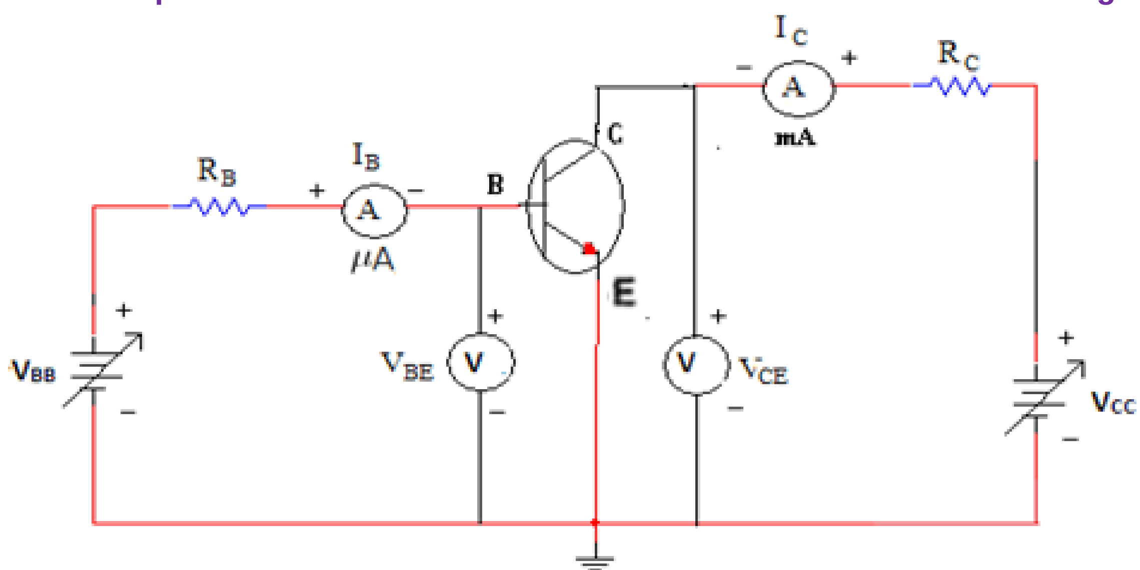

Fig. 3.11 Circuit arrangement for determining common base transistor characteristics

- Following are two important characteristics of a transistor in a common Emitter (CE) configuration.
  - **Input characteristics**
    - These curves give the relationship between the base current (I_B) and the base to emitter voltage (V_{BE}) for a constant collector to emitter voltage (V_{CE}).

➢ **Output characteristics**

- These curves give the relationship between the collector current (I_C) and the collector to emitter voltage (V_{CE}) for a constant base current (I_B).

- In this circuit, the NPN transistor is connected in a common emitter configuration.
- The d.c milli ammeters and d.c voltmeters are connected in the base and collector circuits of a transistor to measure the voltages and currents.

3.6.5.1 Input Characteristics of a Transistor in Common Emitter Configuration

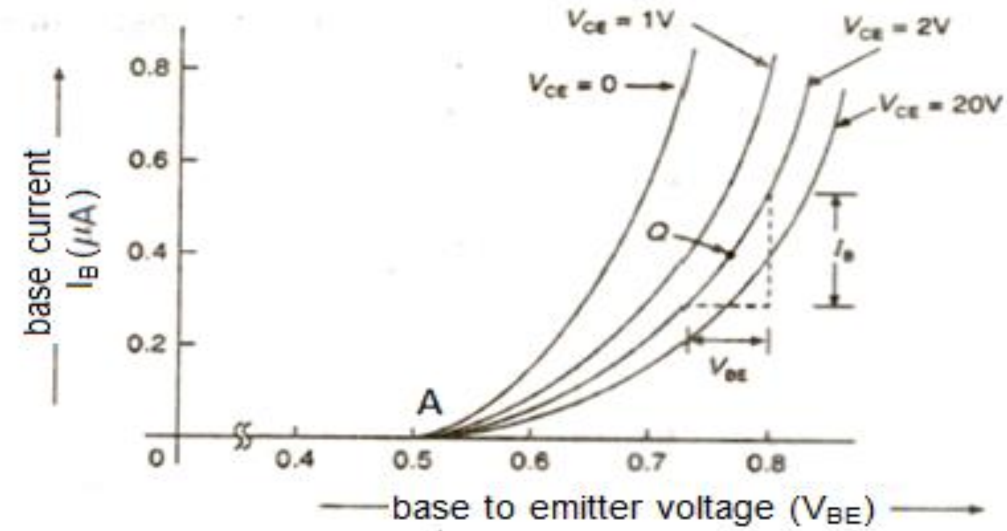

Fig. 3.12 Input characteristics of a common emitter transistor

- These curves may be obtained by using the circuit arrangement as shown in Fig. 3.11.
- First of all, vary the collector to emitter voltage (V_{CE}) to one volt.
- Then increase the base to emitter voltage (V_{BE}) in small suitable steps (i e., of the order of 0.1 V) and record the corresponding values of base current (I_B) at each step.
- Now, if we plot a graph with base to emitter voltage (V_{BE}) along the horizontal axis and the base current (I_B) along the vertical axis, we shall obtain a curve marked V_{CE} = 1 V as shown in Fig. 3.12.
- A similar procedure may be used to obtain curves at different collector to emitter voltage 2 V and 20V as shown in the figure 3.12.
- From the input characteristics the following important points are derived.
  - ➢ Up to region OA, the base current is negligibly small.
  - ➢ Beyond the point A, for a fixed collector to emitter voltage the base current (I_B) increases rapidly with a small increase in base to emitter voltage (V_{BE}).
  - ➢ The input characteristic may be used to determine the value of a.c input resistance.
  - ➢ Its value at any point on the curve is given by the ratio of a change in base to emitter voltage (ΔV_{BE}) to the resulting change in base current (ΔI_B) for a constant collector to emitter voltage (V_{CE}).
  - ➢ Mathematically the a.c input resistance,

$$R_i = \frac{\Delta V_{BE}}{\Delta I_B}$$

3.6.5.2 Output Characteristics of a Transistor in Common Emitter Configuration

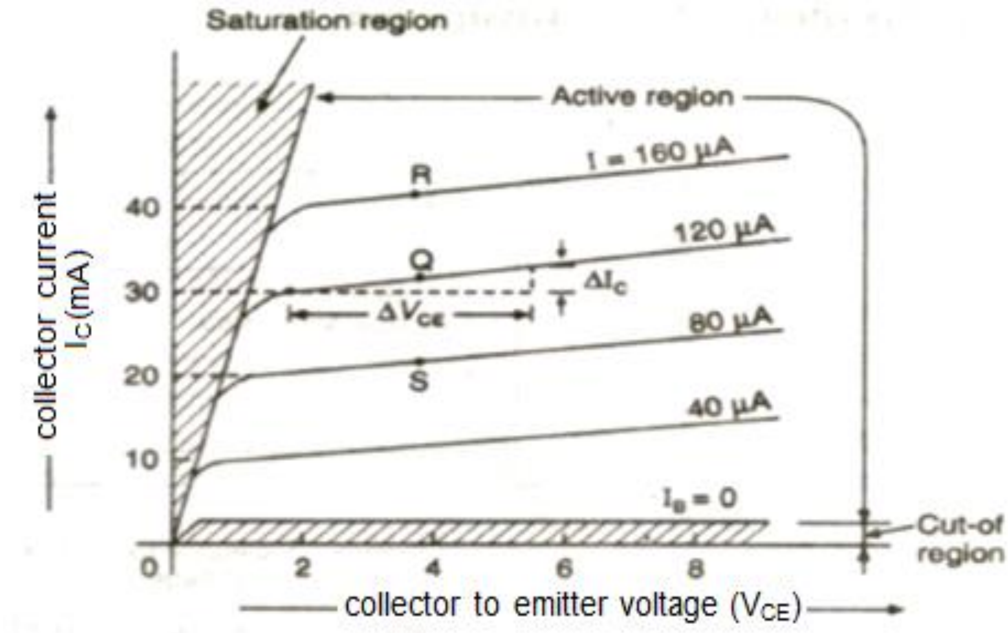

Fig. 3.13 Output characteristics of a common emitter transistor

- These characteristics may be obtained by using the circuit shown in Fig. 3.11.
- First of all, vary the base to emitter voltage (V_{BE}) to get a suitable value of base current (I_E) say 40 μA.
- Keeping the base current constant, we increase the collector to emitter voltage (V_{CE}) from zero in a number of suitable steps and record the corresponding values of the collector current (I_C) at each Step.
- If we plot a graph with collector to emitter voltage (V_{CE}) along the horizontal axis and the collector current (I_C) along the vertical axis, we shall obtain a curve marked I_B = 40 μA as shown in Fig. 3.13.
- A similar procedure may be used to obtain the characteristics at different values of emitter current *i.e.,* I_B = 80, 120 and 160 μA.
- From the output characteristics the following important points are derived.
  - ➢ The output characteristics may be divided into three important regions namely saturation region, active region and cut-off region.
  - ➢ The saturation and cut-off regions are shown by the shaded areas, while the active region is the region between the saturation and cut off region.
  - ➢ As the collector to emitter voltage (V_{CE}) is increased above zero, the collector current (I_C) increases rapidly to a saturation value, depending upon the value of base current.
  - ➢ When collector to emitter voltage (V_{CE}) is increased further, the collector current I_C slightly increases.

- The collector current (I_C) is zero, when the base current (I_B) is zero. Under this condition the transistor is said to be cut off.
- The characteristic may be used to determine the common emitter transistor a.c output resistance.
- Its value at any given operating point *Q* is given by the ratio of a change in collector to emitter voltage (ΔV_{CE}) to the resulting change in collector current (ΔI_C) for a constant base current.
- Mathematically, the a.c output resistance,

$$R_o = \frac{\Delta V_{CE}}{\Delta I_C}$$

3.7 Common Collector Configuration

- The Fig. 3.14 shows the common collector configuration.

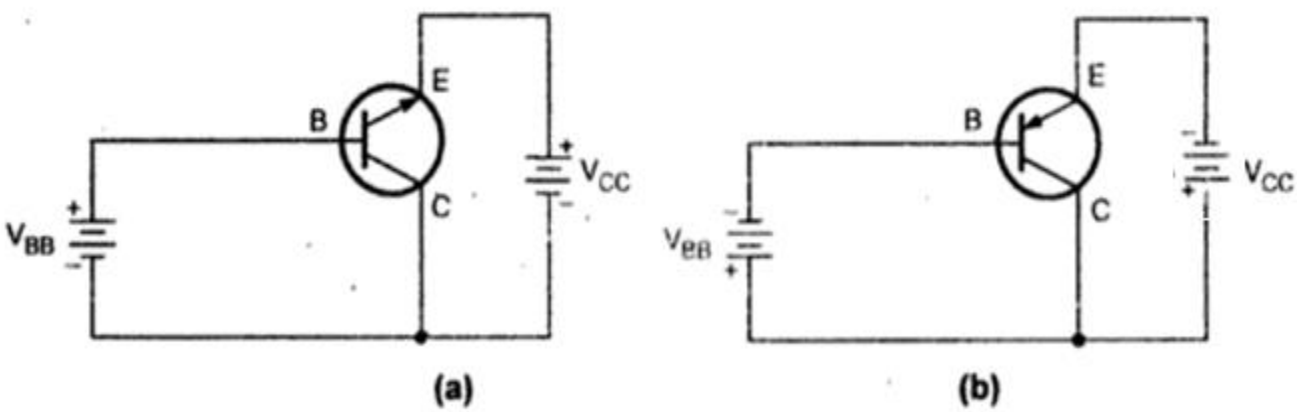

Fig. 3.14 Common collector configurations

- In this configuration input is applied between base and collector, and output is taken from emitter and collector.
- Here, collector of the transistor is common to both input and output circuits, and hence the name common collector configuration.
- Common collector connections for both n-p-n and p-n-p transistors are shown in Fig. 3.14 (a) and (b) respectively.

3.7.1 Common collector d.c current gain (ϒ)

- It is defined as the ratio of emitter current (I_E) to base current (I_B) and is usually designated by ϒ, $ϒ_{DC}$ or h_{FC}
- Mathematically, the common current d.c current gain,

$$\gamma = \frac{I_E}{I_B}$$

- Emitter current of a transistor is much larger than the base current.
- Therefore, current gain ϒ is always greater than unity.

3.7.2 Common collector a.c current gain (Υ_0)

- It is defined as the ratio of small change in emitter current (ΔI_E) to a small change in base current (ΔI_B) for a constant collector to emitter voltage (V_{CE}).
- It is designated by Υ, Υ_{ac} or h_{fc}.
- Mathematically, the common collector a.c current gain

$$\gamma_0 = \frac{\Delta I_E}{\Delta I_B}$$

3.7.3 Current Relations in CC Configuration

- In CC configuration, I_B is the input current and the I_E is the output current.
- Relate the output current I_E with the input current I_B is

$$I_E = (1+\beta_{dc})\, I_B + (1+\beta_{dc})\, I_{CBO}$$

Example : *If $\beta = 100$, $I_{CBO} = 10\ \mu A$ and $I_B = 80\ \mu A$. Find I_E.*

Solution : We know that,

$$I_E = (1+\beta)\, I_B + (1+\beta)\, I_{CBO}$$

$$= (1+100) \times 80 \times 10^{-6} + (1+100) \times 10 \times 10^{-6}$$

$$= \mathbf{9.09\ mA}$$

Example : *If $\alpha = 0.98$, $I_{CBO} = 10\ \mu A$ and $I_B = 100\ \mu A$. Find I_E.*

Solution : We know that, $\beta = \frac{\alpha}{1-\alpha}$

$\therefore \quad \beta = \frac{0.98}{1-0.98} = 49$

Current I_E can be given as,

$$I_E = (1+\beta)\, I_B + (1+\beta)\, I_{CBO}$$

$$= (1+49) \times 100 \times 10^{-6} + (1+49) \times 10 \times 10^{-6} = \mathbf{5.5\ mA}$$

3.7.4 Input and Output Characteristics of a Transistor in a Common Collector Configuration

- Following are two important characteristics of a transistor in a common Collector (CC) configuration.
  - **Input characteristics**
    - These curves give the relationship between the base current (I_B) and the base to collector voltage (V_{BC}) for a constant emitter to collector voltage (V_{EC}).

➢ **Output characteristics**

- These curves give the relationship between the emitter current (I_E) and the emitter to collector voltage (V_{EC}) for a constant base current (I_B).

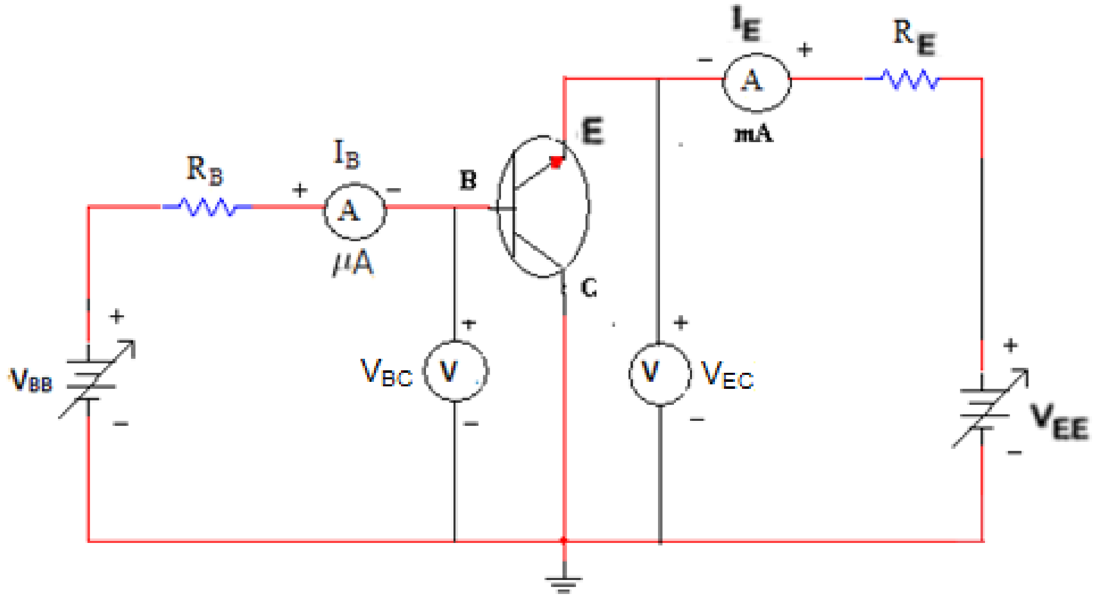

Fig. 3.15 Circuit arrangement for determining common collector transistor characteristics

2.7.4.1 Input Characteristics of a Common Collector Configuration

- It is the graph of input current I_B versus input voltage V_{BC} at constant V_{EC}.
- The base current is taken along Y-axis and collector base voltage V_{BC} is taken along X-axis.
- Fig. 3.16 shows the input characteristics of a typical transistor in common collector configuration.
- The common collector input characteristics are quite different from either common base or common emitter input characteristics.
- This difference is due to the fact that the input voltage V_{BC} is largely determined by the level of emitter to collector voltage V_{EC}.

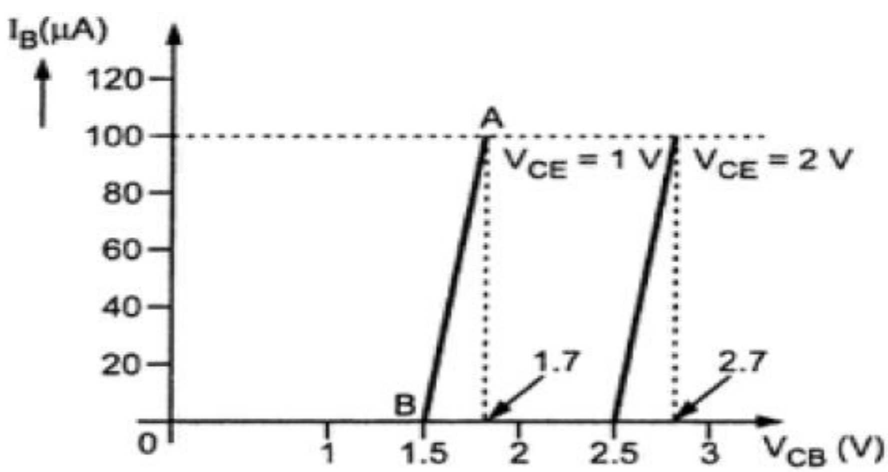

Fig. 3.16 Input characteristics of transistor in CC configuration

3.7.4.2 Output Characteristics of a Common Collector Configuration

- It is the curve between emitter current I_E and collector to emitter voltage V_{CE} at constant base current I_B.
- The emitter current is taken along Y-axis and collector to emitter voltage along X-axis.
- Fig. 3.17 shows the output characteristics of a typical transistor in common collector configuration.

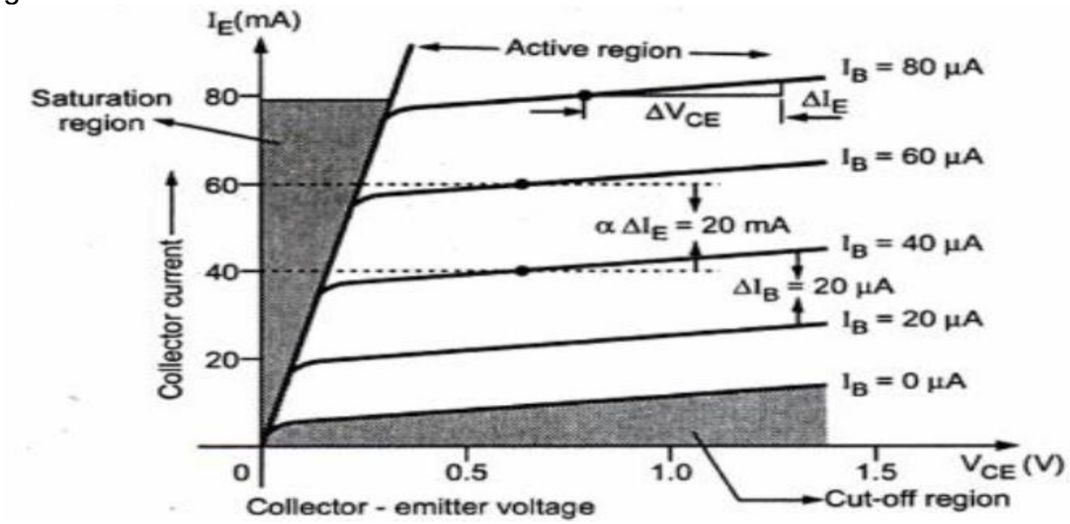

Fig. 3.17 Output characteristics of the transistor In CC configuration

- Since, I_C is approximately equal to I_E, the common collector output characteristics are practically similar to those of the common emitter output characteristics.

3.8 Comparison of Transistor Configurations

Sr. No.	Characteristic	Common Base	Common Emitter	Common Collector
1.	Input resistance (R_i)	Very low (20 Ω)	Low (1 kΩ)	High (500 kΩ)
2.	Output resistance (R_o)	Very high (1 MΩ)	High (40 kΩ)	Low (50 Ω)
3.	Input current	I_E	I_B	I_B
4.	Output current	I_C	I_C	I_E
5.	Input voltage applied between	Emitter and Base	Base and Emitter	Base and Collector
6.	Output voltage taken between	Collector and Base	Collector and Emitter	Emitter and Collector
7.	Current amplification factor	$\alpha_{dc} = \frac{I_C}{I_E}$	$\beta_{dc} = \frac{I_C}{I_B}$	$\frac{I_E}{I_B}$
8.	Current gain (A_i)	Less than unity	High (20 to few hundreds)	High (20 to few hundreds)
9.	Voltage gain (A_v)	Medium	Medium	Less than unity
10.	Applications	As a input stage of multistage amplifier	For audio signal amplification	For impedance matching

3.9 Why CE Configuration is widely used in Amplifier Circuits?

- The CE configuration is the only configuration which provides both voltage gain as well as current gain greater than unity.

3.10 Transistor as a switch

- Transistors are widely used in switching applications.
- In these applications, the voltage levels periodically alternate between a “Low” and a “High” voltage, such as 0 V and + 5 V.
- In switching applications, the transistor operates either in cut-off region or saturation region.
- The circuit diagram for transistor act as a switch is as shown in the Fig. 3.18.

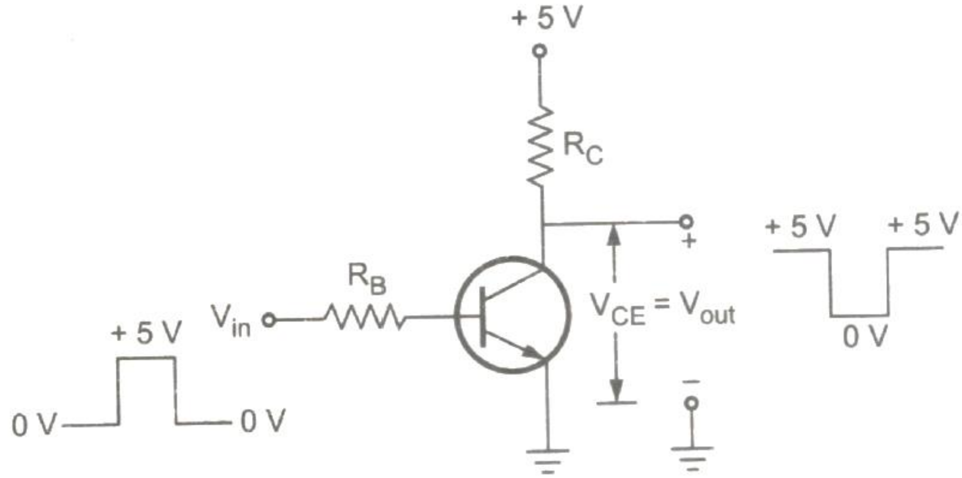

Fig. 3.18 Transistor act as switch

- When input is HIGH, base current and collector current flows and hence transistor is operated in saturation.
- In saturation condition, voltage between collector and emitter, $V_{CE(sat)}$ is typically 0.2 V to 0.3 V and hence transistor acts as closed switch. This is illustrated in Fig. 3.19.

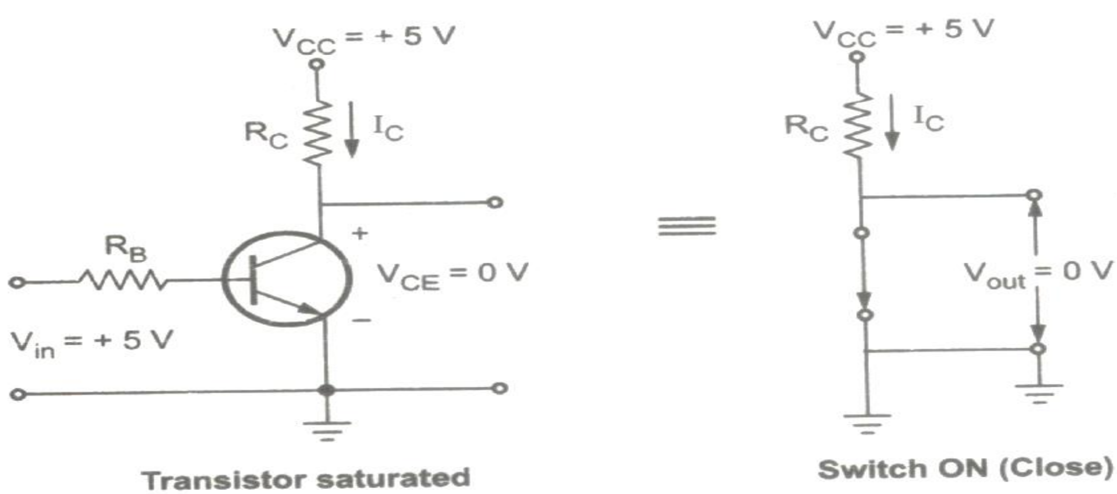

Fig. 3.19 When Input is High

- When input is LOW, base current and collector current is zero and hence transistor is operated in cut-off.
- In cut-off $V_{CE} = V_{CC}$ and transistor acts as open switch. This is illustrated in Fig. 3.20.

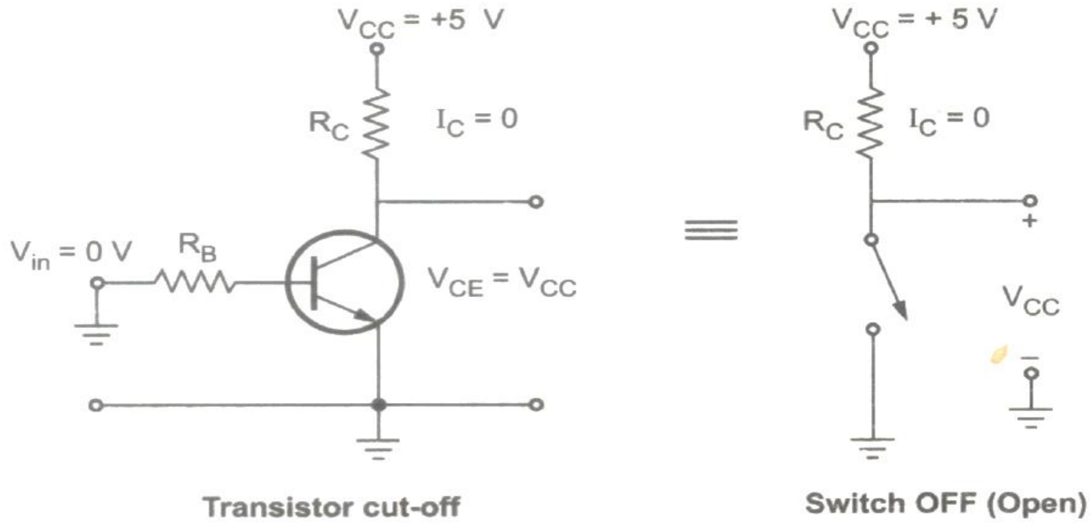

Fig. 3.20 When Input is Low

3.11 Switching times of a transistor

- The switching speed of the transistor is an important quantity when transistor is used as a switch.
- Switching times of a transistor is shown in the figure 3.21.

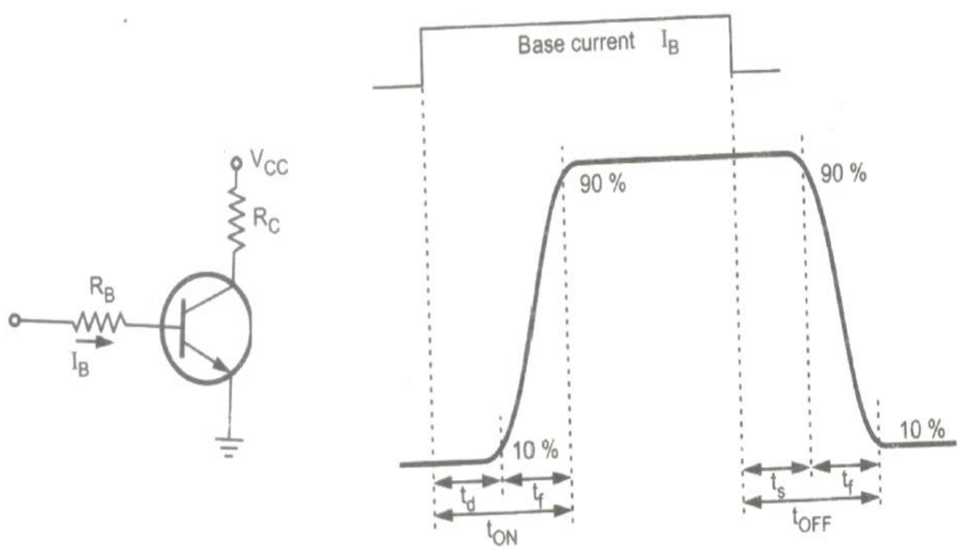

Fig. 3.21 Transistor Turn-ON and Turn-OFF times

- When the base input current I_B is applied, the transistor does not switch on immediately. This is because of the junction capacitance and the transition time of electrons across the junctions.

- The time between the application of the input pulse and the commencement of collector current flow is termed as delay time t_d.
- The time required for I_C to reach 90 % of its maximum level from 10 % level is called the rise time t_r.
- Thus, the turn-on time t_{ON} is the addition of t_r and t_d as shown in the Fig. 3.22.
- When input current I_B is switched OFF, I_C does not go to zero level immediately, but remains almost at its maximum value for a length of time before falling to zero. This period is called the storage time t_S.
- The time required for I_C to go from 90 % to 10 % of its maximum level is called as fall time t_f
- Thus, the turn-off time t_{OFF} is the sum of storage time t_S and fall time t_f as shown in the Fig. 3.22.