10.10 Common Emitter Connection

In this circuit arrangement, input is applied between base and emitter and output is taken from the collector and emitter. Here, emitter of the transistor is common to both input and output circuits and hence the name common emitter connection. Fig. 10.16 (*i*) shows common emitter *npn* transistor circuit whereas Fig. 10.16 (*ii*) shows common emitter *pnp* transistor circuit.

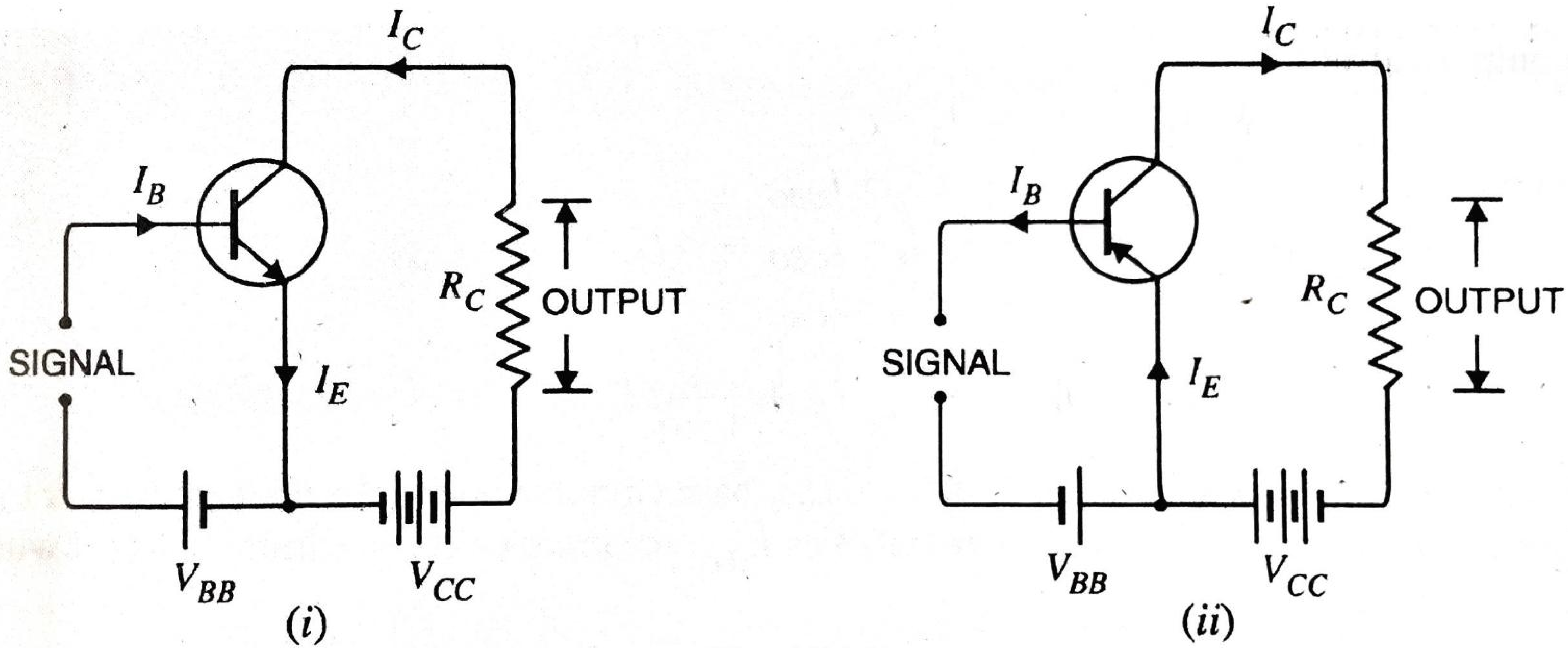

Fig. 10.16

1. **Base current amplification factor (β).** In common emitter connection, input current is I_B and output current is I_C.

The ratio of change in collector current (ΔI_C) *to the change in base current* (ΔI_B) *is known as* **base current amplification factor** *i.e.*

$$\beta^* = \frac{\Delta I_C}{\Delta I_B}$$

In almost any transistor, less than 5% of emitter current flows as the base current. Therefore, the value of β is generally greater than 20. Usually, its value ranges from 20 to 500. This type of connection is frequently used as it gives appreciable current gain as well as voltage gain.

Relation between β and α. A simple relation exists between β and α. This can be derived as follows :

$$\beta = \frac{\Delta I_C}{\Delta I_B} \quad \text{...(i)}$$

$$\alpha = \frac{\Delta I_C}{\Delta I_E} \quad \text{...(ii)}$$

Now $\quad I_E = I_B + I_C$

or $\quad \Delta I_E = \Delta I_B + \Delta I_C$

or $\quad \Delta I_B = \Delta I_E - \Delta I_C$

Substituting the value of ΔI_B in exp. (*i*), we get,

$$\beta = \frac{\Delta I_C}{\Delta I_E - \Delta I_C} \quad \text{...(iii)}$$

Dividing the numerator and denominator of R.H.S. of exp. (*iii*) by ΔI_E, we get,

$$\beta = \frac{\Delta I_C / \Delta I_E}{\frac{\Delta I_E}{\Delta I_E} - \frac{\Delta I_C}{\Delta I_E}} = \frac{\alpha}{1-\alpha} \qquad \left[\alpha = \frac{\Delta I_C}{\Delta I_E}\right]$$

$$\therefore \quad \beta = \frac{\alpha}{1-\alpha}$$

It is clear that as α approaches unity, β approaches infinity. In other words, the current gain in common emitter connection is very high. It is due to this reason that this circuit arrangement is used in about 90 to 95 percent of all transistor applications.

2. Expression for collector current. In common emitter circuit, I_B is the input current and I_C is the output current.

We know $\quad I_E = I_B + I_C \quad$ ...(*i*)

and $\quad I_C = \alpha I_E + I_{CBO} \quad$ ...(*ii*)

From exp. (*ii*), we get, $\quad I_C = \alpha I_E + I_{CBO} = \alpha (I_B + I_C) + I_{CBO}$

or $\quad I_C (1 - \alpha) = \alpha I_B + I_{CBO}$

or
$$I_C = \frac{\alpha}{1-\alpha} I_B + \frac{1}{1-\alpha} I_{CBO} \quad \text{...(iii)}$$

From exp. (*iii*), it is apparent that if $I_B = 0$ (*i.e.* base circuit is open), the collector current will be the current to the emitter. This is abbreviated as I_{CEO}, meaning collector-emitter current with base open.

$$\therefore \quad I_{CEO} = \frac{1}{1-\alpha} I_{CBO}$$

* If d.c. values are considered, $\beta = I_C / I_B$.

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Substituting the value of $\frac{1}{1-\alpha} I_{CBO} = I_{CEO}$ in exp. (*iii*), we get,

$$I_C = \frac{\alpha}{1-\alpha} I_B + I_{CEO}$$

or

$$I_C = \beta I_B + I_{CEO} \qquad \left(\because \beta = \frac{\alpha}{1-\alpha}\right)$$

Concept of I_{CEO}. In *CE* configuration, a small collector current flows even when the base current is zero [See Fig. 10.17 (*i*)]. This is the collector cut off current (*i.e.* the collector current that flows when base is open) and is denoted by I_{CEO}. The value of I_{CEO} is much larger than I_{CBO}.

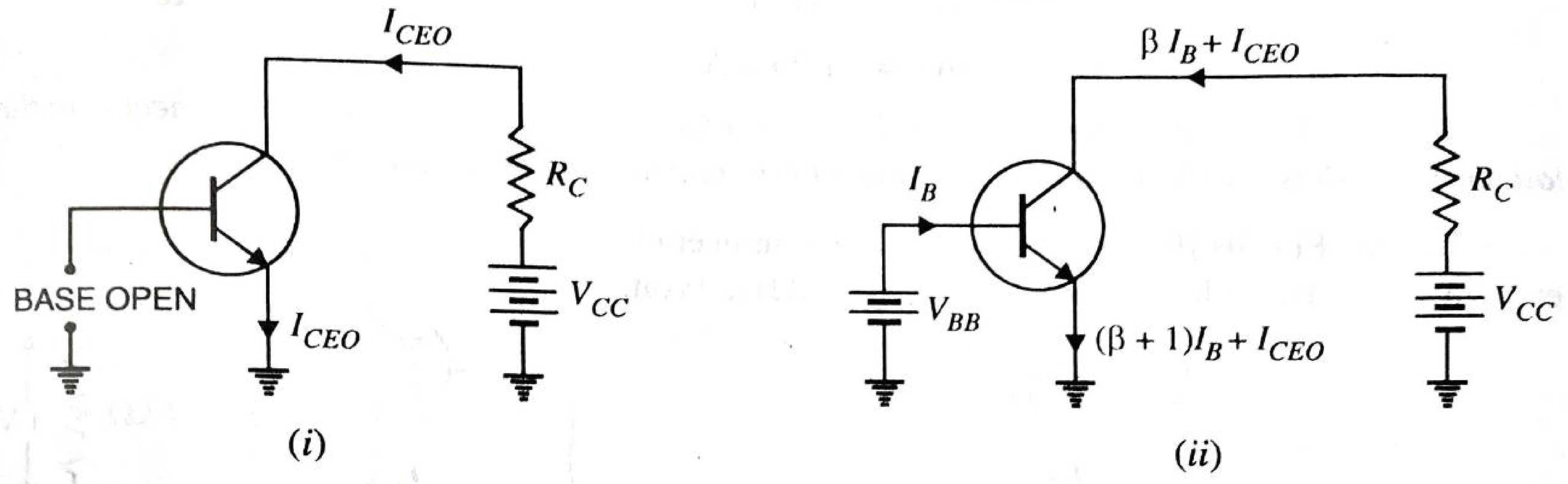


Fig. 10.17

When the base voltage is applied as shown in Fig. 10.17 (*ii*), then the various currents are :

$$\text{Base current} = I_B$$

$$\text{Collector current} = \beta I_B + I_{CEO}$$

$$\text{Emitter current} = \text{Collector current} + \text{Base current}$$

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

It may be noted here that :

$$I_{CEO} = \frac{1}{1-\alpha} I_{CBO} = (\beta + 1) I_{CBO} \qquad \left[\because \frac{1}{1-\alpha} = \beta + 1\right]$$

Example 10.8. *Find the value of β if (i) α = 0.9 (ii) α = 0.98 (iii) α = 0.99.*

Solution. (*i*)
$$\beta = \frac{\alpha}{1-\alpha} = \frac{0.9}{1-0.9} = \mathbf{9}$$

(*ii*)
$$\beta = \frac{\alpha}{1-\alpha} = \frac{0.98}{1-0.98} = \mathbf{49}$$

(*iii*)
$$\beta = \frac{\alpha}{1-\alpha} = \frac{0.99}{1-0.99} = \mathbf{99}$$

Example 10.9. *Calculate I_E in a transistor for which β = 50 and I_B = 20 μA.*

Solution. Here $\beta = 50, \quad I_B = 20\mu A = 0.02 \text{ mA}$

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

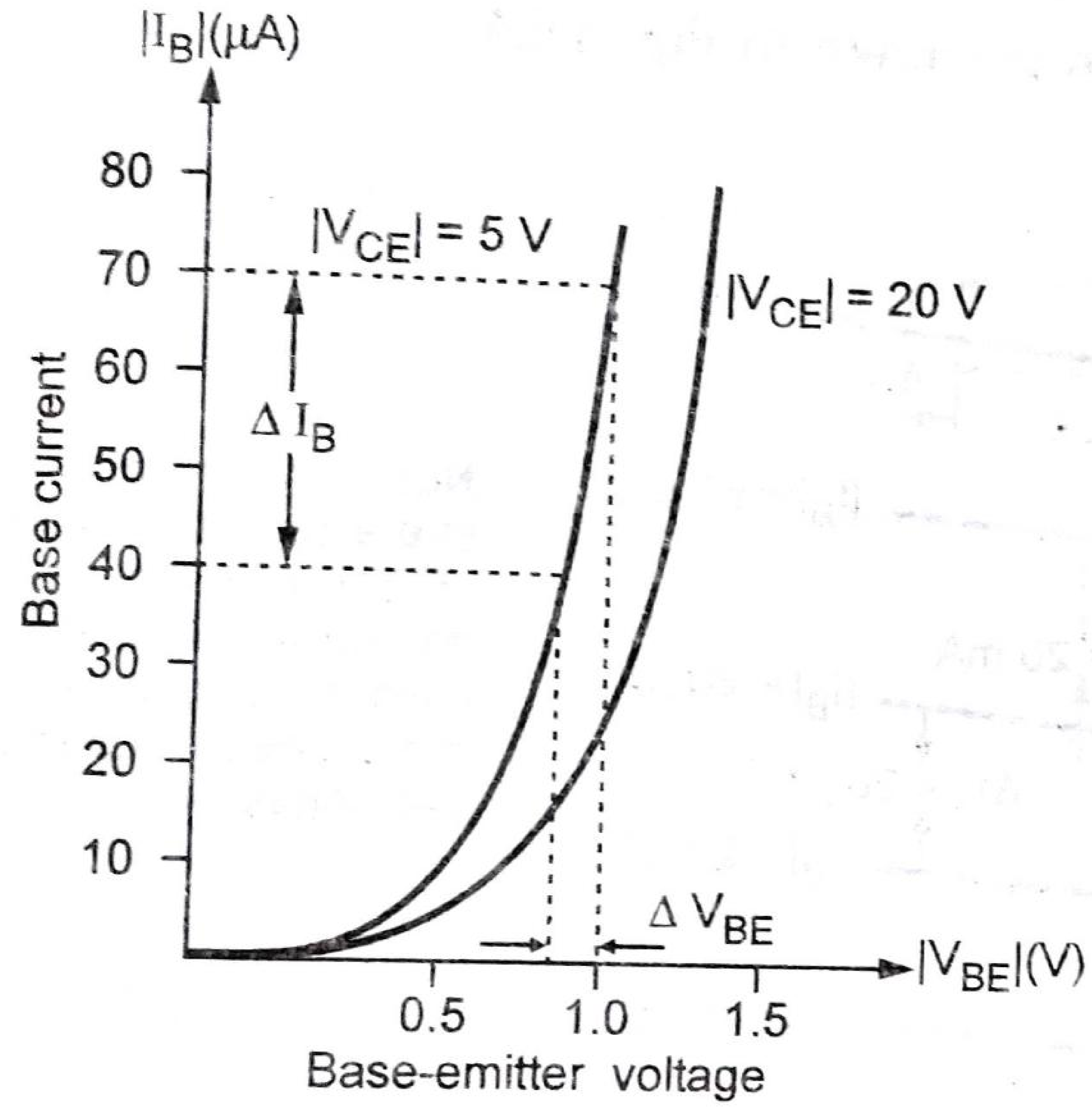
$\therefore$
$$I_C = \beta I_B = 50 \times 0.02 = 1 \text{ mA}$$

Using the relation, $I_E = I_B + I_C = 0.02 + 1 = \mathbf{1.02 \text{ mA}}$

4.5.2 Common Emitter (CE) Characteristics

Input characteristics

- It is the curve between and input voltage V_{BE} (base-emitter voltage) and input current I_B (base current) at constant collector-emitter voltage, V_{CE}. The base current is taken along Y-axis and base emitter voltage V_{BE} is taken along X-axis.
- Fig. 4.5.3 shows the input characteristics of a typical transistor in common-emitter configuration.



Note : While plotting input characteristics the magnitudes of voltage and current are considered Practically the voltage and current polarities are opposite for pnp and npn transistors

Fig. 4.5.3 Input characteristics of the transistor in CE configuration

From this characteristics we observe the following important points :

1. The input resistance is 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}. It is given by,

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

2. The value of r_i in CE configuration is greater than the value of r_i in CB configuration.

3. As the input to a transistor in the CE configuration is between the base-to-emitter junction, the CE input characteristics resembles a family of forward biased diode curves.

4. After the cut-in voltage, the base current (I_B) increases rapidly with small increase in base-emitter voltage (V_{BE}). Thus the dynamic input resistance is small in CE configuration.

5. For a fixed value of V_{BE}, I_B decreases as V_{CE} is increased.

6. Voltages V_{BE} and V_{CE} are positive for npn transistor and they are negative for pnp transistor.

Output characteristics

From this characteristics we observe the following important points :

1. This characteristics shows the relation between the collector current I_C and collector voltage V_{CE}, for various fixed values of I_B. This characteristics is often called collector characteristics. A typical family of output characteristics for an n-p-n transistor in CE configuration is shown in Fig. 4.5.4.

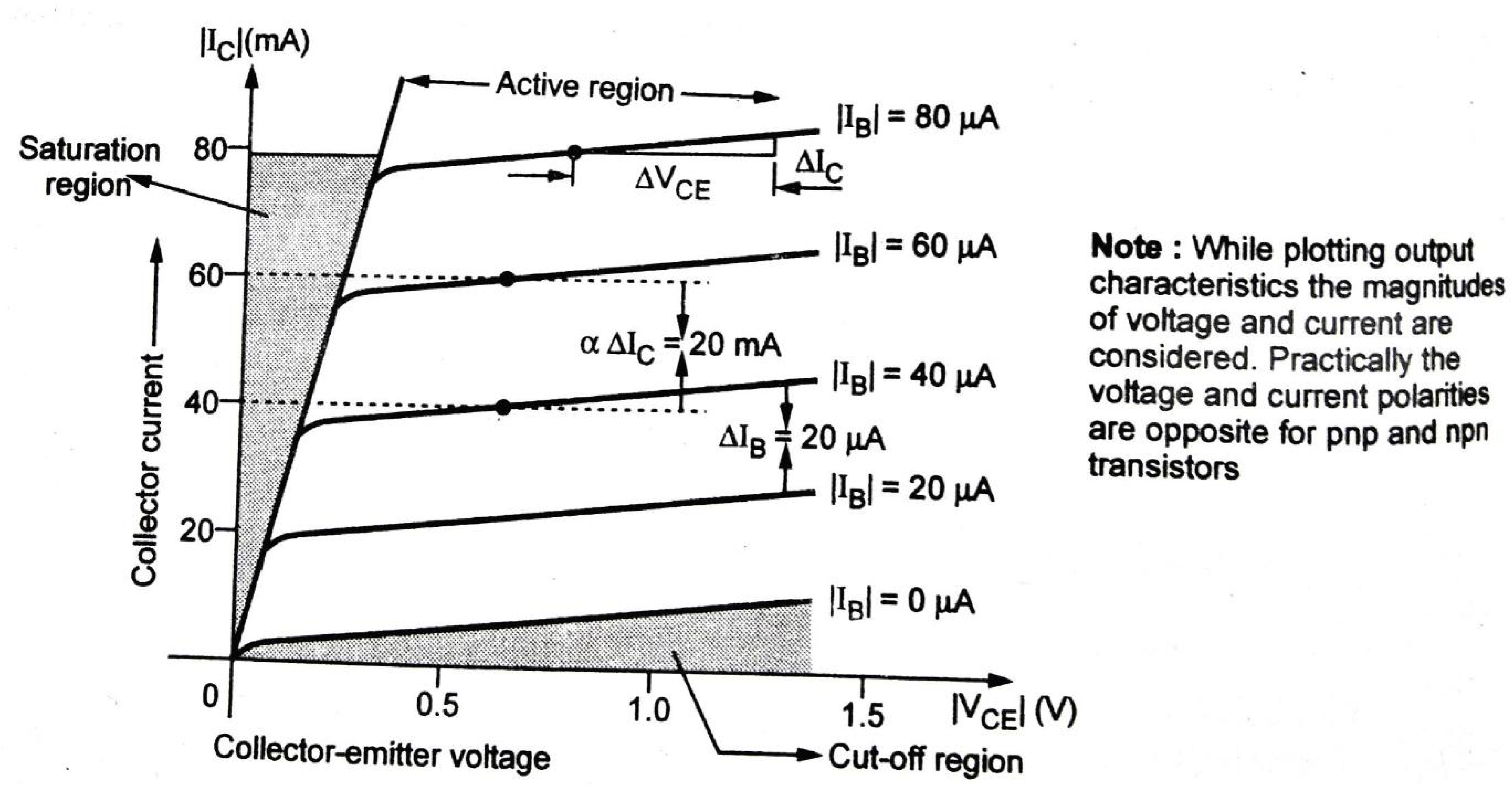


Fig. 4.5.4 Output characteristics of the transistor in CE configuration

2. The value of β_{dc} of the transistor can be found at any point on the characteristics by taking the ratio I_C to I_B at that point, i.e. $\beta_{dc} = I_C / I_B$. This is known as D.C. beta for the transistor.

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3. From the output characteristics, we can see that change in collector-emitter voltage (ΔV_{CE}) causes the little change in the collector current (ΔI_C) for constant base current I_B. Thus the output dynamic resistance is high in CE configuration.

$$r_o = \left.\frac{\Delta V_{CE}}{\Delta I_C}\right|_{I_B = \text{Constant OR } \Delta I_B = 0}$$

4. The output characteristics of common emitter configuration consists of three regions : **Active, Saturation** and **Cut-off.**

5. **Active region :**
   - For the operation in the active region, the emitter-base junction (J_E) is **forward biased** while collector base junction (J_C) is **reverse biased**.
   - The collector current rise more sharply with increasing V_{CE} in the linear region of output characteristics of CE transistor.

6. **Saturation region :**
   - In this region, the emitter-base junction (J_E) and collector base junction (J_C) both are **forward biased**. In this region, I_C does not depend upon the input current I_B.
   - The saturation value of V_{CE}, designated $V_{CE\,(sat)}$, usually ranges between 0.1 V to 0.3 V.

7. **Cut-off region** : The region below $I_B = 0$ is the cut-off region of operation for the transistor. In this region, both the junctions of the transistor are reverse biased.

For saturation : $I_B > \dfrac{I_C}{\beta_{dc}}$

For active region : $V_{CE} > V_{CE}$ **(sat)**

DC current gain : $\beta_{dc} = \beta = \dfrac{I_C}{I_B}$

AC current gain : $\beta_{ac} = \left.\dfrac{\Delta I_C}{\Delta I_B}\right|_{V_{CE} = \text{Constant}}$