Analog Electronics

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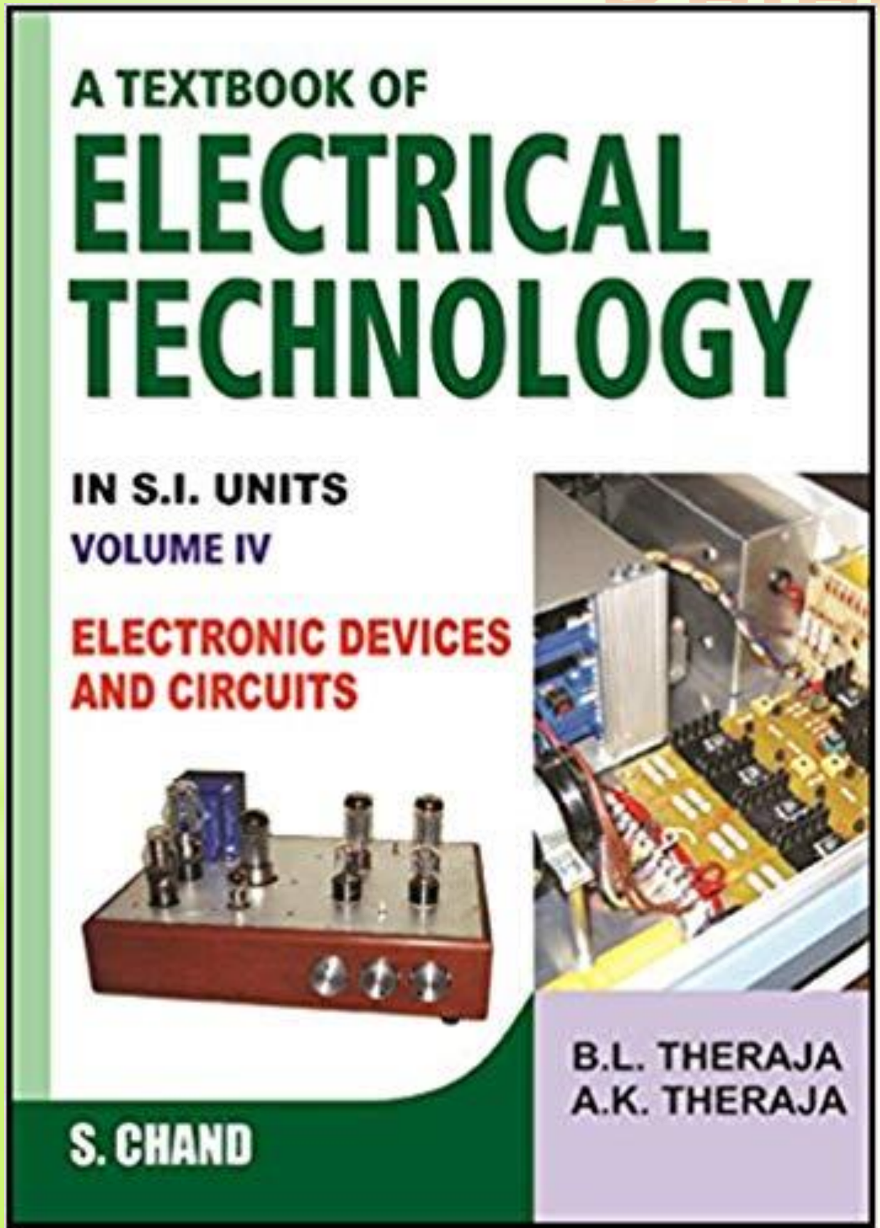
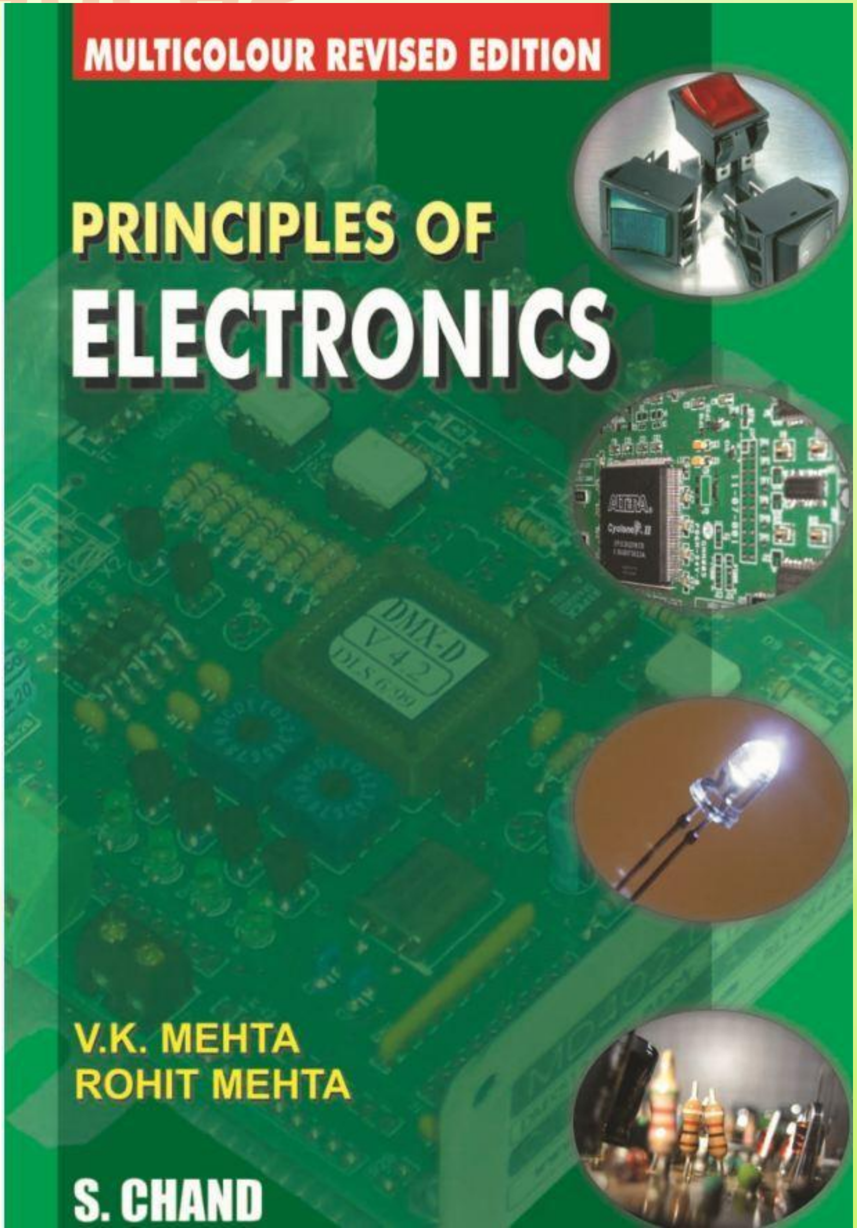
References



A TEXTBOOK OF
ELECTRICAL
TECHNOLOGY
IN S.I. UNITS
VOLUME IV
ELECTRONIC DEVICES
AND CIRCUITS
B.L. THERAJA
A.K. THERAJA
S. CHAND



MULTICOLOUR REVISED EDITION
PRINCIPLES OF
ELECTRONICS
V.K. MEHTA
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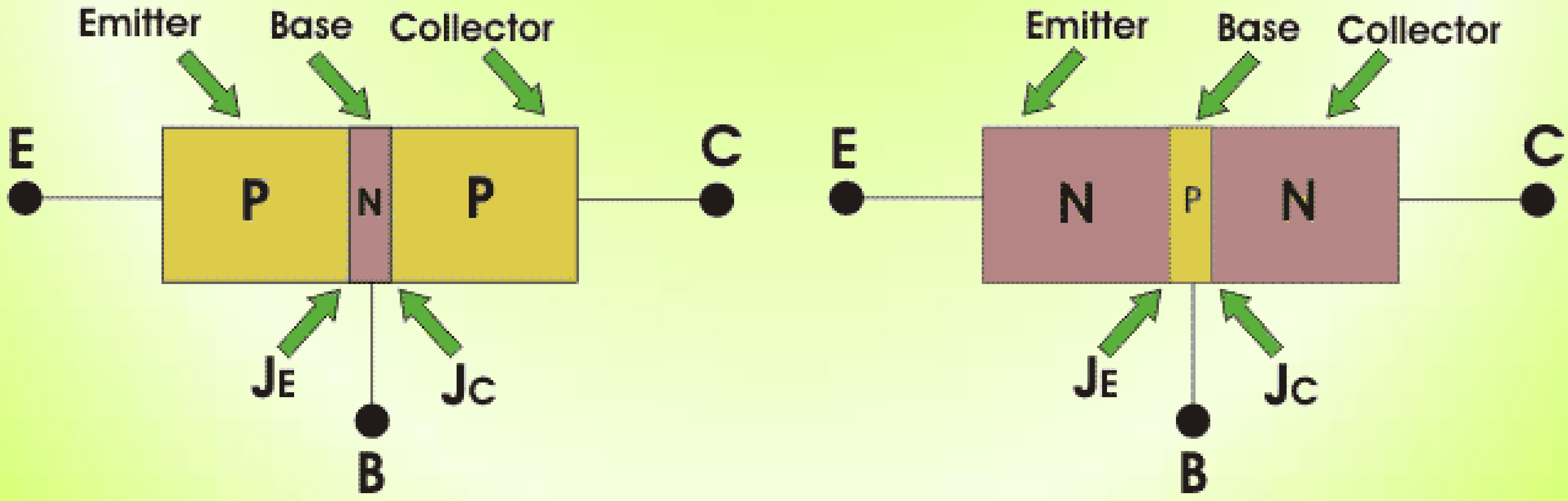
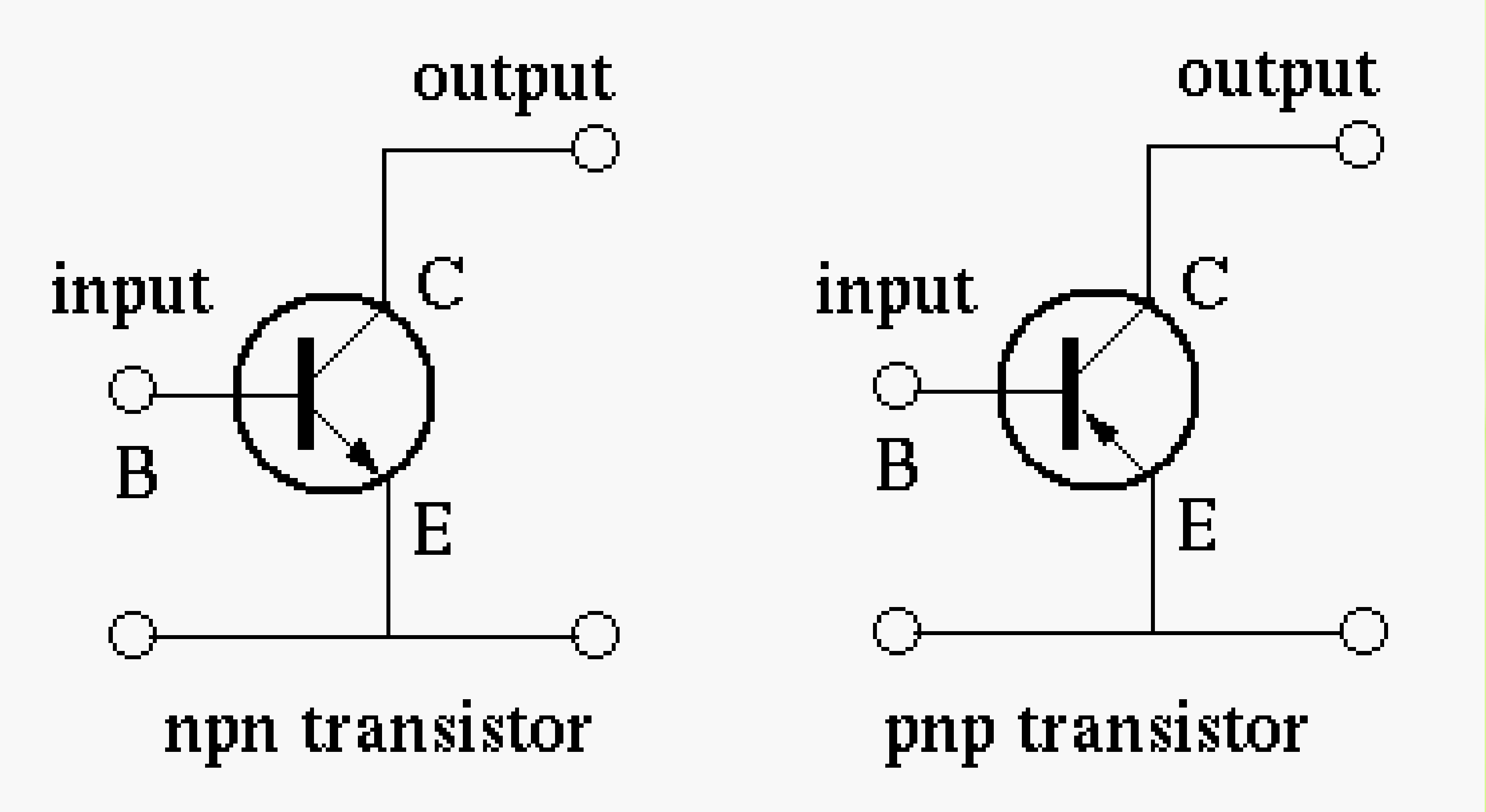
Transistor

A **transistor** consists of two p-n junctions formed by sandwiching either p-type or n-type semiconductor between a pair of opposite types.



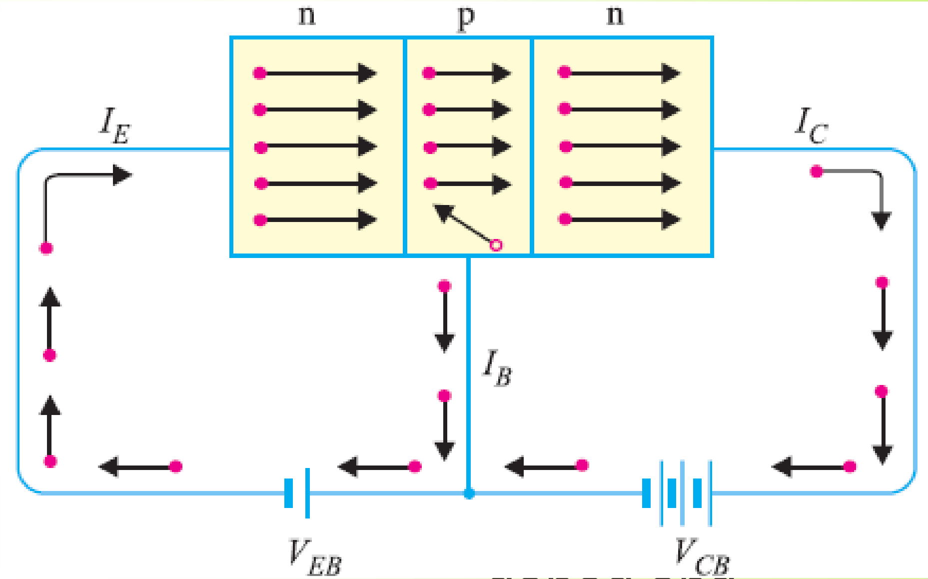
Transistor Symbols



Transistor Action

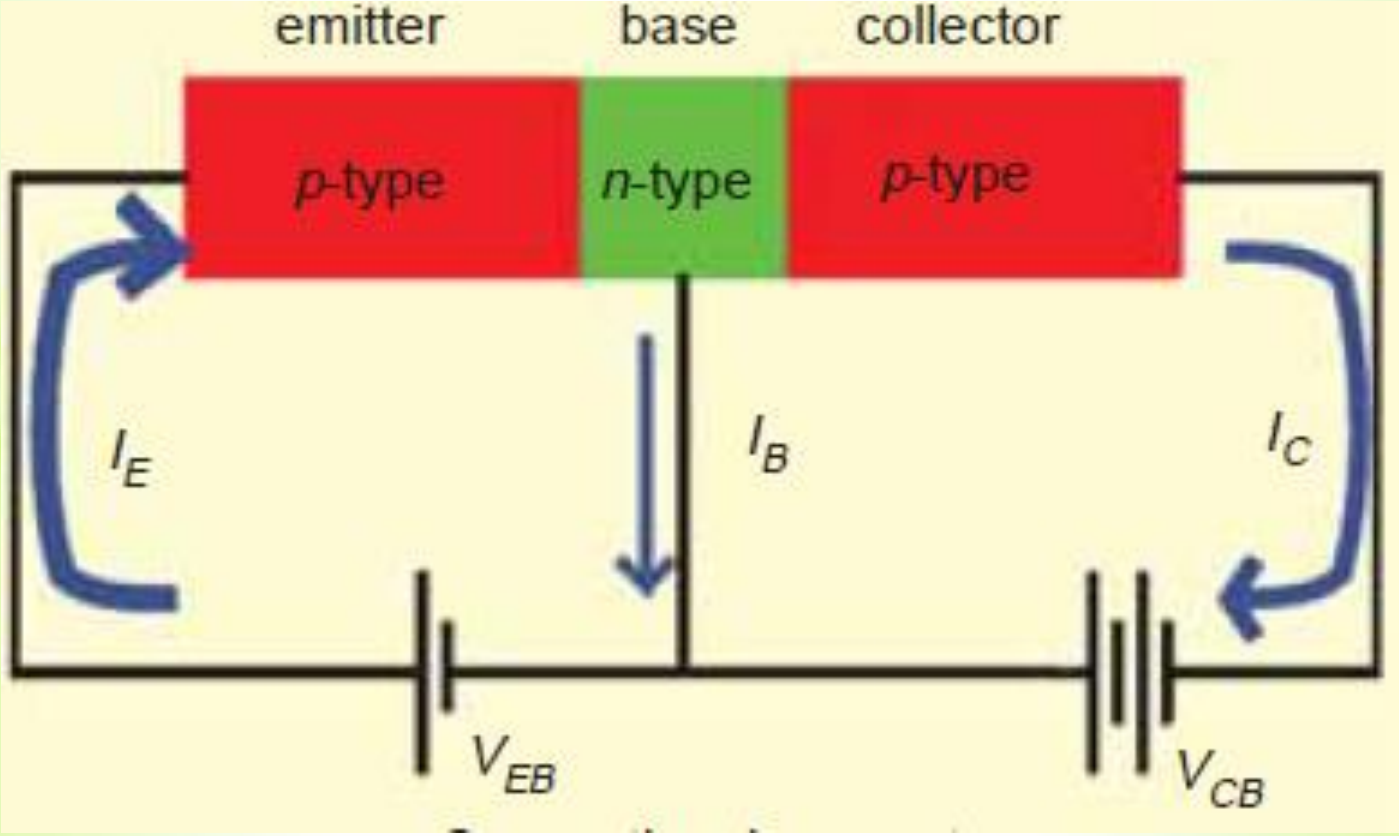
Working of npn transistor

- forward bias to emitter base junction.
- reverse bias to collector-base
- forward bias causes the electrons the *n*-type emitter to flow base. This constitutes I_E.
- As these electrons flow through the type base, they tend to combine holes. As the base is lightly doped and very thin, therefore, only a few electrons (less than 5%) combine with holes to constitute base current I_B.
- The remainder cross over into the collector region to constitute collector current I_C.



$$I_E = I_B + I_C$$

Working of pnp transistor

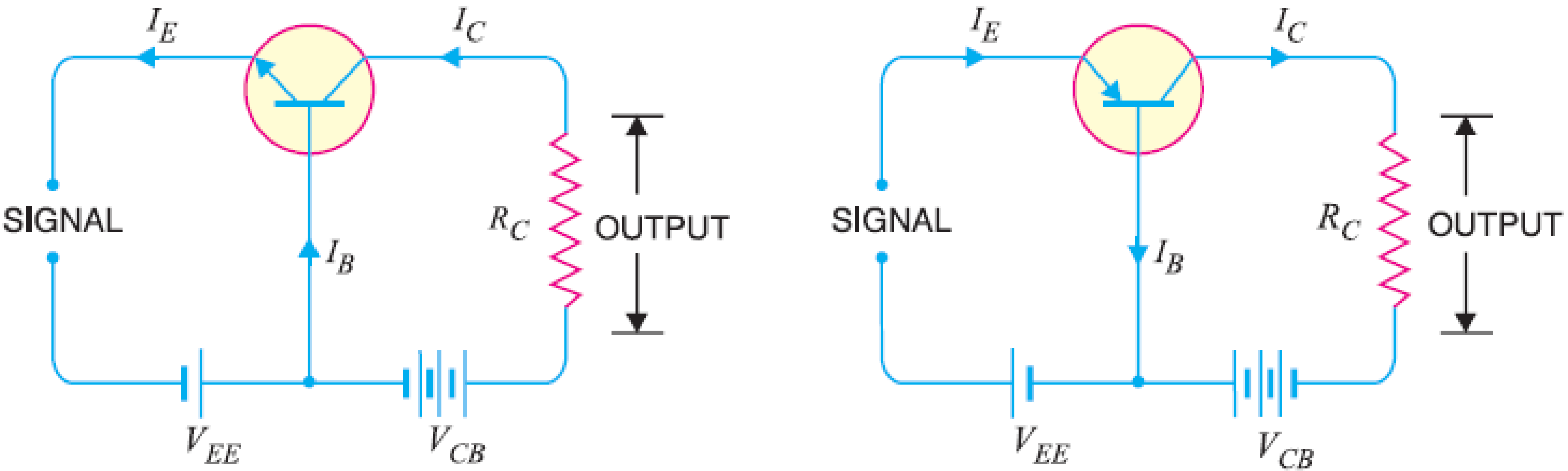


Transistor Connections

- common base connection
- common emitter connection
- common collector connection

Common Base Connection

In this circuit arrangement, input is applied between emitter and base and output is taken from collector and base. Here, base of the transistor is common to both input and output circuits and hence the name common base connection. In Fig. 8.9 (*i*), a common base *npn* transistor circuit is shown whereas Fig. 8.9 (*ii*) shows the common base *pnp* transistor circuit.



Current amplification factor (α)

It is the ratio of output current to input current. In a common base connection, the input current is the emitter current *IE* and output current is the collector current *IC*.

***The ratio of change in collector current to the change in emitter current at constant collector base voltage VCB is known as* current amplification factor.**

$$\alpha = \frac{\Delta I_C}{\Delta I_E} \text{ at constant } V_{CB}$$

α is always less than unity.

Example 8.3: In a common base connection, current amplification factor is 0.9. If the emitter current is 1mA, determine the value of base current.

Example 8.3. *In a common base connection, current amplification factor is 0.9. If the emitter current is 1mA, determine the value of base current.*

Solution. Here, $\alpha = 0.9, \quad I_E = 1 \text{ mA}$

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

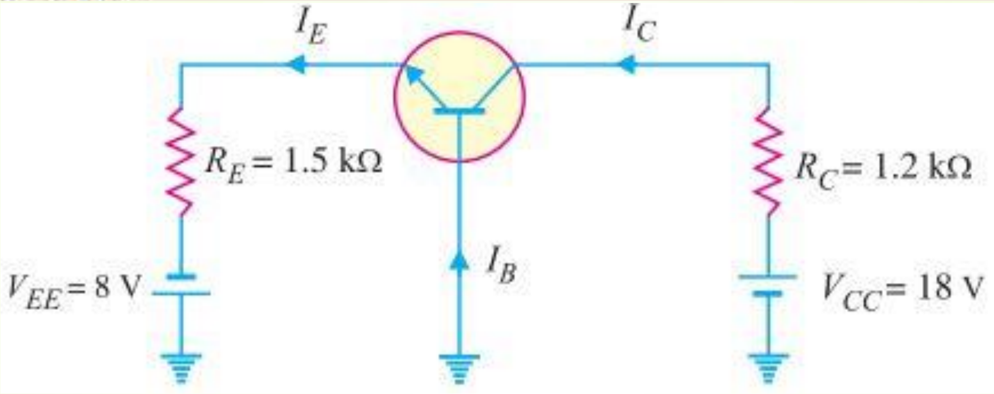
or $$I_C = \alpha I_E = 0.9 \times 1 = 0.9 \text{ mA}$$

Also $$I_E = I_B + I_C$$

$\therefore$ Base current, $I_B = I_E - I_C = 1 - 0.9 = $ **0.1 mA**

P4

Example 8.7. *For the common base circuit shown in Fig. 8.13, determine I_C and V_{CB}. Assume the transistor to be of silicon.*



Example 8.7. *For the common base circuit shown in Fig. 8.13, determine I_C and V_{CB}. Assume the transistor to be of silicon.*

Solution. Since the transistor is of silicon, $V_{BE} = 0.7$V. Applying Kirchhoff's voltage law to the emitter-side loop, we get,

$$V_{EE} = I_E R_E + V_{BE}$$

or $$I_E = \frac{V_{EE} - V_{BE}}{R_E}$$

$$= \frac{8V - 0.7V}{1.5\ k\Omega} = 4.87\ mA$$

$$\therefore \quad I_C \simeq I_E = \mathbf{4.87\ mA}$$

Applying Kirchhoff's voltage law to the collector-side loop, we have,

$$V_{CC} = I_C R_C + V_{CB}$$

$$\therefore \quad V_{CB} = V_{CC} - I_C R_C$$

$$= 18\ V - 4.87\ mA \times 1.2\ k\Omega = \mathbf{12.16\ V}$$

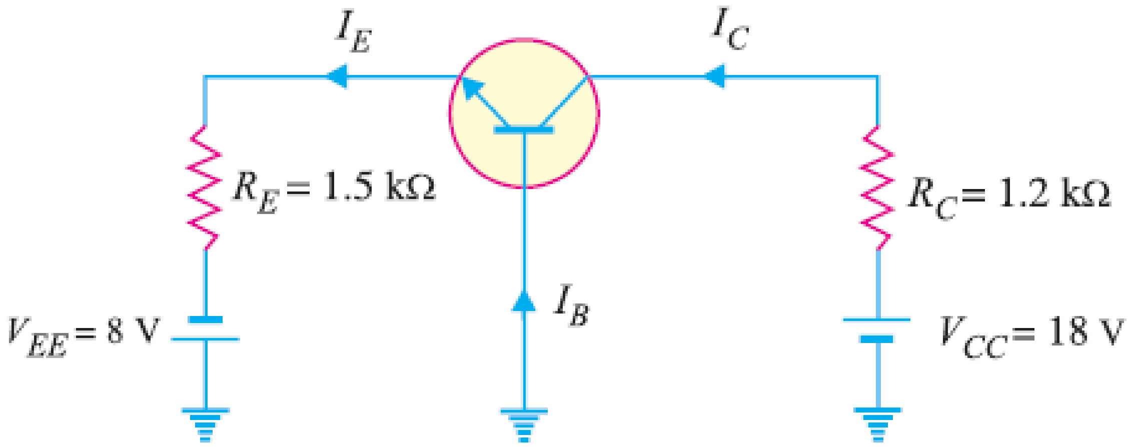
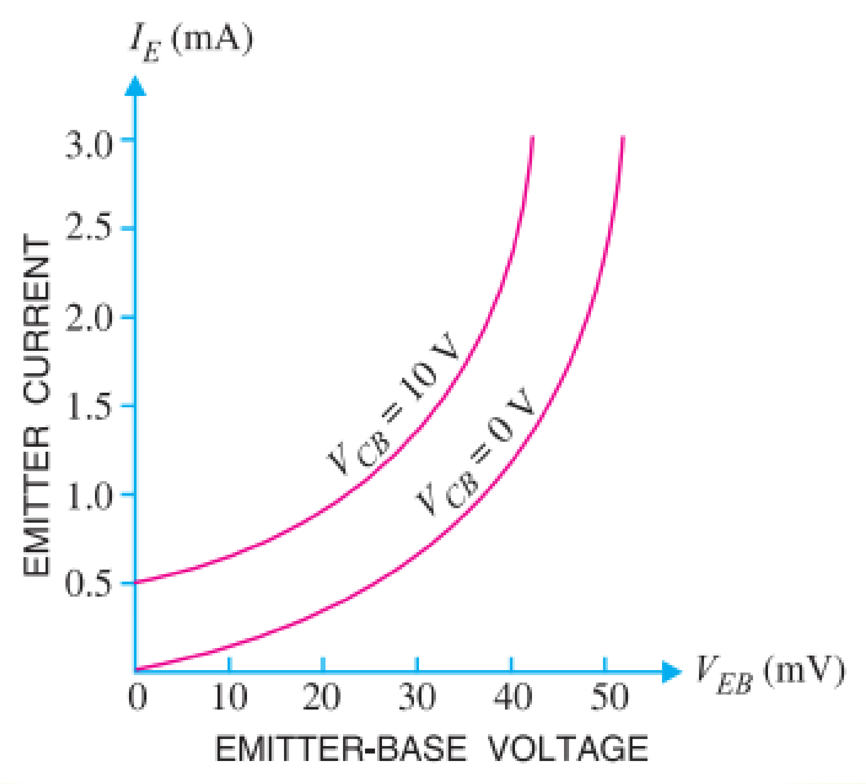


Fig. 8.13

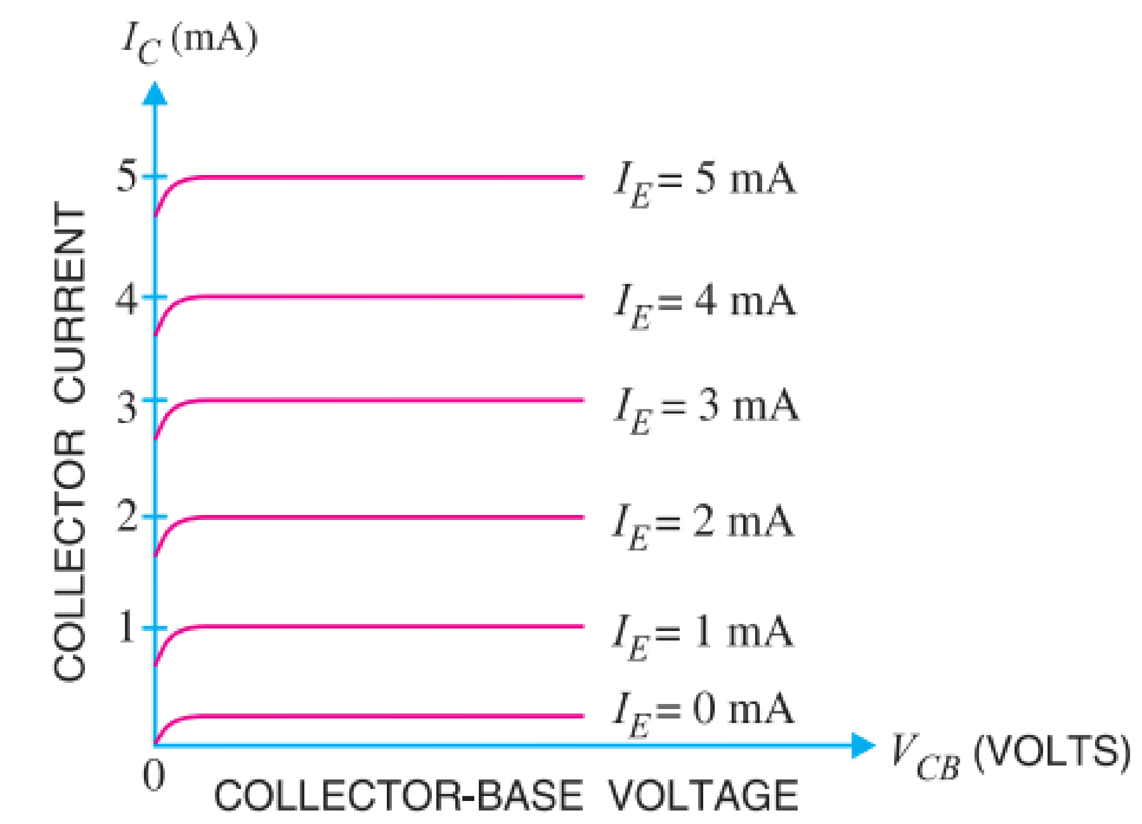
Characteristics of Common Base Connection

Input characteristic



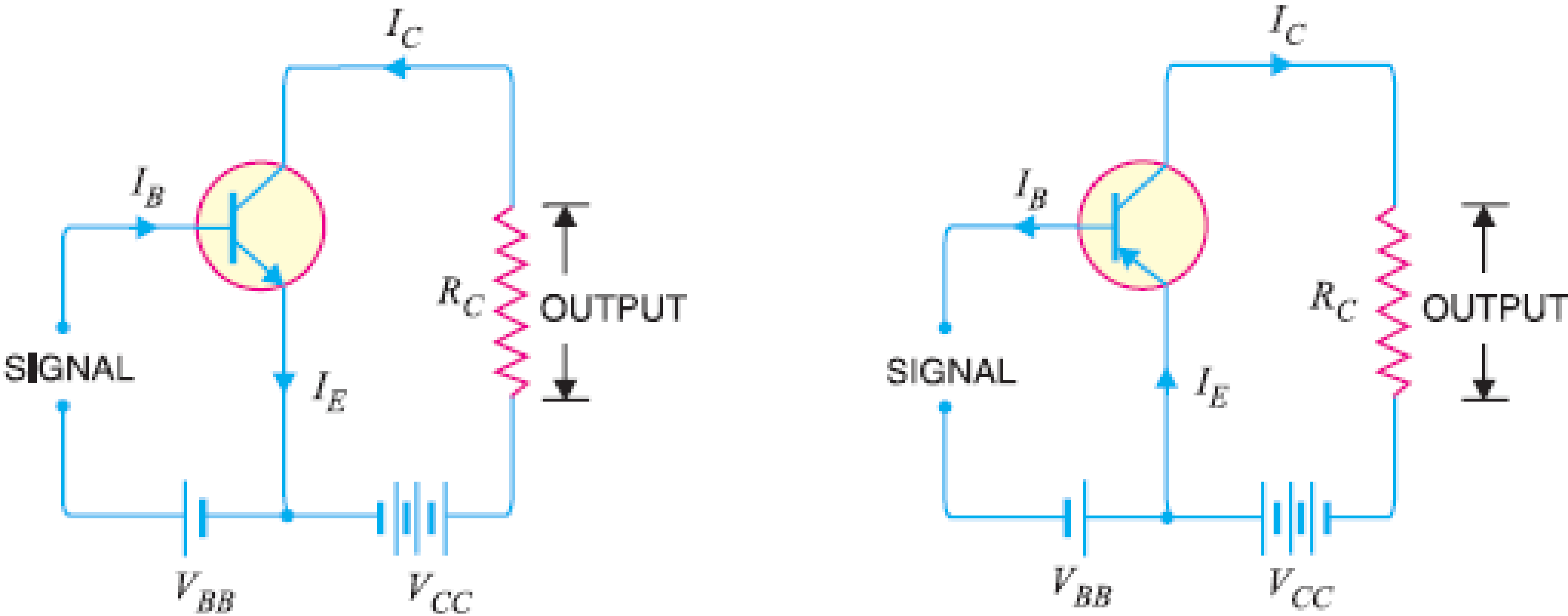
Characteristics of Common Base Connection

Output characteristic



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. 8.16 (*i*) shows common emitter *npn* transistor circuit whereas Fig. 8.16 (*ii*) shows common emitter *pnp* transistor circuit.



Base current amplification factor (β)

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.*

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

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

$$\beta = \frac{\Delta I_C}{\Delta I_B} \qquad \ldots(i)$$

$$\alpha = \frac{\Delta I_C}{\Delta I_E} \qquad \ldots(ii)$$

Now $\qquad I_E = I_B + I_C$

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

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

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

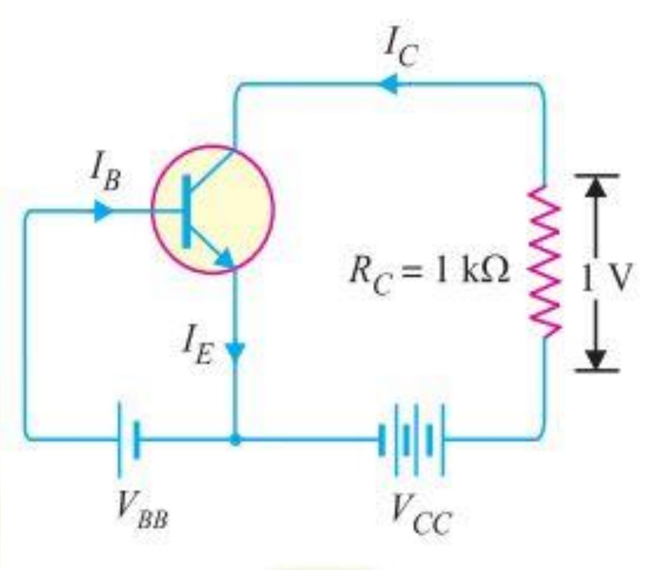
$$\beta = \frac{\Delta I_C}{\Delta I_E - \Delta I_C} \qquad \ldots(iii)$$

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

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

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

Example 8.11. *For a transistor, $\beta = 45$ and voltage drop across $1k\Omega$ which is connected in the collector circuit is 1 volt. Find the base current for common emitter connection.*



Example 8.11. *For a transistor, β = 45 and voltage drop across 1kΩ which is connected in the collector circuit is 1 volt. Find the base current for common emitter connection.*

Solution. Fig. 8.21 shows the required common emitter connection. The voltage drop across R_C (= 1 kΩ) is 1volt.

$$\therefore \quad I_C = \frac{1\,V}{1\,k\Omega} = 1\text{ mA}$$

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

$$\therefore \quad I_B = \frac{I_C}{\beta} = \frac{1}{45} = \mathbf{0.022\ mA}$$

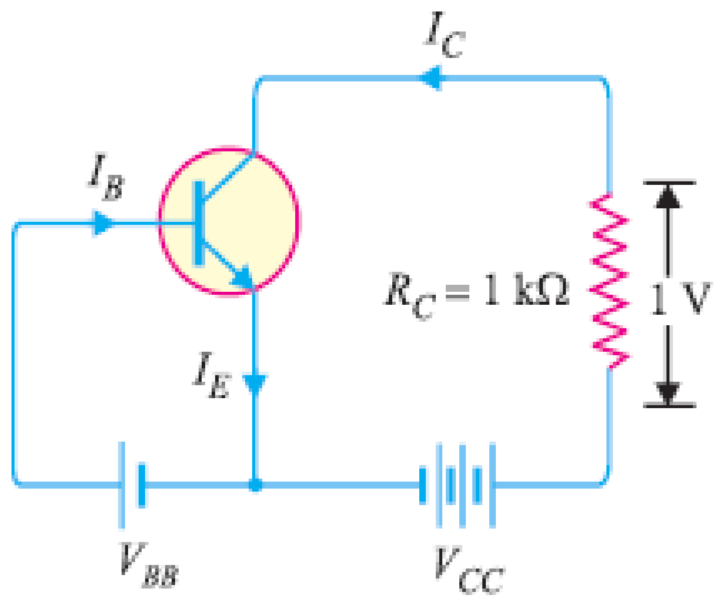
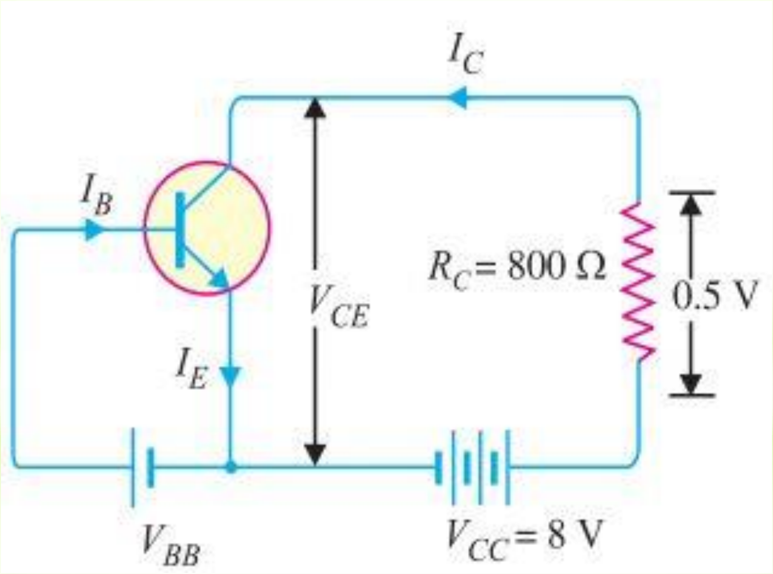


Fig. 8.21

Example 8.12. *A transistor is connected in common emitter (CE) configuration in which collector supply is 8V and the voltage drop across resistance R_C connected in the collector circuit is 0.5V. The value of $R_C = 800\ \Omega$. If $\alpha = 0.96$, determine :*

(i) collector-emitter voltage

(ii) base current



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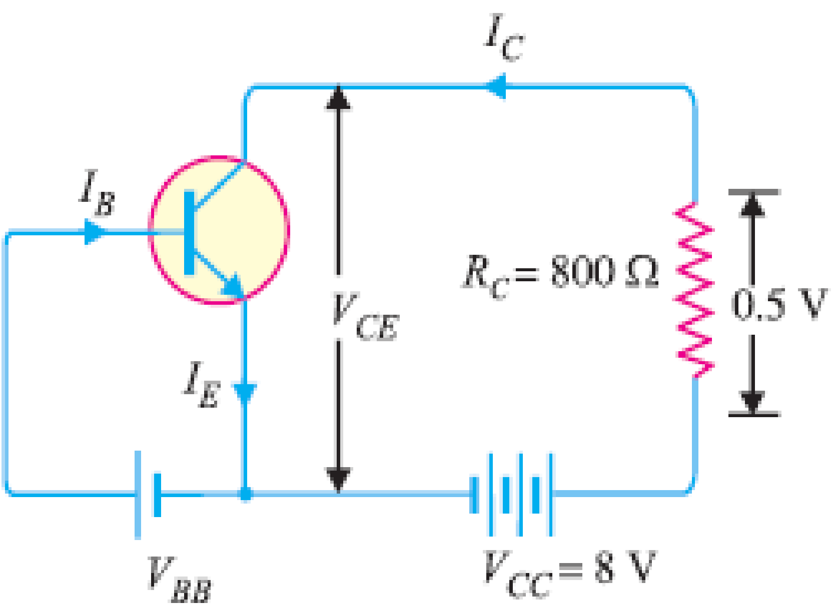


Fig. 8.22

Solution. Fig. 8.22 shows the required common emitter connection with various values.

(*i*) Collector-emitter voltage,

$$V_{CE} = V_{CC} - 0.5 = 8 - 0.5 = \mathbf{7.5\ V}$$

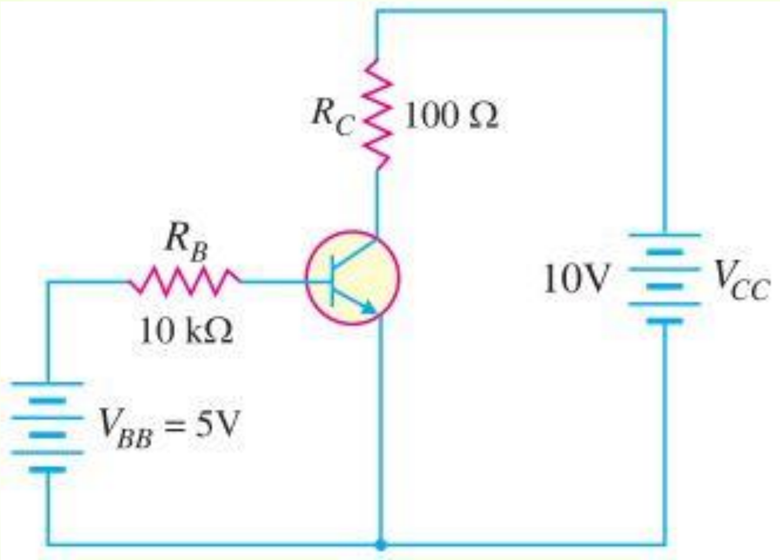
(*ii*) The voltage drop across R_C (= 800 Ω) is 0.5 V.

$$\therefore \quad I_C = \frac{0.5\ \text{V}}{800\ \Omega} = \frac{5}{8}\ \text{mA} = 0.625\ \text{mA}$$

$$\text{Now} \quad \beta = \frac{\alpha}{1-\alpha} = \frac{0.96}{1-0.96} = 24$$

$$\therefore \quad \text{Base current, } I_B = \frac{I_C}{\beta} = \frac{0.625}{24} = \mathbf{0.026\ mA}$$

Example 8.17 *Determine V_{CB} in the transistor * circuit shown in Fig. 8.26 (i). The transistor is of silicon and has $\beta = 150$.*



Example 8.17 *Determine V_{CB} in the transistor * circuit shown in Fig. 8.26 (i). The transistor is of silicon and has $\beta = 150$.*

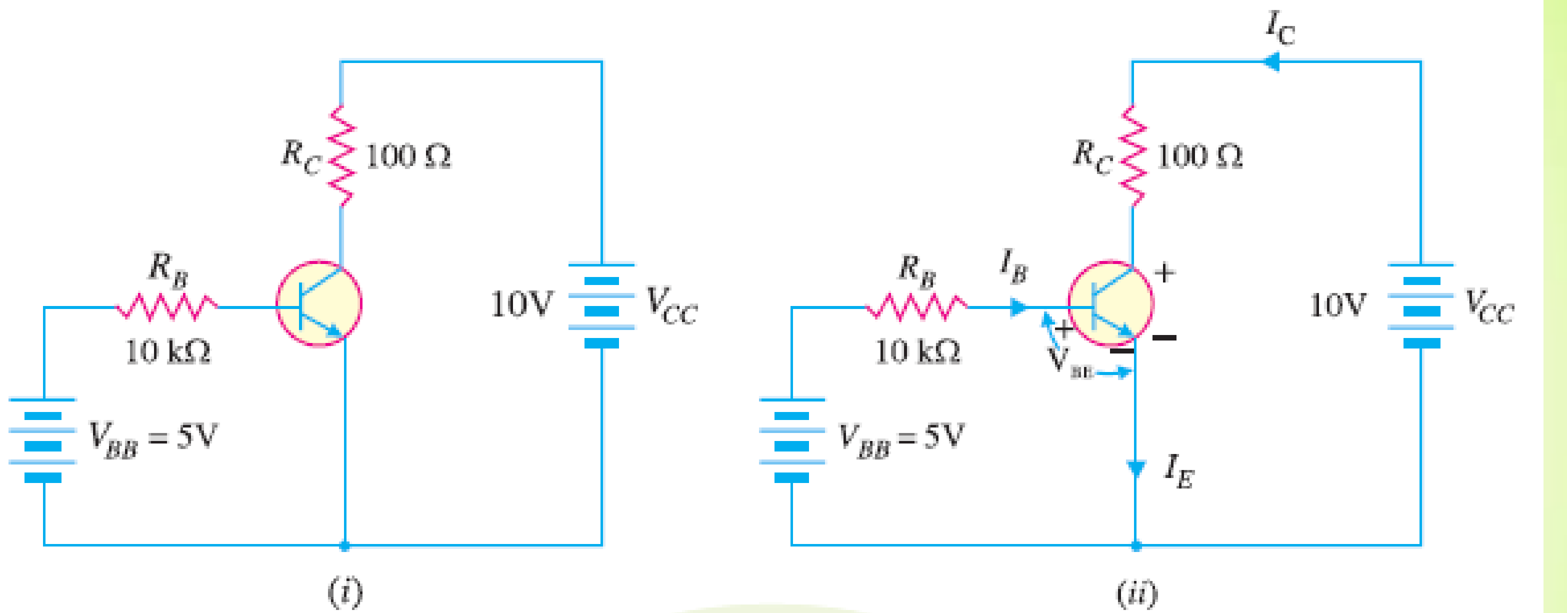


Fig. 8.26

Solution. Fig. 8.26 (*i*) shows the transistor circuit while Fig. 8.26 (*ii*) shows the various currents and voltages along with polarities.

Applying Kirchhoff's voltage law to base-emitter loop, we have,

$$V_{BB} - I_B R_B - V_{BE} = 0$$

or $$I_B = \frac{V_{BB} - V_{BE}}{R_B} = \frac{5V - 0.7V}{10\ k\Omega} = 430\ \mu A$$

∴ $$I_C = \beta I_B = (150)(430\ \mu A) = 64.5\ mA$$

Now $$V_{CE} = V_{CC} - I_C R_C$$

$$= 10V - (64.5\ mA)\ (100\Omega) = 10V - 6.45V = 3.55V$$

We know that : $$V_{CE} = V_{CB} + V_{BE}$$

∴ $$V_{CB} = V_{CE} - V_{BE} = 3.55 - 0.7 = \mathbf{2.85V}$$

Characteristics of Common Emitter Connection

Input characteristic: It is the curve between base current I_B and base-emitter voltage V_{BE} at constant collector-emitter voltage V_{CE}.

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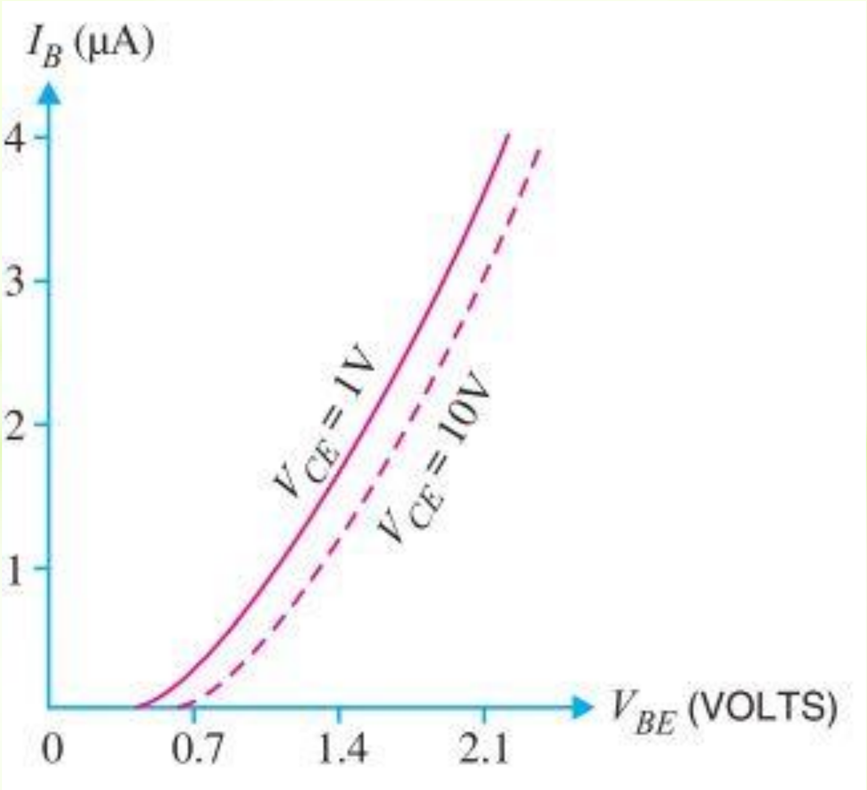
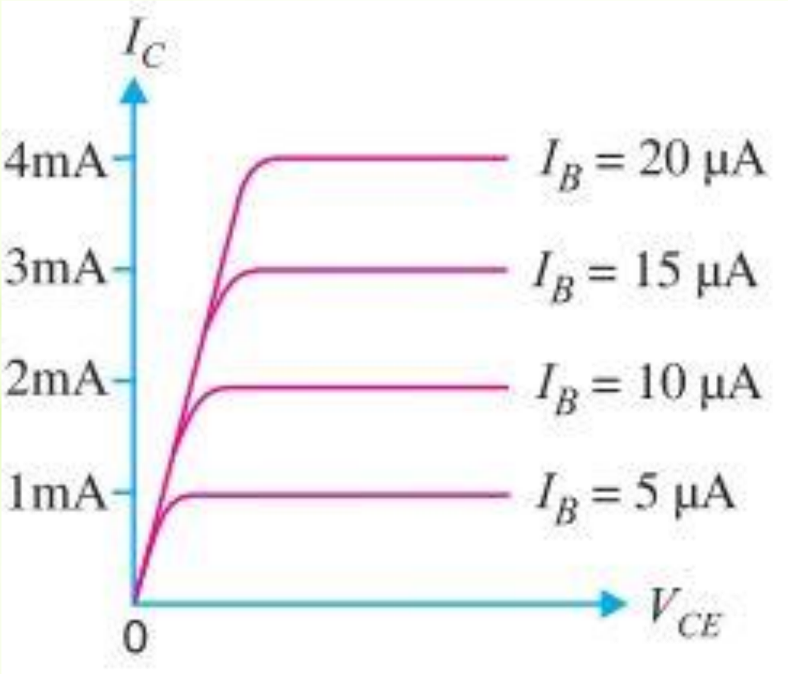


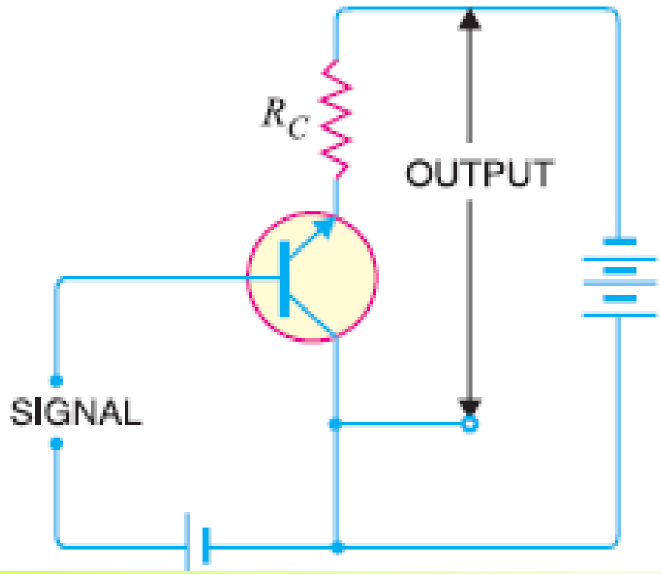
Characteristics of Common Emitter Connection

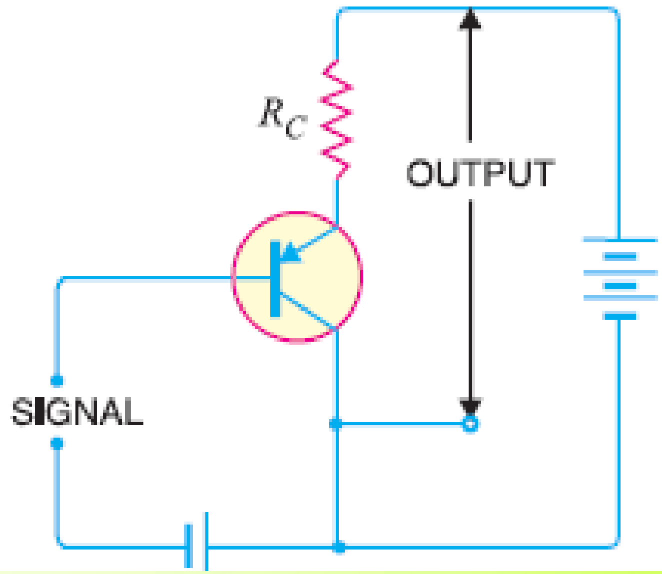
Output characteristic: It is the curve between collector current I_C and collector-emitter voltage V_{CE} at constant base current I_B.



Common Collector Connection

In this circuit arrangement, input is applied between base and collector while output is taken between the emitter and collector. Here, collector of the transistor is common to both input and output circuits and hence the name common collector connection. Fig. 8.32 (*i*) shows common collector *npn* transistor circuit whereas Fig. 8.32 (*ii*) shows common collector *pnp* circuit.





Current amplification factor γ

(*i*) **Current amplification factor γ.** In common collector circuit, input current is the base current I_B and output current is the emitter current I_E. Therefore, current amplification in this circuit arrangement can be defined as under :

The ratio of change in emitter current (ΔI_E) to the change in base current (ΔI_B) is known as **current amplification factor** *in common collector (CC) arrangement i.e.*

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

Relation between γ and α

$$\gamma = \frac{\Delta I_E}{\Delta I_B} \qquad \ldots(i)$$

$$\alpha = \frac{\Delta I_C}{\Delta I_E} \qquad \ldots(ii)$$

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,

$$\gamma = \frac{\Delta I_E}{\Delta I_E - \Delta I_C}$$

Dividing the numerator and denominator of R.H.S. by ΔI_E, we get,

$$\gamma = \frac{\frac{\Delta I_E}{\Delta I_E}}{\frac{\Delta I_E}{\Delta I_E} - \frac{\Delta I_C}{\Delta I_E}} = \frac{1}{1-\alpha} \qquad \left(Q\ \alpha = \frac{\Delta I_C}{\Delta I_E} \right)$$

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

Comparison of Transistor Connections

S. No.	Characteristic	Common base	Common emitter	Common collector
1.	Input resistance	Low (about 100 Ω)	Low (about 750 Ω)	Very high (about 750 kΩ)
2.	Output resistance	Very high (about 450 kΩ)	High (about 45 kΩ)	Low (about 50 Ω)
3.	Voltage gain	about 150	about 500	less than 1
4.	Applications	For high frequency applications	For audio frequency applications	For impedance matching
5.	Current gain	No (less than 1)	High (β)	Appreciable

Transistor as Switch

When using BJT as a switch, usually two levels of control signal are employed. With one level, the transistor operates in the cut-off region (open) whereas with the other level, it operates in the saturation region and acts as a short-circuit. Fig. 57.44 (*b*) shows the condition when control signal $v_i = 0$. In this case, the *BE* junction is reverse-biased and the transistor is open and, hence acts as an open switch. However, as shown in Fig. 57.44 (*c*) if v_i equals a positive voltage of sufficient magnitude to produce saturation *i.e*. if $v_i = v_i$ the transistor acts as a closed switch.

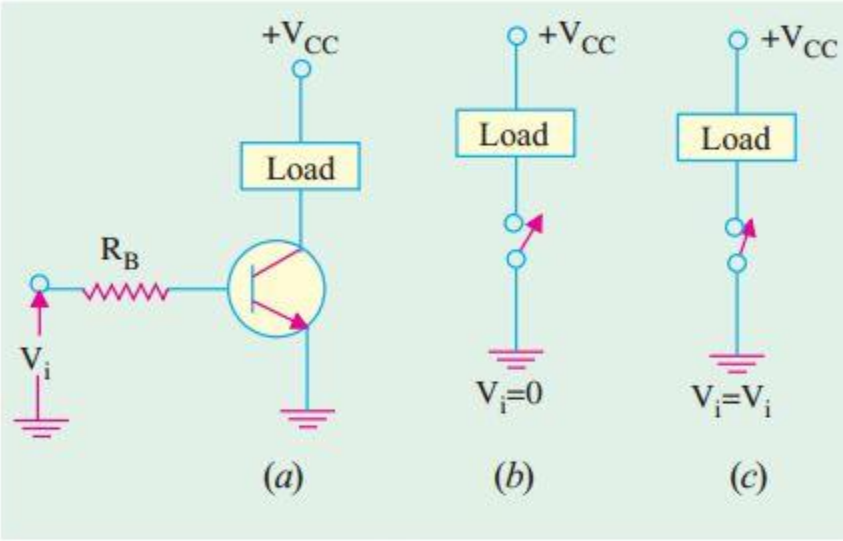


Fig. 57.44

Applications of BJT

- Logic circuits
- Switch
- Amplifier
- Oscillator
- Multivibrator
- Modulator
- Demodulator
- Time delay circuit