

Bipolar Junction Transistor

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Bipolar Junction Transistors

- The transistor is a three-layer semiconductor device consisting of either two n- and one p-type layers of material or two p- and one n-type layers of material.
- The former is called an npn transistor, while the latter is called a pnp transistor

Bipolar Junction Transistors

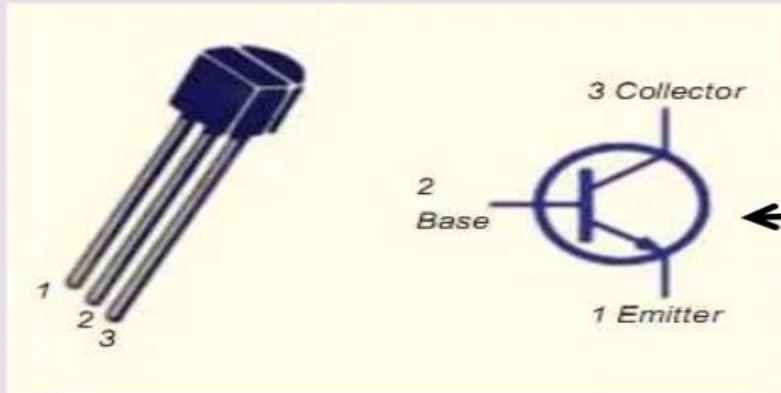


In each transistor following points to be noted-

- i) There are two junction, so transistor can be considered as two diode connected back to back.
- ii) There are three terminals.
- iii) The middle section is thin than other.

Naming of Transistor Terminals

- Transistor has three section of doped semiconductor.
- The section one side is called “emitter” and the opposite side is called “collector”.
- The middle section is called “base”.



Transistor
symbol

Naming of Transistor Terminals

1) Emitter:

- The section of one side that supplies carriers is called emitter.
- Emitter is always forward biased wr to base so it can supply carrier.
- For “nnp transistor” emitter supply holes to its junction.
- For “pnp transistor” emitter supply electrons to its junction.

Naming of Transistor Terminals

2) Collector:

- The section on the other side that collects carrier is called collector.
- The collector is always reversed biased wr to base.
- For “npn transistor” collector receives holes to its junction.
- For “pnp transistor” collector receives electrons to its junction.

Naming of Transistor Terminals

3) Base:

→ The middle section which forms two pn junction between emitter and collector is called Base.

Some important factors to be remembered-

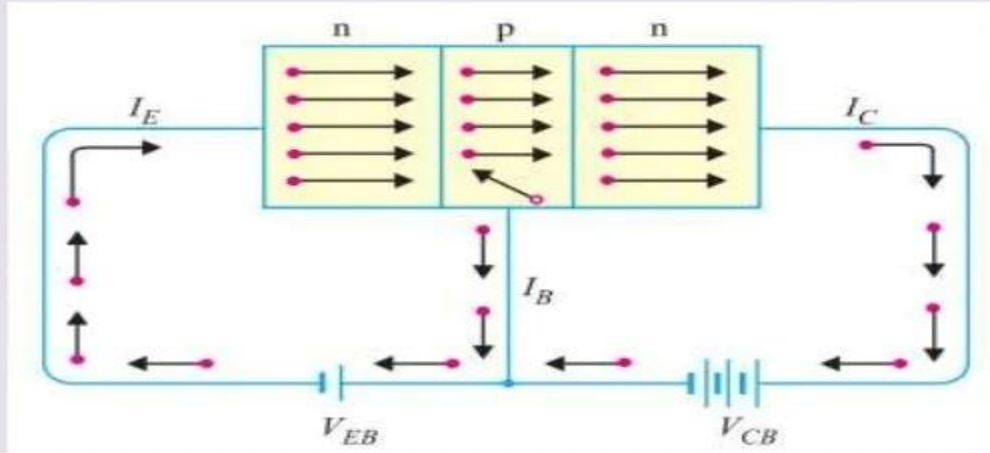
- The transistor has three region named emitter, base and collector.
- The Base is much thinner than other region.
- Emitter is heavily doped so it can inject large amount of carriers into the base.
- Base is lightly doped so it can pass most of the carrier to the collector.
- Collector is moderately doped.

Some important factors to be remembered-

- The junction between emitter and base is called emitter-base junction(emitter diode) and junction between base and collector is called collector-base junction(collector diode).
- The emitter diode is always forward biased and collector diode is reverse biased.
- The resistance of emitter diode is very small(forward) and resistance of collector diode is high(reverse).

Transistor Operation

1) Working of npn transistor:



✓ Forward bias is applied to emitter-base junction and reverse bias is applied to collector-base junction.

✓ The forward bias in the emitter-base junction causes electrons to move toward base. This constitutes emitter current, I_E

Transistor Operation

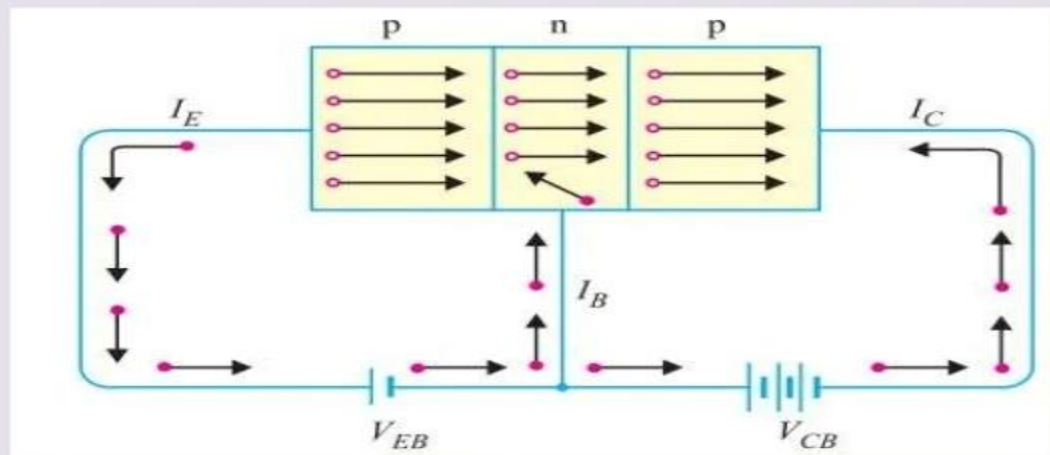
1) Working of npn transistor:

- ✓ As this electrons flow toward p-type base, they try to recombine with holes. As base is lightly doped only few electrons recombine with holes within the base.
- ✓ These recombined electrons constitute small base current.
- ✓ The remainder electrons crosses base and constitute collector current.

$$I_E = I_B + I_C$$

Transistor Operation

2) Working of pnp transistor:



✓ Forward bias is applied to emitter-base junction and reverse bias is applied to collector-base junction.

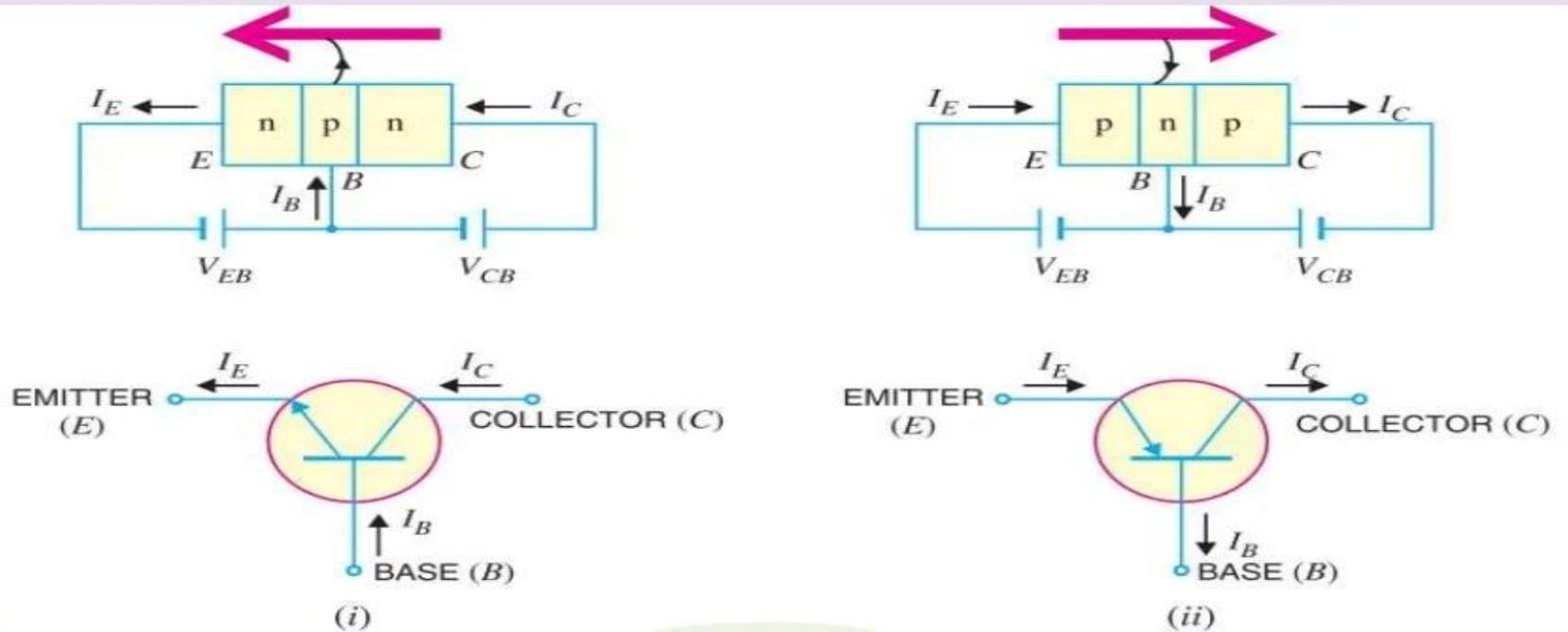
✓ The forward bias in the emitter-base junction causes holes to move toward base. This constitute emitter current, I_E

Transistor Operation

2) Working of pnp transistor:

- ✓ As this holes flow toward n-type base, they try to recombine with electrons. As base is lightly doped only few holes recombine with electrons within the base.
- ✓ These recombined holes constitute small base current.
- ✓ The remainder holes crosses base and constitute collector current.

Transistor Symbol



Transistor Operating Modes

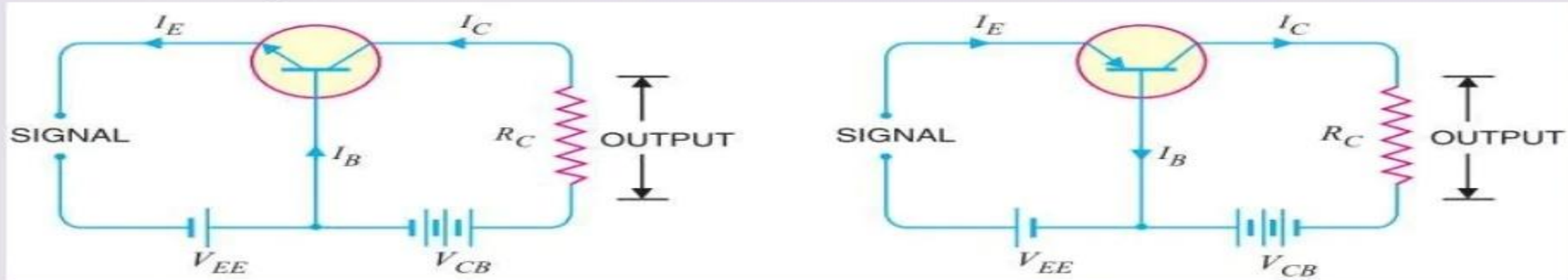
- Active Mode
 - Base- Emitter junction is forward and Base-Collector junction is reverse biased.
- Saturation Mode
 - Base- Emitter junction is forward and Base-Collector junction is forward biased.
- Cut-off Mode
 - Both junctions are reverse biased.

Transistor Connection

- Transistor can be connected in a circuit in following three ways-
 - 1) Common Base
 - 2) Common Emitter
 - 3) Common Collector

Common Base Connection

- The common-base terminology is derived from the fact that the base is common to both the input and output sides of the configuration.



- First Figure shows common base npn configuration and second figure shows common base pnp configuration.

Common Base Connection

- Current amplification factor (α) :

The ratio of change in collector current to the change in emitter current at constant V_{CB} is known as current amplification factor, α .

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

→ Practical value of α is less than unity, but in the range of 0.9 to 0.99

Expression for Collector Current

→ Total emitter current does not reach the collector terminal, because a small portion of it constitute base current. So,

$$I_E = I_C + I_B$$

→ Also, collector diode is reverse biased, so very few minority carrier passes the collector-base junction which actually constitute leakage current, I_{CBO} .

→ So, collector current constitute of portion of emitter current αI_E and leakage current I_{CBO} .

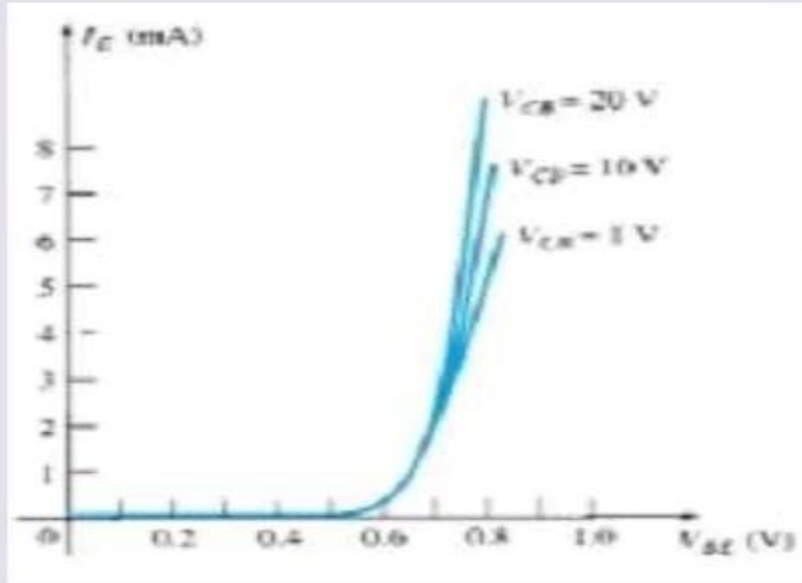
$$I_C = \alpha I_E + I_{CBO}$$

Expression for Collector Current

$$\begin{aligned}I_C &= \alpha (I_C + I_B) + I_{CBO} \\I_C (1 - \alpha) &= \alpha I_B + I_{CBO} \\I_C &= \frac{\alpha}{1 - \alpha} I_B + \frac{I_{CBO}}{1 - \alpha}\end{aligned}$$

Characteristics of common base configuration

- Input Characteristics:



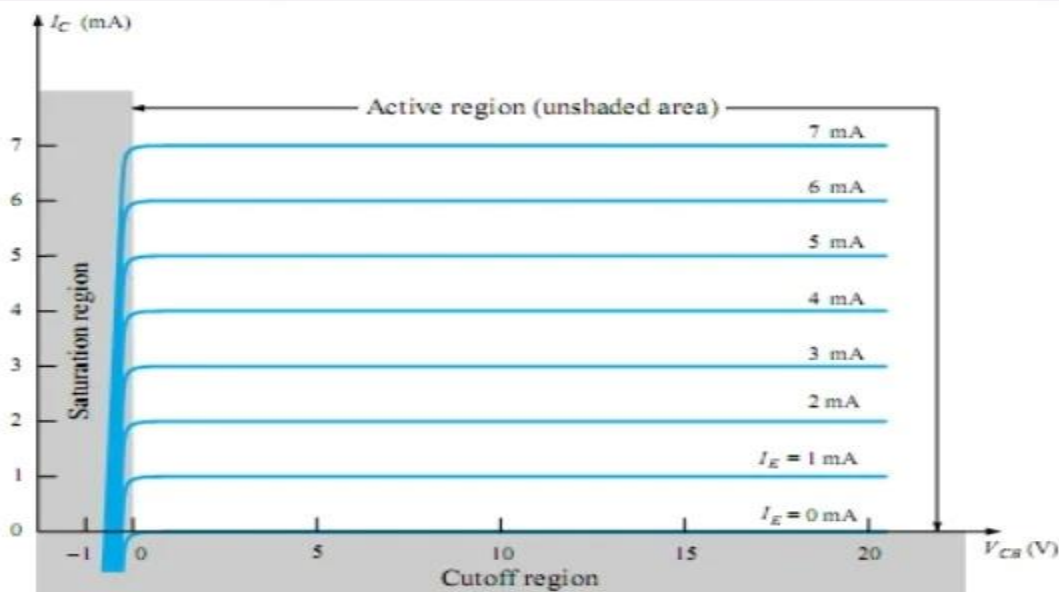
→ V_{BE} vs I_E characteristics called input characteristics.

→ I_E increases rapidly with V_{BE} . It means input resistance is very small.

→ I_E almost independent of V_{CB} .

Characteristics of common base configuration

Output Characteristics:



→ V_{BC} vs I_C

characteristics is called
output characteristics

→ I_C varies linearly
with V_{BC} , only when V_{BC}
is very small.

→ As, V_{BC} increases, I_C
becomes constant.

Input and Output Resistance of common base conf.

- Input Resistance: The ratio of change in emitter-base voltage to the change in emitter current is called Input Resistance.

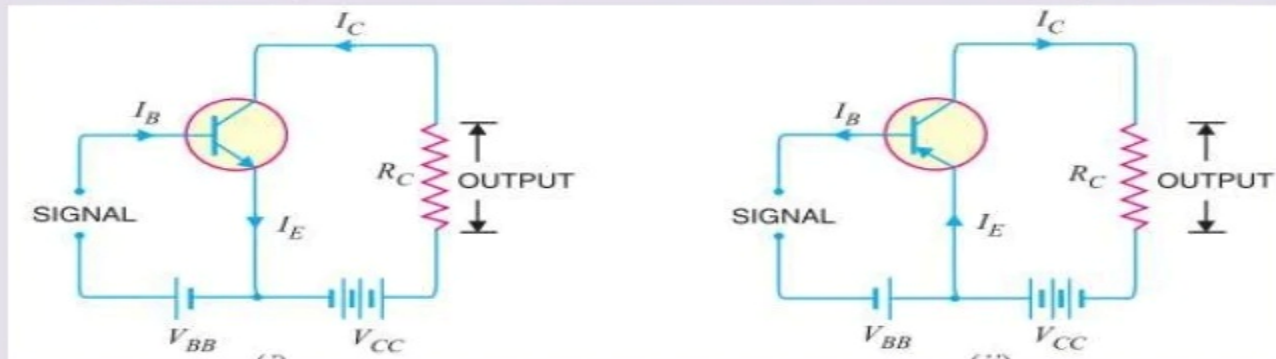
$$r_i = \frac{\Delta V_{BE}}{\Delta I_E}$$

- Output Resistance: The ratio of change in collector-base voltage to the change in collector current is called Output Resistance.

$$r_o = \frac{\Delta V_{BC}}{\Delta I_C}$$

Common Emitter Connection

- The common-emitter terminology is derived from the fact that the emitter is common to both the input and output sides of the configuration.



- First Figure shows common emitter npn configuration and second figure shows common emitter pnp configuration.

Common Emitter Connection

- Base Current amplification factor (β) :
- In common emitter connection input current is base current and output current is collector current.
- The ratio of change in collector current to the change in base current is known as base current amplification factor, β .
$$\beta = \frac{\Delta I_C}{\Delta I_B}$$
- Normally only 5% of emitter current flows to base so amplification factor is greater than 20. Usually this range varies from 20 to 500.

Relation Between β and α

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

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

$$I_E = I_B + I_C$$

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

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

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

$$\beta = \frac{\Delta I_C / \Delta I_E}{\frac{\Delta I_E}{\Delta I_E} - \frac{\Delta I_C}{\Delta I_E}} = \frac{\alpha}{1 - \alpha}$$

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

Expression for Collector Current

$$I_C = \alpha I_E + I_{CBO}$$

$$I_E = I_B + I_C = I_B + (\alpha I_E + I_{CBO})$$

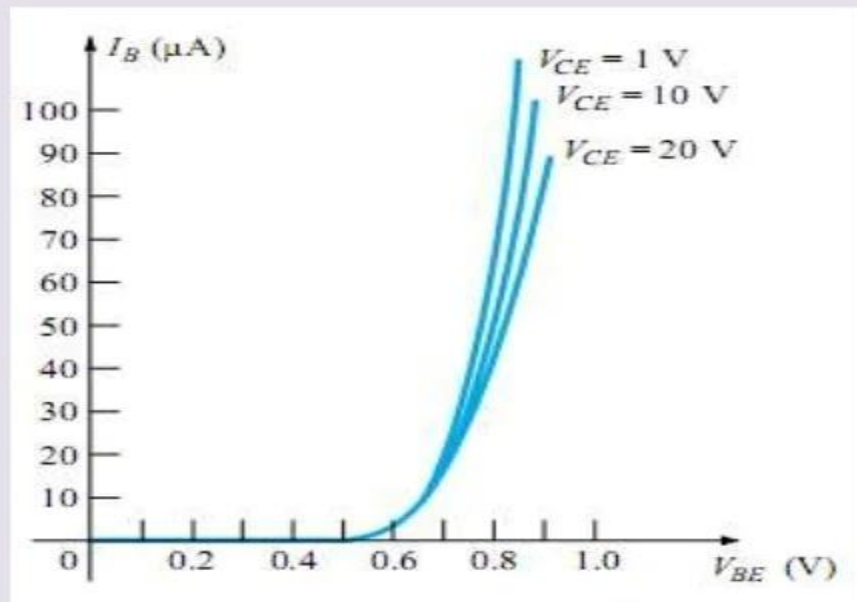
$$I_E (1 - \alpha) = I_B + I_{CBO}$$

$$I_E = \frac{I_B}{1 - \alpha} + \frac{I_{CBO}}{1 - \alpha}$$

$$I_C ; I_E = *(\beta + 1) I_B + (\beta + 1) I_{CBO}$$

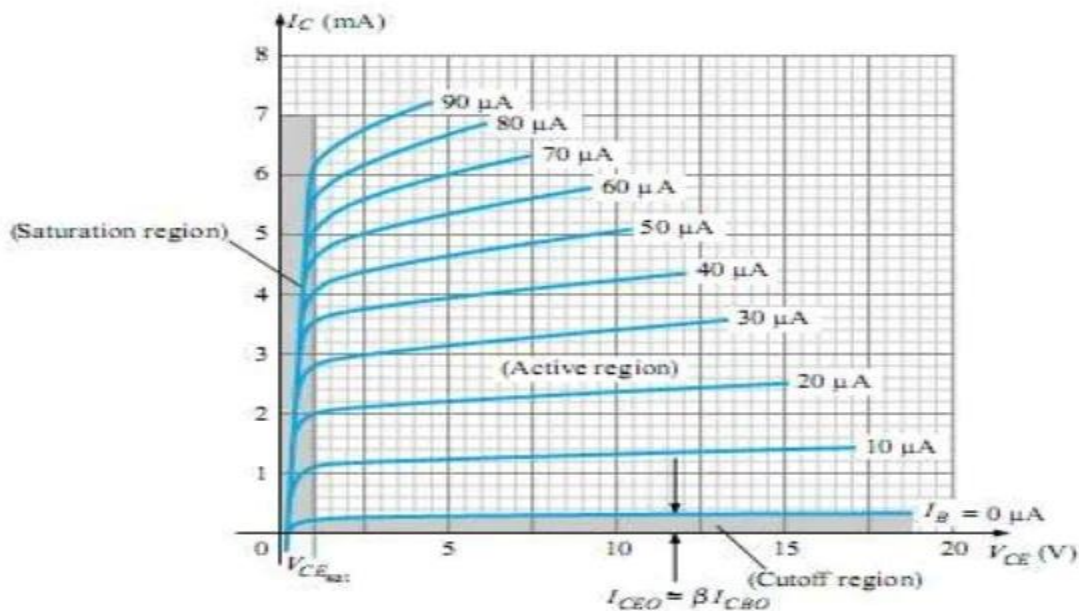
Characteristics of common emitter configuration

- Input Characteristics: $\rightarrow V_{BE}$ vs I_B characteristics called input characteristics.
 - $\rightarrow I_B$ increases rapidly with V_{BE} . It means input resistance is very small.
 - $\rightarrow I_E$ almost independent of V_{CE} .
 - $\rightarrow I_B$ is of the range of microamps.



Characteristics of common emitter configuration

- Output Characteristics:



→ V_{CE} vs I_C

characteristics is called output characteristics.

→ I_C varies linearly with V_{CE} , only when V_{CE} is very small.

→ As, V_{CE} increases, I_C becomes constant.

Input and Output Resistance of common emitter conf.

- Input Resistance: The ratio of change in emitter-base voltage to the change in base current is called Input Resistance.

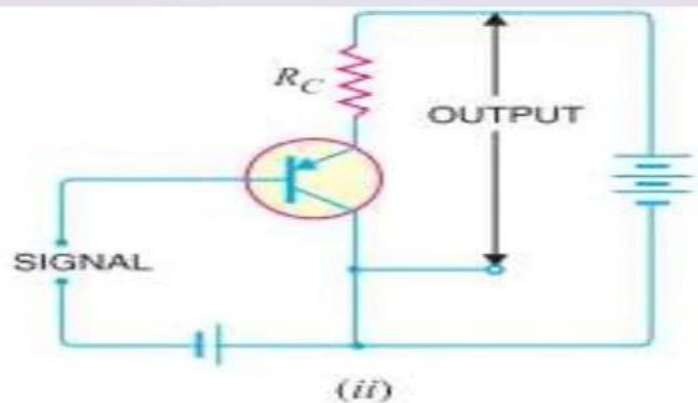
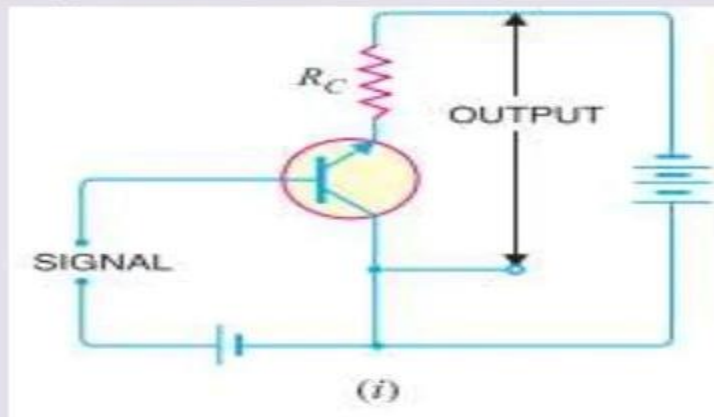
$$r_i = \frac{\Delta V_{BE}}{\Delta I_B}$$

- Output Resistance: The ratio of change in collector-emitter voltage to the change in collector current is called Output Resistance.

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

Common Collector Configuration

- The common-collector terminology is derived from the fact that the collector is common to both the input and output sides of the configuration.



- First Figure shows common collector npn configuration and second figure shows common collector pnp configuration.

Common Collector Configuration

- Current amplification factor (γ) :
- In common emitter connection input current is base current and output current is emitter current.
- The ratio of change in emitter current to the change in base current is known as current amplification factor in common collector configuration.

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

- This circuit provides same gain as CE configuration as,

$$\Delta I_E \approx \Delta I_C$$

Relation Between β and α

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

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

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

$$I_E = I_B + I_C$$

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

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

$$\beta = \frac{\frac{\Delta I_E}{\Delta I_E}}{\frac{\Delta I_E}{\Delta I_E} - \frac{\Delta I_C}{\Delta I_E}} = \frac{1}{1 - \alpha}$$

Expression for Collector Current

$$I_C = \alpha I_E + I_{CBO}$$

$$I_E = I_B + I_C = I_B + (\alpha I_E + I_{CBO})$$

$$I_E (1 - \alpha) = I_B + I_{CBO}$$

$$I_E = \frac{I_B}{1 - \alpha} + \frac{I_{CBO}}{1 - \alpha}$$

$$I_C ; I_E = *(\beta + 1) I_B + (\beta + 1) I_{CBO}$$

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

Comparison of Transistor Connection

S. No.	Characteristic	Common base	Common emitter	Common collector
1.	Input resistance	Low (about $100\ \Omega$)	Low (about $750\ \Omega$)	Very high (about $750\ \text{k}\Omega$)
2.	Output resistance	Very high (about $450\ \text{k}\Omega$)	High (about $45\ \text{k}\Omega$)	Low (about $50\ \Omega$)
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

THANKS TO ALL

for stay with me