EDC

BJT- Bipolar Junction Transistor

Unit -2

Prepared by
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BJT- Bipolar Junction Transistor

The bipolar junction transistor or BJT is a three-terminal semiconductor device that can act as a conductor or insulator based on the applied input signal. And due to this property, the transistor can be used as a switch in digital electronics or as an amplifier in analog electronics.

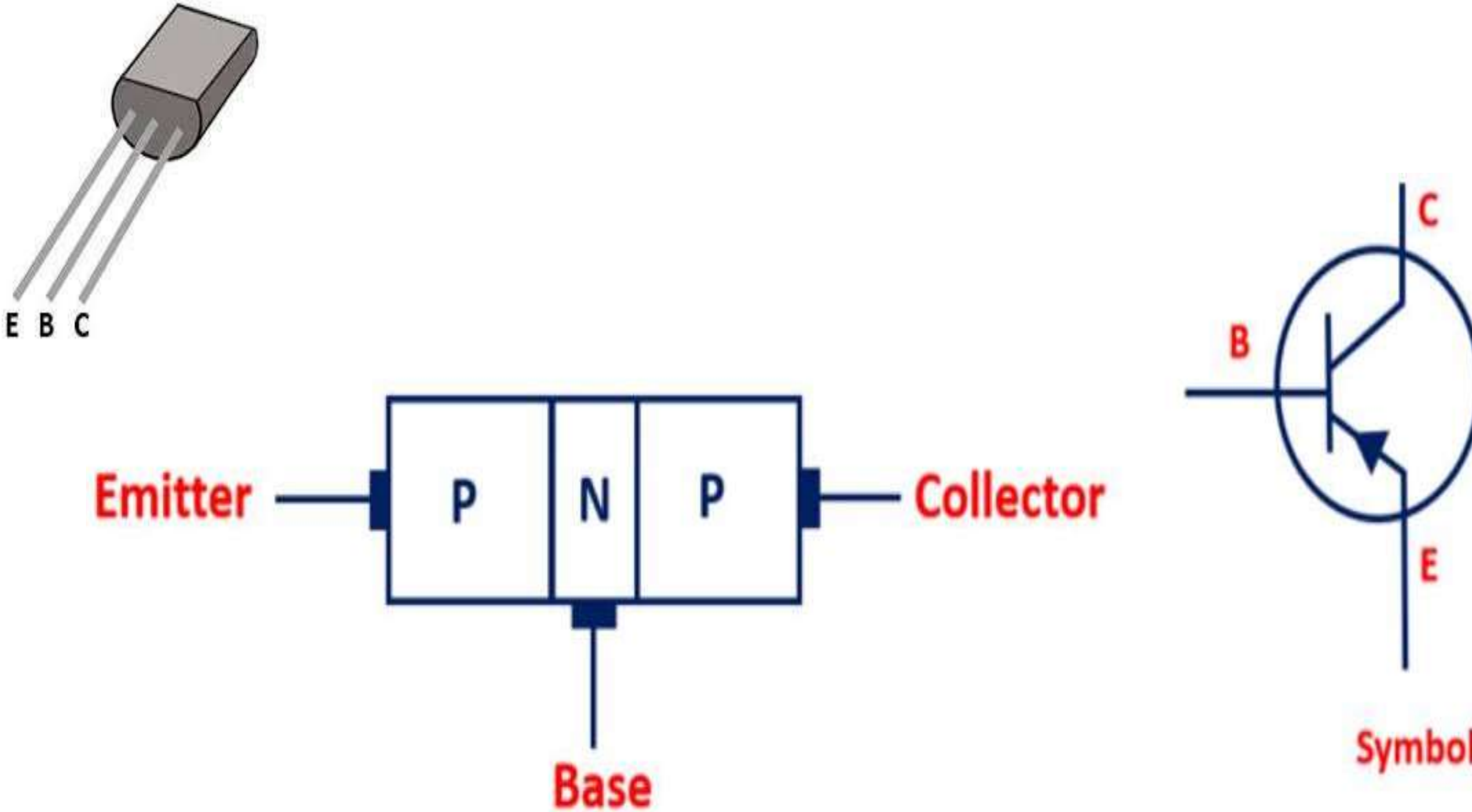


Fig. Bipolar Junction Transistor Basic Structure (PNP Transistor)

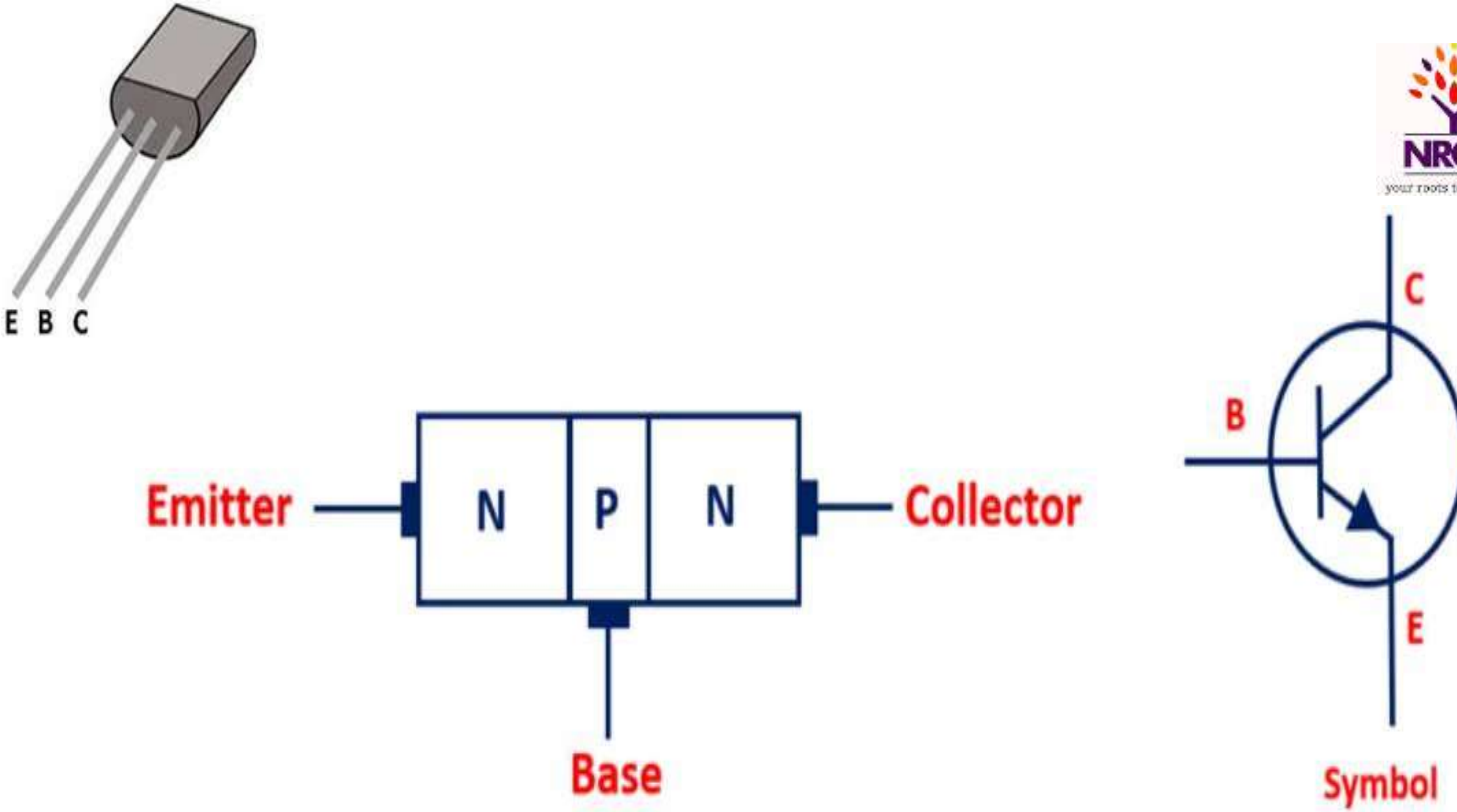


Fig. Basic Structure and Symbol of Bipolar Junction Transistor (NPN Transistor)

Inside the BJT, the two PN junctions are formed One is between the base and emitter and the second is between the base and the collector.

It appears as if two back to back diodes are connected in series.

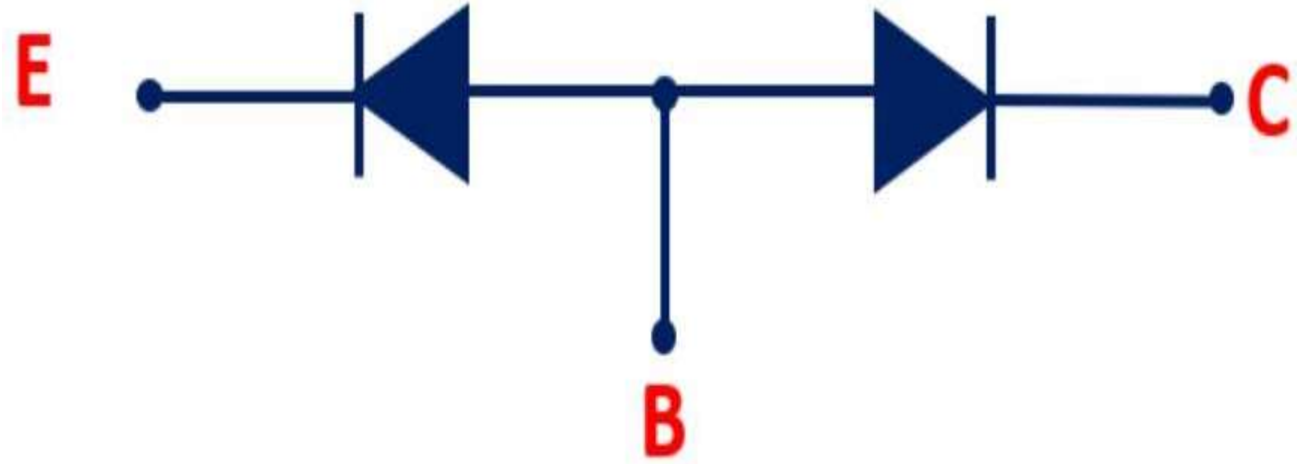


Fig. Two PN junctions in Bipolar Junction Transistor

BJT: Three Regions of Operation

Depending on the biasing, the BJT can be operated in three regions.

1) Active region,

2) Cut-Off region

3) Saturation region.

BJT Region of Operation	Emitter-Base Junction	Collector-Base Junction
Active	FB	RB
Cut-off	RB	RB
Saturation	FB	FB
Reverse- Active	RB	FB

Different BJT Configurations:

As mentioned earlier, when BJT is used for the amplification of the signal, it is operated in the active region. And there are different ways to configure it.

- Common Emitter (CE)
- Common Base (CB)
- Common Collector (CC)

Depending on the requirement and the application, the BJT can be configured in any of the three configurations.

Common Emitter Configuration:

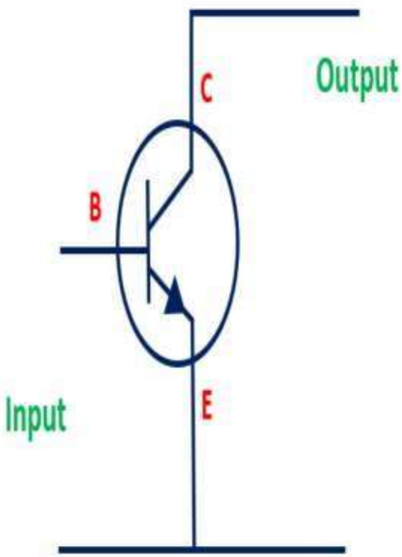


Fig. Common Emitter Configuration of BJT

Common Base Configuration:

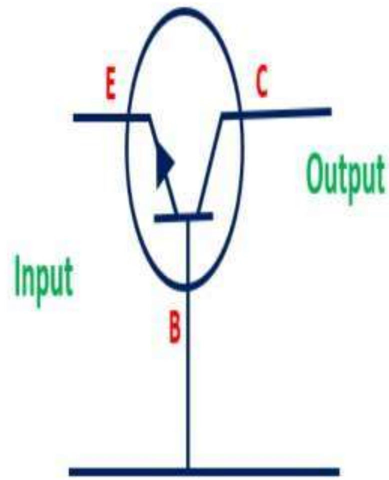


Fig. Common Base Configuration

Common Collector Configuration:

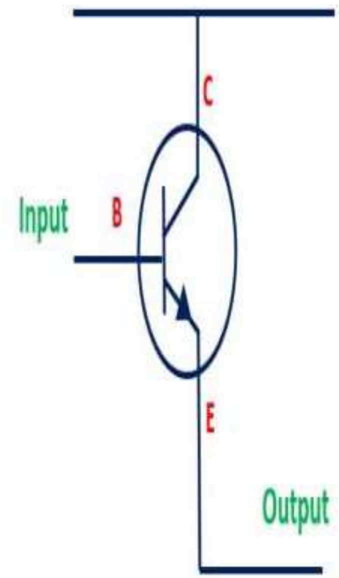


Fig. Common Collector Configuration of BJT

Current Amplification Factor

In a transistor amplifier with a.c. input signal, the ratio of change in output current to the change in input current is known as the current amplification factor.

In the CB configuration the current amplification factor, $\alpha = \frac{\Delta I_C}{\Delta I_E}$

In the CE configuration the current amplification factor, $\beta = \frac{\Delta I_C}{\Delta I_B}$

In the CC configuration the current amplification factor, $\gamma = \frac{\Delta I_E}{\Delta I_B}$

Relationship between α and β We know that $\Delta I_E = \Delta I_C + \Delta I_B$

By definition, $$\Delta I_C = \alpha \Delta I_E$$

Therefore, $$\Delta I_E = \alpha \Delta I_E + \Delta I_B$$

i.e. $$\Delta I_B = \Delta I_E (1 - \alpha)$$

Dividing both sides by ΔI_C, we get

$$\frac{\Delta I_B}{\Delta I_C} = \frac{\Delta I_E}{\Delta I_C}(1 - \alpha)$$

Therefore, $$\frac{1}{\beta} = \frac{1}{\alpha}(1 - \alpha)$$

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

Rearranging, we also get $$\alpha = \frac{\beta}{(1 + \beta)}, \quad \text{or} \quad \frac{1}{\alpha} - \frac{1}{\beta} = 1$$

From this relationship, it is clear that as α approaches unity, β approaches infinity. The CE configuration is used for almost all transistor applications because of its high current gain, β.

Relation among α, β and γ In the CC transistor amplifier circuit, I_B is the input current and I_E is the output current.

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

Substituting $\Delta I_B = \Delta I_E - \Delta I_C$, we get

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

Dividing the numerator and denominator on RHS by ΔI_E, we get

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

Therefore, $$\gamma = \frac{1}{1-\alpha} = (\beta + 1) \qquad (4.26)$$

The three types of configurations are

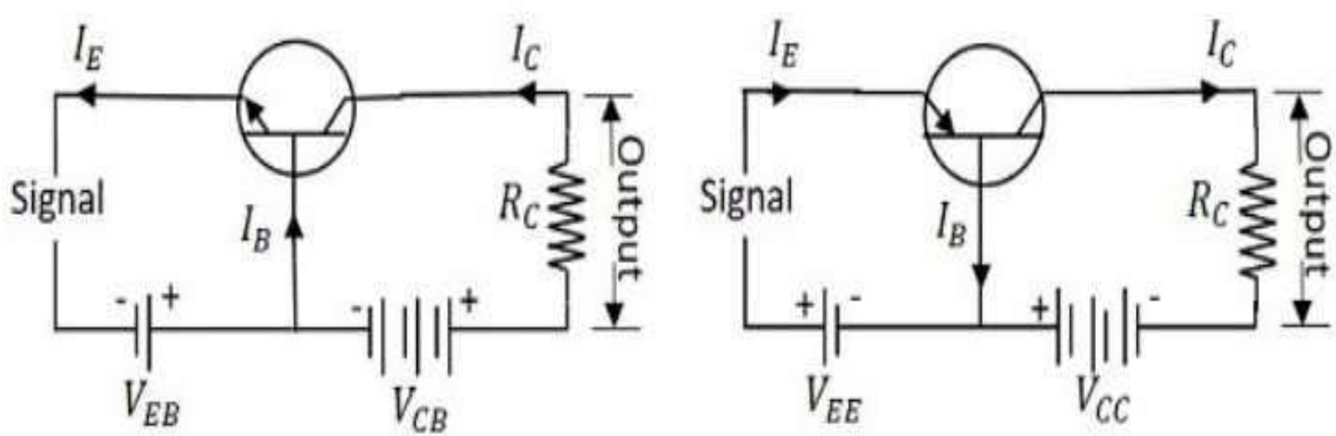
- **Common Base**
- **Common Emitter**
- **Common Collector**

In every configuration, the emitter junction is forward biased and the collector junction is reverse biased.

Common Base CB Configuration

The name itself implies that the Base terminal is taken as common terminal for both input and output of the transistor. The common base connection for both NPN and PNP transistors is as shown in the following figure.

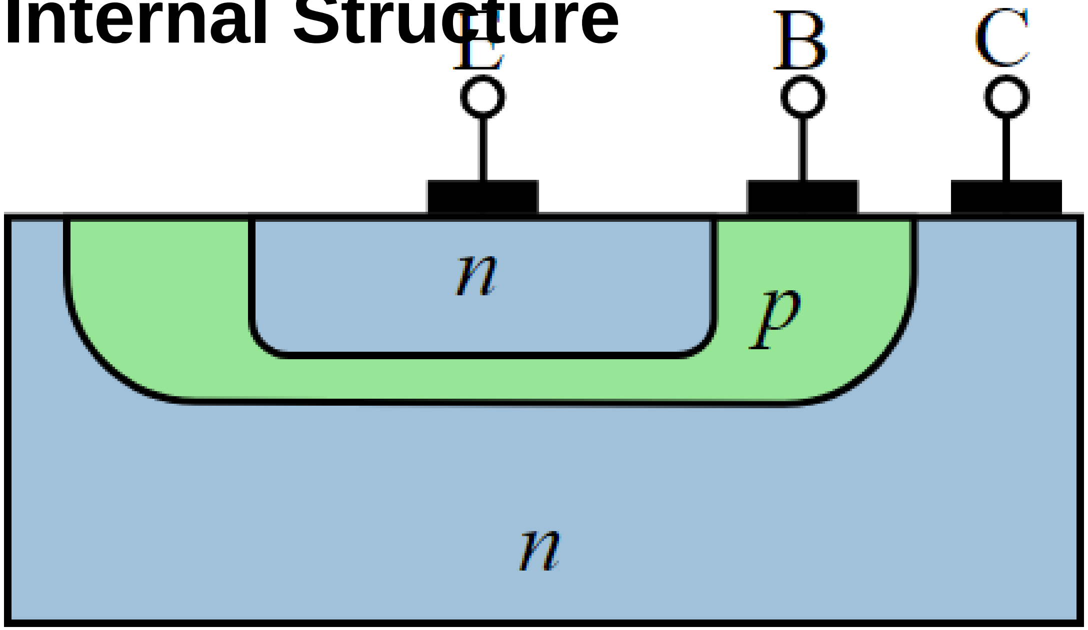
Common Base Connection



Using NPN transistor

Using PNP transistor

BJT: Construction and Internal Structure



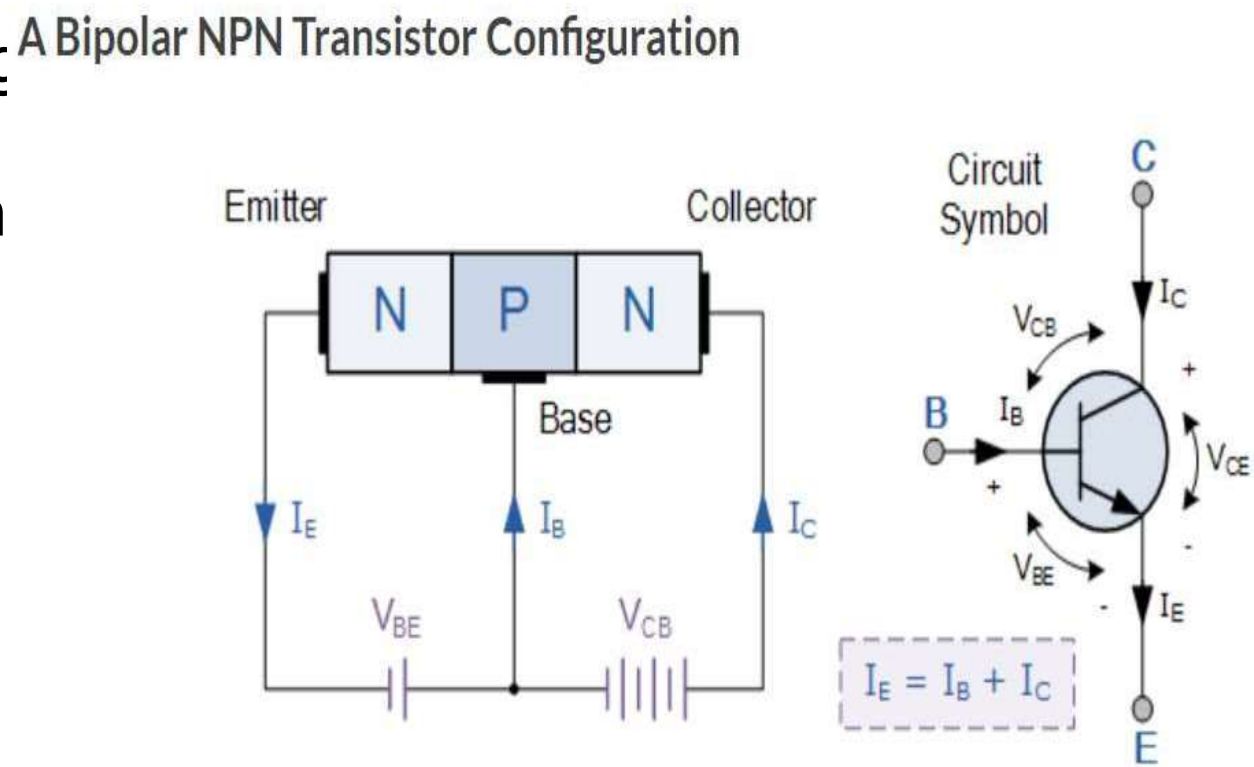
	Base	Emitter	Collector
Width	Narrow	Moderate	Wide
Doping Concentration	Light	Heavy	Moderate

Fig. Doping Concentration and Width of Three Regions in BJT

let us consider NPN transistor in CB configuration.
When the emitter voltage is applied, as it is forwar
biased, the electrons from the negative terminal repel the emitter electrons and current flows through the emitter and base to the collector to contribute collector current.

The collector voltage $\mathbf{V_{CB}}$ is kept constant throughout this.

In the CB confic
emitter current
collector curren



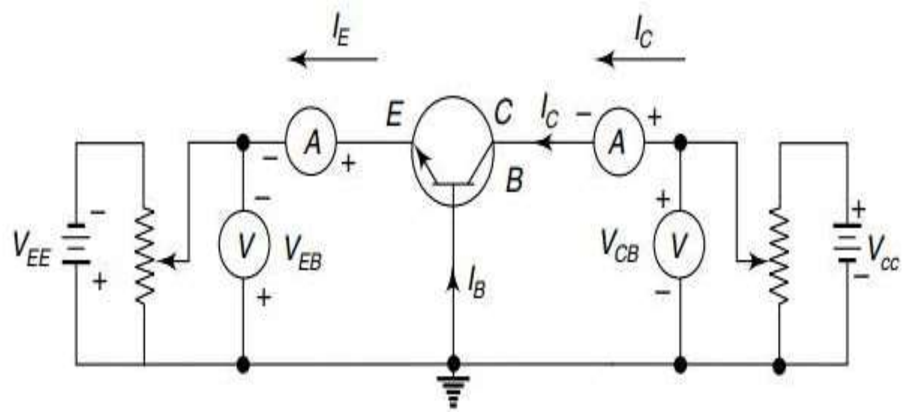


Fig. 4.7 *Circuit to determine CB static characteristics*

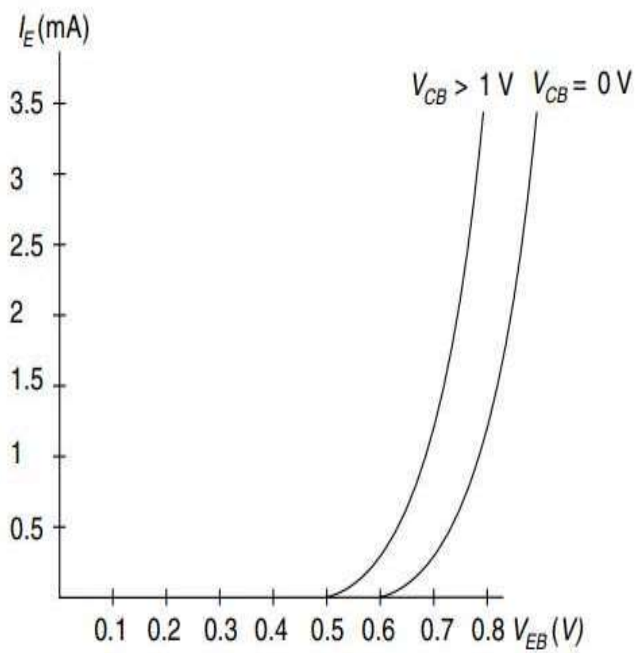


Fig. 4.8 *CB input characteristics*

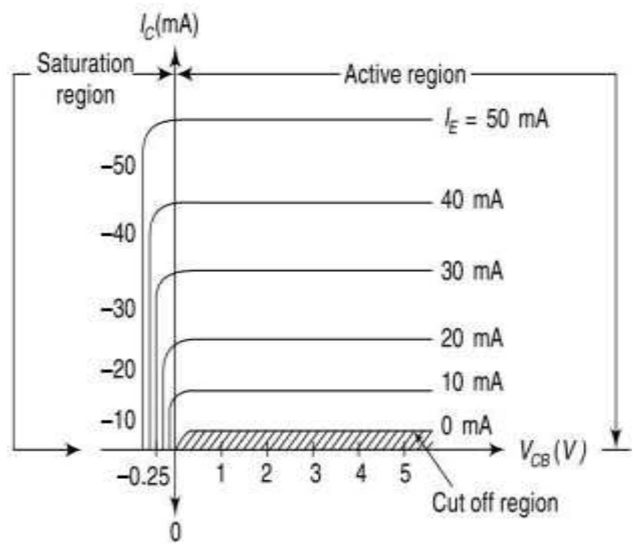


Fig. 4.9 *CB output characteristics*

Early effect or base-width modulation

This decrease in effective base-width has three consequences:

(i) There is less chance for recombination within the base region. Hence, a increases with increasing |VCB|.

(ii) The charge gradient is increased within the base, and consequently, the current of minority carriers injected across the emitter junction increases.

(iii) For extremely large voltages, the effective base-width may be reduced to zero, causing voltage breakdown in the transistor. This phenomenon is called the punch through

Transistor parameters(h-parameters)

(a)Input impedance (h_{ib}) : It is defined as the ratio of the change in (input) emitter voltage to the change in (input) emitter current with the (output) collector voltage VCB kept constant. Therefore

$$h_{ib} = \frac{\Delta V_{EB}}{\Delta I_E}, V_{CB} \text{ constant}$$

(b) Output admittance (h_{ob}) It is defined as the ratio of change in the (output) collector current to the corresponding change in the (output) collector voltage with the (input) emitter current I_E kept constant. Therefore,

$$h_{ob} = \frac{\Delta I_C}{\Delta V_{CB}}, I_E \text{ constant} \qquad (4.15)$$

Transistor parameters(h-

(c) Forward current gain (h_{fb}) It is defined as a ratio of the change in the (output) collector current to the corresponding change in the (input) emitter current keeping the (output) collector voltage V_{CB} constant. Hence,

$$h_{fb} = \frac{\Delta I_C}{\Delta I_E}, \; V_{CB} \text{ constant.}$$

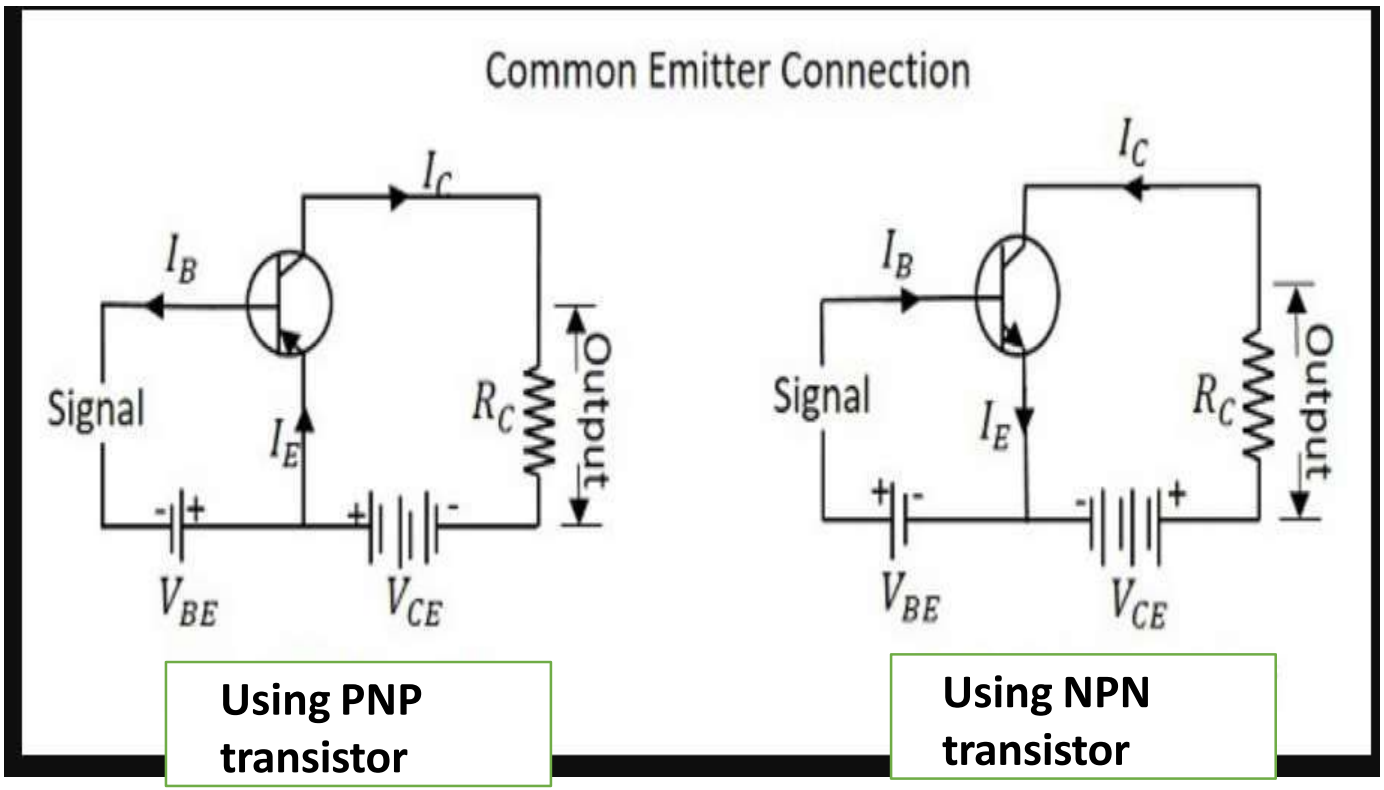
(d) Reverse voltage gain (h_{rb}) It is defined as the ratio of the change in the (input) emitter voltage and the corresponding change in (output) collector voltage with constant (input) emitter current, I_E.

Hence,
$$h_{rb} = \frac{\Delta V_{EB}}{\Delta V_{CB}}, \; I_E \text{ constant}$$

It is the slope of V_{EB} versus V_{CB} curve. Its typical value is of the order of 10^{-5} to 10^{-4}.

Common Emitter CE Configuration

The name itself implies that **the Emitter** terminal is taken as common terminal for both input and output of the transistor. The common emitter connection for both NPN and PNP transistors is as shown in the following figure.



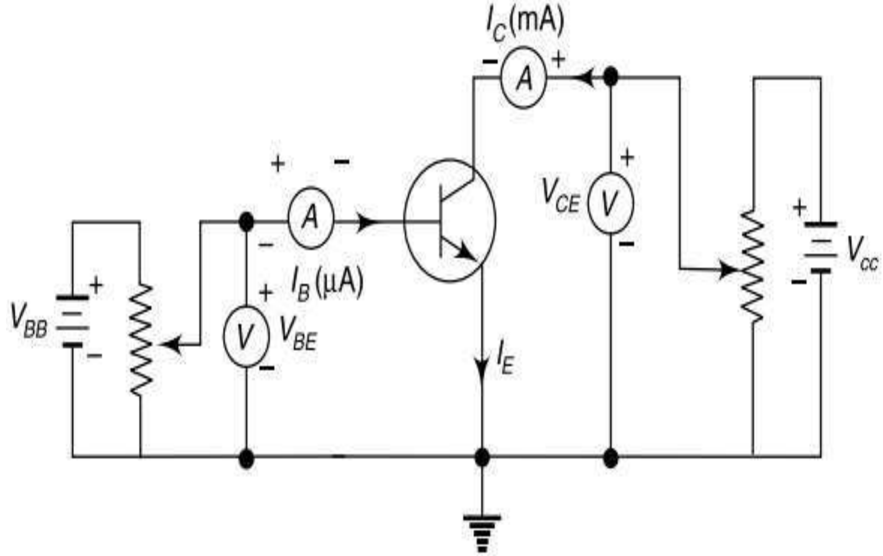


Fig. 4.10 *Circuit to determine CE static characteristics*

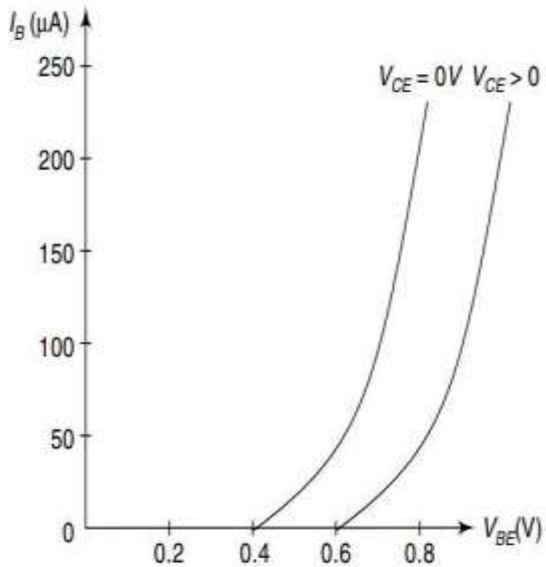


Fig. 4.11 *CE input characteristics*

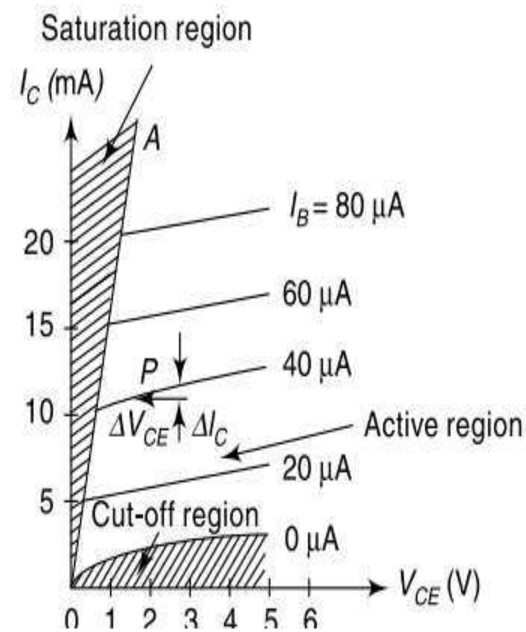


Fig. 4.12 *CB output characteristics*

Transistor parameters(h-)

(a) Input impedance (h_{ie}) It is defined as the ratio of the change in (input) base voltage to the change in (input) base current with the (output) collector voltage V_{CE} kept constant. Therefore,

$$h_{ie} = \frac{\Delta V_{BE}}{\Delta I_B}, V_{CE} \text{ constant}$$

(b) Output admittance (h_{oe}) It is defined as the ratio of change in the (output) collector current to the corresponding change in the (output) collector voltage with the (input) base current I_B kept constant. Therefore,

$$h_{oe} = \frac{\Delta I_C}{\Delta V_{CE}}, I_B \text{ constant}$$

Transistor parameters(h-parameters)

(c) Forward current gain (h_{fe}) It is defined as a ratio of the change in the (output) collector current to the corresponding change in the (input) base current keeping the (output) collector voltage V_{CE} constant. Hence,

$$h_{fe} = \frac{\Delta I_C}{\Delta I_B}, V_{CE} \text{ constant} \quad (4.20)$$

It is the slope of I_C versus I_B curve. Its typical value varies from 20 to 200.

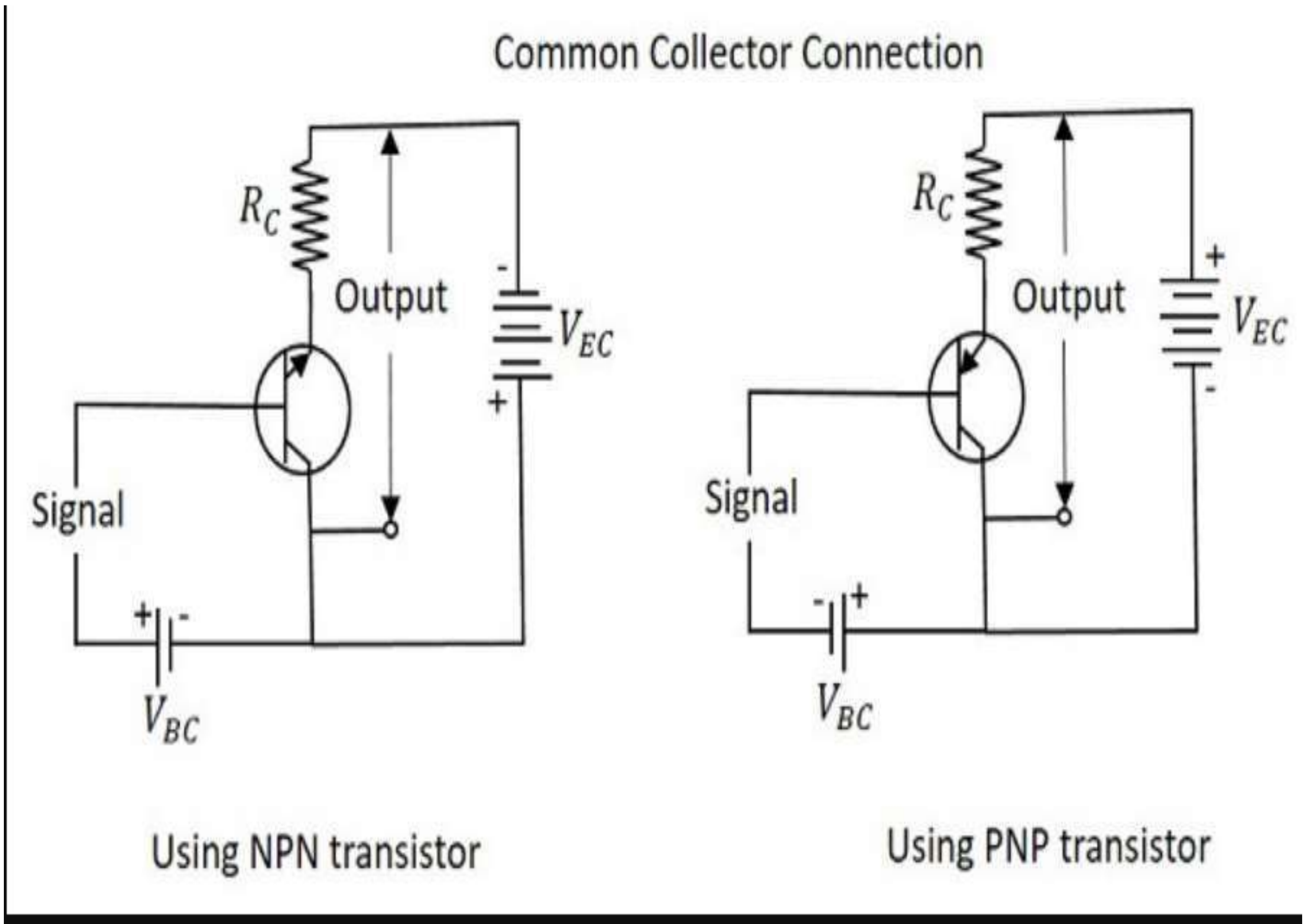
(d) Reverse voltage gain (h_{re}) It is defined as the ratio of the change in the (input) base voltage and the corresponding change in (output) collector voltage with constant (input) base current, I_B. Hence,

$$h_{re} = \frac{\Delta V_{BE}}{\Delta V_{CE}}, I_B \text{ constant} \quad (4.21)$$

It is the slope of V_{BE} versus V_{CE} curve. Its typical value is of the order of 10^{-5} to 10^{-4}.

Common Collector CC Configuration

The name itself implies that the **Collector** terminal is taken as common terminal for both input and output of the transistor. The common collector connection for both NPN and PNP transistors is as shown in the following figure.



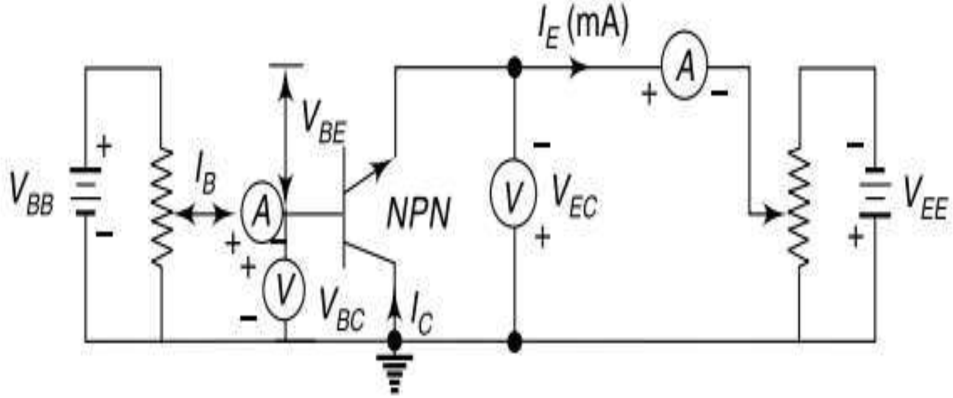


Fig. 4.13 *Circuit to determine CC static characteristics*

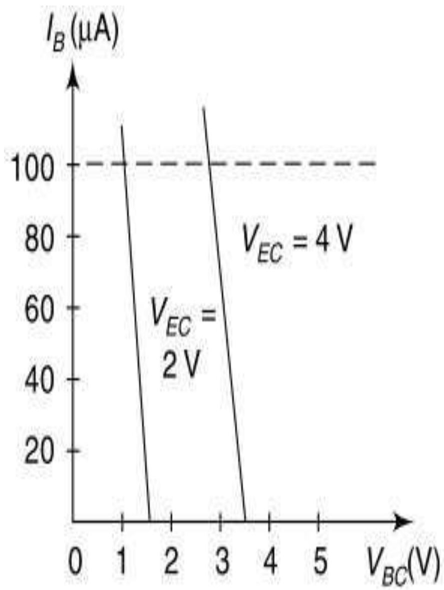


Fig. 4.14 *CC input characteristics*

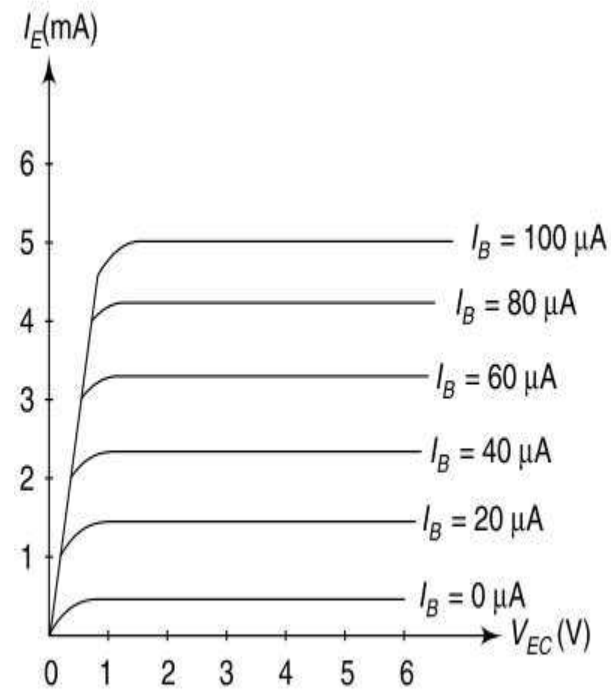


Fig. 4.15 *CC output characteristics*

Table 4.1 *A comparison of CB, CE and CC configurations*

Property	*CB*	*CE*	*CC*
Input resistance	Low (about 100 Ω)	Moderate (about 750 Ω)	High (about 750 kΩ)
Output resistance	High (about 450 kΩ)	Moderate (about 45 kΩ)	Low (about 25 Ω)
Current gain	1	High	High
Voltage gain	About 150	About 500	Less than 1
Phase shift between input & output voltages	0 or 360°	180°	0 or 360°
Applications	for high frequency circuits	for audio frequency circuits	for impedance matching

BJT APPLICATIONS

- The BJT is used as an amplifier.
- The BJT is used as an oscillator.
- It is used for wave shaping in chipping circuits.
- It is used as a modulator.
- It is used as a detector or demodulator.

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