ELECTRONICS DEVICES AND CIRCUITS

UNIT -II

BJT- BIPOLAR JUNCTION TRANSISTOR

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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.

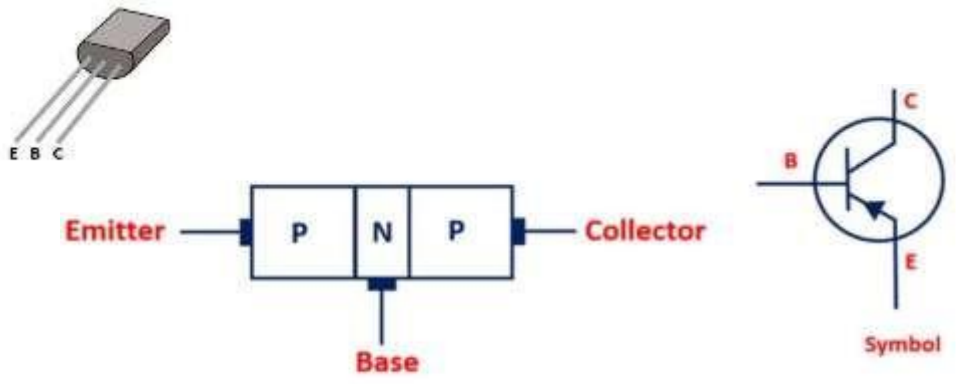


Fig. Bipolar Junction Transistor Basic Structure (PNP Transistor)

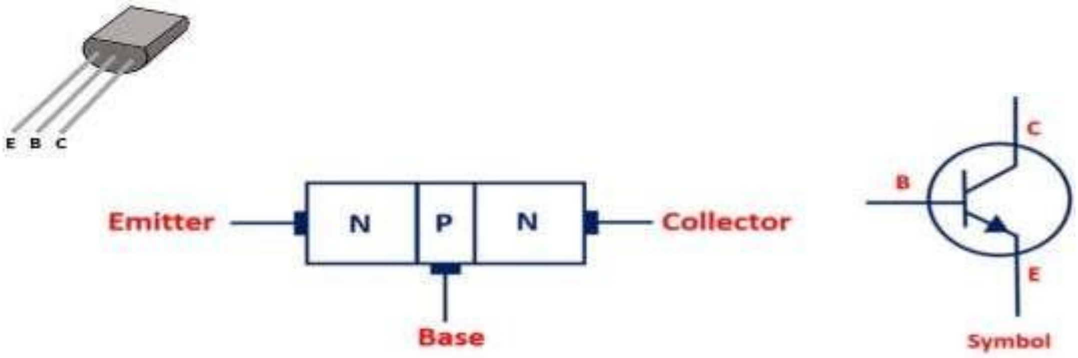


Fig. Basic Structure and Symbol of Bipolar Junction Transistor (NPN Transistor)

The bipolar junction transistor has three doped regions. The emitter, base, and collector.

1. Based on the doping of these three regions NPN or PNP transistor.In the case of the NPN transistor, both emitter and doped with n-type impurity while the base is doped with a p-type impurity.On the other end, in PNP transistor, the base is N-type impurity while the collector and the emitter is doped with a P-type impurity.

2. The term bipolar indicates that both electrons and holes contribute to the current. So BJT is current controlled device

3. 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.

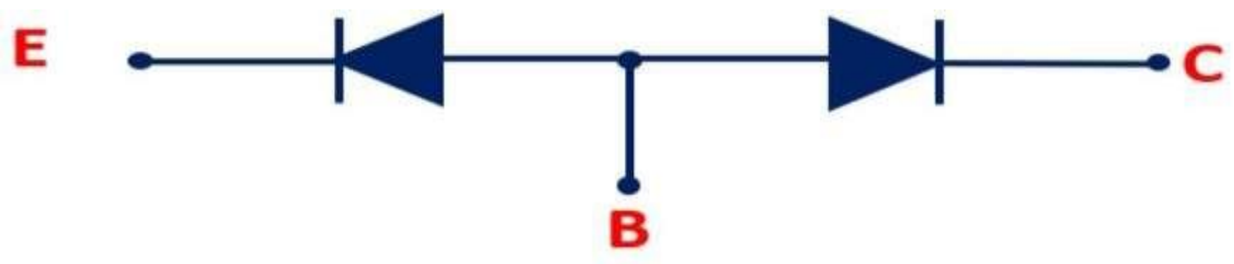


Fig. Two PN junctions in Bipolar Junction Transistor

DIFFERENT BJT CONFIGURATIONS:

As mentioned earlier, when BJT is used for the amplification of the signal, it is operated in the active region. And 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.

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

Common Emitter Configuration:

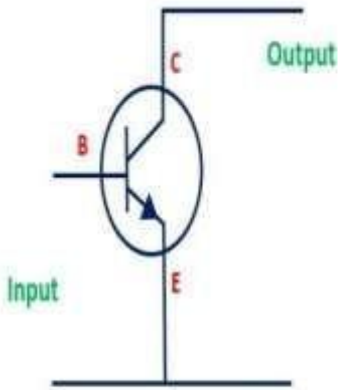


Fig. Common Emitter Configuration of BJT

Common Collector Configuration:

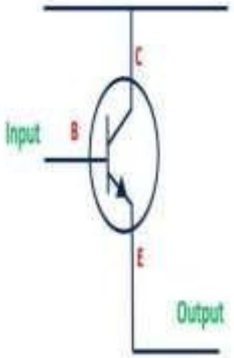


Fig. Common Collector Configuration of BJT

Common Base Configuration:

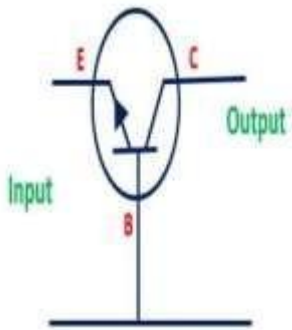


Fig. Common Base Configuration

Working of BJT:

The figure shown below shows the operation of the BJT in the active region, where the base-emitter junction is forw

biased, while the collector-base junction is reverse biased.

Voltage Notations for the BJT: Voltage
V_{BE} - Voltage between the base and the emitter (VB - VE)
V_B - Voltage between the base and the ground
V_E - Voltage between the emitter and the ground
Voltage VCE- Voltage between the collector and the emitter
$V_{CE} = V_C - V_E$
(Please note voltage $V_{BE} = - V_{EB}$ and $V_{CE} = -V_{EC}$)
Voltage V_{BB} and V_{CC} are the supply voltages.

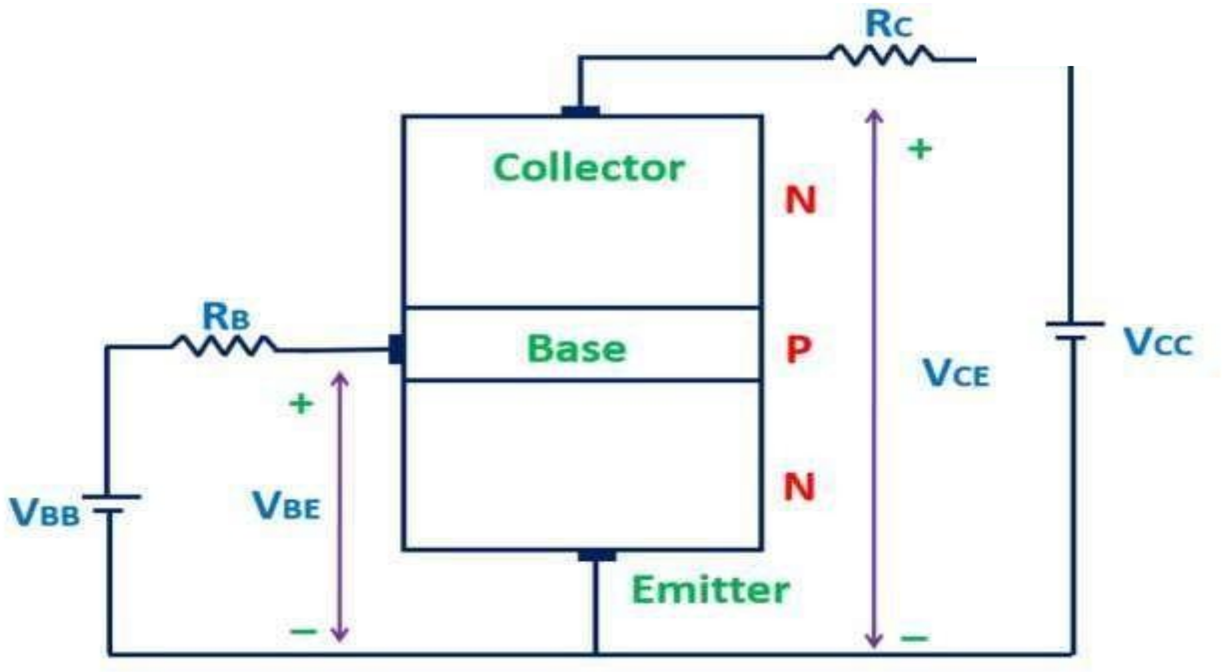


Fig. Operation of NPN Transistor in the active region

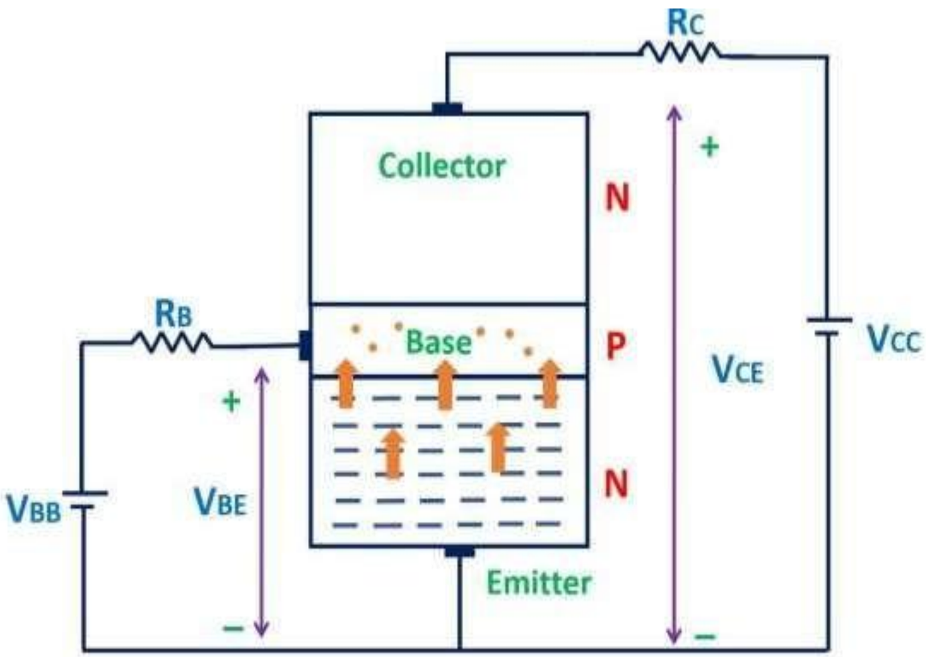


Fig. Movement of electrons (majority charge carriers) from emitter to the base region

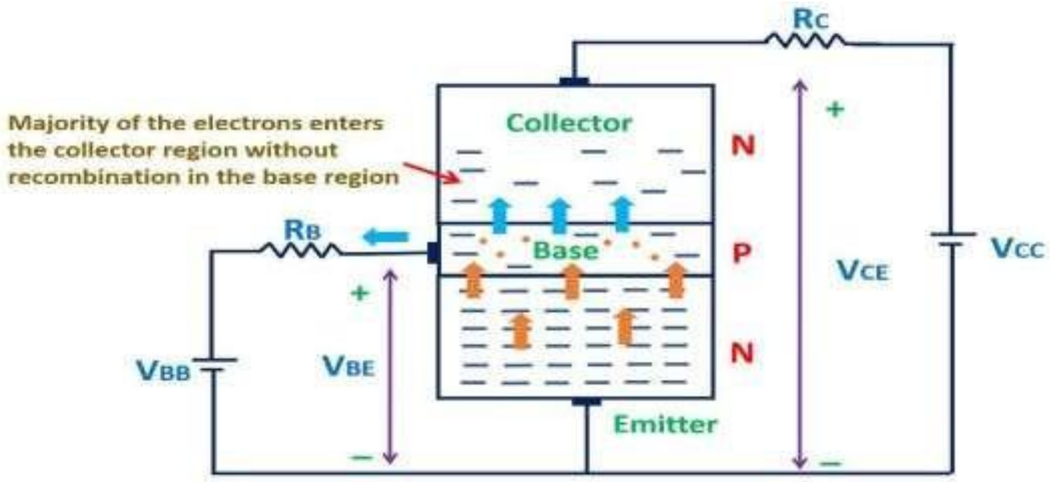
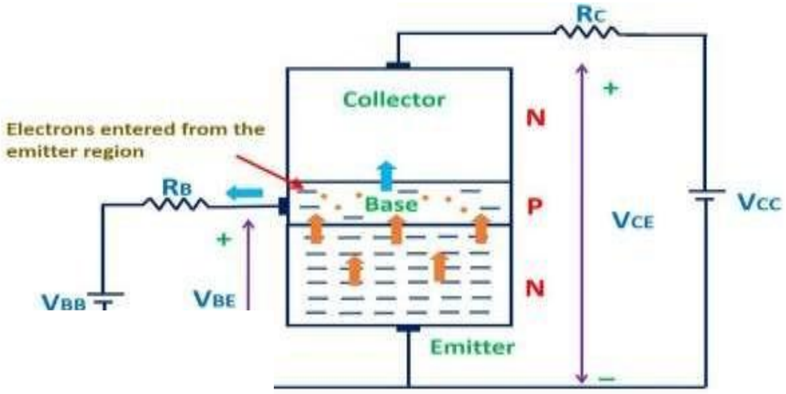


Fig. Movement of electrons from the base to the collector region



of electrons from the base region (two-paths)

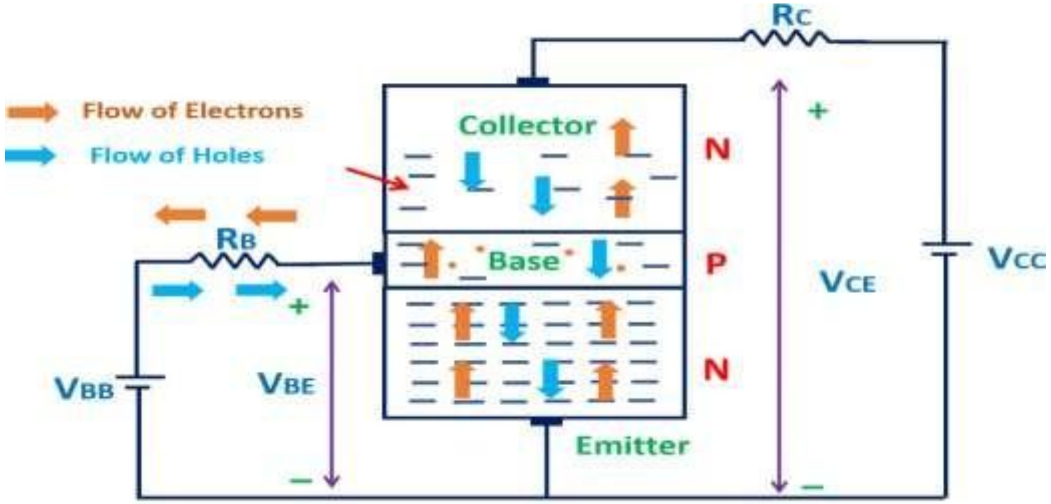


Fig. The direction of flow of electrons and holes in the NPN transistor

Different Currents in the Transistors:

Because of the flow of electrons and holes, three different currents establish in the transistors.

The figure below shows the three different currents in the transistor.

- Base current (I_B)
- Collector Current (I_c)
- Emitter Current (I_E)

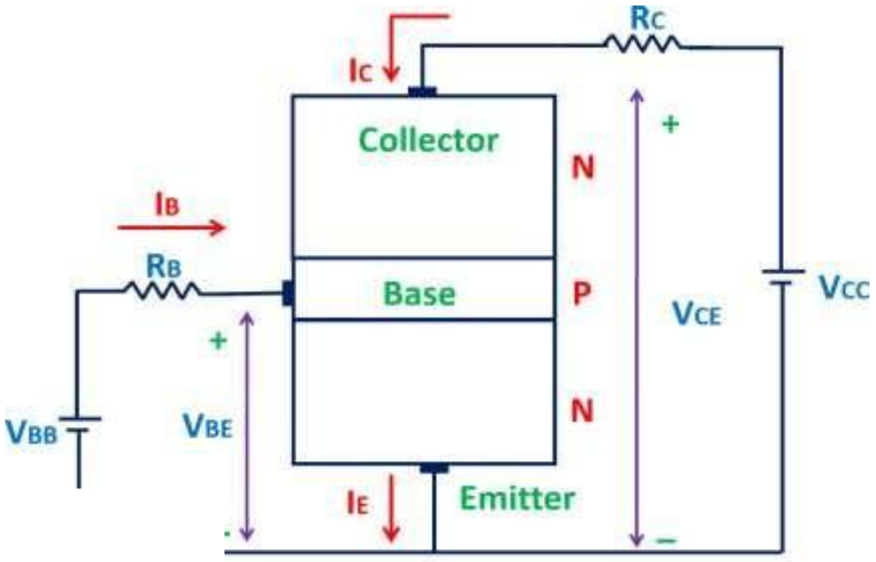


Fig. Different Currents in NPN Transistor

The relation between the Three currents in Transistor

Applying KCL, the relation between the three currents can be easily found.

$\therefore I_E = I_B + I_C$ ———— (1)

The base current is very negligible. (i.e collector current is approximately equal to emitter current)

$I_C = \alpha I_E$ ———— (2)

From equation (1) and (2)

$I_E = I_B + \alpha I_E \implies I_E = (1-\alpha) I_B$

Or $I_C = \alpha / (1-\alpha) I_B \implies I_C = \beta I_B$

Where $\beta = \alpha / (1-\alpha)$

β is known as the current gain. And typically, its value varies from 20 to 400 from transistor to transistor.

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 $\Delta I_E = \Delta I_C +$

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

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

BJT CONFIGURATION :

The Three types of configurations are

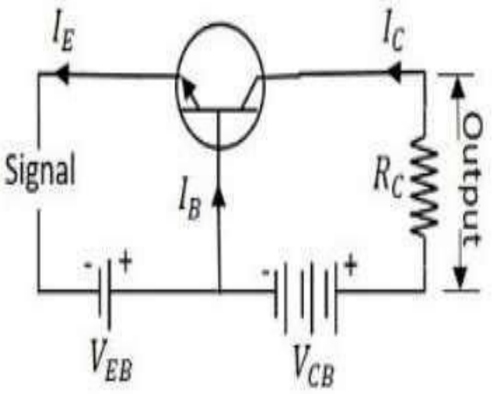
1. Common Base
2. Common Emitter
3. Common Collector

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

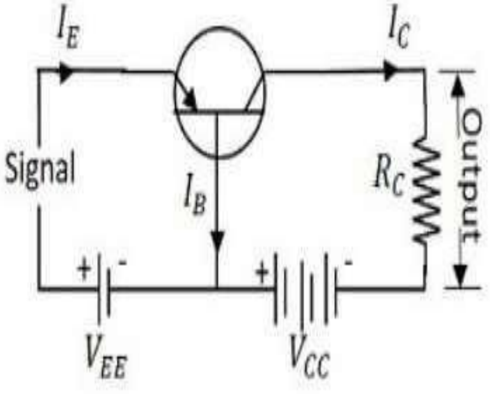
Common Base CB Configuration

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

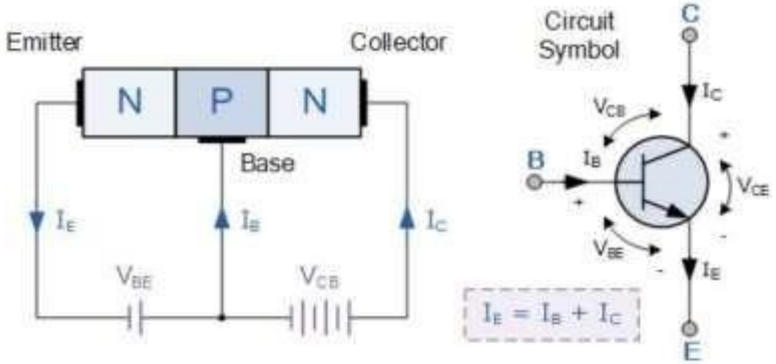


NPN transistor



Using PNP transistor

A Bipolar NPN Transistor Configuration



let us consider NPN transistor in CB configuration. When the emitter voltage isapplied, as it is forward 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 V_{CB} is kept constant throughout this.In the CB configuration, the input current is the emitter current I_E and the output current is the collector current I_C

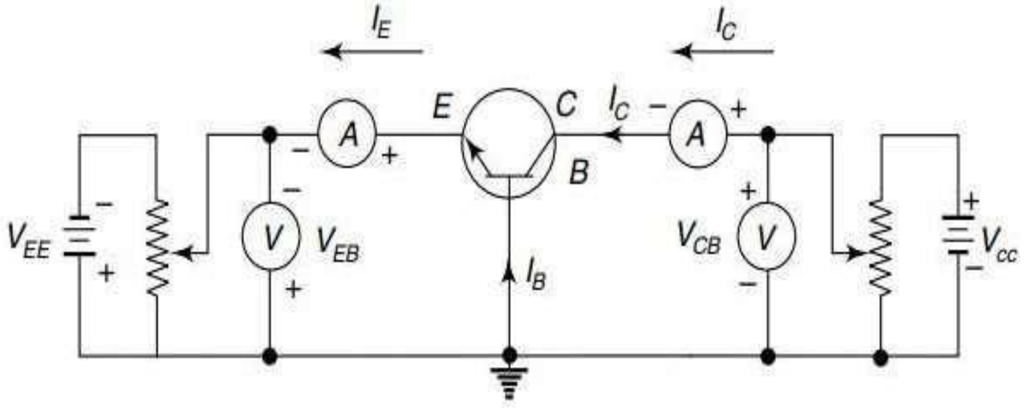
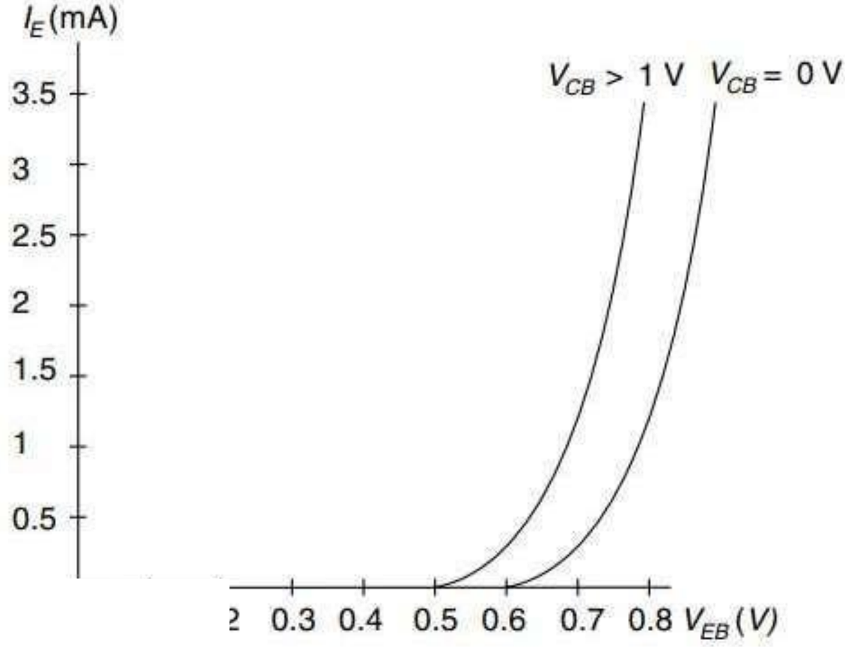


Fig. 4.7 *Circuit to determine CB static characteristics*



. 4.8 *CB input characteristics*

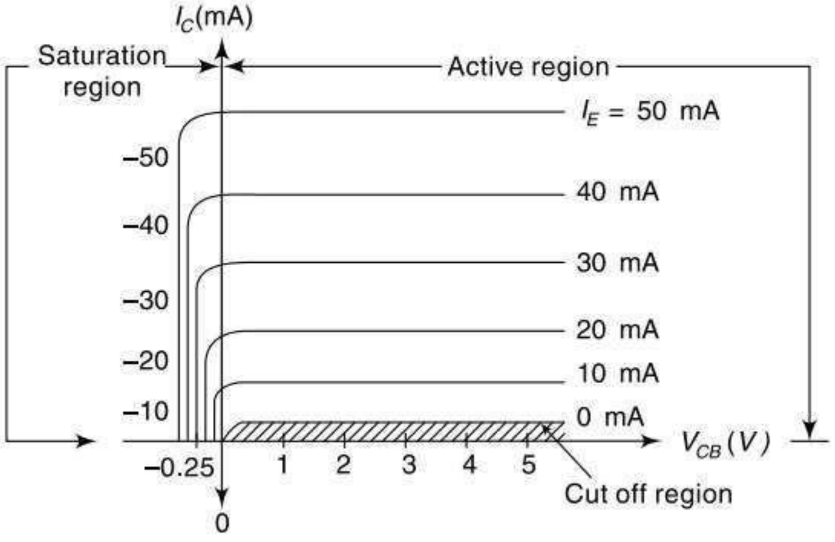


Fig. 4.9 *CB output characteristics*

Early effect or base-width modulation

Early effect or base width modulation 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 effectivebase-width may be reduced to zero, causing voltage breakdown in the transistor. This phenomenon is called the punch through

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Transistor parameters(h-parameters)

(a)Input impedance (hib) : 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,

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

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

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

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

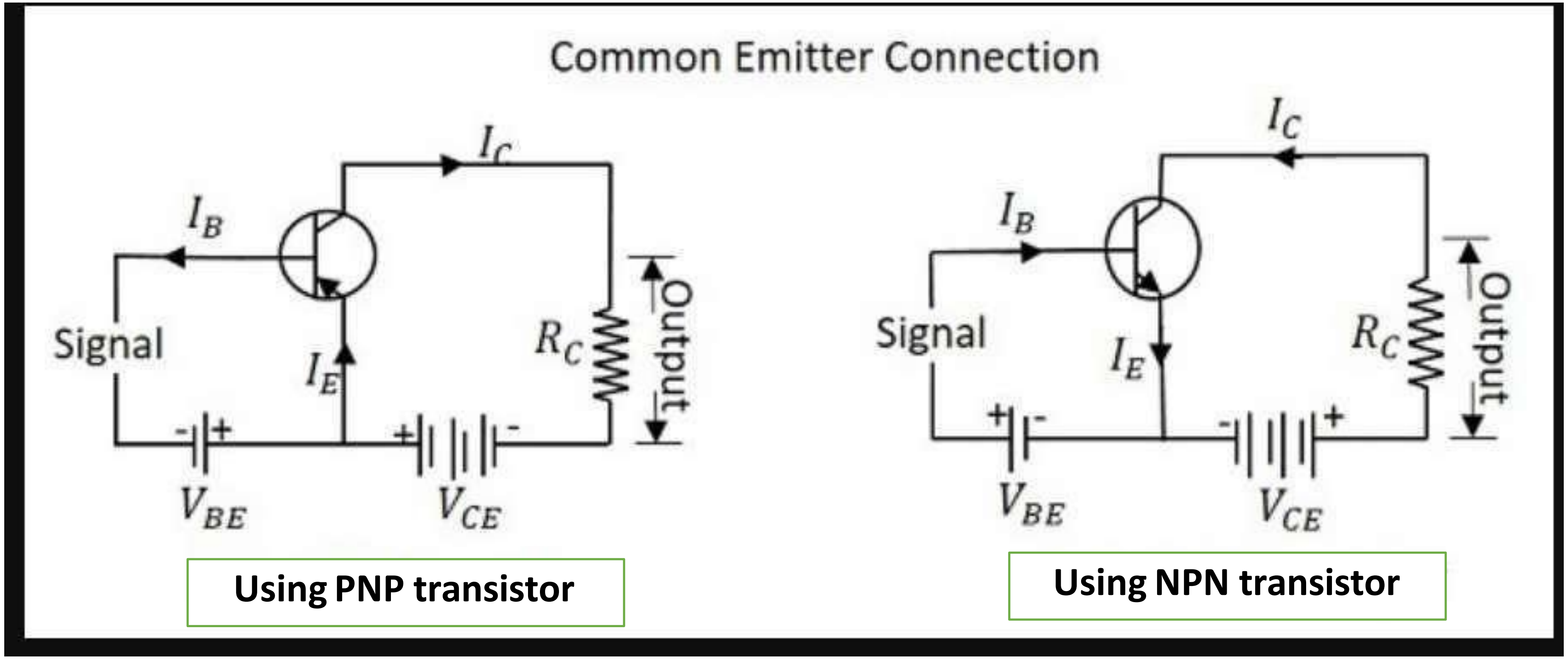
(d) Reverse voltage gain (h_{re}) It is defined as the ratio of the change in the (input) base voltage and the corresponding change in (output) collector voltage with constant (input) base current, I_B. Hence,

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

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 Emitter CE Configuration

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



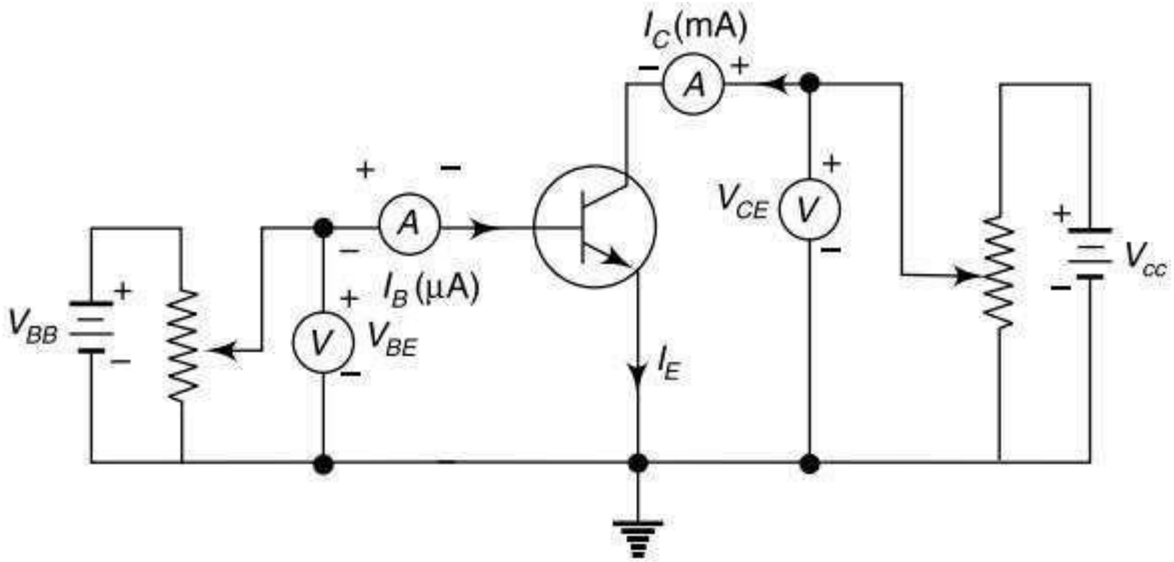


Fig. 4.10 *Circuit to determine CE static characteristics*

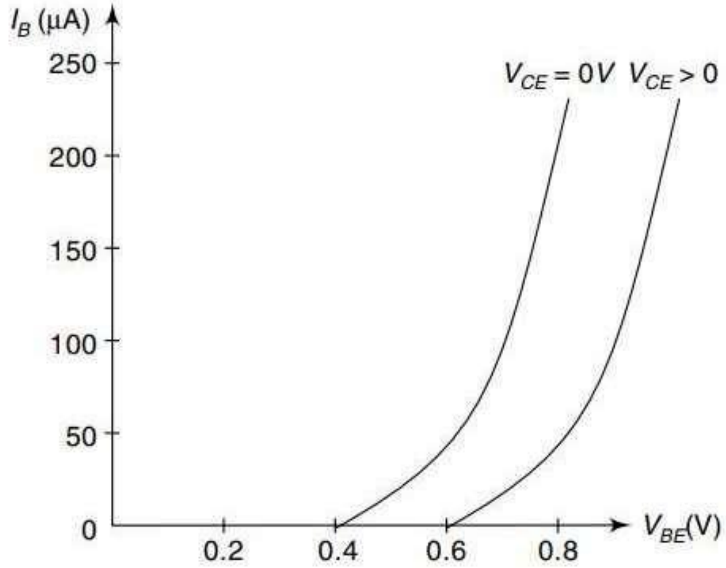


Fig. 4.11 *CE input characteristics*

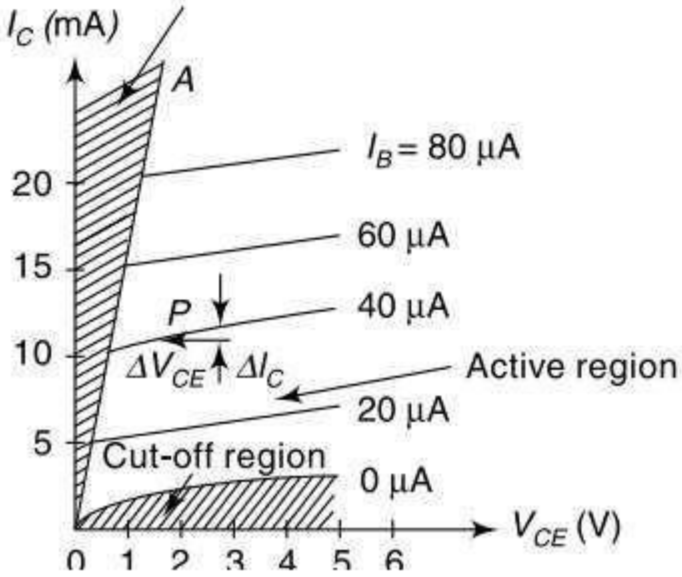
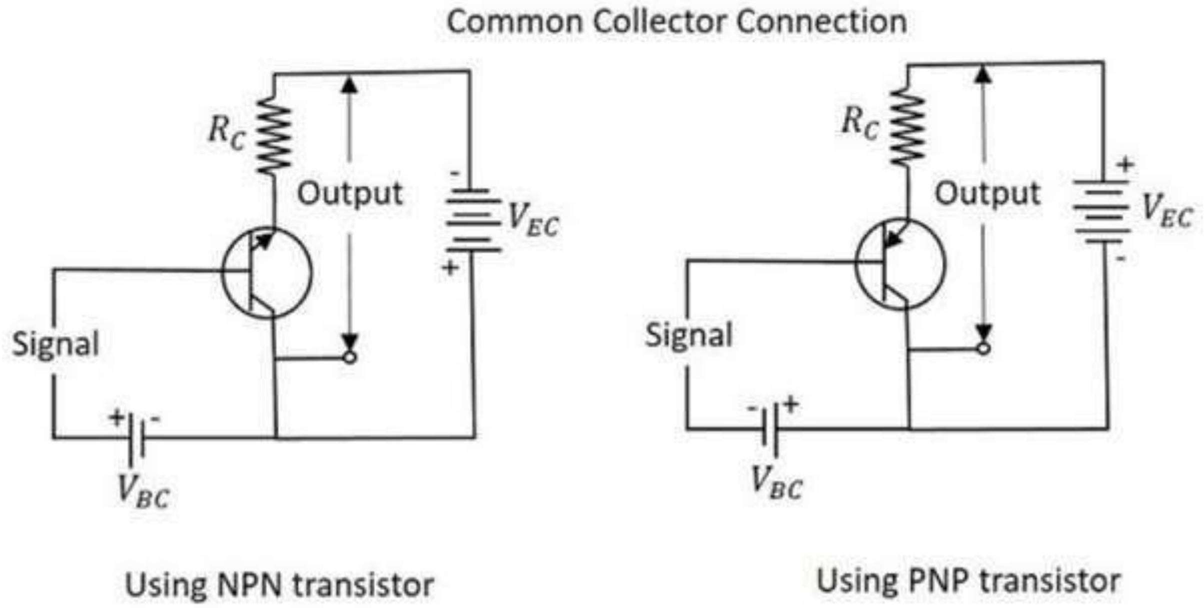


Fig. 4.12 *CB output characteristics*

Common Collector CC Configuration

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



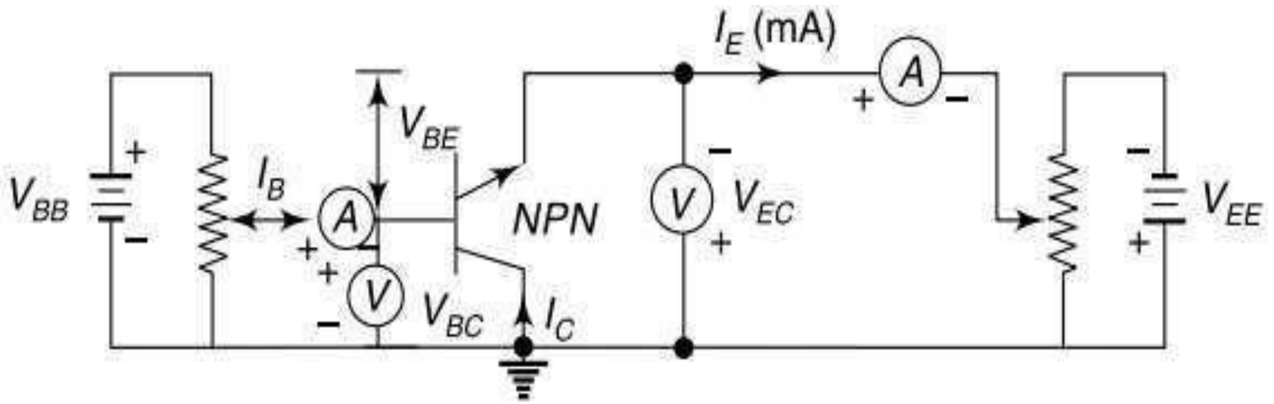


Fig. 4.13 *Circuit to determine CC static characteristics*

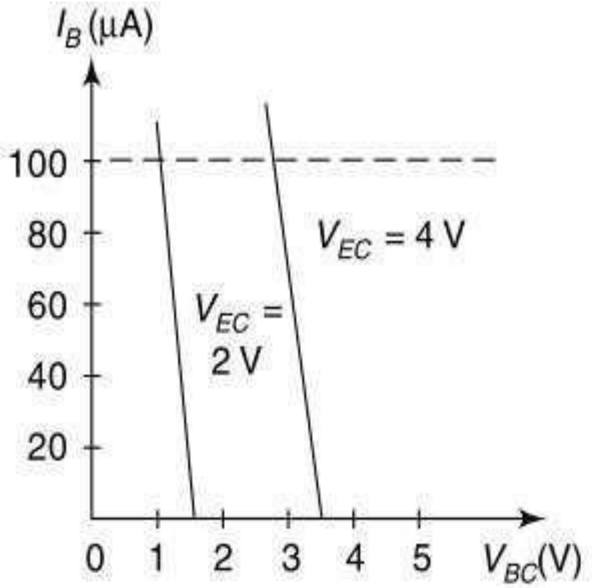


Fig. 4.14 *CC input characteristics*

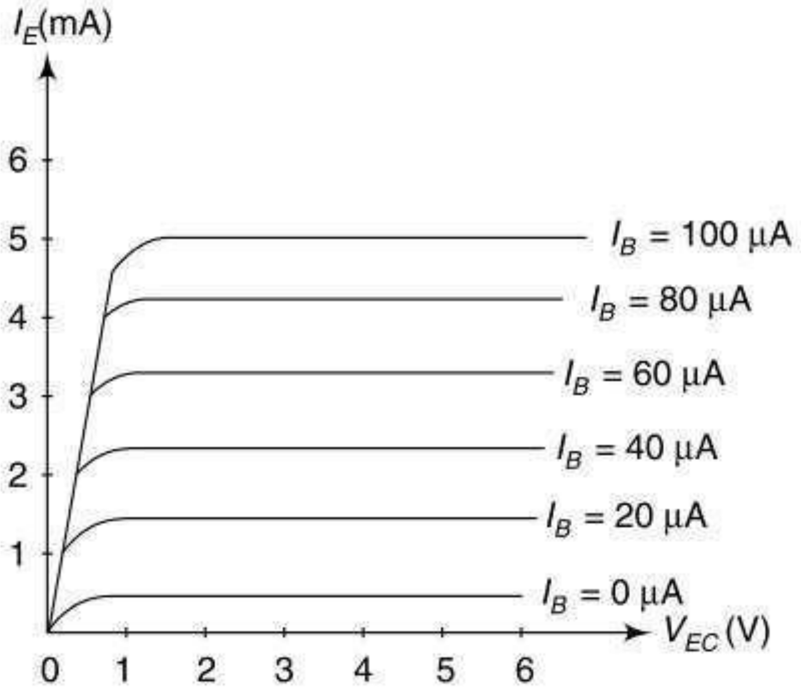


Fig. 4.15 *CC output characteristics*

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