Module-I

Ch-1 :-

BJT (Bipolar Junction Transistor): Fundamentals

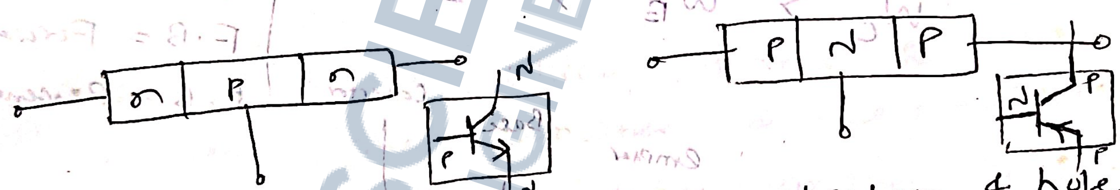
→ A transistor consists of 2 PN junctions formed by sandwiching either p-type or n-type semiconductor between a pair of opposite types.

→ There are 2 types of transistor.
(a) N-p-n transistor (b) P-N-P transistor

→ Invented by Dr. William Shockley
Dr. J. Barden
Dr W.H. Brattain
it is invented.

→ 1948

→ 1956 they got nobel prize

→ 

→ Bipolar (Bi → 2, Here electron & holes both are charge carriers)

→ An n-p-n transistor composed of 2 n-type semiconductors separated by a thin section of p-type.

→ But p-n-p transistor composed of 2 p-type semiconductor separated by a thin section of n-type.

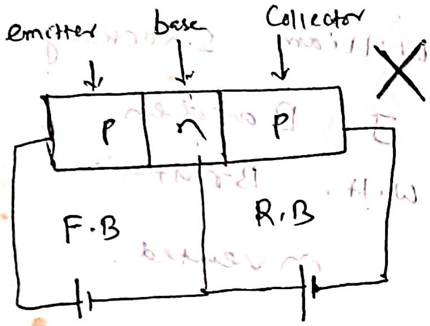
Why transistor ?

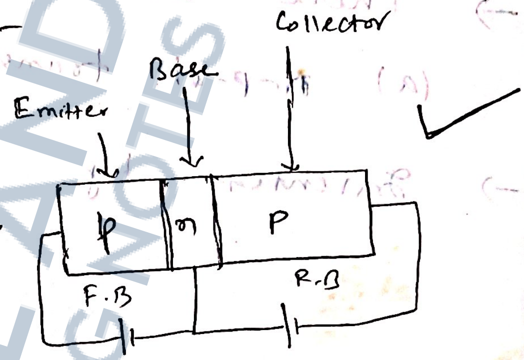
A transistor consists of 2 PN junctions. One junction is forward biased and other is reverse biased. The forward biased junction has low resistance path where as reverse biased junction has a high resistance path.

The weak signal is introduced in a low resistance ckt & o/p is taken from the high resistance ckt. Therefore, transistor transfers a signal from low resistance to high resistance.

Transfer + Resistor = Transistor

→ Transistor Terminals :-

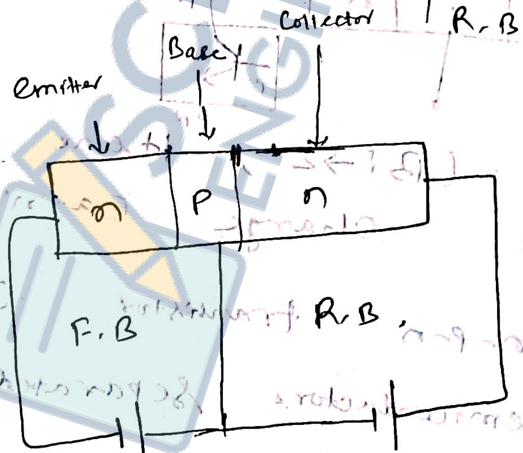




• Width of emitter, base & Collector are not equal

$W_C > W_E > W_B$

W = width
F.B = Forward Biased
R.B = Reverse Biased.



Emitter :- The section on one side that supplies Charge carriers (e or h) is Called emitter.

e → electron
h → hole.

The emitter is always forward biased w.r.t to base so that it can supply a large number of majority carriers. The emitter is heavily doped, so that it can inject large number of charge carriers (e or h) to the base.

Collector :-

The section on the other side which collects the charges is called the collector. The collector is always reverse biased w.r.to base. In p-n-p transistor it receives the holes and in n-p-n transistor, it receives the electrons. Collector is moderately doped. During the transistor operation, much heat is produced at the collector junction, so collector is made larger in size to dissipate the heat.

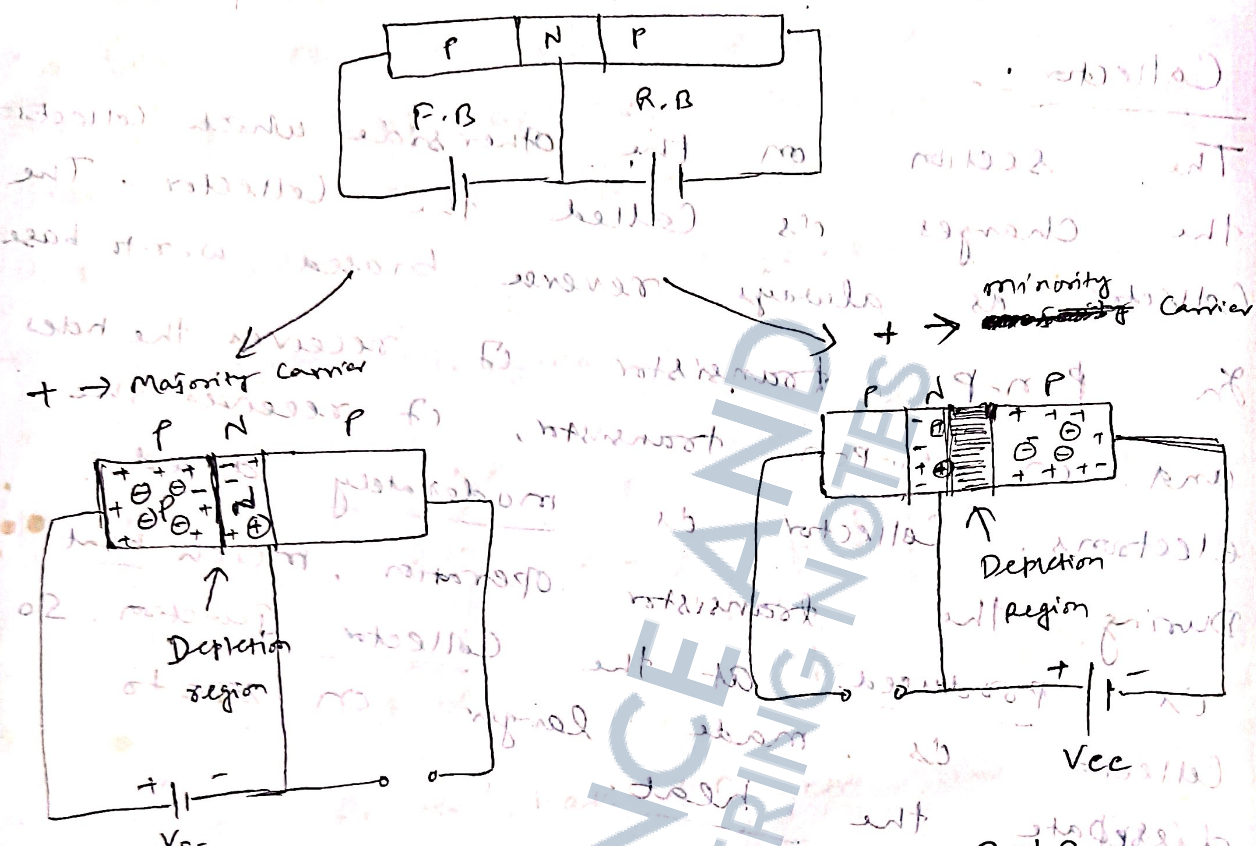
Base :-

The middle section which forms 2 PN junction between the emitter & collector is called the base. The base-emitter junction is forward biased, allowing low resistance for emitter ckt. The base-collector is reverse biased and provides high resistance in the collector ckt.

The base has thin area of cross section & lightly doped. It passes most of the emitter injected charge carriers to the collector.

Transistor Operation :-

PNP transistor can be redrawn without base-to-collector bias. It is similar to PN junction i.e forward biased. The depletion region has been reduced in width due to applied bias, resulting in a heavy flow of majority carriers from p to n type material.



F.B PNP

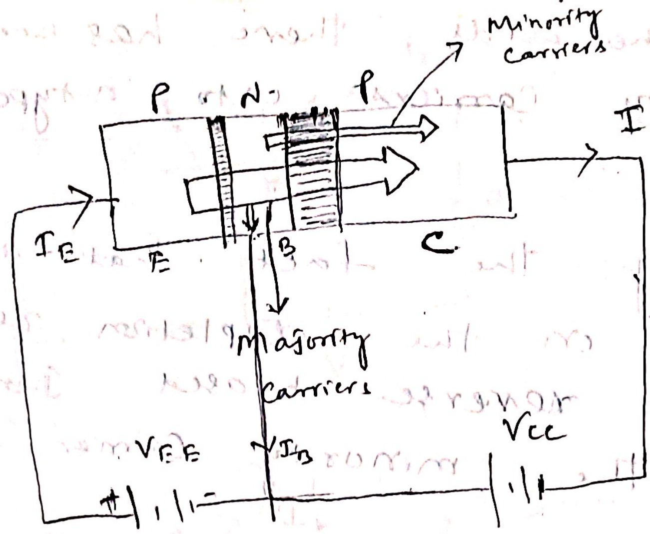
R.B PNP

Now remove base-emitter bias of PNP transistor. Similarly reverse biase the diode. The flow of majority carriers is zero, resulting in only the minority carrier flow.

→ One p-n junction of transistor is reverse biased where other is forward biased.

→ When both biasing potential have been applied to PNP transistor, with the resulting majority and minority carrier flows indicated in figure 1.

→ The width of depletion layer indicates which junction is F.B and which is R.B.



<Fig. 1:- Majority and minority carrier flow of pnp transistor>

→ A large no. of majority carriers will diffuse across the forward-biased p-n junction into n-type material.

→ Since the sandwiched n-type material is very thin & has low conductivity, a very small no. of these carriers will take this path of high resistance to the base material.

→ The magnitude of the base current is typically of the order of μA, as compared to milli ampere for emitter & collector currents.

→ The large no. of majority carriers will diffuse across the reverse-biased junction into p-type material connected to the collector terminal.

→ The reason for the relative ease with which majority carrier can cross the reverse-biased junction is easily understood if we consider that for reverse biased diode injected majority carriers will appear as minority carriers in the n-type material.

→ In other words, there has been an injection of minority carriers into n-type base-region material.

→ Combining the fact that all the minority carriers in the depletion region will cross the reverse biased junction of a diode, the minority carrier flow is shown in fig 1.

→ ∴ Total current

$$I_E = I_B + I_C$$

→ The collector current, however, comprises two component → (majority, minority)

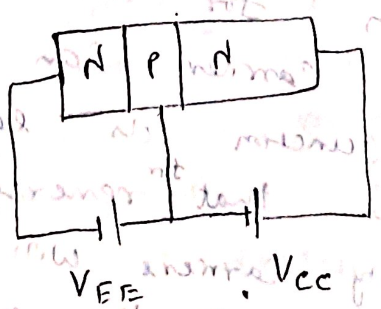
→ The minority current component is called leakage current & is given symbol I_{CO} (I_C current with emitter terminal open)

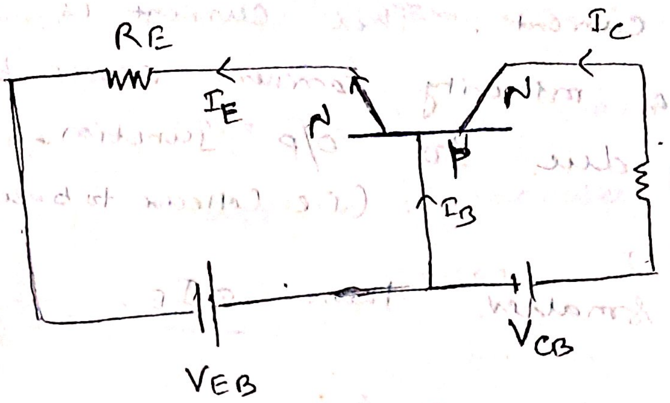
$$\Rightarrow \boxed{I_C = I_{C\,majority} + I_{CO\,minority}}$$

Transistor Configuration :-

1) Common-Base configuration :-

In this configuration, base terminal is common to the i/p and o/p. Input is applied between emitter and base and o/p is taken across collector to base.





$I_E > I_C > I_b$, Since I_b in μA

$I_E \simeq I_C$

→ Since base is common betn i/p & o/p so it is called common base configuration.

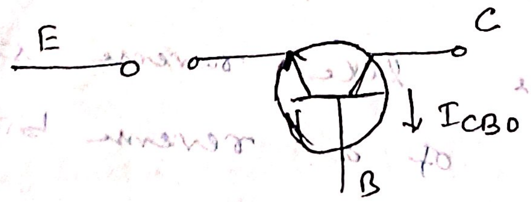
→ During the connection, it should be taken care that EB is forward biased and CB is reverse biased.

Common Base current gain (α)

It is defined as the rate of change of collector current with the change of emitter current under the assumption that voltage betn collector to base is constant.

$$\alpha = \left.\frac{\Delta I_C}{\Delta I_E}\right]_{V_{CB} = const.} \qquad \alpha \simeq 0.95$$

I_{CBO} = It is the leakage current between base & collector when emitter is open.



→ Therefore total collector current consist of

(a) Part of emitter current which reaches the collector terminal i.e. $\boxed{\alpha I_E}$

(b) The leakage current. This current is due to the movement of minority carriers across base collector junction due to o/p junction. i.e (i.e collector to base) reverse biased.

It is much smaller than αI_E.

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

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

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

$$\Rightarrow I_C (1-\alpha) = \alpha I_b + I_{CBO}$$

$$\Rightarrow I_C = \frac{\alpha}{1-\alpha} I_b + \frac{I_{CBO}}{1-\alpha}$$

$$\therefore \boxed{I_C = \frac{\alpha}{1-\alpha} I_b + \frac{1}{1-\alpha} I_{CO}} \quad (1)$$

I_{CBO} may be called I_{CO}.

To calculate I_b

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

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

$$\Rightarrow I_E - \alpha I_E - I_{CBO} = I_B$$

$$\Rightarrow \boxed{I_B = (1-\alpha) I_E - I_{CO}} \quad (2)$$

Note :-

→ I_{CBO} is like reverse saturation current of a reverse biased diode. I_S or I_O

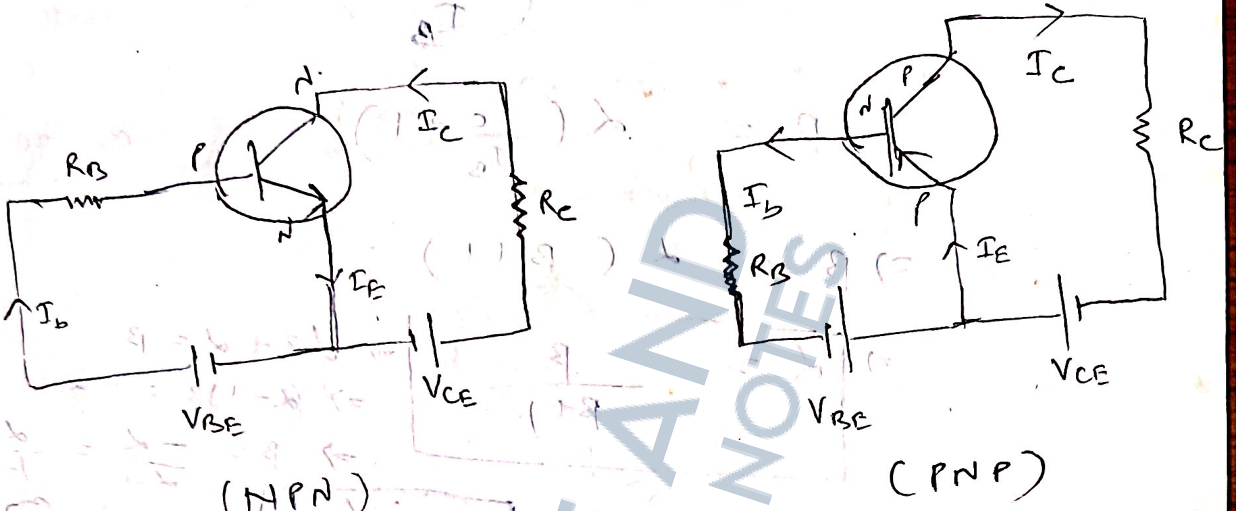
→ It is extremely temp. dependent. I_{CBO} doubles every 10°C rise of temp for Ge & 6°C for Si.

Common emitter Configuration :-

Emitter terminal is Common betn i/p & o/p.

i/p → applied between base & emitter.

o/p → is taken from Collector & emitter.



Current amplification factor

$$\beta = \left.\frac{\Delta I_C}{\Delta I_b}\right]_{V_{CE} = const} = \frac{I_C}{I_b}$$

$\beta \simeq 50$ to 450.

Relation betn α & β

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

$$= \frac{\alpha I_E}{I_B} \qquad \left(\because \alpha = \frac{I_C}{I_E}\right)$$

$$= \frac{\alpha (I_C + I_B)}{I_B}$$

$$= \alpha \frac{I_C}{I_B} + \alpha$$

$$\beta = \alpha . \beta + \alpha = \alpha(1+\beta)$$

$$\Rightarrow \boxed{\alpha = \frac{\beta}{1+\beta}} \quad \text{—— (3)}$$

Or

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

$$= \frac{I_C}{I_E} \cdot \frac{I_E}{I_B}$$

$$= \alpha \cdot \left(\frac{I_C + I_B}{I_B}\right) \qquad \left(\because \alpha = \frac{I_C}{I_E}\right)$$

$$\beta = \alpha\left(\frac{I_C}{I_B} + 1\right)$$

$$\Rightarrow \beta = \alpha(\beta + 1)$$

$$\Rightarrow \boxed{\alpha = \frac{\beta}{\beta + 1}}$$

$$\Rightarrow \alpha\beta + \alpha = \beta$$

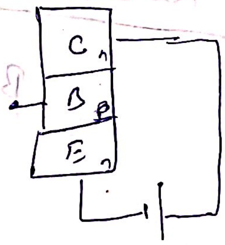
$$\Rightarrow (\alpha - 1)\beta = -\alpha$$

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

$$\Rightarrow \boxed{\beta = \frac{\alpha}{1-\alpha}} \quad \text{——— (4)}$$

Concept of I_{CEO}

In CE configuration, if $I_B = 0$, still a leakage current flows from collector to emitter. It is called I_{CEO}. The subscript specifies that for collector to emitter current when base is open.



From the eqn (1),

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

If $I_B = 0$, $I_C = I_{CEO}$

$$\Rightarrow I_{CEO} = \frac{1}{1-\alpha} \cdot I_{CBO}$$

$$\Rightarrow \boxed{I_{CEO} = (1+\beta) I_{CBO}} \quad \text{(5)}$$

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

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

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

$$\Rightarrow \boxed{1 + \beta = \frac{1}{1-\alpha}}$$

Relⁿ between 2 leakage currents.

Considering leakage current into account

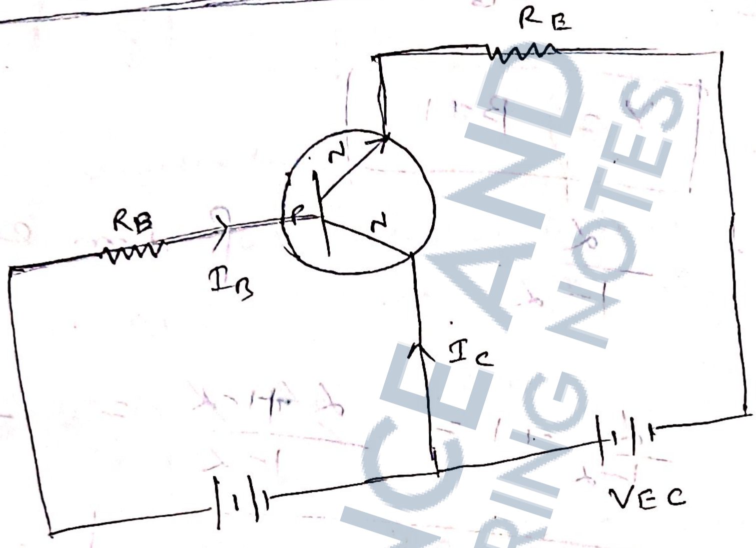
Common emitter

$$I_C = \beta I_B + I_{CEO}$$ — (6)

Common Base

$$I_C = \alpha I_E + I_{CBO}$$ — (7)

Common Collector Configuration :-



→ In this configuration, i/p signal is applied between base & collector & o/p signal is taken out from emitter collector ckt.

→ Here i/p current is (I_B) & o/p current is emitter current (I_E)

→ The current gain of the ckt denoted by (γ) [Gamma] & is defined as ratio of change in emitter current (ΔI_E) to change in base current (ΔI_B), i.e

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

$\gamma \simeq 500$

Relation between α, β, γ

$$\gamma = \frac{\Delta I_E}{\Delta I_B}, \quad \beta = \frac{\Delta I_C}{\Delta I_B}, \quad \alpha = \frac{\Delta I_C}{\Delta I_E}.$$

Rel^n bet^n γ & β

$$\gamma = \frac{I_E}{I_B} = \frac{I_C + I_B}{I_B} = \frac{I_C}{I_B} + 1 = \beta + 1$$

$$\boxed{\gamma = \beta + 1}$$

But $\beta = \frac{\alpha}{1-\alpha}$ [from eq^n (4)]

$$\therefore \gamma = \frac{\alpha}{1-\alpha} + 1 = \frac{\alpha + 1 - \alpha}{1-\alpha} = \frac{1}{1-\alpha}.$$

$$\therefore \boxed{\gamma = \frac{1}{1-\alpha} = 1 + \beta} \quad \text{——— (8)}$$

$$\beta = \frac{I_C}{I_B} = \frac{I_C}{I_E} \cdot \frac{I_E}{I_B} = \alpha \cdot \gamma$$

$$\Rightarrow \boxed{\beta = \alpha\gamma} \quad \text{——— (9)}$$

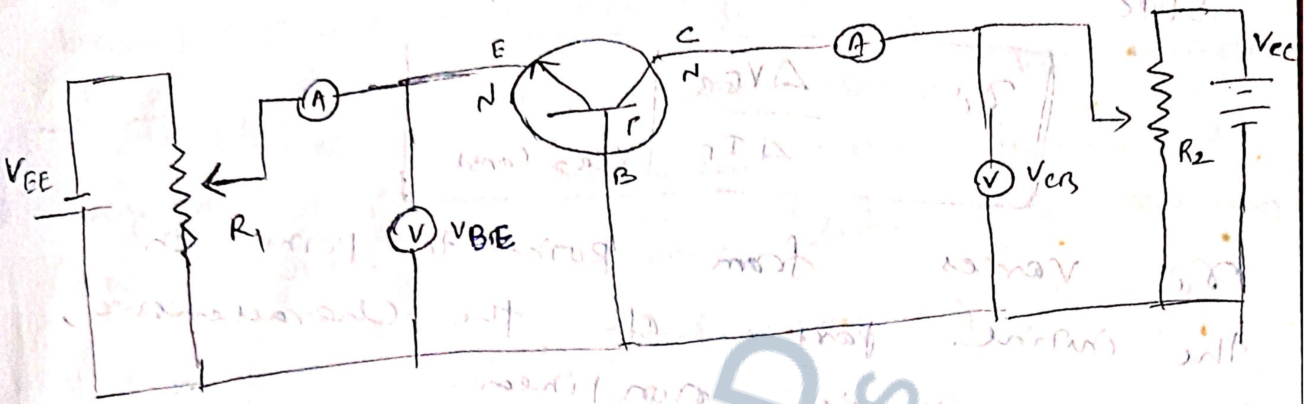
Previously

$$\boxed{\beta = \frac{\alpha}{1-\alpha}} \quad \text{——— (10)}$$

$$\boxed{\alpha = \frac{\beta}{1+\beta}} \quad \text{——— (11)}$$

Characteristics of BJT :-

Common-base Characteristics :-



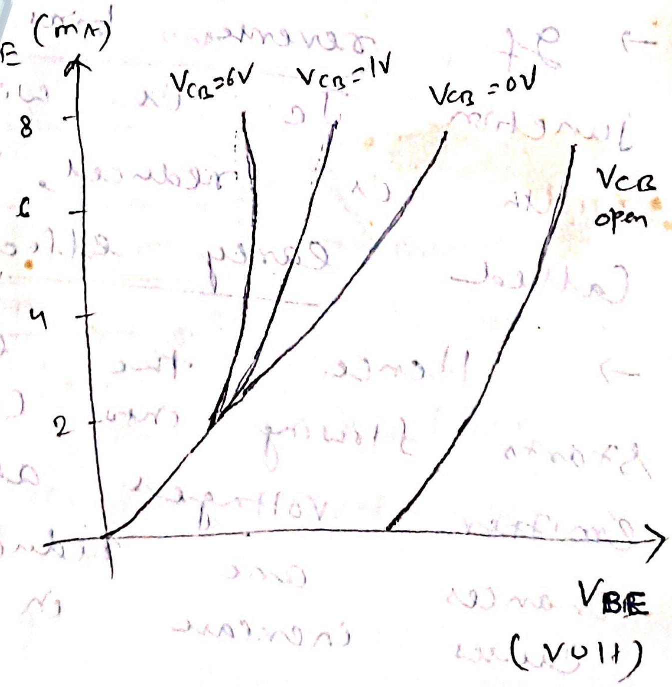
I/P Characteristics :-

The I/P characteristics shows how I_E (emitter current) varies with V_{BE} (base-emitter voltage) when V_{CB} (collector voltage) is held constant.

The voltage V_{CB} is adjustable to a suitable value with help of R_2, then V_{BE} increased in a number of discrete steps and corresponding value of I_E are noted in milli ammeter.

When plotted, we got the i/p characteristics as shown in fig 2.

For a given value of V_{CB} the curve is just like forward biased P-N junction because emitter-base junction is forward biased mode similar to P-N junction.



The characteristics may be used to determine i/p resistance (r_i) of the transistor. Its value is given by reciprocal of its slope

$$r_i = \frac{\Delta V_{EB}}{\Delta I_E} \Big|_{V_{CB} = Const}$$

r_i varies from point to point in the initial part of the characteristic, because it is non linear.

→ With increase in V_{CB}, the current gains its max^m^ value early.

Imp. Early effect :-

→ In P-N junction, we have seen, the barrier potential proportional to the square of the space charge region width.

$$W \propto \sqrt{\text{Reverse Bias}}$$

$$\Rightarrow W^2 = K \cdot (\text{Reverse bias})$$

→ If reverse bias is increased, the J_C is widened & effective base junction width is reduced, This phenomenon is called earey effect.

→ Hence the emitter current I_E starts flowing into collector region at lower emitter voltages as the recombination chances are reduced in the base. This causes increase in current gain α.

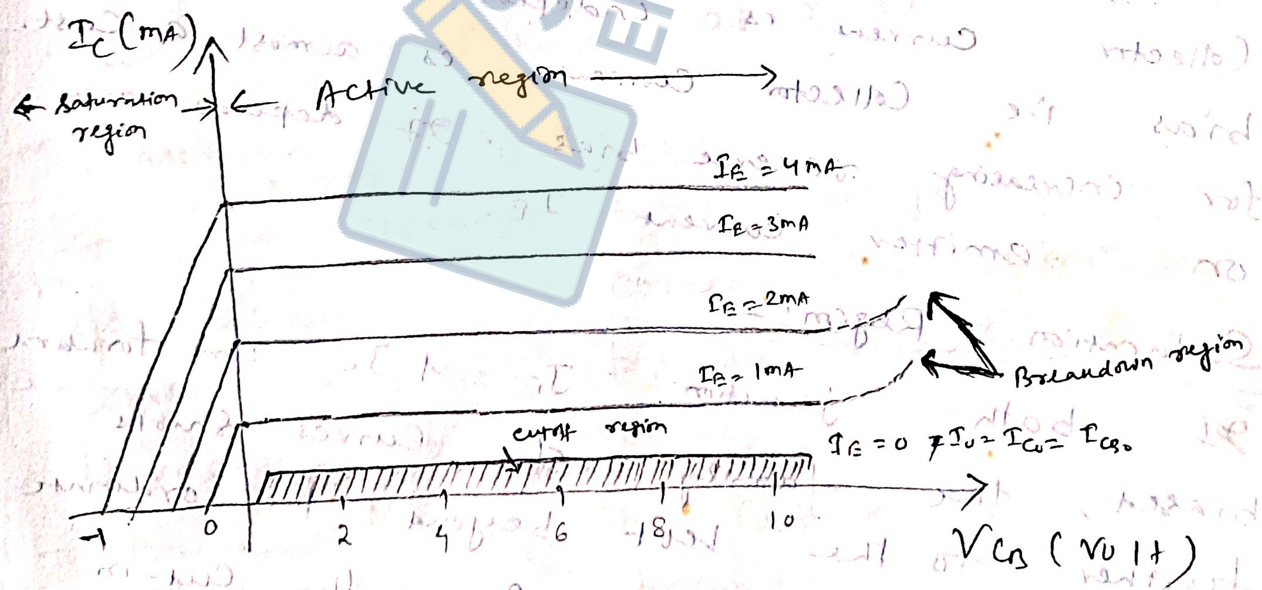
Secondly, as the base width get narrowed, the conc. gradient increases, so that injection of minority carriers (say holes for an n base) increases, there by increasing I_E.

→ Thirdly, if the reverse bias V_{CB} increased beyond point, breakdown may occure as the width W becomes zero. The phenomenon (base width becomes narrow & narrow) called Punch through or reach through.

→ Early effect is also known as base width modulation.

Output Characteristics :-

The o/p characteristics is a family of curves of collector current (I_C) versus collector base voltage V_{CB} at different emitter current I_E.



(o/p Characteristics of CB Configuration for NPN transistor)

J_E	J_C	Remark
F.B	R.B	Active
F.B	F.B	Saturation
R.B	F.B	Reverse Active
R.B	R.B	Cut off.

$J_E \rightarrow$ Emitter-Base Junction.

$J_C \rightarrow$ Collector-Base Junction.

→ If $I_E = 0$, i.e when no forward bias applied to J_E, the reverse saturation current I_{CO} flows on the collector side.

Active region:-

The region of the curve in $V_{CB} - I_C$, when J_E is forward biased & J_C is reverse biased is (collector junction) is called active region.

→ Figure shows, in the active region the collector current is independent of reverse bias i.e collector current is almost a const. for increasing reverse bias. It depends only on emitter current I_E.

Saturation Region:-

If both junction J_E & J_C are forward biased, the family of curves shifts further to the left beyond the ordinate (Y-axis) and starts from the cut-in voltage of collector base diode.

→ In this region, collector current I_C flows even when $V_{CB} \simeq 0$. Even when the externally applied bias voltage is reduced to zero, there is still a barrier potential existing at the collector base junction and this assists in the flow of I_C.

→ I_C increases exponentially as per the law of junction studied in PN junction. The region around the knee is the saturation region.

Cut-off region:-

→ This is the region when both J_E and J_C are reverse biased. A very small current I_C flows even when emitter current $I_E = 0$. This is the collector leakage current I_{CBO} or I_{CO}. The region below the curve is the cutoff region.

Reverse Active region:-

If emitter junction (J_E) is reverse biased and collector junction is forward biased (J_C) then it is known as reverse active mode.

Breakdown Region:-

If the reverse bias voltage on CB config is allowed to exceed the max^m value limit specified by the manufacturer, device breakdown may occure.

→ Breakdown may be caused by the same effect diodes breakdown.

(1) → Breakdown can also result from the CB depletion region penetrating into the base until it makes contact with EB depletion

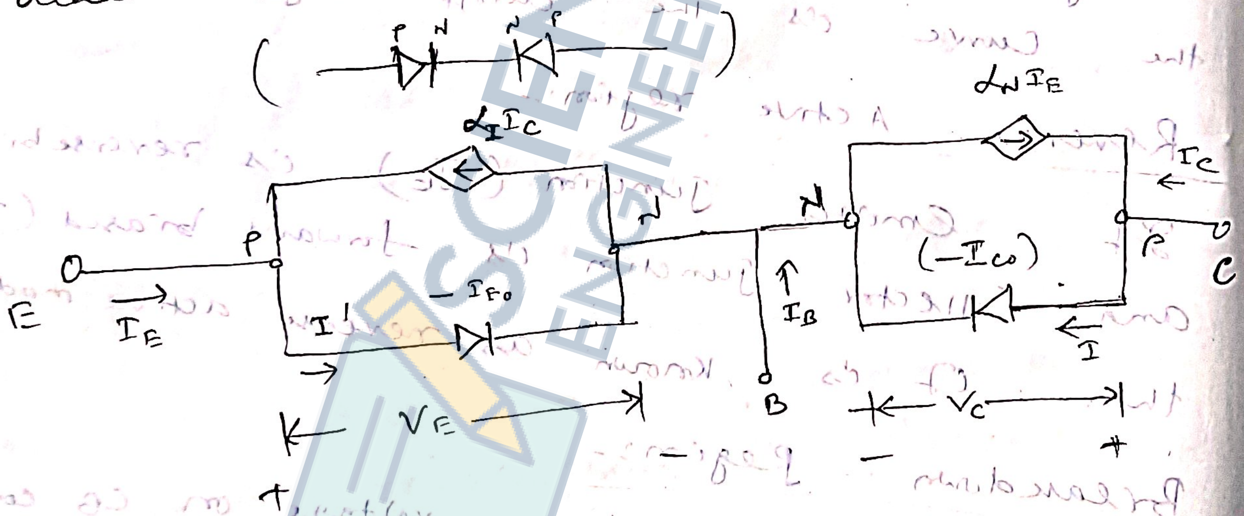
region. This condition is known as punch through or reach through and very large current can flow when it occures, possibly destroy the device.

Base-spreading Resistance :-

Lets consider a NPN transistor. With a depletion layer penetrating the base, the base holes are confined to the the p-type semiconductor. The thin region of resistance of this region (or section) is called the base-spreading resistance r_{bb}'.

*extra Eber-Moll Model :-

→ A transistor can be thought as 2 ideal diodes placed back to back.



→ For a P-N-P transistor, both I_{CO} & I_{EO} are -ve, so that $-I_{CO}$ & $-I_{EO}$ are +ve values, giving the magnitude of the reverse saturation currents of the diodes.

$$I_C = -\alpha_N I_E - I_{CO}\left[e^{V_C/V_T} - 1\right] \quad -(1)$$

$$I_E = -\alpha_I I_C - I_{EO}\left[e^{V_E/V_T} - 1\right] \quad \text{--- (2)}$$

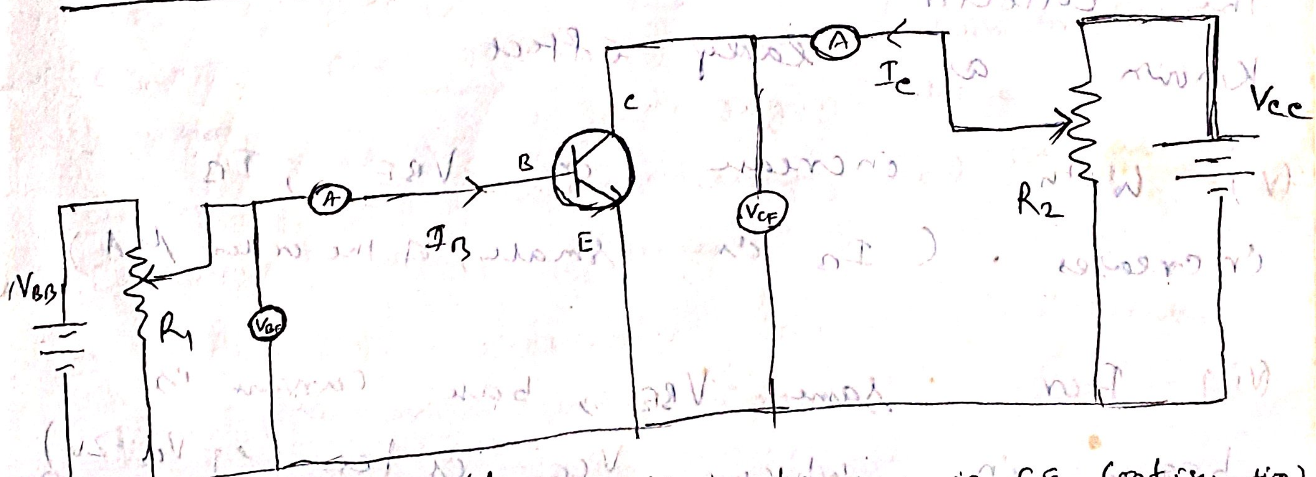
Subscript N to α has been added in order to indicate the normal operation of the transistor.

→ Subscript I stands for inverted mode. α_I is the inverted current gain. I_{EO} is the emitter junction reverse saturation current & V_E is the voltage drop from P side to N side at the emitter junction and is positive for a forward-biased emitter.

→ The dependency of currents in a transistor upon the junction voltages or vice versa are shown in eq^n (1) & (2).

→ The dependent current sources can be eliminated provided $\alpha_N = \alpha_I = 0$, length of the minority carriers in the base, all the minority carriers will recombine in the base & none will survive to reach collector. In such cond^n transport factor β and hence current gain factor α will be zero. Thus under these cond^n the transistor action ceases & we simply have 2 diodes placed back to back.

Common Emitter Characteristics:-

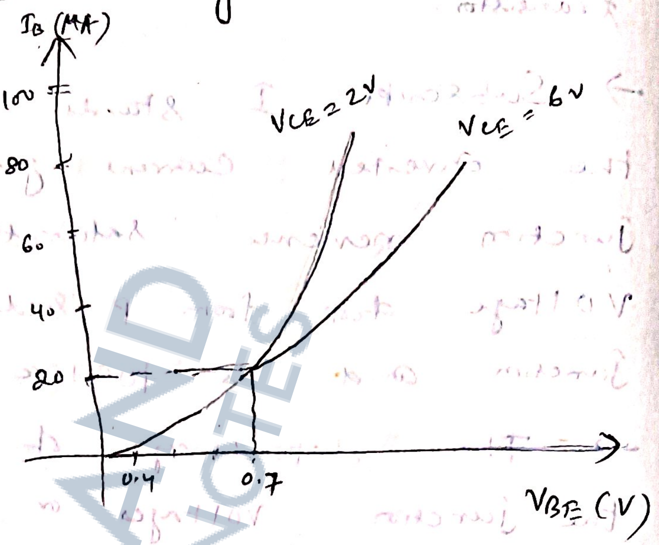


(fig:- NPN transistor in CE configuration)

I/P Characteristics:-

I/P Characteristics is the family of curves of $V_{BE}-I_B$. Base current at different base emitter voltage keeping V_{CE} as constant.

→ We note the following from the curves.



(i) When both I/P voltage V_{BE} and O/P voltage V_{CE} are 0V. No O/P current $I_C=0$, $I_B=0$.

(ii) Current starts flowing into base after the cut-in voltage $V_r = 0.5$ V.

(iii) If the CE junction is short cited ($V_{CE}=0V$) the forward biased BE (Base-emitter) junction behaves essentially like a diode

(iv) When V_{CE} is increased, the space charge width increases reducing the base width so that the majority carriers, 98% of them are able to reach the collector with min recombination, known as early effect.

(v) With increase in V_{BE}, I_B increases. (I_B is small, of the order μA)

(vi) For same V_{BE}, base current is higher in which V_{CE} is less (e.g. $V_{CE}=2V$)

Because as V_{CE} increases, I_C will increase but I_b will decrease.

$$(I_E = I_B\downarrow + I_C\uparrow).$$

(vii) Dynamic resistance (r_i)

$$r_i = \left.\frac{\Delta V_{BE}}{\Delta I_B}\right|_{V_{CE} = \text{constant}} = \frac{1}{\text{Slope}}.$$

O/P Characteristics :-

The O/P characteristics is the family of curves of collector current at different emitter voltages for a given values of base current.

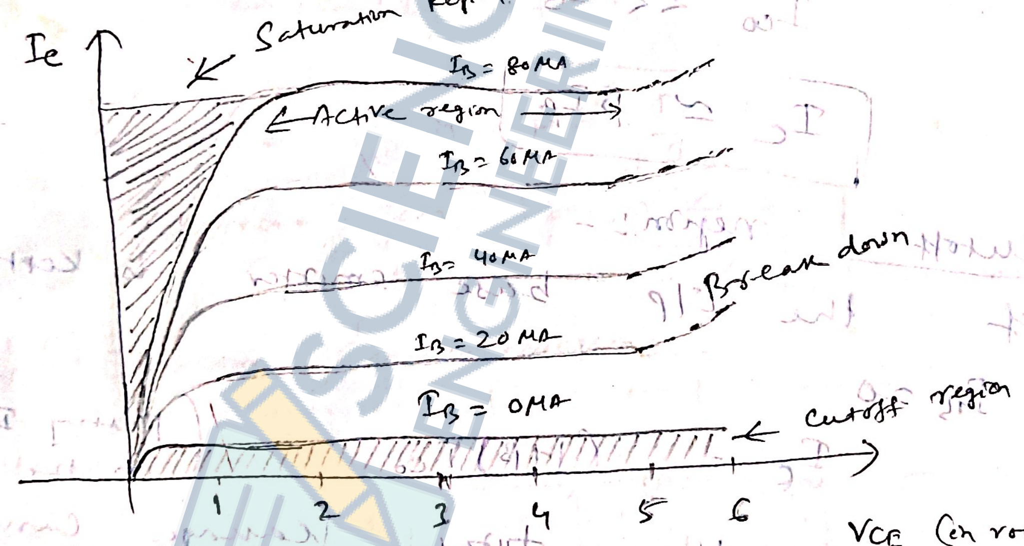


fig:- O/P characteristics for CE NPN transistor.

Active Region :-

It is the forward biased base emitter junction and reverse biased collector emitter junction. It is the region where the O/P current i.e collector current (I_C) is almost constant for different I_B.

→ As the forward bias is increased, I_B increases with consequent increase in I_C.

$$\rightarrow I_C = \alpha I_E + I_{CO}$$

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

$$= \alpha I_B + \alpha I_C + I_{CO}$$

$$\Rightarrow I_C (1-\alpha) = \alpha I_B + I_{CO}$$

$$\Rightarrow I_C = \frac{\alpha}{1-\alpha} I_B + \frac{1}{1-\alpha} I_{CO} \qquad \because \frac{1}{1-\alpha} = 1+\beta$$

$$\Rightarrow \boxed{I_C = \beta I_B + (1+\beta) I_{CO}}$$

I_{CO} = Reverse saturation current due to reverse biasing of CB junction which is very small.

$$I_{CO} << I_B$$

$$\boxed{I_C \simeq \beta I_B}$$

Cutoff region :-

If the i/p base emitter is kept open,

$I_B = 0$

$$I_C = (1+\beta) I_{CO} \quad \text{(Putting } I_B = 0 \text{, in the above eq}^n\text{)}$$

This is the total leakage current flowing through the whole transistor.

Saturation region :-

If both base-emitter & emitter-collector junction are forward biased, $V_{CE} = V_{BE} + V_{BC}$,

→ V_{BE} is only few tenth of the volt, V_{CE} is also of the same order, Hence, the family of curves starts off from very close to ordinate (Y-axis). The knee of curves represent the saturation region.

→ $R_C(sat) = \frac{V_{CE}}{I_C}$

Saturation resistance is very low, of the order 5 Ω or less.

O/P Resistance:-

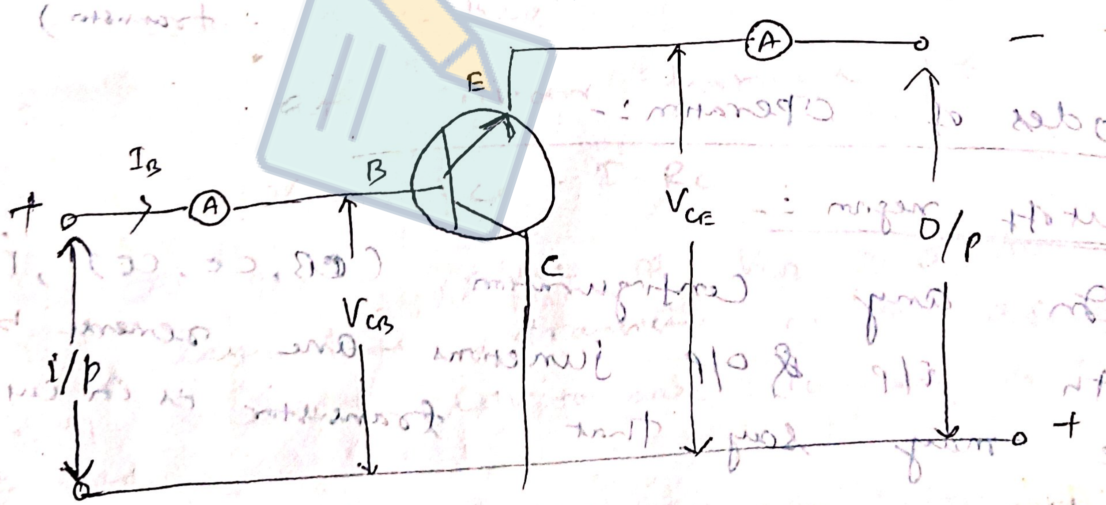
Defined as the ratio of change in collector-emitter voltage (ΔV_{CE}) to the change in the collector current (ΔI_C) at const base current

$$r_o = \left.\frac{\Delta V_{CE}}{\Delta I_C}\right|_{I_B = Const.}$$

DC current gain $\beta = \frac{I_C}{I_B}$

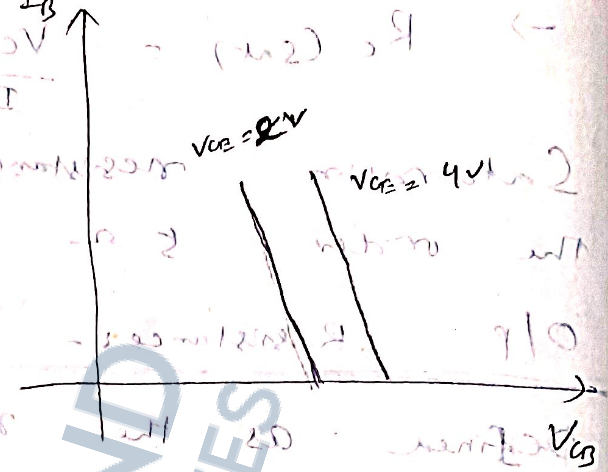
AC current gain $\beta_0 = \left.\frac{\Delta I_C}{\Delta I_B}\right|_{V_{CE} = const.}$

Common Collector Characteristics:-



→ The collector terminal is common to both i/p (CB) & o/p (CE).

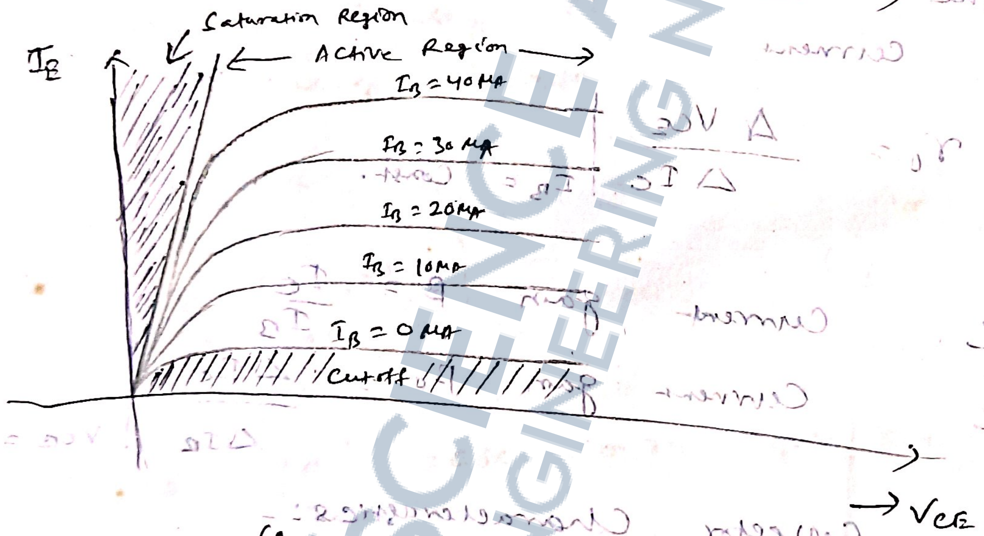
→ Common Collector (CC) i/p characteristic is a plot of V_{CB} versus I_B for different values of V_{CE}. (fig. 1)



(fig. 1)

→ The o/p characteristics is I_E (o/p current) versus V_{CE} for different I_B.

→ The o/p characteristics is practically identical to that of CE ckt, as shown in fig 2



(fig 2 :- o/p characteristics of CC NPN transistor)

Modes of operation :-

Cutoff region :-

→ In any configuration (CB, CC, CE), if both i/p & o/p junctions are reverse biased we may say that transistor is in cutoff mode.

→ Even if the value of the i/p applied voltage V_i is less than the threshold value of transistor (for $S_i = 0.7V$ & $Ge = 0.3V$)

The transistor will n't conduct, very small Current will flow.

→ Therefore, in cutoff mode, the following condⁿ will make.

i.e base current, $I_B = 0$

emitter current, $I_E = 0$

Collector current, $I_C = 0$

Collector potential, $V_C = V_{CC}$

Active Region :-

→ In a active mode of transistor, i/p junction i.e emitter junction should be forward biased and o/p junction must be reverse biased.

→ Since i/p junction is forward biased, the i/p voltage V_i is greater than threshold value of transistor, then we have

$$I_B = \frac{V_i - V_{BE}}{R_B}$$

Now current gain in CE configuration is β

$$\therefore I_C = \beta I_B$$

Potential at collector terminal i.e

$$V_C = V_{CC} - I_C R_C$$

→ If the value of $V_{CB} \geq 0$, then we will say that transistor is in active region because collector-base junction is reverse biased.

Therefore in active region following steps to be followed.

(i) Calculate i/p current i.e base current (I_B)

(ii) Calculate the collector current (I_C)

(iii) Calculate $V_C = V_{CC} - I_C R_C$

(iv) Calculate $V_{CB} = V_C - V_B$

(v) If $V_{CB} \geq 0$, then transistor is in active region.

Saturation Region :-

If both the junctions are forward biased then the transistor is in saturation region.

→ $I_C(sat) = \dfrac{V_{CC} - V_{CE}}{R_C}$

and $I_B = \dfrac{I_C(sat)}{\beta}$

from the ckt, $I_B = \dfrac{V_i - V_{BE}}{R_B}$

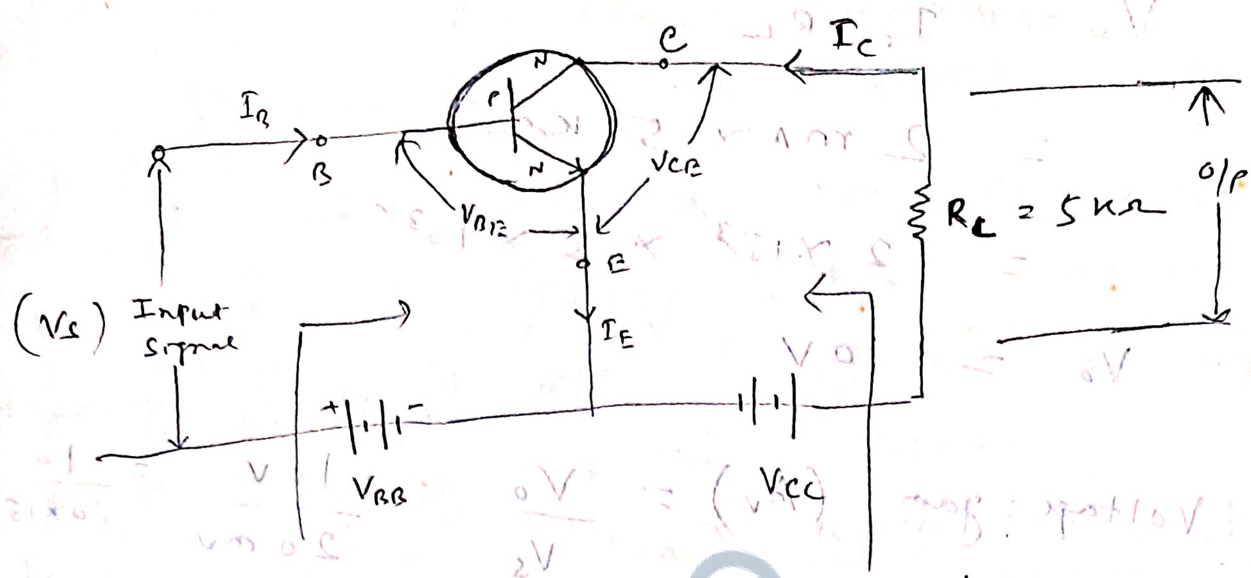
If $I_B > I_B(sat)$, then transistor is in saturation region & the ratio $\dfrac{I_C(sat)}{I_B}$ is called the overdrive factor (β_{force})

$$\boxed{\beta_{force} = \frac{I_C(sat)}{I_B}}$$

BJT as an amplifier :-

→ A device that raises the strength of a weak signal is called an amplifier.

→ Generally CE configuration is used for transistor's amplifying action.



$R_i = 1k\Omega$ $R_o = 10k\Omega$

→ A signal source V_s is connected in the i/p ckt. The load resistance 5 kΩ is connected across the o/p terminal.

→ Since the base-emitter junction is forward biased, it offers very low resistance to the signal source V_s.

→ However collector-emitter (CE) junction due to reverse biased, offers high resistance.

Let

$$V_s = 20\,mV = 20 \times 10^{-3}\,V.$$

$$R_i = 1k\Omega = 1 \times 10^3\,\Omega.$$

$$I_B = \frac{V_s}{R_i} = \frac{20 \times 10^{-3}}{1 \times 10^3} = 20 \times 10^{-6} = 20\,\mu A.$$

Assume, dc current gain (β) of the transistor is 100. So effective value of collector current $I_C = \beta I_B$.

$$\therefore I_C = 100 \times 20 \times 10^{-6} = 2\,mA$$

$V_o = I_C \cdot R_L$

$= 2\ mA \times 5\ k\Omega$

$= 2 \times 10^{-3} \times 5 \times 10^{3}$

$V_o = 10V$

Voltage gain $(A_v) = \frac{V_o}{V_s} = \frac{10V}{20\ mV} = \frac{10}{20 \times 10^{-3}}$

$= 0.5 \times 10^{3}$

$A_v = 500$

Thus, transistor's amplifying action is basically due to capability of transferring its signal current from a low resistance to high resistance ckt.

Transfer + Resistor = Transistor

BJT as a switch:-

→ A BJT can be used as a switch.

→ It is biased off (switch off) when $I_C = 0$ and biased on (switch on) when I_C = maximum.

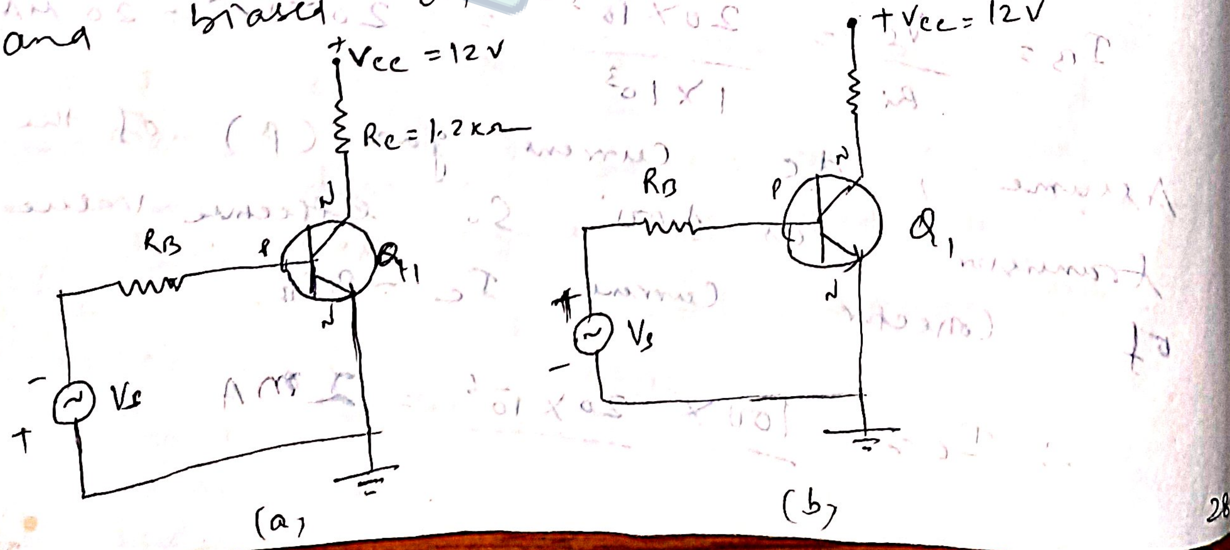


fig (a) — 'off' biased transistor.
(b) — 'on' biased transistor.

→ In fig (a), a −ve polarity of the base i/p voltage (V_i) biased the transistor (Q_1) off. In this case only collector base current flowing is the collector base leakage current (I_{CBO}) which is normally so small that it can be neglected.

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

$$I_B = 0 \Rightarrow I_C = 0. \quad (\because I_C = \beta I_B)$$

$$\therefore V_{CE} = V_{CC} \quad (1).$$

$$\frac{i/p}{0} \rightarrow \frac{o/p}{1}$$

→ In fig (b), a +ve polarity of base i/p voltage ensure transistor is in 'on' state and collector current I_C is max^m.

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

Since I_C is max^m,

$$V_{CC} \simeq I_C R_C$$

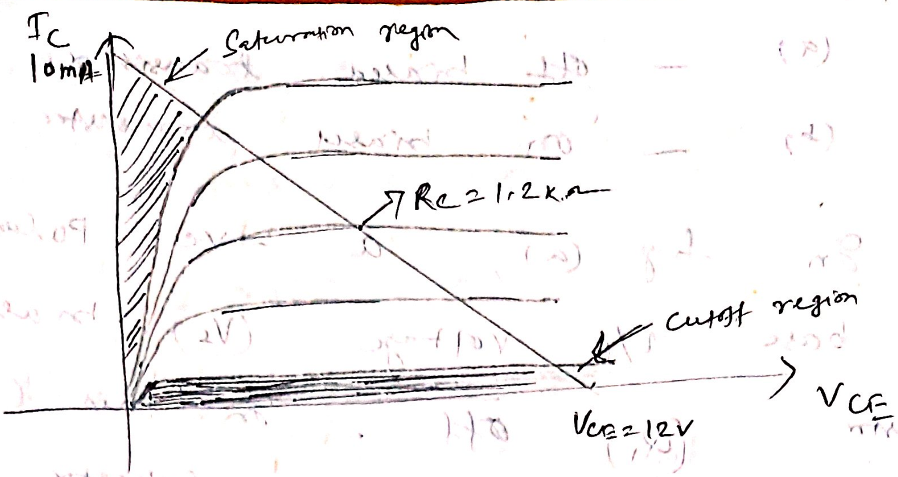
$$\therefore V_{CE} = 0. \qquad \frac{i/p}{1} \rightarrow \frac{o/p}{0}.$$

Summary :-

Imp During cutoff (Switch off)

i/p = 0 or −ve, $I_C = 0$, $V_{CE} \simeq V_{CC}$ (say 12v)

If input 0, so, o/p = 1.



During Saturation (switch on)

i/p = 1 or +ve , $I_C = max^m$ = 10 mA (say) , $V_{CE} \simeq 0$

i/p	o/p
1	0

Thus transistor can act as a switch.

Comparison

Parameters	CB	CE	C-C
1) I/p resistance	very low ($\simeq 100\,\Omega$)	low ($\simeq 750\,\Omega$)	very high ($\simeq 750\,k\Omega$)
2) O/p resistance	very high ($\simeq 1\,M\Omega$)	High ($\simeq 10\,k\Omega$)	low $\simeq 50\,\Omega$
3) Current gain	very less ($\simeq 0.98$) ($\because \alpha < 1$)	High (100-500) ($\beta \gg 1$)	very High (> 500) ($\gamma \gg 1$)
4) voltage gain	small ($\simeq 50$)	very high ($\simeq 500$)	very less (< 1)
uses	As high freq. amplification. a current Buffer ($\alpha \simeq 1$)	As an amplifier & in audio freq application	Impedance matching. As a voltage buffer ($A_V \simeq 1$)

→ CC is never used as amplifier due to less voltage gain. Due to high i/p impedance, it is preferred for impedance matching.

→ CE is used as amplifier, due to high voltage gain & high current gain ⇒ high power gain ($\because$ Power gain = Voltage gain × Current gain)