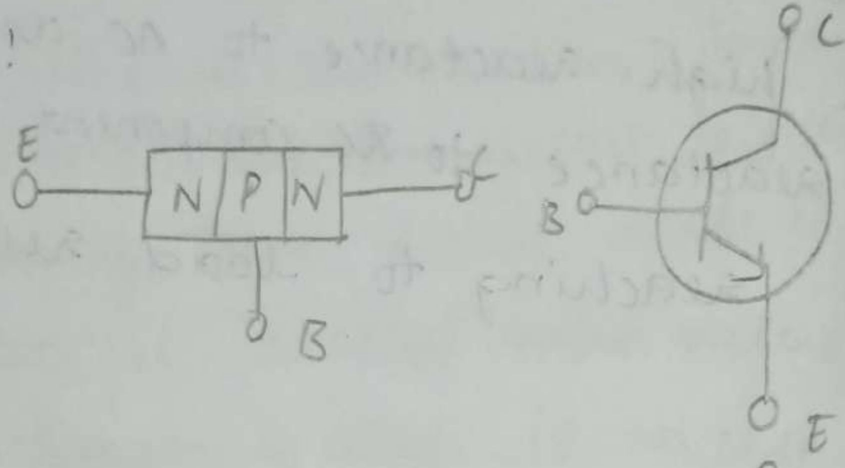
UNIT-V

Transistors

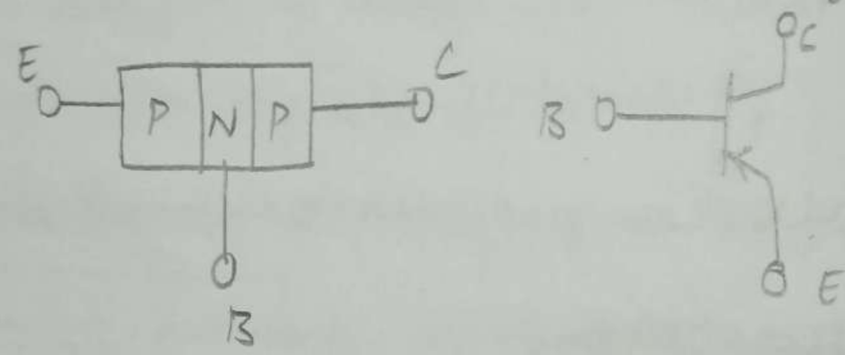
BJT:

Construction:

(i) NPN



(ii) PNP;



BJT:

Bipolar junction transistor (BJT).

Conduction of the current is due to both holes & electrons hence the name Bipolar device.

Purpose of transistor: it is used to strengthen a given weak signal

Here Arrow mark indicates the direction of current.

Transister has 3 different regions namely

1) Emitter
2) Base
3) Collector

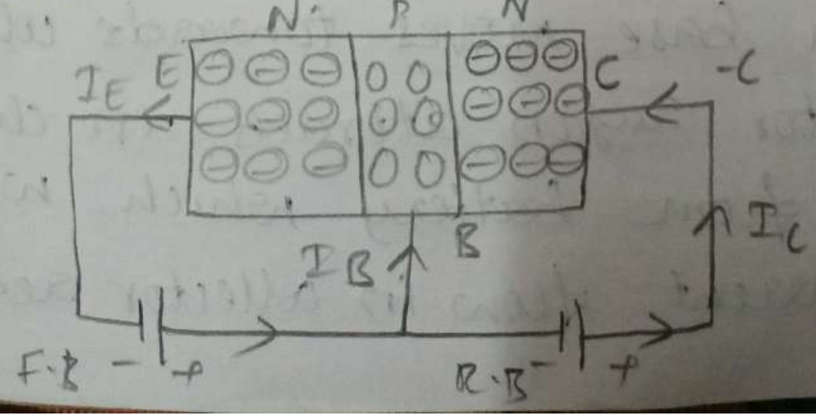
1) Emitter: It is a highly doped region which emits or supplies marjority charge carriers.

2) Collector: It is a moderately doped layer which accepts or collects charge carriers.

3) Base: It is a lightly doped layer located b/w emitter & collector due to narrow width it will not accept or emit charge carriers.

Working of Transistors:

(i) NPN Transistor:



Emitter Base junct

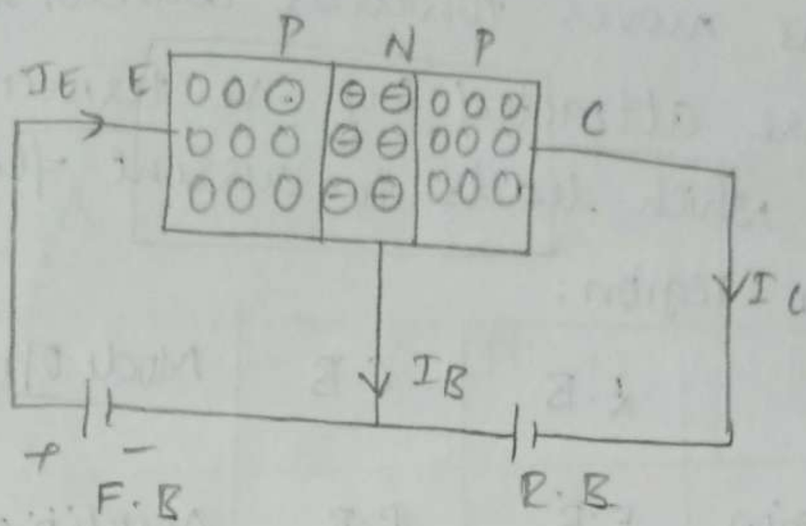
In NPN transistor E-B - Junction is forward biased & B-C- Junction is reverse biased

In E-B Junction positive terminal is connected to base & -ve terminal connected to emitter making it F.B. & In B-C Junction +ve terminal connected to collector & -ve connected to base region making it reverse biased.

In forward biased mode of E-B junction electrons moves towards base region it will cause current flow in emitter. The electrons are recombined with holes in base causing current flow in base region.

Holes from base moves towards collector and collector region attracts +ve charge carriers from battery which will cause current flow in collector region.

(ii) PNP Transistor:



Emitter Base junction is forward biased & B-C junction is reverse biased so that transistor comes into active region

Positive terminal connected to emitter & -ve terminal connected to base region. Making it forward biased & CB junction +ve terminal connected to base & -ve terminal connected to collector making it reverse biased.

In forward biased mode of EB junction holes moves towards base this will cause current flow in emitter & base region. Few electrons now gets recombined with holes causing current flow in base region.

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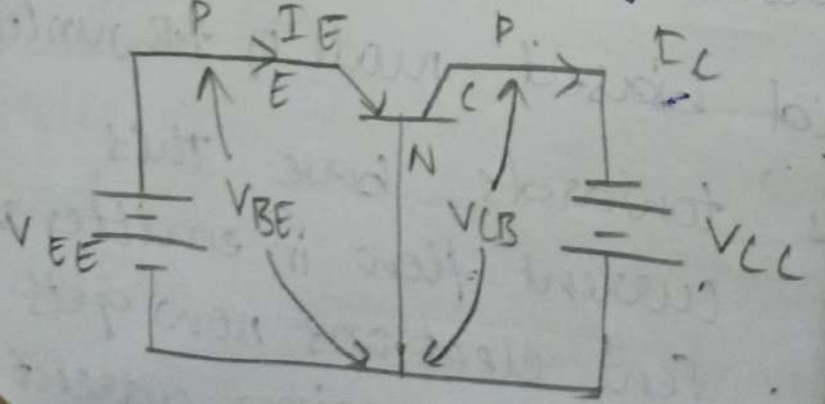
Due to narrow width of base region. few electrons moves towards collector & also holes are attracted by -ve terminal of battery which leads to current flow in collector region.

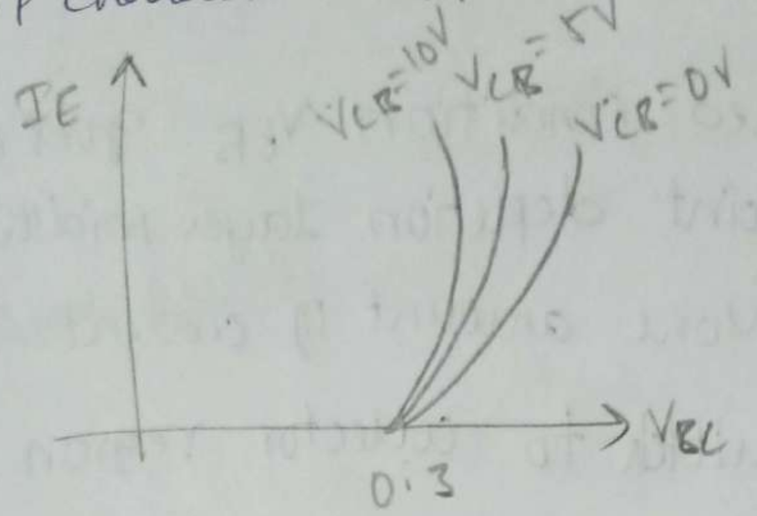
Region	E.B	C.B	Mode of operation
Active region	F.B	R.B	Amplifier.
saturation	F.B	F.B	ON switch.
cutoff	R.B	R.B	OFF switch.

Types of configurations:
(i) Common base
(ii) Common emitter
(iii) Common collector.

(i) Common Base configuration

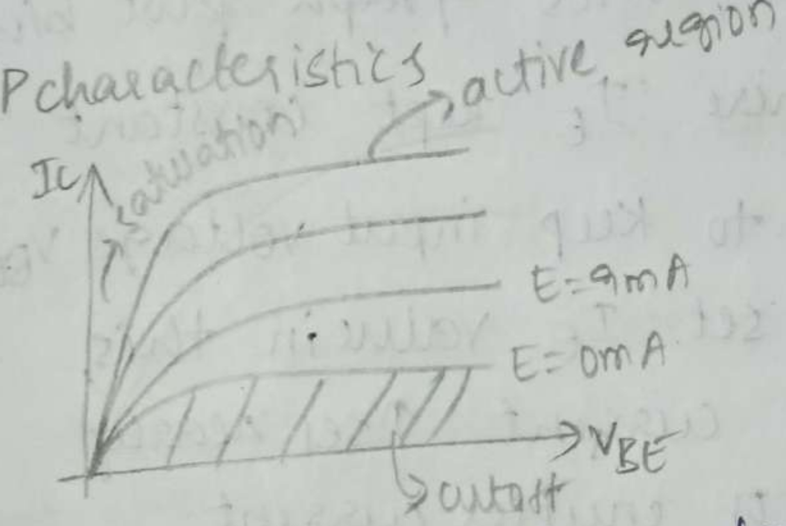


I/P characteristics:



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

O/P characteristics



$$R_0 = \frac{\Delta V_{BE}}{\Delta I_C}$$

In PNP transistor base terminal should be common between input and output known as CB configuration.

The input performance curve plot b/w I_E against V_{BE} at output voltage V_{CB} kept constant.

In this mode emitter to base junction forward biased during graph between I_E & V_{BE} output voltage kept constant & that is V_{CB} will be ↑sed in steps

0, 5V, 10V

In forward biased condition V_{EB} goes on ↑sing at some point depletion layer width becomes zero. More amount of current flows from emitter to collector region.

→ Output characteristics graph plot b/w I_C (vs) V_{CB} where I_E kept constant

→ here, we need to keep input voltage V_{BE} constant then set I_E value in this process collector current ↑ses nearly equal to that of emitter current.

	E.B	C.B
Saturation region	F.B	F.B
Active region	F.B	R.B
Cutoff region	R.B	R.B.

Current amplification factor:

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

$$\boxed{I_C = \alpha I_E}$$

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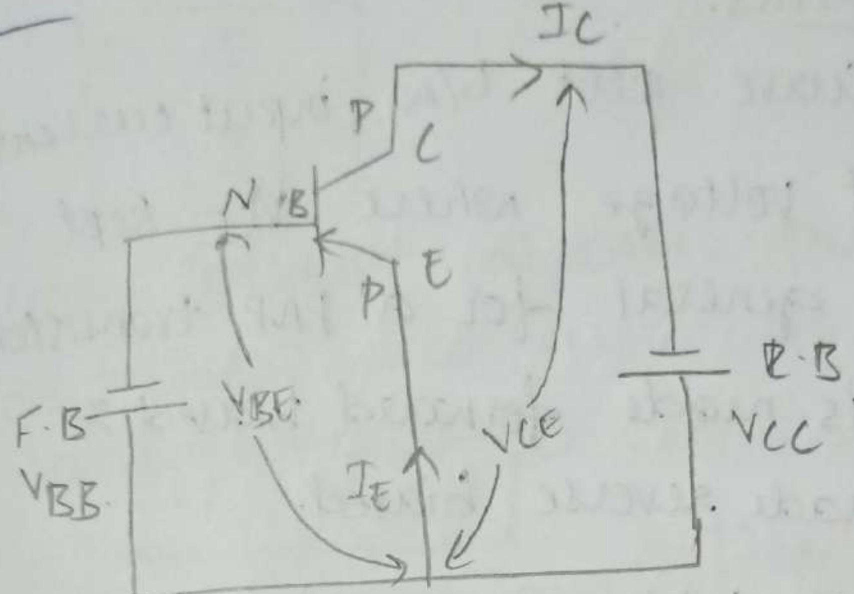
$$\boxed{I_C = \alpha I_E + I_{CBO}}$$

leakage current (μA)   μs

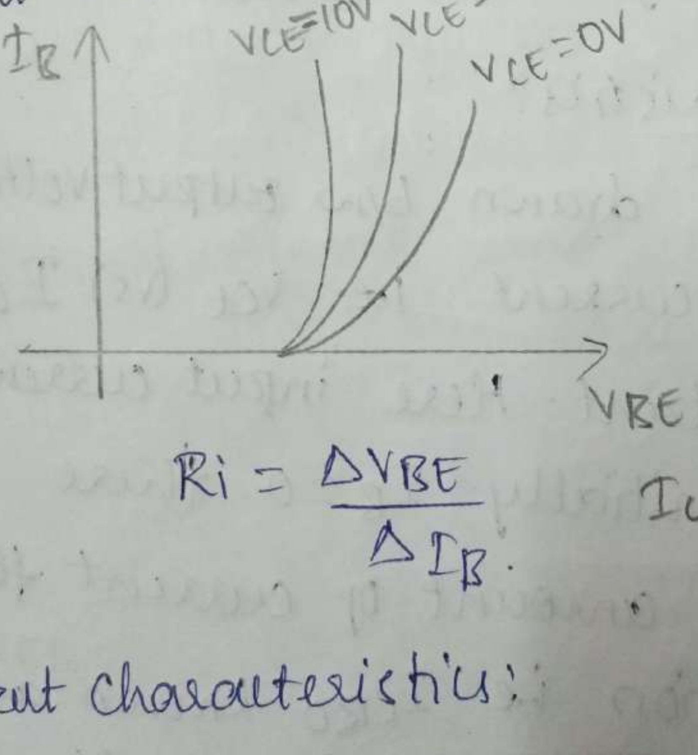
I_C units in mA

Common Emitter (CE):

leakage current is due to biasing provided.



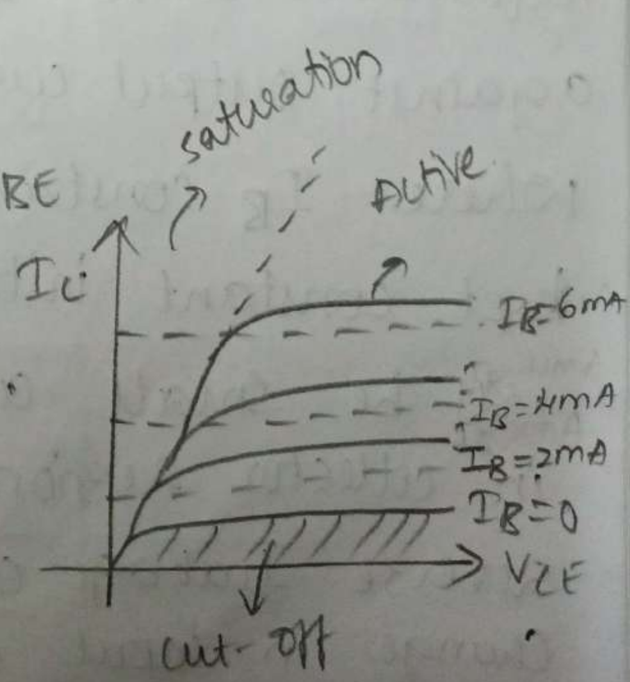
Input characteristics:



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

Output Characteristics:

$$\boxed{R_0 = \frac{\Delta V_{CE}}{\Delta I_C}}$$



In this PNP transistor Emitter connected for both input & output known as CE configuration.

I/P characteristics:

Performance curve plot b/w input current against input voltage where V_{CE} kept constant in general for a PNP transistor EB junction is made forward biased & DC junction made reverse biased.

Input characteristics curve is similar to that of p-n junction diode.

Output characteristics:

Performance curve drawn b/w output voltage against output current i.e V_{CE} (Vs) I_C where I_B constant. Here input current kept constant initially $I_B = 0$ there will be small amount of current flows in collector region i.e I_{CBO} known as reverse leakage current for small change in input current there will be large change in output current I_C

Base amplification factor:

It is defined as the ratio of change in collector to current to base current

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

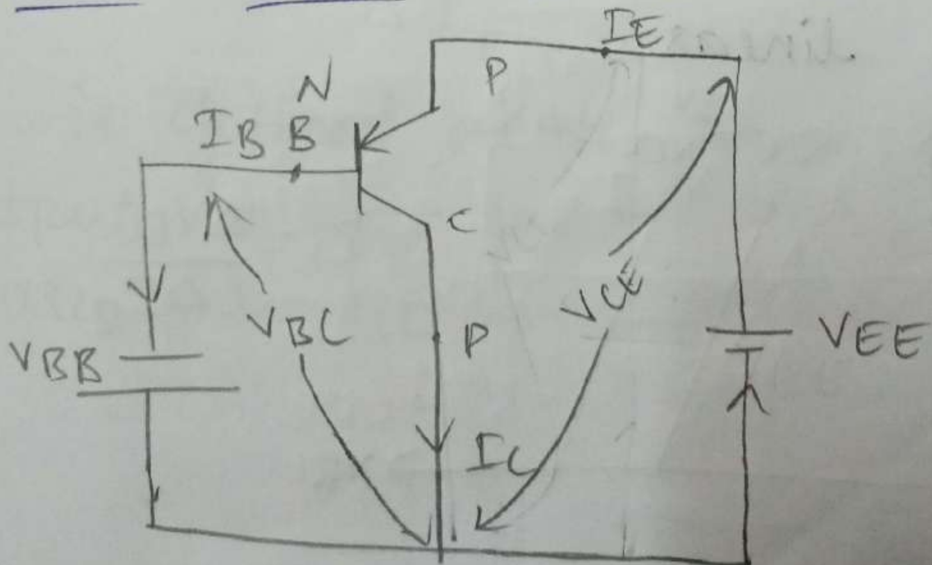
Collector current depends on base amplifica-tion factor

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

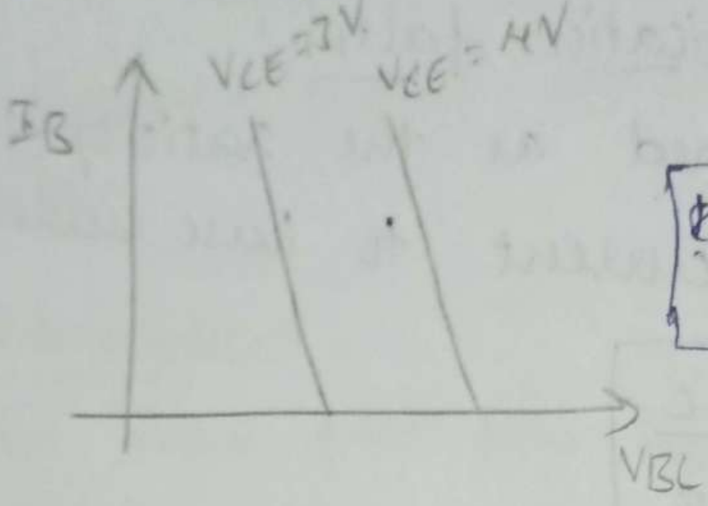
Due to majority carriers there will be leakage current through device I_{CEO}

$$\boxed{I_C = \beta I_B + I_{CEO}}$$

common collector configuration:



Input characteristics:

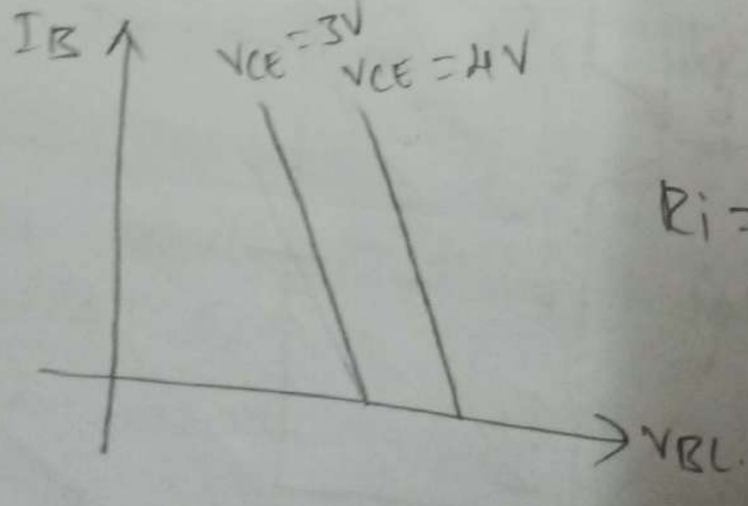


$$\boxed{R_i = \frac{\Delta V_{BC}}{\Delta I_B}}$$

In pnp transistor collector terminal is made common between both input & output known as CC configuration.

Input characteristics

Here performance curve is plot b/w input current I_B against input voltage V_{BC} keeping V_{CE} constant. And now for higher values V_{BC} the graph will be known linear



$$R_i = \frac{\Delta V_{BC}}{\Delta I_B}$$

output characteristics:

Performance curve plot b/w output voltage V_{CE} against output current I_E keeping I_B constant. Here we need to keep V_{BC} constant and Obtain input current I_B later it is also maintained constant and now output voltage V_{CE} is varied in steps so that for small change input current I_B there will be a large change in out put current I_E and here the output chara-cteristics will be same as that of CE configuration.

Output resistance!

$$R_0 = \frac{\Delta V_{CE}}{\Delta I_E}$$

It is defined as the ratio of change in output voltage V_{CE} to change in output current I_E keeping input current I_B constant

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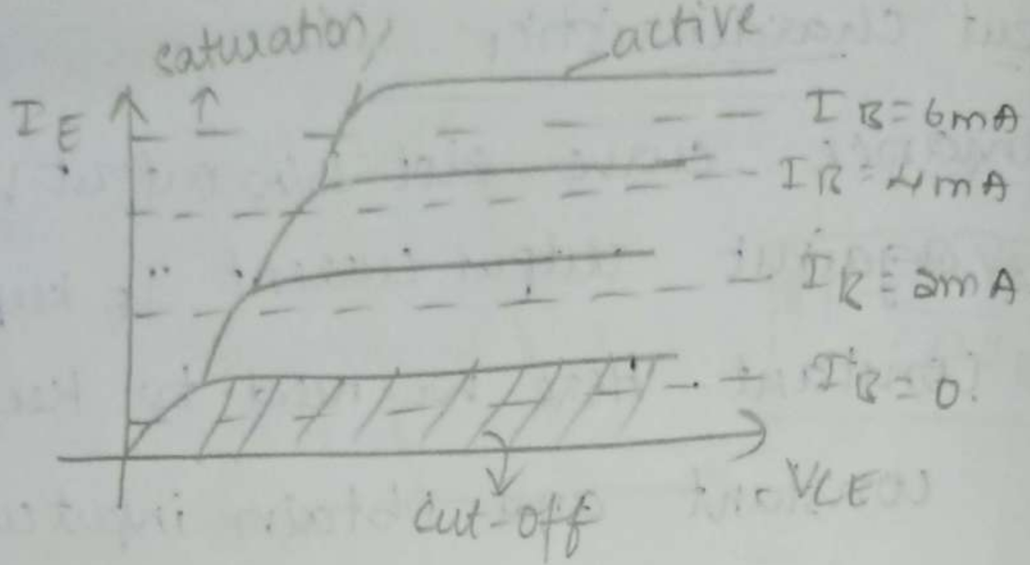

Current amplification factor:

It is defined as the ratio of change in emitter current to change in base current known as current amplification factor.

~~In common base configuration the emitter~~

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

$$\boxed{I_E = \gamma I_B}$$

$$I_E = \gamma I_B + I_{CEO}$$

Q) In common base configuration the emitter current I_E is 1mA & collector current I_C is 0.9mA calculate base current I_B?

$I_E = 1mA$, $I_C = 0.9mA$

$I_E = I_B + I_C$

$1 = I_B + 0.9$

$\boxed{I_B = 0.1mA}$

Q) In a common base configuration collector current is 0.95mA and the base current is 0.05mA calculate current amplification factor!

$I_C = 0.95mA$.

$I_B = 0.05mA$.

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

$I_E = I_B + I_C$

$= 0.05 + 0.95$

$= 1mA$.

$\alpha = \frac{0.95}{1}$

$\boxed{\alpha = 0.95}$ ~~mA~~

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Q) In a CB configuration the emitter current is 1 mA find collector current when the value of α is 0.92

$$I_E = 1mA.$$

$$\alpha = 0.92.$$

$$0.92 = \frac{I_C}{1}$$

$$\boxed{I_C = 0.92 mA}$$

Relation between α, β, γ:

(i) Relation between α, β:

$$\alpha = \frac{I_C}{I_E} - (1) \qquad \beta = \frac{I_C}{I_B} - (2)$$

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

$$\Delta I_B = \Delta I_E - \Delta I_C - (1)$$

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

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

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

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

$$\alpha = \beta - \beta\alpha.$$

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

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

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

Relation between α, β, γ:

(i) Relation between β, γ:

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

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

Dividing above equation with I_B, we get

$$\frac{\Delta I_E}{\Delta I_B} = \frac{\Delta I_B}{\Delta I_B} + \frac{\Delta I_C}{\Delta I_B}$$

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

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

Relation b/w γ, α:

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

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

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

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

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

$$\boxed{\gamma = \frac{1}{1-\alpha}}$$

$$\gamma(1-\alpha) = 1$$

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

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

$$\boxed{\alpha = \frac{\gamma - 1}{\gamma}}$$

Expression for CB configuration:-

from CB configuration

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

$$\boxed{I_C = \left(\frac{\beta}{1+\beta}\right) I_E + I_{CBO}}$$

Expression for CE configuration:

from CB configuration

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

$$I_E = I_B + I_C$$

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

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

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

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

$$I_C = \left(\frac{\alpha}{1-\alpha}\right) I_B + \left(\frac{1}{1-\alpha}\right) I_{CBO}$$

$$\boxed{I_C = \beta I_B + \gamma I_{CBO}}$$

Expression CE CC configuration:

from CB configuration

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

$$I_E = I_B + I_C$$

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

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

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

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

$$= \gamma I_B + \gamma I_{CBO}$$

$\beta = \gamma - 1$

$$\boxed{I_E = (\beta+1) I_B + (\beta+1) I_{CBO}}$$

Q) find the value of β if $\alpha = 0.9$

$$\beta = \frac{\alpha}{1-\alpha} = \frac{0.9}{1-0.9} = \frac{0.9}{0.1} = 9.$$

Q find the value of α if $\beta = 49$.

$$49 = \frac{\alpha}{1-\alpha}.$$

$$49 - 49\alpha = \alpha.$$

$$49 = 50\alpha.$$

$$\alpha = \frac{49}{50}.$$

$$\alpha = 0.98.$$

Q) find the value of I_C where $\beta = 50$ & $I_B = 20mA$ & take I_{CBO} is $10mA$

$$\cancel{= 50 \times 20 +}$$

$$\gamma = 1 + \beta = 51$$

$$I_C = \beta I_B + \gamma I_{CBO}$$

$$= (50)(20) + (51)(10)$$

$$= 1000 + 510$$

$$I_C = 1510 mA.$$

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Q) find the value of ~~of~~ α of a transistor when α is 0.98 calculate the values of β & γ

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

$$= \frac{0.98}{1-0.98} = \frac{0.98}{0.02} = \cancel{48}\ 49$$

$$\gamma = 1+\beta = 50.$$

$$= \cancel{49}.$$

Q) collector current of transistor is 9.945mA emitter current is 10mA & leakage current is ~~5A~~ 5μA. when it is connected in CB configuration α, β, γ.

~~$I_C = 9.$~~

$$I_C = 9.945\,mA, \quad I_E = 10\,mA.$$

$$I_{CBO} = 5\mu A.$$

$$I_C = \left(\frac{\beta}{1+\beta}\right) I_E + I_{CBO}.$$

$$9.945 = \left(\frac{\beta}{1+\beta}\right) 10 + 5\times10^{-3}$$

$$9.945 = \frac{10\beta}{1+\beta} + 0.005$$

$$9.940 = \frac{10\beta}{1+\beta}.$$

Q) find the value of ~~α~~ of a transistor when α is 0.98 calculate the values of β & γ

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

$$= \frac{0.98}{1-0.98} = \frac{0.98}{0.02} = \cancel{48}.49$$

$$\gamma = 1+\beta = 50.$$

$$= \cancel{49}.$$

Q) collector current of transistor is 9.945mA emitter current is 10mA & leakage current is ~~5A~~ 5μA. when it is connected in CB configuration α, β, γ.

~~$I_C = 9$.~~

$I_C = 9.945mA$, $I_E = 10mA$.

$I_{CBO} = 5\mu A$.

$$I_C = \left(\frac{\beta}{1+\beta}\right) I_E + I_{CBO}$$

$$9.945 = \left(\frac{\beta}{1+\beta}\right) 10 + 5\times10^{-3}$$

$$9.945 = \frac{10\beta}{1+\beta} + 0.005$$

$$9.940 = \frac{10\beta}{1+\beta}.$$

$$10\beta = 9.940 + 9.940\beta$$

$$0.06\beta = 9.940$$

$$\beta = 165.6$$

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

$$165.6 = \frac{\alpha}{1-\alpha}$$

$$165.6 - 165.6\alpha = \alpha$$

$$166.6\alpha = 165.6$$

$$\alpha = 0.994$$

$$\gamma = 1+\beta = 165.6+1$$

$$= 166$$

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Comparision of Transistor:

Configuration	CB	CE	CC
I/p R	less 100 Ω	less 750 Ω	very high 750 kΩ
O/p R	very high 450 kΩ	high 45 kΩ	low 50 Ω
Volt gain	150	500	<1
Applications	radio frequency	Audio frequency	Impedence matching

V_{CEO}: This is the maximum voltage which may be applied across the collector emitter terminal with base open

V_{CBO} (Collector to base voltage): The maximum voltage which may be applied to the collector base terminal with emitter open