Semiconductor Diode

When a p type semiconductor having acceptor impurities, is joined to a n-type semiconductor having donor impurities, the thin region in which the carrier changes from p-type semiconductor to n-type semiconductor is known as a pn junction.

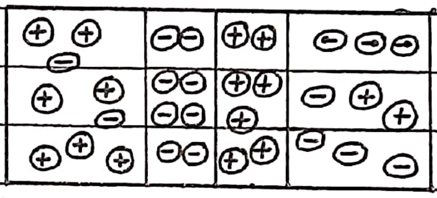
A pn junction forms a very useful device and is called a semiconductor diode or a pn junction diode. All the semiconductor devices contains atleast one pn junction. Therefore it is very important to understand the behaviour of pn junction, when connected in an electronic circuit.

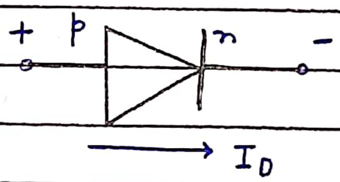
IN|700|4

1 PN Junction

Peak inverse voltage (mV)

Max current (mA)





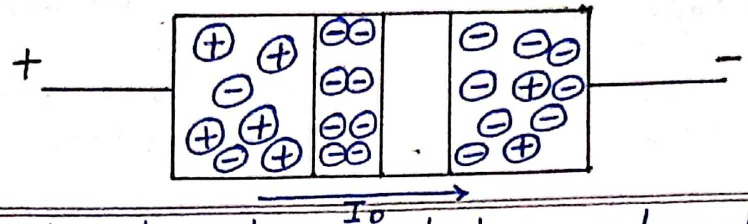
pn - junction

→ Formation of depletion layer is pn junction diode.

→ Biasing of PN-Junction Diode

When a pn junction diode is connected across an external voltage source, the diode is said to be under biasing condition. The external voltage source across the pn-junction diode can be applied in two way.

1. Forward Biasing
2. Reverse Biasing

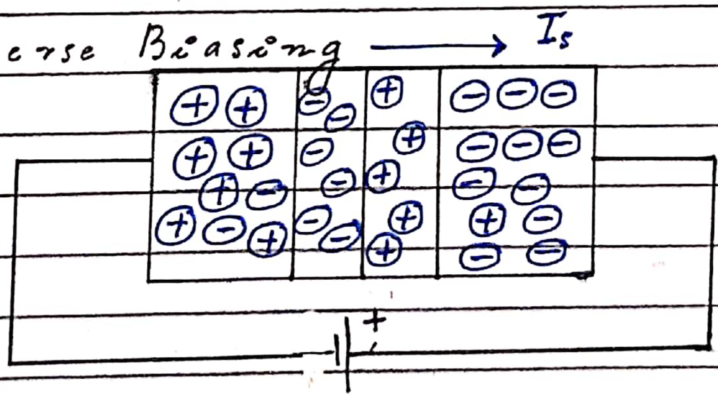


When positive terminal of an external voltage source, p-type semiconductor and negative terminal is connected to n-type semiconductor of pn junction diode is said to be in formed biasing.

The holes are repelled by positive terminal and electron is repelled by negative terminal of the voltage source and move towards the pn junction.

Because, they acquire energy from voltage source, same of the holes and electrons enters in the depletion layer and combine with each other width of depletion layer and barrier potential reduces with forward bias. As, a result of this more majority carrier defuse across the pn junction. Therefore it causes a large current to flow to the pn junction. This current is called forward current I_D, resulting the forward current to rise.

Reverse Biasing



When the positive terminal of an external voltage source is connected to n-type semiconductor and negative terminal is connected to p-type semiconductor, the pn junction diode is said to be in reverse biasing.

The holes in p-type semiconductor are attracted towards the negative terminal of voltage source and the electron in n-type semiconductor are attracted to positive terminal of the voltage source.

Therefore, the majority carriers drawn away from the junction. The increased barrier potential makes it very difficult for the majority carriers to defuse across the pn junction, therefore no current flows due to majority carriers in a reversed biased pn junction diode.

But, the barrier potential helps minority carriers in crossing the pn junction, therefore a small current does flow through the reverse bias pn junction diode.
This current is known as reverse saturation current Is, at this actions occurs is known as Breakdown voltage.

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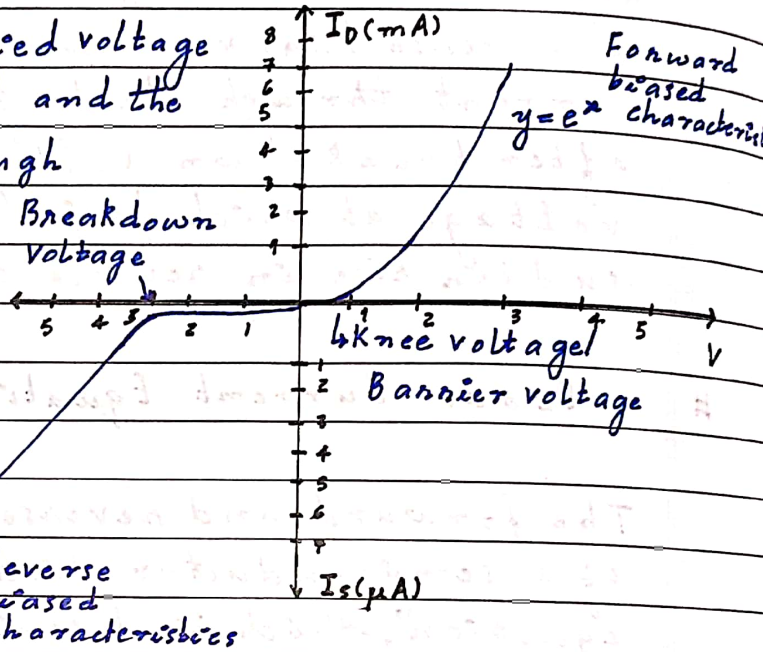
→ VI characteristics of PN Junction Diode

It is the graph between applied voltage across the diode terminal and the current that flows through the diode.
It may be noted that the complete graph can be divided into two parts.



First is Forward biased characteristics and Reversed biased characteristics.

→ Forward Biased Characteristics

In Forward bias, the pn junction barrier potential is reduced after knee voltage. (The minimum voltage applied to the pn junction diode for which it starts current conduction is known as 'knee voltage').
Due to this voltage and forward bias voltage, current increases with the increase in forward bias voltage.
The forward current increases as the voltage exceeds, the pn junction diode behaves like a conductor.
Therefore, the current rises exponentially.

→ Reverse Biased Characteristics

With reverse biased characteristics, the pn junction potential barrier is increased. Therefore, no current flows through the pn-junction diode but actually

"Patience is a key element of success." —Bill Gates a very small current flows through the diode due to movement of minority charge carriers. If reverse bias voltage is made too high, the current through the pn junction diode increases after breakdown voltage. (It is the reverse voltage at which pn junction breakdown with sudden rise in reverse current).

Diode Current Equation. (Schockley's Diode equation)

The forward and reverse biased characteristics of a semiconductor diode is called "diode current equation", which is described as the current equation for forward and reverse biased diode is given by the relation :

$$I_D = I_s \left(e^{V/\eta V_T} - 1 \right)$$

where,

$V \rightarrow$ diode terminal voltage
It is positive for forward bias and negative for reverse bias.

$\eta \longrightarrow$ material or emperical constant

$$\begin{Bmatrix} \eta = 2 \text{ for Silicon} \\ \eta = 1 \text{ for Germenium} \end{Bmatrix}$$

$V_T \rightarrow$ Volt equivalent temperature / Thermal voltage

$$V_T = \frac{KT}{q},$$

$K \rightarrow$ Boltzmann constant $= 1.38 \times 10^{-23}$ J/K
$T \rightarrow$ Temperature in K
$q \rightarrow$ electron charge $= 1.6 \times 10^{-19}$ C

Calculating V_T for room temperature
$\therefore T = 298K$

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$$\Rightarrow V_T = \frac{1.38\times10^{-23}\times298}{1.6\times10^{-19}} = 0.025V = 25mV$$

$I_s \rightarrow$ Reverse Saturation Current
$I_D \rightarrow$ Diode current.

→ When V is positive and $V >>> V_T$, then the term $e^{V/\eta V_T} >>> 1$.
Therefore, the diode equation becomes;

$$I_D = I_s \times e^{V/\eta V_T}$$

→ If V is negative and $V <<< V_T$, then the term $e^{V/\eta V_T} <<< 1$.
Therefore, the diode current under reverse bias is equal to the reverse saturation current I_s.

$$\therefore I_D = -I_s.$$

Q. Determine Germenium pn-junction diode current for the forward biased voltage of 0.22 V at room temperature with I_s of 1mA.

$$\therefore I_D = I_s \times e^{V/\eta V_T}$$

$$= (1mA)\times e^{\frac{0.22}{1\times0.025}}$$

$$I_D = (1mA)\times(6634) = 6634 mA$$

$$I_D = 6.634 A$$ ans.

Q. Derive the equation for the ratio of diode current resulting from two different forward voltage drop if $V \ggg V_T$.

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$$\therefore \quad I_{D_1} = I_s \left(e^{V_1/\eta V_T} \right)$$

$$I_{D_2} = I_s \left(e^{V_2/\eta V_T} \right)$$

Hence :

$$\frac{I_{D_2}}{I_{D_1}} = e^{(V_2 - V_1)/\eta V_T} = e^{\Delta V/\eta V_T}.$$

Q Find the increase in forward voltage if the current of Si diode with $V_T = 26mV$ is doubled.

$$\therefore \quad \frac{I_{D_2}}{I_{D_1}} = e^{\Delta V/\eta V_T}$$

$$\therefore \quad \ln\left(\frac{I_{D_2}}{I_{D_1}}\right) = \frac{\Delta V}{\eta V_T}$$

$$\Delta V = \eta \times V_T \times \ln\left(\frac{I_{D_2}}{I_{D_1}}\right)$$

$$\Delta V = 2 \times 0.026 \times \ln\left(\frac{2 I_{D_1}}{I_{D_1}}\right)$$

$$\Delta V = 2 \times 0.026 \times \ln(2)$$

$$\Delta V = 0.052 \times 0.693$$

$$\Delta V = 0.036V$$

$$\Delta V = 36mV \quad \text{ans}$$

Q. The diode current is 0.6 mA where the applied voltage 400 mV and 20 mA when applied voltage 500 mV.
Determine emperical constant η at room temperature.

$$\frac{I_{D_2}}{I_{D_1}} = e^{\frac{\Delta V}{\eta V_T}}$$

$$\therefore \frac{\Delta V}{\eta \times V_T} = \ln\left(\frac{I_{D_2}}{I_{D_1}}\right)$$

$$\therefore \eta = \frac{\Delta V}{V_T \times \ln\left(\frac{I_{D_2}}{I_{D_1}}\right)}$$

$$\eta = \frac{0.5 - 0.4}{0.025 \times \ln\left(\frac{20}{0.6}\right)}$$

$$\eta = 1.140$$ Ans.

Diode Resistance

The practical diode does not behave as a perfect conductor when it is forward biased, similarly it does not behave as a perfect insulator, when it is reversed bias due to diode resistance.

In other words when a practical diode is forward biased, it offers low resistance to the forward current and when the practical diode is reversed biased it offers very high resistance.

The diode resistance can be classified based on biasing conditions.

There are two types

(i) Forward Diode resistance.

(ii) Reverse Diode resistance.

→ Forward Diode Resistance

Under the forward biased condition, the opposition offered by the diode is known as forward diode resistance. It can be defined in two manners;

(a) Static Forward Diode Resistance

When the diode is used in DC circuit and supplied voltage is DC, the resistance is calculated at a particular point on the VI characteristics of forward bias and the resistance is called Static Forward Diode resistance.

$$R_{F(DC)} = \frac{V_D}{I_D}$$

(b) Dynamic Forward Diode Resistance

The opposition offered by diode to the alternative current flows in forward bias condition is known as Dynamic Forward Resistance or AC resistance.

$$R_{F(DC)} = \frac{\Delta V_D}{\Delta I_D} = \frac{dV}{di}$$

(ii) Reverse Diode resistance

Under reverse bias condition, the opposition offered by the diode to the reverse saturation current is known as reverse diode resistance.
It can also be expressed in two manners;

(a) Static Reverse Diode Resistance

The resistance under DC conditions, it is the ratio of applied reverse voltage to the reverse saturation current.

$$R_{R(DC)} = \frac{V_R}{I_S}$$

(b) Dynamic Reverse Diode Resistance

The resistance under AC condition, it is the ratio of change in reverse voltage to the corresponding change in reverse saturation current.

$$R_{R(AC)} = \frac{\Delta V_R}{\Delta I_S} = \frac{dV_R}{dI_S}$$

→ Expression for Dynamic Diode Resistance

$$R_{(AC)} = \frac{1}{\left(\frac{dI}{dV}\right)} \quad \text{——— (1)}$$

From Diode current equation:

$$I_D = I_S\left(e^{V/nV_T} - 1\right) \quad \text{——— (2)}$$

Differentiating eq ② w.r.t V

$$\frac{dI_D}{dV} = \frac{I_s \cdot e^{V/\eta V_T}}{\eta V_T}$$

∴ Putting in eq ①

$$\therefore R_{r(AC)} = \frac{\eta V_T}{I_s \cdot e^{V/\eta V_T}} = \frac{\eta V_T}{I_D + I_s}$$

From the above equation determining the value of dynamic diode resistance under forward and reverse bias conditions.

Q. Find the static and Dynamic resistance of Ge diode, if temperature is 27°C and saturation current is 1μA for applied forward bias voltage of 0.2V.

$$\therefore V_T = \frac{KT}{q} = \frac{1.38 \times 10^{-23} \times 300}{1.6 \times 10^{-19}} = 0.0258$$

$$\Rightarrow V_T = 0.026 \text{ V}$$

$$\therefore I_D = I_s (e^{V/\eta V_T})$$

$$= 1 \times 10^{-6} \times e^{0.2/0.026}$$

$$I_D = 2.186 \times 10^{-3} \text{ A}$$

$$\therefore R_{F(DC)} = \frac{V_D}{I_D} = \frac{0.2}{2.186 \times 10^{-3}} = 91.491 \Omega$$

$$R_{F(AC)} = \frac{\eta V_T}{I_s + I_D} = \frac{0.026}{2.186 \times 10^{-3} + 10^{-6}} = 11.888 \Omega$$

Ans.

Q. Show that the pn junction resistance for diode is given by the equation

$r_j = \frac{26}{I_D}$ at 27°c where I_D is the forward diode current in mA.

$\therefore \quad V_T = \frac{KT}{q} = \frac{1.38 \times 10^{-23} \times 300}{1.6 \times 10^{-19}} = 26\,mV$

$\therefore \quad R = \frac{\eta V_T}{I_D + I_s}$

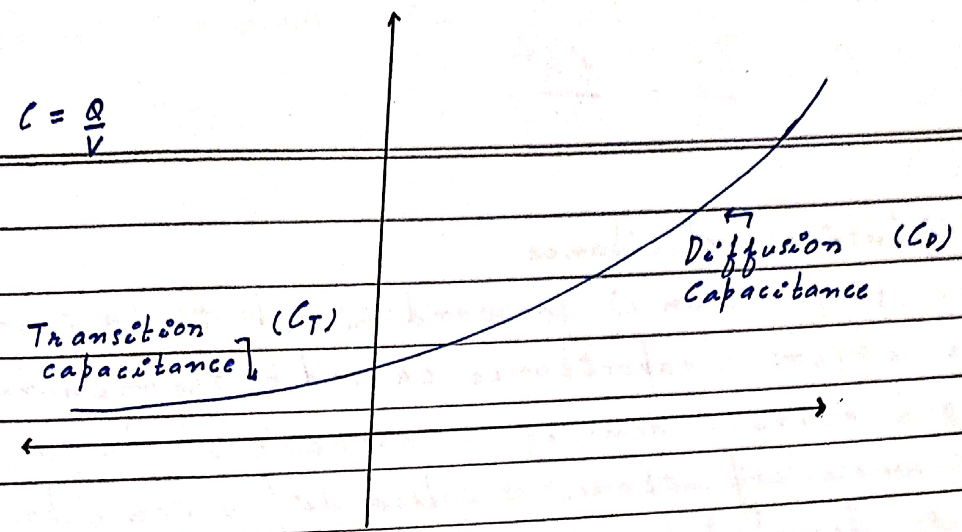
Assuming $\eta = 1$ and

$I_D >>> I_s$

Hence,

$R_j = \frac{V_T}{I_D} = \frac{26}{I_D(mA)}$ Proved.

Diode Capacitance



The depletion layer acts as a dielectric medium between p-type semiconductor and n-type semiconductor and as a parallel plates of capacitor. The capacitance formed in a junction area is called diode capacitance and it is given by the equation.

$$C = \frac{\epsilon A}{w}$$

where ϵ is the permitivitty of the dielectric medium
A is the area of the junction.
w is the width of the depletion layer

The pn junction diode grows in capacitance under biased conditions and it is of two types

1. Transition Capacitance
2. Diffusion Capacitance

Transition Capacitance

When the pn junction diode is reversed biased, than the majority carriers move away from the junction and covered more immobile charges. Therefore, the thickness of depletion layer increases with the increase of reverse bias voltage.

This depletion layer along with concentration of immobile charges maybe considered to a capacitor and whose capacitance is known as transition capacitance (C_T).

$$C_T = \frac{dq}{dV} = \frac{\epsilon A}{w}.$$

2. Diffusion Capacitance

When pn junction is forward biased, the pn junction diode offers a capacitance caused by the minority charged carrier density stored near the pn junction and whose capacitance is called diffusion capacitance. It is denoted by C_D and also expressed by

$$C_D = \frac{\tau \cdot I}{\eta V_T}$$

We know that diffusion capacitance

$$C_D = \frac{dq}{dV}$$

and also, we know that

$$di = \frac{dq}{dt}$$

if $dt = \tau$, then $dq = \tau \cdot di$

Therefore

$$C_D = \frac{\tau \cdot di}{dV}$$

Hence,

$$\frac{dI}{dV} = \frac{I + I_s}{\eta V_T}$$ But $I >>> I_s$

then $$\frac{dI}{dV} = \frac{I}{\eta V_T}$$

Now, the diffusion capacitance

$$C_D = \frac{\tau I}{\eta V_T}$$

The diffusion capacitance is proportional to the diode current.

Q. Find the transition capacitance of Ge Diode whose A = 1 mm² and space charge thickness is 2×10^{-4} cm and permitivity of Germanium diode is $\epsilon_{Ge} = \frac{16}{36\pi} \times 10^{-11}$ F/cm

$$C = \frac{\frac{16}{36\pi} \times 10^{-11} \times 0.01}{2 \times 10^{-4}}$$

$$C = 7.073 \times 10^{-11} F$$

→ Diode Applications

The pn junction diode has an important characteristics that it conducts well in forward direction and poorly in reverse direction. The pn junction diode is very useful in many application such as

→ as a switch in logic circuit

→ as a rectifier

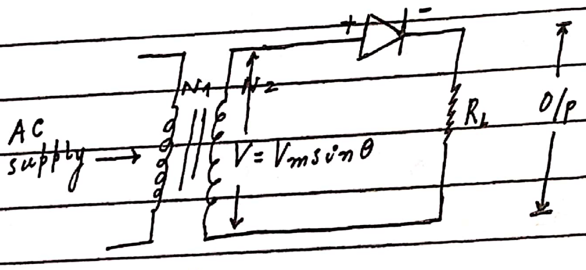
→ as a zener diode in voltage stabilizing circuit.

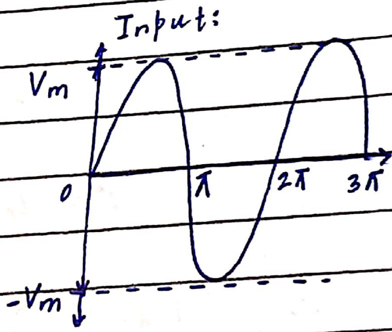
→ as a verector diode in radio and TV receivers.

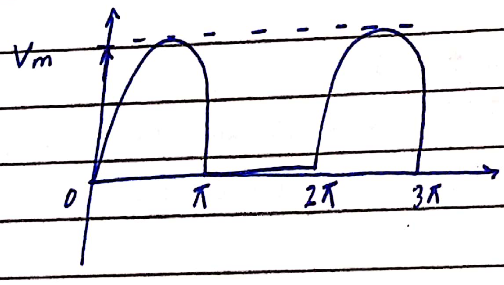
→ as a LED in communication circuits.

→ Diodes as rectifiers

1. Half-wave rectifier circuit







In half-wave rectifier circuit at the input only positive half cycle appears across the load, whereas the negative half-cycle is suppressed.

To determine the efficiency of half-wave rectifier the rectification efficiency is the percentage of total input power is converted into useful DC output power, the ratio of DC output power to the AC input power

$$\eta = \frac{P_{dc}}{P_{AC}} \times 100\%$$

Let the applied voltage across the secondary winding is $V = V_m \sin\theta$, and the forward resistance of diode R_f and load resistor R_L, then the current flows through the load resistor.

$$i = \frac{V_m \sin\theta}{R_f + R_L}$$

When $\sin\theta = 1$, the instantaneous current is maximum

$$i = \frac{V_m}{r_f + R_L}$$

$$i = I_0 \sin\theta$$

$$\therefore \quad P_{dc} = I_{dc}^2 \times R_L$$

$$I_{av} = \frac{\int_0^{\pi} I_m \sin\theta \, d\theta}{\int_0^{2\pi} d\theta}$$

$$I_{av} = \frac{I_m}{\pi}$$

$$\Rightarrow \quad P_{dc} = \frac{I_m^2}{\pi^2} \times R_L$$

$\cos 2\theta = 1 - 2\sin^2\theta$

$\sin^2\theta = \frac{1-\cos 2\theta}{2}$

and $P_{AC} = I_{rms}^2 (r_f + R_L)$

$$\therefore \quad I_{rms} = \sqrt{\frac{\int_0^{\pi} i^2\, d\theta}{\int_0^{2\pi} d\theta}} = \sqrt{\frac{i_m^2 \int_0^{\pi} \sin^2 d\theta}{2\pi}}$$

$\cos 2\theta$

$$I_{rms} = i_m \sqrt{\frac{\left[\frac{\theta}{2}\right]_0^{\pi} - \left[\frac{\sin 2\theta}{4}\right]_0^{\pi}}{2\pi}}$$

$$I_{rms} = \frac{i_m}{2}$$

$$\Rightarrow \quad P_{AC} = \frac{i_m^2}{4} (r_f + R_L)$$

Hence ; $$\eta = \frac{P_{DC}}{P_{AC}}$$

$$\eta = \frac{\cancel{I_m^2} \times R_L \times 4}{\pi^2 \times \cancel{I_m^2} (R_f + R_L)}$$

$$\eta = \frac{4}{\pi^2 \left(1 + \frac{r_f}{R_L}\right)}$$

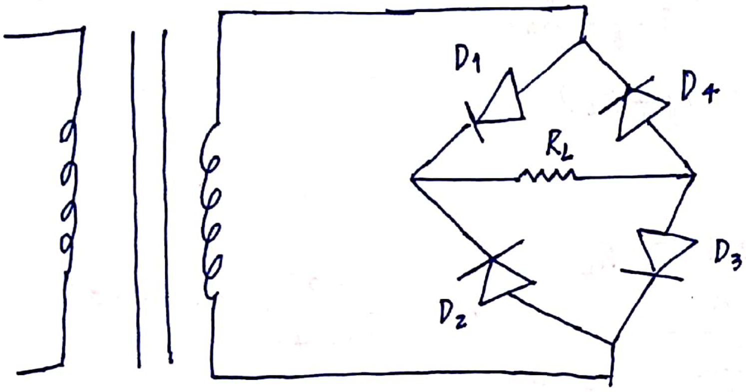
$$\eta = \frac{0.405}{1 + \frac{r_f}{R_L}}$$

The effiency of rectifier will be maximum if r_f is neglected as compared to R_L.

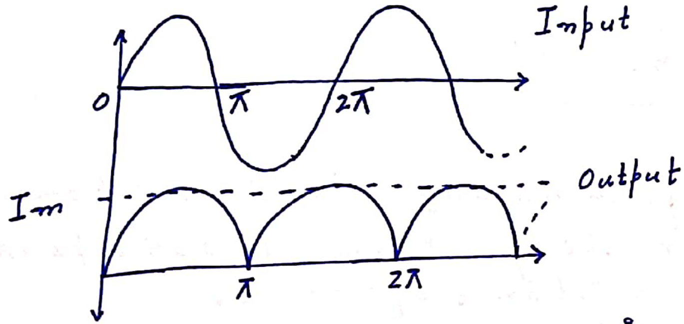
Therefore, $\eta_{max} = 0.405 = 40.5\%$

Full wave-bridge rectifier

In this rectifier, circuit configuration an ordinary transformer is used and in place of center tap transformer and it contains four diodes connected from a bridge.



$\therefore$



$I = I_m \sin\theta$

Break this. $\rightarrow 2\int_0^{\pi} I_m \sin\theta \, d\theta + \int_{\pi}^{2\pi} \cancel{I_m \sin\theta \, d\theta} \rightarrow 0$

$\therefore \quad P_{dc} = I_{dc}^2 \times R_L$

$$\therefore \quad I_{dc} = I_{av} = \frac{\int_0^{2\pi} I_m \sin\theta}{\int_0^{2\pi} d\theta} = \frac{2I_m[\cos\theta]_0^{\pi}}{2\pi}$$

$$= \frac{4 I_m}{2\pi} = \frac{2I_m}{\pi}. \quad \text{Ans.}$$

$$\Rightarrow \quad I_{dc} = I_{avg} = \frac{2I_m}{\pi}$$

$$I_{rms} = \sqrt{\frac{2\int_0^{\pi} I_m^2 \sin^2\theta}{2\pi}} = \frac{I_m}{\sqrt{2}}$$

$$\Rightarrow \quad I_{AC} = I_{rms} = \frac{I_m}{\sqrt{2}}$$

$\therefore\ P_{DC} = I_{avg}^2 \cdot R_L$

$P_{DC} = \frac{4 I_m^2}{\pi^2} \cdot R_L$

$\therefore\ P_{AC} = I_{rms}^2 \cdot (2r_f + R_L)$

$= \frac{I_m^2}{2} \cdot (2r_f + R_L)$

$\Rightarrow\ \eta = \frac{\frac{4 I_m^2}{\pi^2} \cdot R_L}{\frac{I_m^2}{2} \cdot 2r_f + R_L} = \frac{0.812}{2r_f + R_L} = 0.812 \quad (r_f = 0).$

$$\boxed{\eta_{max} = 81.2\ \%}$$

Q. A half wave rectifier having a load resistance of 1000Ω, rectifier and alternating voltage of 325 V peak value and diode has forward resistance of 100Ω.

Calculate:

(i) Peak avg and rms value of current.

(ii) DC output power

(iii) AC input power

(iv) Rectification ~~power~~ efficiency.

$\therefore$ (i) $I_{Max} = \frac{V_{max}}{R_L + r_f} = \frac{325}{1100} = 0.2954\ A$

$I_{avg} = \frac{I_M}{\pi} = \frac{0.295}{\pi} = 94.04 \times 10^{-3}\ A$

$I_{rms} = \frac{I_M}{2} = \frac{0.2954}{2} = 147.70 \times 10^{-3}\ A$

$\therefore\ P_{DC} = I_{avg}^2 \times R_L$

$= 8.84\ W$

$P_{AC} = I_{rms}^2 (r_f + R_L)$

$= 23.996\ W$

$$\therefore \eta = \frac{P_{DC}}{P_{AC}} \times 100 = \frac{8.84}{23.996} \times 100 = 36.81\ \%$$

Analyses of rectifier output

The output wave of full wave rectifier current flows in load resistor. In one direction only. But it varies in magnitude and pulsating in nature.

This pulsating output contains DC as well as AC components. It is clear that the rectifier outputs contains DC component and AC component, these undesirable AC component are called ripples.

The output of rectifier comprises of AC as well as DC component the % of AC component in rectified output is measured by ripple factor.

Ripple Factor (γ):

In a rectifier output, the ratio of RMS value of AC component to the DC component is known as ripple factor.

$$\gamma = \frac{\text{RMS value of AC component}}{\text{Value of DC component}}$$

$$\gamma = \frac{I_{ac}}{I_{dc}} \quad \text{and} \quad I_{ac}^2 = I_{rms}^2 - I_{dc}^2$$

$$\gamma = \frac{\sqrt{I_{rms}^2 - I_{dc}^2}}{I_{dc}} = \sqrt{\left(\frac{I_{rms}}{I_{dc}}\right)^2 - 1}$$

For half wave rectifier:

$$\gamma = \sqrt{\left(\frac{I_M \cdot \pi}{2\, I_M}\right)^2 - 1} = 1.21$$

It mean the AC component exceeds the DC component when the output contains more ripple.

Therefore, the half wave rectifier poorly converts AC into DC.

For full wave rectifier;

$$\gamma = \sqrt{\frac{(I_M/\sqrt{2})^2}{(2\, I_M/\pi)^2} - 1} = \sqrt{(1.11)^2 - 1} = 0.48.$$

It means the AC component is very small compared to DC current, and output contains less ripple.

Therefore, the full wave rectifier better converts AC into DC.

Q. In full wave centre-tap rectifier uses two diodes each having a forward resistance of 25Ω. The rms value of secondary winding voltage fade between centre tap. To each end of secondary winding is 48V and load resistance is $1k\Omega$. Determine (i) DC output power.

(ii) AC input power

(iii) Rectification power

(iv) Ripple factor of rectifier.

$$\therefore \quad V_{rms} = 48V$$
$$R_L = 1000\Omega$$
$$R_f = 25\Omega$$

$$\therefore \quad I_M = \frac{V_M}{r_f + R_L} = \frac{48\sqrt{2}}{25+1000} = 66.33\ mA$$

$\Rightarrow$ (i) $P_{dc} = (I_{dc})^2 \times (R_L)$

$$= \left(\frac{2\ I_M}{\pi}\right)^2 \times 1000 = 1.78\ W$$

(ii) $P_{AC} = (I_{rms})^2 \times (r_f + R_L)$

$$= \frac{(66.33\times10^{-3})^2}{(\sqrt{2})^2} \times (25 + 1000)$$

$$P_{AC} = 2.254\ W.$$

$$\eta = \frac{1.78}{2.254} \times 100 \approx 78.97\ \%.$$

(iii) $r_f = 0.48.$

Q. In 240 V, 50 Hz AC supply is applied to a 5:1 step down transformer, which is used in full-wave bridge rectifier having a load resistance of 200 Ω and each Si diode with 15 Ω forward resistance. Calculate,

(i) DC voltage across the load.

(ii) Current flowing through the diode

(iii) Rectification efficiency and ripple factor.

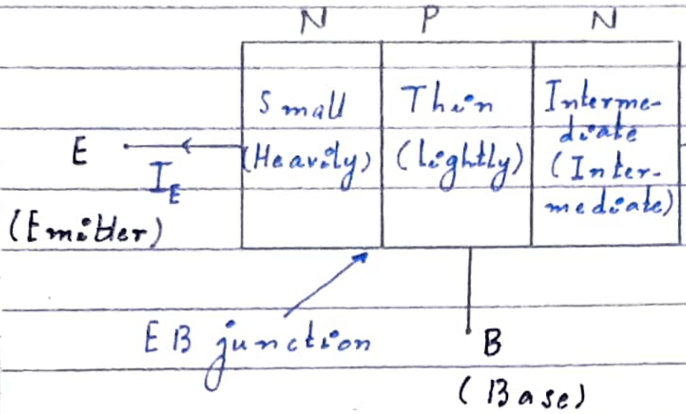
$$\therefore \quad \frac{V_1}{V_2} = \frac{N_1}{N_2}$$

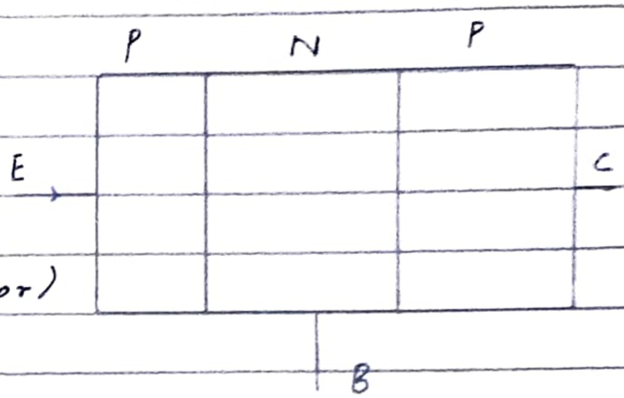
$$\therefore \quad V_2 = \frac{N_2 V_1}{N_1} = \frac{1 \times 240}{5} = 48\,V$$

$\therefore$ (i) $V_{rms} = 48\sqrt{2} = 67.88\,V.$

Transistor

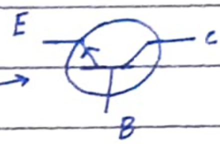
A transistor is a 3 layer semiconductor device consisting of 2 PN junction form by sandwitching either p type or n-type semiconductor between a pair of opposite type of semiconductor is called a transistor.



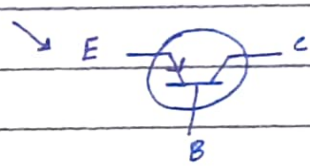


NPN Transistor

→ NPN Transistor



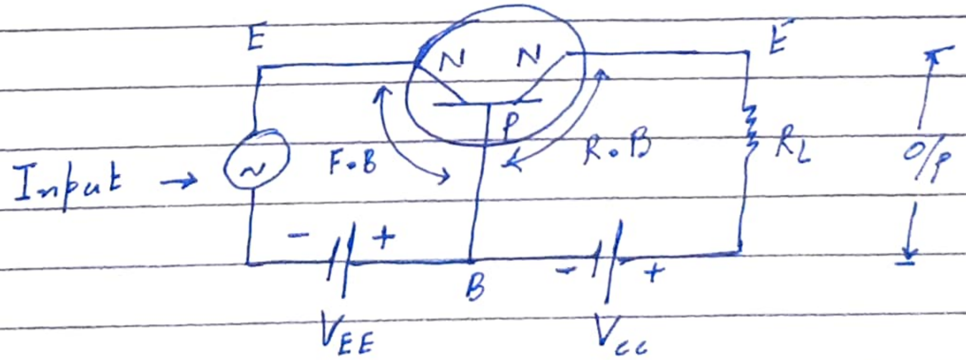
→ PNP Transistor



→ Transistor Biasing / Mode:

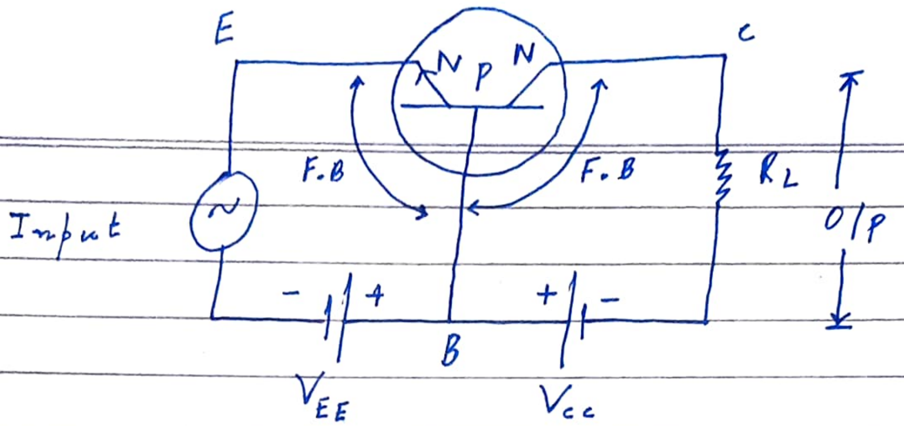
The methods of applying external voltage to a transistor is called transistor biasing. There are 3 different ways of biasing which are also known as mode of transistor operation.

1. Forward Active Mode.



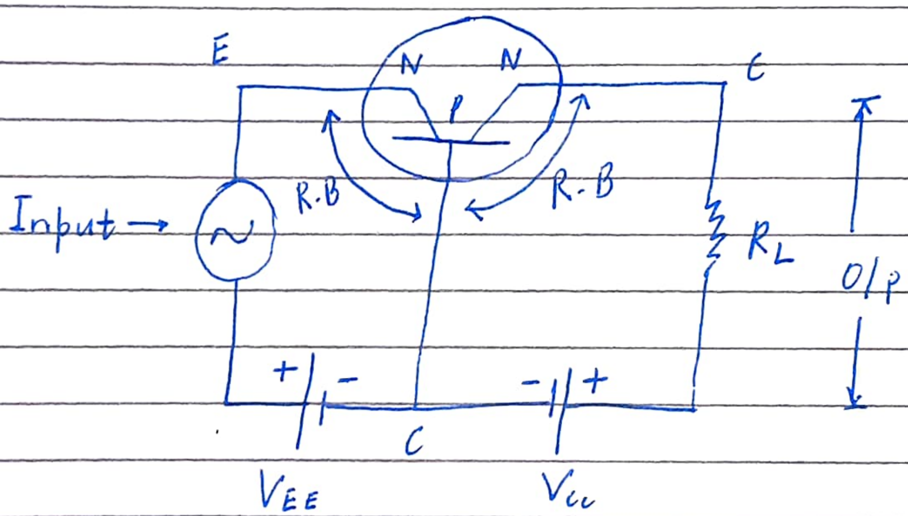
It works as an amplifier

2. Saturation Mode



It works as a closed switch.

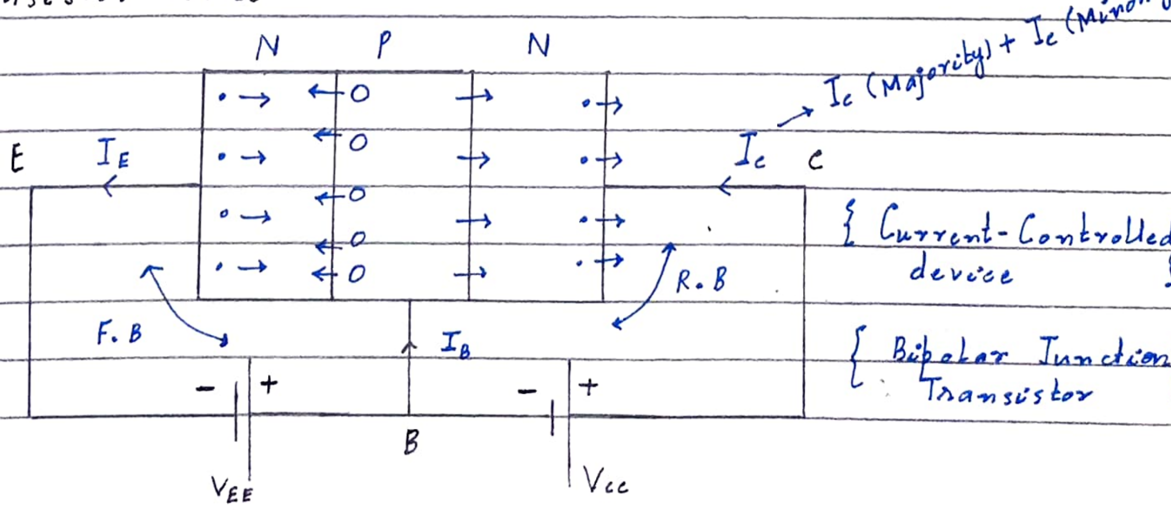
3. Cut-off Mode



It works as an open switch.

$$I_E = I_B + I_C$$

Transistor Device



{Current-Controlled device}

{Bipolar Junction Transistor}

The forward biased on emitter based junction causes the free $e^{\ominus}$ (majority carriers) in N-type emitter terminal to flow towards the base region due to this phenomena flows the emitter current I_E and when the free $e^{\ominus}$ enter into the p-type base region, they tend to combine with holes. Since the base region is lightly doped and very thin. Only few $e^{\ominus}$ combine with holes, due to this phenomena flows the base current I_B. Remaining $e^{\ominus}$ comes into the collector region and attracted by the collector, due to this phenomena flows the collector current I_C, therefore the emitter current is the sum of collector and base current.

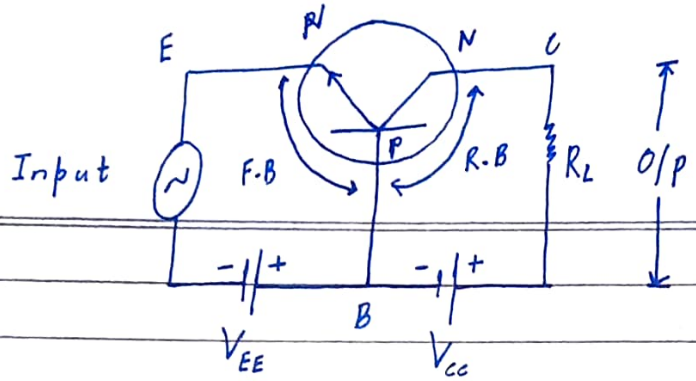
But, the collector current has two components, the majority and minority current carriers. The minority current carriers is called I_C(minority) or reverse leakage current, i.e

$$I_C = I_C(\text{majority}) + I_C(\text{minority})$$

NOTE :-
- → Transistor works as an amplifier.
- → It is a current controlled device
- → It is referred as bipolar junction transistor (BJT) because in this device current conduction takes place by the motion of charge carriers of both $e^{\ominus}$ and holes.
- → Both majority and minority carriers play important roles as a transistor.

Transistor Configuration

Transistor is configured based on common terminal, therefore transistor can be connected in an electronic circuit in three ways:



$$\text{Amplification Factor } (\alpha) = \frac{\text{Output current}}{\text{Input current}}$$

$$\alpha = \frac{I_C}{I_E} \quad (\alpha = 0.9 \text{ to } 0.99)$$

In this configuration, the base terminal of this transistor of is made common to both input and output circuit however the emitter current is the sum of collector current and base current.

Now, the amplification factor or current gain is defined as the rate of output current to input current at constant constant collector base voltage and is denoted by α.

$$\alpha = \frac{\text{Output current}}{\text{Input current}}$$

$$\alpha = \frac{I_C}{I_E} \quad (\text{At constant } V_{CB})$$

$$\alpha_{AC} = \frac{\Delta I_C}{\Delta I_E} \quad (\text{At constant } V_{CB})$$

The value of current amplification factor α is also less than unity and it's value in commercial transistor range is 0.9 to 0.99.

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

$$I_c(\text{majority}) = \alpha I_E$$

$$\therefore \quad I_C = \alpha I + I_{Co}$$

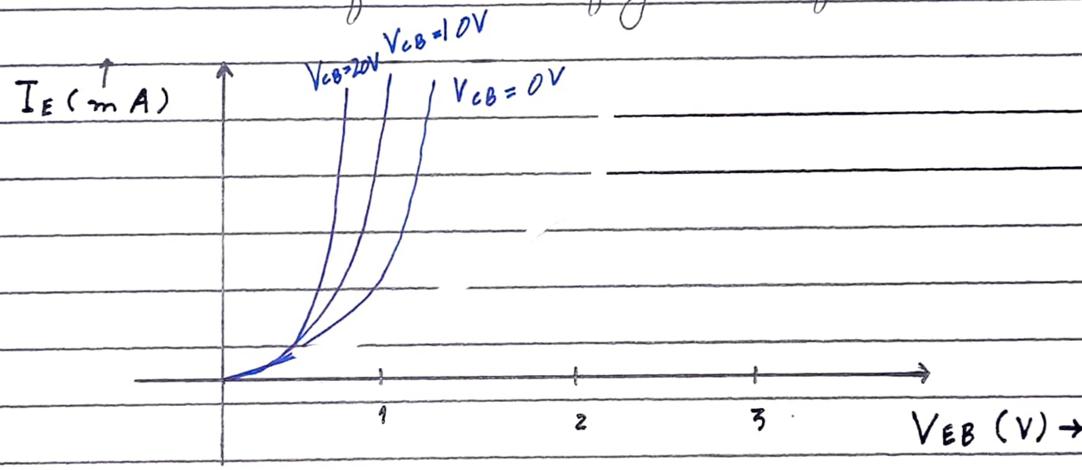
$$I_E = I_B + I$$

$$I_c = \alpha(I_B + I_c) + I_{co}$$

$$I_c(1-\alpha) = \alpha I_B + I_{co}$$

$$I_c = \frac{\alpha}{(1-\alpha)} I_B + \frac{I_{co}}{(1-\alpha)}$$

Characteristics of CB configuration of Transistor



It is very useful to analyse the transistor based circuit.
It has two important characteristics ;

1. Input Characteristics
2. Output Characteristics

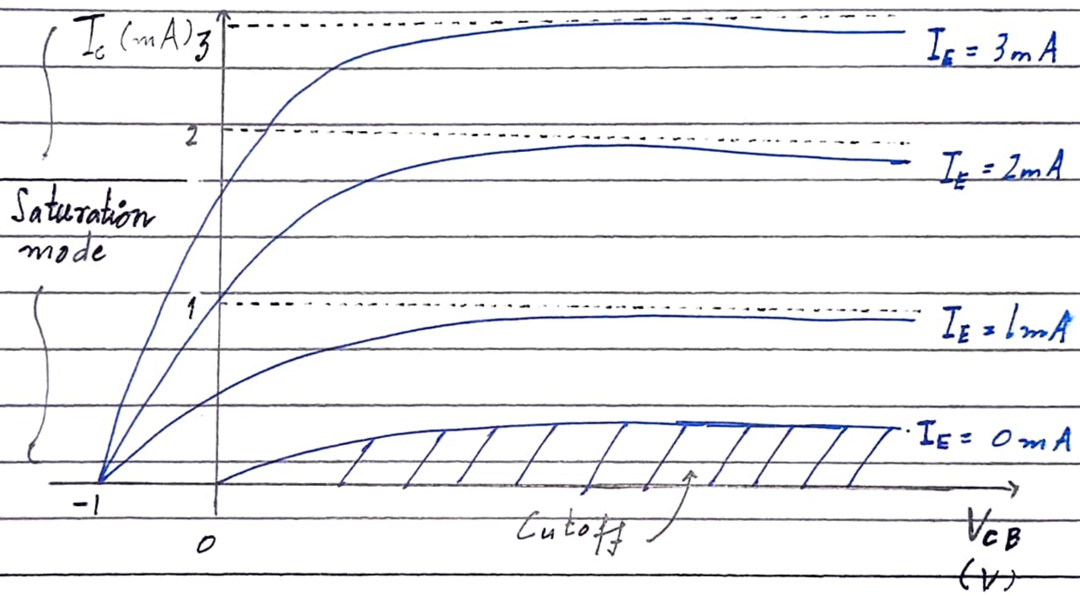
Input Characteristics

In CB configuration, the curve plotted between emitter current I_E and emitter base voltage V_{EB} at constant collector base voltage V_{CB} is called input characteristics.

When $V_{CB} = 0$ and the emitter base junction is forward biased the function behaves as a forward biased diode

characteristics so that emitter current I_E increases exponentially with small increase in emitter base voltage V_{EB}.
When V_{CB} is increased keeping V_{EB} constant, the width of base region will be decrease. This affect the emitter current I_E increases sharply and the curve shift towards the left side.
The emitter current increases exponentially with a small increase in emitter base voltage V_{EB}, as the input resistance $r_i = \frac{V_{EB}}{I_E}$ at constant V_{CB}.

→ Output Characteristics of CB configuration



In CB configuration, the curve plotted between collector current I_C and collector base voltage V_{CB} at constant emitter current I_E is called O/P characteristics.

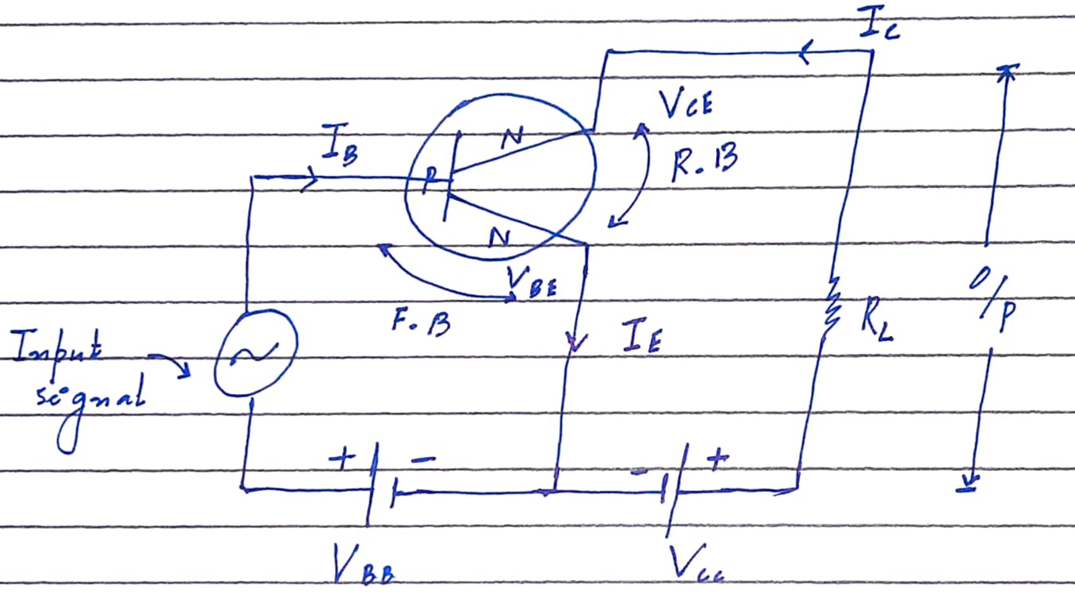
When collector base voltage is reverse biased, the I_C is most equal to the I_E. Therefore, transistor is always operated in active mode.
When V_{CB} becomes −ve, i.e collector base junction is forward biased and collector current I_C for a given emitter current I_B increases in saturation region. In this region, the collector current I_C does not depend upon the emitter current I_E, and when $I_E = 0$, collector current I_C is not equal

to zero.

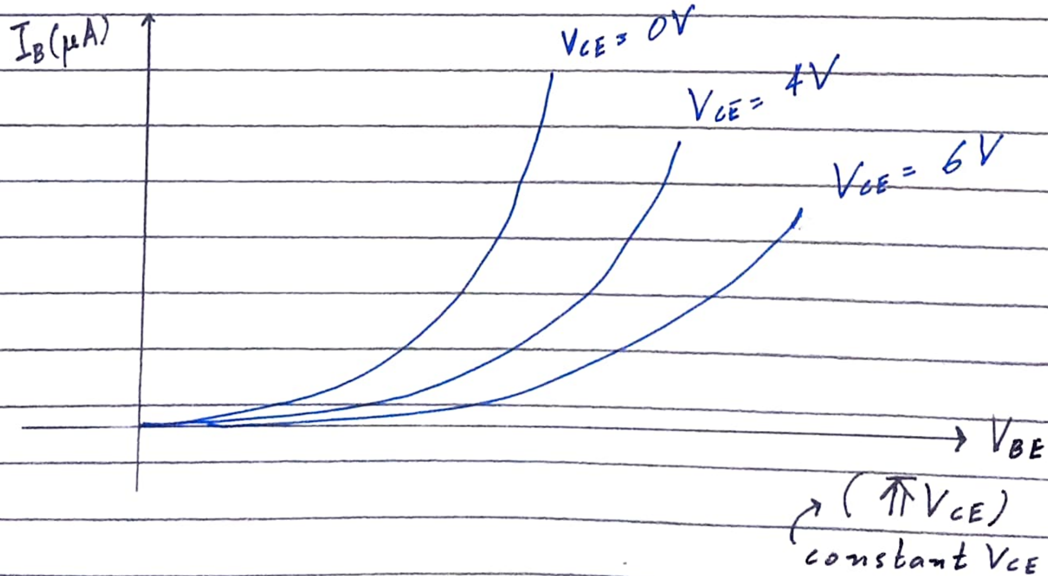
Although it's value is very small due to the reverse leakage current. I_{co} (temperature dependent current). Hence ~~the output resistance,~~

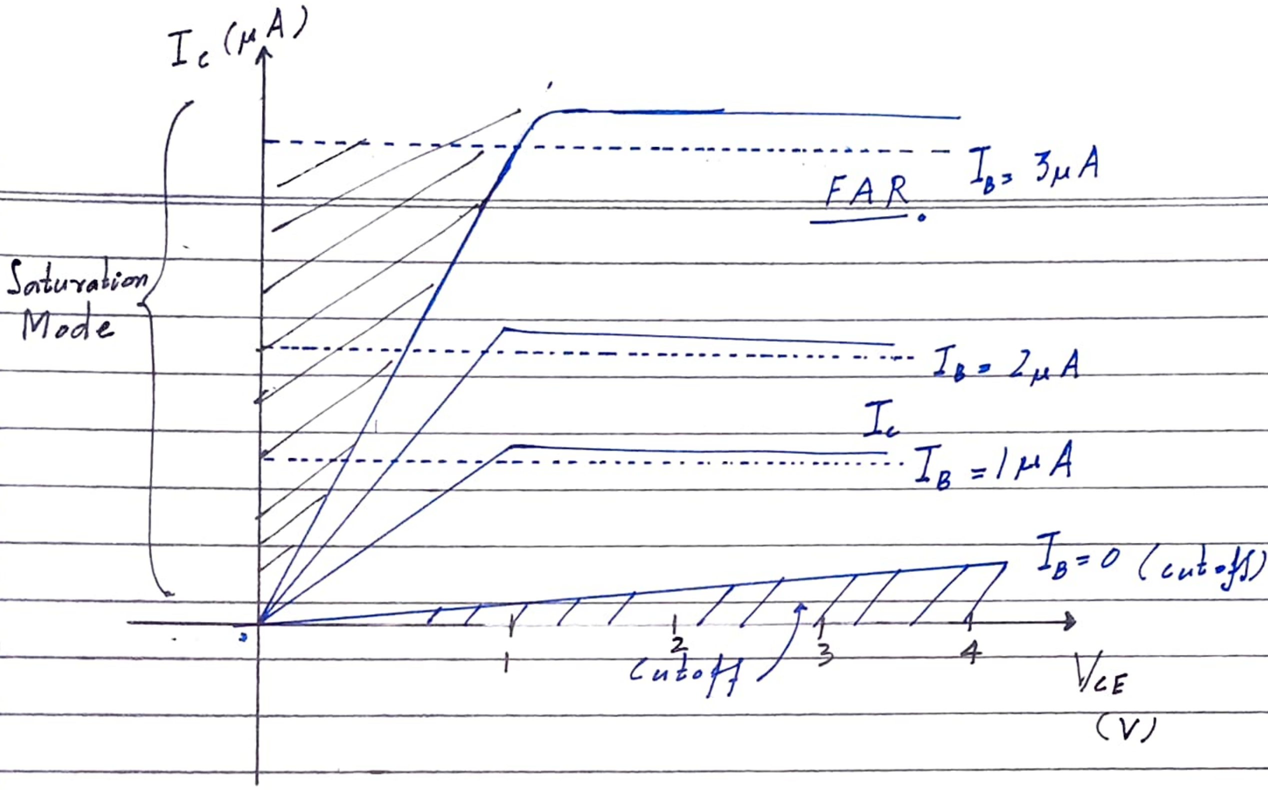
$$r_o = \frac{V_{CB}}{I_c} \text{ at constant } I_E.$$

2. Common Emitter Configuration of Transistor

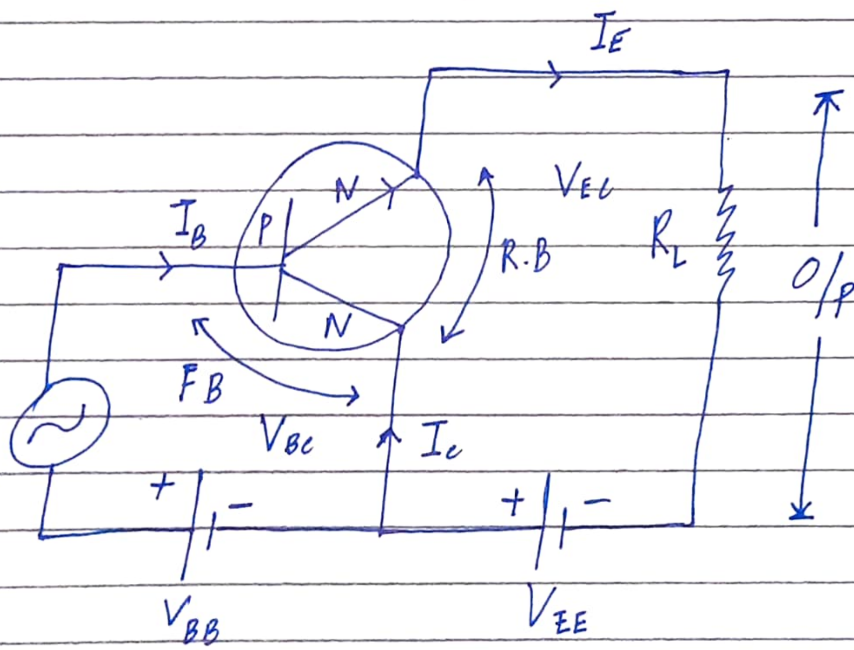


Amplification Factor : $\beta = \frac{I_c}{I_B}$ $\underbrace{(50-200)}_{\text{Commercial Range}}$





3. Common Collector Configuration



$$\text{Amplification Factor } (\gamma) = \frac{I_E}{I_B}$$

→ Relation between α and β;

$$I_E = I_B + I_c \quad (\div I_c)$$

$$I_E / I_c = I_B / I_c + 1$$

$$1/\alpha = 1/\beta + 1$$

$$\Rightarrow \boxed{\beta = \frac{\alpha}{1-\alpha}} < 1 \quad \text{and} \quad \boxed{\alpha = \frac{\beta}{\beta+1}} > 1$$

→ Relation b/w α, γ and β

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

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

These handwritten notes are of ESC-S101 taught to us by Prof. Om Pal, compiled and organized chapter-wise to help our juniors. We hope they make your prep a bit easier.

— **Saksham Nigam** and **Misbahul Hasan** (B.Tech. CSE(2024-28))