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PRINCIPLES *of* ELECTRONICS

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Chapter-05
Semiconductor Physics

Semiconductor: (Mid)

A Semiconductor is a Substance which has resistivity (10^{-4} to $0.5\ \Omega m$) inbetween conductors and insulators.
example: germanium, Silicon, carbon etc

properties of semiconductor:

(i) Resistivity of a Semiconductor is less than an insulator but more than a conductor.

(ii) Resistance of a Semiconductor decreases with the increase in Temperature.

(iii) When a Suitable metallic impurity is added to a semiconductor, its current conducting properties change appreciably.

Crystals:

A Substance in which the atoms ~~are~~ or molecules are arranged in an orderly pattern is known as a crystal.

→ All Semiconductors have crystalline structure.

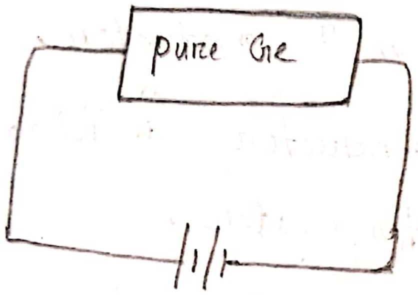
Energy required for break co-valent bonds,

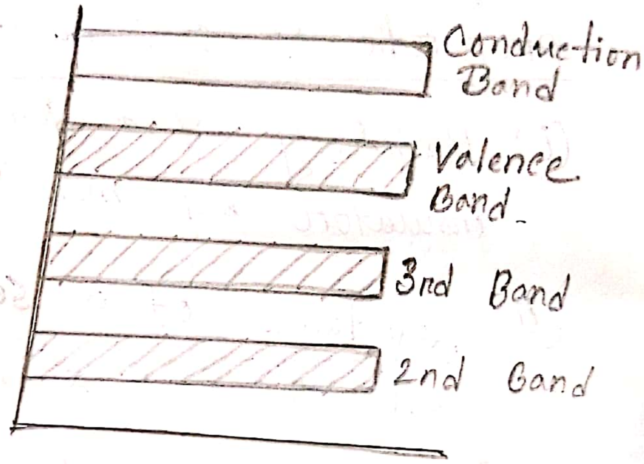
$Ge_{32} \rightarrow 0.7$ eV (valence band থেকে conduction band এ যেতে প্রয়োজনীয় energy)
$Si_{14} \rightarrow 1.1$ eV

IV Effects of temperature in Semiconductor:

(I) At absolute zero:

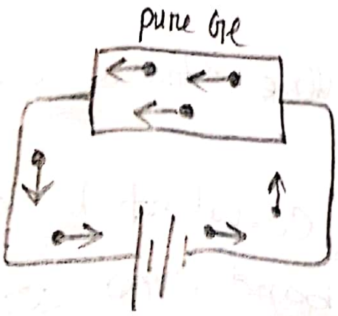
all the electrons are tightly held by the semiconductor atoms. At this temperature co-valent bond are very strong and there are no free electrons.

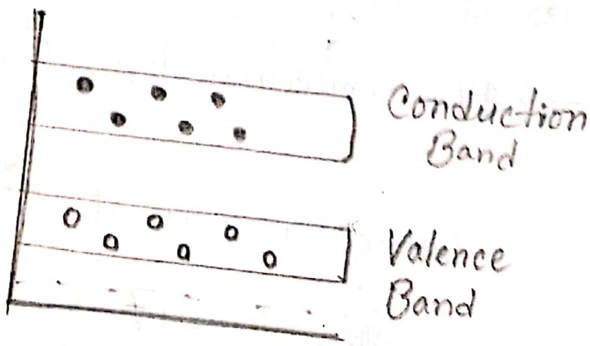




(II) Above absolute zero:

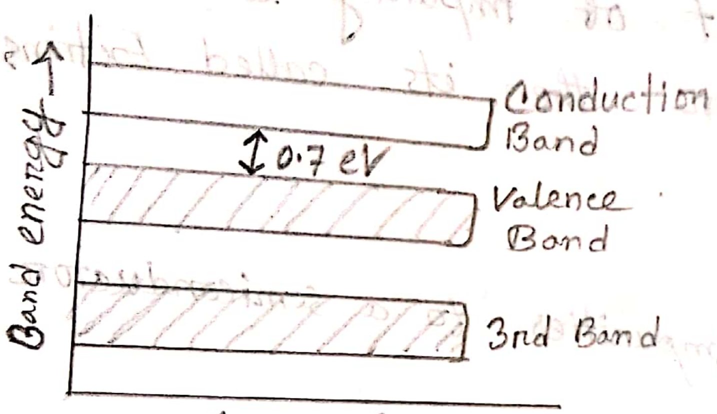
When the temperature is raised some of the covalent bonds in the semiconductor break due to the thermal energy supplied. The result is that a few free electrons exist in the semiconductor. Free electrons produce a tiny electric current if potential different is applied.



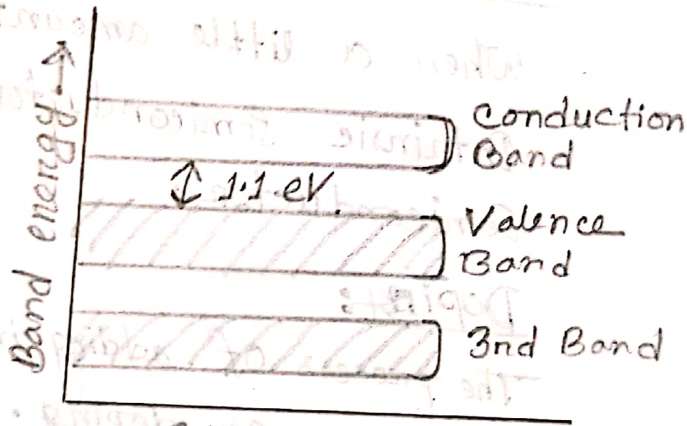


[II] Energy Band description of semiconductors

A semiconductor is a substance which has almost filled valence band and nearly empty conduction band with a very small energy gap ($\simeq 1$ eV) separating the two.



Germanium



Silicon

Forbidden energy gap is very small,
1.1 eV for Silicon & 0.7 eV for Germanium.

Therefore, relatively small energy is needed by their valence electrons to cross over the conduction band.

Types of Semiconductor

Intrinsic Semiconductor

A Semiconductor is an extremely pure form is known as an Intrinsic Semiconductor.

Extrinsic Semiconductor

When a little amount of impurity is added to Intrinsic Semiconductor then its called Extrinsic Semiconductor.

Doping:

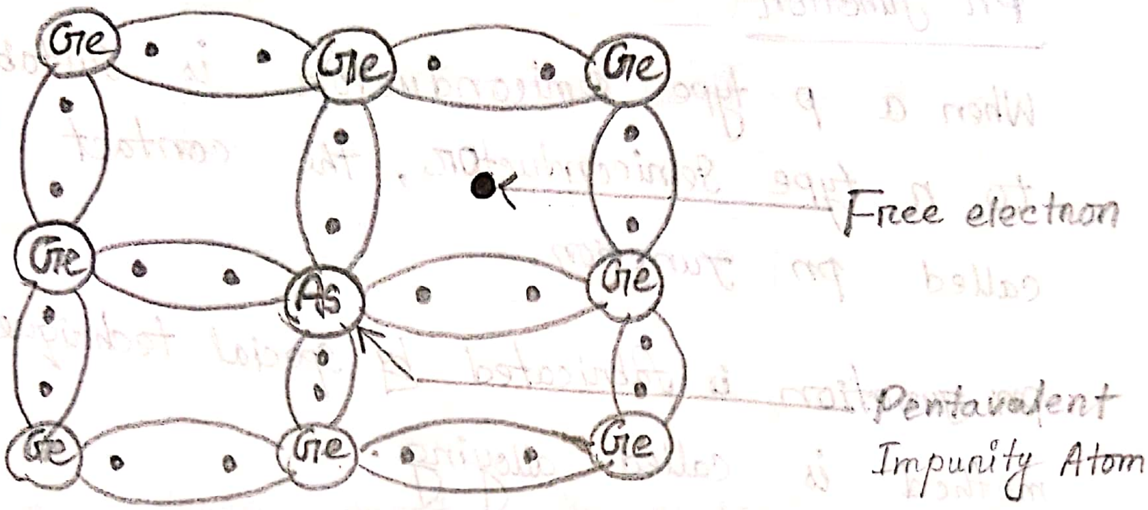
The process of adding impurities to a semiconductor is known as doping.

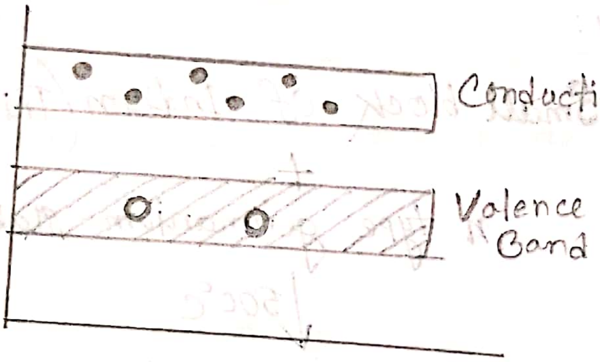
(i) n-type semi conductor
(ii) p-type semi conductor

n-type Semiconductor:

When a Small amount of pentravalent impurity is added to a pure semiconductor, it is known as n-type semiconductor.

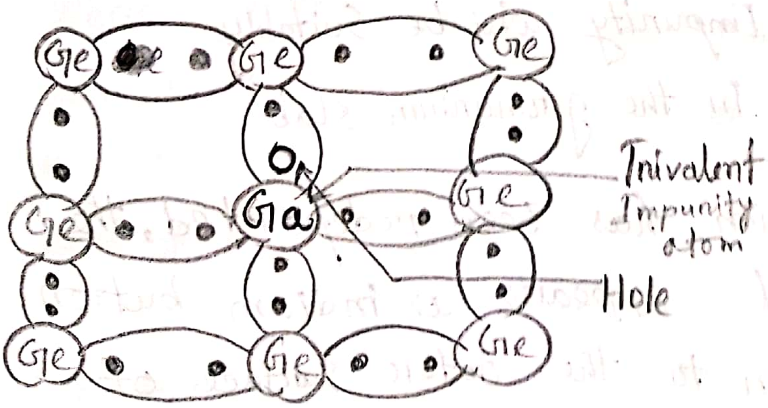
pentravalent Impurity: arsenic, antimony, phosphorus etc

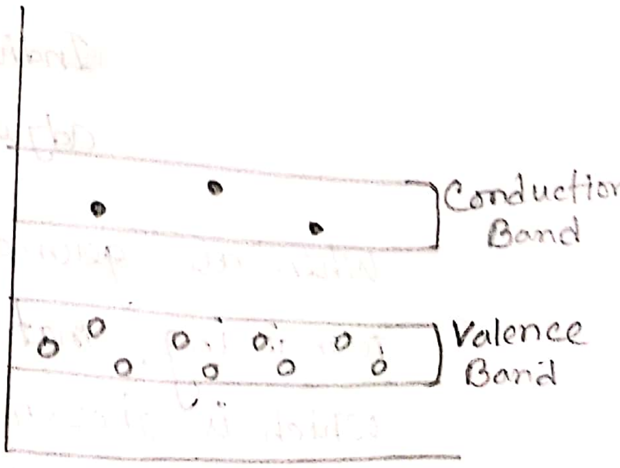




P-type Semiconductor:

When a small amount of trivalent impurity is added to a pure semiconductor, it is called p-type semiconductor.





pn Junction

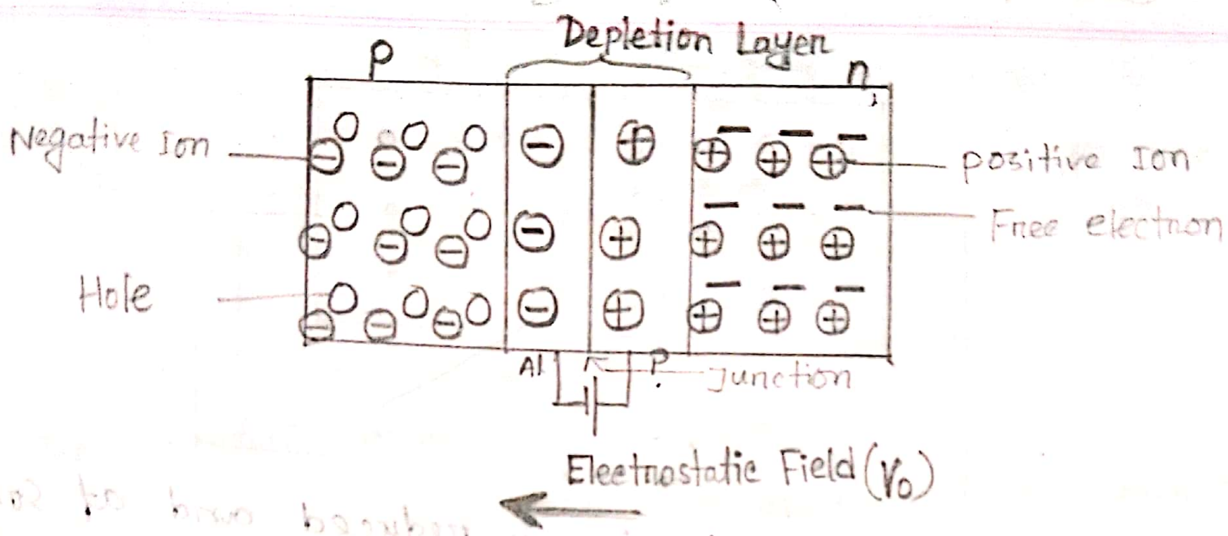
When a p type semiconductor is suitably joined to n type semiconductor, the contact surface is called pn junction.

pn junction is fabricated by special techniques. One method is called alloying.

Formation:

Small block of Indium (Trivalent Impurity)
+
n type germanium slab
↓ 500°C
puddle of germanium-Indium mixture
↓ temperature is then lowered
puddle begins to solidify
↓
Indium Impurity will be suitably adjusted in the germanium slab

When all germanium has been redeposited, the remaining material appears as indium button which is frozen on to the outer surface of the crystallised portion. The button serves as a suitable base for soldering on leads.



When depletion layer created, the diffusion of free electrons stops. The depletion region acts as a barrier. positive and negative charge set up an electric Field.

barrier potential,

For Silicon, $V_0 = 0.7\,V$

For germanium, $V_0 = 0.3\,V$

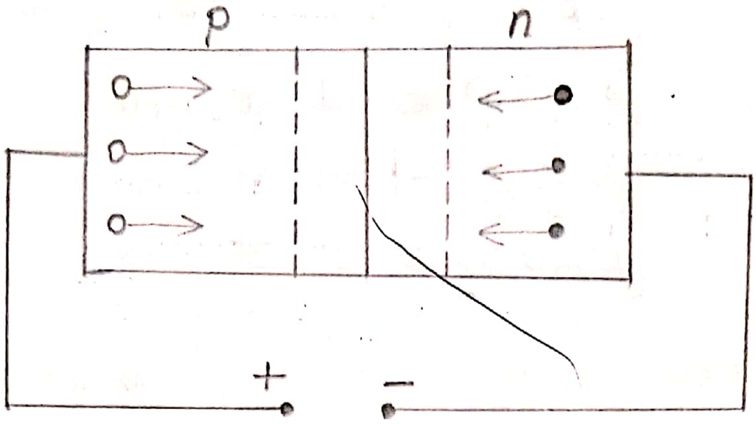
Biasing:

1. Forward biasing:

When external d.c. voltage applied to the Junction is in such a direction that it cancels the potential barrier, thus permitting current flow, it is called forward biasing.

To apply forward bias, connect positive term of the battery to p-type and negative terminal to n-type.

• Current in the n-region by free electron.
• Current in the p-region by holes.



(i) The potential barrier is reduced and at some forward voltage (0.1 to 0.3 V), it is eliminated altogether.

(ii) The junction offers low resistance to current flow.

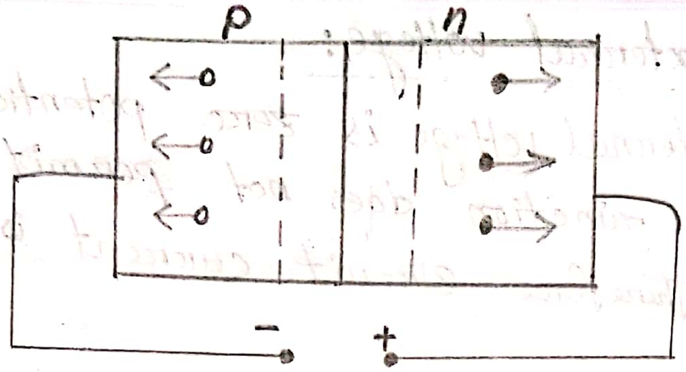
(iii) Current flows in the circuit due to the establishment of low resistance path.

2. Reverse biasing:

When the external d.c. voltage applied to the junction is in such a direction that potential barrier is increased, it is called reverse biasing.

To apply reverse bias, connect negative terminal of the battery to p-type and positive terminal to n-type.

CamScanner

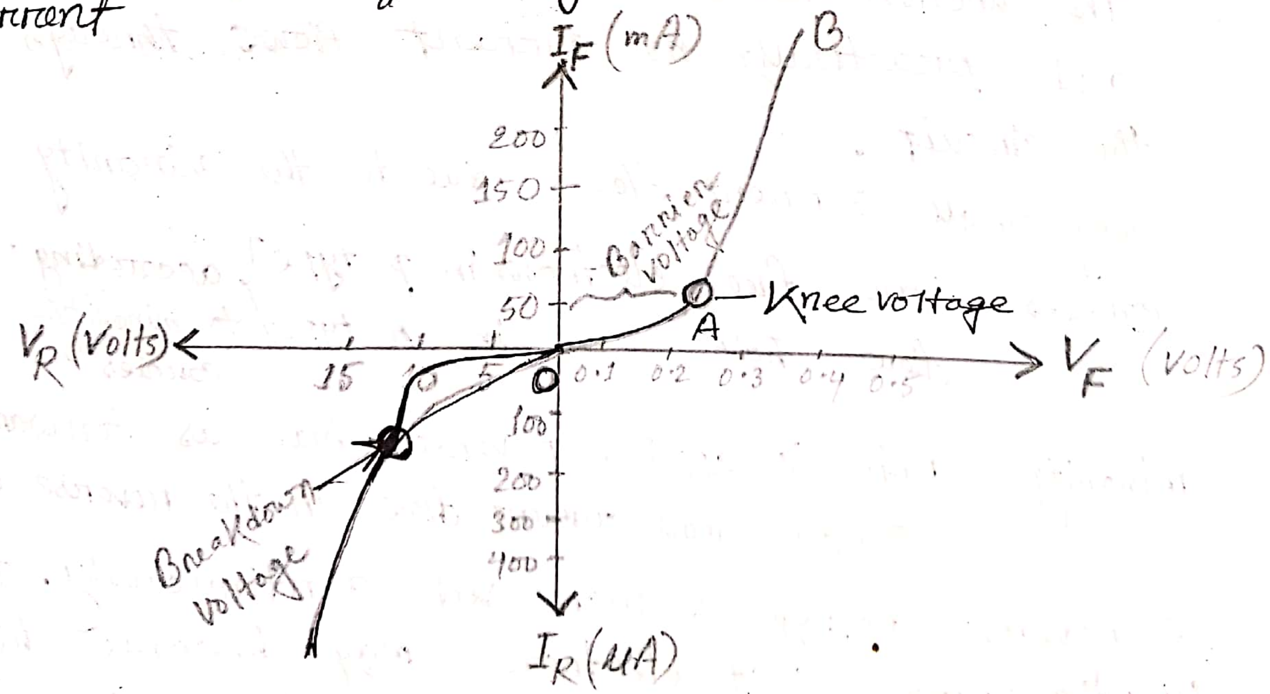


NO current flow.

(i) The potential barrier is increased.
(ii) The junction offers very high resistance to current flow.
(iii) NO current flows in the circuit due to the establishment of high resistance path.

Volt-Ampere characteristics of (pn junction/crystal/Diode):

voltage is taken along = x-axis
current " = y-axis



(i) Zero external voltage:

When external voltage is zero potential barrier at the junction does not permit current flow. Therefore circuit current is zero.

(ii) Forward bias:

potential barrier is reduced. At some forward voltage the potential barrier is altogether eliminated and current starts flowing in the circuit.

rising curve OB is obtained. OA non-linear.

AB almost linear.

(iii) Reverse bias:

The junction resistance becomes very high and practically no-current flows through the circuit.

Very small current flows due to the minority carries. few free electrons in p type, few hole in n type according to minority carries

minority carries → applied reverse bias as forward bias. Therefore small current flows in the reverse direction.

If reverse voltage is increased continuously, the kinetic energy of electrons may become high enough to knock out electrons from the semiconductor atoms. At this stage, breakdown of the junction occurs. So, we see sudden rise of reverse current, sudden fall of resistance.

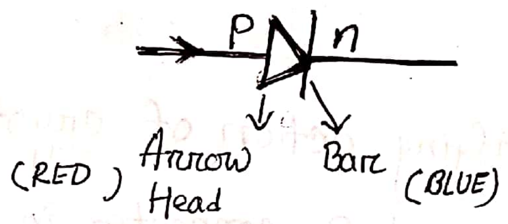
Chapter-06

Semiconductor Diode

Diode:

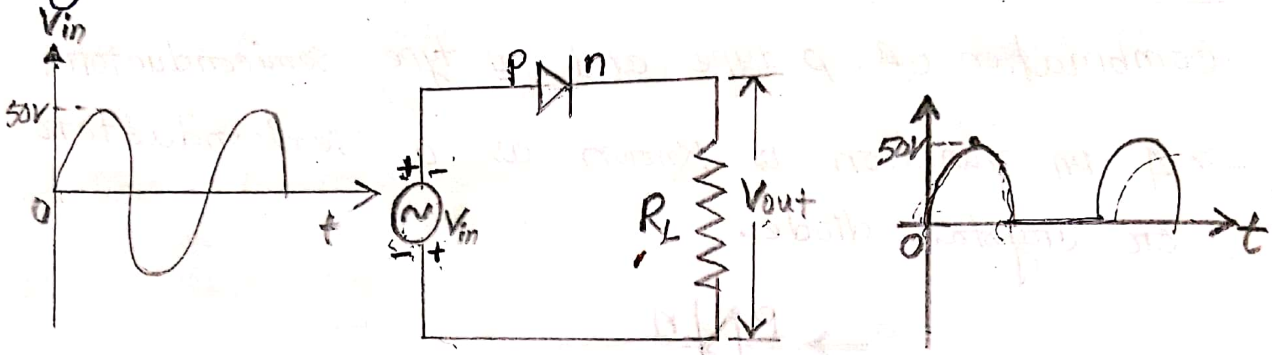
Combination of p-type and n-type semiconductor.

→ A pn junction is known as a semiconductor or crystal diode.



- Arrow Head shows the Direction of current flow.
- If Arrow Head of diode symbol is positive with respect to Bar the diode is forward biased.
- If Arrow Head is negative the diode is reverse biased.
- Reverse bias ↳ current flow হবে না।

Crystal Diode as a Rectifier: – दिष्टकारी (AC → DC)



This figure shows rectifying action of crystal Diode. The crystal Diode and Load R_L connected in Series.

During the positive half cycle of a.c input voltage the arrowHead become positive and the diode is in forward biased. And it conducts current in the circuit.

However during the negative half cycle, the ArrowHead becomes negative and the diode turns into reversed biased. Therefore diode doesn't conduct any current flow.

This way crystal diode work as a rectifier.

Resistance of crystal Diode:

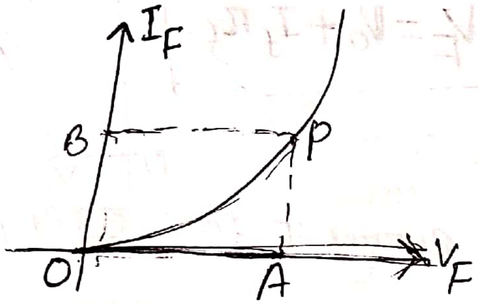
Forward Resistance: The resistance offered by the diode to forward bias is known as forward Resistance.

Forward resistance << Reverse Resistance

$V = IR$
$R = \frac{V}{I}$

(i) d.c. forward resistance:

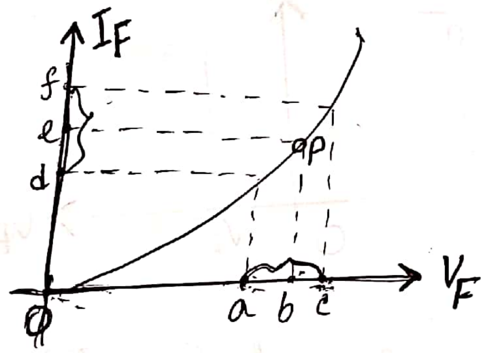
• d.c. forward Resistance, $R_f = \dfrac{\text{forward voltage}}{\text{forward current}}$



$= \dfrac{OA}{OB}$

(ii) a.c. forward resistance:

• a.c. forward resistance, $r_f = \dfrac{\text{change in volt accross diode}}{\text{Corresponding change in current through diode}}$



$\therefore$ a.c. forward resistance, $r_f = \dfrac{\text{Change in forward voltage}}{\text{Change in forward current}}$

$= \dfrac{Oc - Oa}{Of - Od}$

$= \dfrac{ac}{df}$

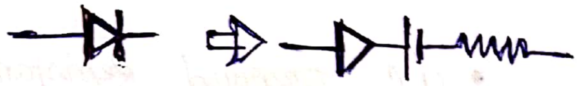
Reverse Resistance:

The resistance offered by the diode to the reverse bias is known as Reverse Resistance.

→ ~~Reverse~~ Forward Resistance of diode is ~~infinite.~~ very small (~~Ideally~~) ~~but not~~

Equivalent circuit of crystal Diode :

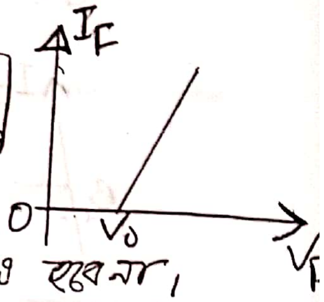
① Approximate model :

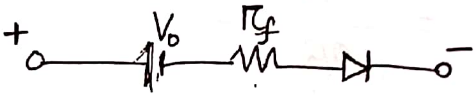


→ Potential barrier V_0

→ Internal drop $I_f r_f$

$$\boxed{V_F = V_0 + I_f r_f}$$

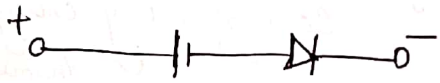




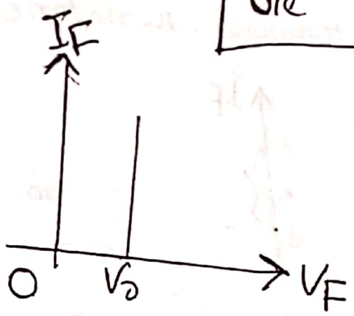
→ potential barrier break না করলে current flow হবে না।

② Simplified model :

→ r_f negligible



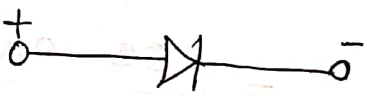
Silicon এর $V_0 = 0.7$ V
Ge এর $V_0 = 0.3$ V



③ Ideal Model :

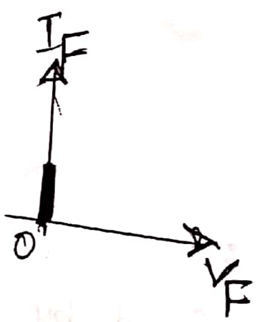
→ forward bias এ থাকলে current flow হবে।

→ Reverse bias এ থাকলে current flow হবে না।



Input = Output

$$\left.\begin{array}{l} V_0 = 0 \\ r_f = 0 \end{array}\right\} \text{negligible}$$



Important term

Forward current:

It is the current following through a forward biased diode.

Peak Inverse Voltage:

It is the maximum reverse voltage that a diode can withstand without destroying the junction.

Reverse current or leakage current:

It is the current that flows through a reverse biased diode.

Crystal Diode Rectifier:

A crystal diode rectifier is a rectifier which rectifies a.c. supply to d.c. supply. There are two types of rectifier.

- Half wave rectifier
- Full wave rectifier

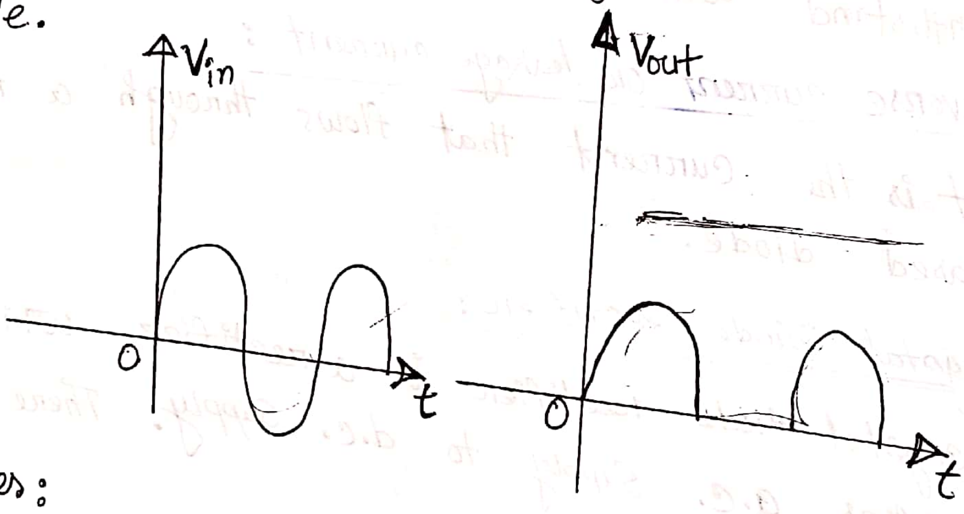
PIV: The maximum reverse voltage that appears accross the diode during reverse bias condition.

→ Secondary ~~voltage~~ transformer দিয়ে যতটুকু voltage accross হব।

- HWR এ PIV $= V_m$
- FWR এ PIV $= 2V_m$
- Bridge Rectifier এ PIV $= V_m$.

① Half wave rectifier:

The rectifier conduct current only during the positive half cycle of input a.c supply. During negative half cycles, no current is conducted and hence no voltage appears accross the load. Therefore current always flows in one direction through the load though after every half-cycle.



Disadvantages:

1. The pulsating current in the load contains alternating component whose basic frequency is equal to the supply frequency. Therefore, an elaborate filtering is required to produce steady direct current.
2. The a.c. supply delivers power only half. Therefore, the output is low.

$$\text{Average Value} = \frac{\text{area under the curve over a cycle}}{\text{Base}} = \frac{\int_0^{\pi} i\,d\theta}{2\pi}$$

Efficiency of half wave rectifier:

$$\text{Rectifier efficiency, } \eta = \frac{\text{d.c. power output}}{\text{Input a.c. power}}$$

$V = V_m \sin\theta$

r_f = diode resistance

R_L = Load resistance

d.c. power:

$$I_{av} = I_{dc} = \frac{1}{2\pi} \int_0^{\pi} i\,d\theta$$

Irms

$$= \frac{1}{2\pi} \int_0^{\pi} \frac{V_m \sin\theta}{r_f + R_L}\,d\theta$$

$$= \frac{V_m}{2\pi(r_f + R_L)} \int_0^{\pi} \sin\theta\,d\theta$$

$-\cos 180 - (-1)$

$-(-1) = (-1)$

$+1 + 1 = 2$

$$= \frac{V_m}{2\pi(r_f + R_L)} \left[-\cos\theta\right]_0^{\pi}$$

$$= \frac{V_m}{\cancel{2}\pi(r_f + R_L)} \times \cancel{2}$$

$$= \frac{V_m}{r_f + R_L} \times \frac{1}{\pi}$$

$$\left[\because I_m = \frac{V_m}{r_f + R_L}\right]$$

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

$\therefore$ d.c. power, $P_{dc} = I_{dc}^2 \times R_L$

$P = I^2 R$

$$= \left(\frac{I_m}{\pi}\right)^2 \times R_L$$

Input a.c. power:

The a.c. power input is given by,

$$P_{a.c.} = I_{rms}^2 (r_f + R_L)$$

For a half wave rectified wave, $I_{rms} = \frac{I_m}{2}$

$$\therefore P_{ac} = \left(\frac{I_m}{2}\right)^2 (r_f + R_L)$$

$\therefore$ Rectifier efficiency $= \dfrac{\text{dc output power}}{\text{ac input power}}$

$$= \frac{(I_m/\pi)^2 \times R_L}{(I_m/2)^2 \times (r_f + R_L)}$$

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

$$= \frac{0.406 R_L}{r_f + R_L}$$

$$= \frac{0.406}{1 + \frac{r_f}{R_L}}$$

The efficiency will maximum if r_f is negligible as compared to R_L.

$\therefore$ Max rectifier efficiency $= 40.6\%$

Exp ⇒ 13, 14, 15

Example-13

An a.c supply of 230 V is applied to a half wave rectifier circuit through a transformer of turn ratio 10:1. Find (i) the output d.c voltage and (ii) the peak inverse voltage. Assume the diode to be ideal.

Answer:

$$\frac{N_1}{N_2} = 10$$

RMS primary voltage $= 230\ V$

$\therefore$ Max primary voltage is, $V_{pm} = \sqrt{2} \times$ rms primary voltage

$$= \sqrt{2} \times 230 = 325.3\ V$$

$$\frac{N_1}{N_2} = \frac{V_{pm}}{V_{sm}}$$

Max secondary voltage, $V_{sm} = V_{pm} \times \frac{N_2}{N_1}$

$$= 325.3 \times \frac{1}{10}$$

$$= 32.53\ V$$

(i) $I_{dc} = \frac{I_m}{\pi}$

$\therefore V_{dc} = \frac{I_m}{\pi} \times R_L = \frac{V_{sm}}{\pi} = \frac{32.53}{\pi}$

$$= 10.36\ V$$

(Ans)

$V_{sm} = I_m R_L$

$I_m = \frac{V_{sm}}{R_L}$

$I_m R_L = V_{sm}$

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

$$I_{dc} = \frac{I_m}{\pi} \qquad I_{rms} = \frac{I_m}{2}$$

(ii) During the negative half cycle of a.c supply the diode is reversed biased and hence conducts no current. Therefore, the maximum Secondary voltage appears accross the diode.

$\therefore$ peak inverse voltage = 32.53 V.

$\boxed{\text{Example-14}}$

Given, $V = 50 \sin \omega t$; $r_f = 20\Omega$; $R_L = 800\,\Omega$

$\therefore$ Maximum voltage, $V_m = 50V$ $[\because V = V_m \sin \omega t]$

(i) $$I_m = \frac{V_m}{r_f + R_L} = \frac{50}{20+800} = 0.061\,A = 61\ mA$$

$$I_{dc} = \frac{I_m}{\pi} = \frac{61}{\pi} = 19.4\ mA$$

$$I_{rms} = \frac{I_m}{2} = \frac{61}{2} = 30.5\ mA$$

(ii) a.c power input $= (I_{rms})^2 \times (r_f + R_L)$

$$= \left(\frac{30.5}{1000}\right)^2 \times (20+800)$$

$$= 0.763 \text{ watt}$$

d.c power output $= I_{dc}^2 \times R_L$

$$= \left(\frac{19.4}{1000}\right)^2 \times 800$$

$$= 0.301 \text{ watt}$$

(iii) d.c output voltage $= I_{dc} R_L$

$= 19.4\ mA \times 800\ \Omega$

$= 15.52$ Volts

(iv) Efficiency of rectification $= \frac{0.301}{0.763} \times 100$

$= 39.5\%$

Example-15

A half wave rectifier is used to supply 50 V d.c to a resistive load of 800 Ω. The diode has a resistance of 25 Ω. Calculate a.c voltage required.

Answer:

Output d.c. voltage, $V_{dc} = 50V$

Diode resistance, $r_f = 25\ \Omega$

Load resistance, $R_L = 800\ \Omega$

V_m Let, V_m be the maximum value of a.c. voltage required,

$$V_{dc} = I_{dc} \times R_L$$

$$= \frac{I_m}{\pi} \times R_L \qquad \left[\because I_m = \frac{V_m}{r_f + R_L}\right]$$

$$= \frac{V_m}{\pi(r_f + R_L)} \times R_L$$

$$\text{or, } 50 = \frac{V_m}{\pi(25+800)} \times 800$$

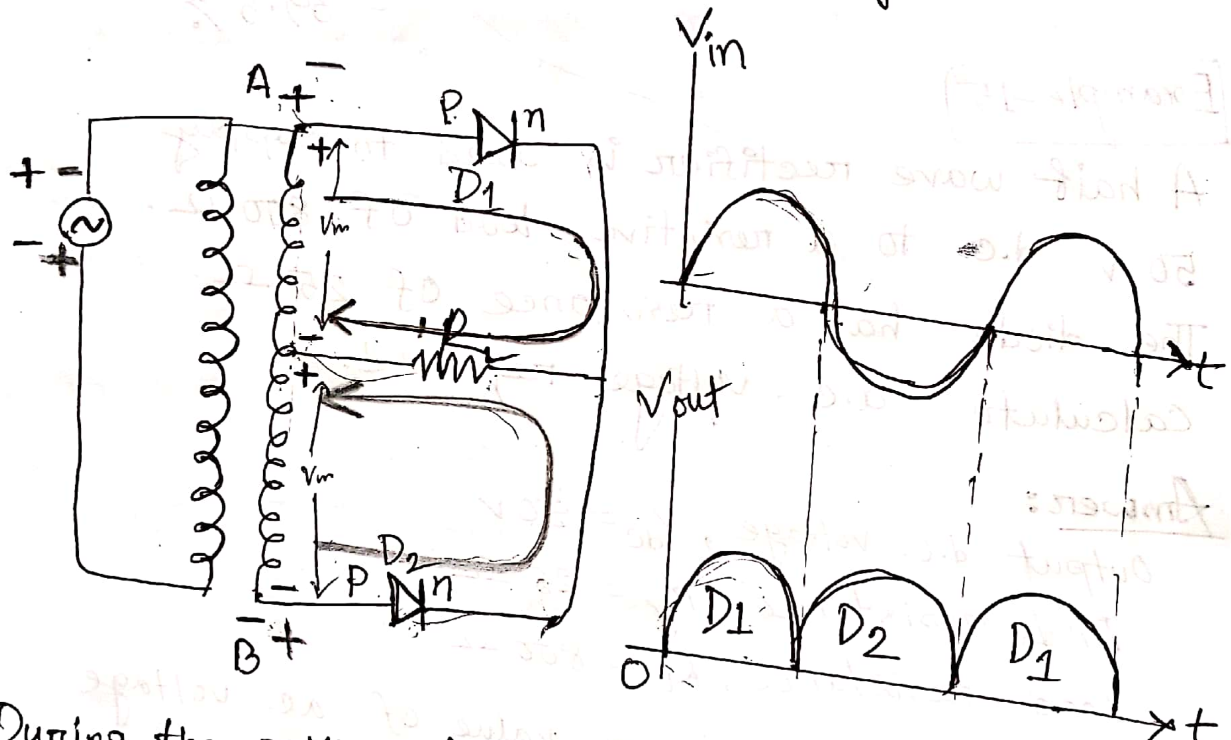
$$V_m = \frac{\pi \times 825 \times 50}{800} = 162\ V$$

Hence a.c voltage of maximum value 162 V is required.

Full wave Rectification : In full wave rectification, current flows through the load in the same direction for both half cycle of input a.c voltage.

Centre tap full wave Rectifier :

Transfer এর ব্যবহার থেকে তার টানা হবে।



During the positive half cycle A is positive, B is Negative. This makes D_1 ~~Posi~~ forward biased and D_2 reverse biased. So, D_1 flow current but D_2 not.

During the negative half cycle B is positive & A is negative. This makes D_2 forward biased and D_1 reverse biased. So, D_2 flow current but D_1 not. It seen that in both half cycle current flow in the same direction through Load R_L.

Peak inverse voltage (PIV) = $2V_m$

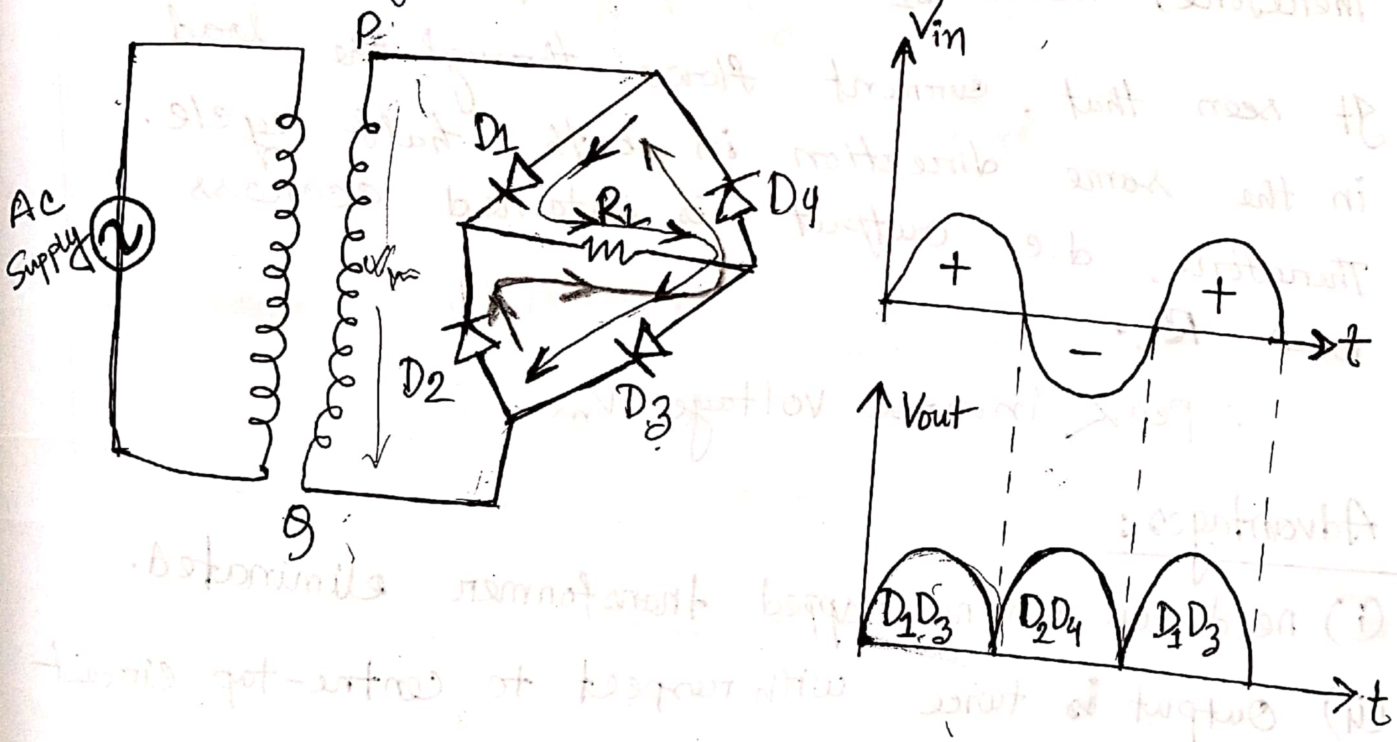
Disadvantages :

(i) difficult to locate centre tap on the secondary winding.

(ii) d.c. output is small as each diode utilies only one-half.

(iii) diodes used must have high peak inverse voltage.

Full-wave Bridge Rectifier :



The need for a centre tapped power transformer is eliminated in the bridge rectifier.

During the positive half cycle of secondary voltage, the P of the secondary winding becomes positive and end Q negative. This makes Diode D_1 and D_3

forward biased while diode D_2 and D_4 are reverse biased. Therefore diodes D_1 and D_3 only conduct current.

During the negative half cycle of secondary voltage the the P is negative and Q beomes positive. This makes Diode D_2 and D_4 forward biased and D_1 and D_3 are reversed biased. Therefore, diodes. D_2 and D_4 only conduct current.

It seen that, current flows through the load in the same direction in both half cycle. Therefore, d.c output is obtained accross load- R_L.

$\therefore$ peak inverse voltage V_m.

Advantages:

(i) need for centre tapped transformer eliminated.
(ii) Output is twice with respect to centre-tap circuit
(iii) PIV is half with respect to centre-tap circuit (for same d.c output)

Disadvantage:

(i) Requires four diodes
(ii) voltage drop in the internal resistance ~~for~~ is twice for each half cycle WRT centre-tap circuit. because input diodes that conducts are in Series.

Efficiency of full wave Rectifier :

$$V = V_m \sin\theta$$

instantaneous current, $i = \dfrac{V}{r_f + R_L} = \dfrac{V_m \sin\theta}{r_f + R_L}$

d.c. output power :

$$I_{dc} = \frac{2 I_m}{\pi}$$

$\therefore$ d.c. power output, $P_{dc} = I_{dc}^2 \times R_L$

$$= \left(\frac{2 I_m}{\pi}\right)^2 \times R_L$$

a.c. ~~power~~ input power :

$\therefore$ a.c input power is,

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

For a full wave rectified wave, we have, $I_{rms} = I_m/\sqrt{2}$

$$P_{ac} = \left(\frac{I_m}{\sqrt{2}}\right)^2 (r_f + R_L)$$

Max ac Voltage = RMS secondary voltge $\times \sqrt{2}$

$\therefore$ Full wave rectification efficiency is

$$\eta = \frac{P_{dc}}{P_{ac}} = \frac{\left(2I_m/\pi\right)^2 R_L}{\left(\frac{I_m}{\sqrt{2}}\right)^2 (r_f+R_L)}$$

$$= \frac{8\cancel{I_m^2}}{\pi^2} \times \frac{R_L}{\cancel{I_m^2}(r_f+R_L)}$$

$$= \frac{0.812\, R_L}{r_f+R_L}$$

$$= \frac{0.812}{1+\frac{r_f}{R_L}}$$

The efficiency will be maximum if r_f is negligible as compared to R_L.

$\therefore$ Maximum efficiency $= 81.2\%$

$\boxed{\text{Example-16}}$

$r_f = 20\,\Omega \qquad R_L = 980\,\Omega$

Max a.c. voltage, $V_m = 50 \times \sqrt{2}$
$= 70.7\ V$

Max load current, $I_m = \frac{V_m}{r_f+R_L} = \frac{70.7V}{(20+980)\Omega}$
$= 0.0707\ A$
$= 70.7\ mA$

CamScanner

(i) $\underbrace{\text{Mean load current}}_{\text{d.c. current}}$, $I_{dc} = \frac{2I_m}{\pi}$

$$= \frac{2\times70.7}{\pi} = 45\ mA$$

(ii) RMS value of load current, $I_{rms} = \frac{I_m}{\sqrt{2}}$

$$= \frac{70.7}{\sqrt{2}}$$

$$= 50\ mA$$

(Ans)

$\boxed{\text{Example-20}}$

$r_f = 1\,\Omega$

$R_L = 480\,\Omega$

Max a.c voltage, $V_m = 240\times\sqrt{2}\ V$

(i) In bridge rectifier, two diodes in series are conducting. $\therefore$ total circuit resistance $= 2r_f + R_L$

Max load current, $I_m = \frac{V_m}{2r_f + R_L}$

$$= \frac{240\sqrt{2}}{2\times1 + 480}$$

$$= 0.7\ A$$

$\therefore$ Mean load current, $I_{dc} = \frac{2I_m}{\pi} = \frac{2\times0.7}{\pi}$

$$= 0.45\ A$$

(ii) power dissipated in each diode

Since each diode conducts only half a cycle, diode rms current is :

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

$$= \frac{0.7}{2} = 0.35\,A$$

power dissipated in each diode $= I_{r.m.s}^2 \times r_f$

$$= (0.35)^2 \times 1$$

$$= 0.1225\,A$$

Ans.

Ripple Factor:

The output of a rectifier consists of a d.c. component and an ac component is known as Ripple.

→ The ratio of r.m.s value of a.c component to the d.c. component in the rectifier output is known as ripple factor.

$$\text{Ripple factor} = \frac{\text{r.m.s value of ac component } (I_{ac})}{\text{value of d.c component } (I_{dc})}$$

Mathematical analysis:

the effective (r.m.s) value of total load current, $I_{rms} = \sqrt{I_{dc}^2 + I_{ac}^2}$

$$I_{ac} = \sqrt{I_{rms}^2 - I_{dc}^2}$$

$$\frac{I_{ac}}{I_{dc}} = \frac{1}{I_{dc}} \sqrt{I_{rms}^2 - I_{dc}^2}$$

$\left\{ \frac{I_{ac}}{I_{dc}} \right.$ is the ripple factor.

$$\therefore \text{Ripple factor} = \frac{1}{I_{dc}} \sqrt{I_{rms}^2 - I_{dc}^2}$$

$$\boxed{\therefore \text{Ripple factor} = \sqrt{\left(\frac{I_{rms}}{I_{dc}}\right)^2 - 1}}$$

(i) For half wave Rectification:

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

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

$$\therefore \text{Ripple factor} = \sqrt{\left(\frac{\frac{I_m}{2}}{\frac{I_m}{\pi}}\right)^2 - 1}$$

$$= \sqrt{\frac{\cancel{I_m^2}}{4} \times \frac{\pi^2}{\cancel{I_m^2}} - 1}$$

$$= 1.21$$

It is clear that a.c. components exceeds the d.c. components in the output. So, half wave rectifier is ineffective for conversion of a.c. into d.c.

(ii) For full wave Rectification:

$$I_{rms} = \frac{I_m}{\sqrt{2}}$$

$$I_{dc} = \frac{2 I_m}{\pi}$$

$$\therefore \text{Ripple factor} = \sqrt{\left(\frac{I_m/\sqrt{2}}{2I_m/\pi}\right)^2 - 1}$$

$$= \sqrt{\frac{\cancel{I_m^2}}{2} \times \frac{\pi^2}{4\cancel{I_m^2}} - 1}$$

$$= 0.48$$

This shows that, the d.c. component is more than the a.c. component. For this reason, full wave rectification is invariably used for conversion of a.c. into d.c.

Filter circuit:

A filter circuit is a device which removes the a.c. component of rectifier output but allows the d.c. component to reach the load.

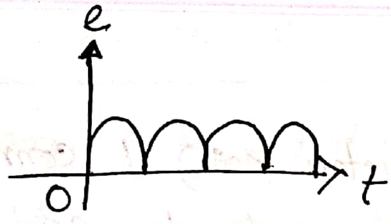
Output of a.c has pulsating character which contains ac. and d.c. component. A filter circuit is generally a combination of inductors (L) and capacitors (C) $\rightarrow$ capacitor does not allow d.c. to pass.

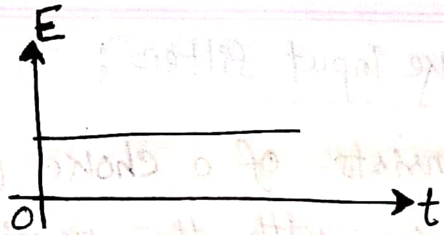
Inductors (L) $\rightarrow$ It allows d.c. to pass through it.

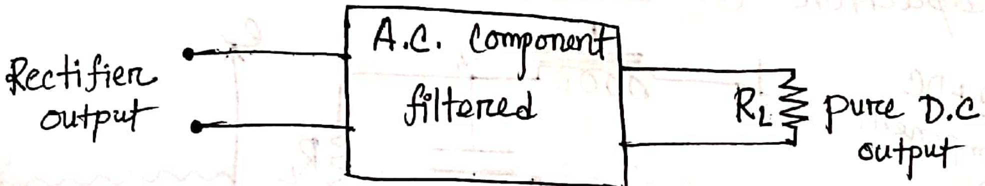
$X_c = \frac{1}{2\pi f C}$ $\quad X_L = 2\pi f L$ $\quad$ DC $\rightarrow f = 0$

AC $\rightarrow f$ = big value

Choke = inductor coil





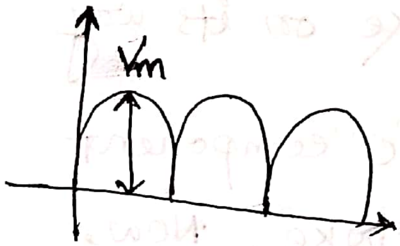


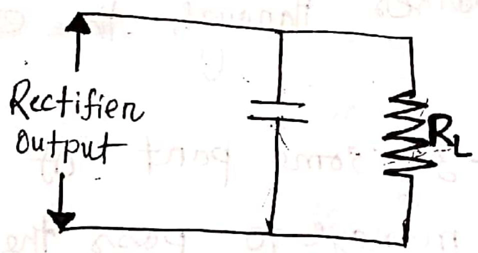
Filter Circuit

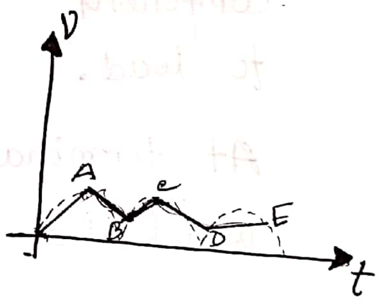
Types of Filter Circuits :

(i) Capacitor filter:

It consists of a capacitor C placed accross the rectifier output in parallel with load R_L.





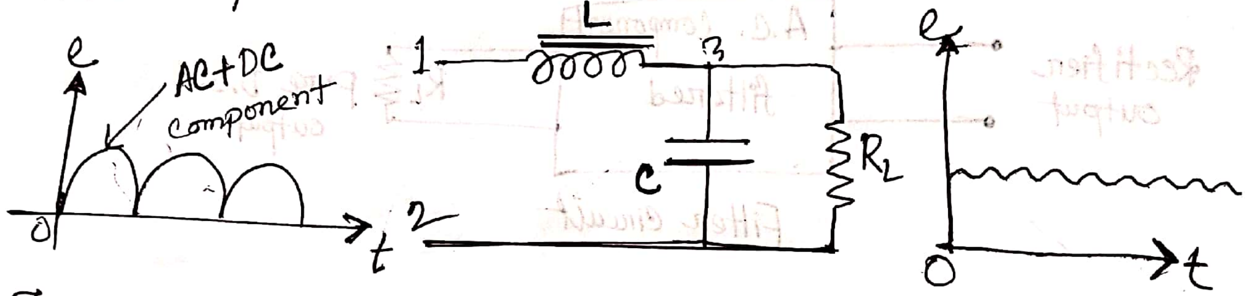


The capacitor is charged to the peak value V_m of the rectifier voltage. Now the rectifier voltage starts to decrease. The voltage across load will decrease only slightly because immediately the next voltage peak comes and recharges the capacitor. It seen that very little ripple is left in the output.

The capacitor filter circuit is extremely popular because of its low cost, small size, little weight & good characteristics.

(ii) choke input filter :

It consists of a choke (inductor coil) L connected in series with the rectifier output and a filter capacitor C accross the load.

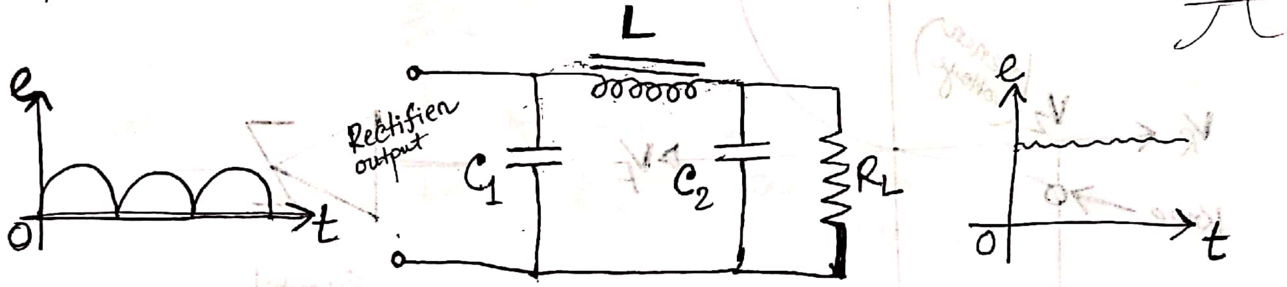


The pulsating output of rectifier contains a.c. and d.c. components. The choke (inductor coil) offers high opposition to the a.c. component but negligible opposition to the d.c. component. So, d.c. Component passes through the choke on its way to load.

At terminal-3 some part of a.c component which has manage to pass the choke. Now, by filter capacitor a.c. component pass but prevents the d.c. component to flow through it. Therefore only d.c. components reaches the load.

(iii) Capacitor input filter or π-filter:

It consists of a filter capacitor C_1 connected across the ~~a~~ rectifier output, a choke L in series and another filter capacitor C_2 connected accross the load.



(i) filter capacitor C_1 allows a.c not d.c. So, d.c component continues its journey to the choke L.

(ii) Choke 'L allows d.c to flow through it, while the a.c. component is blocked.

(iii) filter capacitor C_2 bypass the ac component which the choke has failed to block. Therefore, only d.c. component appears accross the load.

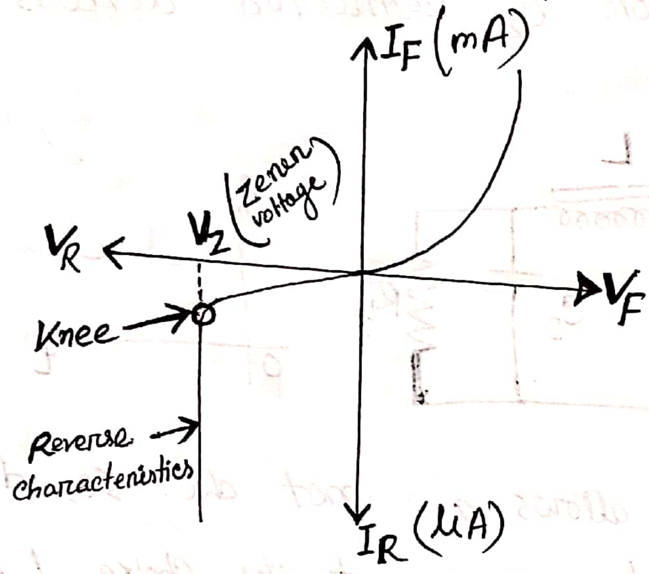
Voltage Stablisation:

~~power supply is that~~ The output voltage changes with the variations in the input voltage or load is a major problem. In many electronic applications, it is desired that the output voltage should remain constant regardless of the variations in the input voltage or load. In order to ensure this, a voltage stablising device called voltage stabliser is used.

a voltage stabliser.

Zener Diode : Heavily dopped Reverse bias এ use হয়।

A properly dopped crystal diode which has a sharp breakdown voltage is known as zener diode.




Symbol

→ Designed to operate under reverse bias in the breakdown region.

→ Used for voltage regulation.

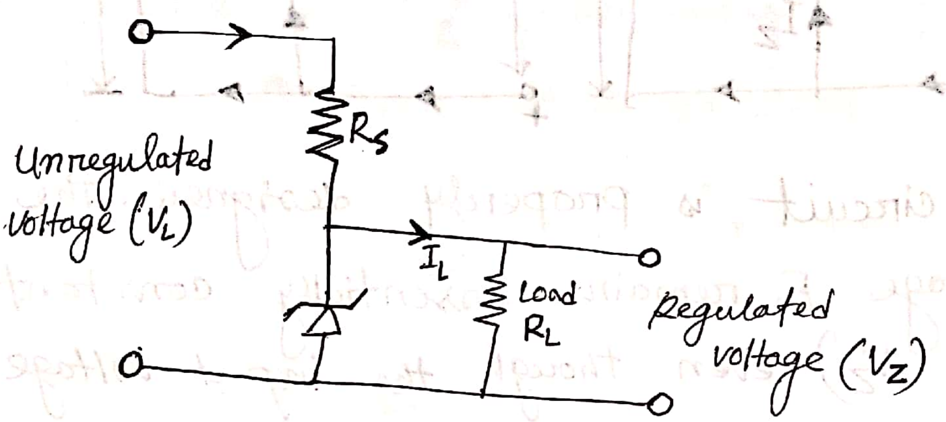
→ When the applied reverse bias voltage (V) reaches the breakdown voltage (V_Z) of the zener diode, there is a large change in the current.

Zener voltage remains constant, even though current through the zener diode varies over a wide range.

This property of the zener diode is used for regulating supply voltages so that they are constant.

Zener diode as a voltage regulation:

To get a constant dc voltage from the dc unregulated ~~output~~ Input of a rectifier, we use a Zener diode.



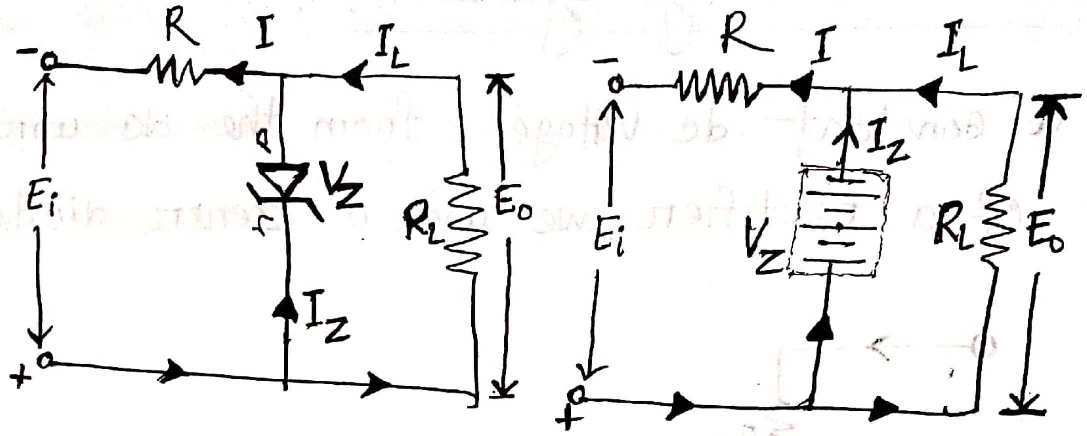
any increase/decrease in the input voltage result in, increase/decrease of the voltage drop R_s, without any change in voltage across the zener diode.

Thus the zener diode acts as a voltage regulator.

| Voltage across the zener diode $\geq$ Zener voltage |

The zener diode of zener voltage V_Z is reverse connected across the load R_L across which constant output is desired.

voltage breakdown অঞ্চলে রাখতে হবে।



When the circuit is properly designed, the load voltage E_o remains essentially constant (equal to V_Z) even though the input voltage E_i and load resistance R_L may vary over a wide range.

<u>input voltage variable, Load resistance constant:</u>

Suppose the input voltage increase. Since the zener is in the breakdown region, the Zener diode is equivalent to a battery V_Z. It is clear that output voltage remain constant at V_Z. The excess voltage is dropped across the series resistance R.

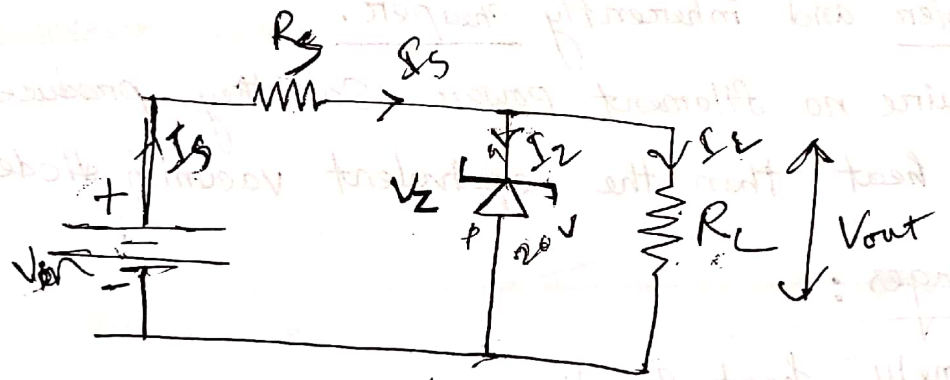
The zener will conduct the increase of current in I while the load current remains constant.

~~input voltage constant, load resistance variable:~~

Reverse bias

- Applied voltage < zener voltage
  → open circuit (as like as normal diode)
- $\boxed{\text{Applied voltage} \geq \text{Zener voltage} \rightarrow \text{Zener voltage এর সমান}}$

Forward bias → As like as normal diode.



$R = \frac{V}{I}$

R_s is used to limit the reverse current through the zener diode to safe value. Voltage Source V_{in} and R_S are selected that the diode operates in breakdown region. Diode voltage in this region is called as zener voltage V_Z, which is also voltage across R_L. $\boxed{V_0 \geq V_Z}$ need to follow

Zener diode Starts conducting.

(I) V_{in} Variable, R_L constant.

(II) V_{in} constant, R_L variable.

Voltage increase করলে R_S এ Voltage drop increase করবে V_{out} constant থাকবে without effect I_L.

Crystal Diodes Vs Vacuum Diodes:

Semiconductor Diodes (crystal Diode) have a number of advantages and disadvantages as compared to their electron tube counterparts (Vacuum diodes)

Advantages :

(i) Smaller, rugged and have a longer life.

(ii) Simpler and inherently cheaper.

(iii) require no filament power. So, they produce less heat than the equivalent vacumm diodes.

Disadvantages :

(i) extremely heat Sensitive.
If temperature exceed the rated value of Diode the increased flow of current may produce enough heat to ruin the pn Junction. On the other hand, vacuum diodes function normally over a wide range of temperature changes.

(ii) handle Small currents and low inverse voltage as compared to vaccum diodes.

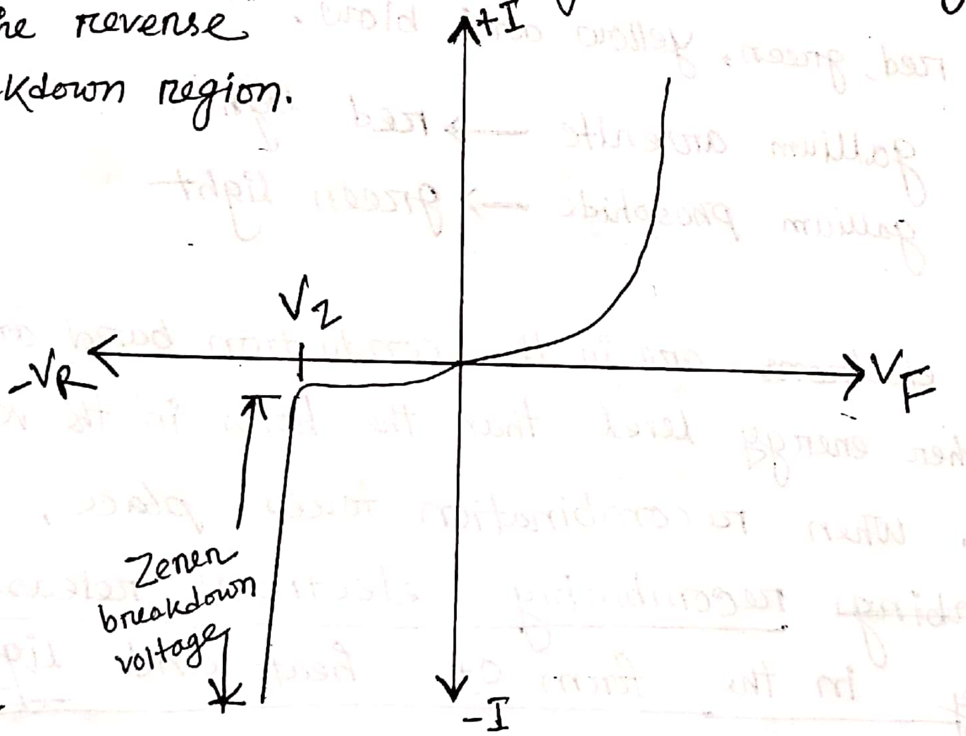
(iii) They cannot stand an overload even for a short period. Vacuum diode can stand an overload for a short time.

Chapter-7
Special purpose Diodes

Zener Diode

A properly dopped crystal diode which has a sharp breakdown voltage is known as zener diode.

→ A zener diode is heavily doped to reduce the reverse breakdown voltage which is designed to operate in the reverse breakdown region.



two things happended when V_Z is reached:

(i) The diode current increases rapidly.

(ii) The reverse voltage V_Z across the diode remains almost constant.

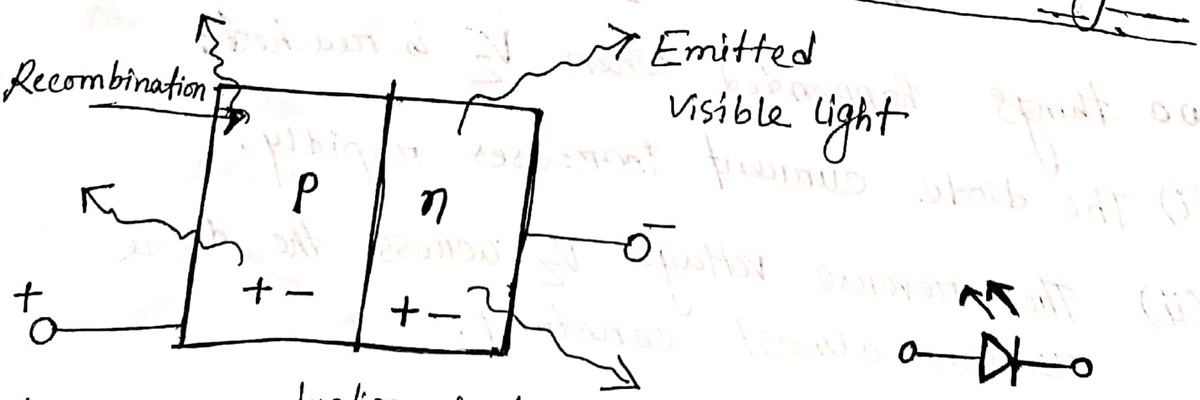
LED (Light-Emitting Diode)

A light emitting diode (LED) is a diode that gives off visible light when forward biased.

By varying the quantities of these elements, (gallium, phosphorus, arsenic) it is possible to produce light of different wavelengths with colours that include red, green, yellow and blow.

gallium arsenite ⟶ red light
gallium phosphide ⟶ green light

⇒ Free electrons are in the conduction band and at a higher energy level than the holes in the valence band. When recombination takes place, the ~~recombinge~~ recombining electrons release energy in the form of heat and light.

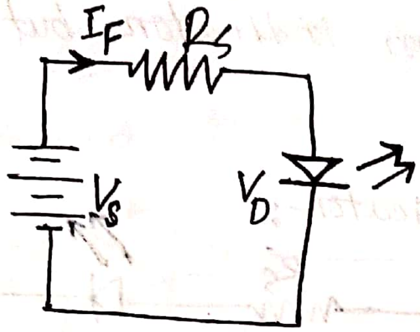


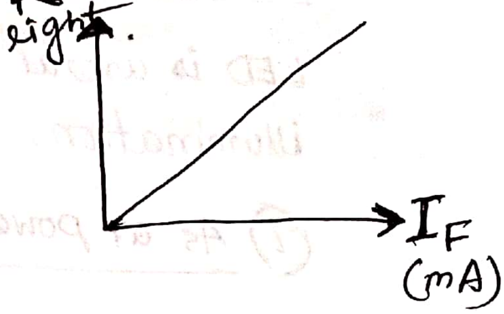
⇒ When a conduction electron falls into a hole in valence band, the energy may be emitted as a photon.

Current divide → parallel
Voltage divide → Series

LED voltage and current:

~~Voltage~~





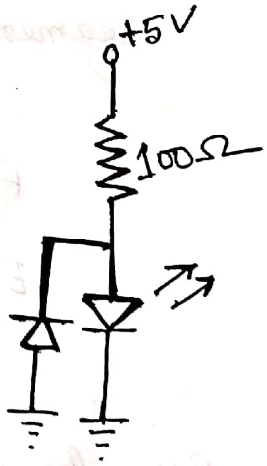
input voltage V_S
& voltage across LED is V_D

$\therefore$ Voltage across. $R_S = V_S - V_D$
Circuit current, $I_F = \dfrac{V_S - V_D}{R_S}$

Advantage of LED:

(I) Low voltage, less power consumed.
(II) Longer life. (more than 20 years)
(III) Fast on-off switching
(IV) colourful light

Protecting LED against reverse bias:



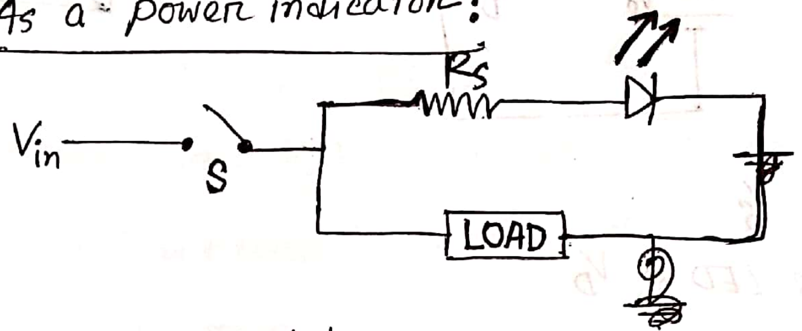
LEDs have low reverse voltage ratings. one must be careful not to use LEDs With a high level of reverse bias.
To protect a LED is to connect a rectifier diode in parallel with LED.
If reverse voltage greater than the reverse voltage rating of LED is accidently applied, the rectifier diode will be turned on. This protects the LED from damage.

Illumination → Lighting

Application of LED:

LED is useful as an indicator but not good for illumination.

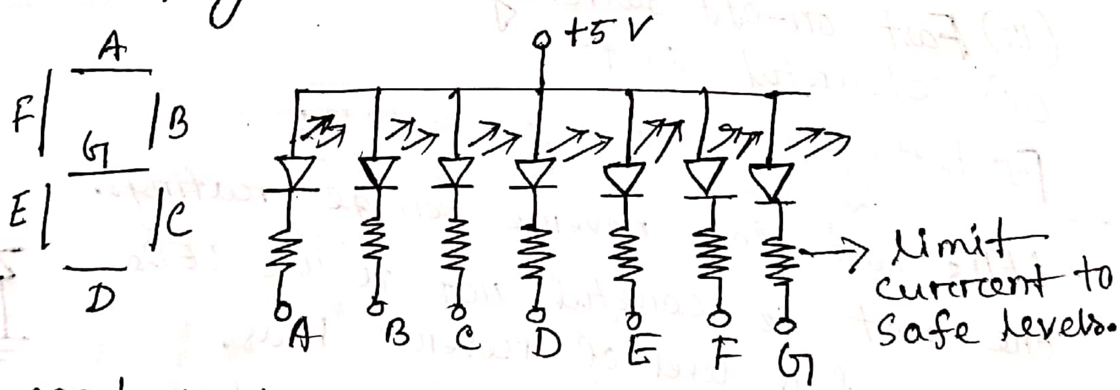
(i) As a power indicator:



· When the switch S is closed, power is applied to the load. At the same time current flows through the LED which lights, indicating power is on. Rs ensure current rating of LED is not exceeded.

(ii) Seven-segment display:

LEDs are often grouped to form seven-segment display.



By forward biasing various combinations of seven LEDs, it is possible to display any number from 0 to 9.

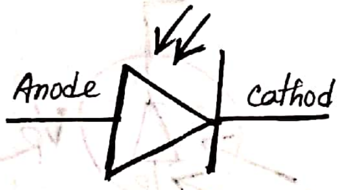
A particular LED is forward biased, that LED or segment will light.

If we ground A, A will be lit.

reverse biased.

Photo Diode

a special purpose pn junction diode fabricated with a transparent window to allow light to fall on the diode.



Light of wavelength λ is sufficient to break the valence bond falls on the junction, new hole-electron pairs are created.

→ used for detecting optical signals.

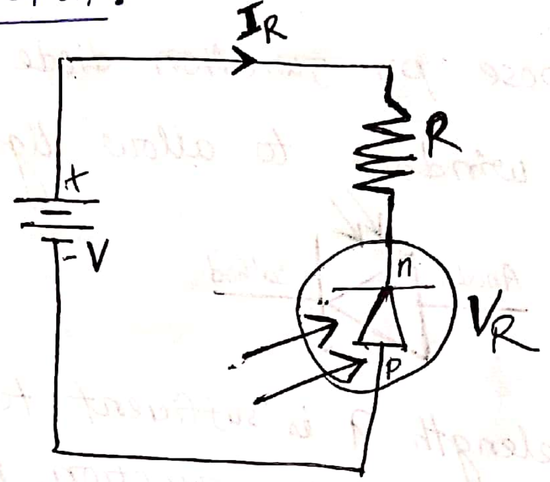
→ There is a significant change in the current with change in the light intensity in reverse bias. Thus photo diode can be used as a photo detector to detect optical signals.

$$\boxed{\text{Intensity of light} \propto \text{reverse Current}}$$

Def: A Photo diode is a reverse-biased silicon or germanium pn junction in which reverse current increases when the junction is exposed to light.

• Transfer energy incident light (photons) to the atoms.

Photo diode operation :



(i) If reverse current I_R is extremely small. This is called dark current.

The resistance of photo diode with no incident light is called dark resistance (R_R).

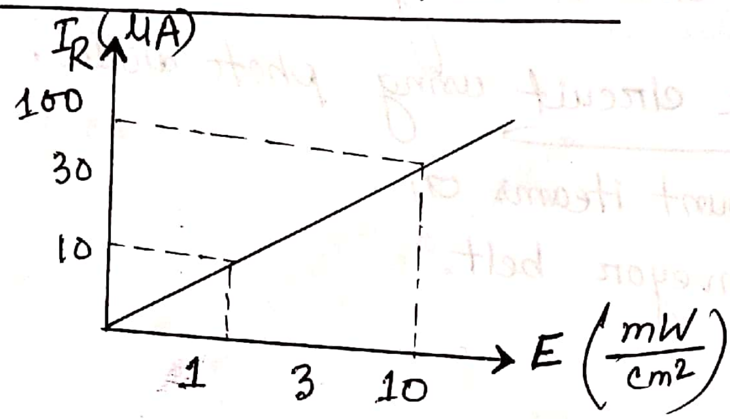
$$\boxed{R_R = \frac{V_R}{\text{Dark Current}}}$$

(ii) When light is incident on the pn junction of the photo diode, there is a transfer of energy from photons to the atoms in the junction. This will create more free electrons and holes. This additional free electrons increase the reverse current.

(iii) As the intensity of light increase the reverse current I_R goes on increasing till it becomes maximum. This is called saturation current.

Characteristics of photo diode:

(i) Reverse Current-Illumination curve

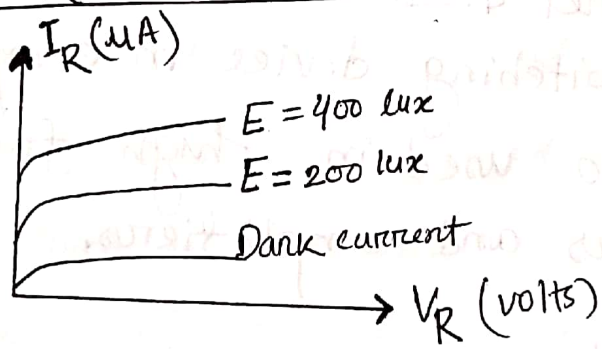


graph is straight line

reverse current (I_R) on the vertical axis.
Illumination on the horizontal axis.

$\therefore I_R = mE$; m = slope of the straight line
$\hookrightarrow$ sensitivity

(ii) Reverse voltage – Reverse Current curve:



Graph for various illumination levels.

For a given reverse biased voltage V_R, the reverse current I_R increases as the illumination (E) on the junction of photo diode is increased.

Applications of photo Diode:

(i) Alarm circuit using Photo diode.

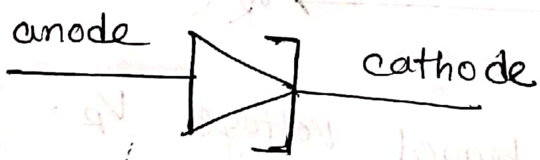
(ii) Counter circuit using photo diode.

To count iteams on a conveyor belt.

Tunnel Diode:

A tunnel diode is a heavily dopped p-n junction diode in which the electric current decreases as the voltage increases. (negative resistance) in forward direction.

→ The tunnel diode is used as a very fast Switching device in computers.
It is also used in high frequency oscillators and amplifiers.



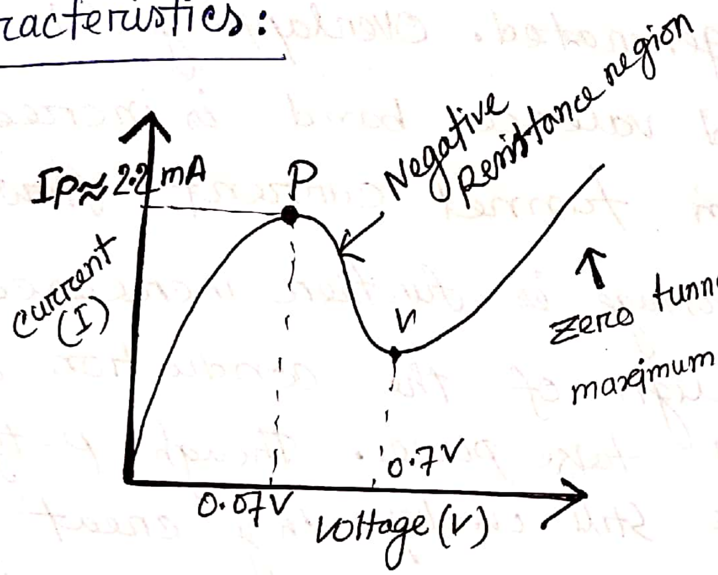
- Anode is a positively charged electrode which attracts electrons.
- cathode is a negatively charged electrode which emits electrons.

Negative resistance → Current decreases as the voltage increased
positive resistance → Current increases as the voltage is increased

tunneling

The movement of valence electrons from the valence energy band to the conduction band with little or no applied forward voltage is called tunneling.

V-I characteristics:



explanation from book

1. When no voltage is applied to the tunnel diode, it is said to be an unbiased tunnel diode. ...... there will be no tunnel current.

2. When a small voltage is applied to the tunnel diode which is less than the built in voltage of the deplation layer, no forward current current through the junction. However a small number of electrons in the conduction band of the n region will tunnel to the empty states of valence band in p-region. This will create a small forward bias tunnel current. Thus, tunnel current starts flowing with a small application of voltage.

3. When the voltage applied to the tunnel diode is slightly increased, a large number of free electrons at n side and holes at p-side are generated. Overlapping of conduction and valence band is increased. So, maximum tunnel current flows.

4. If applied voltage is further increased, a slight misalign of the conduction and valence band take place. Though p-type and n-type still overlap they creat small current flow. So, tunneling current starts decreasing.

5. If the applied voltage is largely increased, the tunneling current drops to zero.

Def:

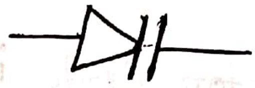
A tunnel diode is a pn junction that exhibits negative resistance between two values of forward voltage.

Varacter Diode

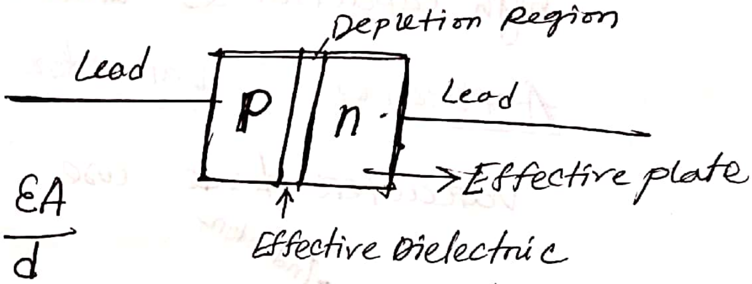
Internal capacitance changes with the applied reverse bias voltage.

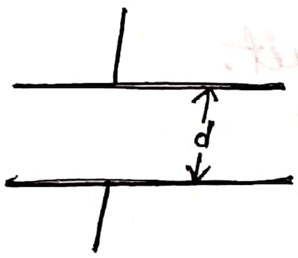
Varicap : Variable Capacitor

Varactor : Variable Reactance



Varactor Diode



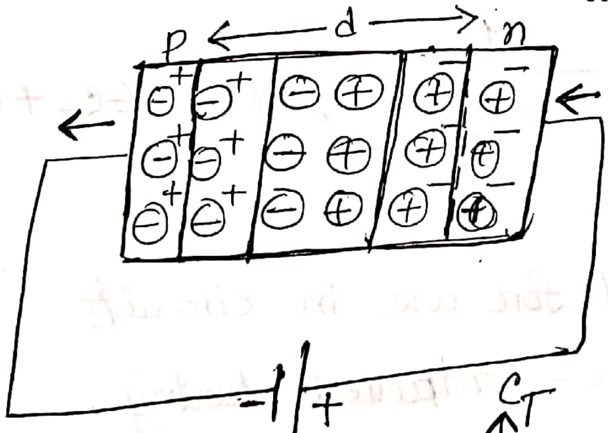


Capacitance, $C_T = \frac{\varepsilon A}{d}$
of the Junction

$A \rightarrow$ area of the plates

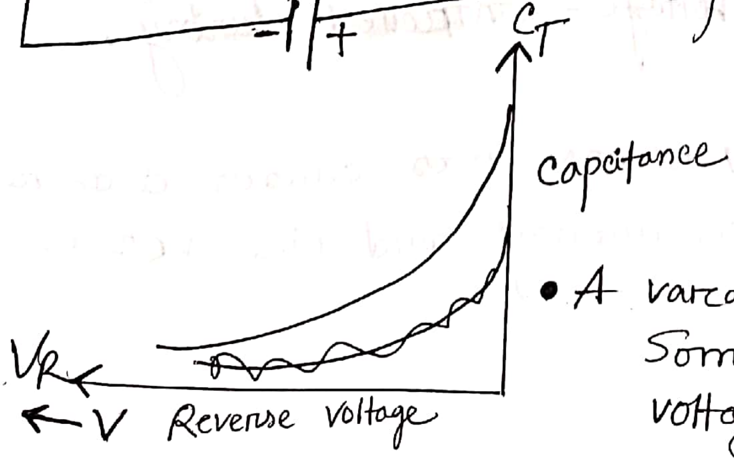
$\varepsilon \rightarrow$ Permittivity

$d \rightarrow$ distance between the two plates / width of the deplation Layer



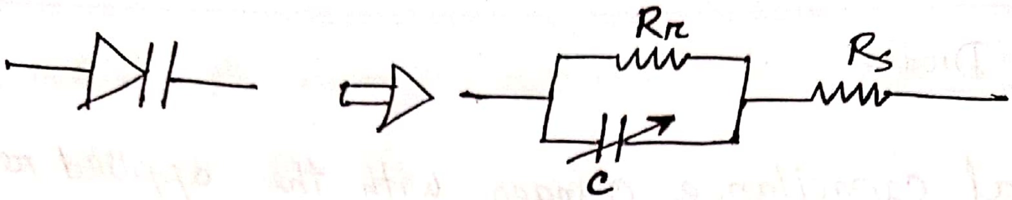
$$\boxed{C_T \propto \frac{1}{d} \quad / \quad C_T \propto \frac{1}{V}}$$

Though d is increased capacitance will decreased.



- A varacter diode is Sometimes called voltage-controlled capacitor.

Reverse bias voltage pn Junction



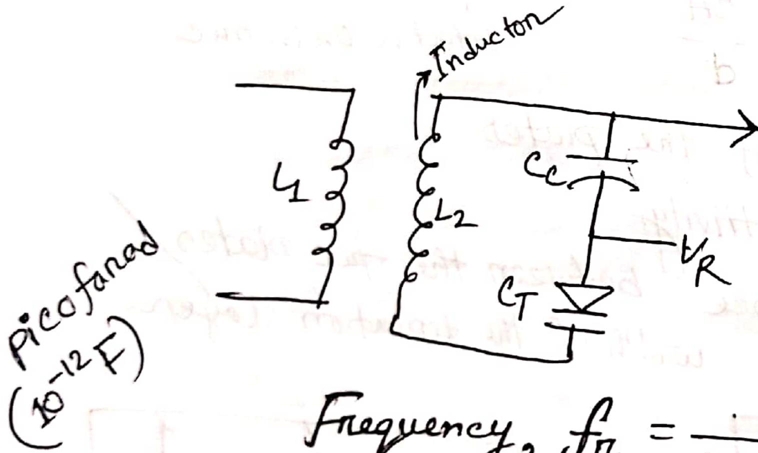
$R_r \to$ Reverse Resistance

$R_s \to$ Ohmic Resistance

A varactor diode is specially constructed to have high capacitance under reverse bias.

Application of varactor Diode :

varacter diode use in a tuned circuit.



Frequency, $f_r = \dfrac{1}{2\pi\sqrt{LC'}}$; where, $C' = C_T + C_c$

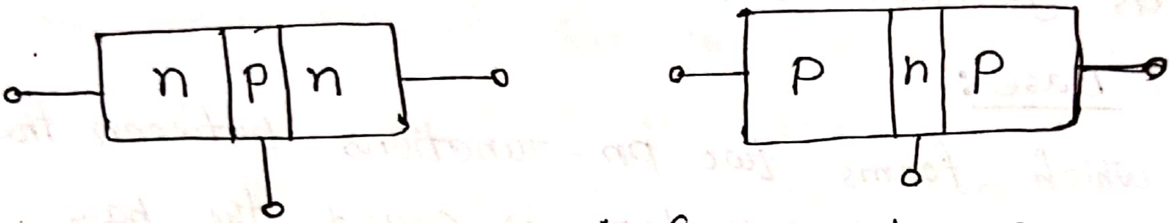
Varacter diode ideal for use in circuits that requires voltage-controlled tuning.

decrease ~~of~~ in reverse bias causes a decrease in resonant frequency and vice versa.

Transistor

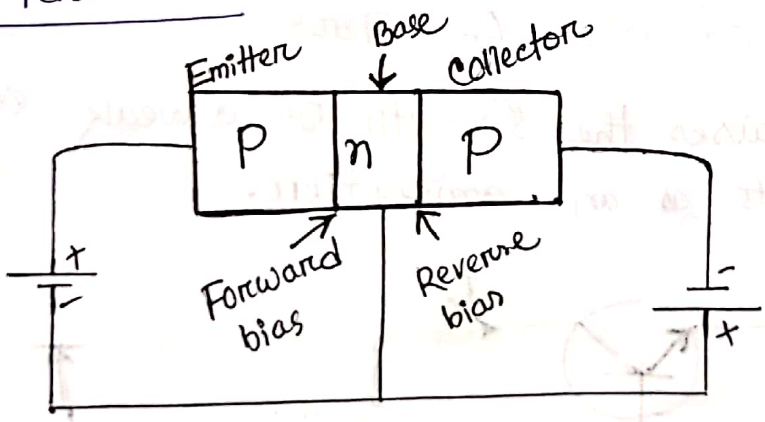
Transistor — n-p-n
— p-n-p

A transistor consists of two pn junctions formed by sandwiching either p type or n type semiconductor between a pair of opposite types.



(i) two pn junctions. one is forward other is reverse biased.
low resistance path — high resistance path
(ii) three terminals.
(iii) middle sector is very thin layer.

Transistor Terminals:



(i) Emitter:

Supplies charge carriers (electron or holes). always in forward biased wrt base. So, it can supply a large number of majority carriers.

emitter always forward biased w.r.t. base.

(ii) **Collector :**

Collects charges. Collector is always reverse biased.

Its function is to remove charges from its junction with the base.

(iii) **Base :**

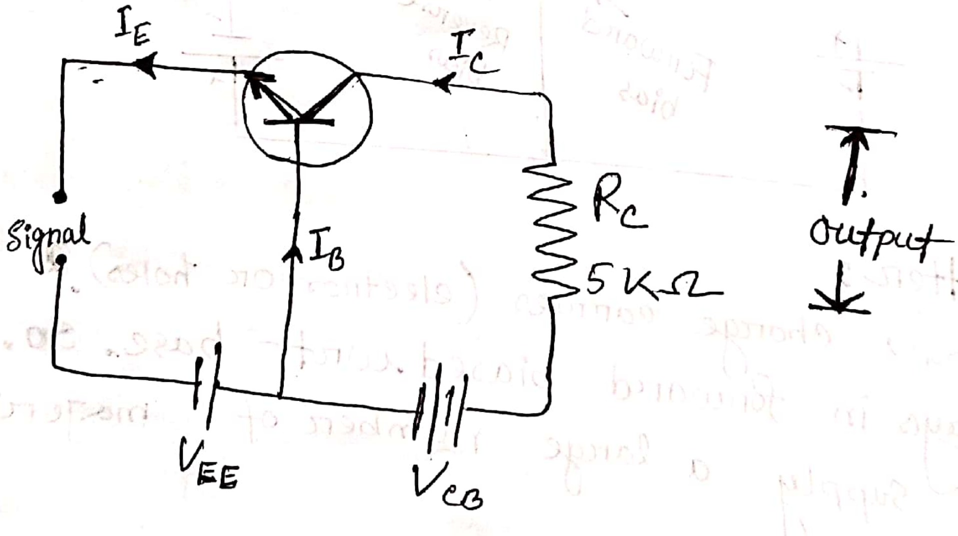
Which forms two pn-junctions between the emitter and collector is called the base.

base - emitter junction → forward biased (low resistance)

base – collector junction → reverse biased (High resistance)

Transistor Circuit as an Amplifier:

transistor raises the strength of a weak signal and then acts as an amplifier.



weak signal is applied between emitter-base junction & output taken across load R_C (in collector circuit).

Input circuit should always remain forward biased. So, we use a d.c. voltage V_{EE}.

As the input circuit has low resistance, therefore a small change in signal voltage causes an appreciable change in emitter current. This causes almost the same change in collector current due to transistor action. Collector current flowing through a high resistance R_C produces a large voltage across it.

In this way, a transistor acts as an amplifier.

$I_{emitter} = 1\ mA$ for change $0.1\ V$

$\therefore I_{collector} = 1\ mA$ $\qquad$ $\boxed{0.1V \text{ to } 5V}$

$R_C = 5\ K\Omega$; produce voltage $= 5\ K\Omega \times 1\ mA$
$= 5\ V.$

Transistor Connections

a transistor can be connected in a circuit in the following three ways:

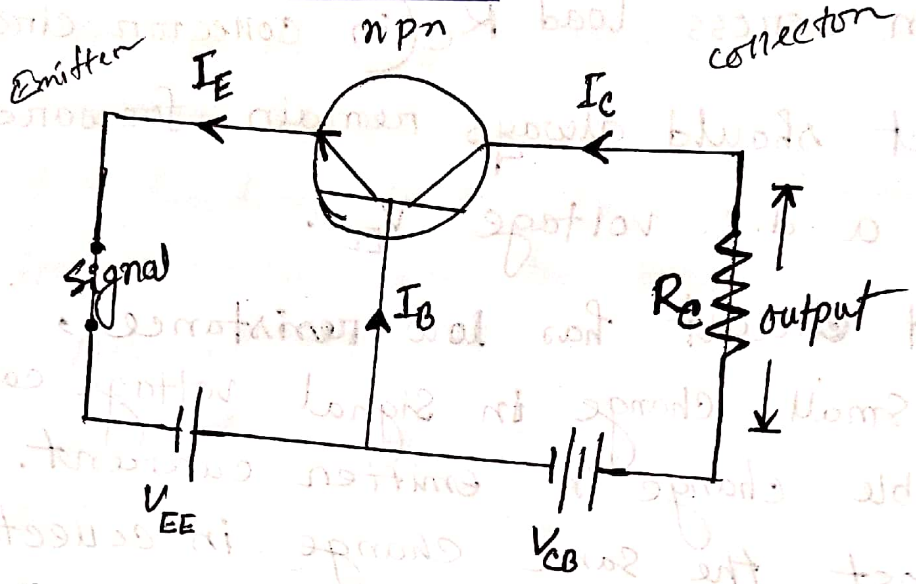
(i) common base connection.

(ii) Common emitter connection.

(iii) common collector connection.

input => emitter & base
output => collector & base

Common Base Connection



1. Current amplification factor (α):

input current → emitter current (I_E)

Output current → collector current (I_C)

$$\alpha = \frac{\Delta I_C}{\Delta I_E} \quad \text{at constant } V_{CB} \quad [\text{For a.c}]$$

• α value (0.9 to 0.99)

2. Expression for collector current:

→ collector base junction is reverse biased, so some leakage current flows due to minority carries. ($I_{leakage}$) $I_{leakage} = I_{CBO}$ (Collector-Base Current with emitter open)

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

αI_E part of emitter current which reaches the collector terminal.

$\therefore$ Total collector current, $I_C = \alpha I_E + I_{leakage}$

$I_{leakage} = I_{CBO}$ (Collector-Base current with emitter open)

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

In transistor, $[I_E = I_C + I_B]$

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

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

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

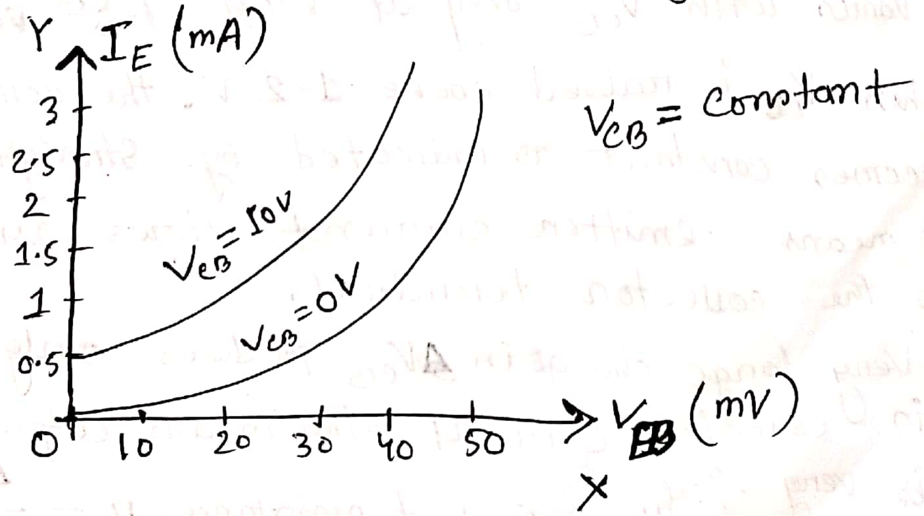
$$\boxed{\therefore I_C = \frac{\alpha}{1-\alpha} I_B + \frac{I_{CBO}}{1-\alpha}}$$

→ collector current equation for Common Base

Characteristics of common Base connections :

Input characteristics :

Graph between current I_E and emitter-base voltage V_{EB}. where collector-Base voltag V_{CB} is constant.



Knee — Ge ⇒ 0.1 V
Knee — Si ⇒ 0.5 V

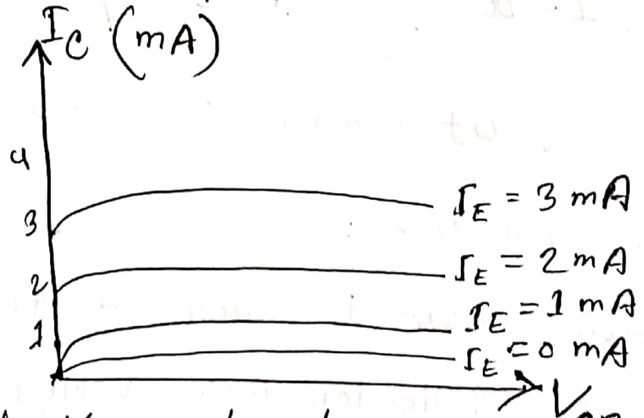
(i) emitter current increases rapidly with small increase in emitter-base voltage. It means that input resistance is very small.

(ii) emitter current is almost independent of collector voltage.

$\therefore$ Input resistance, $r_i = \dfrac{\Delta V_{BE}}{\Delta I_E}$ at constant V_{CB}.

Output characteristics:

graph between collector current I_C and collector-base voltage V_{CB} at constant emitter current. (I_E).



(i) I_C varies with V_{CB} only at very low voltages. (<1V)

(ii) When V_{CB} is raised above 1-2 V, the collector current becomes constant as indicated by straight horizontal curves. It means emitter current flows almost entirely to the collector terminal.

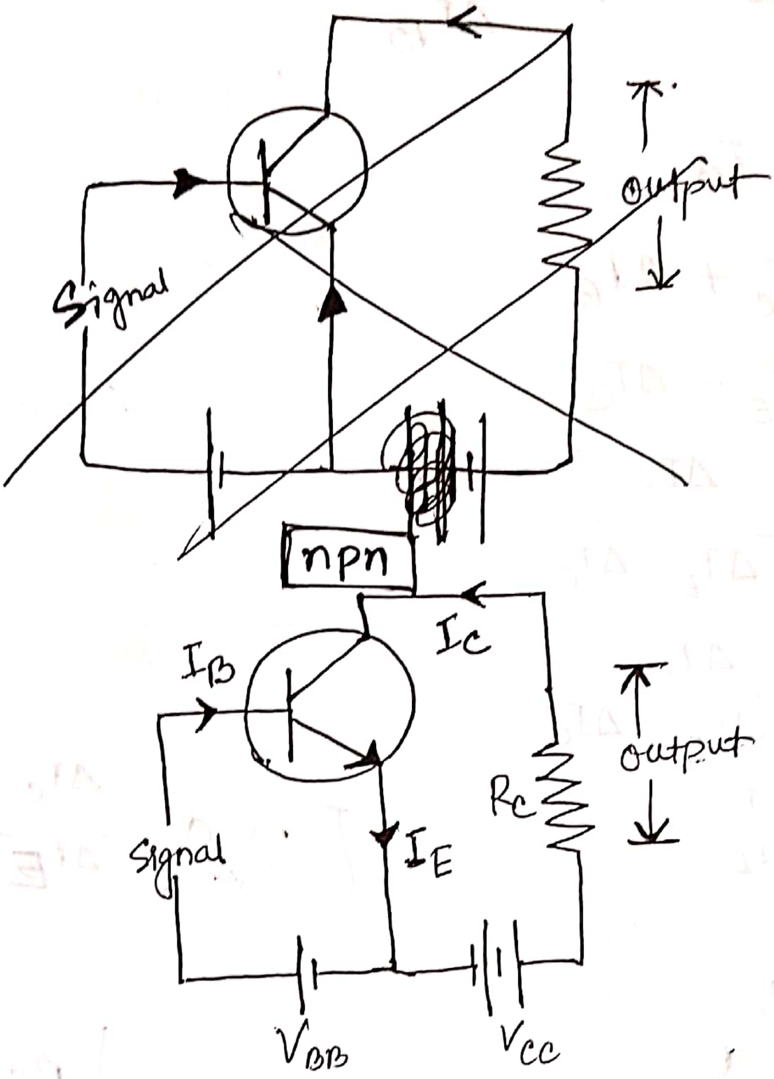
(iii) Very large change in ΔV_{CB} produces only a tiny change in collector current. This means output resistance is very high. $\therefore$ Output resistance, $r_o = \dfrac{\Delta V_{CB}}{\Delta I_C}$ at constant I_E

collector current slightly less than the emitter current.

Input ⇒ base & emitter
Output ⇒ collector & emitter

Common Emitter Connection

npn



1. Base current amplification factor (β)

input current - I_B ; output current I_C

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

Relation between β and α:

$$\alpha = \frac{\Delta I_C}{\Delta I_E} \qquad \beta = \frac{\Delta I_C}{\Delta I_B}$$

$$I_E = I_C + I_B$$

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

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

or, $$\frac{\Delta I_C}{\Delta I_B} = \frac{\Delta I_C}{\Delta I_E - \Delta I_C}$$

or, $$\beta = \frac{\Delta I_C}{\Delta I_E - \Delta I_C}$$

or, $$\beta = \frac{\frac{\Delta I_C}{\Delta I_E}}{\frac{\Delta I_E}{\Delta I_E} - \frac{\Delta I_C}{\Delta I_E}} \qquad \left[\because \alpha = \frac{\Delta I_C}{\Delta I_E}\right]$$

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

~~Com~~ Current gain Common Emitter Connection is very high.

β ~~$\alpha\beta$~~ $= \alpha + \alpha$

β

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

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

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

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

2. Expression for Collector Current:

I_B input, I_C output

$$\boxed{I_E = I_B + I_C}$$

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

[From Common Base Configuration]

Collector-emitter current with base open, $I_B = 0$

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

[CEO ⇒ Collector to emitter current with base open in CE configuration]

$$\boxed{I_C = \frac{\alpha}{1-\alpha} I_B + I_{CEO}}$$

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

$$\left[\because \beta = \frac{\alpha}{1-\alpha}\right]$$

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

Ans

Emitter Current = Collector current + Base current

$$= (\beta I_B + I_{CEO}) + I_B$$

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

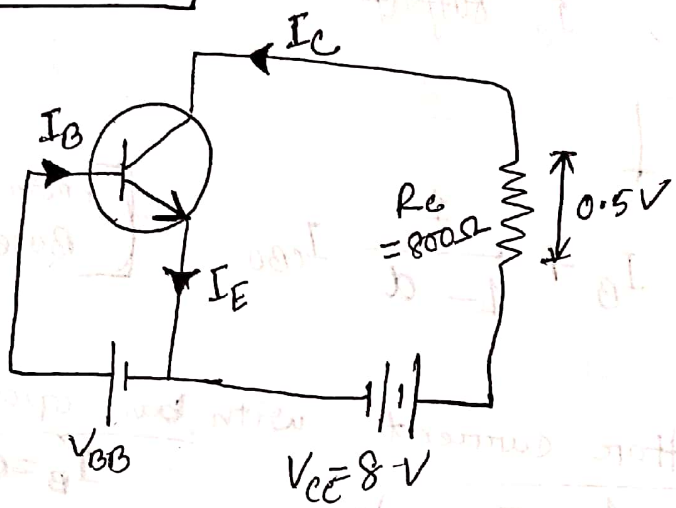
Noted that,

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

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

$$\left[\because \frac{1}{1-\alpha} = \beta+1\right]$$

$\boxed{\text{Example}-8\cdot12}$



(i) Collector-emitter voltage,

$$V_{CE} = V_{CC} - 0.5$$
$$= 8 - 0.5$$
$$= 7.5V$$

(ii) $$I_C = \frac{0.5V}{800\,\Omega} = 0.625\ mA$$

$$\beta = \frac{\alpha}{1-\alpha} = \frac{0.96}{1-0.96}$$
$$= 24$$

$\therefore$ Base Current, $I_B = \frac{I_C}{\beta}$

$$= \frac{0.625}{24}$$

$$= 0.026\ mA$$

(Ans)

Example-14

$I_{CEO} = 300\ \mu A$, $\beta = 120$; $I_{CBO} = ?$

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

$$= \frac{120}{120+1} = 0.992$$

Now,

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

$$I_{CBO} = (1-\alpha) I_{CEO}$$

$$= (1-0.992) I_{CEO}$$

$$= 0.008 \times 300$$

$$= 2.4\ \mu A$$

Leakage current in Common Emitter (CE) => I_{CEO} — base open

Leakage current in Common Base (CB) => I_{CBO} — Emitter open

$$I_{CEO} \gg I_{CBO}$$

Example 8.15

$I_B = 20\ \mu A$

$I_C = 2\ mA$

$\beta = 80$

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

or, $2 = 80 \times 0.02 + I_{CEO}$

$\therefore I_{CEO} = 2 - 80 \times 0.02$

$= 0.4\ mA$

$\alpha = \frac{\beta}{\beta+1} = \frac{80}{80+1} = 0.988$

$I_{CBO} = (1-\alpha) I_{CEO}$

$= (1-0.988) \times 0.44$

$= 0.0048\ mA$

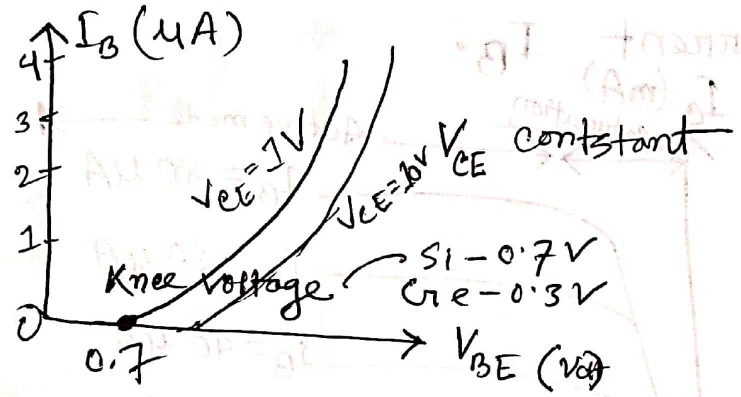
An

Keeping output voltage constant at input

Characteristics of Common Emitter connection:

Input Characteristics:

Curve between base current I_B and base-emitter voltage V_{BE} at constant collector-emitter voltage V_{CE}

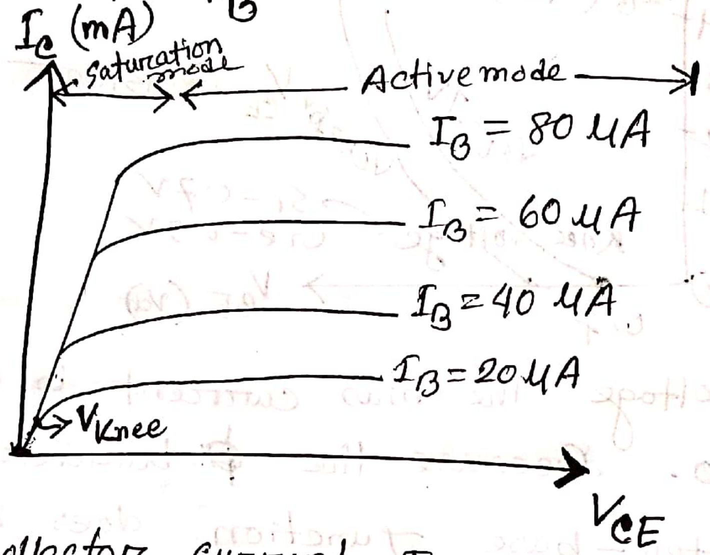


Below knee voltage the bias current is approximately equal to zero. Because the barrier potential at the emitter-base junction does not allow the majority carries to flow through the junction and thus emitter current is zero. and $I_B = 0$.
After reaching knee voltage I_B starts increasing with V_{BE} and curve obtained is same as forward characteristics of PN junction diode, but I_B doesnot increase as rapidly as I_E in CB connection
Therefore input resistance in CE configuration is higher than in CB connection.

$$\therefore \text{Input resistance, } r_i = \frac{\Delta V_{BE}}{\Delta I_B}$$

Output characteristics :

Curve between collector current I_C and collector - emitter voltage V_{CE} at constant base current I_B.



Constant I_B

The collector current I_C varies with V_{CE} for V_{CE} between 0 and 1 V only. After this collector current becomes almost constant. I_C changes with V_{CE} until Knee Voltage reaches. above Knee voltage I_C ~~Kee~~ remains almost constant.

V_{CE} above Knee Voltage $\therefore I_C$ is approximately equal to $\beta \times I_B$

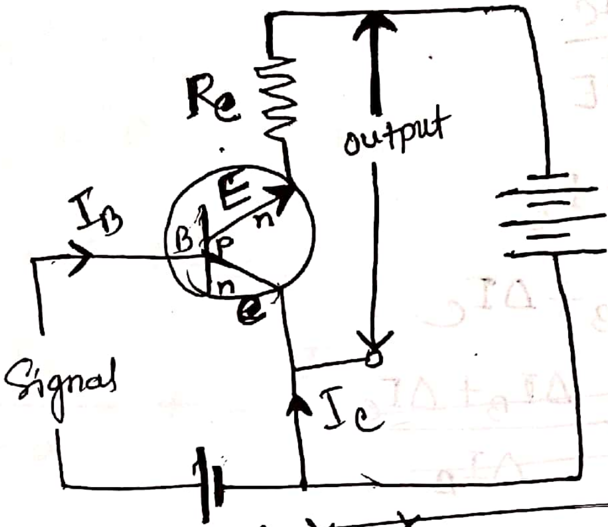
$\frac{I_E}{I_B}$

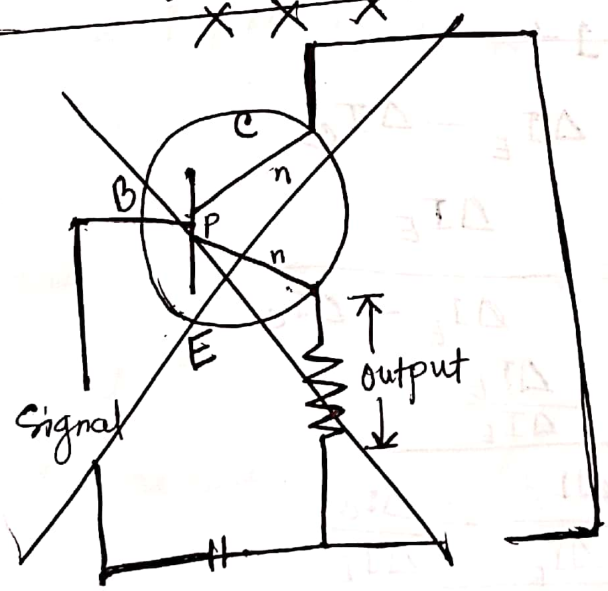
$= \beta I_B$

$\therefore$ Output resistance, $r_o = \frac{\Delta V_{CE}}{\Delta I_C}$ at constant I_B

Common collector connection :

input ⇒ base & collector
output ⇒ emitter & collector





(i) Current amplification factor (γ):

input current → I_B
output current → I_E

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

Relation between γ and α:

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

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

$$I_E = I_B + I_C$$

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

~~or,~~ $\cancel{\frac{\Delta I_E}{\Delta I_B} = \frac{\Delta I_B + \Delta I_C}{\Delta I_B}}$

~~or,~~ $\cancel{\gamma = 1 +}$

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

or, $\frac{\Delta I_E}{\Delta I_B} = \frac{\Delta I_E}{\Delta I_E - \Delta I_C}$

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

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

(ii)

Expression for collector current:

We know,

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

$$I_E = I_B + I_C$$

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

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

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

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

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

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

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

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

Application:

- Voltage gain by this circuit always less than 1.
- high input resistance, low output resistance.

Comparison of transistor connections:

Page NO. – 163

Transistors VS Vacuum Tube

→ Page – 186

Advantage of transistors:

(i) High voltage gain

(ii) Lower supply ~~g~~ voltage

(iii) No heating

(iv) .

(v)

Disadvantage of transistors:

(i) Lower power dissipation

(ii) Lower input impedance

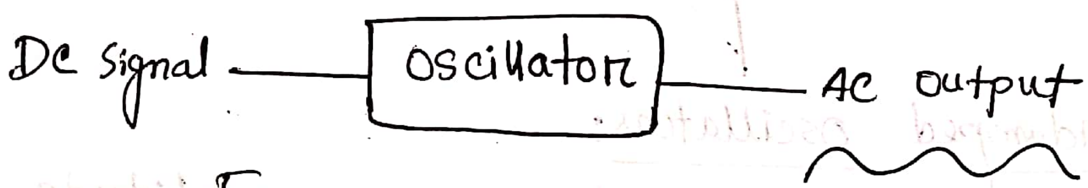
(iii) Temperature dependence

(iv) Inherent variation of parameters.

Sinusoidal oscillator:

An electric device that generates Sinusoidal oscillation of desired frequency is Known as a Sinusoidal Oscillator.

→ input power to an oscillator is the d.c. power supply and changes it into a.c. energy of desired frequency.



alternator can produce Sinusoidal oscillation but it cannot be oscillator

Frequency : Hz to GHz

Oscillator is non-rotating electronic device.

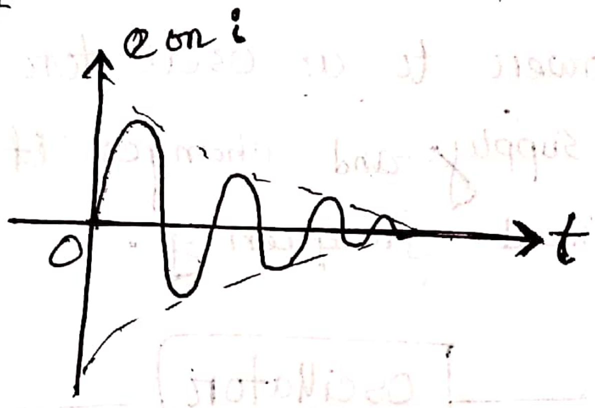
Advantage

1. Though oscillator is a non-rotating device so there is little wear and tear and hence longer life.
2. Due to the absence of moving parts, oscillator is quite silent.
3. Small frequency (20 Hz) produce extremely high frequency (>100 MHz)
4. frequency of oscillator can be changed when desired.
5. good frequency stability.
6. very high efficiency.

Types of Sinusoidal Oscillators:

(i) Damped Oscillators:

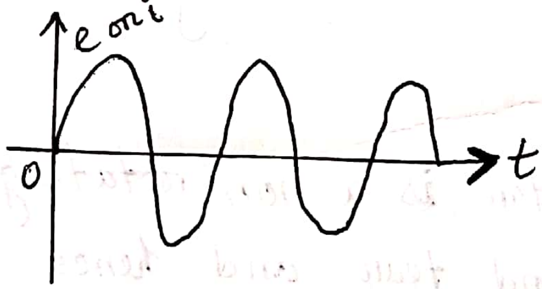
The electrical oscillators whose amplitude goes on decreasing with time are called damped oscillators.



frequency unchanged.

(ii) undamped oscillators:

The electrical oscillators whose amplitude remains constant with time are called undamped oscillators.



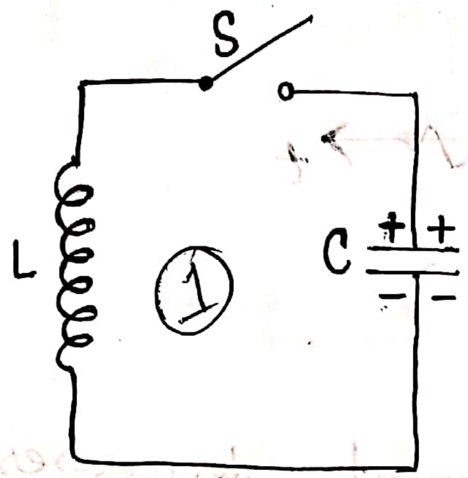
Oscillatory circuit:

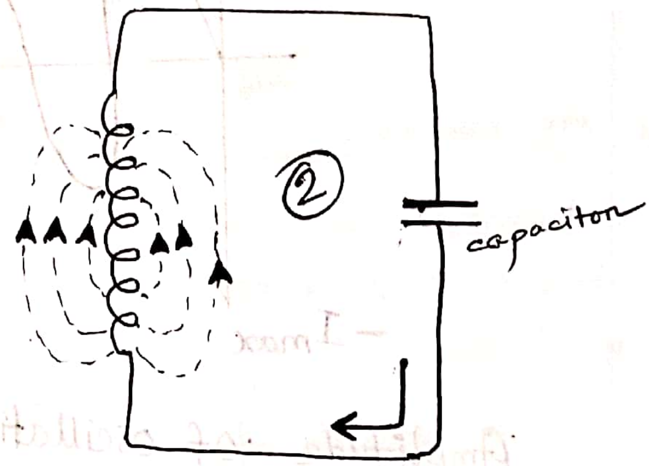
A circuit which produces electrical oscillations of any desired frequency is known as an oscillatory circuit or tank circuit.

→ Circuit consists of a capacitor (C) and inductance coil (L) in parallel.

~~→ Consist~~

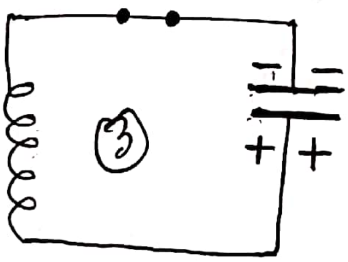
Inductor develop EMF across it.



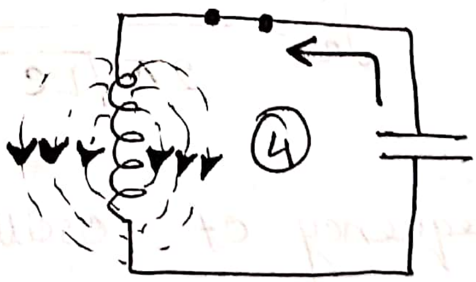


There is a voltage across the capacitor and the Capacitor has electrostatic energy.

Circuit current will be maximum when the capacitor is fully discharged so, electrostatic energy is zero. the electrostatic energy across the capacitor is completely converted into magnetic field energy around the coil.



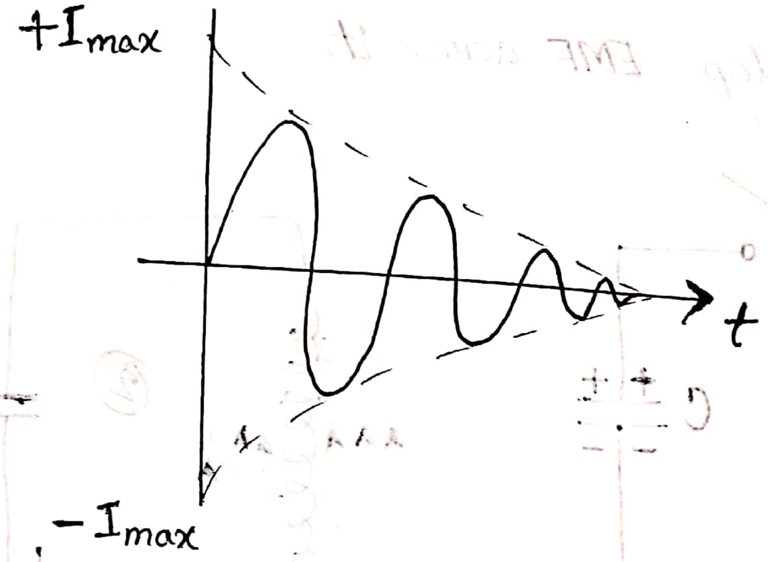
Once the capacitor is discharged the magnetic field begin to decrease and produce a counter emf which keep the current flow. Capacitor now charged with opposite polarity.



After the decreasing field has recharged the capacitor. the capacitor now begins to discharged and maximum current flowing.

The sequence of charge and discharge results in alternating motion of electrons or an oscillating current.

frequency → number of waves in a fixed time.



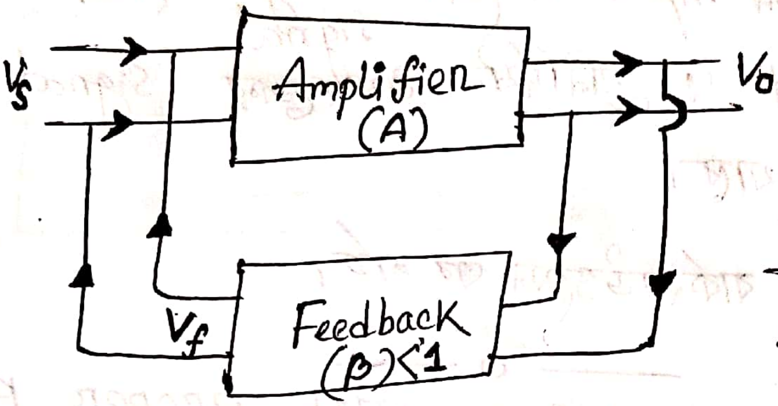
Amplitude of oscillating current decreases gradually and eventually it becomes zero when all the energy is consumed as losses. Therefore, the tank circuit by itself will produce damped oscillations.

Frequeny of oscillations :

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

Frequency of oscillations in the tank circuit is inversly proportional to L and C

Positive Feedback Amplifier — Oscillator



~~[illegible]~~ Amplifier এর ত্রুটি দূর করার জন্য Output থেকে একটি অংশ Input সংকেতের সঙ্গে যুক্ত করার ঘটনাকে feedback বলে।

Voltage Amplifier, $A = \frac{V_o}{V_s}$ আগে

$$V_f = \beta V_o$$

So, Now Amplifier circuit's Input voltage, $V_i = V_s + \beta V_o$

Output voltage, $V_o = AV_i$

or, $V_o = A(V_s + \beta V_o)$

or, $V_o = AV_s + A\beta V_o$

or, $V_o(1 - A\beta) = AV_s$

$$\therefore \frac{V_o}{V_s} = \frac{A}{1 - A\beta}$$ পরে

$A \rightarrow$ মুক্ত লুপ
$A_f \rightarrow$ বদ্ধ লুপ
$A\beta \rightarrow$ লুপ বিবর্ধন

Amplifier circuit Amplification with Feedback circuit, $A_f = \frac{V_o}{V_s} = \frac{A}{1 - A\beta}$

- Negative feedback ; when ~~$A\beta < 1$~~ $(1 - A\beta) > 1 \Rightarrow A_f < A$
- positive feedback ; when $(1 - A\beta) < 1 \Rightarrow A_f > A$

without feedback voltage gain of amplifier

$A\beta = 1 \Rightarrow$ Oscillator $\rightarrow A_f \rightarrow \infty$

এর ফলে input এ কোন ~~voltage~~ signal দেওয়া না হলেও output এ অনির্দিষ্ট অসংখ্যকের signal পাওয়া যাবে।

এটাই বার্কহাউজেন এর শর্ত।

- A transistor amplifier with proper positive feedback can act as an oscillator. It can generate oscillations without any external signal source.
- The circuit needs only a quick trigger signal to start the oscillations. Once the oscillations have started no external signal source is needed.
- To get continuous undamped output, the following condition must be met.

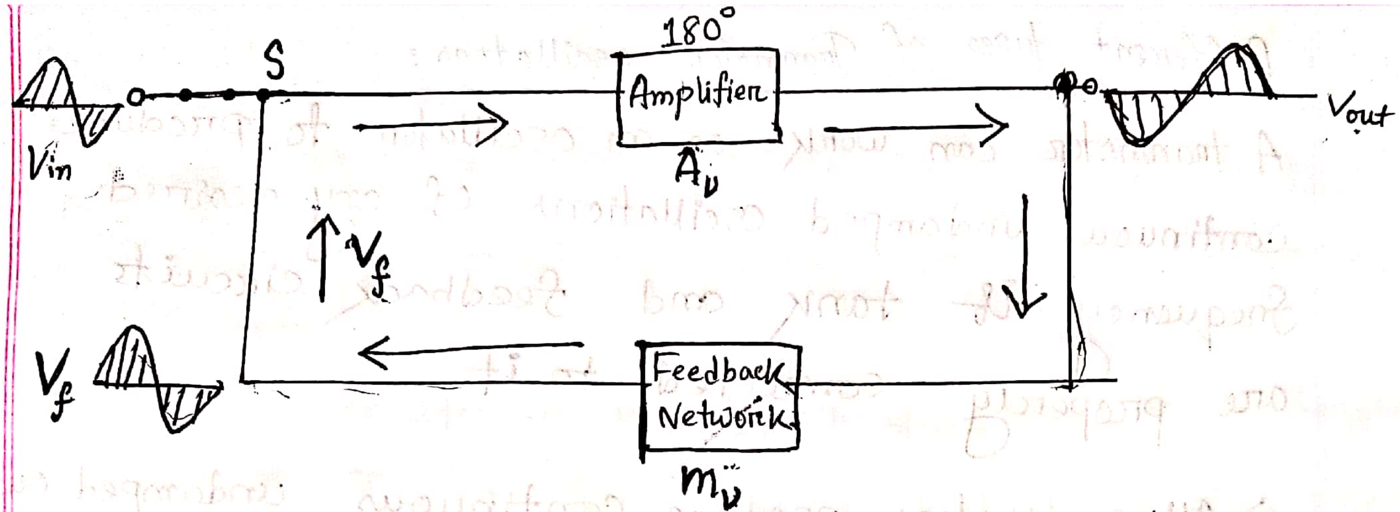
$$m_v A_v = 1 \; ;$$ where,

A_v = Voltage gain of amplifier without feedback.

m_v = feedback fraction

This relation is called

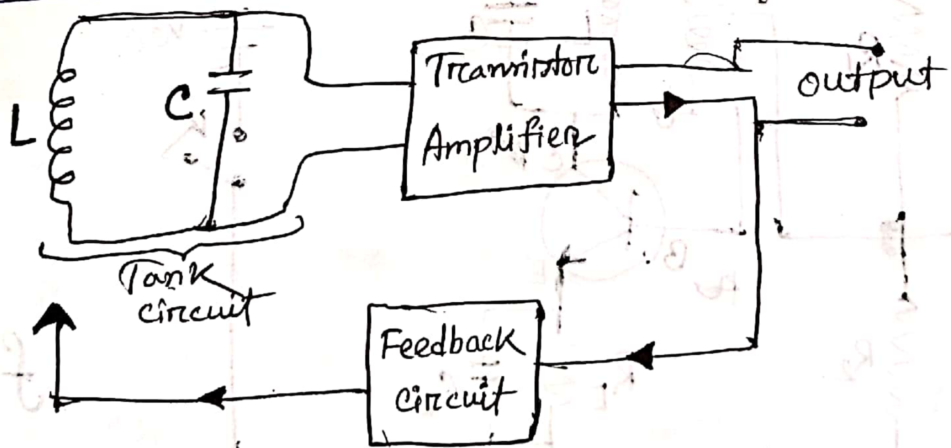
Barkhausen Criterion.



Oscillator is a circuit that produces oscillations without any external signal source.

Feedback network sends a portion of the output back to the input. This process will continue as long as the amplifier is turned on. Therefore, the amplifier produce sinusoidal output with no external signal source.

Essential components of Transistor oscillator:



(i) Tank circuit: Consist of inductance coil (L) connected in parallel with capacitor (C). Produce frequency.

(ii) Transistor Amplifier: ~~receives dc & change into ac~~

(iii) Feedback circuit: Supplies a part of output to the tank circuit

Different types of Transistor oscillators:

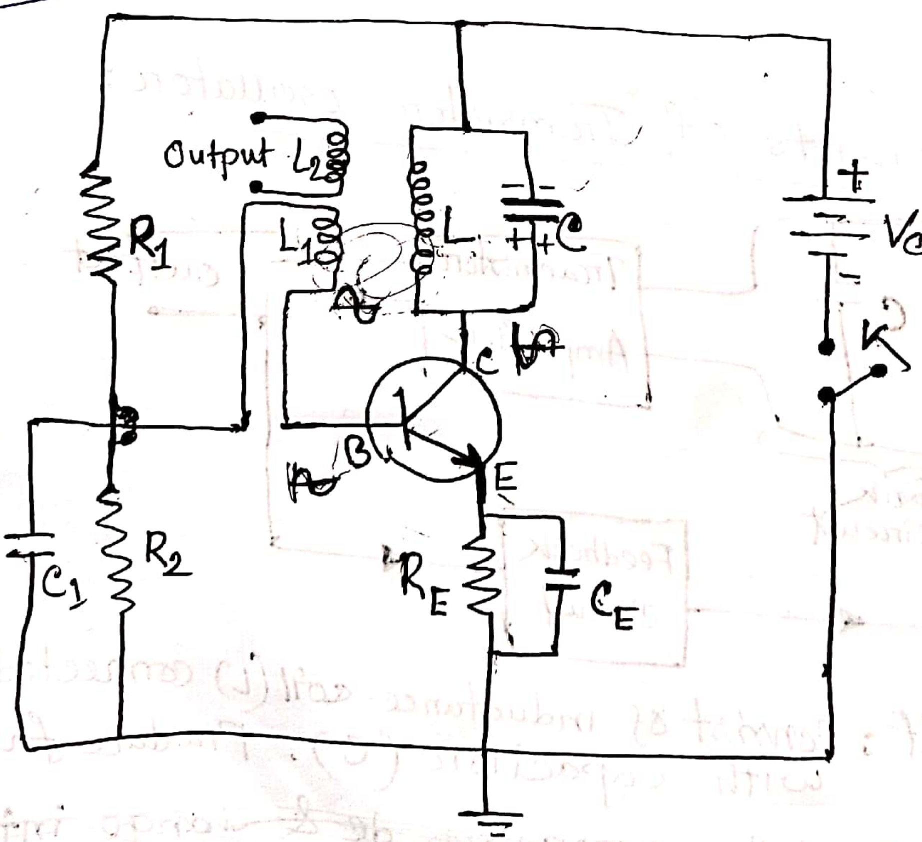
A transistor can work as an oscillator to produce continuous undamped oscillations of any desired frequency if tank and feedback circuits are properly connected to it.

→ All oscillators produce continuous undamped output

↳ major difference between them by which energy is supply to the tank circuit to meet the losses. (ক্ষতি পূরণ)

Tunned Collector oscillator: (Common Emitter) npn

Construction:



$$f = \frac{1}{2\pi\sqrt{L\cdot C}}$$

Circuit operation:

1. When Key K is closed collector current (I_c) starts increasing & charges the capacitor C in tank circuit.

2. When capacitor C is fully charged, then it discharged through coil L. This charging and discharging process sets up damped harmonic oscillation of frequency, $f = \frac{1}{2\pi\sqrt{LC}}$ in tank circuit.

3. The damped oscillation in tank circuit induce some voltage in coil L_1 by mutual induction. The magnitude of induced voltage in L_1 depends upon the no. of turns in L & L_1. Thus induced (a.c) voltage across L_1 is applied between base & emitter & gets amplified by transistor & appears at collector after amplification. Thus the loses in the tank circuit are compensated (ক্ষতিপূরণ) producing undamped harmonic oscillations.

4. A phase shift of 180° is introduced by coil L & L_1 due to transformer action. Another phase shift of 180° is introduced by common-emitter amplifier thus there is phase shift of 360° or 0° between input and feedback signal. Hence feedback is positive.

Example-14.2

Given, $L_1 = 1\ mH = 1\times10^{-3}\ H$

We know, $f = 1\ GHz = 1\times10^{12}\ Hz$

frequency of oscillations is, $f = \dfrac{1}{2\pi\sqrt{L_1C_1}}$

or, $f^2 = \dfrac{1}{4\pi^2 L_1 C_1}$

or, $C_1 = \dfrac{1}{4\pi^2 L_1 f^2}$

$= \dfrac{1}{4\pi^2(1\times10^{-3})(1\times10^{12})^2}$

$= 2.53\times10^{-23}\ F$

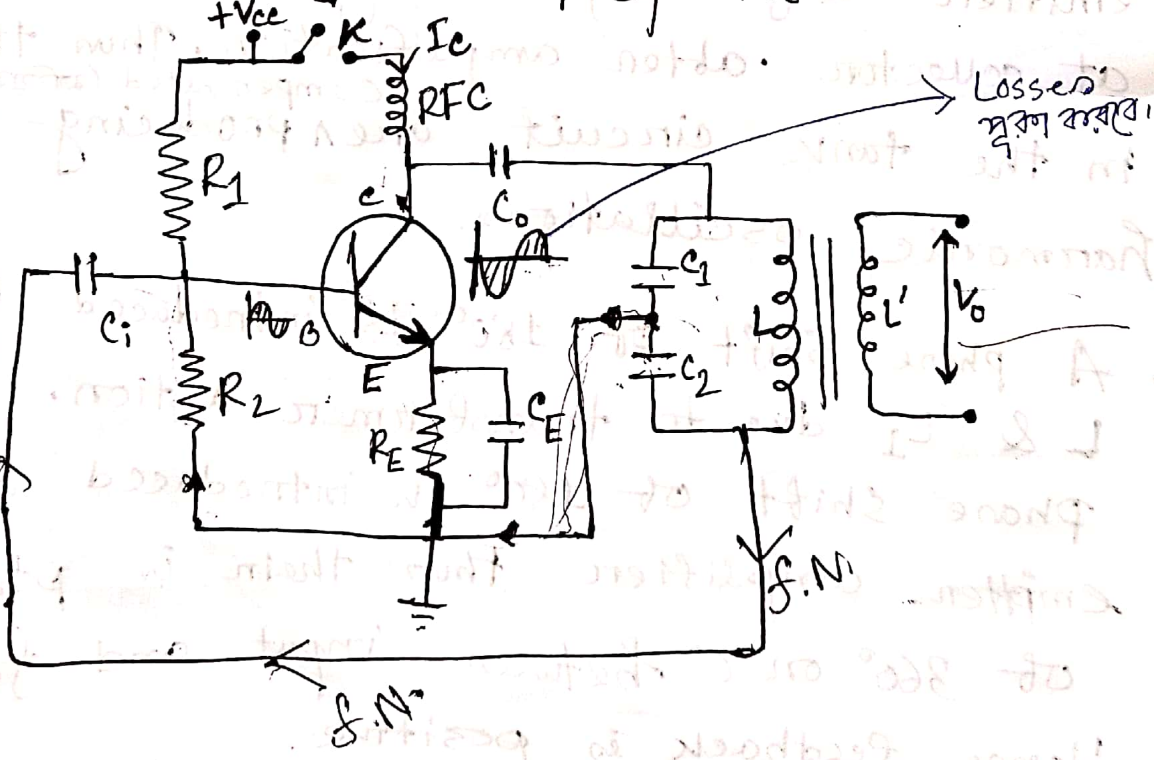
$= 2.53\times10^{-11}\ pF$ (Ans)

Colpitt's oscillator: (Radio frequency oscillator)

common emitter n-p-n transistor

Construction

We will use ~~tap~~ centre tap capacitor



$= 2\pi\nu L$

$= \dfrac{1}{2\pi\nu L}$

180° 깊 Amplifier
+
180° 깊 tank circuit $\Rightarrow$ in total 360° (+)ve feedback

Circuit operation

When Key (K) is closed, the ~~Oscillator~~ Collector current (I_c) starts rising & charges the capacitor C_1 & C_2. When C_1 & C_2 fully charged, they discharge through inductor L. Thus damped harmonic oscillator are set up in tank circuit. These oscillators produces ac voltage across C_2 which are applied to the base emitter junction & appear in the amplified form in the collector circuit. In this way, continuous undamped oscillations will appear in the output circuit.

Phase change of 180° is introduced by CE amplifier. A farther change of 180° is introduced by tank circuit, so total phase change of 360° or 0° is introduced. Thus in case of Colpitts oscillator we can say that feedback is positive. The frequency of undamped harmonic oscillators is given by

$$\boxed{f = \frac{1}{2\pi\sqrt{LC_T}} \quad \text{where } C_T = \frac{C_1 C_2}{C_1 + C_2}} \text{ [series]}$$

The output can be taken out from tank circuit by using coil L' mutually coupled with L.

feedback voltage   feedback fraction   output voltage

capacitive reactance   capacitance

If,

Feedback fraction, $\boxed{m_v = \frac{V_f}{V_{out}}} = \frac{x_{C_2}}{x_{C_1}} = \frac{C_1}{C_2}$

$$\boxed{m_v = \frac{C_1}{C_2}}$$

$$\boxed{\begin{array}{l} x_c = \frac{1}{2\pi \nu c} \\ x_c \propto \frac{1}{c} \end{array}}$$

Example-14.4

Feedback fraction, $m_v = \frac{C_1}{C_2}$

or, $0.25 = \frac{C_1}{C_2}$

$\therefore C_2 = 4C_1$

$L = 1\ mH = 1 \times 10^{-3}\ H$

$f = 1\ MHz = 1 \times 10^{6}\ Hz$

We know,

$$f = \frac{1}{2\pi\sqrt{LC_T}}$$

or, $f^2 = \frac{1}{4\pi^2 L C_T}$

or, $C_T = \frac{1}{4\pi^2 f^2 L}$

$= 25.3 \times 10^{-12}\ F$

$= 25.3\ pF$

$\boxed{1\ PF = 10^{-12}\ F}$

or, $$\frac{C_1 C_2}{C_1 + C_2} = 25.3\ pF$$

or, $$\frac{C_2}{1 + \frac{C_2}{C_1}} = 25.3\ pF$$

or, $$\frac{C_2}{1+4} = 25.3\ pF$$

$$\therefore C_2 = 25.3 \times 5\ pF$$

$$= 126.5\ pF$$

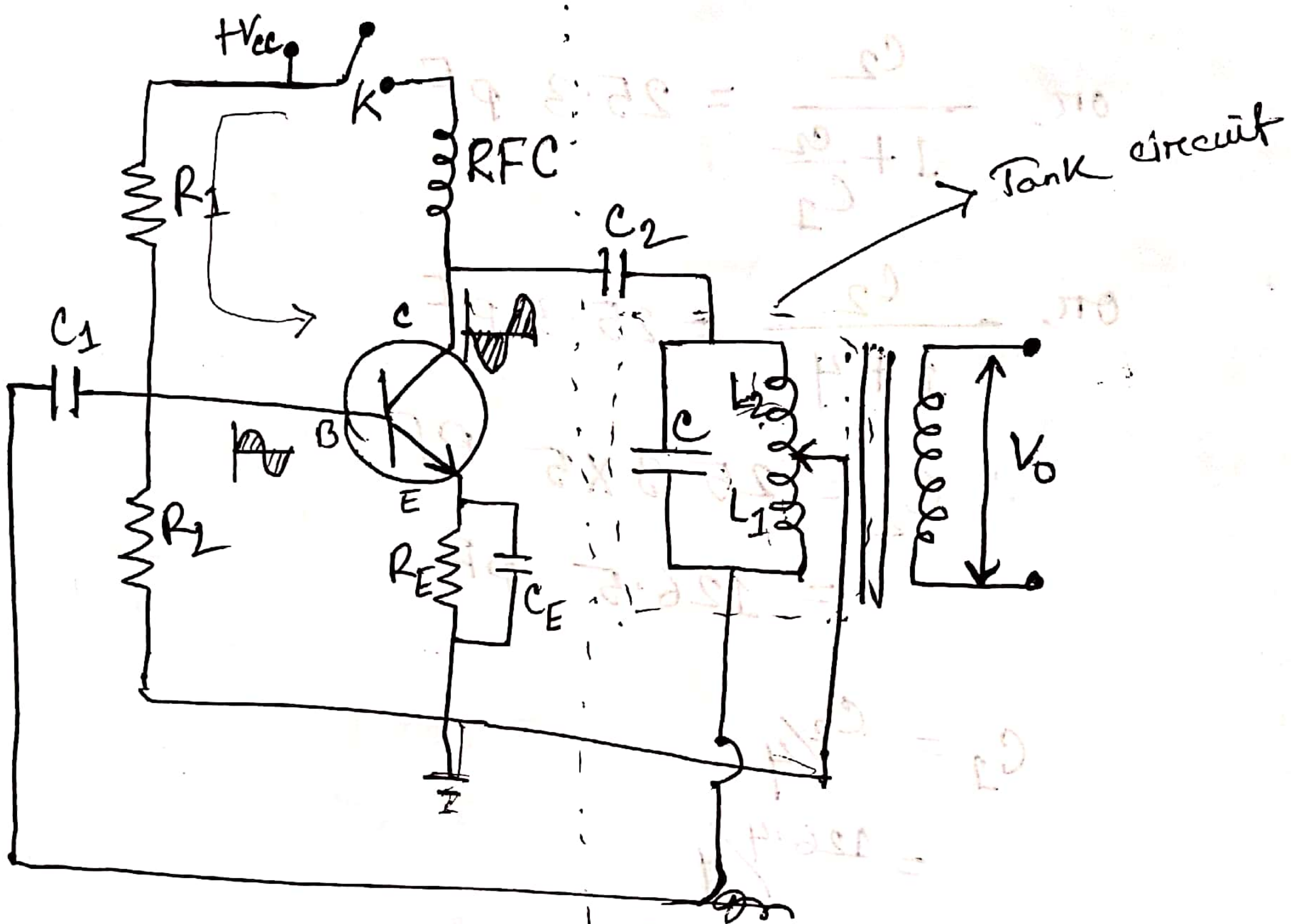
$$C_1 = C_2/4$$

$$= 126.4/4$$

$$= 31.6\ pF$$

Am

Hartley oscillator : → Commonly used in Radio Recievers.



R_1, R_2 potential divider arrangement for proper biasing of the transistor. & R_E helps in bias stablisation (Keeping the operating point stable). AC কে C_E দিয়ে pass করানো হয়, কারণ AC R_E দিয়ে Pass করলে voltag drop হবে gain কমে যাবে।

Circuit operation :

$\boxed{\text{Voltage gain = heat loss হতে হবে}}$

When K is closed the collector current starts rising & charges the capacitor C. When the capacitor C is fully charges, it discharge through L_1 & L_2. Thus damped harmonic oscillations are set up in th tank circuit.

দুটো coil এর জন্য 180° phase change
হয় tank circuit এ।

The oscillations across L_1 are Fedback to the input (Base-emitter) circuit through capacitor C_1 & will appear in the amplified form in output (collector - base) circuit. In this way continuous undamped oscillations will appear in the output circuit.

A phase ~~of~~ change of 180° is introduced by CE amplifier. A further phase change of 180° is introduced by tank circuit. So, a total phase change of 360° or 0° is introduced. So Feedback is positive.

Hanley oscillator's,

Frequency, $f = \dfrac{1}{2\pi\sqrt{LC}}$ where, $L = L_1 + L_2 + 2M$

- M is coefficient of mutual induction of L_1 & L_2

The output can be taken from the tank circuit by using coil 2' mutually coupled with L_1 & L_2.

Feedback fraction, $m_v = \dfrac{V_f}{V_{out}} = \dfrac{X_{L_2}}{X_{L_1}}$

$$\boxed{m_v = \frac{L_2}{L_1}}$$

$X_L = 2\pi \nu L$

$X_L \propto L$

Example - 14.6

Given,

$$m_v = 0.2$$

$$\frac{L_2}{L_1} = 0.2$$

$$\therefore L_1 = 5L_2$$

$$f = 1\ MHz = 1\times10^6\ Hz$$

$$C = 1\ pF = 10^{-12}\ F$$

We know, $$f = \frac{1}{2\pi\sqrt{L_T C}}$$

$$L_T = \frac{1}{4\pi^2 f^2 C}$$

or, $$L_T = \frac{1}{4(3.1416)^2 (10^6)^2 \times 10^{-12}}$$

or, $L_T = 25.3\times10^{-3}$ H (হেনরি)

or, $L_T = 25.3$ mH

or, $L_1 + L_2 = 25.3$ mH

or, $5L_2 + L_2 = 25.3$ mH

$$\therefore L_2 = \frac{25.3}{6} = 4.22\ mH$$

$$\therefore L_1 = 5\times4.22 = 21.1\ mH$$

Ans

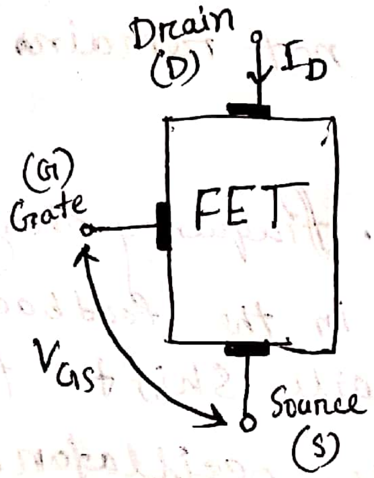
Limitations of LC and RC oscillators :

→ operating frequency does not remains strictly constant.

- circuit warm up. frequency change with temperature.
- If any component in the feedback network is changed. it will shift the operating frequency of the oscillator.

In order to maintain constant frequency piezoelectric crystals are used in place of LC & RC circuits. Oscillators of this type are called crystal oscillators. The frequency of crystal oscillators changes by less than 0.1 % due to temperature and other changes.

Junction Field effect Transistor (JFET):



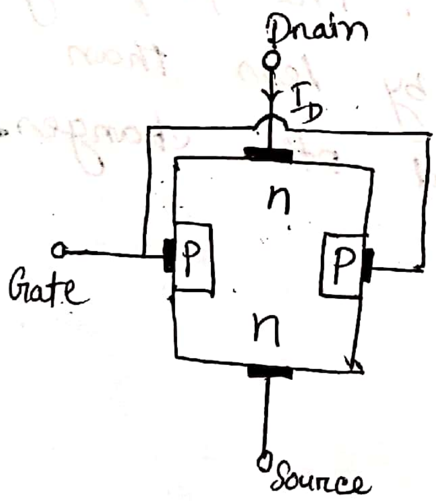
I_D = Drain Current

$I_D = V_{GS}$ এর উপর নির্ভরশীল

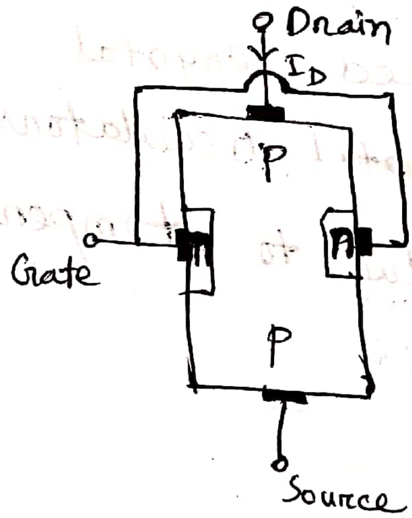
JFET
- → n-Channel
- → P-Channel

Construction

n-Channel JFET



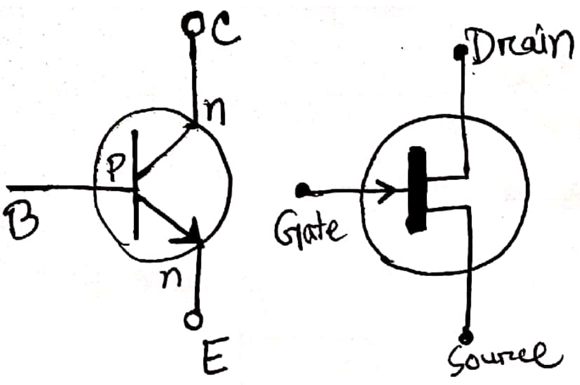
P-Channel JFET



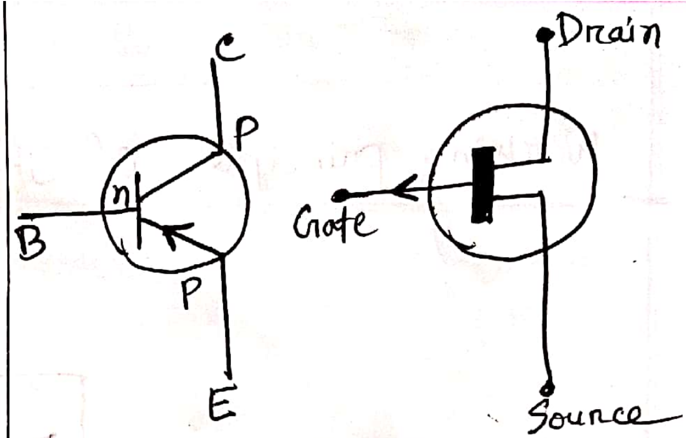
Drain to Source Current flow হয়।

Def:

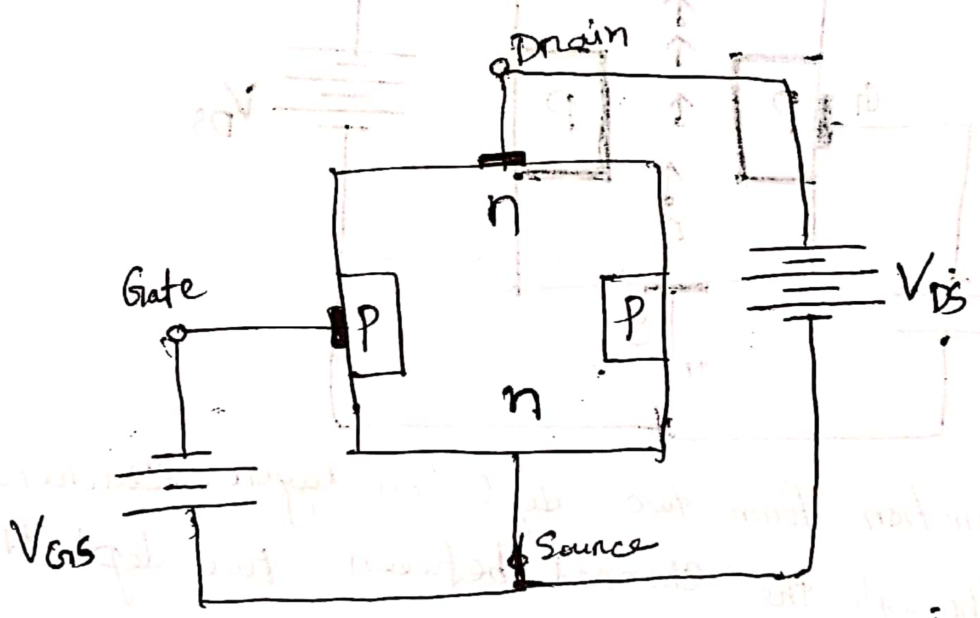
A Junction Field effect transistor is a three terminal Semiconductor device in which current conduction is by one type of carrier. (electrons or hole).



n-channel
JFET Symbol



P-channel
JFET symbol

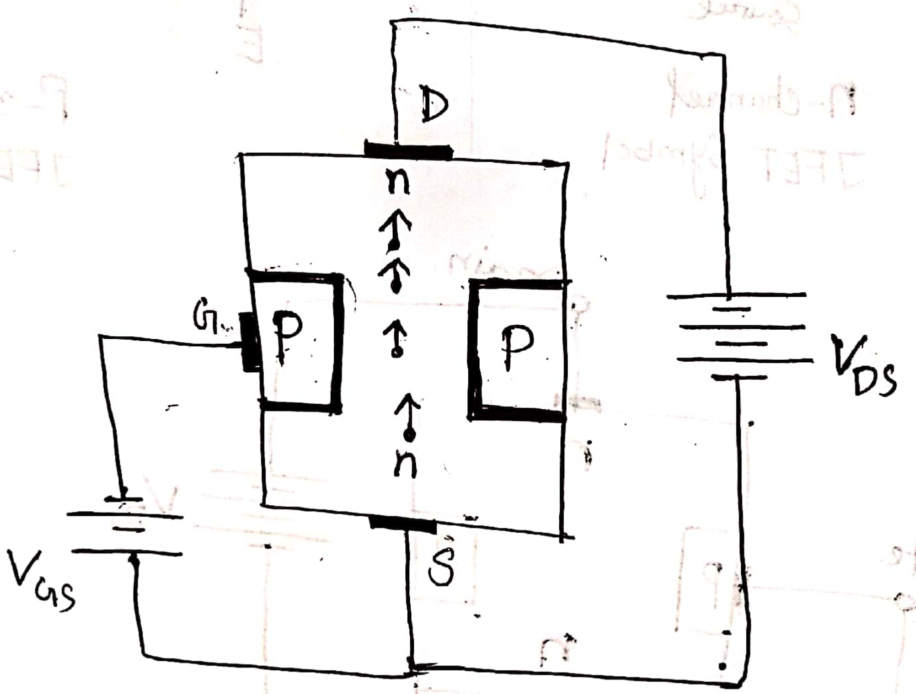


(i) Input circuit (Gate to Source) of a JFET is reversed biased.
high input impedence ([illegible])

(ii) drain is so biased w.r.t source that I_D flows from the source to drain.

(iii) In all JFETS, $I_S = I_D$.

Working principle of JFET :



two pn junction form two deplation layer. current conduct through the channel between two deplation layer. width & resistance controlled by changing the input voltage V_{GS}. The greater the reverse voltage V_{GS}, the wider will be the deplation layer and narrower will be conduction channel. So, greater resistance and source to drain current decrease.

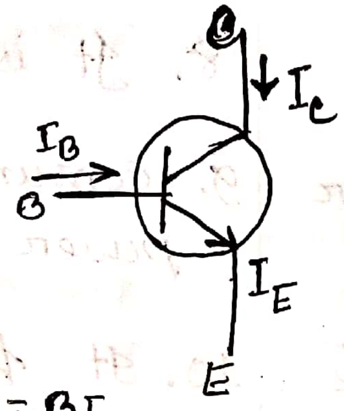
magnitude of drain current (I_D) can be changed by alternating V_{GS}.

Working from book.

Difference between JFET and Bipolar Transistor:

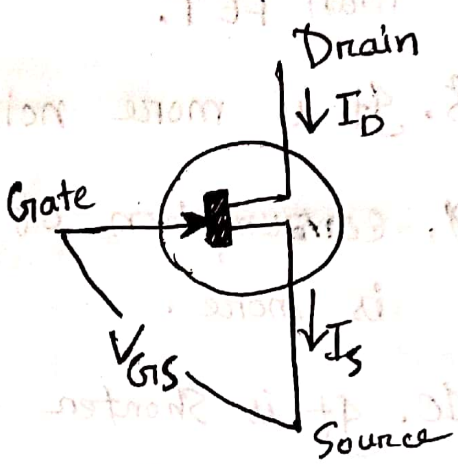
JFET: n-channel, P-channel

Bipolar Transistor: npn, pnp



$I_C = \beta I_B$

I_C = depends of I_B



I_D = depends on V_{GS}

BJT	JFET
1. BJT has 3 terminals namely base, collector, emitter	1. FET also has 3 terminals namely gate, source and drain.
2. It is a bipolar device.	2. It is a unipolar device
3. It working on operation depends on movement of electron & holes both.	3. It working on operations depends either on movement of electron (n-channel FET) or on the movement of hole (P-Channel FET)
4. It is current control device.	4. It is voltage controlled device.
5. Input impedence of BJT is less & output impedence of BJT is high.	5. Input impedence of FET is very ~~low~~ high and output impedence of FET is low.
6. It is cheaper.	6. It is costly.

BJT	JFET
7. It is bigger in size than FET.	7. It is smaller in size than BJT.
8. It is more noisy.	8. It is less noisy.
9. consumption of power is more.	9. Consumption of power is less.
10. It is shorter life & less efficiency.	10. It has longer life and high efficiency.
11. It is preferred for low current applications.	11. It preferred for low voltage applications.
12. It has low heat stability	12. It has high heat stability.
13. In IC fabrications, BJTs are occupying more space.	13. In IC fabrication, FETs are occupying less space.

- In JFET we can only decrease the width of the channel.
- ~~depletion~~ deplation mode operation

Metal oxide Semiconductor FET (MOSFET) :

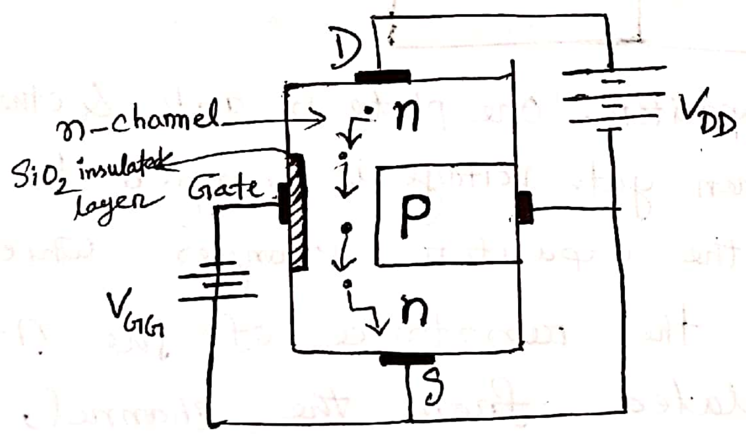
- D-MOSFET (deplation mode & enhancement mode)
- E-MOSFET (enhancement mode)

D-MOSFET

- P Channel D-MOSFET
- N Channel D-MOSFET:

A Field effect Transistor (FET) that can be operated in the enhancement mode is called a MOSFET

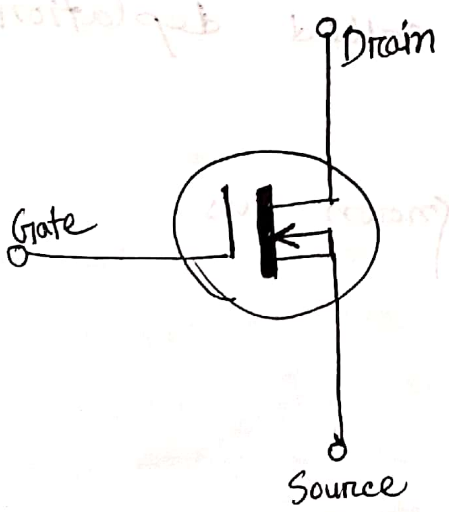
Construction



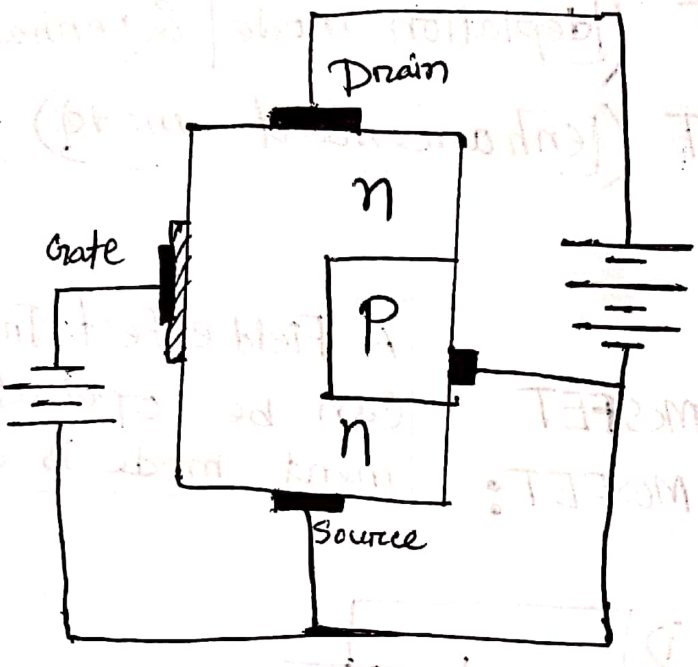
Gate and SiO_2 layer ⇒ forms a capacitor
metal oxide

- one plate is gate
- other plate is SiO_2

দুটি পরিবাহীর মাঝে অপরিবাহী থাকলে Capacitor হিসেবে কাজ করে।



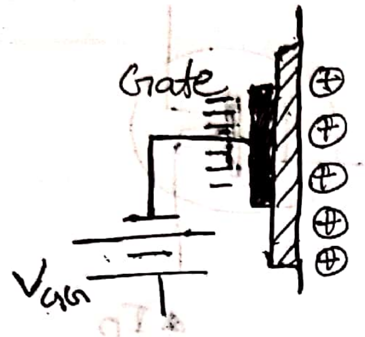
Circuit operation of D-MOSFET



gate forms small capacitor. One plate is gate & other plate is metal oxide. When gate voltage is changed the electric field of the capacitor changes which in turn changes the resistance of the n-channel. The gate is insulated from the channel, we can apply either negative or positive voltage to the gate.

- negative gate operation is called depletion mode.
- positive gate operation is known as enhancement mode.

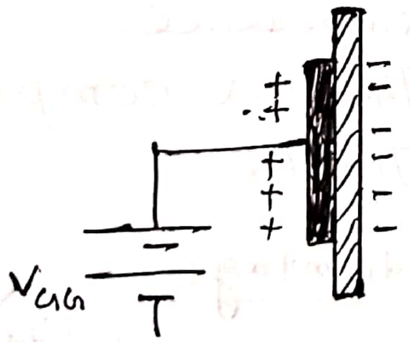
(i) Depletion mode:



- If one plate of the capacitor is negatively charged, it induces positive charge on the other plate.

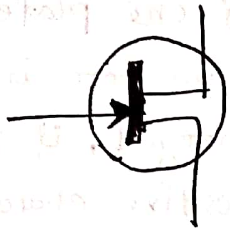
We remove some free electron from the n channel. So resistance of the n channel is increased. The greater the negative voltage on the gate, the lesser is the current from $\boxed{\text{Source to Drain}}$. The negative gate operation is called depletion mode. D-MOSFET is similar to JFET in depletion mode.

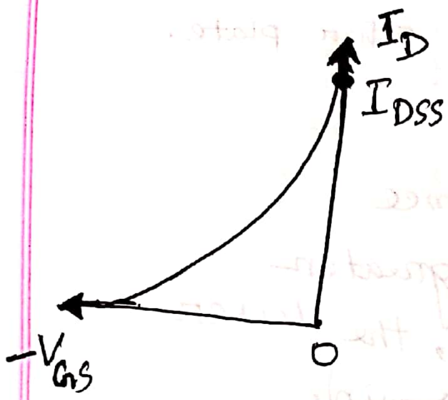
(ii) Enhancement mode:



The gate is positive, it induces negative charges in the n-channel. So, total free electrons in the channel is increased. Thus, positive gate voltage increase the conductivity of the channel. The greater the positive voltage on the gate, greater the conduction from source to drain. Positive gate operation is called enhancement mode.

JFET





→ Depletion only.

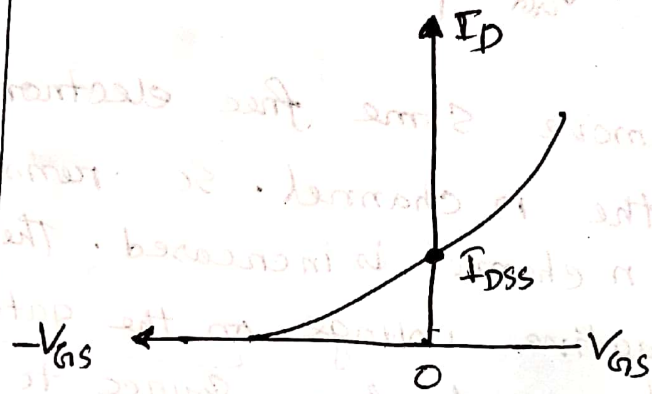
→ Extremely high input impedence.
প্রতিবন্ধকতা

disadvantage

→ Bias instability
→ Can operate only in the depletion mode.

→ Gate bias
Self bias
Voltage-Divider bias

DMOSFET



→ Depletion and enhancement

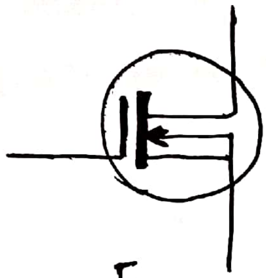
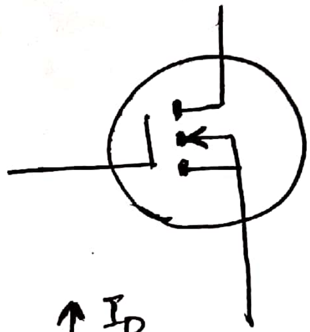
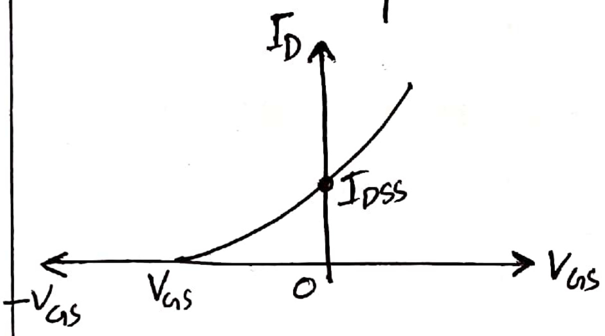
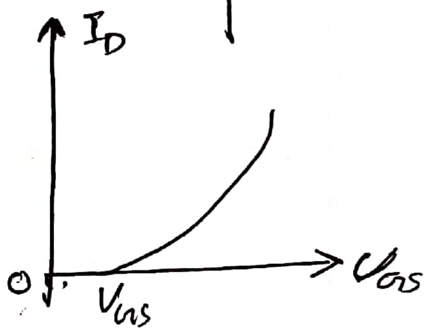
→ Higher input impedence than a comparable JFET.

disadvantage

→ Bias Instability
→ More sensitive to changes to changes in temperature than the JFET.

→ Gate bias, self bias, Voltage Divider bias, zero bias

D-MOSFETs Vs E-MOSFET

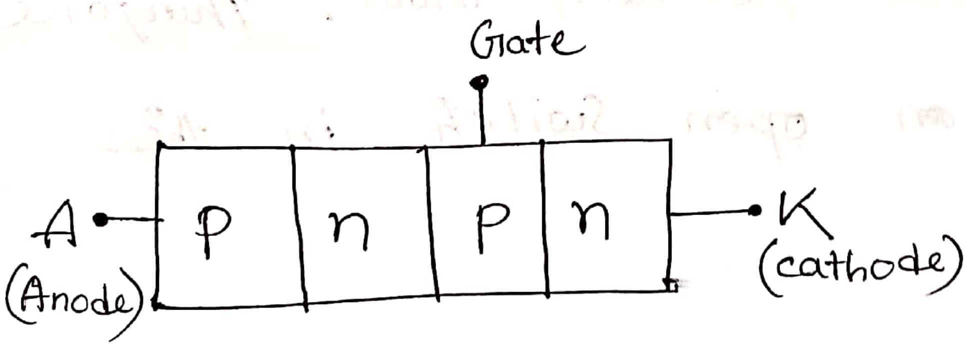
	D-MOSFETs	E-MOSFETs
Schematic Symbol		
Transconductance Curve		
Modes of operation	Depletion and enhancement	Enhancement only
Commonly used bias circuit	(i) Gate bias (ii) Self bias (iii) Voltage divider bias (iv) Zero bias	(i) Gate bias (ii) Voltage Divider bias (iii) Drain feedback bias

Construction
Symbol
Working
V-I Characteristics

- What do you meant by SCR?
- How does SCR act as a mechanical switch?

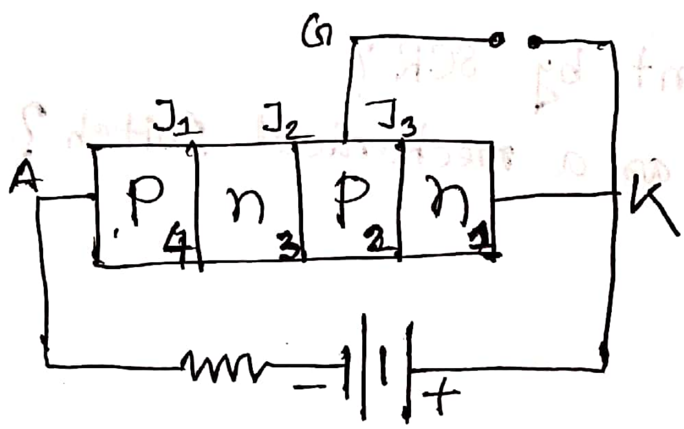
SCR

A silicon controlled rectifier is a semiconductor device that acts as a true electronic switch. It can change alternating current into direct current and at the same time it can control the amount of power to the load. So, SCR combines the feature of a rectifier and a transistor.



Working of SCR

(i) When gate is open : (~~Reverse~~ Forward blocking model)

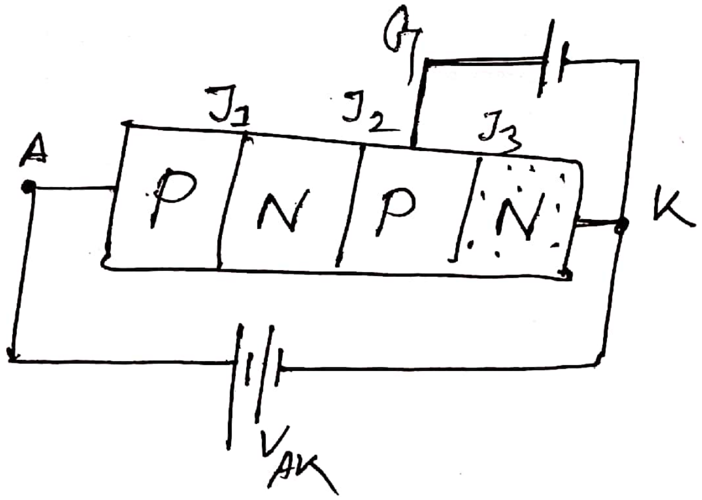


~~$J_1, J_3 \rightarrow$ Reverse bias~~

~~$J_2 \rightarrow$ forward bias~~

Here A is made +ve w.r.k K while G is kept open. Junctions J_1 & J_3 forward biased while the Junction J_2 is Reverse biased. Due to this small leakage current flows through the SCR. SCR offer high impedence to the current flow. Therefore SCR acts as an open switch in this mode.

(ii) Switch ON:



By applying (+)ve voltage to G terminal & avalanche breakdown occurs at J_2. So current starts flowing through the SCR. So, SCR act as a closed switch.

More is the gate current, the minimum will be the time to come in conduction mode.