Lecture 01

Electronics is study of flow of electrons.
There are active and Passive elements / devices in the circuit.

Elements that release energy / power are active elements.
e.g: capacitor.
Elements that consume energy / power are passive elements.
e.g: Resistor

Atomic Structure

No. of n^0 = No. of nucleons (Mass no.) − No. of protons (atomic No.)
$e^{\ominus}$ revolve in orbit/shell no. 'n' = $2n^2$.

If valance $e^{\ominus}$ i.e. VE = 4 then it is semiconductor.
VE < 4, then it is conductor
VE > 4, then it is insulator

e.g: $Si_{(14)}$, VE = 4, It is semiconductor
$_7N$, VE = 5, It is insulator.
$_{13}Al$, VE = 3, It is conductor.

Categorisation based on valance $e^{\ominus}$ (VE)

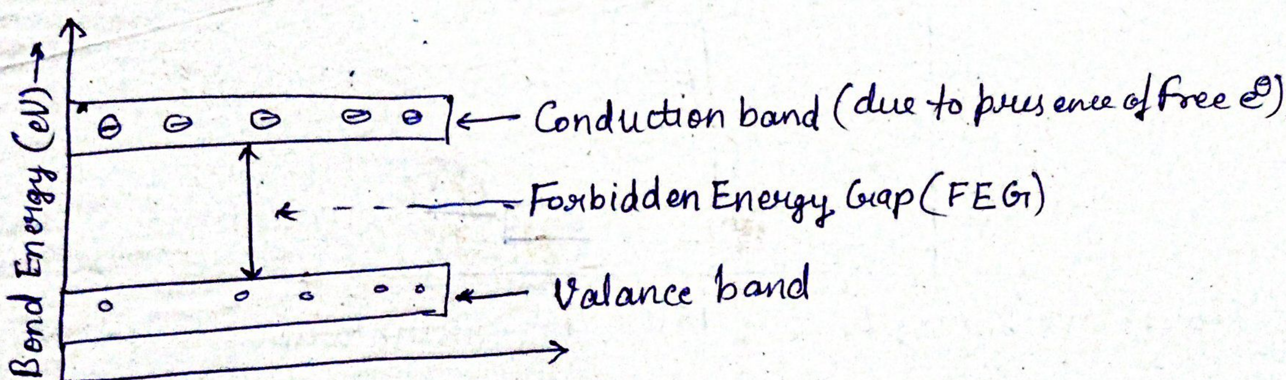
Based on free $e^{\ominus}$

Conductor — Highest no. of free $e^{\ominus}$.

Semi Conductor — very less no. of free $e^{\ominus}$ at room temperature.

Insulator — 0 free $e^{\ominus}$ at room temperature.

Energy Band in solids



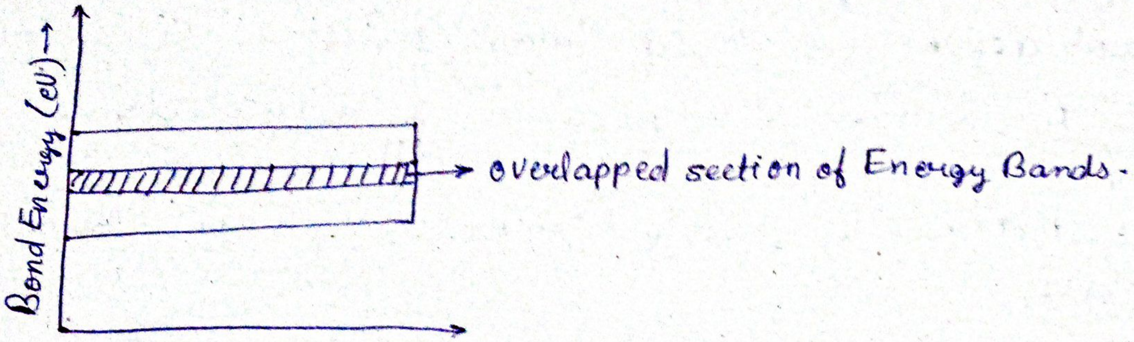
$1\,eV = q \times V = 1.6 \times 10^{-19} C \times 1V = 1.6 \times 10^{-19} J$.

$_{14}Si \rightarrow 2, 8, 4$ FEG = 1.1 eV

$_{32}Ge \rightarrow 2, 8, 18, 4$ FEG = 0.72 eV

Energy Band in Conductors

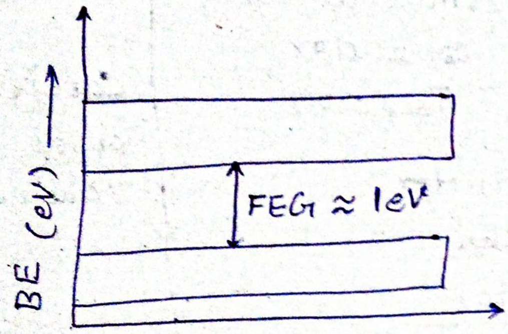
Conduction Band and Valance Band overlaps in conductor.



Forbidden Energy Gap is 0 in conductors.

Energy Band in Semi Conductor

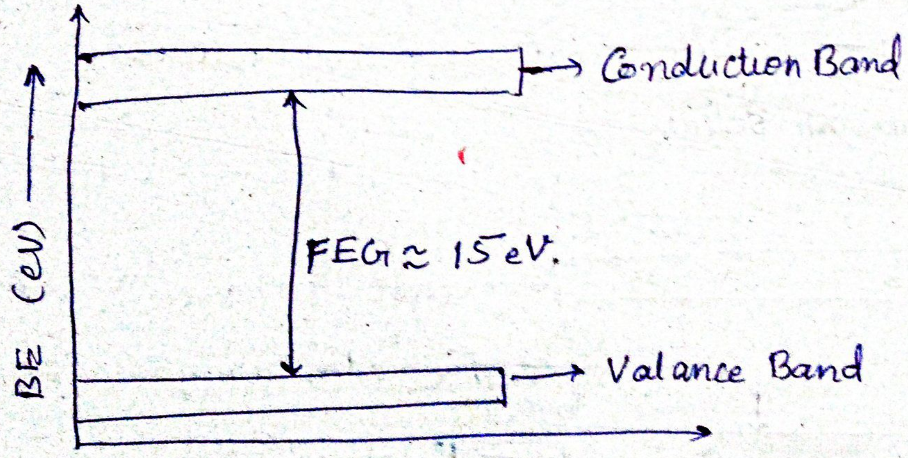
Conduction Band and Valance Band are closer $\approx$ 1eV FEG



Obviously, Forbidden Energy Gap = 1 eV in Semi Conductors.

Energy Band in Insulators

Conduction Band and Valance Band are far away.



Forbidden Energy Gap is 15 eV in Insulators.

The Energy possessed by Free $e^{\ominus}$(s) is Conduction Band.

The Energy possessed by Valance $e^{\ominus}$(s) is Valance Band.

Lecture 02

Semiconductors are the materials whose conductivity lies in between that of conductors and Insulators.

It has −ve temperature coefficient of Resistance i.e. With ↑ in temp. Resistance ↓. Its conductivity can also be changed.

e.g. ${}_{14}Si$, ${}_{32}Ge$.

E_g denotes FEG i.e. Forbidden Energy Gap.

E_g of Ge = 0.72 eV ; E_g of Si = 1.1 eV.

Covalant Bond is present in Germanium and Silicon.

Effect of Temperature on Semi Conductor

(1) At absolute zero i.e. 0 K, Semiconductor behaves as Insulator due to absence of covalant bond.

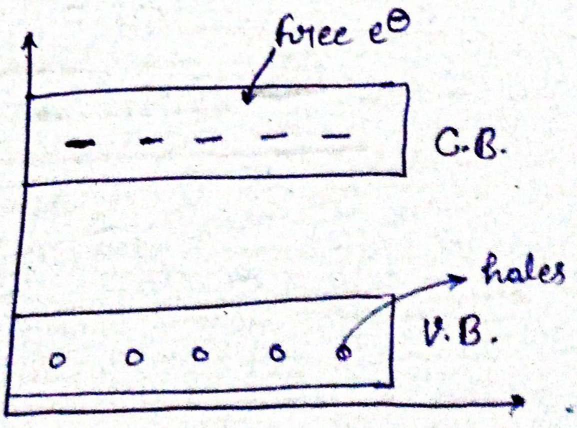
(2) Above absolute zero, $e^{\ominus}$(s) move from VB to CB resulting in formation of holes (+vely charged carrier).

Holes current and $e^{\ominus}$(s) current b/w Condution Band and Valance Band takes place.

The direction of Holes current and $e^{\ominus}$(s) current is always Quite opposite.

Intrinsic Semiconductor (Pure Semiconductor)

The no. of holes in V.B and no. of free $e^{\ominus}$ in C.B. are equal in pure semiconductors.



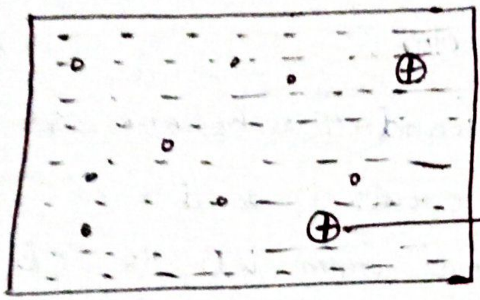
Extrinsic Semiconductor is also k/a Impure or doped Semiconductor.

Pure Semiconductor + Dopents (Impurities) ⟶ Extrinsic Semi Conductor

There are two types of Extrinsic Semiconductor —

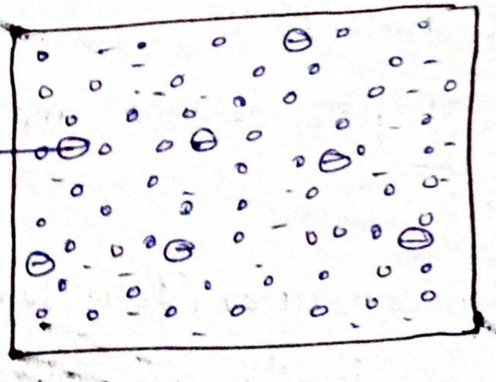
(I) n-type Semiconductor In this semiconductor, Pentavalant Dopents are doped and $e^{\ominus}$(s) are Majority Carriers.

(II) p-type semiconductor In this semiconductor, Trivalant Dopents are doped and Holes are majority carriers.



n-type

Fixed Donor/ Pentavalant Ions

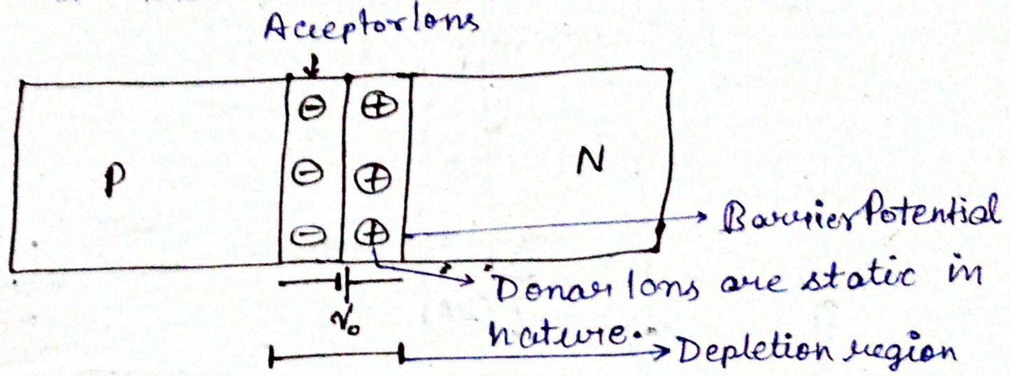


Fixed/ static Acceptor Ions

p-type

Lecture 03

PN Junction is a diode made by Junction of p-type and n-type semiconductor. $e^{\ominus}$ (s) diffuse from N-side to P-side. Due to absence of free carriers, depletion region is formed and its boundaries act as barrier for movement of carriers.

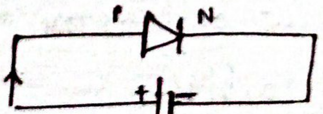


V_0 (Ge) = 0.3 V and V_0 (Si) = 0.7 V.

External Biasing

(I) **Forward Biasing** The external Potential must be greater than Barrier Potential for forward Biasing.

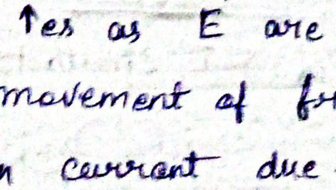
In F.B., the depletion region ↓es and finally Vanishes.

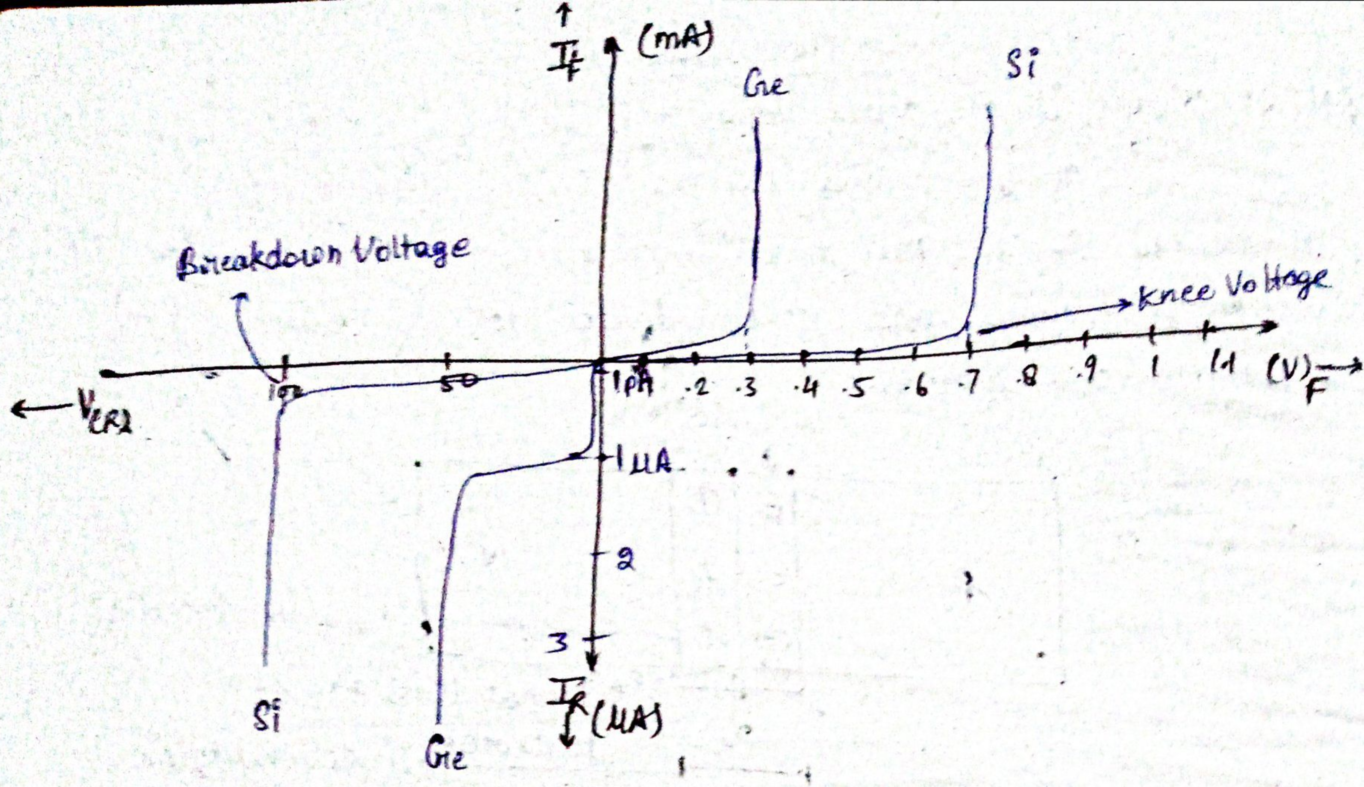


In it, P side is connected to +ve terminal and n-side is connected to -ve terminal of battery.

(II) **Reverse Biasing** In Forward-opposite i.e. Reverse Biasing, P side is connected to -ve terminal and N side is connected to +ve terminal of external Voltage source. The depletion region ↑es as $\vec{E}$ are in same direction resulting no movement of free carriers. $\therefore I_D = 0$.

Reverse saturation current due to minority carriers comes into picture in reverse Biasing.





V-I characteristic of a P-N Junction diode

$I_D = I_o\left(e^{V_D/\eta V_T} - 1\right)$; $\eta(Ge) = 1$ and $\eta(Si) = 2$

$V_T = \frac{K_B T}{Q}$ (Volt equivalent of Temperature) $\simeq$ 26 mV at 300 k.

I_D is diode current and V_D is voltage applied to diode. I_o is reverse saturation current or Reverse leakage current.

In Forward Bias, $I_D \simeq I_o\, e^{V_D/\eta V_T}$:

In Reverse Bias, $I_D \simeq I_o$

Note: Ge, Si are single crystal semiconductors while GaAs is compound semiconductor.

	Knee V (V)	I_o
Ge	0.3	1 μA
Si	0.7	10 pA
GaAs	1.2	5 pA

Temperature dependence of V-I characteristic

In forward Bias, V-I characteristic shifts towards left at a rate of 2.5 mV/°C ↑ in temp.

In Reverse Bias, I_o doubles with 10°C rise in temp., the breakdown voltage also ↑.

Lecture 04

Semiconductor Diode is the diode made up of semiconductor materials.

e.g: PN Junction diode

Properties

(I) It conducts in only one direction and opposes in another.
(II) In ideal conditions, Forward Biased diodes behaves as short circuit while Reverse Biased diodes behaves as open circuit.
(III) During F.B, $V_{in} = V_{out}$, during R.B, $V_{out} = 0$.
(IV) Forward Resistance (R_F) is negligible in diodes.
(V) Under Ideal conditions, Reverse resistance is very high $\approx \infty$.
(VI) For Germanium, $\dfrac{\text{AC reverse Resistance}}{\text{AC forward Resistance}} = 4\times 10^4$.

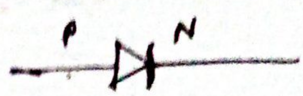
For Silicon, $\dfrac{r_r}{r_f} = 1\times 10^6$.

Resistance in diodes

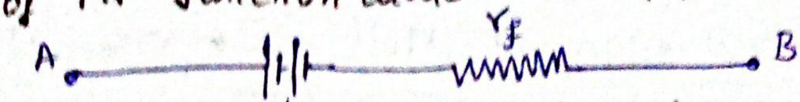
(I) Forward Resistance
(a) AC forward Resistance $(r_f) = \Delta V_F / \Delta I_F$
(b) DC forward Resistance $(R_f) = V_F / I_F$

(II) Reverse Resistance
(a) AC Reverse Resistance (r_r)
(b) DC Reverse Resistance.

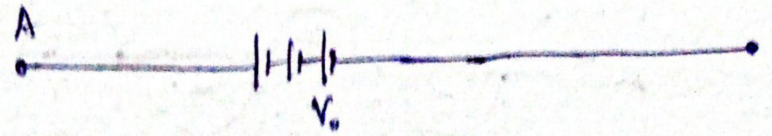
Equivalant circuit of PN Junction diode



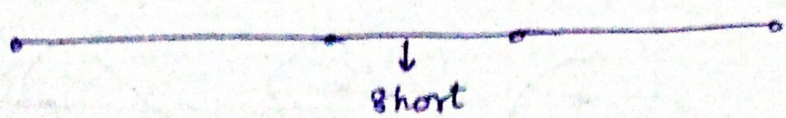
(I) Approximate model



(II) Simplified model

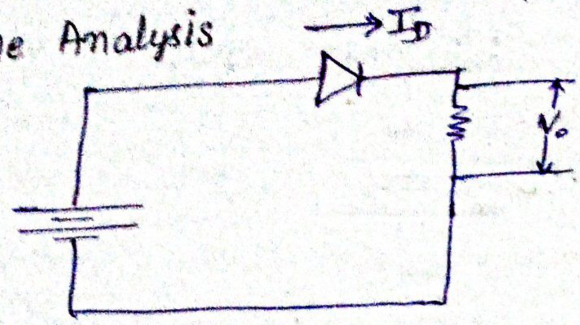


(III) Ideal model

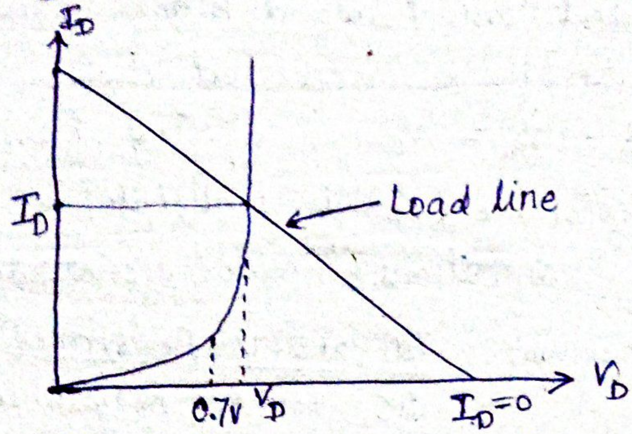


Lecture 03

Load Line Analysis



A/c to KVL, $E_o = V_D + I_D R.$

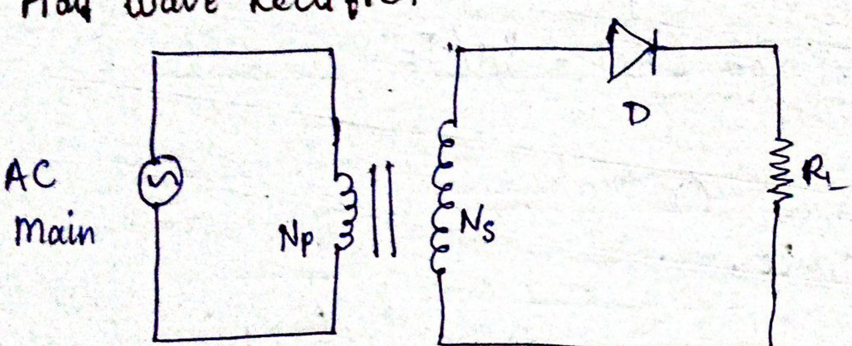


Depending on R, the slope of line varies, $V_D = E$ so it is k/a load line.

Rectifier converts A.C. signal to D.C. signal.

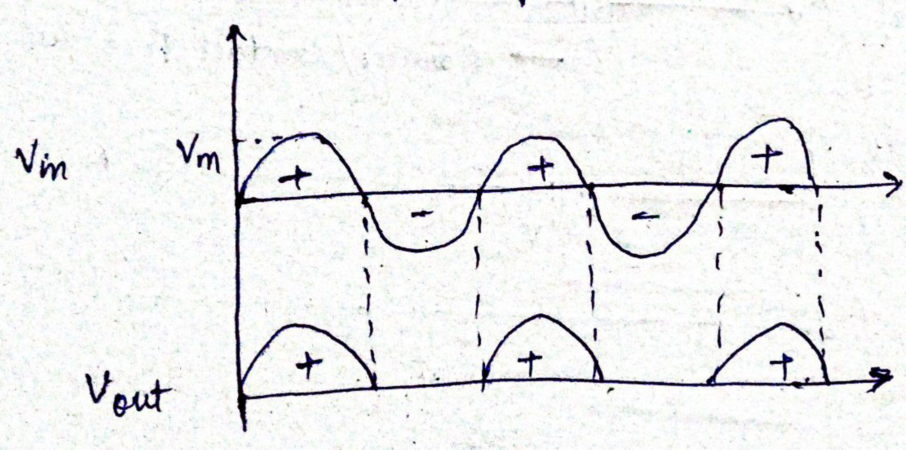
There are two types of Rectifier, Half wave and full wave.

Half wave Rectifier



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

Phasor diagram of Half wave rectifier for an ideal diode



$$I_{rms} = \sqrt{\frac{1}{2\pi}\int_0^{2\pi} i_o^2\, d\theta} = \sqrt{\frac{1}{2\pi}\left[\int_0^{\pi} I_m^2 \sin^2\theta\, d\theta + \int_{\pi}^{2\pi} 0\, d\theta\right]}$$

$$= \sqrt{\frac{I_m^2}{2\pi}\int_0^{\pi}\frac{1-\cos 2\theta}{2}\, d\theta} = \sqrt{\frac{I_m^2}{4\pi}\left|\theta - \frac{\sin 2\theta}{2}\right|_0^{\pi}}$$

$$I_{rms} = I_m/2.$$

For a Half wave rectifier, $I_{rms} = I_m/2$, $V_{rms} = V_m/2$.

$$I_{d.c.} = \frac{\int_0^{\pi} i_L\, d\theta}{2\pi} = \frac{I_m}{\pi} \qquad V_{d.c} = V_m/\pi.$$

Efficiency of a Half wave Rectifier —

$$\eta = \frac{\text{output power}}{\text{Input power}} = \frac{(I_m/\pi)^2 \times R_L}{(I_m/2)^2 \times (R_L + r_f)} = \frac{4}{\pi^2}\frac{R_L}{(R_L + r_f)}.$$

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

H.W.R's $\eta_{max} = 4/\pi^2 \approx 0.406 = 0.406 \times 100 = 40.6\%$.

under ideal condition, i.e. if it is maximum, $V_{out} = V_{in}$

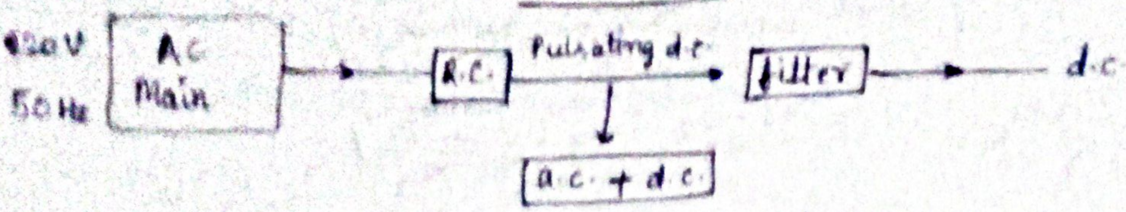
$$\frac{V_{rms}}{V_{dc}} = \text{Form factor} \approx 1.57 = \frac{\frac{1}{V_m/\pi}}{V_m/2} = \frac{V_m/2}{V_m/\pi} = \pi/2.$$

$I_{rms} = I_m/2$. $I_{dc} = I_m/\pi$. $f_{out} = f_{in}$ $(T_{in} = T_{out})$

$\eta = .406$.

Aim of rectifier is to convert A.C. signal to Pulsating D.C. signal which after being filtered gives pure d.c. signal. It is interesting to note $V_{rms} > V_{d.c.}$

Lecture 06



Transformer is used either to ↑/↓ input A.C. voltage and prevent electrical socks. $V_m = V_m \sin\theta$; $\theta = \omega t$

$$\text{Ripple factor} = \frac{\text{rms value of ac component}}{\text{d.c value of d.c output}} = \frac{(I_{rms})_{ac}}{I_{d.c.}}$$

$$\frac{(I_{rms})_{ac}}{I_{dc}} = \frac{\sqrt{(I_{rms})^2 - I_{dc}^2}}{\sqrt{I_{dc}^2}} = \sqrt{\left(\frac{I_{rms}}{I_{dc}}\right)^2 - 1} \approx 1.21 \text{ for HWR.}$$

If Ripple factor is 0, a.c. component in output = 0.

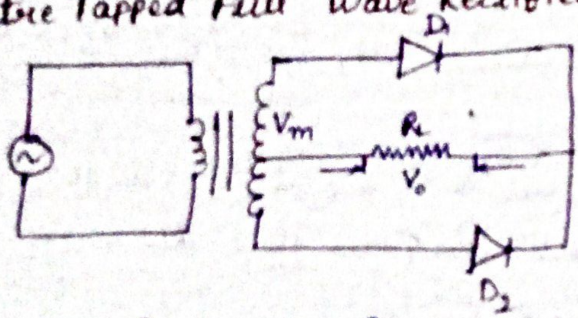
$V_{in} = V_m \sin\theta$.

Full wave Rectifier (FWR)

(1) Centre tapped

(2) Bridge tapped

(1) Centre Tapped Full Wave Rectifier



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

$V_{rms} = V_m/\sqrt{2}$

$V_{dc} = 2V_m/\pi$

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

R_L = Load Resistance

r_f = forward Resistance

$$\text{efficiency, } \eta = \frac{P_{out}}{P_{in}} = \frac{(I_{dc})^2 \times R_L}{(I_{rms})^2 (r_f + R_L)}$$

$$= \frac{(2I_m/\pi)^2 \times R_L}{(I_m/\sqrt{2})^2 (r_f + R_L)} = \frac{2 \times .406}{(1 + r_f/R_L)} = \frac{0.812}{(1 + r_f/R_L)}$$

$$\eta \approx 0.812 = 81.2\%.$$

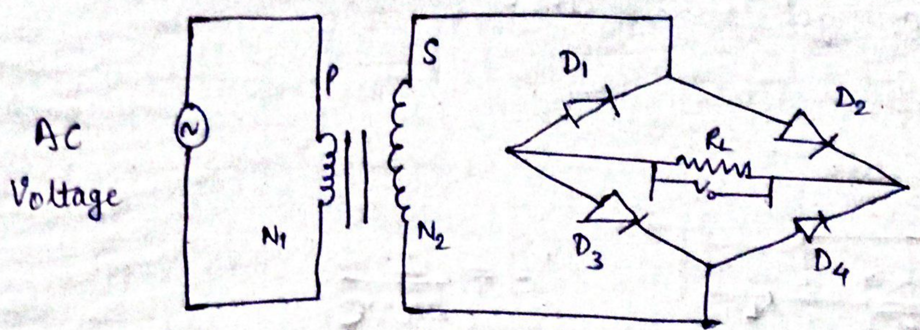
$\eta_{max} = 81.2\%$. $\quad \nu_{out} = 2\nu_{in}$

Peak inverse voltage (PIV) $= 2V_m$. PIV is present during Reverse Bias only.

$$\text{Ripple factor} = \frac{(I_{rms})_{ac}}{I_{dc}} = \sqrt{\left(\frac{I_{rms}}{I_{dc}}\right)^2 - 1} \approx 0.482$$

lower ripple factor, lower the a.c component and better Rectifier Circuit.

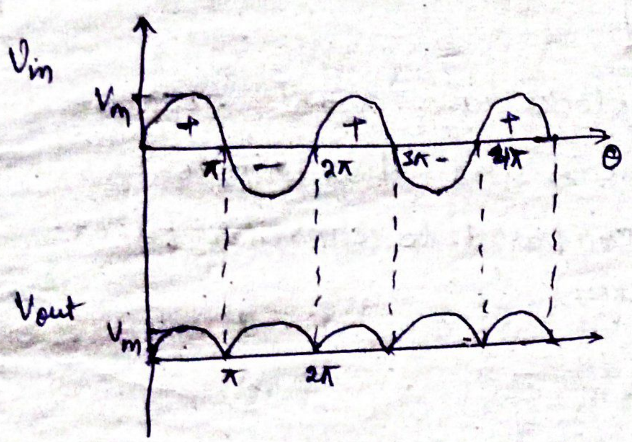
(2) Bridge Tapped Full Wave Rectifier



$V_i = V_m \sin\omega t = V_m \sin\theta$.

Working During +ve Half cycle of input current, D_2 and D_3 are in forward Bias while D_1 and D_4 are in Reverse Bias.

During -ve Half cycle of input current, D_1 and D_4 are in Forward Bias while D_2, D_3 are in Reverse Bias.



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

$V_{rms} = V_m/\sqrt{2}$

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

$V_{dc} = 2V_m/\pi$

$v_{out} = 2v_{in}$

$PIV = V_m$.

Ripple factor $= \frac{(I_{rms})_{dc}}{I_{dc}} = 0.482$ $\eta = \frac{P_{out}}{P_{in}} = .812 \Rightarrow \eta_{max} = 81.2\%$

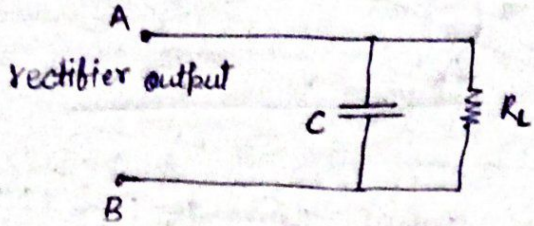
	HWR	CTFWR	BTFWR
No. of Diodes	1	2	4
Transformer	No	C.Taped Transformer	No
I_{rms}	$I_m/2$	$I_m/\sqrt{2}$	$I_m/\sqrt{2}$
I_{dc}	I_m/π	$2I_m/\pi$	$2I_m/\pi$
PIV	V_m	$2V_m$	V_m
Ripple factor	1.21	.482	.482
η_{max}	40.6%	81.2%	81.2%
v_{out}	v_{in}	$2v_{in}$	$2v_{in}$

Lecture 08

Output of rectifier is pulsating d.c. and by using filter circuit, we can get pure d.c.

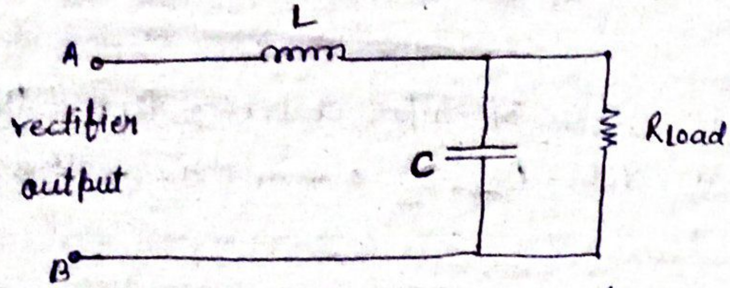
Types of filter circuit

(I) Capacitor filter



$$X_C = \frac{1}{2\pi\nu C}.$$

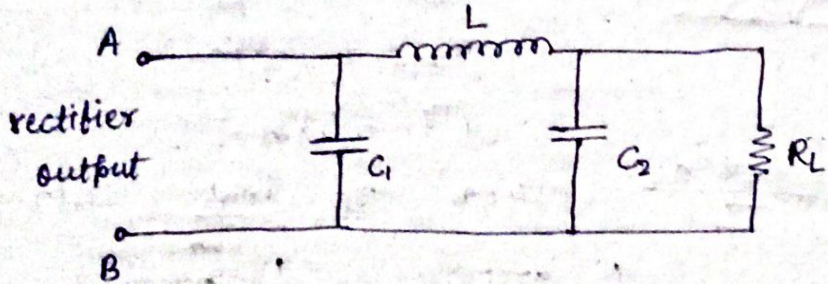
(II) Choke filter circuit



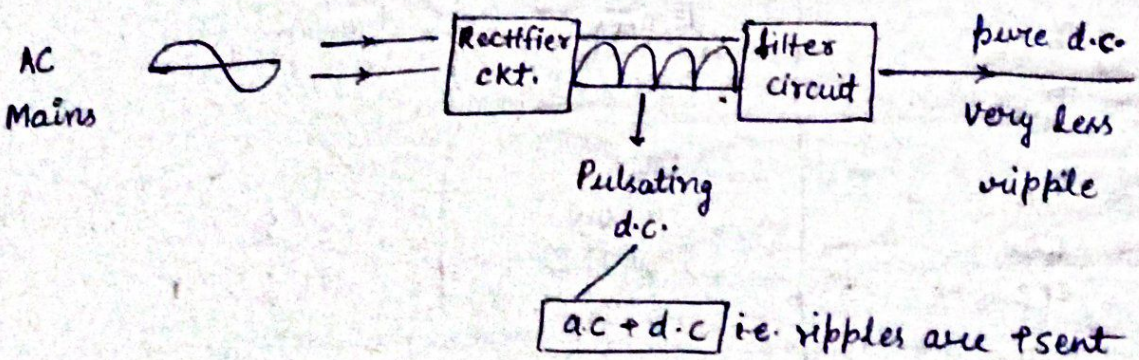
$$X_L = 2\pi\nu L.$$

Inductor passes d.c. signal and blocks a.c. signal because $X_L = 0$ (d.c.) $X_c = \infty$ (a.c.) and thus ripple is reduced in higher extent compared to capacitor filter.

(III) π- filter (Capacitor input filter)



In this case, ripple is reduced at the highest extent.

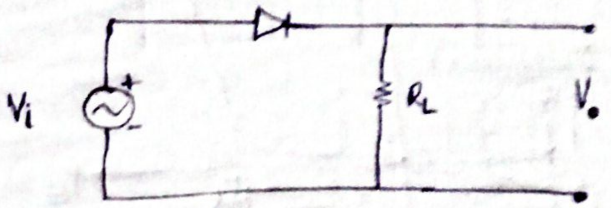


Lecture 09

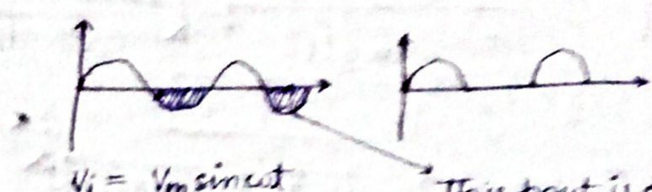
Clipper circuits are that circuit which 'clip' some portions of input waveform without disturbing the remaining part of the waveform.

Types

(I) Series clippers (Simplest form of clipper circuit)



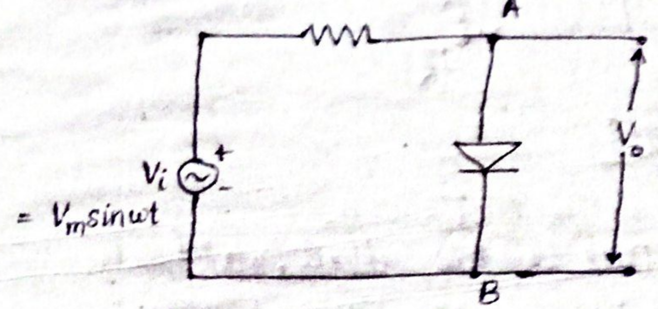
$V_o = V_m$.



$V_i = V_m \sin\omega t$

This part is clipped.

(II) Parallel clipper



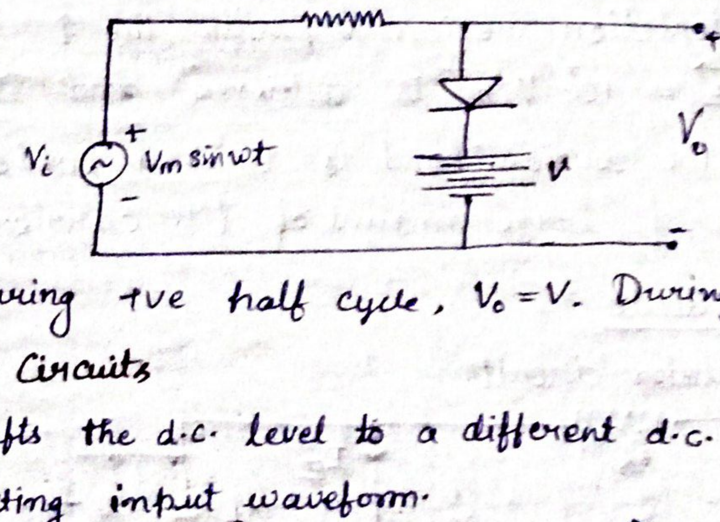
$V_o = V_A - V_B = 0$ [In forward]

As, $V_A = V_B$

But $V_o = -V_m$ [In reverse]

So +ve part is clipped.

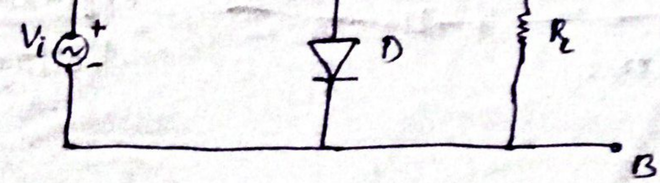
By applying some external D.C. bias, we can clip a specific part of input waveform.



During +ve half cycle, $V_o = V$. During -ve half cycle, $V_o = V_i = -V_m$

Clamper Circuits

It shifts the d.c. level to a different d.c. level without distorting input waveform.



$V_o = 0$] for +ve Half cycle.

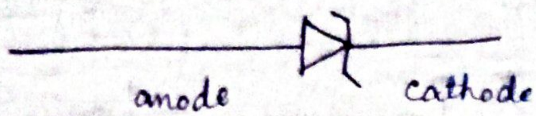
But for -ve Half cycle

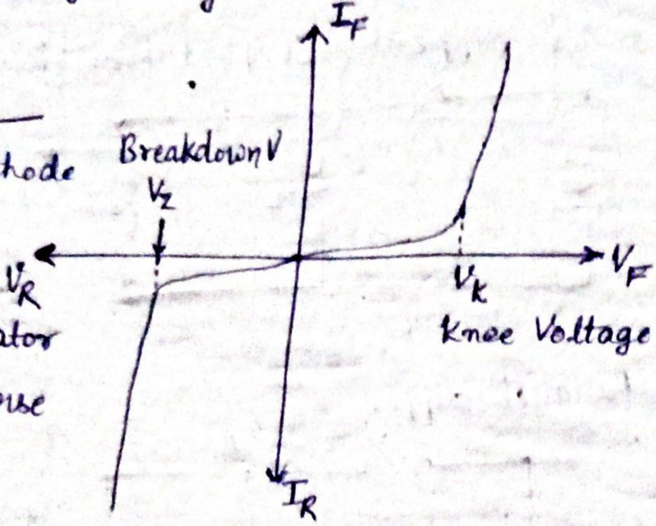
$V_o = (-V) + (-V) = -2V$.

Lecture 10

A fixed d.c supply can be got using voltage regulator.

Concentration of doping level of impurity is very large in zener Diode. It is also a PN Junction diode and special crystal diode that generally works in reverse bias condition.





To use this diode in regulator circuit, It is used in reverse bias generally.

Reverse Bias Breakdown Mechanism

(1) Avalanche effect

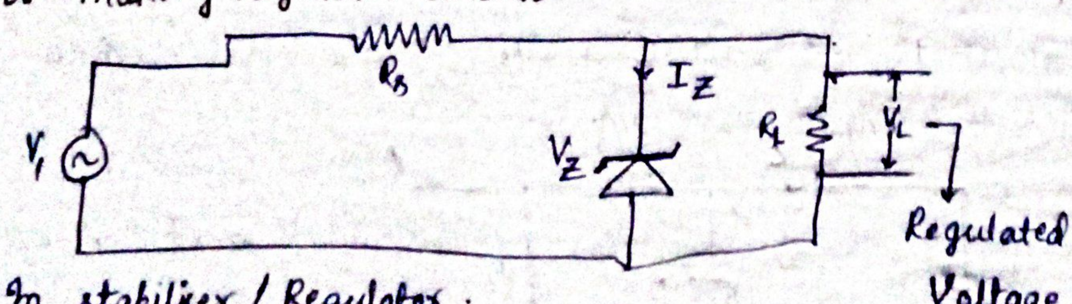
For less doped semiconductor. Due to this effect, a large amount of current is observed just after the breakdown due to +sence of large no. of free charge carrier.

(II) Zener Breakdown effect (due to heavily doped Si)

The depth of depletion region ↓ with the ↑ in doping level. $\vec{E} = 10^7$ V/m is achieved and Due to Very high $\vec{E}$, the covalant bond is broken which leads in creation of large amount of free carriers.

Application of zener diode

(I) For making regulator circuit.



In stabiliser / Regulator :

Case 1 → If $V_{AB} = V_L \geq V_Z$, then Diode is in 'on' condition means diode is replaced by voltage source.

Case 2 → If $V_{AB} = V_L \leq V_Z$, then Diode is in 'off' state means, diode is replaced by open.

During 'ON' state, $I_R = I_Z + I_L$ $[V_{AB} = V_L \geq V_Z]$

$$\Rightarrow I_Z = I_R - I_L.$$

$$I_R = \frac{V_R}{R} = \frac{V_i - V_L}{R} \quad \Rightarrow I_Z = \frac{V_i - V_L}{R} - \frac{V_L}{R_L}.$$

$$I_L = \frac{V_L}{R_L}$$

$$P_Z = V_Z I_Z$$

$$P_Z < P_{Zmax}$$