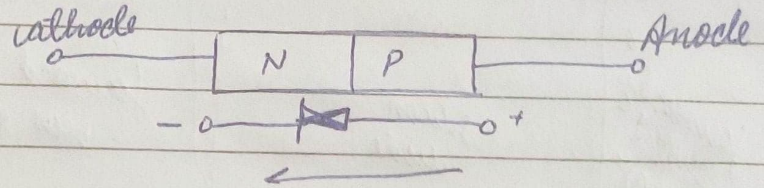
A&DE

Unit :- 1

Q. **PN Junction diode :-**

In a piece of semiconductor, if one half is doped ~~with~~ by P-type impurity and other half is doped by N-type impurity, a PN junction is formed. The plane dividing the two half or zones is called PN junction.



-> In P side, majority carrier is hole and minority carrier is electron (e^-)

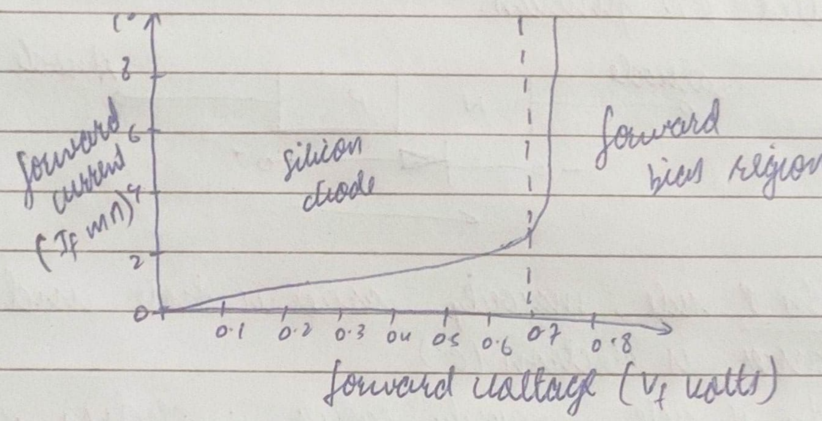
-> In N side, majority carrier is electron and minority is hole.

-> ~~st~~ Electron move from N to P. from high conc. to low.

-> Silicon and germanium are two semiconductor material

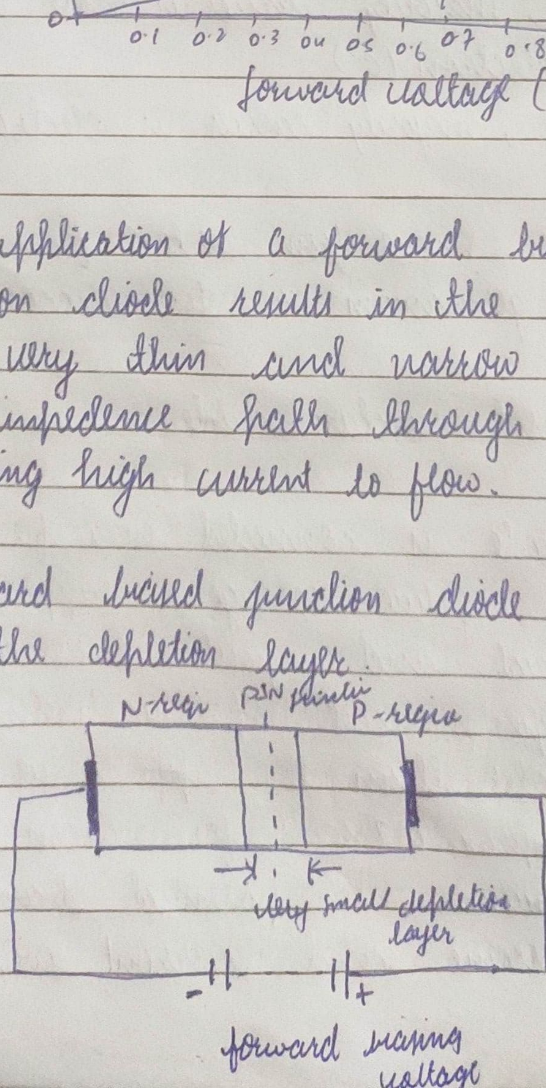
Forward biased junction diode :-

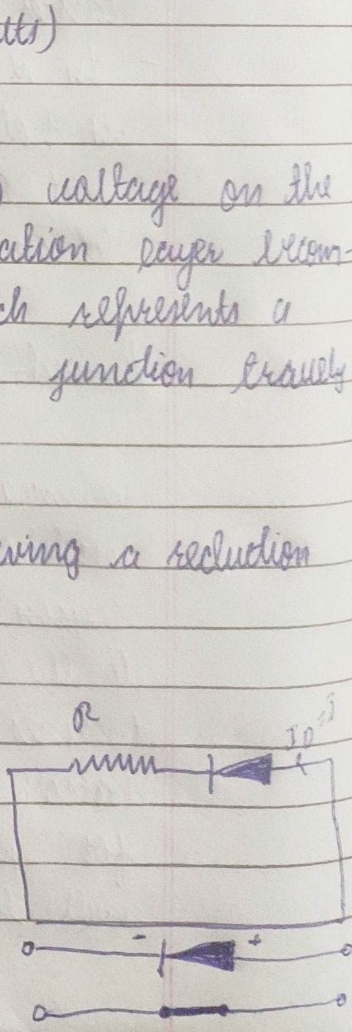
when a diode is connected in a forward bias condition a negative voltage is applied to the N-type ~~region~~ material and a positive voltage is applied to the P-type material. If this external voltage becomes greater than the ~~app~~ value of the potential barrier, approx. 0.7 volts for silicon and 0.3 volts for germanium, the potential barrier opposite will be overcome and current will start to to flow. This is because the negative voltage pushes or repels electrons towards the junction giving them the energy to cross over and combine with the holes being pushed in the opposite direction towards the junction by the positive voltage. This results in a electrostatic curve of zero current following up to this voltage point called the 'knee' on the static curve and then a current flow through the diode with little increase.



The application of a forward biasing voltage on the junction diode results in the depletion layer becoming very thin and narrow which represents a low impedence path through the junction thereby allowing high current to flow.

→ Forward biased junction diode showing a reduction in the depletion layer.

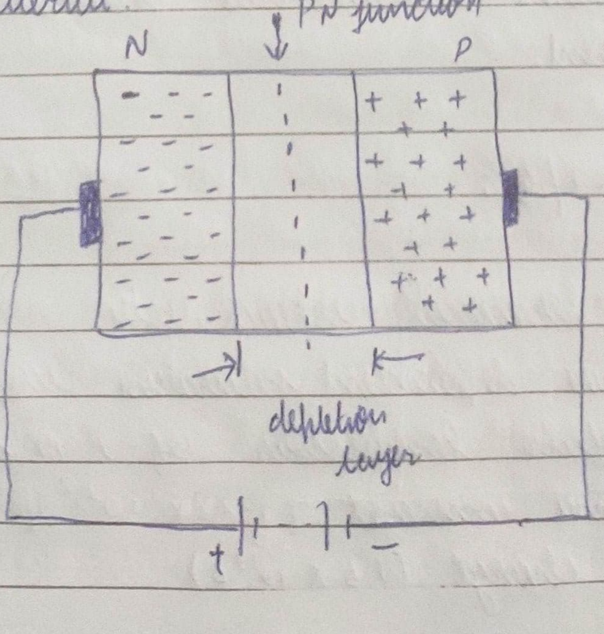


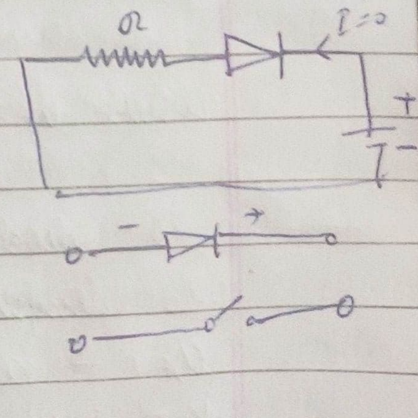


The condition represents the low resistance path the PN juction allowing very large current flow through the diode with only a small increase in voltage. ~~The actual potential difference across the~~

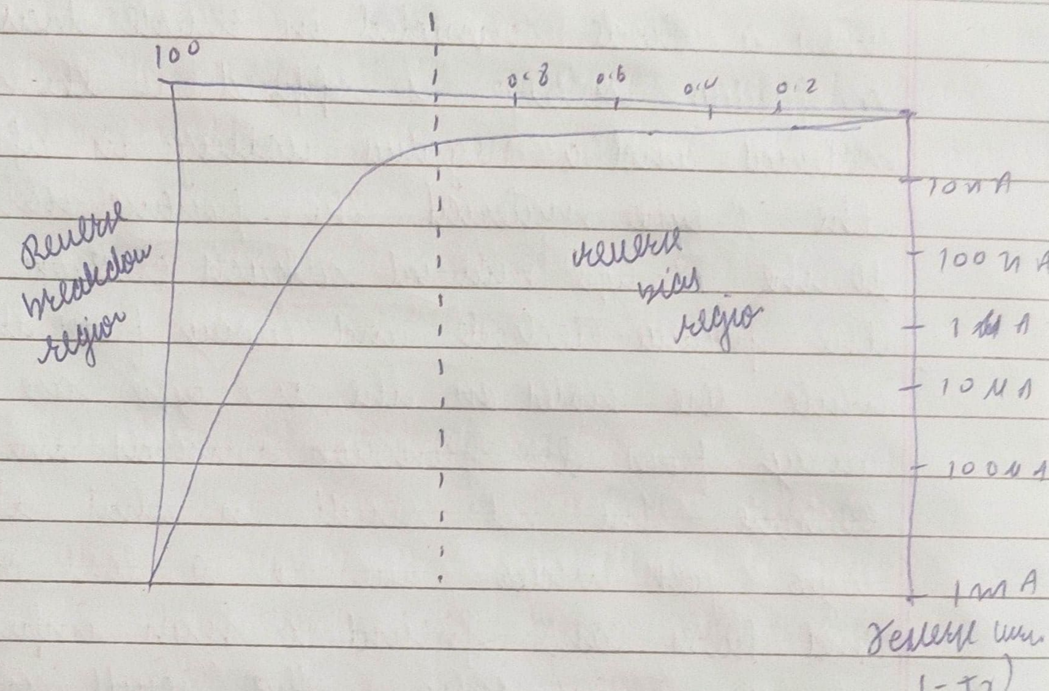
PN Junction under Reverse Bias:

when a diode connected in reverse bias condition a positive voltage is applied to the N-type material and a negative voltage is applied to the P-type material. The positive voltage applied to the N-type material attracts electron toward the positive electrode and away from the ~~pn~~ junction while the holes in the ~~p~~ P-type are also attract away from the junction towards the negative electrode. The net result is that the depletion layer ~~grows~~ wider due to a lack of electron and holes and present a high impedence path, almost an insulator. This result is that a high potential barrier is created preventing current from flowing through the semiconductor material.





The condition represents a high resistance value to the PN junction and partly practically zero current flow through the junction diode with in an increase in junction diode bias voltage. However, a very small leakage current does flow through the junction which can be measured in microamperes (μA).



V-I characteristics :-

Diode terminal characteristic equation for diode junction current:

where $V_T = KT/q$;

V_D diode terminal voltage, volts

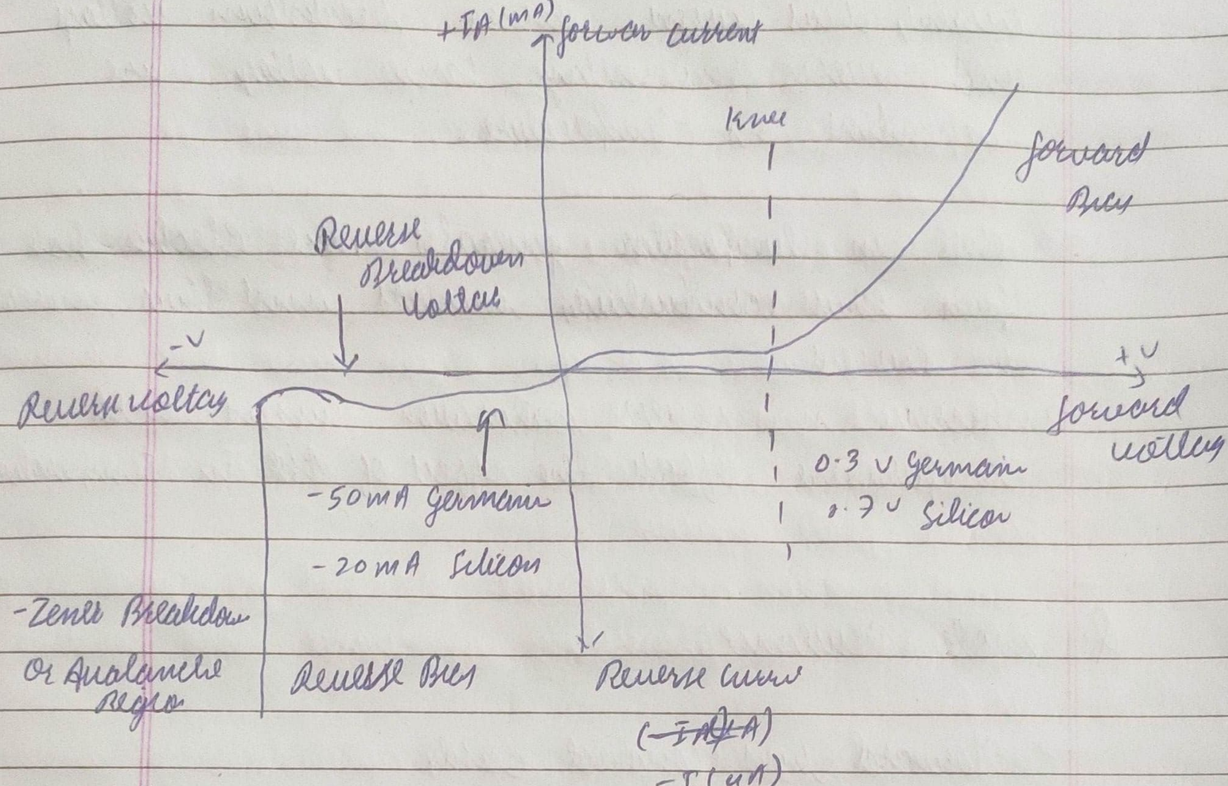
I_0 temperature dependent saturation current. ~~μA~~

μA T - absolute temperature of P-N junction

K - Boltzmann's constant (1.38×10^{23} J/K)

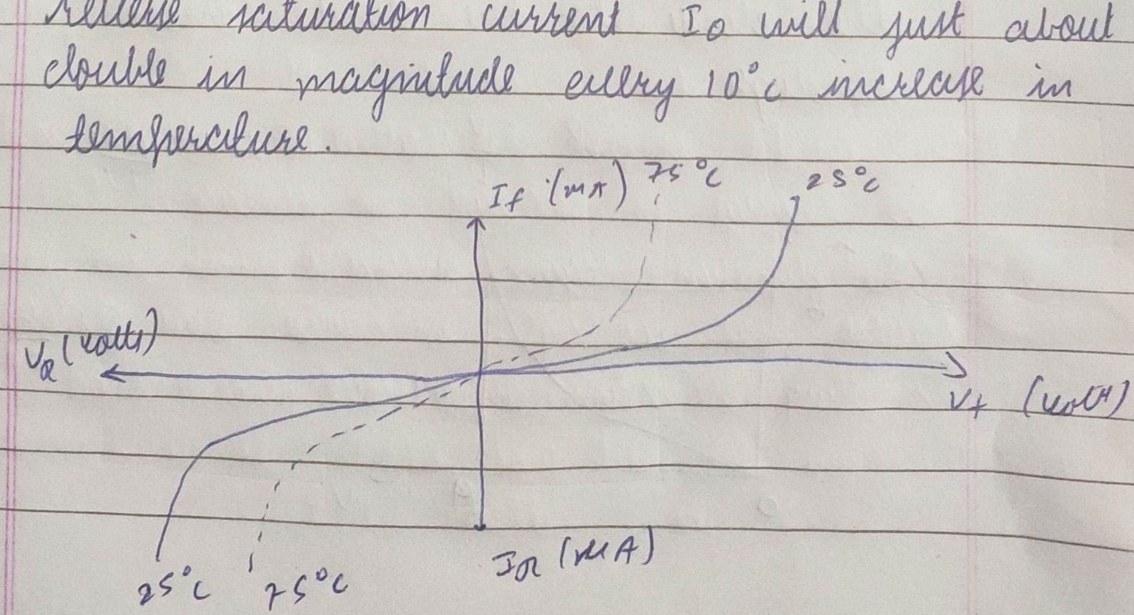
q - electron charge (1.6×10^{19} C)

Empirical constant 1 for Ge and 2 for Si.



Temperature Effect on a diode ?-

Temperature can have a marked effect on the characteristic of a silicon semiconductor diode as. It has been found experimentally that the reverse saturation current I_0 will just about double in magnitude every 10°c increase in temperature.



→ PN junction diode parameter like reverse saturation current, bias current, reverse breakdown voltage and ~~reverse~~ ~~bias voltage~~ barrier voltage are dependent on temperature.

→ Rise in temperature generates more electron-hole pair thus conductivity increases and thus increase in current.

→ Increase in reverse saturation current with temperature offsets the effect of rise in temperature

Q. Diode Resistance:-

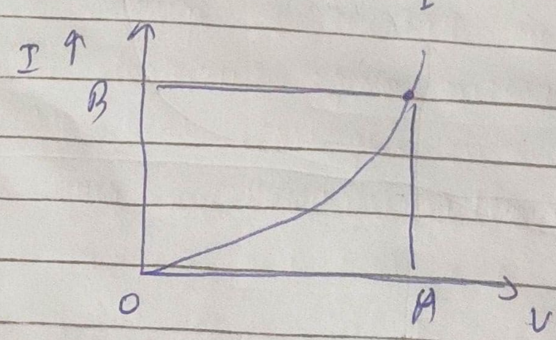
→ Forward bias conduct easily

If we supply DC then its Static Resistance
If we supply AC then its Dynamic Resistance

* DC or static resistance:-

It is simply the ratio of DC voltage across the diode to the direct current following through it

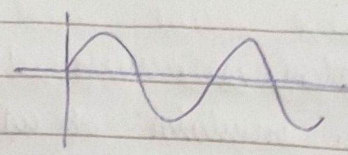
$$R = \frac{V}{I} \qquad R_{dc} = \frac{V_{dc}}{I_{dc}}$$

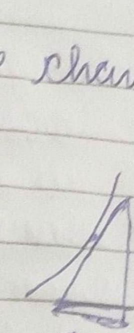


$$R = \frac{OA}{OB}$$

* AC or dynamic Resistance

Resistance offered by a diode to changing forward current.





$$r = \frac{1}{\text{slope}} = \frac{\Delta V}{\Delta I} = \frac{\text{change in voltage}}{\text{change in current}}$$

$$r = \frac{dV}{dI} = \frac{n V_T}{I_0 e^{V/nV_T}}$$

$$\boxed{r_{ac} = \frac{V_{ac}}{I_{ac}}}$$

→ Reverse bias resistance high / block the flow of current.

When we connect the diode in reverse bias condition, there will be a small current following through it which is called the reverse leakage current

Due to this current flow, the diode exhibits reverse resistance characteristic.

$$R_r = \frac{V_r}{I_r}$$

where V_r, and I_r are the reverse voltage and reverse current.

Transition and Diffusion capacitance :-

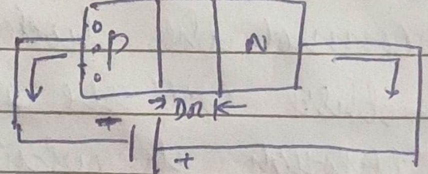
Transition capacitance:
(or space charge)

→ When P-N junction is reverse biased the depletion region act as an insulator or as a dielectric medium and the P-type an N-type region have low resistance and act as the plates.

→ Thus this P-N junction can be considered as a parallel plate capacitor.

→ This junction capacitance is called as space charge capacitance or transition capacitance and is denoted as C_T.

→ Since reverse bias causes the majority charge carriers to move away from the junction, so the thickness of the depletion region denoted as W increases with the increase in reverse bias voltage.



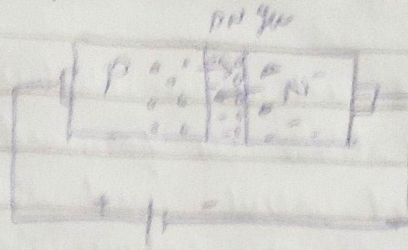
→ This incremental capacitance C_T.

$$\boxed{C_T = \frac{dQ}{dV}}$$

where dQ is the increase in charge and dV is the change or increase in voltage.

→ The depletion region increases ~~with the increase in reverse bias voltage~~. in reverse bias potential the resulting transition capacitance decreases.

→ Diffusion capacitance:-



Density of charge carrier is higher at PN junction and reduces or decays as the distance increases

→ when the junction is forward biased, a capacitance come into play, that is known as diffusion capacitance denoted as C_D. It is much greater than the transition capacitance

$C_D >> C_T$. Thus C_T can be neglected in forward bias

→ During forward biased the potential barrier is reduced. The charge carrier move away from the junction and recombine

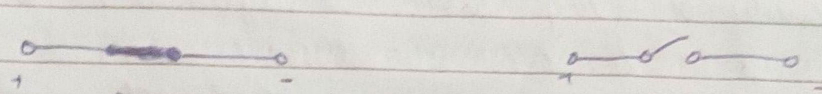
→ Thus in this case charge is stored in the both side of the junction and varies with the applied potential. So as per definition change in charge with respect to applied voltage results in capacitance which here is called as diffusion capacitance.

→ The formula for diffusion capacitance is $C_D = \tau I_D / \eta V_T$. where τ is the mean life time of the charge carrier, I_D is the diode current and V_T is the applied forward voltage and η is generation recombination factor.

→ The diffusion capacitance is directly proportional to diode current.

Diode Switching times :-

-> Diode can be act as an electrical switch.
-> when the diode is forward bias it will act as a closed circuit and whenever it is in reverse bias it will act as an open circuit



forward bias/ closed circuit

Open circuit

-> forward biased diode indicate - ON state
Reverse biased diod indicate - off state.

-> for conversion from ON state to OFF state or OFF state to ON we require two recovery time.
1. Forward Recovery time (t_{fr})
2. Reverse Recovery time (t_{rr})

(1) Forward Recovery time (t_{fr})

-> The time interval taken by the diode to switch from reversed biased (OFF) to a forward biased (ON) is called t_{fr}.

(2) Reverse recovery time (t_{rr})

-> The time interval taken by the diod to switch from forward bias (ON) to a reverse biased (OFF) is called t_{rr}.

Zener Diode :-

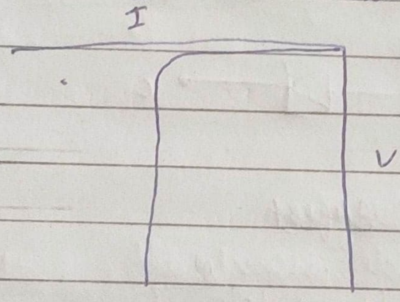
Zener diodes are normal PN junction diodes operating in a reverse biased condition

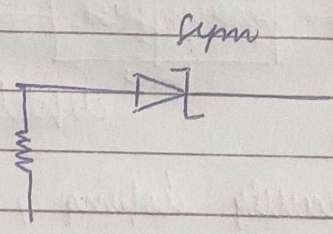
Zener diode can also conduct when it is conducted in reverse bias above its threshod or breakdown voltage.

~~Semiconductor diode in reverse bias condition~~

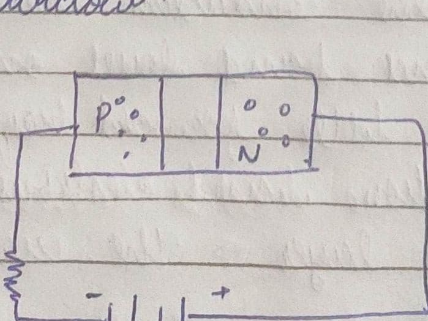
→ ~~It is a special purpose diode, used for operation~~

→ Doping done to have a sharp breakdown voltage





Avalanche breakdown



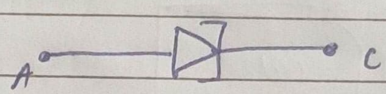
~~The majority charge carriers~~

Tunnel Diode:
[Esaki diode]

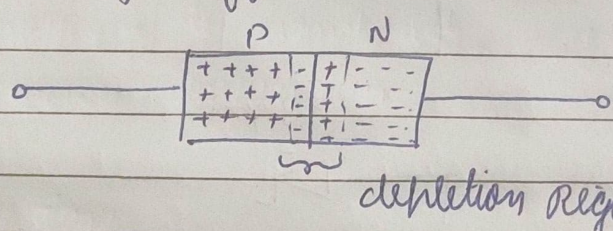
A tunnel diode is a heavily doped P-N Junction diode
→ It has negative resistance characteristics

due to tunneling effect.
→ Tunnel diode worked on based on the concept tunneling effect.

Symbol.



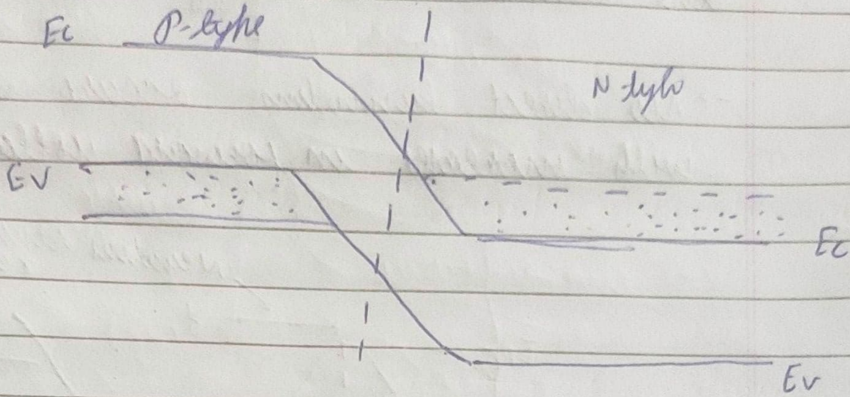
* Tunneling Effect



→ Due to heavily doping, the width of the depletion region becomes very thin and an overlap occurs between the conduction band on the n-side and the valence band level on the p-side
→ under little forward bias condition, the conduction band electrons tunnel through the depletion layer → The current reaches maximum of I_P

Working Principle

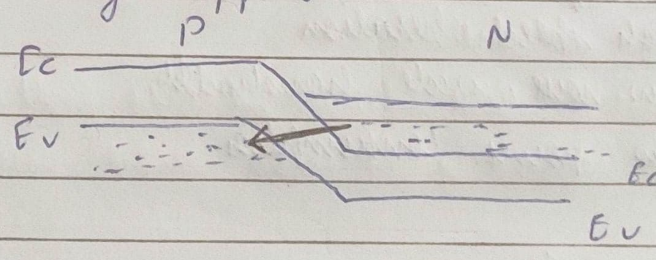
* Zero - bias



-> Due to overlapping, the conduction band electrons at n-side and valence band holes at p-side are at the same energy level.

-> Therefore is no current flow.

* small voltage applied.



-> under small forward bias condition, the conduction band electron tunnels through the depletion layer resulting the tunnel current

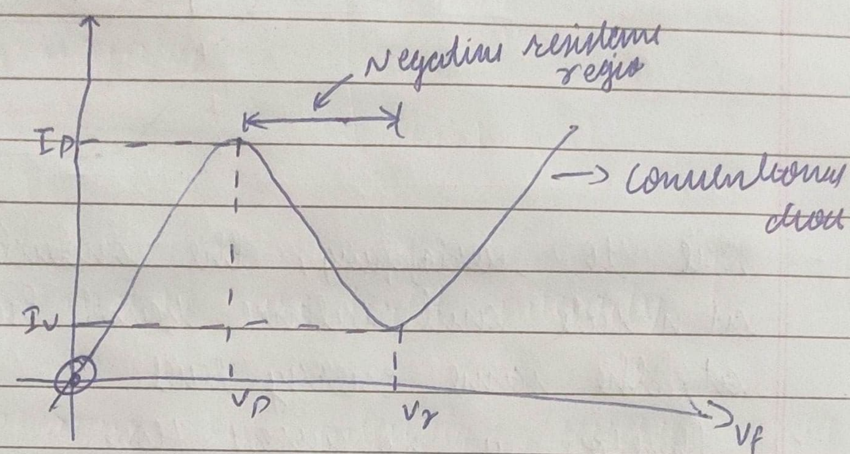
* High forward voltage :-

The current reaches maximum current (I_P) at Peak voltage (V_P)

V-I characteristics :-

→ For further increases of forward bias the conduction band energy level are increased above the valence band energy level.

→ No direct tunneling occurs so current decreases with increases in forward voltage till V_r.



Advantages
→ High speed operation
→ low noise, wide bandwidth
→ low power consumption.

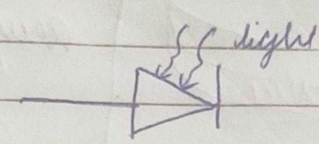
Disadvantages:
→ High cost
→ The input and output are not isolated from each other

Applications :-
→ It can be used as tunnel diode reflection amplifier (TDRA)
→ used as logic memory storage device.
→ used as an ultra high speed switch

PHOTO DIODE:-

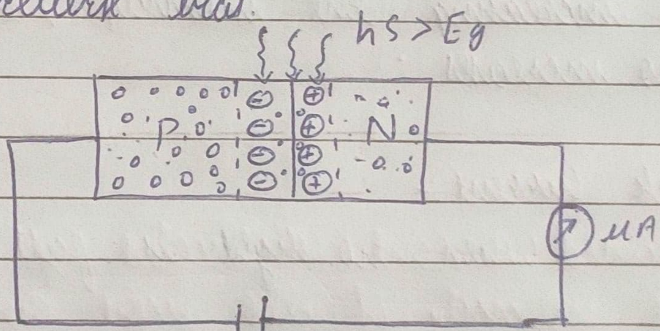
It is a device used to detect & convert light energy into electrical energy. It is operated under reverse bias below breakdown voltage.

Symbol:-



Construction:-

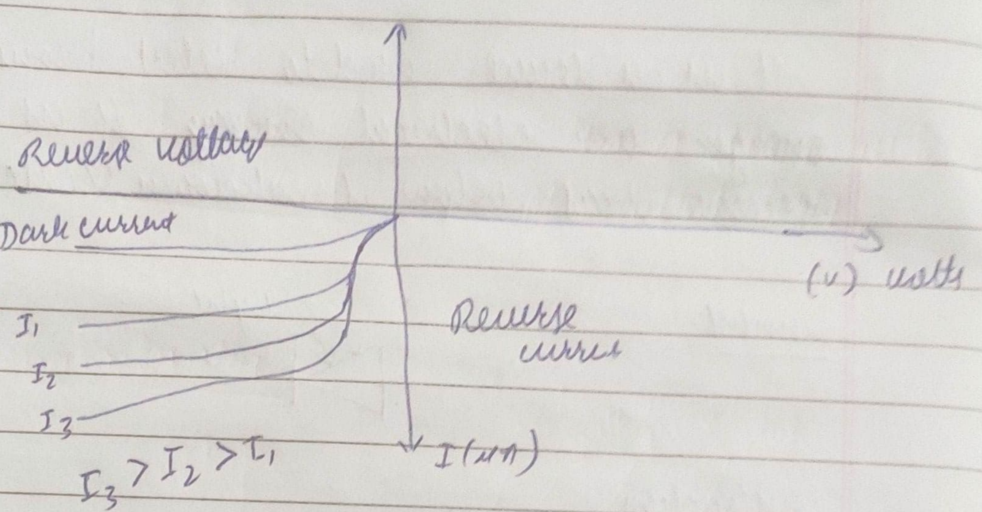
A photodiode fabricated with a transparent cover to allow light to fall on the diode & operand under reverse bias.



Working:-

When a photodiode is illuminated with light with energy greater than the energy gap of the semiconductor than e^- hole pair are generated due to the absorptions of photons. These charge carriers contribute to the reverse current.

V-I characteristics :-



I_1, I_2 and I_3 are light intensity

On increasing the intensity, reverse current also increases.

Dark current :-

When no light is fall on the junction.

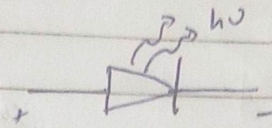
Uses :-

1.) → In photodetection for optical signals
2) In demodulation for optical signal
3) In counting machines
4) In optical communication equipments

LED (light Emitting diode)

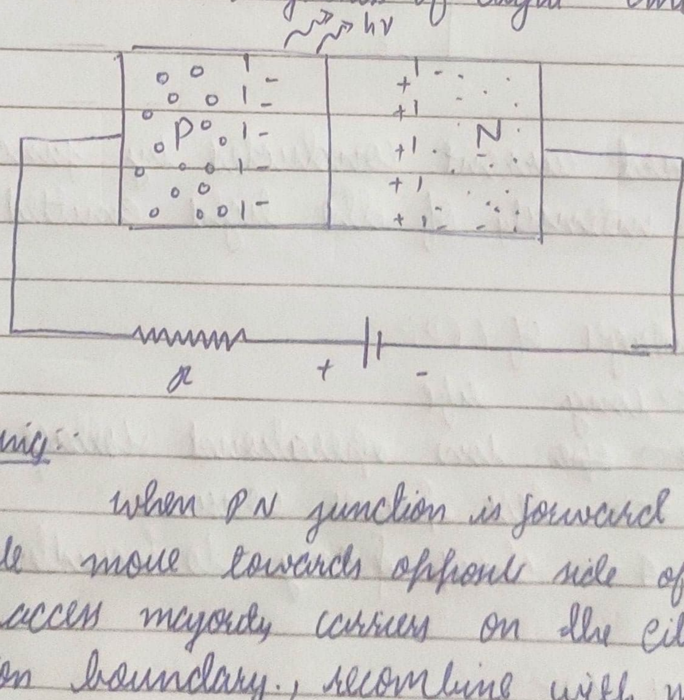
It is heavily dopped P-N junction diode which convert electrical energy into light energy.
This diode emit light under forward biasing.

Symbol:-



Construction:-

In this P-N junction diode is connected from a battery through resistance R which control the brightness of light emitted.



Working:-

when P-N junction is forward biased, electron & hole move towards opposite side of junction. therefore access majority carriers on the either side of junction boundary, recombine with majority carrier near the junction.

ON recombination of e's hole, the energy is given out in the form of light. The released energy is nearly equal to ~~Egp~~ energy gap.

$Eg = h\nu$

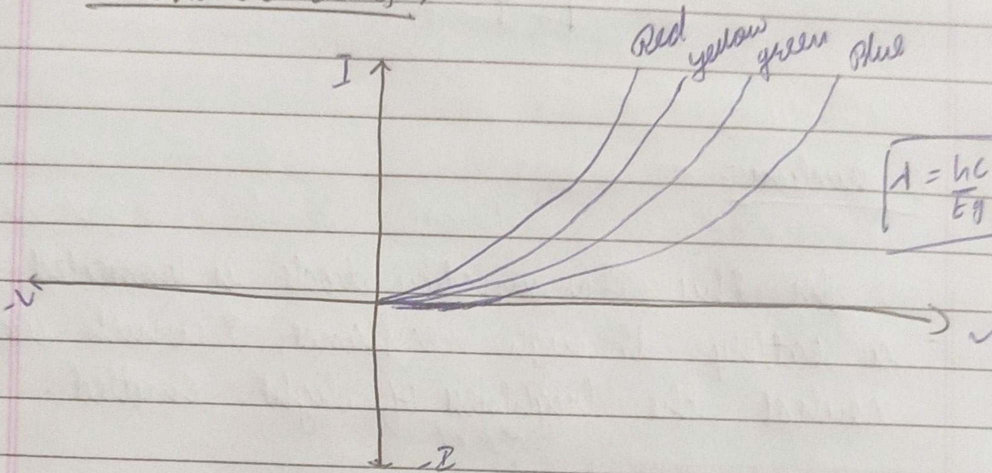
$\therefore Eg = \frac{hc}{\lambda}$

$\boxed{\lambda = \frac{hc}{Eg}}$

$Eg = h\nu$

This is the wavelength of emitted light.

V-I characteristics :-



$\boxed{\lambda = \frac{hc}{Eg}}$

→ Forward current conducted by junction determined the intensity of the light emitted.

Advantages of LED :-

1 → long life

2 → ~~ope~~ low operational voltage

3 → less power consume

4 → cheap & easy to handle.

Uses of LED :-

1 → In burglar alarm system.

2 → calculator digital watches

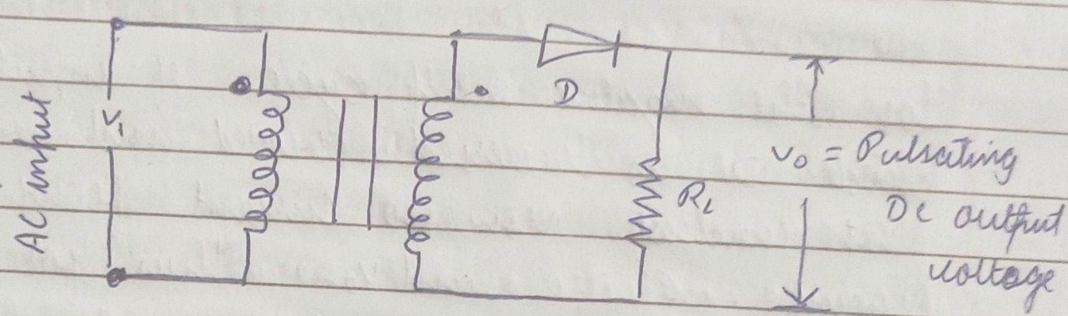
3 → In traffic light.

4 → In remote control.

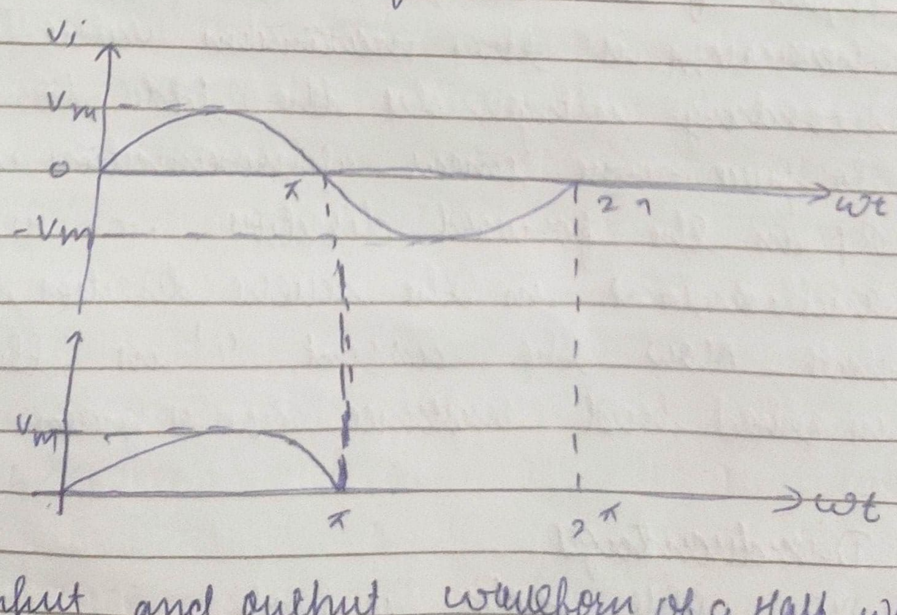
Classification of Rectifier :-

1) Half-wave Rectifier

A half wave rectifier is one, which converts a.c voltage into a pulsating voltage using only one half cycle of the applied ~~do~~ a.c voltage.



The a.c voltage applied to the rectifier circuit using step down transformer. rectifying element i.e p-n junction diode and the source of a.c voltage, all connected in series. The a.c voltage is applied to the rectifier circuit using step-down transformer.



Input and output waveform of a Half wave rectifier.

operation :-

For the positive half-cycle of input a-c vo the diode D is forward biased and hence it ~~conducts~~ conducts. Now a current flows in the circuit and there is a voltage drop across the waveform of the diode current (or) lo current is shown in above graph.

For the negative half cycle of input, the diode D is reversed biased and hence it not conduct. Now no current flows in t circuit. i.e $i = 0$ and $V_0 = 0$. Thus for the ne half-cycle no power is delivered to the lo

Analysis

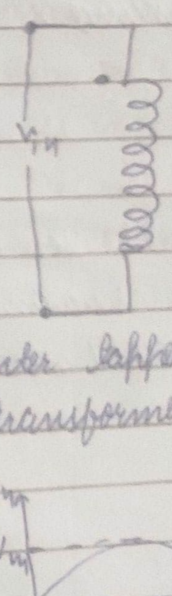
Let a sinusoidal voltage ~~to~~ v_i be applied to input of the rectifier. Then $v = V_m \sin(\omega t)$ where V_m is the maximum value of the secondary voltage. Let the diode be ideal to piece-wise linear approximation with res R_f in the forward direction. i.e in the ON and $R_r (= \infty)$ in the reverse direction, in the state. Now the current 'i' in the diode in the load resistance R_L is given by $V = $

Disadvantages

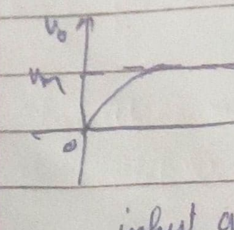
1. The ripple factor is high
2. The efficiency is low.
3. The transformer utilization factor is low.

2) Full wave

A full-wave
a pulsating
the applied
half cycles of
this circuit
with the he
tap transform
sinusoidal
ency but ou
in the seco
full wave



center tapped
transformer



input a

2) Full wave rectifier

A full-wave rectifier converts an ac voltage into a pulsating dc voltage using both half cycles of the applied ac voltage. In order to rectify both the half cycles of ac input, two diodes are used in this circuit. The diode feeds a common load RL with the help of a center-tap transformer. A center-tap transformer is the one, which produces two sinusoidal waveforms of same magnitude and frequency but out of phase with respect to the ground in the secondary winding of the transformer. The full wave rectifier is shown in the fig. below

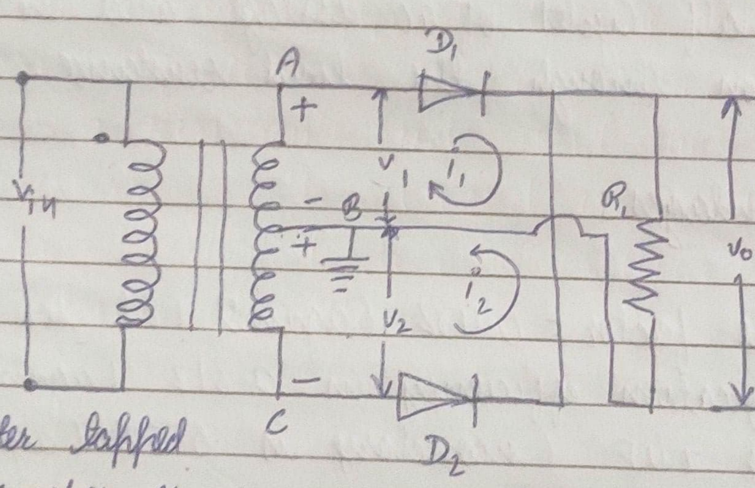
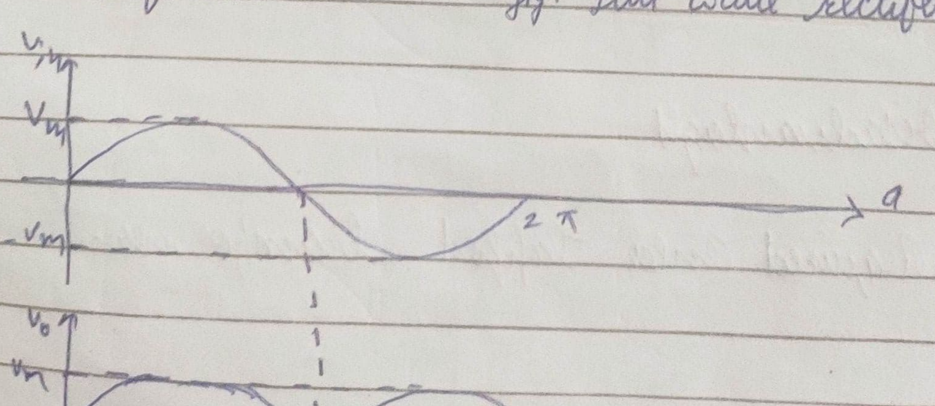


fig. Full wave rectifier



input and output waveforms of fullwave rectifier.

During positive half of the input signal, anode of diode D1 becomes positive and the anode diode D2 becomes negative. Hence D1 conducts and D2 does not conduct. The load current flows through D1 and the voltage drop across RL will be equal to the input voltage.

During the negative half cycle of the input the anode of D1 becomes negatives and the anode of D2 becomes positive. Hence, D1 do not coduct and D2 conducts. The load current flows through D2 and the voltage drop across will be equal to the input voltage. It is noted that the load current flows in the the half cycles of ac voltage and in the same direction through the load resistance.

Advantages:

1) Ripple factor = 0.482 (against 1.21 for HWR)
2) Rectification efficiency is 0.812 (against 0.405
3) Better TUF (secondary is 0.574 (against 0.287

Disadvantages

1) Required center tapped transformer.

Comparison :-

Sl. no.	Parameter	HWR	FWR
1	No. of diodes	1	2
2.	PIV of diode	V_m	$2V_m$
3	Secondary voltage (rms)	V	V-0-V
4.	Ripple factor γ	1.21	0.482
5.	Rectification efficiency	0.406	0.812

Clamping Circuit :-

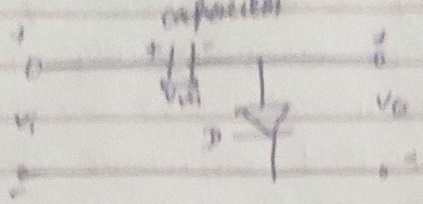
The circuit which is not change input signal wave form it will little move up or down. It is also known as 'd.c inserter' circuit

Capacitor store the input energy.

Classification of clamping circuits :-
Primarily clamps are of two types.
(i) Negative clamp (or positive peak clamper)
(ii) Positive clamp (or Negative peak clamper)

~~If~~ the ~~sw~~

(i) Negative Clamp (or Positive peak clamper)



If the input voltage is positive then it is on means for the diode to conduct 0.7V.
If the circuit is in on state the energy ... by the capacitor. The maximum voltage at ... is V_m.

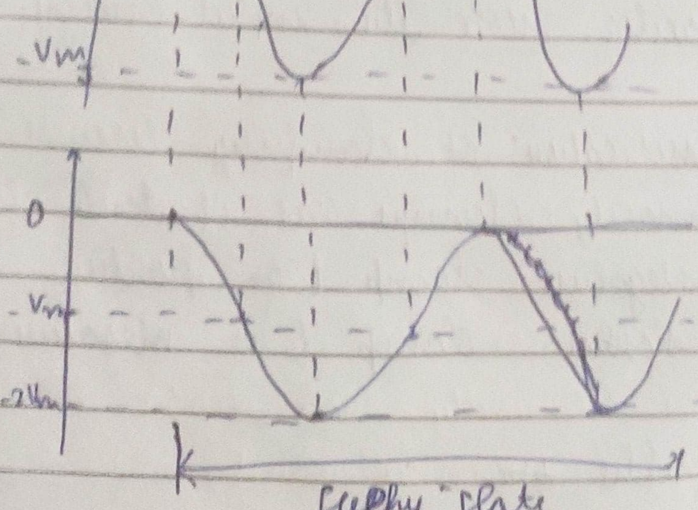
KVL equation:-

$$v_i - V_m - v_0 = 0$$
$$v_0 = v_i - V_m$$

If $v_i = V_m$ then $v_0 = 0$.

if $v_i = 0$, $v_0 = -V_m$

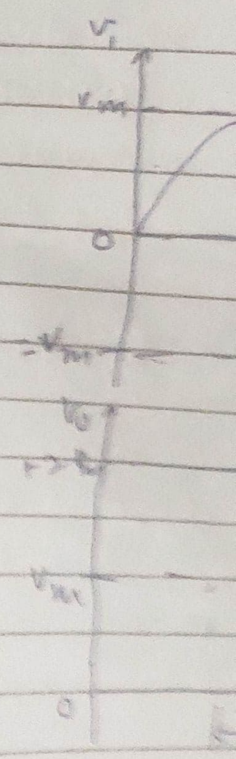
if $v_i = -V_m$, $v_0 = -2V_m$



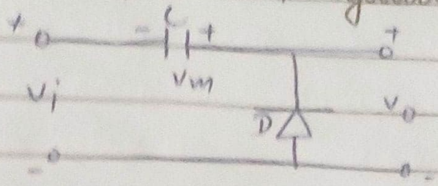
(ii) Positive C...

KVL equation

if $v_i = 0$
$v_0 = V_m$



(ii) Positive Clamp: (Negative peak clamper)



KVL equation: (clockwise)

$$v_i + V_m - V_0 = 0$$ [∵ In C, C goes from -ve to +ve]

$$V_0 = v_i + V_m$$

if $v_i = 0$, $V_0 = V_m$ | if $v_i = V_m$, $V_0 = 2V_m$ | if $v_i = -V_m$, $V_0 = 0$