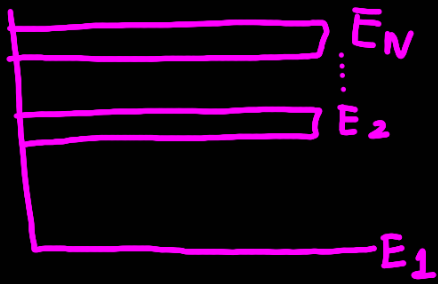
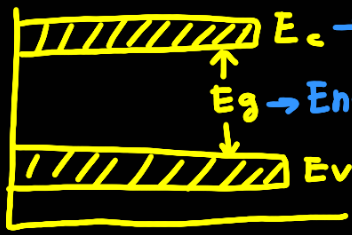
Diode :- → It is an electronic device
↳ Easily control of e^- flow

Semiconductor → Neither a conductor nor insulator

In an atom



Distinct with gaps



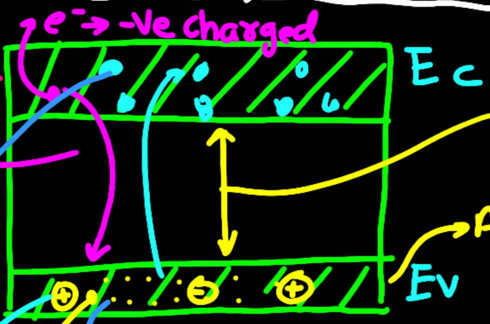
E_c → Conduction band energy
E_g → Energy Gap
E_v → Valence band energy

Any e^- in E_g will return to the valence band & emit radiation

Semiconductor
↓
Tetravalent
↓
4 e^- in the outer orbit

Silicon	Germanium
Used often	Used rarely

Energy diagram of semiconductor



Won't fall

Conduction Band

Valence Band

$E_g \simeq 1.2eV \rightarrow 0.7eV$ for Si

At 0K, all e^-s are in V.B

→ Energy is supplied, e^- rise

→ Attracts the e^- from CB

→ I_e → electron current

→ I_h → hole current

Ion is immobile

Total Current → I_T → $\{I_T = I_e + I_h\}$

This entire process repeats again

Semiconductors

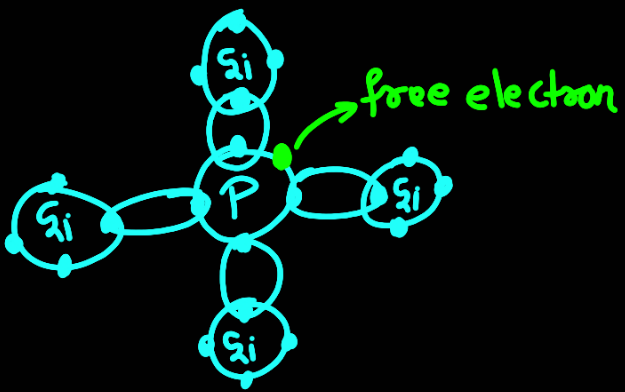
- Intrinsic ↓ Pure Semiconductors, $E_g \approx 1.2eV$
- Extrinsic ↓ Doped with impurities, $E_g \simeq 0.7eV$ for Si, $\approx 0.2eV$ for Ge

Doping :- The method of adding impurities to semiconductors either Si or Ge

Impurities

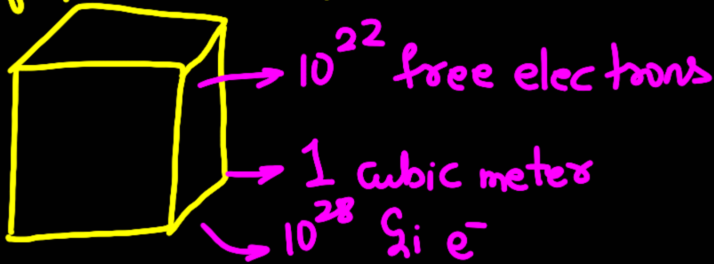
- Trivalent atom ↳ P-type → P & As
- Pentavalent atom ↳ N-type → B & Ac

N-type Semiconductor:-

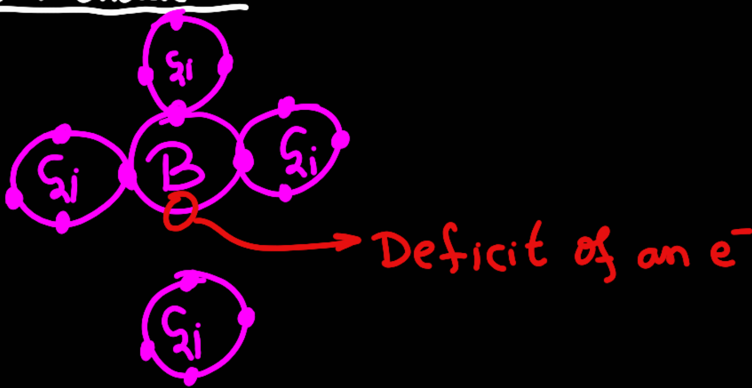


P → donates free e^-
→ Pentavalent donor atom

Add 1 atom of pentavalent atoms to 1 million atoms of 'Si'

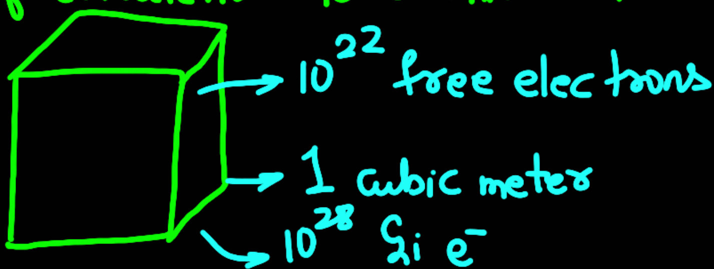


P-type Semiconductor:-



B → Donates hole (has a deficit of e^-)
→ Trivalent acceptor atom

Add 1 atom of trivalent atoms to 1 million atoms of 'Si'

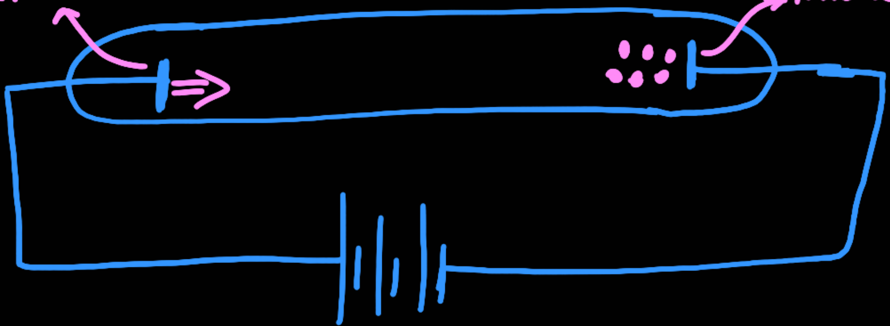


Diode :-

→ Electronic Device
→ Semiconductor Diode

Di ode → 2 electrodes → Cathode, Anode

Cathode   Anode



e^- are emitted by cathode & collected by anode

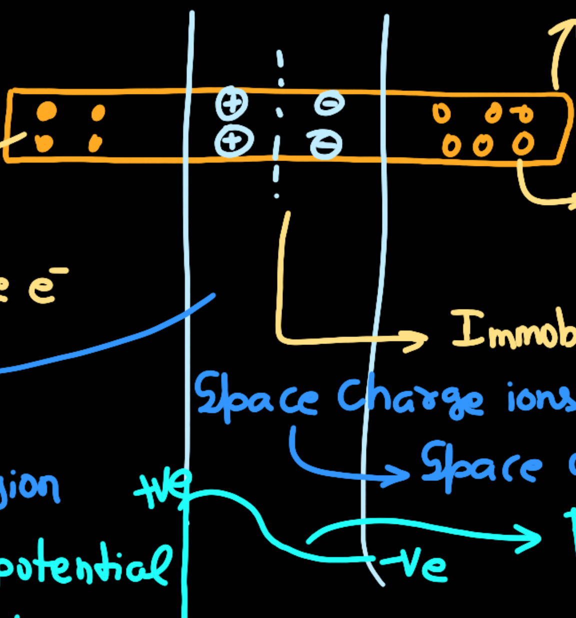
donor atoms   acceptor atoms

free e^- is created

e^- holes
attracted to each other

→ free hole is created

S_i



majority are e^-

→ majority are holes

→ Immobile Ions ⇒ Do not conduct

Space Charge ions → Space charge region

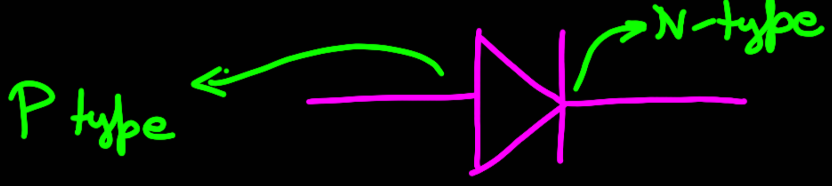
Depletion Region

+ve   -ve

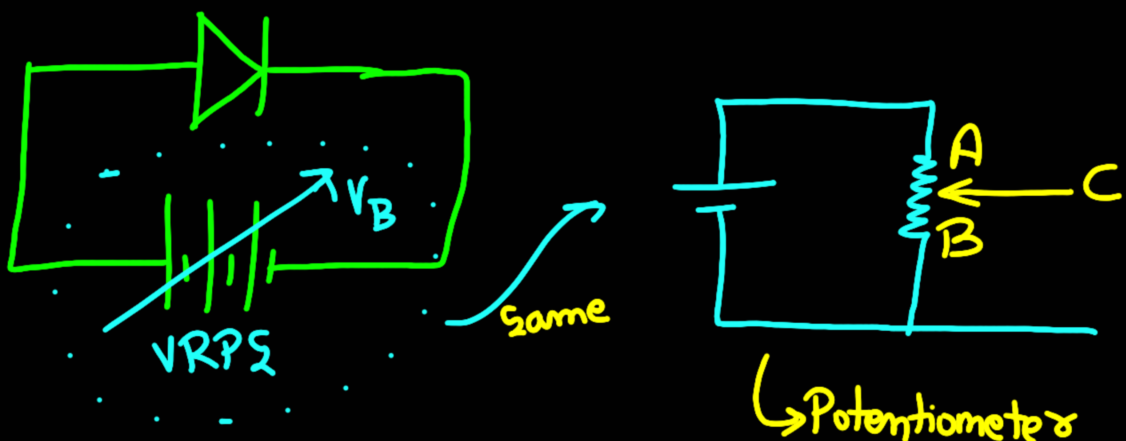
Depletion potential → Potential hill
(or) Cut-in voltage for P-N junction

↳ free charge carrier
e^- must overcome potential hill

Circuit Symbol for diode:-

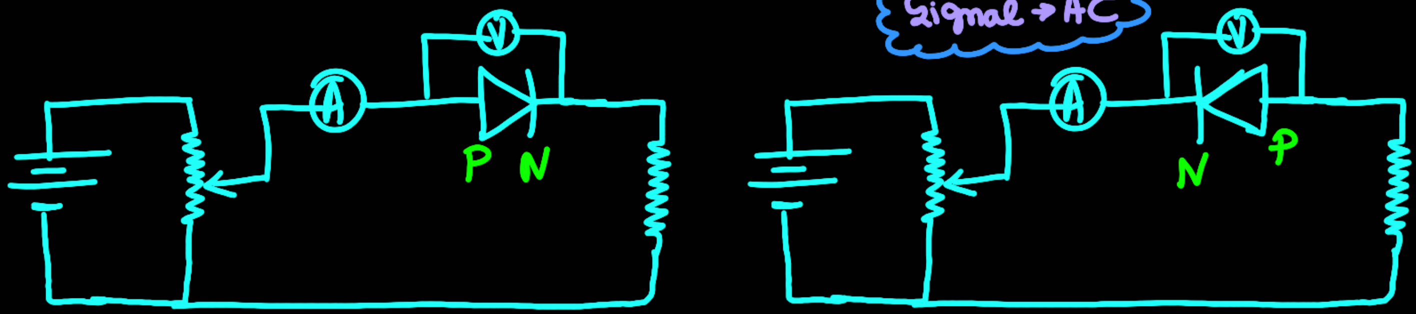


Current Direction



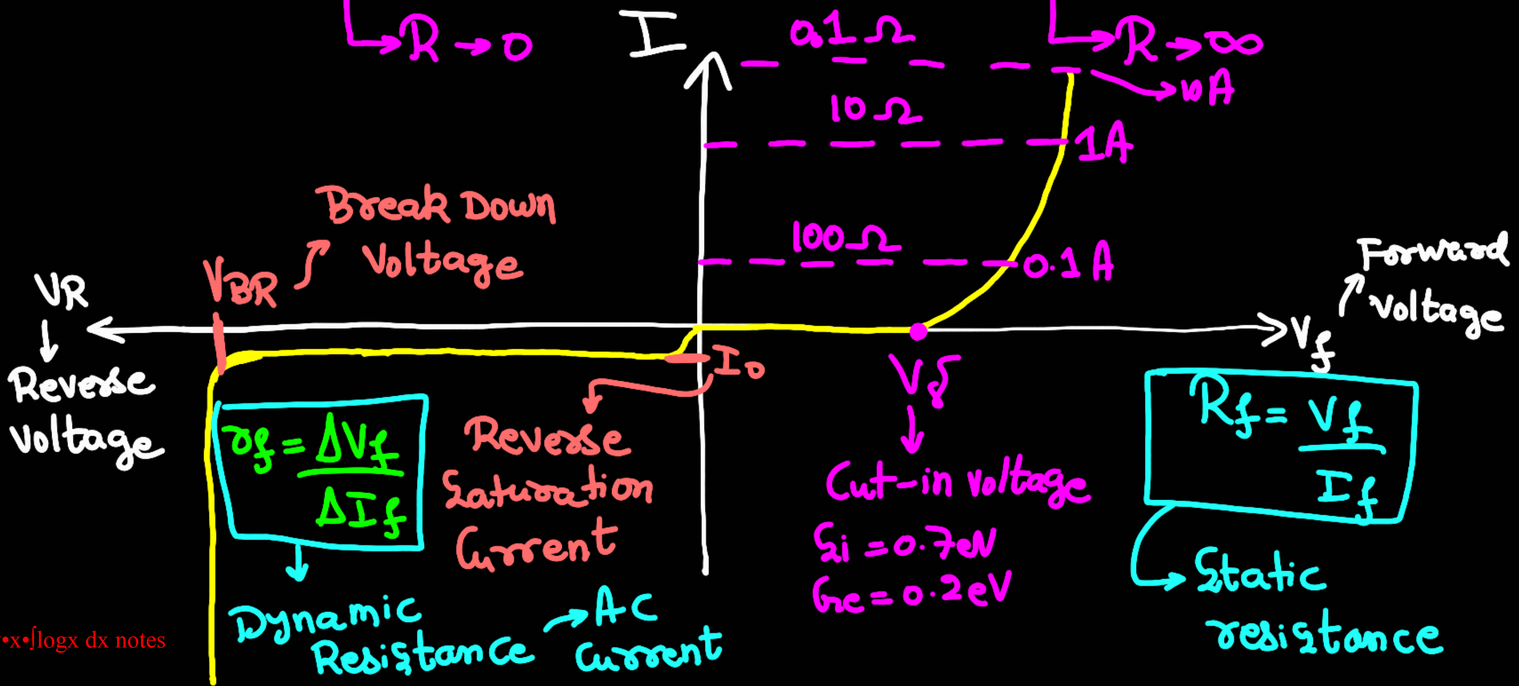
V-I characteristics of a diode:-

Bias → DC
Signal → AC
→ Important

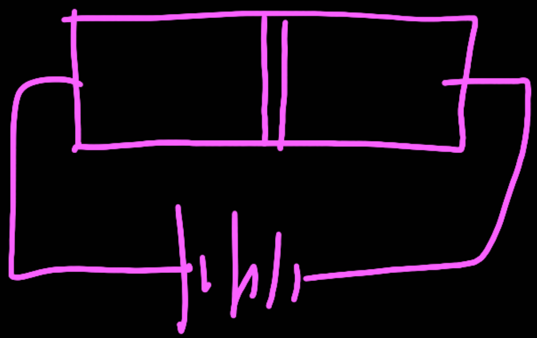


Forward Bias
→ R → 0

Reverse Bias
→ R → ∞



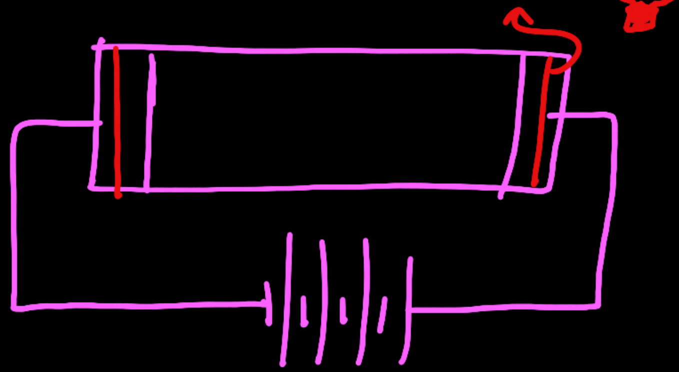
In F.B :-



Depletion layer decreases in size

In R.B :-

KA-BOOM



Depletion layer increases in size

Current Equation :-

$$I_D = I_0 \left(e^{\frac{V}{\eta V_T}} - 1 \right)$$

$I_D \rightarrow$ Current through diode

$I_0 \rightarrow$ Reverse Saturation Current

$V \rightarrow$ Applied Voltage

$\eta \rightarrow$ Constant $\rightarrow$ Si = 2, Ge = 1

$V_T \rightarrow$ Volt equivalent of temperature

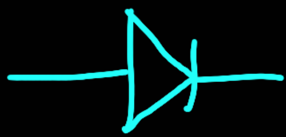
$$V_T = \frac{KT}{q} \Rightarrow V_T = \frac{T}{11600}$$

@ room temp $V_T \approx 26mV$

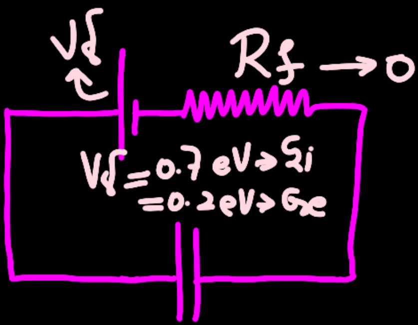
$T \rightarrow$ Temp in 'K'

I_0 doubles for every $10°$ rise in temp

AC & DC equivalent circuit:-

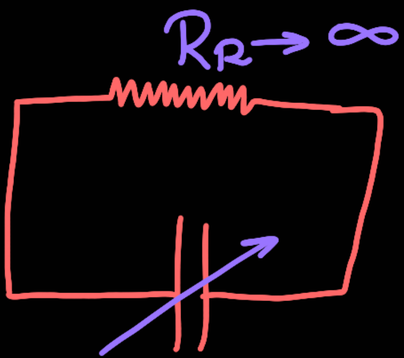


DC equivalent ckt when forward biased



$C_s \to$ Storage Capacitance

DC equivalent ckt when reverse biased:-



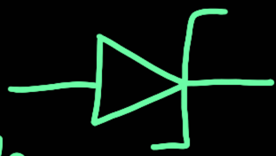
Varies depending on depletion layer width

$C_d \to$ Depletion Capacitance

AC equivalent when Forward Biased

AC equivalent when Reverse Biased

Zener Diode :-

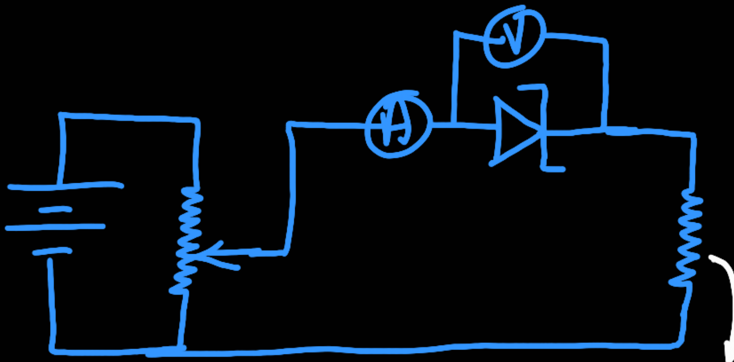
→ Ckt symbol :- 

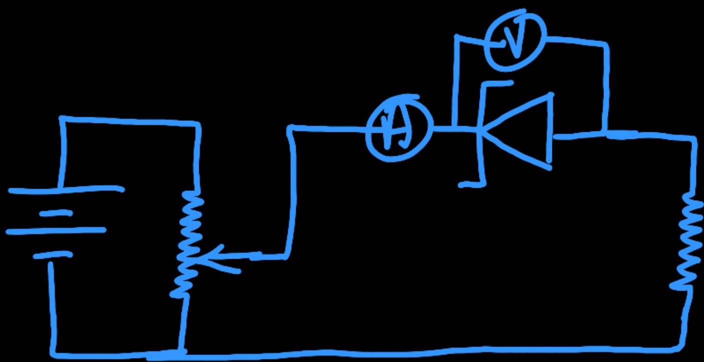
→ P-N junc^n diode

External voltage > V_Z there flows a large current limited to $I_{Z\,max}$

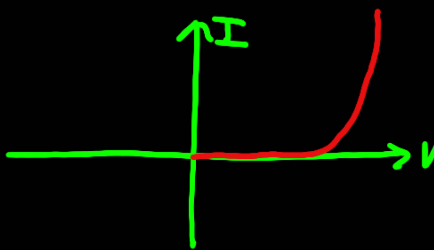
- ★ Heavily doped
- ★ Current before break down is I_0
- ★ Breakdown in rev dir. at smaller voltage
- ★ Operated in rev bias
- ★ Breakdown & maintains constant value called Zener voltage

} Characteristics of Zener Diode

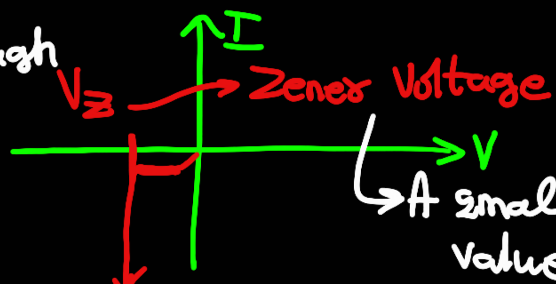


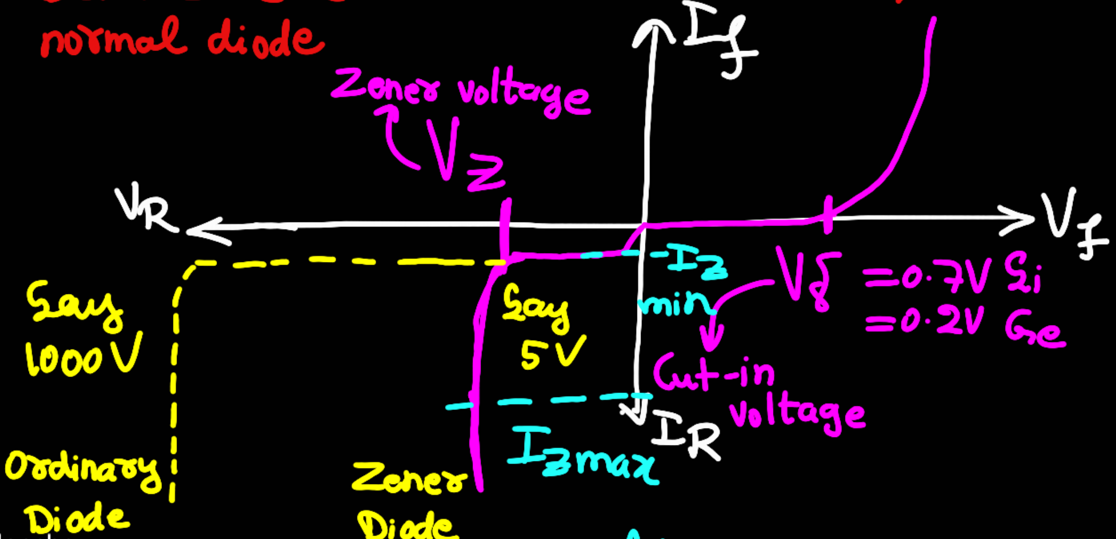


Limits current through zener diode



Behaves as a normal diode





Avalanche breakdown is the breakdown that occurs in normal diode & that happens because of physial effect where electrons impact on the atoms

Zener breakdown is the breakdown that occurs in zener diode & that happens because of quantum effect

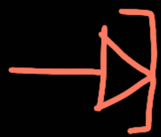
At breakdown, there is heavy power dissipation. This causes the diode to get damaged. Thus, there is a Zener Operating Region

A resistor in series with the zener diode, limits current to $I_{Z(max)}$

$$\boxed{P_{Z_{max}} = V_Z I_{Z_{max}}}$$

$$\boxed{\gamma_Z = \frac{\Delta V_Z}{\Delta I_Z}}$$

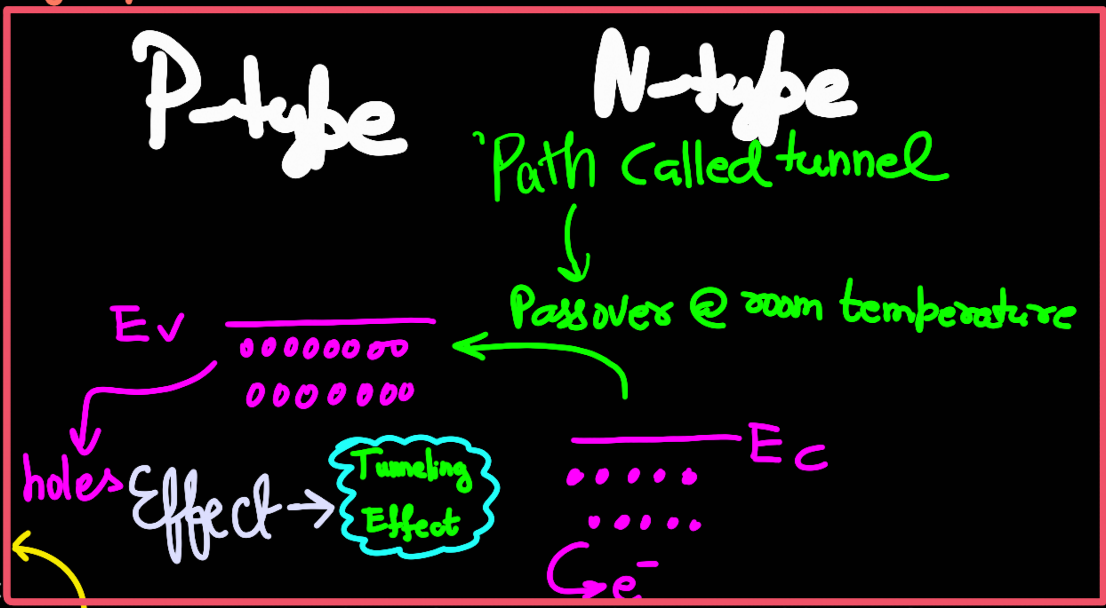
Tunnel diode :-

→ Ckt Symbol :- 

→ Special diode

→ Heavily dope

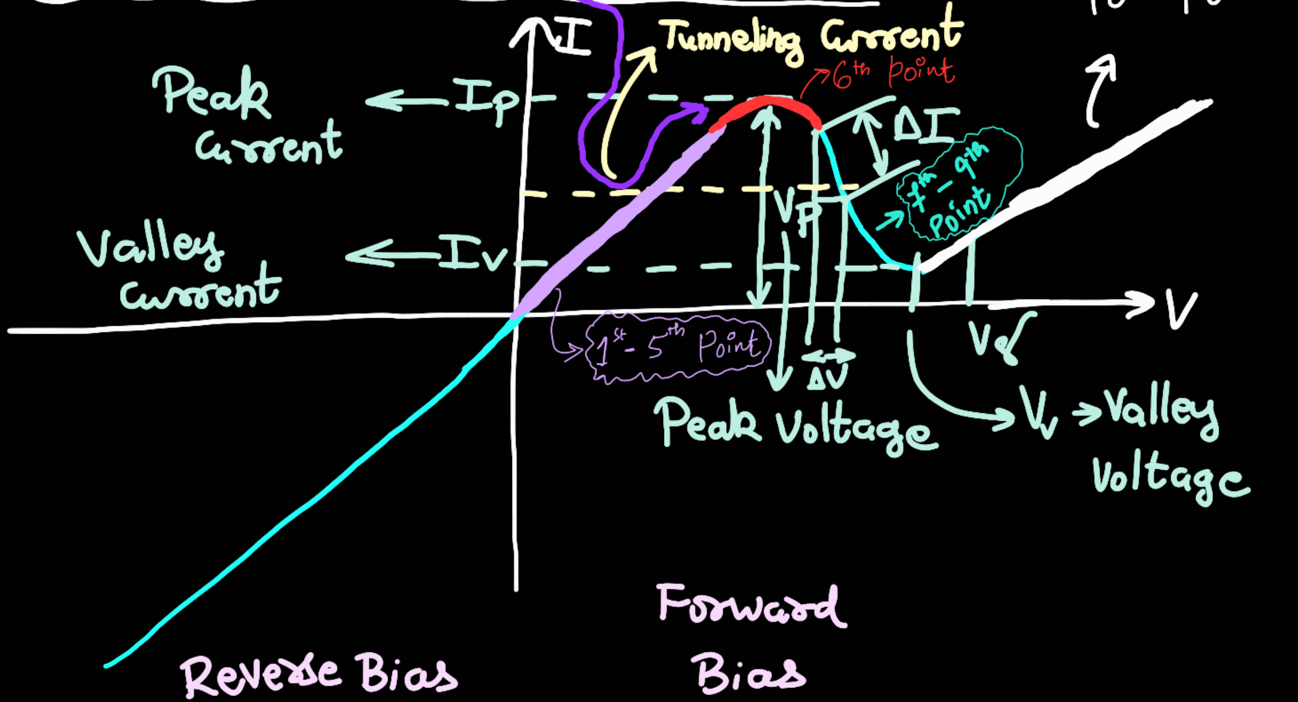
7. On further increment of temperature the conduction band (of N- Type) now goes above the valence band (of P-Type) .
8. The flow of electrons reverses and now moves from Ev to Ec. (From lower potential to higher potential)
9. Now the resistance decreases as the electrons now move from valence band to conduction band. Since now at conduction band electrons keeps on increasing conductivity also increases, *Upto a certain point*.
10. Later tunnel diode breaksdown and burns out on further increment of temp



1. The Ec of N-Type is at a lower potential than Ev of P Type.
2. On increasing temperature the electrons start jumping from Ec to Ev (N-->P type), the path followed is called as tunnel.
3. More temperature Inc. More electrons jump
4. When the electrons jump, the potential of Ec also increases.
5. Resistance keeps on inc. As no. Of electrons in conduction band reduce as they jump into valence band

6. At a point both conducting & valence band Ec & Ev will be at the same level. At that point, Current is highest called as tunneling current.

* V-I characteristics of Tunnel Diode :-



↳ offers very high resistance

* ordinary diode when $V_f > V_v$
* $V_f < V_v$ → Current raises (Tunneling) → for $V_f < V_p$
* $V_p < V_f < V_v$ → Current decreases

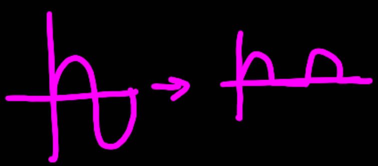
Types of Breakdowns:-

Zener Breakdown	Avalanche Breakdown
✱ Covalent bonds of depletion layer break due to high electric field of very high reverse bias voltage	Covalent bonds of depletion layer are broken by collision of "minorities" which aquire high K.E from elec field of very very high reverse bias voltage
✱ P-N junction having "high doping" & thin depletion layer	✱ P-N junction having "low doping" & thick depletion layers

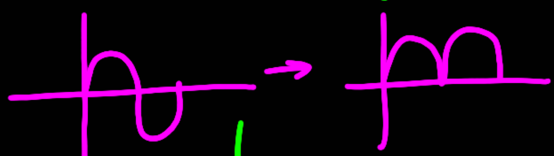
Rectifier:-

↳ Converts AC to DC

- Half-wave rectifier

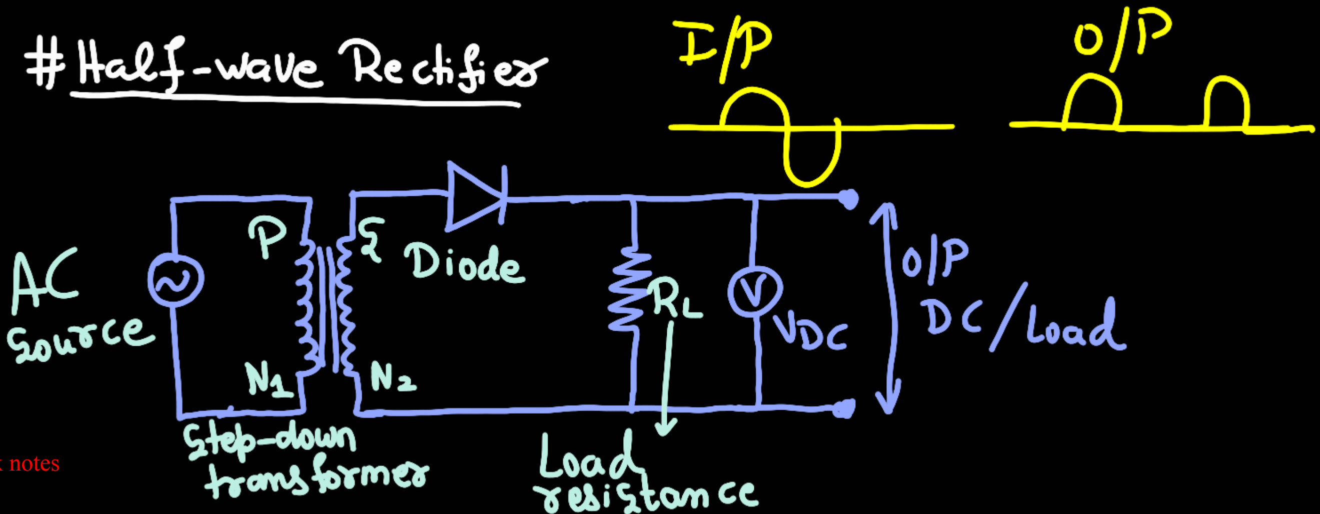


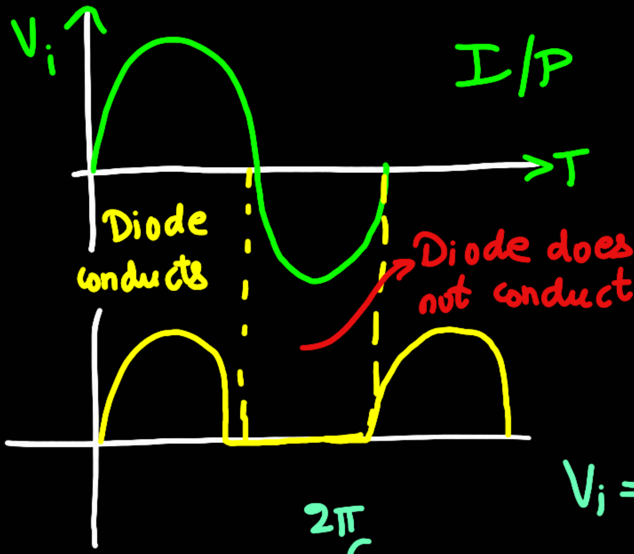
- Full wave rectifier



  - Center tapped FWR
  - Bridge FWR

Half-wave Rectifier





$$\therefore V_{DC} = V_{avg} = \int_0^{2\pi} \frac{V_i \, d\theta}{2\pi}$$

$$V_i = V_m \sin\theta$$

$$V_{DC} = \int_0^{2\pi} \frac{V_m \sin\theta \, d\theta}{2\pi} = \frac{V_m}{2\pi}\int_0^{\pi} \sin\theta \, d\theta + \cancel{\frac{V_m}{2\pi}\int_{\pi}^{2\pi} \frac{\sin\theta \, d\theta}{2\pi}} \rightarrow 0$$

$$\therefore V_{DC} = \frac{V_m}{2\pi}\int_0^{\pi} \sin\theta \, d\theta = \frac{V_m}{2\pi}\left[-\cos\theta\right]_0^{\pi} = \frac{V_m}{2\pi}\left[\cos 0 - \cos\pi\right]$$

$$\boxed{\therefore V_{DC} = \frac{V_m}{\pi}}$$ → Avg DC voltage in HWR

Ripple Factor :-

$$\gamma = \frac{\text{AC component}}{\text{DC component}}$$

AC component → $V_{rms}(o/p) = ??$

DC component → $V_{DC} = \frac{V_m}{\pi}$

→ Measures the quality of DC current converted

$$\therefore V_{rms} = \sqrt{\int_0^{2\pi} \frac{(V_i)^2 \, d\theta}{2\pi}} = \sqrt{\int_0^{\pi} \frac{(V_m \sin\theta)^2}{2\pi} d\theta + \cancel{\int_{\pi}^{2\pi} \frac{(V_m \sin\theta)^2}{2\pi} d\theta}} \rightarrow 0$$ → Diode not conducting

$$V_{rms} = \sqrt{\frac{V_m^2}{2\pi}\int_0^{\pi} \sin^2\theta \, d\theta} = \sqrt{\frac{V_m^2}{2\pi}\int_0^{2\pi} \frac{1-\cos 2\theta}{2} d\theta}$$

$$= \sqrt{\frac{V_m^2}{2\pi} \frac{1}{2}\left[\pi - 0\right]}$$

$$\therefore \boxed{V_{rms} = \frac{V_m}{2}}$$ → At the O/P of the HWR

After Substitution :-

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

Putting $V_{rms} = \frac{V_m}{2}$; $V_{DC} = \frac{V_m}{\pi}$, we get,

$$\boxed{\gamma = 1.21}$$ → Constant for HWR

↓

Implies AC component is 121% more than DC component

☆ Efficiency:-

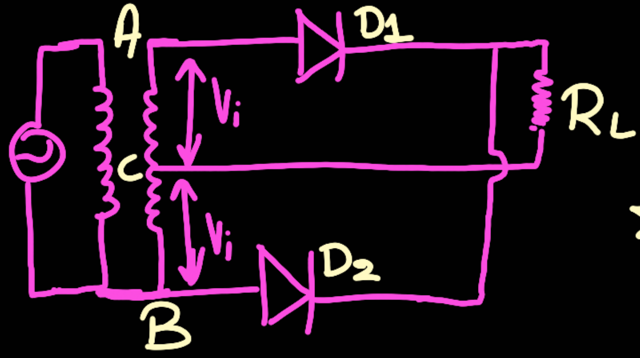
$$\% \eta = \frac{O/P \text{ Power}}{I/P \text{ Power}} \times 100\% = \frac{I_{DC}^2 R_L}{I_{rms}^2 R_L} \times 100\%$$

After putting I_{rms} & I_{DC} values, we get

$$\boxed{\% \eta = 40.5\%}$$ → Due to high ripple

Full-Wave Rectifier:-

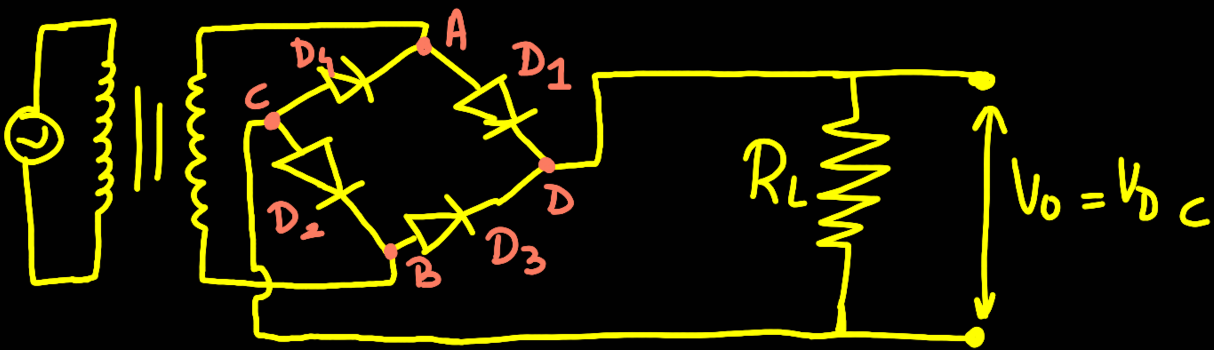
Center-tapped FWR:-



During +ve half cycle
- Point A ⇒ most +ve, B ⇒ -ve
- C is less +ve than A (-ve)
- D1 conducts
- D2 OFF

During -ve half cycle
- Point B ⇒ most +ve, A ⇒ -ve
- C is less +ve than B (-ve)
- D2 conducts
- D1 OFF

Bridge Full Wave Rectifier:-



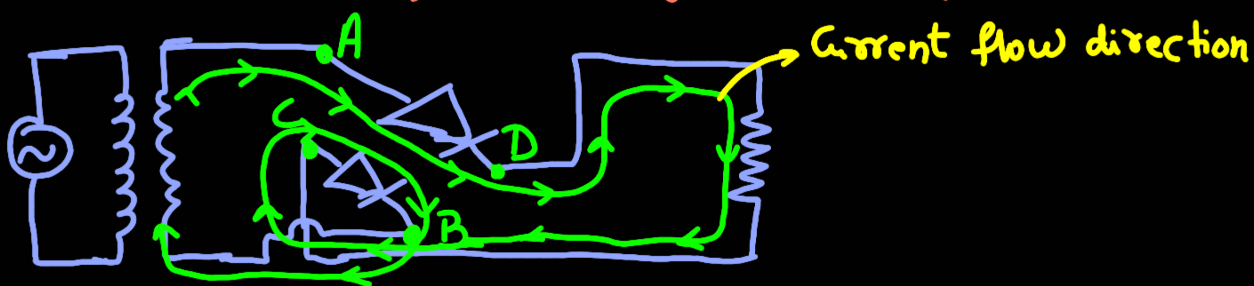
During +ve half cycle

- Point A is most +ve & B is most -ve

$\therefore$ D_1 & D_2 → F.B ⇒ ON ⇒ Conduct

D_3 & D_4 → R.B ⇒ OFF ⇒ Do not conduct

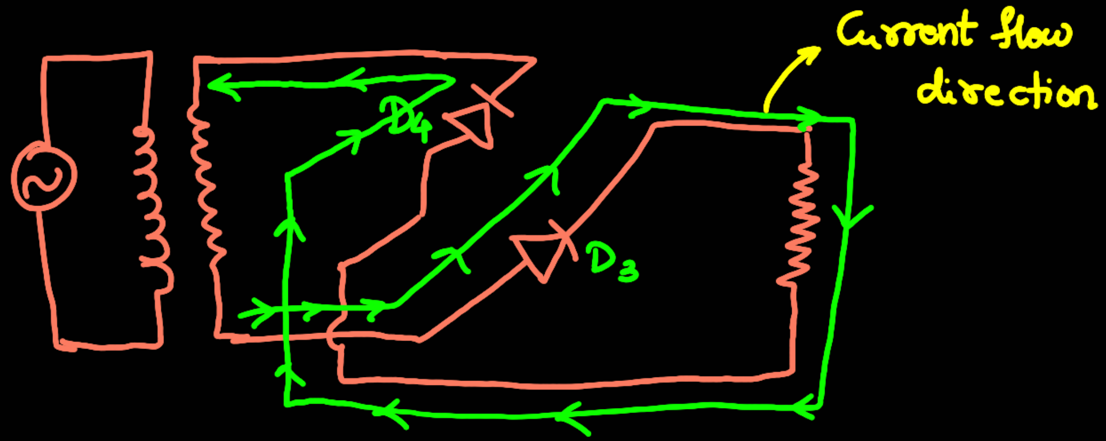
Current flows from D_1, flows through R_L from point D to C



During -ve half cycle

Point B $\rightarrow$ most +ve ; A $\rightarrow$ most -ve

D_3 & D_4 $\rightarrow$ F.B $\rightarrow$ ON $\rightarrow$ Conduct
D_1 & D_2 $\rightarrow$ R.B $\rightarrow$ OFF $\rightarrow$ Do not conduct



V_{DC}, V_{rms} & γ of FWR (same for both) :-

Draw I/P O/P waveforms

$$V_{DC} = \int_0^{2\pi} \frac{V_m \sin\theta \, d\theta}{2\pi} = \int_0^{\pi} \frac{V_m \sin\theta \, d\theta}{2\pi} + \int_{\pi}^{2\pi} \frac{V_m \sin\theta \, d\theta}{2\pi}$$

$$= 2\int_0^{\pi} \frac{V_m \sin\theta \, d\theta}{2\pi} = \frac{V_m}{\pi}\Big[-\cos\theta\Big]_0^{\pi} = \frac{V_m}{\pi}\big(-(-1)+1\big)$$

$$\therefore V_{DC} = \frac{2V_m}{\pi}$$

$$V_{rms} = \sqrt{\int_0^{2\pi} \frac{(V_i)^2 \, d\theta}{2\pi}} = \sqrt{\int_0^{2\pi} \frac{(V_m \sin\theta)^2 \, d\theta}{2\pi}}$$

$$= 2\int_0^{\pi} V_m^2 \left(\frac{1-\cos 2\theta}{2}\right) d\theta$$

$$\Rightarrow \boxed{V_{rms} = \frac{V_m}{\sqrt{2}}}$$

Ripple factor :- γ

$$\gamma = \sqrt{\left(\frac{V_{rms}}{V_{DC}}\right)^2 - 1} = \sqrt{\left(\frac{V_m}{\sqrt{2}} \times \frac{\pi}{2V_m}\right)^2 - 1}$$

$$= \sqrt{\frac{\pi^2}{8} - 1} \quad \Rightarrow \boxed{V_{rms} = 0.483}$$

→ AC component is 48% more than DC component

Efficiency :- $\% \eta = \frac{O/P \text{ Power}}{I/P \text{ Power}} \times 100 = \frac{I_{DC}^2 R_L}{I_{rms}^2 R_L} \times 100$

$$\boxed{\therefore \% \eta = 81.05\%}$$

→ Ideal = $81.05 \left(\frac{R_L}{R_s + R_f + R_L}\right)$

Load resistance

forward bias resistance of diode

Source resistance

R_f → Center tapped FWR

$2R_f$ → Bridge FWR

C-filter :-

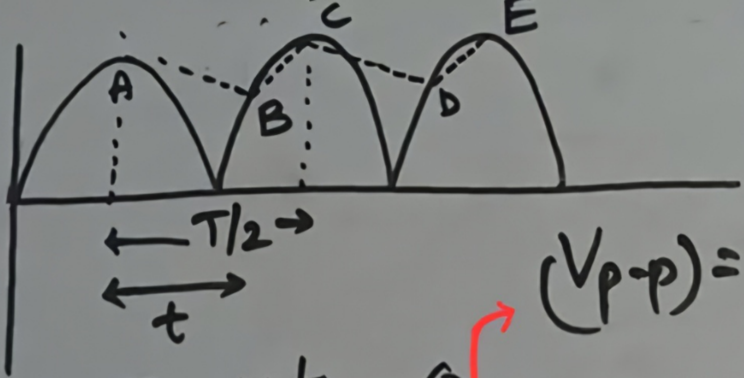
↓

Capacitor

Ripple factor of Capacitor filter

Then Ripple

$$\gamma = \frac{v_{rms}}{v_{dc}}$$



$$dQ = I_{dc} \times t \quad \text{—(1)}$$

$$V_{(p-p)} = \frac{dQ}{C}$$

$$= \frac{I_{dc} \times t}{C}$$

$$= \frac{I_{dc} \times T}{2C}$$

$$(V_{p-p}) = \frac{I_{dc}}{2fC}$$

$$= \frac{V_{dc}}{2fCR_L}$$

then

$f = 50\ Hz$

$c = 1$

$R_L = 1$

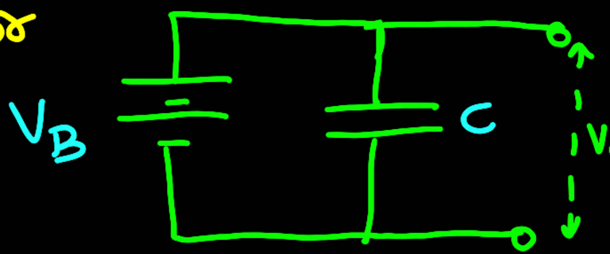
$$V_{rms} = \frac{1}{2\sqrt{3}}(V_{p-p})$$

$$= \frac{V_{dc}}{4\sqrt{3} fCR_L} \quad \text{—(2)}$$

C-filter :-

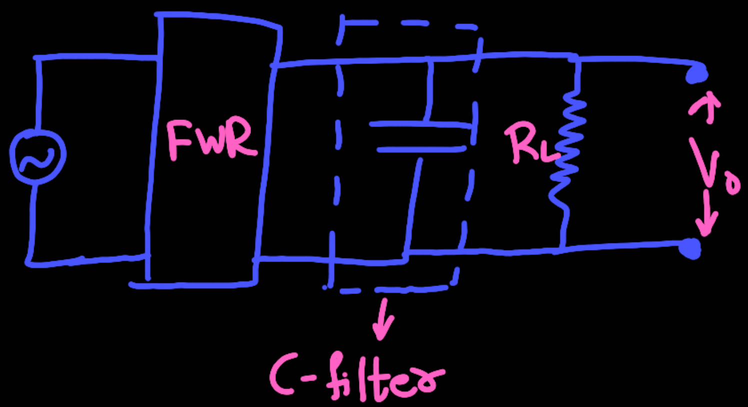
Capacitor

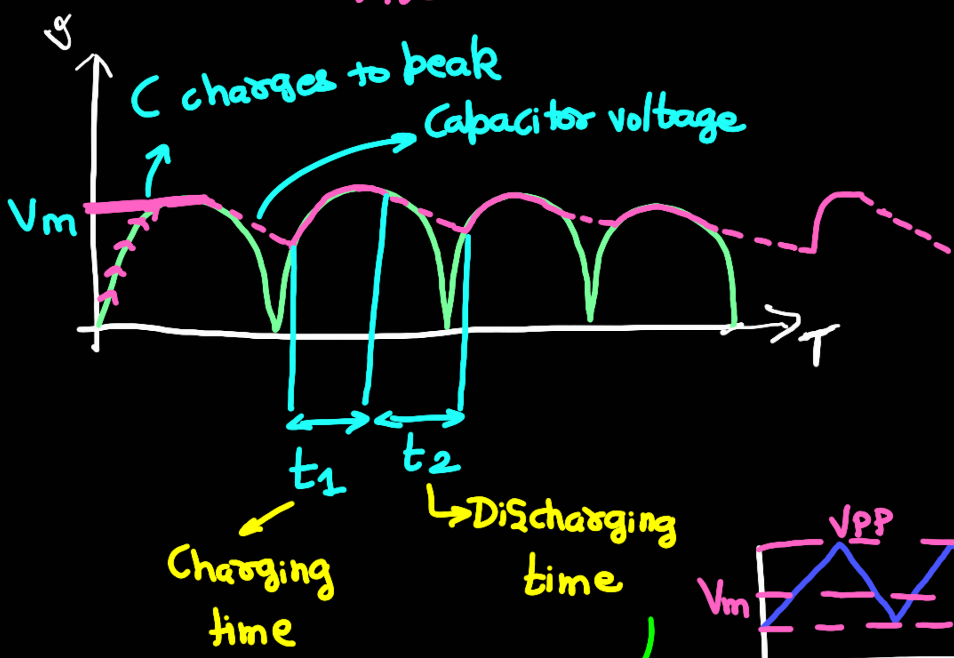
$\boxed{\tau = RC}$ → Time constant

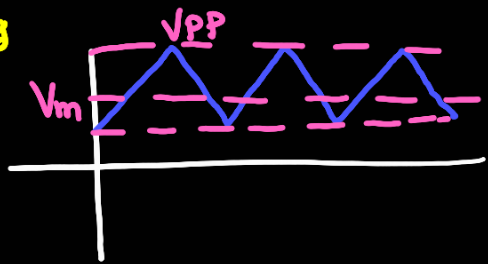


→ Charged in 0^+ sec
→ Retains forever

Capacitor charges until $\boxed{V_c = V_B}$







$$V_{r\,rms} = \frac{V_m}{\sqrt{3}} \; ; \; V_m = \frac{V_{pp}}{2}$$

$$V_{r\,rms} = \frac{V_{pp}}{2\sqrt{3}}$$

$$I_{DC} \times \frac{1}{2f} = V_{pp} \times C$$

$$V_{PP} = \frac{I_{DC}}{2fC} \; ; \; V_{\gamma\,rms} = \frac{I_{DC}}{2fC} \times \frac{1}{2\sqrt{3}}$$

$$V_{\gamma\,rms} = \frac{V_{DC}}{4\sqrt{3}fCR_L}$$

$$\text{Ripple factor} = \frac{V_{\gamma\,rms}}{V_{DC}} = \frac{V_{DC}}{4\sqrt{3}fCR_L} \times \frac{1}{V_{DC}}$$

$$\gamma = \frac{1}{4\sqrt{3}fCR_L}$$

C & $R_L \rightarrow$ Unity

$f = 50\,Hz$

$$\therefore \gamma = 0.00288$$

Numericals:-

Ⓠ Consider a diode with $I_0 = 0.5\,mA$. Determine diode current (forward) at room temp

When the diode is subjected to a temp. of 373 K, find reverse saturation current of same forward current.

Sol^n:- $I_D = I_0\left(e^{\frac{V}{\eta V_T}} - 1\right)$

Case i):- @ room temp. ; $V_T = \frac{T}{11600} = \frac{273+27}{11600}$

$\therefore V_T = 26\,mV$

$V_D = 0.7\,V \rightarrow$ Diode is assumed to be made of Si

$\Rightarrow \eta = 2$

$$I_D = 0.5\left(e^{\frac{0.7}{2\times 26\times 10^{-3}}} - 1\right)\times 10^{-3}$$

$$\Rightarrow \boxed{I_D = 350.946A}$$

Case ii :- $V_T' = \frac{373}{11600} = 32mV$

$$I_D = I_0\left(e^{\frac{V}{\eta V_T}} - 1\right) \Rightarrow 350.946 = I_0\left(e^{\frac{0.7}{2\times 32\times 10^{-3}}} - 1\right)$$

$$\Rightarrow I_0 = \frac{350.946}{56387-1} \Rightarrow \boxed{I_0 = 6.22mA}$$

Q) I/P voltage to a HWR is 10V AC. Determine i) load current ii) RMS current, iii) Ripple factor when I) Diode is ideal ; II) Diode has forward resistance of 5Ω & load resistance of 150Ω

Soln :- Case I) Diode is ideal

i) $V_m = 10\sqrt{2} = 14.14V$

$$I_m = \frac{V_m}{R_L} = \frac{14.14}{150} = 94mA$$

$$I_{DC} = \frac{I_m}{\pi} = \frac{94}{\pi}\times 10^{-3} = 29.9mA \approx 30mA$$

$$I_{rms} = \frac{I_m}{2} = \frac{94\times 10^{-3}}{2} = 47mA$$

$$\gamma = \sqrt{\left(\frac{I_{rms}}{I_{DC}}\right)^2 - 1} = \sqrt{\frac{\pi^2}{4} - 1} = 1.21 \Rightarrow \text{constant for HWR}$$

Case II :-

i) $V_m = 14.14\ V$

$$I_m = \frac{14.14}{150+5} = 91\ mA$$

$$I_{DC} = \frac{91 \times 10^{-3}}{\pi} = 29\ mA$$

$$I_{rms} = \frac{91 \times 10^{-3}}{2} = 45.5\ mA$$

$$\gamma = \sqrt{\frac{\pi^2}{4} - 1} = 1.21$$

Q) Center tabbed FWR has 2^0 voltage $10 \sin 314t$ on both halves. Determine o/p voltage & efficiency when

i) Diode is ideal ; ii) has $R_f = 10\,\Omega$ & $R_L = 50\,\Omega$

Sol^n :-

Case i :- $V_m = 10\ V$

$$V_{DC} = \frac{2V_m}{\pi} = \frac{2 \times 10}{\pi} = 6.366\ V$$

$$\%\eta = \frac{I_{DC}^2}{I_{rms}^2} \times \frac{R_L}{R_L} \times 100\% = \left(\frac{2I_m}{\pi}\right)^2 \times \left(\frac{\sqrt{2}}{I_m}\right)^2 = 81.05\%$$

Case ii :- $V_{DC} = \frac{2V_m}{\pi} \times \frac{R_L}{R_f + R_L} = \frac{2 \times 10}{\pi} \times \frac{50}{10+50}$

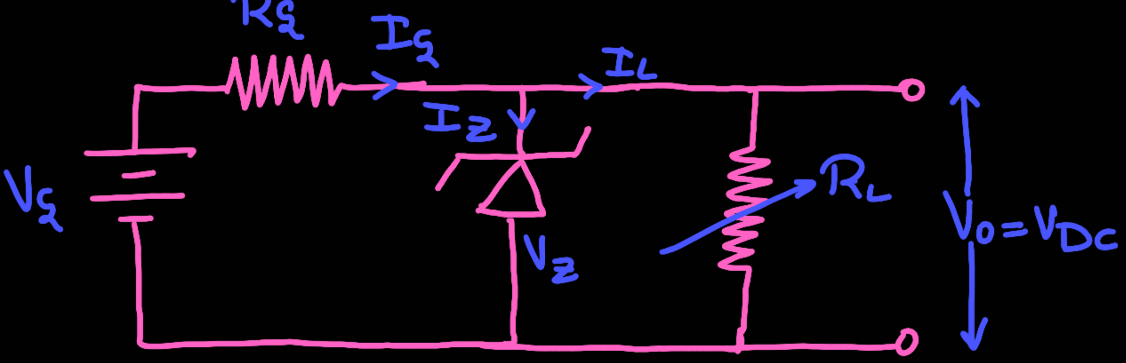
$$V_{DC} = 5.3\ V$$

$$\%\eta = 81.05 \times \frac{50}{50+10} = 67.54\%$$

Zener Regulator:-

→ Maintains a constant voltage (O/P) for any variation in the input voltage or variation in the load resistance

Simple Zener Regulator:-



Line Regulation

When I/P voltage varies but R_L is constant

$$\% R_{line} = \frac{\Delta V_0}{\Delta V_S} \times 100\%$$

Load regulation

→ When R_L varies but I/P voltage is constant

$$\% R_{S(min)} = \frac{V_{S\,min} - V_Z}{I_{Z\,min} + I_{L\,max}}$$

$$\% R_{S(max)} = \frac{V_{S\,max} - V_Z}{I_{Z\,max} + I_{L\,min}}$$

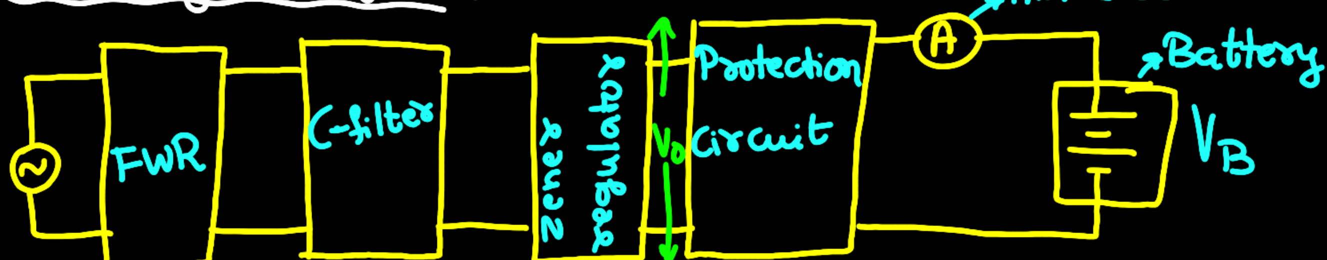
$$\% R_L = \frac{V_{NL} - V_{FL}}{V_{FL}} \times 100\%$$

V_{NL} → No load voltage
V_{FL} → Full load voltage

V_S → Source voltage
V_Z → Voltage across Zener diode
I_Z → Current through Zener diode
I_L → Current through load
R_L → Load resistance
R_S → Source resistance

Battery Charger:-

Block diagram of Battery charger



Δv•x•∫logx dx notes

* The Protection circuit protects the battery from overcharging

* Ammeter is used to monitor the current through the battery

* O/P voltage V_0 must be greater than the battery voltage for charging to occur.

$$\boxed{V_0 > V_B}$$

Clippers :-

* Used to clip part of the I/P wave form

* Clippers are used in wave shaping circuits

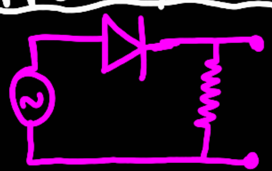
* The clippers can be either positive clipper or negative clipper.

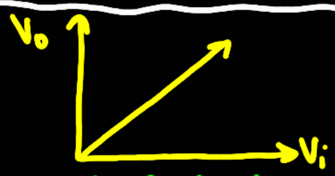
* The +ve or -ve clipper can be either series or shunt

* Clippers & $\underbrace{\text{Transfer}}_{}$ Characteristics :-

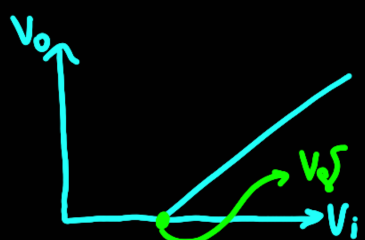
1 I/P element, 1 O/P element

Series -ve Clipper



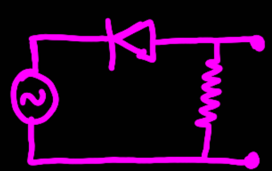


Ideal diode

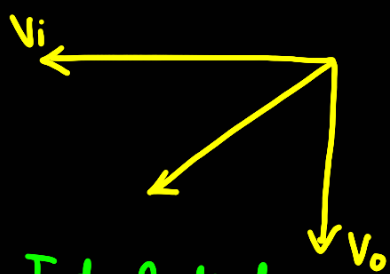


Non-ideal diode

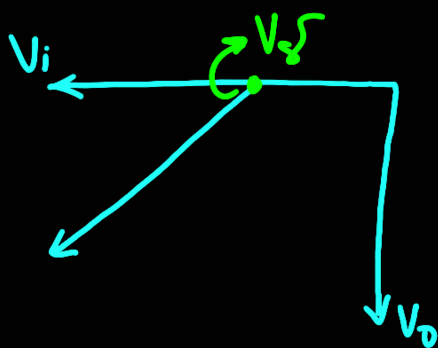
O/P



Series +ve Clipper



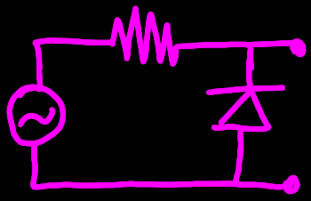
Ideal diode

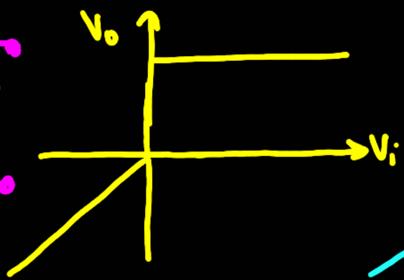


Non-ideal diode

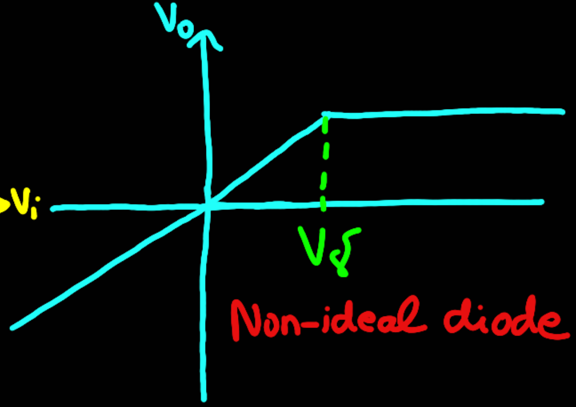
O/P

Shunt +ve Clipper

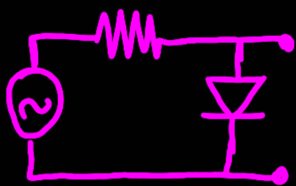


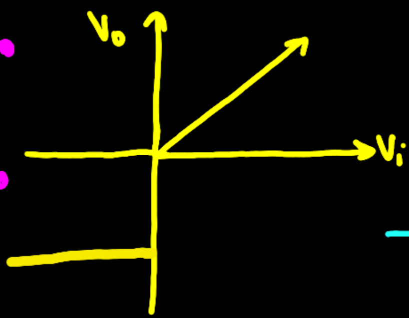


Ideal Diode

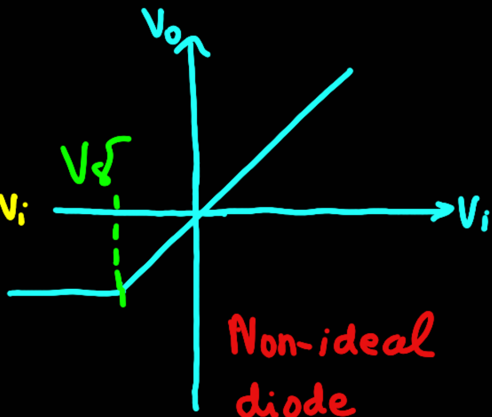


Shunt -ve Clipper



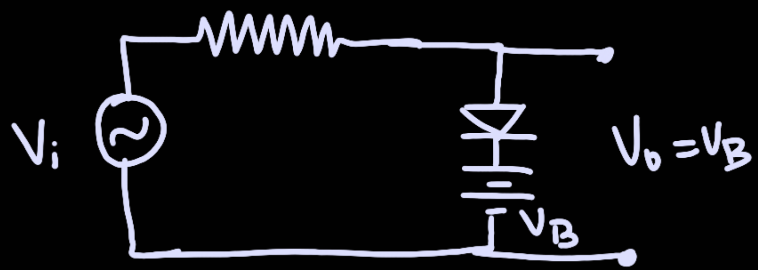


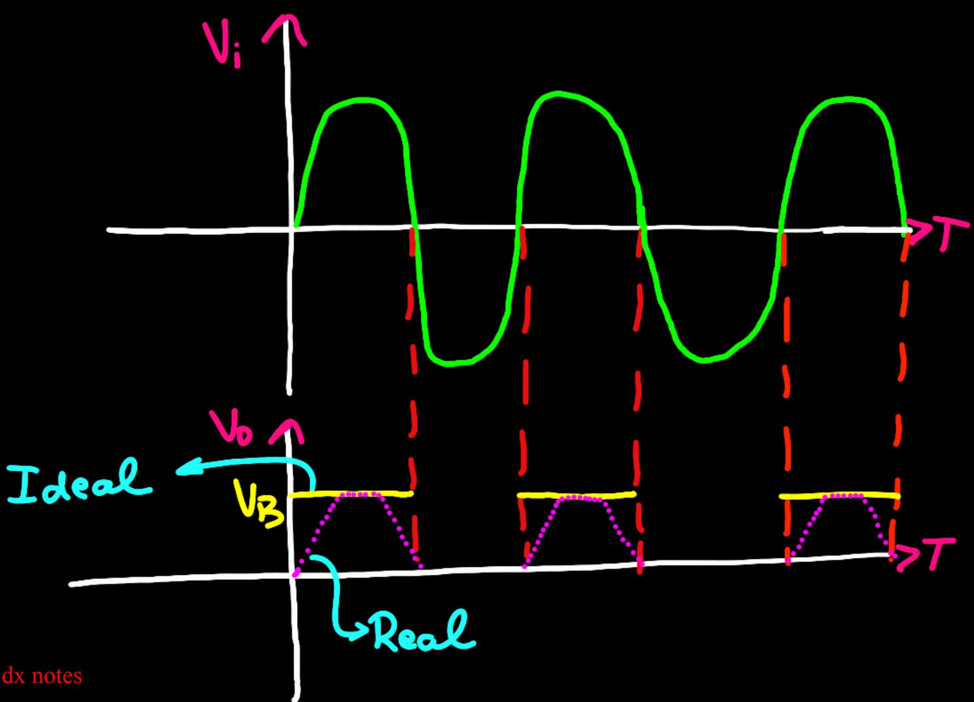
Ideal diode



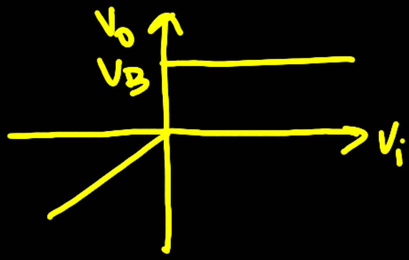
Biased Clipper:-

↳ Applying DC voltage to a clipper

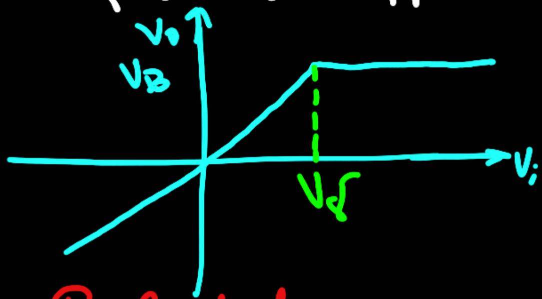




★ Transfer characteristics of biased clipper:-

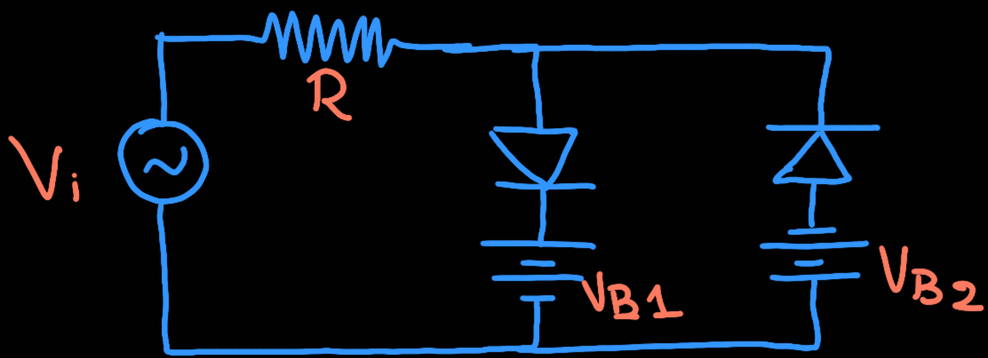


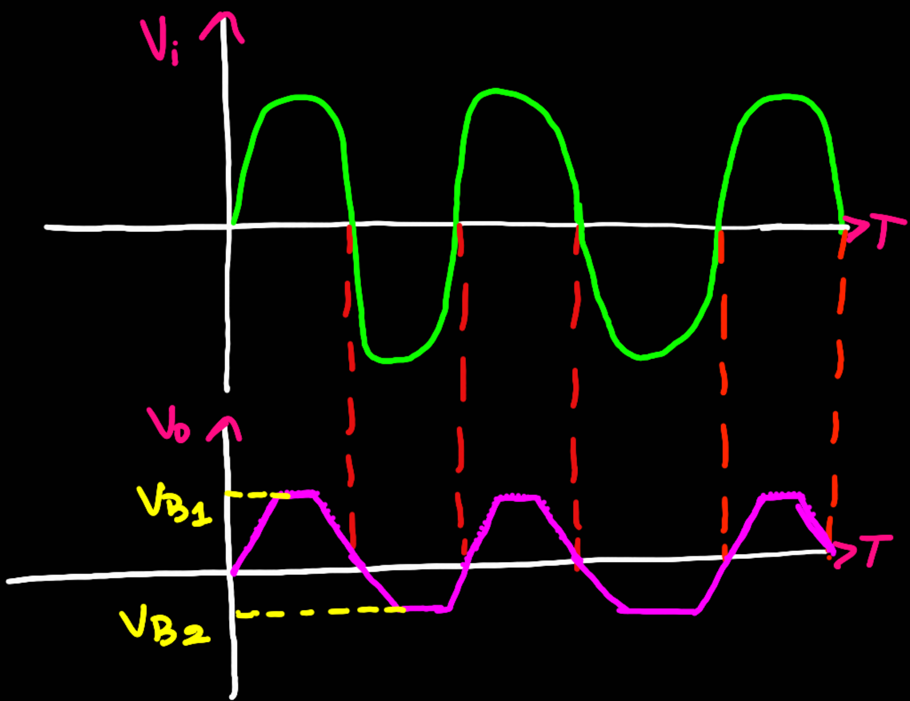
Ideal diode



Real diode

Double ended biased clipper:-

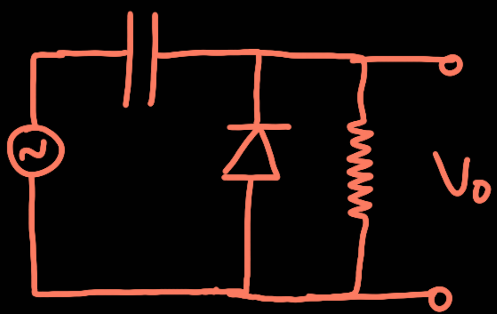


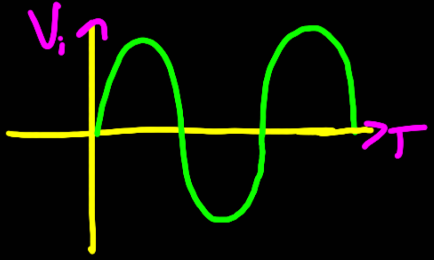


Clampers:-

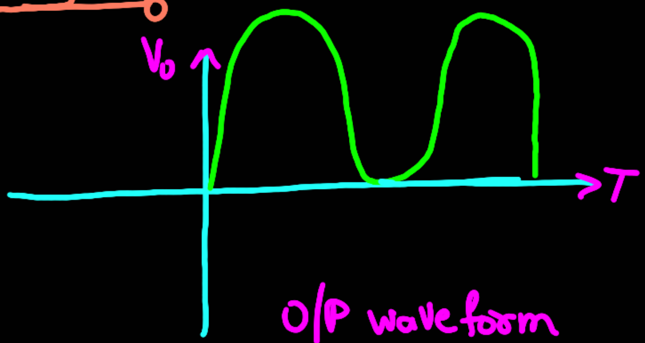
- Clamper ckt add/insert/shift the voltage (add → Accumulation → Capacitor)
- A.K.A DC restorter circuits
- Clamper can be +ve or negative

★ Positive clamper:-



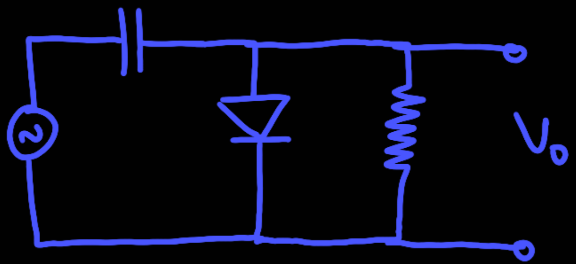


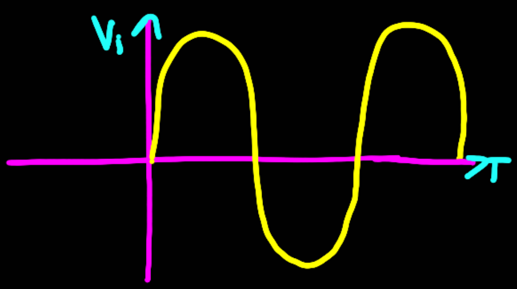
I/P wave form



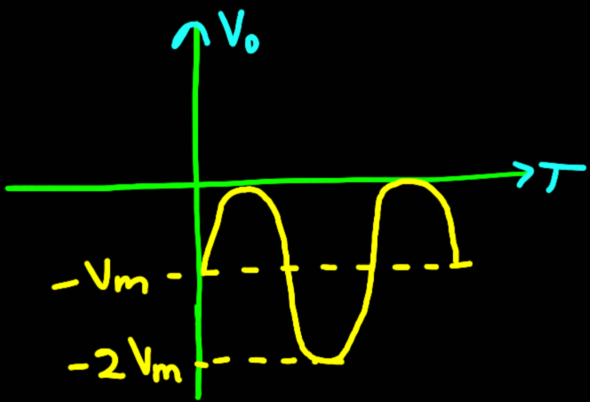
O/P waveform

★ Negative Clamper:-





I/P wave form



O/P wave form

Varactor Diodes:-

P-N j^n diodes

Special diode in which internal capacitance changes with applied reverse bias voltage

AKA:- Varicap diode — Variable Capacitor

Varactor — Variable Reactance

Ckt Symbol:-

Understanding parallel plate capacitor

$$\Rightarrow C = \frac{\varepsilon A}{d}$$

C → Capacitance, ε → Permittivity, A → Area, d → Distance b/w plates

Thus, this P-N j^n can behave as a capacitor

$$C \propto \frac{1}{d}$$

↑ in Reverse bias voltage ⇒ ↑es the width of the depletion layer

$$\boxed{C = \frac{C_0}{\left[1 + \left|\frac{V}{V_f}\right|\right]^n}}$$

n depends on doping profile

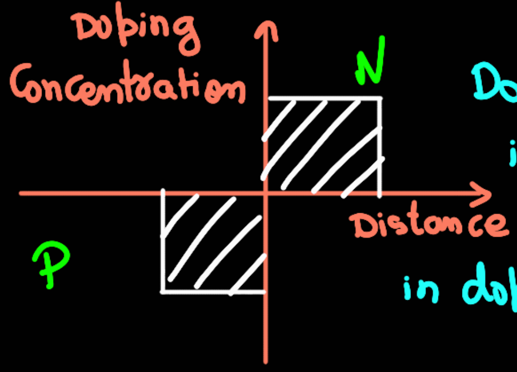
V → Applied R.B

V_f → F.B voltage of diode

C_0 → Capacitance of diode when unbiased

Based on doping profile there types of varactor diodes

Abrupt Varactor diode $n = 1/2$



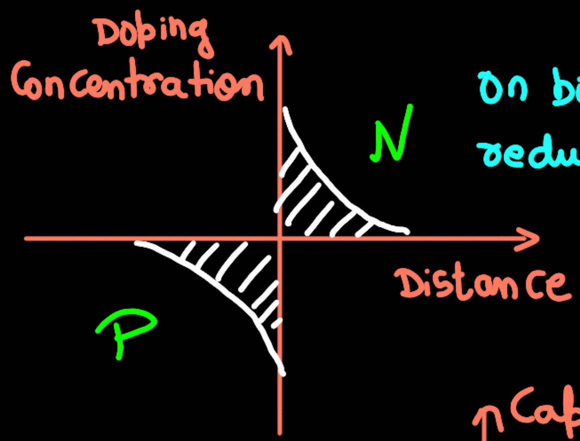
Doping Profile

Doping concentration of P & N type is uniform.

At the j^n there is abrupt change in doping profile

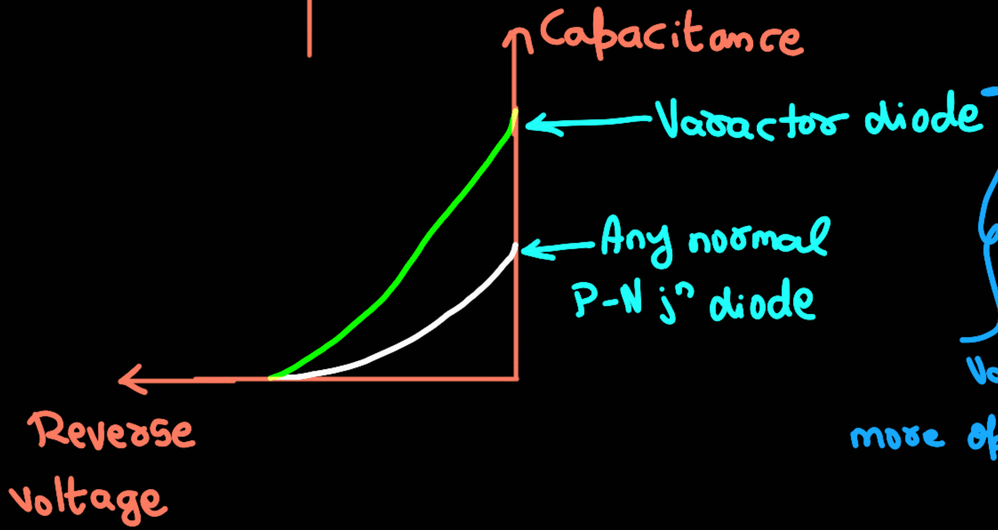
$\boxed{n = 1/2}$ → Seen in normal p-n diodes

Hyper Abrupt Varactor diode :- $n = 2$



On both sides doping concentration reduces rapidly with distance

$\boxed{n = 2}$



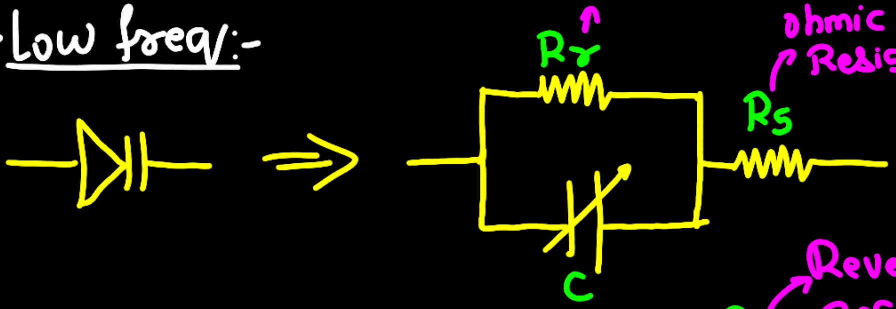
Thus, any P-N j^n diode can be used for changing capacitance, but varactor diodes are more optimised for it

Equivalent Ckt:-
→ At low freq
→ At high freq

Low freq:-

Reverse Resistance → in MΩ → High to avoid leakage current

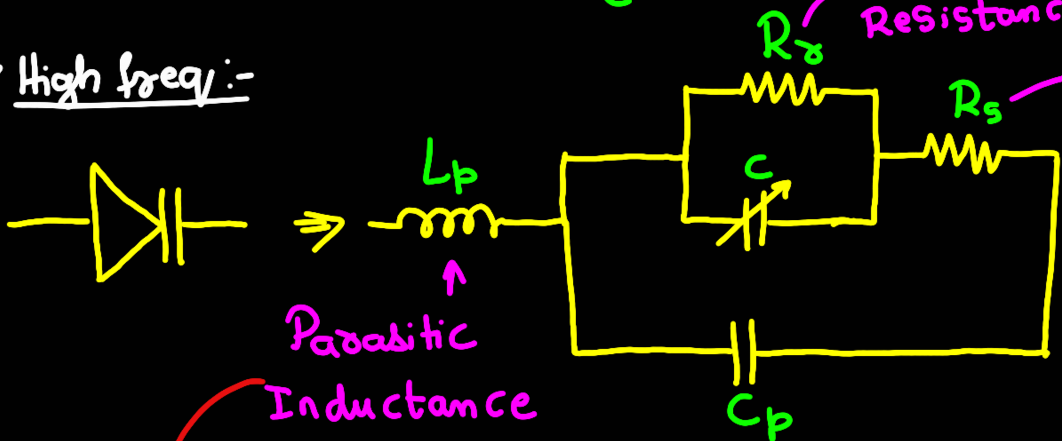
ohmic Resistance



High freq:-

Reverse Resistance

Ohmic Resistance



Parasitic Inductance

Unwated Inductance that arises from the leads and internal connections of varactor diode

Parasitic capacitance

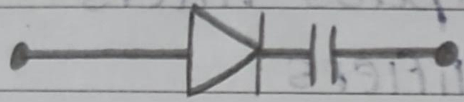
Unwanted capacitance that exists b/w terminals of varactor diode

Applications:-
Used in tuning ckts
In RF Filters
In Frequency & Phase modulators

OR

Refer below notes for Varactor Diode

"Varicap Diode"

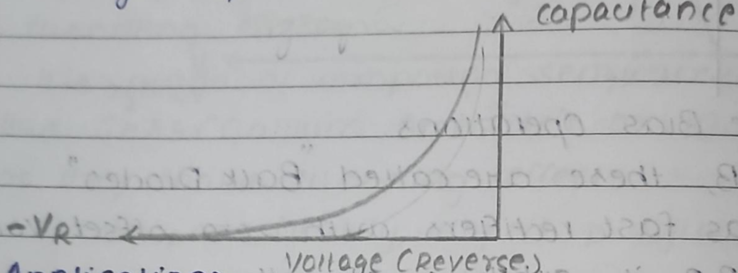


- A special diode that uses transition capacitance property i.e voltage variable capacitance.
- It works under Reverse-Bias conditions
- Under R.B, holes of p-region are attracted to -ve terminal & e^- of n-region are attracted to +ve terminal creating a region devoid of charge carriers. This region behaves as the dielectric of the capacitor
- The Junction capacitance of the diode is inversely proportional to width of depletion layer

$$C_j = \frac{C_k}{(V_b - V)^m}$$

∀ C_j → diode capacitance
C → unbiased diode capacitance
V → voltage applied
V_b → barrier potential
m → constant depending upon material
K → constant = 1

Voltage - Capacitance Curve



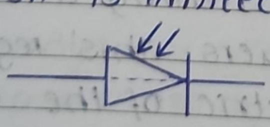
Applications

- Tuned circuits
- FM modulators
- Automated freq. control device
- Adjustable bandpass filters
- parametric amplifiers
- Television recievers

d. Briefly Explain LED, OLED & photo diode

→ Photo Diode

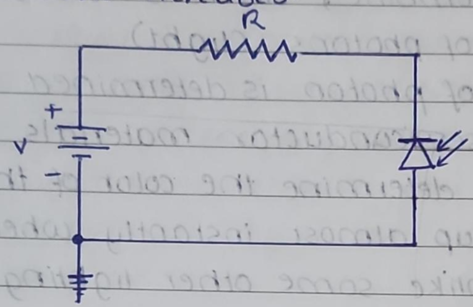
It's a p-n junx device whose region of operation is limited to reverse bias region.



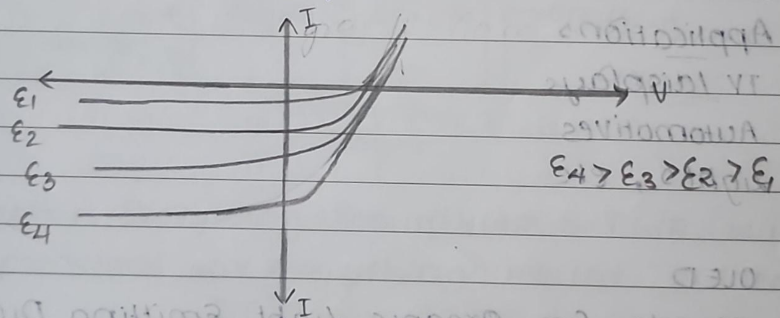
"Principle of Operation"

- Photo diode is a type of a photo detector capable of converting light into either current or voltage.

- Photo diode is designed to operate in RB where the depletion region is large
- When light is incident through glass window on the pn junx. diode, photons in the light bombard the p-n junx and some energy is imparted to the valence e^-'s
- These valence e^-'s break covalent bonds & become free. Thus more e^--hole pair is generated. Thus with increase in minority charge carriers, RB current increases.

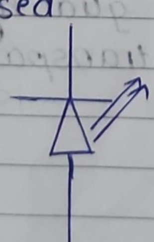


Characteristics of photo diode



→ **LED** (Light Emitting Diode)

It's a special heavily doped pn junx diode that emits spontaneous radiation when forward biased.



- When a forward bias is applied across LED, electrons in the valence band gain enough energy to move to the conduction band. This process is known as electron injection
- Simultaneously holes are created in the valence band.
- The injected electrons in conduction band recombine with the holes in valence band. When they recombine, electrons release energy in the form of photons (light)
- The energy of photon is determined by the bandgap of semiconductor materials and doping levels determine the color of the light.
- LEDs light up almost instantly when a voltage is applied, unlike some other lighting technologies that may have warm-up time

Applications
- TV /displays
- Automotives
- Lights, etc.

→ OLED
- Stands for Organic Light Emitting Diode
- OLED is ~~are~~ an advanced display technology made from thin films of light-emitting organic materials.
- Unparalleled image quality
- Flexible displays / transparent displays

- Working

* OLEDs are made by placing a series of organic films b/w two conductors. When electric current is applied, a bright light is emitted.

* A simple OLED is made up of six layers. On top and bottom there's the glass/plastic substrate. In b/w them, there's a cathode (-ve term) & Anode (+ve term). In b/w cathode & Anode are two layers made from organic molecules called the emissive layer (where light is produced and is next to cathode), usually made of poly fluorine & conductive layer (next to anode) made of poly aniline.

* holes in conduction layer recombine with e^- in emissive layer and light is produced in emissive layer.