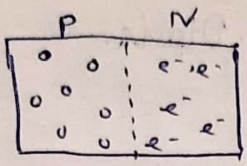
Unit - 5
Power Converter

Forward bias P-N Junction Diode:-



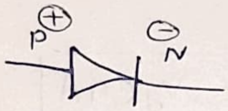
P-N Junction

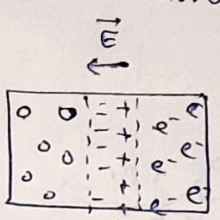
Diode ⇒ Combination of ~~P-N Semi-~~ P type & N type semiconductor. (Low voltage device)

P-N-Junction ⇒ Seperation of boundary of P and N semiconductor.

O ← e⁻ ⇒ Diffusion Current ⇒ momentery motion of electron. (minority)

hole electron





↳ Deplation layer (d)

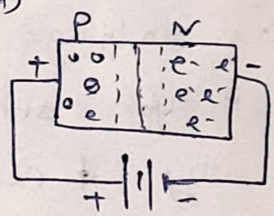
potential barrier

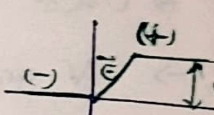
$V = \vec{E} \cdot \vec{d}$

In forward bias

→ diode is active.

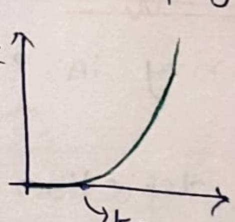
→ current flows.





in forward bias, deplation layer will decrease when it's connected to the external supply.

N type is ~~heavily~~ heavily dopped.



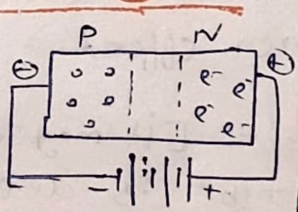
↳ Knee voltage (Cut-in voltage)

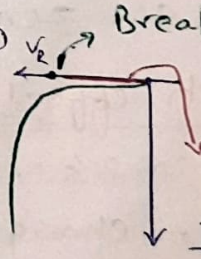
Reverse bias P-N Junction Diode:-

Diode is not active

No current flow.

→ Deplation layer will increase





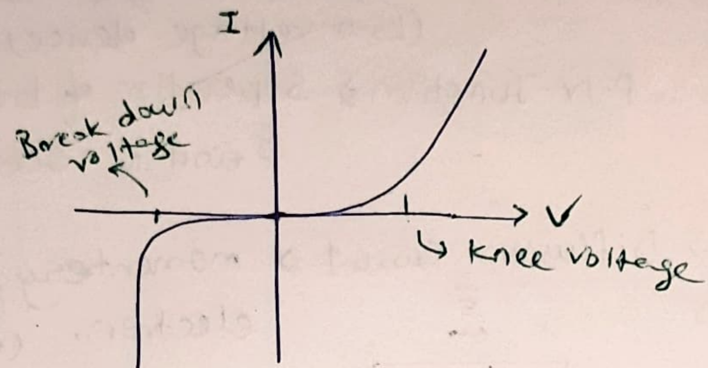
Break down voltage

Current = Reverse seturation current

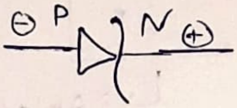
→ Break down voltage ⇒ Current sudden increase at that voltage.

Peak inverse voltage :- max value of reverse voltage that a diode can bear, is called peak inverse voltage. Upto ~~this~~ voltage a diode can not be damaged.

V-I Characterstics of PN Junction Diode.



- **Zener Diode**



$$\boxed{I_J = V_d e n A}$$

→ always connected in reverse biased.
→ Used as voltage Regulator.
→ N and P type semiconductor are heavily dopped that why ~~+~~ current ~~flows~~ flows though the minority charge carriers.

* **Zener effect**

impurity in P & N ↑ ⇒ minority charge carriers will increase

hence depletion layer will decrease ~~the~~ thats why the current flows in Reverse biased. This effect is known as zener effect. [at low potential]

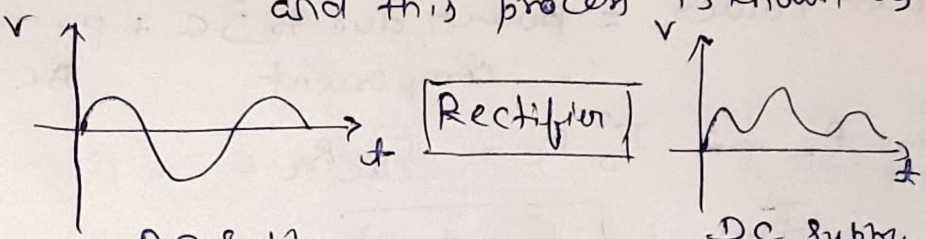
* **Avalanch effect** :- [it may destroy device]

impurity in P & N type is decreasing, depletion layer will increase, charge carriers have maximum energy then it will break bonds and produce free charge carriers. It is called Avalanch effect [at high Potential]

Application of Zener diode

1. As a voltage Regulator
2. As a reference voltage Device.
3. Constant current Source with transistor
4. Over voltage Protection

Rectifier :- It convert AC current into DC current. and this process is known as Rectification.

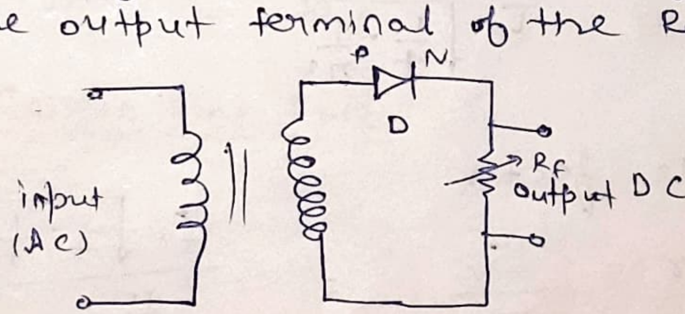


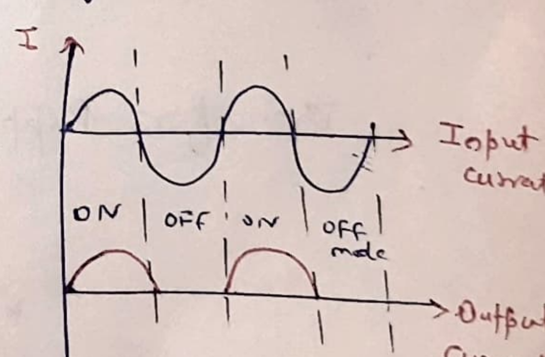
Rectifier

- Half ware Rectifier (HWR)
- full wave Rectifier (FWR)

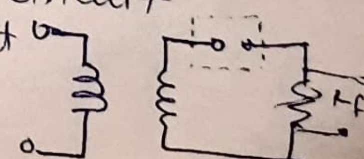
1.) Half wave Rectifier :-

Only positive half cycle of the AC voltage appears at the output terminal of the Rectifier.





in Forward biased, Diode is in turn on mode So current will show on output terminal as DC.
but in Reversed, it will work as open circuit So no current will produce at output terminal.



Ripple factor :- The output wave of a rectifier is not a pure DC of constant magnitude. It is an alternating wave with pulsation. These pulsation are called ripples.

[mixture of pure DC with pure AC component]

Ripple factor

$$\gamma = \frac{I_{ac}}{I_{DC}} \qquad \left(\text{here } I_{DC} = I_{av} \right)$$

& ~~$I_{AC} = I_{rms}$~~

Output Power = power due to DC component + power due to AC component

$$I_{rms}^2 R_L = I_{DC}^2 R_L + I_{AC}^2 R_L$$

$$I_{rms} = \sqrt{I_{DC}^2 + I_{AC}^2}$$

$$I_{AC} = \sqrt{I_{rms}^2 - I_{DC}^2}$$

$$\because \quad I_{DC} = I_{av} = \frac{2 I_0}{\pi} \quad \text{(For half wave)}$$

$$I_{rms} = I_0 / \sqrt{2}$$

$$I_{AC} = \sqrt{\frac{I_0^2}{4} - \frac{I_0^2}{\pi^2}}$$

$$I_{AC} = I_0 \sqrt{\frac{1}{4} - \frac{1}{\pi^2}}$$

Therefor Ripple factor

$$\gamma = \frac{I_{AC}}{I_{DC}} = \frac{I_0 \sqrt{\frac{1}{4} - \frac{1}{\pi^2}}}{I_0 / \pi}$$

*

$$\boxed{\gamma = 1.21 \text{ or } 121\%}$$

* Efficiency of Rectification:

$$\eta = \frac{\text{Output DC Power}}{\text{Input AC Power}}$$

$$\boxed{\eta = \frac{P_{DC}}{P_{AC}}}$$

$$\Rightarrow \quad \eta = \frac{I_{av}^2 R_L}{I_{rms}^2 (R_f + R_L)} \qquad \left[\begin{array}{l} I_{av} = I_0/_{\pi} \\ I_{rms} = I_m/_2 \end{array} \right]$$

$$\eta = \frac{I_0^2}{\pi^2} R_L \Big/ \frac{I_m^2}{4}(R_L + R_f)$$

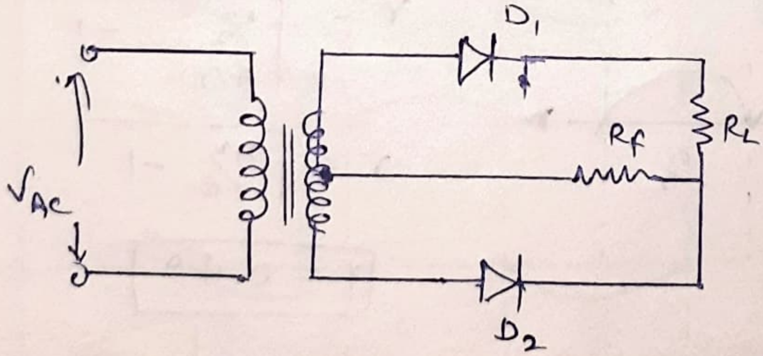
$$\eta = 0.4053 \frac{1}{1 + R_f/R_L} \qquad (R_L >>> R_f)$$

$$\eta = 0.40 \Rightarrow \quad \% \eta = 40.53\% \text{ effeciency.}$$

(2.) **Full wave Rectifier:-** It rectifies the full sinusodial wave on AC current into DC.
(FWR)

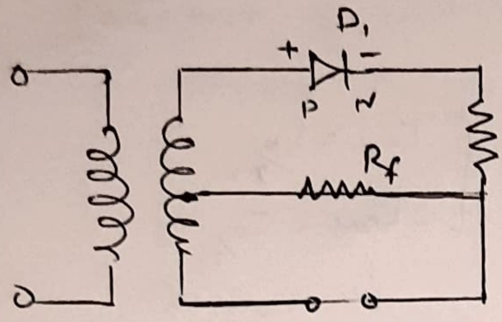
FWR
- Centre Tap FWR
- Bridge Type FWR.

(a) Centre Tap FWR

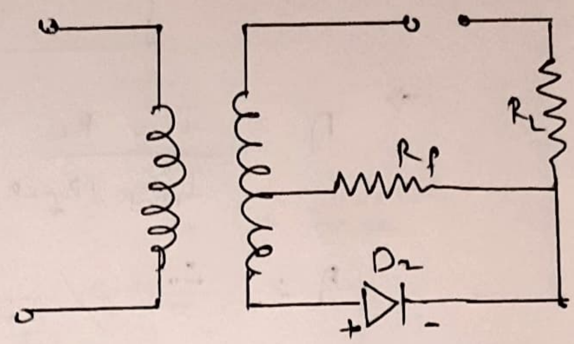


It consists two PN Diode & a centre tap transformer. When we apply forward biase on the circuit, D_1 is activated & D_2 is in reverse biased so only D_1 convert first (+)ive half current in DC.

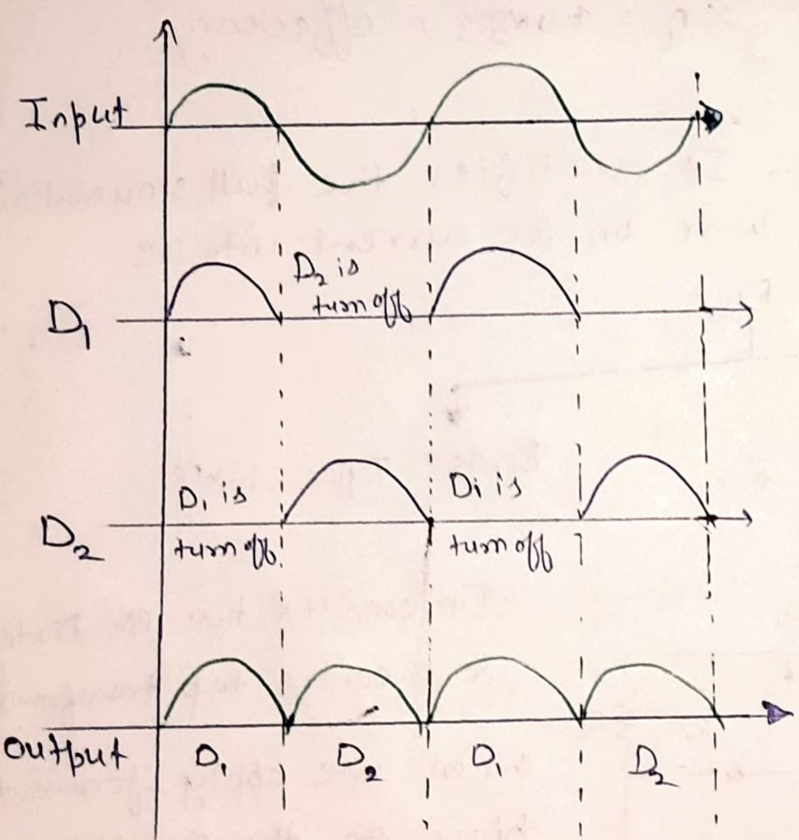
Similarly for D_2,
when reverse voltage applies on the circuit, D_2 is on active mode & converts the current in DC.



D_1 is on turn on mode
& D_2 is on turn off mode
(Forward biased)



D_2 is on turn on mode
D_1 is on turn off mode
&
(Reverse biased)



ripple factor

$$r = \frac{I_{AC}}{I_{DC}} = \frac{\sqrt{I_{rms}^2 - I_{AV}^2}}{I_{AV}}$$

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

here for full wave

$$I_{rms} = I_0/\sqrt{2}, \quad I = \frac{2I_0}{\pi}$$

$$r = \sqrt{\frac{1/2}{4/\pi^2} - 1}$$

$$r = \sqrt{\pi^2/8 - 1}$$

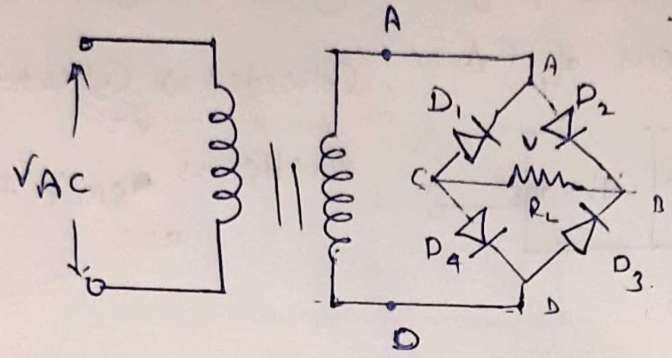
$$\boxed{r = 0.49}$$

$$V_o = \left[\frac{V_m \sin\theta}{R_L + R_f}\right] \times R_L$$

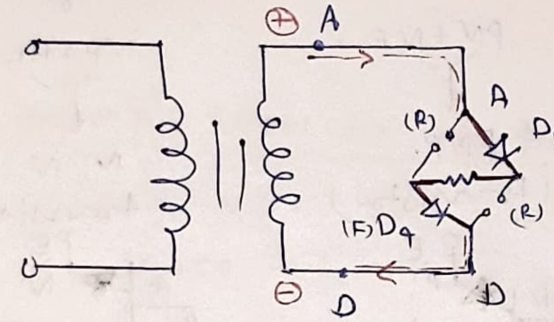
Effeciency $\eta = 0.8105$
$= 81\%$

(b) Bridge Type Rectifier :- Can be used for High voltage

→ effeciency high then FWR.



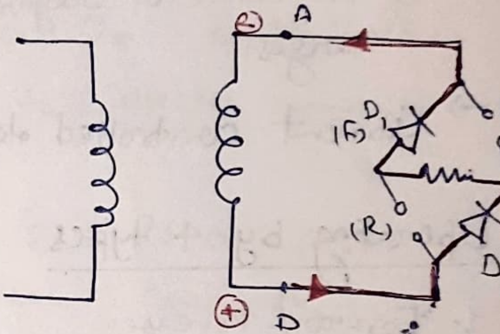
when A → ⊕
D → ⊖



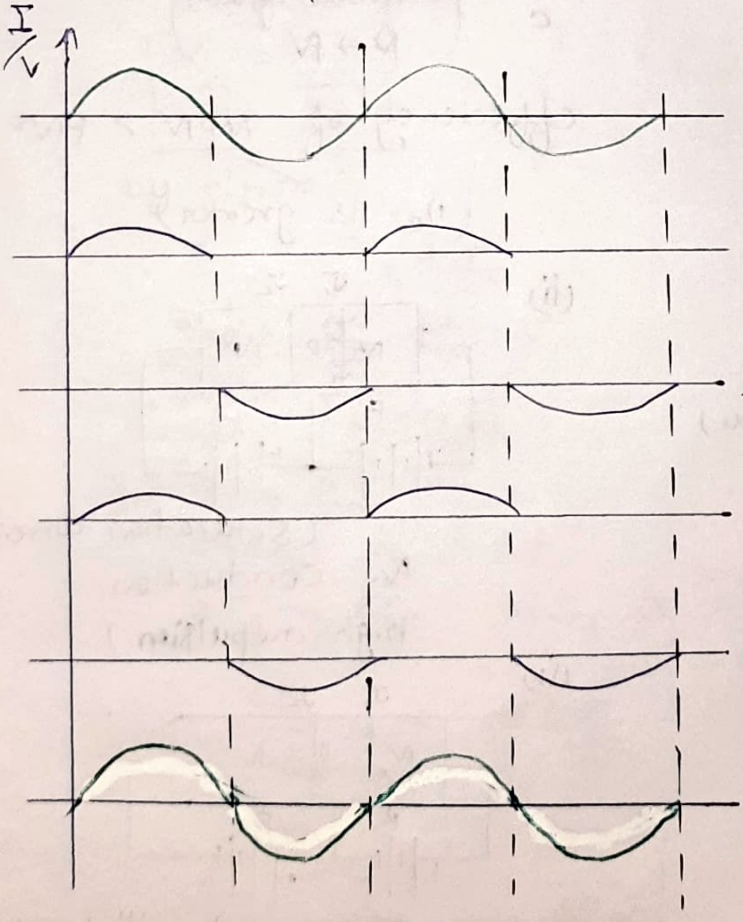
D_1 & D_3 in turn off
& D_2 & D_4 in turn one.

+

when A → ⊖
D → ⊕



D_1 . D_3 in turn one
& D_2 & D_4 in turn off.



$$V_0 = \frac{V_m R_L \sin\theta}{(2R_f + R_L)}$$

* Frequency of Pulsation ⇒ 2f

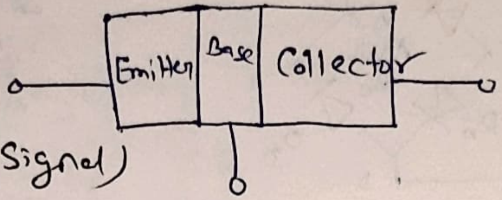
★ Transistor :- A semiconductor device, which have three terminals & generally made of Si or Ge.

(BJT)

It has 3 alternate layers of P & N.

↳ Bipolar Junction Transistor.

(Amplifying the Signal)



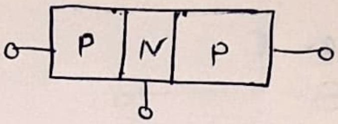
Collecter ⇒ Collect the e^-

emitter ⇒ emit the e^-

→ Emitter is heavily dopped

→ Region of Base is smallest & for collecter region is largest.

→ Current controlled device.

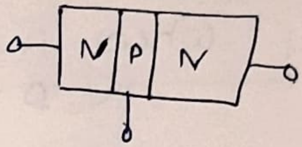


PN + NP

↓

PNP

(transistor)



NP + PN

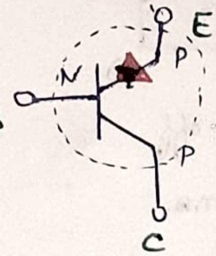
↓

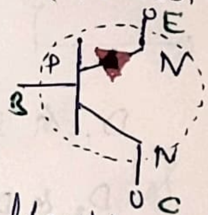
NPN

(transistor)

Operating by 4 types

1. Forward Reverse
2. Forward - Forward
3. Reverse - Reverse
4. Reverse - Forward.



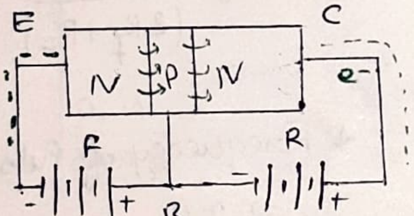


(current flows P → N)

efficiency of NPN > PNP

(n_{e^-} is greater)

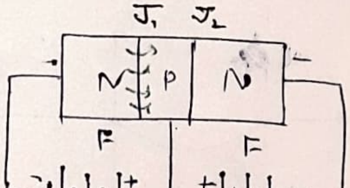
(i)



(Active mode)

when E is in forward biased, then the transistor will active

(ii)

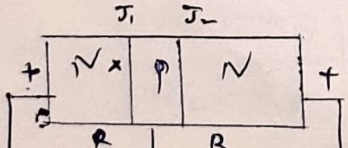


(Saturation current)

No conduction.

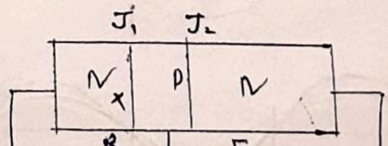
high repulsion.)

(iii)



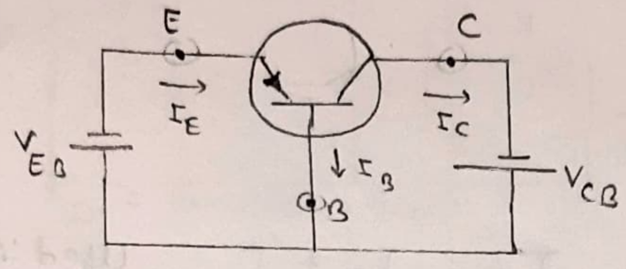
(Cut off mode)

(iv)

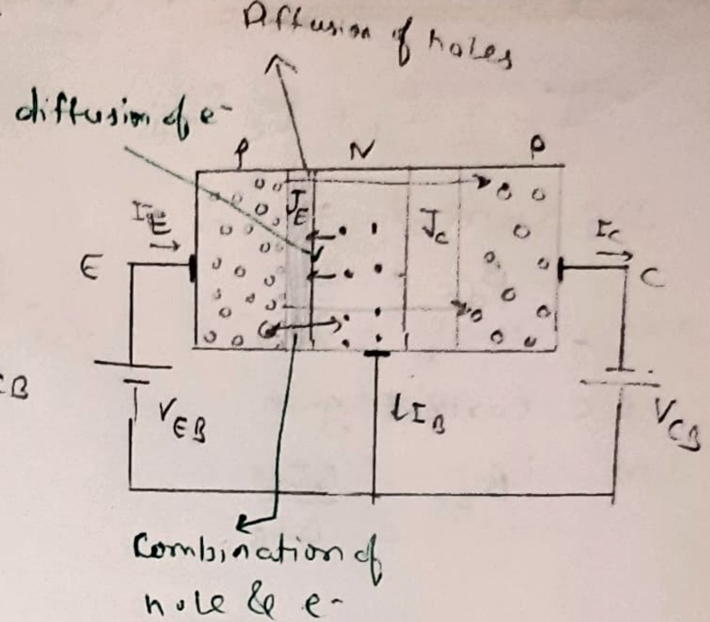


Junction 1. will break

Working of transistor:-



circuit



here J_E = Emitter Junction.

J_C = Collector Junction.

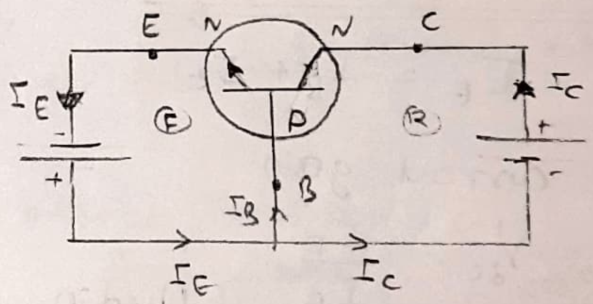
Common Connection of transistors

Transistor has 3 terminals & it is a 2 port device. So there are 3 type of connections.

1: **Common base:-**

→ DC current gain

$$\boxed{\alpha_{dc} = \frac{I_C}{I_E}}$$



by circuit

$$I_E = I_B + I_C$$

$$I_B = I_E - I_C$$

$$I_B = I_E - \alpha_{DC} I_E$$

$$\boxed{\alpha_{AC} = \frac{\Delta I_C}{\Delta I_E}}$$

Similarly for change in current

used in multistage amplifier for high frequency application.

$$\Delta I_B = \Delta I_E - \alpha \Delta I_E \quad \& \quad \alpha_{DC} \to \alpha_{AC}$$

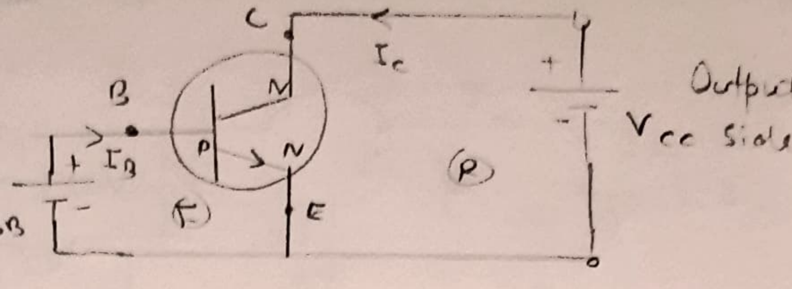
$$\frac{\Delta I_B}{\Delta I_E} = 1 - \alpha \cancel{\frac{\Delta I_E}{\Delta I_E}}$$

$$\boxed{\alpha_{AC} = 1 - \frac{\Delta I_B}{\Delta I_E}}$$

(less then unity)

(ii) Common Emitter :- Also known as Emitter ~~fdd~~ follower.

$I_E = I_B + I_C$ —(i)



DC current gain

$$\beta_{dc} = \frac{I_C}{I_B}$$

AC current gain

$$\beta_{AC} = \frac{\Delta I_C}{\Delta I_B}$$

$$I_E = I_B + I_C$$

$$\frac{I_E}{I_C} = \frac{I_B}{I_C} + 1$$

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

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

Used in as an amplifier specially in audio frequency.

$$\alpha + \alpha\beta = \beta$$

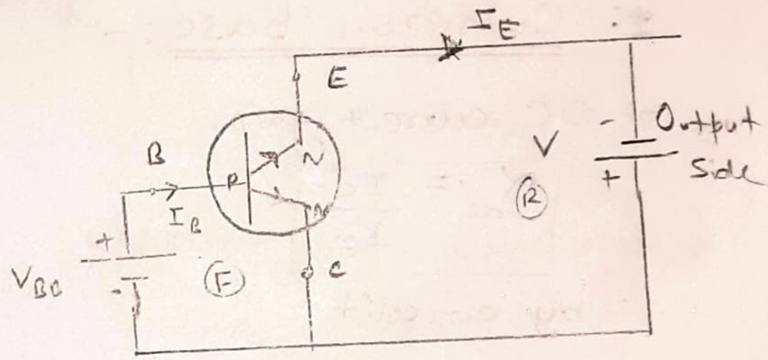
$$\alpha = \beta(\alpha - 1)$$

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

Output current

$$I_C = \beta(I_B) + (1+\beta) I_{CO}$$

(iii) Common Collector :-



$$I_E = I_B + I_C$$

DC current gain

$$\gamma_{dc} = \frac{I_E}{I_B}$$

$$\gamma_{AC} = \frac{\Delta I_E}{\Delta I_B}$$

Used in
(i) Impedence matching ckt
(ii) a buffer in multistage amplifier.

$$I_E = I_B + I_C$$

$$\frac{I_E}{I_B} = 1 + \frac{I_C}{I_B}$$

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

Relation Between γ & β

Output current

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

due to minority (charge carrier)

or $I_E = I_B + I_C$

$$1 \pm \frac{I_B}{I_E} + \frac{I_C}{I_E}$$

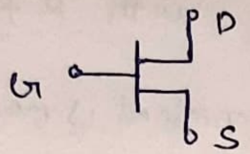
$$1 = \frac{1}{\gamma} + \alpha$$

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

Relation Between γ & α

* FET (Field effect transistor)

→ It is a 3 terminal device



Gate
Drain
Source

I_D = function (V_{GS})

→ It is a voltage controll device.

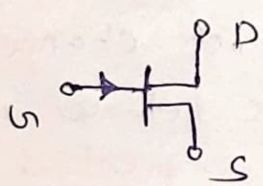
→ Unipolor device

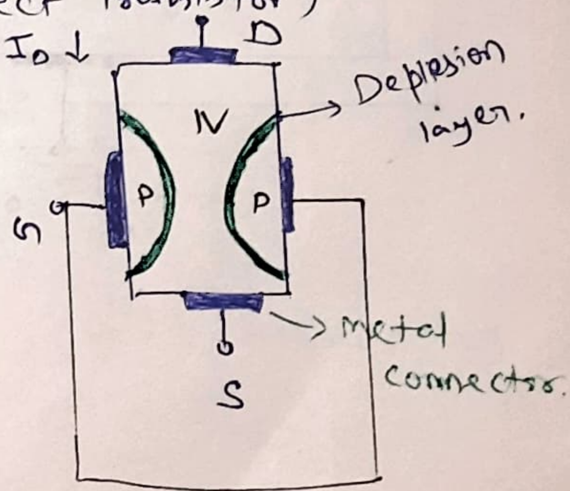
→ Current flows in one direction.

→ Used for switch and Amplifier.

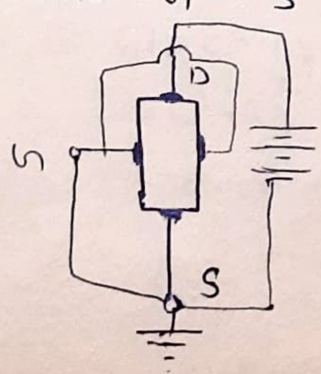
FET
- JFET
  - P Channel (holes are dominant)
  - N Channel (e^- are dominant)
- MOSFET
  - DMOSFET
    - P Channel
    - N Channel
  - EMOSFET
    - P Channel
    - N Channel.

(A) JFET :- (Junction Field effect Transistor)





Bettery is connect between D and S and V_G & V_S = 0



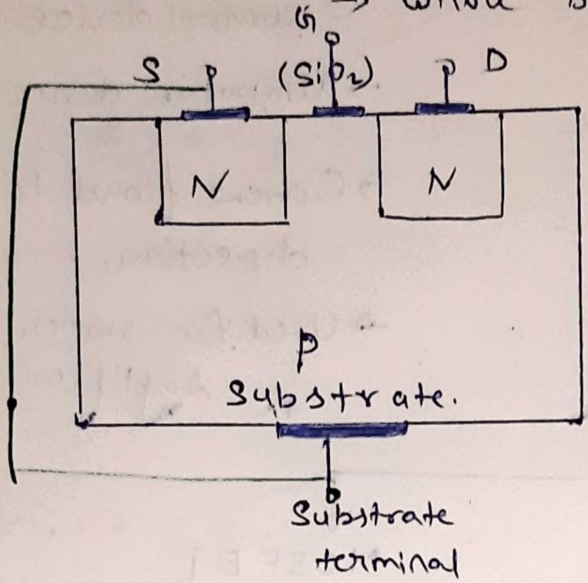
Both P are symmatric (Identical) So they are Connected.

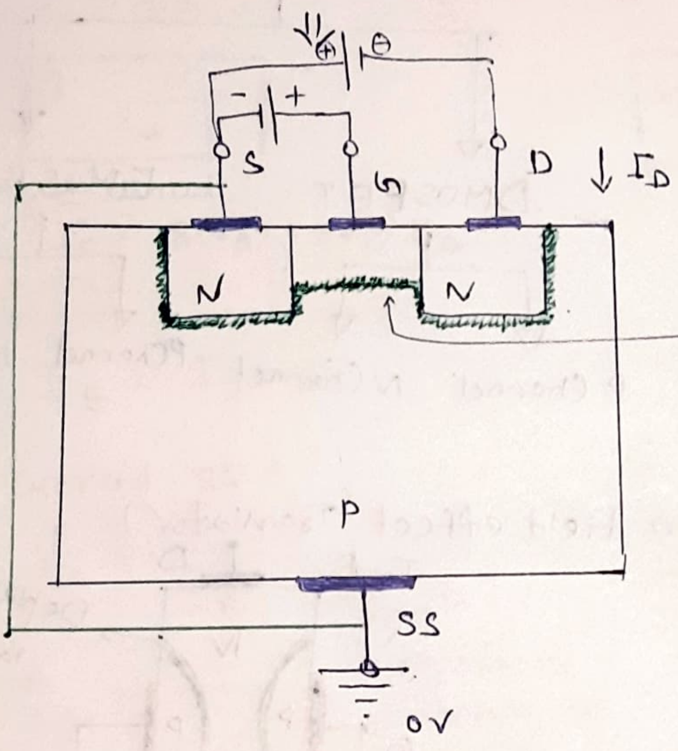
(B) MOSFET

(Metal Oxide semiconductor Field effect transistor)

→ whole body is made with P type.

Gate terminal is made by SiO_2 (Metal Oxide)





* Minority charge (e^- in P) will conduct current Between D to S

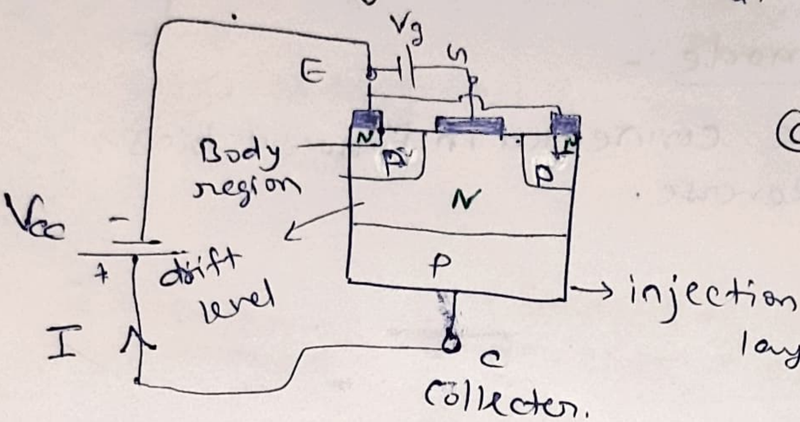
V_{GS} = Throshold Poteiantin

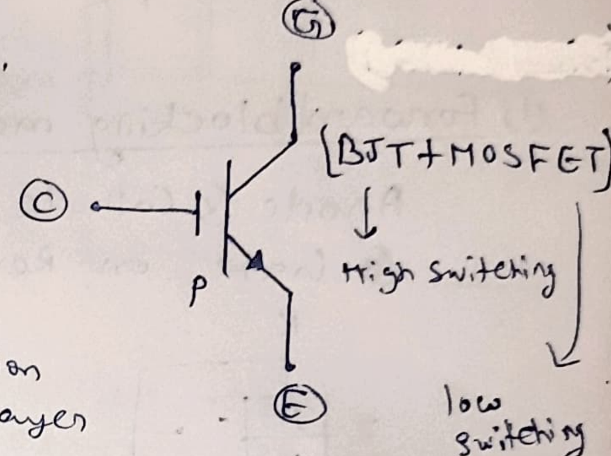
↳ at which channel create between N to N.

★ IGBT :- (Insulated Gate bipolar transistor)

~~Used for~~ a semiconductor device which is used in electronic switch.

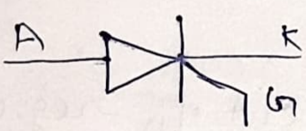
-> Control by gate terminal.



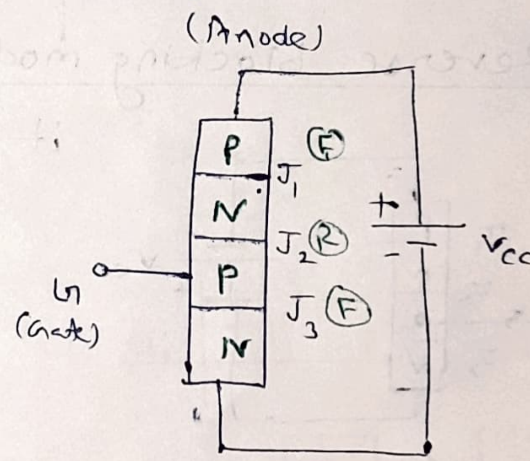


layer -> SiO_2

★ SCR :- (Silicon Controlled Rectifier)



(Symbol)



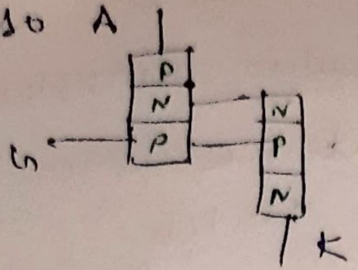
Combo of P-N-P & N-P-N transistor.

for some nano seconds bettery will be connected or disconnected with Gate.

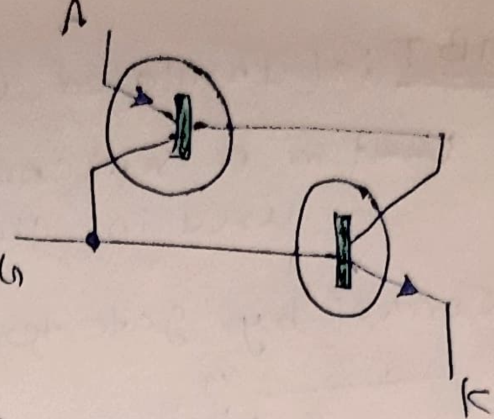
Also known as (Thyristor)

(i) Forward blocking mode
(ii) Reverse blocking mode
(iii) Forward conducting mode.

Also

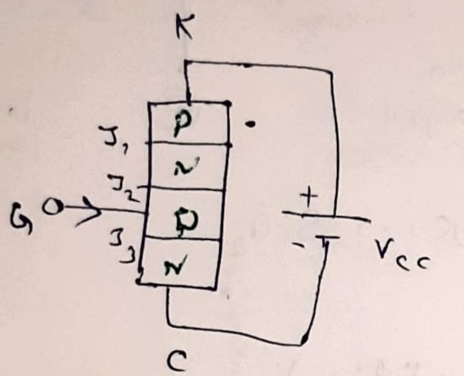


⇒



(i) Forward blocking mode :-

Anode & Cathode connected in Forward bias. & Gate on Reverse.

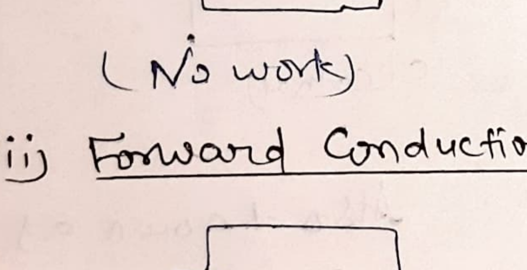


(ii) Reverse blocking mode :-

it is called cut off region mode

J_1 & J_3 ⇒ No conduction (Reverse)

J_2 ⇒ Gate on forward biased.

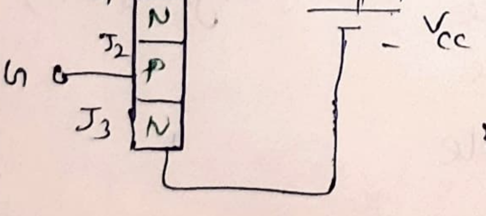


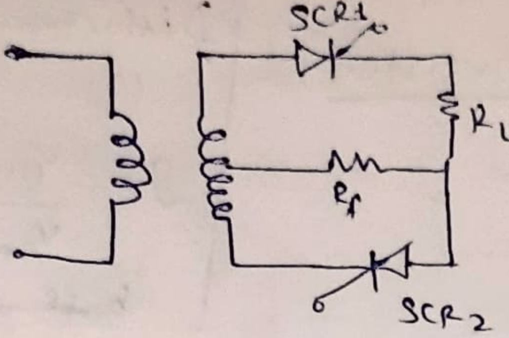
(No work)

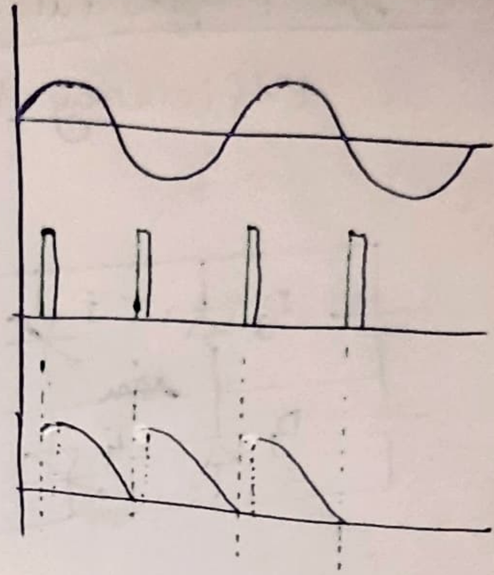
(iii) Forward Conduction mode :-

At a very high voltage at gate, Avalanche break is heppens & J_2 junction will be on conduction mode ~~it~~ is ~~t~~ Hence

J_1, J_2, J_3 :) Conduction mode.







Trigger Phase

gate is triggered for nano seconds.

Inverter :-

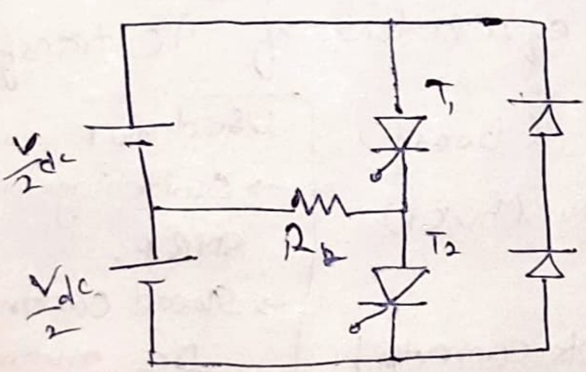
(fixed DC to variable AC)

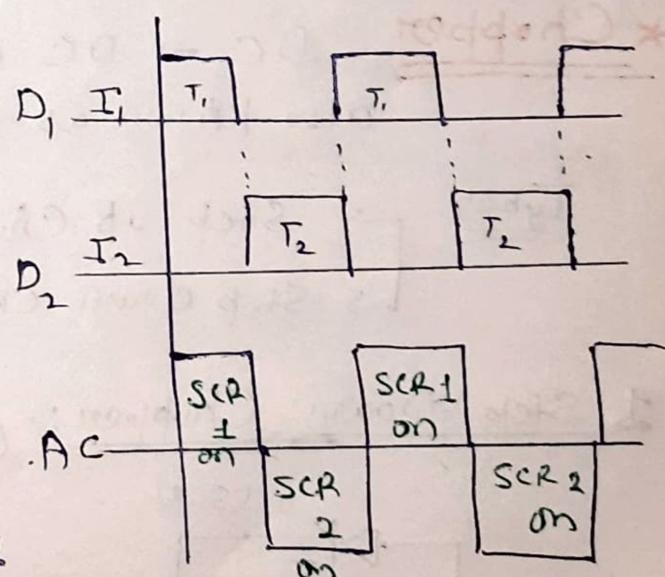
A device that converts d.c power into AC power at desired output voltage & frequency. (Controlled device)

SCR → at below 90° ⇒ Rectifier
at above 90° ⇒ inverter.

* Single phase Bridge Inverter (DC → AC) (Voltage Source)

(A) Single phase half bridge inverter:-





I_g (1) gate pulse of SCR 1

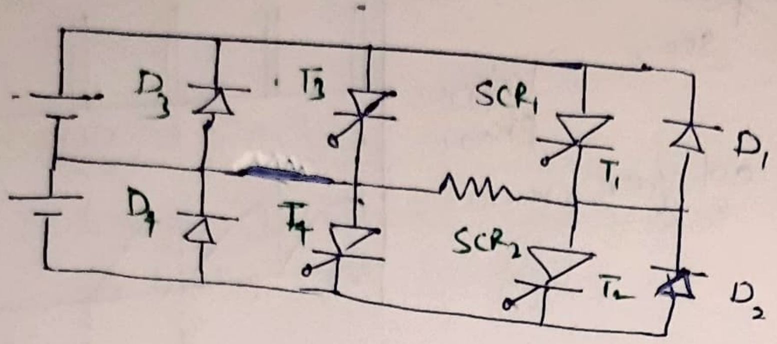
I_g (2) gate pulse of SCR 2

Rms value

$$V_{rms} = \frac{\sqrt{2}\, V_s}{\pi}$$

(2) Single phase full bridge inverter :-

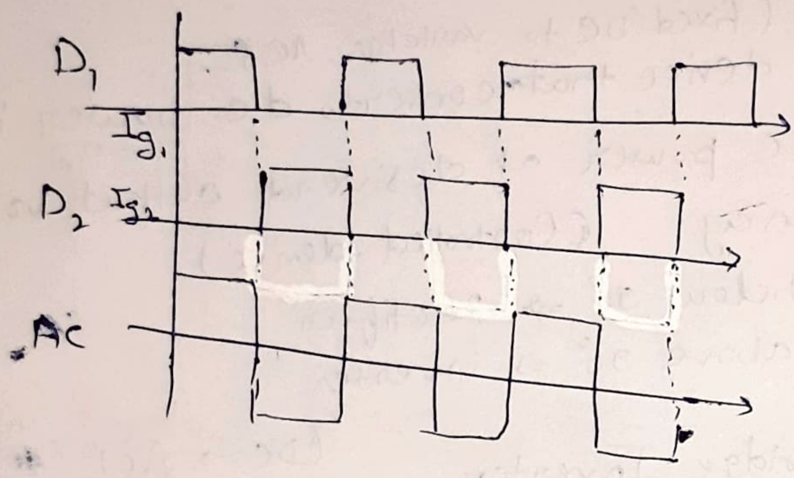
Efficiency high.



Distortion Factor (g)

$$g = \frac{V_{1rms}}{V_{orms}} = \frac{2\sqrt{2}}{\pi}$$

~~half wave~~ $(V_o = V/_2)$



* Chopper

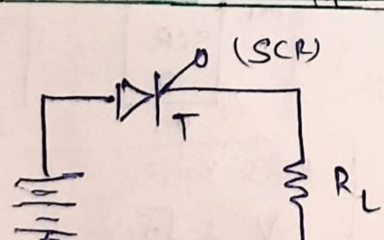
DC to DC Converter (Controlled)

also known as DC equivalent of AC transformer

Types
- → Step up Chopper (boost)
- → Step down Chupper (buck)

Used for
- → Switching in PC, SMPS.
- → Speed control in DC motor.

1 Step Down Chupper :- (Buck converter)



It decrease Output DC voltage.

$$V_o = V\left(\frac{t_{on}}{t_{off} + t_{on}}\right)$$

V_{DC} = Avg value of output DC

I_{DC} = Avg current value of DC

$V_{DC} = V\left(\frac{t_{on}}{T}\right) = Vd$

t_{on} = turn on time

t_{off} = turn off time.

Rms value of Voutput

$f = 1/T$ (frequency)

$$V_o = \sqrt{\frac{1}{T}\int_0^{t_{on}} V^2 dt}$$

$T = T_{on} + T_{off}$

** d = duty cycle.

$$\boxed{d = \frac{T_{on}}{T_{off}+T_{on}} = \frac{T_{on}}{T}}$$

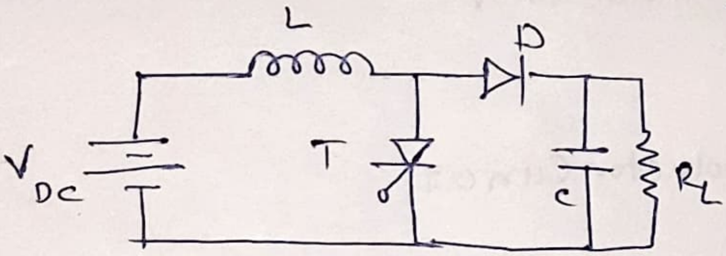
$$V_o = \sqrt{\frac{V^2 \, T_{on}}{T}}$$

$$V_o = \sqrt{\frac{t_{on}}{T}}\, V$$

$$V_o = \sqrt{d}\, V$$

Step UP chopper (Boost converter)

It Boosts output DC voltage.



L => will store megnatic charge for T_1 time.

C work as filters.

on turn off mode
L will release charge through D at load.

by KVL $\quad V_{DC} = V_o + L\frac{di}{dt}$

Energy stored in inductor

$$E_L = V \cdot I \cdot t_{on}$$

Voltage across L = $V_o - V$

energy supplied by inductor at t_{off} ⇒ $I = (V - V_o)\, t_{off}$

energy stored Inductor = Energy supplied by inductor.

$$V I t_{on} = (V_o - V) I \cdot t_{off}$$

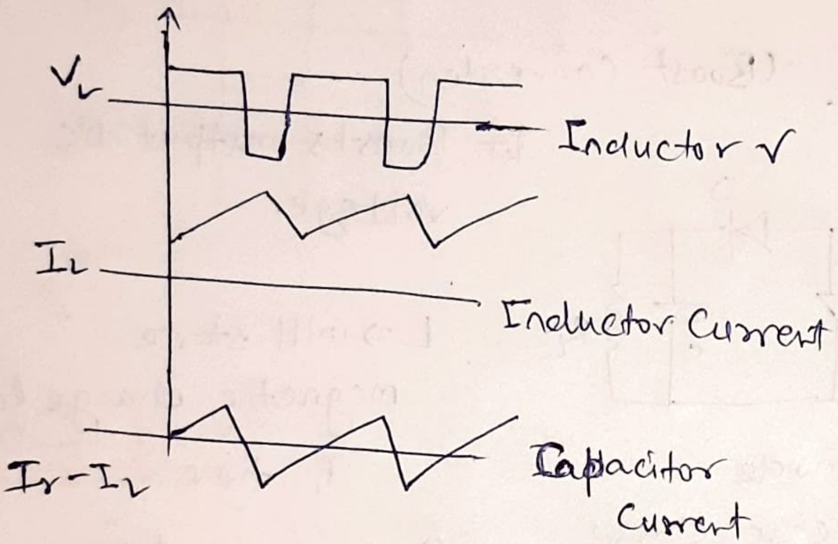
(energy conservation)

$$V_o = \frac{V [T_{on} + T_{off}]}{T_{off}} \qquad (\because T_{on} + T_{off} = T)$$

$$V_o = \frac{V T}{T - T_{on}}$$

$$V_o = \frac{V}{1 - T_{on}/T} \qquad \left(\because \frac{T_{on}}{T} = d\right)$$

★★ $$\boxed{V_o = \frac{V}{1-d}}$$



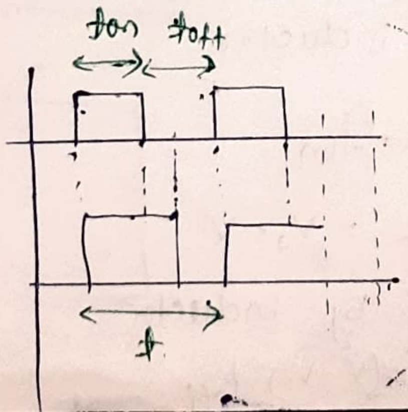
* Controlling Chopper

(i) PWM (Pulse width modulation)

(ii) Variable frequency

(Cheap)

(i) PWM



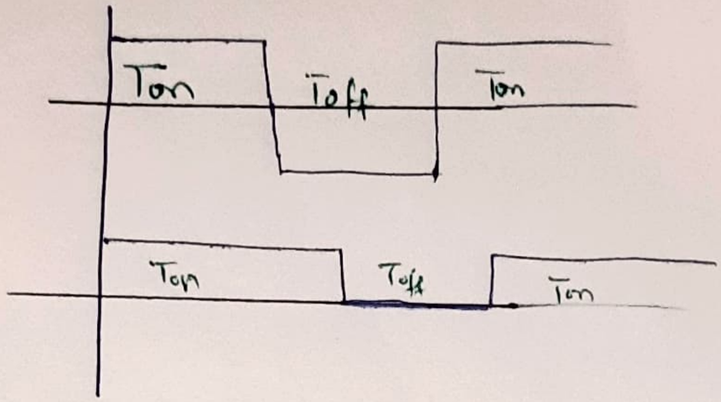
Total time = ton + toff
= Constant

No change in frequency.

(Changing in pulse)

Toff ↓ & Ton ↑

(ii) Variable frequency Controll (Costly)



T_{on} ↑

$T_{off} \Rightarrow$ Constant

So f will change