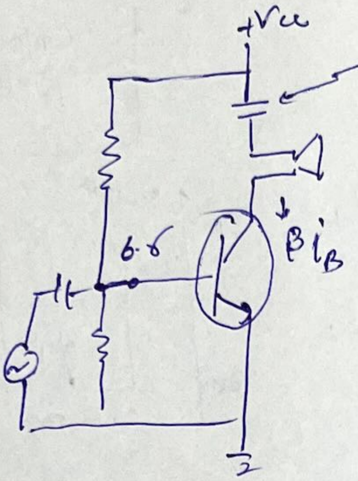
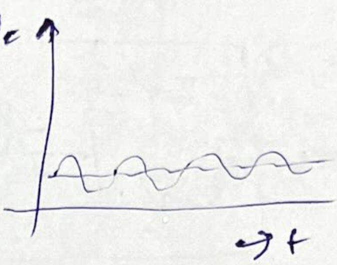
# EED 306 : Power Electronics

- Earth current > 20mA ⇒ Trip. supply (ELCB)
- Application ⇒ HVDC
- Basic Amp. ⇒ ON/OFF , PE ⇒ SMPS
- Power electronics ⇒ Few watts to several mega watts.
  ↳ work in switched mode.




high frequency

0 - 20 kHz → Audio

0 - 10 kHz ← music

Average ← $R_{thermal}$ b/w junction & case

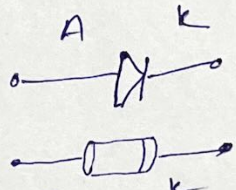
□ Semiconductor device

°C = $R_{Thermal}$ × watts

(temp. rise) ↳ °C/watt

Ambient temp ⇒ 50°C → outside the device

$T_j$ < 110°C → difference = 60°C




si ⇒ $T_j$ < 150°C

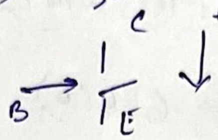
°C/watt = 0.4°C/watt ←

let $R_{thermal}$ ⇒ 10°C/watt {by manufacturer}

10°C/watt × P = 60°

P = 6W is the max^m power that can be desipiated in the device or switch

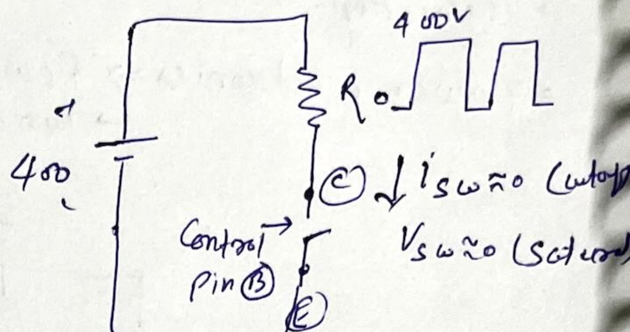
Cut off ⇒ $\boxed{i_{sw} \approx 0}$

Active ⇒ 

Power flow from C to E

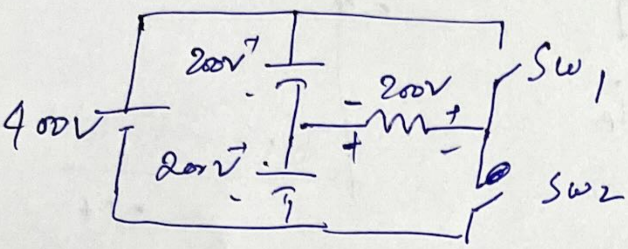
Saturation ⇒ $i_B > \frac{i_c}{\beta}$ ⇒ $V_{CE} = 0.2V$

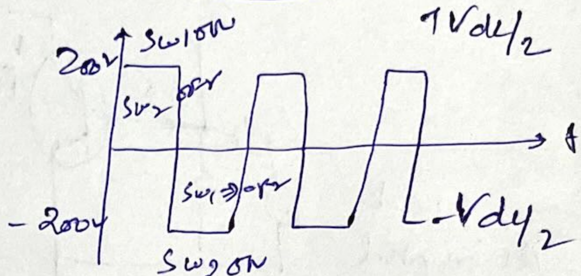
$\boxed{V_{sw} \approx 0}$




Q How to get sine wave?

A:

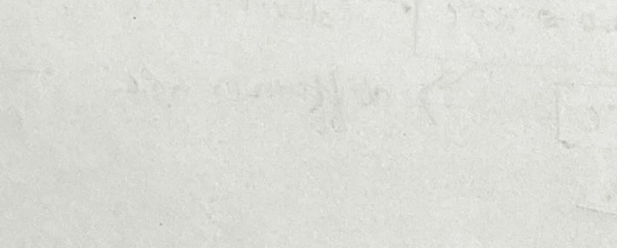



$f_o = 50Hz$

$f_{sw} = 10kHz$

Block high frequency components by using filter

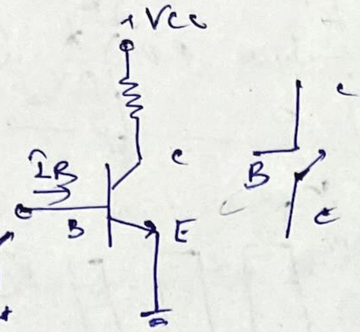


• Essential power conditioning CKAS:

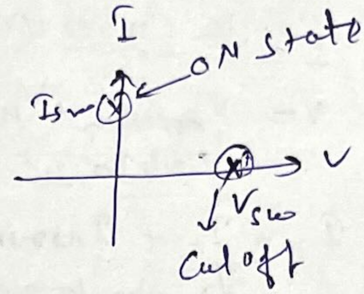
Electrical Power (available form) ⟹ Power Conditioning Ckt ⟹ Electrical Power (required by user)

AC / DC

fixed or variable magnitude of f — variable / fixed low / high




$i_E \approx i_C = \beta i_B$




Saturation $V_{sw} \cong 0V$ ⟹ 0.2–0.3V ⟹ for signal diode
→ 2–3V ⟹ for Power diode

cutoff $I_{sw} \cong 0A$

• Thermal resistance ⟹ Junction —/\/\/\—/\/\/\— ambient
$R_{Th\,j,c}$ $R_{Th\,c,a}$

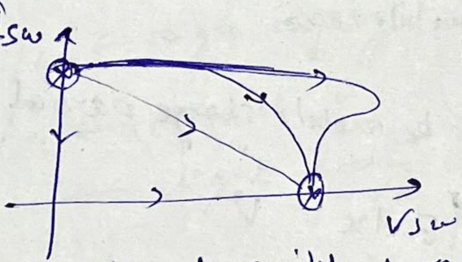
Approx (140°C)

• As Temp. ↑ Si crystal became polycrystal from monocrystal

single

poly

• Nowadays we use silicon carbide ⟹ 600°C limit
(SiC)




Trajectories of switch from ON to off condition.

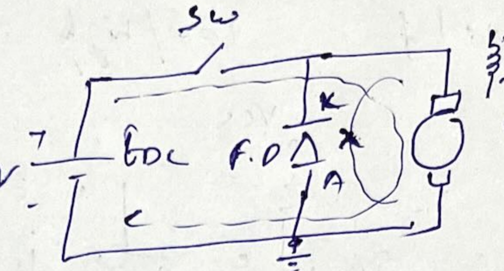
• If $I_{sw}$ is ↑ ⟹ $P_{loss}$ ↑

• When Sw → ON ⟹ Conduction loss
• " Sw → ON to OFF or OFF to ON ⟹ Switching loss } at junction

At junction $\boxed{\Delta T = R_{Th} \times \text{watts}}$  jun —mm— mm— Amb.
$R_{Th\,j,c}$ . $R_{Th\,c,a}$

- In small motors $R_a$ is more than larger motors because wire is thinner.
- The sparking in the Switch during on & off Condition due to inductance.

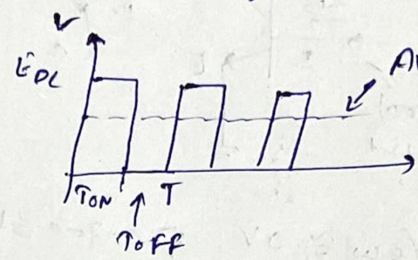
- Buck Converter:




$e_L = L\frac{di}{dt}$

$V = V_{\cancel{fundamental}} + V_{Harmonic}$
↳ due to DC component

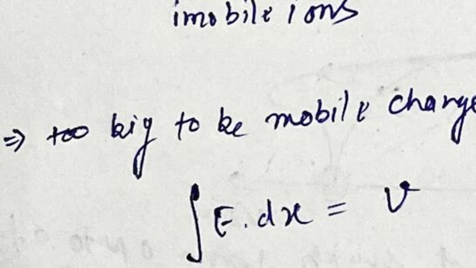
$I = I + I_{Harmonic}$
↳ due to DC compont.




$\boxed{\frac{t_{ON}}{T} = D}$  $0 < D < 1$

$V_{drop} = D\,E_{dc}\,i$

- Diode:




depletion region {No mobile charge exist}

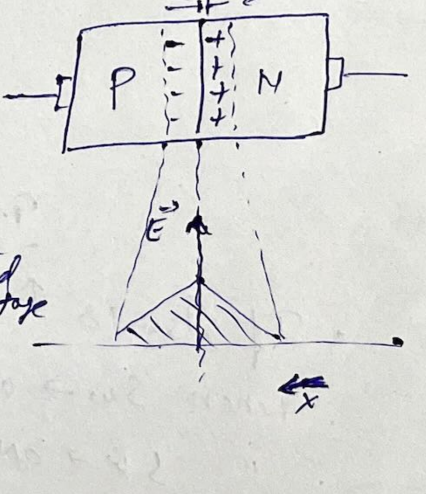
ohmic metal contact

imobile ions

$e^-$
$h$
ion ⇒ too big to be mobile charge partial

$\int E.dx = v$

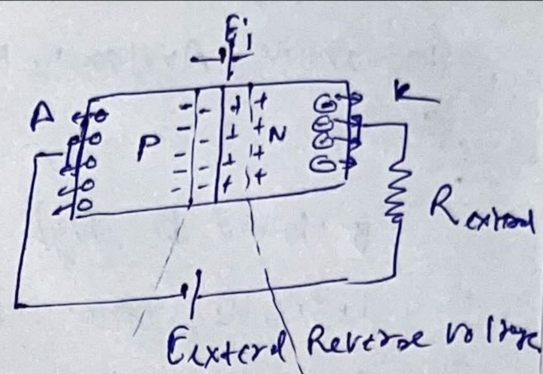
$v =$



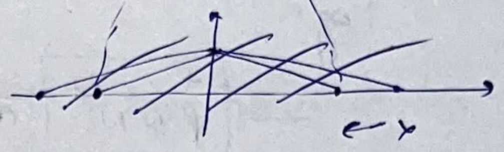

→ Reverse Biased voltage

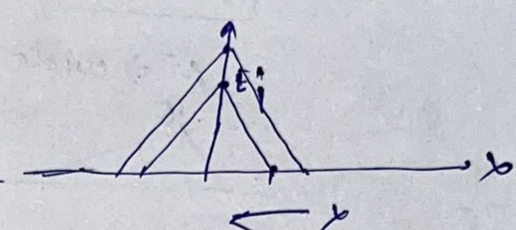
signal level ⇒ 1A/50V
power elect. ⇒ 5000A/10kV

- As $W_d \uparrow$, $E_j \uparrow$ ∴ slope of $E_j$ remains constant.

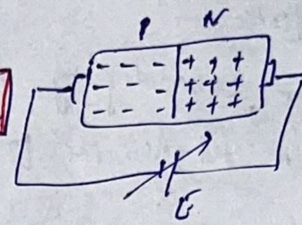


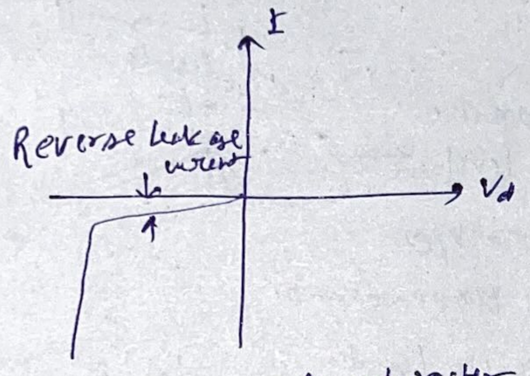

- $\overset{-}{—}\!\!\triangleright\!|\!\overset{+}{—}$ the $I_0$ will flow in reverse direction but only for short amount of time as $E_j = E_{external}$ $I_0 = 0$ & No current flow.






- If $E_{external}$ in reverse keep on $\uparrow$ $W_d \uparrow\uparrow$, it will touch metal contact $|I_0|$ will be very large & breakdown of diode occures ⇒ This condition is called $\boxed{\text{Reach Through}}$




Steady state charecter

## Avalanche B/D

when $\vec{E}$ is too high force on $e^-$ is high

$\vec{F} = e\vec{E}$

$e^-$ ⇒ has high KE it will collide with other atom & create $e^-h$ pair & process continouse & there will be large amount of $e^-h$ pair & $I_0$ will be large from P to N

Called avalanche B/D

(Si) → $10^{27}$/cc

doping → $10^{18} - 10^{14}$/cc ← High doping

$10^{14} - 10^{16}$/cc ← Normal "

$10^{11} - 10^{13}$/cc ← light doping

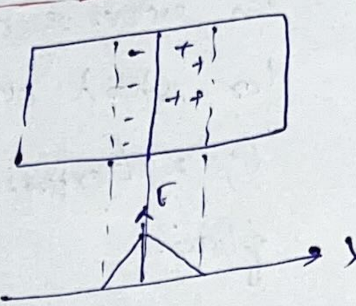
- Thermally generated $e^-h$ pair mostly from Si.
movement of $e^-$ in the opposite direction
" " h in " same direc.

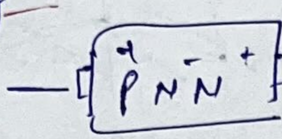
NOTE: • Breakdown due to Reach through or Avalanche B/D $\{\vec{E} > 2 \times 10^5 \, V/cm\}$ occurs inside semiconductor

To avoide Avalanche B/D we need to avoid high $\vec{E}$.

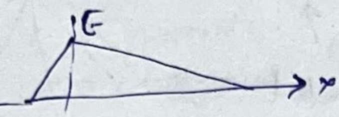
$$\int E \cdot dx = V$$

V should be high as per application but $\vec{E}$ should be less. If one side is lighty doped then slope will be Large.






$N^{-} \Rightarrow$ wide drift region

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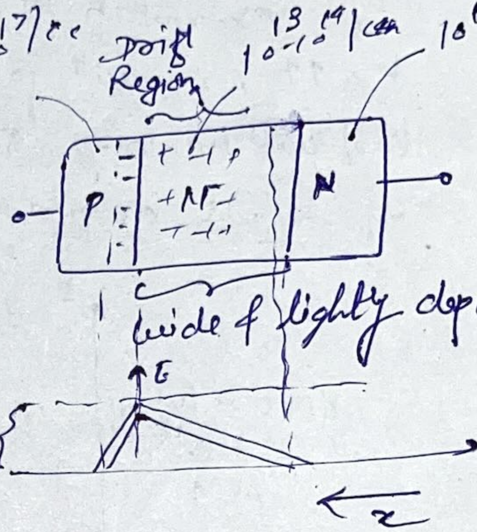
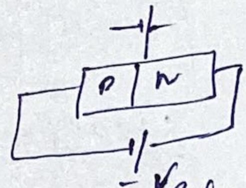
- Less doping less $\vec{E}$ slope
- Higher the V, less is the doping



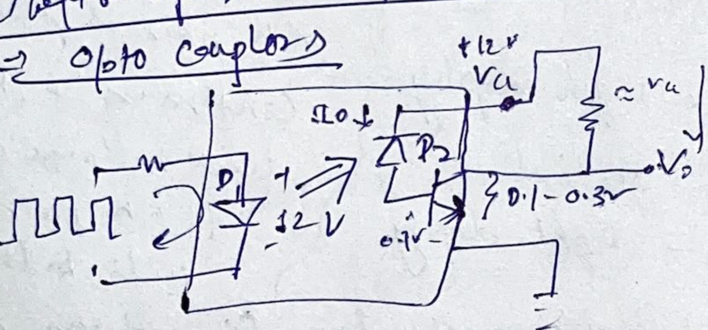

- Drift region ⇓ Highly resistive

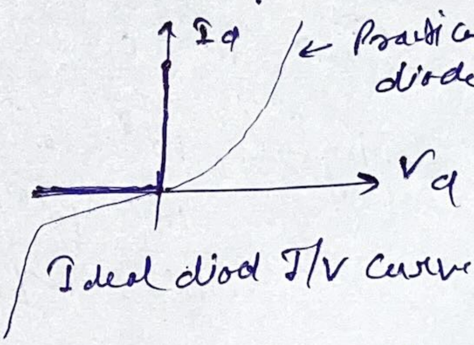
- Reverse current is function of temperature
- If photo bombardment is done on Junction e-h pair may introduce




Application of Normal Diode

⇒ Opto couplers



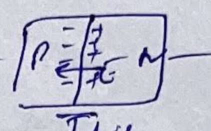

Ideal diod I/V curve

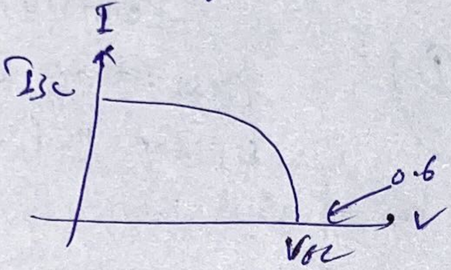
e-h pair generated from Si because its density is high $10^{27}$/cc compared to impared to Impurity $10^{13}$-$10^{19}$/cc

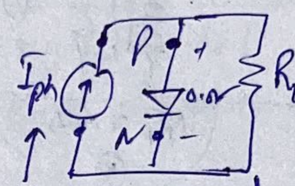
- $V_i \Rightarrow$ High $\Rightarrow$ D $\rightarrow$ ON $\Rightarrow$ Emitts light $\Rightarrow$ $D_q \Rightarrow$ R.B. $I_0$ flows
Transistor $\Rightarrow$ ON $\Rightarrow$ $I_C \approx \beta I_{BE} \Rightarrow$ drop in $R_C \approx \beta I_B R_L$
$V_{R_C} \approx V_{CC}$ & $V_{op} \approx 0$
- $V_i \Rightarrow$ Low $\Rightarrow$ D $\Rightarrow$ ON $\Rightarrow$ No emission of light $\Rightarrow$ $D_q \rightarrow$ off, $I_B = 0$
$I_C = 0$, $V_{R_C} \approx 0$, & $V_{op} = V_{CC}$
- In this connection R.B Diode may take time to recombine after every operation

② Another c/p $\Rightarrow$ PV cell

in OC condition $I_{Diffusion} = I_{drift}$ & $I \approx 0$

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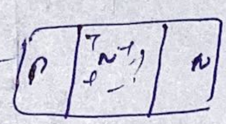
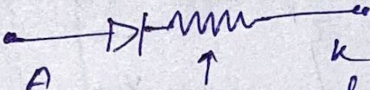
Power diode

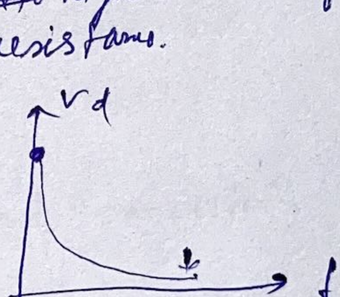
Drawback $\Rightarrow$



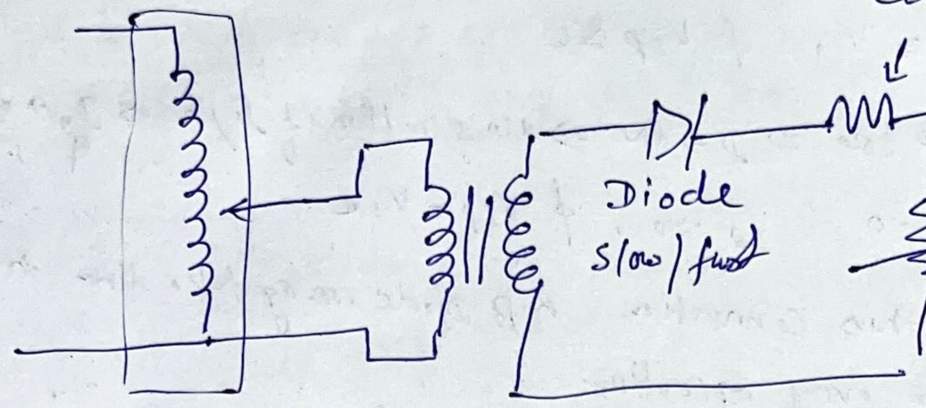

So high voltage drop in large resistance.

Conductivity modulation:



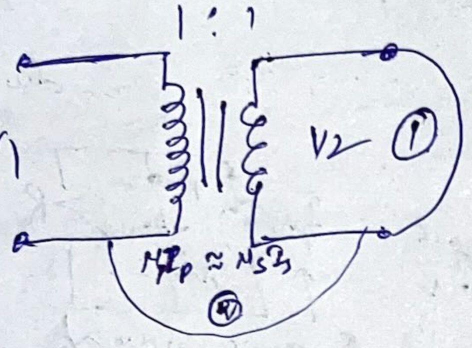
⇒ Power Transistor

Lab ⇒



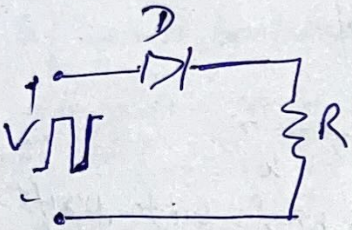

One WND T/F

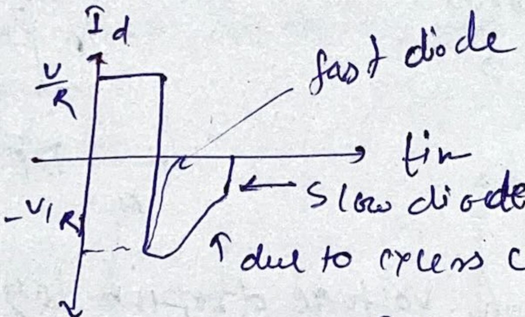
Varial / Auto T/F / Dimmerstat

- 

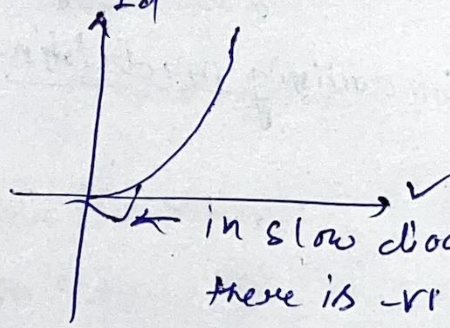

Connection 1 or 2 won't cause any damage in the T/F because $V_1$ & $V_2$ are floating voltage

- Energy density = $\frac{1}{2}\frac{B^2}{\mu}$ = $\frac{\text{Energy}}{\text{Volume}}$

- 

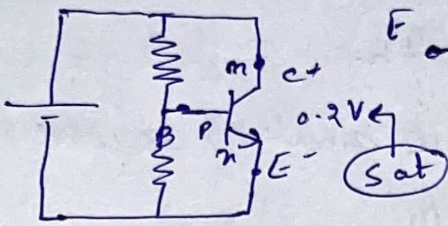

↑ due to excess charges recombination

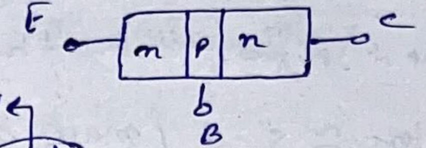


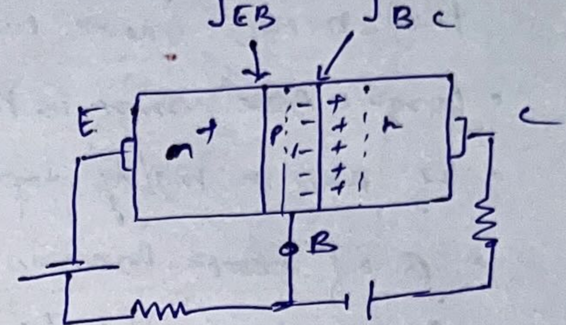

in slow diode there is -ve current can be observed

2/10/2022

- Power Transistor:
  - Singnal level transistor.




$I_E$ = predominantly by due to $e^-$ flow from $n^+$ (E) to P (B)

Base ⇒ Lightly doped & thinner

$e^-$s which enter B are swept to Collector region by $\vec{E}$

only for active mode

$$\boxed{\alpha I_E = I_C} \quad 0 < \underset{0.99}{\alpha} < 1$$

$$\boxed{I_B = (1-\alpha) I_E}$$

* neglecting hole component of Base current.

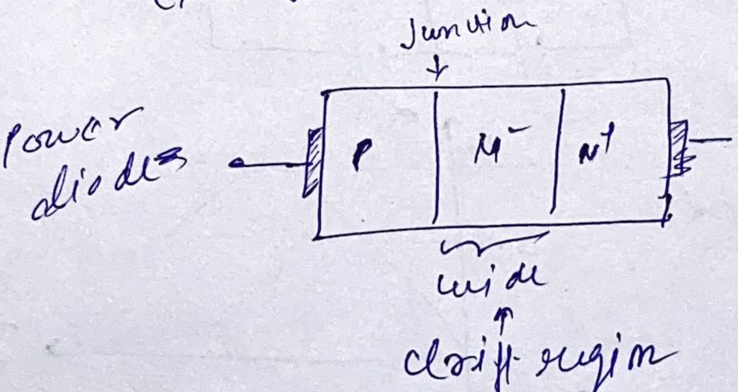
$$\boxed{\frac{I_C}{I_B} = \frac{\alpha}{1-\alpha} = \beta = h_{fe}} \approx 100$$

$$\boxed{I_C = \beta I_B}$$

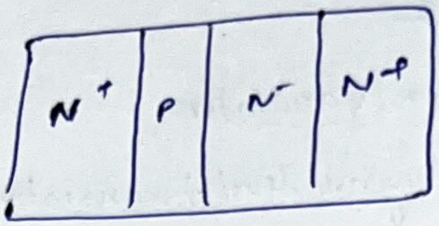
- Saturation ⇒ 0.2V Small voltage drop in Sat

- Power Transistor:
  - ↳ High Voltage rating
  - ↳ High current rating

ex- IN2222, 60V, 0.8A {signal Transistor}



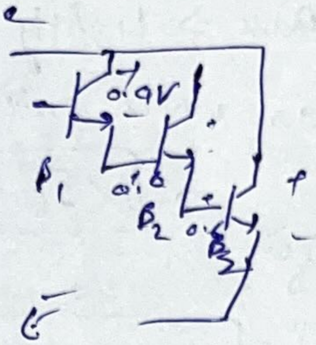
- In power transistor, Base is a little wider than signal transistor. that means more width in $V_{RB}$.




- Larger Base more is the recombination
- If Base in highly doped higher will be $I_n$.
- $\beta$ of power transistor $\simeq$ 5-6 [much smaller] because of compromise with base region & doping.
- ✓ single Power $T_r$ will have high $I_B$ for control so we use Darlington pair for operation

$\Delta\uparrow \Rightarrow \beta_1 \beta_2 \beta_3$

But higher Voltage drop. (0.7+0.6+0.6)

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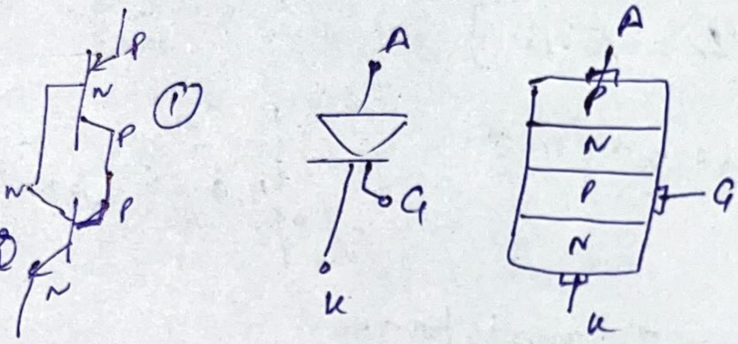
- Thyristor:

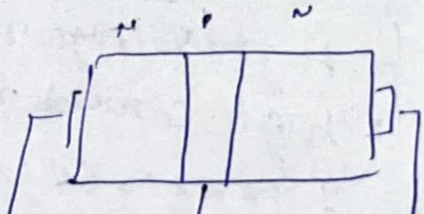



$I_C \simeq \alpha I_E$

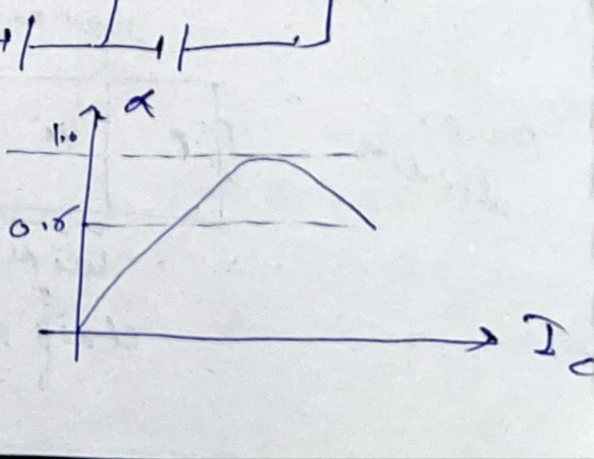
$I_B = (1-\alpha) I_E$

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

for $\alpha > 0.5$, $\beta > 1$




- But for Si $\alpha$ does goes beyond 0.5 easily

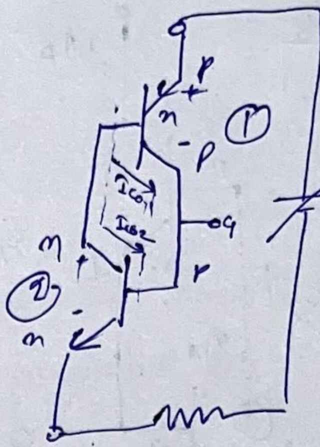


If 'B' of 1 & 2 are > 1.0

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

$I_{B_2} = I_{C01}$

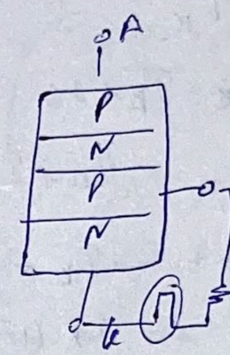
if $\beta_1$ & $\beta_2$ > 1.0 $I_{C0_1}$ & $I_{C0_2}$ drop adding up




$I_B \approx I_C$

If $I_B > \frac{I_C}{\beta}$ transistors enters into saturation Region

for $I_B = \frac{I_C}{\beta}$ (in active region)

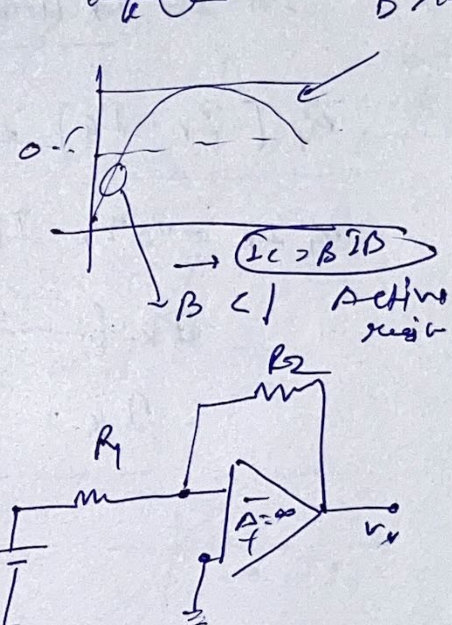



as $I_G$ is provided at G.

$I_C = \beta I_B \uparrow$

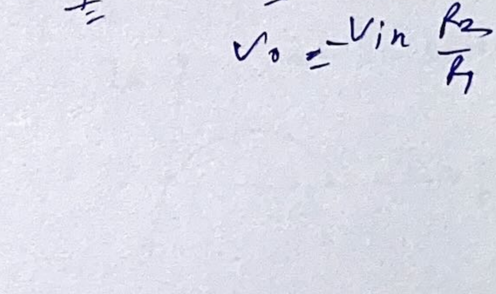
So current through transistor correspond ↑ & ~~A~~ will go beyond 0.6 &

B go more than 1. Current starts to build up like +ve feedback that will make it go saturation



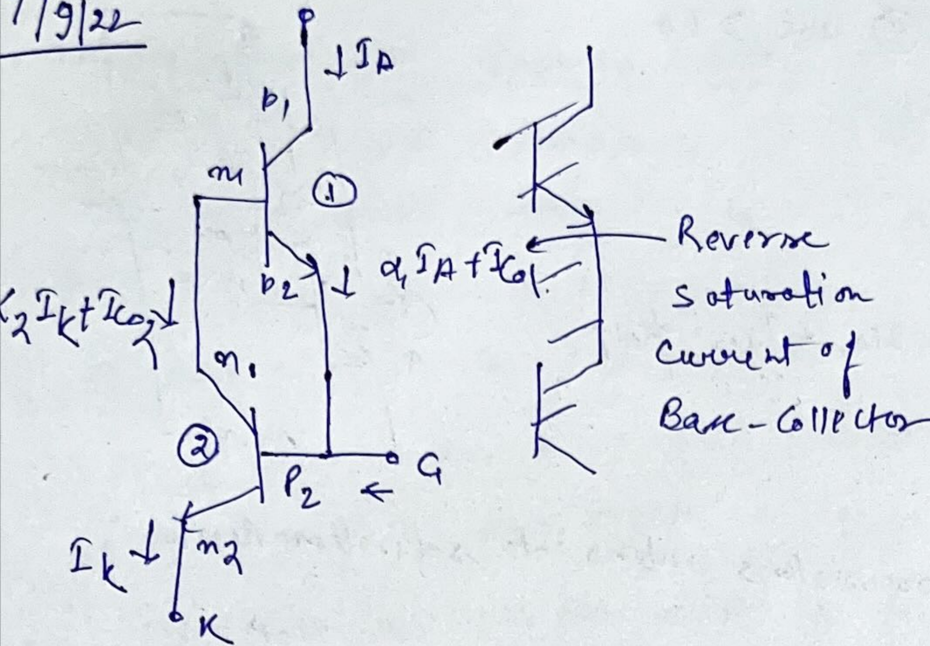

$I_{C0_1}\uparrow \rightarrow I_{B_2}\uparrow \rightarrow I_{C0_2}\uparrow \rightarrow I_{B_1}\uparrow \rightarrow I_{C0_1}\uparrow$

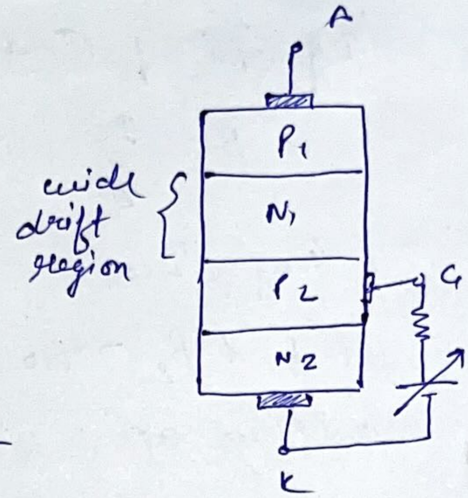
So both parallel currents become equal




$V_o = -V_{in}\frac{R_2}{R_1}$

7/9/22




$I_K = I_A + I_G$

~~$I_K =$~~

$I_K = \alpha_1 I_A + I_{CO1} + \alpha_2 I_K + I_{CO2}$

$\alpha_1 I_A = I_K - \alpha_2 I_K - I_{CO1} - I_{CO2}$

$I_A = \dfrac{I_K(1-\alpha_2) - (I_{CO1} + I_{CO2})}{\alpha_1}$

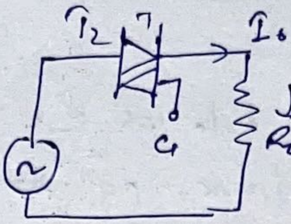
$\alpha_1 [I_K - I_G] = I_K - \alpha_2 I_K - (I_{CO1} + I_{CO2})$

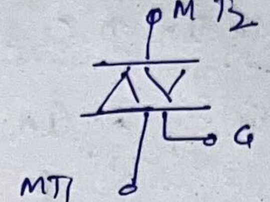
$\alpha_1 I_K - \alpha_2 I_K - I_K = I_G \alpha_1 - (I_{CO1} + I_{CO2})$

~~$I_K f_1$~~

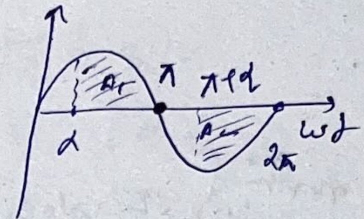
$I_K = \dfrac{I_{CO1} + I_{CO2}}{1-\alpha_1-\alpha_2} + \dfrac{I_G(1+\alpha_1)}{(1-\alpha_1-\alpha_2)}$ $\quad \beta = \dfrac{I_C}{I_B} \approx \dfrac{100}{21} = \alpha \approx .99$

TRIAC:



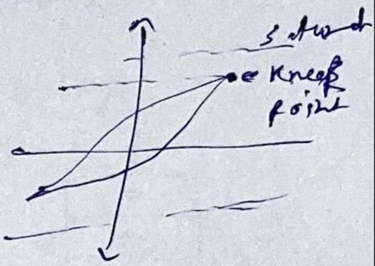

- It is more sensitive to +Gate current compared to -ve Gate current
- that means + $I_g$ ≃ small magnitude required to Turn on
  - $I_g$ ≃ comparatively larger magnitude required to Turn on
- In SCR & TRIAC once Turned on the current decided by $R_L$.
- Triggering or firing: once TRIAC is turned on so that it starts to conduct is known as Triggering or firing




O/P should not have dc component i.e. $A_1 = A_2$

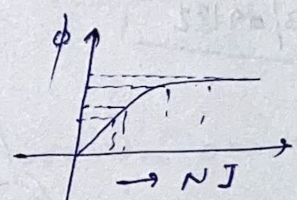
because if this O/P is sent to T/F, & IDC in magnetising Branch BH curve may shift up or down depending on the direction of IDC. & it may go into saturation

As T/P is designed closed to knee point.

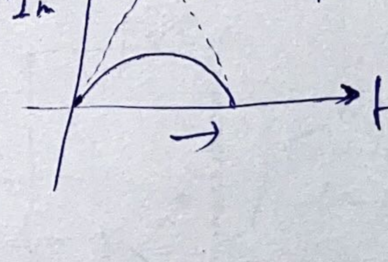



- If It is designed far from the knee point the A should be high & Cost would be high

$$V = 4.44 f \underbrace{B_m \times A_c}_{\phi_m} N$$



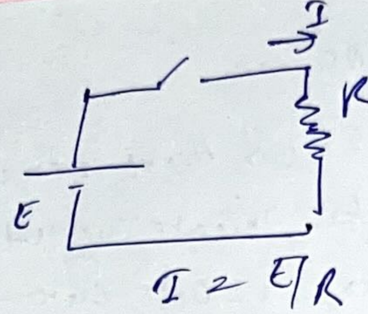

- In saturation to ↑ ϕ by small value high Imag. is required.
- So magnetizing current become peaky while ϕ will still be sinusoidal

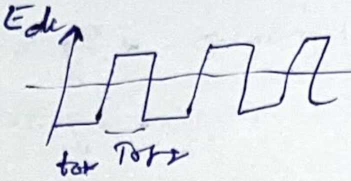



- Harmonics ↑.

- TRIAC should be fired Symmetrically only

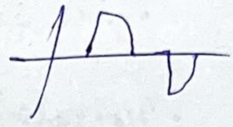
- In DC supply
  - In DC, so $\alpha \approx 1$
  - previous eq doesn't apply.



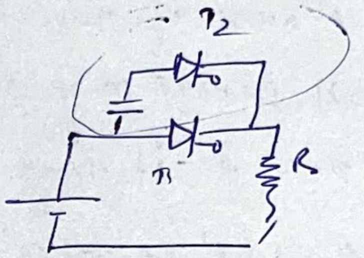

In AC if $\alpha = 90°$ load RMS ≠ Half

$= \frac{V_s}{\sqrt{2}}$ RMS

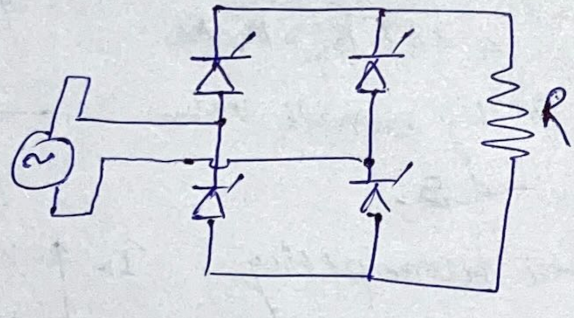


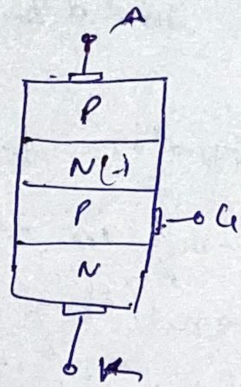
mean square = 1/2 of $V_s$ at 0°

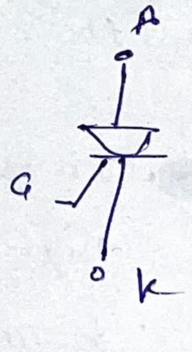
- normal multimeter does not measure true RMS. [if does not use it accurately]
- So we use true RMS meter.

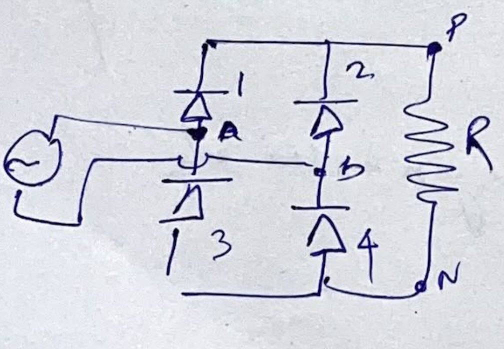


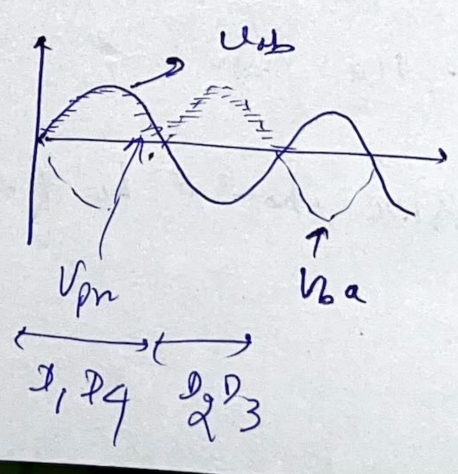

08/09/22



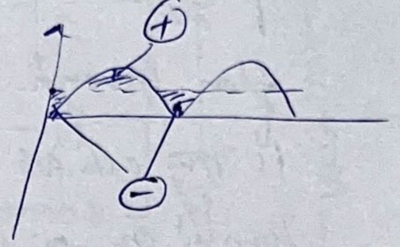



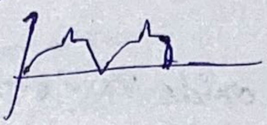
$$V_{pn.avg} = \frac{1}{\pi}\int_0^{\pi} V_m \sin\omega t \, d\omega t$$

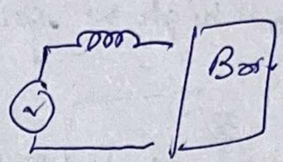
$$= \frac{V_m}{\pi}\Big[\underbrace{-\cos\omega t}_{2}\Big]_0^{\pi}$$




$$\underset{(dc)}{V_{pn.avg}} = \frac{2V_m}{\pi}$$

- Average of Ripple voltage = 0 in Diode Bridge
- for 230 V, diode rating ⇒ $V_{diode} = 230\sqrt{2} \approx 311V$
- for weak line spike may come due to change in load (ex. neighbour load)

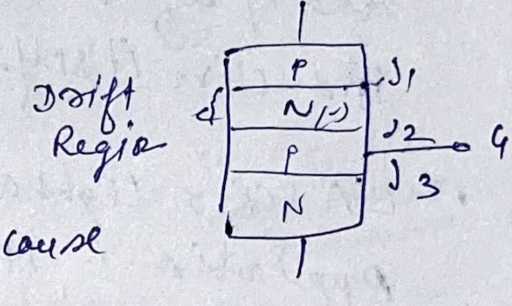





- For SCR ⇒ Rating 1200 V ⇒ Peak forward Voltage & Peak Reverse voltage

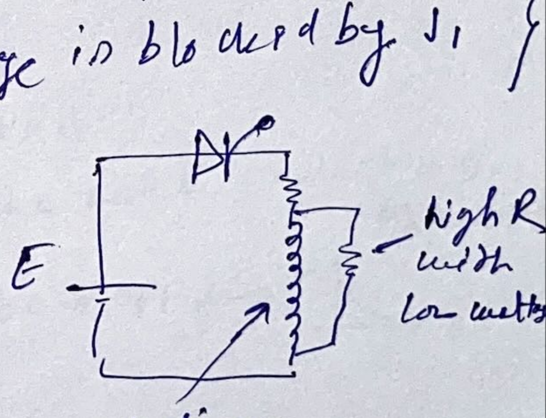
- Drift Region ⇒ wide & lightly doped

$J_1$ & $J_3$ ⇒ RB



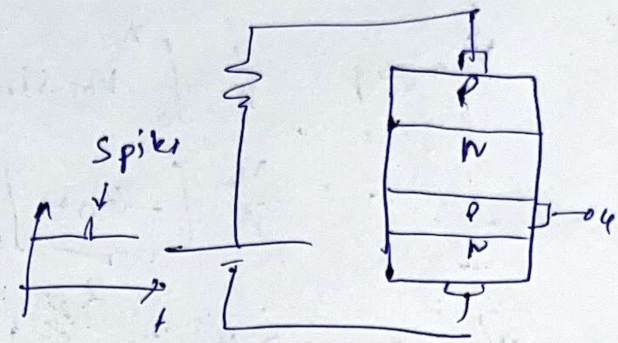

- $J_3$ Blocks small portion of $V_{RB}$ because doping is higher

{ It is a little advantage as if $I_G$ is provided accidently It may turn on but higher voltage is blocked by $J_1$ }




$L\frac{di}{dt} = E$

- $\frac{dv}{dt}$ turn ON:

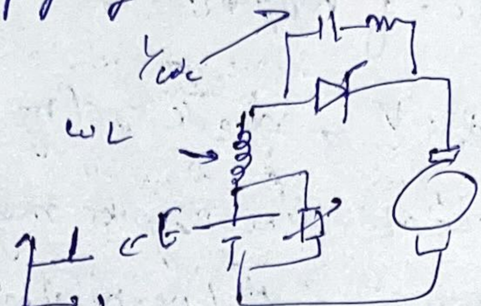



if $\frac{dv}{dt}\uparrow$ in F.B. Reverse current flow through $J_2$ momentarily it may act as $I_G$ and may turn it on or unscheduled turn on.

- It may occur in AC or dc supply by sudden change of load too.

- spike ⇒ high freq very component ($\omega\uparrow$)

for high $\omega$ spike $\omega L\uparrow$ but $\frac{1}{\omega C}\downarrow$

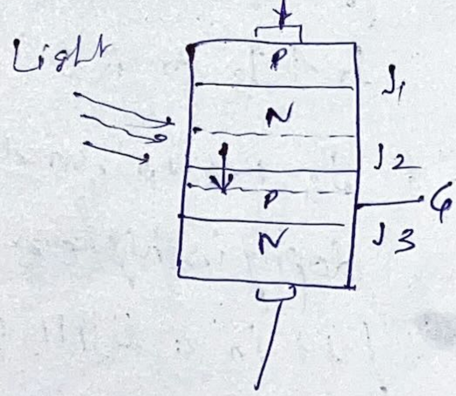



eg MOV (metal oxide varistor)

- To avoid false turnON ⇒ we provide snubber ckt

adding of ⌇ is not in generally require as line is inductive itself.

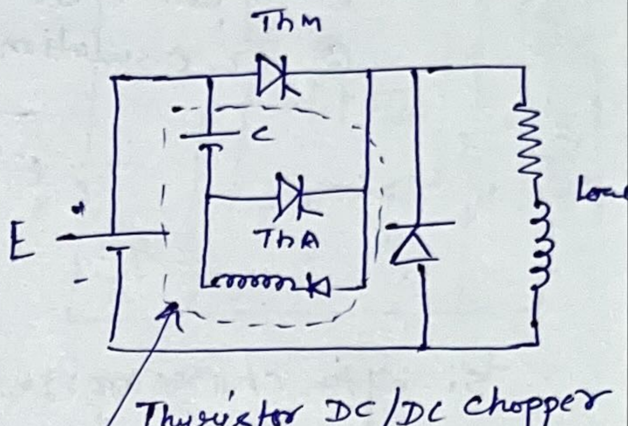
- LASCR = Light activated SCR.
  Application :- HVDC as rating is high so insulation required is also high



12/09/22

- Thyristor turn-off

initially c ⇒ discharge of ThA is FB




Thyristor DC/DC chopper

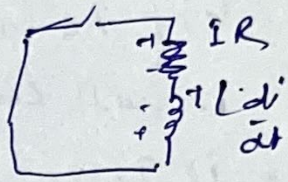
Commutation ckt for ThM

- As 1st ThA → ON current path

E → C → THA → RL(load)

as $V_c$ (charges) tends to E no current i should flow in path but due to load inductance, current will not be zero immediately.

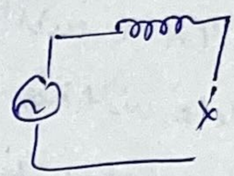
---




Sparking occurs in similar manner in welding T/F as inductive effect.

$e = L\frac{di}{dt}$ ⇒ ~~will~~ must be large to produce high voltage to ionise the air around the switch

- $\frac{di}{dt}$ = -ve (decaying)



welding t/f large leakage inductance

---

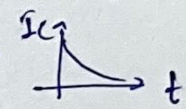
now due to current by L a little extra voltage come across C ⇒ E+ΔE & $V_{load} = (E - V_c)$

So D → F.B. (F.D)

- So two path for inductor ① Through C ② " FD (L)

current flow through FD & current through ThA will be reduced to 0. ThA = OFF

{ if load ⇒ R as $V_c = E$ $I_{Th} = 0$ & ThA ⇒ OFF } →

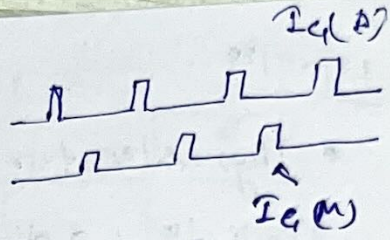


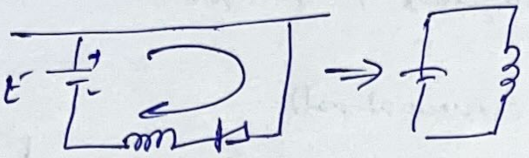

- Now C is charged to E.

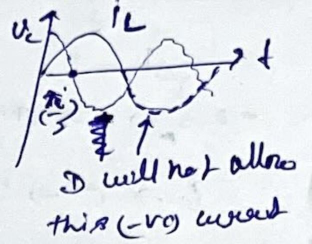
This is the main requirement for turning OFF ThM

• when ThM → ON

① E connected to L & D
② LC oscillation occurs.




So after charge reverse of $V_C$, $i_L$ will stop.

After charge reverse

ThA → FB

& if $I_G$ is given to ThA

it will conduct.

if $I_G > 0$, ThA ⇒ ON

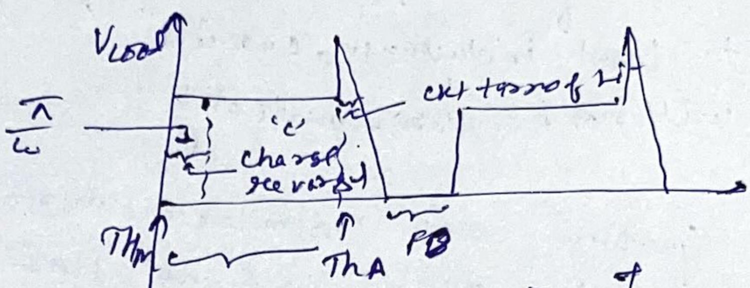
ThM will be RB

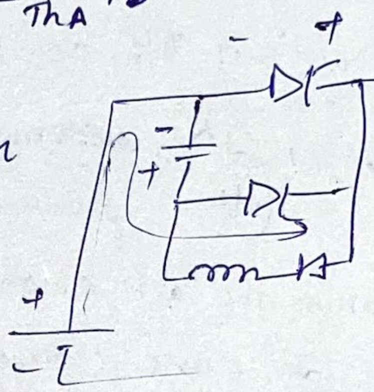
• We will have to keep ThM RB

for some time so that charge

in ThM can recombine other

wise it will be turn off failure.

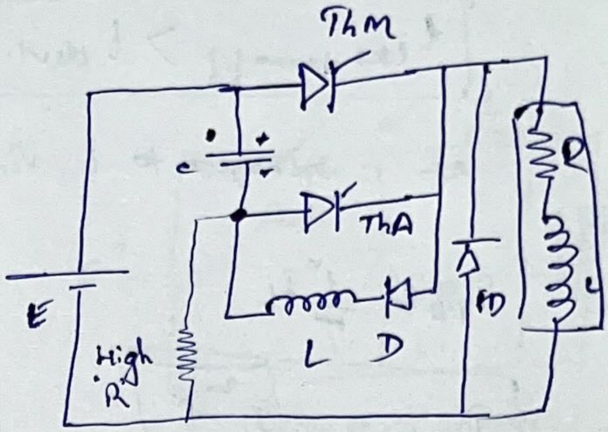


• I path → E → C → ThA → Load No C → charge but ThM

is still RB. & $V_L = 0$ after some time

- **Thyristor commutation**

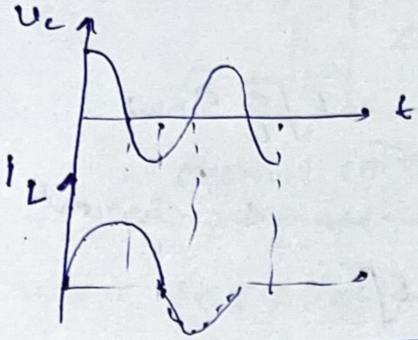


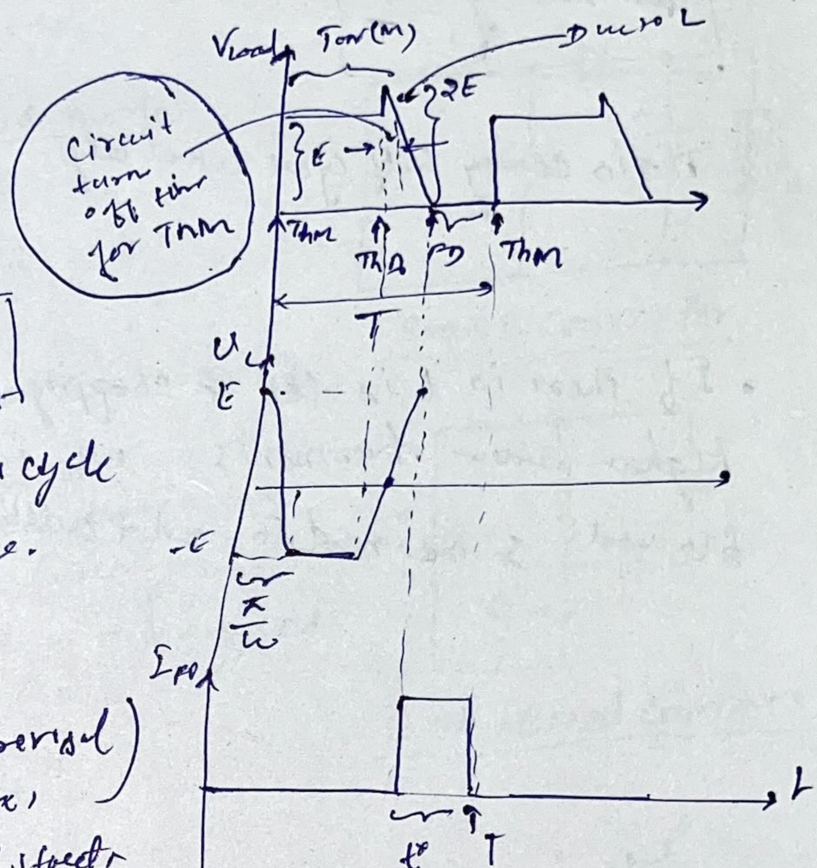

C - charge to E by source voltage

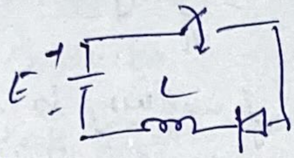
- ThM ⇒ ON

current path C-D-L (LC ckt)

so we get LC oscillation




This ckt is for charge reversed -ve cycle will not occur due to Diode.

$$\omega = \frac{1}{\sqrt{LC}}$$

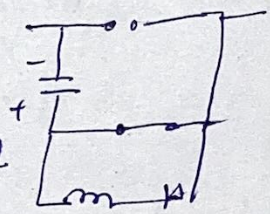
$T_{ON(M)\,min} > \frac{\pi}{\omega}$ (charge reversal time)

ThM → ON ⇒ charge reversal is fixed.

As ThA → ON

ThM → off (RB)

Current → E-C-ThA-Load



$V_{Load} = E + v_C$

$CE = I \times t_{ckt\text{-}turnoff}$

$I$ = Load current at the time of commutation

↳ constant [if chopping freq is high]

$\boxed{t_{ckt\ turnoff} > t_{device\ turnoff}}$ → defined by manufacturer around 50 μs

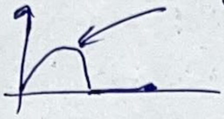
As C → charges to E $V_{load} = 0$ As $V_{load}$ goes a little Reverse FD → ON
or $V_c > E$

$I_{FD} = \frac{t^{\circ}}{T} I_L$

$$\boxed{I_{FD\,rms} = \sqrt{I_L^2 \frac{t^{\circ}}{T}}}$$

$E\sqrt{\frac{C}{L}} \sin \omega t$

D → is carrying half cycle current only



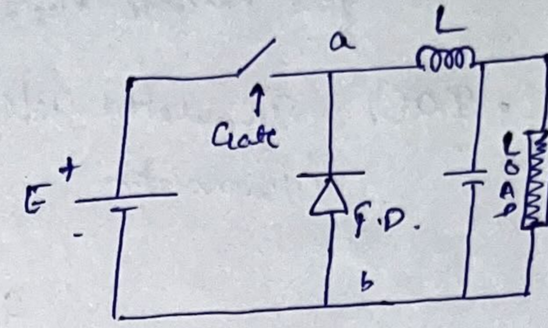
LC current

$= \frac{1}{\pi} E\sqrt{\frac{L}{C}}$

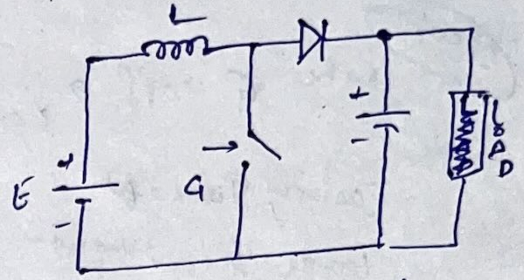
- If there is L in ckt & chopping frequency is high then for higher order harmonics $\omega L$ is high it is automatically blocked so no need to add addition inductor in ckt.

16/09/2022

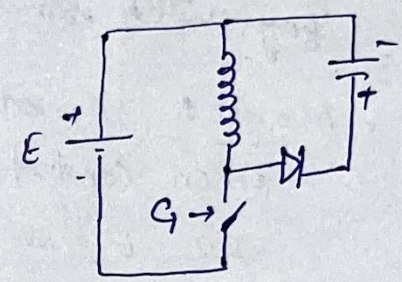
## • DC to DC Converter




Buck converter (Chopper)



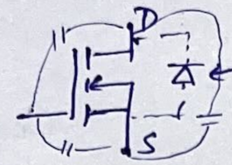

Boost Converter




Buck / Boost converter

• Sw consider is Gate controlled (both turn ON & turn off through Gate to source voltage)

Ex-




'n' channel enhancement mode MOSFET

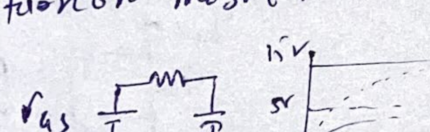
when $V_{GS} > V_{GS}|_{Threshold}$

Sw. conducts.

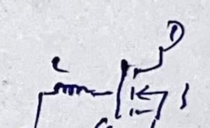
$|V_{GS}| < 20\,V$ {In normal Power MOSFET}

if $V_{GS} \uparrow \Rightarrow V_{DS} \downarrow$ two losses
① conduction loss
② switching loss

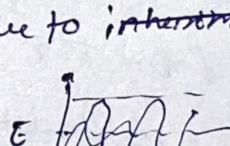
• $I_g \approx 0$ but charging current is to be supplied to turn on MOSFET

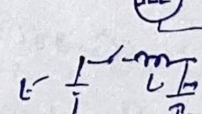



• LC oscillation may happen due to ~~inherent~~ stray inductor




• if undamped cur $V_{GS} = E$
under damped cas

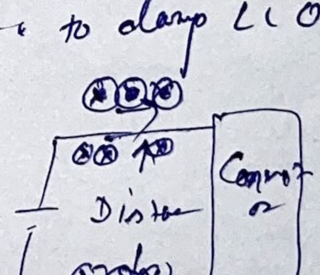


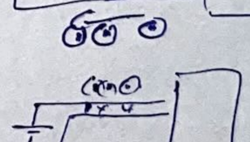
• So we put R in series of stray inductance to damp LC oscillation

• Higher the distance ⇒ Higher the inductance

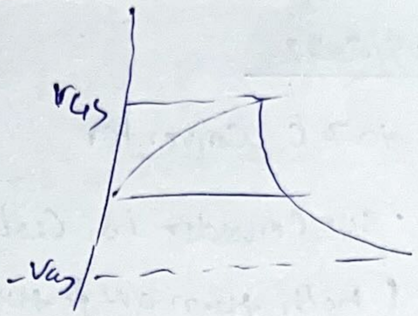
$LI = \phi$



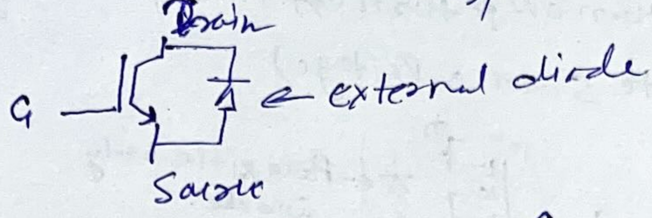

• If they are close ⊙ & ⊗ cancels and we minimize the inductance. also by twisting wires.



During Turnoff if $V_G = 0$ slow turnoff
to fast Turnoff $V_{GS} = -V_t$

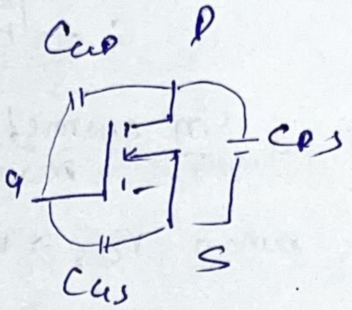



• IGBT: Insulated Gate Bipolar junction transistor

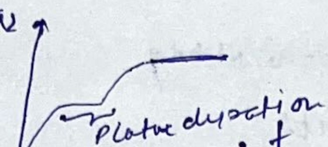



Bcuk

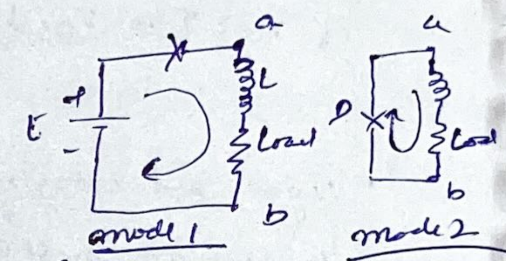
when G → off ⇒ E appears at $C_{DS}$ & blocked




During Turnoff
large I is required
5A (for large drive)
$E_{avg}$ will be small

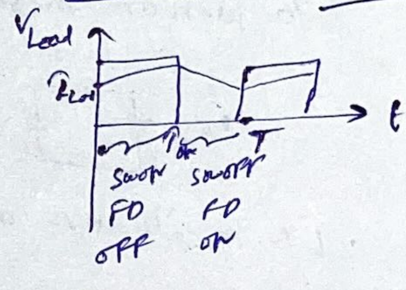



• Mode 1 Sw on
when control ckt is ON
I → E → SW → L → Load

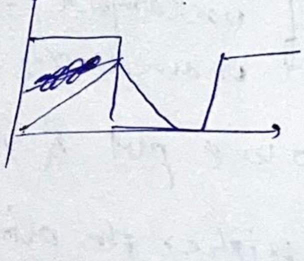



mode 2 Sw off
I → L → Load → FD

$\delta$ or $D = \frac{t_{on}}{T}$ , $0 < \delta < 1$



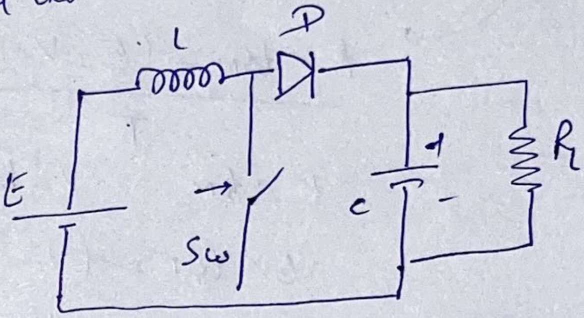

mode 3 G → off, FD → off
$I_{Load} = 0$ i.e discontinuous mode



21/09/22

• DC to DC Boost Converter

under steady state condition and continuous inductor current {ideal ckt elements.

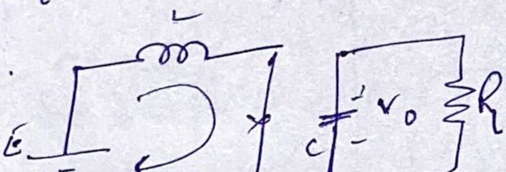



2 modes of operation:

mode I when sw is on from

$0 < t < t_{on}$, D is R.B. {because $V_0 > E$}

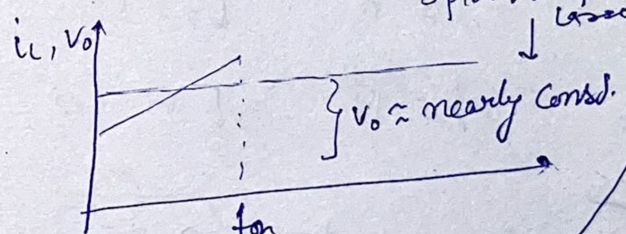
Eq. ckt.




$i_L$ builds linearly. $\because E = L\frac{di}{dt}$ {E & L = constant.

due to high freq operation & large C

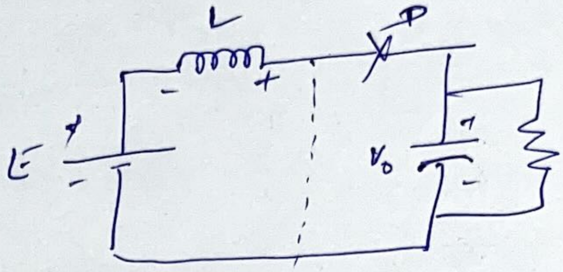
$V_0 \simeq V_c$




{in high freq, very C does not discharge immediately}

Mode 3 starts with turning off of 'SW'

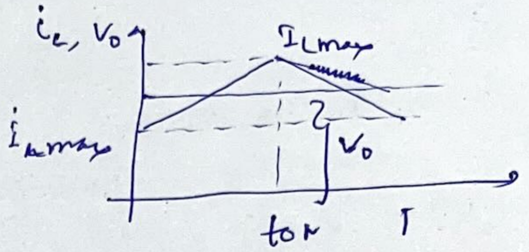
$t_{ON} < t < T$





$e_L = L\frac{di}{dt} = E - V_0$,

If $V_0 \approx$ constant. linear fall of $i_L$.





$e_L|_{avg}$ over 'T' $= 0$

$e_L = L\frac{di}{dt}$

$i_C = C\frac{dv}{dt}$

$$\frac{E \times t_{ON} + (E - V_0)\, t_{off}}{T} = 0$$

$E \times t_{ON} = V_0 t_{off} - E t_{off}$

~~$E \times t_{ON} = (V_0 - E)(T - t_{ON})$~~

$E \times t_{ON} + E t_{off} = V_0 (T - t_{ON})$

$E \times T = V_0 (T - t_{ON})$

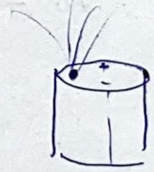
$\left(1 - \frac{t_{ON}}{T}\right) V_0 = E$

$\boxed{V_0 = \frac{E}{1-\delta}}$ $\quad 0 < \delta < 1$

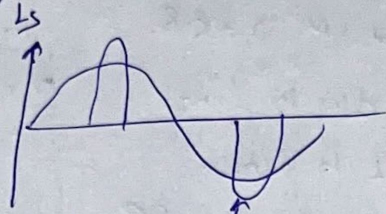
$\delta = 0$ $\quad V_0 = E$ {Cap. charged to E always}

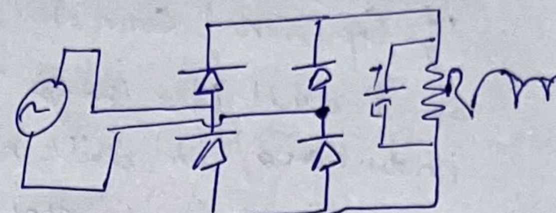
$\delta = 1$ $\quad$ SW is always on

Cap. electrolyt. ⇒ DC $\quad$ charging $\quad$ discha



So. Avg $i_C = 0$ but Avg $i_C \neq 0$ (Current ripples)



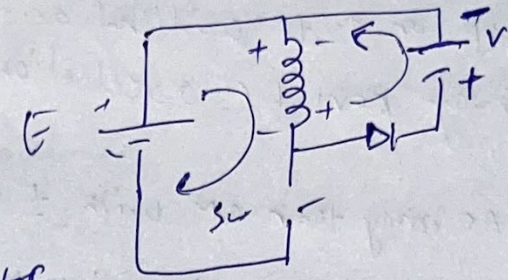
Is peaky
due to large 'C' & D conducts for small time

So harmonics

- **Buck boost converter:**

Mode 1 ⇒ sw = ON, $V_L = E$

Mode 2 ⇒ sw = off, $V_L = -V_0$




$$e_L\,avg = 0 = \frac{E \times t_{on} - V_0 \times t_{off}}{T}$$

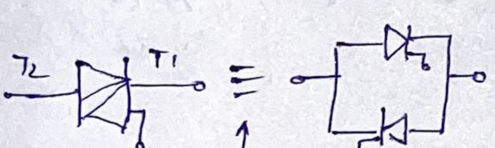
$$E\,t_{on} = V_0\,(T - t_{on})$$

$$V_0 = \frac{E\,(t_{on}/T)}{(T - t_{on})/T}$$

$$\boxed{V_0 = E\left[\frac{\delta}{1-\delta}\right]}$$

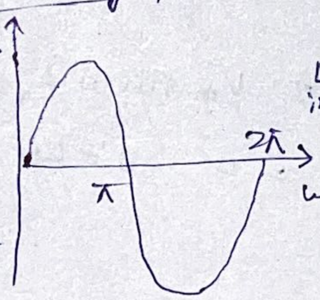
26/09/2022

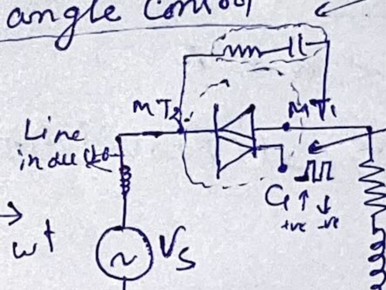
- **1 ϕ AC to AC Conversion using phase angle control**




cheaper
but inferior characteristics
especially $\frac{dv}{dt}$ rating

functionally equivalent

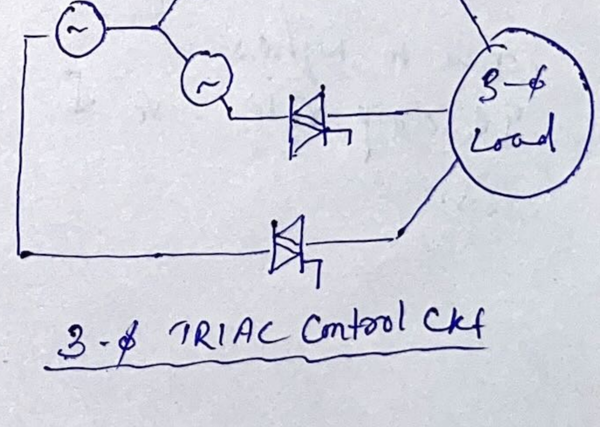



snubber ckt

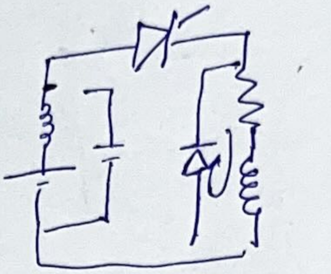
for Low power ckt

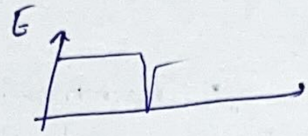
$$\frac{dv}{dt} < 5V/\mu sec$$




3-ϕ TRIAC Control Ckt

If Cap is not connected. & T → ON. D → R.B.
So I will flow through T but due to line inductance it will not let I to flow.
So Now T is turning on & D is turning off
so we connect Cap. . It will supply the current when I is building in L & voltage dip or dv/dt will not occur. But there may have LC oscillations

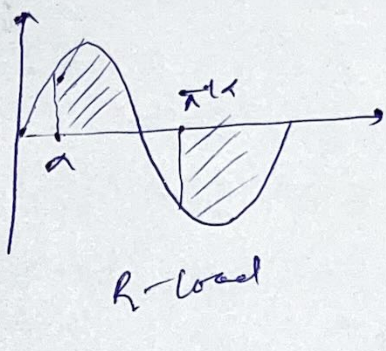





- TRIAC may turn ON with $\pm I_g$ & $\pm MT_1 MT_2$

But it is more sensitive to $+MT_2$ & $-MT_1$ with +ve $I_g$ (i.e. less $I_g$ is required). & more sensitive to $+MT_1$ ~~with~~ & $MT_2$ with −ve $I_g$

→ fundamental of component → rotating torque
higher order harmonics. → heating
} in motor load.




R-Load

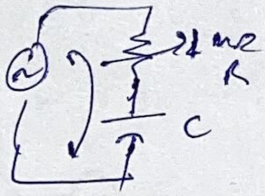
→ R-Load.

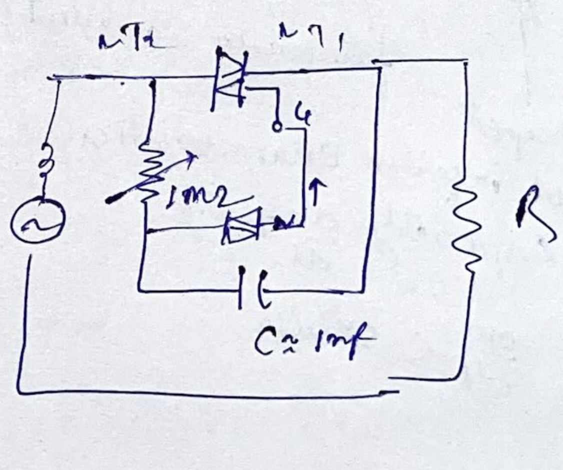
$0 < \alpha < \pi$

$V_{Load}(\text{Resistive}) = V_m \sin\omega t, \quad \alpha < \omega t < \pi$ {for half cycle}
$= 0 \quad 0 < \omega t < \alpha$

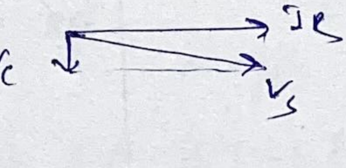
firing ckts.

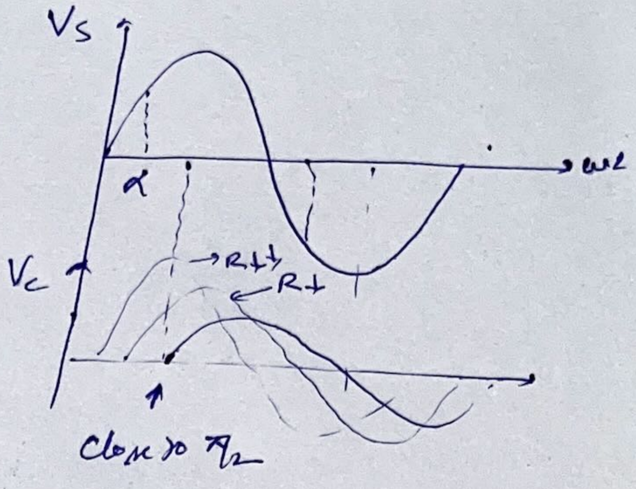
during on →




. Due to higher IR drop Vc is less.






- when $V_c$ is less DIAC is off.
  It blocks $V_c$ upto $\pm V_{BO}$
- As $V_c > V_{BO}$, $V_{DIAC}$ starts to drop & starts to conduct. sudden V drop in diac but Cap does not allow it so
  $V_c = V_{BO}$ & $V_{DIAC} \approx 10V$ (let) during ON

so current flow b/w DIAC $\rightarrow$ G $\rightarrow$ PN junction $\rightarrow$ C.

same thing happen in -ve cycle in opposite direction.

- when TRIAC is ON it is like short so RC charging doesn't occur. it starts to discharge with small current without affecting the I forward in TRIAC.