POWER ELECTRONICS
B.E., VII Semester, Electronics & Communication Engineering
Course Code 17EC73 CIE Marks 40

RNS INSTITUTE OF TECHNOLOGY

DEPARTMENT OF ELECTRONICS AND COMMUNICATION

POWER ELECTRONICS NOTES:

MODULE-2

Shambr:

P-1

MODULE - 2

THYRISTORS | SYLLABUS | TEXT-2
MD Singh.

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Gate Trigger Circuit :

Resistance firing ckt, Resistance Capacitance firing Circuit UJT firing Circuit

3.5 and 3.6

INTRODUCTION

SCR → Silicon Controlled Rectifier.

Or Thyristor derived from Thyratron and Transistor words

Features :

1. A four layer device (PNPN)

2. A latching type of device. (On conduction jumps from low Cur to high Current and Continuous to be ON when anode Cur > latching Current)

3. It Can handle large power (voltage and Cur in ~~KA~~ KVA range.

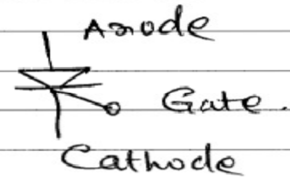
4. Current Controlled device with gate Control for Switching on.

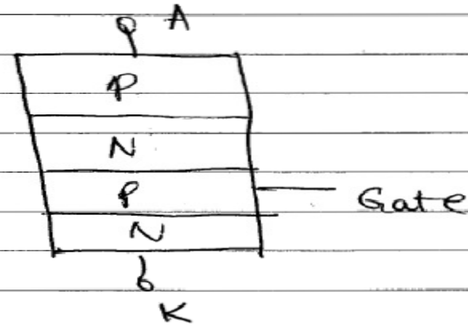
5. It Can act as Switch with on & off state.

6. on State voltage across device is very Small (< 1 V)

7. It Can be visualised as two transistors Connected back to back.

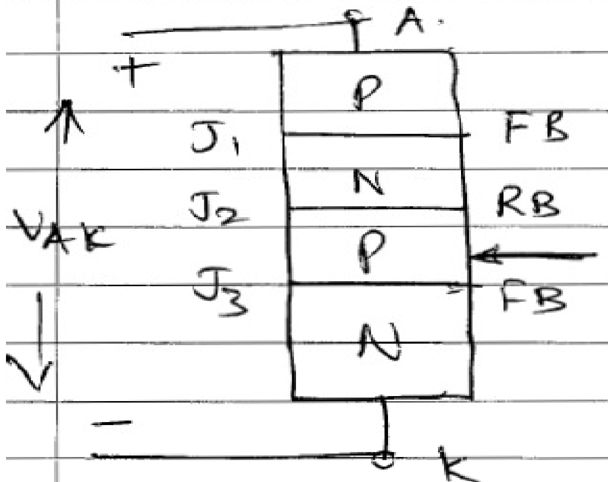
SYMBOL





Operation :

Under Forward bias Condition that is when anode is Supplied with +ve volt and Cathode to -ve.



Jn J_1 is forward bio

J_2 is Rev. Bias

J_3 is Forward Bias.

As V_{AK} anode to Cathode voltage is applied Conduction of SCR will not take place as J_2 is reverse biased.

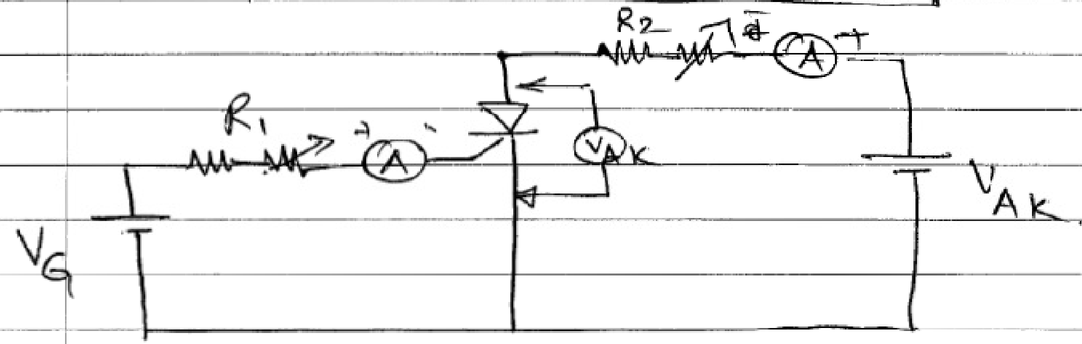
Increasing of V_{AK} will Cause Avalanche break down of J_2 which is Called as Specified V_{BO} of the device or Break over voltage of the device

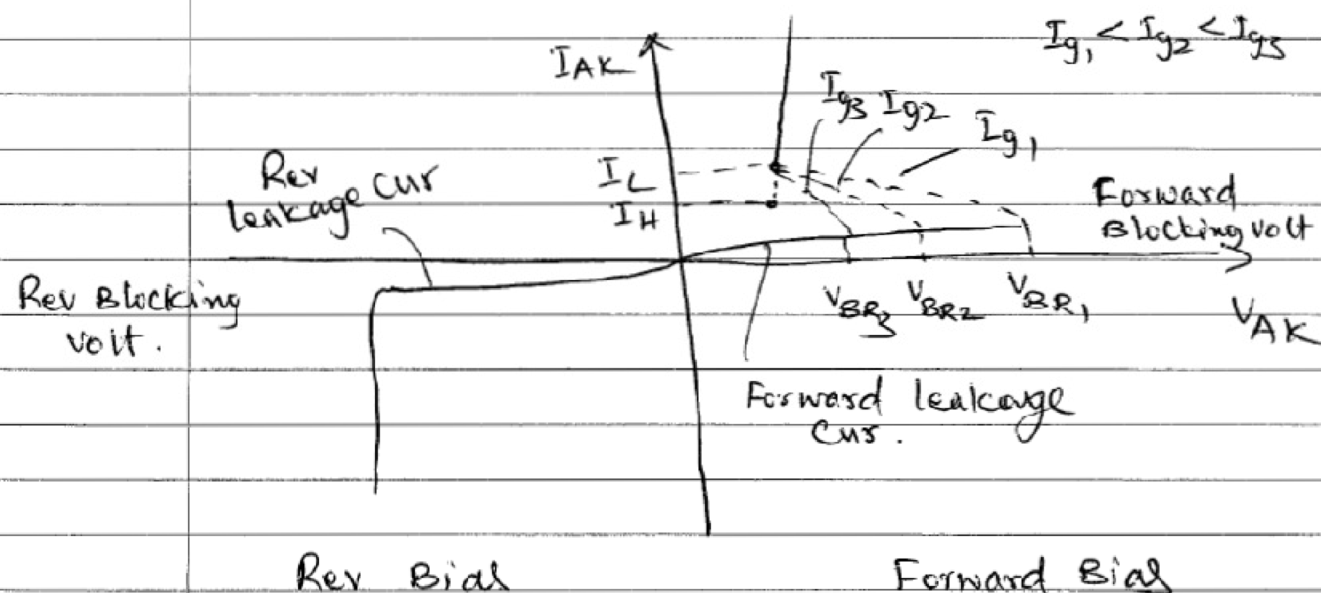
However making the device to have break over will Cause damage to J_2. Hence providing gate Cur will Cause an avalanche break down due to gate cur.

This will be $V_{BR} < V_{BO}$. This break over is reversible and regenerative making SCR to Conduct.

STATIC ANODE AND CATHODE CHARACTERISTIC.

VI - CHARACTERISTIC.





Forward Bias

1. For a given I_g when V_{AK} is increased there is a small Cur due to J_2 reverse bias condition which is forward leakage Cur.

2. SCR will block V_{AK} till V_{BR} (Forward blocking voltage)

3. ~~anode~~ ~~At~~ once $V_{AK} > V_{BR_1}$; Junction J_2 will have avalanche breakdown hence

I_{AK} jumps to a higher cur.

Note: At this time if $I_{AK} < I_L$ and gate cur is removed device will s/w off.

4. The device I_{AK} will continue to increase as V_{AK} is increased and volt across

SCR is a small value or < 1V

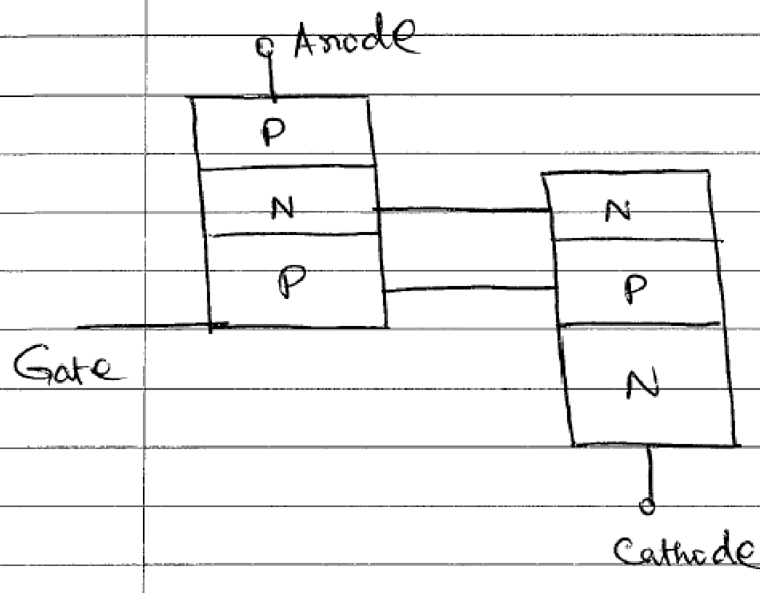
5. Latching Cur. : It is the minimum anode current required to keep the SCR in ON-State, while switching on even if gate current is not there or zero.

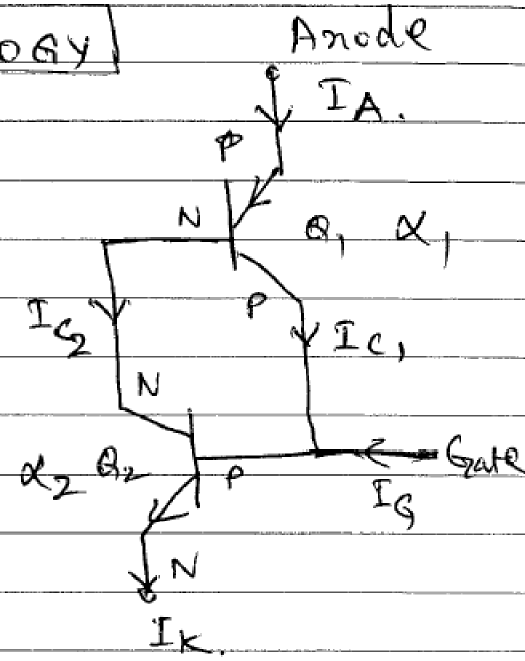
6. Holding cur. : It is the minimum anode current required for device to be ON while in conduction. If anode cur goes below holding cur the SCR will turn off

Reverse bias :

1. The device charateristic is similar to diode reverse charateristic. with J_1 & J_3 junctions reverse biased and J_2 forward biased.

TWO TRANSISTOR ANALOGY





~~Case~~ In a transistor :

$$I_C = \alpha I_E + I_{CO}$$

In Q1. $I_{C_1} = \alpha_1 I_A + I_{CO_1}$ ∵ $I_{E_1} = I_A$

In Q2 $I_{C_2} = \alpha_2 I_K + I_{CO2}$ ∵ $I_{E2} = I_K$.

TOTAL Anode Cur: $I_A = I_{C_1} + I_{C_2}$

∴ $I_A = \alpha_1 I_A + \alpha_2 I_K + I_{CO_1} + I_{CO2}$

$$\boxed{I_A = \alpha_1 I_A + \alpha_2 I_K + I_{CO}} \quad - (1)$$

where $I_{CO_1} + I_{CO2} = I_{CO}$

Case-1 : when $I_G = 0$

$$I_A = I_K$$

$\therefore$ eqn (1) will be

$$I_A = \alpha_1 I_A + \alpha_2 I_A + I_{C0} = I_A(\alpha_1 + \alpha_2) + I_C$$

or $I_A(1 - (\alpha_1 + \alpha_2)) = I_{C0}$

or $$\boxed{I_A = \frac{I_{C0}}{1 - (\alpha_1 + \alpha_2)}} \quad — (2)$$

Case-2: when $I_G \neq 0$ $\therefore I_K = I_A + I_G$

$\therefore$ Eqn (1) will be

$$I_A = \alpha_1 I_A + \alpha_2 (I_A + I_G) + I_{C0}$$

or $$\boxed{I_A = \frac{\alpha_2 I_G + I_{C0}}{1 - (\alpha_1 + \alpha_2)}} \quad — (3)$$

Hence it can be observed that small I_G can cause large I_A.

—o—

GATE CHARACTERISTICS

The SCR conduction is controlled by gate current. A safe operating region, which would ensure successful switching on of the SCR so also not causing any damage to Gate is defined by Gate characteristics.

Important parameters restricting the Oper-
-ating Zone are

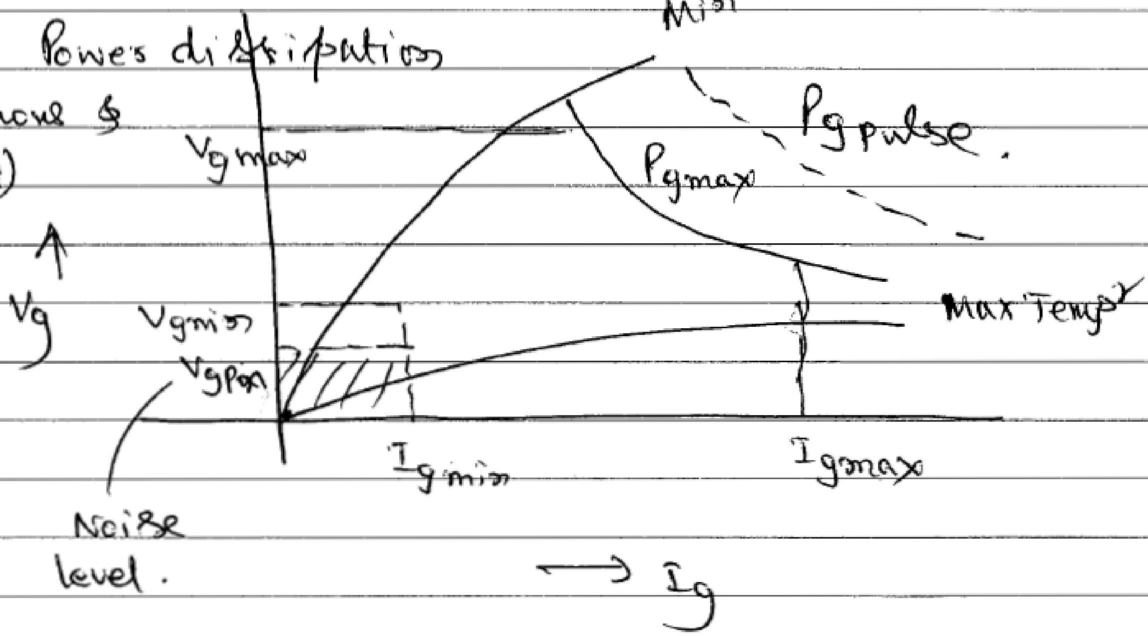
(i) Gate Current : Max value & Min value
I_{gmax} & I_{gmin}

(ii) Gate volt : Max & Min value
(V_{gmax} & V_{gmin})

(iii) Temperature: max and min value.

(iv) Noise triggering value.

(v) Power dissipation
(Continuous & Pulsed)



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$\boxed{\text{TURN ON METHODS}}$ of SCR.

→ 1. Forward Voltage Triggering:
When V_{AK} Anode to Cathode Voltage is increased more than forward Break over Voltage V_{BO} of SCR, J_2 will have avalanche breakdown hence SCR turns on.

2. $\boxed{\text{Thermal or Temperature Triggering}}$

Increase in temperature decreases depletion layer

V_{AK} at close to V_{BO} forward break over volt, increase in junction temperature causes SCR to turn ON

3. $\boxed{\text{Radiation or Light Triggering}}$

In SCRs like LASCR, external radiation or light causes more number of electron - hole pair to be created. Eventually causing SCR to turn ON.

4. dv/dt Triggering :

A sudden increase in Anode to Cathode voltage can trigger SCR to switch ON.

$$i_c = \frac{dQ}{dt}$$ where Q is the charge.

$$= \frac{d}{dt}(C_j V)$$ C_j = Jn Capacitance.

$$i_c = V\frac{d}{dt}C_j + C_j\frac{dV}{dt}$$

As $\frac{d}{dt}C_j$ rate of change of Jn capacitance is very small.

$$i_c \approx C_j\frac{dV}{dt}$$ ∴ Sudden increase in voltage can trigger the SCR.

5. GATE TRIGGERING.

Most popular and Commonly used method.

(i) DC Gate Triggering: A Continuous DC Supply provides the required gate current for SCR to Switch ON.

This method Suffers lack of isolation and both power & Control Circuits are DC.

(ii) AC Gate Triggering: A step down AC is applied to the gate to provide gate Current during Positive cycles.

This method provides isolation as transformer is present but at the same time increases power loss and Cost of the circuit.

(iii) Pulse gate triggering:

Most popular technique used for triggering the SCR

In this a single pulse appears multiple times so that SCR will turn on and power dissipation requirement is also less.

This method provides isolation between high current and Control Circuit.

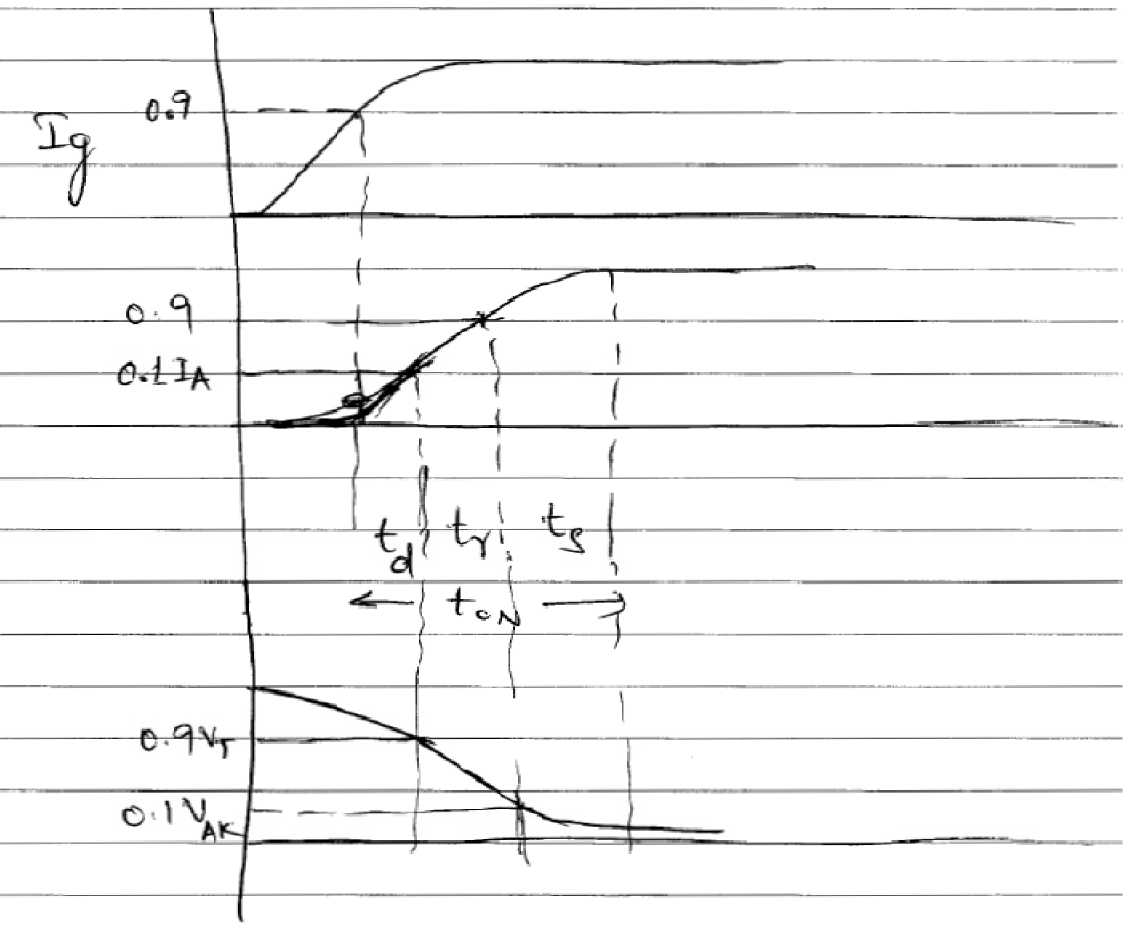
Further losses in gate circuit is also less.

NOTE: REFER PPT FOR MORE EXPLAINATION. P-11

DYNAMIC TURN ON CHARACTERISTICS

SWITCHING CH OF SCR.

1. Switching on Characteristics.



$t_{ON} = t_d + t_r + t_s$

where $t_d \Rightarrow$ delay time: Time taken by I_{AK} to reach 10% of final value.

The delay is due to the Conduction limited to gate and cathode.

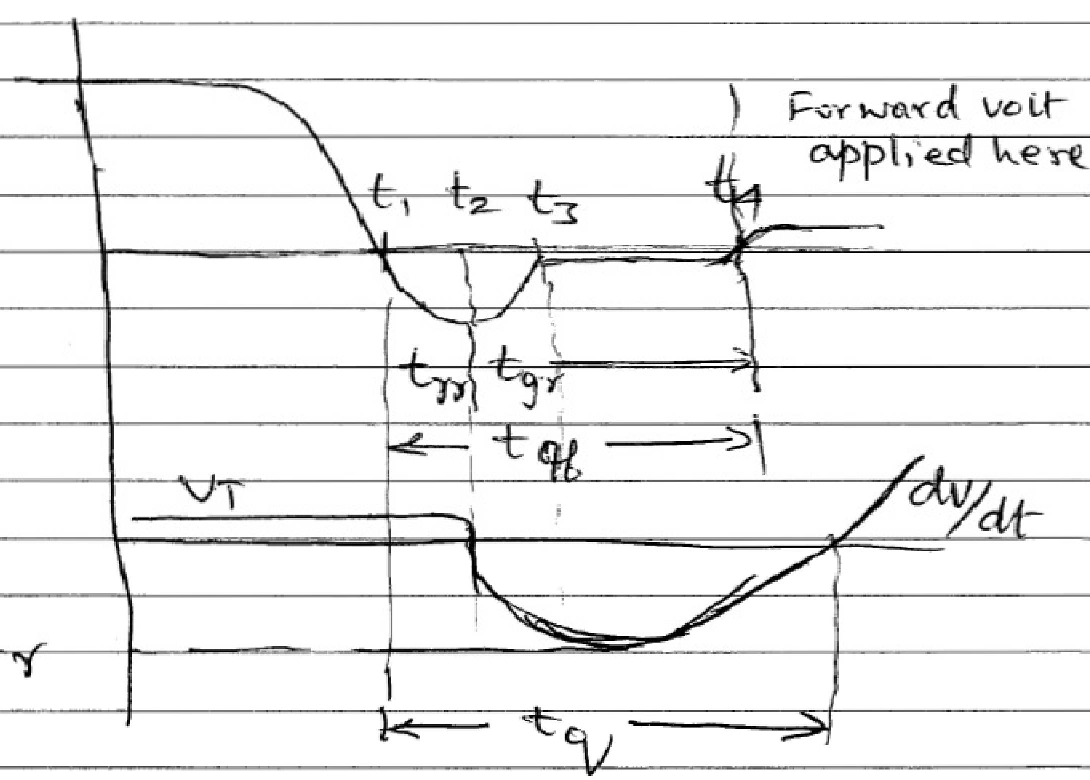
$t_r \Rightarrow$ rise time: Time taken by output reach from 10% to 90% of final value.

→ This is attributable to load inductor ~~and~~ value and rate of increase in I_{AK}.

$t_s \Rightarrow$ Spread time: Time taken by output current to reach final value from 90%.

→ This is the time taken by the current to spread on complete cathode area. Depends on surface area and the current value.

TURN OFF CHARACTERISTICS



$t_{off} = t_{rr} + t_{gr}$.

$t_{rr} \rightarrow$ reverse recovery time: Time taken by excessive carriers to settle back

$t_{gr} \rightarrow$ reverse gate recovery time.
- Time taken by trapped charges to recombine and settle back

$t_q \Rightarrow$ Switch off time which includes gate recovery due to reverse induced voltage V_{rr} (reverse recovery voltage)

$t_c \rightarrow$ Circuit time. (S/wing time of the circuit.

$$t_c > t_q.$$

Note $V_{rr} < V_{rrm}$ (rev rec volt of SCR specified by manufacturer)

—c—

TURN OFF METHODS

Commutation means change of current path. In thyristor it is used to signify that the current from one thyristor is changed to other. But this is not possible unless the current is made zero in the thyristor

Circuit used for reducing the current

below the holding cur is known as Turn off method or Commutation Circuit.

Methods of Commutation :

Natural
↓
OR
Line Commutation.
↓
uses the i/p AC voltage to naturally reduce the SCR current in -ve cycle.

Forced
↓
An external commutation ckt is used to s/w off the thyristor.

CLASS A COMMUTATION.

by resonating the load.

OR.

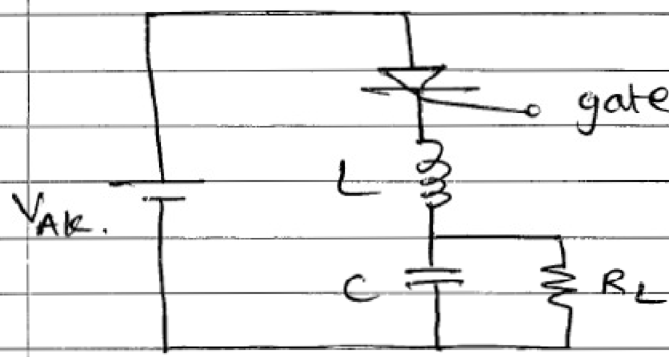
LC Commutation:

OR CURRENT COMMUTATION :

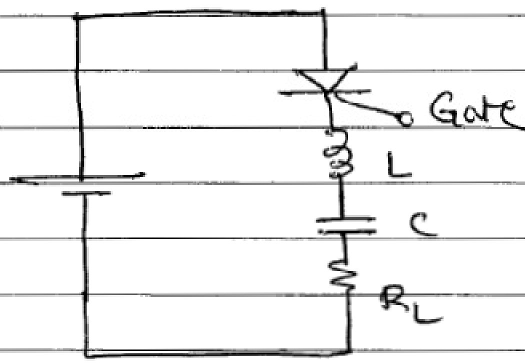
An LC circuit is used to resonate and reduce the SCR current below holding current

I method : Load in parallel.

II method : load in series.



Load in ||lel to Capacitor.



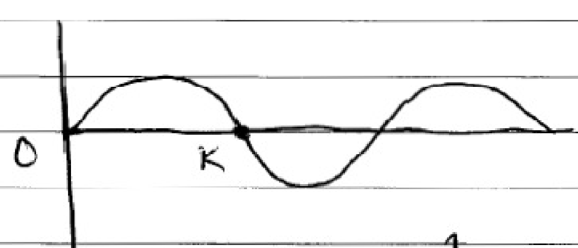
Load in Series with Capacitor.

Features :

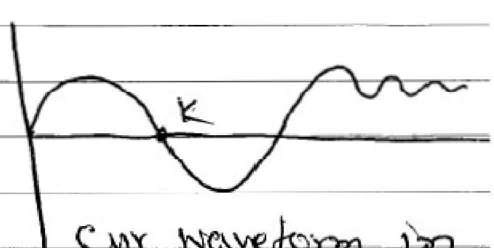
1. LC tank Circuit is used
2. Cap Can be in ||lel or in Series to load
3. Commutation or S/W off of SCR is due to reduction of Current below the holding cur.

Hence Can be termed as Current Commutation also.

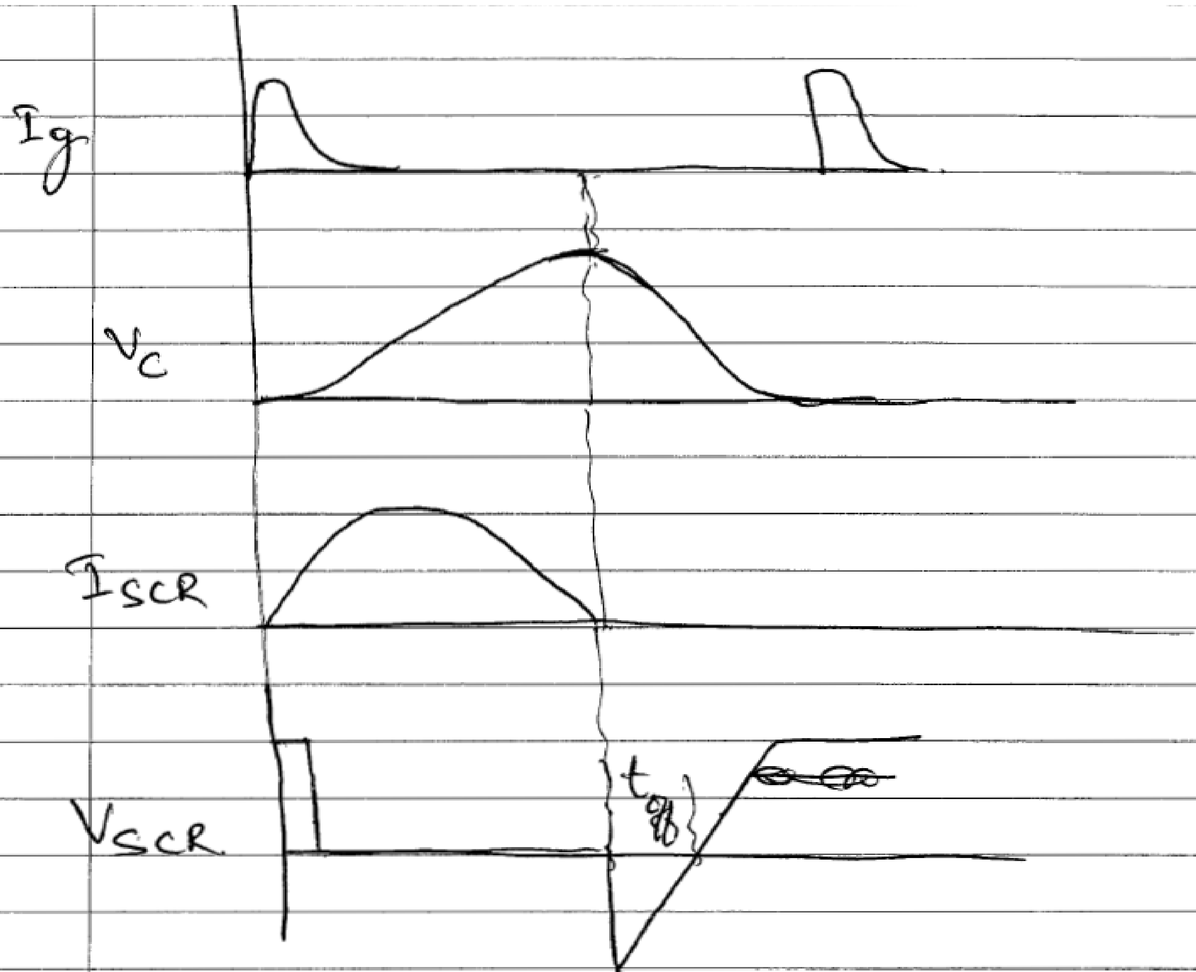
Current wave form in LC Circuit



Current wave form for RLC Series Config



Cur waveform in ||lel Config.



DESIGN CONSIDERATION :

When R_L is in ||lel to Capacitor.

$$E_{dc} = L\frac{di}{dt} + V$$ where V = volt across load

$$i(t) = C\frac{dv}{dt} + \frac{V}{R}$$

Taking laplace transform

$$E_{dc}(s) = I(s)LS + V(s)$$

$$I(s) = CS\,V(s) + \frac{V(s)}{R}$$

$$V(S) = E_{dc}(S) - LS\, I(S)$$

$$I(S) = \left(CS + \frac{1}{R}\right)\left[E_{dc}(S) - LS\, I(S)\right]$$

$$I(S) * \left[1 + LS\left(CS + \frac{1}{R}\right)\right] = E_{dc}(S)\left[CS + \frac{1}{R}\right]$$

$$I(S) = \frac{\dfrac{E_{dc}}{S}\,\dfrac{(RCS+1)}{R}}{\dfrac{R + RLCS^2 + LS}{R}}$$

$$I(S) = \frac{E_{DC}(1 + RCS)}{S(RLC)\left(S^2 + \frac{1}{RC}S + \frac{1}{LC}\right)}$$

which is a second order system and by partial fraction and taking laplace inverse

$$i(t) = \frac{E_{dc}}{R}\left[1 + \frac{\omega_n^2}{\xi\sqrt{1-\xi^2}}\, e^{-t/RC}\sin(\omega t + \phi)\right]$$

where $\omega_n = \dfrac{1}{\sqrt{LC}}$ $\quad \xi = \dfrac{\frac{1}{RC}}{2 * \frac{1}{\sqrt{LC}}} = \dfrac{1}{2R}\sqrt{\dfrac{L}{C}}.$

$$\omega = \omega_n\sqrt{1-\xi^2} = \frac{1}{\sqrt{LC}}\sqrt{1 - \frac{L}{4R^2C}} =$$

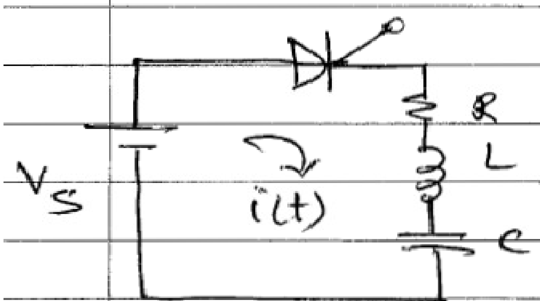
$$\omega = \sqrt{\frac{1}{LC} - \frac{1}{4R^2C^2}}$$

$$\phi = \tan^{-1} 2RC\omega$$

$$V(s) = \frac{E_{dc}}{LC\left(s^2 + \frac{1}{RC}s + \frac{1}{LC}\right)}$$

$$\boxed{v(t) = E_{dc}\frac{\omega_n}{\sqrt{1-\xi^2}} e^{-t/2RC} \sin \omega t + E_{dc}}$$

EXPRESSION FOR SERIES RLC CONFIGURATION



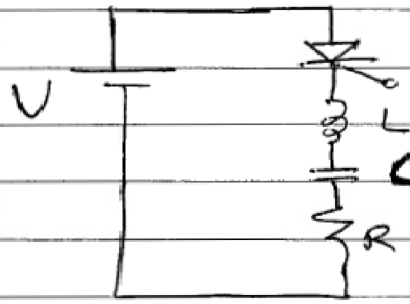
Conditions under which SCR turns off are

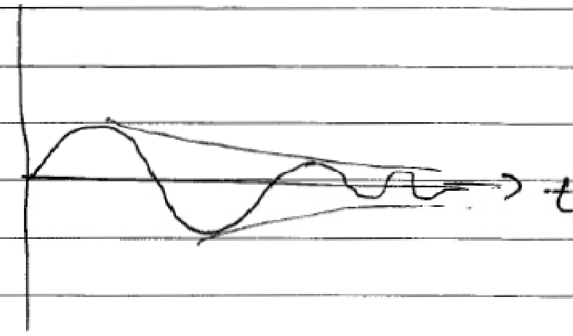
(i) when Cur thr' SCR becomes Zero

(ii) when reverse bias is applied externally across the SCR.

(iii) when external current pulse is forced in reverse direction

(iv) Resonating load, which reverse biases the SCR.





By KVL $\quad V = i(t)R + L\dfrac{di}{dt} + \dfrac{1}{C}\int i(t)\,dt$

$$= \frac{V}{S} = I(S)R + LS\,I(S) + \frac{1}{CS}\left[I(S) + CV_0\right]$$

where CV_0 = cus due to initial charge of cap
If $V_0 = 0$ no charge in caps initially then
$CV_0 = 0$.

$$\therefore \quad \frac{V}{S} = \frac{I(S)\left[RCS + LCS^2 + 1\right]}{CS} + \frac{V_0}{S}$$

$$I(S) = \frac{\dfrac{V}{L} - \dfrac{V_0}{L}}{S^2 + \dfrac{R}{L}S + \dfrac{1}{LC}}$$

Roots of denominator : $s^2 + 2\xi w_n s + w_n^2 = 0$

$$S_{1,2} = -\frac{R}{2L} \pm j\sqrt{\frac{1}{LC} - \left(\frac{R}{2L}\right)^2}$$

$$= -\xi w_n \pm j\left(\sqrt{1-\xi^2}\right)w_n$$

$$s^2 + \frac{R}{L}s + \frac{1}{LC} = s^2 + 2\xi w_n s + w_n^2$$

$$= (s + \xi w_n)^2 + w_d^2$$

where $w_n = \frac{1}{\sqrt{LC}}$ $\quad \xi = \frac{R}{2L \frac{1}{\sqrt{LC}}} = \frac{R}{2}\sqrt{\frac{C}{L}}$

$$\xi w_n = \frac{R}{2L} \qquad w_d = w_n\sqrt{1-\xi^2}$$

$$w_d = \sqrt{\frac{1}{LC} - \frac{R^2}{4L^2}}$$

$$I(s) = \frac{\frac{V}{L} - \frac{V_0}{L}}{s^2 + \frac{R}{L}s + \frac{1}{LC}} = \frac{\frac{V}{L} - \frac{V_0}{L}}{(s+\xi w_n)^2 + w_d^2}$$

$$I(s) = \frac{V - V_0}{w_d L}\left[\frac{w_d}{(s+\xi w_n)^2 + w_d^2}\right]$$

$$\boxed{i(t) = \frac{V - V_0}{w_d L} e^{-\xi w_n t} \sin w_d t}$$

Current $i(t)$ reaches natural zero

when $w_d t_0 = \pi$ or $t_0 = \frac{\pi}{w_d}$

or $t_0 = \dfrac{\pi}{\sqrt{\frac{1}{LC} - \frac{R^2}{4L^2}}}$

For System to be underdamped ie Cns to decay exponentially

$$W_d > 0$$

$$\therefore \quad \frac{1}{LC} - \frac{R^2}{4L^2} > 0$$

$$\text{or} \quad \boxed{R < \sqrt{\frac{4L}{C}}}$$

Voltage across Capacitor.

Case - 1 : when $V_0 = 0$ ie no initial Charge on Capacitor.

$$V_C = V - V_L = V - L\frac{di}{dt}.$$

$$i(t)\Big|_{V_0 = 0} = \frac{V}{W_d L} e^{-\xi W_n t} \sin W_d t.$$

$$\frac{di}{dt} = \frac{V}{W_d L}\left[-\xi W_n e^{-\xi W_n t} \sin W_d t + e^{-\xi W_n t} (+\cos W_d t) * W_d\right]$$

$\cos\pi = -1 \qquad \sin\pi = 0$

Max voltage across Cap is when

$w_d t = \pi$.

$$\therefore \frac{di}{dt} = \frac{V}{w_d L}\left[0 - e^{-\xi w_n \frac{\pi}{w_d}} * w_d\right]$$

$$= -\frac{V}{L} e^{-\frac{\pi \xi w_n}{w_d}}$$

$$\therefore V_c = V - L\frac{di}{dt} = V + L * \frac{V}{L} e^{-\frac{\pi \xi w_n}{w_d}}$$

$$V_c = V\left[1 + e^{-\frac{\pi \xi w_n}{w_d}}\right]$$

If $V_0 \neq 0$

Then $\cancel{V_c = V[1+}$

$$\boxed{V_c = V + (V - V_0)\, e^{-\frac{\pi \xi w_n}{w_d}}.}$$

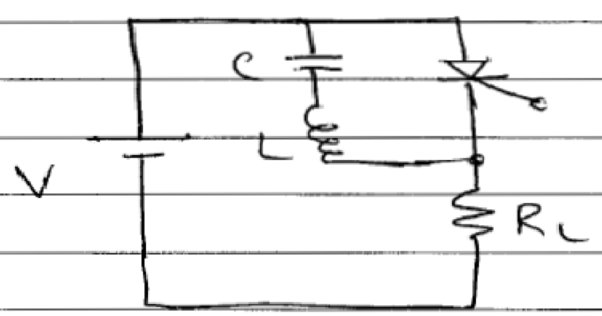
[CLASS - B] [SELF COMMUTATION]

- This type of Commutation is used in Chopper and inverter ckts.

- In Class A load cur passes thro'ug L and C.

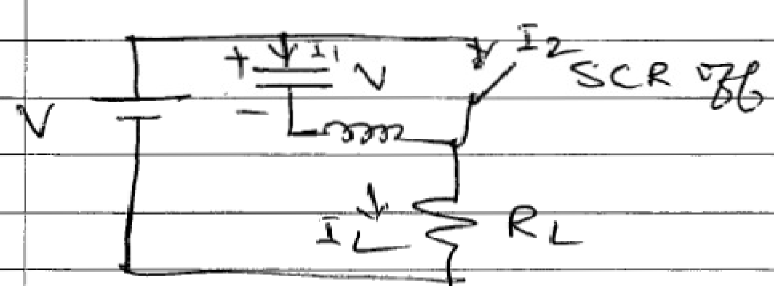
i.e Commutating Components take load cur

- In Class B load cur is independent of LC Components



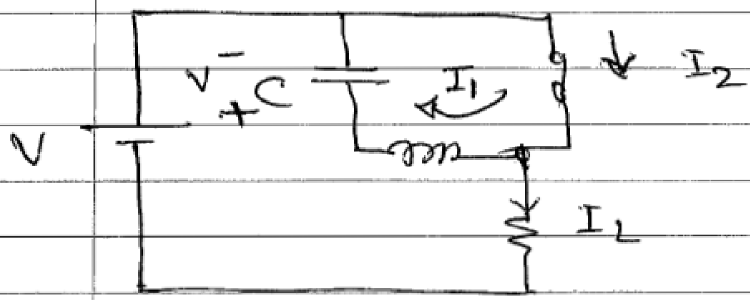
[operation]

Case-1: When SCR off. [STAGE-1]



$I_L = I_1$ $\quad I_{SCR} = I_1 + I_2$ $\quad I_2 = 0$

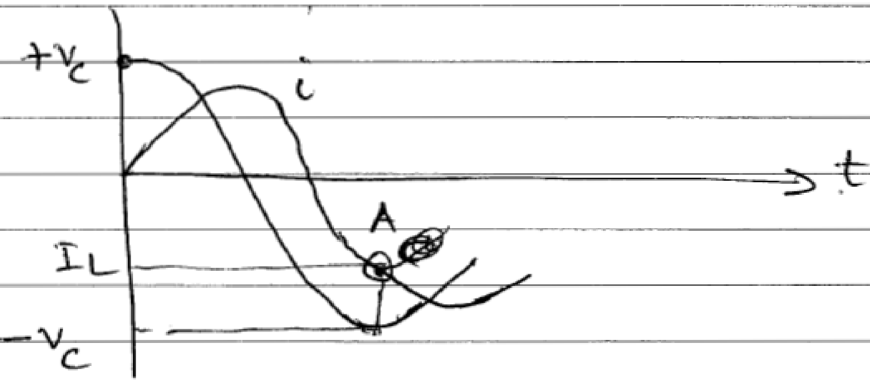
Stage-2 : When SCR is ON (Triggered from Stage-1)



$I_L = I_1 + I_2$

$I_{SCR} = I_L$

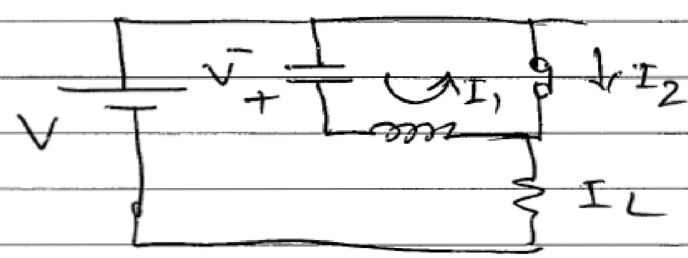
Cap charges from $+V_c$ to $-V_c$ or $+V$ to $-V$.



At A $I_1 = I_2$

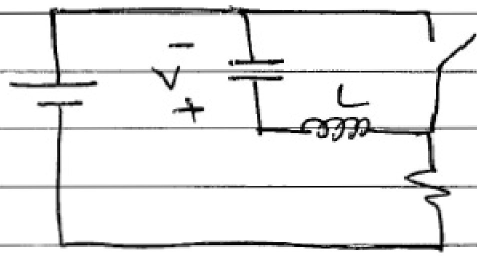
once Cap charges to $-V$ $I_1 = 0$ & reverses direction making $I_{SCR} = I_2 - I_1$

Stage 3 :



$I_{SCR} = I_2 - I_1$

Stage 4 :



SCR off as $I_{SCR} < I_H$

Stage 5 Back to Stage 1.

This continuous so that SCR is turned ON and off continuously. RC product controls the time of S/W on and off.

DESIGN CONSIDERATION

Consider the LC circuit i.e. eq^n for I_1 (loop of LC & SCR)

$$L\frac{di}{dt} + \frac{1}{C}\int i(t)\,dt = V$$

By laplace Transform

$$\frac{V}{S} = \left[LS + \frac{1}{CS}\right] I(S)$$

$$\text{or } I(S) = \frac{V/S}{\frac{L}{S}\left(S^2 + \frac{1}{LC}\right)} = \frac{V/L}{\left(S^2 + \frac{1}{LC}\right)}$$

$$I(S) = \frac{V/L}{S^2 + \left(\frac{1}{\sqrt{LC}}\right)^2} = \frac{V/L}{\frac{1}{\sqrt{LC}}} * \frac{\frac{1}{\sqrt{LC}}}{S^2 + \left(\frac{1}{\sqrt{LC}}\right)^2}$$

Taking laplace inverse of the same

$$\boxed{i(t) = V\sqrt{\frac{C}{L}}\ \sin w_n t}$$

where $w_n = \frac{1}{\sqrt{LC}}$.

$\therefore$ $i(t)$ is a sinusoidal variation

Voltage across Capacitor.

$$V_C = V - L\frac{di}{dt}$$

$$= V - L * V * \sqrt{\frac{C}{L}}\ (\cos w_n t) * w_n$$

$$= V - \cancel{L} * V\sqrt{\frac{\cancel{C}}{\cancel{L}}} * \frac{1}{\cancel{\sqrt{LC}}}\ \cos w_n t$$

$$\boxed{V_C = V\left[1 - \cos w_n t\right]}$$

Peak Cur $I_{Peak} = I_m = V\sqrt{\frac{C}{L}}$

$$= 2 I_L$$

at least double the load cur or when $I_1 = I_2$

or $Q = 2I_1 = 2I_2 = 2I_L$

Commutating time is taken as $\frac{1}{4}$ of the period of Sinusoidal oscⁿ or 2π

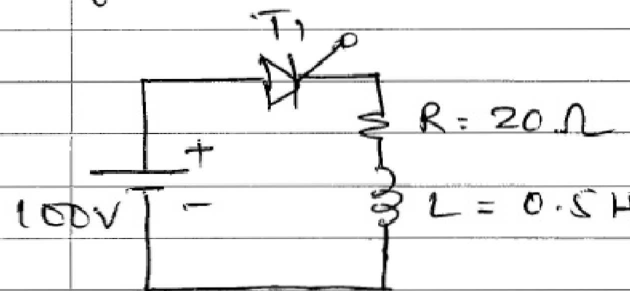
$\therefore \quad \omega_n t = \frac{\pi}{2}$

or $\boxed{t = \frac{\pi}{2} * \sqrt{LC}}$

— o —

PROBLEMS

Prob ①: The latching cur of a thyristor in shown circuit is 50 mA. The duration of firing pulse is 50 μs will the thyristor get fired and continue to be ON.



By KVL ~~i(t) = i(t)~~ $V = i(t)R + L\frac{di}{dt}$

By laplace Tfom. $\frac{V}{S} = (R + LS)\, I(S)$

or $I(S) = \frac{V/S}{L(S + \frac{R}{L})} = \frac{V/L}{S(S + R/L)}$

By Partial fraction $I(S) = \frac{A}{S} + \frac{B}{S + R/L}$

$\therefore \; V/L = A(S + R/L) + BS$

Let $S = 0$: $\quad V/L = A\, R/L$ or $\boxed{A = V/R}$

Let $S = -R/L$ $\quad \frac{V}{L} = -B\frac{R}{L}$ $\quad \boxed{B = -V/R}$

$\therefore \; I(S) = \frac{V}{R} * \frac{1}{S} - \frac{V}{R}\frac{1}{S + R/L}$

By laplace inverse.

$$i(t) = \frac{V}{R}\left(1 - e^{-t R/L}\right)$$

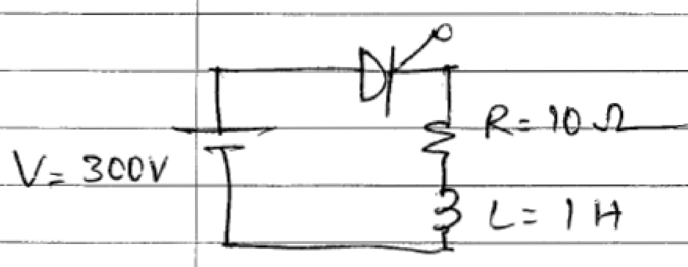
$$\therefore\ i(t)\Big|_{t=50\mu s} = \frac{100}{20}\left(1 - e^{-\frac{50\times10^{-6}\times 20}{0.5}}\right)$$

$$= 9.99\,mA \simeq \boxed{10\ mA}$$

The SCR will be ON only for the duration of gate pulse and then s/w off as Anode cur is 10 mA at 50 μs < Latching cur.

— o —

Prob ②. The SCR has latching cur of 25 mA is fired by the gate pulse width of 60 μs Find State of SCR.



ⓑ Find the trigger pulse width if latching cur is 10 mA

Ans : Part (a) $i(t) = \frac{V}{R}\left(1 - e^{-tR/L}\right)$

$$i(t)\Big|_{t = 60\mu s} = \frac{300}{10}\left(1 - e^{-\frac{60*10^{-6}*10}{1}}\right)$$

$$\boxed{i(t) = 17\ mA}$$ which is $< I_L = 25m$

Hence SCR is off.

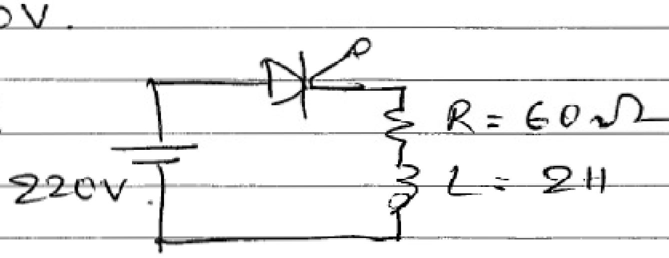
Part (b): $i(t) = I_L = 10*10^{-3} = \frac{300}{10}\left(1 - e^{-\frac{t\,10}{1}}\right)$

$$= \boxed{t = \ldots\ldots\ \mu\ secs}$$

Prob (3): The thyristor is triggered by Pulse width of 40μs and latching cur is 36 mA for a load of 60Ω in series with 2H inducto

will the thyristor remain ON, if not then how it can be overcome. The supply voltage is 220V.

Ans: Ckt:



$$i(t) = \frac{V}{R}\left(1 - e^{-t\,R/L}\right)$$

8/6/2021:

$$i(t) = \frac{220}{60}\left(1 - e^{-\frac{40*10^{-6}*60}{2}}\right)$$

$$i(t)\Big|_{t=40\mu s} = 4.397 \text{ mA} < I_L$$

$\therefore$ SCR is off after $40\mu S$.

Part (b):

$$i(t) = I_L = 36*10^{-3} = \frac{V}{R}\left(1 - e^{-t R/L}\right)$$

$$= 36*10^{-3} = \frac{220}{60}\left(1 - e^{-t*\frac{60}{2}}\right)$$

$$t = 0.329 \text{ mSec}$$

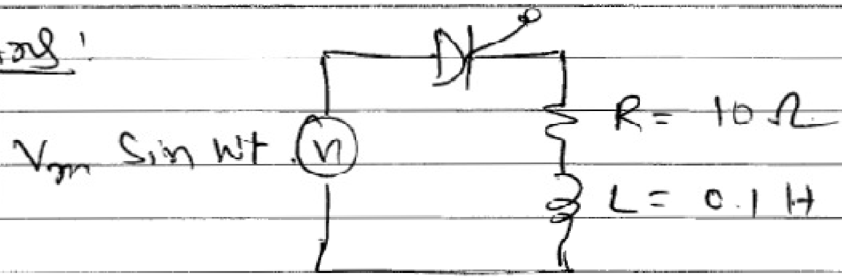
or $\boxed{329 \mu Sec.}$

Increase the gate trig pulse width to $329 \mu S$ from $40\mu Sec$.

Prob (4): The input volt is $325 \sin wt$ for a thyristor with latching cur of 15 mA and a load of 10Ω with 0.1 H inductor, obtain the gate trigger pulse width for the SCR to be on at $\pi/6$ angle of the half cycle.

~~Slom(2)~~ :

Ans :



At $\omega t = \pi/6$ $\quad V_{in} = 325 \sin \pi/6$

$$\boxed{V_{in} = 162.5\,V.}$$

$$i(t) = I_L = \frac{V_{in}}{R}\left(1 - e^{-tR/L}\right)$$

$$= 15 * 10^{-3} = \frac{162.5}{10}\left(1 - e^{-t\frac{10}{0.1}}\right)$$

$$\boxed{t = 9.23\,\mu\,\text{Secd}}$$

—o—

Prob (5) : Same Prob (4) with $R = 20\,\Omega$

$L = 0.5\,H$ $\quad V_{in} = 325 \sin \omega t$

$I_L = 20\,mA$ $\quad$ firing lle $= \pi/3$

Ans: $V_{in} = 325 \sin \pi/3 = \boxed{281.45\,V.}$

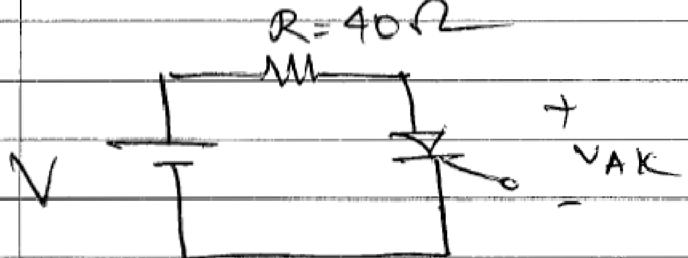
$$i(t) = I_L = \frac{V_{in}}{R}\left(1 - e^{-tR/L}\right)$$

$$20 \times 10^{-3} = \frac{281.45}{20}\left(1 - e^{-t\frac{20}{0.5}}\right)$$

$$\boxed{t = 0.355 \mu secs}$$

—o—

Prob ⑥: The on state volt drop across SCR is 0.8V. The thyristor has a holding cur of 15 mA with $I_g = 0$. If SCR is turned ON by a momentary gate pulse find the voltage value below which SCR will turn off.



By KVL $V = i(t)R + V_{AK}$

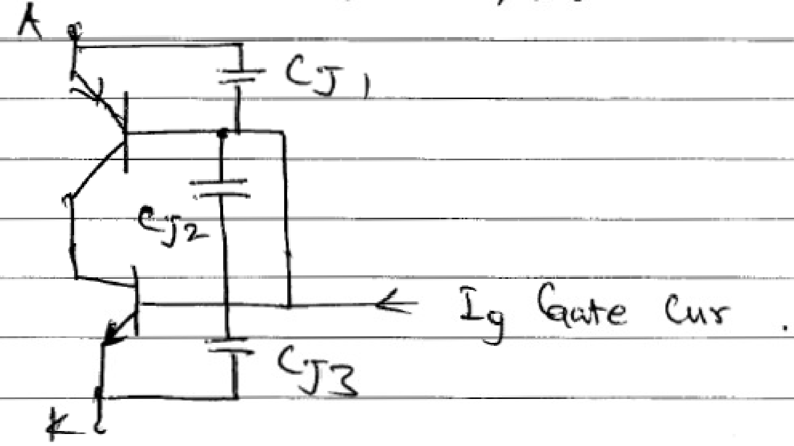
$$i(t) = \frac{V - V_{AK}}{R}$$

if $i(t) < I_H$ SCR will turn off

$\therefore \frac{V - V_{AK}}{R} \leq I_H$ for turning off.

$\therefore \boxed{V \leq 1.4 V.}$

Prob (7): If the Capacitance of the reverse biased jn J2 of SCR $C_{j2} = 30pF$ assuming it to be independent of off state volt and the limiting value of Charging Current to turn ON SCR is 12 mA Calculate the critical value of dv/dt.



$$i_{j2} = \frac{d}{dt}(q_{J2}) = \frac{d}{dt}(C_{J2}V) = C_{J2}\frac{dv}{dt} + V\frac{dC_{J2}}{dt}$$

$\frac{dC_{J2}}{dt}$ is very small and may be neglected.

$$\therefore i_{j2} = C_{J2}\frac{dv}{dt}$$

$$\therefore \frac{dv}{dt} = \frac{i_{J2}}{C_{J2}} = \frac{12 * 10^{-3}}{30 * 10^{-12}} = 400 * 10^{6}\, V/s$$

or $\boxed{\frac{dv}{dt} = 400\, V/\mu sec}$

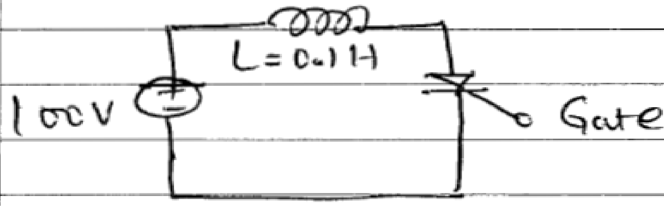
Prob (8): The limiting value of charging cur to turn ON the SCR is 5 mA. If the critical value of $\frac{dv_{AK}}{dt}$ is 200 V/μ sec

calculate jn capacitance.

From previous prob.

$$C_{j2} = \frac{i_{J2}}{dv/dt} = \frac{5*10^{-3}}{200*10^{6}} = 25\,pF.$$

Prob (9): If the latching cur in the circuit shown is 4 mA obtain the minimum width of the gating pulse required to properly turn ON the SCR.



By KVL $L\frac{di}{dt} = V$ Neglecting V_{SCR} while on.

$$L\,di = V\,dt$$

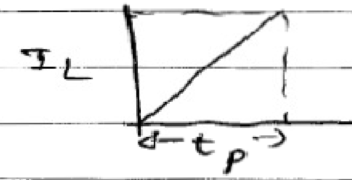
By $\int^{ng}$ $L\,i(t) = V * t$

or $t = \frac{L}{V}\, i(t)$

$$t = \frac{0.1}{100} * 4*10^{-3} = \boxed{4\ \mu\,Secs}$$

Prob 10 : In Certain thyristor circuit the initial rate of rise of anode cur is 4000 A/μsec. Find the min width of the gate pulse required to turn ON the SCR if latching cur is 20mA

$$\frac{di}{dt} = \frac{I_L}{t_p}$$

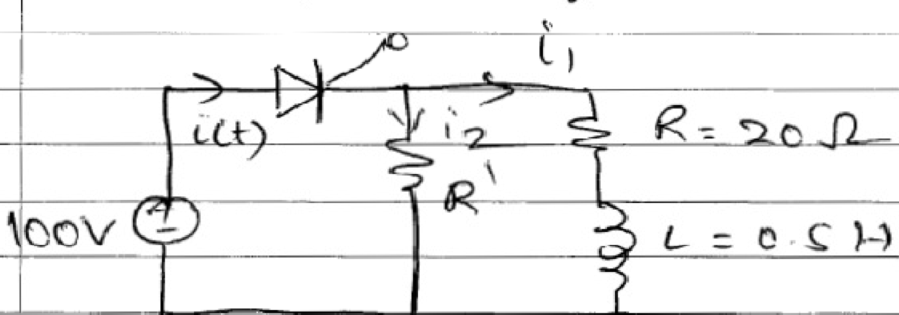


$$\therefore t_p = \frac{20 * 10^{-3}}{4000 * \cancel{10^6}} =$$

Neglecting t_d & t_r

$$\boxed{t_p = 5\,\mu\,\text{sec}.}$$

Prob 11 : The thyristor in circuit has a latching cur of 50mA and is triggered by gate pulse width 50μS. Show that without resistance R' the thyristor will fail to remain ON, when gating pulse ends. Also find maximum value of R' to ensure firing of SCR. The ON state volt across SCR may be neglected.



$$i(t) = i_A \Big|_{t = 50\mu S} = \frac{V}{R}\left(1 - e^{-tR/L}\right)$$

$$i_A(t)\Big| = \frac{100}{20}\left(1 - e^{-\frac{50 \times 10^{-6} \times 20}{0.5}}\right)$$

Without R'

$$= \underline{10\ mA} < I_L$$

i_2 = Cur thr' $R' = i(t) - i_1(t)$

$$= I_L - i_1(t)$$

$$= 50\,mA - 10\,mA = 40\,mA.$$

$$\therefore\ R' = \frac{V}{i_2(t)} = \frac{100}{40\,mA} = \boxed{2.5\,K\Omega}$$

$\therefore\ R' \le 2.5\,K\Omega$ to make $i(t) \geq I_L$

Prob 12: A thyristor has forward break over voltage of 175V when a pulse of 2mA is made to flow. Find conduction angle if sinusoid of 350V peak is applied

$$V_s = 350 \sin wt$$

or $350 \sin\alpha = 175$

or $\alpha = \sin^{-1}\dfrac{175}{350} = 30^\circ$ or $\pi/6$

REFER PPT FOR MORE PROBS

PROBLEMS ON COMMUTATION

1 In a half wave rectifier circuit turn off time of SCR is 20 μsec $V = 100\sqrt{2} \sin \omega$

Find whether line or natural commutation is possible in following cases.

(a) $\omega = 100\pi$; $\alpha = 0$ $R = 5\,\Omega$

(b) $\omega = 100\pi$; $\alpha = \pi/2$ $R = 5\,\Omega$

(c) $\omega = 100 \times 10^3 \pi$; $\alpha = 0$; $R = 5\,\Omega$

Ans: (a) $\omega = 100\pi$ or $f = \dfrac{100\pi}{2\pi} = 50\,Hz$

$T = \dfrac{1}{f} = 20$ m secs.

$\therefore$ $T/2$ ½ cycle time $= \boxed{10 \text{ m secs}}$

t_{off} of SCR = 20 μsec $\therefore$ SCR will be off commutation is successful.

Case-2 : $\alpha = \pi/2$ $\therefore$ off time is 10 m secs and 5 m secs from the cycle.

Commutation is successful.

Case-3: $\omega = 100 * 10^3 * \pi$

or $f = 50\ kHz$

or $T = 20\mu$ sec.

$1/2$ cycle time $= T/2 = 10\mu$ sec.

$t_{off} = 20\mu$ sec.

$\therefore T/2 < t_{off}$ hence SCR will not s/w off completely.

Commutation fails

VTU 2002: Compare Natural and forced Commutation.

SL No.	Parameter	Natural Commutation	Forced Commutation
1.	Need of Commutating Components	Nil	Necessary
2.	Type of Supply	AC	DC
3.	Power loss in Commutating Ckt	Nil	Yes
4.	Type of Commutation	$\because I_A < I_H$ as V_{AK} is reversed	Cur or volt Commutation

5	Cost of Commutation Ckt	Nil	Costly
6	Size of Circuit	Small	Big.

—o—

VTU Aug 2002

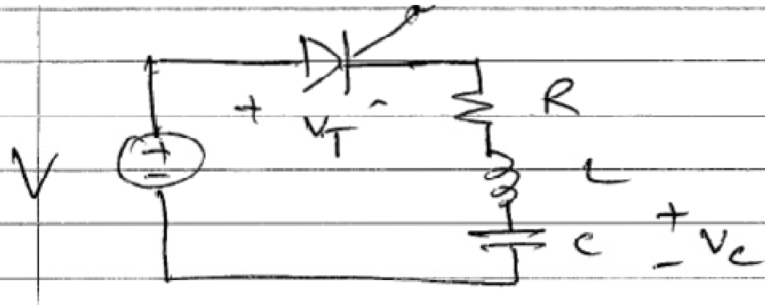
Compare Volt & Cur Commutation Ckt.

VOLTAGE	CURRENT
1. Turned off due to -ve V_{AK}.	1. Turned off as $I_A < I_H$
2. A charged Capacitor is placed across SCR	2. A Cap is discharged thr' SCR
3. Line Commutation is Volt Commutation	3. Natural Commutati is Cur Commutation
4. Complementary or Aux or impulse.	Self Commutation or Resonant pulse

—o—

VTU Mar 03 6mks

Prob ①: In the load Commutation Circuit shown in fig has $R = 10\Omega$ $L = 10mH$ $C = 10\mu F$, $V = 100V$ determine whether thyristor will be self commutated or not. If it is commutated calculate volt across Capacitor at that time.



For Commutation to be successfull.

$$\omega_d t_0 = \pi$$

$$\text{or } t_0 = \frac{\pi}{\omega_d} = \frac{\pi}{\sqrt{\frac{1}{LC} - \frac{R^2}{4L^2}}}$$

$$t_0 = 1.006 * 10^{-3} \text{ or } \boxed{1 \text{ m Sec}}$$

$$V_c = V\left[1 + e^{-\frac{\pi \xi \omega_n}{\omega_d}}\right]$$

$$= V\left[1 + e^{-\frac{\pi R}{2L\sqrt{\frac{1}{LC} - \frac{R^2}{4L^2}}}}\right]$$

$$\boxed{V_C = 160.463 \text{ V}}$$

---o---

Prob ②: In the previous problem if Cap is charged to $-500V = V_c(0)$

$L = 15 \mu H$ and $C = 50 \mu F$ and $R = 0$

and SCR turned on at $t=0$ find

ⓐ Peak value of resonant Cur.

ⓑ Conduction time of thyristor.

Ans: If Cap is Charged initially.

$$i(t) = \frac{V - V_0}{W_d L} e^{-\zeta W_n t} \sin W_d t$$

SCR is ON at $t=0$, and $v=0$

$$\therefore \left. i(t) \right|_{t=0} = -\frac{V_0}{W_d L} \sin W_d t$$

$i(t)$ is max when $X_c = X_L$ or $W_d = W_n = \frac{1}{\sqrt{LC}}$

and $W_n t = \pi/2$

$$\left. i(t) \right|_{Peak} = -\frac{V_0}{W_n L} = -V_0 \sqrt{\frac{C}{L}}$$

$$= \frac{-500}{\sqrt{15 * 10^{-6}}} * \sqrt{50 * 10^{-6}}$$

$$\left(\left. i(t) \right|_{Peak} \right) = \boxed{912.87\ A.}$$

Conduction time of SCR is cur = 0
$t=0$ SCR starts conducting till cur becomes zero again.

$\therefore$ $W_n t = \pi$ makes $i(t) = 0$.

$\therefore$ $t = \frac{\pi}{W_n} = \pi\sqrt{LC}$

$$\boxed{t = 86.04\,\mu S}$$

Prob ③ : A thyristor commutation circuit has commutating elements L & C in series with load resistance R

If $R = 0.8\Omega$, $L = 10\mu H$, $C = 50\mu F$

Check that the circuit is underdamped and thyristor conduction time.

Ans: In series RLC commutation circuit

for system to be underdamped

$$R < \sqrt{\frac{4L}{C}} \quad \text{or} \quad W_d > 0$$

$$\sqrt{\frac{1}{LC} - \frac{R^2}{4L^2}} > 0$$

$\therefore$ $R < 0.8944\,\Omega$

Given $R = 0.8\,\Omega$ hence Condition for underdamping is satisfied.

For Conduction time $\omega_d t_o = \pi$.

or $t_o = \dfrac{\pi}{\omega_d} = \dfrac{\pi}{\sqrt{\dfrac{1}{LC} - \dfrac{R^2}{4L^2}}}$

$$\boxed{t_o = 157.08\,\mu\,\text{Secs}}$$

SCR Commutates when $t = t_o$ or conducts till t_o.

—o—

Prob (4): In a self Commutating Circuit load cur is 8A supply volt is 90V and required turn off time is $40\,\mu S$

Find values L & C of the Commutation Ckt.

Ans: Assume $I_{peak} = 2I_L$

SCR rev biased for $\frac{1}{4}$ of total time peri

$I_{peak} = V\sqrt{\dfrac{C}{L}} = 2I_L = 16$

$= 90\sqrt{\dfrac{C}{L}} = 16$ or $\boxed{\sqrt{\dfrac{C}{L}} = \dfrac{16}{90}}$ - (1)

$$\omega_n t = \pi/2 = t_c$$

$$\text{or } t = \frac{\pi}{2} * \frac{1}{\omega_n} = \frac{\pi}{2}\sqrt{LC} = 40*10^{-6}$$

as $t_c = 40\mu\,\text{Sec}$.

$$\therefore \boxed{\sqrt{LC} = \frac{80*10^{-6}}{\pi}} \quad -②$$

By multiplying ① & ②.

$$\boxed{C = 4.522*10^{-6}\ F}$$

By dividing ① & ②

$$\boxed{L = 143.24*10^{-6}\ H.}$$

—o—

TRIGGERING CIRCUITS

Need : The gate Cur and voltage of SCR needs to be within limits as seen in gate characteristics.

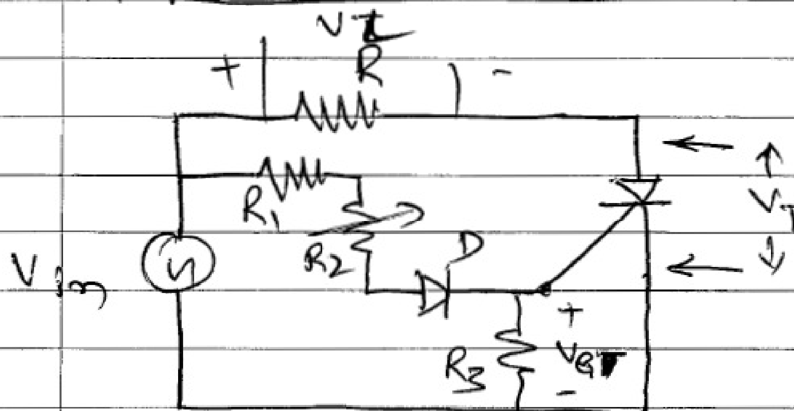
Further duration of gate trigger must be such that the anode Cur of SCR will be at least or more than latching Current If not the SCR will not be in ON Conditi

Hence a separate triggering Circuit is required for SCR.

TRIGGERING CIRCUITS :

1. R Triggering Ckt
2. RC Triggering Ckt
3. UJT Triggering Ckt.

1. R-TRIGGERING CIRCUIT



OPERATION / WORKING.

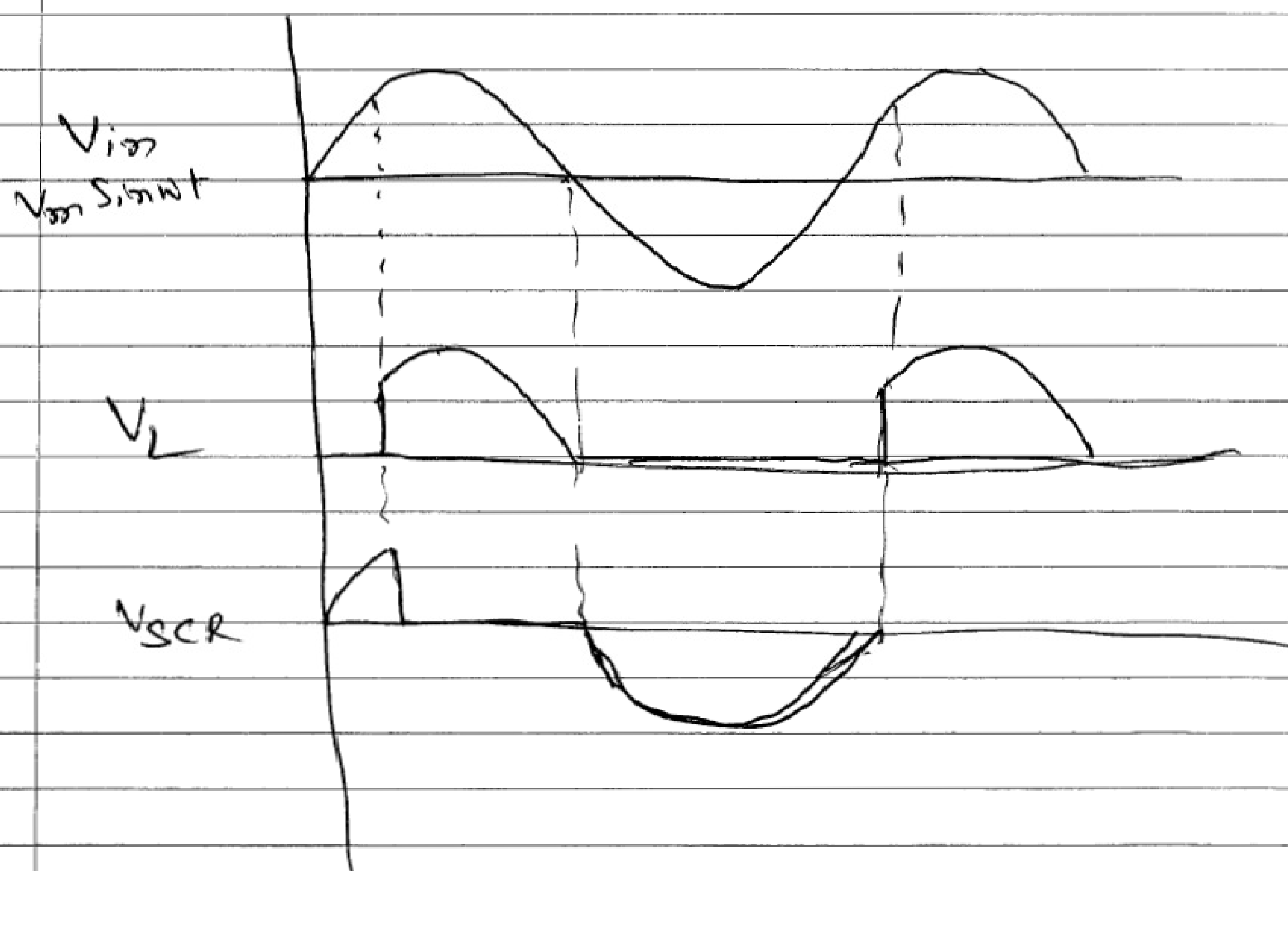
1. I/P is a sine wave or $V_m \sin \omega t$

2. Based on R_2 value gate curr I_g varies which will influence the triggering or conducting voltage of V_{AK} or V_{SCR}.

3. More R_2 value less is I_g more is V_{AK} reqd for SCR to conduct.

4. Diode D stops reverse curr from SCR to gate ckt.

Waveform :



DESIGN CONSIDERATION

1. $\left.\dfrac{V_m}{R_1 + R_2}\right|_{\text{Max when } R_2 = 0} = \dfrac{V_m}{R_1} \leq I_{gm}$

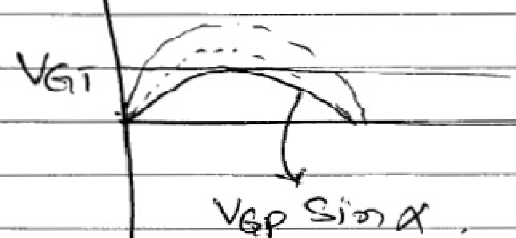
I_{gm} max gate cur of device or SCR

$\therefore \boxed{R_1 \geq \dfrac{V_m}{I_{gm}}}$ — (1)

2. $\dfrac{V_m}{R_1 + R_3} * R_3 \leq V_{Gm}$ where V_{Gm} is max gate volt of device or SCR

$\therefore \boxed{R_3 \leq \dfrac{V_m R_1}{V_m - V_{Gm}}}$ — (2)

3. SCR fires when



$V_{GP} \sin \alpha = V_{GT}$

or $\alpha = \sin^{-1} \dfrac{V_{GT}}{V_{GP}}$

$= \sin^{-1} \dfrac{V_{GT}}{\dfrac{V_m}{R_1 + R_2 + R_3} * R_3}$

V_{GP} = volt drop across R_3

$= \dfrac{V_m R_3}{R_1 + R_2 + R_3}$

$\alpha = \sin^{-1} \dfrac{V_{GT}(R_1 + R_2 + R_3)}{V_m R_3}$

Instantaneous volt at the time of Conduction

$$v = I_{GT}(R_1 + R_2) + V_\gamma + V_{GT}$$

where I_{GT} gate triggering Cur

V_{GT} Gate triggering volt

V_γ Drop across Diode D.

—o—

Main Disadvantage of R triggering is that

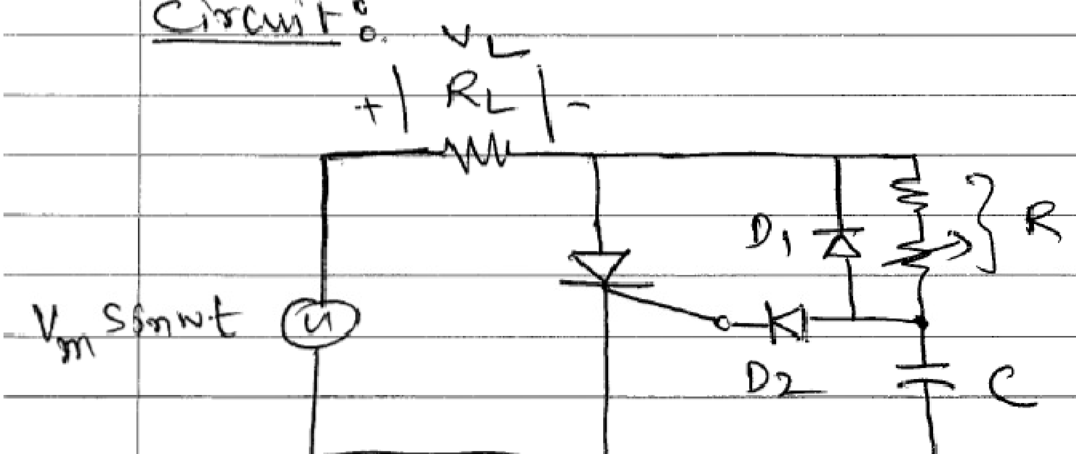
$$\boxed{\text{Max Firing } \angle\text{le } \alpha < 90^\circ}$$

—o—

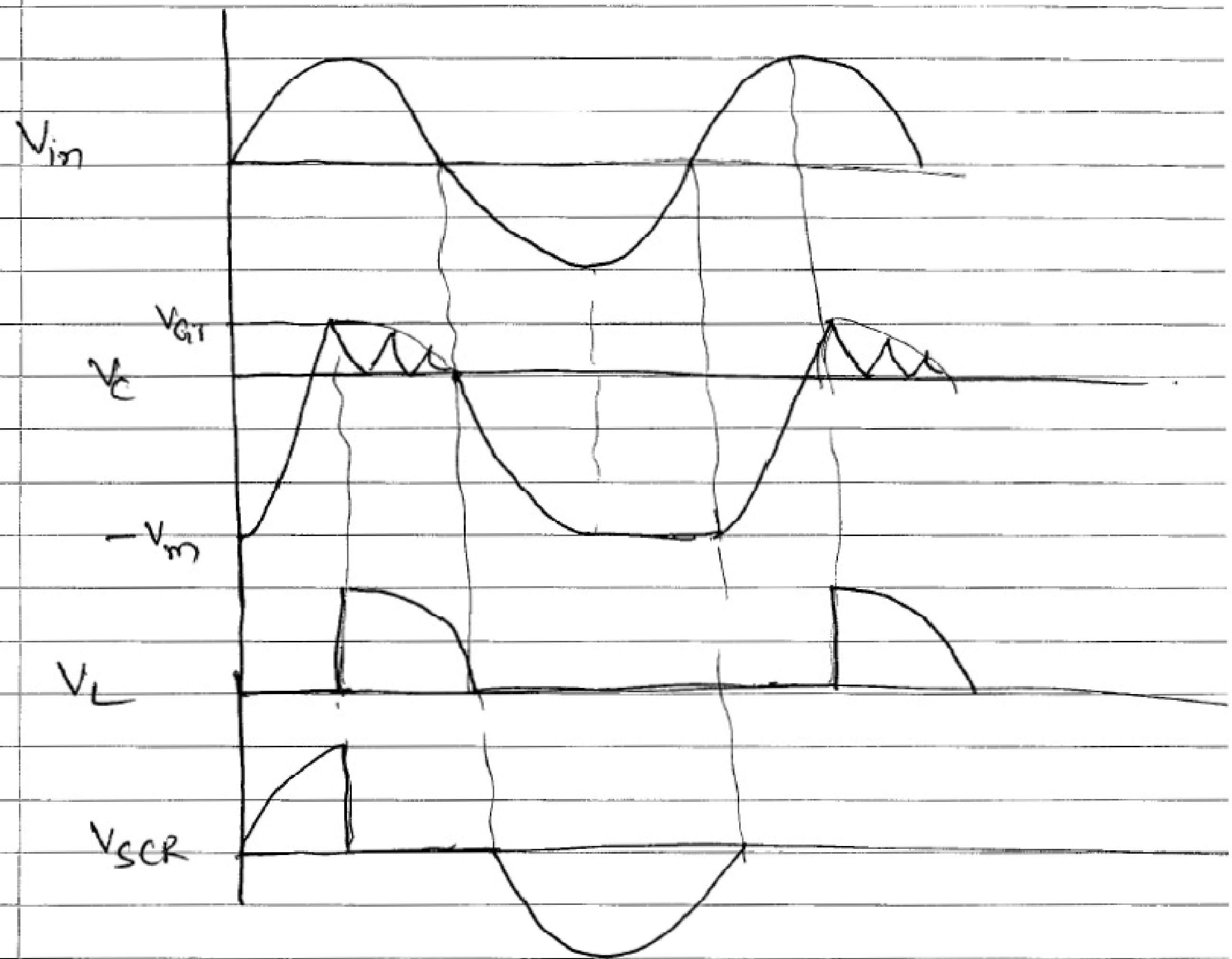
RC TRIGGERIN CIRCUIT.

Half wave rectifier Configuration

Circuit:



Wave forms :



Working :- Cap C gets charged to $-V_m$ during -ve half cycle thr' diode D_1

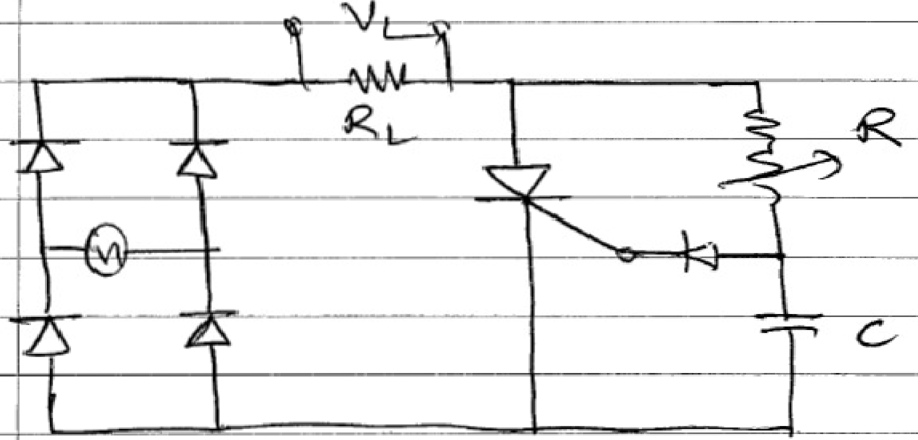
- Cap C charges to $+V_m$ during +ve half cycle and before it reaches V_m based on the V_{gt} Diode D_2 is forward biased and triggers SCR.

- The Cap Charging time during +ve half

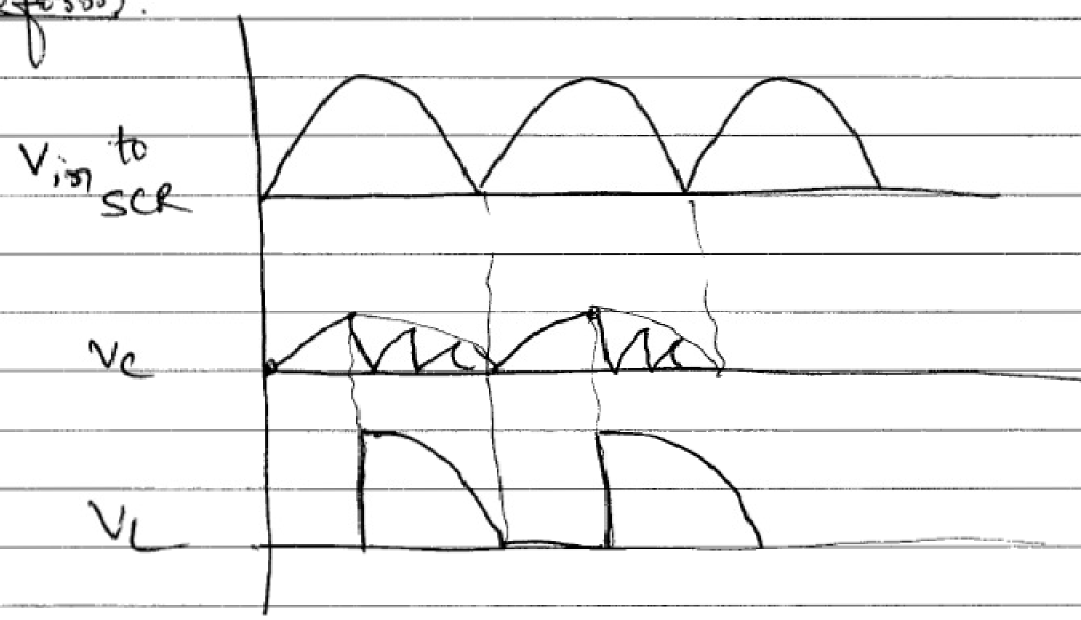
cycle is Controlled by RC time Constant.

Thus time of firing of SCR depends on R value.

~~DESI~~ FULL WAVE CONFIGURATION



Waveform:



The Capacitor is charged thr' R in every half cycle. The SCR fires based on anode ~~cur~~ ~~and~~ Voltage and Corresponding gate cur.

DESIGN EQUATIONS :

HW Configuration $RC \geq \frac{1.3}{2} T$

FW Configuration $RC \geq 25T$.

where T is operating time period.

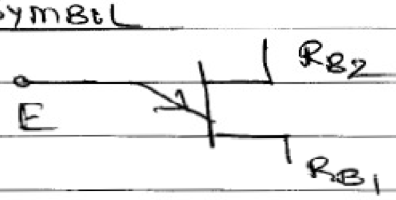
$$R = R_1 + R_2 = \frac{V - V_{GT} - V_r}{I_{gt}} \quad \text{HW Config}$$

$$R = R_1 + R_2 = \frac{V - V_{GT}}{I_{g\,min}} \quad \text{FW Config.}$$

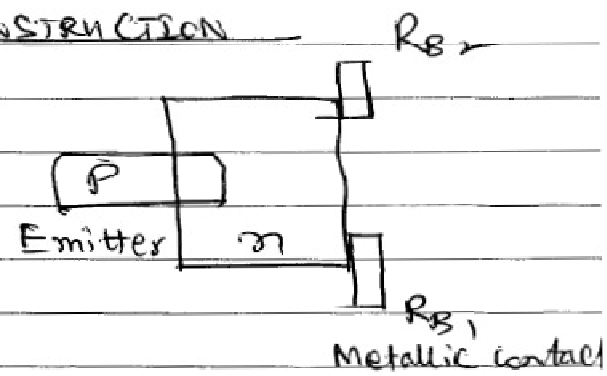
UJT TRIGGERING CKT.

INTRODUCTION TO UJT.

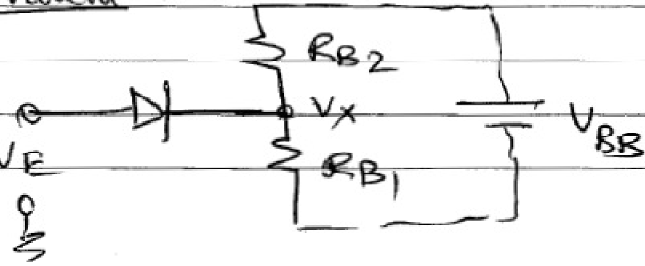
Symbol



CONSTRUCTION



Equivalent :



$$V_x = \frac{R_{B1}}{R_{B1} + R_{B2}} V_{BB}$$

$$V_x = \eta V_{BB} \quad \text{where } \eta = \frac{R_{B1}}{R_{B1}+R_{B2}}$$

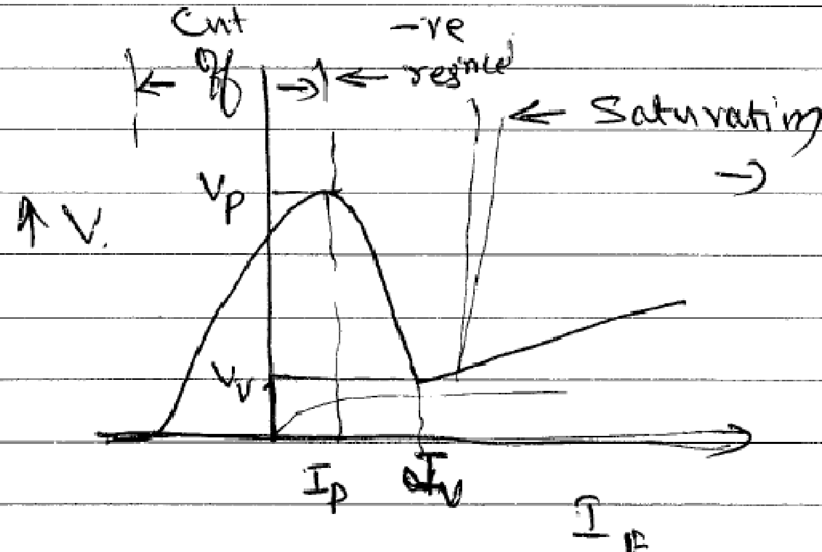
Intrinsic Stand off ratio (η)

η 0.5 to 0.82

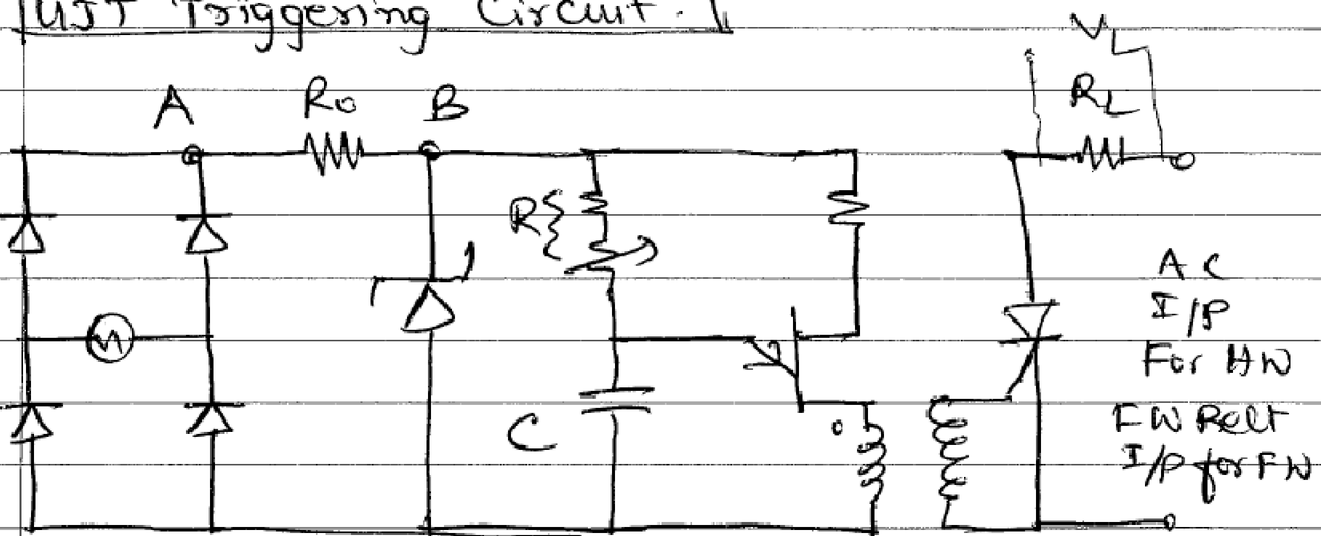
$\therefore$ For UJT to conduct $V_E \geq \eta V_{BB} + V_\gamma$

$$\boxed{V_E \geq V_P}$$

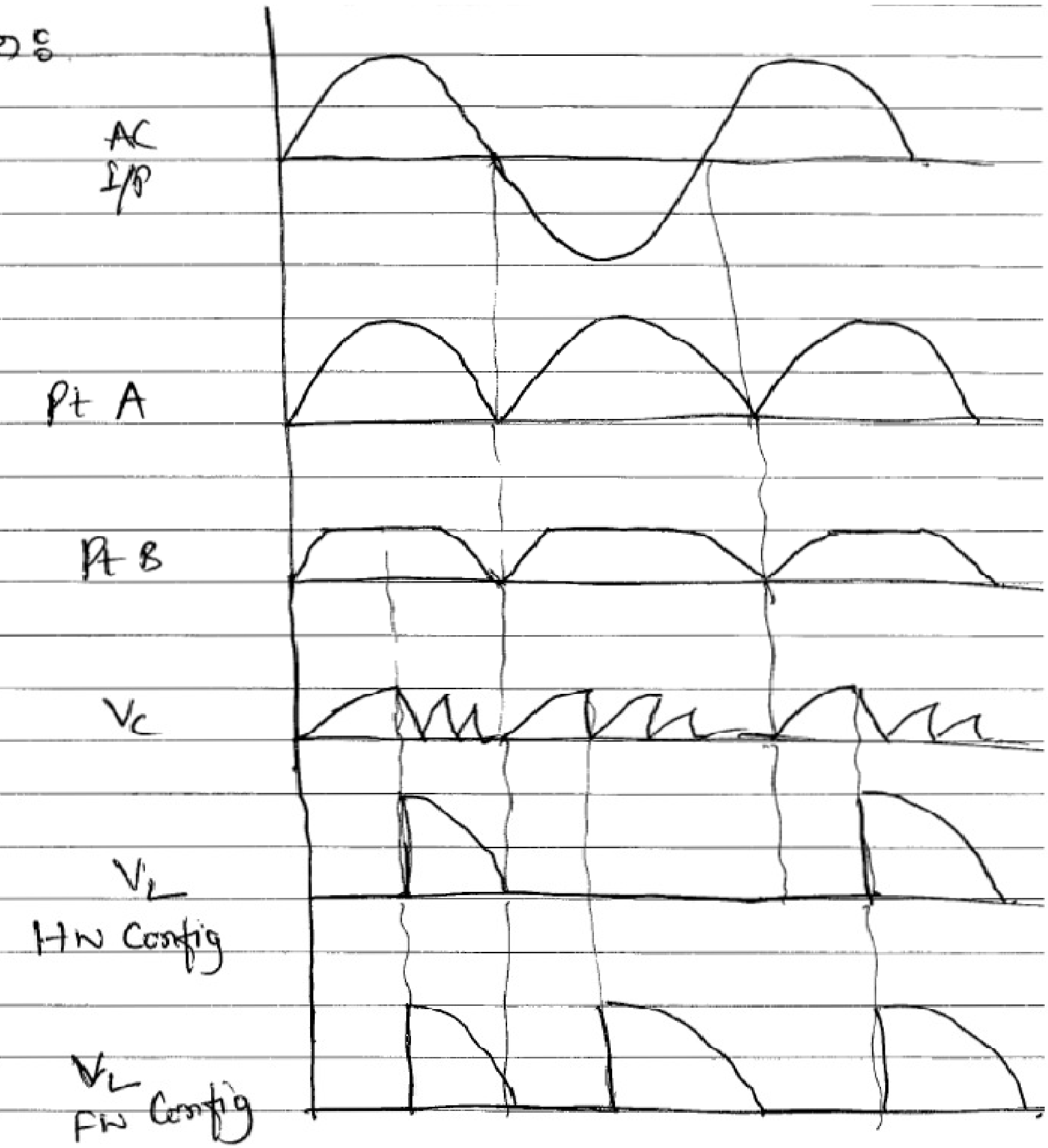
Ch of UJT :



UJT Triggering Circuit



Waveforms:



Working:

1. FW rectifier supplies FW rectified signal to V_Z or Zener.

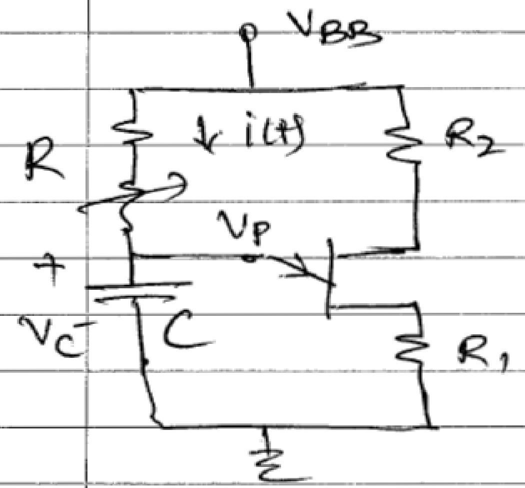
2. Zener diode regulates converts this to Const Volt i/p for RC Ckt for linear Control.

3. Based on RC value Cap charges to V_m

4. As and when $V_C \geq V_p$ the UJT Conducts a trigger through pulse transformer is given to gate of SCR.

5. Based on HW or FW i/p to SCR o/p across load will be Controlled rectified out put.

DESIGN CONSIDERATION



When UJT is off or Cap Charging time

By KVL

$$V_{BB} = i(t) R + \frac{1}{c}\int i(t)\,dt$$

Take Laplace Tfm.

$$\frac{V_{BB}}{S} = \left(R + \frac{1}{CS}\right) I(S)$$

$$\text{or} \quad I(S) = \frac{\frac{V_{BB}}{R}}{\left(S + \frac{1}{RC}\right)}$$

$$\mathcal{L}^{-1} \quad \boxed{i(t) = \frac{V_{BB}}{R} e^{-t/RC}} \quad -(1)$$

At any given time. $V_C = V_{BB} - i(t) R$

$$V_C = V_{BB} - \frac{V_{BB}}{R} e^{-t/RC} * R$$

Rahul

$$\therefore \boxed{v_C = V_{BB}(1 - e^{-t/RC})} \quad -(2)$$

For UJT to Conduct $v_C \geq V_P$ is ηV_{BB}.

$$\therefore V_{BB}(1 - e^{-T/RC}) = \eta V_{BB}.$$

where T is the time of UJT turning on.

$$\therefore \boxed{T = RC \ln \frac{1}{1-\eta}} \quad -(3)$$

Rmax & Rmin Design.

For UJT to be on

$$V_C = V_{BB} - I_P R_{max} \geq V_P.$$

or

$$\boxed{R_{max} \leq \frac{V_{BB} - V_P}{I_P}.} \quad -(4)$$

$$V_C = V_{BB} - I_V R_{min} \leq V_V$$

For UJT to be off

or

$$\boxed{R_{min} \geq \frac{V_{BB} - V_V}{I_V}} \quad -(5)$$

$$\boxed{R_2 = \frac{0.7 (R_{B1} + R_{B2})}{\eta V_{BB}} \text{ or } \frac{10^4}{\eta V_{BB}}.} \quad -(5)$$

Design of R_1 There are three methods

1. $R_1 I_{\text{Leakage}} < V_{g\,min}$
Discharge

$$\therefore R_1 \leq \frac{V_{g\,min}}{I_{discharge}}.$$

2. $V_{BB} = I_{leakage}(R_1 + R_2 + R_{B_1} + R_{B_2})$

or $$R_1 = \frac{V_{BB}}{I_{Leakage}} - R_2 - R_{B_1} - R_{B_2}$$

3. $R_1 C \geq t_g$

or $5R_1 C \geq t_g$ if safety factor is considered.

$t_g =$ gate trigger pulse width.

———o———

Freq of UJT.

$$f_{max} = \frac{1}{T_{min}} = \frac{1}{R_{min} C \ln \frac{1}{1-\eta}}$$

$$f_{min} = \frac{1}{T_{max}} = \frac{1}{R_{max} C \ln \frac{1}{1-\eta}}$$

Firing $\angle$le of UJT $= \omega T = (2\pi f) \times RC \ln \frac{1}{1-\eta}$

PROBLEMS OF TRIGGERIN CKT

Prob (1): In R triggering circuit gate trigger volt required to trigger SCR is $V_{GT} = 0.6V$ and corresponding gate cur is $I_{GT} = 250 \mu A$

The material used for diode is Silicon and input volt is $v = 100 \sin \omega t$ Find firing ∠e if $R_1 = 10 k\Omega$ & $R_2 = 220 k\Omega$

Ans:

$V_\gamma = 0.7V$ as Si diode

$v = I_{GT}(R_1 + R_2) + V_{GT} + V_\gamma$

$= 250 * 10^{-6} (10 + 220) * 10^{3} + 0.6 + 0.7$

$\boxed{v = 58.8V}$

$v = V_m \sin\alpha = 100 \sin\alpha = 58.8$

$\alpha = \sin^{-1} \frac{58.8}{100} = 36.01^\circ$

∴ $\boxed{\text{SCR fires at } 36.01^\circ}$

Prob (2): For the R triggering circuit firing angle required is 60°. If the input is $100 \sin \omega t$ find the value of resistor R_2 when $R_1 = 300 k\Omega$ $V_{GT} = 0.8V$

$I_{GT} = 200 \mu A$ & diode is of Germanium.

Ans: $V_m \sin \omega t = 100 \sin 60^\circ = \boxed{86.6\,V}$

$\therefore\ v = 86.6 = I_{GT}(R_1 + R_2) + V_{GT} + V_\gamma$

$= 200 * 10^{-6}(300 * 10^3 + R_2) + 0.8 + 0.3$

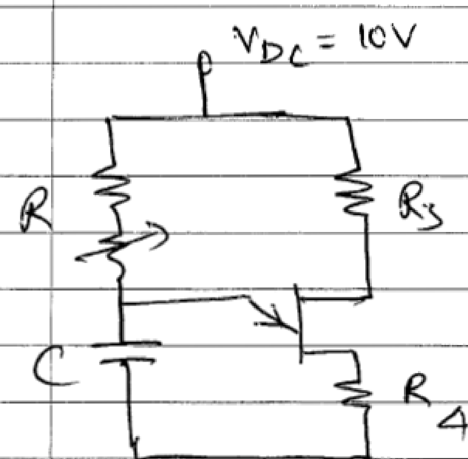
$R_1 + R_2 = 427.5\,k\Omega$

or $\boxed{R_2 = 127.5\,k\Omega}$

or $\underline{200\,k\Omega \text{ Pot}}$.

REFER PPT for more Probs

Prob ③ : A relaxation oscillator is to be designed to generate 2 ~~K~~Hz output. $V_{DC} = 10V$ $\eta = 0.6$, peak discharge curr 5 mA. Neglect discharge time for calculating freq.



Assume $V_\gamma = 0.5\,V$

$V_p = \eta V_{BB} + V_\gamma$

$= 0.6 * 10 + 0.5$

$\boxed{V_p = 6.5\,V.}$

$R_{max} \leq \dfrac{V_{BB} - V_P}{I_P} = \dfrac{10 - 6.5}{5 * 10^{-3}} \leq 700\,\Omega$

Assume $\boxed{C = 0.5 \mu F}$.

$$T = \frac{1}{f} = RC \ln \frac{1}{1-\eta}$$

or $$R = \frac{1}{fC \ln \frac{1}{1-\eta}} = \cancel{2.4\times 10}$$

$$= \frac{1}{2*10^3 * 0.5*10^{-6} \ln \frac{1}{1-0.6}}$$

$$\boxed{R = 1091\ \Omega}$$

<u>Note</u>: Permitted $R_{max} < 700\ \Omega$
this R value is not acceptable.

Let $C = 1 \mu F$.

$$R = \frac{1}{2*10^3 * 1*10^{-6} \ln \frac{1}{1-\eta}} = \boxed{545.7\ \Omega}$$

Now $R < R_{max}$ hence acceptable.

$$R_3 = \frac{10^4}{\eta V_{BB}} = \frac{10^4}{6}\ \Omega$$

— o —

Prob ④ : Design a UJT relaxation oscillator for triggering a thyristor. The UJT has following parameters.

$\eta = 0.72$, $I_P = 60 \mu A$, $V_V = 2.5V$ $I_V : 4 mA$

$V = 15V$ $R_{BB} = 5 k\Omega$ The leakage Cur with emitter open is 1 mA.

The triggering freq is 1 KHz and

$V_{gmin} = 0.3V$. Also find min & max of triggering freq.

Ans: Let $V_\gamma = 0.6V$ and $C = 0.05 \mu F$.

$$R = \frac{T}{C \ln \frac{1}{1-\eta}} = \frac{1 * 10^{-3}}{0.05 * 10^{-6} \ln \frac{1}{1-0.72}}$$

$$\boxed{R = 15.71 k\Omega}$$

$$V_P = \eta V_{BB} + V_\gamma = 0.72 * 15 + 0.6$$

$$\boxed{V_P = 11.4V}$$

$$R_{max} \leq \frac{V_{BB} - V_P}{I_P} \leq \frac{15 - 11.4}{60 * 10^{-6}}$$

$$\leq 60 k\Omega$$

$$R_{min} \geq \frac{V_{BB} - V_V}{I_V} = \frac{15 - 2.5}{4 * 10^{-3}}$$

$$\geq 3.125 \, K\Omega$$

$\therefore \quad R_{min} < R < R_{max}$

$3.125K < 15.71\,K < 60K\Omega$

is satisfied.

$$R_2 = \frac{0.7 (R_{BB})}{\eta V_{BB}} \simeq \frac{10^4}{\eta V_{BB}} = \boxed{925.93\,\Omega}$$

I method

$$\underline{\underline{R_1}} = \frac{V_{BB}}{I_{leakage}} - R_2 - R_{BB}$$

$$= \frac{15}{1 * 10^{-3}} - 925.93 - 5 * 10^3$$

$$\boxed{R_1 \simeq 9\,K\Omega}$$

II method: $\quad R_1 = \frac{V_{gmin}}{I_{leakage}} = \frac{0.3}{1 * 10^{-3}} = \underline{\underline{300\,\Omega}}$

$$f_{min} = \frac{1}{T_{max}} = 261.86 \text{ Hz}$$

$$f_{max} = \frac{1}{T_{min}} = \frac{1}{R_{min} C \ln \frac{1}{1-\eta}} = 5.03\,K\,Hz$$

Prob (5): Design a UJT firing circuit with parameters

$\eta = 0.66$, $I_p = 25\mu A$, $V_v = 2.5V$ $I_V = 10mA$

$V = 25V$. The freq of osc^n is 500Hz and width of triggering pulse is $10\mu s$

Assume $V_\gamma = 0.6V$.

Ans: Let $C = 0.1\mu F$.

$$R = \frac{T}{C \ln \frac{1}{1-\eta}} = \frac{2 * 10^{-3}}{0.1 * 10^{-6} * \ln \frac{1}{1-0.66}}$$

$$\boxed{R = 18.54 \, K\Omega}$$

$$V_p = \eta V_{BB} + V_\gamma = 0.66 * 25 + 0.6 = \boxed{17.1 V}$$

$$R_{max} \leq \frac{V_{BB} - V_p}{I_p} = \frac{25 - 17.1}{25 * 10^{-6}} = \boxed{316 \, K\Omega}$$

$$R_{min} \geq \frac{V_{BB} - V_v}{I_V} = \frac{25 - 2.5}{10 * 10^{-3}} = \boxed{2.25 K\Omega}$$

$\therefore$

$$\boxed{\begin{array}{l} R_{min} < R < R_{max} \\ 2.25 K\Omega < 18.54 K\Omega < 316 K\Omega \end{array}}$$

Hence R & C values are acceptable

Step 2: $R_2 = \dfrac{10^4}{\eta V_{BB}} = \boxed{606.06\ \Omega}$

Step 3: $5R_1C \geq t_g$.

or $R_1 \geq \dfrac{t_0}{5C} = \boxed{20\ \Omega}$

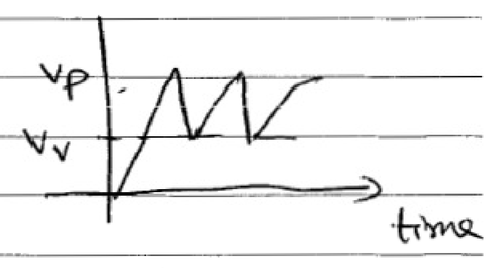
$R_1C \geq t_g$ would result $\boxed{R_1 = 100\ \Omega}$

Prob ⑥ VTU Apr 99 ; Apr 96.

A Cap used in UJT oscr circuit is charged by Const Cur Source. The value of the Cap is 0.5 μF and that of the Const Cur is 1 mA. The saw tooth volt of oscillator is found to have crest value of 8.5V and valley level of 2.5V. Calculate freq of oscillator.

Ans: Given $C = 0.5\ \mu F$ $i_c = 1\ mA$ $V_p = 8.5V$ $V_v = 2.5V$

$$V_c = V_p = \frac{1}{C}\int_0^T i(t)\,dt + V_{c0^-}$$



$$= \frac{1}{C}\, i_{Const}\int_0^T dt + V_v$$

Cap Chargings

As $i(t)$ is Const Charging Cur. V_v is the initial Volt on Capacitor

$$\therefore \quad 8.5 = \frac{1 * 10^{-3}}{0.5 * 10^{-6}} * T + 2.5$$

$$\boxed{T = 3 * 10^{-3} \text{ Sec}}$$

$$\text{or} \quad f = \frac{1}{T} = \boxed{\frac{1}{3} \text{ KHz}}$$

—o—

Prob (7) : Sep oct 1998 :

A UJT trigger circuit is used to fire a PNPN device. It is supplied from a source across the SCR to be triggered thr' a 10V Zener. valley and peak volt are 1V and 7V respectively. Calculate intrinsic stand of ratio and freq of oscillator if R = 1 KΩ C = 1 μF.

Assume $V_\gamma = 0.8V$

Ans : $V_p = \eta V_{BB} + V_\gamma$

$$\therefore \eta = \frac{V_p - V_\gamma}{V_{BB}} = \frac{7 - 0.8}{10} = \boxed{0.62}$$

$$f = \frac{1}{RC \ln \frac{1}{1-\eta}} = \boxed{1.033 \text{ KHz}}$$

Sham21

Mar 98 10 Mks

Prob (8): An SCR is to be triggered with UJT trig ckt where $\eta = 0.7$, $I_p = 2\mu A$, $V_p = 16.5V$

Normal leakage cur with emitter open is 3 mA

$V_v = 1V$ $I_v = 6 mA$, $R_{B_1 B_2} = 5.5 K\Omega$

Triggering freq is 100 Hz. Design the circuit with $C = 0.1\mu F$; let $V_\gamma = 0.7 V$.

Ans: $$R = \frac{1}{f\, C \ln \frac{1}{1-\eta}} = \boxed{83.05 K\Omega}$$

$V_p = \eta V_{BB} + V_\gamma$ $\boxed{V_{BB} = 22.57}$

$$R_{max} \leq \frac{V_{BB} - V_p}{I_p} = \boxed{7.78 M\Omega}$$

$$R_{min} \geq \frac{V_{BB} - V_v}{I_v} = \boxed{3.595 K\Omega}$$

$\therefore$ $$\boxed{\begin{array}{l} R_{min} < R < R_{max} \\ 3.595 K < 83.05 K < 7.78 M\Omega \end{array}}$$

$\therefore$ R & C acceptable.

$$R_2 = \frac{10^4}{\eta V_{BB}} = \boxed{633 \Omega}$$

$$R_1 = \frac{V_{BB}}{I_{leakage}} - R_2 - R_{BB} = \boxed{1.39 K\Omega}$$

Prob (9): Design a UJT relaxation oscillator for a single phase controlled converter fed from 50 Hz mains. Use 2N 2646 UJT whose parameters at Junction temperature of 25°C are as under. Max value of V_{BB} = 35V Max average power dissipation = 300 mW. Range of R_{BB} 4.7 kΩ to 9.1 kΩ (typical value is 5.6 kΩ at V_{BB} = 12V) Valley point Cur 4 mA

$\eta = 0.56$ to 0.75 with typical value of 0.63 V_D = 0.5 V valley volt is 2V peak point Cur I_p = 5 μA Max volt which will not trigger SCR is 0.18V

Ans: Given $V_{BB} = 12V$, $R_{BB} = 5.6\,k\Omega$ $V_D = 0.5V$
$V_v = 2V$, $I_v = 4\,mA$, $I_p = 5\,\mu A$
$\eta = 0.63$ $V_{trig} = 0.18V$.

Design:

$$V_p = \eta V_{BB} + V_\gamma = 0.63 * 12 + 0.5 = \boxed{8.06\,V}$$

$$R_{max} \leq \frac{V_{BB} - V_p}{I_p} = \frac{12 - 8.06}{5 * 10^{-6}} = \boxed{788\,k\Omega}$$

$$R_{min} \geq \frac{V_{BB} - V_V}{I_V} = \frac{12 - 2}{4 * 10^{-3}} \geq \boxed{2.5\,k\Omega}$$

Assume $\boxed{C = 0.02\,\mu F}$

$$R = \frac{1}{f C \ln \frac{1}{1-\eta}} = 1005.78\ k\Omega$$

$R > R_{max}$.

$\therefore$ Let $C = 0.04\ \mu F$.

$$R = \frac{1}{f C \ln \frac{1}{1-\eta}} = \boxed{502.89\ k\Omega}$$

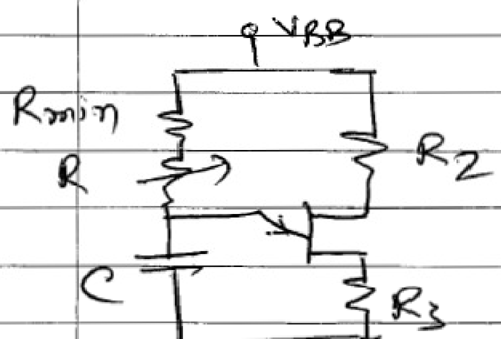
$\therefore$ $R_{min} < R < R_{max}$ or $2.5k < 502k < 788k$

Hence R & C is acceptable.

Here $R_{TOT} = R_{min} + R = 502.89K + 2.5K$
$= 505.3 K\Omega < R_{max}$

(*) $R_2 = \frac{10^4}{\eta V_{BB}} = \boxed{1.32 * 10^3\ \Omega}$

Note: when emitter open drop across R_3 should not trigger SCR.



$\therefore$ $\frac{V_{BB} * R_3}{R_2 + R_3 + R_{BB}} < V_{trig}$.

or $R_3 < \frac{V_{trig}(R_2 + R_{BB})}{(V_{BB} - V_{trig})}$

$\boxed{R_3 < 103\ \Omega}$

Minimum & Max firing $\angle$le.

$$T_{min} = R_{min} C \ln \frac{1}{1-\eta}$$

$$T_{min} = 0.0994 * 10^{-3} \text{ secs.}$$

Supply volt is 50 Hz or $T = 20$ m sec.

$\therefore$ $\angle$le in degrees / m.sec $= \frac{360}{20 * 10^{-3}}$

$\therefore$ $\angle$le for $T_{min} = 0.0994 * 10^{-3} * \frac{360}{20 * 10^{-3}}$

or $0.994 * 18^{\circ} = \boxed{1.79^{\circ}}$

As $\angle$le $= 18^{\circ}$/ msec.

$$T_{max} = R_{max} C \ln \frac{1}{1-\eta} = 19.98 \text{ m secs}$$

$\therefore$ Max $\angle$le $= 19.98 * 18^{\circ} = \boxed{359.7^{\circ}}$

Prob (10) A UJT is connected across a 20V DC supply. The valley volt and peak volt are 1V and 15V respectively. The period of UJT relaxation oscillator is 20 m sec. Find values of charging cap if charging resistor is 100 KΩ. Assume $V_{\gamma} = 0.8V$

8/10/21

VTU E&E 95 : 8 mks

$V_p = \eta V_{BB} + V_\gamma$ ∴ $\eta = \dfrac{V_p - V_\gamma}{V_{BB}}$

$\eta = \dfrac{15 - 0.8}{20} = \boxed{0.71}$

$C = \dfrac{1}{TR \ln \frac{1}{1-\eta}} = \boxed{0.162\,\mu F}$

—o—

E&C Mar 98 8 mks. VTU.

Prob (11): A UJT is used to trigger the thyristor whose min gate triggering voltage is 6.2V $\eta = 0.66$ $I_p = 0.5\,mA$ $I_v = 3\,mA$

$R_{B_1} + R_{B_2} = 5\,K\Omega$ $I_{leakage} = 3.2\,mA$.

$V_p = 14\,V$ $V_v = 1\,V$. osc^n freq = 2 kHz.

$C = 0.04\,\mu F$ Design the Ckt.

Ans: $T = \dfrac{1}{RC \ln \frac{1}{1-\eta}} = \boxed{11.6\,K\Omega}$

$R_{max} \le \dfrac{V_{BB} - V_P}{I_P} = 12\,K\Omega$

$R_{min} \ge \dfrac{V_{BB} - V_V}{I_V} = 6.33\,K\Omega$

$$R_2 = \frac{0.7\,(R_{B_1} + R_{B2})}{\eta V_{BB}} = \boxed{265\,\Omega}$$

$$V_{BB} = I_{leakage}\,(R_1 + R_2 + R_{B_1} + R_{B_2})$$

$$R_1 = \frac{V_{BB}}{I_{leakage}} - R_2 - R_{B_1} - R_{B_2}$$

$$\boxed{R_1 = 985\,\Omega}$$

Prob (12) : Aug 95 8mks

Design the UJT ckt for SCR with $V_{BB} = 20V$ $\eta = 0.6$, $I_p = 10\mu A$, $V_v = 2V$

$I_v = 10mA$ freq $= 100Hz$ triggering Pulse width $= 50\mu$ sec

Assume $C = 1\mu F$. $V_\gamma = 0.7V$

$$R = \frac{1}{TC \ln \frac{1}{1-\eta}} = \boxed{10.91\,K\Omega}$$

$$R_{max} \le \frac{V_{BB} - V_P}{I_P} = \frac{20 - 12.7}{10 * 10^{-6}} = \boxed{0.73M\Omega}$$

$$V_p = \eta V_{BB} + V_\gamma = 0.6 * 20 + 0.7 = 12.7V$$

$$R_{min} \geq \frac{V_{BB} - V_V}{I_V} = \frac{20 - 2}{10 * 10^{-3}} = \boxed{1.8\ K\Omega}$$

$$R_2 = \frac{10^4}{\eta V_{BB}} = \boxed{833.3\ \Omega}$$

$$R_1 C \geq t_g \quad \text{or} \quad R_1 \geq \frac{50 * 10^{-6}}{1 * 10^{-6}} = \boxed{50\,\Omega}$$

$$\text{or} \quad 5 R_1 C \geq t_g \quad \text{or} \quad \boxed{R_1 \geq 10\ \Omega}$$

—o—