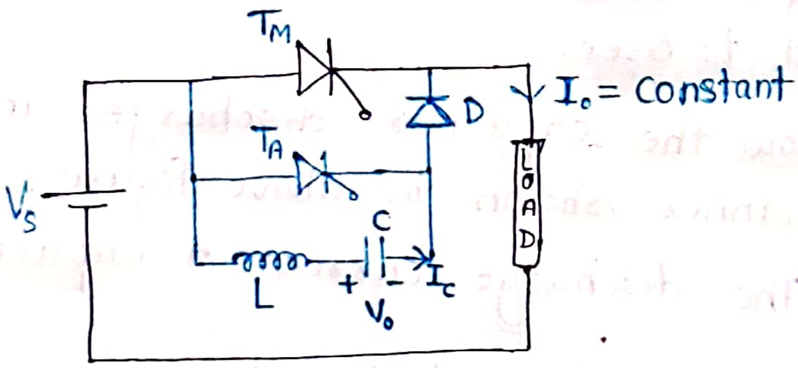
Forced Commutation.

- Forced commutation circuits are very important from competition point of view, where questions are asked for finding.
  - ↳ conduction time of thyristors.
  - ↳ turn-off time of thyristors.
  - ↳ Circuit turn-off time of thyristors.
  - ↳ peak value of current through thyristor etc.

- So, while studying these topics, pay special attention to above mentioned questions.

(a) Resonant-Pulse Commutation or Current Commutation or Class-B commutation.



Assumptions :-

1) load current is assumed to remain constant at I_o. (i.e. Load is highly inductive).

2). Capacitor is initially charged with V_s volts as shown in above figure.

3). Before $t = 0$ sec., T_M is in ON state and $I_M = I_o$.

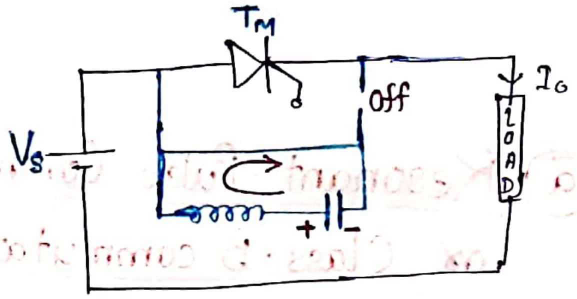
In the above circuit,

- T_M → Main thyristor, which needs to be commutated.
- T_A → Auxiliary thyristor, which helps in commutation of T_M.
- D → Diode.

→ Operation of the circuit can be understood in 3-Steps.

<u>Step 1</u> :- At t = 0 sec. T_A is turned-on, in order to initiate commutation of T_M.

- capacitor has initial voltage V_s, in such a manner that it forward biases T_A.



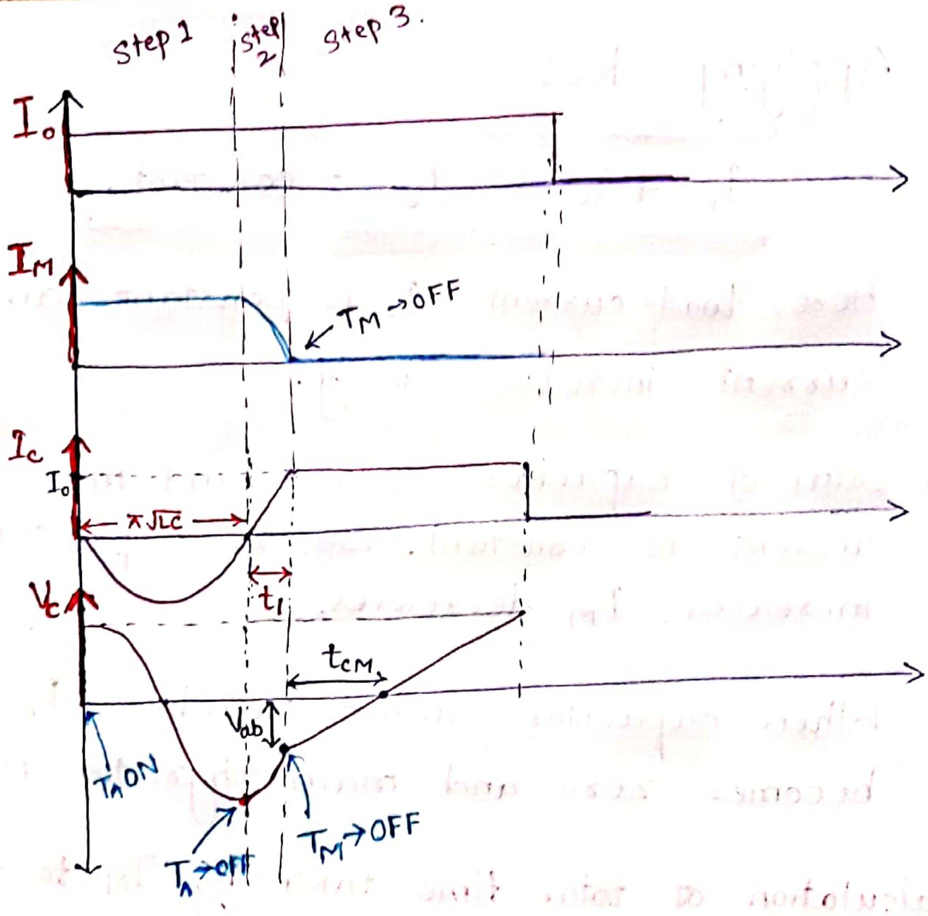
- T_A is turned on at t = 0 sec.
- Now the capacitor discharges in the manner shown in above figure.
- The discharge current of capacitor is given by

$$I_c = -I_p \sin \omega_0 t$$

I_p → peak current

I_c → instantaneous value of discharge current.

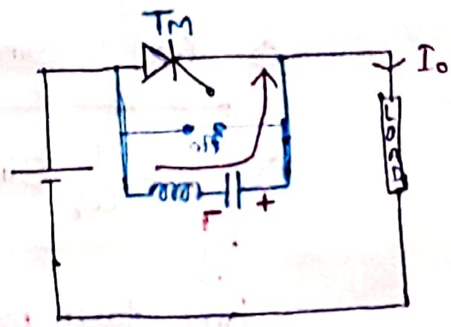
- When discharge current decays to zero, the capacitor voltage reverses its polarity.



- Capacitor voltage is cosine when I_c is Sine function.
- At end of ~~mod~~ step 1, capacitor polarity reverses and T_A turns off.
  ↳ at $\omega_0 t_0 = \pi$

Step 2 :- T_A turns-off and diode D turns-on.

- Capacitor polarity has reversed. So, when T_A turns-off, capacitor voltage applies a forward bias across the diode. So, diode ~~cu~~ turns on.



- Now, the capacitor current increases from zero to I_0. (See the waveform for step-2.)

Applying KCL,

$$I_M + I_c = I_o = \text{constant}.$$

- Here, load current I_o is constant and capacitor current increases slowly.
- Sum of capacitor current and main thyristor current is constant. So, as capacitor current increases, I_M decreases.
- When capacitor current reaches I_o, then I_M becomes zero and main thyristor is turned off.

Calculation of total time taken by T_M to turn-off

- Let time taken by capacitor current to reach I_o after t_o time be t_1. (Shown in waveform).
- T_M is off when $I_c = I_o$

$$\Rightarrow I_p \sin \omega_o t_1 = I_o$$

$(\because I_c = I_p \sin \omega_o t)$

$\left(I_p = V\sqrt{\frac{C}{L}}\right)$ → peak current

$$\Rightarrow \sin \omega_o t_1 = \frac{I_o}{I_p}$$

$\left(\omega_o = \sqrt{LC}\right)$ → resonant angular freq.

$$\Rightarrow \omega_o t_1 = \sin^{-1}\left(\frac{I_o}{I_p}\right)$$

$$\Rightarrow \boxed{t_1 = \frac{1}{\omega_o}\sin^{-1}\left(\frac{I_o}{I_p}\right)} \Rightarrow \boxed{t_1 = \sqrt{LC}\,\sin^{-1}\left(\frac{I_o}{I_p}\right)}$$

↓ time taken by T_M to switch-off after t_o sec.

So, total time taken by T_M to turn-off from the instant T_A is turned-on at $t=0$

$$= t_o + t_1 = \pi\sqrt{LC} + \sqrt{LC}\,\sin^{-1}\left(\frac{I_o}{I_p}\right)$$

Important

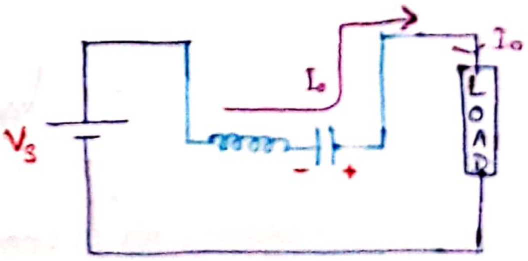
∵ Total time taken by T_M to turn off

$$= \pi\sqrt{LC} + \sqrt{LC}\,\sin^{-1}\left(\frac{I_o}{I_p}\right)$$

- Conduction time of auxiliary thyristor, $T_A = t_o = \pi\sqrt{LC}$
- Peak value of current through auxiliary thyristor $= I_p = V_s\sqrt{\frac{C}{L}}$
- Peak value of current through main thyristor $= I_o$

Step 3 :- T_M is already turned off, but we need to maintain reverse bias voltage across it to enable blocking capability. This reverse bias voltage is maintained in step 3.

- When $I_c = I_o$, T_M has turned off.



- Now, capacitor current I_c remains constant, till the capacitor charges to $+V_s$.

- Now capacitor current is no longer sinusoidal. Load is suppressing it and maintaining constant current I_o.

→ **To Find Circuit-turn-off time of T_M :-**

Capacitor voltage is, $V_c = \frac{1}{C}\int I_o\,dt$

I_o = constant.

Circuit turn-off time is the duration for which reverse bias voltage is applied across the thyristor, to enable it to regain blocking capability.

- In the waveform, t_{cM} represents the circuit turn-off time of main thyristor T_M.
- In the waveform, the value of reverse voltage which appears across the T_M, when it gets turned-off is V_{ab}.

Now, putting the values in the expression for capacitor voltage:

$$V_c = V_{ab} = \frac{1}{C}\int I_o\,dt$$

$$\Rightarrow V_{ab} = \frac{I_o}{C}.t_{cM}$$

$$\Rightarrow \boxed{t_{cM} = \frac{V_{ab}.C}{I_o}}$$

Imp

- Finding value of V_{ab}.
  - Capacitor voltage is a cosine function.
  - V_{ab} is capacitor voltage at time t_1.

$$\because V_{ab} = V_c$$

$$= V_s \cos \omega_o t_1$$

$$\boxed{V_{ab} = V_s.\cos\left\{\sin^{-1}\left(\frac{I_o}{I_p}\right)\right\}}$$

$\because \omega_o t_1 = \sin^{-1}\frac{I_o}{I_p}$ and $I_p = V_s\sqrt{\frac{C}{L}}$

$\therefore$ $$t_{cM} = V_{ab} \cdot \frac{C}{I_o}$$

$$V_{ab} = V_s \cdot \cos\left(\sin^{-1}\frac{I_o}{I_p}\right)$$

$$I_p = V_s\sqrt{\frac{C}{L}}$$

$$\omega_o t_1 = \sin^{-1}\frac{I_o}{I_p}$$