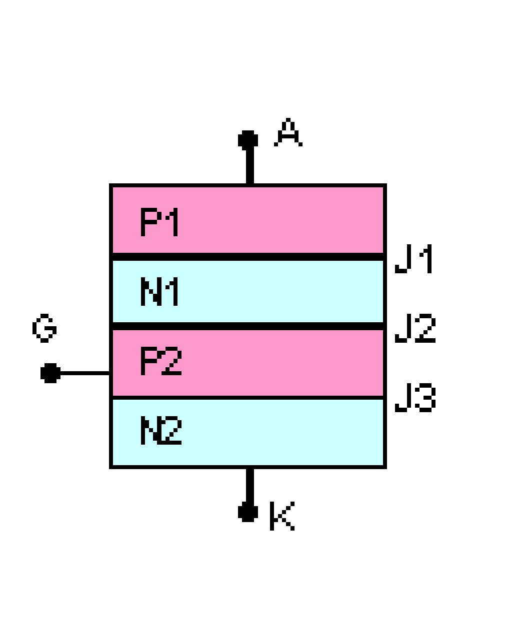
Thyristor Characteristics, Two Transistor Model Of Thyristor & Thyrisror Turn On And Off.

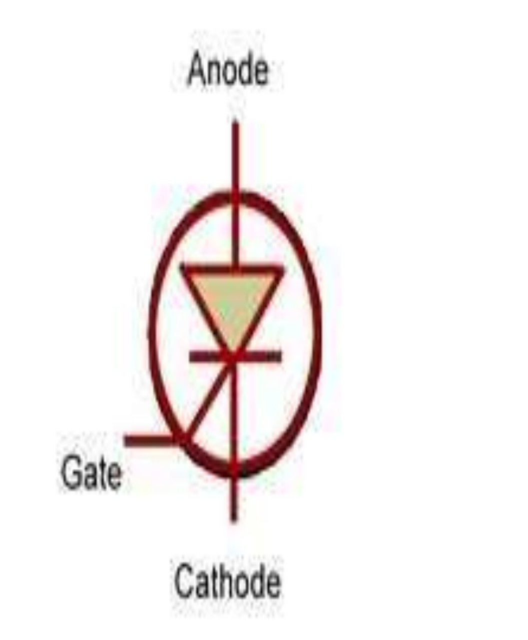
Thyristor Characteristics.

- A thyristor is a four layer, semiconductor device of p-n-p-n structure with three p-n junctions J1, J2 & J3 respectively.
- It has three terminals, the anode, cathode and the gate.

Simplified Model Of SCR



SCR Symbol



CONTI…..

Forward blocking or off state condition.

- Anode voltage is made +ve w.r.t. cathode, the junctions j1 & j3 are forward biased.
- Junction j2 becomes reverse biased & only small leakage current flows.
- The SCR is then said to be in the forward blocking or off state.

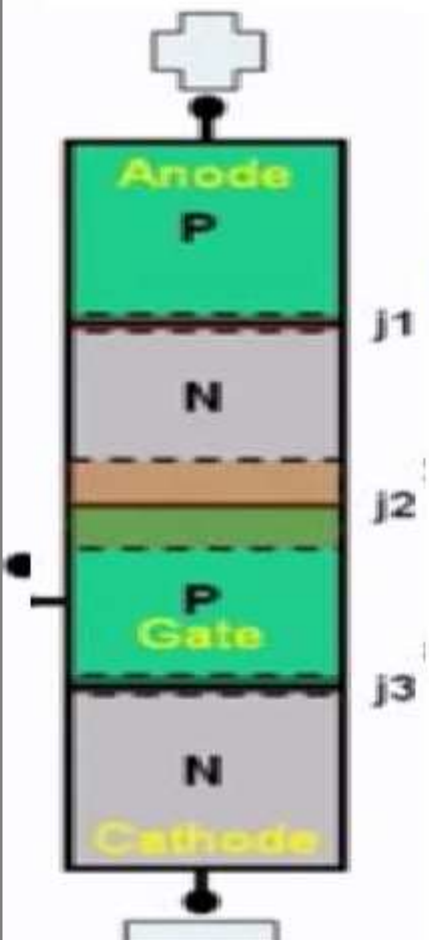
Forward breakdown voltage V_{bo}.

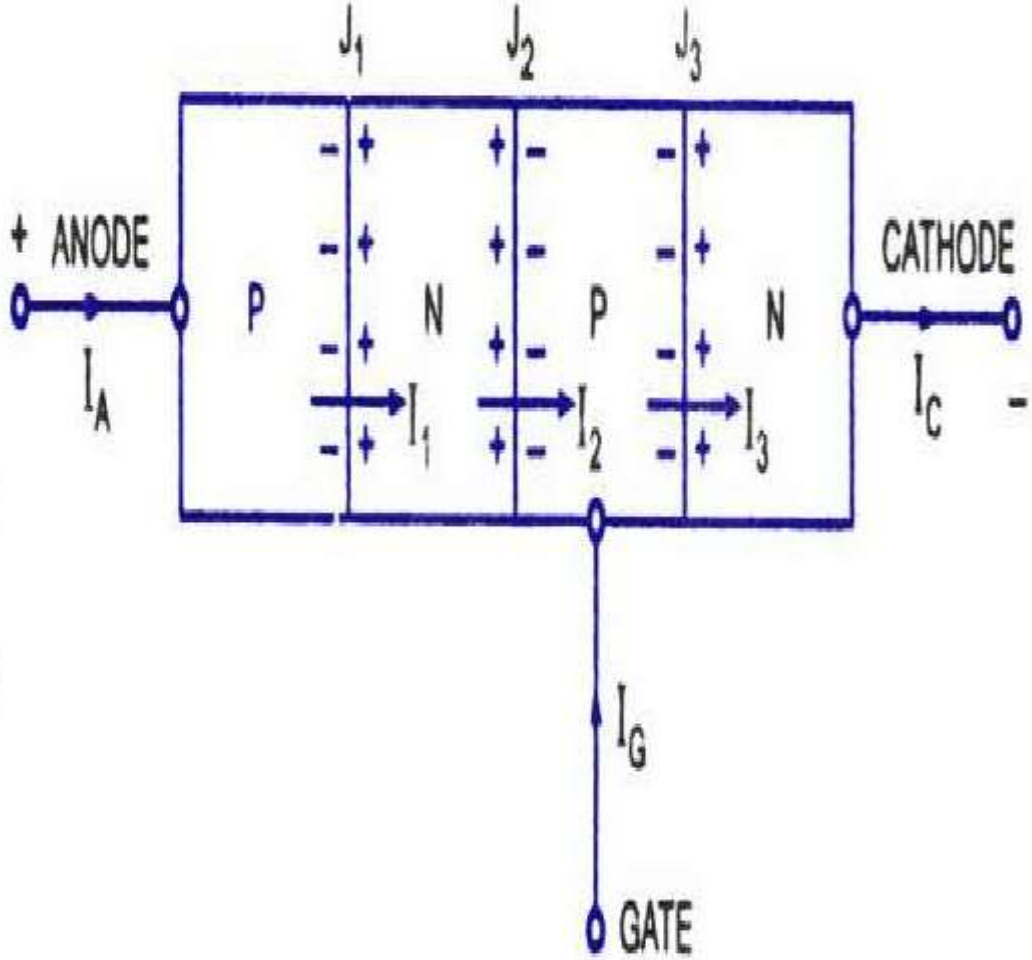
- If V_{ak} is further increased j2 will breakdown due to avalanche effect resulting in a large current through the device.
- The corresponding voltage is called the forward breakdown voltage V_{bo}.
- Now, the device is in forward conduction or ON state.

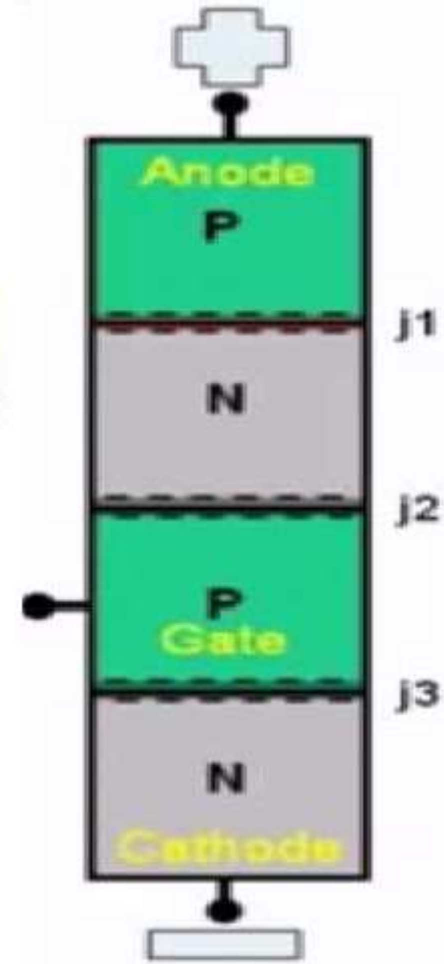
CONTI.....

Forward blocking or off state condition.

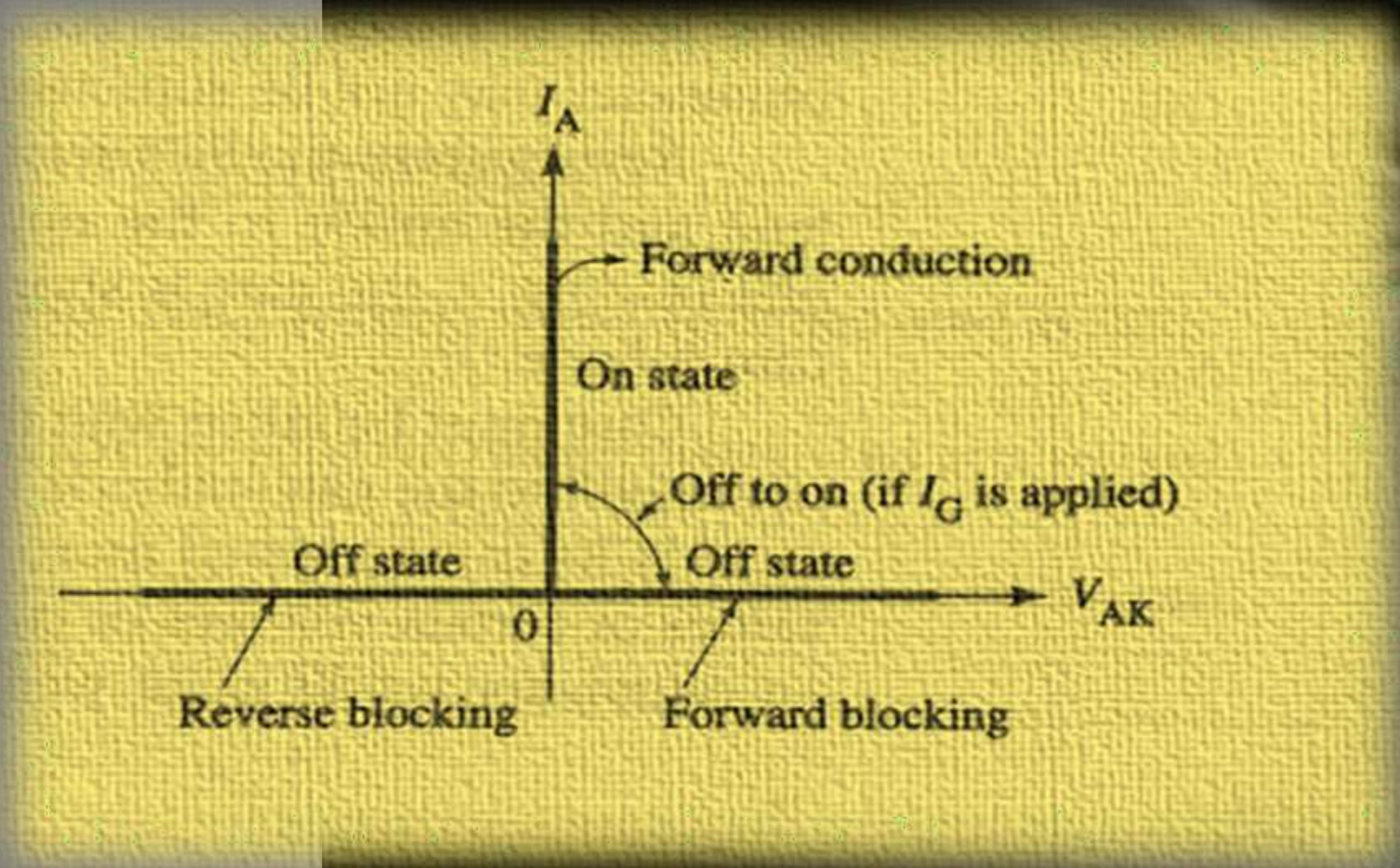
Forward breakdown voltage







Ideal Characteristic Of SCR



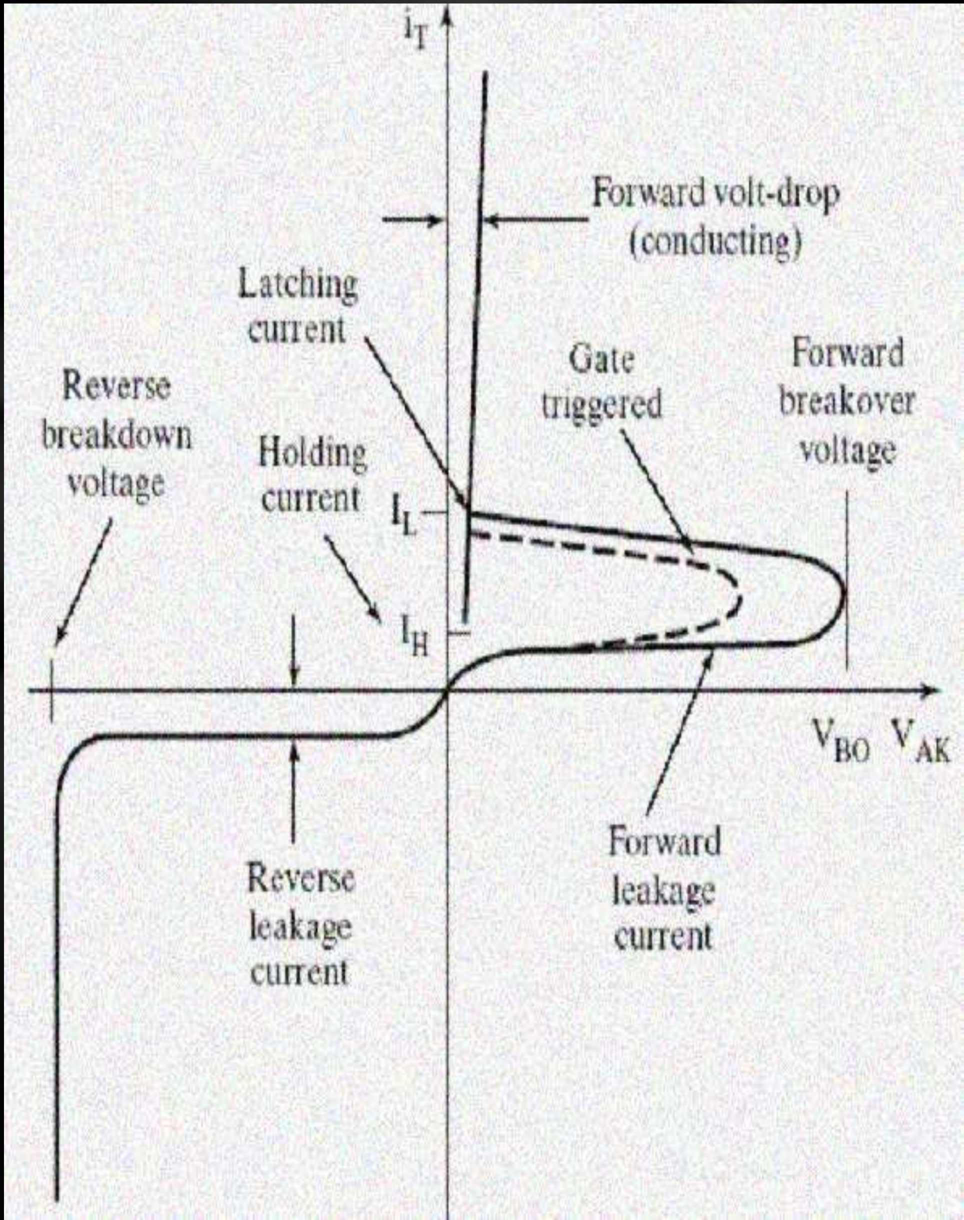
V-I Characteristics

Latching Current IL

- After the SCR has switched on, there is a minimum current required to sustain conduction.
- This current is called the latching current IL.
- Usually IL is associated with turn ON of the device.

Holding Current IH

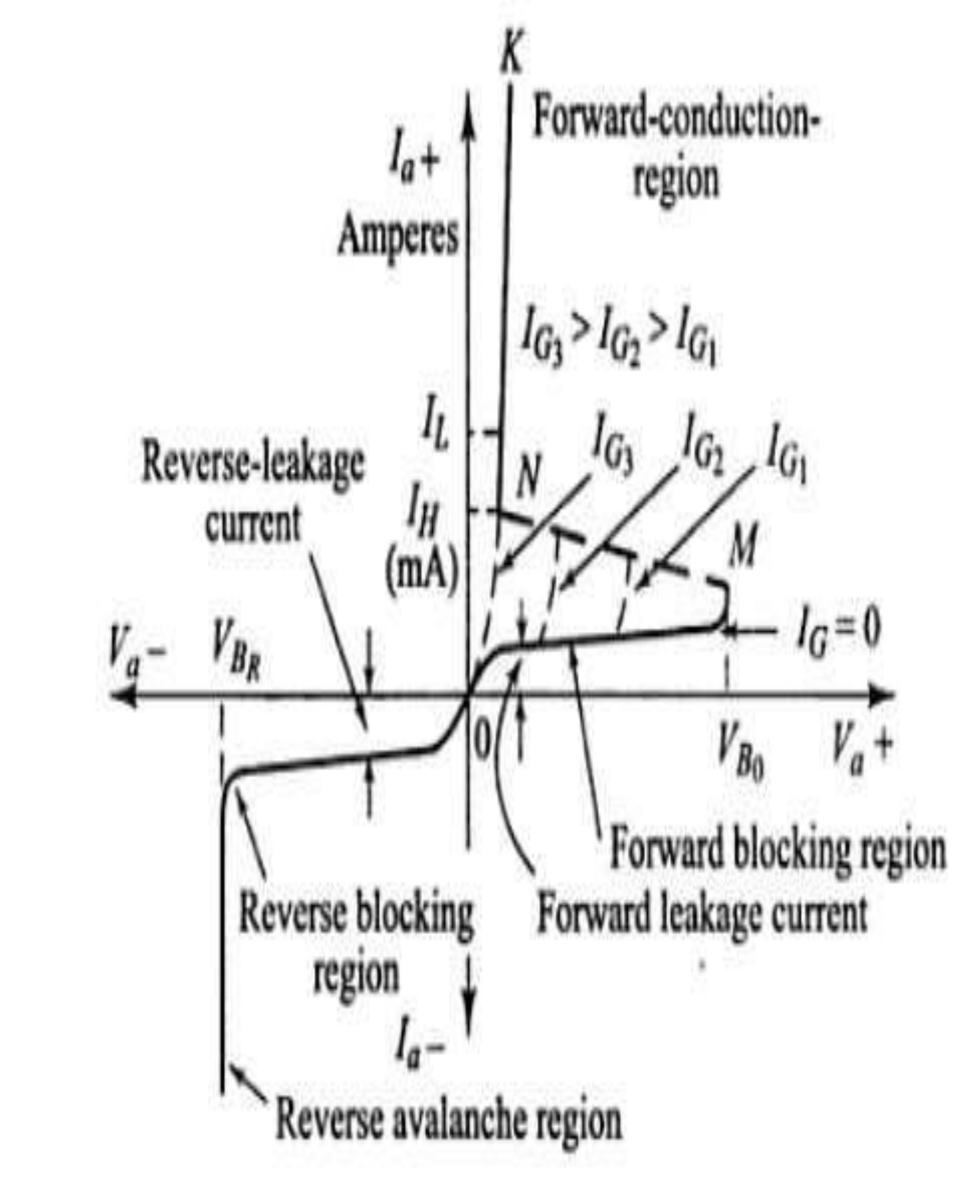
- SCR returns in its orignal off state if anode current falls below low level called holding current IH.
- So, holding current IH is minimum anode current to maintain thyristor in on state.
- Usually IH is associated with turn off of the device.



V-I Characteristics

Effects of gate current on Vbo.

- If gate signal is applied, the thyristor turn on before Vbo is reached.
- So, forward voltage depends upon magnitude of gate current.
- Higher the gate current lower the forward breakover voltage.
- The typical gate current magnitudes are of order of 20 to 200mA.

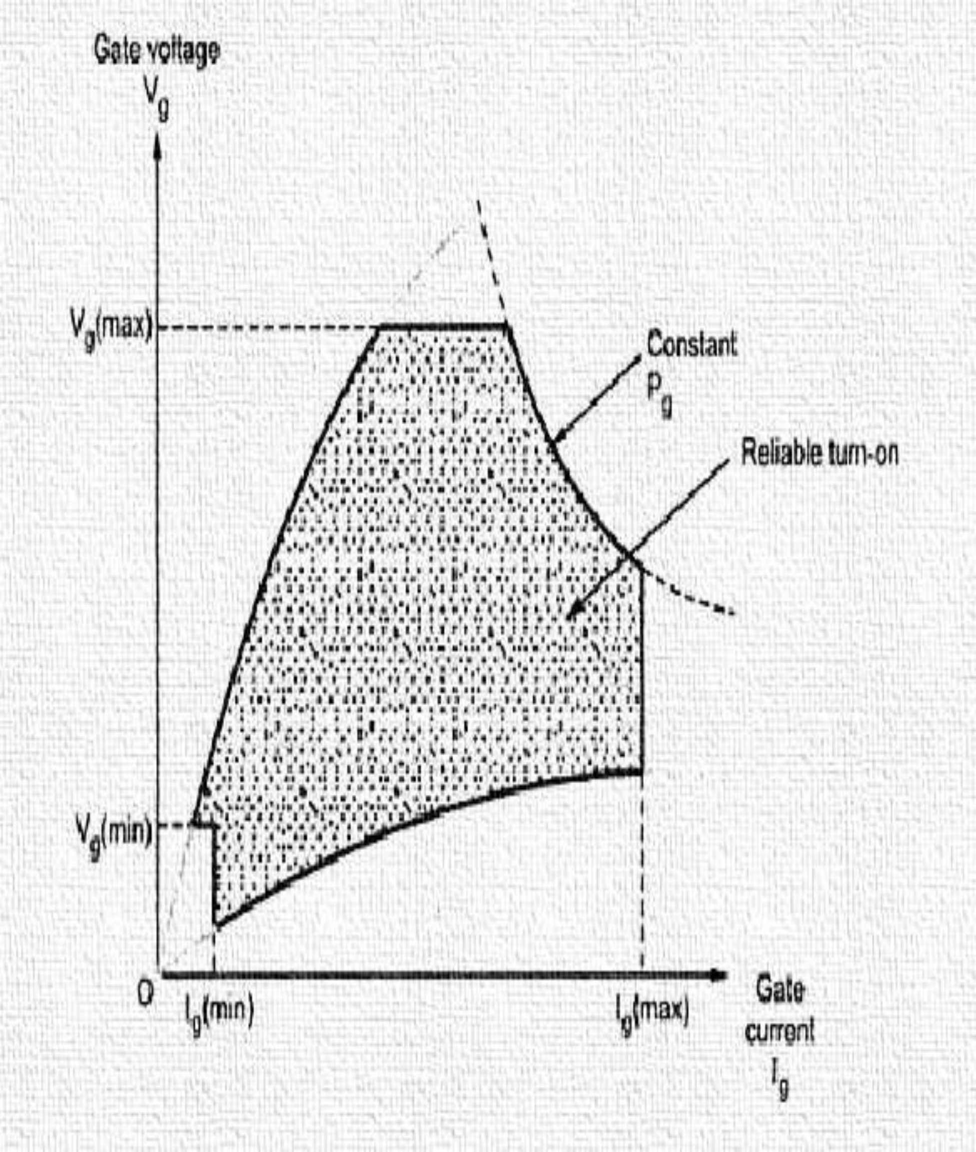


Thyristor Gate Characteristics

- Ig(max) and Vg(max) are the maximum gate current and voltages that can flow through the thyristor without damaging it .
- Vg (min) and Ig(min) are minimum gate voltage and current, below which thyristor will not be turned-on.
- Hence to turn-on the thyristor successfully

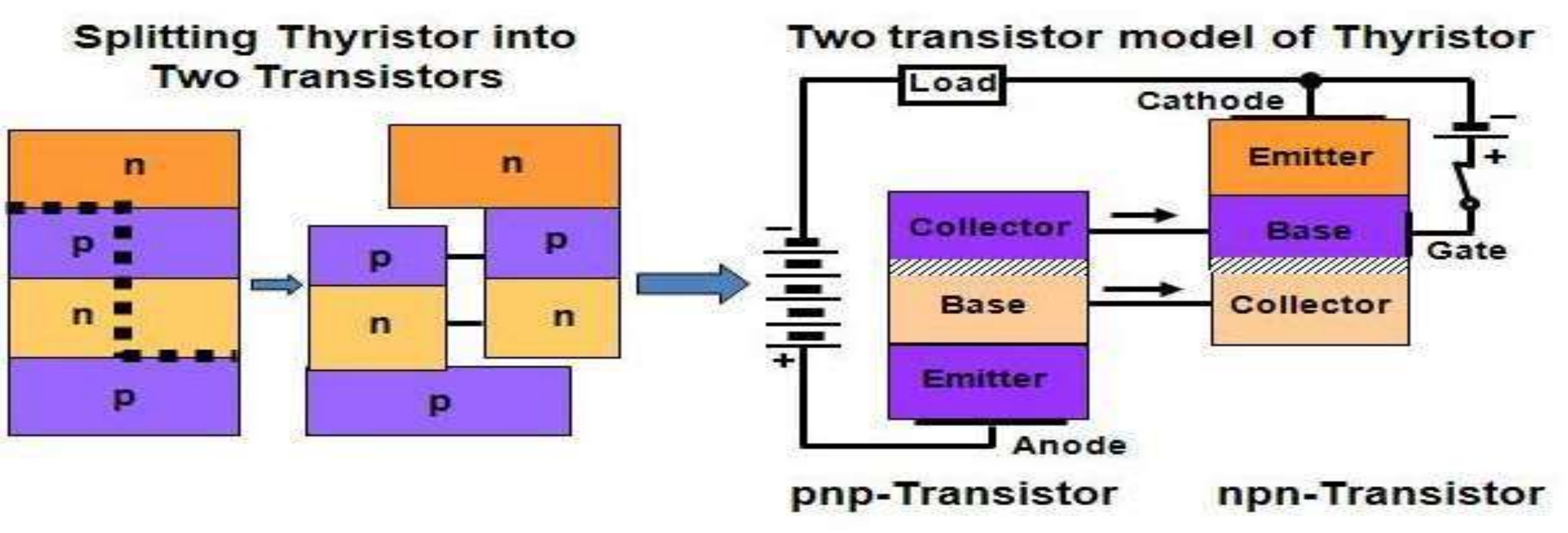
$$I_g(min) < I_g < I_g(max)$$

$$V_g(min) < V_g < V_g(max)$$



Two Transistor Model Of Thyristor

- The operation of thyristor can also be explained in a simple way by two transistor analogy.
- One transister is pnp and second is npn.
- The collector of one is attached with base of other & vice versa.



CONTI.....

As from fig.b

Derivation for anode current

General transistor equation is

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

For transistor 1

General transistor equation is

$I_C = \alpha I_E + I_{CBO}$ $I_{E_1} = I_A$

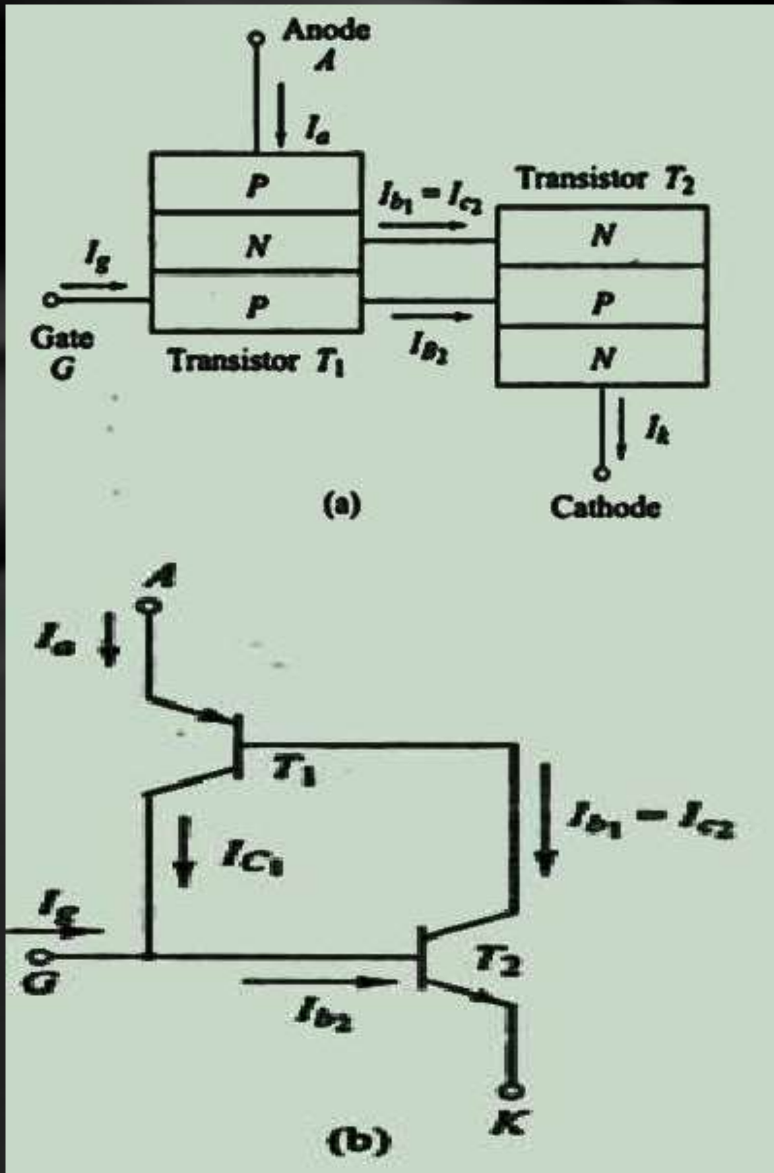
For transistor 2

$I_{C2} = \alpha_2 I_{E_2} + I_{CBO_2}$;

$I_{E_2} = I_K$ and $I_K = I_A + I_G$

There fore There fore

$I_A = I_{C_1} + I_{C_2}$ $I_A = I_{C_1} + I_{C_2}$

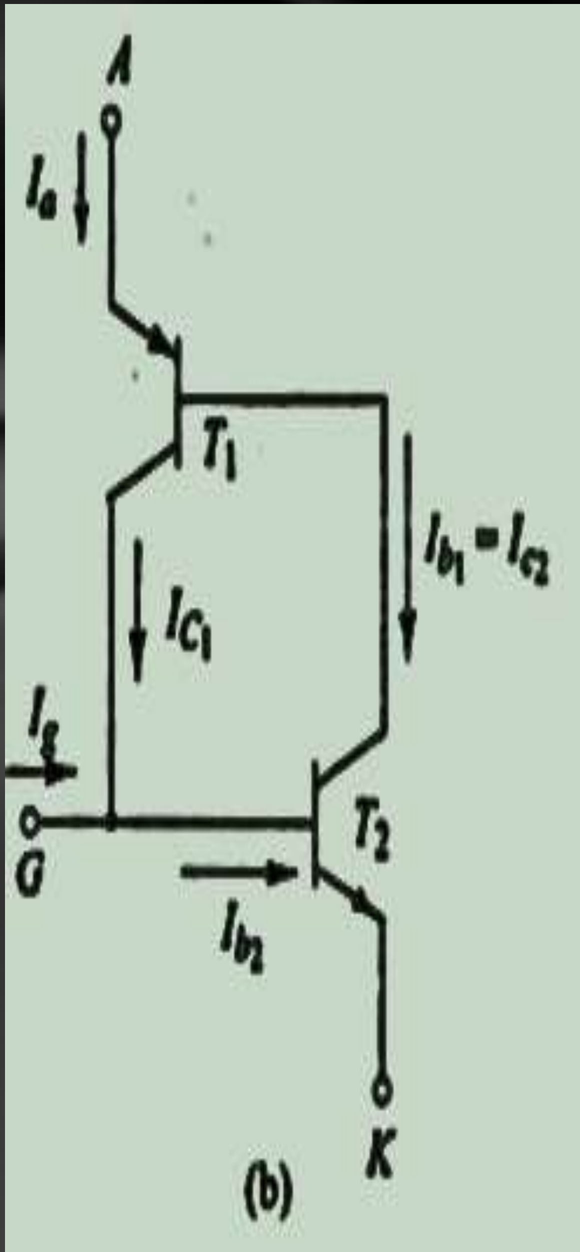


CONTI…..

$I_A = \alpha_1 I_A + I_{CBO_1} + \alpha_2 (I_A + I_G) + I_{CBO_2}$

$$\therefore \qquad I_{C_2} = I_{B_1}$$

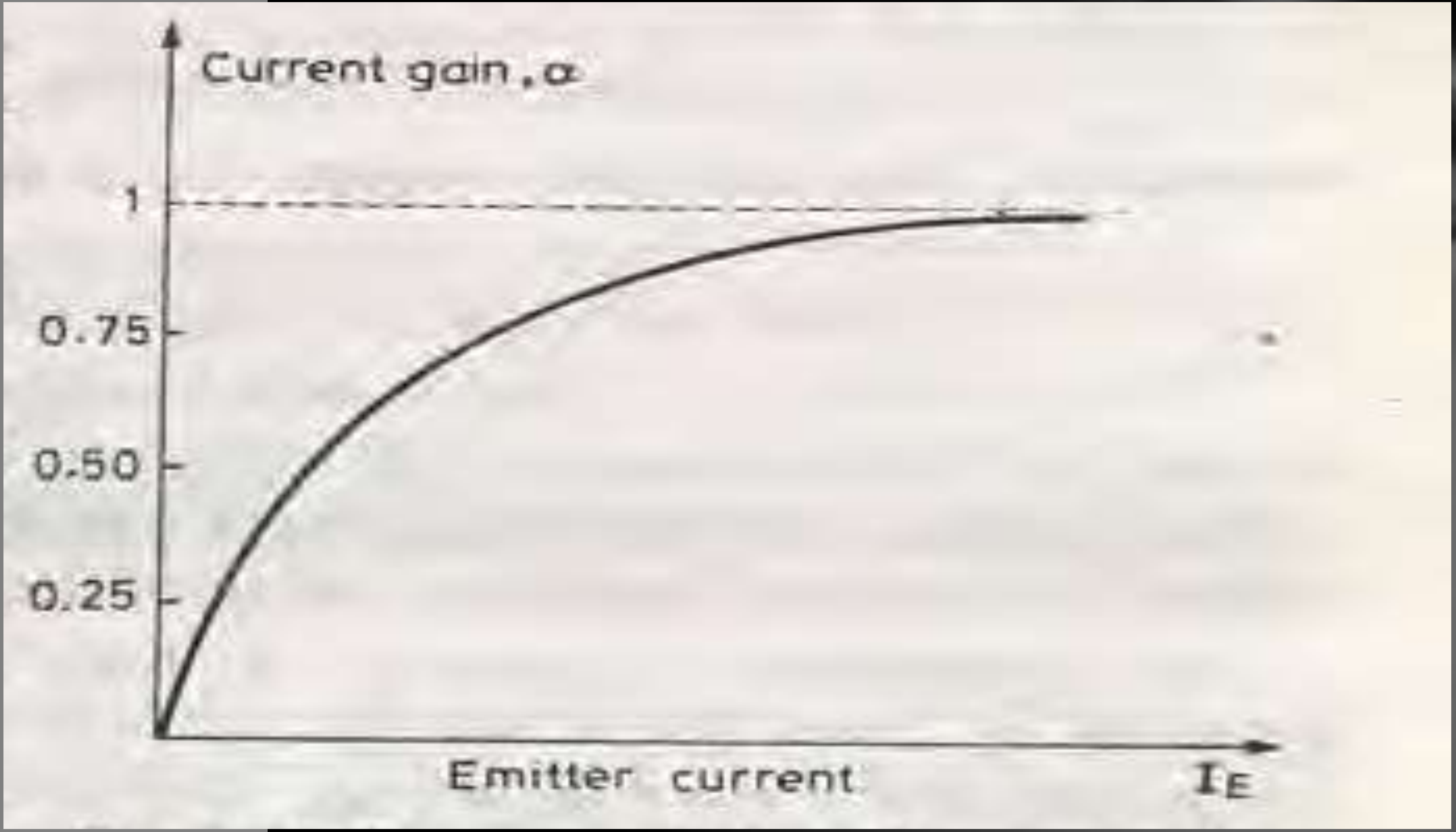
$$\Rightarrow \qquad I_A = \frac{\alpha_2 I_g + I_{CBO1} + I_{CBO2}}{1 - (\alpha_1 + \alpha_2)}$$



CONTI.....

- If in equation
- $\alpha 1+\alpha 2=1$
- $Ia = \infty$
- SCR suddenly latches to the ON state from OFF state condition
- This characteristic of device is called regenerative action.

Two transistor model



Latching action of SCR

$$I_{C_1} = \beta_1 I_{B_1}$$

$$I_{C_1} = I_{B_2}$$

$$I_{C_2} = \beta_1 \beta_2 I_{B_1}$$

$$I_A \pm I_{C_1} + I_{C_2}$$

$$I_{C_2} = I_{B_1}$$

$$I_{C_1} = \beta_1^2 \beta_2 I_{B_1}$$

$$I_{C_2} = \beta_1^2 \beta_2^2 I_{B_1}$$

$$\vdots$$

$$I_{C_2} = \beta_1^n \beta_2^n I_{B_1}$$

Thyristor turn on Methods

The turning on Process of the SCR (turning the SCR from Forward-Blocking state to Forward-Conduction state)is known as Triggering.

The various SCR triggering methods are

- Forward Voltage Triggering
- Thermal or Temperature Triggering
- Radiation or Light triggering
- dv/dt Triggering
- Gate Triggering

CONTI…..

Thermal Triggering (Temperature Triggering):

- Depletion layer of SCR decreases with increase in junction temp.
- In SCR when V_{ak} is very near its breakdown voltage, the device is triggered by increasing the junction temperature.
- By increasing the junction temperature the reverse biased junction collapses thus the device starts to conduct

Radiation Triggering (or) Light Triggering

- For light triggered SCRs a special terminal niche is made inside the inner P layer instead of gate terminal.
- When light is allowed to strike this terminal, free charge carriers are generated.
- When intensity of light becomes more than a normal value, the thyristor starts conducting.
- This type of SCRs are called as LASCR

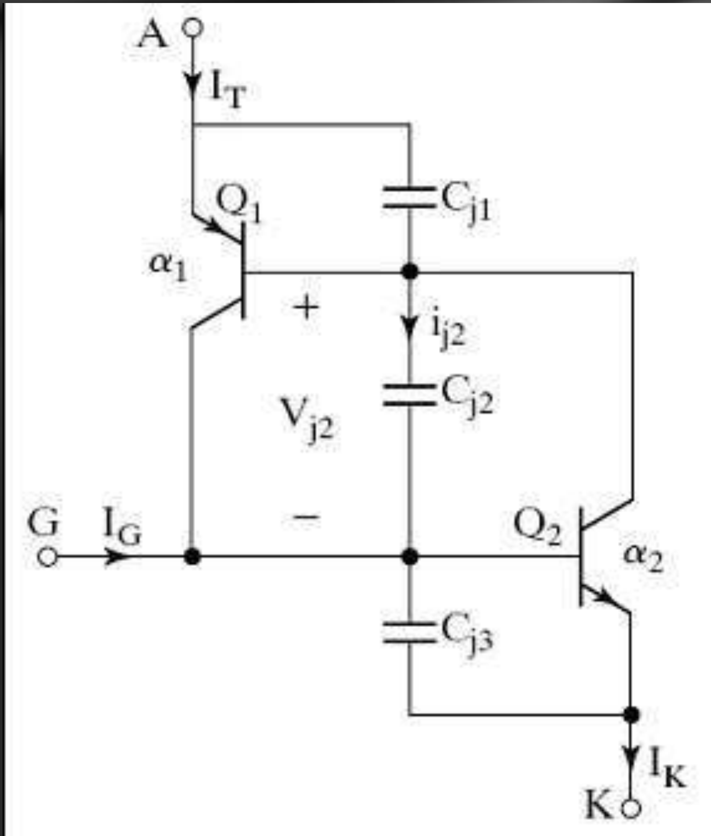
dv/dt Triggering.

Junction J2 behaves as a capacitor, due to the charges existing across the junction.

If voltage across the device is V, the charge by Q and capacitance by C then

- $i_c = dQ/dt$
- $Q = CV$
- $i_c = d(CV) / dt$
- $ic = C.\ dV/dt + V.\ dC/dt$
- $dC/dt = 0$ (C = constant)
- $i_c = C.dV/dt$
- The dV/dt across the device

becomes large & scr will turn on



Gate Triggering

This is most widely used SCR triggering method.

Three types .

1. DC Gate Triggering:-
2. AC Gate Triggering:-
   I. Resistance triggering:
   II. RC Triggering
3. Pulse Gate Triggering:-

DC gate triggering:-

- A DC voltage of proper polarity is applied between gate and cathode (Gate terminal is positive with respect to Cathode).
- When applied voltage is sufficient to produce the required gate Current, the device starts conducting.

Drawbacks :

- One drawback of this scheme is that both power and control circuits are DC and there is no isolation between the two.
- Another disadvantages is that a continuous DC signal has to be applied. So gate power loss is high.

AC Gate Triggering:-

- Here AC source is used for gate signals.
- This scheme provides proper isolation between power and control circuit.

Drawback:

- Drawback of this scheme is that a separate transformer is required to step down ac supply.

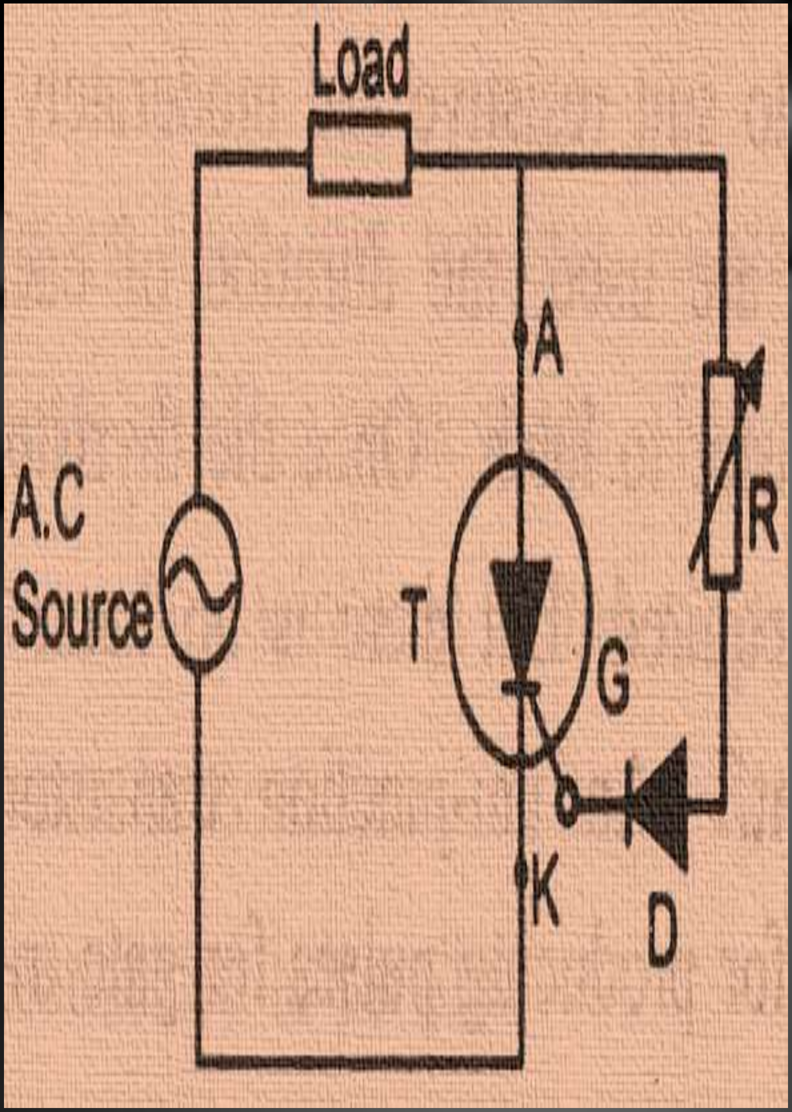
Two methods of AC voltage triggering namely

(i) R Triggering

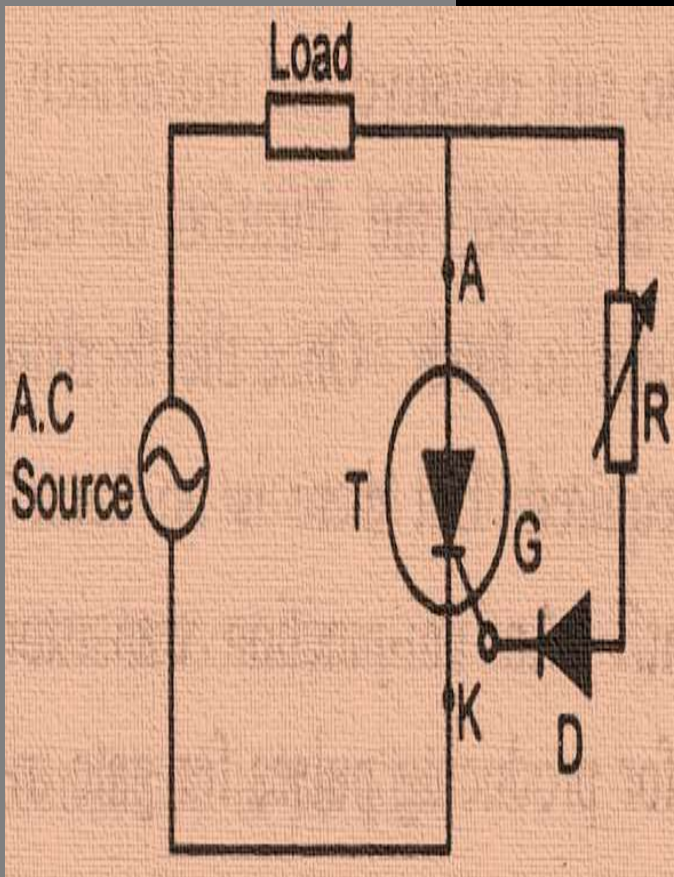
(ii) RC triggering

Resistance triggering:

- R is used to control the gate current.
- Depending on R, when the gate current reaches the IL (latching) the SCR starts to conduct.
- The diode D is called as blocking diode. It prevents the gate cathode junction from getting damaged in the negative half cycle.
- By considering that the gate circuit is purely resistive, the gate current is in phase with the applied voltage.
- By using this method we can achieve maximum firing angle up to 90.



Firing Angle



$$V_{gp} \sin\alpha = V_{gt}$$

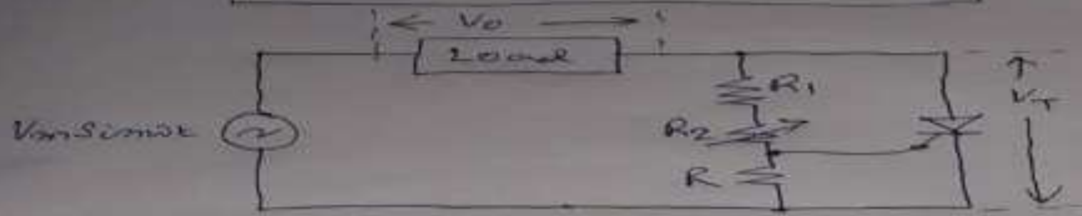
or
$$\alpha = \sin^{-1}(V_{gt}/V_{gp})$$

Since
$$V_{gp} = \frac{V_m R}{R_1 + R_2 + R}$$

$$\alpha = \sin^{-1}\left[\frac{V_{gt} \cdot (R_1 + R_2 + R)}{V_m R}\right]$$

As V_{gt}, R_1, R and V_m are fixed, $\alpha \propto \sin^{-1}(R_2)$ or $\alpha \propto R_2$.

Resistance Triggering



Resistance values are large

Initially $R_2 \to 0$

$$I_{gp} = \frac{V_m}{R+R_1} < I_{gm}$$

$$V_{gp} = \frac{V_m}{R+R_1} \cdot R < V_{gm}$$

Let $R_2 \nearrow$

$$I_{gp} = \frac{V_m}{R+R_1+R_2} \geqslant I_{gt}$$

$$V_{gp} = \frac{V_m}{R+R_1+R_2} \cdot R \geqslant V_{gt}$$

$$V_{gp} \sin\alpha = V_{gt} \quad , \quad \alpha = \text{Firing Angle}$$

$$\sin\alpha = \frac{V_{gt}}{V_{gp}} = \frac{V_{gt}\,[R+R_1+R_2]}{V_m \cdot R}$$

$$\alpha = \sin^{-1}\left[\frac{V_{gt}\,(R+R_1+R_2)}{V_m \cdot R}\right]$$

$$\alpha \propto \sin^{-1}[R_2]$$

$$\boxed{\alpha \propto R_2}$$

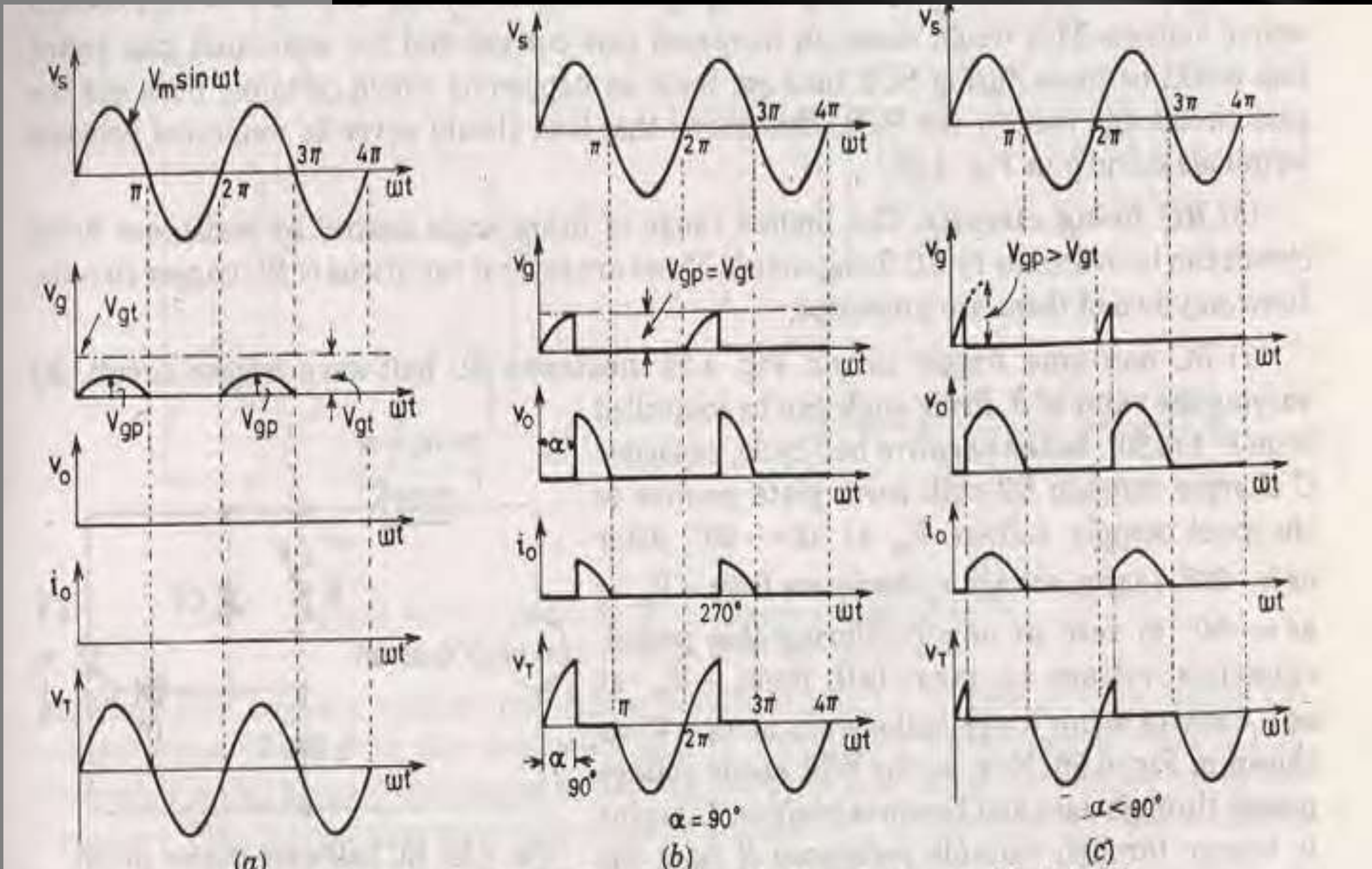
Points to be noted.

① When SCR is off, negligible current thru' trg. ckt., $V_o \simeq 0$, $V_T \simeq V_m \sin\omega t$

② When SCR is on, $V_T \simeq 1$ to $2\,V$

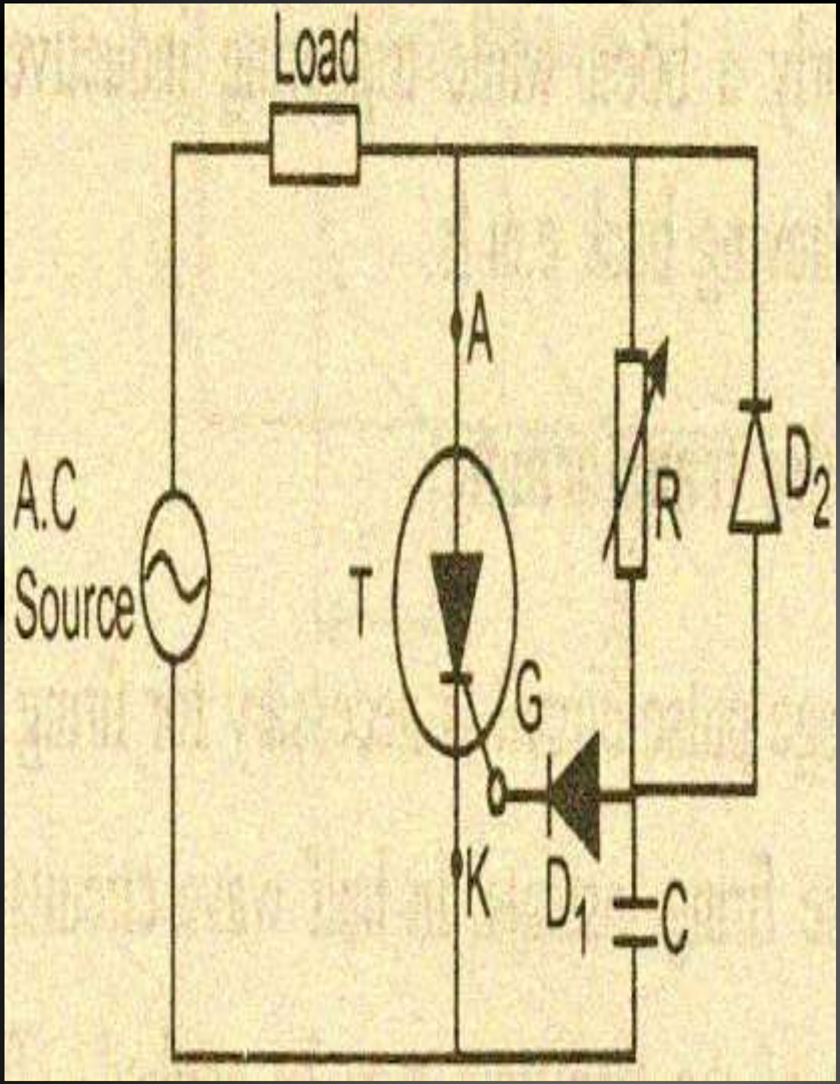
$V_o \simeq$ Higher load voltage

Graphical Representation

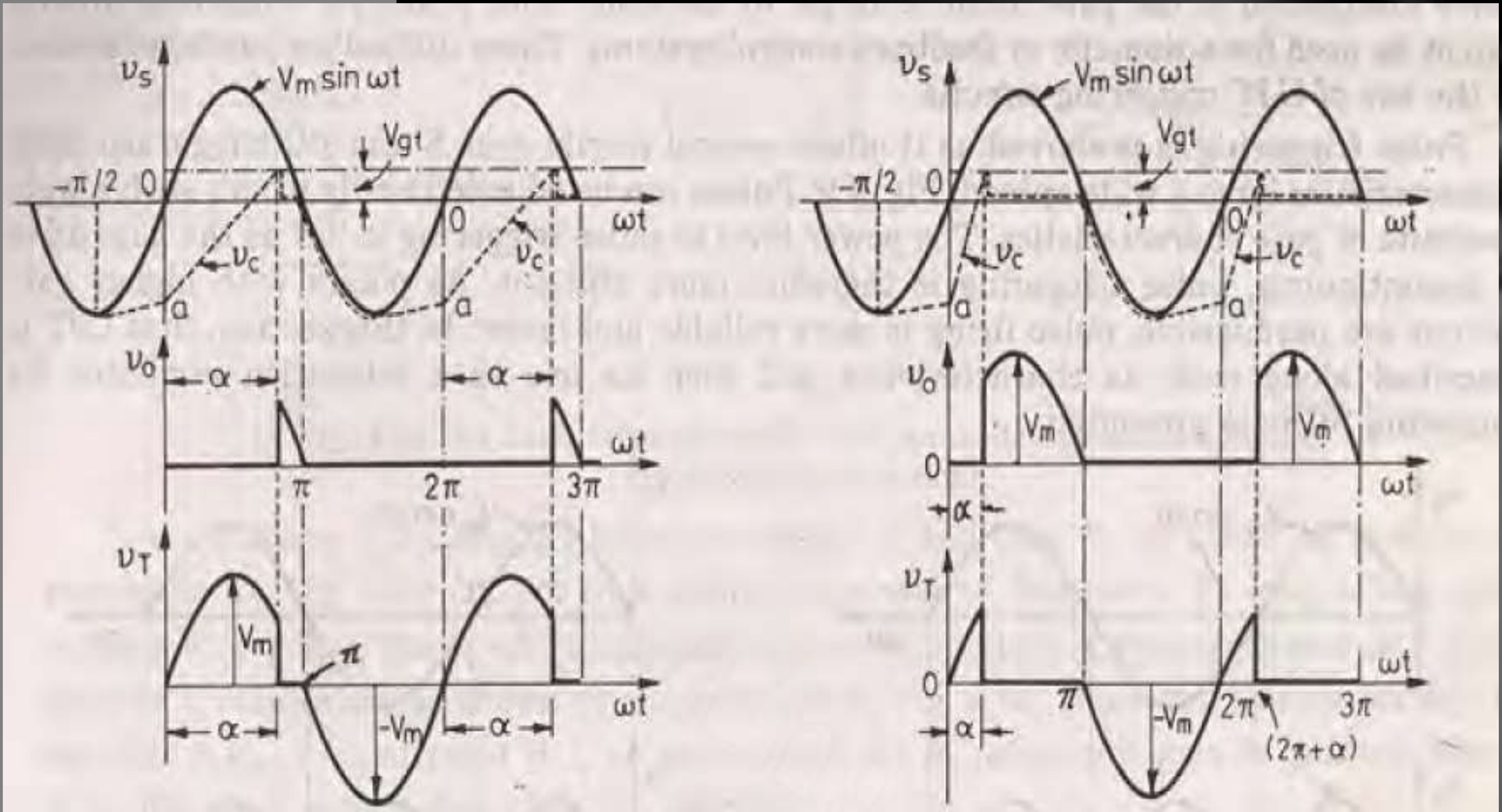


RC Triggering [Half Wave]

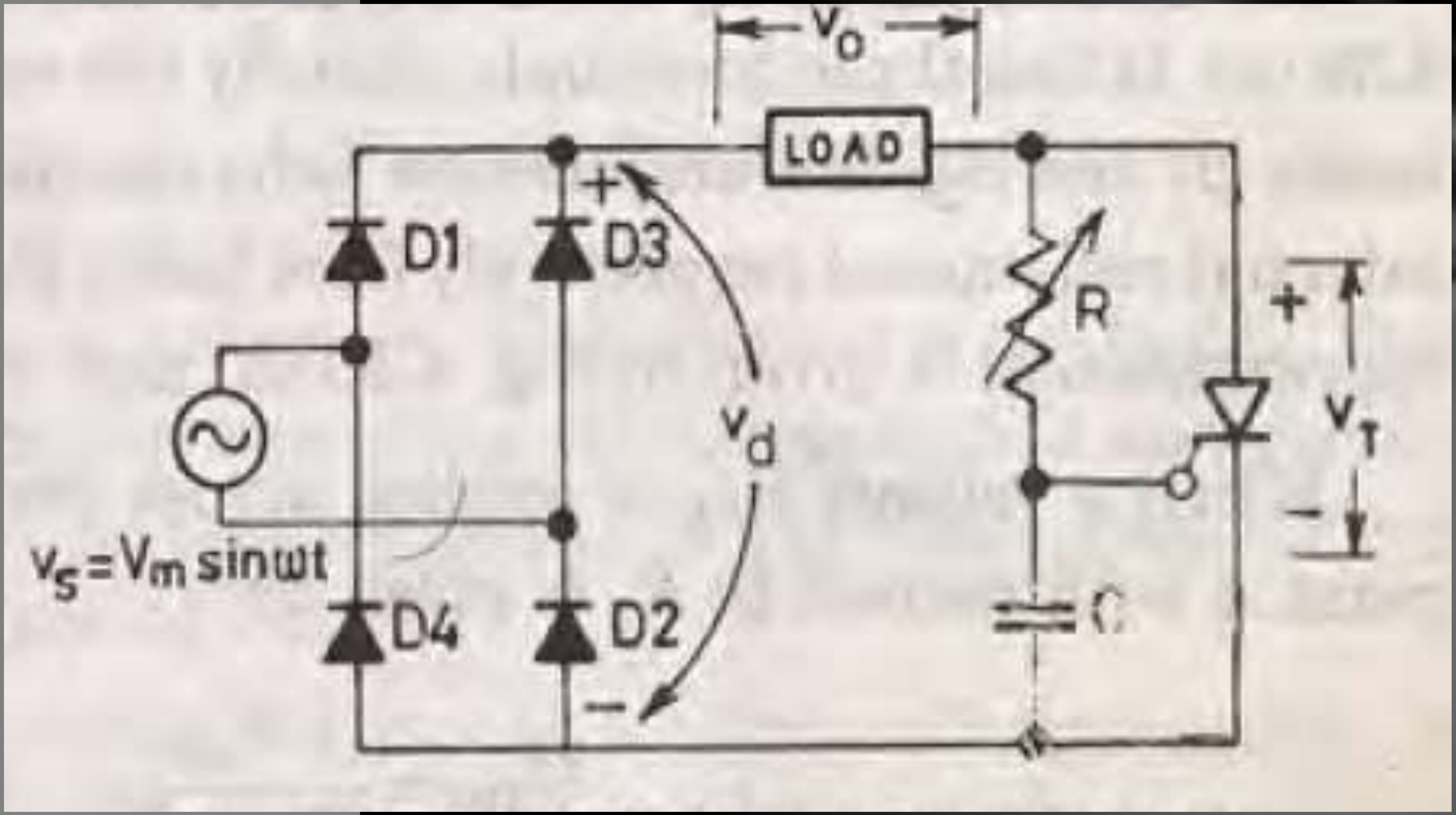
- Using this we can achieve firing angle more than 90°.
- In the positive half cycle, the capacitor is charged through the variable resistance R up to the peak value of the applied voltage.
- The variable resistor R controls the charging time of the capacitor.
- Depends on Vc, when sufficient amount of gate current will flow in the circuit, the SCR starts to conduct.
- In the negative half cycle, the capacitor C is charged up to the negative peak value through the diode D2.



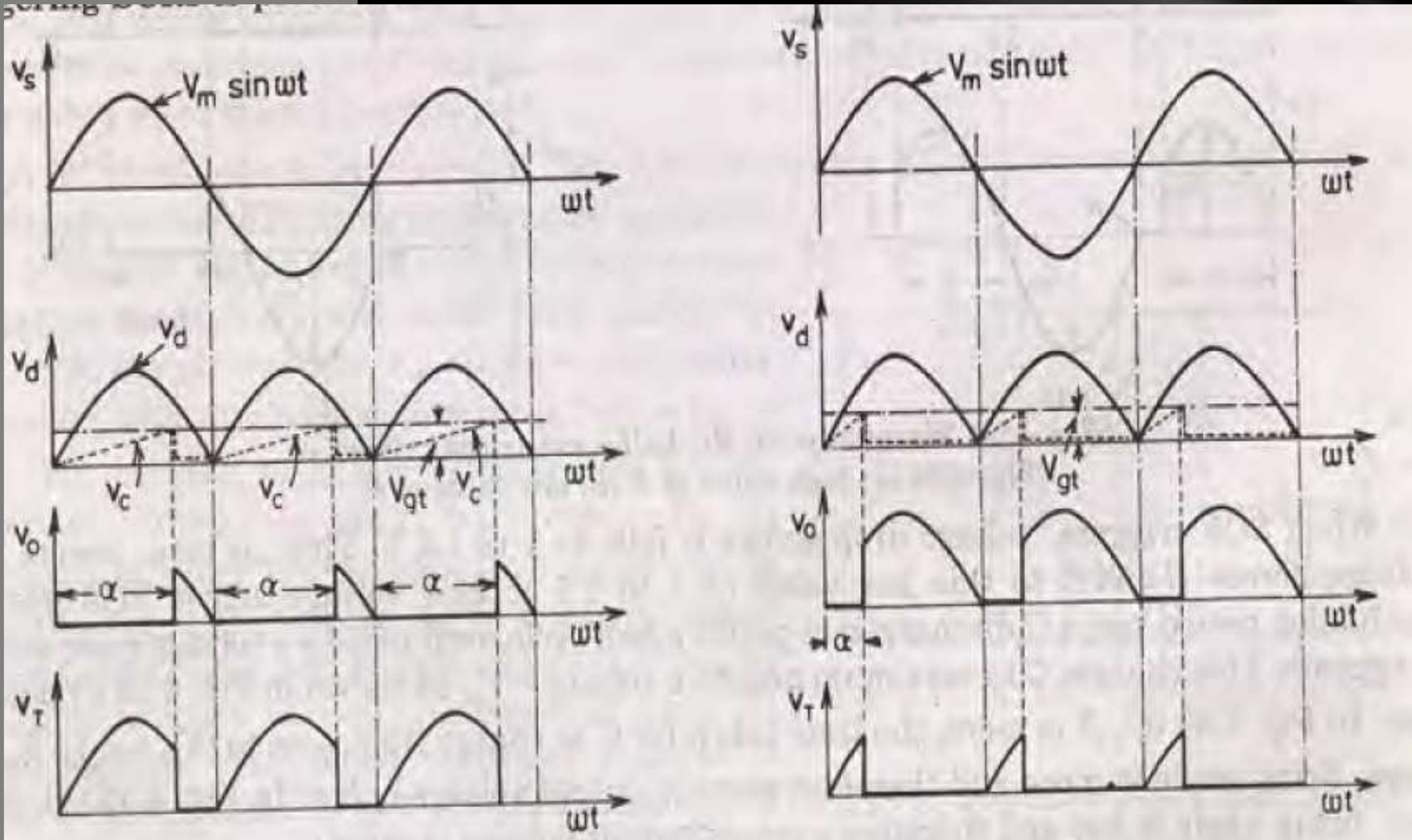
Graphical Representation



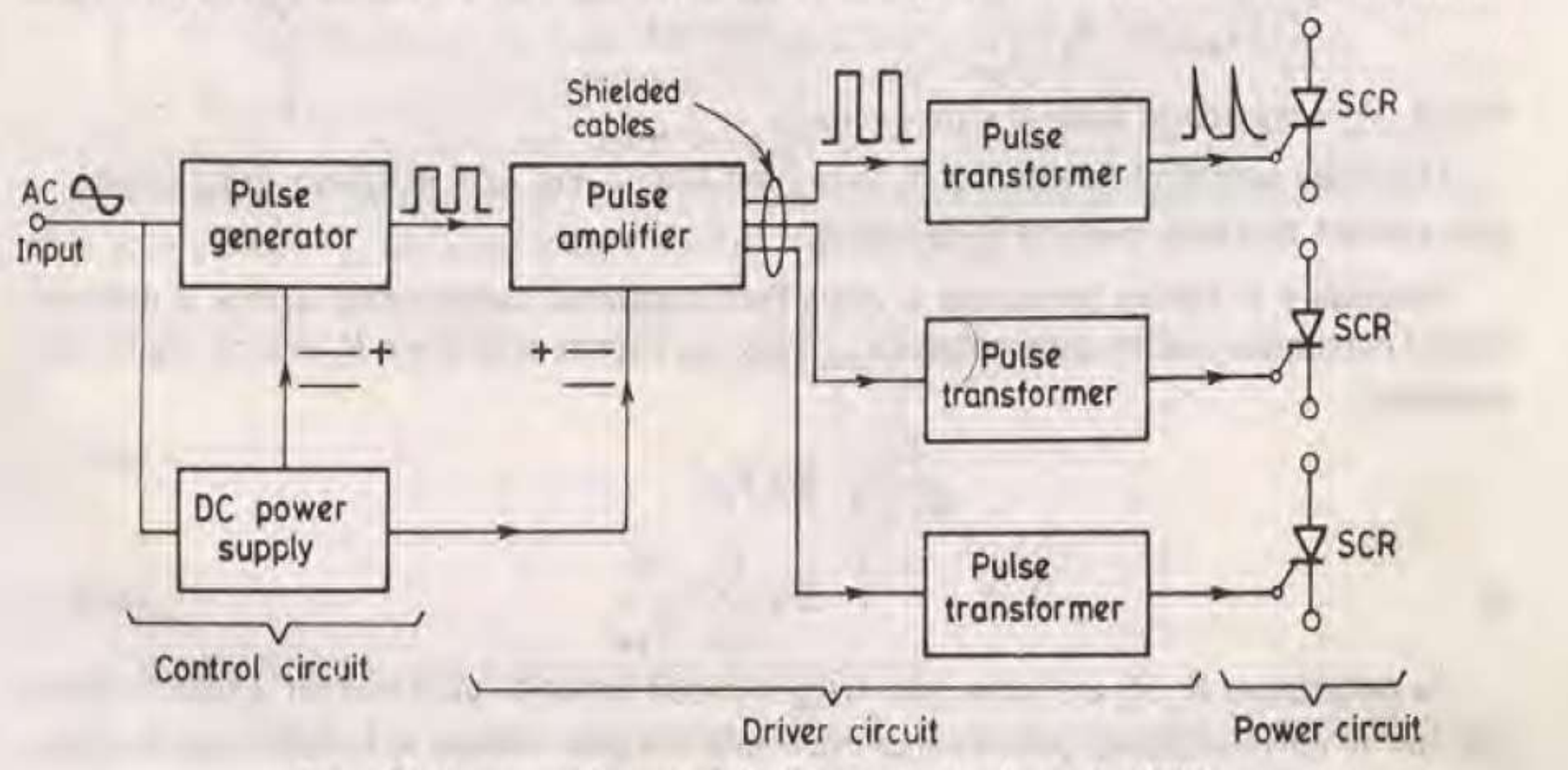
RC Triggering Circuit [Full Wave]



Graphical Representation



General Layout of the firing circuit schemes for SCRs



Pulse Gate Triggering:-

- In this method the gate drive consists of a single pulse appearing periodically (or) a sequence of high frequency pulses.
- This is known as carrier frequency gating.

Advantages

1. Low gate dissipation at higher gate current.
2. Small gate isolating pulse transformer
3. Low dissipation in reverse biased condition is possible.So simple trigger circuits are possible in some cases
4. When the first trigger pulse fails to trigger the SCR, the following pulses can succeed in latching SCR.