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UNIT-2
SCR CONTROL CIRCUITS

Methods of Turn-On of SCR:

SCR can be turned ON from its OFF or Non-conducting state by following methods.

1) **Forward voltage (break over voltage) triggering:**
When anode to cathode forward voltage is increased with gate circuit open, reverse biased junction J_2 will break, then SCR will starts to conduct.

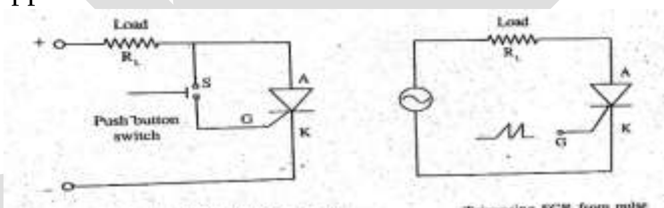
2) **dv/dt (Rate of change of voltage) triggering:**
With a forward bias across the device the central junction J_2 is reverse biased. The barrier (depletion layer) developed at junction J_2. If a forward voltage is suddenly increased, a large current (leakage current) will flow across the J_2 junction and the SCR will starts to conduct.

3) **Temperature triggering:**
During forward blocking, most of the applied voltage appears across reverse biased junction J_2. This voltage across junction J_2 associated with leakage current may raise the temperature of the junction. At higher temperature, there are more electron hole pairs across the junction. This increases leakage current and the SCR will starts to conduct.

4) **Light triggering:**
Thyristor can be turned ON by light. When the light falls on the central junction (J_2) of the SCR it induces electron-hole pairs, which helps to increase the leakage current, then SCR will start to conduct.

5) **Gate triggering:**
With a forward bias across the junction J_2, the gate voltage applied in between gate & cathode. Thus reverse biased junction J_2 will break due to more electron-hole pairs across the junction, then SCR will start to conduct.

- The gate pulses can be supplied either from a DC source or AC source.



Triggering SCR from d.c source   Triggering SCR from pulse

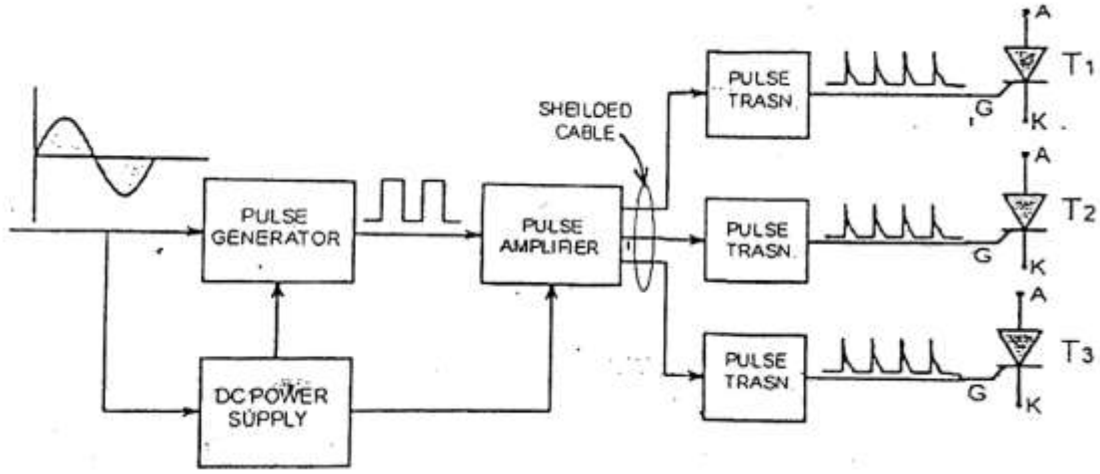
- SCR connected to DC source through load. In this case the gate signal is generated by a push button switch (s). When the switch is pressed momentarily, a positive voltage is applied at the gate. As a result of this, the SCR is turned ON.
- SCR connected to the AC source through load. In this circuit the gate signal is provided by timing pulses. Such pulses can be generated from the triggering devices.

Functions of gate control circuits:

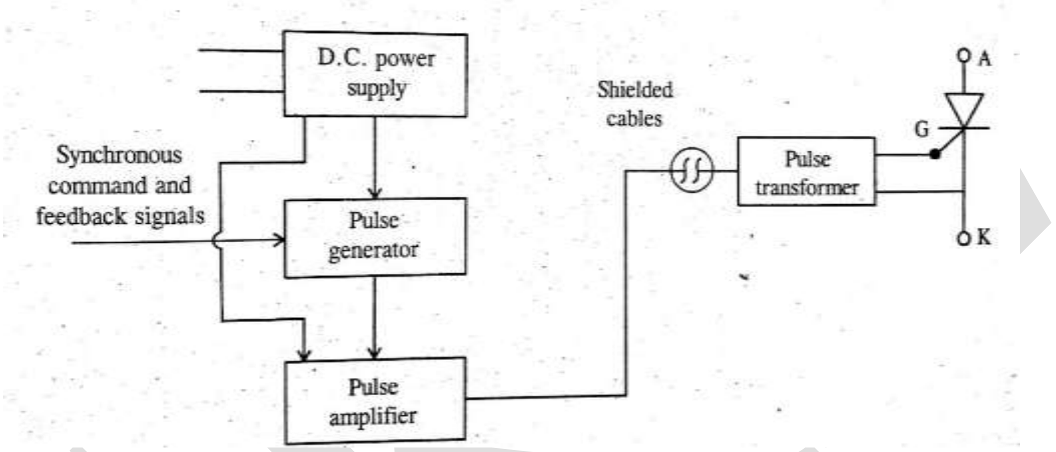
A thyristor may be turned ON by applying a gate pulse. The gate control circuits are called firing or triggering circuits. These are generally low power electronic circuits. They must full fill two general functions.

1. Gate control circuit can produce voltage pulses for each thyristor at the appropriate instant of time in a periodic manner and with a particular sequence depending upon the type of power circuits.
2. Gate pulses should be raised to sufficient level through Driver circuit (control circuit).

<u>Block diagram of firing circuit</u> or **<u>general layout of the firing circuit:</u>**



Or

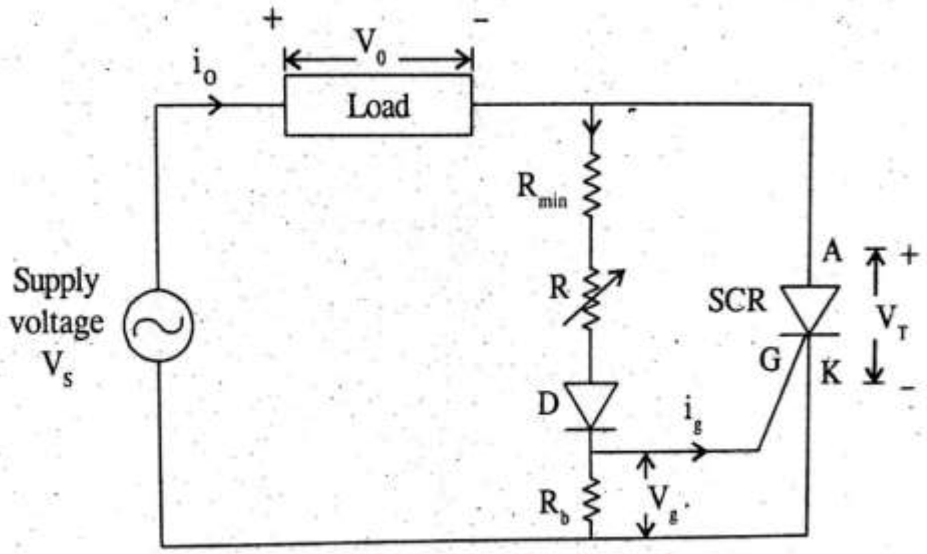


- The electronic pulse generator is separate and away from the assembly of thyristors.
- A separate DC & AC power supply is provided for the pulse generator.
- The pulse generator will generate a pulse as per the feedback signals, but generated pulses are very week so the output of generator is fed to the amplifier.
- Amplified pulse is again fed to the pulse transformer through the shielded cables (one or more insulated conductors enclosed by a common conductive layer).
- The output of the pulse amplifier goes through the pulse transformer and clamping (Diode) network before the pulses are coupled to the gate and cathode terminals of a thyristor.
- The control or firing circuit operates at low voltage level (5 to 20volts) and the thyristor operates at high voltage levels (greater than 250 volts).
- The functions of pulse transformer is to isolate the low voltage gate control circuit from the high voltage anode circuit.
- The clamping network consists of a diode in series with a gate.

<u>Gate Turn-ON Methods of SCR:</u>

1. R firing circuit.
2. RC firing circuit.
3. UJT relaxation oscillator.
4. Digital firing scheme.
5. Temperature & light triggering.

1. **R firing circuit:**

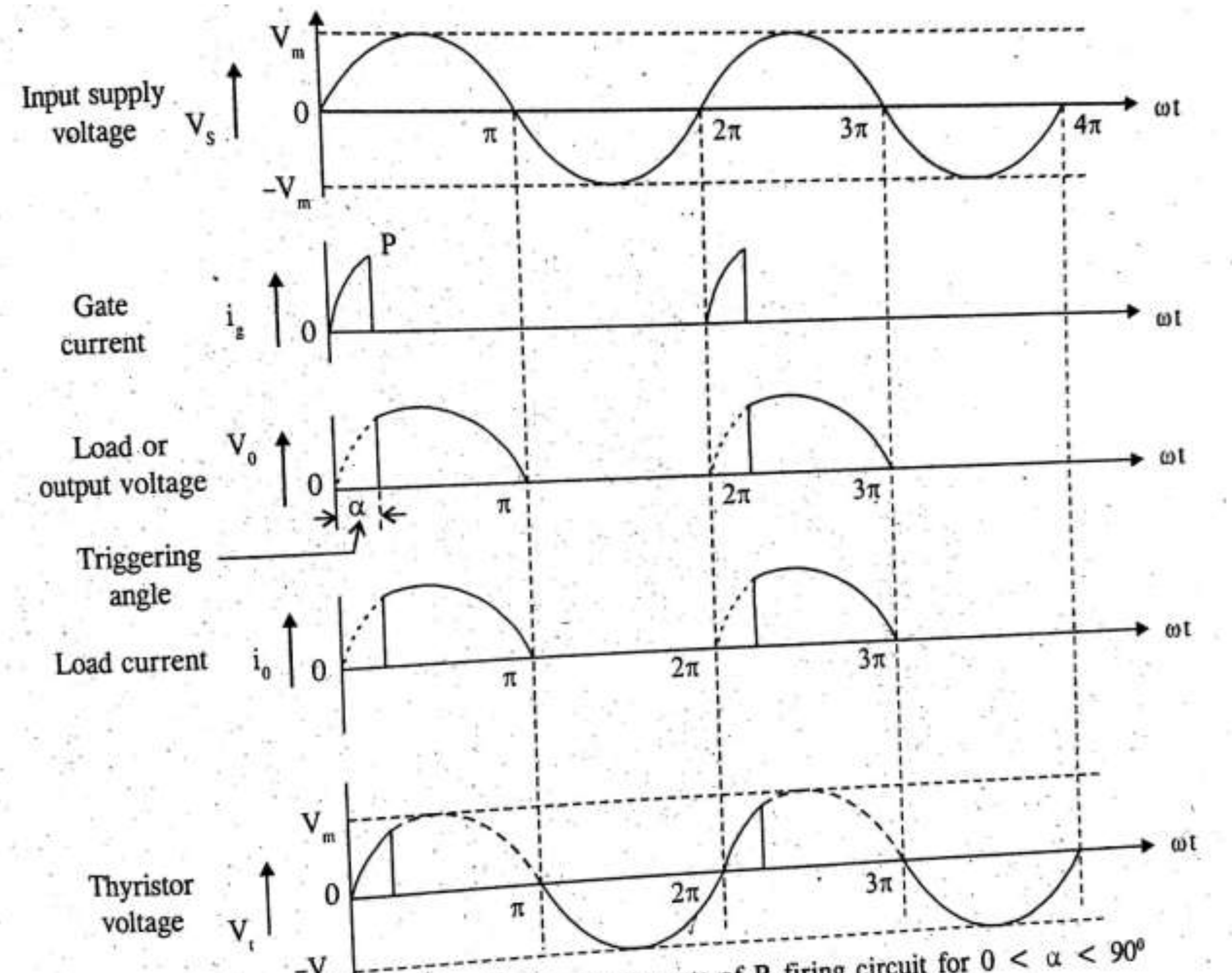


Construction:

- Above figure shows the resistance firing circuit of SCR.
- The gate current is supplied by an AC voltage source V_S through R_{min}, R and diode D.
- To limit gate current (I_g) to its maximum value a resistance R_{min} is connected in between anode and gate.
- If $I_{g(max)}$ is maximum gate current and V_m is maximum supply voltage then R_{min} will be
  $\mathbf{R_{min} \geq (V_m / I_{g(max)})}$
- Resistance R_b is called stabilising resistor. The voltage across it does not exceed the minimum forward gate voltage otherwise the thyristor will turn ON directly.

Working:

- Supply voltage V_S is positive, SCR gets forward biased but it will not conduct ($V_0 = 0$)
  Output voltage is zero until the gate current exceeds I_{gmin}.
- The diode D and gate cathode of SCR is forward biased causing flow of gate current I_g.
- As V_S increases towards its peak value, the gate current I_g also increases and reaches a value I_{gmin}, the SCR turns ON and the output voltage V_0 and load current $i_0 = (V_m/R_L)$ is shown in the below waveform.
- The SCR remains ON until V_S decreases to zero and begins to go negative.
- When V_S goes negative SCR is reverse biased and SCR now turns OFF and remains OFF.
- SCR next turn ON by positive half cycle and procedure continuous ON and OFF of SCR until the supply voltage present.
- Diode D prevents gate cathode reverse bias from peak reverse gate voltage during negative half cycle of V_S.
- The waveform of load voltage V_0 may be controlled by varying the gate circuit resistance R.
- R value is increased the gate current reaches its trigger value I_{gmin} at a larger value of V_S, it causes SCR to trigger at a latter point in the positive half cycle of voltage V_S.
- If R is made too large, the SCR gate current never reaches the trigger value I_{gmin} and SCR remain OFF.
- The triggering angle 'α' (firing angle) increases, the power delivered to the load decreases.
- The triggering angle α only in 0^0 to 90^0 and conduction angle β only in 90^0 to 180^0.



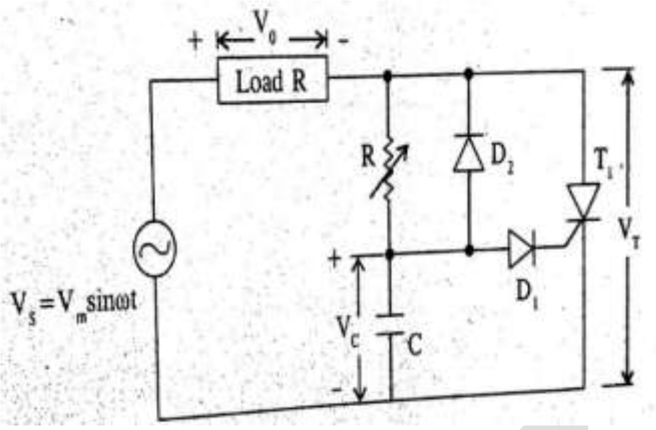
Waveforms of voltages and currents of R firing circuit for $0 < \alpha < 90^0$

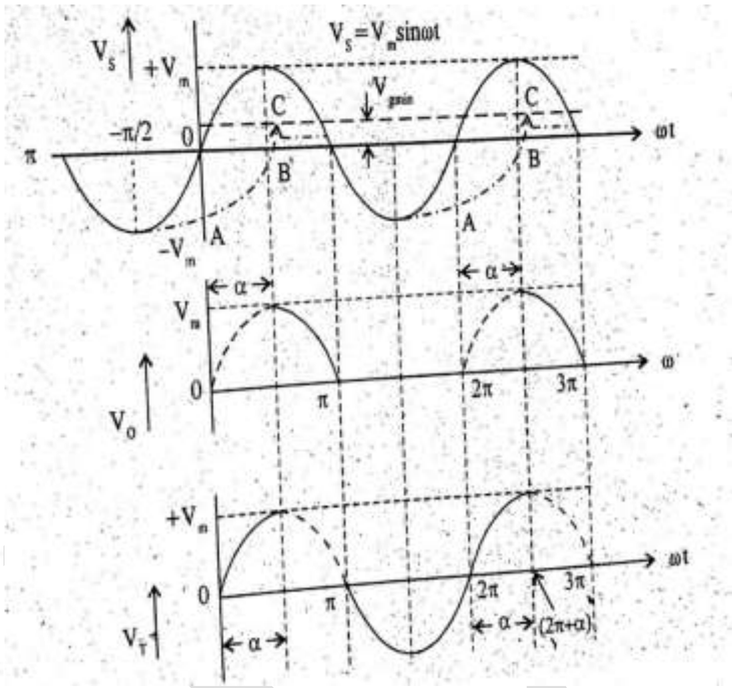
Drawback of R-firing:

- Trigger angle is depending on I_{gmin} of SCR.
- The maximum triggering angle can be varied only up to approximately 90^0.

2. **RC firing circuit:**

i. **RC half wave firing circuit:**





The major drawback of R-firing circuit is that, the firing angle can't varied beyond 90^0 & is eliminated in R-C firing circuit.

Construction:

- The combining of resistance (R) and capacitor (C) is use to produce triggering pulses in RC firing circuit with two diodes.
- The resistance R is variable, by using this the firing angle can be controlled from 0^0 to 180^0.
- The capacitor is used to provide the positive gate current to the gate of SCR.

Working:

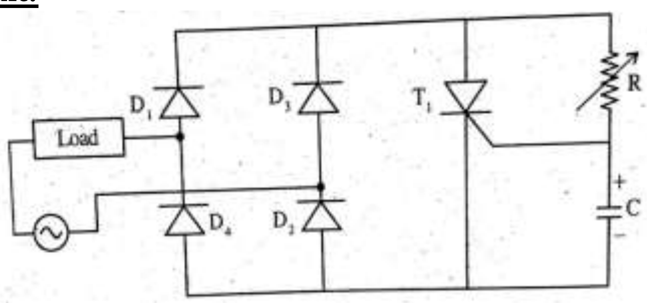
Case 1:

- In the positive half cycle the capacitor is charged through the variable resistor "R", up to the +ve peak value of the capacitor voltage.
- After obtain (increase in) sufficient voltage across the capacitor the diode D_1 turn to conduction mode and gate current fed to SCR.
- Gate current is not flowing to SCR, in the time of capacitor voltage decreases to minimum voltage of the capacitor.

Case 2:

- In the negative half cycle the capacitor charged up to the –ve peak value through diode D_2.
- In the negative half cycle the thyristor is not in ON condition, because there is no gate current.
- D_1 prevents the reverse breakdown of the gate cathode junction in the –ve half cycle.

ii. **<u>RC full wave firing circuit:</u>**

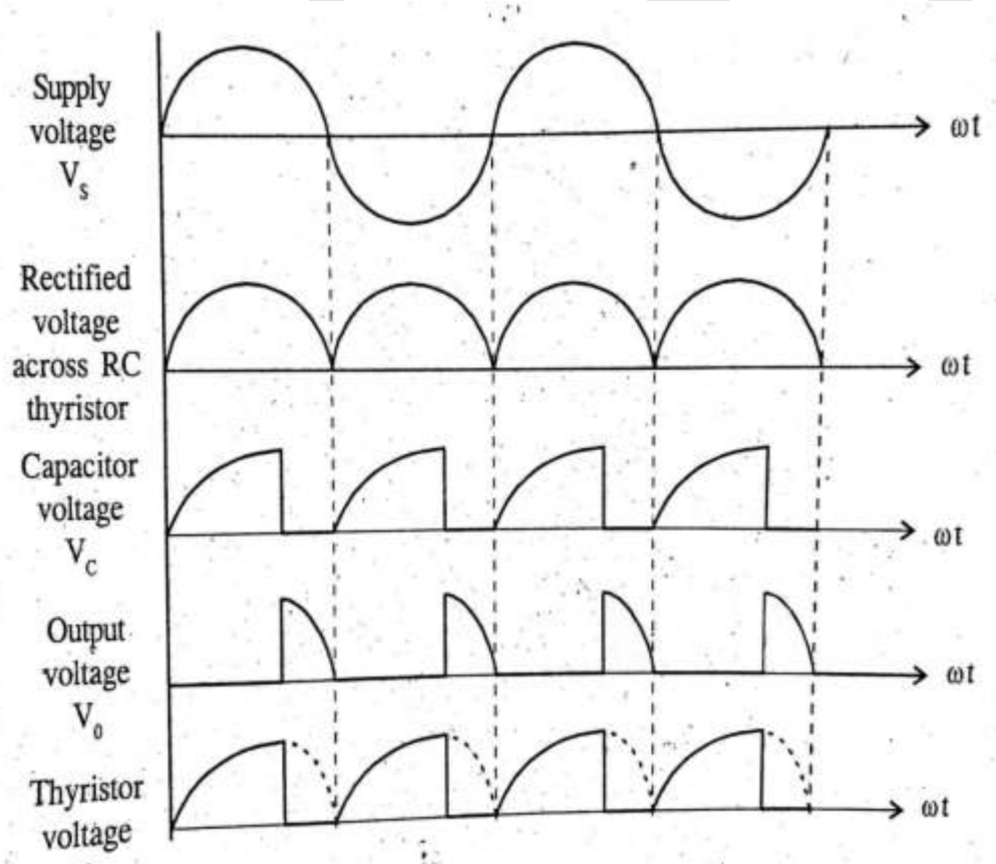


<u>Construction:</u>

- In the full wave RC firing circuit, the full bridge rectifier is used to convert AC to DC of supply voltage given to RC firing circuit.
- Variable resistor is used to control the firing angle of the SCR.
- Capacitor is charged by DC supply from bridge rectifier and creates a forward break down voltage across the gate cathode terminals.

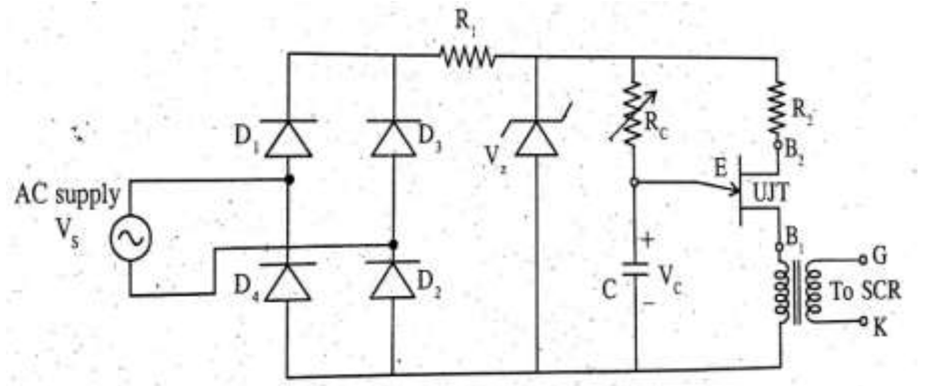
<u>Working:</u>

- Full wave RC firing circuit working on both +ve and –ve half cycle of AC supply.
- In both +ve and –ve half cycle the capacitor will charged by the current limiting element (variable resistor).
- When the capacitor voltage is greater than the V_{gmin}, the capacitor discharges the energy and the current starts flowing to gate, finally SCR turns ON from forward conduction mode.

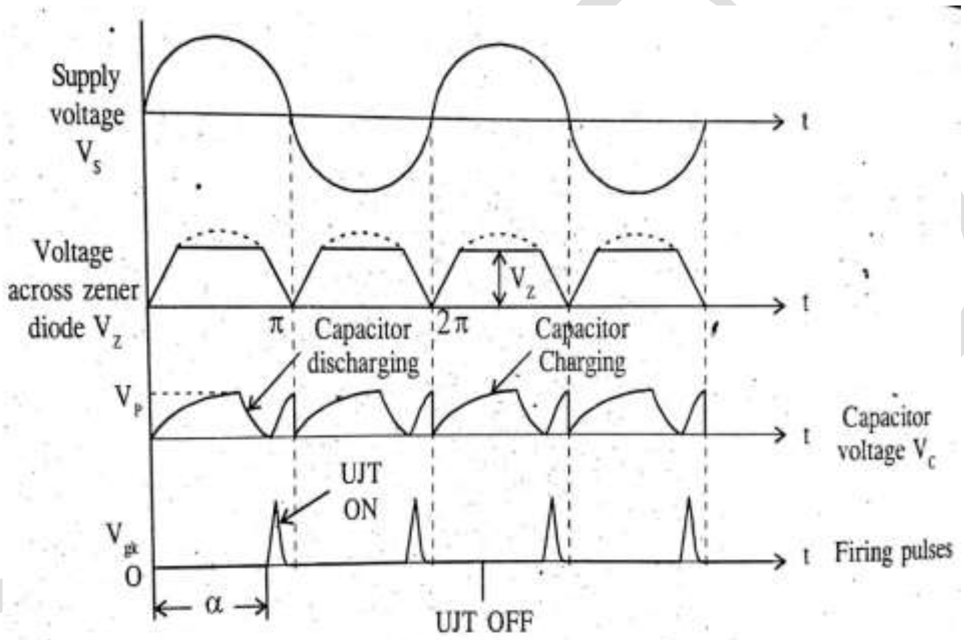


Waveforms of full wave RC firing circuit

3. **<u>UJT Pulse Trigger Circuit:</u>**



UJT triggering circuit



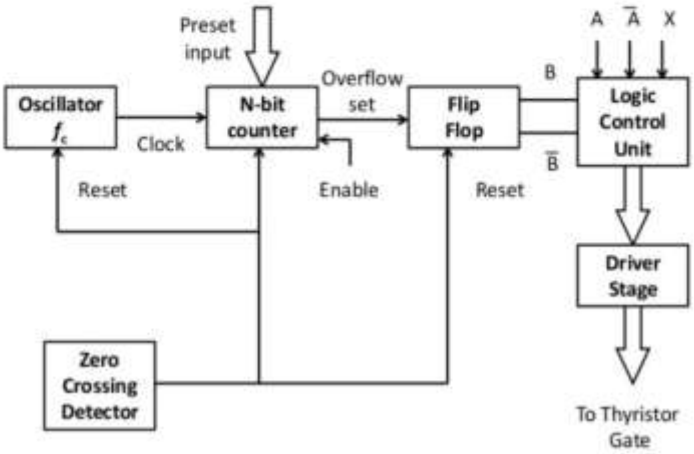
Waveforms of UJT triggering circuit

- The unijunction transistor triggering circuit is used in most of the applications. UJT is used as a relaxation oscillator to obtain sharp and repetitive pulses.
- The pulse transformer is used to isolate the control circuit from the main power circuit.
- The supply voltage is rectified and is given to the zener regulator. Zener diode clamps the rectified voltage to a standard level of V_Z (Zener voltage) as shown in the waveform.
- Voltage V_Z is applied to the UJT circuit. It acts as a supply voltage to UJT.
- In the UJT pulse trigger circuit R_1 is used to limit the current flowing through zener diode.
- The capacitor charges through resistance R_C. When the capacitor voltage becomes equal to V_P, the peak voltage of UJT it turns ON.
- The capacitor discharges through emitter (E), base (B_1), and primary of pulse transformer. The UJT is turned ON when the capacitor discharges.
- Since current flows through the primary of pulse transformer, a pulse is generated. This pulse is gate triggering pulse.
- When the capacitor discharges up to a voltage called valley voltage (V_V), the capacitor discharges below the valley voltage, the UJT turns OFF and capacitor again starts charging is shown in the waveform.
- Firing angle (α) and charging of the capacitor can be varied by resistance R_C. The resistance R_C is low the capacitor will fully charge in less time and firing time is also less.

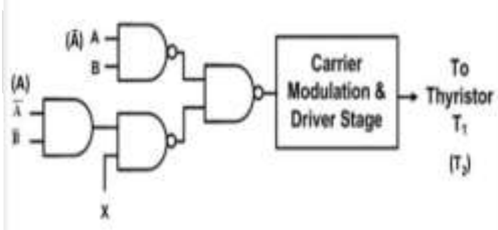
Comparision of Triggering Circuits

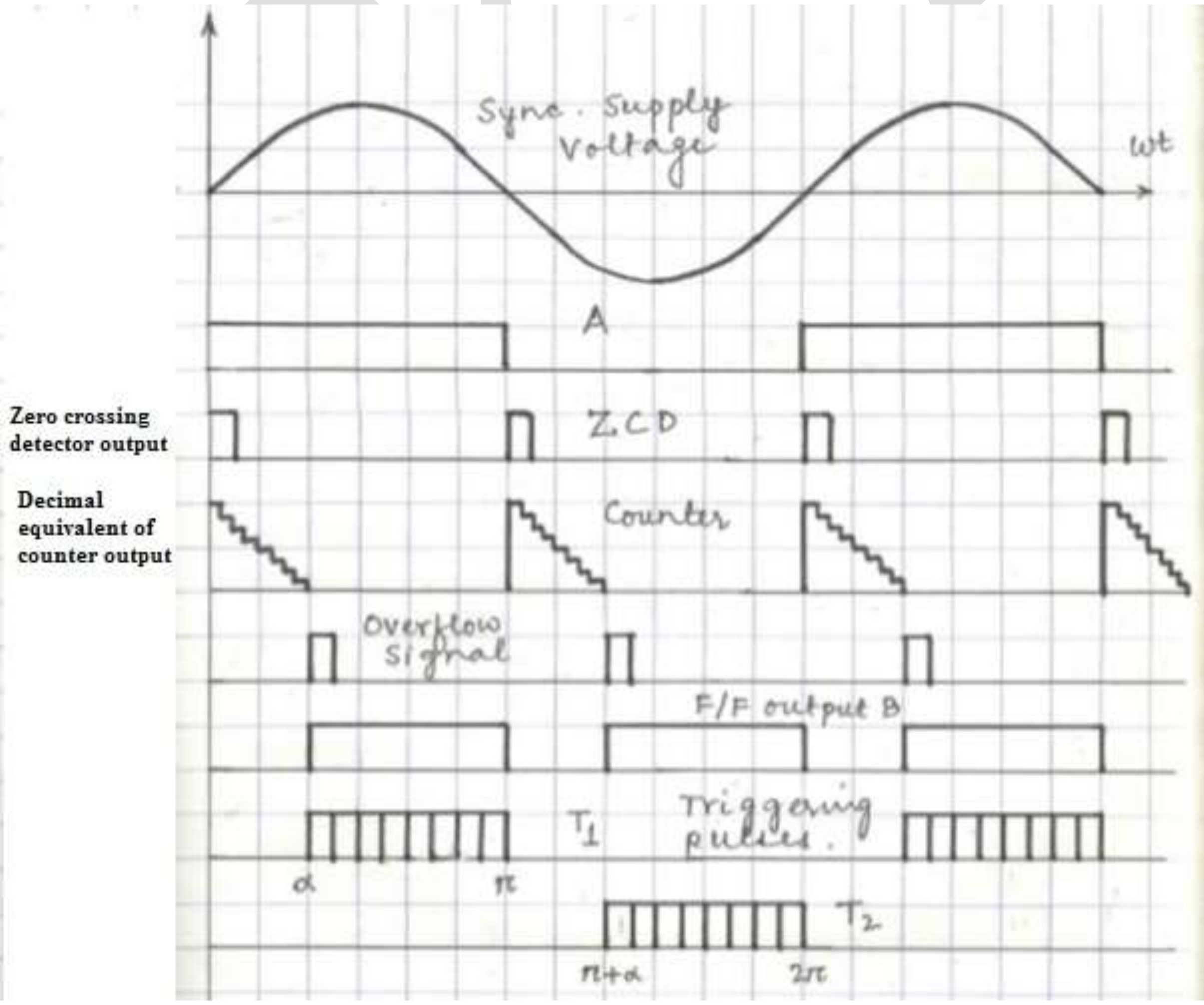
S.No.	Parameter	R Triggering	RC Triggering	UJT Triggering
1.	Range of firing angle	0 to 90°	0 to 180°	0 to 180°
2.	Power dissipation	High	High	Low
3.	Isolation	Not possible	Not possible	Possible because of pulse transformer
4.	Firing of multiple SCRs	No	No	Yes
5.	Cost	Least	Low	High
6.	Types of Triggering	AC gate triggering	AC gate triggering	Pulsed triggering

4. <u>Digital firing circuit:</u>



Logic control driver block





- Above figure shows the basic block diagram of digital firing scheme.
- It can be used to trigger single phase-controlled rectifiers, AC regulators, Inverter, chopper.
- It consists of a resettable counter, oscillator, ZCD, Flip-flop (F/F) & a logic control unit with NAND/ AND functions.
- The counter is pre-set to the decimal equivalent value N of the counter signal at each zero crossing of the supply voltage.
- Then the counter starts counting down @ f_c per second.
- When the count becomes zero it gives overflow signal which sets the F/F & its output states B & $\bar{B}$ change accordingly.
- With the help of F/F & a logic control & driver stage, the trigger pulses for thyristor T_1 & T_2 are produced.
- By varying the pre-set input, it is possible to control the firing angle.
- The logic variable X=0 or 1 enables to select the pulse duration either from α to π or α to π+α (Above waveforms are for X=0).

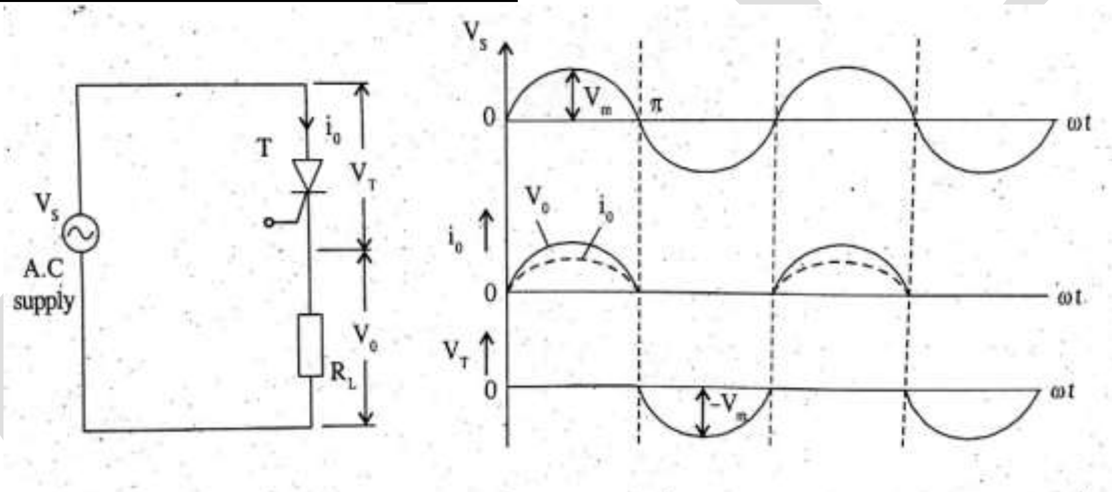
<u>Commutation:</u>

The process of turning off a SCR is called commutation.

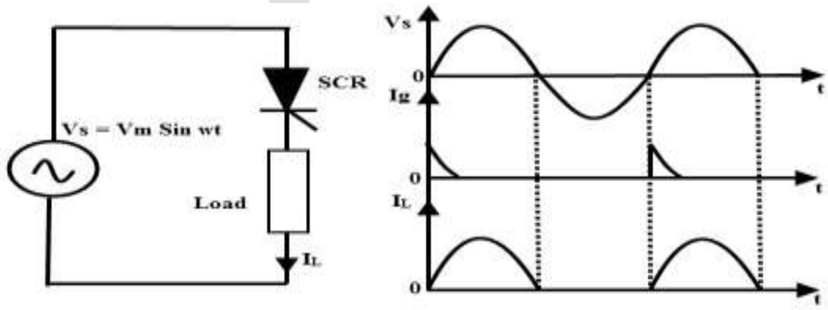
Commutation can be classified in to two types, they are

1. Line commutation (Natural commutation).
2. Forced commutation.

1. <u>Line commutation (Class-F commutation):</u>



Line commutation



- The SCR turns OFF automatically during negative half-cycle of alternating supply when reverse voltage applied across SCR for sufficient time.
- Line commutation does not need any external components. It uses supply voltage for turning OFF the SCR.
- When AC supply is applied across a thyristor, after every half cycle, voltage available across SCR will be reversed due to the natural reversal of the line voltage and the device is turned off when anode current falls below the holding current.

- Natural commutation takes place only when the supply voltage is AC.

  Case-1:

  During the positive half cycle of AC supply, when SCR triggered & it starts to conduct current in the circuit.

  SCR is triggered in the positive half cycle at $\alpha = 0$ i.e at $\omega t = 0$, since the SCR is forward biased and it starts conducting, load current i_0 also starts flowing.

$$I_0 = (V_0/R_L)$$

  Case-2:

  When AC voltage (line voltage) is reverse polarity during negative half cycle, the SCR is reverse biased and is turned OFF. Voltage appears across the SCR which provides necessary reverse bias; hence it does not conduct. (At $wt=\pi$, $V_0 = I_0 = 0$).

- Line commutation used in AC to DC converters, Inverters, AC regulators and cycloconverters.

2. **Forced commutation:**

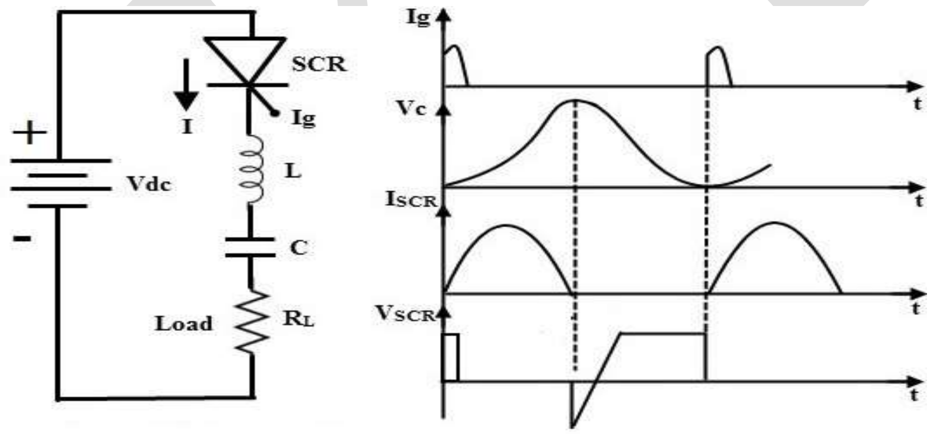
   The thyristor can be turned off by using active or passive components is called forced commutation.

- Forced commutation is used when the supply is DC.

  Forced commutation can be broadly classified into five types, they are

a. Class A (Self commutation / load commutation / Resonant commutation).
b. Class B (Auxiliary current commutation / resonant pulse commutation).
c. Class C (Complementary commutation).
d. Class D (Auxiliary voltage commutation / impulse commutation).
e. Class E (External pulse commutation).

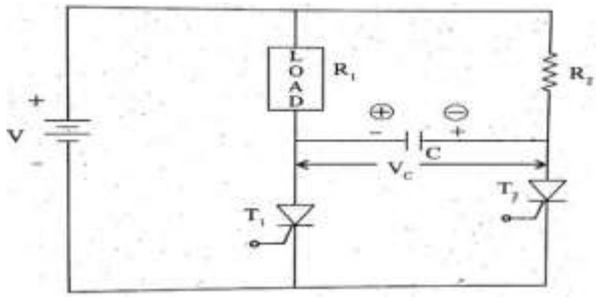
1) **Class A commutation:**



- In forced commutation, the SCR is connect to the commutating components L and C in series with load resistance R as shown in above figure.
- When the SCR is triggered, the forward currents starts flowing through it and during this the capacitor is charged up to the peak value of capacitor voltage.
- Once the capacitor is fully charged (more than the supply source voltage) the SCR becomes reverse biased and hence the commutation of the device. Due to this the higher voltage across the cathode (K) side with respect to anode (A) side, the SCR acts like a reverse bias and turns it OFF.
- The capacitor discharges through the load resistance to make ready the circuit for the next cycle of operation.
- The time for switching OFF the SCR depends on the inductance and capacitance value.
- In the turning OFF time, the voltage across the SCR is zero, after some time it gains the voltage is shown in the above waveform.

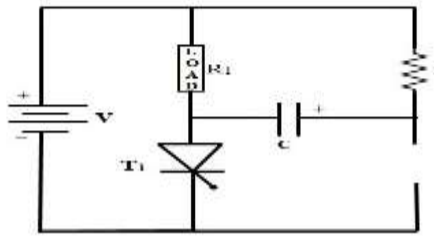
2) **<u>Class C commutation:</u>**

A thyristor carrying load current is commutated by transferring its load current to another incoming thyristor is called complimentary commutation.



- The SCR T_1 is the main SCR which is connected in series with the load. The commutative capacitor "C" is connected in between anode terminals of T_1 & T_2.
- The firing of SCR T_1 commutates T_2 and firing of SCR T_2 commutates T_1, both SCR's carry load current.

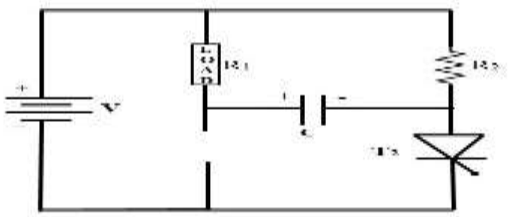
<u>Case-1:</u>



When T_1 is turned ON the capacitor C is charged from supply voltage (V) through R_2, C & T_1 with polarity as shown in above figure.

T_1=ON, T_2=OFF & V_C=V & load current path is V, R_1, T_1 & V.

<u>Case-2:</u>



- When T_2 is triggered, the charged capacitor (c) negative polarity is applied to anode of T_1 & positive polarity of C is applied to cathode of T_1. It causes reverse bias & C discharges & discharging current of the capacitor opposes the load current T_1 & SCR T_1 off.
- SCR T_2 conducts the load current, the capacitor C will be charged in the opposite direction through R_1, C & T_2. The polarities of charging of C are reversed.
- T_1=OFF, T_2=ON & V_C = -V & load current path is V, R_1, C & T_2. If T_1 conducts, the same capacitor reverse biases T_2 & turns it off.

<u>Comparison between natural and forced commutation:</u>

Natural commutation	Forced commutation
No external components are required	External components are required
Requires AC voltage at the input	Requires DC voltage at the input
No power loss	Power loss takes place
SCR turns OFF due to negative supply voltage	SCR can be turned OFF due to both voltage and current
Cost is NIL	Cost of commutation is high