CHAPTER-1

(INTRODUCTION TO THYRISTORS AND OTHER POWER ELECTRONIC DEVICES)

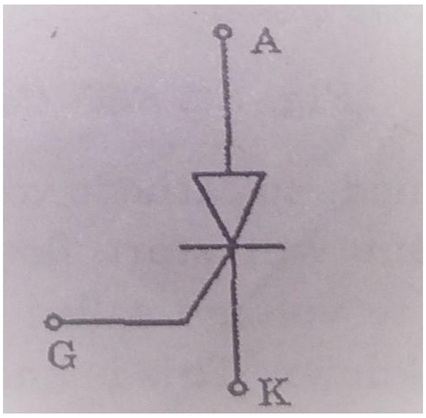
1-INTRODUCTION OF THYRISTOR

Thyristor is fabricated and developed by Bell Laboratories by General Electrical Company of USA in 1956. Thyristor family consist of many solid state devices like Triac, Diac and silicon controlled Switch. One of the oldest member of this family is SCR (silicon controlled rectifier). In this silicon is used in its constriction and its operation, is like a rectifier having low resistance in the forward direction-and high resistance in the reverse direction.

2-SCR

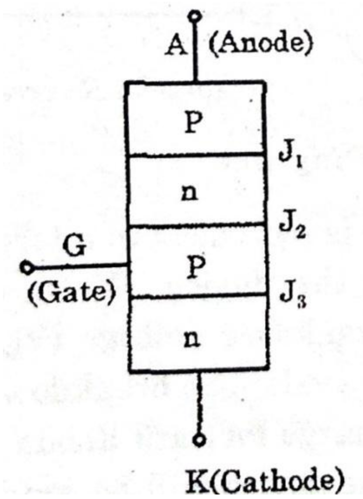
It is stands for silicon controlled rectifier. It is four layers p-n-p-n semi conductor device which consists of three terminals; anode, cathode and gate is called SCR. It is unidirectional device.

SYMBOL OF SCR



CONSTRUCTION OF SCR

SCR are four-layer (p-n-p-n) semi conductor device with three terminals; anode, cathode and gate. Fig. 1.1 (a) shows the construction of Thyristor or SCR.



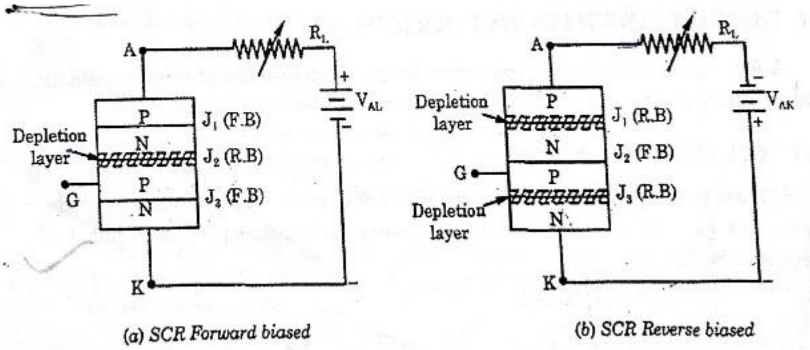
In p-n-p-n type structure the anode terminal is connected at p-type material layer and cathode terminal is connected at n-type material layer .similarly the gate terminal of the scr is connected at p-type material layer which is nearest

To the cathode type material layer.

Basically for large current rating applications, SCR needs better cooling ; this is achieved by mounting them onto heat sinks. SCR is a unidirectional.

WORKING-

The working principle of SCR can be explained with the help of figure 1.2 as show below. When the anode voltage is made positive w.r.t cathode, the p-n junction J1 and J3 are forward biased, whereas the junction J2 is reverse biased as shown in figure 1.2 (a).,Therefore small leakage current flow from anode to cathode. Thus no conduction will be occur in the device. This state of SCR is called forward Blocking state or forward off state.



(a) SCR Forward biased (b) SCR Reverse biased

Fig. 1.2. SCR Conducting Diagram

Now, When the anode to cathode voltage (V_{AK}) is increased to a large value, the forward leakage current will start flow through the device. When the forward voltage (V_{AK}) is reach to voltage called forward breakover voltage (V_{Bo}), then the junction J_2 will be breakdown. This is known as the avalanche breakdown, since the junction J_1, J_3 are more forward biased as a result large forward anode current will start flowing in the device. Thus we can say that the device will be conducting or in ON state. I the on-state the anode current is limited by external resistance R_L, as shown in fig 1.2.

When the cathode is made positive w.r.t anode, the junction J_1 & J_3 will be reverse biased, whereas the junction J_2 will be forward biased as shown in figure 1.2 (b). A small reverse leakage current will flow As the cathode to Anode voltage is increased to a large value, the junction J1 and j3 will breakdown. The voltage at which this condition is achieved is known as reverse breakover voltage(V_{BR}).

CHARACTERISTIC OF SCR

V-I characteristics of a SCR is shown below in figure 1.3. The V-I characteristics of SCR can be explained with the help of three mode of operation ; such as forward blocking (off- state), forward conduction (on state) and reverse blocking mode.

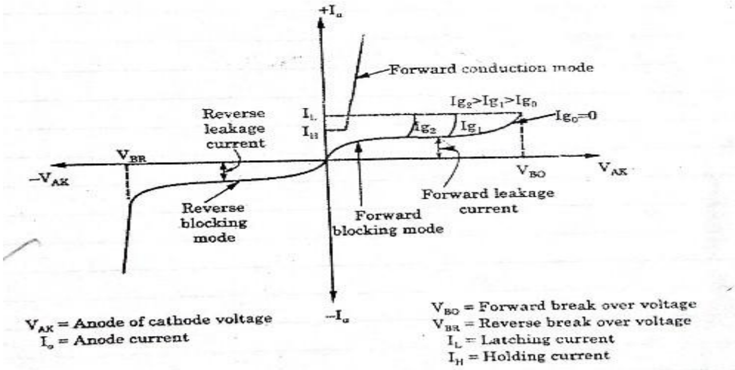


Fig. 1.3. V–I *Characteristics of SCR*

(a) Forward blocking mode :-

When the anode voltage is +ve w.r.t cathode, the thyristor is forward biased as shown in figure 1.2 (a). When the forward voltage is less than the forward breakdown voltage (V_{BO}) then it is known as forward blocking mode (off state). In this mode small forward leakage current will be flow:

(b) Forward conducting-

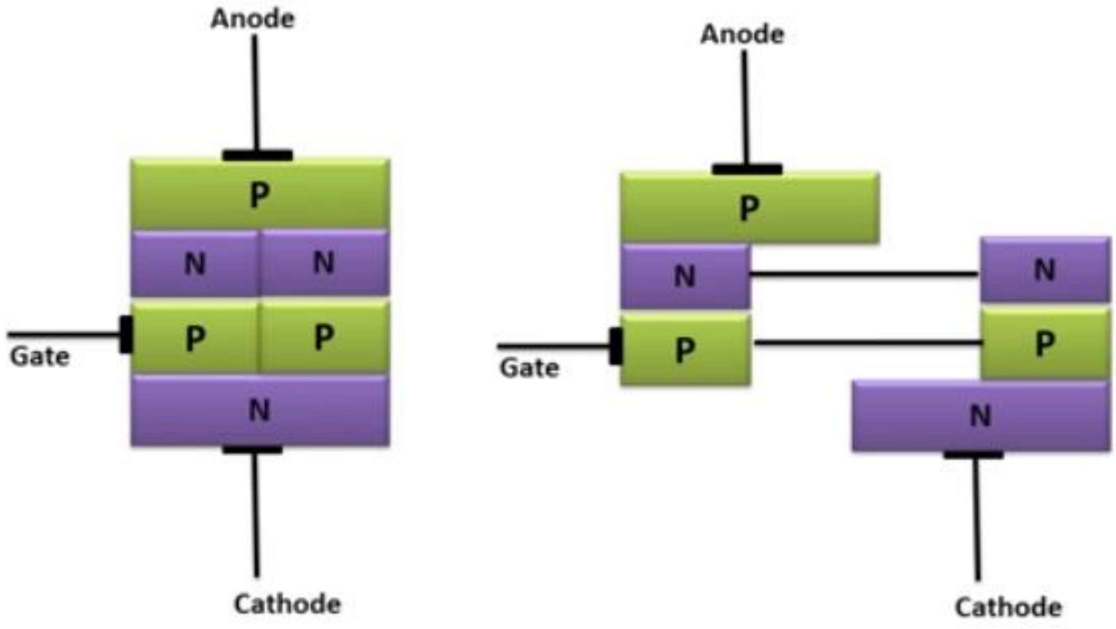
When the anode to cathode voltage is greater than the forward breakdown voltage (V_{BO}), the thyristor is brought from forward blocking mode to conducting mode. The anode current must be more than the latching current (I_L). If the current is reduced to less than the holding current (I_H), the thyristor switches back to forward blocking mode.

(c) Reverse blocking mode:-

When the cathode is made positive w.r.t anode, the thyristor is reverse biased as shown in figure 1.2 (b). A small reverse current start flows. If the cathode to anode voltage (V_{KA}) is increased, at a critical breakdown value, called reverse breakdown voltage (Vss),then an avalanche breakdown Will occurs and a large amount of current start flows. This mode of operation is known as Reverse blocking mode.

3-TWO TRANSISTOR MODEL OF A THYSISTOR

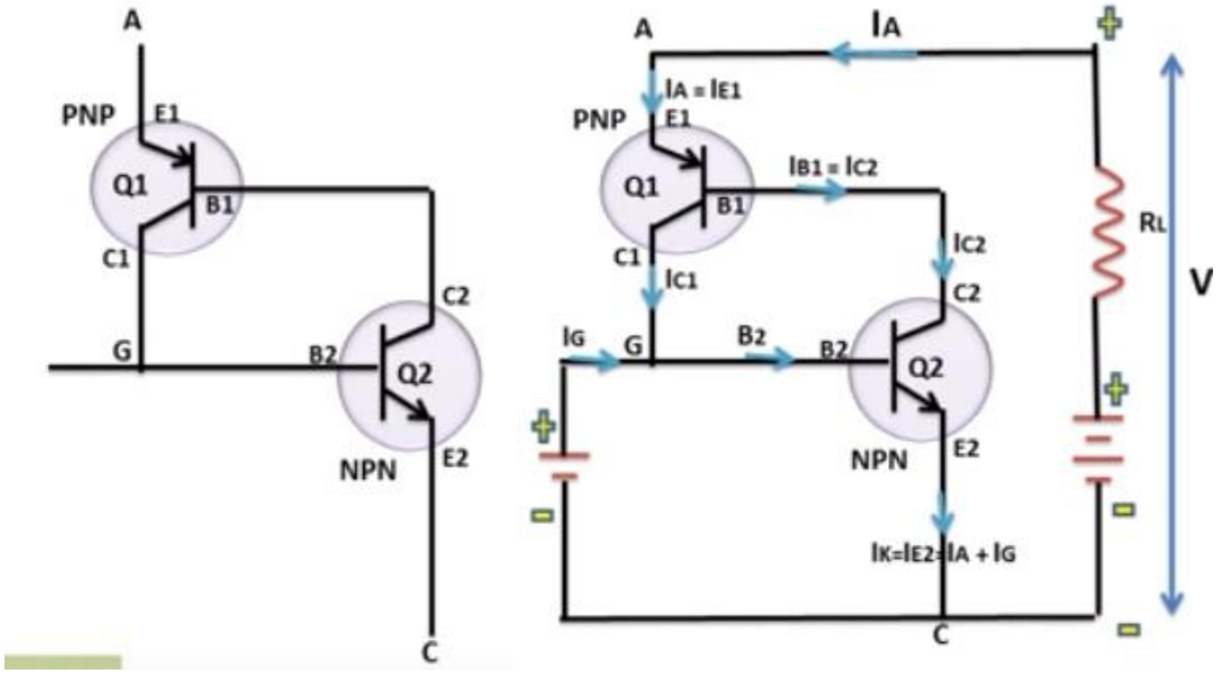
Thyristor operation can be easily explained by bisecting the two middle layer of a thyristor into two separate parts, one is n-p-n transistor and other is p-n-p transistor. The basic structure of two transistor model is shown in figure (a) and the equivalent circuit of two transistor model is shown in figure (b).



When then Gate signal is zero, the collector current of transistor Q2 (n-p-n) is almost zero & the transistor Q2 is in off-state. The collector current of Q2 transistor is the base current of Q1 transistor. Hence the transistor Q1 is also off- state and the thyristor is in forward blocking state.

Now, when the positive signal is applied to the gate terminal, the collector current start flow into the Q2 transistor. The collector current of Q2 transistor is the base current of transistor Q1. Therefore the Q2, transistor as well as Q1 transistor start conducting. And the collector current of Q1 transistor is the base current of Q2 transistor as shown in figure bellow. Therefore, current of one transistor increase the current of other transistor.

NOTE-SEE IN YOUTUBE-------------https://www.youtube.com/watch?v=_ynzDK3yIQ0



4-SCR SPECIFICATIONS AND RATING-

Thyristor rating indicate voltage , power, current and temperature limits . Which a thyristor use without damage , rating and specification serve as a link between the designer and the user of SCR system. For reliable operation it is ensure that current and voltage rating not exceed during its working .

ANODE VOLTAGE RATING-

Anode voltage rating waveform are shown in fig.

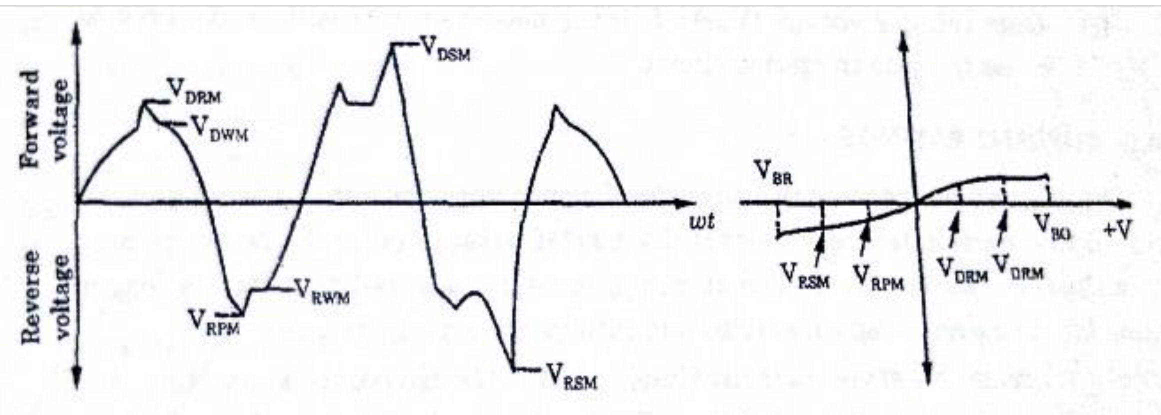


Fig. 1.5. (a) *Anode Voltage Rating*

(a) Peak working forward blocking voltage (V_{DWM})-

It is the maximum forward off-state(blocking) voltage that a thyristor can with stand during off-state.(working condition में रहने की कोशिस करता है ।)

(b) Peak repetitive forward blocking voltage (V_{DRM})-

It specifies the peak transient voltage that a thyristor can with stand periodically in its forward direction during off -state.

(c)Peak surge(non repetitive) forward blocking voltage (V_{DSM})-

It specifies the peak value of the forward surge voltage in the forward direction during oft state. Its value is about 1.3 of V_{DRM} but its value must be less than forward break down voltage(V_{BO}). This voltage is non-repetitive.

(d)Peals working reverse voltage (V_{RWM})-

It specifies the 'maximum reverse voltage that a thyristor can withstand repeatedly.(reverse की वो maximum voltage जिसपे हमारा thyristor work करने की कोशीश करे ग।)

(e) Peak repetitive reverse voltage (V_{RPM})-

It specifies the maximum transient voltage in the reverse direction and its occurs repeatedly.(reverse cycle में repeat होती रहती है ।)

(f) Peak surge reverse voltage (V_{RSM})-

It specifies the maximum value of the surge voltage in the reverse direction. Its value is about 1.3 of V_{RPM} but its value less than the forward breakdown voltage (V_{BR}). This voltage is non-repetitive.

(g) On-state voltage drop (V_T)-

When the thyristor is in on-state, there will be drop across the anode and cathode. Its value in between 1 to 1.51V.

(h) Forward dv/dt rating-

It is the maximum rate of rise of the anode voltage that will not trigger the thyristor, without any gate signal.

(i)Gate trigger voltage (V_{GT})-

it is the maximum gate voltage required to cause the gate triggering circuit.

POWER RATINGS

Due to the power loss ; heat to be generated into the thyristor. This heat tends to increase the temperature of junction which may damage the device.

(**a)Turn-on and turn-off loss –**

At the time of turn ON, the voltage drop across thyristor is high. Thus the power loss occur during turn - on period.

Similarly during the turn off period, the reverse current may be high. Thus the loss take palce during turn-off period also.

(b) Gate power loss-

This loss equals the product of gate voltage and gate current. To avoid gate power loss by triggering the thyristor using gate pulse signals.

(c)Forward and reverse blocking loss –

This loss is occurs when a forward voltage is applied but the thyristor is not conducting. A small forward leakage current flow during this period. It is the product of forward blocking voltage and forward leakage current.

Similarly, when the reverse voltage is applied. A reverse leakage current flow during this period. It is equal to the product of reverse voltage and reverse leakage current. This loss is very small.

5-METHODS OF TRIGGERING OF SCR

When the anode voltage is positive w.r.t to cathode voltage, thyristor will be turned on by any one of the following Techniques.

(a) Forward voltage triggering

(b) dv/dt triggering

(c) Temperature triggering

(d) Light triggering

(e) Gate triggering.

Turn on the SCR is called triggering or firing of SCR. .../

(a)Forward voltage Triggering-

When the anode voltage w.r.t cathode voltage is increased, the junction J_2 will be breakdown. This is known as avalanche breakdown and the voltage at which avalanche occurs is called forward breakdown voltage (V_{Bo}). At this mode thyristor change from forward blocking state to forward conducting state.

(b) dv/dt Triggering-

If the rate of rise of voltage dv/dt is made more than the value of critical rate of rise of voltage, the SCR start conducting. This method of triggering is not desirable because a high charging current may damage the thyristor.

(c)Temperature triggering –

When the temperature of p-n junction increase, leakage current through junction J_2 further increase. Due to this temperature, depletion layer across junction J_2 will be breakdown and the thyristor start conducting. High temp. may cause thermal run away and is generally avoided.

(d)Light Triggering-

When the light is triggered in the inner p layer as shown in figure 1.6. Free charge carries are generated just like when gate signal is applied between gate and cathode. When the intensity of light throw exceeds(से अधिक) a certain value, forward biased SCR is turned on. Such thyristor is known as light activated SCR (LASCR).

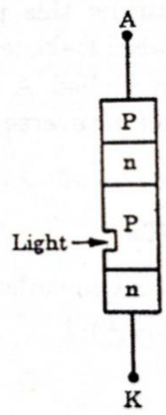


Fig. 1.6 (a) *Elementary Lascr*

(d) Gate triggering –

Thyristor can be turned on by applying the positive signal to the gate of a forward biased SCR. This type of triggering is known as gate triggering.

6-DIFFRENT COMMUTATION CIRCUITS FOR SCR

COMMUTATION-

the process of turning-off a thyristor is known as commutation. When thyristor on conducting state, Gate loses the control, over the device, therefore, some external arrangement are used to commutate the thyristor. Them are basically two commutation techniques which are discussed as below-

(a)Forced commutation

(b) Natural commutation

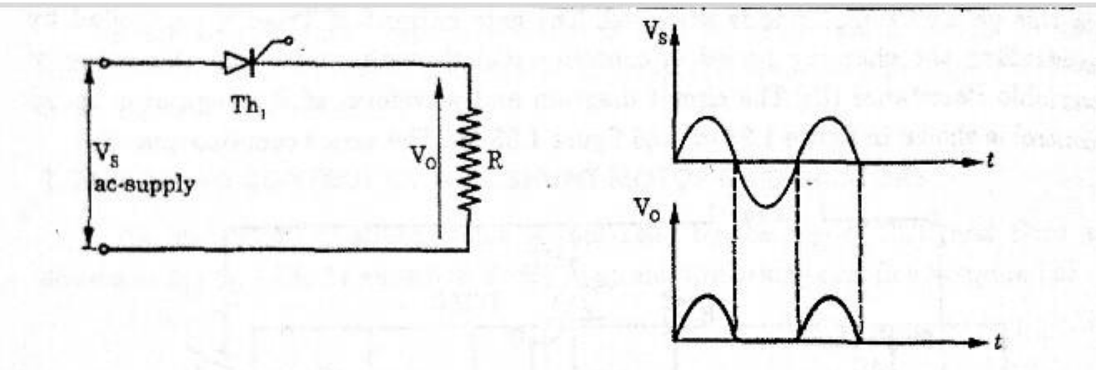
(a)FORCED COMMUTATION

In such commutation techniques SCR has to be turned off by a special commutation circuit using extra circuit components. This techniques is known as forced commutation. The forced commutation is classified into Five category

(i) Class A Commutation
(ii) Class B Commutation
(iii) Class C Commutation
(iv) Class D Commutation
(v) Class E Commutation.

(b)NATURAL COMMUTATION-

It is also known as class F commutation. The circuit diagram and waveform of natural commutation is shown in figure 1.30 (a) and figure 1.30 (b) . When the source voltage is a.c , the thyristor current goes through a natural zero and a reverse voltage appears across the thyristor. The device is automatically turned off due to natural behaviour of the source voltage for this reason, it is known as natural commutation.



(a) Circuit Diagram (b) Voltage Waveform

Fig. 1.30. ***Natural Commutation***

As shown in figure during the positive half cycle of the input voltage, the thyristor conducts and the input voltage feeds to the load. During negative half cycle, a reverse voltage is applied to the thyristor (Th_1) and it will turn off the thyristor.

7-SERIES AND PARALLEL OPERATION OF THYRISTORS

Why connect SCR in Series or in parallel?

Now a day, SCR with voltage and current rating of 10KV & 3KA are available. For some industrial applications, the demand for voltage and current ratings is so high. These requirement a single SCR cannot be fulfill.

In such cases, more than one SCRs are connected in series or in parallel

- SCRs are connected in SERIES to fulfill the high voltage demand.
- SCRs are connected in PARALLEL to fulfill the high current demand.

Problems in SCR series operation

- When the thyristors are connected in series, they have small differences in their ratings. We know that no two devices are having identical characteristics(v-i characteristics).

- This creates unequal voltage or current division among them. Hence every SCR is not fully utilized in the series connection.

- So equalization is necessary in the series connection.

String Efficiency & Detracting Factor

String efficiency is used for measuring the degree of utilization of SCRs in a string. The string efficiency of SCRs connected in series/parallel is defined as

$$\text{String Efficiency} = \frac{\text{Actual voltage/current rating of the whole string}}{\text{voltage/current rating of one SCR} \times \text{Number of SCRs in the string}}$$

string efficiency can never be equal to one. Always less than one.

Detracting Factor

Detracting factor is used to measure the reliability of string is given by

DRF = 1- String Efficiency

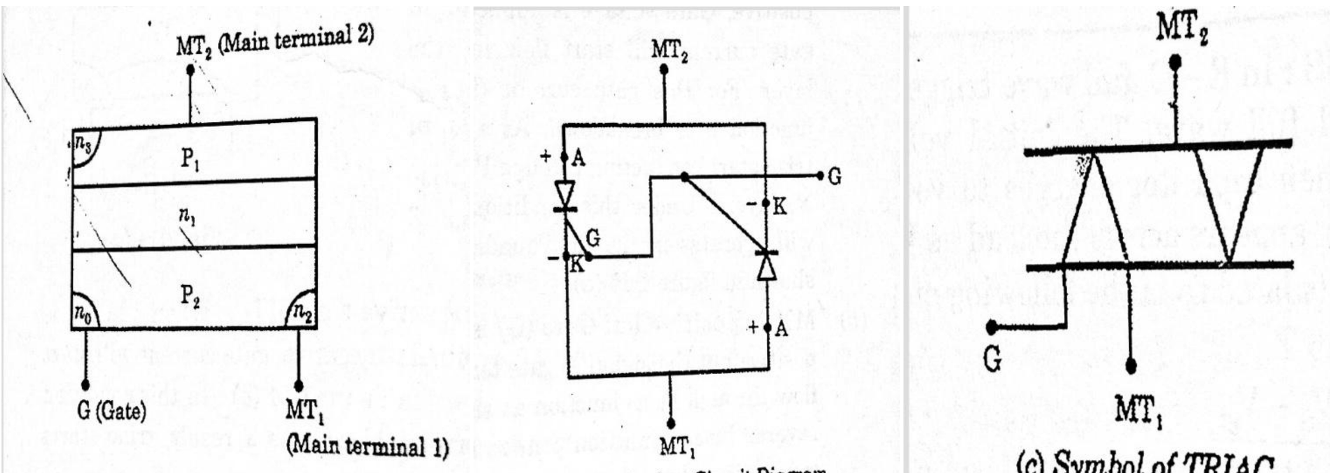
NOTE SEE IN YOUTUBE-https://www.youtube.com/watch?v=bf6gZXIbA6Y

8-TRIAC

A SCR can be conducting in only one direction.So only the positive half cycle of the circuit can be controlled. But due to the requirement of many application is to controlled the both input of the half cycle. This requirement is fulfill if we connect the two SCRs in anti-parallel combination. This arrangement is known as the TRIAC.,Therefore a triac, can conduct in both the direction, So it is called bidirectional device.

CONSTRUCTION ARRACGEMENT OF TRIAC-

Figure 1.13 (a), 1.13 (b), 1.13 (c) shows the constructional arrangement, Equivalent circuit and the symbol of TRIAC. As the triac can conduct in both the directions, therefore the terms anode and cathode are not applicable to triac. Its Consist of three terminals MT1 , MT2 and Gate G. When the two PNPN SCRS are connected in anti-parallel configuration with common gate, than TRIAC can be found as shown in figure 1.13.



(a) Constructional Arrangement (b) Equivalent Circuit Diagram (c) Symbol of TRIAC

WORKING PRINCIPLE OF TRIAC-

Triac is a bidirectional device. When no signal to gate, the triac will block both half cycle of applied voltage. The triac can be turned on in each half cycle of the applied voltage, when MT2 is +Ve w.r.t MT1 or when MT1 is +Ve w.r.t MT2 with a positive or negative gate signal is applied.

(a)MT2 is positive and Gate G is also positive w.r.t. MT1-

When MT2 is positive w.r.t MT1, the junction P1 N1 P2 N2 are forward biased but the junction n1P2 are reverse biased as shown in figure 1.14 (a). When positive, Gate voltage is applied, then gate current will start flow in p2 n2 layer. For this gate current (Ig), the junction n1p2 breakdown. As a result triac start conducting through P1 N1 P2 N2 layers.

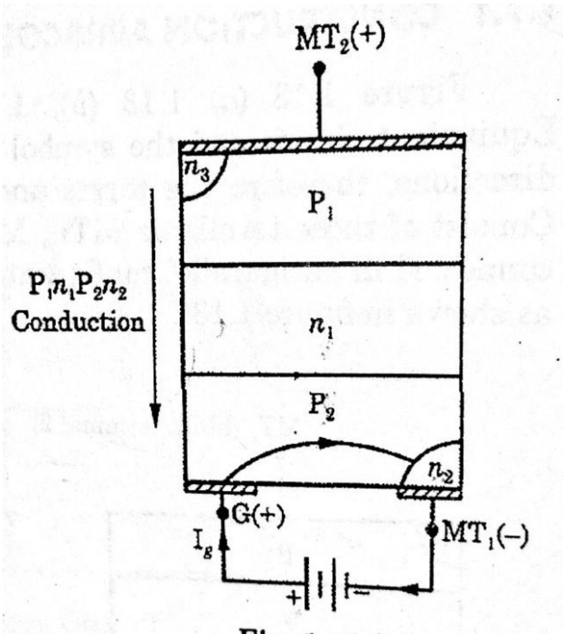


Fig. 1.14 (a)

(b)MT2 is positive but Gate (G) is negative w.r.t MT1-

When MT2 is positive but the signal to gate terminal is negative, gate current will start flow through P2 no junction as shown in figure 1.14 (b) . In this condition reverse biased junction p2n1 is forward biased. As a result, triac starts conducting through p1 n1 p2 no layers.

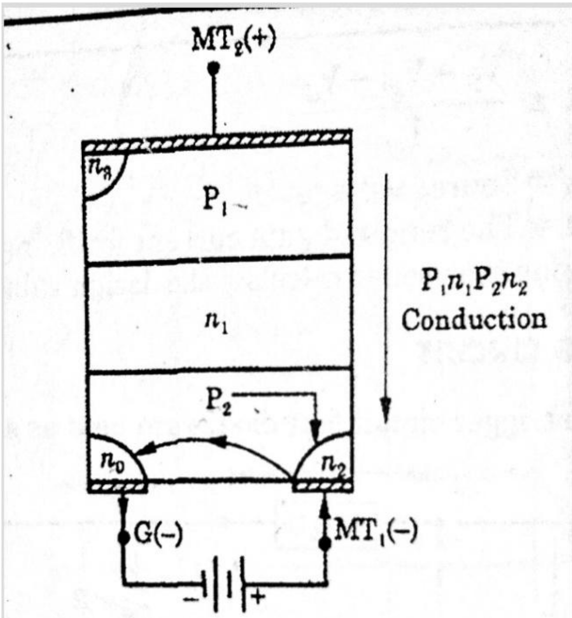


Fig. 1.14 (b)

(c) MT2is negative but Gate (G) is positive w.r.t. MT1 –

When MT2 is negative w.r.t MT1 but the signal to the gate (G) is positive, then the junction n1p1 is reverse biased. When the gate current start flow, the reverse biased junction n1 p1 breakdown. Finally the layers p2 n1 p1 n3 start conducting as shown in figure 1.14 (c).

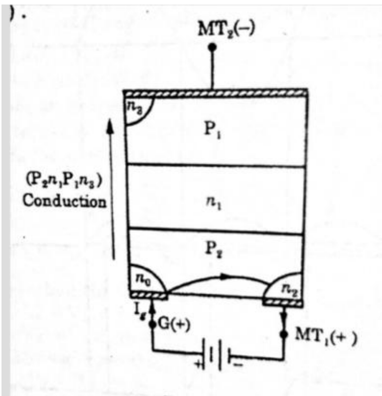


Fig. 1.14 (c)

(d)MT2 is negative and Gate (G) is also negative w.r.t MT1 –

When the MT2 is negative w.r.t MT1, then gate current (Ig) start flow from p2 no region. Therefore the reverse biased junction n1 p1 is breakdown. Finally the layers p2 n1 p1 n3 start conducting as shown in figure 1.14 (d).

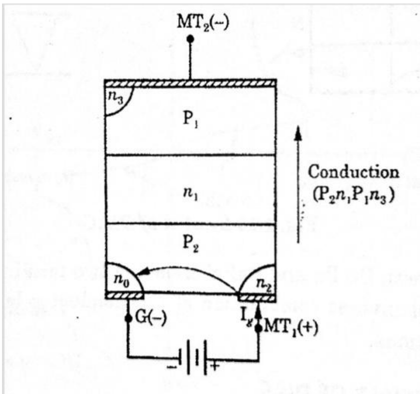


Fig. 1.14 (d)

V-I CHARACTERISTICS OF TRIAC-

Figure 1.15 (a) shows the V-I characteristics of triac.

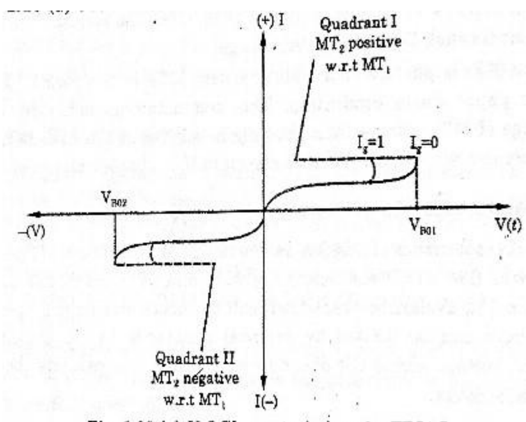


Fig. 1.15 (a) *V-I Characteristics of a TRIAC*

The triac can be conduct in two quadrant (quadrant 1 and quadrant 3) with either a positive or negative gate voltage is applied. As like SCR, the triac remain in if state until the breakdown voltage VBO1 and VB02. is not reached. When the gate signal is zero, the breakdown voltage are Vsoi and Vso2. As the gate current is increased (Ig = 1), then the breakdown voltage will be reduced.

APPLICATION-

Triac application are given below .
1-It can be extensively used in residential lamp dimmers and heat control.
2- It can also be used for speed control of small single phase series and induction motors.
3-TRIAC can be used for AC systems as a switch.
4-They are used in control circuits.
5-It is used in High power lamp switching.
6-It is used in AC power control.

Advantages of Triac-

•It can be triggered with positive or negative polarity of gate pulses.
• It requires only a single heat sink of slightly larger size, whereas for SCR, two heat sinks should be required of smaller size.
• It requires single fuse for protection.
• A safe breakdown in either direction is possible but for SCR protection should be given with parallel diode.

Disadvantages of Triac-

•They are not much reliable compared to SCR.
•R has (dv/dt) rating lower than SCR.
• Lower rating, are available compared to 5CR.
• We need to be careful about the triggering circuit as it can be triggered in either direction.

WHAT IS DIAC?

•DIAC means Diode Alternating Current. Diode work on complete cycle of AC.
• The DIAC is a bi-directional semiconductor switch that can be turned on in both forward and reverse polarities AC signal.

CONSTRUCTION ARRANGEMENT OF DIAC-

The constructional arrangement of DIAC with all its layers and junction are shown in figure 1.16 (a) and the symbol of DIAC are shown in figure 1.16 (b).

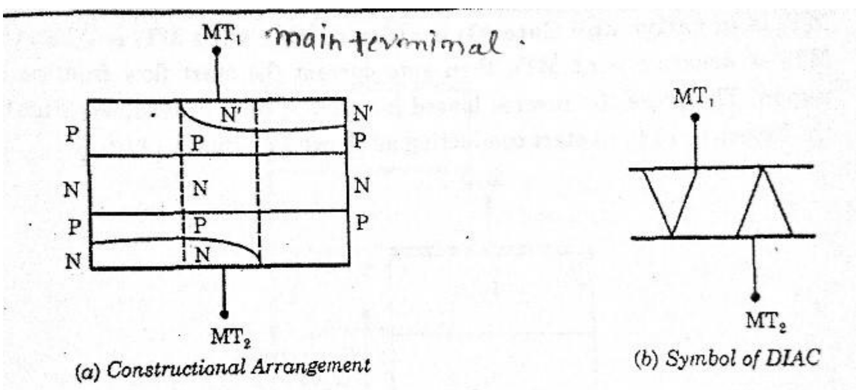


Fig. 1.16 Symbol of DIAC

DIAC is a four layers, pn pn and pn pn’ & having two terminals MT1 and MT2. DIAC is the parallel inverse combination of semiconductor layers that permits triggering in both direction.

WORKING PRINCIPLE OF DIAC-

The two mode of operation of a dice are explain below.

(a) When MT1 is positive w.r.t MT2-

. When MT1 is positive w.r.t MT2 , the layers pnpn start conducting. This conduction is achieved when the voltage of MT1 terminal is more than the breakdown voltage (V_{BO1}).

(b) When MT2 Is positive w.r.t MT1-

. When MT2 is positive w.r.t. MT1 , the layer. pnpn' starts conducting. This conduction is achieved when the voltage of MT2 is more than the breakdown voltage of MT2 is more than the breakdown voltage (V_{BO2}).

V-I CHARACTERISTICS OF DIAC-

The V - I characteristics of DIAL is shown in figure 1.17. When MT1 is +ve very small current will flow untill the voltage of MT1 and MT2 reach the breakdown voltage. At this point, avalanche breakdown will be occurs and current become very large. This current can be limited by external resistance in the circuit. As the current increase, voltage across the diac decreases. Thus diac exhibits the negative resistance characteristics.

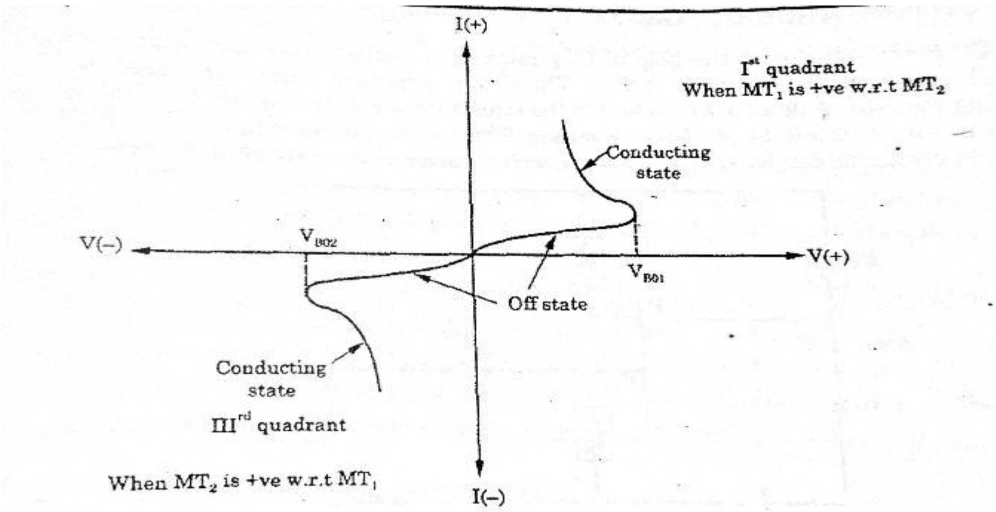


Fig. 1.17. *V–I Characteristics of DIAC*

When the MT2 is positive w.r.t MT1, the diac will conduct the current but in opposite direction. The behaviour in both directions is similar because the voltage drop is some in both directions.

APPLICATIONS OF DIAC-

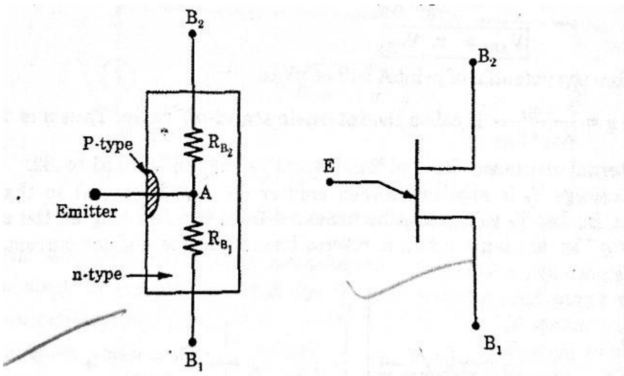
- Dias is used for turn -on the triac.
- It provides the positive or negative gate signal to the tries for turn on. Therefore combinations of Disc triac are used in various control circuits.
- The DIAC is widely used to triggering of a TRIAC when used in AC switches.
- DIACs are used in Heat control ckt.
- Also used in starter circuits for florescent lamps.

9- UJT

UJT stand for unijunction transistor. It is 3 terminal singal PN junction device. It consists of a lightly doped N type silicon bar with ohmic contacts at the two ends called base B1 and base B2.

CONSTRUCTION OF UJT-

'The constructional diagram of UJT is shown in figure 1.18 (a) and the symbol of UJT is shown in figure 1.18 (b). An UJT is made up of a n - type silicon base to which p- type emitter is embedded. UJT is a bar of high resistivity semiconductor with ohmic contact at each end. The bar is usually n-type material.



(a) Basic Structure of UJT *(b) Symbol Representation*

Fig. 1.18. *Uni-junction Transistor Arrangement*

It has three terminals, namely emitter E,base - one (Bi) and Base two (B2). Between bases B1 and B2, the unijunction behaves like an ordinary resistance. The resistance between Bi and B2 is a few kilo ohms. R_{B1} and R_{B2} are the internal resistance respectively from bases B1 and B2 to point A.

WORKING PRINCIPLE AND V-1 CHARACTERSTICS-

It can be explained by the use of equivalent circuit of the UJT. The equivalent circuit of IJJT is shown in figure 1.19.

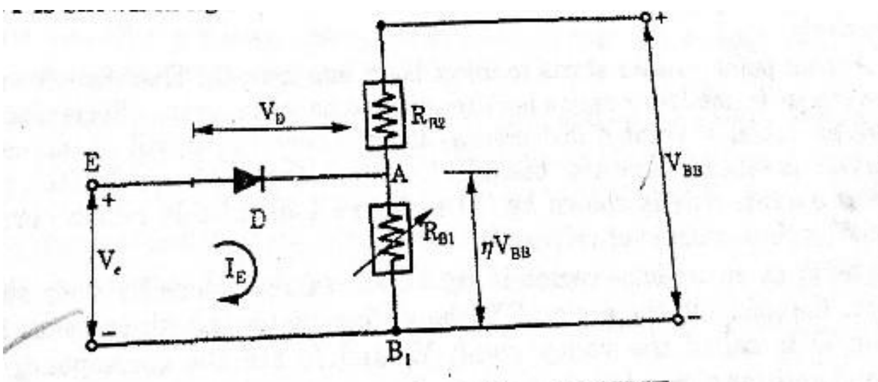


Fig. 1.19. *Equivalent Circuit of UJT*

When a positive voltage V_{BB} is applied across two base terminalsB1, and B2 , the potential of point A with respect to B1 is given by

$$V_{AB1} = \frac{V_{BB}}{R_{B1}+R_{B2}}.R_{B1}$$

$$V_{AB1} = \frac{R_{B1}}{R_{B1}+R_{B2}}.V_{BB}$$

$$\boxed{V_{AB1} = \eta.\ V_{BB}}$$

Therefore the potential of point A will be nB_{BB}.
Where

$$\eta = \frac{R_{B1}}{R_{B1}+R_{B2}}$$

is called the intrinsic stand-off ratio. Thus n is depend upon the internal resistances Rb1 and RB2. Typical values of n are 0.51 to .82 .

Let a voltage V_e is applied between emitter (E) and Base (B1) so that E is positive w.r.t B1. Let Ve voltage can be increased from zero. As long as the emitter voltage Ve <n V_{BB}, the p-n junction is reverse biased and the emitter current (IE) is negative as shown by the curve AB in fig 1.20.

Now when the voltage Ve=n V_{BB} + V_D at point A,

where V_D is the forward voltage drop of the diode, then the currant (Ie) is positive and the P-N junction will forward biased. The point C is called the peak point and he corresponding emitter potential and current are denoted by Vp (Peak point voltage) and Ip (peak point current) respectively.

At that point emitter starts to inject holes into base B1. Therefore the number of charge carries in the lower region is increased and hence resistance R_{B1} is decreased. As a result potential at point A is decreases and the current (Ie) will be increased. Thus the device is highly forward biased. Therefore the device exhibits, a negative resistance region, this is shown by CD in figure 1.20. In this region current (Ie) is increased by the decrease of voltage Ve.

At point D, entire base region is saturated and resistance R_{B1} does not decrease any more. Therefore in the region DE, the voltage increase with increase in current. The point D is called the valley point; Vv and Iv are the corresponding emitter voltage and emitter current at that point. .

<u>The following Fig shows V- I characteristics of UJT</u>

It is observed from the characteristics that for the emitter potential less than the peak point voltage V_P (V_P = n V_{BB} + V_P), the emitter base . junction is reversed biased. So that magnitude of the emitter current is zero. Only the reverse leakage current I_{EO} will flow and the UJT is said to be in OFF position. This portion of curve is called cut off region of UJT. When the emitter voltage reaches V_P the emitter base junction becomes forward biased. After this point, the small increase in V_E is followed by sudden increase in emitter current I_E. It is seen that as the current increases, the voltage V_E decreses giving a negative resistance region of characteristics which lasts until the valley point voltage Vv is reached. In this region the UJT is said to be in ON state.

Beyond valley point any further increase in I_E is accompanied by increase in V_E . this region to the right of V_V is called saturation region of UJT.

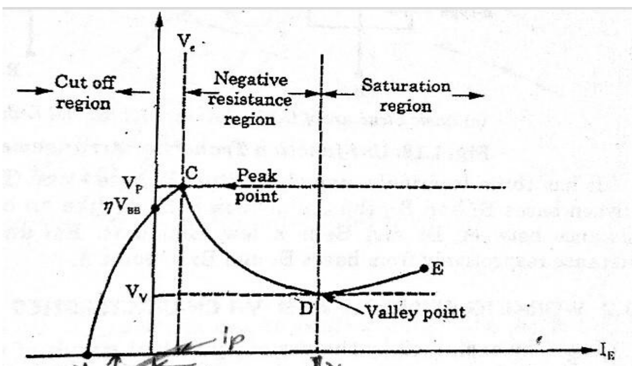


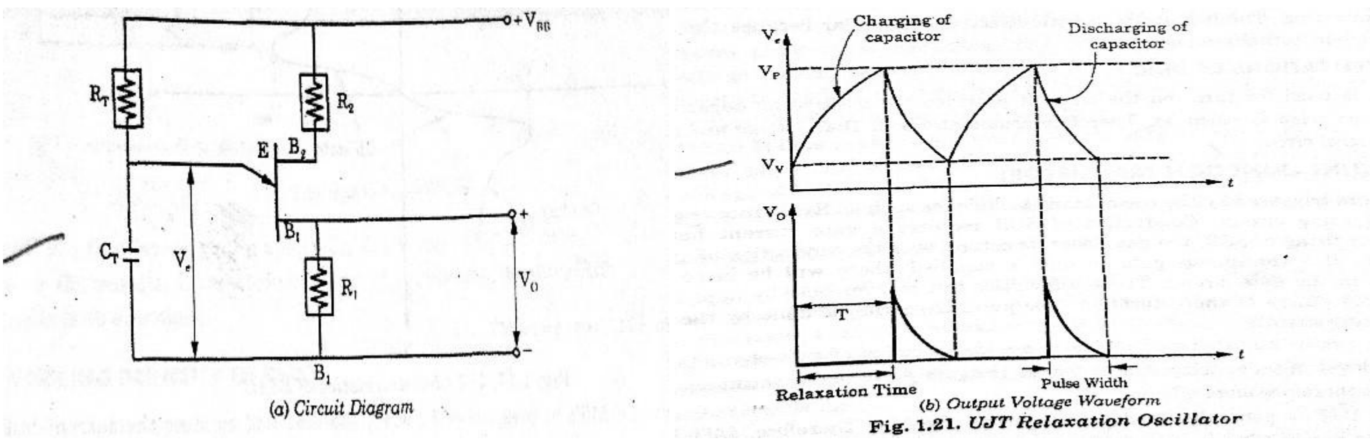
Fig. 1.20. V–I Characteristics of UJT

APPLICATION OF UJT-

1-it is used in phase control.
2-it is used in sawtooth generator .
3- it is used in sine wave generator.
4- it is used in switching .
5- it is used in timing and trigger circuits.

RELAXATION OSCILLATOR –

SCR is triggered with the help of UJT relaxation oscillator because, it produce the high powered low duration pulse. These low duration pulses are used for triggering the SCR. Figure 1.21 (a) shows the circuit for a relaxation oscillator using UJT. It is very suitable for generating pulses. The output pulses generated by UJT relaxation oscillator can be applied as a triggering pulses to the gate of SCR.



(a) Circuit Diagram (b) Output Voltage Waveform

Fig. 1.21. *UJT Relaxation Oscillator*

In figure 1.21(a), when source voltage V_{BB} is applied, capacitor C_T begins to charge through resistance R_T exponentially toward V_{BB}. When the emitter voltage V_e reaches the peak - point voltage $Vp=n\ V_{BB} + V_D$, the unijunction between E –B_1 breaks down. As a result, UJT turns on or starts conducting. Capacitor C_T will be discharge through low resistance R1. When the emitter voltage decays to the valley-point voltageVv, UJT turn -off. The time T required for capacitor C_T to charge from initial voltage Vv to the peak point voltage Vp, through large resistanceR_T, can be obtained as under.

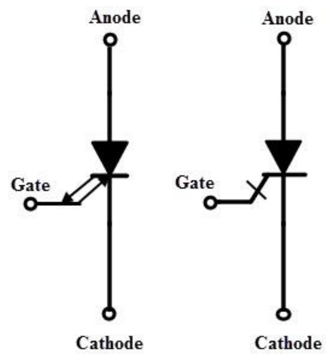
$$T = R_T C_T \ In(l-n) \qquad \text{(assuming } V_U \text{ small)}$$

The external resistances R1 , R2 are small in comparison with the internal resistances R_{B1}, R_{B2} of UJT bases. For UJT, n is about 0.63. Capacitor C_T now again charge from Ve= $V_V$to voltage $nV_{BB} + V_D$, E-B_1, junction breakdown and above cycle repeates . Figure 1.21 (b) shows the voltage waveform of UJT relaxation oscillator.

10-Basics of GTO (Gate Turn OFF Thyristor)

• The full form of GTO is Gate Turn Off Thyristor. It is a special type of Thyristor.
• GTO a active semiconductor device. It was invented at General Electric.
•GTO is d fully controllable switch which can be turn ON and turn OFF by gate signal .Where as conventional thyristor can be turn ON by gate pulse but can not turn OFF by gate pulse.
• During turn ON it is work like a conventional thyristor.
•GTO is a three terminal ,four layer device. has high voltage blocking capability and high over current capability.
•GTO is use for chopper and PWM Inverter applications.

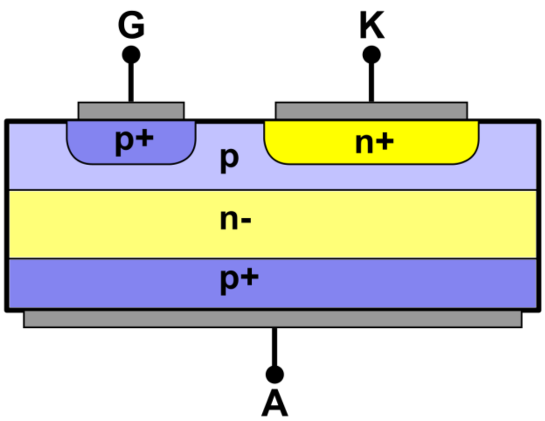
Symbol of GTO-



Gate Turn-Off Thyristor Symbols

CONSTUCTION OF GTO-

The construction of GTO is shown in the fig.



Just like SCR it is four layer device pnpn. here will be p^+ n^- p n^+ from which main terminal anode and cathode is connected. Anode is connected with p^+ and cathode is connected with n^+.

P^+ means it is highly doped p type semiconductor layer. N^- means it is lightly doped n type semiconductor material layer. N^+ means it is highly doped n type semiconductor layer. p^+ layer is deposit bellow the gate terminal.

WORKING AND V-I CHARACTERISTIC OF GTO-

The imp. point is given bellow

1-GTO is turn ON by applying +Ve gate pulse.
2-GTO can be Off by applying –Ve gate pulse.
3-GTO turn ON is not reliable as SCR.

4-GTO is 10 times faster than SCR.
5-To turn Off process we connect GTO in parallel.

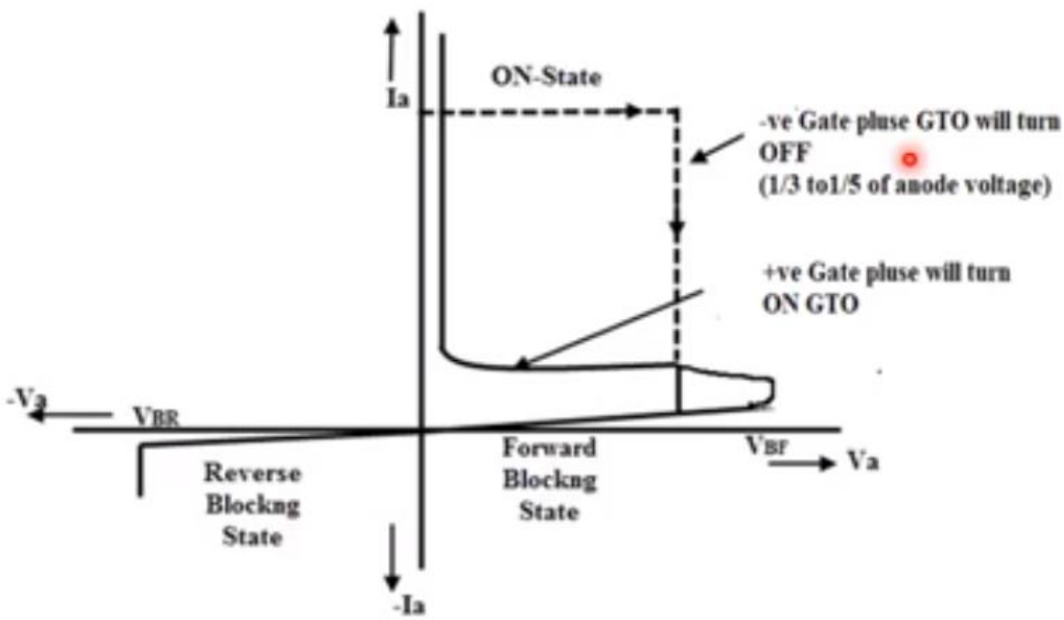
In layer structure when we deposit pn pn layer then 3 junction is form .1st junction is firm between p and n^+ which is known as J_1 , 2nd junction is form between $n^-$and p which is known as J_2 and 3rd junction formed between p^+ and n^- which is known as J_3.

1-in case of reverse base characteristic anode is made –Ve w.r.t cathode. in this condition J_3,J_1 are in reverse biase and J_2 is forward biase. Due to reverse biase of junction J_1 and j_3 it block the flow of current from cathode toward anode but reverse minute current will flow due to the movement of minority carrier toward K to A in reverse direction. When K to A voltage will increase a point will find where reverse biase junction will break down and large reverse current will flow in reverse direction. This voltage is known as reverse break down voltage.

2-in case of forward biase characteristic anode is made +Ve w.r.t cathode. in this condition J_2 is in reverse biase and J_1 ,J_3 are forward biase. J_2 block the flow of current A toward K in forward direction but due to movement of minority carrier a small forward leakage current will flow. When we increase forward applied voltage then a point will fiend where the junction J_2 will break down and large current will flow from A toward K and the device will be turn on. This voltage is known as reverse break down voltage.

Device is turn on with the help of +Ve gate pulse. Anode to cathode voltage is no extend up to break over voltage and gate is connect +Ve w.r.t to cathode then the device is turn on. In this time large current will flow.

The device is turn off by applying -Ve gate pulse. It will be remember that the gate voltage is 1/3 to 1/5 of anode voltage.



V-I Characteristic of GTO

Comparison of SCR and GTO

Characteristic	Description	Thyristor (1600 V, 350 A)	GTO (1600 V, 350 A)
$V_{T\,ON}$	On state voltage drop	1.5 V	3.4 V
t_{on}, Ig_{on}	Turn on time, gate current	8 µs,200 mA	2 µs,2 A
t_{off}	Turn off time	150 µs	15 µs

PROGRAMMABLE UNIJUNCTION TRANSISTOR (PUT)-

A programmable unijunction transistor (PUT for Short) is also a 4-layer P-n-p-n device with an anode gate G as shown in figure 1.44. The anode A and the gate G from a p-n junction that controls the operation of the device. The word programmable in the name simply highlights the fact that the gate voltage is externally controlled.

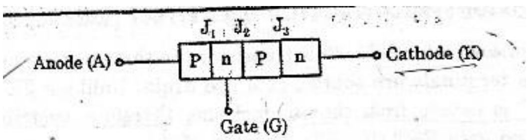
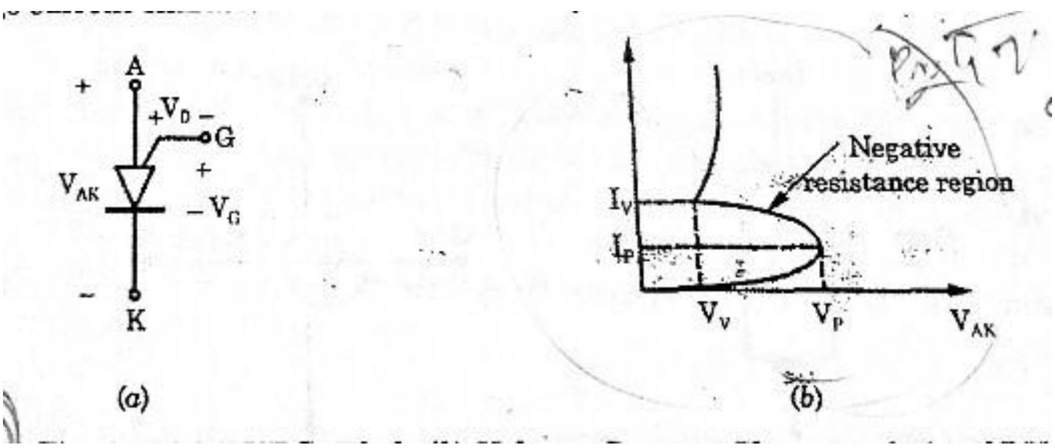


Fig. 1.44. *Programmable Unijunction Transistor*

When the cathode terminal is taken as reference ,t he gate voltage is positive w.r.t cathode. The device will remain in the off state as long as the gate voltage is positive with respect to anode. The device will switch from its, off state to on state only when voltage is on diode voltage drop higher than the gate. The voltage current characteristic and the circuit symbol of a PUT are given in figure.1.45



METAL OXIDE SEMICONDUCTOR FIELD EFFECT TRANSISTOR (MOSFET)-

A metal oxide semiconductor held effect transistor is a three terminal semiconductor device. The three terminals are source, gate and drain. Unlike a FET, the gate in ease of MOSFET is isolate from the channel and, therefore, sometimes it is also known as insulated gate FET (IGFET). Because of the gate current is very small whether the gate is positive or negative.

Construction-

An n-channel MOSFET is shown in fig. 1.46.(a). The shows its constructional detail. Its construction details is similar to the FET expect with the fallowing modification.

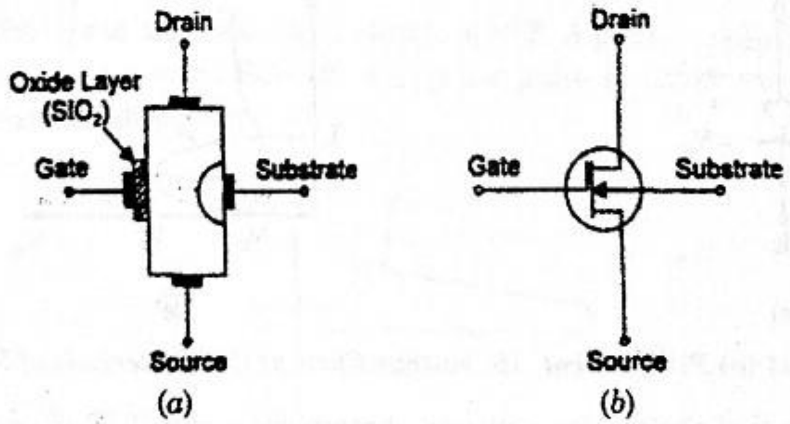
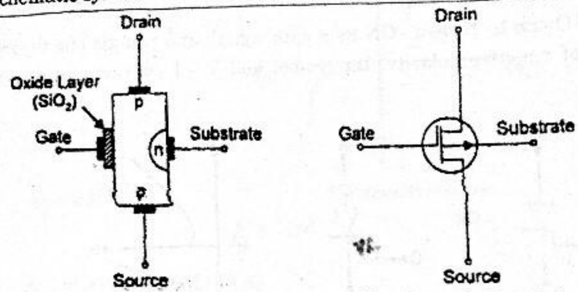


Fig. 1.46. n-Channel MOSFET

(i) There is only one p-region instead of two. This region is known as substrate.
(ii) On the left side of the channel, a thin layer of metal oxide (usually silicon dioxide SiO2) is deposited. A metallic gate is deposited over silicon dioxide layer as shown in fig. 1.46 (a). The gate is insulated from the channel since silicon dioxide is an insulator. Because of this it is also known as insulted gate FET.
(iii) Since the gate is insulated from the channel by a thin layer of silicon 'oxide, the input impedance of MOSFET is very high (of the order of 10^{10} to 10" ohms).
(iv) Unlike the FET, a MOSEET has no gate diode but it form a capacitor. The capacitor hade gate and channel as electrodes and the oxide layer as dielectric. Because of this property, the device can be operated with negative as well as positive gate voltage.

The schematic symbol of n-channel MOSFET is shown in fig. 1.46 *(b)*.



(a) Construction detail of p-channel MOSFET

(b) schematic Symbol

Fig. 1.47

Fig.1.47 (a) shows the constructional details of a p-channel MOSFET, whereas fig. 1.47(b) shows the schematic symbol of a p-channel MOSFET.

WORKING PRINCIPLE OF MOSFET-

The circuit diagram of an n-channel MOSFET with normal polarities is shown in fig. 1.48. Unlike the FET, a MOSFET has no gate diode rather it forms a capacitor which has two electrodes i.e. gate and channel. The oxide layer acts as dielectric medium. When negative voltage is applied to the gate, electrons accumulate on it.

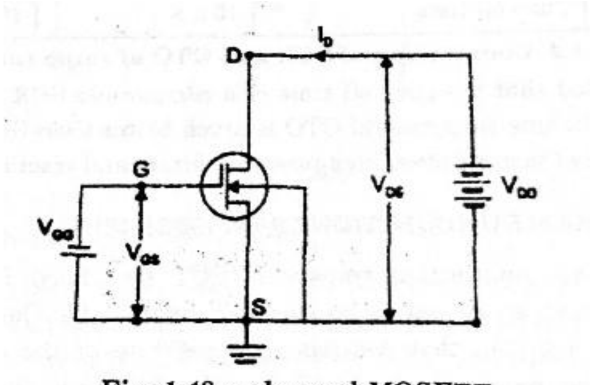


Fig. 1.48 n-channel MOSFET

These electrons repel the conduction band electrons in the n-channel. Therefore the number of conduction electrons available for current conduction through the channel will ruduce.the greater the negative potential on the gate the lesser the current conduction from source to drain. In this case if the gate is given position voltage, more electrons are made available in the n-channel. Therefore current from source to drain increases.

The following points are worth nothing
(i) In a MOSFET, the source to drain current is controlled by the electric field set up by the capacitor formed at the gate rather than depletion layer of the junction.
(ii) Unlike the FET, a MOSFET has no gate diode. because of this, the device can be operated with negative or positive gate voltage as shown in the 'Output characteristics shown in fig. 1.49

'output characteristics shown in fig. 1.49

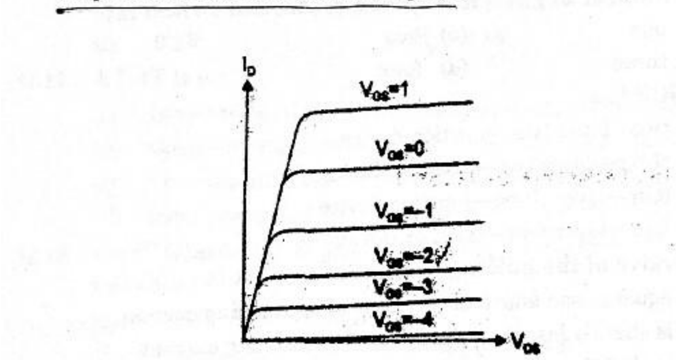


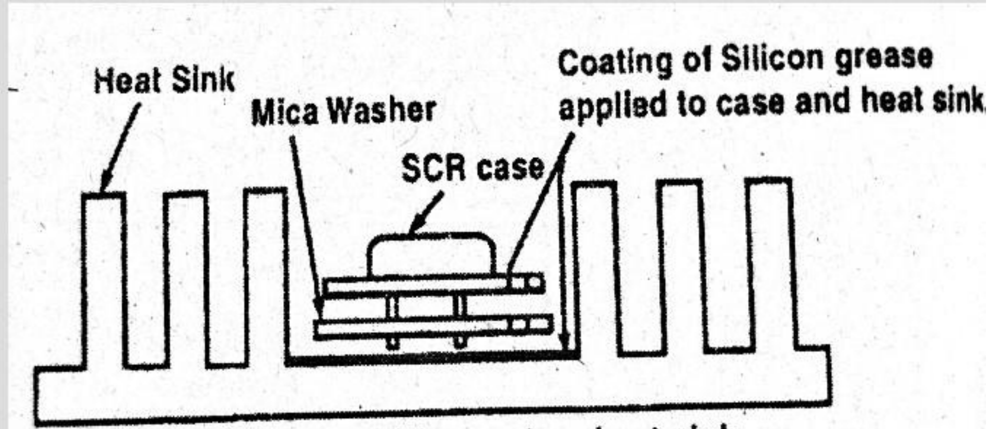
Fig. 1.49. Output Characteristics of a MOSFET

(iii) Since the gate is insulated from the channel by an oxide layer, a negligible gate current flows due to gate capacitance whether the voltage applied at the gate is negative or positive. Consequently, the input impedance of MOSFET is very high ranging from 10^{10} ohms to 10^{15} ohms.

11-Write a note selection of Heat sinks for thyristors.

When a thyristor is carrying current or operating, some power loss occurs in the thyristor. The electrical losses produce thermal heat which must be removed from the junction region. The thermal losses and hence the temperature rise increases with the thyristor rating and cooling becomes more difficuilt as the thyristor rating increases. The heat produced in a thyristor by electrical dissipated to ambient fluid (air or water) by mounting the device on a Heat sink. Effectiveness of particular heat sink depends upon following factors.

1- thermal conductivity of metal used for heat sink,
2-Surfacearea of heat sink.
3- Thickness of metal
4- design of heat sink.
Material used for making heat Sink is either copper or aluminium. lead mounted SCRs below.
1. Amp rating do not require any heat sink. They can be directly soldered into circuit. Above one ampere rating, SCRs are generally mounted to a fin or other type of heat sink capable of passing heat losses to surroundings. Medium and high current are available in stud mounted versions may consist of a busbar, chasis, cooling system, cold plate or cooling fins. Fig shows mounting of SCR case to heat sink.



Mounting an SCR case to a heat sink

12-APPLICANS SUCH AS

LIGHT INTENSITY CONTROL-

Light intensity control is commonly known as illumination control. light intensity of a lama can directly be controlled by varying the voltage across the lamp. Heat produced in the lamp and hence intensity of light is directly proportional to the voltage fed to the lamp.

Illumination control using SCR : The circuit is shown in fig 1.35. Full eave pulsating d.c is obtained through a bridge rectifier.

The Capacitance (C) start charging through fixed Resistance (R1) and variable resistance (R2). When the voltage of capacitor (Vc) is reach to the peak point voltage UJT, it will start to conduct. As a result high powered pulse is gone to the SCR gate which trigger the SCR and the voltage across the lamp will appear.

If we increase the value A Resistance (R), the Capacitor (C) takes longer time to turn on the UJT and voltage fed to the lamp is decreased. The voltage fed to the lamp is directly proportional to the intensity of light. As a result, when the voltage fed is decreased, the brightness of lamp is also decreased. Similarly for increasing the lamp intensity the value of R2 it decreased.

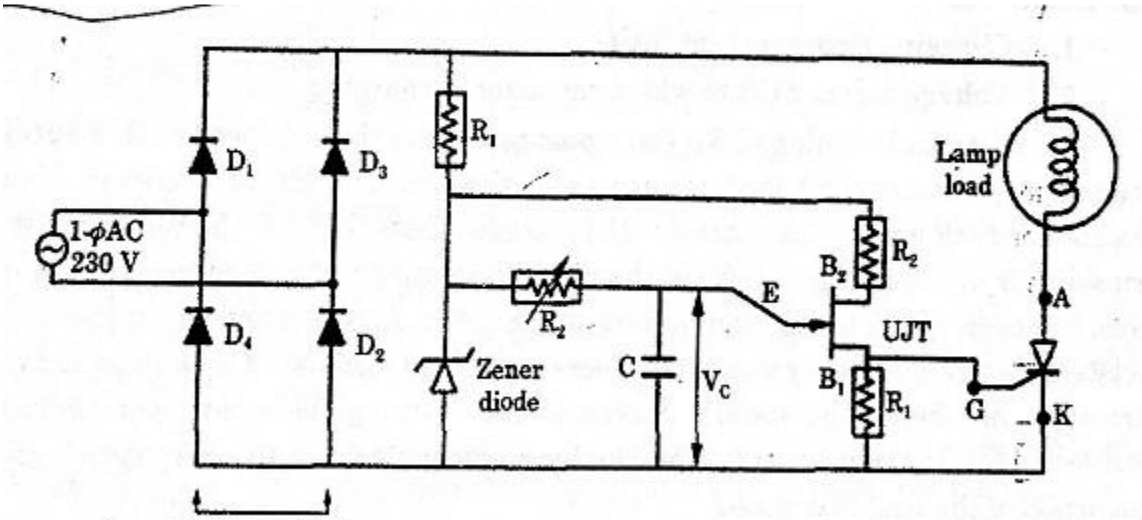


Fig. 1.35. ***Light Intensity Control by Thyrutor***

BATTERY CHARGER USING THYRISTORS-

The fully charged battery are used for many commercial applications. Therefore, the flattery is charged with the help of thyristors. The circuit diagram of battery charging by the use of thyristor are shown in figs. 1.32. A centre tapped transformer along with diode (D1) and diode (D2) generate the full wave rectified voltage.

This rectified voltage is applied to the battery which is in series with the SCR1. When the battery start charging the thyristor (SCR1) is forward biased. When the full wave rectified voltage is reach to the maximum permissible value, the gate current of SCR1 is start increasing. As a result, the SCR1 turn on and the battery start charging. The gate current of SCR1 is controlled by the resistance (R3) through diode (D3).

when the charging near completion, the battery voltage start to rise. When his voltage(V) reach to a value, near the zener breakdown voltage, the gate current will be start flow into the SCR2. AS a result SCR2 is start conducting.

Qnce the SCR2 is turned on, the voltage divider formed by resistances (R3) and (R4) will cause the diode (Ds) to be reverse biased as a result SCR1 will goes to the off state. Therefore, the charging of battery is stopped. The diode (D4) and resistances (R1), (R2) are used to continue the flow of charging current into the battery when the quick charging is over. It is protect the battery.

FAN REGULATOR CONTROL/USING THYRISTORS-

When the 1- ф 230V, 50 Hz supply is on, the capacitor (C3) will start charging. The diac turn - on , when the voltage across capacitor (C3) more the breakover voltage of Diac. When the Diac turn on, the gate current will start flow in Triac.

Due to this gate current, Triac is triggered. The gate current of Triac is controlled by controlling the charging period of capacitor (C3) through controlling the value of variable Resistance (R3).

The circuit diagram and waveform of fan regulator speed control is shown in figure 1.33 (a) and figure 1.33 (1). The series combination of resistance(R1) and capacitance (C1) is used for protection of circuit far any distrurbances occur in main supply. The. capacitor(C2) is used for protection of diac from any transient effect.

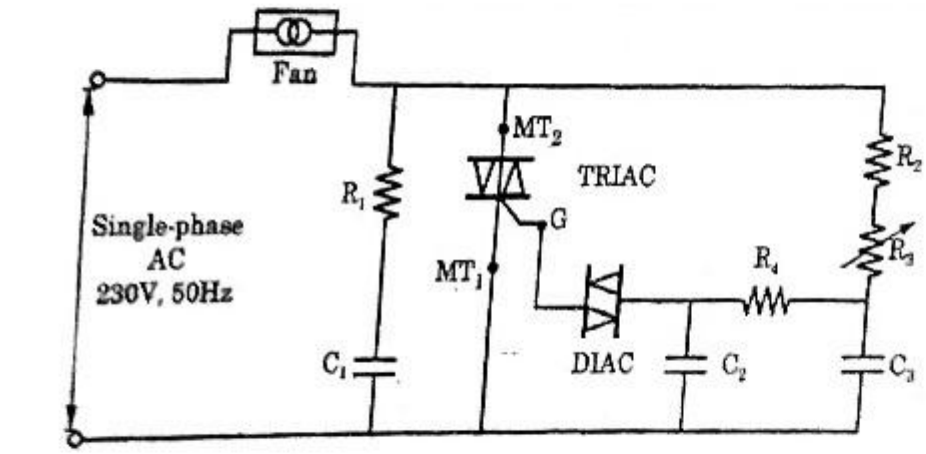
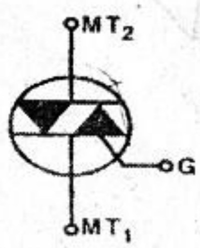


Fig. 1.33 (a) Circuit Diagram of Fan Regulator Speed Control

DIFFRENCE BETWEEN DIAC AND TRIAC-

	SCR	Triac
1.	SCR is a unidirectimal device	Triac is a bidirectional device.
2.	Circuit symbol of SCR is as shown in fig. 	Circuit symbol of Triac is as shown in fig. 
3.	It consists of three terminals i.e. anode cathode and gate.	It also consists of three terminals i.e. MT_1, MT_2 and gate.
4.	SCR is a four layer semi conductor device	Triac is five layer semi conductor device
5.	SCR appears to be equivalent of two transistors PNP and N-P-N, the output of one transistor being fed to input of other.	Triac can be considered as two SCRs connected in anti parallel
6.	SCR finds applications in controlled rectifier output of which can be varied by controlling the firing angle of SCR.	It is used in AC control applica-tions such as fan regulator dimmers, AC control of drives etc.

1. Name the devices that belong to Thyristor family /
   Ans. (i) SCR (ii) DIAC (iii) Triac
2. What is Triggering of an SCR
   Ans. Process of turning ON of an SCR is called its Triggering or Firing.
3. What is commutation.
   Ans. Process of turning off of an SCR is called commutation.
4. Define forward break over voltage of the SCR
   Ans. It is the maximum anode to cathode voltage at which the SCR starts conducting when gate is open.
5. Why SCRs are mounted on heat sinks
   Ans. SCRS are mounted on heat sinks in order to dissipate heat with minimum rise in junction temperature.
6. Which material is used for making heat sinks
   Ans. (i) Copper (ii) Aluminium
7. What are the gate ratings of an SCR.
   Ans. (i) Maximum gate current I_{GTMAX}. (ii) Minimum gate current I_{GTMIN}.
8. Silicon Controlled Rectifier combines the features of transistor and........... both.
   Ans. Rectifier.
9. Number of PN junctions in a thyristor is ....(TwolThree)
   Ans. Three.
10. SCR,DIAC & Triac are the devices that belongs to.............family .
    Ans.Thyristor.
11. process of turning on SCR is called its..........or........
    Ans. Triggering, Firing.
12. Process of Turnning off of a SCR is called............
    Ans. Commutation.
13. UJT stands for ....
    Ans. Unijunction Transistor.
14. UJT is used to generate for.................. triggering of SCRs
    Ans. Pulses.
15. The device which is used to generate pulses for triggering SCRs bUt is not a member of Thristor family is
    Ans. UJT
16. A thyristor can be termed as .... (DC/AC/Square) wave switch.
    Ans AC
17. Triac is......... device. (Unidirectional /Bidirectional)
    Ans Bidirectional
18. Controlling the instant of firing an SCR is called...........
    Ans. Phase Control.
19. DIAC is a device.
    Ans. Bidirectional.
20. DIAC is used for triggering of...............
    Ans. TRIACs
21. Forward voltage at which a device Is turned ON is called
    Ans forward breakover voltage.
22. IGBT stands for............
    Ans Insulated Gate Bipolar transistor
23. IGBT consitutes advantages of both MOSFET and ....
    Ans Bipolar Transistor
24. PUT stands for....
    Ans Programmable Uni Junction Transistor

25. PUT is a.................... device like SCR.(PNPN/NPN)
    Ans. PNPN.
26. LASCR stands for.
    Ans. Light Activated Silicon Controlled Rectifier.
27. MOSFET stands for............
    Ans Metal Oxide Semiconductor Field Effect Transistor.
28. RCT is a....................... .
    ans-Reverse Conducting Thristor
29. GTO is a Gate Turn off.................
    Ans- thyristor
30. SUS is a silicon............ switch.
    Ans. Unilateral.
31. UJT has a negative resistance region
    Ans- True
32. An SCR is a three layer device
    Ans. False
33. An SCR is a three terminal four layer device
    Ans-True
34. When Triggering pulse is removed, an SCR is turned off.
    Ans. False
35. Holding current is more than the latching current.
    Ans. False
36. SCR is a bidirectional device.
    Ans. False
37. SUS triggers one fixed Anode to cathode voltage.
    Ans. True.
38. MOSFET is a current controlled device.
    Ans. False.

UNIT-2

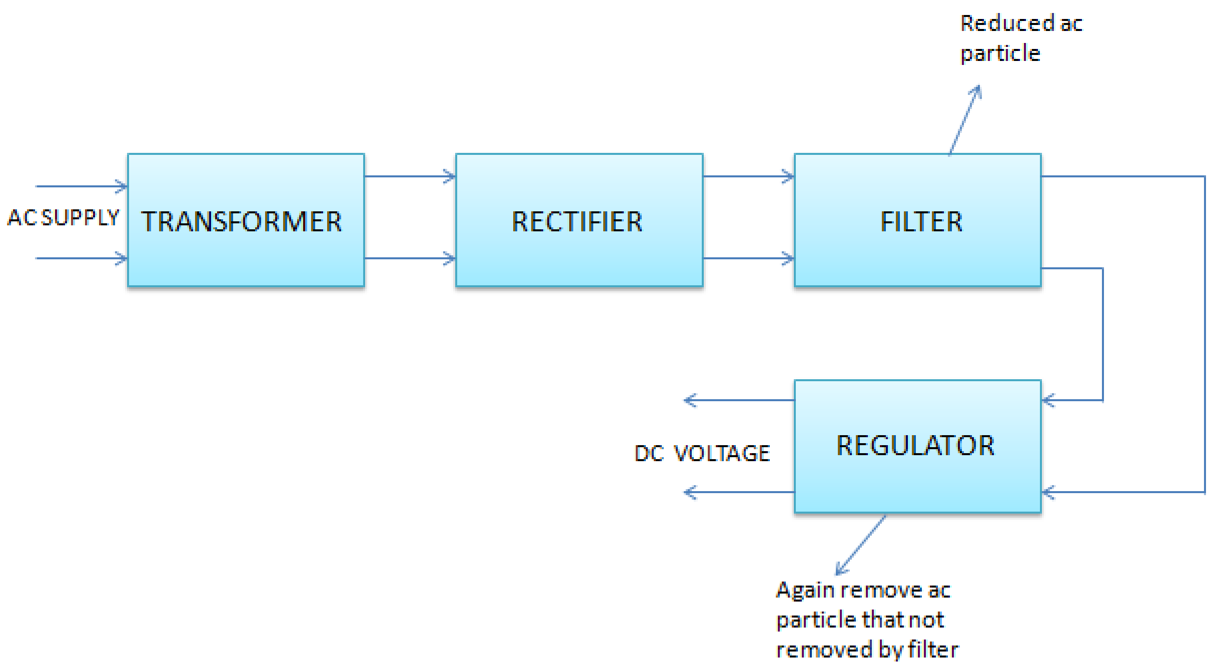
(CONTROLLED RECTIFIER)

<u>RECTIFER-</u>

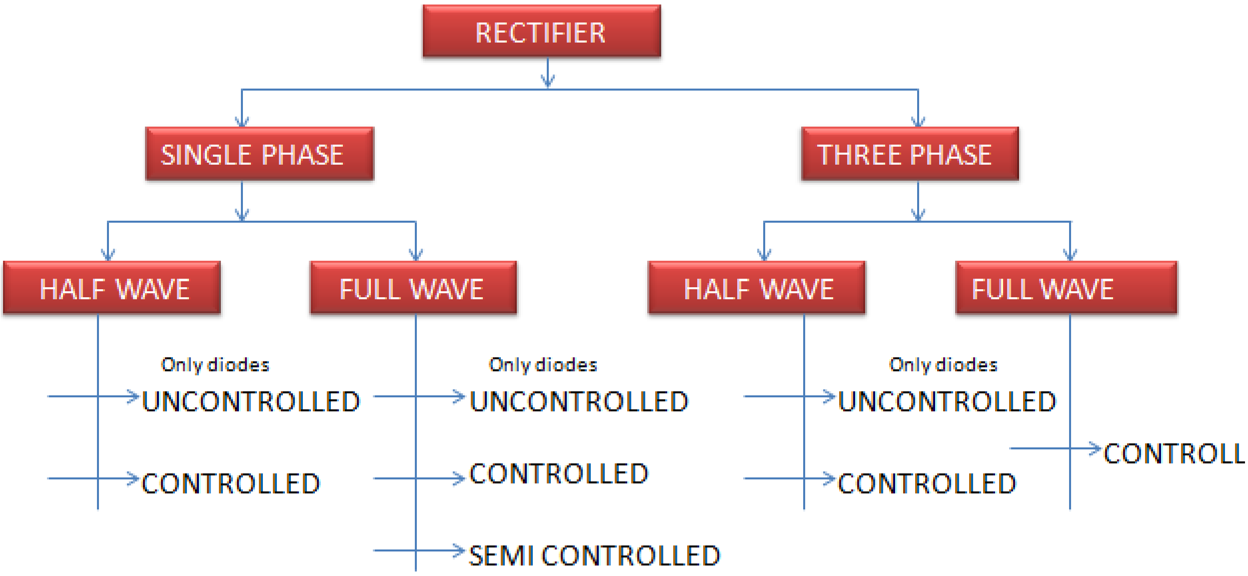
A rectifier is a device that converts alternating current(AC) to direct current(DC). The process of conversion is called rectification.

sssaa

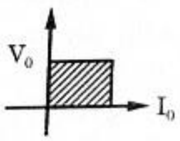
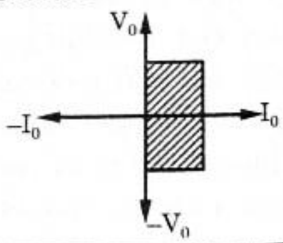
<u>HOW TO GET REGULATED DC POWER SUPPLY-</u>



CLASSIFICATION OF RECTIFIER-



COMPARISON BET WEEN DIFFERENT TYPE OF RECTIFIER-

Uncontrolled Rectifier	Half Controlled Rectifier	Fully Controlled Rectifier
Contains only diodes	Contains mixture of diodes and SCR	All rectifying elements are SCRs.
Give a d.c load voltage diced in magnitude if a.c. supply magnitude is fixed.	Mean d.c load voltage can be controlled but reversal of load voltage is not possible	By suitable control of phase angle (firing angle) at which the SCRs are turned ON, it is possible to control mean d.c. voltage and to reverse the d.c. load voltage as well.
—	It operate in Ist quadrant. 	It is two quadrant converter 
It is a **unidirectional converter** as power flow is only from a.c. supply to d.c. load	It is also a **unidirectional** converter as power flow is only from ac. supply to d.c. load	It is a Bidirectional converter, as it allows the power flow in either direction between the a.c. supply and d.c. load.

SINGLE CONTROLLED RECTIFIER-

Single phase controlled rectifiers are primarily of two types; half controlled rectifiers and fully- controlled rectifiers. A half controlled rectifier uses a mixture of diode and thyristors and limited control over the level of DC output voltage. The fully controlled rectifier uses tyristors only and there is a wider control over the level of dc output voltage.

(a) SINGLE PHASE HALF WAVE CONTROLLED RECTIFIER (WITH RESISTIVE LOAD)-

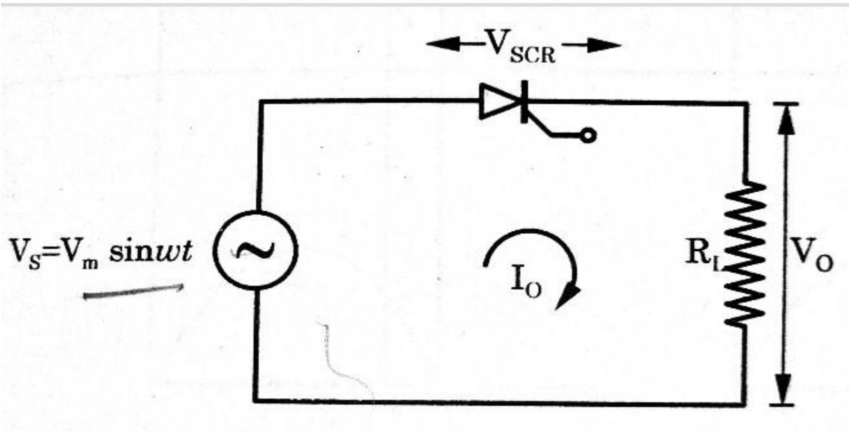


Fig. 2.1 (a) : shows the circuit diagram of a single phase half wave controlled rectifier. The load is assumed to be purely resistive. On state forward voltage drop V_T across SCR assumed to be zero.

Let Vs= V_m sin wt be the input voltage to the circuit.

WORKING :

In positive half of the input a.c cycle the SCR is forward biased and start conducting when a firing pulse given to the gate terminal at firing angle ‘α’. Prior to firing SCR is off and the output voltage is zero as there is no link between input and output. At α, SCR turns ON and acts like a closed switch, thus whatever is the input voltage become available as output. Load current (i_0) flows whose magnitude is depend on output voltage(V_0) and load resistance R_L i.e. $i_0 = V_0/R_L$ at any instant of time.

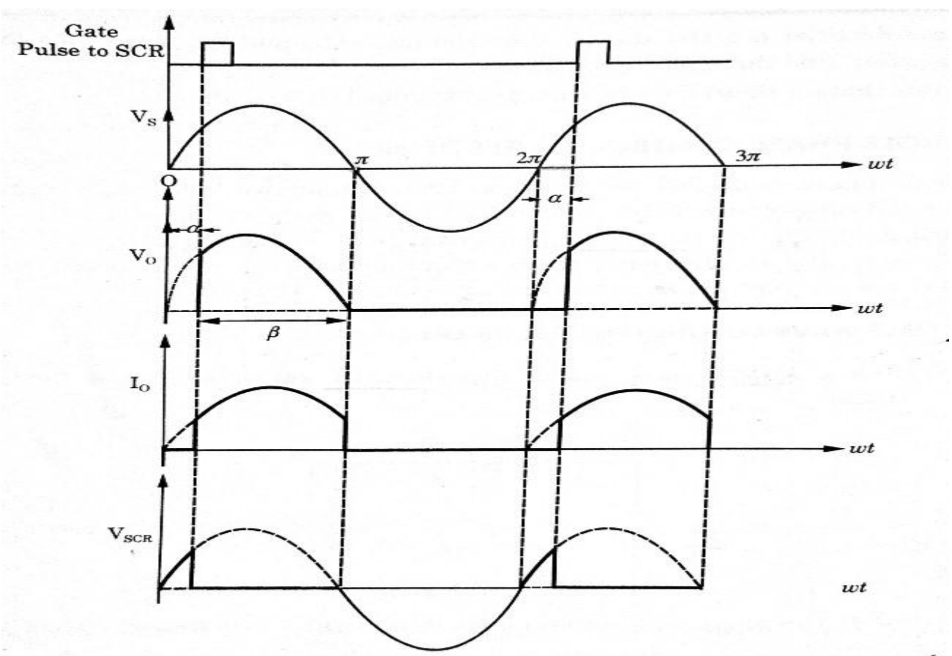


Fig. 2.1. (b) ***Waveform of Half Controlled Rectifier with Resistive Load***

At wt = π,

the input voltage becomes zero, so the current through the SCR also becomes zero and SCR turns off. Immediately, after this negative half cycle begins helping the SCR to turn off and SCR is reverse biased. SCR remains off till the next gate pulse at (2π +α) and output remains zero as shown in figure 2.1(b).

At ωt= (2π+α),

SCR is again fired to get the output voltage and current.

In phase control, power across the load is controlled by triggering thyritors at a fixed phase angle 'α' which is known as firing angle. And the duration during which the SCR conducts is known as conduction angle β . In this case,

$$\beta = \pi - \alpha$$

Lower the firing angle 'α', higher is the conduction period SCR. so the output voltage across the load and hence power delivered to the load will he mote. so by Controlling firing angle, d.c voltage available to the load can chanted.

(b) Single phase half wave converter controlled rectifier (with RL load)-

The Rl load circuit is connected to the supply through a SCR and a freewheeling diode as shown in fig.

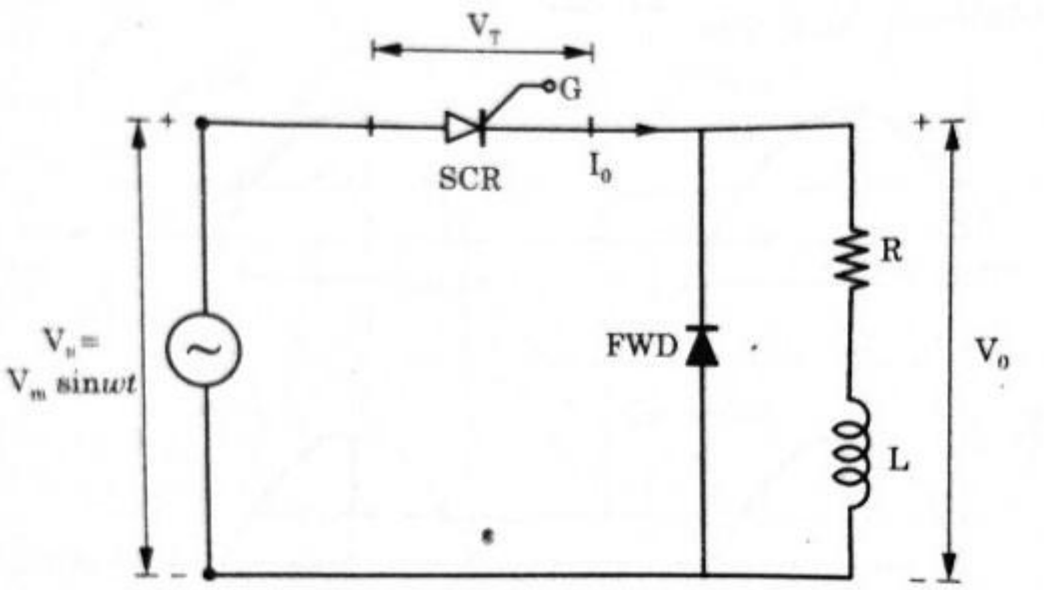


Fig. 2.2 (a) *Single Phase Half Wave Controlled Rectifier with RL Load*

WORKING :

In positive half of the input a.c cycle the SCR is forward biased and starts conducting when a firing pulse is given to its gate terminal at firing angle 'α'. At wt = α , the SCR turns ON and acts like a closed switch, thus whatever is the input voltage (Vs) becomes available as output. Load current (Io) flows whose magnitude is dependent on output voltage (Vo) and load at any instant of time.

As soon as the thyristor is fired during forward bias mode of the thyristor, the load current starts increasing. Due to the presence of inductor, energy is stored in the inductor during forward current conduction state and till the voltage is reversed.

Here a free wheeling diode is connected across the inductive load to prevent output from going negative. When the output is positive, FWd becomes reverse biased has no effect on output.

After wt =π, the load current continues to flow through the load due to the stored energy in inductor but now it gets a less resistive path through the free wheeling diode (FWD). In case there is no free wheeling diode (FWD), during negative half cycle, the thyristor sends back the energy stored in the inductance to the supply. However, with the free wheeling diode, stored power in the inductance is not returned to the source.

Therefore current continues flow till the energy stored in the inductance is dissipated in the load resistor and a part of energy is consumed, the forward current stop and due to reverse bias mode, the thyristor is turned off as shown in figure 2.2 (b). It is assured that during FWD period load current does not decay to zero until the SCR is triggered again at ωt= 2π + α.

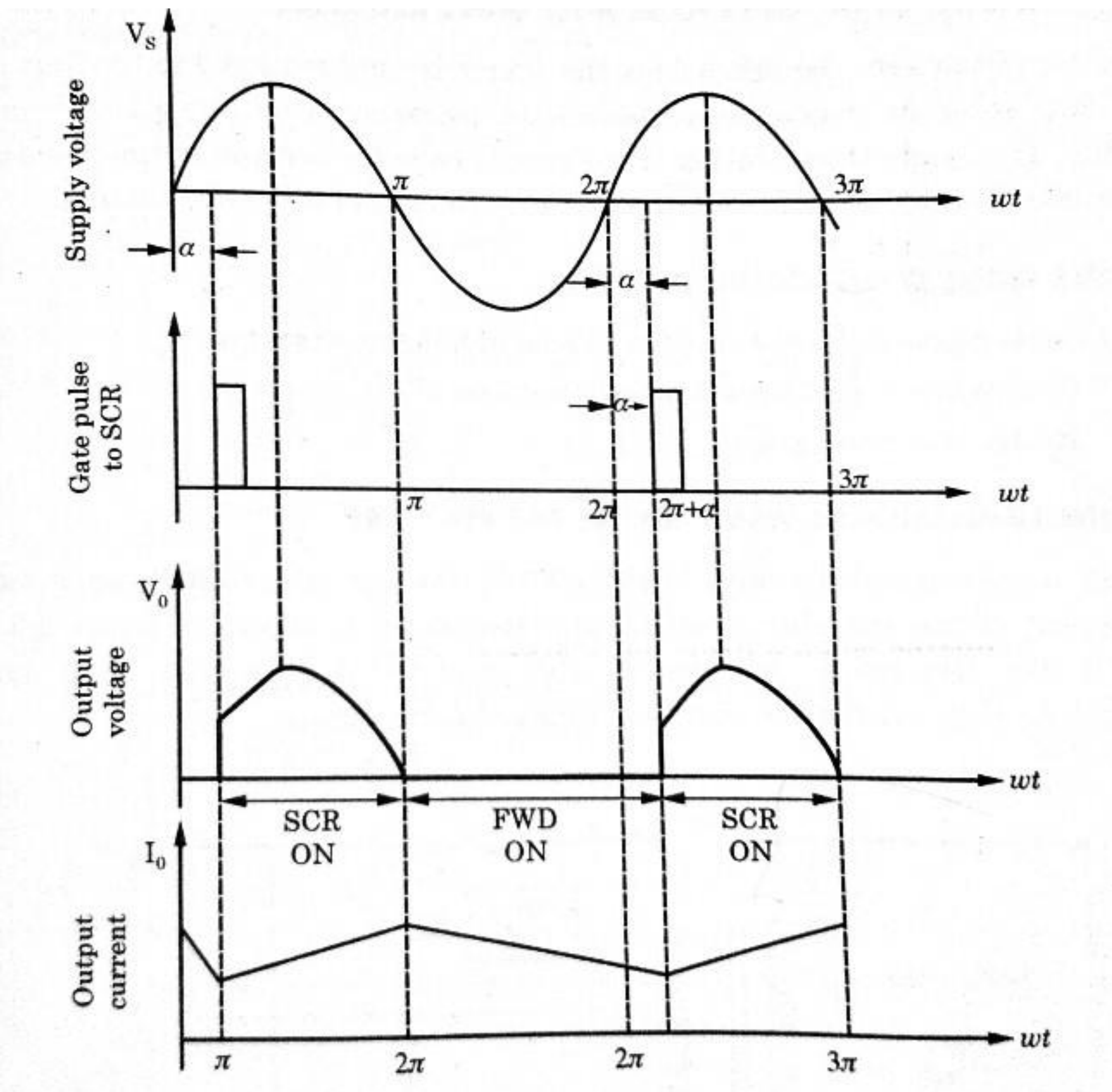


Fig. 2.2. *(b) Waveform of Half Controlled Rectifier with RL Load*

At ωt = 2π + α during next repetitive cycle, the SCR turned on again by the gate pulse and the process is repeated. Hence, we get one half of the input voltage across the load and that load voltage can be controlled by controlling the level of gate current.

NOTE : By using the freewheeling diode, load current (Io) is improved. Some advantages of using FWD is given below.

1. It improve the input power factor (because the ratio of reactive power flow from the input to the total power consumed in the load becomes less). 2. It allow the SCR to regain its blocking state at the voltage zero by transferring the load current away from the thyristor.

DRAWBACK OF SINGLE PHASE HALF WAVE RECTIFIER

The supply current (Is) taken from the source is unidirectional in the from of dc pulses. Thus these half wave converter circuit introduce a dc component into the supply line. This leads to saturation of the supply transformer and harmonics drawn in the circuits. These difficulties are overcome by the use of full wave circuits.

FULL WAVE CONTROLLED RECTIFIER -

The single phase full wave rectifier can be of following two types

(i) Centre tap or mid point converters
(ii) Bridge type converts.

(d) INGLE PHASE FULL WAVE CENTRE TAP RECTIFIER-

A full wave controlled output is obtained by the use of two SCR connected to centre tapping of the secondary winding of transformer as shown in figure 2.3 (a). Each SCR are forward biased during the positive and negative half cycles respectively. So they are fired from a synchronized firing circuit.

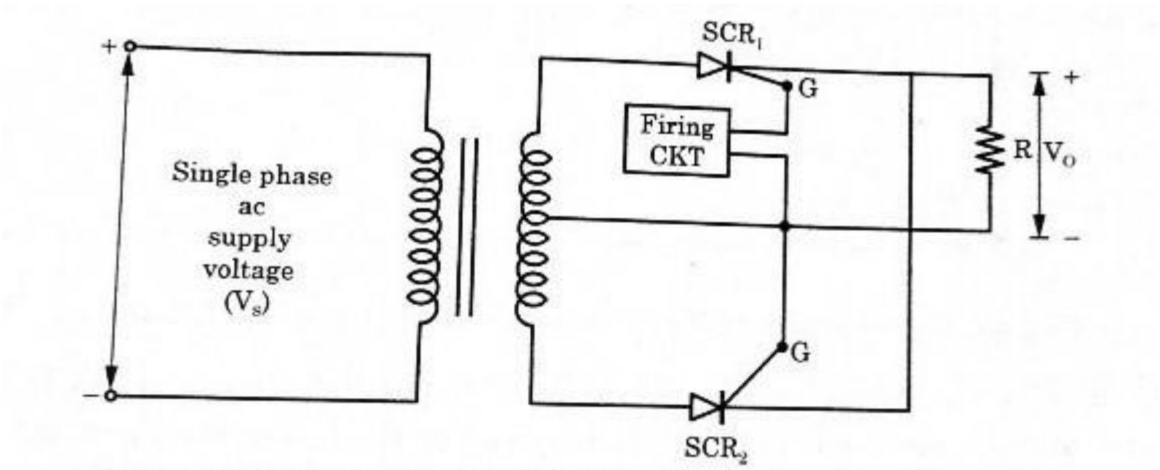


Fig. 2.3 (*a*) *Single Phase Full Wave Centre Tap Rectifier*

At ωt = α, the gate pulse is applied to SCR1. As a result SCR1 is turned on and a load voltage (Vo) is appear across the load. So the load current (Io) start to flow from ωt = α to ωt = π.

At ωt = π, the current through SCR1 is zero. The supply voltage is immediately reverse for that the reverse voltage is applied to SCR1. As a result, SCR1 is turned off by natural commutation.

Now at ωt = π+ α , the SCR2is turned on by applying the gate pulse to SCR2. As a result load voltage is appear as shown in figure 2.3 (b)

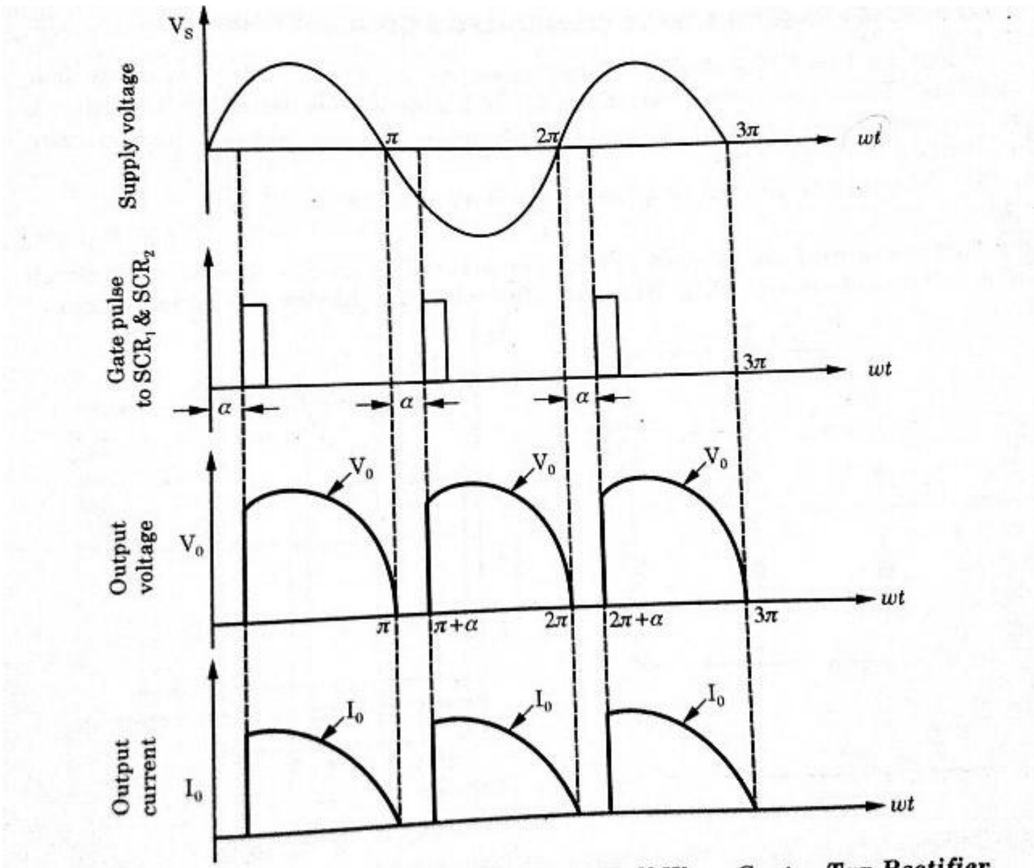


Fig. 2.3. (b) *Waveform of Single Phase Full Wave Centre Tap Rectifier*

In this case, the average value of output voltage will be.

$$Vo(avg) = \frac{\pi}{2}\int_{\alpha}^{\pi} \sin\omega t \, d(\omega t)$$

$$= \frac{Vm}{\pi}[1+ \cos \alpha]_{\alpha}^{\pi} \quad = \quad \frac{Vm}{\pi}[1+ \cos \alpha] \text{ volts}$$

Therefore, the output voltage to be controlled by controlling the firing angle (α). The firing angle (α) is varied from 0° to 90° only.

SINGLE PHASE FULL WAVE CONTROLLED BRIDGE RECTIFIER-

When an input transformer is not essential, a bridge system is often more economical. There are several variations of the bridge circuit using two thyristor, or four thyristor. Figure 2.4 shows the different circuit of single-phase bridge rectifier.
These circuit are explain below.

1. Circuit with two thyristors and two diodes :
Or
(c) Full wave half controlled bridge rectifie :

Figure 2.4 (a) shows the circuit of I-Ø full wave half controlled bridge rectifier with two thyristors and two diodes.

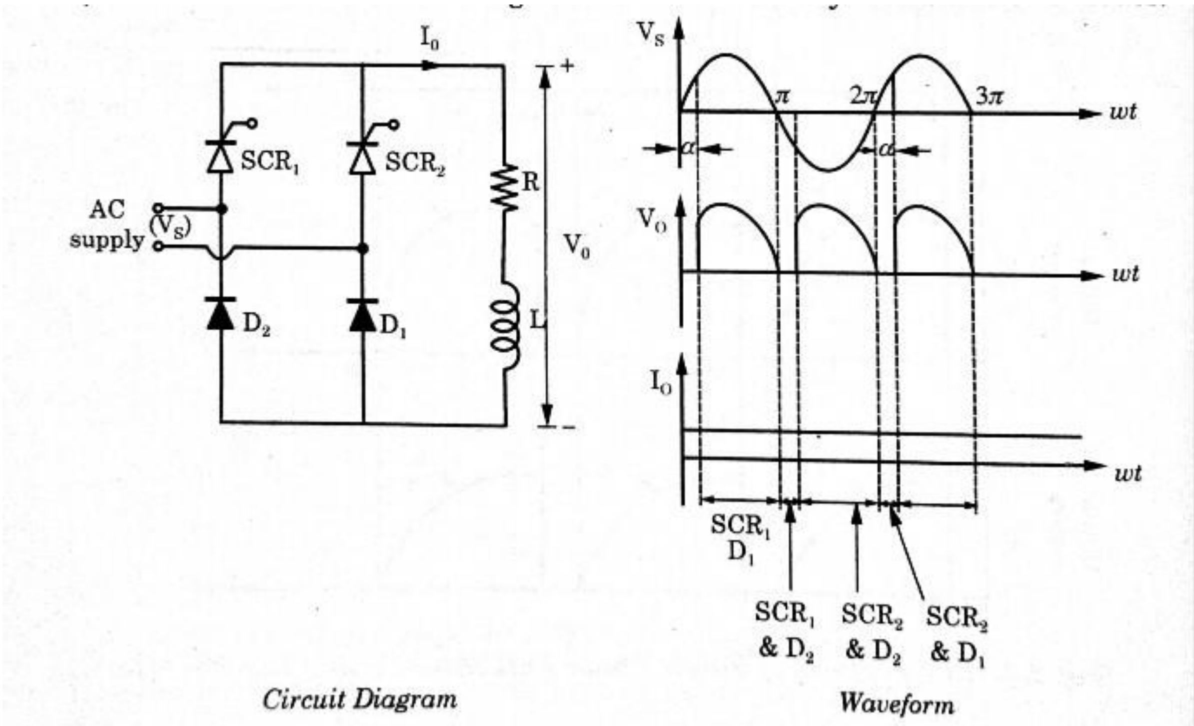


Fig. 2.4 (a) *1-φ Full Wave Fully Controlled Bridge Rectifier*

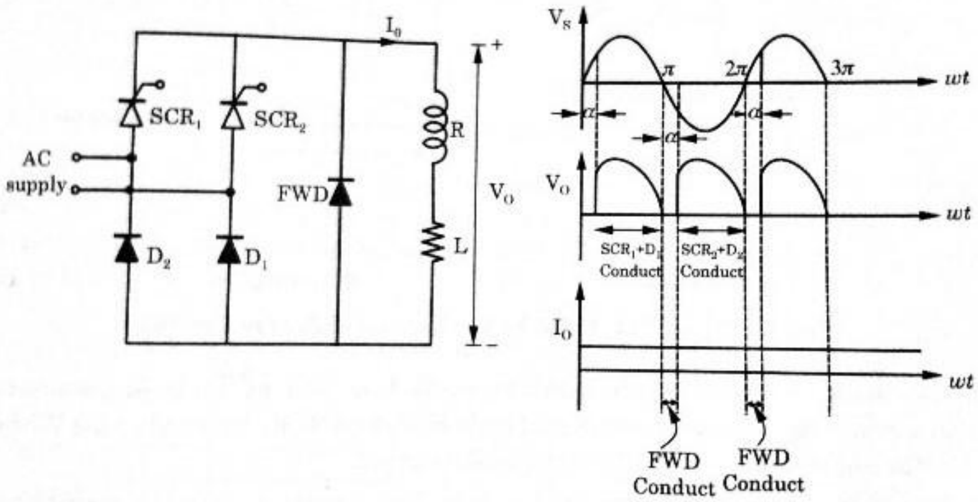
In this the load energy would be free-wheel through D1 and SCR1 or D2 and SCR2. As shown in figure when a gate pulse is applied to SCR1, the SCR1 is turned on and the current start flow through SCR1-R-L-D1. When the supply voltage is reversed, the conduction of diode (D1) is stopped and at same time (D2) start conducting. As a result load current continue to flow through during the interval $\omega t = \pi$ to $\pi+\alpha$ as shown in wave form.

At $\omega t = \pi + \alpha$, in the negative half cycle, a firing pulse is applied to SCR2. As a result SCR2 is start conducting and SCR1 is turned off by natural commutation. Therefore the load current continue to flow through SCR1 and D2. The above cycle is repeated.

With high L/R ratio, even if the gate trigger pulses are removed from the thyristors, the load current would flow through the entire negative half cycle and hence the circuit would lose control.

2. Bridge with two thyristors and two diodes, plus a free-wheeling diode
OR
Full wave half controlled bridge rectifier with free wheeling diode :

The circuit diagram of full wave half controlled bridge rectifier with two thyristors and three diode as shown in figure 2.4 (b).



Circuit Diagram *Waveform*

Fig. 2.4 (b) *1-ϕ Full Wave Half Controlled Bridge Rectifier FWD*

The operation of the circuit is similar to the one discussed above. In this case, the freewheeling diode (being of lower impedance than a thyristor and diode in series), allows the circulation of the stored energy of the load.

The SCR, and diode (D1) conduct for the first half cycle while the SCR2 and diode (D2) Conduct for the next half cycle. The freewheeling diode will help in circulating the load energy through the load and keeping the load current more or less continuous. Also during turning off of the thyristor, the freewheeling diode damps the transient voltage, so the thyristors do not see any high voltage spikes.

UNIT-3

Choppers-

•Chopper is a basically static power electronics device which converts fixed DC voltage/power to variable DC voltage or power.

•It is nothing but a high speed switch which connects and disconnects the load from source at a high rate to get variable or chopped voltage at the output.

• Chopper can increase or decrease the DC voltage level at its output side.

Step down Chopper (Buck converter) -

Step down chopper as Buck converted is used to reduce the input voltage level at the output side. Vo < Vs

The circuit diagram of step down chopper is shown in fig.

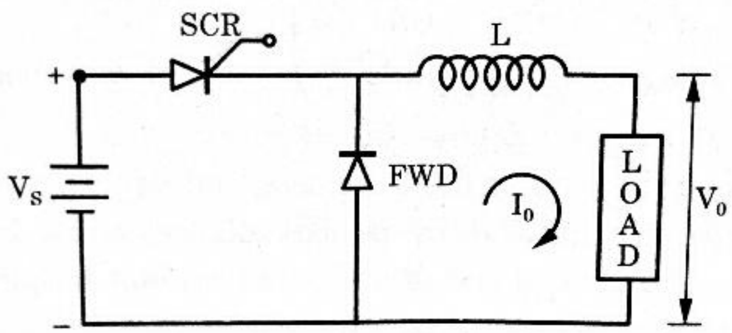


Fig. 3.11. ***Circuit Diagram of Step Down Chopper***

It consists one scr and a free whiling diode. The diode is connected in parallel with the load and inductor is connected in series with the load. Vs voltage is applied in the circuit.

Working-

(a) When the SCR is on- When the SCR is on the load voltage(V0) is equal to the source voltage(Vs).because the load voltage is directly connected through the source voltage and FWD in reverse biased. This period is called T_{ON} period. In this time current flow thru Vs,L,Load,Vs. In this condition , inductor starts charging.

(b) when the SCR is off- In this condition the Load voltage (V_0) becomes zero because the load voltage is not connected through the source voltage but the load current continuous flow through the load due to stored energy in the Inductor. In this condition the FWD is in ON condition. The current flow in the direction L,V_0,FWD,L . This period is called T_{OFF} period.

The Voltage Current waveform is shown in the fig bellow-------

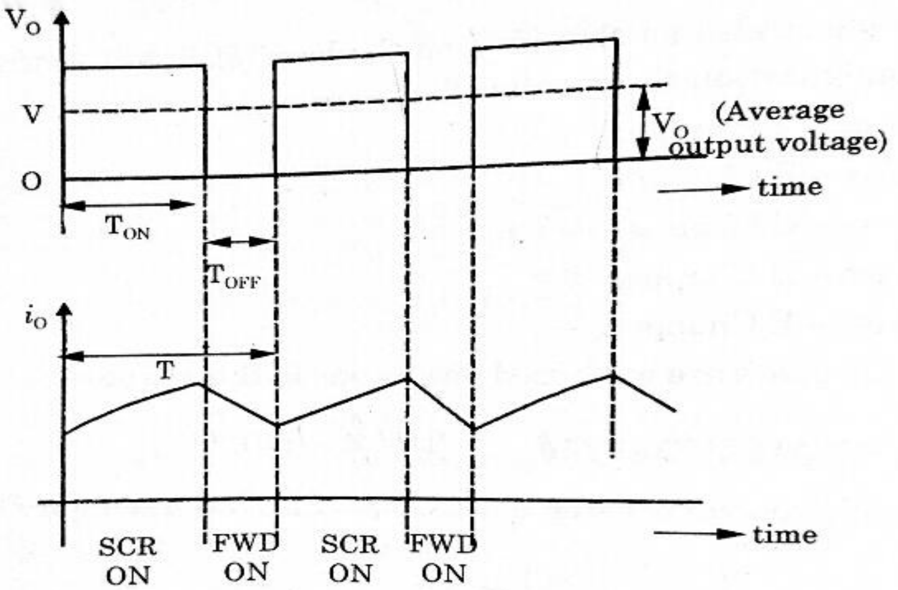


Fig. 3.12. ***Voltage and Current Waveform of Step Down Chopper***

so, we can conclude(निष्कर्ष निकालना) that output voltage is always less than the input voltage and hence the name step down chopper is justified.

The average voltage(V_0) is given by –

$$V_0 = \frac{TON}{TON+TOFF} . V_S$$

chopping period-

$$T = T_{ON} + T_{OFF}$$

Duty cycle of chopper-

$$\alpha = T_{ON} / T$$

Chopping frequency-

$$F_{ch} = 1 / T$$

Advantage-

1- It is a smaller size filter.
2- It gives fast responce.

Application of step down choppers-

1-It is used in subway cars.

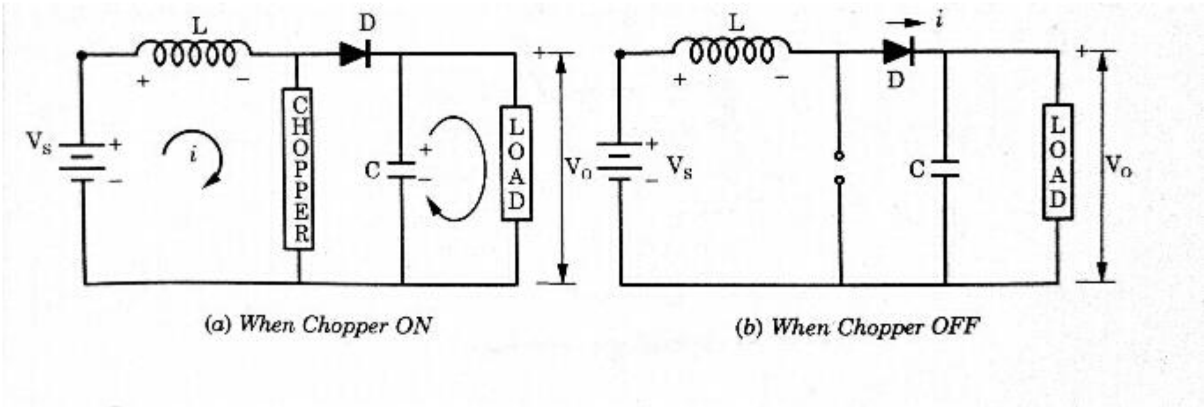
2-it is used in trolly buses.

3-battery operated vehicles.

Step Up Chopper (Boost converter)-

Step-up chopper is used to obtain a load voltage higher than the input voltage V. Vo > Vs

The circuit diagram of step up chopper is shown in the fig.



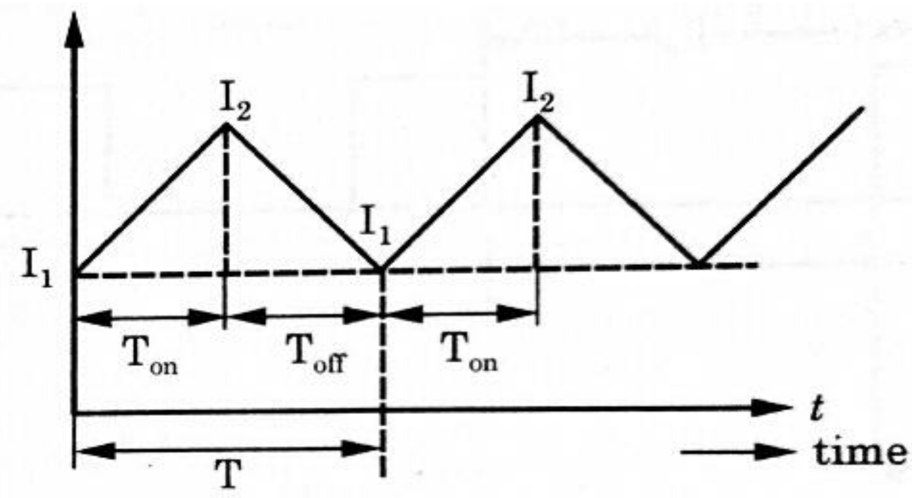
It consists a chopper which my be a thyristor, diode, gto etc . inductor is connected in series with the source voltage V_S . A capacitor which is connected in parallel with the load and a diode which is in series with capacitor load circuit.

WORKING- It have two operation mode----

(a) **When the chopper is on-** when the chopper is ON the source voltage(V_s) disconnect thru the load. This time the inductor start charging with voltage V_s . when inductor is charging its current increase from its minimum value I_1 to max value I_2 as shown in fig 3.15. The current flow in path V_s,L,Cho,V_S. This is known as T_{ON} time. This time the output voltage across the load is zero.

(b) **When the chopper is off-** when the chopper is off the inductor start discharging from its max value I_2 to $I_!$ As shown in fig 3.15. and is polarity is changed as shown in fig (b). In this mode The diode start conducting and current flow in direction L, D, LOAD, V_S, L. In this time the output voltage across the load is $V_S + V_L$. Thus the chopper is act as step up chopper.

The current wave form is shown in the fig bellow-----



(c) *Current Waveform*

Fig. 3.15. ***Step Up Chooper***

The average voltage(V_0) is given by –

$$V_0 = \frac{TON+TOF}{TOFF} . V_S$$

chopping period-

$$T = T_{ON} + T_{OFF}$$

Duty cycle of chopper-

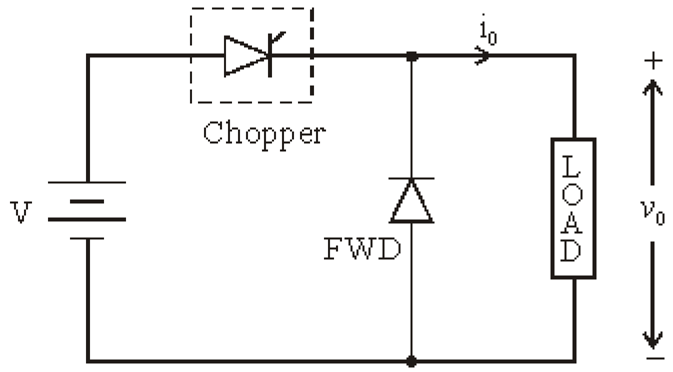
$$\alpha = T_{ON} / T$$

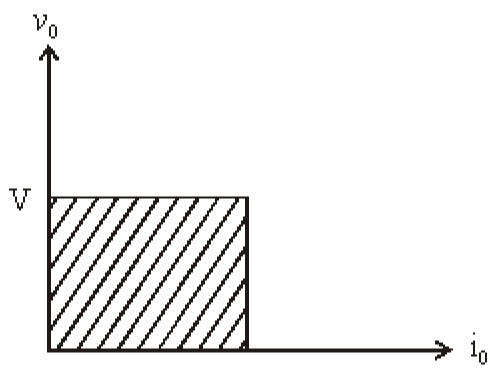
Chopping frequency-

$$F_{ch} = 1 / T$$

CHOPPER CIRCUIT CONFIGURATIONS-

1- **CLASS A CHOPPER-** This kind of chopper is also known as first quadrant chopper. The circuit diagram of 1st quadrant chopper is shown in the fig. Bellow. V-I graph of load current and voltage are positive .
When SCR is on – the o/p voltage is equal to the source voltage. In this condition FWD is in off mode. The current is flow in direction V_S, chop, Load,V_S .
When the chopper is off- the o/p voltage is zero . The inductor changes its polarity and starting discharging . In this time the current flow in direction LOAD,FWD,LOAD.
Class A chopper is step down chopper.

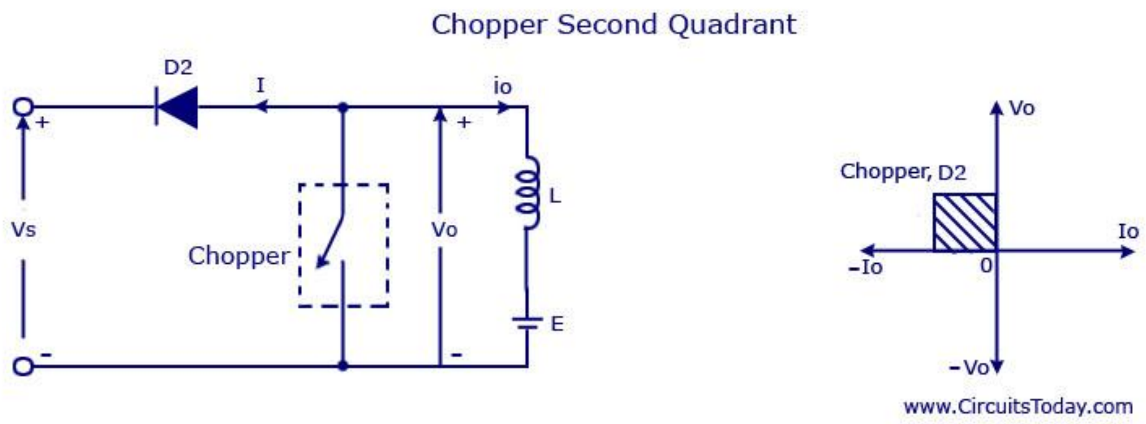




2- **CLASS B CHOPPER-** this kind of chopper is known as 2nd quadrant of chopper. The circuit diagram of chopper is shown in the fig bellow. Here the o/p voltage is always +ve but the current is negative, thus the operation takes place in second quadrant only.

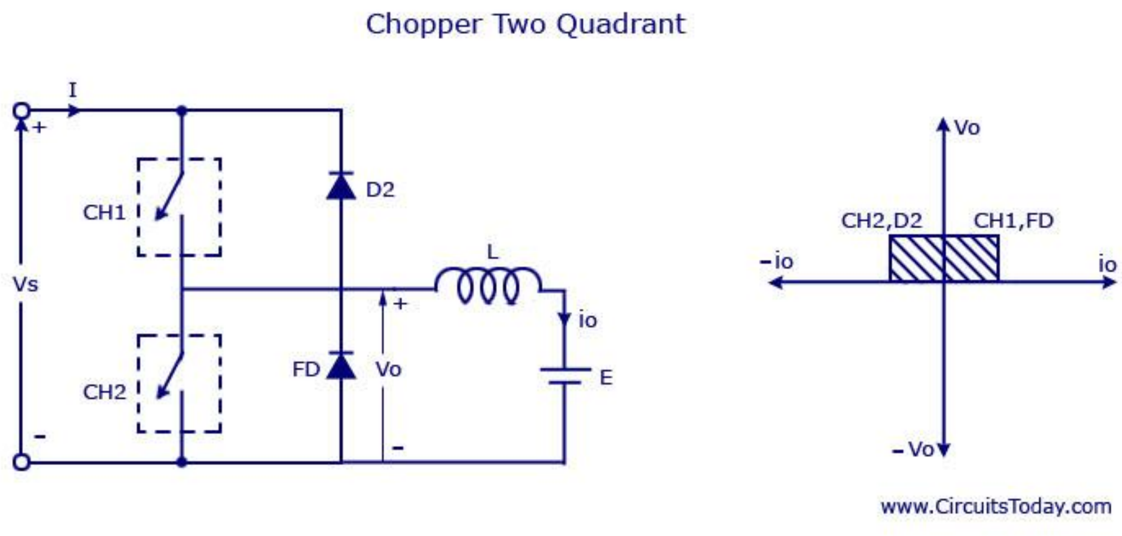
When the chopper is on- when the chopper is on the source voltage disconnect from the load and the diode is in reverse biased so it is in off condition. In this time Battery E charges the Inductor and current flow in reverse direction E,L, CHOPP,E. And the o/p voltage is positive.

When the chopper is off- when the chopper is off then the inductor start discharging and the diode is in forward biased. The current flow in reverse direction L,D2, Vs, L. In this time the total voltage at the o/p is $V_0 = Vs + V_L$. so it is a step up chopper.



It is used for regenerative breaking of dc motor.

3- CLASS C CHOPPER-This type of chopper operate in 1st and 2nd quadrates. It is the two quadrant chopper. It is a parallel combination of a class-A and a class-B chopper as shown in the figer.in thiin



In this chopper the o/p voltage is always +ve. The o/p current is +Ve when the 1st chopper ch-1 is in ON state but o/p current is –Ve when second chopper ch-2 is in ON state**.**

Some imp point of class c chopper-

1- The 1st chopper ch-1 and FWD together work as a class-A chopper, operating in 1st quadrant .
2- The second chopper ch-2 and diode D-2 together work as class B chopper, operating in 2nd quadrant.
3- The load current is +ve when chopper ch-1 or the FWD is in ON state.
4- The load current is –ve when chopper ch-2 or the diode D-2 in on state.
5- $V_0 > 0$ always but $i_0 > 0$ or $i_0 < 0$.
6- The chopper ch-1 and ch-2 operate one by one at a time.

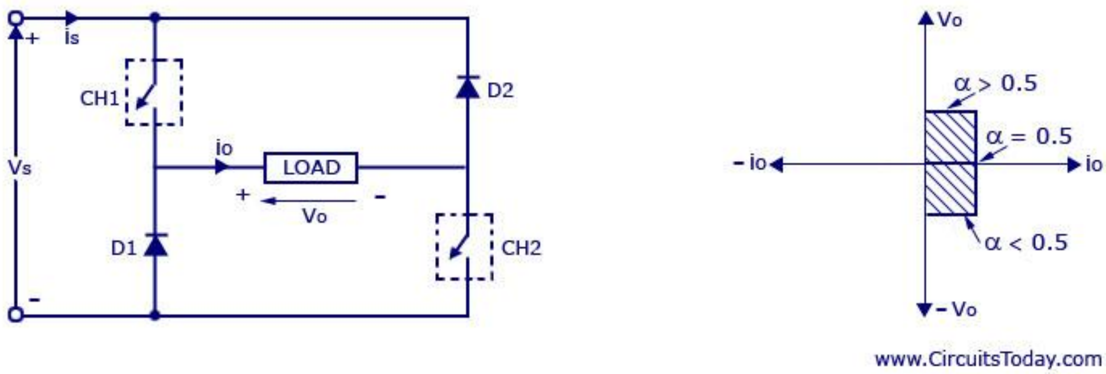
4- CLASS D CHOPPER-

It is a two quadrate chopper . it operate in 1st and 4th quadrate as shown in the fig. The load current always + ve but the o/p voltage is + ve or –ve.

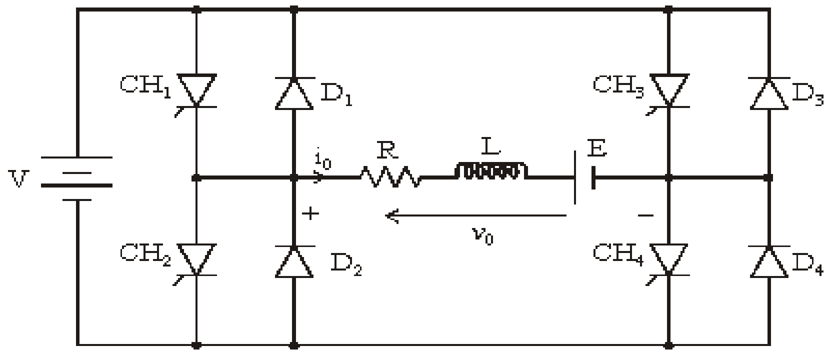
Some imp point is given bellow---

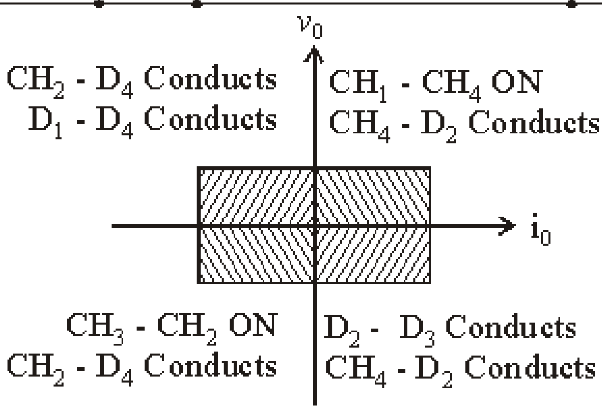
1- When both chopper ch-1 and ch-2 are in ON state then the o/p voltage is equal to the source voltage but when both chopper is in Off state and diode D-1 , D-2 in on state , $V_0 = -V_s$ is observed.
2- In case $T_{ON} > T_{OFF} \rightarrow V_0 > 0$ and if $T_{on} < T_{off} \rightarrow V_0 < 0$.
3- The load current is always in unidirectional.

Two Quadrant Type B-chopper or D-chopper Circuit



4- **CLASS E CHOPPER-** Chopper E is a four quadrant chopper . it is the parallel combination of two class c chopper. As shown in circuit diagram





The operation of class E chopper is explain fallows------

(a) First quadrant operation- In this operation chopper -1 and chopper-4 is ON while chopper -2 and chopper -3 is off. The current flow in direction V_S, CH-1, L, E, CH-4, V_s and $V_0 = V_S$ .thus both i_0 and V_0 both are positive, therefore circuit operate in 1st quadrant.

(b) Second quadrant operation- in this operation ch-2 and D-4 is in conducting state and other component are in off state. The load current flow from ch-2 and diode D-4 . The inductor store the energy during the ch-2 ON condition. When the CH-2 off and the feedback current flow through D1 and D4. This operation give + V_0 and negative i_0 .

(c) Third quadrant operation- In this operation CH-1 and CH-2 is on and other component is off state. In this V_0 and i_0 both are negative.

(d) Fourth quadrate operation- In this operation CH-4 and D-2 are in on state .the load current floe through CH-4, D2, L and E direction. When the chopper CH-4 is off then D-2 and D-3 are conduct. Then the current flow through D3, source, D-2 ,L and E. The current is +ve while the current is –Ve.

Cycloconverter-

- Cycloconverter is a power electronic equipment which converts constant voltage AC power to adjustable voltage and adjustable frequency AC power without any intermediate DC link.
- A cycloconverter is also known as cycle converter.

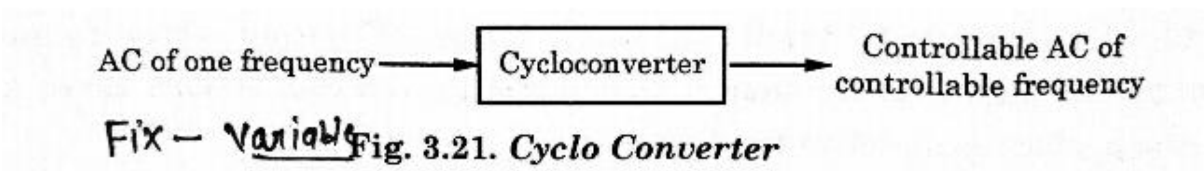


Fig. 3.21. *Cyclo Converter*

CLASSIFICATION OF CYCLOCONVERTERS-

It can be classified into following types—

1. single phase cycloconverter

(a) Centre tapped cycloconverter (b) Bridge type cycloconverter 2. Three pulse cycloconverter

3. Six pulse cycloconverter

4. Three phase to single phase cycloconverter

5. Three phase to three phase cycloconverter.

SINGLE PHASE CYCLOCONVERTER-

- It has single phase AC input and single phase AC output whose frequency is some fraction of the input frequency.

(a) CENTRE TAPPED CYCLOCONVERTER-

- ✓ The cycloconverter which consist of centre tapped 1-ϕ transformer with four thyristor whose output frequency is greater than the input frequency are known as cycloconverter.
- ✓ It is also known as step up cycloconverter.

The circuit diagram of centre tapped transformer are shown in the fig bellow----
It consists a centre tapped transformer and 4 thyristors. Thyristor TH-1 , TH-2 and TH-3, TH-4 are connected in antiparallel as shown in fig. LOAD is connected between the point O and C.

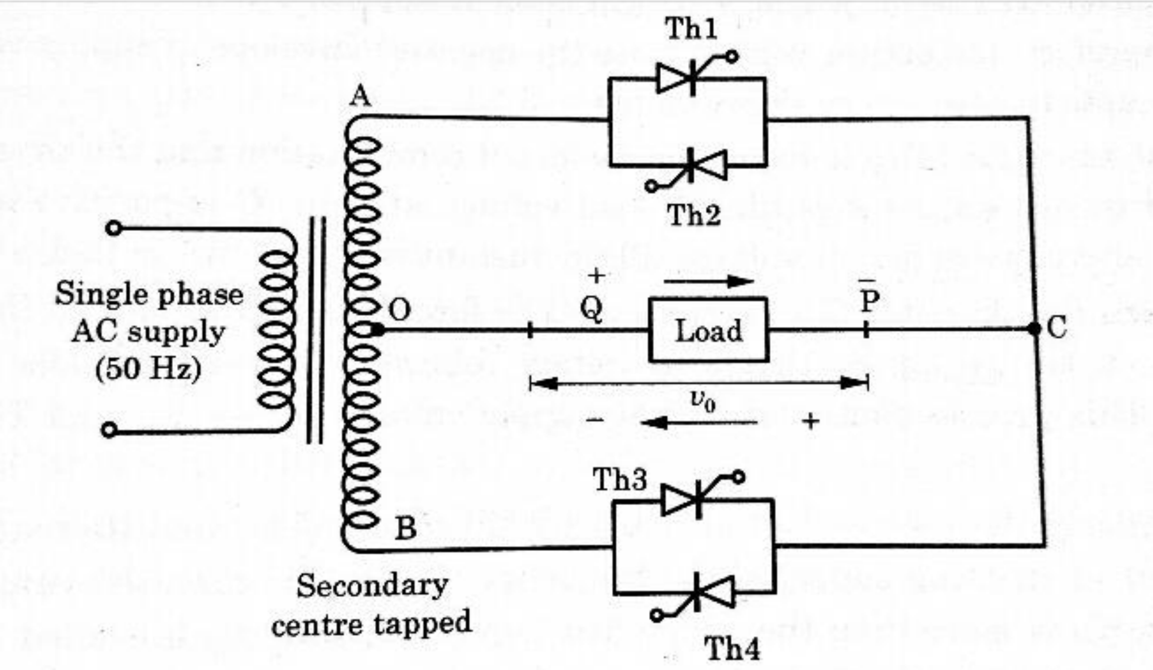


Fig. 3.22. ***Centre Tapped Cycloconverter***

Working- During the +ve half cycle of AC power supply point A is +ve wrt to O and point B is –Ve wrt to O as shown in fig 3.22. In this time thyrister Th-1 is on at wt=0 and the current flow in direction A, Th-1, C, LOAD, O. The o/p voltage is +Ve wrt to C As shown in fig 3.23.

At wt1 thyristor Th-1 is turned off by forced commutation and thyrister Th-4 is turned on. In this condition the current flow in direction O,LOAD,C,Th-4,B. In this condition the o/p voltage is –Ve.

At wt2 The thyristor (Th-4) is turned off by forced commutation and the thyristor (Th-1) is again turned on. As a result the load voltage at point C is positive.

At wt3 thyristor (Th-1) is turned off by forced commutation and the thyristor (Th-4) again turned on. In this time o/p voltage is –ve. This process continues till the supply voltage across Th-1 and Th-4 becomes zero.

Similarly the process is reputed with thyristors Th-2 and thyristors (Th-3) to get output alternating supply of the frequency (ft). In this case, the value of output fequency (f0) is more than the supply frequency (fs), so it is also called the step up cycloconverter.

The o/p frequency is given by $f_0 = 6f_s$.

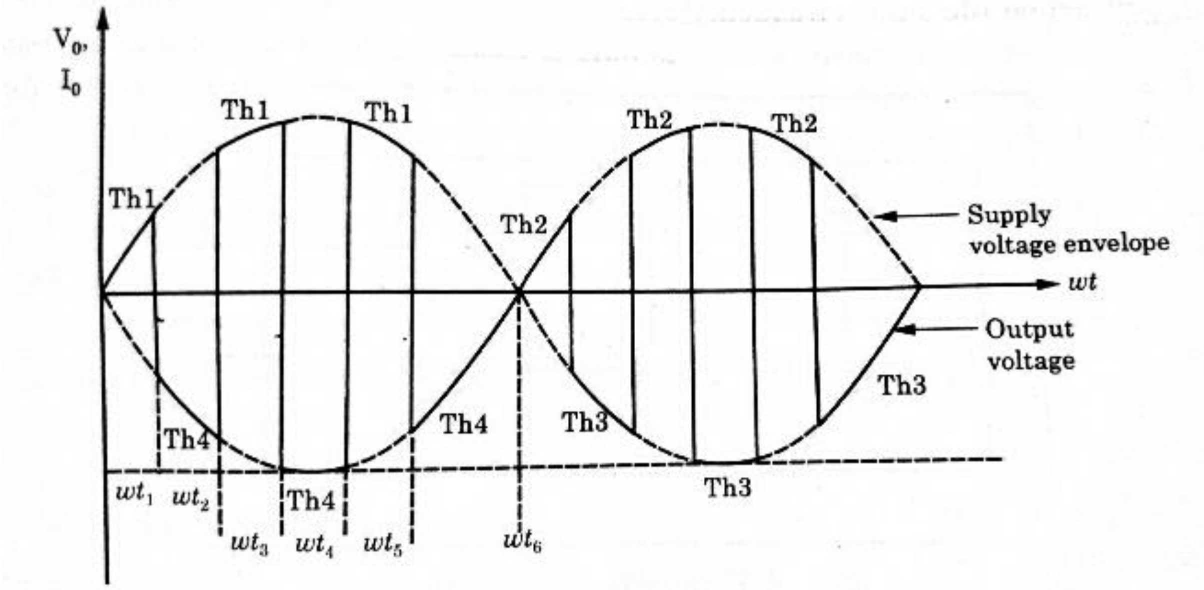


Fig. 3.23. *Wave Term of Center Tapped Cyclo-converter*

CHAPTER-5

UNINTERRUPTIBLE POWER SUPPLIES

Q-1 Draw and explain the block diagram of UPS. Differentiate between online and off line ups? (10)

Ans- *UPS- UPS is stand for uninterruptible power supply. Uninterruptible power supply is an arrangement to get continuous A.C. power for the critical loads like computers, hospitals and other emergency loads.*

The block diagram of a commonly used U.P.S is shown in figure.

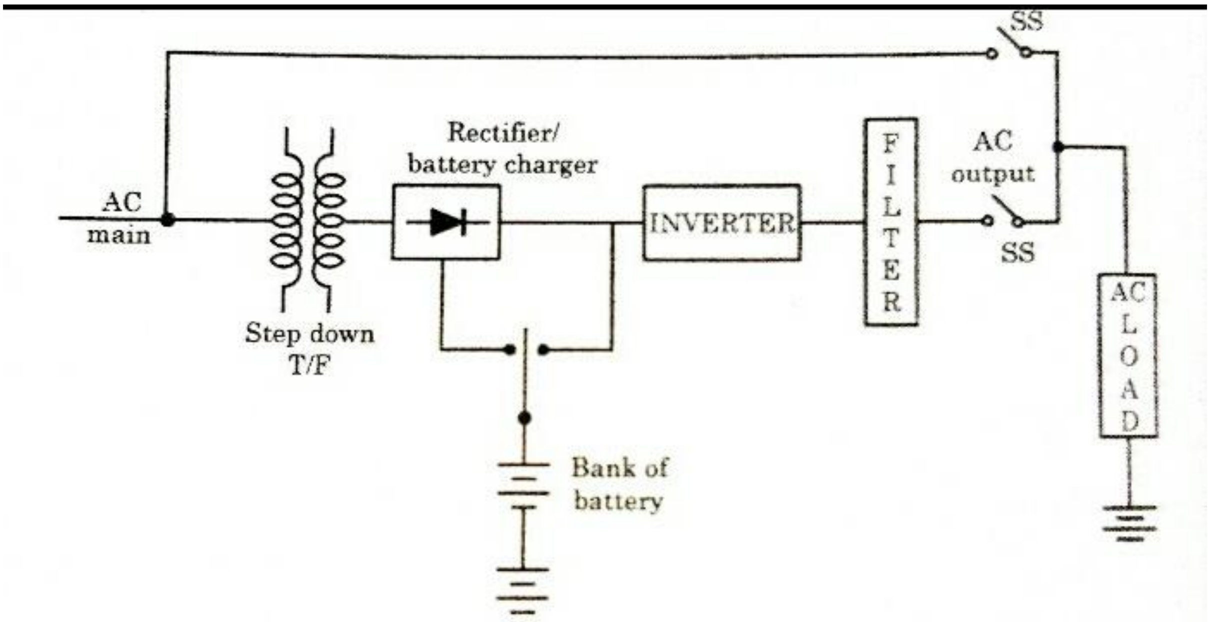


Fig. 5.1. ***Uninterrupted Power Supply***

An U.P.S is just such as alternative source. A static UPS step consists of a down T/F, a rectifier, a battery charging unit, a battery bank, an inverter ,a filter and switch.

The function of its basic parts are fallows..........

- Step down transformer- The commercial AC input pass through the step down T/F it reduced the voltage at the o/p. Now this low AC voltage passed through the rectifier.
- Rectifier- Rectifier converts the low ac voltage into dc voltage. This DC voltage then passed through the battery charger.
- Battery charger- It is used for charging the battery. When the battery is fully charged then it stop charging the battery (the battery is not overcharged). It will charge a discharged battery at a constant rate.
- Bank of Battery- It supply the full load current in case of main supply failure. This DC current pass through the Inverter.

- Inverter- Inverter is a device which converts DC in to AC. Then this ac is pass through the filter.
- Filter- It eliminates the higher order harmonics.
- Switch- Switch is used to connect the load from inverter or from the supply. Its required operating time is 10ms.

COMPARISON BETWEEN ON - LINE UPS AND OFF - LINE UPS-

Sr. No.	ON LINE UPS	OFF LINE UPS
1.	It supplies the power continuously to the load i.e 24 hours a day. Means inverter is ON all the times	It supplies battery power to the connected load only during the main supply off. means inverter is ON only when mains is off.
2.	Most expensive, biggest and heaviest in size.	It is least expensive types.
3.	Its running time of the inverter is generally 10 min to 30 min.	Its running time is generally 10 min to 30 min also.
4.	Its switching time is generally 0 ms.	Its switching time is generally less than 5 ms.
5.	It is used for network environments e.g. file server supporting many users.	It is sufficient for stand alone pc.
6.	It gives sine - wave output.	It gives square wave or sine wave output.

TYPES OF UPS

There are mainly three types of UPS

(i) off line UPS

(ii) ON line UPS

(iii) Line interactive UPS.

OFF LINE UPS

It supplies battery power to the connected load only during the main supply off. means inverter is ON only when mains is off.

In the off line UPS, the inverter is normally in off state. When the main supply is not available, the load is automatically connect with the inverter by using static contractor switch.

The offline UPS is also known as stand by mode of UPS, because inverter is on stand by as long as the commercial/main power source is not available. When the supply is restored, the inverter is again shut off. The block diagram of off - line UPS is shown in figure.......

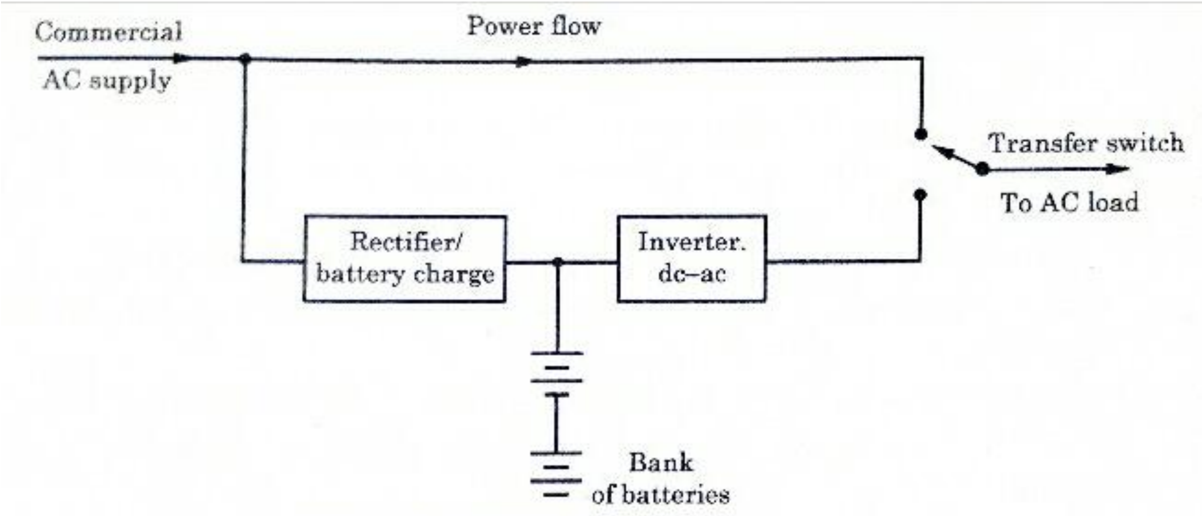


Fig. 5.2. ***Off-Line UPS System***

It is least expensive types. Its running time is generally 10 min to 30 min also. Its switching time is generally less than 5 ms. It is sufficient for stand alone pc. It gives square wave or sine wave output.

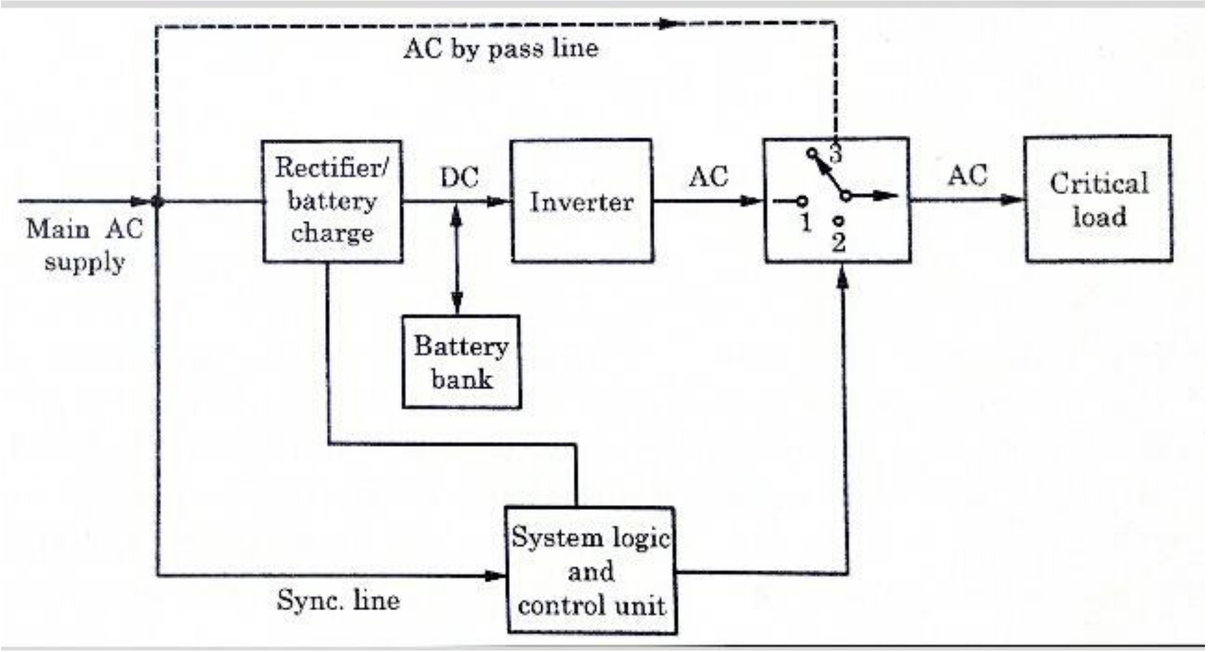
ON-LINE UPS

In this system, the load is always connected by the inverter. Therefore, the rectifier and inverter are always on.

It supplies the power continuously to the load i.e 24 hours a day.

Means inverter is ON all the times. Most expensive, biggest and heaviest in size. Its running time of the inverter is generally 10 min to 30 min. Its switching time is generally 0 ms. It is used for network environments e.g. file server supporting many users. It gives sine - wave output.

The figure 5.3 gives the block diagram of an online UPS.



On line UPS has three modes of operation……

When input supply is available : In this case the main supply directly

feed the load through the rectifier and inverter circuit. In this battery is in charged condition. It is known as normal mode.

When input supply is not available : In this case, the battery feeds the load through the inverter. It is known as outage mode.

By pass mode : When the fault develops in UPS or inverter, then this mode will exist. In this mode, the bye-pass switch automatically transfers the load to the main supply line.