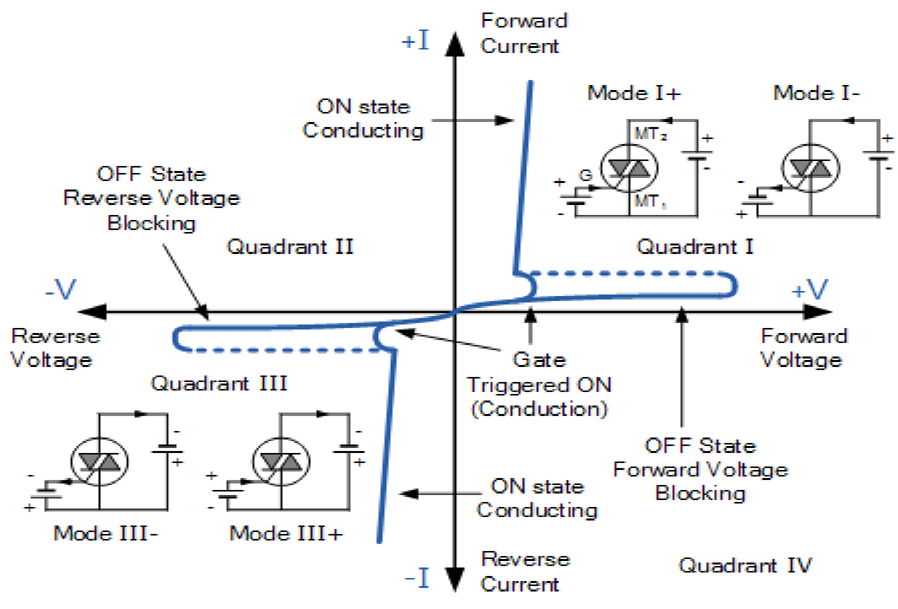
UNIT-1 (18 M)

1. Describe with neat sketch the V-I characteristics of TRIAC. 4M

Ans:



Because the triac essentially consists of two SCRs of opposite orientation fabricated in the same crystal, its operating characteristics in the first and third quadrants are the same except for the direction of applied voltage and current flow.

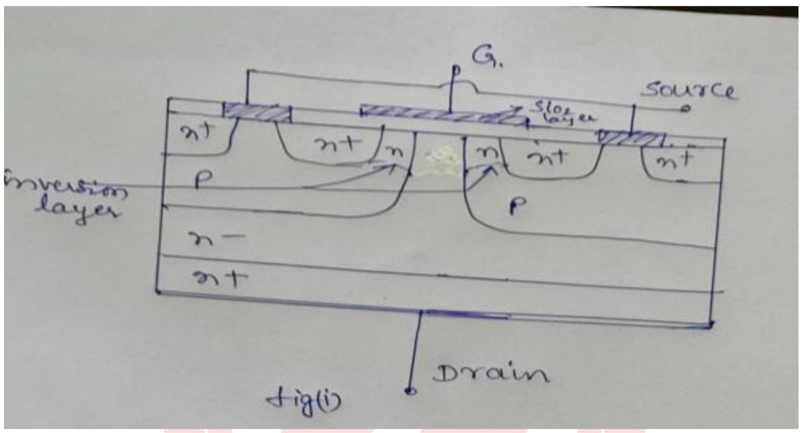
The following points may be noted from the triac characteristics:

1. The V-I characteristics for triac in the Ist and IIIrd quadrants are essentially identical to those of an SCR in the Ist quadrant.
2. The triac can be operated with either positive or negative gate control voltage but in normal operation usually the gate voltage is positive in Ist quadrant and negative in IIIrd quadrant.

The supply voltage at which the triac is turned ON depends upon the gate current. The greater the gate current, the smaller the supply voltage at which the triac is turned on. This permits to use a triac to control a.c. power in a load from zero to full power in a smooth and continuous manner with no loss in the controlling device.

2. Explain with sketch the operation of power MOSFET. 4M

Ans:

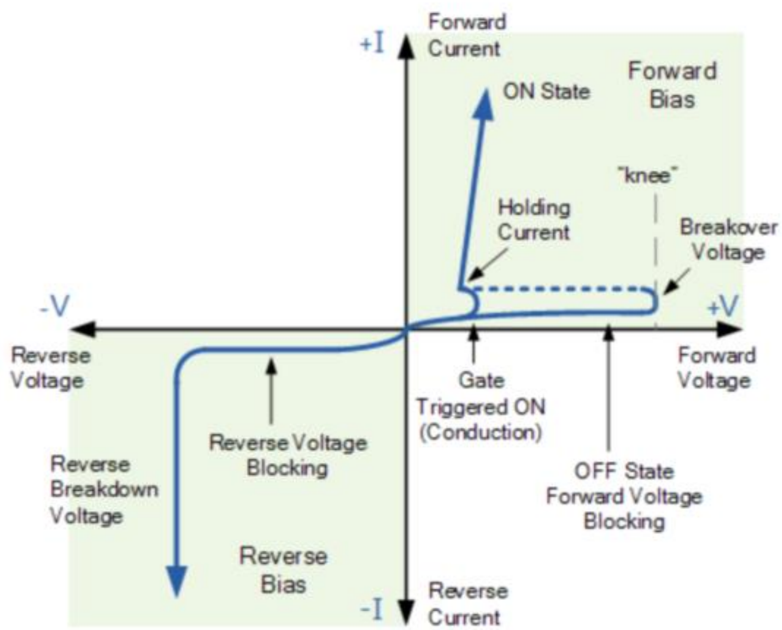


The Power MOSFET has a vertically oriented four layer structure of alternating P and N type (n+p n–n+) layers.

- The P type middle layer is called as body of MOSFET. In this region, the channel is formed between source and drain.
- The n- layer is called as drift region, which determines the breakdown voltage of the device. This n- region is present only in Power MOSFETs not in signal level MOSFET.
- The gate terminal is isolated from body by silicon dioxide layer.
- When the positive gate voltage is applied with respect to source, the n-type channel is formed between source to drain n allowing electrons to flow.
- Hence a positive gate voltage sets up a surface channel for current flow from drain to source.

3. Explain with the characteristics the effect of gate current on break over voltage of SCR. Define holding and latching current. 4M

Ans:



V-I Characteristics of SCR

It is the curve between anode-cathode voltage (V) and anode current (I) of an SCR at constant gate current.

Fig.1 shows the V-I characteristics of a typical SCR .

Fig.1: V-I characteristics of a SCR

Forward Characteristics

When anode is positive w.r.t. cathode, the curve between V and I is called the forward characteristics.

In fig.1, OABC is the forward characteristics of SCR at I_G=0.

If the supply voltage is increased from zero, a point reached (point A) when the SCR starts conducting.

Under this condition,the voltage across SCR suddenly drops as shown by dotted curve AB and most of supply voltage appears across the load resistance R_L .

If proper gate current is made to flow, SCR can close at much smaller supply voltage.

Reverse Characteristics

When anode is negative w.r.t. cathode, the curve between V and I is known as reverse characteristics.

The reverse voltage does come across SCR when it is operated with a.c. supply.

If the reverse voltage is gradually increased, at first the anode current remains small (i.e. leakage current) and at some reverse voltage, avalanche breakdown occurs and the SCR starts conducting heavily in the reverse direction as shown by the curve DE.

This maximum reverse voltage at which SCR starts conducting heavily is known as reverse breakdown voltage.

Holding Current-

It is the maximum anode current, gate being open, at which SCR is turned OFF from ON condition.

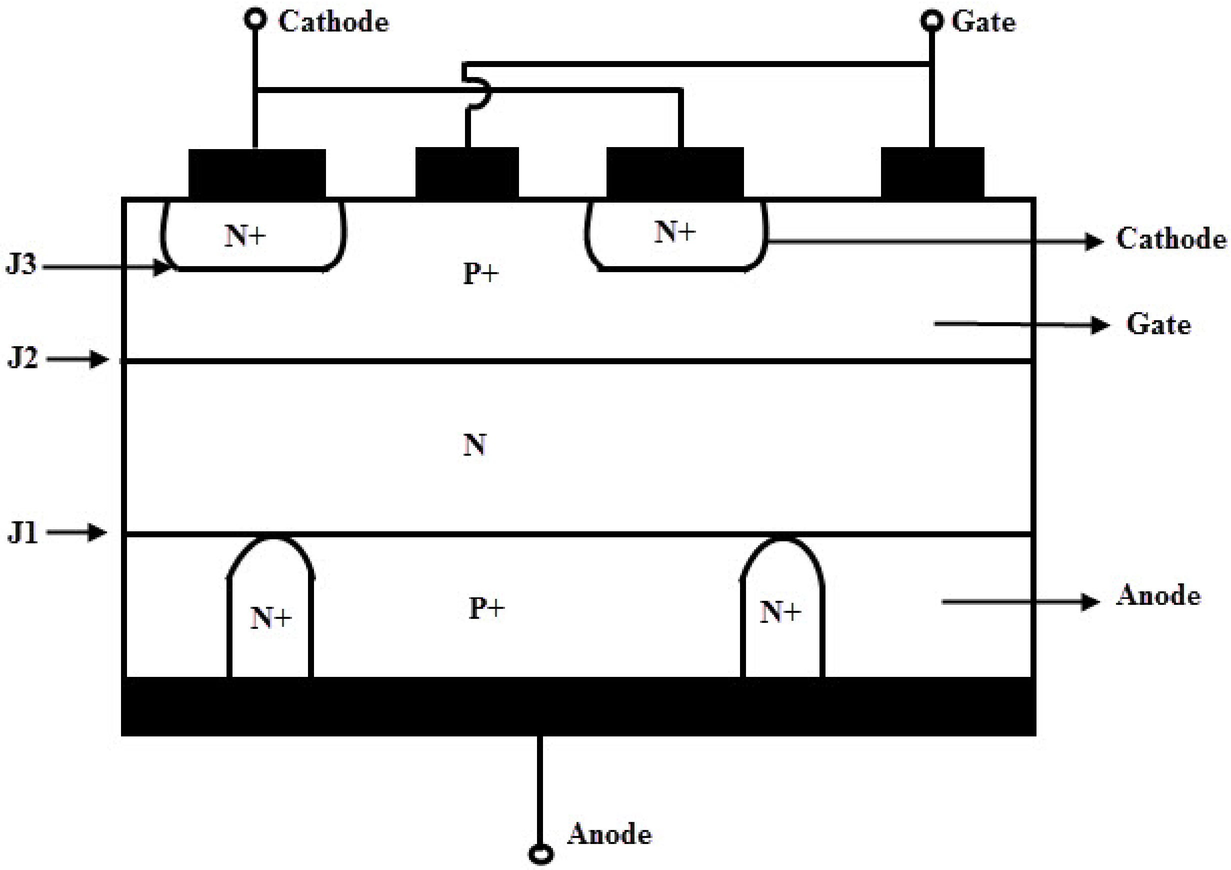
When SCR is in the conducting state, it can not be turned OFF even if gate voltage is removed

Latching Current-

Latching current can be defined as it is the least amount of anode current which is necessary to supply from the anode terminal to the cathode terminal to activate the SCR

4. Draw labelled constructional diagram for GTO and describe its working principle with V-I characteristics. State two applications of GTO. 4M

Ans:



Consider the below structure of GTO, which is almost similar to the thyristor. It is also a four layer, three junction P-N-P-N device like a standard thyristor. In this, the n+ layer

at the cathode end is highly doped to obtain high emitter efficiency. This result the breakdown voltage of the junction J3 is low which is typically in the range of 20 to 40 volts.

The doping level of the p type gate is highly graded because the doping level should be low to maintain high emitter efficiency, whereas for having a good turn OFF properties, doping of this region should be high. In addition, gate and cathodes should be highly interdigited with various geometric forms to optimize the current turn off capability.

The junction between the P+ anode and N base is called anode junction. A heavily doped P+ anode region is required to obtain the higher efficiency anode junction so that a good turn ON properties is achieved. However, the turn OFF capabilities are affected with such GTOs.

Principle of Operation

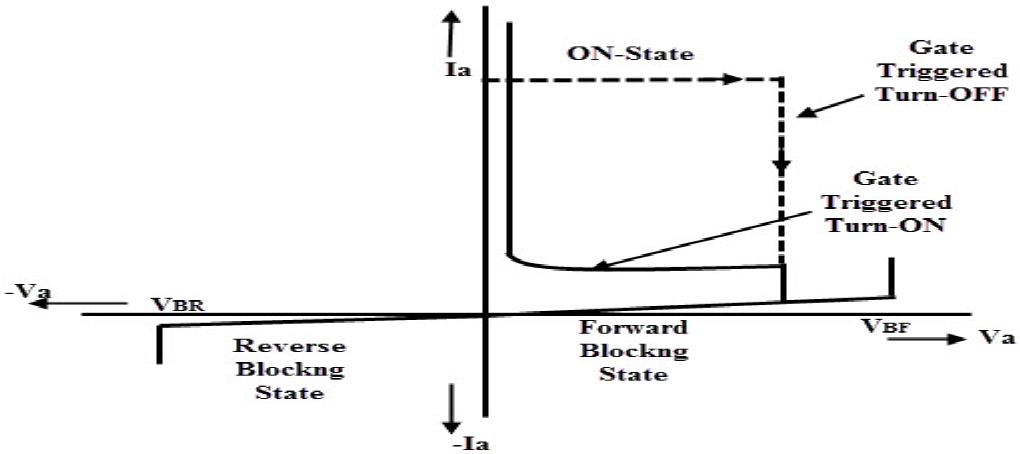
The turn ON operation of GTO is similar to a conventional thyristor. When the anode terminal is made positive with respect to cathode by applying a positive gate current, the hole current injection from gate forward bias the cathode p-base junction.

This results in the emission of electrons from the cathode towards the anode terminal. This induces the hole injection from the anode terminal into the base region. This injection of holes and electrons continuous till the GTO comes into the conduction state.

In case of thyristor, the conduction starts initially by turning ON the area of cathode adjacent to the gate terminal. And thus, by plasma spreading the remaining area comes into the conduction.

To turn OFF a conducting GTO, a reverse bias is applied at the gate by making the gate negative with respect to cathode. A part of the holes from the P base layer is extracted through the gate which suppress the injection of electrons from the cathode.

In response to this, more hole current is extracted through the gate results more suppression of electrons from the cathode. Eventually, the voltage drop across the p base junction causes to reverse bias the gate cathode junction and hence the GTO is turned OFF.



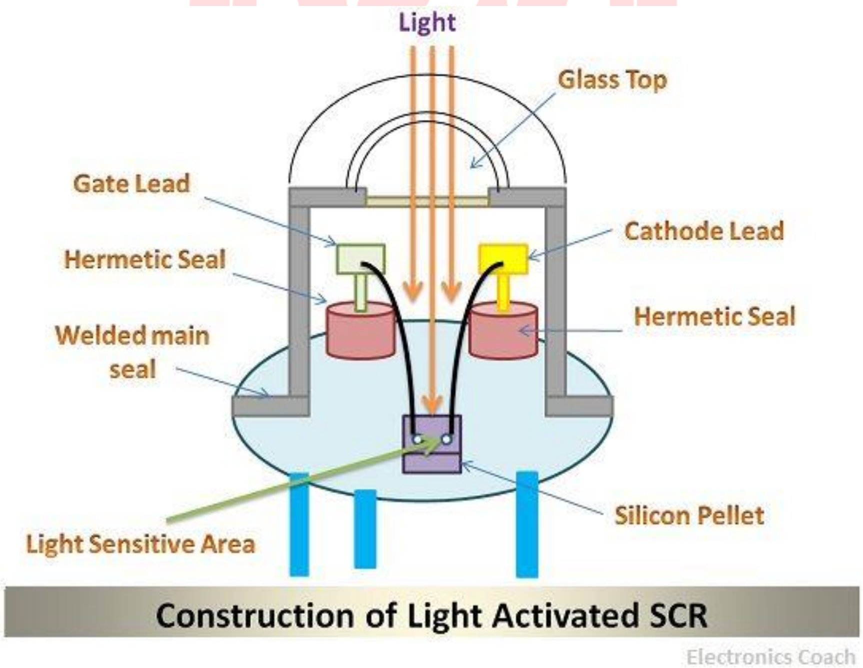
Applications

Some of these applications are

- AC drives
- DC drives or DC choppers
- AC stabilizing power supplies
- DC circuit breakers
- Induction heating

5. Describe the working of LASCR with it's constructional diagram and state its two industrial applications. 6M

Ans:



Working of LASCR

The LASCR works on the principle of photoconduction that is conduction due to photon striking the semiconductor surface. The LASCR is basically a thyristor; it is made up of semiconductor material. The light rays falling on the device are focused at one place to intensify it.

The more the intensity of light, the more will be the current through the LASCR. The internal architecture of LASCR consists of two transistors in such a way that the collector of one transistor is connected to the base of another transistor.

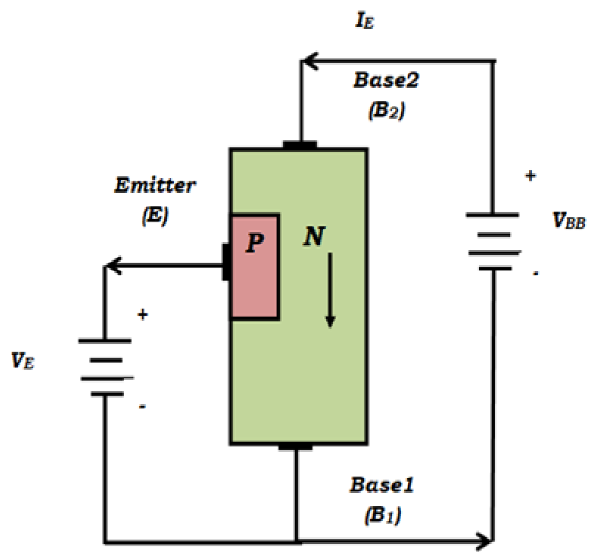
The light falling on the light activated SCR generates the electron from the valence band, and these electrons will enter conduction band. The electrons will move from collector of one region to base of another region, and then the cascading effect can be seen.

Applications of the Light Activated SCR

1. Low Power Applications: The Light activated SCR are generally used for the application which requires low power to operate. This is because power generated by SCR is low in magnitude.
2. Motor Control: The Light Activated SCR finds applications in the working of Motor Control.
3. Computer Applications: The components used in the computer system also require LASCR for meeting power requirements.
4. Optical light Controls: The optical light control use the principle of photoconduction for generating the control signals. Therefore, the LASCR finds extensive application in Optical light control.
5. Solid State Relay: In solid state relays, two LASCR are connected in reverse parallel so that they can generate power in both the half cycle of AC. The construction architecture of solid state relay can be understood with the help of the below diagram

6. With help of circuit diagram and V-I characteristics, explain working principle of UJT and state it's two applications. 6M

Ans:



Working of UJT

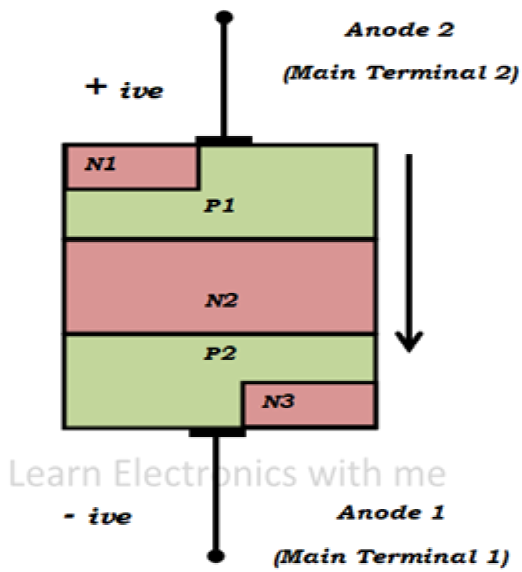
- When no voltage is applied at the emitter, the resistance in the channel is high and the device is turned OFF, till the applied voltage is higher than the triggering voltage.
- When the PN Junction is forward biased, positive voltage is applied at the emitter terminal and Base 2 is made positive with the Base1. The majority carrier which is the holes in the P type enters the N channel and since Base2 is positive it gets repelled and attracted towards Base1 terminal. So the resistance decreases. The Emitter current increases and reaches the peak and starts decreasing. After it reaches the valley point again it starts increasing.
- When the PN Junction is reverse biased, the emitter current doesn't flow and it is cut-off.

Application of Unijunction Transistor:

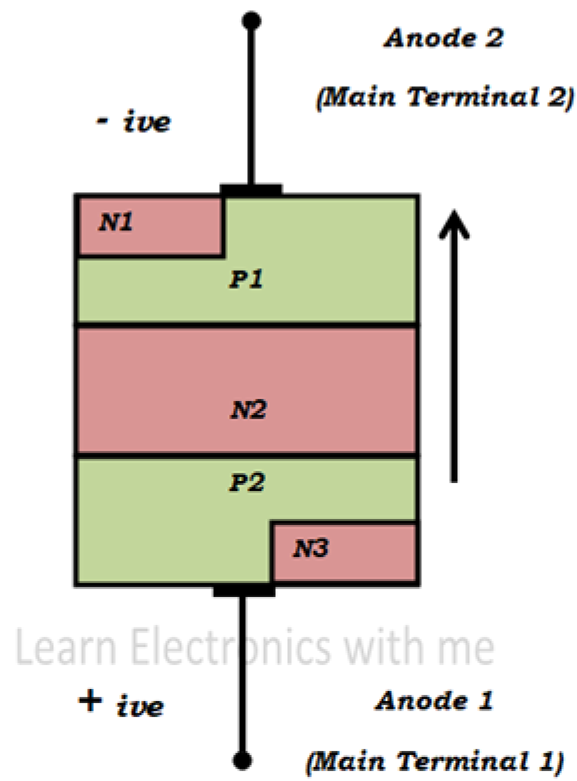
- *Used in timing circuits*
- *Used as switching device*
- *Used as oscillators*
- *Used for phase control*
- *Used in sawtooth generators*

7. With help of circuit diagram and V-I characteristics, explain working principle of DIAC and state it's two applications. 6M

Ans:



When the terminal MT1 is positive the direction of the flow of current will be in the order P1-N2-P2-N3. The junction between P1 and N2 is forward biased, the junction between N2 and P2 is reverse biased and the junction between P2 and N3 is forward biased.



When the terminal MT2 is positive the direction of the flow of current will be in the order N1-P1-N2-P2. The junction between N1 and P1 is forward biased, the junction between P1 and N2 is reverse biased and the junction between N2 and P2 is forward biased.

Application of Diac:

- Used in TRAIC triggering circuit
- Used in Lamp dimmer circuit
- Used in heat control circuit
- Used in speed control of a universal motor.

UNIT-2 (14 M)

8. List different Turn ON methods of SCR and explain any one in details. 4M

Ans:

With anode positive with respect to cathode, A thyristor can be turned ON by one of the following techniques;

(A) Forward Voltage Triggering

(B) Thermal Triggering (Temperature Triggering)

(C) Radiation Triggering (Light Triggering)

(D) dv/dtTriggering
(E) Gate Triggering

(A) Forward Voltage Triggering : When anode-to-cathode forward voltage is increased with gate circuit open, the reverse biased junction J_2 will have an avalanche breakdown at a voltage called forward breakover voltage V_{BO} . At this voltage, a thyristor changes from OFF state to ON-state characterised by a low voltage across it with large forward current. The forward voltage-drop across the SCR during the ON state is of the order of 1 to 1.5 V and increases slightly with load current.
(B) Thermal Triggering (Temperature Triggering) : Like any other semiconductor, the width of the depletion layer of a thyristor decreases on increasing the junction temperature. Thus, in a thyristor when the voltage applied between the anode and cathode is very near to its breakdown voltage, the device can be triggered by increasing its junction temperature. By increasing the temperature to a a certain value, a situation comes when the reverse biased junction collapses making the device conduct. This method of triggering the device by heating is known as the thermal triggering process.

Dv/dt **Triggering :** We know that with forward voltage across the anode and cathode of a device, the junctions $J_1$and J_3 are forward biased, whereas the junction J_2 becomes reverse biased.This reverse biased junction J_2has the characteristics of a capacitor due to charges existing across the junction. If a forward voltage is suddenly applied, a charging current will flow tending to turn the device ON.

9. Explain class B commutation with neat circuit diagram. 4M

Ans:

In this method the LC resonating circuit is across the SCR and not in series with the load. The commutating circuit is shown in Fig.1 and the associated waveforms are shown in Fig.2.

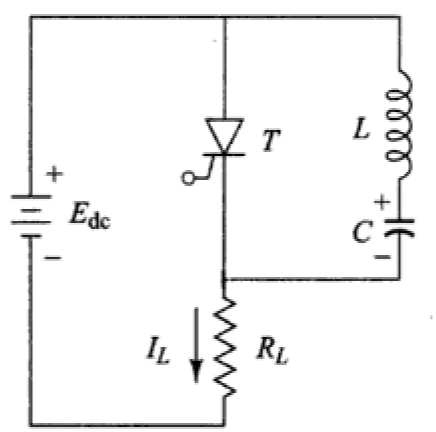
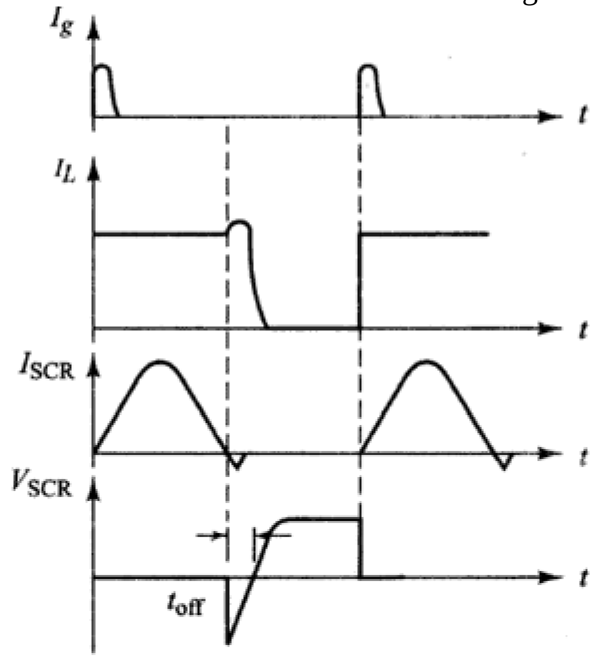


Fig.1 *Class B commutation circuit*



Fig,2 *Associated waveforms*

Initially, as soon as the supply voltage Edc
is applied, the capacitor C starts getting charged with its upper plate positive and the lower plate negative, and it charges up to the voltage Edc.
When thyristor T is triggered, the circuit current flows in two directions:

(1) The load current IL
flows through the path Edc+−T−RL−Edc−
(2) Commutating current Ic

The moment thyristor T is turned ON, capacitor C starts discharging through the path
C+−L−T−C−
.When the capacitor C becomes completely discharged, it starts getting charged with reverse polarity. Due to the reverse voltage, a commutating current IC
starts flowing which opposes the load current IL.
When the commutating current IC
is greater than the load current IL
, thyristor T becomes turned OFF. When the thyristor T is turned OFF, capacitor C starts getting charged to its original polarity through L and the load. Thus, when it is fully charged, the thyristor will be ON again.

Hence, from the above discussion it becomes clear that the thyristor after getting ON for sometime automatically gets OFF and after remaining in OFF state for sometime, it again gets turned ON. This process of switching ON and OFF is a continuous process.

10. Explain with circuit diagram the operation of class C commutation. 4M

Ans:

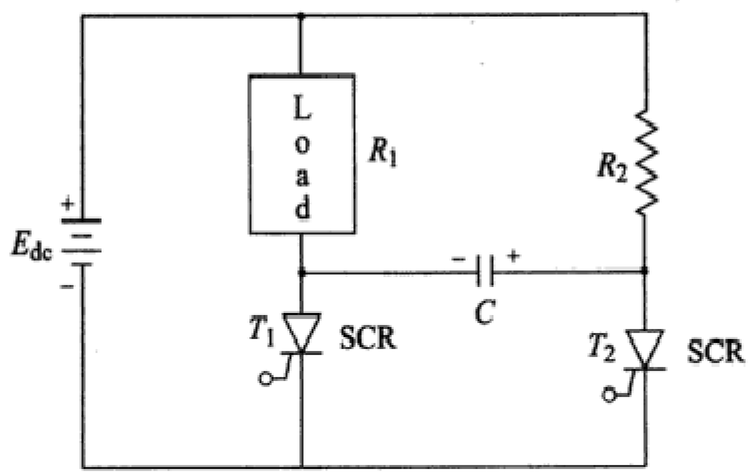


Fig.1 Class C–commutation circuit

The Class C commutation circuit is shown in Fig.1. In this method, the main thyristor (SCR T1

) that is to be commutated is connected in series with the load. An additional thyristor (SCR T2), called the complementary thyristor is connected in parallel with the main thyristor.
Circuit Operation:

(a) Mode 0 [Initial-state of circuit] : Initially, both the thyristors are OFF.

Therefore, the states of the devices are,

$T1 \longrightarrow OFF, T2 \longrightarrow OFF, \therefore Ec1=0$
(b) Mode 1 : When a triggering pulse is applied to the gate of T1, the thyristor T1 is triggered. Therefore, two circuit current, namely, load current IL and charging current IC start flowing. Their paths are:

Load current IL ;

$Edc+ - R1 - T1 - Edc-$
Charging current IC ;

$Edc+ - R2 - C+ - C- - T1 - Edc-$
Capacitor C will get charged by the supply votage Edc with the polarity shown in Fig.1 . The states of circuit components becomes

$T1 \longrightarrow ON, T2 \longrightarrow OFF, Ec1=Edc$
(c) Mode 2 : When a triggering pulse is applied to the gate of T2,T2 will be turned on. As soon as T2 is ON, the negative polarity of the capacitor C is applied to the anode of T1 and simultaneously, the positive polarity of capacitor C is applied to the cathode. This causes the reverse voltage across the main thyristor T1 and immediately turns it off.

Charging of capacitor C now takes place through the load and its polarity becomes reverse. Therefore, charging path of capacitor C becomes,

$Edc+ - R1 - C+ - C- - T2(a-k) - Edc-$

Hence, at the end of Mode2 the states of the devices are

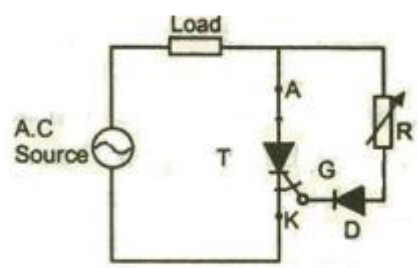
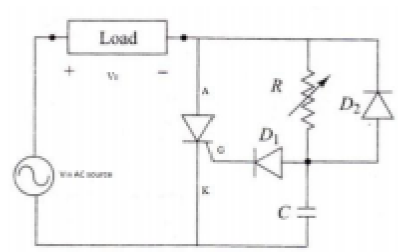
T1⟶OFF,T2⟶ON,Ec1=−Edc
(d) Mode 3: Now, when thyristor T1
is triggered, the discharging current of capacitor turns the complementary thyristor T2
OFF. The state of the circuit at the end of this Mode 3 becomes,

T1⟶ON,T2⟶OFF,Ec1=Edc
Therefore, this Mode 3 operation is equivalent to Mode 1 operation.

The waveforms at the various points on the commutation circuit are shown in Fig.2. An example of this class of commutation is the well known McMurray-Bedford inverter . With the aid of certain accessories, this class is very useful at frequencies below about 1000 Hz. Sure and reliable . commutation is the other characteristic of this method.

11. Compare R-triggering and RC- triggering of SCR (any four points) 4M

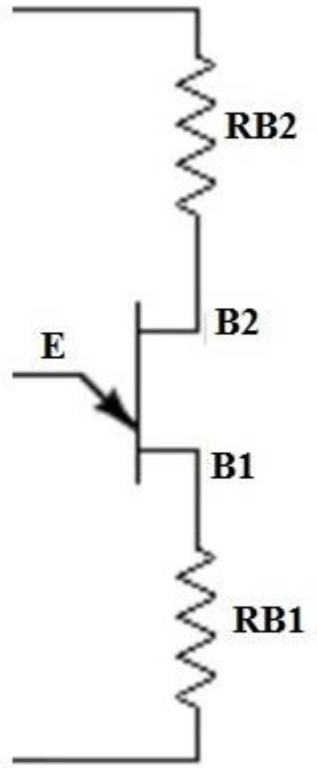
Ans:

Sr .No.	Parameter	R Triggering	RC Triggering
1	circuit diagram		
2	Firing angle	Can vary From 0 to 90₀900	Can vary From 0 to 180₀1800

Sr .No.	Parameter	R Triggering	RC Triggering
3	Cost	Less	More
4	Average output voltage	Can be controlled from 100% (for α=0₀=00) down to 50% (for α=90₀900)	Can be controlled from 100% for α=0₀=00)down to 0% (for α=180₀=1800)
5	Type of Triggering	AC gate triggering	AC gate triggering

12. Describe the operation of PUT as relaxation oscillator. 6M

Ans:



UJT is the short form for UniJunction Transistor. It is a three-terminal device used as an ON-OFF switching transistor. These are constructed using P and N-type semiconductor material, forming a single PN junction in the N-type channel of the device. It has unidirectional conductivity and negative resistance characteristics. It acts as a variable voltage divider during breakdown conditions. Here, the P-type material is fused into the N-type silicon channel. The N-Type channel of the UJT acts as the main current-carrying channel with two outer connections Base1 and Base2. The P-type material forms the emitter connection.
UJT Relaxation Oscillator consists of a UJT circuit with its emitter connected to a resistor and a capacitor. The timing of the output waveform is determined using the RC time constant. Supply voltage VBB is applied to the circuit. The capacitor starts charging through the resistor R1.
UJT Relaxation Oscillator Theory
When the capacitor charges to the threshold peak value of the UJT, UJT gets switched ON and the capacitor starts discharging. The capacitor discharges through the resistor R2. The capacitor discharges till the voltage reduces to the valley point of the UJT, where the UJT gets switched

OFF and the capacitor starts charging again. The output voltage collected across R2 forms the non-sinusoidal waveform. The voltage waveform is generated when the UJT is in ON state. Initially the voltage across the capacitor Vc =0. The capacitor starts charging through the resistor R1, $V = V0(1- e^{1/R_1} C)$. The capacitor continues to charge till the UJTis switched ON, where it starts discharging through the resistor R2. This process of charging and discharging continues. The voltage across the capacitor when plotted on the graph shows a sweep waveform. The continuous charging and discharging of the capacitor have generated a sweep waveform across the capacitor. Thus, the output of the relaxation oscillator generates continuous non-sinusoidal waveforms.

13. State the need of protection circuit of SCR ,describe the working of snubber circuit with neat diagram. 6M

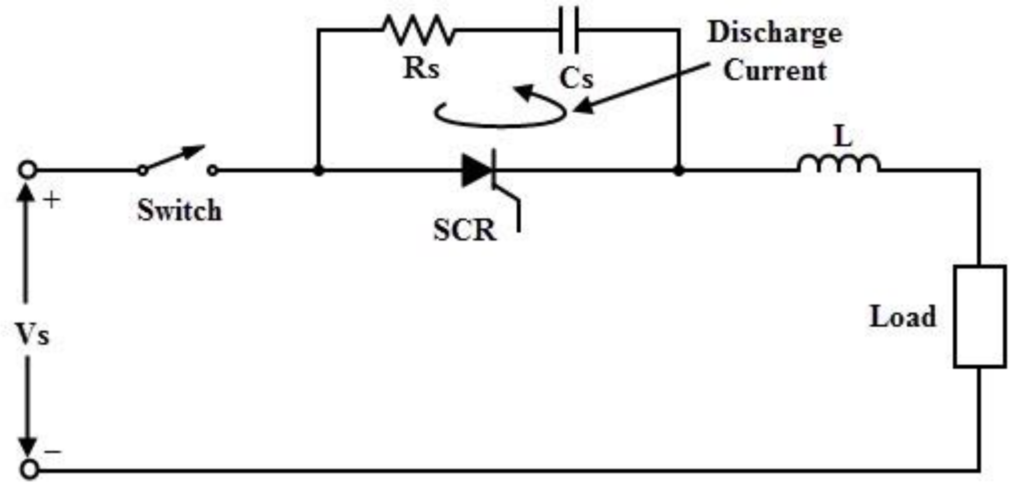
Ans:

For satisfactory and reliable operation, the specified ratings of an SCR should not be exceeded due to overload, voltage transients and other abnormal conditions. If the ratings are exceeded, there is a chance of damage permanently to the SCR. Due to the reverse recovery process during the turn OFF the SCR, the voltage overshoots occur in the SCR.

Also, during turn ON, switching action produces over voltages in the presence of inductance. In the event of a short circuit, a large current flows through the SCR which is very larger than the rated current. Therefore, to avoid the undesirable effects on the SCR due to these abnormal conditions, SCR must be provided with suitable protection circuits.

RC snubber circuit-

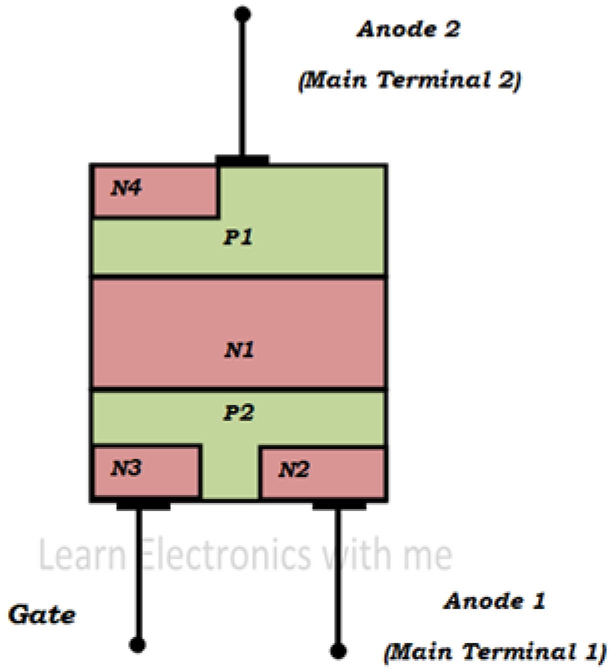
the protection against high voltage reverse recovery transients and dv/dt is achieved by using an RC snubber circuit. This snubber circuit consists of a series combination of capacitor and resistor which is connected across the SCR. This also consist an inductance in series with the SCR to prevent the high di/dt. The resistance value is of few hundred ohms. The snubber network used for the protection of SCR is shown below.



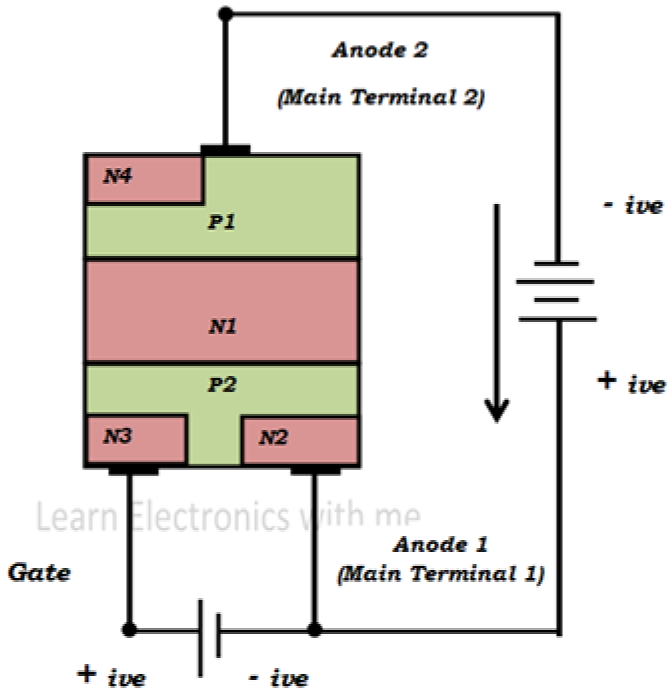
When the switch closed, a sudden voltage appears across the SCR which is bypassed to the RC network. This is because the capacitor acts as a short circuit which reduces the voltage across the SCR to zero. As the time increases, voltage across the capacitor builds up at slow rate such that dv/dt across the capacitor is too small to turn ON the SCR. Therefore, the dv/dt across the SCR and the capacitor is less than the maximum dv/dt rating of the SCR.
Normally, the capacitor is charged to a voltage equal the maximum supply voltage which is the forward blocking voltage of the SCR. If the SCR is turned ON, the capacitor starts discharging which causes a high current to flow through the SCR.
This produces a high di/dt that leads to damage the SCR. And hence, to limit the high di/dt and peak discharge current, a small resistance is placed in series with the capacitor as shown in above. These snubber circuits can also be connected to any switching circuit to limit the high surge or transient voltages.

14. Suggest a suitable power device which can be turned OFF by applying negative pulse to its gate terminal. Also draw its labelled constructional diagram.

Ans:



Triac is a four layer, six doped region and a three terminal device. Gate terminal is connected to both N3 and P2 so that gate triggers the device when both positive and negative voltage is applied. In the Same way MT1 or Anode1 is also connected to N2 and P2 regions, and MT2 or Anode2 is connected to the P1 and N4 regions. So the polarity between the terminals decide the direction of the current through the layers.

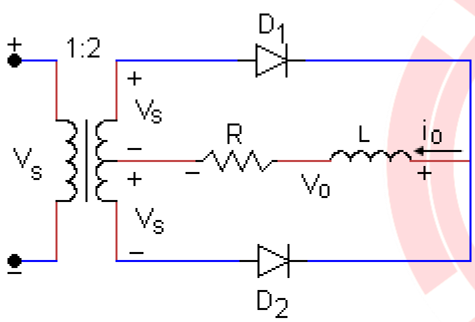


When the MT2 terminal is made positive with respect to the terminal MT1 and when negative voltage is applied at the gate terminal the path of the current flow from MT2 to MT1 will be P2N1P1. The Junctions P2N1 and P1N4 are forward biased and the junction N1P1 is reverse biased. So in this mode Triac work in a negative biased region.
When the MT2 terminal is made negative with respect to the terminal MT1 and when negative voltage is applied at the gate terminal the path of the current flow from MT2 to MT1 will be P2N1P1N4.
Mode2 and mode3 are less sensitive and need more gate current to turn ON the device. Mode1 and mode4 have greater sensitivity when gate polarity and MT2 are of same polarity.

UNIT-3 (14 M)

15. Explain with circuit diagram and waveform the operation of single phase center tapped full wave controlled rectifier with R load. 4M

Ans:



+
1:2
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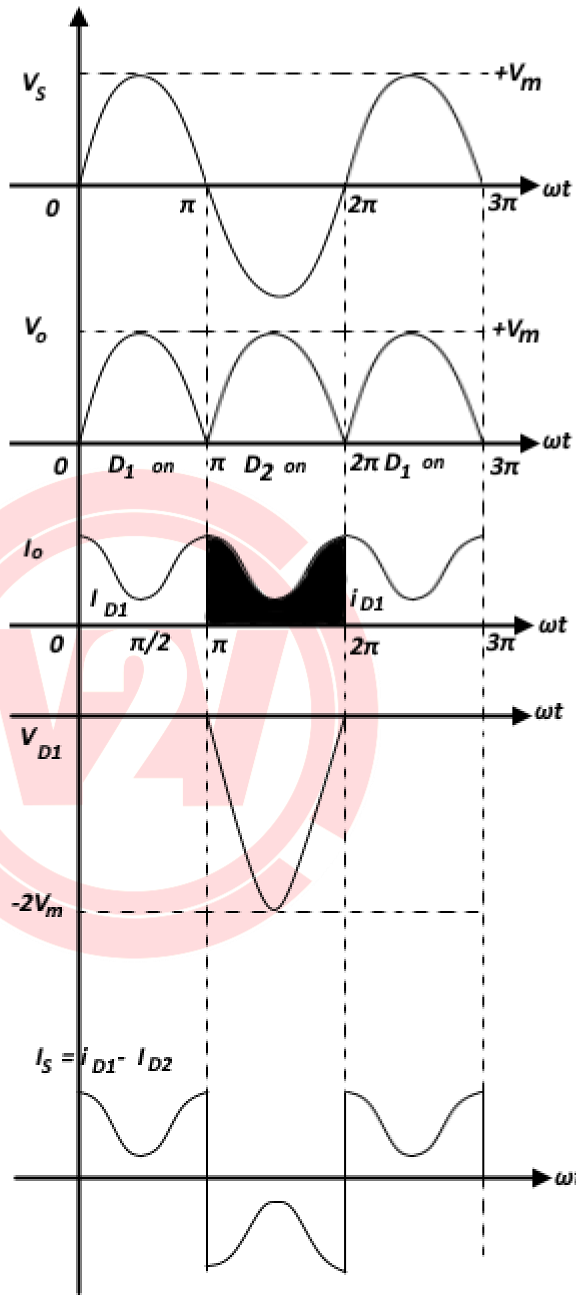
(a)



Vs
+Vm
ωt
0
π
2π
3π
Vo
+Vm
ωt
0
D1 on
π
D2 on
2π
D1 on
3π
Io
I D1
i D1
ωt
0
π/2
π
2π
3π
ωt
V D1
-2Vm
Is = i D1 - I D2
ωt

(b)

The circuit consist of four thyristors T1, T2, T3 and T4, a voltage source Vs and a R Load.

- During the positive half cycle of the input voltage, the thyristors T1 & T2 is forward biased but itdoes not conduct until a gate signal is applied to it.
- When a gate pulse is given to the thyristors T1 & T2 at ωt = α, it gets turned ON and begins toconduct.
- When the T1 & T2 is ON, the input voltage is applied to the load through the path VsT1-Load-T2-Vs.
- During the negative half cycle, T3 & T4 is forward biased, the thyristor T1 & T2 gets reverse biasedand turns OFF
- When a gate pulse is given to the thyristor T3 & T4 at ωt = π+α, it gets turned ON and begins toconduct.
- When T3 & T4 is ON, the input voltage is applied to the load Vs-T3-Load-T4-Vs.
- Here the load receives voltage during both the half cycles.
- The average value of output voltage can be varied by varying the firing angle α.
- The waveform shows the plot of input voltage, gate current, output voltage, output current andvoltage across thyristor.

16. A single phase full wave controlled rectifier is supplied with a voltage V = 230 sin 314t.if firing angle 'α' is 300. Find: (i) Average dc output voltage (ii) Load current for the load resistance of 100 Ω 4M

Ans:

Given:

V= 230 sin 314 t

$\alpha = 30^o$

R_L = 100 Ω

Required:

Vdc = ?

I_L = ?

Solution:

Average output voltage $= \frac{Vm}{\pi}(1 + \cos \alpha)$

$= \frac{230}{\pi}(1 + \cos 30)$

$= 73.211 * 1.866 = 136.6$ V

Load current $I_L = \frac{Vdc}{RL} = \frac{136.6}{100} = 1.366$ A

17. Describe the operation of single phase half wave controlled rectifier with RL load. 4M

Ans:

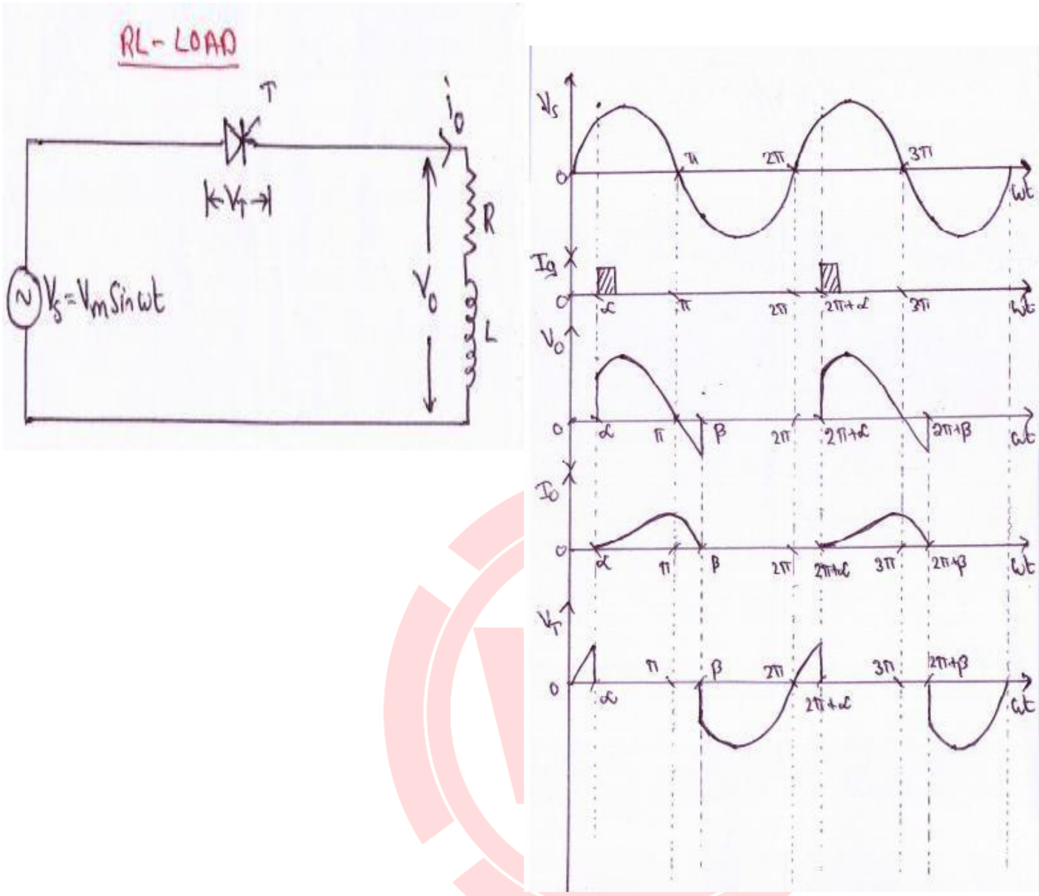


Figure: 2.4 Single phase half wave rectifier with RL load with waveforms

Figure above shows the single-phase half wave rectifier with RL Load.

The circuit consist of a thyristor T, a voltage source Vs, an inductive load L and a resistiveload R.

- During the positive half cycle of the input voltage, the thyristor T is forward biased but itdoes not conduct until a gate signal is applied to it.
- When a gate pulse is given to the thyristor T at $\omega t = \alpha$, it gets turned ON and begins to conduct. When the thyristor is ON, the input voltage is applied to the load but due to the inductor present in the load, the current

through the load builds up slowly.

- During the negative half cycle, the thyristor T gets reverse biased but the current throughthe thyristors is not zero due to the inductor.
- The current through the inductor slowly decays to zero and when the load current (i.e thecurrent through the thyristor) falls below holding current, it gets turned off.
- So here the thyristor will conduct for a few duration in the negative half cycle and turns offat $\omega t = \beta$. The angle β is called extinction angle.
- The duration from α to β is called conduction angle.
- So the load receives voltage only during the positive half cycle and for a small duration innegative half cycle.
- The average value of output voltage can be varied by varying the firing angle α.
- The waveform shows the plot of input voltage, gate current, output voltage, output currentand voltage across thyristor.

Problem: A single phase half controlled rectifier supplied with voltage V=100 sin 314t, $\alpha = 30°$ and load resistance is 50 Ω. Find average output DC voltage and load current.

Given:

V= 100 sin 314 t

$\alpha = 30^0$

$R_L = 50\ \Omega$

Required:

Vdc = ?

I_L = ?

Solution:

Average output voltage $= \frac{Vm}{\pi}(1 + \cos\alpha)$

$= \frac{100}{\pi}(1 + \cos 30)$

= 31,8309* 1.866 = 59.396 V

Load current $I_L = \frac{Vdc}{RL} = \frac{59.396}{50}$ = 1.188 A

Applications of Phase Controlled Rectifier

Phase controlled rectifier applications include paper mills, textile mills using DC motordrives and DC motor control in steel mills.

- AC fed traction system using a DC traction motor.
- Electro-metallurgical and Electrochemical processes.
- Reactor controls.
- Magnet power supplies.
- Portable hand instrument drives.
- Flexible speed industrial drives.
- Battery charges.
- High voltage DC transmission.
- UPS (Uninterruptible power supply systems).

18. With the help of circuit diagram and waveforms explain the working of single phase half wave controlled rectifier with R-load. 4M

Ans:

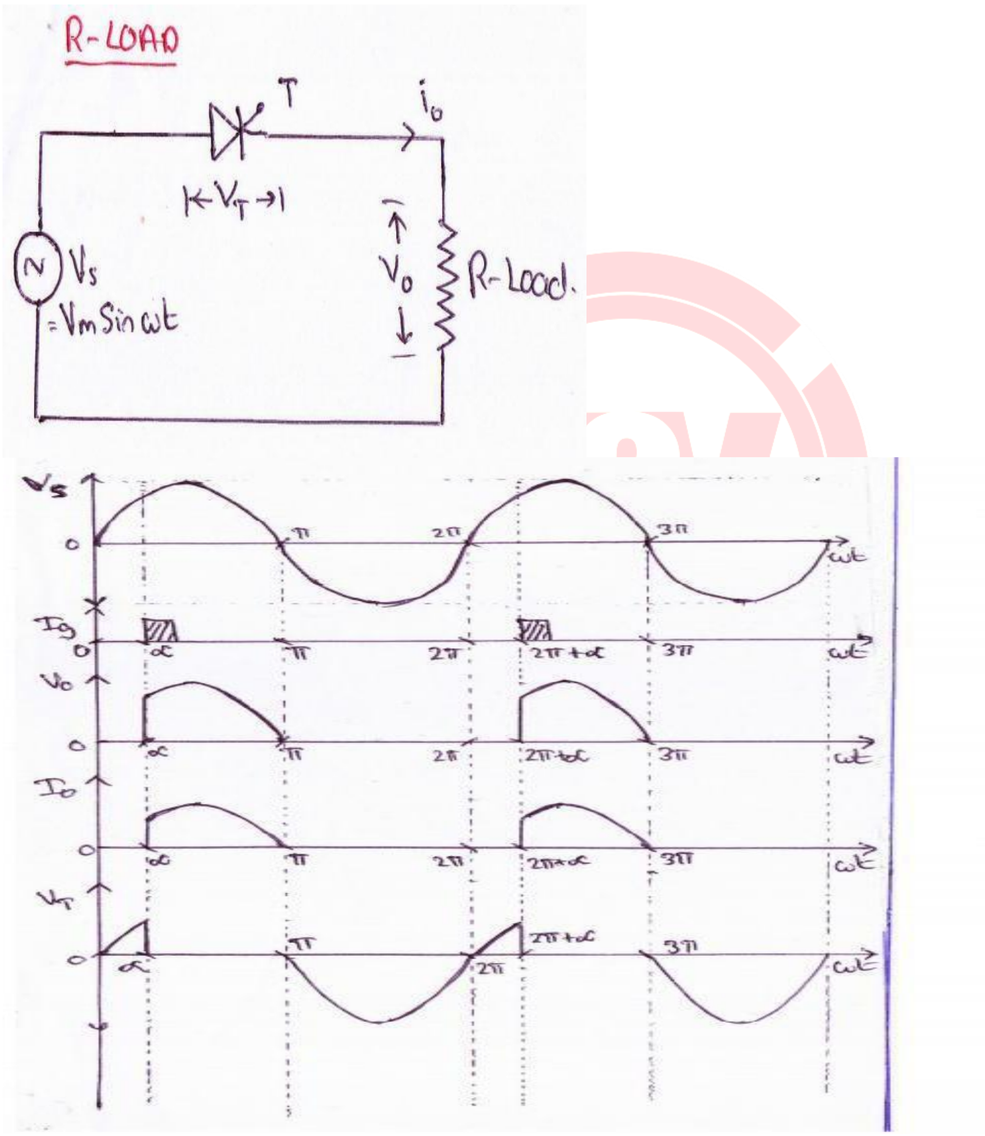


Figure: 2.3 Single phase half wave rectifier with R load with waveforms

As shown in figure below primary of transformer is connected to ac mains supply with whichSCR becomes forward bias in positive half cycle.
T1 is triggered at an angle α, T1 conducts
and voltage isapplied across R.
The load current i0 flows through „R"
the waveforms for voltage & current are as
shown above. As load is resistive,
Output current is given as,

$$I_0 = \frac{V_0}{R}$$

Hence shape of output current is same as output voltage
As T1 conducts only in positive half cycle as it is reversed bias in negative cycle, the ripplefrequency of
output
voltage
isfripple=
50 Hz
(supply
frequency)
Average output voltage is given as,

$$V_0(Avg) = \frac{1}{T}\int_0^T V_0(wt)\,dwt$$

i.e Area under one cycle.
Therefore T=2π&Vo(ωt) = Vm sinωt from α to π& for rest of the period Vo(ωt)=0

$$\therefore V_0(Avg) = \frac{1}{2\pi}\int_0^{2\pi} V_m sin(wt)\,dwt$$

$$= \frac{V_m}{2\pi}[-coswt]_\alpha^\pi$$

$$= \frac{V_m}{2\pi}(1+cos\alpha)$$

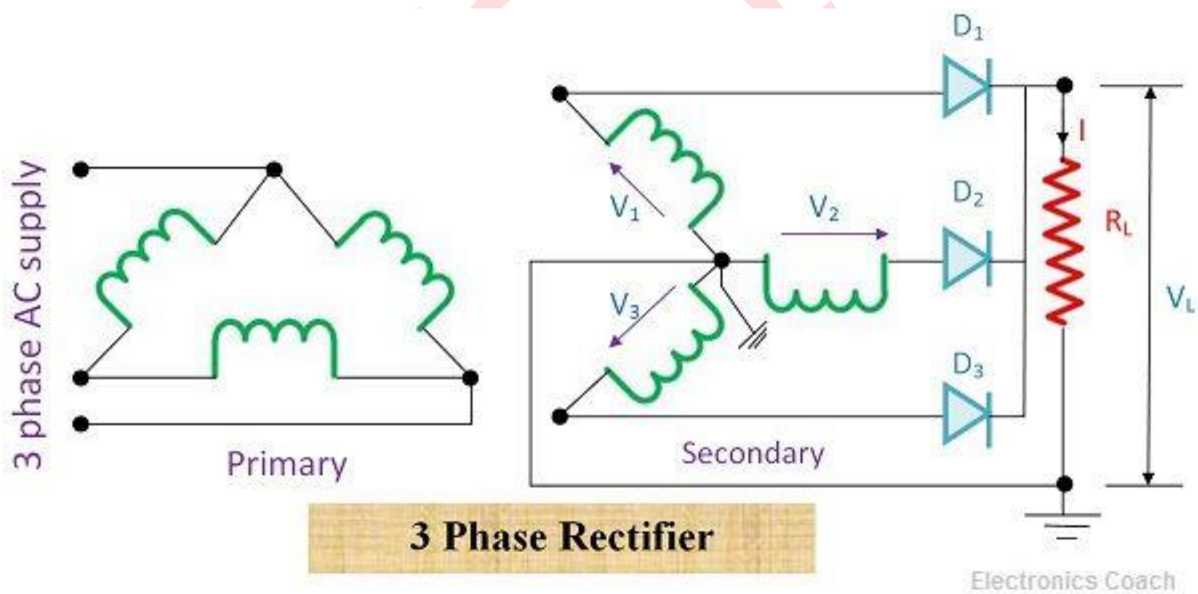
Power transferred to load,

$$P_O(Avg) = \frac{V_O^2(Avg)}{R}$$

Thus, power & voltage can be controlled by firing angle.

19. Explain the operation of three phase half wave controlled rectifier with circuit diagram and also sketch its input and output waveform 6M

Ans:



Circuit Diagram and Waveform of 3 Phase Half Controlled Rectifier with RL Load

The circuit consist of a delta star transformer and 3 thyristors T1, T2, T3 which are connected on thesecondary star connected winding and a RL load.

• When Va is positive, T1 becomes forward biased and conducts. During the negative cycle of Va, thecurrent through T1 is not zero due to inductor present in the load.
• So T1 will remain ON during the negative cycle of Va
• When Vb is positive, T2 is triggered and the load current gets transferred from T1 to T2. At thisinstant, T1 turns OFF.
• During the negative cycle of Vb, the current through T2 is not zero due to inductor present in theload.
• So T2 will remain ON during the negative cycle of Vb
• When T3 is triggered during positive cycle of Vc, the load current is transferred from T2 to T3. Atthis instant, T2 turns OFF
• Similarly, T3 conducts during the negative cycle of Vc and turns OFF when T1 is triggered.
• The average output voltage can be varied by varying the firing angles of the thyristors.
• The waveforms show the output voltage for various firing angles.
• In the waveform, Va is denoted as Van, Vb as Vbn, Vc as Vcn.

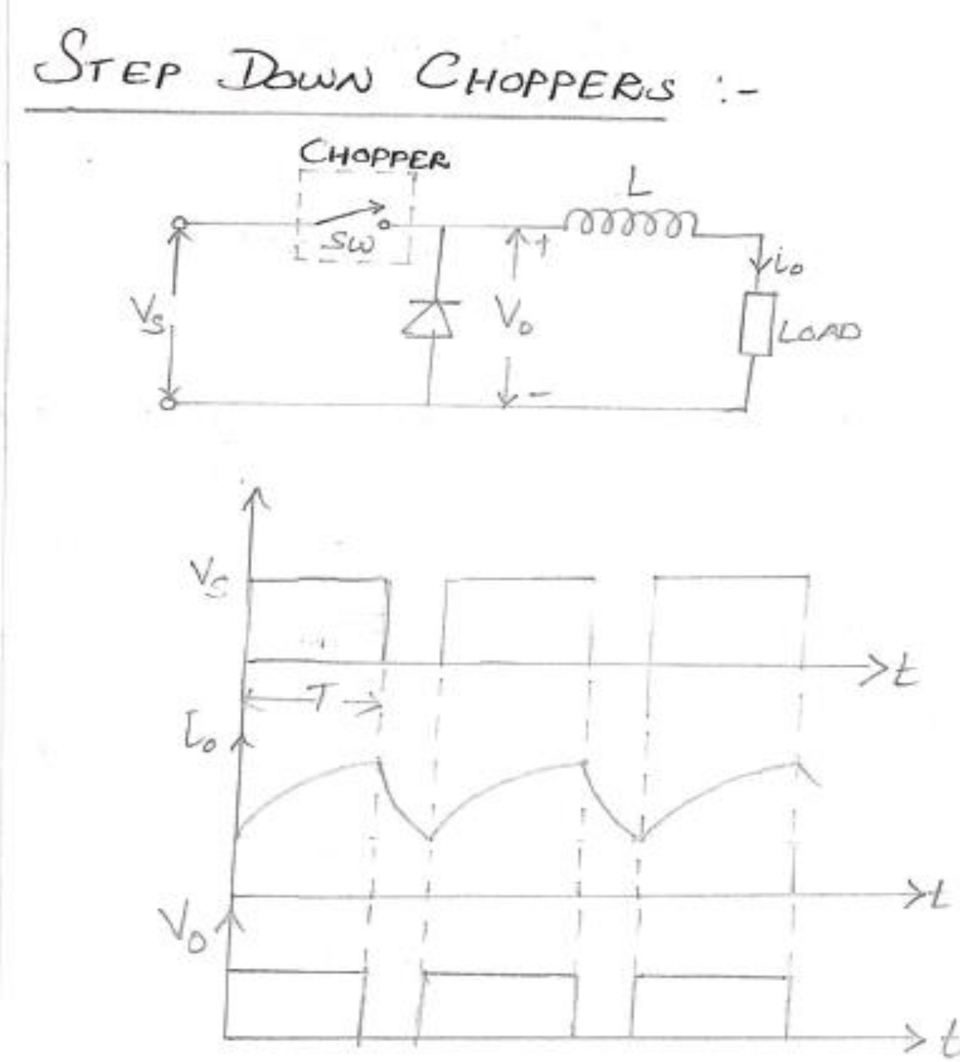
Circuit Diagram and Waveform of 3 Phase Half Controlled Rectifier with RL Load

• The circuit consist of a delta star transformer and 3 thyristors T1, T2, T3 which are connected onthe secondary star connected winding and a RL load.
• When Va is positive, T1 becomes forward biased and conducts. During the negative cycle of Va, thecurrent through T1 is not zero due to inductor present in the load.
• So T1 will remain ON during the negative cycle of Va • When Vb is positive, T2 is triggered and theload current gets transferred from T1 to T2. At this instant, T1 turns OFF.
• During the negative cycle of Vb, the current through T2 is not zero due to inductor present in theload.
• So T2 will remain ON during the negative cycle of Vb
• When T3 is triggered during positive cycle of Vc, the load current is transferred from T2 to T3. Atthis instant, T2 turns OFF
• Similarly, T3 conducts during the negative cycle of Vc and turns OFF when T1 is triggered.
• The average output voltage can be varied by varying the firing angles of the thyristors.
• The waveforms shows the output voltage for various firing angles. • In the waveform, Va isdenoted as Van, Vb as Vbn, Vc as Vcn.

UNIT-4 (14 M)

20. Name the suitable chopper to decrease the output voltage and also explain its operation with neat circuit diagram. 4M

Ans:



* A chopper is a high speed on/off Semiconductor switch.

* It connects source to load & disconnects the load from source at a fast speed.

* Chopper (switch) may be turned ON or OFF as desired.

* During the period T_{ON}, the chopper is ON and the load vge is equal to the source voltage V_S.

* During the period T_{OFF}, the chopper is OFF & the load current flows through the freewheeling diode FD.

* During T_{OFF}, the load terminals are short circuited by FD & load vge is therefore zero.

⇒ During T_{ON} → load current rises

T_{OFF} → load current decays.

Avg. load voltage, $V_o = \frac{T_{on}}{T_{on} + T_{off}} V_s$

$V_o = \frac{T_{on}}{T} V_s = \alpha V_s$

$T_{on} \rightarrow$ on-time

$T_{off} \rightarrow$ Off-time

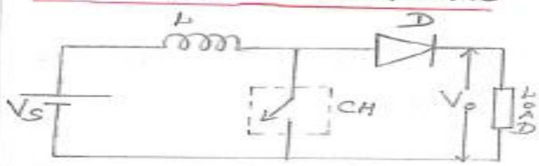
$T = T_{on} + T_{off}$ (Chopping Period)

$\alpha = \frac{T_{on}}{T}$ (Duty cycle)

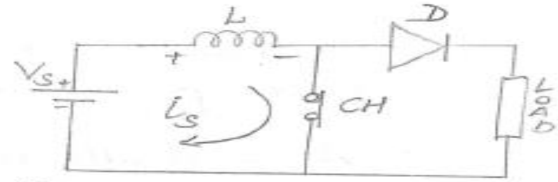
21. Draw circuit diagram of step up chopper. State its output voltage expression and draw its input output wave forms. 4M

Ans:

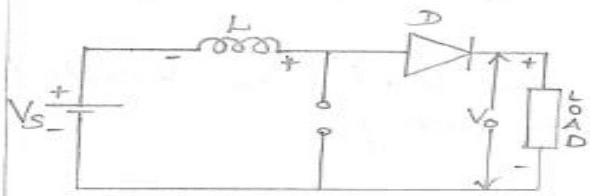
STEP UP CHOPPERS :-



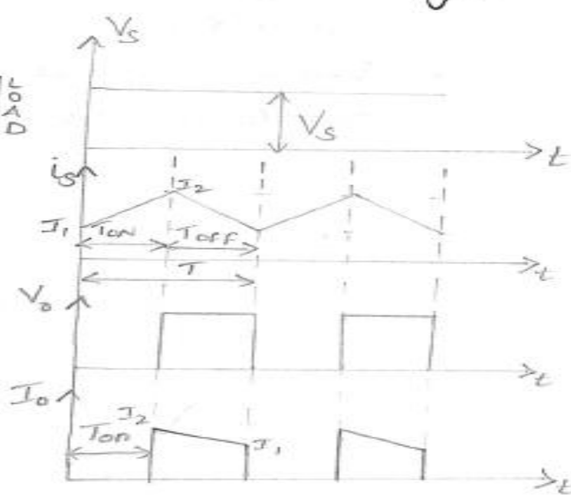
(a) Step-up chopper



(b) L stores charge



$L\frac{di}{dt}$ is added to V_s.



* Avg. o/p voltage V_o greater than the input voltage V_s.

$V_o > V_s$.

⇒ Called as Step-up chopper.

* Inductor 'L' in series with source vge V_s.
* When CH is ON, the inductor stores the energy.
* During T_{ON} → L stores the energy.

* When chopper CH is off inductor current can't die down instantaneously, the current is forced to flow through the diode & load for a time T_{off}.

* As a result the current tends to decrease, polarity of the emf induced in L is reversed.

* Voltage across the load, $V_o = V_S + L\left(\frac{di}{dt}\right)$ exceeds the source voltage.

⇒ When CH is ON, the current thru. the inductance L would rise from I_1 to I_2.

⇒ When CH is OFF, current would fall from I_2 to I_1.

⇒ CH → ON → $V_S = V_L$

CH → OFF → $V_L = V_0 - V_S$

V_L → Vge across L.

Avg. o/p vge, $V_o = V_S\left(T/T_{off}\right)$

$$V_o = V_S\left(\frac{1}{1-\alpha}\right)$$

22. Explain operation of series inverter with neat circuit diagram and waveform. 4M

Ans:

SERIES INVERTOR-

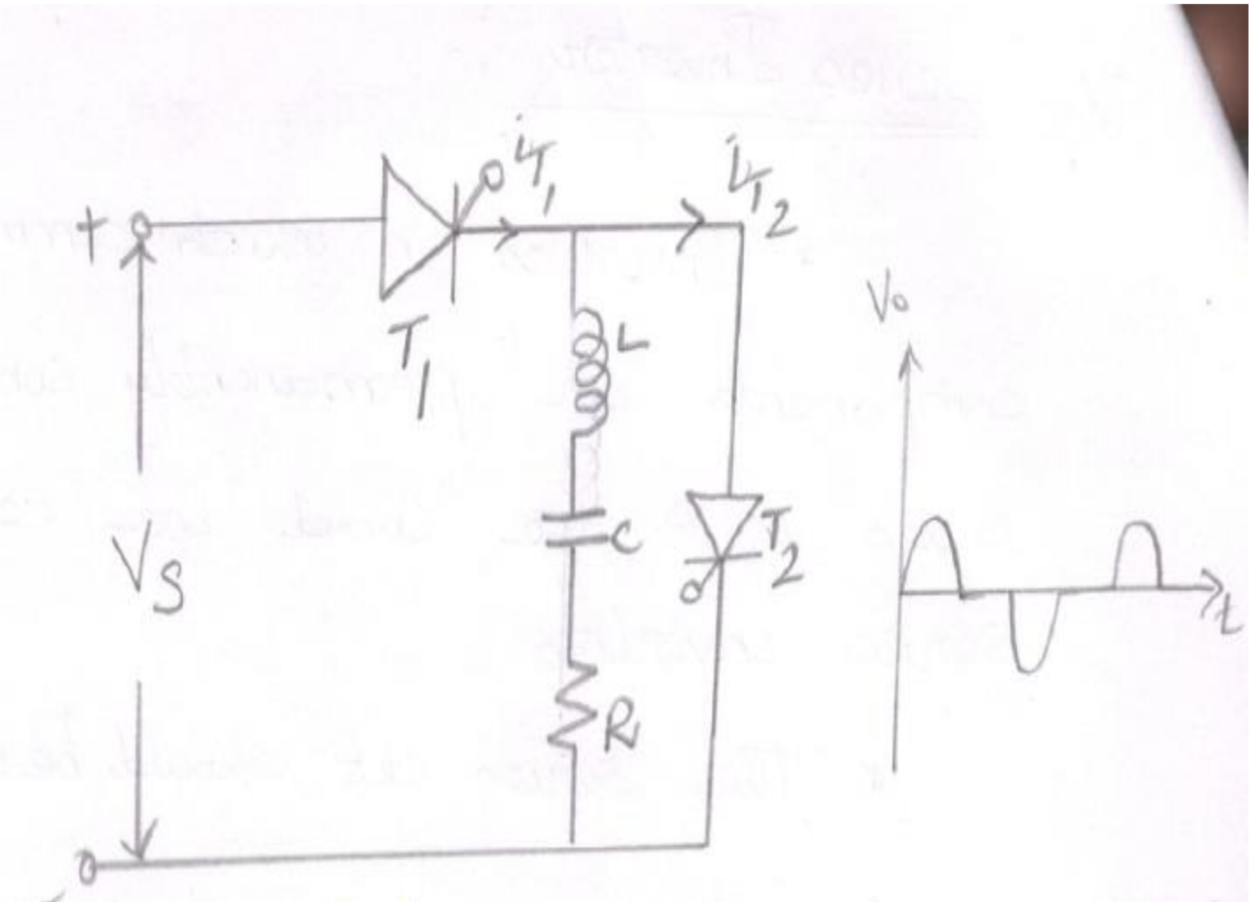
Series Inverters :-

* Inverters in which commutating components are permanently connected in series with the load are called series inverters.
* The series ckt should be underdamped.
* Self commutated (or) Load commutated inverters.
* Operate at HF (200 Hz to 100 kHz).

Basic Series Inverter :-

Basic Series Inverter :-

* Consists of Load resistance R in series with components i) Comutating components L & C.
* Values of L & C are chosen so that it forms under damped ckt.
* T_1 T_2 turned on appropriatly so that o/p vge. of desired freq. can be obtained.


+
i_{T1}
i_{T2}
T_1
L
C
R
T_2
V_S
V_o
t

* When T_1 turned ON, with T_2 turned off current i starts builing up in the RLC ckt.

* Since ckt is underdamped, load current after reaching some peak value decays to zero at point a.

* At point 'a' load current tends to reverse, SCR T_1 is turned off.

* After instant a, some min. time $t_{q,min}$ must elapse for T_1 to regain its f/d blocking capability.

$$t_{q,min} = \frac{\pi}{\omega} - \frac{\pi}{\omega_r} = \frac{1}{2}\left(\frac{1}{f} - \frac{1}{f_r}\right)$$

$\omega \rightarrow$ o/p freq. in rad/sec

$\omega_r \rightarrow$ ckt ringing freq. in rad/sec.

* time interval b/w T_2 turned ON & T_1 turned off is indicated by T_{off} = ab

$T_{off} > t_{q\,min}$.

* After T_1 has commutated, upper plate of capacitor attains +ve polarity.

* When T_2 is turned on at instant b, capacitor begins to discharge & load current in the reversed direction builds up to some peak negative value & then decay to zero at instant c.

* After this time T_{off} = cd must elapse for T_2 to recover.

* At d, T_1 is again turned on & the process repeats.

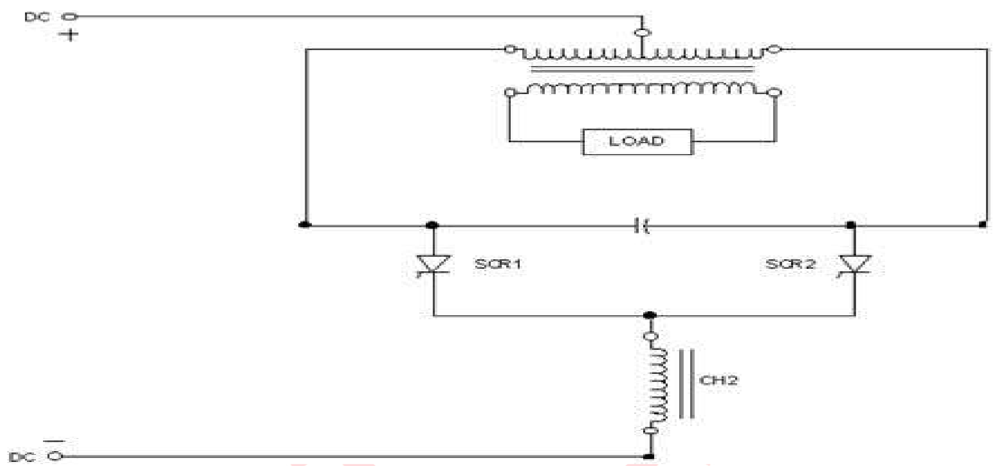
⇒ In this way, dc is converted to ac with the help of series inverter.

* C stores charge in one half cycle & releases the same amt during next half cycle.

23.Explain with neat circuit diagram the operation of parallel inverter. 6M

Ans:

- The single-phase parallel inverter circuit consists of two SCRs T1 and T2, an inductor L, an output transformer and a commutating capacitor C.
- The output voltage and current are Vo and Io respectively. The function of L is to make the source current constant.
- During the working of this inverter, capacitor C comes in parallel with the load via the transformer. So, it is called a parallel inverter.



The operation of this inverter can be explained in the following modes.\

Mode I

- In this mode, SCR T1 is conducting and a current flow in the upper half of primary winding. SCR T2 is OFF. As a result an emf Vs is induced across upper as well as lower half of the primary winding.
- In other words total voltage across primary winding is 2 Vs. Now the capacitor C charges to a voltage of 2Vs with upper plate as positive.

Mode II

- At time to, T2 is turned ON by applying a trigger pulse to its gate. At this time t=0, capacitor voltage 2Vs appears as a reverse bias across T1, it is therefore turned OFF. A current Io begins to flow through T2 and lower half of primary winding.
- Now the capacitor has charged (upper plate as negative) from +2Vs to -2Vs at time t=t1. Load voltage also changes from Vs at t=0 to –Vs at t=t1.

Mode III

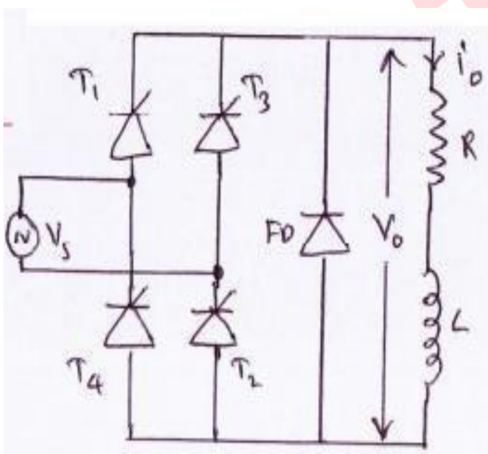
- When capacitor has charged to –Vs, T1 may be tuned ON at any time When T1 is triggered, capacitor voltage 2Vs applies a reverse bias across T2, it is therefore turned OFF. After T2 is OFF, capacitor starts discharging, and charged to the opposite direction, the upper plate as positive.

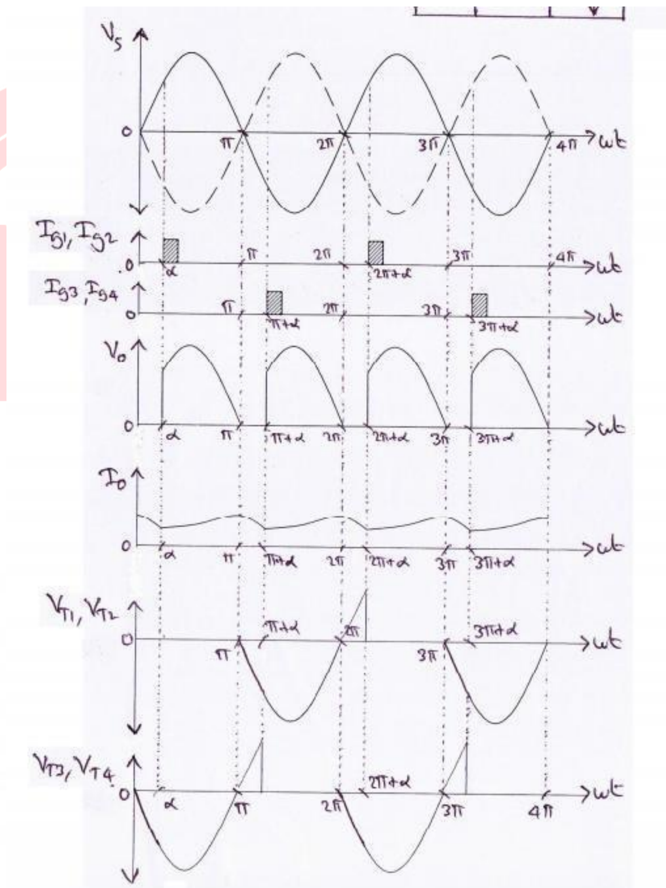
24. Draw full-wave controlled rectifier with R-L load with Free wheeling diode. Explain the effect of free wheeling diode on the circuit with output voltage waveforms. 6M

Ans:

- The circuit consist of four thyristors T1, T2, T3 and T4, a voltage source Vs, a RL Load and afreewheeling diode across the load.
- During the positive half cycle of the input voltage, the thyristors T1 & T2 is forward biased but itdoes not conduct until a gate signal is applied to it.
- When a gate pulse is given to the thyristors T1 & T2 at ωt = α, it gets turned ON and begins toconduct.
- When the T1 & T2 is ON, the input voltage is applied to the load but due to the inductor present inthe load, the current through the load builds up slowly through the path Vs-T1-Load-T2-Vs.
- During the negative half cycle (at ωt = π), T3 & T4 is forward biased, the thyristor T1 & T2 getsreverse biased.
- The current shifts its path to the freewheeling diode and circulates through the loop FD-R-L-FD.
- Thus T1 & T2 turns off at ωt = π
- When a gate pulse is given to the thyristor T3 & T4 at ωt = π+α, it gets turned ON and begins toconduct.

- When T3 & T4 is ON, the current through the load builds up slowly through the path Vs-T3-Load-T4-Vs.
- During the next positive half cycle (at ωt = 2π), T1 & T2 is forward biased, the thyristor T3 & T4 getsreverse biased.
- The current shifts its path to the freewheeling diode and circulates through the loop FD-R-L-FD.
- Thus T3 & T4 turns off at ωt = 2π
- So here all the thyristor will conduct only in the positive half cycle.
- The load receives voltage during both the half cycles.
- The average value of output voltage can be varied by varying the firing angle α.
- The waveform shows the plot of input voltage, gate current, output voltage, output current andvoltage across thyristor.





25.(i) Define Chopper. State its classification. (ii) Compare step-down and step-up Chopper (any four points). 6M

Ans:

(i)

* A chopper is a high speed on/off Semiconductor switch.

* It connects source to load & disconnects the load from source at a fast speed.

* Chopper (Switch) may be turned ON or OFF as desired.

* During the period T_{ON}, the chopper is ON and the load vge is equal to the source voltage V_S.

* During the period T_{OFF}, the chopper is OFF & the load current flows through the freewheeling diode FD.

* During T_{OFF}, the load terminals are short circuited by FD & load vge is therefore zero.

⇒ During T_{ON} → load current rises

T_{OFF} → load current decays.

Avg. load voltage, $V_o = \frac{T_{on}}{T_{on} + T_{off}} V_s$

$V_o = \frac{T_{on}}{T} V_s = \alpha V_s$

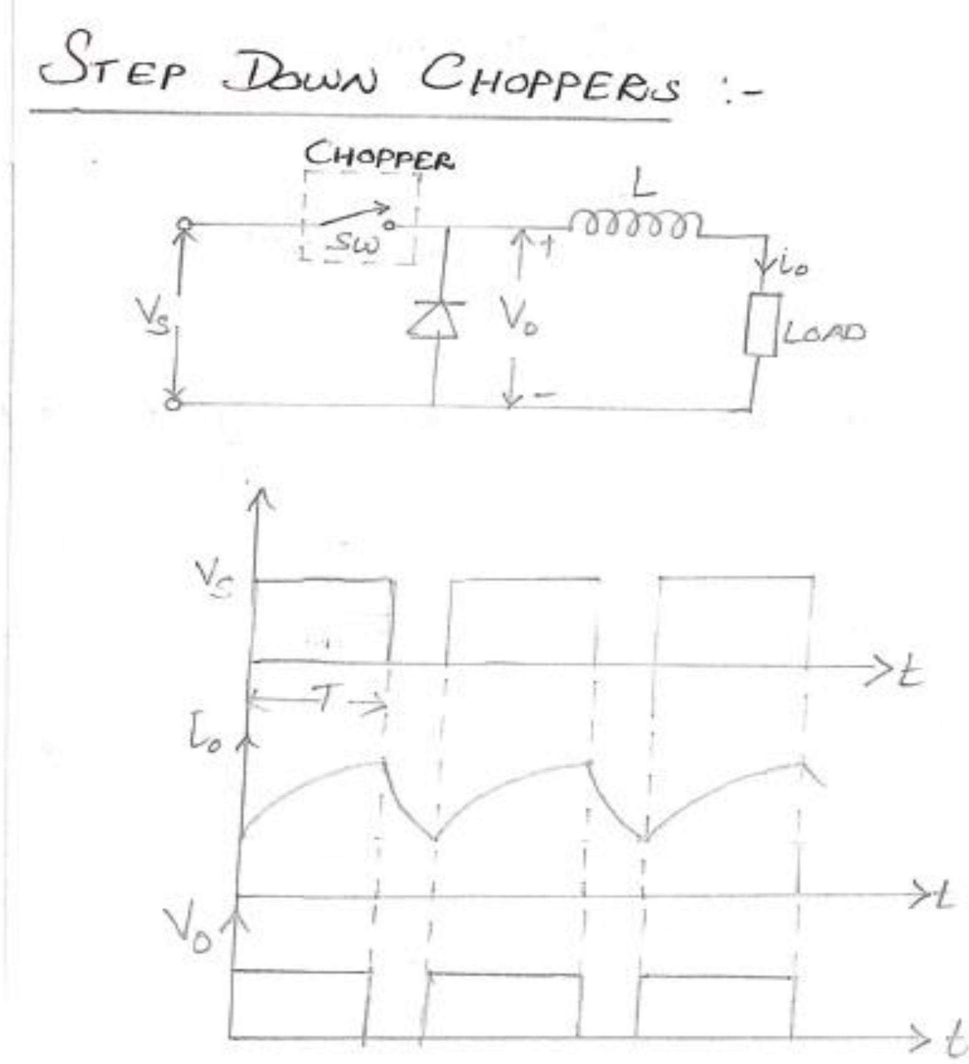
$T_{on} \rightarrow$ on-time

$T_{off} \rightarrow$ Off-time

$T = T_{on} + T_{off}$ (Chopping Period)

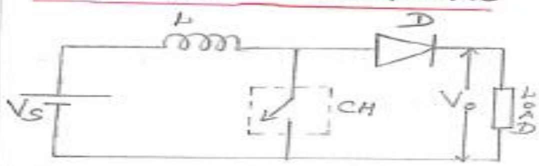
$\alpha = \frac{T_{on}}{T}$ (Duty cycle)

1) Step Down Chopper-

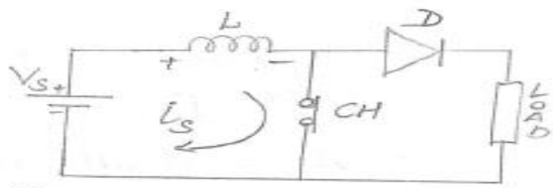


Step Up Chopper-

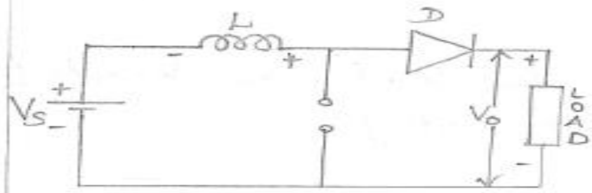
Step up Choppers :-



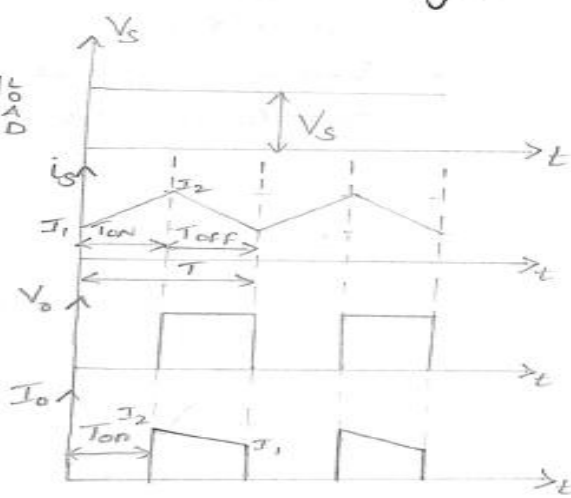
(a) Step-up chopper



(b) L stores charge



$L\frac{di}{dt}$ is added to Vs.



* Avg. o/p voltage V_o greater than the input voltage V_S.

  $V_o > V_S$.

⇒ Called as Step-up chopper.

* Inductor 'L' in series with source vge V_S.
* When CH is ON, the inductor stores the energy.
* During T_{ON} → L stores the energy.

* When chopper CH is off inductor current can't die down instantaneously, the current is forced to flow through the diode & load for a time T_{off}.

* As a result the current tends to decrease, polarity of the emf induced in L is reversed.

* Voltage across the load, $V_0 = V_S + L\left(\frac{di}{dt}\right)$ exceeds the source voltage.

⇒ When CH is ON, the current thru. the inductance L would rise from I_1 to I_2.

⇒ When CH is OFF, current would fall from I_2 to I_1.

⇒ CH → ON → $V_S = V_L$

CH → OFF → $V_L = V_0 - V_S$

V_L → Vge across L.

Avg. o/p vge, $V_0 = V_S\left(T/T_{off}\right)$

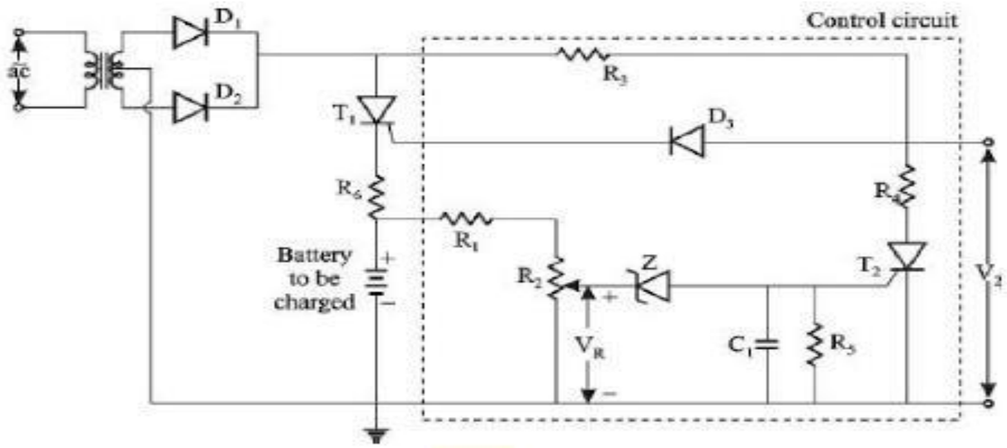
$$V_0 = V_S\left(\frac{1}{1-\alpha}\right)$$

Sr No.	Parameter	Step Up Chopper	Step Down Chopper
1	Position of chopper switch	In parallel with load	In series with load
2	Output voltage	More than input voltage	Less than input voltage
3	Expression of output voltage	$V_o=V_{dc}/(1-\alpha)$Volts$V_o=V_{dc}/(1-$�$)$Volts	$V_o=V_{dc}\cdot\alpha$Volts$V_o=V_{dc}\cdot$�Volts
4	Quadrant of operation	Second	First
5	Type of Chopper	Single quadrant	Single quadrant
6	External Inductance	Required	Not Required
7	Application	Battery charging, voltage booster	Motor speed control

UNIT-5 (10 M)

26.Describe with circuit diagram the operation of battery charger using SCR. 4M

Ans:



Working:

The figure above shows battery charger circuit using SCR.

- A 12V discharged battery is connected in series with an SCR T1.The single-phase 230V supply is stepped down to (15-0-15) V by a centre-tapped transformer.
- The diodes D1 and D2 provide full wave rectified output across the SCR, T1 and the battery to be charged.
- R3 –D3 provide trigerring circuit for T1. AS T1 is ON battery starts charging.
- When the battery is full, voltage provided by the voltage divider circuit will become the zener voltage making the SCR T2 to switch ON.
- When T2 is ON a short circuit results in the voltage divider circuit R3 & R4, making T1 to switch OFF.
- This prevents over charging of the battery.

27.Explain with circuit diagram the operation of emergency lighting system. 4M

Ans:

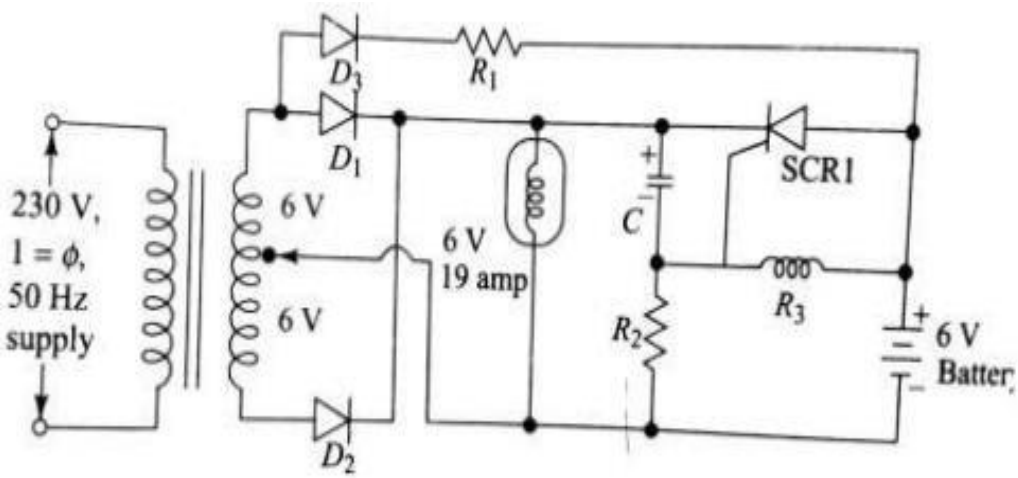
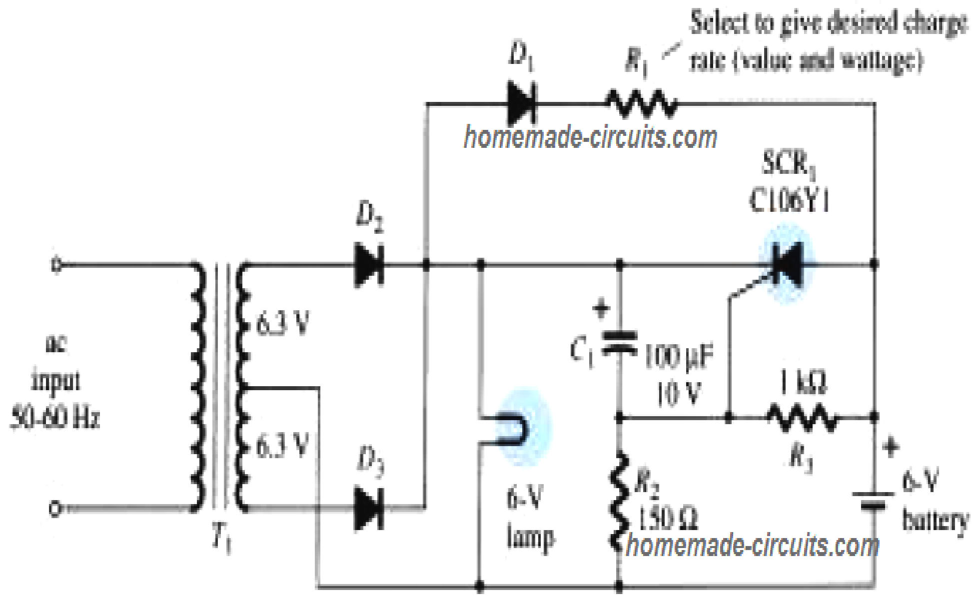


Fig. above shows a simple emergency lighting circuit. The 230v ac supply is applied as input. Supply is stepped down using a Center tapped transformer. The full wave rectifier converts ac to dc voltage.

- When supply is ON, voltage appears across it and the lamp glows. Pulsating current also flows through D3 & R1 to charge the battery. Thus, battery charging is carried out.
- The capacitor C gets charged with upper plate positive to some voltage less than secondary voltage of transformer. Due to capacitor voltage, gate cathode junction of SCR1 gets reverse biased. The anode is at battery voltage & cathode is at rectifier output voltage, which is slightly higher, hence SCR1 is reverse biased & cannot conduct. The lamp glows due to rectifier output dc voltage.
- If power fails, the capacitor C discharges through D3, R1 & R3 until the cathode of SCR, is less positive than anode. At the same time the junction of R2 & R3 becomes positive & establishes a sufficient gate to cathode voltage to trigger the thyristor. Once the thyristor turns ON, the battery discharges through it, & turns the lamp ON. When power is restored, the thyristor is connected & commutated & capacitor C is recharged.

OR



The next SCR application talks about a single-source emergency lamp design in which a 6 V battery is kept in a topped up charged condition, so that the connected lamp can be seamlessly switched ON whenever a power failure happens.

When power is available, a full wave rectified DC supply using D1, D2 reaches the connected 6 V lamp.

C1 is allowed to charge to a level that's slightly lower than the difference between the peak DC of the fully rectified supply and the voltage across R2, as determined by the supply input and charge level of the 6 V battery.

Under any circumstances, the cathode potential level of the SCR is help higher than its anode, and also gate to cathode voltage is held negative. This make sure that the SCR stays in the non-conducting state.

The charging rate of the attached battery is determined by R1, and enabled through the diode D1.

The charging is sustained only as long a the D1 anode remains more positive than its cathode.

While the input power is present, the full wave rectified across the emergency lamp keeps it switched ON.

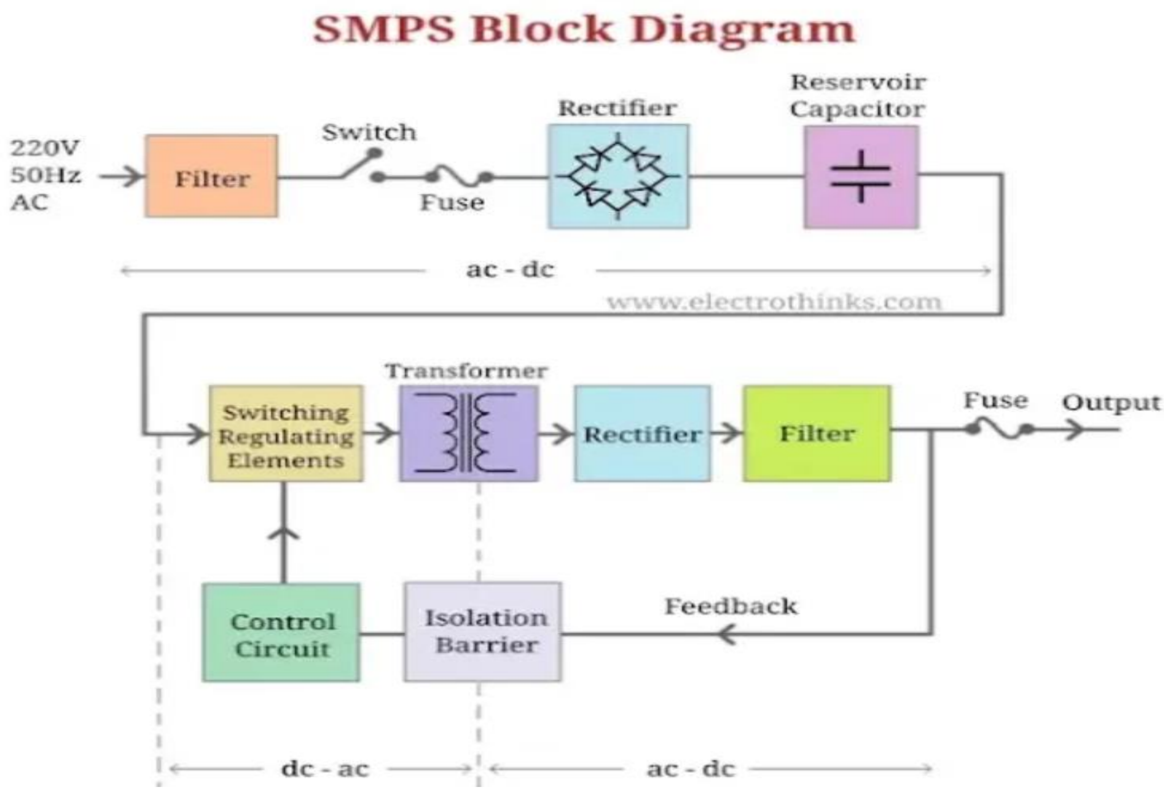
During power failure situation, the capacitor C1 begins discharging through D1, R1, and R3, until the point where the SCR1 cathode becomes less positive than its cathode.

Also, meanwhile the R2, R3, junction goes positive resulting in an increased gate to cathode voltage for the SCR, turning it ON.

The SCR now fires and allows the battery to get connected with the lamp, instantly illuminating it through battery power.
The lamp is allowed to stay in the illuminated state as if nothing had happened.
When power returns, the capacitors C1 is yet again recharged, causing the SCR to switch OFF, and cutting off the battery power to the lamp, so that the lamp now illuminates through the input DC supply.

28.Draw and explain the block diagram of SMPS.

Ans:



- The input AC voltage is rectified, smoothed and supplied to a dc-ac converter.
- This dc-ac conversion is done by pulse width Modulation (PWM) technique.

- Generally, transistors (MOSFET) are used as regulating switching device whose input is a train of pulses.
- The duty cycle of the switching transistor is adjusted with a control circuit.
- The control circuit senses the output voltage and makes changes in order to keep output voltage constant irrespective of load and input voltages changes.
- The output of the transistor is applied to the primary of a transformer.
- The secondary voltage is rectified and soothed to give the required DC output.
- This part corresponds to the second ac-dc conversion stage while the first ac-dc stage is connected at the input to the witching element.
- Without the first ac-dc stage, this system can be operated from a battery or DC source.
- The transformer provides necessary isolation.
- Fuses are attached to both input and output for short circuit / overload protection.
- The Filter at the input removes Radio Frequency Interference (RFI) and Electro Magnetic Interference (EMI).
- Transistor, that serves as the main switching element, operates at a frequency above the audible range (25-250 KHz) to prevent noise.

Advantages of SMPS

- Low Weight and Smaller Size
- Higher Efficiency
- Wider AC input Voltage Range
- Reduced Cost

Disadvantages of SMPS

- Circuit Complexity
- Regulation

- Others

Applications

1. **STEP-DOWN mode:** Generation of 5V supply for TTL based circuit from 12V battery.
2. **STEP-UP mode:** Generation of 25V from a 5V supply in an EPROM programmer.
3. **INVERTED mode:** Generation of double ended supply (±5V or ±12V) from a single ended supply for operational amplifier.

29.Describe the working of battery charger using SCR.

Ans:

Working:

The figure above shows battery charger circuit using SCR.

- A 12V discharged battery is connected in series with an SCR T1.The single-phase 230V supply is stepped down to (15-0-15) V by a centre-tapped transformer.
- The diodes D1 and D2 provide full wave rectified output across the SCR, T1 and the battery to be charged.
- R3 –D3 provide trigerring circuit for T1. AS T1 is ON battery starts charging.
- When the battery is full, voltage provided by the voltage divider circuit will become the zener voltage making the SCR T2 to switch ON.
- When T2 is ON a short circuit results in the voltage divider circuit R3 & R4, making T1 to switch OFF.
- This prevents over charging of the battery.

30.With the help of block diagram explain working of ONLINE UPS system. 4M

Ans:

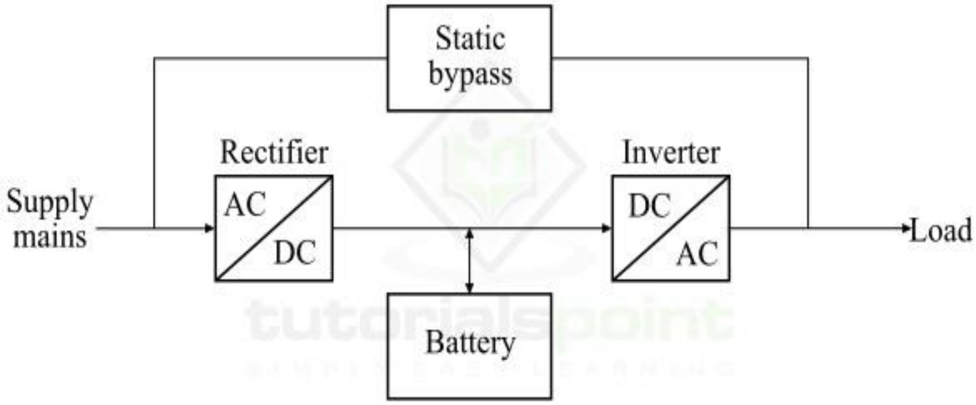


Figure 2 - On Line UPS

The **On-Line UPS** system uses a double conversion method. That means, in this UPS system, the input AC power is first converted into DC power by a rectifier to charge the UPS battery, and then this DC power is converted back into AC power by a power inverter to power the load equipment. Therefore, the On-Line UPS systems are commonly used in such systems where electrical isolation is required between the input and output. The block diagram of a typical On-Line UPS system is shown in Figure-2.

In this system, the rectifier circuit receives ac power from the supply mains and directly drives the inverter circuit. Thus, it involves two simultaneous conversion processes and is hence referred to as a **Double Conversion UPS System**.

In the case of supply mains power failure, the rectifier circuit becomes inactive and the DC power stored in the battery is converted into AC by the inverter and supplied to the load. Once the mains power is restored, the rectifier circuit again starts charging the battery. A current limiting mechanism is also provided in the system to protect the battery from overheating. Although, on-line ups systems are slightly expensive due to their design and components used.