SUMMER – 14 EXAMINATION

Important Instructions to examiners:

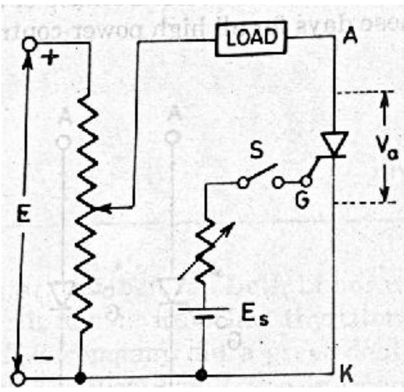
1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given more Importance (Not applicable for subject English and Communication Skills).
4) While assessing figures, examiner may give credit for principal components indicated in the figure. The figures drawn by candidate and model answer may vary. The examiner may give credit for any equivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate's answers and model answer.
6) In case of some questions credit may be given by judgement on part of examiner of relevant answer based on candidate's understanding.
7) For programming language papers, credit may be given to any other program based on equivalent concept.

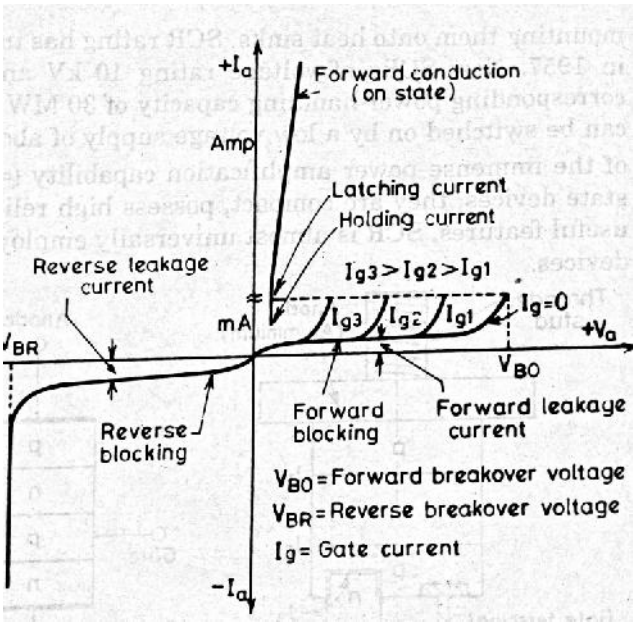
Q1 a) i) State different methods of triggering of SCR. Describe any one. **2+2**

With forward bias voltage, a thyristor can be made to conduct (on state) by any of the four techniques

(a) Exceeding forward breakover voltage
(b) Gate triggering
(c) dv/dtturn on
(d) Irradiation of gate-cathode junction.

DC gate trigger: In this type of triggering, a d.c. voltage of proper magnitude and polarity is applied between the gate and the cathode of the device in such a way that the gate becomes positive with respect to the cathode. When the applied voltage is sufficient to produce the required gate current, the device starts conducting.

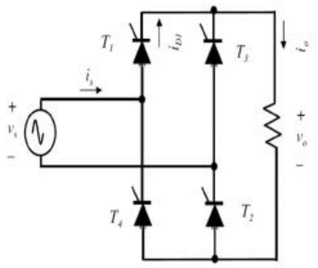


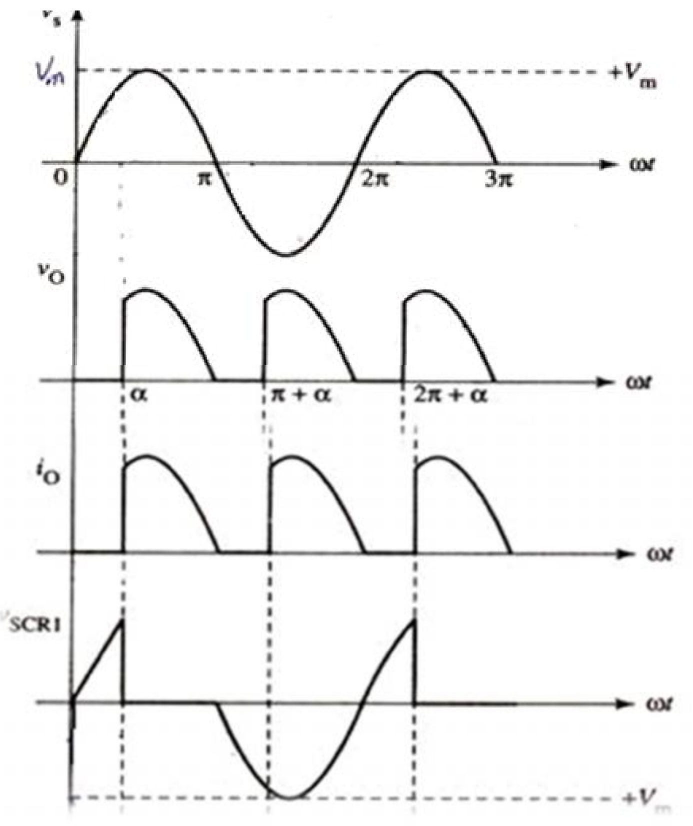
ii) State significance of holding current and latching current. Label them on V-I characteristics of SCR. Latching Current I_L This is the minimum anode current required to maintain the thyristor in the on-state immediately after a thyristor has been turned on and the gate signal has been removed. Holding Current I_H This is the minimum anode current required to maintain the thyristor in the on-state. To turn off a thyristor, the forward anode current must be reduced below its holding current for a sufficient time for mobile charge carriers to vacate the junction.  	**2+2**

iii) Describe the operation of 1 -phase fully controlled bridge converter with resistive load, with neat circuit diagram and waveform,	**2+2**

Bridge converter is formed by four thyristors T1, T2, T3, T4. During positive half cycle T1 and T2 are forward biased and during negative half cycle T3 and T4 are forward biased. Thyristors T1 and T2 are triggered at ωt =α during positive half cycle. The load voltage follows the supply voltage and load current follows load voltage. At ωt =2π + α, thyristors T3 and T4 are forward biased and triggered.

$$\therefore \quad V_{O(dc)} = V_{dc} = \frac{V_m}{®}\left(1+\cos\sim\right)$$





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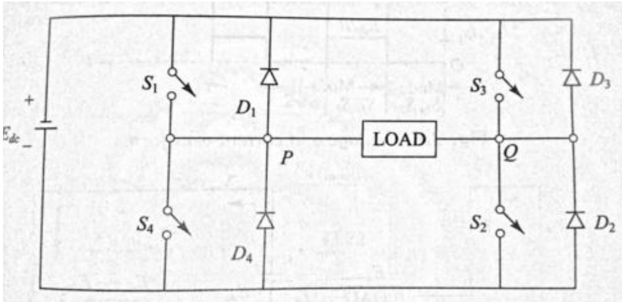
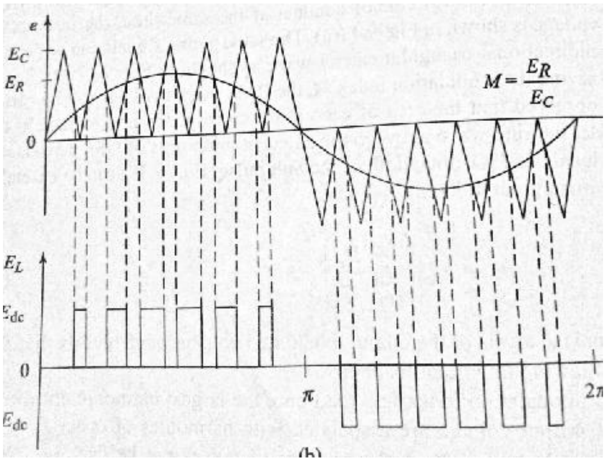
iv) Describe operation of single phase sinusoidal PWM inverter with relevant diagrams	**2+2**

The single phase SPWM inverter is formed by using a bridge configuration as shown in figure. The inverter switches are turned on as per sinusoidal pulse width modulation.



Sinusoidal Pulse Width Modulation

By comparing a sinusoidal reference signal with a triangular carrier wave of frequency fc, the gating signals are generated, as shown in Fig. The frequency of reference signal, fr determine the inverter output frequency, fo, and its peak amplitude, Er, controls the modulation index, M, and then in turn the RMS output voltage, EL. The number of pulses per half-cycle depends on the carrier frequency. By varying the modulation index M, the RMS output voltage can be varied.



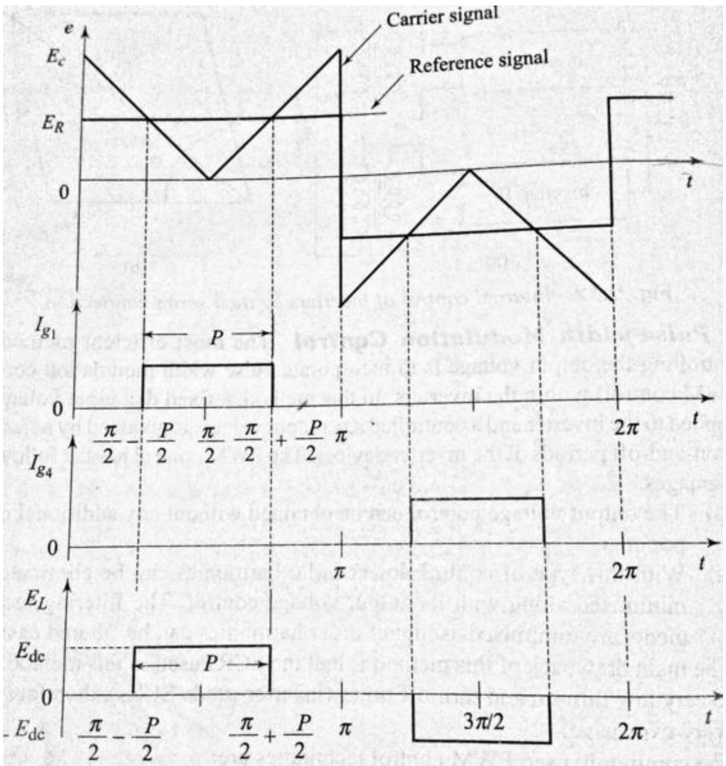
Q1) b) i) Define amplitude modulation index for PWM in inverters. With the help of amplitude modulation index and relevant diagram, describe single pulse width modulation **2+2**

Modulation index for a PWM inverter can be defined as

$m = \frac{Er}{Ec}$ where E_r is the value of reference signal and E_c is the carrier signal.

Single pulse width modulation:

In single pulse width modulation, there is only one pulse per half cycle and width of the pulse is varied to control the inverter output voltage. The gating pulses are generated by comparing rectangular reference Er with triangular carrier Ec. The pulse width can be varied (0 to 180^0), by changing Er. The ratio of Er/Ec is called modulation index. By adjusting pulse width a particular odd harmonic can be eliminated



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Q1 b) ii) State the methods of speed control of three phase induction motor. Explain how the speed of three phase induction motor is controlled using cycloconverter. **2+2**

Speed of three phase induction motor can be expressed as

$$N = \frac{120 \times f}{P}$$

By controlling frequency of stator supply Speed of motor can be controlled.

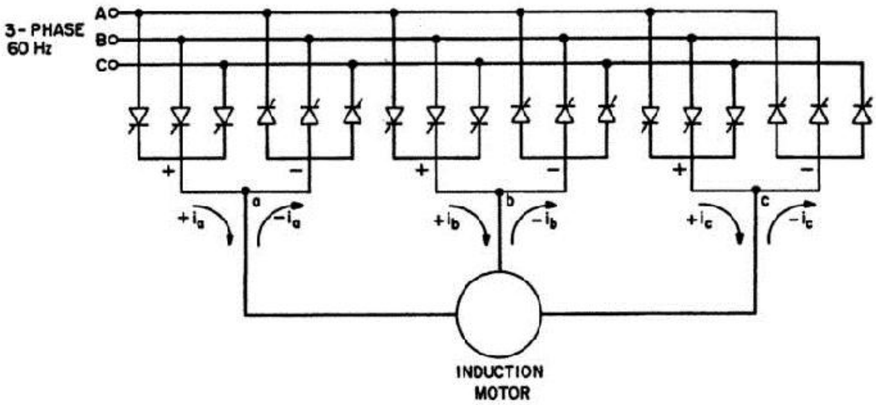
For three phase induction motor stator voltage can be expressed as

$$V1 = K \times f_1 \times \emptyset_1$$

To avoid magnetic saturation, stator voltage to freq ratio has to be maintained constant.

The torque speed characteristics with v/f control is shown below which shows that controlling stator frequency controls speed of the induction motor keeping maximum torque constant.

By using three phase cyclo-converter speed of three phase induction motor can be controlled. The circuit configuration is as shown consists of the three phase bridge type configuration. By controlling output voltage and frequency speed of induction motor can be controlled.



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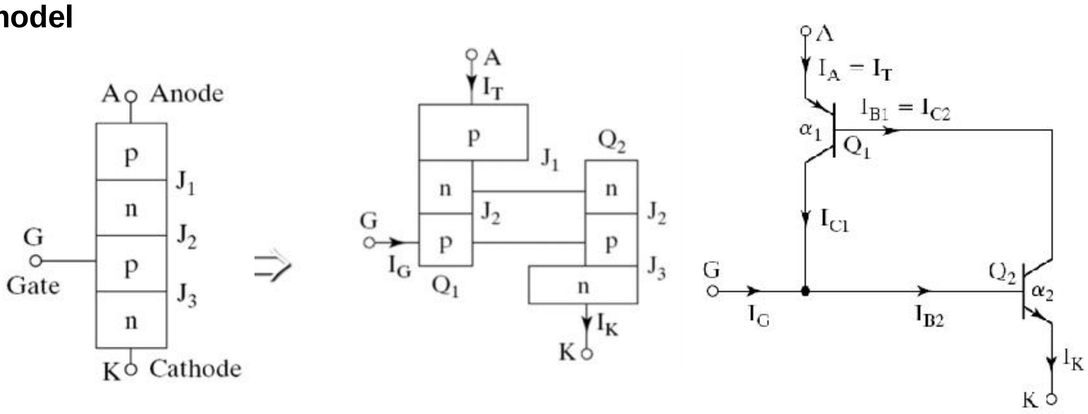
Q2. i) Draw and explain construction of SCR using two transistor model **2+2**



Positive Gate bias turns ON Q2, This allows IC2 to flow IC2 = IB2 If the anode is positive (i.e emitter of Q1), PN junction of Q1 will be forward biased and Q1 turns ON .This allows IC1 to flow which adds to base current IB2. This regenerative action continues till Q1 and Q2 are driven to saturation

Now Removal of gate bias does not affect ON State of Q1 and Q2

From the equivalent circuit,
we see that

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

$$\Rightarrow \quad I_A = \frac{\sim_2 I_g + I_{CBO1} + I_{CBO2}}{1-(\sim_1 + \sim_2)}$$

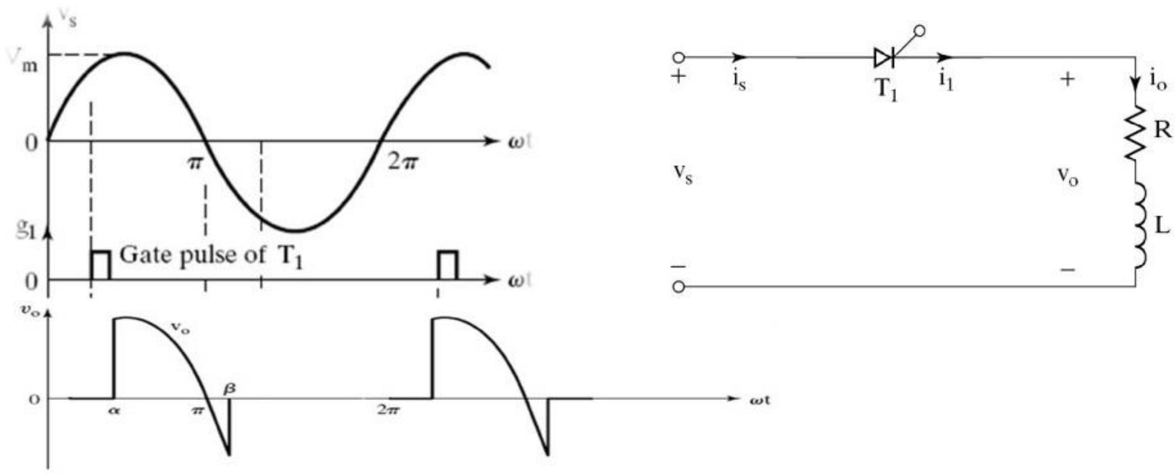
When gate current IG is positive, $\sim_1 + \sim_2$ approaches unity and anode is driven to saturation and thyristor behaves as a closed switch.

ii) List eight applications of thyristor in power electronics — **½ each**

Thyristors are commonly used in variety of power electronic circuits such as,

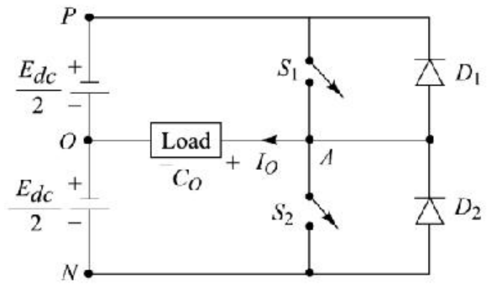
1) AC-DC controlled converters: battery chargers, dc drives, hvdc converters
2) DC-AC inverters: inverters used for AC drives, welding power supplies, ultrasonic power supplies, Uninterruptible power supplies
3) Static VAr compensation systems: Thyristor controlled reactors, Thyristor switched capacitors
4) DC-DC converters i.e. choppers used for battery operated vehicles, forklift drives

iii) Draw circuit for single phase half wave controlled converter with R-L load and draw its load voltage waveform — **2+2**



$$V_{O(dc)} = V_L = \frac{V_m}{2®}\left(\cos\sim - \cos\quad\right)$$

iv) With the help of circuit diagram, describe working of single phase half bridge inverter	**2+2**

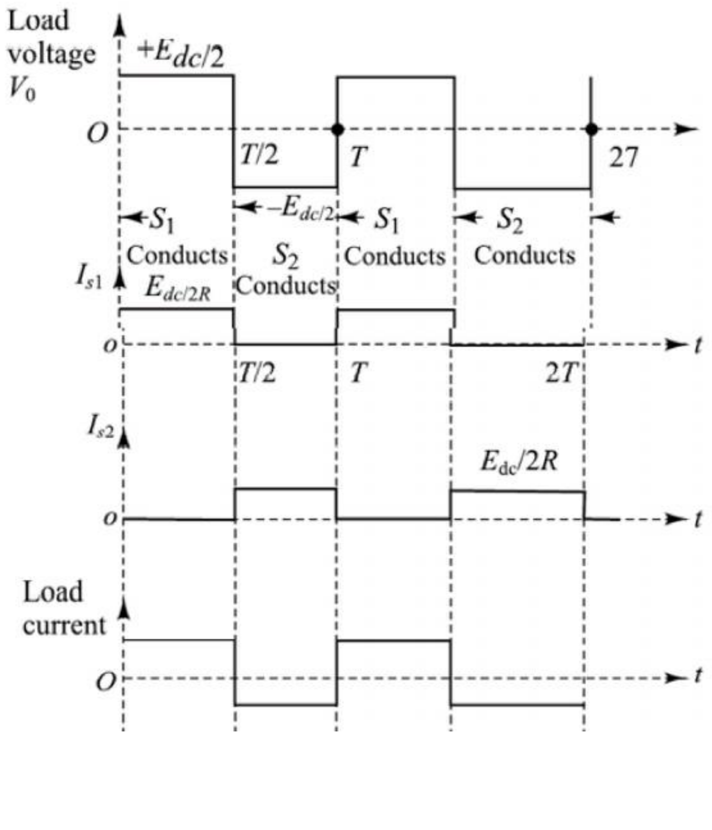


The operation of the circuit can be divided into two periods:

(i) Period-I, where switch S_1 is conducting from $0 \le 1 \le T/2$ and

(ii) Period-II, where switch S_2 is conducting from $T/2 \le t \le T$,

where $T = 1/f$ and f is the frequency of the output voltage waveform. Figure 9.2 shows the waveforms for the output voltage and switch currents for a resistive-load.



v) State need for reduction of harmonics in inverter **1+1+1+1**

Harmonics are voltage and current components at frequency that is integral multiple of fundamental frequency drawn by a power electronic load. Presence of harmonics poses problems on operation of electrical system such as,

1) Overheating of neutral conductor because of high neutral current with third harmonics
2) Torque pulsation of induction motor
3) Drop in efficiency of transformer
4) Mal operation of switchgear
5) Possibility of overvoltage because of resonance

This creates a need for reduction/filtering of harmonics present in an electrical system.

vi) Draw circuit and explain speed control of a dc series motor by a single phase full converter **2+2**

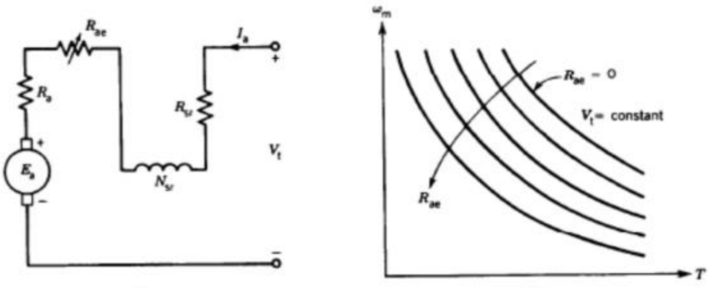
- magnetic linearity

$$K_a \Phi = K_{sr} I_a$$

$$E_a = K_{sr} I_a \omega_m$$

$$T = K_{sr} I_a^2$$

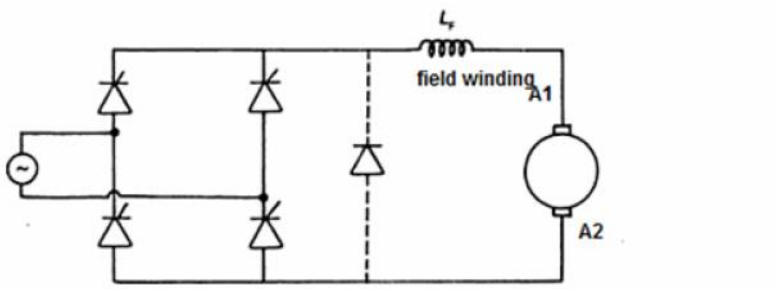
$$E_a = V_t - I_a (R_a + R_{ae} + R_{sr})$$



(a) (b)

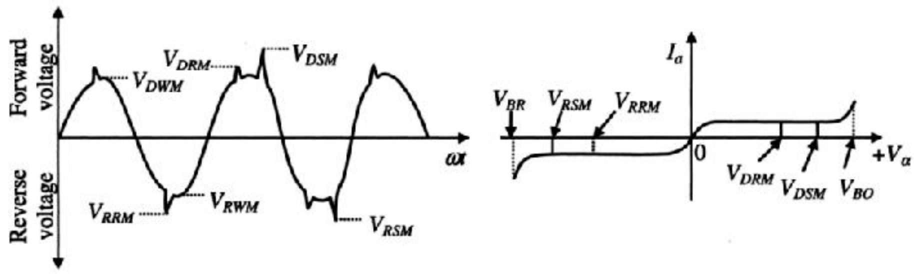
$$\omega_m = \frac{V_t}{K_{sr} I_a} - \frac{R_a + R_{sr} + R_{ea}}{K_{sr}} = \frac{V_t}{\sqrt{K_{sr}}\sqrt{T}} - \frac{R_a + R_{sr} + R_{ea}}{K_{sr}}$$

The above characteristics indicate that the speed of dc series motor is inversely related to torque and controlled by armature voltage.



Q3. i) Give four voltage ratings and describe each in brief for SCR. **1+1+1+1**

(i) V_{DWM}—*Peak working forward-blocking voltage*
It specifies the maximum forward-blocking voltage that a thyristor can withstand during its operation. Figure shows that V_{DWM} is equal to the peak value of the sinusoidal supply voltage wave.

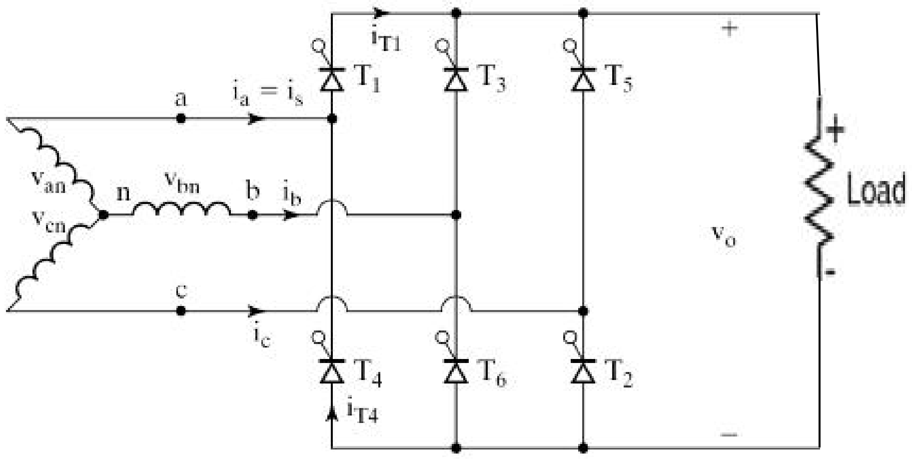


(ii) V_{DRM}—*Peak repetitive forward-blocking voltage*
It refers to the peak transient voltage that a thyristor can withstand repeatedly or periodically in its forward-blocking mode. The rating is specified at a maximum allowable junction temperature with gate circuit open or with a specified biasing resistance between gate and cathode.

(iii) V_{DSM}—*Peak surge (or non-repetitive) forward blocking voltage*
It refers to the peak value of the forward surge voltage that does not repeat. Its value is about 130% of V_{DRM}, but V_{DSM} is less than forward breakover voltage V_{BO} as shown in Fig.

(iv) V_{RWM}—*Peak working reverse voltage*
It is the maximum reverse voltage that a thyristor can withstand repeatedly. Actually, it equals the peak negative value of a sine voltage wave, Fig.

ii) Draw circuit diagram of three phase fully controlled bridge converter with resistive load and list the two conduction modes with time period.	**2+2**



Three phase full converter is a fully controlled bridge controlled rectifier using six thyristors connected in the form of a full wave bridge configuration. All the six thyristors are controlled switches which are turned on at a appropriate times by applying suitable gate trigger signals. The three phase full converter is extensively used in industrial power applications upto about 120kW output power level, where two quadrant operation is required. The figure shows a three phase full converter with highly inductive load. This circuit is also known as three phase full wave bridge or as a six pulse converter. The thyristors are triggered at an interval of π/ 3 radians. The frequency of output ripple voltage is 6fs (fs is supply frequency). The thyristors are numbered in the circuit diagram corresponding to the order in which they are triggered. The trigger sequence (firing sequence) of the thyristors is T1T2, T2T3, T3T4, T4T5, T5T6, T6T1, T1T2, T2T3, and so on

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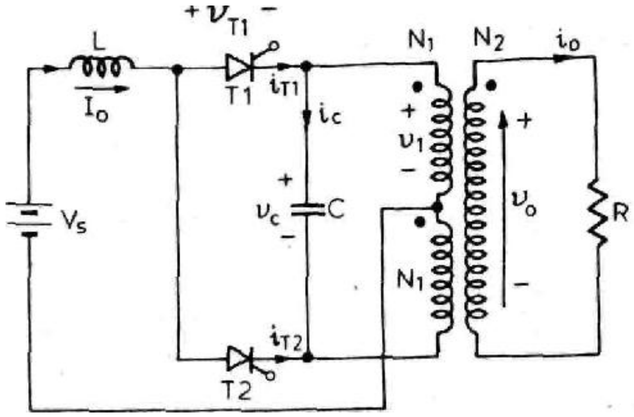
iii) Describe operation of basic parallel inverter. **2+2**



The operation of this inverter can be explained in some well-defined modes as under :

Mode I : In this mode, thyristor T1 is conducting and a current flows in the upper half of primary winding. This current establishes magnetic flux that links both the halves of primary winding. As a result, an emf Vs is induced across upper as well as lower half of primary winding. In other words, total voltage across primary winding is 2Vs. This voltage charges the commutating capacitor C to a voltage of 2Vs with upper plate positive as shown in Fig. Thyristor T2 is forward biased through T1 by the capacitor voltage 2Vs Eventually, a steady state current Io flows through Vs, L, T1and upper half of primary winding.

Mode II: At time t = 0, thyristor T2 is turned on by applying a triggering pulse to it. At this time t = 0, capacitor voltage 2Vs appears as a reverse bias across T1, it is therefore turned off. Load voltage swings to –Vs. The capacitor voltage now becomes -2Vs with lower plate positive.

Mode III: when thyristor T1 is triggered, the capacitor voltage reverse bias thyristor T2 and turns it off. The load voltage swings to +Vs. The capacitor voltage again swings to +2Vs with upper plate positive.

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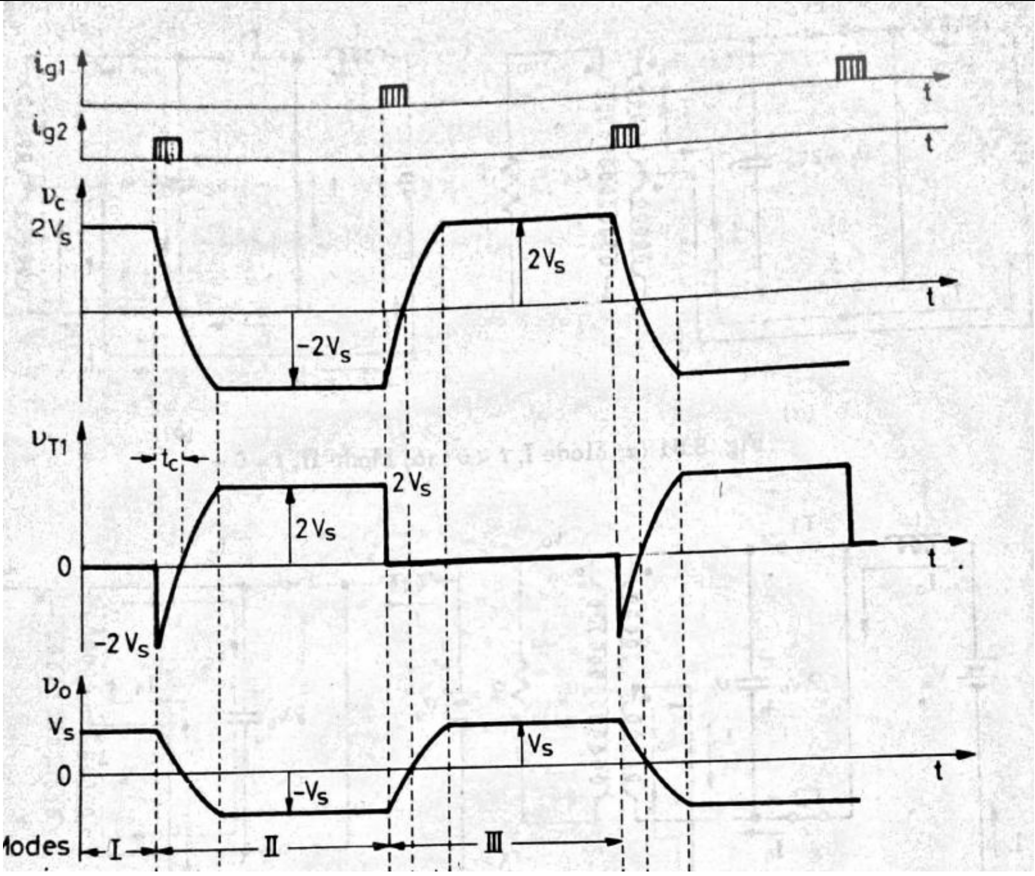


iv) Describe any one technique to reduce harmonics in inverters

2+2

Harmonics can be controlled by control of waveform
- By Single Pulse Width Modulation
- By Transformer Connections
- By Using Filter (LC, Resonant, and OTT Filter)

Single pulse Width Modulation:

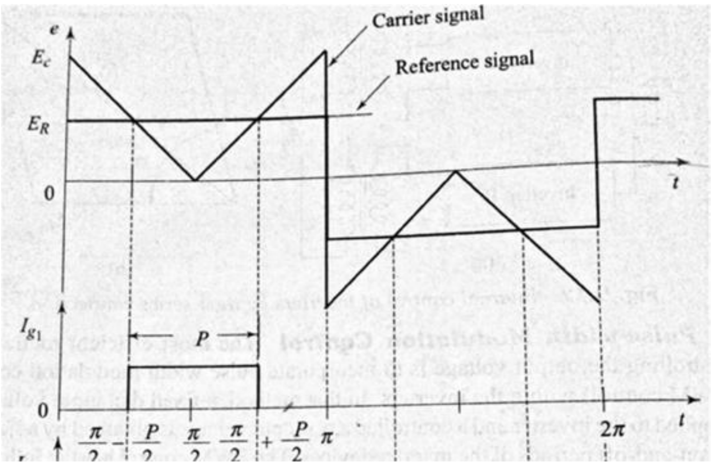
In the case of single –pulse width modulation, the width of the pulse is adjusted to reduce harmonic content. The RMS value of the amplitude of the harmonic voltage of single pulse width modulated wave is given by

$$E_{Ln} = \frac{4\,E_{dc}}{\sqrt{2}\,n\pi}\sin\frac{np}{2} = \frac{2\sqrt{2}\,E_{dc}}{n\pi}\sin\frac{np}{2}$$

where P is the width of the pulse and E_{dc} is the supply d.c. voltage. For example, if the third harmonic is to be eliminated, $E_{L_3} = 0$,

$$\therefore \quad E_{L_3} = \frac{4\,E_{dc}}{3\sqrt{2}\,\pi}\sin\frac{3p}{2} = 0 \quad \therefore P = 120°$$

Similarly, to eliminate fifth harmonic, $P = 72°$.
By this method, therefore, only one harmonic can be eliminated at a time.



v) Classify choppers based on output voltage and quadrants of operation. List four applications of chopper.	**2+2**

Applications of chopper:

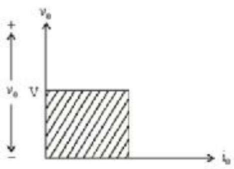
1) Used in DC drives with regenerative braking
2) Battery charging
3) Battery operated vehicles
4) Subway cars, Fork lifts
5) Electromagnet power supply

Classification of choppers based on quadrants

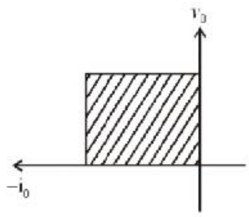
CLASSIFICATION OF CHOPPERS

Choppers are classified as follows
- Class A Chopper
- Class B Chopper
- Class C Chopper
- Class D Chopper
- Class E Chopper

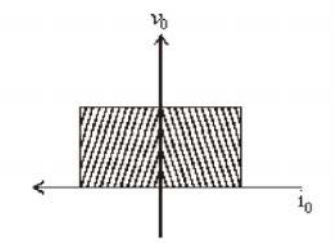
CLASS A CHOPPER



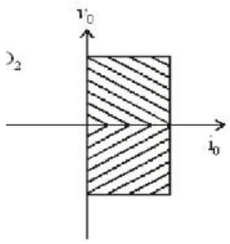
CLASS B CHOPPER



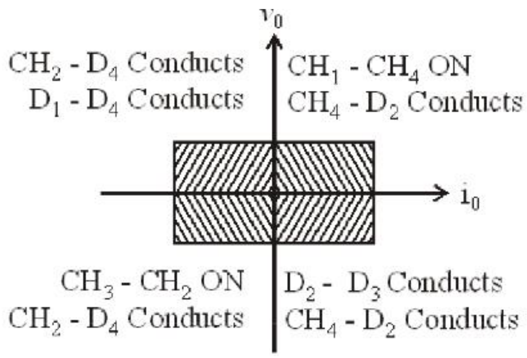
CLASS C CHOPPER



CLASS D CHOPPER



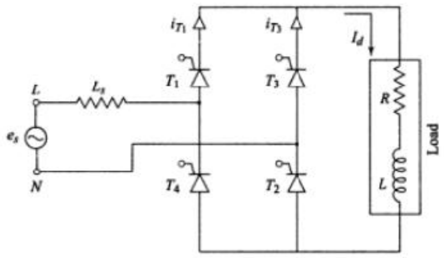
CLASS E CHOPPER

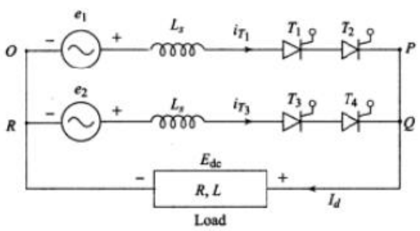


Q4 i) Compare single phase and three phase controlled converter on the basis of number of SCRs, current capacity, application and cost, **1+1+1+1**

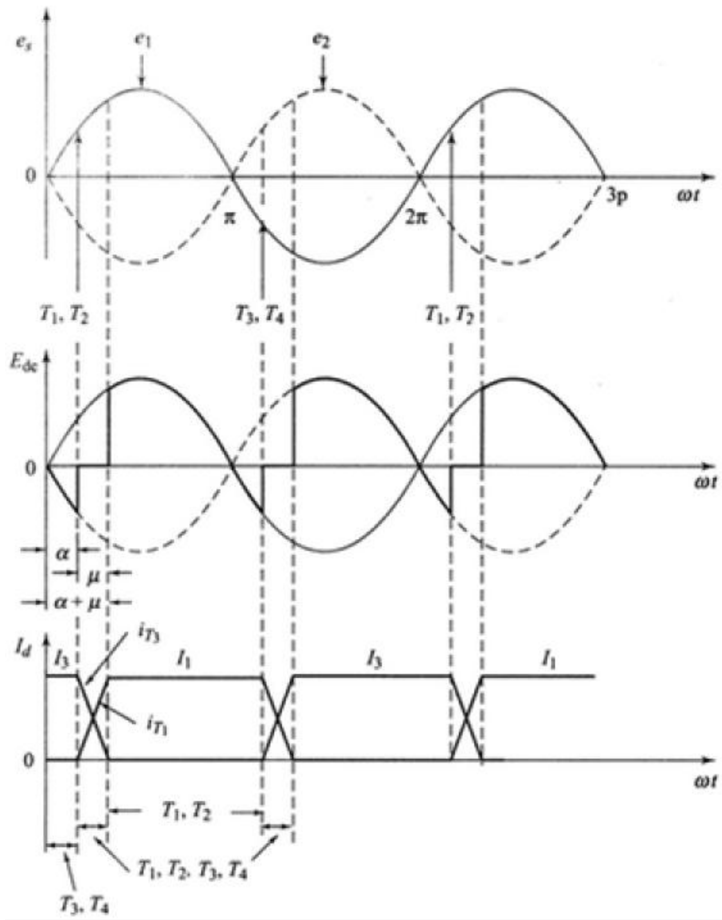
Single phase controlled converter	Three phase controlled converter
2,4 SCRs	3,6 SCRs
useful for supplying small dc loads rarely exceeding 5 KW	Above 5 KW
Used for battery charging, small dc drives	High capacity online-UPS, HVDC systems
Economical for small rating	Economical for large rating

Q4 ii) What is the effect of source impedance on performance of single phase fully controlled bridge converter ? **2+2**



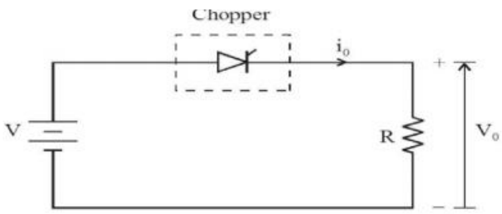


The effect of source inductance is delay in commutation of thyristors , as it takes a finite time for the current to decay to zero in the outgoing thyristor, while the current will rise at the same rate in the incoming thyristor. Thus, in practice, the commutation process may occupy a quite significant period of time, during which both the "incoming" and "outgoing" thyristors arc simultaneous in conduction. This period, during which both the outgoing and incoming thyristors are conducting, is known as the overlap period and the angle for which both devices share conduction is known as the overlap angle or commutation angle. The output average voltage is dropped due to loss of output voltage during commutation angle

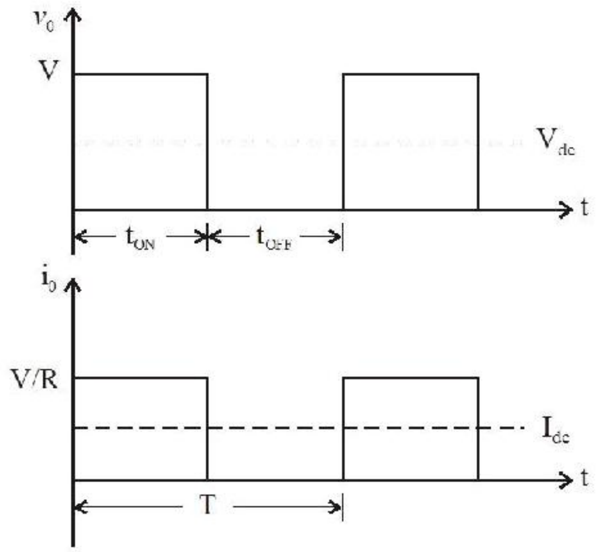


Q.4 (III)Describe step-up and step-down chopper **2+2**

Step-down chopper



- A step-down chopper with resistive load.
- The thyristor in the circuit acts as a switch.
- When thyristor is ON, supply voltage appears across the load
- When thyristor is OFF, the voltage across the load will be zero.



Average Output Voltage

$$V_{dc} = V\left(\frac{t_{ON}}{t_{ON}+t_{OFF}}\right)$$

$$V_{dc} = V\left(\frac{t_{ON}}{T}\right) = V.d$$

$$but \left(\frac{t_{ON}}{t}\right) = d = \text{duty cycle}$$

PRINCIPLE OF STEP-UP CHOPPER

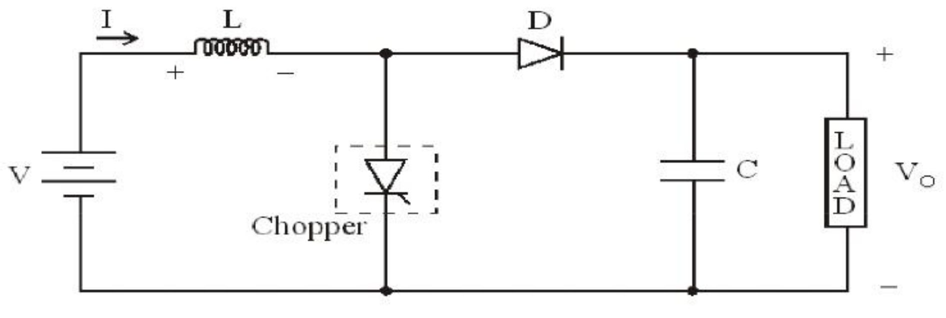
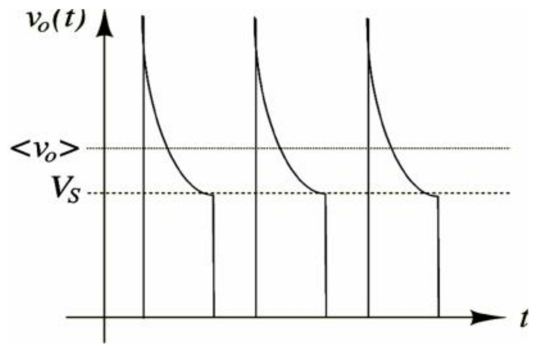


Figure 2.13 shows a step-up chopper to obtain a load voltage V_O higher than the input voltage *V*. The values of *L* and *C* are chosen depending upon the requirement of output voltage and current. When the chopper is *ON*, the inductor *L* is connected across the supply. The inductor current *'I'* rises and the inductor stores energy during the *ON* time of the chopper, t_{ON}. When the chopper is off, the inductor current *I* is forced to flow through the diode *D* and load for a period, t_{OFF}. The current tends to decrease resulting in reversing the polarity of induced EMF in *L*. Therefore voltage across load is given by

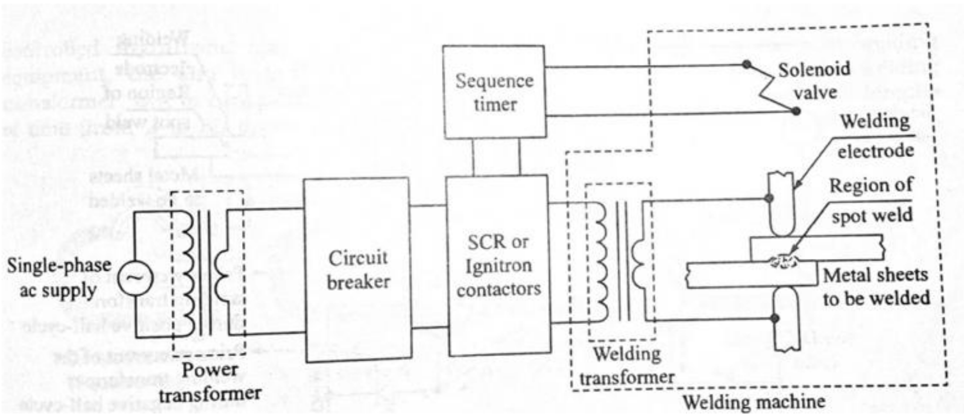
$$V_O = V + L\frac{dI}{dt} \quad i.e., \quad V_O > V \qquad \ldots(2.27)$$



Q4) A) iv) State and describe principle of resistance welding with neat diagram. **2+2**

The welding machine receives ac power, by means of a timing device, through a *power transformer,* a circuit breaker, and an SCR. Inside the welding *machine, a* welding transformer reduces the voltage at the electrode tips (1 to 10 V) and supply a *large welding* current, while drawing about 50 to 2000 A from the ac supply. The *electrode tips* are water-cooled and must be kept clear,. A solenoid valve applies air pressure to the electrodes for bringing them together and squeezing the workpieces (metal pieces) properly. Welding current then flows to heat the workpiece and make the weld. The workpiece is held under pressure for a few moments until the weld hardens. Then the electrodes separate so that the workpiece can be moved before the next weld is started.

The resistance between the metal pieces decreases when they are forced together by the electrodes with greater pressure. To make a weld, current needs to flow for only a fraction of a second. The SCR controlled circuits are used which must close and open the circuit quickly, and it does this hundreds of times each hour. The timings of the welding process which may be divided into squeeze time, weld time, hold time, and OFF time, are controlled by a sequence timer. In early days, the sequence weld timers could control the welding current.

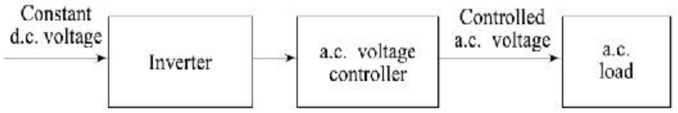


Q4 b) i) Describe following voltage control techniques used for ~~chopper~~ inverter:

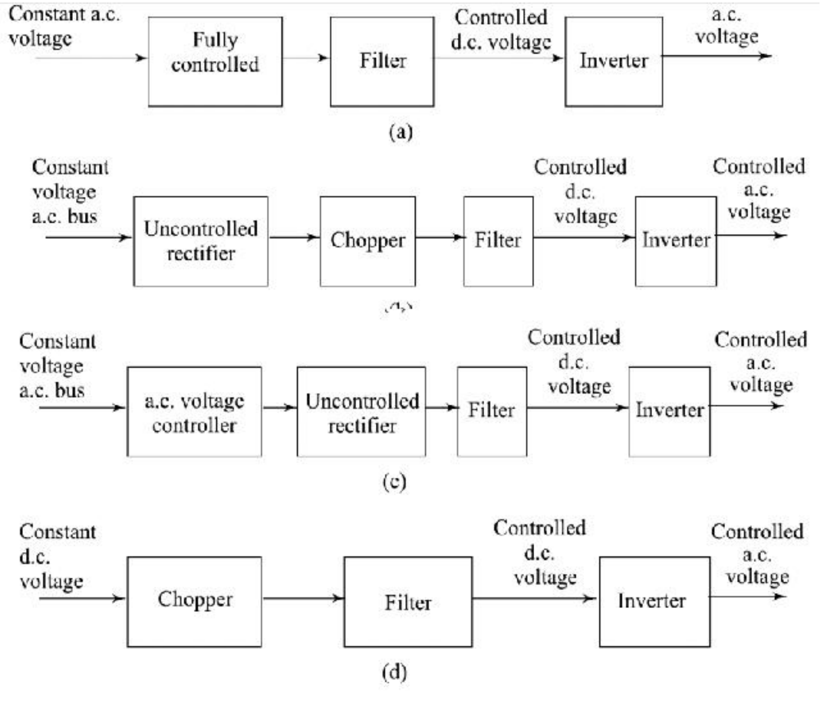
i) External AC control ii) External DC control

2+4

External AC control



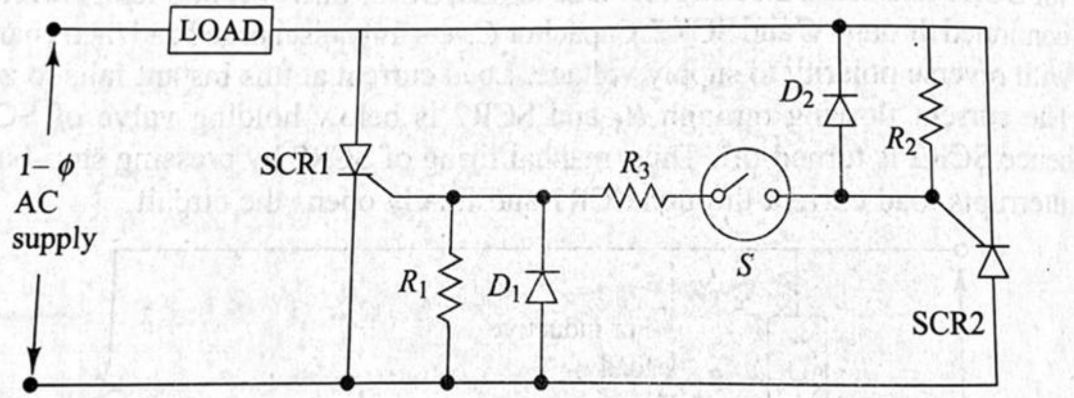
External DC control



Q4) b) ii) Draw and explain AC static circuit breaker.	**3+3**

SCR 1 and 2 are triggered in positive and negative half cycles respectively when switch S is closed. During positive half-cycle of the input, SCR1 receives gate current through ($D_2 \parallel R_2$), switch S and R_3 and it conducts. At the end of positive half-cycle, SCR1 is turned-off due to natural current zero.

SCR2 receives gate-current through ($D_1 \parallel R_1$), R_3 and switch S during negative half-cycle and conducts. It is turned-off at the end of this negative half-cycle due to natural current zero value. When the load current is required to be interrupted, the switch S is opened. Opening of switch S results in blocking of gate currents of both SCRs and hence both SCRs are maintained-off. When switch S is opened at any instant in a particular half-cycle, the load current continues to flow through conducting SCR till the end of this half-cycle, however in the next half-cycle the other SCR is not triggered due to nonavailability of gate current. Thus, the maximum time delay for breaking the circuit is one half-cycle.



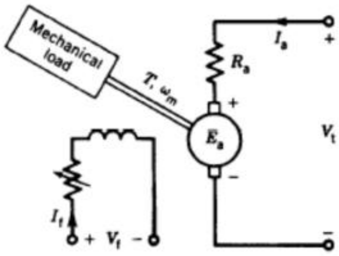
Q5 i) Describe speed control of DC motor using chopper with suitable schematic diagram and waveforms

Basic theory of dc motor speed control

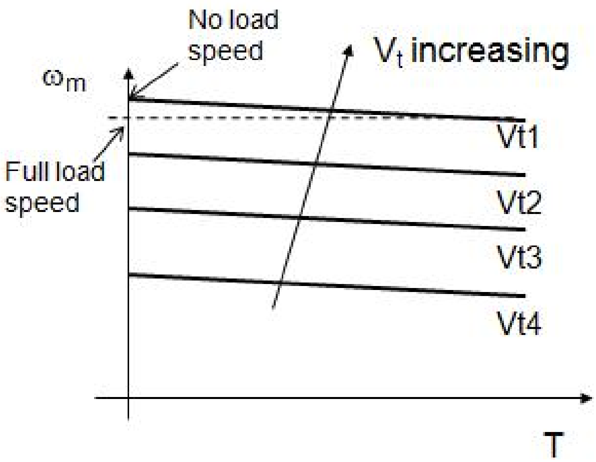
$$E_a = K_a \Phi \omega_m = V_t - I_a R_a$$

$$T = K_a \Phi I_a$$

$$\omega_m = \frac{V_t - I_a R_a}{K_a \Phi} = \frac{V_t}{K_a \Phi} - \frac{R_a}{(K_a \Phi)^2} T$$



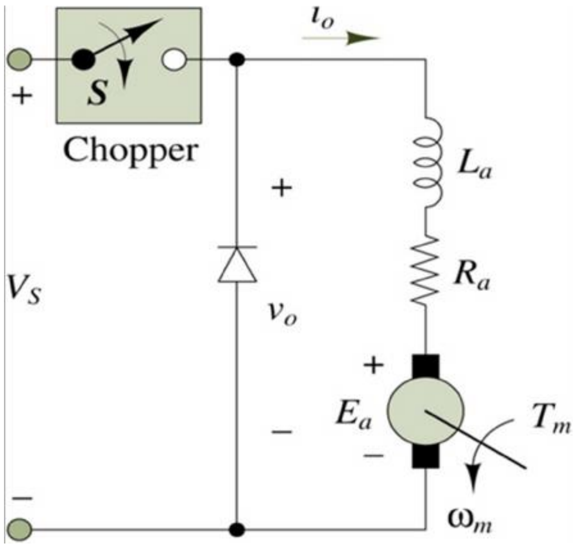
2



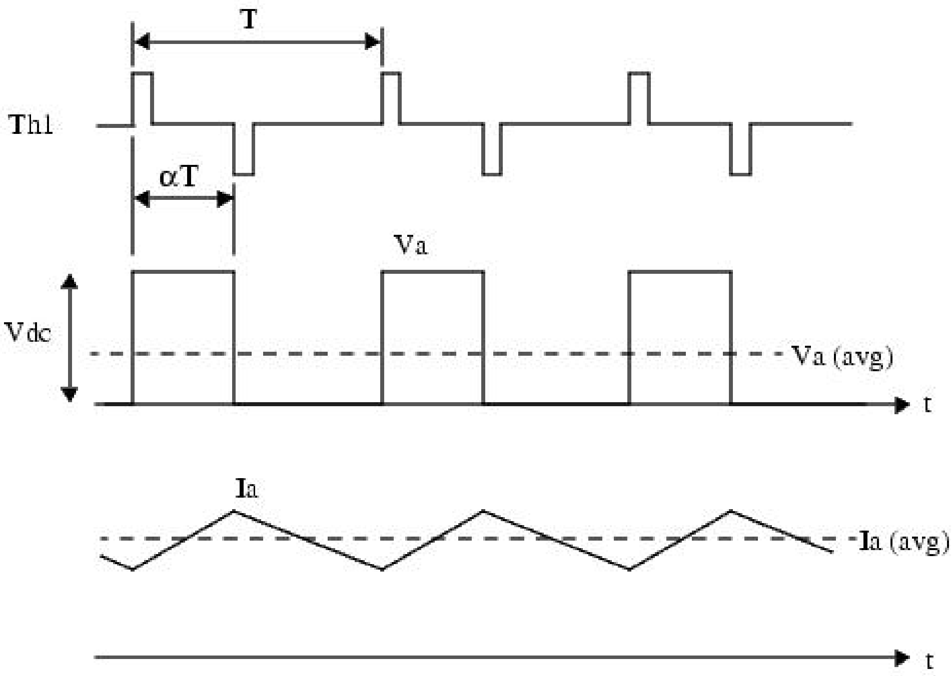
The above graph indicates that increase in armature voltage increases speed of dc motor. In chopper based dc drive. By controlling ON time of chopper, the dc output average voltage is controlled which controls speed of dc motor.

2

2


i_o
S
Chopper
+
L_a
R_a
V_S
v_o
+
E_a
T_m
−
−
−
ω_m

2


T
Th1
αT
Va
Vdc
Va (avg)
t
Ia
Ia (avg)
t

Q5 ii) Draw circuit diagram of CSI for AC motor drive and describe its working, **4+4**

Current-source inverters requires a "stiff" constant current source input - thus are sometimes referred to as CSI (current source inverters or current stiff inverters).

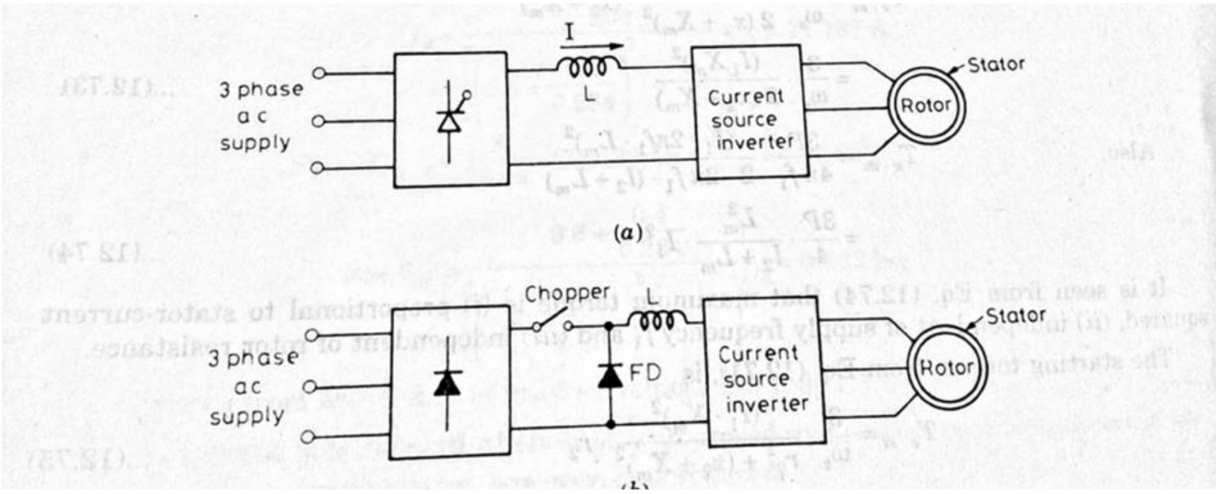
A large inductance can be used to change a variable voltage input to a variable current input.

VSI-inverters and CSI-inverters are dual to each other.

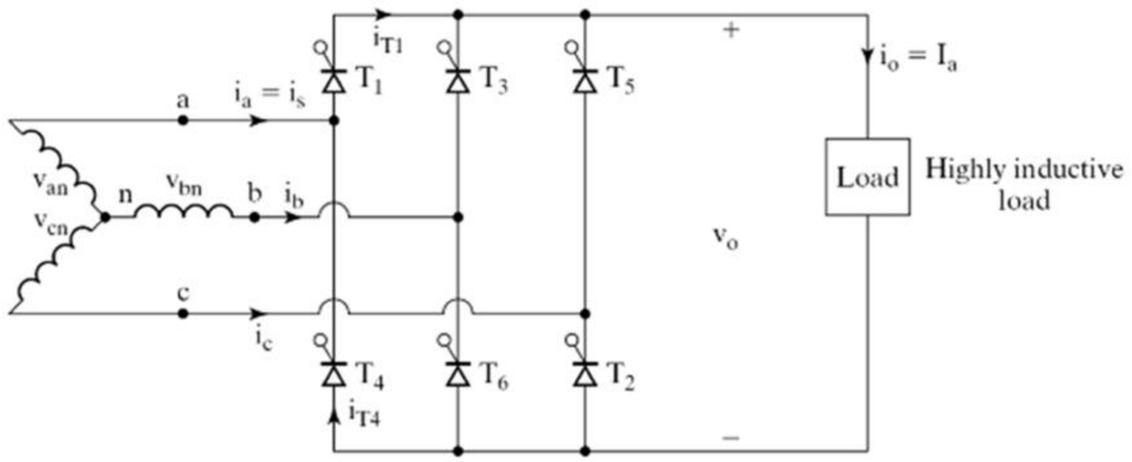
The constant dc current Id is switched through the thyristors to create a 3phase 6-step symmetrical line current waves.

The current is switched sequentially into one of the motor phases by the top half of the inverter and returns to the dc link from another of the phases via the bottom half of the inverter.

By switching every 2π/3 radians, a 6-step current waveform can be applied to the motor.



Q5 iii) Describe operation of three phase fully controlled bridge converter with R-L load with neat circuit diagram. Sketch different input and output waveforms. **2+2+4**

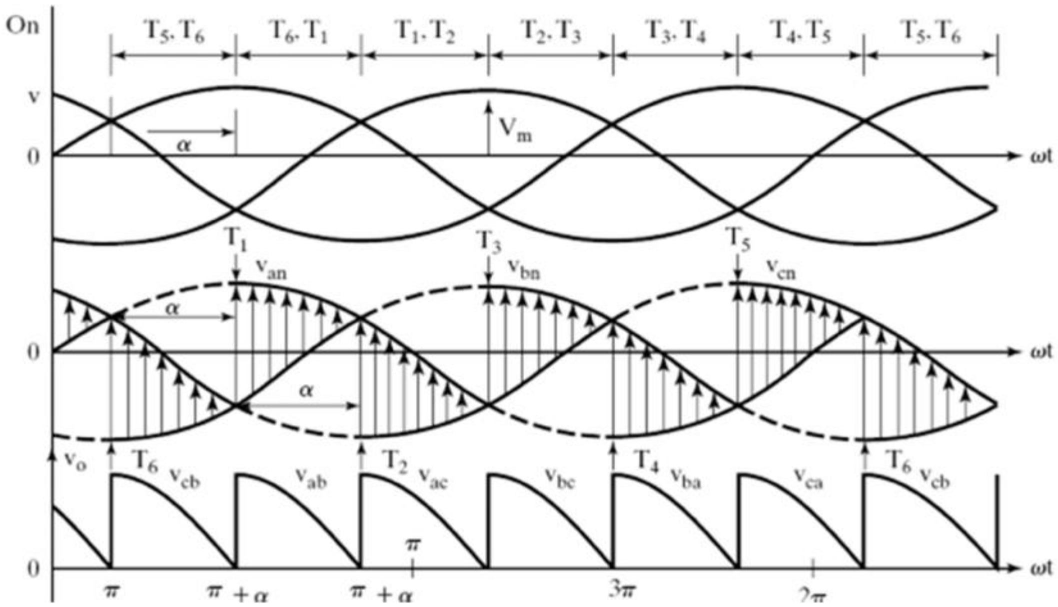


Three phase full converter is a fully controlled bridge controlled rectifier using six thyristors connected in the form of a full wave bridge configuration. All the six thyristors are controlled switches which are turned on at a appropriate times by applying suitable gate trigger signals. The three phase full converter is extensively used in industrial power applications upto about 120kW output power level, where two quadrant operation is required. The figure shows a three phase full converter with highly inductive load. This circuit is also known as three phase full wave bridge or as a six pulse converter. The thyristors are triggered at an interval of π/ 3 radians. The frequency of output ripple voltage is 6fs (fs is supply frequency). The thyristors are numbered in the circuit diagram corresponding to the order in which they are triggered. The trigger sequence (firing sequence) of the thyristors is T1T2, T2T3, T3T4, T4 T5, T5T6, T6T1, T1T2, T2T3, and so on.

The average dc output voltage is given by

$$V_{dc} = \frac{3\sqrt{3}V_m}{\pi}\cos\alpha$$

SUMMER – 14 EXAMINATION



Q6 i) Draw and explain basic series inverter circuit with neat waveforms.	**2+2**

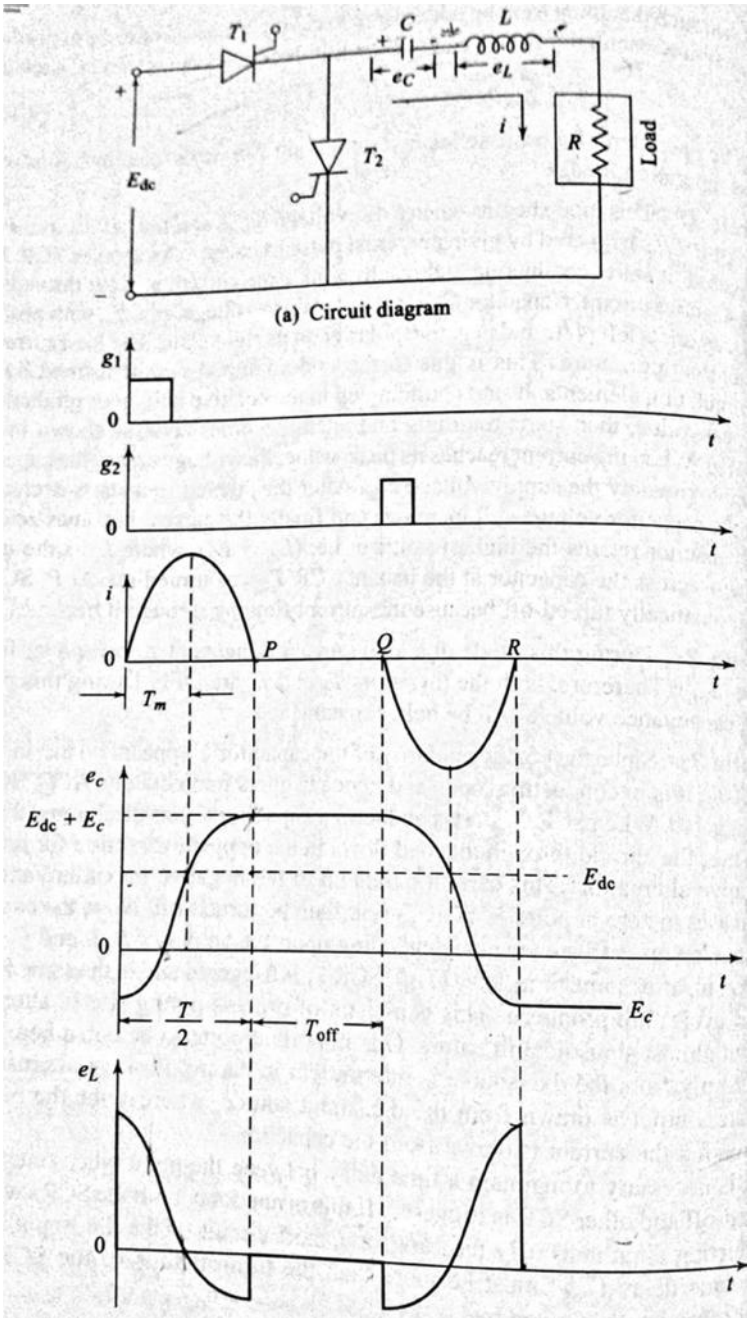
The basic series inverter is formed by RLC underdamped circuit. This is necessary to produce the required oscillations. This condition is fulfilled by selecting L and C such that R2< 4L/C

Mode 1: This mode begins when a d.c. voltage Edc is applied to the circuit and thyristor T1 is triggered by giving external pulse to its gate. As soon as SCR T1 is triggered, it starts conducting and resulting in some current to flow through the R-L-C series circuit. Capacitor C gets charged up to voltage, say, Ec, with positive polarity on its left plate and negative polarity on its right plate. The load current is of alternating nature. This is due to the underdamped circuit formed by the commutating elements. It starts building up in the positive half, goes gradually to its peak-value, then starts returning and again becomes zero. When the current reaches its peak-value, the voltage across the capacitor is approximately the supply voltage Edc. After this, the current starts decreasing but the capacitor voltage still increases and finally the current becomes zero but the capacitor retains the highest voltage, i.e. (Edc + Ec), where Ec is the initial voltage across the capacitor at the instant SCR T1, was turned-on. At P, SCR T1 is automatically turned-off because the current flowing through it becomes zero.

Mode 2: During this mode, the load current remains at zero for a sufficient time (Toff). Therefore, both the thyristors T1 and T2 are OFF. During this period PQ, capacitance voltage will be held constant.

Mode 3: Since the positive polarity of the capacitor C appears on the anode of SCR T2, it is in conducting mode and hence triggers immediately. At Q, SCR T2 is triggered. When SCR T2 starts conducting, capacitor C gets discharged through it. Thus, the current through the load flows in the opposite direction forming the negative alternation. This current builds up to the negative maximum and then decreases to zero at point R. SCR T2 will then be turned-off. Now, the capacitor voltage reverses to some value depending upon the values of R, L and C.

Again, after some time, delay (T0FF), SCR T1 is triggered and in the same fashion other cycles are produced. This is a chain of process giving rise to alternating output almost sinusoidal in nature.


T_1
C
L
e_C
e_L
i
R
Load
T_2
E_{dc}
(a) Circuit diagram
g_1
g_2
i
P
Q
R
T_m
e_c
$E_{dc} + E_c$
E_{dc}
E_c
$\frac{T}{2}$
T_{off}
e_L
0
t

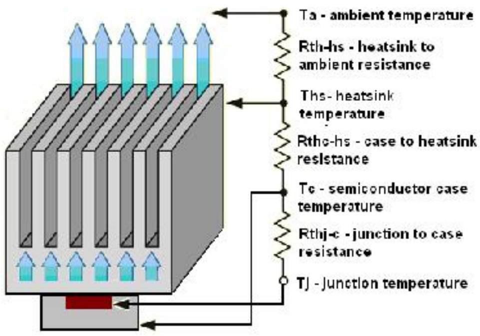
SUMMER – 14 EXAMINATION

Q6 ii) Differentiate series and parallel inverter. **2+2**

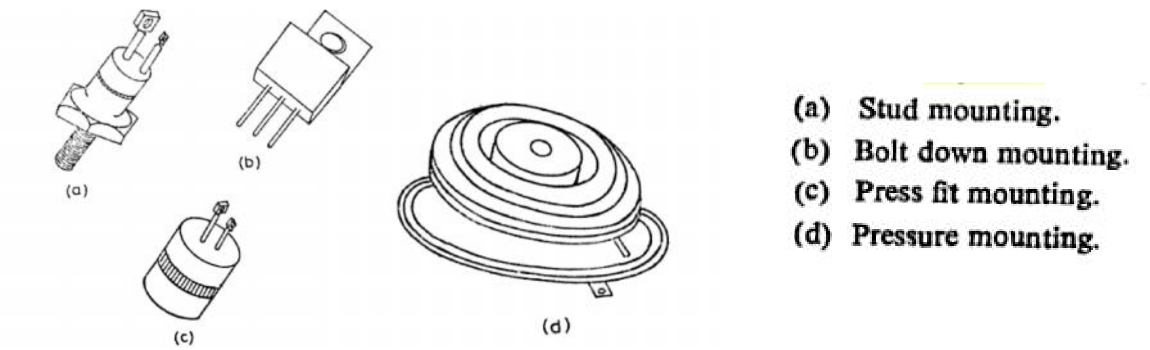
Series inverter	Parallel Inverter
Commutating components are in series with load	Commutating components are in parallel
Output waveshape is near to sinusoid	Output waveshape is square wave
Transformer is not required	Transformer with center tapped primary is required
There is a risk of short circuit across supply in case both thyristors are made ON	There no such problem with parallel inverter
Suitable for producing high frequency output	Suitable for low frequency operation
Class A commutation	Class D commutation

Q6) iii) Describe different heat sinks and mountings used for thyristors.	**2+2**

Heat sinks are the devices on SCR is mounted for increasing surface area for better heat dissipation and thus preventing increase in junction temperature . Heat sinks are made up of aluminium and have fins. Cooling is provided by natural air, forced air etc.



Different mounting techniques of SCR



SUMMER – 14 EXAMINATION

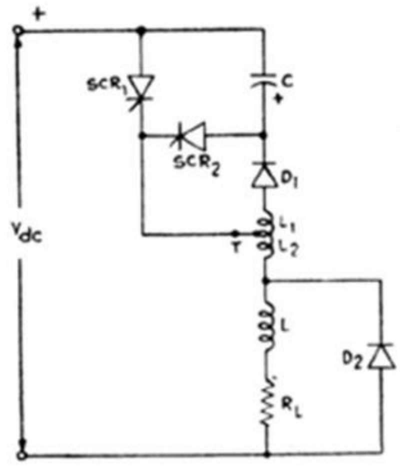
Q6 iv) Describe Jones chopper with waveforms **2+2**

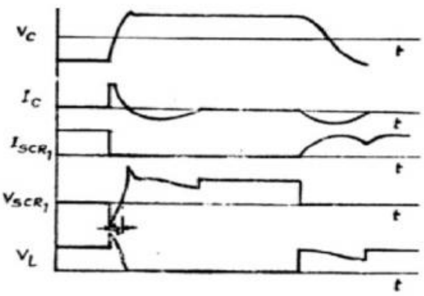
When SCR1 is turned on, the capacitor C discharges resonantly through SCR1, L1, and D1
This discharge current does not flow through L2 and back to the battery because of the transformer action of T.
This discharge current does not flow through L2 and back to the battery because of the transformer action of T.
The load current is picked up by SCR1, and the flywheel diode D1 is reverse-biased and its current reduced to zero.
As the capacitor voltage swings negative, the reverse bias on diode D2 decreases. This continues up to a time and capacitor voltage assumes a polarity as shown in figure.

When SCR2 is turned ON, the negative voltage on capacitor C is applied across SCR1 which is turned OFF after its recovery current becomes zero.

The load current which is nominally constant starts to flow in SCR2 and capacitor C.
The capacitor C is charged positively at first up to a voltage equal to the supply voltage Vdc.

The flywheel diode becomes forward biased and begins to pick up the load current and capacitor current starts to reduce.

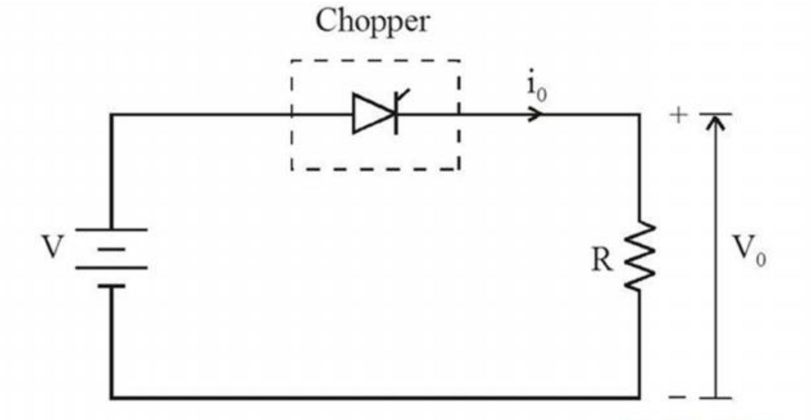




Q6 V) Describe constant frequency system of control technique of chopper	**2+2**

Chopper is a dc-dc converter. The input is uncontrolled dc and the output is a controlled dc. A thyristor chopper with resistive load is shown in fig.

- The thyristor in the circuit acts as a switch.
- When thyristor is ON, supply voltage appears across the load
- When thyristor is OFF, the voltage across the load will be zero.



Average Output Voltage

$$V_{dc} = V\left(\frac{t_{ON}}{t_{ON}+t_{OFF}}\right)$$

$$V_{dc} = V\left(\frac{t_{ON}}{T}\right) = V.d$$

$$\left(\frac{t_{ON}}{T}\right) = d = \text{duty cycle}$$

Constant frequency operation

t_{ON} is varied keeping chopping frequency 'f' & chopping period 'T' constant.
Output voltage is varied by varying the ON time t_{ON}