WINTER – 2019 EXAMINATION
MODEL ANSWER

Subject: Power Electronics Application (Elective-I) **Subject Code: 22527**

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.

Q. No.	Sub Q.N.	Answer	Marking Scheme
1.		**Attempt any FIVE of the following:**	**10**
	(a)	**State the applications of IGBT.**	**2M**
	Ans.	**Applications of IGBT:** 1. The insulated gate bipolar transistor (IGBT) is used Ac and DC motor drivers. 2. The IGBT is used in unregulated power supply (UPS) system. 3. The IGBT is used to combines the simple gate-drive characteristics of MOSFET with the high-current and low-saturation-voltage of bipolar transistors. 4. The IGBT is used in switched-mode power supplies (SMPS). 5. It is used in traction motor control and induction heating. 6. It is used in inverters. 7. The IGBT is used to combines an isolated-gate FET for the control input and a bipolar power transistor as a switch in a single device.	***Any two applications 1M each***
	(b) **Ans.**	**Draw symbol and V-I characteristics of power MOSFET.**	**2M**

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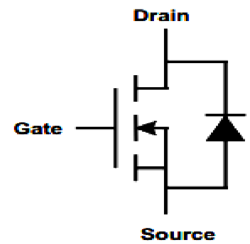
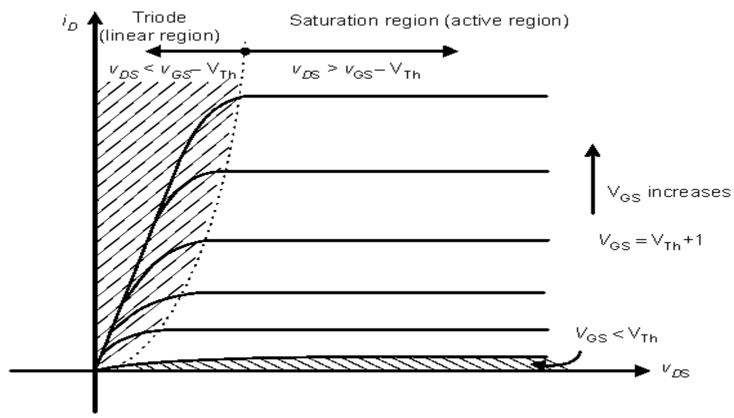
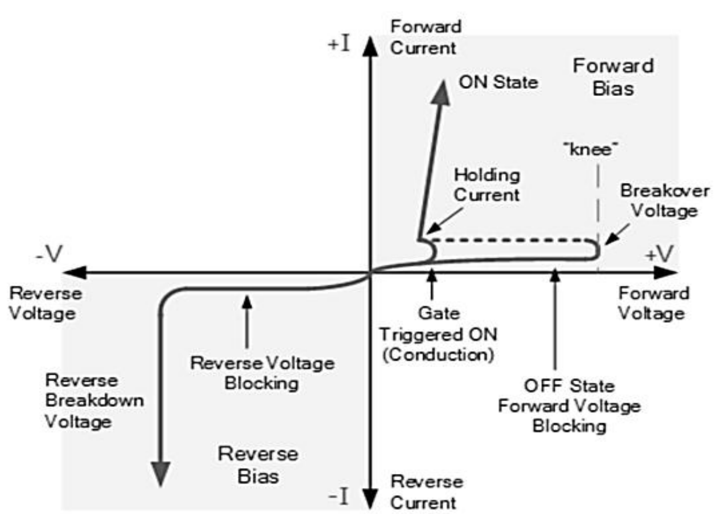
		Symbol:  V-I characteristics:  	***Symbol 1M*** ***V-I characteristics 1M***
	(c) **Ans.**	**Draw V-I characteristics of SCR.**  	**2M** ***Characteristics 2M***

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	(d) **Ans.**	**List four switching components used in inverters.** **Switching components used in inverters:** 1. SCR 2. MOSFET. 3. IGBT. 4. GTO.	**2M** ***Any two components 1M each***
	(e) **Ans.**	**List the different types of inverter.** There are three different types of outputs we get from inverters, and hence we classify inverters into three primary classes, which are: 1. The Square Wave inverter 2. The Modified Sine wave inverter or quasi sine wave inverter 3. A Pure sine wave inverter	**2M** ***Any two types 1M each***
	(f) **Ans.**	**State any two applications of dual converters.** **Applications of dual converters:** 1. Direction and Speed control of DC motors. 2. Applicable wherever, the reversible DC is required. 3. Industrial variable speed DC drives.	**2M** ***Any two applications 1M each***
	(g) **Ans.**	**State the applications of power electronics.** Power electronics applications are extended to various fields such as: 1. Aerospace, 2. Automotive electrical and electronic systems, 3. commercial, 4. industrial, 5. residential, 6. telecommunication, 7. transportation, 8. utility systems,	**2M** ***Any four applications ½M each***
2.	 **(a)** **Ans.**	**Attempt any THREE of the following:** **With a neat circuit diagram, explain the working principle of Jones Chopper.** • The basic circuit of the Jones chopper is shown in the figure:	**12** **4M**

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		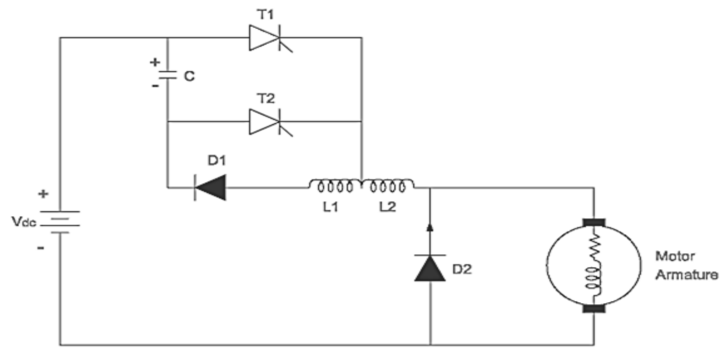	***Diagram 2M***
		• The Class D commutation circuit is used in the Jones chopper. • The SCR T1 is main SCR whereas SCR T2, diode D1, capacitor C and auto – transformer T makes commutating circuit for SCR T1. • The inductor L1 and L2 are closely coupled and they provide sufficient energy to capacitor to turn off main SCR T1. • The capacitor initially charges with upper plate positive and lower plate negative. • When the SCR T1 is turned on, the load current flows through path (+)V_{dc} – T1 – L2 – MOTOR ARMATURE – V_{dc} (–). • The capacitor discharges through path (+)C – T1 – L1 – D1 – C(–). Once capacitor discharges, it will again charges with reverse polarity with upper plate negative and lower plate positive. • The stored energy of load flows through freewheeling diode when SCR T1 is turned off. • The SCR T1 gets reverse voltage and turned off when SCR T2 is turned on. The load current flows through path (+)V_{dc} – C – T2 – L2 – MOTOR ARMATURE – V_{dc} (–). • As the load current flows, the capacitor again charges with upper plate positive and lower plate negative. • When the voltage across capacitor is equal to supply voltage, the charging current of capacitor is less than the holding current therefore the SCR T2 is turned off. • When SCR T1 is turned on once again cycle will repeat. The speed of the motor in the range of maximum to minimum can be achieved by switching of SCR T1 frequently or by adjusting its duty cycle.	***Working 2M***

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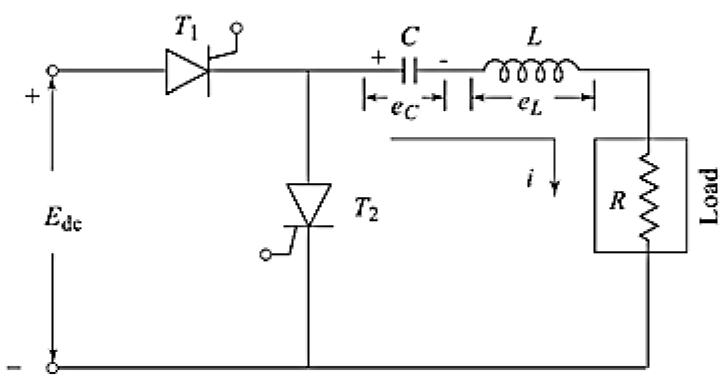
	(b)	**Explain with a neat labelled sketch the working principle of the single phase series inverter.**	4M
	Ans.	Figure shows the circuit diagram of basic series inverter. Two thyristors T1 and T2 are used to produce the two halves in the output.As shown, the commutation elements L and C are connected in series with the load R to form the series R−L−C circuit. The values of L and C are chosen such that, they form an underdamped circuit. This is necessary to produce the required oscillations. This condition is fulfilled by selecting L and C such that R2<4LC  The operation of a basic series inverter circuit can be divided into following three operating modes. **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 serity 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, as shown in Fig.1 (b). 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	*Diagram 2M* *Working 2M*

capacitor at the instant SCRT1 was turned-on. At P,SCRT1 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 (T off). 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 SCRT2, it is in conducting mode and hence triggers immediately. At Q, SCR T2 is triggered. When SCRT2 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.SCRT2 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 (T off),SCRT1 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. One important point to be noted here is that the supply from the d.c. source is intermittent in nature. Positive alternation of the a.c. output is drawn from the d.c. input source, whereas for the negative alternation the current is drawn from the capacitor.

It is necessary to maintain a time delay between the point when one SCR is turned-off and other SCR is triggered. If this is not done, both the SCRs will start conducting simultaneously resulting in a short circuit of the d.c. input source. This time delay (T off) must be more than the turn-off time of the SCRs. The output frequency is given by

$$F = \left[\frac{1}{T/2 + T_{\text{off}}}\right] \text{Hz}$$

where T is the time period for oscillations and is given by

$$\frac{T}{2} = \frac{\pi}{\sqrt{1/LC - R^2/4L^2}}$$

and T off is the time-delay between turn-off of one SCR and turn-on of the other SCR. Thus, by changing the value of Toff, frequency can be changed without changing the commutating elements.

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(c) Explain the operation of cyclo converter with a neat diagram. **4M**

Ans. A cycloconverter is a device that converts AC, power at one frequency into AC power of an adjustable but lower frequency without any direct current, or DC, stage in between. It can be considered as a static recurrence charger and holds silicon-regulated rectifiers. Cyclo-converters are used in very large variable frequency drives with ratings from few megawatts up to many tens of megawatts.

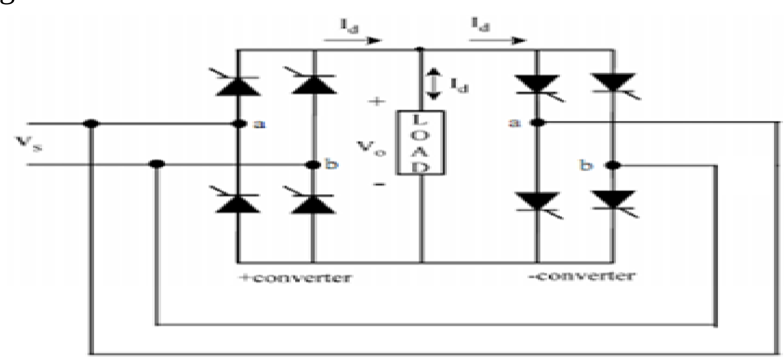
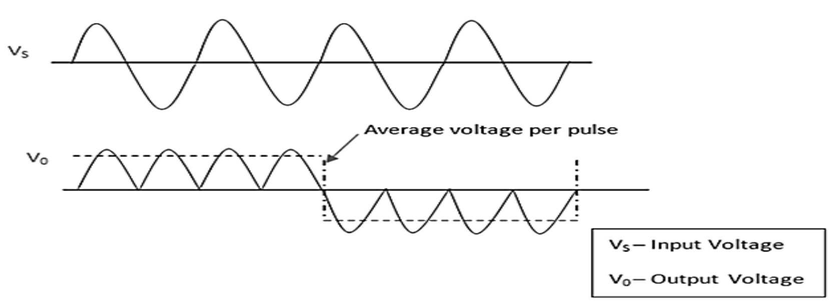


Diagram 2M

This converter is having back to back connection of two full wave rectifiers. Suppose for getting one fourth of input voltage at the output, for the first two cycles of Vs the positive converter operates supplying current to the load and it rectifies the input voltage. In the next two cycles the negative converter operates supplying current in the reverse direction. When one of the converters operates the other one is disabled, so that there is no current circulating between rectifiers. In the below figure Vs represents input supply voltage and Vo is the required output voltage which is one fourth of supply voltage.

Explanation with waveform 2M



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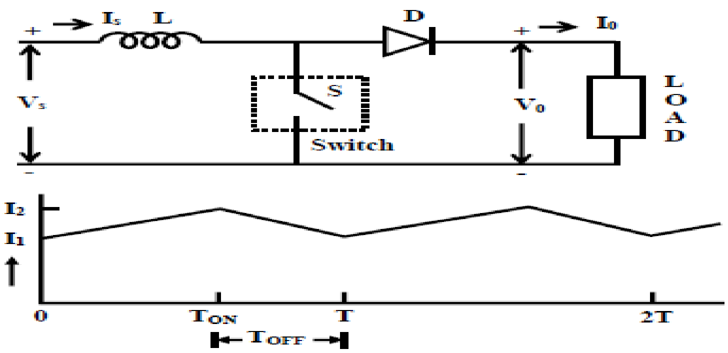
	(d) **Ans.**	**Draw a schematic of step up-chopper and explain it.** Figure below shows the Circuit Diagram and Waveform of step up chopper.  Step-up chopper is used to obtain a load voltage higher than the input voltage V. The values of L are chosen depending upon the requirement of output voltage and current. 1. When the chopper is ON, the inductor L is connected across the supply. The inductor current rises and the inductor stores energy during the ON time of the chopper, tON. 2. When the chopper is off, the inductor current I is forced to flow through the diode D and load for a period, tOFF. The current tends to decrease resulting in reversing the polarity of induced EMF in L. Therefore voltage across load is given by, Hence, V0 > V.	**4M** ***Diagram 2M*** ***Explana tion with wavefor m 2M***
3.	 **(a)** **Ans.**	**Attempt any THREE of the following:** **Draw a neat circuit diagram of class D chopper and give its operation with waveform.**	**12** **4M**

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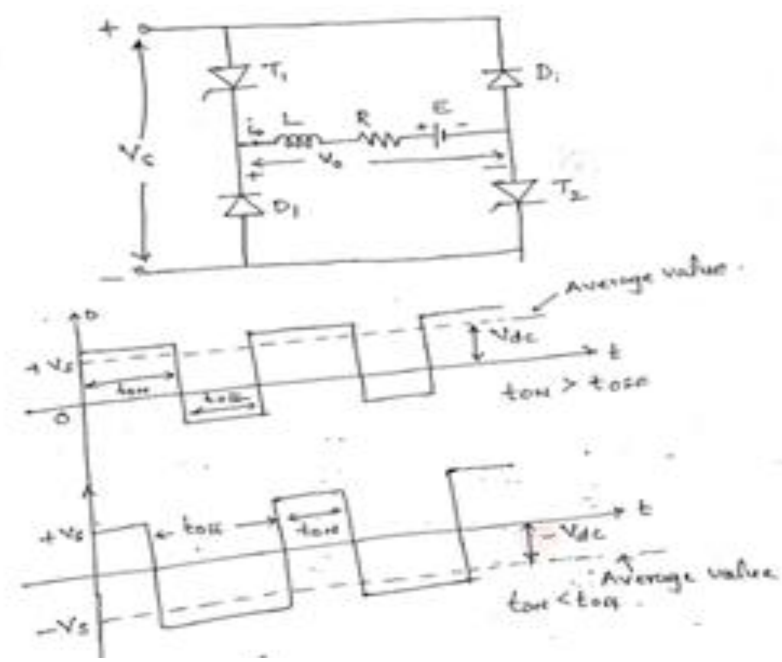
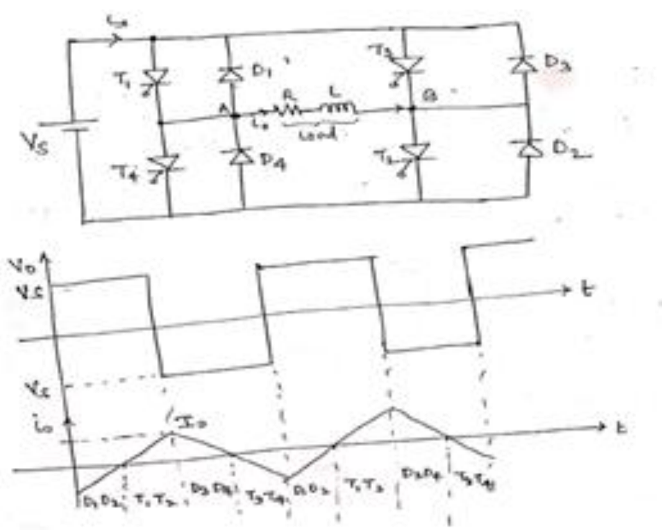
		 When both thyristors are triggered the current flows through the path V_s, T_1, L, R,T_2 and lack to V_s. Therefore the supply voltage V_s appears across the load and the load current to increases. When only one thyristor is triggered, then some of the energy stored in the inductor L is dispatched through the load and one of the diodes (such as T_1 and D_2). When both thyristors are turned off, diodes D_1 and D_2 provide a path for the load current, and the load voltage has reverse polarity. Thus the direction of the load current is always positive because thyristors and diodes can carry current in only one direction. However the average output voltage is positive when the thyristors turn-ON time is move than its turn-OFF time, whereas the average output voltage is negative, when its turn-ON time is less than the turn-OFF time.	*Diagram 2M* *Explanation with waveform 2M*
	(b) Ans.	**Draw a neat circuit diagram of single phase full bridge inverter with R-L load and give its operation.**	4M

			***Diagram 2M***
		Before $t = 0$, thyristors T_3, T_4 are conducting and load current I_o is flowing from B to A that is in the received direction. After T_3, T_4 are turned off at $t = 0$, current I_o cannot change its direction immediately because of the nature of the load. As a result, diodes D_1, D_2 starts conducting after $t = 0$ and allows I_0 to flow against the supply voltage V_s. As soon as D_1, D_2 begins to conduct, load is subjected to $V_{s.}$ Though T_1, T_2 are gated at $t = 0$., these SCRs will not turn ON as these are reverse biased by voltage drops across diodes D_1, & $D_{2.}$ When load current through D_1, D_2 falls to zero, T_1 and T_2 become forward biased by source voltage $V_{s.}$ T_1 and T_2 therefore gets turned ON as these are gated for a period T/2 sec. Now load current I_0 flow in the positive direction from A to B. At $t = T/2$; T_1 and T_2 are turned OFF by forced commutation and as load current cannot reverse immediately, diodes D_3, D_4 come into conduction to allow the flow of current I_0 after T/2. Thyristors T_3, T_4, through gated, will not turn ON as these are reverse biased by the voltage drop in diodes D_3, D_4. When current in diodes D_3, D_4 drops to zero, T_3, T_4 are turned ON as these are already gated.	***Operation 2M***

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(c) **Explain with circuit diagram the working principle of the circulatory current free mode converters.** **4M**

Ans.

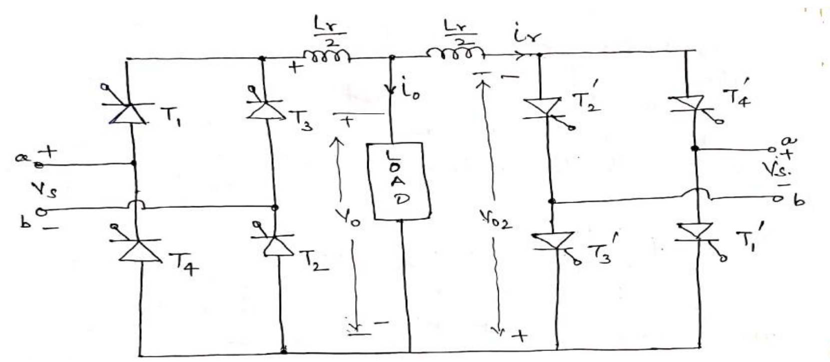


Diagram 2M

If two of the full converters are connected back to back both the output voltage and load current flow can be reversed. If $\alpha_1$and α_2 are the delay angles of converters 1 and 2; respectively, the corresponding average output voltages are Vde_1 and Vde_2.
The delay angles are controlled such that one converter operates as a rectifier and the other converter operates as an inverter; but both converter produce the same average output voltage.

$$V_{dc\,1} = -V_{dc\,2} \text{ or } \cos\alpha_2 = -\cos\alpha_1 = \cos(\pi - \alpha_1)$$

Therefore $\alpha_2\ (\pi - \alpha_1)$

Because the instantaneous output voltages of the two converters are out of phase, there can be an instantaneous voltage difference and this can result in circulating current between two converters.
This circulating current cannot flow through the load and is normally limited by a circulating current reactor L_r.
The circulating current maintains continuous conduction of both converters over the whole current range, independent of the load.

Explanation 2M

(d) **Draw the diagram of electric welding control and describe its operation.** **4M**
(Note: Any other diagram shall be considered)

Ans.

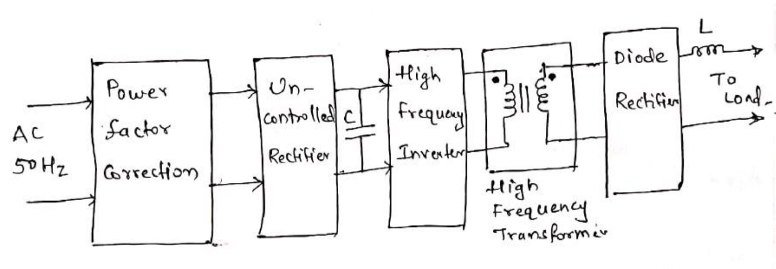


Diagram 2M

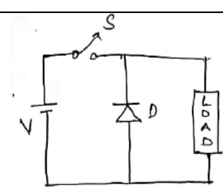
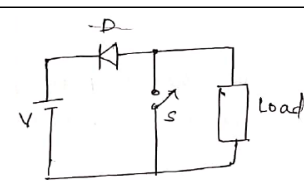
In all welding applications, the output needs to be electrically isolated from the utility input. The voltage current characteristics of the welder depends on the type of welding process employed. Also another requirement is to maintain a low ripple current after they are is established. In the above diagram the isolation is provided by a high frequency transformer. A small inductance L is needed at the output to limit the output current ripple at high frequencies. The efficiency of such welder is in 85-90% range. Also these welders have smaller weight and size compared with the welders employing a 50Hz power transformer.

Description 2M

4. **Attempt any THREE of the following:** **12**

(a) **Differentiate between class A and class B chopper (any four points).** **4M**

Ans.

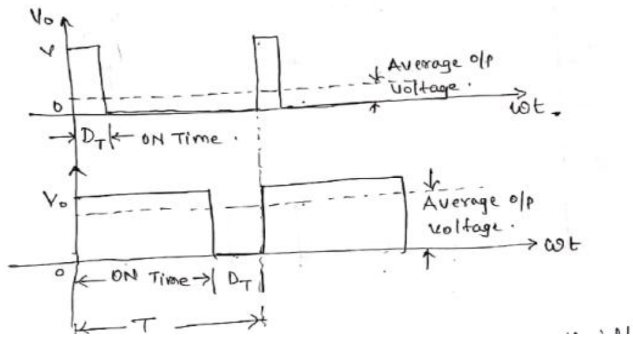
Sr. No.	Parameter	Class A chopper	Class B chopper
1	Quadrant of operation	I^{st}	II^{nd}
2	Configuration		
3	Power flow	Source to load	Load to source
4	Application	As a motoring chopper	As a regenerating chopper.
5	Load voltage	Positive	Positive
6	Load current	Positive	Negative

Any four points 1M each

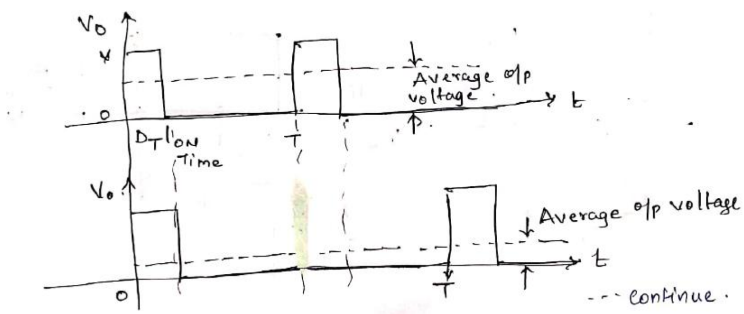
(b) **Explain the control techniques of a chopper with a neat waveform.** **4M**

Ans.

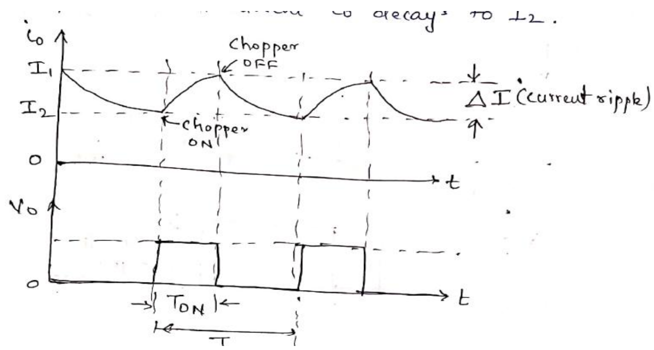
i) Pulse Width Modulation (PWM): In this technique the switches are turned ON at a constant chopping frequency. $f = {}^{1}/_{T}$. The average output voltage is directly proportional to the ON time of chopper. ***1M***



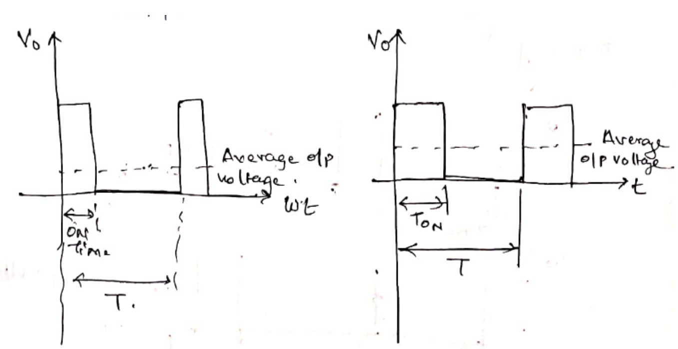
ii) Frequency Modulation (Constant pulse width variable frequency): In this method ON time of the chopper is kept constant and the variation in average load voltage is obtained by varying the chopping frequency f. ***1M***

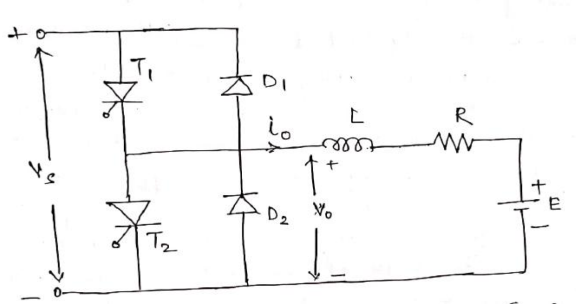


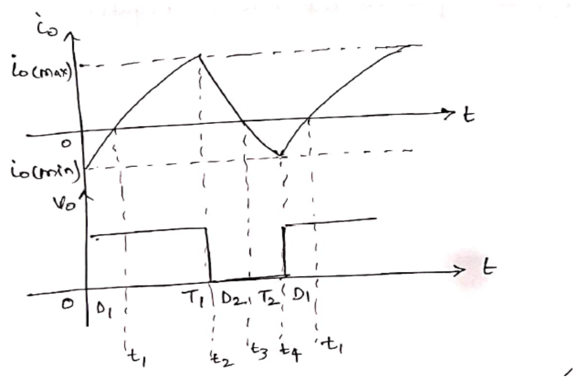
iii) Current Limit Control (CLC): In this method the chopper is turned ON when the output current i_o equals a preset value I_2. The chopper is kept ON till i_o increases to another preset value I_1. The chopper is turned OFF when i_o equal I_1 and is kept OFF till current i_o delay to I_2. ***1M***

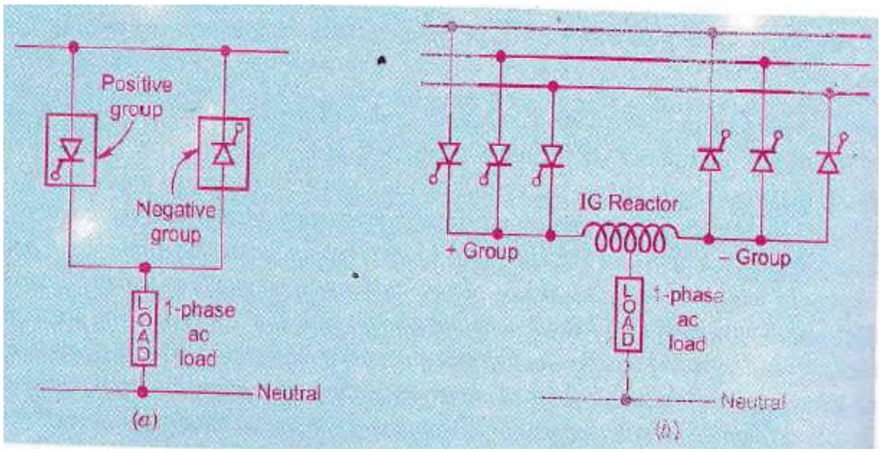
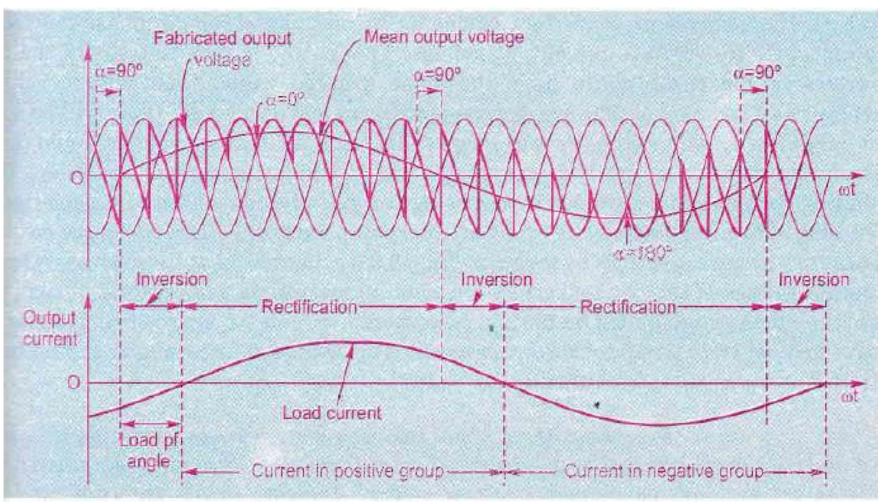


iv) Variable Pulse Width and Frequency: The average output voltage of the chopper is determined by the ratio T_{on}/T. Thus both the pulse width T_{ON} and the frequency 1/T may be varied to obtain a particular value of T_{on}/T. — *1M*



	(c)	**Explain the operation of class C chopper with neat circuit diagram. Also draw the waveform.**	**4M**
	Ans.	**Class C chopper:** 	*Diagram 1M*

		Waveforms:  	***Waveforms 1M***
		The output voltage is always positive because of the presence of flywheel diodes across the load, while the load current is either positive or negative. Initially when both thyristors and diodes are OFF, the load is isolated from the supply. When thyristor T_1 is triggered, the load current i_0 is positive and the load receiver power from the supply. Therefore the output voltage $V_0 = V_s$ and the conductor L stores energy. At a time $t = t_1$, thyristor T_1 is turned OFF and stored energy in inductor L forces the load current to flow through the flywheel diode D_2. till is value become equal to the battery voltage E of the load and the load current i_0 becomes zero. Thus the conduction period for the flywheel diode is from t_1 to t_2. At a time $t_1 = t$, if the thyristor T_2 is triggered, the load battery E forces the current to flow in the opposite direction through the inductor L and the thyristor T_2. When thyristor T_2 is turned OFF at $t = t_3$., the stored inductive energy forces current through the diode D_1 to the supply up to the time $t = t_4$. During this interval, i.e. $(t_3 - t_4)$, the input current becomes negative.	***Explanation 2M***
	(d) **Ans.**	**Draw the circuit diagram of single phase to three phase cyclo-converter and sketch the input/output waveforms.** ***(Note: Not possible to produce three phase waveform from single phase. If the student written the answer of three phase to single phase cyclo-conveter shall be considered)***	**4M**

			***Diagram 1M***
			***Waveform 1M***
		When output current is positive (above the reference line ωt), positive converter conducts. Under this condition, positive converter acts as a rectifier when output voltage is positive and as an inverter when output voltage is negative. When output current is negative, the negative converter conducts; under this condition, negative converter acts as a rectifier when output voltage is negative and as an inverter when output voltage is positive. It can thus be inferred, in general, that one of two component converters in figure1. would operate as rectifier if the output voltage and current have the same polarity and as an inverter if these are of opposite polarity.	***Explanation 2M***

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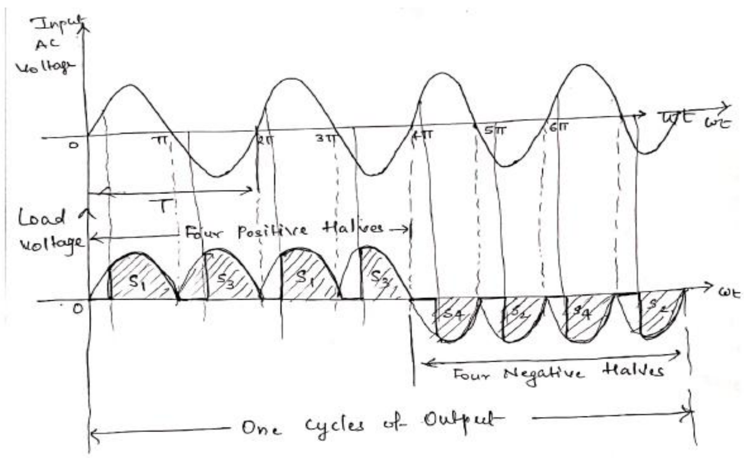
(e) **Draw input and output waveforms of cycloconverter to produce $\frac{1^{th}}{4}$ of input frequency. Show the firing sequence of thyristors in the relevant waveform.** **4M**

Ans.

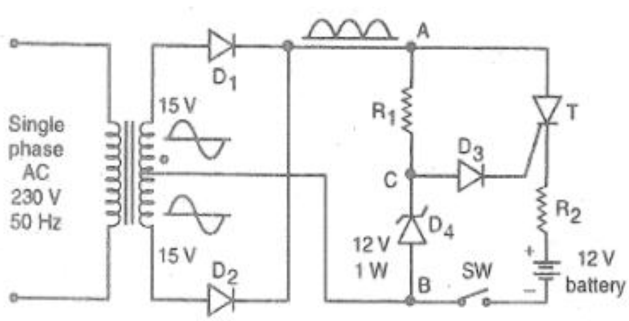


Correct waveforms 4M

5. **Attempt any TWO of the following:** **12**

(a) **Explain the operation of Battery charger control with a neat diagram.** **6M**

Ans.

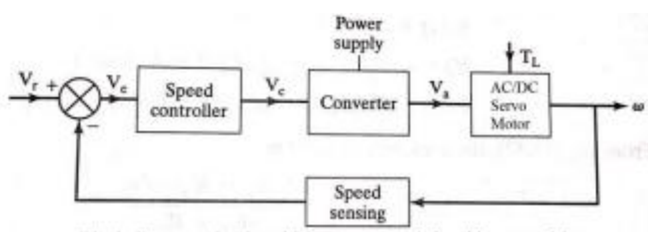


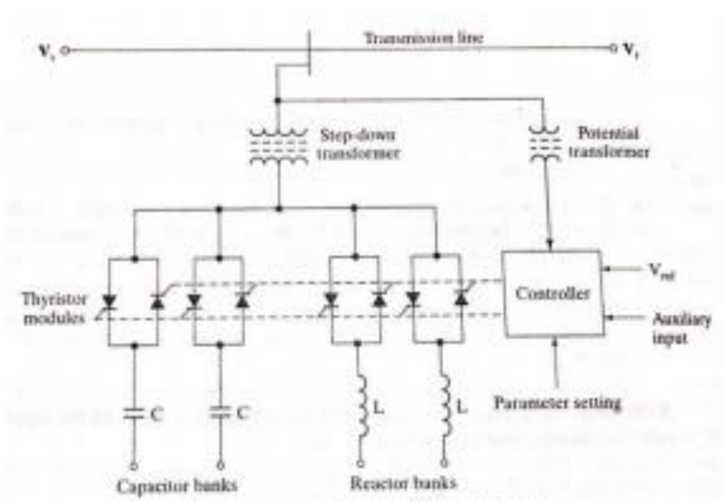
Automatic battery charger using SCR

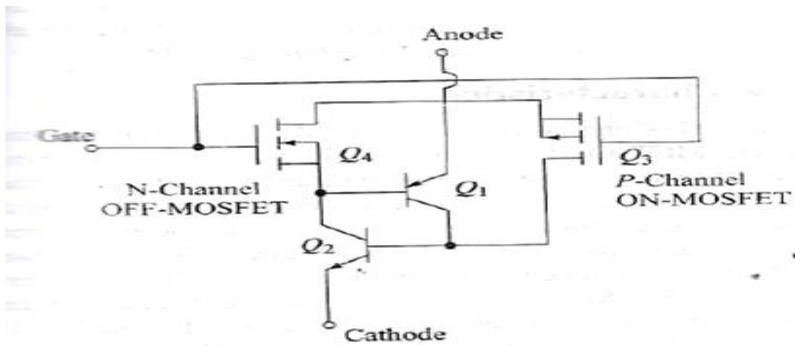
Diagram 3M

The figure shows the battery charger circuit using SCR. A 12V discharged battery is connected in the circuit and switch SW is closed. The singlephase 230V supply is stepped down to (15-0-15) V by a centre-tapped transformer. The diodes D1 and D2 forms full wave rectifier and pulsating DC supply appears across terminals A and B. When SCR is off, its cathode is held at the potential of discharged battery. During each positive half-cycle, when the potential of point C rises to sufficient level so as to forward bias

Explanation 3M

		diode D3 and gate-cathode junction of SCR, the gate pulse is provided and SCR is turned on. When SCR is turned on, the charging current flows through battery. Thus during each positive half-cycle of pulsating DC supply, voltage across A-B, SCR is fired and charging current is passed till the end of that half-cycle. Due to Zener diode D4, the maximum voltage at point C is held at 12V. Due to the charging process, the battery voltage rises and finally attains full value of 12V. When the battery is fully charged, the cathode of SCR is held at 12V. So the diode D3 and gatecathode junction of SCR cannot be forward biased, since the potential of point C can reach up to 12V. Therefore, no gate current is supplied and SCR is not fired. In this way, after full charging, further charging is automatically stopped.	
	(b) **Ans.**	**Describe the operation of close loop speed control method for AC servo motor with the help of diagram.**  A general scheme of closed loop speed control for servomotors is shown in fig. For both types of servomotors, voltage control based speed control scheme is used. DC servomotor is fed from ac-dc converter and AC servomotor is fed from ac controller or inverter. The speed of motor changes with the load torque. To maintain a constant speed, the motor voltage should be varied continuously by varying the delay angle converter. In practical drive systems it is required to operate the drive at a constant torque or constant power with controlled acceleration and deceleration. A closed-loop control system has the advantage of improved accuracy, fast dynamic response and reduced effects of load disturbances and system nonlinearities. If the speed of servomotor does not match with the set speed, the speed error Ve increases. The speed controller responses with as increased control signal Vc. This control signal changes the operation of converter and voltage supplied to servomotor is changed so as to minimize the speed error.	**6M** ***Diagram 3M*** ***Description 3M***

	(c) Ans.	**Explain the operation of static VAR compensation system with a neat diagram.**  General arrangement of static VAR compensator **Static VAR compensator:** • Static VAR compensation is a process of compensating the reactive power in the power system using static switches (semiconductor switches). In this process, the reactors and capacitors are switched to absorb or supply the reactive power respectively. • Static VAR compensators (SVC) consists of combinations of thyristor controlled reactor (TCR), thyristor switched capacitor (TSC) and fixed capacitor (FC). • The electrical transmission and distribution networks are dominantly reactive in nature. During no or light load condition, the line capacitances play major role to produce the reactive power. If this reactive power is not absorbed by load then voltage rises and may cross the limit. In this situation, TCR is used to insert reactors in power system to absorb the reactive power. • During peak load condition, most of the loads are inductive and they demand the reactive power. In this situation, TSC is used to insert capacitors in power system to generate the reactive power. • In fact, SVC comprises combinations like (TCR+TSC), (TCR+FC) as per the need. • In TCR, phase control is used to vary the effective inductance of the	6M *Diagram 3M* *Explanation 3M*

		inductor. • In TSC, the integral-cycle control is employed to vary the effective capacitance of the capacitor.	
6.		**Attempt any TWO of the following:**	**12**
	(a) **Ans.**	**With neat diagram, explain the operation of MCT and state two applications of MCT.**  **Working:** MCT turn ON: If the gate of the MCT is negative with respect to anode a p-channel is created in p-FET and p-channel ON FET causes the forward biasing of n-p-n transistor.(base drive to n-p-n transistor), the n-p-n transistor applies base drive to p-n-p transistor and regenerative action starts and the device is latched(turns ON). MCT turn OFF : If the gate of MCT is positive with respect to anode, turn off the ON FET and N-channel is created in n-FET and n-channel FET turns ON which short circuit the base emitter junction of p-n-p transistor, this diverts the base drive of the transistor through OFF FET and breaks the regenerative process and the device will turn off. **Applications of MCT:** 1. MCT's are used in the circuit breakers 2. It is used in high power applications like high power conversions 3. MOS Control thyristor are used in induction heating.	**6M** ***Diagram 2M*** ***Working 3M*** ***Any two applications ½M each***
	(b) **Ans.**	**Explain the operation of McMurray half bridge inverter with circuit diagram.**	**6M**

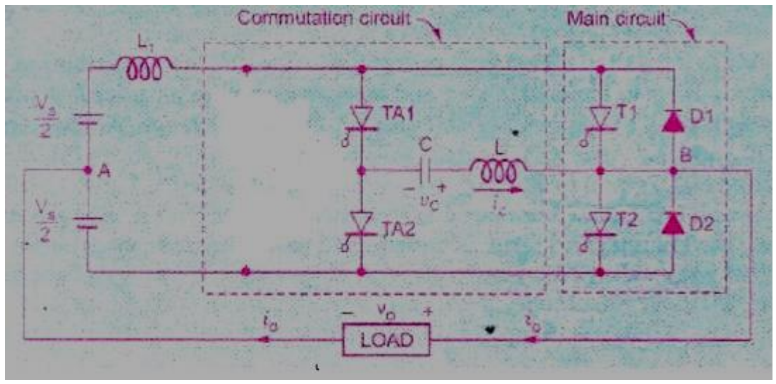
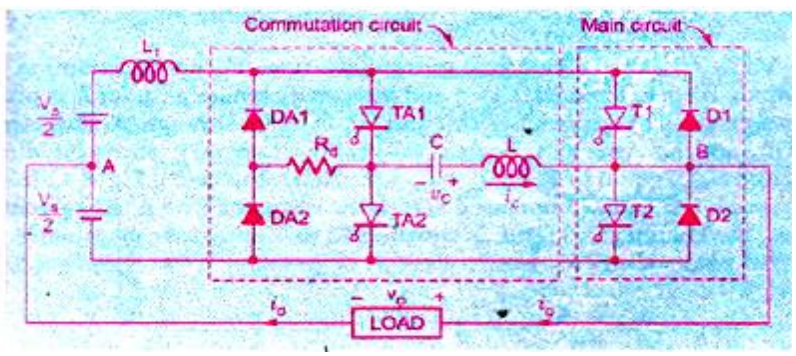


Diagram 3M

OR



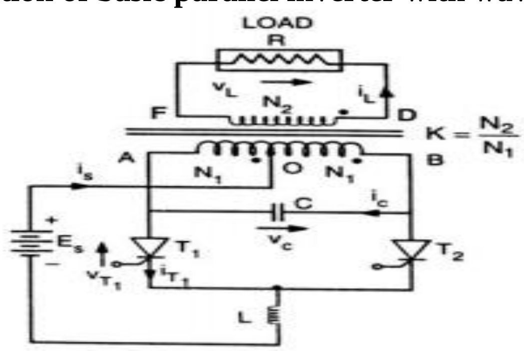
Mode 1: Thyristor T1 is conducting a constant load current I_0 i.e. $i_{T1} = I_0$. Capacitor C is already charged to a voltage V_s with right hand plate positive because of the commutation of previously conducting thyristor T2.

Operation 3M

Mode II: Auxiliary thyristor TA1 is triggered at t=0 to turn off the main thyristor T1. As TA1 is fired, capacitor current i_c starts building up through resonant circuit consisting of L, T1, TA1 and C. Voltage drop across T1 reverse biases D1, current i_c can therefore flow only through T1 and not through D1. As I_0 is constant, an increase in i_c causes a corresponding decrease i_{T1} so that $i_{T1} = I_0 - i_c$ (KCL at node B). AT t_1, i_c rises to I_0 and therefore $i_{T1} = 0$. As a result, main thyristor T1 is turned off at t_1.

Mode III: After t_1, as resonant current i_c exceeds I_0, the excessive current $i_c - I_0 = i_{D1}$ circulates through feedback diode D1 figure. The voltage drop across D1 reverse biases T1 to bring it to forward

		blocking capability. When capacitor voltage v_c discharges to zero. resonant current i_c rises to peak value $I_{cp.}$ After attaining I_{cp}, i_c begins to decrease and in so doing. C begins to get charged in the revrese direction. At t_2, i_c falls to I_0. In case v_c is somewhat more than source voltage V_S *at* t_2, diode D2 gets forward biased and starts conducting. **Mode IV:** After t_2, as i_c tends to fall below $I_{0,}$ diode current i_{D1} becomes zero adn D1, therefore, stops conducting. Constant load current $I_{0,}$ diode current i_{D1} becomes zero and D1, therefore, stops conducing. Constant load current I_0 continues flowing through $V_s/2$, TA1, C, L and load. Load current charges capacitor C linearly with reverse polarity and at T_3, v_c is somewhat more than $V_{s.}$ **Mode V:** At T_3, as v_c becomes slightly more than $V_{s.}$ an examination of figure reveals that diode D2 gets forward biased and thus an alternate path for I_0 is provided. Load current I_0 is now shared by resonant circuit and D2. Current through D2 flows through lower source $V_s/2$, D2 and load. After t_3, i_c begins to decrease whereas i_{D2} starts building up so that the sum of i_c and i_{D2} is equal to $I_{0,}$ *i.e.* $i_c + i_{D2} = I_0$ (KCL at node B). The supply voltage V_s, through D2 is now impressed across the resonant circuit. As current i_c is falling from I_0 to zero, the energy stored in L is transferred to C and as a consequence, capacitor is overcharged to a peak voltage V_m at T_4. The main thyristor T2 is usually given the trigger pulse $\pi\sqrt{LC}$ seconds after thyristor TA1 is fired. i.e. between the interval t_3 and t_4. But T2 will not turn on because of the reverse bias applied to it by the voltage drop in D2. **Mode VI:** At $t_{4,}$ i_{D2} rises to I_0 and at the same time i_c falls to zero. As i_c tends to reverse. TA1 is turned off at t_4. Now $v_c > V_s$ capacitor C therefore discharges through R_d, DA1, source voltage V_S, D2, L and C. Note that current i_c is now negative as it is flowing opposite to its positive direction. For a constant load current I_0, KCL at node B gives $i_{D2} = i_c + I_0$. During this mode, i_{D2} is more than I_0. The circuit traced by i_c is usually critically damped so that v_c gradually reduces to V_s. Excess energy stored in C is partly dissipated in R_d and partly fed back to source V_s. At t_5, i_c becomes zero, $v_c = -V_s$ and $i_{D2} = I_0$. Just after t_5, as i_c tends to reverse, DA1 is turned off. The voltage drop across R_d and DA1 applies a reverse bias across TA1 and completes its commutation process. **Mode VII:** As stated before, soon after t_5, DA1 is off and T1, D1 and TA1 are already off. In this mode, the only conducting device is	

		diode D2. A part of energy stored in the load is delivered to source. The decreasing load current $i_0 = i_{D2}$ becomes zero at t_6. Main thyristor T2 is already gated on during t_4- t_3 interval, i.e. $\pi \sqrt{LC}$ seconds after TA1 is fired. But it will not get turned on at this moment because of the reverse bias applied to it by voltage drop in D2 due to current i_{D2} . At t_6, $i_{D2} = 0$ and T2 is no longer reverse biased. Therefore, after t_6, source voltage applies a forward bias across T2 and the trigger pulse already applied to it turns it on. Load is now subjected to negative current as desired. Note that load was already subjected to negative voltage through D2 to t_3 at the commencement of its conduction. After t_6, capacitor charged to voltage - V_s (i.e. with the left plate positive) is ready for the next commutation process. The commutation process from T2 to D1 is identical to that described above.	
	(c) **Ans.**	**Explain operation of basic parallel inverter with waveform.**  	**6M** ***Diagram 2M*** ***Wavefor m 2M***

		Working: SCR1 and SCR2 are switched alternately to connect the input dc source. This induces square wave voltage across the load in the transformer. C is commutating Capacitor. Mode1: When SCR 1 is turned On, the dc source voltage appears across left half of primary OA The primary current flow from O to A. Due to0 the transformer action the voltage between AB is 2V Volts. Hence the capacitor is charged to a voltage of 2V Volts. The load voltage is positive, so is the load current. Mode II: The firing of SCR2 turns off SCR, by the principle of parallel capacitor communication. (The capacitor voltage is applied across SCR, directly to reverse bias it). The input de voltage now gets connected across winding OB. The primary current flows form O to B through SCR2. The load voltage changes its polarity and the direction of load current is reversed. The square wave is obtained at the output.	***Operation 2M***