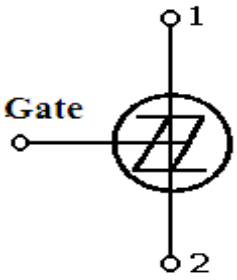
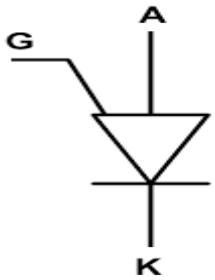
WINTER-19 EXAMINATION

Subject Name: Basic Power Electronics **Subject Code:** 22427

Model Answer

Important Instructions to examiners:

1) The answers should be examined by key words and not as word-to-word as given in themodel answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may tryto assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given moreImportance (Not applicable for subject English and Communication Skills.
4) While assessing figures, examiner may give credit for principal components indicated in thefigure. The figures drawn by candidate and model answer may vary. The examiner may give credit for anyequivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constantvalues 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.	Answers	Marking Scheme
1	(A)	**Attempt any FIVE of the following:**	**10- Total Marks**
	(a)	**Draw labeled symbol of SBS and PUT.**	**2M**
	Ans:	**Symbol: SBS**  **PUT** 	**1M each**
	(b)	**State two applications of GTO.**	**2M**
	Ans:	**Applications of GTO: (Any two)** • Variable speed motor drives.	**1M each**

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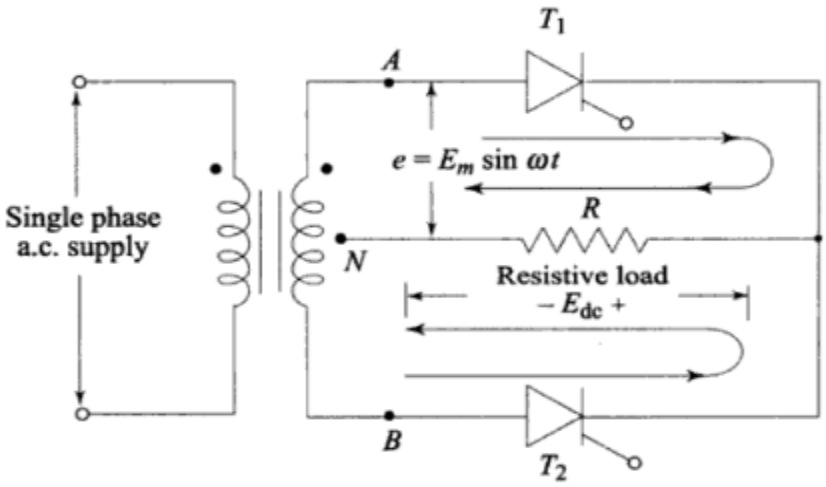
		• High power inverter. • Traction. • DC drives or DC choppers. • AC drives. • AC stabilizing power supplies. • Induction heater. • Field oriented control scheme used in rolling mills, robotics and machine tools. **(Note: Any other application may also be considered).**	
	(c)	**List the types of turn-off methods of SCR.**	**2M**
	Ans:	• Natural Commutation • Forced Commutation 1. Class A: Self commutated by a resonating load. 2. Class B: Self commutated by an LC circuit. 3. Class C: C or L-C switched by another load carrying SCR. 4. Class D: C or L-C switched by an auxiliary SCR. 5. Class E: An external pulse source for commutation. 6. Class F: AC line commutation.	**2M**
	(d)	**Draw circuit diagram of single phase center - tapped full wave controlled rectifier with R-load.**	**2M**
	Ans:		**2M**
	e)	**Define converters and state its types.**	**2M**

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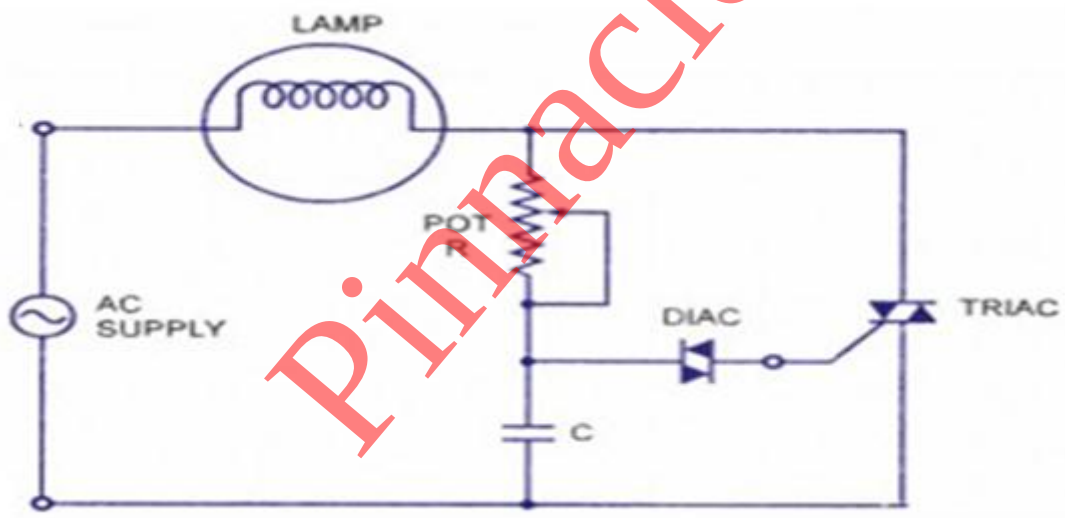
	Ans:	**Define:** A converter is a solid state device/circuit for converting electrical energy. It may be converting AC to or from DC, or the voltage or frequency, or some combination of these. **Types:** 1. Choppers. 2. Inverters.	**1M** **1M**
	f)	**Define term Inverter.**	**2M**
	Ans:	An inverter is a solid state device that converts direct current (DC) to alternating current (AC).	**2M**
	g)	**Draw circuit diagram of light dimmer using DIAC- TRIAC.**	**2M**
	Ans:		**2M**

Q. No.	Sub Q. N.	Answers	Marking Scheme
2		**Attempt any THREE of the following:**	**12- Total Marks**
	a)	**Draw V-I characteristics of SCR. Define holding current and latching current.**	**4M**

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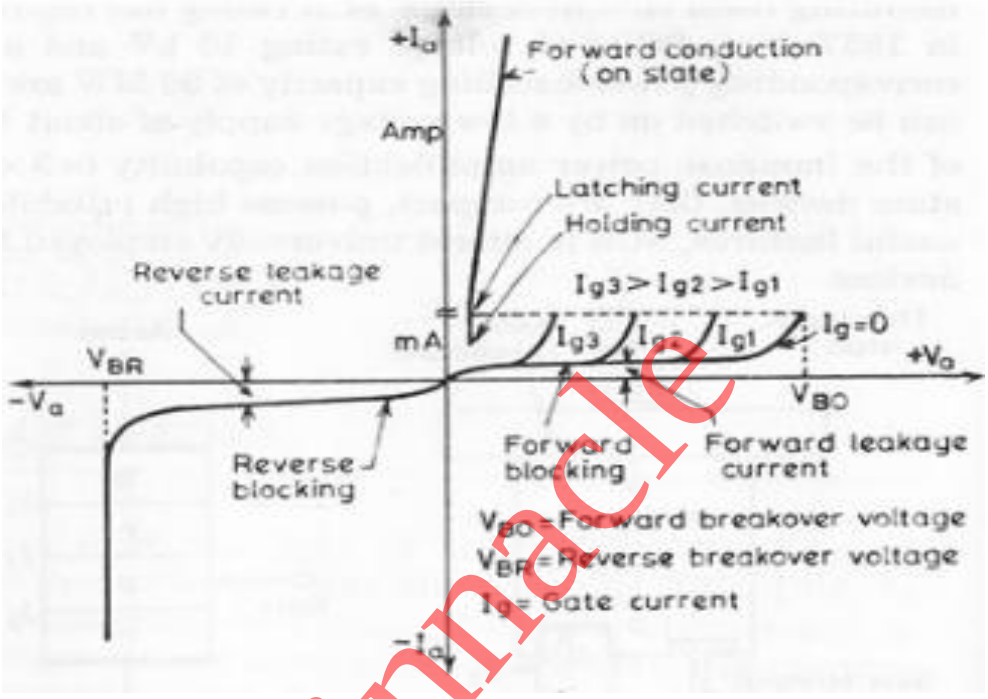
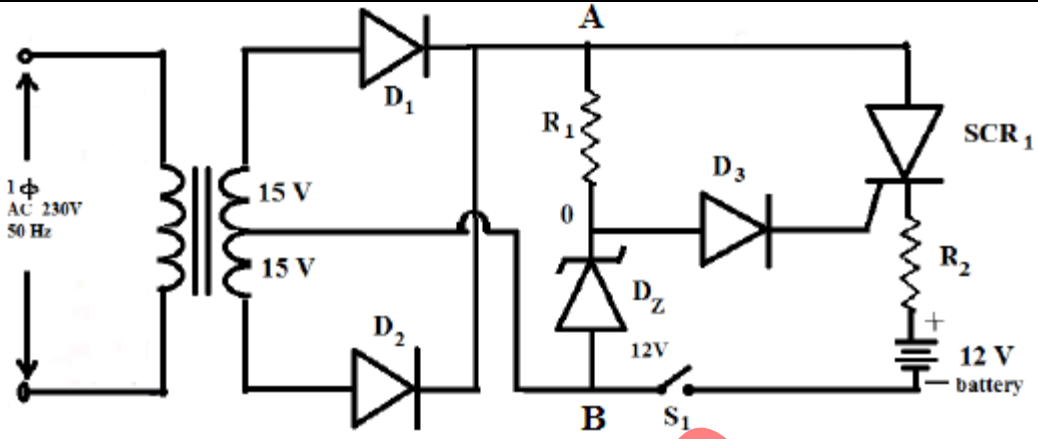
	Ans:	**V-I characteristics of SCR:**  • **Latching current**: It is the minimum anode to cathode current required to maintain the SCR in the conduction state, even when the gate signal has been removed. • **Holding current**: It is the minimum anode to cathode current required to hold the SCR in the ON state. When the anode current goes below the holding current, the device will go to OFF state.	**2M - V-I char** **1M - latching current** **1M - holding current**
	b)	**Describe the working of battery charger using SCR.**	**4M**
	Ans:	**Working :** • The figure shows the battery charger circuit using SCR. • A 12V discharged battery is connected in the circuit and switch SW is closed. The single-phase 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, as the diode D3 is forward biased, gate pulse is provided to the SCR and is turned on when a sufficient anode to cathode voltage appears.	**2M – circuit diagram**

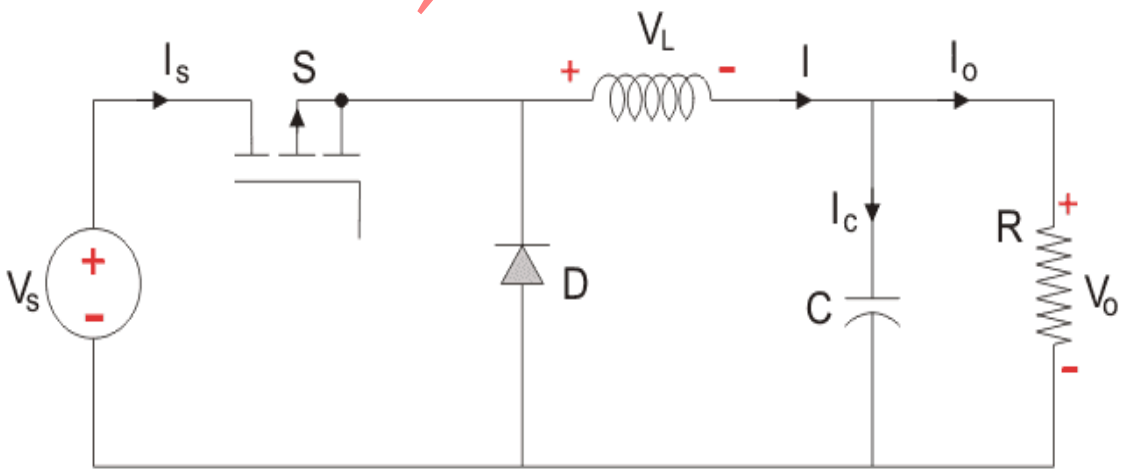


- When SCR is turned on, the charging current flows through battery. Thus during each positive half-cycle of pulsating DC supply, voltage across A-B, SCR is fired and charging current is passed till the end of that half-cycle.
- Due to Zener diode D4, the maximum voltage at point C is held at 12V. Due 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 gate-cathode junction of SCR cannot be forward biased, since the potential of point O can reach up to 12V only.
- Therefore, no gate current is supplied and SCR is not fired. In this way, after full charging, further charging is automatically stopped.

2M - working

c) Describe the working principle of step down chopper using power MOSFET. **4M**

Ans:

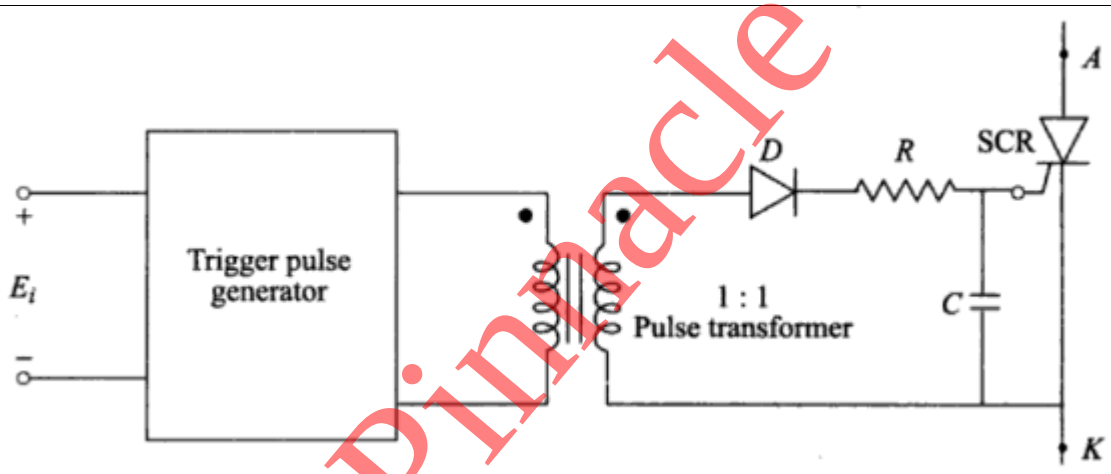


2M – circuit diagram

Working:

- When the MOSFET is turned ON, Vs directly appears across the load as shown in figure.

2M - working

		So VO = VS. • When the MOSFET is turned off, Vs is disconnected from the load. So output voltage VO = 0. • Disruption of voltage causes the inductor to induce a voltage. • The freewheeling diode provides path for load current when MOSFET is OFF. • Thus the energy stored in the inductor during the ON period is dissipated in the load resistance, and helps to maintain a constant current through the load.	
	d)	**With neat sketch describe the operation of pulse transformer used in triggering circuits of SCR.**	**4M**
	Ans:	 **Explanation:** • Pulse transformers are often used to couple a trigger pulse generator to a thyristor in order to obtain electrical isolation between the two circuits. • The transformers commonly used for thyristor control are either 1:1 two winding or 1:1:1 three winding types. • Figure shows a complete output circuit to fire a thyristor correctly. • The series resistor R either reduces the SCR holding current or balances gate current in a three winding transformer connected to two SCRs. • The series diode D prevents reverse gate current in the case of ringing or reversal of the pulse transformer output voltage. • The diodes also reduce holding current of the SCR. In some cases where high noise levels are present it may be necessary to load the secondary of the transformer with a resistor to prevent false triggering.	**2M – circuit diagram** **2M - Explanation**

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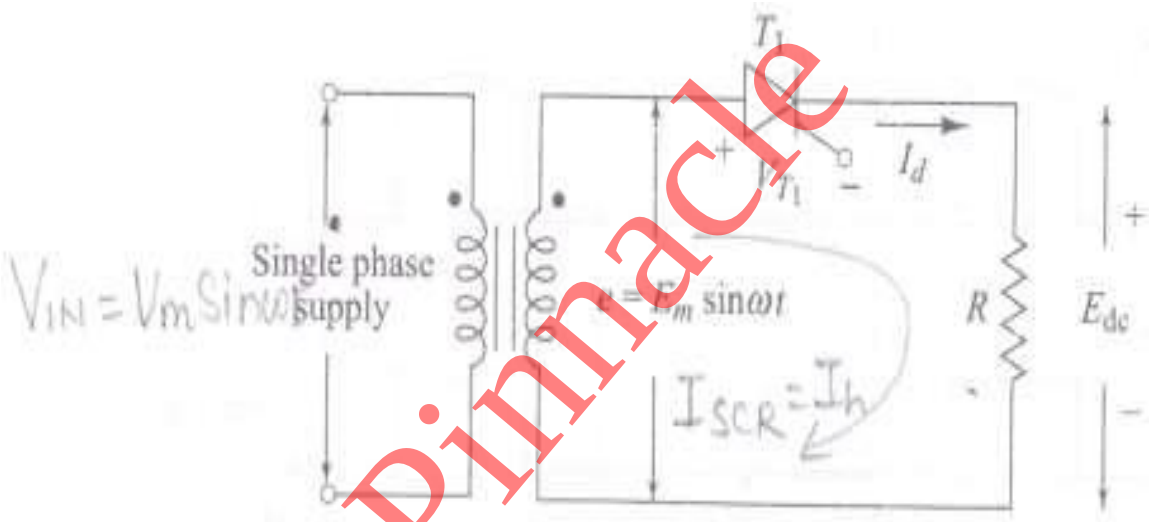
3		**Attempt any THREE of the following :**	**12- Total Marks**
	a)	**With the help of circuit diagram and waveforms explain the working of single phase half wave controlled rectifier with R-load.**	**4M**
	Ans:	**Circuit diagram:**  **Waveforms:**	**Circuit:2M explanation:1M waveforms:1M**

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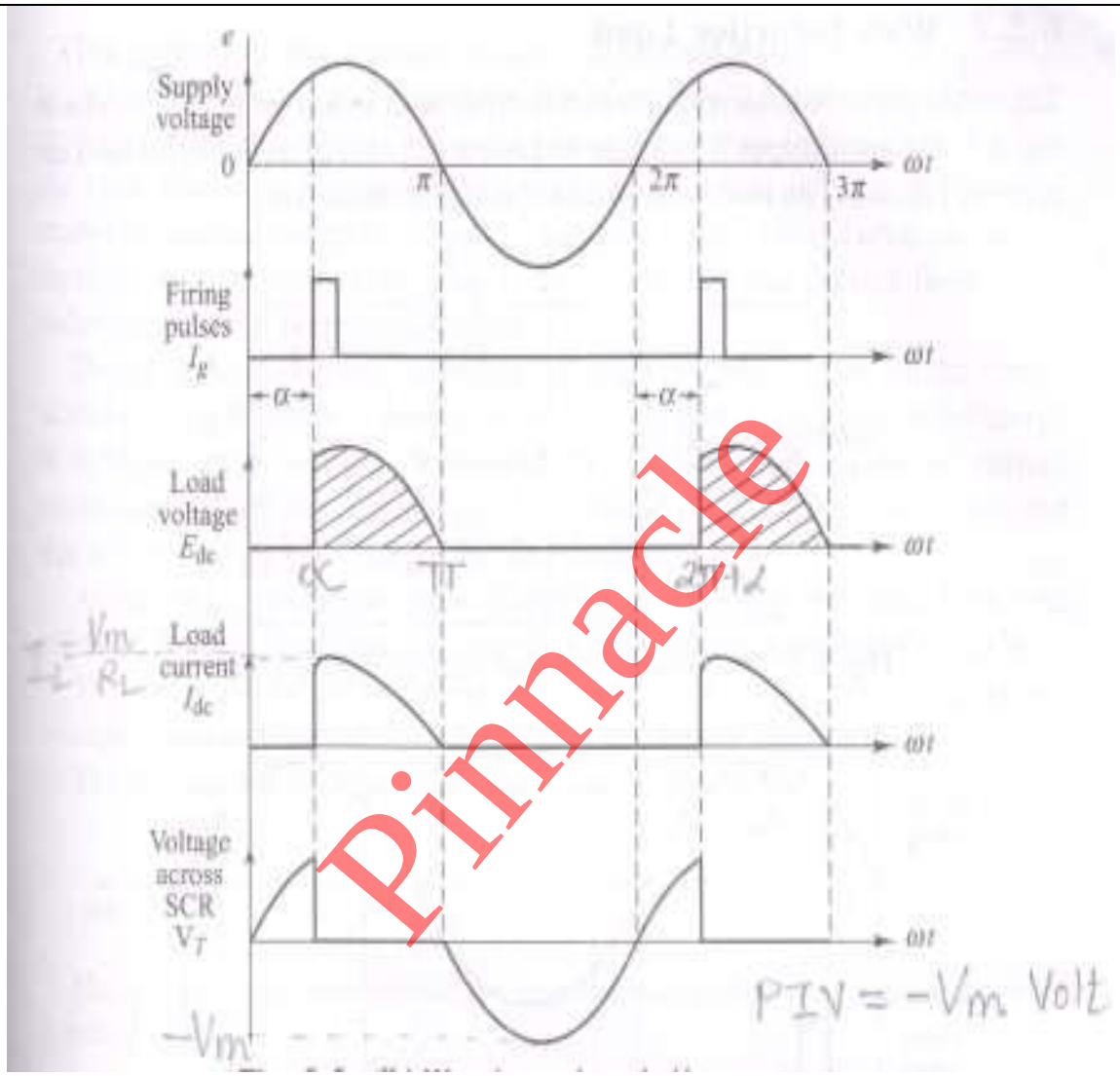

Working:-

- During the positive half cycle of input voltage, SCR is forward biased. But as Vm< VBO and gate current is not given, SCR remains off. At ωt =α sufficient gate current is given to trigger the SCR. Since voltage drop across the SCR can be neglected the entire input voltage appears across R_L.
- For the remaining entire positive half cycle, SCR is forward biased and remains ON. Hence output voltage VO is exactly same as the input voltage for the remaining positive cycle from α to π.
- During the negative half cycle, at ωt = π SCR is reverse biased and remains off. It will continue remain off in the next positive half cycle until triggered by gate current at 2π+α.

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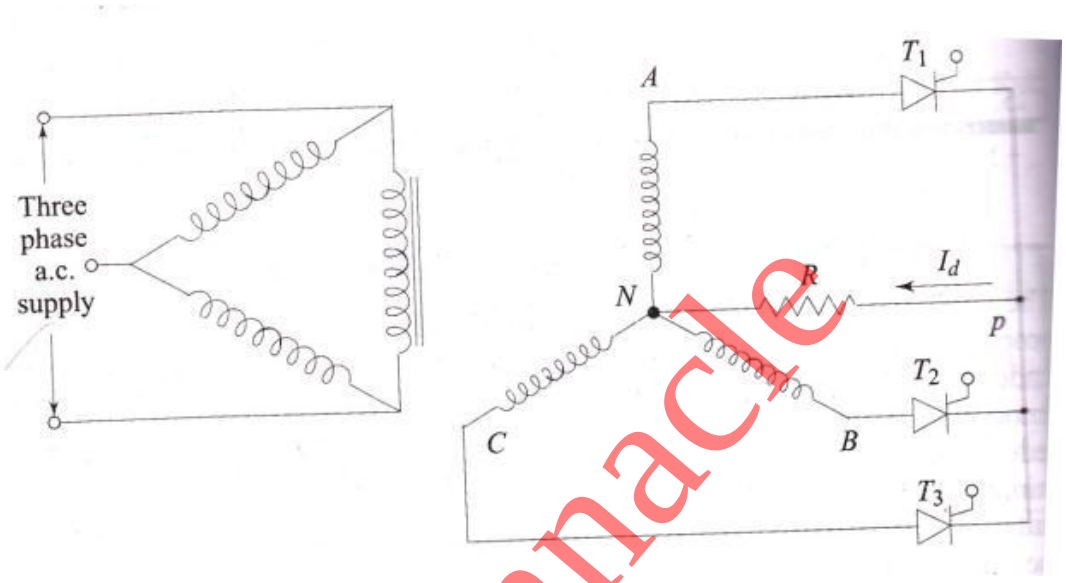
	b)	**Draw circuit diagram and input and output voltage waveforms of 3-Φ half wave rectifier with resistive load.**	**4M**
	Ans:	**Circuit diagram:-** 	**Circuit: 2M wave forms:-2M**

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		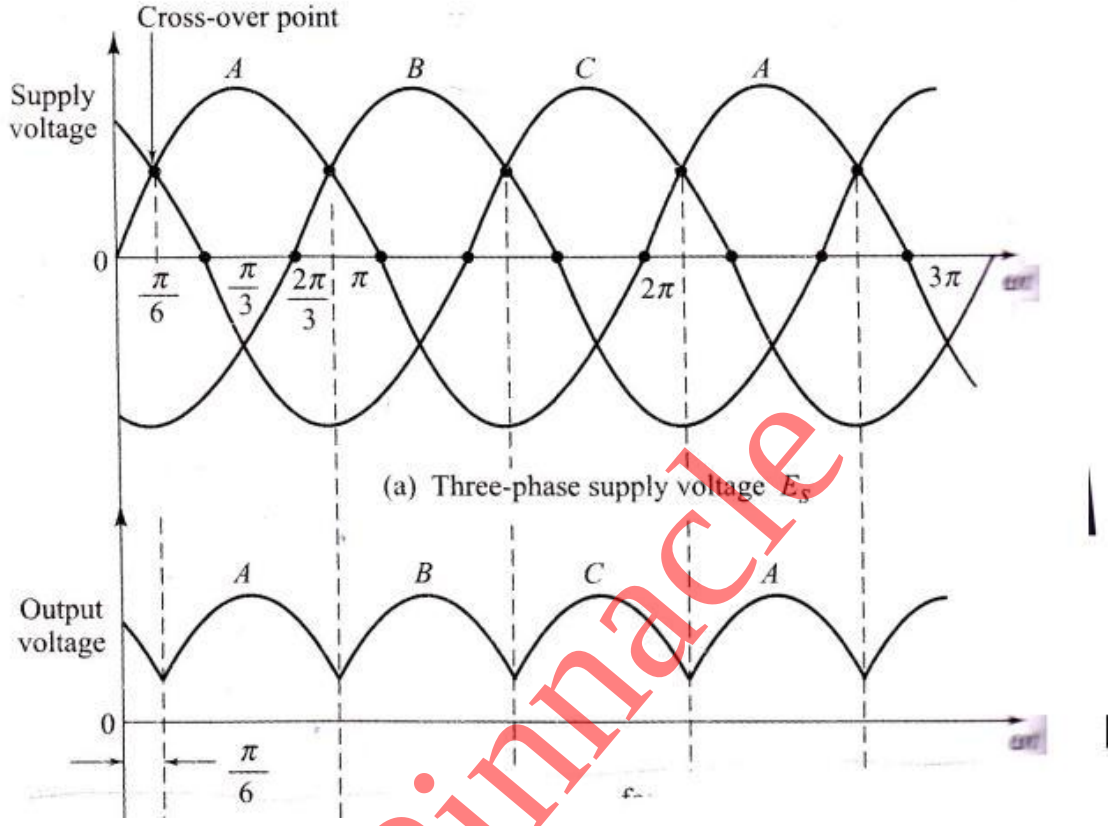 *(Note: as not specified uncontrolled rectifier also may be considered)*	
c)	**Suggest the suitable type of inverter to produce square wave output and write it's operation with neat diagram.**		**4M**
Ans:	Parallel inverter produces square wave output. **Circuit diagram:**		**Identification of inverter:1 M** **Circuit dia & wavefom: 2m operation: 1m**

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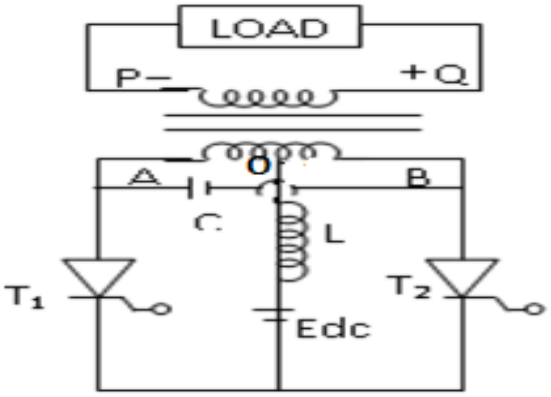
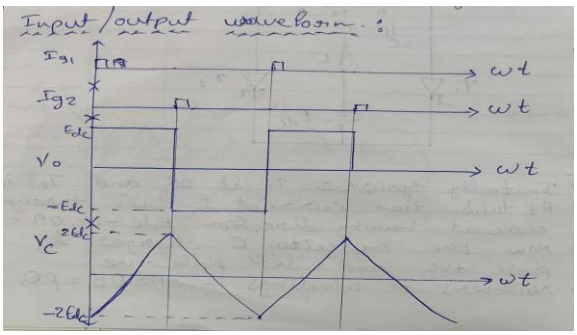


Operation:

- Initially, SCR T_1 is triggered and current flows through E_{dc}–L–0 -T_1 – E_{dc}. As the no. of turns in OA is equal to no. of turns in OB and is equal to no. of turns in PQ, the secondary voltage will be E_{dc} as shown above (Q +ve w.r.t. P)
- As the rate of change of load current remains constant, the secondary voltage also remains constant as shown below.
- Due to transformer action, capacitor is charged up to $2E_{dc}$ with right plate +ve and left plate –ve .
- When the capacitor is fully charged up to $2E_{dc}$, SCR T_2 is triggered and the capacitor potential is applied across SCR T_1. Hence SCR T_1 goes into OFF state due to voltage commutation. As SCR T_2 is conducting now current starts flowing through E_{dc} – L– O- B – T_2 – E_{dc}. Since the direction of current is reversed, the direction of load voltage is also reversed as shown below. Hence P is +ve w.r.t Q.
- Now the capacitor charges upto 2Edc with left plate +ve & right plate –ve. With this capacitor potential $SCRT_1$ is triggered. As soon as SCR comes into conduction SCR T_2 goes into off state due to voltage commutation and the cycle repeats.
- **Waveforms: (optional)**



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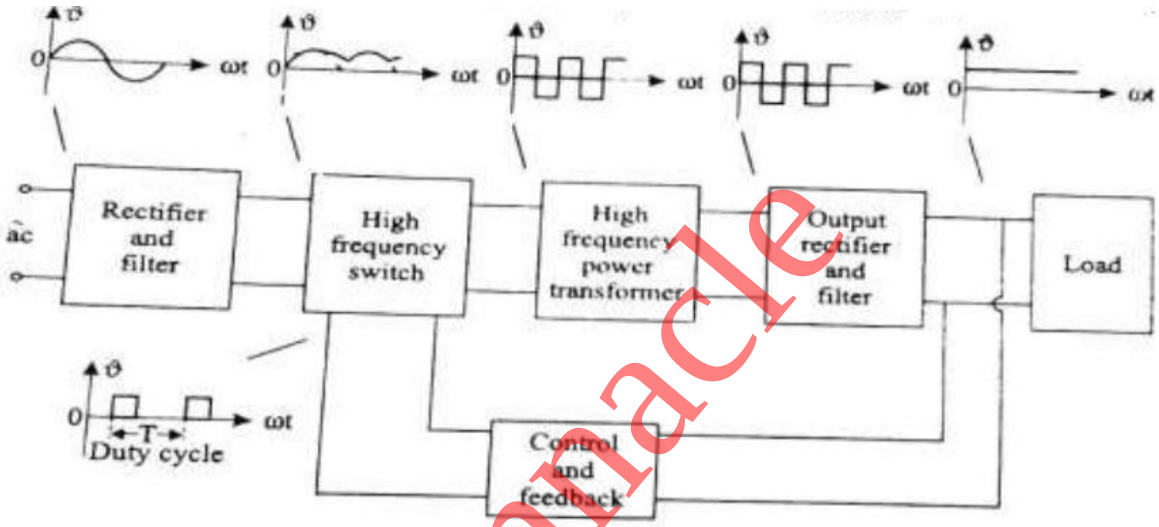
	d)	**Draw block diagram of SMPS and state function of each block.**	**4M**
	Ans:	 **Function of each Block:** • SMPS converts unregulated AC or DC voltage into a regulated voltage. • **Rectifier& Filter:** Converts Ac supply into pulsating DC which is then filtered out to reduce the ripple. • **High Frequency Switch:** It uses either MOSFETs or Power BJTs to convert the DC voltage into high frequency AC square wave. • **High frequency Power Transformer:** It provides isolation between i/p and o/p circuits & step up or step down the applied voltage to the desired level. • **Output rectifier and filter:** The high frequency AC is converted to pure DC by the rectifier and filtered before being given to the load. • **Control & Feedback Element:** It contains a pulse width modulator to vary the duty cycle of pulse to provide a controlled DC output voltage.	**Diagram:2 m function of each block : 2m**

Q.	Sub	Answers	Marking

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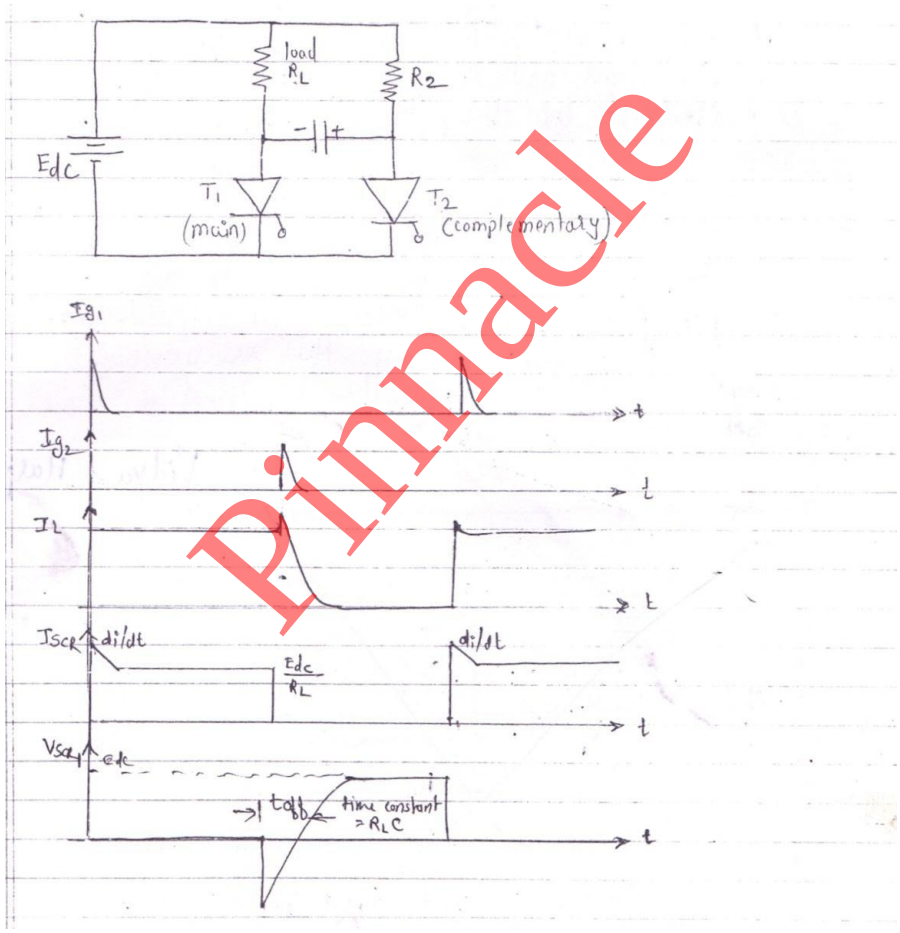
No.	Q. N.		Scheme
4		**Attempt any THREE of the following :**	**12- Total Marks**
	(a)	**Describe the working of class C commutation with neat diagram and waveforms.**	**4M**
	Ans:	**Circuit Diagram:**  Working:- • At first, when the SCR1 is triggered load current flows IL starts flowing through (Vdc+, RL, SCR1, Vdc-). • At the same time, capacitor 'C' will charge through Vdc+ , R, C, SCR1, Vdc- with right side plate positive. • When it is fully charged to Vs charging current becomes zero. • To turn off SCR1, SCR2 is triggered.	**Circuit diagram : 2M** **Working : 2M**

		• When SCR2 is turned ON the reverse voltage across 'C' is applied across SCR1, turning it OFF. • Now capacitor will start charging through Vdc+, RL, C, SCR2, Vdc- with left side plate positive. • Similarly, as SCR1 is turned ON the reverse voltage across 'C' is applied across SCR2, turning SCR2 OFF. **(Note: Waveform is optional).**	
	(b)	**A single phase fully controlled rectifier supplied with voltage V=100 sin 314t, α = 30° and load resistance is 50 Ω. Find average output DC voltage and load current.**	**4M**
	Ans:	**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	**Formula :1/2m each, Vdc:2m Idc : 1m**
	(c)	**Describe the working of step up chopper with neat circuit diagram.**	**4M**
	Ans:	**Circuit diagram:**	**Circuit:2 m working: 2m**

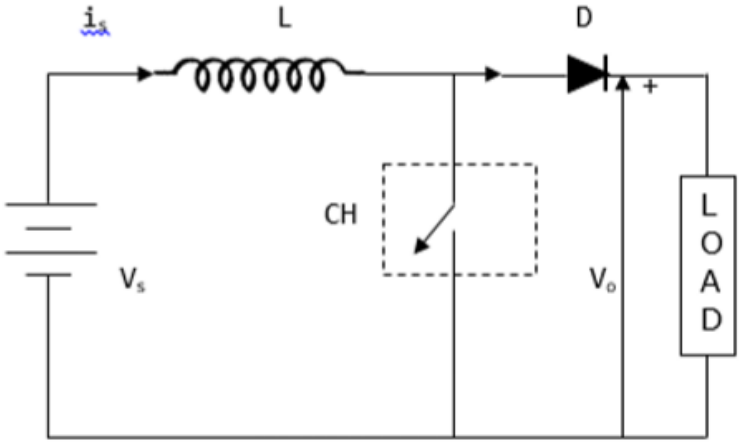


Fig shows basic step up chopper circuit when average output voltage Vdc is greater than dc input voltage Vs then it is called step up chopper.

- When switch CH is closed the current I flow through the closed path including Vs & L as shown in fig current i rises and energy is stored in inductor L during time interval Ton (T1).
- When switch CH is open, the energy stored in inductor L is transferred to the load via diode D and inductor current falls during the interval Toff (T2)
- During period T1,

$$V_L = L\, di / dt$$

- During period T2, As the current tends to decrease, polarity of the emf induced in L gets reversed so average voltage across the load is given by,

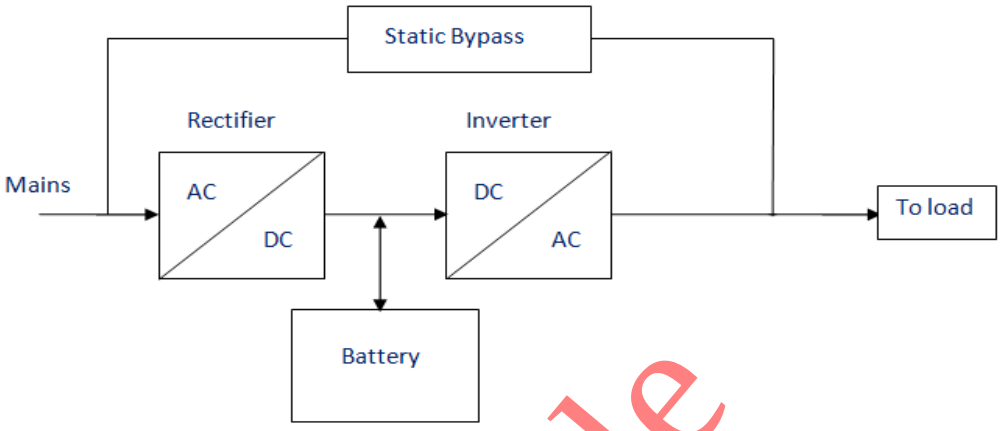
$$Vdc = Vs + L\,(di / dt)$$

- This voltage Vdc exceeds the input voltage Vs . So circuit act as step up chopper. As the duty cycle increases, output voltage also increases and is given by

$$Vdc = Vs/(1-\delta)$$

Where δ is called duty cycle . By varying δ from 0 to 1 the output voltage can be varied from Vs to infinity.

(d)	**With the help of block diagram explain working of ONLINE UPS system.**	**4M**
Ans:	**Block diagram of On line UPS:**	**Block dia:2M**

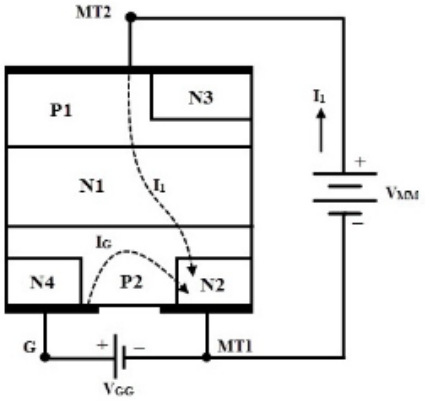


- In online UPS, the rectifier which is powered with the normal AC current is directly driving the inverter. Hence it is also known as Double conversion UPS.
- In this type of UPS, double conversion method is used. Here, first the AC input is converted into DC by rectifying process for storing it in the rechargeable battery. This DC is converted into AC by the process of inversion and given to the load.
- During normal operation when the supply mains is ON the load is directly connected through a static switch.
- When there is any power failure, the steady power stored in the battery which is connected to the inverter is given to the load by means of transfer switch.
- Once the power is restored, the rectifier begins to charge the batteries. To prevent the batteries from overheating due to the high power rectifier, the charging current is limited.

Working :2M

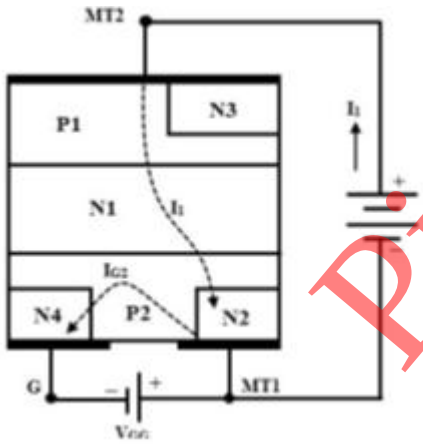
(e)	**List different Turn ON methods of SCR and explain any one in details.**	**4M**
Ans:	**SCR can be turned on by any of the following methods:** **i**. Forward voltage triggering ii. Gate triggering iii. Temperature/thermal triggering iv. Light/radiation triggering v. dv/dt triggering **dv/dt triggering :** In construction of SCR there are four layers and three junctions J1,J2& J3. Under forward bias condition junction J1 & J3 are forward biased whereas junction J2 is reverse biased. This reverse biased junction J2 behaves as a capacitor. Now if the forward voltage is applied suddenly a charging current will flow through capacitor. Thus device turns	**Methods:2m** **explanation:2m**

		on. If V = voltage applied across the device C_J = junction capacitance Then the instantaneous current is due to suddenly applied voltage is $I_C = C_J\, dv/dt$ If dv/dt is large, the device may turn-on or trigger on, even when the voltage across the device is small.	
Q. No.	Sub Q. N.	Answers	Marking Scheme
5.		**Attempt any TWO of the following:**	**12- Total Marks**
	a)	**Suggest a suitable power device having 1st and 3rd quadrant symmetrical characteristics and describe its operation with modes.**	**6M**
	Ans:	Power device having 1st and 3rd quadrant symmetrical characteristics is TRIAC There are four different operating modes of TRIAC: 1) MT2 and gate are positive with respect to terminal MT1(Mode1) : Here terminal MT2 is positive with respect to terminal MT1 current flows through path P1-N1-P2-N2.The two junctions P1-N1 and P2-N2 are forward biased whereas junction N1-P2 is blocked. The TRIAC is now said to be positively biased. A positive gate with respect to terminal MT1 forward biases the junction P2-N2 and the breakdown occurs as in a normal SCR.	**2 Marks** **(Each mode 1 Mk)**



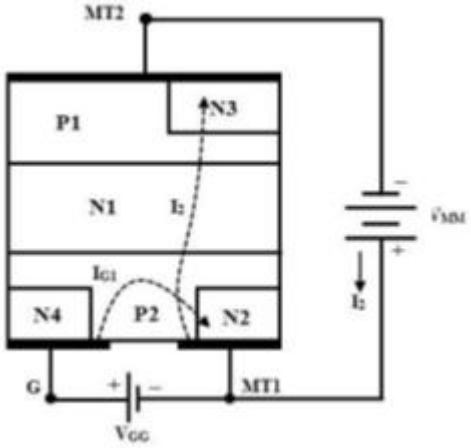
2) MT2 is positive but gate is negative with respect to terminal MT1(Mode2):

Though the flow path of current remains the same as in mode 1 but now junction P2-N3 is forward biased and current carriers injected into P2 turn on the TRIAC.



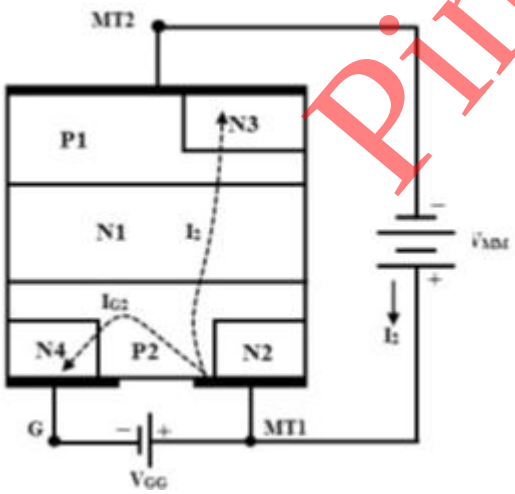
3) MT2 is negative but gate is positive with respect to terminal MT1(Mode3) :

Though the flow path of current remains the same as in mode 3 but now junction P2-N2 is forward biased, current carriers are injected and therefore, the TRIAC is turned on.



4) MT2 and gate are negative with respect to terminal MT1(Mode4) :

When terminal MT2 is negative with respect to terminal MT1, the current flow path is P2-N1-P1-N4. The two junctions P2-N1 and P1 – N4 are forward biased whereas junction N1-P1 is blocked. The TRIAC is now said to be negatively biased. A negative gate with respect to terminal MT1 injects current carriers by forward biasing junction P2-N3 and thus initiates the conduction.



(Note: DIAC also can be considered)

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

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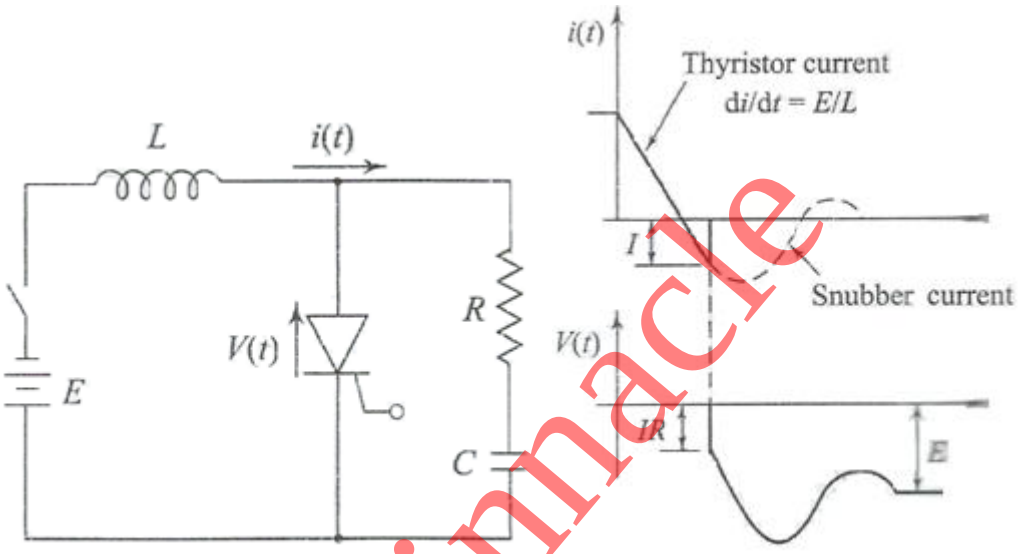
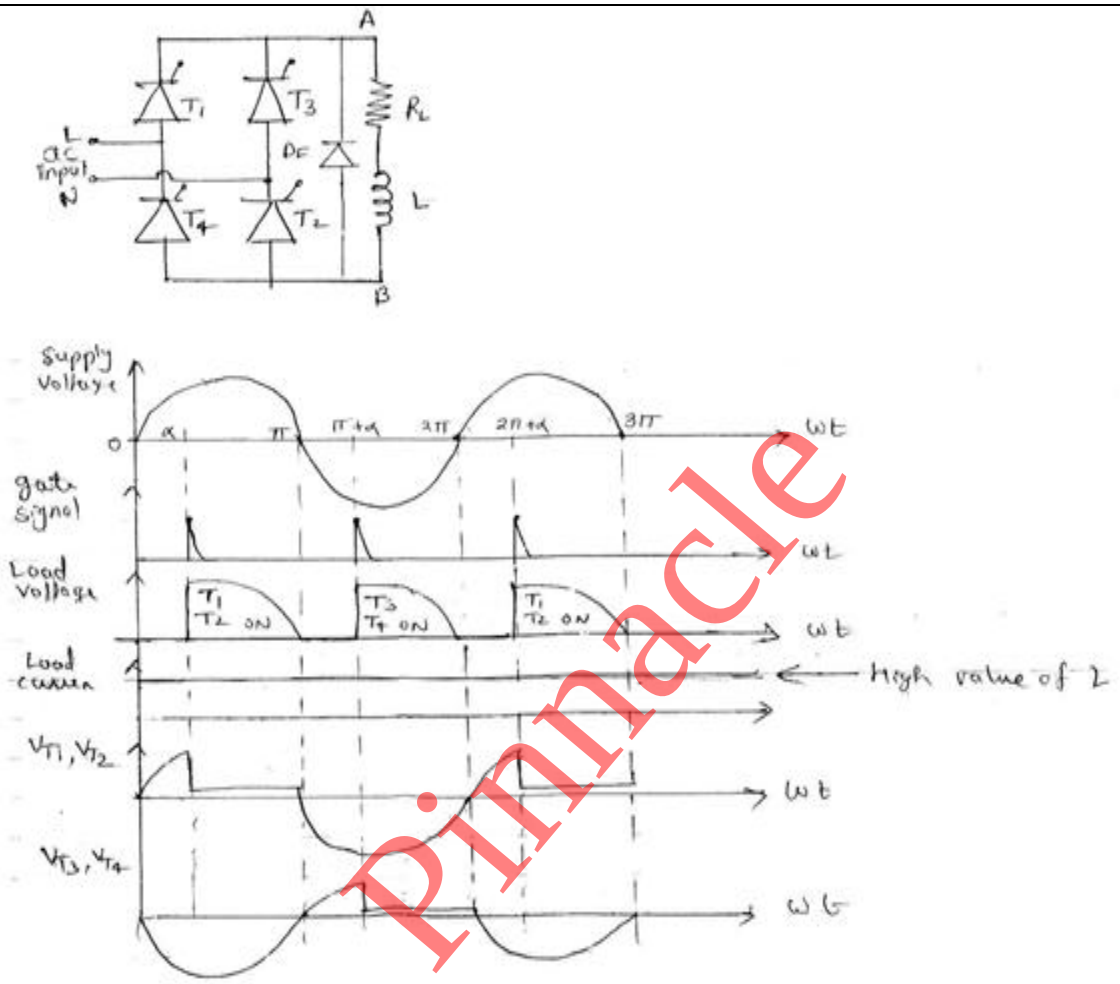
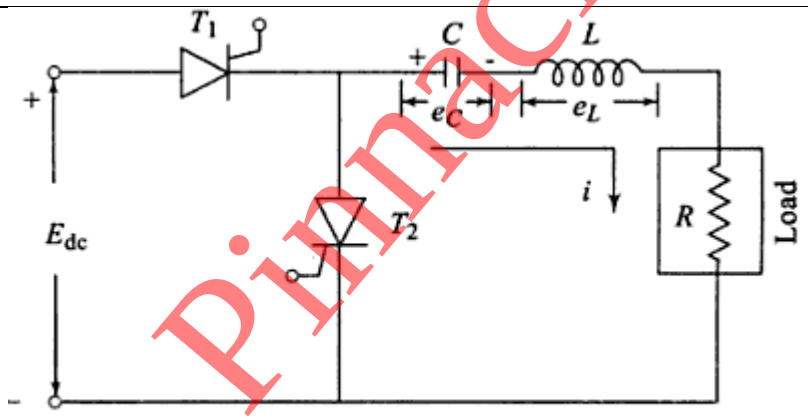
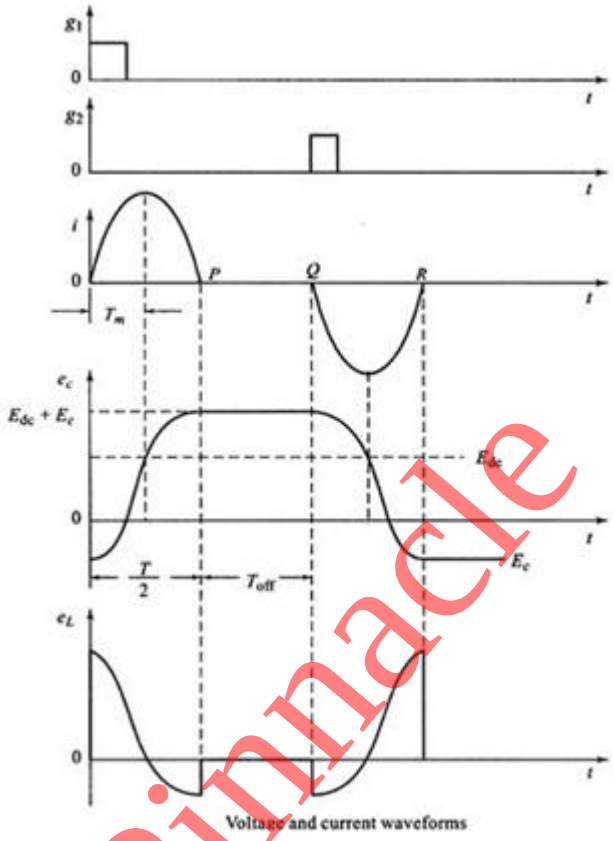
	Ans:	**Need of protection circuit:** In most Power electronic circuits, protection is necessary against the effects of excessive rate of rise of forward voltage (dv/dt) across the devices, which can otherwise cause unintended break over, leading to malfunction of the circuit and possible failure of the devices.  **Working:** 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. When Thristor T1 turns on, the snubber capacitor C discharges in to the SCR. But resistor R limits the discharge current and prevents excessive di/dt at turn on. Thus, the presence of resistor impairs the forward dv/dt limiting performance of the snubber. This also consist an inductance in series with the SCR to prevent a high di/dt.	**NEED-2 Mks** **Diagram-2Mks** **Description -2 Mks**
	c)	**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:	 Effects of freewheeling diode : With a freewheeling diode connected in a controlled rectifier with RL load, the thyristor will not be able to conduct beyond 180^0 (a problem with RL load). During negative half-cycle as the current changes its direction, emf is induced in the inductor. This energy is dissipated in the load resistance through the freewheeling diode. Hence at 180^0, current through the SCR is cut-off and a reverse voltage appears across the SCR turns it OFF instantly. Its effects in the circuit can be, (i) The load voltage does not become negative and hence gives more average d.c. output voltage than without freewheeling diode. (ii) Load current becomes continuous i.e. ripple free.	Diagram-2Mks, Description -2 Mks, Input Output Waveform-2Mks)

		(iii) It prevents reversal of load voltage. (iv) Input power factor is improved.	
Q. No.	Sub Q. N.	Answers	Marking Scheme
6.		**Attempt any TWO of the following :**	**12- Total Marks**
	a)	**Describe the working of series Inverter with neat diagram and state its two applications.**	**6M**
	Ans:	 Circuit diagram	**(Diagram-2 Mks, Working -2Mks, 2 Applications-2 Mks)**



Voltage and current waveforms

(Note: Waveform optional)

Working:

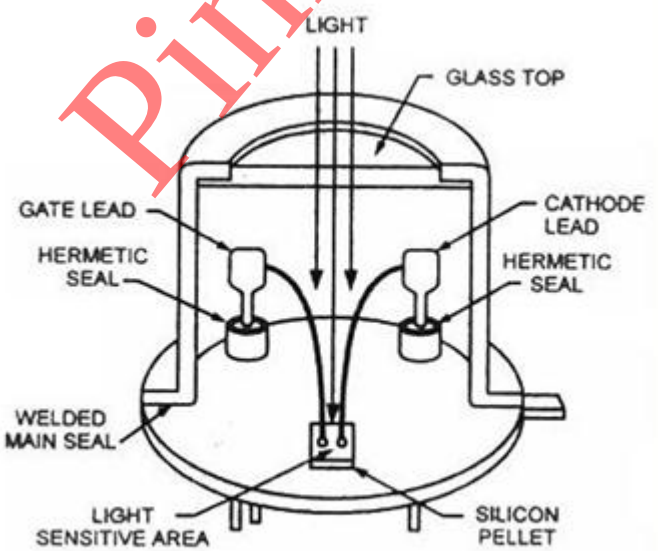
· When T1 is triggered the capacitor starts charging with left side plate positive with respect to right and when the voltage on capacitor is slightly greater than Edc T1 turns off; but there is no discharge path for capacitor hence it holds the charge.

· When trigger pulse is applied to T2, T2 start conducting and current starts flowing in opposite direction.

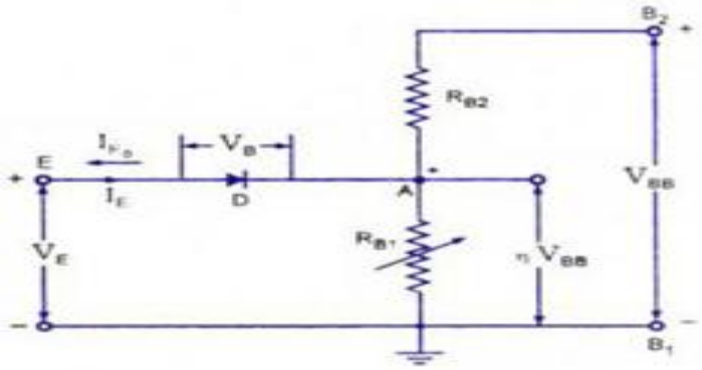
· In this way due to charging and discharging of capacitor and switching of T1 and T2 current will flow in RC circuit. Hence sinusoidal current starts flowing in the load.

Applications:

a. Uninterrupted power supply (UPS).

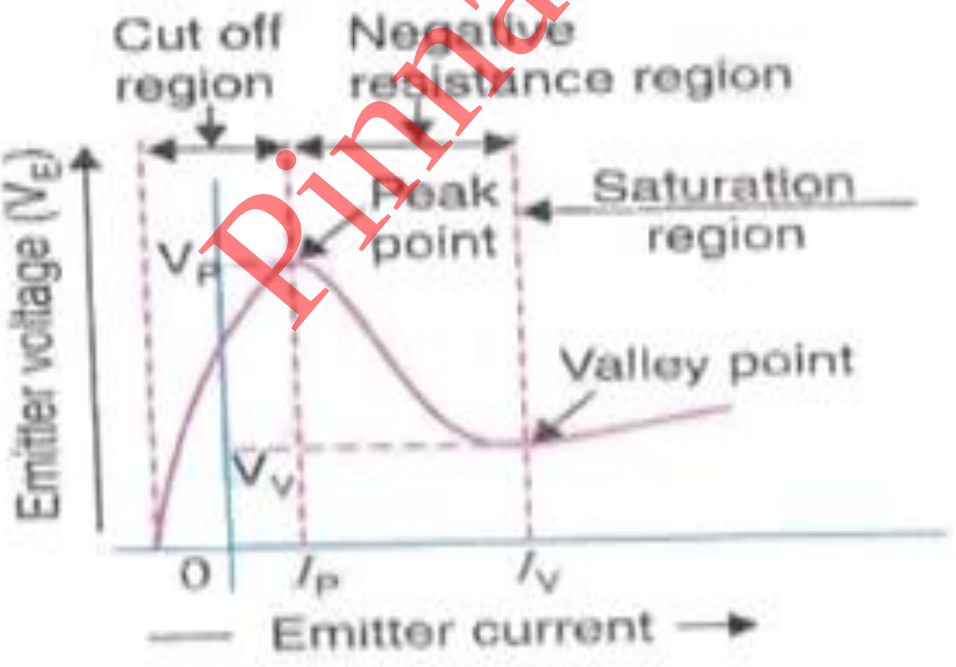
		b. AC motor speed controller. c. Centrifugal fans and pumps. d. Conveyors. e. Induction heating. f. Aircraft power supply g. High voltage DC transmission lines h. Battery vehicle drives. i. Regulated voltage and frequency power supplies	
	b)	**Describe the working of LASCR with it's constructional diagram and state its two industrial applications.**	**6M**
	Ans:	 *Basic Construction* **Working:** i) LASCR is turned on by direct radiation of light on the silicon wafer.	**(Construction Diagram -2 Mks ,** **Working -2Mks,** **2 Applications-2 Mks)**

		ii) Electron hole pairs created due to radiation produce triggering gate current under the influence of electric field. iii) The gate structure is designed to provide sufficient gate sensitivity for triggering from practical sources (e.g. LED). iv) Once the LASCR is triggered to ON state, it behaves like a normal SCR. v) LASCR will stay ON even if the light disappears, it will turn OFF only if its anode current is decreased below IH. **Applications of LASCR** 1) light coupling 2) Triggering circuits 3) Photoelectric control 4) Relays 5) Motor speed control 6) Used in computer 7) Used in high voltage dc transmission (HVDC) 8) Static reactive power or volt ampere reactive (VAR) compensation.	
	c)	**With help of circuit diagram and V-I characteristics, explain working principle of UJT and state it's two applications.**	**6M**
	Ans:	**Circuit diagram:**	**Circuit Diagram -2Mks ,** **V-I characteristics - 1Mks ,** **Working**



Equivalent Circuit of a UJT

V-I Characteristics:



Working principle:

As long as V_E is less than V_A , diode D will be reverse biased and UJT is switched OFF. When the emitter voltage exceeds V_A by a threshold voltage V_D, UJT starts conducting. This voltage is called peak point voltage, Vp.

principle 1M,

Applications-2 Mks

		$Vp = V_x + V_D = \eta V_{BB} + V_D$ $\eta = \frac{R_{B1}}{R_{BB}}$ $R_{BB} = R_{B1} + R_{B2}$ Once the UJT is ON resistance R_{B1} reduces rapidly. Decrease in R_{B1} causes Vx to decrease and I_E increases. **APPLICATIONS:** 1) Triggering device for SCR's and TRIAC's 2) Non sinusoidal oscillators 3) Saw-tooth generators 4) Timing circuits	