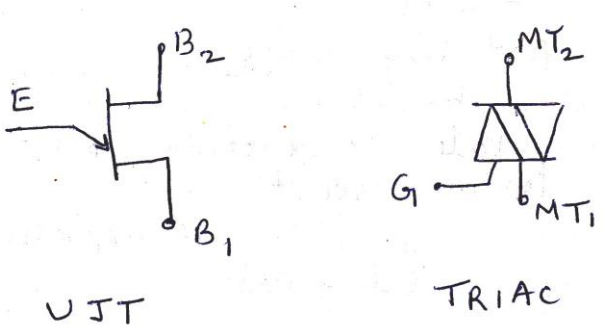
Important Instructions to examiners:

1) The Answer 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.
   The language errors such as grammatical, spelling errors should not be given more Importance (Not applicable for subject English and Communication Skills.
3) 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.
4) 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 Answer and model Answer.
5) In case of some questions credit may be given by judgment on part of examiner of relevant Answer based on candidate's understanding.
6) For programming language papers, credit may be given to any other program based on equivalent concept.

Q1 Answer any SIX of the following :- **(12 Marks)**

i) Draw the symbols of : 1) UJT 2) TRIAC

Answer: **(1M each)**



ii) State two advantages of IGBT.

Answer: **(any two: 2M)**

- High input impedance
- No second breakdown
- Low on-state conduction loss
- Simple driver circuit
- High power, high frequency application
- Large safe operation area.

iii) List two applications of TRIAC

Answer: **(any two 2M)**

- Phase control circuits
- Liquid level control
- Power switches
- Temperature control circuits
- Speed control of large fans and motors.
- In light dimmer circuit

iv) Write classification of choppers

Answer: **(each type 1M)**

1) Chopper are classified as

a) Step up chopper

b) Step down chopper

2) According to the direction of output voltage and current.

I. Class A(type A)
II. Class B (type B)
III. Class C (type C)
IV. Class D (type D)
V. Class E (type E)

3) According circuit operation

i) First quadrant chopper
ii) Two quadrant chopper
iii) Four quadrant chopper

4) According to commutation method

i) Voltage commutated
ii) Current commutated
iii) Load commutated
iv) Impulse commutated

v) What are the limitations of R triggering circuit?

Answer: **(2M)**

i) The firing angle is limited to 90^0
ii) The firing angle changes due to fluctuation in input voltage supply, Variation in temperature.

vi) List application of inverters.(any four)

Answer: **(any four 2M)**

- Variable speed a c motor drivers
- Induction heating
- Aircraft power supplies
- Uninterrupted power supplies (UPS)
- High voltage d c transmission lines
- Battery vehicles drives
- Regulated voltage and frequency power supplies

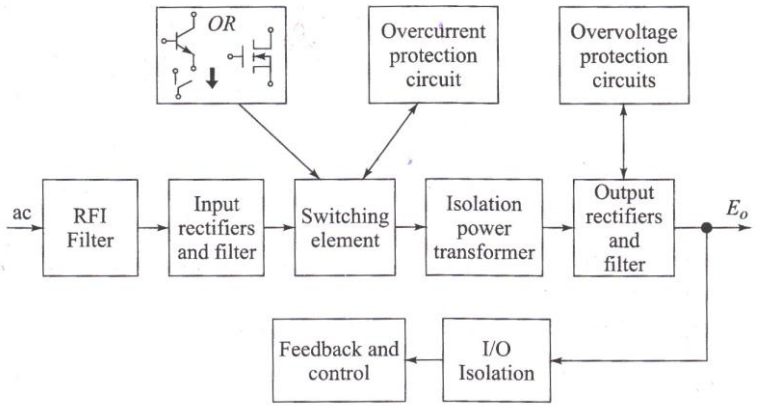
vii) State the need of polyphase rectifiers.

Answer: **(any two 2M)**

i) Output power is more
ii) Ripple factor is less
iii) Efficiency is high

viii) Draw the block diagram of SMPS and label it.

Answer: **(2M)**



b) Answer any Two of the following :- (8 Marks)

i) A single phase full controlled bridge rectifier is supplied with voltage v =230 sin (314 t); and is delivering power to a resistive load. Find the average output voltage, if the firing angle $\alpha=45^0$

Answer: (4M)

$v = 230 \sin(314t)$

$\alpha = 45°$

Average dc. o/p voltage $= \frac{V_m}{\pi}(1+\cos\alpha)$

$V_m = 230\,V \quad \therefore V_{dc} = \frac{230}{\pi}(1+\cos 45°)$

=125 Volts

ii) Define inverter. Give classification of inverters

Answer: (Definition 1M, Classification 3M)

Inverter is a circuit which converter d.c power into a.c power at desired output voltage and frequency

They are classified as

i) According to nature of input source
- Voltage source inverter (VSI)
- Current source inverters (CSI)
- Current source inverter (CSI)

2) According to the wave shape of the output voltage.
- Sine wave inverter
- Square wave inverter
- Quasi square wave inverter
- Pulse width modulated inverter

3) According to the wave inverter
- line commutated inverter
- forced commutated inverter

4) According to the connection of thyristor and commutation components
- Series inverter
- Parallel inverters
- Bridge inverters which are further classified as half bridge and full bridge.

5) According to the semiconductor device used
   - Thyristorised inverter
   - Transistorized inverter
   - MOSFET based inverter
   - IGBT based inverter

iii) Define the following terms with respect to inverters.

1) **Harmonic factor of n^{th} harmonic**
2) **Total harmonic distortion**
3) **Distortion factor**
4) **Lowest order harmonics.**

Answer: **(Each definition 1M)**

1) **Harmonic factor of n^{th} harmonic -:**
   It is defined as the ratio of the rms voltage of a particular harmonic component to the r.m.s value of fundamental component.

OR

$$H_{F_n} = \frac{E_{n\,rms}}{E_{1\,rms}}$$

2) **Total harmonic distortion -:** it is a measure of closeness in a shape between the output voltage waveform and its fundamental component.

OR

$$THD = \frac{\sqrt{\sum_{n=2,3,\ldots}^{\infty} E_{n\,rms}^2}}{E_{1\,rms}}$$

$$= \sqrt{\frac{E_{0\,rms}^2 - E_1^2}{E_1}}$$

It is defined as the ratio of the rms value of its total harmonic component of the output voltage and the rms value of the fundamental component.

OR

3) **Distortion factor -:** It indicates the amount of harmonies that remain in the output voltage waveform after the waveform has been subject to second order attenuation

OR

$$DF = \sqrt{\frac{\sum_{n=2,3,\ldots}^{\infty} \left(\frac{E_{n_{rms}}}{n^2}\right)^2}{E_{1_{rms}}}}$$

4) **Lowest order harmonics -:** It is the lowest frequency harmonic with a magnitude greater than or equal to 3% of the magnitude of the fundamental component of the output voltage.

Q2 Attempt any four of the following: (16 Marks)

a) Define firing angle and conduction angle. What is the effect of firing angle on average output voltage?

Answer: (Definition 2M, Effect 2M)

Firing angle (α) is the angle of sine wave at which SCR is turned ON

This varies from 0 to 180^0

Conduction angle (β) is the angle for which SCR remains on .

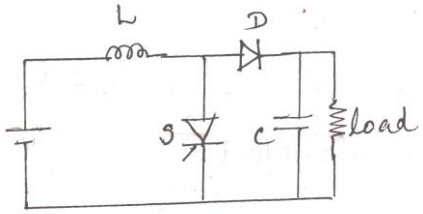
$\beta = \pi - \alpha$

When SCR is used in a rectifier, load voltage is 0 if SCR is OFF. Load voltage is equal to input voltage when SCR in ON.

As firing angle increase average voltage decreases.

b) Draw the circuit diagram of step up chopper. State its operating principle.

Answer: (circuit diagram 2M, operating principle 2M)



In a step up chopper the average output voltage is greater than the supply voltage. When the SCR switch is closed, current through the inductor increases and energy gets stored in the inductor.

When the switch is open a back emf across the inductor comes in series with supply voltage. Output is received from the inductor as well as the input supply.

$$The\ load\ voltage = V_{D=V_{dc+L\frac{di}{dt}}}$$

$V_{D=\frac{Vdc}{1-D}}$ Where D is duty cycle.

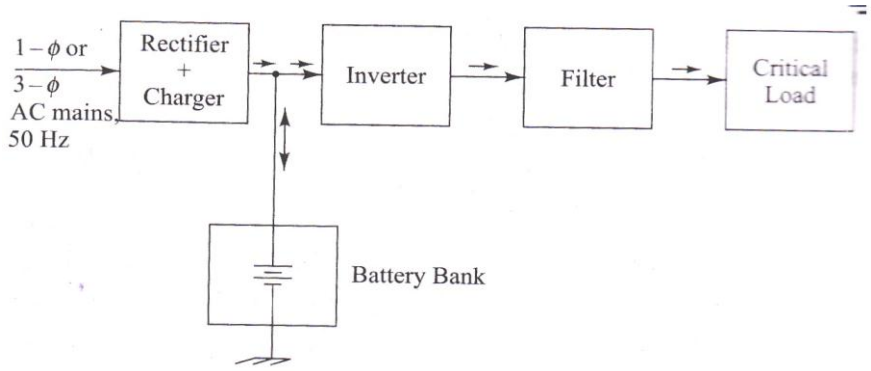
For D=0 , V0=Vdc

For D=1 , Vo = ∞

To ensure a constant and continuous output voltage a large value of capacitor filter is connected across the load.

c) Draw the block diagram of UPS. State the function of each block.

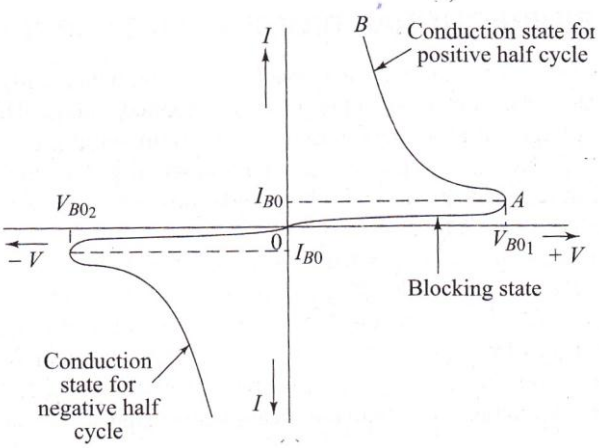
Answer: **(Block diagram 2M, function 2M)**



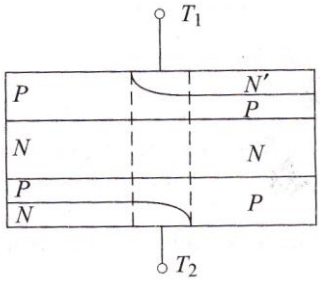
A rectifier converts a single- phase or three- phase a.c voltage into dc. Which supplies power to the inverter as well as the battery bank (to charge it)? The inverter gets a d c input voltage from the rectifier when the ac main is ON, and from the battery bank when the a.c mains is OFF. Inverter converts this d.c voltage into a.c voltage and through a suitable filter applies it to the load. If the PWM inverter is used, then the filter can be eliminated. A static switch will connect or disconnect the battery form the input of the inverter depending on the status of a.c mains.

d) Draw the constructional details of DIAC. draw the VI characteristics of DIAC

Answer: (constructional details 2M, VI characteristics 2M)



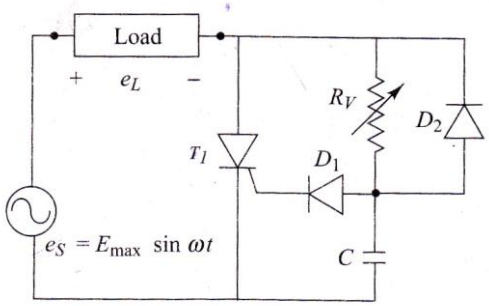
VI characteristics of DIAC



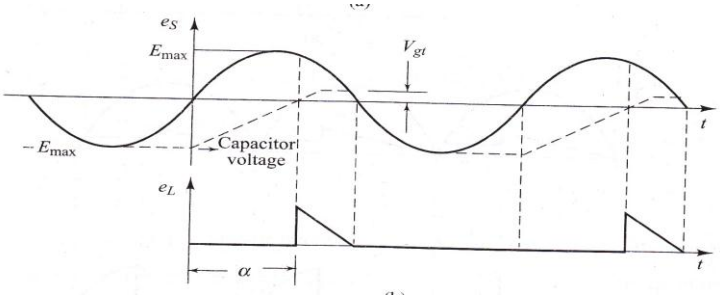
Constructional Details

e) Draw the circuit diagram of full wave RC triggering circuit to turn ON the thyristor. Draw the waveforms of input voltage and output voltage.

Answer: (circuit diagram 2M, waveforms 2M)



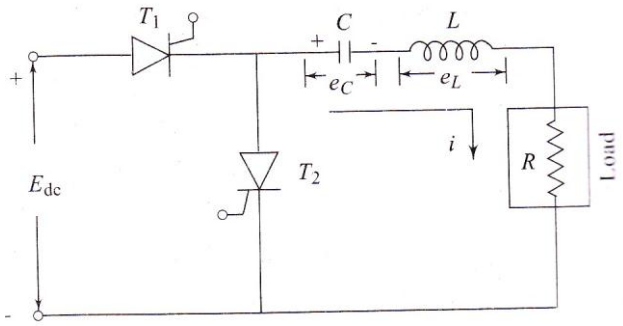
Circuit diagram

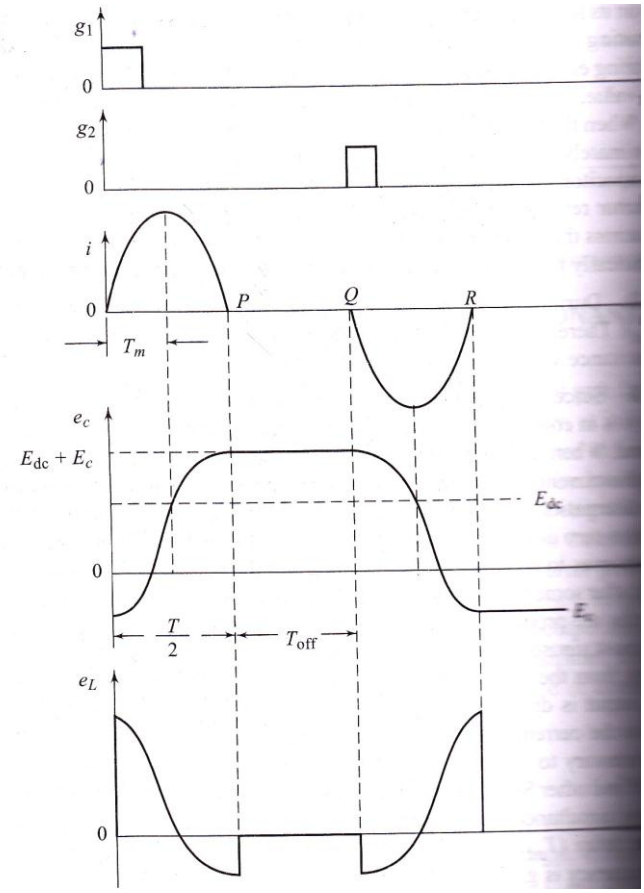


Waveforms

f) Draw the circuit diagram of series inverter. Draw the input and output waveforms

Answer: **(circuit diagram 2M, waveforms 2M)**



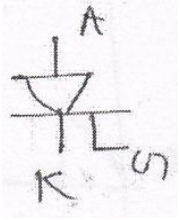
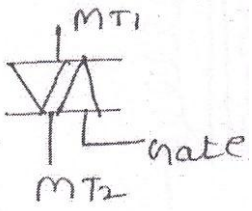
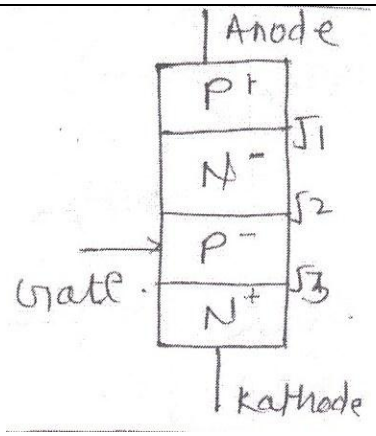
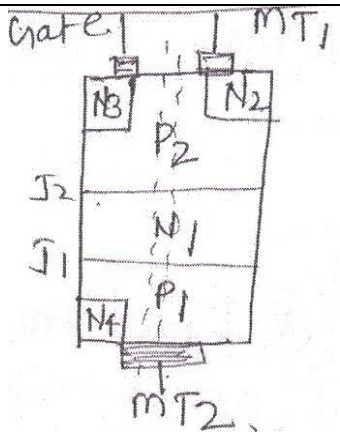


Q3) Answer any four of the following:- **(16 Marks)**

a) Differentiate between SCR and TRIAC on the basis of:

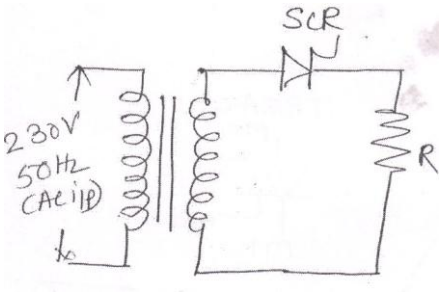
- Symbol
- Layered diagram
- Operating quadrant and
- Application

Answer: - **(one point one Mark)**

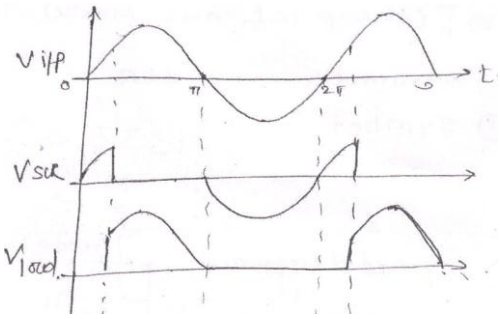
Parameter	SCR	TRAIC
• **Symbol**		
Layered daigram		
Operating quadrant	Only 1st quadrant	Depending upon supply either 1st quadrant or 3rd quadrant.
Application	Controlled Rectifies, in inverters, Battery charger, speed control of DC and AC motors.	As a static switch fans Regulator, lamp dimmer, in AC voltage stabilizer.

b) Draw the circuit diagram of single phase half wave controlled rectifier with R load. Draw the waveforms of input voltage, load voltage and voltage across SCR.

Answer: - Circuit Diagram: (ckt diagram 1Mark, each W/F 1Mark)

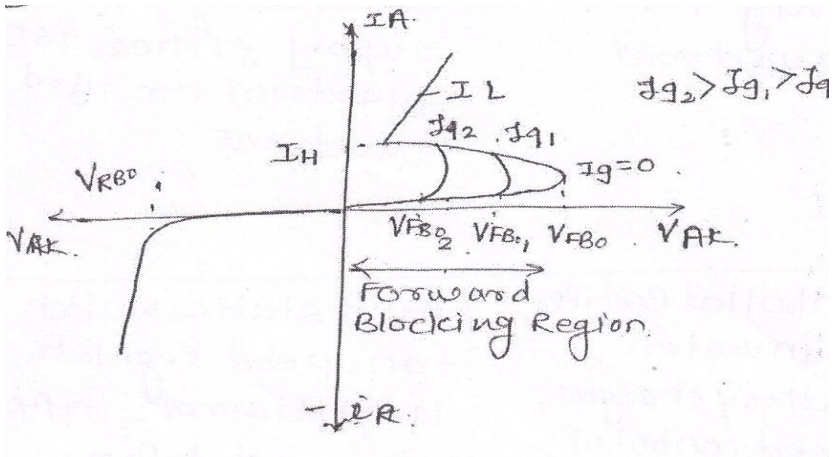


Waveform Diagram:



c) Draw the VI characteristics of SCR. State the effects of gate current on the break over voltage.

Answer:- (VI characteristics 3M, effect 1M)



I_L = Latching current.

I_H = Holding current.

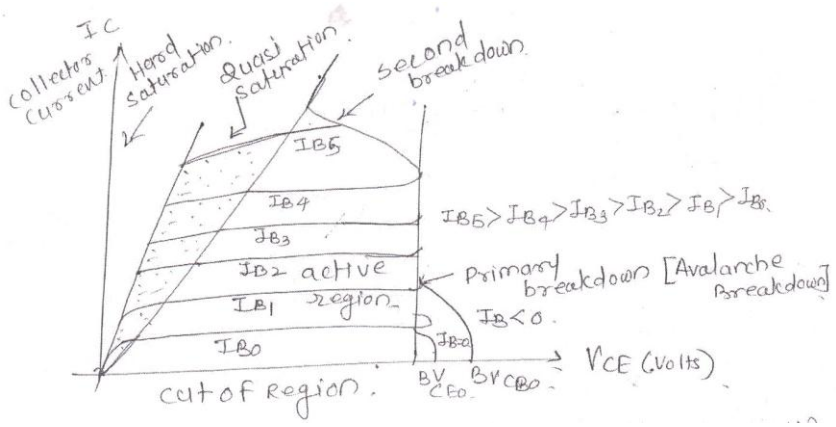
VFB_O = Forward Break over voltage at Zero gate.

VRB_O = Reverse Break down voltage.

Effects of Gate current: As the value of gate current (Figure) increases, the value of Forward Break over voltage decreases.

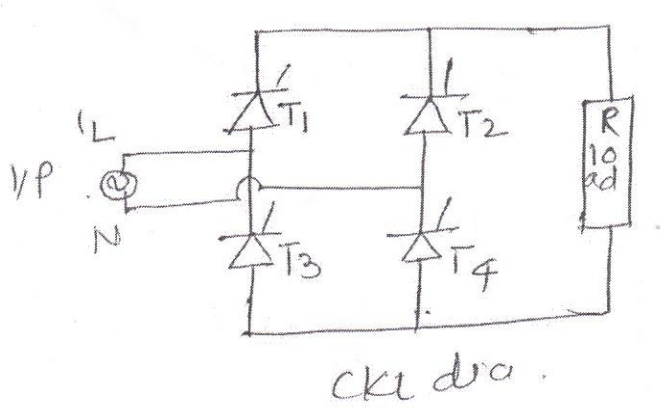
d) Draw the VI characteristics of power transistor. Label different region.

Answer:- **(Diagram 4 Mark with label)**

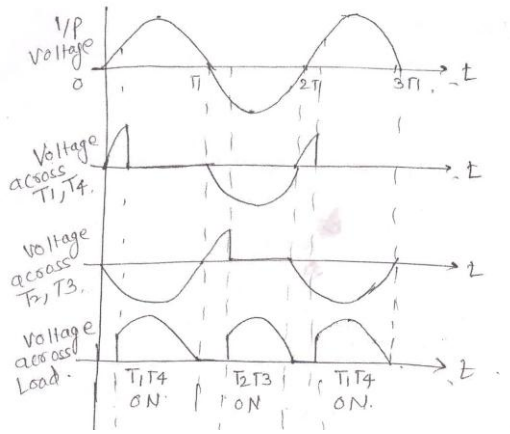


e) Draw the single phase full wave bridge type controlled rectifier. Draw the waveforms of input voltage, Load voltage and voltage across SCR.

Answer:- Circuit Diagram: **(ckt Diagram 1 Mark, each W/F 1 Mark)**



Waveforms:



f) Differentiate between controlled and uncontrolled rectifiers. (Any four points)

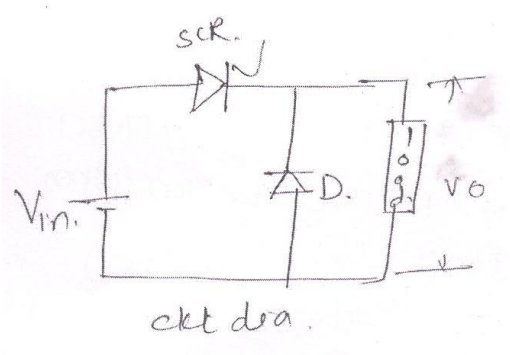
Answer: - **(Any 4 points 4 Mark)**

Parameter	Controlled Rectifier	Uncontrolled Rectifier
Device used	SCR and Diodes.	Only Diodes.
Control of Load Voltage	Load voltage can be controlled.	Load voltage cannot be controlled.
Direction of Power Flow	Source to load and sometimes load to source.	Source to load only.
Free Wheeling diode	Required if inductive load.	Not necessary.
Triggering circuit	Required.	Not required.
Application	DC motor controller, Battery chargers.	Power supply.

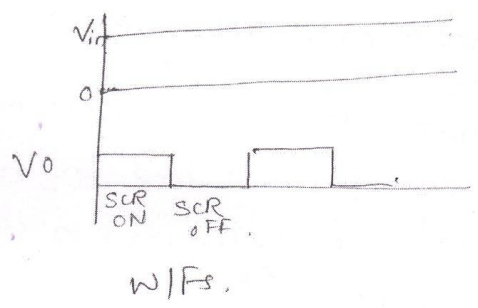
Q4) Answer any Four of the Following:- **(16 Marks)**

a) Draw the circuit diagram of step down chopper. Draw the input output waveforms.

Answer:- Circuit Diagram: **(2 Mark for ckt, 2Mark for W/Fs)**

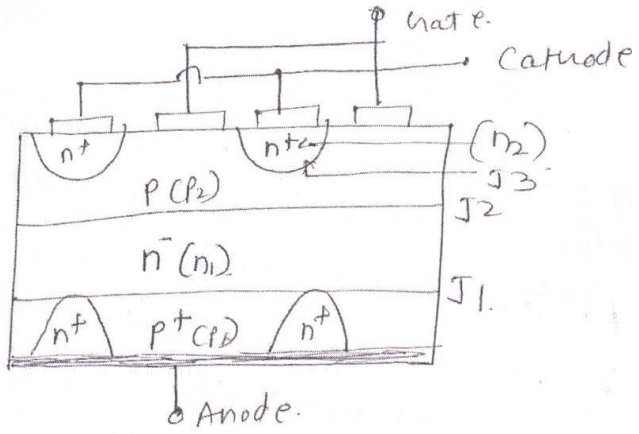


Waveforms:



b) Draw the constructional diagram of GTO. State the operating principle.

Answer:- **(Diagram 2 Mark operating principle 2 Mark)**



Operating Principle:-

- Basic operation of GTO is same as that of the conventional SCR but the major difference between is that the conducting GTO can be turned off by applying a negative gate current to it. Thus positive gate current turns it on and negative gate current turns it off.

- From two transistor model of GTO both transistor Q1 and Q2 are in saturation when the GTO is in it's on state.

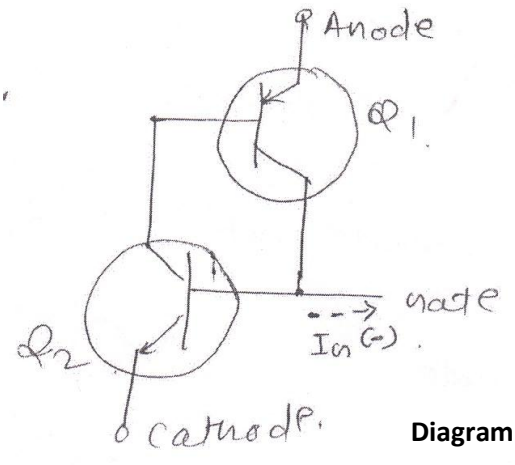


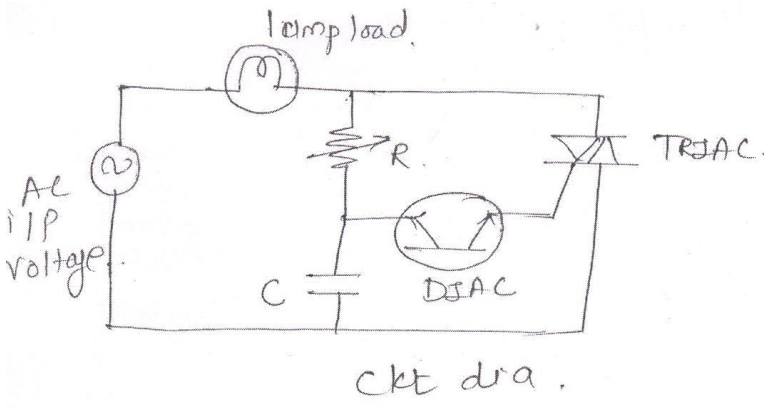
Diagram A

- If the base current of Q2 could be made less than the value needed for maintaining it in saturation, then Q2 will come out of saturation and will be in active state, this will reduce the regeneration and GTO will begin to turn off.

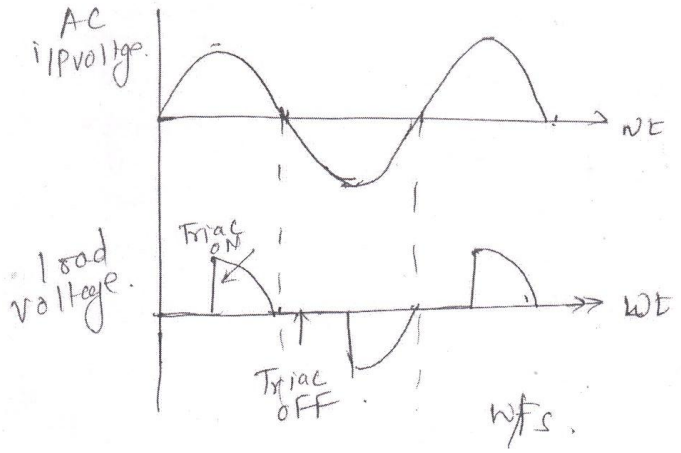
- In order to reduce the base current of Q2 & –ve gate current must flow in the direction as shown in diagram A.It can be proved that the negative gate current required for turning off a conducting GTO.

c) Draw the circuit diagram of light dimmer using DIAC and TRIAC and sketch the i/p – o/p voltage waveforms.

Answer:- Circuit: **(2 Marks for ckt diagram , 2Marks for W/F)**

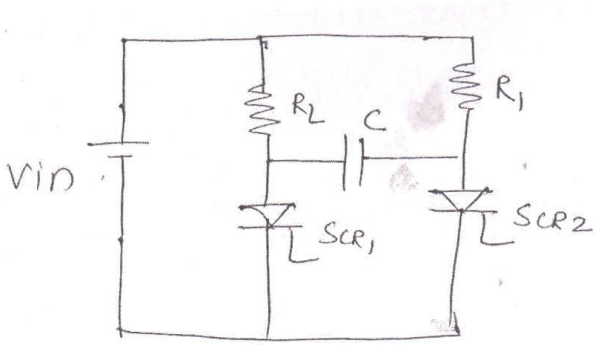


Waveforms:

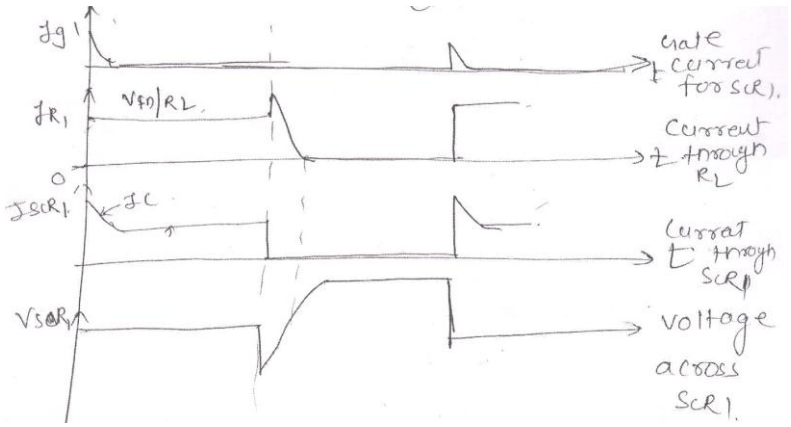


d) Draw the circuit diagram of class C commutation circuit. Draw the waveforms.

Answer:- Circuit Diagram: **(1 Mark for ckt diagram, 3 Mark for W/F)**



Waveforms:



e) Draw the circuit diagram of a battery charger. State it's operation.

Answer: - ckt diagram A **(2 Marks for ckt diagram, Working 2M)**

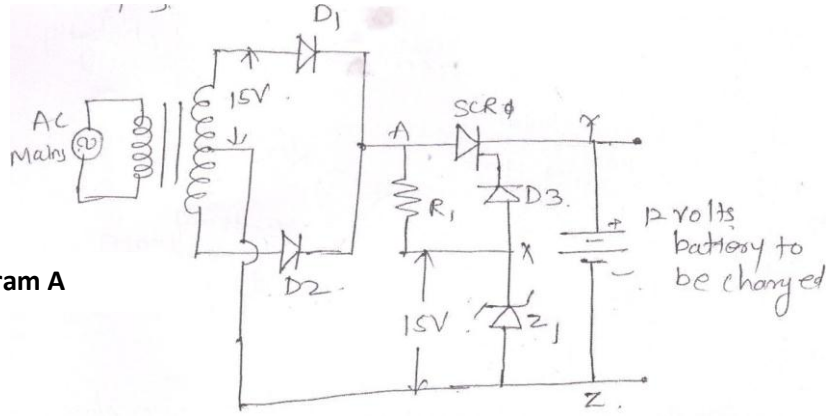


Diagram A

- Zener diode z, maintains a constant voltage of 15 volts, at point x as show in diagram A rectified voltage wave form A as shown in diagram B.
- Dotted line in diagram B indicates battery voltage when voltage at point A greater than battery voltage the SCR is forward biased and can conduct if the gate junction is also forward biased.
- Thus SCR conducts from point P to R as shown in diagram B and charges the 12 Volts battery connected in circuit.
- As the battery accumulates more charge dotted lines goes up and point P and R will come closer to Q.
- When battery is fully charges about 14 volts, cathode output SCR is at 14 volts and the gate is at 14.3 volts.
- Difference 0.3 volts between gate and cathode cannot forward bias the gate junction and will not be triggered.

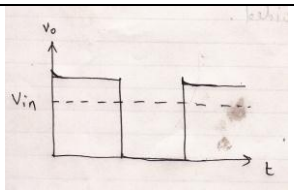
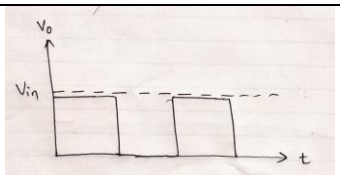
- Thus battery is cut off from supply and charging will stop automatically**.**

Diagram B

f) Compare between step up and step down chopper with respect to:

- **Input and output waveforms.**
- **Output voltage equation.**
- **Switch position (connection).**
- **Application.**

Answer:-

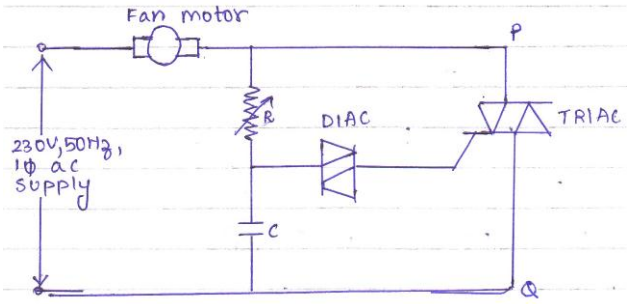
Parameter	**Step up chopper**	**Step down chopper**
Input output voltage waveform		
Output voltage equation.	**V_0 = V / (1-D) Volts**	**V_0 = DxV volts**
Switch position (connection)	**In parallel with load**	**In series with load**
Application	**Battery charging, voltage booster**	**Motor speed control.**

Q5) Answer any FOUR of the following: **(16 Marks)**

a) Draw the neat circuit diagram of Fan Speed Regulation using TRIAC. Describe its working.

Answer: **(circuit Diagram 2M, Working 2M)**

Operation:



In the above circuit DIAC is used to trigger TRIAC.

During the positive half cycle (when P is positive) the TRIAC requires a positive gate signal for turning it ON. This is provided by the capacitor C. When the voltage across capacitor is above the breakdown voltage of the DIAC. DIAC turns ON & the capacitor discharge through the TRIAC gate i.e. positive gate signal is given to the TRIAC & thus TRIAC turns ON. So current starts flowing through load.

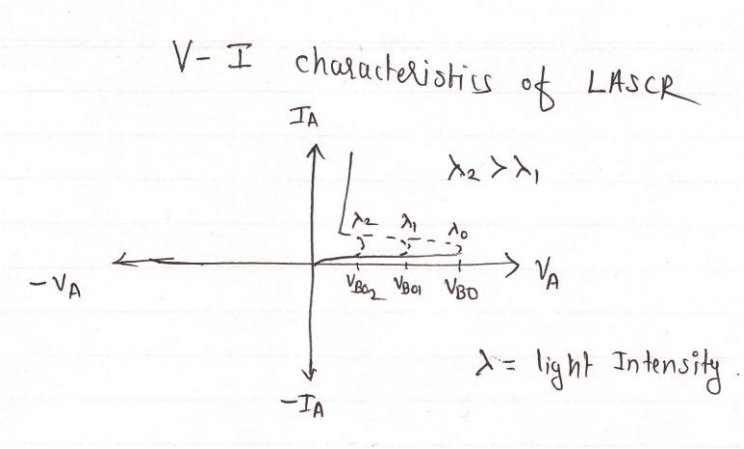
A similar operation takes place in the negative half cycle & a negative gate pulse will be applied when the DIAC breaks down in the reverse direction. The charging rate of capacitor C can be changed by varying the resistance R & hence the firing angle can be controlled.

Thus if firing angle is less speed of fan motor is more & if firing angle is more speed fan motor is less. Thus by controlling the α we can control speed of fan using TRIAC.

b) Draw the VI characteristics of LASCR. What is the effect of light intensity on forward break over voltage?

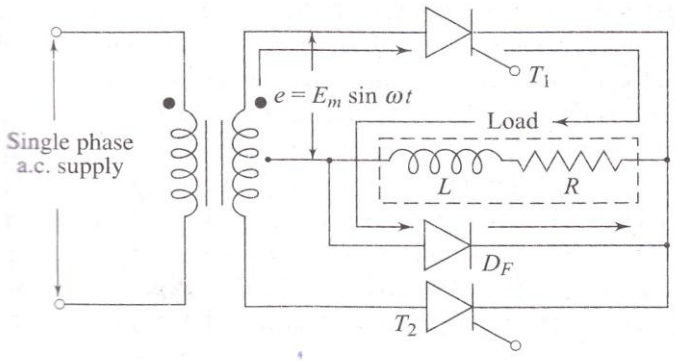
Answer: **(VI characteristics 3M, Effect 1M)**

As light intensity increases forward break over voltage goes on decreasing.



c) Describe the effect of freewheeling diode with respect to single phase center tap full controlled rectifier with RL load.

Answer: **(Circuit Diagram 1M, Waveform 1M, Explanation 2M)**



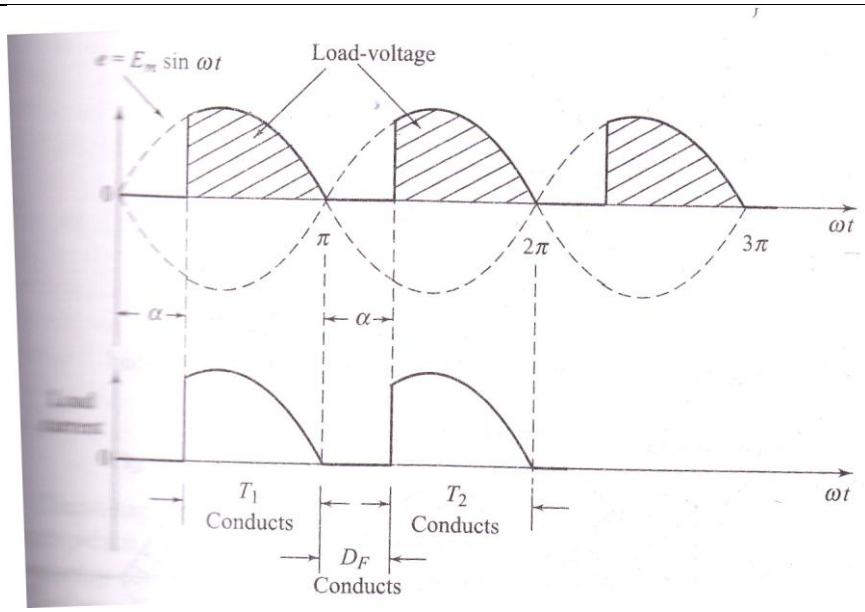
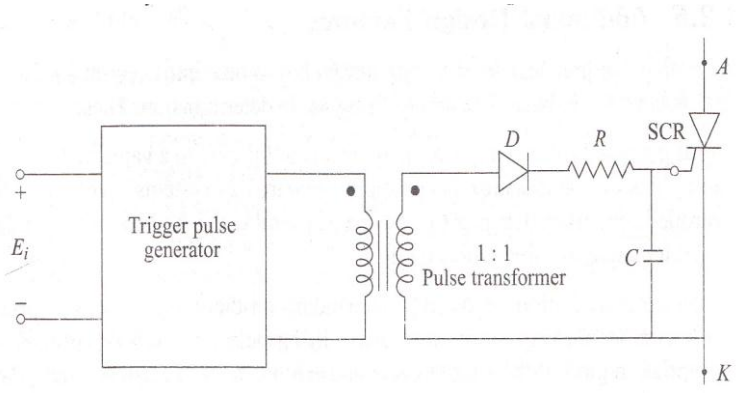


Figure shows the full wave center tap phase controlled thyristor circuit with inductive load & freewheeling diode. The load voltage & current waveform are also shown in figure. As shown in figure the thyristors are triggered at angle α. The variable d.c. voltage at the load is obtained by varying this firing angle α. From the same figure, it is also clear that as the supply voltage goes through zero at 180^0, the load voltage cannot be negative since the freewheeling diode; D_f starts conducting & clamps the load voltage to zero volts. A constant load current is maintained by freewheeling current through the diode. The conduction period of thyristors & diode also shown in figure. The stored energy in the inductive load circulates current through the feedback diode in the direction shown in figure.

d) Describe the operation of pulse transformer used in triggering circuit.

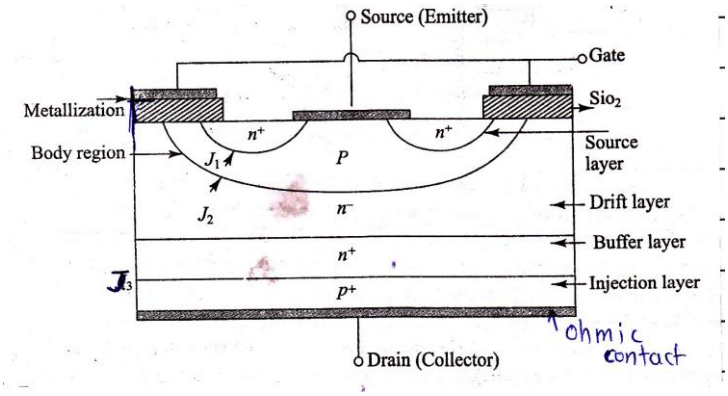
Answer: **(Diagram 1M, Operation 3M)**



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.

e) Draw the labeled construction diagram of N-channel IGBT.

Answer:- **(Diagram 4M)**



f) Differentiate between single phase controlled half wave rectifier & single phase controlled full wave rectifier.

Answer: **(Any 4 Points, Each 1M)**

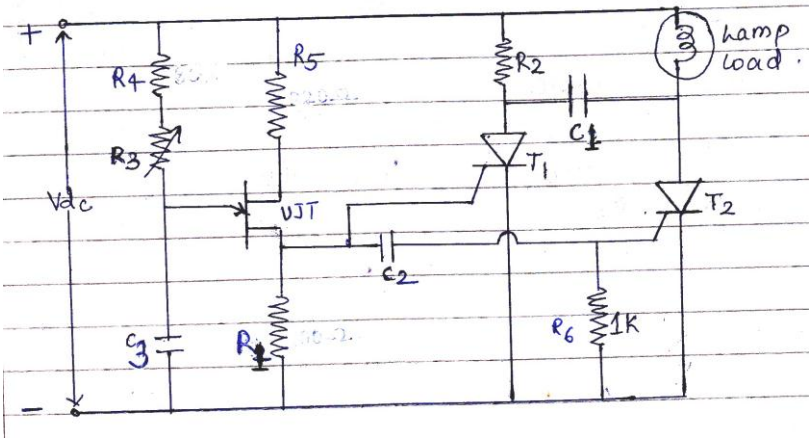
Sr.No.	**Parameter**	**single phase controlled half wave rectifier**	**single phase controlled full wave rectifier**
1	No. of SCRs	One SCR	Two Or Four SCRs
2	Devices Used	One SCR	All SCR , or SCR & diode
3	Ripple Frequency	$50H_Z$	$100\ H_Z$
4	Average load voltage	Less	More

5	Load power present	Only one positive half cycle of the power supply load power is present	In both half cycle of the power supply load power is present
6	Application	In small battery chargers	In dc motor speed control

Q6) Answer any FOUR of the following: (16 Marks)

a) Draw the circuit diagram of DC low power flasher. Describe its operation.

Answer:- **(Diagram 2M, Operation 2M)**



Operation:

Low power dc flasher:

Above figure shows low power flasher circuit. Here UJT operates as a relaxation oscillator & produces a train of trigger pulses to the thyristor gates through resistor R_1.

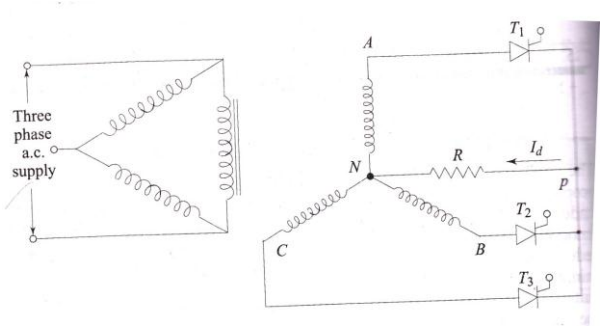
When thyristor T_2 is triggered, the lamp load glows when the next pulse trigger thyristor T_1, thyristor T_2 is turned off by the commutating capacitor C_1. Since the commutating pulses have a longer duration than the trigger pulses, thyristor T_2 cannot be re-triggered at this time.

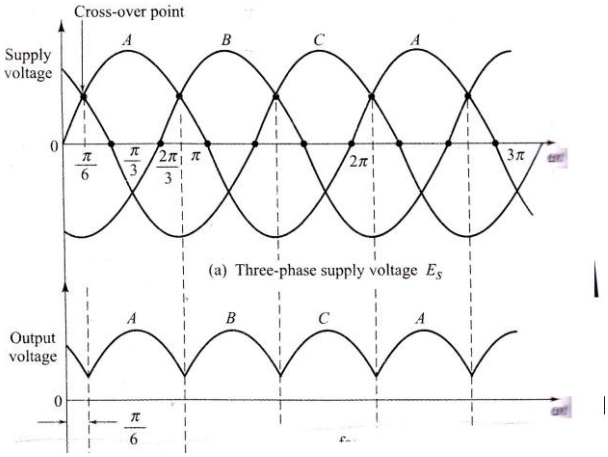
Thyristor T_2 can again be retriggered by the next pulse from resistor R_2.

At a time anyone thyristor should be triggered if both thyristor conduct together the flash circuit fails. This can be prevented by making thyristor T_1 turned off independently from the commutating capacitor. This can be done by using resistor R_2 of very large value so that thyristor T_2 is unable to remain on, except to discharge the capacitor C_1. During reminder of the cycle T_1 is off & capacitor C_1 is always able to develop a commutating voltage for T_2.The flash rate can be changed by varying the value of variable resistance R_3.

b) Draw the circuit diagram of three phase half wave controlled rectifier. Draw the waveforms of input voltage & output voltage.

Answer: **(Circuit Diagram 2M, Waveforms 2M)**





c) What is forward voltage triggering method of turning on the thyristor?

Answer: **(4 M)**

Voltage triggering:

When anode to cathode forward voltage is increased with gate circuit open, the reverse biased junction J_2 will have an avalanche breakdown at a voltage called forward break over voltage V_{BO}.

At this voltage a thyristor changes from OFF state (high voltage with low leakage current) to ON state. The forward voltage drop across the SCR during ON state is of the order of 1 to 1.5 V.

d) State two applications each for:

i) SCR

ii) PUT

Answer: Applications of SCR: (any 2, 2M)

1. Controlled rectifier
2. Choppers
3. Inverters
4. High voltage DC transmission system
5. Battery charger circuit
6. Dc drivers
7. Subway cars
8. SMPS
9. UPS
10. Emergency lighting system
11. Electronic timer
12. Temperature controller

Applications of PUT: (any 2, 2M)

1. Time delay circuit
2. Logic circuit
3. SCR trigger circuit

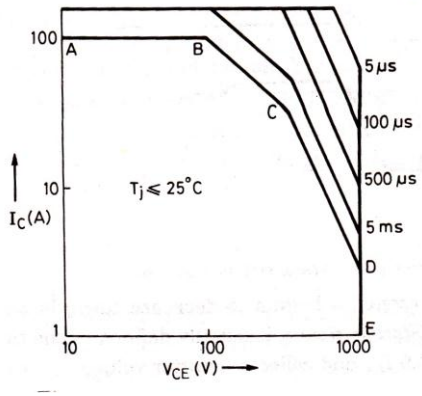
e) What is the second breakdown in power BJT? How is it avoided?

Answer: Second Breakdown in Power BJT: (2M)

In the active region the ratio of collector current to base current (DC current gain (β)) remains fairly constant up to certain value of the collector current after which it falls of rapidly. At still higher levels of collector currents the allowable active region is further restricted by a potential failure mode call "the second breakdown". It appears on the o/p characteristics of the BJT as a precipitous drop in the collector emitter voltage at large collection currents. The collector voltage drop is often accompanied by significant rise in the collector current & a substantial increase in the power dissipation. Most importantly this dissipation is not uniformly spread over the entire volume of the device but is concentrated in highly localized regions. This localized heating is a combined effect of the intrinsic non uniformity of the collector current density distribution across the cross section of the device & the negative temperature. Coefficient of resistively of minority carrier devices which leads to the formation of "current filaments" (localized across of very high current density) by a positive feedback mechanism.

Once current filaments are formed localized "thermal runaway" quickly takes the junction temperature beyond the safe limit & the device is destroyed.

How to avoid secondary breakdown: (2M)



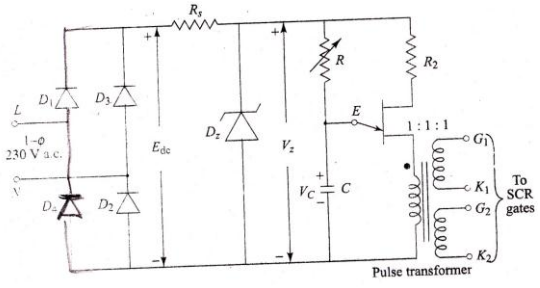
Secondary breakdown can be avoided by using power transistor in safe operating area.

The safe operating area (SOA) of a power transistor specifies the safe operating limit of collector current I_C verses collector emitter voltage V_{CE}. For reliable operation of the transistor the collector current & voltage must always lie within this area.

FBSOA is for its dc a well as single pulse operation & for temperature of 25^0 C. Boundary AB is the maximum limit for dc & continuous current for V_{CE} less than about 80 V. For V_{CE} more than 80V, collector current has to be reduced to BC so as to limit the junction temperature to safe values. For still higher V_{CE} current should further be reduced so as to avoid second breakdown limit.

f) Draw the circuit diagram of synchronized UJT triggering & describe it's working.

Answer: (Diagram 2M, Working 2M)



Operation:

Synchronized UJT triggering circuit is shown in figure. The diode bridge D_1-D_4 rectifies a.c. to d.c. Resistor R_S lowers E_{DC} to a suitable value for the zener diode & UJT. The zener diode D_Z is used to clip the rectified voltage to a fixed voltage V_Z. This voltage V_Z is applied to the charging circuit RC. Capacitor C charges

through R until it reaches the UJT trigger voltage V_P. The UJT then turns "ON" & C discharges through the UJT emitter & primary of the pulse transformer. The winding of the pulse transformer have pulse voltages at their secondary terminals. Pulses at the two secondary winding feed the same in phase pulse to two SCRs of a full wave circuit. SCR with positive anode voltage would turn ON. Rate of rise of capacitor voltage can be controlled by varying R. The firing angle can be controlled up to about 150^0. This method of controlling the output power by varying charging resistor R is called as ramp control, open loop control or manual control.

As the zener diode voltage V_Z goes to zero at the end of each half cycle, the synchronization of the trigger

Circuit with the supply voltage across SCRs is achieved. Thus the time t, equal to α/ω, when the pulse is

Applied to SCR for the first time will remain constant for the same value