B.Tech.

(SEM. VI) ODD SEMESTER THEORY EXAMINATION, 2013-14

POWER ELECTRONICS

Time : 3 Hours Max. Marks : 100

Note : Answer **all** the questions.

1. Attempt any **four** parts of the following : **(4 × 5 = 20)**

a. What are the characteristics of ideal power switching devices ? Compare characteristics of MOSFET and IGBT.

Ans: Refer Q. 1.18, Page 1–22A, Unit-1.

b. What are the primary and secondary breakdowns in semiconductor devices, differentiate between them ?

Ans:

A. Primary breakdown :

1. The primary breakdown takes place because of avalanche breakdown.
2. The avalanche process occurs when carriers in the transition region are accelerated by the electric field to energies sufficient to create mobile or free electron-hole pairs via collisions with bound electrons.
3. Large power dissipation normally leads to primary breakdown.

B. Secondary breakdown :

1. Secondary breakdown is caused by fly-back pulses, load shorts, or large load fluctuations.
2. Secondary breakdown further increases the current after primary breakdown, and once a certain voltage or current level is reached, operation suddenly moves to a low impedance region, a high current flows and semiconductor device damage occurs.

C. Difference :

No.	Primary breakdown	Secondary breakdown
1.	The primary breakdown takes place because of avalanche breakdown.	Secondary breakdown is caused by fly-back pulses, load shorts, or large load fluctuations.

c. Obtain the expression of input power factor for a single-phase half wave controlled rectifier feeding a purely resistive load.

Ans. Refer Q. 3.1, Page 3–2A, Unit-3.

d. List specifications of power electronic switches.

Ans. Refer Q. 2.2, Page 2–4A, Unit-2.

e. A DC supply of 100 V feeds a load resistance of 10 ohm and an inductance of 5 H through a thyristor. The latching current of thyristor is 50 mA. Find the minimum width of the gate pulse.

Ans. Refer Q. 1.25, Page 1–30A, Unit-1.

f. The voltage and current ratings in a particular circuit are 5 kV and 100A. Thyristors with ratings of 1000 V and 150 A are available. Minimum derating factor is 20 %. Calculate the number of series connected thyristors required to handle the given source voltage and current.

Ans. Refer Q. 2.14, Page 2–23A, Unit-2.

2. Attempt any **two** parts of the following : **(2 × 10 = 20)**

a. What do you understand by chopper ? Describe the various types of chopper configurations with appropriate diagrams.

Ans. **Chopper :** A chopper is basically a DC to DC converter whose main function is to create adjustable DC voltage from fixed DC voltage sources through the use of semiconductors.

Types of configurations :

A. Type A Chopper or first-quadrant chopper

1. This type of chopper is shown in the Fig. 1.
2. When the chopper is ON, $v_0 = V_s$ and the current flows in the direction of the load.

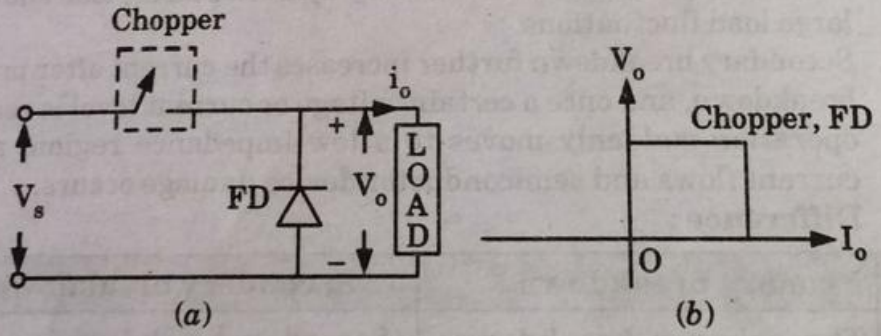


Fig. 1.

3. But when the chopper is OFF v_0 is zero but I_0 continues to flow in the same direction through the freewheeling diode *FD*, thus average value of voltage and current V_0 and I_0 will be always positive as shown in the graph in Fig. 1(*b*).
4. In type *A* chopper the power flow will be always from source to the load. The average voltage V_0 is less than the dc input voltage V_s

B. Type *B* chopper or second-quadrant chopper

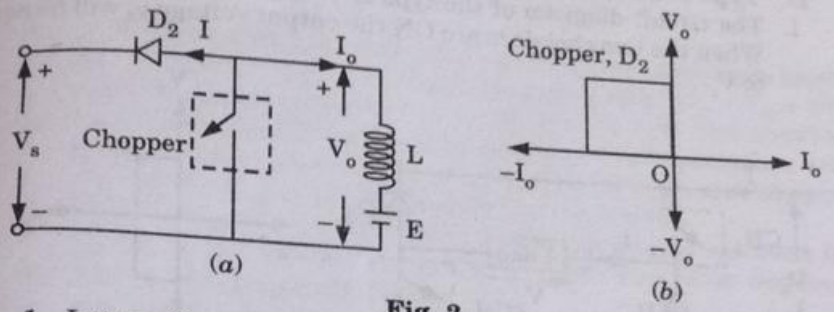


Fig. 2.

1. In type *B* or second quadrant chopper the load must always contain a DC source *E*.
2. When the chopper is ON, v_0 is zero but the load voltage *E* drives the current through the inductor *L* and the chopper, *L* stores the energy during the time T_{ON} of the chopper.
3. When the chopper is OFF, $v_0 = (E + L \, . \, di/dt)$ will be more than the source voltage V_s. Because of this the diode D_2 will be forward biased and begins conducting and hence the power starts flowing to the source.
4. No matter the chopper is ON or OFF the current I_0 will be flowing out of the load and is treated negative. Since V_0 is positive and the current I_0 is negative, the direction of power flow will be from load to source.

C. Type C chopper or two-quadrant type-A chopper :

1. Type *C* chopper is obtained by connecting type-*A* and type-*B* choppers in parallel.

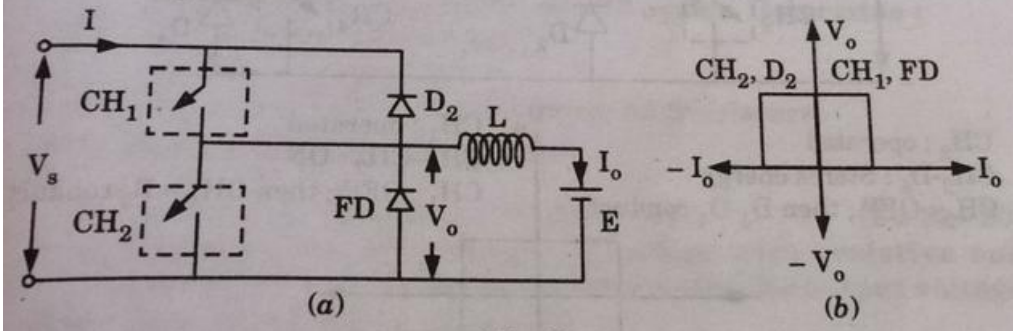


Fig. 3.

2. The average voltage will be always positive but the average load current might be positive or negative.
3. The power flow may be in the first quadrant operation *i.e.*, from source to load or from load to source like the second quadrant operation.
4. For regenerative braking and motoring these type of chopper configuration is used.

D. Type *D* chopper or two-quadrant type *B* chopper :

1. The circuit diagram of the type *D* chopper is shown in Fig. 4(*a*). When the two choppers are ON the output voltage v_0 will be equal to V_s.

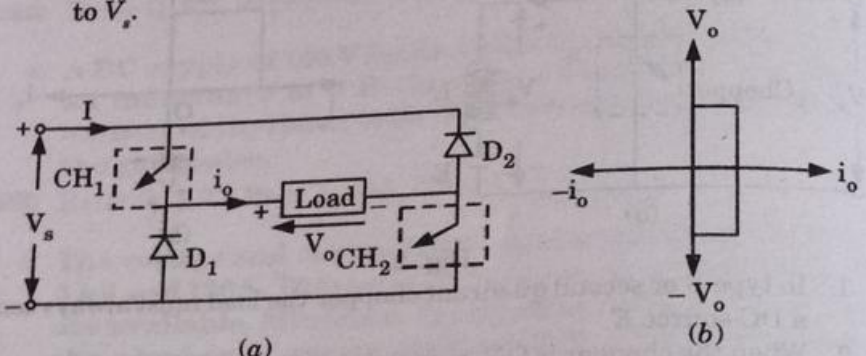
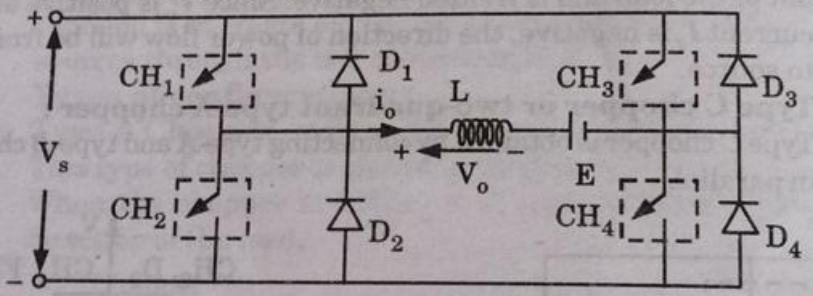


Fig. 4.

2. When $v_0 = -V_s$ the two choppers will be OFF but both the diodes D_1 and D_2 will start conducting.
3. V_0 the average output voltage will be positive when the choppers turn-ON.

E. Type-*E* chopper or the fourth-quadrant chopper :

1. Type *E* or the fourth quadrant chopper consists of four semiconductor switches and four diodes arranged in antiparallel.



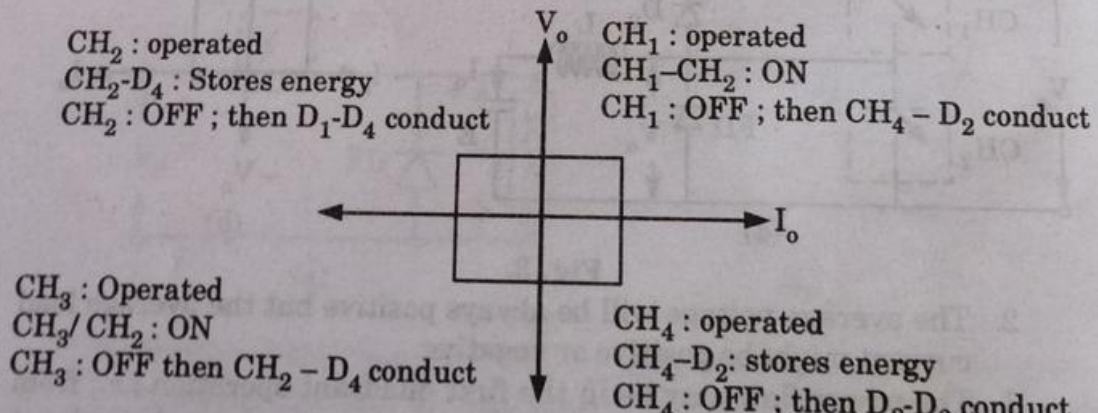


Fig. 5.

b. Discuss the two transistor model of a thyristor. Using this model, describe the various mechanisms of turning ON a thyristor.

Ans. Refer Q. 1.23, Page 1–28A, Unit-1.

c. A complementary commutation circuit operates from a DC supply of 200 Volts and has resistance $R_1 = R_2 = 10\ \Omega$, commutating capacitor $C = 10\ \mu F$. Sketch the thyristor voltage waveform for one complete cycle of operation, when the two thyristors T_1 and T_2 in the circuit are triggered periodically one after the other. Calculate :

i. Peak transient repetitive on state thyristor current that flows, at the instant of triggering the thyristor device

ii. The circuit turn-off time.

Ans. Refer Q. 2.9, Page 2–16A, Unit-2.

3. Attempt any **two** parts of the following : **(2 × 10 = 20)**

a. Discuss the single phase dual converter under circulating current conduction mode of operation and derive the expression for inductor voltage.

Ans. Refer Q. 3.23, Page 3–35A, Unit-3.

b. Explain operation of single phase fully controlled bridge converter feeding highly inductive load and draw its relevant output voltage and current waveforms.

Ans. Refer Q. 3.9, Page 3–12A, Unit-3.

c. A single phase full wave (bi-directional) AC voltage controller has resistive load $R = 10\ \Omega$ and the rms input voltage, $V_s = 230$ V, 50 Hz. The thyristor switch is on for $n = 25$ cycles and is off for $m = 75$ cycles. Determine :

i. The rms output voltage V_o

ii. The input power factor

iii. The average and rms currents of thyristors.

Ans. Refer Q. 4.4, Page 4–6A, Unit-4.

4. Attempt any **two** parts of the following : **(2 × 10 = 20)**

a. Describe 1-ϕ AC voltage controller with resistive and inductive loads. Describe an expression for output voltage.

Ans. Refer Q. 4.6, Page 4–9A, Unit-4.

b. Discuss the principle of working of a single phase series inverter. What are the advantages and disadvantages of series inverters ?

Ans.

A. 1ϕ series inverter :

1. The commutating components L and C are connected in series with the load therefore this inverter is called as series inverter.
2. The value of commutating components is selected such that the circuit becomes under damped.

3. The anode current itself becomes zero in this inverter resulting the SCR turns OFF automatically therefore this inverter is also called as self commutated or load commutated inverter.
4. The power circuit diagram of the series inverter is shown in the Fig. 6.
5. The SCR T_1 and SCR T_2 are turned ON at regular interval in order to achieve desirable output voltage and output frequency.
6. The SCR T_2 is kept off at starting condition.

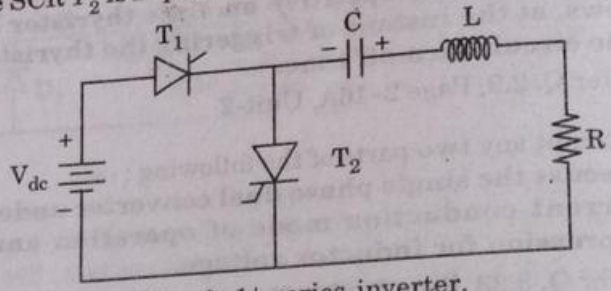


Fig. 6. 1ϕ series inverter.

Modes of operation :

Mode 1 :

1. The voltage V_{dc} directly applies to *RLC* series circuit as soon as the *SCR* T_1 is turned on.
2. The nature of the load current is alternating as there is underdamped circuit of the commutating components.
3. The voltage across capacitor becomes $+V_{dc}$ when the load current becomes maximum.
4. The voltage across capacitor becomes $+2V_{dc}$ when the load current becomes zero at point *a*. The SCR T_1 automatically turns OFF at point *a* because the load current becomes zero.

Mode 2 :

1. The load current becomes zero from point *a* to *b* as the SCR T_1 turns OFF in this time period.
2. The SCR T_1 and SCR T_2 are turned OFF in this time duration and voltage across capacitor becomes equal to $+2V_{dc}$.

Mode 3 :

1. The SCR T_2 is turned ON at point *b* due to it receives positive capacitor voltage. The discharging of capacitor is done through SCR T2 and *R-L*.
2. The load current becomes zero after it becomes maximum in the negative direction.
3. The capacitor discharges from $+2V_{dc}$ to $-V_{dc}$ during this time and SCR T_2 turns OFF automatically at point *c* due to load current becomes zero.
4. The SCR T_2 turns OFF during point *c* to *d* and SCR T_1 again turns ON.
5. This way cycle repeat after it complete one turns.

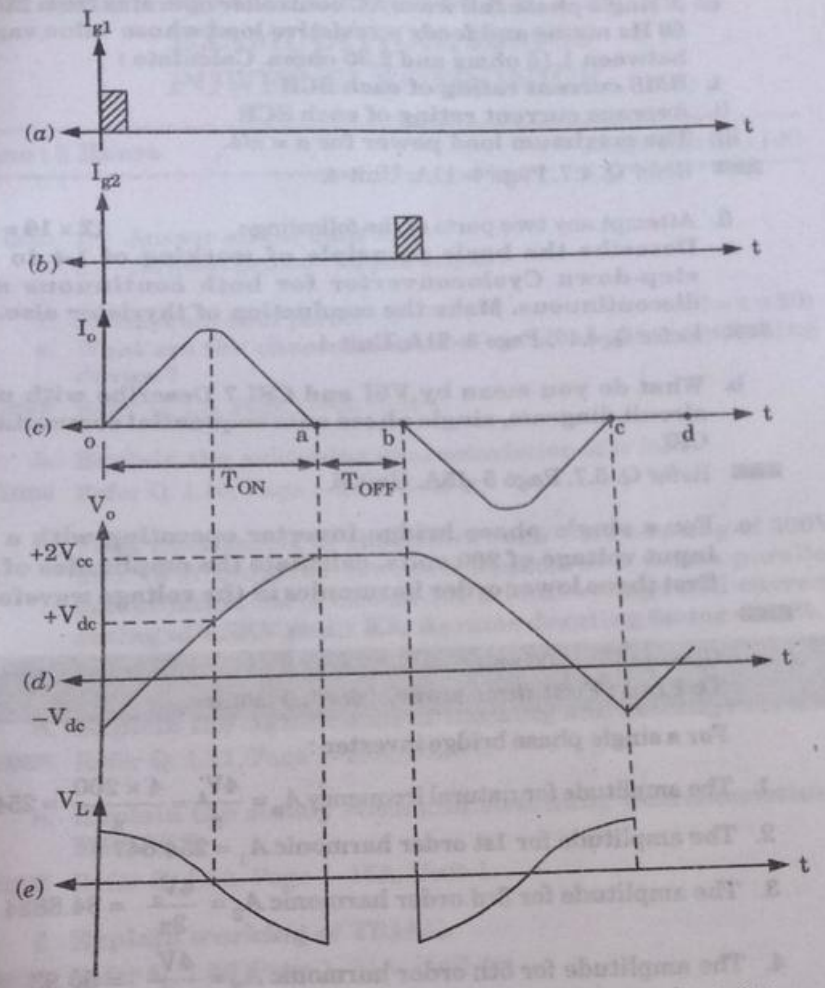


Fig. 7. Voltage and current waveforms of series inverter (*a*) Gate pulse for SCR T_1 (*b*) Gate pulse for SCR T_2 (*c*) Output current, (*d*) Capacitor voltage (*e*) Load voltage

B. Advantages :

This type of inverter generates sinusoidal waveforms whose output frequency is high (200 Hz to 100 kHz).

C. Disadvantages :

1. The load current flows only during positive half cycle from supply source.
2. The DC supply source gets short circuited if SCR T_1 and SCR T_2 simultaneously turned ON.

c. A single phase full wave AC controller operates from 230 V, 50 Hz mains and feeds a resistive load whose value varies between 1.15 ohms and 2.30 ohms. Calculate :

i. RMS current rating of each SCR

ii. Average current rating of each SCR

iii. The maximum load power for $\alpha = \pi/4$.

Ans: Refer Q. 4.7, Page 4–11A, Unit-4.

5. Attempt any **two** parts of the following : **(2 × 10 = 20)**

a. Describe the basic principle of working of 1-ϕ to 1-ϕ step-down Cycloconverter for both continuous and discontinuous. Make the conduction of thyristor also.

Ans: Refer Q. 4.12, Page 4–21A, Unit-4.

b. What do you mean by VSI and CSI ? Describe with neat circuit diagram, single phase auto sequential commutated CSI.

Ans: Refer Q. 5.7, Page 5–15A, Unit-5.

c. For a single phase bridge inverter operating with a DC input voltage of 200 volts, calculate the amplitudes of the first three lower order harmonics in the voltage waveform.

Ans:

Given : $V_s = 200$ volt,
To Find : First three lower order harmonics.

For a single phase bridge inverter :

1. The amplitude for natural frequency $A_0 = \frac{4V_s}{\pi} = \frac{4 \times 200}{\pi} = 254.647$
2. The amplitude for 1st order harmonic $A_1 = 254.647$
3. The amplitude for 3rd order harmonic $A_3 = \frac{4V_s}{3\pi} = 84.8824$
4. The amplitude for 5th order harmonic $A_5 = \frac{4V_s}{5} = 50.93$