CBCS SCHEME

17EC73

USN 2VD16EC039

Seventh Semester B.E. Degree Examination, Feb./Mar. 2022
Power Electronics

Time: 3 hrs. Max. Marks: 100

Note: Answer any FIVE full questions, choosing ONE full question from each module.

Module-1

1 a. List out any five applications of power electronics. (05 Marks)

b. Give symbol and characteristics features of the following devices:
i) SCR ii) TRAIC iii) IGBT iv) GTO v) LASCR. (10 Marks)

c. Explain the peripheral effects of power electronics. (05 Marks)

OR

2 a. Explain the steady state V-I characteristics of IGBT and switching characteristics of MOSFET. (10 Marks)

b. List out the merits of MOSFETs. (05 Marks)

c. Explain how transistors are protected against high di/dt. (05 Marks)

Module-2

3 a. With a neat sketch, describe the two transistor model of a thyristor and obtain the expression for anode current. (10 Marks)

b. Explain, thyristor characteristics and modes of operations. (10 Marks)

OR

4 a. Bring out the differences between natural and forced commutations. (04 Marks)

b. Explain the operation of a full wave RC firing circuit with waveforms. (08 Marks)

c. A UJT is connected across a 20V DC supply the valley and peak point voltages are 1 volt and 15V. The period of UJT relaxation oscillator is 20ms. Find the value of charging capacitor, if a charging resistor of 100KΩ is used. (08 Marks)

Module-3

5 a. Explain the working of single phase dual converter. How if operates in four quadrants? (10 Marks)

b. Derive an expression for average value of output voltage for 1ϕ full wave controlled rectifier with RL load. (10 Marks)

OR

6 a. With a neat diagram and relevant waveforms explain 1ϕ full wave controller for ON-OFF control. Derive an expression for rms value of load voltage in on-off AC voltage controller. (10 Marks)

b. Explain 1ϕ Bidirectional AC voltage controllers with inductive loads. (06 Marks)

c. In an ON-OFF control circuit using 1ϕ, 230V, 50hz supply the ON time is 10 cycles and OFF time is 4 cycles. Calculate the RMS value of the output voltage. (04 Marks)

Module-4

7 a. Explain the principle of operation of step down chopper with R load. **(08 Marks)**

b. A DC chopper has a resistive load of 30Ω and input voltage $V_S = 220V$. When the chopper is ON, the voltage drop is 1.5V and chopping frequency is 20kHz. If duty cycle is 60%, determine the average output voltage, rms output voltage and chopper on time. **(08 Marks)**

c. With relevant graphs, explain how choppers are classified. **(04 Marks)**

OR

8 a. With neat figure, explain buck regulator. **(10 Marks)**

b. With the help of circuit diagram and relevant waveforms, explain the working of a Buck-Boost regulator. **(10 Marks)**

Module-5

9 a. Explain the operation of single phase half bridge inverter with inductive load, derive the expression for rms output voltage if the input is square wave with peak output voltage is V/2. **(10 Marks)**

b. Explain the performance parameters of inverters. **(10 Marks)**

OR

10 a. Explain the operation of thyristorized current source inverter. What are its advantages? **(10 Marks)**

b. Write short note on:
i) DC-link inverter ii) Sinusoidal PWM. **(10 Marks)**

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Department : Electronics & Communication Engg.

Sem : VII Sem B.E Degree

Subject : Power Electronics

Subject code : 17EC73

Note : Scheme is as per the requirement of Subject

Subject teacher

[signature] 24/3/2022

(Prof. Rohini Kallur)

[signature] 29-03-2022

Module 1

1)a) List out any five applications of power Electronics [05 Marks]

Ans The importance of power electronics can be found in industrial automation, energy systems, energy generation and conservation and indirectly for environmental pollution control.

i) Home appliances – Refrigerators, sewing machines, photography, air conditioner

ii) Games and Entertainment – Games and toys, television

iii) Aerospace – Aircraft power systems, Space vehicle power systems.

iv) Automotive – Alarms and security systems, electric vehicles

v) Medical – fitness machines, laser power supplies, Medical Instrumentation.

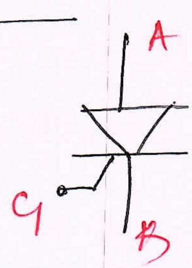
Mentioning of 5 applications – 5 Marks.

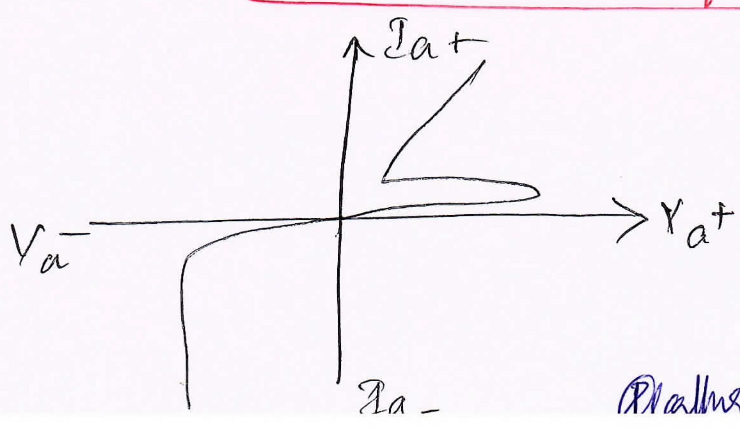
1.b) Give symbol and characteristics features of the following devices.

i) SCR ii) TRIAC iii) IGBT iv) GTO v) LASCR [10 marks]

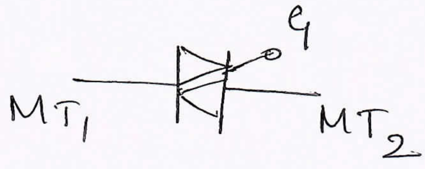
Symbol of each device – 1M
Characteristics of each device – 1M

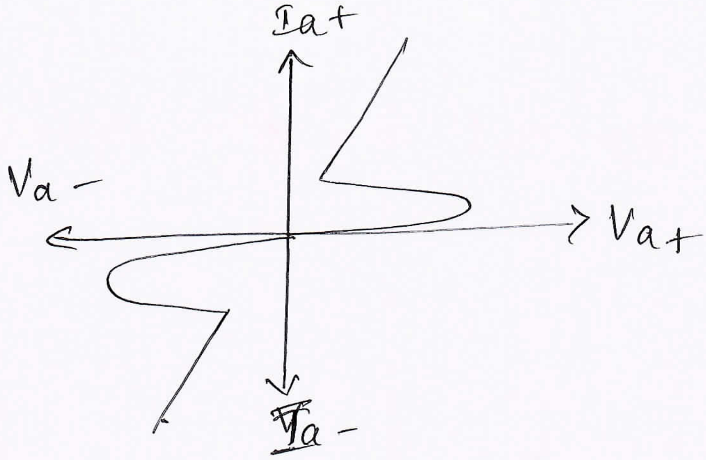
Ans: i) SCR :-



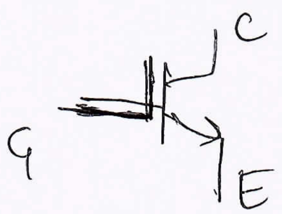


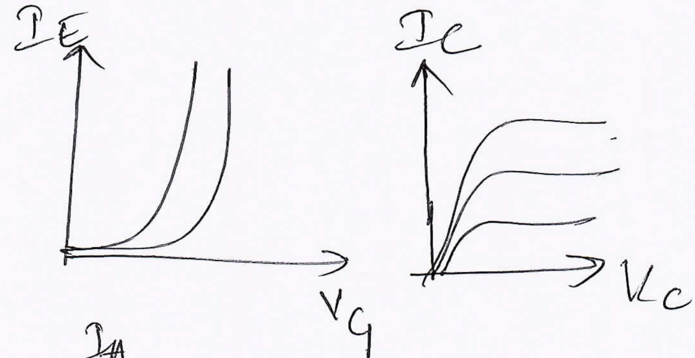
ii) TRIAC :-



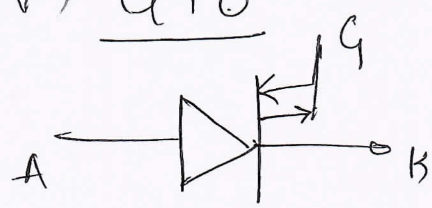


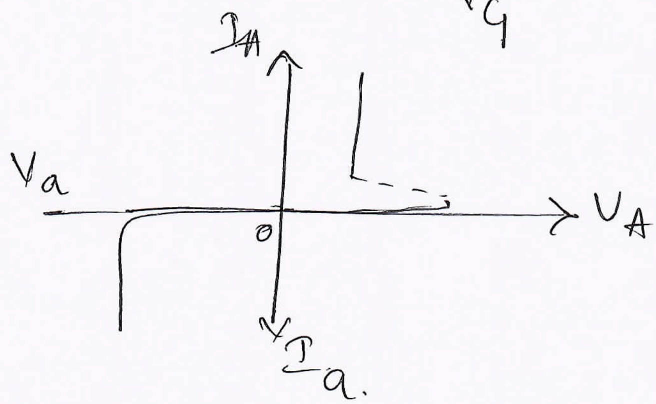
iii) IGBT



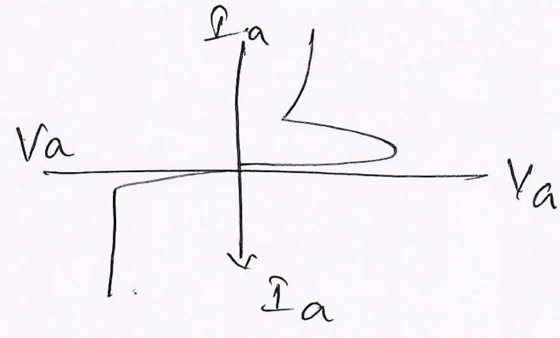


iv) GTO





v) LASCR



1-C) Explain the peripheral effects of power Electronics. [05 Marks]

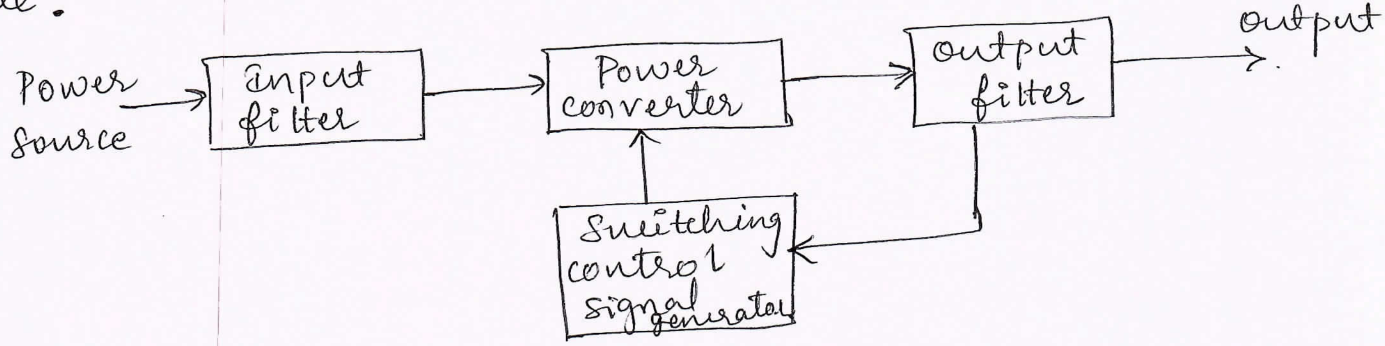
Block diagram - 2M

Explaination - 3M

Ans:- The operations of the power converters are based mainly on the switching of power semicon-ductors devices; and as a result of the

Converters introduce current and voltage harmonics into the supply system and on the output of the converters. These can cause problems of distortion of the output voltage, harmonic generation into the supply system, and interference with the communications and signalling circuits.

It is normally necessary to introduce filters on the input and output of a converter system to reduce the harmonic level to an acceptable magnitude.



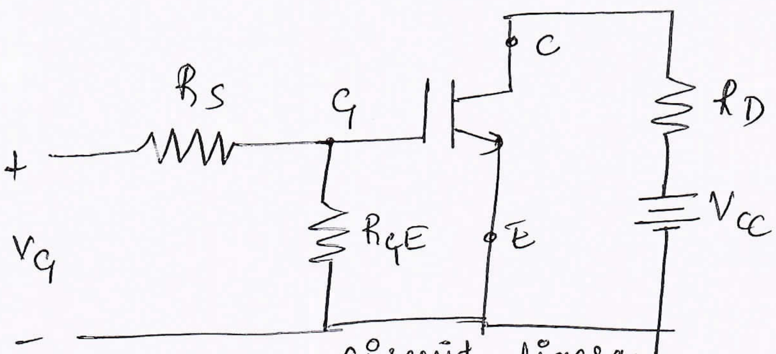
The figure above shows block diagram of a generalized power converter. The application of power electronics to supply sensitive electronic loads poses a challenge on the power quality issues and raises problems and concerns to be resolved by researchers. Factors such as total harmonic distortion (THD), Displacement Factor (DF), and input power factor (IPF) are the measures of the quality of a waveform. The power converters can cause radio frequency interference due to electromagnetic radiation, and the gating circuits may generate erroneous signals. This interference can be avoided by grounded shielding.

2. a) Explain the steady state V–I characteristics of IGBT and switching characteristics of MOSFET.

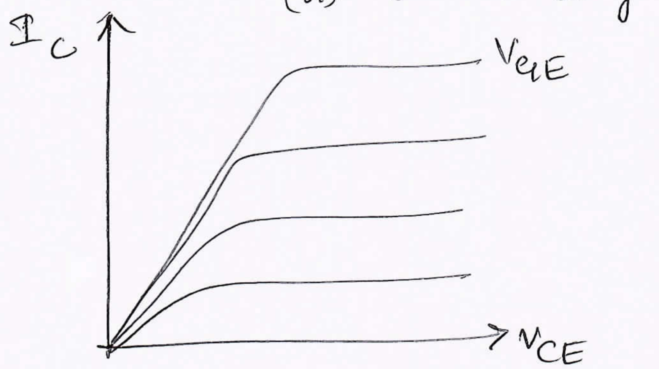
[10 Marks]

V–I characteristics of IGBT – 5M
Switching characteristics of MOSFET – 5M.

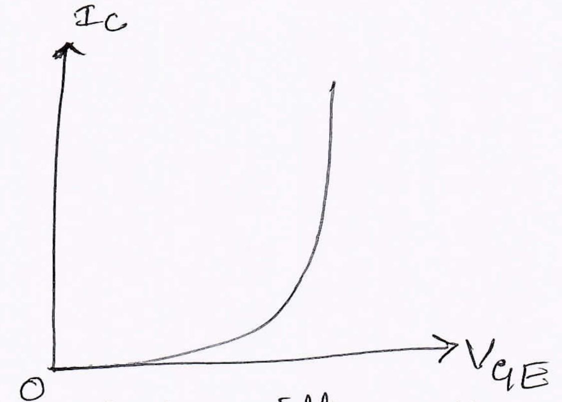
Ans: V–I characteristics of IGBT →



(a) circuit diagram



(b) Collector emitter voltage



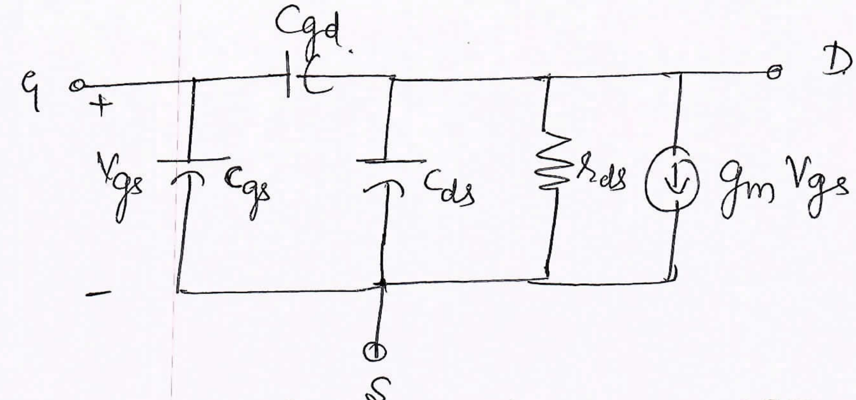
(c) Gate emitter voltage

The symbol and circuit of an IGBT are shown in above figure. The three terminals are gate, collector and emitter. The typical output characteristics of i_C versus V_{CE} are shown in figure above. [up to 1200V,] The current rating of a single IGBT can be upto 1200V, 400A and the switching frequency can be up to 20KHZ.

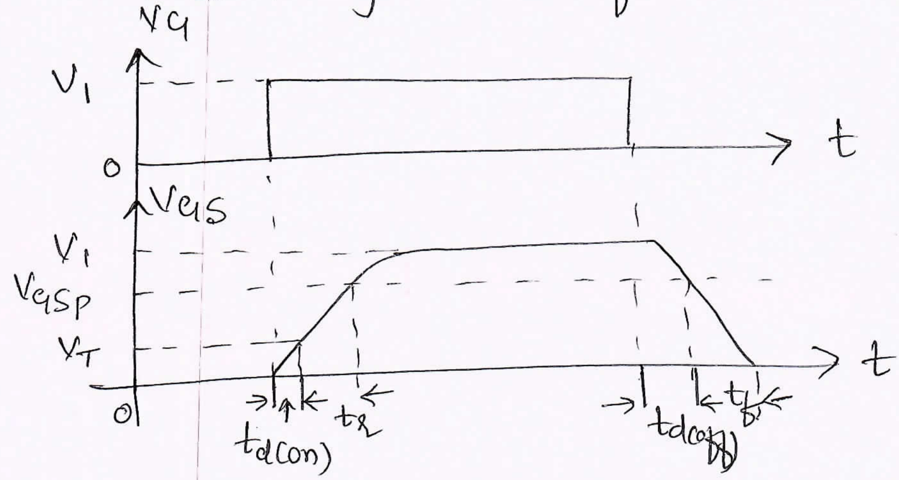
Switching characteristics of MOSFET →

→ The MOSFET is a fast switching device having a switching frequency of 25KHZ.

The switching model of MOSFET is as shown in figure below along with the waveforms and times



(a) Switching model of MOSFETs



(b) Switching waveforms and times

The turn on delay, $t_{d(on)}$ is the time that is required to charge the input capacitance to threshold voltage level. The rise time, t_r is the gate charging time from the threshold level to the full gate voltage V_{GSP}, which is required to drive the transistor into the linear region.

→ The turn off delay time $t_{d(off)}$ is the time required for the input capacitance to discharge from the overdrive gate voltage V_1 to the pinch off region. V_{GS} must decrease significantly before V_{DS} begins to rise. The fall time t_f is the time that is required for the input capacitance to discharge from the pinch off region to threshold voltage. If $V_{GS} \le V_T$, the transistor turns off.

Q.b.) List out the merits of MOSFETs. [05 Marks]

5 advantages → 5M.

Ans:- Advantages of MOSFET are

1) Low gate energy
2) Very fast switching Speed
3) Low switching losses
4) Very high Input resistance
5) Very high drain resistance

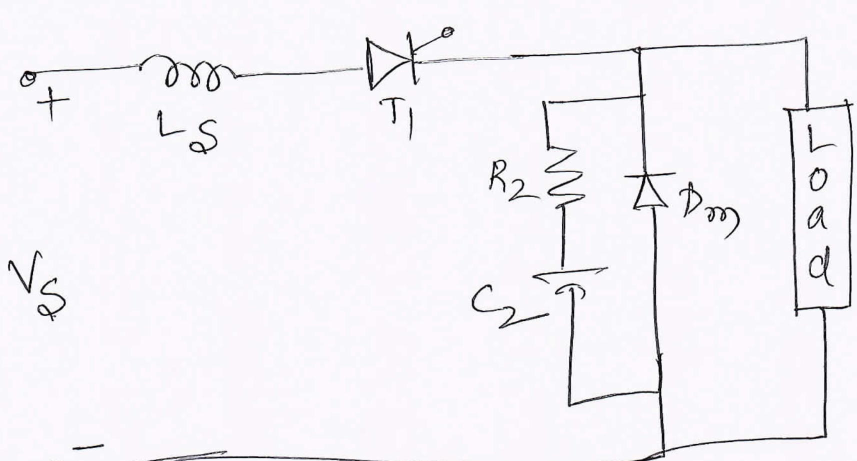
Q.c) Explain how transistors are protected against high di/dt. [05 Marks]

Ans— The protection against high voltage reverse recovery transients and dv/dt is achieved by using RC snubber circuit.

This snubber circuit consists of a series combination of capacitor and resistor which is connected across the SCR.

The di/dt is limited by adding a series inductor L_s, i.e series inductance, including any stray inductance.

Explaination - 2M, Circuit - 3M.

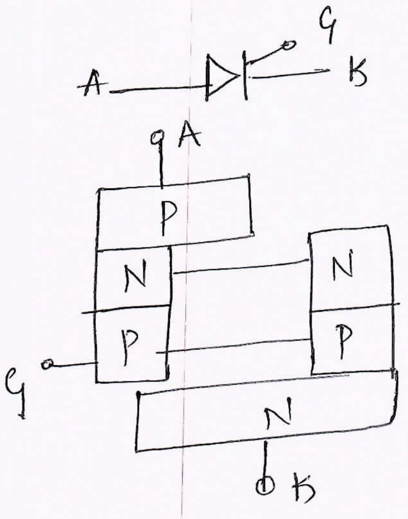


Module - 2

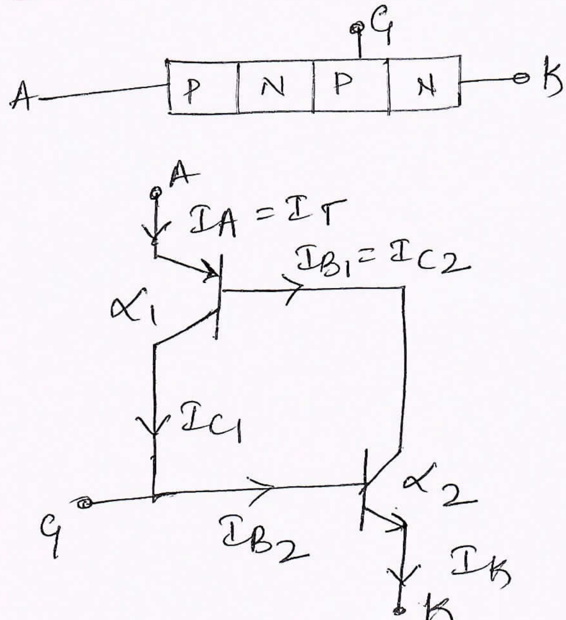
3.a) With a neat sketch, describe the two transistor model of SCR and obtain the expression for anode current. [10 Marks]

Circuit diagram - 4M
Explaination - 3M
Derivation - 3M

Ans:



(a) Basic Structure



(b) Equivalent circuit.

The regenerative or latching action due to a positive feedback can be demonstrated by using a two transistor model of thyristor. A thyristor can be considered as two complementary transistors, one PNP transistor Q_1 and other NPN transisto[r] Q_2 as shown in fig (a). The equivalent circuit model is shown in figure (b).

The collector current I_C of a thyristor is related, in general, to the emitter current I_E and the leakage current of the collector-base junction I_{CBO} as,

$$I_C = \alpha I_E + I_{CBO} \quad \text{--- (1)}$$

and the common base current gain is defined as

$$\alpha = \frac{I_C}{I_E}.$$

For transistor Q_1, the emitter current is the anode current I_A and the collector current I_{C_1} can be found from ①,

$$I_{C_1} = \alpha_1 I_A + I_{CBO_1} \quad — ②$$

For Q_2,

$$I_{C_2} = \alpha_2 I_K + I_{CBO_2} \quad — ③$$

By combining I_{C_1} & I_{C_2} we get,

$$I_A = I_{C_1} + I_{C_2}.$$

$$= \alpha_1 I_A + I_{CBO_1} + \alpha_2 I_K + I_{CBO_2}$$

For a gating current,

$$I_K = I_A + I_G$$

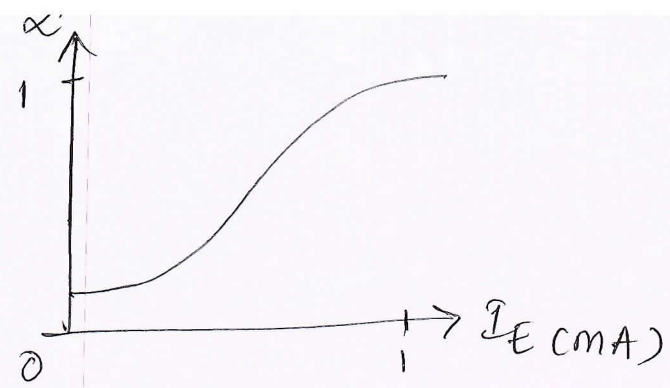
$$I_A = \alpha_1 I_A + I_{CBO_2} + \alpha_2 (I_A + I_G) + I_{CBO_2}$$

$$I_A = \alpha_1 I_A + \alpha_2 I_A + \alpha_2 I_G + I_{CBO_1} + I_{CBO_2}$$

$$I_A - (\alpha_1 + \alpha_2) I_A = \alpha_2 I_G + I_{CBO_1} + I_{CBO_2}$$

$$I_A = \frac{\alpha_2 I_G + I_{CBO_1} + I_{CBO_2}}{1 - (\alpha_1 + \alpha_2)} \quad — ④$$

The current gain α_1 varies with the emitter current, $I_A = I_E$ and α_2 varies with $I_K = I_A + I_G$.



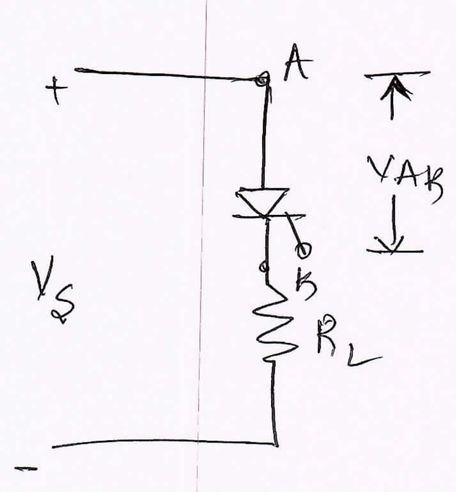
(d) Variation of current gain with emitter current.

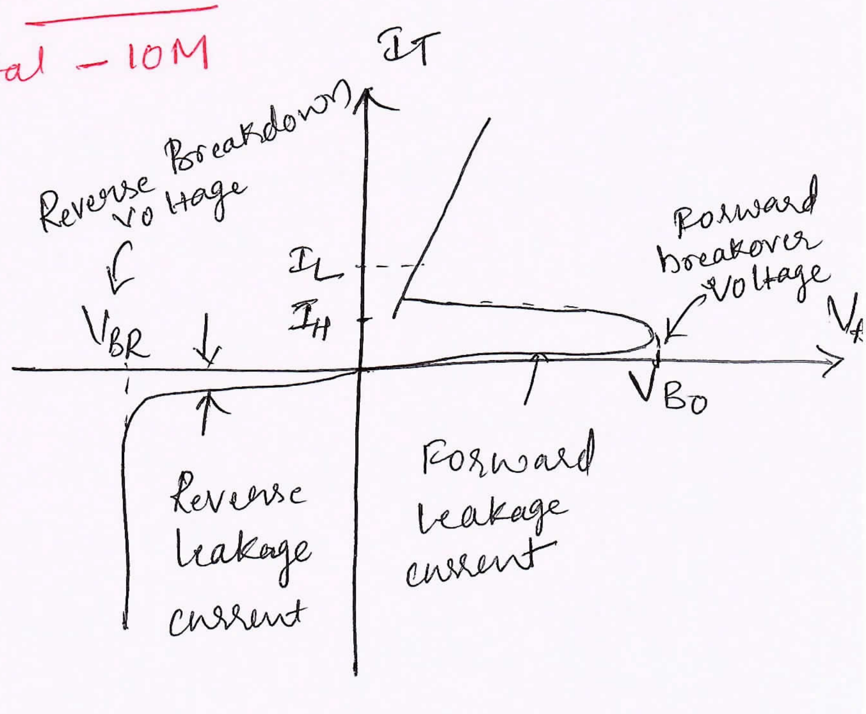
If the gate current I_G is suddenly increased, say from 0 to 1 mA, this immediately increases anode current I_A which would further increase α_1 and α_2. The increase in the values of α_1 and α_2 further increases I_A. Therefore, there is a regenerative or positive feed back effect. If $(\alpha_1 + \alpha_2)$ tends to be unity, the denominator in the equation (4) approaches zero, resulting in a large value of anode current I_A and the thyristor turns on with a small gate current.

3.b) Explain thyristor characteristics and modes of operation. [10 Marks]

characteristics — 5 M
Explaination of regions — 5 M
Total — 10 M

Ans:-





When the anode voltage is made positive with respect to the cathode, the junctions J_1 and J_3 are forward biased. The junction J_2 is reverse biased and only a small leakage current flows from anode to cathode. The thyristor is then said to be in the forward blocking or off state, condition and the leakage current is known as off-state current I_D.

If the anode to cathode voltage V_{AK} is increased to a sufficiently large value, the reverse biased junction J_2 breaks. This is known as avalanche breakdown and the corresponding voltage is called forward breakdown voltage, V_{BO}. Because the other junctions J_1 and J_3 are already forward biased, there is free movement of carriers across all three junction resulting in a large forward current. The device is then in a conducting state, or on-state.

The voltage drop would be due to the ohmic drop in the four layers and it is small, typically 1V. In the on state, the anode current is limited by an external impedance or a resistance, R_L as shown in figure above. The anode current must be more than a value known as latching current I_L, to maintain the required amount of carrier flow across the junction, otherwise, the device reverts to the blocking condition as the anode to cathode voltage is reduced.

Latching current, I_L → is the minimum current required to maintain the thyristor in the on-state immediately after a thyristor has been turned on & the gate signal has been removed.

Holding current, I_H → is the minimum anode current to maintain the thyristor in the on state.

Always the holding current is less than the Latching current.

4. a) Bring out the differences between natural and forced commutation. [04 Marks]

4 Differences — 4 Marks

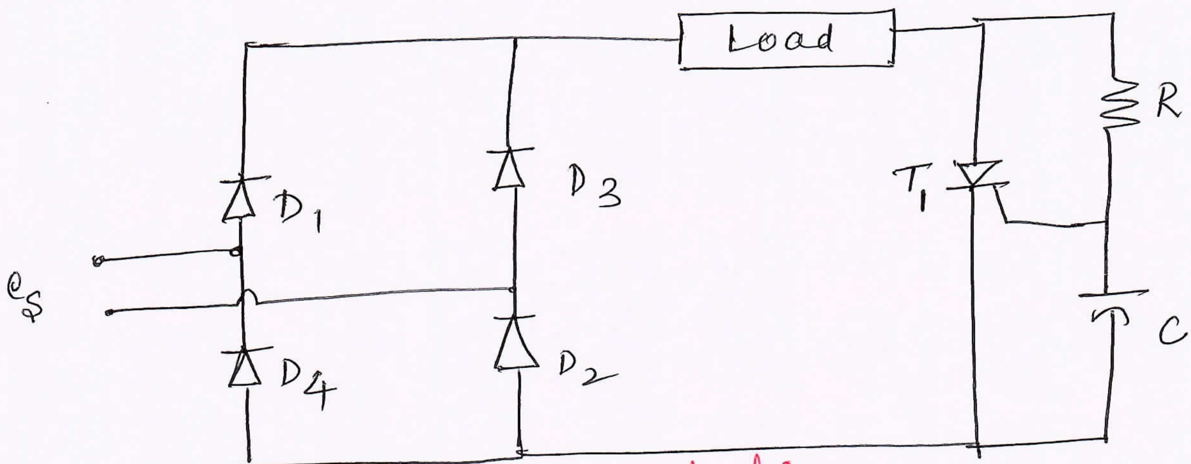
Ans:

Natural commutation	Forced commutation
① Requires AC voltage at input	① Required DC voltage at input
② External components are not required	② External components are required
③ Used in controlled rectifiers, AC voltage controller. etc.	③ Used in choppers, inverters etc.
④ No power loss takes place during commutation	④ Power loss takes place during commutation.
⑤ SCR turns off due to negative supply voltage.	⑤ SCR turns off due to current & voltage both.
⑥ Zero cost	⑥ Significant cost.

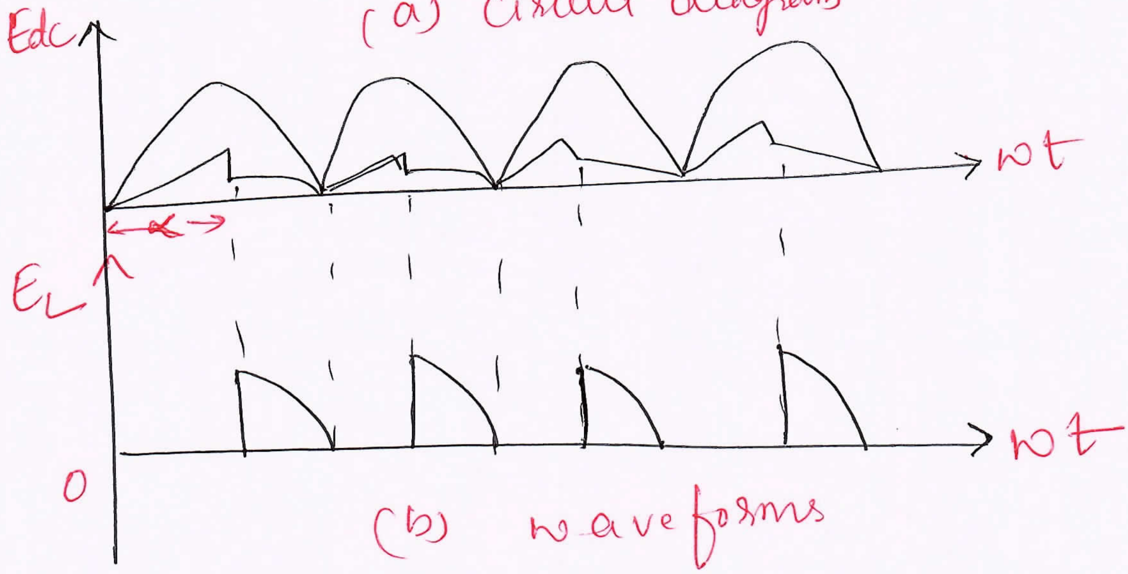
4) b) Explain the operation of a full wave RC firing circuit with waveforms. [08 Marks]

Circuit diagram — 2 M
waveforms — 3 M
Explaination — 3M
Total 8M

Ans:



(a) circuit diagram



(b) waveforms

By the RC network, a larger variation in the value of the firing angle can be obtained by changing the phase and amplitude of the gate current. By varying resistance R, the firing angle can be controlled from 0 to 180°

During the positive half cycle of e_s because of SCR conducts only when it is forward biased.

This limitation can be overcome in several ways, one of which is shown in fig (a) above. Here the ac line voltage is converted to pulsating dc by the full wave diode bridge. This allows the SCR to be triggered on for both half cycle of the line voltage, which doubles the available power to the load.

In this circuit, the initial voltage from which capacitor C charges is almost zero. Capacitor C is set to this low positive voltage by the V_{gt}, SCR triggers and rectified voltage E_{dc} appears across load as e_L.

The value of R_{VC} is obtained from the following relation:

$$R_V C \geq 50 \frac{T}{2} = \frac{157}{\omega}$$

The value of R_V is given by,

$$\boxed{R_V \leq \frac{e_s - V_{gt}}{I_{gc(min)}}}$$

4) c) A UJT is connected across a 20V DC supply the valley and peak point voltages are 1 volt and 15V. The period of UJT relaxation oscillator is 20ms. Find the value of charging capacitor, if a charging resistor of 100kΩ is used. [08 Marks]

Given,

$V_{BB} = 20V$

$V_V = 1V$

$V_P = 15V$

$T = 20ms$

$R = 100k\Omega$

Let us assume,

$\eta = 0.6$

$$T = RC \ln\left(\frac{1}{1-\eta}\right)$$

$$20\times10^{-3} = 100\times10^{3}\times C \ln\left(\frac{1}{1-0.6}\right)$$

$$20\times10^{-3} = 91629.07\,C$$

$$C = \frac{20\times10^{-3}}{91629.07} = \underline{\underline{218\,\eta F}}$$

Module 3

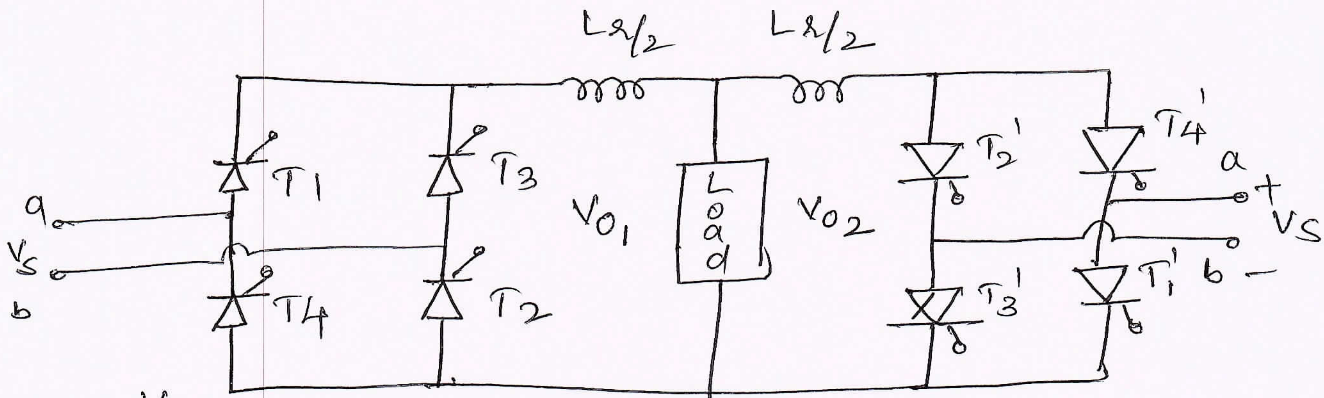
5)a) Explain the working of single phase dual converter How it operates in four quadrants?

[10 Marks]

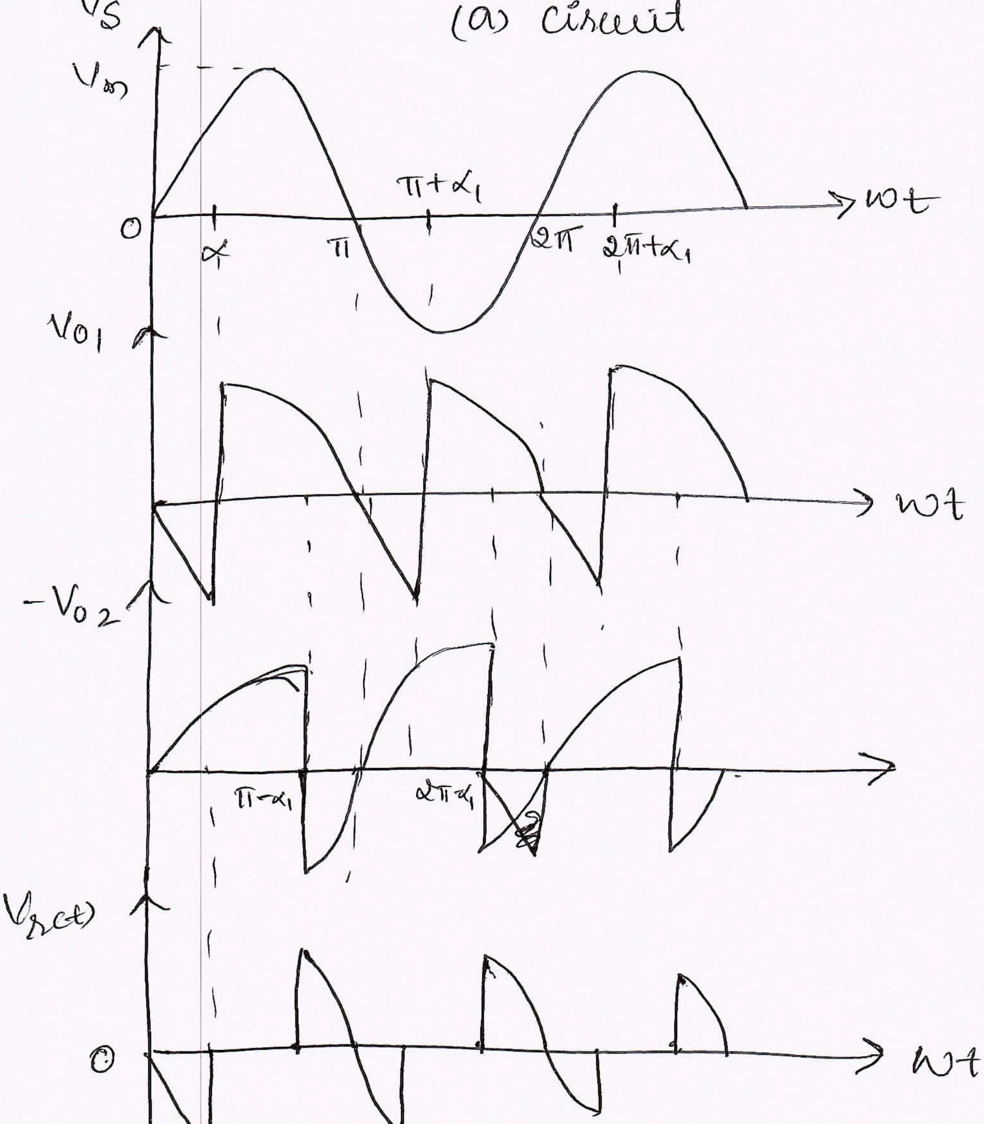
Circuit diagram – 3 M
wave forms – 3 M
Explaination – 4 M

Total – 10 M.

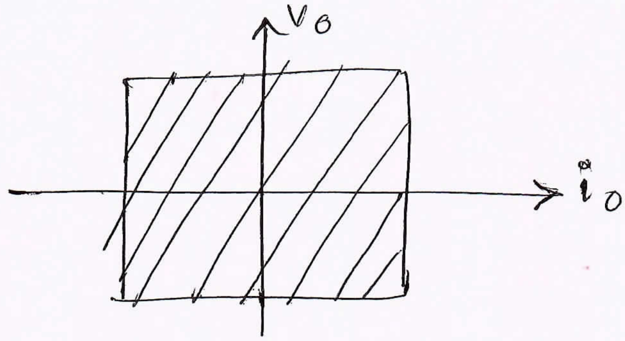
Ans:



(a) circuit



(b) waveforms



(c) quadrant

The Single phase full converters with inductive loads allow only a two quadrant operation. If two of these full converters are connected back to back as shown in figure (a), both the o/p voltage and the load current flow can be reversed. The System provides a four quadrant Operation operation and is called a dual converter. Dual converters are normally used in high power variable speed drives. If α_1 and α_2 are the delay angles of converters 1 and 2 respectively, the corresponding average output voltages are V_{dc1} & V_{dc2}.

The delay angles are controlled Such that One converter Operates as a rectifier and the other converter operates as an inverter but both converters produce the same average o/p voltage. Fig (b) Shows the o/p waveforms for two converters, where the two average output voltages are the same.

Fig (c) Shows the V-i characteristics of dual converter.

The average o/p Voltages are,

$$V_{dc_1} = \frac{2V_m}{\pi} \cos\alpha_1$$

$$V_{dc_2} = \frac{2V_m}{\pi} \cos\alpha_2$$

Because one converter is rectifying and the other one is inverting,

$$V_{dc_1} = -V_{dc_2}$$

$$\cos\alpha_2 = -\cos\alpha_1 = \cos(\pi - \alpha_1)$$

$$\therefore \alpha_2 = \pi - \alpha_1$$

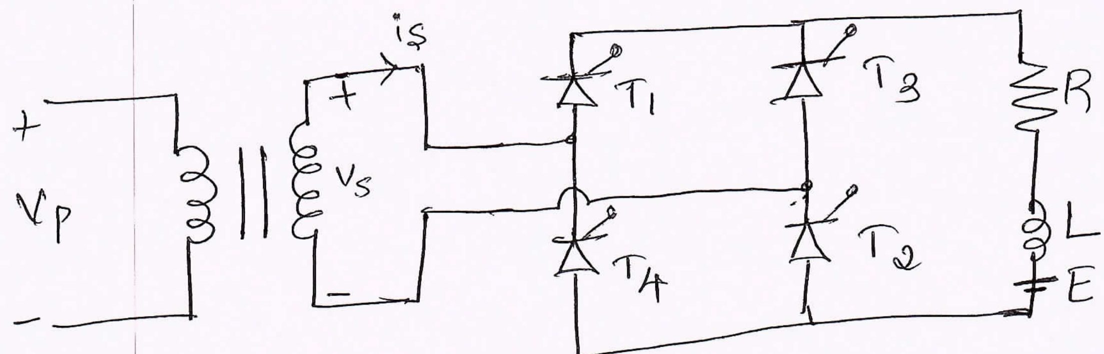
Because the instantaneous o/p voltages of the two converters are out of phase, there can be an instantaneous voltage difference and this can result in circulating current between the two converters. This circulating current can now flow through the load.

5.6) Derive an expression for average value of output voltage for 1ϕ full wave controlled Rectifier with RL load. [10 marks]

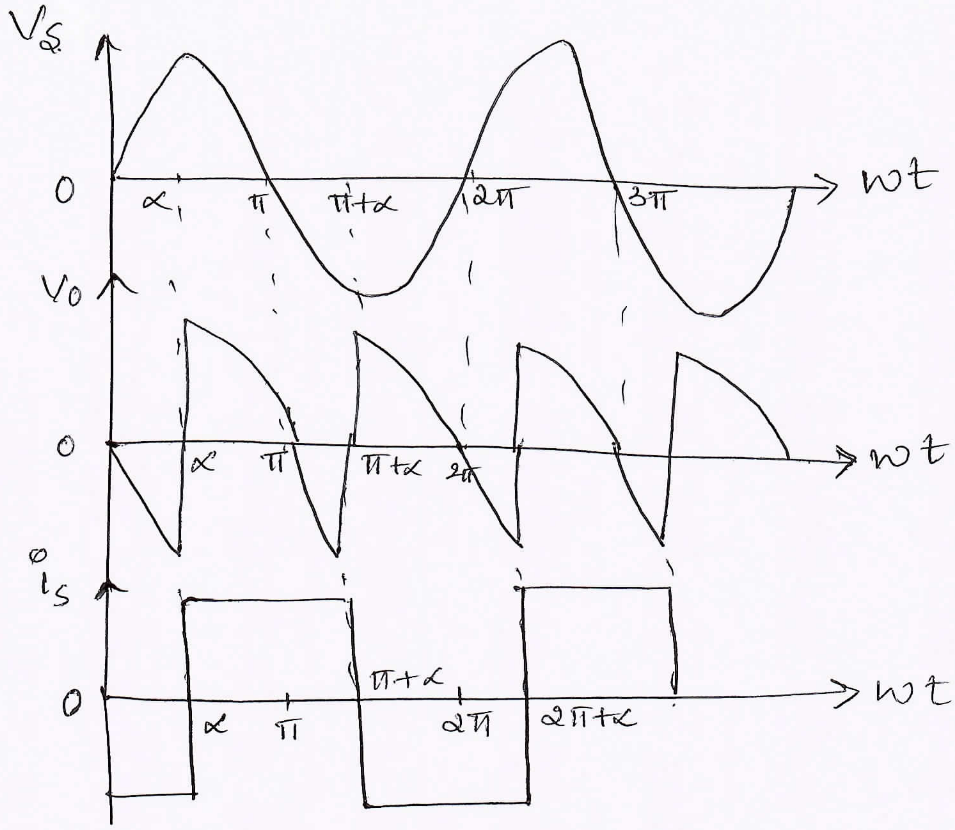
Circuit — 3M
waveforms - 2M
Explaination - 2M
Derivation - 3M

Total 10M

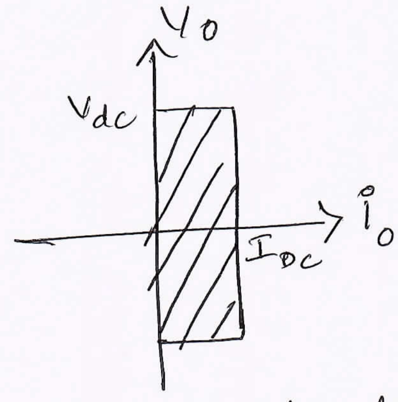
Soln:



(a) Circuit



(b) waveforms



(c) Quadrant

The circuit arrangement of a single phase full converter is shown in figure a with a highly inductive load so that the load current is continuous and ripple free.

During the positive half cycle, thyristors T_1 and T_2 are forward biased; and when these two thyristors are fired simultaneously at $\omega t = \alpha$, the load is connected to the input supply through T_1 and T_2. Due to inductive load, thyristors T_1 and T_2 continue to conduct beyond $\omega t = \pi$, even though the input voltage is already negative.

During the negative half cycle of the input voltage, thyristors T_3 and T_4 are forward biased; and firing of thyristors T_3 and T_4 applies the supply voltage across thyristors T_1 and T_2 as reverse blocking voltage.

T_1 and T_2 are turned off due to line or natural commutation and the load current is transferred from T_1 and T_2 to T_3 and T_4.

→ Fig. c. Shows the regions of converter operation and fig (b) shows the waveforms.

→ During the period from α to π, the input voltage V_s and input current i_s are positive and the Power flows from the supply to the load. So the converter is in <u>Rectification mode</u>.

→ During the period from π to $\pi+\alpha$, the input Voltage V_s is negative and the input current i_s is positive, and reverse power flows from the load to the supply. The converter is said to be operated in <u>Inversion mode</u>.

The average output Voltage can be found from,

$$V_{dc} = \frac{2}{2\pi}\int_{\alpha}^{\pi+\alpha} V_m \sin \omega t \, d(\omega t)$$

$$= \frac{2V_m}{2\pi}\left[-\cos \omega t\right]_{\alpha}^{\pi+\alpha}$$

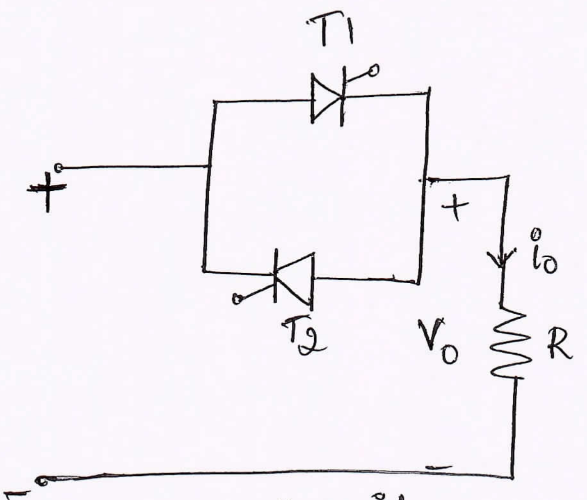
$$\boxed{V_{dc} = \frac{2V_m}{\pi}\cos\alpha}$$

6) a) With a neat diagram and relevant waveforms explain 1Ø full wave controller for ON-OFF control. Derive an expression for RMS value of load voltage in ON-OFF AC Voltage controller. [10 Marks]

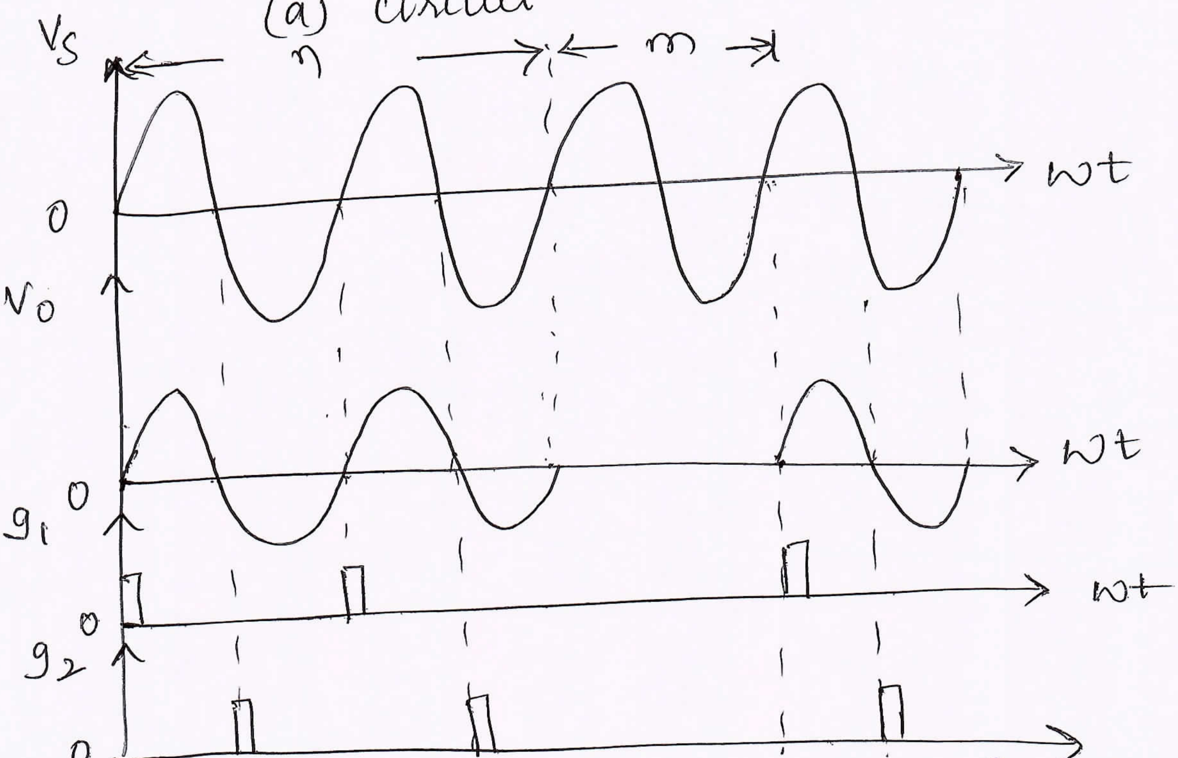
Circuit diagram – 2M
waveforms – 3M
Explaination – 2M
Derivation of RMS voltage – 3M

Total 10M

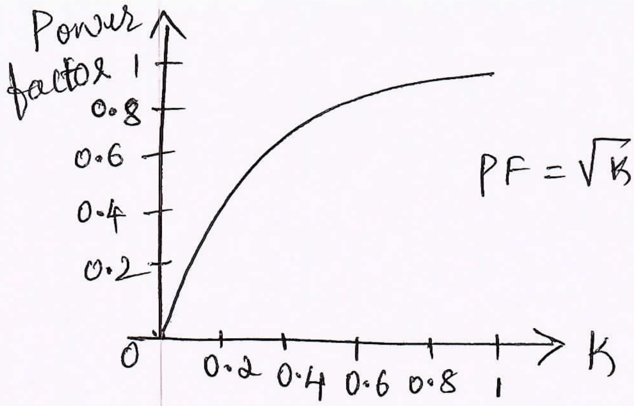
Ans:



(a) circuit



(b) waveforms



(c) Power factor

The Principle of on-off control can be explained with a single phase full wave controller as shown in figure a). The thyristor switch connects the ac supply to load for a time t_n, the switch is turned off by a gate pulse inhibiting for time t_o.

The on-time t_n usually consists of an integral number of cycles. The thyristors are turned on at the zero-voltage crossings of ac input voltage. The gate pulses for thyristors T_1 and T_2 and the waveforms for input and output voltages are shown in fig(b)

This type of control is applied in applications that have a high mechanical inertia and high thermal time constant. Due to zero voltage and zero current switching of thyristors, the harmonics generated by switching actions are reduced.

For a sinusoidal i/p voltage, $V_s = V_m \sin\omega t$

$$V_S = \sqrt{2} V_S \sin\omega t.$$

If the i/p voltage is connected to load for n cycles and is disconnected for m cycles, the RMS o/p voltage can be found from,

$$V_0 = \left[\frac{n}{2\pi(n+m)}\int_0^{2\pi} 2V_s^2 \sin^2\omega t \, d(\omega t)\right]^{1/2}$$

$$= V_s\sqrt{\frac{n}{n+m}}.$$

$$\boxed{V_0 = V_s\sqrt{K}}$$

where $K = \frac{n}{n+m}$ and K is called duty cycle.

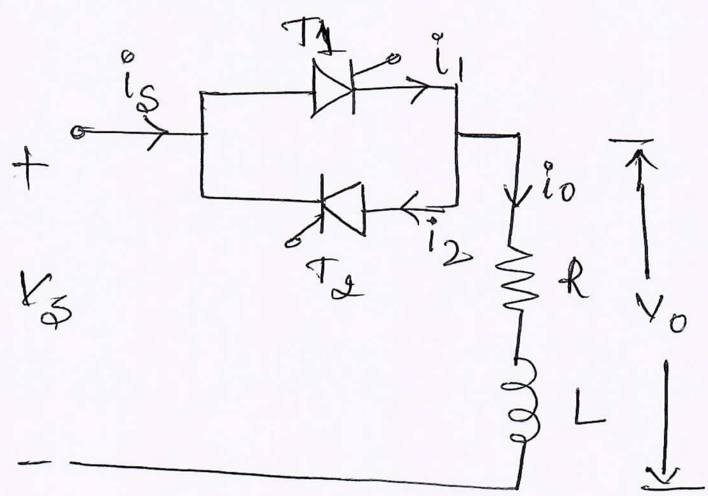
V_s is the RMS phase voltage.

6.b) Explain 1∅ Bidirectional AC voltage controller with inductive loads. [06 Marks]

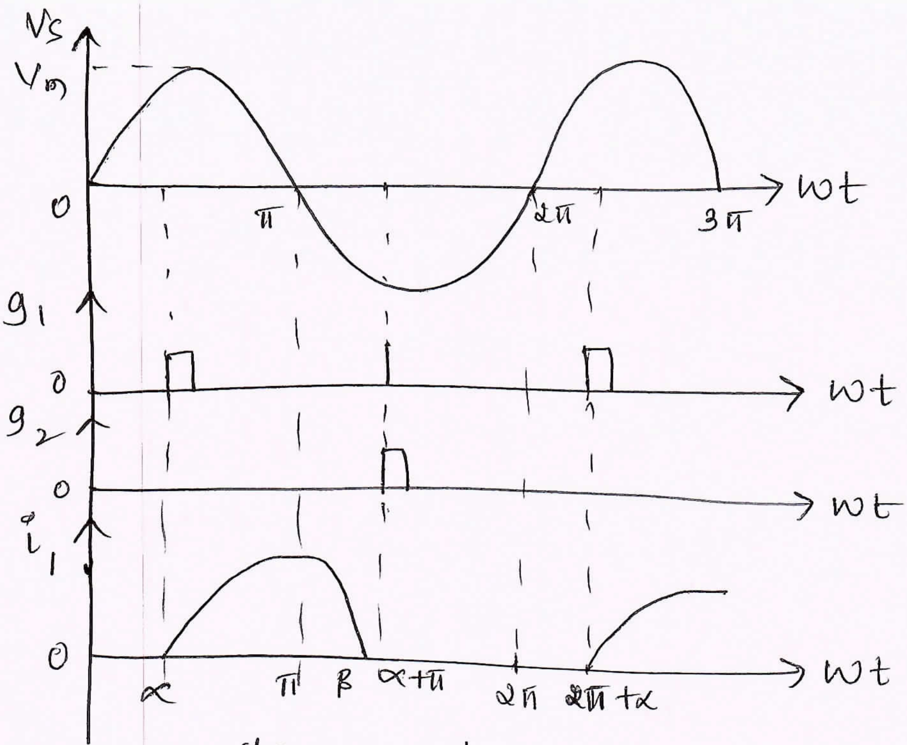
Circuit — 2M
waveform — 2M
Explaination — 2M

Total - 6M

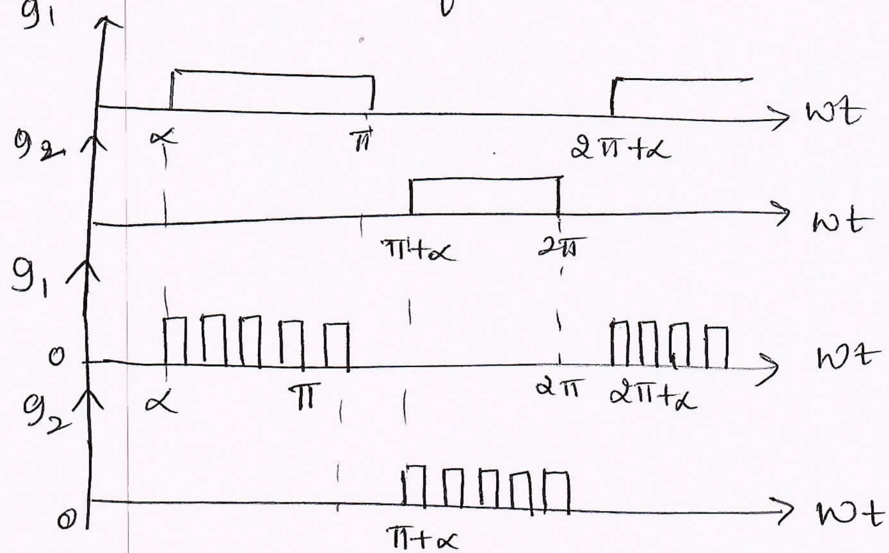
Ans:-



(a) Circuit



(b) wave forms.



(c) Gating Sequence.

A full wave controller with an RL is shown in figure (a). Let us assume that thyristor T_1 is fired during the positive half cycle and carries the load current. Due to inductance in the circuit, the current of thyristor T_1 would not fall to zero at $\omega t = \pi$, when the input voltage starts to be negative. Thyristor T_1 continues to conduct until its current i_1 falls to zero at $\omega t = \beta$. The conduction angle of thyristor T_1 is $\delta = \beta - \alpha$ and depends on the delay angle α and the PF angle of load θ. The waveforms for the thyristor current, gating pulses and input voltage are shown in fig (b).

6.c) In an ON-OFF control circuit using 1ϕ, 230V, 50Hz supply the ON time is 10 cycles and OFF time is 4 cycles. Calculate the RMS value of o/p voltage.
[04 Marks]

Formula – 1M
Calculation – 3M
Total – 4M

Given
$n = 10$
$m = 4$
$V_S = 230V$

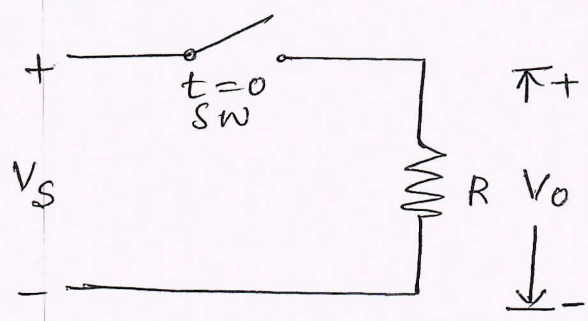
Soln:
$$V_0 = V_S\sqrt{K}$$
$$= V_S\sqrt{\frac{n}{n+m}}$$
$$= 230\sqrt{\frac{10}{10+4}}$$
$$\boxed{V_0 = 194.38\,V.}$$

Module 4

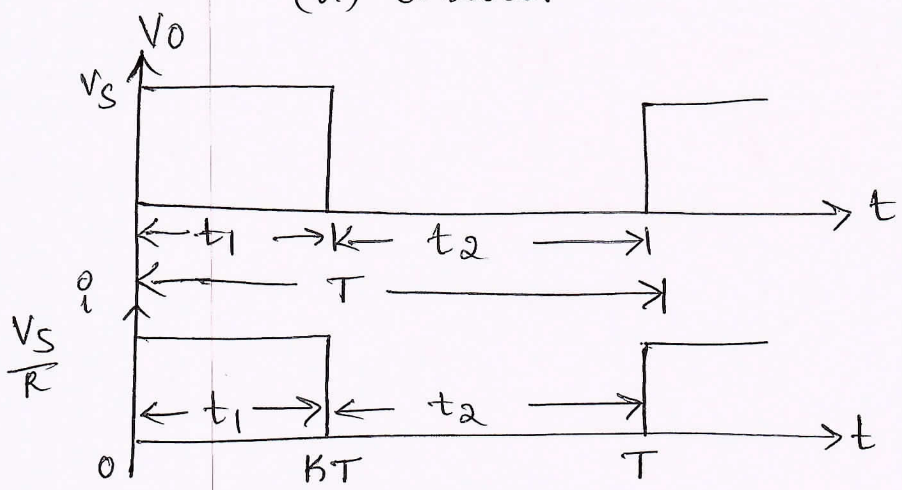
7.a) Explain the principle of operation of step down chopper with R load.
[08 Marks]

Circuit – 2M
Waveform – 3M
Explaination – 3M
Total – 8M

Ans:-



(a) circuit



(b) waveforms

The principle of operation can be explained by figure (a). When switch SW, known as the chopper is closed for a time t_1, the input voltage V_s appears across the load. If the switch remains off for a time t_2, the voltage across the load is zero. The waveforms for the output voltage and load current are also shown in fig (b).

The converter switch can be implemented by using a 1) Power BJT 2) Power MOSFET 3) GTO 4) IGBT. The Practical devices have a finite voltage drop ranging from 0.5 to 2V and for the sake of simplicity, we shall neglect the voltage drops of these power semiconductor devices.

7.b) A DC chopper has a resistive load of 30 Ω and input voltage $V_s = 220V$. When the chopper is ON, the voltage drop is 1.5 V and chopping frequency is 20 KHZ. If duty cycle is 60%. determine the average output voltage, RMS output voltage and chopper ON time. [08 Marks]

Average o/p Voltage – 4M
RMS o/p Voltage – 4M
Total – 8M

Ans: Average o/p voltage,

Given
$V_S = 220V$
$V_{ch} = 1.5V$
$K = 60\%$
$f = 20 KHZ$

$$V_0 = K \times V_S -$$
$$= K \times (V_S - V_{ch})$$
$$= 0.6 \times (220 - 1.5)$$
$$\boxed{V_0 = 131.1 V}$$

RMS o/p voltage,

$$V_0 = \sqrt{K} \times V_S$$
$$= \sqrt{K} \times (V_S - V_{ch})$$
$$= \sqrt{0.6} \times (220 - 1.5)$$
$$\boxed{V_0 = 169.24 V}$$

7.c) With relevant graphs, Explain how choppers are classified.

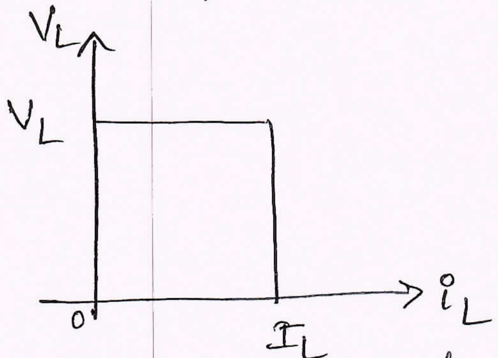
[04 Marks]

chopper classification - 3M

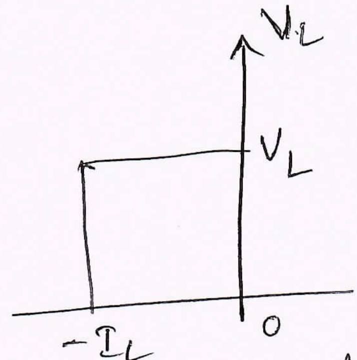
graphs - 1M.

Soln:- Depending on the directions of current and voltage flows, dc converters can be classified into five types.

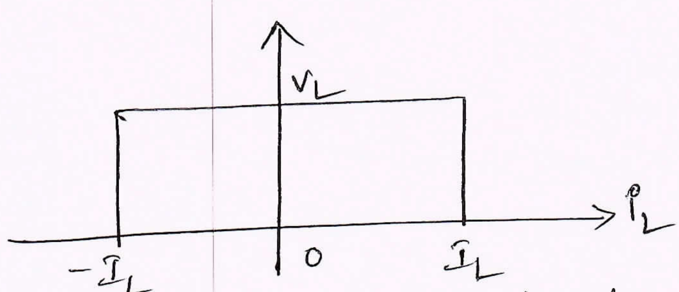
i) First quadrant converter
ii) Second quadrant converter
iii) First and second quadrant converter
iv) Third and fourth quadrant converter
v) Four quadrant converter.



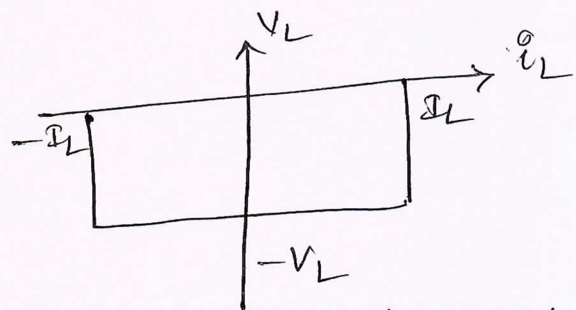
a) First quadrant converter



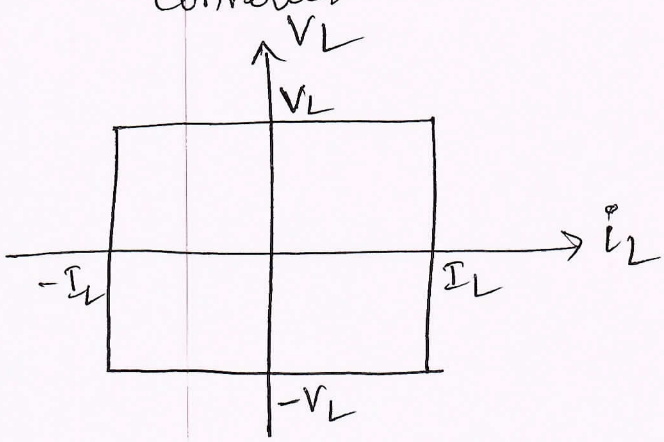
(b) Second quadrant converter



(c) first and Second quadrant converter



(d) Third and Fourth quadrant converter



(e) Four quadrant converter

First quadrant converter -

The load current flows into the load. Both the load voltage and load current is positive as shown in fig(a).

Second quadrant converter -

The load current flows out of the load. The load voltage is positive, but the load current is negative as shown in fig(b).

First and second quadrant converter -

The load current is either positive or negative as shown in figure (C).

Third and Fourth quadrant converter -

The load voltage is always negative. The load current can be either positive or negative, as shown in fig(d).

Four quadrant converter -

The load current is either positive or negative and load voltage is also either positive or negative as shown in fig(e)

8) a.) With neat figure, explain Buck Regulator [10 Marks]

Circuit - 3 M
Wave forms - 4 M
Explainatation - 3 M
Total - 10M

Ans:

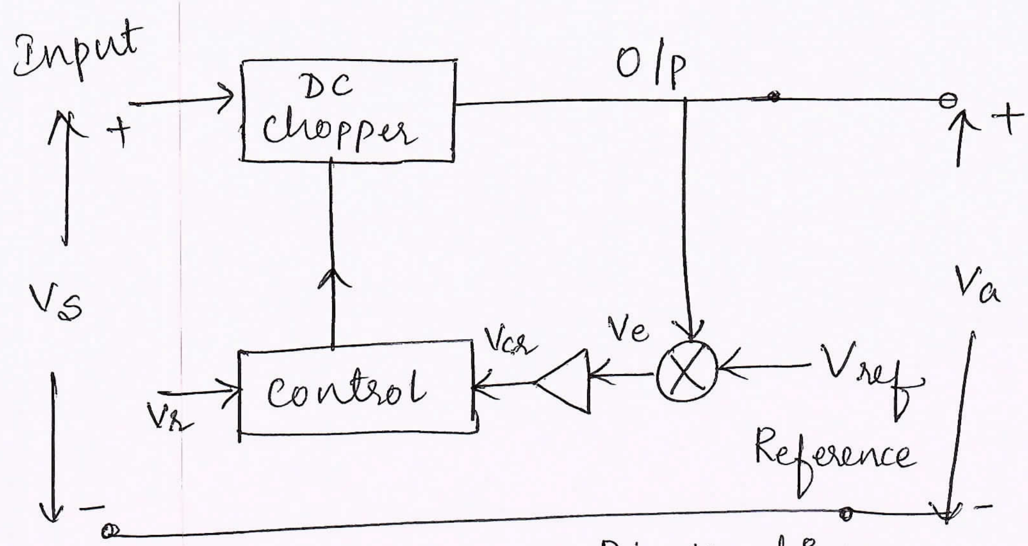
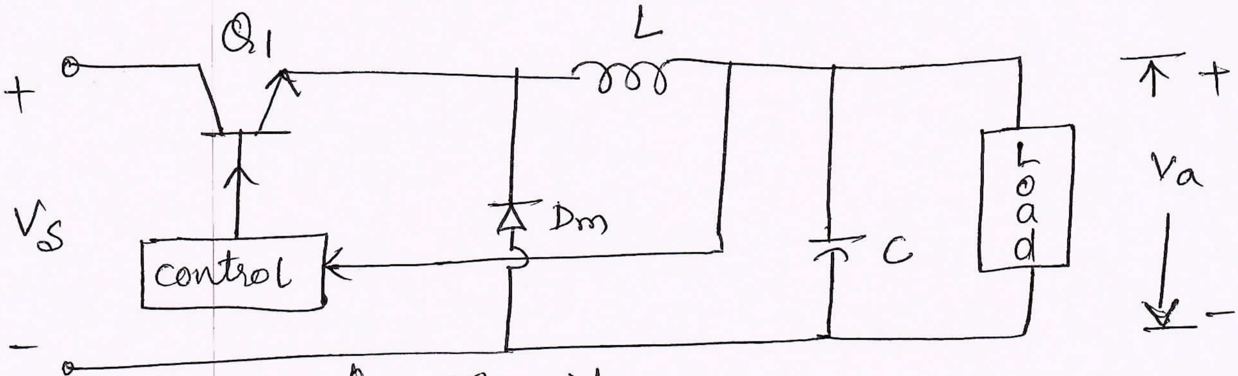
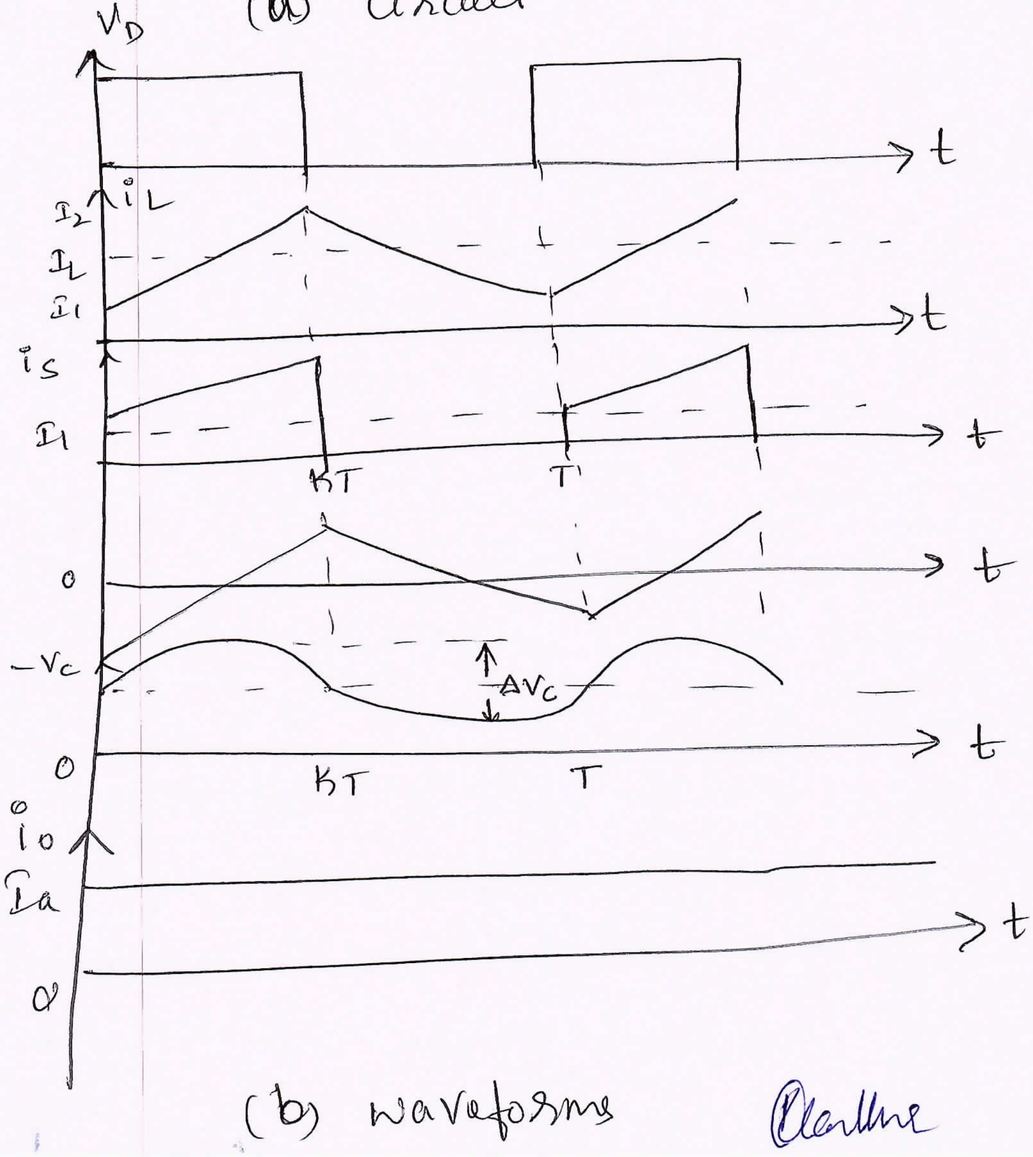


Fig: ~~(a) Circuit~~ Block diagrams



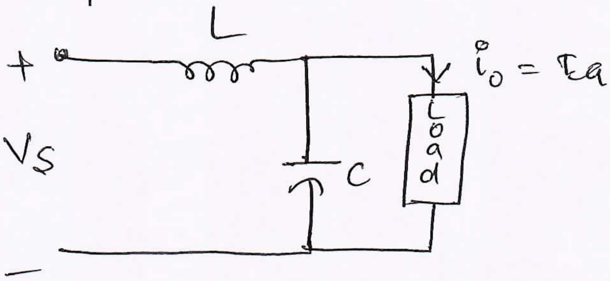
(a) circuit



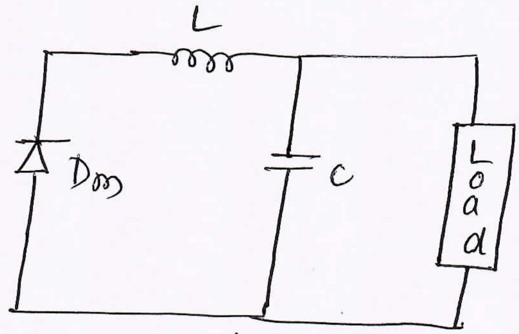
(b) waveforms

In a Buck Regulator, the average O/p voltage V_a, is less than the input voltage, V_s hence the name Buck, a very popular regulator.

The circuit diagram of a buck regulator using a Power BJT as shown in fig(a) and this is like a Step down converter.



Mode 1



Mode 2

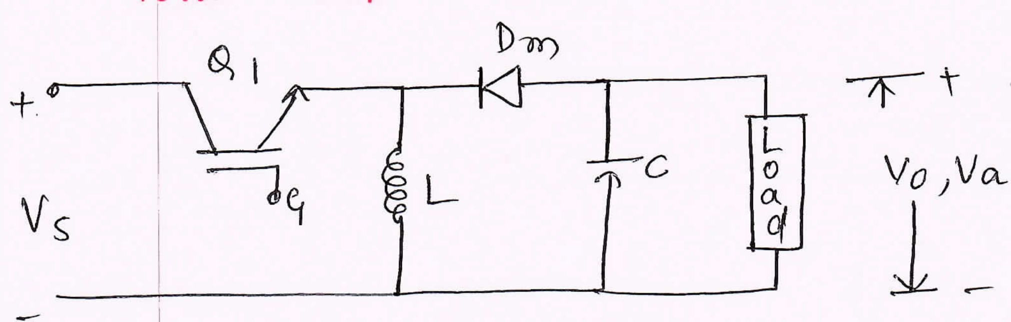
The circuit operation can be divided into two modes. Mode 1 begins when transistor Q_1 is switched on at $t=0$. The input current, which rises, flows through filter inductance L, filter capacitor C and load resistor R. Mode 2 begins when transistor Q_1 is switched off at $t=t_1$. The free wheeling diode Dm conducts due to energy stored in the inductor and the inductor current continues to flow through L, C, load and diode Dm. The inductor current falls until Transistor Q_1 is switched on again in the next cycle. The equivalent circuits for the modes of operation are shown in figure above. The waveforms for the voltages and currents are shown in figure(b) for a continuous current flow in the inductor L. It is assumed that current rises and falls linearly. Depending on the switching frequency, filter inductance, and capacitance, the inductor current could be discontinuous.

8.b.) With the help of a circuit diagram and relevant waveforms, explain the working of a Buck - Boost Regulator [10 marks]

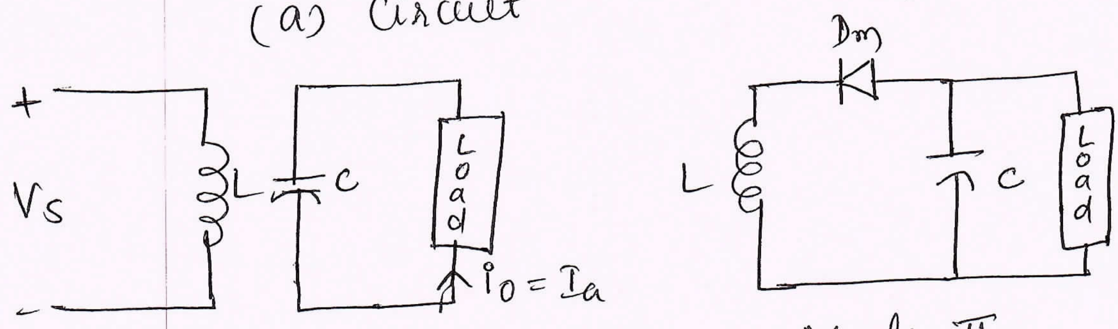
Circuit – 3M
waveforms – 4M
Explaination – 3M

Total – 10M

Ans:



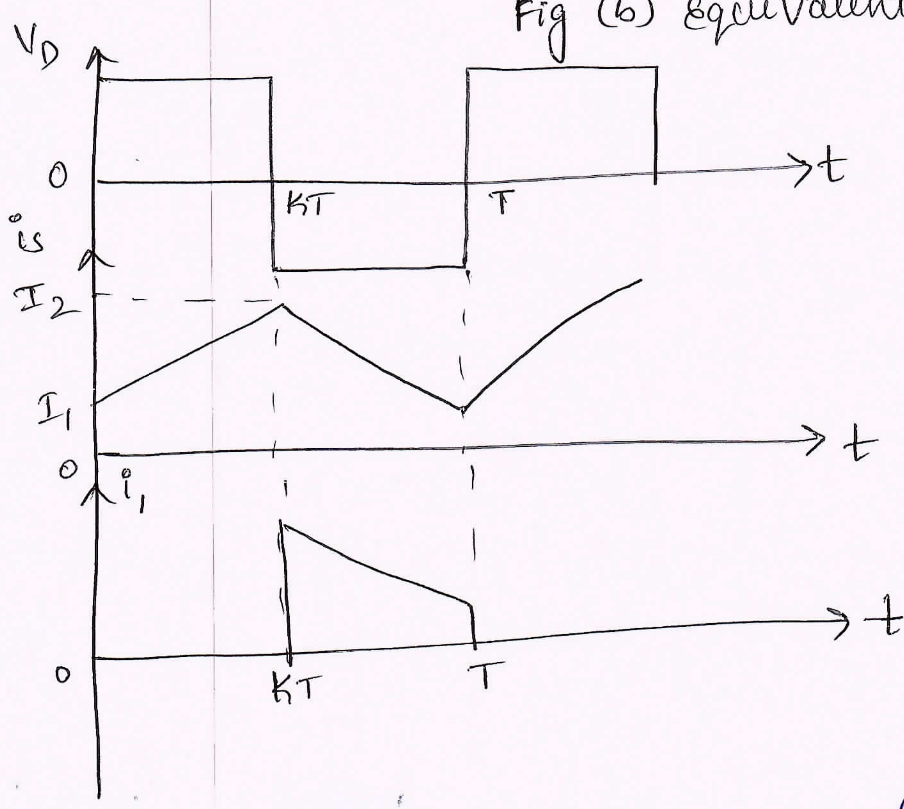
(a) Circuit

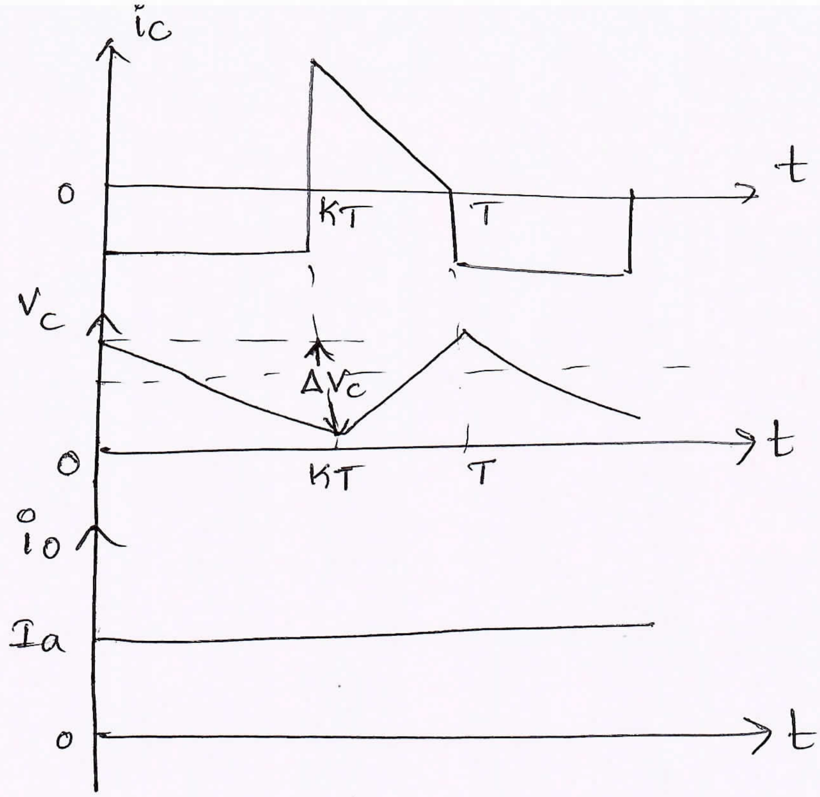


Mode I

Mode II

Fig (b) Equivalent circuits





(c) waveforms

A Buck Boost regulator provides an output voltage that may be less than or greater than the input voltage - hence the name Buck-Boost, the output voltage polarity is opposite to that of input voltage. This regulator is also known as an inverting regulator. The circuit arrangement of a buck-boost regulator is shown in figure (a).

The circuit operation can be divided into two modes. During mode I, transistor Q_1 is turned on and diode D_m is reversed biased. The input current which rises, flows through inductor L and transistor Q_1.

During mode 2, transistor Q_1 is switched off and the current, which was flowing through the inductor L would flow through L, C, D_m and the load.

The energy stored in inductor L would be transferr-
-ed to the load and the inductor current would fall untill transistor Q_1 is switched on again in the next cycle. The equivalent circuits for the modes are shown in fig(b). The waveforms for Steady State Voltages and currents of the Buck-Boost regulator are shown in figure (c) for a continuous load current.

Module 5

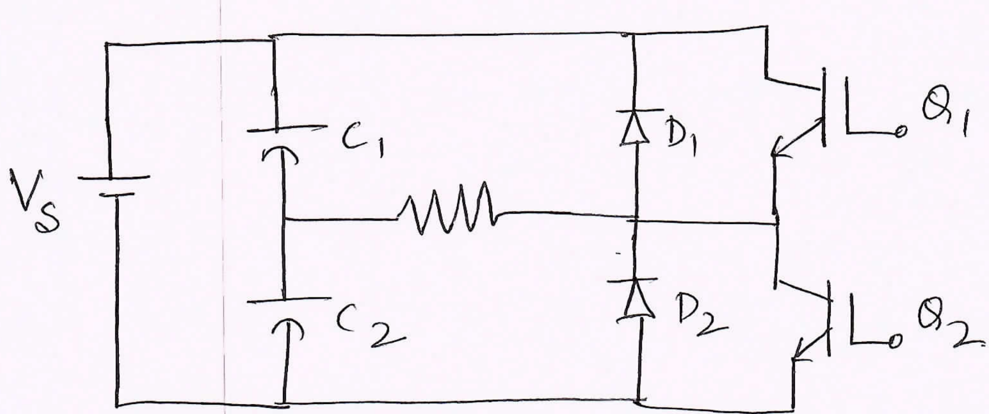
9.a.) Explain the operation of single phase half bridge inverter with inductive load, derive the expression for rms output voltage if the input is square wave with peak output voltage is V/2.

[10 Marks]

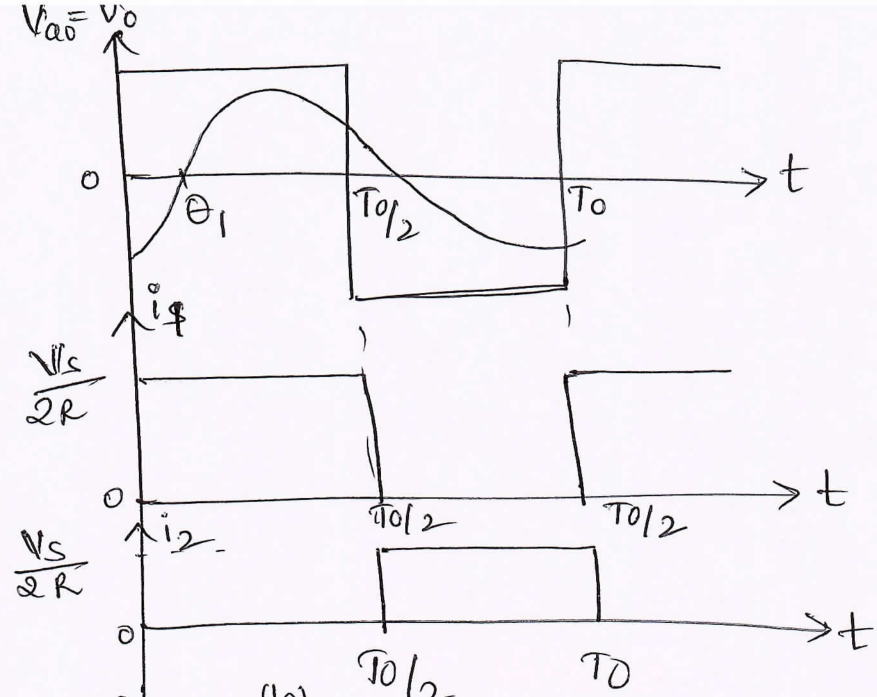
Circuit — 2M
waveforms — 3M
Explaination - 2M
Derivation of RMS o/p voltage - 3M

Total - 10M.

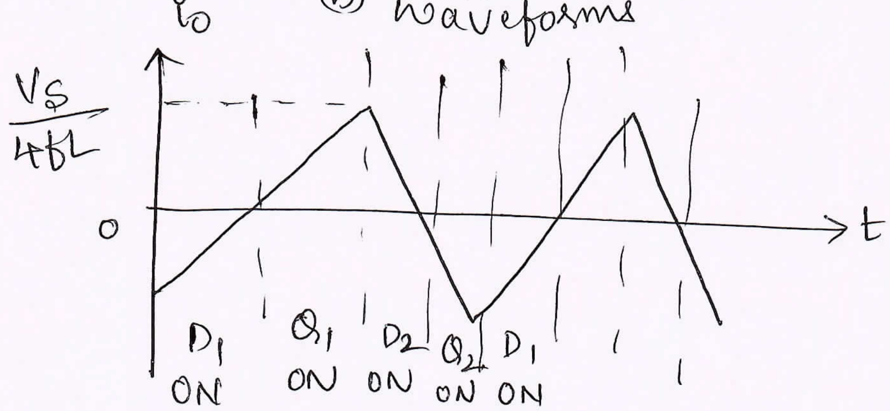
Ans:



(a) Circuit



(b) waveforms



(C) Load current with highly inductive load.

The principle of single phase inverters can be explained as fig(a). The inverter circuit consists of two choppers. when only transistor Q_1 is turned on for a time To/2, the instantaneous Voltage across the load V_o is $V_o/2$. If transistor Q_2 only is turned on for a time To/2, $-V_s/2$ appears across the load. The logic circuit should be designed such that Q_1 and Q_2 are not turned on at the same time.

Fig (b) shows the waveforms for the output voltage and transistor currents with a resistive load.

Dlakhmi

This inverter requires a three wire dc source, and when a transistor is off, its reverse voltage is V_s instead of $V_s/2$. This inverter is known as a half bridge inverter.

The Root Mean square output voltage can be found from,

$$V_o = \left(\frac{2}{T_o} \int_0^{T_o/2} \frac{V_s^2}{4} dt \right)^{1/2}$$

$$= \left[\frac{2}{T_o} \cdot \frac{V_s^2}{4} \cdot [1]_0^{T_o/2} \right]^{1/2}$$

$$= \left[\frac{2}{T_o} \cdot \frac{V_s^2}{4} \cdot \left[\frac{T_o}{2} - 0 \right] \right]^{1/2}$$

$$= \left[\frac{\cancel{2}}{\cancel{T_o}} \cdot \frac{V_s^2}{4} \cdot \frac{\cancel{T_o}}{\cancel{2}} \right]^{1/2}$$

$$\boxed{V_o = \frac{V_s}{2}}$$

Q.6. Explain the performance parameters of inverters. [10 Marks]

4 performance parameters – 2.5M Each

Total – 10M

Ans:- **Harmonic factor of n^{th} harmonic (HF_n) →**

The harmonic factor which is a measure of individual harmonic contribution is defined as,

$$HF_n = \frac{V_{on}}{V_{o1}} \quad \text{for } n > 1$$

where V_1 is the rms value of the fundamental component and V_{on} is the rms value of the n^{th} harmonic component.

Total Harmonic Distortion (THD) →

The total harmonic distortion, which is a measure of closeness in shape between a wave-form and its fundamental component, is defined as,

$$THD = \frac{1}{V_{o1}} \left(\sum_{n=2,3,\ldots}^{\infty} V_{on}^2 \right)^{1/2}$$

Distortion Factor (DF)

Distortion Factor is a measure of effective-ness in reducing unwanted harmonics without having to specify the values of a second-order load filter and is defined as

$$DF = \frac{1}{V_{o1}} \left[\sum_{n=2,3,\ldots}^{\infty} \left(\frac{V_{on}}{n^2} \right)^2 \right]^{1/2}$$

The DF of an individual harmonic components is defined

$$DF_n = \frac{V_{on}}{V_{o1}\, n^2} \quad \text{for } n > 1$$

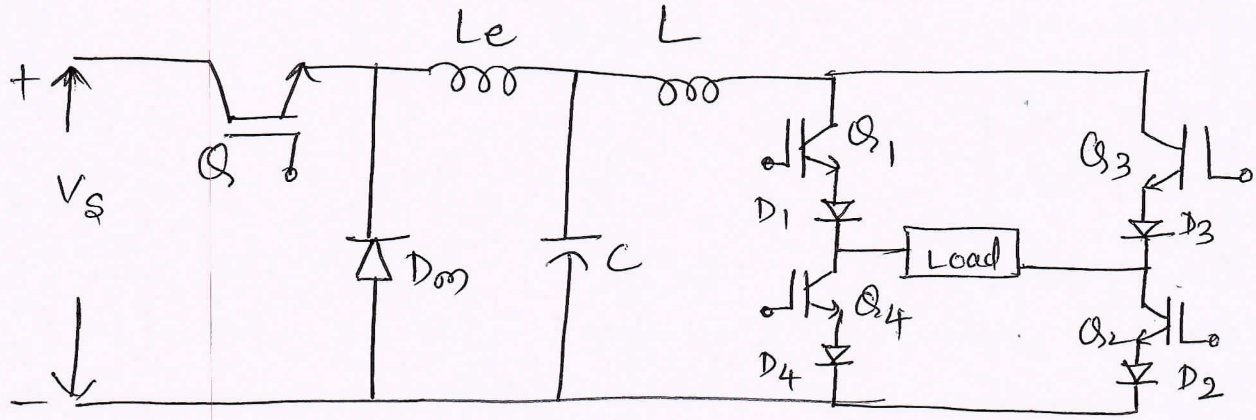
Lowest Order Harmonic (LOH)

The LOH is that harmonic component whose frequency is closest to the fundamental one, and its amplitude is greater than or equal to 3% of the fundamental component.

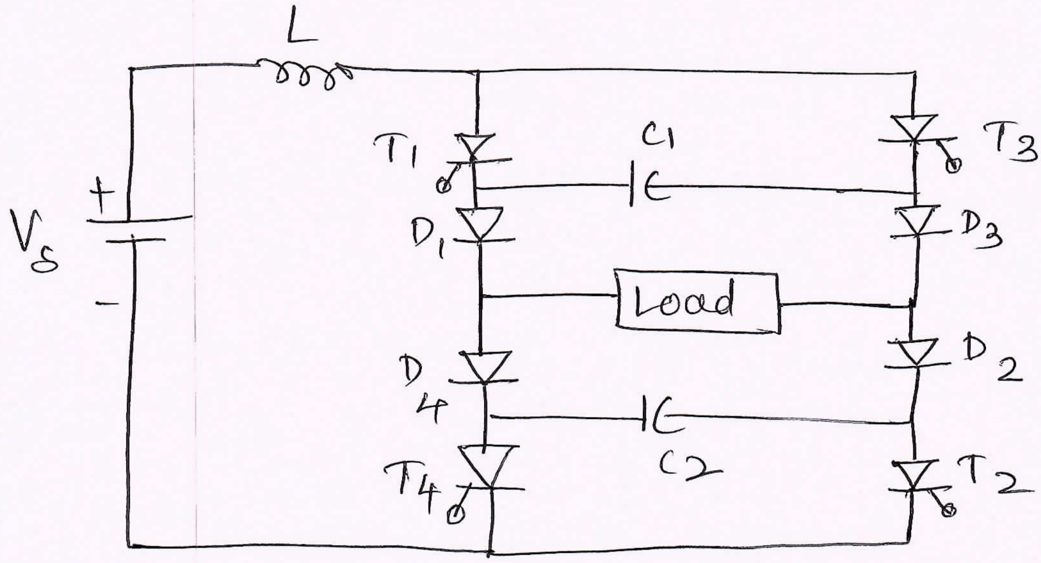
Q.a) Explain the operation of thyristorized current source inverter. What are its advantages? [10 Marks]

Circuit — 2M
Waveforms — 3M
Explaination — 3M
Advantages — 2M
Total — 10M

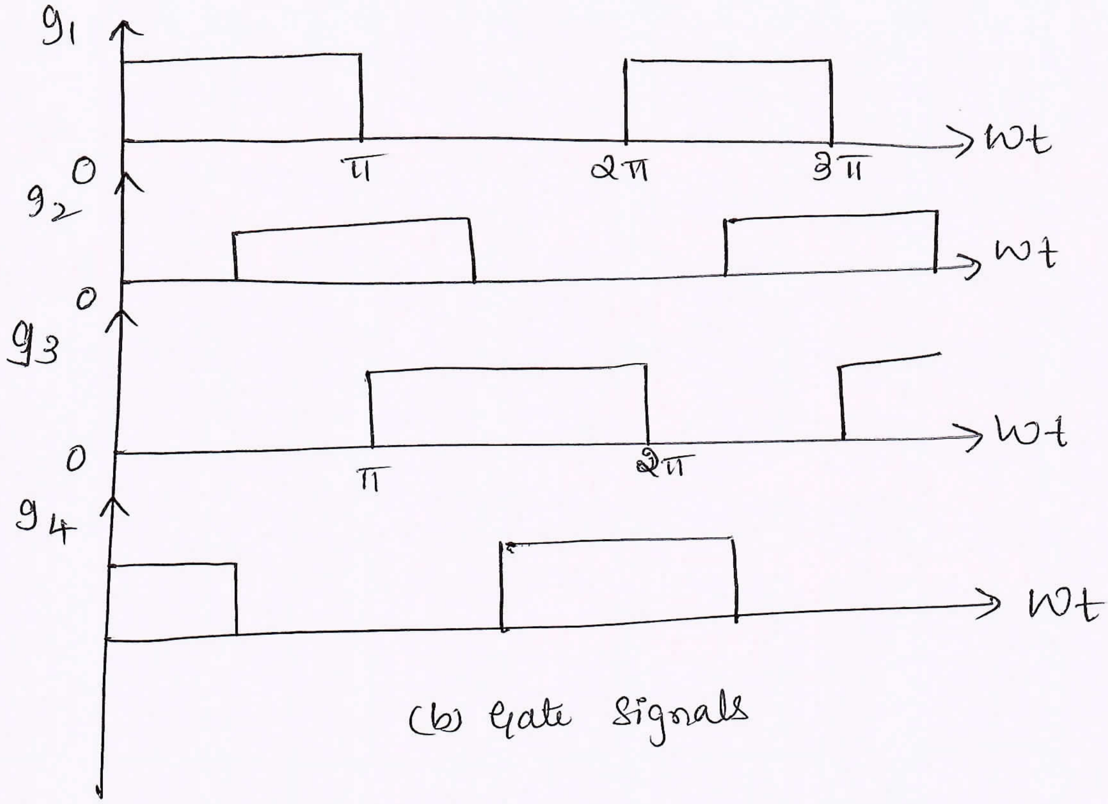
Ans:



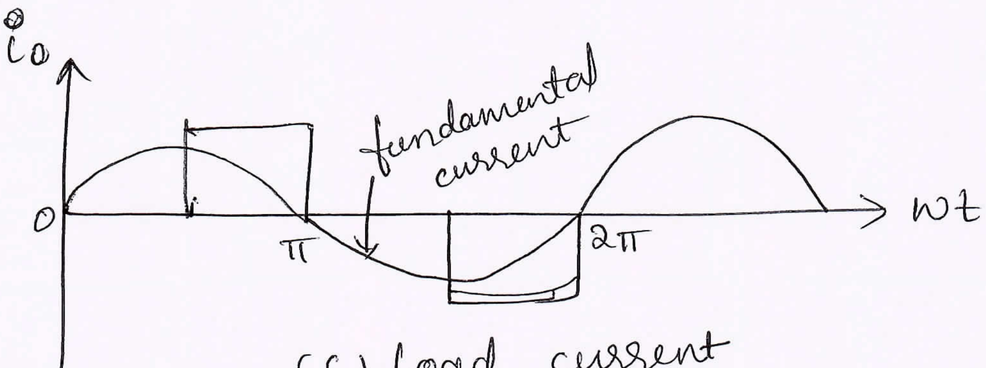
(a)



(a) Circuit



(b) Gate signals



(c) Load current

A current source inverter that utilizes capacitor to turn off the switching devices such as shown in figure (a). Let us assume that T_1 and T_2 are conducting and capacitors C_1 & C_2 are charged with polarity as shown.

Firing of thyristors T_3 and T_4 reverse biase thyristors T_1 and T_2. T_1 and T_2 are turned off by impulse commutation. The current now flows through $T_3 C_1 D_1$, load and $D_2 C_2 T_4$.

The capacitors C_1 and C_2 are discharged and charged at a constant rate determined by load current, $I_m = I_L$.

When C_1 and C_2 are charged to the load voltage and their currents fall to zero, the load current is transferred from diode D_1 to D_3 and D_2 to D_4. D_1 and D_2 are turned off when the load current is completely reversed. The capacitor is now ready to turn off T_3 and T_4 if thyristors T_1 and T_2 are fired in the next half-cycle. The commutation time depends on the magnitude of load current and load voltage. The diodes in figure(a) isolate the capacitors from the load voltage.

The advantages of Current Source Inverters are:

1) Since the input DC current is controlled and limited, misfiring of switching devices or a Short circuit, would not be serious problems

2) the peak current of power devices is limited

3) the commutation circuits for thyristors are simpler

4) It has the ability to handle reactive or regene-rative load without freewheeling diodes.

10.b.) Write short-note for,

i) Dc-link inverter ii) Sinusoidal PWM

[10 Marks]

Dc-link inverter — 5M

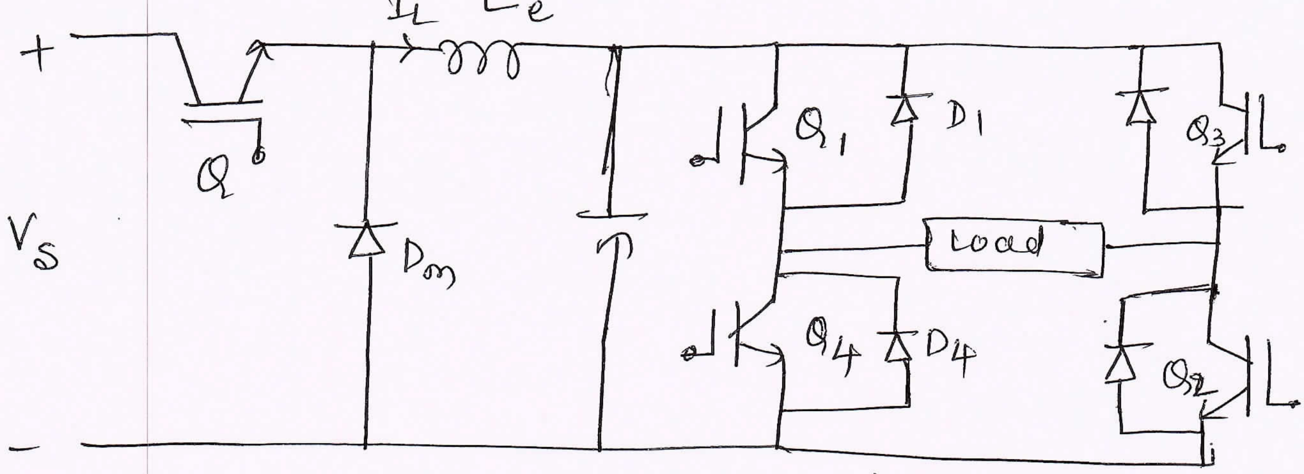
Sinusoidal PWM — 5M

Total- 10M

Soln: Dc link Inverter :-

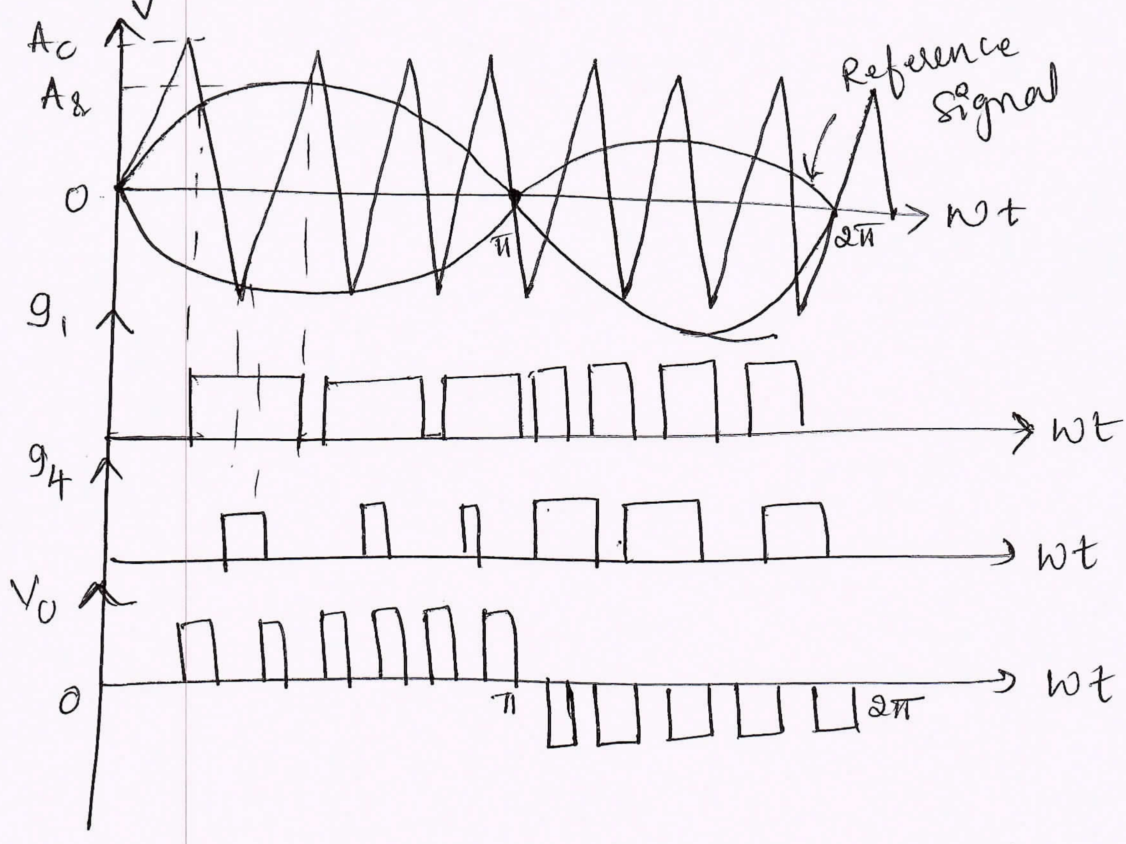
The o/p voltage of an inverter can be controlled by varying the modulation index and maintaining the Dc input voltage constant; however, in this type of voltage control, a range of harmonics would be present on the o/p voltage. The pulse widths can be maintained fixed to eliminate or reduce certain harmonics and the o/p voltage can be controlled by varying the level of Dc input voltage. Such an arrangement is shown below is known as variable dc-link inverter.

This arrangement requires an additional converter stage; and if it is a converter, the power cannot be fed back to the dc source. To obtain the desired quality and harmonics of the output voltage, the shape of the output voltage can be predetermined as shown in fig (b).



(a) Varible DC-link inverter

ii) Sinusoidal PWM



The gating signals as shown in fig. above are generated by comparing a sinusoidal reference signal with a triangular carrier wave of freq f_c. This sinusoidal pulse width modulation (SPWM) is commonly used in industrial applications.

The frequency of the reference signal f_r determines the inverter o/p frequency f_o, and its peak amplitude A_r, controls the modulation index M, and then in turn the rms output votage V_o. Comparing the bidirectional carrier signal V_{cr} with two sinusoidal reference signals v_r and $-V_r$ shown in fig above produces gating signals g_1 and g_4 respectively.

The o/p voltage $v_o = V_s(g_1 - g_4)$

The number of pulses per half cycle depends on the carrier frequency. within the constraint that the two transistors of the same arm (Q_1 and Q_4) cannot conduct at the same time, the instantaneous o/p voltage is shown in figure.