CMR
INSTITUTE OF
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Internal Assesment Test - V

Sub:	**Power Electronics**							Code:	**18EE53**
Date:	07.02.2022	Duration:	90 mins	Max Marks:	50	Sem:	V	Branch:	EEE

Answer Any FIVE FULL Questions

		Marks	OBE CO	OBE RBT
1a	Explain working of different types of power electronic converters with the help of circuit diagram, input and output waveforms.	6	CO1	L2

The power electronics circuits can be classified into six types:

1. Diode rectifiers
2. Ac–dc converters (controlled rectifiers)
3. Dc–dc converters (dc choppers)
4. Dc–ac converters (inverters)
5. Ac–ac converters (ac voltage controllers)
6. Static switches

1. Diode rectifiers

- **It converts AC Voltage into a FIXED DC Voltage**

- Converts fixed ac voltage into fixed dc voltage
- Input could be either single or three phase
- Example circuit for single phase diode rectifier is shown

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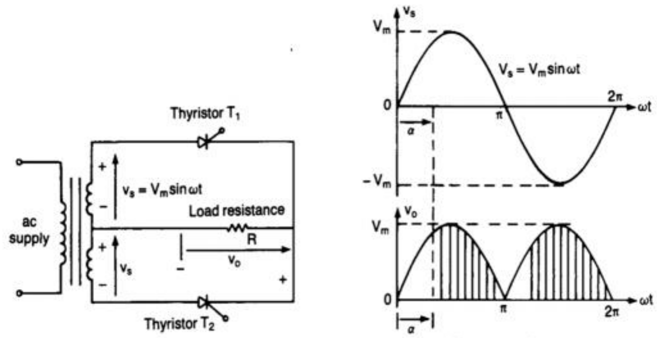
Ac–dc converters (controlled rectifiers)

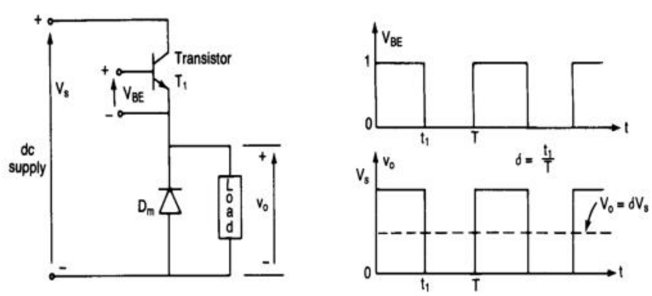
- **A single-phase** converter with two natural commutated thyristor is shown
- Average value of the output voltage can be controlled by varying the conduction time of thyristors
- This converters are also known as *controlled rectifiers*



(a) Circuit diagram (b) Voltage waveforms

Dc–dc converters (dc choppers)

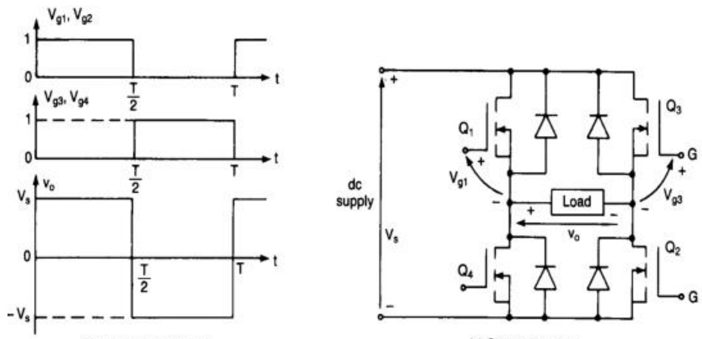
- Is also known as Chopper or Switching Regulator
- The average output voltage is controlled by varying the conduction of transistor, t1 .
- If T is the chopping period, then t1=δT
- δ is called as the duty cycle of chopper



(a) Circuit diagram (b) Voltage waveforms

DC-AC Converters

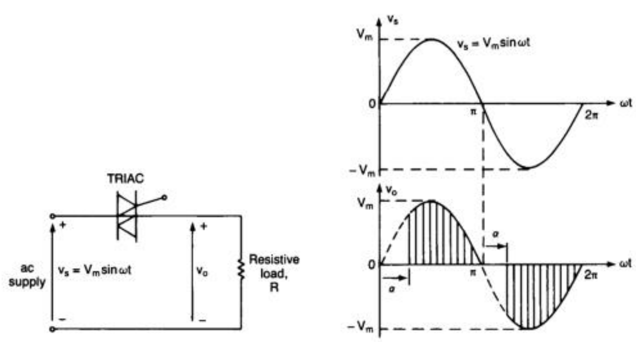
- Is also known as Inverter
- If transistor Q1 and Q2 conduct for one-half period and Q3 and Q4 conduct the other half, the output voltage is of alternating form
- Fixed dc voltage to variable ac voltage
- Voltage control is obtained by controlling duty cycle
- Also known as inverter



(b) Voltage waveforms (a) Circuit diagram

AC-AC Converters

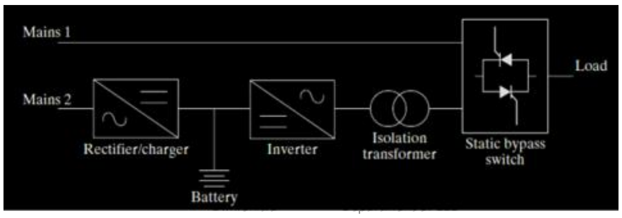
- AC Voltage Controller / Cyclo Converter
- **Fixed AC source** into **variable AC** output voltage
- a single-phase converter with a TRIAC is shown below



(a) Circuit diagram (b) Voltage waveforms

Static Switches

- Power devices can be operated as static switches or contactors
- Supply to these switches could **be either AC or DC**
- **The switches are called as *AC static switches or DC switches***
- Power electronic devices used as static switches in an UPS shown
- Mains 1 and 2 are connected to same supply
- Mains 1 supplies the load thro static bypass switch
- The rectifier charges the battery from Mains 2.
- The inverter supplies the emergency power to the load



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1b	Explain the peripheral effects of power electronic equipments.	4	CO1	L2

Harmonics

- **Harmonics** are unwanted higher frequencies which superimposed on the fundamental waveform (50 Hz) creating a distorted wave pattern.
- **Harmonic** is a
  - voltage or current waveforms at a multiple of the fundamental frequency of the system,
  - produced by the action of non-linear loads such as rectifiers, discharge lighting, or saturated magnetic devices.
- "harmonics" are multiples of the fundamental frequency f and can therefore be expressed as: $2f$, $3f$, $4f$, etc.

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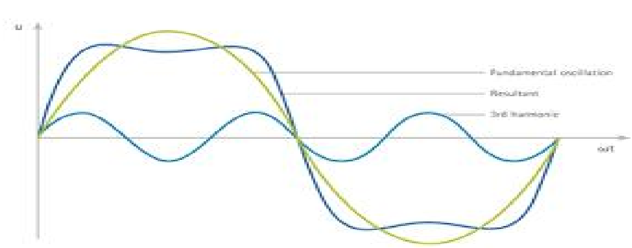


Need for Filter

Effects of Harmonics

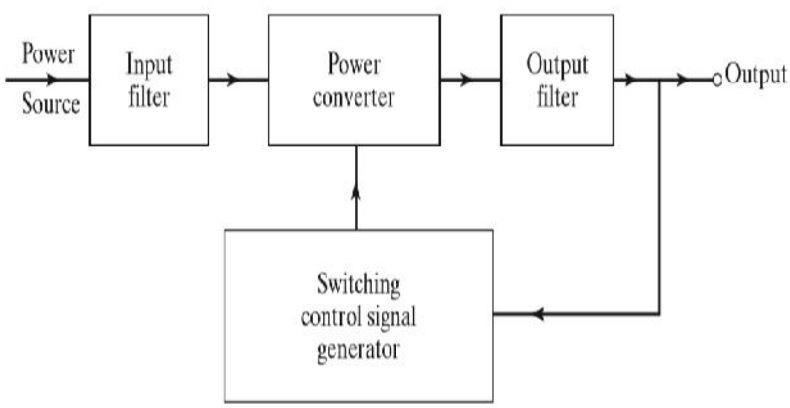
The operations of the power converters are based mainly on the switching of power semiconductor devices

- As a result 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 and current**
  - **harmonic generation into the supply system**
  - **Interference with the communication and signalling circuits.**
  - Harmonic frequencies in the power grid are a frequent cause of power quality problems.
  - Increased heating in the equipment and conductors
  - Misfiring in variable speed drives
  - Torque pulsations in motors.

Need for filter

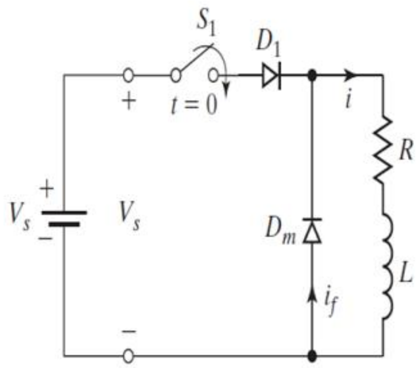
- It is normally necessary to introduce filters on the input and output of a converter system to reduce the harmonic level to an acceptable magnitude.

Generalized Power Converter System



2	Explain the function of a freewheeling diode in a switched RL load with the help of circuit diagram and waveforms.	10	CO1	L2

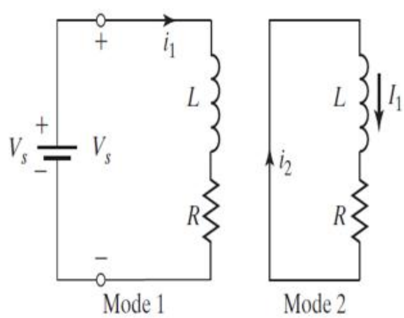
Freewheeling diodes with RL Load



(a) Circuit diagram

D1 – Normal Diode
Dm – Freewheeling Diode

- If switch *S*1 is closed for time *t*1, a current is established through the load;
- If the switch is opened, a path must be provided for the current in the inductive load.
- Otherwise, the inductive energy induces a very high voltage and this energy is dissipated as heat across the switch as sparks.
- This is normally done by connecting a diode *Dm* as shown in Figure, and this diode is usually called a *freewheeling diode.*
- Diode *Dm* is needed to prove a path for the inductive load current.
- Diode *D*1 is connected in series with the switch and it will prevent any negative current flow through the switch if there is an ac input supply voltage.
- But for dc supply, there is no need for *D*1.



(b) Equivalent circuits

- The circuit operation can be divided into Two modes.
- Mode 1 begins when the switch is closed at *t* = 0
- Mode 2 begins when the switch is opened.
- The equivalent circuits for the modes are shown in Figure.
- Variables *i*1 and *i*2 are defined as the instantaneous currents for mode 1 and mode 2, respectively;
- *t*1 and *t*2 are the corresponding durations of these modes.

Mode 1

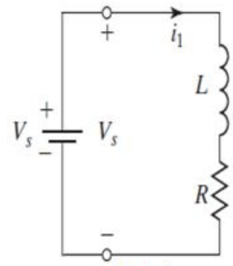
- Diode current i1

$$i_1(t) = \frac{V_s}{R}\left(1 - e^{-tR/L}\right)$$

- When the switch is opened at $t = t1$ (at the end of this mode),
- Diode current i1 at $t = t1$ becomes

$$I_1 = i_1(t = t_1) = \frac{V_s}{R}\left(1 - e^{-tR/L}\right)$$

- If the time $t1$ is sufficiently long, the current practically reaches a steady-state current of $Is = Vs/R$ flows through the load.



Mode 1

Mode 2

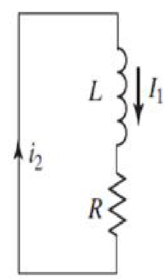
- This mode begins when the switch is opened and the load current starts to flow through the freewheeling diode *Dm*.
- Redefining the time origin at the beginning of this mode, th freewheeling diode is found f

$$0 = L\frac{di_2}{dt} + Ri_2$$

- with initial condition *i2 (t = t1) = I1.*
- *the free i2 is given by*

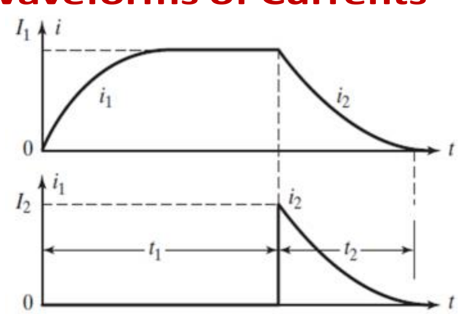
$$i_2(t) = I_1 e^{-tR/L}$$

- at *t = t2 this current decays exponentially to practically zero provided that t2 > L/R.*



Mode 2

Waveforms of Currents



(c) Waveforms

3	Explain steady state and switching characteristics of Power MOSFET.	10	CO2	L2

Steady-State Characteristics

- The MOSFETs are voltage-controlled devices and have a very high input impedance.
- The gate draws a very small leakage current, on the order of nano amperes.
- The current gain, which is the ratio of drain current *ID to input gate current IG*, *is typically on* the order of 10^9.
- The *transconductance,* which is the ratio of drain current to gate voltage, defines the transfer characteristics and is a very important parameter. $gm = \Delta I_D / \Delta V_{GS}$, when VDS is constant.
- Drain current is calculated as

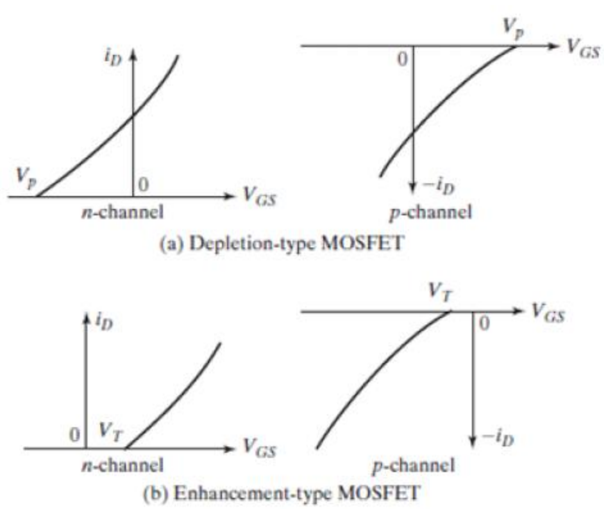
$$i_D = K_n(v_{GS} - V_T)^2 \text{ for } v_{GS} > V_T \text{ and } v_{DS} \geq (v_{GS} - V_T)$$

where K_n is the MOS constant, A/V^2

v_{GS} is the gate-to-source voltage, V

V_T is the threshold voltage, V

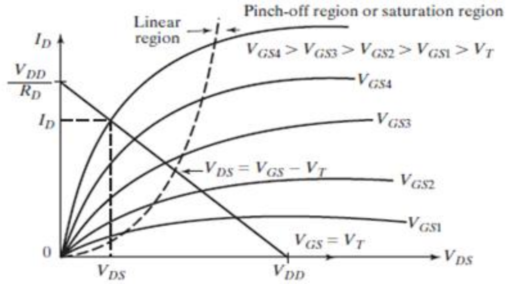
Transfer characteristics of MOSFETs



(a) Depletion-type MOSFET

(b) Enhancement-type MOSFET

Output characteristics - Enhancement-type MOSFET



There are three regions of operation: (1) cutoff region, where $V_{GS} \leq V_T$; (2) pinch-off or saturation region, where $V_{DS} \geq V_{GS} - V_T$; and (3) linear region, where $V_{DS} \leq V_{GS} - V_T$. The pinch-off occurs at $V_{DS} = V_{GS} - V_T$.

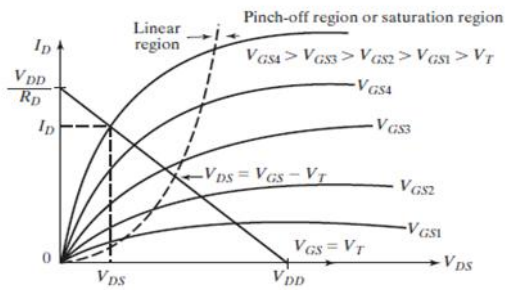
The load line of a MOSFET with a load resistance R_D can be described by

$$i_D = \frac{V_{DD} - v_{DS}}{R_D}$$

where $i_D = V_{DD}/R_D$ at $v_{DS} = 0$ and $v_{DS} = V_{DD}$ at $i_D = 0$

In order to keep the value of V_{DS} low, the gate–source voltage V_{GS} must be higher so that the transistor operates in the linear region.

Output characteristics - Enhancement-type MOSFET



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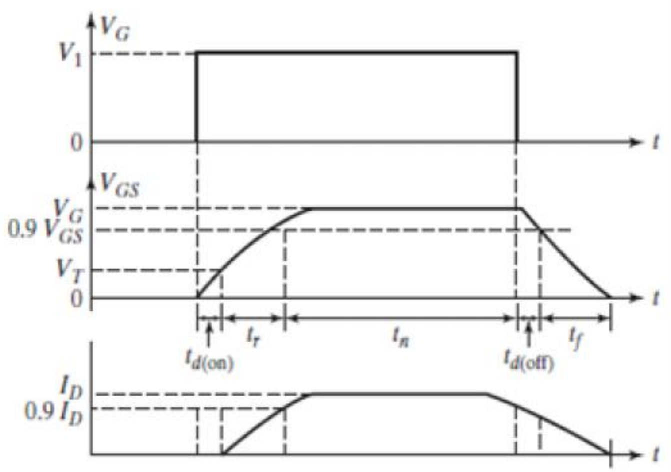
In order to keep the value of V_{DS} low, the gate–source voltage V_{GS} must be higher so that the transistor operates in the linear region.

Switching Characteristics of MOSFETs

Parasitic model of enhancement of MOSFETs

- Without any gate signal, the enhancement-type MOSFET may be considered as two diodes connected back to back (*np and pn diodes) or as an NPN-transistor.*
- *The gate structure has parasitic capacitances to the source, Cgs, and* to the drain, *Cgd.*
- *The NPN-transistor has a reverse-bias junction from the drain to* the source and offers a capacitance, *Cds.*
- Hence, a MOSFET may be considered as having an internal diode and the parasitic capacitances are dependent on their respective voltages.

Switching waveforms and times



Definitions

- *Delay time $t_{d(on)}$ / Turn on Delay time is the time that is required to charge the input capacitance to threshold voltage level.*
- *It is time taken by the VGS increases from 0 to VT (Threshold voltage)*
- *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.*
- *It is time taken by ID to increase from 0 to 90% & VGS increase from VT to VGSp (Full gate voltage)*
- *Turn-off delay time $t_{d(off)}$ / storage time is the time required for the input capacitance to discharge from the overdrive* gate voltage *V1 to the pinch-off region.*
- *It is time taken by ID to decrease from 100% to 90% & VGS decrease from VGS to VGSp (Full gate voltage)*
- F*all time t_f is the time that is required for the input capacitance to discharge* from the pinch-off region to threshold voltage.
- *It is time taken by ID to decrease from 90% to 0 & VGS decrease from VGSp to 0.*
- *If VGS ≤ VT, transistor turns off.*

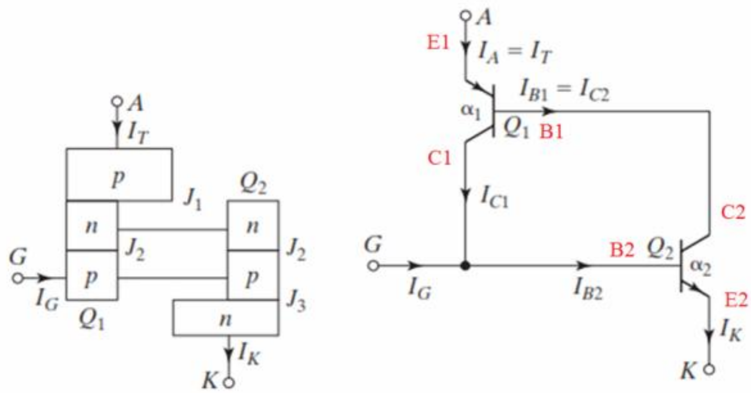
4	Explain the two-transistor analogy, and derive an expression for the anode current of thyristor.	10	CO3	L2

Two-transistor Model of Thyristor

- 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*-transistor, *Q2.*

Two-transistor Model of Thyristor

Two-transistor model of thyristor.



(a) Basic structure (b) Equivalent circuit

Derivation of Anode Current

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

$$I_C = \alpha I_E + I_{CBO} \tag{9.1}$$

and the *common-base current* gain is defined as $\alpha \simeq I_C/I_E$. For transistor Q_1, the emitter current is the anode current I_A, and the collector current I_{C1} can be found from Eq. (9.1):

$$I_{C1} = \alpha_1 I_A + I_{CBO1} \tag{9.2}$$

where α_1 is the current gain and I_{CBO1} is the leakage current for Q_1. Similarly, for transistor Q_2, the collector current I_{C2} is

$$I_{C2} = \alpha_2 I_K + I_{CBO2} \tag{9.3}$$

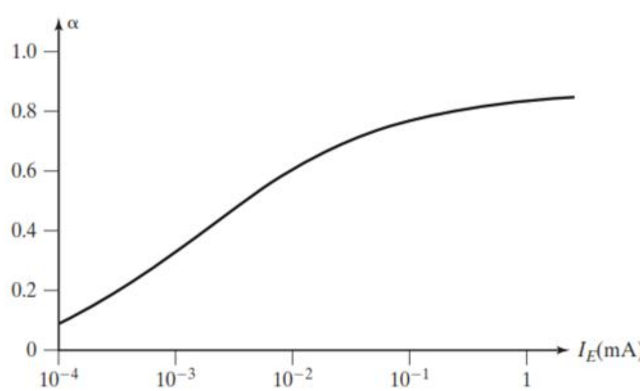
where α_2 is the current gain and I_{CBO2} is the leakage current for Q_2. By combining I_{C1} and I_{C2}, we get

$$I_A = I_{C1} + I_{C2} = \alpha_1 I_A + I_{CBO1} + \alpha_2 I_K + I_{CBO2} \tag{9.4}$$

For a gating current of I_G, $I_K = I_A + I_G$ and solving Eq. (9.4) for I_A gives

$$I_A = \frac{\alpha_2 I_G + I_{CBO1} + I_{CBO2}}{1 - (\alpha_1 + \alpha_2)} \tag{9.5}$$

Variation of Current Gain with Emitter Current



Typical variation of current gain with emitter current.

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

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.

Current gain α_2 depends on I_A and I_G.

The increase in the values of α_1 and α_2 further increases I_A.

Therefore, there is a regenerative or positive feedback effect.

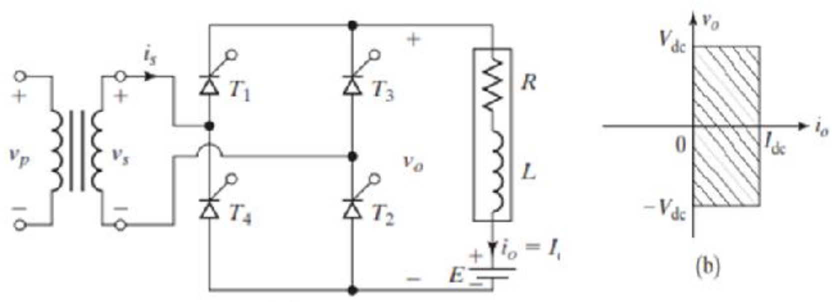
If $(\alpha_1 + \alpha_2)$ tends to be unity,

the denominator of Eq. $I_A = \dfrac{\alpha_2 I_G + I_{CBO1} + I_{CBO2}}{1 - (\alpha_1 + \alpha_2)}$ approaches zero,

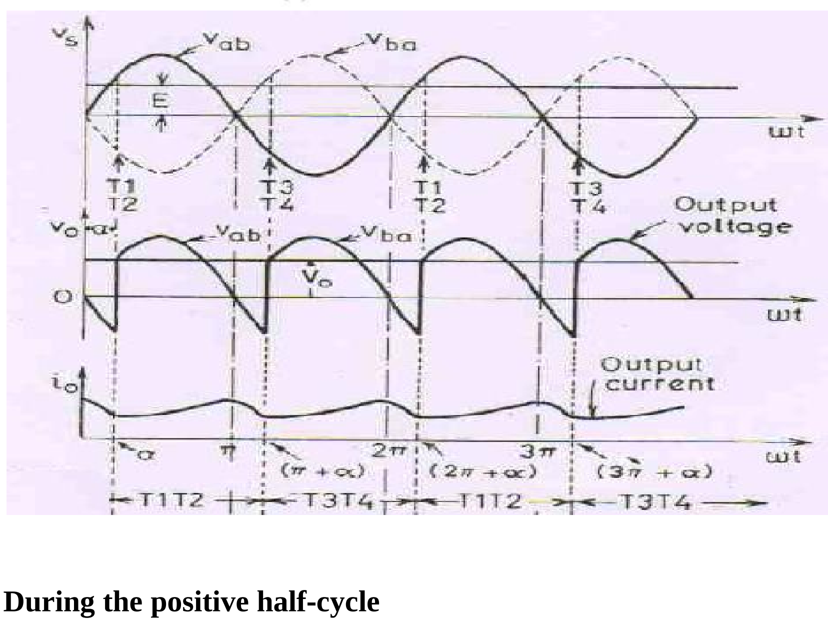
resulting in a large value of anode current I_A,

and the thyristor turns on with a small gate current.

5	Explain single phase fully controlled converter with RLE load with neat diagram and waveform and derive the expression for average and RMS voltage.	10	CO4	L2



(a) (b)



During the positive half-cycle

- The fully controlled bridge converter consists of four thyristors *T1, T2, T3 and T4* connected in the form of full wave bridge configuration.
- Each thyristor is controlled and turned on by its gating signal and naturally

turns off when a reverse voltage appears across it (Line commutation or Natural commutation).

- Thyristors $T1$ and $T2$ are forward biased (0 to π);
- when these two thyristors are turned on simultaneously at $\omega t = \alpha$, the load is connected to the input supply through $T1$ and $T2$.
- Due to the inductive load, thyristors $T1$ and $T2$ continue to conduct beyond $\omega t = \pi$, even though the input voltage is already negative.
- $T1$ and $T2$ conduct from $\omega t = \alpha$ to $\pi + \alpha$
- The output voltage across the load follows the input voltage $v_o = v_m \sin \omega t$

During the negative half-cycle of the input voltage

- Thyristors $T3$ and $T4$ are forward biased (π to 2π);
- Turning on of thyristors $T3$ and $T4$ applies the supply voltage across thyristors $T1$ and $T2$ as reverse blocking voltage.
- *T3 & T4 are triggered at* $\omega t = \pi + \alpha$
- $T1$ and $T2$ are turned off due to *line* or *natural commutation.*
- The output voltage across the load follows the input voltage $v_o = -v_m \sin \omega t$
- Load current is transferred from $T1$ *and* $T2$ to $T3$ and $T4$.
- $T3$ and $T4$ conduct from $\omega t = \pi + \alpha$ to $2\pi + \alpha$
- During next half cycle T3 and T4 are turned off

During Period from α to π - *Rectification* mode

- The input voltage v_s and input current i_s are positive,
- Power flows from the supply to the load.
- The converter is said to be operated in ***rectification* mode.**

During Period from π to π + α - *Inversion* mode

- The input voltage vs is negative and the input current is is positive,
- Reverse power flows from the load to the supply.
- The converter is said to be operated in inversion mode.
- This converter is extensively used in industrial applications up to 15 kW .
- Depending on the value of **α**, the average output voltage could be either positive or negative and it provides two-quadrant operation.

Average Output Voltage Vdc

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$$V_{O(dc)} = V_{dc} = \frac{2}{2\pi}\left[\int_{\alpha}^{\pi+\alpha} V_m \sin \omega t.d(\omega t)\right]$$

$$V_{O(dc)} = V_{dc} = \frac{1}{\pi}\left[\int_{\alpha}^{\pi+\alpha} V_m \sin \omega t.d(\omega t)\right]$$

$$V_{O(dc)} = V_{dc} = \frac{V_m}{\pi}\left[-\cos(\pi+\alpha)+\cos\alpha\right]$$

$$\cos(\pi+\alpha) = -\cos\alpha$$

$$V_{O(dc)} = V_{dc} = \frac{V_m}{\pi}\left[\int_{\alpha}^{\pi+\alpha} \sin \omega t.d(\omega t)\right]$$

Therefore $V_{O(dc)} = V_{dc} = \frac{2V_m}{\pi}\cos\alpha$

$$V_{O(dc)} = V_{dc} = \frac{V_m}{\pi}\left[-\cos \omega t\right]_{\alpha}^{\pi+\alpha}$$

RMS Output Voltage Vrms

The rms value of the output voltage is given by

$$V_{rms} = \left[\frac{2}{2\pi}\int_{\alpha}^{\pi+\alpha} V_m^2 \sin^2 \omega t \, d(\omega t)\right]^{1/2}$$

$$= \left[\frac{V_m^2}{2\pi}\int_{\alpha}^{\pi+\alpha} (1 - \cos 2\omega t) \, d(\omega t)\right]^{1/2}$$

$$= \frac{V_m}{\sqrt{2}} = V_s$$

With a purely resistive load, thyristors T_1 and T_2 can conduct from α to π, and thyristors T_3 and T_4 can conduct from $\alpha + \pi$ to 2π.

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Illustrate the single-phase dual converter with neat diagram and waveform and also explain the significance of circulating current in dual converter.

- Dual converter- the name itself indicates that it has two converters in it.
- The dual converter system will provide four quadrant operation
- Normally used in high power industrial variable speed drives.
- In the case of a single phase full converter with inductive loads, the converter can operate in two different quadrants in the *Vdc* versus *Idc* operating diagram.
- If two single phase full converters are connected in parallel and in opposite direction (connected in back to back) across a common load four quadrant operation is possible.

Such a converter is called as a dual converter.

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<td>CO4</td>
<td>L2</td>
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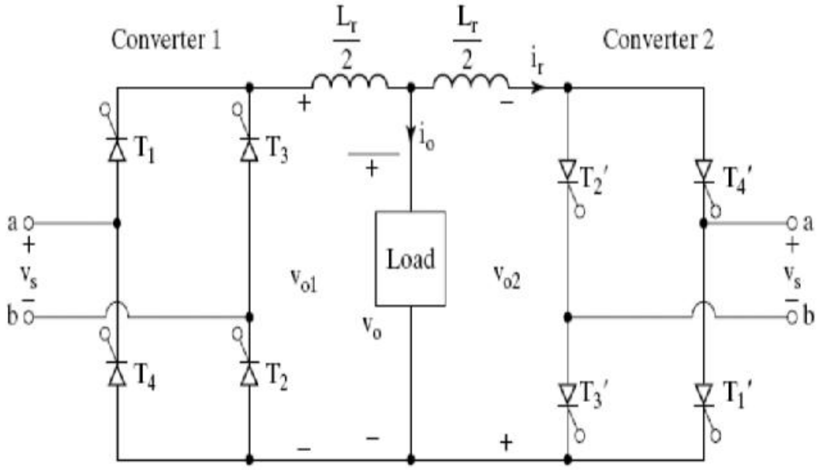


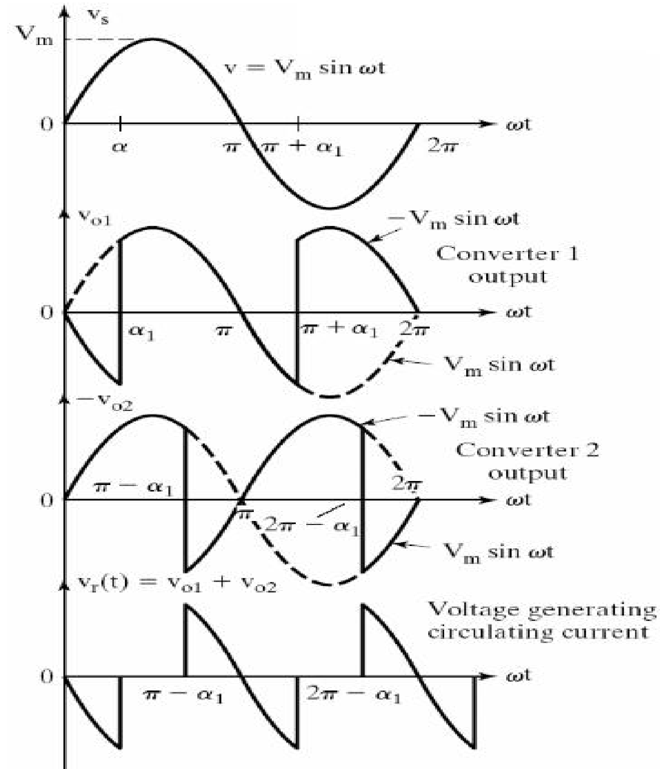
- Two single phase full converters are connected in parallel and in opposite direction (connected in back to back) across a common load

Converter 1

- The converter number 1 provides a positive dc output voltage and a positive dc load current, when operated in the rectification mode.
- The converter number 1 provides a negative dc output voltage and a positive dc load current, when operated in the inverter mode.

Converter 2

- The converter number 2 provides a negative dc output voltage and a negative dc load current when operated in the rectification mode.
- The converter number 2 provides a positive dc output voltage and a negative dc load current when operated in the inverter mode.
- We can have **bi- directional load current and bi-directional dc output voltage.**
- The magnitude of output dc load voltage and the dc load current can be controlled by varying the trigger angles **α** 1 & **α** 2 of the converters 1 and 2 respectively.
- **α 1 - Firing angle for converter 1**
- **α 2 - Firing angle for converter 2**



(b) Waveforms

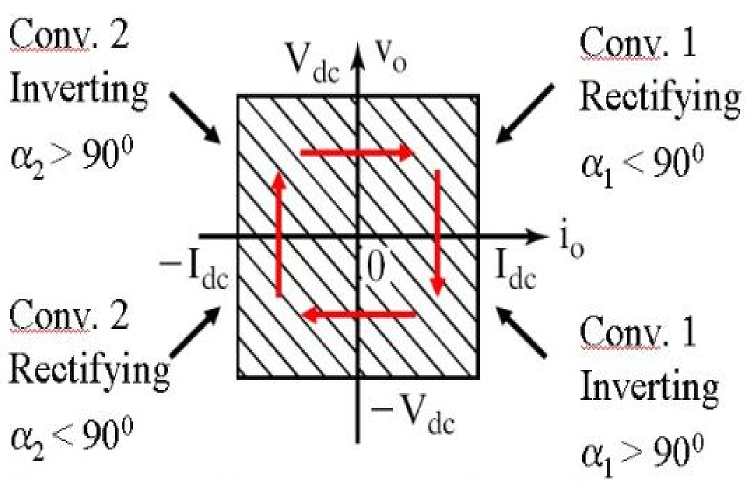


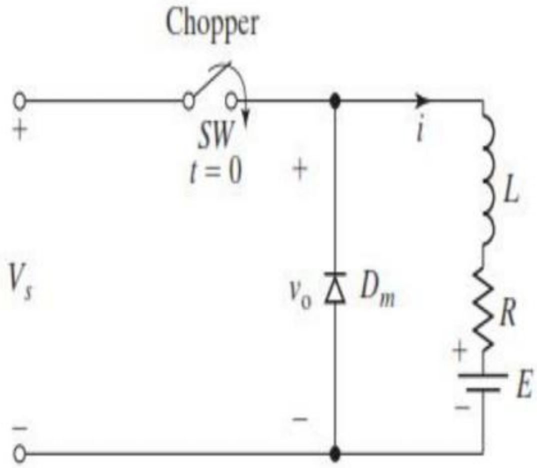
Fig.: Four quadrant operation of a dual converter

CIRCULATING CURRENT

- In this mode of operation both the converters 1 and 2 are switched on and operated simultaneously and both the converters are in a state of conduction.
- If converter 1 is operated as a controlled rectifier by adjusting the trigger angle **α_1 between 0 to 90^o ($0<\alpha_1< 90^o$**)
- The second converter 2 is operated as a line commutated inverter by increasing its trigger angle **α_2 above 90 ($90^o<\alpha_2<180^o$**).

	• The trigger angles α_1 and α_2 are adjusted such that they produce the same average dc output voltage across the load terminals. • Instantaneous output voltages of two converters are out of phase , this voltage difference causes circulating current between two converters. • This cannot flow through the load, and it is limited by limiting reactor. • In the circulating current mode a current builds up between the two converters even when the load current falls to zero. • In order to limit the circulating current flowing between the two converters, we have to include current limiting reactors in series between the output terminals of the two converters. **Significance of circulating current** • We can have faster reversal of load current as the two converters are in a state of conduction simultaneously. • This greatly improves the dynamic response of the output giving a faster dynamic response. • The output voltage and the load current can be linearly varied by adjusting the trigger angles α_1 **and** α_2 to obtain a smooth and linear output control. • The control circuit becomes relatively simple. • Output response is very fast. • The load current is free to flow in either direction at any time. The reversal of the load current can be done in a faster and smoother way.			
7a	Explain working of step-down chopper. Draw the relevant waveform. Derive an expression for average and output rms voltage.	5	CO5	L2

Step-down Chopper with RL Load



➢A dc-dc converter with an *RL* load is shown in Figure.

➢The operation of the converter can be divided into two modes.

➢During mode 1, the converter is switched on and the current flows from the supply to the load.

➢During mode 2, the converter is switched off and the load current continues to flow through freewheeling diode *D*

Modes of Operation

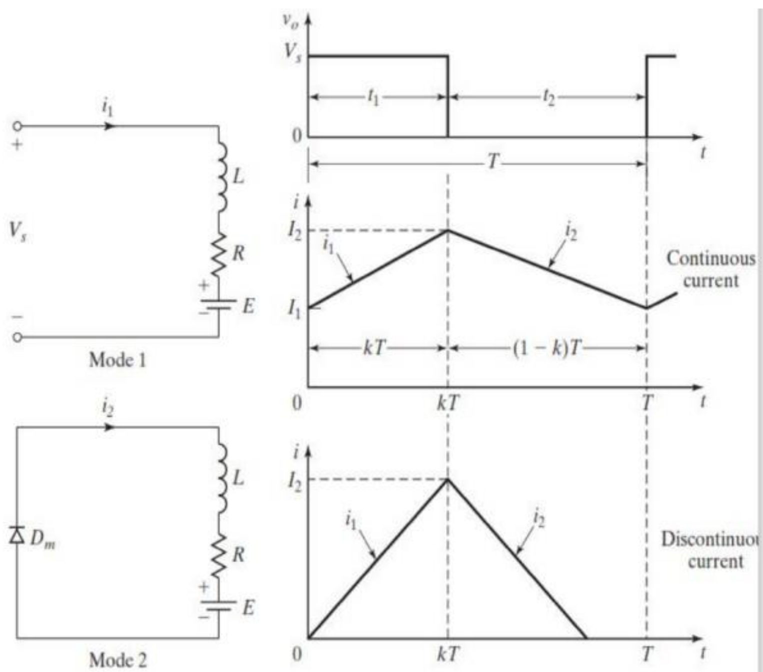
Current may be

- Continuous
- Discontinuous

Assumption

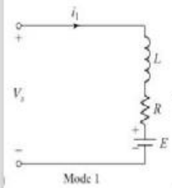
load current rises linearly.

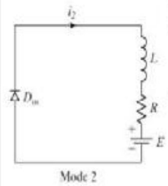
However, the current flowing through an *RL* load rises or falls exponentially with a time constant.



(a) Equivalent circuits (b) Waveforms

The load time constant $(\tau = L/R)$ i





The load current for mode 1 can be found from

$$V_s = Ri_1 + L\frac{di_1}{dt} + E$$

which with initial current $i_1(t = 0) = I_1$ gives the load current as

$$i_1(t) = I_1 e^{-tR/L} + \frac{V_s - E}{R}(1 - e^{-tR/L}) \quad (5.19)$$

This mode is valid $0 \le t \le t_1 (= kT)$; and at the end of this mode, the load current becomes

$$i_1(t = t_1 = kT) = I_2 \quad (5.20)$$

The load current for mode 2 can be found from

$$0 = Ri_2 + L\frac{di_2}{dt} + E$$

With initial current $i_2(t = 0) = I_2$ and redefining the time origin (i.e., $t = 0$) at the beginning of mode 2, we have

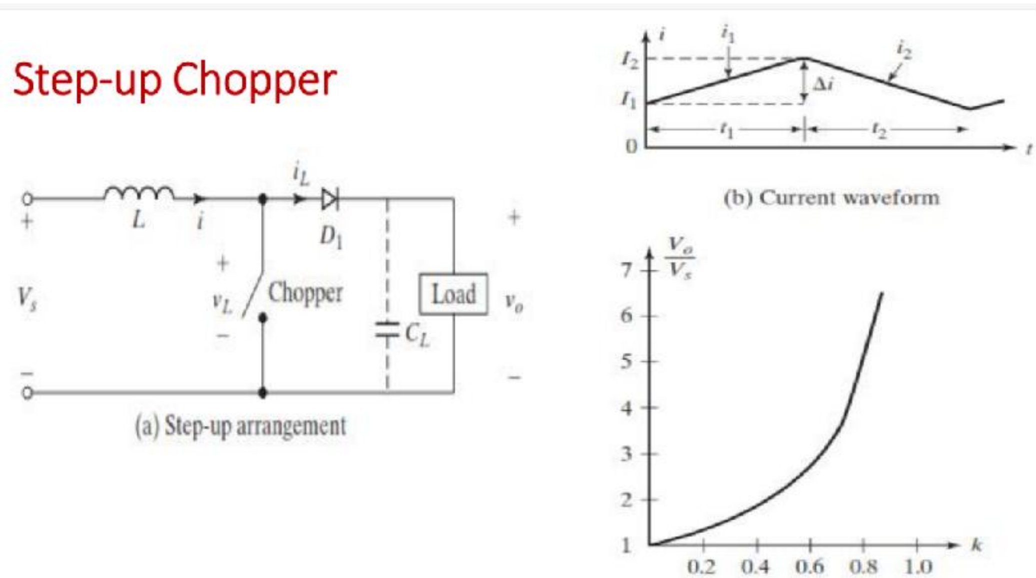
$$i_2(t) = I_2 e^{-tR/L} - \frac{E}{R}(1 - e^{-tR/L}) \quad (5.21)$$

This mode is valid for $0 \le t \le t_2 [= (1 - k)T]$. At the end of this mode, the load current becomes

$$i_2(t = t_2) = I_3 \qquad I_3 = I_1 \quad (5.22)$$

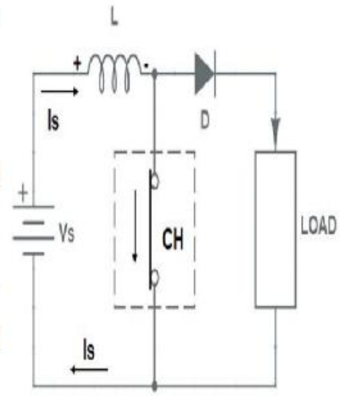
7b	Explain the operation of step-up chopper. Draw the relevant waveform. Derive an expression for average output voltage.	5	CO5	L2

- Step-up chopper is a static device whose average output DC voltage is greater than its input DC voltage.
- A converter can be used to step-up a dc voltage and an arrangement for step-up operation. When switch SW is closed for time t, the inductor current rises and energy is stored in the inductor L.
- If the switch is opened for time t1, the energy stored in the inductor is transferred to load through diode D and the inductor current falls



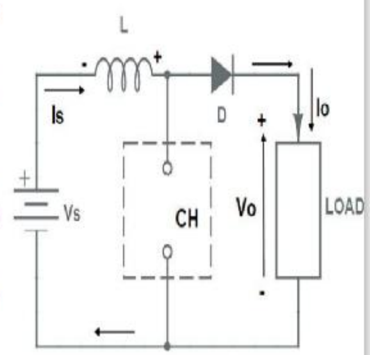
Mode 1: Switch is ON

- When chopper (CH) is switched ON, the current will flow through the closed path formed by supply source Vs, inductor L and chopper CH.
- During this period, no current will flow through the load.
- Only source current i_s will flow and the value of load current i_o will be ZERO during the ON period.
- Also, during the T_{ON} period, energy is stored in the inductor L.
- This energy storage in L is essential to boost the load output voltage above the source voltage.
- Therefore, a large value of L is essential in a step-up chopper.



Mode 2: Switch is OFF

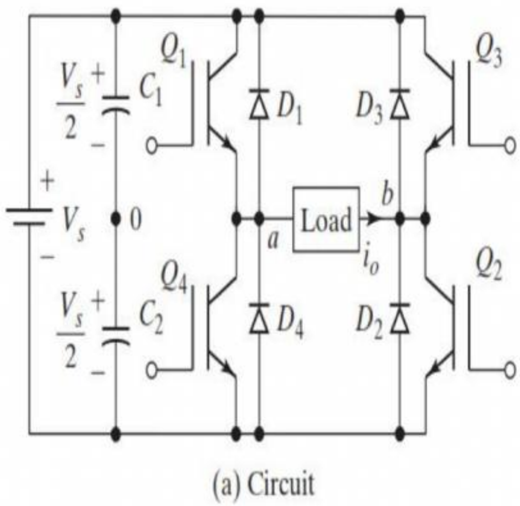
- When the chopper CH is switched OFF, the current through the L can not reduce instantaneously rather it decays exponentially.
- Due to this behavior of L, it will force the current through the diode D and load for the entire time period T_{OFF}.
- Since, the current through the inductor L tends to decrease, the polarity of the emf induced in inductor L is reversed as shown in above figure.
- As a result, the voltage across the load becomes equal to the sum of source voltage and emf induced in inductor.
- Thus, the output voltage exceeds the source voltage V_s.
- The load / output voltage may be written as below.



$$V_0 = V_S + L(di/dt)$$

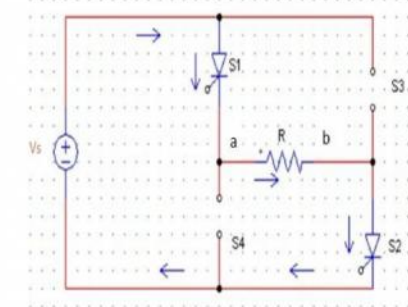
	Average Output Voltage Equation When the converter is turned on, the voltage across the inductor is $v_L = L\frac{di}{dt} \Rightarrow di = \frac{v_L}{L}dt = \frac{V_s}{L}t_1$ and this gives the peak-to-peak ripple current in the inductor as $\Delta I = \frac{V_s}{L}t_1$ The average output voltage is $v_o = V_s + L\frac{\Delta I}{t_2}$ $\quad \Delta I = \frac{V_s}{L}t_1$ $= V_s\left(1 + \frac{t_1}{t_2}\right) = V_s\left(1 + \frac{kT}{(1-k)T}\right)$ $\quad t_1 = kT$, $\quad t_2 = (1-k)T$ $= V_s\frac{1}{1-k}$ $v_o = V_s\frac{1}{1-k}$ K value can be changed from 0 to 1.			
8	With the neat circuit diagram and waveforms, Explain the operation of single-phase full bridge inverter supplying resistive a load. **Single Phase Bridge Inverter** • Full bridge single phase inverter is a switching device that generates a square wave AC output voltage on the application of DC input by adjusting the switch turning ON and OFF based on the appropriate switching sequence, where the output voltage generated is of the form +Vs, -Vs, Or 0. • A single-phase bridge voltage-source inverter (VSI) • It consists of four choppers (Q1 D1, Q2 D2, Q3 D3, Q4 D4). • When transistors *Q1* and *Q2* are turned on simultaneously, the input voltage *Vs* appears across the load. • If transistors *Q3* and *Q4* are turned on at the same time, the voltage across the load is reversed and is *-Vs*.	10	CO5	L2

Single Phase Bridge Inverter

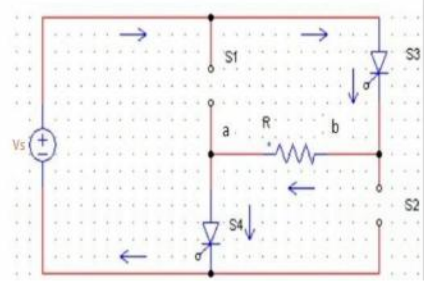


(a) Circuit

Mode 1



Mode 2

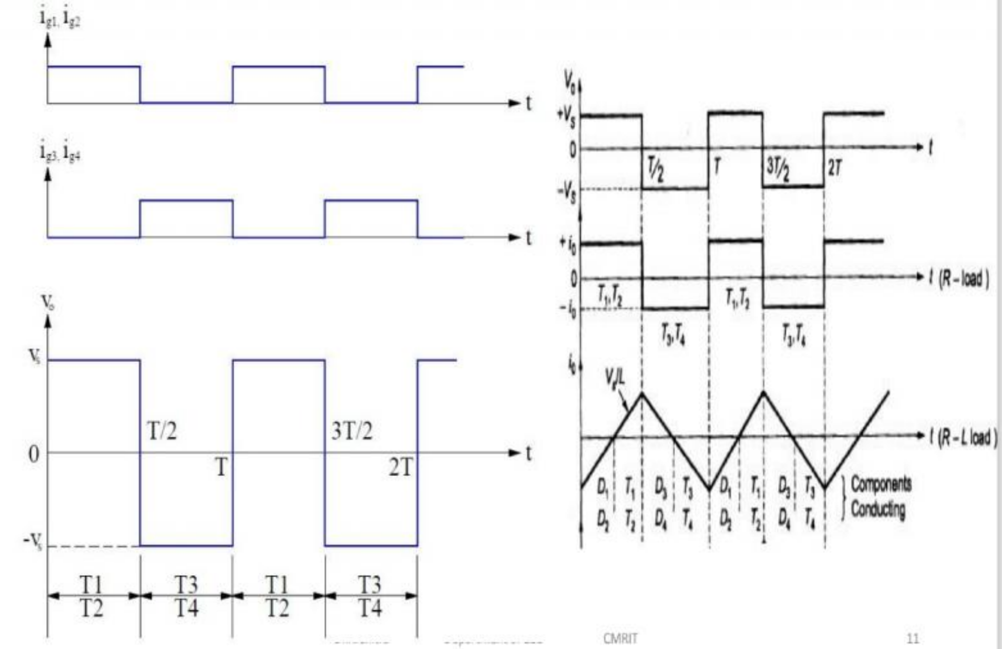


Mode 1 (0 to T/2):-

- During this mode switch S1 and switch S2 are ON and switch S3 and switch S4 are OFF From period 0 to T/2.
- Current flowing path during this mode is Vs – S1- a -R(load reistor) – b – S2 – Vs.
- Voltage across the load resistor is positive Vs. (Vo = Vs)

Mode 2 (T/2 to T):-

- During this mode switch S3 and switch S4 are ON and switch S1 and switch S2 are OFF From period T/2 to T.
- Current flowing path during this mode is Vs – S3 – b – R(load resistor) – a – S4 – Vs.
- Voltage across the load resistor is negative Vs. (Vo = -Vs)



Switching States of single phase full bridge inverter

Switch States for a Single-Phase Full-Bridge Voltage-Source Inverter

State	State No.	Switch State*	v_{ao}	v_{bo}	v_o	Components Conducting
S_1 and S_2 are on and S_4 and S_3 are off	1	10	$V_S/2$	$-V_S/2$	V_S	S_1 and S_2 if $i_o > 0$ D_1 and D_2 if $i_o < 0$
S_4 and S_3 are on and S_1 and S_2 are off	2	01	$-V_S/2$	$V_S/2$	$-V_S$	D_4 and D_3 if $i_o > 0$ S_4 and S_3 if $i_o < 0$
S_1 and S_3 are on and S_4 and S_2 are off	3	11	$V_S/2$	$V_S/2$	0	S_1 and D_3 if $i_o > 0$ D_1 and S_3 if $i_o < 0$
S_4 and S_2 are on and S_1 and S_3 are off	4	00	$-V_S/2$	$-V_S/2$	0	D_4 and S_2 if $i_o > 0$ S_4 and D_2 if $i_o < 0$
S_1, S_2, S_3, and S_4 are all off	5	off	$-V_S/2$ $V_S/2$	$V_S/2$ $-V_S/2$	$-V_S$ V_S	D_4 and D_3 if $i_o > 0$ D_1 and D_2 if $i_o < 0$

CI **CCI** **HOD**