# CBCS SCHEME

USN 2VD19EE013 **18EE53**

## Fifth 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. With neat circuit diagram, input and output waveform, explain the different types of Power Electronics Converters. **(10 Marks)**

b. With block diagram, explain the peripheral effects of power electronic equipment. **(06 Marks)**

c. Compare the advantages and disadvantages of full wave bridge rectifier and full wave centre tapped transformer rectifier. **(04 Marks)**

**OR**

2 a. Briefly explain the different types of Power diodes and its applications. **(08 Marks)**

b. List the applications of Power Electronics. **(04 Marks)**

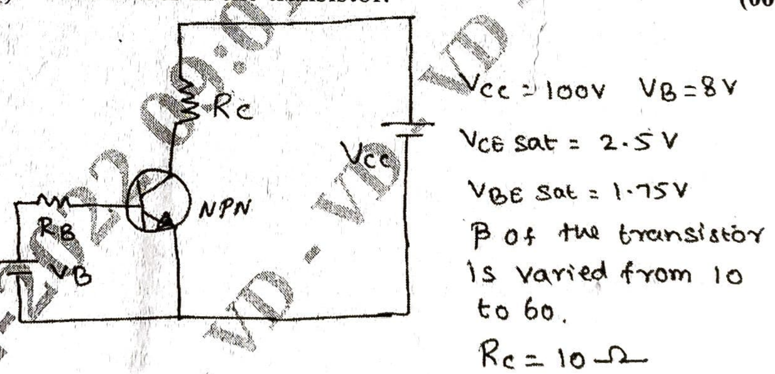
c. With circuit diagram and waveform, explain the working of single phase full wave uncontrolled rectifier with R load. **(08 Marks)**

### Module-2

3 a. Explain Switching characteristics of BJT with waveforms. **(08 Marks)**

b. A power BJT is connected as a switch as in figure Q3(b) with the following data. Calculate
i) The value of $R_B$ that will result in saturation with an overdrive factor of 20.
ii) The forced β iii) Power loss in the transistor. **(06 Marks)**

Fig. Q3(b)




c. Give a comparison between BJT and MOSFET. **(06 Marks)**

**OR**

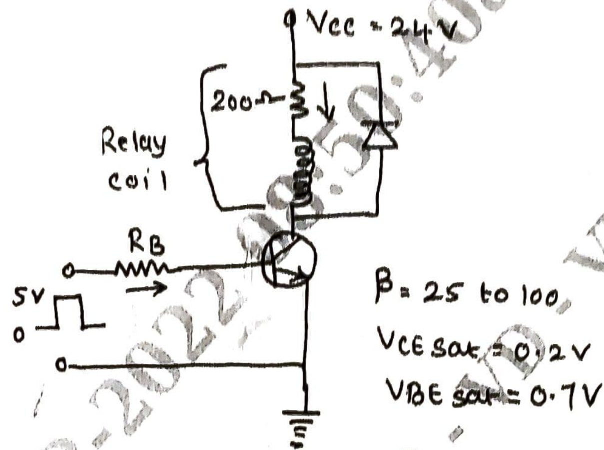
4 a. Discuss the need of base drive control in a Power transistor. **(08 Marks)**

b. A simple transistor switch is used to connect a 24V DC supply across a relay coil, which has a DC resistance of 200Ω. An input pulse of 0 to 5V amplitude to applied through a series base resistor $R_B$ at the base so as to turn ON the transistor switch. Sketch the device current waveform with reference to the input pulse. Calculate : i) $I_{Csat}$.
ii) Value of resistor $R_B$ required to obtain over drive factor of 2.
iii) Total Power dissipation in the transistor that occurs during the saturation state. **(06 Marks)**



Important Note : 1. On completing your answers, compulsorily draw diagonal cross lines on the remaining blank pages.
2. Any revealing of identification, appeal to evaluator and /or equations written eg, 42+8 = 50, will be treated as malpractice.

Fig. Q4(b)




c. Explain steady state characteristics of n channel power MOSFET with necessary diagram. **(06 Marks)**

## Module-3

5 a. Explain the V.I characteristics of SCR also define :
   i) Holding current ii) Latching current. **(12 Marks)**

b. Explain any four method of Turn – ON used for Thyristors. **(04 Marks)**

c. The latching current of an SCR used in a phase controlled circuit. Comprising an inductive load of R = 10Ω and L = 0.1H is 15mA. The input voltage is 325 sin 314t. Obtain the minimum gate pulse width required for reliable triggering of the SCR if gated at $\frac{\pi}{3}$ angle in every positive half cycle. **(04 Marks)**

**OR**

6 a. Derive an expression for anode current using two transistor model of Thyristor. **(08 Marks)**

b. A UJT is connected across a 220V DC supply. The valley and peak point voltages are 1V and 15V. The period of UJT relaxation oscillator is 20MS. Find the value of charging capacitor, if a charging resistor of 100kΩ is used. **(06 Marks)**

c. Explain Half wave RC firing circuit with necessary diagrams. **(06 Marks)**

## Module-4

7 a. With the help of circuit diagram and waveform, explain the working of single phase full wave AC voltage controller with R load. **(10 Marks)**

b. The single phase full wave AC voltage controller operates on a single phase supply voltage of 230V rms at 50Hz. If the triac is triggered at a delay angle of 45° during each half cycle of input supply. i) RMS value of output voltage ii) RMS value of current through heater iii) Average value of triac current iv) RMS value of triac current v) Input power factor. **(10 Marks)**

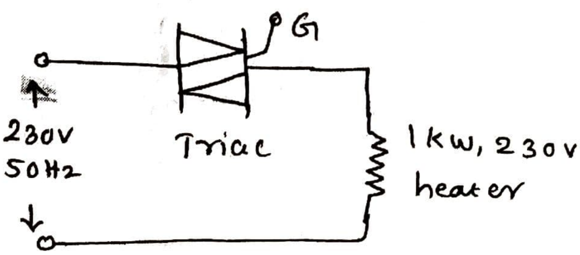



Fig. Q7(b)

**OR**

8 a. Explain Half wave controlled rectifier with $R_L$ load, without freewheeling diode. Draw necessary diagrams. **(10 Marks)**

b. A single phase half wave converter is operated from a 120V , 50Hz supply and the load resistance R = 10Ω. If the average output voltage is 25% of the maximum possible average output voltage calculate : i) Delay angle α ii) The rms and average output currents iii) The average and rms thyristor currents iv) The input power factor. **(10 Marks)**

## Module-5

9 a. A Chopper circuit drives an Inductive load from 200V DC supply. Given the load resistance as 4Ω, the average load current as 30A and operating frequency is 400Hz. Compute the ON period and OFF period of the Chopper. Also determine the duty cycle of the Chopper. **(06 Marks)**

b. With the help of circuit and waveforms, explain the operation of step up Chopper. **(08 Marks)**

c. Explain Performance Parameters of Chopper. **(06 Marks)**

**OR**

10 a. Explain Single Phase full bridge Inventor operation with R load. Draw necessary diagrams. **(10 Marks)**

b. Draw and explain Single Phase Transistorised Current Source Inverter. **(10 Marks)**



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# Question Paper Solution

of

# POWER ELECTRONICS

(18EE53)

(March 2022 Question Paper)

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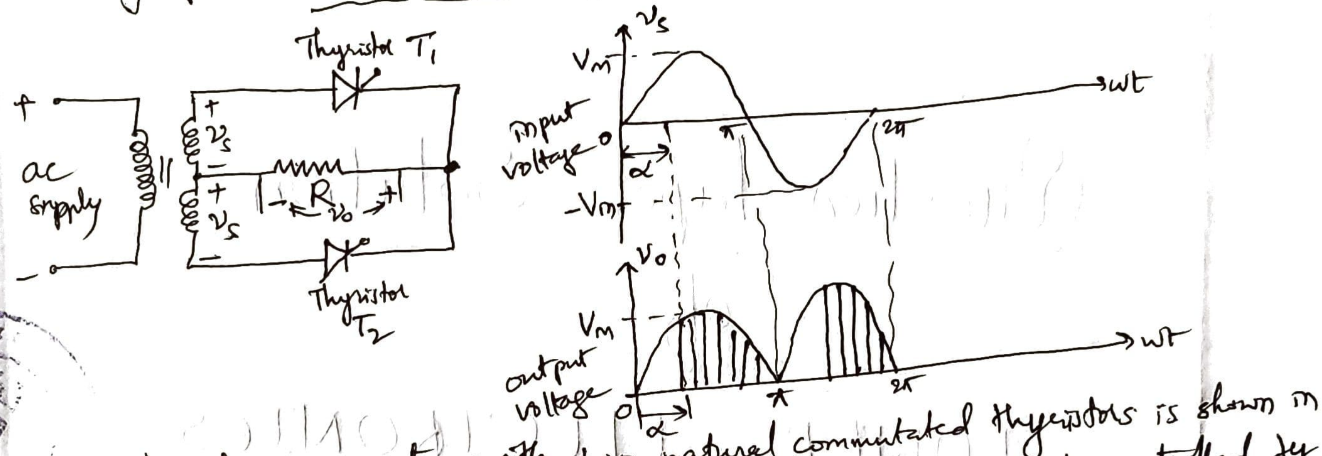
Prof. Kirankumar Hittanagi

1) a) With a neat circuit diagram, input and output waveform, explain the different types of power electronic converters. (10 marks)

Ans:

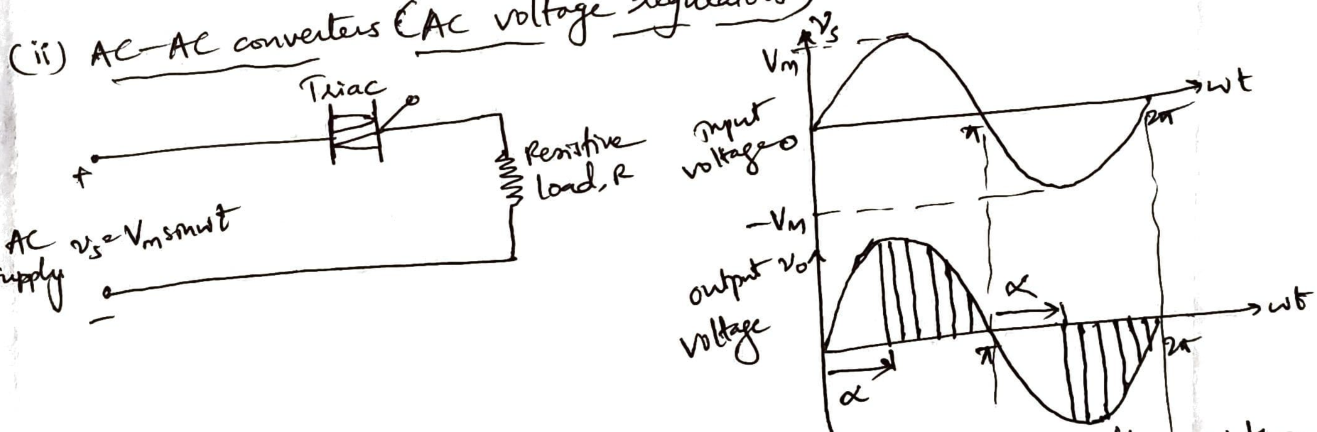
(i) ~~Single phase~~ AC – DC converters (Controlled rectifiers)





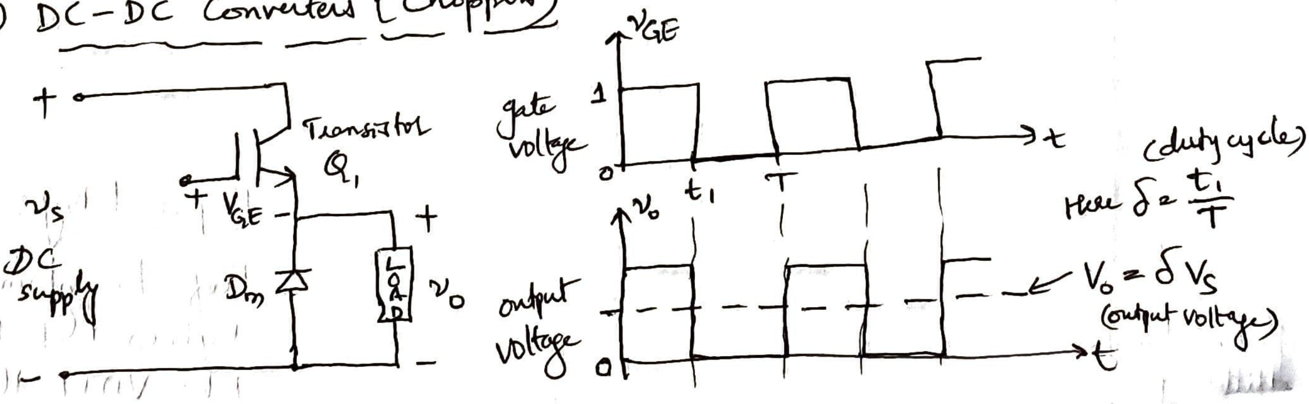

– A single phase converter with two natural commutated thyristors is shown in above fig. The average value of the output voltage $v_o$ can be controlled by varying the conduction time of thyristors or firing delay angle, α. The input could be a single or three phase source. These converters are also known as controlled rectifiers.

(ii) AC – AC converters (AC voltage regulators)



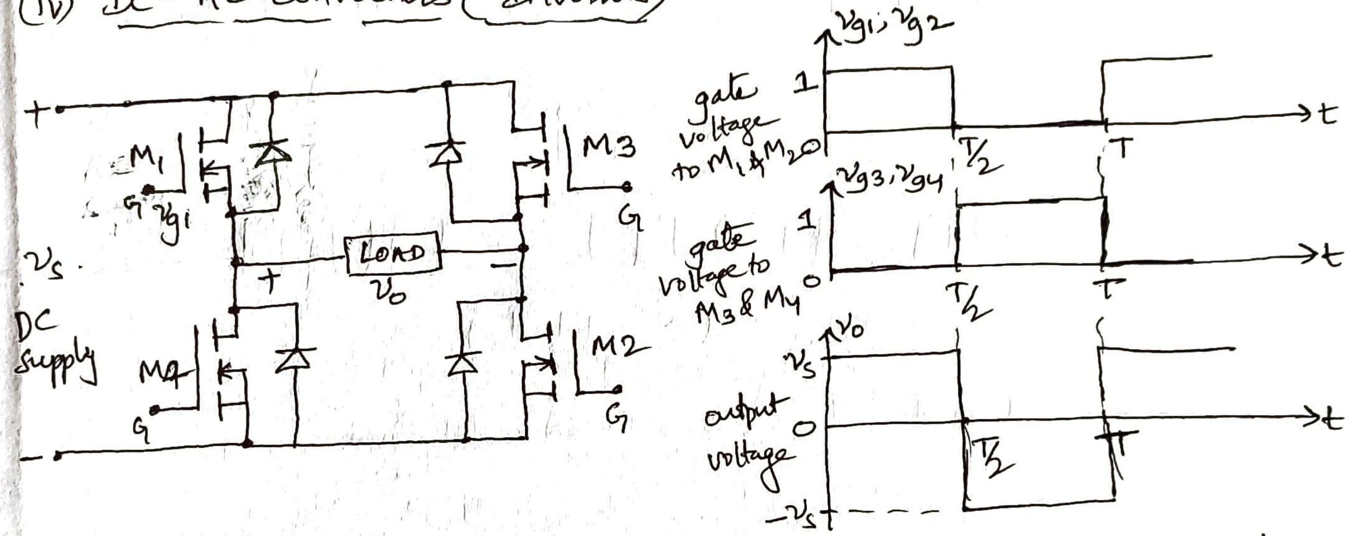

– These converters are used to obtain a variable AC output voltage $v_o$ from a fixed AC source and a single phase converter with TRIAC is shown in fig. The output voltage is controlled by varying the conduction time of a TRIAC or firing delay angle α. These types of converters are also known as ~~ac~~ AC voltage regulators.

(iii) DC – DC Converters (Choppers)



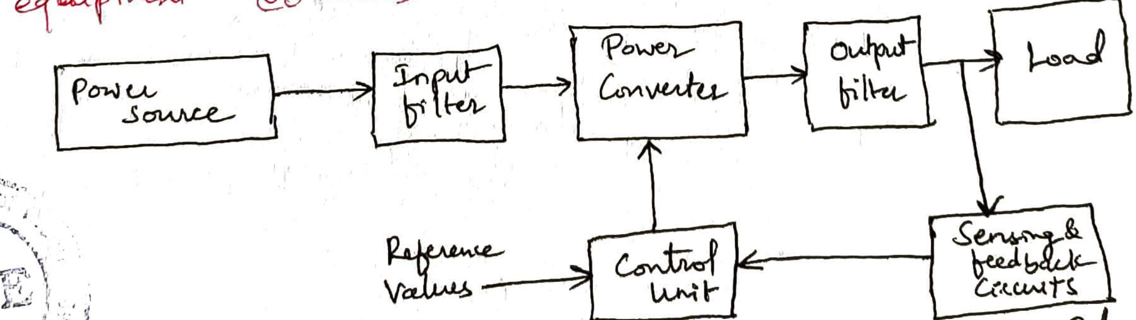
- A DC-DC converter is also known as a chopper, or switching regulator, and a transistor chopper is shown in fig. The ~~advantage~~ average output voltage '$v_0$' is controlled by varying the conduction time $t_1$ of transistor $Q_1$. If 'T' is the chopping period, then $t_1 = \delta T$. '$\delta$' is called as the duty cycle of the chopper.

(iv) DC - AC converters (Inverters)




- A DC-AC converter is also known as an inverter. A single phase transistor inverter is shown in fig. of circuit diagram. If transistors $M_1$ & $M_2$ conduct for one half of a period and $M_3$ & $M_4$ conduct for the other half, the output voltage is of the alternate form. The output voltage can be controlled by varying the conduction time of transistors.

1) b) With block diagram, explain the peripheral effects of power electronic equipment (06 marks)






Block diagram of the system having power converter (electrical motor drive)

- As shown in fig. it takes input power from the power source and delivers it to the load. The power converter normally uses switches to convert input power in required form. Because of the switching actions following things are going to take place.

1) Switching voltage / current pulses are induced in the power supply.

2) Harmonics are induced in power supply due to improper waveforms.

3) Load contains voltage / current spikes and harmonics

4) Interference is radiated (RFI & EMI) due to switching of devices.

These problems are reduced by putting filters before and after the power converters. These filters attenuate the harmonics and noise spikes.

1)c) Compare the advantages and disadvantages of full wave bridge rectifier and full wave centre tapped transformer rectifier. (4 marks)

Ans:

| Single phase centre tapped transformer rectifier | 1-ϕ full wave bridge rectifier |
|---|---|
| i) a centre tapped transformer is used in the input side | i) Normal step down transformer is used in the input side. |
| ii) Two diodes are used in the circuit | ii) 4 diodes are used in the circuit |
| iii) Voltage stress on the diodes is comparatively more (high) | iii) Voltage stress on the diodes is comparatively less. |
| iv) Current stress on the diodes is comparatively high | iv) Current stress on the diodes is comparatively less |

2)a) Briefly explain the different types power diodes & its applications (8 marks)



Ans: (i) General purpose diodes:

- High reverse recovery time of about 25μs.
- used in low power applications such as rectifiers and converters.
- frequency rating: upto 1 kHz  Voltage: 50V–500V  Current: 1A to 1000A.
- General purpose diodes are available in 2 configurations: i) Stud mounted type ii) Disk type

(ii) Fast recovery diodes:

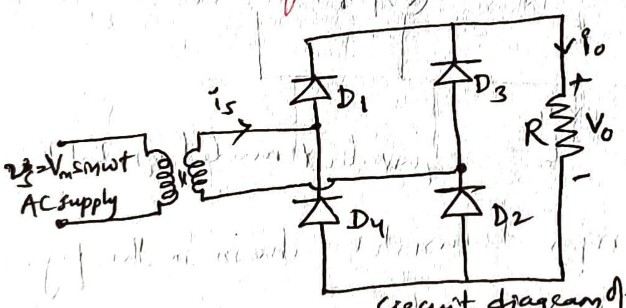
- Reverse recovery time less than 5 μs.
- used in high speed applications such as choppers & inverters
- Ratings: 1 A to 100 A & 50V to 3 kV
- For voltage rating above 400 V, fast recovery diodes are generally made by diffusion and recovery time is controlled by platinum or gold diffusion.
- For voltage rating below 400 V, epitaxial diodes provide faster switching speeds than others.

iii) Schottky Diodes:
- In schottky diodes the pn junction is eliminated.
- high switching frequency & less turn-off time
- On state losses are very less.
- The leakage current of schottky diode is much higher than a p-n junction diode.
- Voltage rating is limited to 100V and current ratings range from 1-400A.

2) b) List the applications of power electronics (4 marks)

Ans: a) Uninterrupted power supplies
b) resistance welding, induction heating & electrolysis.
c) Power conversion of HVDC & HVAC transmission systems.
d) Speed control of motors used in different industries.
e) Power compensators, static contactors, transformer tap changers etc.
f) power supplies for communication systems, telephone exchanges, satellite systems etc.

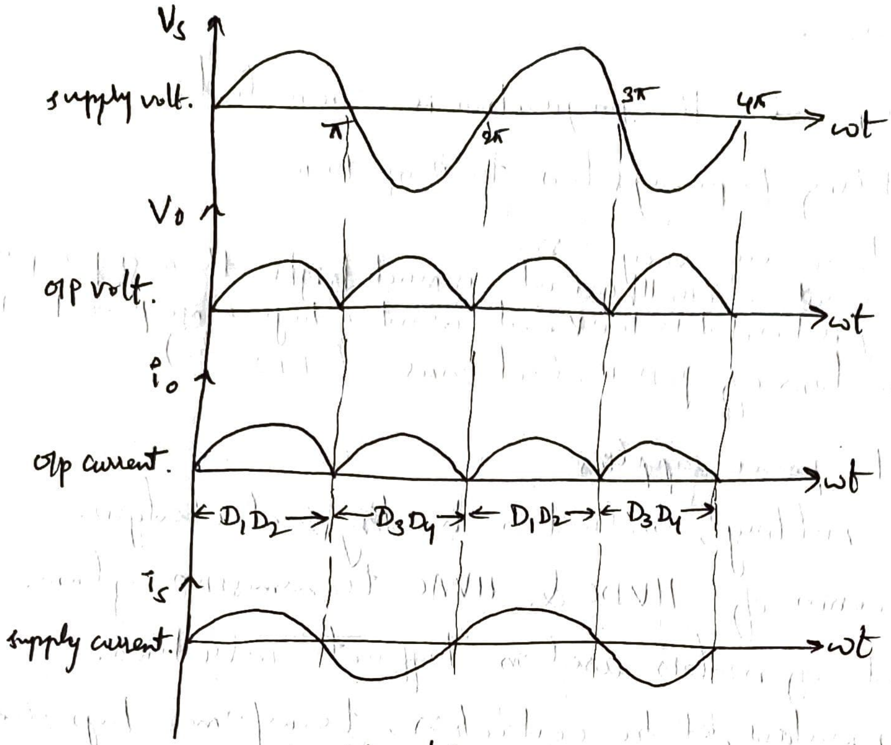
2) c) With circuit diagram & waveform explain the working of single phase uncontrolled rectifier with R-load. (8 marks)




circuit diagram of bridge rectifier.

- fig. shows the circuit diagram of bridge rectifier with R-load.
- There are four diodes used. Hence called as bridge rectifier.
- Diodes $D_1$ & $D_2$ conduct in +ve half cycle and $D_3$ & $D_4$ conduct in the -ve half cycle
- Average value of o/p voltage, $(V_o)_{av}$ is given by

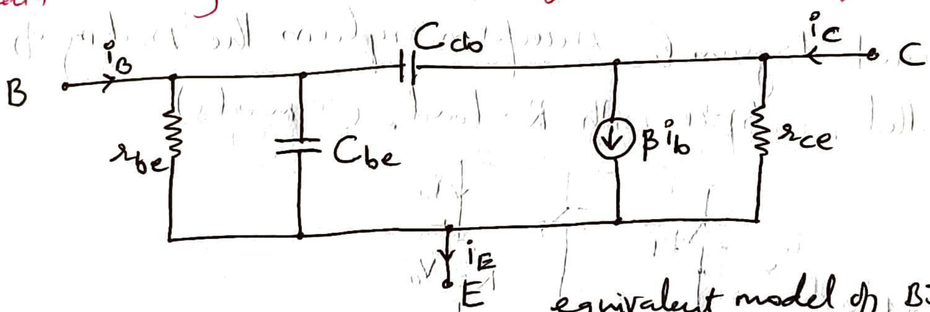
$$(V_o)_{av} = \frac{2V_m}{\pi} = 0.637 V_m$$




Waveforms.

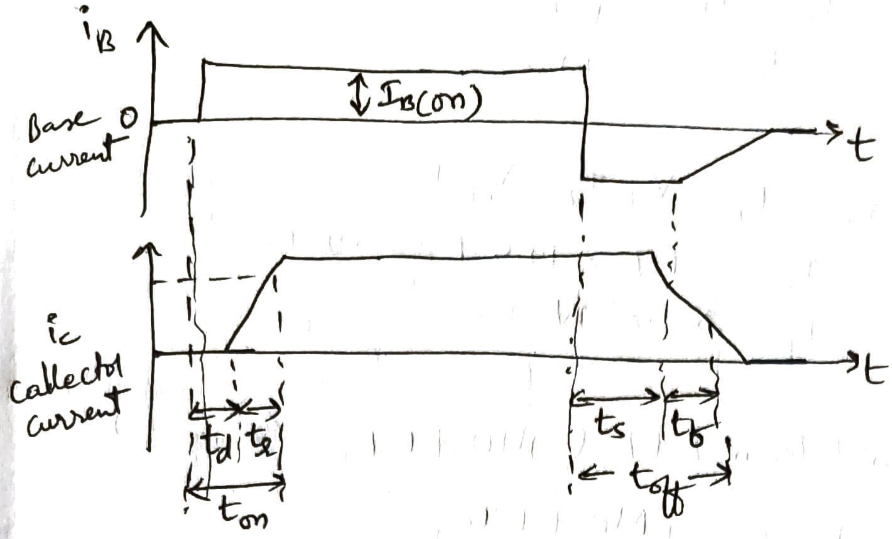
## Module -02

3) a) Explain switching characteristics of BJT with waveforms (8 marks)




equivalent model of BJT

- Consider the model of npn transistor shown in the fig. above.
- The equivalent collector base junction capacitance ($C_{cb}$) and base emitter junction capacitances ($C_{be}$) play significant role during turn on and turn off.
- Effect of these capacitances can be neglected under steady state conditions. But turn on and turn off are affected due to internal capacitances of BJT. The values of internal capacitances depend upon junction voltages & physical construction of the BJT.




as per the waveform shown above

turn ON time ($t_{on}$) of the BJT is given by

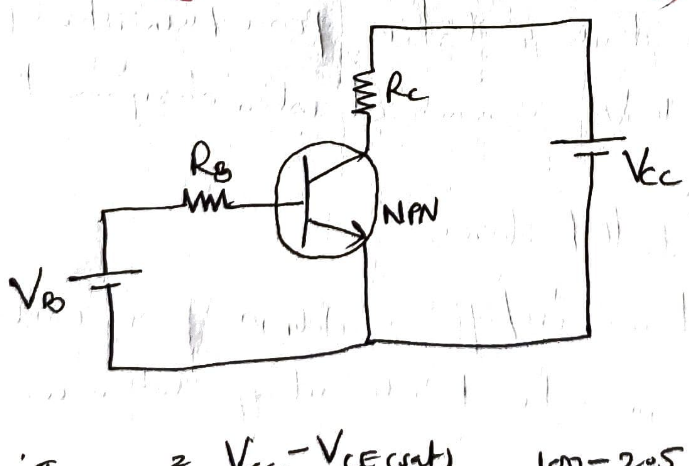
$$t_{on} = t_d + t_r.$$

similarly turn off time of the BJT is given by

$$t_{off} = t_s + t_f$$

3) b) A power BJT is connected as a switch as shown in fig. shown below with the following data. Calculate the i) value of $R_B$ ii) forced $\beta$ (iii) Power loss in the transistor

(06 marks)




$V_{CC} = 100V$  $V_B = 8V$

$V_{CE\,sat} = 2.5\,V$

$V_{BE\,sat} = 1.75\,V$

$\beta$ of the transistor is varied from 10 to 60

$R_C = 10\Omega$

(i) $I_{C(sat)} = \dfrac{V_{CC} - V_{CE(sat)}}{R_C} = \dfrac{100 - 2.5}{10} = 9.75\,A$

$I_{B(sat)} = \dfrac{I_{C(sat)}}{\beta_{min}} = \dfrac{9.75}{10} = 0.975\,A$

$ODF = \dfrac{I_B}{I_{B(sat)}} \Rightarrow 20 = \dfrac{I_B}{0.975} \Rightarrow I_B = 19.5\,A.$

$V_B = I_B R_B + V_{BE}$

$8 = 19.5 \times R_B + 1.75 \Rightarrow R_B = 0.32\,\Omega$

(ii) $\beta_{forced} = \frac{I_{C(sat)}}{I_B} = \frac{9.75}{19.5} = 0.5$

(iii) Power loss in transistor, $P_T = V_{BE} I_B + V_{CE} I_C$

$P_T = 1.75 \times 19.5 + 2.5 \times 9.75$

$P_T = 58.5 \text{ W}$

3) c) Give a comparison between BJT & MOSFET (6 marks)

| BJTs | MOSFETs. |
|---|---|
| (i) Small turn on losses | (i) high on-state losses. |
| (ii) Base is the control terminal | (ii) Gate is the control terminal. |
| (iii) This is bipolar device | (iii) This is majority carrier device |
| (iv) Current controlled device | (iv) Voltage controlled device. |
| (v) Drive circuit is complex | (v) Drive circuit is simple |
| (vi) Switching frequency is lower than MOSFET | (vi) Switching frequency is high. |

4) a) Discuss the need of base drive control in power transistor (8 marks)

- Following points are to be remembered when designing the base drive circuit for transistor

i) BJTs are current controlled device

ii) Power BJT is used as on/off switch in power electronics

iii) Power BJT operates in saturation & cut off when used as a switch

iv) Sufficient base current is required to drive BJT in saturation.

v) Amount of carrier injected in base region determine storage time of BJT

(vi) storage time determines turn on & turn off times of BJT.

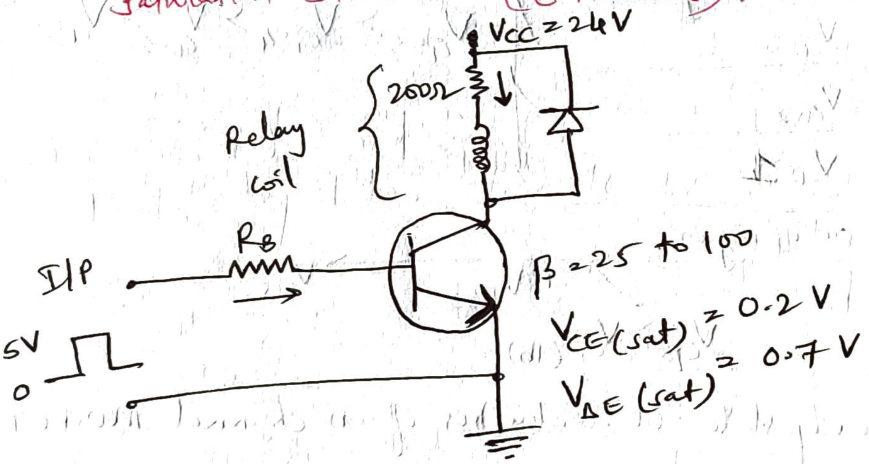
vii) There should be mechanism to control the amount of saturation so as to control storage time.

(viii) base drive control is adopted both during turn-on & turn off.

4) b) A simple transistor switch is used to connect a 24 V DC supply across a relay coil, which has a DC resistance of 200 Ω. An input pulse of 0 to 5 V amplitude is applied through a series base resistor $R_B$ at the base so as to turn on the transistor switch. Sketch the device current waveform with reference to the input pulse.

Calculate: i) $I_{C(sat)}$ (ii) Value of resistor $R_B$ required to obtain over drive factor 2.

(iii) Total power dissipation in the transistor that occurs during the saturation state. (6 marks).




(i) $I_{C(sat)} = \dfrac{V_{CC} - V_{CE(sat)}}{R_C} = \dfrac{24 - 0.2}{200} = 0.12\ A$

(ii) $I_{B(sat)} = \dfrac{I_{C(sat)}}{\beta_{(minimum)}} = \dfrac{0.12}{25} = 4.8\ mA$

$ODF = \dfrac{I_B}{I_{B(sat)}}$

If $ODF = 2$ ; $2 = \dfrac{I_B}{4.8\,mA}$

$I_B = 9.6\ mA$

From base emitter loop we get,

$$V_B = I_B R_B + V_{BE}$$

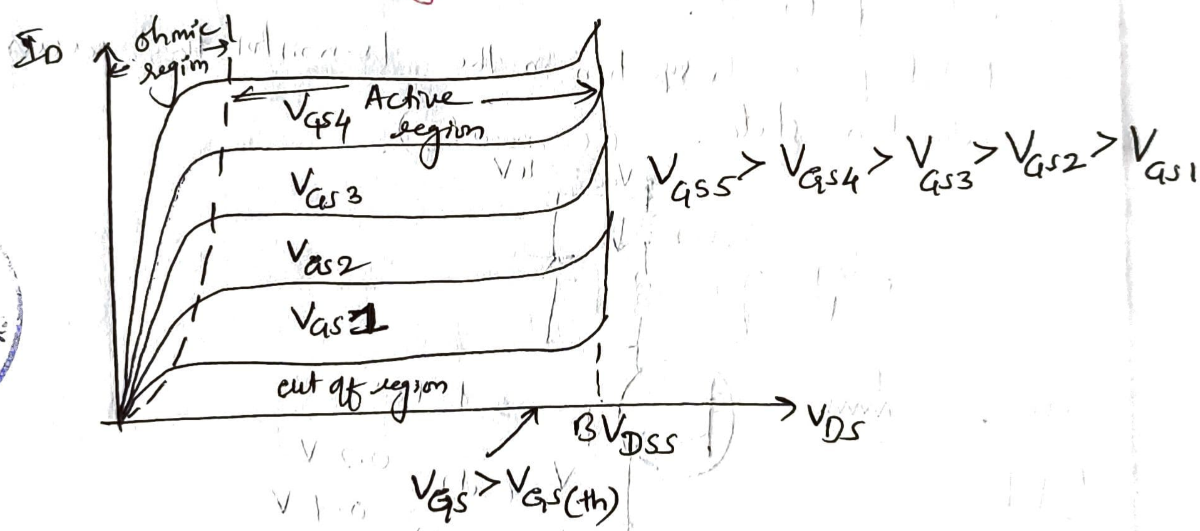
$$R_B = \frac{V_B - V_{BE}}{I_B} = \frac{5 - 0.7}{9.6\,mA} = 448\,\Omega$$

(iii) Total power dissipation will be

$$P_T = V_{BE} I_B + V_{CE} I_C = 0.7 \times 9.6 \times 10^{-3} + 0.2 \times 0.12$$

$$= 0.0307\,W = 30.7\,mW$$

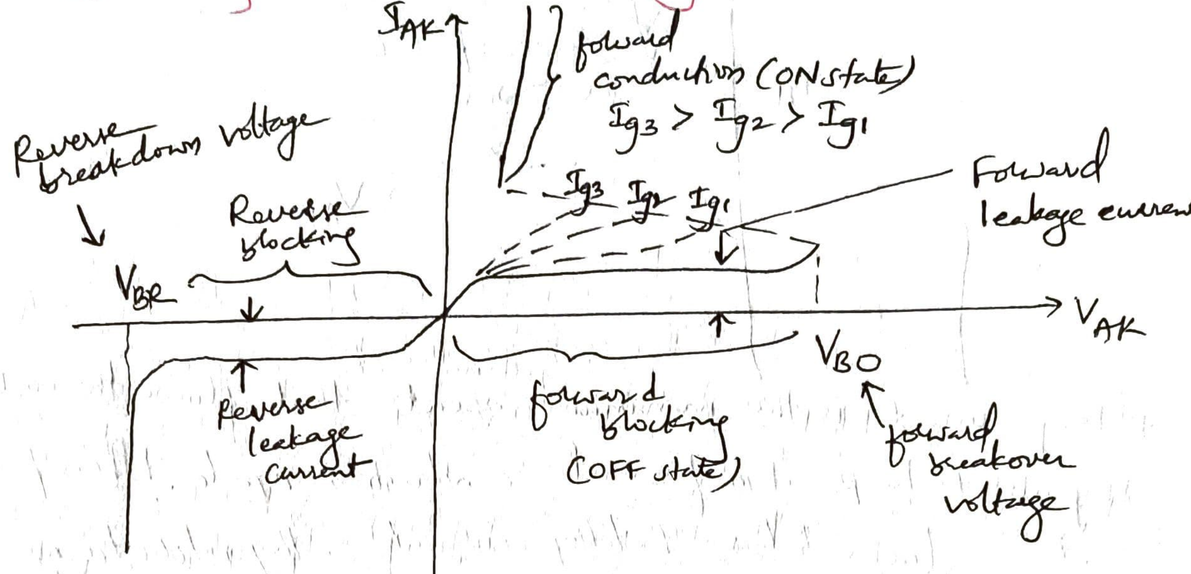
4)c) Explain the steady state characteristics of n channel power MOSFET with necessary diagram. (6 marks)






- Fig. shows the steady state characteristics of n channel MOSFET.
- The drain current $I_D$ is plotted with respect to drain to source voltage $V_{DS}$. These characteristics are plotted for various values of gate source voltages ($V_{GS}$).
- There are three regions in the characteristics : ohmic region, active region and cut off region.
- In the cut off region the MOSFET is said to be in OFF state when $V_{GS} < V_{GS(th)}$. Here $V_{GS(th)}$ is threshold gate source voltage.
- In the ohmic region the MOSFET conducts heavily. Hence it is said to be 'ON'.

5) a) Explain the V-I characteristics of SCR also define (12 marks)
(i) Holding current (ii) Latching current



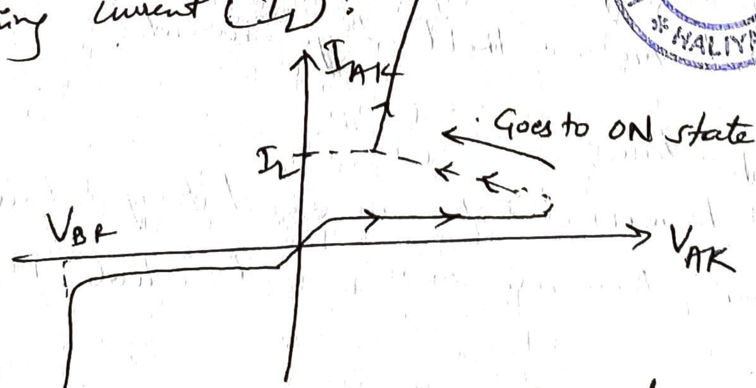

V-I characteristics of a thyristor (SCR).

- The working of the thyristor can be discussed in three modes: Reverse blocking mode, forward blocking mode and forward conduction mode.
- Above fig. shows the V-I characteristics of SCR. The anode to cathode current $I_{AK}$ is plotted with respect to anode to cathode $V_{AK}$. The voltage $V_{BO}$ is the forward breakover voltage.
- $V_{BR}$ is the reverse breakover voltage & $I_{g1}$, $I_{g2}$, $I_{g3}$ are gate currents applied to the thyristor.



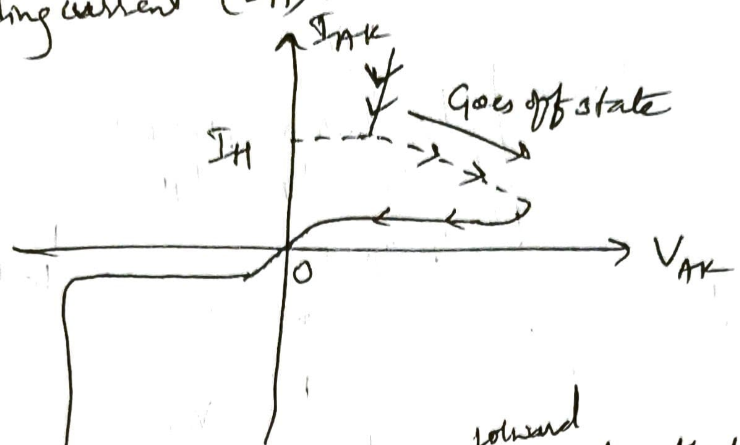
Latching and holding currents:

(i) Latching current ($I_L$):




Latching current is the minimum forward current that flows through the thyristor to keep it in forward conduction mode at the time of triggering. This latching current is of the order: 10 - 15 mA

(ii) Holding current ($I_H$):




Holding current is the minimum forward current that flows through the thyristor to keep it in forward conduction mode. When forward current reduces below holding current, thyristor turns-off

5) b) Explain the any four method of turn on used for thyristors (4 marks)

(i) Gate drive:
Thyristor can be turned on by applying positive gate-cathode voltage

(ii) High forward voltage:
Thyristor turns on when its anode-cathode voltage exceeds forward break over voltage i.e $V_{AK} > V_{BO}$.

(iii) Light:
Thyristor can be turned on by light, when it falls on gate cathode junction of the thyristor light induces electronic hole pairs and it helps to increase the leakage current.

(IV) High temperature:
Thyristor turns on due to increased temperature. AT higher temperature, there are more electron hole pairs across junctions.

5) c) The latching current of an SCR used in a phase controlled circuit comprising and inductive load of $R = 10\,\Omega$ & $L = 0.1\,H$ is 15 mA. The input voltage is $325 \sin 314t$. Obtain the minimum gate pulse width required for reliable triggering of the SCR if gated at $\frac{\pi}{3}$ angle in every half cycle. (04 marks)

Ans: $V_s = 325 \sin \frac{\pi}{3} = 281.458\ V$

& the current through load is given by

$$i(t) = \frac{V_s}{R}\left(1 - e^{-t \cdot \frac{R}{L}}\right)$$

here $i(t) = I_L = 15\ mA$

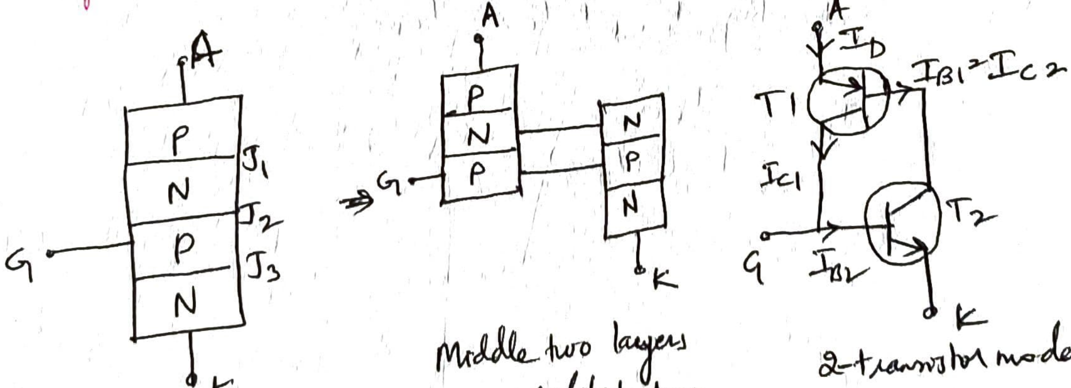
$$\therefore\ 15 \times 10^{-3} = \frac{281.458}{10}\left[1 - e^{-t \times \frac{10}{0.1}}\right]$$

solving for t, we get $t = 5.33\,\mu S$

Thus the minimum gate pulse should be $5.33\,\mu S$ to reliably turn-on the SCR.

6) a) Derive an expression for anode current using two transistor model of thyristor. (8 marks)

Ans:




four layer structure of thyristor

Middle two layers are split to two parts.

2-transistor model.

- The operation of the thyristor can be explained with the help of two transistor model. as shown in previous fig.
- Middle two layers are split into to two separate parts. Because of this the two transistors are formed. These transistors are also shown in fig.
- transistor $T_1$ is pnp where as $T_2$ is npn. The base of $T_1$ is connected to collector of $T_2$. Similarly base of $T_2$ is connected to collector of $T_1$. These transistors are in common base configuration.
- The collector current, emitter current and leakage currents of $T_1$ are related as.

$$I_{C1} = \alpha_1 I_{E1} + I_{CO1}$$

$I_{E1} = I_D$ and $I_{CO1}$ is leakage current of $T_1$. Similarly for $T_2$

$$I_{C2} = \alpha_2 I_{E2} + I_{CO2}$$

here, $I_{E2} = I_D$ and $I_{CO2}$ is leakage current of $T_2$

W.K.T from fig $I_D = I_{C1} + I_{C2}$

$$\therefore I_D = \alpha_1 I_D + I_{CO1} + \alpha_2 I_D + I_{CO2}$$

$$I_D = (\alpha_1 + \alpha_2) I_D + I_{CO1} + I_{CO2}$$

$$I_D = \frac{I_{CO1} + I_{CO2}}{1 - (\alpha_1 + \alpha_2)}$$

denoting $I_{CO1} + I_{O2} = I_{CO}$

$$\therefore I_D = \frac{I_{CO}}{1 - (\alpha_1 + \alpha_2)}$$

6) b) A UJT is connected across a 220 V DC supply. The valley & peak point voltages are 1V & 15 V. The period of UJT relaxation oscillator is 20mS. Find the value of charging capacitor, if a charging resistor of 100 kΩ is used. (6 marks)

Ans: given :-

$V_{BB} = 220\text{ V}$

$V_v = 1$, $V_p = 15\text{V}$

$T = 20 \times 10^{-3}$

$R_C = 100\text{ k}\Omega$

The peak voltage of the UJT is given as

$V_p = \eta V_{BB} + V_D$

Let $V_D = 0.8$ & putting values in above equation

$15 = \eta \times 20 + 0.8 \Rightarrow \eta = 0.71$

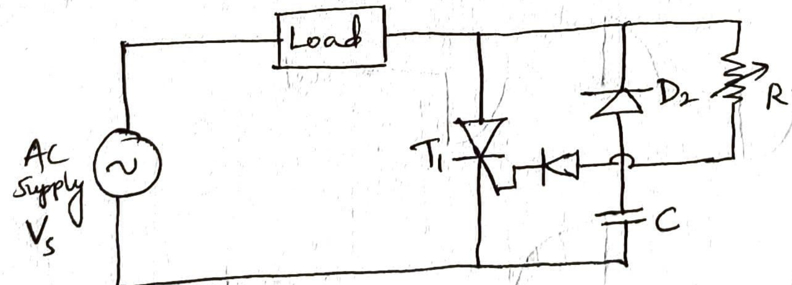
We also have $T = R_C C \ln\left(\frac{1}{1-\eta}\right)$

substituting values in the above equation

$20 \times 10^{-3} = 10 \times 10^{3} \times C \times \ln\left(\frac{1}{1-0.71}\right)$

$\therefore C = 0.162\,\mu F.$

6) c) Explain half wave RC firing circuit with necessary diagrams. (6 marks)





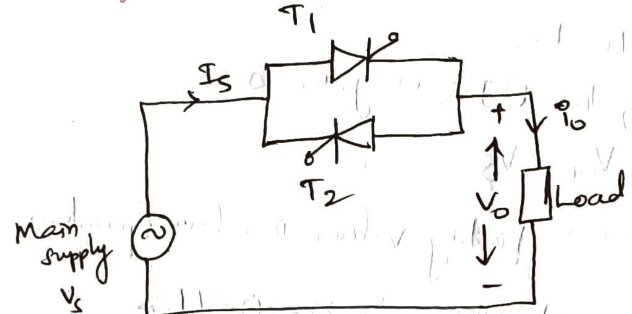

- fig. shows the circuit diagram of RC firing circuit.
- In the negative half cycle, the capacitor charges through diode $D_2$ to negative supply voltage. The capacitor charges to $-V_m$ of the supply.
- The capacitor then discharges through resistor R during the positive half cycle of the supply.

$RC \geq \frac{1.3}{2f}$

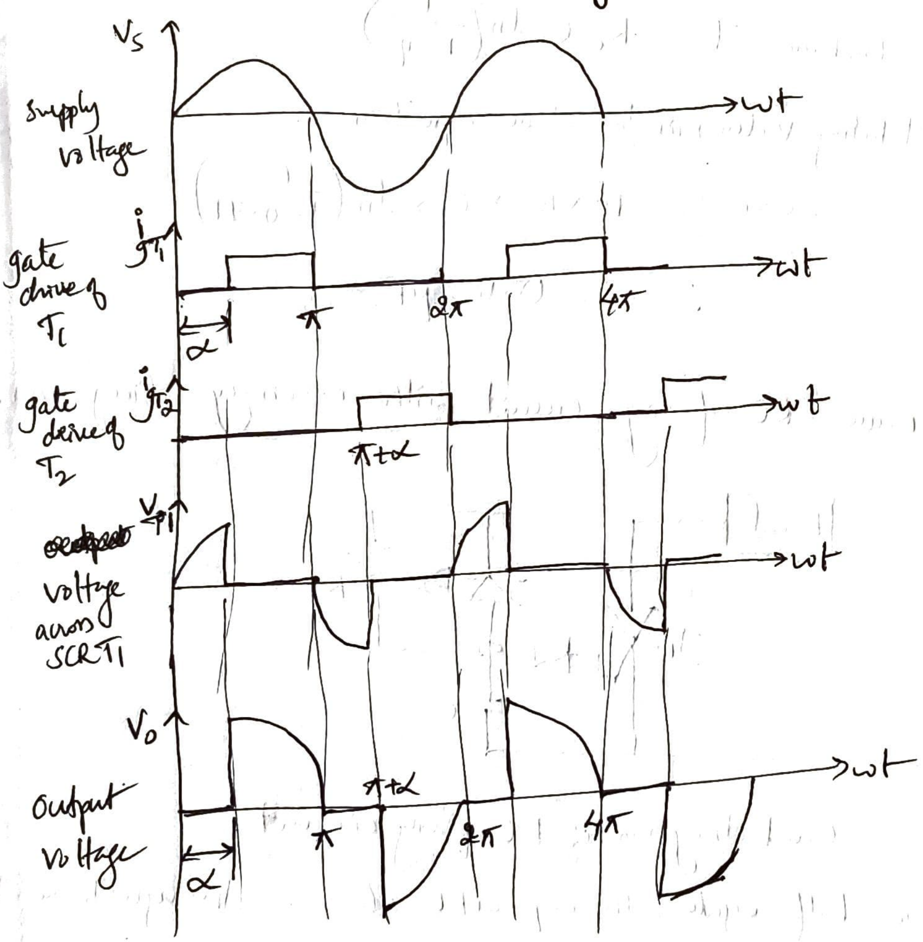
- Here 'f' is the supply frequency. Since triggering is controlled only in one half cycle of the supply, this circuit is also called halfwave RC firing circuit.

## Module-04

7) a) With a help of circuit diagram and waveforms explain the working of single phase full wave AC voltage controller with R-load (10 marks)




circuit diagram




Waveforms.

- Circuit diagram shows 1-ϕ full wave controller. It has two SCRs $T_1$ & $T_2$. In the positive half cycle of the supply $T_1$ controls the power flow to the load. And in the negative half cycle of the supply $T_2$

controls the power flow to the load. The waveforms of this circuit are shown in the waveforms for resistive load.

- The rms value is given by

$$V_{o(rms)} = \left[\frac{1}{T}\int_0^T v_o^2(\omega t)\cdot d\omega t\right]^{\frac{1}{2}}$$

upon simplification the final equation we get. in terms of 'α'

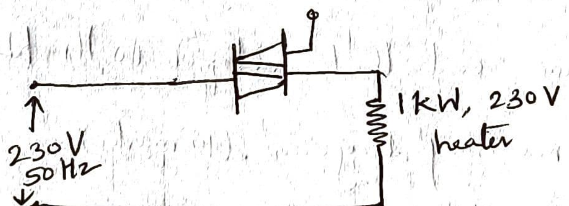
$$V_{o(rms)} = V_m\sqrt{\frac{\pi-\alpha+\frac{\sin 2\alpha}{2}}{2\pi}}$$

- In this above equation
  when $\alpha=0$, $V_{o(rms)} = \frac{V_m}{\sqrt{2}} = V_s$

  when $\alpha=\pi$, $V_{o(rms)} = 0$

- Hence the o/p can be controlled from zero to $V_{s(rms)}$

7) b) The single phase full wave AC voltage controller operates on a single phase supply voltage of 230V rms at 50Hz. If the TRIAC is triggered at a delay angle of 45° during each half cycle of input supply.
Calculate : i) RMS value of output voltage ii) RMS value of current through heater (10 marks)
(iii) Average value of triac current iv) RMS value of triac current
(v) Input p.f




here: $V_s = 230V$
$\alpha = 45°$

AC voltage controller using triac

(i) to obtain $V_{o(rms)}$

$$V_{o(rms)} = V_m\sqrt{\frac{\pi-\alpha+\frac{\sin 2\alpha}{2}}{2\pi}} = 230\sqrt{2}\sqrt{\frac{\pi-\frac{\pi}{4}+\frac{\sin\left(2\cdot\frac{\pi}{4}\right)}{2}}{2\pi}}$$

$$V_{o(rms)} = 219.3\ V$$

(ii) To obtain rms value of output current

The resistance of heater will be, $R_L = \frac{(230)^2}{1000} = 53\Omega$

Hence rms current through heater will be

$$I_{O(rms)} = \frac{V_{O(rms)}}{R_L} = \frac{219.3}{53} = 4.137\ A.$$

(iii) To obtain average value of triac current

The average value is zero, since positive & negative half cycles of current flowing through triac are symmetric.

(iv) RMS value of triac current

$$I_{T(rms)} = I_{O(rms)} = 4.137\ A.$$

(v) To obtain input p.f

$$\text{active load power} = I_{O(rms)}^2 R_L = (4.137)^2 \times 53 = 907\ W$$

$$I_{S(rms)} = I_{O(rms)} = 4.137\ A$$

$$\therefore \text{Total rms input power} = V_{S(rms)} \times I_{S(rms)}$$

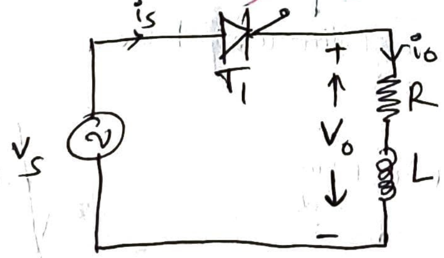
$$= 230 \times 4.137$$

$$= 951.5\ VA$$

$$\therefore PF = \frac{\text{Active load power}}{\text{total input power}} = \frac{907}{951.5} = 0.953$$

8) a) Explain half wave controlled rectifier with RL load without freewheeling diode. Draw necessary diagram. (10 marks)

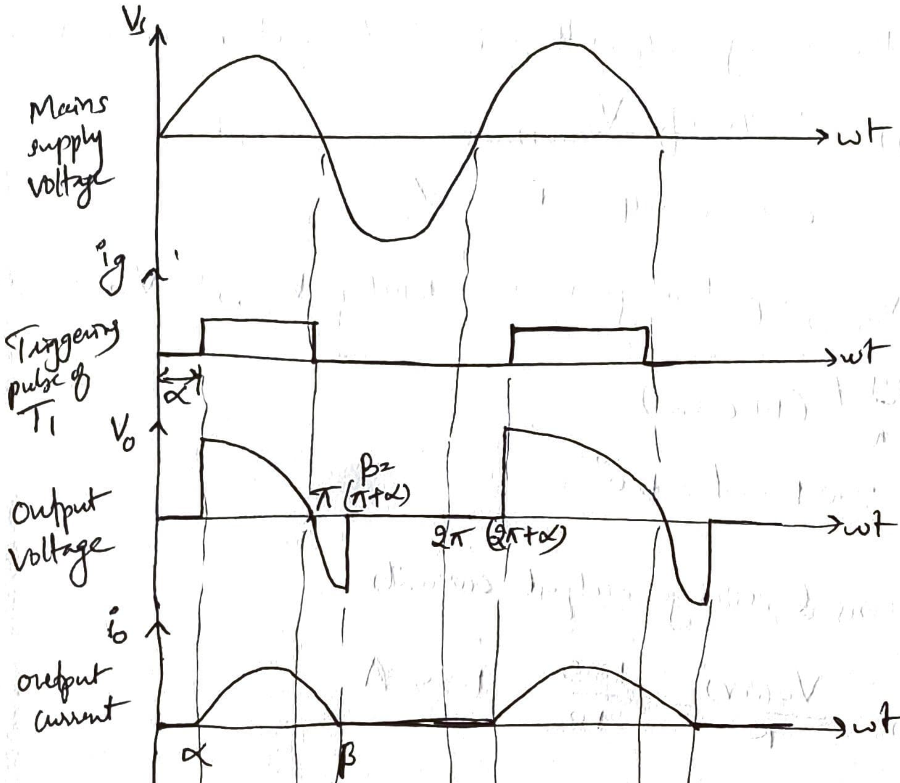
Ans:






Half wave controlled rectifier with RL load.

- SCR will be forward biased in positive half cycle of the supply. Hence SCR is applied with firing angle pulses in the positive half cycle.
- Here 'L' indicate armature or field coil inductance & R is the resistance of coils.




- $T_1$ conducts from $\pi$ to $\beta$ due to load inductance.
- $V_L$ is given by $V_L = L \cdot \frac{di_o}{dt}$.

8)b) A single phase half wave converter is operated from 120 V, 50 Hz supply & the load resistance $R = 10\,\Omega$. If the average output voltage is 25% of the maximum possible average output voltage calculate -
(i) Delay angle '$\alpha$'  ii) The rms & average output currents
(iii) The rms & average thyristor currents  (iv) The input power factor. (10 marks)

given: $V_s = 120$ V , $V_m = \sqrt{2} \times 120 = 169.7$ V

Load resistance $R = 10\,\Omega$

average output voltage $V_{o(av)} = 25\%$ of $V_{o(av)}$ maximum

(i) To obtain delay angle

average o/p voltage, $V_{o(av)} = \frac{V_m}{2\pi}(1 + \cos\alpha)$

$(V_o)_{av}$ will be maximum at $\alpha = 0$

$\therefore V_{o(av)_{max}} = \frac{V_m}{2\pi}(1 + \cos 0) = \frac{V_m}{\pi} = \frac{169.7}{\pi} = 54$ V it is given that the average o/p voltage is 25% of its maximum value i.e

$$V_{o(av)} = 25\% \text{ of } V_{o(av)\,max}$$

$$V_{o(av)} = 0.25 \times 54 = 13.5\ V$$

Considering $V_{o(av)}$ equation again & substituting $V_{o(av)}$ & $V_m$ we get 'α' value as

$$13.5 = \frac{169.7}{2\pi}(1+\cos\alpha)$$

$$\therefore \alpha = 2.09\ rad = 120^\circ$$

(ii) To obtain rms & average output currents

$$I_{o(av)} = \frac{V_{o(av)}}{R} = \frac{13.5}{10} = 1.35\ A$$

$$I_{o(rms)} = \frac{V_{o(rms)}}{R} = \frac{37.718}{10} = 3.77\ A$$

(iii) RMS & average thyristor currents

$$I_{T(av)} = I_{o(av)} = 1.35\ A$$

$$\& \ I_{T(rms)} = I_{o(rms)} = 3.77\ A$$

(iv) To obtain input power factor

$$\text{Total supply power} = V_{s(rms)} \times I_{s(rms)} = 120 \times 3.77 = 452.4\ VA$$

Active load power will be

$$\text{active load power} = \frac{V_{o(av)}^2}{R} = \frac{(13.5)^2}{10} = 18.225$$

$$\therefore \text{powerfactor} = \frac{\text{active load power}}{\text{total supply power}} = \frac{18.225}{452.4} = 0.04 \text{ lagging.}$$

9) a) A chopper circuit drives an inductive load from 200V DC supply. Given the load resistance as 4Ω, the average load current as 30 A & operating frequency is 400 Hz. Compute the ON period and OFF period of the chopper. Also determine the duty cycle of the chopper. (6 marks)

Given data: Supply voltage $V_s = 200V$, load resistance $R = 4\Omega$

output current $I_{o(av)} = 30A$, frequency $f = 400 Hz$

(i) To obtain $V_{o(av)}$

$$V_{o(av)} = R \times I_{o(av)} = 4 \times 30 = 120V$$

(ii) To obtain $\delta$

$$V_{o(av)} = \delta V_s$$

$$\therefore \delta = \frac{V_{o(av)}}{V_s} = \frac{120}{200} = 0.6$$

(iii) To obtain $T_{on}$ & $T_{off}$

$$\delta = \frac{T_{on}}{T} = T_{on} \times f$$

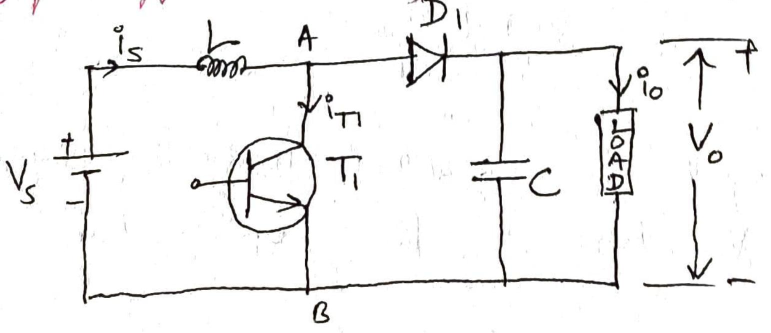
$$T_{on} = \frac{\delta}{f} = \frac{0.6}{400} = 1.5 \text{ msec}$$

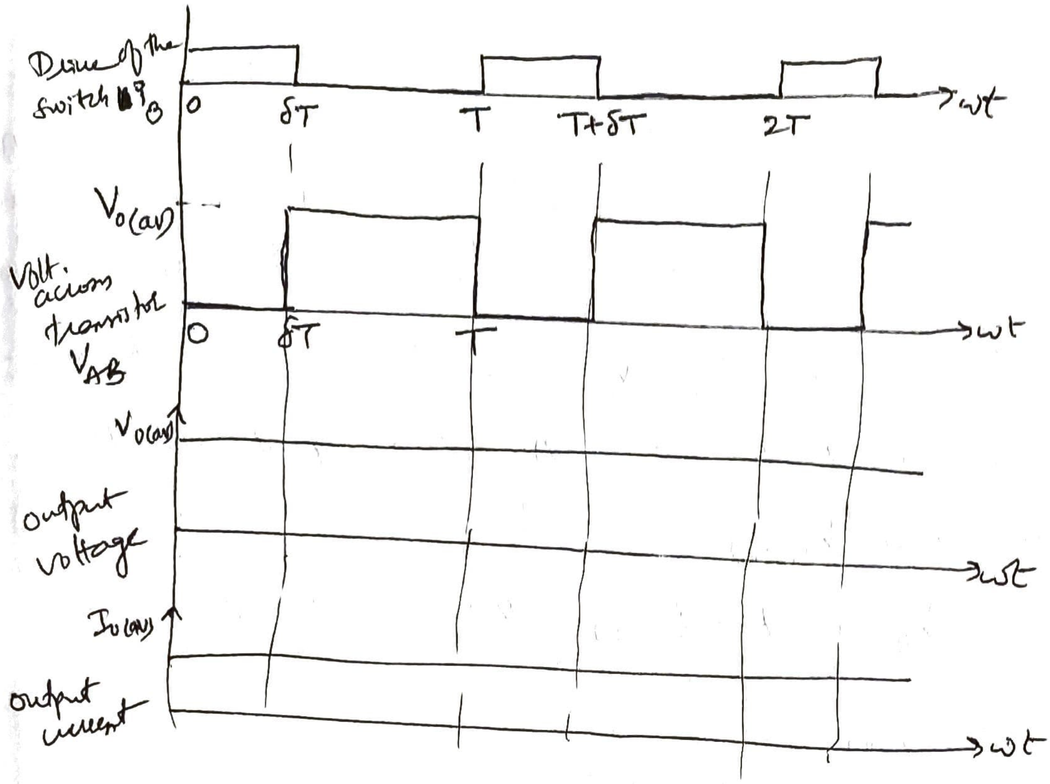
$$T = T_{on} + T_{off}$$

$$T_{off} = T - T_{on} = \frac{1}{f} - T_{on} = \frac{1}{400} - 1.5\times10^{-3}$$

$$= 1 \text{ msec}$$

9) b) With the help of circuit diagram & waveforms, explain the operation of step-up chopper. (8 marks)






- Circuit diagram shows the step up chopper. There is an inductance in series with the supply $V_s$. A switch (transistor GTO, MOSFET etc.) is connected across inductance & supply. A filter capacitor 'C' is used across the load to make $V_o$ smooth.
- The diode $D_1$ blocks the reverse flow of output current when switch is switched ON.
- In the wave forms, the transistor is turned on from 0 to δT. Hence current flows through the inductance from the supply. The inductance current rises and inductor stores the energy from the supply.
- Here we assume the output voltage & current to be continuous & ripple free.
- The output voltage equation is

$$v_o = V_s + L \cdot \frac{di_L}{dt}$$



- Thus from above equation we can see that output voltage is greater than supply voltage $V_s$. This shows the step up operation.

9) c) Explain performance parameters of chopper (6 marks)

Ans: (i) Duty cycle (δ):

duty cycle of the chopper controls its output voltage.
The value of duty cycle lies between 0 to 1.

(ii) Operating speeds of switch:

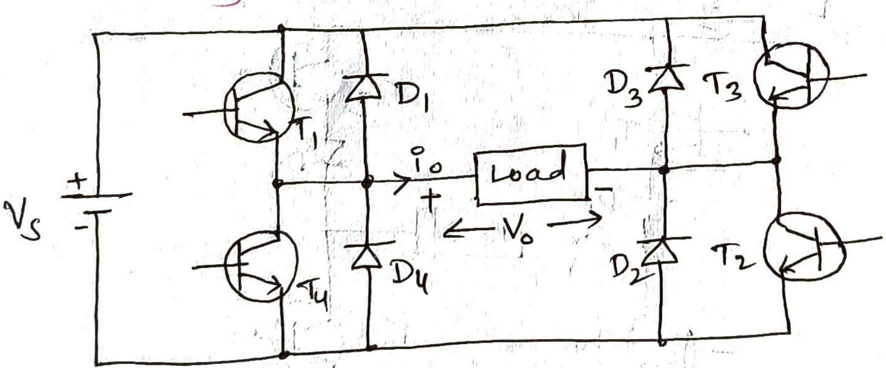
Operating speed of switch depends on turn on & turn off time of switch.
Switching frequency of switch also depends upon speed of the device.

(iii) Frequency of the chopper (f):

The frequency of the chopper $f = \frac{1}{T}$, where T is the period of o/p voltage waveform. As the switching frequency is increased, the ripple frequency of $v_o$ & $i_o$ also increases. Hence the cost & size of filtering components L & C is reduced.

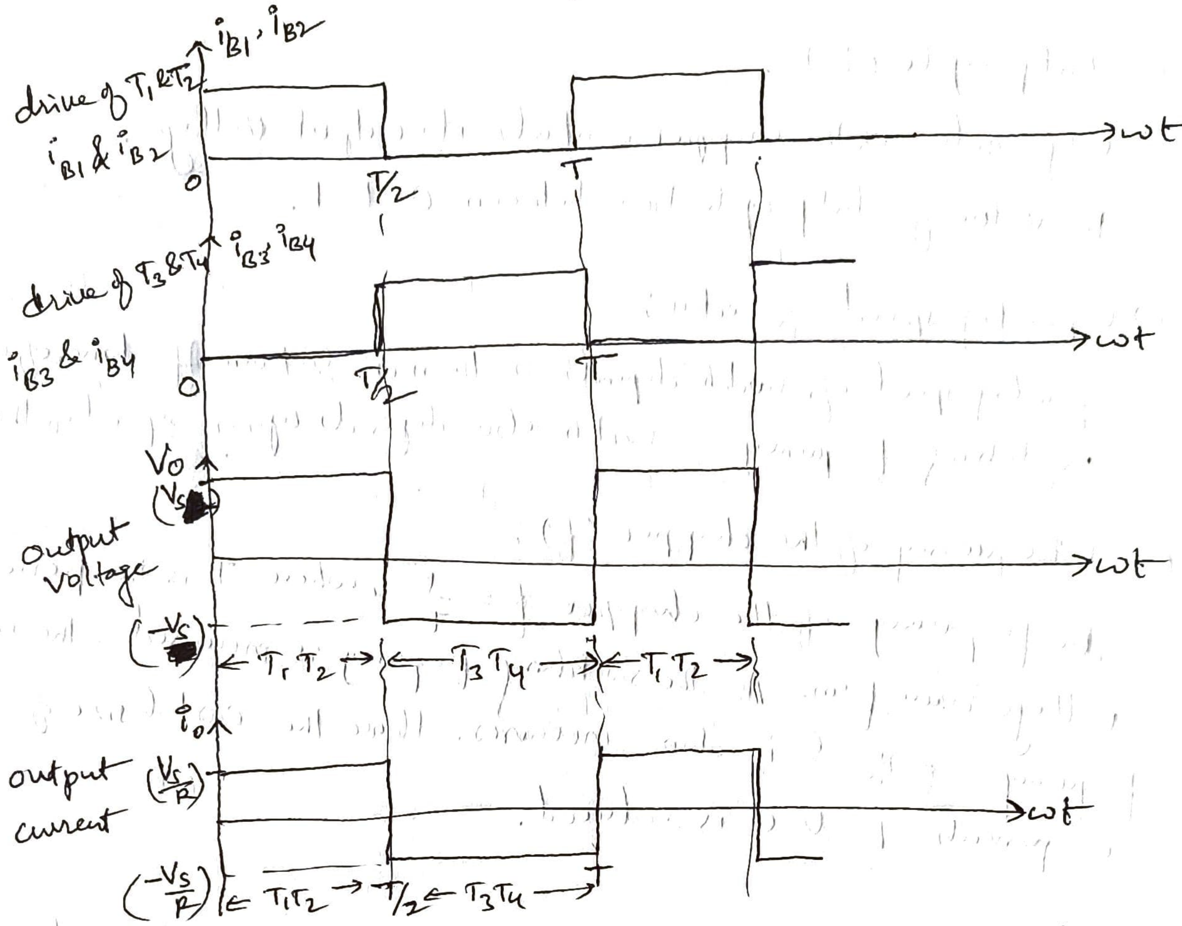
10) a) Explain single phase full bridge inverter operation with R load.
Draw necessary diagrams (10 marks)

Ans:

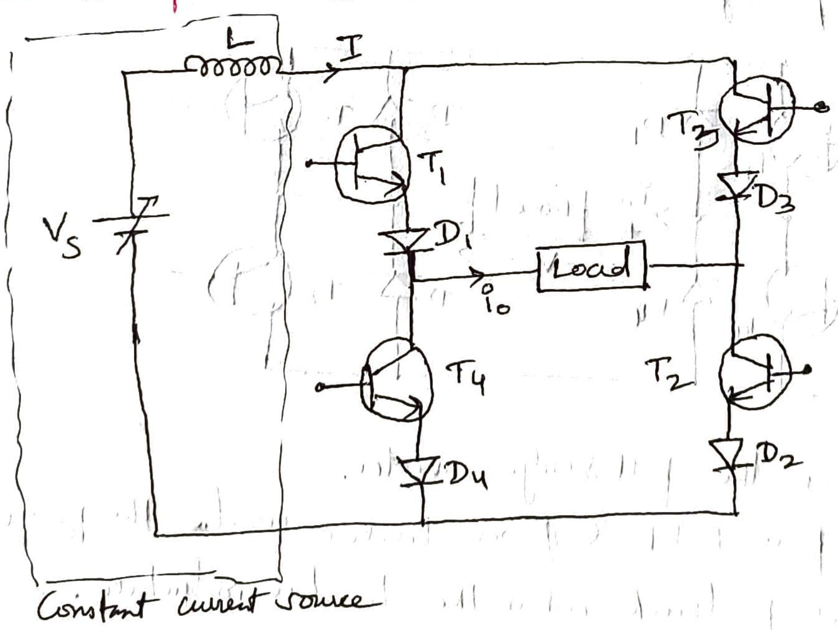



- diagram shows the full bridge inverter.
  There are four BJTs & power diodes used. The power diodes are required for feedback when the load is inductive.
- When the load is resistive, the diodes do not carry any current.
- The transistors $T_1$ & $T_2$ conduct from 0 to $\frac{T}{2}$.
  the output voltage & current are positive.
- At $T/2$, transistor $T_1$ & $T_2$ are turned off. Transistors $T_3$ & $T_4$ conduct from $\frac{T}{2}$ to T. The output voltage & current are negative.

- The amplitude of O/P voltage is $\pm V_s$ - The output is square wave.

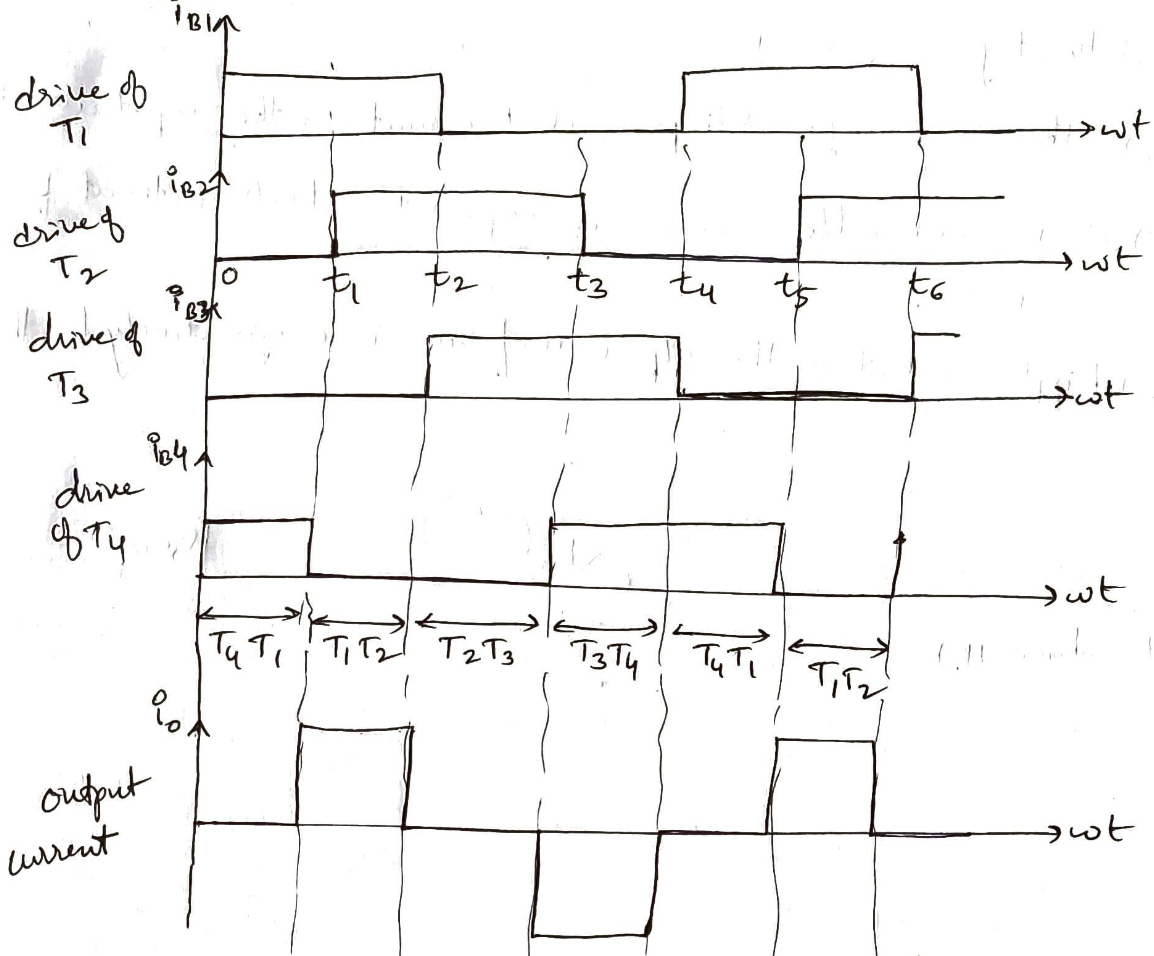



10) b) Draw & explain single phase transistorised current source inverter. (10 marks)




- fig. shows the circuit diagram of 1-ϕ transistorized CSI. there are four transistors $T_1, T_2, T_3$ & $T_4$ used along with four power diodes $D_1, D_2, D_3$ & $D_4$.
- The diodes are used to block reverse voltages appearing across the transistors.

- Since the input current remains constant, it must flow continuously. Hence any two transistor must be always on.




Waveforms of transistorized CSI

- From 0 to $t_1$, transistors $T_1$ & $T_4$ are conducting. Hence no current flows through the load. The load current is zero.
- The supply current is kept constant by connecting a large inductor 'L' in series with DC supply. The supply voltage '$V_s$' is adjusted to keep current constant.
- Let the current flows for the duration of 'δ' in the load for half cycle. Then the load current can be expressed in fourier series as

$$i_{on} = \sum_{n=1,3,5\ldots}^{\infty} \frac{4I}{n\pi} \sin\frac{n\delta}{2} \sin(n\omega t)$$

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- Advantages of CSI:

i) There is no possibility of short circuit as the input current is constant
ii) CSI can handle reactive or regenerative loads without freewheeling diodes.
iii) Ripple content in the o/p waveforms is comparatively less than VSIs.

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