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CBCS SCHEME

USN 18EC36

Third Semester B.E. Degree Examination, Jan./Feb. 2021
Power Electronics and Instrumentation

Time: 3 hrs. Max. Marks: 100

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

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.

Module-1

1 a. Discuss various power converter circuits with necessary sketches and applications of each. (07 Marks)

b. With necessary sketches, explain the static V-I characteristics of SCR and its operation. (08 Marks)

c. List different turn-on methods, explain all in brief. (05 Marks)

OR

2 a. Explain turn-ON/turn-OFF dynamic characteristics of SCR with neat diagram. (07 Marks)

b. With suitable diagram and waveform, explain the working of RC full wave firing circuit. (08 Marks)

c. Describe the operation of UJT with neat sketches. (05 Marks)

Module-2

3 a. Explain the working of 1ϕ full wave center tapped controlled rectifier for resistive load with necessary sketches and also develop mathematical model to evaluate performance parameter of same (V_{dc}, V_{rms}, Efficiency). (10 Marks)

b. Evaluate performance parameter of 1ϕ half controlled rectifier with resistive load. has a transformer secondary voltage of 230V, 50Hz with R = 10Ω and firing angle α = 60°. Determine:
i) Average voltage and current
ii) Rms value of voltage and current
iii) Efficiency
iv) Ripple factor
v) Form factor. (10 Marks)

OR

4 a. Input to the step-up chopper is 200V the output required is 600V, if the conduction time of thyristor is 200μsec. Compute:
i) Chopping frequency
ii) If the pulse width is halved for constant frequency operation, find the new output voltage. (07 Marks)

b. Explain the operation step-up chopper with neat diagram and derive an expression for output voltage. (08 Marks)

c. Elaborate on the control techniques used in choppers and also give detailed classification of choppers. (05 Marks)

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Module-3

5 a. With neat circuit diagram and waveforms. Explain the operation of 1ϕ full bridge inverter for RL load. **(07 Marks)**

b. Design a multi range ammeter with range 0-1A, 0-5A and 0-10A employing individual shunt in each a D'Arsonval movement with an internal resistance of 500Ω and full scale deflection of 10mA is available. **(08 Marks)**

c. What are the errors encountered in measurement process? Explain all with suitable example. **(05 Marks)**

OR

6 a. Design modified multirange voltmeter with basic D'Arsonval movement with an internal resistance of 50Ω and full scale deflection of 2mA, with voltage ranges of 0-10V, 0-50V, 0-100V and 0-250V. Draw the schematic diagram and show all values after design. **(07 Marks)**

b. Explain the various static characteristics of measuring instruments. **(08 Marks)**

c. With neat diagram, explain the operation of isolated flyback converter. **(05 Marks)**

Module-4

7 a. With neat block diagram, explain the operation of Ramp type Digital voltmeter. **(07 Marks)**

b. Explain the operation of Time measurement with neat block diagram. **(08 Marks)**

c. Draw the schematic diagram of Wheatstone's bridge and derive an expression for calculating unknown resistance and explain. **(05 Marks)**

OR

8 a. Explain the operation inductance comparision bridge with necessary equations. **(07 Marks)**

b. Discuss the operation of successive approximation type DVM with necessary diagram. **(08 Marks)**

c. An unbalanced Wheatstone bridge shown in Fig.Q.8(c), calculate the current through the galvanometer. **(05 Marks)**

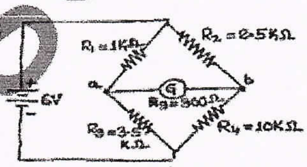

Fig.Q.8(c)

Module-5

9 a. Draw the schematic diagram to measure displacement using resistive transducer and explain. **(07 Marks)**

b. Explain the operation of PLC with neat block diagram. **(05 Marks)**

c. Explain the operation of Instrumentation amplifier using transducer bridge and derive equation for output voltage. **(08 Marks)**

OR

10 a. Explain the construction and working principle of LVDT with characteristic curve. **(07 Marks)**

b. What are factors to be considered for selecting the transducer? **(08 Marks)**

c. Illustrate working of analog weight scale. **(05 Marks)**

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Name of Institution : KLS's VDIT Haliyal

Department : Electronics and Communication Engg

Sem : III sem B.E Degree

Subject : Power Electronics and Instrumentation

Subject code : 18EC36

Note : Scheme is as per the requirement of Subject.

Subject Teacher

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15.03.2022

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Solution of Jan / Feb 2021

Subject: Power Electronics & Instrumentation

Subject code: 18EC36

Module 1

1\. a. Discuss various power converter circuits with necessary sketches and applications of each. [07 Marks]

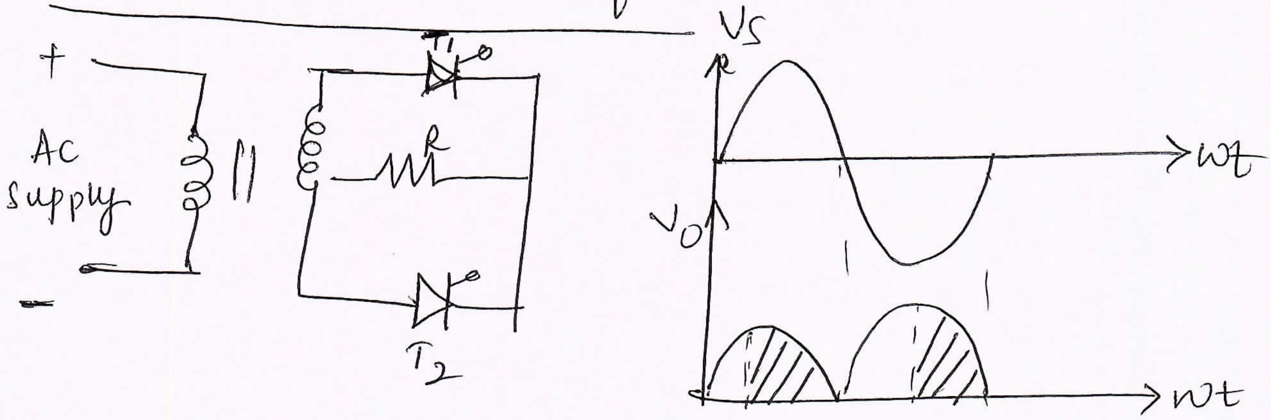
Ans: Power Electronic circuits are also called as Power converters.

Different types of power converters are:

a) Phase controlled Rectifiers
b) Choppers
c) Inverters
d) cycloconverters
e) Ac voltage controllers

List — 02 Marks
Each converter = 1M
Total 7M

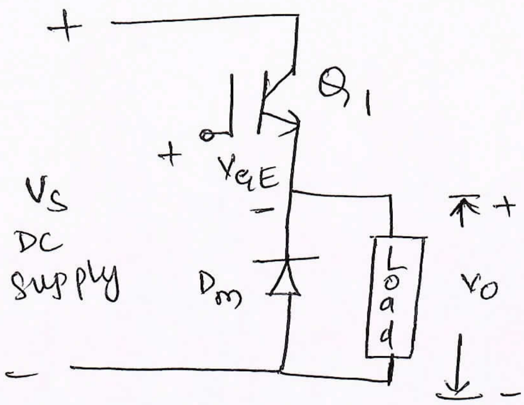
a. Phase controlled Rectifiers

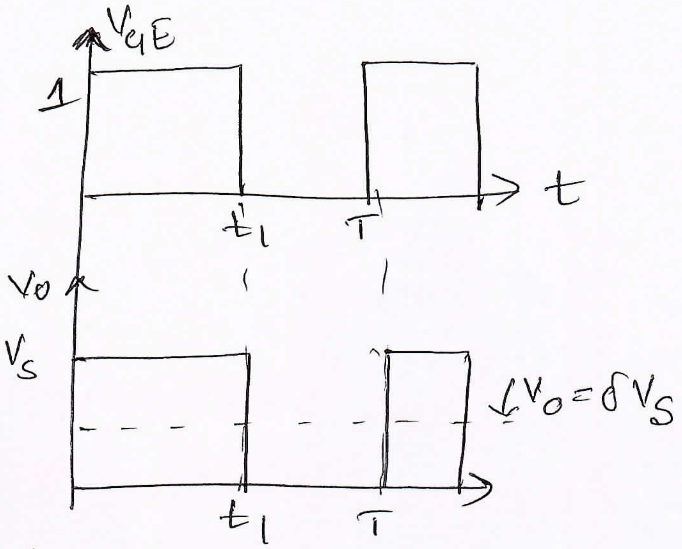


These controllers convert fixed Ac voltage to a variable Dc o/p voltage. These converters takes power from one or more ac voltage/current sources of single or multiple phases and delivers to a load.

Applications :- HVDC transmission systems, DC motor drives, Regulated DC power supplies, static VAR compensator.

2) choppers :-

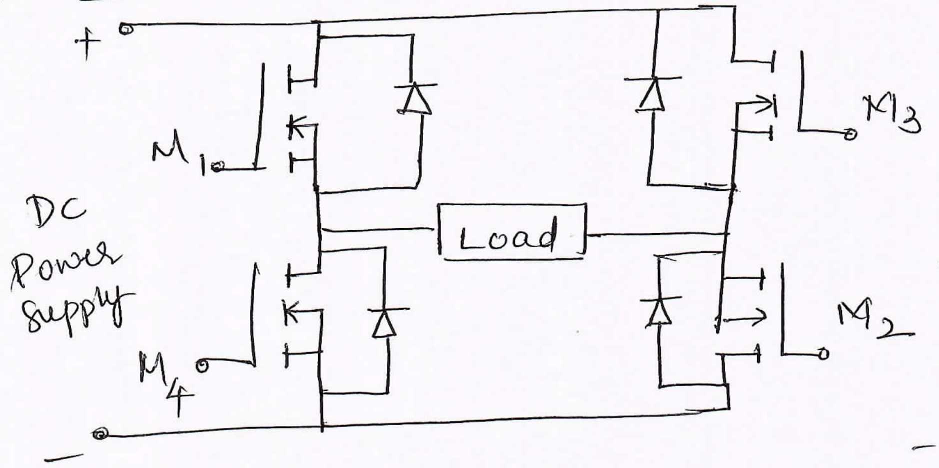


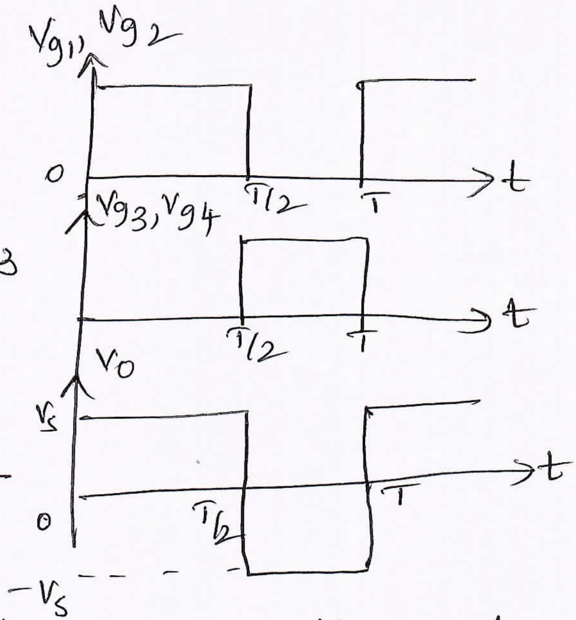


A chopper converts fixed DC input voltage to a Variable DC output Voltage. The DC o/p voltage may be different in amplitude than the input source voltage.

Applications :- DC drives, Subway cars, Battery driven vehicles, Electric traction, SMPS.

3) Inverters -





An inverter converts a fixed dc voltage to an AC voltage of variable frequency and of fixed or variable magnitude. Inverters are designed using semiconductor devices such as power transistors, MOSFETs, IGBTs, GTOs and thyristors.

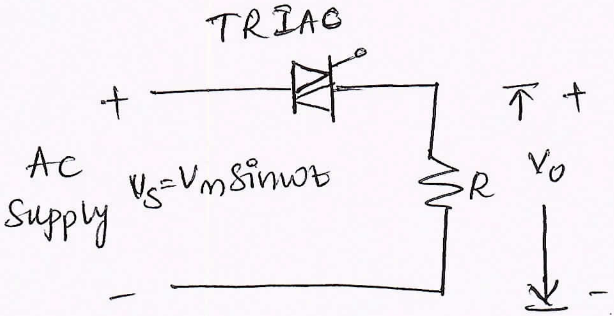
Applications :- UPS, Aircraft and Space power supplies, Induction and Synchronous motor drives, HVDC transmission s/m.

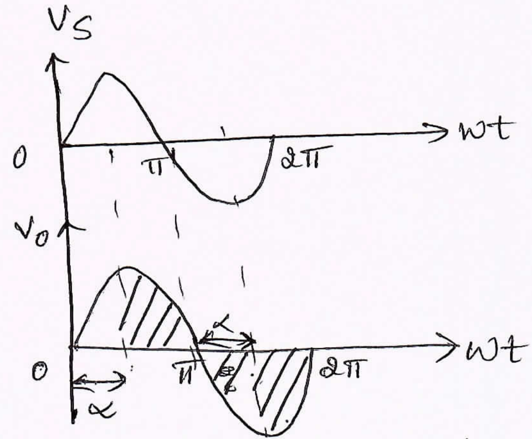
4) Cycloconverters :-

These circuit convert input power at one frequency to o/p power at a different frequency through one stage conversion. The o/p frequency is lower than the source frequency. o/p frequency in cycloconverter is a simple fraction such as 1/3, 1/5 and so on of the source frequency.

Applications: Ac drives like rotary kilns, multi-MW ac motor drives.

5) Ac voltage controllers



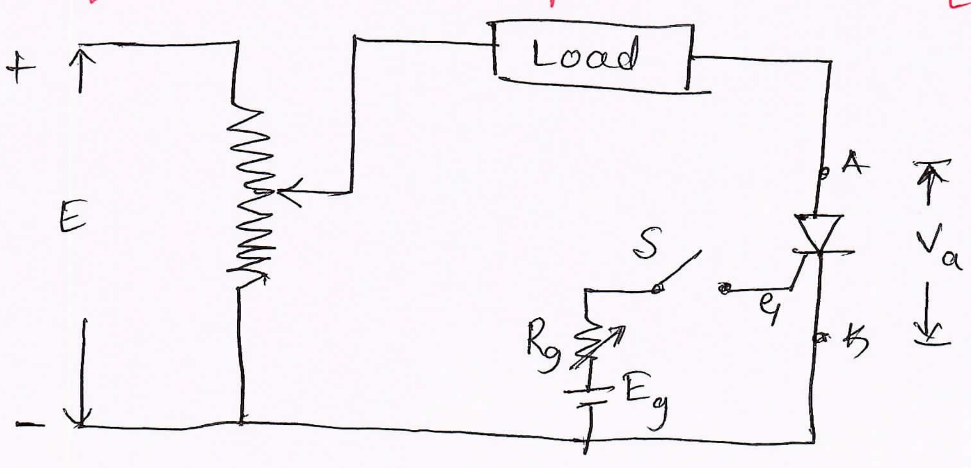


These converters convert fixed Ac voltage directly to a variable ac voltages at the same frequency using line commutation. These converters employs a thyristorised voltage controller.

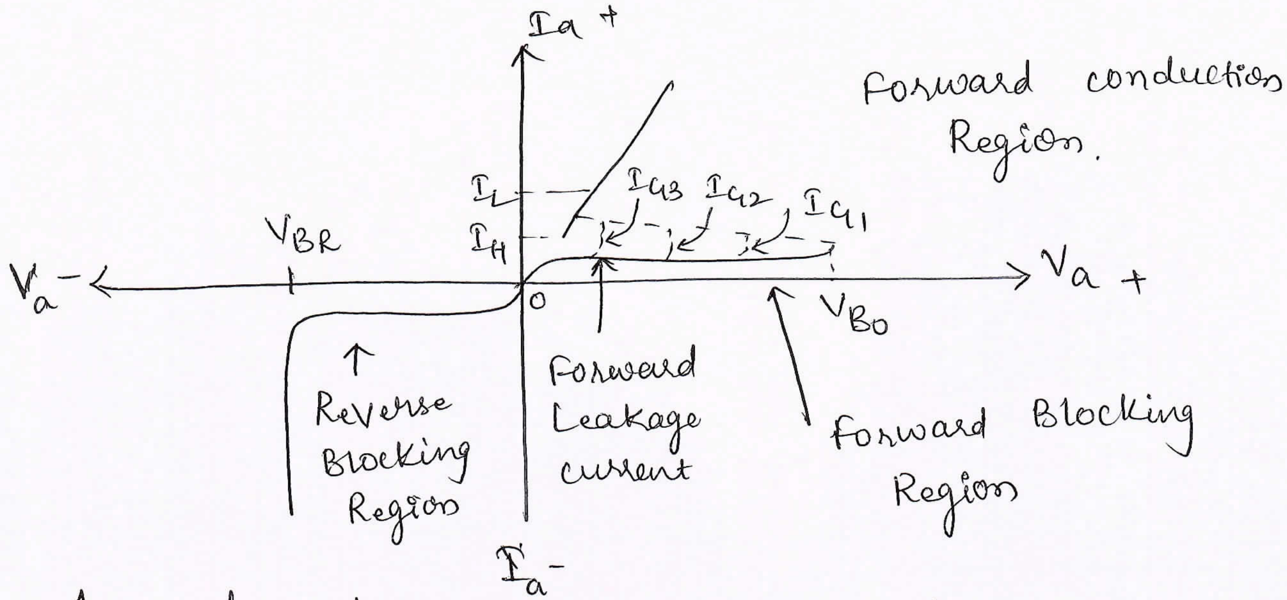
Applications: Lighting control, speed control of large fans, pumps, Electronic tap changers.

1.b) With necessary sketches, explain the static V-I characteristics of SCR and its operation. [08 Marks]

Ans:



Circuit - 2M
Characteristics - 4M
Explaination - 2M
Total 8M



An elementary circuit diagram for obtaining static V-I characteristics of a thyristor is shown in figure ~~below~~ above.. Here, the anode and cathode are connected to the main source through a load. The gate and cathode are fed from another source Eg.

The static V-I characteristics of an SCR is as shown in the figure above. The thyristor V-I characteristics is divided into three regions of operation. They are,

a) Reverse Blocking region
b) forward Blocking region
c) forward conduction region.

Reverse Blocking Region

When the cathode is made positive with respect to anode with the switch 'S' open as shown in fig. In the reverse biased condition, the outer junction J_1 and J_3 are reverse biased and the middle junction J_2 is forward biased. Therefore, only a small leakage current flows.

Dolly

Forward Blocking Region

In this region, the anode is made positive with respect to the cathode and therefore, junction J_1 and J_3 are forward biased while the junction J_2 remains reverse biased. Hence the anode current is a small forward leakage current.

Forward Conduction Region

When the cathode and anode forward voltage is increased with the gate circuit kept open, avalanche breakdown occurs at the junction J_2 at a critical forward break over voltage (V_{BO}), and the SCR switches into a low impedance condition.

→ In the VI characteristics shows that, for gate current $I_g = 0$, the forward breakover voltage is V_{BO}. For I_{g1}, the forward breakover voltage is less than V_{BO} and for $I_{g2} > I_{g1}$, it is still further reduced. The two currents, I_H and I_L are Holding current, Latching current. $I_L > I_H$.

1.c) List different turn-on Methods, explain all in brief. [05 Marks]

Ans: A thyristor can be switched from a non-conducting state to a conducting state in several ways describes follows:

List - 1M
Explaination of ~~each~~ 4 Methods - 4M
Total 5M

a) Forward Voltage triggering →

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

2) Thermal triggering –

Like any other semiconductor, the width of the depletion layer of a thyristor decreases on increasing the junction temperatu[re]. Thus in a thyristor, when the voltage appl[ied] between the anode and cathode is very nea[r] to its breakdown voltage, the device can be triggered by increasing its junction tempera-ture.

3) Radiation triggering →

If light is allowed to strike the junction of a thyristor, the electron-hole pai[rs] increase and the thyristor may be turned ON. The light activated SCRs are turned on by allo-wing light to strike the silicon wafers.

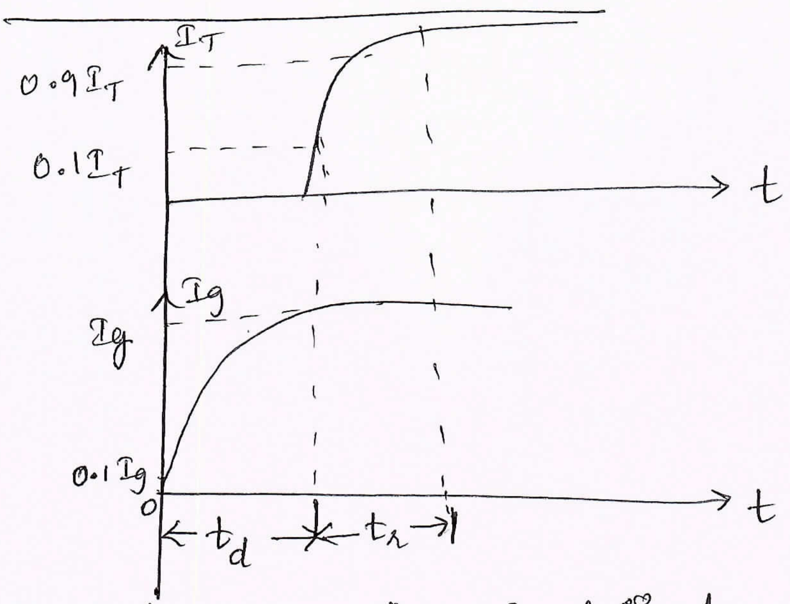
4) Gate current

If a thyristor is forward biased, the injection of gate current by applying positive gate voltage between the gate and cathode terminals turns ON the thyristor.

2)a) Explain turn-ON / turn-OFF dynamic characteristics of SCR with neat diagrams. [07 Marks]

Turn ON chs – 4M
Turn off chs – 3M
Total 7M

Ans: Turn-ON characteristics



The turn on time is defined as,

$$T_{on} = t_d + t_r$$

T_{on} is defined as the time interval between 10% of steady state gate current ($0.1 I_g$) and 90% of the steady state thyristor on state current ($0.9 I_T$).

→ Delay time, is defined as the time interval between 10% of gate current ~~cur~~ ($0.1 I_g$) and 10% of thyristor on-state current ($0.1 I_T$).

→ Rise time, is the time required for the anode current to rise from 10% of the on-state current ($0.1 I_T$) to 90% of on-state current ($0.9 I_T$).

Turn-OFF characteristics –

The turn-off time of the thyristor is defined as the minimum time interval between the instant at which the anode current becomes zero and the instant at which the device is capable of blocking the forward voltage.

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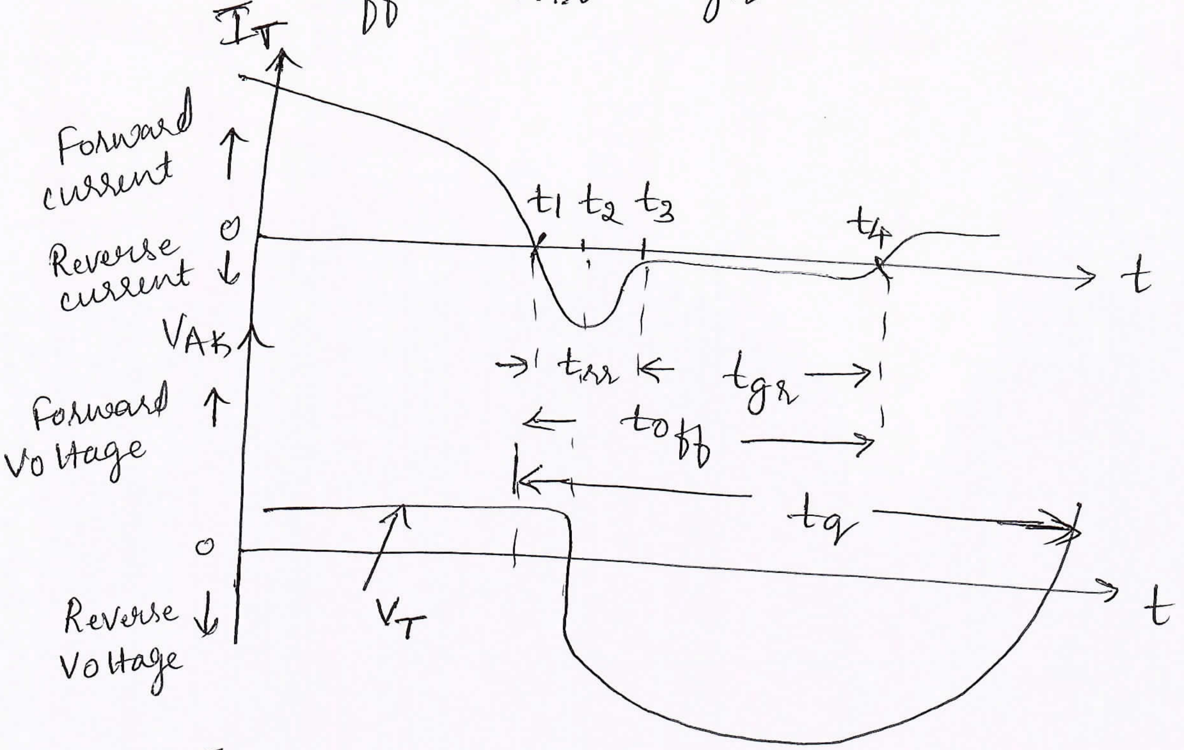
$T_{off} = t_{rr} + t_{gr}$

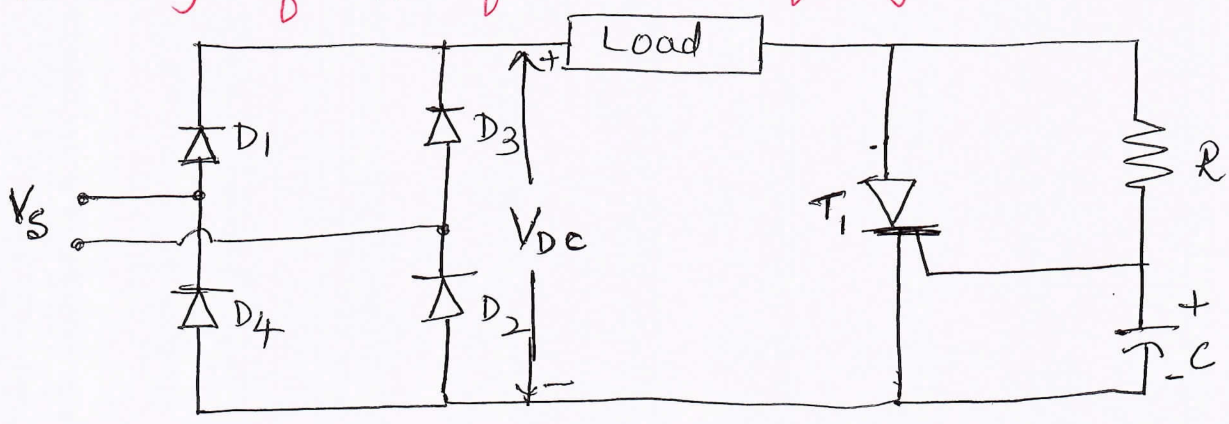


The total turn-off time t_{off} is divided into two time intervals the reverse recovery time, t_{rr} and the gate recovery time t_{gr}.

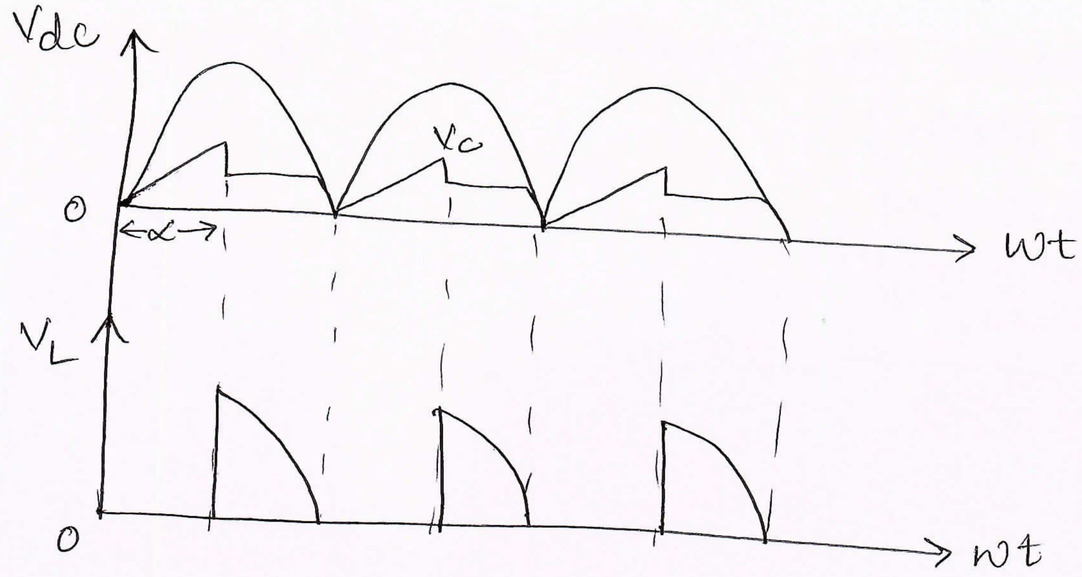
→ The total turn-off time (t_q) required for the device is the sum of the duration for which the reverse recovery current flows after the application of reverse voltage and the time required for the recombination of all excess carriers in the inner two layers of the device.

2) b) With suitable diagram and waveform, explain the working of RC full wave firing circuit. [5 Marks]

Ans:



Circuit- 2M
waveform-2M
Expleination- 1M



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 +ve voltage by the clamping action of SCR gate.

→ When the capacitor charges to a voltage equal to V_{gt}, SCR triggers and rectified voltage V_{dc} appears across the load as V_L.

→ The value of $R_v C$ is obtained from the following relation.

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

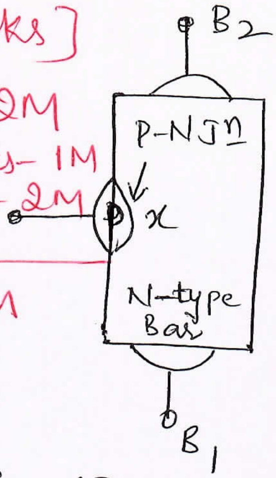
$$R_v \leq \frac{e_s - V_{gt}}{I_{g(min)}}$$

Q-C) Describe the operation of UJT with neat sketches.

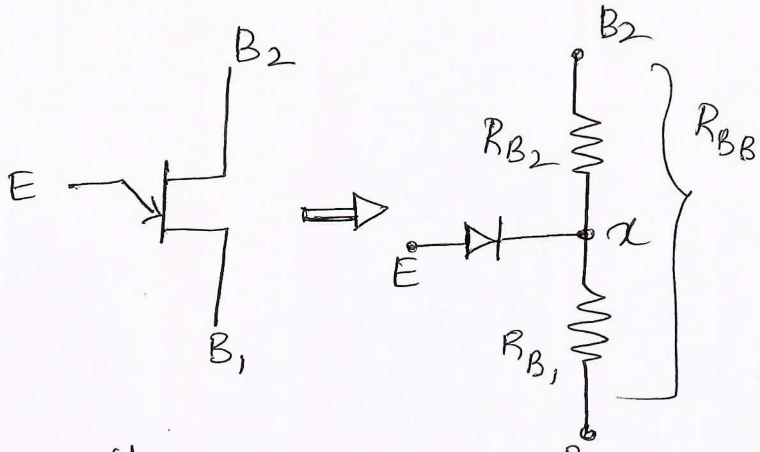
Ans: [05 Marks]

Circuit – 2M
Characteristics – 1M
Explaination – 2M

Total – 5M



(a) Basic UJT structure



(b) UJT symbol & equivalent ckt

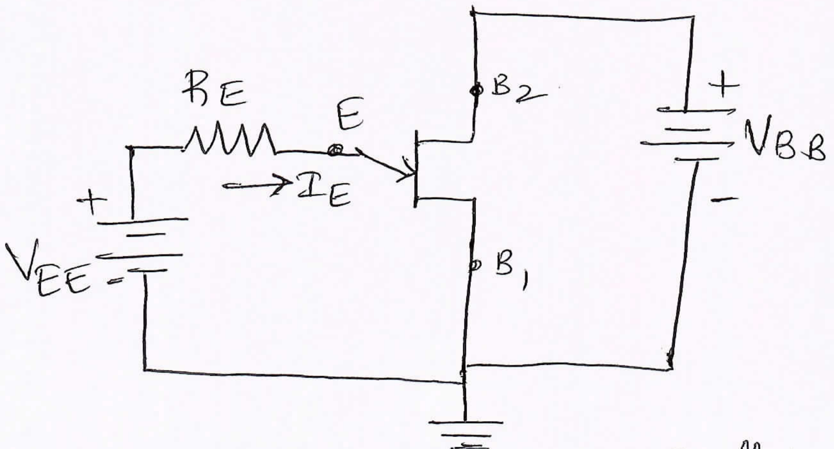
Unijunction transistor consists of a lightly doped, N-type silicon bar provided with ohmic contacts at each end. There are two bases, Base-1, B_1 and Base-2, B_2.

→ The interbase resistance R_{BB} is divided R_{B_1} & R_{B_2}.

→ When the emitter diode is Reverse biased, only a very small emitter current flows under this condition on R_{B_1} is at its normal high value ($4K\Omega$).

This is UJT's off state.

→ When the emitter diode becomes Forward biased, R_{B_1} drops to a very low value, so that the total resistance between E and B_1 becomes very low, allowing emitter current to flow rapidly. This is the 'ON' State.



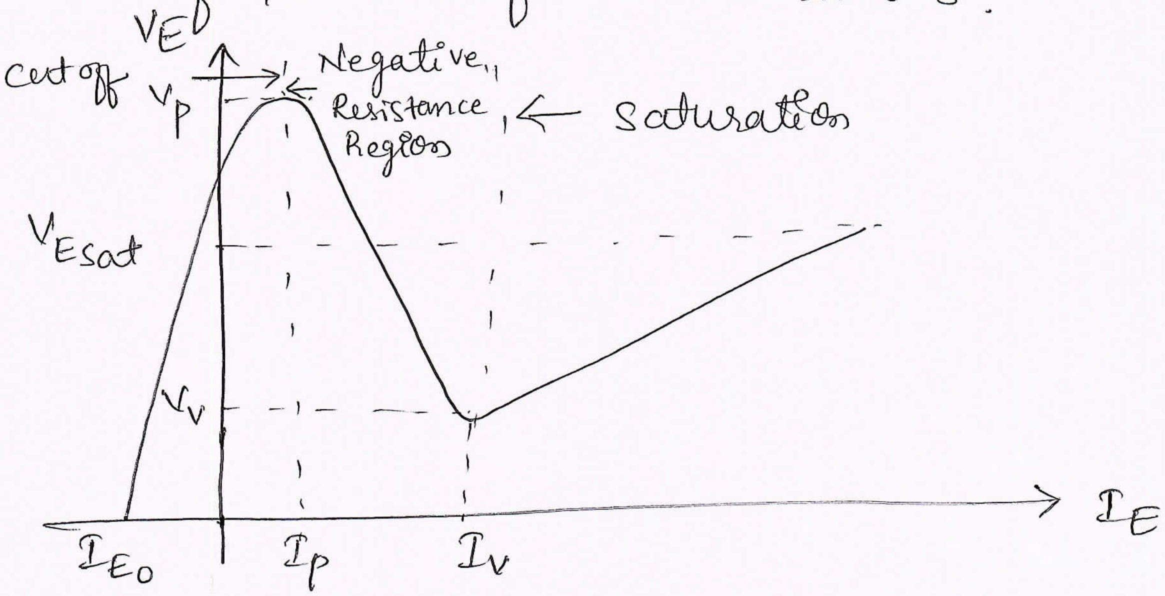
$$V_x = \frac{R_{B1}}{R_{B1} + R_{B2}} \times V_{BB}$$

$$V_x = \frac{R_{B1}}{R_{BB}} \times V_{BB}$$

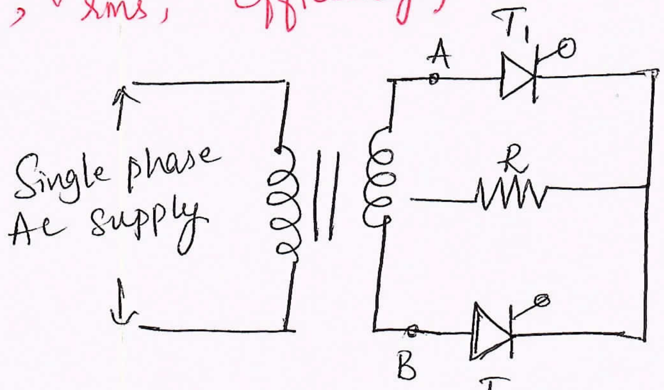
$$V_x = \eta V_{BB}$$

where η = Intrinsic Stand off Ratio.

Value of η varies from 0.5 to 0.8.



3) a) Explain the working of 1ø full wave center tapped controlled rectifier for resistive load with necessary sketches and also develop mathematical model to evaluate performance parameter of the same. (Vdc, Vrms, Efficiency) [10 Marks]



Circuit - 2
waveform - 3
Derivation - 3
Explaination - 2 M

Total 10

This type of full wave rectifier circuit uses two SCRs connected to the centre tapped secondary of a transformer as shown in the figure.

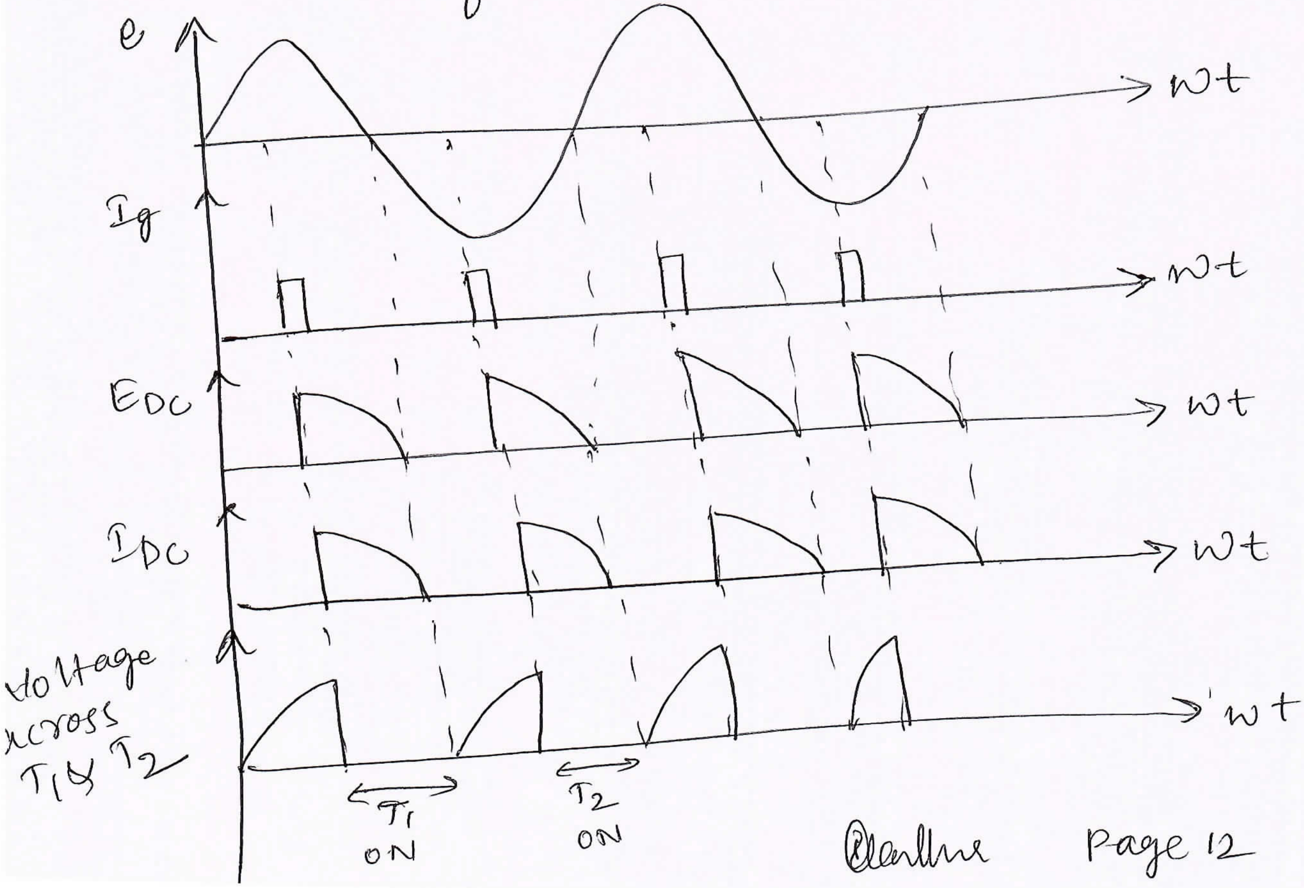
The i/p Signal is coupled through the transformer to the centre tapped Secondary.

→ During Positive half cycle, SCR T_1 is forward biased and T_2 is reverse biased. Since no triggering pulses are given to the gates of the SCRs, initially they are in off state.

→ when SCR T_1 is triggered at a firing angle α, current would flow from terminal A through SCR$_1$, the resistive load R and back to the Centre tap of the transformer.

→ During the negative half cycle of the ac supply, the terminal B of the transformer is positive w.r.t N. SCR_2 T_2, is forward biased.

→ when SCR_2 is triggered at an angle $(\pi+\alpha)$, current would flow from B through T_2, R and back to Centre tap of the transformer.



Average Dc O/p voltage

$$E_{dc} = \frac{1}{\pi}\int_{\alpha}^{\pi} E_m \sin\omega t \, d(\omega t)$$

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

$$E_{dc} = \frac{E_m}{\pi}(1+\cos\alpha)$$

RMS Load voltage

$$V_{RMS} = \left[\frac{1}{\pi}\int_{\alpha}^{\pi} E_m^2 \sin^2\omega t \, d\omega t\right]^{1/2}$$

$$= E_m\left(\frac{1}{\pi}\int_{\alpha}^{\pi}\sin^2\omega t \, d\omega t\right)^{1/2}$$

$$\sin^2\omega t = \frac{1-\cos 2\omega t}{2}$$

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

$$= E_m\left[\frac{1}{2\pi}\left(\pi-\alpha - \frac{\sin 2\pi + \sin 2\alpha}{2}\right)\right]^{1/2}$$

$$V_{RMS} = E_m\left[\frac{\pi-\alpha}{2\pi} + \frac{\sin 2\alpha}{4\pi}\right]^{1/2}$$

3)b) Evaluate performance parameter of 1Ø half controlled rectifier with resistive load has a transformer secondary voltage of 230V, 50Hz with R = 10Ω and firing angle α = 60°. Determine i) Average voltage and current ii) RMS value of voltage and current iii) Efficiency iv) Ripple factor v) Form factor

[10 Marks]
2M for each calculation

Soln: $V_s = 230V$, $f = 50Hz$, $R = 10\Omega$, $\alpha = 60°$

i) Average voltage, $E_{dc} = \frac{E_m}{2\pi}[1+\cos\alpha]$

$= \frac{230}{2\pi}[1+\cos 60°] = 54.90V$

i) current $= I_{dc} = \frac{E_{dc}}{R} = \frac{54.90}{10} = 5.490A$

ii) RMS value of voltage, $V_{RMS} = E_m\left[\frac{\pi-\alpha}{4\pi} + \frac{\sin 2\alpha}{8\pi}\right]^{1/2}$

$= 230\left[\frac{\pi-60}{4\pi} + \frac{\sin 2(60)}{8\pi}\right]^{1/2} = 230(0.166 + 6.0\times10^{-4})^{1/2}$

$= 93.87V$

$I_{RMS} = \frac{V_{RMS}}{R} = 9.387A$

iii) Efficiency, $\eta = \frac{P_{dc}}{P_{ac}}$, $P_{dc} = \frac{E_{dc}^2}{R} = 301.4W$

$P_{ac} = \frac{V_{RMS}^2}{R} = 881.1W$

$\eta = \frac{301.4W}{881.1W} = 0.342\times100$

$= 34.2\%$

iv) Ripple factor $= (FF^2-1)^{1/2} = (1.709^2-1)^{1/2} = 1.386$

$= 138.6\%$

v) Form factor $= \frac{E_{rms}}{E_{dc}} = 1.709 = 170.9\%$

4)a) Input to the step up chopper is 200V the o/p required is 600V, if the conduction time of thyristor is 200μsec. Compute:
i) chopping frequency ii) If the pulse width is halved for constant frequency operation, find the new output voltage.

[07 Marks]

Chopping freq = 4M
New o/p voltage = 3M
Total 7M

$$V_o = V_{in}\left(\frac{T}{T - T_{ON}}\right)$$

$$\frac{V_o}{V_{in}} = \frac{T}{T - 200\mu}$$

$$3 = \frac{T}{T - 200\mu}$$

$$3T - 600\mu = T$$

$$T = 300\mu s$$

→ If pulse width is half then, new value of pulse T_{ON}' width will be,

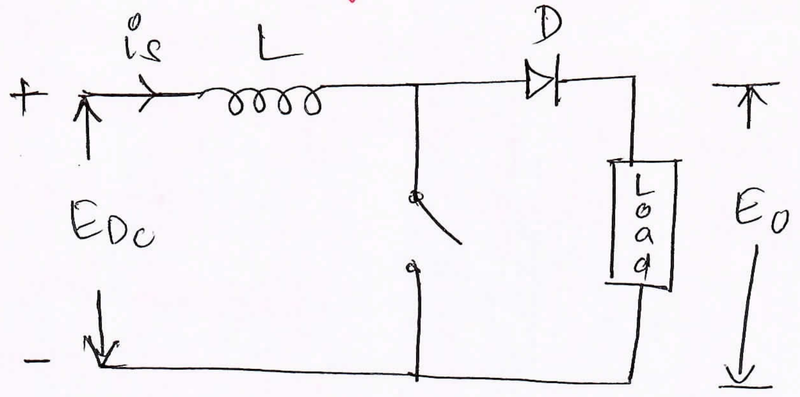
$$T_{ON}' = \frac{T_{ON}}{2} = \frac{200\mu}{2} = 100\mu$$

$$V_o' = V_{in}\left(\frac{T}{T - T_{ON}'}\right) = 200 \times \left(\frac{300}{300 - 100}\right)$$

$$V_o' = 300V$$

Chopping freq, $f = \frac{1}{T} = 3.3\ KHz$

4)b) Explain the operation of step up chopper with neat diagram and derive expression for output voltage. [08 Marks]



Circuit – 3
Explaination – 3
Output voltage = 2
Total 8M

The chopper can also be used to produce higher voltages at the load than the i/p voltage (i.e $E_0 \geq E_{dc}$). This is called as step-up chopper and as shown in the figure above.

→ when the chopper is ON, the inductor L is connected to the supply Edc and inductor stores energy during ON-period, Ton.

→ when the chopper is OFF, the inductor current is forced to flow through the diode and load for a period T_{off}.

As the current tends to decrease, polarity of the emf induced in inductor L is reversed to that of shown in figure above. and as a result voltage across the load E_0 becomes,

$$E_0 = E_{dc} + L\frac{di_s}{dt}.$$

During Ton, when chopper is ON, the energy i/p to the inductor from the source is given as

$$W_i = E_{dc} I_s T_{on}$$

During T_{off}, when chopper is OFF, energy released by the inductor to the load is given by,

$$W_0 = (E_0 - E_{dc}) I_s T_{off}$$

Assume that the system is loss less,

$$E_{dc} \cdot I_s T_{on} = (E_0 - E_{dc}) I_s \cdot T_{off}$$

$$E_{dc} I_s T_{on} = E_0 I_s T_{off} - E_{dc} I_s T_{off}$$

$$E_0 = \frac{E_{dc}(T_{on} + T_{off})}{T_{off}}$$

$$E_0 = E_{dc}\left(\frac{T}{T - T_{on}}\right)$$

$$E_0 = E_{dc}\left(\frac{T/T}{T/T - T_{ON}/T}\right)$$

$$E_0 = E_{dc}\left(\frac{1}{1-\alpha}\right)$$

For $\alpha = 0$, $E_0 = E_{dc}$

$\alpha = 1$, $E_0 = \infty$

4)c) Elaborate on the control techniques used in choppers and also give detailed classification of choppers. [05 Marks]

control techniques = 2M
classification = 3M
Total 5M

Ans: The control techniques used in choppers are

i) Time Ratio Control
ii) Current limit control

Time Ratio control

In the time ratio control, $\frac{T_{on}}{T}$ is varied. This is effected in two ways such as, variable frequency operation and constant frequency operation.

Current limit control

In this technique, the chopper is switched ON and OFF so that the current in the load is maintained between two limits when the current exceeds upper limit, the chopper is switched off. During off period, the load current free wheels and decreases exponential.

Chopper can be classified as:

a) According to i/p o/p voltage levels.

i) Step down chopper

ii) Step up chopper

b) According to directions of o/p voltage and current

i) class A chopper

ii) class B chopper

iii) class C chopper

iv) class D chopper

v) class E chopper

c) According to circuit operation

i) First quadrant chopper

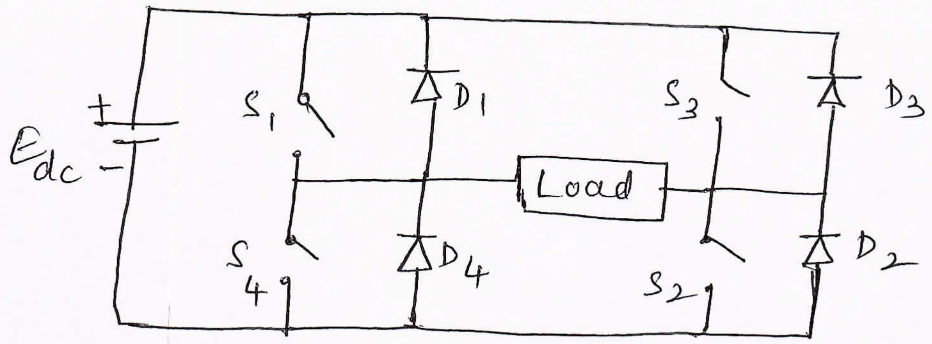
ii) Two quadrant chopper

iii) Four quadrant chopper

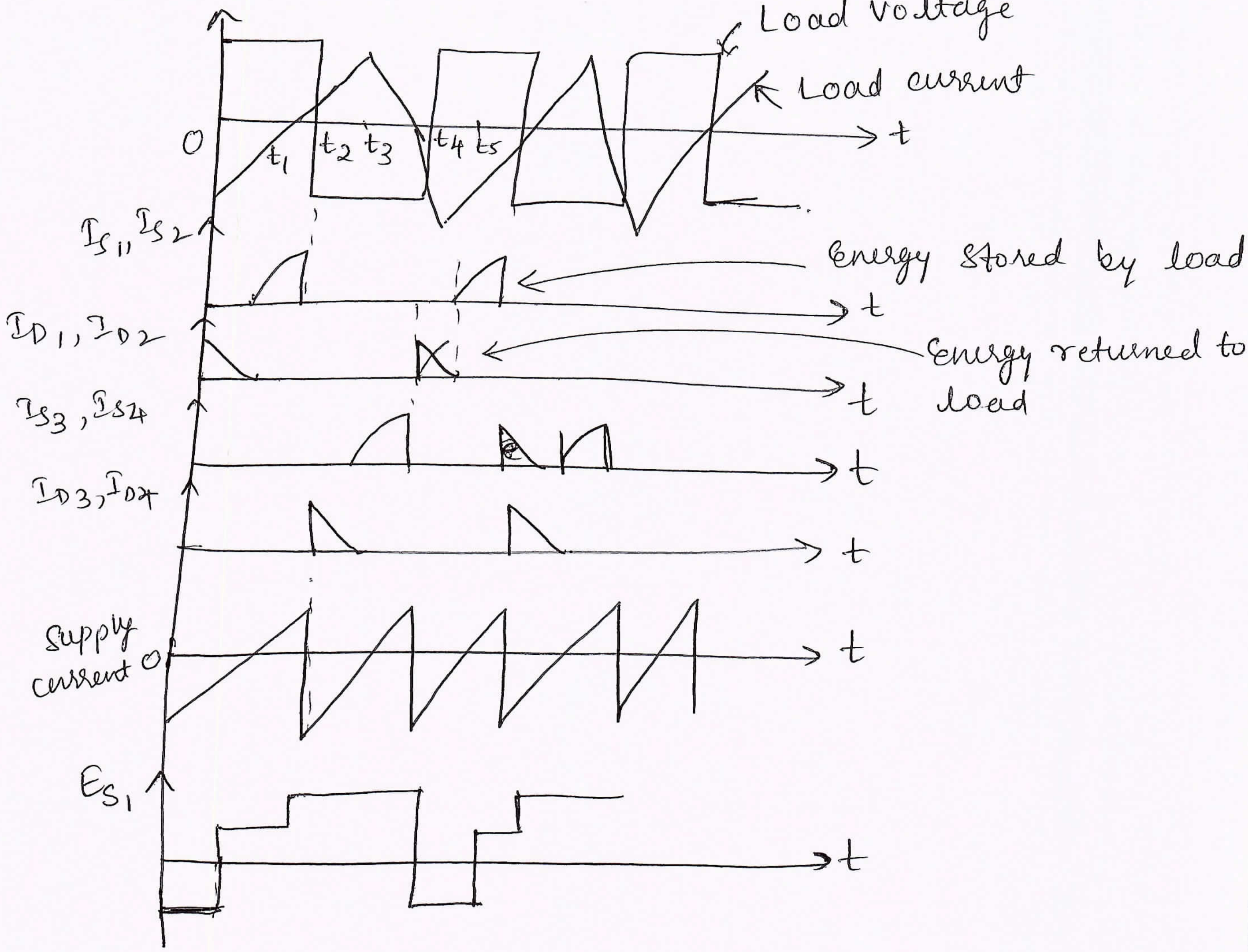
Module 3

5) a) With neat diagram and waveforms. Explain the operation of 1ø full bridge inverter for RL load. [07 Marks]

Circuit - 2
waveforms - 3
Explaination - 2
Total 7



The above circuit shows single phase full bridge inv-erter with RL load.



The Operation of the circuit can be explained in four modes.

i) <u>Mode I ($t_1 \le t \le t_2$)</u>

At instant t_1, the switch S_1 and S_2 are turned ON. Switches are assumed to be ideal switch-es. Point P gets connected to positive point of d.c source E_{dc} through S_1 and Point Q gets connected to negative point of input supply.

The output voltage, $e_0 = +E_{dc}$.

ii) <u>Mode II ($t_2 \le t \le t_3$)</u>

Both the switches S_1 and S_2 are turned off at instant t_2. Due to the inductive nature of the load, the load current does not reduce to zero instantaneously. There is a self-induced voltage across the load which maintains the flow of current in the same direction. The polari[ty] of this voltage is exactly opposite to that in mode. The o/p voltage becomes $-E_{dc}$.

iii) <u>Mode III ($t_3 \le t \le t_4$)</u>

Switch S_3 and S_4 are turned on simultaneous[ly] at instant t_3. Load voltage remains negative ($-E_{dc}$) but the direction of load current will reverse. The current increases exponentially in the other direction and load again stores the energy.

iv) <u>Mode IV ($t_4 \le t \le t_1$)</u>

Switches S_3 and S_4 are turned off at instant t_0. The load inductance tries to maintain the load current in the same direction by inducing the positive load voltage. This will forward bias the diodes D_1 and D_2. ~~This will forward bias the diodes D_1 and D~~. The load energy is returned back to the input DC supply. The load voltage becomes $e_0 = +E_{dc}$, but the load current remains negative and decreases exponentially towards 0.

5)b) Design a multi range ammeter with range 0–1 A, 0–5 A and 0–10 A employing individual shunt in each a D' Arsonval movement with an internal resistance of 500Ω and full scale deflection of 10mA is available. (08 Marks)

Soln: case 1: For the range 0–1 A, i.e 1000mA

$$R_{sh_1} = \frac{I_m \times R_m}{I - I_m} = \frac{10mA * 500}{1000mA - 10mA}$$

Formulas – 2M
Each case = 2M
8M

$$R_{sh_1} = \frac{5000}{990} = 5.05\Omega$$

case 2: For the range 0–5 A, i.e 5000mA

$$R_{sh_2} = \frac{I_m \times R_m}{I - I_m} = \frac{10mA \times 500}{5000mA - 10mA}$$

$$= \frac{5000}{4990} = 1.002\Omega$$

case 3: For the range 0–10 A i.e, 10000mA

$$R_{sh_3} = \frac{I_m \times R_m}{I - I_m} = \frac{10mA \times 500}{10000mA - 10mA}$$

$$= \frac{5000}{9990} = 0.050\Omega$$

Hence the values of shunt resistances are, 5.05Ω, 1.002Ω and 0.050Ω

5)c) What are the errors encountered in measurement process? Explain all with suitable ~~process~~ Example. [05 Marks]

Ans: Measurement is the process by comparing an unknown quantity with an accepted standard quantity. Absolute error may be defined as the difference between the expected value of the variable and the measured value of the variable, or

Type of errors - 5M

$$e = Y_n - X_n$$

$$\% \text{ Error} = \frac{\text{Absolute value}}{\text{Expected value}} \times 100 = \frac{e}{Y_n} \times 100$$

Types of Static Errors →

Static errors are categorised as gross errors or human errors, systematic errors and random errors.

Gross Errors →

These errors are mainly due to human mistake in reading or in using instruments or errors in recording observations.

Systematic Errors →

These errors occur due to shortcomings of the instrument, such as defective or worn parts, or ageing or effects of the environment on the instrument.

i) Instrumental Errors

Instrumental errors are inherent in measuring instruments, because of their mechanical structure.

ii) Environmental Errors

Envirommental errors are due to conditions external to the measuring device, including conditions in the area surrounding the instrument, such as the effects of change in temperature, humidity, barometric pressure or of magnetic or electrostatic fields.

iii) **Observational Errors →**

Observational errors are errors introduced by the observer.

iv) **Random errors**

These are errors that remain after gross and systematic errors have been substantially reduced or atleast accounted for.

6) a) Design modified multirange voltmeter with basic D'Arsonval movement with an internal resistance of 50Ω and full scale deflection of 2mA, with voltage ranges of 0-10V, 0-50V, 0-100V and 0-250V. Draw the schematic diagram and show all values after design. [07 Marks]

Soln:- For a 10V range, the total circuit resistance is,

Formulas - 1
Each case - 2M
Total - 7M

$$R_t = \frac{V}{I_{fsd}} = \frac{10}{2mA} = 5K\Omega$$

$$\therefore R_4 = R_t - R_m = 5K - 50 = 4950\Omega$$

For 50V Range, the total circuit resistance is,

$$R_t = \frac{V}{I_{fsd}} = \frac{50}{2mA} = 25K\Omega$$

$$\therefore R_3 = R_t - (R_4 + R_m) = 25K - (4950 + 50)$$
$$= 25K - 5K$$
$$R_3 = 20K\Omega$$

For 100V range, the total circuit resistance is,

$$R_t = \frac{V}{I_{fsd}} = \frac{100}{2mA} = 50K\Omega$$

$$\therefore R_2 = R_t - (R_3 + R_4 + R_m)$$

$$= 50K - (20K + 4950 + 50)$$

$$R_2 = 50K - 25K = 25K\Omega$$

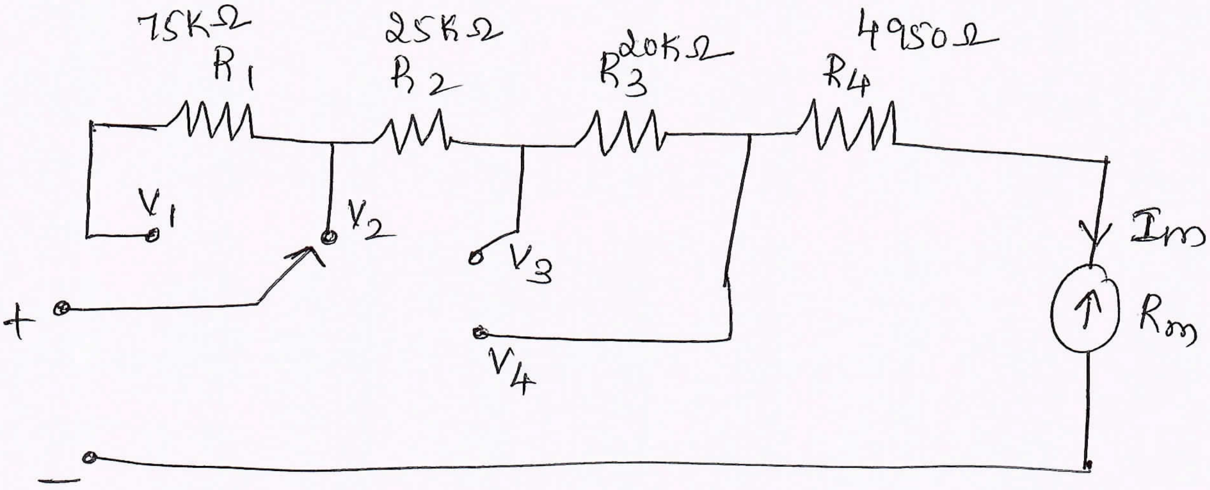
For 250V range, the total resistance is,

$$R_t = \frac{V}{I_{fsd}} = \frac{250}{2mA} = 125K\Omega$$

$$\therefore R_1 = R_t - (R_2 + R_3 + R_4 + R_m)$$

$$= 125K - (25K + 20K + 4950 + 50)$$

$$= 125K - 50K = 75K\Omega$$



6.b.) Explain the various static characteristics of measuring instruments. [08 Marks]

Soln: The static error of a measuring instrument is the numerical difference between the true value of a quantity and its value as obtained by measurement i.e repeated measurement of the same quantity gives different indications. Types of errors - 8M

Static errors are categorised as gross errors, human errors, systematic errors and random errors.

Gross Errors

These errors are mainly due to human mistakes in reading or in using instruments or errors in recording observations.

Systematic Errors

These errors occur due to shortcomings of the instrument, such as defective or worn parts, or ageing or effects of the environment on the instrument.

There are three types of systematic errors.

i) Instrumental ii) Environmental iii) Observational

Instrumental errors

These are inherent in measuring instruments, because of their mechanical structure.

Environmental errors

These are due to conditions external to the measuring device, including conditions in the area surrounding the instrument, such as the effects of change in temperature, humidity, barometric pressure or of magnetic or electrostatic fields.

Observational errors

These are errors introduced by the observer. The most common error is the parallax error introduced in reading a meter scale, and the error of estimation when obtaining a reading from a meter scale.

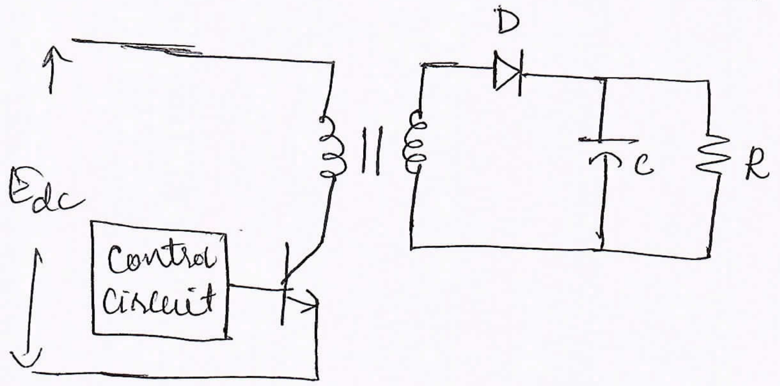
Random Errors

These are errors that after gross and Systematic errors have been substantially reduced or at least accounted for.

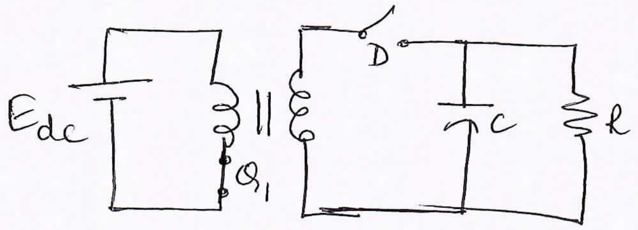
6)c) With neat diagram, Explain the operation of isolated flyback converter. [05 Marks]

Ans: In isolated converters, the ferrite core high-freq transformer is used for electrical isolation between the load and the source. Another advantage of using transformer is the possibility to get multiple o/ps.

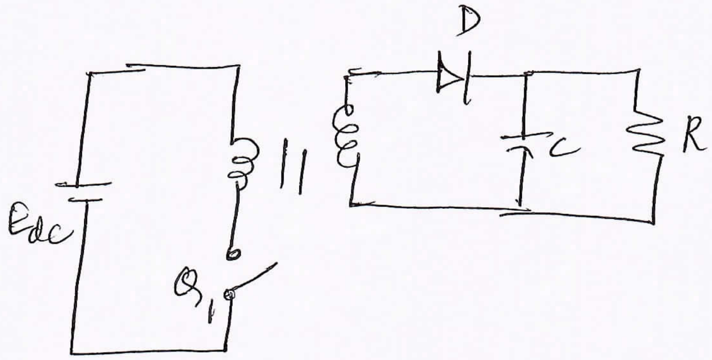
Circuit – 2
waveform – 2
Explaination – 1M
Total – 5M



(a)



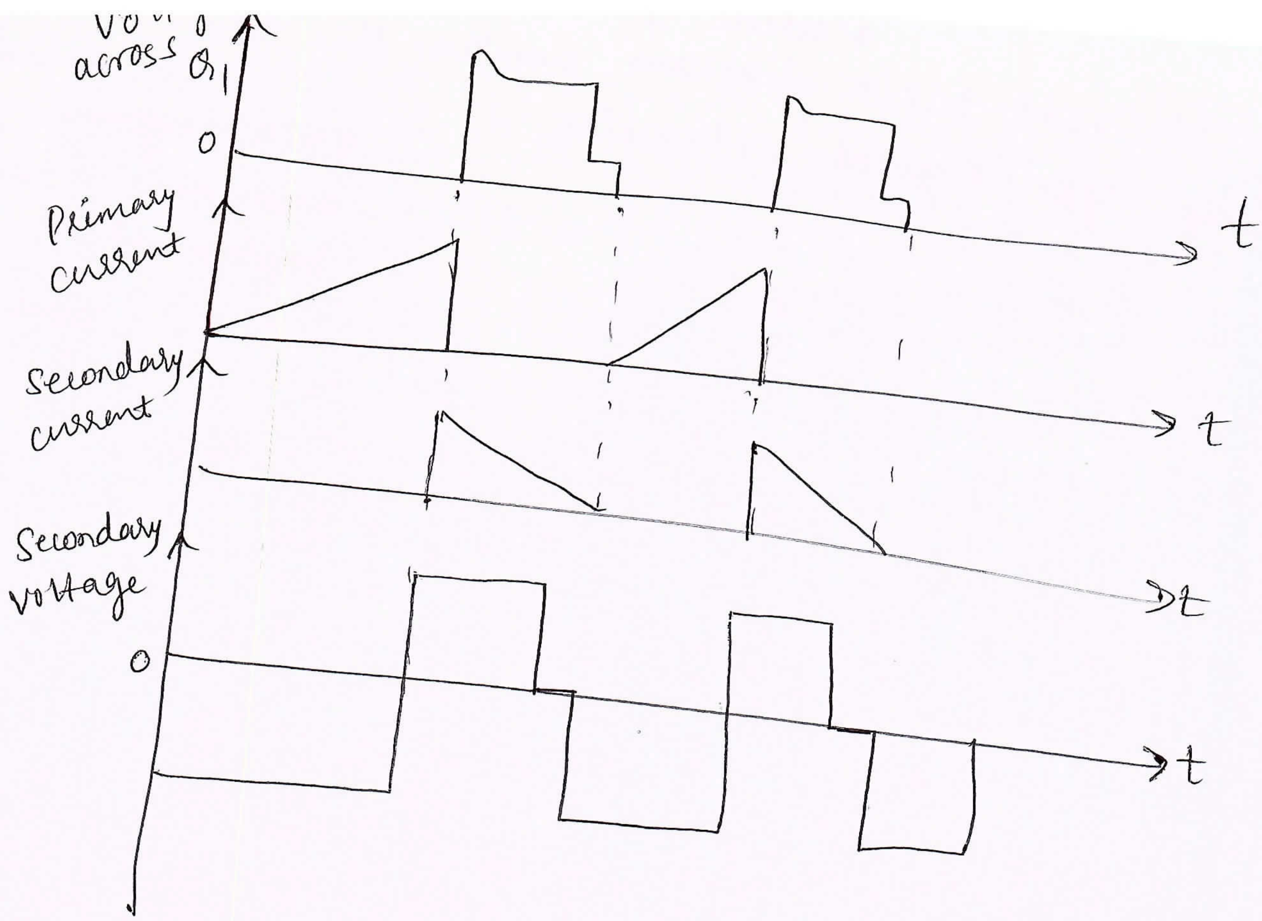
(b) Mode 1



(c) Mode 2.

Mode I ($t_0 - t_1$)

When transistor Q_1 is ON at $t=0$, primary current starts to build up in the primary winding storing energy. Due to the opposite primary arrangement between the i/p and o/p windings of the transformer choke, there is no energy transf-erred to the load, since diode D is reverse



Reverse biased.

Mode II

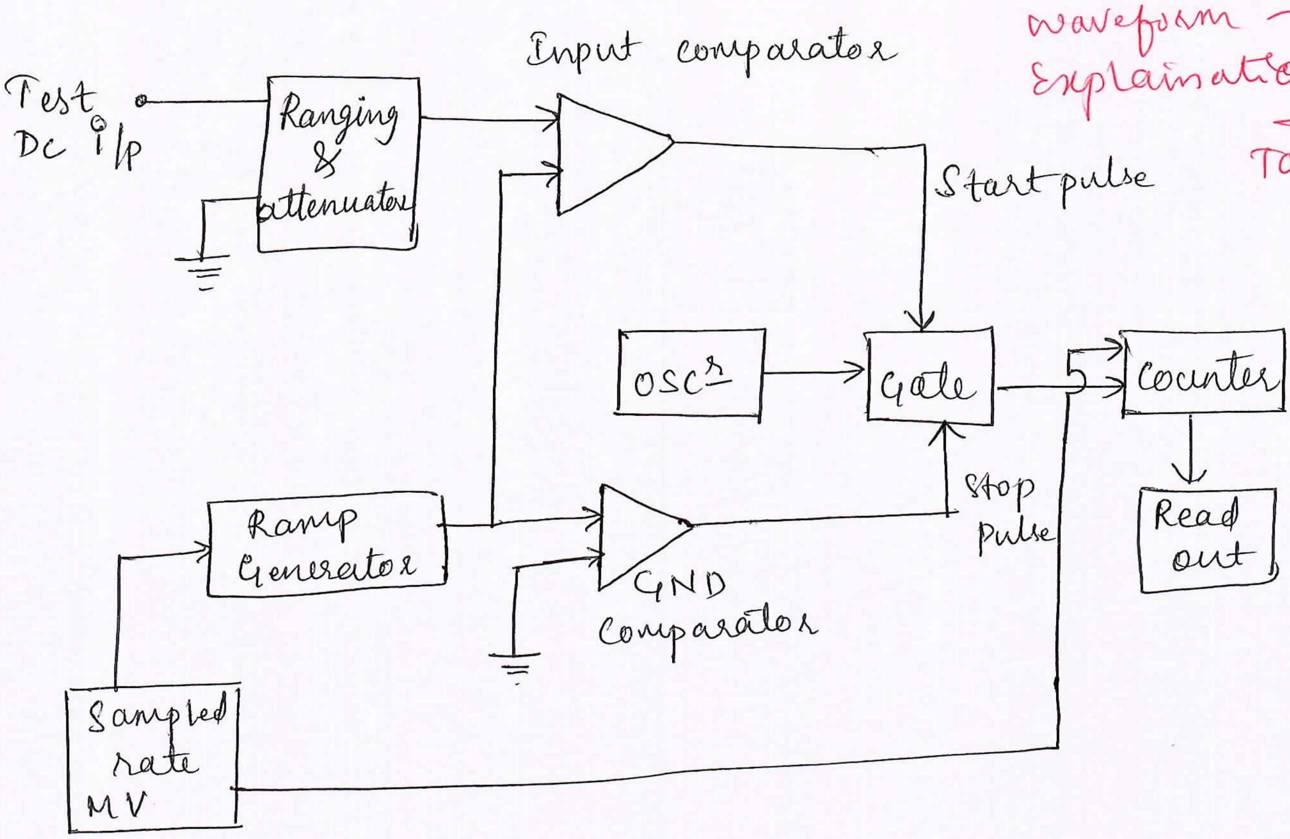
When the transistor is turned off at $t = t_1$, the polarity of the windings reverses due to the collapsing magnetic field. Now diode D is conducting, charging the o/p capacitor C and delivering current I_C to load.

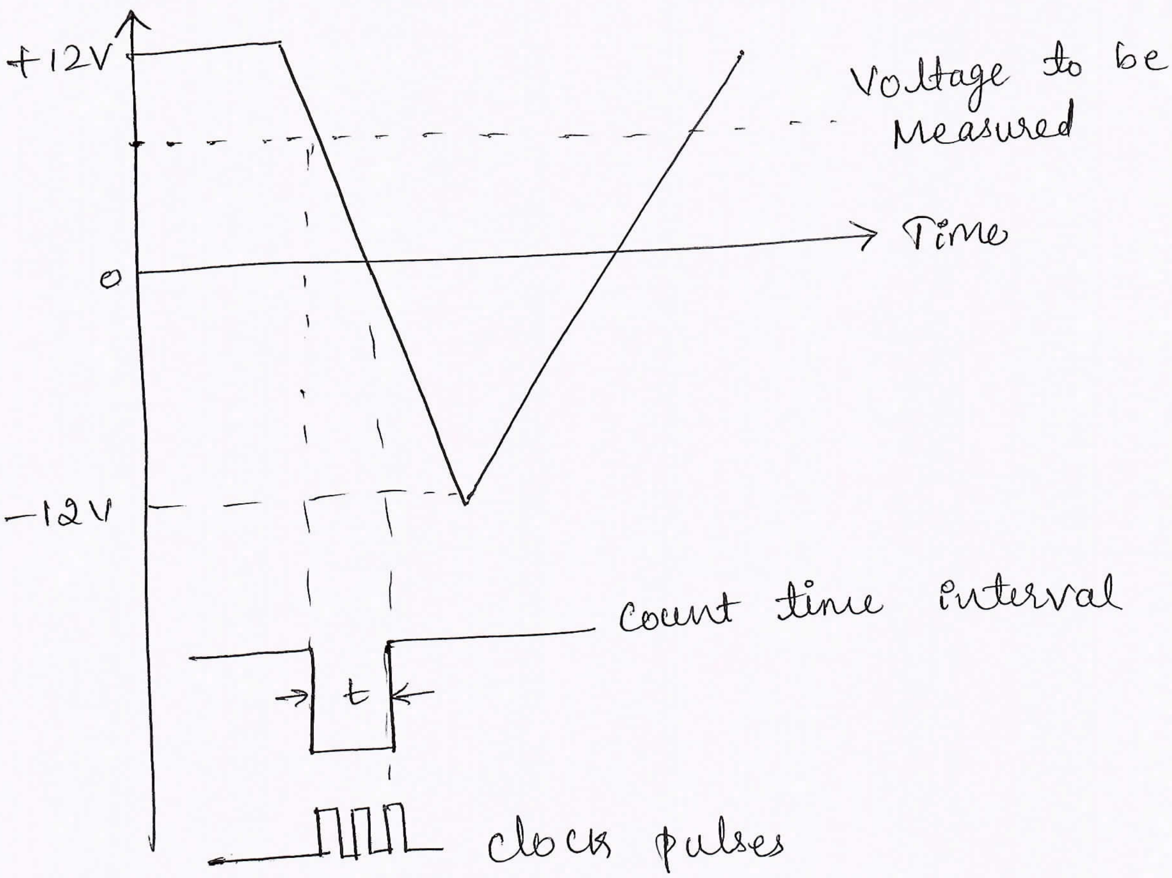
Mode III

In this mode, transistor and diode both are in the off state. Therefore primary and secondary currents are zero. As there is no voltage drop across the primary winding of the transformer, the voltage across the transistor Q_1 is equal to the dc supply voltage (E_{DC}).

7)a) With neat block diagram, explain the operation of Ramp type Digital voltmeter. (07 Marks)

Block diagram - 3 M
waveform - 2 M
Explaination - 2 M
Total 7M





The operating principle is to measure the time that a linear ramp takes to change the i/p level to the ground level or vice versa. This time period is measured with an electronic time interval counter and the count is displayed as a number of digits on an indicating tube or display.

At the start of the measurement a ramp voltage is initiated. The ramp voltage is continuously compared with the voltage that is being measured.

→ At the instant these two voltages become equal, a coincidence circuit generates a pulse which open a gate i-e the o/p comparator generates a start pulse.

→ The ramp continues until the second comparator circuit senses that the ramp has reached zero value. The ground comparator compares the ramp with ground.

→ When the ramp voltage equals zero or reaches ground potential, the ground comparator generates a stop pulse. The o/p pulse from this comparator closes the gate. The time duration of the gate opening is proportional to the input voltage value.

7)b) Explain the operation of Time measurement with neat block diagram. (08 Marks)

To obtain good accuracy at low freq, we should take measurements of the period, rather than make direct freq measurements.

The figure below shows the circuit for measurement of time period. The gating signal is derived from the unknown i/p signal, which now controls the enabling and disabling of the main gate.

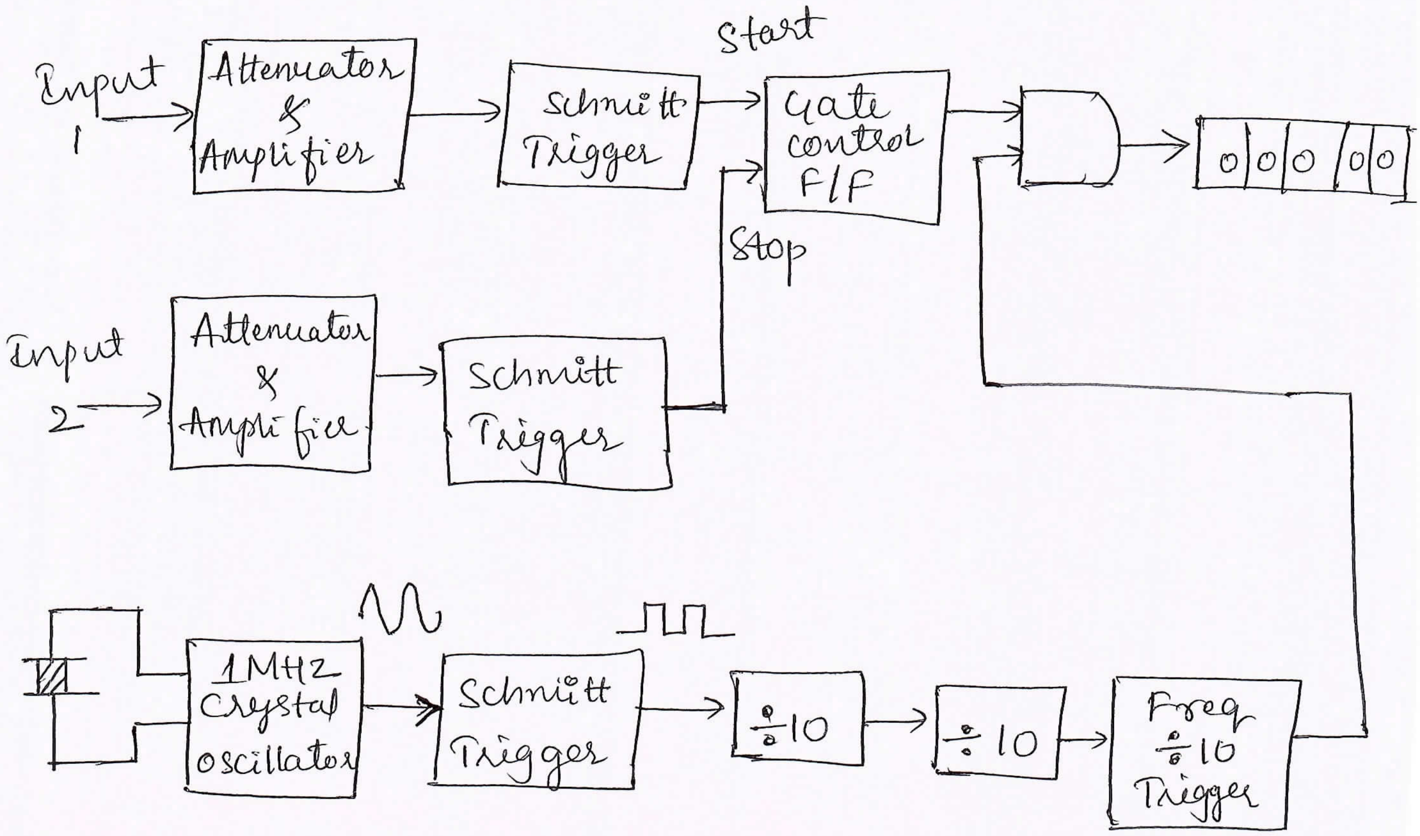
The number of pulses which occur during One Period of the unknown signal are counted & displayed by the decade counting assemblies

The Only disadvantage is that for measuring the frequency in the low frequency range, the operator has to calculate the frequency from the time by using the equation,

$$f = \frac{1}{T}$$

Block diagram - 4
Explaination - 4

Total 8M



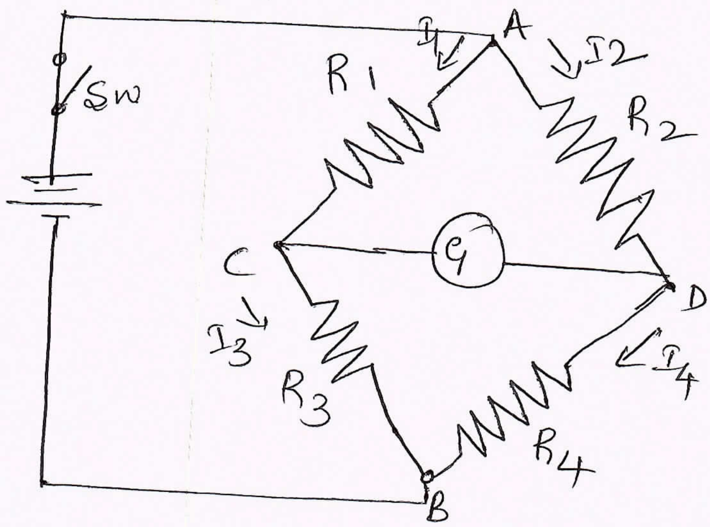
For example, when measuring the period of a 60Hz frequency, the electronic counter might display 16.6673 ms. Hence the frequency is,

$$f = \frac{1}{T} = \frac{1}{16.6673 \times 10^{-3}} = 59.9977\ Hz.$$

The accuracy of the period measurement and hence of frequency can be greatly increased by using the multiple period average mode of operation.

7c.) Draw the schematic diagrams of Wheatstone's bridge and derive an expression for calculating unknown resistance and explain. [05 Marks]

Ans: Wheatstone's bridge is the most accurate method for measuring resistances and is popular for laboratory use. The circuit diagram of a typical wheatstone's bridge is given below.



Circuit - 1
derivation - 2
explaination - 2
Total 5M

The Source of Emf and switch is connected to points and while a sensitive current indicating meter, the galvanometer is connected to points C & D. The galvanometer is a sensitive micro ammeter with a zero center scale.

When there is no current through the meter, the galvanometer pointer rests at 0 i.e mid scale. Current in one direction causes the pointer to deflect on one side and current in the opposite direction to the other side.

When switch SW_1 is closed, current flows and divides into the two arms at point A i.e I_1 & I_2.
To obtain bridge balance equation,

$$I_1 R_1 = I_2 R_2 \quad — (1)$$

$$I_1 = I_3 = \frac{E}{R_1 + R_3} \quad — (2)$$

$$I_2 = I_4 = \frac{E}{R_2 + R_4} \quad — (3)$$

Substituting I_1 & I_2 in eqn (1) we get

$$\frac{ER_1}{R_1 + R_3} = \frac{ER_2}{R_2 + R_4}$$

$$R_1 (R_2 + R_4) = R_2 (R_1 + R_3)$$

$$R_1 R_2 + R_1 R_4 = R_1 R_2 + R_2 R_3$$

$$\boxed{R_4 = \frac{R_2 R_3}{R_1}}$$

$$\therefore \boxed{R_x = \frac{R_2 R_3}{R_1}}$$ is the equation to calculate unknown resistance.

8)a) Explain the operation of Inductance comparison bridge with necessary equations. [07 Marks]

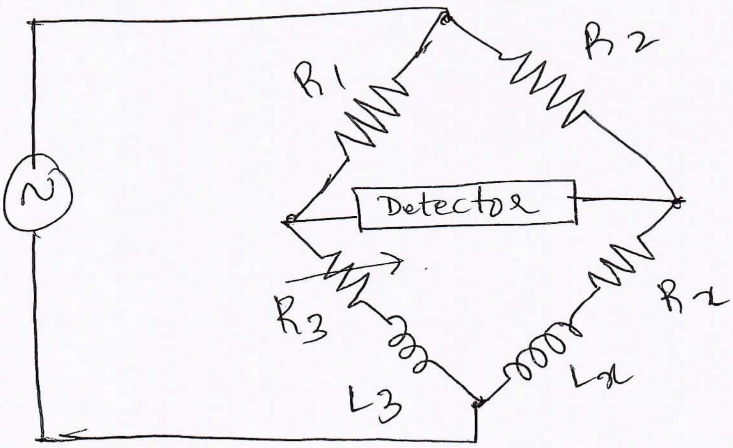


Figure – 4 M
Explaination – 3M
Total (7M)

Figure above gives a schematic diagram of an inductance comparison bridge. In this, Values of the unknown inductance L_x and its internal resistance R_x are obtained by comparison with the standard inductor and resistance i.e L_3 and R_3.

The equation for balance condition is

$$Z_1 Z_x = Z_2 Z_3$$

The Inductive balance equation yields

$$L_x = \frac{L_3 R_2}{R_1} \quad — (1)$$

and Resistive balance equation yields

$$R_x = \frac{R_2 R_3}{R_1} \quad — (2)$$

In this bridge R_2 is chosen as the inductive balance control and R_3 as the resistance balance control. Balance is obtained by alternatively varying L_3 or R_3.

8.6. Discuss the operation of successive approximation type DVM with necessary diagram. [08 Marks]

Block diagram – 3 M

Example Problem – 3 M

Explaination – 2 M

Total 08 M

Ans: The successive approximations DVM block diagram is as shown below.

→ When the start pulse signal activates the control circuit, the successive approximation Register is cleared. The o/p of the SAR is 00000000.

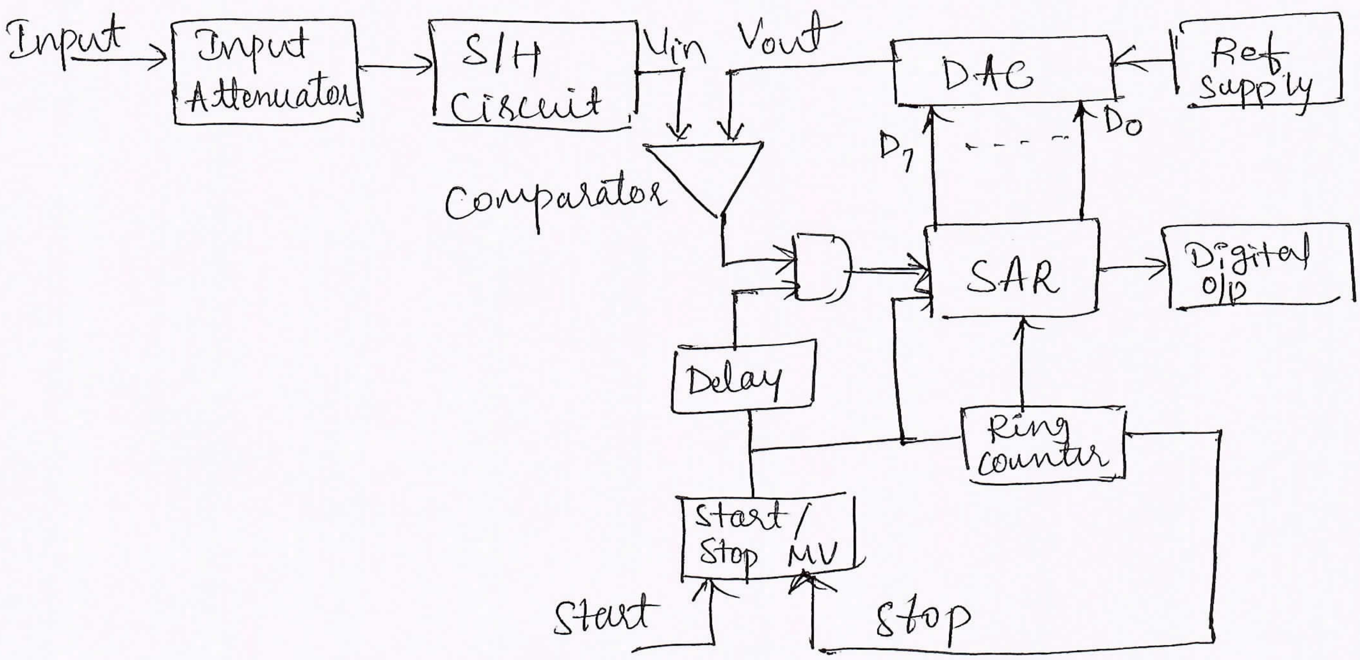
Vout of the DAC is 0.

Dlalhus

Now if $V_{in} > V_{out}$, the comparator output is positive.
→ During first clock pulse, the control circuit sets the D_7 to 1 and Vout jumps to half the reference voltage.
→ The SAR output is 10000000. If Vout is greater than V_{in} the comparator o/p is negative and the control circuit resets D_7.
→ If V_{in} is greater than Vout, the comparator o/p is positive and the control circuit keeps D_7 set.

$V_{in} = 1V$, $V_{ref} = 5V$

Operation	D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0	compare	o/p	voltage
D_7 set	1	0	0	0	0	0	0	0	Vin < Vout	D_7 Reset	2.5 V
D_6 set	0	1	0	0	0	0	0	0	Vin < Vout	D_6 Reset	1.25
D_5 set	0	0	1	0	0	0	0	0	Vin > Vout	D_5 Set	0.625
D_4 set	0	0	1	1	0	0	0	0	Vin > Vout	D_4 Set	0.9375
D_3 set	0	0	1	1	1	0	0	0	Vin < Vout	D_3 Reset	1.09375
D_2 set	0	0	1	1	0	1	0	0	Vin < Vout	D_2 Reset	1.015625
D_1 set	0	0	1	1	0	0	1	0	Vin > Vout	D_1 Set	0.97656
D_0 Set	0	0	1	1	0	0	1	1	Vin > Vout	D_0 Set	0.996095

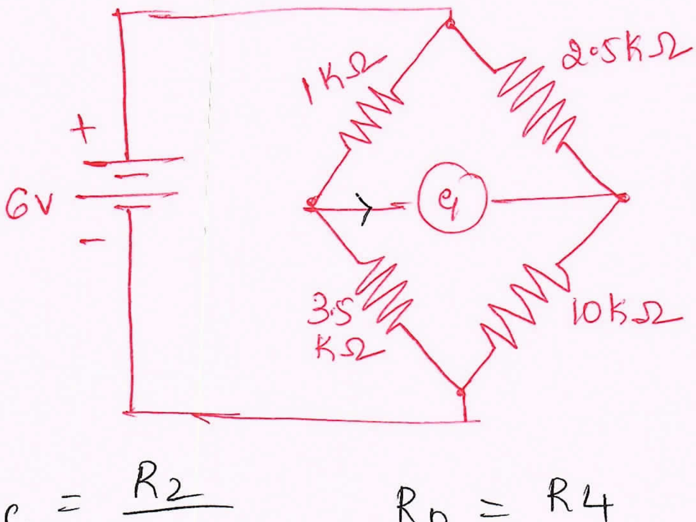


Similarly the rest of the bits beginning from D_7 to D_0 are set and tested. Therefore the measurement is completed in 8 clock pulses.

At the beginning of the measurement cycle, a start pulse is applied to the start-stop multivibrator. This sets a 1 in the MSB of the control register and a 0 in all bits, its reading would be 10000000. This initial setting of the registers causes the o/p of the DAC to be half the reference voltage i.e $\frac{1}{2}V$. This converter o/p is compared to the unknown i/p by the comparator.

Finally when the ring counter reaches its final count, the measurement cycle stops and the digital o/p of the control register represents the final approximation of the unknown i/p voltage.

8.c) An unbalanced wheatstone bridge shown in fig below, calculate current through the galvanometer.



$$R_C = \frac{R_2}{R_1 + R_2} \qquad R_D = \frac{R_4}{R_3 + R_4}$$

At balance, $R_C = R_D = \frac{R_2}{R_1 + R_2} = \frac{R_4}{R_3 + R_4}$

$$R_4 = \frac{R_2 R_3}{R_1}$$

$I = V/R = 6V \div (1K + 3.5K) = 1.33 mA$

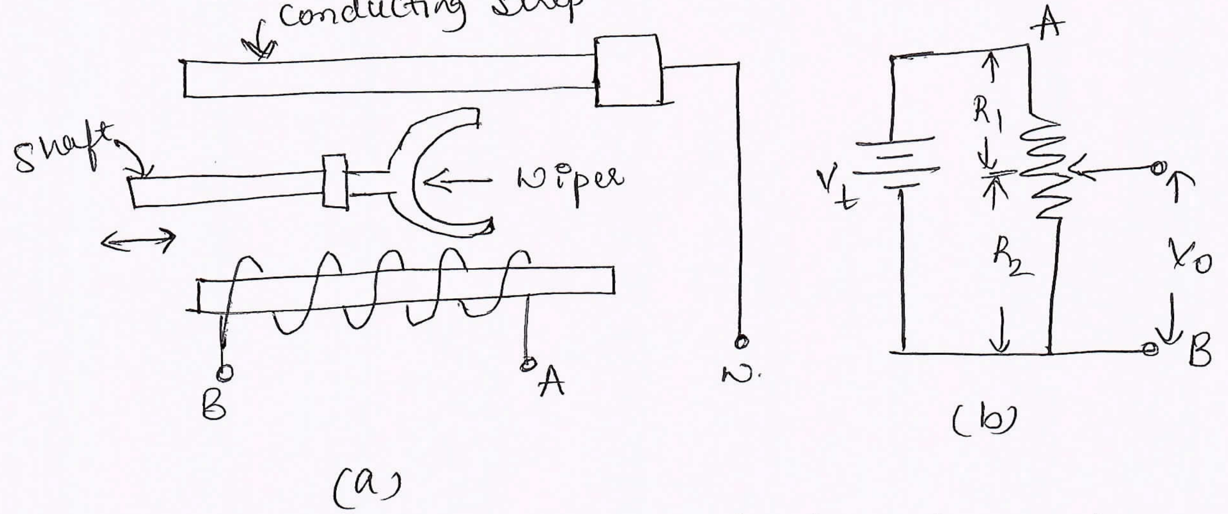
Module 5

9) a) Draw the schematic diagrams to measure displacement using resistive transducer and explain [07 marks]

Figure – 4M
Explaination – 3M

Total : 7M

Ans:



One type of displacement transducer uses a resistive element with a sliding contact or wiper linked to a object being monitored or measured.

Thus the resistance between the slider and one end of the resistance element depends on the position of the object. Fig(a) gives a construction of this type of transducer. Fig(b) shows a typical method of use. The o/p voltage depends on the wiper position and is therefore a function of the shaft position. This voltage may be applied to a voltmeter calibrated in cms for visual display.

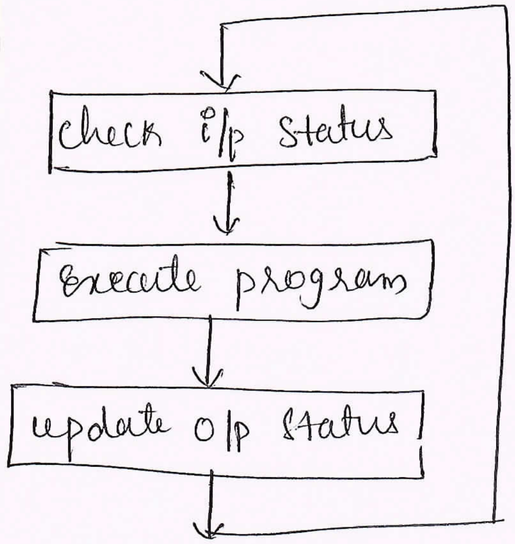
Considering fig (b) if the circuit is unloaded, the o/p voltage, V_o is a certain fraction of V_t, depending upon the position of the wiper.

$$\frac{V_o}{V_t} = \frac{R_2}{R_1+R_2}$$

Q.b) Explain the operation of PLC with neat block diagram. [05 Marks]

Block diagrams – 2 M
Explaination – 3 M
Total 5 M

Ans:



A PLC works by continually scanning a program. This scan cycle can be considered as made up of three important states as shown in figure above.
In addition there are also more than three states and these are used for checking the system updating

the internal counter and timer values.

The three important states are:

i) <u>check i/p status</u> →

First the PLC takes a look at each input to determine if it is ON or OFF. In other words, it checks and senses whether the sensor connected to the first input is ON, to the second input is ON, to the third input is ON. It records this data into its memory to be used during the next step.

ii) <u>Execute program</u> →

The PLC next executes the program, one instruction at a time. For example, if the program says that if the first input was ON then it should turn ON the first output. Since it already knows which inputs are ON/OFF from the previous step, it will be able to decide whether the first o/p should be turned ON based on the state of the first input.

iii) <u>Update output status</u> →

Finally the PLC updates the status of the o/ps. It updates the o/ps based on which inputs were ON during the first step and the results of executing the program during the second step. Based on example in step 2, it would now turn ON the first o/p because the first i/p was ON and the program said to turn ON the first o/p when this condition is true.

After the third step, the PLC goes back to step one and repeats these steps continuously.

The time taken to execute the above steps or

One instruction cycle is defined as scan time.

9.c. Explain the operation of Instrumentation amplifier using transducer bridge and derive equation for Output voltage. [08 marks]

Circuit diagram – 3M
Explaination – 3M
Derivation of O/p voltage – 2M
Total – 8M

Ans:

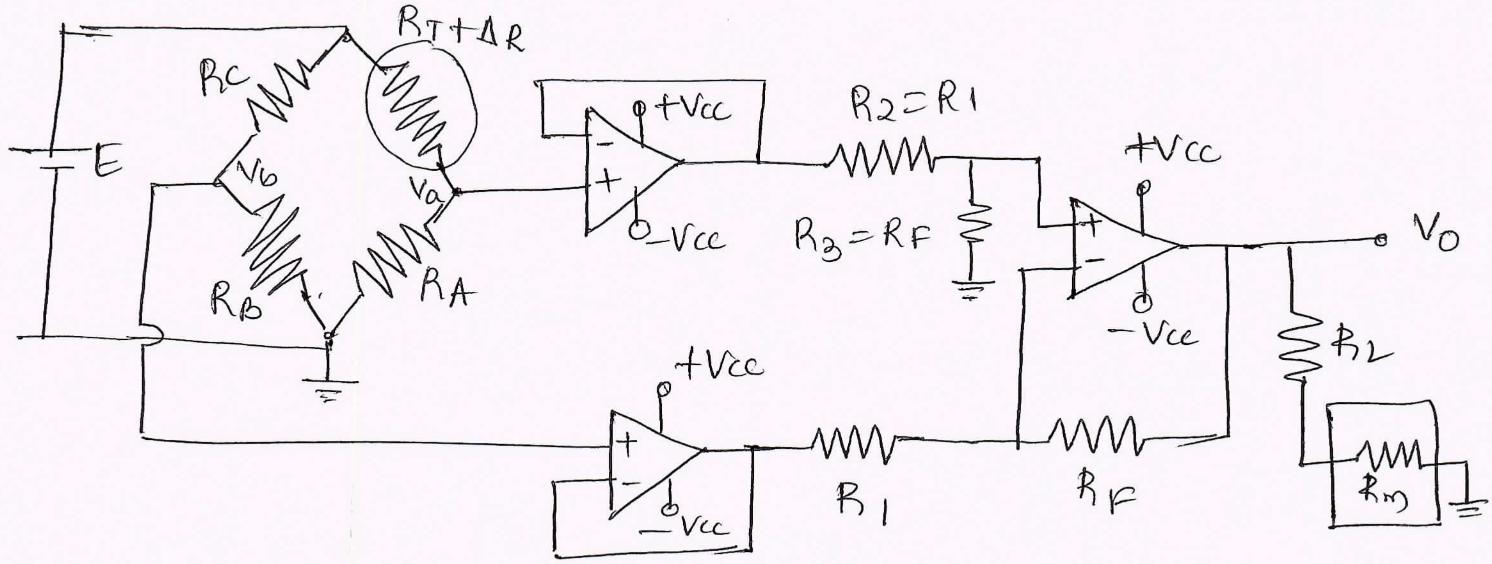


Figure above shows a simplified circuit of a differential instrumentation amplifier using a transducer bridge. In this circuit a resistive transducer is connected to one arm of the bridge.

Let R_T be the resistance of the transducer and ΔR the change in resistance of the resistive transducer. Hence the total resistance of the transducer is $(R_T \pm \Delta R)$.

The condition for bridge balance is $V_a = V_b$.

$$\frac{R_B(E)}{R_B + R_C} = \frac{R_A(E)}{R_A + R_T}$$

$$\therefore \frac{R_C}{R_B} = \frac{R_T}{R_A}$$

The bridge is balanced at a desired reference condn ~~at~~ which depends on the specific value of the physica quantity to be measured. Under this condition, resisto R_A, R_B and R_C are so selected that they are equa in value to the transducer resistance R_T.

Let the change in resistance of the transducer be ΔR. Since R_B and R_C are fixed resistors, the voltage V_b is constant, however the voltage V_a changes as a function of the change in the transducer resistance.

∴ Applying the voltage divider rule, we have,

$$V_a = \frac{R_A(E)}{R_A + (R_T + \Delta R)} \quad \text{and} \quad V_b = \frac{R_B \cdot E}{R_B + R_C}$$

The output voltage across the bridge terminal V_{ab} given by,

$$V_{ab} = V_a - V_b$$

Therefore, $$V_{ab} = \frac{R_A(E)}{R_A + (R_T + \Delta R)} - \frac{R_B(E)}{R_B + R_C}$$

However, if $R_A = R_B = R_C = R_T = R$, then,

$$V_{ab} = \frac{R \cdot E}{2R + \Delta R} - \frac{R \cdot E}{2R}$$

$$= E\left(\frac{R}{2R + \Delta R} - \frac{1}{2}\right)$$

$$V_{ab} = E\left(\frac{2R - 2R - \Delta R}{2(2R + \Delta R)}\right)$$

$$V_{ab} = -\frac{\Delta R \cdot E}{2(2R + \Delta R)} \quad \text{—} (1)$$

The o/p voltage Vab of the bridge is applied to the differential amplifier through the voltage followers to eliminate the loading effect of the bridge circuit.

The gain of the basic amplifier is (R_F/R_1) and therefore the o/p voltage Vo of the circuit is given by,

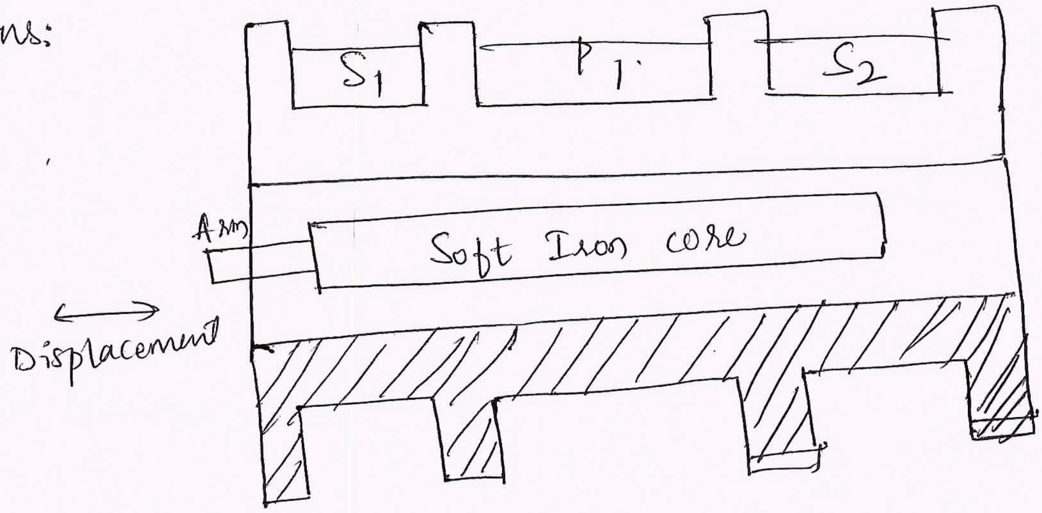
$$V_o = V_{ab}\left(\frac{R_F}{R_1}\right) = \frac{-\Delta R \cdot E}{2(2R+\Delta R)} \times \frac{R_F}{R_1} \quad -(2)$$

10.a) Expleins the construction of and working principle of LVDT with characteristic curve. [07 Marks]

Block diagram — 3 M
Characteristics curve — 2 M
expleination — 2 M

Total 7M

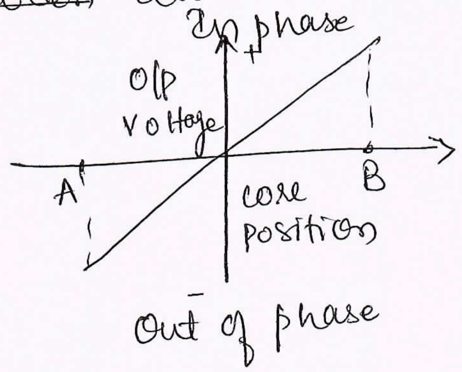
Ans:



The differential transformer is a positive inductive transformer. It is also known as a Linear variable Differential Transformer (LVDT).

The transformer consists of a single primary winding P_1 and two Secondary windings S_1 and S_2 wound on a hollow cylindrical former. The Secondary windings have an equal number of turns and are identically placed on either side of the primary windings. The primary winding is connected to an ac source.

An movable soft iron core slides within the hollow former and therefore affects the magnetic coupling between the primary and the two secondaries. The dis-placement to be measured is applied to an arm ~~between~~ attached to the soft iron core.



Above diagram shows characteristic curve. The curve is practically linear for small displacements. Beyond thi rang, the curve starts to deviate.

10.b) What are factors to be considered for selecting the transducer? [08 Marks]

One factor - 1M

8 factors - 8M

Ans: The following points should be considered while selecting a transducer.

i) Operating range

choosen to maintain range requirements and good resolution.

ii) Sensitivity

Choosen to allow sufficient output

iii) Frequency response and Resonant frequency

Flat over the entire desired range.

iv) Environmental compatibility

Temperature range, corrosive fluids, pressure shocks, interaction, size and mounting restrictions.

v) Minimum Sensitivity –

To expected stimulus, other than the measurand

vi) Accuracy –

Repeatability and calibration errors as well as errors expected due to sensitivity to other stimuli.

vii) Usage and ruggedness

Ruggedness, both of mechanical and electrical intensities versus size and weight.

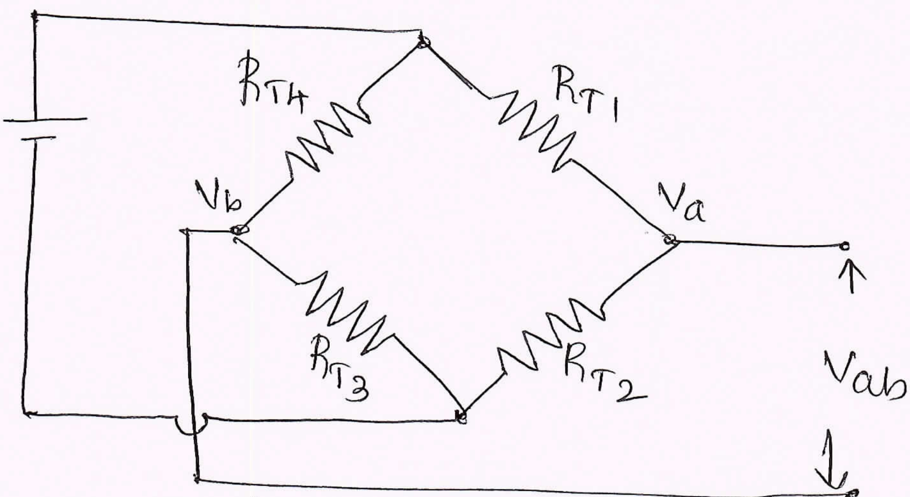
viii) Electrical parameters

Length and type of cable required, signal to noise ratio when combined with amplifiers and frequency limitations.

10.c) Illustrate working of analog weight scale. [05 Marks]

Circuit diagram – 2 M
Explaination – 3 M
Total – 5M

Ans:



Differential instrumentation amplifier circuit can be converted into a simple analog weight scale by connecting strain gauges in the bridge circuit. These strain gauges are connected in all the four arms of the bridge as shown above.

The Strain gauge elements are mounted on a base of the Specially made weight platform, on which an external force or weight is placed. One pair of Strain gauge elements in opposite arms elongates, while the other pair compresses and vice-versa.

The bridge is balanced when no external force or weight is applied, i.e $R_{T_1} = R_{T_2} = R_{T_3} = R_{T_4} = R$. and the output voltage of the weight scale is zero.

The unbalanced voltage V_{ab} is given by

$$V_{ab} = +E\left(\frac{\Delta R}{R}\right)$$

The differential instrumentation amplifier then amplifies the voltage V_{ab}, giving a deflection on the meter movement. As the gain of the amplifier is $\left(+\frac{R_F}{R_1}\right)$, the o/p voltage V_o is given by,

$$V_O = E \times \frac{\Delta R}{R} \times \frac{R_F}{R_1}.$$

The gain of the amplifier is selected depending on the Sensitivity of the strain gauge and on the full scale deflection requirements of the meter.