S.Y. Diploma : Sem. III
[ME/MH/MI/PG/PT]

Basic Electronics & Mechatronics

Time: 3 Hrs.] Prelim Question Paper Solution **[Marks : 100**

Q.1(a) Attempt any SIX of the following : [12]

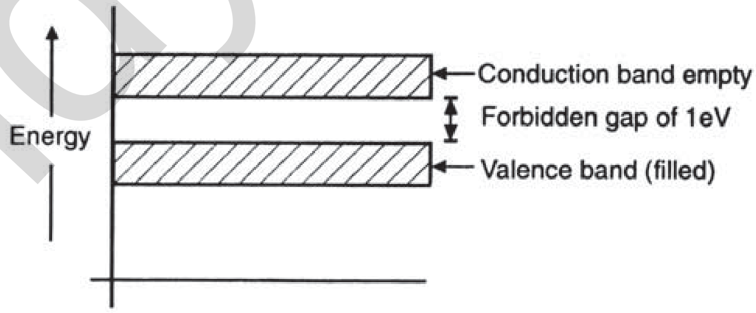
(i) What is extrinsic Semiconductor? [2]

(A) **Extrinsic Semiconductor :** When semiconductors are to be used for specific application, their current carrying capacity must be larger. This is achieved by adding a small amount of suitable impurity to a semiconductor.

The process of adding an impurity to a semiconductor is known as **doping**. The purpose of adding impurity is to increase either the number of free electrons or holes in semiconductors. If pentavalent impurity (having five electrons in its outermost shell) is added to the semiconductor, a large number of free electrons are produced in the semiconductor.

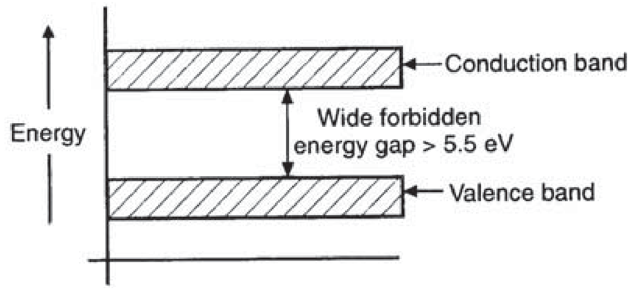
On the other hand, addition of trivalent impurity (having three electrons) creates a large number of holes in the semiconductor crystal. Depending upon the type of impurity added, extrinsic semiconductors are classified into N-type and P-type semiconductors.

Semiconductors : Conductivity of semiconductor material is less than conductor and more than insulator e.g. silicon, germanium. In this case, the valence band is full and conduction band is almost empty. The forbidden energy gap is very small. It is of the order of 1 eV.
(For germanium, E_G = 0.72 eV and for silicon, E_G = 1.12 eV).



Thus, even heat energy at room temperature is sufficient to lift the electrons from valence band to conduction band. Some electrons jump from valence band to conduction band. Thus, at room temperature, it conducts some electric current. With increase in temperature, width of forbidden energy band is decreased, so that some of the electrons are liberated into the conduction band. In other words, conductivity of semiconductor increases with temperature.

Insulator : In case of insulator, the gap between valence band and conduction band i.e. forbidden energy gap is very wide. E_G is greater than 5.5 eV. Because of this, it is practically not possible for an electron in valence band to jump in conduction band. So these materials work as insulator, e.g. Glass, wood, rubber, plastic, etc.



Q.1(a) (ii) Draw the symbols of LED? **[2]**
(A)

Symbol

Q.1(a) (iii) Draw the symbols of BJT (npn and pnp) **[2]**
(A)

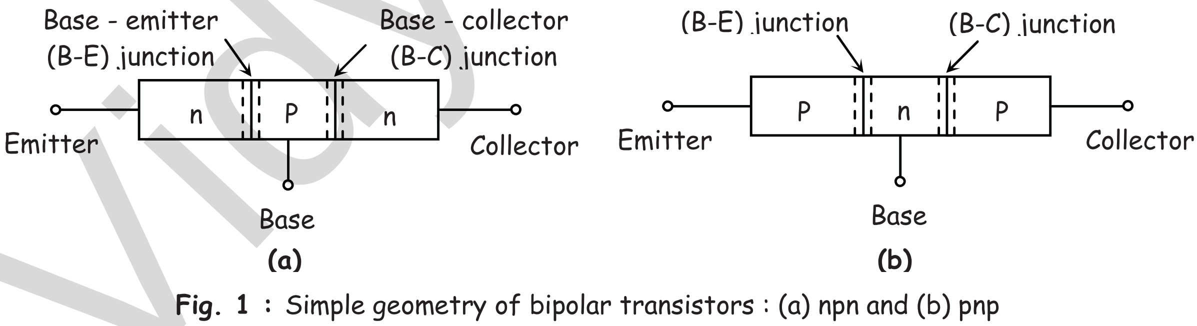


Fig. 1 : Simple geometry of bipolar transistors : (a) npn and (b) pnp

Q.1(a) (iv) List types of coupling used in Multistage Amplifier. **[2]**
(A) **Coupling Methods :**
(a) Resistance - capacitance (RC) coupling.
(b) Impedance or inductance (LC) coupling.
(c) Transformer coupling (TC).
(d) Direct coupling

Q.1(a) (v) List any four application of OP-Amp. [2]

(A) List of application of OP-Amp :

(a) Amplifier
(b) Active filter
(c) Arithmetic circuits i.e. Adder, subtractor, multiplier, Log, Antilog, Amplifier.
(d) Voltage comparator
(e) Waveform generator
(f) Precision rectifier
(g) Times
(h) Regulated power supplies

Q.1(a) (vi) List application of Dual timer IC '556'. [2]

(A) Applications of Dual Timer IC 556

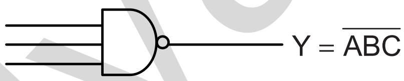
The applications of IC 556 are :

(a) Sequential timer
(b) Tone-burst generator
(c) Precision timing
(d) Pulse generation
(e) Time delay generation
(f) Pulse width modulation
(g) Pulse position modulation
(h) Linear ramp generator

Q.1(a) (vii) Explain in brief with neat sketches : Fan in. [2]

(A) Fan in :

The total number of inputs connected to the gate is called as fan in of the gate.



fan in = 3

Q.1(a) (viii) Enlist advantages of LVDT. [2]

(A) Advantages of LVDT :

(a) Upto displacement of 5mm the o/p voltage of LVDT varies linearly.
(b) The o/p voltage of LVDT do not varies in step thus it gives better resolution.
(c) It gives high o/p voltage no need of amplification.
(d) It has high sensitivity upto 40 V/mm.
(e) Since it do not have any sliding contact $\therefore$ it use or gives less friction.
(f) It passes very less hysterisis losses.

Q.1(b) Attempt any TWO of the following : [8]

(i) Draw and explain Energy level diagram of semiconductor and insulator. [4]

(A) **Semiconductors** : Conductivity of semiconductor material is less than conductor and more than insulator e.g. silicon, germanium. In this case, the valence band is full and conduction band is almost empty. The forbidden energy gap is very small. It is of the order of 1 eV.

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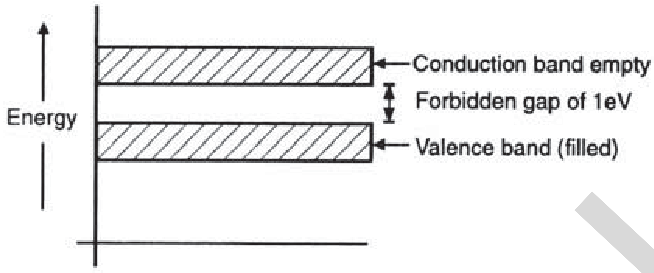

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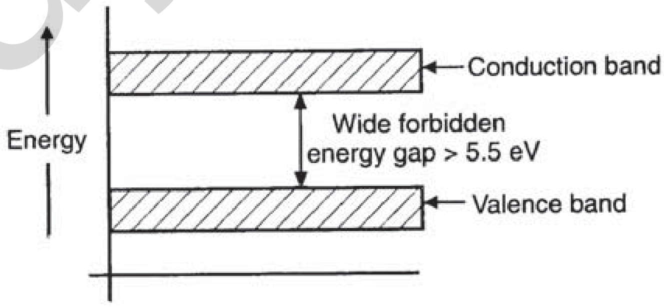


Q.1(b) (ii) Explain the operation of PN junction under reverse bias condition. [8]

(A) **P-N junction with reverse bias :**

If we connect a battery to a P-N junction such that the positive terminal of the battery is connected to the N-region and the negative terminal to the P-region, then the P-N junction is said to be reverse biased as shown in figure.

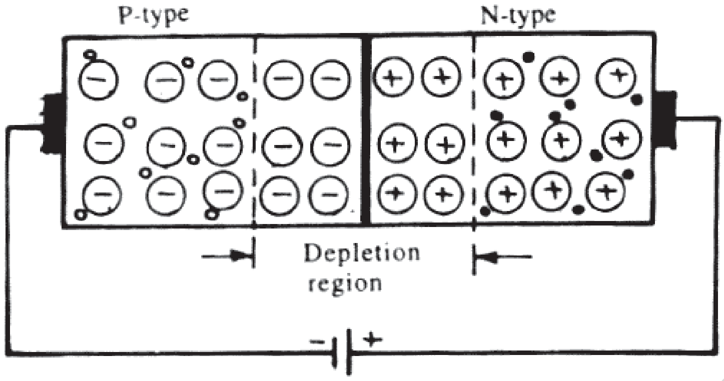


Fig. : Reverse biased P-N junction

When a P-N junction is reverse biased as shown in figure, the holes in the P-region are attracted towards the negative terminal of the battery, and the free electrons in the N-region are attracted to the positive terminal of the battery. Thus, the majority carriers are drawn away from the junction. This widens the depletion region and increases the barrier potential.

The increased barrier potential makes it very difficult for the majority carriers to diffuse across the junction. Thus, there is no current due to the majority carriers in a reverse biased P-N junction. In other words, the junction offers very high resistance. However, the barrier potential helps the minority carriers in crossing the junction. In fact, as soon as a minority carrier is generated, it is swept (i.e. drifted) across the junction because of the barrier potential. Hence a small amount of current flows through the reverse biased P-N junction due to minority carriers. The amount of this current depends upon the number of minority carriers diffusing across the junction. This, in turn, depends upon the generation of minority carriers within the P-region and N-region. It may be noted that the generation of minority carriers is dependent upon the temperature and is independent of the applied reverse voltage. If the temperature is fixed, the rate of generation of minority carriers remains constant. Therefore, the current due to the flow of minority carriers remains constant, whether the applied voltage is increased or decreased. Because of this reason, this current is known as reverse saturation current (I_o). This current is very small as the number of minority carriers is very small. It is of the order of nanoamperes (nA) in Silicon P-N junctions and microamperes (μ.A) in Germanium P-N junctions. This current increases with the increase in temperature i.e. doubles for every 10°C rise in temperature.

Q.1(b) (iii) Explain construction and working principle of zener diaode. **[8]**

(A) ZENER DIODE :

Construction :

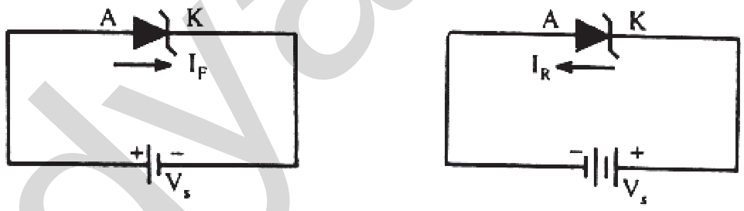
A properly doped P-N junction diode, which has a sharp breakdown, is known as a Zener diode. It is also called a voltage reference, voltage regulator or breakdown diode. The Zener diodes are silicon P-N junction devices which differ from rectifier diodes in the sense, they are operated in the reverse breakdown region and the breakdown voltage is set by carefully controlling the doping level during manufacturing process. Thus, by controlling the junction width and doping concentration of P-N junction diode, it is possible to make it to breakdown at a sharp specified Zener voltage.

A Zener diode is represented by a schematic symbol as shown in Fig. 1. It has two terminals namely, anode and cathode. As a memory aid, it may be noted that at the end of the arrow looks like the letter Z.

Fig. 1 Symbol of a Zener diode

Working Principle :

When a Zener diode is forward biased as shown in Fig. 2(a), it conducts the current due to majority carriers and behaves as an ordinary P-N junction diode. Therefore, its forward characteristic will be similar to that of an ordinary diode.



(a) Forward bias (b) Reverse bias

Fig. 2 :Conduction of Zener Diode

When a Zener diode is reverse biased as shown in Fig. 2(b), it conducts the current due to minority carriers and this current will be very small so long as the reverse voltage is less than breakdown voltage. As the reverse voltage is increased to breakdown voltage, a large number of electron-hole pairs are produced and the reverse current sharply increases. This reverse current is known as Zener current and the breakdown voltage is Zener voltage. If the voltage is again increased beyond the Zener voltage, then the Zener current increases, but the voltage across the Zener diode remains constant. Thus, it provides a constant voltage and can be used as a constant voltage source.

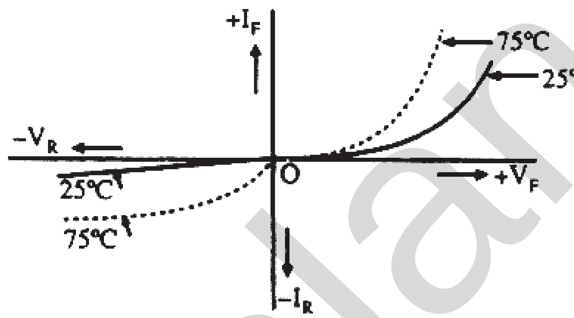
Q.2 Attempt any FOUR of the following : [16]

Q.2(a) Describe V-I characteristics of point contact diode, with application. [4]

(A) V-I Characteristics of Point Contact Diode :

The solid curve is for the abient temperature of 25°C and the dotted curve is for 75°C.

Very low value of the capacitance of the point contact (i.e. barrier layer) and minimized effect of the minority-carrier storage make the point-contact diodes very suitable for operation at the frequencies as high as 10 GHz or more and for applications in pulse circuits. In contrast, the principle use of junction diode is as a power rectifier, due to its capability of handling larger currents and its larger rectification ratio, i.e. the ratio of forward to reverse current at a given applied voltage.



V-I Characteristics of point contact diode

Properties of Point Contact Diode :

The point-contact diode offers a spreading resistance due to the concentration of the current at the contact. It offers a non-linear resistance, which is small, to forward bias voltage and large, to reverse bias voltage. Its capacitance, which is very small, is a function of the applied voltage. This capacitance may be about 1 pF or less.

Applications of Point Contact Diode :

The low capacity makes it suitable for use in high frequency operation. Its use is found in following applications :

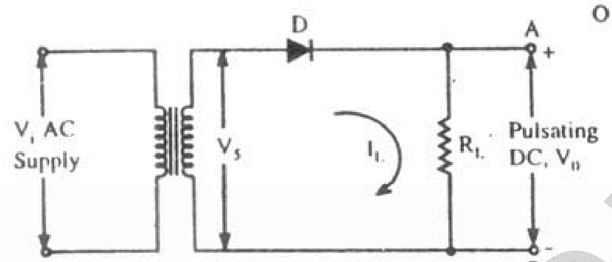
(i) It is used as video detectors.
(ii) It is used in microwave mixer circuits.
(iii) It is used in pulse circuits
(iv) It is used in high frequency circuits of the order of 10 GHz or more.
(v) It is used in frequency conversion circuits.
(vi) It is used in non-linear i.e., rectifying elements of R.F. signal detection.

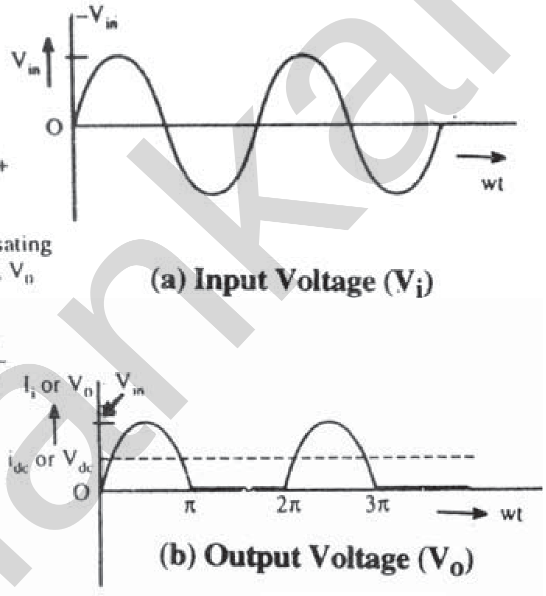
Q.2(b) Draw the circuit diagram of a half wave rectifier. Draw its input-output waveforms. **[4]**

(A) Half-Wave Rectifier :

In half-wave rectification, the rectifier conducts current only during the positive half-cycles of input AC supply. The negative half-cycles of AC signal are suppressed i.e., during negative half cycles there is no current and hence no voltage drop across the load. Therefore, current always flows only in one direction (i.e. DC) through the load, though after every half-cycle.

Circuit Details :





Diode as a Half-wave **Fig. 1** **Waveforms**

Fig. 1 shows the circuit of a half-wave rectifier. It consists of a single P-N junction diode in series with a load resistance R_L. The AC supply to be rectified is applied in series with the diode and the load resistance. Generally, the input AC supply is given through a transformer. The use of transformer allows two advantages. Firstly, it allows the source voltage to be stepped up or stepped down the AC input voltage as the situation demands. Secondly, the AC power source is electrically isolated from the rectifier and thus it reduces the chances of reducing the electric shock. The output voltage is taken across the load R_L.

Operating Principle :

The primary of the transformer is connected to the AC power supply. The AC voltage is induced across the secondary of the transformer. This voltage may be less than, or equal to, or greater than the primary voltage depending upon the turns ratio of the transformer.

Fig. 1(a) shows how this voltage varies with time. It has alternate positive and negative half-cycles. Voltage V_m is peak value of this alternating voltage.

During the positive half cycle of the AC input voltage, the polarity of the voltage across the secondary is such that the diode is forward-biased. The diode conducts and a current I_L flows through load resistor R_L for all instantaneous voltages greater than knee voltage (0.6 V for Silicon and 0.2 V for Germanium diodes). However, for all practical purposes, we assume that the diode is forward biased whenever the AC input voltage goes above zero. While conduction, the diode acts as a short-circuit so that the circuit current flows and produces a voltage across the load resistor R_L. This current makes the terminal A positive with respect to terminal B. Therefore, the voltage appearing across the load terminals A and B is practically the same as that of the positive input half cycle of AC input voltage as shown in Fig. 1(b).

During the negative half-cycle of the input voltage, the polarity gets reversed so that the diode is reverse biased. Hence, it does not conduct and practically there is no flow of current through the circuit. Therefore, almost no voltage is developed across the load resistor R_L i.e. V_0= 0. All the input voltage now appears across the diode itself. The result is that only the positive half cycle of the AC input voltage is utilized for delivering DC power and the output voltage is almost the same as the input voltage. The complete waveform of the output voltage across the load R_L is as shown in Fig. 1(b).

It is evident that though the output voltage is not a steady (or perfect) DC is at least unidirectional. But it is only a pulsating DC wave having the frequency equal to the input voltage frequency. It is evident from the above discussion that as the circuit uses only one-half cycle of the AC input voltage, therefore it is popularly known as a half-wave rectifier.

Q.2(c) Define the following forms : **[4]**

(i) Peak inverse voltage.

(ii) Ripple factor

(iii) Rectification efficiency

(iv) Transformer utilization factor (TUF)

(A) Important Terms :

(i) Peak Inverse Voltage (PIV):

The maximum value of reverse voltage that a diode can withstand without destroying its P-N junction during the non-conduction period is called peak inverse voltage. The diode should be so chosen as to withstand this reverse voltage.

(ii) Ripple factor:

The ripple factor of a rectifier is a ratio of r.m.s. value of the alternating components in the load to the DC components in the load of a rectifier. It is denoted by a letter V which is defined as :

$$r = \frac{\text{RMS value of AC components in the load}}{\text{Average or d.c. components in the load}} \qquad = \sqrt{\left(\frac{I_{rms}}{I_{dc}}\right)^2 - 1}$$

It is an indication of how successful is a rectifier circuit in converting AC to DC. The ripple factor of half-wave and full-wave rectifier is 1.21 and 0.482 respectively. Thus, ripple factor is a measure of purity of the DC output of a rectifier.

(iii) Rectification efficiency :

The rectification efficiency of a rectifier is a ratio of the DC power output delivered to the load to the AC power input supplied to the rectifier circuit. It is denoted by a latter t|, which is defined as

$$\eta = \frac{\text{DC power output}}{\text{AC input power from transformer secondary}}$$

It is a figure of merit (a measure of efficiency) to compare different rectifiers. The maximum rectification efficiency of half-wave and full wave rectifier is 40.6% and 81.2% respectively.

(iv) Transformer Utilization Factor (TUF):

It is the ratio of DC power delivered to the load to the AC rating of the transformer secondary. It is denoted as TUF and is defined as :

$$\text{TUF} = \frac{\text{DC power de livered to the load}}{\text{AC rating of the transformer secondary}}$$

The TUF for a halfwave rectifier is 0.287 whereas for centre-tap and bridge rectifier is 0.693 and 0.812 respectively.

Q.2(d) Explain the principle of operation of capacitor input (or π filter) with advantages and disadvantages. **[4]**

(A) Capacitor Input (Or π) Filter :

Principle of Operation :

When the additional DC voltage across L_1 cannot be tolerated in the circuit of a Fig. 1, a CLC filter will give a similar magnitude of ripple, but with poorer voltage regulation.

Fig. 1 shows a network for a capacitor input filter circuit. It consists of a filter capacitor C_1 connected across the rectifier output, a choke L in series and another filter capacitor C_2 connected across the load resistor R_L. Only one filter section is shown, but several such identical sections are often used to improve the smoothing action. This filter is called a π filter as its shape is like a Greek letter π (pi). The rectifier feeds output directly into the capacitor C_1. Therefore, this filter is also called capacitor input filter.

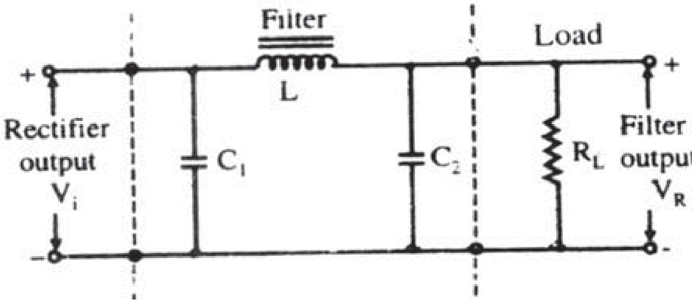


Fig. 1 : Capacitor input filter

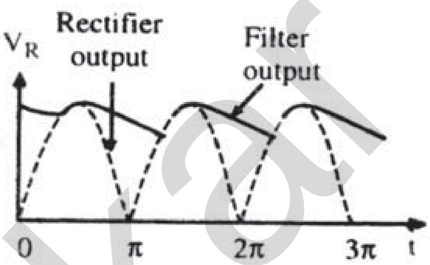


Fig. 2 : Rectifier and filter output waveform

The pulsating output from the rectifier is applied at the input terminals of the capacitor-input filter. The action of this filter can be understood by looking this filter made up of two parts :

(i) Shunt capacitor filter formed by capacitor C_1.

(ii) LC filter formed by choke L and capacitor C_2.

Here the rectifier output first charges the capacitor GI to the peak value of the rectifier output This capacitor tends to hold this charge between successive peaks discharging slowly through the choke L and the load resistor R_L. As a result, the filter output voltage drops slightly between the successive peaks as shown in Fig. 1. The capacitor input filter thus gives a higher output voltage than that of a choke-input filter for the same AC input voltage. The remaining output fluctuations are opposed by the series choke and bypassed to ground through the capacitor C_2. The output voltage of this filter falls rapidly with increasing load current. This means that the voltage regulation of a capacitor input filter is not as good as that of a choke-input filter.

Since the rectifier feeds into the capacitor C_1, the capacitor input filter can be used together with a half-wave rectifier whereas the choke-input filter cannot be used with a half-wave filter.

The ripple factor (for 50 Hz mains supply) of a π-filter is given by the relation,

$$r = \frac{1}{4\sqrt{2}.\omega^2.C_1.C_2.L.R_L} = \frac{5700}{C_1 C_2 L R_L}$$

where, C_1 and C_2 are in microfarad (μF), L is in henry (H) and R_L in ohm (Ω).

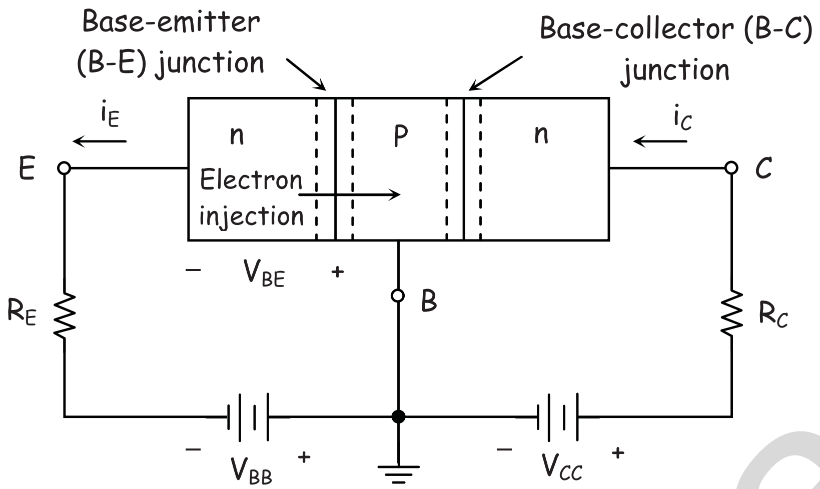
It is evident from the above relation that the ripple factor in a π-filter is dependent only on the product of the capacitance values of the capacitors C_1 and C_2. But the DC output voltage will be high only if the value of capacitor C_1 is large. Hence, for a given ripple factor, the π-filter is designed with a large value of capacitor C_1.

It should be noted that under some conditions of small load currents, it is possible to replace the choke L_1, with a resistor R equal in value to the reactance of choke L_1 at the ripple frequency of 100 Hz without changing the ripple factor. However, the increased resistance of DC current flow will make this impractical except where the load current is very small. The approximate value of the resistor R may be 100 to 200 Ω. It is then called capacitor input RC filter. This means a saving in the expense, weight and space of the choke. Such a replacement of a resistor R for a choke L_1, is often practical only for low-current power-supplies.

Advantages :
Main advantages of a π-filter are :
(i) Smaller ripple factor than that obtained by the use of multisection LC filter with the same total value of L and C.
(ii) Higher DC output voltage ($V_{dc} = V_m$) at high loads.

Disadvantages :
The disadvantages of a π-filter are :
(i) It has poorer voltage regulation, as it has increased voltage drop in the filter.
(ii) It has increased peak anode current.
(iii) It requires higher PIV.
(iv) It is costlier and bulky.

Q.2(e) With a neat diagram. Explain the working of NPN transistor. **[4]**
(A) NPN transistor working and diagram
- **npn Transistor :** Forward-Active Mode Opertaion
- If the transistor is used as an amplifying device, the base-emitter (B–E) junction is forward biased and the base-collector (B-C) junction is reverse biased, in a configuration called forward-active operating mode or simply the active mode.



An npn bipolar transistor biased in the forward-active mode.

- Emitter of the transistor is n-type mean majority carrier in the emitter region are electrons since the B-E junction is forward biased, electrons from the emitter are injected across the B-E junction into the base as shown by an arrow.
- Since the B-C junction is reverse biased the electron centralization at the edge of that junction (B-C junction) is approximately zero.
- So electrons from n-type emitter are injected into Base region and at the same there are less no. of electonsin B-C junction this creates large concentration gradient in the base region.
- Because of above mentioned concentration gradient, electrons injected from the emitter diffuse across the base into the B-C space charge region, where the electric field sweeps them into the collector region.

Q.3 Attempt any FOUR of the following : [16]

Q.3(a) Given β = 150, i_B = 15μA and transistor is biased in the forward active mode to find i_c = ?, i_E =? and α = ? [4]

(A) $i_C = \beta\, i_B$

$= 150\ (15\ \mu A)$

$= 2.25 mA$

$i_E = (1 + \beta)\, i_B$

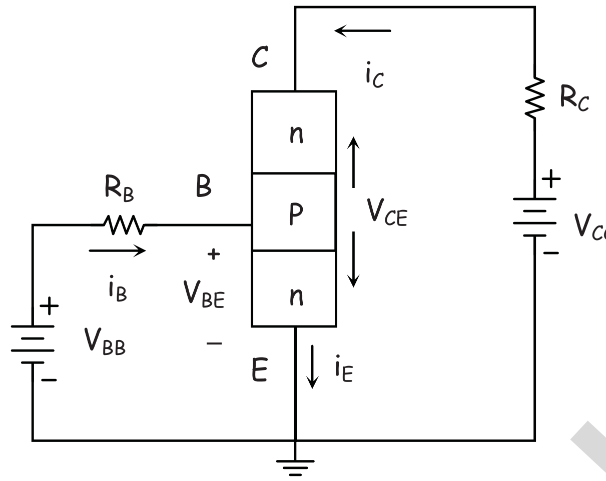
$= (151)\ (15\ \mu A)$

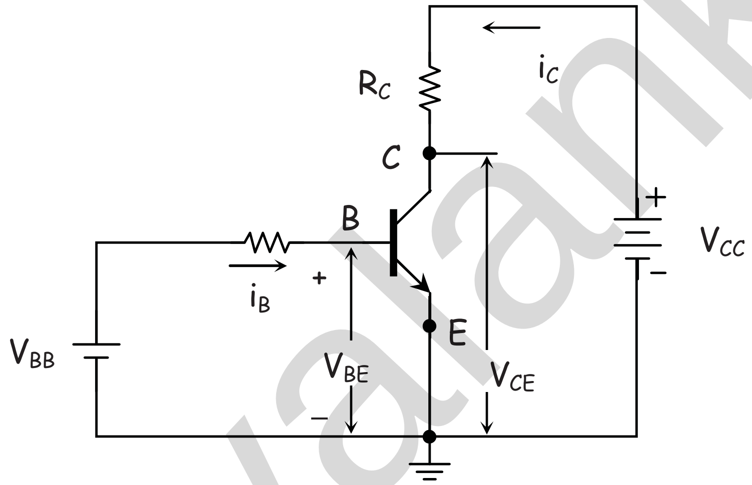
$= 2.27 mA$

$$\alpha = \frac{\beta}{1+\beta} = \frac{150}{151} = 0.9934$$

Q.3(b) Explain common Emitter configuration with the help of input and output characteristics. **[4]**

(A) Common-Emitter (CE) Configuration

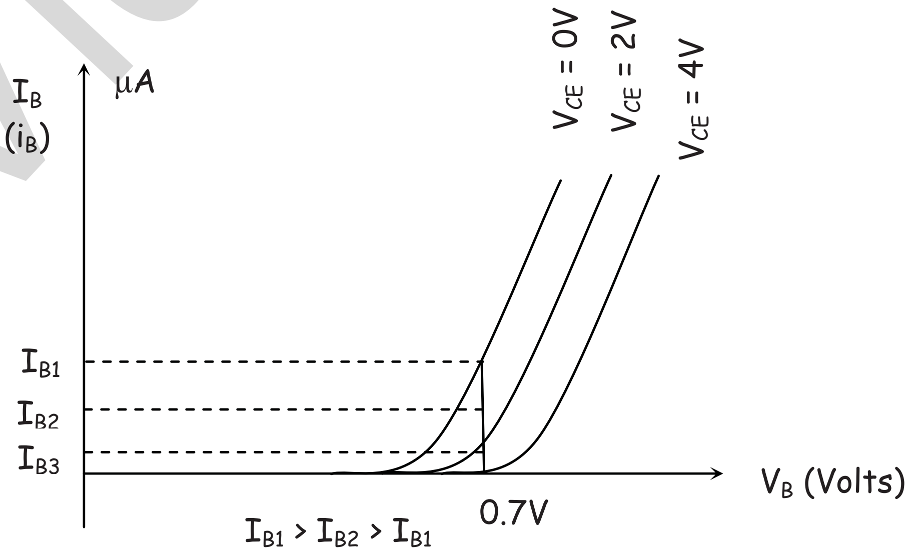




An npn transistor circuit in the common-emitter configuration.

- When emitter terminal is made common as both the input as well as the output BJT is said to operates in common emitter configuration.

Input Characteristics

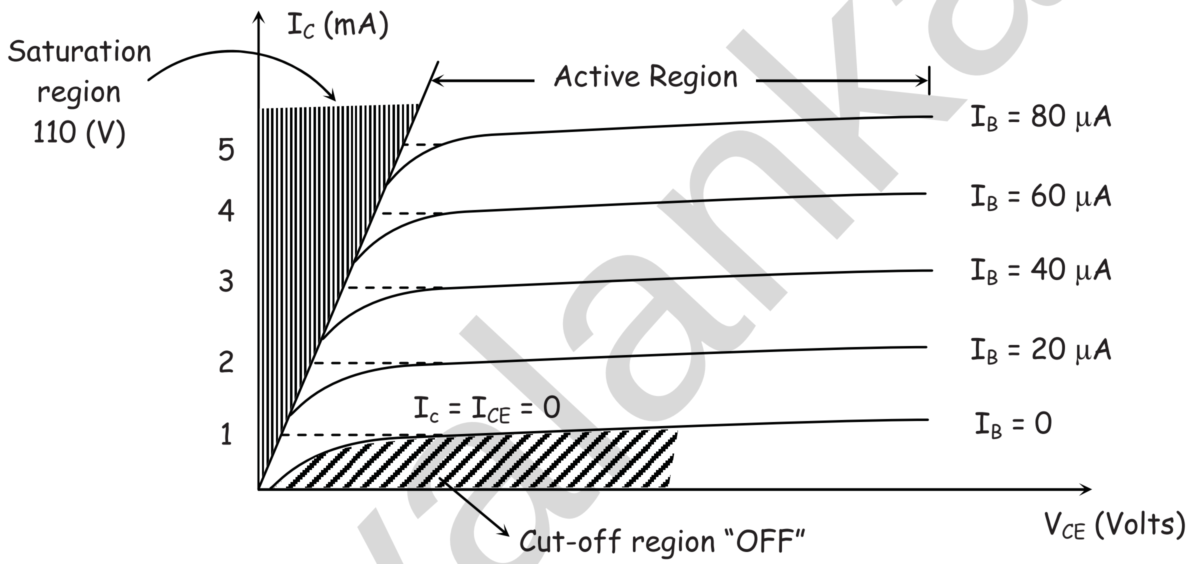


- Input characteristics are curves of variation of input current (i_B) against input voltage (V_{BE}) at constant output voltage (V_{CE}).
- When V_{CE} increases, junction width increases, base width decreases, due to the decrease in recombination in base the base current i_B decreases.
- The dynamic input impedance.

$$\gamma_i = \left.\frac{\Delta V_{BE}}{\Delta I_B}\right|_{V_{CE} = \text{constant}}$$

Output Characteristics

These are curves of variation of output current (I_C) against output voltage (V_{CE}) at constant input current (I_B).



Output characteristics of α npn transistor in CE configuration

- From the transistor output characteristics it can be seen that I_C is independent of V_{CE} but depends on I_B. Hence transistor operates as a current controlled current source (CCCS).
- The dynamic output impedance is given by

$$\gamma_0 = \left.\frac{\Delta V_{CE}}{\Delta I_C}\right|_{I_B = \text{constant}}$$

[Explanation for saturation region, Active region, and cut-off region are same as in CB configuration]

Q.3(c) Explain need of cascade Amplifier and coupling used in Amplifiers. [4]

(A) Need of Cascade Amplifier :

An amplifier is the basic building block of most of the electronic systems. Just as one brick does not make a house, a single stage amplifier is not sufficient to construct a practical electronic system. The gain of a single stage small signal amplifier is limited and it is not sufficient for all practical applications. Therefore, in order to achieve more voltage gain and power gain, we have to use more than one stage of amplification, such an amplifier is called a multistage amplifier. To achieve this, the output of each amplifier stage is coupled in some way to the input of the next stage. Such a connection of amplifiers is called cascading. The resulting amplifier is also called cascaded amplifier. Much higher gain can be obtained from the multistage amplifiers. The amplifier used in radio and television receivers is, usually, a multistage amplifier.

A transistor circuit containing more than one stage of amplification is known as multistage transistor amplifier. A multistage amplifier using two or more single stage C.E. amplifiers is called a cascade amplifier. On the other hand, a multistage amplifier with CE amplifier as the first stage and CB (or CC) amplifier as the second stage is called a cascade amplifier.

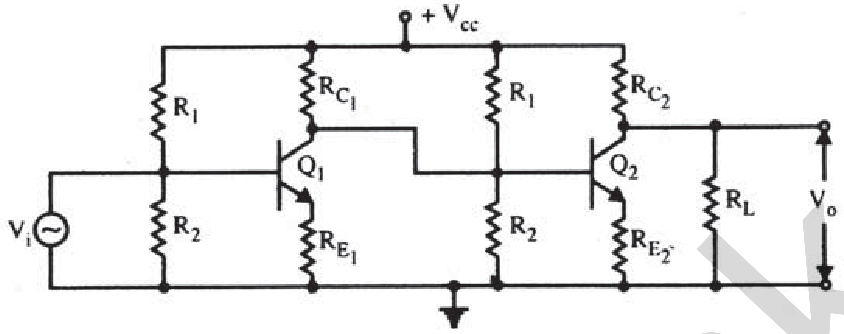
Coupling Used In Amplifiers :
In a multistage amplifier, the output of one stage becomes the input of the next stage. The output terminals of one amplifier cannot be connected directly to the input terminals of the next amplifier all the times due to some practical difficulties. As a matter of fact, all amplifier need some kind of coupling networks. Even a single stage amplifiers needs coupling to the input source and output load. The multistage amplifiers need a suitable coupling between two stages so that a minimum loss of voltage occurs when the signal passes through this coupling network to the next stage. Also, the DC voltage at the output of one stage should not be permitted to go to the input of the next

Q.3(d) "Explain two stage impedance coupled CE amplifier with neat sketch" [4]

(A) Two Stage Direct Coupled (DC) CE Amplifier :
The transformer coupled amplifiers suffer from the drawback that they cannot amplify the very low frequency signals (i.e. below 10 Hz) including direct current of zero frequency. This limitation is overcome by the use of Direct Coupled (DC) amplifier. It is also called as DC amplifier. It may be noted that the capacitors, inductors and transformers cannot be used as a coupling network at very low frequencies because the size of these passive components becomes very large at very low frequencies. In this method, amplifiers are connected directly without any intervening coupling devices. This type of coupling is known as *direct* coupling.

Circuit Details :

It may be noted that the output of first stage is directly connected to the base of the next transistor Q_2. Moreover, there are no input or output coupling capacitors and also the emitter bypass capacitors. Since there are no coupling capacitors between the two stages, there is a DC as well as AC interaction between the stages. The input resistance of the second stage is very large and loading of the first stage is very low.



Two stage direct coupled CE amplifier

Applications :

The applications of direct coupled amplifier are as follows :

(i) It is used is analog computation.
(ii) It is used in power supply voltage regulators.
(iii) It is used for bioelectric measurements.
(iv) It is used in linear integrated circuits.

Q.3(e) Compare to different types of coupling on the basis of following factor : **[4]**

(i) Cost **(ii) Space and weight**
(iii) Frequency response **(iv) Impedance matching**
(v) Distortion **(vi) Hum**
(vii) Voltage gain **(viii) Application**

(A) Comparison Of Different Types of Couplings :

The performance of different types of coupling is as given below :

	Particulars	RC coupling	Transformer coupling	Direct coupling
(i)	Cost	Less	More	Least
(ii)	Space and Weight	Less	More	Least
(iii)	Frequency response	Excellent in A.F.	Poor	Best
(iv)	Impedance matching	Not good	Excellent	Good
(v)	Distortion	Amplitude	Frequency	No distortion

(vi)	Hum	No	More	Less
(vii)	Voltage gain	Least	More	less
(viii)	Application	Voltage amplification	Power amplification	Amplifying extremely low frequencies

Q.4 Attempt any FOUR of the following : [16]

Q.4(a) Define the following parameters of 'OP-amp' [4]

(i) Input bias current (I_B)

(ii) Input offset current (Iios)

(iii) Open Loop voltage gain.

(iv) Differential input resistance (Ri)

(A) Parameters of op-amp

(i) Input bias current (I_B) : Input bias current is the average of the currents flowing into the two input terminals of the op-amp. I_{B_1}, is current flowing into non-inverting and I_{B_2} is current flowing into inverting terminal.

Input bias current $I_B = \frac{I_{B_1} + I_{B_2}}{2}$

I_{B_1} and I_{B_2} must be zero but practically I_{B_1} and I_{B_2} is having a finite value due finite value of input resistance R_i.

(ii) Input offset current (I_{ios}) : The difference between the currents flowing into the inverting and non-inverting terminals of op-amp is called as input offset current I_{ios}.

$I_{ios} = |I_{B_1} - I_{B_2}|$

(a) Ideally it is zero, practically it is in nanoamp.
(b) This offset current exist due to mismatch of internal transistor.

(iii) Open loop voltage gain (A_v) : It is gain of amplifier in open loop mode. Open loop mode is the mode of operation without any feedback.

$V_0 = A\,Vd$

$A \Rightarrow$ Open loop gain $\Rightarrow 2 \times 10^5$

(iv) Differential input resistance (R_i) : is defined as resistance which can be measured at either the inverting or non-inverting terminal with the other terminal connected to ground.

It is few mega Ω for transistor input stage and extremely high (thousand of $G\Omega$) for op-amp having FET based input stages. $-R_i = 2M\Omega$.

Q.4(b) Determine S.R. of a OP-amp at room temp. which has unity cross-over frequency of 5MHz. **[4]**

(A) (i) Gain B. W. = $5MH_3$ as Gain = 1

$\therefore$ B. W. = $5MH_3$

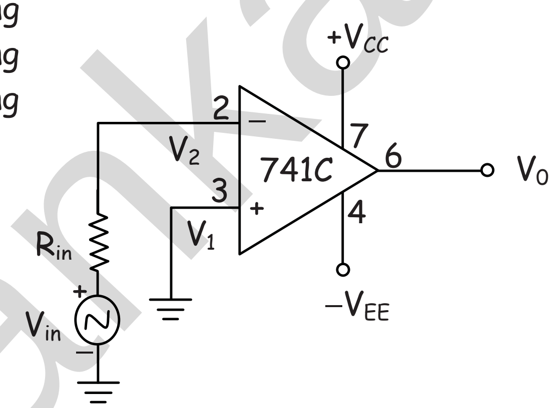
(ii) Saturation voltage = $\pm$ 1μv i.e. V_p = 14V

$$S.R. = \frac{2\pi f V_p}{10^6} = \frac{2\pi \times 5 \times 10^6 \times 14}{10^6}$$

S.R. = 439.8 V/μsec.

Q.4(c) Explain with symbol inverting and Non-inverting Amplifier. **[4]**

(A) **Inverting Amplifier :** In the inverting amplifier, input is applied to the inverting input of Op-amp and the non-inverting input terminal is grounded.



$V_{NI} = V_1 = 0$ V

$V_{INV} = V_2 = V_{in}$

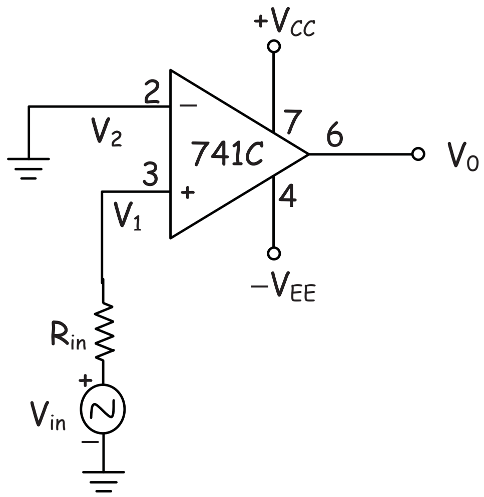
$V_0 = A\,(V_{NI} - V_{INV})$

$= A\,(0 - V_{in})$

$= -A\,V_{in}$

The negative sign indicates that the output voltage is out of phase w.r.t. input by 180°. Thus, in the inverting amplifier the input signal is amplified by gain A and the output is inverted.

Non-Inverting Amplifier : In the open loop non-inverting configuration, the input is applied to the non-inverting input terminal and the inverting terminal is connected to ground.



$V_{NI} = V_1 = V_{in}$

$V_{INV} = V_2 = 0$

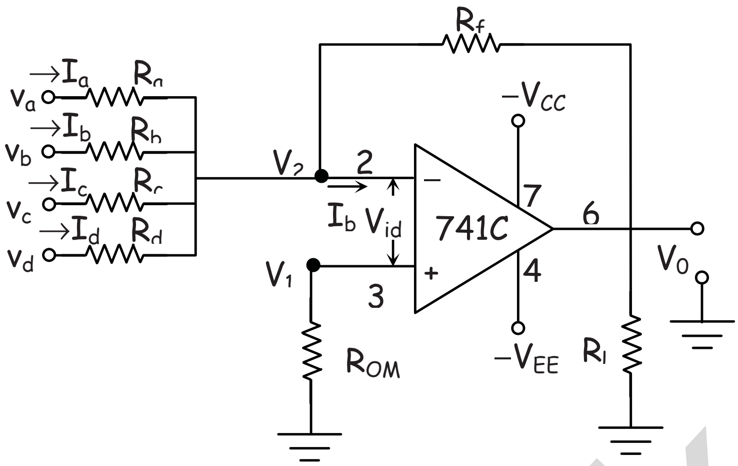
$V_0 = A\,(V_1 - V_2) \quad = A\,(V_{NI} - V_{INV})$

$= A\,(V_{in} - 0) \quad = A\,V_{in}$

Thus, the output voltage is greater than the input voltage by gain A times and is in phase with the input signal.

Q.4(d) Explain summing scaling and averaging amplifier? **[4]**

(A) Summing, Scaling and Averaging Amplifier (Inverting Mode)



Scaling Amplifier : As shown in the above circuit diagram, a number of voltage sources can be connected to the inverting input of op-amp. The value of voltages and resistors can be varied. For an ideal op-amp,

$$A_V = \infty$$

$$A_V = \frac{V_0}{V_{id}} = \infty$$

$$\therefore \quad V_{id} = \frac{V_0}{\infty} = 0$$

$$\therefore \quad V_{id} = V_1 - V_2 = 0$$

$$\therefore \quad V_1 = V_2$$

Since $V_1 = 0$, $V_2 = 0$ (By concept of "VIRTUAL GROUND")

As $R_i = \infty$, for ideal op-amp, $I_B \approx 0$.

Applying KCL at the inverting input terminal,

$$I_a + I_b + I_c + I_d = I_f \quad (\because I_B \approx 0)$$

$$\therefore \quad \frac{V_a - V_2}{R_a} + \frac{V_b - V_2}{R_b} + \frac{V_c - V_2}{R_c} + \frac{V_d - V_2}{R_d} = \frac{V_2 - V_0}{R_f}$$

$\because$ $V_2 = 0$ (By concept of VIRTUAL GROUND)

$$\therefore \quad \frac{V_a}{R_a} + \frac{V_b}{R_b} + \frac{V_c}{R_c} + \frac{V_d}{R_d} = -\frac{V_0}{R_f}$$

$$\therefore \quad V_0 = -\left[\frac{R_f}{R_a}V_a + \frac{R_f}{R_b}V_b + \frac{R_f}{R_c}V_c + \frac{R_f}{R_d}V_d\right]$$

Thus, the circuit works as a scaling amplifier, since each voltage is multiplied by different scaling factors.

Summing Amplifier :
In the above circuit, if $R_a = R_b = R_c = R_d = R_f = R$
then each scaling factor becomes unity.
$\therefore \quad V_0 = -(V_a + V_b + V_c + V_d)$
Since the output voltage is a –ve sum of all input voltages, this circuit is known as a Summation Amplifier in inverting mode.

Average Amplifier :
In the above circuit, if $R_a = R_b = R_c = R_d = R_f = R$

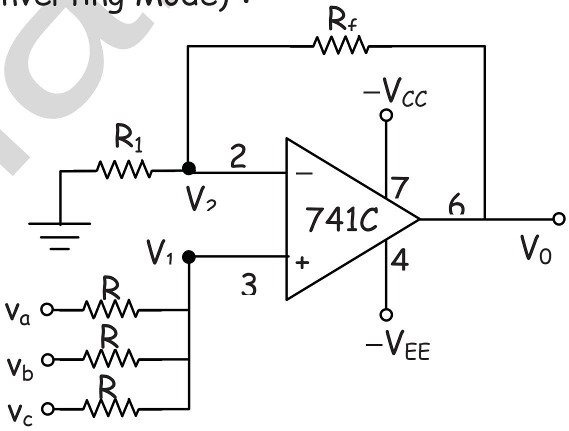
$$\therefore \quad V_0 = -\frac{R_f}{R}(V_a + V_b + V_c + V_d)$$

Let $\frac{R_f}{R} = \frac{1}{n}$ where n is the no. of input signals

$$\therefore \quad \frac{R_f}{R} = \frac{1}{4}$$

$$\therefore \quad V_0 = -\frac{1}{4}(V_a + V_b + V_c + V_d)$$

Summing, Averaging Amplifier (Non-inverting Mode) :
The op-amp is used in the non-inverting mode and 3 D.C. voltages V_a, V_b and V_c are given to the +ve input terminal through resistors of same value.



For a non-inverting amplifier,

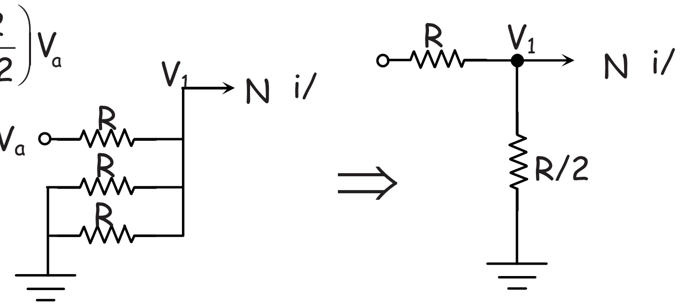
$$A_{fb} = 1 + \frac{R_f}{R_1}$$

To find the expression for the output voltage, apply superposition theorem.

(i) V_a is kept in the circuit with V_b and V_c replaced by the equivalent short circuit.
Applying potential divider formula,

$$V_1' = \left(\frac{R/2}{R + (R/2)}\right)V_a = \left(\frac{R/2}{3R/2}\right)V_a$$

$$V_1' = \frac{V_a}{3} \qquad \text{... (i)}$$



Similarly for the other two voltage sources
V_b and V_c.

$\therefore \quad V_1'' = \frac{V_b}{3}$ … (ii)

$V_1''' = \frac{V_c}{3}$ … (iii)

By superposition theorem,

$$V_1 = V_1' + V_1'' + V_1''' = \frac{V_a}{3} + \frac{V_b}{3} + \frac{V_c}{3}$$

$$V_1 = \left(\frac{V_a + V_b + V_c}{3}\right)$$

This is the input to the non-inverting amplifier whose gain is $\left(1 + \frac{R_f}{R_1}\right)$.

$$\therefore \quad V_0 = \text{gain} \times V_1 = \left(1 + \frac{R_f}{R_1}\right)\left(\frac{V_a + V_b + V_c}{3}\right)$$

Summation Amplifier :

Let $\left(1 + \frac{R_f}{R_1}\right) = n = 3$

$\therefore \quad \frac{R_f}{R_1} = 2$

$\therefore \quad R_f = 2\,R_1$

Thus, suitable value of R_f and R_1 can be selected.

$$\therefore \quad V_0 = \left(1 + \frac{R_f}{R_1}\right)\left(\frac{V_a + V_b + V_c}{3}\right) = 3\left(\frac{V_a + V_b + V_c}{3}\right)$$

$\therefore \quad V_0 = V_a + V_b + V_c$

Average Amplifier :

Let $\left(1 + \frac{R_f}{R_1}\right) = 1$

This is done by making $R_f = 0$ and $R_1 = \infty$, i.e., the op-amp is used as a "Voltage follower".

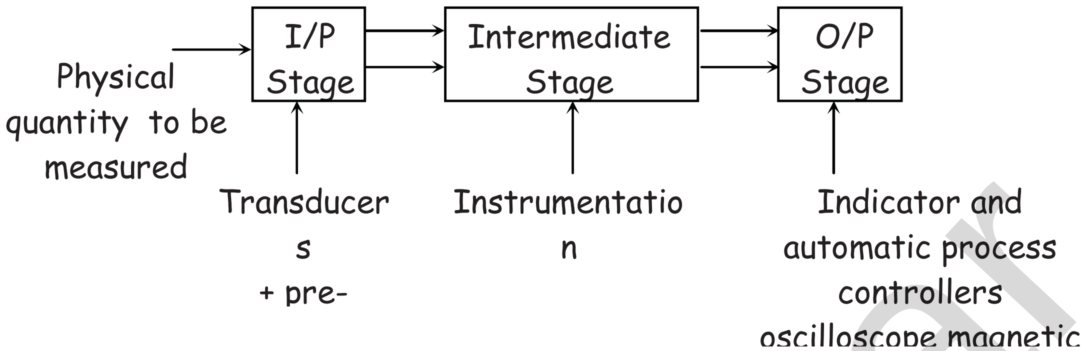
$$\therefore \quad V_0 = \left(1 + \frac{R_f}{R_1}\right)\left(\frac{V_a + V_b + V_c}{3}\right)$$

$$\therefore \quad V_0 = \frac{V_a + V_b + V_c}{3}$$

Note : In case of non-inverting configuration as summing and average amplifier, all the resistors must be same through the various input voltages.
This is not the case in inverting configuration (R_a, R_b, R_c).
Hence, non-inverting mode cannot be used as "SCALING AMPLIFIER".

Q.4(e) Explain process of instrumentation amplifier with any four requirement of instrumentation amplifier. **[4]**

(A) Instrumentation Amplifier



(i) In many industrial application, physical quantities like temperature pressure, humidity, light intensity are required to be measured and controlled. Transducers which convert energy from one form to another form are used for this purpose. e.g. Thermocouple, LDR strain gauge etc. In analogy instrumentation, these transducers are frequently located some distance away from measurement system. The signal levels at the transducer side are often low and their source impedance are high. A special purpose amplifier is required to amplify these signals. These are known as instrumentation amplifier.

(ii) Instrumentation system is used to measured the output signals produced by a transducer and often to control the physical signals producing it.
Many transducer produce output which do not have sufficient strength
To amplify the low-level output produced by transducer is the main function of instrumentation amplifier so that it can driven display or indicator.

(iii) Instrumentation system consist of 3 blocks Input stage is transducers and pre-amplifier which is used to convert physical quantity in to electrical signal. This signal is amplified by pre-amplifier 2nd stage is instrumentation amplifier. As output of first is very low level signal which can not drive output stage so it is amplified by instrumentation amplifier and then given to output stage which may be indicator, records etc.

Requirement of Instrumentation Amplifier

1) **Precise low level signal Amplification :** Instrumentation Amplifier is expected to amplify signals of very small amplitudes, gain should be high, accurate and stable.
2) **Low noise :** Instrumentation amplifier is a differential amplifier so it rejects noise so low noise.

3) **Low thermal drift** : Parameter of instrumentation amplifier should not change due to temperature variations.
4) **High input resistance** : Instrumentation Amplifier must have a very high input impedance to avoid loading of input source.
5) **Accurate closed loop gain and easy gain adjustment** : Closed loop gain should be accurate as well as adjustable using potentiometer
6) **Low power dissipation** : Power consumption should be as low as possible.
7) **High CMRR** : High CMRR in order to reject common mode noise at the input of instrumentation amplifier.
8) **High slew rate** : Transducer output are fast varying signals (high frequency signals). So slew rate of op-amplifier should be high to ensure maximum undistorted output voltage swing.

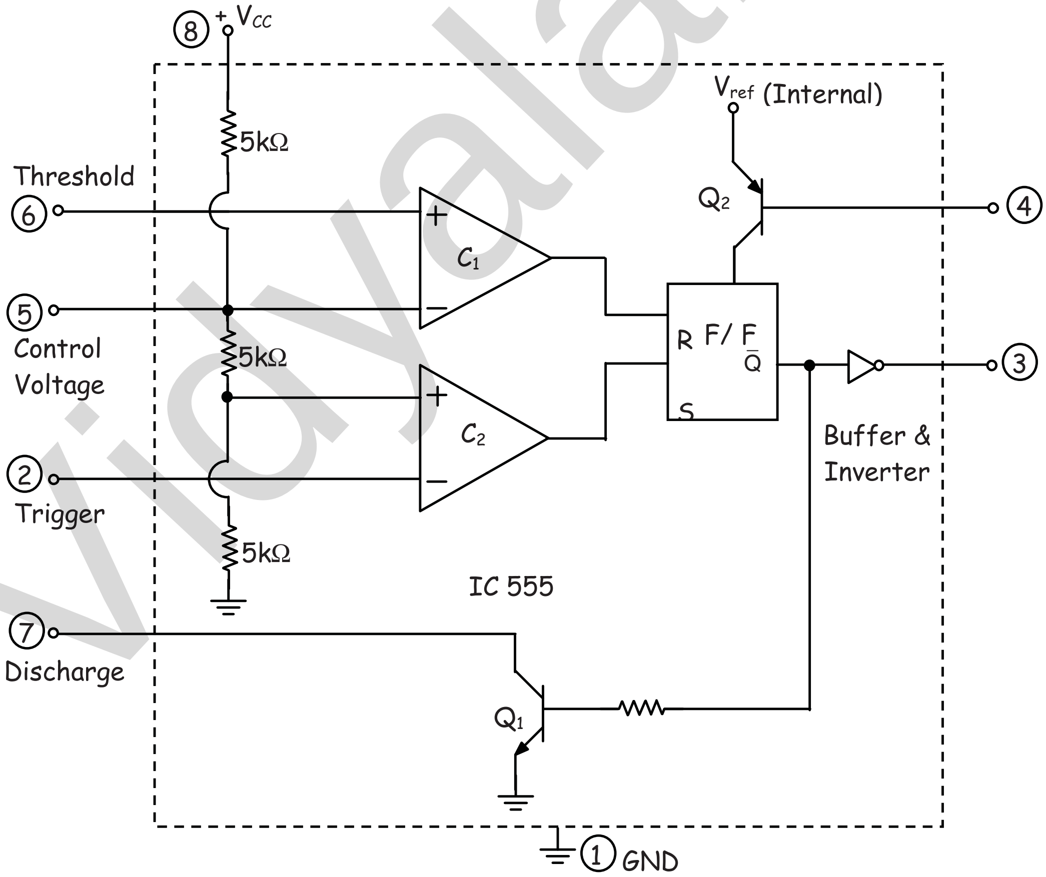
Q.5 Attempt any FOUR of the following : [16]

Q.5(a) With neat block diagram explain operation of Time ic 555. [4]

(A) BLOCK OF DIAGRAM OF IC 555 AND ITS OPERATION

Timer IC 555

Functional diagram



The important internal block of the I.C. are

(i) 2 No. of comparators : (a) Thresh–hold comparator C_1,
(b) Trigger comparator C_2.

(ii) R–S F/F
(iii) Buffer cum inverter
(iv) 2 Transistors :
    (a) Discharge transistor Q_1,   (b) Reset Transistor Q_2.
(v) Potential divider formed by 3 equal value 5kΩ resistors.

Operation : When the supply is given, the output depends upon the voltages at pin no.2 (trigger) and 6 (thresh–hold). If $V_2 > 1/3\ V_{CC}$ and $V_6 < \frac{2V_{CC}}{3}$ are satisfied at the start, the output of C_1 and C_2 are low, the F/F is reset. The output $v_0 = 0$ and the circuit is in quiscent state. The internal Transistor Q_1 is in saturation which clamps the pin 7 (discharge) to the ground potential. This prevents C_{EXT}. from charging towards $+V_{CC}$. Normally the quiscent condition is achieved by connecting pin 2 to $+V_{CC}$ through a resistor. Pin No.6 is connected to ground, through C_{EXT}. (or R) .

Now to initiate, a negative going trigger pulse is given to pin 2 and its voltage is brought below $v_{CC}/3$. The output of C_2 goes high, thus S = 1 and R = 0. This sets the F/F. $\bar{Q}$ of F/F goes low, internal transistor Q_1 is cut–off and allows C_{EXT} to charge. At the same time $v_0 = +V_{CC}$ due to inverter. Normally pin No.6 is also tied to C_{EXT}. When the C_{EXT}. charges to (2/3) V_{CC}, C_1 comparator output goes high, making S = 0 and R = 1. The F/F is reset and its output $\bar{Q}$ =1. The final output at pin No.3 once again becomes 0 volt. The internal Transistor Q_1 goes into saturation and C_{EXT}. starts discharging through internal Q_1 and some R_{EXT} connected at pin no.7.

Thus basically pin no.2 controls the trigger comparator and voltage at pin No.6 controls the thresh–hold comparator C_1. The output of these 2 comparators are used to control i..e set or reset the F/F. If F/F is reset then final $v_0 = 0$ and internal Q_1 is in saturation. On the other hand if F/F is set then $v_0 = +V_{CC}$ and internal Q_1 is cut–off.

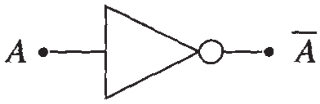
By connecting different components in different manners at pin nos. 2, 6, and 7, the I. C. can be used as Astable, Monostable, Bistable multivibrator, Schmitt trigger. Similarly varying the voltage at pin no.5 (control voltage), the circuit can be used as a voltage to frequency converter. By giving a negative pulse at pin No.4(Reset) and bringing it down to below +0.4v (Normally this pin is held at $+V_{CC}$), any ongoing operation can be curtailed at any instant.

Q.5(b) Give the symbol, truth table and function for the following gates. [4]
(i) NOT (ii) OR (iii) AND (iv) NOR

(A) (i) NOT gate :

Consider a binary variable A. The NOT operation transforms A into the output NOT(A) with the following effect :

If A = 0, then NOT (A) = 1;
If A = 1, then NOT (A) = 0.

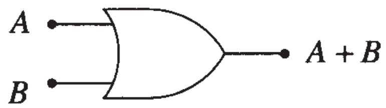


Inverter symbol

Inpu ↓ Outpu ↓

A	$\overline{A}$
0	1
1	0

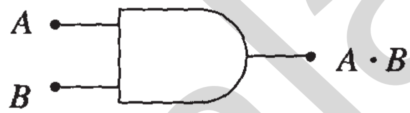
(ii) OR Gate :



A	B	$A + B$
0	0	0
0	1	1
1	0	1
1	1	1

Y = A + B

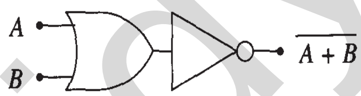
(iii) AND Gate :



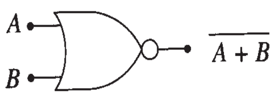
A	B	$A \cdot B$
0	0	0
0	1	0
1	0	0
1	1	1

Y = A · B

(iv) NOR Gate :



(a) NOT–OR cascade



(b) NOR gate symbol

A	B	$\overline{A+B}$
0	0	1
0	1	0
1	0	0
1	1	0

$Y = \overline{A+B}$

Q.5(c) Prove the following logic expression using Boolean algebra. [4]

AB + CD = (A + C) (A + D) (B + C) (B + D)

(A) B + CD = (A + C) (A + D) (B + C) (B + D)

RHS = (A + C) (A + D) (B + C) (B + D)

= (AA + AD + AC + CD) (BB + BD + BC + CD)

= (A + AD + AC + CD) (B + BD + BC + CD) … (A · A = A)

= [A (1 + D + C) + CD] [B (1 + B + C) + CD]

= (A + CD) (B + CD) … (∵ 1 + B + C = 1 AND 1 + D + C = 1)

$= AB + ACD + BCD + CD$ ... ($\because$ $CD \cdot CD = CD$)

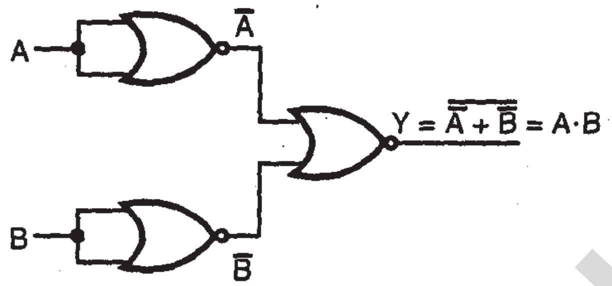
$= AB + CD\,(A + B + 1)$ ... ($\because$ $A + B + 1 = 1$)

$= AB + CD$ ... ($\because$ $A + B + 1 = 1$)

$\therefore$ RHS = LHS ... Hence proved.

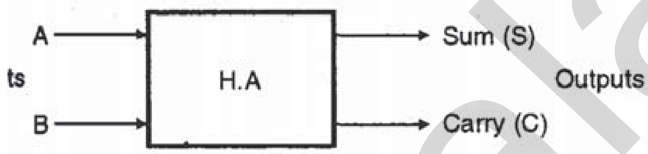
Q.5(d) Design AND using NOR gate. **[4]**

(A)



Q.5(e) Design a Half adder, using K-map. **[4]**

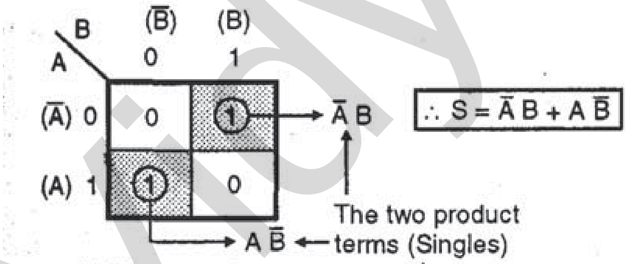
(A)



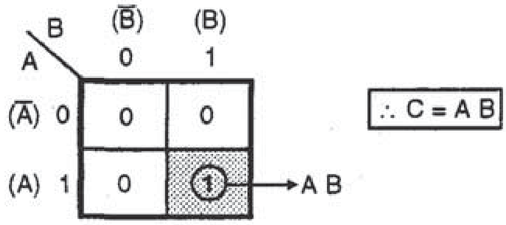
(a) Block diagram

Inputs		Outputs	
A	B	Sum	Carry
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

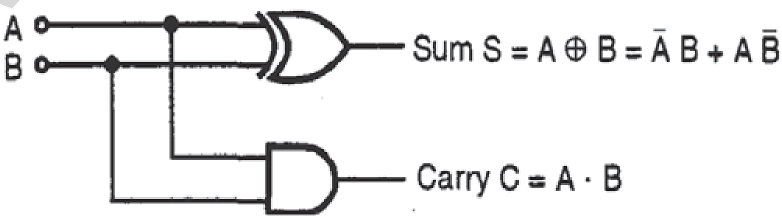
(b) Truth table



(a) K - map for sum output



(b) K - map for carry output



Q.6 Attempt any FOUR of the following : [16]

Q.6(a) Define transducer & classified on the basic of active type and passive type. [4]

(A) Transducer

Definition

- Transducer is a device which converts a physical quantity to be measured into an equivalent electrical signal (voltage or current).
- The physical quantity to be measured can be temperature, pressure, displacement, flow, vibration etc.
- The electrical signal obtained from the transducer is then used to control the physical quantity automatically and / or to display the same, as shown in figure.

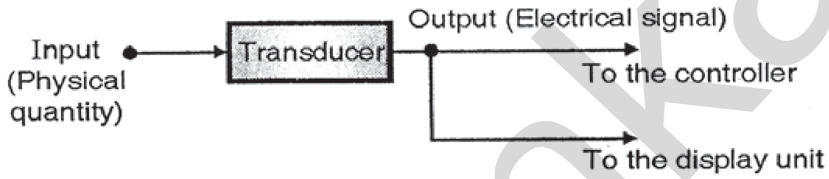


Fig. : Transducer

Classification of Transducers:

Active or Passive Transducers

(i) Active transducers:

- These transducers do not need any external source of power for their operation. Therefore they are also called as self generating type transducers.
- The active transducers are self generating devices which operate under the energy conversion principle.
- At the output of active transducers we get an equivalent electrical output signal e.g. temperature to electric potential, without any external source of energy being used.
- Typical examples of active transducers are:
  - **Piezoelectric sensors:** They generate a charge corresponding to pressure.
  - **Photo voltaic cell:** It produces an emf proportional to the intensity of light incident on it.
  - **Thermocouple:** It produces an emf proportional to the change in temperature.

(ii) Passive transducers:

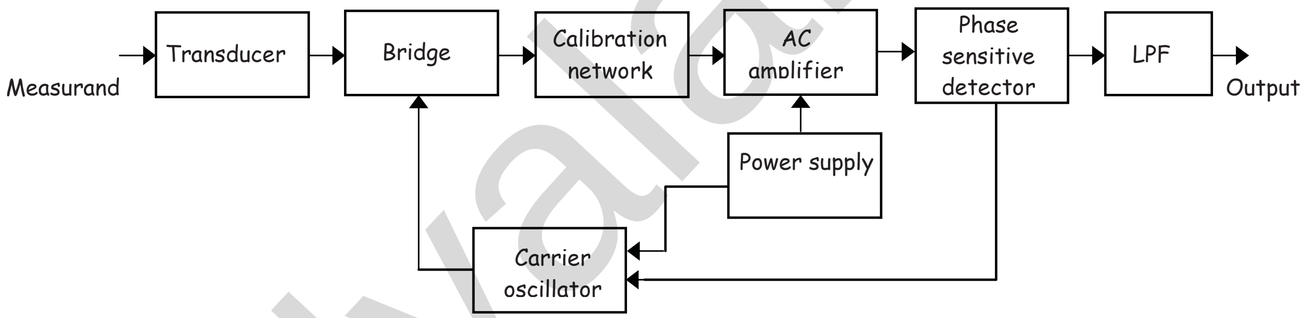
- These transducers need external power supply for their operation. So they are not "self generating type" transducers.
- A DC power supply or an audio frequency generator is used as an external power source.

- These transducers produce the output signal in the form of variation in resistance, capacitance or some other electrical parameter in response to the quantity to be measured.
- Typical examples of passive transducers are as follows:
  - **Strain gauge:** Converts pressure into equivalent change in resistance.
  - **Thermistor:** Converts temperature variations into equivalent resistance changes.
  - **Photodiode:** Converts light intensity into current changes.

Q.6(b) Explain with block diagram "AC signal conditioning system". [4]

(A) *AC Signal Conditioning System:*

- The problem of drift in the dc signal conditioning system can be overcome using an ac signal conditioning system.
- Figure 1 shows the block diagram of an ac signal conditioning system.
- This system is known as ac system using carrier type ac signal.
- Variable resistance or variable inductance type transducers are used in this ac signal conditioning system. The transducer forms one arm of the bridge.



- The ac bridge receives an ac carrier signal from a carrier oscillator which operates at a frequency between 50 kHz and 200 kHz. The carrier frequencies are at least 5 to 10 times higher than the signal frequencies.
- The output of transducer is applied to the bridge circuit. The output of this bridge is an amplitude modulated carrier signal.
- An ac amplifier is used to amplify this amplitude modulated signal. An ac amplifier is RC coupled amplifier or transformer coupled amplifier.
- The amplifier output is applied to a phase sensitive demodulator (detector). The phase sensitive detector produces a dc signal which indicates the direction of parameter change in the bridge output.

Advantages :

(i) No frequency drift problem
(ii) No spurious signal is present

Disadvantage:

(i) It is difficult to obtain a stable carrier oscillator frequency.

Q.6(c) Describe "AC tachogenerator". **[4]**

(A) AC tachogenerator :

Constructionally AC tachogenerator is similar to 2ϕ induction motor having stator & rotor as main components.

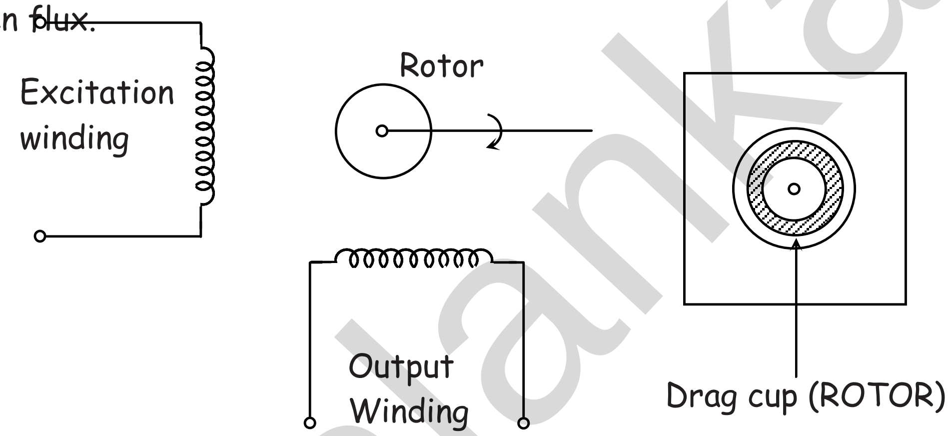
Stator has 2 windings 90° apart from each other. One winding is called excitation winding & the other winding is known as o/p winding.

The rotor can be of any one of the following types.

(i) High resistance required cage type

(ii) Drag cup type.

When excitation voltage is applied to excitation winding then it produces flux. Thus flux induces emf in rotor winding & in turn rotor winding produces its even flux.



Since the combine flux of excitation & rotor winding don't have any component along the axis of o/p winding, the o/p voltage is zero when rotor is stationary.

Q.6(d) Explain procedure of "LVDT" with neat sketch. **[4]**

(A) LVDT : LINEAR VARIABLE DIFFERENTIAL TRANSFORMER

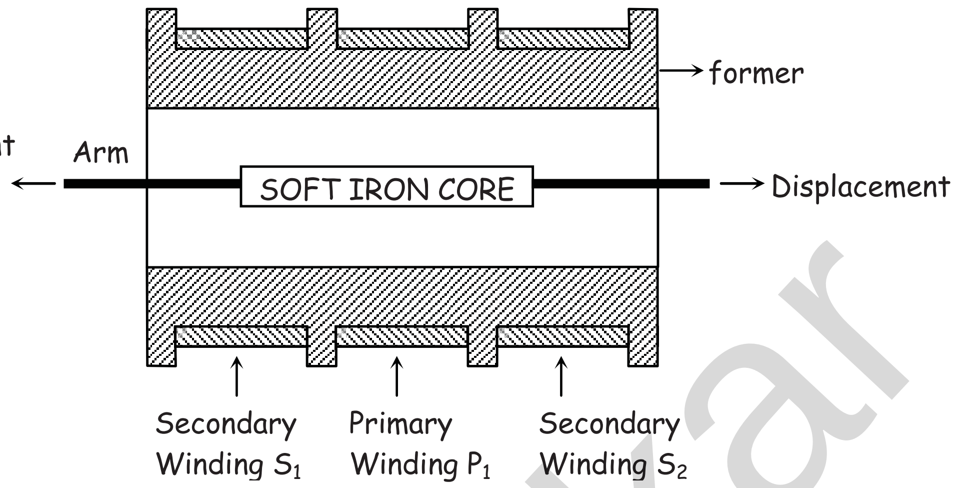
(Used as pressure measurement device & displacement)

It is an inductive passive transducer which convert linear motion or displacement into a electrical signal. Its working principle is similar to that of transformer. It carriers of single primary winding p_1 & two secondary winding S_1 & S_2 & all the windings are wound an cylindrical former. Both secondary winding has equal no. of trans & they are identically place an either side of P in subtractive series connection.

A movable soft iron care is placed inside the former one terminal of each secondary are brought outside.

Working :

As mentioned before the working of LVDT is similar to a transformer. When we apply AC line voltage of 50Hz to 20KHz. Primary winding produced varing flux. This varing flux then links with secondary coil & induces an emf in it. Thus εS_1 emf induces in S_1 & εS_2 emf in S_2.



In order to get single o/p voltage 2 secondary winding S_1 & S_2 are connected in series opposition it means the induced voltage of each winding opposes each other. Thus $e_0 = es_1 - es_2$

When the core is at null position then flux linking with both the secondary winding are equal & hence equal emf are induced in it.

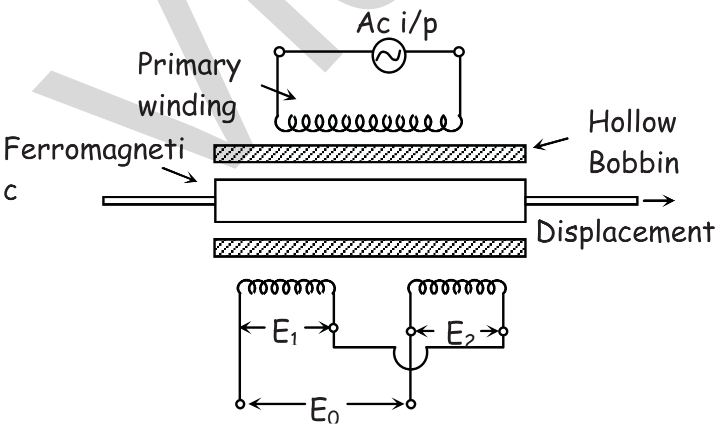
$\therefore \quad e_0 = 0 \;\; \because es_1 = es_2$

Thus if core is more to left from null then more flux link with winding S_1 & less flux with winding S_2.

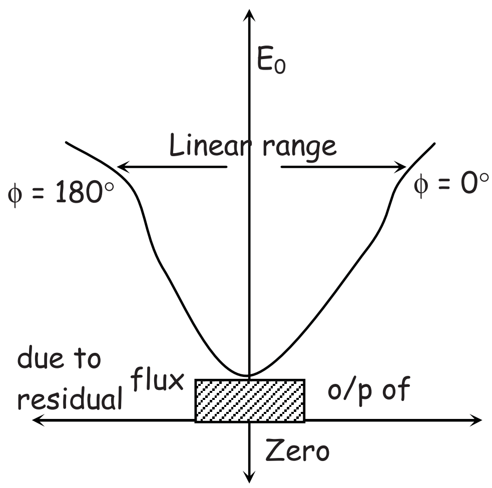
$\therefore \quad es_1 > es_2$

magnitude of o/p voltage is in phase with e_{s_1} similarly when core is more to right from null position then flux linking with S_2 is more than that of winding S_1

$\therefore \quad es_2 > es_1$ & therefore o/p voltage is in phase with es_2 i.e. o/p voltage of secondary winding S_2.



$E_0 = E_1 - E_2$



Centre position of core

Thus o/p voltage of LVDT linearly varies with displacement of core from null position. The figure shows the variation of o/p voltage with respect to displacement. As shown in figure as the core is more in one direction from null position then magnitude of o/p voltage goes on increasing but phase difference remains same i.e. 0. On the other hand when core is moved in other direction from null position then also magnitude of o/p goes on increasing but now phase difference is maintain at 180°.

Thus by comparing magnitude & phase difference of secondary voltage with that of primary voltage then we can easily find out displacement of core.

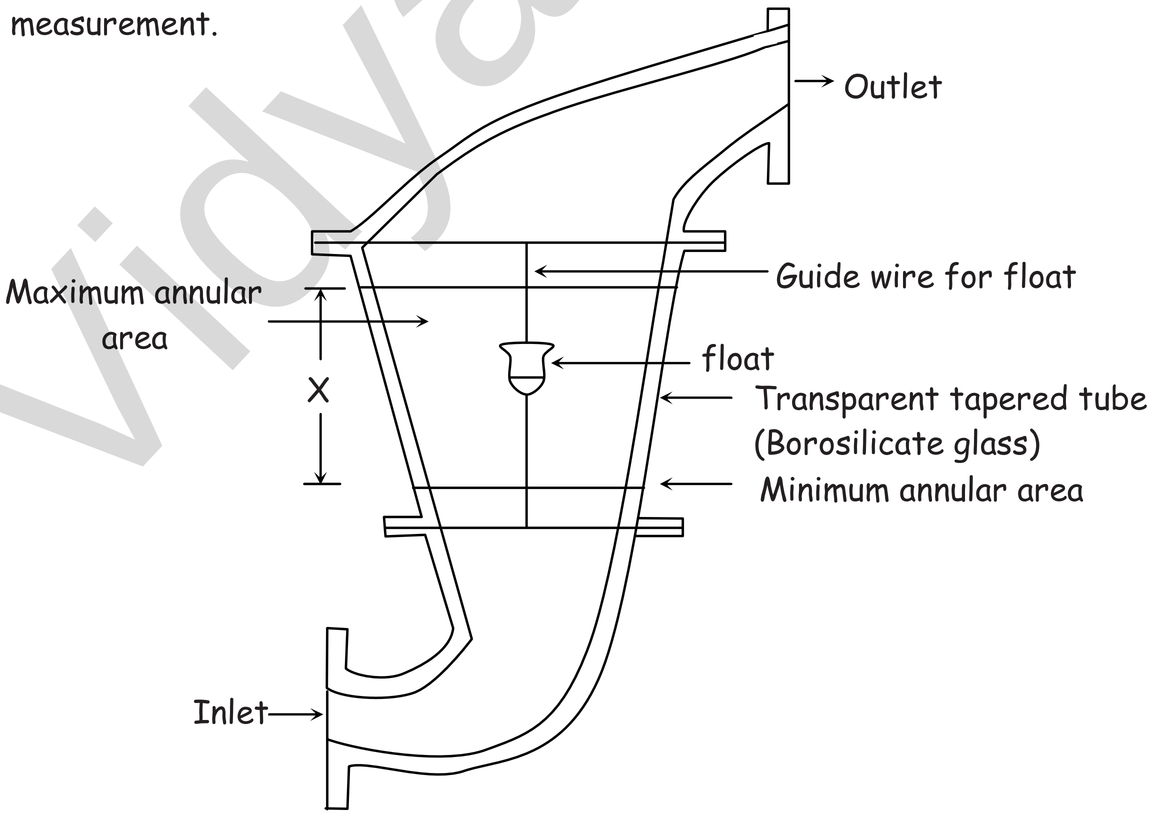
Advantages of LVDT :

(i) Upto displacement of 5mm the o/p voltage of LVDT varies linearly.
(ii) The o/p voltage of LVDT do not varies in step thus it gives better resolution.
(iii) It gives high o/p voltage no need of amplification.
(iv) It has high sensitivity upto 40 V/mm.
(v) Since it do not have any sliding contact ∴ it use or gives less friction.
(vi) It passes very less hysterisis losses.

Q.6(e) Explain with neat sketch. "Rotameter". **[4]**

(A) Rotameter :

Rotameter is a variable area type of flow meter widely used for flow measurement.



It consists of vertical tapered tube with a float which is free to move in up and down direction. The free area between the float and inside wall of the tube is known as annular orifice. The tube is mounted vertically with a small end at the bottom. The fluid whose flow is to be measured enters the tube from bottom and passes upward around a float and leaves from the top.
The venturi tubes are usually made of cast iron or select & are build in several shapes.

Advantages :
(i) Causes low permanent pressure loss.
(ii) Widely used for high flow rates.
(iii) Available in very large pipe sizes.
(iv) Has will known characteristics.
(v) More accurate over wide flow ranges than orifice plates or nozzles.

Disadvantages :
(i) High Cost
(ii) More difficult to inspect due to its construction.
(iii) Limitation of a lower Reynolds number of 150,000.

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