QP code: 25815

Q.1 (a) – DYNAMIC CHARACTERISTICS OF INSTRUMENTS

(i) **Speed of Response :-** It is the rapidity with which the instrument responds to changes in the measured quantity being measured.

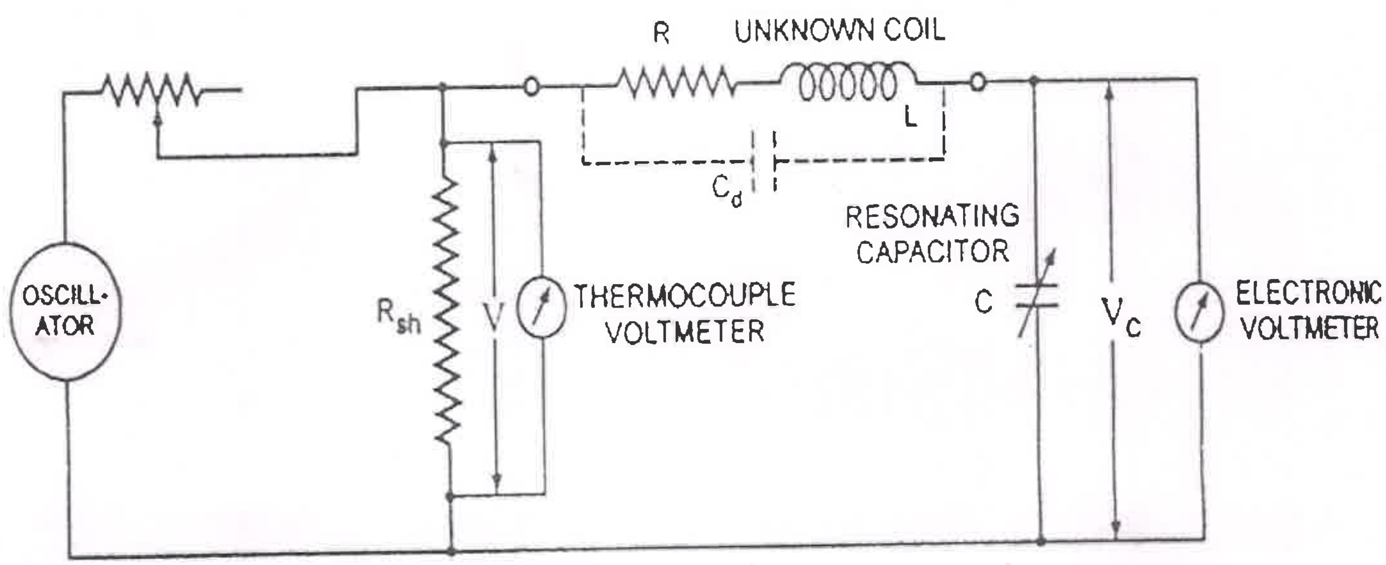
(ii) **Fidelity :-** It is the degree to which, instrument indicates the changes in the measured variable without any dynamic error (faithful reproduction).

(iii) **Lag (Delay) :-** It is the retardation or delay in the response of an instrument to changes in the measured variable.

(iv) **Dynamic Error :-** It is the difference between the true value of a quantity changing with time & the value indicated by the instrument, if no static error is assumed.

The dynamic response is determined by nature of the input excitation – step, linear or sinusoidal change.

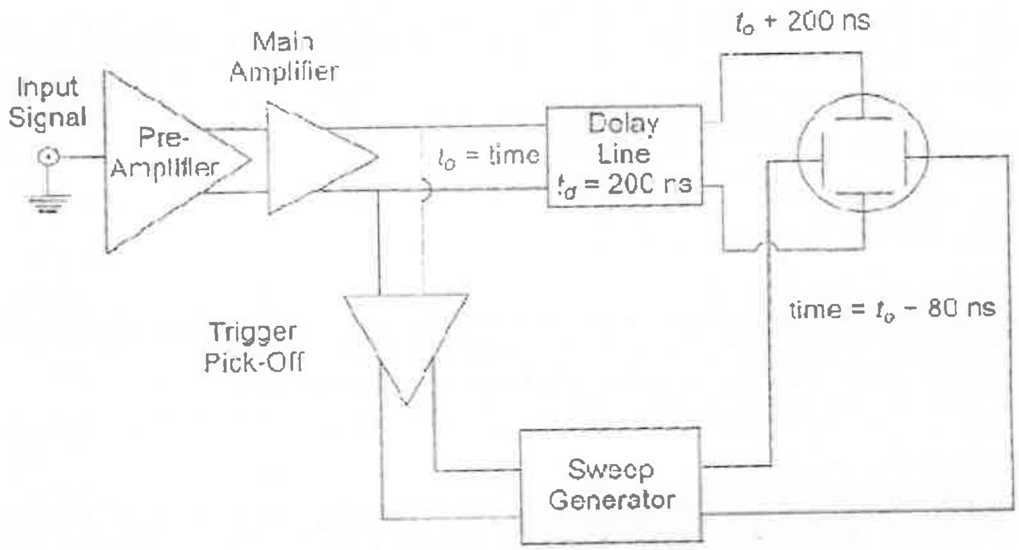
Q.1 (b) – LCR – Q METER CONSTRUCTION & OPERATION



- Internally, a minimal Q meter consists of tune-able RF generator with a very low (pass) impedance output and a detector with a very high impedance input.
- There is usually provision to add a calibrated amount of high Q capacitance across the component under test to allow inductors to be measured in isolation.
- The generator is effectively placed in series with the tuned circuit formed by the components under test and having negligible output resistance, does not materially affect the Q factor.
- The detector measures the voltage developed across one element (usually the capacitor) and being high impedance in shunt does not affect the Q factor significantly either.
- Ratio of developed RF voltage to applied RF current with knowledge of reactive impedance from resonant frequency & source impedance allows Q factor to be directly read by scaling the voltage.

Q.1 (c) – NEED / FUNCTION OF DELAY LINE IN C.R.O.

The diagram shows that when the delay line is not used, the initial part of the signal is lost and only part of the signal is displayed. To counteract this disadvantage the signal is not applied directly to the vertical plates but is passed through a delay line circuit, as shown. This gives time for the sweep to start at the horizontal plates before the signal has reached the vertical plates. The trigger pulse is picked off at a time t_0 after the signal has passed through the pre-amplifier & the main amplifier. The sweep generator delivers the sweep to the horizontal amplifier and the sweep starts at the horizontal deflection plates (HDP) at time t_0 + 80 ns. Hence this ensures the sweep starts well in time, since the signal arrives at the vertical deflection plates (VDP) at the time of t_0 + 200 ns.



Q.1 (d) – HETERODYNE WAVE ANALYZER

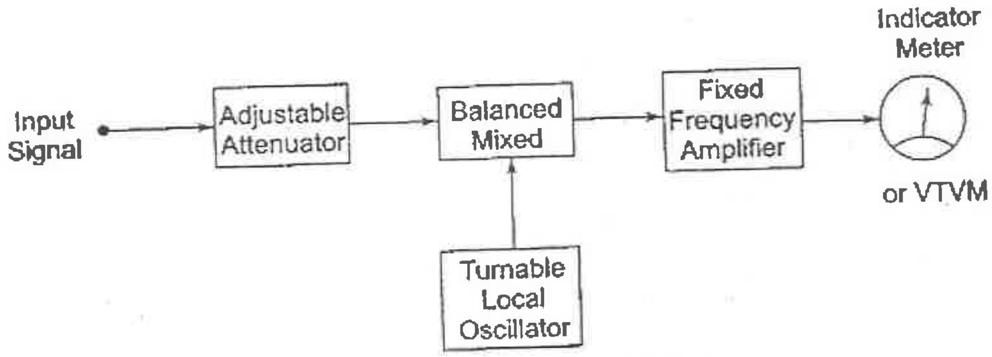


Fig. 9.3 Heterodyne Wave Analyzer

In this wave analyzer, the input signal to be analyzed is heterodyned with the signal from the internal tunable local oscillator in the mixer stage to produce a higher IF frequency. By tuning the local oscillator frequency, various signal frequency components can be shifted within the pass-band of the IF amplifier. The output of the IF amplifier is rectified and applied to the meter circuit. The input signal is heterodyned to the known IF by means of a tunable local oscillator. The amplitude of the unknown component is indicated by the VTVM or output meter. The VTVM is calibrated by means of signals of known amplitude. The frequency of the component is identified by the local oscillator frequency, i.e. the local oscillator frequency is varied so that all the components can be identified. The local oscillator can also be calibrated using input signals of known frequency. The fixed frequency amplifier is a multistage amplifier which can be designed conveniently because of its frequency characteristics. This analyzer has good frequency resolution and can measure the entire AF frequency range. With the use of a suitable attenuator, a wide range of voltage amplitudes can be covered. Their disadvantage is the occurrence of spurious cross-modulation products, setting a lower limit to the amplitude that can be measured.

Q.1 (e) – DIGITAL TIME MEASUREMENT

Q.1 (f) – CLASSIFICATION / TYPES OF TRANSDUCERS

Some of the common methods of classifying transducers are given below :-

- Based on their application.
- Based on the method of converting the non-electric signal into electric signal.
- Based on the output electrical quantity to be produced.
- Based on the electrical phenomenon or parameter that may be changed due to the whole process.

Some of the most commonly electrical quantities in a transducer are resistance, capacitance, voltage, current or inductance. Thus, during transduction, there may be changes in resistance, capacitance and induction, which in turn change the output voltage or current.

- Based on whether the transducer is active or passive.

Q.2 (a) – NUMERICAL EXAMPLE OF STATIC CHARACTERISTICS

Observation No.	Measured Values
1	$d_1 = 10.25$ V
2	$d_2 = 10.05$ V
3	$d_3 = 9.9$ V
4	$d_4 = 9.95$ V
5	$d_5 = 10.15$ V
6	$d_6 = 9.85$ V

(a) Arithmetic Mean (average) is given by the following equation :-

$$\bar{d} = \frac{d_1 + d_2 + d_3 + d_4 + d_5 + d_6}{n}$$ where n = 6 (total no. of observations)

Hence the arithmetic mean (average) of the above observations is 10.025 V

(b) For 4th observation, true value (TV) = 10 V & measured value (MV) = 9.95 V from which the percentage error (% e) can be calculated as follows :-

$$\%e = \left(\frac{TV - MV}{TV}\right) \times 100$$

Hence the percentage error of the fourth (4th) observation is % e = 0.5 %

(c) For 2nd observation, true value (TV) = 10 V & measured value (MV) = 10.05 V from which accuracy (A) can be calculated as follows :-

$$A = 1 - \left|\frac{TV - MV}{TV}\right|$$

Hence the accuracy of the second (2nd) observation is A = 0.995 or % A = 99.5 %

(d) For 5th observation, true value (TV) = 10 V & measured value (MV) = 10.15 V from which precision (P) can be calculated as follows :-

$$P = 1 - \left|\frac{d_5 - \bar{d}}{\bar{d}}\right|$$

Hence the precision of the fifth (5th) observation is P = 0.9875 or % P = 98.75 %

(e) The deviations (x_n) of each individual observations (d_n) can be tabulated as follows :-

Observation No.	Measured Values	Deviation from Mean
1	$d_1 = 10.25$ V	$x_1 = 0.225$ V
2	$d_2 = 10.05$ V	$x_2 = 0.025$ V
3	$d_3 = 9.9$ V	$x_3 = -0.125$ V
4	$d_4 = 9.95$ V	$x_4 = -0.075$ V
5	$d_5 = 10.15$ V	$x_5 = 0.125$ V
6	$d_6 = 9.85$ V	$x_6 = -0.175$ V

The standard deviation (σ) of the above readings can be expressed from the following equation :-

$$\sigma = \sqrt{\frac{x_1^2 + x_2^2 + x_3^2 + x_4^2 + x_5^2 + x_6^2}{n}}$$ where n = 6 (total no. of observations)

Hence the standard deviation is given by σ = 0.1407 V

(f) The average deviation (d_{avg}) can be calculated from the following equation :-

$$d_{avg} = \frac{|x_1| + |x_2| + |x_3| + |x_4| + |x_5| + |x_6|}{n}$$ where n = 6 (total no. of observations)

Hence the average deviation (d_{avg}) for the above set of observations is 0.125 V

Q.2 (b) – WIEN BRIDGE

The Wien bridge shown in Fig. 11.28 has a series *RC* combination in one arm and a parallel combination in the adjoining arm. Wien's bridge in its basic form, is designed to measure frequency. It can also be used for the measurement of an unknown capacitor with great accuracy.

The impedance of one arm is

$Z_1 = R_1 - j/\omega C_1$.

The admittance of the parallel arm is

$Y_3 = 1/R_3 + j\,\omega\, C_3$.

Using the bridge balance equation, we have $Z_1 Z_4 = Z_2 Z_3$.

Therefore, $Z_1 Z_4 = Z_2/Y_3$, i.e. $Z_2 = Z_1 Z_4 Y_3$.

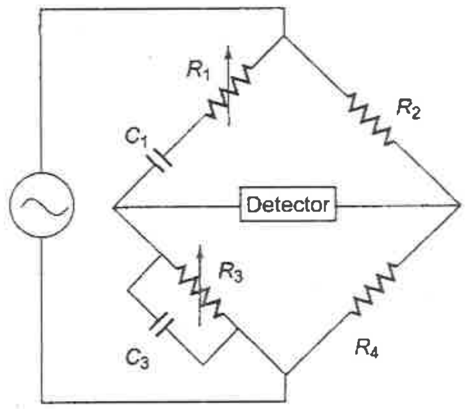


Fig. 11.28 Wein's bridge

$$\therefore \quad R_2 = R_4\left(R_1 - \frac{j}{\omega C_1}\right)\left(\frac{1}{R_3} + j\omega C_3\right)$$

$$R_2 = \frac{R_1 R_4}{R_3} - \frac{j R_4}{\omega C_1 R_3} + j\,\omega\, C_3 R_1 R_4 + \frac{C_3 R_4}{C_1}$$

$$R_2 = \left(\frac{R_1 R_4}{R_3} + \frac{C_3 R_4}{C_1}\right) - j\left(\frac{R_4}{\omega C_1 R_3} - \omega C_3 R_1 R_4\right)$$

Equating the real and imaginary terms we have

$$R_2 = \frac{R_1 R_4}{R_3} + \frac{C_3 R_4}{C_1} \quad \text{and} \quad \frac{R_4}{\omega C_1 R_3} - \omega C_3 R_1 R_4 = 0$$

Therefore $$\frac{R_2}{R_4} = \frac{R_1}{R_3} + \frac{C_3}{C_1} \qquad (11.21)$$

and $$\frac{1}{\omega C_1 R_3} = \omega C_3 R_1 \qquad (11.22)$$

$$\therefore \quad \omega^2 = \frac{1}{C_1 R_1 R_3 C_3}$$

$$\omega = \frac{1}{\sqrt{C_1 R_1 C_3 R_3}}$$

as $\omega = 2\pi f$

$$\therefore \quad f = \frac{1}{2\pi\sqrt{C_1 R_1 C_3 R_3}} \qquad (11.23)$$

Q.3 (a) – CATHODE RAY OSCILLOSCOPE (CRO)

1. Cathode Ray Tube :- It is the heart of the oscilloscope. When the electrons emitted by the electron gun strikes the phosphor screen of the CRT, a visual signal is displayed on the CRT.

2. Vertical Amplifier :- The input signals are amplified by the vertical amplifier. Usually, vertical amplifier is a wide band amplifier which passes the entire band of frequencies.

3. Delay Line :- As the name suggests that, this circuit is used to, delay the signal for a period of time in the vertical section of CRT. The input signal is not applied directly to the vertical plates because the part of the signal gets lost, when delay time not used. Therefore, the input signal is delayed by a period of time.

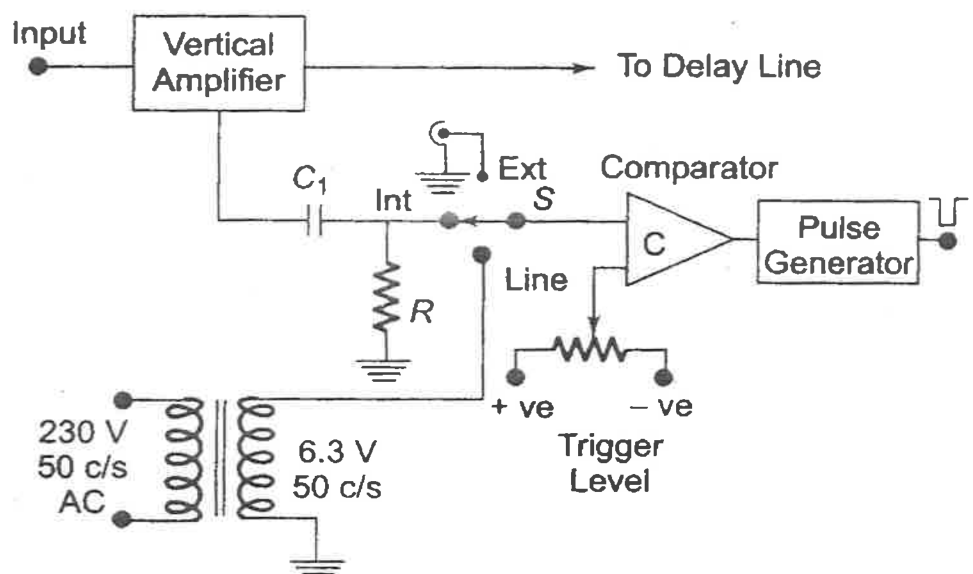
4. Time Base Circuit :- Time base circuit uses a uni-junction transistor, which is used to produce the sweep. The saw tooth voltage produced by the time base circuit is required to deflect the beam in the horizontal section. The spot is deflected by the saw tooth voltage at a constant time dependent rate.

5. Horizontal Amplifier :- The saw tooth voltage produce by the time base circuit is amplified by the horizontal amplifier before it is applied to horizontal deflection plates.

6. Trigger Circuit :- The signals which are used to activate the trigger circuit are converted to trigger pulses for the precision sweep operation whose amplitude is uniform. Hence input signal and the sweep frequency can be synchronized.

The trigger circuit is activated by signals of a variety of shapes and amplitudes, which are converted to trigger pulses of uniform amplitude for the precision sweep operation. If the trigger level is set too low, the trigger generator will not operate. On the other hand, if the level is too high, the UJT may conduct for too long and part of the leading edge of the input signal may be lost.

The trigger selection is a 3-position switch, Internal-External-Line, as shown in Fig. 7.12. The trigger input signal is applied to a voltage comparator whose reference level is set by the Trigger Level control on the CRO front panel.



Q.3 (b) – LISSAJOUS PATTERNS FOR FREQUENCY & PHASE MEASUREMENT

The oscilloscope is a sensitive indicator for frequency and phase measurements. The techniques used are simple and dependable, and measurement may be made at any frequency in the response range of the oscilloscope.

One of the quickest methods of determining frequency is by using Lissajous patterns produced on a screen. This particular pattern results when sine waves are applied simultaneously to both pairs of the deflection plates. If one frequency is an integral multiple (harmonic) of the other, the pattern will be stationary, and is called a Lissajous figure.

In this method of measurement a standard frequency is applied to one set of deflection plates of the CRT tube while the unknown frequency (of approximately the same amplitude) is simultaneously applied to the other set of plates. However, the unknown frequency is presented to the vertical plates and the known frequency (standard) to the horizontal plates. The resulting patterns depend on the integral and phase relationship between the two frequencies. (The horizontal signal is designated as f_h and the vertical signal as f_v.)

Typical Lissajous figures are shown in Figs 7.31 and 7.32 for sinusoidal frequencies which are equal, integral and in ratio.

7.20.1 Measurement Procedure

Set up the oscilloscope and switch off the internal sweep (change to Ext). Switch off sync control. Connect the signal source as given in Fig. 7.33. Set the horizontal and vertical gain control for the desired width and height of the pattern. Keep frequency f_v constant and vary frequency f_h, noting that the pattern spins in alternate directions and changes shape. The pattern stands still whenever f_v and f_h are in an integral ratio (either even or odd). The $f_v = f_h$ pattern stands still and is a single circle or ellipse. When $f_v = 2f_h$, a two loop horizontal pattern is obtained as shown in Fig. 7.31.

To determine the frequency from any Lissajous figure, count the number of horizontal loops in the pattern, divide it by the number of vertical loops and multiply this quantity by f_h (known or standard frequency).

In Fig. 7.31 (g), there is one horizontal loop and 3 vertical loops, giving a fraction of 1/3. The unknown frequency f_v is therefore 1/3 f_h. An accurately calibrated, variable frequency oscillator will supply the horizontal search frequency for frequency measurement. For the case where the two frequencies are equal and in phase, the pattern appears as a straight line at an angle of 45° with the horizontal. As the phase between the two alternating signals changes, the pattern changes

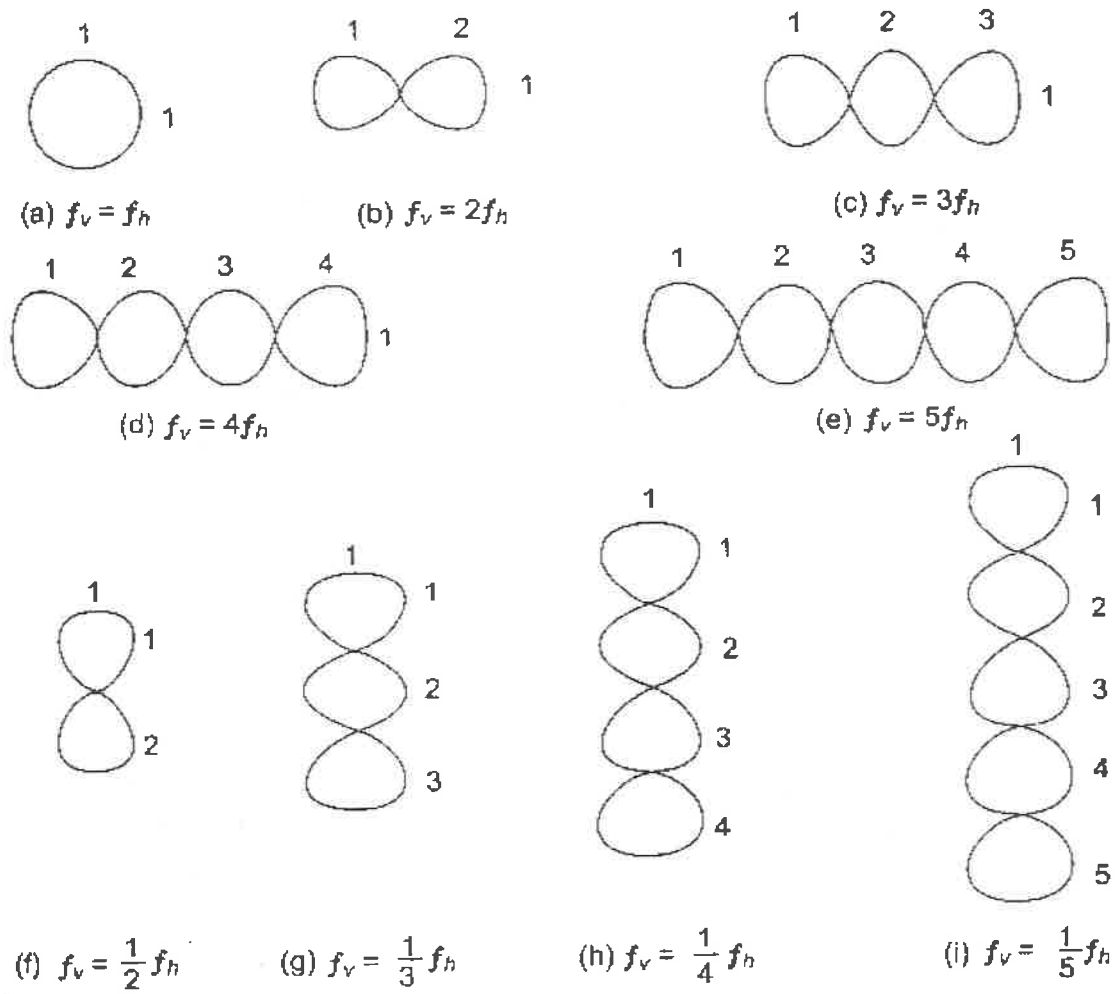


Fig. 7.31 Lissajous patterns for integral frequencies

cyclically, i.e. an ellipse (at 45° with the horizontal) when the phase difference is $\pi/4$, a circle when the phase difference is $\pi/2$ and an ellipse (at 135° with horizontal) when the phase difference is $3\pi/4$, and a straight line pattern (at 135° with the horizontal) when the phase difference is π radians.

As the phase angle between the two signals changes from π to 2π radians, the pattern changes correspondingly through the ellipse-circle-ellipse cycle to a straight line. Hence the two frequencies, as well as the phase displacement can be compared using Lissajous figures techniques.

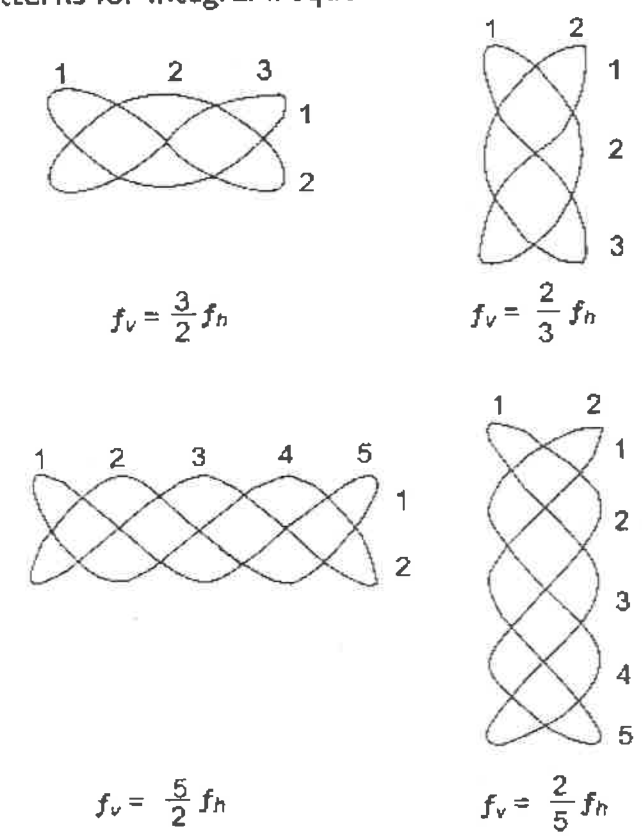


Fig. 7.32 Lissajous patterns for non-integral frequencies

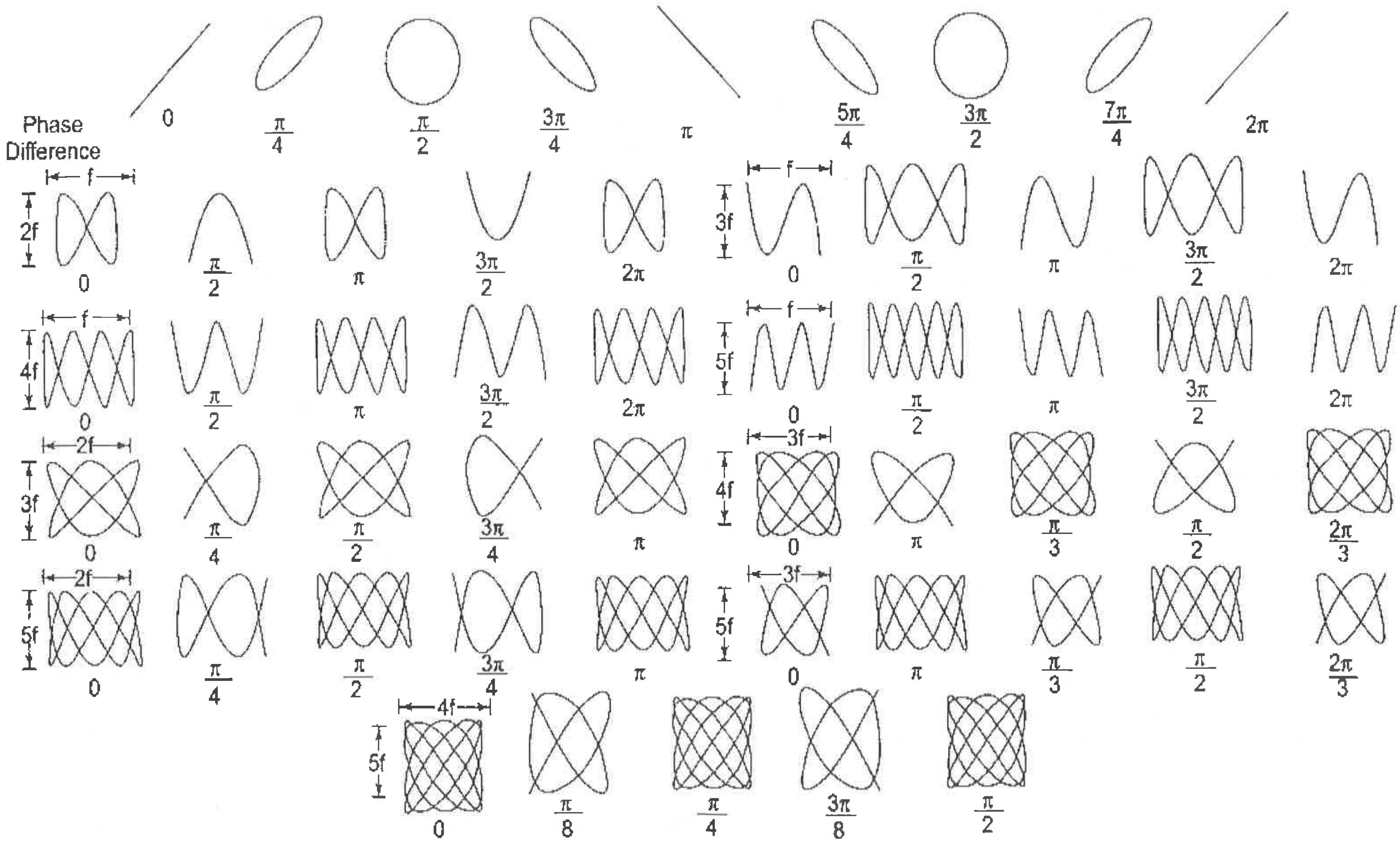


Fig. 7.43 Lissajous pattern

Observing the figure (Fig. 3) the phase angle by Lissajous pattern measurement is given by :-

$$\theta = \sin^{-1}\left[\frac{X_1}{X_2}\right] = \sin^{-1}\left[\frac{Y_1}{Y_2}\right]$$

By observation we have $X_1 = 2.33$ & $X_2 = 5$ hence giving $\mathbf{\theta = 27.813°}$

Q.4 (a) – RAMP TYPE DIGITAL VOLTMETER (DVM)

The operating principle is to measure the time that a linear ramp takes to change the input 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. The operating principle and block diagram of a ramp type DVM are shown in Figs 5.1 and 5.2.

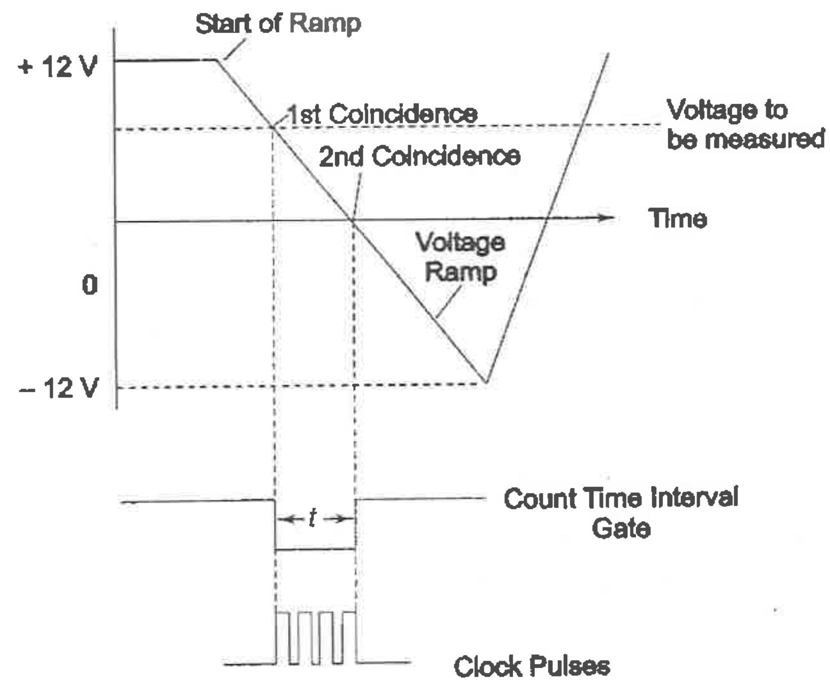


Fig. 5.1 Voltage to time conversion

The ramp may be positive or negative; in this case a negative ramp has been selected.

At the start of the measurement a ramp voltage is initiated (counter is reset to 0 and sampled rate multivibrator gives a pulse which initiates the ramp generator). The ramp voltage is continuously compared with the voltage that is being measured. At the instant these two voltage become equal, a coincidence circuit generates a pulse which opens a gate, i.e. the input 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 output pulse from this comparator closes the gate. The time duration of the gate opening is proportional to the input voltage value.

In the time interval between the start and stop pulses, the gate opens and the oscillator circuit drives the counter. The magnitude of the count indicates the magnitude of the input voltage, which is displayed by the readout. Therefore, the voltage is converted into time and the time count represents the magnitude of the voltage. The sample rate multivibrator determines the rate of cycle of measurement. A typical value is 5 measuring cycles per second, with an accuracy of ± 0.005% of the reading. The sample rate circuit provides an initiating pulse for the ramp generator to start its next ramp voltage. At the same time a reset pulse is generated, which resets the counter to the zero state.

Any DVM has a fundamental cycle sequence which involves sampling, displaying and reset sequences.

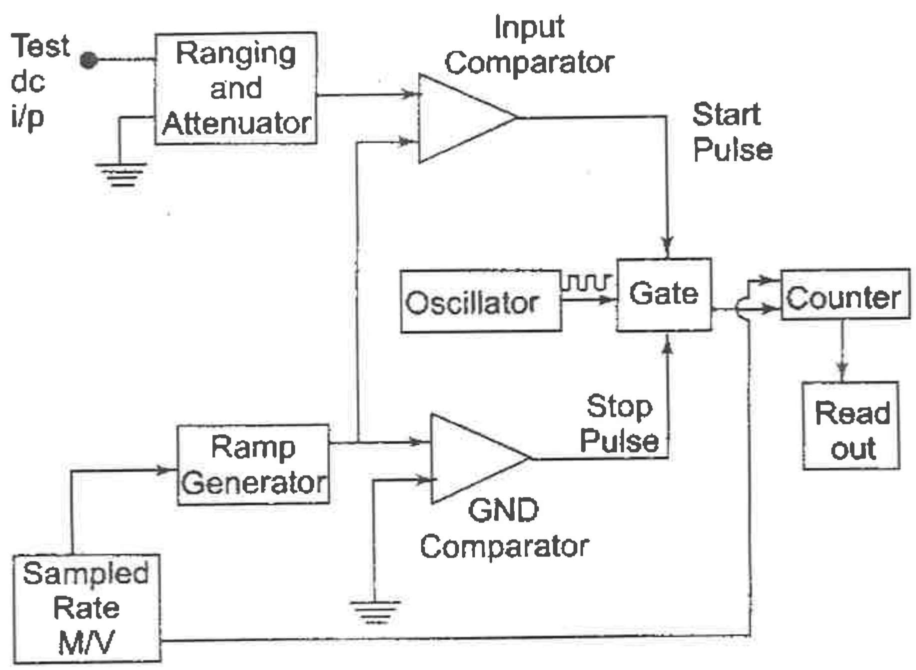
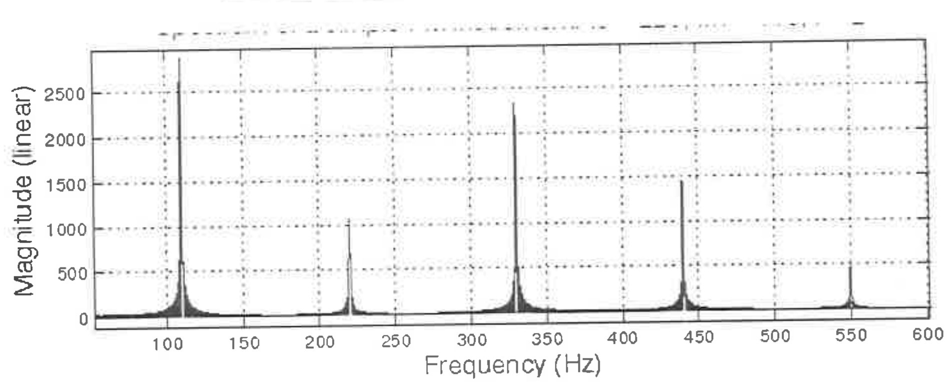


Fig. 5.2 Block diagram of ramp type DVM

Advantages and Disadvantages The ramp technique circuit is easy to design and its cost is low. Also, the output pulse can be transmitted over long feeder lines. However, the single ramp requires excellent characteristics regarding linearity of the ramp and time measurement. Large errors are possible when noise is superimposed on the input signal. Input filters are usually required with this type of converter.

Q.4 (b) – SPECTRUM ANALYZER



oscillator. As the oscillator sweeps from f_{min} to f_{max} of its frequency band at a linear recurring rate, it beats with the frequency component of the input signal and produce an IF, whenever a frequency component is met during its sweep. The frequency component and voltage tuned oscillator frequency beats together to produce a difference frequency, i.e. IF. The IF corresponding to the component is amplified and detected if necessary, and then applied to the vertical plates of the CRO, producing a display of amplitude versus frequency.

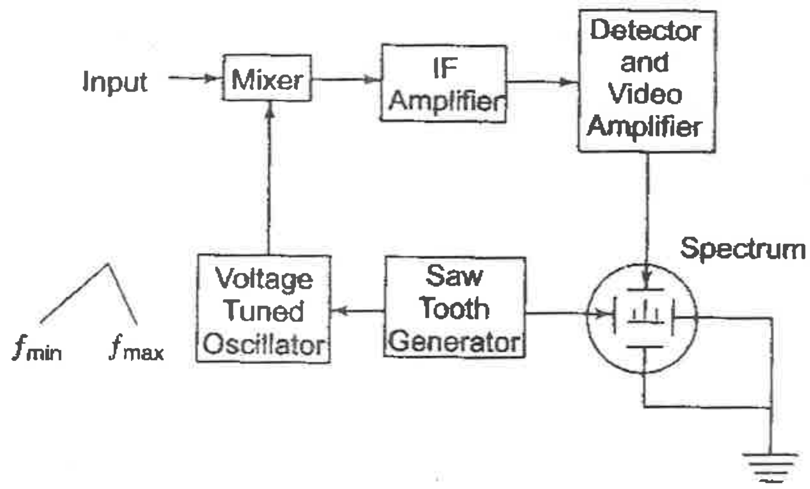


Fig. 9.9 (b) Spectrum analyzer

The spectrum produced if the input wave is a single toned A.M. is given in Figs 9.10, 9.11, and 9.12.

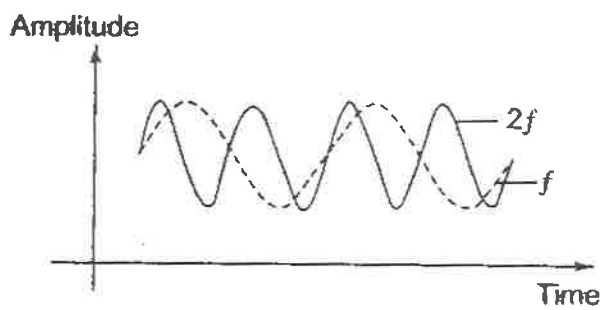


Fig. 9.10 Test wave seen on ordinary CRO

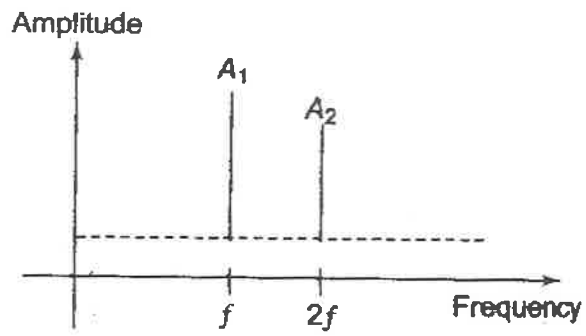


Fig. 9.11 Display on the spectrum CRO

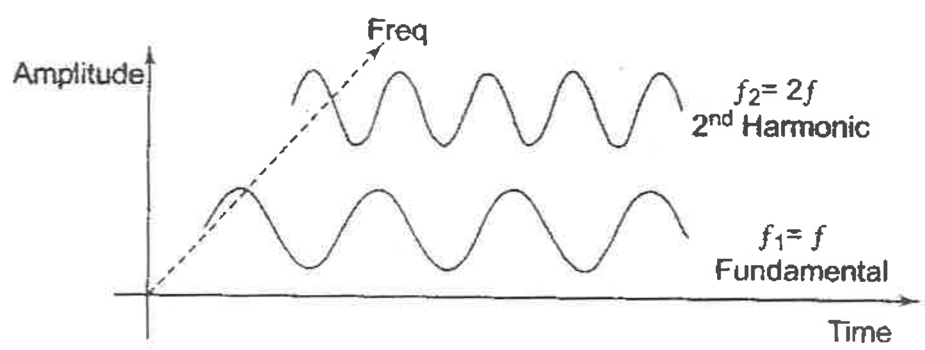


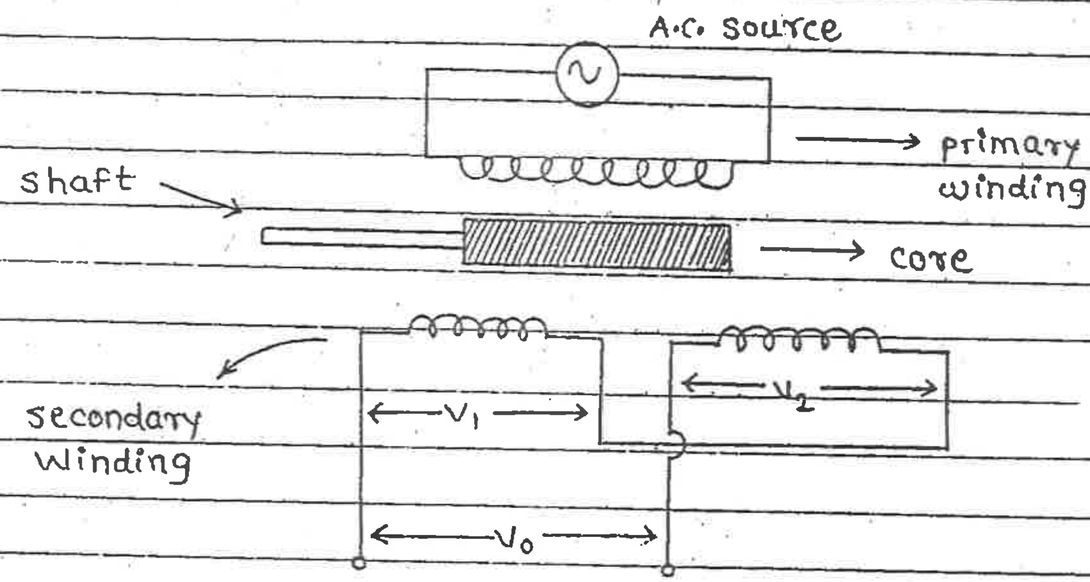
Fig. 9.12 Test waveform as seen on X-axis (Time) and Z-axis (Frequency)

One of the principal applications of spectrum analyzers has been in the study of the RF spectrum produced in microwave instruments. In a microwave instrument, the horizontal axis can display as a wide a range as 2 – 3 GHz for a

Linear Variable Differential Transformer

LVDT is inductive electromechanical transducer converting displacement into change of electrical voltage at output. It operates using Faraday's Laws of electromagnetism that states emf induced in conductor depends upon number of turns of coil and rate of change of flux.

operation :-

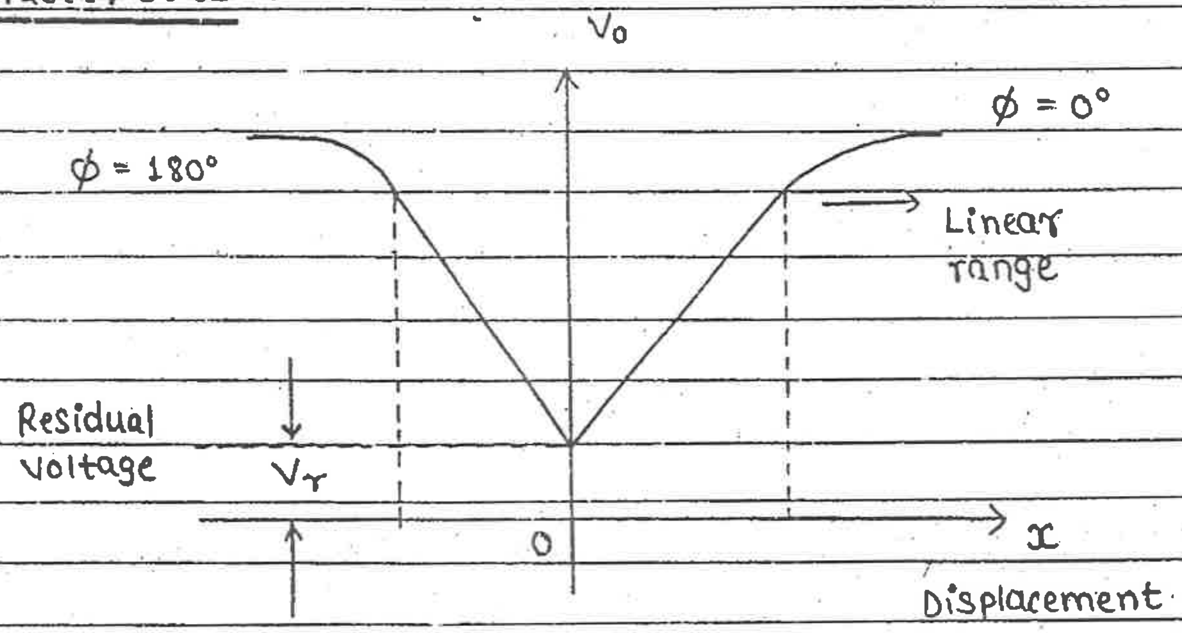


Any physical displacements of the core causes the voltage of one secondary winding to increase while simultaneously reducing the voltage in other secondary winding. Difference of the two voltages appears across output terminals of the transducer and gives measure of the physical position of the core and hence the displacement. when the core is in neutral or zero position, voltages induced in secondary windings are equal and opposite and net output assumed to be negligible. As the core is moved in one direction from the null position, the differential voltage increases maintaining inphase relationship with voltage from input source. In other direction voltage again will increase but will be 180° out of phase with input voltage. Hence with this displacement can be easily determined.

Construction :-

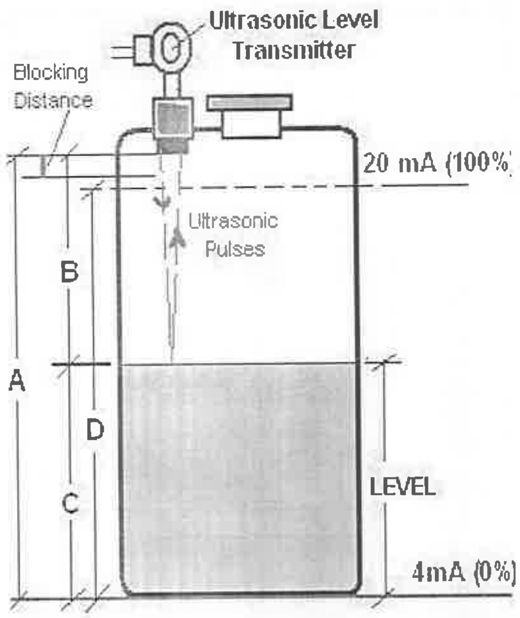
LVDT consists of primary winding and two secondary windings. The windings are arranged next to each other and concentrically. They are wound over hollow bobbin which is usually of non-magnetic and insulating material such as mica or plastic. Ferromagnetic core in shape of rod or cylinder is attached to the sensing shaft. The core slides freely within hollow portion of the bobbin. AC voltage is applied to the primary winding and the moveable core is varying between core and secondary windings.

Characteristics :-



Above graph shows the characteristics for the linear variable differential transformer (LVDT) when displacement is applied in both directions. It can be observed that output voltage increases linearly with displacement on both sides. However after some level of displacement magnetic core saturates causing the characteristics to become nonlinear as shown. often at no displacement some output voltage persists called residual voltage. This occurs because the core cannot align itself exactly in the centre due to frictional losses, wear and tear.

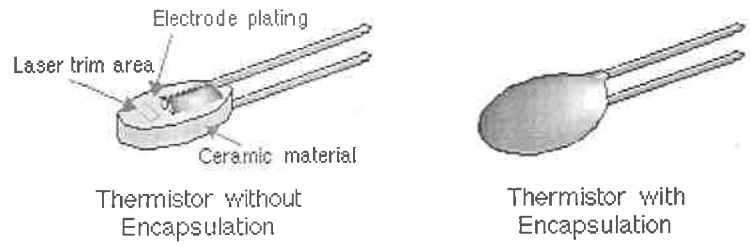
Q.5 (b) – ULTRASONIC LEVEL MEASUREMENT TRANSDUCER



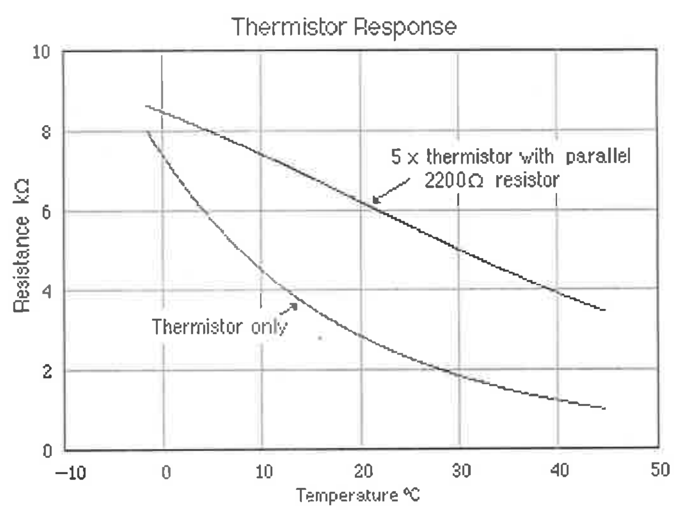
A= Empty Distance, B=Distance of Sensor from Fluid Level
C= Fluid Level , D= Measurement Span

Ultrasonic waves are used to measure level of liquids and solid objects in industries. Ultrasonic level measurement is contactless principle and most suitable for level measurements of hot, corrosive and boiling liquids. The normal frequency range used for ultrasonic level measurements is within a range of 40 200 KHz. Ultrasonic waves detect an object in the same way as RADAR does it. Ultrasonic uses the sound waves, and Radar uses radio waves. When ultrasonic pulse signal is targeted towards an object, it is reflected by the object and echo returns to the sender. The time travelled by the ultrasonic pulse is calculated, and the distance of the object is found. Bats use well known method to measure the distance while travelling. Ultrasonic level measurement principle is also used to find out fish positions in ocean, locate submarines below water level, also the position of a scuba diver in sea. An ultrasonic level transmitter is fixed at the top of a tank half filled with liquid. The reference level for all measurements is the bottom of the tank. Level to be detected is marked as C and B is the distance of the ultrasonic sensor from the liquid level. Ultrasonic pulse signals are transmitted from the transmitter, and it is reflected back to the sensor. Travel time of the ultrasonic pulse from sensor to target and back is calculated. Level C can be found by multiplying half of this time with the speed of sound in air. The measuring unit final result can be centimeters, feet, inches etc.

Q.6 (b) – THERMISTORS



Thermistor temperature sensors are constructed from sintered metal oxide in a ceramic matrix that changes electrical resistance with temperature. They are sensitive but highly non-linear. Their sensitivity, reliability, ruggedness and ease of use, has made them popular in research application, but they are less commonly applied to industrial applications, probably due to a lack on interchangeability between manufactures. Thermistors are available in large range of sizes and base resistance values (resistance at 25°C). Interchangeability is possible to ± 0.05°C although ± 1°C is more common. Mechanically the thermistor is simple and strong, providing the basis for a high reliability sensor. The most likely failure mode is for the lead to separate from the body of the thermistor - an unlikely event if the sensor is mounted securely and with regard to likely vibration. The sintered metal oxide material is prone to damage by moisture, so is passivated by glass or epoxy encapsulation. If the encapsulation is compromised and moisture penetrates, silver migration under the DC bias can eventually cause shorting between the electrodes. Like other temperature sensors, thermistors are often mounted in stainless steel tubes, to protect them from the environment in which they are to operate. Grease is typically used to improve the thermal contact between the sensor and the tube.



A problem with the thermistor is the varying measured temperature resolution that is achieved over the temperature range. Usually resolution is good at lower temperatures, but poor at higher temperatures. If the measuring device has a single scale, this can be an irritating characteristic. One way to simply fix this problem is to connect a resistor in parallel with the thermistor. The resistors value should equal thermistors resistance at mid-range temperature. The result is a significant reduction in non-linearity, as the following diagram illustrates above.