Q.2 a. What are main types of errors in instrumentation system? What are their source, effect and ways to reduce or eliminate these error? Explain in brief. (8)

Answer:
Chapter 3 of "A Course in Electrical and Electronic Measurements and Instrumentation", A K Sawhney.

b. What is difference between accuracy and precision? (4)

Answer:

2.13 ACCURACY AND PRECISION

In ordinary usage, the distinction between words "**Accuracy**" and "**Precision**" is usually very vague. In fact even the dictionaries invariably link the definition of one with the other. But as far as field of measurements is concerned, there is a difference between the two terms as they have sharp differences in meanings. As far as measurements are concerned, the two terms may be defined as :

2.13.1 Accuracy

It is the closeness with which an instrument reading approaches the true value of the quantity being measured. Thus accuracy of a measurement means conformity to truth.

The accuracy may be specified in terms of *inaccuracy or limits of errors* and can be expressed in the following ways :

1. ***Point accuracy.*** This is the accuracy of the instrument only at one point on its scale. The specification of this accuracy does not give any information about the accuracy at other points on the scale or in other words, does not give any information about the general accuracy of the instrument. However, the general accuracy may be given by drawing up a table that specifies the accuracy at a number of points throughout the range of instrument.

2. ***Accuracy as "Percentage of Scale Range".*** When an instrument has uniform scale, its accuracy may be expressed in terms of scale range. For example, the accuracy of a thermometer having a range of 500°C may be expressed as ± 0.5 percent of scale range. This means that the accuracy of the thermometer when the reading is 500°C is $\pm 0.5\%$ which is negligible, but when the reading is 25°C (*i.e.*, 20 percent of scale range), the error is as high as $(500/25) \times (\pm 0.5) = 10$ percent and therefore specification of accuracy in this manner is highly misleading.

3. ***Accuracy as "Percentage of True Value".*** The best way to conceive the idea of accuracy is to specify it in terms of the true value of the quantity being measured *i.e.*, within ± 0.5 per cent of true value. This statement means thus as the readings get smaller so do the errors. Thus at 5 percent of full scale the accuracy of the instrument would be 20 percent better than that of an instrument which is accurate to ± 0.5 % of scale range.

2.13.2 Precision

It is a measure of the reproducibility of the measurements, *i.e.*, given a fixed value of a quantity, precision is a measure of the degree of agreement within a group of measurements. The term '**Precise**' means clearly or sharply defined. As an example of the difference in meaning of the two terms accuracy and precision, suppose that we have an ammeter which possesses high degree of precision by virtue of its clearly legible, finely divided, distinct scale and a knife edge pointer with mirror arrangements to remove parallax. Let us say that its readings can be taken to 1/100 of an ampere. At the same time, its zero, adjustment is wrong. Now every time we take a reading, the ammeter is as **precise** as ever, we can take readings down to 1/100 of an ampere, and the readings are consistent and *"clearly defined"*. However, the readings taken with this ammeter are not **accurate**, since they do not confirm to **truth** on account of its faulty zero adjustment.

Let us cite another example. Consider the measurement of a known voltage of 100 V with a meter. Five readings are taken, and the indicated values are 104, 103, 105, 103 and 105 V. From these values it is seen that the instrument cannot be depended on for an accuracy better than 5% (5 V in this case), while a precision of $\pm 1\%$ is indicated since the maximum deviation from the mean reading of 104 V is only 1.0 V. Thus we find that the instrument can be calibrated so that it could be used to read ± 1 V dependably. This example illustrates that **accuracy** can be improved upon but not the **precision** of the instrument by calibration. Another point which is evident from above is that although the readings are close together they have a small scatter (or dispersion) and thus have a high degree of precision but the results are far from accurate. The precision of an instrument is usually dependent upon many factors and requires many sophisticated techniques of analysis.

Thus, when it is stated that a set of readings shows precision it means that the results agree among themselves. Agreement, however, is no guarantee of accuracy, as there may be some systematic disturbing effect that causes all the measured values to be in error.

c. A 500 V voltmeter is specified to be accurate within +/-1.5% of full scale. Calculate the limiting error when the instrument's used to measure a 150 V source. (4)

Answer:

The magnitude of the limiting error

€ = 0.015 x500

= 7.5 V

The limiting error at 150 V = 7.5/150 x 100 = +/- 5 % 4 marks

Q.3 a. What is Megger? Explain the method for measurement of earth resistors using Megger. (8)

Answer:

2. **Earth tester.** The resistance of earth can be measured by an earth tester shown in Fig. 14.35. The "Earth Tester" is a special type of Meggar (See Art. 9.8 page 256) and it has some additional constructional features additional constructional features and they are :

(*i*) a rotating current reverser, and

(*ii*) a rectifier

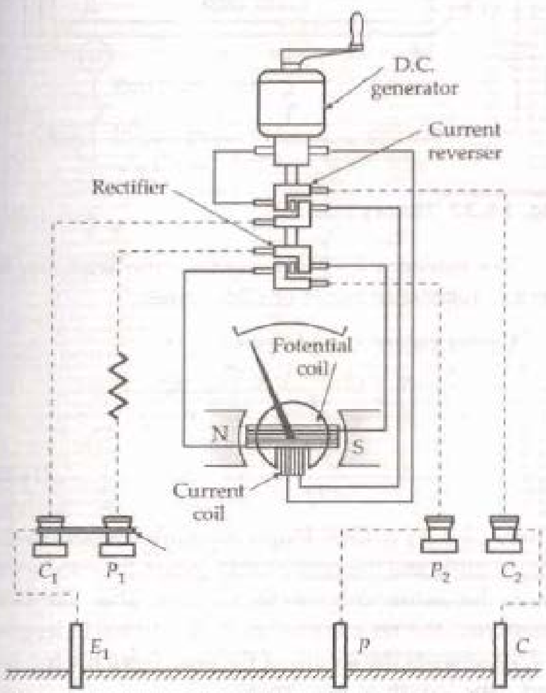

Fig. 14.35 Earth tester.

Both these additional features consist of simple commutators made up of '*L*' shaped segments. They are mounted on the shaft of the hand driven generator. Each commutator has four fixed brushes. One pair of each set of brushes is so positioned that they make contact alternately with one segment and then with the other as the commutator rotates. The second pair of each of set of brushes is positioned on the commutator so that continuous contact is made with one segment whatever the position of the commutator.

The earth tester has four terminals P_1, P_2. Two terminals P_1 and C_1 are shorted to form a common point to be connected to the earth electrode. The other two terminals P_2 and C_2 are connected to auxiliary electrodes *P* and *C* respectively.

The indication of the earth tester depends upon the ratio of the voltage across the pressure coil and the current through the coil. The deflection of its pointer indicates the resistance of earth directly. Although the "Earth Tester", which is a permanent magnet moving coil instrument and can operate on d.c. only, yet by including the reverser and the rectifying device it is possible to make measurements with a.c. flowing in the soil.

The sending of a.c. current through the soil has many advantages and therefore this system is used. The use of a.c. passing through the soil eliminates unwanted effects due to production of a back emf in the soil on account of electrolytic action. Also the instrument is free from effects of alternating or direct currents presents in the soil.

b. Explain the working of Kelvin Double Bridge used for the measurement of low resistance. (8)

Answer:

14.3.2 Kelvin Double Bridge Method of Measurement of Low Resistances

The Kelvin bridge is a modification of the Wheatstone bridge and provides greatly increased accuracy in measurement of low value resistances. An understanding of the Kelvin bridge arrangement may PV be obtained by a study of the difficulties that arise in a Wheatstone bridge on account of the resistance of the leads and the contact resistances while measuring low valued resistors.

Consider the bridge circuit shown in Fig. 14.15 where r represents the resistance of the lead that connects the unknown resistance R to standard resistance S. Two galvanometer connections indicated by dotted lines, are possible. The connection may be either to point 'm' or to point 'n'. When the galvanometer is connected to point m, the resistance, r, of the connecting leads is added to the standard resistance S, resulting in indication of too low an indication for unknown resistance R. When the connection is made to point n, the resistance, r, is added to the unknown resistance resulting in indication of too high a value for R.

Suppose that instead of using point m, which gives a low result, or n, which makes the result high, we, make the galvanometer connection to any intermediate point 'd' as shown by full line in Fig. 14.16. If at point 'd' the resistance r is divided into two parts, r_1 and r_2, such that

$$\frac{r_1}{r_2} = \frac{P}{Q} \qquad ...(14.36)$$

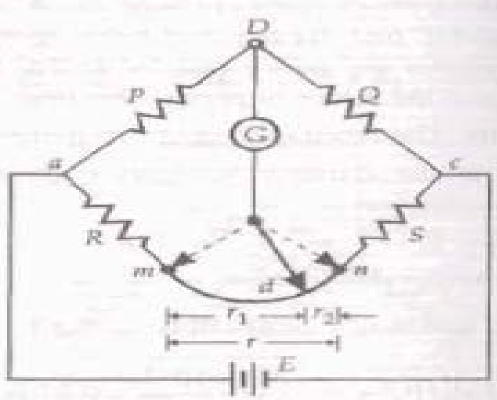

Fig. 14.16 Illustrating principle of Kelvin's bridge.

Then the presence of r_1 the resistance of connecting leads, causes no error in the result. We have,

$$R + r_1 = \frac{P}{Q}\cdot(S + r_2) \quad \text{but} \quad \frac{r_1}{r_2} = \frac{P}{Q} \qquad ...(14.37)$$

or $$\frac{r_1}{r_1+r_2} = \frac{P}{P+Q}$$

or $$r_1 = \frac{P}{P+Q}\cdot r$$

as $r_1 + r_2 = r$ and $r_2 = \frac{Q}{P+Q}\cdot r$

$\therefore$ We can write Eqn. 14.37 as

$$\left(R+\frac{P}{P+Q}r\right) = \frac{P}{Q}\left(S+\frac{Q}{P+Q}r\right)$$

or $$R = \frac{P}{Q}\cdot S \qquad ...(14.38)$$

Therefore we conclude that making the galvanometer connection as at *c* the resistance of leads does not affect the result.

The process described above is obviously not a practical way of achieving the desired result, as there would certainly be a trouble in determining the correct point for galvanometer connections. It does, however, suggest the simple modification, that two actual resistance units of correct ratio be connected between points *m* and *n*, the galvanometer be connected to the junction of the resistors. This is the actual Kelvin bridge arrangement, which is shown in Fig. 14.17.

The Kelvin double bridge incorporates the idea of a second set of ratio arms – hence the name double bridge – and the use of four terminal resistors for low resistance arms. Figure 14.17 shows the schematic diagram of the Kelvin bridge. The first of ratio arms is *P* and *Q*. The second set of ratio arms, *p* and *q* is used to connect the galvanometer to a point *d* at the appropriate potential between points *m* and *n* to eliminate the effect of connecting lead of resistance *r* between the known resistance, *R*, and the standard resistance, *S*.

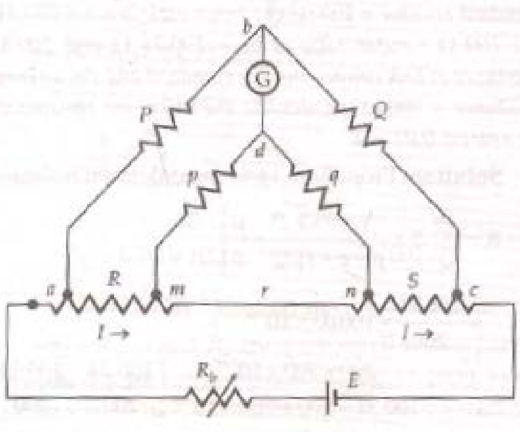

Fig. 14.17 Kelvin double bridge

The ratio p/q is made equal to P/Q. Under balance conditions there is no current through the galvanometer, which means that the voltage drop between *a* and *b*, E_{ab} is equal to the voltage drop E_{amd} between *a* and *c*.

Now $$E_{ab} = \frac{P}{P+Q}E_{ac}$$

and $$E_{ac} = I\left[R+S+\frac{(p+q)r}{p+q+r}\right] \qquad ...(14.39)$$

and $$E_{amd} = I\left[R+\frac{p}{p+q}\left\{\frac{(p+q)r}{p+q+r}\right\}\right]$$

$$= I\left[R+\frac{pr}{p+q+r}\right] \qquad ...(14.40)$$

For zero galvanometer deflection,

$$E_{ab} = E_{amd}$$

or $$\frac{P}{P+Q}I\left[R+S+\frac{(p+q)r}{p+q+r}\right] = I\left[R+\frac{pr}{p+q+r}\right]$$

or $$R = \frac{P}{Q}\cdot S + \frac{qr}{p+q+r}\left[\frac{P}{Q}-\frac{p}{q}\right] \qquad ...(14.41)$$

Now, if $P/Q = p/q$, Eqn. 14.41 becomes,

$$R = \frac{P}{Q}\cdot S. \qquad ...(14.42)$$

Equation 14.42 is the usual working equation for the Kelvin bridge. It indicates that the resistance of connecting lead, *r*, has no effect on the measurement, provided that the two sets of ratio arms have equal ratios. Equation 14.41 is useful, however, as it shows the error that is introduced in case the ratios are not exactly Ω equal. It indicates that it is desirable to keep *r* as small as possible in order to minimize the errors in case there is a difference between ratios P/Q and p/q.

The effect of thermo-electric emfs can be eliminated by making another measurement with the battery connections reversed. The true value of *R* being the mean of the two readings.

In a typical Kelvin bridge, the range of resistance covered is 0.1 μΩ to 1.0 Ω.

The accuracies are as under :

From 1000 μΩ to 1.0 Ω : 0.05%.

From 100 μΩ to 1000 μΩ : 0.2% to 0.05%.

From 10 μΩ to 100 μΩ : 0.5%. to 0.2,

limited by thermoelectric emfs.

In this bridge there are four internal resistance standards of 1 Ω, 0.1 Ω, 0.01 Ω and 0.001 Ω respectively.

Q.4 a. Explain the operating Principal of Digital PH meter. (4)

Answer:

The measurement of hydrogen ion activity (pH) in a solution can be accomplished with the help of a pH meter. For those unfamiliar with the terminology, a very brief review is included.

pH is a quantative measure of acidity. If the pH is less than 7, the solution is acidic (the lower the pH, the greater the acidity). A neutral solution has a pH of 7 and alkaline (basic) solutions have a pH greater than 7.

The pH unit is defined as

$$pH = -\log(\text{concentration of } H^+)$$

where H^+ is the hydrogen or hydronium ion. (Analog pH meters are discussed in Chapter 10.)

A digital pH meter differs from an ordinary pH meter, in this the meter is replaced by an analog to digital converter (ADC) and a digital display. A frequently used ADC for this application is the dual slope converter. A basic block diagram of a digital pH meter is shown in Fig. 6.20.

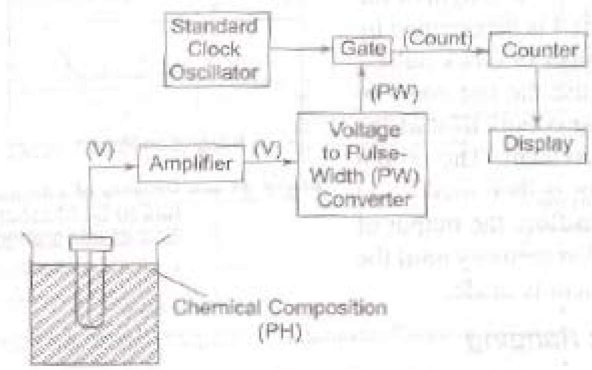

Fig. 6.20 Digital pH Meter

The dual slope circuit produces a pulse which has a duration proportional to the input signal voltage, that is, a *T* pulse width signal. The pulse width is converted to a digital signal using the pulse to turn an oscillator On or Off, generating a count digital signal. The count signal is in turn counted or converted to a parallel digital signal for display by the counter.

b. A coil with resistance of 10Ω is connected in the 'direct measurement' mode. Resonance occurs when oscillator frequency is 1.0 MHz and the resonating capacitor is set at 65 pF. Calculate the percentage error introduced in the calculated value of Q by the 0.02Ω insertion resistance. (4)

Answer:

The effective Q of the coil = $1/\omega CR = 1/ 2\pi \times (10^6)(65 \times 10^{-12}(10)) = 244.9$

The indicated Q of the coil = $1/ \omega C(R + 0.02) = 244.4$

The percentage error = 244.9-244.4/ 244.9 x 100 % = 0.2 % 4 marks

c. With the help of neat diagram, explain the working of Dual Slope Type DVM. (8)

Answer:

Principle of Dual Slope Type DVM

As illustrated in Fig. 5.3, the input voltage 'e_i' is integrated, with the slope of the integrator output proportional to the test input voltage. After a fixed time,

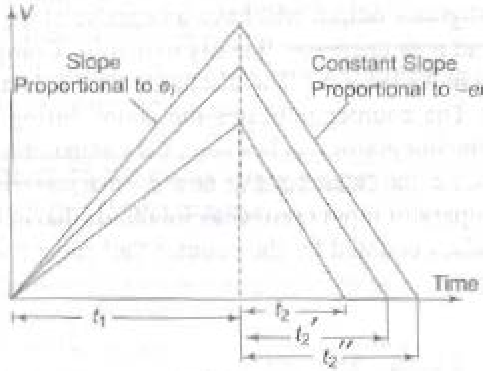

Fig. 5.3 Basic Principle of Dual Slope Type DVM

equal to t_1, the input voltage is disconnected and the integrator input is connected to a negative voltage $-e_r$. The integrator output will have a negative slope which is constant and proportional to the magnitude of the input voltage. The block diagram is given in Fig. 5.4.

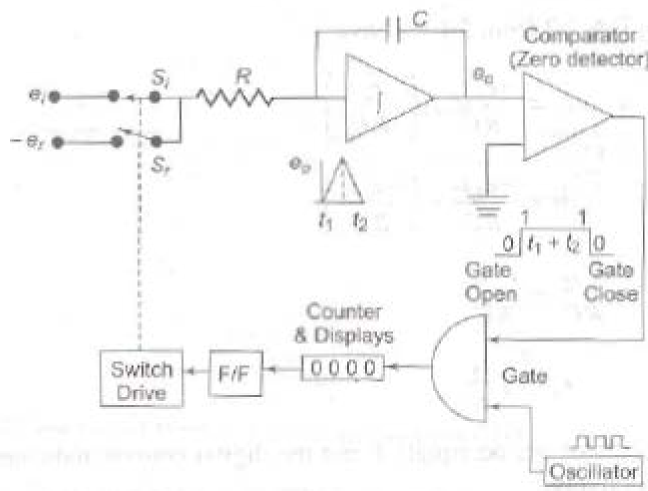

Fig. 5.4 Block Diagram of a Dual Slope Type DVM

At the start a pulse resets the counter and the F/F output to logic level '0'. S_i is closed and S_r is open. The capacitor begins to charge. As soon as the integrator output exceeds zero, the comparator output voltage changes state, which opens the gate so that the oscillator clock pulses are fed to the counter. (When the ramp voltage starts, the comparator goes to state 1, the gate opens and clock pulse drives the counter.) When the counter reaches maximum count, i.e. the counter is made to run for a time 't_1' in this case 9999, on the next clock pulse all digits go to 0000 and the counter activates the F/F to logic level '1'. This activates the switch drive, e_i is disconnected and $-e_r$ is connected to the integrator. The integrator output will have a negative slope which is constant i.e. integrator output now decreases linearly to 0 volts. Comparator output state changes again and locks the gate. The discharge time t_2 is now proportional to the input voltage. The counter indicates the count during time t_2. When the negative slope of the integrator reaches zero, the comparator switches to state 0 and the gate closes, i.e. the capacitor C is now discharged with a constant slope. As soon as the comparator input (zero detector) finds that e_o is zero, the counter is stopped. The pulses counted by the counter thus have a direct relation with the input voltage.

During charging

$$e_o = -\frac{1}{RC}\int_0^{t_1} e_i\,dt = -\frac{e_i t_1}{RC} \tag{5.1}$$

During discharging

$$e_o = \frac{1}{RC}\int_0^{t_2} -e_r\,dt = -\frac{e_r t_2}{RC} \tag{5.2}$$

Subtracting Eqs 5.2 from 5.1 we have

$$e_o - e_o = \frac{-e_r t_2}{RC} - \left(\frac{-e_i t_1}{RC}\right)$$

$$0 = \frac{-e_r t_2}{RC} - \left(\frac{-e_i t_1}{RC}\right)$$

$$\Rightarrow \qquad \frac{e_r t_2}{RC} = \frac{e_i t_1}{RC}$$

$$\therefore \qquad e_i = e_r \frac{t_2}{t_1} \tag{5.3}$$

If the oscillator period equals T and the digital counter indicates n_1 and n_2 counts respectively,

$$\therefore \qquad e_i = \frac{n_2 T}{n_1 T} e_r \quad \text{i.e.} \quad e_i = \frac{n_2}{n_1} e_r$$

Now, n_1 and e_r are constants. Let $K_1 = \frac{e_r}{n_1}$. Then $e_i = K_1 n_2$ (5.4)

From Eq. 5.3 it is evident that the accuracy of the measured voltage is independent of the integrator time constant. The times t_1 and t_2 are measured by the count of the clock given by the numbers n_1 and n_2 respectively. The clock oscillator period equals T and if n_1 and e_r are constants, then Eq. 5.4 indicates that the accuracy of the method is also independent of the oscillator frequency.

The dual slope technique has excellent noise rejection because noise and superimposed ac are averaged out in the process of integration. The speed and accuracy are readily varied according to specific requirements; also an accuracy of ±0.05% in 100 ms is available.

Q.5 a. Explain the working of CRO with the help of neat block diagram. (8)

Answer:

The major block circuit shown in Fig. 7.4, of a general purpose CRO, is as follows:

1. CRT
2. Vertical amplifier
3. Delay line
4. Time base
5. Horizontal amplifier
6. Trigger circuit
7. Power supply

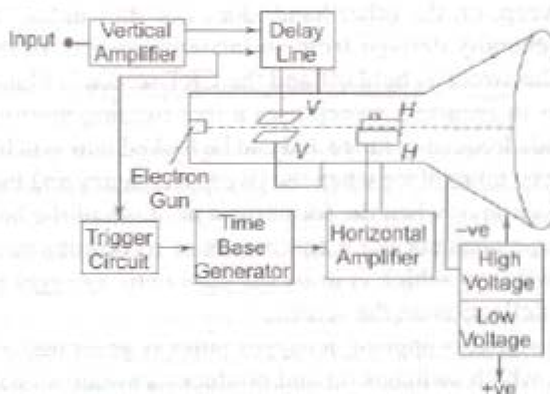

Fig. 7.4 Basic CRO Block Diagram

The function of the various blocks are as follows.

1. CRT

This is the cathode ray tube which emits electrons that strikes the phosphor screen internally to provide a visual display of signal.

2. Vertical Amplifier

This is a wide band amplifier used to amplify signals in the vertical section.

3. Delay Line

It is used to delay the signal for some time in the vertical sections.

4. Time Base

It is used to generate the sawtooth voltage required to deflect the beam in the horizontal section.

5. Horizontal Amplifier

This is used to amplify the sawtooth voltage before it is applied to horizontal deflection plates.

6. Trigger Circuit

This is used to convert the incoming signal into trigger pulses so that the input signal and the sweep frequency can be synchronised

7. Power Supply

There are two power supplies, a –ve High Voltage (HV) supply and a +ve Low Voltage (LV) supply. Two voltages are generated in the CRO. The +ve volt supply is from + 300 to 400 V. The –ve high voltage supply is from – 1000 to – 1500 V. This voltage is passed through a bleeder resistor at a few mA. The intermediate voltages are obtained from the bleeder resistor for intensity, focus and positioning controls.

Advantages of using –ve HV Supply

(i) The accelerating anodes and the deflection plates are close to ground potential. The ground potential protects the operator from HV shocks when making connections to the plates.
(ii) The deflection voltages are measured wrt ground, therefore HV blocking or coupling capacitor are not needed, but low voltage rating capacitors can be used for connecting the HV supply to the vertical and horizontal amplifiers.
(iii) Less insulation is needed between positioning controls and chasis.

7.5 SIMPLE CRO

The basic block diagram of a simple CRO is shown in Fig. 7.5. The ac filament supplies power to the CRT heaters. This also provides an accurate ac calibrating voltage. CRT dc voltage is obtained from the HV dc supply through voltage dividers $R_1 - R_5$. Included along with this voltage divider is a potentiometer (R_3) which varies the potential at the focusing electrode, known as focus control, and one which varies the control grid voltage, called the intensity control (R_5).

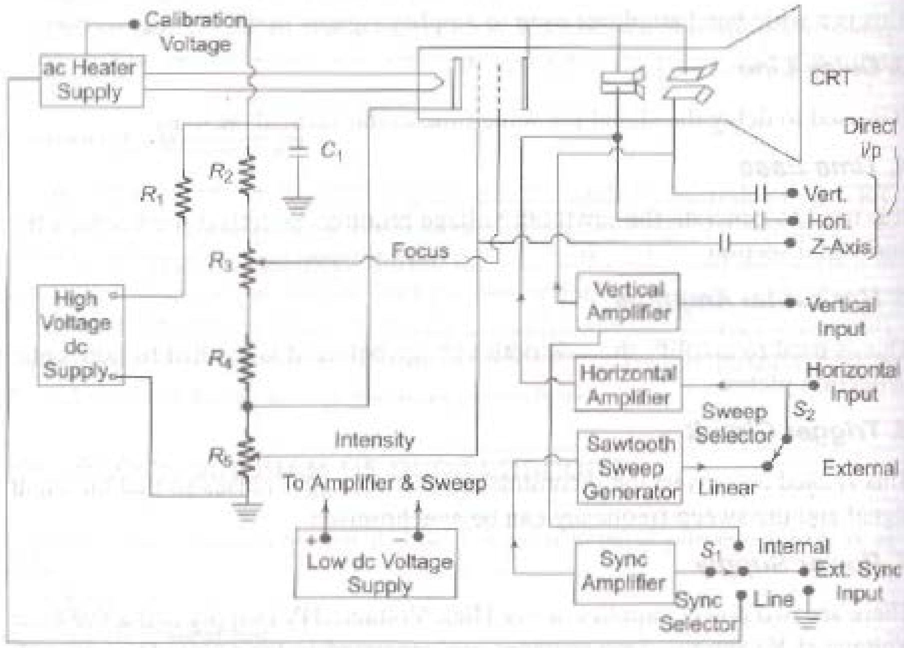

Fig. 7.5 Simple CRO

Capacitor C_1 is used to ground the deflection plates and the second anode for the signal voltage, but dc isolates these electrodes from the ground.

Normally S_2 is set to its linear position. This connects the sweep generator output to the horizontal input. The sweep voltage is amplified before being applied to the horizontal deflecting plates.

When an externally generated sweep is desired, S_2 is connected to its external position and the external generator is connected to the input. The sweep synchronising voltage is applied to the internal sweep generator through switch S_1, which selects the type of synchronisation.

b. What are major blocks of diagram of Standard Signal Generator? What does each block do? Explain. (8)

Answer:

A standard signal generator produces known and controllable voltages. It is used as power source for the measurement of gain, signal to noise ratio (S/N), bandwidth, standing wave ratio and other properties. It is extensively used in the testing of radio receivers and transmitters.

The instrument is provided with a means of modulating the carrier frequency, which is indicated by the dial setting on the front panel. The modulation is indicated by a meter. The output signal can be Amplitude Modulated (AM) or Frequency Modulated (FM). Modulation may be done by a sine wave, square wave, triangular wave or a pulse. The elements of a conventional signal generator are shown in Fig. 8.2 (a).

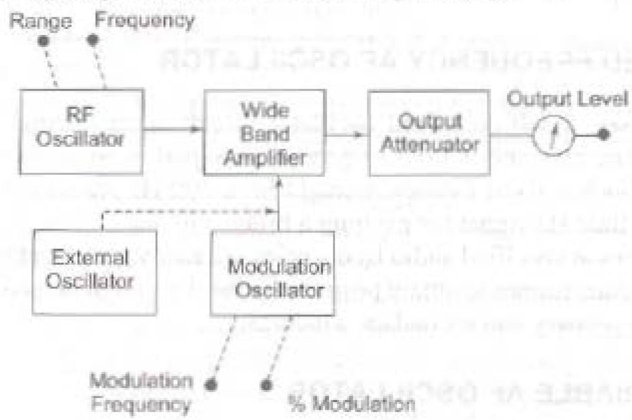

Fig. 8.2 (a) Conventional Standard Signal Generator

The carrier frequency is generated by a very stable RF oscillator using an LC tank circuit, having a constant output over any frequency range. The frequency of oscillations is indicated by the frequency range control and the vernier dial setting. AM is provided by an internal sine wave generator or from an external source.

(Modulation is done in the output amplifier circuit. This amplifier delivers its output, that is, modulation carrier, to an attenuator. The output voltage is read by an output meter and the attenuator output setting.)

Frequency stability is limited by the LC tank circuit design of the master oscillator. Since range switching is usually accomplished by selecting appropriate capacitors, any change in frequency range upsets the circuit design to some extent and the instrument must be given time to stabilise at the new resonant frequency.

In high frequency oscillators, it is essential to isolate the oscillator circuit from the output circuit. This isolation is necessary, so that changes occurring in the output circuit do not affect the oscillator frequency, amplitude and distortion characteristics. Buffer amplifiers are used for this purpose.

Figure 8.2(b) illustrates a commercial AM/FM signal generator (IE900A) having a frequency range from 100 kHz – 110 MHz, along with a frequency counter and TTL output.

Q.6 a. Explain the method of measurement of very large current using thermocouple. List the limitation thermocouple. (8)

Answer:

Thermocouples instruments with heaters large enough to carry very large currents may have an excessive skin effect. Ordinary shunts cannot be used because the shunting ratio will be affected by the relative inductance and resistance, resulting in a frequency effect.

One solution to this problem consists of minimising the skin effect by employing a heater, which is a tube of large diameter, but with very thin walls.

Another consists of employing an array of shunts of identical resistance arranged symmetrically as shown in Fig. 3.7 (a).

In Fig. 3.7 (a) each filament of wire has the same inductance, so that the inductance causes the current to divide at high frequencies, in the same way as does the resistance at low frequencies. In Fig. 3.7 (b) the condensor shunt is used such that the current divides between the two parallel capacitors proportional to their capacitance, and maintains this ratio independent of frequency, as long as the capacitor that is in series with the thermocouple has a higher impedance than the thermocouple heater and the lead inductance is inversely proportional to the capacitances.

In Fig. 3.7 (c) the current transformer is used to measure very large RF currents at low and moderate frequencies using a thermocouple instrument of ordinary range. Such transformers generally use a magnetic dust core. The current ratio is given by $\frac{\text{Primary Current}}{\text{Secondary Current}}$

$$= \frac{1}{K}\sqrt{\frac{L_s}{L_p}}\sqrt{1+\frac{1}{Q_s}}$$

where L_s = secondary inductance

L_p = primary inductance

K = coefficient of coupling between L_p and L_s

r_s = resistance of secondary, including meter resistance

$Q_s = \omega L_s / r_s = Q$ of the secondary circuit taking into account meter resistance

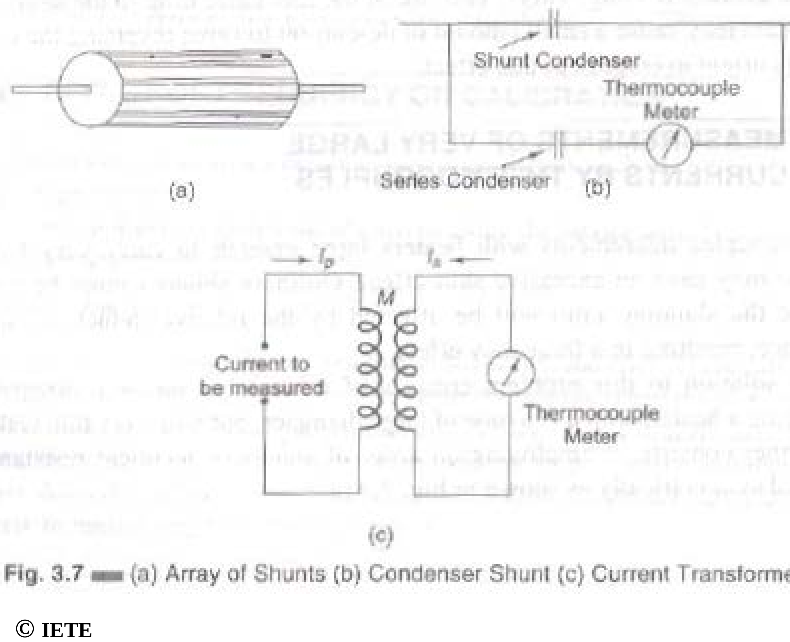

Fig. 3.7 (a) Array of Shunts (b) Condenser Shunt (c) Current Transformer

If Q of the secondary winding is appreciable (i.e. greater than 5), the transformation ratio is independent of frequency.

A current ratio of 1000 or more can be obtained at low and moderate RF by using a many turn secondary wound on a toroidal ring.

b. A 150 V voltmeter has an inductance of 0.75 H and a total resistance of 2000ohm. It is calibrated to read correctly on a 50 Hz circuit. What series resistance would be necessary to increase its range to 600V? (8)

Answer:

Impedance of the voltmeter ,

$Z= \surd(2000x2000 +(2\pi x50 x 0.75)^2$

= 2010 ohm

Current through voltmeter for full scale deflection

I= 150/2010 = 0.0746 A

The impedance required when used for 600 V

Z' = 600/0.0746 = 8040 ohm

Hence the total resistance of Voltmeter

$R' = \surd(8040 X 8040 -(2\pi x50 x 0.75)^2$

= 8036 ohm

And additional series resistance required = 8036-2000 = 6036 Ω Ans 8 marks

Q.7 a. What is self balancing? How it is achieved in a bolometer bridge? (8)

Answer:

The term self balancing is used to describe bridges which are automatically rebalanced when unknown RF power is applied to the bolometer. A typical circuit is illustrated in Fig. 20.4.

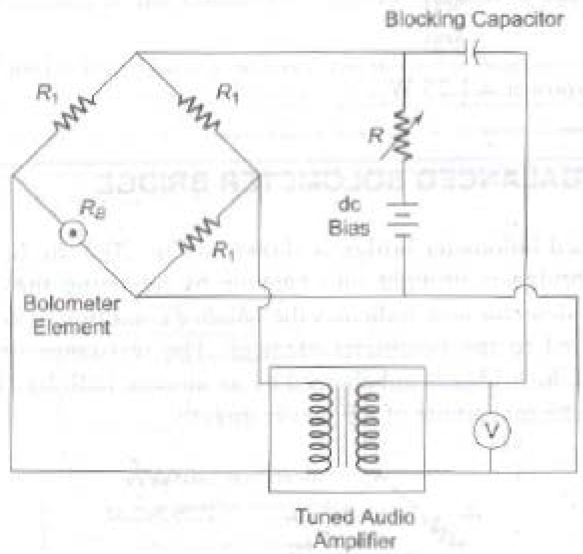

Fig. 20.4 Self Balancing Bolometer Bridge

The bolometer bridge is used as the coupling network between the output and input of a high gain frequency selective audio amplifier. The feedback is in proper phase to produce sustained AF oscillations of such amplitude as well maintain the resistance of the bolometer at the fixed value which nearly balances the bridge.

When the supply is switched ON, the bridge is unbalanced. The gain of the amplifier is large, so that oscillations are allowed to build up until the bridge is almost balanced. The higher the gain of the amplifier, the more closely the bridge balances.

The test RF is now dissipated into the bolometer element, which causes an imbalance in the bridge circuit. The AF output voltage automatically adjusts itself to restore the bolometer resistance to its original value. The amount by which the AF power level in the bolometer is reduced equals the applied RF power. The voltmeter reads the AF voltage and can be calibrated to read the magnitude of RF power directly.

A typical bridge circuit offers seven power ranges, from 0.1 – 100 mW full scale, for use with bolometers having a resistance within + 10% of five selected values from 50 – 250 Ω.

b. Draw the circuit diagram and explain the working of a heterodyne type wave analyser. (8)

Answer:

Wave analyzers are useful for measurement in the audio frequency range only. For measurements in the RF range and above (MHz range), an ordinary wave analyzer cannot be used. Hence, special types of wave analyzers working on the principle of heterodyning (mixing) are used. These wave analyzers are known as Heterodyne wave analyzers.

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.

An instrument that involves the principle of heterodyning is the Heterodyning tuned voltmeter, shown in Fig. 9.3.

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

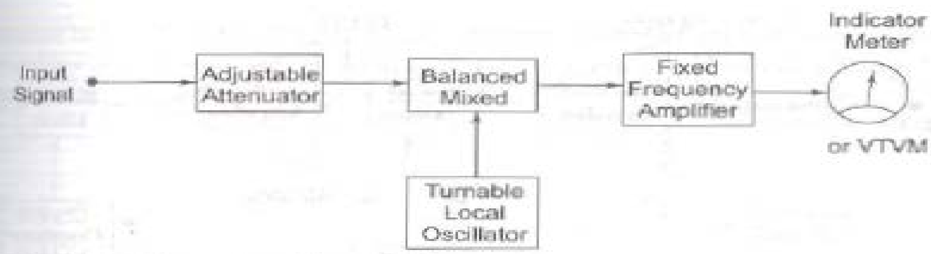

Fig. 9.3 Heterodyne Wave Analyzer

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.

Two types of selective amplifiers find use in Heterodyne wave analyzers. The first type employs a crystal filter, typically having a centre frequency of 50 kHz. By employing two crystals in a band-pass arrangement, it is possible to obtain a relatively flat pass-band over a 4 cycle range. Another type uses a resonant circuit in which the effective Q has been made high and is controlled by negative feedback. The resultant signal is passed through a highly selective 3-section quartz crystal filter and its amplitude measured on a Q-meter.

When a knowledge of the individual amplitudes of the component frequency is desired, a heterodyne wave analyzer is used.

A modified heterodyne wave analyzer is shown in Fig. 9.4. In this analyzer, the attenuator provides the required input signal for heterodyning in the first mixer stage, with the signal from a local oscillator having a frequency of 30 – 48 MHz.

The first mixer stage produces an output which is the difference of the local oscillator frequency and the input signal, to produce an IF signal of 30 MHz. This IF frequency is uniformly amplified by the IF amplifier. This amplified IF signal is fed to the second mixer stage, where it is again heterodyned to produce a difference frequency or IF of zero frequency.

The selected component is then passed to the meter amplifier and detector circuit through an active filter having a controlled band-width. The meter detector output can then be read off on a db-calibrated scale, or may be applied to a secondary device such as a recorder.

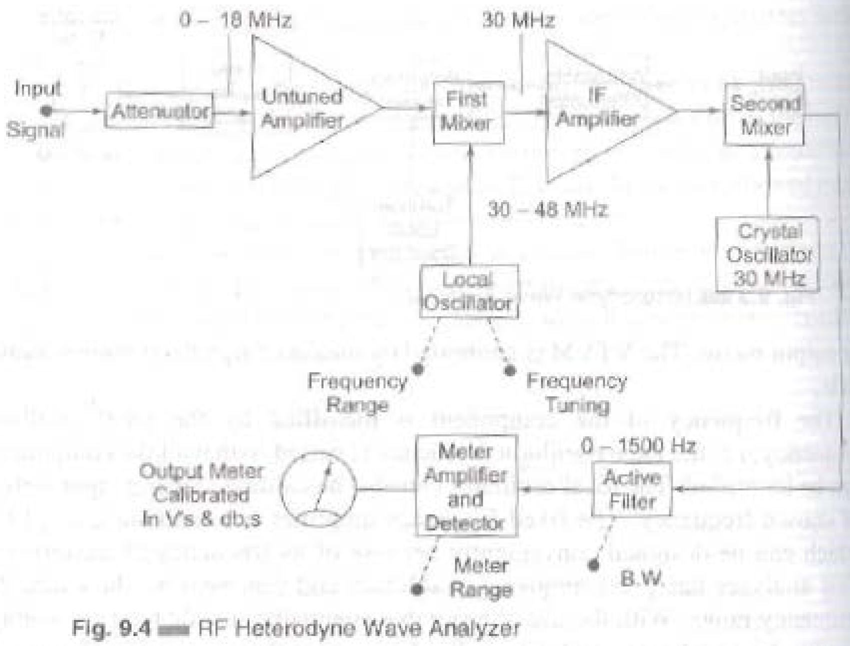

Fig. 9.4 RF Heterodyne Wave Analyzer

This wave analyzer is operated in the RF range of 10 kHz – 18 MHz, with 18 overlapping bands selected by the frequency range control of the local oscillator. The bandwidth, which is controlled by the active filter, can be selected at 200 Hz, 1 kHz and 3 kHz.

Q.8 a. What are the advantages and disadvantages of semiconductor strain gauge? (4)

Answer:

Advantages of Semiconductor Strain Gauge

1. Semiconductor strain gauges have a high gauge factor of about + 130. This allows measurement of very small strains, of the order of 0.01 micro strain.
2. Hysteresis characteristics of semiconductor strain gauges are excellent, i.e. less than 0.05%.
3. Life in excess of 10×10^6 operations and a frequency response of 10^{12} Hz.
4. Semiconductor strain gauges can be very small in size, ranging in length from 0.7 to 7.0 mm.

Disadvantages

1. They are very sensitive to changes in temperature.
2. Linearity of semiconductor strain gauges is poor.
3. They are more expensive.

b. The output of an LVDT is connected to a 5V voltmeter through an amplifier with a gain of 250. An output of 2mV appears at the terminals of the LVDT, when the core moves through a distance of 0.5mm. Calculate the sensitivity of of LVDT and also that of whole setup. (4)

Answer:

Sensitivity of LVDT = output voltage/Displacement = $2x10^{-3}/0.5$ = 4mV/mm

Sentivity of instrument = gain X sensitivity of LVDT = 1000mV /mm

c. **List three types of Temperature transducers and describe the applications of each type of transducer.** **(8)**

Answer:

13.20.1 Introduction to Temperature Transducers

Temperature is one of the most widely measured and controlled variable in industry, as a lot of products during manufacturing requires controlled temperature at various stages of processing.

A wide variety of temperature transducers and temperature measurement systems have been developed for different applications requirements.

Most of the temperature transducers are of Resistance Temperature Detectors (RTD), Thermistors and Thermocouples. Of these RTD's and Thermistor are passive devices whose resistance changes with temperature hence need an electrical supply to give a voltage output. On the other hand thermocouples are active transducers and are based on the principle of generation of thermoelectricity, when two dissimilar metals are connected together to form a junction called the *sensing junction*, an emf is generated proportional to the temperature of the junction. Thermocouple operate on the principle of *seeback effect*. Thermocouple introduces errors and can be overcomed by using a reference junction compensation called as a *cold junction compensation*.

Thermocouples are available that span cryogenic to 2000°C temperature range. They have the highest speed of response. Thermocouples can be connected in series/parallel to obtain greater sensitivity called a *Thermopile*.

RTD commonly use platinum, Nickel or any resistance wire whose resistance varies with temperature and has a high intrinsic accuracy. Platinum is the most widely used RTD because of its high stability and large operating range. RTD's are usually connected in a Wheatstones bridge circuit. The lead wire used for connecting the RTD's introduces error, hence compensation is required. This is obtained by using three-wire or four wire compensation, but 3-wire compensation is mostly used in the industry.

Another form of temperature measurement is by the use of thermistor. A thermistor is a thermally sensitive resistor that exhibits change in electrical resistance with change in temperature. Thermistors made up of oxides exhibit a negative temperature coefficient (NTC), that is, their resistance decreases with increase in temperature. Thermistor are also available with positive temperature coefficient (PTC), but PTC thermistor are seldom used for measurement since they have poor sensitivity.

Thermistors are available in various sizes and shapes such as beads, rods, discs, washers and in the form of probes.

Radiation pyrometer are used where non-contact temperature is required to be measured. It measures the radiant (energy) heat emitted or reflected by a hot object. Radiation pyrometers are of two types total radiation pyrometer and infrared pyrometer.

Total radiation pyrometer virtually receives all the radiation from a heated body and measures temperature in the range around 1200°C–3500°C. Infrared pyrometers are partial or selective radiation pyrometers and are used in the range of 1000°C–1200°C.

Optical pyrometers are used in the visible wavelength. The most common type of optical pyrometer is the disappearing filament type and is used in temperature range of 1400°C and can be extended up to 3000°C. Optical pyrometers are widely used for accurate measurement of temperatures of furnaces, molten metals etc.

Q.9 Write short note on the following: (16)
(i) XY Recorder
(ii) Potentiometric recorder

Answer:

In most research fields, it is often convenient to plot the instantaneous relationship between two variables [$Y = f(x)$], rather than to plot each variable separately as a function of time.

In such cases, the X–Y recorder is used, in which one variable is plotted against other variable.

In an analog X–Y recorder, the writing head is deflected in either the x-direction or the y-direction on a fixed graph chart paper. The graph paper used is generally squared shaped, and is held fixed by electrostatic attraction or by vacuum.

The writing head is controlled by a servo feedback system or by a self balancing potentiometer. The writing head consist of one or two pens, depending on the application.

In practice, one emf is plotted as a function of another emf in an X–Y recorder.

In some cases, the X–Y recorder is also used to plot one physical quantity (displacement, force, strain, pressure, etc.) as a function of another physical quantity, by using an appropriate transducer, which produces an output (EMF) proportional to the physical quantity.

The motion of the recording pen in both the axis is driven by servo-system, with reference to a stationary chart paper. The movement in x and y directions is obtained through a sliding pen and moving arm arrangement.

A typical block diagram of an X–Y recorder is illustrated in Fig. 12.9.

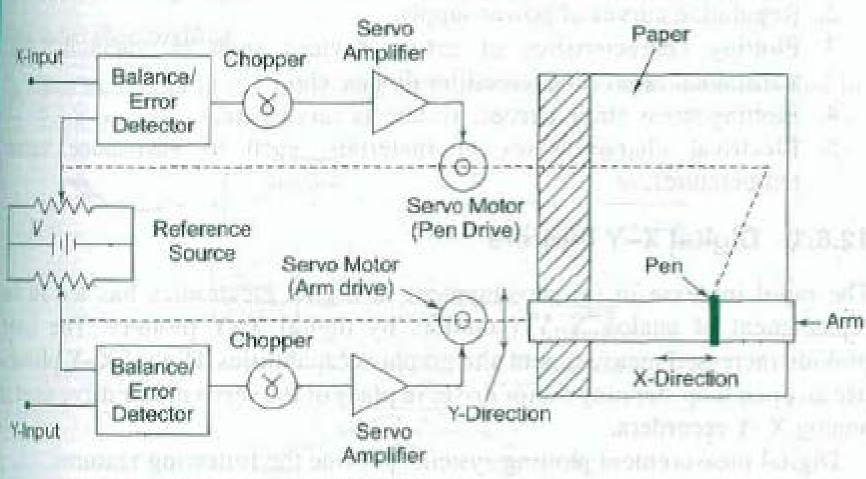

Fig. 12.9 Basic X–Y Recorder

Referring to Fig. 12.9, each of the input signals is attenuated in the range of 0–5 mV, so that it can work in the dynamic range of the recorder. The balancing circuit then compares the attenuated signal to a fixed internal reference voltage. The output of the balancing circuit is a dc error signal produced by the difference between the attenuated signal and the reference voltage. This dc error signal is then converted into an ac signal with the help of a chopper circuit. This ac signal is not sufficient to drive the pen/arm drive motor, hence, it is amplified by an ac amplifier. This amplified signal (error signal) is then applied to actuate the servo motor so that the pen/arm mechanism moves in an appropriate direction in order to reduce the error, thereby bringing the system to balance. Hence as the input signal being recorded varies, the pen/arm tries to hold the system in balance, producing a record on the paper.

The action described above takes place in both the axes simultaneously. Hence a record of one physical quantity with respect to another is obtained.

Some X–Y recorders provides x and y input ranges which are continuously variable between 0.25 mV/cm and 10 V/cm, with an accuracy of ± 0.1% of the full scale. Zero offset adjustments are also provided.

The dynamic performance of X–Y recorders is specified by their slewing rate and acceleration. A very high speed X–Y recorder, capable of recording a signal up to 10 Hz at an amplitude of 2 cm peak to peak, would have a slewing rate of 97 cm/s and a peak acceleration of 7620 cm/s.

An X–Y recorder may have a sensitivity of 10 µV/mm, a slewing speed of 1.5 ms and a frequency response of about 6 Hz for both the axis. The chart size is about 250 × 180 mm. The accuracy of X–Y recorder is about ± 0.3%.

Applications of X–Y Recorders

These recorders are used to measure the following.

1. Speed-torque characteristics of motors.
2. Regulation curves of power supply.
3. Plotting characteristics of active devices such as vacuum tubes, transistors, zener diode, rectifier diodes, etc.
4. Plotting stress-strain curves, hysteresis curves, etc.
5. Electrical characteristics of materials, such as resistance versus temperature.

The thermocouple or millivolt signal is amplified by a non-inverting MOSFET, chopper stabilised, feedback amplifier. This configuration has a very high input impedance and the current passing through the signal source is a maximum of 0.5 nA (without broken sensor protection). With the use of span control, the output signal is adjusted to 5 V (nominal), for an input signal change, e.g. to full scale deflection of the pen.

The pre-amplifier output signal is then compared with a reference voltage picked off the measuring slide wire, which is energised by a stabilised power supply, and the difference amplified by a servo amplifier, whose output drives a linear motor. The motor carriage carries the indicating pointer pen and the sliding contact on the slide wire.

The motor itself consists of a coil assembly, travelling in a magnetic field (Fig. 12.14). The servo amplifier drives the carriage in the appropriate direction, to reduce the difference signal to zero.

An input filter circuit reduces any spurious signals picked up by the input leads. The B–E junctions of the transistor are used for overload protection.

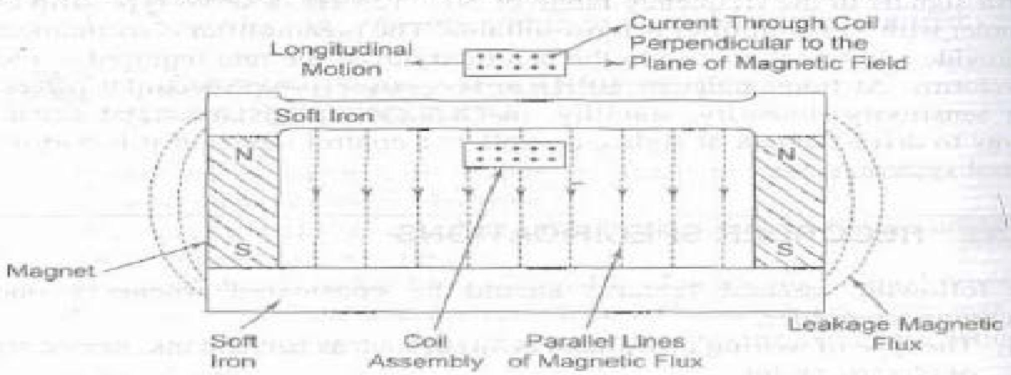

Fig. 12.14 Linear Motor Operating Principle

In multipoint versions of the recorder, a signal selector switch is driven by a synchronous motor. The pen changeover and dotting action are actuated by a second synchronous motor (Fig. 12.15). The pen operation is electrically synchronised to the rotation of the signal selector switch—should they get out of step, the pen motor stops at a predetermined point and restarts only when the signal selector switch has rotated to its correct alignment. The linear motor is ated during the signal changeover, but dotting always takes place with the system live. The standard dotting interval is 6s (Fig. 12.15). The linear motor consists of a coil assembly travelling in a magnetic field. The direction of the field is as shown in Fig. 12.14. The current passing through the coil produces a magnetic field which is perpendicular to the existing field and causes the carriage to move in a direction given by Fleming's left hand rule.

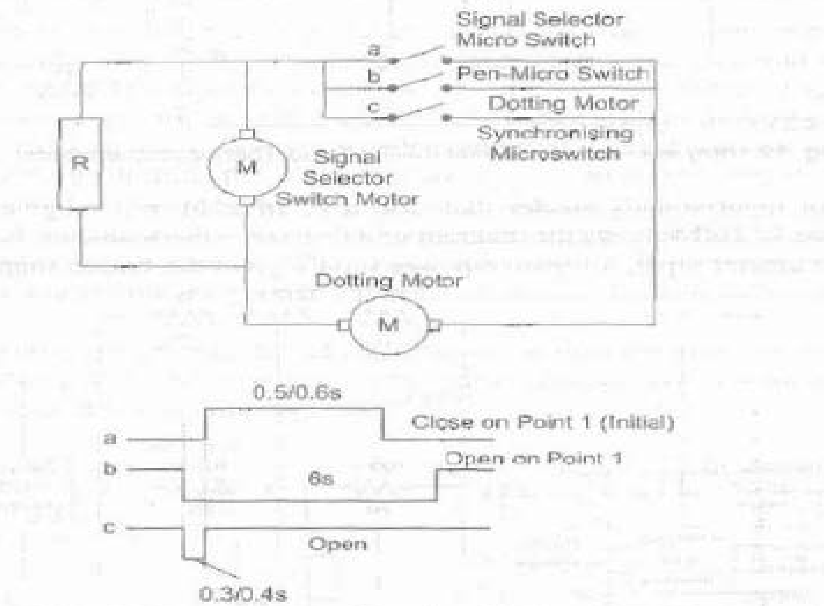

Fig. 12.15 Multipoint Recording Synchronising Circuit

Q.		Unit, Text Book, Page Contents No
Q.2	a. Types of errors – 2 source – 2 effect – 2 ways to reduce – 2 Total 8	
	b. 4	
	c. Magnitude of limiting error – 2 % Limiting error – 2	
Q.3	a. What is Megger 2 Method – 6	
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	b. effective Q – 1 Indicated Q – 1 % error – 2	
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			No.
	a.	Diagram – 3 Explanation – 5	
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Q.6	a.	Measurement – 6 Limitations – 2	
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Q.7	a.	Self balancing 3 How it is achieved 5	
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Q.8	a.	Advantages 2 Disadvantages 2	
	b.	Sensitivity of LVDT 2 " of setup 2	
	c.	Three Types 3 Applications 5	
Q.9	a.	8	
	b.	8	

TEXT BOOK

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II. Electronic Instrumentation, H.S Kalsi, Tata McGraw Hill, Second Edition 2004