Q.2 a. What is meant by hysteresis? Explain its phenomenon in measurement systems with neat diagrams. (7)

Answer:

2.19. Hysteresis. Hysteresis effects show up in any physical, chemical or electrical phenomenon. Hysteresis is a phenomenon which depicts different output effects when loading and unloading whether it is a mechanical system or an electrical system and for that matter any system. Hysteresis is non-coincidence of loading and unloading curves. Hysteresis, in a system, arises due to the fact that all the energy put into the stressed parts when loading is not recoverable upon unloading. This is because the second law of thermodynamics rules out any perfectly reversible process in the world.

Consider an instrument which has no friction due to sliding parts. When the input of this instrument is slowly varied from zero to full scale and then back to zero, its output varies as shown in Fig. 2.8 (*a*). The non-coincidence of output when the input is increased and then decreased is on account of internal friction or hysteretic damping. Why we do not obtain the same output for both increasing and decreasing values of the input is explained by the fact that the energy put into the stressed parts when loading cannot be recovered back when unloading. Thus we obtain two different values of output for the same input under increasing and decreasing conditions. In case of instruments which are used on both sides of zero *i.e.* input applied on both positive and negative side, the variation of output is as shown in Fig. 2.8 (*b*).

In case of instruments, which do not have internal friction, but have external sliding friction *i.e.* constant coulomb friction the input-output relationships are like the ones shown in Fig. 2.8 (*c*) and (*d*). Similar input-output relationships are exhibited if there is any free play or any looseness in any mechanism of the instrument.

Hysteresis effects are there in electrical phenomena. One of the examples is the relationship between output voltage and field current in a d.c. generator. This is due to magnetic hysteresis. The relationship between field current and output voltage is similar to the one shown in Fig. 2.8 (*b*).

In a given instrument a number of causes, such as listed above, combine to give an overall effect which may result in output-input relationship such as shown in Fig. 2.8 (*e*). The numerical value of hysteresis can be specified in terms of either output or input and usually is given as a percentage of full scale.

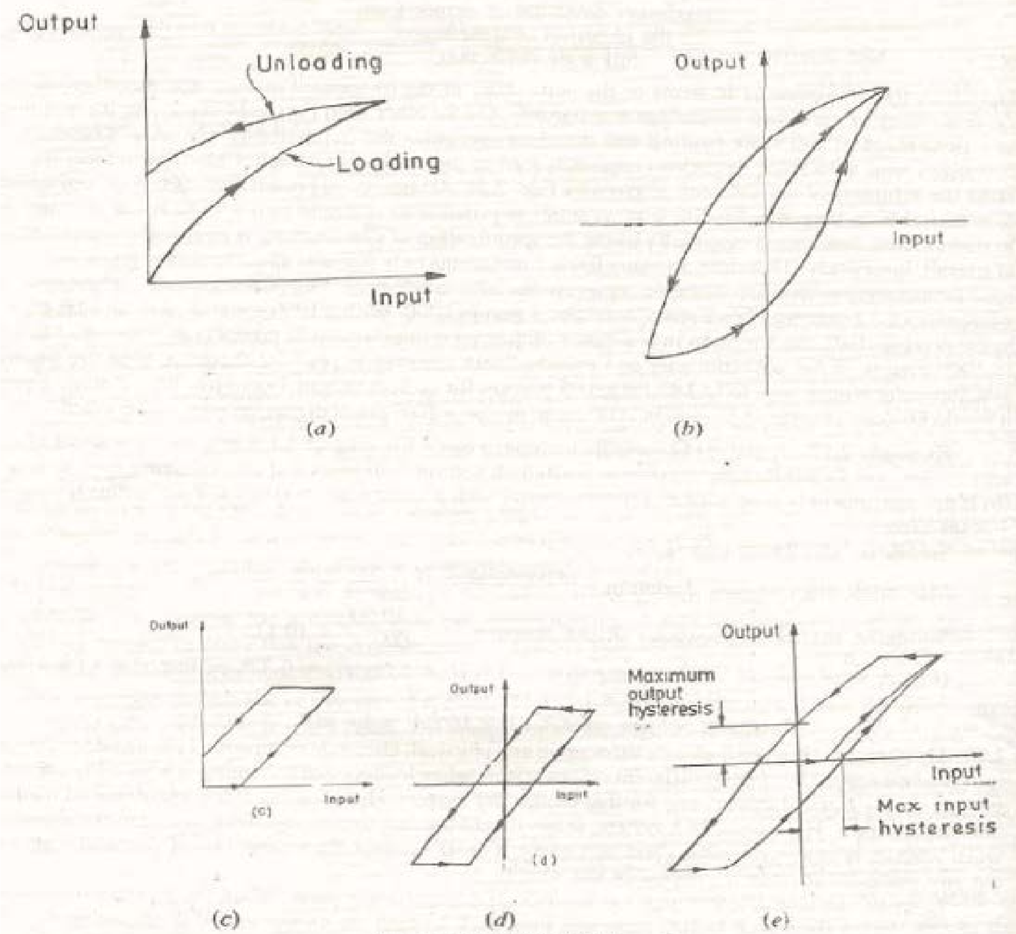

Fig. 2.8 Hysteresis effects.

b. A voltmeter having a sensitivity of 1000 Ω/ V reads 100V on its 150 V scale when connected across an unknown resistor in series with a milli-ammeter. When the milli-ammeter reads 5mA. Calculate:
(i) apparent resistance of the unknown resistor,
(ii) actual resistance of the unknown resistor and
(iii) error due to the loading effect of voltmeter. (6)

Answer:

(i) Total circuit resistance $R_T = \frac{E_T}{I_T} = \frac{100}{5X10^{-3}} = 20K\Omega$

Neglecting the resistance of milli-ammeter, **the value of unknown Resistor** $R_s = 20K\Omega$

(ii)Resistance of voltmeter $R_v = 1000\Omega X 150\Omega = 150K\Omega$

As the voltmeter is in parallel with the unknown resistance, we have:

$R_T = \frac{R_X R_V}{R_V + R_X}$, from this equation the

unknown resistance R_X can be written and found out as:

$$R_X = \frac{R_T R_V}{R_V - R_T} = \frac{20X150}{150-20} = 23.077K\Omega$$

(iii)**Percentage Error** is calculated as:

$$\frac{MeasuredValue - TrueValue}{TrueValue} X100 = \frac{20-23.077}{23.077} X100 = -13.33\%$$

c. Write the basic difference between steady state response and transient response. (3)

Answer:

4.1. Dynamic Response. The *response* is the evaluation of the system's ability to faithfully transmit and present all the pertinent information included in the input signal and to exclude all else.

Invariably measurement systems, especially in industrial, aerospace and biological applications are subjected to inputs which are not static but are dynamic in nature *i.e.*, the inputs that vary with time. The input varies from instant to instant, and therefore, so does the output. The behaviour of the system under such conditions is described by its **dynamic response.**

The dynamic (varying with time) inputs are of two types : (*i*) transient and (*ii*) steady state periodic.

The **steady state periodic** quantity is one whose magnitude has a definite repeating time cycle, whereas the time variation of a **transient** magnitude does not repeat.

All measurement systems include one or more energy storage elements. The examples of energy storage elements are electrical inductance and capacitance, mass and inertia, and thermal and fluid capacitance.

When an input is applied to a system, the energy storage elements do not allow an immediate flow of energy and therefore the measurement system does not respond to the input immediately. The measurement system goes through a *transient state* before it finally settles to its *steady state position.*

The response of a measurement system subjected to a time varying input like a sudden change in temperature can be divided into two parts, the *transient response*, and the *steady state response*. If $c(t)$ is the total time response of a system, then in general,

$$c(t) = c_t(t) + c_{ss}(t) \quad ...(4.1)$$

where $c_t(t)$ and $c_{ss}(t)$ denote respectively the transient and steady state portions of the response. In measurement systems, the **steady state response** is simply the response when time reaches infinity.

Transient response is defined as the part of response which goes to zero as time becomes large. Therefore, $c_t(t)$ has the property,

$$\lim_{t \to \infty} c_t(t) = 0 \quad ...(4.2)$$

Therefore, after a time $t = \infty$, the system response is,

$$c(t) = c_{ss}(t) \quad ...(4.3)$$

i.e., the system response is the *steady state response*.

Some measurements are made under conditions that sufficient time is available for the measurement system to settle to its final steady state conditions. Under such conditions, the study of behaviour of the system under transient state is not of much importance ; only steady state response of the system is considered. However, in many areas of measurement system applications, it becomes necessary to study the response of the system under both transient as well as steady state conditions. In many applications, the transient response of the system *i.e.*, the way system settles down to its final steady state conditions is more important than the steady state response. As an example, suppose a body is subjected to a sudden severe mechanical impact lasting for a few milliseconds. The body is accelerated and the transient response which is an acceleration-time relationship lasting for a few milliseconds during which the body is subjected to severe strains is of utmost importance.

Q.3 a. Draw the circuit of Wheatstone Bridge used for measurement of medium resistance. Explain its operation and derive the condition for its balance. (8)

Answer:

14.2.3. Wheatstone Bridge. A very important device used in the measurement of medium resistances is the Wheatstone bridge. A Wheatstone bridge has been in use longer than almost any electrical measuring instrument. It is still an accurate and reliable instrument and is extensively used in industry. The Wheatstone bridge is an instrument for making *comparison measurements* and operates upon a *null indication* principle. This means the indication is independent of the calibration of the null indicating instrument or any of its characteristics. For this reason, very high degrees of accuracy can be acheived using Wheatstone bridge. Accuracy of 0.1% is quite common with a Wheatstone bridge as opposed to accuracies of 3% to 5% with ordinary ohmmeter for measurement of medium resistances. Fig 14.3 shows the basic circuit of a Wheatstone bridge. It has four resistive arms, consisting of resistances *P, Q, R* and *S* together with a source of emf (a battery) and a null detector, usually a galvanometer *G* or other sensitive current meter. The current through the galvanometer depends on the potential difference between points *c* and *d*. The bridge is said to be balanced when there is no current through the galvanometer or when the potential difference across the galvanometer is zero. This occurs when the voltage from point '*b*' to point '*a*' equals the voltage from point '*d*' to point '*b*'; or, by referring to the other battery terminal, when the voltage from point '*d*' to point '*c*' equals the voltage from point '*b*' to point '*c*'.

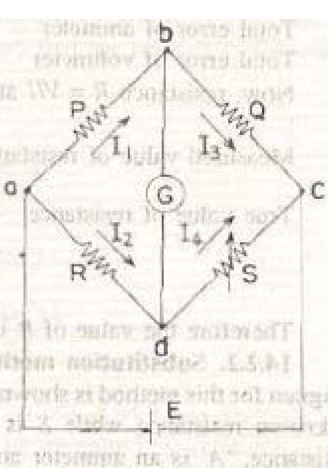

Fig. 14.3. Wheatstone bridge.

For bridge balance, we can write :

$$I_1P = I_2R \quad ...(14.11)$$

For the galvanometer current to be zero, the following conditions also exist :

$$I_1 = I_3 = \frac{E}{P+Q} \quad ...(14.12)$$

and

$$I_2 = I_4 = \frac{E}{R+S} \quad ...(14.13)$$

where E = emf of the battery.

Combining Eqns. 14.11, 14.12 and 14.13 and simplifying, we obtain :

$$\frac{P}{P+Q} = \frac{R}{R+S} \quad ...(14.14)$$

from which

$$QR = PS \quad ...(14.15)$$

Eqn. 14.15 is the well known expression for the balance of wheatstone bridge. If three of the resistances are known, the fourth may be determined from Eqn. 14.15 and we obtain :

$$R = S\frac{P}{Q} \quad ...(14.16)$$

where *R* is the unknown resistance *S* is called the '*standard arm*' of the bridge and *P* and *Q* are called the '*ratio arms*'.

In the industrial and laboratory form of the bridge, the resistors which make up *P*, *Q* and *S* are mounted together in a box, the appropriate values being selected by dial switches. Battery and galvanometer switches are also included together with a galvanometer and a dry battery in the portable sets. *P* and *Q* normally consist of four resistors each, the values being 10, 100, 1000 and 10,000 Ω respectively *S* consists of a 4 dial or 5 dial decade arrangement of resistors. Fig. 14.4 shows the commercial form of Wheatstone bridge.

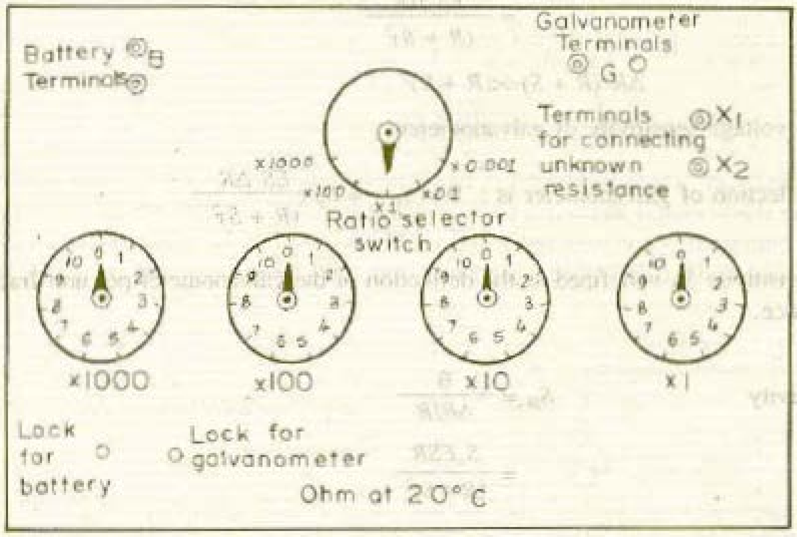

Fig. 14.4. Commercial form of Wheatstone bridge.

b. A Wheatstone bridge has ratio arms of 1000 Ω and 100 Ω and is being used to measure an unknown resistance of 25 Ω. Two galvanometers are available. Galvanometer 'A' has a resistance of 50 Ω and a sensitivity of 200 mm/µA and galvanometer 'B' has values of 600 Ω and sensitivity of 500 mm/µA. The galvanometer is connected from the junction of the ratio arms to the opposite concerns. Find out: (5)

(i) The value of standard resistance under balance condition.

(ii) Which of the two galvanometers is more sensitive to a small unbalance on the above bride and the ratio of sensitivities.

Answer:

(i) In Wheatstone bridge, **value of standard resistance under balance conditions**:

$$S = R.\frac{Q}{P} = 25X\,\frac{1000}{100} = 250\Omega.$$

(ii)Internal resistance of bridge from Wheatstone bridge can be written as:

$$R_O = \frac{RS}{R+S} + \frac{PQ}{P+Q} = \frac{25X\,250}{25+250} + \frac{100X1000}{100+1000} = 113.6\Omega$$

Therefore, **the Ratio of deflection for two galvanometers** is given by:

$$\frac{\theta_A}{\theta_B} = \frac{(S_i)_A ES\Delta R}{(R_O + G_A)(R+S)^2} \Big/ \frac{(Si)_B ES\Delta R}{(R_O + G_B)(R+S)^2} = \frac{(S_i)_A}{(S_i)_B}.\frac{R_O + G_B}{R_O + G_A} = \frac{200}{500}\frac{(113.6+600)}{(113+50)} = 1.75$$

Hence the galvanometer A has a sensitivity of 1.75 times that of galvanometer B as far as this bridge is concerned, even though on its own galvanometer A is less sensitive than galvanometer B.

c. Write the applications of high voltage Schering bridge. (3)

Answer:

16.6.3. High Voltage Schering Bridge. (Schering bridge is widely used for capacitance and dissipation factor measurements. In fact Schering bridge is one of the most important of the a.c. bridges. It is extensively used in the measurement of capacitance in general, and in particular in the measurement of the properties of insulators, capacitor bushings, insulating oil and other insulating materials. This bridge is particularly suitable for small capacitances, and is then usually supplied from a high frequency or a high votlage source. The measurements done on small capacitances suffer from many disadvantages if carried out at low voltages. High voltage Schering bridge is certainly preferable for such measurements.)

Q.4 a. What is a DC Voltmeter? Draw the circuit of basic DC Voltmeter. Explain its operation and derive an expression for its series resistance (R_S). (6)

Answer:

A basic D'Arsonval movement can be converted into a dc voltmeter by adding a series resistor known as multiplier, as shown in Fig. 4.1. The function of the multiplier is to limit the current through the movement so that the current does not exceed the full scale deflection value. A dc voltmeter measures the potential difference between two points in a dc circuit or a circuit component.

To measure the potential difference between two points in a dc circuit or a circuit component, a dc voltmeter is always connected across them with the proper polarity.

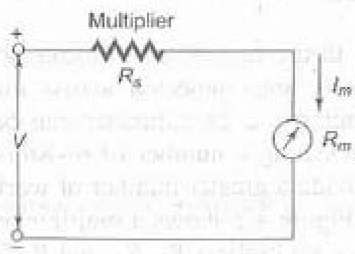

Fig. 4.1 Basic dc Voltmeter

The value of the multiplier required is calculated as follows. Referring to Fig. 4.1,

I_m = full scale deflection current of the movement (I_{fsd})

b. A basic D'Arsonval movement with a Full Scale Deflection of 50 μA and internal resistance of 500 Ω is used as a voltmeter. Determine the value of the multiplier resistance needed to measure a voltage range of 0 – 10 V. (3)

Answer:

Given data: Voltage Range (V) = 0 – 10 V.

Full Scale Deflection Current: $I_m = 50\mu A$

and Internal Resistance: $R_m = 500\Omega$

Therefore, the value of the **multiplier resistance** needed to measure the above range of voltage of 0 to 10V is:

$$R_s = \frac{V}{I_m} - R_m = \frac{10}{50\mu A} - 500 = 199.5K\Omega$$

c. With the help of a neat block diagram, explain the working of a basic Digital Multimeter. (7)

Answer:

Analog meters require no power supply, they give a better visual indication of changes and suffer less from electric noise and isolation problems. These meters are simple and inexpensive.

Digital meters, on the other hand, offer high accuracy, have a high input impedance and are smaller in size. They gives an unambigious reading at greater viewing distances. The output available is electrical (for interfacing with external equipment), in addition to a visual readout.

The three major classes of digital meters are panel meters, bench type meters and system meters.

All digital meters employ some kind of analog to digital (A/D) converters (often dual slope integrating type) and have a visible readout display at the converter output.

Panel meters are usually placed at one location (and perhaps even a fixed range), while bench meters and system meters are often multimeters, i.e. they can read ac and dc voltage currents and resistances over several ranges.

The basic circuit shown in Fig. 6.2 (a) is always a dc voltmeter. Current is converted to voltage by passing it through a precision low shunt resistance while alternating current is converted into dc by employing rectifiers and filters. For resistance measurement, the meter includes a precision low current source that is applied across the unknown resistance; again this gives a dc voltage which is digitised and readout as ohms.

A basic digital multimeter (DMM) is made up of several A/D converters, circuitry for counting and an attenuation circuit. A basic block diagram of a DMM is shown in Fig. 6.2 (b). The current to voltage converter shown in the block diagram of Fig. 6.2 (b) can be implemented with the circuit shown in Fig. 6.2 (c).

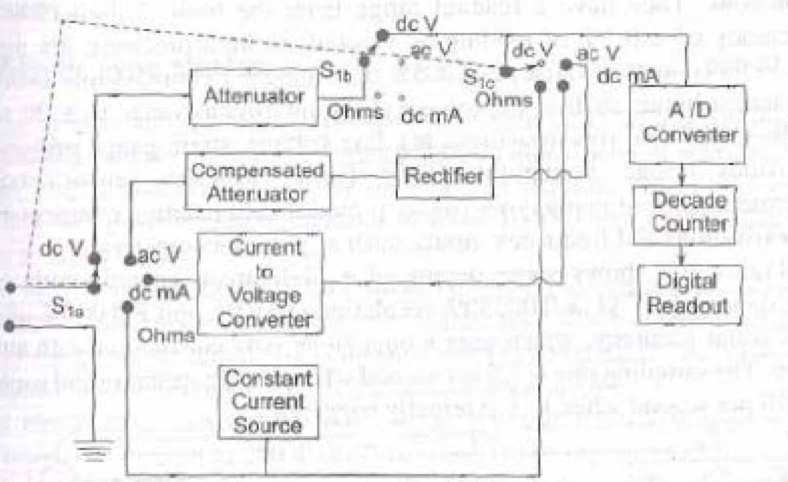

Fig. 6.2 (b) Block Diagram of a Basic Digital Multimeter

Q.5 a. Explain the working of Dual Slope Integrating type DVM with neat block diagram. Give its advantages. (8)

Answer:

In ramp techniques, superimposed noise can cause large errors. In the dual ramp technique, noise is averaged out by the positive and negative ramps using the process of integration.

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,

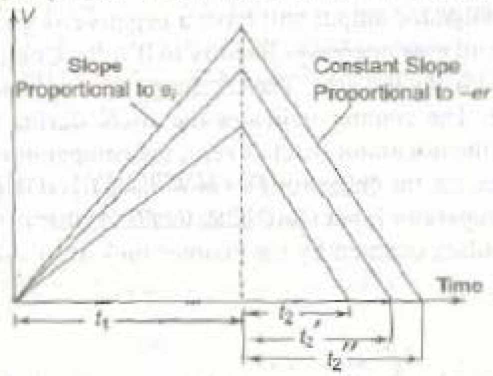

Fig. 5.3 Basic Principle of Dual Slope Type DVM

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.

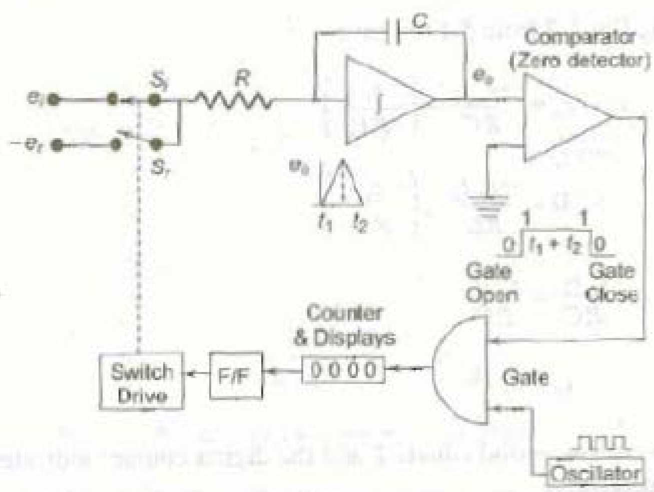

Fig. 5.4 Block Diagram of a Dual Slope Type DVM

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

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

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

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

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

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

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

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.

b. Draw the circuit diagram of Output Power Meter and explain its operation. Write its applications. (8)

Answer:

The output power Wattmeter is designed to directly measure the output power in an arbitrary load. The instrument provides a set of resistive loads to be selected for power measurements. In addition to power, the output meter can be used to measure impedance and frequency response characteristics. A simple circuit is illustrated in Fig. 10.1.

The input impedance network consist of two tapped resistances and a coil. The input impedance can be varied in steps from 2.5 Ω to 40 kΩ. At low impedance values, the coil shunts a portion of R_1 – an increase in resistance results in fewer turns of the coil. This arrangement keeps the meter reading proportional to the energy dissipated by the resistor. At high impedance values, the coil is replaced by another tapped resistance R_2.

The RC frequency compensator is in parallel with the coil. At low frequency, the capacitive reactance X_c is high; it decreases as frequency increases. This compensates for the losses of the coil at low frequencies. The frequency range

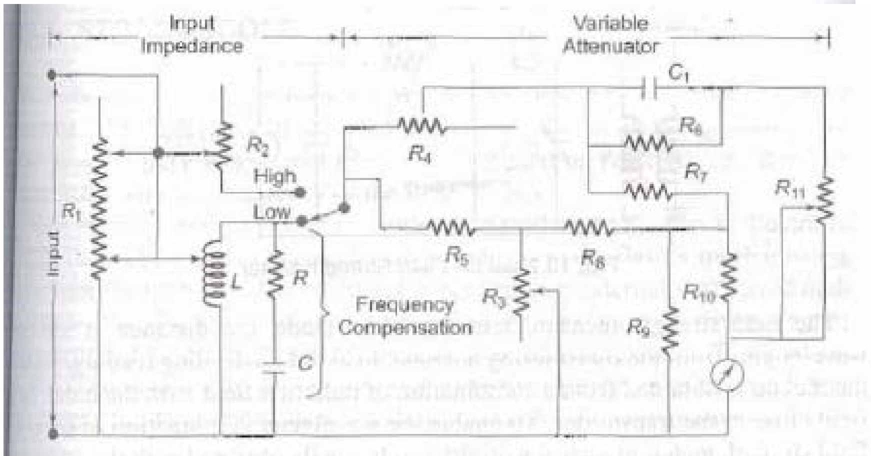

Fig. 10.1 Output-Meter Circuit

is generally between 20 Hz and 20 kHz. R_3 is the control in a variable *T*-network. This amounts to a variable meter shunt, which is used to extend the range of the meter. The lowest meter range is normally 5 mW, but it can be extended in decade steps of 50 mW, 500 mW, etc.

The remaining circuit is a combination of a calibration and frequency compensation network. A meter of this type may have a midscale accuracy of ±2% at 1 KHz. Over the frequency range of 20 Hz – 15 KHz, the accuracy may be within ± 2% of the 1 kHz value.

The input meter is subjected to an waveform error when the input is other than sinusoidal. (Practical instruments for measuring the power output of oscillators, amplifiers, transformers, transducers and low frequency lines use an input impedance of a tapped transformer with 48 impedance setting). It can be used to measure output impedance by adjusting the maximum power. It can also be used to check the frequency response characteristics of audio frequency devices.

Q.6 a. Draw the block diagram of a Function Generator and explain the method of producing: (8)

(i) Square waves and

(ii) Sine waves

Answer:

A function generator produces different waveforms of adjustable frequency. The common output waveforms are the sine, square, triangular and sawtooth waves. The frequency may be adjusted, from a fraction of a Hertz to several hundred kHz.

The various outputs of the generator can be made available at the same time. For example, the generator can provide a square wave to test the linearity of an amplifier and simultaneously provide a sawtooth to drive the horizontal deflection amplifier of the CRO to provide a visual display.

Capability of Phase Lock

The function generator can be phase locked to an external source. One function generator can be used to lock a second function generator, and the two output signals can be displaced in phase by adjustable amount.

In addition, the fundamental frequency of one generator can be phase locked to a harmonic of another generator, by adjusting the amplitude and phase of the harmonic, almost any waveform can be generated by addition.

The function generator can also be phase locked to a frequency standard and all its output waveforms will then have the same accuracy and stability as the standard source.

The block diagram of a function generator is illustrated in Fig. 8.5. Usually the frequency is controlled by varying the capacitor in the LC or RC circuit. In this instrument the frequency is controlled by varying the magnitude of current which drives the integrator. The instrument produces sine, triangular and square waves with a frequency range of 0.01 Hz to 100 kHz.

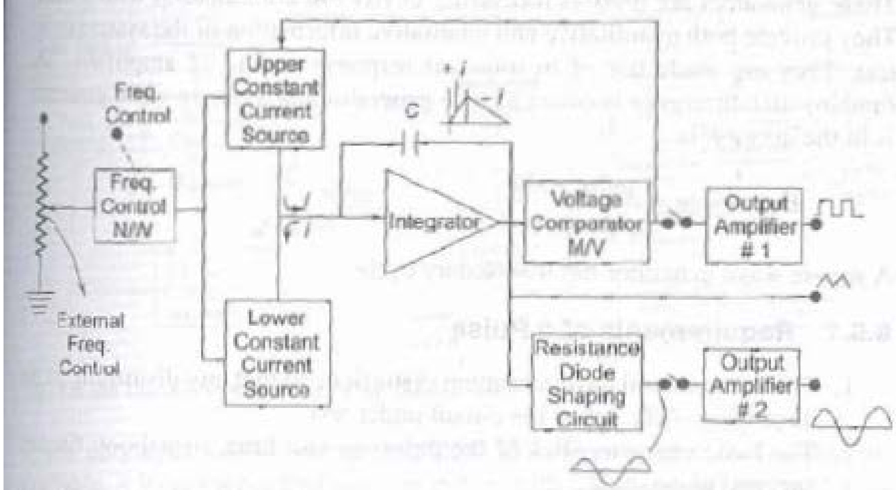

Fig. 8.5 Function Generator

The frequency controlled voltage regulates two current sources. The upper current source supplies constant current to the integrator whose output voltage increases linearly with time, according to the equation of the output signal voltage.

$$e_{out} = -\frac{1}{C}\int_0^t i\,dt$$

An increase or decrease in the current increases or decreases the slope of the output voltage and hence controls the frequency.

The voltage comparator multivibrator changes states at a pre-determined maximum level of the integrator output voltage. This change cuts off the upper current supply and switches on the lower current supply.

The lower current source supplies a reverse current to the integrator, so that its output decreases linearly with time. When the output reaches a pre-determined minimum level, the voltage comparator again changes state and switches on the upper current source.

The output of the integrator is a triangular waveform whose frequency is determined by the magnitude of the current supplied by the constant current sources.

The comparator output delivers a square wave voltage of the same frequency. The resistance diode network alters the slope of the triangular wave as its amplitude changes and produces a sine wave with less than 1% distortion.

8.9 SQUARE AND PULSE GENERATOR (LABORATORY TYPE)

These generators are used as measuring devices in combination with a CRO. They provide both quantitative and qualitative information of the system under test. They are made use of in transient response testing of amplifiers. The fundamental difference between a pulse generator and a square wave generator is in the duty cycle.

$$\text{Duty cycle} = \frac{\text{pulse width}}{\text{pulse period}}$$

A square wave generator has a 50% duty cycle.

8.9.1 Requirements of a Pulse

1. The pulse should have minimum distortion, so that any distortion, in the display is solely due to the circuit under test.
2. The basic characteristics of the pulse are rise time, overshoot, ringing, sag, and undershoot.
3. The pulse should have sufficient maximum amplitude, if appreciable output power is required by the test circuit, e.g. for magnetic core memory. At the same time, the attenuation range should be adequate to produce small amplitude pulses to prevent over driving of some test circuit.
4. The range of frequency control of the pulse repetition rate (PRR) should meet the needs of the experiment. For example, a repetition frequency of 100 MHz is required for testing fast circuits. Other generators have a pulse-burst feature which allows a train of pulses rather than a continuous output.

5. Some pulse generators can be triggered by an externally applied trigger signal; conversely, pulse generators can be used to produce trigger signals, when this output is passed through a differentiator circuit.
6. The output impedance of the pulse generator is another important consideration. In a fast pulse system, the generator should be matched to the cable and the cable to the test circuit. A mismatch would cause energy to be reflected back to the generator by the test circuit, and this may be re-reflected by the generator, causing distortion of the pulses.
7. DC coupling of the output circuit is needed, when dc bias level is to be maintained.

The basic circuit for pulse generation is the asymmetrical multi-vibrator. A laboratory type square wave and pulse generator is shown in Fig. 8.6.

The frequency range of the instrument is covered in seven decade steps from 1 Hz to 10 MHz, with a linearly calibrated dial for continuous adjustment on all ranges.

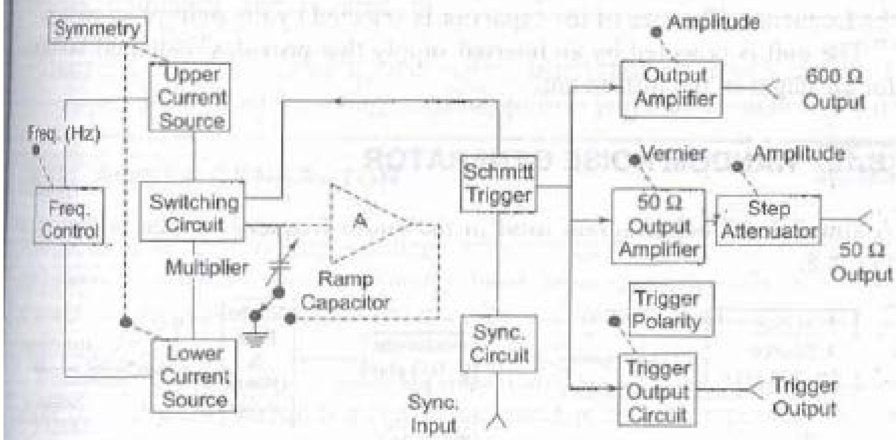

Fig. 8.6 Block Diagram of a Pulse Generator

The duty cycle can be varied from 25 – 75%. Two independent outputs are available, a 50 Ω source that supplies pulses with a rise and fall time of 5 ns at 5 V peak amplitude and a 600 Ω source which supplies pulses with a rise and fall time of 70 ns at 30 V peak amplitude. The instrument can be operated as a free-running generator, or it can be synchronised with external signals.

The basic generating loop consists of the current sources, the ramp capacitor, the Schmitt trigger and the current switching circuit, as shown in Fig. 8.7.

The upper current source supplies a constant current to the capacitor and the capacitor voltage increases linearly. When the positive slope of the ramp voltage reaches the upper limit set by the internal circuit components, the Schmitt trigger changes state. The trigger circuit output becomes negative and reverses the condition of the current switch. The capacitor discharges linearly, controlled by the lower current source. When the negative ramp reaches a

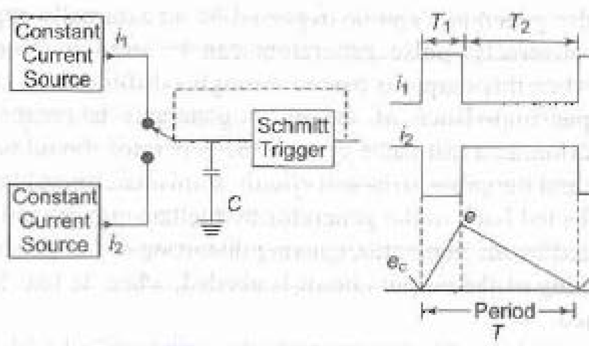

Fig. 8.7 Basic Generating Loop

predetermined lower level, the Schmitt trigger switches back to its original state. The entire process is then repeated. The ratio i_1/i_2 determines the duty cycle, and is controlled by symmetry control. The sum of i_1 and i_2 determines the frequency. The size of the capacitor is selected by the multiplier switch.

The unit is powered by an internal supply that provides regulated voltages for all stages of the instrument.

b. What is the need of Sampling Oscilloscope? Draw its block diagram and explain its working with the help of waveforms at each block. (8)

Answer:

An ordinary oscilloscope has a B.W. of 10 MHz. The HF performance can be improved by means of sampling the input waveform and reconstructing its shape from the sample, i.e. the signal to be observed is sampled and after a few cycles the sampling point is advanced and another sample is taken. The shape of the waveform is reconstructed by joining the sample levels together. The sampling frequency may be as low as 1/10th of the input signal frequency (if the input signal frequency is 100 MHz, the bandwidth of the CRO vertical amplifier can be as low as 10 MHz). As many as 1000 samples are used to reconstruct the original waveform.

Figure 7.24 shows a block diagram of a sampling oscilloscope. The input waveform is applied to the sampling gate. The input waveform is sampled whenever a sampling pulse opens the sampling gate. The sampling must be

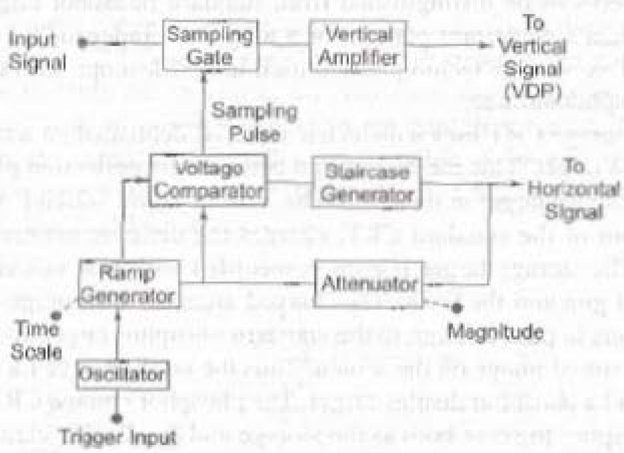

Fig. 7.24 Sampling Oscilloscope

synchronised with the input signal frequency. The signal is delayed in the vertical amplifier, allowing the horizontal sweep to be initiated by the input signal. The waveforms are shown in Fig. 7.25.

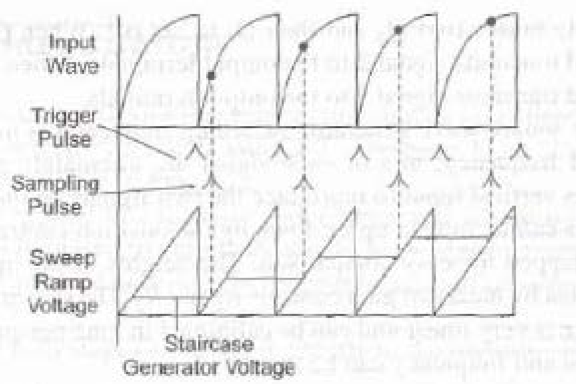

Fig. 7.25 Various Waveforms at Each Block of a Sampling Oscilloscope

At the beginning of each sampling cycle, the trigger pulse activates an oscillator and a linear ramp voltage is generated. This ramp voltage is applied to a voltage comparator which compares the ramp voltage to a staircase generator. When the two voltages are equal in amplitude, the staircase advances one step and a sampling pulse is generated, which opens the sampling gate for a sample of input voltage.

The resolution of the final image depends upon the size of the steps of the staircase generator. The smaller the size of the steps the larger the number of samples and higher the resolution of the image.

Q.7 a. Explain the working of Frequency Selective Wave Analyzer. Give its applications. (8)

Answer:

The wave analyzer consists of a very narrow pass-band filter section which can be tuned to a particular frequency within the audible frequency range (20 Hz – 20 kHz). The block diagram of a wave analyzer is as shown in Fig. 9.1(b).

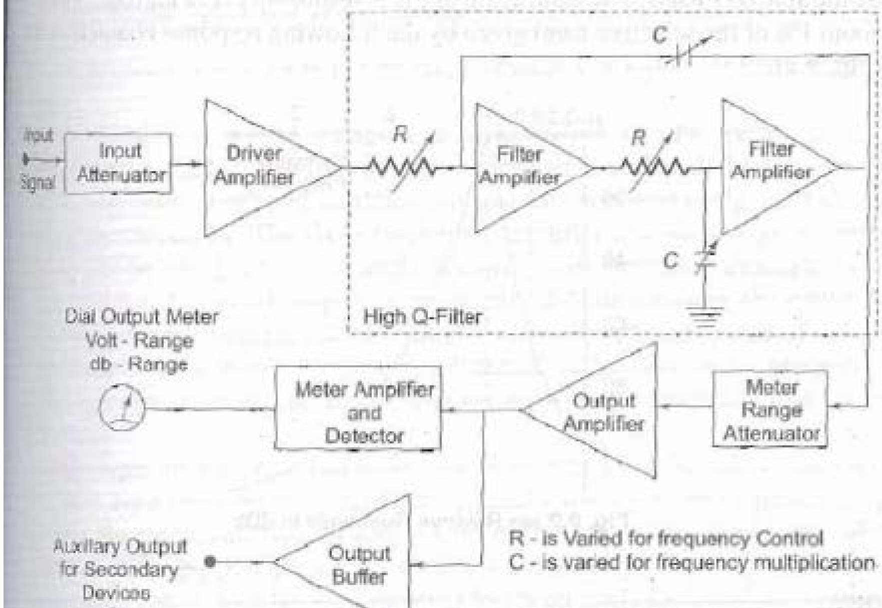

Fig. 9.1 (b) Frequency Selective Wave Analyzer

The complex wave to be analyzed is passed through an adjustable attenuator which serves as a range multiplier and permits a large range of signal amplitudes to be analyzed without loading the amplifier.

The output of the attenuator is then fed to a selective amplifier, which amplifies the selected frequency. The driver amplifier applies the attenuated input signal to a high-Q active filter. This high-Q filter is a low pass filter which allows the frequency which is selected to pass and reject all others. The magnitude of this selected frequency is indicated by the meter and the filter section identifies the frequency of the component. The filter circuit consists of a cascaded RC resonant circuit and amplifiers. For selecting the frequency range, the capacitors generally used are of the closed tolerance polystyrene type and the resistances used are precision potentiometers. The capacitors are used for range changing and the potentiometer is used to change the frequency within the selected pass-band. Hence this wave analyzer is also called a Frequency selective voltmeter.

The entire AF range is covered in decade steps by switching capacitors in the RC section.

The selected signal output from the final amplifier stage is applied to the meter circuit and to an untuned buffer amplifier. The main function of the buffer amplifier is to drive output devices, such as recorders or electronics counters.

The meter has several voltage ranges as well as decibel scales marked on it. It is driven by an average reading rectifier type detector.

The wave analyzer must have extremely low input distortion, undetectable by the analyzer itself. The bandwidth of the instrument is very narrow, typically about 1% of the selective band given by the following response characteristic (Fig. 9.2).

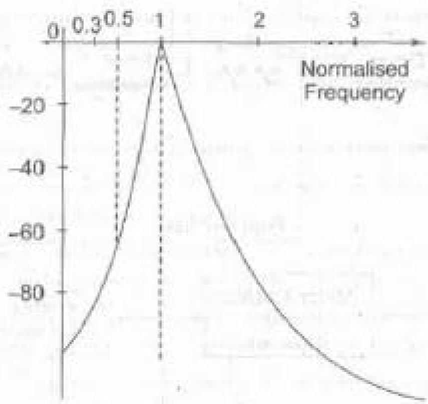

Fig. 9.2 Relative Response in dBs

b. What is a Bolometer? Explain the working of Bolometer Mount with the help of a neat diagram. (8)

Answer:

Bolometric measurements are based on the dissipation of the RF power in a small temperature sensitive resistive element, called a Bolometer. This bolometer may be a short ultra thin wire having a positive temperature coefficient (PTC) of resistance, called Baretter, or a bead of semi-conductor having a negative temperature coefficient (NTC) called Thermistor.

Both Baretters and Thermistors can measure small powers, of the order of a fraction of micro-watts. They can also indicate or monitor large amounts of power by inserting a directional coupler.

The RF power to be measured heats the bolometer and causes a change in its electrical resistance, which serves as an indication of the magnitude of power.

The bolometer is generally used in a bridge network so that small changes in resistance can be easily detected and hence power can be measured.

The bolometer support consists of a thin mica disc on one side of which silver electrodes are sprayed. Silver painted holes through the mica connect the (lower) outer electrode to a circular electrode on the opposite side. Between the centre and outer electrodes are mounted two short (1 mm) lengths of deplated Wollaston wires of 1 micron diameter, each measuring 100Ω at dc with normal bias power. The mica disc is clamped in the holder, as shown in Fig. 20.1, so that the upper electrode makes contact with the metal case, while the other two electrodes are insulated from a co-axial line by a thin mica sheet which provides the bypass capacitor necessary to complete the RF circuit, and to place two wires in RF parallel across the line.

Q.8 a. What is meant by Strip Chart Recorder? Explain basic Strip Chart Recorder with neat block diagram and write its applications. (9)

Answer:

Strip chart recorders are those in which data is recorded on a continuous roll of chart paper moving at a constant speed. The recorder records the variation of one of more variables with respect to time. The basic element of a strip chart recorder consists of a pen (stylus) used for making marks on a movable paper, a pen (stylus) driving system, a vertically moving long roll of chart paper and chart paper drive mechanism and a chart speed selector switch, (as shown in Fig. 12.1(a)).

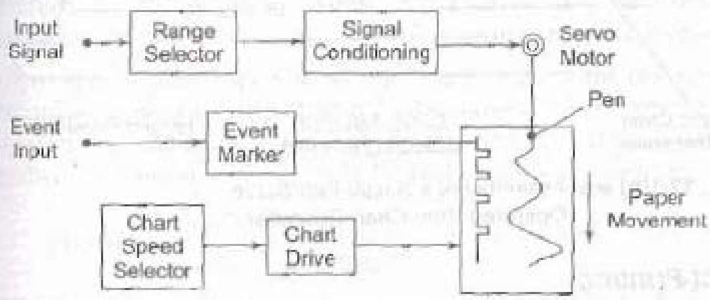

Fig. 12.1(a) Basic Strip Chart Recorder

Most recorders use a pointer attached to the stylus, so that the instantaneous value of the quantity being recorded can be measured directly on a calibrated scale. The assembly of a strip chart recorder is shown in Fig. 12.1(b). This recorder uses a single pen and is servo driven.

Most strip chart recorders use a servo feedback system, to ensure that the displacement of the pen (stylus) across the paper tracks the input voltage in the required frequency range.

A potentiometer system is generally used to measure the position of the writing head (stylus).

The chart paper drive system generally consists of a stepping motor which controls the movement of the chart paper at a uniform rate.

The data on the strip chart paper can be recorded by various methods.

1. Pen and Ink Stylus

The ink is supplied to the stylus from a refillable reservoir by capillary action. Modern technology has replaced these pens by disposable fibre tip pens. In addition, multichannel operation can be performed, i.e. at any instant, a maximum of six pens can be used to record data. When using multiple pens, staggering of the pens are necessary to avoid mechanical interference.

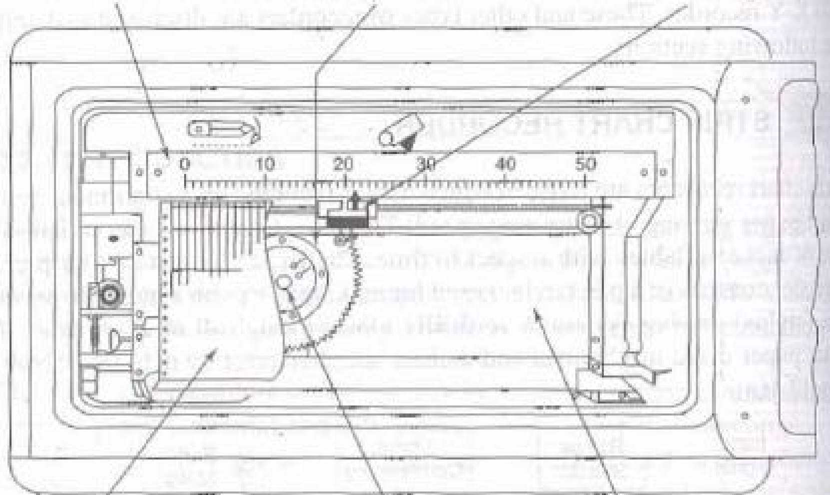

Fig. 12.1(b) Assembly of a Single Pen Servo Operated Strip Chart Recorder

2. Impact Printing

The original impact system consisted of a carbon ribbon placed between the pointer mechanism and paper, which provided the ink for recording data. The mark was made on the paper by pressing the pointer mechanism on it. The advantage of impact printing over the pen and ink method is that, it can record data on up to 20 variables simultaneously. This is achieved with the help of a wheel with an associated ink pad which provides the ink for the symbol on the wheel. The wheel is moved across the paper in response to the variable being recorded.

In some mechanisms, pressure sensitive paper is used. The markings on the paper are done with chopper bar, which applies the pressure on the paper. The frequency of the chopper bar is once per second.

3. Thermal Writing

In this system, a special movable pen which is thermally heated by passing an electric current through it is used. This system requires a thermally sensitive paper which changes its colour on application of heat.

4. Electric Writing

This technique is based on the principle of electrostatics.

In this method, a special chart paper is used. This paper consists of a paper base coated with a layer of coloured dye (black, blue or red), which in turn is coated with a thin surface of aluminium.

The stylus (pen) consists of a tungsten wire moving over the aluminium surface. Markings on the paper are achieved by applying a potential of 35 V to the stylus. This causes an electric discharge which removes the aluminium, revealing the coloured dye.

5. Optical Writing

In this technique of writing, a special photo sensitive chart paper, sensitive to ultra violet light is used. This technique is mostly used in galvanometer system.

Ultra violet light is used to reduce unwanted effects from ambient light. The paper can be developed in daylight or under artificial light without the need for special chemicals, which is not possible if ordinary light is used.

Most recorders use a pointer attached to the stylus. This pointer moves over a calibrated scale giving the instantaneous value of the quantity being recorded.

(a) *Paper drive system* The paper drive system should move the paper at a uniform speed. A spring wound mechanism may be used in most recorders. A synchronous motor is used for driving the paper.

(b) *Chart speed* Chart speed is a term used to express the rate at which the recording paper in a strip chart recorder moves. It is expressed in in/s or mm/s and is determined by mechanical gear trains. If the chart speed is known, the period of the recorded signal can be calculated as

$$\text{Period} = \frac{\text{time}}{\text{cycle}} = \frac{\text{time base}}{\text{chart speed}}$$

and frequency can be determined as $f = 1/\text{period}$.

b. Discuss the objectives and requirements of recording data. (7)

Answer:

12.10 OBJECTIVES AND REQUIREMENTS OF RECORDING DATA

1. Recording is often carried out in order to preserve the details of measurement at a particular time.
2. The accuracy of the recording must be the same as the accuracy of the measurement, for best results.
3. A record should be legible and capable of being maintained properly.
4. Most of the critical parameters which influence the performance of the process or equipment has to be recorded for taking necessary action from time to time.
5. The recorded chart at a glance provides an overall picture of the performance of the unit. (All parameters automatically regulated are invariably recorded to depict the performance of automatic regulating loop.)
6. The recorded chart also reflects immediately what actions the operator had taken during his shift.
7. The necessary data for determining the efficiency, etc. is easily and readily provided.
8. Charts are also used as permanent records to provide answers to queries which may come up at a later time with respect to product quality.
9. It is also very valuable from the point of preventive maintenance.
10. Manufacturers of equipment often ask for the use of a recorder for recording certain parameters which are very critical for the performance of the equipment. The recorded chart indicates whether the equipment has been used as per their instructions or not.

Q.9 a. Write the applications of the following: (8)
(i) Differential Output Transducer
(ii) Capacitive Transducer
(iii) Strain Gauge
(iv) Resistive Transducer

Answer:

13.10 DIFFERENTIAL OUTPUT TRANSDUCERS

The differential output transducer consists of a coil which is divided into two parts, as shown in Figs. 13.17(a) and (b).

(Inductive transducers using self inductance as a variable use one coil, while those using mutual inductance as a variable use multiple coils.)

Normally the change in self inductance, ΔL, for inductive transducers, (working on the principle of change of self inductance) is not sufficient for detection of subsequent stages of the instrumentation system.

However, if successive stages of the instrument respond to ΔL or ΔM, rather than $L + \Delta L$, or $M + \Delta M$, the sensitivity and accuracy will be much higher.

The transducers can be designed to provide two outputs, one of which represents inductance (self or mutual) and the other the decrease in inductance (self or mutual). The succeeding stages of the instrumentation system measure the difference between these outputs. This is known as differential output.

Advantages of Differential Output

1. Sensitivity and accuracy are increased.
2. Output is less affected by external magnetic fields.
3. Effective variations due to temperature changes are reduced.
4. Effects of change in supply voltages and frequency are reduced.

In response to a physical signal (which is normally displacement), the inductance of one part increases from L to $L + \Delta L$, while that of the other part decreases from L to $L - \Delta L$. The change is measured as the difference of the two, resulting in an output of $2\,\Delta L$ instead of ΔL, when one winding is used. This increases the sensitivity and also eliminates error.

Inductive transducers using the change in the number of turns to cause a change in the self inductance are shown in Fig. 13.17.

Figure 13.17(a) is used for measurement of linear displacement using an air cored coil.

Figure 13.17(b) is used for the measurement of angular displacement using an iron cored coil.

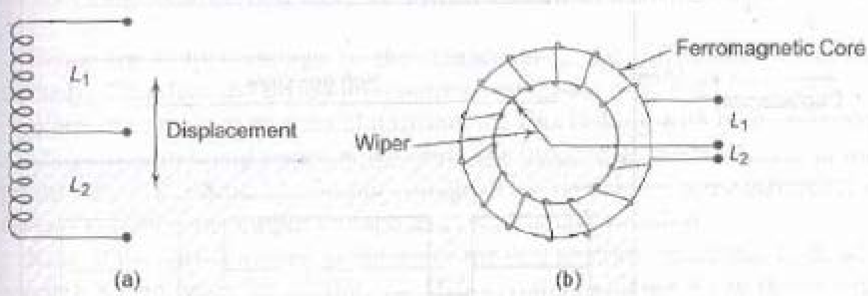

Fig. 13.17 (a) Linear Differential Output Transducer
(b) Angular Differential Output Transducer

Figure 13.18 shows an inductive transducer giving a differential output. The output represents a change of self inductance due to change of reluctance. (This inductive transducer also works on the principle of change of self inductance of the two coils with change in reluctance of the path of the magnetic circuit. The target as well as cores on which the coil is wound are made up of iron.)

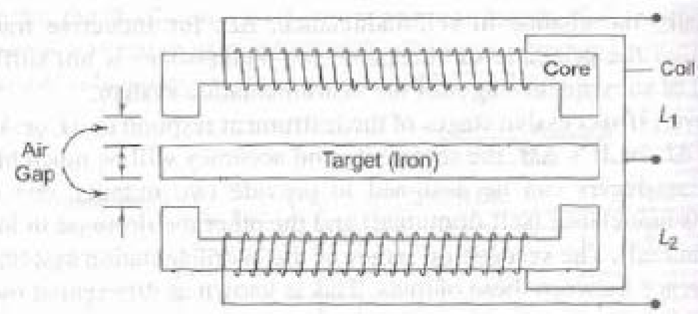

Fig. 13.18 Inductive Transducer Differential Output (Reluctance Principle)

13.13 CAPACITIVE TRANSDUCER (PRESSURE)

A linear change in capacitance with changes in the physical position of the moving element may be used to provide an electrical indication of the element's position.

The capacitance is given by $C = KA/d$ (13.14)

where K = the dielectric constant
A = the total area of the capacitor surfaces
d = distance between two capacitive surfaces
C = the resultant capacitance.

From this equation, it is seen that capacitance increases (i) if the effective area of the plate is increased, and (ii) if the material has a high dielectric constant.

The capacitance is reduced if the spacing between the plates is increased.

Transducers which make use of these three methods of varying capacitance have been developed.

With proper calibration, each type yields a high degree of accuracy. Stray magnetic and capacitive effects may cause errors in the measurement produced, which can be avoided by proper shielding. Some capacitive dielectrics are temperature sensitive, so temperature variations should be minimised for accurate measurements.

A variable plate area transducer is made up of a fixed plate called Stator and a movable plate called the Rotor.

The rotor is mechanically coupled to the member under test. As the member moves, the rotor changes its position relative to the stator, thereby changing the effective area between the plates. A transducer of this type is shown in Fig. 13.28.

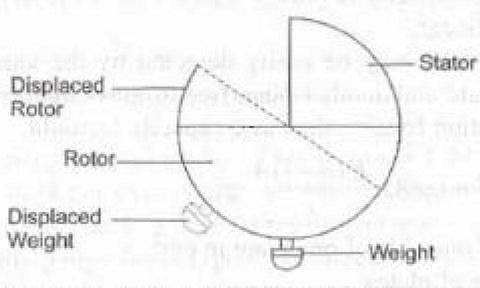

Fig. 13.28 Capacitive Transducer

Such a device is used to detect the amount of roll in an aircraft. As the aircraft rolls to the left, the plates moves to the relative position shown by dashed lines in Fig. 13.28 and the capacitance decreases by an amount proportional to the degree of roll. Similarly to the right. In this case the stator, securely attached to the aircraft, is the moving element. The weight on the rotor keeps its position fixed with reference to the surface of the earth, but the relative position of the plates changes and this is the factor that determines the capacitance of the unit.

Figure 13.29 shows a transducer that makes use of the variation in capacitance resulting from a change in spacing between the plates. This particular transducer is designed to measure pressure (in vacuum).

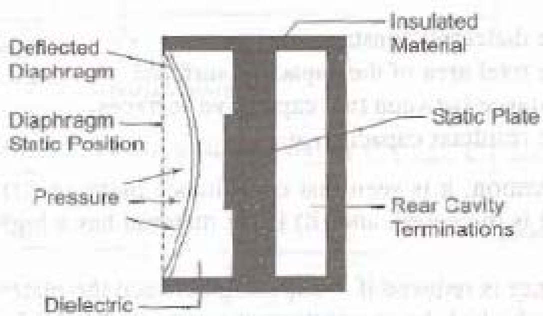

Fig. 13.29 Capacitive Pressure Transducer

Enclosed in an airtight container is a metallic diaphragm which moves to the left when pressure is applied to the chamber and to the right when vacuum is applied. This diaphragm is used as one plate of a variable capacitor. Its distance from the stationary plate to its left, as determined by the pressure applied to the unit, determines the capacitance between the two plates. The monitor indicates the pressure equivalent of the unit's capacitance by measuring the capacitor's reactance to the ac source voltage.

(The portion of the chamber to the left of the moving plate is isolated from the side into which the pressurised gas or vapour is introduced. Hence the dielectric constant of the unit does not change for different types of pressurised gas or vapour. The capacity is purely a function of the diaphragm position.) This device is not linear.

Changes in pressure may be easily detected by the variation of capacity between a fixed plate and another plate free to move as the pressure changes. The resulting variation follows the basic capacity formula.

$$C = 0.885\,\frac{K(n-1)A}{t}\ \text{pf} \qquad (13.15)$$

where A = area of one side of one plate in cm^2

n = number of plates

t = thickness of dielectric in cm

K = dielectric constant

The capacitive transducer, as in the capacitive microphone, is simple to construct and inexpensive to produce. It is particularly effective for HF variations.

However, when the varying capacitance is made part of an ac bridge to produce an ac output signal, the conditions for resistive and reactive balance generally require much care to be taken against unwanted signal pickup in the high impedance circuit, and also compensation for temperature changes. As a result, the receiving instrument for the capacitive sensor usually calls for more advanced and complex design than is needed for other transducers.

13.14 LOAD CELL (PRESSURE CELL)

The load cell is used to weigh extremely heavy loads. A length of bar, usually steel, is used as the active element. The weight of the load applies a particular stress to the bar. The amount of strain which results in the bar for different values of applied stress is determined, so that the strain may be used as a direct measure of the stress causing it.

The load cell shown in Fig. 13.30 is a good example of the use of strain gauges in weighing operations.

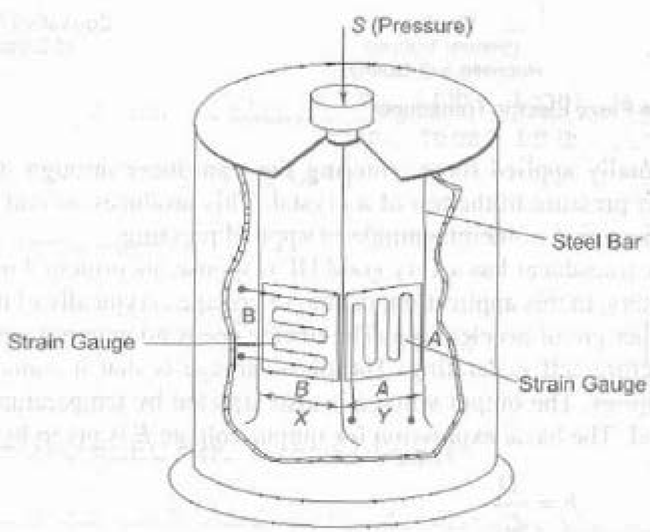

Fig. 13.30 Strain Gauge Load Cell

As the stress is applied along the direction of S (shown by the arrow in Fig. 13.30), the steel bar experiences a compression along that axis and an expansion along the X and Y axes. As a result, gauge A experiences a decrease in resistance, while gauge B undergoes an increase in resistance. When these two gauges and the gauges on the two remaining sides of the steel are connected to form a bridge circuit, four times the sensitivity of a simple gauge bridge is

13.6 STRAIN GAUGES

The strain gauge is an example of a passive transducer that uses the variation in electrical resistance in wires to sense the strain produced by a force on the wires.

It is well known that stress (force/unit area) and strain (elongation or compression/unit length) in a member or portion of any object under pressure is directly related to the modulus of elasticity.

Since strain can be measured more easily by using variable resistance transducers, it is a common practice to measure strain instead of stress, to serve as an index of pressure. Such transducers are popularly known as strain gauges.

If a metal conductor is stretched or compressed, its resistance changes on account of the fact that both the length and diameter of the conductor changes. Also, there is a change in the value of the resistivity of the conductor when subjected to strain, a property called the *piezo-resistive effect.* Therefore, resistance strain gauges are also known as *piezo resistive gauges.*

Many detectors and transducers, e.g. load cells, torque meters, pressure gauges, temperature sensors, etc. employ strain gauges as secondary transducers.

When a gauge is subjected to a positive stress, its length increases while its area of cross-section decreases. Since the resistance of a conductor is directly proportional to its length and inversely proportional to its area of cross-section, the resistance of the gauge increases with positive strain. The change in resistance value of a conductor under strain is more than for an increase in resistance due to its dimensional changes. This property is called the piezo-resistive effect.

The following types of strain gauges are the most important.

1. Wire strain gauges
2. Foil strain gauges
3. Semiconductor strain gauges

13.4 RESISTIVE TRANSDUCER

Resistive transducers are those in which the resistance changes due to a change in some physical phenomenon. The change in the value of the resistance with a change in the length of the conductor can be used to measure displacement.

Strain gauges work on the principle that the resistance of a conductor or semiconductor changes when strained. This can be used for the measurement of displacement, force and pressure.

The resistivity of materials changes with changes in temperature. This property can be used for the measurement of temperature.

b. Explain Multi Channel Data Acquisition System with neat block diagram. (8)

Answer:

17.5 MULTI-CHANNEL DAS

The various sub-systems of the DAS can be time shared by two or more input sources. Depending on the desired properties of the multiplexed system, a number of techniques are employed for such time shared measurements.

17.5.1 Multi-Channel Analog Multiplexed System

The multi-channel DAS has a single A/D converter preceded by a multiplexer, as shown in Fig. 17.5.

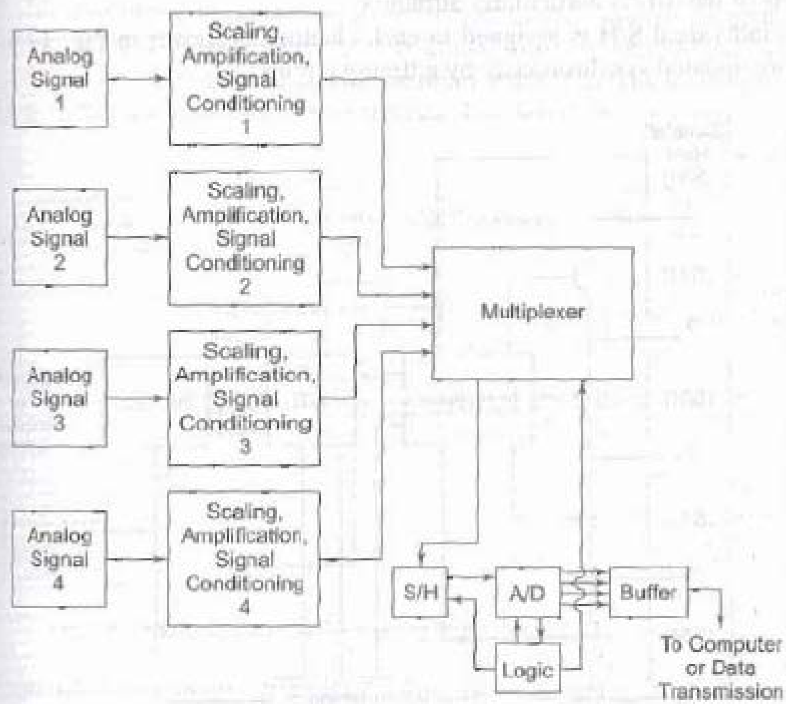

Fig. 17.5 Multi-channel DAS (A/D Preceded by a Multiplexer)

The individual analog signals are applied directly or after amplification and/or signal conditioning, whenever necessary, to the multiplexer. These are further converted to digital signals by the use of A/D converters, sequentially.

For the most efficient utilisation of time, the multiplexer is made to seek the next channel to be converted while the previous data stored in the sample/hold is converted to digital form.

When the conversion is complete, the status line from the converter causes the sample/hold to return to the sample mode and acquires the signal of the next channel. On completion of acquisition, either immediately or upon command, the S/H is switched to the hold mode, a conversion begins again and the multiplexer selects the next channel. This method is relatively slower than systems where S/H outputs or even A/D converter outputs are multiplexed, but it has the obvious advantage of low cost due to sharing of a majority of sub-systems.

Sufficient accuracy in measurements can be achieved even without the S/H, in cases where signal variations are extremely slow.

TEXT BOOK

I. A Course in Electrical and Electronic Measurements and Instrumentation, A.K Sawhney, Dhanpat Rai & Co,New Delhi, 19th Revised Edition 2011(Reprint 2012)
II. Electronic Instrumentation, H.S Kalsi, Tata McGraw Hill, 3rd Edition (fourth reprint 2012)