Q.2 a. What are 'systematic errors' in electric and electronic measuring instruments? Discuss these errors giving suitable examples.

Answer:

Systematic Error

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

These errors are sometimes referred to as bias, and they influence all measurements of a quantity alike. A constant uniform deviation of the operation of an instrument is known as a systematic error. There are basically three types of systematic errors—(i) Instrumental, (ii) Environmental, and (iii) Observational.

(i) Instrumental Errors

Instrumental errors are inherent in measuring instruments, because of their mechanical structure. For example, in the D'Arsonval movement, friction in the bearings of various moving components, irregular spring tensions, stretching of the spring, or reduction in tension due to improper handling or overloading of the instrument.

Instrumental errors can be avoided by

(a) selecting a suitable instrument for the particular measurement applications. (Refer Examples 1.3 (a) and (b)).

(b) applying correction factors after determining the amount of instrumental error.

(c) calibrating the instrument against a standard.

(ii) Environmental Errors

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

These errors can also be avoided by (i) air conditioning, (ii) hermetically sealing certain components in the instruments, and (iii) using magnetic shields.

(iii) Observational Errors

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

These errors are caused by the habits of individual observers. For example, an observer may always introduce an error by consistently holding his head too far to the left while reading a needle and scale reading.

b. A voltmeter reading 70V on its 100V range and an ammeter reading 80 mA on its 150 mA range are used to determine the power dissipated in a resistor. Both these instruments are guaranteed to be accurate within ± 1.5% at full scale deflection. Determine the limiting error of power.

Answer:

Magnitude of limiting error of Voltmeter

0.015 x 100 = 1.5V

Limiting error at 70 V is $\frac{1.5}{70} \times 100 = 2.143\%$

Magnitude of limiting error of Ammeter

0.015 x 150 mA = 2.25mA

limiting error at 80mA is $\frac{2.25}{80} \times 100 = 2.813\%$

limiting error in power = 2.43% + 2.813% = 4.956%

Q.3 a. Find the equivalent series resistance and inductance of Rx and Lx at balance for a given bridge: (6)

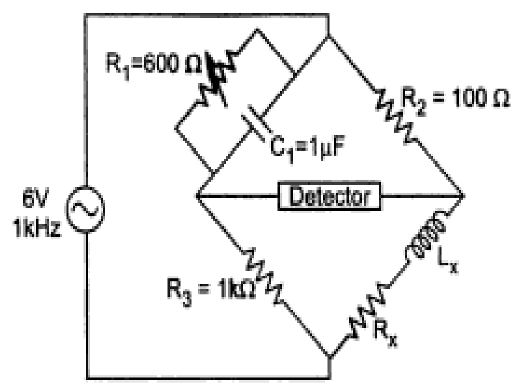

Fig.1

Answer:

$$\therefore \quad Y_1 = \frac{1}{R_1} + j\omega C_1$$
$$= \frac{1}{600} + j\left(2\pi \times 1000 \times 1 \times 10^{-6}\right)$$
$$= 1.66 \times 10^{-3} + j\,6.283 \times 10^{-3}$$
$$Z_2 = 100\,\Omega$$
$$Z_3 = 1000\,\Omega$$
$$Z_4 = R_x + j\,X_L = Z_x$$

From the basic balance equation,

$$Z_1 Z_4 = Z_2 Z_3$$
$$\therefore \quad Z_4 = \frac{Z_2 Z_3}{Z_1} = Z_2 Z_3 Y_1$$
$$= 100 \times 1000 \times [1.66 \times 10^{-3} + j\ 6.283 \times 10^{-3}]$$
$$= 166 + j\,628.3\,\Omega$$
$$= R_x + j\,X_L\,\Omega$$
$$\therefore \quad R_x = 166\,\Omega$$
$$\therefore \quad X_L = 628.3 = 2\pi f L_x$$
$$\therefore \quad L_x = \frac{628.3}{2\pi \times 1000}$$
$$= 0.099\text{ H}$$

b. Derive the equations of balance for an Anderson's bridge. Draw the phasor diagram for the conditions under balance. Discuss the advantages and disadvantages of the bridge.

Answer:

In this method, the unknown inductance is measured in terms of a known capacitance and resistance, as shown in Fig.

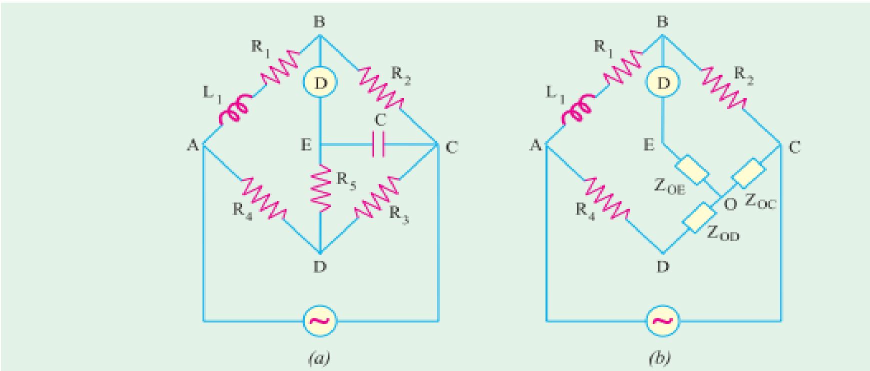

Fig.

The balance conditions for this bridge may be easily obtained by converting the mesh of impedances C, R_5 and R_3 to an equivalent star with star point O by Δ / Y transformation. As seen from Fig. (b).

$$\mathbf{Z}_{OD} \quad \frac{R_3 R_5}{(R_3 \quad R_5 \quad 1/j \quad C)}; \quad \mathbf{Z}_{OC} \quad \frac{R_3 / j \quad C}{(R_3 \quad R_5 \quad 1/j \quad C)} \quad \mathbf{Z}_3$$

With reference to Fig. 16.7 (b) it is seen that

$\mathbf{Z}_1 = (R_1 + j\omega L_1)$ $\mathbf{Z}_2 = R_2$; $\mathbf{Z}_3 = \mathbf{Z}_{OC}$ and $\mathbf{Z}_4 = R_4 + \mathbf{Z}_{OD}$

For balance $Z_1Z_3 = Z_2Z_4$ ∴ $(R_1 \;\; j \;\; L_1) \;\; Z_{OC} \;\; R_2(R_4 \;\; Z_{OD})$

$$\therefore \; (R_1 \;\; j \;\; L_1)\frac{R_3/j\;C}{(R_3 \;\; R_5 \;\; 1/j\;C)} \;\; R_2 \;\; R_4 \;\; \frac{R_3R_5}{R_3 \;\; R_5 \;\; 1/j\;C}$$

Further simplification leads to $R_2R_3R_4 \;\; R_2R_4R_5 \;\; j\frac{R_2R_4}{C} \;\; R_2R_3R_5 \;\; j\frac{R_1R_3}{C} \;\; \frac{R_3L_1}{C}$

$\therefore \;\; \frac{jR_2R_4}{C} \;\; \frac{jR_1R_3}{C}$ or $R_1 \;\; R_2R_4/R_3$

Also $\frac{R_3L_1}{C} \;\; R_2R_3R_4 \;\; R_2R_3R_5 \;\; R_2R_4R_5 \;\; \therefore \; L_1 = CR_2 \;\; R_4 + R_5 + \frac{R_4R_5}{R_3}$

This method is capable of precise measurements of inductances over a wide range of values from a few micro-henrys to several henrys and is one of the commonest and the best bridge methods.

Phasor diagram

Q.4 a. Explain the principle of operation of thermocouple. (8)

Answer:

Principle of Operation thermocouple:

The thermoelectric e.m.f. generated in a thermocouple is proportional to the difference of temperatures of hot and cold junctions. This relation is parabolic in nature and given by,

$$e = a(T_1 - T_2) + b(T_1 - T_2)^2 \quad \text{... (1)}$$

where a, b = constants depending on metals

$T_1 - T_2$ = Temperature difference of hot and cold junctions

Let $\Delta t = T_1 - T_2$ = Difference in temperatures

$$\therefore \quad e = a\,\Delta t + b\,\Delta t^2 \quad \text{... (2)}$$

The equation (2) shows that thermo-electric e.m.f. e has a parabolic relationship with the temperature difference Δt. The constant a is of the order of 40 to 50 μV per °C difference of temperature. The constant b is of the order of few tenths or hundredths of a microvolt per $(°C)^2$.

The heater element carries the current to be measured and heat produced is proportional to square of the r.m.s. value of the current. Thus the rise in temperature of hot junction is proportional to $I^2 R$ where I is the r.m.s. value of the current and R is the resistance of the heater element.

If the cold junction is maintained at ambient temperature then the rise in temperature of hot junction is equal to temperature rise of hot junction above the ambient temperature.

∴ Δt = Rise in temperature

And $\Delta t \propto I^2 R$ i.e. $\Delta t = K_1 I^2 R$ ... (3)

Key Point: *The equation (3) shows that thermocouple instruments show the square law response.*

Practically the value of constant b is very small and can be neglected.

∴ $e = a\,\Delta t$ ... (4)

∴ $e = a\,K_1 I^2 R$ ... (5)

This e.m.f. drives the PMMC instrument to cause the deflection θ proportional to e.m.f. e.

∴ θ = deflection of instrument ∝ e

∴ $\theta = K_2\, e = K_2\,[a\,K_1\, I^2\, R]$

$$\therefore \quad \theta = K_3\, I^2 \quad \text{... (6)}$$

where $K_3 = K_1\, K_2\, a\, R$ = Constant

b. Calculate the multiplier resistor required for a 100Vrms range on the voltmeter shown in given fig.2 **(8)**

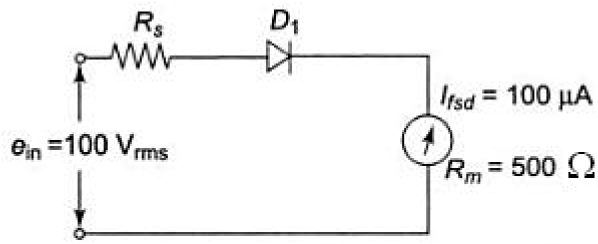

Fig.2

Answer:

Sensitivity of the voltmeter is given by

$$S_{dc} = 1/I_{fsd} = 1/100\ \mu A = 10^6/100 = 10\ k\Omega/V$$

$$R_s = S_{dc} \times \text{range} - R_m = 10\ k\Omega/V \times 0.45\ V \times 100 - 500\ \Omega$$

$$= 450\ k\Omega - 500\ \Omega = 449.5\ k\Omega$$

Q.5 a. Explain the merits and limitations of DVM over analog voltmeter.

Answer:

Comparison of Analog and Digital Instruments

Sr. No.	Parameter	Analog	Digital
1.	Accuracy	Less upto ± 0.1 % of full scale.	Very high accuracy upto ± 0.005 % of reading.
2.	Resolution	Limited upto 1 part in several hundreds.	High upto 1 part in several thousands.
3.	Power	Power required is high hence can cause loading.	Negligible power is required hence no loading effects.
4.	Cost	Low in cost.	High in cost compared to analog but now-a-days cost of digital instruments is also going down.
5.	Frictional errors	Errors due to moving parts are present.	No moving parts hence no errors.
6.	Range and polarity	No facility of autoranging and autopolarity.	Has the facility of autoranging and autopolarity.
7.	Input impedance	Low input impedance.	Very high input impedance.
8.	Observational errors	Errors such as parallax errors and approximation errors are present.	Due to digital displays, the observational errors are absent.
9.	Compatibality	Not compatible with modern digital instruments.	The digital output can be directly fed into memory of modern digital instruments.
10.	Speed	Reading speed is low.	Reading speed is very high.
11.	Programming facility	Not available.	Can be programmed and well suited for the computerised control.

b. Explain with the help of a neat diagram, the working of a digital frequency meter. (8)

Answer:

Block Diagram of Digital Frequency Meter

For the unknown frequency measurements the digital frequency counter is the most accurate and reliable instrument available. With the highest accuracy digital frequency counters, the accuracy of the atomic time standards can be achieved. As most of the events now a days can be converted into an electrical signal consisting train of pulses, the digital frequency counter can be used for counting heart beats, passing of radioactive particles, revólutions of motor shaft, light flashes etc. The block diagram of digital frequency counter is as shown in the Fig.

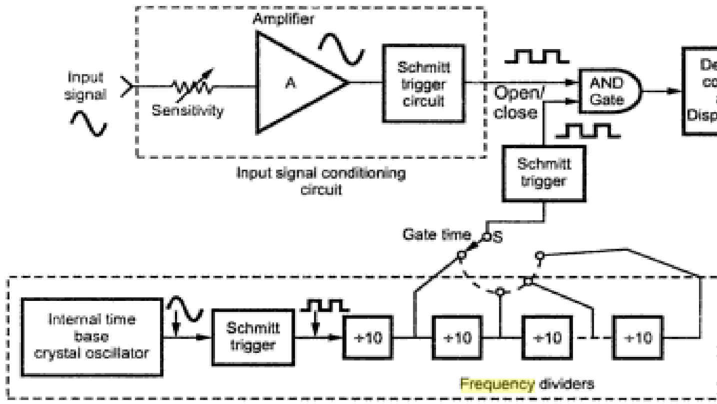

Fig. Block diagram of digital frequency counter

The major components of the digital frequency counter are as given below.

1. Input signal conditioning circuit
2. Time base generator
3. Gating circuit
4. Decimal counter and display unit.

Q.6 a. Explain the working of a square pulse generator. (8)

Answer: Refer article 8.9 of Text Book -II

b. Explain the following with reference to a CRO:
(i) Vertical amplifier
(ii) Horizontal Deflection system (8)

Answer:

(i) Vertical Amplifier:

The sensitivity (gain) and frequency bandwidth (B.W) response characteristics of the oscilloscope are mainly determine by the vertical amplifier .Since the gain-B W. product is constant, to obtain a greater sensitivity the B.W. is narrowed, or vice-versa.Some oscilloscopes give two alternatives, switching to a wide bandwidth position, and switching to a high sensitivity position.

Block Diagram of a Vertical Amplifier

The block diagram of a vertical amplifier is a shown fig

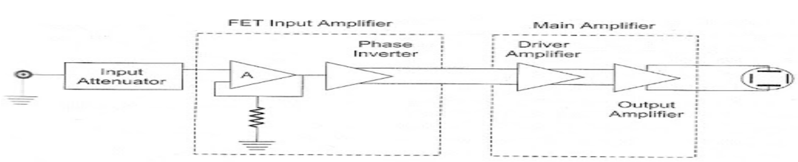

fig 4.1 Vertical Amplifier

The vertical amplifier consists of several stages, with fixed overall sensitivity gain expressed in V/div. The advantage of fixed gain is that the amplifier can be more easily designed to meet the requirements of stability and B.W. The vertical amplifier is kept within its signal handling capability by proper selection the input attenuator switch. The first element of the pre-amplifier is the input stage, often consisting of a FET source follower whose high input impedance isolates the amplifier from the attenuator. FET input stage is followed by a BJT emitter follower, to match the medium impedance of FET output with the low impedance input of the phase inverter. This phase inverter provides two anti phase output signals which are required operate the pushpull output amplifier. The push-pull output stage delivers equal signal voltages of opposite polarity to the vertical plates of the CRT. The advantages of push-pull operation in CRO are similar to those obtained from push-pull operation in other applications; better voltage cancellation ran the source or power supply (i.e. dc), even harmonic suppression, especially large 2nd harmonic is cancelled out, and greater power output per tube as a suit of even harmonic cancellation. In addition, a number of defocusing and non linear effects are reduced, because neither plate is at ground potential.

(ii) **Horizontal Defleting System:**
The horizontal deflecting system consist of a time,base Generator and an output amplifier.

Sweep or Time Base Generator:
A continuous sweep CRO using a UJT as a time base generator , The UJT is used to produce the sweep. When the power is first applied, the UJT is off and the CT charges exponentially through RT. The UJT emitter voltage VE rises towards VBB and when VE reaches the peak voltage VP, as shown in Fig. 4.3, the emitter to base '1' (B1) diode becomes forward biased and the UJT triggers ON. This provides a low resistance discharge path and the capacitor discharges rapidly. The emitter voltage VE reaches the minimum value rapidly and the UJT goes OFF. The capacitor recharges and the cycle repeats.

To improve sweep linearity, two separate voltage supplies are used, a low voltage supply for UJT and a high voltage supply for the RTCT circuit. RT is used for continuous control of frequency within a range and CT is varied or changed in steps for range changing. They are sometimes called as timing resistor and timing capacitor respectively. The sync pulse enables the sweep frequency to be exactly equal to the input signal frequency, so that the signal is locked on the screen and does not drift.

Q.7 a. Explain with the help of a neat diagram, the working of a spectrum analyzer.

Answer: Refer article 9.6 of Text Book-II

b. Explain power measurement using Bolometer Bridge. Draw neat schematic diagram. (8)

Answer:

Bolometer Bridge for Measurement of Power

The measurement of unknown R.F. power is done by using bolometer bridge in which a known A.F. power is superimposed on unknown R.F. power. The schematic of power measurement using bolometer bridge is as shown in the Fig.

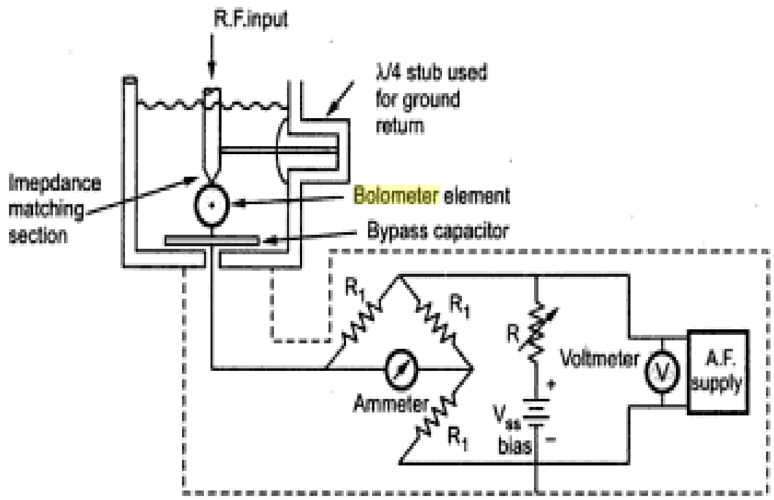

Fig. Schematic of power measurement using Bolometer bridge

Using the variable resistance R and the d.c. bias voltage V_{ss}, the current is adjusted till bolometer element is heated and its resistance equals R_1. With this value, bridge achieves balance condition. The test R.F. input is switched off which again unbalances bridge. To achieve the balance condition again, the A.F. voltage is increased till R.F. power equals,

$$\text{R.F. power} = \frac{V_2^2 - V_1^2}{4\,R_1}$$

In case of a co-axial line, the bolometer mount must provide proper impedance matching. For this tapered impedance matching section is used.

Q.8 a. Explain the working of a potentiometric recorder. (8)

Answer:

Principle of Operation :

These recorders are based on the principle of self balancing or null conditions. When the input signal given by sensor or transducer is applied to the measuring unit of the recorder, the balanced condition of the instrument gets disturbed. This unbalance signal produces error signal. This operates on some device which converts this error signal to some action so that the balanced condition of instrument is achieved. Now, this action is nothing but the magnitude of the error signal which is directly proportional to the change in the input signal. As this recorder is based on the principle of null condition, it is also called as Null Type Recorder.

The signal from transducer may be voltage, current or change in resistance, inductance, capacitance, etc. The recorder must be able to accept any input ; Following are the different types of the null type recorders having same principle of operation.

1. Potentiometric Recorders,
2. Bridge Recorders,
3. LVDT Recorders,

Self Balancing Potentiometric Recorder

The basic circuit diagram of a potentiometric recorder is as shown in Fig.

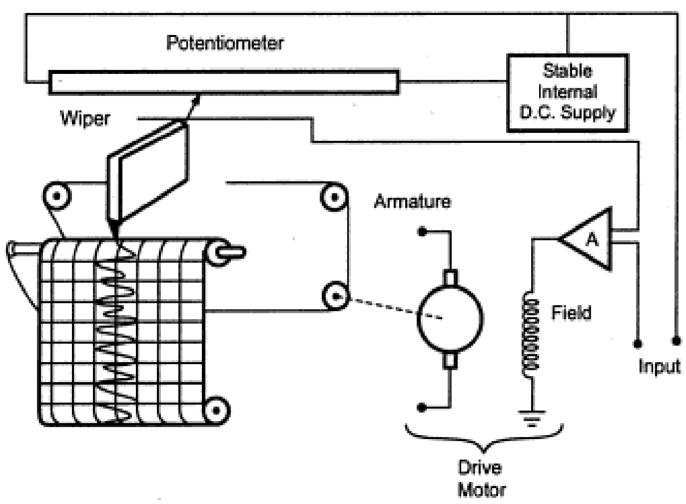

Fig. : Basic circuit diagram of self balancing potentiometric recorder

b. Discuss in detail the objectives and requirements of recording data.

Answer:

– **Objectives and Requirements of Recording Data**

i) The recording of any physical quantity is done in order to preserve the details of that quantity time to time. This helps in analyzing that quantity with some other quantities or parameters.

ii) The recorder provides display of any quantity with respect to time as well as with respect to other quantity.

iii) In many applications, there are some critical parameters of the process or equipment. For better performance of process or equipment these parameters are recorded for taking necessary action time to time.

iv) The performance of the unit, equipment or the process can be overviewed by just looking at the recorded chart.

v) The recorded chart also reflects the necessary action taken by the operator for better performance of process or equipment.

vi) The efficiency of process or equipment can be determined easily by using recorded chart.

vii) The answers to the problems come up with the product quality can be obtained by analysing the permanent record charts.

viii) The permanent record charts also helps in analysing the process or the equipment completely form the point of view of preventive maintenance.

ix) The recorded chart indicated the performance of the equipment as per the specifications provided by the manufacturer.

x) The accuracy of the recording must match the accuracy of measurement so as to obtain good results.

xi) The record must be maintained properly.

Q.9 a. Discuss the merits and limitations of RTDs.

Answer:

The RTD has several advantages over the traditional bourdon spring sensing device. These include:
• improved accuracy
• interchangeable sensors
• recorders can be placed in areas far from the sensing device.
• no drift

The disadvantages include:
• more expensive
• the response time is slower
• the ability to exchange an approved unit with a non-conforming unit. Sealing the RTD to the receiving module can minimize this concern.

b. Consider the following bridge circuit:

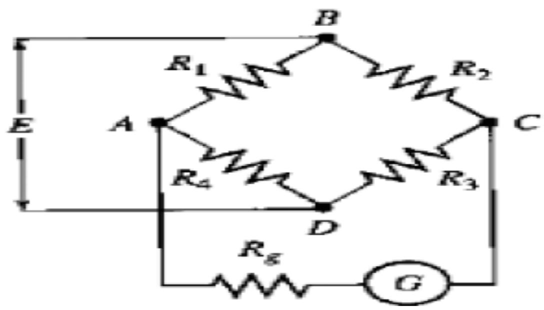

Fig.3

The galvanometer resistance is 75Ω. The strain gauge resistance $R_2 = R_3$ = 120Ω and R_1 = 100Ω at zero strain and the resistor R_4 is adjusted to balance the bridge at zero-strain conditions. The gauge factor is 2.5. Calculate the output voltage when the strain is 400 × 10^{-6}. Take the battery voltage as 9.0 V

Answer:

A9. $R_4 = 100\Omega$

$\Delta R = \varepsilon F R_4 = 4e-4 \times 2.5 \times 100 = 0.1\Omega$

The voltage is given by: $E_g = E\left(\frac{R_1}{R_1 + R_4 - \Delta R} - \frac{R_2}{R_2 + R_3}\right) = 9\left(\frac{100}{200 - 0.1} - 0.5\right) = 2.245mV$

TEXT BOOKS

I. A Course in Electrical and Electronic Measurements and Instrumentation, A.K Sawhney, Dhanpat Rai & Co., New Delhi, 18th Edition 2007.

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