Q.2 a. Define the following: **(8)**
(i) Accuracy
(ii) Linearity
(iii) Dead zone
(iv) Hysteresis

Answer:

b. Explain the following errors giving suitable example & write methods to minimize these **(4+4)**
(i) Gross errors
(ii) Random errors

Answer (i)

Gross Errors

These errors are mainly due to human mistakes in reading or in using instruments or errors in recording observations. Errors may also occur due to incorrect adjustment of instruments and computational mistakes. These errors cannot be treated mathematically.

The complete elimination of gross errors is not possible, but one can minimise them. Some errors are easily detected while others may be elusive.

One of the basic gross errors that occurs frequently is the improper use of an instrument. The error can be minimized by taking proper care in reading and recording the measurement parameter.

In general, indicating instruments change ambient conditions to some extent when connected into a complete circuit. (Refer Examples 1.3(a) and (b)).

(ii)

Random Errors

These are errors that remain after gross and systematic errors have been substantially reduced or at least accounted for. Random errors are generally an accumulation of a large number of small effects and may be of real concern only in measurements requiring a high degree of accuracy. Such errors can be analyzed statistically.

These errors are due to unknown causes, not determinable in the ordinary process of making measurements. Such errors are normally small and follow the laws of probability. Random errors can thus be treated mathematically.

For example, suppose a voltage is being monitored by a voltmeter which is read at 15 minutes intervals. Although the instrument operates under ideal environmental conditions and is accurately calibrated before measurement, it still gives readings that vary slightly over the period of observation. This variation cannot be corrected by any method of calibration or any other known method of control.

Q.3 a. Calculate current passing through unbalanced Wheatstone bridge's galvanometer

Resistance of galvanometer Rg = 300Ω

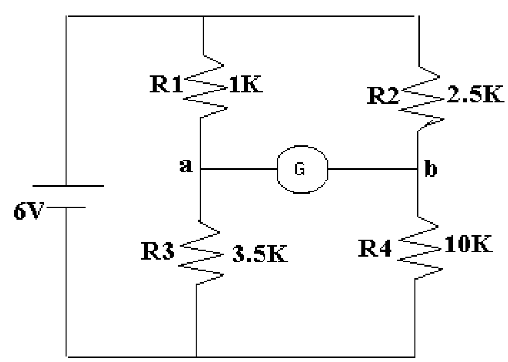


Fig. 1

Answer:

By thevenin's theorem

$$E_{th} = E_a - E_b$$

$$= E\left[\frac{R_4}{R_2+R_4} - \frac{R_3}{R_1+R_3}\right]$$

$$= 6\left[\frac{10}{12.5} - \frac{3.5}{4.5}\right] = 0.132\ \text{Volt}$$

(2)

Thevenin's equivalent resistance

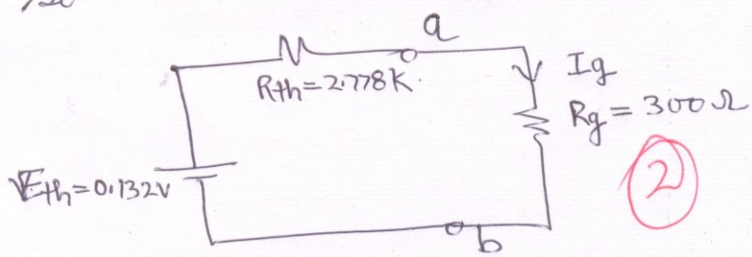
$$R_{th} = \frac{R_1 R_3}{R_1+R_3} + \frac{R_2 R_4}{R_2+R_4}$$

$$= \frac{1\times 3.5}{4.5} + \frac{2.5\times 10}{12.5}$$

$$= 2.778\,K$$

(2)

So thevenin's equivalent circuit is



(2)

$$I_g = \frac{E_{th}}{R_{th}+R_g}$$

$$= \frac{0.132}{2778+300}$$

$$= 42.88\ \mu A$$

(2)

b. A sample of insulation was placed in arm AB of a schering bridge, when the bridge, was balanced at a frequency of 50Hz the other arms of bridge were **(8)**
Arm BC → A non inductor R of 100Ω
Arm CD → A non inductive R of 300Ω in parallel with a capacitor of 0.5μF
Arm DA → A loss free capacitor of 100 pf
Determine the capacitance, equivalent series resistance and power factor of the insulation in test arm AB.

Answer:

$R_3 = 100\,\Omega$

$R_4 = 300\,\Omega \quad C_4 = 0.5\,\mu F$

$C_2 = 100\,pf \quad f = 50\,Hz$

$\omega = 2\pi f = 2 \times 3.14 \times 50 = 314$ (2)

$C_1 = \frac{R_4}{R_3} C_2 = \frac{300}{100} \times 100\,pf = 300\,pf$ (2)

$R_1 = \frac{C_4}{C_2} R_3 = \frac{0.5\,\mu F}{100\,pf} \times 100$ (2)

$= 0.5\,M\Omega$

Power factor $= \omega R_4 C_4$

$= 314 \times 300 \times 0.5 \times 10^{-6}$

$= 0.0471$ (2)

Q.4 a. Design a multirange ammeter with range of 0-1A, 5A & 10A employing individual shunt in each. A D'Arsonal movement with an internal resistance of 500Ω and a full scale deflection of 10 mA is available. **(8)**

Answer:

$I_m = 10\,mA$ & $R_m = 500\,\Omega$

For range 0-1 A i.e 1000 mA

$R_{sh1} = \frac{I_m R_m}{I - I_m} = \frac{10 \times 500}{1000 - 10} = \frac{5000}{990} = 5.05\,\Omega$ (2)

for range 0-5 A i.e. 5000 mA

$R_{sh2} = \frac{I_m R_m}{I - I_m} = \frac{10 \times 500}{5000 - 10} = \frac{5000}{4990} = 1.002\,\Omega$ (2)

for range 0-10 A i.e. 10 000 mA

$R_{sh3} = \frac{I_m R_m}{I - I_m}$

$= \frac{10 \times 500}{10000 - 10}$

$= \frac{5000}{99990} = 0.050\,\Omega$ (2)

Value of shunt resistances are

$5.05\,\Omega$, $1.002\,\Omega$, & $0.050\,\Omega$ (2)

b. Calculate the value of the multiplier resistance for a 50 V rms ac range on the voltmeter as shown in Fig.2 **(8)**

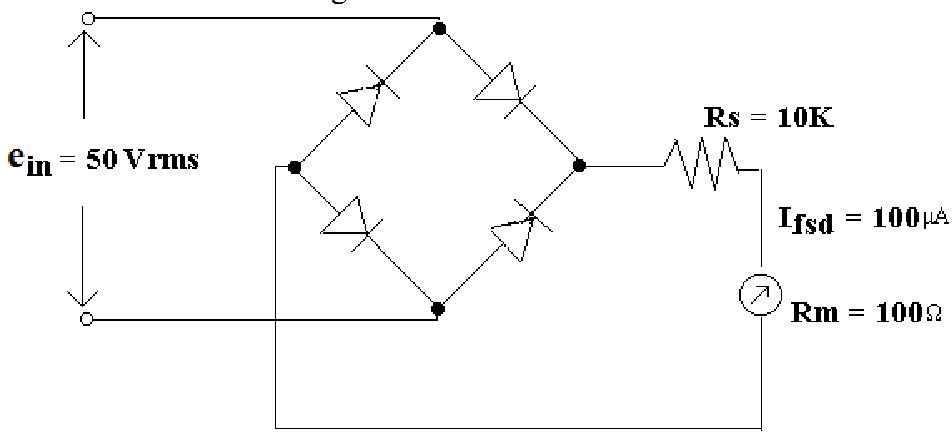


Fig.2

Answer:

$I_{fsd} = 100\ \mu A$ & $R_m = 100\ \Omega$

dc sensitivity $S_{dc} = \frac{1}{I_{fsd}} = \frac{1}{100\ \mu A} = 10\ K\Omega/V$

AC sensitivity $S_{ac} = 0.9 \times S_{dc} = 9\ K\Omega/V$

multiplier resistance is given by

$R_s = (S_{ac} \times \text{range}) - R_m$

$= (9 \times 50)K - 100\ \Omega$

$= 450K - 100$

$= 449.9\ K\Omega$

Q.5 a. Draw block diagram of integrating type DVM and explain its working. **(8)**

Answer:

INTEGRATING TYPE DVM (VOLTAGE TO FREQUENCY CONVERSION)

The principle of operation of an integrating type DVM is illustrated in Fig. 5.5. A constant input voltage is integrated and the slope of the output ramp is proportional to the input voltage. When the output reaches a certain value, it is discharged to 0 and another cycle begins. The frequency of the output waveform is propor-tional to the input voltage. The block diagram is illustrated in Fig. 5.6.

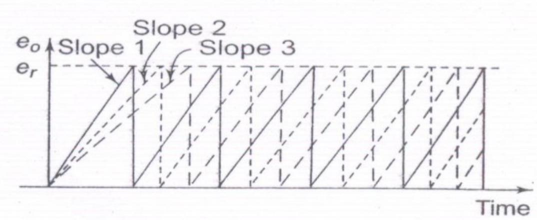


Fig. 5.5 Voltage to Frequency Conversion

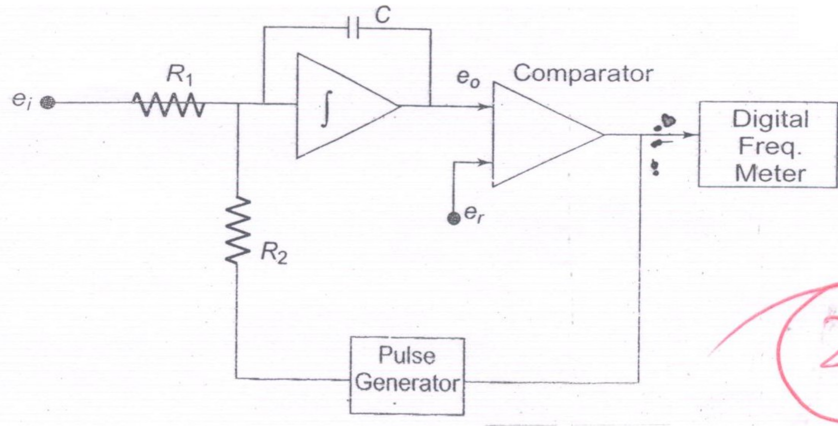


Fig. 5.6 Block Diagram of an Integrating Type DVM

The input voltage produces a charging current, e_i/R_1, that charges the capacitor 'C' to the reference voltage e_r. When e_r is reached, the comparator changes state, so as to trigger the precision pulse generator. The pulse generator produces a pulse of precision charge content that rapidly discharges the capacitor. The rate of charging and discharging produces a signal frequency that is directly proportional to e_i.

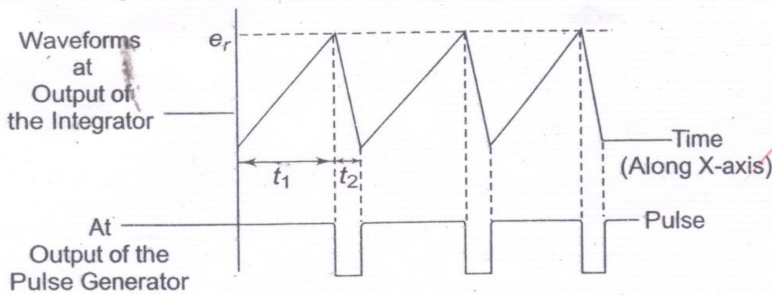


Fig. 5.7

The voltage-frequency conversion can be considered to be a dual slope method, as shown in Fig. 5.7.

Referring to Eq. 5.3 we have

$$e_i = \frac{e_r t_2}{t_1}$$

But in this case e_r and t_2 are constants.

Let $K_2 = e_r t_2$

$$\therefore \quad e_i = K_2 \left(\frac{1}{t_1}\right) = K_2 (f_0)$$

The output frequency is proportional to the input voltage e_i. This DVM has the disadvantage that it requires excellent characteristics in linearity of the ramp. The ac noise and supply noise are averaged out.

b. Draw block diagram of digital capacitance meter & explain its working. **(8)**

Answer:

DIGITAL CAPACITANCE METER

Since the capacitance is linearly proportional to the time constant, when a capacitor is charged by a constant current source and discharged through a fixed resistance, we can use a 555 timer along with some digital test equipment to measure capacitances.

One obvious way is to measure the time period of the oscillations. By choosing the right size of charging resistance, we can get a reading directly in microfarads or *nanofarads*. Unlike many capacitance measuring schemes, this one easily handles electrolytics up to the tens of thousands of microfarads.

A better way is to measure only the capacitor discharge time, as shown in Fig. 6.27. With this method, any leakage in the capacitor under test will make the capacitor appear smaller in value than it actually is, and is an effective indicator of how the test capacitor will behave in most timing and bypass circuits.

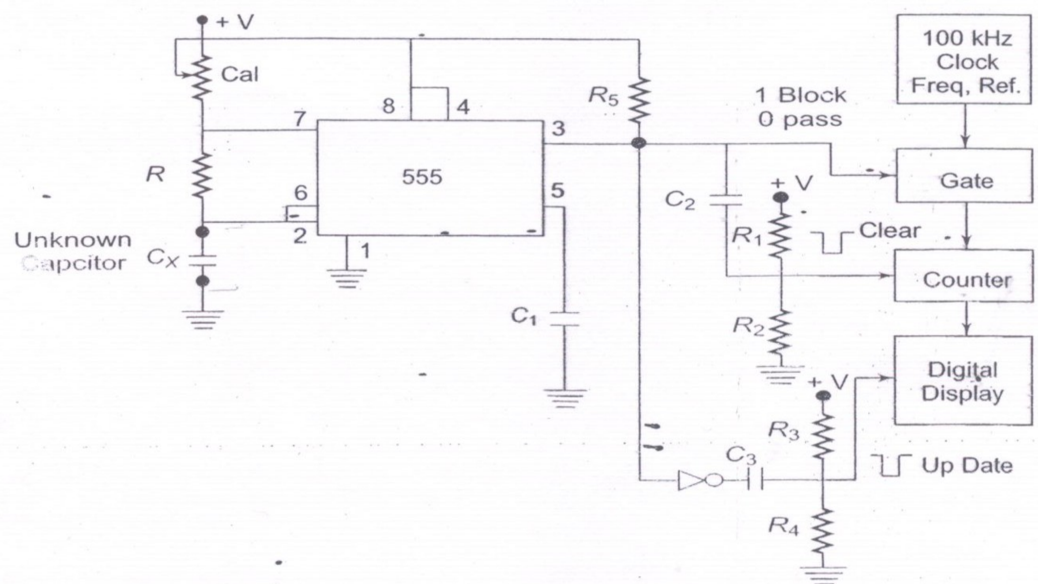


Fig. 6.27 Block Diagram of a Basic Digital Capacitance Meter

In this circuit, the 555 timer is used as an astable multivibrator. At the peak of the charging curve, a digital counter is reset and a clock of 100 kHz pulses is turned on and routed to the counter. When the discharge portion of the cycle is completed, the display is updated and the value of the capacitor is readout. By selecting the proper reference frequency and charging currents, one can obtain a direct digital display of the value of the capacitance.

Be sure to properly shield the leads and keep them short for low capacity measurements, since the 50 Hz hum can cause some slight instability.

Q.6 a. Using circuit diagram & output wave form explain working of triggered sweep in CRO. **(8)**

Answer:

TRIGGERED SWEEP CRO

The continuous sweep is of limited use in displaying periodic signals of constant frequency and amplitude. When attempting to display voice or music signals, the pattern falls in and out of sync as the frequency and amplitude of the music varies resulting in an unstable display.

A triggered sweep can display such signals, and those of short duration, e.g. narrow pulses. In triggered mode, the input signal is used to generate substantial pulses that trigger the sweep. Thus ensuring that the sweep is always in step with the signal that drives it.

As shown in Fig. 7.10, resistance R_3 and R_4 form a voltage divider such that the voltage V_D at the cathode of the diode is below the peak voltage V_P for UJT conduction. When the circuit is switched on, the UJT is in the non-conducting stage, and C_T charges exponentially through R_T towards V_{BB} until the diode becomes forward biased and conducts; the capacitor voltage never reaches the peak voltage required for UJT conduction but is clamped at V_D. If now a –ve pulse of sufficient amplitude is applied to the base and the peak voltage V'_p is momentarily lowered, the UJT fires. As a result, the C_T discharges rapidly through the UJT until the maintaining voltage of the UJT is reached; at this point the UJT switches off and the C_T charges towards V_{BB}, until it is clamped again at V_D. Figure 7.11 shows the output waveform.

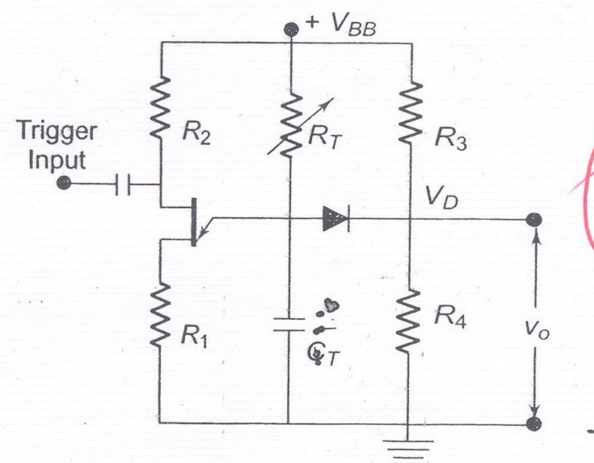


Fig. 7.10 Triggered Sweep

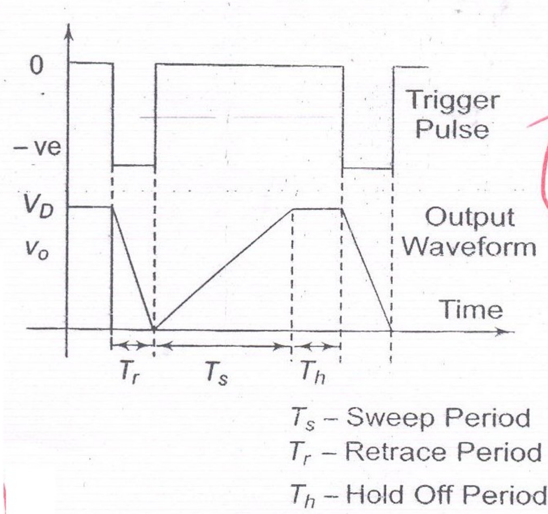


Fig. 7.11 Output Waveform

b. Draw block diagram of function generator and explain its working. **(8)**

Answer:

FUNCTION GENERATOR

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.

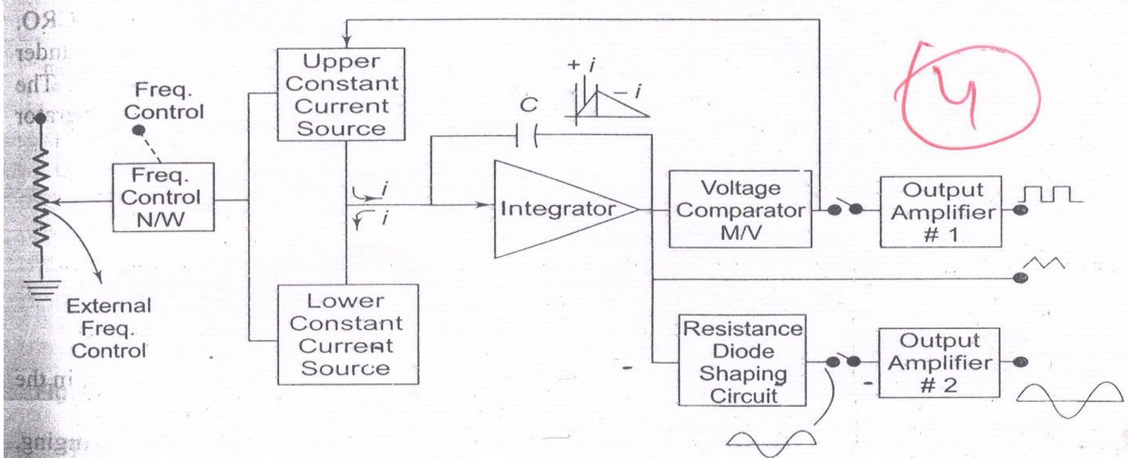


Fig. 8.5 Function Generator

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.

Q.7 Explain the following with the help of block diagram.
(i) Spectrum Analyzer
(ii) Self balancing bolometer bridge **(16)**

Answer: (i) Spectrum Analyzer

The most common way of observing signals is to display them on an oscilloscope, with time as the X-axis (i.e. amplitude of the signal versus time). This is the time domain. It is also useful to display signals in the frequency domain. The instrument providing this frequency domain view is the spectrum analyzer.

A spectrum analyzer provides a calibrated graphical display on its CRT, with frequency on the horizontal axis and amplitude (voltage) on the vertical axis.

Displayed as vertical lines against these coordinates are sinusoidal components of which the input signal is composed. The height represents the absolute magnitude, and the horizontal location represents the frequency.

These instruments provide a display of the frequency spectrum over a given frequency band. Spectrum analyzers use either a parallel filter bank or a swept frequency technique.

In a parallel filter bank analyzer, the frequency range is covered by a series of filters whose central frequencies and bandwidth are so selected that they overlap each other, as shown in Fig. 9.9(a).

Typically, an audio analyzer will have 32 of these filters, each covering one third of an octave.

For wide band narrow resolution analysis, particularly at RF or microwave signals, the swept technique is preferred.

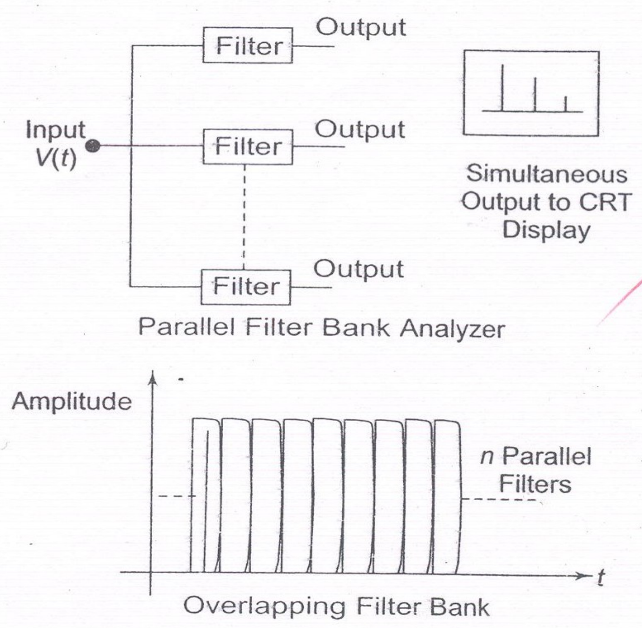


Fig. 9.9 (a) Spectrum Analyzer
(Parallel Filter Bank Analyzer)

(ii) Self balancing bolometer bridge

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.

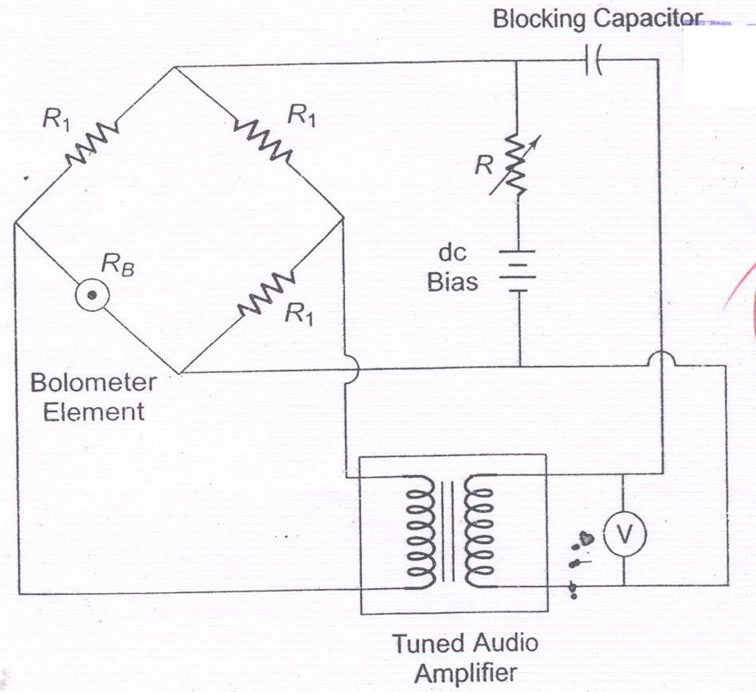


Fig. 20.4 Self Balancing Bolometer Bridge

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.

Q.8 Discuss the working of the following using block diagrams.
(i) Potentiometric recorders
(ii) Magnetic recorders **(16)**

Answer (i) Potentiometric recorders

The basic disadvantage of a galvanometer type recorder is that is has a low input impedance and a limited sensitivity.

This disadvantage can be overcome by using an amplifier between the input terminals and the display or indicating instruments. This amplifier provides a high input impedance and improved sensitivity at the cost of low accuracy.

To improve the accuracy of the instrument, the input signal is compared with a reference voltage using a poteniometer circuit.

The self-balancing feature is obtained with a servo motor, a motor whose speed and direction of rotation follows the output of an amplifier. In a dc system, this is simply a reversible motor, such as the type that uses a permanent magnet for its field. In the ac system, it takes the form of a two-phase motor.

Figure 12.3 is a basic circuit of a potentiometric or self-balancing recorder.

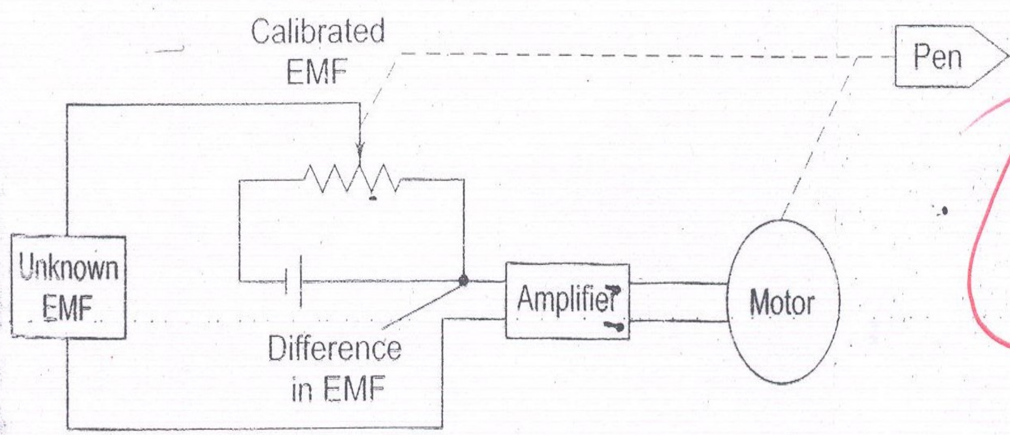


Fig. 12.3 Basic Circuit of a Self-Balancing or Potentiometric Recorder

The difference between the input signal and the potentiometer voltage is the error signal. This error signal is amplified and is used to energize the field coil of a dc motor. In this circuit, instead of obtaining a balance between two opposing voltages by rotating the arm of the voltage divider, an error current is allowed to flow, either clockwise or counter clockwise, depending on which voltage is higher. This error serves as the input to the electronic detector, and the amplified error is then fed to the balancing motor. This motor is so connected that it turns in a direction that rotates the voltage divider arm (geared) to it in the direction that reduces the error. As the error becomes smaller, the motor slows down and finally stops at the point where the error is zero, thus producing the null balance.

This is achieved by mechanically connecting the wiper/variable arm to the armature of the dc motor. The pen is also mechanically connected to the wiper. Hence as the wiper moves in a particular direction, the pen also moves in synchronism in the same direction, thereby recording the input waveform. The wiper comes to rest when the unknown signal voltage is balanced against the voltage of the potentiometer. This technique results in graphical recorders having a very high input impedance.

A sensitivity of 4 V/mm is attained with an error of less than ± 0.25% with a bandwidth of 0.8 Hz.

A motor synchronised to power line frequency is used to drive the chart drive for most potentiometer recorders.

Hence the speeds of the chart drive can be changed by the use of a gear train which uses different gear ratios.

Potentiometer recorders are mostly used for the recording and control of process temperature.

Figure 12.4 is the basic block diagram of a dc self balancing system. Instrument that record changes of only one measured variable are called single point recorders.

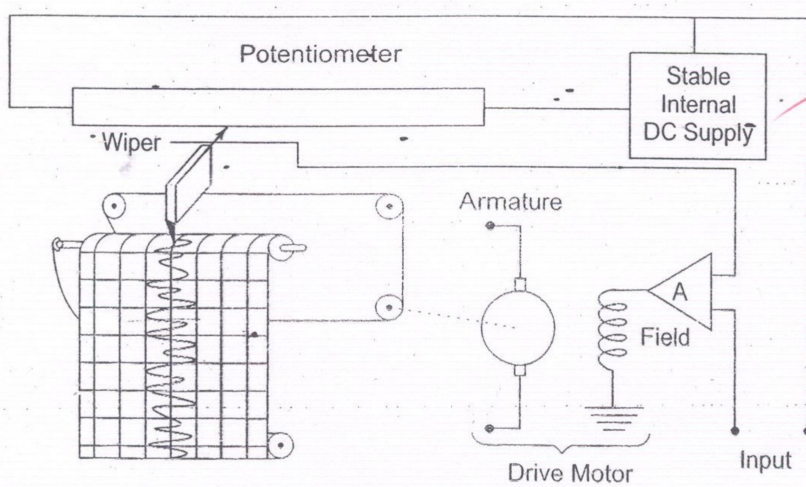


Fig. 12.4 Block Diagram of Self-Balancing Potentiometer Recorder

Multipoint recorders are those in which one recorder may be used for recording several inputs. These may have as many as 24 inputs, with traces displayed in six colours. The data is recorded on an 8 inch chart, at frequencies from dc to 5 kHz, models up to 36 channels are also available.

(ii) Magnetic recorders

The major advantage of using a magnetic tape recorder is that once the data is recorded, it can be replayed an almost indefinite number of times.

The recording period may vary from a few minutes to several days. Speed translation of the data captured can be provided, i.e. fast data can be slowed down and slow data speeded up by using different record and reproduce speeds.

The recorders described earlier have a poor high frequency response. Magnetic tape recorder, on the other hand, have a good response to high frequency, i.e. they can be used to record high frequency signals. Hence, magnetic tape recorders are widely used in instrumentation systems.

Basic Components of a Tape Recorder

A magnetic tape recorder consists of the following basic components.

1. Recording Head
2. Magnetic Head
3. Reproducing Head
4. Tape transport mechanism
5. Conditioning devices

Magnetic Recording

The basic elements of a simple magnetic recording system are illustrated in Fig. 12.10(a).

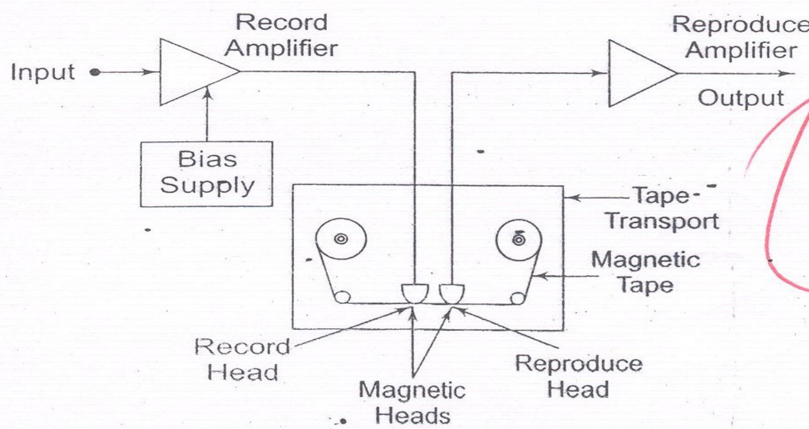


Fig. 12.10(a) Elementary Magnetic Tape Recorder

The magnetic tape is made of a thin sheet of tough, dimensionally stable plastic, one side of which is coated with a magnetic material.

Some form of finely powdered iron oxide is usually cemented on the plastic tape with a suitable binder. As the tape is transferred from one reel, it passes across a magnetising head that impresses a residual magnetic pattern upon it in response to an amplified input signal.

The methods employed in recording data on to the magnetic tape include direct recording, frequency modulation (FM) and pulse code modulation (PCM).

Q.9 Write short notes on the following: **(4×4)**

(i) Selection of transducers (ii) Thermistors
(iii) Flow measurement (iv) Objectives of a DAS

Answer:

(ii) Thermistors

The electrical resistance of most materials changes with temperature. By selecting materials that are very temperature sensitive, devices that are useful in temperature control circuits and for temperature measurements can be made.

Thermistor (THERMally sensitive resISTOR) are non-metallic resistors (semiconductor material), made by sintering mixtures of metallic oxides such as manganese, nickel, cobalt, copper and uranium.

Thermistors have a Negative Temperature Coefficient (NTC), i.e. resistance decreases as temperature rises. Figure 13.12 shows a graph of resistance vs temperature for a thermistor. The resistance at room temperature (25°C) for typical commercial units ranges from 100 Ω to 10 MΩ. They are suitable for use only up to about 800°C. In some cases, the resistance of thermistors at room temperature may decrease by 5% for each 1°C rise in temperature. This high sensitivity to temperature changes makes the thermistor extremely useful for precision temperature measurements, control and compensation.

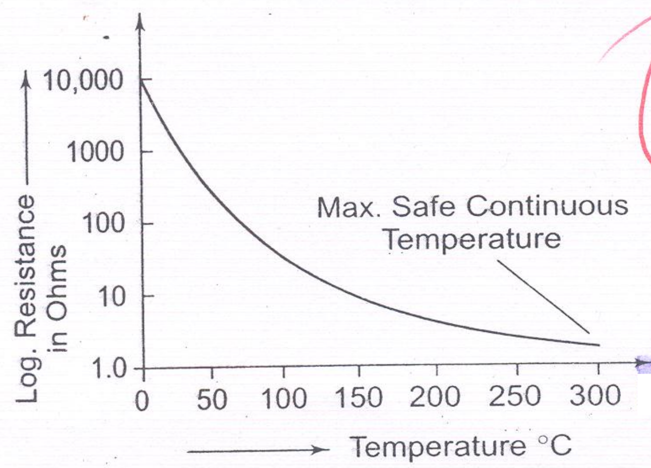


Fig. 13.12 Resistance vs Temperature Graph of a Thermistor

The smallest thermistors are made in the form of beads. Some are as small as 0.15 mm (0.006 in.) in diameter. These may come in a glass coating or sealed in the tip of solid glass probes. Glass probes have a diameter of about 2.5 mm and a length which varies from 6 – 50 mm. The probes are used for measuring the temperature of liquids. The resistance ranges from 300 Ω to 100 MΩ.

(iii) Flow measurement

The measurement of flow rate and quantity is the oldest of all measurements of process variables in the field of instrumentation. It is used to determine the amount of materials flowing in or out of a process.

Without flow measurements, plant material balancing, quality control and the operation of any continuous process would be impossible. Flow velocities are also measured by inductive transducers. The measurement of liquids containing suspended solids, such as sewage or feed to paper mills, present considerable problems. This is overcomed by the use of a flowmeter.

The transducer can be used to measure the flow of any flowing material that is electrically conductive. (The meter can be regarded as a section of pipe that is lined with an insulating material.)

Two saddle coils are arranged opposite each other and electrodes diametrically opposite are arranged flush with the inside of the lining. If the coils are energised, the moving liquid, (as a length of conductor) cuts the lines of force, resulting in the generation of an electromotive force that is picked up by the electrodes. By suitable circuitry and amplification, an electrical signal proportional to the flow can be obtained.

Many accurate and reliable methods are available for measuring flow, some of which are applicable only to liquids, some only to gases and some others to both. Fluids measured may be clear or opaque, clean or dirty, wet or dry, erosive or corrosive. Fluid streams may be multiphase, vapour, liquid or slurries. The flow may be turbulent or laminar, and viscosity and pressure may vary from vacuum to many atmospheres. Temperature may range from cryogenic to hundreds of °C.

(iv) Objectives of a DAS

1. It must acquire the necessary data, at correct speed and at the correct time.
2. Use of all data efficiently to inform the operator about the state of the plant.
3. It must monitor the complete plant operation to maintain on-line optimum and safe operations.
4. It must provide an effective human communication system and be able to identify problem areas, thereby minimising unit availability and maximising unit through point at minimum cost.
5. It must be able to collect, summarise and store data for diagnosis of operation and record purpose.
6. It must be able to compute unit performance indices using on-line, real-time data.
7. It must be flexible and capable of being expanded for future requirements.
8. It must be reliable, and not have a down time greater than 0.1%.

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