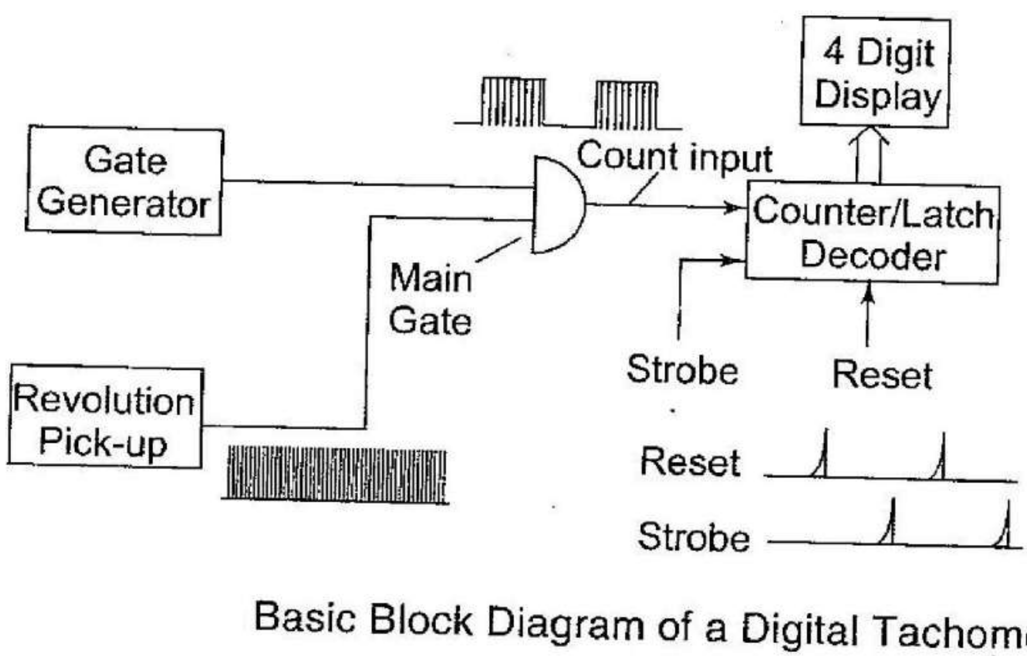
CHAPTER-5

MEASUREMENT OF SPEED, FREQUENCY AND POWER FACTOR

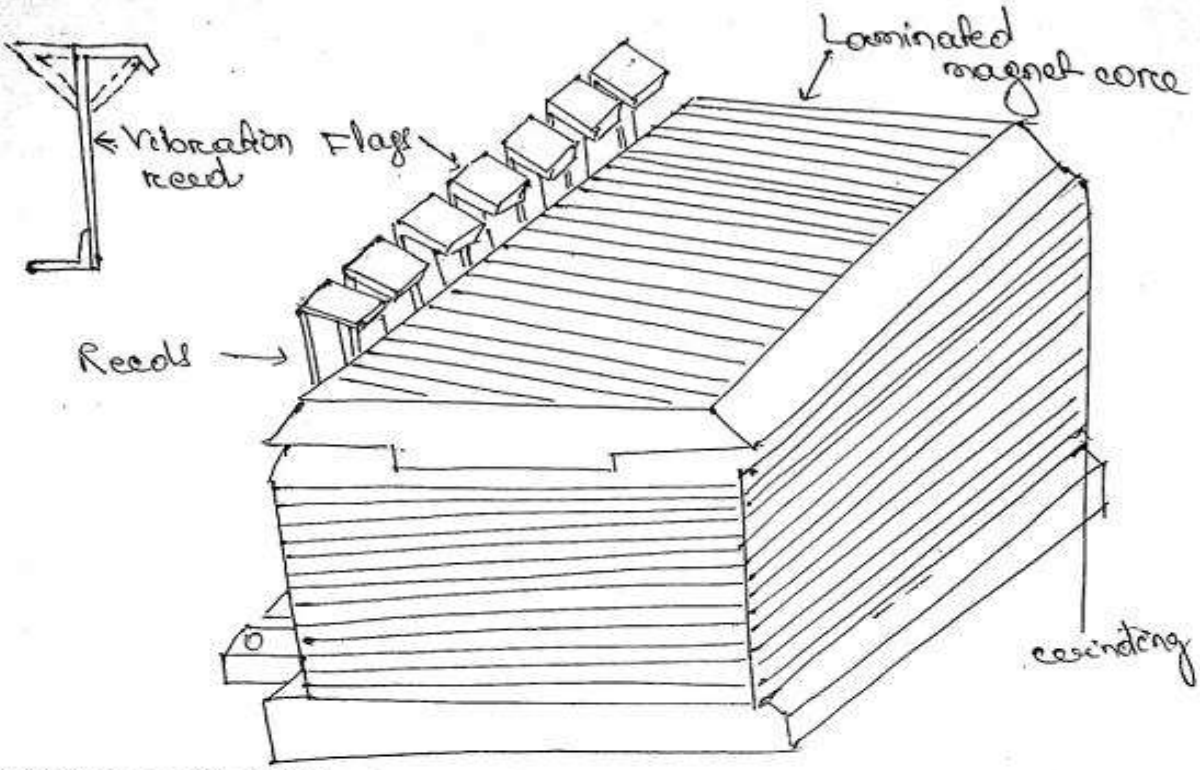
DIGITAL TACHOMETER

The technique employed in measuring the speed of a rotating shaft is similar to the technique used in a conventional frequency counter, except that the selection of the gate period is in accordance with the rpm calibration. Let us assume that the rpm of a rotating shaft is R. Let P be the number of pulses produced by the pickup for one revolution of the shaft. Therefore, in one minute the number of pulses from the pickup is R x P. Then, the-frequency of the signal from the pickup is (R x P)/60. Now, if the gate period is G s the pulses counted are (R x P x G)/60. In order to get the direct reading in rpm, the number of pulses to be counted by the counter is R. So we select the gate period as 60/ P, and the counter counts (Rx P x 60)/ 60P = R pulses and we can read the rpm of the rotating shaft directly. So, the relation between the gate period and the number of pulses produced by the pickup is G = 60/P. If we fix the gate period as one second (G= 1 s), then the revolution pickup must be capable of producing 60 pulses per revolution. Figure shows a schematic diagram of a digital tachometer.



Basic Block Diagram of a Digital Tachometer

MECHANICAL RESONANCE TYPE FREQUENCYMETER:



CONSTRUCTION:-

- The meter consists of number of thin steel strips, known as reeds. These reeds are arranged alongside and close to a electromagnet.
- The electromagnet is a laminated iron core. ~~and~~ Its coil is connected in series with a resistance across the supply circuit whose freq. is to be measured.
- Bottom portion of reeds are fixed and upper portion is kept free to vibrate. At the free end reeds are bent to form a flag. The reeds are painted white to distinguish them against black background.

- The reeds have either different dimensions or carry different weights or flags at their tops.
- The reeds are so designed and arranged that the natural freq. of one reed is differ from another by one or half cycle. So if the freq. meter has a range of 47 – 53 Hz then natural freq. of first reed will be 47 Hz and, 2nd reed be 47.5 Hz 3rd be 48 Hz and so on.

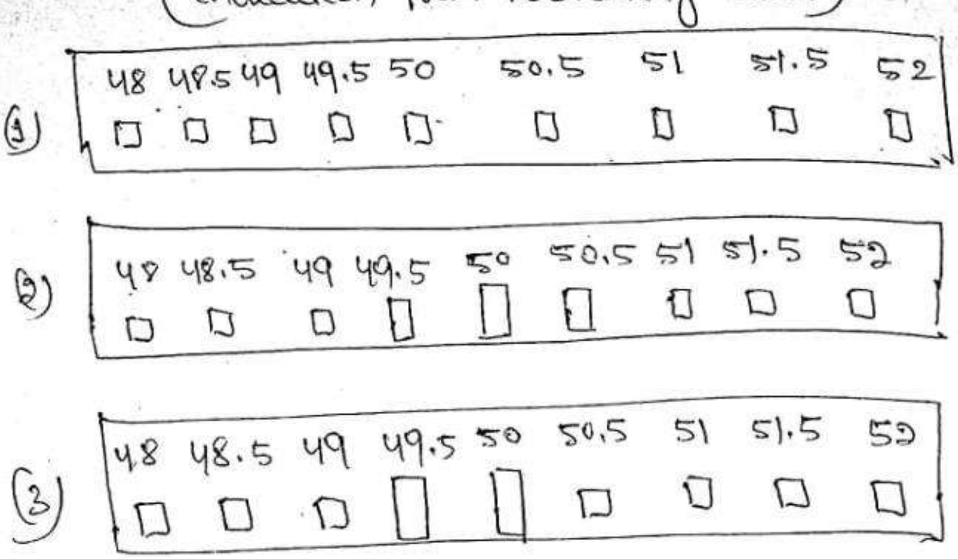
Operation :-

When the freq. meter is connected across the supply whose freq. is to be measured, the coil of electromagnet carries a current i. Due to the alternating field, a force of attraction is experienced between the reeds and the electromagnet, which is proportional to i^2 and ∴ this force varies at twice the supply frequency. Thus the force is exerted on the reeds varies every half cycle. As a result all the reeds will tend to vibrate, but the reeds whose natural freq. is equal to twice the supply freq. will vibrate with maxm amplitude. The vibration of other reeds are so slight as to be unobserved. The freq. is determined, by noting the scale reading opposite the reed that vibrate with maxm amplitude. If two adjacent reeds vibrate with equal amplitude then the supply freq. will be half way between the frequencies of two adjacent reeds.

The usual range of freq. meters of this type is about 6Hz (say from 47 Hz to 53 Hz)

(1) Show the condn when the meter is not connected to the supply
(2) Show the condn when 50 Hz reed is vibrating with its maxm app. amplitude.
(3) Show the condn when the freq. is exactly midway between 49.5 Hz and 50Hz.

(indication from vibrating reeds)



The range of the instrument may be doubled by polarizing its reeds. The polarizing may be done by using a dc winding in addition to the ac winding or by using a permanent magnet.

In the presence of alternating flux, the reeds are attracted two times in a cycle and the reed whose freq. is twice the supply freq. will responds. If the electromagnet is polarized by dc wdg in addition to ac wdg, the fields (ac and dc) will cancel each other in one half cycle and will reinforce each other in other half cycle, so the and will be attracted only once in a cycle. So the reeds whose natural freq. is 100Hz will. Thus a reed when the electromagnet is unpolarized will respond to 50Hz when the electromagnet is polarized and to 100Hz when the electromagnet is polarized.

Advantage

The freq. to be measured is independent of waveform of supply voltage.

Disadvantage:

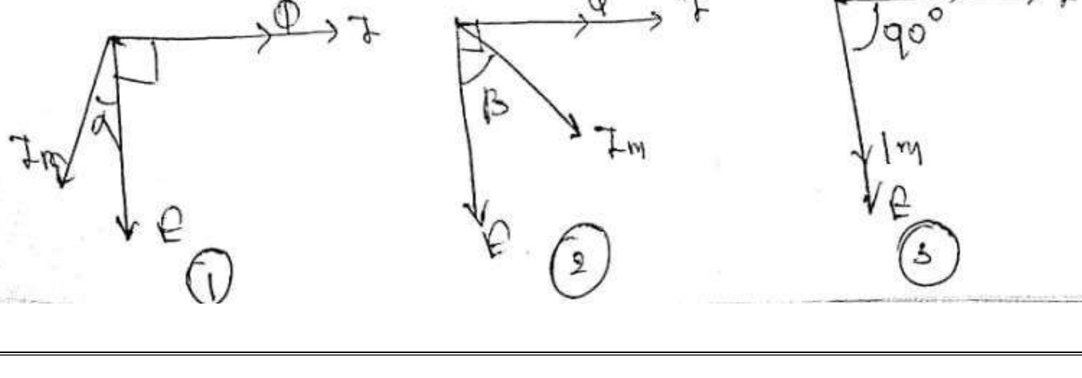
1. Amplitude of vibration depends upon the voltage and if voltage is too low to give appreciable amplitude of vibration, readings will be unreliable.
2. These are not for precision measurement of frequency since adjacent reeds have only difference of 0.5Hz of natural frequency.

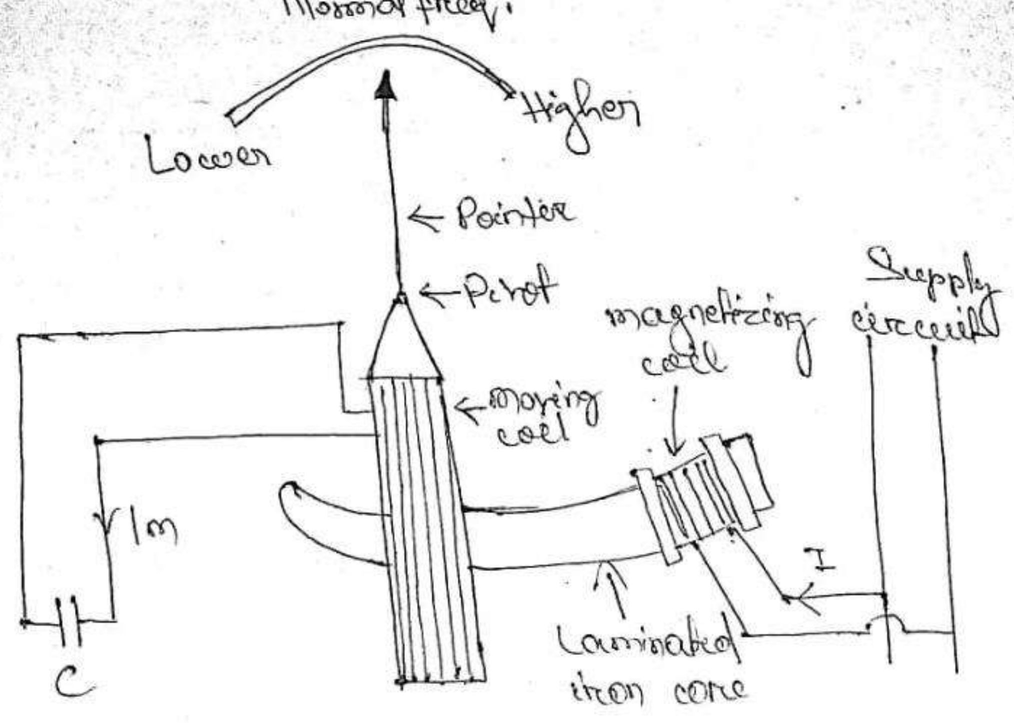
Electrical Resonance Type Frequency meter

(1) Ferrodynamic type Freq. meter :-

Construction: It consists of fixed coil which is connected across the supply whose freq. is to be measured. This coil is called magnetizing coil. The magnetizing coil is mounted at one end of a laminated iron core of varying cross section (max^m near the end where magnetizing coil is mounted and minimum at other end). A moving coil and with a pointer is pivoted over this iron core so that it can move freely over the iron core. The moving coil is connected across a capacitor C.

Working: The op^n of the instrument can be understood from the three phasor diagram.





When the magnetizing coil is connected across the supply circuit, current I flows through it and ~~a flux ϕ~~ produces a flux ϕ, (in phase with its current I), in the iron core. This flux induces an emf E in the moving coil which lags behind the flux ϕ by 90°. This emf E circulate a current Im in the moving coil. The phase of this current Im depends on the inductance of the moving coil and the capacitance C.

phasor

(1) when $X_L > X_C$, Im lags behind E by α.

$\therefore T_d \propto I_m \cos(90+\alpha)$

(2) when $X_L < X_C$, Im leads E by β

$\therefore T_d \propto I_m \cos(90-\alpha)$

(3) when $X_L = X_C$, Im is in phase with E (resonance cond^n)

$\therefore T_d \propto I_m \cos 90 = 0$

For a fixed freq. the capacitive reactance is constant but the X_L of moving coil is not constant, This is bec. ~~it~~ X_L depends on the posn occupied by MC on the iron core. X_L becomes maxm when MC is closer to magnetizing coil and minimum when it is at the other end.

Hence the moving coil is pulled towards the magnetizing coil until $X_L = X_C$ or $\omega L = \frac{1}{\omega C}$ and the torque is zero i.e the circuit of moving coil is in resonance.

The value of C is so chosen that the moving coil take up a mean posn at its normal value. If frequency increases $\frac{1}{\omega C}$ or X_C decreases and X_L i.e ωL increases, Thus the circuit becomes largely inductive which produce deflecting torque which tries to pull the moving coil to an equilibrium posn i.e a posn where $X_L = X_C$. This can be obtained by moving the moving coil away from magnetizing coil. The coil moves farther 'on' to the core if freq. decreases.

<u>Advantages</u> Great sensitivity can be achieved ~~with its use~~ if the inductance of moving coil changes slowly with the variation of its posn on the core.

CHAPTER -6

MEASUREMENT OF RESISTANCE, INDUCTANCE, CAPACITANCE

Explain the working of Wheatstone Bridge(Measurement of Resistance)

For measuring accurately any electrical resistance Wheatstone bridge is widely used. There are two known resistors, one variable resistor and one unknown resistor connected in bridge form as shown below. By adjusting the variable resistor the electric current through the Galvanometer is made zero. When the electric current through the galvanometer becomes zero, the ratio of two known resistors is exactly equal to the ratio of adjusted value of variable resistance and the value of unknown resistance. In this way the value of unknown electrical resistance can easily be measured by using a Wheatstone Bridge.

Wheatstone Bridge Theory

The general arrangement of **Wheatstone bridge circuit** is shown in the figure below. It is a fourarms bridge circuit where arm AB, BC, CD and AD are consisting of electrical resistances P, Q, Sand R respectively. Among these resistances P and Q are known fixed electrical resistances andthese two arms are referred as ratio arms. An accurate and sensitive Galvanometer is connectedbetween the terminals B and D through a switch S2. The voltage source of this Wheatstonebridge is connected to the terminals A and C via a switch S1 as shown. A variableresistor S isconnected between point C and D. The potential at point D can be varied by adjusting the valueof variable resistor. Suppose electric current I1 and electric current I2 are flowing through thepaths ABC and ADC respectively. If we vary the electrical resistance value of arm CD the valueof electric current I2 will also be varied as the voltage across A and C is fixed. If we continue toadjust the variable resistance one situation may comes when voltage drop across the resistor Sthat is I2.S is becomes exactly equal to voltage drop across resistor Q that is I1.Q. Thus thepotential at point B becomes equal to the potential at point D hence potential difference betweenthese two points is zero hence electric current through galvanometer is nil. Then the deflection inthe galvanometer is nil when the switch S2 is closed.

Now, from **Wheatstone bridge circuit**

$$\text{current } I_1 = \frac{V}{P + Q}$$

and

$$\text{current } I_2 = \frac{V}{R + S}$$

Now potential of point B in respect of point C is nothing but the voltage drop across the resistorQ and this is

$$I_1.Q = \frac{V.Q}{P + Q}\text{------------------(i)}$$

Again potential of point D in respect of point C is nothing but the voltage drop across theresistor S and this is

$$I_2.S = \frac{V.S}{R + S}\text{------------------(ii)}$$

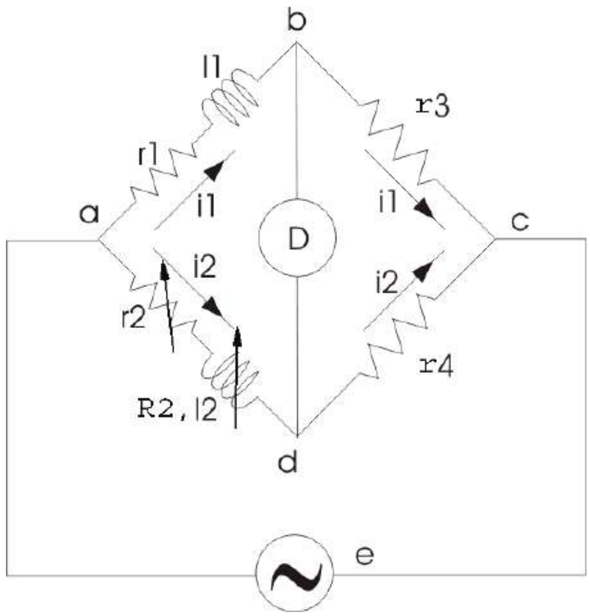
Equating, equations (i) and (ii) we get,

$$\frac{V.Q}{P+Q} = \frac{V.S}{R+S} \Rightarrow \frac{Q}{P+Q} = \frac{S}{R+S}$$
$$\rightarrow \frac{P+Q}{Q} = \frac{R+S}{S} \rightarrow \frac{P}{Q} + 1 = \frac{R}{S} + 1 \rightarrow \frac{P}{Q} = \frac{R}{S}$$
$$\rightarrow R = SX\frac{P}{Q}$$

Here in the above equation, the value of S and P / Q are known, so value of R can easily be determined. The electrical resistances P and Q of the Wheatstone bridge are made of definite ratio such as 1:1; 10:1 or 100:1 known as ratio arms and S the rheostat arm is made continuously variable
from 1 to 1,000 Ω or from 1 to 10,000 Ω.

MAXWELLS BRIDGE:

This bridge is used to find out the self inductor and the quality factor of the circuit. As it is basedon the bridge method (i.e. works on the principle of null deflection method), it gives veryaccurateresults. Maxwell bridgeis an AC bridge so before going in further detail let us know moreaboutthe ac bridge.Let us now discuss Maxwell's inductor bridge. The figure shows the circuit diagram ofMaxwell's inductor bridge.

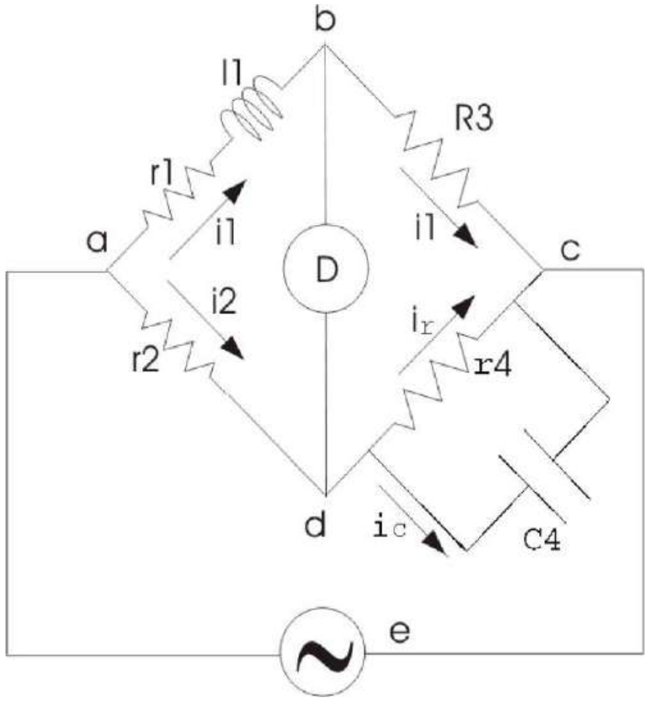


Maxwells Bridge

In this bridge the arms bc and cd are purely resistive while the phase balance depends on the arms ab and ad.
Here l1 =Unknown inductor of r1.
l2 =Variable inductor ofresistanceR2.
r2 =variable electricalresistance
As we have discussed in ac bridge according to balance condition, we have at balance point
$l_1 = \frac{r_3}{r_4} l_2$ and $r_1 = \frac{r_3}{r_4}(r_2 + R_2)$
We can vary R3 and R4 from 10 ohms to 10,000 ohms with the help of resistance box.

MAXWELL'S INDUCTANCE CAPACITANCE BRIDGE

In this Maxwell Bridge, the unknown inductor is measured by the standard variable capacitor. Circuit of this bridge is given below.



Maxwell's Inductance Capacitance Bridge

Advantages of Maxwell's Bridge

(1) The frequency does not appear in the final expression of both equations, hence it isindependent of frequency.

(2) Maxwell's inductor capacitance bridge is very useful for the wide range of measurementof inductor at audio frequencies.

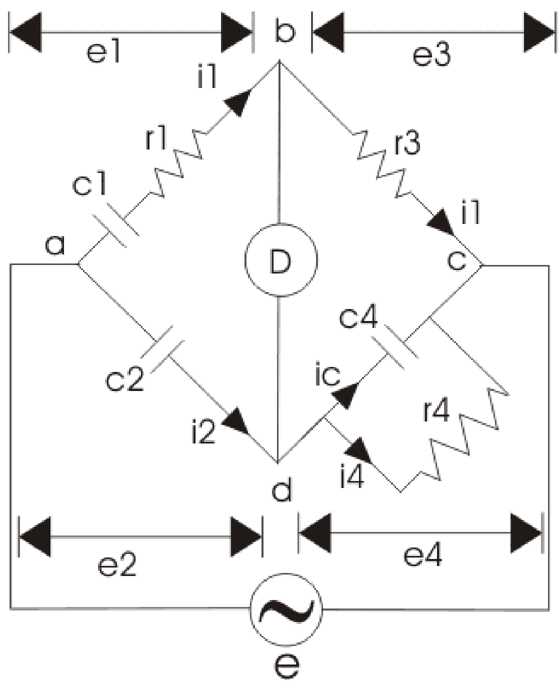
Disadvantages of Maxwell's Bridge

(1) The variable standard capacitor is very expensive.

(2) The bridge is limited to measurement of low quality coils ($1 < Q < 10$) and it is also unsuitable
for low value of Q (i.e. $Q < 1$) from this we conclude that a Maxwell bridge is used suitable only for medium Q coils.

SCHERING BRIDGE THEORY

This bridge is used to measure to the capacitance of the capacitor, dissipation factor andmeasurement of relative permittivity. Let us consider the circuit of Schering bridge as shownbelow



Schering Bridge

Here, c1 is the unknown capacitance whose value is to be determined with series electricalresistance r1.

c2 is a standard capacitor.

c4 is a variable capacitor.

r3 is a pure resistor (i.e. non inductive in nature).

And r4 is a variable non inductive resistor connected in parallel with variable capacitor c4.

Now the supply is given to the bridge between the points a and c. The detector is connectedbetween b and d. From the theory of ac bridges we have at balance condition

$$z_1 z_4 = z_2 z_3$$

Substituting the values of z_1, z_2, z_3 and z_4 in the above equation, we get

$$\left(r_1 + \frac{1}{j\omega c_1}\right)\left(\frac{r_4}{1 + j\omega c_4 r_4}\right) = \frac{r_3}{j\omega c_2}$$

$$\left(r_1 + \frac{1}{j\omega c_1}\right) r_4 = \frac{r_3}{j\omega c_2}(1 + j\omega c_4 r_4)$$

$$r_1 r_4 - \frac{j r_4}{\omega c_1} = -\frac{j r_3}{\omega c_2} + \frac{r_3 r_4 c_4}{c_2}$$

Equating the real and imaginary parts and the separating we get,

$$r_1 = \frac{r_3 c_4}{c_2}$$

$$c_1 = c_2 \frac{r_4}{r_3}$$

Application:

This bridge is used to measure to the capacitance of the capacitor, dissipation factor andmeasurement of relative permittivity.

TRANSDUCERS AND SENSORS

METHOD OF SELECTING TRANSDUCERS

While selecting the proper transducer for any applications, or ordering the transducers the following specifications should be thoroughly considered.

1) Ranges available
2)Squaring System
3)Sensitivity
4) Maximum working temperature
5) Method of cooling employed
6) Mounting details
7) Maximum depth
8) Linearity
and hysteresis
9) Output for zero input
10) Temperature co-efficient of zero drift
11) Natural Frequency.

ADVANTAGES OF ELECTRICAL TRANSDUCERS

1. Very small power is required for controlling the electrical or electronic system
2. The electrical output can be amplified to any desired level
3. Mass inertia effects are reduced to minimum possible.
4. The size and shape of the transducers can be suitably designed to achieve the optimum weight and volume

5. The output can be indicated and recorded remotely at a distance from the sensing medium .
6. The outputs can be modified to meet the requirements of the indicating or controlling equipment.

RESISITIVE TRANSDUCERS

The resistance of a conductor is expressed by a simple equation that involves a few physical quantities . The relationship is given by

$R = \rho L/A$

Where , R= resistance, Ω

ρ = Resistivity of conductor materials, Ω-m

L= Length of conductor, m

A = Cross sectional area of the conductor,m^2

Any method of varying one of the quantities involved in the above relationship can be the designedbasis of an electrical resistance transducer. There are a number of ways in whichresistance can bechanged by a physical phenomenon.The translational and rotationalpotentiometer which work on the basis of change in the value ofresistance with change in length of the conductor can be used for measurement of translational orrotary displacements.

The resistivity of materials changes with the change of temperature thus causing a change ofresistance. This property may be used for measurement of temperature.In a resistance transducer an indication of measured physical quantity is given by a change in theresistance. It may be classified as follows

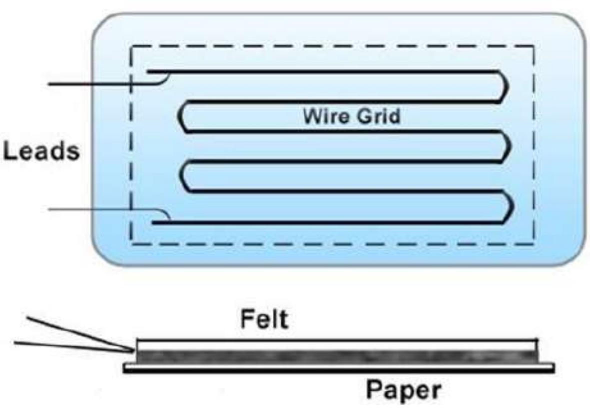
1. Mechanically varied resistance - POTENTIOMETER
2. Thermal resistance change – RESISTANCE THERMOMETER
3. Resistivity change - RESISTANCE STRAIN GAUGE

STRAIN GAUGE
INTRODUCTION

When a metal conductor is stretched or compressed , its resistance changes on account of the fact thatboth length and diameter of conductor change . The value of resistivity of conductor also changes.When it is strained it's property is called piezo-resistance .Therefore , resistance strain gauges arealso known as piezo- resistive gauges .The strain gauge is a measurement transducer for measuring strain and associated stress inexperimental stress analysis.

TYPES

Four types of Strain gauges are :
1. Wire –wound strain gauge
2. Foil-type strain gauge
3. Semiconductor strain gauge
4. Capacitive strain gauge.



WORKING PRINCIPLE

Strain gauges work on the principle that the resistance of a conductor or a semiconductor changeswhen strained .This property can be used for measurement of displacement, force and pressure .When a strain gauge is subjected to tension (positive strain) it's length increases while it's crosssectional area decreases. Since the resistance of a conductor is proportional to it's length and inverselyproportional to it's area of cross section, The resistance of the gauge increases with positive strain .Strain gauges are most commonly used in wheat –stone bridge circuits to measure the change ofresistance of grid of wire for calibration proposes; the 'GAUGE FACTOR' is defined as the ratio ofper unit change in resistance to per unit change in length.

i.e , Gauge factor (Gf) = $\Delta R/R \div \Delta L/L$

Where, ΔR = corresponding change in resistance, R

ΔL = Change in length per unit length, L

$R= \rho L/A$

Where, R= resistance, Ω

ρ = Resistivity of conductor materials, Ω-m

L= Length of conductor, m

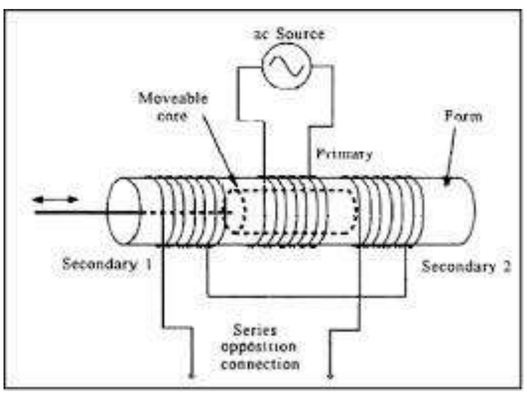
A = Cross sectional area of the conductor, m^2

L.V.D.T

LVDT is a passive inductive transducer and is commonly employed to measure force(or weight,pressure and acceleration etc. Which depend on force)in terms of the amount and direction ofdisplacement of an object.

WORKING PRINCIPLE

When the core is in the centre (called reference position) the induced voltages E1 and E2 are equal andopposite. Hence they cancel out and the output voltages V0 is zero.When the external applied force moves the core towards the coil S2 ,E2 is increased but E1 isdecreased in magnitude though they are still antiphase with each other. The net voltage available is(E2-E1) and is in phase with E2.



Similarly , When movable core moves towards coil S1, E1>E2 and Vo = E1-E2 and is in phase with E1.

ADVANTAGES

1. It gives a high output and therefore many a times there is no need for intermediate amplification
devices.
2. The transducer possess a high sensitivity as high as 40V/mm

3. It shows a low hysteresis and hence repeatability is excellent under all conditions.
4. Most of the LVDTs consume a power of less than 1W.
5. Less friction and less noise

DISADVANTAGES

1. These transducers are sensitive to stray magnetic fields but shielding is possible .This is done byproviding magnetic shields with longitudinal slots.
2. Relatively large displacements are required for appreciable differential output.
3.Several times, the transducer performance is affected by vibrations.

APPLICATIONS

1. Measurement of material thickness in hot strip or slab steel mills
2. In accelerometers.
3. Jet engine controls in close proximity to exhaust gases.

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 $C = KA/d$

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.

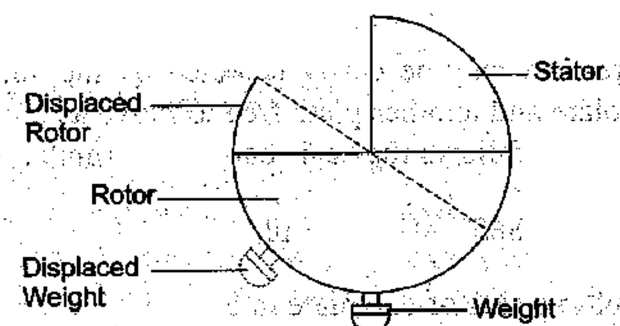


Fig. 13.28 Capacitive Transducer

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).

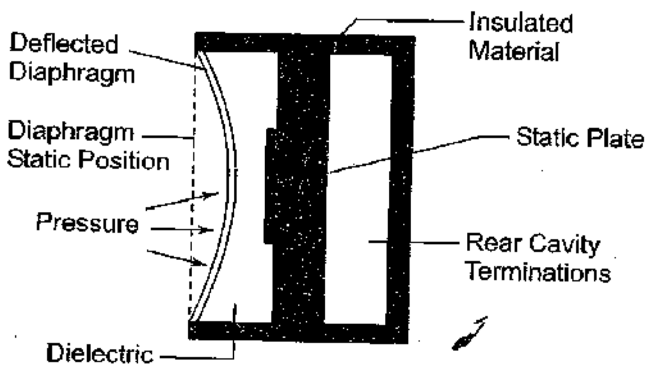


Fig. 13.29 Capacitive Pressure Transducer

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.

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

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

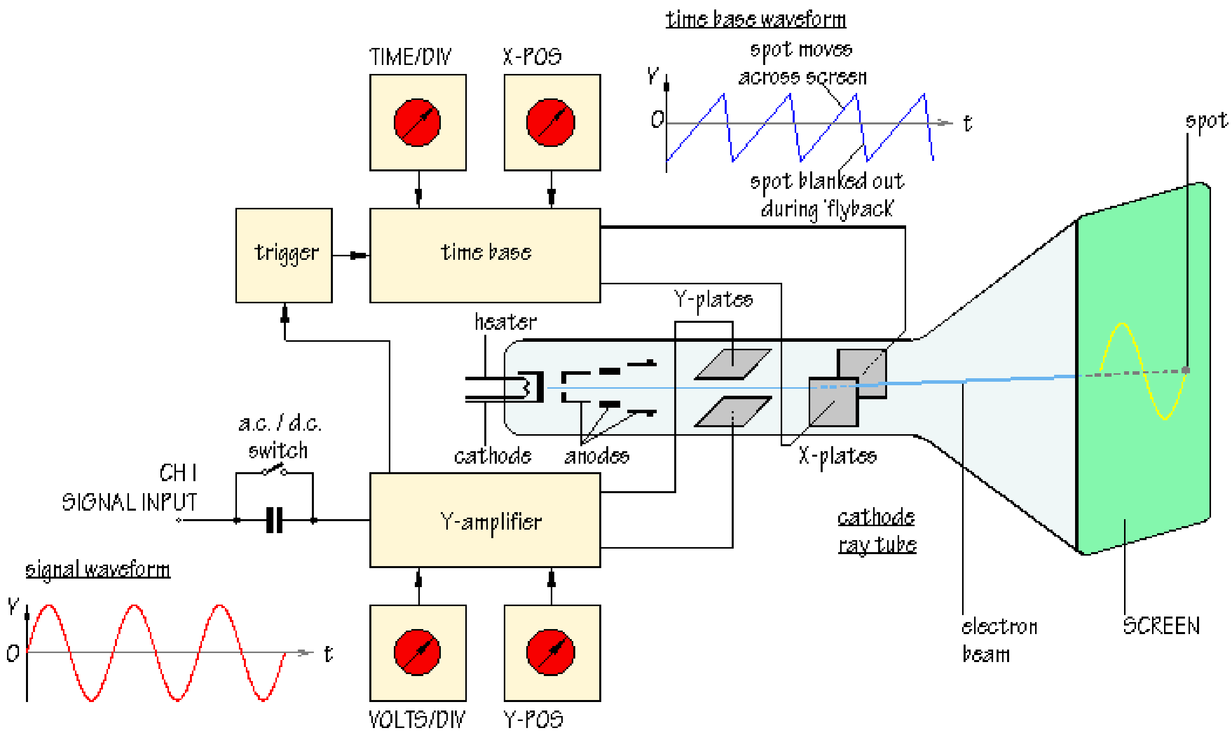
n = number of plates

t = thickness of dielectric in cm

CHAPTER 8- OSCILLOSCOPE

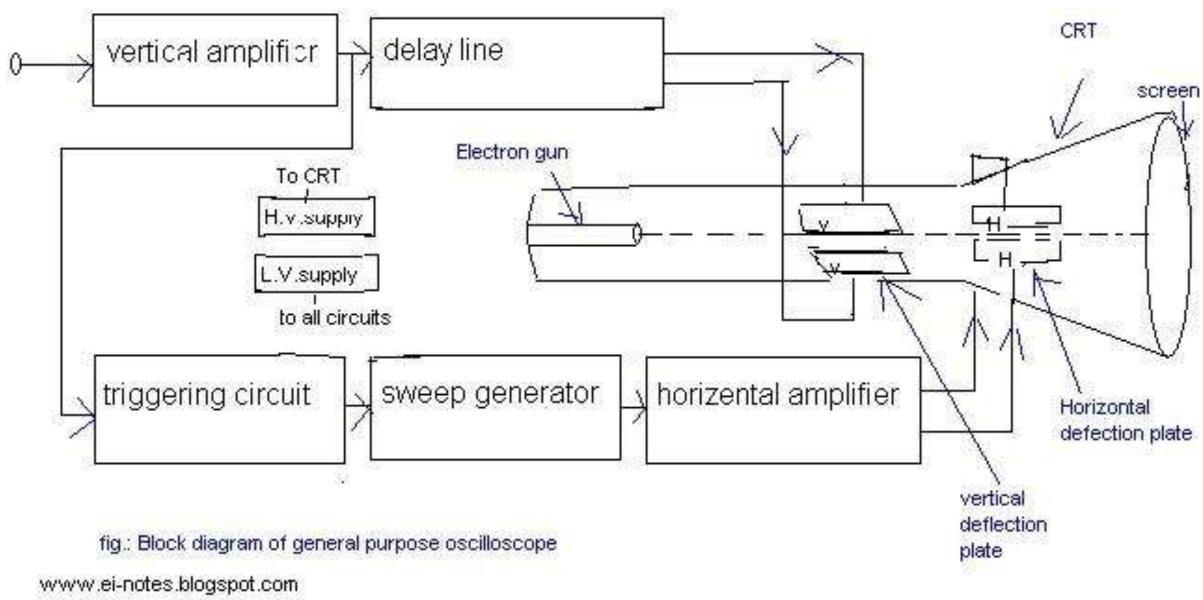
BASIC PRINCIPLE OF OSCILLOSCOPE.

A CRO (Cathode-Ray Oscilloscope), or DSO (Digital Storage Oscilloscope), is a typeof electronic test instrument that allows observation of constantly varyingsignalvoltages, usually as a two-dimensional plot of one or more signals as a functionof time.



BLOCK DIAGRAM OF OSCILLOSCOPE & SIMPLE CRO.

The block diagram of simple CRO is as shown in figure below.Herethe Oscilloscopes areused to observe the change of an electrical signal over time, such that voltage and timedescribe a shape which is continuously graphed against a calibrated scale. Theobserved waveform can be analyzed for such propertiesasamplitude, frequency,rise time,time interval, distortion and others. Modern digital instruments may calculate and displaythese properties directly. Originally, calculation of these values required manuallymeasuring the waveform against the scales built into the screen of the instrument.



The oscilloscope can be adjusted so that repetitive signals can be observed as a continuousshape on the screen. A storage oscilloscope allows single events to be captured by theinstrument and displayed for a relatively long time, allowing human observation of events toofast to be directly perceptible.Oscilloscopes are used in the sciences, medicine, engineering, and telecommunicationsindustry. General-purpose instruments are used for maintenance of electronic equipmentand laboratory work. Special-purpose oscilloscopes may be used for such purposes as analyzing an automotive ignition system or to display the waveform of the heartbeat asan electrocardiogram.

DUAL TRACE CRO:

The block diagram of dual trace oscilloscope which consist of following steps**,**

1. Electronics gun (single)
2.Separate vertical input channels (Two)
3. Attenuators
4.pr-amplifiers
5. Electronic switch.

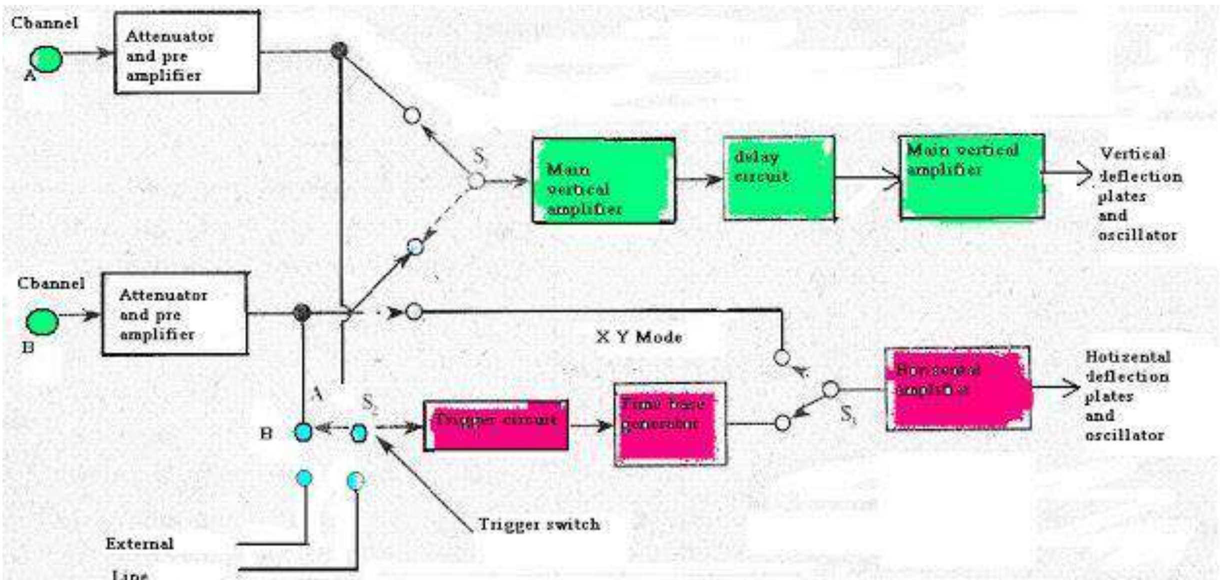


Fig: Block diagram of Dual Trace Oscilloscope

The two separate input signals can be applied to single electron gun with the helpof electronic switching it Produces a dual trace display .Each separate vertical inputchannel are uses separate attenuators and pr-amplifier stages, so the amplitude of eachsignal can be independentlycontrolled. Output of the pr-amplifiers is given to theelectronic switch, which passes one signal at a time into the main vertical amplifier of theoscilloscope.The time base-generator is similar to that of single input oscilloscope.By using switch S2 the circuit can be triggered on either A or Bchannel, waveforms, or an external signal, or on line frequency. The horizontalamplifier canbefed from sweep generator or from channel B by switching S1. When switch S, is in channelB, itsoscilloscope operates in the X-Y mode in which channel A acts as the vertical inputsignal andchannelBasthe horizontal inputsignal.

From the front panel several operating modes can be selected for display, like channel Bonly,channel A only, channels B and A as two traces, and signals A + B, A - B, B ~ A or - (A + B)as a single trace. Two types of common operating mode are there for the electronicswitch,namely,

1.Alternatemode

2.Chopmode**.**