ELECTRONICS MEASUREMENT & INSTRUMENTATION

LECTURES NOTE

TH - 4

3RD SEM ETC, DIPLOMA ENGG.

[UNIT-01]
QUALITIES OF MEASURMENT

1. INSTRUMENT AND MEASUREMENT-

1. INSTRUMENT-
It is a device for determining values or magnitude of a quantity or variable through agiven set of formulas.
2. MEASUREMENT-
It is a process of comparing an unknown quantity with an accepted standard quantity.

ELECTRONIC MEASUREMENT &INSTRUMENTATION-

It is the branch of Electronics which deals with the study of measurement and variations ofdifferent parameters of various instruments.

- Why measurement of parameters and study of variations for a particular instrument arerequired?
  The measurement of parameters and its variations for a particular instrument is requiredbecause it helps in understanding the behaviour of an instrument.

CONDITION FOR A MEASURING INSTRUMENT:-

The measuring instrument must not affect the quantity which is to be measured.

2. MEASUREMENT SYSTEM PERFORMANCE:-

The performance of the measurement system/instruments are divided into two categories.

1. Static Characteristics
2. Dynamic Characteristics

STATIC CHARACTERISTICS OF INSTRUMENT-

These are those characteristics of an instrument which do not vary with time and are generally considered to check if the given instrument is fit to be used for measurement. The static characteristics are from one form or another by the process called Callibration.They are as follows:-

1. ACCURACY- It is defined as the ability of a device or a system to respond to a true value of a measure variable under condition.
2. PRECISION-Precision is the degree of exactness for which an instrument is design orintended to perform.
3. REPEATABILITY- The repeatability is a measuring device may be defined as the closeness of an agreement among a number of consecutive measurements of theoutput for the same value of the input under save operating system.
4. REPRODUCIBILITY- Reproducibility of an instrument is the closeness of the output for the same value of input. Perfect reproducibility means that the instrument has no drift.
5. SENSITIVITY- Sensitivity can be defined as a ratio of a change output to the change input at steady state condition.

6. *RESOLUTION*- Resolutions the least increment value of input or output that can bedetected, caused or otherwise discriminated by the measuring device.
7. *TRUE VALUE*-True value is error free value of the measure variable it is given asdifference between the Instrument Reading and Static error.
   Mathematically,

   True value= Obtained Instrument reading – static error.

Note- $\%Error = \frac{\text{Standard Reference Value} - \text{Obtained Reading}}{\text{Standard Reference Value}} * 100$

DYNAMIC CHARACTERISTICS OF INSTRUMENT-

The Dynamic Characteristics are those which change within a period of time that is generallyvery short in nature.

1. *SPEED OF RESPONSE*-It is the rapidity with which an instrument responds to thechanges to in the measurement quantity.
2. *FIDELITY*-The degree to which an instrument indicate the measure variable withoutdynamic error.
3. *LAG*-It is retardation or delay in the response an instrument to the changes in themeasurement.

ERROR- The deviation or change of the value obtained from measurement from the desired standard value.

Mathematically,

Error = Obtained Reading/Value – Standard Reference Value.There are three types of error. They are as follows:-

1. *GROSS ERRORS*-This are the error due to humans mistakes such as careless readingmistakes in recoding observation incorrect application of an instrument.

A. *SYSTEMATIC ERROR*-A constant uniform deviation of an instrument is as systematicerror. There are two types of systematic error.

   a) *STATIC ERROR*-

   The static error of a measuring instrument is the numerical different between the truevalue of a quantity and its value as obtained by measurement.

   b) *DYNAMIC ERROR*-

   1. It is the different between true value of a quantity changing with and valueindicated by the instrument.
   2. The Dynamic Errors are caused by the instrument not responding fast enough tofollow the changes in the measured value.

B. *RANDOM ERROR*-The cause of such error is unknown or not determined in theordinary process of making measurement.

TYPES OF STATIC ERROR-

i. *INSTRUMENTAL ERROR- Instrumental error are errors inherent in mastering instrument because of the mechanical construction friction is bearing in various movingcomponent. It can be avoided by*
   a. *Selecting a suitable instrument for the particular measurement.*
   b. *Applying correction factor after determining the amount ofinstrumental error.*

ii. *ENVIROMENTAL ERROR -Environmental error are due to conditions external to the measuring device including condition al in the area surrounding the instrument such aseffect of change in temperature , humidity or electrostatic field it can be avoided*
   a. *Providing air conditioning.*
   b. *Use of magnetic shields.*

iii. *OBSERVATIONAL ERROR- The errors introduced by the observer. These errors arecaused by habits of the observers like tilting his/her head too much while reading a "Needle - Scale Reading".*

Q METER:

A **Q meter** is a piece of equipment used in the testing of radio frequency circuits. It has been largely replaced in professional laboratories by other types of impedance measuring device, though it is still in use among radio amateurs. It was developed at Boonton Radio Corporation in Boonton, New Jersey in 1934 by William D. Loughlin.[1]

A Q meter measures Q, the quality factor of a circuit, which expresses how much energy is dissipated per cycle in a non-ideal reactive circuit:

$$Q = 2\pi \times \frac{\text{Peak Energy Stored}}{\text{Energy dissipated per cycle}}.$$

This expression applies to an RF and microwave filter, bandpass LC filter, or any resonator. It also can be applied to an inductor or capacitor at a chos n frequency. For inductors

$$Q = \frac{X_L}{R} = \frac{\omega L}{R}$$

Where X_L is the reactance of the inductor, L is the inductance, ω is the angular frequency and R is t e resistance of the inductor. The resistance R represents the loss in the inductor, nainly due to the resistance of the wire.Q meter works on the principle of series resonance.

For LC band pass circuits and filters:

$$Q = \frac{F}{BW}$$

Where F is the resonant frequency (center frequency) and BW is the filter bandwidth. In a band pass filter using an LC resonant circuit, when the loss (resistance) of the inductor increases, its Q is reduced, and so the bandwidth of the filter is increased. In a coaxial cavity filter, there are no inductors and capacitors, but the cavity has an equivalent LC model with losses (resistance) and the Q factor an be applied as well.\

Internally a mini al Q meter consists of a\ tuneable RF ge erator, with a low impedance output, and a detector with a very high veryimpedance input.

Additionally ther is usually provision to add calibrated amounts of high Q capacitance across the component under test to allow inductors to be measured in isolation. The generator is effectively placed in series with the tuned circuit formed by the components under test, and having negligible output resistance, does not materially affect the Q factor, while the detector measures the voltage developed across one element (usually the capacitor) and being high impedance in shunt does not affect the Q factor significantly either. The ratio of the developed RF voltage to the applied RF current, coupled with knowledge of the reactive impedance from the resonant frequency, and the source impedance, allows the Q factor to be directly read by scaling the detected voltage.

UNIT-02

INDICATING INSTRUMENT

INTRODUCTION

MEASURING INSTRUMENTS:-

Measuring instruments are classified according to both the quantity measured by the instrument and the principle of operation.

There are three general principles of operation:

- electromagnetic, which utilizes the magnetic effects of electric currents;
- electrostatic, which utilizes the forces between electrically-charged conductors;
- Electro-thermic, which utilizes the heating effect.

The essential requirements of measuring instruments are:-

- It must not alter the circuit conditions.
- It must consume very small amount of power.

Electric measuring instruments and meters are used to indicate directly the value of current,voltage, power or energy.

An electromechanical meter (input is as an electrical signal results mechanical force or torqueas an output) that can be connected with additional suitable components in order to act as an ammeters and a voltmeter.

The most common analogue instrument or meter is the permanent magnet moving coil instrument and it is used for measuring a dc current or voltage of an electric circuit.

TYPES OF FORCES/TORQUES ACTING IN MEASURING INSTRUMENTS:

1. DEFLECTING TORQUE/FORCE:

- The defection of any instrument is determined by the combined effect of the deflecting torque/force, control torque/force and damping torque/force.
- The value of deflecting torque must depend on the electrical signal to be measured.
- This torque/force causes the instrument movement to rotate from its zero position.

2. CONTROLLING TORQUE/FORCE:

- This torque/force must act in the opposite sense to the deflecting torque/force, and the movement will take up an equilibrium or definite position when the deflecting and controlling torque are equal in magnitude.
- The Spiral springs or gravity usually provides the controlling torque.

3. DAMPING TORQUE/FORCE:

- A damping force is required to act in a direction opposite to the movement of the movingsystem.
- This brings the moving system to rest at the deflected position reasonably quickly withoutany oscillation or very small oscillation.

- This is provided by
  - i) Air friction
  - ii) Fluid friction
  - iii) Eddy current.
- It should be pointed out that any damping force shall not influence the steady statedeflection produced by a given deflecting force or torque.
- Damping force increases with the angular velocity of the moving system, so that its effectis greatest when the rotation is rapid and zero when the system rotation is zero.

BASIC METER MOVEMENT &PMMC MOVEMENT

BASIC METER MOVEMENT OR D'ARSONVAL METER MOVEMENT

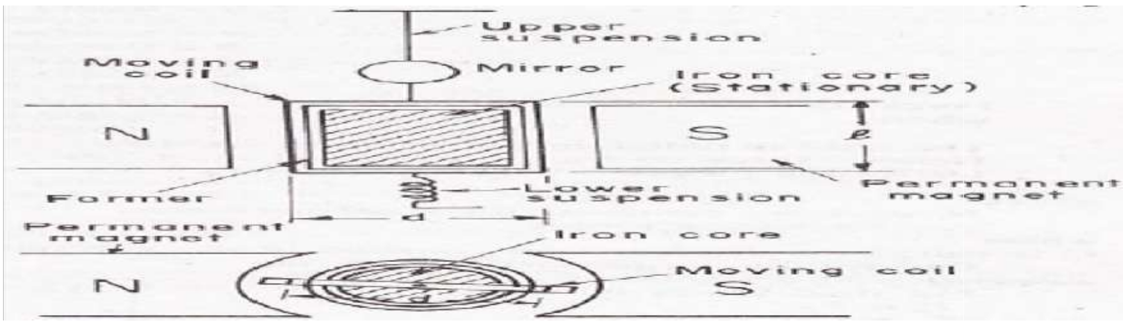
PRINCIPLE:-

Whenever electrons flow through a conductor, a magnetic field proportional to the current iscreated. This effect is useful for measuring current and is employed in many practical meters.

- The basic dc meter movement is known as the D'Arsonval meter movement because it was first employed by the French scientist, D'Arsonval, in making electrical measurement.
- This type of meter movement is a current measuring device which is used in the ammeter,voltmeter, and ohmmeter.
- An ohmmeter is also basically a current measuring instrument, it differs from the ammeter and voltmeter in that it provides its own source of power and contains other auxiliary circuits.

D'ARSONVAL GALVANOMETER:

This instrument is very commonly used in various methods of resistance measurement andalso in d.c. potentiometer work.



Fig

1) MOVING COIL:

- It is the current carrying element.
- It is either rectangular or circular in shape and consists of number of turns of fine wire.
- This coil is suspended so that it is free to turn about its vertical axis of symmetry.
- It is arranged in a uniform, radial, horizontal magnetic field in the air gap between polepieces of a permanent magnet and iron core.

- The iron core is spherical in shape if the coil is circular but is cylindrical if the coil isrectangular.
- The iron core is used to provide a flux path of low reluctance and therefore to providestrong magnetic field for the coil to move in.
- This increases the deflecting torque and hence the sensitivity of the galvanometer. Thelength of air gap is about 1.5mm.
- In some galvanometers the iron core is omitted resulting in of decreased value of fluxdensity and the coil is made narrower to decrease the air gap.
- Such a galvanometer is less sensitive, but its moment of inertia is smaller on account ofits reduced radius and consequently a short periodic time.

2) **DAMPING:**

- There is a damping torque present owing to production of eddy currents in the metalformer on which the coil is mounted.
- Damping is also obtained by connecting a low resistance across the galvanometer terminals.
- Damping torque depends upon the resistance and we can obtain critical damping byadjusting the value of resistance.

3) **SUSPENSION:**

- The coil is supported by a flat ribbon suspension which also carries current to the coil.
- The other current connection in a sensitive galvanometer is a coiled wire. This is calledthe lower suspension and has a negligible torque effect.
- This type of galvanometer must be leveled carefully so that the coil hangs straight andcentrally without rubbing the poles or the soft iron cylinder.
- The upper suspension consists of gold or copper wire of nearly 0.012–5 or 0.02–5 mmdiameter rolled into the form of a ribbon.
- This is not very strong mechanically so that the galvanometers must he handled carefullywithout jerks.

4) **INDICATION:**

- The suspension carries a small mirror upon which a beam of light is cast. The beam of light is reflected on a scale upon which the deflection is measured. This scale is usually about 1 meter away from the instrument, although ½ meter may be used for greater compactness.

5) **ZERO SETTING:**

- A torsion head is provided for adjusting the position of the coil and also for zero setting.

PMMC INSTRUMENTS:

- These instruments are used either as ammeters or voltmeters and are suitable for d.c workonly.
- PMMC instruments work on the principle that, when a current carrying conductor isplaced in a magnetic field, a mechanical force acts on the conductor.
- The current carrying coil, placed in magnetic field is attached to the moving system.
- With the movement of the coil, the pointer moves over the scale to indicate the electricalquantity being measured.
- This type of movement is known as D' Arsenoval movement.

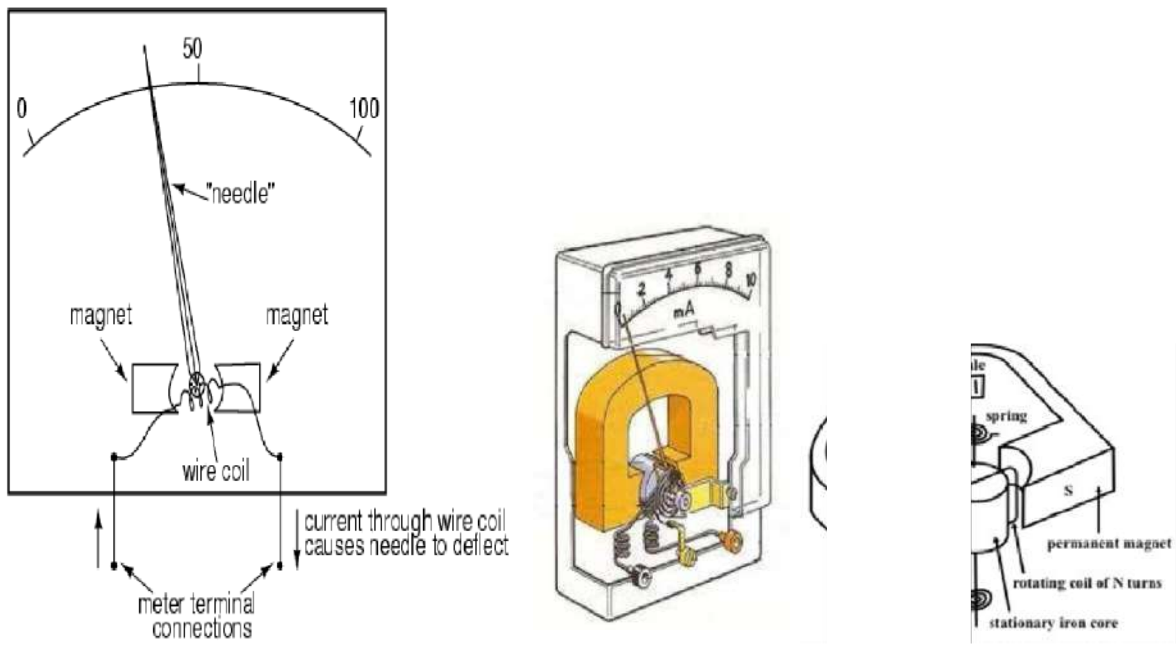
CONSTRUCTION:

- It consists of a light rectangular coil of many turns of fine wire wound on an aluminiumformer inside which is an iron core as shown in fig.
- The coil is delicately pivoted upon jewel bearings and is mounted between the poles of apermanent horse shoe magnet.
- Two soft-iron pole pieces are attached to these poles to concentrate the magnetic field.
- The current is led in to and out of the coils by means of two control hair- springs, one above and other below the coil, as shown in Fig.
- These springs also provide the controlling torque. The damping torque is provided byeddy currents induced in the alluminium former as the coil moves from one position to another.

WORKING:

- When the instrument is connected in the circuit to measure current or voltage, the operating current flows through the coil.
- Since the current carrying coil is placed in the magnetic field of the permanent magnet, a mechanical torque acts on it.
- As a result of this torque, the pointer attached to the moving system moves in clockwise direction over the graduated scale to indicate the value of current or voltage beingmeasured.
- This type of instruments can be used to measure direct current only.
- This is because, since the direction of the field of permanent magnet is same, the deflecting torque also gets reversed, when the current in the coil reverses.
- Consequently, the pointer will try to deflect below zero. Deflection in the reverse direction can be prevented by a "stop" spring.

Permanent magnet, moving coil (PMMC) meter movement



Fig

DEFLECTING TORQUE EQUATION:-

- The magnetic field in the air gap is radial due to the presence of soft iron core. Thus, the conductors of the coil will move at right angles to the field. When the current is passed through the coil, forces act on its both sides which produce the deflecting torque.

Let, B = flux density, Wb/m2
l = length or depth of coil,
mb = breadth of the coil.
N = no. of turns of the coil.

- If a current of 'I' Amperes flows in the coil, then the force acting on each coil side isgiven by,

Force on each coil side, F = BIlN Newtons.

- Deflecting torque, T_d = Force x perpendicular distance
= (BIlN) x b
T_d = BINA Newton metre.

Where, A = l x b, the area of the coil in m^2.

- Thus, $T_d \alpha I$
- The instrument is spring controlled so that, $T_c \alpha \theta$
- The pointer will comes to rest at a position, where $T_d = T_c$
- Therefore, $\theta \alpha I$.
- Thus, the deflection is directly proportional to the operating current.
- Hence, such instruments have uniform scale.

ADVANTAGES:

a) Uniform scale.ie, evenly divided scale.
b) Very effective eddy current damping.
c) High efficiency.
d) Require little power for their operation.
e) No hysteresis loss (as the magnetic field is constant).
f) External stray fields have little effects on the readings (as the operating magnetic field isvery strong).
g) Very accurate and reliable.

DISADVANTAGES:

a) Cannot be used for a.c measurements.
b) More expensive (about 50%) than the moving iron instruments because of their accuratedesign.
c) Some errors are caused due to variations (with time or temperature) either in the strengthof permanent magnet or in the control spring.

APPLICATIONS:

a) In the measurement of direct currents and voltages.
b) In d.c galvanometers to detect small currents.
c) In Ballistic galvanometers used for measuring changes of magnetic flux linkages.

OPERATION OF MOVING IRON INSTRUMENT:-

Moving Iron instruments are mainly used for the measurement of alternating currents andvoltages, though it can also be used for d.c measurements.

PRINCIPLE OF MOVING IRON INSTRUMENT:-

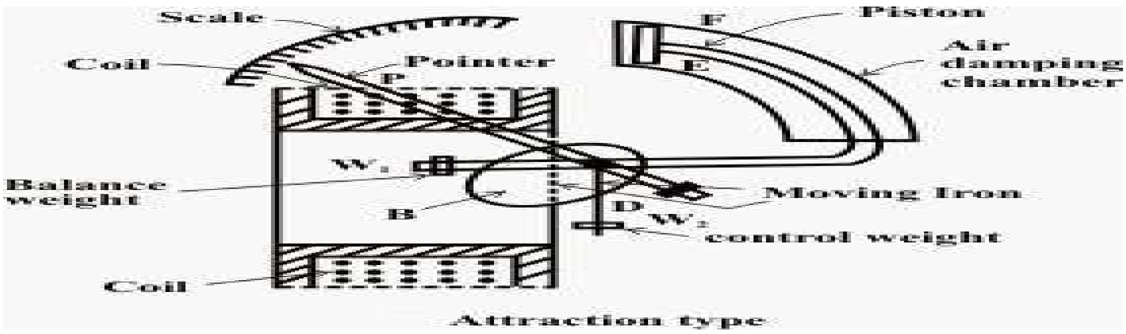
- Let a plate or vane of soft iron or of high permeability steel forms the moving element ofthe system.
- The iron vane is situated so as, it can move in a magnetic field produced by a stationarycoil.
- The coil is excited by the current or voltage under measurement.
- When the coil is excited, it becomes an electromagnet and the iron vane moves in such away so as to increase the flux of the electromagnet.
- Thus, the vane tries to occupy a position of minimum reluctance.
- Thus, the force produced is always in such a direction so as to increase the inductance ofthe coil.

TYPES OF MOVING IRON INSTRUMENTS:

There are two types of Moving- iron instruments

1. **ATTRACTION TYPE:**

In this type of instrument, a single soft iron vane (moving iron) is mounted on the spindle,and is attracted towards the coil when operating current flows through it.



Fig**DEFLECTING**

TORQUE EQUATION:

- The force F, pulling the soft –iron piece towards the coil is directly proportional to
  - a) Field strength (H) produced by the coil.
  - b) Pole strength (m) developed in the iron piece.
- F α Mh Since m α H,
- Therefore F α H^2
- Instantaneous deflecting torque α H^2 .
- The field strength H = μi .
- If the permeability (μ) of the iron is assumed constant, then H α I .Where i → instantaneous coil current (Ampere).
- Instantaneous deflecting torque α i^2.
- Average deflecting torque, T_d α mean of i^2 over a cycle.
- Since the instrument is spring controlled, hence T_c α θ .

- In the steady position of deflection, $T_d = T_c$.
- Therefore θ α mean of i^2 over a cycle => θ α I^2(mean of i^2 over a cycle = I^2).
- Since the deflection is proportional to the square of coil current, the scale of such instruments is non-uniform (being crowded in the beginning and spread out near the finishing end of the scale).

2. **REPULSION TYPE:-**

- In this two soft iron vanes are used; one fixed and attached the stationary coil, while theother is movable (moving iron), and mounted on the spindle of the instrument.
- When operating current flows through the coil, the two vanes are magnetized, developingsimilar polarity at the same ends.
- Consequently, repulsion takes place between the vanes and the movable vane causes thepointer to move over the scale.
- It is of two types:-

a) Radial vane type: - vanes are radial strips of iron.
b) Co-axial vane type:-vanes are sections of coaxial cylinders.

DEFLECTING TORQUE:

- The deflecting torque results due to repulsion between the similarly charged soft - ironpieces or vanes.
- If the two pieces develop pole strength of m_1 and m_2 respectively, then Instantaneousdeflecting torque is α $m_1 m_2$ α H^2.
- If the permeability of iron is assumed constant, then H α i, where i is the coil current.
- Instantaneous deflecting torque α i^2.
- Average deflecting torque, T_d α mean of i^2 over a cycle.
- Since the instrument is spring controlled, T_c α θ.
- In the steady position of deflection, $T_d = T_c$ i.e. θ α mean of i^2 over a cycle => θ α I^2 (mean of i^2 over a cycle = I^2).
- Thus, the deflection is proportional to the square of the coil current.
- The scale of the instrument is non- uniform being crowded in the beginning and spreadout near the finish end of the scale.
- However, the non- linearity of the scale can be corrected to some extent by the accurateshaping and positioning of the iron vanes in relation to the operating coil.

PRINCIPLE OF OPERATION OF DC AMMETER AND MULTIRANGE AMMETER

D.C. AMMETER:-

- The PMMC galvanometer constitutes the basic movement of a dc ammeter.
- The coil winding of a basic movement is small and light, so it can carry only very small currents.
- A low value resistor (shunt resistor) is used in DC ammeter to measure large current.
- PMMC movement can be used as DC ammeter by connecting resistor in shunt with it, so that shunt resistance allows a specific fraction of current [excess current greater than full scale deflection current (IFSD)] flowing in the circuit to bypass the meter movement.

- The fractions of the current flowing in the movement indicate the total current flowing inthe circuit.
- DC ammeter can be converted into multirange ammeter by connecting number of resistances called multiplier in parallel with the PMMC movement.
- Let R_m = internal resistance of the movement.
- I = full scale current of the ammeter + shunt (i.e. total current)
- R_{sh} = shunt resistance in ohms.
- I_m = full-scale deflection current of instrument in ampere.
- $I_{sh} = (I - I_m)$ = shunt current in ampere.
- Since the shunt resistance is in parallel with the meter movement, the voltage drop acrossthe shunt and movement must be the same.
- Therefore, $V_{sh} = V_m$
- $I_{sh}R_{sh} = I_mR_m$,
- $R_{sh} = (I_mR_m)/I_{sh}$
- But $I_{sh} = I - I_m$
- Hence $R_{sh} = (I_mR_m) / (I-I_m)$.
- $(I-I_m)/I_m = R_m/R_{sh}$
- $(I/I_m)-1 = R_m/R_{sh}$
- $I/I_m = 1+ R_m/R_{sh}$.
- The ratio of the total current to the current in the movement is called Multiplying Powerof the Shunt i.e Mathematically, Multiplying Power (m) $=I/I_m = 1+ R_m/R_{sh}$.

MULTIRANGE DC AMMETER:

- The range of the dc ammeter is extended by a number of shunts, selected by a rangeswitch. Such a meter is known as Multirange DC Ammeter.
- The resistors is placed in parallel to give different current ranges.

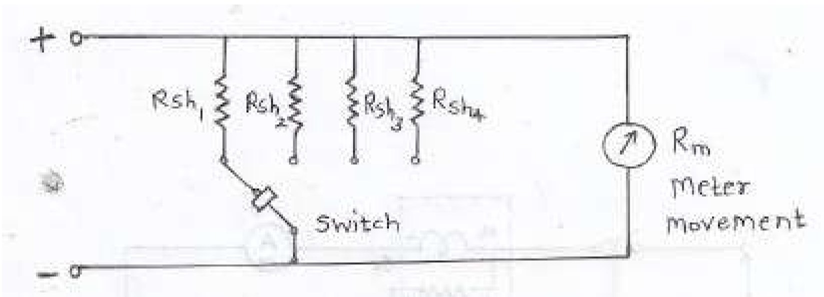


Fig.2.5

- Above figure shows a diagram of multirange ammeter.
- The circuit has 4 shunts R_{sh1}, R_{sh2}, R_{sh3} and R_{sh4} which can be put in parallel with metermovement to give 4 different current ranges I_1, I_2, $I_3$and I_4.

  Let m_1, m_2, m_3 and m_4 be the shunt multiplying powers for currents I_1, I_2, I_3 and I_4.
  - $R_{sh1} = R_m/(m_1-1)$
  - $R_{sh2} = R_m/(m_2-1)$
  - $R_{sh3} = R_m/(m_3-1)$
  - $R_{sh4} = R_m/(m_4-1)$
- In the Ammeter the multiposition make-before-break switch is used.

- This type of switch is essential in order that meter not damaged when movement ischanging from the current range one to another.
- If we provide an ordinary switch the meter remains without a shunt and it is unprotectedand therefore it can be damaged when the range is changed.
- Multirange Ammeters are used for the range from the 1 to 50 A.

AC AMMETER AND MULTIRANGE AMMETERS:

- The PMMC movement cannot be used directly for ac measurements since the inertia ofPMMC acts as an averager.
- Because A.C. current has zero average value and it produces a torque that has also zeroaverage value, the pointer just vibrates around zero on the scale.
- In order to make ac measurements, a bridge rectifier circuit is combined with PMMC asshown below.

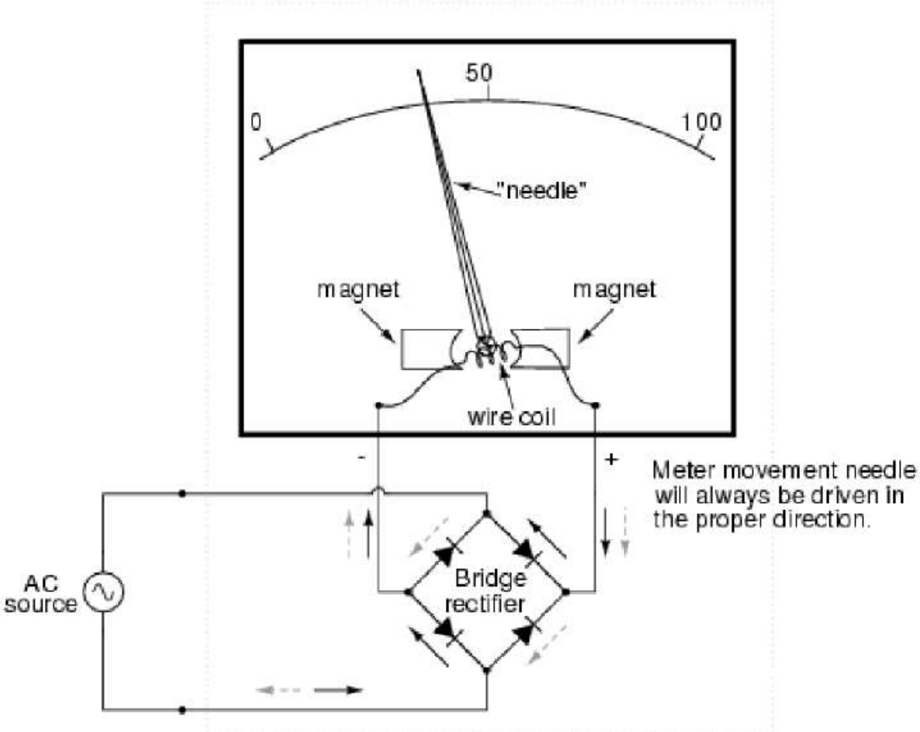


Fig.

BASIC OPERATION OF OHMMETER:

ELECTRICAL RESISTANCE:

- Electrical resistance is a measure of how much an object opposes allowing an electricalcurrent to pass through it.

OHMMETER:

- It is an electronic device used to measure electrical resistance of a circuit element of lowdegree of accuracy.
- This resistance reading is indicated through a meter movement.

- The ohmmeter must then have an internal source of voltage to create the necessary current to operate the movement, and also have appropriate ranging resistors to allowdesired current to flow through the movement at any given resistance.
- An ohmmeter is useful for
  1. Determining the approximate resistance of circuit components such as heater elementsor machine field coils.
  2. Measuring and sorting of resistors used in electronic circuits.
  3. Checking of semiconductor diodes and for checking of continuity of circuit.
  4. To help the precision bridge to calculate the approximate value of resistance whichcan save time in balancing the bridge.
- There are two types of schemes are used to design an ohmmeter –

a) series type

b) shunt type.

- The series type of ohmmeter is used for measuring relatively high values of resistance,while the shunt type is used for measuring low values of the resistance.

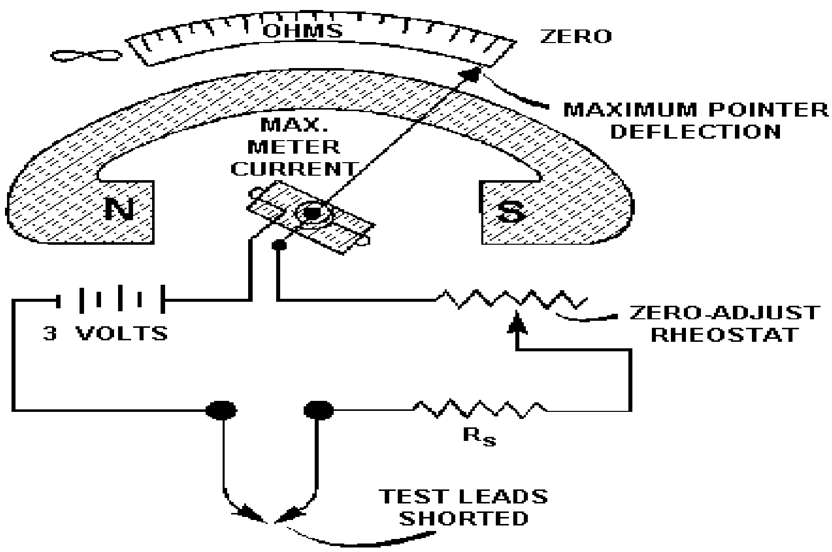
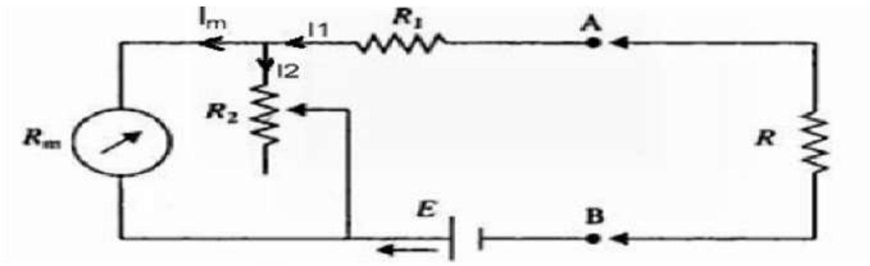


Fig.

- Ohmmeters come with different levels of sensitivity.
- Some Ohmmeters are designed to measure low-resistance materials, and some are usedfor measuring high-resistance materials.
- A Micro Ohmmeter is used to measure extremely low resistances with high accuracy atparticular test currents and is used for bonding contact applications.
- Mega Ohmmeter is used to measure large resistance values.
- Milli-Ohmmeter is used to measure low resistance at high accuracy confirming the valueof any electrical circuit.

SERIES TYPE OHMMETER;

- It consists of basic d'Arsonval movement connected in parallel with a shunting resistorR_2.
- This parallel circuit is in series with resistance R_1 and a battery of emf E.
- The series circuit is connected to the terminals A and B of unknown resistor R_x.

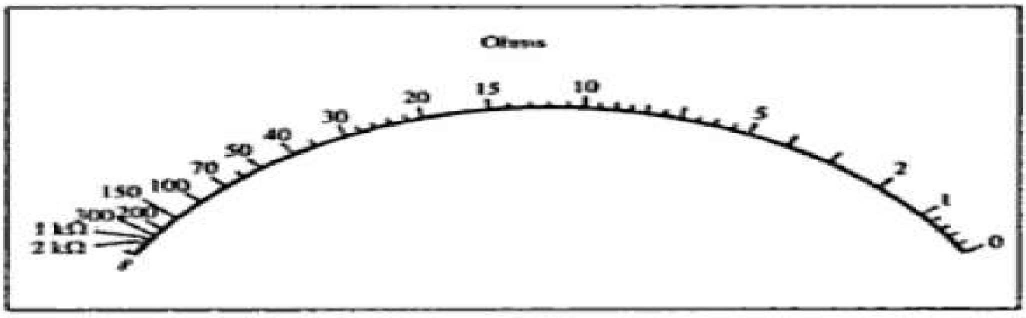


Fig

- From the figure,

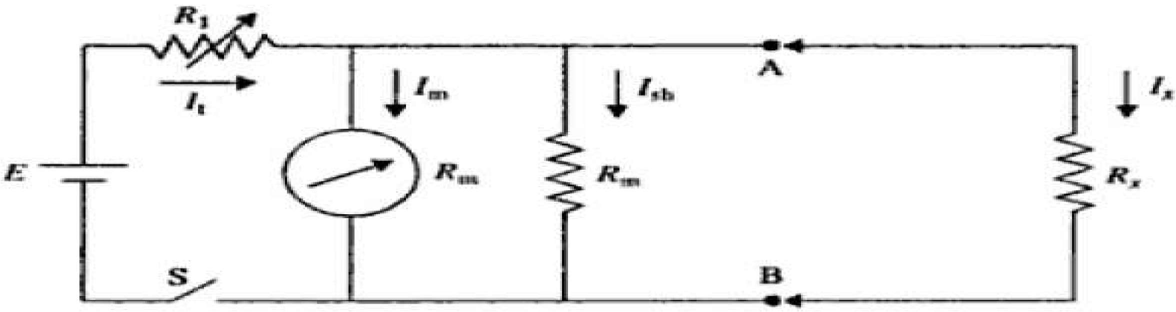
  R_1 = current limiting resistor; R_2 = zero adjusting resistor; E = emf of internal battery; R_m = internal resistance of d'Arsonval movement.

  - When the unknown resistance $R_x = 0$ (terminals A and B shorted) maximum current flows through the meter. Under this condition resistor R_2 is adjusted until the basic movement meter indicates full scale current Ifs.
  - The full scale current position of the pointer is marked "0Ω" on the scale.
  - Similarly when R_x is removed from circuit $R_x = \infty$ (i.e. when terminal A and B are open), the current in the meter drops to the zero and the movement indicates zero current which is the marked "∞".
  - Thus the meter will read infinite resistance at the zero current position and zero resistance at full scale current position.
  - Since zero resistance is indicated when current in the meter is the maximum and hence the pointer goes to the top mark.
  - When the unknown resistance is inserted at terminal A, B the current through themeter is reduced and hence pointer drops lower on the scale.
  - Therefore the meter has "0" at extreme right and "∞" at the extreme left.
  - Intermediate scale marking may be placed on the scale by different known values ofthe resistance R_x to the instrument.
  - A convenient quantity to use in the design of the series ohmmeter is the value of theR_x which causes the half scale deflection of the meter.
  - At this position, the resistance across terminals A and B is defined as the half scaleposition resistance R_h.
  - The design can be approached by recognizing the fact that when R_h is connectedacross A and B the meter current reduces to one half of its full scale value or with R_x = R_h, $I_m = 0.5\, I_{fs}$, where I_m = current through the meter, I_{fs} = current through the meterfor full scale deflection.
  - This clearly means that R_h is equal to the internal resistance of the ohmmeter lookinginto terminals A and B.



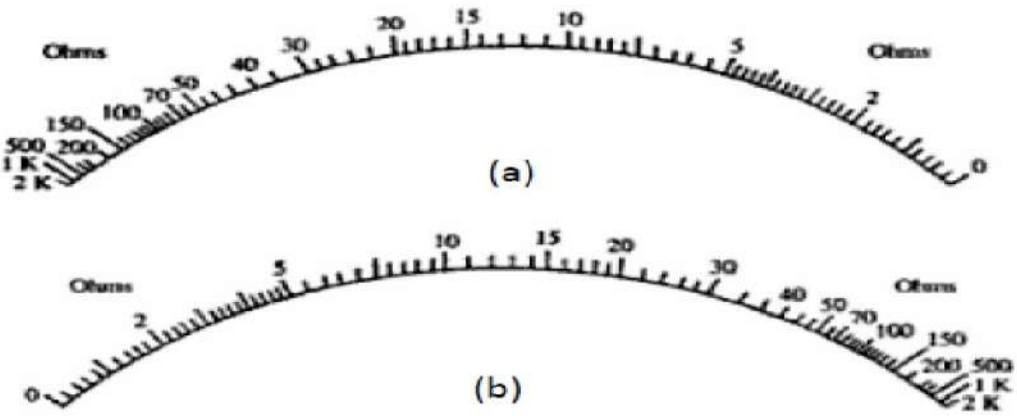
Fig

SHUNT TYPE OHMMETER:-



Fig

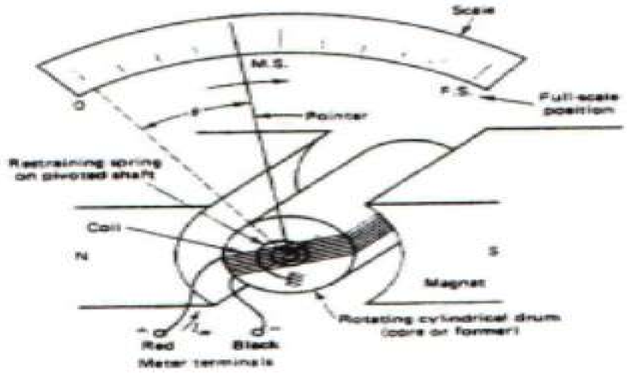
- This circuit consists of a battery in series with an adjustable resistor R_1 and a basicD'Arsonval movement (meter).
- The unknown resistance is connected across terminals A and B, parallel with the meter.
- In this circuit it is necessary to have an ON-OFF switch to disconnect the battery from thecircuit when the instrument is not in use.
- When the unknown Resistor R_x= 0Ω, (i.e. A and B are shorted), the meter current is zero.
- If the unknown Resistor R_x=∞Ω, (i.e. A and B are open), the meter current flows only through the meter and by selecting a proper value of the resistance R_1, the pointer may bemade to read full scale.
- This ohmmeter therefore, has zero marking on the left hand side of the scale (no current)and ∞ mark on the right hand side of the scale.



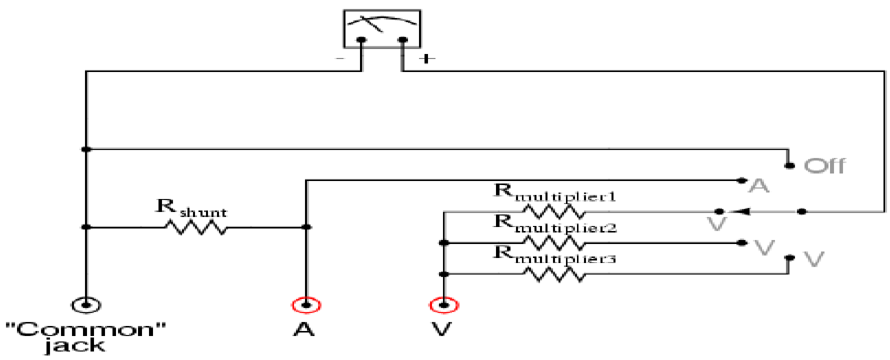
Fig

ANALOG MULTIMETER:-

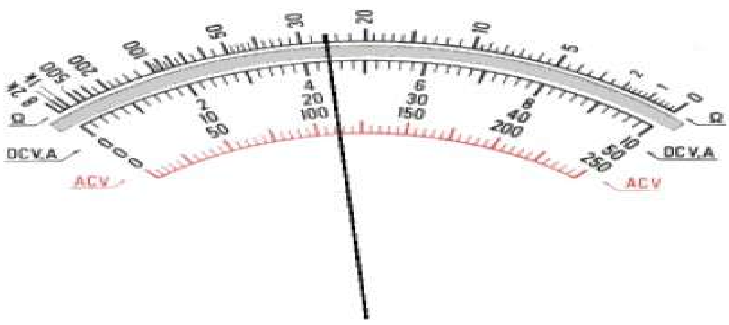
- The main part of an analog multi meter is the D'Arsonval meter movement also known asthe permanent-magnet moving-coil (PMMC) movement.
- This common type of movement is used for dc measurements.



Fig



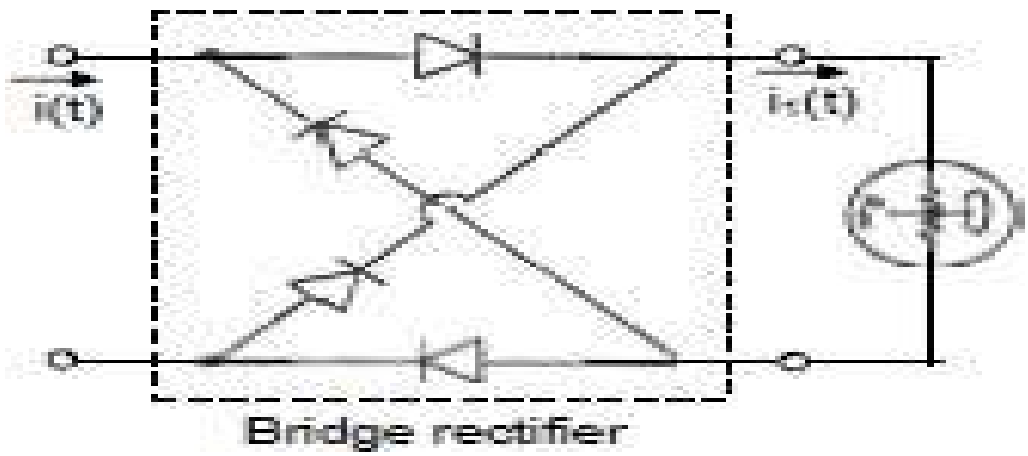
Fig



Fig

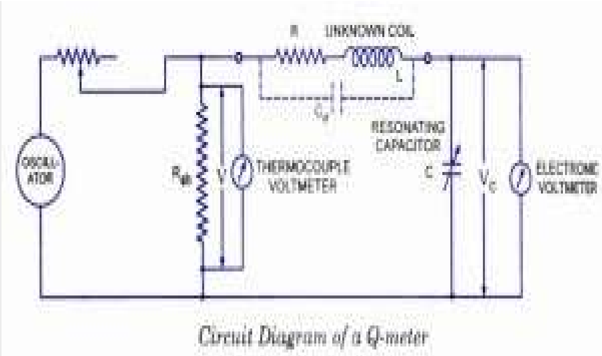
- When the meter current I_m flows in the wire coil in the direction indicated in figure amagnetic field is produced in the coil.
- This electrically induced magnetic field interacts with the magnetic field of the horseshoe-type permanent magnet.

- The result of such an interaction is a force causing a mechanical torque to be exerted on the coil.
- Since the coil is wound and permanently fixed on a rotating cylindrical drum as shown, the torque produced will cause the rotation of the drum around its pivoted shaft.
- When the drum rotates, two restraining springs, one mounted in the front onto the shaft and the other mounted onto the back part of the shaft, will exhibit a counter torque opposing the rotation and restraining the motion of the drum.
- This spring-produced counter-torque depends on the angle of deflection of the drum, θ or the pointer. At a certain position (or deflection angle), the two torques are in equilibrium.
- Each meter movement is characterized by two electrical quantites
  a) R_m: the meter resistance which is due to the wire used to construct the coil
  b) I_{FS}: the meter current which causes the pointer to deflect all the way up to the full-scale position on the fixed scale.
- This value of the meter current is always referred to as the full scale current of the metermovement.
- The PMMC movement cannot be used directly for ac measurements since the inertia ofPMMC acts as an averager.
- Since ac current has zero average value and it produces a torque that has also zeroaverage value, the pointer just vibrates around zero on the scale.
- In order to make ac measurements, a bridge rectifier circuit is combined with PMMC asshown in figure below.



Fig

Q-Meter



q-meter-circuit diagram

We know that every inductor coil has a certain amount of resistance and the coil should have lowest possible resistance. The ratio of the inductive reactance to the effective resistance of the coil is called the quality factor or Q-factor of the coil.

So $Q = X_L / R = \omega L / R$

A high value of Q is always desirable as it means high inductive reactance and low resistance. A low value of Q indicates that the resistance component is relatively highand so there is a comparatively large loss of power.

The effective resistance of the coil differs from its dc resistance because of eddy current and skin effects and varies in a highly complex manner with the frequency. For this reason Q is rarely computed by determination of R and L.

One possible way for determination of Q is by using the inductance bridge but such bridge circuits are rarely capable of giving accurate measurements, when Q is high. So special meters are used for determination of Q accurately.

The Q-meter is an instrument designed for the measurement of Q-factor of the coil as well as for the measurement of electrical properties of coils and capacitors. -This instru- ment operates on the principle of series resonance i.e. at resonate condition of an ac series circuit voltage across the capacitor is equal to the applied voltage times of Q of the circuit. If the voltage applied across the circuit is kept-constant then voltmeter connected across the capacitor can be calibrated to indicate Q directly.

Circuit diagram of a Q-meter is shown is figure. A wide-range oscillator with frequency range from 50 kHz to 50 MHz is used as a power supply to the circuit. The output of the oscillator is shorted by a low-value resistance, R_{sh} usually of the order of 0.02 ohm. So it introduces almost no resistance into the oscillatory circuit and represents a voltage source with a very small or of almost negligible internal resistance. The voltage across the low-value shunt resistance R_{sh}, V is measured by a thermo-couple meter and the voltage across the capacitor, V_c is measured by an electronic voltmeter.

For carrying out the measurement, the unknown coil is connected to the test terminals ofthe instrument, and the circuit is tuned to resonance either by varying the frequency of the oscillator or by varying the resonating capacitor C. Readings of voltages across capacitor C and shunt resistance R_{sh} are obtained and Q-factor of the coil is determined as follows :

By definition Q-factor of the coil,

$Q = X_L / R$

And when the circuit is under resonance condition

$X_L = X_C$

Or $IX_L = IX_C = V_C$

And the voltage applied to the circuit.

$V = IR$

So, **$Q = X_L / R = IX_L / R = V_C / V$**

This Q-factor is called the circuit Q because this measurement includes the losses of the resonating capacitor, voltmeter and the shunt resistor R_{sh}. So, the actual Q-factor of the coil will be somewhat greater than the calculated Q-factor. This difference is usually very small and maybe neglected., except when the resistance of the coil under test is relatively small in comparison to the shunt resistance R_{sh}.

The inductance of the coil can also be computed from the known values of frequency f and resonating capacitor C as follows.

At resonance, **$X_L = X_C$ or $2\prod fL = 1/2\prod fC$ or $L = 1/ (2\prod f)^2$** Henry.

UNIT- 3

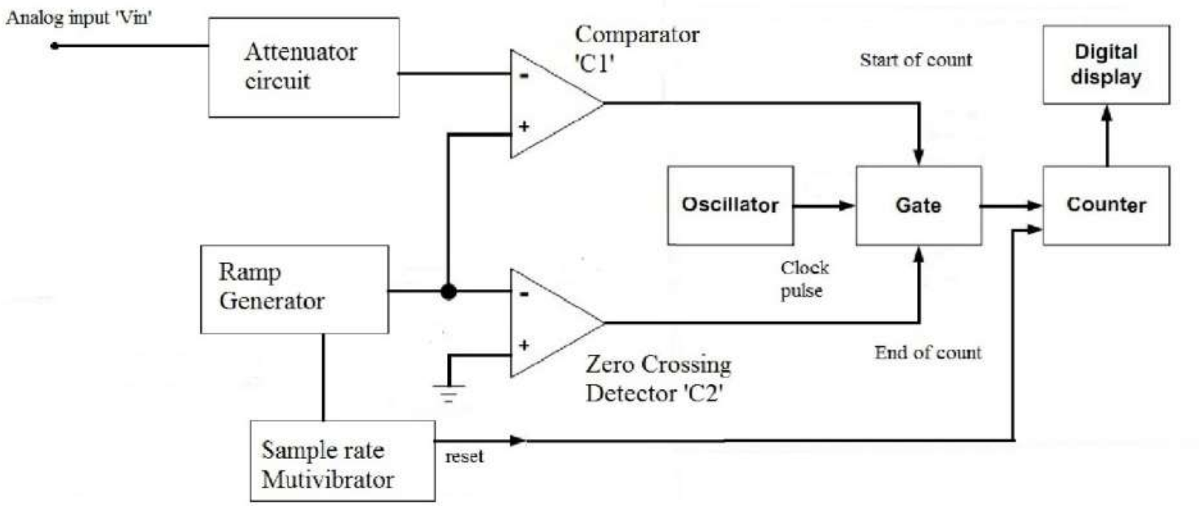
DIGITAL INSTRUMENTS

Ramp-type DVM

The principle of operation of the ramp-type DVM is based on the measurements of the time it takes for linear lamp voltage to rise from 0 V to the level of input voltage, or decrease fromthe level of the input voltage to zero. This interval of time is measured with an electronic time interval counter, and the count is displayed as a number of digits on electronic indicatingtubes.

Fig. shows the 'voltage-to-time conversion' using gated clock pulses.

Block Diagram - Ramp type DVM

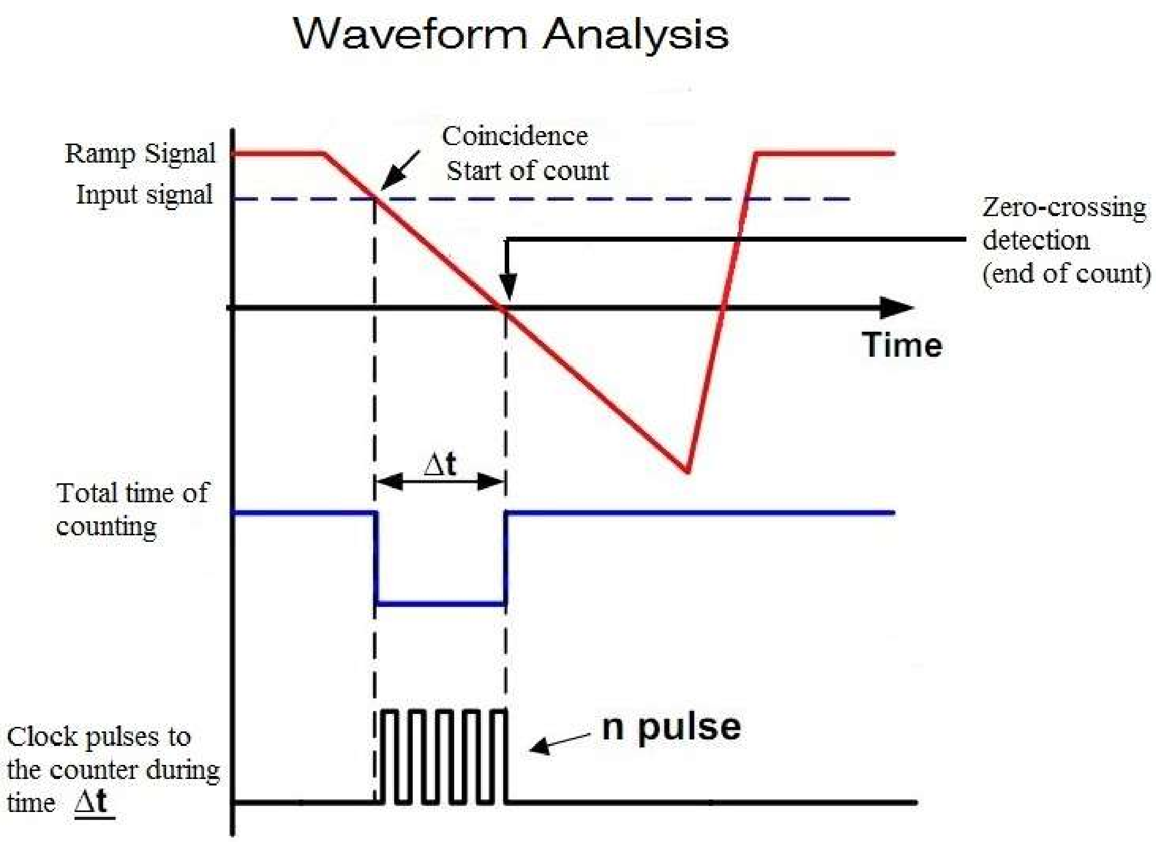


At the start of the measuring cycle, a ramp voltage is initiated; this voltage can be positive going or negative going. The negative going ramp, shown in the fig. is continuously compared with theunknown input-voltage.

At the instant that the ramp voltage equals the unknown voltage , a coincidence circuit, comparator, generates a pulse which open a gate[see fig.].The ramp voltage continues to decreasewith time until it finally reaches 0 V[or ground potential] and a second comparator generates an output pulses which closes the gate.

An oscillator generates clock pulses which are allowed to pass through the gate to a number of decadecounting units [DCUs] which totalise the number of pulses passed through the gate.

The decimal number, displayed by the indicator tubes associated with the DCUs, is a measure of themagnitude of the input voltage.



The sample-rate multi-vibrator[MV] determines the rate at high the measurement cycle are initiated.The sample-rate circuit provides an initiating pulse for the ramp generator to start its next ramp voltage. At the same time ,a reset pulse is generated which returns all the DCUs o their zero state, removing the display momentarily from the indicator tubes.

Characteristics of Digital Meters

Following are the few specifications which characterise digital meters:

1. Resolution- It is defined as the number of digit positions or simply the number of digits used in ameter.

If a number of full digits is n, then resolution,

$$R=1/10^n$$

For n=4 $R=1/10^4=0.0001$ or 0.01%.

A three-digit display on the digital meter for 0-1 V range will be able to indicate from 000 to 999mV,with smallest increment (resolution) of 1mV.

2. Sensitivity-It is the smallest change in input which a digital meter is able to detect. Thus, it is thefull-scale value of the lowest voltage range multiplied by the resolution of the meter .In other words,

$$\text{Sensitivity}, S=(fs)_{min} * R$$

Where, (fs)=Lowest full-scale value of digital meter, and

R=Resolution is decimal.

DIGITAL FREQUENCY METER

Principle of Operation

Frequency is one of the most basic parameters in electronic, it has very close relationshipwith many measurement schemes of electric parameter and measurement results, so the frequency measurement becomes more important, it has been widely used in aerospace, electronics, measurement and control field .

Digital frequency meter composed by oscillator, frequency dividers, shaping circuit, counting & decoding IC circuit. Oscillation circuit generates frequency signal, we can get a 0.5HZ signal whenthe frequency signal through frequency divider.

Diagram of digital frequency meter as

shownin Fig.

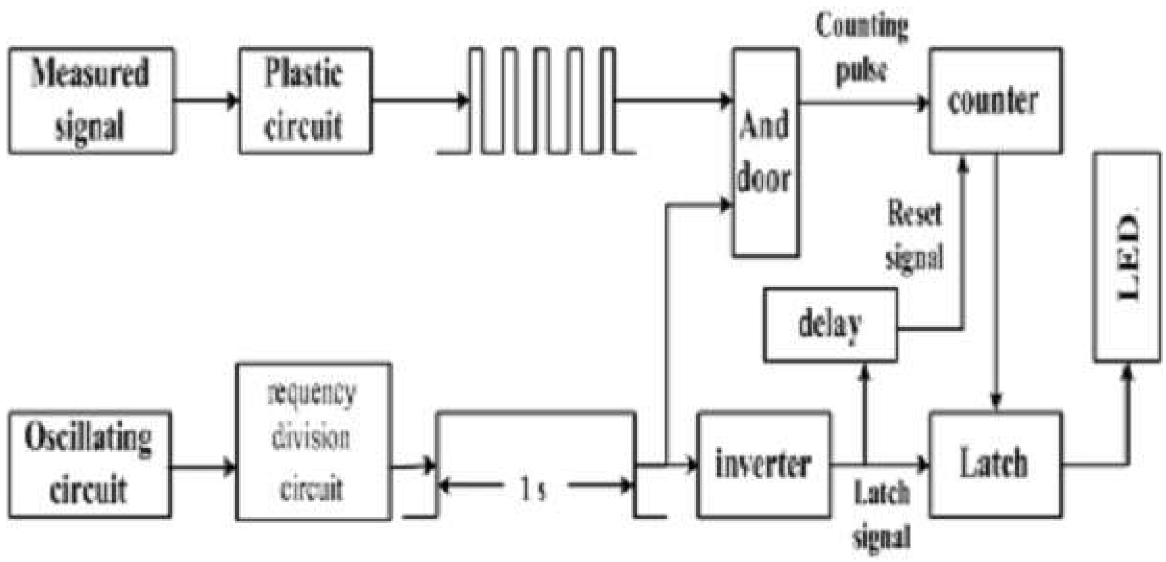


Fig .1 Digital frequency meter principle diagram

Design and simulation of digital frequency meter : Two types are circuits being used in thefrequency meter.

Oscillator circuit and frequency division circuit

(1) Oscillator circuit

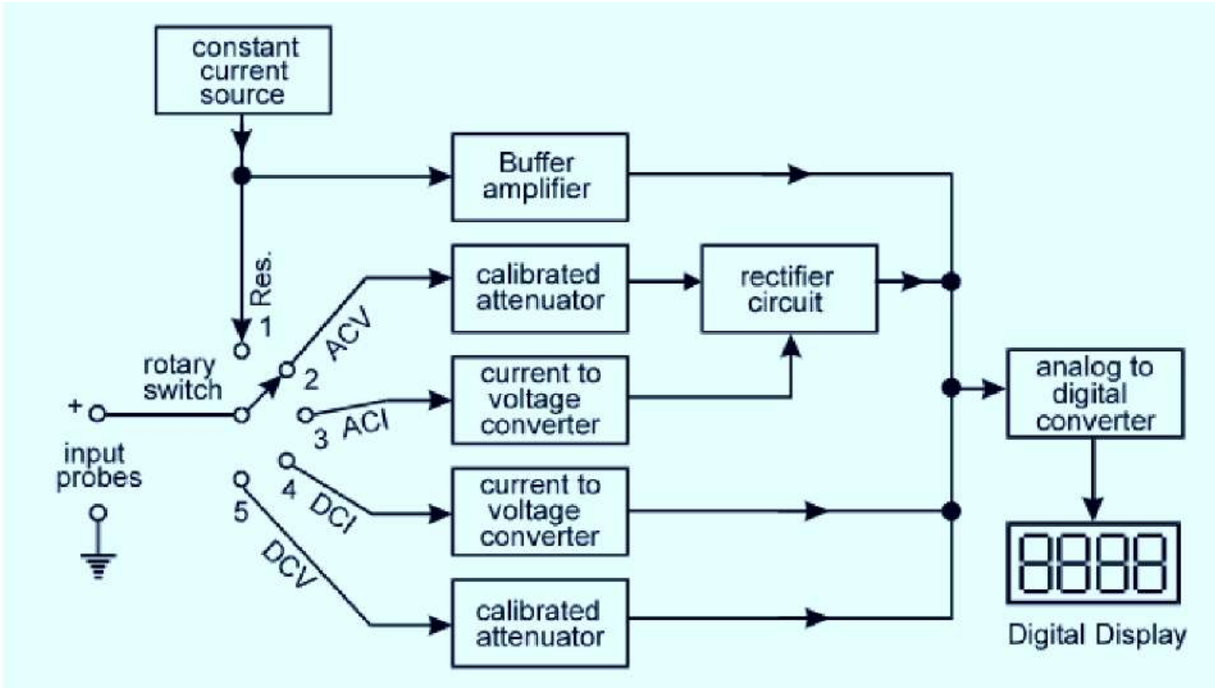
Oscillator is the core of timer, stability and the accuracy of oscillator frequency determine the timer accuracy[9-10], using IC 555 timing and RC constitute the oscillator which frequency is 500HZ,

(2) Frequency division circuit : Oscillator produce a rectangle wave is 500Hz, using frequency dividers to get 0.5Hz timer signal, 74LS90 is a 2-5 -10 decimal additions counter, use frequency dividers which composed by three 74LS90 can divided 500HZ rectangular pulse into 0.5 HZ.

DIGITAL MULTIMETER

A Digital multimeter offers increased versatility due to its additional capability to measure A.Cvoltage and current, D.C voltage and current, resistance.

The FIG. Shows the block diagram of a digital multimeter (DMM)



- In the "A.C voltage mode" ,the applied input is fed through a calibrated/ compensated attenuator ,to a precision fu;; wave rectifier circuit followed by a ripple reduction filter
- The resulting D.C fed to ADC and the subsequent display system.
- Fr current measurements the drop across an internal calibrated shunt is measured ,directlyBy the ADC in the "D.C current mode" , and after A.C to D. C conversion in the " A.C current mode". This drop is often in the range of 200 mv.
- Due to lack of precision in the A.C -D.C conversions, the accuracy in the A.C range is ingeneral of the order of 0.2 to 0.5%. In addition , the measurement range is often limited toabout 50 Hz at the lower frequency end due to the ripple in the rectified signal becoming anon negligible percentage of the display and hence in fluctuation of the displayed number.
- In the resistance range the multimeter operates by measuring the voltage across the externallyconnected resistance ,resulting from a current forced through it from a calibrated internal current source.

- The accuracy of resistance measurement is of the order of 0.1 to0.5% depending on the accuracy and stability of the internal current sources the accuracy may be proper in the highest range which is often about 10 to 20 MΩ. In the lowest range the full scale may be200Ω with a resolution of about 0.01Ω for a digital multimeter.

Measurement of Time (Period Measurement)

- In some cases it is necessary to measure the time period rather than the frequency. This is especially true in the measurement of frequency in the low frequency range. To obtain good accuracy at low frequency, we should take measurements of the period, rather than make direct frequency measurements. The circuit used for measuring frequency (Fig.)can be used for the measurement of time period if the counted signal and gating signal are interchanged.
- Figure shows the circuit for measurement of time period. The gating signal is derived from the unknown input signal, which now controls the enabling and disabling of the main gate. The number of pulses which occur during one period of the unknown signal are counted and displayedby the decade counting assemblies. The only disadvantage is that for measuring the frequency in the low frequency range, the operator has to calculate the frequency from the time by using the

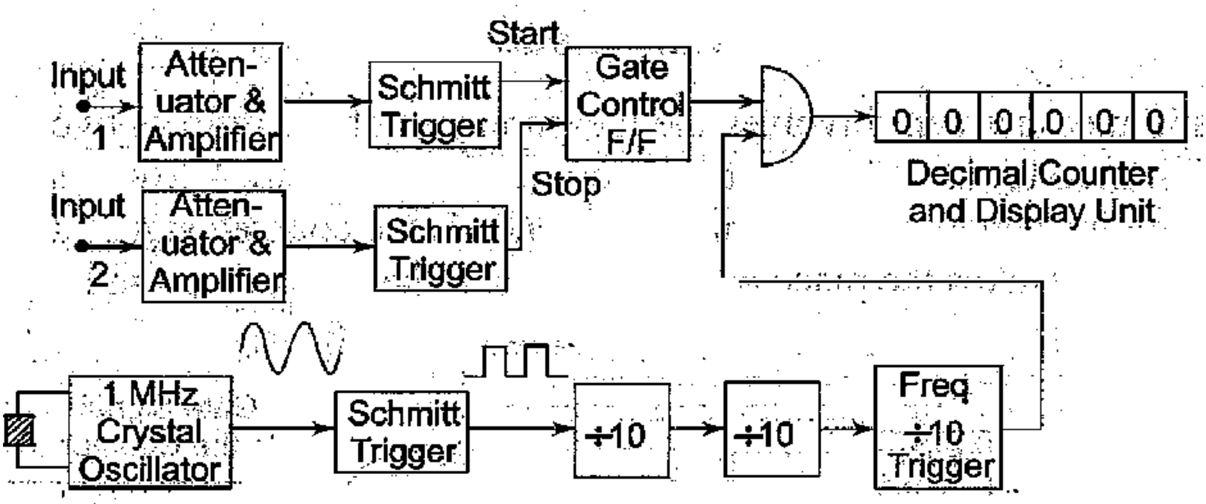


Fig. Basic Block Diagram of Time Measurement

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The accuracy of the period measurement and hence of frequency can be greatly increased by using the multiple period average mode of operation. In this mode, the main gate is enabled for more than one period of the unknown signal. This is obtained by passing the unknown signal through one or more decade divider assemblies (DDAs) so that the period is extended by a factor of 10,000 or more.

Hence the digital display shows more digital of information, thus increasing accuracy. However, the decimal point location and measurement units are usually changed each time an additional decade divider is added, so that the display is always in terms of the period of one cycle of the input signal, even though the measurements may have lasted for 10,100 or more cycles.

Figure 6.10 show the multiple average mode of operation. In this circuit, five more decade dividing assemblies are added so that the gate is now enabled for a much longer interval of time than it was with single DDA.

DIGITAL MEASUREMENT OF FREQUENCY (MAINS)

The conventional method of measuring the frequency of an electrical signal consists of counting the number of cycles of the input electrical signal during a specified gate interval. The length of the gate interval decides the resolution of the measurement. The shorter the gate interval, the lesser is the resolution. Now, for frequencies of the order of kHz and above, it is possible to get a resolution of 0.1% of better with a nominal gate time of 1 (sec). But for low frequencies, in order to obtain a resolution of even 0.5%, the gate time has to be considerably larger. For example, consider the case when the input electrical signal frequency is around 50 Hz. In order to obtain a resolution of 0.1 Hz, the gate interval has to be 10 seconds and in order to obtain a resolution of 0.01 Hz, the gate interval has to be 100 s. These gate periods of 10 s and 100 s are too long and in many cases it is desirable to obtain an indication of the frequency in far less time. Hence, direct or ordinary frequency counters are at a great disadvantage when it comes to low frequency measurements.

For the mains frequency monitor, the frequency range of interest is rather narrow, (50 ± 5%) Hz. The technique employed in the measurement of mains frequency, yields only a parabolic calibration curve. But within the narrow frequency range, which in this case is (50 ± 5%) Hz, the calibration is conveniently flat. Hence, the error due to the non-linear calibration is less than 0.2% at a frequency deviation as large as 5% from the centre frequency, which is 50 Hz. The error is 0.02% at a frequency deviation as large as 2% from the centre frequency and as the frequency approaches the centre value of 50 Hz, the error approaches zero.

DIGITAL TACHOMETER

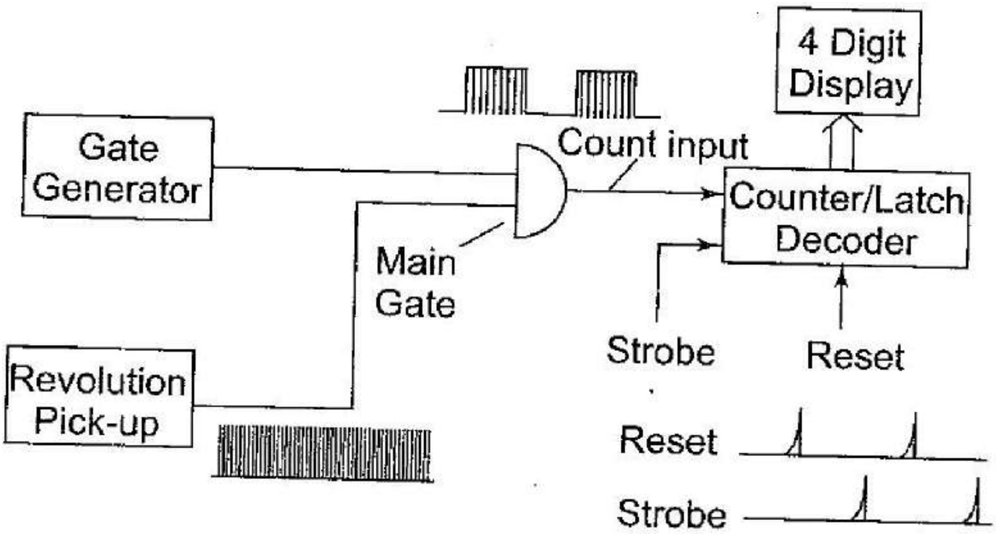
The technique employed in measuring the speed of a rotating shaft is similar to the technique used in a conventional frequency counter, except that the selectionof the gate period is in accordance with the rpm calibration.

Let us assume, that the rpm of a rotating shaft is R. Let P be the number of pulses produced by the pick up for one revolution of the shaft. Therefore, in oneminute the number of pulses from the pick up is R x P. Then, the-frequency of the signal from the pick up 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 periodas 60/ P, and the counter counts

$$(R \times P \times 60)/ 60P = R \text{ pulses}$$

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. Ifwe 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