Module-1
Units & Dimensions

Units

To specify and perform calculations with physical quantities , the physical quantities must be defined both in time and magnitude.

The std. measure of each type of physical quantitity to be measured is called unit. Mathematically the procedure of measurement can be expressed as

Magnitude of measurand = numerical ratio * unit

Where numerical ratio = number of times the unit occurs in any given amount of same quantity. Hence it is also called no. of measures . it is also called numerical multiplier.

Hence, process of measurement is to find numerical ratio. The numerical ratio has no physical meaning without the unit.

Ex: If we say the weight of 5kg means well defined weight is one kg and 5 such units are there in the measured weight. Thus, the numerical ratio is 5/1 while the unit is kg.

Fundamental Units

The units which are independently chosen and not dependent on any other units are called fundamental units. These are also called base units.

The length, mass and time are fundamental to most of the physical quantities. Hence the units which are the measures of length, mass and time are called primary fundamental units.

Ex : m, kg, s

The measures of certain physical quantitative related to numerical, therma, illumination etc. are called auxiliary fundamental units.

Ex: k, candela , ampere

Derived Units

All the units which are expressed in terms of the fundamental units using the physical equations are called derived Units.

Ex: Area of rectangle = l * b

Each of l & b is measured in m. Thus the product becomes m * m = m2. Hence the new unit which is derived as sq. m. for expressing the area is called derived units

Dimensions

Every physical quantity has its own identity. Such an identity is nothing but its quality with which it can be distinguished from all the other quantities . Such a unique quality possessed by a quantity is called its dimension. Symbolically, the dimension is expressed in the characteristic notation which is []

For Ex: the dimension of length is expressed as [L], the dimension of mass is [M]. The dimension of time is [T].

Similar to fundamental unit , each derived unit also has a unique dimension associated with it.

Ex: The volume , V = l * b* h where the dimension of each l, b and h is [L]. Hence the equation is dimensional form becomes,

V = [L][L][L]

V = [L3]

Any constants existing in the equations are always dimensionless. Thus, it can be said the complete algebraic formula to obtain the derived unit from the fundamental units is nothing but the dimension of the derived unit. Thus the equality in terms of dimensions and should not be mixed up with actual numerical values

Dimensional Equations

The equation obtained by replacing each quantity in the mathematical equation by respective dimensions is called dimensional equations.

Dimensional equations help

- In conversion from one system of units to another system of units
- In derivation of equations for physical quantities
- In checking the accuracy of an equation

Dimensions of Mechanical Quantitites

For deriving the dimensions , let us use the equality sign in the known relations in terms of dimensions

Force Force = m * a = [M] [LT-2] = [MLT-2]

a = velocity/time = [LT-1]/[T] = [LT-2]

v = distance/time = [l]/[T] = [LT-1]

Work work = force * distance

= [MLT-2][L]

= [ML2T-2]

Power = work / time = [ML2T-2]/ [T] = [ML2T-3]

Energy = Power * Time = [ML2T-3]/[T-1] = [ML2T-2]

Momentum = mass * velocity = [M][LT-1] = [MLT-1]

Torque = Force * distance = [MLT-2] [L] = [ML2T-2]

Stiffness = Torque/ angle = [ML2T-2]

Surface tension = force / length = [MLT-2]/[L] = [ML0T-2]

C.G.S. System of Units

The CGS system of units was used earlier during the 19th century in the development of the electrical theory In cgs system of units length , mass and time are the centimeter, gram, the second respectively. In this system of units, in addition to [LMT] an additional fourth quantity is used. Such a fourth fundamental unit is used on based on either electrostatic relations or electromagnetic relations.

Electromagnetic units:

In this system of units the fourth fundamental unit used is μ which is permeability of the medium . all dimensions are derived in terms of these 4 basic dimensions L,M,T, μ. The permeability of free space is assumed to be 1 in such systems. Such a system is called electromagnetic system of units.

Electrostatic units

In this system of units the fourth fundamental unit used is є . which is permittivity of the medium, in addition to 3 basic units L,M and T. All dimensions are derived in terms of these 4 basic dimensions L,M,T and є. The permittivity of free space i.e., vacuum is assumed to be 1 in such system. Such a system is called electrostatic system of units

Dimensions in electrostatic system of units

Charge Q = Q2/ єd2

Q = l·√F єd2

Q = d√Fє

[L][MLT-2]1/2[є1/2]

[L][M1/2L1/2T-1][є1/2]

[M1/2L3/2T-1є1/2]

Current I = Q/T = [M1/2L3/2T-1є1/2]/[T] = [T] = [M1/2L3/2T-2є1/2]

Potential difference E = workdone / charge = W/ Q = [M1/2 L1/2 T-1 є-1/2]

Capacitance C = q/v = [M1/2 L3/2 T-1 є1/2]/ [M1/2L1/2T-1є-1/2] = [єL]

Resistance R = V/I = [M1/2L1/2 T-1 є-1/2]/[M1/2L3/2T-2є1/2] = [L-1Tє-1]

Inductance L = E / di/dt = [M1/2L1/2T-1є-1/2]/[M1/2L3/2T-2є1/2]/[T] = [L-1T2є-1]

SI Units

For the sake of uniformity of units all over the world, an international organization the general conference of weights and measures recommended a unified systematically constituted system of units. This system of units is called SI system of units.

The SI system of units is divided into 3 categories namely

Fundamental units
Supplementary units
Derived units

Fundamental units

The units which are not dependent on any other unit is called fundamental unit. Seven such base units form SI units

Meter
Kilogram
Second
Ampere
Kelvin
Mole
Candela

Supplementary units

In addition to the fundamental units , there are two supplementary units added tp SI system of units they are

Radians for plane angles
Steradian for solid angles

Derived units

The units other than fundamental and supplementary are derived from the fundamental and supplementary units . hence these units are called derived units.. they are mainly classified as

Mechanical units such as mass, velocity etc.
Electric and magnetic units such as power , energy, weber, tesla etc
Thermal units such as talent heat , calorific value etc

Advantages of SI system of units

The advantages of SI system of units are

- The SI system of units use decimals and powers of 10 which simplifies the signification of any quantity.
- The value of any particular quantity in SI system of units can be further simplified by the use of prefixes
- The various SI prefixes such as milli, micro, nano etc simplify the expressions of the units of various quantities
- As the current I is used as fourth fundamental quantity, the derivation of dimensional equations for various quantities are simplified

Questions

1. Discuss briefly on these i) SI Units ii) Dimensional equations – Jan/ Feb 2004
2. Explain the terms ‘ dimensions of a physical quality’ and the significance of the dimensional equations July/Aug 2004
3. Explain the usefulness of dimensional equations July/Aug 2005
4. Derive the dimensions of resistance , inductance, capacitance and permeability in MTI system July/Aug 2006
5. Mention the advantages of SI system of units July/Aug 2007
6. Derive the dimensions of MMF, EMF, magnetizing force and flux density in LMTI system Jan/ Feb 2008
7. Mention the uses and limitations of dimensional analysis Jan/ Feb 2012
July/Aug 2011

B. Measurement of Resistance

1. With a neat sketch explain the working of a megger July/Aug 2004
2. Explain the fall of potential of measurement of earth resistance July/Aug 2005
3. Derive the expression for the measurement of unknown resistance using Kelvin’s double bridge. How the effect of connecting lead resistance is eliminated in this arrangement Jan /Feb 2005, July/Aug 2006
4. Write short notes on Megger July/Aug 2008
5. Explain how a megger is used for the measurement of earth resistance
July/Aug 2007
6. Define voltage sensitivity of a galvanometer and hence obtain an expression for whetstone’s bridge sensitivity. When will be Sb maximum? Jan / Feb 2008
7. State and explain sensitivity of whetstone’s bridge?
Jan/ Feb 2012, July/Aug 2008

Problems:

1. Deriving equation for resistance is Hay’s bridge, the following expression is obtained. $R = w^2R1R2e^2/ 1+w^2R_2^2C$ Find whether the equation is dimensionally correct or not. Incase there is an error find the error and correct equation accordingly Jan/ Feb 2012

In MKSA rationalized system, $[R] = [ML^2T^{-3}I^{-2}]$
$[C] = [M^{-1}L^{-2}T^4I^2]$
$[w] = 1/[T]$

R.H.S. = $w^2R_1R_2R_3e^2 / 1+w^2R_2^2C$
= $[T-1]\ [ML^2T^{-3}I^{-2}]3\ [M^{-1}L^{-2}T^4I^2]2\ /\ 1+ [T-1]2\ [ML^2T^{-3}I^{-2}]2\ [M^{-1}L^{-2}T^4I^2]$

$= [T^{-1}] [M^3L^6T^{-9}I^{-6}] [M^{-2}L^{-4}T^8I^4] \;/\; 1+ [T^{-2}] [M^2L^4T^{-6}I^{-4}]2 [M^{-1}L^{-2}T^4I^2]$

$= [M^1L^2T^{-3}I^{-2}] \;/\; [M^1L^2T^{-4}I^{-2}]$

L.H.S. $= [M^1L^2T^{-3}I^{-2}]$

$[M^1L^2T^{-3}I^{-2}] = [M^1L^2T^{-3}I^{-2}] \;/\; [M^1L^2T^{-4}I^{-2}]$

Multiply $[M^{-1}L^{-2}T^4I^2]$ to Dr

$[M^1L^2T^{-3}I^{-2}] = [M^1L^2T^{-3}I^{-2}]$

$[M^{-1}L^{-2}T^4I^2] = C$

Therefore multiply the equation by C

$R = w^2R1R2e^2/ 1+w^2R_2{}^2C^2$

Thus , dimensionally equation is not correct. It can be seen that numerator dimension of R.H.S> are same as the dimensions of L.H.S.. Hence, to satisfy the equation dimensionally , denominator of R.H.S. must be dimensionless. So, to balance the denominator of R.H.S., it must be multiplied by $[M^{-1}L^{-2}T^4I^2]$. Theses are the dimensions of capacitor C. this indicates the term $w^2R_2{}^2C$ must be multiplied by one more C to satisfy the equation dimensionally correct.

The expression for mean torque of an electrodynamometer type wattmeter may be written as $T \alpha M^p E^q Z^t$. Where M = mutual inductance between fixed and moving coils. E = applied voltage , Z = impedence of load circuit . determine the values of p,q,t performing dimensional analysis July/Aug 2007

$[T] = [ML^2T^{-2}]$

$[M] = [M^1L^2T^{-2}I^{-2}]$

$[E] = [M^1L^2T^{-3}I^{-1}]$

$[Z] = [M^1L^2T^{-3}I^{-2}]$

$T = k M^p E^q Z^t$.

$[ML^2T^{-2}] = k [M^1L^2T^{-2}I^{-2}]^p [M^1L^2T^{-3}I^{-1}]^q [M^1L^2T^{-3}I^{-2}]^t$

$= [M^{p+q+t} L^{2p+2q+2t} T^{-2p-3q-3t} I^{-2p-q-2t}]$

By comparing and solving p= 1, q = 2, t = -2

2. Derive the dimensional equation for resistance R, inductance and capacitance C. hence check for dimensionally correctness of the expression below obtained for inductance from ac bridge measurements , point out the error, if any in the expression and suggest the required correction that makes the expression dimensionally valid

$$L = C (R_3/R4) (R_2+R_4 +R_2R_4)$$

$$L = [M^1L^2T^{-2}I^{-2}]$$
$$[R] = [M^1L^2T^{-3}I^{-2}]$$
$$[C] = [M^{-1}L^{-2}T^4I^2]$$

R.H.S. $= [M^{-1}L^{-2}T^4I^2] [M^1L^2T^{-3}I^{-2}] / [M^1L^2T^{-3}I^{-2}] ([M^1L^2T^{-3}I^{-2}] + [M^1L^2T^{-3}I^{-2}] + [M^1L^2T^{-3}I^{-2}]$
$[M^1L^2T^{-3}I^{-2}])$

$$[M^1L^{-2}T^4I^2] ([M^1L^2T^{-3}I^{-2}] + [M^1L^2T^{-3}I^{-2}])$$

$$= [T] [T] + [M^1L^2T^{-2}I^{-2}]$$

But dimensionally addition is valid only if all the terms to be added are dimensionally same. Thus the given eq is dimensionally incorrect.

To have it correct, multiply R_2 and R_4 by another resistance. Thus the correct equation becomes

$$L = C (R_3/R4) (R_2\, r +R_4\, r +R_2R_4)$$

4. Expression for eddy current loss p/meter length of wire may be written as $p \,\alpha\, f^a Bm^b d^c \rho^g$

Where f = frequency, Bm = Max. flux density, d= diameter of wire, ρ – resistivity of material. Find the values a, b,c,and g using L,M,T,I system

$$P = k f^a Bm^b d^c \rho^g$$
$$[P] = [I^1L^{-1}]$$
$$[f] = [T^{-1}]$$
$$[Bm] = [M^1T^{-2}I^{-1}]$$
$$[d] = [L]$$
$$[\rho] = [M^1 L^3 T^{-3}I^{-2}]$$

$$[I^1L^{-1}] = k [T^{-1}]^a [M^1T^{-2}I^{-1}]^b [L]^c [M^1 L^3 T^{-3}I^{-2}]^g$$

$$[I^1L^{-1}] = k [T^{-a}] [M^bT^{-2b}I^{-b}] [L^c] [M^g L^{3g} T^{-3g}I^{-2g}]$$

By comparing and solving a = 2, b = 2, g=1 , c=4

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Measurement of resistance, inductance and capacitance

Introduction:

A bridge circuit in its simplest form consists of a network of four *resistance arms* forming a closed circuit. A source of current is applied to two opposi te junctions. The current detector is connected to other two junctions.

The bridge circuits use the comparison measurement methods and operate on null-indication principle. The bridge circuit compares the value of an unknown component with that of an accurately known standard component. Thus *the* accuracy depends on the bridge components and not on the null indicator. Hence high degree of accuracy can be obtained.

Advantages of Bridge Circuit:

The various advantages of the bridge circuit are,

1) The balance equation is independent of the magnitude of the input voltage or its source impedance. These quantities do not appear in the balance equation expression.

2) The measurement accuracy is high as the measurement is done by comparing the unknown value with the standard value.

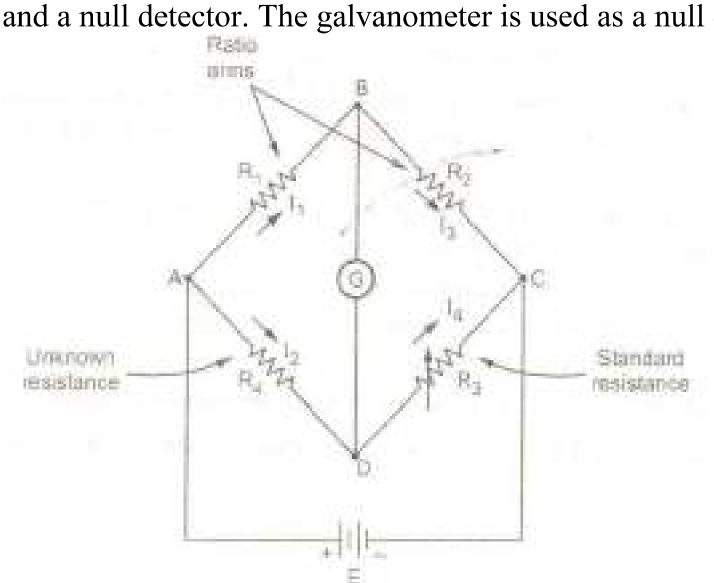
3) The accuracy is independent of the characteristics of a null detector and is dependent on the component values.

4) The balance equation is independent of the sensitivity of the null detector, the impedance of the detector or any impedance shunting the detector.

5) The balance condition remains unchanged if the source and detector are interchanged.

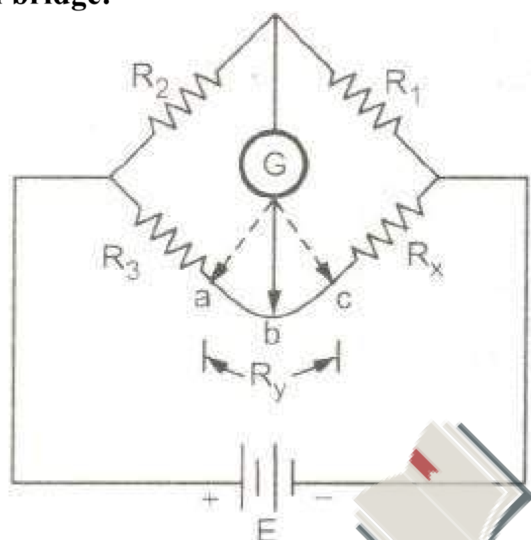
Wheatstone's bridge:

The bridge consists of four resistive arms together with a source of e.m.f. and a null detector. The galvanometer is used as a null detector.



The arms consisting the resistances R] and R2 are called ratio arms. The arm consisting the standard known resistance R3 is called standard arm. The resistance R4 is the unknown resistance to be measured. The battery is connected between A and C while galvanometer is connected between Band D.

Kelvin bridge:



In the Wheatstone bridge, the bridge contact and lead resistance causes significant error, while measuring low resistances. Thus for measuring the values of resistance below 1 -n, the modified form of Wh~tstone bridge is used, known as Kelvin bridge. The consideration of the effect of contact and lead resistances is the basic aim of the Kelvin bridge.

The resistance Rv represents the resistance of the connecting leads from R., to R,. The resistance Rx is the unknown resistance to be measured.

\ The galvanometer can be connected to either terminal a, b or terminal c. When it is connected to a, the lead resistance Ry gets added to Rx hence the value measured by the bridge, indicates much higher value of Rx.

If the galvanometer is connected to terminal c, then Ry gets added to R3. This results in the measurement of Rx much lower than the actual value.

The point b is in between the points a and c, in such a way that the ratio of the resistance from c to b and that from a to b is equal to the ratio of R] and R2.

$$\frac{R_{cb}}{R_{ab}} = \frac{R_1}{R_2}$$

A.C. Bridges:

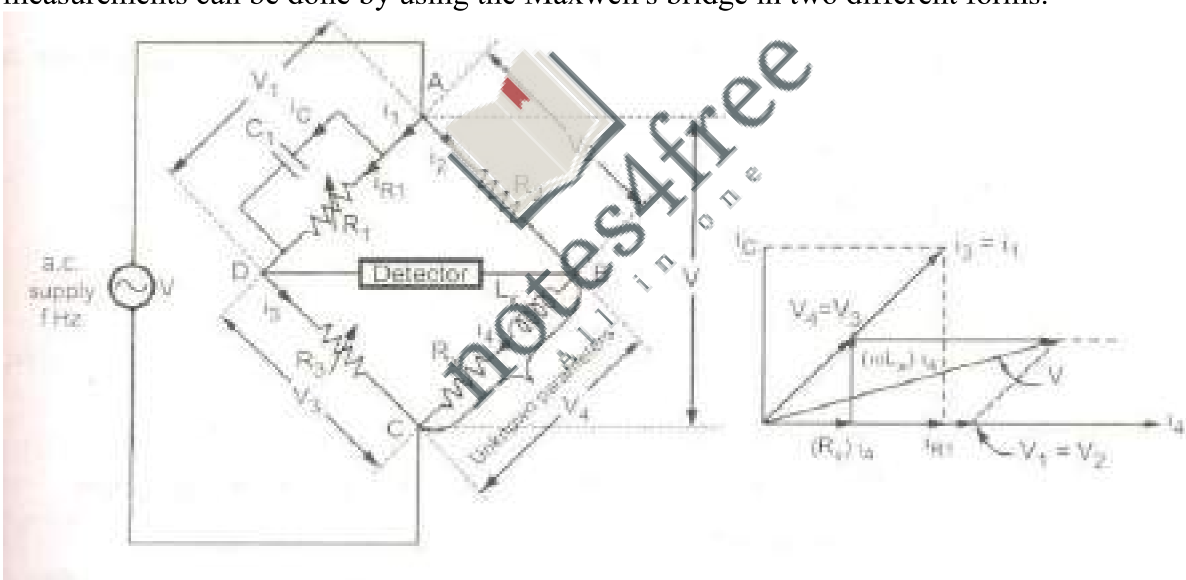
An a.c. bridge in its basic form consists of four arms, a source of excitation and a balance detector. Each arm consists of an impedance. The source is an a.c. supply which supplies a.c. voltage at the required frequency. For high frequencies, the electronic oscillators are used as the source. The balance detectors commonly used for a.c. bridge are head phones, tunable amplifier circuits or vibration galvanometers. The headphones are used as detectors at the frequencies of 250 Hz to 3 to 4 kHz. While working with single frequency a tuned detector is the most sensitive detector. The vibration galvanometers are useful for low audio frequency range from 5 Hz to 1000 Hz but are commonly used below 200 Hz. Tunable amplifier detectors are used for frequency range of 10 Hz to 100 Hz.

Hay's Bridge:

In the capacitance comparison bridge the ratio arms are resistive in nature. The impedance Z 3 consists of the· known standard capacitor C3 in series with the resistance R3. The resistance R3 is variable, used to balance the bridge. The impedance Z4 consists of the unknown capacitor Cx and its small leakage resistance Rx.

Maxwell's Bridge :

Maxwell's bridge can be used to measure inductance by comparison either with a variable standard self inductance or with a standard variable capacitance. These two measurements can be done by using the Maxwell's bridge in two different forms.



(a) Circuit diagram (b) Phasor diagram

Maxwell's inductance capacitance bridge

Methods of Measurement of Earth Resistance

Fall of Potential Method

Fig below shows the circuit diagram used for the measurement of earth resistance by fall of potential method. E is the earth electrode. The electrode Q is the auxillary electrode. The current I is passed through the electrodes E & Q with the help of external battery E. another auxillary electrode P is introduced in between the electrodes E & Q. the voltage between the electrodes E & P is measured with the help of voltmeter.
Thus if the distance of electrode P is changed from electrode E electrode Q, the electrode P experiences changing potential near the electrodes while a constant potential between the electrodes E & Q but away from the electrodes from Q.

The potential rises near the electrodes E & Q due to higher current density in the proximity of the electrodes. By measuring the potential between the electrodes E & P as Vep, the earth resistance can be obtained as

$$R_E = V_{EP} / I$$

Shielding and grounding of bridges

This is one way of reducing the effect of stary capacitances. But this technioque does not eliminate the stray capacitances but makes them constsnt invalue and hence they can be compensated.

One very effective and popular methode of eliminating the stray capacitances and the capacitances between the bridges arms is using a ground connection called Wagner Ground connection.

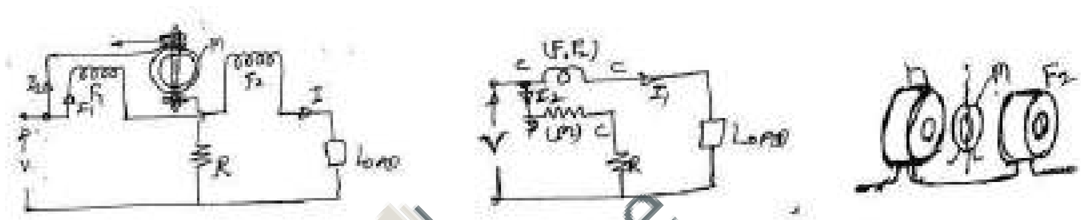
Questions from Question Paper:

1. Explain maxwell's bridge?June/July2009
2. Explain kelvin's bridge? Dec/Jan2008, Jan/ Feb 2012
3. Explain the importance of Wheatstone bridge? May/June2010
4. Explain the Capacitance Comparison Bridge? Dec/Jan2010
5. Explain the Maxwell's bridge?June/July 2009
6. Explain the Wagner's earth connection? Dec/Jan08, Jan/ Feb 2012
7. Derive the balance equations of the Schering bridge circuit configuration used for measurement of capacitances and hence derive at the expression for loss angle of the test capacitor. Draw the phasor diagram at balance.
   Jan/Feb-2004, July/Aug 2004, Jan/ Feb- 2008
8. Write a short note on the Wagner earthing device
   July/Aug-2004/2010,Jan/Feb-2011
9. Derive the expression for the measurement of capacitance and loss angle of a lossy capacitor using Schering bridge. Draw the phasor diagram at balance condition. What modifications are introduced when the bridge is used at high voltages Jan/Feb-2005, July/Aug 2004
10. Write briefly on the significance of shields used in ac bridge circuit. Hence discuss on the shielding of resistors and capacitors of the circuit
    July/Aug 2005, Jan/ Feb 2005
11. Draw a neat sketch to explain the theory and measurement of unknown inductance and resistance by Anderson bridge. What is type of null detector used in this bridge? What are the sources of errors? Draw phasor diagram at balance
    July/Aug 2006, Jan/ Feb 2006, Jan/ Feb 2012
12. Write short notes on source and detectors July/Aug 2008, Jan/ Feb 2007

Module-2
Measurement of power, Energy,power factor and frequency

DYNAMOMETER TYPE WATTMETER

In this type there will not be any permanent magnets and there will be a pair of fixed coils connected in series when energized gives the same effect as that of the permanent magnets. In the field of these fixed coils there will be a moving coil which when energized acted upon by a torque by which it deflects



F_1 F_2: Fixed coils

M: Moving coil

R: High resistance in series with m

I_1 : load current

I_2: current through

The two fixed coils in series act as the current coil and the moving coil in series with R act as the potential coil. The moving coil is pivoted between the two fixed coils carries a current I_2 proportional to V. This current is fed to m through two springs which also provides the necessary controlling torque. This instrument can be used on both ac and dc circuits as both the coils are energized simultaneously by a common source due to which a unidirectional torque is produced.

Energy meter

It works on the principle of induction i.e. on the production of eddy currents in the moving system by the alternating fluxes. These eddy currents induced in the moving system interact with each other to produce a driving torque due to which disc rotates to record the energy.

In the energy meter there is no controlling torque and thus due to driving torque only, a continuous rotation of the disc is produced. To have constant speed of rotation braking magnet is provided.

Construction:

There are four main parts of operating mechanism

1) Driving system 2) moving room 3) braking system 4) registering system.

1) **Driving system:** It consists of two electromagnets whose core is made up of silicon steel laminations. The coil of one of the electromagnets, called current coil, is excited by load current which produces flux further. The coil of another electromagnetic is connected across the supply and it carries current proportional to supply voltage. This is called pressure coil. These two electromagnets are called as series and shunt magnets respectively.

   The flux produced by shunt magnet is brought in exact quadrature with supply voltage with the help of copper shading bands whose position is adjustable.

2) **Moving system:** Light aluminium disc mounted in a light alloy shaft is the main part of moving system. This disc is positioned in between series and shunt magnets. It is supported between jewel bearings. The moving system runs on hardened steel pivot. A pinion engages the shaft with the counting mechanism. There area no springs and no controlling torque.

3) **Braking system:** a permanent magnet is placed near the aluminium disc for barking mechanism. This magnet reproduced its own field. The disc moves in the field of this magnet and a braking torque is obtained. The position of this magnet is adjustable and hence braking torque is adjusted by shifting this magnet to different radial positions. This magnet is called braking magnet.

4) **Registering mechanism:** It records continuously a number which is proportional to the revolutions made by the aluminium disc. By a suitable system, a train of reduction gears, the pinion on the shaft drives a series of pointers. These pointers rotate on round dials which an equally marked with equal division.

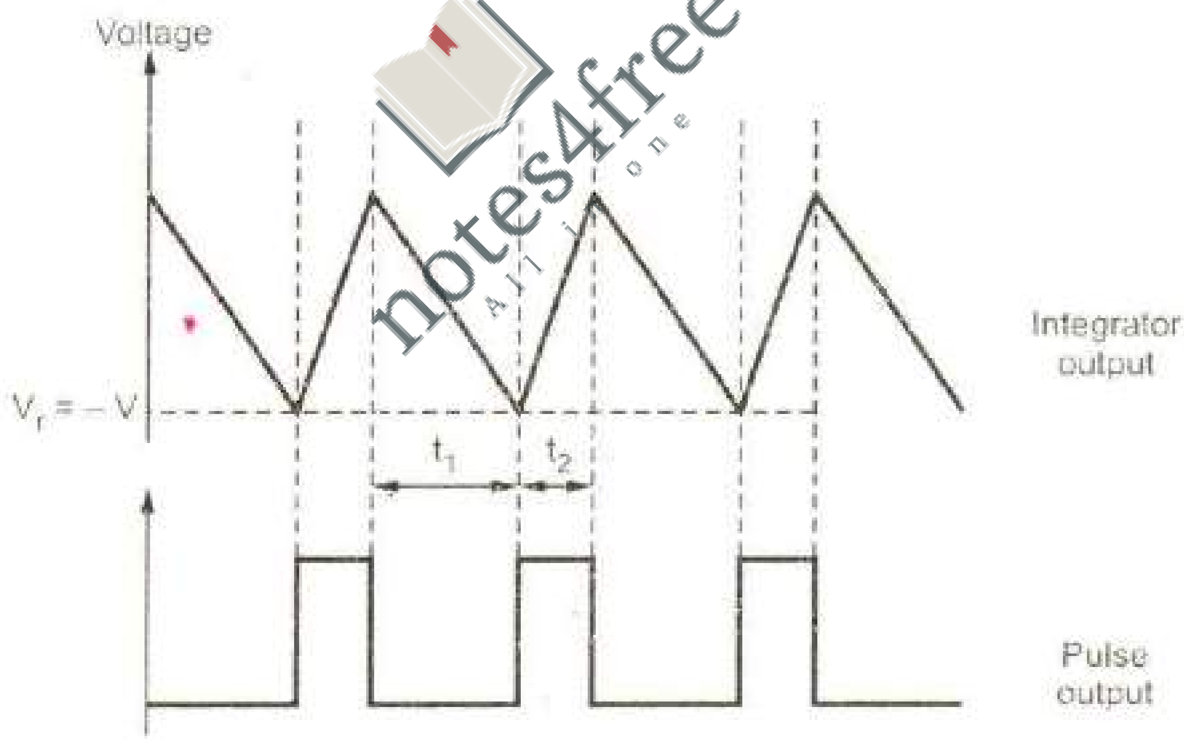
Working: since the pressure coil is carried by shunt magnet M_2 which is connected across the supply, it carries current proportional to the voltage. Series magnet M_1 carries current coil which carries the load current. Both these coils produced alternating fluxes Φ_1 and Φ_2 respectively. These fluxes are proportional to currents in their coils. Parts of each of these fluxes link the disc and induces e.m.f. in it. Due to these e.m.f.s eddy currents are induced in the disc. The eddy current induced by the electromagnet M_2 react with magnetic field produced by M_1 react with magnetic field produced by M_2. Thus each portion of the disc experiences a mechanical force and due to motor action, disc rotates. The speed of disc is controlled by the C shaped magnet called braking magnet. When disc rotates in the air gap, eddy currents are induced in disc which oppose the cause producing them i.e. relative motion of disc with respect to magnet. Hence braking torque T_b is generated. This is proportional to speed N of disc. By adjusting position of this magnet, desired speed of disc is obtained. Spindle is connected for recording mechanism through gears which record the energy supplied.

Electronic Energy Meter

The function of the Electronic Energy Meter is to produce a pulse of precision charge content. The polarity of this charge is opposite to that of capacitor charge. Thus the pulse generated by the Electronic Energy Meter rapidly discharges the capacitor. Hence the output of the op-amp again becomes zero. This process continues so as to get a sawtooth waveform at the output of op-amp. The frequency of such waveform is directly proportional to the applied input voltage. Thus if the input voltage increases, the number of teeth per unit time in the sawtooth waveform also increases i.e. the frequency increases.

Each teeth produces a pulse at the output of the pulse generator so number of pulses is directly related to the number of teeth i.e. the frequency. These pulses are allowed to pass through the pulse transformer. These are applied at one input of the gate. Gate length control signal is applied at the other input. The gate length' may be 0.1 sec, Isec, 20 msec etc. The gate remains open for this much time period.

The wavefoms of integrator output and output of a pulse generator are shown In the Fig



From the analysis of dual slope technique, we can write,

$$V_{in} = V_r \frac{t_2}{t_1}$$

But in this type, both V1 and t2 are constants.

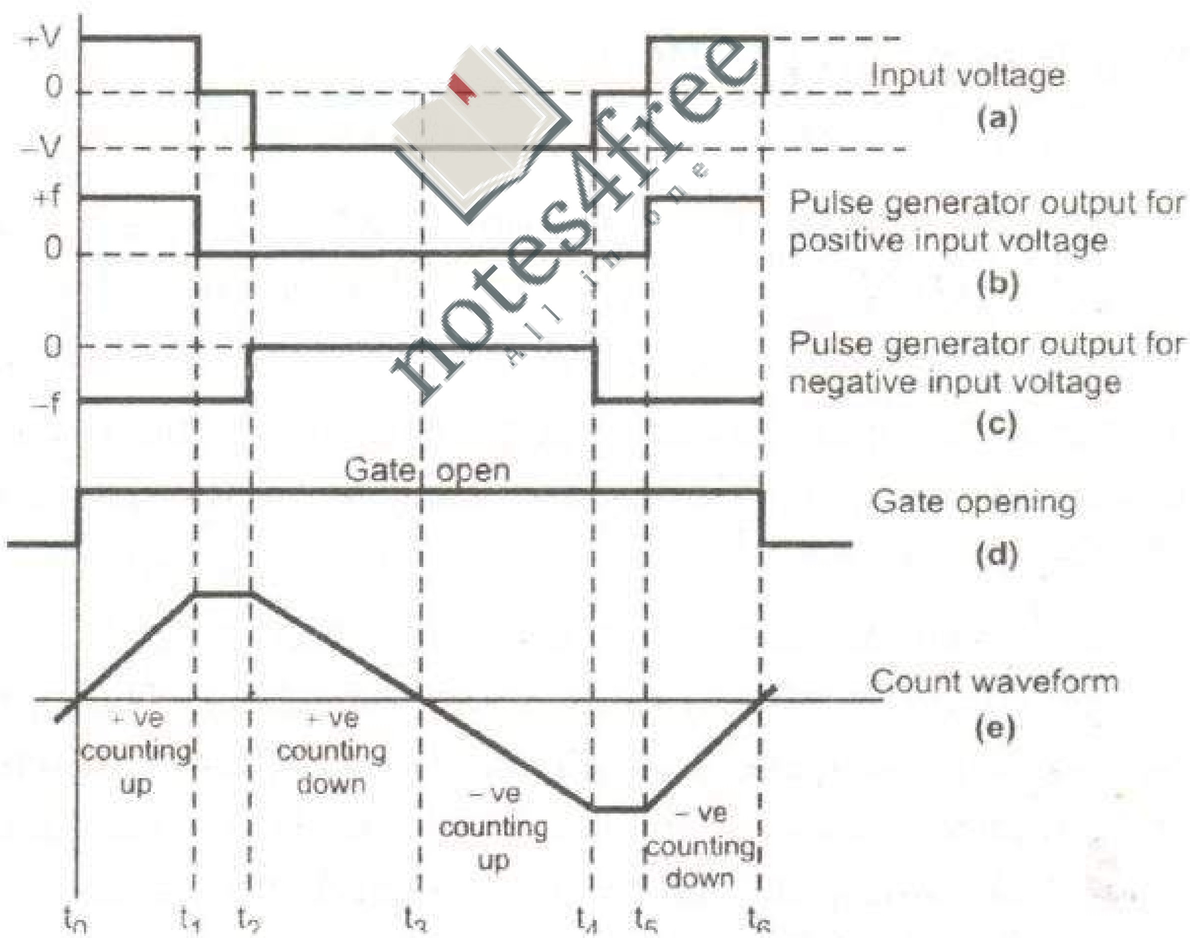
$$K_2 = V_r t_2$$

$$V_{in} = K_2\left(\frac{1}{t_1}\right) = K_2(f_o)$$

Accuracy: The accuracy of voltage to frequency conversion technique depends on the magnitude and stability of the charge produced by the pulse generator. Thus the, accuracy depends on the precision of the charge fedback in every pulse and also on the linearity, between voltage and frequency.

To obtain the better accuracy the rate of pulses generated by the pulse generator is kept equal to,

i) the voltage time integration of the input signal ii) the total voltage time areas of the feedback pulses.



When input voltage polarity is positive i.e. for the periods t (t0 to t1 and t5 to t6 the output of the pulse generator is high. For other time period it is low. This is shown in the Fig . When the input voltage polarity is negative i.e. for the period t 1 to t 4 the output of the pulse generator is high. This is due to other pulse generator used for the bipolar

voltages. This is shown in the Fig. For the period t0 to t1, it is positive counting up. For the period t2 to t3 it is positive counting down. For t 3 to t 4 negative counting up while for the period t 5 to t6, it is negative counting down. To increase the operating speed of this type of Electronic Energy Meter
the upper frequency can be increased i.e. increasing V*I* f conversion rate. But this results into reduced accuracy and design cost of such circuit is also very high. Hence another method in which 5 digit resolution is available, is used to increase the speed of operation. This is the modified version of V*I* f integrating type Electronic Energy Meter and is called interpolating integrating Electronic Energy Meter

Questions

1. With a neat diagram explain the construction and working principle of a single phase induction type energy meter
   July/Aug 2004, Jan/ Feb 2004, July/Aug 2009, Jan/ Feb 2006, Jan/ Feb 2009
2. Explain the advantages of electronic energy meters over the conventional disc type induction energy meters Jan/ Feb 2004
3. With a neat diagram explain the construction and operation of an electrodynamometer type wattmeter. Derive expression for the same
   Jan/ Feb 2004, Jan/ Feb 2009, Jan/ Feb 2011, Jan/ Feb 2009
4. What is creep in energy meter? How is it prevented? July/Aug -2004
5. With a neat circuit arrangements, explain how the calibration of single phase induction type energy meter is carried out in laboratories. Explain the need for adjustments to be followed earlier to calibration analysis
   July/Aug -2005, Jan/ Feb -2011
6. Write a short note on low power factor wattmeter July/Aug -2005
7. What are sources of errors in energy meter and how are they eliminated?
   May/June-2010, Jan/ Feb -2006
8. Explain the principle of operation of low power factor meter
   July/Aug -2009, Jan/ Feb -2006, Jan/ Feb -2004
9. Discuss with a block diagram the principle of operation of electronic energy meter
   May/June-2010, July/Aug -2006, July/Aug -2008
10. Explain the working of single phase induction type energy meter and discuss its errors. How can the errors be initialized
    July/Aug -2007, July/Aug -2008, Jan/ Feb -2007, Jan/ Feb 2012
11. Discuss the adjustment required in energy meter for accurate reading
    Jan/ Feb -2008
12. Write a note on measurement of reactive power in 3 phase system
    July/Aug -2009, Jan/ Feb 2012

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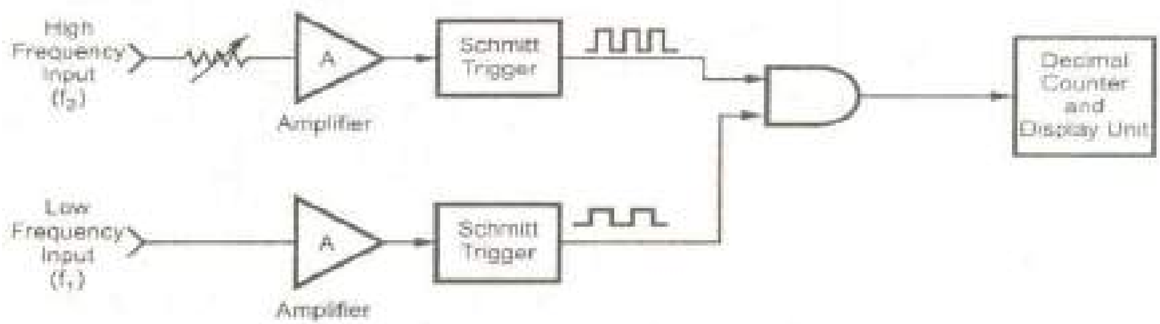
Weston Frequency Meter



This is a moving iron type instrument and is used to measure frequency.

Construction

It consists os a fixed coil each split into 2 equal parts A & B and there 2 coils are mounted perpendicular to each other .

Force acting on the soft iron needle depends upon variation in current distribution between 2 coils. Values of resistances and inuctances are so selected that at nrmal frequdency of supply .

If the frequency increases above the normal value then reactances increases while R and remains same . hence current through coil A is reduced. Therefore current through coil B increases. And this makes magnetic field produced by coil B.

When frequency decrease than normal value the opposite action takes place and pointer deflects to left indicating lower frequency.

Phase sequence Indicator

This type of indicator works on the principle of induction . it consists of 3 stationary coils which are connected in the form of star connection . the 2 ends of these coils are brought out for connection purpose. And 3 phase supply whose sequence is to be determined is given to these ends star connected. When star connected coils are excited by a 3 phase supply, then each coil produces an alternating flux. Due to the interaction of these 3 fluxes a rotating magnetic field is produced. These rotating flux passed over the disc and there is rotating. Hence emf's gets induced in this disc which circulates eddy current through disc. These eddy currents produce a flux which interacts with the rotating flux to produce a torque and the disc starts rotating. The direction of the disc indicates the phase sequence of the supply.

If the disc rotates in the same direction as indicated by arrow on the disc, then phase sequence of the supply is same as the that marked on disc i.e. RYB. If the disc rotates in the reverse direction , phase sequence of supply is RBY

Electro dynamo meter type Power factor Meter

The basic construction of Electro dynamo meter type Power factor Meter is shown in the fig.

The F1-F2 are the two fixed coild which are rigidly connected in series. The A-B are the two moving coils which are connected to each other so that axes are at 90 to each other. The moving coils A-B move together and carry the pointer which indicates the power factor of the circuit.

The moving coils are connected in parallel across the supply voltage and hence called pressure coils. The currents through coils A & B are proportional to the supply voltage. The coils A has non inductive resistance R in series with it while the coil B has an inductance L in series with it. The values of R & L are so adjusted that the coils A & B carry equfal currents at normal frequency.

The currents in the coils A & B are equal and produce the magnetic fields of equal strength, which have phase difference of 90 between them. The coils are also mutually perpendicular to each other.

Module-3
Extension of Instrument ranges

Introduction

Moving coil instruments, which are used as ammeters and voltmeters are designed to carry max.current of 50mA and withstand a voltage of 50mV. Hence, to measure larger currents and voltages , the ranges of these meters have to be extended. The following methods are employed to increase the ranges of ammeters and voltmeters

- By using shunts the range of dc ammeters is extended
- By using multipliers, the range of dc voltmeter is extended
- By using current transformers the range of ac ammeter is extended
- By using potential transformer the range of ac voltmeter

3.1 Shunt

When heavy currents are to be measured , the major part of current if bypassed through a low resistance called shunt. It is shown in the below fig

The shunt resistance can be calculated as ,

Let Rm = internal resistance of coil
Rsh = shunt resistance
Im = full scale deflection current
Ish = shunt current
I = Total current

Now, I = Ish + Im
Ish Rsh = ImRm
Rsh = ImRm/Ish

Rsh = Rm / (I/Im - 1)

Rsh = Rm / m-1 where m = I/Im

And m is called multiplying power of shunt and is defined as the ratio of total current to the current through the coil

3.2 Multirange ammeters

The range of basic dc ammeter can be extended by using no. of shunts and a selector switch, such a meter is called multirange ammeter and is shown in the fig

3.3 Range extension of voltmeter

Multiplier

The resistance is required to be connected in series with basic meter to use it as a voltmeter. This series resistance is called a multiplier

The main function of the multiplier is to limit the current through the basic meter, so that meter current does not exceed full scale deflection value.

The multiplier resistance can be calculated as

Let Rm is the internal resistance of the coil.

Rs = series multiplier resistance

Im = full scale deflection current

V = full range voltage to be measured

$V = ImRm + ImRs$

$ImRs = V – ImRm / Im$

$Rs = V/Im - Rm$

The multiplying factor for multiplier is the ratio of full range voltage to be measured and the drop across the basic meter

$M = V/v$

3.4 Instrument Transformers

They are divided into two types

- Current transformers
- Potential transformers

3.4.1 Current transformer

CT is the one which is to be measure a large current in ckt using low range ammeter.

The primary winding of CT which has few no of turns is connected in series with load. The secondary of transformer is made up of large number of turns. This is connected to the coil of normal range ammeter, which is usually rated for 5A. the representation of CT is as shown fig.

3.4.2 Potential Transformer

P.T. is the one which is used to measure a large voltage using a low range voltmeter. The representation of P.T. is as shown in the fig.

The primary winding consists of large number of turns while secondary has less number of turns. The primary is connected across high voltage line while secondary is connected to low range voltmeter coil.

The high voltage Vp being measured is given by, $Vp = nVs$

Where, $n = Np/Ns$ = turns ratio\

3.4.3 Why secondary of C.T. should not be open?

It is very important that secondary of C.T. should not be kept open. If it is left open, then current through secondary becomes zero. Hence, the ampere turns produced by secondary which generally oppose primary ampere turns becomes zero. As there is no counter m.m.f., unopposed primary mmf produces high flux in the core. This produce excessive core loss , heating the core beyond limits. Similarly heavy emf's will be induced on the primary and secondary side. This may damage the insulation of winding and this is danger from operator point of view as well

Hence, never open secondary winding ckt of a CT, while its primary winding is energized.

3.5. Ratios of instrument transformers

The various ratios defined for instrument transformers are

Actual ratio® :

The actual transformation ratio is defined as the ratio of the magnitude of actual primary phasor to the corresponding magnitude of actual secondary phasor

C.T. R = magnitude of actual primary current / magnitude of actual sec. current

P.T. R = magnitude of actual primary voltage / magnitude of actual sec.voltage

Nominal ratio (Kn)

The nominal ratio is defined as the ratio of rated pri quantity to rated sec.quantity, either current or voltage

C.T. Kn = rated pri.current / rated sec. current

P.T., Kn = rated pri.voltage/ rated sec. voltage

Turns ratio(n)

C.T. , n = no.of turns of sec. winding / no. of turns of primary winding

P.T., n = no. of turns of primary winding / no. of turns of sec. winding

3.5.1 Burden of an instrument transformer

The permissible load across sec. winding expressed in volt amperes and the rated sec. winding , voltage or current such that errors do not exceed the limits is called burden of an instrument transformer.

Total sec. winding burden = (sec. winding induced voltage)^2 / total impedance of sec. ckt including load and winding

Derivation of actual ratio R

Consider triangle BAC as shown in small section where

$$BC / AC = \sin(90-\delta-\alpha)$$
$$BC = AC \sin(90-\delta-\alpha)$$
$$BC = AC \cos(\delta+\alpha)$$

$$AB / AC = \cos(90-\delta-\alpha)$$
$$AB = AC \cos(90-\delta-\alpha)$$
$$AB = AC \cos(90-(\delta+\alpha))$$
$$AB = AC \sin(\delta+\alpha)$$

Also,

$$OC^2 = OB^2 + BC^2$$
$$IP^2 = (OA + AB)^2 + BC^2$$

$$Ip^2 = [nIs + I_0 \sin(\delta+\alpha)]^2 + I_0 \cos(\delta+\alpha)]^2$$
$$= nIs^2 + 2nIs\, I_0 \sin(\delta+\alpha) + I_0^2 \sin^2(\delta+\alpha) + I_0^2 \cos^2(\delta+\alpha)]$$

$$Ip^2 = nIs^2 + 2nIs\, I_0 \sin(\delta+\alpha) + I_0^2$$
$$Ip = \sqrt{nIs^2 + 2nIs\, I_0 \sin(\delta+\alpha) + I_0^2}$$

$$R = Ip / Is = \sqrt{nIs^2 + 2nIsI_0 \sin(\delta+\alpha) + I_0^2 \sin^2(\delta+\alpha)}$$

$$\sqrt{[nIs + I_0 \sin(\delta+\alpha)]^2} / Is$$

$$nIs + I_0 \sin(\delta+\alpha) / Is$$

$$n + I_0 / Is \sin(\delta+\alpha)$$
$$n + I_0 / Is\ (\sin\delta .\cos\alpha + \cos\delta \sin\alpha)$$

$$\underline{R = n + I_m \sin\delta\ \ Ic.\cos\delta / Is}$$

<u>Errors in C.T.</u>

There are 2 types os errors in instrument transformer . They are

- Ratio error
- Phase angle error

Ratio error

The ratio error is defined as %ratio error = nominal ratio – actual ratio / actual ratio *100

Ratio error = Kn – R /R *100

Phase angle error

The phase angle error is given by $\theta = 180 / \pi\ [\ \underline{I_m \cos\delta\ \ - Ic.\sin\delta}\ \ / nIs\ ]$

Question paper Problems

1. Design a multirange dc milliammeter with a basic meter having a resistance 75Ω and full scale deflection for the current of 2 mA. The required ranges are 0-10mA, 0-50mA, 0-100mA\

Rm = 75 Ω, Im = 2mA

Rsh = = Rm / I/Im – 1
75 / 10/2 – 1 = 75/5-1 = 18.75 Ω

Rm = 75 / 50/2 – 1 = 75/25-1 = 3.125 Ω
75 / 100/2 – 1 = 75/49 = 1.53 Ω

2. A moving coil meter takes 50mA to produce fullscale deflection , the p.d.across its terminals be 75mV. Suggest a suitable scheme for using the instrument as a voltmeter reading 0-100V and as an ammeter reading 0-50A **Jan/ Feb 2012**

As an ammeter
V = IR
Rm = V/Im = 5 Ω

Rsh = Rm / I/Im – 1 = 1.501m Ω

As an voltmeter
Rs = V/Im - Rm = 6.661 kΩ

3. A c.t. has a single turn primary and 400 secondary turns. The magnetizing current is 90A while coreloss current is 40A. secondary ckt phase angle is 28. calculate the actual primary current and ratio error when secondary current carries 5A current

Ip = nIs
Ip = (Ns / Np) . Is

% ratio = Kn – R / R * 100

n = Ns / Np = 400

$R = n + I_m \sin\delta \ Ic.\cos\delta / Is$

$= 400 + \underline{90\sin 28 + 40\cos 28} / 5$

$= 415.513$

%ratio error = 400 – 415.513/415.513 *100 = -3.733%

I p = nIs
Ip = Ns/Np(5) = 400(5) = 2000A

R = Ip /Is
Ip = RIs = 415.513(5) = 2077.57A

4. At its rated load of 25VA, a 10/5 current transformer has an ironloss of 0.2W and magnetizing current of 1.5A. calculate its ratio error and phase angle when supplying rated o/p to a meter having a ratio of resistance to reactance of 5

% ratio = Kn – R / R * 100

$R = n + I_m \sin\delta \ Ic.\cos\delta / Is$

To find Ic

EpIp = 25VA
Ep = 25/100 = 0.25V
Ic = P /Ep = 0.2/0.25 = 0.8A

To find δ

δ = tan-1 Xs / Rs = 11.309

$R = n + I_m \sin\delta \ Ic.\cos\delta / Is$
20+ 1.5(0.1961) + 0.8(0.9805)/ 5 = 20.214

% ratio = Kn – R / R * 100

20-20.215/20.215 * 100 = -1.063%

To find θ $\theta = 180 / \pi \ [\ \underline{I_m \cos\delta - Ic.\sin\delta} \ / nIs \ ]$

$= 180 / \pi \ [\ \underline{1.5(0.9805) - 0.8(0.1961)} \ / 20(5) \ ]$

$= 0.752$

5. A C.T. of turns ratio 1:199is rated as 1000/5A, 25VA. The coreloss is 0.1Wand magnetizing current is 7.2A, under rated conditions . determine the phase angle and ratio errors for rated burden and rated sec.current 0.8p.f. lagging. Neglect winding resistance and reactance

$$R = n + I_m \sin\delta \;\; Ic.\cos\delta / Is$$

$$199 + 7.2(0.6) + 4(0.8) \;/\; 5 = 200.504$$

$$\%\text{ ratio error} = Kn - R / R * 100$$

$$= 200 - 200.504/20.504 \quad * 100$$

$$= 0.251\%$$

$$\theta = 180/\pi \; [\, \underline{I_m \cos\delta \;\; - Ic.\sin\delta} \;/\; nIs \,]$$

$$\theta = 180/\pi \; [\, \underline{7.2(0.8) \;\; - 4(0.6)} \;/\; 199*5 \,]$$

$$= 0.1934^{o}$$

Descriptive Questions

1. Discuss briefly on the shunts and multipliers used for expression of meters in electrical measurements July/Aug 2005, Jan/ Feb 2004,2007
2. Write a note on the turns compensation used in instrument transformers July/Aug 2010, Jan/ Feb 2004, Jan/ Feb 2012
3. Discuss the various methods generally adopted for range extension of ammeters and voltmeters July/Aug 2004, July/Aug 2009
4. Briefly explain the design features of a CT July/Aug 2004
5. What are the disadvantages of shunts and multipliers used in measurement system Jan/ Feb 2005
6. What are the differences between CT and PT Jan/ Feb 2005,Jan/ Feb 20042007,2009,2010
7. What happens if the secondary of a CT is open circuited while the primary is carrying normal load current Jan/ Feb 2006
8. Explain clearly how shunts and multipliers are used to extend the range of instruments July/Aug 2007
9. Explain with circuit diagram Silsbee's method of testing of current transformer July/Aug 2007, Jan/ Feb 2012
10. Explain the principle of range extension of ammeter Jan/ Feb 2008
11. What are the advantages of instrument transformers July/Aug 2008, Jan/ Feb 2009,2011

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Module-4

Electronic and digital Instruments

Introduction:

The measurement of any quantity plays very important role not only in science but in all branches of engineering, medicine and in almost all the human day to day activities.

The technology of measurement is the base of advancement of science. The role of science and engineering is to discover the new phenomena, new relationships, the laws of nature

and to apply these discoveries to human as well as other scientific needs. The science and engineering is also responsible for the design of new equipments. The operation, control and the maintenance of such equipments and the processes is also one of the important functions of the science and engineering branches. All these activities are based on the proper measurement and recording of physical, chemical, mechanical, optical and many other types of parameters.

The measurement of a given parameter or quantity is the act or result of a quantitative comparison between a predefined standard and an unknown quantity to be measured. The major problem with any measuring instrument is the error. Hence, it is necessary to select the appropriate measuring instrument and measurement procedure which minimises the error. The measuring instrument should not affect the quantity to be measured.

An electronic instrument is the one which is based on electronic or electrical principles for its measurement function. The measurement of any electronic or electrical quantity or variable is termed as an electronic measurement.

Advantages of Electronic Measurement

The advantages of an electronic measurement are

1. Most of the quantities can be converted by transducers into the electrical or electronic signals.
2. An electrical or electronic signal can be amplified, filtered, multiplexed, sampled and measured.
3. The measurement can easily be obtained in or converted into digital form for automatic analysis and recording.
4 The measured signals can be transmitted over long distances with the help of cables or radio links, without any loss of information.
5. Many measurements can be carried either simultaneously or in rapid succession.
6. Electronic circuits can detect and amplify very weak signals and can measure the events of very short duration as well.
7. Electronic measurement makes possible to build analog and digital signals. The digital signals are very much required in computers. The modern development in science and technology are totally based on computers.
8. Higher sensitivity, low power consumption and a higher degree of reliability are the important features of electronic instruments and measurements. But, for any measurement, a well defined set of standards and calibration units is essential. This

chapter provides an introduction to different types of errors in measurement, the characteristics of an instrument and different calibration standards.

Voltmeters and multimeters

Basic meter:

A basic d.c. meter uses a motoring principle for its operation. It stntes that any current carrying coil placed in a magnetic field experiences a force, which is proportional to the magnitude of current passing through the coil. This movement of coil is called D'Arsonval movement and basic meter is called D'Arsonval galvanometer.

D.C instruments:

a) Using shunt resistance, d.c. current can be measured. The instrument is d.c. microammeter, milliammeter or ammeter.

b) Using series resistance called multiplier, d.c. voltage can be measured. The instrument is d.c. millivoltmeter, voltmeter or kilovoltmeter.

c) Using a battery and resistive network, resistance can be measured. The instrument is ohmmeter.

A.C instruments:

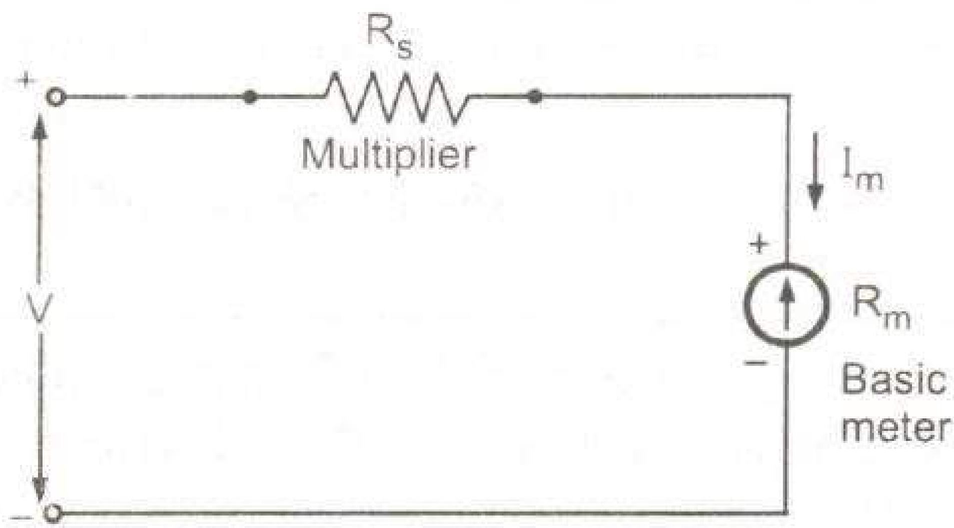
a) Using a rectifier, a.c. voltages can be measured, at power and audio frequencies. The instrument is a.c. voltmeter.

b) Using a thermocouple type meter radio frequency (RF) voltage or current can be measured.

c) Using a thermistor in a resistive bridge network, expanded scale for power line voltage can be obtained.

Basic voltmeter:

The basic d.c. voltmeter is nothing but a permanent magnet moving coil (PMMC) 0' Arsonval galvanometer. The resistance is required to be connected in series with the basic meter to use it as a voltmeter. This series resistance is called a **multiplier.** The main function of the multiplier is to limit the current through the basic meter so that the meter current does not exceed the full scale deflection value. The voltmeter measures the voltage across the two points of a circuit or a voltage across a circuit component. The basic d.c. voltmeter is shown in the Fig.



The voltmeter must be connected across the two points or a component, to measure the potential difference, with the proper polarity.
The multiplier resistance can be calculated as:

Let R_m = internal resistance of coil i.e. meter

R_s = series multiplier resistance

I_m = full scale deflection current

V = full range voltage to be measured

From Fig. 2.1, $\therefore V = I_m(R_m + R_s)$

$$\therefore \quad V = I_m R_m + I_m R_s$$

$$\therefore \quad I_m R_s = V - I_m R_m$$

$$\therefore \quad \boxed{R_s = \frac{V}{I_m} - R_m}$$

Let v = drop across the basic meter = $I_m R_m$

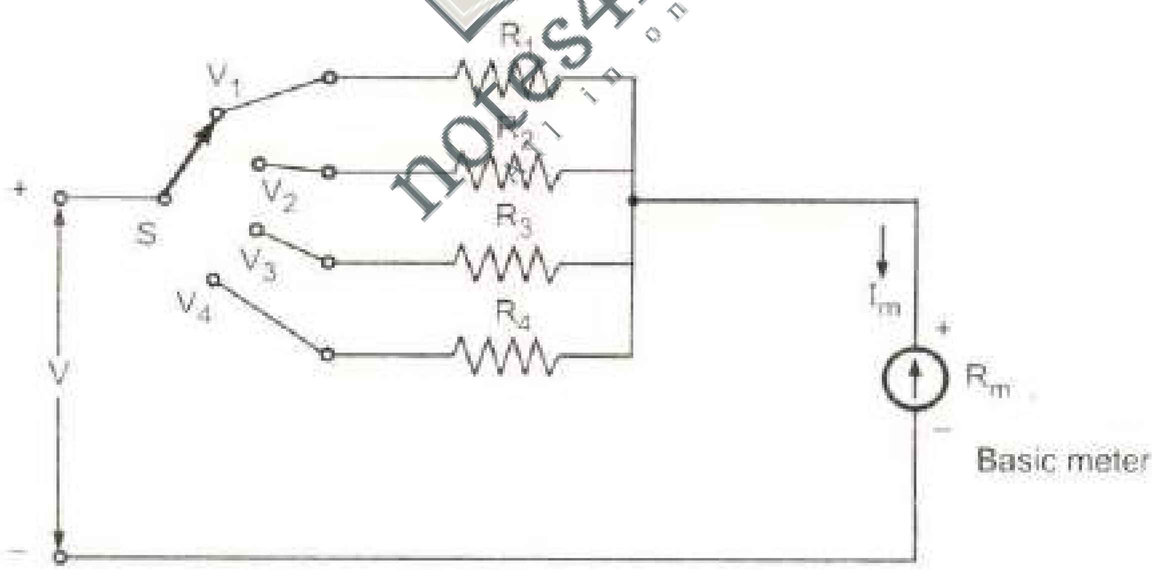
$\therefore$ m = multiplying factor = $\frac{V}{v}$

$$= \frac{I_m (R_m + R_s)}{I_m R_m}$$

$$m = 1 + \frac{R_s}{R_m}$$

Multirange voltmeters:

The range of the basic d.c. voltmeter can be extended by using number of multipliers clnd a selector switch. Such a meter is called **multirange** voltmeter



The R:, R2, R) and R~ are the four series multipliers. When connected in series with the meter, they can give four different voltage ranges as V1, V2,V3, and V4. The selector switch S is multiposition switch by which the required multiplier can be selected in the circuit.

The mathematical analysis of basic d.c. *voltmeter* is equally applicable for such multirange *voltmeter*. Thus,

$$R_1 = \frac{V_1}{I_m} - R_m \qquad R_2 = \frac{V_2}{I_m} - R_m \qquad \text{and so on.}$$

Sensitivity of voltmeters:
In a multirange voltmeter, the ratio of the total resistance R r to the voltage range remains same. This ratio is nothing but the reciprocal of the full scale deflection current,of the meter i.e. 1/101. This value is called sensitivity of the voltmeter. Thus the sensitivity of the voltmeter is defined ,

$$S = \frac{1}{\text{Full scale deflection current}}$$

$$\boxed{S = \frac{1}{I_m}\ \Omega/V \text{ or } k\Omega/V}$$

True RMS Responding voltmeter

The voltmeters can be effectively used in a.c. voltmeters. The rectifier is used to convert a.c. voltage to be measured, to d.c. This d.c., if required is amplified and then given to the movement. The movement gives the deflection proportional to the quantity to be measured.

The r.m.s. value of an alternating quantity is given by that steady current (d.c.) which when flowing through a given circuit for a given time produces the same amount of heat as produced by the alternating current which when flowing through the same circuit for the same time. The r.m.s value is calculated by measuring the quantity at equal intervals for one complete cycle. Then squaring each quantity, the average of squared v,llues is obtained. The square root of this average value is the r.m.s. value. The r.m.s means root-mean square i.e. squaring, finding the mean i.e. average and finally root.

If the waveform is continuous then instead of squaring and calculating mean, the integratioll is used. Mathematically the r.m.s. value of the continuous a.c. voltage having time period T is given by,

$$V_{rms} = \sqrt{\frac{1}{T}\int_0^T V_{in}^2 \, dt}$$

The $\frac{1}{T}$ term indicates the mean value or average value.

For **purely sinusoidal quantity,**

$$V_{rms} = 0.707 \; V_m$$

where V_m = peak value of the sinusoidal quantity

If the a.c. quantity is continuous then average value can be expressed mathematically using an integration as,

$$V_{av} = \frac{2}{T}\int_0^{T/2} V_{in} \, dt$$

The interval T/2 indicates the average over half a cycle.

For **purely sinusoidal quantity,**

$$V_{av} = \frac{2}{\pi} V_m = 0.636 \; V_m$$

where V_m = Peak value of the sinusoidal quantity.

The form factor is the ratio of r.m.s. value to the average value of an alternating quantity.

$$K_f = \frac{\text{r.m.s. value}}{\text{average value}} = \text{form factor}$$

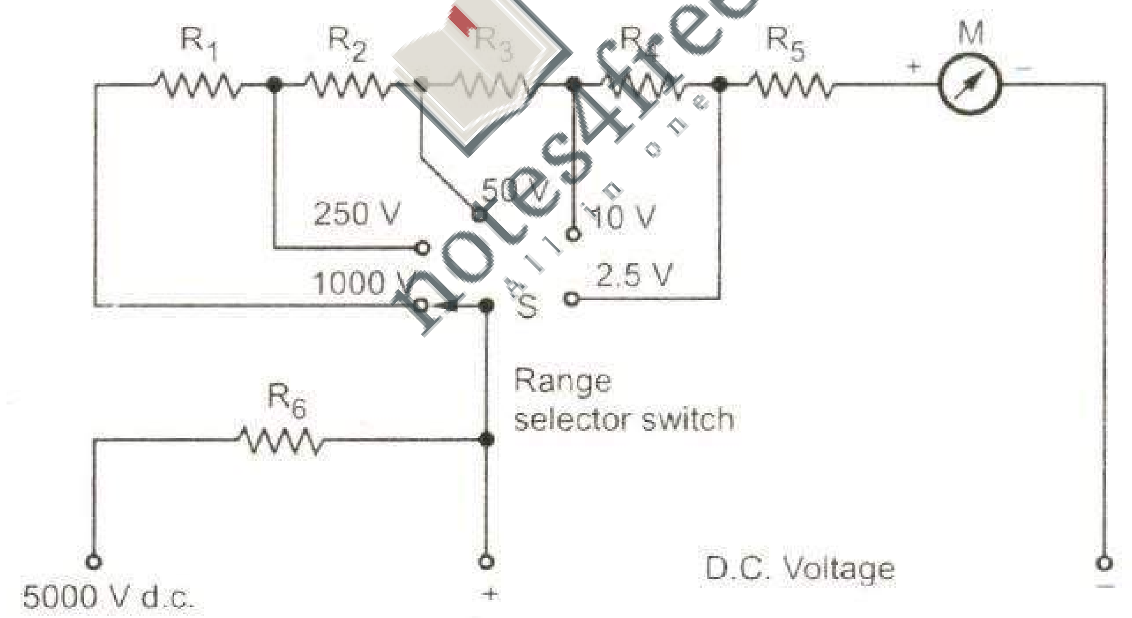
When the a.c. input is applied, for the positive half cycle, the diode 01 conducts and causes the meter deflection proportional to the average value of that half cycle. In the negative cycle, the diode O2 conducts and 01 is reverse biased. The current through the meter is in opposite direction and hence meter movement is bypassed. Thus due to diodes, the rectifying action produces pulsating d.c. and lile meter indicates the average value of the input.

Electronic multimeter:

For the measurement of d.c. as well as a.c. voltage and current, resistance, an electronic multimeter is commonly used. It is also known as Voltage-Ohm Meter (VOM) or multimeter The important salient features of YOM are as listed below.

1) The basic circuit of YOM includes balanced bridge d.c. amplifier.
2) To limit the magnitude of the input signal, RANGE switch is provided. By properly adjusting input attenuator input signal can be limited.
3) It also includes rectifier section which converts a.c. input signal to the d.c. voltage.
4) It facilitates resistance measurement with the help of internal battery and additional circuitry.
5) The various parameters measurement is possible by selecting required function using FUNCTION switch.
6) The measurement of various parameters is indicated with the help of indicating Meter.

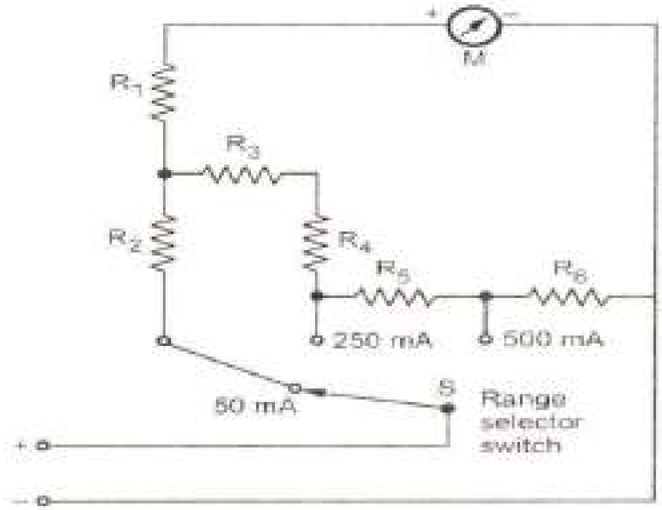
Use of multimeter for D.C measurement:



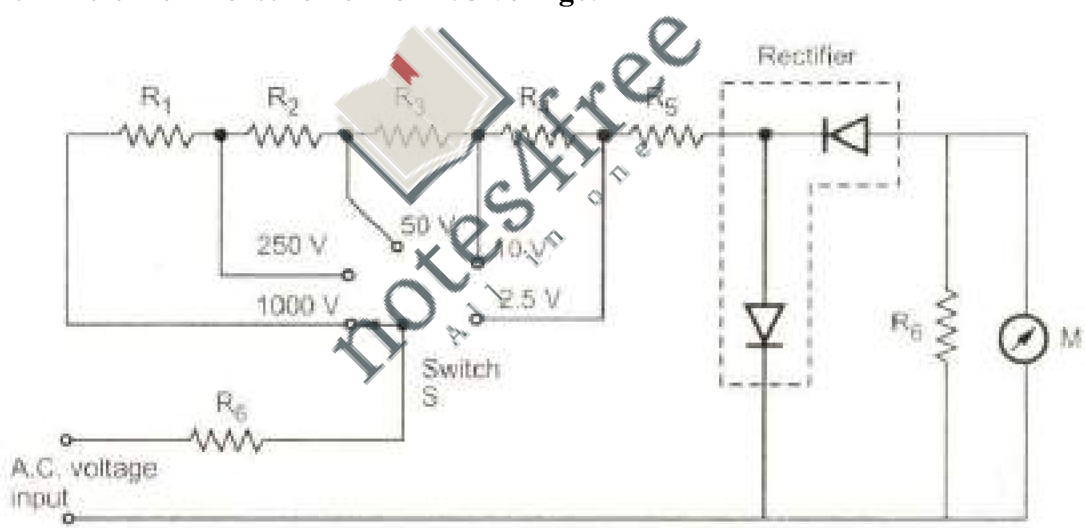
For getting different ranges of voltages, different series resistances are connected in series which can be put in the circuit with the range selector switch. We can get different ranges to measure the d.c. voltages by selecting the proper resistance in series with the basic meter.

Use of multimeter as ammeter:

To get different current ranges, different shunts are connected across the meter with the help of range selector switch. The working is same as that of PMMC



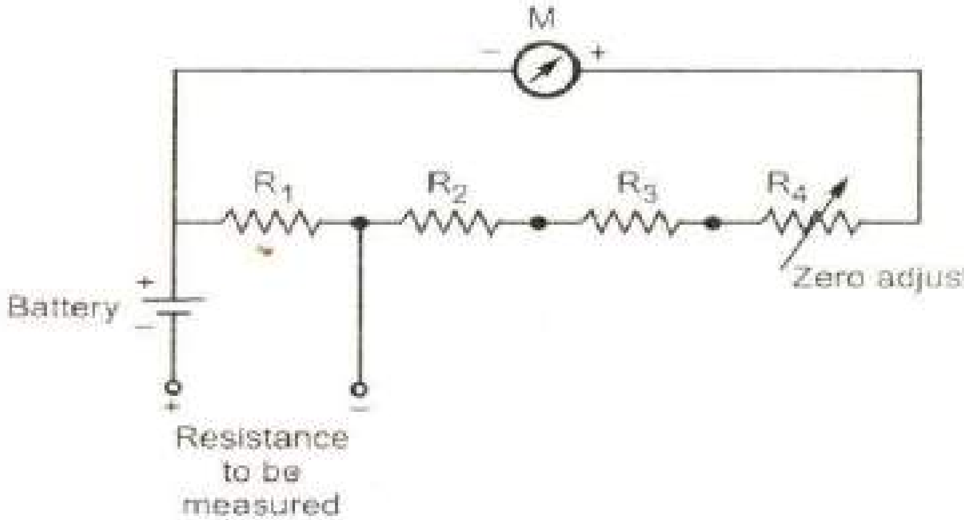
Use of multimeter for measurement of A.C voltage:



The rectifier used in the circuit rectifies a.c. voltage into d.c. voltage for measurement of a.c. voltage before current passes through the meter. The other diode is used for the protection purpose.

Use of multimeter for resistance measurement:

The Fig shows ohmmeter section of multimeter for a scale multiplication of 1. Before any measurement is made, the instrument is short circuited and "zero adjust" control is varied until the meter reads zero resistance i.e. it shows full scale current. Now the circuit takes the form of a variation of the shunt type ohmmeter. Scale multiplications of 100 and 10,000 can also be used for measuring high resistances. Voltages are applied the circuit with the help of battery.



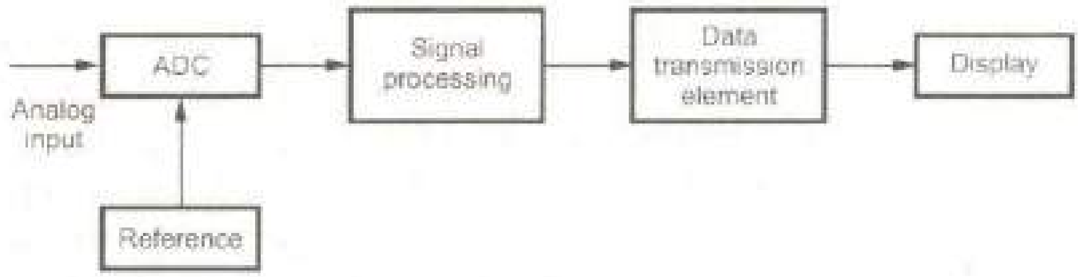
Digital Voltmeters

Performance parameters of digital voltmeters:

1. **Number of measurement ranges:**
The basic range of any DVM is either 1V or 10 V. With the help of attenuator at the Input, the range can be extended from few microvolts to kilovolts.
2. **Number of digits in readout:** The number of digits of DVMs varies from 3 to 6. More the number of digits, more is the resolution.
3. **Accuracy:** The accuracy depends on resolution and resolution on number of digits. Hence more number of digits means more accuracy. The accuracy is as high up to ± 0.005% of the reading.
4. **Speed of the reading:** In the digital voltmeters, it is necessary to convert analog signal into digital signal. The various techniques are used to achieve this conversion. The circuits which are used to achieve such conversion are called digitizing circuits and the process is called digitizing. The time required for this conversion is called digitizing period. The maximum speed of reading and the digitizing period are interrelated. The instrument user must wait, till a stable reading is obtained as it is impossible to follow the visual readout at high reading speeds.
5. **Normal mode noise rejection:** This is usually obtained through the input filtering or by use of the integration techniques. The noise present at the input, if passed to the analog to digital converting circuit then it can produce the error, especially when meter is used for low voltage measurement. Hence noise is required to be filtered.
6. **Common mode noise rejection :** This is usually obtained by guarding. A guard is a sheet metal box surrounding the circuitry. A terminal at the front panel makes this 'box' available to the circuit under measurement.
7. **Digital output of several types:** The digital readout of the instrument may be 4 lines BCD, single line serial output etc. Thus the type of digital output also determines the variety of the digital voltmeter.
8. **Input impedance :** The input impedance of DVM must be as high as possible which red l1ces the loading effects. Typically it is of the order of 10 :M.ohm.

Block diagram of DVM

Any digital instrument requires analog to digital converter at its input. Hence first block in a general DVM is ADC as shown in the Fig.



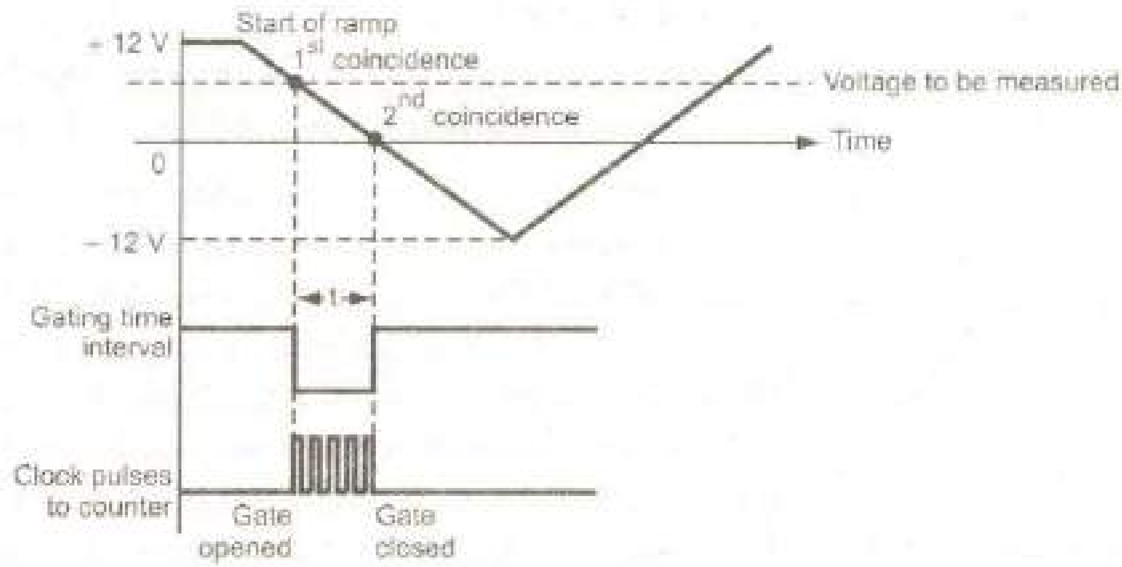
Every ADC requires a reference. The reference is generated internally and reference generator circuitry depends on the type of ADC technique used. The output of ADC is decoded and signal is processed in the decoding stage. Such a decoding is necessary to drive the seven segment display. The data from decoder is then transmitted to the display. The data transmission element may be a latches, counters etc. as per the requirement. A digital display shows the necessary digital result of the measurement.

Ramp type DVM:

Linear ramp technique:

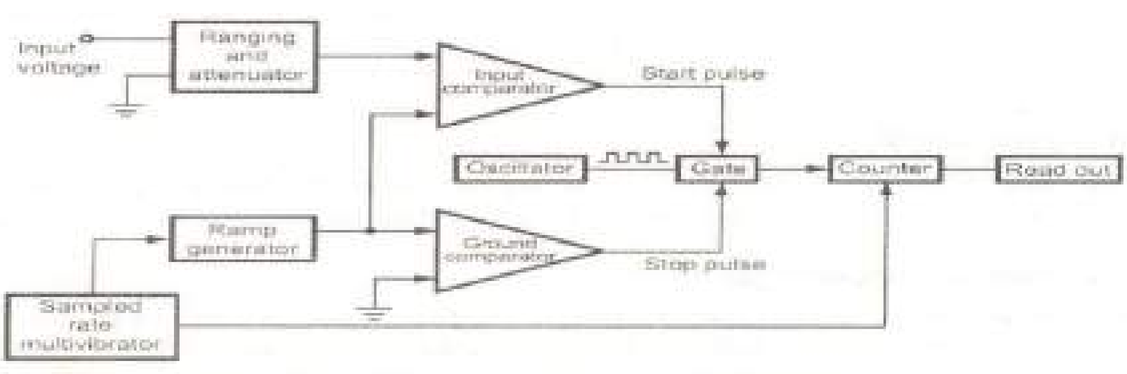
The basic principle of such measurement is based on the measurement of the time taken by l1 linear ramp to rise from a V to the level of the input voltage or to decrease from the level of the input voltage to zero. This time is measured with the help of electronic time interval counter and the count is displayed in the numeric form with the help of a digital

.



Basically it consists of a linear ramp which is positive going or negative going. The range of the ramp is ± 12 V while the base range is ± 10 V. The conversion from a *voltage* to c1 time interval is shown in the fig

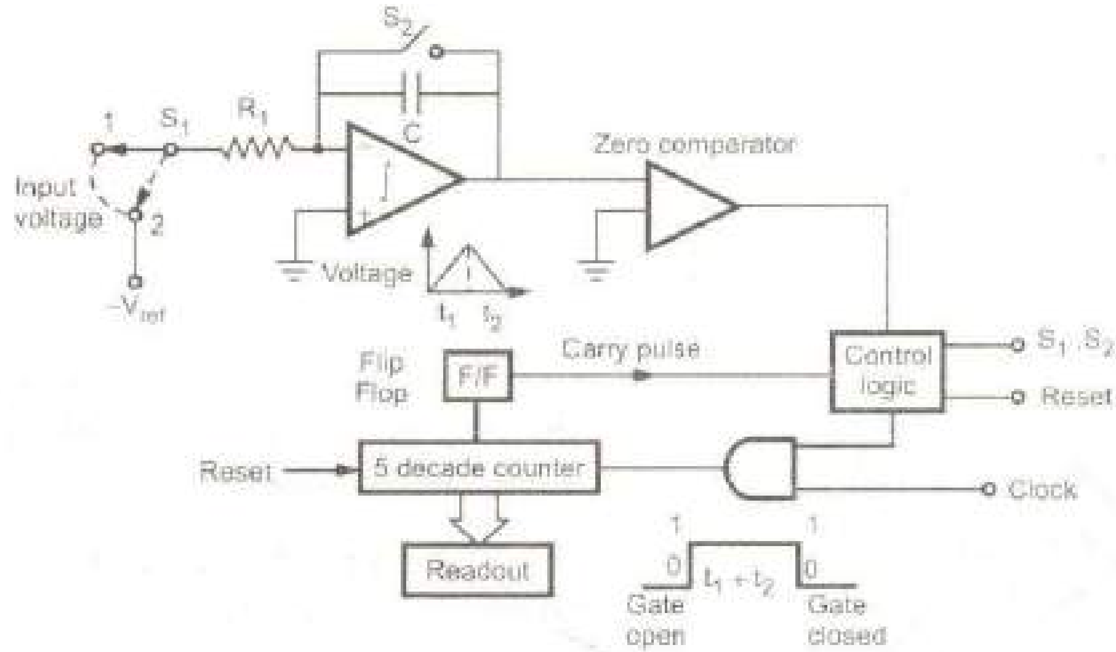
At the start of measurement, a ramp *voltage* is initiated which is continuously compared with the input voltage. When these two voltages are same, the comparator generates a pulse which opens a gate i.e. the input comparator generates a start pulse. The ramp continues to decrease and finally reaches to 0 V or ground potential. This is sensed by the second comparator or ground comparator. At exactly 0 V, this comparator produces a stop pulse which closes the gate. The number of clock pulses is measured by the counter. Thus the time duration for which the gate is opened, is proportional to the input voltage. FN the time interval between starts and stop pulses, the gate remains open and the oscillator circuit drives the counter. The magnitude of the count indicates the magnitude of the input voltage, which is displayed by the display. The block diagram of linear ramp DVM is shown in the Fig



Properly attenuated input signal is applied as one input to the input comparator. The ramp generator generates the proper linear ramp signal which is applied to both ten comparators. Initially the logic circuit sends a reset signal to the counter and the readout. The comparators are designed in such a way that when both the input signals of comparator are equal then only the comparator changes its state. The input comparator is used to send the start pulse while the ground comparator is used to send the stop pulse.
When the input and ramp are applied to the input comparator, and at the point when negative going ramp becomes equal to input voltages the comparator sends start pulse, due to which gate opens. The oscillator drives the counter. The counter starts counting the pulses *received* from the oscillator. Now the same ramp is applied to the ground comparator and it is decreasing. Thus when ramp becomes zero, both the inputs of ground compactor becomes zero (grounded) i.e. equal and it sends a stop pulse to the gate due to which gate gets closed. Thus the counter stops receiving the pulses from the local oscillator. A definite number of pulses will be counted by the counter, during the start and stop pulses which is measure of the input voltage. This is displayed by the digital readout.'
The sample rate multivibrator determines the rate at which the measurement cycles are initiated. The oscillation of this multivibrator is usually adjusted by a front panel control named rate, from few cycles per second to as high as 1000 or more cycles per second. The typical value is 5 measuring cycles/second with an accuracy of ± 0.005% of the reading. The sample rate provides an initiating pulse to the ramp generator to start its next ramp voltage. At the same time, a reset pulse is also generated which resets the counter to the zero state.

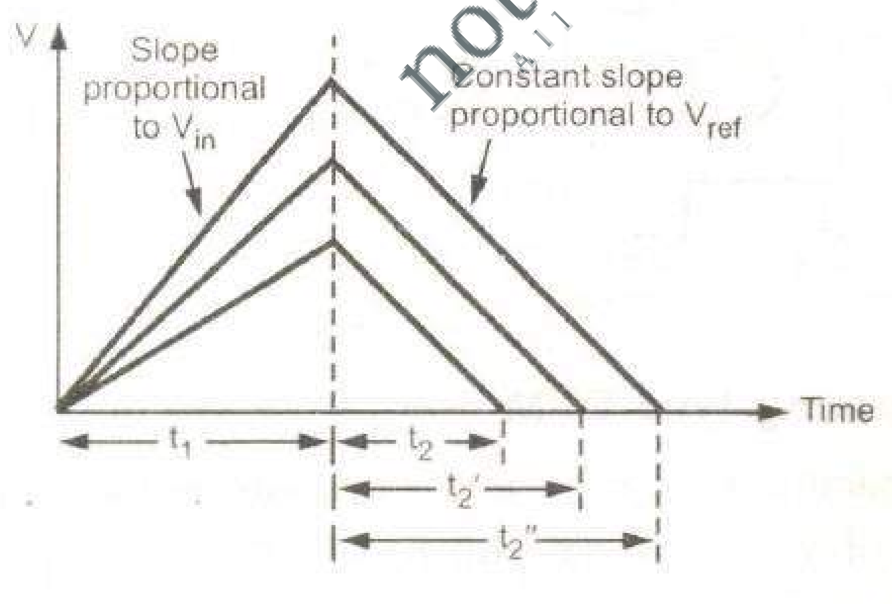
Dual slope integrating type DVM

This is the most popular method of analog to digital conversion. In the ramp techniques, the noise can cause large errors but in dual slope method the noise is averaged out by the positive and negative ramps using the process of integration. The basic principle of this method is that the input signal is integrated for a fixed interval of time. And then the same integrator is used to integrate the reference voltage with reverse slope. Hence the name given to the technique is **dual** slope integration technique.
The block diagram of dual slope integrating type DVM is shown in the Fig. It consists of five blocks, an op-amp used as an integrator, a zero comparator, clock pulse generator, a set of decimal counters and a block of control logic.



When the switch Sl is in position 1, the capacitor C starts charging from zero level. The rate of charging is proportional to the input voltage level. The output of the op-amp is given by,

After the interval t I, the input voltage is disconnected and a negative voltage -Vref is connected by throwing the switch S1 in position 2. In this position, the output of the op-ilmp is given by,



Thus the input voltage is dependent on the time periods t] and t2 and not on the values of R] and C. This basic principle of this method is shown in the Fig.

At the start of the measurement, the counter is resetted to zero. The output of the flip-flop is also zero. This is given to the control logic. This control sends a signal so as to close an

electronic switch to position 1 and integration of the input voltage starts. It continues till the time period t.
As the output of the integrator changes from its zero value, the zero comparator output changes its state. This provides a signal to control logic which inturn opens the gate and the counting of the clock pulses starts.
The counter counts the pulses and when it reaches to 9999, it generates a carry pulse and all digits go to zero. The flip flop output gets activated to the logic level T. This activates the control logic. This sends a signal which changes the switch 5\ position from 1 to 2 Thus -Vref gets connected to op-amp. As Vref polarity is opposite, the capacitor starts discharging. The integrator output will have constant negative slope as shown in the Fig. 3.5"1. The output decreases linearly and after the interval t2, attains zero value, when the capacitor C gets fully discharged.

From equation (3) we can write,

$$V_{in} = V_{ref} \cdot \frac{t_2}{t_1}$$

Let time period of clock oscillator be T and digital counter has counted the counts n1 and n2 during the period t] and t2 respectively.

$$\boxed{V_{in} = V_{ref} \cdot \frac{n_2 T}{n_1 T} = V_{ref} \cdot \frac{n_2}{n_1}}$$

Thus the unknown voltage measurement is not dependent on the clock frequency, but dependent on the counts measured by the counter.

The advantages of this technique are:
i) Excellent noise rejection as noise and superimposed arc. are averaged out during the process of integration.
ii) The RC time constant does not affect the input voltage measurement.
iii)The capacitor is connected via an electronic switch. This capacitor is an auto zero capacitor and avoids the effects of offset voltage.
iv)The integrator responds to the average value of the input hence sample and hold circuit is not necessary.
v) The accuracy is high and can be readily varied according to the specific requirements.

Questions:
1. Explain the construction and working of i) Phase sequence indicators
ii) Electrodynamometer type power factor meters
July/Aug -2007, Jan/ Feb -2011, July/Aug -2009, Jan/ Feb -2012

2) With a neat sketch explain the construction and working of a Weston frequency meter
July/Aug -2004, Jan/ Feb -2005
3) What is a rotating type phase sequence indicator and how it is used
July/Aug -2008, Jan/ Feb -2009, Jan/ Feb 2012

4. Explain the principle of operation of a static type of phase sequence indicator
July/Aug -2006, Jan/ Feb -2011
5. Discuss about the working principle of digital voltmeter employing the successive approximation technique
July/Aug-2005, Jan/Feb-2005, July/Aug-2009, Jan/ Feb -2004, Jan/ Feb -2010
6. Discuss the different practical method of connection the unknown components to the test terminals of a Q meter Jan/ Feb -2004

1. With a block diagram explain the working of a True RMS responding voltmeter
July/Aug-2004, Jan/Feb-2007, July/Aug-2009, Jan/ Feb -2005, Jan/ Feb -2008
July/Aug-2008, Jan/Feb-2009, July/Aug-2010, Jan/ Feb -2011
2. With a block diagram explain the working of a Ramp type DVM
July/Aug-2004, July/Aug-2010
3. List the elements of the basic circuit of an electronic multimeter
July/Aug-2004
4. What is a Q meter? Discuss how the unknown components can be connected to its test terminals July/Aug-2005
5. Explain with the help of block diagram the function of integrating type digital voltmeter Jan/ Feb -2006
6. Explain the principle of operation of electronic multimeter
July/Aug-2007, Jan/Feb-2006
7. Explain with block diagram any one type of digital voltmeter
July/Aug-2006
8. What are the advantages of using electronic measuring instruments
July/Aug-2007
9. Explain the operation of a electronic multimeter to measure current, voltage and resistance Jan/ Feb -2011
10. What is the working principle of Q-Meter? How can the distributed capacitance of the coil be measured using Q-Meter? July/Aug-2006 , Jan/ Feb 2012
11. Mention the salient features of digital voltmeter
July/Aug-2007