JHARSUGUDA ENGINEERING SCHOOL

DEPARTMENT OF ELECTRONICS AND TELECOMMUNICATION

LEARNING MATERIALS

ELECTRONICS MEASUREMENT & INSTRUMENTATION

3RD SEM ETC, DIPLOMA ENGG. *Under SCTE&VT, Odisha*

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[CHAPTER-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 a given set of formulas.

2. *MEASUREMENT*

It is a process of comparing an unknown quantity with an accepted standard quantity.

1.1. *ELECTRONIC MEASUREMENT &INSTRUMENTATION*

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

Why measurement of parameters and study of variations for a particular instrument are required?

The measurement of parameters and its variations for a particular instrument is required because it helps in understanding the behaviour of an instrument.

1.2. *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*

2.1. ***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 or intended 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 the output 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 be detected, caused or otherwise discriminated by the measuring device.* 7. *TRUE VALUE-True value is error free value of the measure variable it is given as difference between the Instrument Reading and Static error.*

Mathematically,

True value= Obtained Instrument reading – static error.

** 100*

Note- %Error =

2.2. *DYNAMIC CHARACTERISTICS OF INSTRUMENT*

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

1. *SPEED OF RESPONSE-It is the rapidity with which an instrument responds to the changes to in the measurement quantity.*
2. *FIDELITY-The degree to which an instrument indicate the measure variable without dynamic error.*
3. *LAG-It is retardation or delay in the response an instrument to the changes in the measurement.*

2.3. *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 reading mistakes in recoding observation incorrect application of an instrument.* A. *SYSTEMATIC ERROR-A constant uniform deviation of an instrument is as systematic error. There are two types of systematic error.*

a) *STATIC ERROR*

The static error of a measuring instrument is the numerical different between the true value 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 value indicated by the instrument.*
2. *The Dynamic Errors are caused by the instrument not responding fast enough to follow the changes in the measured value.*

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

2.3.1. *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 moving component. It can be avoided by*

a. *Selecting a suitable instrument for the particular measurement.*
b. *Applying correction factor after determining the amount of instrumental 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 as effect 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 are caused by habits of the observers like tilting his/her head too much while reading a "Needle – Scale Reading".

CHAPTER-02

INDICATING INSTRUMENT

2.1. INTRODUCTION

2.1.1. 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 torque as 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.

2.1.2. 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 moving system.

This brings the moving system to rest at the deflected position reasonably quickly without any oscillation or very small oscillation.

This is provided by

i) Air friction

ii) Fluid friction
ii) Fluid friction

iii) Eddy current.
iii) Eddy current.

It should be pointed out that any damping f
It should be pointed out that any damping force shall not influence the steady state
orce shall not influence the steady state

deflection produced by a given deflecting force or torque.
deflection produced by a given deflecting force or torque.

Damping force increases with the angular velocity of the moving system, so that its effect

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Damping force increases with the angular velocity of the moving system, so that its effect
is greatest when the rotation is rapid and zero when the system
is greatest when the rotation is rapid and zero when the system rotation is zero.

rotation is zero.

2.2. BASIC METER MOVEMENT &PMMC MOVEMENT

BASIC METER MOVEMENT &PMMC MOVEMENT

2.2.1. BASIC METER MOVEMENT OR D'ARSONVAL METER

BASIC METER MOVEMENT OR D'ARSONVAL METER

BASIC METER MOVEMENT OR D'ARSONVAL METER

MOVEMENT

MOVEMENT

PRINCIPLE:-

Whenever electrons flow through a conductor, a magnetic field proportional to the current is

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

meters. ing current and is employed in many

practical meters.

The basic dc meter movement is known as the D'Arsonval meter movement because it The basic dc meter movement is known as the D'Arsonval meter movement because it

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was first employed by the French scientist, D'Arsonval, in making electrical
was first employed by the French scientist, D'Arsonval, in making electrical
was first employed by the French scientist, D'Arsonval, in making electrical measurement.

This type of meter movement
This type of meter movement is a current measuring device which is used in the ammeter,
is a current measuring device which is used in the ammeter,
voltmeter, and ohmmeter.
voltmeter, and ohmmeter.

An ohmmeter is also basically a current measuring instrument, An ohmmeter is also

basically a current measuring instrument, it differs from the

it differs from the
ammeter and voltmeter in that it provides its own source of power and contains other

ammeter and voltmeter in that it provides its own source of power and contains other

ammeter and voltmeter in that it provides its own source of power and contains other
auxiliary circuits.

<u>D’ARSONVAL GALVANOMETER:</u>
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This instrument is very commonly used in various methods of resistance measurement and

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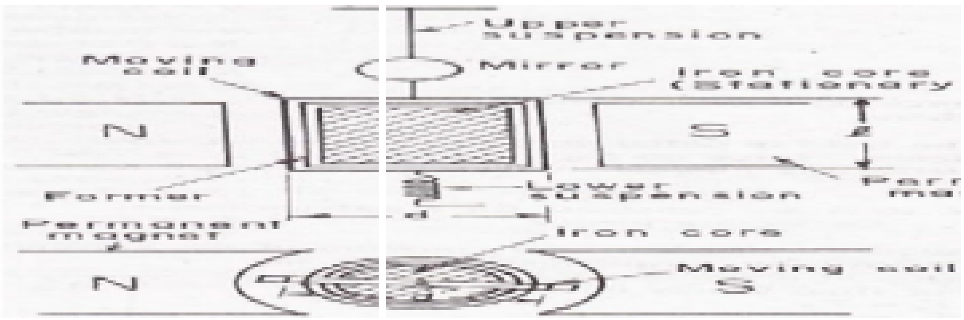
This instrument is very commonly used in various methods of resistance measurement and
also in d.c. potentiometer work.
. potentiometer work.



Fig

1) **<u>MOVING COIL:</u>**

It is the current carrying element.
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It is either rectangular or circular in shape and consists of number of turns of fine wire.

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This coil is suspended so that it is free to turn about its vertical axis of symme

This coil is suspended so that it is free to turn about its vertical axis of symme

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 pole

It is arranged in a uniform, radial, horizontal magnetic field in the air gap between pole
It is arranged in a uniform, radial, horizontal magnetic field in the air gap between pole
pieces of a permanent magnet and iron core.

pieces 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 is rectangular.

The iron core is used to provide a flux path of low reluctance and therefore to provide strong magnetic field for the coil to move in.

This increases the deflecting torque and hence the sensitivity of the galvanometer. The length of air gap is about 1.5mm.

In some galvanometers the iron core is omitted resulting in of decreased value of flux density 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 of its reduced radius and consequently a short periodic time.

2) DAMPING:

There is a damping torque present owing to production of eddy currents in the metal former 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 by adjusting 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 called the lower suspension and has a negligible torque effect.

This type of galvanometer must be leveled carefully so that the coil hangs straight and centrally 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 mm diameter rolled into the form of a ribbon.

This is not very strong mechanically so that the galvanometers must he handled carefully without 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.

2.2.2. PMMC INSTRUMENTS:

These instruments are used either as ammeters or voltmeters and are suitable for d.c work only.

PMMC instruments work on the principle that, when a current carrying conductor is placed 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 electrical quantity 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 aluminium It

consists of a light rectangular coil of many turns of fine wire wound on an aluminium

It consists of a light rectangular coil of many turns of fine wire wound on an aluminium former inside which is an iron core as shown in fig.

former inside which is an iron core as shown in fig.

The coil is delicately pivoted upon jewel bearings and is mounted between the pol

The coil is delicately pivoted upon jewel bearings and is mounted between the pol

The coil is delicately pivoted upon jewel bearings and is mounted between the poles of a permanent horse shoe magnet.

permanent horse shoe magnet.

Two soft-iron pole pieces are attached to these poles to concentrate the magnetic field.

iron pole pieces are attached to these poles to concentrate the magnetic field.

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

The current is led in to and out of the coils by means of two control hair

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.

above and other below the coil, as shown in Fig.

These springs also provide the controlling torque. The damping torque is provided by

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These springs also provide the controlling torque. The damping torque is provided by eddy currents induced in the alluminium former as the coil moves from one position to another.

eddy currents induced in the all uminium former as the coil moves from one position to

WORKING:

When the instrument is connected in the circuit to measure current or voltage, the When the

instrument is connected in the circuit to measure current or voltage, the

When the instrument is connected in the circuit to measure current or voltage, the operating current flows through the coil.

operating current flows through the coil.

Since the current carrying coil is placed in the magnetic

Since the current carrying coil is placed in the magnetic field of the permanent magnet, a mechanical torque acts on it.

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 As

a result of this torque, the pointer attached to the moving system moves in clockwise

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 being
direction over the graduated scale to indicate the value of current or voltage being
direction over the graduated scale to indicate the value of current or voltage being
measured.

This type of instruments can be used to measure direct current only.
e of instruments can be used to measure direct current only.

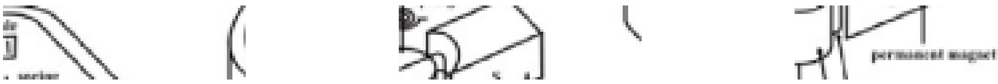
This is because, since the direction of the field of permanent magnet is same, the This is

because, since the direction of the field of permanent magnet is same, the

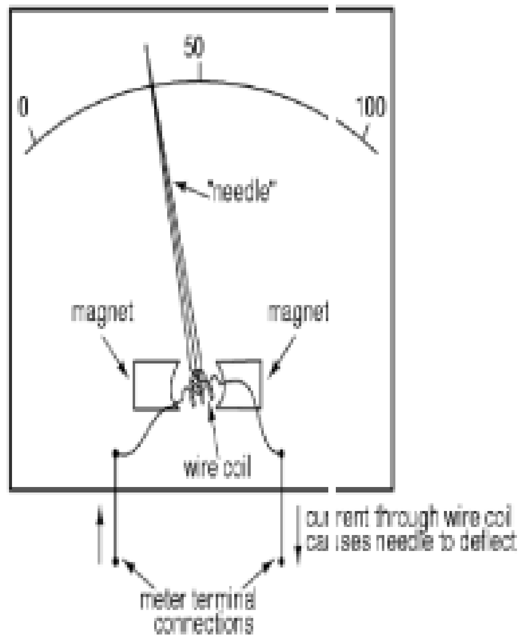
This is because, since the direction of the field of permanent magnet is same, the
deflecting torque also gets reversed, when the current in the coil reverses.
deflecting torque also gets reversed, when the current in the coil reverses.
deflecting torque also gets reversed, when the current in the coil reverses.

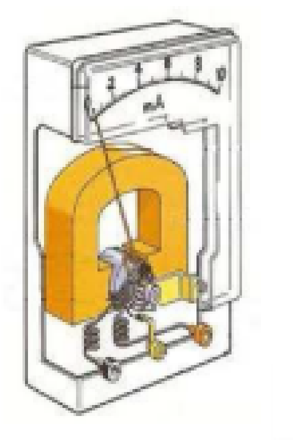
Consequently, the pointer will tr

Consequently, the pointer will try to deflect below zero. Deflection in the reverse
y to deflect below zero. Deflection in the reverse
direction can be prevented by a “stop” spring.
direction can be prevented by a “stop” spring.



Permanent magnet, moving coil (PMMC) me ter 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, m

b = 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 is given by,

Force on each coil side, F = BIlN Newtons.

Deflecting torque, T_d = Force × perpendicular distance

= (BIlN) × b

T_d = BINA Newton metre.

Where, A = l × 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 is very 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 accurate design.
c) Some errors are caused due to variations (with time or temperature) either in the strength of 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.

2.3. OPERATION OF MOVING IRON INSTRUMENT:-

Moving Iron instruments are mainly used for the measurement of alternating currents and voltages, 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 of the system.

The iron vane is situated so as, it can move in a magnetic field produced by a stationary coil.

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 a way so as to increase the flux of the electromagnet.

Thus, the vane tries to occupy a position of minimum reluctance.

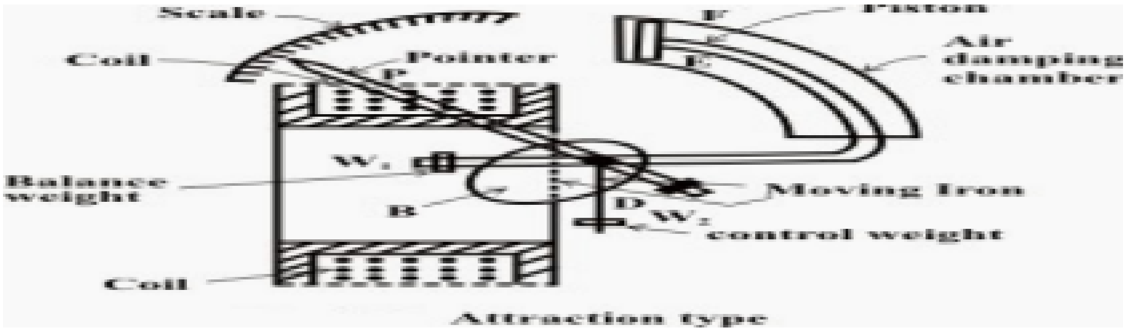
Thus, the force produced is always in such a direction so as to increase the inductance of the coil.

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 the other is movable (moving iron), and mounted on the spindle of the instrument. When operating current flows through the coil, the two vanes are magnetized, developing similar polarity at the same ends.

Consequently, repulsion takes place between the vanes and the movable vane causes the pointer 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- iron pieces or vanes.

If the two pieces develop pole strength of m_1 and m_2 respectively, then Instantaneous deflecting torque is $\alpha\ m_1 m_2\ \alpha\ H^2$.

If the permeability of iron is assumed constant, then H α i, where i is the coil current.

Instantaneous deflecting torque $\alpha\ i^2$.

Average deflecting torque, $T_d\ \alpha$ mean of i^2 over a cycle.

Since the instrument is spring controlled, $T_c\ \alpha\ \theta$.

In the steady position of deflection, $T_d = T_c$ i.e. $\theta\ \alpha$ mean of i^2 over a cycle => $\theta\ \alpha\ I^2$ (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 spread out near the finish end of the scale.

However, the non- linearity of the scale can be corrected to some extent by the accurate shaping and positioning of the iron vanes in relation to the operating coil.

2.4. PRINCIPLE OF OPERATION OF DC AMMETER AND MULTIRANGE AMMETER

2.4.1. 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 in the 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 across the 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 Power of the Shunt i.e Mathematically, Multiplying Power (m) $= I/I_m = 1 + R_m/R_{sh}$.

2.4.2. MULTIRANGE DC AMMETER:

The range of the dc ammeter is extended by a number of shunts, selected by a range switch. Such a meter is known as Multirange DC Ammeter.

The resistors is placed in parallel to give different current ranges.

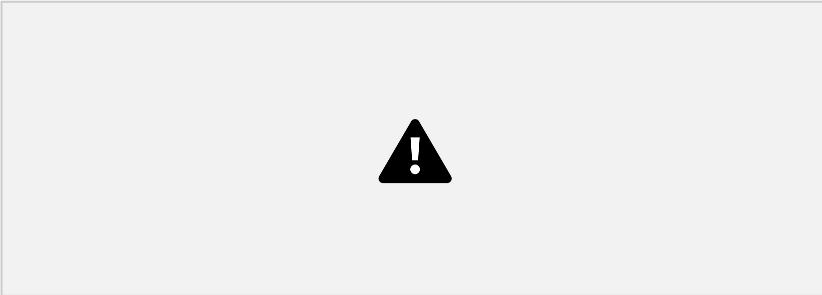


Fig.2.5

Above figure shows a diagram of multirange ammeter.

The circuit has 4 shunts R_{sh1}, Rs_{h2}, R_{sh3} and R_{sh4} which can be put in parallel with meter movement 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 movement is not damaged when This

type of switch is essential in order that meter movement is not damaged when

This type of switch is essential in order that meter movement is not damaged when

changing from the current range one to another.

changing from the current range one to another.

If we provide an ordinary

If we provide an ordinary switch the meter remains without a shunt and it is unprotected

switch the meter remains without a shunt and it is unprotected

and therefore it can be damaged when the range is changed.

and therefore it can be damaged when the range is changed.

Multirange Ammeters are used for the range from the 1 to 50 A.

Multirange Ammeters are used for the range from the 1 to 50 A.

2.5. AC AMMETER AND MULTIRANGE AMMETERS:

AC AMMETER AND MULTIRANGE AMMETERS:

The PMMC movement cannot be used directly for ac measurements since the inertia of

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The PMMC movement cannot be used directly for ac measurements since the inertia of

PMMC acts as an averager.

PMMC acts as an averager.

Because A.C. current has zero average value and it produces a torque that has also zero

Because A.C. current has zero average value and it produces a torque that has also zero

Because A.C. current has zero average value and it produces a torque that has also zero average value, the pointer just vibrates around zero on the scale.
average value, the pointer just vibrates around zero on th
In order to make ac measurements, a bridge rectifier circuit is combined with PMMC as

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In order to make ac measurements, a bridge rectifier circuit is combined with PMMC as shown below.

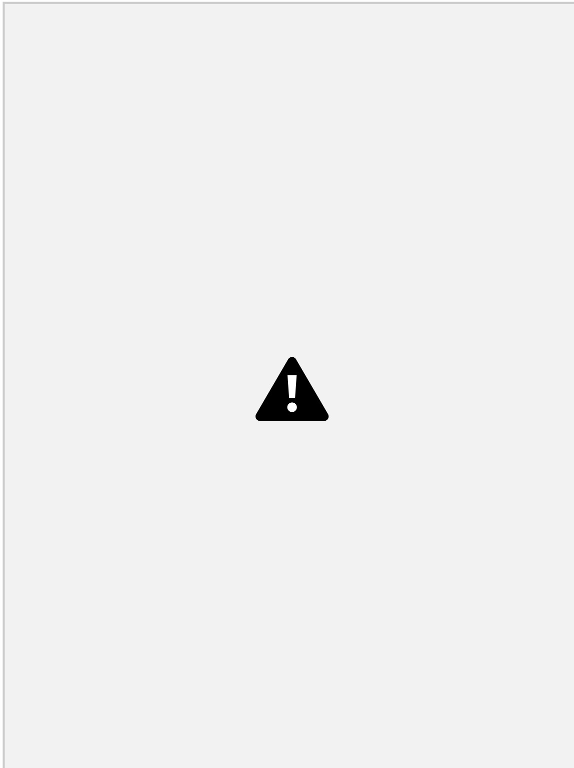


Fig.

2.6. BASIC OPERATION OF OHMMETER:
BASIC OPERATION OF OHMMETER:

ELECTRICAL RESISTANCE:
ELECTRICAL RESISTANCE:

Electrical resistance is a measure of how much an object opposes allowing an electrical

Electrical resistance is a measure of how much an object opposes allowing an electrical

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

OHMMETER:

It is an electronic device used to measure electrical resistance of a circuit element of low

It is an electronic device used to measure electrical resistance of a circuit element of low

It is an electronic device used to measure electrical resistance of a circuit element of low
degree of accuracy.

This resistance reading is indicated through a meter movement.
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 allow desired 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 elements or 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 which can 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.

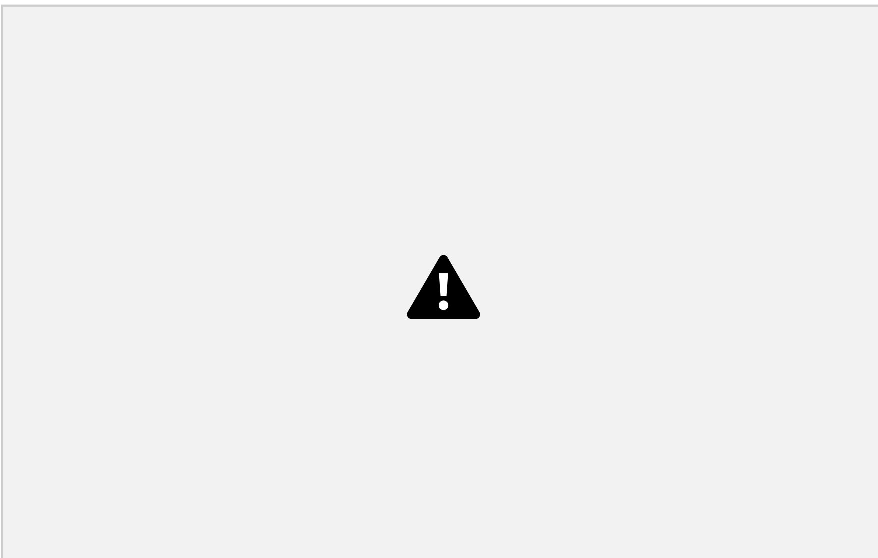


Fig.

Ohmmeters come with different levels of sensitivity.

Some Ohmmeters are designed to measure low-resistance materials, and some are used for measuring high-resistance materials.

A Micro Ohmmeter is used to measure extremely low resistances with high accuracy at particular 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 value of any electrical circuit.

SERIES TYPE OHMMETER:

It consists of basic d'Arsonval movement connected in parallel with a shunting resistor R_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
= current limiting resistor; R_2 = zero adjusting resistor; E = emf of internal battery;
= zero adjusting resistor; E = emf of internal battery;

R_m = internal resistance of d'Arsonval movement.
= internal resistance of d'Arsonval movement.

When the unknown resistance R
When the unknown resistance R_x = 0 (terminals A and B shorted) maximum current
= 0 (terminals A and B shorted) maximum current
flows through the meter. Under this con
flows through the meter. Under this condition resistor R_2 is adjusted until the basic
is adjusted until the basic
movement meter indicates full scale current Ifs.
movement meter indicates full scale current Ifs.

The full scale current position of the pointer is marked "0Ω" on the scale.

The full scale current position of the pointer is marked "0Ω" on the scale.

The full scale current position of the pointer is marked "0Ω" on the scale.

Similarly when R_x is removed from circuit R
is removed from circuit R_x = ∞ (i.e. when terminal A and B are
∞ (i.e. when terminal A and B are
open), the current in the meter drops to the zero and the movement indicates zero

pen), the current in the meter drops to the zero and the movement indicates zero

pen), the current in the meter drops to the zero and the movement indicates zero
current which is the marked "
current which is the marked "∞".

Thus the meter will read infinite resistance at the zero current position and zero Thus

the meter will read infinite resistance at the zero current position and zero

Thus the meter will read infinite resistance at the zero current position and zero
resistance at full scale current position.
resistance at full scale current position.

Since zero resistance is indicated when current in the meter is the maximum and stance

is indicated when current in the meter is the maximum and

stance is indicated when current in the meter is the maximum and

hence the pointer goes to the top mark.

hence the pointer goes to the top mark.

When the unknown resistance is inserted at terminal A, B the current through the When

the unknown resistance is inserted at terminal A, B the current through the

When the unknown resistance is inserted at terminal A, B the current through the

meter is reduced and hence pointer drops lower on the scale.

meter is reduced and hence pointer drops lower on the scale.

Therefore the meter has “0” at extreme right and “

re the meter has “0” at extreme right and “∞” at the extreme left.

∞” at the extreme left.

Intermediate scale marking may be placed on the scale by different known values of

Intermediate scale marking may be placed on the scale by different known values of

Intermediate scale marking may be placed on the scale by different known values of

the resistance R_x to the instrument.

to the instrument.

A convenient quantity to use in the design of the series ohmmeter is A

convenient quantity to use in the design of the series ohmmeter is

A convenient quantity to use in the design of the series ohmmeter is the value of the R_x which causes the half scale deflection of the meter.

which causes the half scale deflection of the meter.

At this position, the resistance across terminals A and B is defined as the half scale At

this position, the resistance across terminals A and B is defined as the half scale

At this position, the resistance across terminals A and B is defined as the half scale

position resistance R_h.

.

The design can be approached by recognizing the fact that when R The

design can be approached by recognizing the fact that when R

The design can be approached by recognizing the fact that when R_h is connected across A and B the meter current reduces to one half of its full scale value or with R

across A and B the meter current reduces to one half of its full scale value or with R

across 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

, where I_m = current through the meter, I_{fs} = current through the meter

= current through the meter

for full scale deflection.

for full scale deflection.

This clearly means that R

This clearly means that R_h is equal to the internal resistance of the ohmmeter looking

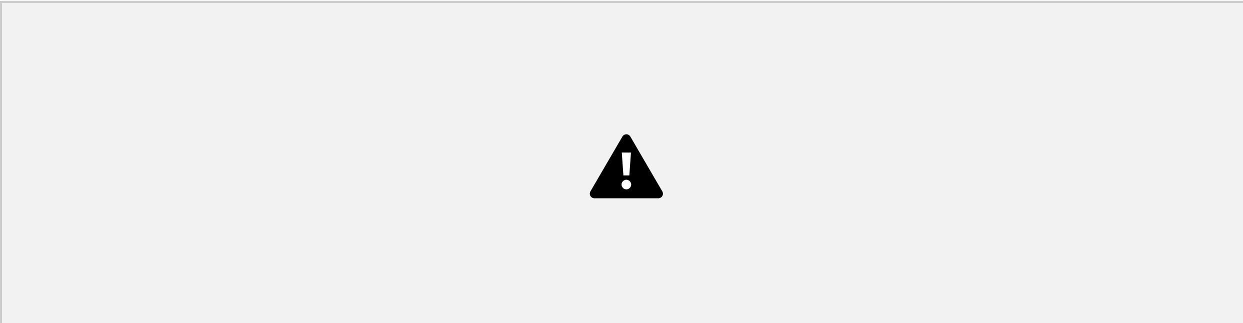
he internal resistance of the ohmmeter looking

into terminals A and B.

into terminals A and B.

Fig

<u>SHUNT TYPE OHMMETER:-</u>



Fig

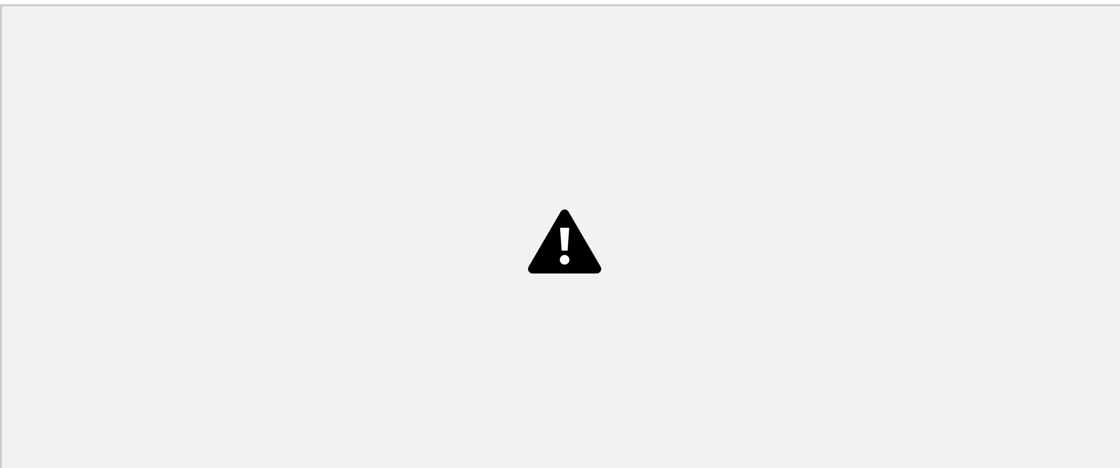
This circuit consists of a battery in series with an adjustable resistor R_1 and a basic D'Arsonval movement (meter).

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 the circuit when the instrument is not in use.

When the unknown Resistor $R_x = 0\Omega$, (i.e. A and B are shorted), the meter current is zero.

If the unknown Resistor $R_x = \infty\Omega$, (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 be made 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

2.7. <u>ANALOG MULTIMETER:-</u>

The main part of an analog multi meter is the D'Arsonval meter movement also known as the 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 a magnetic 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 meter movement.

The PMMC movement cannot be used directly for ac measurements since the inertia of PMMC acts as an averager.

Since ac current has zero average value and it produces a torque that has also zero average value, the pointer just vibrates around zero on the scale.

In order to make ac measurements, a bridge rectifier circuit is combined with PMMC as shown in figure below.

Fig

<u>3rd CHAPTER</u>

<u>DIGITAL INSTRUMENTS</u>

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 from the 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 indicating tubes.

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

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 the unknown 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 decrease with 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 decade counting 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 the magnitude 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 a meter.

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 the full-scale value of the lowest voltage range multiplied by the resolution of the meter .In other words,

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 relationship with 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 when the frequency signal through frequency divider.

Diagram of digital frequency meter as shown

in Fig.

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

Oscillator circuit and frequency division circuit

(1) Oscillator circuit

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

(2) Frequency division circuit : Oscillator produce a rectangle wave is 500Hz, using frequency

Oscillator produce a rectangle wave is 500Hz, using frequency

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

HZ. hree 74LS90 can divided 500HZ rectangular pulse into

0.5 HZ.

hree 74LS90 can divided 500HZ rectangular pulse into 0.5 HZ.

DIGITAL MULTIMETER

DIGITAL MULTIMETER

A Digital multimeter offers increased versatility due to its additional capability to measure A.C

A Digital multimeter offers increased versatility due to its additional capability to measure A.C

A Digital multimeter offers increased versatility due to its additional capability to measure A.C

voltage and current, D.C voltage and current, resistance.
D.C voltage and current, resistance.

The FIG. Shows the block diagram of a digital multimeter (DMM)
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 In the “A.C voltage mode” ,the applied input is fed through a calibrated/ compensated
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
attenuator ,to a precision fu;; wave rectifier a ripple reduction filter
circuit followed by

• The resulting D.C fed to ADC and the subsequent display system.
The resulting D.C fed to ADC and the subsequent display system.

• Fr current measurements the drop across an internal calibrated shunt is measured ,directly Fr

current measurements the drop across an internal calibrated shunt is measured ,directly

Fr current measurements the drop across an internal calibrated shunt is measured ,directly
By the ADC in the “D.C current mode” , and after A.C to D. C conversion i
By the ADC in the “D.C current mode” , and after A.C to D. C conversion i
By 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.

current mode". This drop is often in the range of 200 mv.

• Due to lack of precision in the A.C

Due to lack of precision in the A.C –D.C conversions, the accuracy in the A.C range is in

D.C conversions, the accuracy in the A.C range is in

general of the order of 0.2 to 0.5%. In addition , the measurement range is often limited to

general of the order of 0.2 to 0.5%. In addition , the measurement range is often limited to

general of the order of 0.2 to 0.5%. In addition , the measurement range is often limited to

about 50 Hz at the lower frequency end due to the ripple in the rectified signal becoming a

out 50 Hz at the lower frequency end due to the ripple in the rectified signal becoming a

out 50 Hz at the lower frequency end due to the ripple in the rectified signal becoming a

non negligible percentage of the display and hence in fluctuation of the displayed number.

non negligible percentage of the display and hence in fluctuation of the displayed number.

non negligible percentage of the display and hence in fluctuation of the displayed number.

• In the resistance range the multimeter operates by measuring the voltage ac

In the resistance range the multimeter operates by measuring the voltage ac

In the resistance range the multimeter operates by measuring the voltage across the externally

connected resistance ,resulting from a current forced through it from a calibrated internal

connected resistance ,resulting from a current forced through it from a calibrated internal

connected 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 be 200Ω 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 displayed by 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 equation/= 1/T. •

[Page **23**]

DIGITAL TACHOMETER

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

Let us assume, that the rpm of a rotating shaft is R. Let P be the number of pulses produced by the pick up for one revolution of the shaft. Therefore, in one minute 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 period as 60/ P, and the counter counts

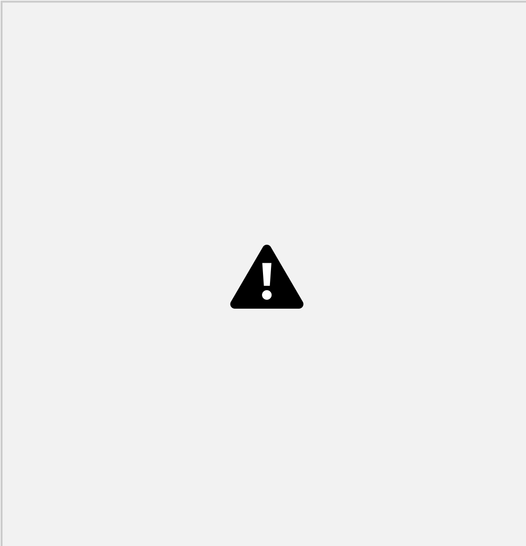
(Rx P x 60)/ 60P = R pulses

and we can read the rpm of the rotating shaft directly. So, the relation between the gate period and the number of pulses produced by the pickup is G = 60/P. If we fix the gate period as one second (G = 1 s), then the revolution pickup must be capable of producing 60 pulses per revolution.

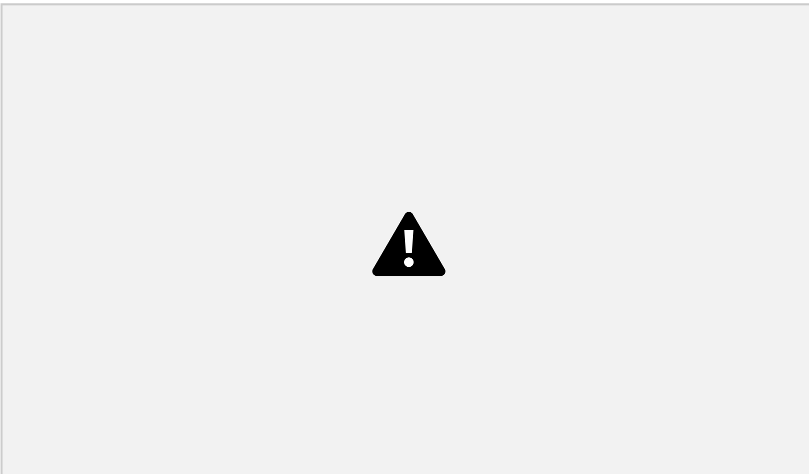
Figure shows a schematic diagram of a digital tachometer.

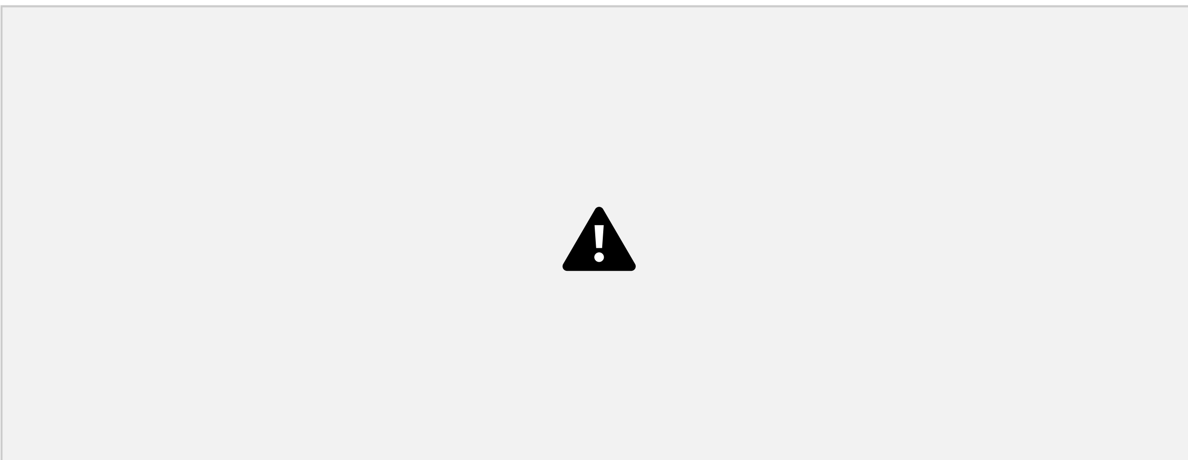
AUTOMATION

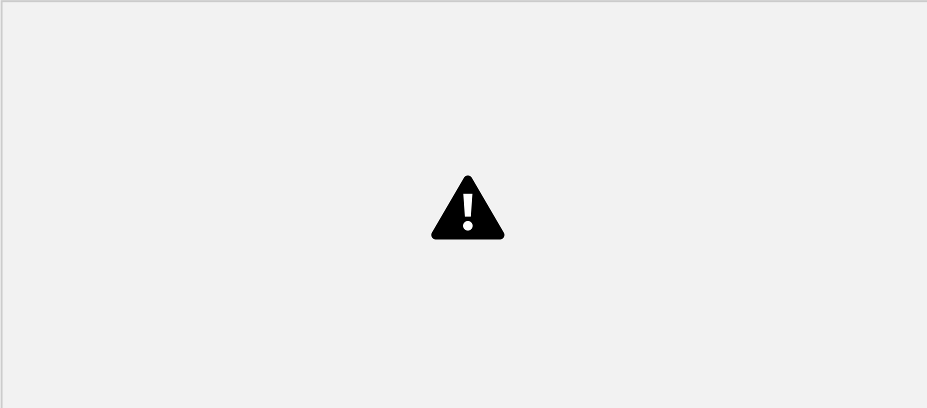
1. **Automatic Polarity Indication** :The polarity indication is generally obtained from the information in the ADC. For integrating ADCs, only the polarity of the integrated signal is of importance. The polarity should thus be measured at the very end of the integration period (see Fig. 6.21). As the length of the integration period is determined by counting a number of clock pulses, it is logical to use the last count or some of the last counts to start the polarity measurement. The output of the integrator is then used to set the polarity flip-flop, the output of which is stored in memory until the next measurement is made.



2. **Automatic Ranging**: The object of automatic ranging is to get a reading with optimum resolution under all circumstances (e.g. 170 m V should be displayed as 170.0 and not as 0.170). Let us take the example of a 3Yz digit display, i.e. one with a maximum reading of 1999. This maximum means that any higher value must be reduced by a factor of 10 before it can be displayed (e.g. 201 m Vas 0201). On the other hand, any value below 0200 can be displayed with one decade more resolution (e.g. 195 mV as 195.0). In other words, if the display does not reach a value of 0200, the instrument should automatically be switched to a more sensitive range, and if a value of higher than 1999 is offered, the next less sensitive range must be selected.







DIGITAL LCR METER

This type of meter is used to measure the resistance , inductance ,capacitance and dissipation factor. The desired function can be selected by using a rotary switch . The various ranges available are

1) 200μH/pF/Ω , 2) 2000μH/pF/Ω , 3) 200mH/nF/kΩ , 4) 200mH/nF/kΩ , 5) 2H/μF/MΩ

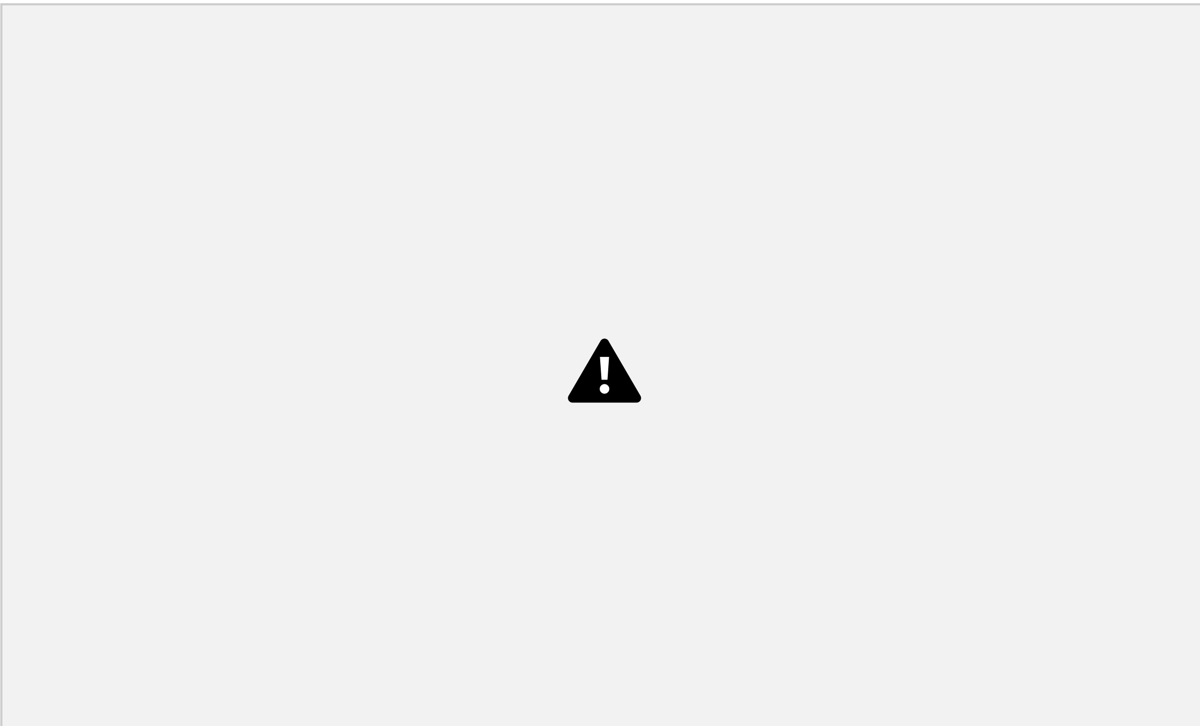
With the help of this instrument , the following ranges of various measurements can be made Resistance : From 200 Ω to 20 M Ω;
Inductance : From 2000 μH to 2 H ;
Capacitance : From 2000 pF to 2 μF

CHAPTER -4

4.OSCILLOSCOPE

4.1 Discuss the basic principle of Oscilloscope.

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

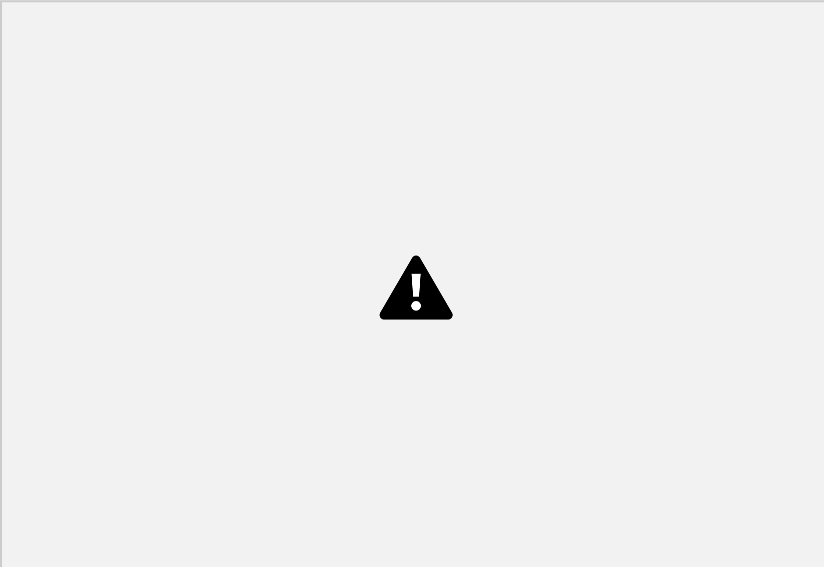


4.2 Discuss the Block Diagram of Oscilloscope & Simple CRO.

The block diagram of simple CRO is as shown in figure below.Here the Oscilloscopes are used to observe the change of an electrical signal over time, such that voltage and time describe a shape which is continuously graphed against a calibrated scale. The observed waveform can be analyzed for such propertiesas amplitude, frequency,rise time, time interval, distortion and others. Modern digital instruments may calculate and display these properties directly. Originally, calculation of these values required manually measuring the waveform against the scales built into the screen of the instrument.

The oscilloscope can be adjusted so that repetitive signals can be observed as a continuous shape on the screen. A storage oscilloscope allows single events to be captured by the instrument and displayed for a relatively long time, allowing human observation of events too fast to be directly perceptible.

Oscilloscopes are used in the sciences, medicine, engineering, and telecommunications industry. General-purpose instruments are used for maintenance of electronic equipment and laboratory work. Special-purpose oscilloscopes may be used for such purposes as analyzing an automotive ignition system or to display the waveform of the heartbeat as an electrocardiogram.



4.3 Discuss the block diagram of Dual Trace Oscilloscope:

Dual Trace CRO:

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

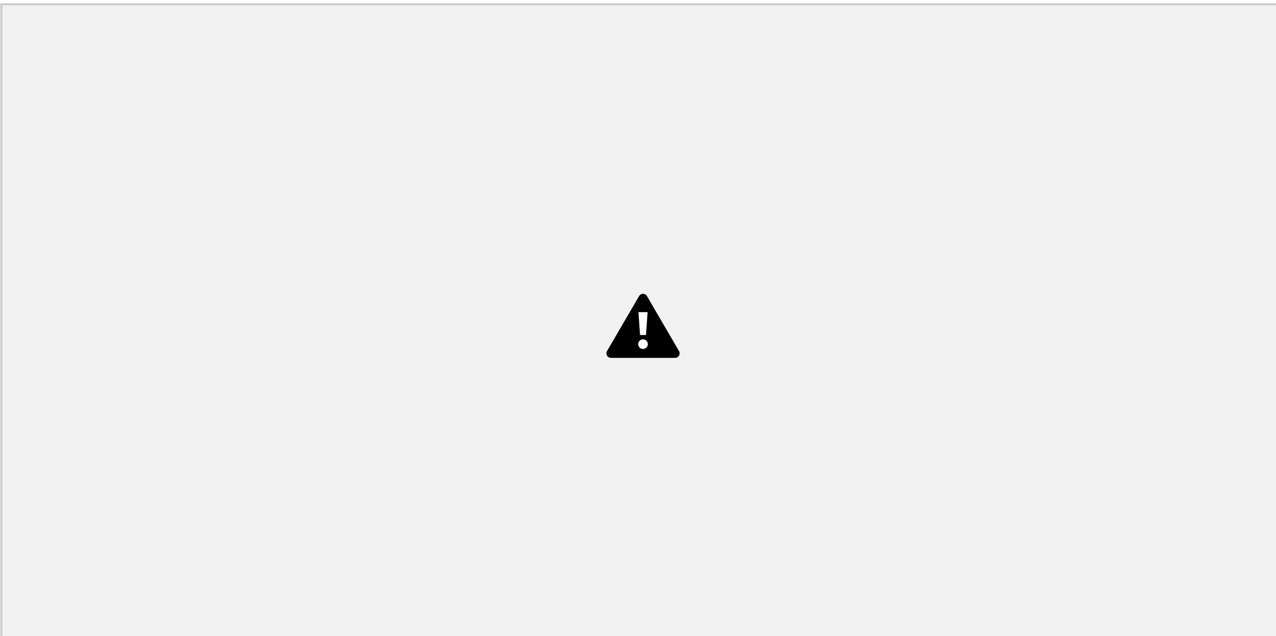
1. Electronics gun (single)

2.Separate vertical input channels (Two)

3. Attenuators

4.pr-amplifiers

5. Electronic switch.



The two separate input signals can be applied to single electron gun **with the help of** electronic switching **it Produces a dual trace display .Each separate vertical input channel are uses separate** attenuators and pr-amplifier **stages, so the amplitude of each signal can**

be independently controlled. Output of the pr-amplifiers is given to the electronic switch, which passes one signal at a time into the main vertical amplifier **of the oscilloscope.**

The time base-generator **is similar to that of single input oscilloscope.**

By using switch S2 the circuit can be triggered **on either A or B channel, waveforms, or an external signal, or on line frequency. The** horizontal amplifier **can be fed from sweep generator or from channel B by switching S1. When switch S, is in channel B, itsoscilloscope operates in the X-Y mode in which channel A acts as the vertical input signal andchannelBasthe horizontal inputsignal.**

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

2.Chopmode.

4.4 Discuss the Dual Trace CRO Specification:

Specifications:30MHZ Dual Trace CRO

Vertical Sensitivity accuracy 1mV/DIV to 2mV/DIV: ±5%

5mV/DIV to 5V/DIV: ±3%

Bandwidth 1mV/DIV to 2mV/DIV: DC to 7MHz

5mV/DIV to 5V/DIV: DC to 30MHz

AC coupling > 10Hz (reference: 100kHz, 8DIV, –3dB)

Rise time 1mV/DIV to 2mV/DIV: Approx. 50nS ,5mV/DIV to 5V/DIV: Approx. 11.7nS

Input impedance Approx. 1M ohm // 25pF.

Square wave characteristics≤ 5% Overshoot at 10mV/DIV

Other ranges: 5% added to the above

Linearity ±0.1DIV when moving 2 DIV at center

Vertical mode CH1, CH2, DUAL, ADD

Chop frequency Approx. 250kHz

Input coupling AC, GND, DC

Max input voltage CAT II 300Vpeak (AC: ≤ 1kHz)

Max effective readout

Probe1:1 40Vpp (14Vrms Sine wave)

Probe10:1 400Vpp (140Vrms Sine wave)

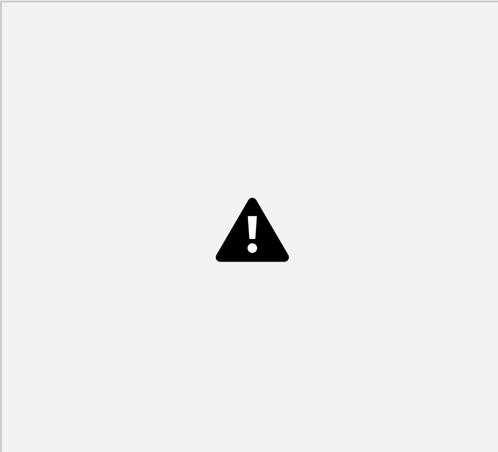
Common mode rejection ratio ≥ 50:1 at 50kHz sine wave (CH1 and CH2 vertical scales are equal)

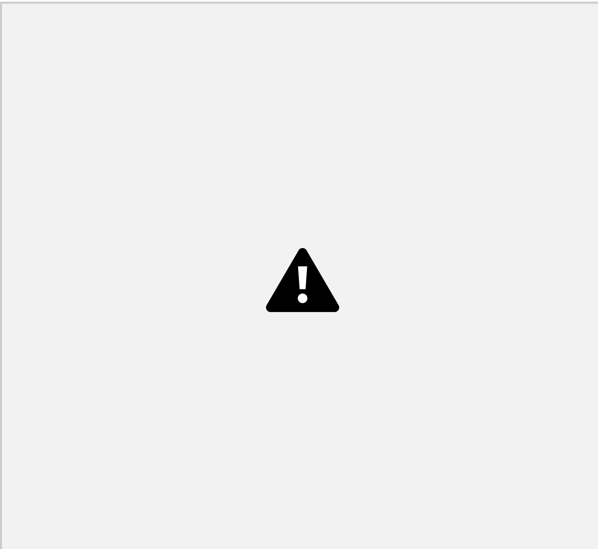
Channel isolation @ 5mV/DIV >1000:1 at 50kHz>30:1 at 30MHz

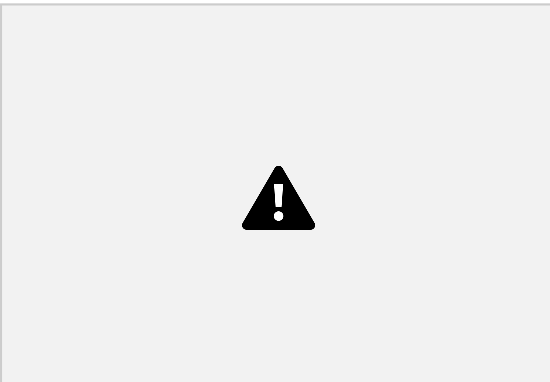
CH1 signal output ≥ 20 mV/DIV @ 50Ω, 50Hz to 5MHz

CH2 INV BAL. ≤1 DIV (Reference at centergraticule)

4.5 Explain the use of Lissajous method for Phase & Frequency Measurement.

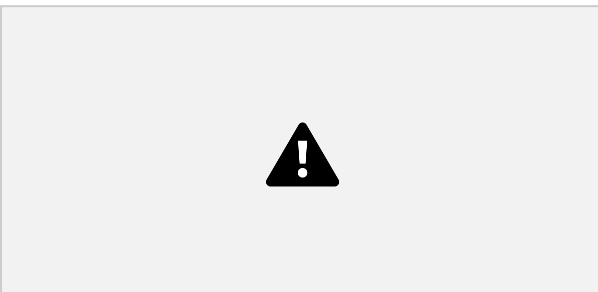


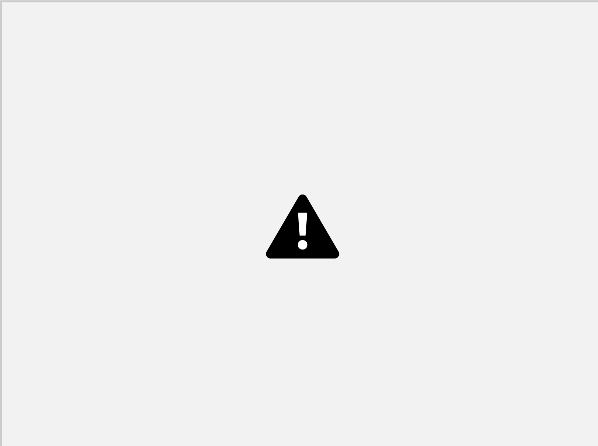




4.6 Application of Oscilloscope.

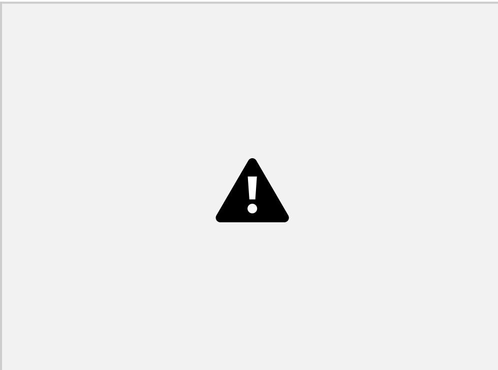
Time Period Measurement:

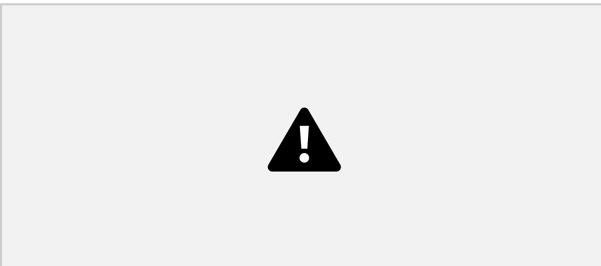




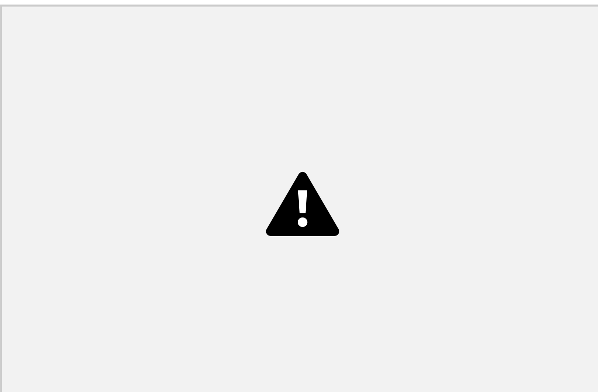
Voltage Period Measurement:

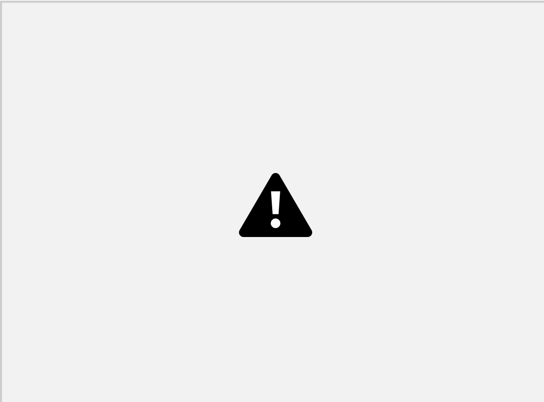
[Page **33**]

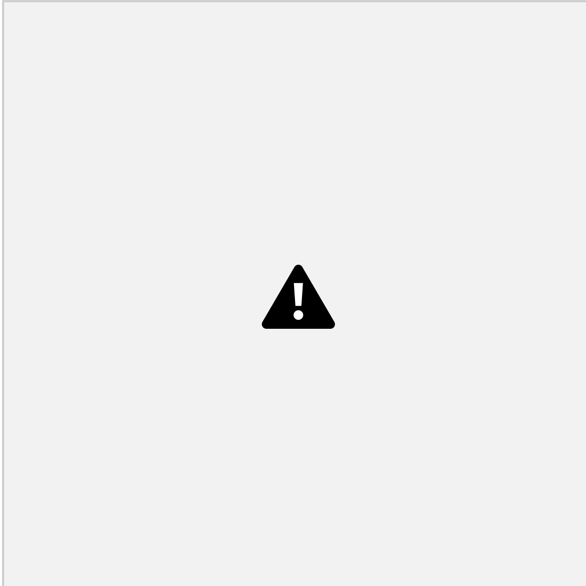




Phase Measurements:

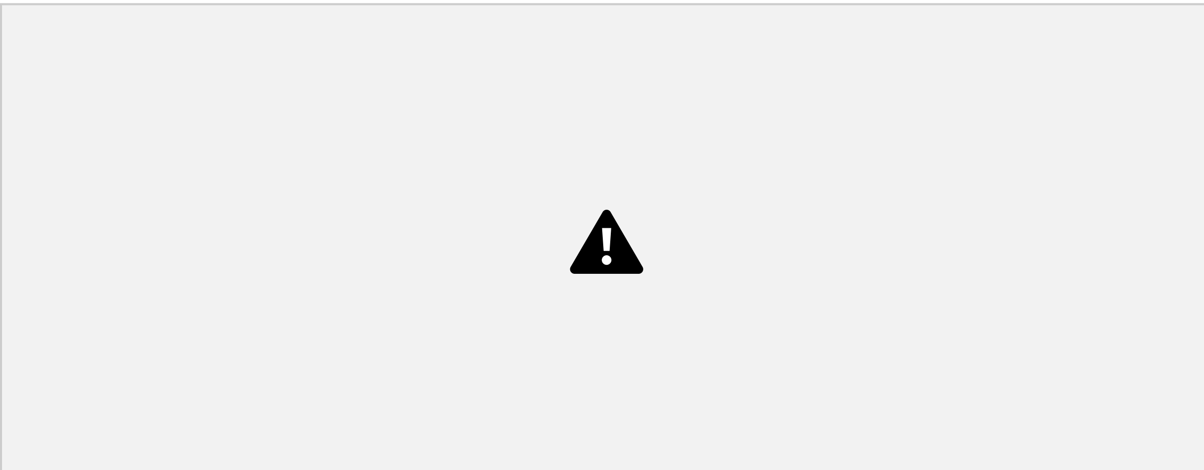


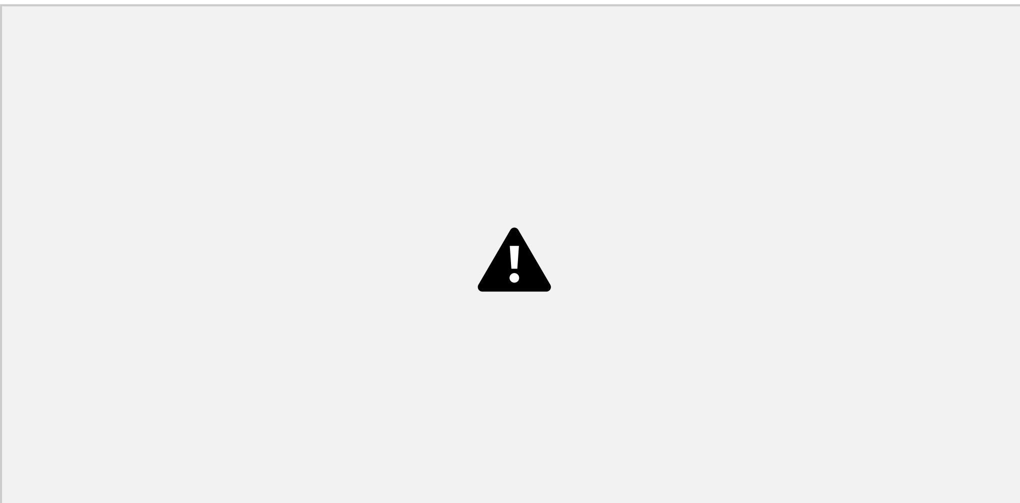




4.7 Explain the operation of Digital Storage Oscilloscope.

Digital Storage Oscilloscope:





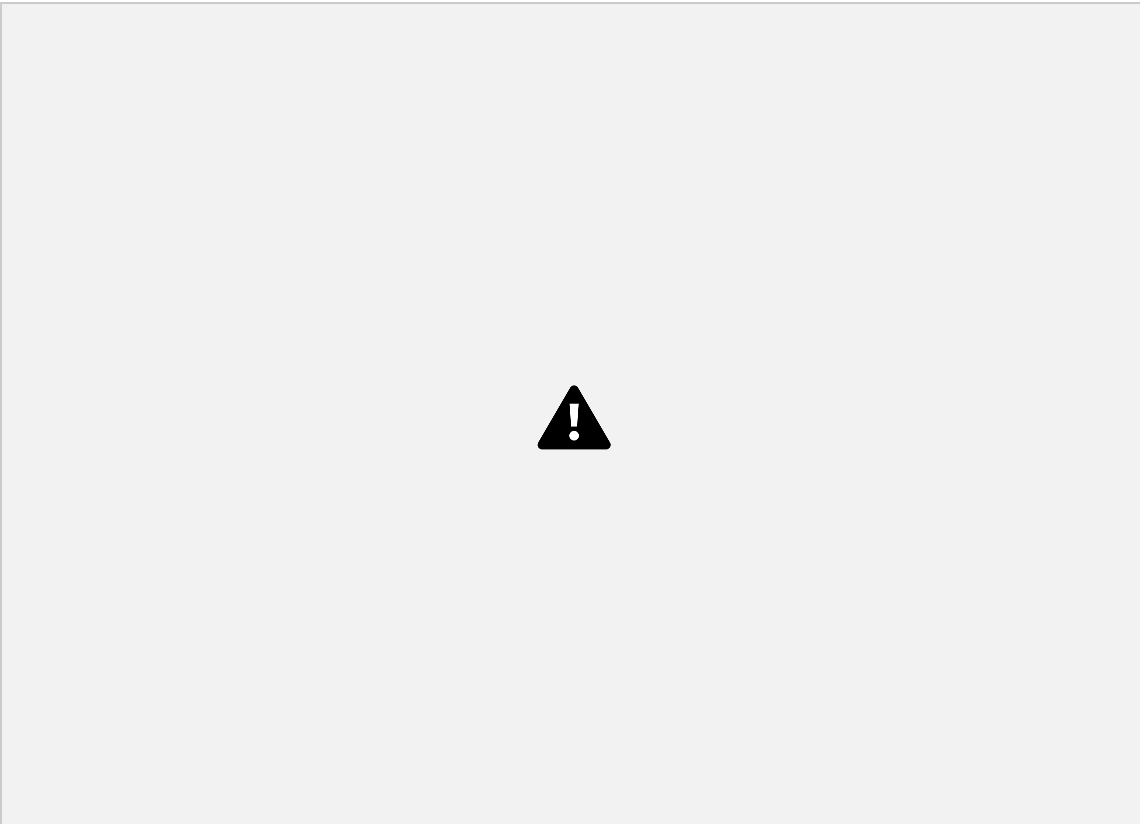
CHAPTER -5

5. BRIDGES:

5.1 Explain the working of Wheatstone Bridge(Measurement of Resistance)

Wheatstone Bridge

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



Wheatstone Bridge Theory

The general arrangement of **Wheatstone bridge circuit** is shown in the figure below. It is a four arms bridge circuit where arm AB, BC, CD and AD are consisting of electrical resistances P, Q, S and R respectively. Among these resistances P and Q are known fixed electrical resistances and these two arms are referred as ratio arms. An accurate and sensitive Galvanometer is connected between the terminals B and D through a switch S_2. The voltage source of this Wheatstone

bridge is connected to the terminals A and C via a switch S_1 as shown. A variableresistor S is connected between point C and D. The potential at point D can be varied by adjusting the value of variable resistor. Suppose electric current I_1 and electric current I_2 are flowing through the paths ABC and ADC respectively. If we vary the electrical resistance value of arm CD the value of electric current I_2 will also be varied as the voltage across A and C is fixed. If we continue to adjust the variable resistance one situation may comes when voltage drop across the resistor S that is $I_2.S$ is becomes exactly equal to voltage drop across resistor Q that is $I_1.Q$. Thus the potential at point B becomes equal to the potential at point D hence potential difference between these two points is zero hence electric current through galvanometer is nil. Then the deflection in the galvanometer is nil when the switch S_2 is closed.

Now, from **Wheatstone bridge circuit**

and

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

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

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

Here in the above equation, the value of S and P/Q are known, so value of R can easily be determined.

The electrical resistances P and Q of the Wheatstone bridge are made of definite ratio such as 1:1; 10:1 or 100:1 known as ratio arms and S the rheostat arm is made continuously variable from 1 to 1,000 Ω or from 1 to 10,000 Ω

AC Bridges

AC Bridges consist of a source, balance detector and four arms. In AC bridges, all the four arms consists of impedance. The AC bridges are formed by replacing the DC battery with an AC source and galvanometer by detector of Wheatstone bridge.They are highly useful to find out inductance, capacitance, storage factor, dissipation factor etc.

Now let us derive general expression for an AC bridge balance

Figure given below shows AC bridge network:

Here Z_1, Z_2, Z_3 and Z_4 are the arms of the bridge.

Now at the balance condition, the potential difference between b and d must be zero. From this, when the voltage drop from froma to d equals to drop from a to b both in magnitude and phase.

Thus, we have from figure $e_1 = e_2$

5.2 Explain the measurement of self inductance by Maxwells

Bridge: **MAXWELLS BRIDGE:**

This bridge is used to find out the self inductor and the quality factor of the circuit. As it is based on the bridge method (i.e. works on the principle of null deflection method), it gives very accurate results. **Maxwell bridge** is an AC bridge so before going in further detail let us know more about the ac bridge.

Let us now discuss **Maxwell's** inductor **bridge**. The figure shows the circuit diagram of Maxwell's inductor bridge.

[Page **39**]

In this bridge the arms bc and cd are purely resistive while the phase balance depends on the arms ab and ad.

Here l_1 =Unknown inductor of r_1.

l_2 =Variable inductor ofresistanceR_2.

r_2 =variable electricalresistance.

As we have discussed in ac bridge according to balance condition, we have at balance point

We can vary R_3 and R_4 from 10 ohms to 10,000 ohms with the help of resistance box.

Maxwell's Inductance Capacitance Bridge

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

Maxwell's Inductance Capacitance Bridge

Here, I_1 is unknown inductance, C_4 is standard capacitor.

Now under balance conditions we have from ac bridge that $Z_1.Z_4 = Z_2.Z_3$

Let us separate the real and imaginary parts, the we have,

Now the quality factor is given by,

Advantages of Maxwell's Bridge

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

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

Disadvantages of Maxwell's Bridge

(1)The variable standard capacitor is very expensive.

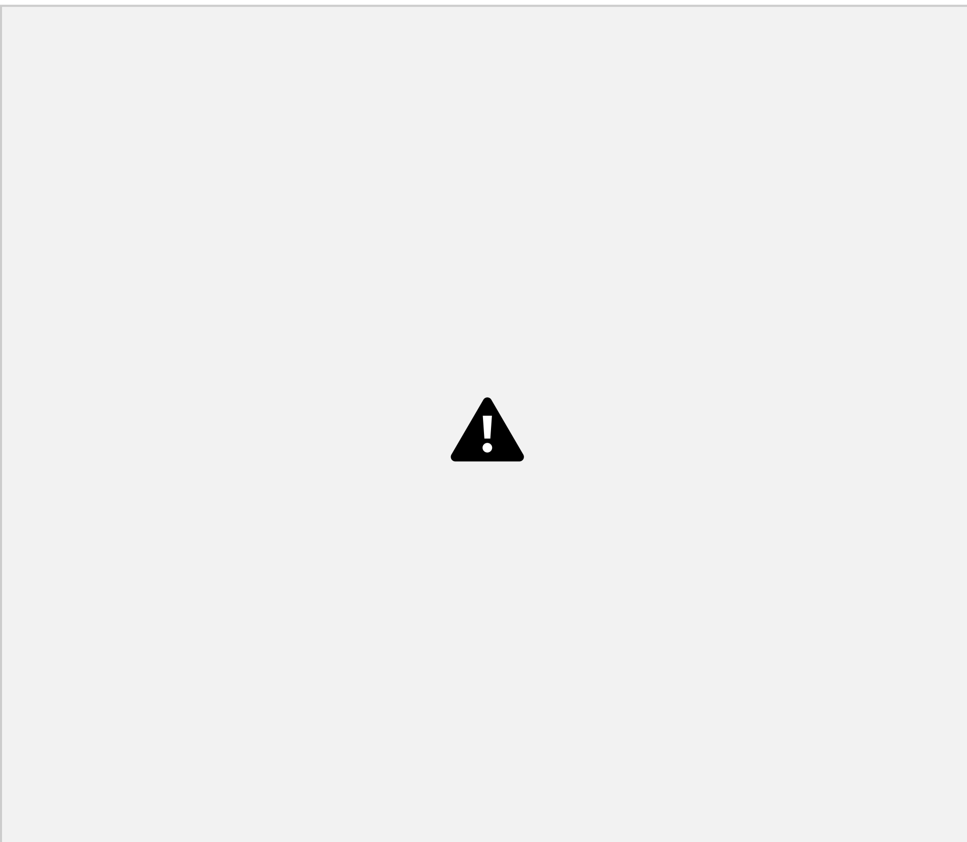
(2) The bridge is limited to measurement of low quality coils ($1 < Q < 10$) and it is also unsuitable for low value of Q (i.e. $Q < 1$) from this we conclude that a Maxwell bridge is used suitable only for medium Q coils.

The above all limitations are overcome by the modified bridge which is known as Hey'sbridgewhich does not use an electrical resistance in parallel with the capacitor.

5.3 Explain the measurement of self inductance by Hay’s Bridge:

Hay's Bridge :

A **Hay's bridge** is modified Maxwell bridge, now question arises here in our mind that where we need to do modification. In order to to understand this, let us consider the connection diagram given below:



Hay's Bridge Circuit

In this bridge the electrical resistance is connected in series with the standard capacitor. Here l_1 is unknown inductor connected in series with resistance r_1. c_4 is standard capacitor and r_2, r_3, r_4 are pure electrical resistance forming other arms of the bridge.

From the theory of ac bridge we can write at balance point,

Substituting the values of z_1, z_2, z_3 and z_4 in equation (1) we get,

Now, Q factor of a coil is given by

The equations (4) and (5) are dependent on the source frequency hence, in order to find the accurate value of l_1 and r_1 we should know the correct value of source frequency. Let us rewrite the expression for l_1,

Now if we substitute Q >10 then $1/Q^2 = 1 / 100$ and hence we can neglect this value, thus neglecting $1/Q^2$ we get $r_2 r_3 c_4$ which is same as we have obtained in Maxwell bridge hence **Hay's bridge circuit** is most suitable for high inductor measurement.

Hay's Bridge Applications

Before we introduce **Hay's bridge** let us recall the limitations of Maxwell bridge, in order to understand what is the necessity of **Hay's bridge applications**. Maxwell bridge is only suitable for measuring medium quality factor coils however it is not suitable for measuring high quality factor (Q > 10). In order to to overcome from this limitation we need to do modification inMaxwellbridge so that it will become suitable for measuring Q factor over a wide range. This modified Maxwell bridge is known as **Hay's bridge**.

Advantages of Hay's Bridge

(1) The bridge gives very simple expression for the calculation of unknown inductor of high value. The Hay's bridge require low value of r_4 while Maxwell bridge requires high value of r_4. Now let us analyse why should put low value of r_4 in this bridge:

Consider the expression of quality factor,

As r_4 presents in the denominator hence for high quality factor, r_4 must be small.

Disadvantages of Hay's Bridge

Hay's bridge is not suitable for measurement of quality factor (Q<10) for Q<10 we should useMaxwell bridge.

5.4 Explain the measurement of self inductance by Schering Bridge:

Schering Bridge Theory

This bridge is used to measure to the capacitance of the capacitor, dissipation factor and measurement of relative permittivity. Let us consider the circuit of Schering bridge as shown below:

Here, c_1 is the unknown capacitance whose value is to be determined with series electrical

resistance r_1.

c_2 is a standard capacitor.

c_4 is a variable capacitor.

r_3 is a pure resistor (i.e. non inductive in nature).

And r_4 is a variable non inductive resistor connected in parallel with variable capacitor c_4.

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

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

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

Application:

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

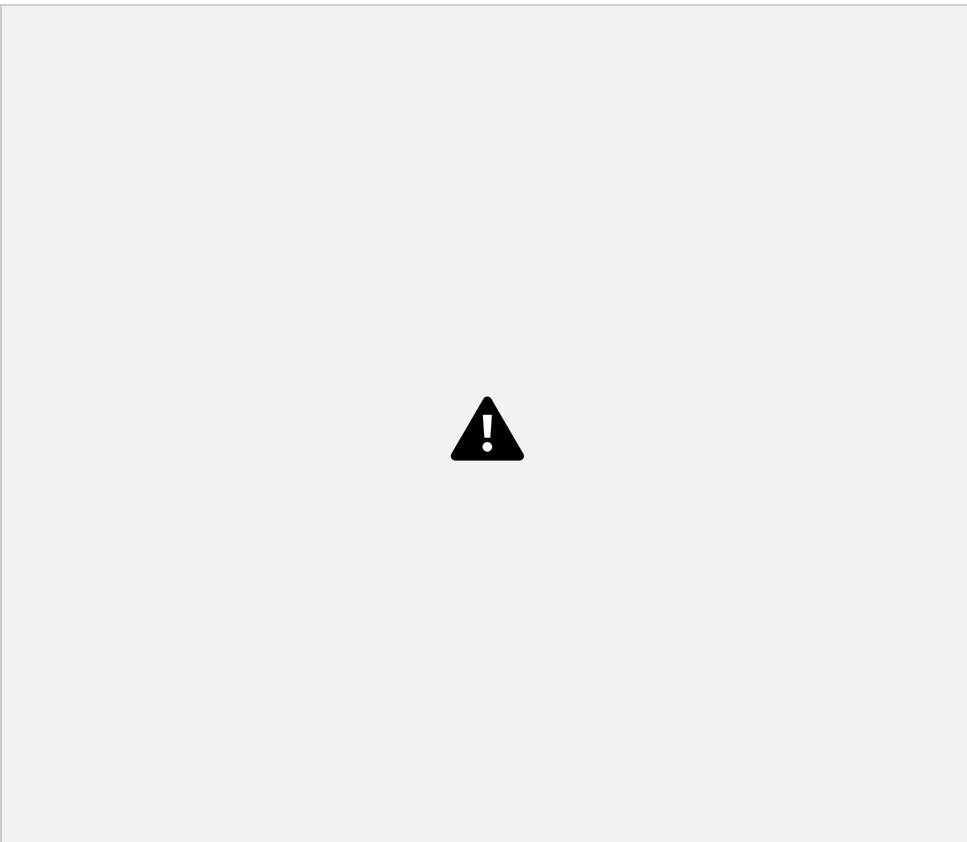
5.5 Explain the measurement of Capacitanve by Wein,sBridge:

Theory of Owen's Bridge

We have various bridges to measure inductor and thus quality factor, like Hay's bridge is highly suitable for the measurement of quality factor greater than 10, Maxwell's bridge is highly suitable for measuring medium quality factor ranging from 1 to 10 and Anderson bridge can be successfully used to measure inductor ranging from few micro Henry to several Henry. So what is the need of **Owen's bridge**?.

The answer to this question is very easy. We need a bridge which can measure inductor over wide range. The bridge circuit which can do that, is known as Owen's bridge. It is ac bridge just like Hay's bridge and Maxwell bridge which use standard capacitor, inductor and variableresistors connected with ac source for excitation. Let us study **Owen's bridge circuit** in more detail.

An Owen's bridge circuit is given below.



The ac supply is connected at a and c point. The arm ab is having inductor having some finiteresistance let us mark them r_1 and l_1. The arm bc consists of pure electrical resistance marked by r_3 as shown in the figure given below and carrying the electric current i_1 at balance point which is same as the electric current carried by arm ab. The arm cd consists of pure capacitorhaving no electrical resistance.The arm ad is having variable resistance as well as variablecapacitor and the detector is connected between b and d. Now how this bridge works? this bridge measures the inductor in terms of capacitance. Let us derive an expression for inductorfor this bridge.

Here l_1 is unknown inductance. And c_2 is variable standard capacitor.

Now at balance point we have the relation from ac bridge theory that must hold good i.e.

Putting the value of z_1, z_2, z_3 and in above equation we get,

Equating and then separating the real and the imaginary parts we get the expression for l_1 and r_1 as written below:

Advantages of Owen's Bridge

(1) The for inductor l_1 that we have derived above is quite simple and is independent of frequency component.

(2) This bridge is useful for the measurement of inductor over wide range.

Disadvantages of Owen's Bridge

(1) In this bridge we have used variable standard capacitor which is quite expensive item and also the accuracy of this is about only one percent.

(2) As the measuring quality factor increases the value of standard capacitor required increases thus expenditure in making this bridge increases.

5.6 Discuss the working principle of Q Meter.

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:

This expression applies to an
This expression applies to an RF and microwave filter, bandpass LC filter
LC filter, or any

resonator. It also can be applied to an inductor or capacitor at a chosen frequency. For

resonator. It also can be applied to an inductor or capacitor at a chosen frequency. For

resonator. It also can be applied to an inductor or capacitor at a chosen frequency. For

inductors

Where is the reactance of the inductor,
is the reactance of the inductor, is the resistance of the inductor. The resistance

is the inductance, is the angular represents the

frequency and is the

loss in the inductor, mainly due to the resistance of the wire.Q meter works on the

loss in the inductor, mainly due to the resistance of the wire.Q meter works on the

loss in the inductor, mainly due to the resistance of the wire.Q meter works on the

principle of series resonance.

principle of series resonance.

For LC band pass circuits and filters:
For LC band pass circuits and filters:

Where is the resonant frequency (cente
is the resonant frequency (center frequency) and
r frequency) and is the filter

bandwidth. In a band pass filter using an
bandwidth. In a band pass filter using an LC resonant circuit
LC resonant circuit, when the loss

(resistance) of the inductor increases, its Q is reduced, and so the bandw

(resistance) of the inductor increases, its Q is reduced, and so the bandw (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 the filter is increased. In a coaxial cavity filter, there are no inductors and 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) capacitors, but the cavity has an equivalent LC model with losses (resistance) capacitors, but the cavity has an equivalent LC model with losses (resistance) and the Q factor can be applied as well.\
and the Q factor can be applied as well.

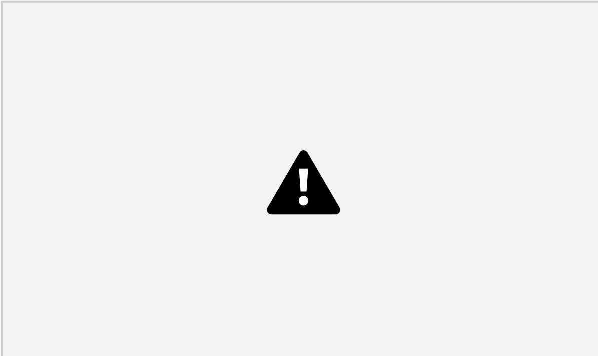
Internally a minimal Q meter consists of a\ tuneable RF generator, with a very
Internally a minimal Q meter consists of eable RF generator, with a very
a

low impedance output, and a detector with a very high impedance input. low impedance output, and a detector with a very high impedance input. low impedance output, and a detector with a very high impedance input. Additionally there is usually provision to add calibrated amounts of high Q Additionally there is usually provision to add calibrated amounts of high Q Additionally there is usually provision to add calibrated amounts of high Q capacitance across the component under test to allow inductors to be measured
capacitance across the component under test to allow inductors to be measured 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 in isolation. The generator is effectively placed in series with the tuned circuit in isolation. The generator is effectively placed in series with the tuned circuit formed by the components under test, and having negligible output resistance, formed by the components under test, and having negligible output resistance, formed by the components under test, and having negligible output resistance, does not materially affect the Q factor, while the detector measures the voltage does not materially affect the Q factor, while the detector measures the voltage does not materially affect the Q factor, while the detector measures the voltage developed across one element (usually the capacitor) and being high impedance oss one element (usually the capacitor) and being high impedance oss one element (usually the capacitor) and being high impedance in shunt does not affect the Q factor significantly either. The ratio of the in shunt does not affect the Q factor significantly either. The ratio of the 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 developed RF voltage to the applied RF
current, coupled with knowledge 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.

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 high and 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 of the 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

$$X_L = X_C$$

$$\text{Or } IX_L = IX_C = V_C$$

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}.

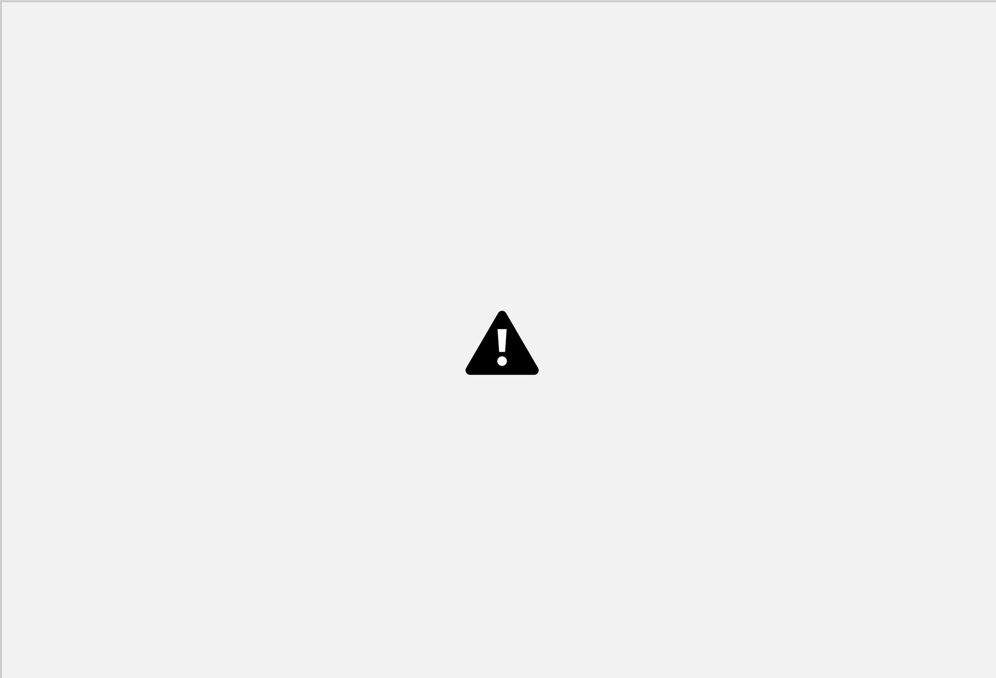
The inductance of the coil can also be computed from the known values of frequency f and resonating capacitor C as follows.

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

5.8Discuss the working principle of LCR Bridge:

LCR METER:

An **LCR meter** is a piece of electronic test equipment used to measure the inductance (L), capacitance (C), and resistance (R) of a component. In the simpler versions of this instrument the true values of these quantities are not measured; rather the impedance is measured internally and converted for display to the corresponding capacitance or inductance value. Readings will be reasonably accurate if the capacitor or inductor device under test does not have a significant resistive component of impedance. More advanced designs measure true inductance or capacitance, and also the equivalent series resistance of capacitors and the Q factor of inductive components.

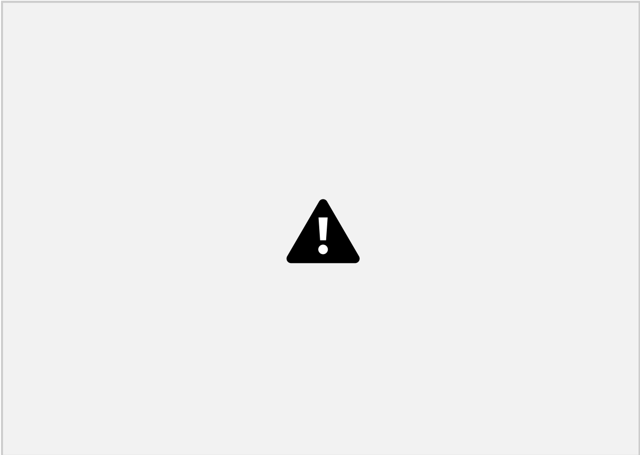


Usually the device under test (DUT) is subjected to an AC voltage source. The meter measures the voltage across and the current through the DUT. From the ratio of these the meter can determine the magnitude of the impedance. The phase angle between the voltage and current is also measured in more advanced instruments; in combination with the impedance, the equivalent capacitance or inductance, and resistance, of the DUT can be calculated and displayed. The meter must assume either a parallel or a series model for these two elements. The most useful assumption, and the one usually adopted, is that LR measurements have the elements in series (as would be encountered in an inductor coil) and that CR measurements have the elements in parallel (as would be encountered in measuring a capacitor with a leaky dielectric). An LCR meter can also be used to judge the inductance variation with respect to the rotor position in permanent magnet machines (however care must be taken as some LCR meters can be damaged by the generated EMF produced by turning the rotor of a permanent-magnet motor).

Hand held LCR meters typically have selectable test frequencies of 100 Hz, 120 Hz, 1 kHz, 10 kHz, and 100 kHz for top end meters. The display resolution and measurement range capability will typically change with test frequency.

Benchtop LCR meters typically have selectable test frequencies of more than 100 kHz. They often include possibilities to superimpose a DC voltage or current on the AC measuring

signal. Lower end meters offer the possibility to externally supply these DC voltages or currents while higher end devices can supply them internally. In addition benchtop meters allow the usage of special fixtures to measure SMD components, air-core coils or transformers.



n order to understand the concept of **errors in measurement**, we should know the two terms that defines the error and these two terms are written below:

True Value

It is not possible to determine the true of quantity by experiment means. True value may be defined as the average value of an infinite number of measured values when average deviation due to various contributing factor will approach to zero.

Measured Value

It may be defined as the approximated value of true value. It can be found out by taking means of several measured readings during an experiment, by applying suitable approximations on physical conditions.

Now we are in a position to define static error. Static error is defined as the difference of the measured value and the true value of the quantity. Mathematically we can write an expression of error as, $dA = A_m - A_t$ where dA is the static error A_m is measured value and A_t is true value.

It may be noted that the absolute value of error cannot be determined as due to the fact that the true value of quantity cannot be determined accurately.

Let us consider few terms related to errors.

Limiting Errors or Guarantee Errors

The concept of guarantee errors can better clear if we study this kind of error by considering one example. Suppose there is a manufacturer who manufacture an ammeter, now he should promises that the error in the ammeter he is selling not greater the limit he sets. This limit of error is known as limiting errors or guarantee error.

Relative Error or Fractional Error

It is defined as the ratio of the error and the specified magnitude of the quantity. Mathematically we write as,

Where dA is the error and A is the magnitude.

Now here we are interested in computing resultant limiting error under the following cases:

(a) By taking the sum of two quantities: Let us consider two measured quantities a_1 and a_2. The sum of these two quantities can be represented by A. Thus we can write $A = a_1 + a_2$. Now the relative incremental value of this function can be calculated as

Separating the each term as shown below and by multiplying and dividing a_1 with the first term and a_2 with the second term we have

From the above equation we can see that the resultant limiting error is equal to the sum of products formed by multiplying the individual relative limiting errors by the ratio of each term to the function. Same procedure can be applied to calculate the resultant limiting error due to summation of more than two quantities. In order to calculate the resultant limiting error due to difference of the two quantities just change the addition sign with subtraction and rest procedure is same.

(b) By taking the product of two quantities: Let us consider two quantities a_1 and a_2. In this case the product of the two quantities are expressed as $A = a_1.a_2$. Now taking log both sides and differentiating with respect to A we have resultant limiting errors as

From this equation we can see that the resultant error is summation of relative **errors in measurement** of terms. Similarly we can calculate the resultant limiting error for power of factor. Hence the relative error would be n times in this case.

Types of Errors

Basically there are three **types of errors** on the basis; they may arise from the

source. **Gross Errors**

This category of errors includes all the human mistakes while reading, recording and the readings. Mistakes in calculating the errors also come under this category. For example while taking the reading from the meter of the instrument he may read 21 as 31. All these types of error are come under this category. Gross errors can be avoided by using two suitable measures and they are written below:

(i) A proper care should be taken in reading, recording the data. Also calculation of error should be done accurately. (ii) By increasing the number of experimenters we can reduce the gross errors. If each experimenter takes different reading at different points, then by taking average of more readings we can reduce the gross errors.

Systematic Errors

In order to understand these kinds of errors, let us categorize the systematic errors

as **(i) Instrumental Errors**

These errors may be due to wrong construction, calibration of the measuring instruments. These types of error may be arises due to friction or may be due to hysteresis. These types of errors also include the loading effect and misuse of the instruments. Misuse of the instruments results in the failure to the adjust the zero of instruments. In order to minimize the gross errors in measurement various correction factors must be applied and in extreme condition instrument must be re-calibrated carefully.

(ii) Environmental Errors

This type of error arises due to conditions external to instrument. External condition includes temperature, pressure, humidity or it may include external magnetic field. Following are the steps that one must follow in order to minimize the environmental errors:

(A)Try to maintain the temperature and humidity of the laboratory constant by making some arrangements.
(B)Ensure that there should not be any external magnetic or electrostatic field around the instrument.

Observational Errors

As the name suggests these **types of errors** are due wrong observations. The wrong observations may be due to PARALLAX. In order to minimize the PARALLAX error highly accurate meters are required, provided with mirrored scales.

Random Errors

After calculating all systematic errors, it is found that there are still some errors in measurement are left. These errors are known as random errors. Some of the reasons of the appearance of these errors are known but still some reasons are unknown. Hence we cannot fully eliminate these kinds of error.

ermanent Magnet Moving Coil Instrument

The **permanent magnet moving coil instrument** or **PMMC type instrument** uses two permanent magnets in order to create stationary magnetic field. These types of instruments are only used for measuring the dc quantities as if we apply ac electric current to these type of

instruments the direction of electric
electric current will be reversed during negative half cycle and hence
will be reversed during negative half cycle and hence

the direction of torque will also be reversed which gives
the direction of torque will also be reversed which gives average value of torque zero. The

average value of torque zero. The

pointer will not deflect due to high frequency from its mean position showing zero reading.

pointer will not deflect due to high frequency from its mean position showing zero reading.

pointer will not deflect due to high frequency from its mean position showing zero reading.

However it can measure the direct

However it can measure the direct electric current very accurately.

Let us move towards the constructions of
Let us move towards the constructions of **permanent magnet moving coil instrument**

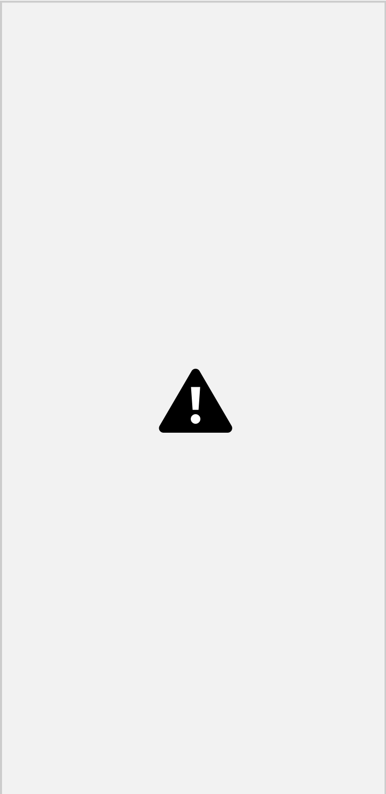
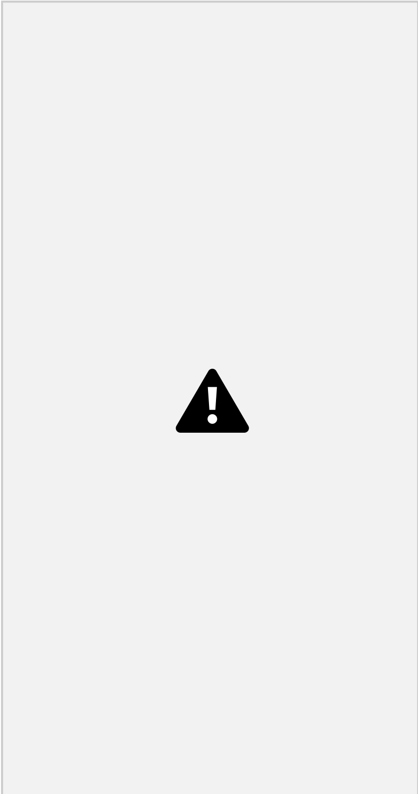
instruments. We will

see the construction of these types of instruments in five parts and they are described

below: hese types of instruments in five parts and they are

described below:

hese types of instruments in five parts and they are described below:

(a) **Stationary part or magnet**

magnet system: In the present time we use magnets of high field
In the present time we use magnets of high field

intensities, high coercive force instead of using U shaped permanent magnet having soft iron
intensities, high coercive force instead of using U shaped permanent magnet having soft iron
intensities, high coercive force instead of using U shaped permanent magnet having soft iron

pole pieces. The magnets which we are using nowadays are made up of materials like alcomax

pieces. The magnets which we are using nowadays are made up of materials like alcomax

pieces. The magnets which we are using nowadays are made up of materials like alcomax and

alnico which provide high field strength.
and alnico which provide high field strength.

(b) **Moving coil:** The moving coil can freely moves between the two permanent magnets as The moving coil can freely moves between the two permanent magnets as The moving coil can freely moves between the two permanent magnets as shown in the figure given below. The coil is wound with many turns of copper wire and is placed

shown in the figure given below. The is placed
coil is wound with many turns of copper wire and

on rectangular aluminium which is pivoted on jeweled bearings.
on rectangular aluminium which is pivoted on jeweled bearings.

(c) **Control system:** The spring generally acts as control system for PMMC instruments. The The spring generally acts as control system for PMMC instruments. The The spring generally acts as control system for PMMC instruments. The spring also serves another important functi

spring also serves another important function by providing the path to lead electric electric

current in and

out of the coil.

(d) **Damping system:** The damping force hence torque is provided by movement of aluminium former in the magnetic field created by the permanent magnets.

(e) **Meter:** Meter of these instruments consists of light weight pointer to have free movement and scale which is linear or uniform and varies with angle.

Let us derive a general expression for torque in permanent magnet moving coil instruments or**PMMC instruments**. We know that in moving coil instruments the deflecting torque is given by the expression:

T_d = NBldI where N is number of turns,

B is magnetic flux density in air gap,

l is the length of moving coil,

d is the width of the moving coil,

And I is the electric current.

Now for a moving coil instruments deflecting torque should be proportional to current, mathematically we can write T_d = GI. Thus on comparing we say G = NBIdl. At steady state we have both the controlling and deflecting torques are equal. T_c is controlling torque, on equating controlling torque with deflection torque we have GI = K.x where x is deflection thus electric current is given by

Since the deflection is directly proportional to the electric current therefore we need a uniform scale on the meter for measurement of current.

Now we are going to discuss about the basic circuit diagram of the ammeter. Let us consider a circuit as shown below:

Basic Ammeter Circuit

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The electric current I is shown which breaks into two components at the point A. The two components are I_s and I_m. Before I comment on the magnitude values of these currents, let us know more about the construction of shunt resistance. The basic properties of shunt resistanceare written below,

The electrical resistance of these shunts should not differ at higher temperature, it they should posses very low value of temperature coefficient. Also the resistance should be time independent. Last and the most important property they should posses is that they should be able to carry high value of electric current without much rise in temperature. Usually manganin is used for making dc resistance. Thus we can say that the value of I_s much greater than the value of I_m as resistance of shunt is low. From the we have,

Where R_s is resistance of shunt and R_m is the electrical resistance of the coil.

From the above two equations we can write,

Where m is the magnifying power of the shunt.

Errors in Permanent Magnet Moving Coil Instruments

There are three main types of errors: (a) Errors due to permanent magnets: Due to temperature effects and aging of the magnets the magnet may lose their magnetism to some extent. The magnets are generally aged by the heat and vibration treatment.

(b) Error may appear in PMMC Instrument due to the aging of the spring. However the error caused by the aging of the spring and the errors caused due to permanent magnet are opposite to each other, hence both the errors are compensated with each other.

(c) Change in the resistance of the moving coil with the temperature: Generally the temperature coefficients of the value of coefficient of copper wire in moving coil is 0.04 per degree celsius rise in temperature. Due to lower value of temperature coefficient the temperature rises at faster rate and hence the resistance increases. Due to this significant amount of error is caused.

Advantages of Permanent Magnet Moving Coil Instruments

(1)The scale is uniformly divided as the electric current is directly proportional to deflection of the pointer. Hence it is very easy to measure quantities from these instruments.

(2)Power consumption is also very low in these types of instruments.

(3)Higher value of torque is to weight ratio.

(4)These are having multiple advantages, a single instrument can be used for measuring various quantities by using different values of shunts and multipliers.

Instead of various advantages the permanent magnet moving coil instruments or PMMC Instrument posses few disadvantages.

Disadvantages of Permanent Magnet Moving Coil Instruments

(1) These instruments cannot measure ac quantities.

(2) Cost of these instruments is high as compared to moving iron instruments.

Moving Iron Instrument:

This instrument is one of the most primitive forms of measuring and relay instrument. Moving iron type instruments are of mainly two types. Attraction type and repulsion type instrument.

Whenever a piece of iron is placed nearer to a magnet it would be attracted by the magnet. The force of this attraction depends upon the strength said magnetic field. If the magnet is electromagnet is electromagnet then the magnetic field strength can easily be increased or decreased by increasing or decreasing electric current through its coil. Accordingly the attraction force acting on the piece of iron would also be increased and decreased. Depending upon this simple phenomenon attraction type **moving iron instrument** was developed.

Whenever two pieces of iron are kept side by side and a magnet is brought nearer to them the iron pieces will repulse each other. This repulsion force is due to same magnetic poles induced in same sides the iron pieces due external magnetic field. This repulsion force increases if field strength of the magnet is increased. Like case if the magnet is electromagnet, then magnetic field strength can easily be controlled by controlling input electric current to the magnet. Hence if the electric current increases the repulsion force between the pieces of iron is increased and it

the electric current decreases the repulsion force between them is decreased. Depending upon this phenomenon repulsion type **moving iron instrument** was constructed.

Construction of Moving Iron Instrument

Attraction type moving iron instrument

The basic construction of attraction type moving iron instrument is illustrated bellow A thin disc of soft iron is eccentrically pivoted in front of a coil. This iron tends to move inward that is from weaker magnetic field to stronger magnetic field when electric current flowing through the coil. In attraction moving instrument gravity control was used previously but now gravity control method is replaced by spring control in relatively modern instrument. By adjusting balance weight null deflection of the pointer is achieved. The required damping force is provided in this instrument by air friction. The figure shows a typical type of damping system provided in the instrument, where damping is achieved by a moving piston in an air syringe.

Theory of Attraction Type Moving Iron Instrument

Suppose when there is no electric current through the coil, the pointer is at zero, the angle made by the axis of the iron disc with the line perpendicular to the field is φ. Now due electric current I and corresponding magnetic field strength, the iron piece is deflected to an angle θ. Now component of H in the direction of defected iron disc axis is $H\cos\{90 - (\theta + \varphi)$ or $H\sin(\theta + \varphi)$. Now force F acting on the disc inward to the coil is thus proportional to $H^2\sin(\theta + \varphi)$ hence the force is also proportional to $I^2\sin(\theta + \varphi)$ for constant permeability. If this force is acting on the disc at a distance l from the pivot, then deflection torque, *Working of Moving Iron Instrument*

Since I is constant.

Where k is constant.

Now, as the instrument is gravity controlled, controlling torque will be

Where k' is constant.

At steady state condition,

Where K is constant.

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CHAPTER 6
TRANSDUCERS AND SENSORS

METHOD OF SELECTING TRANSDUCERS

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

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

ADVANTAGES OF ELECTRICAL TRANSDUCERS

1. Very small power is required for controlling the electrical or electronic system 2. The electrical output can be amplified to any desired level

3. Mass inertia effects are reduced to minimum possible.

4. The size and shape of the transducers can be suitably designed to achieve the optimum weight and volume

5. The output can be indicated and recorded remotely at a distance from the sensing medium .

6. The outputs can be modified to meet the requirements of the indicating or controlling

equipment.

RESISITIVE TRANSDUCERS

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

$R = \rho L/A$

Where , R= resistance, Ω

ρ = Resistivity of conductor materials, Ω-m

L= Length of conductor, m

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

Any method of varying one of the quantities involved in the above relationship can be the designed basis of an electrical resistance transducer. There are a number of ways in which resistance can be changed by a physical phenomenon.

The translational and rotational potentiometer which work on the basis of change in the value of resistance with change in length of the conductor can be used for measurement of translational or rotary displacements

The resistivity of materials changes with the change of temperature thus causing a change of resistance. This property may be used for measurement of temperature.

In a resistance transducer an indication of measured physical quantity is given by a change in the resistance. It may be classified as follows

1. Mechanically varied resistance - POTENTIOMETER

2. Thermal resistance change – RESISTANCE THERMOMETER

3. Resistivity change - RESISTANCE STRAIN GAUGE

STRAIN GAUGE

INTRODUCTION

When a metal conductor is stretched or compressed , its resistance changes on account of the fact that both length and diameter of conductor change . The value of resistivity of conductor also changes. When it is strained it's property is called **piezo-resistance .** Therefore , resistance strain gauges are also known as **piezo- resistive gauges** .

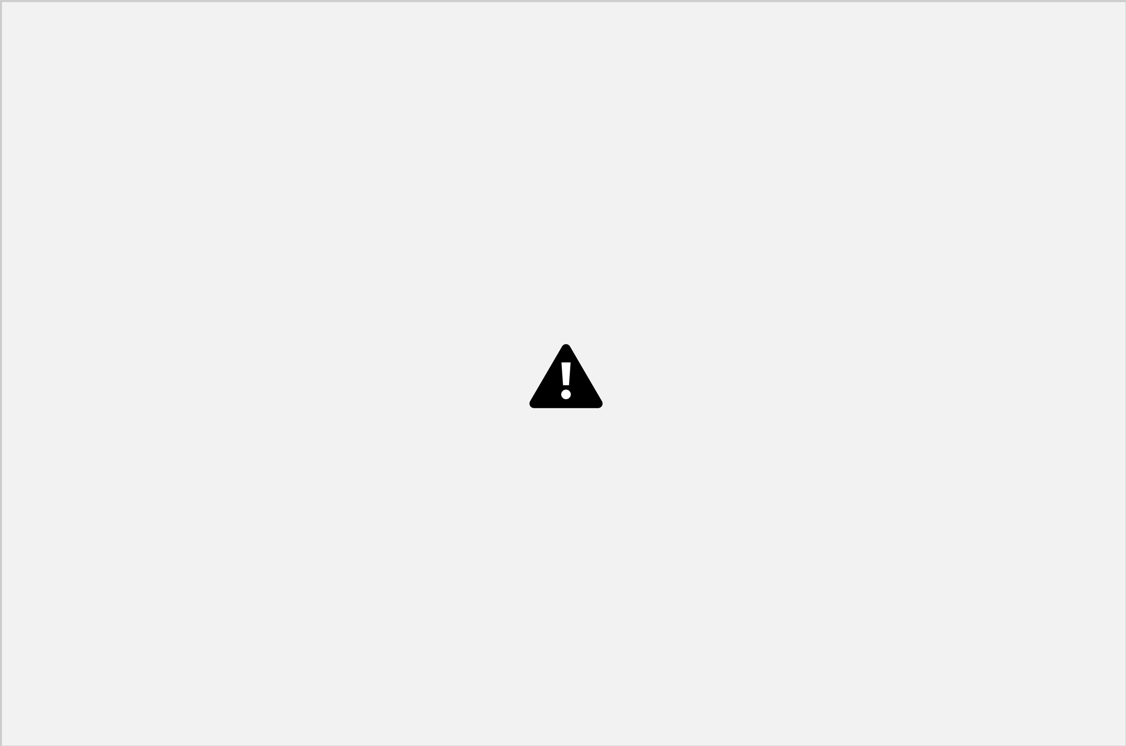
The strain gauge is a measurement transducer for measuring strain and associated stress in experimental stress analysis.

TYPES

Four types of Strain gauges are :

1. Wire –wound strain gauge
2. Foil-type strain gauge
3. Semiconductor strain gauge
4. Capacitive strain gauge.

DIAGRAM WIRE-WOUND STRAIN GAUGE



WORKING PRINCIPLE

Strain gauges work on the principle that the resistance of a conductor or a semiconductor changes when strained .This property can be used for measurement of displacement, force and pressure .

When a strain gauge is subjected to tension (positive strain) it's length increases while it's cross sectional area decreases. Since the resistance of a conductor is proportional to it's length and inversely proportional to it's area of cross section, The resistance of the gauge increases with positive strain .

Strain gauges are most commonly used in **wheat –stone bridge** circuits to measure the change of resistance of grid of wire for calibration proposes; the '**GAUGE FACTOR'** is defined as the ratio of per unit change in resistance to per unit change in length.

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

Where, ΔR = corresponding change in resistance, R

ΔL = Change in length per unit length, L

$R = \rho L/A$
Where, R= resistance, Ω
ρ = Resistivity of conductor materials, Ω-m
L= Length of conductor, m
A = Cross sectional area of the conductor, m^2

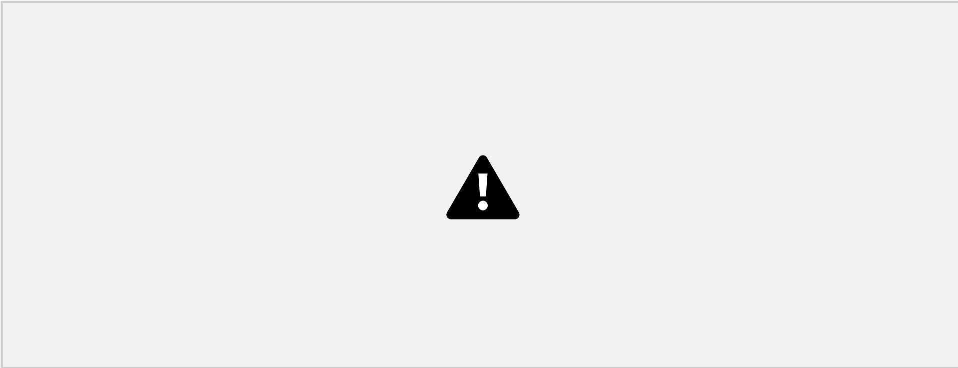
L.V.D.T

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

WORKING PRINCIPLE

When the core is in the centre (called reference position) the induced voltages E_1 and E_2 are equal and opposite. Hence they cancel out and the output voltages V_0 is zero.

When the external applied force moves the core towards the coil S_2 ,E_2 is increased but E_1 is decreased in magnitude though they are still antiphase with each other. The net voltage available is (E_2-E_1) and is in phase with E_2.



Similarly , When movable core moves towards coil S_1, $E_1 > E_2$ and $V_o = E_1 - E_2$ and is in phase with E_1.

ADVANTAGES

1. It gives a high output and therefore many a times there is no need for intermediate amplification devices.
2. The transducer possess a high sensitivity as high as 40V/mm
3. It shows a low hysteresis and hence repeatability is excellent under all conditions. 4. Most of the LVDTs consume a power of less than 1W.
5. Less friction and less noise .

DISADVANTAGES

1. These transducers are sensitive to stray magnetic fields but shielding is possible .This is done by providing magnetic shields with longitudinal slots.

2. Relatively large displacements are required for appreciable differential output.
3.Several times, the transducer performance is affected by vibrations.

APPLICATIONS

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

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LOAD CELLS

Load cells are sensors which are used to measure the level or pressure by converting the force (torque or mass) into electrical signals and then these signals are displayed by the display unit to show the level or pressure. Load cells are also known as load transducers. In dictionary, a load cell is known as "weight measuring device necessary for electronic signal that displays weight in the form of digits."

Load cells can be classified according to their operations:

Load cells that utilize liquid pressure or air pressure.

Load cells that utilize elasticity.

Load cells that utilize a magnetostriction or piezoelectric effect.

The strain gauge load cell is the mostly used among the all kinds of load cells. Therefore, when we say "load cell," we are mostly referring to strain gauge load cells. Although there are many other measurement devices, such as piezoelectric sensors, Magnetostrictive sensors, capacitance sensor and other sensors.

1.2-Types of Load cells

Strain gauge load cells

Tension load cells

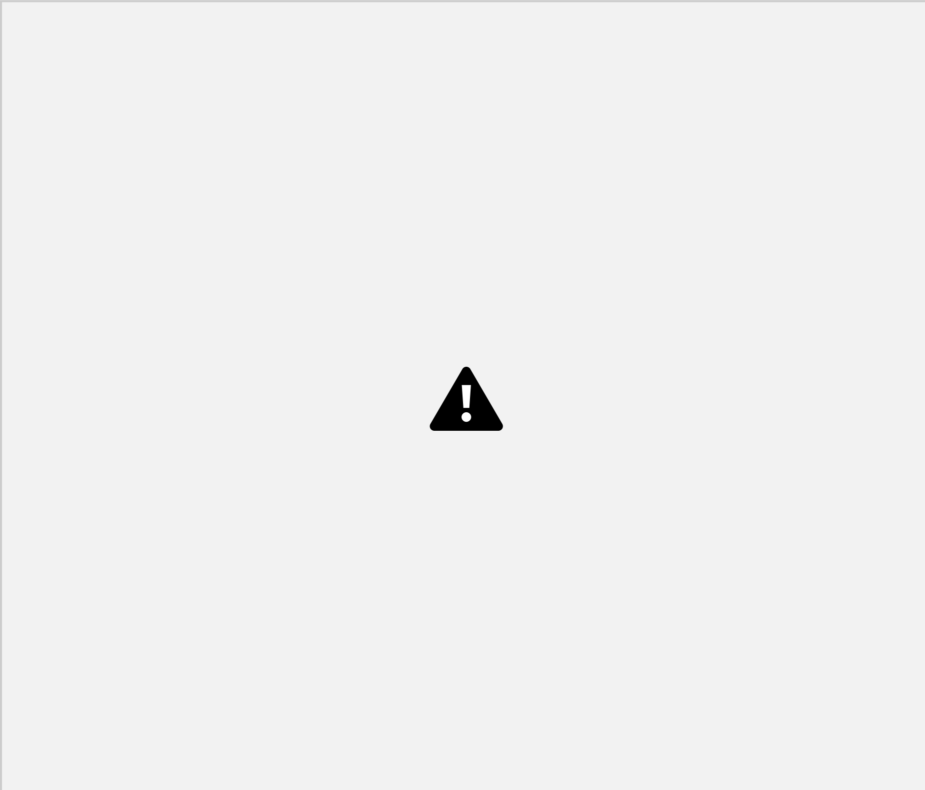
Pneumatic load cells

Hydraulic load cells

Strain Gauge Load Cells

This is a type of load cell which is use to measure the level of any storage vessel. When pressure is applied on a conductor its length changes due to which resistance of the conductor changes and relative to the change in resistance display unit displays the change in level.

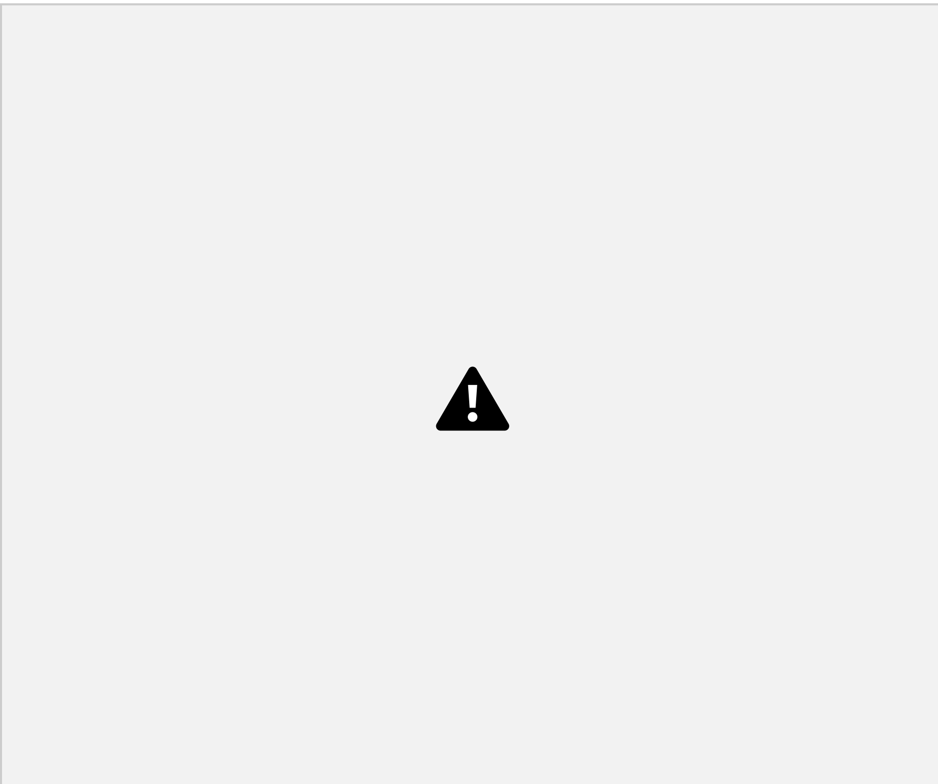
A strain gauge is consists of a long length conductor which is arranged in zigzag way on the flexible membrane which is exposed to the applied pressure area. This conductor is connected in a wheat stone bridge as a resistor and when pressure or weight is applied on the membrane which is connected to the conductor it gets stretched and due to stretching the length of the conductor changes and due to change in length the resistance of the conductor increases.



Pneumatic Load Cells

This is another type of load cells which are used to measure the weight in the industry and these are used for low capacity. This type of load cells works on “the force-balance principle.” Which means

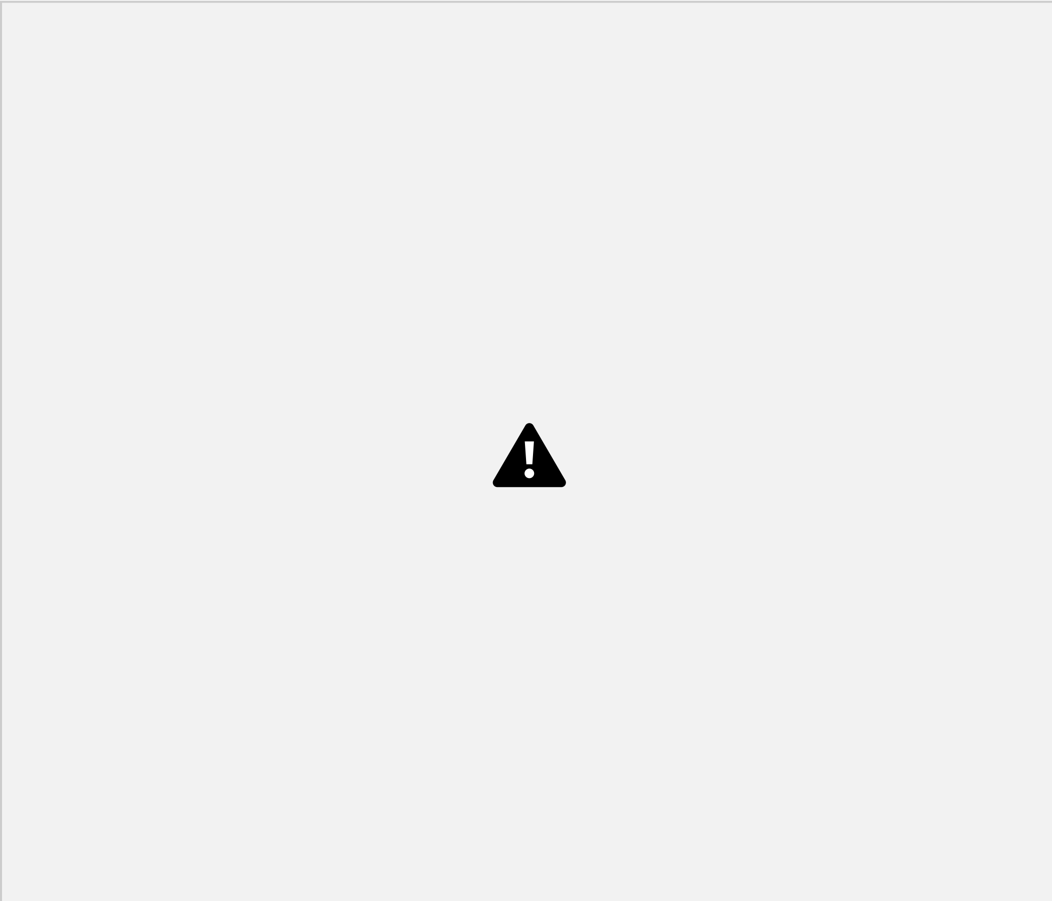
The inertial force produced by a seismic ground motion shifts the mass from its original equilibrium position, and the change in position or velocity of the mass is then interpreted into an electric signal. This principle is for low range load cells. For long range load cells the inertial force is balanced with an electrically generated force so that the mass moves as low as possible.



This kind of load cells consist of a sensing element which is exposed to the site or the vessel of which pressure or lying fluid weight is to be measured. And in this kind of load cell the force transferring medium is air as compare to the any other fluid in case of hydraulic load cell. When force is applied by the lying fluid on the sensing part of the load cell it transfers this force to the inside air and then this force is applied on the potentiometer which is placed in the wheat stone bridge. As the force is applied on the sensing part of the load cell the resistance of the variable resistance potentiometer changes due to this force and thus the potential equilibrium between the resistances is disturbed and this shows the magnitude of the applied force on the sensing element by displaying it on the display unit.

Hydraulic Load Cells

This is another type of load cells which are used to measure the magnitude of the applied force and their conversion to the electric signals and its digital display. This type of load cells also work on “the force-balance principle.”The difference between the pneumatic load cell and hydraulic load cell is only the transferring medium. In case of pneumatic load cell the force transferring medium is air while in hydraulic load cells the force transferring medium is mostly liquid or incompressible oil which is also known as break oil.



Hydraulic load cell consists of a fluid which act as a force transferring medium and a piezoelectric crystal which is use to convert this applied force into potential difference and then there is an arrangement for the conversion of this potential difference in terms of weight or pressure. There is a diaphragm which is use to sense the force exerted from the external side and the whole casing in which this complete cell is enclosed. When the pressure or weight by the vessel or column is applied on the diaphragm of the load cell it sense that force and then transfers this force to the fluid which is filled in the casing of this load cell.

TEMPERATURE TRANSDUCERS

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PROXIMITY SENSORS

A **proximity sensor** is a sensor able to detect the presence of nearby objects without any physical contact.

A proximity sensor often emits an electromagnetic field or a beam of electromagnetic radiation (infrared, for instance), and looks for changes in the field or return signal. The object being sensed is often referred to as the proximity sensor's target. Different proximity sensor targets demand different sensors. For example, a capacitive or photoelectric sensor might be suitable for a plastic target; an inductive proximity sensor always requires a metal target.

The maximum distance that this sensor can detect is defined "nominal range". Some sensors have adjustments of the nominal range or means to report a graduated detection distance.

Proximity sensors can have a high reliability and long functional life because of the absence of mechanical parts and lack of physical contact between sensor and the sensed object.

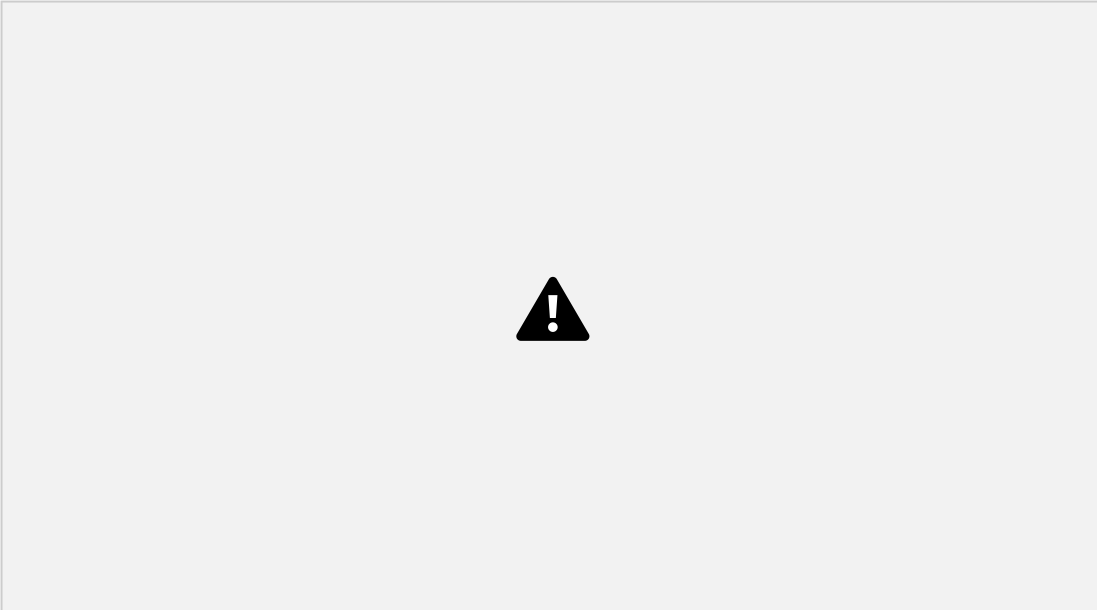
Proximity sensors are commonly used on smart phones to detect (and skip) accidental touch screen taps when held to the ear during a call.[1] They are also used in machine vibration monitoring to measure the variation in distance between a shaft and its support bearing. This is common in large steam turbines, compressors, and motors that use sleeve-type bearings.

International Electro technical Commission (IEC) 60947-5-2 defines the technical details of proximity sensors.

A proximity sensor adjusted to a very short range is often used as a touch switch.

This presence detector or proximity sensor circuit reacts in presence of any conductor object including humans. Sensitivity is adjustable with P1 which will be located at a great distance from the rest of the presence detector circuit. This circuit does not detect object movement but can act as an proximity sensor!

Presence, Proximity Sensor Circuit Schematic



proximity sensor circuit schematic

The sensitivity of the proximity sensor circuit can be adjusted with P1 for the desired "distance". One of its obvious uses is to open a door automatically. For this the sensor must be placed on the front of the door.

The presence detector is made of one oscillator with T1 and a mono-stable. The oscillator is a Clapp one, well known for its frequency stability. The surface of the sensor acts as a capacitor for the oscillator circuit and in this configuration the frequency is around 1 MHz.

The switching time can be adjusted with P2. Do not bring metallic objects in the proximity of the circuit because if doing so the relay will stay closed! This circuit can be used as a detector of aggressive liquids, the advantage being that the surface of the sensor will not come in contact with the liquid.

Light Sensors

A Light Sensor generates an output signal indicating the intensity of light by measuring the radiant energy that exists in a very narrow range of frequencies basically called "light", and which ranges in frequency from "Infra-red" to "Visible" up to "Ultraviolet" light spectrum.

The Light Sensor is a passive devices that convert this "light energy" whether visible or in the infra-red parts of the spectrum into an electrical signal output.