

SEMESTER - V
ELECTRONIC INSTRUMENTATION
UNIT - I : INTRODUCTION TO INSTRUMENTS



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UNIT - I

1. Define accuracy and precision and Resolution?

Ans. **Accuracy** is how closely an instrument's reading matches the true value of a quantity, indicating its correctness.

Precision refers to the consistency or reproducibility of repeated measurements, showing how much they agree with each other, even if not accurate.

for example, reading 3.4 MW for a true value of 3.385,695 W.

Resolution:

Resolution is the smallest input change an instrument can reliably detect. It refers to the minimum increment needed to cause a noticeable change in output, also called discrimination.

2. A digital voltmeter has a read-out reading from 0 to 9,999 counts. Determine the resolution of the instrument in volt when the full scale reading is 9.999 V.

Ans: The resolution of this instrument is 1 or 1 count in 9,999.

$$\text{Resolution} = \frac{1}{9999} \text{Count}$$

$$= \frac{1}{9999} 9.999 \text{volt}$$

$$= 10^{-3} \text{V}$$

$$= 1 \text{mV}$$

3. Explain Measurement of errors?

Ans: No measurement is perfectly accurate, so it's important to determine its accuracy and identify error sources. Errors may arise from human mistakes, instrument faults, or environmental effects.

It is classified into 3 types

1. Gross Error: Gross Error

The gross error occurs due to the human mistakes in reading or using the instruments. These errors cover human mistakes like in reading, calculating and recordings etc. It sometimes occurs due to incorrect adjustments of instruments.

The minimisation of gross errors is following ways:

1. It can be avoided by taking care while reading and recording the measurement data.
2. Taking more than one reading of same quantity. At least three or more reading must be taken by different persons.

2. Systematic Errors: A systematic error is divided in three different categories: instrumental errors, environmental errors and observational errors.

2.1. Instrumental Errors

The instrument error generate due to instrument itself. It is due to the inherent shortcomings in the instruments, misuse of the instruments, loading effects of instruments. For example in the D' Arsonval movement friction in bearings of various moving components may cause incorrect readings. There are so many kinds of instrument errors, depending on the type of instrument used.

Instrumental errors may be avoided by

- (a) Selecting a suitable instrument for the particular measurement application
- (b) Applying correction factors after determining the amount of instrumental error
- (c) Calibrating the instruments against a standard.

2.2: Environmental Errors

Environmental errors arise as a result of environmental effects on instrument. It includes conditions in the area surrounding the instrument, such as the effects of changes in temperature, humidity, barometric pressure or of magnetic or electrostatic fields.

For example when making measurements with a steel rule, the temperature when the measurement is made might not be the same as that for which the rule was calibrated.

Environmental errors may be avoided by

- (a) Using the proper correction factor and information supplied by the manufacturer of the instrument.
- (b) Using the arrangement which will keep the surrounding condition constant like use of air condition, temperature controlled enclosures etc.
- (c) Making the new calibration under the local conditions.

2.3. Observational Errors: Observational errors are mistakes in measurement caused by the operator's carelessness, such as parallax error, incorrect scale selection, or personal habits during reading.

Example:

Misreading a needle's position on a scale due to viewing angle (parallax error).

3. Random Errors: Random errors are unpredictable variations in measurement caused by unknown or uncontrollable factors.

Example:

Variations in repeated weight readings due to scale resolution limits or mechanical vibrations.

4. Absolute Error : Measurement is the process of comparing an unknown quantity with an accepted standard quantity.

Absolute error may be defined as the difference between the measured value of the variable and the true value of the variable.

$$\Delta A = A - A_m$$

ΔA = absolute error

A_m = expected value

A = measured value

5. Relative Error: The relative error is the ratio of absolute error to the true value of the quantity to be measured. Mathematically, the relative error can be expressed as $\frac{\Delta A}{A}$

4. Explain Classification of Instruments?

A multimeter is a device that can be used to measure multiple quantities. When a single device is used to measure multiple quantities, the device is called a multimeter. Based on output representation, there are two types of multimeters

1. Analog multimeter
2. Digital multimeter

Analog Multimeter:

- An analog multimeter is a Permanent Magnet Moving Coil (PMMC) meter type measuring instrument.
- It works on the principle of d'Arsonval galvanometer.
- The analog multimeter has an analog display that uses the deflection of a pointer on the scale to indicate the level of measurement being made.
- The pointer deflects from its initial position increasingly as the measuring quantity increases.

Working of Analog Multimeter The analog multimeter is a PMMC type instrument. When a current is passed through its coil, the coil moves in a magnetic field produced by the permanent magnet. A pointer is attached with the coil. When current flows in the coil, a deflecting torque acts on the coil that will rotate it by an angle, the pointer moves over a scale. A pair of hairsprings is attached to the spindle to provide the controlling torque.

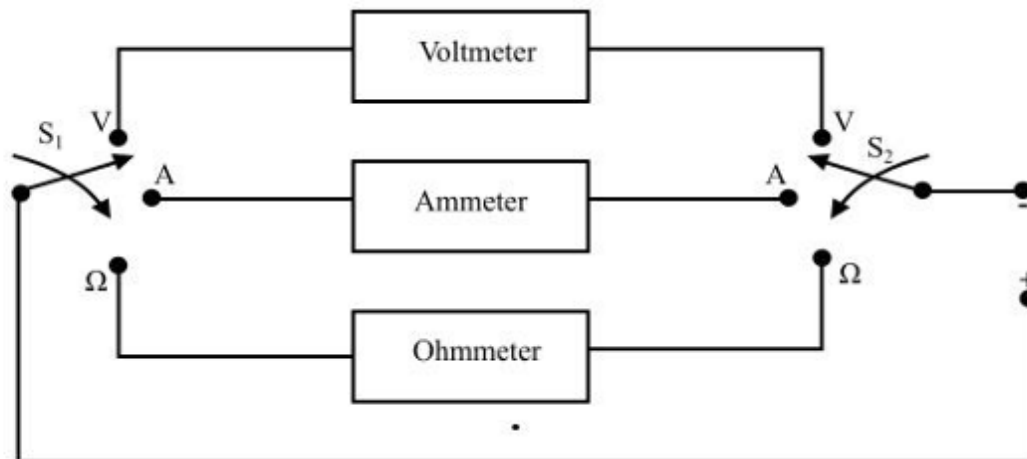
Uses:

As DC Voltage- Voltmeter

• As AC Voltage- Voltmeter

As DC Current- Ammeter

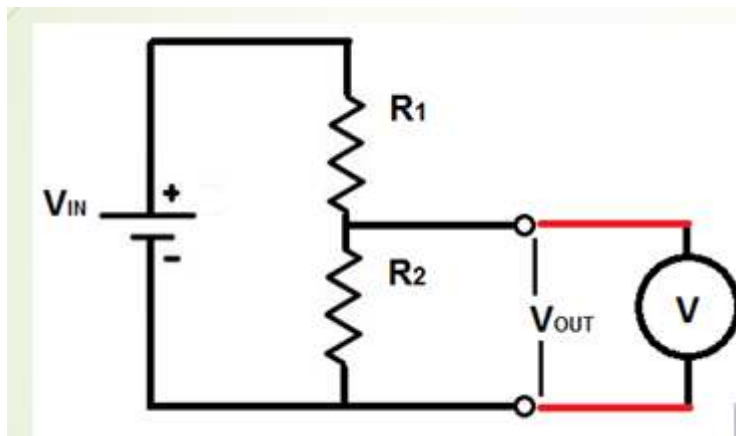
As Resistance- Ohmmeter



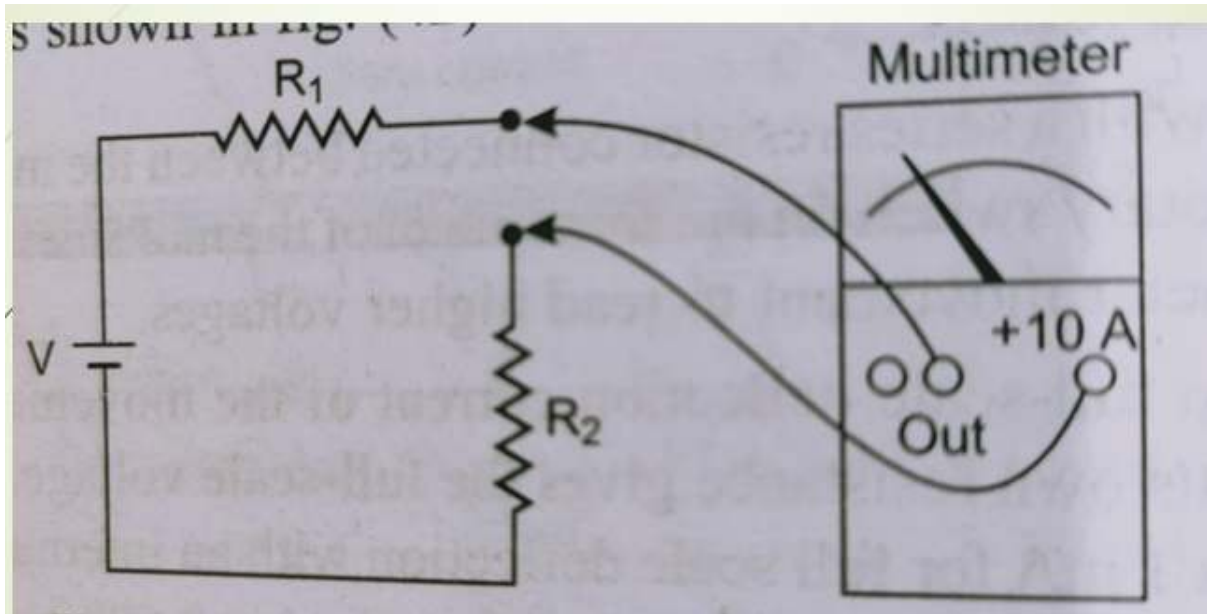
Here, two switches S_1 and S_2 are used to select the desired meter. It also has a rotary range-selector switch to choose a particular range of current, voltage and resistance.

Steps for the use of Analog Multimeter— •Insert the probes into the correct connections. •Set switch to the correct measurement types and range for the measurement to be made. •While selecting the range, ensure that the maximum range is above than that is expected. •The range of multimeter is then optimized for the best reading.

Measurement of Voltage:



Measurement of Current:



Measurement of Resistance :

- With the instrument switched off, check the pointer zero and adjust the mechanical zero control as necessary.
- Set the Function switch to OHM and with the instrument terminal open-circuited adjust the DC ZERO/ Ω control until the pointer indicates infinity on the resistance scale.
- Select a resistance range to suit the approximate value of the resistance to be measured.
- Connect the resistance to the COM and OHM terminals and adjust the RANGE control to give a resistance reading as close as possible to centre of the scale.

Advantages of Analog Multimeter:

- It gives the continuous reading, thus a sudden change in signal can be detected which is not possible with digital multimeter.
- Analog multimeters are very cheap.
- All measurements can be made using a single meter only.

Disadvantages of Analog Multimeter:

- They are bulky and larger sized.
- Multiple scales, these can cause confusion.
- Low input resistance.
- Analog multimeters do not have auto-polarity function. Therefore, it is necessary to connect probes correctly.

- Less accurate than a digital multimeter.

5. Explain the construction and working of Digital multimeter?

A Digital Multimeter (DMM) is an electronic measuring instrument used to measure various electrical quantities. The standard measurements that are performed by a DMM are current, voltage and resistance. This is also called Volt Ohm Milli Ammeter (VOM)

DMM Controls and Connection Ports A typical DMM has a rotary switch, digital display and connecting jacks for the probes.

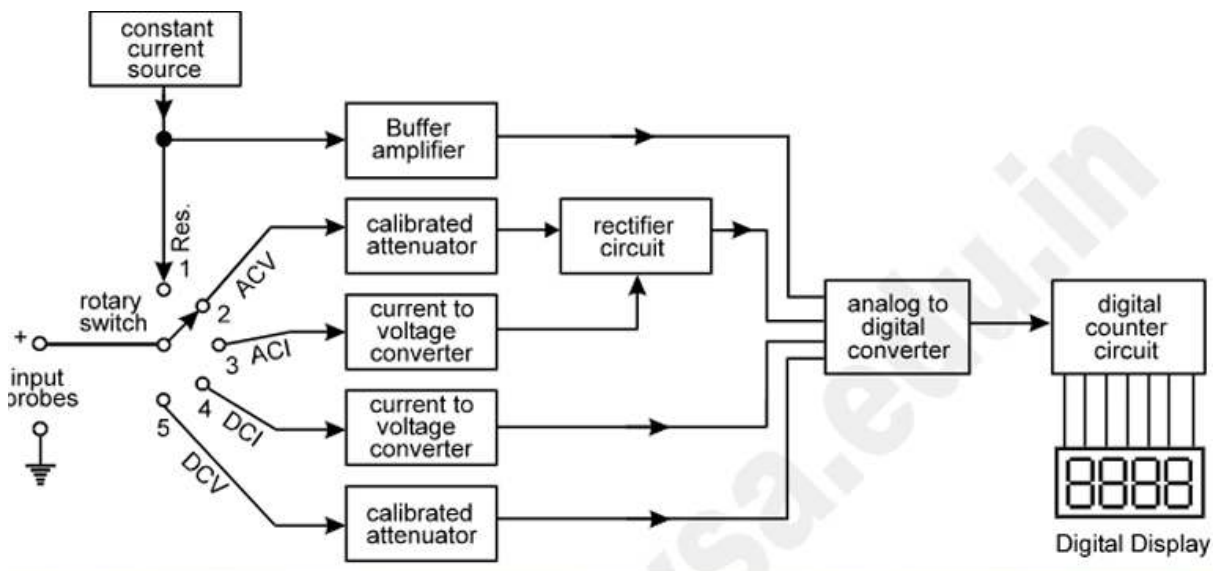
Display – The DMM has an illuminated display screen for better visualisation. Most DMMs have a four-digit display, the first of which can only be either a 0 or 1 and a + / - indication as well. There may also be some more indicators like AC / DC etc.

Connection Ports – There are three or four ports available on the front of the DMM. However, only two are needed at a time. Typical ports of the DMM are – Common – It is used with all measurements. The negative (black) probe is connected to this.

VΩmA Port – This port is used for the most measurements and positive (red) probe is connected to it. 10A Port – It is used to measure the large currents in the circuits.

Dial (Selection Knob) – There is a rotary switch to select the types of measurement to be made and range that is needed. **Additional Connections** – There are some additional connections in DMM for other measurements like temperature, transistor gains etc.

Additional Buttons and switches – There are a few additional buttons present in a DMM. The main one is ON/OFF button.



Uses:

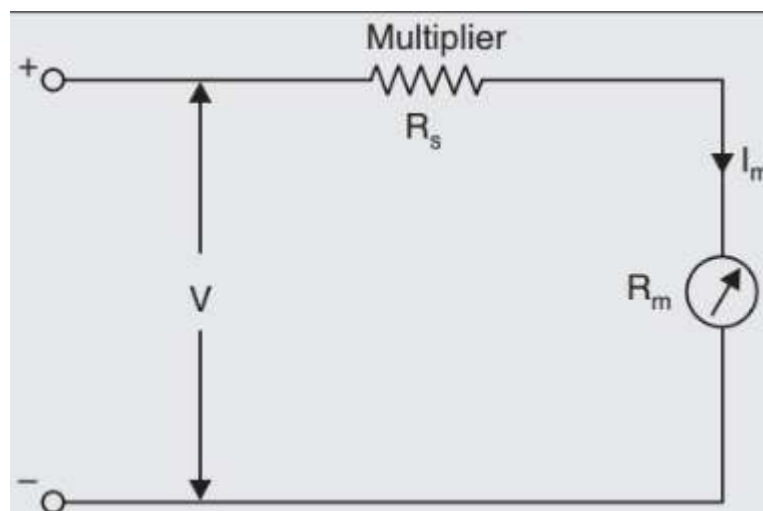
Used to Measurement of resistance, current and voltage

- **Advantages of Digital Multimeter** : They are having high input impedance, So there is no loading effect.
- They are having higher accuracy.
- An unambiguous reading is obtained.
- The output can be interfaced with external equipment.
- They are available in smaller sizes.
- It can be used for measurement of A.C. and D.C. both quantity.
- It can be used for measurement of various parameters such as resistance, voltage, current etc.
- It has sensitivity of $20 \text{ k}\Omega/\text{V}$ which is fairly high.
- Measurement of quantities with different range can be possible
- It is small in size or compact.
- It is very simple to use unlike analogmultimeter as results are displayed in numeric value directly and user need not have to read manually from the scale.

6. Explain the working of DC Voltmeter?

Ans: Voltmeter is used for measuring voltage or the potential difference. Fig. 3.12 shows the instrument and symbol of voltmeter.

circuit diagram



The high resistor is connected in series with the D' Arsonval movement. This resistor is called multiplier. The multiplier limits the current so that it does not exceed the full-scale deflection current. The voltmeter is always connected across the source of emf or a circuit.

Where, R_m = internal resistance of the movement coil

R_s = multiplier resistance

I_m = full scale deflection current of the movement

$V_m =$ full range voltage of the instrument

From the circuit $V_m = I_m(R_s + R_m)$

7. Explain the working of AC Voltmeter?

Ans: The instrument, which is used to measure the AC voltage across any two points of electric circuit is called AC voltmeter. If the AC voltmeter consists of rectifier, then it is said to be rectifier based AC voltmeter.

The DC voltmeter measures only DC voltages. If we want to use it for measuring AC voltages, then we have to follow these two steps.

Step1 – Convert the AC voltage signal into a DC voltage signal by using a rectifier.

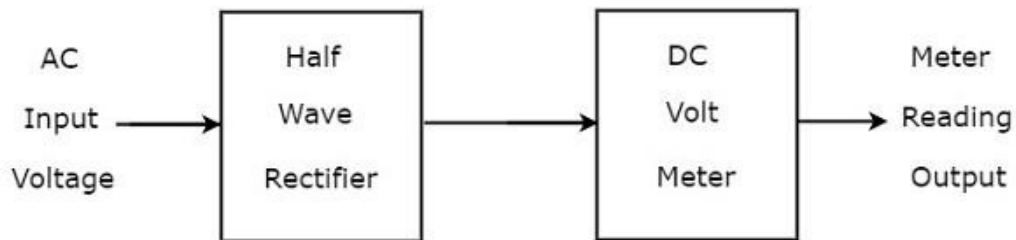
Step2 – Measure the DC or average value of the rectifiers output signal.

Types of Rectifier based AC Voltmeters

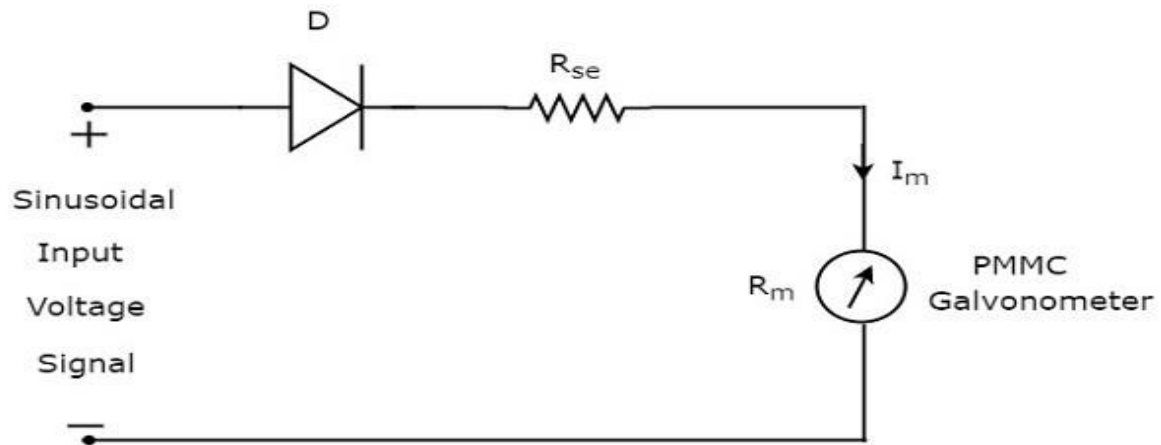
1. AC voltmeter using Half Wave Rectifier
2. AC voltmeter using Full Wave Rectifier

1. AC Voltmeter using Half Wave Rectifier

The block diagram of AC voltmeter using Half wave rectifier is shown in below figure.



The above block diagram consists of two blocks: half wave rectifier and DC voltmeter. We will get the corresponding circuit diagram, just by replacing each block with the respective component(s) in above block diagram. So, the circuit diagram of AC voltmeter using Half wave rectifier will look like as shown in below figure.



The **rms value** of sinusoidal (AC) input voltage signal is

$$V_{rms} = \frac{V_m}{\sqrt{2}}$$

$$\Rightarrow V_m = \sqrt{2}V_{rms}$$

$$\Rightarrow V_m = 1.414V_{rms}$$

Where,

V_m is the maximum value of sinusoidal (AC) input voltage signal.

The **DC** or average value of the Half wave rectifiers output signal is

$$V_{dc} = \frac{V_m}{\pi}$$

Substitute, the value of V_m in above equation.

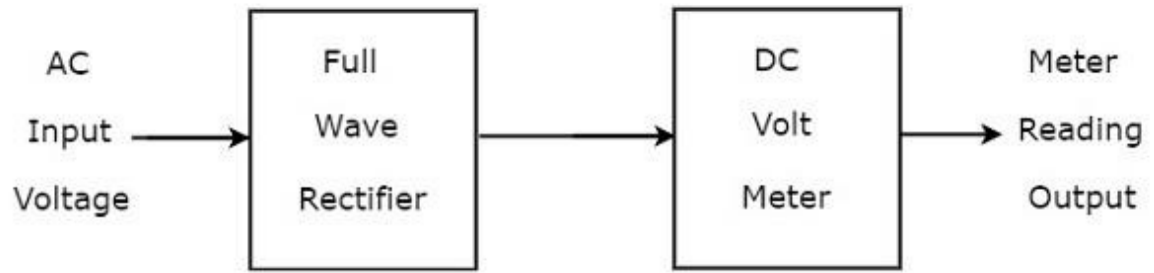
$$V_{dc} = \frac{1.414V_{rms}}{\pi}$$

$$V_{dc} = 0.45V_{rms}$$

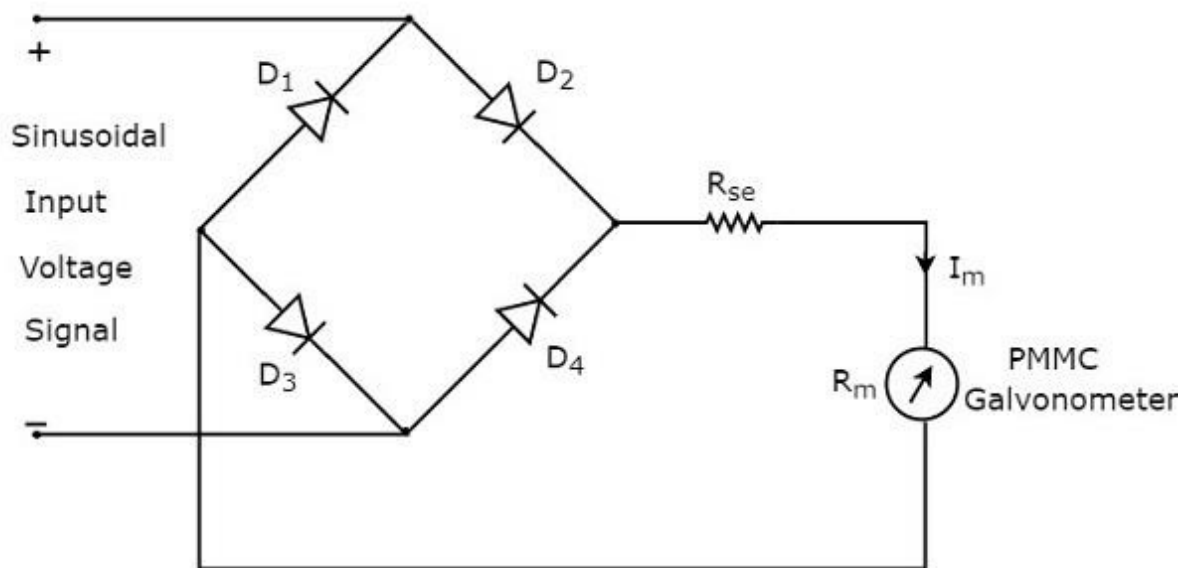
Therefore, the AC voltmeter produces an output voltage, which is equal to **0.45** times the rms value of the sinusoidal (AC) input voltage signal

AC Voltmeter using Full Wave Rectifier

The block diagram:



The above block diagram consists of two blocks: full wave rectifier and DC voltmeter. We will get the corresponding circuit diagram just by replacing each block with the respective component(s) in above block diagram.



The **rms value** of sinusoidal (AC) input voltage signal is

$$V_{rms} = \frac{V_m}{\sqrt{2}}$$
$$\Rightarrow V_m = \sqrt{2} V_{rms}$$
$$\Rightarrow V_m = 1.414 V_{rms}$$

Where,

V_m is the maximum value of sinusoidal (AC) input voltage signal.

The **DC** or average value of the Full wave rectifiers output signal is

$$V_{dc} = \frac{2V_m}{\pi}$$

Substitute, the value of V_m in above equation

$$V_{dc} = \frac{2 \times 1.414 V_{rms}}{\pi}$$
$$V_{dc} = 0.9 V_{rms}$$

Therefore, the AC voltmeter produces an output voltage, which is equal to **0.9** times the rms value of the sinusoidal (AC) input voltage signal.

8. Explain about Sources of errors in the Measurement of resistance, voltage and current?

Ans: 1. Errors in Resistance Measurement

1. **Contact Resistance:** Poor connections or dirty terminals introduce extra resistance.
2. **Lead Resistance:** The resistance of test leads can affect low-resistance measurements.
3. **Temperature Effects:** Resistance varies with temperature; most conductors increase resistance as temperature rises.
4. **Parallax Error:** Misreading analog scale due to angle of view.
5. **Instrument Calibration:** If the ohmmeter or bridge is not properly calibrated, errors result.
6. **Self-heating:** Current through the resistor may heat it, changing its resistance during measurement.

2. Errors in Voltage Measurement

1. **Instrument Loading:** Voltmeter draws current; if its internal resistance is low, it affects the circuit and gives a lower reading.
2. **Connection Errors:** Improper or loose connections can cause voltage drops.
3. **Parallax Error:** Misreading analog voltmeter needle.
4. **Electromagnetic Interference (EMI):** External fields can induce voltages, distorting readings.
5. **Temperature Drift:** Internal resistance of voltmeter may change with temperature.

3. Errors in Current Measurement

1. **Ammeter Insertion Loss:** Inserting an ammeter introduces small resistance, affecting the circuit.
2. **Shunt Resistance Error:** If internal shunt is inaccurate or temperature-affected, current reading will be off.
3. **Instrument Range Selection:** Choosing an incorrect range may result in inaccurate or zero readings.
4. **Inductive Effects:** Sudden changes in current can induce opposing EMF in the ammeter coil.
5. **Parallax and Human Error:** Visual misreading of the pointer on analog ammeters

Minimizing these errors involves using properly calibrated digital instruments, ensuring good connections, using high-resistance voltmeters and low-resistance ammeters, and avoiding temperature extremes and electromagnetic interference.

9. Explain about Balancing and damping Moving iron instruments?

Ans: One of the most accurate instrument used for both AC and DC measurement is moving iron instrument.

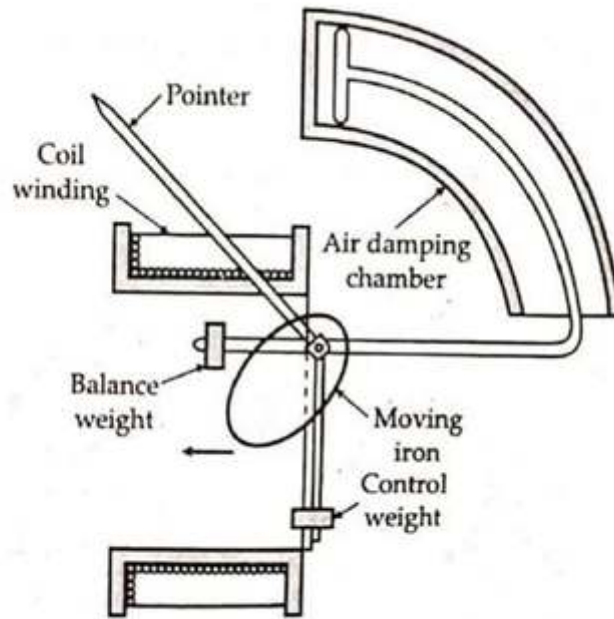
There are two types of moving iron instrument.

1. Attraction type
2. Repulsion type

Construction: It consists of a fixed coil and moving iron piece. The moving iron piece is a flat disc which is mounted on the spindle. The controlling torque is provided by either spring control or gravity control. Here the damping torque is provided by the Air friction damping.

Working principle: When supply is given, then current flow through the fixed coil and magnetic field is produced by Electromagnet. Then moving iron piece is attracted by this electromagnet and deflecting torque is produced this attraction force. Since the moving iron is

attached with the spindle, the spindle rotates and the pointer moves over the scale. But the force of attraction depends on the current flowing through the coil.



Attraction type moving iron instrument.

Suppose, I = The initial current

L = instrument inductance

θ = Angle of deflection +

If the current increases by the ' dI ' in ' dt ' time then the deflection angle changes by ' $d\theta$ ', and the inductance changes by ' dL '

In order to affect the increment ' dI ' in the current there must be an increase in the applied voltage given by

$$V = \frac{d(LI)}{dt}$$

$$V = L \frac{dI}{dt} + I \frac{dL}{dt}$$

Electrical energy supplied to coil

$$V \times I \, dt = \left(L \frac{dI}{dt} + I \frac{dL}{dt} \right) \times I \, dt$$

$$V \, I \, dt = I^2 \, dL + I \, L \, dI \text{ -----(1)}$$

Initially energy store in a coil = $\frac{1}{2} Li^2$

$$\text{Change in stored energy} = \frac{d\left(\frac{1}{2} Li^2\right)}{dt}$$

$$= \frac{1}{2} (L2i \, di + i^2 \, dL)$$

$$= Lidi + \frac{1}{2}i^2 dL \text{ -----(2)}$$

$$\text{Mechanical work done by coil in 'dt' sec} = T_d d\theta \text{ -----(3)}$$

From the principle of conservation of energy Electrical energy supplied = increase in stored energy + mechanical work done

$$\text{Eq. 1} = \text{Eq. 2} + \text{Eq.3}$$

$$i^2 dL + I L dI = Lidi + \frac{1}{2}i^2 dL + T_d d\theta$$

$$\text{On solving we get, } T_d = \frac{1}{2}i^2 \frac{dL}{dt}$$

The Spring control method is provided for controlling torque, $T_C = K\theta$

At Equilibrium Position, $T_C = T_d$

$$\theta = \frac{1}{2k} i^2 \frac{dL}{dt}$$

$$\theta \propto i^2$$

Advantages:

1. MI can be used in AC and DC.
2. It is cheap.
3. There is no current carrying path in the moving systems hence the instruments are reliable
4. Simple construction.
5. The Range of instrument can be increased or decreased.

Disadvantages:

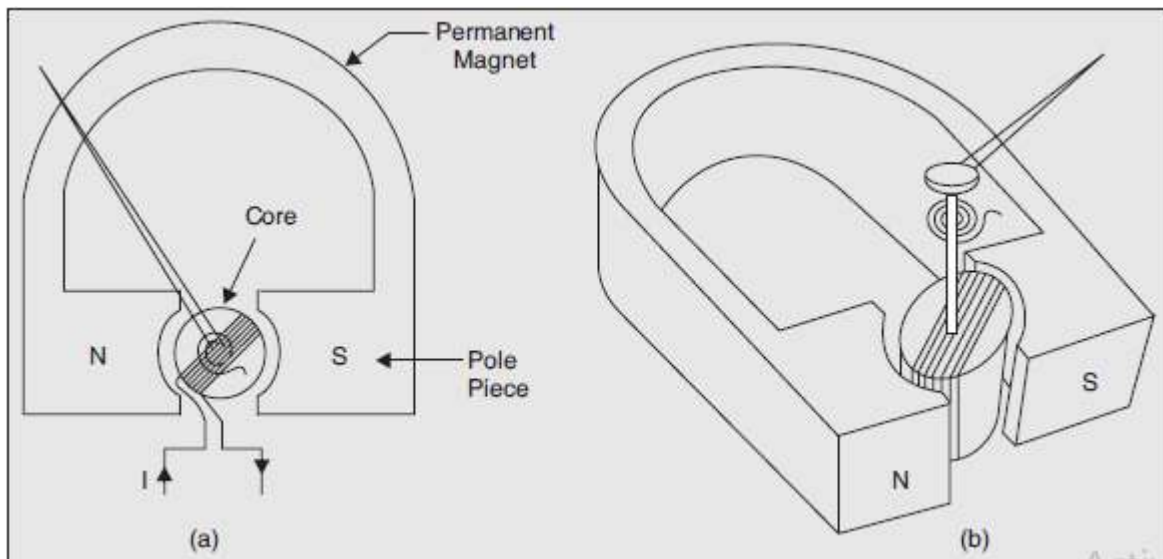
1. Scale is not uniform.
2. Error due to frequency, stray magnetic field ,eddy current and hysteresis error.
3. It consumed more power.
4. Calibration is different for AC and DC operation.

10. Explain about Balancing and damping PMMC instrument?

Ans: It is also called D' Arsonval meter movement or a permanent-magnet moving-coil (PMMC) meter movement.

1. Construction

The device has a horseshoe magnet with soft iron pole pieces and a cylindrical soft iron core placed between them. A fine wire coil on a metal frame rotates around the core and moves a pointer when current flows. A spring provides restoring torque to control rotation. Modern versions use taut-band movement, replacing pivots and jewels with spring metal bands that both support the coil and offer restoring force.



Principle of Operation

The deflection of the pointer is directly proportional to the amount of current passing through the coil. When direct current flows through the coil, the magnetic field so produced reacts with the field of the permanent magnet. The resultant force turns the coil along with its pointer. The amount of deflection is directly proportional to the amount of current in the coil. Hence, their scale is linear.

Deflecting Torque

If the coil is carrying a current of i A, the force on a coil side = $BilN$

torque due to both coil sides = $(2r)(BilN)$

= Gi

$G = 2rBlN = NBA$

Where $G = \text{constant}$

$A = 2rl = \text{area of the coil}$

$N = \text{no. of turns of the coil.}$

$B = \text{flux density in Wb/m}^2.$

$l = \text{length of the vertical side of the coil, } m.$

$2r = \text{breadth of the coil, } m$

$i = \text{current in ampere.}$

Controlling Torque

For spiral springs and strip suspensions, the controlling torque is directly proportional to the angle of deflection of the coil.

Control torque = Cq

Where, $q = \text{deflection angle in radians}$

C = spring constant

Characteristics of Moving Coil Meter Movement

- (i) full-scale deflection current (I_m),
- (ii) internal resistance of the coil (R_m),
- (iii) sensitivity (S).

Advantage

1. It has uniform scale.
2. Operating current is small.
3. It has high sensitivity.
4. It consumes low power, of order of 25 W to 200 mW.
5. It has high accuracy.
6. Extension of instrument range is possible.
7. Not affected by external magnetic fields called stray magnetic fields.

Disadvantage

1. Used only for D.C measurements.
2. The cost of the instrument is high.