U-1: Introduction to Instruments

Instrument - is defined as a device for measuring the value or magnitude of a physical quantity like, voltage, current, pressure, temperature etc.

Types of Instruments.

The two main catagories of instruments are -

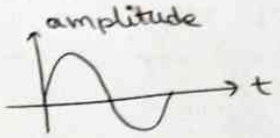
① Analog Instruments and

② Digital Instruments

Analog Signal - a continous time signals are called analog signals. represented as $x(t)$.

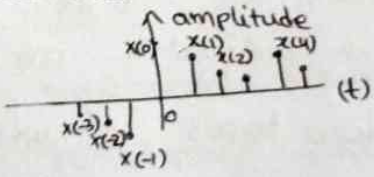
⇒ The value of a continous signal varies continously with respect to time.

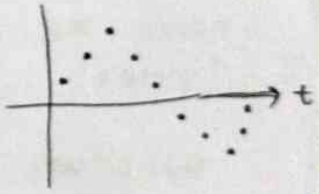
ex: Sine wave



Discrete Signal - a discontinous time signals are called discrete signals. represented as $x(n)$.

where 'n' is





→ Thus Analog Instruments process analog signals or continous signals.

→ In analog instruments, the quantities can vary over a continous range of values.

→ Digital systems or digital instruments processes logical information (or) digital data (binary) form.

→ The quantities are represented in discreet or digital values (form) only.

Comparision between Analog and Digital Instruments.

Digital Instruments	Analog Instruments
→ Digital instruments require power supply (Battery)	→ Do not require separate power supply.
→ They have high accuracy.	→ Donot have better accuracy
→ The o/p is electrical.	→ o/p is mechanical
→ They provide high input impedance.	→ They provide low input impeda-nce.
→ These are complex and little costly.	→ These are simple and inexpensive.
→ The display screens are used for displaying the readings ex: LED, LCDs etc.	→ The pointer deflection is used to display the readings.

Voltmeter -

volt meter is a measuring instrument which measures voltage connected across the meter.

Hence the name is 'volt' which indicates voltage and 'meter' which indicates an instrument.

They are two types of voltages AC, DC.

hence we design AC voltmeter and DC voltmeter seperately.

DC Voltmeter -

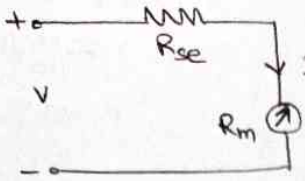
It measures DC voltage (direct current) across any two points of an electric circuit.

⇒ if we place a series resistor with a PMMC permanent moving magnet coil galvanometer, then it acts as a DC voltmeter.

The series resistance is used as a multiplier resistance or simply a multiplier.

It limits the current flows into the galvanometer.

and prevent the meter from exceeding the full deflection value.



(permanent Magnet moving coil Galvanometer)

⇒ To measure the DC voltage across any two nodes where the potential difference is to measured these the DC voltmeter two ends are connected accordingly.

∴ By applying KVL

$$\Rightarrow V = I_m R_{se} + I_m R_m$$

$$\Rightarrow V - I_m R_{se} - I_m R_m = 0$$

$$\therefore R_{se} = \frac{V - I_m R_m}{I_m}$$

$$\Rightarrow \boxed{R_{se} = \frac{V}{I_m} - R_m}$$

here V = voltage measured (to be)

R_{se} = Series resistance value = multiplier resistance. (Ω)

I_m = full scale deflection current

R_m = the internal resistance of the galvanometer.

⇒ consider V_m = voltage drop across the galvanometer

and $m = \frac{V}{V_m}$ called the <u>multiplying factor</u>

$$\therefore V = I_m R_{se} + I_m R_m$$

$$\Rightarrow V = I_m R_{se} + V_m$$

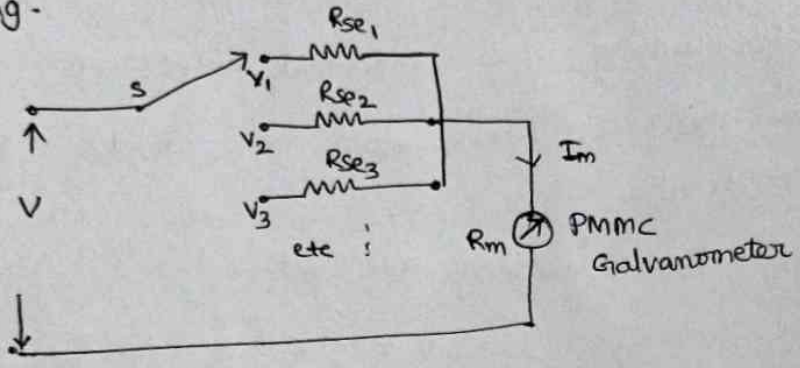
$$\therefore \frac{V}{V_m} = \frac{I_m R_{se}}{V_m} + 1$$

$$\Rightarrow m - 1 = \frac{R_{se}}{R_m}$$

$$\therefore \frac{R_{se}}{R_m} = m-1 \Rightarrow \boxed{R_{se} = R_m(m-1).}$$

this is the relationship b/n the multiplier resistance and internal resistance of the PMMC galvanometer.

⇒ we can also implement multi Range DC voltmeter also as following.



→ if we need to measure different range of voltages over a single DC voltmeter we need a multirange DC voltmeter. as above figure.

→ That range is adjusted by the help of a switch 's'. which measures V_1, V_2, V_3 and so on respectively with the multiplier resistance R_{se_1}, R_{se_2}, R_{se_3} --- etc. respectively.

here multiplying factors m_1, m_2, m_3 --- are given as

$$m_1 = \frac{V_1}{V_m}$$

$$m_2 = \frac{V_2}{V_m}$$

$$m_3 = \frac{V_3}{V_m} \quad \text{---} \quad \text{respectively.}$$

→ we can measure any one of the available voltage ranges at a time.

$$\therefore R_{se_1} = R_m(m_1 - 1)$$

$R_{se_2} = R_m(m_2 - 1)$

$R_{se_3} = R_m(m_3 - 1)$ ---- so on respectively.

and voltages of different ranges can be easily measured with this multi-range DC volt meter.

AC Voltmeter - This is used to measure AC voltage across an two nodes of an electric circuit.

* Its simply done with a rectifier based AC voltmeter.

It involves -

step1: converts the AC voltage signal into a DC voltage signal by a rectifier circuit.

step2: measures the DC or Average Value of the rectifier's output.

→ we have two types of Rectifiers →① HWR
→② FWR

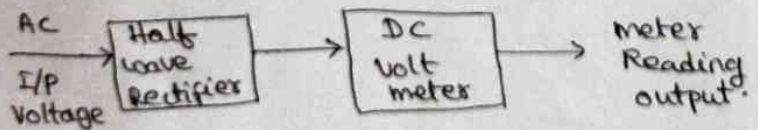
hence we have two types of AC voltmeters → they are

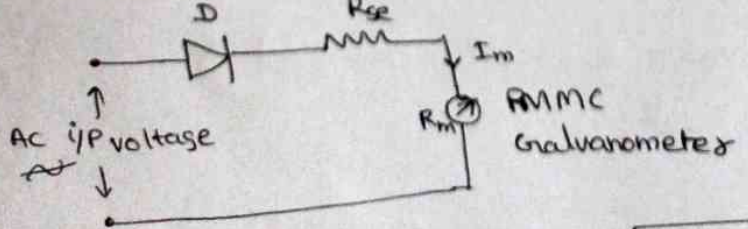
① AC voltmeter using HWR.
② AC voltmeter using FWR.

① AC Voltmeter using Half wave Rectifier -

If a HWR is connected or placed before a DC voltmeter then it is treated as an AC voltmeter using HWR.

→ the block diagram of it is as follows.





The RMS Value of voltage $V_{RMS} = \frac{V_m}{\sqrt{2}}$

$V_m = \sqrt{2}\ V_{RMS}$

$V_m = 1.414\ V_{RMS}$

here $V_m \Rightarrow V_{maximum}$

$\Rightarrow$ maximum value of a sinusoidal voltage 

The dc or Average value of HWR is

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

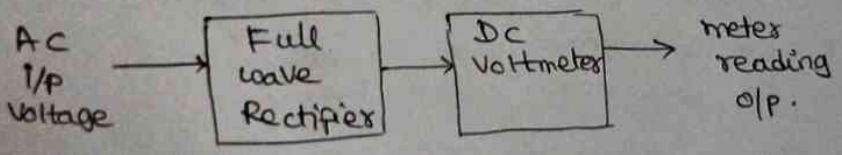
$$\therefore V_{dc} = \frac{1.414\ V_{RMS}}{\pi} = 0.45\ V_{RMS}$$

$\therefore$ The AC voltmeter produces an output voltage,

V_{out} = 0.45 times of V_{RMS}.

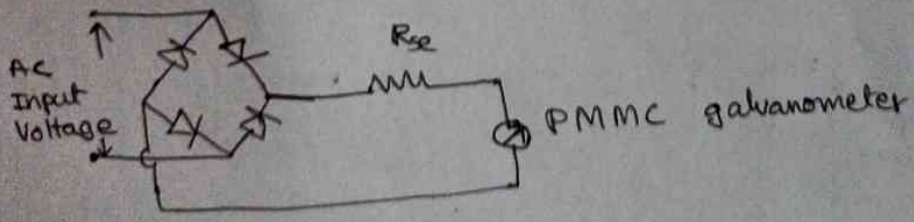
② AC voltmeter using Full wave Rectifier -

$\Rightarrow$ In this voltmeter a full wave rectifier is connected before a DC voltmeter to measure AC voltages, hence it will become an AC voltmeter with FWR.



Block diagram is as shown above.

→ the circuit diagram is as follows.



The RMS value of input sinusoidal (AC) voltage signal is

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

$$\therefore V_m = \sqrt{2}\ V_{RMS} = 1.414\ V_m$$

the dc value (or) average value of a FWR is

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

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

∴ The output AC voltage measure is 0.9 times of the RMS value of AC input voltage.

Multimeter - as the name suggests, it measures multiple quantities on a single device. like, voltage, current, resistance, transistor gain etc.

Hence its named as a multimeter.

There are two types of multimeters -
- ① Analog multimeter
- ② Digital multimeter.

Analog multimeter - its a PMMC type meter.
- It works on the principle of PMMC galvanometer.
- It has an ~~alone~~ analog display that uses the deflection pointer on the scale to indicate the reading

working of Analog multimeter -

As the analog multimeter is a PMMC type instrument, so when 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, ~~a de~~ with an angle. Thus it shows the readings.

→ Analog multimeters are used to measure the following electrical quantities.

1) DC voltage
2) AC voltage
3) DC current
4) Resistance etc.

1) DC current measurement -

An analog multimeter acts as an Ammeter (DC) with a very low resistance to measure DC current. A shunt resistance is conned across the PMMC galva-nometer to measure current (DC) in the ranges of milli Amperes to Amperes.

2) DC voltage measurement

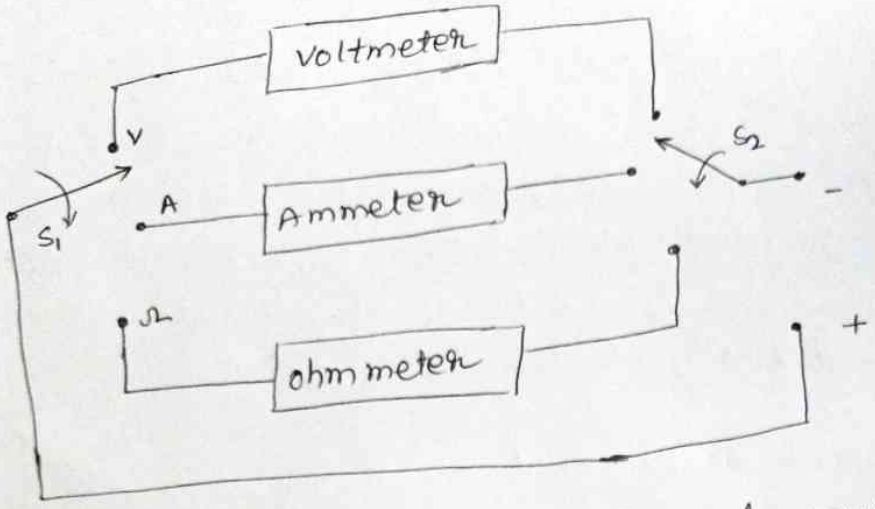
By adding a multiplier resistor (Rse) in series with the PMMC galvanometer then the multi~~am~~meter becomes a DC voltmeter in the ranges of milli volts to volts.

③ Resistance measurement -

By adding a battery and a resistor, the analog multimeter can work as an ohm meter. By changing the shunt resistance in the network, different resistances can be measured.

④ AC voltage measurement - By adding a rectifier in the analog multimeter circuit, the AC voltages and currents can be measured.

Block diagram of Analog multimeter -



steps to be followed for the use of analog multimeter-

→ Insert the probes in the correct connections as per the required measured values.

→ set switch to the correct measurement types and range.

→ once the measurement is completed, it's wise to place the probes into the voltage measurement sockets and set the range to maximum. It can prevent the damage of multimeter if accidentally high voltages are connected also.

Digital multimeter - A digital multimeter (DMM) is a measuring instrument used to measure various electrical quantities like voltage, current and resistance -also it can measure temperature, capacitance, continuity, frequency, transistor gains etc.

→ Dmm connections - A Dmm is provided with two jacks (probes) for connecting.

It has a rotary switch to change its position & ranges.

- It's provided with a digital display to show the readings in terms of decimal numbers (0 to 9).

Measurement of different quantities using DMM -

- In AC-voltage mode - the applied input voltage is fed through a calibrated, compensated attenuator, to a full-wave rectifier followed by a ripple reduction filter. the resultant DC is fed to Analog to Digital Converter (ADC) and finally to the display system.

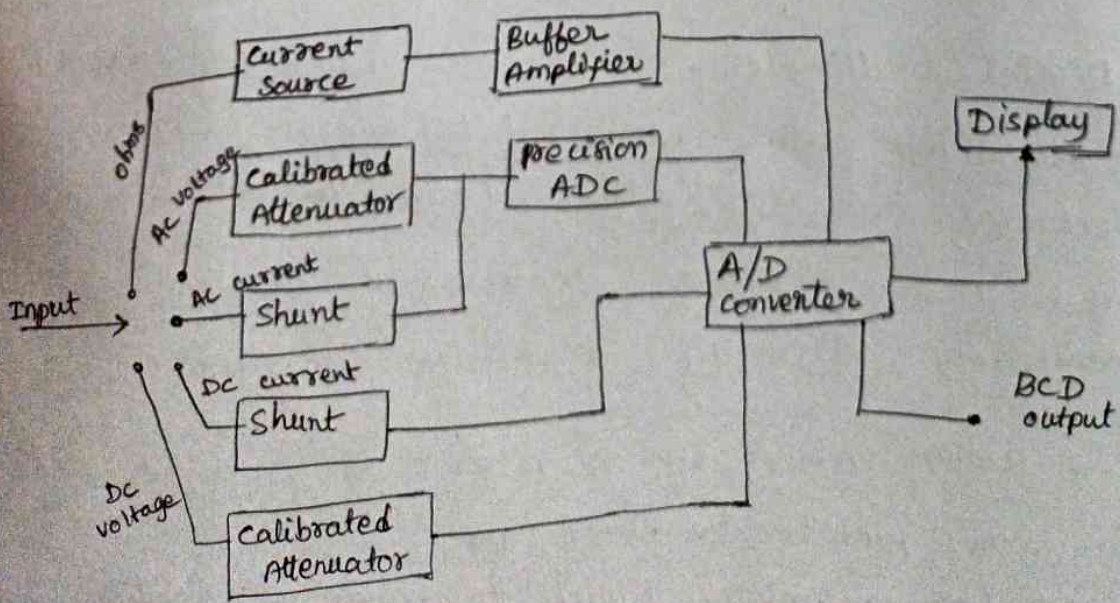
- for current measurement -

* In DC current mode - The drop across the internal calibrated shunt is measured directly by ADC.
* In AC current mode - After AC to DC conversion, the drop across the internal calibrated shunt is measured by the ADC.

- for Resistance measurement -

A DMM is provide with an internal battery, hence resistance measurement is done by DMM.

* Block Diagram of Digital multimeter -



Characteristics of Digital Instrument -

The important characteristics of digital instruments are:

① Resolution
② Sensitivity.

① **Resolution** - It's defined as the number of digits used in a digital meter.

A display on a meter for (0-1) volt range will be able to show from 0 to 999 mV with resolution of 1mV.

if 'n' is the number of full digits (which can show 0 to 9 numbers)

$\therefore$ Resolution $R = \frac{1}{10^n}$

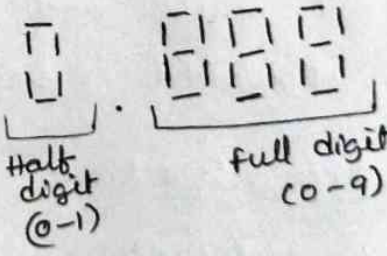
② **Sensitivity** - This is the smallest change in the input that can be detected by a meter. This is the lowest full scale value of the meter multiplied by the resolution (R). It's denoted by S.

$$S = V \times R$$

where V = lowest full scale value of the meter
R = resolution.

⇒ **$3\frac{1}{2}$ digit display** -

The number of digit positions used in a digital display will determine the resolution.



Hence a 3 digit display on a Digital voltmeter for (0-1)V range will indicated the values from 0 to 999 mV with smallest increment of 1mV.

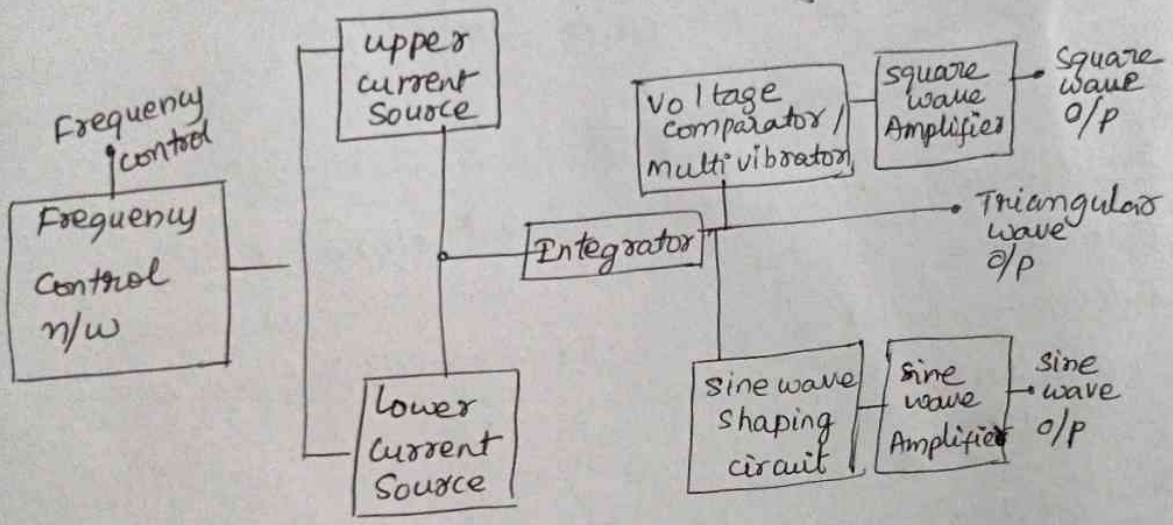
Here the three (3) full digits can show 0 to 9 values and the half digit displays (0 or 1).

These kind of displays are called $3\frac{1}{2}$ digit displays

Function Generator -

Function generator is a signal generator, which generates three or more periodic waves. Conside the function generators mostly produces sine waves, Square waves and triangular waves.

Block diagram of function generator -



There are two current sources, namely the upper current source and lower current source. These two are regulated by the frequency - controlled network.

→ Triangular wave network -

The integrator present in the above block diagram, gets constant current alternately from the upper and lower current source for an equal amount of time repeatedly.

Hence the integrator produces two types of output for the same time repeatedly.

* the o/p voltage increases linearly w.r.t time

during the period where the integrator receives current from upper current source.

* the output voltage of the integrator will decrease linearly w.r.t time during the period where the integrator gets current from lower current source.

In this way it repeatedly produces like wise which produces a Δle triangular wave at the o/p.

Square wave & Sine wave production-

- The output of the integrator i.e triangular wave is applied as an input to two other blocks as shown in the above block diagram to get square wave and Sine wave respectively.

Square wave n/w -

The triangular wave has positive slope and negative slope alternately for equal amount of time repeatedly

→ So, the voltage comparator multivibrator present in the block diagram will produce the following 2 types of outputs for equal amount of time repeatedly

* one type of High (constant) voltage at the multivibrator / comparator o/p for the period during which the comparator receives positive slope of the triangular wave.

* Another type of low (constant) voltage at the comparator for the period during which the comparator gets negative slope of triangular wave at its input.

- Thus the comparator produces a square wave at its output.
- If its Amplitude is not sufficient then it can be amplified by a square wave amplifier.

Sine wave n/w -

The sine wave shaping n/w or circuit will produce a sine wave output from the triangular wave.

Basically it consists of diode resistance n/w.

If the amplitude of sine wave is insufficient, then a sine wave amplifier is available to amplify it to the required level.