UNIT - 1

Introduction :

Instrumentation is a technology of measurement which serves not only science but all branches of engineering, medicine etc.

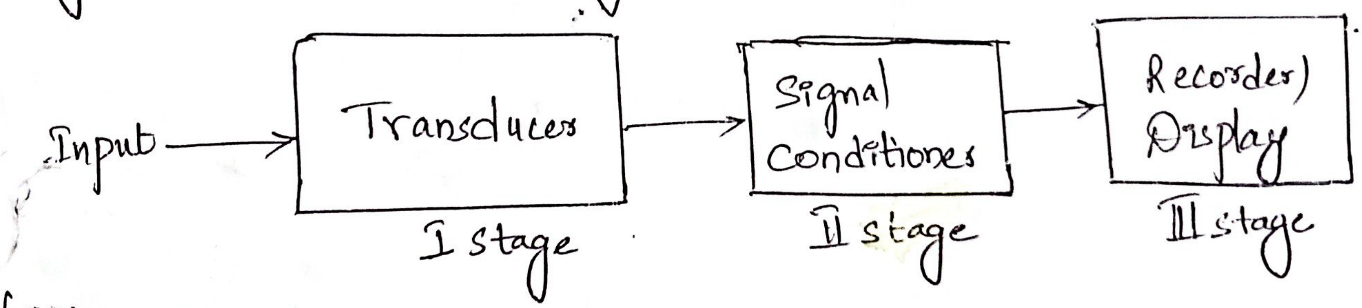
→ Measuring is basically used to monitor (or) control a process.

Ex:- Thermometers, barometers, anemometers used to indicate environmental conditions. Similarly water, gas & electric meters are used to monitor the quantity used.

→ The major problem with any measuring instrument is Error.

→ The basic concern of any measuring instrument is it should not effect the quantity being measured.

→ Any Instrument basically consists of three stages.



I stage : Transducer : It is a device activated by an energising input from one (or) more transmission media and generates an appropriate signal in different form to one (or) more transmission systems. The input may be electrical, mechanical (or) acoustical. The output may be analog, digital (or) frequency modulated.

"It is a device that converts one form of energy in to another form"

The converted electrical (or) mechanical signal is given as input to second stage i.e signal conditioner. Ex:- Photodetector, Strain gauge etc.

Stage-II : Signal conditioners:

The output of the first stage has to be modified before it be suitable to the signal indicating stage. A signal conditioner equipment has to perform linear processes such as amplification, attenuation, Integration, differentiation, addition (or) Subtraction. There are also some non-linear processes such as modulation, demodulation, sampling, filtering, clipping, clamping etc. Transducers output is brought to the required level to make it useful for conversion, processing, Indicating and recording Ex: opamp, modulator etc

Stage-III :

The measuring instruments quantity is displayed (or) recorded in this stage

Recorder: It is a measuring instrument that displays a time-varying signal, even after the original signal does not exist.

Ex: potentiometer recorders, null type recorders, X-Y recorders etc

Display (or) Indicator: The essential requirement of an Indicator is to display the data in a readily understandable form. They provide visual display of numbers, letters and symbols in response to the given input.

Performance characteristics:

⇒ A knowledge of Performance characteristics of an instrument is essential for selecting most suitable instrument for specific measure.

The performance characteristics of any measuring devices are of two types.

1. Static characteristics.
2. Dynamic characteristics.

...ic Characteristics of Instrument : These are the characteristics that are used to determine present value of the quantity under measurement. Static characteristics are :

(1) precision
(2) Expected value
(3) Error
(4) Accuracy
(5) Resolution
(6) Sensitivity

(1) precision :

It is the measure of consistency (or) repeatability of measurements i.e successive readings donot differ. (precision is the consistancy of the instrument output for a given value of input".) ex- $\pi = 3.14$ is correct value (or) true value and it is accurate but $\pi = 3.1428574$ is precise as well as accurate value. $\pi = 3.2428574$ is precise but not accurate.

(2) Expected value :

It is the design value i.e the most probable value that calculations indicate one should expect to measure. ex:- voltage is measured then the value expected is in uv, mv (or) in volts (or) 100's of volts etc.

(3) Error :

The deviation of the true value from the desired value is called an Error. when the measured value exceeds the true value the error is said to be positive else negative. By minimizing error accuracy can be increased.

(4) Accuracy :

The degree of exactness (or closeness) of measurement compared to Expected (desired) value.

The accuracy of the whole system depends upon the accuracy of individual instruments of that system. Ex: If A = ±1% for 100V voltmeter then the maximum error for any reading will not exceed ±1V.

(5) Resolution:

The smallest change in a measured variable to which an instrument will respond. Ex: A 100V voltmeter may not be able to measure 100mV. Only for minimum input of 0.5V the needle deflects. Hence resolution of that instrument is of 0.5V.

(6) Sensitivity:

The ratio of change in output (response) of the instrument to a change of input or measured variable. Its units are mm/µA (or) mm/Ω (or) counts per volts etc

$$\boxed{\text{Sensitivity} = \frac{\text{Change of output}}{\text{Change of input}}}$$

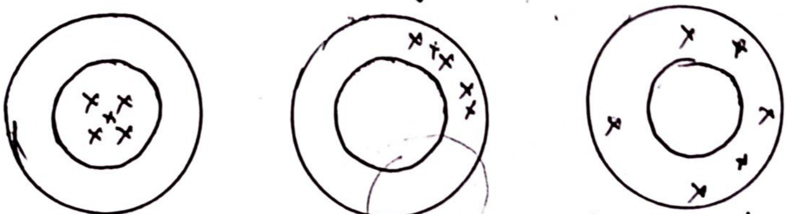
$$\boxed{\text{Deflection factor} = \frac{1}{\text{Sensitivity}}}$$

Difference between accuracy and precision:

→ Accuracy and precision depends upon systematic and random errors.

→ An accurate measurement might not be precise vice-versa.

→ For example consider game of darts, when one is asked to strike the target by center circle. The center circle represents true value and the result achived by the strikes has been indicated "x". Ex 1:

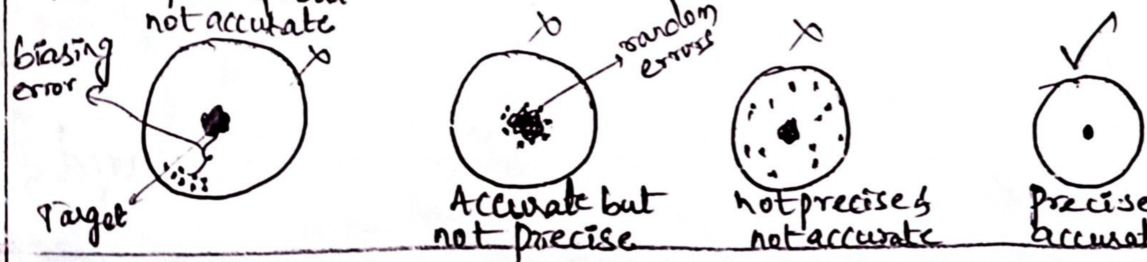


(a) High Accuracy High precision

(b) Low accuracy High precision

(c) Low Accuracy Low precision

Ex: 2: Precise but not accurate



Accurate but not precise

not precise & not accurate

Precise & accurate

An instrument should have high accuracy & high precision.

Error In measurement:

The most important static characteristics of an instrument is its accuracy. which is generally expressed in terms of the error called static error.

"It is the algebric difference between the true value (expected value) and the indicated value of the quantity to be measured is called an error." It is denoted as 'e'.

$e \rightarrow$ error

$$\boxed{e = A_t - A_m}$$

$A_t \rightarrow$ True value of quantity

$A_m \rightarrow$ Measured value of quantity

$$\% \text{ of error} = (A_t - A_m) \times 100$$

Relative error $e_r = \frac{\text{Absolute error}}{\text{True value}} = \frac{\text{True value} - \text{measured value}}{\text{True value}}$

$$e_r = \frac{A_t - A_m}{A_t}$$

$$\boxed{\% e_r = \left(\frac{A_t - A_m}{A_t}\right) \times 100}$$

The accuracy can be mathematically expressed as

$A \rightarrow$ Relative accuracy

$$A = 1 - e_r$$

$$\boxed{A = 1 - \left|\frac{A_t - A_m}{A_t}\right|}$$

$$\boxed{a = A \times 100\%}$$

$a \rightarrow$ Percentage accuracy

Ex: Expected value of the voltage across a resistor is 80V. However, the measurement gives a value of 79V. Calculate (i) Absolute error, (ii) % error (iii) relative accuracy and (iv) % accuracy (v) Error in FSD if scale ranges for 0–200V.

Sol:

(i) Absolute error $= A_t - A_m = 80 - 79 \Rightarrow 1V$ //

(ii) % error $= \frac{A_t - A_m}{A_t} \times 100 = \frac{80 - 79}{80} \times 100 \Rightarrow 1.25\%$ //

(iii) Relative accuracy $A = 1 - \left|\frac{A_t - A_m}{A_t}\right| \Rightarrow 1 - \left|\frac{80 - 79}{80}\right| = 0.9875$ //

(iv) % of accuracy $a = 100 \times A$

$= 100 \times 0.9875$

$\boxed{a = 98.75\%}$

(v) % of error expressed as % of full scale reading is,

$$= \frac{A_t - A_m}{f.s.d} \times 100$$

$$= \frac{1}{200} \times 100$$

$$= 0.5\%$$

→ Precision is expressed mathematically as

$$\boxed{P = 1 - \left| \frac{X_n - \overline{X_n}}{\overline{X_n}} \right|}$$

X_n → value of n^{th} measurement

$\overline{X_n}$ → average set of measurement

Ex: The table shows set of 5 measurements recorded in a lab. Calculate precision of 3rd measurement.

Measurement number	Measurement value X_n
1	49
2	51
3	52
4	50
5	49

Sol: $\overline{X_n} = \frac{\text{Sum of readings}}{\text{no. of readings}} = \frac{251}{5} = 50.2$

The value of 3rd measurement is $X_n = 52$

when $n = 3$ $P = 1 - \left| \frac{X_n - \overline{X_n}}{\overline{X_n}} \right|$

$$P = 1 - \left| \frac{52 - 50.2}{50.2} \right|$$

$$P = 0.964 \text{ (or) } 96.4\%$$

Types of Static Errors: Generally they are classified as,

(1) Gross errors (Human errors)

(2) Systematic errors ~~and~~ (biasing errors) and

(3) Random (or) accidental errors

(1) Gross errors:

→ Human mistakes in reading (or) using instruments and in recording and calculating measurement results.

→ These errors may occur due to computational mistakes.

→ It is not possible to eliminate these errors but they can be minimized by

(i) Special attention should be taken in reading and recording the data.

(ii) The experimenter should not depend on only one reading, atleast three (or) even more readings must be taken

(2) Systematic Errors: (biasing errors)

→ These errors occur due to shortcomings of the instrument, such as defective (or) worn parts (or) ageing (or) effects of the environment on the instrument.

→ A constant uniform deviation of the operation of an instrument is known as systematic error.

→ There are basically three types i. Instrumental errors
(ii) Environmental errors
(iii) Observational errors

(i) Instrumental Errors:

→ Instrumental errors are inherent in measuring instruments, because of their mechanical structure.

→ For example D'Arsonval movement, friction in bearings of different components, irregular spring tensions, stretching of the spring (or) overloading of the instrument.

Instrument errors can be avoided by

(a) Select a suitable instrument for particular measurement applicati

(b) After determining instrument errors, apply correction factors.

(c) The instrument must be re-caliberated carefully.

(ii) Environmental Errors:

→ Due to changes in the environment surrounded to the instrument that may affect the instrument characteristics, such as temperature, humidity, pressure, magnetic field (or) electrostatic field

→ These errors can be avoided by (a) air conditioning

(b) Hermetically sealing certain components in the instrument and

(c) Using magnetic sheilds.

(iii) Observational Errors:

→ These errors are caused due to observes. Ex: parallax errors

→ These are caused by habits of individual observers.

→ To minimize parallax errors, modern instruments have digital outputs.

(3) Random (or) accidental Errors:

→ These are found even the Gross and systematic Errors are minimized.

→ The accumilation of large number of small effects causes these type of errors.

→ These are caused due to

(a) Certain Human errors: Inconsistency in estimating successive readings from the instrument by an observer.

(b) Errors caused due to disturbance in equipment.

(c) Errors caused due to fluctuating experimental conditions

Dynamic characteristics:

Type of instrument needed depends upon the type of data.

1. <u>Steadystate data</u>: If data varies in the range of 0-5Hz.
2. <u>Transient data</u>: If the parameters variation is at much higher rate (greater than 5Hz).
3. <u>Dynamic data</u>: If the parameters variation is periodic.

Static characteristics indicate response of slow varying data (or time invarient data. Instrument testing, design and evaluation is performed based on these parameters.

The <u>dynamic behaviour</u> of an instrument is determined by subjecting its primary element (sensing element) to some known predetermined variations in the measured quantity. The three most common variations in measured quantity are:

1. <u>Step input</u>:

This represents sudden, instantaneous and finite change in the input
Ex: Sudden application of force to mechanical system, instantaneous closing of switch in electrical circuits etc.

→ The step input of magnitude A is denoted as $Au(t)$ and shown in fig

Its laplace transform $\boxed{F(s) = \frac{A}{s}}$

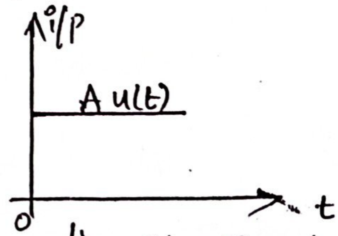


fig: Step input

2. <u>Ramp input</u>:

This represents linear change in input. The input ie measured variable varies linearly with time. It is denoted with $Atu(t)$

Laplace transform $\boxed{F(s) = \frac{A}{s^2}}$

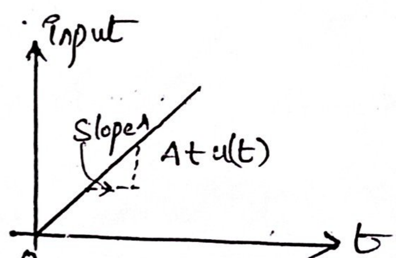


fig: Ramp input

when $A = 1 \Rightarrow$ Unit ramp

3. Sinusoidal input :

This represents an input which changes in accordance with a sinusoidal function of constant amplitude. The frequency is independent variable in this case.

Analysing the dynamic behaviour includes the study of variations in output amplitude and phase as input is sinusoidal.

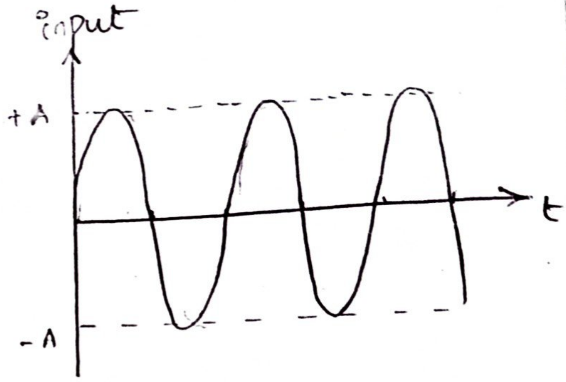


fig: Sinusoidal input

→ The sinusoidal input is given as $A\sin\omega t$

Laplace transform $\boxed{F(s) = \frac{A\omega}{s^2+\omega^2}}$

→ The various dynamic characteristics of instrument are :-

1. Speed of response
2. Fedility
3. Lag
4. Dynamic error.

1. speed of response:

It is the rapidity (or) quickness of the instrument with which it responds to the sudden change in the input signal. It indicates the activeness of the system. It is also stated as the total time taken by the system to come closer to steady state condition.

2. Fedility: (faithful reproduction)

Degree to which an instrument indicates the change in the measured variable without any dynamic error. The perfect fedility is obtained by a zero order system i.e fedility is the degree of nearness with which the output reproduces the time varying input with in a conversion factor.

3) Lag:

Every system takes some time, whatever small it may be, to respond to the changes in the measured variable. This retardation or delay in the response is called lag. It is also called measuring lag. It is of two types:

(a) Retardation lag:

In this case, the response of the system begins immediatly after a change in the variable, has occured.

(b) Time delay:

In this case, Response begins after some time called dead time, after the application of input. This shift causes dynamic error

4) Dynamic Error:

It is the difference between true value of the quantity to be measured to the value indicated by the instrument, assuming zero static error.

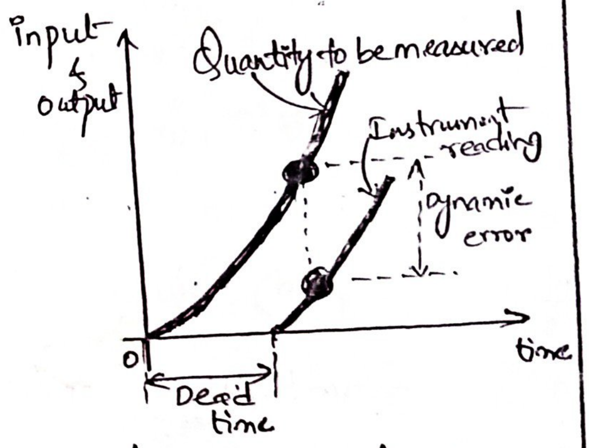


fig: Dynamic characteristics

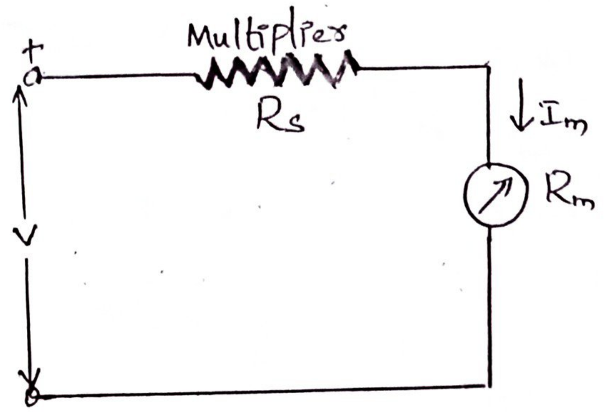
DC – Voltmeter :

→ The Most commonly used DC-Voltmeter is based on fundamental principle of the motor.

→ Motor action is produced by a small amount of current through a moving coil which is positioned in a permanent magnetic field.

→ This basic moving system is called as "D'Arsonval movement"

→ A basic D'Arsonval movement can be converted into dc-voltmeter by adding a series resistor known as multiplier.



fig①. Basic dc- Voltmeter

→ The function of the multiplier is to limit the current through the movement so that the current does not exceed the full scale deflection (FSD) value.

→ A dc-voltmeter measures the potential difference between two points in a dc-circuit.

→ Always dc-voltmeter is connected in parallel with proper polarity.

→ The value of the multiplier required is given as :

I_m = full scale deflection current of the movement (I_{fsd})

R_m = Internal resistance of the movement

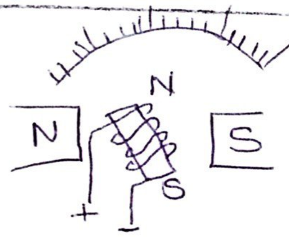
R_s = Multiplier resistance

V = full range voltage of the instrument

from fig① ⇒ $V = I_m(R_s + R_m)$

$$R_s = \frac{V - I_m R_m}{I_m}$$

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

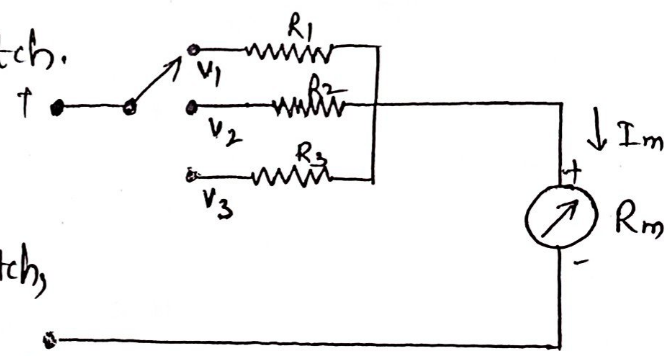


'D' Arsonval Principle

The multiplier limits the current through the movement, so as to not exceed I_{fsd}.

Multirange Voltmeter:

→ A number of shunt resistances are connected across the movement with a multiple positioned switch.



→ figure ① shows a multi-range voltmeter using three position switch, and three multipliers R_1, R_2 & R_3, for voltage values V_1, V_2, V_3.

fig ①: multi range voltmeter

→ fig ① can be modified further to improve the practical arrangement

→ fig ② is more practical arrangement of multiplier resistors of multi range voltmeter.

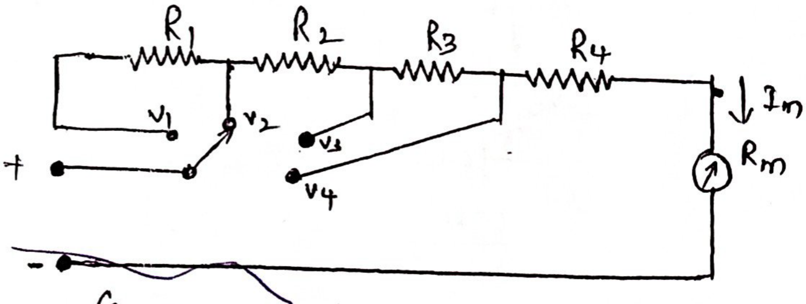
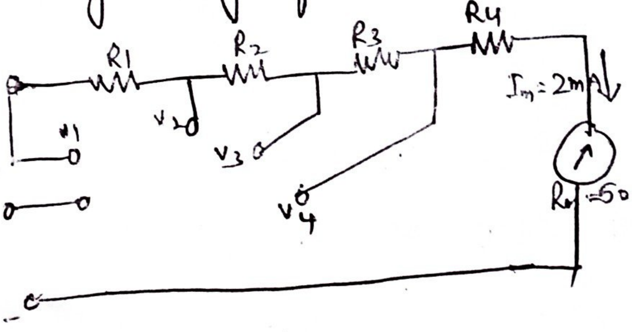


fig ②: Multipliers connected in series string.

→ Here multipliers are connected in series string, and range selector selects the appropriate amount of resistance required in series with movement.

→ The first resistance (or) low range multiplier R_4, is specially manufactured to meet the circuit requirements.

Examples: Convert a basic D'Arsonval movement with an internal resistance of 50Ω and fullscale deflection current of 2mA into a multirange dc-voltmeter with voltage range of 0–10V, 0–50V, 0–100V & 0–250V.



Sol: for 10V range (V_4 position of switch), the total resistance

$$R_t = \frac{V}{I_{fsd}} = \frac{10}{2mA} \Rightarrow 5KΩ$$

$\therefore R_4 = R_t - R_m \Rightarrow 5000Ω - 50Ω = 4950Ω \Rightarrow \underline{4.95KΩ}$

→ for 50V range (V_3 position), the total circuit resistance

$$R_t = \frac{V}{I_{fsd}} \Rightarrow \frac{50^{25}}{2\times10^{-3}} = \underline{25KΩ} \text{ (or) } 25000Ω$$

$R_3 = R_t - R_m - R_4 \Rightarrow 25000 - (50 + 4950) = 25K - 5K = \underline{20KΩ}$

→ for 100V range (V_2 position), the total resistance

$$R_t = \frac{V}{I_{fsd}}$$

$$= \frac{100}{2\times10^{-3}} \Rightarrow 50KΩ$$

$R_2 = R_t - (R_m + R_4 + R_3) \Rightarrow 50,000 - (50 + 4950 + 20,000)$

$\Rightarrow 50k - 25K$

$\boxed{R_2 \Rightarrow 25KΩ}$

→ For 250V (V_1 position), the total resistance R_T is given as

$$R_T = \frac{V}{I_{fsd}} \Rightarrow \frac{250}{2\times10^{-3}} = 125KΩ$$

$R_1 = R_t - (R_m + R_4 + R_3 + R_2) = 125,000 - (25k + 20k + 4950 + 50) \Rightarrow 125k - 50k = \underline{75KΩ}$

Extending Voltmeter range:

→ The range of a Voltmeter Can be extended to measure high Voltages.

→ This is achieved by using an external multiplier resistor. & By using high voltage probe.

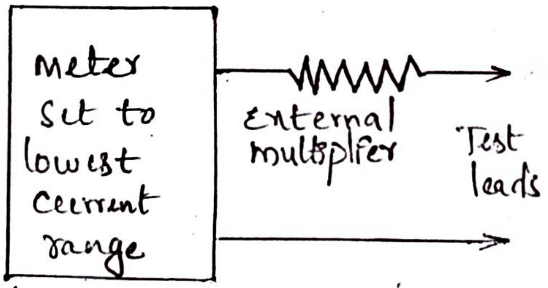


fig: extending voltage range

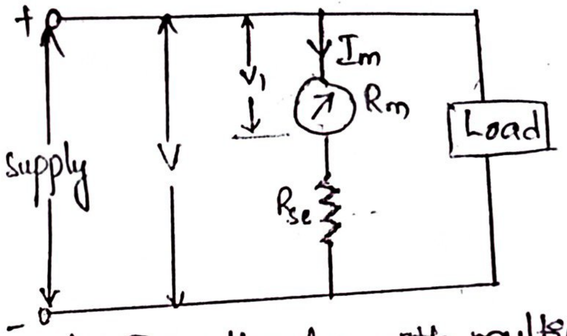


fig ②: voltmeter with multiplier

where V → Device full range voltage

V_1 → Voltage across the basic meter movement.

R_{se} → Series resistance

I_m → full scale deflection current of the movement

R_m → Internal resistance of the coil.

from fig ② ⟹ $V_1 = I_m R_m$ —— ①

$V = I_m R_m + I_m R_{se}$ —— ②

$V = I_m(R_m + R_{se})$

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

The multiplication factor of the multiplier is given by,

$m = \dfrac{V}{V_1}$

$\dfrac{I_m R_m}{I_m R_m} + \dfrac{I_m R_{se}}{I_m R_m}$

$\therefore m = \dfrac{I_m(R_m + R_{se})}{I_m R_m} \Rightarrow \boxed{m = \left(1 + \dfrac{R_{se}}{R_m}\right)}$

$\boxed{R_{se} = R_m(m-1)}$ —— ③

$\dfrac{R_m + R_{se}}{R_m}$

eq ③ is called resistance of multiplier

Voltmeter Sensitivity: (ohms per volts rating of voltmeter)

It is the ratio of total circuit resistance to the voltage range.

It is the reciprocal of full scale deflection current represented by 'S', given as

$$\boxed{S = \frac{1}{I_{fsd}}}$$

Sensitivity of a dc-voltmeter is used to calculate the value of multiplier resistor i.e

$R_{se} = R_T - R_m$ & $R_T = S \times V$

$$\boxed{R_{se} = (S \times V) - R_m}$$

$R_T \rightarrow$ total resistance

$R_T = R_{se} + R_m$

$S \rightarrow$ sensitivity of voltmeter

$V \rightarrow$ voltage range set by switch

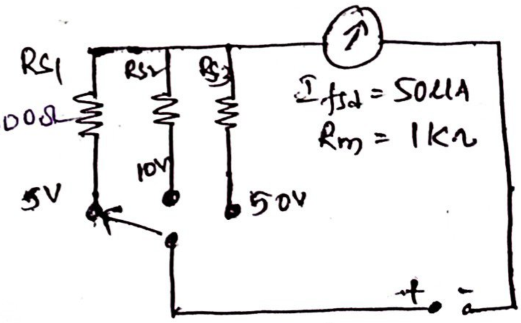
$R_m \rightarrow$ internal resistance.

→ Calculate the value of multiplier required for the multirange dc-voltmeter as shown in figure below.

Sol: Sensitivity $S = \frac{1}{I_{fsd}}$

$= \frac{1}{50\mu A} = \frac{1}{50 \times 10^{-6}} = 20000\Omega$

$$\boxed{S = 20\,k\Omega/V}$$



for 5V range the value of multiplier resistance is

$R_{s1} = (S \times V) - R_m \Rightarrow 20k \times 5 - 1k = 100k - 1k = \underline{99k\Omega}$

for 10V range the value of multiplier resistance is

$R_{s2} = (S \times V) - R_m \Rightarrow 20k \times 10 - 1k\Omega = 200k - 1k\Omega \Rightarrow \underline{199\,k\Omega}$

for 50V range the value of multiplier resistance is

$R_{s3} = (S \times V) - R_m \Rightarrow 20k \times 50 - 1k\Omega = 1000k - 1k \Rightarrow \underline{999\,k\Omega}$

$\therefore R_{s1} = 99k\Omega$; $R_{s2} = 199k\Omega$, $R_{s3} = \underline{999\,k\Omega}$ respectively

Solid state voltmeter :

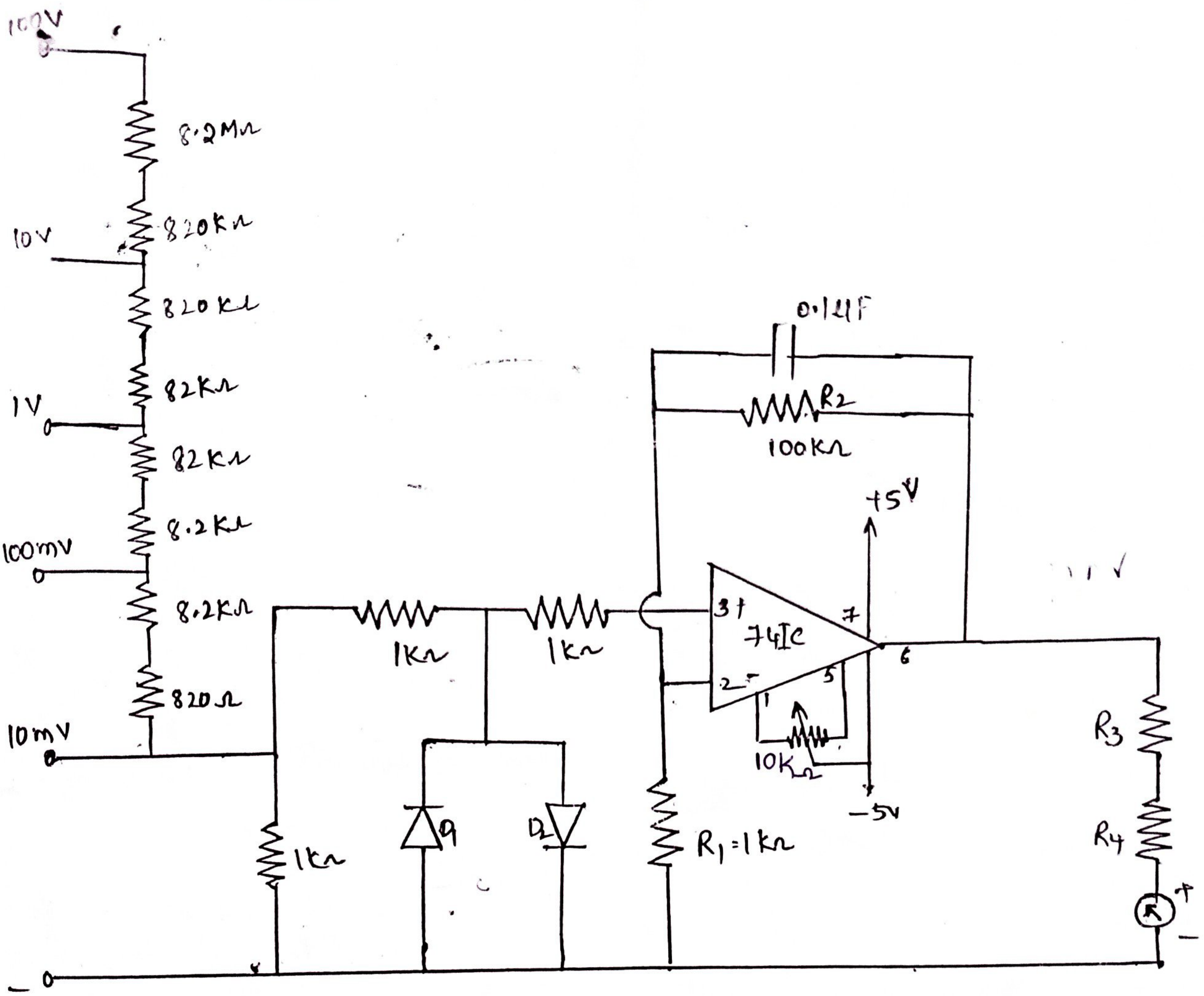


fig: solid state 'mv' voltmeter using IC 741C opamp.

→ solid state voltmeters are directly coupled, very high gain amplifiers.

→ The ratio of R_2/R_1 determines gain. with terminals 1 & 5 as offset null terminals.

→ To provide a negative feed back, a resistance 'R_2' is connected to pin 2 to pin 6.

→ from the figure, the gain $\frac{R_2}{R_1} = \frac{100k\Omega}{1k\Omega} \Rightarrow \boxed{100 = \text{gain}}$

→ A 10kΩ potentiometer is connected between 1 & 5, used for adjusting zero output for zero input.

→ The two diodes D_1, D_2 are used for protecting the IC. Under normal conditions they are non-conducting, as maximum voltage across them is 10mV.

→ If excess voltage (>10mV) appears across them, then one of the diode conducts and protects IC.

→ A 50–1000μA full scale deflection can be used as an indicator. R_4 is adjusted to get maximum fsd (full scale deflection).

Differential voltmeters

Basic differential voltmeter. (or) Potentiometric Voltmeter:

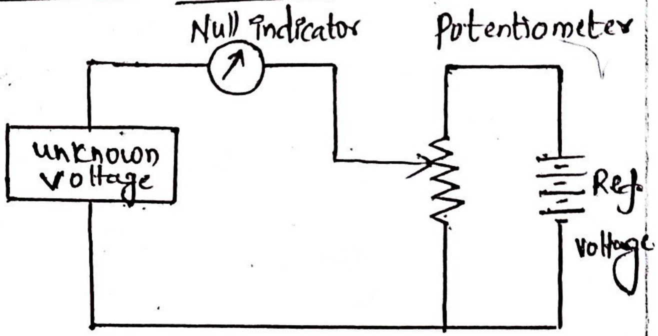


fig: Basic differential voltmeter

→ It is one of the most common and accurate methods of measuring unknown voltages.

→ In this technique, a voltmeter is used to indicate the difference between the known and unknown voltages, i.e an "unknown voltage is compared with known voltage."

→ from the fig the potentiometer is varied until the voltage across it equals the unknown voltage, indicated by null indicator as zero.

→ Under null condition, the meter draws current neither from the reference source nor the unknown voltage source.

→ To detect small differences the meter movement should be sensitive.

→ The reference source is usually a 1Vdc standard, source or a Zener ~~diode~~ controlled precision supply.

AC - differential Voltmeters:

→ In order to convert Ac-voltages in to dc a typical Ac-differential voltmeter uses a precision rectifier circuit.

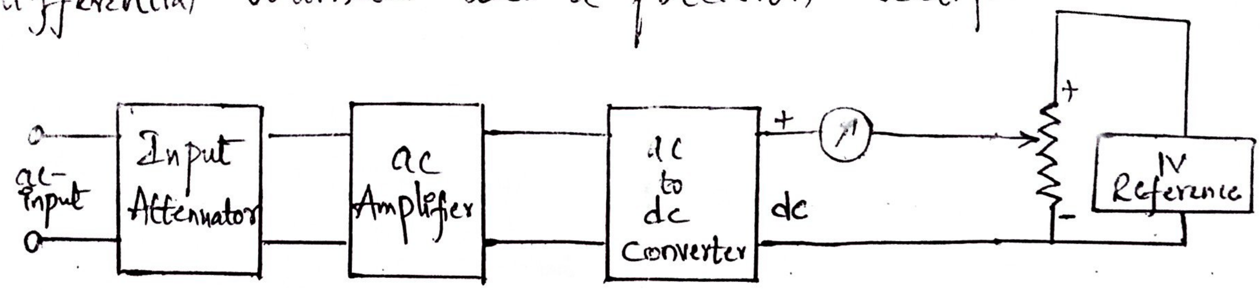
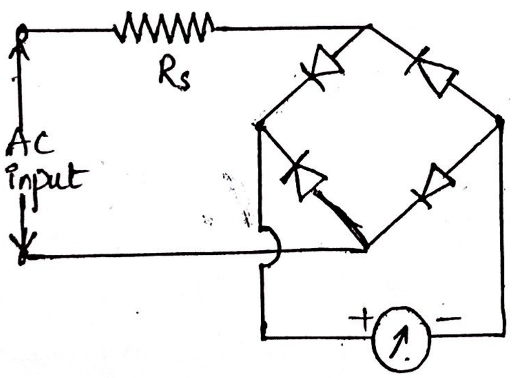


fig: Block deagram of Ac differential voltmeter

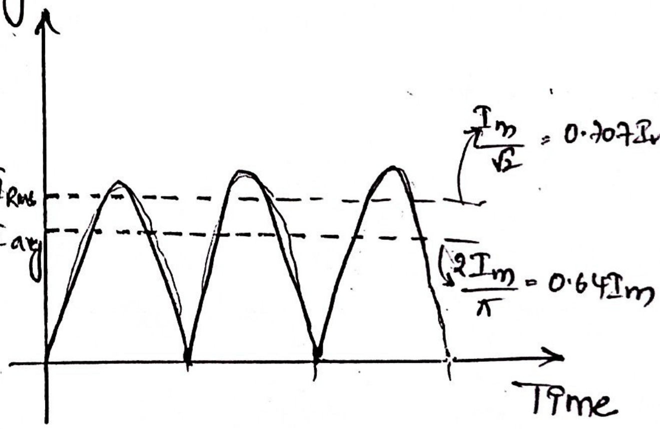
AC voltmeter:

→ A rectifier type instruments generally use PMMC (Permanent magnet moving coil) movement along with a rectifying arrangement.

→ Silicon diodes are prefered due to their low reverse current and high forward current ratings.



fig①: AC voltmeter



fig②: RMS and average value of current

→ A rectifier bridge produces a full wave D.C signal as its input. The steady deflection is proportional to the average value of the current (I_{avg}) as shown in fig ③.

→ The meter scale is usually caliberated to give RMS value of alternating sine wave input.

→ In the reverse bias, rectifier exhibits capacitance properties which bypass high frequencies.

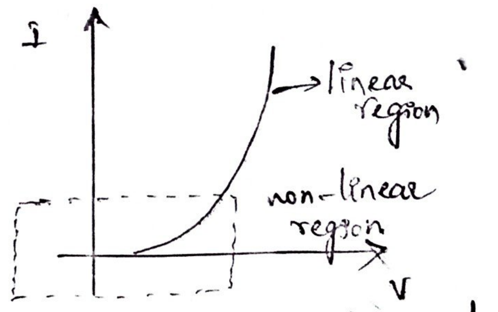
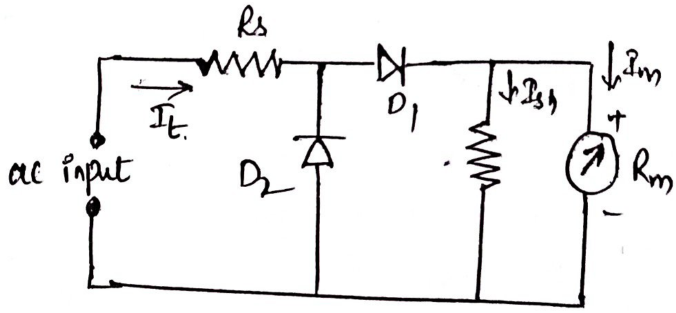


fig ③ : Diode Characteristics

→ Thus the ac voltmeter reading may be in error by 0.5 % decrease for every 1 KHz rise in frequency

→ In figure ④ the diode D1 conducts during positive half of the input cycle and the meter deflects in according to the average value of the half cycle.



④ fig: general rectifier-type AC-voltmeter

→ The meter movement is shunted by the resistor (R_{sh}) in order to draw more current through D1 and for linearization

→ The diode D2 conducts during negative half cycle of AC input and current passes through the measuring circuit in opposite direction. This current bypasses the meter movement.

Multi-range Ac-Voltmeter :

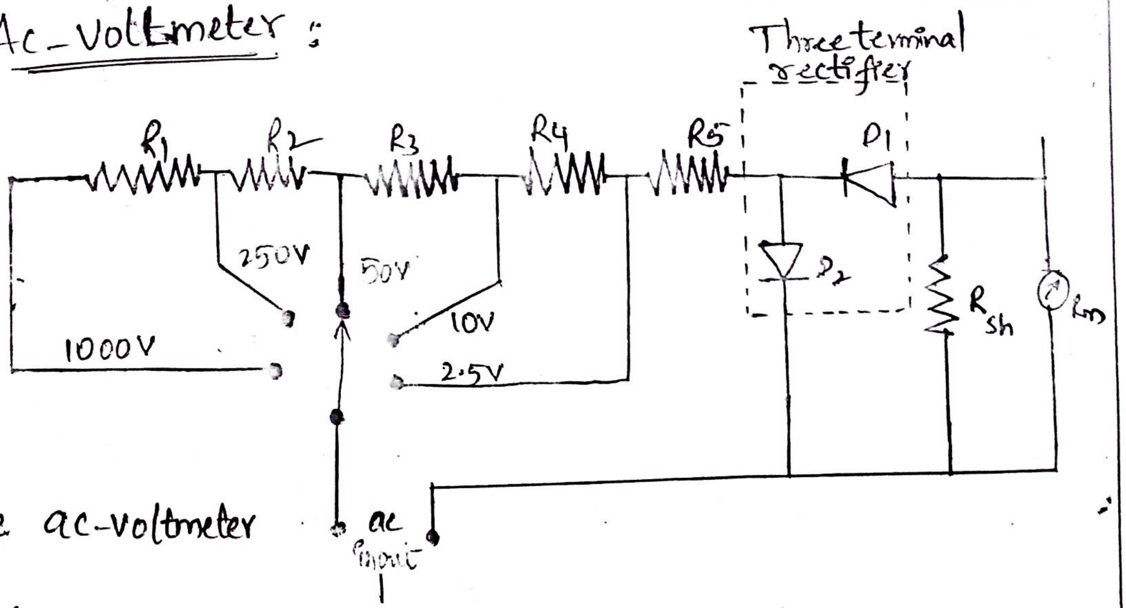


fig: multirange ac-voltmeter

→ The basic circuit for measuring ac voltages for different ranges is shown in the above figure.

→ The resistances R_1, R_2, R_3 and R_4 form a chain of multipliers for voltage ranges of 1000V, 250V, 50V, 10V ~~and 2.5V~~.

→ The resistor R_5 acts as a multiplier whose voltage range is 2.5V.

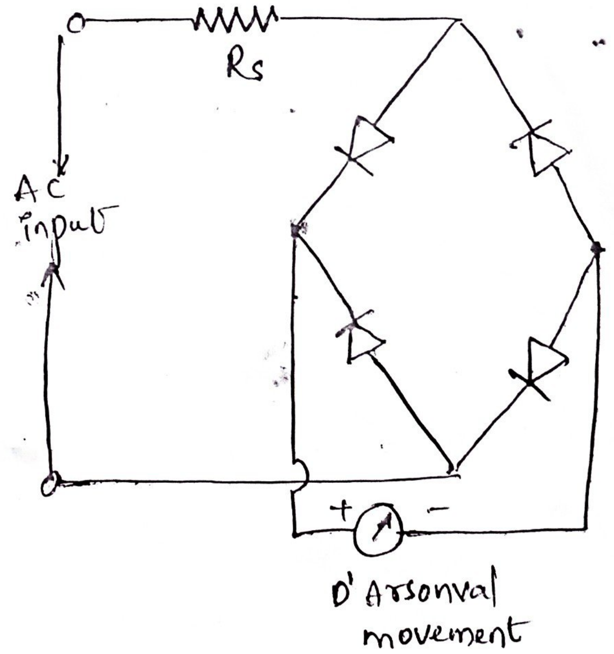
→ In order to improve rectification operation R_{sh} is acted as Shunt in meter.

Range extension of an AC voltmeter:

→ An AC Voltmeter is a rectifier type device which uses PMMC (Primary-magnetic-moving-coil) movement along with rectifier arrangement.

→ The basic circuit is shown below, with 4 diodes used in rectifying elements form a full wave rectifier bridge.

→ Rectifier element converts AC to unidirectional DC and a meter responsive to DC is used to indicate the value of rectified.



→ Generally silicon diodes are used in the bridge rectifiers since it has high forward current and low reverse current

→ In the figure the value of current is limited by multiplier "Rs" ($I_m \leq I_{FSD}$)

the dc sensitivity of rectifier type device is

$$S_{dc} = \frac{1}{I_{FSD}}$$

I_{FSD} → Full scale deflection current

→ The AC sensitivity of the device is different for half-wave rectifier and full wave rectifier.

For half-wave rectifier : $S_{AC} = 0.45 S_{DC}$ — ①

For Full-wave rectifier : $S_{AC} = 0.9 S_{DC}$ — ②

eq ① & ② are not valid for non-sinusoidal input waveforms

→ Consider 'V' applied voltage and V_1 as voltage drop across PMMC instrument then

→ To extend the range of half wave rectifier for AC-Voltmeter the value of multiplier is

$$R_s = S_{AC}V - R_m - R_d$$

$$\boxed{R_s = 0.45 S_{DC}V - R_m - R_d}$$ ($\because S_{AC} = 0.45 S_{DC}$)

To extend the range of full wave rectifier for AC-voltmeter the value of multiplier is

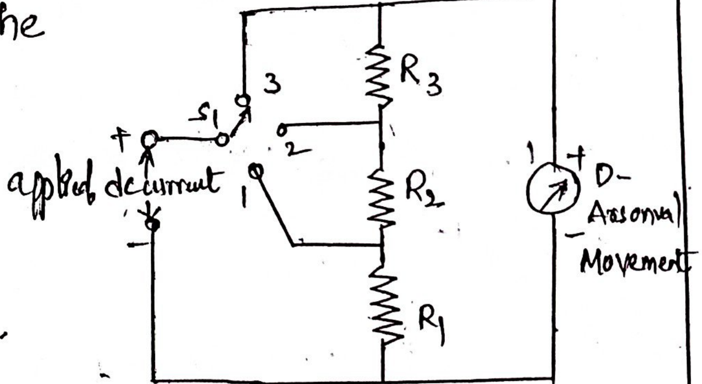
$$\boxed{R_s = 0.95 S_{DC}V - R_m - 2R_d}$$

$R_d \rightarrow$ Resistance across diodes

Shunt (or) Ayrton shunt: ☆☆ (To avoid extra shunt in Ammeter)

→ It is also known as universal Shunt.

→ The shunt meter improves the Sensitivity of the meter.



→ From the figure the series combination of R_2, R_3 and the meter movement is in parallel with R_1 when the switch S_1 is connected in position "1".

→ Therefore the current through the meter movement is less than the current through the shunt, thereby it protects the meter movement.

→ In position "2" the series combination of R_3 and meter movement is in parallel with resistors R_1 and R_2. ~~Here~~ Here also $I_{sh} < I_{meter}$

→ where I_{sh} → current through shunt resistance

I_{meter} → current through meter.

→ In position "3" $R_1, R_2, \& R_3$ are parallel with meter movement, now the current flowing through the I_{sh} is very less where as I_{meter} is high (very).

→ Thus the sensitivity of the meter movement increases by Aryton shunt.

Thermo couple type RF ammeter:

→ A Thermocoupler is a device which produces the voltage in accordance to the temperature changing (heating) element

→ It consists of two metals which forms as a junction, the current to be measured is used to heat the junction of two metals then they produce a voltage proportional to heating effect

→ The output voltage is driven by a sensitive dc-ammeter this gives a reading proportional to magnitude of AC-input.

→ The alternating currents heats up the junction where the heating effect is same for both half cycles of the ac, because the polarity is always having same magnitude

→ Various types of thremocouples are available which works on the principle of "Thermo electric action".

(a) Mutual type thermocouple ammeter:

→ Here the AC-current passes through the thermo-couple itself and not through a heating wire. The sensitive DC ammeter shunts the thermocouple which is the basic draw back of this device.

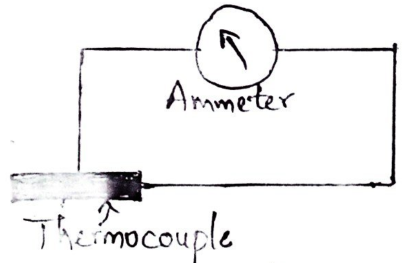


fig: mutual type thermocouple

(b) Contact type thermocouple Ammeter:

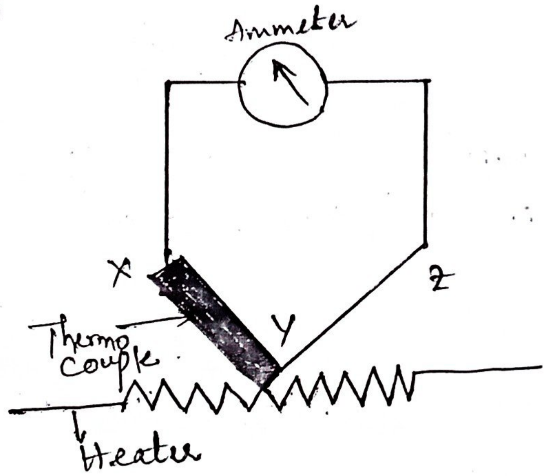
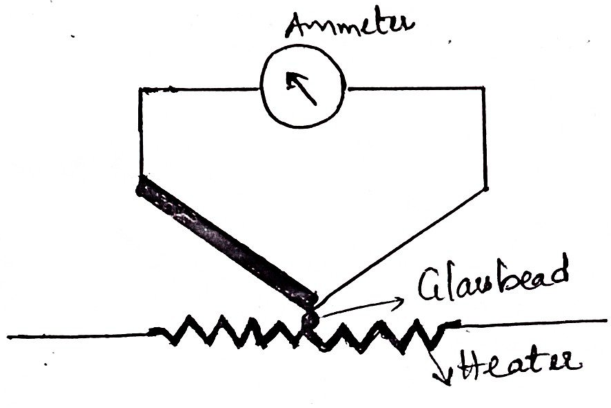


fig: Contact type thermocouple

→ These are low sensitive devices compared to mutual type.

→ In figure, X-Y is the thermocouple element. It seperates thermocouple leads, that conduct away the heat from metal wire of heater.

(c) Seperate heater types:



→ In this type of ammeter, the thermocouple is held near the heater but not in contact and insulated by a glass bead.

→ This makes the instrument less sensitive as the temperature drops in the glass bead.

→ In RF current measurements this type of arrangement is preferred.

→ To increase sensitivity of the instrument it is placed in vacuum.

Bridge type:

→ This is one of mutual type of thermocouple instrument. Sensitivity of this device is high.

→ This type avoids the shunting effect of the ammeter.

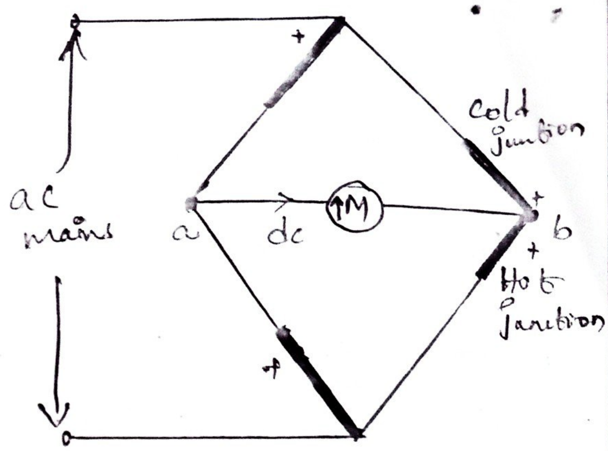


fig: Bridge type thermocouple

→ There is no requirement of heating element, the electric current which directly passes through the thermocouple rises the temperature i.e

$Ta \rightarrow$ Temperature at point a
$Tb \rightarrow$ Temperature at point b

$$\boxed{T_a - T_b \propto I^2 R}$$

→ The connected meter between the junctions a and b will shows the potential difference between them.

Ohmmeters:

→ These are the instruments used to measure resistance.

→ They are mainly divided into two types. 1. Series type
2. Shunt type.

Series type ohmmeter:

→ In the figure the resistor R_1 and the battery V are connected in series with D'Arsonval movement.

→ The unknown resistance 'R_x' is connected between A & B.

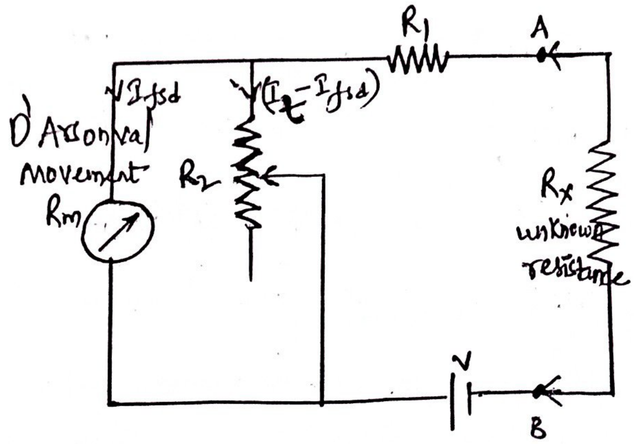


fig: series type ohmmeter

→ The current flowing through the movement depends on the magnitude of unknown resistance.

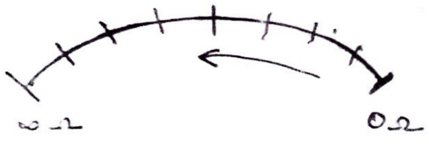


fig: Dail of Series ohmeter.

→ Therefore, the meter deflection is directly praportional to the value of unknown resistance.

Calibration of the series type ohmmeter:

→ Initially the terminals A and B are shorted, therefore the current through unknown resistance (R) is maximum i.e $R_x = 0$.

→ In this case maximum current flows through the circuit. The resistor R_2 connected in shunt adjusts until the movement on scale shows full scale current I_{fsd}. This position is marked as '0'Ω on the scale.

→ In the same way, to mark "∞" on the scale, the terminals A & B are open circuited.

→ Therefore the current through R_x is zero i.e $R_x = \infty$. In this case no current flows through circuit and the point doesnot show any deflection. This position of pointer is marked as "∞Ω".

→ Intermediate markings on the scale are corresponded to various unknown value of resistances (R_x) connected across A and B terminals.

→ due to time and ageing problem, the battery 'V' voltage connected in series decreases. Thus even R = 0Ω the scale cannot show it as 0Ω. To bring pointer to 0Ω, the zero adjusting resistor (R_2) is connected across meter movement.

→ The full scale deflection current is adjusted by varying R_1.

→ The value of R_1 is very high compared to R_m.

→ Instead of varying R_1 for full scale current representation by decreasing R_1 the current flowing through the meter increases

→ This brings pointer to full scale deflection position.

→ The value of R_1 and R_2 are determined from the value of R_x which gives half the full scale deflection.

$$R_h = R_1 + (R_2 \| R_m) = R_1 + \frac{R_2 R_m}{R_2 + R_m};$$

R_h = half of fullscale deflection resistance

→ The total ~~current~~ resistance presented in the battery is $2R_h$ and the battery current needed to supply half deflection is $\frac{V}{2R_h}$

$$I_h = \frac{V}{2R_h}$$

To produce full scale current the battery current has to be doubled.

So total current of circuit $I_t = \frac{V}{R_h}$

Shunt current through R_2 is $I_2 = I_t - I_{fsd}$

→ the voltage across shunt is equal to voltage across meter

$$V_{sh} = V_m$$

$$I_2 R_2 = I_{fsd} R_m$$

$$R_2 = \frac{I_{fsd} R_m}{I_2} \quad \text{—— (1)}$$

but $I_2 = I_t - I_{fsd}$ — (2)

sub eq (2) in (1) $\Rightarrow$ $R_2 = \dfrac{I_{fsd} R_m}{I_t - I_{fsd}}$ — (3)

but $I_t = \dfrac{V}{R_h}$

eq (3) $\Rightarrow$ $R_2 = \dfrac{I_{fsd} R_m}{V/R_h - I_{fsd}}$ $\Rightarrow$ $\boxed{\dfrac{I_{fsd} R_m R_h}{V - R_h I_{fsd}} = R_2}$

but $R_h = R_1 + \dfrac{R_2 R_m}{R_2 + R_m}$

$\therefore$ $R_1 = R_h - \dfrac{R_2 R_m}{R_2 + R_m}$

$$R_1 = R_h - \frac{\left(\frac{I_{fsd} R_m R_h}{V - R_h I_{fsd}}\right) R_m}{\frac{(I_{fsd} R_m R_h)}{(V - R_h I_{fsd})} + R_m}$$

$$\boxed{R_1 = R_h - \frac{I_{fsd} R_m R_h}{V}}$$

Thus R_1 & R_2 can be determined.

Shunt type ohmmeter:

→ It consists of a battery in series with an adjustable resistor R1 and a D'Arsonval movement.

→ The unknown resistance is connected in parallel with meter, hence it is shunt type.

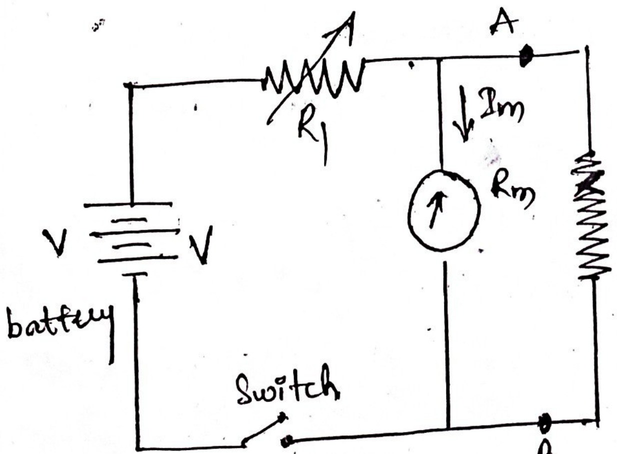


fig: shunt type voltmeter

Caliberation on shunt type ohmmeter:

→ To make "0Ω" reading on the scale, terminals A and B are shorted i.e the unknown resistance $R_1 = 0$, and the current through the meter movement is zero.

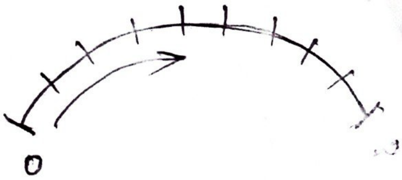


fig: dail of shunt type voltmeter

→ Similarly to make "∞Ω" reading on the scale, the terminals A and B are opened i.e the unknown resistance $R_1 = \infty$ and current through the meter is fullscale reading.

→ Intermediate markings can be done by connecting the known values of standard resistors to A and B.

→ This type is mostly suited for low resistance measurements

→ Hence it is used as a test instrument in laboratories for low resistance applications

series type ohmmeter	shunt type ohmmeter
1) It does not have on/off switch.	1) It consists of on/off switch.
2) The dail has 0Ω on right side and ∞Ω on left.	2) The dail has 0Ω on leftside and ∞Ω on right side.
3) For high resistance measurements.	3) For low lab purpose resistance measurement.
4) R_1 and battery are in series with meter.	4) R_1 and battery are in parallel to meter.
5) The battery voltage of series type ohmeter decreases with time and ageing.	5) The battery voltage of shunt type ohmmeter is not decreased with time and age