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Instrument :

(Indirect) | (Direct)

Absolute instrument

4

Secondary instrument

(Mode)

Analog instrument

Digital instrument

How they indicate the end of Measurement.

Deflecting

Null Deflection

Type of o/p

Indicating Instrument

Integrating Instrument

Recording instrument

MEASUREMENT

Measurement - Measurement is a process of comparison between a Std and an unknown resulting in knowing the magnitude of the unknown in terms of standard.

Instrument - Instrument is a device that facilitated this comparison.

The 2 most essential characteristics of an electrical instrument are

- (i) The operational power consumption should be minimal.

- (ii) The instrument should not change the ambient condition for the ckt in which it has been introduced.

Absolute instrument are those which gives the value of parameter under measurement in terms of the physical constant of instrument. These instrument based on their operation on the indirect methodology of measurement & since they contain less no. of moving mechanical parts they are highly accurate. These instruments are used in Std. inst. Calibrating laboratories and typical example of these instrument are tangent galvanometer & rayleighs Current balance.

-2. The secondary instrument give their o/p directly in terms of the parameter under measurement.

-3. These instrument based their operation on the direct methodalogy of measurement & since they contain large no. of moving mechanical parts they are relatively less ~~in~~accurate. These instruments are generally used for day to day measurement in the industry and typical example of secondary instrument are Ammeter, Voltmeter, Watt meter etc.

-4. An analog instrument is the one whose o/p varies Continuously w.r.t time all the while maintaining a constant relationship with the i/p.

-5. A digital instrument is the one whose o/p varies discretely w.r.t time all the while maintaining a constant relationship with i/p.

~~-6.~~ A digital instrument ~~is the one~~ whose o/p varies discretly w.r.t ~~time~~

-6. Deflecting instruments are those which indicate their end of measurement with the deflection of a pointer away from the zero position. (7)

Note: Due to finite amount of power consumed i order to indicate the value under measurem these instruments are relatively less accurate

7. Null deflection instrument are those which indicate their end of measurement with zero or NULL deflection.

8. Due to Negligible power being consumed at the end of the measurement these instrument are highly accurate.
Ex: AC & DC bridges.

9. An indicating instrument is the one which gives the instanteneous value of th parameter under measurement.
Ex: Ammeter, Voltmeter, Wattmeter, etc

10. An integrating instrument is one which gives the sum or total of the electric parameter consumed over the period of tim
Ex: Energy meter.

11. An recording instrument is the one whi gives the historical ~~instrument~~ information about the measurement in terms of a Continuous

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record of the measurement over a specified period of time.

EX: Recording Voltmeter.

(8)

Essential of an indicating instruments:

The three essential forces that are required by an indicating instrument in order to efficiently indicate the value of parameter under measurement are:

(i) The Deflecting torque.
(ii) Controlling torque (Restoring torque).
(iii) The Damping torque

Deflecting Torque:

The Utility of the deflecting torque is to deflect the pointer away from the zero position. It is produced by the parameter under measurement itself due to one of those effect of electrical current which converts electrical energy into mechanical energy. The magnitude of deflecting torque produced in an indicating instrument is proportional to the parameter under measurement.

9

Controlling Torque:

The controlling torque has a two fold utitity.

- (i) It bring the pointer to rest at the steady state position where the angular displacement pointer is proportional to the magnitude of the paramater under measurement
- (ii) It bring the pointer to zero position when the parameter under measuremen is removed from the terminal of instrument.

→ The Controlling torque is ~~Controlling~~ produced by a control mechanism and the most commonly used control mechanism are "spring contr mechanism" and "Gravity Control mechanism"

(A) Spring Control

$$\boxed{T_c = K\theta}$$

$$\boxed{T_c = \frac{Ebt^3}{12l}\cdot\theta \ Nm}$$

Where,

K = Spring Constant
= Control Constant
= Restore Constant
= Torsion Constant

E = Young Modulus N/m^2
b = Width of spring 'm'
t = thickness 'm'
l = length 'm'
θ = angular deflection 'ra

$$\boxed{T_c \propto \theta}$$

Assume

$T_d \propto I$

and we know,

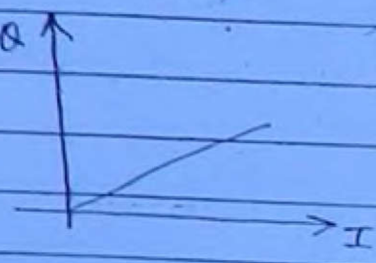
$T_c \propto \theta$

at steady state,

$T_c = T_d$

$$\boxed{\therefore\ \theta \propto I}$$

Uniform
Scale



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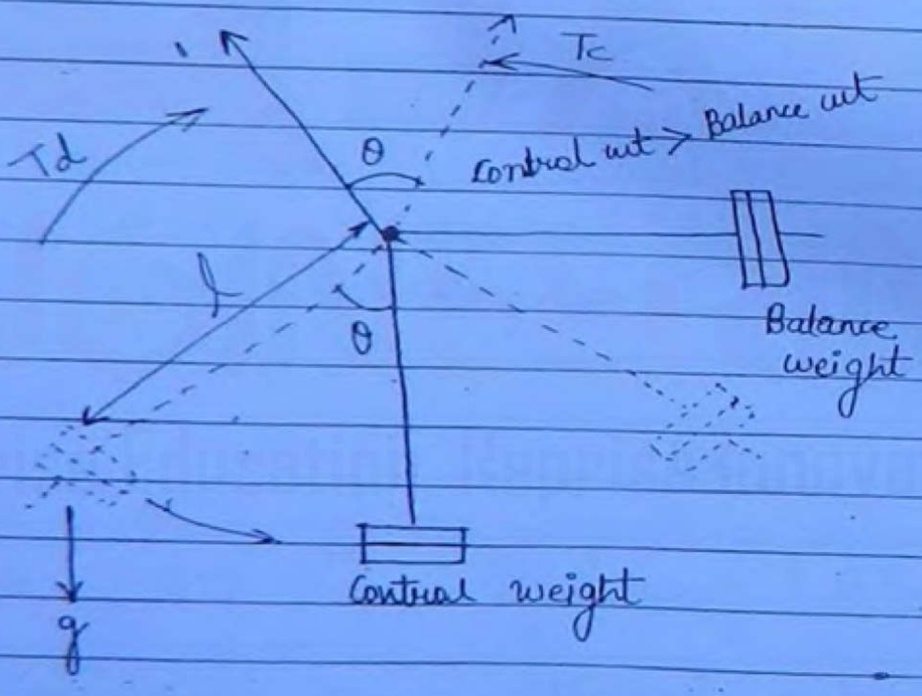
(B) Gravity control mechanism



$$\boxed{T_c = w \cdot l \cdot \sin\theta} \text{ N-m}$$

l = distance of control weight from spindle

$w = m \cdot g$ = weight of the controlling weight.

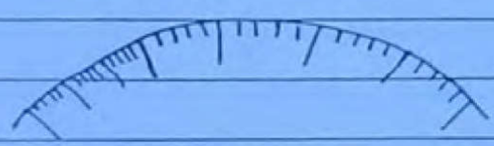
$T_c = K \sin\theta$

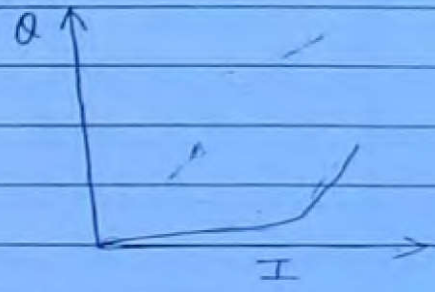
$\boxed{T_c \propto \sin\theta}$

Assume $\boxed{T_d \propto I}$ and as we know $\boxed{T_c \propto \sin\theta}$

At ~~steady~~ Steady position

$\boxed{I \propto \sin\theta}$





Note : The gravity control mechanism is used in instance where the instruments are being used for continuous monitoring and are generally mounted on a panel in the vertical position.

: The spring control mechanism is used in instances where, the instrument is being used as a table top laboratory typ instrument intended for periodic usage.

→ The essential qualities of a spring that is used as a control mechanism are :

- (i) It should undergo minimal mechanical stress. ~~to~~
- (ii) It should be non - magnetic by nature.
- (iii) Control springs are generally made up of 'Phosphor - Bronze'.

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→ The utility of the damping torque is to damp the Oscillation of the pointer at the steady state position. (12)

This torque is produced by the damping mechanism and the various damping mechanisms used are

(a) air friction damping mechanism
(used when the operating field that produces the deflecting torque is weak).

(b) Eddy Current damping Mechanism.
(Used when the operating field that produces the deflecting torque is Strong).

(c) Fluid friction damping mechanism
~~(used when the operating field that produces the deflecting~~
(used in electrostatic instruments for the measurement of high voltages).

INDICATING INSTRUMENTS

- Magnetic effect
  - Moving Coil
    - ** (DC)
    - → PMMC ($\theta \propto I$)
    - → Electrodynamometer Instrument ($\theta \propto I_1 I_2$)
      - → Power
  - Moving Iron ($\theta \propto I^2$) (AC/DC)
    - → Attraction Type
    - → Repulsion Type
- Electrostatic effect ($\theta \propto V^2$)
  - (i) Quadrant Electrometer
  - (ii) Kelvin Multicellular Voltmeter
  - (iii) Absolute / Attracted disk electrometer
- Thermoelectric effect ($\theta \propto I^2$)
  - (i) Hotwire Instrument
  - (ii) Thermocouple Instrument
  - (iii) Bolometer.
- Induction effect ($\theta \propto I$)
  - (i) ~~Splitting~~ split ring Inst.
  - (ii) Shaded Pole Instrument

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Note :

— (i) If the angle of deflection of an indicating instrument is proportional to either the square of or the product of the parameter under measurement then the instrument is said to exhibit a "square law response". (16)

— (ii) From the above classification it can be seen that all the instrument except the PMMC instrument exhibit a square law response.

— (iii) The electrostatic type of instrument which are also known as Electrometers are used as Voltmeters only that too for the measurement of R.M.S Value of an a.c voltage of a high magnitude. (in KV range) of any wave shape.

$$\boxed{I_{rms} = \sqrt{I_{DC}^2 + \left(\frac{I_m}{\sqrt{2}}\right)^2}}$$

— (iv) Instruments which based their operation of thermoelectric effect of electric current are known as "radiofrequency instruments" and are specially useful for the measurement of Current and Voltage at very high frequency.

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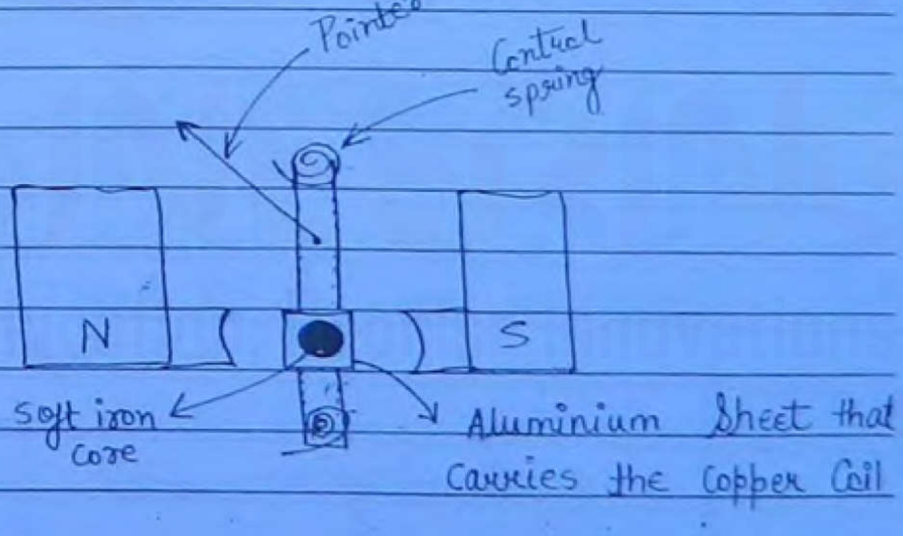
PMMC

(12)

1. The PMMC instrument utilizes the "magnetic effect of electric Current" to produce the deflecting torque.

2. The deflecting torque in this instrument is produced on the basis of the fact that, 'Whenever the Current Carrying Conductor is placed in a magnetic field the Conducto experiences a force that tends to push it away from the direction of magnetic field (Fleming's left hand rule).

Construction



Operation:

1. The fixed system of this instrument consists of a permanent magnet and 2 soft iron pole pieces are drilled on to its poles as shown in fig. above.

IES — The permanent magnet is generally made up of AL-Ni-co.

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-2. The utility of the soft iron pole pieces is to make the field due to the permanent magnet radial by nature. (18)

-3. The moving system of the instrument consist of a spindle onto which a set of control springs, a soft iron core, an aluminium struct carrying the copper coil and a pointer are mounted.

-4. The moving system is so placed that the aluminium struct and the soft iron core area concentric w.r.t a virtual circle drawn by taking the sectorial surfaces of the soft iron core pieces into consideration.

Imp -5. The control spring in this instrument have a two fold utility:

-(a) They are used to produce a controlling torque.

-(b) They are also used to lead the current into the moving system.

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6. Due to the presence of a Strong operating field an eddy current damping mechanism is used to produce the damping torque.

(79)

7. The mathematical expression that governs the deflecting torque produced in this instrument is given by the expression.

$$\boxed{T_d = NBAI \quad Nm}$$

where,

N = no. of turns of the moving coil.

B = flux density of the permanent magnet in Wb/m^2.

A = Surface area of the coil in m^2

I = Current in Ampere's through the coil (mA)

8. As a spring control mechanism is being used

$$\boxed{T_c = K\theta}$$

and Since N, B and A are constant

$$\boxed{T_d = K'I}$$

∴ At Steady state position

$$T_c = T_d$$

$$\boxed{\therefore \theta \propto I}$$

Advantages :

-1. As the torque to weight ratio is high, this instrument have a low operational power consumption (25 - 200 μwatt). (26)
*Imp P.S.U

-2. These instruments gives a larger sensitivity and higher accuracy (±2% of f.s.d). Imp

-3. Due to the presence of a strong operating field these instruments are not easily effected by stray magnetic fields, hence does not require a magnetic shielding.

-4. As $\theta \propto I$, these instruments give a uniform scale.

Disadvantages :

-1. As the direction of the magnetic field of a permanent magnet does not change with the change in the polarity of a.c parameter. These instruments can be used only on D.C.

P.S.U / imp Note: When the high frequency ac signal is applied to the terminals of the PMMC instrument the pointer would vibrate around the 'zero' position due to its (2) small time period. If a low frequency ac signal is applied to the terminals of (centre 0) PMMC instr in that case, the pointer of the instrument would oscillate betⁿ +ve and -ve peaks due to its large time period.

2. As a thin and a light wire is used to wind the moving system the current carrying capacity of these instrument is 'Small'. Thin and light wire is used for maintain the high torque to weight ratio.

P.S.U Note: The maximum current carrying capacity of an optimally designed PMMC instrument is limited to 100 mA.

Sources of Errors:

1. Errors due to the ageing of springs. (These errors are compensated by using a Pre-aged spring in which Pre-ageing is done by subjecting it to mechanical stress).

2. Errors due to the ageing of the permanent magnet.
(These errors are compensated by using a pre-aged permanent magnet, where

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Pre-ageing is done by subjecting the magnet (to thermal and Vibrational Stress).

(22)

-3. Errors due to the change in resistance of the spring and the copper coil due to the heating effect of electric current.

-4 These errors can be compensated as follows:
As the resistance of the copper wire varies negligibly w.r.t temperature due to its low temperature Co-efficient (0.00392/°C) the change in resistance of the copper coil is generally neglected.

-5. The essential characteristics of the spring used as a control mechanism in PMMC instrument are
Imp
- (a) low resistance.
- (b) Small temperature Co-efficient.
- (c) Should not age rapidly
- (d) Should be non-magnetic.

Note: The most commonly used material for fabricating a control spring in an PMMC instrument is 'Phosphor Bronze'.

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Q1. A moving coil of ammeter has 100 turns & length & depth of 10 mm & 20 mm resp. It is positioned in a uniform radial flux density of 200 militesta. If the coil carries a current of 15mA then the torque acting on the coil is ?

Soln:

(23)

Continued from pg: 12 :

Note:

(i) The angular deflection displacements of these instruments are proportional to the "R.M.S value of the a.c parameter under measurement".

(ii) These instruments give a "non-uniform scale".

(iii) The Electrodynamometer and Thermo couple type of Instruments are used as "transfer type" of instrument for calibrating A.C ammeter and Voltmeter.

Gate 2004 (electrical)

Q1. The moving coil of a meter has 100 turns and the length and depth of 10mm and 20 mm resp. If it is positioned in the radial uniform flux density of 2000 mTesla and carries a current of 50mA, the torque acting on the coil is (24)

Soln

$N = 100$

$B = 200\text{ mT} = 200 \times 10^{-3}\ \text{wb/m}^2$

$A = 10\text{ mm} \times 20\text{ mm} = 10 \times 10^{-3} \times 20 \times 10^{-3}\ \text{m}^2$

$I = 50\text{mA} = 50 \times 10^{-3}\ A$

$\therefore T_d = NBAI\ \ N\text{-}m$

$= 100 \times 200 \times 10^{-3}$

Q2 A PMMC Voltmeter is connected across a combination of a d.c voltage source $V_1 = 2V$, and an a.c voltage source of $V_2(t) = 3 \sin 4t\ V$. The meter reads

Soln: The instrument reads only the dc components. Hence the reading will be 2V.

P.S.U Q3. A 0-5A PMMC Ammeter is supplied with a current of 3A. If the lower control spring of the instrn suddenly snaps. The instrument

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will then give a reading of

a) 5A

b) >3 But <5

c) <5

d) 0.1

23

Soln: As the lower control spring snaps there will be a 'zero' current passing through a moving system, as the current through the PMMC instrument is lead through the spring. Then the upper Control spring will bring back the pointer back to zero in absence of deflecting torque.

Imp.

Q4) In an PMMC instrument the Control spring Cons and strength of the magnet decrease by 0.04 and 0.02 % resp. due to the rise in temperature by 1°C. With the rise in temperature of 10°C the instrument reading wi

a) ↑ by 0.2%

b) ↓ by 0.2%

c) ↑ by 0.6%

d) ↓ by 0.6%

Soln: We know,

$$\theta = \frac{NBAI}{K} \text{ radians} \quad —(1)$$

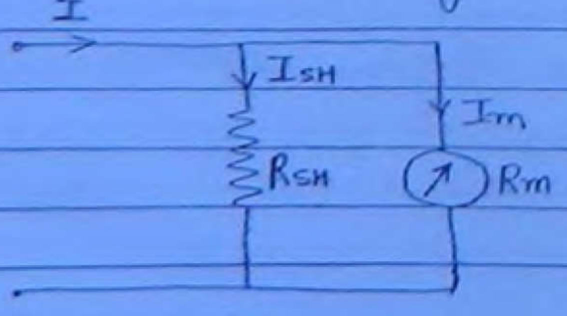
1. As the angular deflection of the pointer in an PMMC instrument is directly proportional to the Current. These instruments can be directly used as a Ammeter. 26

2. But in order to maintain high Torque-to-weight ratio a thin and a light wire was used to wind the moving coil.
This limits the Current carrying capacity of such a instrument.

Imp
PSU 3. In order to extent the range of basic PMMC instrument, a low resistance is connected across it.

4. This low resistance is known as the Shunt. resistance bypasses a major portion of Current I through it, thereby protecting it from damage.

5. The value of the shunt resistor R_{SH} is calculated as follows,



In the above ckt,

$$I_{SH} R_{SH} = I_m R_m$$

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$$\therefore R_{SH} = \frac{I_m R_m}{I_{SH}}$$

$$\boxed{R_{SH} = \frac{I_m R_m}{(I - I_m)}} \quad \text{——— (1)}$$

Taking the reciprocal of eq-(1) and Multiply by R_m on both sides,

$$\therefore \frac{R_m}{R_{SH}} = \frac{(I - I_m) \cancel{R_m}}{I_m \cancel{R_m}}$$

$$\frac{R_m}{R_{SH}} = \frac{I}{I_m} - 1$$

The ratio between I and I_m is known as the "Multiplying Factor" of the shunt denoted by,

$$\boxed{m = \frac{I}{I_m} = 1 + \frac{R_m}{R_{SH}}} \quad \text{——— (2)}$$

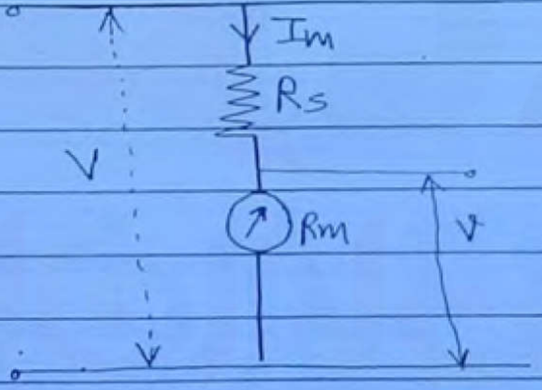
Expressing the value of R_{SH} in terms of m.

$$\boxed{R_{SH} = \frac{R_m}{(m-1)}} \quad \text{——— (3)}$$

Imp (35) The basic PMMC movement is modified as a Valtmeter by connecting a high resistance in series with the meter.

This high resistance known as the Multiplier resistance limits the current passing through the meter movement, Thereby protecting it from damage.

The value of Multiplier resistance Rs is calculated as follows,



We have,

$$v = I_m R_m$$

$$V = I_m (R_s + R_m)$$

$$V = I_m R_m + I_m R_s$$

$$R_s = \frac{V}{I_m} - R_m \quad \text{——— (1)}$$

'm' is the multiplying factor of the Multiplier can be expressed as,

$$m = \frac{V}{v}$$

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

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

$$= 1 + \frac{R_s}{R_m} \quad \text{—— (2)}$$

Expressing R_s in terms of m

$$R_s = (m - 1) R_m \quad \text{—— (3)}$$

p.s.u

Sensitivity of Voltmeter

(91)

The Sensitivity of a voltmeter is defined as the resistance of the voltmeter for a single volt range.

Mathematically expressed as,

$$\boxed{S_V = \frac{R_T}{V} \quad \Omega/V}$$

$$R_T = R_m + R_s$$

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

$$\boxed{\therefore S_V = \frac{1}{I_m} \quad \Omega/V}$$

Q1. p.s.u Which one of the following meters is more sensitive than the other and why?

1. Voltmeter A with a range of 0 – 10 V and a Multiplier resistance of 18 $K\Omega$.

2. Voltmeter B with a range of 0 – 300 V and a Multiplier resistance of 298 $K\Omega$.

Note: both the meters have an internal resistance of 2 $K\Omega$

A	B
$R_S = 18K$	$R_S = 298K$
$R_m = 2K$	$R_m = 2K\Omega$
$R_T = 20K$	$R_T = 300K\Omega$
$V = 10$	$V = \cancel{10}\,300$
$\therefore S_V = 2K\Omega/V$	$S_V = 1K\Omega/V$.

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→ From above analysis it can be said that meter A requires $\frac{1}{2}$ the Current required by B to produce full scale deflection.

Hence A is more sensitive than meter B.

Q2) A dc Voltmeter has a sensitivity of $1000\ \Omega/V$. When it measures half full scale ~~limits~~ in its 100 V range, the Current through the Voltmeter is

$$S_V = \frac{R_T}{V}$$

$$R_T = S_V \cdot V$$

$$= 1000 \times 100$$

$$\therefore R_T = 100 \times 10^3\ \Omega$$

$$I_m = \frac{V}{R_T} = \frac{50}{100 \times 10^3} = 0.5\ mA$$

Voltmeters and multimeters: Basic meters:

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

D.C instruments:

1. Using shunt resistance, d.c. current can be measured. The instrument is d.c. microammeter, milliammeter or ammeter.
2. Using series resistance called multiplier, d.c. voltage can be measured. The instrument is d.c. millivoltmeter, voltmeter or kilo voltmeter.

A.C instruments:

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

1.8 Moving Iron (MI) instruments

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.

- Attraction type
- Repulsion type

1.8.1 Attraction type M.I. instrument

Construction: The moving iron fixed to the spindle is kept near the hollow fixed coil (Fig. 1.10). The pointer and balance weight are attached to the spindle, which is supported with jeweled bearing. Here air friction damping is used.

Principle of operation

The current to be measured is passed through the fixed coil. As the current is flow through the fixed coil, a magnetic field is produced. By magnetic induction the moving iron gets magnetized. The north pole of moving coil is attracted by the south pole of fixed coil. Thus the deflecting force is produced due to force of attraction. Since the moving iron is attached with the spindle, the spindle rotates and the pointer moves over the calibrated scale. But the force of attraction depends on the current flowing through the coil.

Torque developed by M.I

Let 'θ' be the deflection corresponding to a current of 'i' amp

Let the current increases by di, the corresponding deflection is '$\theta + d\theta$'

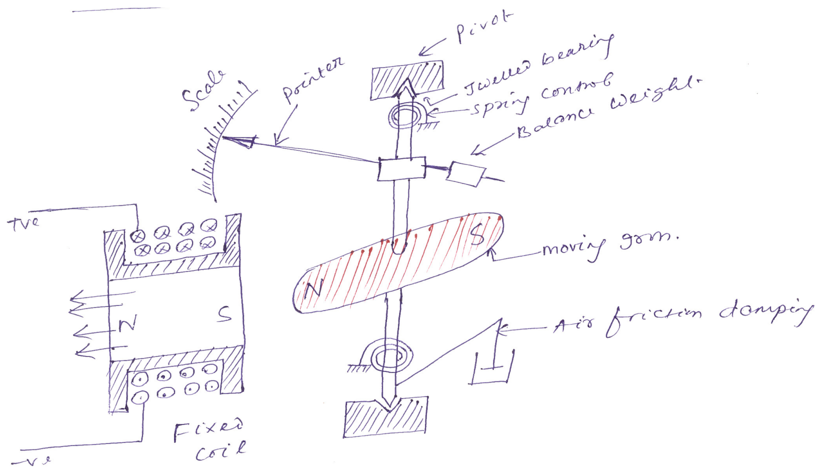


Fig. 1.10

There is change in inductance since the position of moving iron change w.r.t the fixed electromagnets.

Let the new inductance value be ‘L+dL’. The current change by ‘di’ is dt seconds.

Let the emf induced in the coil be ‘e’ volt.

$$e = \frac{d}{dt}(Li) = L\frac{di}{dt} + i\frac{dL}{dt} \tag{1.22}$$

Multiplying by ‘idt’ in equation (1.22)

$$e \times idt = L\frac{di}{dt} \times idt + i\frac{dL}{dt} \times idt \tag{1.23}$$

$$e \times idt = Lidi + i^2 dL \tag{1.24}$$

Eq^n (1.24) gives the energy is used in to two forms. Part of energy is stored in the inductance. Remaining energy is converted in to mechanical energy which produces deflection.

Fig. 1.11

Change in energy stored=Final energy-initial energy stored

$$=\frac{1}{2}(L+dL)(i+di)^2-\frac{1}{2}Li^2$$

$$=\frac{1}{2}\{(L+dL)(i^2+di^2+2idi)-Li^2\}$$

$$=\frac{1}{2}\{(L+dL)(i^2+2idi)-Li^2\}$$

$$=\frac{1}{2}\{Li^2+2Lidi+i^2dL+2ididL-Li^2\}$$

$$=\frac{1}{2}\{2Lidi+i^2dL\}$$

$$=Lidi+\frac{1}{2}i^2dL \tag{1.25}$$

Mechanical work to move the pointer by $d\theta$

$$=T_d d\theta \tag{1.26}$$

By law of conservation of energy,
Electrical energy supplied=Increase in stored energy+ mechanical work done.

Input energy= Energy stored + Mechanical energy

$$Lidi+i^2dL=Lidi+\frac{1}{2}i^2dL+T_d d\theta \tag{1.27}$$

$$\frac{1}{2}i^2dL=T_d d\theta \tag{1.28}$$

$$T_d=\frac{1}{2}i^2\frac{dL}{d\theta} \tag{1.29}$$

At steady state condition $T_d=T_C$

$$\frac{1}{2}i^2\frac{dL}{d\theta}=K\theta \tag{1.30}$$

$$\theta=\frac{1}{2K}i^2\frac{dL}{d\theta} \tag{1.31}$$

$$\theta\propto i^2 \tag{1.32}$$

When the instruments measure AC, $\theta\propto i^2{}_{rms}$

Scale of the instrument is non uniform.

Advantages

- ✓ MI can be used in AC and DC
- ✓ It is cheap
- ✓ Supply is given to a fixed coil, not in moving coil.
- ✓ Simple construction
- ✓ Less friction error.

Disadvantages

- ✓ It suffers from eddy current and hysteresis error
- ✓ Scale is not uniform
- ✓ It consumed more power
- ✓ Calibration is different for AC and DC operation

1.8.2 Repulsion type moving iron instrument

Construction: The repulsion type instrument has a hollow fixed iron attached to it (Fig. 1.12). The moving iron is connected to the spindle. The pointer is also attached to the spindle in supported with jeweled bearing.

Principle of operation: When the current flows through the coil, a magnetic field is produced by it. So both fixed iron and moving iron are magnetized with the same polarity, since they are kept in the same magnetic field. Similar poles of fixed and moving iron get repelled. Thus the deflecting torque is produced due to magnetic repulsion. Since moving iron is attached to spindle, the spindle will move. So that pointer moves over the calibrated scale.

Damping: Air friction damping is used to reduce the oscillation.

Control: Spring control is used.

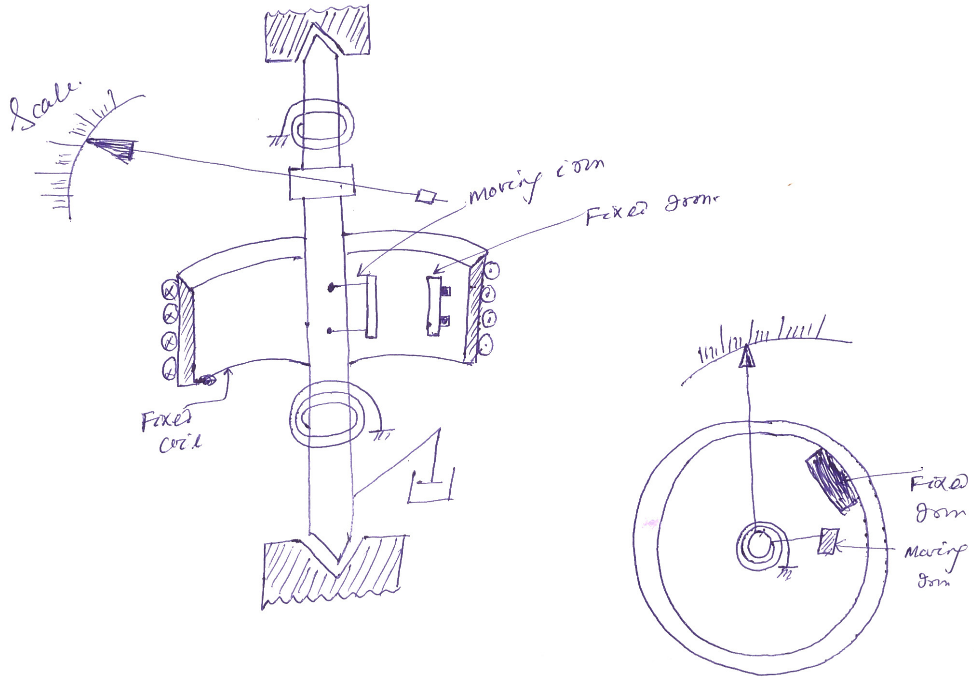

Scale.
Moving iron
Fixed iron
Fixed coil
Fixed iron
Moving iron

Fig. 1.12

OHMMETER (SERIES TYPE OHMMETER)

A D'Arsonval movement is connected in series with a resistance R_1 and a battery which is connected to a pair of terminals A and B, across which the unknown resistance is connected. This forms the basic type of series ohmmeter, as shown in Fig. 4.30 (a).

The current flowing through the movement then depends on the magnitude of the unknown resistance. Therefore, the meter deflection is directly proportional to the value of the unknown resistance.

Referring to Fig. 4.30 (a)

R_1 = current limiting resistance
R_2 = zero adjust resistance
V = battery
R_m = meter resistance
R_x = unknown resistance

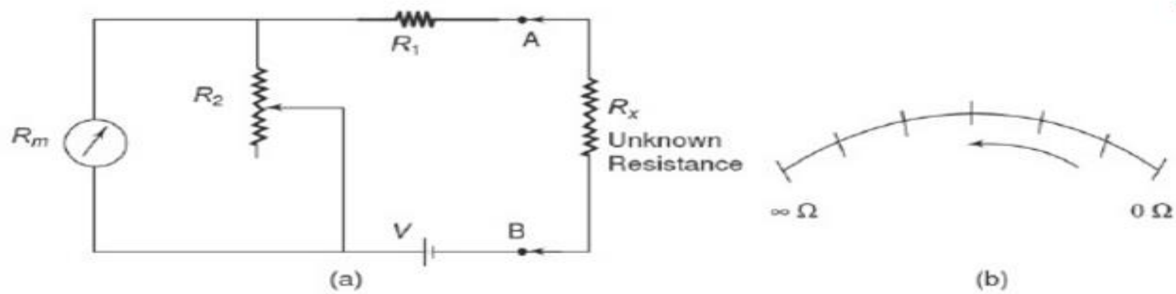


Fig. 4.30 (a) Series type ohmmeter (b) Dial of series ohmmeter

Calibration of the Series Type Ohmmeter

To mark the "0" reading on the scale, the terminals A and B are shorted, i.e. the unknown resistance $R_x = 0$, maximum current flows in the circuit and the shunt resistance R_2 is adjusted until the movement indicates full scale current (I_{fsd}). The position of the pointer on the scale is then marked "0" ohms.

Similarly, to mark the "∞" reading on the scale, terminals A and B are open, i.e. the unknown resistance $R_x = \infty$, no current flow in the circuit and there is no deflection of the pointer. The position of the pointer on the scale, is then marked as "∞" ohms.

By connecting different known values of the unknown resistance to terminals A and B, intermediate markings can be done on the scale. The accuracy of the instrument can be checked by measuring different values of standard resistance, i.e. the tolerance of the calibrated resistance, and noting the readings.

A major drawback in the series ohmmeter is the decrease in voltage of the internal battery with time and age. Due to this, the full scale deflection current drops and the meter does not read "0" when A and B are shorted. The variable shunt resistor R_2 across the movement is adjusted to counteract the drop in battery voltage, thereby bringing the pointer back to "0" ohms on the scale.

It is also possible to adjust the full scale deflection current without the shunt R_2 in the circuit, by varying the value of R_1 to compensate for the voltage drop. Since this affects the calibration of the scale, varying by R_2 is much better solution. The internal resistance of the coil R_m is very low compared to R_1. When R_2 is varied, the current through the movement is increased and the current through R_2 is reduced, thereby bringing the pointer to the full scale deflection position.

The series ohmmeter is a simple and popular design, and is used extensively for general service work.

Therefore, in a series ohmmeter the scale marking on the dial, has "0" on the right side, corresponding to full scale deflection current, and "∞" on the left side corresponding to no current flow, as given in Fig. 4.30 (b).

Values of R_1 and R_2 can be determined from the value of R_x which gives half the full scale deflection.

$$R_h = R_1 + R_2 \parallel R_m = R_1 + \frac{R_2 R_m}{R_2 + R_m}$$

where R_h = half of full scale deflection resistance.

The total resistance presented to the battery then equals $2R_h$ and the battery current needed to supply half scale deflection is $I_h = V/2\,R_h$.

To produce full scale current, the battery current must be doubled.

Therefore, the total current of the ckt, $I_t = V/R_h$

The shunt current through R_2 is given by $I_2 = I_t - I_{fsd}$

The voltage across shunt, V_{sh}, is equal to the voltage across the meter.

Therefore $\quad V_{sh} = V_m$

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

Therefore $\quad R_2 = \dfrac{I_{fsd} R_m}{I_2}$

But $\quad I_2 = I_t - I_{fsd}$

$\therefore \quad R_2 = \dfrac{I_{fsd} R_m}{I_t - I_{fsd}}$

But $\quad I_t = \dfrac{V}{R_h}$

Therefore $\quad R_2 = \dfrac{I_{fsd} R_m}{V/R_h - I_{fsd}}$

Therefore $\quad R_2 = \dfrac{I_{fsd} R_m R_h}{V - I_{fsd} R_h}$

As $\quad R_h = R_1 + \dfrac{R_2 R_m}{R_2 + R_m}$

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

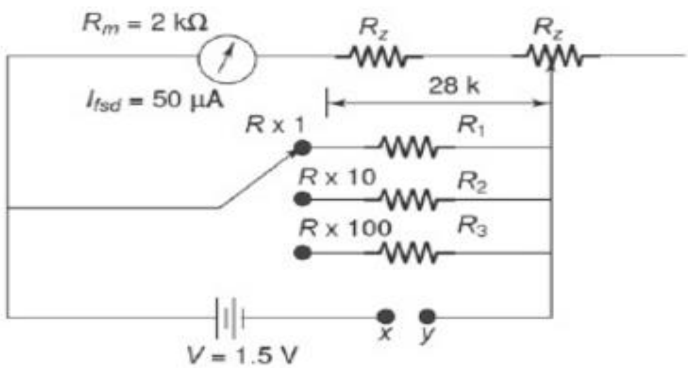
Just remember the final expression. Derivation is not important here.

Hence $$R_1 = R_h - \frac{\dfrac{I_{fsd}\, R_m\, R_h}{V - I_{fsd}\, R_h} \times R_m}{\dfrac{I_{fsd}\, R_m\, R_h}{V - I_{fsd}\, R_h} + R_m}$$

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

Hence, R_1 and R_2 can be determined.

Multirange Ohmmeter The ohmmeter circuit shown in Fig. is only for a single range of resistance measurement. To measure resistance over a wide range of values, we need to extend the ohmmeter ranges. This type of ohmmeter is called a multirange ohmmeter, shown in Fig. 4.31.



SHUNT TYPE OHMMETER

The shunt type ohmmeter given in Fig consists of a battery in series with an adjustable resistor R_1, and a D'Arsonval movement

The unknown resistance is connected in parallel with the meter, across the terminals A and B, hence the name shunt type ohmmeter.

In this circuit it is necessary to have an ON/OFF switch to disconnect the battery from the circuit when the instrument is not used.

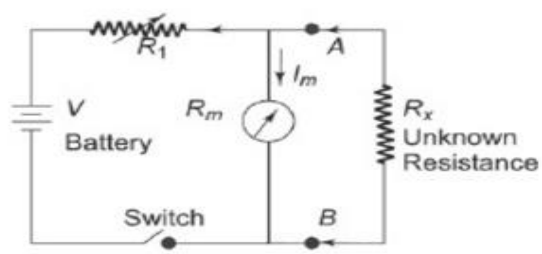


Fig. Shunt type ohmmeter

Calibration of the Shunt Type Ohmmeter

To mark the "0" ohms reading on the scale, terminals A and B are shorted, i.e. the unknown resistance $R_x = 0$, and the current through the meter movement is zero, since it is bypassed by the short-circuit. This pointer position is marked as "0" ohms.

Similarly, to mark "∞" on the scale, the terminals A and B are opened, i.e. $R_x = \infty$, and full current flows through the meter movement; by appropriate selection of the value of R_1, the pointer can be made to read full scale deflection current. This position of the pointer is marked "∞" ohms. Intermediate marking can be done by connecting known values of standard resistors to the terminals A and B.

This ohmmeter therefore has a zero mark at the left side of the scale and an ∞ mark at the right side of the scale, corresponding to full scale deflection current as shown in Fig.

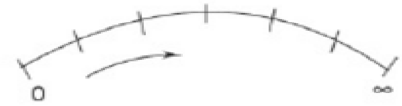


Fig. Dial of shunt type ohmmeter

The shunt type ohmmeter is particularly suited to the measurement of low values of resistance. Hence it is used as a test instrument in the laboratory for special low resistance applications.

Voltmeter

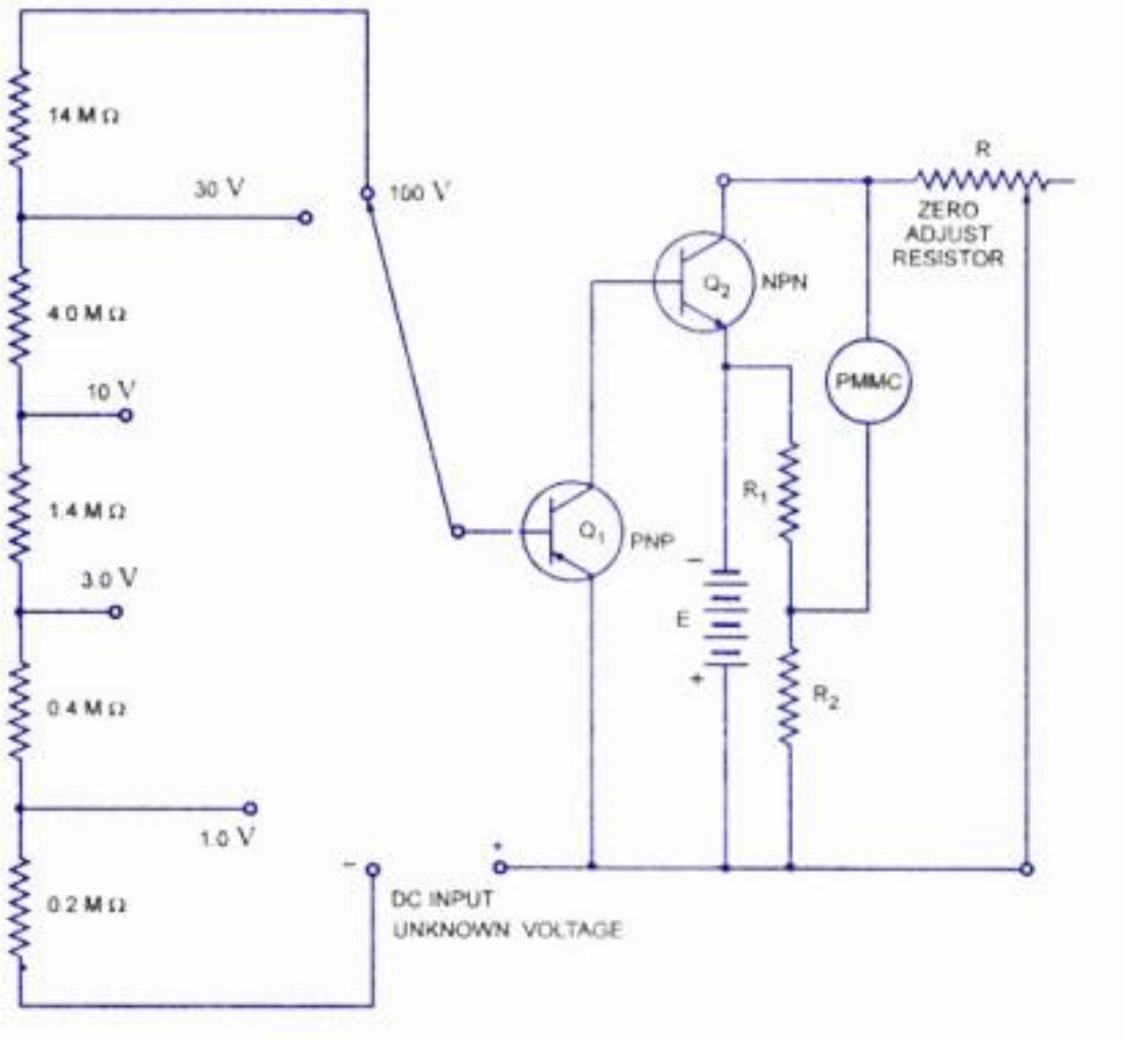
Content

- Direct Coupled DC Voltmeter.
- Chopper Type DC Voltmeter.
- Solid State DC Voltmeter.
- AC Voltmeter using Rectifier.

Direct Coupled DC Voltmeter

- This type of voltmeter is very common because of its low cost.
- This instrument can be used only to measure voltages of the order of milli-volts owing to limited amplifier gain.
- The circuit diagram for a direct coupled amplifier dc voltmeter using cascaded transistors.
- An attenuator is used in input stage to select voltage range.
- A transistor is a current controlled device so resistance is inserted in series with the transistor Q_1 to select the voltage range.

Direct Coupled DC Voltmeter Cont.



Direct Coupled Amplifier DC Voltmeter Using Cascaded Transistors

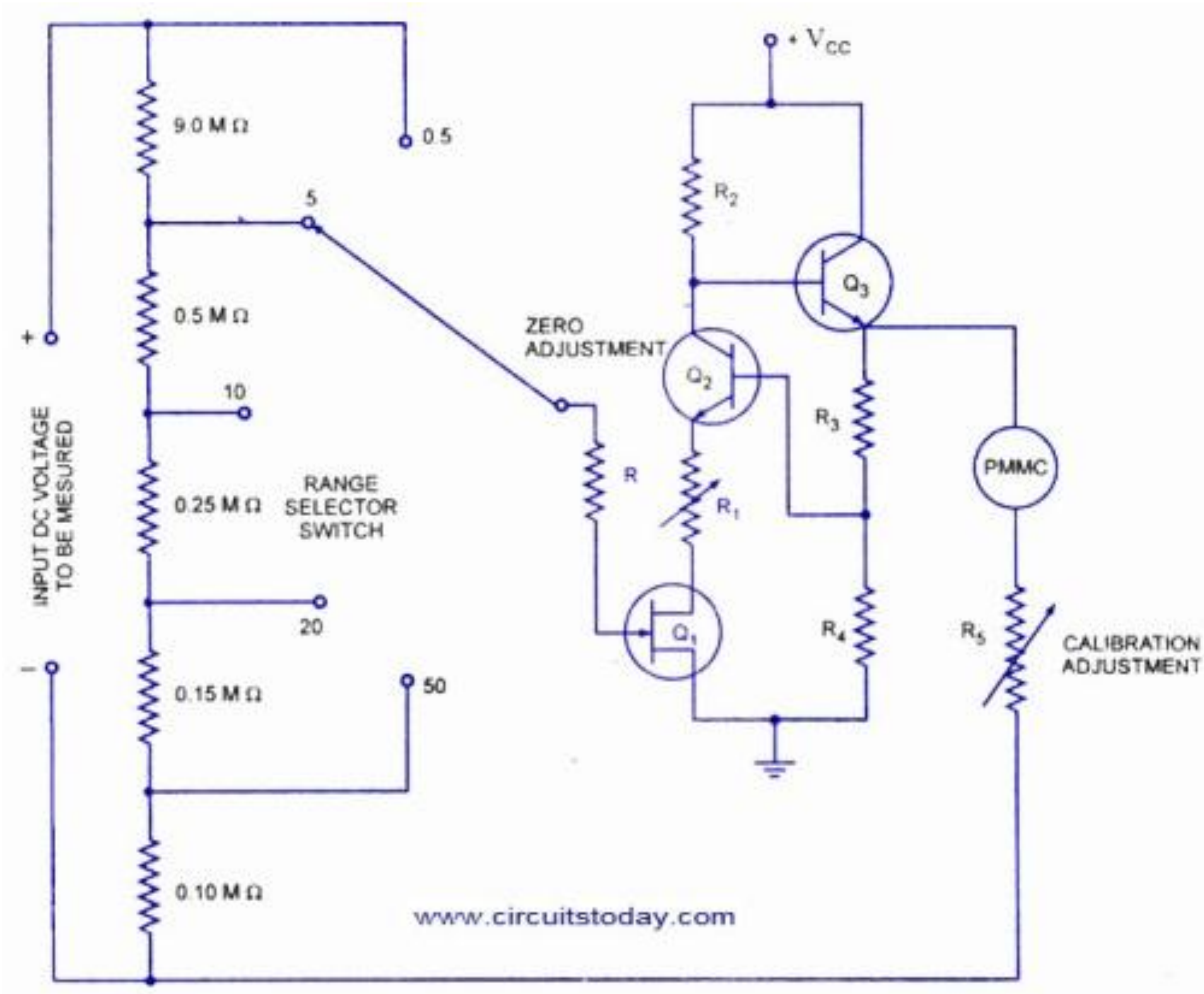
Direct Coupled DC Voltmeter Cont.

- Two transistors in cascaded connections are used instead of using a single transistor for amplification in order to keep the sensitivity of the circuit high.
- Transistors Q_1 and Q_2 are taken complement to each other and are directly coupled to minimize the number of components in the circuit.
- They form a direct coupled amplifier. A variable resistance R is put in the circuit for zero adjustment of the PMMC.
- R controls the bucking current from the supply E to buck out the quiescent current.

Disadvantage

- The draw-back of such a voltmeter is that it has to work under specified ambient temperature to get the required accuracy otherwise excessive drift problem occurs during operation.

Direct Coupled DC Voltmeter Cont.



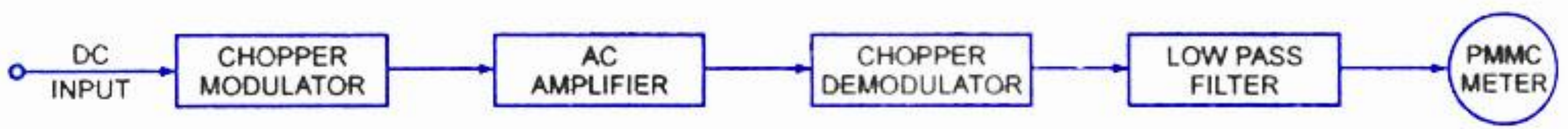
Direct Coupled Amplifier Transistorized DC Voltmeter Using FET

Advantages

- The high input impedance, this circuit has another advantage that when input voltage exceeds its limit, amplifier gets saturated which limits the current passing through the PMMC meter. So meter does not burn out.

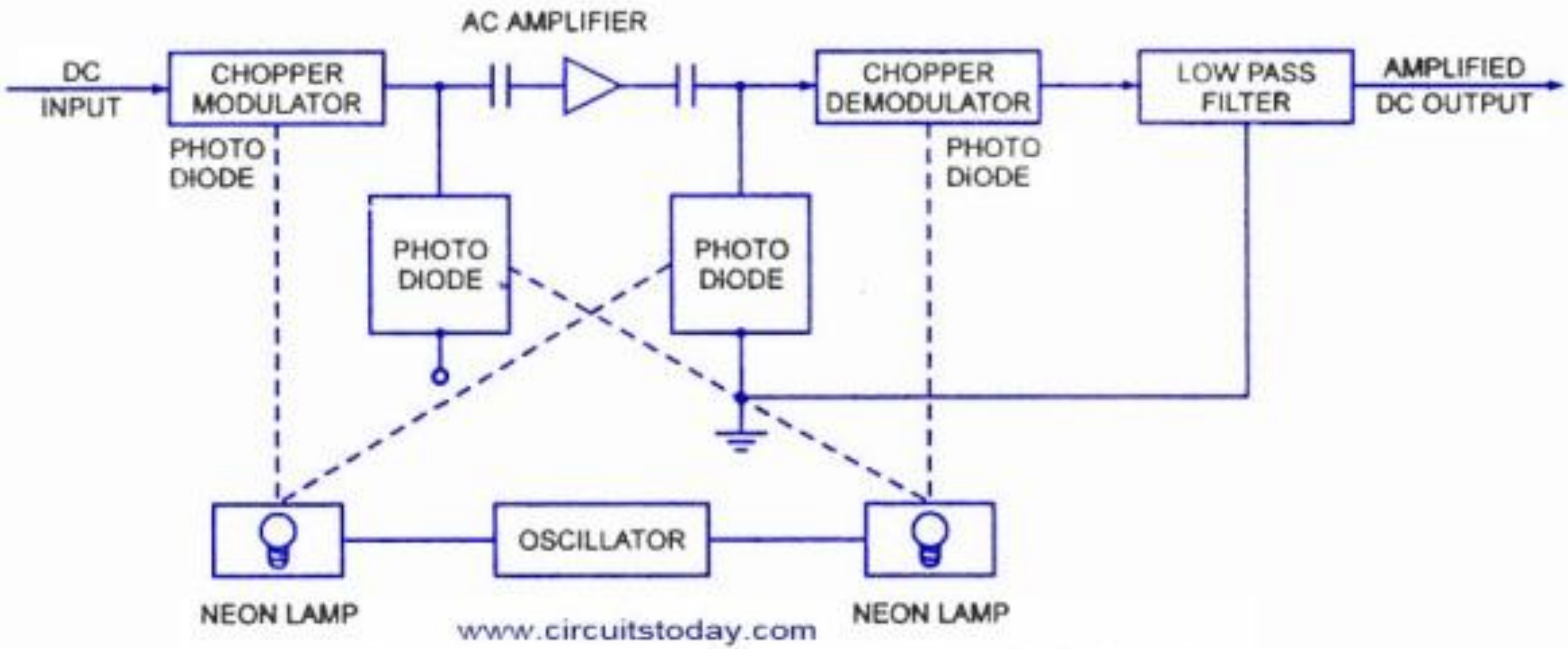
Chopper Type DC Voltmeter

- ***Chopper type dc amplifier is used in highly*** sensitive dc electronic voltmeters.
- Firstly dc input voltage is converted into ac voltage by chopper modulator and then it is supplied to an ac amplifier,
- Output of amplifier is then demodulated to a dc voltage proportional to the original input voltage.
- Modulator chopper and demodulator chopper act in anti-synchronism.
- Chopper system may be either mechanical or electronic.



Block Diagram of Chopper Type DC Voltmeter

Chopper Type DC Voltmeter Cont.



Circuit Diagram of Chopper Type DC Voltmeter

Chopper Type DC Voltmeter Working

- ***Circuit diagram of an electronic chopper*** employing photo diodes.
- Photo diodes change its resistance under different illumination conditions, this property of photo diode is used in chopper amplifier.
- Its resistance changes from the order of few mega-ohms to few hundred ohms when it is illuminated by a light source in the dark place.
- Two neon lamps are used in this circuit, these are supplied by an oscillator for alternate half cycles. Two photo diodes are used in input stage which acts as half-wave modulators.

Chopper Type DC Voltmeter Working Cont.

- Output of chopper modulator is a square wave voltage (proportional to the input signal) .
- Square wave is supplied to the ac amplifier through a capacitor. Amplified output is again passed through a capacitor and then fed to chopper demodulator.
- Capacitor is used to remove dc drift from the signal.
- Chopper demodulator gives a dc output voltage (proportional to the input voltage) which is passed through the low pass filter to remove any residual ac component.
- Now this dc output voltage is supplied to the PMMC meter for measurement of input voltage.

Advantage

- The input impedance of a Chopper Amplifier is usually of the order of 10 MΩ or higher, except on very low input ranges.
- The drift in an ordinary dc amplifier is of the order of mV. The full scale range of an ordinary dc amplifier is limited to measuring input signal of 1— 100 mV. In a chopper modulator system with the use of ac amplifier, drift can be cut down by a factor of 100, thus allowing an input signal range of about 0.01 mV = 10 μV full scale to be handled.

Applications

- In chopper amplifier dc voltmeter, input impedance is of the order of hundred mega-ohms and it has sensitivity of one micro-volt per scale division.

Solid State DC Voltmeter

- Solid State Voltmeter is designed using Semiconductor Devices(like: Op-Amp, Transistor, Diodes).
- Op-amp is a directly coupled very high gain amplifier. The gain of the Op-Amp can be adjusted to any suitable lower value by providing appropriate resistance between its output terminal, and Neg. Feedback is provided using inverting terminal of Op-Amp.
- The ratio R_2/R_1 determines the gain of an amplifier circuit.
- The two diodes used are for IC protection. Under normal conditions, they are non-conducting, as the maximum voltage across them is 10 mV.

Solid State DC Voltmeter Cont.

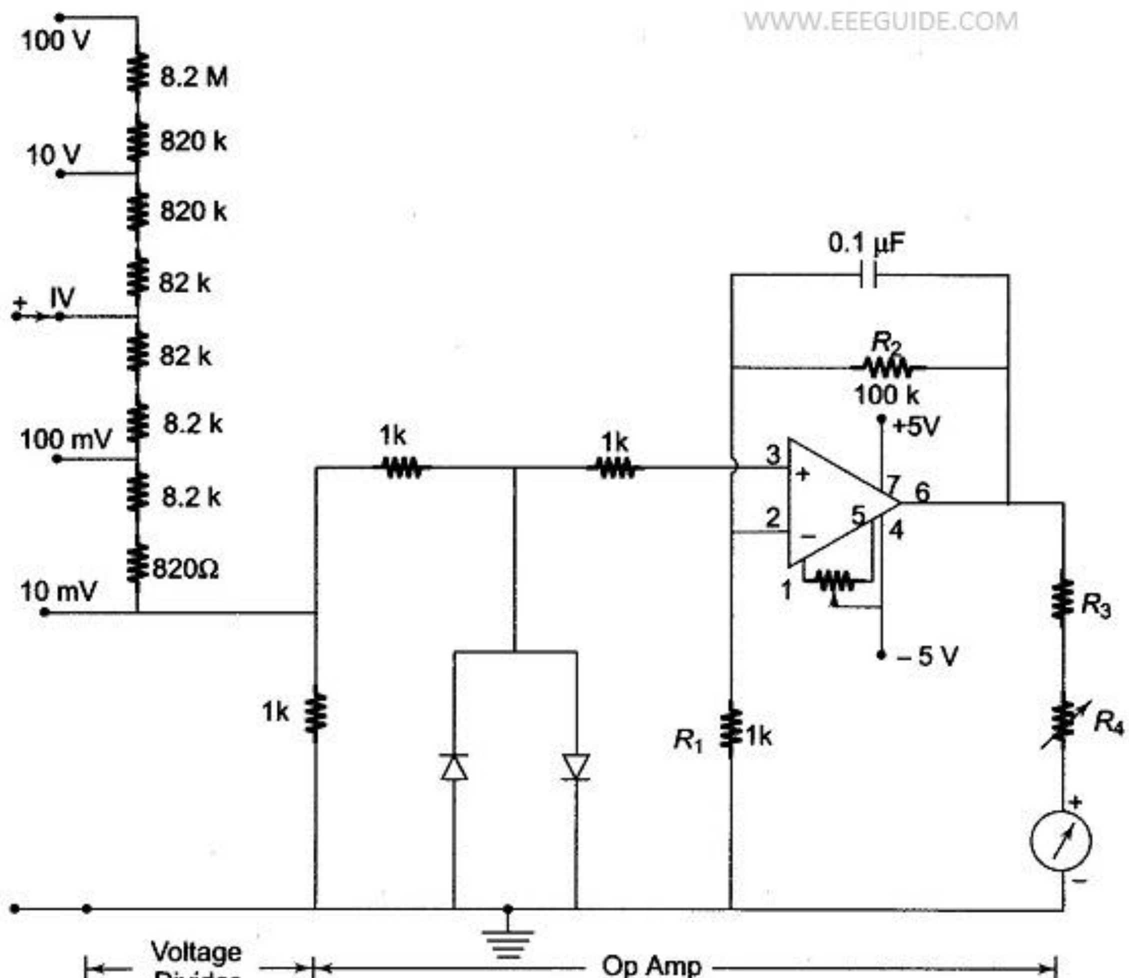


Fig. 4.13 Solid State mV Voltmeter Using OpAmp

Solid State DC Voltmeter Cont.

- If an excessive voltage, say more than 100 mV appears across them, then depending upon the polarity of the voltage, one of the diode conducts and protects the IC.
- A µA scale of 50 — 1000 µA full scale deflection can be used as an indicator. R_4 is adjusted to get maximum full scale deflection.

AC Voltmeter using Rectifier

- Rectifier type instruments generally use a PMMC movement along with a rectifier arrangement.
- Silicon diodes are preferred because of their low reverse current and high forward current ratings.
- an ac voltmeter circuit consisting of a multiplier, a bridge rectifier and a PMMC movement.
- The bridge rectifier provides a full wave pulsating dc. Due to the inertia of the movable coil, the meter indicates a steady deflection proportional to the average value of the current.
- The meter scale is usually calibrated to give the RMS value of an alternating sine wave input.

AC Voltmeter using Rectifier Cont.

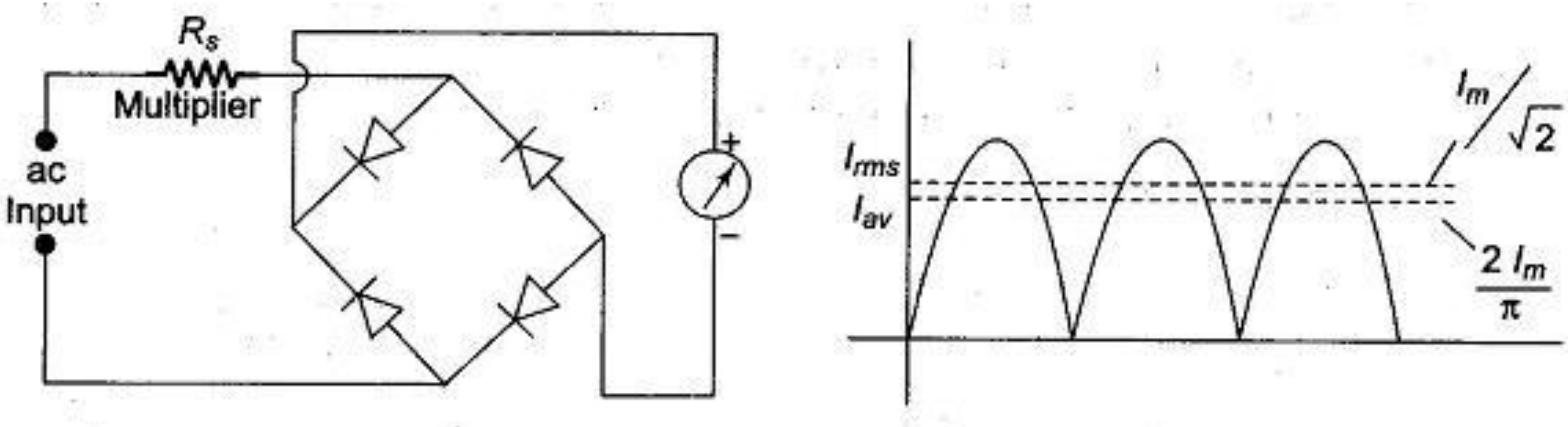
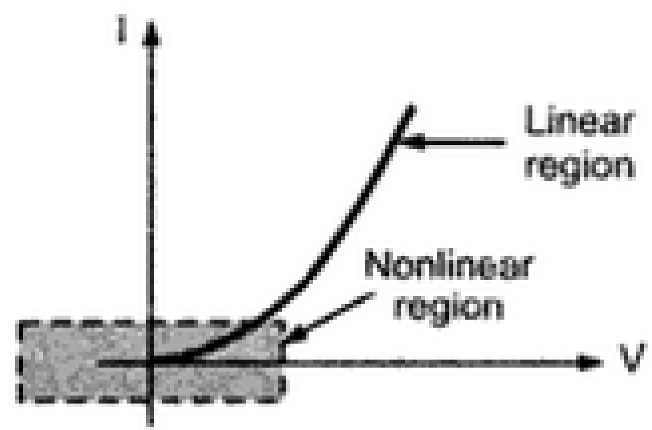


Fig. 4.16 (a) ac Voltmeter (b) Average and RMS Value of Current



Forward Characteristics of Diode

AC Voltmeter using Rectifier Cont.

- Practical rectifiers are non-linear devices particularly at low values of forward current.
- Hence the meter scale is non-linear and is generally crowded at the lower end of a low range voltmeter. In this part the meter has low sensitivity because of the high forward resistance of the diode. Also, the diode resistance depends on the temperature.

AC Voltmeter using Rectifier Cont.

- Diode D_1 conducts during the positive half of the input cycle and causes the meter to deflect according to the average value of this half cycle.
- The meter movement is shunted by a resistor, R_{sh} in order to draw more current through the diode D_1 and move the operating point into the linear portion of the characteristic curve, In the negative half cycle,
- Diode D_2 conducts and the current through the measuring circuit, which is in an opposite direction, bypasses the meter movement.

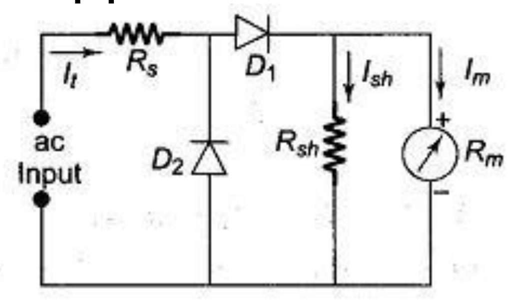


Fig. 4.17 General Rectifier Type ac Voltmeter