UNIT – 1

Performance characteristics of instruments, Static characteristics, Accuracy, Resolution, Precision, Expected value, Error, Sensitivity. Errors in Measurement, Dynamic Characteristics-speed of response, Fidelity, Lag and Dynamic error. DC Voltmeters- Multi-range, Range extension/Solid state and differential voltmeters, AC voltmeters-multi range, range extension, shunt. Thermocouple type RF ammeter, Ohmmeters series type, shunt type, Multi-meter for Voltage, Current and resistance measurement.

INTRODUCTION:

Instrumentation is a technology of measurement which serves not only science but all branches of engineering, medicine, and almost every human Endeavour. The knowledge of any parameter largely depends on the measurement. The in-depth knowledge of any parameter can be easily understood by the use of measurement, and further modify captions can also be obtained.

Measuring is basically used to monitor a process or operation, or as well as the controlling process. For example, thermometers, barometers, anemometers are used to indicate the environmental conditions. Similarly, water, gas and electric meters are used to keep track of the quantity of the commodity used, and also special monitoring equipment are used in hospitals.

Whatever may be the nature of application, intelligent selection and use of measuring equipment depends on a broad knowledge of what is available and how the performance of the equipment renders itself for the job to be performed.

But there are some basic measurement techniques and devices that are useful and will continue to be widely used also. There is always a need for improvement and development of new equipment to solve measurement problems.

The major problem encountered with any measuring instrument is the error. Therefore, it is obviously necessary to select the appropriate measuring instrument and measurement method which minimizes error. To avoid errors in any experimental work, careful planning, execution and evaluation of the experiment are essential.

The basic concern of any measurement is that the measuring instrument should not effect the quantity being measured; in practice, this non-interference principle is never strictly obeyed. Null measurements with the use of feedback in an instrument minimize these interference effects.

PERFORMANCE CHARACTERISTICS OF INSTRUMENTS:

A knowledge of the performance characteristics of an instrument is essential for selecting the most suitable instrument for specific measuring jobs. It consists of two basic characteristics—static and dynamic.

STATIC CHARACTERISTICS:

The static characteristics of an instrument are, in general, considered for instruments which are used to measure an unvarying process condition. All the static performance characteristics are obtained by one form or another of a process called calibration. There are a number of related definitions (or characteristics), which are described below, such as accuracy, precision, repeatability, resolution, errors, sensitivity, etc.

1. ***Instrument:*** A device or mechanism used to determine the present value of the quantity under measurement.
2. ***Measurement***: The process of determining the amount, degree, or capacity by comparison (direct or indirect) with the accepted standards of the system units being used.
3. ***Accuracy:*** The degree of exactness (closeness) of a measurement compared to the expected (desired) value.
4. ***Resolution***: The smallest change in a measured variable to which an instrument will respond.
5. ***Precision***: A measure of the consistency or repeatability of measurements, i.e. successive reading do not differ. (Precision is the consistency of the instrument output for a given value of input).
6. ***Expected value:*** The design value, i.e. the most probable value that calculations indicate one should expect to measure.
7. ***Error:*** The deviation of the true value from the desired value.
8. ***Sensitivity:*** The ratio of the change in output (response) of the instrument to a change of input or measured variable.

ERROR IN MEASUREMENT:

Measurement is the process of comparing an unknown quantity with an accepted standard quantity. It involves connecting a measuring instrument into the system under consideration and observing the resulting response on the instrument. The measurement thus obtained is a quantitative measure of the so-called "true value" (since it is very difficult to define the true value, the term "expected value" is used). Any measurement is affected by many variables, therefore the results rarely reflect the expected value. For example, connecting a measuring instrument into the circuit under consideration always disturbs (changes) the circuit, causing the measurement to differ from the expected value.

Some factors that affect the measurements are related to the measuring instruments themselves. Other factors are related to the person using the instrument. The degree to which a measurement nears the expected value is expressed in terms of the error of measurement.

Error may be expressed either as absolute or as percentage of error. Absolute error may be defined as the difference between the expected value of the variable and the measured value of the variable, or

$$e = Y_n - X_n$$

where

e = absolute error

Y_n = expected value

X_n = measured value

Therefore % Error = (Absolute value/ Expected value) * 100

$= (e/ Y_n) * 100$

$= ((Y_n - X_n)/ Y_n) * 100$

It is more frequently expressed as a accuracy rather than error.

Therefore $A = 1 - [((Y_n - X_n)/ Y_n)]$

where A is the relative accuracy.

Accuracy is expressed as % accuracy

$$a = 100\% - \%\ \text{error}$$

$$a = A * 100\ \%$$

where a is the % accuracy

DYNAMIC CHARACTERISTICS:

Instruments rarely respond instantaneously to changes in the measured variables. Instead, they exhibit slowness or sluggishness due to such things as mass, thermal capacitance, fluid capacitance or electric capacitance. In addition to this, pure delay in time is often encountered where the instrument waits for some reaction to take place. Such industrial instruments are nearly always used for measuring quantities that fluctuate with time. Therefore, the dynamic and transient behavior of the instrument is as important as the static behavior. The dynamic behaviour of an instrument is determined by subjecting its primary element (sensing element) to some unknown and predetermined variations in the measured quantity. The three most common variations in the measured quantity are as follows:

1. Step change, in which the primary element is subjected to an instantaneous and finite change in measured variable.
2. Linear change, in which the primary element is following a measured variable, changing linearly with time.
3. Sinusoidal change, in which the primary element follows a measured variable, the magnitude of which changes in accordance with a sinusoidal function of constant amplitude.

The dynamic characteristics of an instrument are

(i) ***Speed of Response:*** It is the rapidity with which an instrument responds to changes in the measured quantity.

(ii) ***Fidelity*** :It is the degree to which an instrument indicates the changes in the measured variable without dynamic error (faithful reproduction).

(iii) **Lag**: It is the retardation or delay in the response of an instrument to changes in the measured variable.

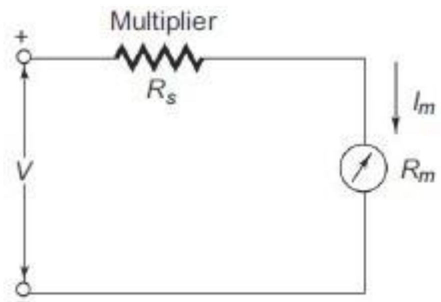
(iv) ***Dynamic Error*** :It is the difference between the true value of a quantity changing with time and the value indicated by the instrument, if no static error is assumed.

When measurement problems are concerned with rapidly varying quantities, the dynamic relations between the instruments input and output are generally defined by the use of differential equations.

DC VOLTMETERS

A basic D'Arsonval movement can be converted into a dc voltmeter by adding a series resistor known as multiplier, as shown in Fig. 4.1. The function of the multiplier is to limit the current through the movement so that the current does not exceed the full scale deflection value.

A dc voltmeter measures the potential difference between two points in a dc circuit or a circuit component. To measure the potential difference between two points in a dc circuit or a circuit component, a dc voltmeter is always connected across them with the proper polarity. The value of the multiplier required is calculated as follows. Referring to Fig. below



I_m = full scale deflection current of the movement (I_{fsd})
R_m = internal resistance of movement
R_s = multiplier resistance
V = full range voltage of the instrument

From the circuit of Fig. 4.1

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

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

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

The multiplier limits the current through the movement, so as to not exceed the value of the full scale deflection I_{fsd}. The above equation is also used to further extend the range in DC voltmeter

Multi-range voltmeter

As in the case of an ammeter, to obtain a multirange ammeter, a number of shunts are connected across the movement with a multi-position switch. Similarly, a dc voltmeter can be converted into a multirange voltmeter by connecting a number of resistors (multipliers) along with a range switch to provide a greater number of workable ranges.

Figure 4.2 shows a multirange voltmeter using a three position switch and three multipliers R_1, R_2, and R_3 for voltage values V_1, V_2, and V_3. Figure 4.2 can be further modified to Fig. 4.3, which is a more practical arrangement of the multiplier resistors of a multirange voltmeter. In this arrangement, the multipliers are connected in a series string, and the range selector selects the appropriate amount of resistance required in series with the movement.

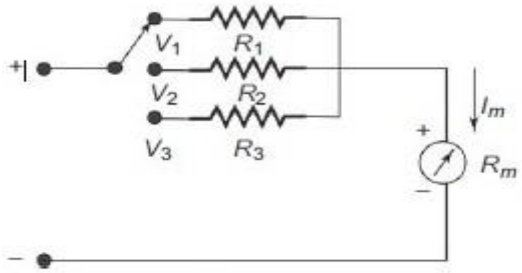


Fig. 4.2 Multirange voltmeter

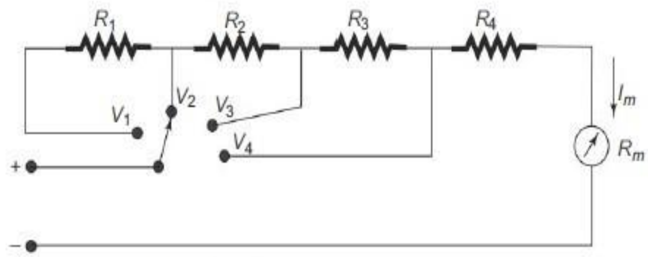


Fig. 4.3 Multipliers connected in series string

This arrangement is advantageous compared to the previous one, because all multiplier resistances except the first have the standard resistance value and are also easily available in precision tolerances.

The first resistor or low range multiplier, R_4, is the only special resistor which has to be specially manufactured to meet the circuit requirements.

Voltmeter Range Extension:

The range of a voltmeter can be extended to measure high voltages, by using a high voltage probe or by using an external multiplier resistor, as shown in Fig. 4.4.

In most meters the basic movement is used on the lowest current range. Values for multipliers can be determined using the procedure of Section 4.4. The basic meter movement can be used to measure very low voltages. However, great care must be used not to exceed the voltage drop required for full scale deflection of the basic movement.

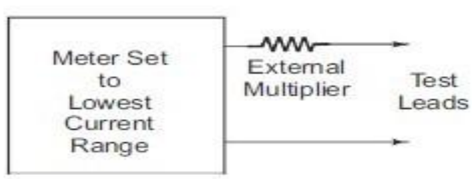


Fig. 4.4 Extending voltage range

Sensitivity: The sensitivity or Ohms per Volt rating of a voltmeter is the ratio of the total circuit resistance R_t to the voltage range. Sensitivity is essentially the reciprocal of the full scale deflection current of the basic movement.

Therefore, $S = 1/I_{fsd}\ \Omega/V$. The sensitivity 'S' of the voltmeter has the advantage that it can be used to calculate the value of multiplier resistors in a dc voltmeter. As,

R_t = total circuit resistance [$R_t = R_s + R_m$]
S = sensitivity of voltmeter in ohms per volt
V = voltage range as set by range switch
R_m = internal resistance of the movement

Since $R_s = R_t - R_m$ and $R_t = S \times V$

Therefore $R_s = (S \times V) - R_m$

<u>Solid State Voltmeter</u> :

Figure 4.13 shows the circuit of an electronic voltmeter using an IC OpAmp 741C. This is a directly coupled very high gain amplifier. The gain of the OpAmp can be adjusted to any suitable lower value by providing appropriate resistance between its output terminal, Pin No. 6, and inverting input, Pin No. 2, to provide a negative feedback. The ratio R_2/R_1 determines the gain, i.e. 101 in this case, provided by the OpAmp. The 0.1 µF capacitor across the 100 k resistance R_2 is for stability under stray pick-ups.

Terminals 1 and 5 are called offset null terminals. A 10 k **Ω** potentiometer is connected between these two offset null terminals with its centre tap connected to a – 5V supply. This potentiometer is called zero set and is used for adjusting zero output for zero input conditions.

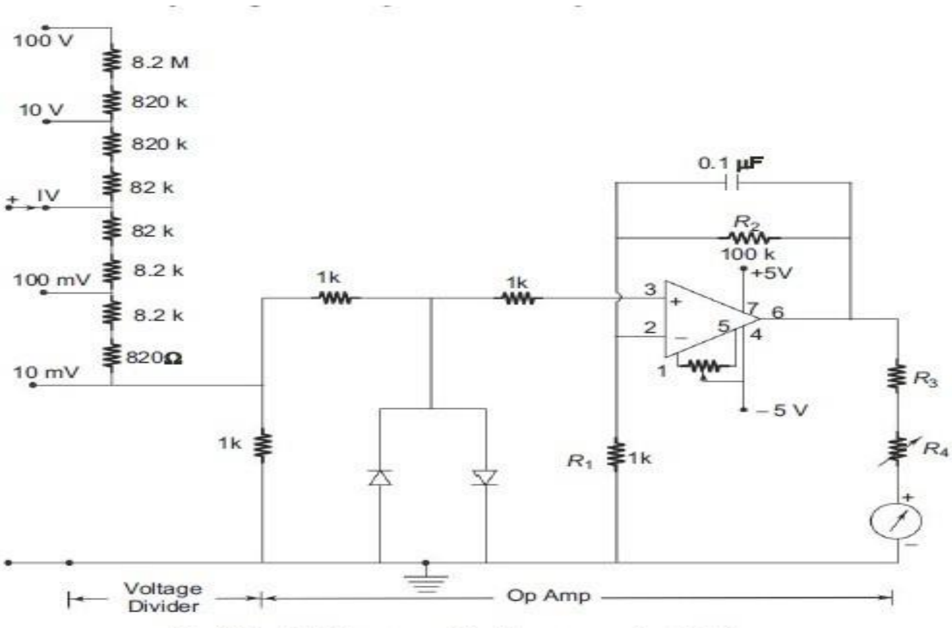


Fig. 4.13 Solid state mV voltmeter using OpAmp

The two diodes used are for IC protection. Under normal conditions, they are non-conducting, as the maximum voltage across them is 10 mV. If an excessive voltage, say more than 100 mV appears across them, then depending upon the polarity of the voltage, one of the diodes 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.

Differential Voltmeter:

Basic Differential Measurement The differential voltmeter technique, is one of the most common and accurate methods of measuring unknown voltages. In this technique, the voltmeter is used to indicate the difference between known and unknown voltages, i.e., an unknown voltage is compared to a known voltage. Figure 4.14 (a) shows a basic circuit of a differential voltmeter based on the potentiometric method; hence it is sometimes also called a potentiometric voltmeter.

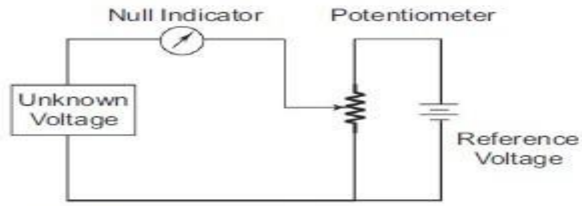


Fig. 4.14 (a) Basic differential voltmeter

In this method, the potentiometer is varied until the voltage across it equals the unknown voltage, which is indicated by the null indicator reading zero. Under null conditions, the meter draws current from neither the reference source nor the unknown voltage source, and hence the differential voltmeter presents infinite impedance to the unknown source. (The null meter serves as an indicator only.)

To detect small differences the meter movement must be sensitive, but it need not be calibrated, since only zero has to be indicated. The reference source used is usually a 1 V dc standard source or a zener controlled precision supply. A high voltage reference supply is used for measuring high voltages. The usual practice, however, is to employ voltage dividers or attenuators across an unknown source to reduce the voltage.

The input voltage divider has a relatively low input impedance, especially for unknown voltages much higher than the reference standard. The attenuation will have a loading effect and the input resistance of voltmeter is not infinity when an attenuator is used. In order to measure ac voltages, the ac voltage must be converted into dc by incorporating a precision rectifier circuit. A block diagram of an ac differential voltmeter is shown in Fig. 4.14 (b).

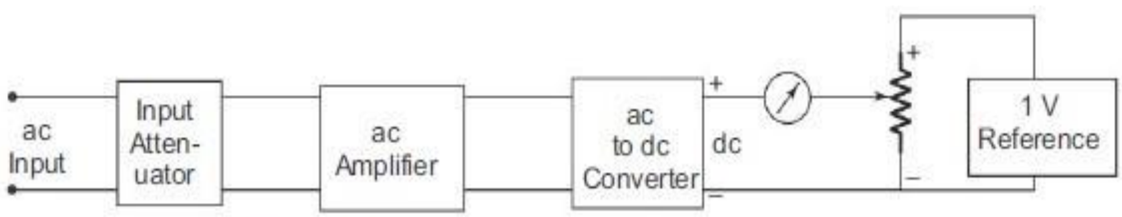


Fig. 4.14 (b) Block diagram of an ac differential voltmeter

AC VOLTMETERS:

Multi Range AC Voltmeters:

Figure 4.24 is circuit for measuring ac voltages for different ranges. Resistances R1, R2, R3 and R4 form a chain of multipliers for voltage ranges of 1000 V, 250 V, 50 V, and 10 V respectively. On the 2.5 V range, resistance R5 acts as a multiplier and corresponds to the multiplier R_s shown in Fig. 4.17. R_{sh} is the meter shunt and acts to improve the rectifier operation.

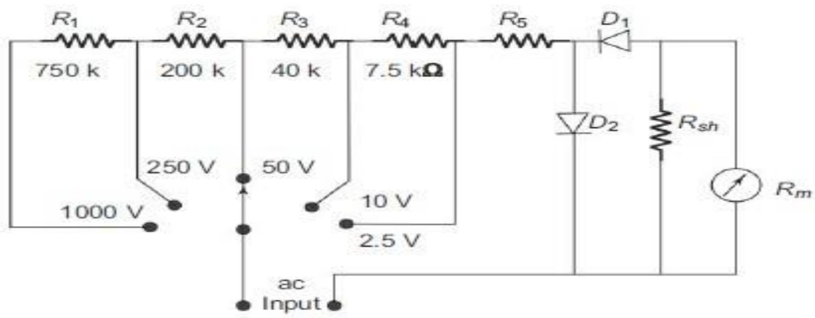


Fig. 4.24 Multirange ac voltmeter

Range extension AC Voltmeters

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. Figure 4.16 (a) gives an ac voltmeter circuit consisting of a multiplier, a bridge rectifier and a PMMC movement.

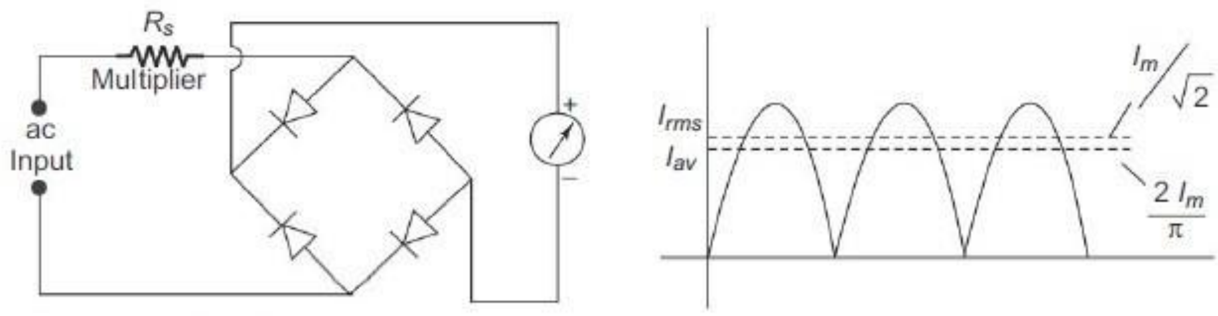


Fig. 4.16 (a) ac voltmeter (b) Average and RMS value of current

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 (Fig. 4.16 (b)). The meter scale is usually calibrated to give the RMS value of an alternating sine wave input.

Rectifier Instruments are frequently used for the measurement in communication circuits and all other light current work. In the fig.4.16 (a) the value of current is limited by R_s which does not exceeds the current rating of PMMC.

The DC sensitivity of a rectifier type device is given by

$S_{DC} = 1/I_{fsd}$ where I_{fsd} is full scale deflection current

The AC sensitivity of a rectifier type device is different for half wave and full wave rectifiers. The AC sensitivity of a half wave rectifier with sinusoidal input is given by

$S_{AC} = 0.45\, S_{DC}$

The AC sensitivity of a full wave rectifier with sinusoidal input is given by

$S_{AC} = 0.9\, S_{DC}$

To extend the range of half wave rectifier of AC voltmeter, the value of multiplier is given by

$R_s = S_{AC}\, V - R_m$ where V is Voltmeter range to be extend. R_m is internal resistance of PMMC

Therefore $R_s = 0.45\, S_{DC}\, V - R_m$

To extend the range of full wave rectifier of AC voltmeter, the value of multiplier is given by

$R_s = S_{AC}\, V - R_m$

Therefore $R_s = 0.9\, S_{DC}\, V - R_m$

Aryton shunt or Universal shunt

The Aryton shunt eliminates the possibility of having the meter in the circuit without a shunt. This advantage is gained at the price of slightly higher overall resistance. Figure 3.3 shows a circuit of an Aryton shunt ammeter. In this circuit, when the switch is in position “1”, resistance Ra is in parallel with the series combination of Rb, Rc and the meter movement.

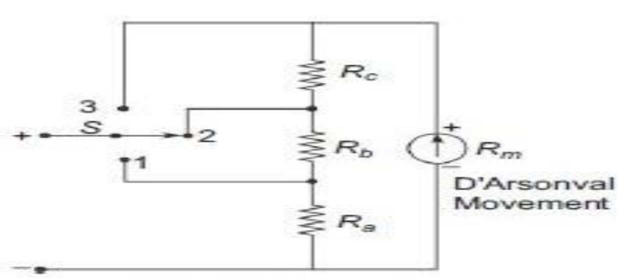


Fig. 3.3 Aryton shunt

Hence the current through the shunt is more than the current through the meter movement, thereby protecting the meter movement and reducing its sensitivity. If the switch is connected to position “2”, resistance Ra and Rb are together in parallel with the series combination of Rc and the meter movement. Now the current through the meter is more than the current through the shunt resistance. If the switch is connected to position "3" Ra, Rb and Rc are together in parallel with the meter. Hence maximum current fl ows through the meter movement and very little through the shunt. This increases the sensitivity

Thermocouple type RF ammeter

Thermocouple Instruments

Thermocouples consists of a junction of two dissimilar wires, so chosen that a voltage is generated by heating the junction. The output of a thermocouple is delivered to a sensitive dc microammeter. (Calibration is made with dc or with a low frequency, such as 50 cycles, and applies for all frequencies for which the skin effect in the heater is not appreciable. Thermocouple instruments are the standard means for measuring current at radio frequencies.) The generation of dc voltage by heating the junction is called thermoelectric action and the device is called a thermocouple.

Different Types of Thermocouples

In a thermocouple instrument, the current to be measured is used to heat the junction of two metals. These two metals form a thermocouple and they have the property that when the junction is heated it produces a voltage proportional to the heating effect. This output voltage drives a sensitive dc microammeter, giving a reading proportional to the magnitude of the ac input.

The alternating current heats the junction; the heating effect is the same for both half cycles of the ac, because the direction of potential drop (or polarity) is always be the same. The various types of thermocouples are as follows.

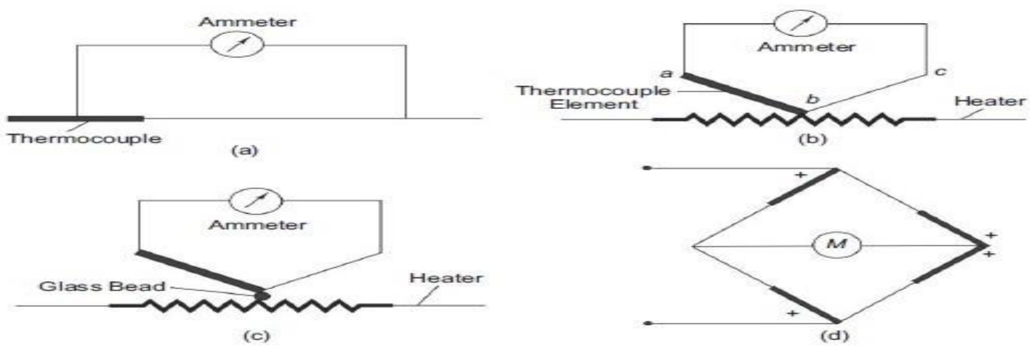


Fig. 3.6 (a) Mutual type (b) Contact type (c) Separate heater type (d) Bridge type thermocouple

<u>*Mutual Type*</u> (Fig. 3.6 (a)) In this type, the alternating current passes through the thermocouple itself and not through a heater wire. It has the disadvantages that the meter shunts the thermocouple.

<u>*Contact Type*</u> (Fig. 3.6 (b)) This is less sensitive than the mutual type. In the contact type there are separate thermocouple leads which conduct away the heat from the heater wire.

<u>*Separate Heater Type*</u> (Fig. 3.6 (c)) In this arrangement, the thermocouple is held near the heater, but insulated from it by a glass bead. This makes the instrument sluggish and also less sensitive

because of temperature drop in the glass bead. The separate type is useful for certain applications, like RF current measurements. To avoid loss of heat by radiation, the thermocouple arrangement is placed in a vacuum in order to increase its sensitivity.

Bridge Type (Fig. 3.6 (d)) This has the high sensitivity of the mutual type and yet avoids the shunting effect of the microammeter.

The sensitivity of a thermocouple is increased by placing it in a vacuum since loss of heat by conduction is avoided, and the absence of oxygen permits operation at a much higher temperature. A vacuum thermocouple can be designed to give a full scale defl ection of approximately 1 mA. A similar bridge arrangement in air would require about 100 mA for full scale deflection.

Series type Ohmmeter

A D'Arsonval movement is connected in series with a resistance R1 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 fl owing 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) R1 = current limiting resistance R2 = zero adjust resistance V = battery Rm = meter resistance Rx = unknown resistance

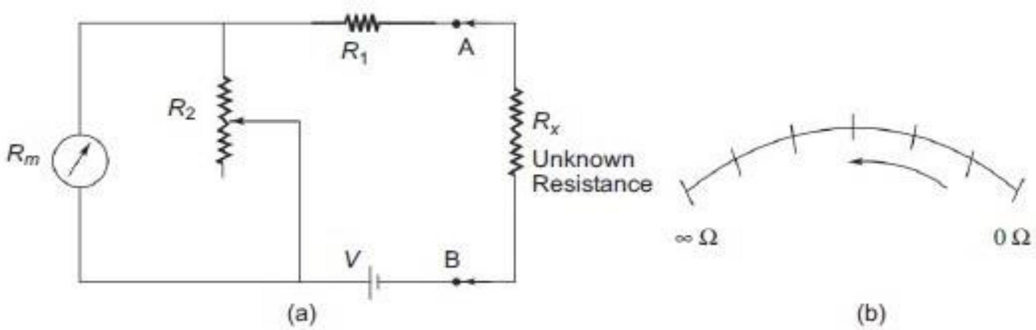


Fig. 4.30 (a) Series type ohmmeter (b) Dial of series ohmmeter

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 Rx = 0, maximum current flows in the circuit and the shunt resistance R2 is adjusted until the movement indicates full scale current (Ifsd). 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 Rx = ∞, 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 R2 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 R2 in the circuit, by varying the value of R1 to compensate for the voltage drop. Since this affects the calibration of the scale, varying by R2 is much better solution.

The internal resistance of the coil Rm is very low compared to R1. When R2 is varied, the current through the movement is increased and the current through R2 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 R1 and R2 can be determined from Rx 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 $\quad R_2 = \dfrac{I_{fsd} R_m R_h}{V - I_{fsd} R_h} \quad (4.1)$

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

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

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

Therefore $\quad R_1 = R_h - \dfrac{I_{fsd} R_m R_h}{V} \quad (4.2)$

Hence, R_1 and R_2 can be determined.

Shunt type Ohm-meter

The shunt type ohmmeter given in Fig. 4.32 consists of a battery in series with an adjustable resistor R1, 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.

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 Rx = 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. Rx = ∞, and full current flows through the meter movement; by appropriate selection of the value of R1, 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. 4.33. 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.

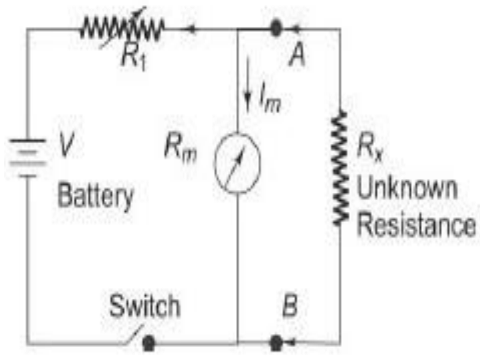


Fig. 4.32 Shunt type ohmmeter

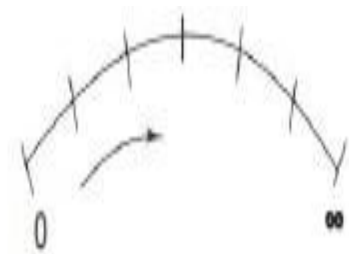


Fig. 4.33 Dial of shunt type ohmmeter

Multi-meter for Voltage, Current and resistance measurement

A multimeter is basically a PMMC meter. To measure dc current the meter acts as an ammeter with a low series resistance. Range changing is accomplished by shunts in such a way that the current passing through the meter does not exceed the maximum rated value. A multimeter consists of an ammeter, voltmeter and ohmmeter combined, with a function switch to connect the appropriate circuit to the D'Arsonval movement.

Figure 4.35 shows a meter consisting of a dc milliammeter, a dc voltmeter, an ac voltmeter, a microammeter, and an ohmmeter.

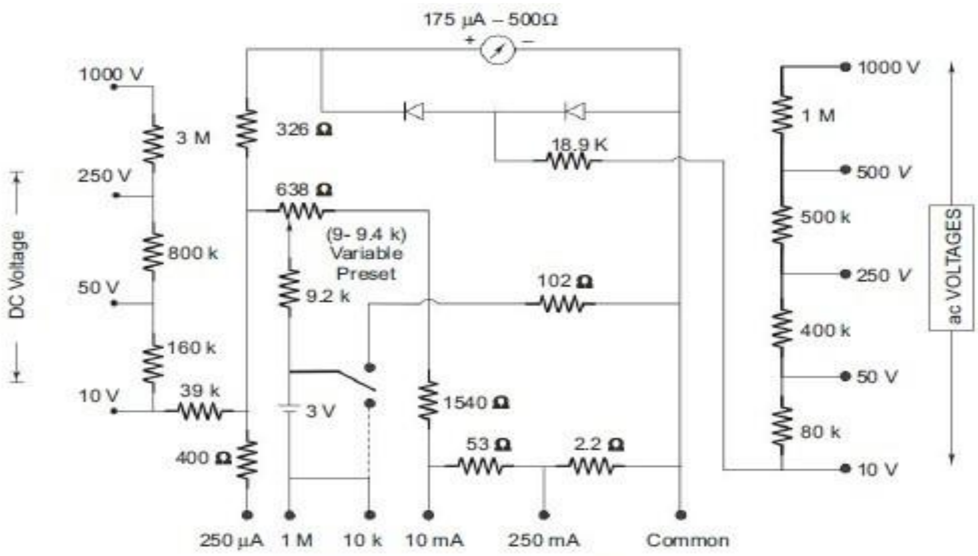


Fig. 4.35 Diagram of a multimeter

Micro ammeter: Figure 4.36 shows a circuit of a multimeter used as a microammeter.

DC Ammeter: Figure 4.37 shows a multimeter used as a dc ammeter.

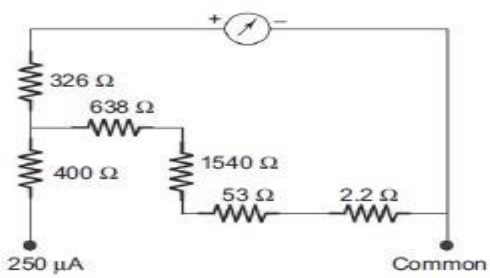


Fig. 4.36 Microammeter section of a multimeter

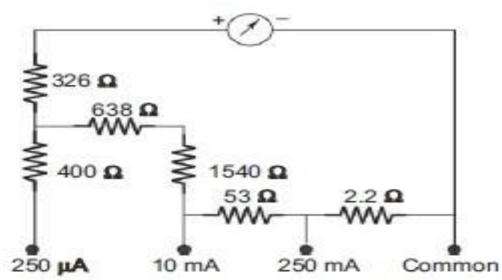


Fig. 4.37 dc ammeter section of a multimeter

DC

Voltmeter: Figure 4.38 shows the dc voltmeter section of a multimeter.

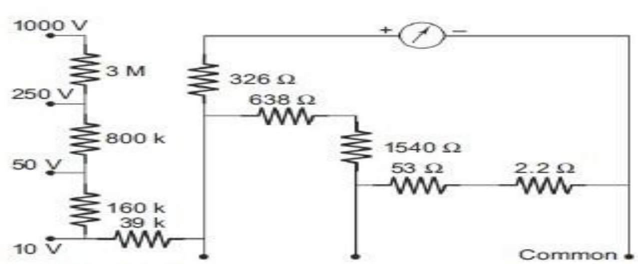


Fig. 4.38 DC voltmeter section of a multimeter

AC Voltmeter: Figure 4.39 shows the ac voltmeter section of a multimeter. To measure ac voltage, the output ac voltage is rectified by a half wave rectifier before the current passes through the meter. Across the meter, the other diode serves as protection. The diode conducts when a reverse voltage appears across the diodes, so that current bypasses the meter in the reverse direction.

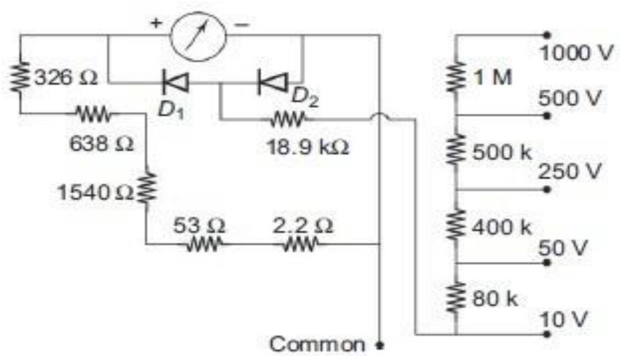


Fig. 4.39 AC voltmeter section of a multimeter

Ohmmeter: Referring to Fig. 4.40 which shows the ohmmeter section of a multimeter, in the 10 k range the 102 W resistance is connected in parallel with the total circuit resistance and in the 1 MW range the 102 W resistance is totally disconnected from the circuit. Therefore, on the 1 M range the half scale deflection is 10 k. Since on the 10 k range, the 102 W resistance is connected across the total resistance, therefore, in this range, the half scale deflection is 100 W. The measurement of resistance is done by applying a small voltage installed within the meter. For the 1 M range, the internal resistance is 10 kW, i.e. value at midscale, as shown in Fig. 4.41. And for the 10 k range, the internal resistance is 100 W, i.e. value at mid-scale as shown in Fig. 4.42.

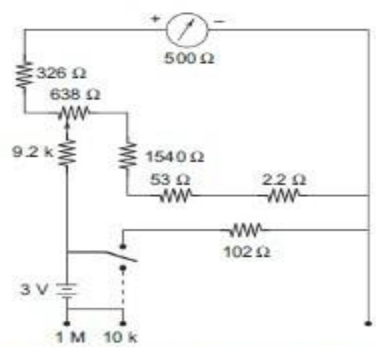


Fig. 4.40 Ohmmeter section of a multimeter

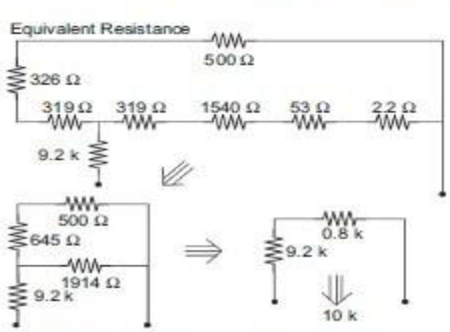


Fig. 4.41 Equivalent resistance on 1 M Ω range

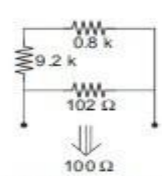


Fig. 4.42 Half scale deflection is 100 Ω on 10k range

The range of an ohmmeter can be changed by connecting the switch to a suitable shunt resistance. By using different values of shunt resistance, different ranges can be obtained. By increasing the battery voltage and using a suitable shunt, the maximum values which the ohmmeter reads can be changed.