Ohmmeter

1. An ohmmeter is an instrument used to measure resistance and check the continuity of electrical circuits and component. This resistance reading is indicated through a meter movement.
2. The ohmmeter must then have an internal source of voltage to create the necessary current to operate the movement, and also have appropriate ranging resistors to allow desired current to flow through the movement at any given resistance.
3. Two types of schemes are used to design an ohmmeter – series type and shunt type.
4. The series type of ohmmeter is used for measuring relatively high values of resistance, while the shunt type is used for measuring low values of the resistance.

Series type ohmmeter

1. In this Figure1, R_1 is the current limiting resistor, R_2 is the zero adjust resistor, R_X is the unknown resistor, E is the internal battery voltage and R_m is the internal resistance of the d'Arsonval movement. A and B are the output terminals of the ohmmeter across which an unknown resistor is connected.

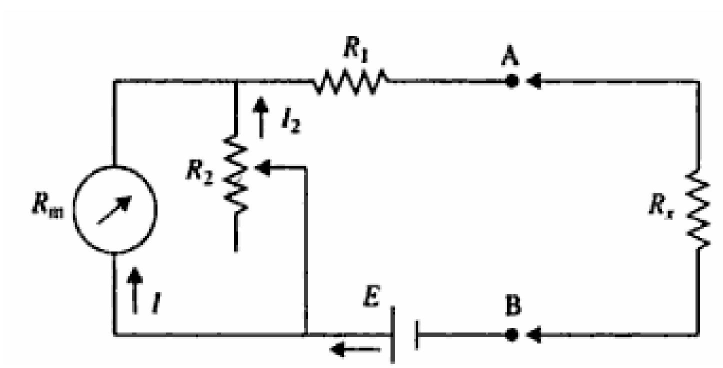

Figure1: Basic series type ohmmeter.

2. When $R_X = 0$ (short circuit), R_2 is adjusted to get full-scale current through the movement. Then, $I = I_{fsd}$. The pointer will be deflected to its maximum position on the scale. Therefore, this full-scale current reading is marked 0 ohms.
3. When $R_X = \infty$ (open circuit), $I = 0$. The pointer will read zero. Therefore, the zero current reading is marked ∞ ohms.
4. By connecting different values of R_X, intermediate values are marked. The overall accuracy of the scale markings depends on the repeating accuracy of the movement and tolerance of the resistors used for calibration. Figure 2 shows a typical scale of the series type ohmmeter. Note that the scale is logarithmic – "expended" at the low end of the scale and "compressed" at the high end to be able to span a wide range from zero to infinite resistance.

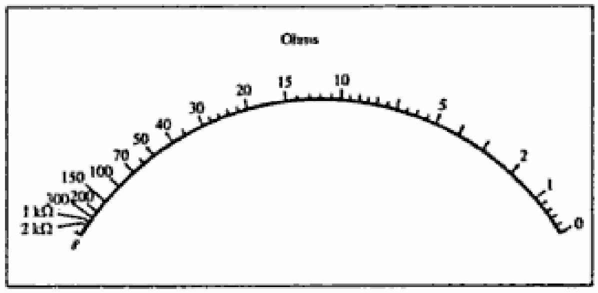

Figure2: Typical scale of series type ohmmeter.

<u>To Calculate R1 and R2</u>

1. R_1 and R_2 used in Figure 1 can be determined by using a value of R_X corresponding to half the deflection of the meter. For the given movement, I_{fsd} and Rm are known.
2. Let R_h be the half deflection resistance. For this value of R_X, $I = I_{fsd}/2$.
   Further, at half deflection,
   R_h = internal resistance of the circuit looking from terminals A and B.

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

   Battery current needed to supply half-scale deflection is given by

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

   Total current, It, is supplied by the battery for full-scale deflection is double of this current, i.e.

   $$I_t = \frac{E}{R_h}$$

   and

   $$I_2 = I_t - I_{fsd}$$

   Using KVL

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

   Solving these equations, we get

   $$R_2 = \frac{I_{fsd} R_m R_h}{E - I_{fsd} R_h} \qquad R_1 = R_h - \frac{I_{fsd} R_m R_h}{E}$$

Example 1

In the circuit of Figure 1, a 1mA meter movement with an internal of 50Ω is to be used. The battery voltage is 3V. Half-scale deflection should be for 2500 Ω

a) Calculate the values of R_1 and R_2
b) Find the change in the value of R_2 if the battery voltage reduces by 10%.
c) What is the half-scale deflection if battery voltage reduces by 10%?

Solution

a) $$R_2 = \frac{I_{fsd} R_m R_h}{E - I_{fsd} R_h} = \frac{10^{-3}\,\mathrm{A} \times 50\Omega \times 2500\Omega}{3\vee - (10^{-3}\,\mathrm{A} \times 2500\Omega)} = \underline{250\Omega}$$

$$R_1 = R_h - \frac{I_{fsd} R_m R_h}{E} = 2500\Omega - \frac{10^{-3}\,\mathrm{A} \times 50\Omega \times 2500\Omega}{3\vee} = \underline{2458.33\Omega}$$

b) E = 3V – 0.3V = 2.7V

$$R_2 = \frac{I_{fsd} R_m R_h}{E - I_{fsd} R_h} = \frac{10^{-3}\,\mathrm{A} \times 50\Omega \times 2500\Omega}{2.7\vee - (10^{-3}\,\mathrm{A} \times 2500\Omega)} = \underline{625\Omega}$$

R2 should be changed from 250Ω to 625Ω to compensate for this reduction in battery voltage.

c) $$R_h = R_1 + \frac{R_2 R_m}{R_2 + R_m} = 2458.33\Omega + \frac{625\Omega \times 50\Omega}{675\Omega} = \underline{2504.63\Omega}$$

Half-scale deflection now correspond to 2504.63Ω instead of 2500Ω

Shunt type ohmmeter

1) Figure 3 shows the basic circuit of the shunt-type ohmmeter where movement mechanism is connected parallel to the unknown resistance. In this circuit it is necessary to use a switch, otherwise current will always flow in the movement mechanism.

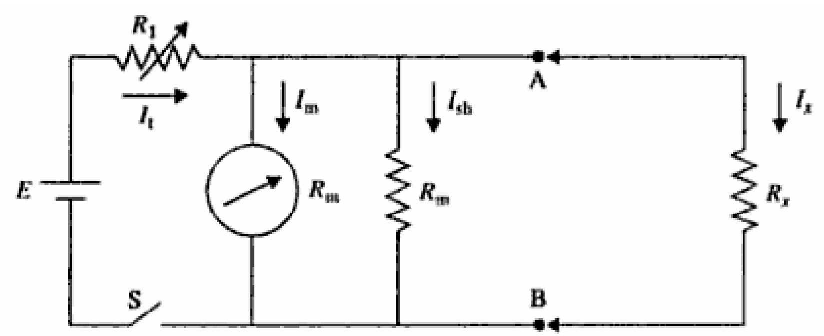

Figure3: Basic shunt-type ohmmeter

2) Resistor R_{sh} is used to bypass excess current.
3) Let the switch be closed. When $R_X = 0$ (short circuit), the pointer reads zero because full current flows through Rx and no current flows through the meter and R_{sh}. Therefore, zero current reading is marked 0 ohms.
4) When $R_X = \infty$ (open circuit), no current flows through R_X. Resistor R_1 is adjusted so that full-scale current flows through the meter. Therefore, maximum current reading is marked ∞ ohms. Comparison of series and shunt ohmmeter scales is shown in Figure 4.

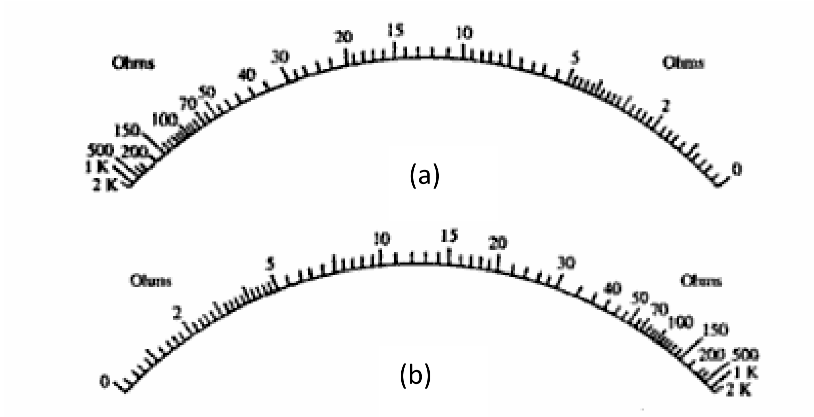

Figure4: Ohmmeter scales : (a) series scale and (b) shunt scale

To Calculate R_1 and R_{sh}

1. Again, we can use the concept of half-scale deflection.
2. Let R_h be the half-deflection resistance. For this value of R_X,

   $Im = I_{fsd}/2$

   Further, at half deflection, current through R_h is equal to sum of the currents through R_{sh} and R_m, i.e.

   $$I_x = I_{sh} - I_m$$

   Also

   $$I_x = \frac{E}{R_h} - \frac{I_m R_m}{R_h}$$

   Solving for I_{sh}, we get

   $$I_{sh} = I_m \left(\frac{R_m - R_h}{R_h} \right)$$

   Therefore,

   $$R_{sh} = \frac{I_m R_m}{I_{sh}}$$

   Now,

   $$I_t = I_m + I_{sh} + I_x = 2(I_m + I_{sh})$$

   $$= 2I_m \frac{R_m}{R_h}$$

   Therefore,

   $$R_1 = \frac{E - I_m R_m}{I_t}$$

Example 1

In the circuit of Figure3, a 1 mA meter movement with an internal resistance if 50Ω is to be used. The battery voltage is 3V. Half-scale deflection should be for 0.5Ω. Calculate the values of R_1 and R_{sh}.

Solution

For half-scale deflection

$$I_m = 0.5I_{fsd} = 0.5mA$$

$$I_{sh} = I_m\left(\frac{R_m - R_h}{R_h}\right) = 0.5\times 10^{-3}A\left(\frac{50-0.5}{0.5}\right) = 45mA$$

Therefore,

$$R_{sh} = \frac{I_m R_m}{I_{sh}} = \frac{0.5mA\times 50\Omega}{45mA} = 555.56m\Omega$$

$$I_t = 2I_m\frac{R_m}{R_h} = 2\times 0.5mA\left(\frac{50\Omega}{0.5\Omega}\right) = 100mA$$

$$R_1 = \frac{E - I_m R_m}{I_t} = 3V - \frac{(0.5mA\times 50\Omega)}{100mA}$$

$$\underline{= 29.75\Omega}$$

we can thus see that shunt-type ohmmeter can measure low values of resistance.