Conversion of voltmeter to ammeter and vice-versa

Objective

- Convert a given voltmeter to an ammeter of suitable range and calibrate the ammeter so prepared.
- Convert a given (micro or milli) ammeter to a voltmeter of suitable range and calibrate the ammeter so prepared.

Apparatus

Voltmeter, (micro or milli) Ammeter, resistance boxes (1Ω – 10kΩ and fractional), wires, digital voltmeter and milli-ammeter or multimeter, power supply (0–5 volt).

Working Theory

Voltmeter measures voltage drop across resistance by putting it in parallel to the resistance as shown in Fig 1. The internal resistance of a voltmeter is quite high \( (R_m \gg R) \) and, therefore, when connected in parallel the current through the voltmeter is quite small \( (i_v \approx 0) \). This keeps the current \( i_r \) flowing through the resistance \( R \) almost the same as when the voltmeter was not connected. Hence, the voltage drop \( (i_r R) \) measured across the resistance by a voltmeter is also almost the same as the voltage drop without the voltmeter across the resistance.

On the other hand, ammeter measures current through resistance by connecting it in series with the resistance, Fig 1. An ammeter has very low resistance \( (R_m \ll R) \) and changes the effective resistance of the circuit only by a tiny amount \( (R + R_m \approx R) \), not altering the original current by too much. Therefore, the current measured by the ammeter is about the same as without the ammeter in the circuit.

Fig 1. Schematic diagram of voltmeter and ammeter connections

Conversion of voltmeter to ammeter

Since the internal resistance of a voltmeter is much greater than ammeter, for conversion to ammeter we need to decrease the voltmeter’s internal resistance by adding appropriate shunt i.e. resistance in parallel to the meter. Let the range of the voltmeter be \( 0 – V_0 \) volt and we convert it to an ammeter of range \( 0 – I_0 \) Amp.

To calculate the shunt resistance, we need to know the resistance of the voltmeter. This is done by half-deflection (potential divider) method using the circuit shown in
Fig 2(a). Let $R_m$ be the internal resistance of the voltmeter, and when $R = 0$ the voltmeter reading is $V_m$, the current through the circuit is $i = V_m/R_m$. But when $R \neq 0$ and the voltmeter reads $V_m/2$, the current in the circuit reduces by half implying $i/2 = V_m/(R + R_m)$. The voltmeter resistance $R_m$ is given by,

$$\frac{V_m}{2R_m} = \frac{V_m}{R + R_m} \Rightarrow R_m = \frac{R}{1}$$  \hspace{1cm} (1)

Once $R_m$ is determined, the shunt $R_{sh}$ can be determined by noting that, to get full-scale reading $V_0$ of the voltmeter we need a maximum current of $I_m = V_0/R_m$. For full-scale reading of voltmeter $V_0$ corresponding to full-scale reading $I_0$ of our constructed ammeter, we need to send a current $I_m$ through the voltmeter and the remaining $I_{sh}$ through the shunt. Therefore the shunt resistance $R_{sh}$, the maximum resistance that can allow minimum $I_{sh}$ current, is calculated as,

$$I_{sh} = I_0 - I_m \Rightarrow R_{sh} = \frac{V_0}{I_{sh}}$$  \hspace{1cm} (2)

![Circuit diagram](image1)

![Circuit diagram](image2)

**Conversion of ammeter to voltmeter**

Converting an ammeter to a voltmeter involves increasing the resistance of the ammeter. This is done by adding a high resistance in series with the ammeter. Let the range of the ammeter be $0 - I_0$ Amp and we convert it to a voltmeter of range $0 - V_0$ volt.

To calculate the series resistance $R_{ss}$, we first determine the ammeter resistance using the circuit Fig 3(a). Let $R_m$ be the internal resistance of the ammeter, then the current flowing through the circuit is $i = E/(R + R_m)$, where $E$ is the input voltage. The voltage drop across $R$ is $V_r$ and the current is $i_r = V_r/R$. Since $i = i_r$, the ammeter resistance $R_m$ is obtained as,

$$R_m = \frac{(E - V_r)R}{V_r}$$  \hspace{1cm} (3)
To calculate $R_{ss}$ we note that the voltage drop across the ammeter, showing full scale reading $I_0$, is $V_m = I_0 \times R_m$. To make ammeter full-scale to read full-scale voltage $V_0$, the remaining voltage $V_{ss} = V_0 - V_m$ should drop across $R_{ss}$ and from this consideration we calculate series resistance as,

$$\frac{V_{ss}}{R_{ss}} = \frac{V_m}{R_m} \implies R_{ss} = R_m \frac{V_{ss}}{V_m}$$

(4)

Experimental procedure

1. The first step to convert a voltmeter to an ammeter is to determine the resistance $R_m$ of the voltmeter. Make the circuit connections as shown in Fig 2(a).

2. Keeping $R = 0$, adjust the supply voltage $E$ so that the voltmeter shows large readings $V_m$.

3. Choose suitable $R$ to reduce the voltage recorded in voltmeter to half, $V_m/2$. The voltmeter resistance is then $R_m = R$. You may choose to plot the $R_m$ against serial numbers and draw an average line through them to obtain the average $R_m$.

4. Calculate the shunt resistance $R_{sh}$ and fabricate the circuit shown in Fig 2(b). Use a digital ammeter or a multimeter, set to appropriate range, as the standard ammeter.

5. Changing the supply voltage for a fixed $R$ (chosen such that the maximum current in the circuit is little above $I_0$), record the converted and the standard ammeter readings $I_{new}$ and $I_{standard}$.

6. Plot the calibration curve $I_{new} - I_{standard}$ versus $I_{standard}$. 

Fig 3. (a) Circuit for determination of ammeter resistance, (b) circuit for using the ammeter as voltmeter.
7. Begin converting an ammeter to a voltmeter by determining the resistance $R_m$ of the ammeter. Make the circuit connections as shown in Fig 3(a). The resistance $R$ in series with the ammeter must be kept at large value to prevent large current from flowing through the ammeter and damaging it.

8. Change $R$ appropriately and each time measure the voltage drop across it $V_r$ with a digital voltmeter or a multimeter. Also change the supply voltage $E$ to change the $V_r$. Calculate $R_m$ from these set of readings either by direct averaging or by plotting $R_m$ versus serial number and drawing an average line.

9. Calculate the series resistance $R_{ss}$ and fabricate the circuit as shown in Fig 3(b). Use a digital voltmeter or a multimeter, set to appropriate range, as the standard voltmeter.

10. Changing the supply voltage for a fixed $R$ (chosen such that the maximum voltage in the circuit is little above $V_0$), record the converted and the standard voltmeter readings $V_{\text{new}}$ and $V_{\text{standard}}$.

11. Plot the calibration curve $V_{\text{new}} - V_{\text{standard}}$ versus $V_{\text{standard}}$.

Data recording and Observations

Converting voltmeter ...... volt to ammeter ...... Amp

Full-scale reading of the voltmeter = ...... volt
Number of divisions in the scale = .......
Value of minimum division of the voltmeter = ...... volt

Full-scale reading of the converted ammeter = ...... Amp
Number of divisions in the scale = .......
Value of minimum division of the converted ammeter = ...... Amp

<table>
<thead>
<tr>
<th>Serial No.</th>
<th>Full deflection $V_m$ volt</th>
<th>$R_m$ Ohm</th>
<th>Half deflection $V_m/2$ volt</th>
<th>$R_m/2$ Ohm</th>
<th>Average $R_m$ Ohm</th>
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Calculation of $R_{sh}$:
$I_m = V_0/R_m = \ldots$ Amp
$I_{sh} = I_0 - I_m = \ldots$ Amp
$R_{sh} = V_0/I_{sh} = \ldots$ Ohm
Table 2. Calibration of the converted Ammeter

<table>
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<tr>
<th>Converted ammeter</th>
<th>Standard ammeter</th>
<th>Correction</th>
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<td>$I_{\text{new}}$ Amp</td>
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<td>$I_{\text{new}} - I_{\text{standard}}$ Amp</td>
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Converting Ammeter ...... Amp to Voltmeter ...... volt

Full-scale reading of the ammeter = ...... Amp
Number of divisions in the scale = ......
Value of minimum division of the ammeter = ...... Amp

Full-scale reading of the converted voltmeter = ...... volt
Number of divisions in the scale = ......
Value of minimum division of the converted voltmeter = ...... volt

Table 3. Measurement of ammeter resistance $R_m$

<table>
<thead>
<tr>
<th>Serial No.</th>
<th>$E$ volt</th>
<th>$R$ Ohm</th>
<th>$V_r$ volt</th>
<th>$R_m = (E - V_r)V_r/R_r$ Ohm</th>
<th>Average $R_m$ Ohm</th>
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Calculation of $R_{ss}$:
$V_m = I_0 \times R_m = ......$ volt
$V_{ss} = V_0 - V_m = ......$ volt
$R_{ss} = R_m V_{ss}/V_m = ......$ Ohm

Table 2. Calibration of the converted Voltmeter

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