# Measuring resistance using non-ideal devices

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# 1 Abstract

It tends to be pretty difficult and obviously not convenient to perform measurements using voltage and current sensors whose impedance is comparable with the impedance of resistor itself.
That's why it makes sense to apply optimization methods to improve accuracy.
So, we've constructed all the possible schemes and proved, that there aren't any other reasonable schemes can be constructed using the given set of instruments.
Finally, we've extracted all the data from those schemes.

## 2 The Plan

The task is to measure the impedance of the given resistor as precise as possible.
To achieve this aim, we decided to perform these operations:

- Compute the resistance and its dispersion individually for each scheme
- Deduct which scheme's results stand out from the center ($\mu$), for example, the threshold value of remoteness from the center might be equal to $2 \cdot \sigma$
- Dropout the data outliers (outstanding measurements)
- For those verified measurements we use them to construct an equation system.
- Optimize the function which is $\sum_{i=0}^{i<n_{equations}} \left(EQ_{i_{left}} - EQ_{i_{right}}\right)^2$ where $EQ_{i_{left}}$ and $EQ_{i_{right}}$ are left and right sides of $i^{th}$ equation respectively
- As the result, we'll find the resultant resistance.
  Obviously, the target function won't be equal to zero because we have 8 equations and only one variable, but the accuracy of the result will be significantly better than it is for all the initial results.
- Thus, the final result should be definitely found this way.

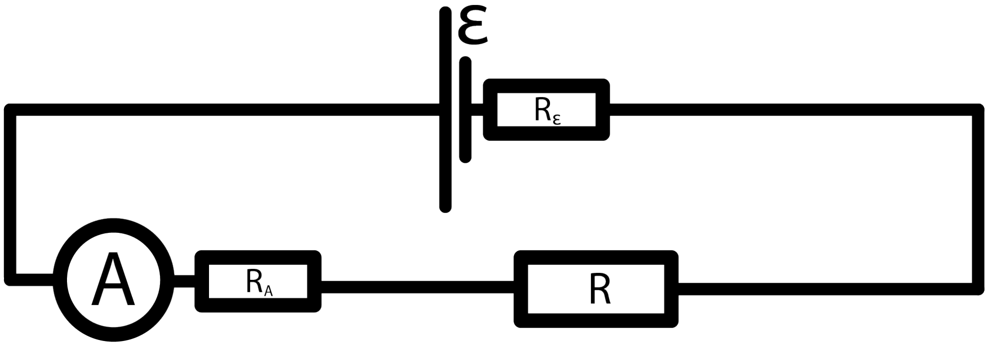
## 3 Schemes and Equations

There are only 8 ***reasonable*** schemes can be assembled using these items:

- Exactly one battery
- Exactly one resistor to measure
- Not more than one amperemeter
- Not more than one voltmeter

Here are the schemes:

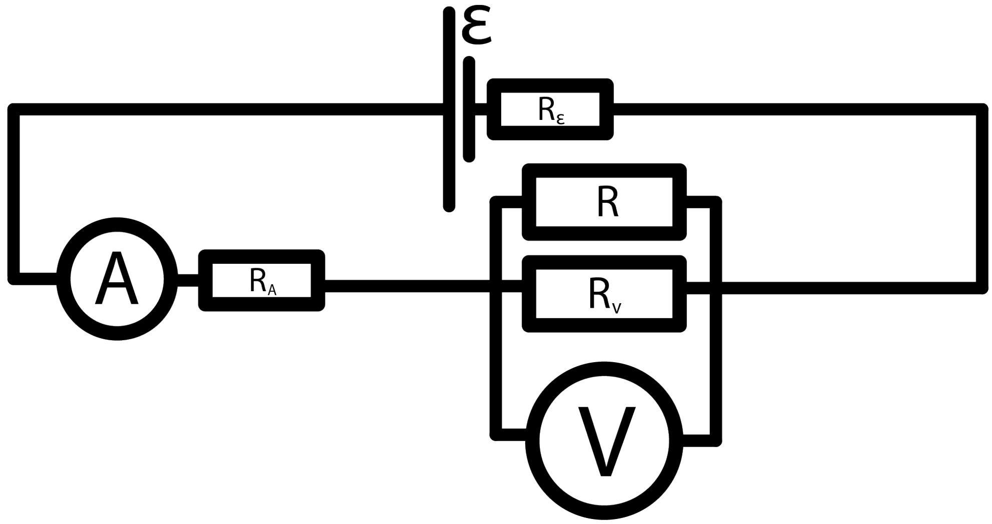
**Scheme 1**




$$A = \frac{\varepsilon}{R_\varepsilon + R_A + R}$$

$$R = \frac{\varepsilon}{A_1} - R_\varepsilon - R_A \tag{1}$$

**Scheme 2**




$$A_2 = \frac{\varepsilon}{R_\varepsilon + R_A + \frac{1}{\frac{1}{R}+\frac{1}{R_V}}}$$

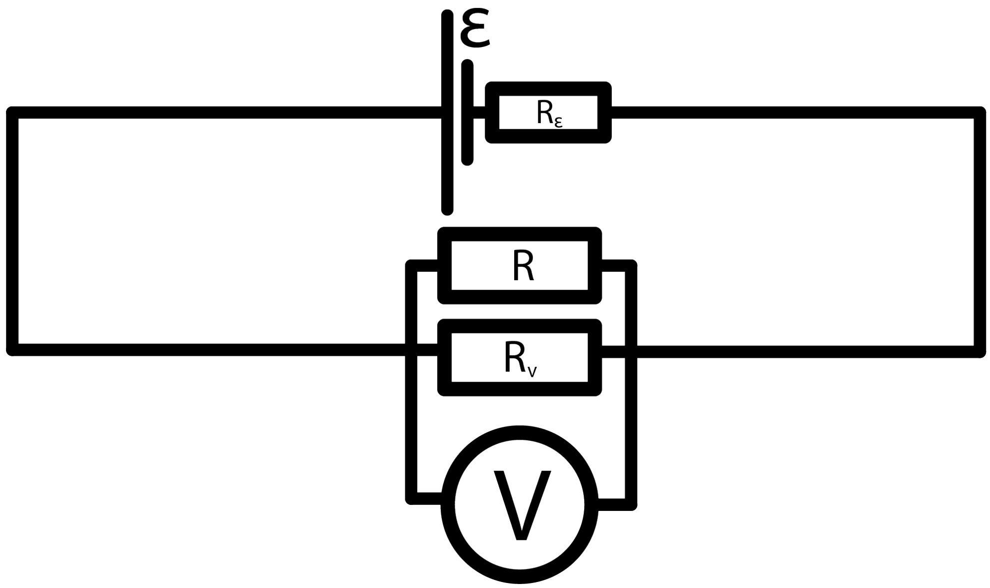
$$V_2 = A_2 \cdot \frac{1}{\frac{1}{R}+\frac{1}{R_V}}$$

$$\frac{1}{R} + \frac{1}{R_V} = \frac{A_2}{V_2}$$

$$\frac{1}{R} = \frac{A_2}{V_2} - \frac{1}{R_V}$$

$$R = \frac{1}{\frac{A_2}{V_2} - \frac{1}{R_V}} \qquad (2)$$

**Scheme 3**




*let* $R_{sum}$ *be* $\frac{1}{\frac{1}{R}+\frac{1}{R_V}}$

$$V_3 = \frac{\varepsilon}{R_\varepsilon + R_{sum}} \cdot R_{sum}$$

$$R_\varepsilon + R_{sum} = R_{sum} \cdot \frac{\varepsilon}{V_3}$$

$$R_\varepsilon = R_{sum} \cdot \left(\frac{\varepsilon}{V_3} - 1\right)$$

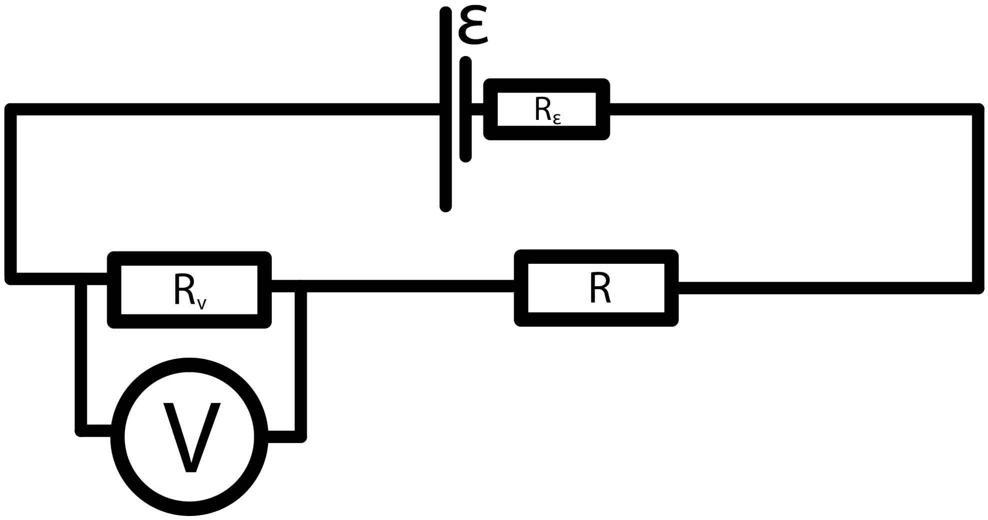
$$\frac{1}{\frac{1}{R}+\frac{1}{R_V}} = R_{sum} = \frac{R_\varepsilon}{\left(\frac{\varepsilon}{V_3} - 1\right)}$$

$$\frac{1}{R} + \frac{1}{R_V} = \frac{\left(\frac{\varepsilon}{V_3} - 1\right)}{R_\varepsilon}$$

$$\frac{1}{R} = \frac{\left(\frac{\varepsilon}{V_3} - 1\right)}{R_\varepsilon} - \frac{1}{R_V}$$

$$R = \frac{1}{\frac{\left(\frac{\varepsilon}{V_3}-1\right)}{R_\varepsilon} - \frac{1}{R_V}} \tag{3}$$

**Scheme 4**

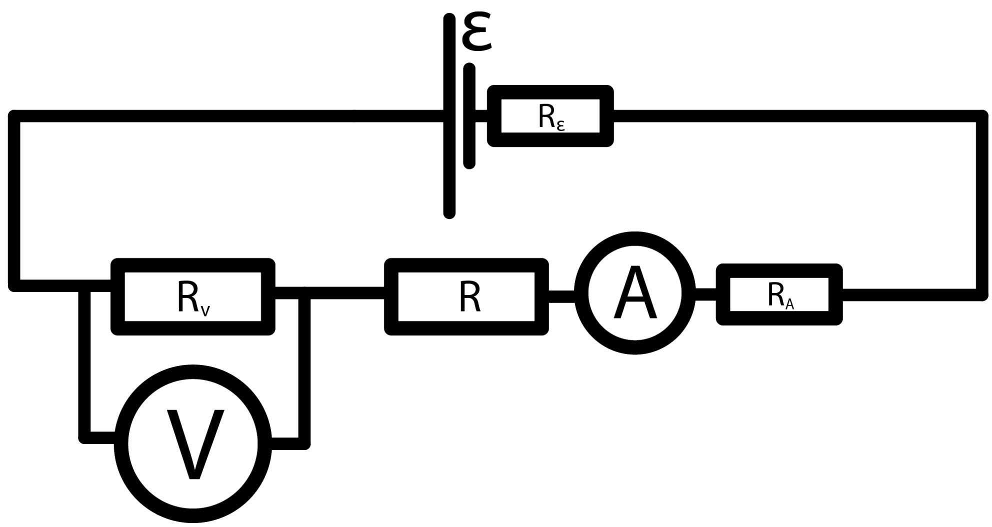



$$V_4 = \varepsilon \cdot \frac{R_V}{R_\varepsilon + R + R_V}$$

$$R_\varepsilon + R + R_V = R_V \cdot \frac{\varepsilon}{V_4}$$

$$R = R_V \cdot \frac{\varepsilon}{V_4} - R_\varepsilon - R_V \tag{4}$$

**Scheme 5**




$$V_4 = \varepsilon \cdot \frac{R_V}{R_\varepsilon + R + R_V}$$

$$R_\varepsilon + R + R_V = R_V \cdot \frac{\varepsilon}{V_4}$$

$$R = R_V \cdot \frac{\varepsilon}{V_4} - R_\varepsilon - R_V \tag{5}$$

# 4 Dispersion

We've tried to perform the measurements more than once, but soon I realized, that it's quite a stupid idea. The random dispersion is negligibly small compared to the measurement dispersion.
As mentioned above (**??**), the accuracy of the result will be significantly better than it is for all the initial results.

# 5 Measurement Results

# 6 Looking for Data Outliers

# 7 Optimizing the Target Function

# 8 The Answer

# 9 Conclusion