# On non-ideal voltage and current measurement tools

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# Contents

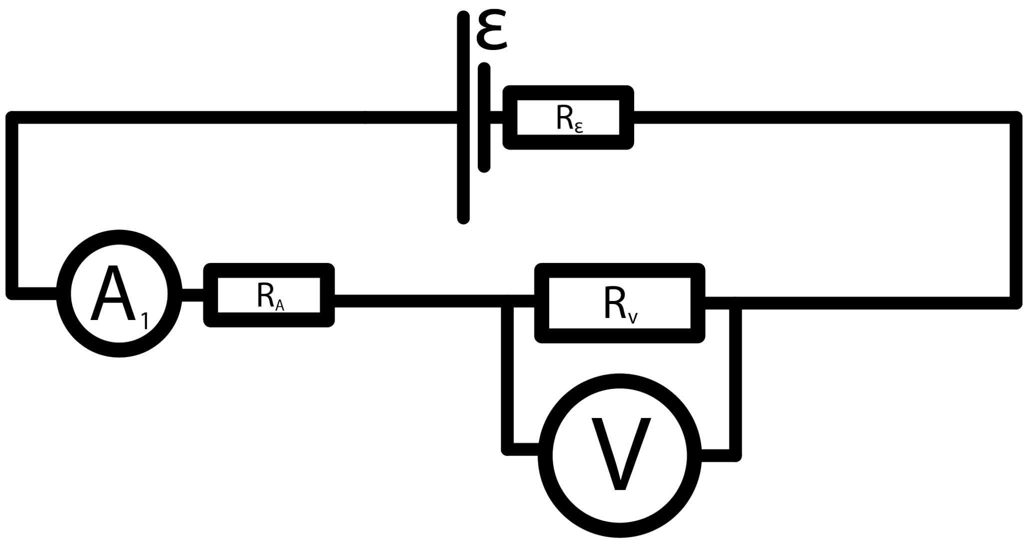
## 0.1 Abstract

The contents of this section should be too abstract for me to be able to write it.

## 0.2 Experiments

There were 3 experiments and 4 measurements arranged:

### Experiment №1: Sequential plugging in

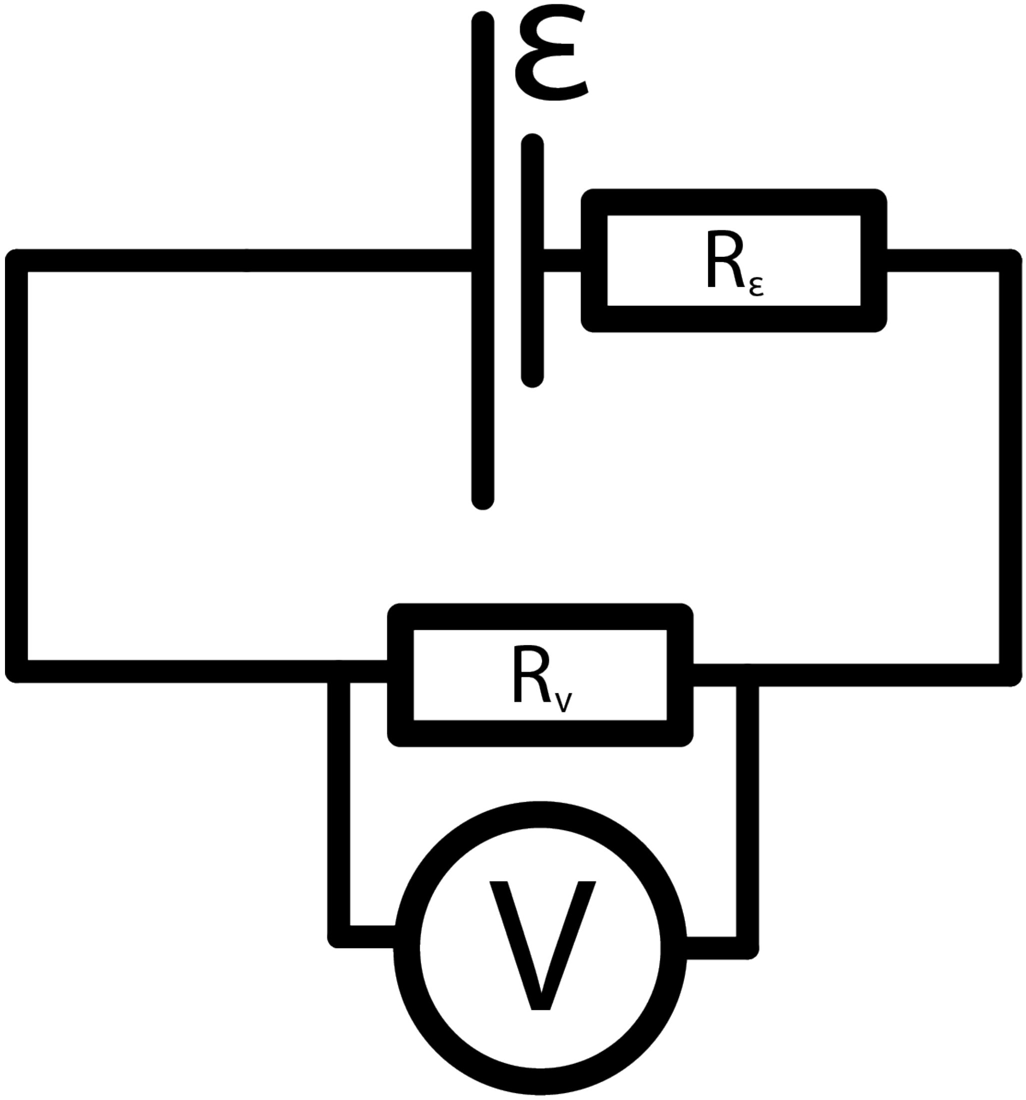



$$A_1 = \frac{\varepsilon}{R_{all}}$$

$$V_1 = \varepsilon \cdot \frac{R_v}{R_{all}}$$

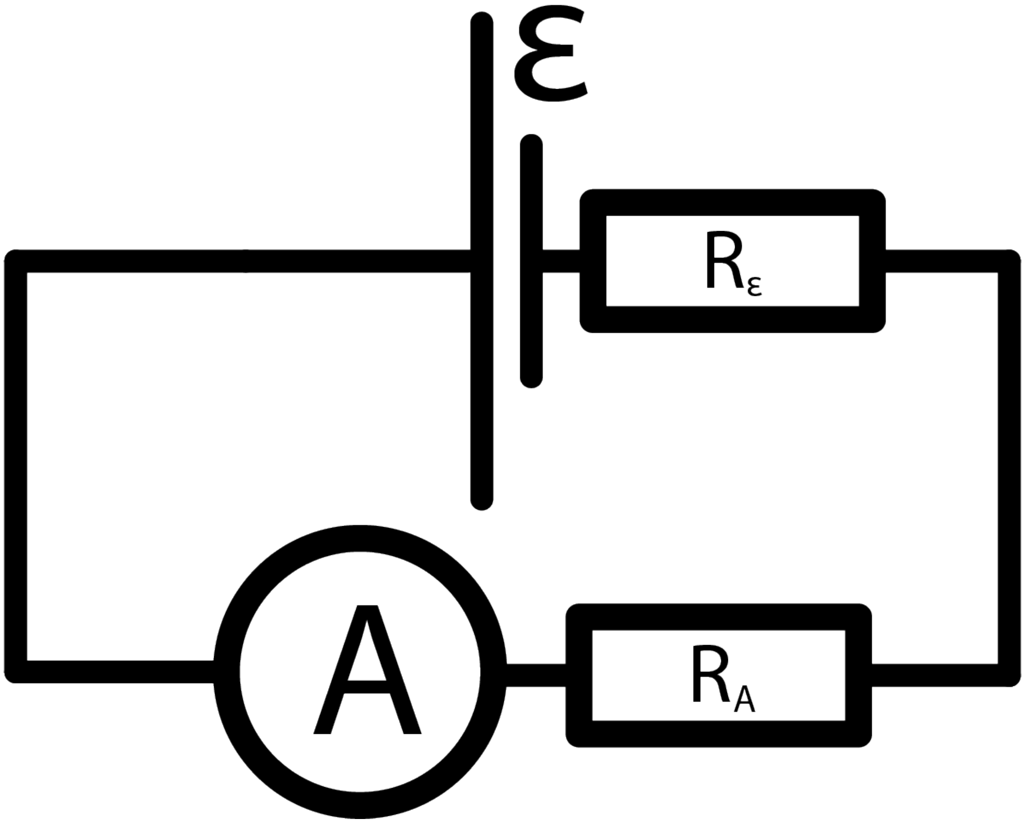
$$R_{all} = R_\varepsilon + R_A + R_v$$

### Experiment №2: Only Voltmeter




$$V_2 = \varepsilon \cdot \frac{R_v}{R_v + R_\varepsilon}$$

### Experiment №3: Only Ampermeter




$$A_3 = \varepsilon \cdot \frac{1}{R_A + R_\varepsilon}$$

## 0.3 Solving equation system

***Some bold, italic and underlined text here***

$$A_1 = \frac{\varepsilon}{R_{all}} \tag{1}$$

$$V_1 = \varepsilon \cdot \frac{R_v}{R_{all}} \tag{2}$$

$$R_v = \frac{V_1}{A_1}$$

$$V_2 = \varepsilon \cdot \frac{R_v}{R_v + R_\varepsilon} \tag{3}$$

$$\varepsilon = V_2 + V_2 \cdot \frac{R_\varepsilon}{R_v}$$

$$A_3 = \varepsilon \cdot \frac{1}{R_A + R_\varepsilon} = \left(V_2 + V_2 \cdot \frac{R_\varepsilon}{R_v}\right) \cdot \frac{1}{R_A + R_\varepsilon} \tag{4}$$

$$A_3 \cdot R_A + A_3 \cdot R_\varepsilon = V_2 + R_\varepsilon \cdot \frac{V_2}{R_v}$$

$$R_\varepsilon \cdot \left(A_3 - \frac{V_2}{R_v}\right) = V_2 + A_3 \cdot R_A$$

$$R_\varepsilon = \frac{V_2 + A_3 \cdot R_A}{A_3 - \frac{V_2}{R_v}}$$

$$(1) \to A_1 = \frac{\varepsilon}{R_{all}} = \frac{\varepsilon}{R_v + R_A + R_\varepsilon} = \frac{\varepsilon}{R_v + R_A + \frac{V_2 + A_3 \cdot R_A}{A_3 - \frac{V_2}{R_v}}} = \frac{\varepsilon}{R_v + \frac{V_2}{A_3 - \frac{V_2}{R_v}} + R_A \cdot \left(1 + \frac{A_3}{A_3 - \frac{V_2}{R_v}}\right)}$$

$$\varepsilon = V_2 + V_2 \cdot \frac{\frac{V_2 + A_3 \cdot R_A}{A_3 - \frac{V_2}{R_v}}}{R_v} = V_2 + V_2 \cdot \frac{\frac{V_2}{A_3 - \frac{V_2}{R_v}} + \frac{A_3 \cdot R_A}{A_3 - \frac{V_2}{R_v}}}{R_v} = V_2 + \frac{V_2^2}{R_v \cdot A_3 - V_2} + R_A \cdot \frac{A_3 \cdot V_2}{A_3 \cdot R_v - V_2}$$

$$V_2 + \frac{V_2^2}{R_v \cdot A_3 - V_2} + R_A \cdot \frac{A_3 \cdot V_2}{A_3 \cdot R_v - V_2} = A_1 \cdot R_v + \frac{V_2 \cdot A_1}{A_3 - \frac{V_2}{R_v}} + R_A \cdot A_1 \cdot \left(1 + \frac{A_3}{A_3 - \frac{V_2}{R_v}}\right)$$

$$R_A \cdot \frac{A_3 \cdot V_2}{A_3 \cdot R_v - V_2} - R_A \cdot A_1 \cdot \left(1 + \frac{A_3}{A_3 - \frac{V_2}{R_v}}\right) = A_1 \cdot R_v + \frac{V_2 \cdot A_1}{A_3 - \frac{V_2}{R_v}} - V_2 - \frac{V_2^2}{R_v \cdot A_3 - V_2}$$

$$R_A \cdot \left(\frac{A_3 \cdot V_2}{A_3 \cdot R_v - V_2} - A_1 \cdot \left(1 + \frac{A_3}{A_3 - \frac{V_2}{R_v}}\right)\right) = A_1 \cdot R_v + \frac{V_2 \cdot A_1}{A_3 - \frac{V_2}{R_v}} - V_2 - \frac{V_2^2}{R_v \cdot A_3 - V_2}$$

$$R_A = \frac{A_1 \cdot R_v + \frac{V_2 \cdot A_1}{A_3 - \frac{V_2}{R_v}} - V_2 - \frac{V_2^2}{R_v \cdot A_3 - V_2}}{\frac{A_3 \cdot V_2}{A_3 \cdot R_v - V_2} - A_1 \cdot \left(1 + \frac{A_3}{A_3 - \frac{V_2}{R_v}}\right)}$$

$$R_\varepsilon = \frac{V_2 + A_3 \cdot R_A}{A_3 - \frac{V_2}{R_v}}$$

$$\varepsilon = V_2 + V_2 \cdot \frac{R_\varepsilon}{R_v}$$

## 0.4 Measurement Results

We‘re neglecting the inaccuracy of the pre-determined upper device measurement limit which is written on those devices. It‘s inaccuracy is pretty low!

$$A_1 = ((0.6 \pm 0.07)\, Ampere) \times \frac{15.8}{2000} = (4.7 \pm 0.6)\, milliAmpere$$

$$V_1 = ((3.25 \pm 0.1)\, Volt) \times \frac{6.1}{6} = (3.30 \pm 0.1)\, Volt$$

$$V_2 = ((3.7 \pm 0.1)\, Volt) \times \frac{6.1}{6} = (3.76 \pm 0.1)\, Volt$$

$$A_3 = ((1.8 \pm 0.07)\, Ampere) \times \frac{15.8}{2000} = (14.22 \pm 0.6)\, milliAmpere$$

## 0.5 The Answer

So, the impedance values are the following:

$R_v = 1$ $R_e = 1$ $R_A = 1$ $\varepsilon = 1$