Metrology

Laboratory

THEME:

DC VOLTAGE MEASUREMENT

OBJECTIVES:

- to learn how to measure DC voltages,
- to learn how to use an analogue voltmeter and a digital multimeter properly and what are their parameters,
- to learn how to calculate measurement errors and what are their sources.

EQUIPMENT:

- Analogue Voltmeter
- Digital Multimeter
- Decade Resistor
- DC Power Supply
- Voltage Divider

BACKGROUND:

The voltage is defined as the difference between potentials at two nodes in electrical circuit and it is measured by connecting a voltmeter to these two nodes (realising a direct method of measurement). Two commonly performed voltage measurements are direct current (DC) and alternating current (AC) measurements. Hereafter, DC voltage is considered. To measure voltage, an analogue or a digital voltmeter can be used. In both cases the meter must be properly set and connected. It means that one has to set a voltage function using a multimeter, chose a proper range and then connect the test probes (ensuring proper input terminals polarity). Then one should read the indicated value and information needed to calculate the limiting measurement error. The measurement error is primarily caused by the accuracy of a meter, but also another source of errors can be noticed. An ideal voltmeter has infinite internal resistance, so current does not flow through it and power is not taken by such an instrument. Real voltmeters have finite resistance, so they have impact on a circuit under the test, specifically on measured voltage.

A connection diagram for such a measurement task is shown in Fig. 1. It is too general to be analysed precisely.

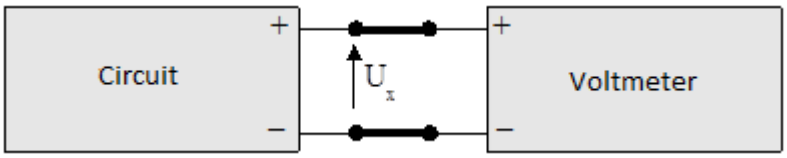

Fig. 1. Connection diagram of direct voltage measurement.

Using the Thevenin equivalent for the tested circuit and the equivalent circuit of a real voltmeter, a more detailed circuit (Fig. 2.), consisting of ideal components presenting the measured value (U_x), a meter (V) and parameters influencing measurement (Rc – internal or equivalent circuit resistance and Rv – internal voltmeter resistance), can be obtained.

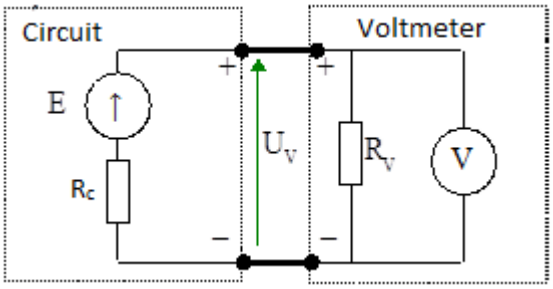

Fig. 2. An equivalent circuit for direct voltage measurement with components influencing the measurement.

For the above circuit, it is easy to write down the following expressions:

$$U_x = E, \qquad U_V = U_{R_V} = E - U_{R_c} \neq E, \qquad U_V \neq U_x$$

The inequality of the true value of voltage U_x (the value of voltage before connection of a meter) and the value measured by voltmeter U_V indicates the existing error of the method. This is a systematic error and its value can be calculated using the definition of a measurement error

$$\Delta_m U = U_V - U_x = U_{R_c} = -I \cdot R_c = -\frac{U_V}{R_V} \cdot R_c = -U_V \cdot \frac{R_c}{R_V},$$

$$\delta_m U = \frac{U_V - U_x}{U_x} = \frac{-I \cdot R_c}{U_x} = -\frac{E}{R_c + R_V} \cdot \frac{R_c}{U_x} = -\frac{R_c}{R_c + R_V},$$

where: $I = I_V = \frac{U_V}{R_V} = \frac{E}{R_V + R_c}$

As one can see, this error can be calculated without knowing the true value U_x. Needed are only: voltmeter indication, voltmeter internal resistance (a voltmeter's parameter) and the tested circuit resistance. Knowing about the existence of the method error, one has to calculate the so called correction factor:

$$c = -\Delta_m U$$

and then include it in the final measurement result in the following way:

$$U_c \pm \Delta U_V, \qquad U_c = U_V + c$$

where ΔU_V is the limiting error (uncertainty).

It is important to know that for multi-range instruments, the input resistance varies as the instrument is switched to different ranges.

PROCEDURE:

1. Measurement of output voltage of a voltage source

Connect the measurement circuit shown in Fig. 3. Treat the decade resistor as circuit's internal resistance (R_c). Set the decade resistor to 0Ω, 10Ω, 100Ω, 1kΩ, 10kΩ and measure voltage Ux, using all the given voltmeters. For each measurement record also voltmeter's resistance.

Calculate the errors for each measurement and compare them. Write down properly the results of measurements.

2. Measurement of the voltage divider

Connect the circuit shown in Fig. 4. Set the voltage divider ratio to values 0.1, 0.5 and 0.9, and measure the values of input and output voltages, using all the given voltmeters. For each measurement record also voltmeter's resistance.

Calculate the divider ratio, its error for each measurement and compare the results. Write down properly the results of the measurements.

Warning:
Do not change the output voltage of a power supply after setting it at the beginning!

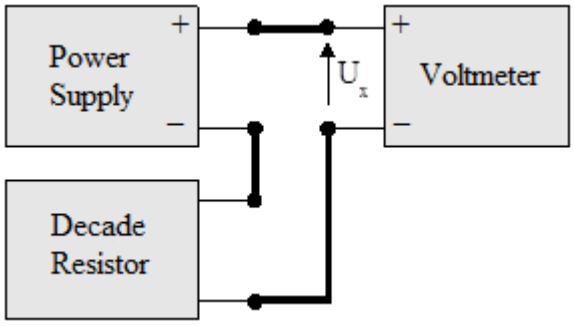

Fig. 3.

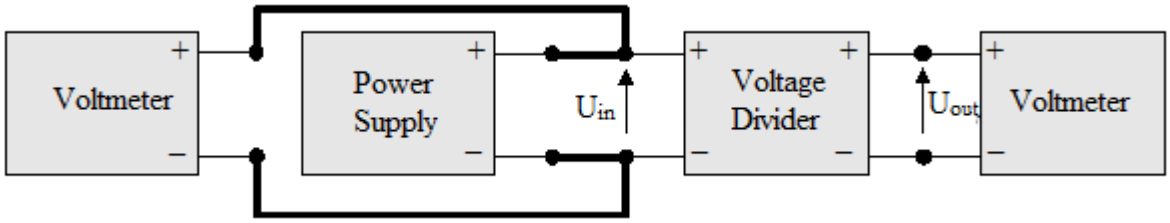

Fig. 4.