DC MEASUREMENTS

Electronic Measurements Lab

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Preliminaries

In this lab you will practice with analogue and digital multimeters for DC measurements. Have a look at your workbench, you will need the following laboratory equipment (check here for specifications), components and cables:

- Bench DC power supply (Aplab, Labornetzgerat, Philips or Topward)
- Handheld analog multimeter (tester) (Metrix MX1)
- Bench digital multimeter (Agilent/Hewlett-Packard 34401A)
- Resistor box with 4 unknown resistors (fig. 1)
- 1 kΩ variable resistor (fig. 2)
- 220 kΩ fixed resistor (fig. 3)
- Multimeter test leads (fig. 4)
- Banana plug to banana plug cables (fig. 5)

Note: In the following, instrument keys will be denoted by boxed symbols, e.g. $\boxed{\text{DC V}}$, $\boxed{\Omega\ \text{2W}}$, $\boxed{\text{Shift}}+\boxed{\text{AC V}}$.

Warning: Excessive overload can permanently damage the instruments.

Figure 1: Resistor box.

Figure 2: Variable resistor.

Figure 3: A 220 kΩ resistor.

Figure 4: Test leads.

Figure 5: A banana plug.

(Preliminaries)

1 Voltage measurements

Without connecting any instrument, turn on the DC power supply and adjust its output voltage (one section only) to about 8 V.

1.1 Agilent 34401A digital multimeter

To measure a DC voltage, press the DC V key on the multimeter front panel. At power-on, the multimeter is in autoranging mode, so you do not have to choose the range manually. Connect the test leads as in figure 6.

1 Measure the power supply output voltage.

2 Determine the uncertainty of the above measurement (click here for specifications).

3 Disable the autoranging feature by pressing the Auto/Man key. Select different ranges by pressing the ∨ and ∧ keys. See what happens when measuring the power supply output voltage. Exchange also the polarity of the test leads. Enable again autoranging by pressing the Auto/Man key.

4 Try different resolutions with Shift + 4 Digit, Shift + 5 Digit or Shift + 6 Digit.

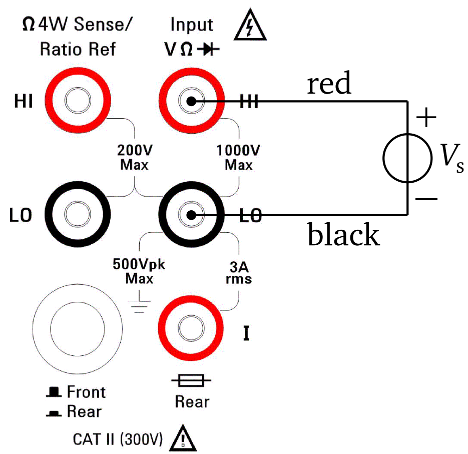

Figure 6: To measure a DC voltage with the Agilent 34401A multimeter, connect the red test lead to the *Input HI* terminal and the black test lead to the *Input LO* terminal (colours are assigned conventionally). Then, connect the test leads *across* two points of the circuit under test (e.g. the two output terminals of the power supply), here represented by the voltage source V_S. The *Input LO* terminal is the reference terminal for voltage and current measurements. (§1.1)

1.2 Metrix MX1 analogue multimeter

To measure a DC voltage, follow the instructions of figure 7.

1 Measure the power supply output voltage. You should read the black scale with a full-scale value of 15. To avoid parallax error, move your head until you see the index lined up with its reflection on the mirror, so that the line of sight is perpendicular to the scale.

2 Determine the uncertainty of the above measurement (click here for specifications).

3 Change the full-scale range to 50 V and repeat the above steps. This time you should read the black scale with a full-scale value of 50. Compare the relative uncertainties.

Figure 7: To measure a DC voltage with the Metrix MX1 multimeter, you must firstly select the proper range manually (15 V in this case). Next, connect the red test lead to the *V.Ω* terminal and the black test lead to the *COM.* terminal. Finally, connect the test leads *across* two points of the circuit under test (e.g. the two output terminals of the power supply), here represented by the voltage source V_S. The *COM.* terminal is the reference terminal for voltage and current measurements. (§1.2)

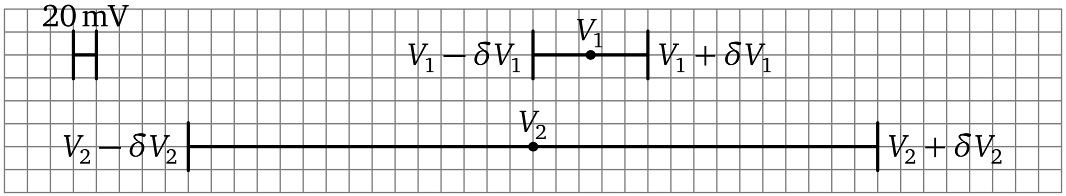

Figure 8: To check the compatibility between two measurements V_1 and V_2, with uncertainties δV_1 and δV_2, respectively, draw to scale the two values with the corresponding uncertainty bars, which should overlap.

1.3 Compatibility between the results

To check the compatibility between the measurements just made, draw to scale, on a sheet of grid paper, the measured values together with the corresponding uncertainty bars, as shown in figure 8. There is compatibility when the uncertainty bars overlap.

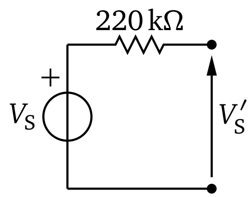

Figure 9: Circuit to test the effect of voltmeter loading.

1.4 Voltmeter loading

Connect a 220 kΩ resistor in series with the positive terminal of the power supply output, as shown in the circuit diagram of figure 9.

1 Measure the voltage V_S' by means of the Agilent 34401A multimeter.

2 Measure the voltage V_S' by means of the Metrix MX1 multimeter. Try different ranges.

3 Discuss, on the basis of the instruments' specifications, the results obtained above.

2 Current measurements

Disconnect any instrument from the power supply. Turn the power supply current limit knob completely to the left (counter-clockwise). Short-circuit the power supply output (use a banana-plug to banana-plug cable). Turn the current limit knob until you read a short-circuit current of about 1 A on the built-in ammeter. Disconnect the short circuit.

Warning: *Never* connect an ammeter to a source which is not current-limited.

2.1 Agilent 34401A digital multimeter

To measure a DC current (3 A maximum), press the Shift + DC I key on the multimeter front panel. Verify that the instrument is in autoranging mode. Connect the test leads as shown in figure 10.

1. Measure the power supply short-circuit current by connecting the test leads to the power supply output.
2. Determine the uncertainty of the above measurement (click here for specifications).

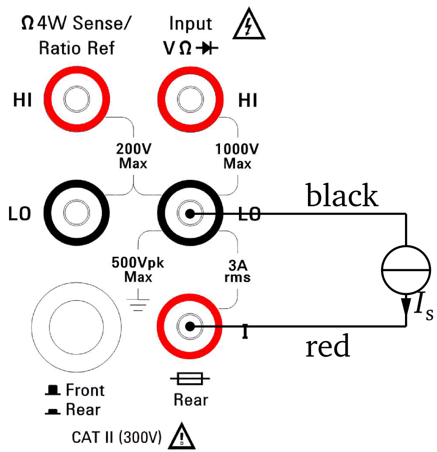

Figure 10: To measure a DC current with the Agilent 34401A multimeter, connect the red test lead to the *Input I* terminal and the black test lead to the *Input LO* terminal. Then, connect the test leads *in series* with a branch of the circuit under test, here represented by the current source I_S. (§2.1)

2.2 Metrix MX1 analogue multimeter

To measure a DC current, follow the instructions of figure 11.

1 Measure the power supply short-circuit current by connecting the test leads to the power supply output.

2 Determine the uncertainty of the above measurement (click here for specifications).

3 Check the compatibility between this measurement and the one made with the digital multimeter.

2.3 0.5 A current

Set the power supply current limit to 0.5 A. Repeat the measurements of §2.1 and §2.2.

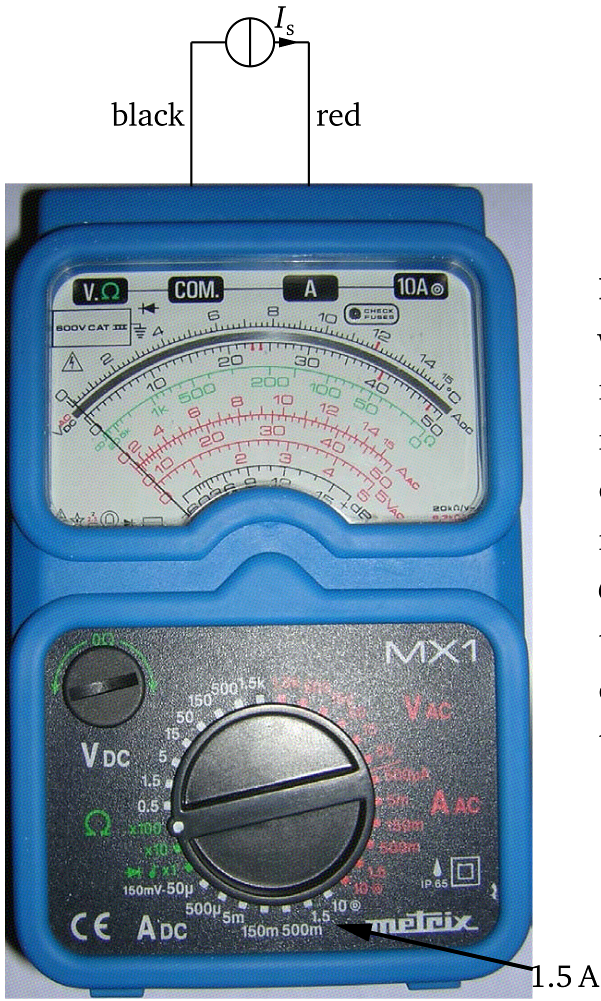

Figure 11: To measure a DC current with the Metrix MX1 multimeter, you must firstly select the proper range manually (1.5 A in this case). Next, connect the red test lead to the *A* terminal and the black test lead to the *COM.* terminal. Finally, connect the test leads *in series* with a branch of the circuit under test, here represented by the current source I_S. (§2.2)

3 Resistance measurements

In this section you will measure the four resistances of the resistor box and you will characterize the potentiometer.

3.1 Agilent 34401A digital multimeter

The Agilent 34401A multimeter can make both two-wire and four-wire resistance measurements.

3.1.1 Two-wire measurements

To make a two-wire resistance measurement, press the $\boxed{\Omega\ 2W}$ key on the multimeter front panel and connect the test leads as in figure 12. Verify that the instrument is in autoranging mode. In this kind of measurement the instrument actually measures the sum of the unknown resistance and the lead wire resistances (see figure 13). This can cause a significant systematic error when the resistance value to be measured is low.

1. Measure the values of the four resistor in the resistor box.
2. For each measured value determine its uncertainty (click here for specifications).

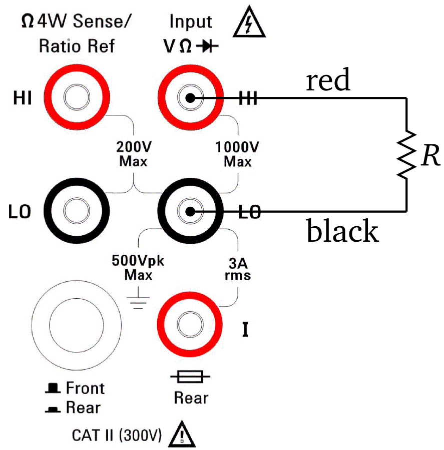

Figure 12: Two-wire resistance measurements with the Agilent 34401A: connect the red test lead to the *Input HI* terminal and the black test lead to the *Input LO* terminal. Then, connect the two leads to the unknown resistance R. (§3.1.1)

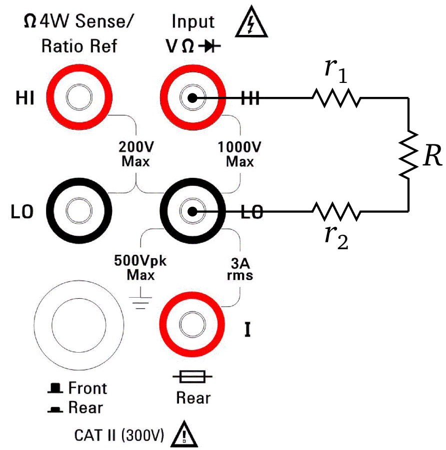

Figure 13: In a two-wire resistance measurement, the multimeter actually measures the sum $R + r_1 + r_2$, where r_1 and r_2 are the lead wire and contact resistances. (§3.1.1)

3.1.2 Four-wire measurements

To make a four-wire resistance measurement, press the Shift + Ω 4W key on the multimeter front panel and connect the test leads as in figure 14. Verify that the instrument is in autoranging mode. In this kind of measurement, two more wires, carrying negligible current, are used to directly measure the voltage across the unknown resistance (fig. 15).

1. Measure again the lowest resistance of the resistor box.
2. Compare the value obtained above with that obtained in §3.1.1.

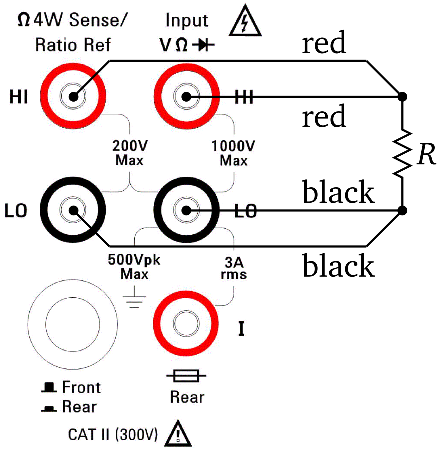

Figure 14: Four-wire resistance measurements with the Agilent 34401A: the *Input HI* and the *Sense HI* terminals should be connected to one of the resistor terminals; the *Input LO* and the *Sense LO* terminals should be connected to the other resistor terminal. (§3.1.2)

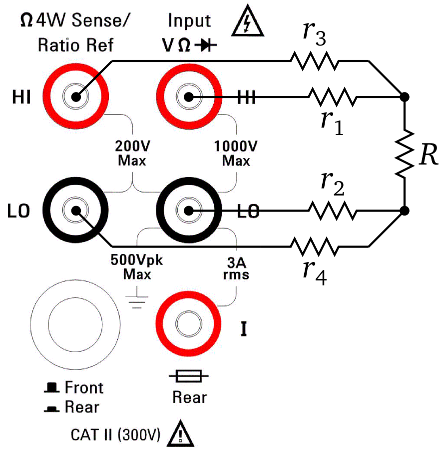

Figure 15: In a four-wire resistance measurement, the multimeter uses the *Input* terminals to inject a current through r_1, R and r_2, and uses the *Sense* terminals to measure the voltage directly across R. The voltage drop across resistances r_3 and r_4 is negligible because the current flowing into the *Sense* terminals is virtually zero. (§3.1.2)

3.2 Metrix MX1 analogue multimeter

The Metrix MX1 multimeter can only make two-wire resistance measurements. To measure a resistance, connect the test leads as in figure 16. You should read the value from the *green* scale. Starting from the $\Omega \times 100$ range, turn the knob until the index is around the scale center. Once you have chosen the correct scale, before making any measurement, you should adjust the zero: short-circuit the test leads and turn the $0\,\Omega$ adjustment button until the index is lined up with the green scale zero.

1 Measure the values of the four resistor in the resistor box.

2 Compare the values obtained above with that obtained in §3.1.1. In this case, the measurement uncertainty of the Metrix MX1 multimeter cannot be evaluated in a reliable way.

Figure 16: To measure a resistance with the Metrix MX1 multimeter, connect the red test lead to the *V.Ω* terminal and the black test lead to the *COM.* terminal. (§3.2)

3.3 Potentiomer

The variable resistor of figure 2 is a 10-turn potentiometer and its resistance varies linearly from $0\,\Omega$ to $1\,\mathrm{k}\Omega$ as the shaft is rotated from 0.0 to 10.0 (as read on the knob dial).

1 For each position $x_0 = 0.0, x_1 = 1.0, \ldots, x_{10} = 10.0$, measure the resistance $R_i = R(x_i)$ of the potentiometer (make 2-wire resistance measurements with the Agilent 34401A).

2 For each measured value R_i, determine the corresponding uncertainty.