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Constructor University Bremen

Natural Science Laboratory

Electrical Engineering I

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Lab Experiment 1- Usage of Multimeter

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Place of execution: Teaching Lab EE
Rotation III, Bench 8

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1.INTRODUCTION

This laboratory experiment aimed to investigate the effective utilization of a multimeter for electrical measurements and to demonstrate and analyze instrumental and methodical errors associated with voltage and current measurements. The experiment involved demonstrating various measurement techniques, including voltage, current and resistance measurements, using different circuit configurations and ranges.

The experiment delves into essential electrical measurements using a multimeter. Ohm's Law($v = IR$) where V is the voltage, I is the current and R is the resistance. Ohm's Law serves as the foundation, guiding voltage, current, and resistance measurements. Voltage is measured in parallel, current in series, and resistance through known current application.

The goal of the first set up was to show the influence of the multimeter range on the accuracy of the result.

In the second set up we were proving if neglecting methodical errors of Voltage and only focusing on the instrument errors is applicable to any circuit.

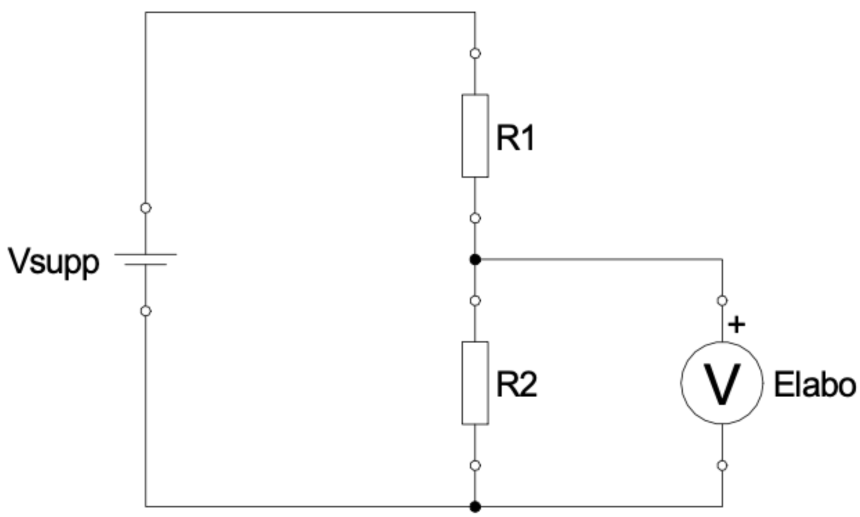
Similar to the second set up, in our third set up we dealt with current.

2. EXECUTION

Experiment Setup
Workbench No.8

Used tools and instruments:
Breadboard, Tools box from workbench, Multimeters TENMA and ELABO, Resistor decade

Experiment Part 1A – Setup
In this part we used the ELABO multimeter as a voltmeter. We measured a single value and determined the change of the value in the different ranges. We assembled the circuit below on the breadboard. Our goal was to show the influence of the multimeter range on the accuracy of our results.



$$\text{Settings : } V_{SUPP} = 0.9\,\mathrm{V} \quad R_1 = 820\mathrm{R}\,\Omega \quad R_2 = 180\mathrm{R}\,\Omega$$

Fig.1 Voltage Measurement Circuit

Before we started using the ELABO multimeter, we first set the measure mode and the range. In our case ’V’ and ’DC’, and since we always start in the highest range, we then turned the wheel to the 2000 V.

Experiment Part 1A – Execution and Results
We measured and recorded the voltage value for the range 2000 V, 200 V, 20 V, 2 V, 0.2 V, with the resistance being R_1 = 820RΩ and R_2 = 180RΩ and the voltage supply being 0.9V.

Results:

Range (V)	Voltage(V)
2000	0.2
200	0.19
20	0.186
2	0.184
0.2	184.36mV

Table 1: Voltage across at Different Ranges

Experiment Part 1B – Setup

In this part we used the ELABO as our voltmeter to measure the Thevenin's voltage. The goal was to demonstrate and analyze instrumental and methodical errors associated with voltage measurements.

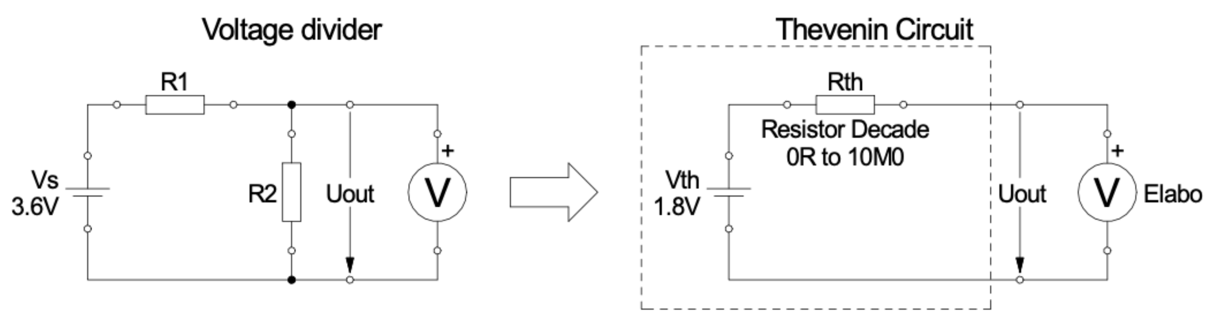


Fig 2: voltage measurement pitfall circuit

The voltage divider converts to ⇒ $V_{th} = V_s(R_2/(R_1 + R_2))$ *and* $R_{th} = (R_1R_2)/(R_1 + R_2)$

This time we didn't have to change the mode of the multimeter, but we set the range back to 2000 V. In general we were able to reduce every resistive DC circuit to an ideal voltage source and a resistor to a so-called Th´evenin circuit.

Experiment Part 1B – Execution and Results

We switched on the power and adjusted the supply to V_{th}, Selected 0 R at the resistor decade and then set the range of the voltmeter to the best resolution which was 2V in our case. We then recorded the values at the voltmeter for 0 R, 10R, 100R, 1K00, 10K0, 100K, 1M00, 10M0.

Results:

Resistance(Ω)	Voltage(V)
0	1.9018
10	1.9018
100	1.9018
1K	1.9016
10K	1.8999
100K	1.8831
1M	1.7299
10M	0.9503

Table 2: Measured Voltage at different parameters

Experiment Part 2 – Setup

In this part we used the TENMA as our ammeter to measure the current at different ranges namely, Amps, milliAmps and microAmps. The goal was to demonstrate and analyze instrumental and methodical errors associated with current measurements.

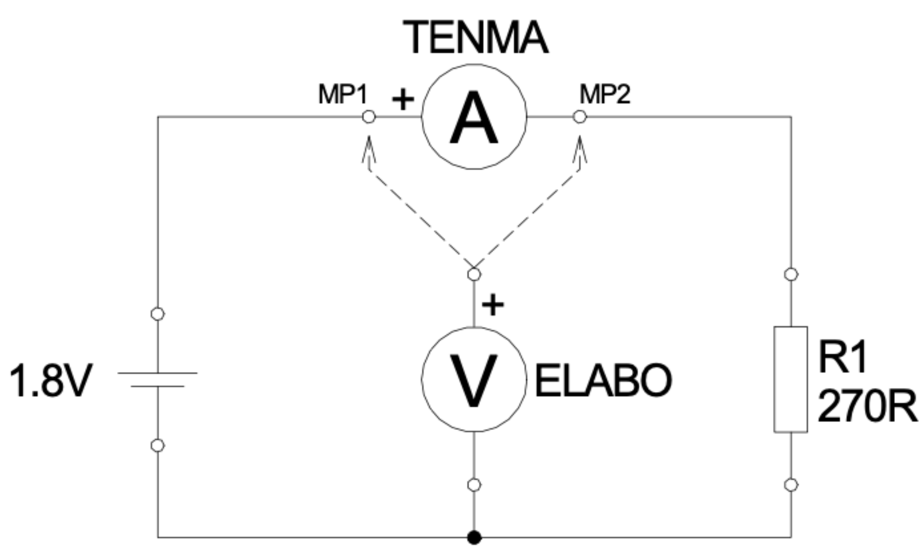


Fig 3: Current measurement pitfall circuit

We first set the voltmeter to the best range which was 2V in our case. We then connected the voltmeter in a way that 'MP1' and 'MP2' where the plugs at the ammeter. This was to reduce/eliminate the influence of the connecting wires to the ammeter.

Experiment Part 2 – Execution and Results

We connected the circuit to the power supply and chose the best range for the voltmeter. We then recorded the range of the voltmeter. The ammeter was already set to the highest range. We later recorded the voltages at MP1 and MP2 and the current at the ammeter. We changed the input terminal at the ammeter from 'A' to ' mAμA' and recorded the voltages and the current at each range.

Results:

Plug	Switch	V MP1(V)	V MP2(V)	Current (A)
A	A	1.9015	1.9008	0.005
mAμA	mA	1.9013	1.858	6.88E-03
mAμA	μA	1.9016	0.6668	2.47E-03

Table 3: Current and Voltage measurements at different parameters

3.Evaluation

Part 1A : Voltage Measurement

1. To calculate all absolute and relative errors of the values measured with the multimeter the calculations below were done using values in table 1.

1.1 Range 2000V

Absolute error = ±(0.03% f.Value + 0.01% f.Range)

$$=\pm\ [((0.03/100)\ *\ 0.2)\ +\ ((0.01/100)\ *\ 2000)]$$

$$=\pm\ 0.20006$$

$$E_{rel}\ =\ [(Absolute\ error)/true\ value]\ *\ 100$$

$$=\ (0.20006/0.2)\ *\ 100$$

$$=\ 100.03\%$$

Range (V)	Voltage(V)	Absolute Error	Relative Error	Relative Error (%)
2000	0.2	0.20006	1.0003	100.03
200	0.19	0.02006	0.1056	10.56
20	0.186	0.00206	0.0111	1.11
2	0.184	0.00026	0.0014	0.14

do not split tables..

0.2	184.36mV	0.05533	0.0003	0.03

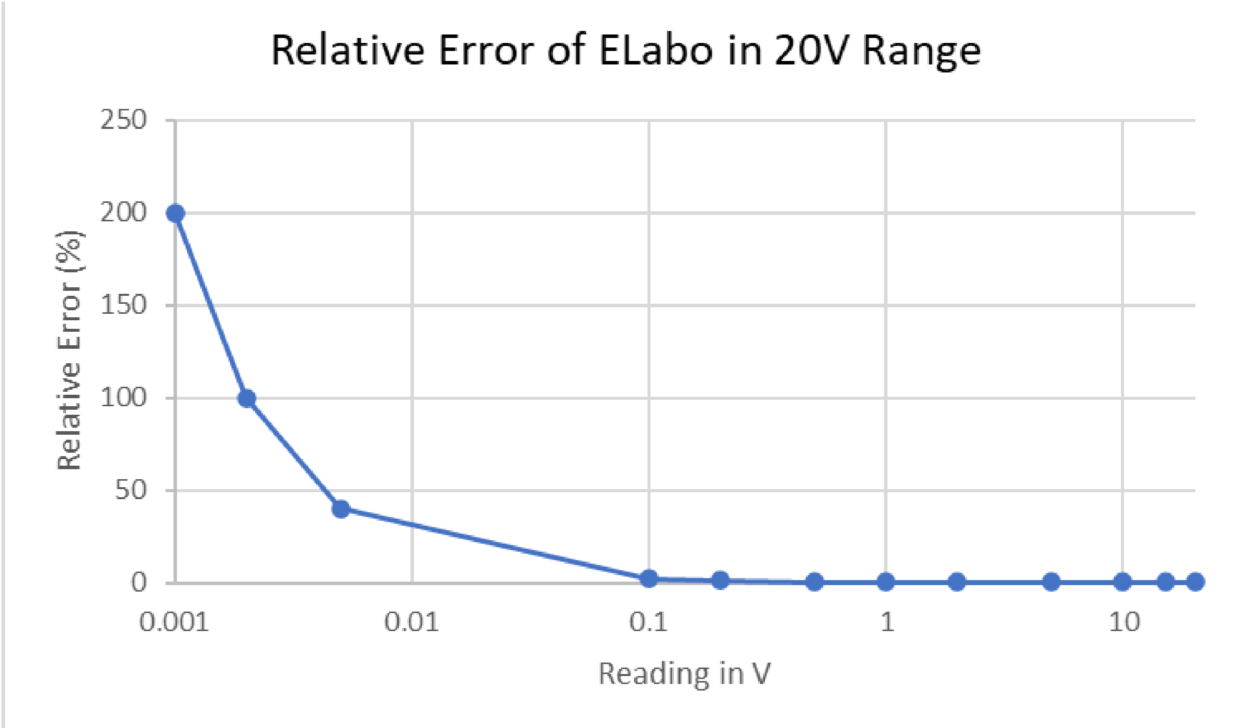
2. Our conclusion regarding the usage of voltage ranges was that the smaller the range, the more accurate the readings depending on the connected value.

3.

True Value (V)	Absolute Error	Relative Error (%)
0.001	0.0020003	200.03
0.002	0.0020006	100.03
0.005	0.0020015	40.03
0.1	0.00203	2.03
0.2	0.00206	1.03
0.5	0.00215	0.43
1	0.0023	0.23
2	0.0026	0.13
5	0.0035	0.07
10	0.005	0.05
15	0.0065	0.04
20	0.008	0.04

Table 4: Relative Error (%) for 20V Range

The Absolute Error and Relative Error were calculated in excel using the formulas ±(0.03% f.Value + 0.01% f.Range) and $[(Absolute\ error)/true\ value]\ *\ 100$, respectively.



The plot above was created by excel using table 4

Part 1B : Voltage Measurement Pitfall

1. To calculate the relative error of the measured U_{th} value for all R_{th} settings the calculations below were done using the formula below in excel.

1.1 Range 0Ω

Absolute error = ±(0.03% f.Value + 0.01% f.Range)

$$=\pm\ [((0.03/100)\ *\ 1.9018)\ +\ ((0.01/100)\ *\ 2)]$$

$$=\pm\ 0.00077054$$

$$E_{rel} = [(Absolute\ error)/true\ value]\ *\ 100$$

$$= (0.00077054/1.9018)\ *\ 100$$

$$= 0.04\ \%$$

Resistance(Ω)	Voltage(V)	Absolute Error	Relative Error (%)
0	1.9018	0.00077054	0.04

do not split tables..

10	1.9018	0.00077054	0.04
100	1.9018	0.00077054	0.04
1K	1.9016	0.00077048	0.04
10K	1.8999	0.00076997	0.04
100K	1.8831	0.00076493	0.04
1M	1.7299	0.00071897	0.04
10M	0.9503	0.00048509	0.05

2. To Calculate the relative methodical error for all cases using the formula below in excel, with our True value being 1.901V. why is this value the true value?

2.1 Range 0Ω

$$Methodical\,error = (Vmeas - Vtrue)/Vtrue$$
$$= (1.9018 - 1.901)/1.901$$
$$= 0.0004051635293$$

Resistance(Ω)	Voltage(V)	Absolute Error	Relative Error (%)	Methodical Error
0	1.9018	0.00077054	0.04	0.0004051635293
10	1.9018	0.00077054	0.04	0.0004051635293
100	1.9018	0.00077054	0.04	0.0004051635293
1K	1.9016	0.00077048	0.04	0.0004051745898
10K	1.8999	0.00076997	0.04	0.0004052686984
100K	1.8831	0.00076493	0.04	0.0004062078488
1M	1.7299	0.00071897	0.04	0.0004156136193
10M	0.9503	0.00048509	0.05	0.0005104598548

As shown above, our methodical error should have been zero, but since the internal resistance of a circuit is greater than the internal resistance of the voltmeter we have a methodical error.

explain how we get the meth. error...

3. The internal resistance of the voltage was 10M ohms, and to reduce the methodical error to zero the internal resistance of the voltmeter should be greater than the internal resistance of the circuit.

Part 2 : Current Measurement and Pitfalls

1. To calculate the relative error of the measured current for all settings, we used the necessary formulas found in the Tenma 72-7732A Multimeter data sheet as shown below.

1.1 Range A

$$Absolute\ error =\pm\ (0.5\% * Measured\ value + 30 * resolution)$$

$$=\pm\ [(0.5\% * 0.005) + (30 * 0.001)]$$

$$=\pm\ 0.0300250$$

$$E_{rel} = (absolute\ error/T_v) * 100$$

$$= (0.0300250/0.005) * 100$$

$$= 600.50$$

1.2 Range μA

$$Absolute\ error =\pm\ (0.1\% * Measured\ value + 15 * resolution)$$

$$=\pm\ [(0.1\% * 2.47E - 03) + (15 * 0.01 * 10^\wedge - 6)]$$

$$=\pm\ 0.0000026$$

$$E_{rel} = (Absolute\ error/T_v) * 100$$

$$= (0.0000026/2.47E - 03) * 100$$

$$= 0.37$$

1.3 Range mA

$$Absolute\ error = \pm\ (0.15\% * Measured\ value + 15 * resolution)$$

$$= \pm\ [(0.15\% * 6.88E - 03) + (15 * 0.001 * 10^\wedge - 3)]$$

$$= \pm\ 0.0000253$$

$$E_{rel} = (Absolute\ error/T_v) * 100$$

$$= (0.0000253/6.88E - 03) * 100$$

$$= 0.11$$

2. To calculate the relative methodical error for all settings. We first found the true value using the measured voltage V_{MP1} and the resistor value $R_1 = 270\ \Omega$.

Range A

$$True\ value = V_{MP1}/270$$

$$= 1.9015/270$$

$$= 0.007042592593$$

$$Relative\ Methodical\ Error = [(Measured\ Value - True\ Value)/True\ Value] * 100$$

$$= [(0.005 - 0.007042592593)/0.007042592593] * 100$$

$$=- 29.00$$

Switch	V MP1(V)	Current (A)	True Current Value (A)	Relative Methodical Error
A	1.9015	0.005	0.007042592593	-29.00
mA	1.9013	6.88E-03	0.007041851852	-2.34
µA	1.9016	2.47E-03	0.007042962963	-64.95

3.1 In our case the range with the best accuracy is mA, because its methodical error is closest to zero.

3.2 In our case the range with the smallest systematically error is μA.

3.3 The 'A'mper range does not have the smallest methodical error because its current is not as precise as the other ranges.

error propagation in the calculation...

4.1 In our case, mA is the best/most acceptable range when considering instrument and methodical instrument errors

4.2 Our conclusion on the use of an ammeter is that the range also affects the accuracy of the readings.

5. To Calculate the resistance of the ammeter in all three ranges, the calculations below were done using two different formulas as shown below. R_1 was given in the manual as 270Ω.

5.1 Range A

$$R_i = (V_{MP1} - V_{MP2})/I$$

$$= (1.9015 - 1.9008)/0.005$$

$$= 0.14\Omega$$

$R_i = (V_{MP1}/I) - R_1$

$= (1.9015/0.005) - 270$

$= 110.3\Omega$

Switch	V MP1(V)	V MP2(V)	Current (A)	R =(VMP1 − VMP2)/I	R =(VMP1/I) − R1
A	1.9015	1.9008	0.005	0.14	110.3
mA	1.9013	1.858	6.88E-03	6.293604651	6.351744186
µA	1.9016	0.6668	2.47E-03	499.9190283	499.8785425

6. To determine the error propagation in the µA range for both Ri formulas, the calculations below were done.

6.1 $R_i = (V_{MP1} - V_{MP2})/I$

$$\Delta R = \left|\left[(1/I) * (\Delta V_{MP1})\right]\right| + \left|\left[(-1/I) * (\Delta V_{MP2})\right]\right| + \left|\left[(-1/I^2)(V_{MP1} - V_{MP2}) * (\Delta I)\right]\right|$$

$= |[(1/0.0247) * (0.00077048)]| + |[(-1/0.0247) * (0.00040004)]| + \left|[(-1/0.0247^2)(1.9016 - 0.6668) *\right.$

$= 1.00E + 00$

2

6.2 $R_i = (V_{MP1}/I) - R_1$

$$\Delta R = \left|[(1/I) * (\Delta V_{MP1})\right| + \left|[(-V_{MP1}/I^2)(\Delta I)\right| + \left|(-1) * (\Delta R_1)\right|$$

$= |[(1/0.0247) * (0.00077048)| + \left|[(-1.9016/0.0247^2)(0.0000026)\right| + |(-1) * (0.01)|$

$= 3.83E + 00$

We have two different values because we used two different formulas for R leading to different structures after differentiation. Our conclusion on using measured values in calculations is that they are more accurate because they have close to zero errors.

... taking care of the used functions

... try to use formulas with as least componnets as possible...

4.Conclusion

Our experiment aimed to explore the nuances of current and voltage measurements, shedding light on both instrumental and methodical errors and to also demonstrate the several usages of a multimeter, such as it being used for voltage and current measurements, not only that we were able to see how much influence the ranges had on the readings which meant that the range needed to be adjusted to the best resolution depending on the experiment . Our experiment also demonstrated how the internal resistance of the devices can affect the accuracy of the readings and also contribute to the errors. Through careful analysis of the results, it is evident that the measured current and voltage exhibited variations when compared to theoretical values. This variance could be attributed to several factors, including inaccuracies in the instruments used, imperfect experimental conditions, and human error.

5.Reference

1. Pagel Uwe, General Electrical Engineering 1 Lab Manual (2023). Constructor University