GENERAL ELECTRICAL ENGINEERING LAB

USAGE OF MULTIMETER

Experiment 1

CH-120-B

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Introduction

The most important objective of this experiment was to get familiar with the usage of a multimeter, which is an instrument used to measure the basic electrical properties and a basic tool to troubleshoot circuit problems. It also included a short course on safety instructions, overview about errors and error calculations and a brief introduction on how to write a lab report.

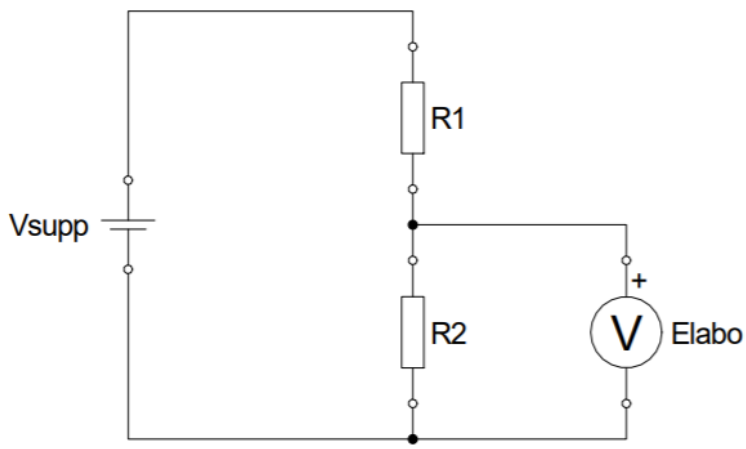
For the analysis of the measurements, we need a basic understanding of Ohm's Law and Kirchhoff's Laws. Ohm's Law ties together voltage (V), current (I) and resistance (R) with V=IR. Kirchhoff's Laws involve the current law which states that the algebraic sum of a current at a particular node is zero and the voltage law which states that the algebraic sum of the voltages in a complete loop add up to zero.

General uses for the multimeter involve testing, diagnosing, and troubleshooting electrical circuits, components, and devices. It is used primarily to measure voltage (volts), current (amps), and resistance (ohms). As an example, for resistance measurements, usually a small constant current is passed through the device under test and the digital multimeter reads the resultant voltage drop.

Some common errors when using the multimeter involve using the wrong range and underestimating the effect of the multimeter on the circuit (the circuit can sometimes be modified depending on the setting and components used; more on this below).

Experimental Set-up and Results

For the first part of the experiment, the set-up was as follows,

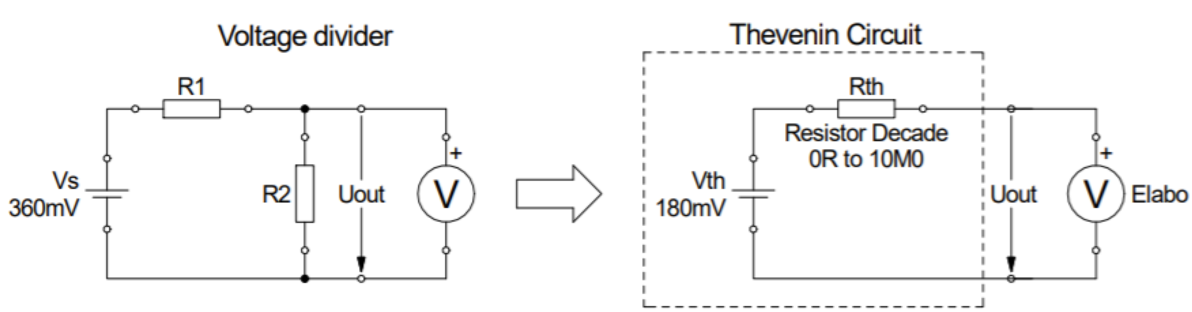


Settings : $V_{SUPP} = 9.0\,\mathrm{V} \quad R_1 = 8K20\,\Omega \quad R_2 = 1K80\,\Omega$

The mode was set to ‘V’ and ‘DC’ on the Elabo Multimeter and put to the range of 2000V. Values were recorded for the ranges 2000V, 200V, 20V, 2V and 0.2V.

Range(V)	Reading(V)
2000	1.6
200	1.61
20	1.616
2	1.6151
0.2	OL

The second part of the experiment was set-up as follows,

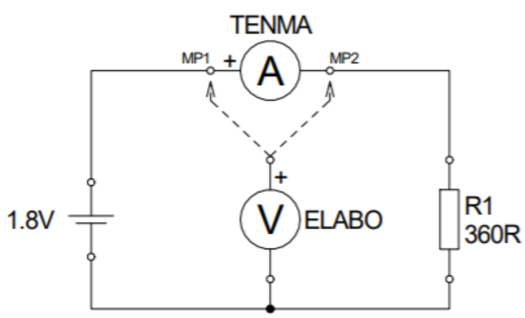


The voltage divider converts to $\Rightarrow V_{th} = V_S \dfrac{R_2}{R_1 + R_2}$ and $R_{th} = \dfrac{R_1 + R_2}{R_1\,R_2}$

Here, the values of voltage were measured for 0 R, 10 R, 100 R, 1 K00, 10 K0, 100 K, 1 M00, 10 M0 resistors.

	Range 2V
Resistance(Ohms)	2
0	0.1795
10	0.1795
100	0.1795
1000	0.1795
10000	0.1794
100000	0.1778
1000000	0.1635
10000000	0.0907

In the next part, the circuit is set-up in the following manner,



Voltages and currents for both MP1 and MP2 were measured at the different ranges.

Plug	Switch	Vmp1/V	Vmp2/V	CURRENT/ A
A	A	1.8109	1.8105	0.003
mAµA	mA	1.8109	1.7804	0.004909
mAµA	µA	1.811	0.7596	0.0020953

Evaluation

5.6.1 Part 1A: Voltage Measurement

1.

⍰ Elabo Multimeter ΔE = ±(0.03% f.Value + 0.01% f.Range) – ΔE in [V]

Relative Error = Absolute Error / Reading

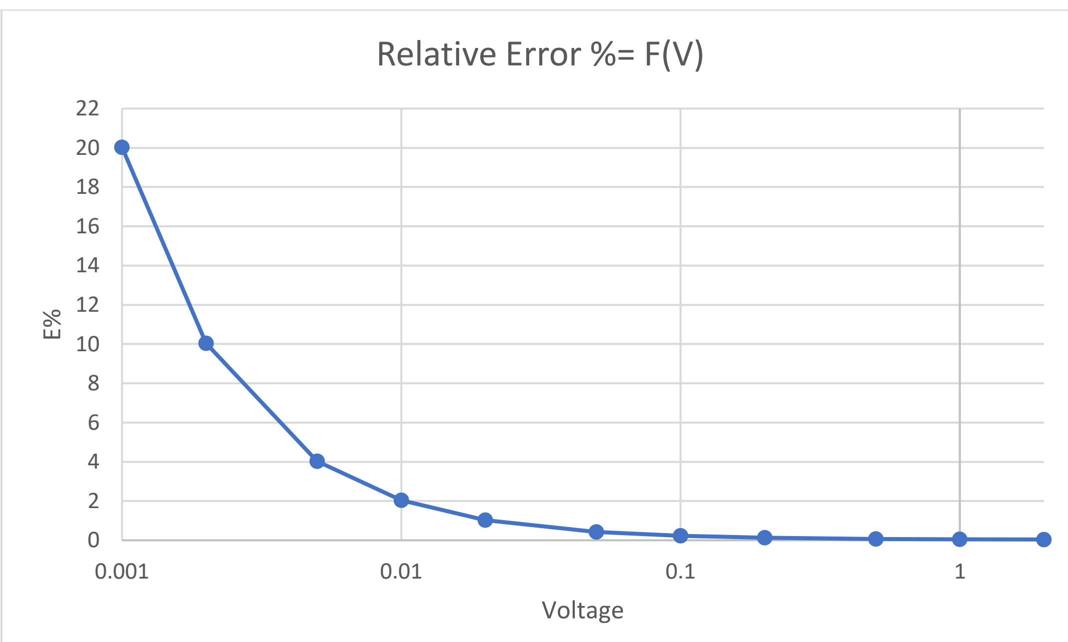
Range(V)	Reading(V)
2000	1.6
200	1.61
20	1.616
2	1.6151
0.2	OL

Absolute Error	Relative Error
0.20048	0.1253
0.020483	0.01272236
0.0024848	0.001537624
0.00068453	0.000423831
OL	OL

2.

As the range decreases, so does the absolute and relative errors. A smaller range leads to a greater accuracy.

3.



Range	Voltage	Column1	Absolute Error	Relative Error %
2	0.001		0.0002003	20.03
2	0.002		0.0002006	10.03
2	0.005		0.0002015	4.03
2	0.01		0.000203	2.03
2	0.02		0.000206	1.03
2	0.05		0.000215	0.43
2	0.1		0.00023	0.23
2	0.2		0.00026	0.13
2	0.5		0.00035	0.07
2	1		0.0005	0.05
2	2		0.0008	0.04

5.6.2 Part 1B: Voltage Measurement Pitfall

1.

The relative error for all the found Voltage values and methodical errors were found using the equations below;

$$E_{meth} = \frac{|Val_{meas} - Val_{true}|}{Val_{true}}$$

Example calculation from resistance value of 0 Ohms at the 2V range.

$$\mathrm{E}_{rel} = \frac{|\pm(0.03\% * \ 0.1795 + \ 0.01\% * 0.1795)|}{0.1795} = 0.001414206$$

$$E_{meth} = \frac{|0.1795 - 0.1795|}{0.1795} = 0$$

The errors found for the other resistance values are as shown in the table below;

Resistance(Ohms)	Range 2V (V)	Methodical Error	Relative Error
0	0.1795	0	0.001414206
10	0.1795	0	0.001414206
100	0.1795	0	0.001414206
1000	0.1795	0	0.001414206
10000	0.1794	-0.0005571	0.001414039
100000	0.1778	-0.0094708	0.001411365
1000000	0.1635	-0.0891365	0.001387465
10000000	0.0907	-0.4947075	0.001265794

2.

The source of the error is the internal resistance of the voltmeter. When the resistance of the resistor becomes large enough, the circuit behaves like a voltage divider.

3.

The internal resistance given is 10MΩ. To reduce methodical error to zero, the internal resistance should be increased to infinity.

5.6.3 Part 2: Current Measurement and Pitfalls

1/2.

The following formula was used to calculate the relative errors;

$$E_{Abs} = \pm\left(x\% * I_{found} + 15\% * Resolution\right)$$

The following is an example;

$$E_{Abs} = \pm(0.5\% * 0.003 + 15\% * 0.001) = 0.030015$$

$$\mathrm{E}_{rel} = \frac{|0.030015|}{0.003} = 10.005$$

$$E_{meth} = \frac{|0.003 - \frac{1.8109}{360}|}{\frac{1.8109}{360}} = -0.403611$$

Plug	Switch	Vmp1/V	Vmp2/V	CURRENT/ A	Absolute Error (A)	Relative Error	Relative Methodical Error
A	A	1.8109	1.8105	0.003	0.030015	10.005	-0.403611
mAµA	mA	1.8109	1.7804	0.004909	2.23635E-05	0.004556	-0.02411
mAµA	µA	1.811	0.7596	0.0020953	3.5953E-06	0.001716	-0.583485

3.

The µA range has the best accuracy with the smallest relative error, since it has the highest resolution compared to the mA and A ranges. However, the mA range has the smallest methodical error because as we decrease the range of the measurement, the internal resistance of the ammeter used increases and hence, the circuit is changed (the circuit starts to behave like a voltage divider). By this logic, the A range should have the smallest methodical error, but as seen by the results, this is not the case since the current measured by the ammeter is too small for the resolution at this range, hence, the values measured in the A range are pointless.

4.

Therefore, using the 'mA' range seems to be the best option for the choice of ammeter.

5.

The internal resistance of each range was found using two methods given by;

$$R_i = \frac{V_{MP1} - V_{MP2}}{I}$$

$$R_i = \frac{V_{MP1}}{I} - R$$

The results obtained are given below;

Range	Vmp1/V	Vmp2/V	CURRENT/ A	Internal Resistance Formula 1 (Ω)	Internal Resistance Formula 2 (Ω)
A	1.8109	1.8105	0.003	0.133333	243.6333
mA	1.8109	1.7804	0.004909	6.213078	8.893868
µA	1.811	0.7596	0.0020953	501.7897	504.3154

6.

The error propagation was also found for the µA range for both methods as shown by the following equations.

$$E_1 = \left|\frac{\mathrm{d}R}{dV_{MP1}} * \Delta V_{MP1}\right| + \left|\frac{\mathrm{d}R}{dV_{MP2}} * \Delta V_{MP2}\right| + \left|\frac{\mathrm{d}R}{d\mathrm{I}} * \Delta \mathrm{I}\right|$$

$$E_1 = \left|\frac{1}{I} * \Delta V_{MP1}\right| + \left|\frac{1}{I} * \Delta V_{MP2}\right| + \left|\frac{V_{MP1} - V_{MP2}}{I^2} * \Delta \mathrm{I}\right|$$

$$E_2 = \left|\frac{\mathrm{d}R}{dV_{MP1}} * \Delta V_{MP1}\right| + \left|\frac{\mathrm{d}R}{d\mathrm{I}} * \Delta \mathrm{I}\right| + |\Delta \mathrm{R}|$$

$$E_2 = \left|\frac{1}{I} * \Delta V_{MP1}\right| + \left|\frac{-V_{MP1}}{I^2} * \Delta \mathrm{I}\right| + |\Delta \mathrm{R}|$$

From method one, the propagated error was calculated to be ≈9.1476Ω and from the second method, the calculated value was ≈14.8875Ω. The difference in these values show us that using actual measured values in our calculation is much better as shown by the calculated value for method 1, rather than using values set by an instrument with its own additional instrumental errors as shown by method 2.

Conclusion

Finally, one could come to the conclusion that when using a multimeter, it is always advisable to select the smallest appropriate range for measuring a particular voltage so that the actual reading's accuracy would be greater. This was demonstrated in part 1A when we saw how the error was reduced as the range of the multimeter was decreased.

When it comes to part 1B, the effect of methodical errors while using a multimeter becomes clearer. This is due to the fact that physical voltmeters have a limit on how large their internal resistance can be. If the voltage across a very large resistance is measured, the internal resistance of the multimeter affects the reading up to a large extent, since the circuit is now essentially, a voltage divider. Therefore, this showcases the effects of methodical errors on readings.

From the next part of the experiment, one could arrive at the conclusion that when using the multimeter as an Ammeter, taking measurements in the mA range is the best option when possible. We could also summarize that it is always better to use actual measured values in our calculations since the propagated error would be lesser.

References

Lab Manual (jacobs-university.de)

Appendix