GENERAL ELECTRICAL ENGINEERING LAB

Thevenin's and Norton's Theorem

Experiment 2

CH-120-B

Location: Jacobs University Bremen, Research 1

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Semester: 1

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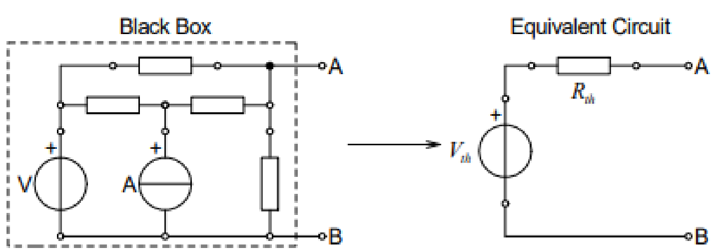
Introduction

The most important objective of this experiment was to explore and analyze relatively complex circuits by using Thevenin's and Norton's theorems.

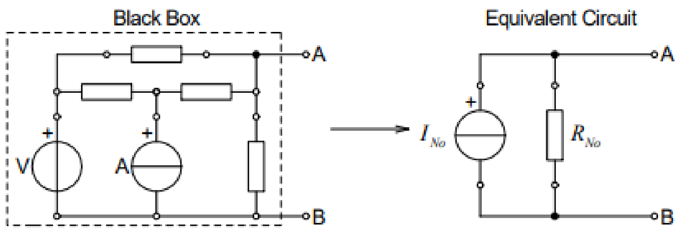
Thevenin's Theorem states that "*Any linear circuit containing several voltages and resistances can be replaced by just one single voltage in series with a single resistance connected across the load* ". In other words, it is possible to simplify any electrical circuit, no matter how complex, to an equivalent two-terminal circuit with just a single constant voltage source in series with a resistance (or impedance) connected to a load.

Norton's Theorem states that "*Any linear circuit containing several energy sources and resistances can be replaced by a single Constant Current generator in parallel with a Single Resistor* ". In other words, it is possible to simplify any complex electrical circuit to an equivalent circuit which contains a single constant current source in parallel to a single resistance (or impedance).



- The equivalent voltage V_{th} is the voltage obtained at terminals $A-B$ of the network with terminals $A-B$ open circuited.
- The equivalent resistance R_{th} is the resistance obtained at terminals $A-B$ of the network with all its independent current sources open circuited and all its independent voltage sources short circuited.

Ref. 1: Thevenin Transformation of a Circuit (from Lab Manual)

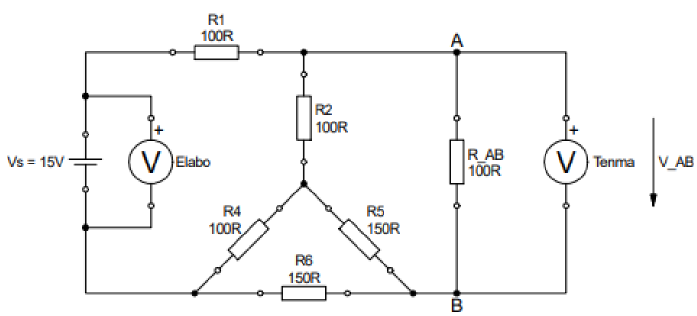


- This equivalent current I_{No} is the current obtained at terminals $A - B$ of the network with terminals $A - B$ short circuited.
- The equivalent resistance R_{No} is the resistance obtained at terminals $A - B$ of the network with all its voltage sources short circuited and all its current sources open circuited.

Ref. 2: Norton's Transformation of a Circuit (from Lab Manual)

Experimental Set-up and Results

Part 1: Linear Network



Ref. 3: Set-up for Part 1 and 2 of experiment (from Lab Manual)

The circuit was set-up as shown in Ref. 3. The values of V_s and V_{AB} were read and recorded.

$$V_s = 15.02V$$

$$V_{AB} = 3.3308V$$

Part 2: Determining Thevenin's and Norton's parameters

First, V_{TH} (Thevenin's voltage) was found by removing the load (R_AB) from between points A-B. This was done using the Tenma multimeter.

$$V_{TH} = 7.501V$$

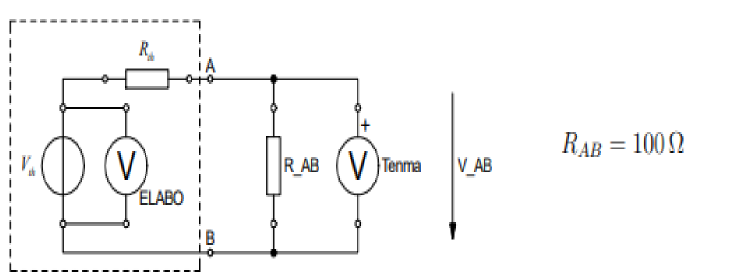
Next, the equivalent current for Norton's transformation, (I_{No}) was measured by replacing the load resistor in Ref. 3 by a short. This was accomplished by switching the Tenma multimeter from a Voltmeter to an Ammeter. Since Ammeters are technically supposed to have zero resistance, this is a good approximation of a short circuit.

$$I_{No} = 56.77mA$$

R_{TH} and R_{No} were then measured by replacing the power supply by a short and using the Tenma multimeter at points A-B in the Ohm setting. As we know, the Thevenin's and Norton's resistances are equal for a given circuit. Hence,

$$R_{TH} = R_{No} = 125.43\ \Omega$$

Part 3: Determining V_{AB} using Thevenin's Circuit



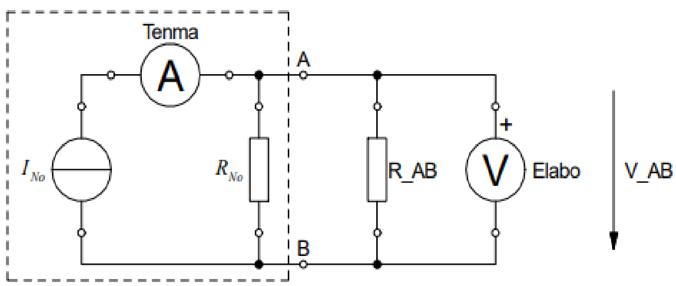
Ref. 4: Set-up for Part 3 of experiment (from Lab Manual)

The circuit was set-up as shown in Ref. 4 with V_{TH} and the R_{TH} being set as closely as possible to the values found in Part 2. A Decade Resistor was used to get the approximate value for the resistance. The V_{TH} and V_{AB} values were then measured and recorded, respectively.

$$V_{TH}= 7.499V$$

$$V_{AB}=3.330V$$

Part 4: Determining V_{AB} using Norton's Circuit



Ref. 5: Set-up for Part 4 of experiment (from Lab Manual)

Initially, the voltage of the voltage source was set to 10V while switching the power supply to a constant current mode. The output terminals were short circuited, and the current was set to the needed 56.77mA. Next, with the help of a Decade Resistor set at a 125Ω for R_{No}, the circuit shown above was set up. The values recorded were as such,

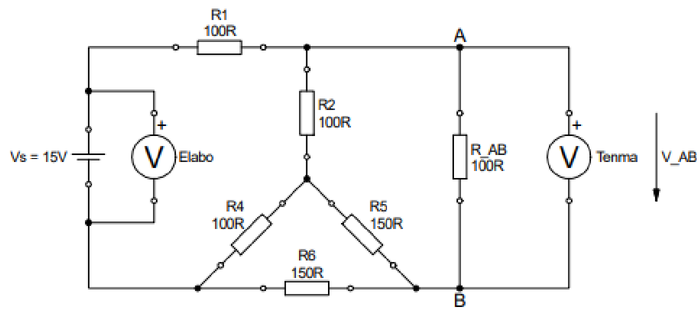
$$I_{No}= 57.00mA$$

$$V_{AB}=3.164V$$

Evaluation

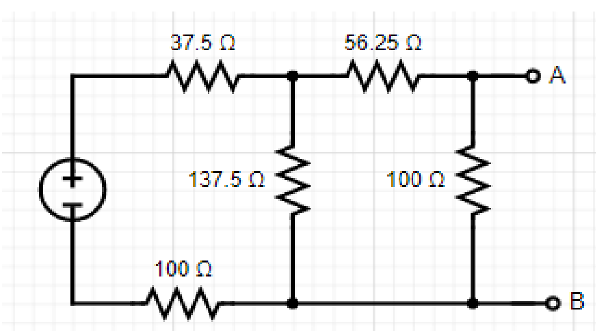
Part 1

To calculate V_{AB}, a Delta Wye transformation was performed on Ref. 3 shown below.



Ref. 3: Set-up for Part 1 and 2 of experiment (from Lab Manual)

This resulted in Ref. 6 also shown below.



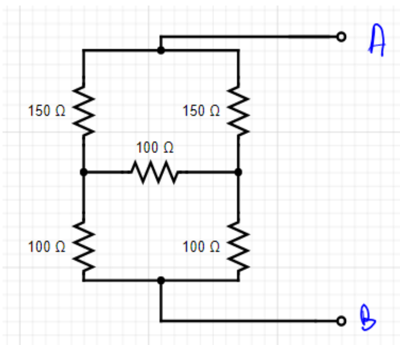
Ref. 6: After Delta-Wye Transformation

Next, by applying KVL and KCL respectively, the current passing through the 100Ω resistor parallel to A-B was calculated to be 0.1/3 A. And since the voltage through that branch and the A-B "\branch are the same since they are in parallel,

$$V_{AB} = 100 * \frac{0.1}{3} = 3.33333 \ldots V$$

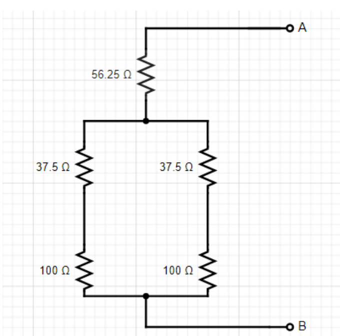
Part 2,3,4

To find the R_{th} and R_{No} of the circuit with the voltage source shorted out as shown below, another Delta-Wye transform was applied.



Ref. 7: Circuit with short Circuited Voltage

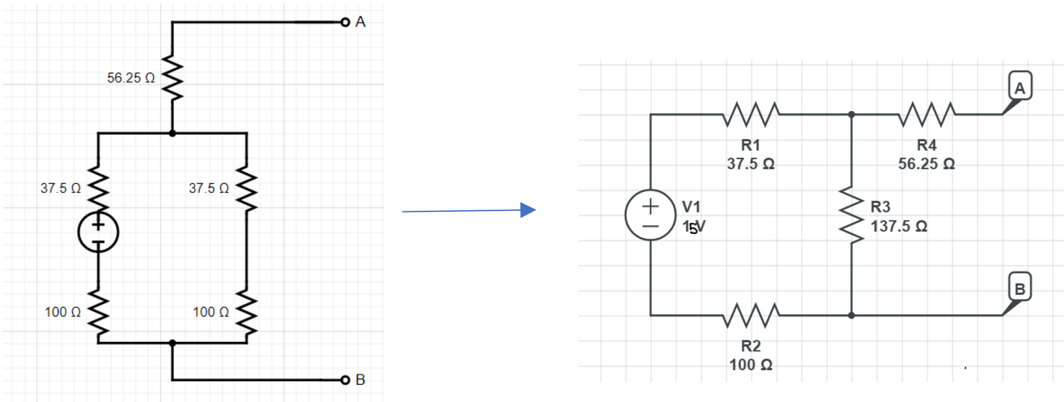
After the Delta-Wye transform, the following circuit was obtained.



Ref. 8: Delta-Wye transform of the circuit

Using Ref. 8, and by doing some basic arithmetic (rules of summing resistors in series and summing inverses of resistors in parallel), it is easy to obtain the overall equivalent Norton and Thevenin's resistance of 125Ω from the circuit.

For calculating of V_{th} and I_{No}, another Delta-Wye transform was used, but this time with the voltage source still included in the circuit. This result is shown in the diagrams below.



Ref. 9: Delta-Wye transform of circuit with voltage source

Next, KVL can be used to find the current passing through R3.

$$15 = 100\text{i} + 137.5\text{i} + 37.5\text{i}$$
$$15 = 275\text{i}$$
$$\therefore \text{i} \approx 55mA$$

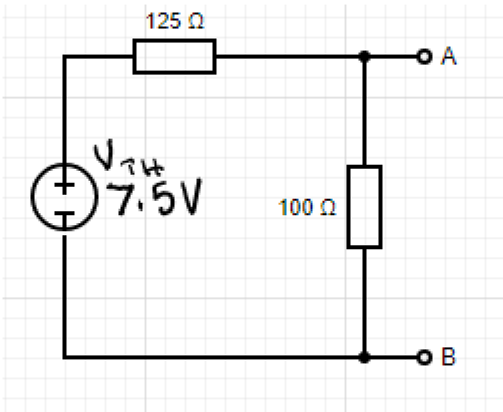
By implementing Ohms Law with this value if I, V_{th} can be calculated to be approximately 7.5V.

Then by using a simple source transformation, I_{No} can also be calculated as shown below.

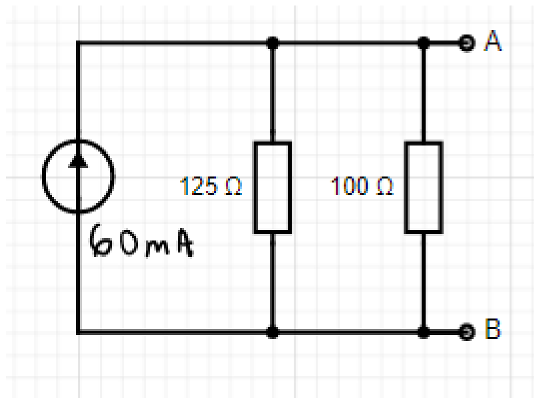
$$I_{No} = \frac{V_{th}}{R_{th}} = \frac{7.5}{125}A$$

Therefore, I_{No} was calculated to be 60mA.

The equivalent diagrams are shown below.



Ref. 10: Thevenin's Equivalent Circuit



Ref. 11: Norton's Equivalent Circuit

Thevenin's V_{AB}:

$$V_{AB} = \frac{100}{100 + 125} * 7.5$$
$$= 3.3333 \ldots V$$

Norton's V_{AB}:

$$V_{AB} = 3.3333 \ldots V$$

These are the theoretical values obtained by calculation.

Given below is a table comparing measured and calculated values.

Table 1: Comparison of Calculated to Measured Values		
	Calculated Value	Measured Value
V_{AB}	3.3333V	3.3308V
R_{TH}	125Ω	125.43Ω
V_{TH}	7.5V	7.501V
Thevenin's V_{AB}	3.3333…V	3.3330V
I_{No}	60mA	56.77mA
Norton's V_{AB}	3.3333….V	3.164V

When comparing the values obtained both by calculating and through measurements, some observations can be made. It is seen that the measured values obtained from the experiment are sufficiently accurate except in the case of the measured Norton's current and Norton's V_{AB} . However, this inaccuracy was caused by a methodical error (the effect of the internal resistance of the Tenma ammeter in the mA setting), so there is this observation does not disprove either of the two theorems. Another factor that should be considered are the systematic errors which could be caused by the limited precision of the instruments etc.

Conclusion

Through the execution of this experiment, Thevenin's and Norton's theorems were successfully introduced. By careful consideration of the obtained results, the conclusion arrived to was that, when using measured values to build up equivalent circuits, the methods for achieving Thevenin's equivalent circuit produce more accurate results because there is a higher chance of a methodical error when if Norton's equivalents are used.

References

Lab Manual (jacobs-university.de)

HTTPS://WWW.ELECTRONICS-TUTORIALS.WS/DCCIRCUITS/DCP_7.HTML

HTTPS://WWW.ELECTRONICS-TUTORIALS.WS/DCCIRCUITS/DCP_8.HTML

Appendix

Data collected from Ohm's Law Lab. Done on: Nov 26, 2020

Part 1: Resistance of a Copper Wire

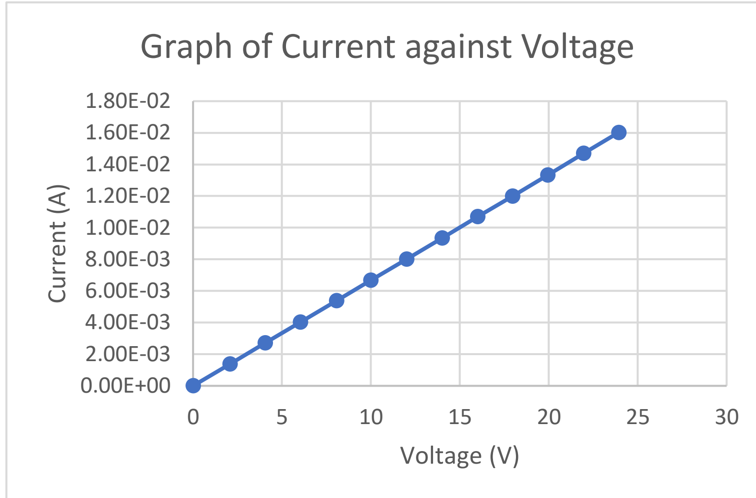
Current: 1000.5 mA

Voltage: 67.99mV

Resistance: 6.80 ×10^3 Ω

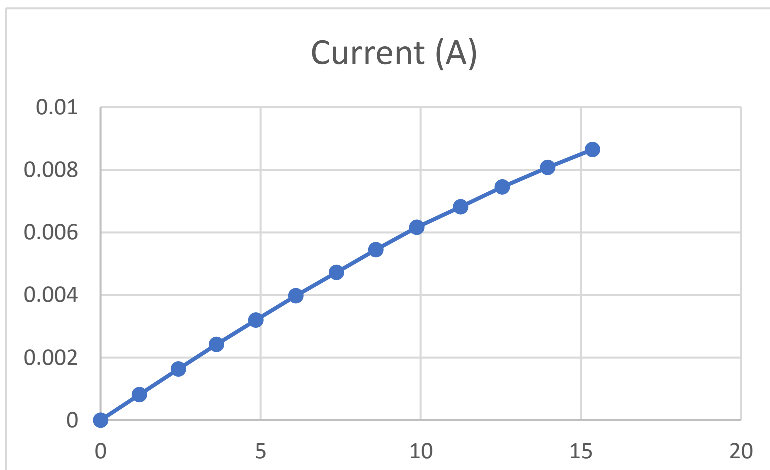
Part 2: Resistance of a Metal Film Resistor

Index	Voltage(on Elabo)	Current (A)
0	0	0.00E+00
2	2.073	1.3810E-03
4	4.054	2.7030E-03
6	6.036	4.0250E-03
8	8.065	5.379E-03
10	9.998	6.6690E-03
12	12.005	8.0110E-03
14	14.005	9.3490E-03
16	16.009	1.0688E-02
18	17.962	1.1995E-02
20	19.939	1.3319E-02
22	21.96	1.4696E-02
24	23.93	1.6022E-02



Part 3: Resistance of a PTC Resistor

Index	Voltage(on Elabo)	Current (A)
0	0	0
2	1.21	8.15E-04
4	2.43	1.64E-03
6	3.62	2.42E-03
8	4.85	3.20E-03
10	6.1	3.98E-03
12	7.37	4.72E-03
14	8.6	5.45E-03
16	9.88	6.16E-03
18	11.24	6.82E-03
20	12.54	7.45E-03
22	13.96	8.08E-03
24	15.36	8.65E-03



Part 4: Resistance of a NTC Resistor

Index	Voltage (V)	Current (A)
0	0	0
2	1.3	7.39E-04
4	2.56	1.51E-03
6	3.75	2.32E-03
8	4.83	3.23E-03
10	5.8	4.25E-03
12	6.7	5.36E-03
14	7.19	6.85E-03
16	7.65	8.43E-03
18	8.16	9.93E-03
20	8.31	1.17E-02
22	8.43	1.36E-02
24	8.73	1.53E-02