Thevenin, Norton, and Matching

Laboratory 2

EE 101 Winter 2016

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Introduction

The purpose of this lab was to understand and find the equivalent circuits using Thevenin and Norton measurements. Through my theoretical calculations, I was able to compare with the experimental values found. I then determined how large the discrepancy of my measurements were and the reasoning for them. Essentially the goals in this lab was to understand Thevenin Equivalent, Norton's Equivalent, and Power Transfer Functions.

As for a further explanation to each the relevant topics, for the first topic: Thevenin's Equivalent, it is to zero the sources in the original network and the computing the resistance between the terminals. This is because when zeroing a voltage source it becomes a short circuit or an open circuit. Following Thevenin's Equivalent, Norton's Equivalent would be complementary, where one would determine the short-circuit current and then zero the sources to find the Thevenin resistance and use Vt /Rt = In, to find the current source. Lastly, the Power Transfer Function is to find when the maximum power from a two-terminal circuit is held. So in theory, the maximum power transfer theorem states that the maximum amount of power will be dissipated by a load resistance if it is equal to the Thevenin or Norton resistance of the circuit. To derive R load = Rth, take a Thevenin equivalent circuit. P load = (I^2) (R load) = (Vth / Rth + Rload)^2 * Rload by plugging in what I was, using voltage divider. Then, V^2/ ((Rth^2/Rload) + 2Rth + Rload). This then means that the power load maximum is proportional to the result of the denominator. If we take differentiate Rload in the denominator, we get –(Rload/Rth) ^2 + 1. We then get multiply and take the square root to obtain, Rload = +/- Rth.

Part 1: Basics of Equivalent Circuits

1. Ideally for the first part I wanted to obtain a circuit which includes the following: V1 = 5V, R1 = R2 = 1kΩ, and R3 = 2 kΩ and should resemble Figure 1.

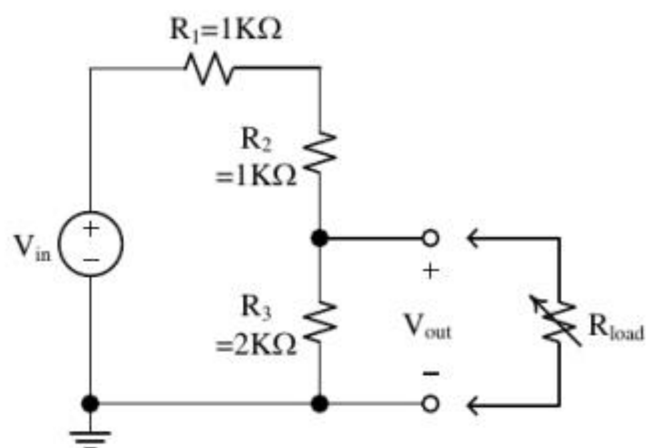


Figure 1: Circuit for part 1

Theoretically we obtain Vout by taking the voltage divider where, V = (R3/ (R1 + R2 + R3) * Vin). This will give us the theoretical value of Vout to be 2.5V. However, when I measured Vout I obtained it to be 2.48V. This could be because the values for R1, R2, and R3 measurements were not exact. R1 = 0996 kΩ, R2= 1.001kΩ, and R3 = 1.98kΩ. Hence, the value of Vout was off by 2.5V - |2.48V| = 0.02V.

2. In the second part of the first part, we were to measure the short circuit current, Is, at the output. I did this using two methods, a theoretical value and experimental value. For this part I used the same values as Figure 1, and obtained that Isc = 5V / 2kΩ = 2.5mA. Connecting the ammeter to the output terminals, in parallel with R3, I obtained Isc = 2.48mA. Using this calculation and the Vout, I used Rt = Vout/ Isc = 2.48V / 2.48mA = 1kΩ.

3. The third part of this lab was to draw the circuit for the Thevenin equivalent and Norton equivalent. Here in figure 2, we are able to draw them with respect to the output terminals.

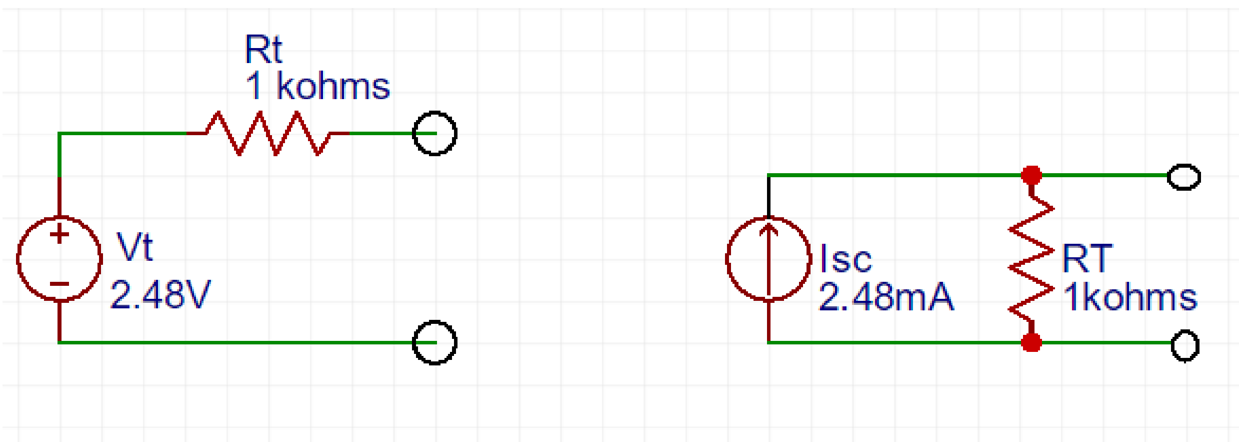


Figure 2: Left (Thevenin) and Right (Norton)

4. For the fourth part of the lab, we are to connect a 10kΩ potentiometer and set it to 1kΩ. Then connect this in parallel with R3 to calculate the power, Pload, dissipated in Rload. Ideally, I wanted the potentiometer set at 1kΩ, however I got it as close as 0.98 kΩ. Experimentally, I obtained Vout to be 2.6V and the P = V^2 / R = (2.6 V) ^2 / (0.98 kΩ) = 0.0689 W.

5. The fifth part asks us to use Excel for a quick computation of the vary points Rload vs Pload have. In Figure 3, we see the chart, where x-axis is Rload, measured in Ω, and y-axis is in Pload, watts.

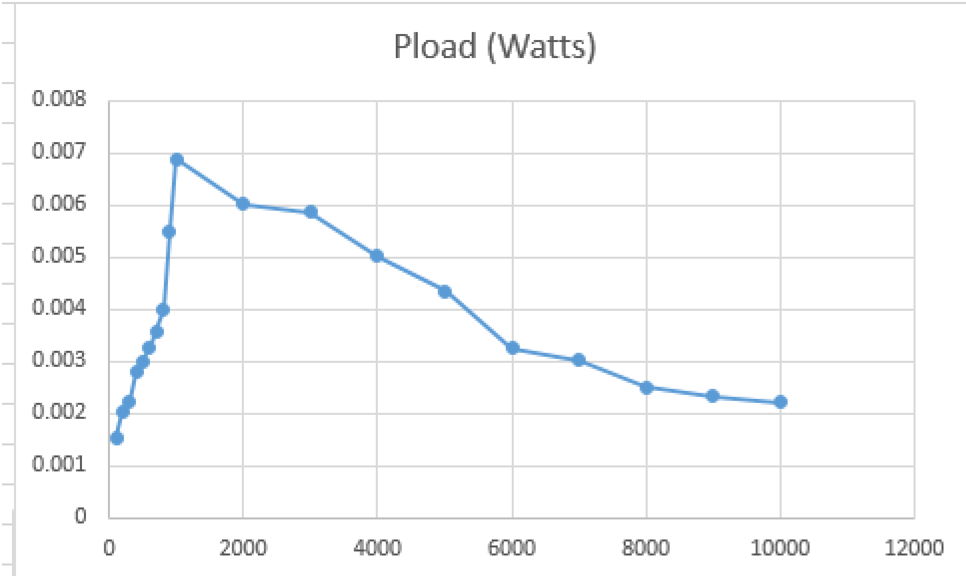


Figure 3: Graph of Pload vs. Rload

Rload (Ω)	Pload (Watts)
100	0.00153
200	0.00201
300	0.00223
400	0.00278
500	0.003
600	0.00325
700	0.00358
800	0.004
900	0.0055
1000	0.00689
2000	0.00602
3000	0.00587
4000	0.00502
5000	0.00435
6000	0.00324
7000	0.00302
8000	0.0025
9000	0.00232
10000	0.0022

Figure 4: Record of all measurements taken to achieve Figure 3

6. My theoretical maximizing of Rload value was to have dPl/dRl = 0, which would be the load resistance that absorbs the maximum power from the two-terminal circuit. As we take, Pload = (Vt / Rt + Rload) ^2*Rload, we maximize the amount of power dissipated when Rload is nearing Rt. Here we have Pload =

(Vt)^2 / (Rt + 0 (Rload)) = (2.5) ^2 / (1kΩ) = 0.00625 W. Compared to my value 0.00689 W, the discrepancy was 0.00625 W – 0.00689 W = 0.64 mW or 90.71%. The discrepancy could have been due to the voltage source not being precise as we measured 2.6V for our source and the potentiometer at 0.98kΩ rather than 1kΩ.

Part 2: Realistic Voltage Source

1. For this part we were to obtain a circuit that is identical to Figure 5, from this we were to determine the open-circuit voltage Vt = Voc. Measuring the Thevenin voltage by measuring the open circuit voltage across the 9V battery, I obtained Vt = 8.95V

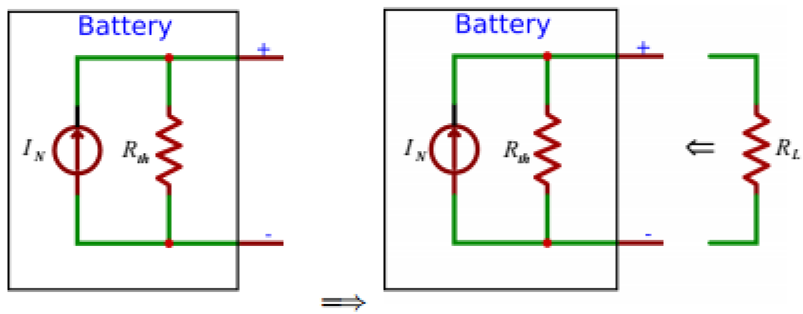
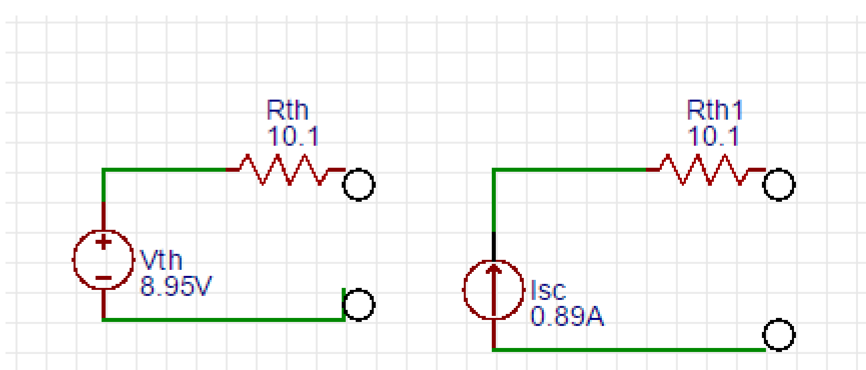


Figure 5: Ideal Circuit for a 9V battery in an open circuit

2. The second part of this lab was to use the same ideal short-circuit as Figure 5 (right picture) and measure for In. From here, I obtained the In to be 0.89A with the Rload being 1kΩ. Then using the theoretical value, we can compute Rth by Rth = Voc/ In = 8.95V / 0.89A = 10.1Ω.

3. These are the circuit diagrams of Thevenin and Norton equivalent of the battery:



Part 3: Finding Open Circuit

Unfortunately, due to not having “black boxes from the TA, Armando specifically designed a circuit for us students to experiment with and obtain the values of Thevenin voltage, I short circuit, and Rth. The ideal circuit can be seen in Figure 6. The measured values of Voltage source were not ideal but approximately close enough. Vs = 9.99V, R1 = 998Ω, R2 = 990Ω, R3 = 993Ω, R4= 1.97kΩ, R5 = 1.98kΩ, and lastly R6 = 1.97kΩ.

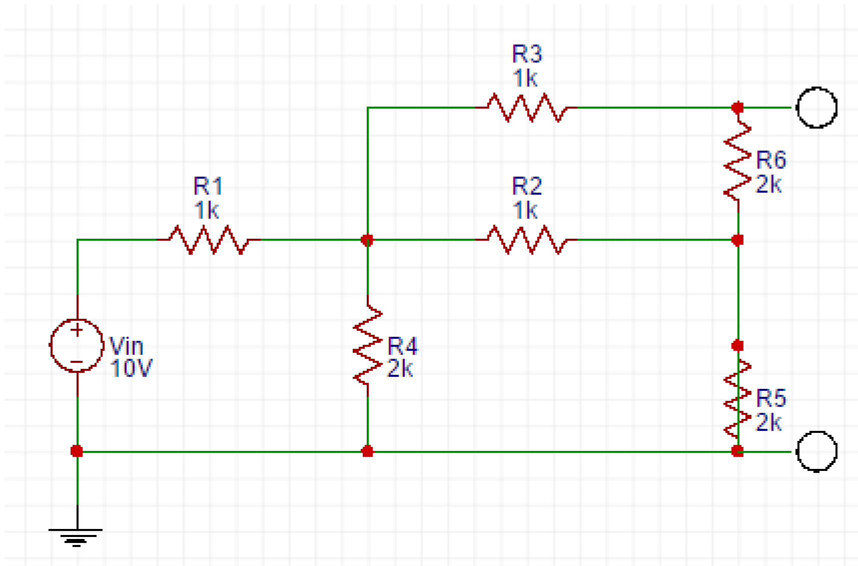
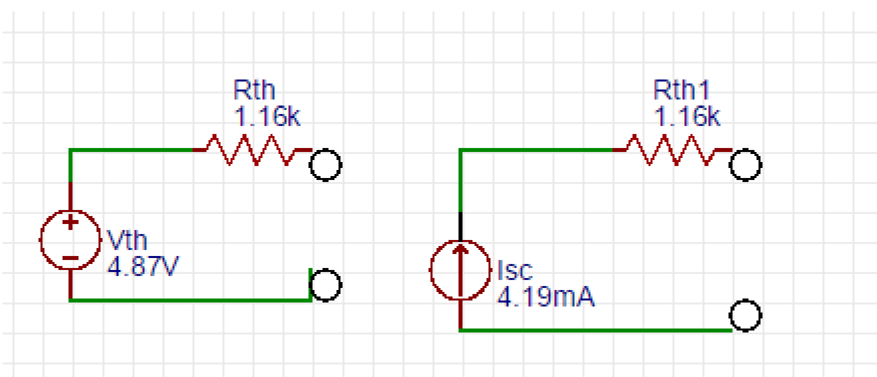


Figure 6: Ideal circuit for part 3

Here, I designed the circuit and experimentally obtained Voc = 4.87V. Then I measured the short circuit current to be 4.19mA. With these experimental values, I could obtain Rth by the equation Voc/ Isc = (4.87V/ 4.19mA) = 1.16kΩ. Lastly, the thevenin and Norton equivalent circuits of the Figure 6 are as is:



Conclusion

In total, this lab demonstrated the fundamentals of Thevenin, Norton equivalent circuits; along with power maximization. By being able to experimentally obtain these values in circuit, we proved that the theoretical values were not too off. I liked that this allows us to calculate values theoretically, without having to build circuits and verify that the complete equivalent values do correctly model an open/short circuit. We also were familiarized with maximum power transfer and this heled understand that as the load resistance is equal to the Thevenin or Norton resistance, it will produce the maximum amount of power. For future labs, it would be great if we could get back up batteries so that the students can work on the initial experiments.