Student's Name: Date:

Introduction to Circuit Analysis Laboratory

Lab Experiment 11

Thevenin's Theorem and Maximum Power Transfer

11.1. Thevenin's Theorems

Thevenin's Theorem is applied to analyze a load does not care where it gets its energy from. As a matter of fact, as long as a load gets the same required energy, it "does not know" what circuit it is connected to. To this, Thevenin said that instead of using the original circuit to supply the required energy to the load, he will substitute the original circuit with a battery in series with a resistor, each of the proper value of course, and this combination will supply the load with the same required energy as the original circuit.

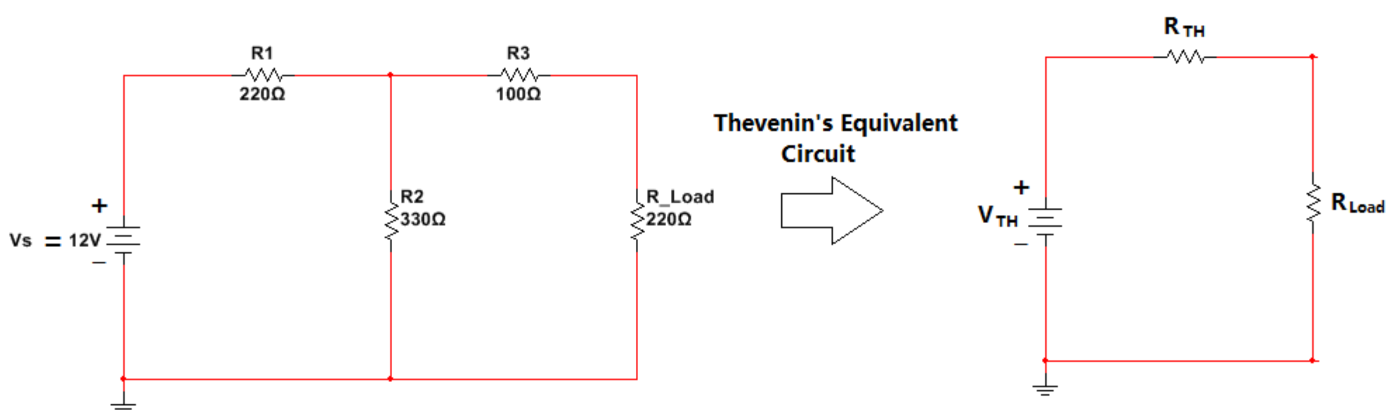


Figure 11.1 – Thevenin's Equivalent Circuit

11.2. Maximum Power Transfer, MTP

One important fact of circuit analysis is to find the conditions that should be imposed on the source and load resistance to ensure that it will deliver the maximum power to the load.

The maximum power transfer theorem states that *a load will receive maximum power from a network when its resistance is exactly equal to the Thevenin resistance of the network applied to the load.*

$$\boldsymbol{R_{L(MPT)} = R_{TH}}$$

Formula 11.1 – Load resistance at maximum power

If the load resistance is equal to the Thevenin's resistance, then the voltage across the load resistance, at maximum power, is half of the Thevenin's voltage:

$$\boldsymbol{V_{L(MPT)} = \frac{V_{TH}}{2}}$$

Formula 11.2 – Load voltage at maximum power

Now, we use the power formula to find the maximum power, MPT:

$$\boldsymbol{P_{L(MPT)} = \frac{{V_{L(MPT)}}^2}{R_{L(MPT)}}}$$

Formula 11.3a – Maximum Power Transfer

We can also substitute $V_{L(MPT)}$ and $R_{L(MPT)}$ with the Thevenin's equivalent values:

$$P_{L(MPT)} = \frac{\left(\frac{V_{TH}}{2}\right)^2}{R_{TH}} = \frac{\frac{{V_{TH}}^2}{4}}{R_{TH}} = \frac{{V_{TH}}^2}{4 \times R_{TH}}$$

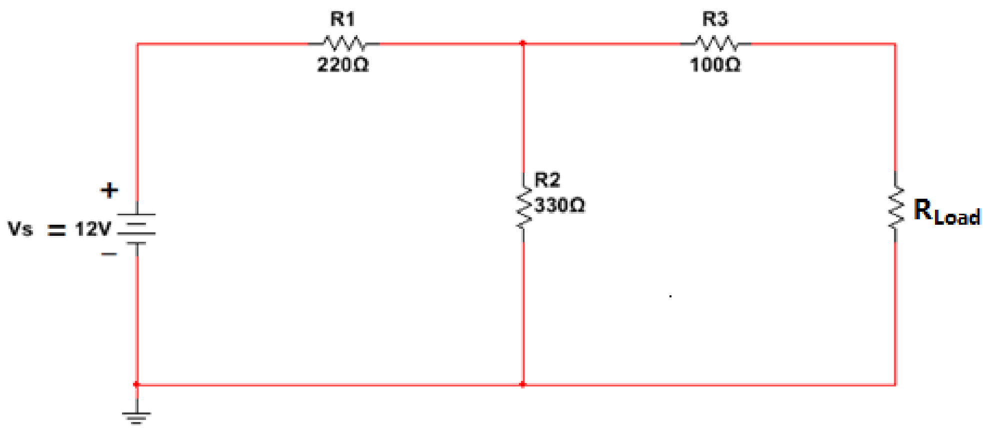
$$\boldsymbol{P_{L(MPT)} = \frac{{V_{TH}}^2}{4 \times R_{TH}}}$$

Formula 11.3b – Maximum Power Transfer with Thevenin's equivalent values

Lab Experiment Procedure

Part 1: Original Circuit Measurements

Circuit 11.1 shows a circuit with a 12V battery connected to a series parallel circuit consisting of R_1, R_2 and R_3. This circuit feeds energy to a load resistor R_L (1 kΩ potentiometer). The expected values of load current, load voltage and power to the load are also shown. You will be asked to confirm these values in your write-up.



Circuit 11.1 Original Circuit Feeding Load Resistor

1. Obtain 220 Ω, 330 Ω, and 100Ω resistor from your components kit. Measure their resistance individually, and record the measured values in Table 11.1.
2. Obtain a 1 kΩ potentiometer and set the potentiometer to 500 Ω. Record measurement in Table 11.1.
3. Find the percentage of difference between the given and measured resistance and record result in Table 11.1:

$$\% \, difference = \left(\frac{R_{given} - R_{measured}}{R_{given}} \right) \times 100$$

Given Resistance	Measured Resistance (Include unit)	% difference
R1 = 220 Ω		
R2 = 330 Ω		
R3 = 100 Ω		
R_{Load} = 1 kΩ pot		

Table 11.1 – Resistance measurement

4. Build Circuit 11.1 in a protoboard.
5. Prepare the DMM and circuit to measure current.
6. Measure the current through R_{Load}. Record measurement in Table 11.2
7. Prepare the DMM and circuit to measure voltage.
8. Measure the voltage across R_{Load}. Record measurement in Table 11.2
9. Multiply the voltage and the current through R_{Load} to obtain the power. Record the power in Table 11.2

	Voltage across the load resistance, V_L	**Current through the load resistance, I_L**	**Power dissipation at the load resistance, P_L**
Measured Value (Include Unit)			

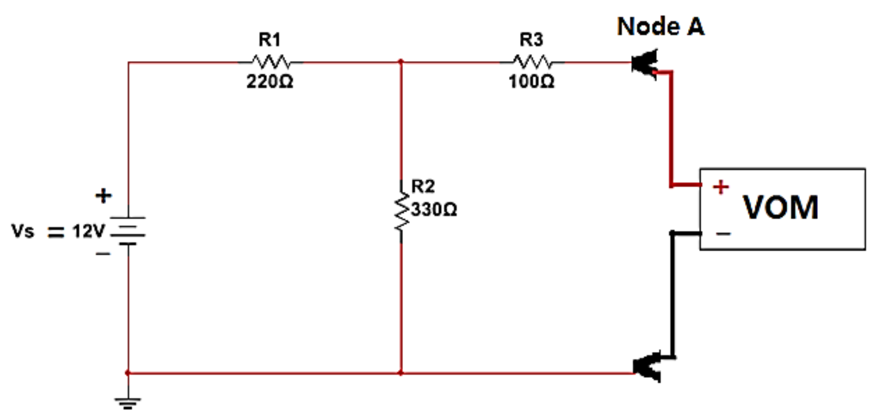
Table 11.2 Original Circuit Measurements

Part 2 - Thevenin's Equivalent Circuit

Circuit with R_{Load} Removed - Thevenin's Voltage

Circuit 11.2 shows the circuit with the load resistor removed. The open circuit voltage from Node A to ground is the Thevenin Voltage [V_{TH}].

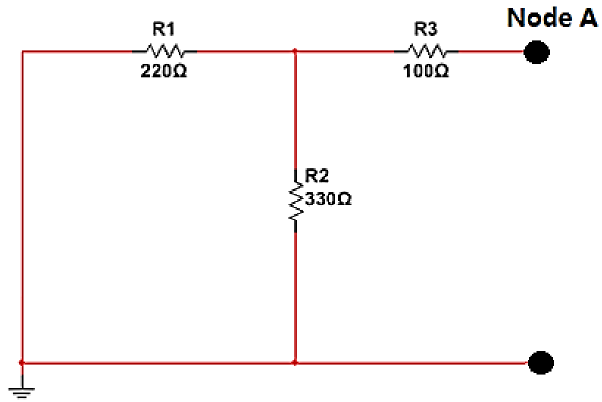
10. Remove the load resistor, 220 Ω, from the circuit and place a jumper wire where the connections of R_{Load} were. Check Circuit 11.2 for reference
11. Prepare the DMM to measure voltage (VOM)
12. Measure the voltage across the open circuit where R_{Load} was connected, between Node A and ground. This voltage is known as the Thevenin's voltage.
13. Record this measured value in Table 11.3.



Circuit 11.2 Thevenin Voltage Measurement

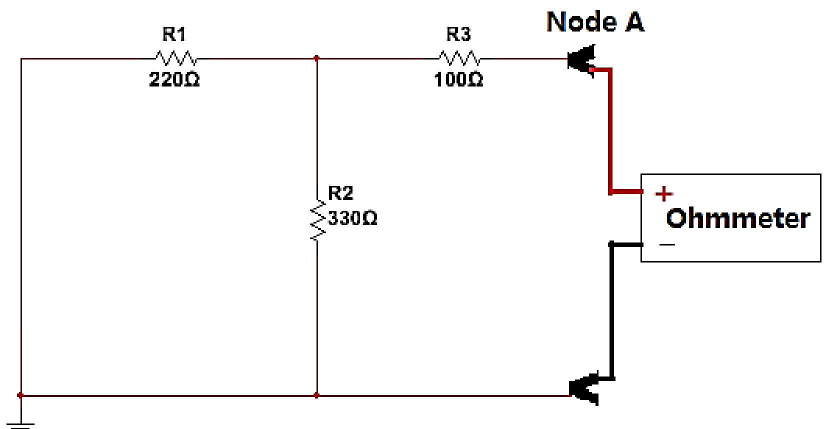
Measuring the Thevenin's resistance

14. Move one terminal of R1, the one that is connected to + power, to ground. Check Circuit 11.3 for reference.



Circuit 11.3. Remove power source from Circuit 11.2

15. Prepare the DMM to measure resistance.
16. Measure the resistance in between the open circuit where R_{Load} was connected, between Node A and ground. This resistance is known as the Thevenin's resistance.



Circuit 11.4. Thevenin's resistance measurement

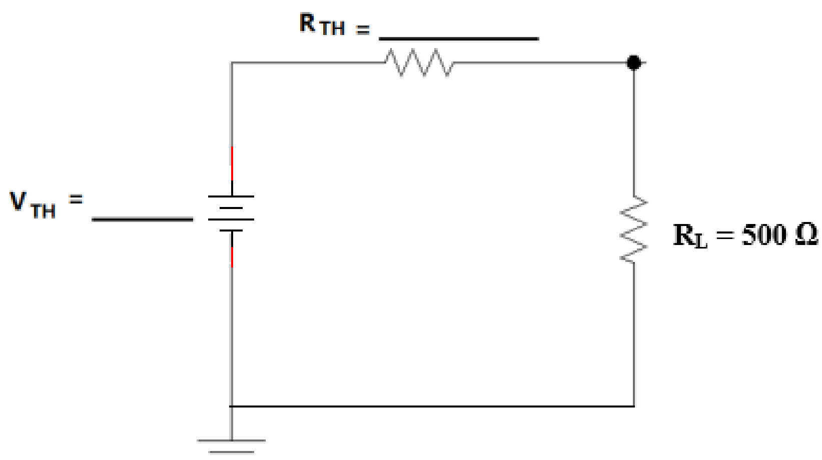
17. Record this measured value in Table 11.3 as R_{TH}
18. Disassemble the circuit, turn off of lab equipment, organize the equipment leads, and organize the lab components.
19. Proceed with calculations.

Thevenin's Equivalent Circuit Measurements		
	Voltage across the open circuit Thevenin's voltage, V_{TH}	**Resistance between the open circuit Thevenin's resistance, R_{TH}**
Measurements (Include all unit)		

Table 11.3 Thevenin Equivalent Circuit Measurements

Calculating the voltage, current, and power at the R_{Load} using the Thevenin's Equivalent circuit

20. Fill up the Circuit 11.5, which is the Thevenin's equivalent circuit, with measured values from Table 11.3.



Circuit 11.5 – Thevenin's equivalent Circuit

21. Calculate the voltage, current, and power through $R_L = 500\Omega$

Show calculations for R_L here:

22. Record calculation in table 11.4

Load Resistance calculation using the Thevenin's Equivalent Circuit			
	Voltage across the load resistance, V_L	**Current through the load resistance, I_L**	**Power dissipation at the load resistance, P_L**
Calculations (Include all unit)			
Table 11.4 – Load analysis from the Thevenin's Equivalent Circuit			

23. Record the value of V_L, I_L, and P_L from Table 11.2 and Table 11.4 into Table 11.5. Also and calculate the percent of difference between the Original Circuit and the Thevenin's Equivalent measurement.

Load Resistor Analysis			
	Voltage across the load resistance, V_L	**Current through the load resistance, I_L**	**Power dissipation at the load resistance, P_L**
Original Circuit Table 11.2			
Thevenin's Equivalent Table 11.4			
$\%\ \boldsymbol{difference}$			
Table 11.5 – Load Resistance Analysis			

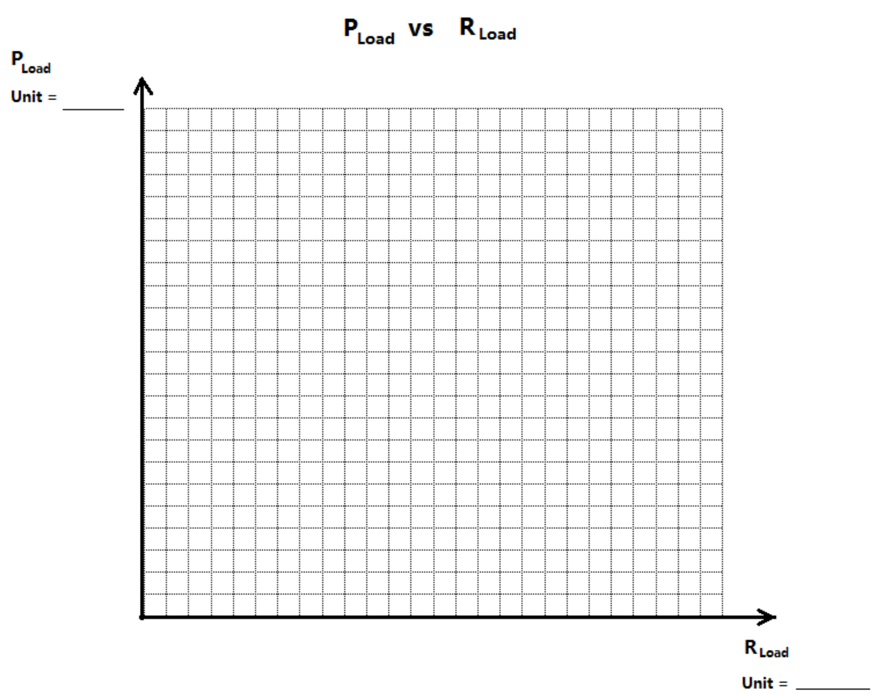
Part 3 – Maximum Power Transfer Analysis

24. Build the Thevenin's equivalent circuit with its respective R_{TH} and V_{TH} values as shown in Circuit 11.5. Note: if you don't have the exact R_{TH} resistor in your components' kit, you can use another potentiometer, resistors connected in series, and set it to the resistance of R_{TH}.
25. Set the R_{Load} potentiometer to 0 **Ω**
26. Prepare the multimeter and circuit to measure voltage.
27. Measure the voltage across R_{Load} and record the measurement in Table 11.6
28. Increment the resistance of R_{Load} according to Table 11.6, measure the voltage across R_{Load}, and record the measurement in Table 11.6.
29. Once all data are recorded, disassemble the circuit, turn off of lab equipment, organize the equipment leads, and organize the lab components.

Power Analysis Through R_{Load}		
R_{Load} Ω	**Measured V_{Load} (Include unit)**	**Calculated P_{LOAD} (Include unit)** $\textit{Load Power}, P_{Load} = \frac{(V_{Load})^2}{R_{Load}}$
0 Ω		
100 Ω		
180 Ω		
270 Ω		
390Ω		
470 Ω		
560 Ω		
680 Ω		
820 Ω		
1000 Ω = 1 kΩ		

Table 11.6 – Power dissipation through R_{Load}

30. Using the graph paper below, plot P_{Load} versus R_{Load}



Graph 11.1 – Maximum Power Transfer Plot - P_{Load} vs R_{Load}

31. From Graph 11.1, estimate or measure the *Maximum Power Transfer* through load resistor, R_{Load} and record the measurement in Table 11.7
32. Calculate the Maximum Power Transfer through the load resistor using Formula 11.3a or 11.3b. Record calculation in Table 11.7

Maximum Power Transfer Analysis		
Measured Maximum Power from Graph 11.1 (Include Unit)	**Calculated Maximum Power using Formula 11.3 (Include Unit)**	**% of difference**

Table 11.7 – Maximum Power Transfer Analysis for Circuit 11.1

Questions

1. From the Thevenin's Equivalent circuit, Circuit 11.5, would the polarity of V_{TH} affect the load voltage and current measurement? Explain your answer.
2. From Table 11.6, explain the power behavior with respect to the R_{Load}
3. Can you estimate the maximum power through the load by using the data from Table 11.6? How? Explain your answer.
4. Thevenin's equivalent circuit, Circuit 11.5, was used to obtain the power behavior for Table 11.6. If the original circuit, Circuit 11.1, was used instead of Circuit 11.5, would the power behavior be the same or different? Explain your answer.

Answer

Student's Signature: _____________ Lab Instructor's Signature _____________Date: _______

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