

OBJECTIVES

1. To apply Thevenin's theorem in solving circuit analysis.
2. To verify maximum power transfer theorem

INTRODUCTION

Thevenin's theorem is one of the circuit analysis techniques which reduce any linear network to one equivalent circuit that has only one voltage source and one series resistor as shown in Figure 1. According to Alexander Sadiku (2005),

“Thevenin's theorem states that a linear two-terminal circuit can be replaced by an equivalent circuit consisting of a voltage source V_{TH} in series with a resistor R_{TH} , where V_{TH} is the open-circuit voltage at the terminals and R_{TH} is the input or equivalent resistance at the terminals when the independent sources are turned off.”

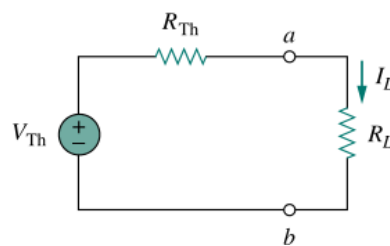


Figure 1

By using Thevenin's theorem the maximum power transfer can be obtained. It is stated that the maximum power received across the load is the power when the load resistance is same with the Thevenin resistance (Robbins & Miller, 2003).

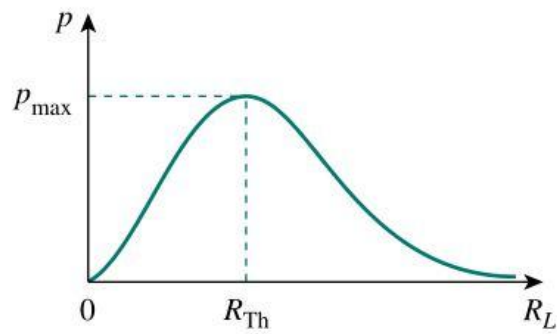


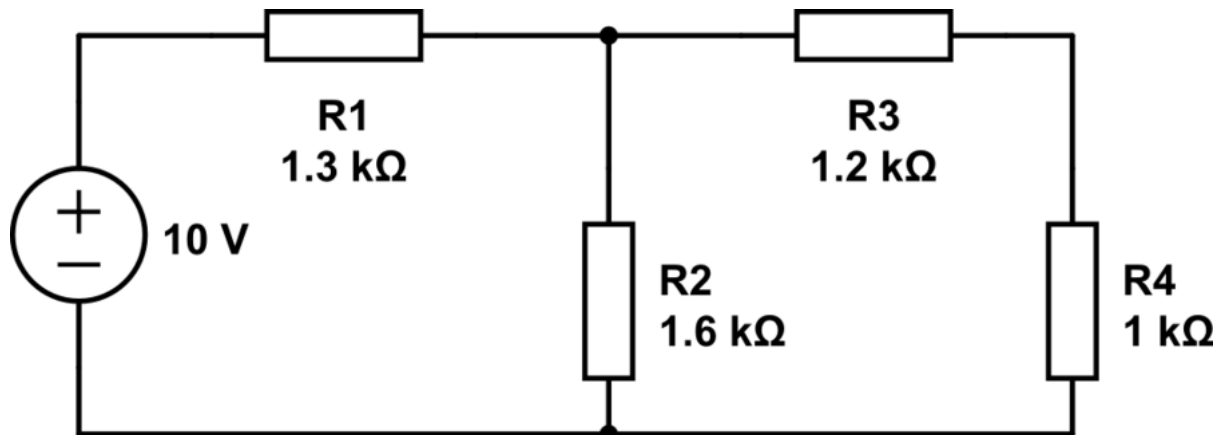
Figure 2

The figure 2 shows that when the load resistance R_L equals the Thevenin resistance R_{Th} the power transfer that takes place is the maximum. Shown below is the maximum power transfer formula.

$$p = i^2 R_L = \left(\frac{V_{Th}}{R_{Th} + R_L} \right)^2 R_L \quad \text{----- (Eq 1)}$$

By differentiating the p in the above equation (eq1) , it concluded that maximum power transfer takes place when the load resistance, R_L equals the Thevenin resistance, R_{Th} .

PROCEDURE



Part A (Calculation)

1. The current flowing through RL transistor is calculated using Thevenin's Theorem
2. The Maximum Power Transfer at terminal AB of the circuit is calculated
3. The values are recorded in Table 1.

Part B (Measurement)

1. The circuit was constructed as in Figure 1.
2. RL was removed for an open circuit connection and Thevenin's voltage (V_{th}) was measured between terminal A-B.
3. V_1 was short circuited and the Thevenin's resistance (R_{th}) was measured between terminals A-B.
4. The measured values were recorded in Table 1.
5. Thus, the Thevenin's equivalent circuit was constructed.
6. The load resistance (R_L) was replaced with DRB.
7. The value of Decade Resistance Box (DRB) was manipulated as in Table 2 and the current I_{RL} was measured.
8. The values obtained were recorded in Table 2.
9. The graph Power versus load resistor R_L was plotted.

CALCULATION

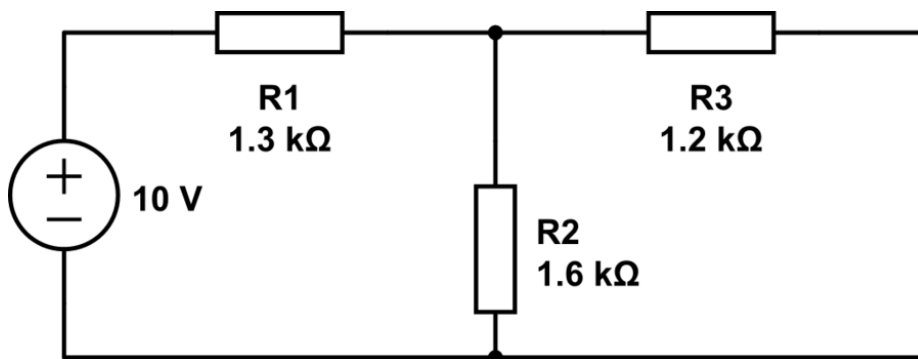


Figure 3- R_L removed to find R_{TH}

$$R_{TH} = (1.3K // 1.6K) + 1.2K$$

$$= 1.9172K$$

$$V_{TH} = \frac{1.6K}{1.3K+1.6K} \times 10$$

$$= 5.52 V$$

$$V_{RL} = \frac{1K}{1.917K+1.6K} \times 5.52$$

$$= 1.892V$$

$$I_{RL} = \frac{1.892}{1000} = 1.892mA$$

Calculation For Maximum Power Transfer

$$I_{RL} = \frac{5.52}{1.917K+1.917K} = 1.44mA$$

$$\text{Maximum Power} = I^2 R_L$$

$$\text{Transfer} = (1.44 \times 10^{-3})^2 (1.917)$$

$$= 3.98mW$$

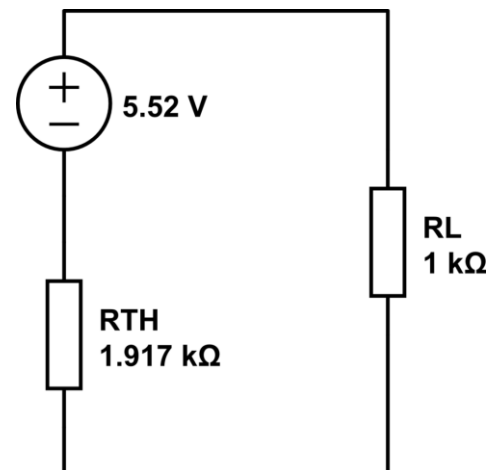


Figure 4-Thevenin Equivalent Circuit

RESULTS

	V_{TH}	R_{TH}
Measured Values	5.44 V	1.892 k Ω
Calculated Values	5.52 V	1.9172 k Ω

Table 1

$R_L(DRB), \Omega$	V_{RL}, V	I_{RL}, mA	P_{RL}, mW
100	0.28	2.73	0.764
500	1.16	2.27	2.629
700	1.49	2.10	3.133
1k	1.89	1.89	3.583
2k	2.81	1.40	3.935
3k	3.35	1.11	3.720
5k	3.96	0.78	3.088
7k	4.29	0.61	2.619
8k	4.41	0.54	2.380
9k	4.50	0.50	2.252
10k	4.58	0.45	2.062

Table 2

ANALYSIS

1. Based on Table 1, the measured Thevenin's resistance differs from the calculated value by 1.3% while the Thevenin's voltage has a difference of 1.45%. This is because every resistor has a tolerance value that varies from one another. It may be $\pm 5\%$, $\pm 10\%$ or $\pm 20\%$ depending on the colour code of the resistor. These tolerance values show how far the resistance value can be from its nominal value and this is often neglected when calculation method is used. Other than that, the carbon-core resistors that are used in this experiment are likely to experience large changes in value due to temperature variation. Robbins and Miller (2003) stated that the resistance of a carbon-core resistor can change as much as 5% when the temperature changes by 100°C .
2. From Table 2 and Graph 1, it can be observed that as the load resistance, R_L increases to $10\text{k}\Omega$, the voltage across the load, V_{RL} increases while the current flowing through the load, I_{RL} decreases because it obeys Ohm's Law ($V = IR$). It can also be seen that the maximum power delivered to the load is when R_L is $2\text{k}\Omega$ which is 3.935mW . Based on the definition of maximum power introduced in the theory, the circuit obeys the maximum power transfer theorem because its Thevenin's resistance, R_{TH} is $1.92\text{k}\Omega \approx 2\text{k}\Omega$.
3. Based on the theorem, maximum load power can only be obtained when the load resistance, R_L is equal to the internal resistance, R_i in this case Thevenin's resistance, R_{TH} . When the value of R_L is smaller than R_{TH} , most of the power ends up to be dissipated in the R_{TH} which results in smaller amount of power dissipated in R_L . Although the total power dissipated in the circuit is high, the amount of power dissipated in the load is low due to the small value of total resistance. However, when the value of R_L is increased higher than the value of R_{TH} , more power is transferred to the load, but the value is low because of the high total resistance in the circuit.

CONCLUSION

Thevenin's theorem is applied to circuit to find the Thevenin's voltage, V_{TH} and the Thevenin's resistance, R_{TH} which by those values, an equivalent circuit consisting of V_{TH} and R_{TH} and load resistance, R_L can be constructed to find the maximum power transfer. It may be considered that Thévenin's theorem have no obvious advantages compared with, Kirchhoff's laws. However, the theorem can be used to analyse part of a circuit and in much more complicated networks, the method of replacing the supply with a constant voltage source (V_{TH}) in series with a resistance (or impedance) is very useful. The maximum power transfer theorem is used to find the maximum power delivered across the load resistance which occurs when the Thevenin's resistance, R_{TH} is equal to the R_L . The maximum power transfer theorem can only be applied when the Thevenin's theorem is applied before-hand to isolate a portion of the network and replace it with an equivalent network.

REFERENCES

1. Robbins, A., & Miller, W. (2003). *Circuit analysis with devices: Theory and practice*. Clifton Park, NY: Thomson/Delmar Learning
2. Alexander, C. K. A. M. N. O. S. (2007). *Fundamentals of electric circuits*. New York: Mcgraw-Hill



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CIRCUIT THEORY

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LABORATORY REPORT:

**THEVENIN'S THEOREM AND MAXIMUM POWER
TRANSFER**

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