Using MUTISIM software to reinforce use and application of Thevenin's theory in electrical circuits

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Abstract:

MULTISIM is a computer simulation software that among other things simulates the performance of electric circuits. This article demonstrates using MULTISIM as an educational tool to enhance student learning process. The specific example subject demonstrated in this article is Thevenin's circuit analysis theory.

The traditional textbooks only demonstrate the final result of a circuit analysis using MULTISIM. The approach taken in this article is different. This article demonstrates using the software as an aid to check the intermediate steps of the hand calculation techniques that must be used if no computer software were being used. An example which was a part of a lecture is presented where every step of finding the Thevenin's equivalent circuit using a hand calculation technique was verified by simulating the step in MULTISIM.

By using the mixed approach of using a hand calculation technique and MULTISIM, the students have the opportunity to verify the accuracy of every step of the process which will improve the students' learning and will allow the students to find and correct their own error.

Keywords:

- MULTISIM
- Thevenin's theory
- Distance Learning
- Electrical Engineering
- Hardware Descriptive Language

Introduction:

The introductory electrical Circuits course for non-electrical engineering technology majors at the author's institution contains a weekly lab component. However, due to Covid-19 pandemic the whole class and the lab was converted to an online format. Consequently, the lab could not be held in a traditional laboratory setting.

It was decided to use MULTISIM simulation software in place of the physical lab. It was quickly discovered that not only MULTISIM can replace the traditional labs, but it can also be a valuable teaching aid in enhancing student understanding of circuit analysis techniques.

This article discusses and demonstrates the use of MULTISIM software to enhance student understanding and provide a verification technique for Thevenin's theory technique when multiple power sources are present. This article presents segments of selected lectures and labs using the combination of classical calculation techniques and MULTISIM.

Overview of supporting literature:

The supporting literature listed in the reference section of this article have numerous examples of using MUTISIM. However, they only demonstrate the final result of a circuit analysis using MULTISIM. The approach taken in this article is more detailed and unique from a teaching point of view by using the software as an aid in the verifying and if necessary correcting the hand calculation steps of finding an equivalent Thevenin circuit of a complex circuit.

Description of the innovative teaching approach:

The unique approach demonstrated in this article illustrates a hybrid use of MULTISIM where the software can be used to verify all the steps of a hand calculation technique that will enable the students to become more self-reliant in their studies.

Description of the hybrid approach

The basic idea behind Thevenin's theorem is to replace a circuit with an equivalent circuit consisting of an equivalent Thevenin resistor and an equivalent Thevenin voltage. Consider the circuit of figure 1. Assume that it is desired to find the current through R6 using Thevenin's theorem. The circuit can then be replaced by an equivalent Thevenin circuit shown in figure 2.

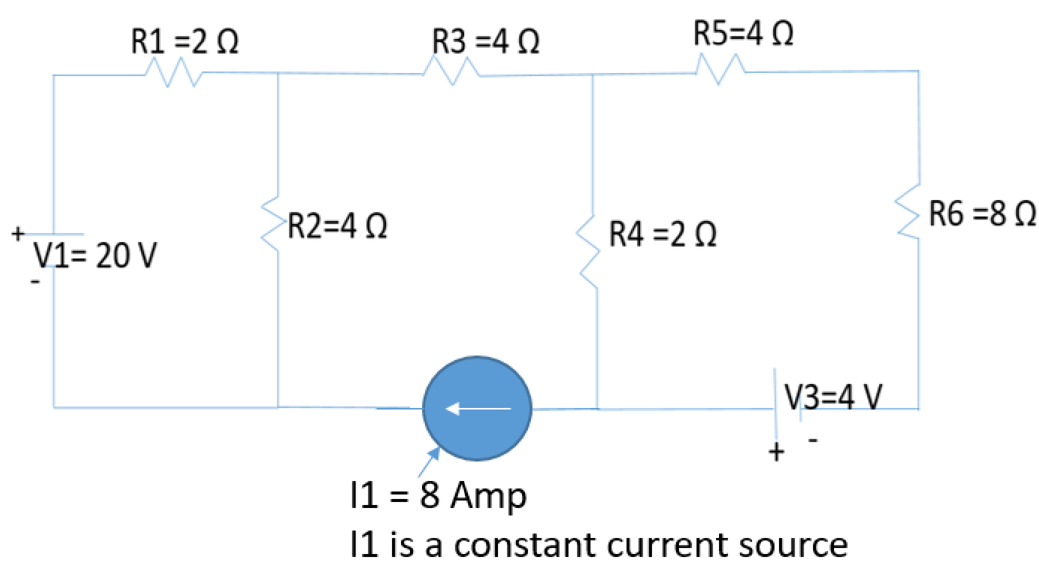

Figure 1: Circuit to be analyzed by Thevenin's theorem

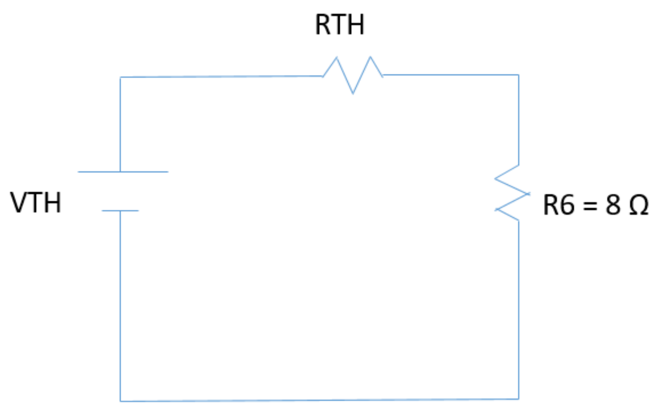

Figure 2: Equivalent Thevenin's circuit of figure 1

In order to calculate VTH, R6 should be removed from the circuit, and 2 open terminals are added in its place. The voltage across the 2 open terminals is VTH. Figure 3 illustrates the concept.

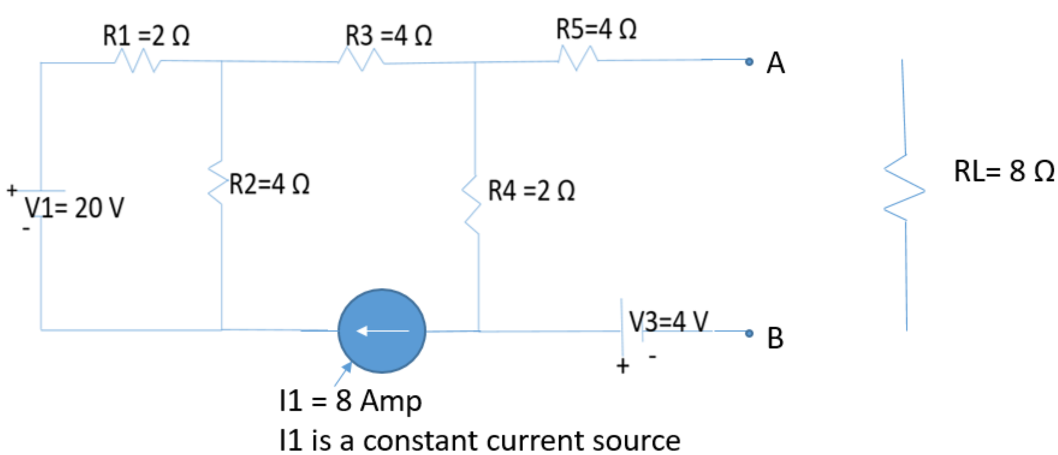

Figure 3: Voltage across open terminals A & B is VTH.

The voltage across A & B can be calculated and/or determined by using MUTLISIM. Figure 4 is a MULTISIM simulation that shows the voltage across A & B is 20 volts.

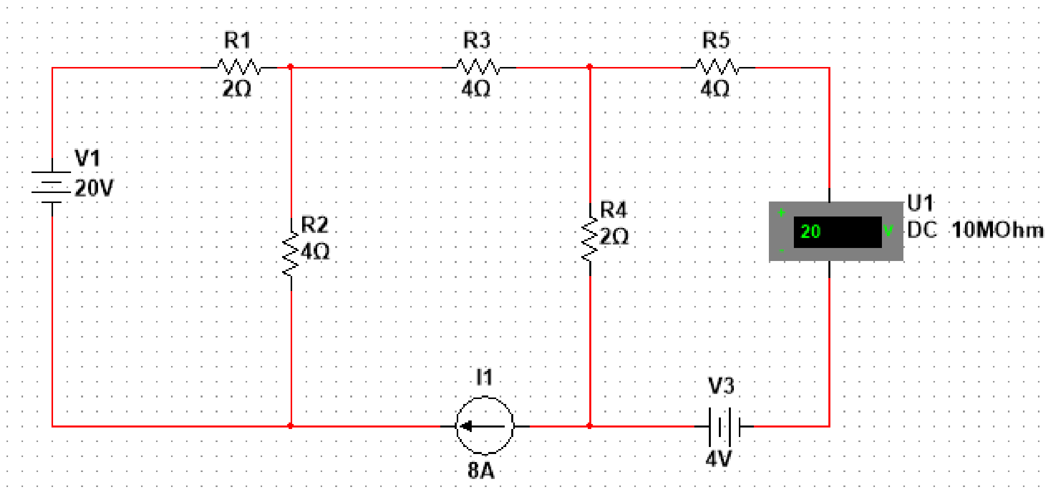

Figure 4: MULTISIM simulation of the voltage measurement across terminals A & B of figure 3

RTH is the resistance from the point of view of A & B when all the voltage sources are shorted out and the current source is opened. Figure 5 shows the circuit for calculating the resistance across A & B.

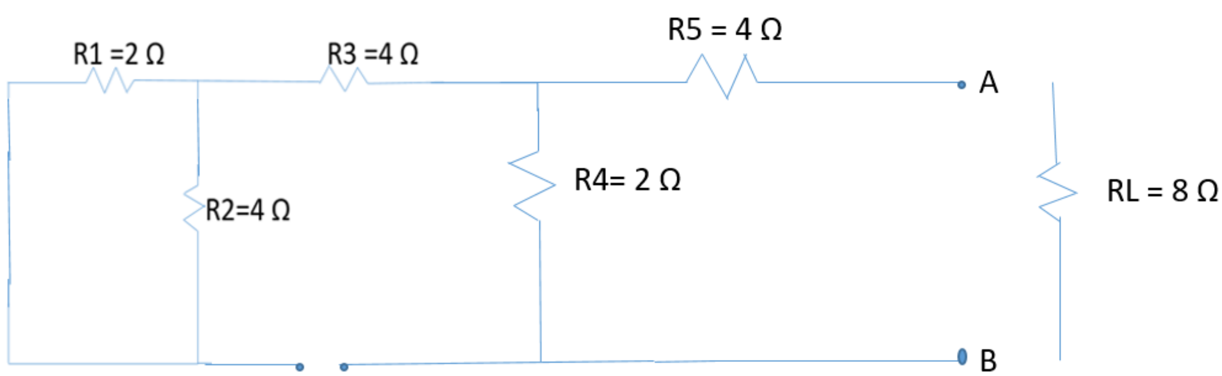

Figure 5: The total resistance across A & B is RTH

Figure 6 is the MULTISIM simulation of the circuit of figure 5.

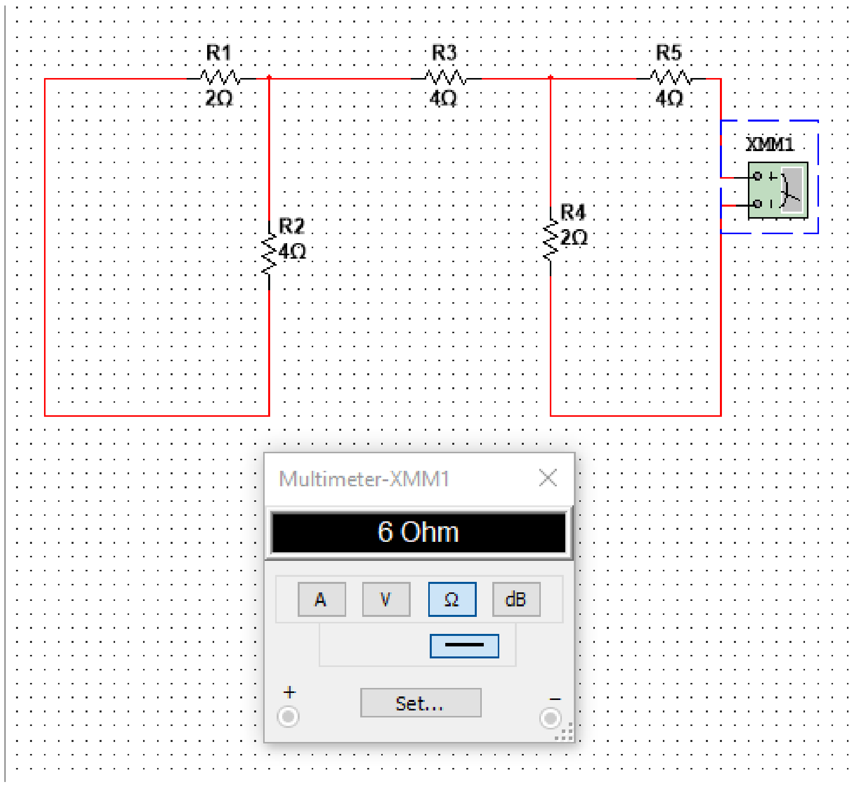

Figure 6: MULTISIM simulation of figure 5

As it is shown on Figure 6, RTH= 6 Ω.

Then the Thevenin's equivalent circuit is as shown in figure 7

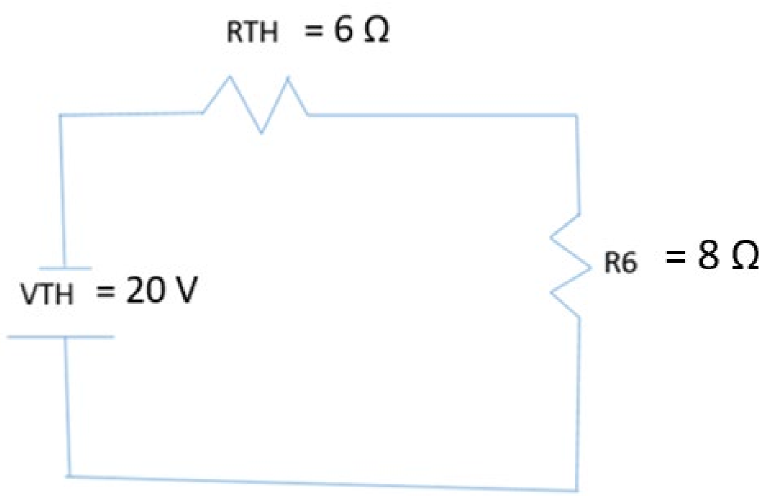

Figure 7: Thevenin's equivalent circuit of circuit of figure 1 for R6

The current through R6 can be calculated by Ohm's law as shown below.

$I_{R6} = V_{TH} / (R_{TH} + R6) = (20\ V) / (6\Omega + 8\Omega) = 1.43$ Amp

Figure 8 is the MULTISIM simulation of circuit of figure 1 with an ammeter measuring the current through R6. The MULTISIM simulation of figure 8, confirms the results obtained from Thevenin circuit of figure 7.

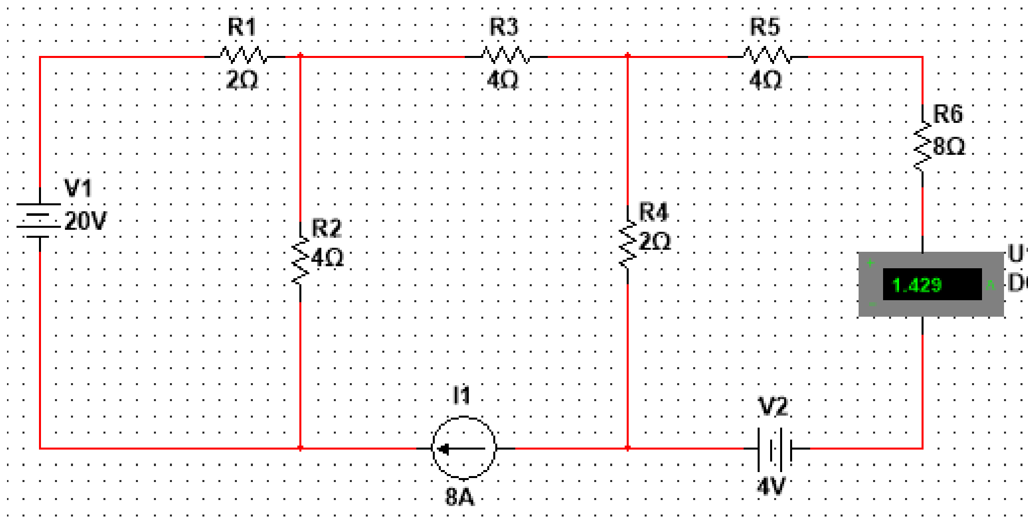

Figure 8: MULTISIM simulation showing current through circuit of figure 1

Taking the approach taken up to this point in the article has significant educational value. But this approach can be extended to enhance the students' abilities. Thevenin's voltage & Thevenin's resistance can be calculated and in fact should be calculated by manual techniques from an educational point of view. These manual techniques can be enhanced and verified by using MULTISIM. The material presented in the remainder of this article demonstrates the mixed use of hand calculation (manual) techniques and MULTISIM simulation for determining and checking the accuracy of physical interpretation of the circuits and their associated mathematical implementation used for calculating VTH & RTH.

Figure 9 further explains the concept of Thevenin's voltage.

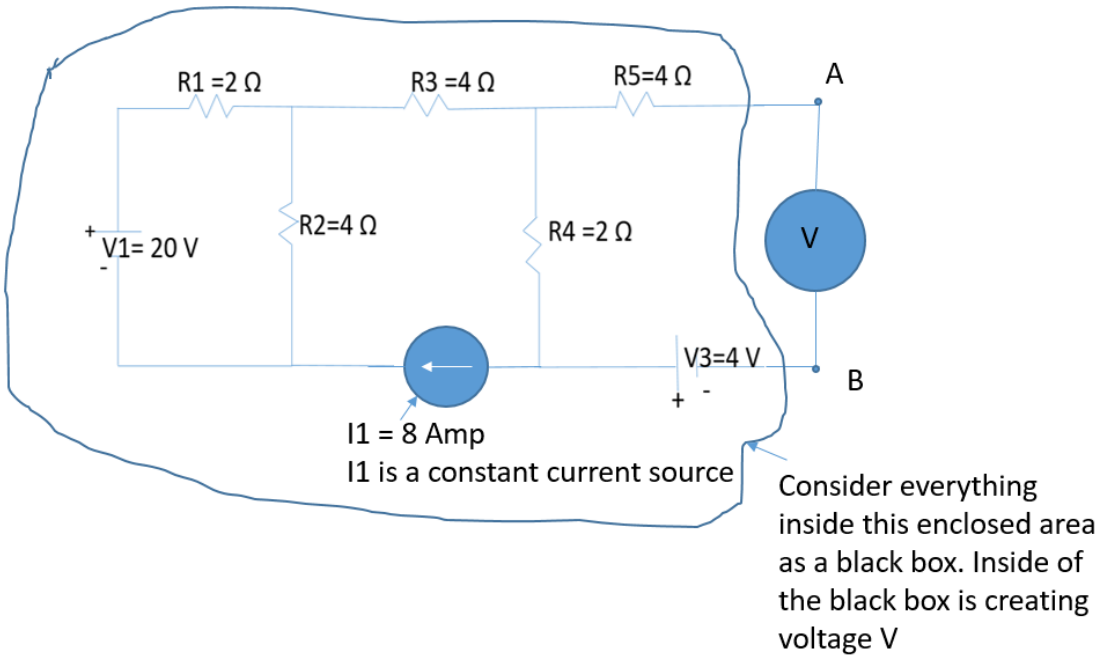

Figure 9: Voltage created by the components inside the black box is VTH.

Since points A & B are not connected (because R6 was removed in order to form the circuit for calculating V_{TH}), the voltage across A & B is a function of the voltage across R4 and the voltage source V3. Superposition principle will be used to calculate the voltage across R4.

There is a difference between how a current source and how a voltage source are treated when superposition technique is being used. When taking out a voltage source, the voltage sources is replaced by a short. When a current source is taken out, the location of the current source is treated as an open. Based on these rules, figure 10 is the circuit for calculating the current through R4 from voltage source V1 when the current source is not a part of the calculation.

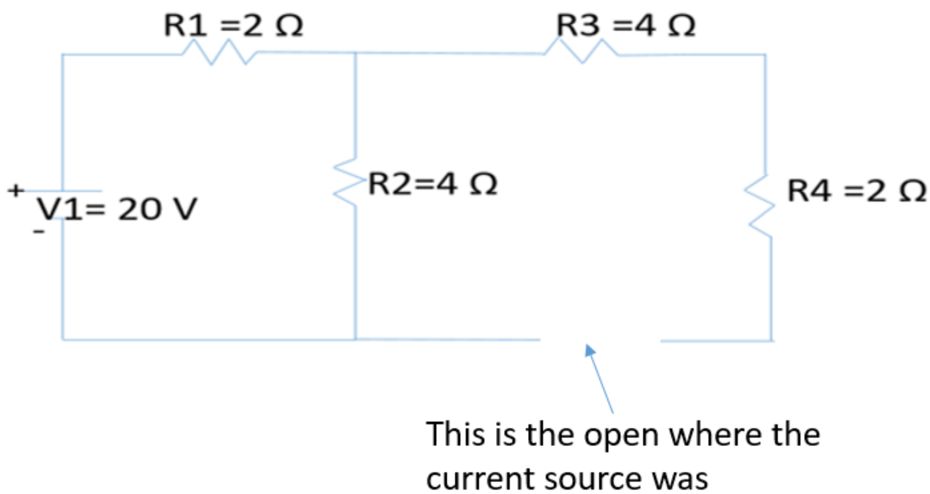

Figure 10: circuit for calculating the current through R4 from voltage source V1 when the current source is not a part of the calculation.

Because of the open, the effective circuit is the left portion of the circuit of figure 10. The effective circuit and the direction of current from V1 is shown in figure 11. Note that in MULTISIM the current goes from the positive pole to the negative pole and in figure 11, the direction of IT1 is chosen as shown to keep the chosen direction consistent with MULTISIM.

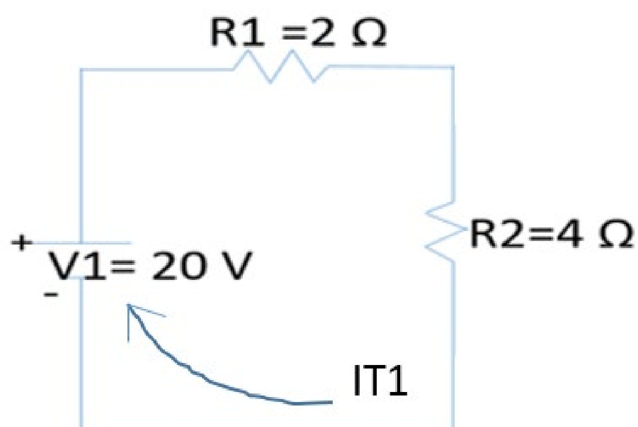

Figure 11: Effective circuit for the circuit shown in figure 10

IT1 = V1 / (R1 + R2)
IT1 = (20 V) / (2 + 4) = 10/3 Amp

Figure 12 shows the currents for the Thevenin's circuit from voltage source V1. As it can be observed on figure 12, there is no current through R4 and there is no voltage contribution from the current source for R4.

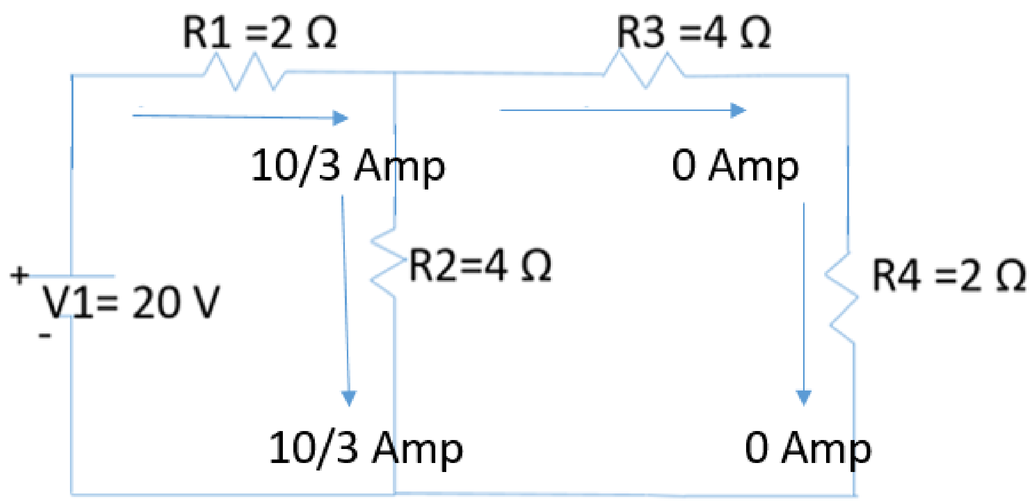

Figure 12: Currents for Thevenin's circuit from voltage source V1 calculated manually

Figure 13 shows the circuit of figure 12 simulated in MULTISIM. In the simulation of figure 13, the value of the current in the current source is set to zero (0) which has the same effect as shorting the location of the current source. The simulation of figure 13 confirms the results shown in figure 12. The presence of a "u" indicates a zero (0) reading for the ammetrs measuring the currents for R3 & R4.

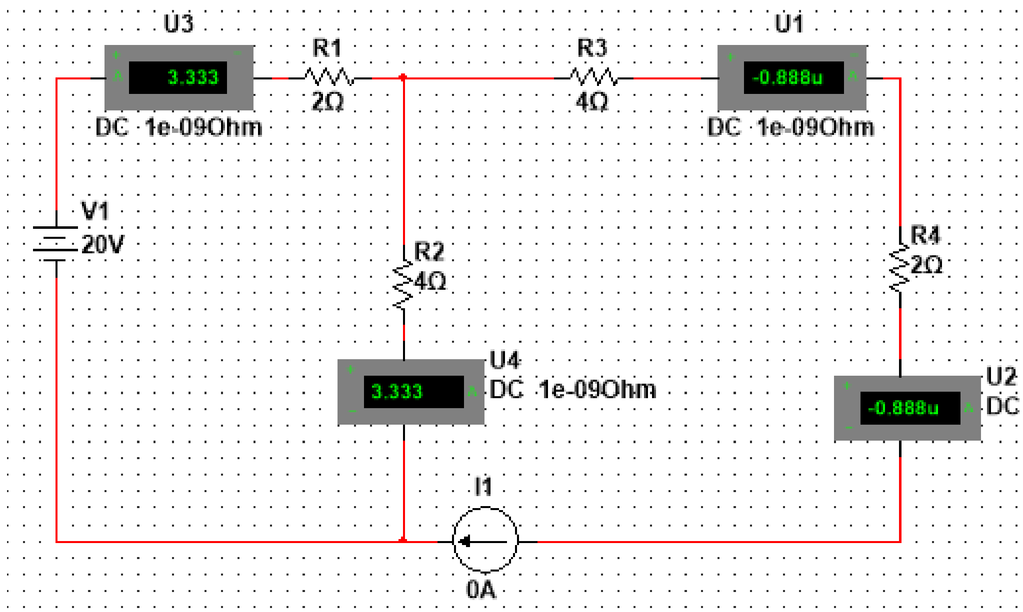

Figure 13: MULTISIM simulation of circuit of figure 12

Figure 14 is the circuit for calculating the current through R4 from constant current source I1

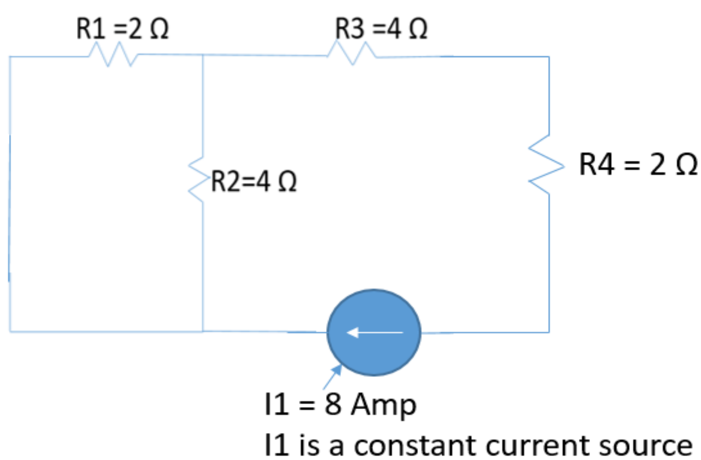

Figure 14: Circuit for calculating current through R4
from constant current source I1

R1 & R2 from the point of view of current source I1 are parallel.
Let us call the mathematical equivalence of R1 & R2, RT1 as shown in figure 15.

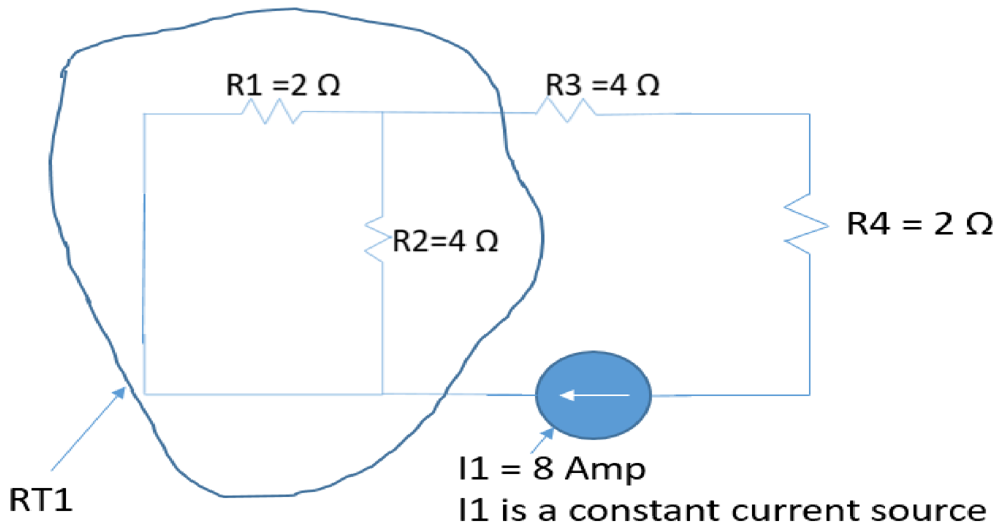

Figure 15: First step in manually solving the
Circuit of figure 14

The following shows the manual calculation of the currents through resistors R1, R2, R3 & R4.
1/RT1 = (1/R1) + (1/R2) = (1/2) + (1/4)
RT1 = 1.33 Ω
The voltage created both across R1 & R2= (I1)(RT1) = (8)(1.33) = 10.64 V
Current through R1 = (voltage across R1)/R1 = 10.64/2 = 5.32 Amp
Current through R2 = I1 – Current through R1 = 8 – 5.32 = 2.68 Amp
Current through R3 = Current through R4 = I1 = 8 Amp
Figure 16 shows the manually calculated currents and their direction from constant current source I1.

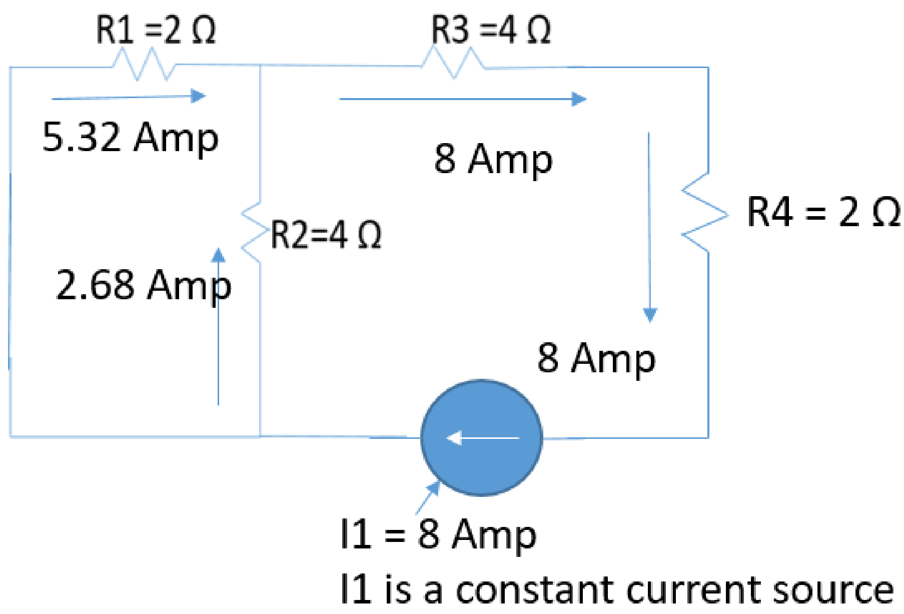

Figure 16: The manually calculated currents from I1

Figure 17 is the simulation of the circuit of figure 16 in MULTISIM by setting the current to 8 Amp, and by setting the voltage V1 to zero (0). A comparison of figures 16 & 17 shows that the results of the manual calculations and the MULTISIM simulation are the same.

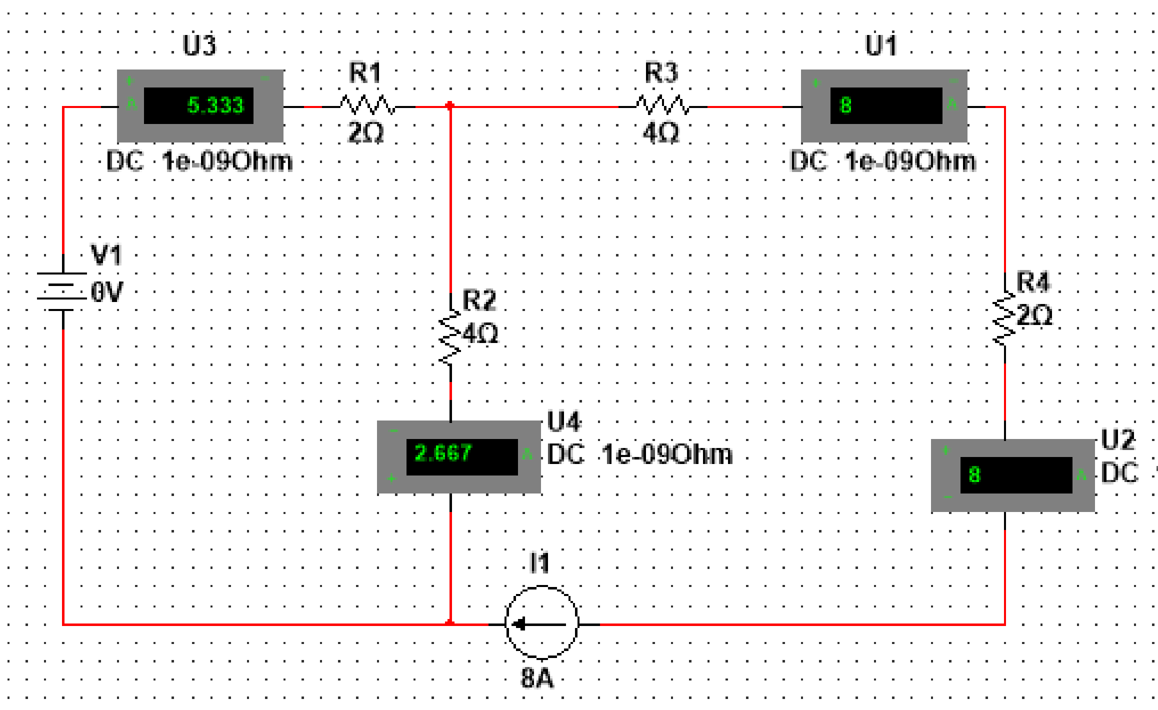

Figure 17: MULTISIM simulation of the circuit of figure 16

By algebraic summation of the results of figures 12 and 16, the total current shown in figure 18 for the complete circuit consisting of V1 & I1 can be obtained. Algebraic summation means accounting for the direction of the currents.

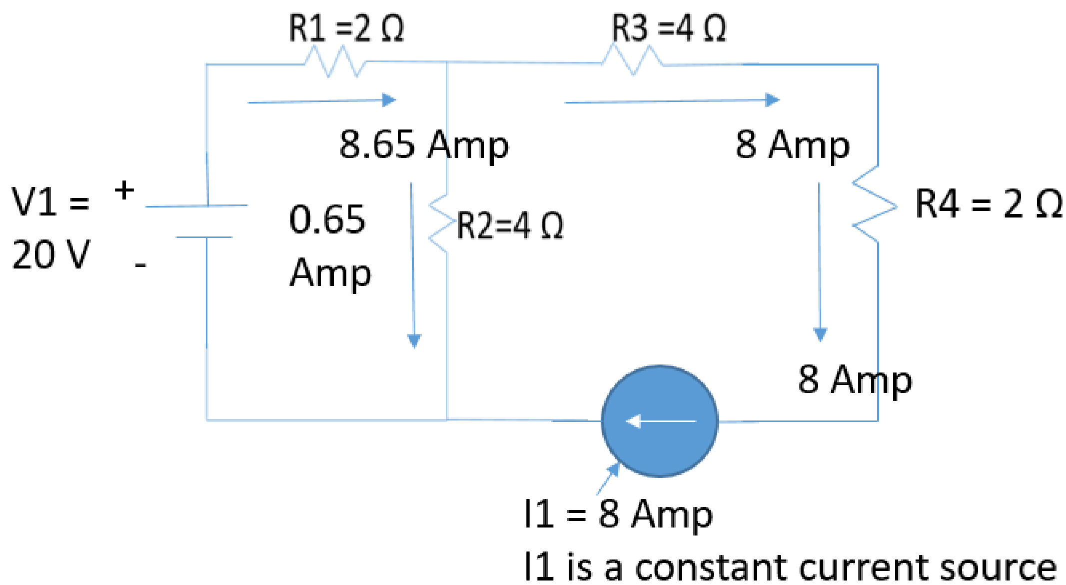

Figure 18: Currents for components from both V1 & I1

The results shown in figure 18 are simulated in MULTISIM and are shown in figure 19. A comparison of figures 18 and 19 show that the manually calculated results and the simulation results are the same.

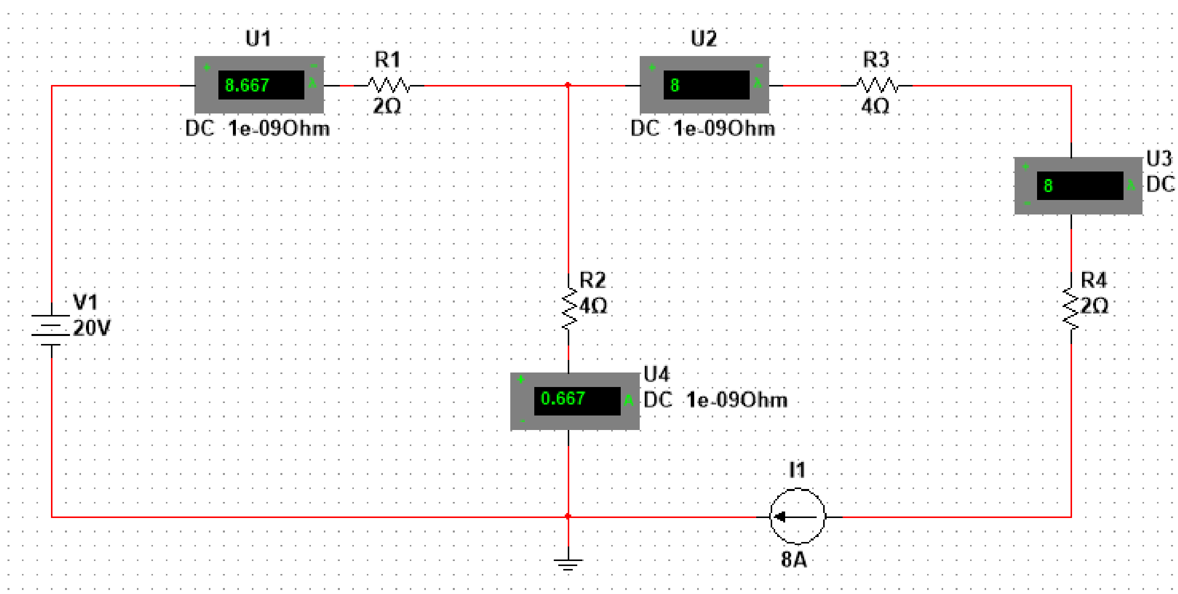

Figure 19: MULTISIM simulation of circuit of figure 18

Figure 20 shows the entire circuit with R6 (load resistor) removed with the currents of figure 18 displayed on the whole circuit.

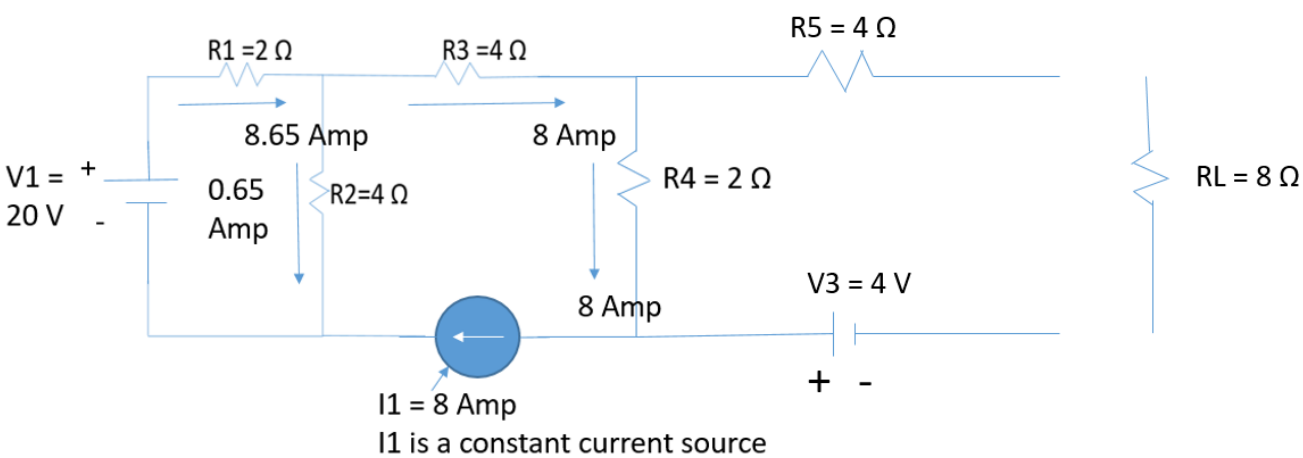

Figure 20: complete Thevenin circuit with currents

Figure 21 shows only the necessary information for calculating the voltage across therminals A & B. In figure 21, the voltage across R4 is calculated based on the current shown in figure 20. Since points A & B are not connected (because R6 was removed in order to form the circuit for calculating V_{TH}), the voltage across A & B is a function of the voltage across R4 and the voltage source V3.

$V_{AB} = V_{R4} + V3 = 16 + 4 = 20$ V

$V_{TH} = V_{AB} = 20$ V

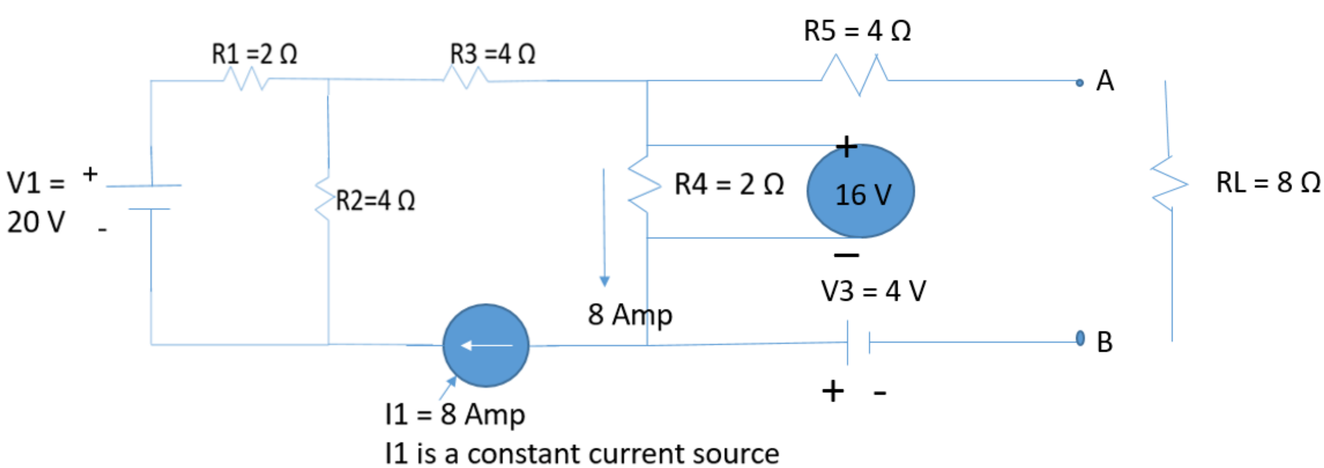

Figure 21: Necessary information for calculating the voltage across A-B

Figure 22 is the MULTISIM simulation of figure 21. A comparison of figures 21 & 22 shows that the calculations for Thevenin's voltage are correct so far.

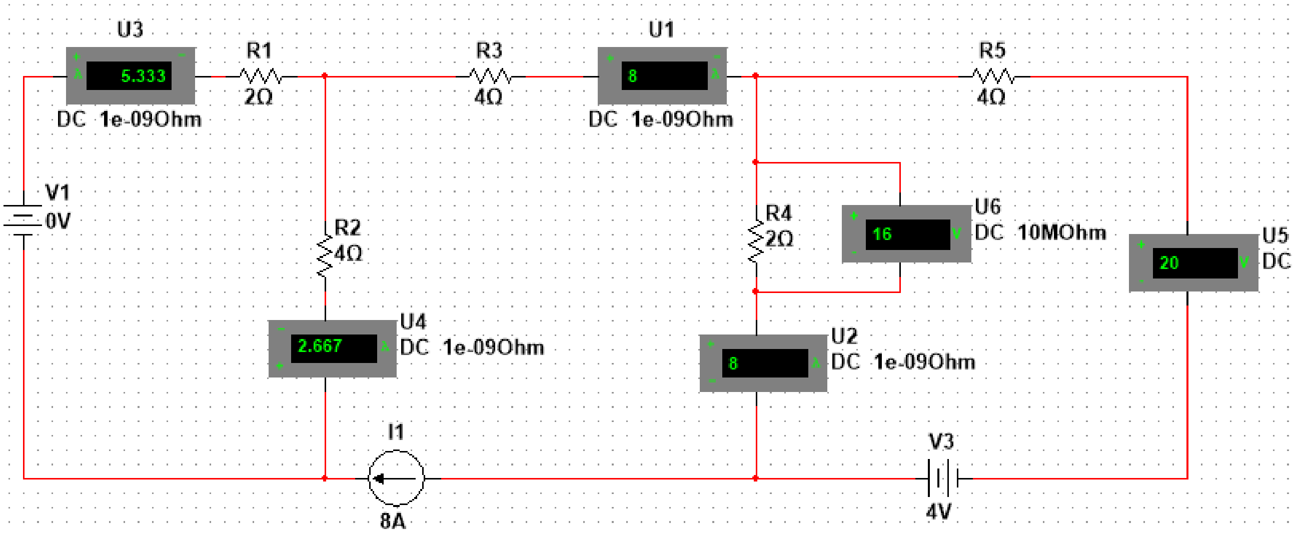

Figure 22: MULTISIM simulation of the circuit of figure 21

R_{TH} is the resistance from the point of view of A & B when all the voltage sources are shorted out and the current source is opened. Figures 23 & 24 show the circuit when all the voltage sources are shorted and the current source is opened

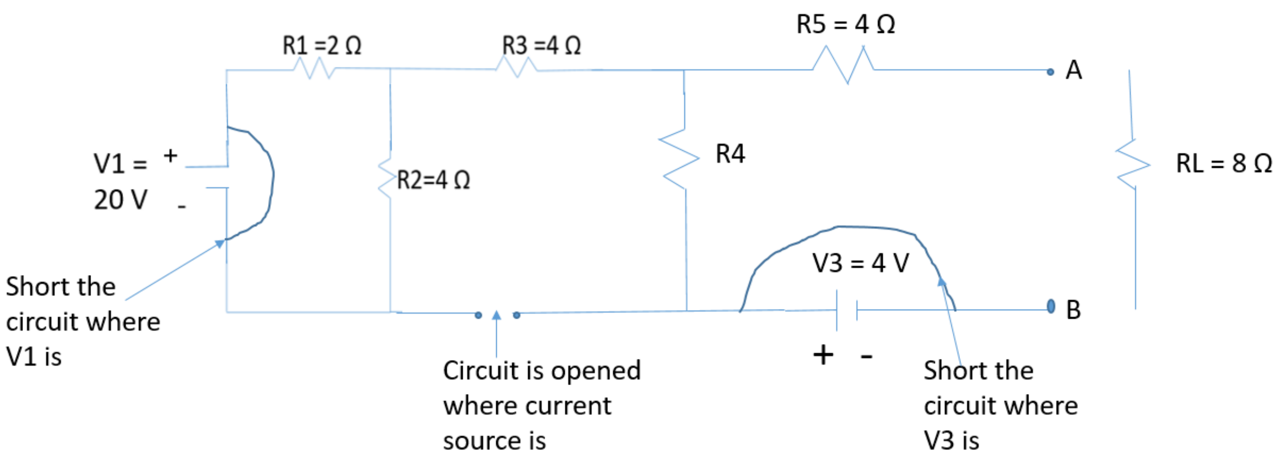

Figure 23: Circuit showing the procedure for calculating R_{TH}

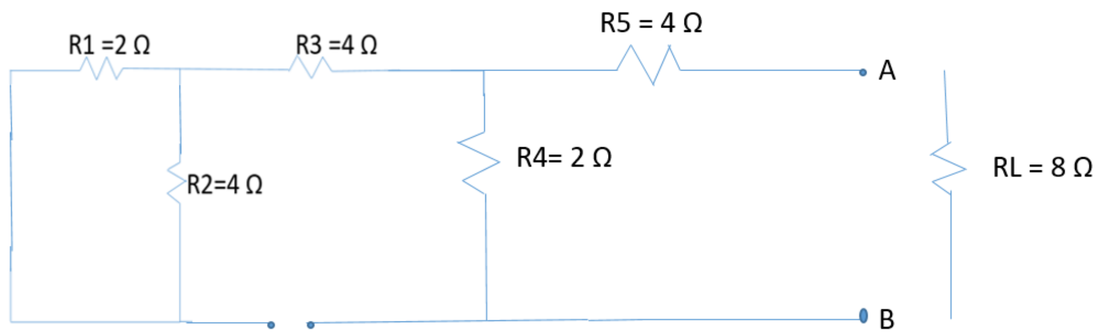

Figure 24: Circuit for calculating R_{TH}

The resistance from the point of view of A & B, is the sum of R4 & R5. Thevenin's equivalent resistance is then the sum of R4 & R5.

R_{TH} = R4 + R5 = 2 Ω+ 4 Ω = 6 Ω

A comparison of the calculated value for R_{TH} and figure 6 confirm the accuracy of the techniques being used.

The Thevenin's equivalent circuit is then confirmed to be as it was shown in figure 7 and the current of 1.43 Amp calculated for the current through R6 is confirmed.

Figure 8 is the MULTISIM simulation of the entire circuit. The results shown in figure 8 show that the current determined through R6 by Thevenin's method is correct.

Student reaction & assessment of the technique:

End of the semester comments from the students were positive. The students indicated that the detailed MULTISIM instructions helped them to quickly start using the software. And the students also indicated that the hybrid use of the software as an addition to the hand calculation techniques were useful.

Conclusion & summary

In this article, the use of MULTISIM simulation software as a physical lab substitute and as a supplement for enhancing student understanding of the Thevenin's theorem when more than one power source is present is presented.

The techniques are not technically complicated. However, that is precisely the point of this article. The techniques are suitable as teaching aids for students that are just beginning to learn electrical engineering concepts.

These techniques demonstrated in this article can and have been used in other areas of electrical circuits teaching. The technique was the backbone of the online course that was developed due to the facts that all courses had to be taught remotely due to Covid-19.

References

[1] Foundations of Electronics Circuits and Devices by Meade
[2] Principles of Electric Circuits by Floyd
[3] Lab Manual; Introduction to Circuits by National Instruments Corporation

Biographical Information

Dr. Hagigat is teaching undergraduate and graduate engineering technology courses at The University of Toledo. Dr. Hagigat has an extensive industrial background, and he is continuously emphasizing the practical applications of engineering subjects covered in a typical engineering technology course.