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1 Report of lab 1

In lab 1, there are 10 problems to be solved. In each problem, we need to solve it first by hand and then verify the result by using simulation tools. In this report, we will use PSpice for TI to verify our results.

1.1 Exercise 1

Given the following circuit. Calculate the value of the voltage v_0 and the current i. Then, simulate the circuit to check it out.

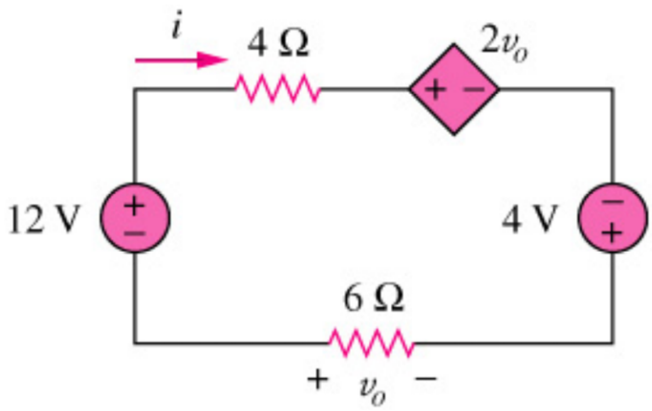


Figure 1.1: Find the voltage and the current in the given circuit using KVL

1.1.1 Calculation

Notes: *Explanations, formulas, and equations are expected rather than only results.*

According to the KVL (Kirchhoff's Voltage Law), we have the equations of the loops as follows:

$$12 - 0 = 4i + 2v_0 - 4 + 6i \tag{1.1}$$

According to the Ohm's Law, we have:

$$i = \frac{-v_0}{6} \tag{1.2}$$

From (1) and (2), we have:

$$12 = 4\left(\frac{-v_0}{6}\right) + 2v_0 - 4 + 6\left(\frac{-v_0}{6}\right) \Rightarrow v_0 = 48(V)$$

By substituting $v_0 = 48$ into (2), we have: $i = \dfrac{-48}{6} = -8(A)$

1.1.2 simulation

After redrawing the circuit in PSpice for TI, and run then simulation, we have the results as follows:

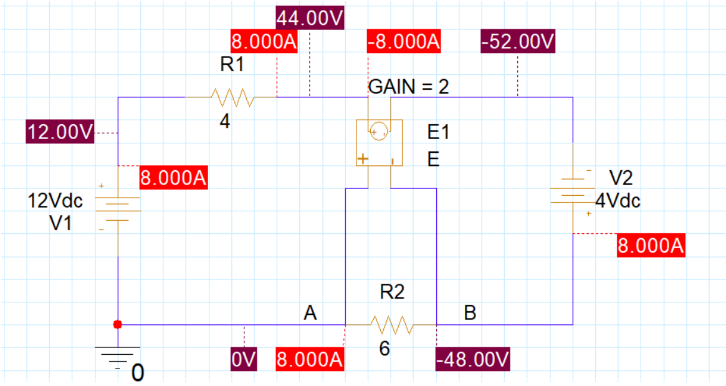


Figure 1.2: Simulation result of the circuit in Figure 1.1

Let A and B be the nodes across the voltage source v_0. From the simulation result in Figure 1.2, we have:

$$\begin{cases} v_0 = V_A - V_B = 48(V) \\ i = I = -8(A) \end{cases}$$

Even though the current i has a negative value, it is still correct because the direction of the current in the simulation is opposite to the assumed direction in the calculation.

Conclusion: The result of PSpice simulation matches the result of the calculation. Therefore, the calculation is correct.

1.2 Exercise 2

Given the following circuit, students rearrange the circuit to clarify its serial and/or parallel topology. Then, apply the knowledge you've learned to find the equivalent resistance value between two circuit terminals A and F. Finally, perform the simulation to check if the current through the whole circuit is correctly calculated.

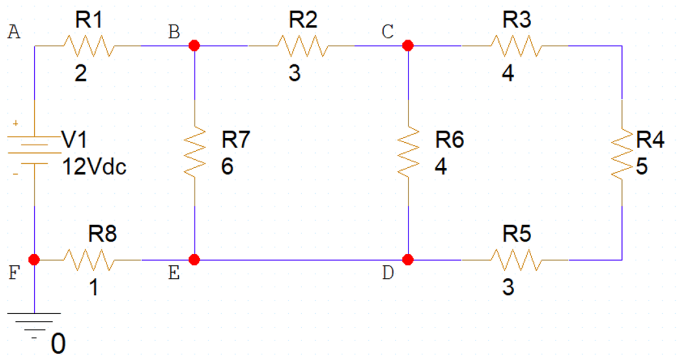


Figure 1.3: Find the equivalent resistance between terminals A and F

1.2.1 Rearrange the circuit

By extending wire between nodes B and E, we have the following rearranged circuit:

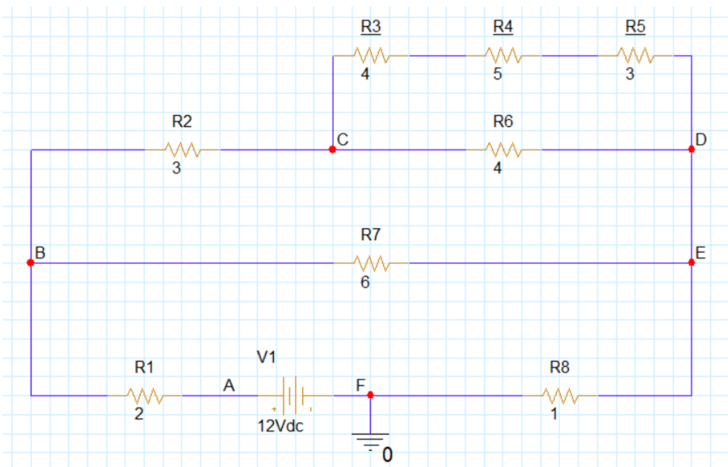


Figure 1.4: Rearranged circuit

1.2.2 Calculation

Convention: *The equivalent resistance between the two terminals A and B of a circuit segment containing only R1, R2, R3, and R4 may be named* R_{AB_1234}.

Belong to the rearranged circuit, we have: $R6 \parallel (R3 + R4 + R5)$. Thus, we calculate the equivalent resistance R_{CD_3456} as follows:

$$R_{CD\_3456} = \frac{1}{\frac{1}{R_6} + \frac{1}{R_3 + R_4 + R_5}} = \frac{1}{\frac{1}{4} + \frac{1}{4+5+3}} = 3(\Omega)$$

Next, looking at the circuit between B and E, we have: $R7 \parallel (R2 + R_{CD\_3456})$. Thus, we calculate the equivalent resistance R_{BE} as follows:

$$R_{BE} = \frac{1}{\frac{1}{R_7} + \frac{1}{R_2 + R_{CD\_3456}}} = \frac{1}{\frac{1}{6} + \frac{1}{3+3}} = \frac{1}{\frac{1}{2} + \frac{1}{6}} = 3(\Omega)$$

Now move to A and F, we have: $R1 + R_{BE} + R8$. Thus, we calculate the equivalent resistance R_{AF} as follows:

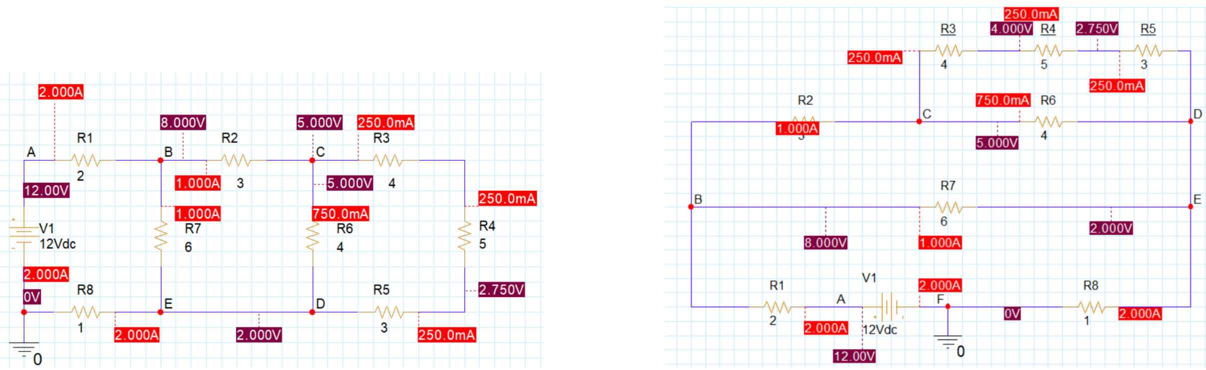
$$R_{AF} = R_1 + R_{BE} + R_8 = 1 + 3 + 2 = 6(\Omega)$$

By applying Ohm's law, we can find the current I_{AB} through the whole circuit:

$$I_{AB} = I = \frac{U}{R_{AF}} = \frac{12}{6} = 2(A)$$

1.2.3 Simulation

To verify the calculation above, we did perform the simulation twice: first, for original circuit; second, for rearranged circuit. The results are as follows:



(a) Simulation for original circuit

(b) Simulation for rearranged circuit

Figure 1.5: Simulation results

As shown, the value of current I and voltage V between corresponding terminals in both simulations are the same. Thus, our calculation and rearrangement are correct.

1.3 Exercise 3

Given the following circuit, students rearrange the circuit to clarify its serial and/or parallel topology. Next, apply the knowledge you've learned to find the equivalent resistance value between two circuit terminals A and F, the voltage values at A, B, C, D, and E. Finally, perform the simulation to check your calculation.

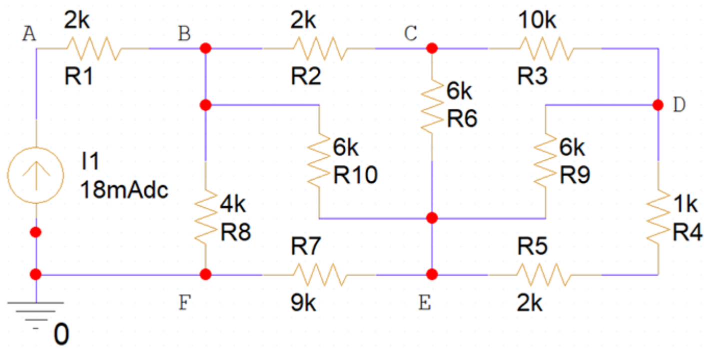


Figure 1.6: Find the whole-circuit equivalent resistance and the voltages at A, B, C, D, and E

1.3.1 Rearrange the circuit

By drawing a wire with current source I1, A, B, C, D, and E, we can clarify the circuit topology. As follows:

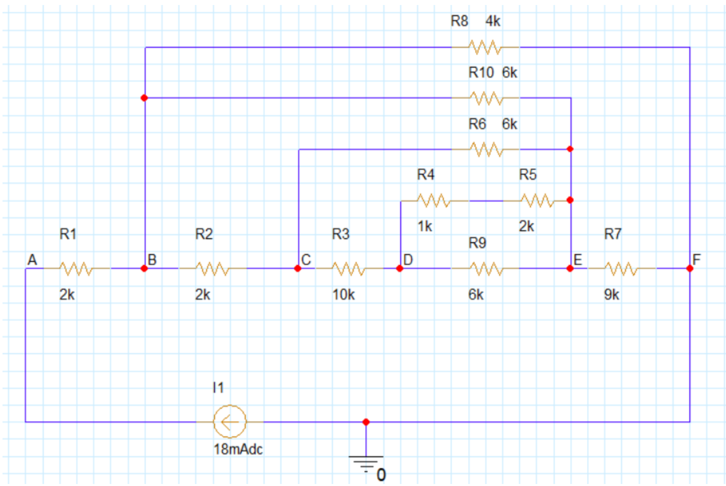


Figure 1.7: Rearranged circuit

1.3.2 Calculation

As the rearranged circuit showed in Figure 1.7, we can calculate the equivalent resistance R_{AF} by the following steps: First, we calculate R_{DE}. Because $R9 \parallel (R4 + R5)$, we have:

$$R_{DE} = \frac{1}{\frac{1}{R_9} + \frac{1}{R_4 + R_5}} = \frac{1}{\frac{1}{6} + \frac{1}{1+2}} = 2(k\Omega)$$

Next, we calculate R_{CE}. Because $R6 \parallel (R3 + R_{DE})$, we have:

$$R_{CE} = \frac{1}{\frac{1}{R_6} + \frac{1}{R_3 + R_{DE}}} = \frac{1}{\frac{1}{6} + \frac{1}{10+2}} = 4(k\Omega)$$

Now, we calculate R_{BE}. Because $R10 \parallel (R2 + R_{CE})$, we have:

$$R_{BE} = \frac{1}{\frac{1}{R_{10}} + \frac{1}{R_2 + R_{CE}}} = \frac{1}{\frac{1}{6} + \frac{1}{2+4}} = 3(k\Omega)$$

We then calculate R_{BF}. Because $R8 \parallel (R7 + R_{BE})$, we have:

$$R_{BF} = \frac{1}{\frac{1}{R_8} + \frac{1}{R_7 + R_{BE}}} = \frac{1}{\frac{1}{4} + \frac{1}{3+9}} = 3(k\Omega)$$

Finally, we calculate R_{AF}. Because $R1 + R_{BF}$, we have:

$$R_{AF} = R_1 + R_{BF} = 2 + 3 = 5(k\Omega)$$

By applying Ohm's law, we can find the voltage value between terminals A and F:

$$V_{AF} = V = I \cdot R_{AF} = 18 \cdot 5 = 90(V)$$

We have voltages at nodes A, B, C, D, and E as follows:

$$\begin{cases} V_A - V_F = V_{AF} = 90 \Rightarrow V_A = 90 + V_F = 90 + 0 = 90(V) \\ V_{BF} = I \cdot R_{BF} = 18 \cdot 3 = 54(V) \Rightarrow V_B = V_F + V_{BF} = 0 + 54 = 54(V) \end{cases}$$

By applying the voltage divider rule, we have:

$$V_{EF} = V_{BF} \cdot \frac{R7}{R_{BE} + R7} = 54 \cdot \frac{9}{3+9} = 40.5(V) \Rightarrow V_E = V_F + V_{EF} = 0 + 40.5 = 40.5(V)$$

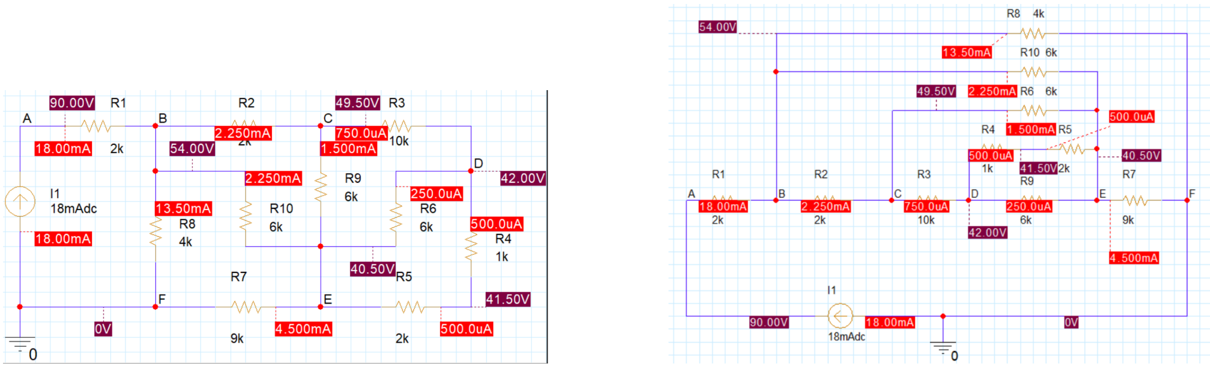
$$V_{CE} = V_{BE} \cdot \frac{R_{CE}}{R_{CE} + R_{DE}} = (V_B - V_E) \cdot \frac{R_{CE}}{R_{CE} + R_{DE}} = (54 - 40.5) \cdot \frac{4}{4+2} = 9(V)$$
$$\Rightarrow V_C = V_E + V_{CE} = 40.5 + 9 = 49.5(V)$$
$$V_{DE} = V_{CE} \cdot \frac{R_{DE}}{R_{DE} + R_3} = (V_C - V_E) \cdot \frac{R_{DE}}{R_{DE} + R_3} = (49.5 - 40.5) \cdot \frac{2}{2+10} = 1.5(V)$$
$$\Rightarrow V_D = V_E + V_{DE} = 40.5 + 1.5 = 42(V)$$

Conclusion: After rearranging the circuit and calculating step-by-step, we have:

$$\begin{cases} R_{AF} = 5(k\Omega) \\ V_A = 90(V), V_B = 54(V), V_C = 49.5(V), V_D = 42(V), V_E = 40.5(V) \end{cases}$$

1.3.3 Simulation

To verify the calculation above, we did perform the simulation twice: first, for original circuit; second, for rearranged circuit. The results are as follows:



(a) Simulation for original circuit

(b) Simulation for rearranged circuit

Figure 1.8: Simulation results

From the simulation results in Figure 1.8, we can see that the equivalent resistance R_{AF} and voltages at nodes A, B, C, D, and E are the same for both original and rearranged circuits. The simulation results confirm our calculations are correct.

1.4 Exercise 4

Given the following circuit, find I_1, I_2, I_3, V_a, and V_b. Present your calculation steps and check them out by performing the simulation.

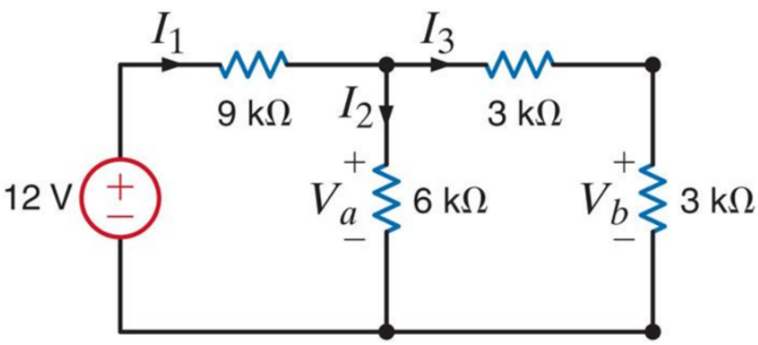


Figure 1.9: Find I_1, I_2, I_3, V_a, and V_b

1.4.1 Calculation

The whole circuit equivalent resistance:

$$R_{eq} = 9 + \frac{1}{\frac{1}{6} + \frac{1}{3+3}} = 9 + \frac{1}{\frac{1}{6} + \frac{1}{6}} = 12(\Omega)$$

By applying Ohm's law, we can find the total current I_1:

$$I_1 = \frac{V}{R_{eq}} = \frac{12}{12} = 1(mA)$$

By the current division rule, we can find I_2 and I_3:

$$I_2 = I_1 \cdot \frac{6}{6+3+3} = 1 \cdot \frac{6}{12} = 0.5(mA)$$
$$I_3 = I_1 \cdot \frac{3+3}{6+3+3} = 1 \cdot \frac{6}{12} = 0.5(mA)$$

By applying Ohm's law, we can find V_a and V_b:

$$V_a = I_2 \cdot 6 = 0.5 \cdot 6 = 3(V)$$
$$V_b = I_3 \cdot 3 = 0.5 \cdot 3 = 1.5(V)$$

1.4.2 Simulation

By performing the simulation in PSpice for TI, we have the following results:

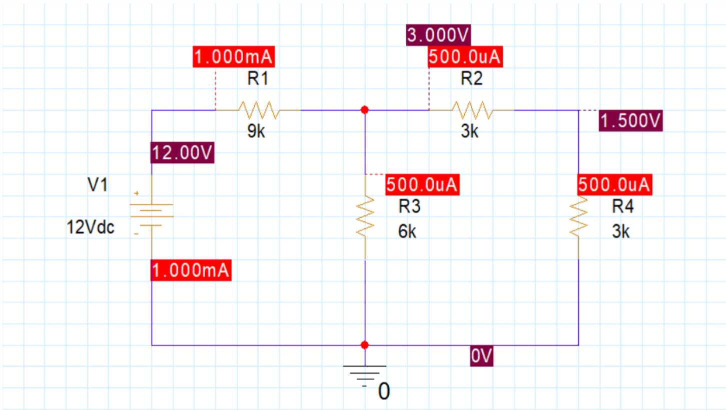


Figure 1.10: Simulation results of Exercise 4

As shown in Figure 1.10, the simulation results match our calculation.

1.5 Exercise 5

Given the network as shown below

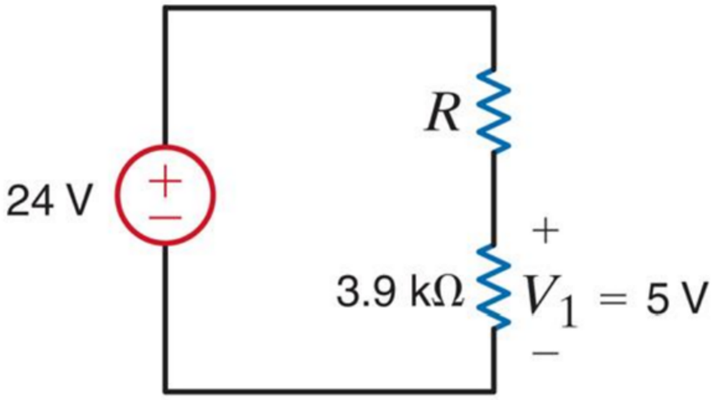


Figure 1.11: Select resistor R from the standard resistors list and do the following requirements

a. Find the required value for the resistor. By applying Ohm's law for $3.9k\Omega$ resistor, we have:

$$I = I_1 = \frac{5}{3.9} = 1.282(mA)$$

Then by applying Ohm's law for resistor R, we have:

$$R = \frac{V}{I} = \frac{24-5}{1.282} = 14.821(k\Omega)$$

b. Use Table 2.1 in the lecture slide to select a standard 10% tolerance resistor for R. R in the circuit may be a single resistor or a combination of resistors as long as these resistors meet the standard values and are available in the market.

c. Using the resistor selected in (b), determine the voltage across the 3.9 kΩ resistor.

d. Calculate the percent error in the voltage V_1 if the standard resistor selected in (b) is used.

e. Determine the power rating for this standard component.

References

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