

To: Dr. Evans
From: Luke DeVries
Date: September 26, 2024
Re: Electrical Design Project

Introduction

This project was intended to challenge students with the design process of a simple electrical circuit. This accompanying memo was intended to challenge students' technical writing abilities while ensuring that math concepts were understood regarding electrical circuit problems.

Introduction

Students were instructed to create a voltage divider with five test nodes, and the design was given a few constraints. Firstly, students were given five of the following: 10k Ω resistor, 3.3k Ω resistor, 2.2k Ω resistor, 330 Ω resistor, 220 Ω resistor. All resistors have a tolerance of $\pm 5\%$. Secondly, they were to include at least one parallel pair of resistors in the design. Students were required to acknowledge and test for the allotted tolerance of the resistors in their design and complete the circuit within 5% of the specified voltages. Table 1 below lists the design specification values from the given circuit network (37), calculated values after designing the resistor configurations, the expected voltages based on the resistor configurations, and percent differences. Appendix A (page 3) is a completed list of calculations made to yield those values.

Table 1. Specified and calculated values for Network 37 with percent difference.

	Design Specification Sheet				From Your Calculations			+/- 5% Check	
Node	Node Voltage (SpecV)	ΔV (Spec ΔV)	I_{Tot} (Spec I_{Tot})	R_{eq} (Spec R_{eq})	Design R_{eq} (Calc R_{eq})	Design Current (I) (Calc I_{Tot})	Design ΔV (Calc ΔV)	Design Node Voltage (ExpectV)	%Diff (ExpectV vs SpecV)
0	18 V	-----	-----	-----	-----	-----	-----	-----	-----
1	17.276 V	0.724 V	0.0009 A	804 Ω	825 Ω	0.0009 A	0.7425 V	17.2575 V	-0.1%
2	9.4742 V	7.8018 V		8669 Ω	8630 Ω		7.767 V	9.4905 V	0.2%
3	4.1538 V	5.3204 V		5912 Ω	5940 Ω		5.346 V	4.1445 V	-0.2%
4	1.8978 V	2.256 V		2507 Ω	2500 Ω		2.25 V	1.8945 V	-0.2%
5	0 V	1.8978 V		2109 Ω	2120 Ω		1.908 V	-0.0135 V	Undef
Total		18 V	-----	20001 Ω	20015 Ω	-----	18.0135 V	-----	-0.3%

Calculations

Equation 1.1 $\Delta V = V_1 - V_2$

Equation 1.2 $V_2 = V_1 - \Delta V$

Equation 2.1 $V = I * R$

Equation 2.2 $R = \frac{V}{I}$

Equation 2.3 $I = \frac{V}{R}$

$$\text{Equation 3.1} \quad R_{eq} = R_1 + R_2 + \dots$$

$$\text{Equation 3.2} \quad R_{eq} = \left(\frac{1}{R_1} + \frac{1}{R_2} + \dots \right)^{-1}$$

$$\text{Equation 4} \quad \% \text{ Diff (ExpectV vs SpecV)} =$$

$$\left(\frac{\text{ExpectV} - \text{SpecV}}{\text{SpecV}} \right) * 100\%$$

To find the table values for Node 1, the following steps were taken. To calculate Spec ΔV , equation one was used with $V_1 = 18 \text{ V}$ and $V_2 = 17.276 \text{ V}$ which yielded $\Delta V = 0.724 \text{ V}$. Spec I_{Tot} was given in the Network Specifications. For Spec R_{eq} , equation 2.2 was used with $V = \Delta V = 0.724 \text{ V}$ and $I = 0.0009 \text{ A}$ which yielded $R_1 \approx 804 \Omega$. For Calc R_{eq} , equation 3.2 was used $R_1 = 3300 \Omega$ and R_2 and $R_3 = 2200 \Omega$ which yielded $R_{eq1} = 825 \Omega$. Calc $R_{eq\text{Tot}}$ is the summation of Calc R_{eq} for all nodes and equaled 20015Ω . For Calc I_{Tot} , equation 2.3 was used with $V = 18 \text{ V}$ and $R_{eq\text{Total}} = 20015 \Omega$ which yielded $I_{\text{Tot}} \approx 0.0009 \text{ A}$. For Calc ΔV , equation 2.1 was used with $I = 0.0009 \text{ A}$ and $R = 825 \Omega$ which yielded $\Delta V = 0.7245 \text{ V}$. For ExpectV, equation 1.2 with $V_1 = 18 \text{ V}$ and $\Delta V = 0.7245 \text{ V}$ which yielded $V_2 = 17.2575 \text{ V}$. For percent difference, equation 4 was used with ExpectV = 17.2575 V and SpecV = 17.276 V yielding -0.1%.

Voltages and Percent Difference Values

The percent differences are the primary check to see that the design will function within the constraints of the project. By keeping the differences within $\pm 5\%$, students would be able to confidently test their design, even with the tolerance of the resistors of 5%. Since students were limited to 25 resistors, the combinations could not perfectly fit those of the Spec R_{eq} column, but this caused the ExpectV column to not be exactly like SpecV. Although these constraints limited students' designs, it also challenged them to maximize their decision-making in anticipation of testing their circuit.

Computer Generated Schematic

Figure 1 below illustrates the designed circuit and its resistor values.

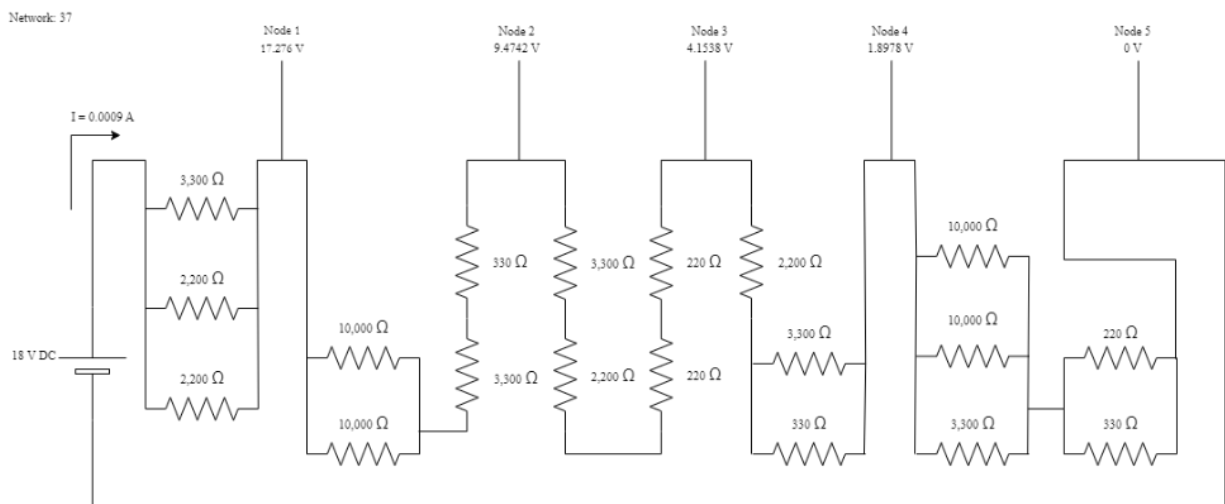


Figure 1. The designed resistor configuration for circuit Network: 37.

I have neither given nor received any unauthorized help on this assignment, nor witnessed any violation of the UNC Charlotte Code of Student Academic Integrity.

Luke DeVries 9/26/24

Appendix A. Design Calculations

Equations Used

Equation 1.1 $\Delta V = V_1 - V_2$

Equation 1.2 $V_2 = V_1 - \Delta V$

Equation 2.1 $V = I * R$

Equation 2.2 $R = \frac{V}{I}$

Equation 2.3 $I = \frac{V}{R}$

Equation 3.1 $R_{eq} = R_1 + R_2 + \dots$

Equation 3.2 $R_{eq} = (\frac{1}{R_1} + \frac{1}{R_2} + \dots)^{-1}$

Equation 4 $\% Diff (ExpectV \text{ vs } SpecV) = \left(\frac{ExpectV - SpecV}{SpecV} \right) * 100\%$

Spec ΔV

Node 1: $Spec\Delta V = 18 \text{ V} - 17.276 \text{ V} = .724 \text{ V}$

Node 2: $Spec\Delta V = 17.276 \text{ V} - 9.4742 \text{ V} = 7.8018 \text{ V}$

Node 3: $Spec\Delta V = 9.4742 \text{ V} - 4.1538 \text{ V} = 5.3204 \text{ V}$

Node 4: $Spec\Delta V = 4.1538 \text{ V} - 1.8978 \text{ V} = 2.256 \text{ V}$

Node 5: $Spec\Delta V = 1.8978 \text{ V} - 0 \text{ V} = 1.8978 \text{ V}$

Total: $Spec\Delta V = .724 \text{ V} + 7.8018 \text{ V} + 5.3204 \text{ V} + 2.256 \text{ V} + 1.8978 \text{ V} = 18 \text{ V}$

Spec R_{eq}

Node 1: $SpecR_{eq} = \frac{.724 \text{ V}}{0.0009 \text{ A}} \approx 804 \Omega$

Node 2: $SpecR_{eq} = \frac{7.8018 \text{ V}}{0.0009 \text{ A}} \approx 8669 \Omega$

Node 3: $SpecR_{eq} = \frac{5.3204 \text{ V}}{0.0009 \text{ A}} \approx 5912 \Omega$

Node 4: $SpecR_{eq} = \frac{2.256 \text{ V}}{0.0009 \text{ A}} \approx 2507 \Omega$

Node 5: $SpecR_{eq} = \frac{1.8978 \text{ V}}{0.0009 \text{ A}} \approx 2109 \Omega$

Total: $SpecR_{eq} = 804 \Omega + 8669 \Omega + 5912 \Omega + 2507 \Omega + 2109 \Omega = 20001 \Omega$

Calc R_{eq}

Node 1: $CalcR_{eq} = (\frac{1}{3300 \Omega} + \frac{1}{2200 \Omega} + \frac{1}{2200 \Omega})^{-1} = 825 \Omega$

Node 2: $CalcR_{eq} = (\frac{1}{10000 \Omega} + \frac{1}{10000 \Omega})^{-1} + 3300 \Omega + 330 \Omega = 8630 \Omega$

Node 3: $CalcR_{eq} = 3300 \Omega + 2200 \Omega + 220 \Omega + 220 \Omega = 5940 \Omega$

Node 4: $CalcR_{eq} = 2200 \Omega + (\frac{1}{3300 \Omega} + \frac{1}{330 \Omega})^{-1} = 2500 \Omega$

$$\text{Node 5: } \text{Calc}R_{eq} = \left(\frac{1}{10000 \Omega} + \frac{1}{10000 \Omega} + \frac{1}{3300 \Omega} \right)^{-1} + \left(\frac{1}{220 \Omega} + \frac{1}{330 \Omega} \right)^{-1} \approx 2120 \Omega$$

$$\text{Total: } \text{Calc}R_{eq} = 825 \Omega + 8630 \Omega + 5940 \Omega + 2500 \Omega + 2120 \Omega = 20015 \Omega$$

CalcI_{Tot}

$$\text{Total: } I_{Tot} = \frac{18 \text{ V}}{20015 \Omega} = 0.0009 \text{ A}$$

CalcΔV

$$\text{Node 1: } \text{Calc}\Delta V = (0.0009 \text{ A}) * (825 \Omega) = 0.7425 \text{ V}$$

$$\text{Node 2: } \text{Calc}\Delta V = (0.0009 \text{ A}) * (8630 \Omega) = 7.767 \text{ V}$$

$$\text{Node 3: } \text{Calc}\Delta V = (0.0009 \text{ A}) * (5940 \Omega) = 5.346 \text{ V}$$

$$\text{Node 4: } \text{Calc}\Delta V = (0.0009 \text{ A}) * (2500 \Omega) = 2.25 \text{ V}$$

$$\text{Node 5: } \text{Calc}\Delta V = (0.0009 \text{ A}) * (2120 \Omega) = 1.908 \text{ V}$$

$$\text{Total: } \text{Calc}\Delta V = 0.7425 \text{ V} + 7.767 \text{ V} + 5.346 \text{ V} + 2.25 \text{ V} + 1.908 \text{ V} = 18.0135 \text{ V}$$

ExpectV

$$\text{Node 1: } \text{Expect}V = 18 \text{ V} - 0.7425 \text{ V} = 17.2575 \text{ V}$$

$$\text{Node 2: } \text{Expect}V = 17.2575 \text{ V} - 7.767 \text{ V} = 9.4905 \text{ V}$$

$$\text{Node 3: } \text{Expect}V = 9.4905 \text{ V} - 5.346 \text{ V} = 4.1445 \text{ V}$$

$$\text{Node 4: } \text{Expect}V = 4.1445 \text{ V} - 2.25 \text{ V} = 1.8945 \text{ V}$$

$$\text{Node 5: } \text{Expect}V = 1.8945 \text{ V} - 1.908 \text{ V} = -0.0135 \text{ V}$$

% Diff

$$\text{Node 1: } \% \text{ Diff } (\text{Expect}V \text{ vs } \text{Spec}V) = \left(\frac{17.2575 \text{ V} - 17.276 \text{ V}}{17.276 \text{ V}} \right) * 100\% = -0.1\%$$

$$\text{Node 2: } \% \text{ Diff } (\text{Expect}V \text{ vs } \text{Spec}V) = \left(\frac{9.4905 \text{ V} - 9.4742 \text{ V}}{9.4742 \text{ V}} \right) * 100\% = 0.2\%$$

$$\text{Node 3: } \% \text{ Diff } (\text{Expect}V \text{ vs } \text{Spec}V) = \left(\frac{4.1445 \text{ V} - 4.1538 \text{ V}}{4.1538 \text{ V}} \right) * 100\% = -0.2\%$$

$$\text{Node 4: } \% \text{ Diff } (\text{Expect}V \text{ vs } \text{Spec}V) = \left(\frac{1.8945 \text{ V} - 1.8978 \text{ V}}{1.8978 \text{ V}} \right) * 100\% = -0.2\%$$

$$\text{Node 5: } \% \text{ Diff } (\text{Expect}V \text{ vs } \text{Spec}V) = \left(\frac{-0.0135 \text{ V} - 0 \text{ V}}{0 \text{ V}} \right) * 100\% = \text{undef}$$

$$\text{Total: } \% \text{ Diff } (\text{Expect}V \text{ vs } \text{Spec}V) = -0.1\% + 0.2\% - 0.2\% - 0.2\% = -0.3\%$$