Node Voltage Analysis

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Abstract

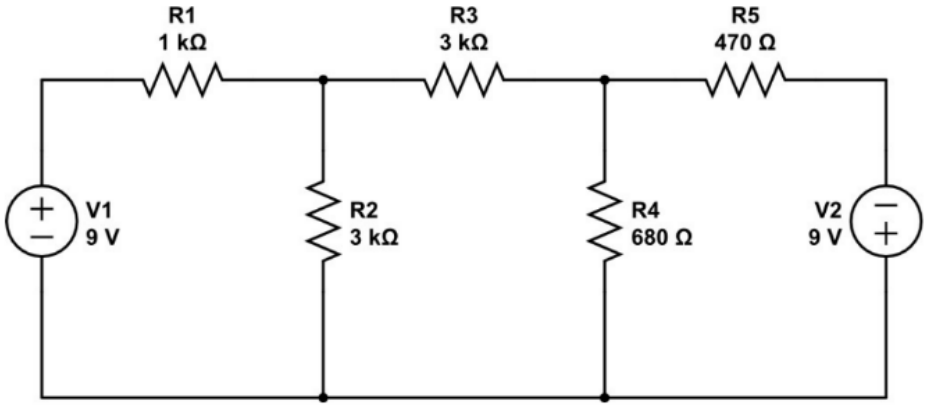
In this lab we will build two different circuits and then analyze them. First we will physically observe the circuits using a digital multi-meter, then analytically, using nodal analysis. One circuit will be made entirely of resistors and another utilizing a diode as a fixed voltage source, this being done to simulate a "supernode". We will then compare our measured voltage values at the nodes in the circuit with our calculated values.

Equipment

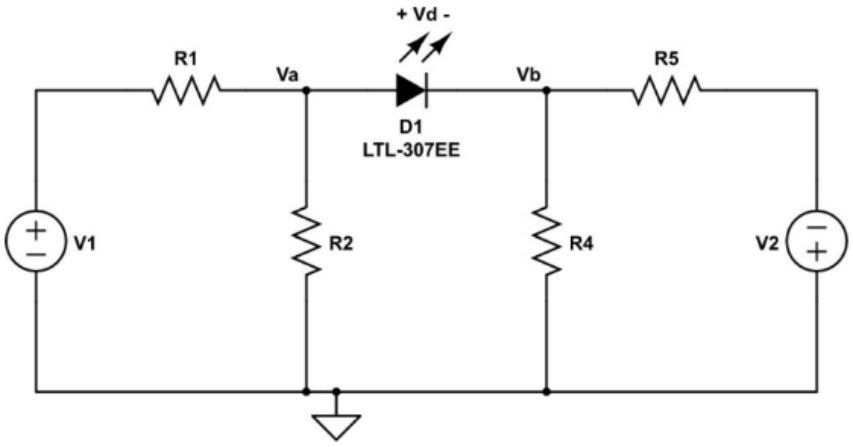
- Extech EX330
- GWINSTEK GPE-3323 Serial: GER901898
- LED
- 470, 680, 100 and 2 x 3,000 Ω Resistor
- Acer Nitro 5 - OS: Ubuntu 22.04.1 LTS
- LTspice - Version: 17.0.35.0

Procedure

1. Measure the values of the resistors.
2. Connect the circuit as shown below.



3. Measure and record the node-voltages V_a and V_b.
4. Repeat steps 2 and 3 for the circuit shown below.



5. Calculate V_d, as $V_d = V_a - V_b$
6. Use node-voltage analysis to solve the first circuit schematic for voltages V_a and V_b. Use the measured part values to do the calculations.
7. Calculate the percent difference between the measured and the calculated values of V_a and V_b.
8. Repeat steps 6 and 7 for the second circuit. Treat the diode as an ideal diode.
9. Simulate the second circuit using LTSpice, use a voltage source in place of the LED and set its value to V_d.

Measurements

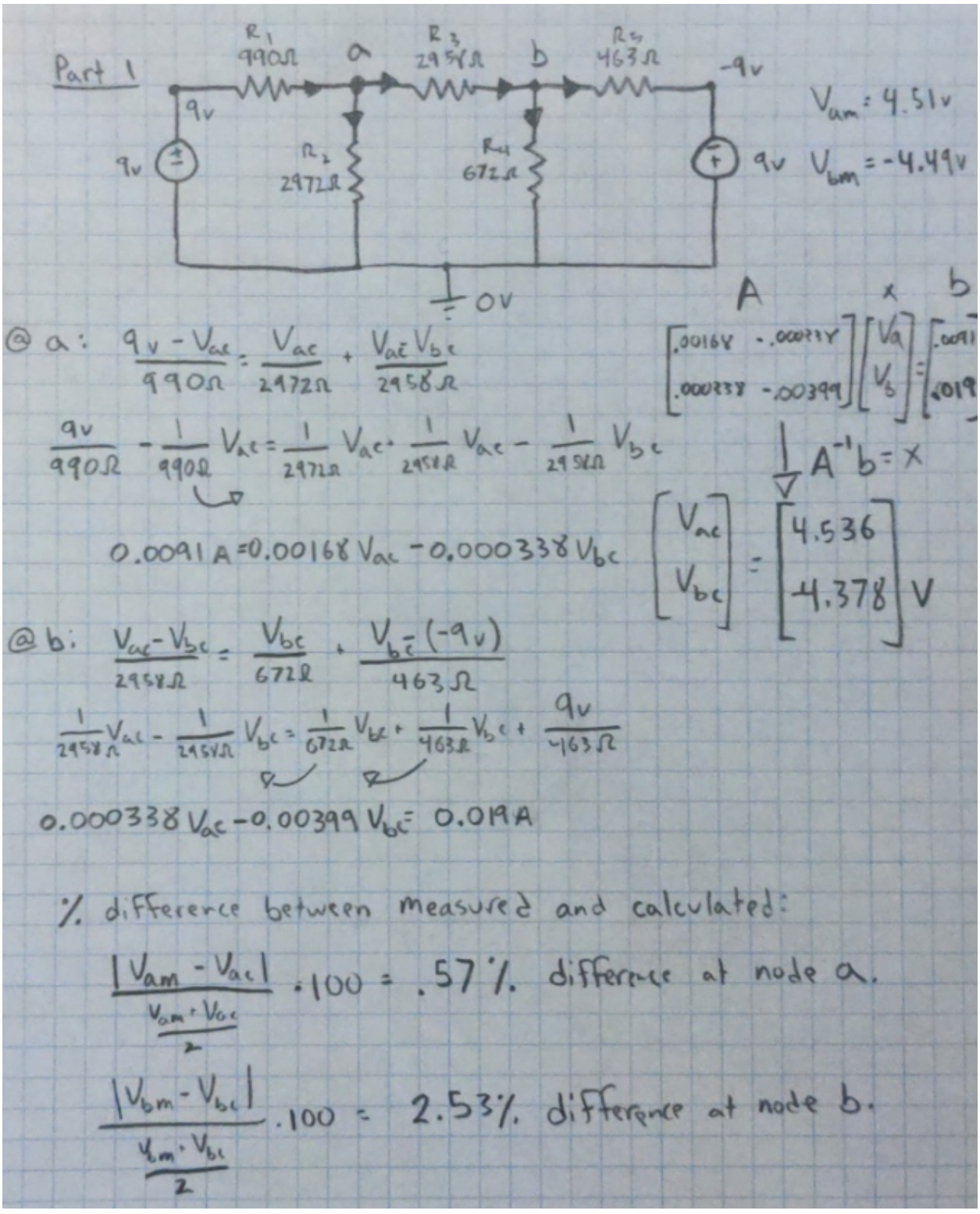
Measured Values of Resistors:

Resistor	Nominal	Actual
R1	1000 Ω	990 Ω
R2	3000 Ω	2972 Ω
R3	3000 Ω	2958 Ω
R4	680 Ω	672 Ω
R5	470 Ω	463 Ω

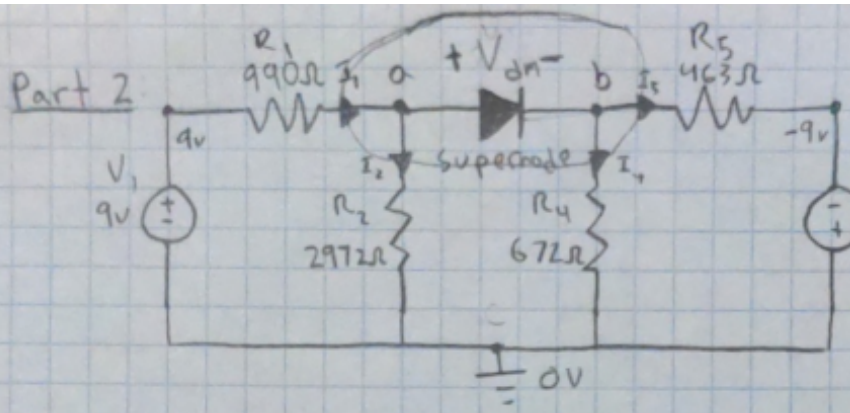
Measured Values of Voltages:

Circuit	Node a; V_{am}	Node b; V_{bm}	Diode; V_{dm}
Circuit 1	4.51 V	-4.49 V	-
Circuit 2	-2.247 V	-0.43 V	2.247 V

Analysis


Part 1
R1 990Ω
a
R3 2958Ω
b
R5 463Ω
-9v
9v
9v
R2 2972Ω
R4 672Ω
9v
0v
Vam = 4.51v
Vbm = -4.49v
@ a: (9v - Vac)/990Ω = Vac/2972Ω + (Vac - Vbc)/2958Ω
9v/990Ω - 1/990Ω Vac = 1/2972Ω Vac + 1/2958Ω Vac - 1/2958Ω Vbc
0.0091A = 0.00168 Vac - 0.000338 Vbc
@ b: (Vac - Vbc)/2958Ω = Vbc/672Ω + (Vbc - (-9v))/463Ω
1/2958Ω Vac - 1/2958Ω Vbc = 1/672Ω Vbc + 1/463Ω Vbc + 9v/463Ω
0.000338 Vac - 0.00399 Vbc = 0.019A
A x b
.00168 -.000338
.000338 -.00399
A^-1 b = x
Vac = 4.536
Vbc = 4.378 V
% difference between measured and calculated:
|Vam - Vac| / ((Vam + Vac)/2) · 100 = .57% difference at node a.
|Vbm - Vbc| / ((Vbm + Vbc)/2) · 100 = 2.53% difference at node b.

Part 2



$V_{dm} = 2.247V$

$V_{am} = -0.43V$

$V_{bm} = -2.674V$

Supernode: $V_{ac} - V_{dm} = V_{bc} \rightarrow V_{ac} - V_{bc} = 2.247\ V$

@ supernode:

$$\frac{9V - V_{ac}}{990\Omega} = \frac{V_{ac}}{2972\Omega} + \frac{V_{bc}}{672\Omega} + \frac{V_{bc} - (-9V)}{463\Omega}$$

$$\frac{9V}{990\Omega} - \frac{V_{ac}}{990\Omega} = \frac{V_{ac}}{2972\Omega} + \frac{V_{bc}}{672} + \frac{V_{bc}}{463\Omega} + \frac{9V}{463\Omega}$$

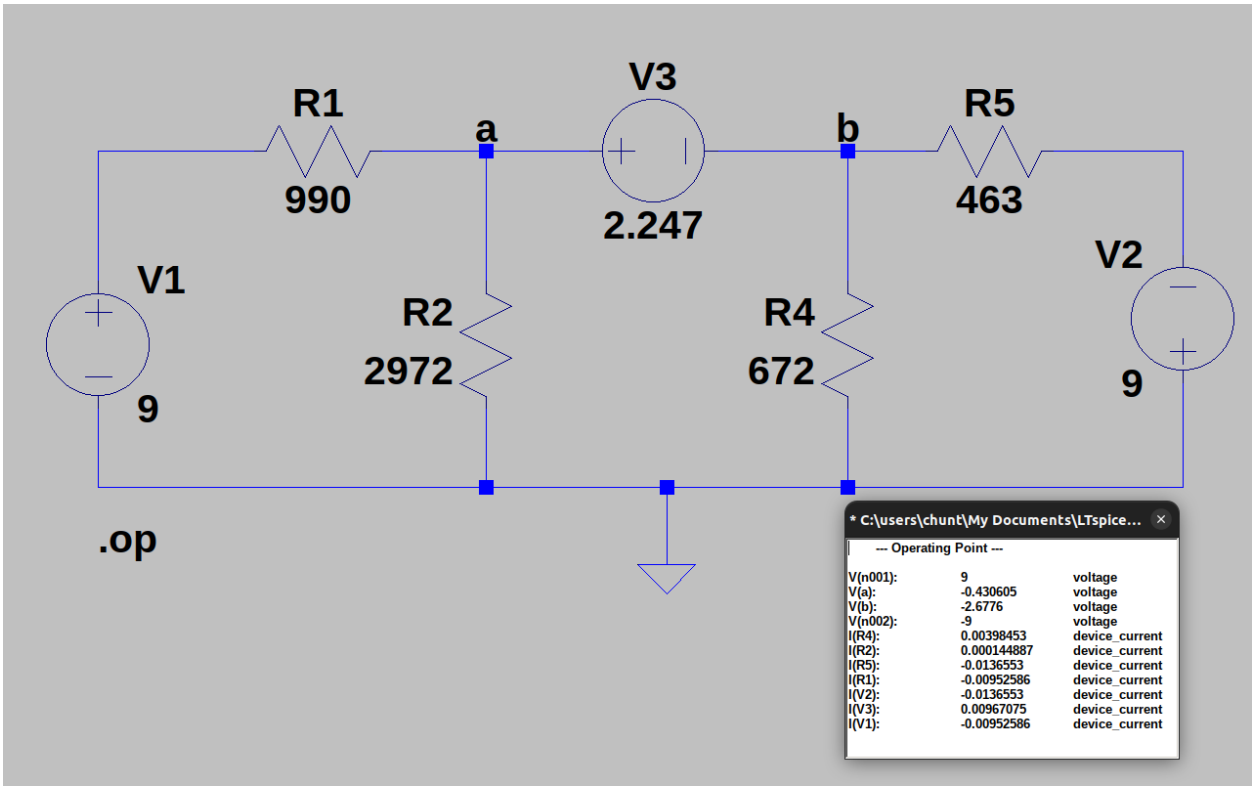
$$-0.0103A = 0.00135\Omega V_{ac} + 0.00365\Omega V_{bc}$$

$$\underset{A}{\begin{bmatrix} 1 & -1 \\ .00135 & .00365 \end{bmatrix}} \underset{x}{\begin{bmatrix} V_{ac} \\ V_{bc} \end{bmatrix}} = \underset{b}{\begin{bmatrix} 2.247 \\ -.0103 \end{bmatrix}} \xrightarrow{A^{-1}b = x} \begin{bmatrix} V_{ac} \\ V_{bc} \end{bmatrix} = \begin{bmatrix} -.420 \\ -2.667 \end{bmatrix} V$$

% difference between measured and calculated:

$$\frac{|V_{am} - V_{ac}|}{\frac{V_{am} + V_{ac}}{2}} \cdot 100 = 2.353\%\ \text{difference at node a.}$$

$$\frac{|V_{bm} - V_{bc}|}{\frac{V_{bm} + V_{ac}}{2}} \cdot 100 = 0.262\%\ \text{difference at node b.}$$



Conclusion

In this lab we analyzed a circuit by three different means - physical measurement, analytical calculation, and simulated calculation. We found that the percentage differences between the measured voltages and the analytically calculated voltages ranged between 0.262% to 2.53%.