Getting Acquainted with LTspice

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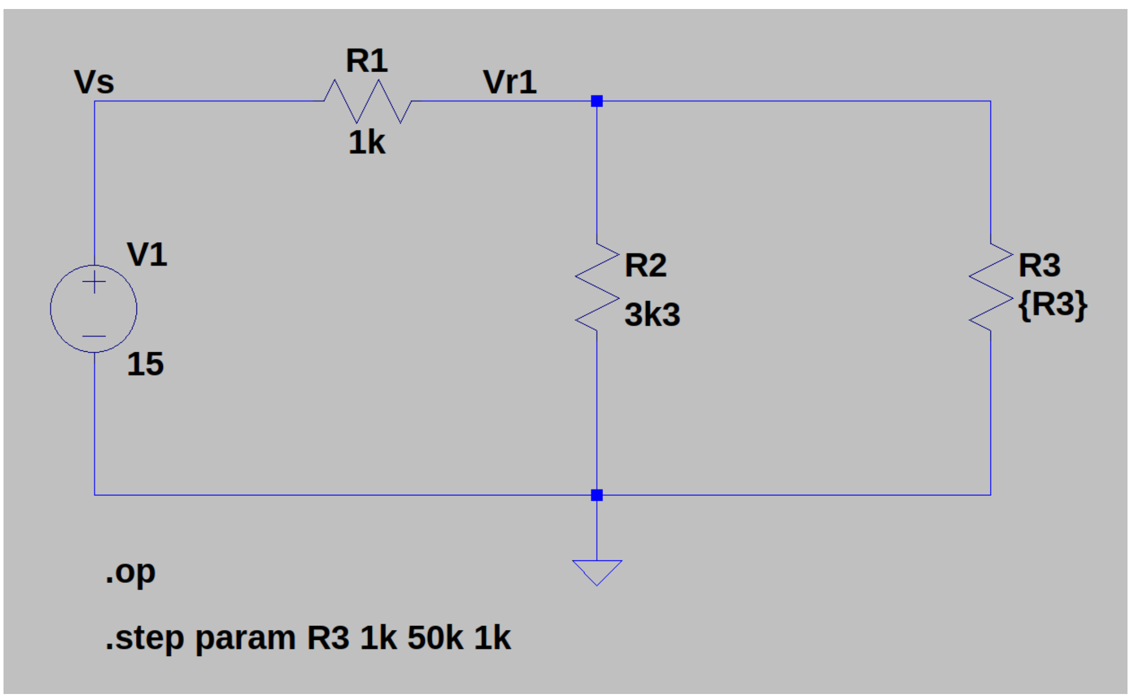
Abstract

In this weeks lab we are tasked to analyze a circuit which has one unknown resistor value. We must utilize both theoretical calculations as well as modeling software, LTspice, to find values for V_x, I_s, I_1, and I_2 with respect to our unknown resistance, R_3. We will compare our results from both methods of analysis.

Equipment

- Acer Nitro 5 - OS: Ubuntu 22.04.1 LTS
- LTspice - Version: 17.0.35.0

Procedure

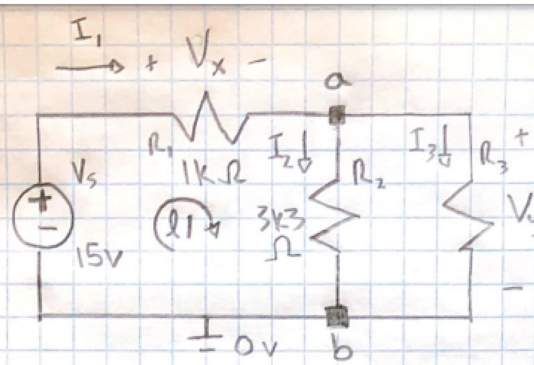


Utilizing the schematic above, complete the following steps:

1. Using Kirkhoff's Current and Voltage Law's and Ohm's Law, theoretically calculate the equations for V_x, V_y, I_1, I_2, and I_3 with respect to
2. Using LTspice, construct the circuit shown above.

3. Run the DC simulation using the making calculations for values of R_3 ranging from 1kΩ to 50kΩ using steps of 2k.
4. Acquire data from these simulations.
5. Make graphs of V_x, V_y, I_1, I_2, and I_3 with respect to R_3
6. Compare theoretical calculations with simulated data.

Theoretical Equation Derivation



Variables

$R_1 = 1k\Omega$ $\quad V_s = 15V$

$R_2 = 3k\Omega$ $\quad V_x = $ Dep.

$R_3 = $ Ind. $\quad V_y = $ Dep.

$I_1 = $ Dep. $\quad I_2 = $ Dep. $\quad I_3 = $ Dep.

$R_{tot} = R_1 + \frac{R_2 \cdot R_3}{R_2 + R_3}$

KCL:

a) $I_1 = I_2 + I_3$

KVL:

ℓ1) $V_s = V_x + V_y$

Find $V_x(R_3)$ using Ohm's Law:

$$I_1 = \frac{V_s}{R_{tot}} = \frac{V_x}{R_1} \Rightarrow \frac{V_x}{R_1} = \frac{V_s}{R_1 + \frac{R_2 \cdot R_3}{R_2 + R_3}} = \boxed{V_x(R_3) = \frac{V_s \cdot R_1}{R_1 + \frac{R_2 \cdot R_3}{R_2 + R_3}}}$$

Find $V_y(R_3)$ using KVL and substitution:

$$V_s = V_x + V_y \Rightarrow V_y = V_s - V_x \Rightarrow \boxed{V_y(R_3) = V_s - \frac{V_s \cdot R_1}{R_1 + \frac{R_2 \cdot R_3}{R_2 + R_3}}}$$

Find $I_1(R_3)$, $I_2(R_3)$, and $I_3(R_3)$ using KCL and substitution:

$$I_1 = I_2 + I_3 \Rightarrow I_1(R_3) = \frac{V_y(R_3)}{R_2} + \frac{V_y(R_3)}{R_3}$$

$$\Downarrow$$

$$I_2 = I_1 - I_3 \Rightarrow I_2(R_3) = \frac{V_x(R_3)}{R_1} - \frac{V_y(R_3)}{R_3}$$

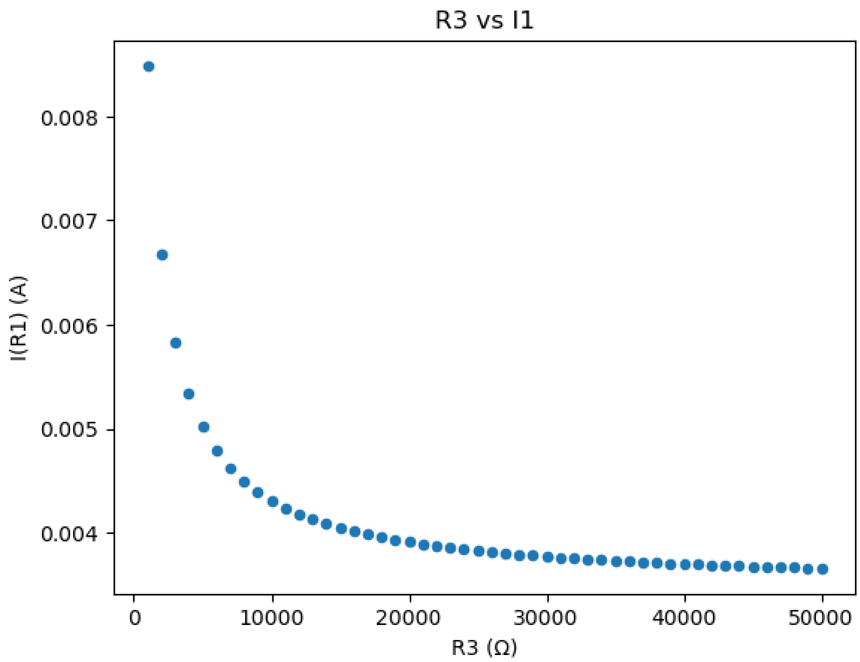
$$\Downarrow$$

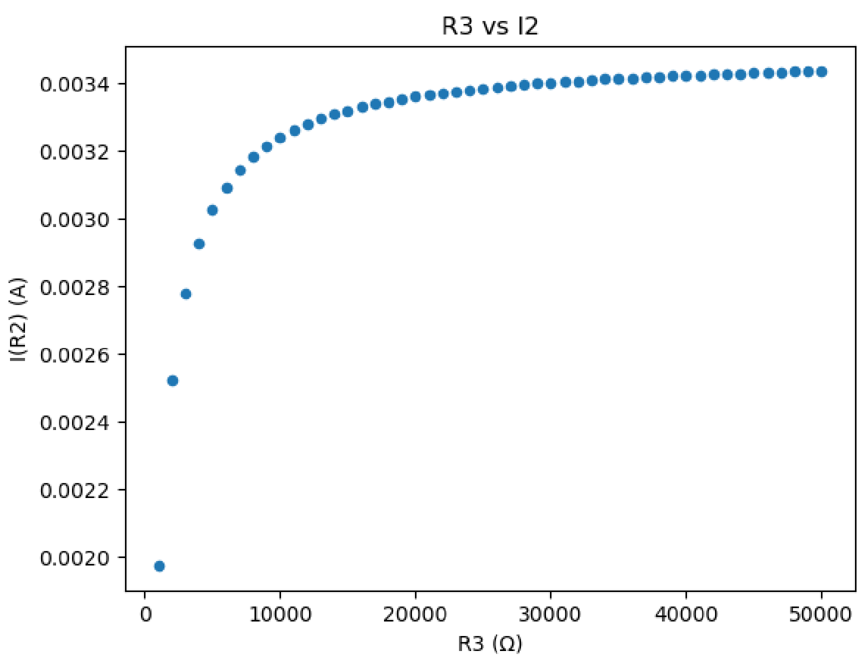
$$I_3 = I_1 - I_2 \Rightarrow I_3(R_3) = \frac{V_x(R_3)}{R_1} - \frac{V_y(R_3)}{R_2}$$

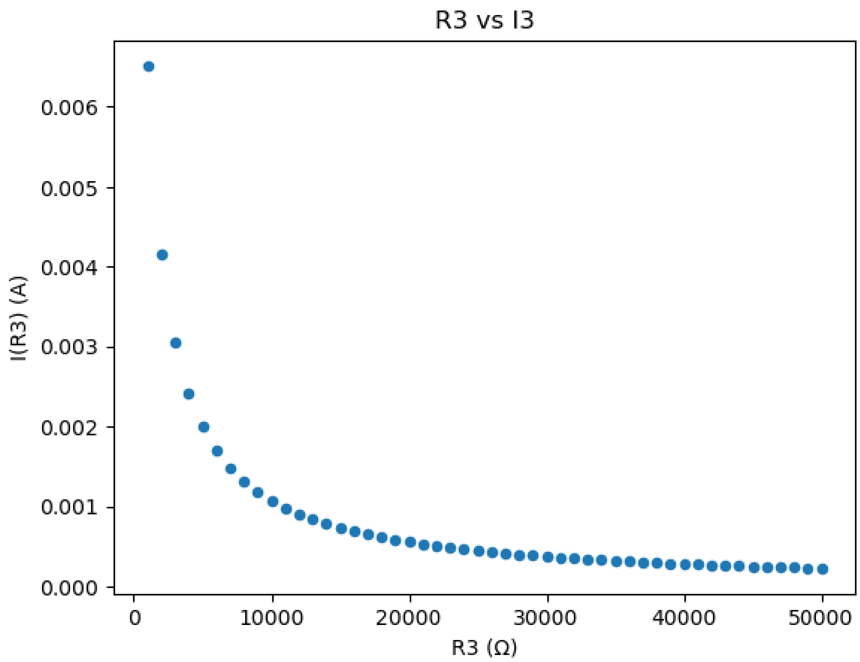
Data

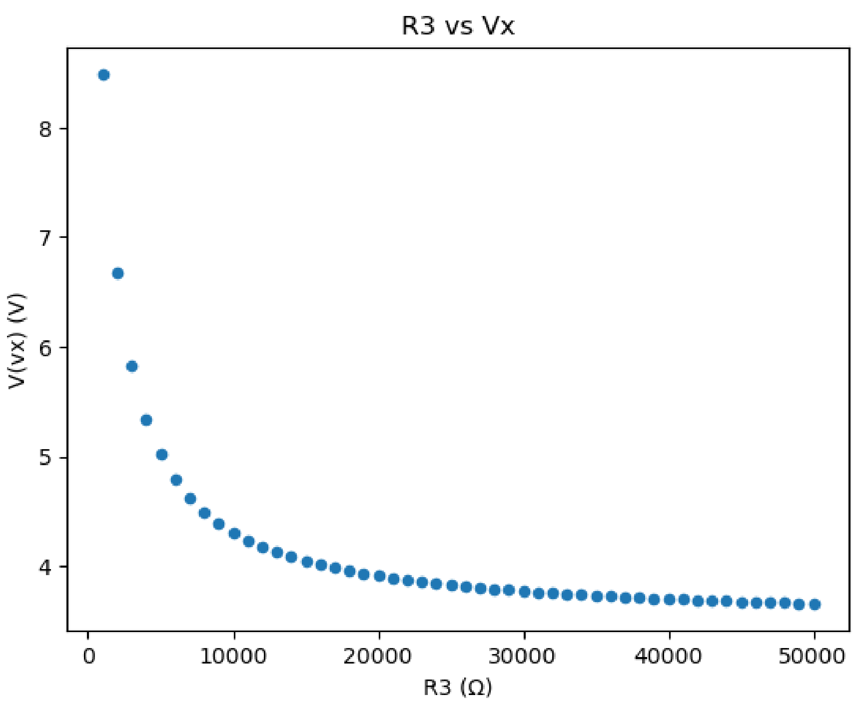
Data From LTspice Simulation

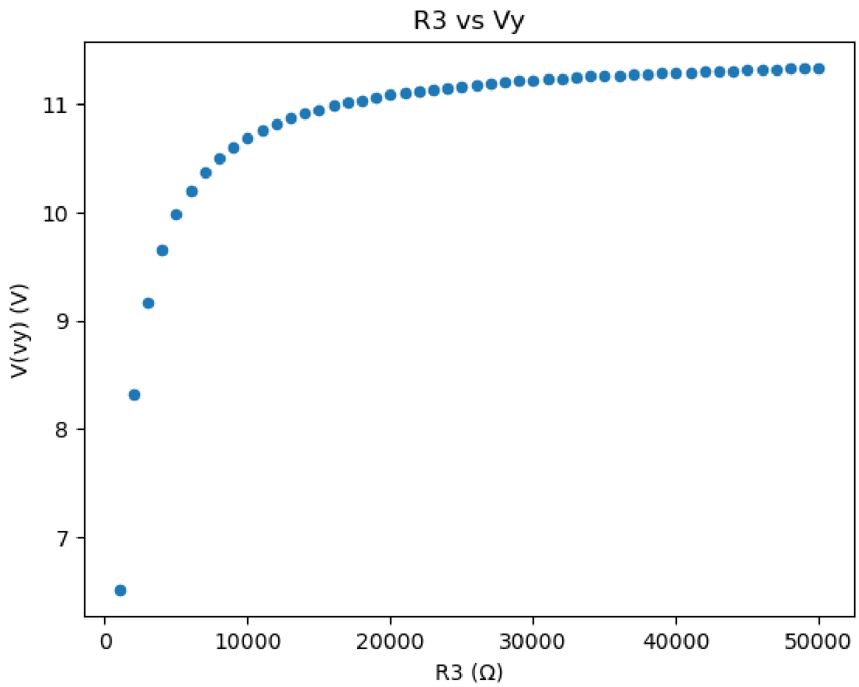
	R3 (Ω)	V(vs) (V)	V(vx) (V)	V(vy) (V)	I(R1) (A)	I(R2) (A)	I(R3) (A)	I(V1) (A)
0	1000	15	8.486842	6.513158	0.008487	0.001974	0.006513	-0.008487
1	3000	15	5.833333	9.166667	0.005833	0.002778	0.003056	-0.005833
2	5000	15	5.020162	9.979838	0.005020	0.003024	0.001996	-0.005020
3	7000	15	4.625750	10.374250	0.004626	0.003144	0.001482	-0.004626
4	9000	15	4.392860	10.607140	0.004393	0.003214	0.001179	-0.004393
5	11000	15	4.239130	10.760870	0.004239	0.003261	0.000978	-0.004239
6	13000	15	4.130070	10.869930	0.004130	0.003294	0.000836	-0.004130
7	15000	15	4.048670	10.951330	0.004049	0.003319	0.000730	-0.004049
8	17000	15	3.985600	11.014400	0.003986	0.003338	0.000648	-0.003986
9	19000	15	3.935290	11.064710	0.003935	0.003353	0.000582	-0.003935
10	21000	15	3.894230	11.105770	0.003894	0.003365	0.000529	-0.003894
11	23000	15	3.860080	11.139920	0.003860	0.003376	0.000484	-0.003860
12	25000	15	3.831230	11.168770	0.003831	0.003384	0.000447	-0.003831
13	27000	15	3.806530	11.193470	0.003807	0.003392	0.000415	-0.003807
14	29000	15	3.785160	11.214840	0.003785	0.003398	0.000387	-0.003785
15	31000	15	3.766470	11.233530	0.003766	0.003404	0.000362	-0.003766
16	33000	15	3.750000	11.250000	0.003750	0.003409	0.000341	-0.003750
17	35000	15	3.735370	11.264630	0.003735	0.003414	0.000322	-0.003735
18	37000	15	3.722290	11.277710	0.003722	0.003417	0.000305	-0.003722
19	39000	15	3.710530	11.289470	0.003711	0.003421	0.000289	-0.003711
20	41000	15	3.699890	11.300110	0.003700	0.003424	0.000276	-0.003700
21	43000	15	3.690220	11.309780	0.003690	0.003427	0.000263	-0.003690
22	45000	15	3.681400	11.318600	0.003681	0.003430	0.000252	-0.003681
23	47000	15	3.673320	11.326680	0.003673	0.003432	0.000241	-0.003673
24	49000	15	3.665890	11.334110	0.003666	0.003435	0.000231	-0.003666
25	50000	15	3.662390	11.337610	0.003662	0.003436	0.000227	-0.003662


R3 vs I1
0.008
0.007
0.006
0.005
0.004
I(R1) (A)
0
10000
20000
30000
40000
50000
R3 (Ω)


R3 vs I2
0.0034
0.0032
0.0030
0.0028
0.0026
0.0024
0.0022
0.0020
I(R2) (A)
0
10000
20000
30000
40000
50000
R3 (Ω)


R3 vs I3
I(R3) (A)
R3 (Ω)
0.006
0.005
0.004
0.003
0.002
0.001
0.000
0
10000
20000
30000
40000
50000


R3 vs Vx
V(vx) (V)
R3 (Ω)
8
7
6
5
4
0
10000
20000
30000
40000
50000



Theoretical Calculations

To compare my theoretical formulas with the simulated data we will take several values for R_3 within our testing range and compare the output with our simulated data. We will be rounding our answers to two significant figures.

$$V_x(R_3) = \frac{V_s * R_1}{R_1 + \frac{R_2 * R_3}{R_2 + R_3}} \Rightarrow V_x(R_3) = \frac{15 * 1000}{1000 + \frac{3300 * R_3}{3300 + R_3}}$$

$$V_y(R_3) = V_s - V_x(R_3) \Rightarrow V_y(R_3) = 15 - V_x(R_3)$$

$$I_1(R_3) = \frac{V_y(R_3)}{R_2} + \frac{V_y(R_3)}{R_3} \Rightarrow I_1(R_3) = \frac{V_y(R_3)}{3300} + \frac{V_y(R_3)}{R_3}$$

$$I_2(R_3) = I_1(R_3) + \frac{V_y(R_3)}{R_3}$$

$$I_3(R_3) = I_1(R_3) - \frac{V_y(R_3)}{R_2} \Rightarrow I_3(R_3) = I_1(R_3) - \frac{V_y(R_3)}{3300}$$

$R_3 = 3000$
$V_x(R_3) = 5.83V$
$V_y(R_3) = 9.167V$
$I_1(R_3) = 0.0058A$
$I_2(R_3) = 0.0028A$
$I_3(R_3) = 0.0031A$

$R_3 = 17000$
$V_x(R_3) = 3.99V$
$V_y(R_3) = 11.01V$
$I_1(R_3) = 0.004A$
$I_2(R_3) = 0.0033A$
$I_3(R_3) = 0.00064A$

$R_3 = 29000$
$V_x(R_3) = 3.79V$
$V_y(R_3) = 11.21V$
$I_1(R_3) = 0.0038A$
$I_2(R_3) = 0.0034A$
$I_3(R_3) = 0.00039A$

$R_3 = 45000$
$V_x(R_3) = 3.68V$
$V_y(R_3) = 11.31V$
$I_1(R_3) = 0.0037A$
$I_2(R_3) = 0.0034A$
$I_3(R_3) = 0.00025A$

Conclusion

The values calculated using our theoretically derived equations compared to our simulated data were nearly identical, the deviation arising from rounding to two significant figures. We find that for I_1, I_3, and V_x demonstrate an inverse relationship with respect to R_3, while for I_2 and V_y have a logarithmic relationship with respect to R_3. Utilizing simulation software appears to be an efficient way to analyze the nature of various circuits.