Laboratory Two — DC Circuits

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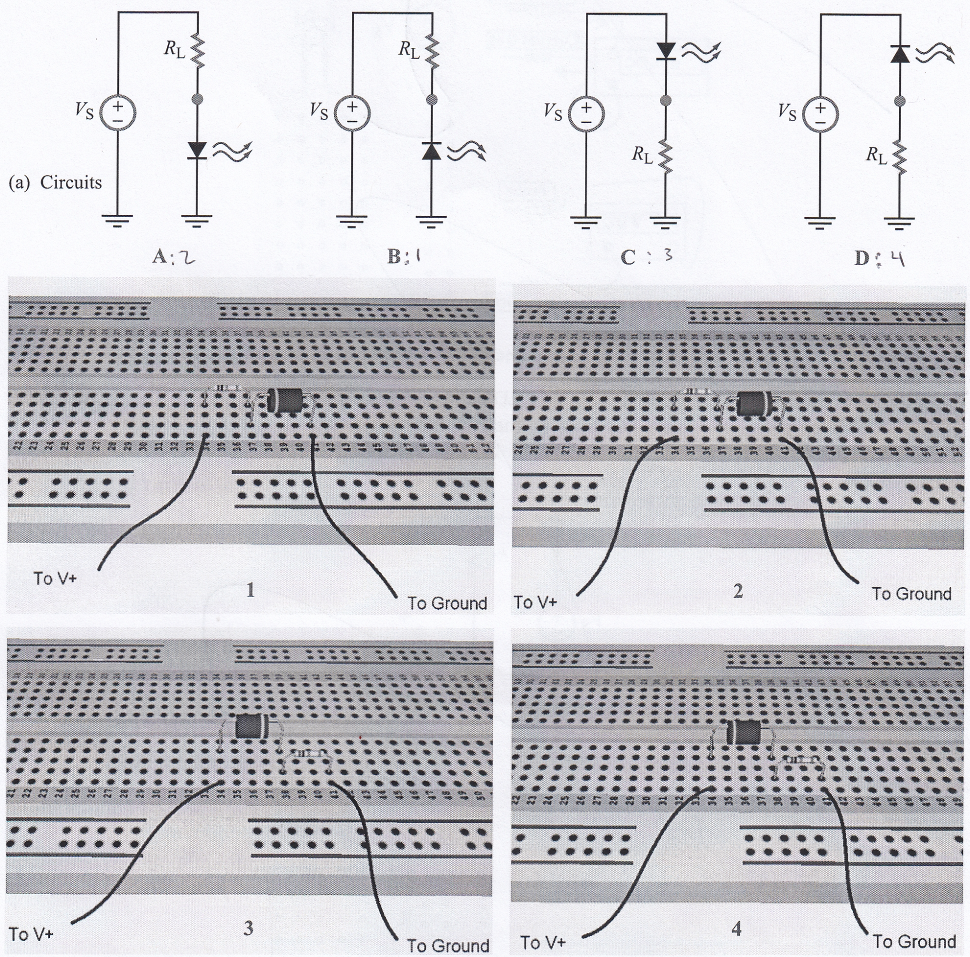
Pre-Lab

3. PRE-LAB ASSIGNMENT

The Pre-Lab includes 6 problems. Make sure to complete them all before the lab.

1. Identify which circuit diagram in Figure 15(a) corresponds to each 3-D picture of the prototyping boards in Figure 15 (b).



(b) Prototyping boards

Figure 15: Four different circuit diagrams and four different protoboard arrangements.

2. Draw connections for the measurements of the voltage across and the current through a forward-biased LED (be careful with the polarity) as shown in Figure 16. In this circuit, no load resistor is needed. The power supply should be connected to the bus lines on the left and the LED should be connected to individual nodes on the right.

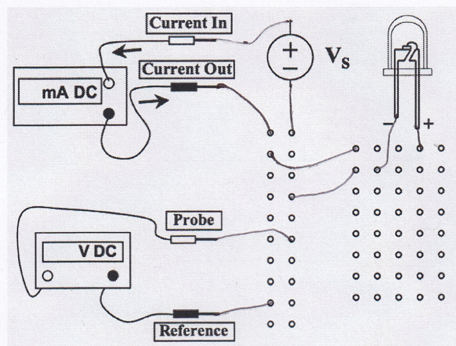


Figure 16: Connecting source and multimeter to circuit on protoboard.

3. Draw connections for a circuit with an LED and resistor as shown in Figure 17. The power supply should be connected to the bus lines on the left, the resistor and LED should be connected to the individual nodes on the right, and the voltmeter should measure the output voltage across the LED.

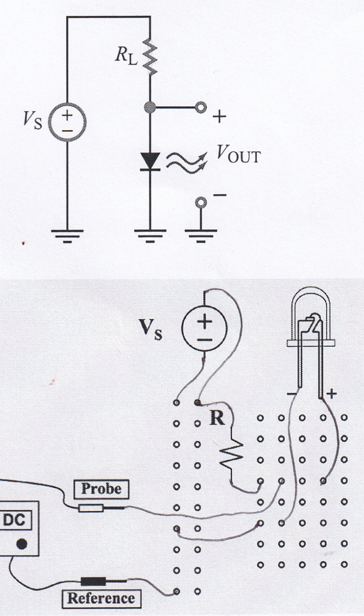


Figure 17: Implementation of resistor-LED circuit.

4. In the lab, you will build the circuit in Figure 18 and measure currents through resistors, node voltages, and the equivalent resistances. Assume $V_S = 6$ V and the following resistances:

   $R_1 = 51\ \Omega$
   $R_2 = 1000\ \Omega$
   $R_3 = 470\ \Omega$
   $R_4 = 150\ \Omega$
   $R_5 = 200\ \Omega$

   Calculate the following and record in the table below:

   - Node voltages V_c and V_d in volts
   - Total current I_{Total} and the current through each resistor.
   - The circuit's equivalent resistance in ohms between nodes *a* and *b*.

V_c	V_d	I_1	I_2	I_3	I_4	I_5	I_{Total}	R_{eq}
5.14V	2.79V	0.017A	0.005A	0.007A	0.019A	-0.012A	0.036A	166.75Ω

   Simulate the circuit in SPICE and verify that your values agree.

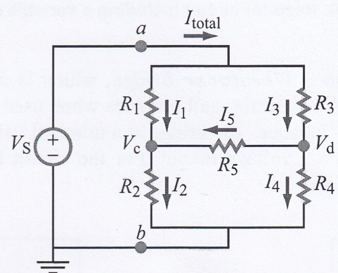
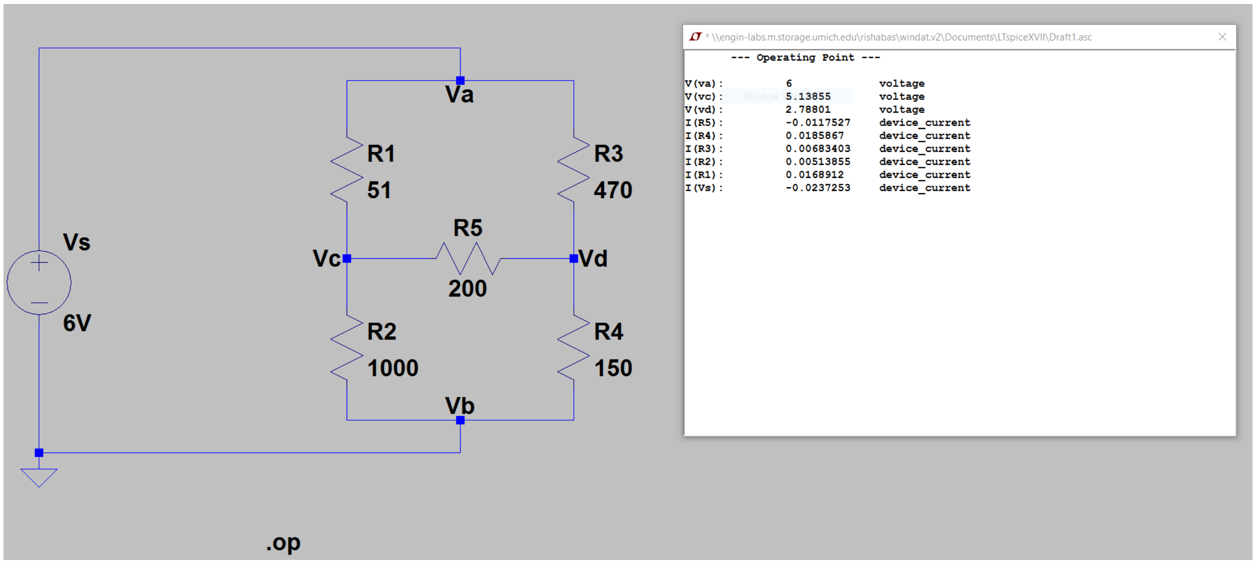


Figure 18: Resistor circuit for equivalent resistance.


Va
R1
51
R3
470
Vs
R5
Vc
Vd
200
6V
R2
1000
R4
150
Vb
.op
* \\engin-labs.m.storage.umich.edu\rishabas\windat.v2\Documents\LTspiceXVII\Draft1.asc
--- Operating Point ---
V(va): 6 voltage
V(vc): 5.13855 voltage
V(vd): 2.78801 voltage
I(R5): -0.0117527 device_current
I(R4): 0.0185867 device_current
I(R3): 0.00683403 device_current
I(R2): 0.00513855 device_current
I(R1): 0.0168912 device_current
I(Vs): -0.0237253 device_current

5. The circuit shown in Figure 19 is built with the same resistors as the circuit shown in Figure 18, except for the addition of the variable resistor R_X. Determine the value of R_X such that the current I_5 vanishes.

Your result: R_X = ______________ Ω

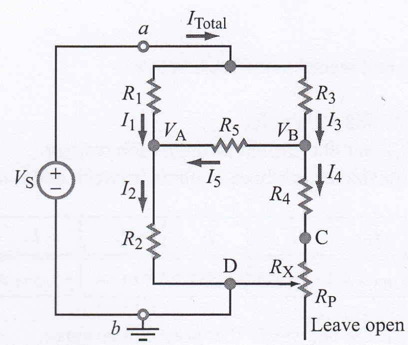


Figure 19: Resistor circuit including a variable resistor.

6. Circuit 3 is also known as a ***Wheatstone Bridge***, which is an effective circuit for measuring changes such as light intensity, strain, and pressure when used with a sensor. A variable resistor (potentiometer) is used to "balance" the bridge at a nominal value, where small changes from the nominal value will produce a voltage output. For the circuit below, derive the value of V_{out} in terms of V_S, R_1, R_2, R_3, and R_4.

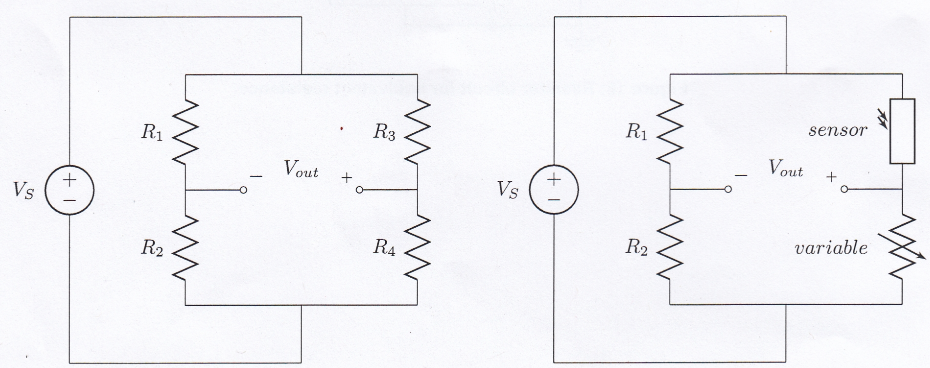


Figure 20: Wheatstone Bridge and example application as a light detector.

$$V_{out} = \left(\frac{R_2}{R_1+R_2} - \frac{R_4}{R_4+R_3}\right) V_s$$

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Post-Lab

Thevenin Equivalent

Component	Nominal Value (Ω)	Measure (Ω)	Measured V_L (V)	$I_L = V_{L,meas}/R_{L,meas}$ (mA)
R_S	100	99.049	0	0
R_{L1}	20	19.784	1.0149	50.62121
R_{L2}	51	50.824	2.0349	40.03817
R_{L3}	100	97.885	2.9804	30.44797
R_{L4}	200	199.000	4.0036	20.11859
R_{L5}	470	474.040	4.9625	10.46853
R_{L6}	1000	984.600	5.4515	5.53676

Table 1: Thevenin Equivalent circuit data

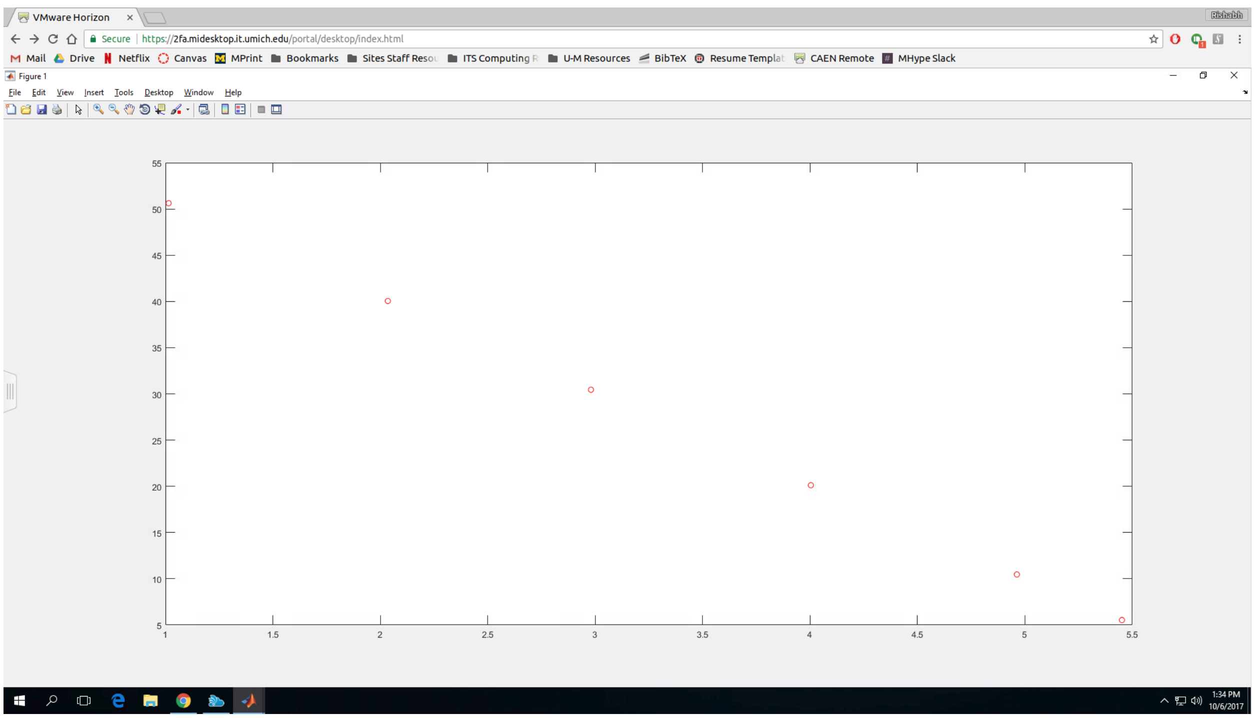

Figure 1: Graph of I_L versus V_L

```
>> x = [1.0149,2.0349,2.9804,4.0036,4.9625,5.4515];
>> y = [50.62121,40.03817,30.44797,20.11859,10.46853,5.53676];
>> linearCoefficients = polyfit(x, y, 1);
>> plot(x,y, 'ro');
>> linearCoefficients

linearCoefficients =

  -10.1451   60.7794

>> 
```

Figure 2: Code used to find V_T and R_T

The calculated values for V_T and R_T are $V_T = 60.7794V$ and $R_T = -10.1451\Omega$. This is very different than the calculated value.

Light Sensor

I

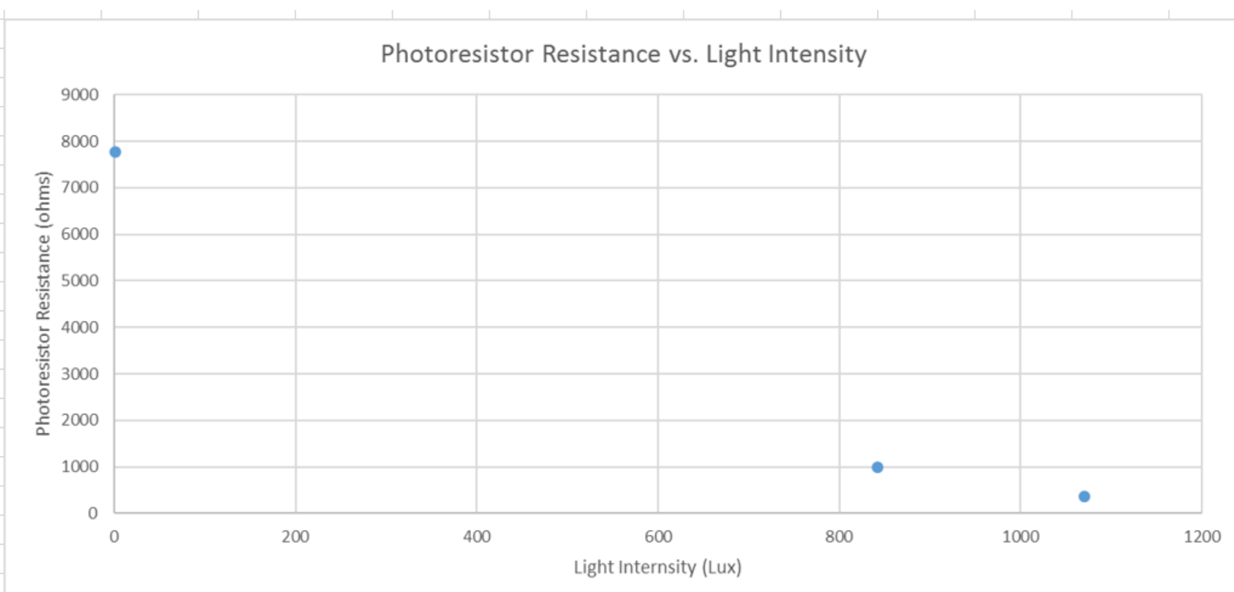

Figure 3: Graph of photoresistor resistance versus light intensity

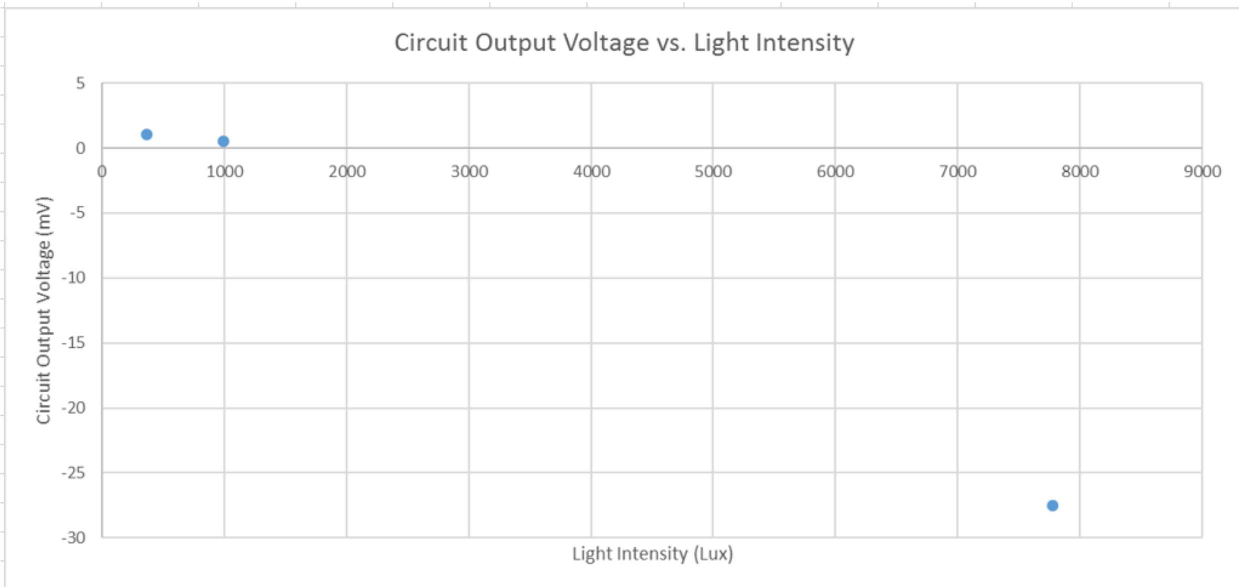

Figure 4: Graph of circuit output voltage versus light intensity

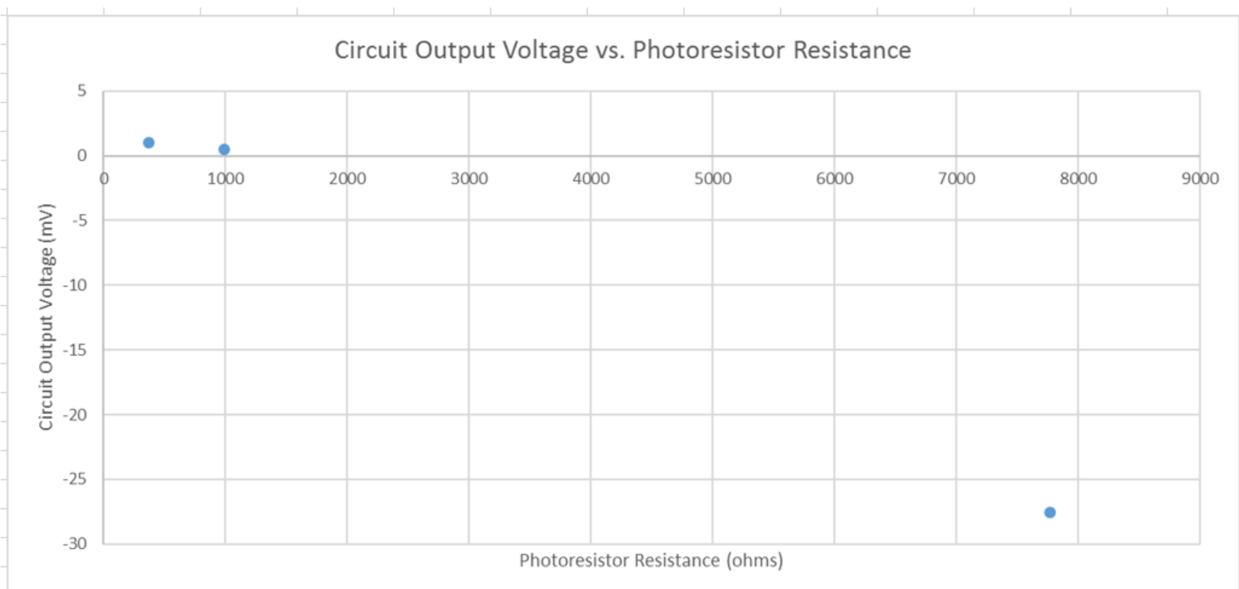

Figure 5: Graph of circuit output voltage versus photoresistor resistance

II

$$S = \frac{\Delta R}{\Delta lux} = \frac{7775.2 - 370.45}{1 - 1070} = -6.9268\Omega/lux$$

$$S = \frac{\Delta V_{out}}{\Delta lux} = \frac{-27.530 - 1.123}{1 - 1070} = 0.0268V/lux$$

III

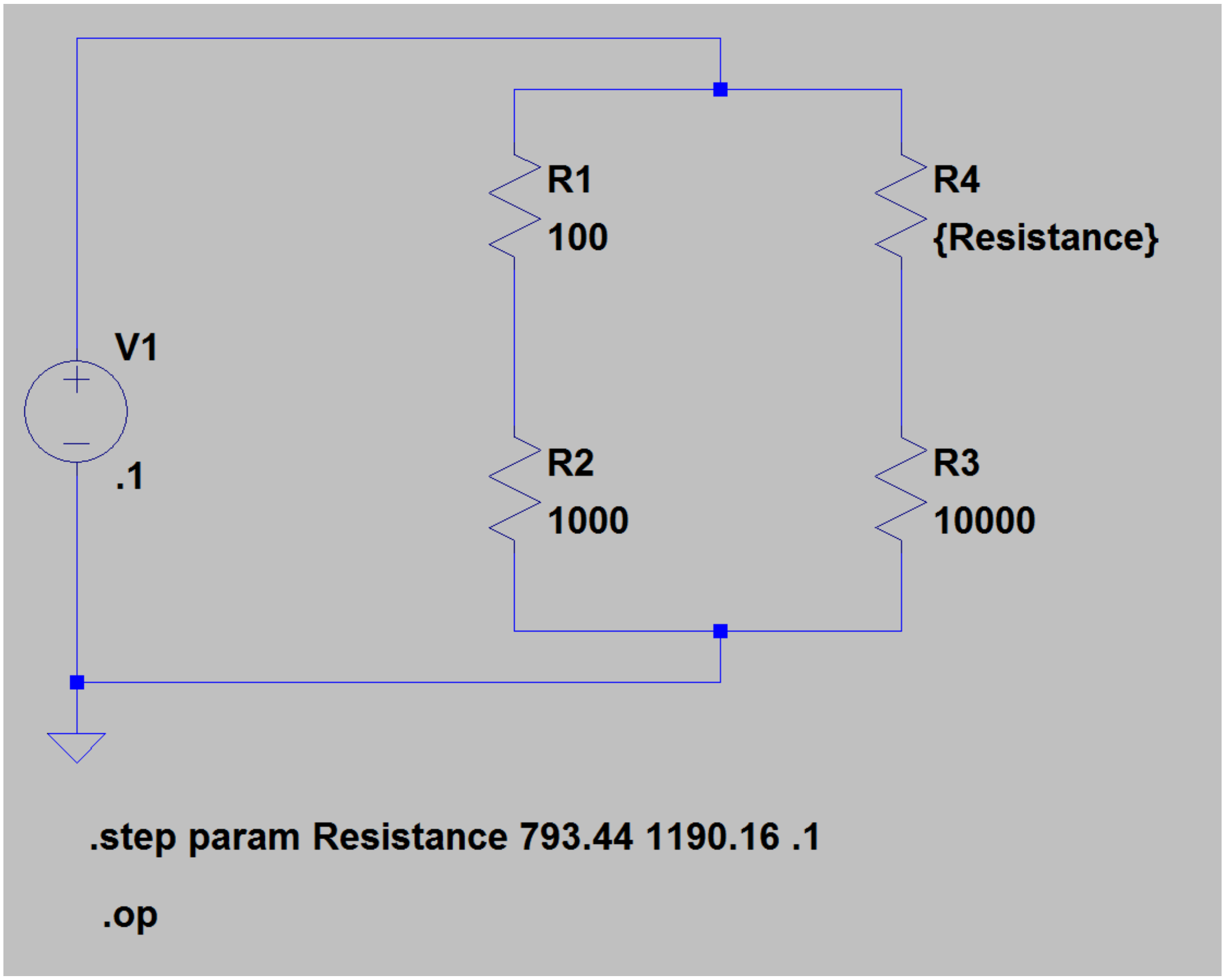

Figure 6: Photoresistor circuit simulated in LTSPice

IV

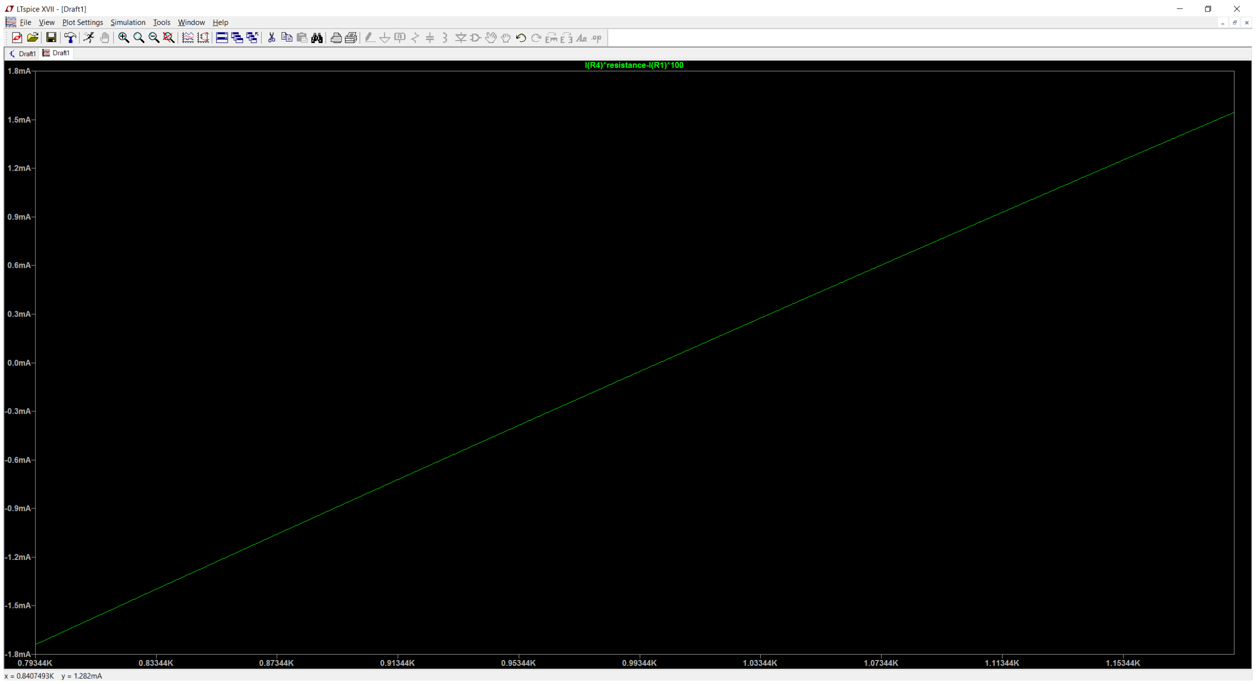

Figure 7: Simulated graph of circuit output voltage versus photoresistor resistance

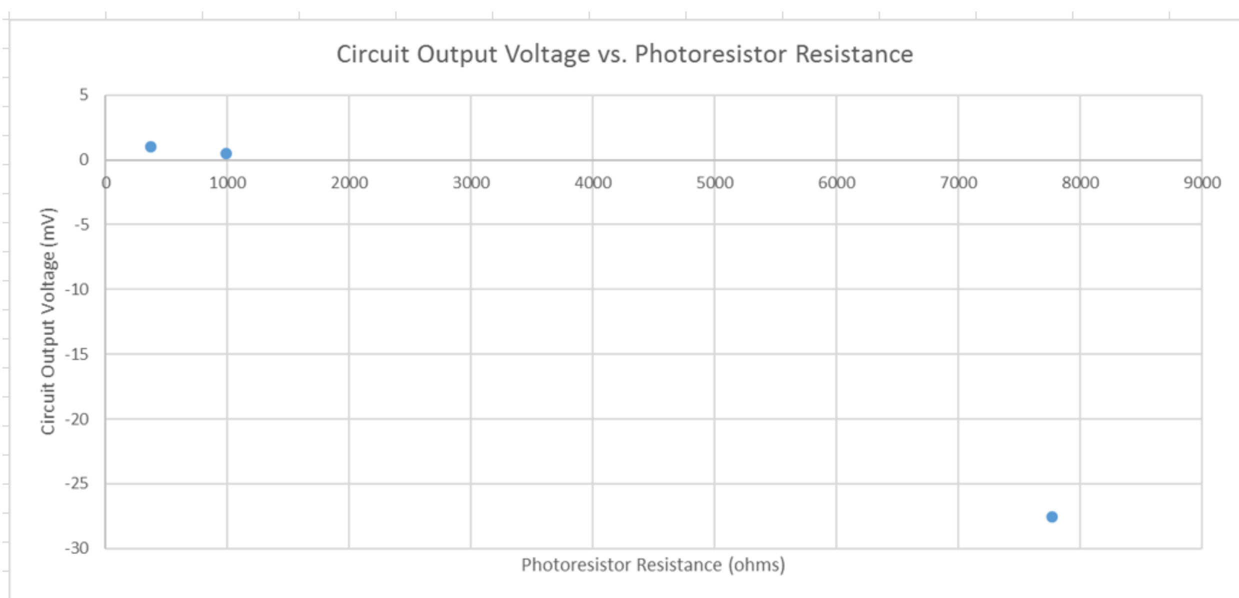

Figure 8: Graph of circuit output voltage versus photoresistor resistance

When comparing the measured data to the simulated data, it looks like the slope of the graph is opposite. This is due to the voltmeter having the reversed polarity when measuring. Disregarding the reversed polarity, the two graphs are fairly similar.

V

The sensitivity of our circuit is fairly high, as we have a sensitivity of 6 Ω per lux. This means that for every increase in lux, the resistance of the photoresistor increases by 6 Ω. The circuit is fairly linear, as shown by the graphs in Part I. The accuracy of the circuit is also fairly high due to the similarities between the simulated graph and the measured data, including the slope of both graphs.

VI

An application of our circuit is on a solar tracking device. In such a device, photoresistors are used to compare the amount of light on all sides of a solar panel. Then the output voltages are compared, and the side with the highest amount of light is the direction in which the solar panel will be moved. This results in maximum electrical output for the solar panel. The sensitivity of the photoresistor circuits is fairly important, especially if the device is tracking at a high rate. This results in the light variation per side being much lower than if the device is tracking at a low rate. The accuracy of the photoresistor is also important, as noisy data will result in the device incorrectly tracking. The linearity of the photoresistors is not important, as the values are compared, rather than used individually.