Electrical Engineering 110L Circuits Measurements Lab

Lab 3: Superposition; Sensors (Part II)

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Objective

The objective of this lab is to demonstrate the principle of superposition for a simple circuit. We will test and verify the theory behind the superposition principle and then later test for issues with non-ideal power supply. In the test with non-ideal power supply we will see that the superposition principle fails. Our other objective is to setup a thermometer using a Wheatstone bridge circuit with a thermistor as one of its resistor.

Theory

In this lab we will be using the following governing equations to conduct experiments and verify principles:

Governing Equations	Equations Information
[1] $P = I^2R = V^2/R = VI$	I = current (A), P = power (W), R = resistance (Ω)
[2] $V = IR$	V = voltage (V)
[3] $I_{meter} = I_{total}*R_{shunt}/(R_{shunt}+R_{meter})$	(This equation will be use find maximum current I.)
[4] $V = (P*R)^{1/2}$	Max voltage can be applied to resistor (derive from [1])
[5] $V_{R1}=R1/(R1+R2)*V_{tot}$	Voltage divider (note: one possible form)
[6] $I_{R1}=R2//(R1+R2)*I_{tot}$	Current divider (note: one possible form)
[7] $R_{eq}=R_1*R_2/(R_1+R_2)$	Equivalent resistance for parallel
[8] $V_+=V_{in}R_3/(R_1+R_3)+\Delta V_{in}R_3/(R_1+R_3)$	Derive from the voltage divider equation for the Wheatstone bridge

Table 1: Governing Equations for the experiments that follow.

Reading resistor's value will require understanding of the color values. This is the general equations that give the resistor's resistance. $R = (1^{st}2^{nd}) \times 10^{3rd}\ \Omega \pm 4^{th}$
The 1^{st} denote the first color band, 2^{nd} denote the second color band and so on. Plugging in the values into the respective location will give the resistance and tolerance of the resistor. The 4^{th} is the tolerance of the resistor normally in percentage and needs to be converted to Ω for finding the range of resistance.

Superposition Principle – (assuming linearity in circuits) states that any circuit voltage OR current with independent source(s) may be calculated using algebraic sum of voltages or currents resulting from independent source.

Procedure

Lab experiment 1:

In this first experiment we setup the circuit base on figure 8 in the lab manual. We then short circuit each power supply individually and measure the voltage and current across the 2kΩ in the circuit using the DMM. After finishing shorting each power supply and collecting the data connect both power supply and collect the voltage and current again. This completes this experiment.

Lab experiment 2:

In this experiment we set up the circuit similar to figure 9 in the lab manual to verify the validity of superposition principle on the circuit. To begin we first create an open circuit for each power supply and adjust their voltage level to 5V and 10V. Then connect the circuit and measure the voltage across the 1kΩ. Collect the data to complete this experiment.

Lab experiment 3:

In this part of the lab we will be setting up the circuit design similar to figure 10 of the lab manual. After setting it up by adjusting the voltage to 5V when it is an open circuit we can now connect the rest of the circuit and its components. The opposite voltage source we will be reducing it to almost 3V voltage if possible. After connecting the DMMs to measure the voltage and current across the 5V power supply the experiment can begin. The power source that is at 3V will now be increment by 1V and the voltage and current across the 5V DC will be recorded during each 1V interval. Continue this process until 12V is reached.

Lab experiment 4:

The purpose of this part of the lab is to design a thermometer using the Wheatstone circuit design and replacing one of the resistors in the Wheatstone circuit with a thermistor. After setting up the Wheatstone circuit and switching out two of its resistors with a thermistor and a variable resistor we then calibrate the thermistor temperature sensor with that of the room temperature. The room temperature will be our reference temperature. After the necessary calibration are done the experiment can begin.

Data, Data Analysis, Error Analysis, and Discussion

Error Analysis

If the general equation is $F(x_1, x_2, \ldots, x_n)$ then the error for F (identified as σ_F) would be given by the following error propagation equation:

$$\sigma_F = \sqrt{(\frac{dF}{dx_1}\sigma_{x_1})^2 + (\frac{dF}{dx_2}\sigma_{x_2})^2 + \cdots + (\frac{dF}{dx_n}\sigma_{x_n})^2}$$

Lab experiment 1:

Data

	Pre-Lab	Measured Value		% error
$R_{2k\Omega}$ (kΩ)	2.0	2.079	±0.0005	3.95
$R_{3.3k\Omega}$ (kΩ)	3.3	3.431	±0.0005	3.97
$R_{5k\Omega}$ (kΩ)	5.0	5.630	±0.0005	12.60
V_{DC7} (V)	7.0	7.00	±0.005	0.00
V_{DC8} (V)	8.0	8.00	±0.005	0.00

Table 2: List of measured value for our superposition experiment

Power Source On	$I_{2k\Omega}$ (mA)		$V_{2k\Omega}$ (V)	
7V	1.05	±0.005	2.174	±0.005
8V	0.73	±0.005	1.511	±0.005
Sum of 7V & 8V	1.78	±0.007	3.685	±0.007
Measured 7V & 8V	1.77	±0.005	3.681	±0.005
% difference	0.56	%	0.11	%

Table 3: Shows that two independent voltage sources summed together equaled the expected superposition principle.

Data Analysis

It seems that the superposition principle holds as there is small percent difference between the sums of the individual independent sources with the original circuit when both voltage sources are active. The uncertainties also fall within the range for the measured and summed value. This means that our data analysis results that come from this experiment fully support the superposition principle.

Discussion

The data above shows that the superposition principle holds. The row “Sum of 7V & 8V” shows the independent voltage sources being added to equal the measured total as expected base on the superposition principle. This means that from adding the voltage and current from two or more sources in a linear circuit does give you the same result even if both sources were connected.

Lab experiment 2:

Data

	Pre-Lab	Measured Value		% error
$R_{150\Omega}$ (Ω)	150.0	201.8	±0.05	34.53
$R_{270\Omega}$ (Ω)	270.0	320.2	±0.05	18.59
$R_{1k\Omega}$ (kΩ)	1.0	1.072	±0.0005	7.20
V_{DC5} (V)	5.0	5.80	±0.005	16.00
V_{DC10} (V)	10.0	10.00	±0.005	0.00

Table 4: This table shows the basic measure value compare to the pre-lab expected value.

Power Source On	Pre-Lab (V)	$V_{1k\Omega}$ (V)		%error
5.8V	2.93	2.977	±0.0005	1.604096
10V	3.25	3.280	±0.0005	0.923077
Sum of 5.8V & 10V	6.18	6.257	±0.0007	1.245955
Measured 5.8V & 10V	------	6.700	±0.0005	8.414239
% difference	------	6.84	%	
* The last two value in % error is compare to prelab sum.				

Table 5: This table presents the issue when two voltages do not add up as in superposition principle.

Data Analysis

To compare the data we have to first note that the pre-lab value used to calculate the % error does not really mean much. This is just how far off we are from the materials we wanted but nonetheless the experiment in this case can continue. In table 5 we are adding up the $V_{1k\Omega}$ from the 5.8V and the 10V row. This will show us if the superposition how for this case or not. The values come out to have a percent error of 6.84%. So does this means that superposition fail? This is not necessary the case.

Discussion

The superposition principle does not fail so the Trojans are wrong because there is another issue that arises. It is due to the power supply acting like a load in this case. When the source act like a load it actually take some of the voltage away from the resistors so there is a reduction in the value.

Lab experiment 3:

Data

V_R (V)		V_S (V)		I_L (mA)	
3.1	±.05	5.061	±.0005	8.30	±.005
4.0	±.05	5.061	±.0005	5.20	±.005
5.0	±.05	5.061	±.0005	2.88	±.005
6.0	±.05	5.061	±.0005	0.70	±.005
7.0	±.05	5.061	±.0005	-1.56	±.005
8.0	±.05	5.061	±.0005	-3.69	±.005
9.0	±.05	5.253	±.0005	-5.39	±.005
10.0	±.05	5.784	±.0005	-5.94	±.005
11.0	±.05	6.385	±.0005	-6.55	±.005
12.0	±.05	6.990	±.0005	-7.17	±.005
At about 6.1V the current becomes zero at the load					

Table 6: Raw data for graphing the I vs. V plot

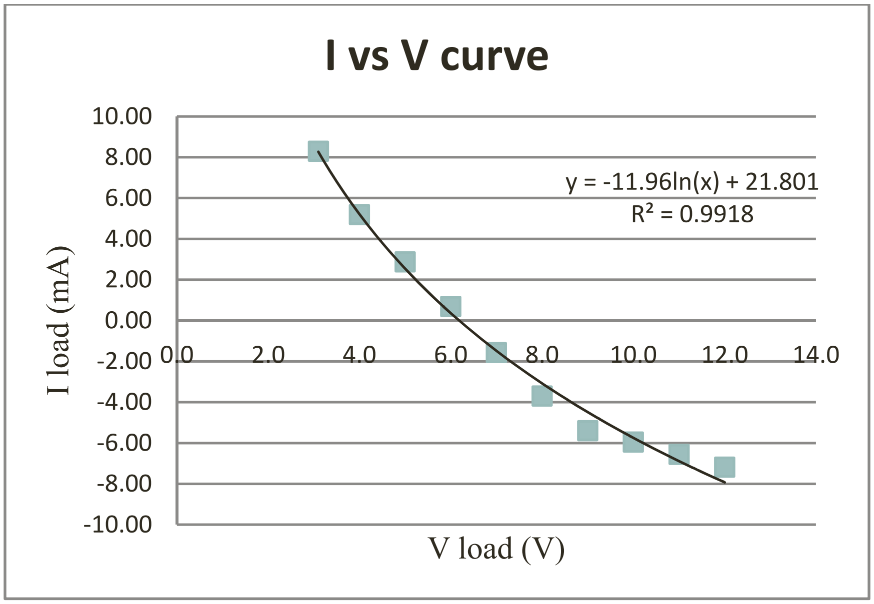

Figure 1: Graph of I vs V showing the point where current is zero through the load as well.

Data Analysis

From the data that we collected from the experiment we can plot the I and V corresponding to the resistor. This gives us figure 1 that is necessary for later discussion. The general equation $y = -11.96\ln(x)+21.80$ will give us a good approximate for calculating the location when current through the 1kΩ resistor will be zero.

Discussion

From the figure 1 and the equation found using excel regression or trend line method we can determine when the current through the load resistor 1kΩ will be zero. Solving for the equation mathematically we get 6.1V the cut of point when current is zero. After that the current will begin to reverse direction and flow the other way around.

Lab experiment 4:

Data

	Prelab	Measured	% error
R1 (kΩ)	33.00	32.55	1.4
R2 (kΩ)	33.00	32.57	1.3
Thermistor (kΩ)	33.00	33.36	1.1
Variable Resistor (kΩ)	33.00	31.85	3.5

Table 7: This table shows the desired value we wanted in the Pre-lab and the measured value we obtain from the experiment.

Power Supply (V)		V_{ab} (V)	
3.7	±0.05	0.394	±0.0005
4.7	±0.05	0.503	±0.0005
5.7	±0.05	0.595	±0.0005

Table 8: This table display the linear result of body temperature on thermistor against voltage across V_{ab}.

Data Analysis

In this part of the experiment to obtain the desire data first we actually have to zero the V_{ab} value and record it as .008V. We then hold the thermistor to obtain the linear relationship between the power supply voltage and the V_{ab} voltage. Since in our experiment we want to vary the voltage from 0V to .5V our choice is going to be 4.7V for power supply and .503V for V_{ab}.

Discussion

From the data analysis we picked the 4.7V power supply voltage to obtain the .503V at body temperature. During this data collection of table 8 we would warm the thermistor to our body temperature which should be approximately be 98.6 ºF. During the initial setup we have already set the reference point to room temperature to .008V (as close to 0V as possible). This means that the Wheatstone thermometer design is now set to measure voltage from 0-.5V which corresponds to room temperature to body temperature respectively.

Questions

1. From our experiment the restriction turns out to be around 4.7V (when the thermistor is exposed to my body temperature) from the power supply to give .503V which is as close as we can get to .5V. The 0V would be from the reference case (the room temperature). By setting the power supply to 4.7V we should obtain 98.6 ºF at .5V.

   In the case of thermistor we should look at the $P=V^2/R$ equation. It tells us that at higher resistance there is lower power dissipation and power dissipation is related to temperature. Since power is inversely proportional to R then temperature will be as well. This means that we have to choose a highly resistive thermistor to keep power dissipation low as it may affect the temperature it measure if it dissipates too much heat itself. The output voltage will also be small when at body temperature. This will help improve the temperature measurement with the thermistor as well.

2. Schematic of Wheatstone bridge circuit used with the thermistor.

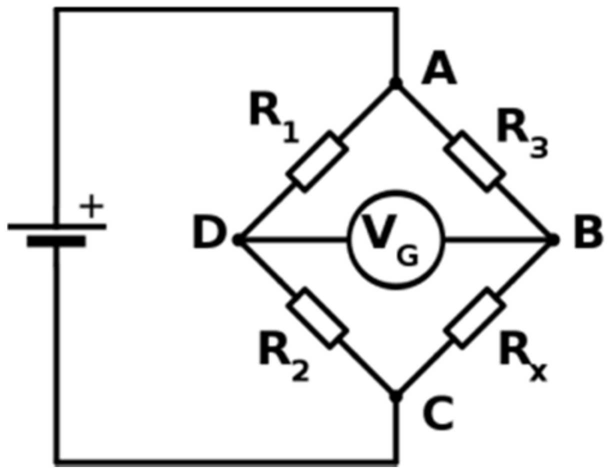

Figure 2: Let assume R_x is the thermal resistor in this case. (http://mrmackenzie.co.uk/tag/thermistor/)

Output voltage at room temperature V_{ab} = .008V
Output voltage at body temperature V_{ab} = .503V

3. The Trojans were incorrect in their assumption that the superposition fail. The issue arises only because the power supply sources were having an effect on one another. One of the power supply were acting like a sink this means that voltage source was not ideal and therefore result in the issue that make the Trojan believe there is something wrong with the superposition principle. The sink in our experiment turns out to be the 5V as the difference in V becomes too high the sink effect of the 5V kicks in.

4. The output voltage increase when we make the power supply into a current sink instead of a current source. From our data in table 6 we can see that the V_s which is the power supply increases as it act as a power sink. This occurs because current is flowing back through the source. If this was exchange with a battery the case will be different. There will be no external power to increase the voltage like the power supply would.

Conclusions

In this lab our experiments were very successful and we were able to demonstrate and verify the superposition principle. We were able to prove that the Trojans were wrong which was probably not even necessary as they are always wrong. (☺) They did not consider the issue of power supply acting like a sink and therefore falsely accuse the superposition principle. Our thermistor experiment was pretty successful as well since we were able to get the .008V (closest to 0V) to correspond to room temperature and .503V to correspond to body temperature.

The only main issues that we encounter were the many faulty resistors that was completely from our pre-lab picked choice. The recommended approach to this is to recalculate all of our values base on the measured values rather then trying to find the correct values.