

# ENGINEERING NOTEBOOK



**THE A - TEAM**

Aaron Sprunger and Raphaël Wolff

**THE  
A-TEAM**

**LAB 1**

## Lab 1 – Reading and Sorting Resistors

Names: Aaron Sprunger and Raphaël Wolff

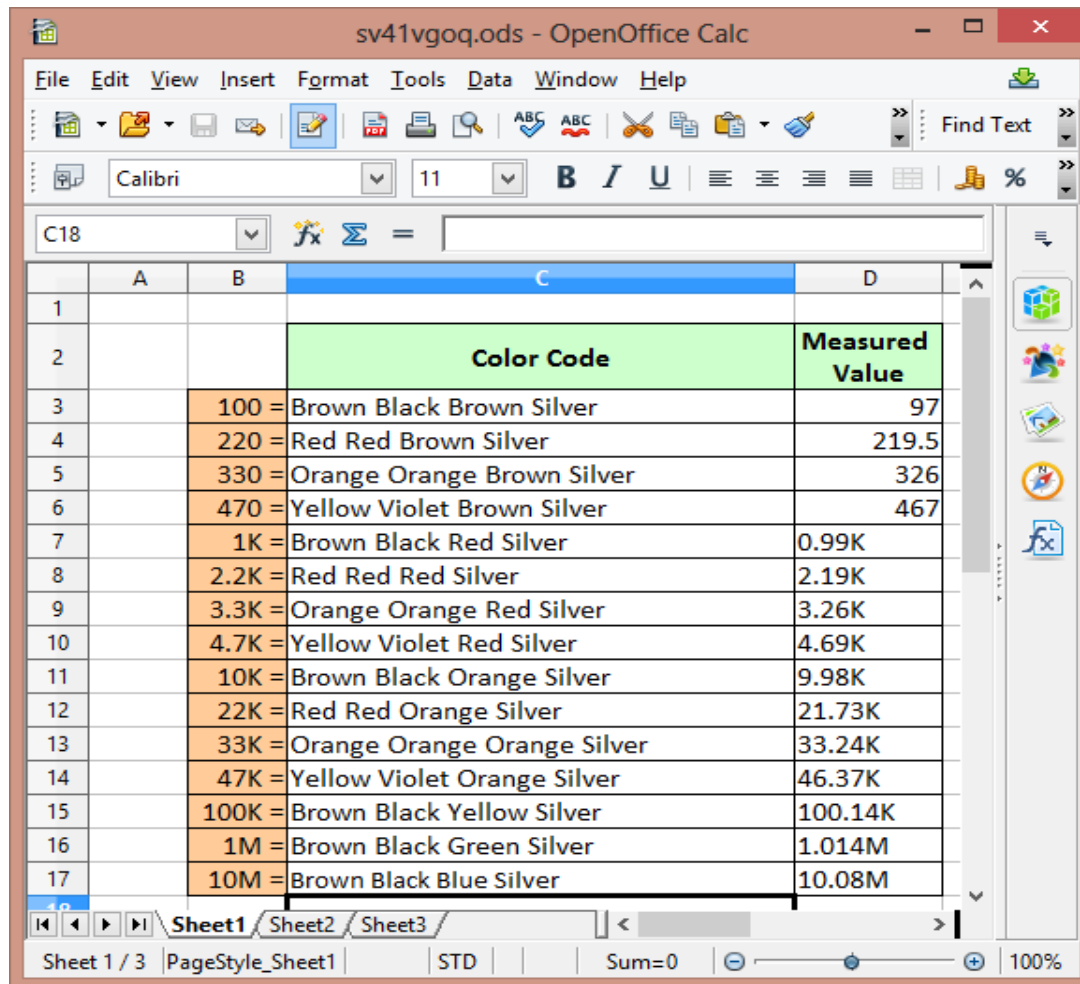
Date: 22 August 2013

The purpose of this lab is to:

Learn the resistor color code using 15 resistors which must be sorted from smallest to largest value. Build a resistor kit that includes 15 resistors and, sort resistors based on color code from smallest to largest and measure the resistance of each resistor and verify sorting

Equipment needed:

1 – Digital Multimeter



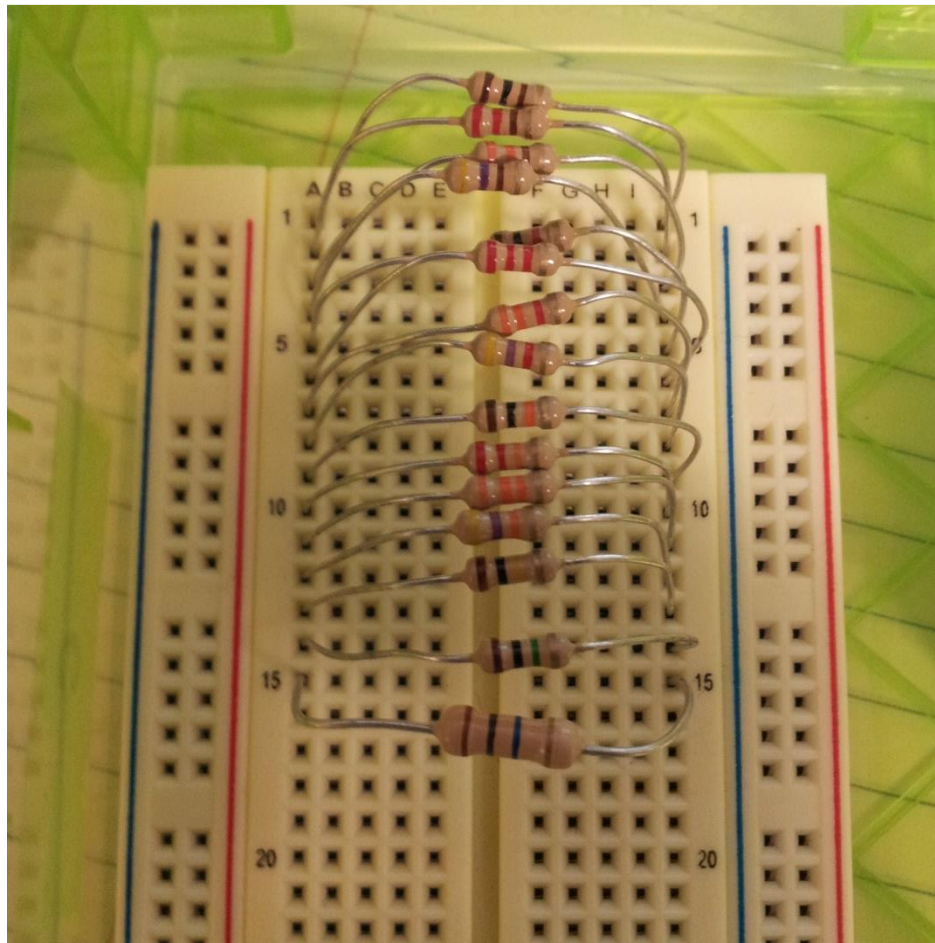
The screenshot shows an OpenOffice Calc spreadsheet titled 'sv41vgoq.ods'. The spreadsheet contains a table with 17 rows of resistor data. The columns are labeled A, B, C, and D. Column C is titled 'Color Code' and Column D is titled 'Measured Value'. The data is sorted by measured value from smallest to largest. The status bar at the bottom shows 'Sheet 1 / 3', 'PageStyle\_Sheet1', 'STD', 'Sum=0', and '100%'.

	A	B	C	D
1				
2			<b>Color Code</b>	<b>Measured Value</b>
3		100 =	Brown Black Brown Silver	97
4		220 =	Red Red Brown Silver	219.5
5		330 =	Orange Orange Brown Silver	326
6		470 =	Yellow Violet Brown Silver	467
7		1K =	Brown Black Red Silver	0.99K
8		2.2K =	Red Red Red Silver	2.19K
9		3.3K =	Orange Orange Red Silver	3.26K
10		4.7K =	Yellow Violet Red Silver	4.69K
11		10K =	Brown Black Orange Silver	9.98K
12		22K =	Red Red Orange Silver	21.73K
13		33K =	Orange Orange Orange Silver	33.24K
14		47K =	Yellow Violet Orange Silver	46.37K
15		100K =	Brown Black Yellow Silver	100.14K
16		1M =	Brown Black Green Silver	1.014M
17		10M =	Brown Black Blue Silver	10.08M

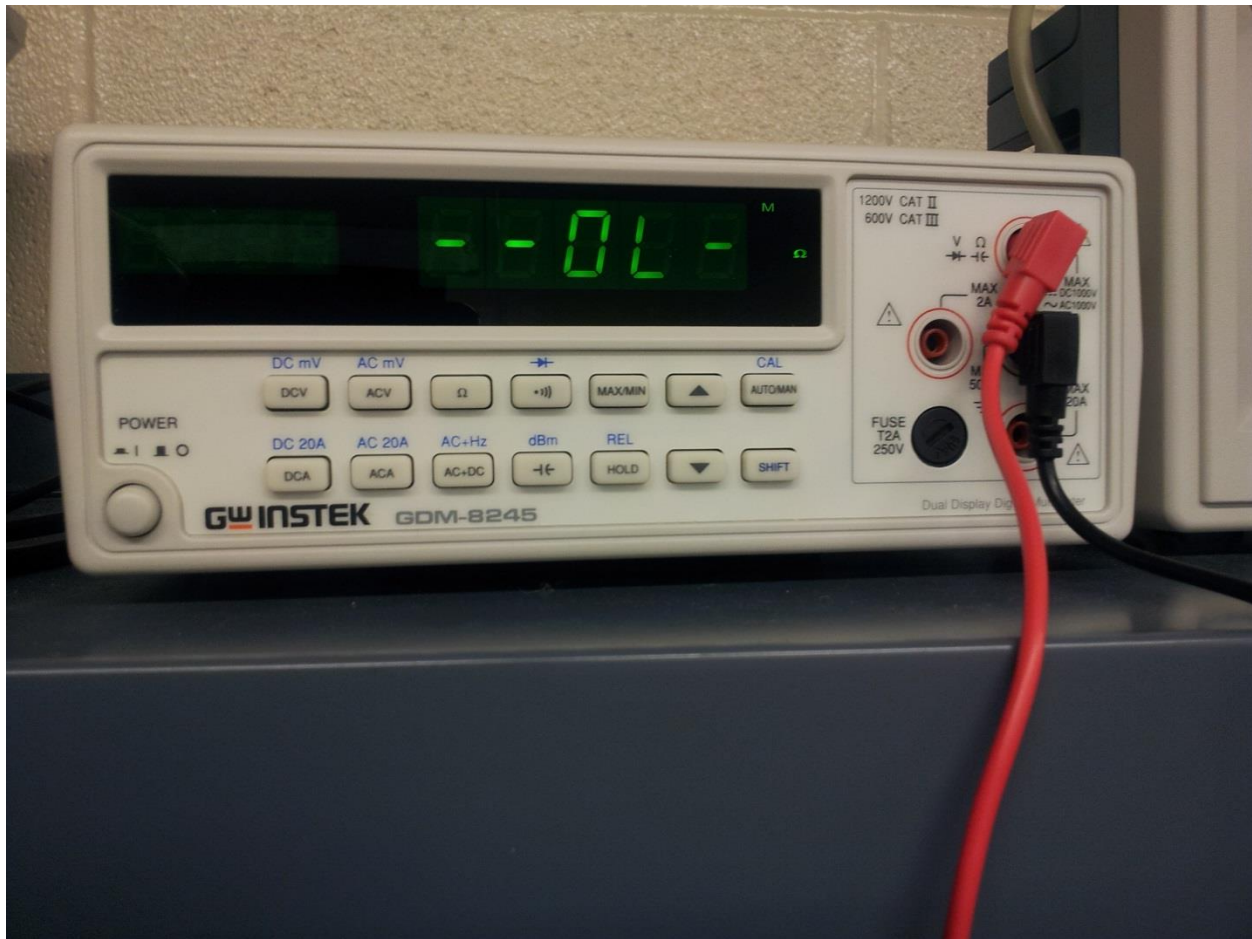
1 – 15 unique resistors

Observations: There is a small variance on every resistor. Not one measured exactly perfectly, but all were within the tolerance range. It was also noted at how hard it is to determine the colors codes on the individual resistors.

This is our resistors displayed on a breadboard. Originally, we had the resistors laid out in order, but took them apart and put them back in the drawers they came from without first taking a picture. So, this is a recreation of that breadboard putting them back in order – mostly.



This is a photo of the multi-meter we used. We discussed the variance of the resistors, but we also talk about the variance that the multimeter might have. For example, when the police use a radar detector to determine if a speeding ticket should be issued, often times, or so I have heard, defendants will claim that the radar detector is not as accurate as claimed; and therefore, no fine should be issued.

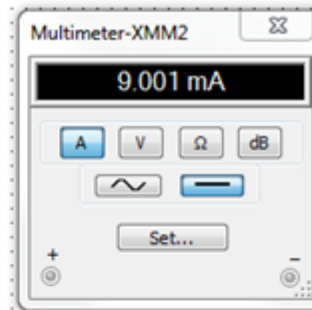
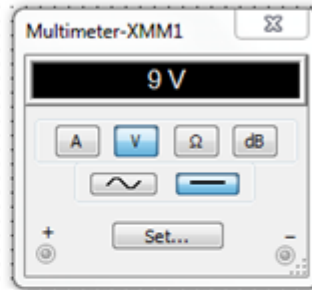
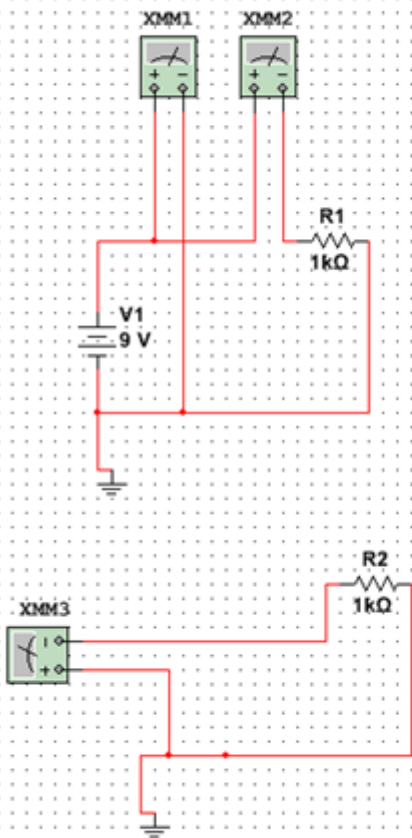


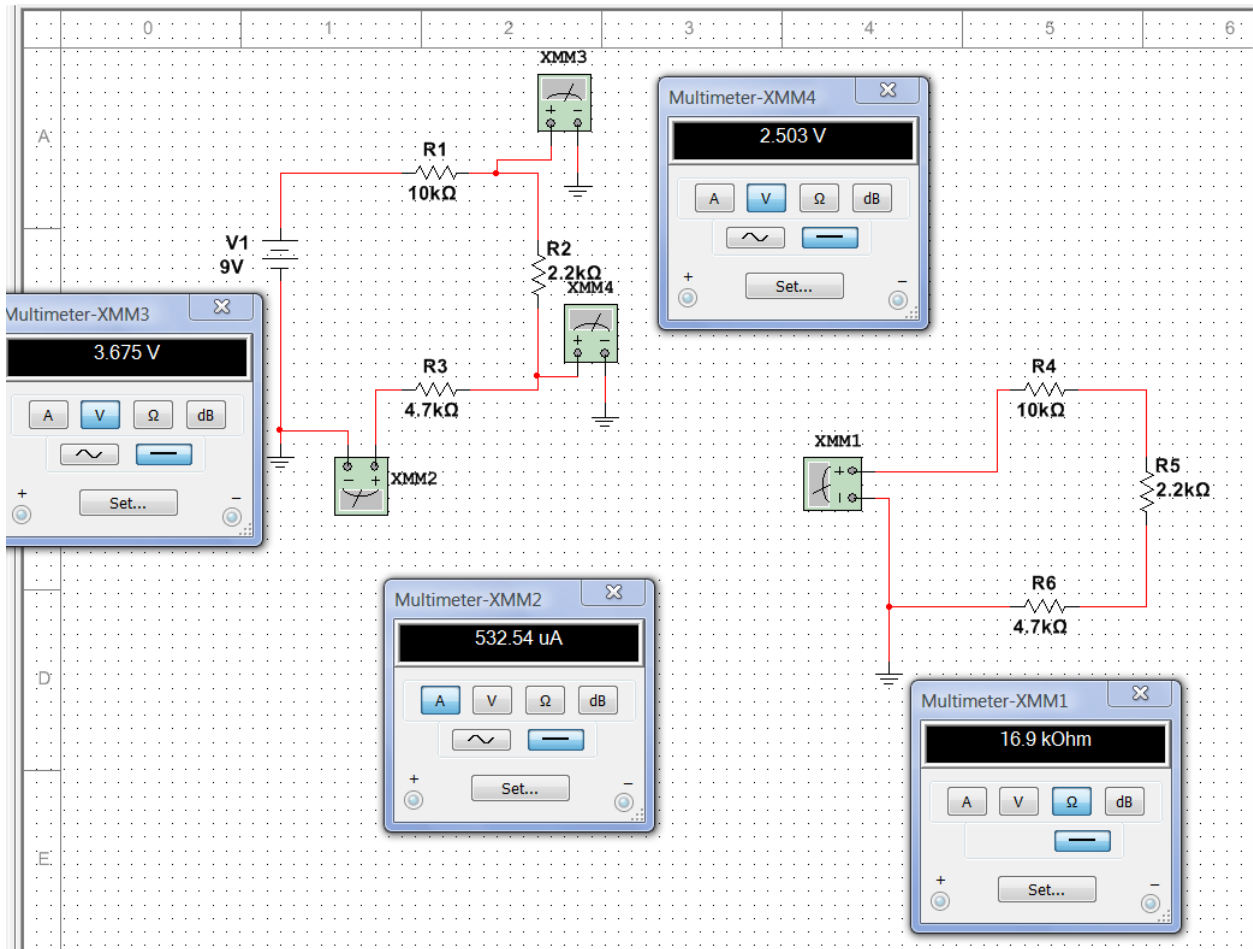
Equipment Used:

National Instruments Elvis II Serial Number 1677D1e, Software version number NT2012.

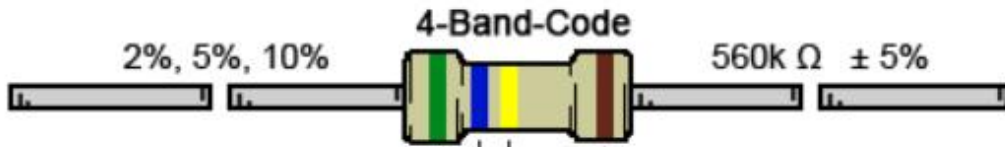
GW Instel Multimeter Model Number: GDW-8245, Serial Number CL860259

Dell PC running MS Windows 7. Asset tag number A242461.

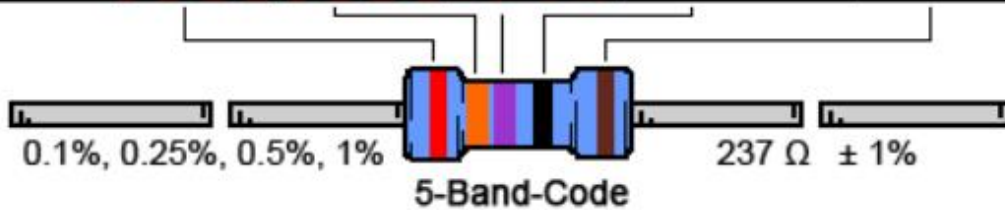




	A	B	C
1	Voltage	9.00	V
2	Resistance	10.0E+3	Ω
3	Resistance	2.2E+3	Ω
4	Resistance	4.7E+3	Ω
5	Sum Ω	16.9E+3	Ω
6	IT=	532.5E-6	A
7	V3=	3.7E+0	Ω
8	V4=	2.5E+0	Ω



COLOR	1 <sup>ST</sup> BAND	2 <sup>ND</sup> BAND	3 <sup>RD</sup> BAND	MULTIPLIER	TOLERANCE
Black	0	0	0	1 $\Omega$	
Brown	1	1	1	10 $\Omega$	$\pm$ 1% (F)
Red	2	2	2	100 $\Omega$	$\pm$ 2% (G)
Orange	3	3	3	1K $\Omega$	
Yellow	4	4	4	10K $\Omega$	
Green	5	5	5	100K $\Omega$	$\pm$ 0.5% (D)
Blue	6	6	6	1M $\Omega$	$\pm$ 0.25% (C)
Violet	7	7	7	10M $\Omega$	$\pm$ 0.10% (B)
Grey	8	8	8		$\pm$ 0.05%
White	9	9	9		
Gold				0.1 $\Omega$	$\pm$ 5% (J)
Silver				0.01 $\Omega$	$\pm$ 10% (K)





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**LAB 2**

## Lab 2 –Resistor Variability

Names: Aaron Sprunger, Raphaël Wolff

Date: 29 August 2013

The purpose of this lab is to:

Learn the how resistors vary using 25 resistors with the same color code.

	Sample 1.00E+03	Tolerance %	Unit
1	988.90	-1.11%	ohms
2	1.00E+03	0.11%	ohms
3	997.3	-0.27%	ohms
4	991	-0.90%	ohms
5	996	-0.40%	ohms
6	997.9	-0.21%	ohms
7	996.6	-0.34%	ohms
8	995.4	-0.46%	ohms
9	991.3	-0.87%	ohms
10	997.4	-0.26%	ohms
11	991.9	-0.81%	ohms
12	989.8	-1.02%	ohms
13	993.3	-0.67%	ohms
14	999.8	-0.02%	ohms
15	997.8	-0.22%	ohms
16	999.8	-0.02%	ohms
17	997.8	-0.22%	ohms
18	990.6	-0.94%	ohms
19	988.1	-1.19%	ohms
20	991.8	-0.82%	ohms
21	994.2	-0.58%	ohms
22	996.5	-0.35%	ohms
23	993.4	-0.66%	ohms
24	995.8	-0.42%	ohms
25	986.6	-1.34%	ohms

Select a set of 25 resistors.

Measure and record the resistance of each resistor.

Equipment needed:

1 – Digital Multimeter

1 – 25 resistors with the same color code.

Resistor color code = brown black red gold



Resistor value =  $1\text{k}\Omega$

Resistor tolerance =  $\pm 5\%$

Using Microsoft Excel plot the resistor values and determine:

Smallest resistance =  $0.9866\text{k}\Omega$

Largest resistance =  $1.0011\text{k}\Omega$

Average resistance =  $0.9944\text{k}\Omega$

Standard Deviation =  $0.003945\text{k}\Omega$

Do any of your resistor values exceed the part tolerance?

Observations: Difficulty in holding resistor and measuring. All the resistors being in tolerance means that the manufacturing process is sound.

National Instruments Elvis II Serial Number 1677D1e, Software version number NT2012.

GW Instel Multimeter Model Number: GDW-8245, Serial Number CL860259

Dell PC running MS Windows 7. Asset tag number A242461.

## Resistivity Homework Assignment

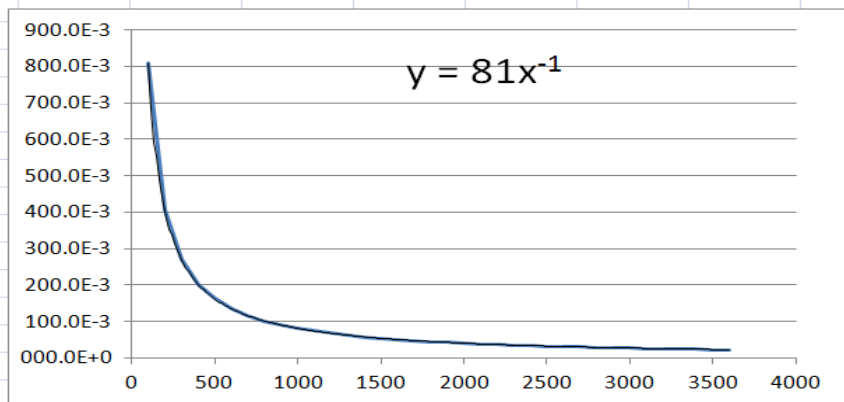
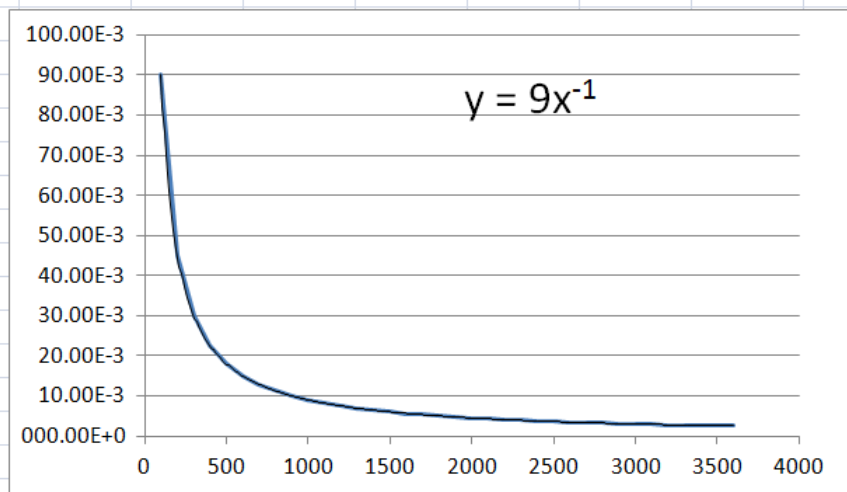
Resistivity		
Formula	$R = \rho L / A$	R = Resistance in ohms $\rho$ = circular-mil-foot in ohms L = length A = circular mils
Metal	AWG Wire Gauge	Calculation
Aluminum	24	$17.02\Omega \times 1000\text{ft.} / 404\text{cm} = 42.03\Omega/\text{ft}$
	26	$17.02\Omega \times 1000\text{ft.} / 254\text{cm} = 67.01\Omega/\text{ft}$
	28	$17.02\Omega \times 1000\text{ft.} / 160\text{cm} = 106.34\Omega/\text{ft}$
Copper	24	$10.37\Omega \times 1000\text{ft.} / 404\text{cm} = 25.67\Omega/\text{ft}$
	26	$10.37\Omega \times 1000\text{ft.} / 254\text{cm} = 40.83\Omega/\text{ft}$
	28	$10.37\Omega \times 1000\text{ft.} / 160\text{cm} = 64.81\Omega/\text{ft}$
Gold	24	$14.7\Omega \times 1000\text{ft.} / 404\text{cm} = 36.39\Omega/\text{ft}$
	26	$14.7\Omega \times 1000\text{ft.} / 404\text{cm} = 57.87\Omega/\text{ft}$
	28	$14.7\Omega \times 1000\text{ft.} / 404\text{cm} = 91.88\Omega/\text{ft}$
Silver	24	$9.8\Omega \times 1000\text{ft.} / 404\text{cm} = 24.25\Omega/\text{ft}$
	26	$9.8\Omega \times 1000\text{ft.} / 404\text{cm} = 38.58\Omega/\text{ft}$
	28	$9.8\Omega \times 1000\text{ft.} / 404\text{cm} = 61.25\Omega/\text{ft}$

Observations: Silver has the least resistance over Aluminum which is surprising. We would have thought gold would have turned out better than silver especially given it has only one valence electron.

# In class assignment: Power Dissipation of a Resistor Network -- More PIE



V =	9	
I =	5.0E-3	
R =	1.8E+3	
R	I	P
100	90.00E-3	810.0E-3
200	45.00E-3	405.0E-3
300	30.00E-3	270.0E-3
400	22.50E-3	202.5E-3
500	18.00E-3	162.0E-3
600	15.00E-3	135.0E-3
700	12.86E-3	115.7E-3
800	11.25E-3	101.3E-3
900	10.00E-3	90.0E-3
1.0E+3	9.00E-3	81.0E-3
1.1E+3	8.18E-3	73.6E-3
1.2E+3	7.50E-3	67.5E-3
1.3E+3	6.92E-3	62.3E-3
1.4E+3	6.43E-3	57.9E-3
1.5E+3	6.00E-3	54.0E-3
1.6E+3	5.63E-3	50.6E-3
1.7E+3	5.29E-3	47.6E-3
1.8E+3	5.00E-3	45.0E-3
1.9E+3	4.74E-3	42.6E-3
2.0E+3	4.50E-3	40.5E-3
2.1E+3	4.29E-3	38.6E-3
2.2E+3	4.09E-3	36.8E-3
2.3E+3	3.91E-3	35.2E-3
2.4E+3	3.75E-3	33.8E-3
2.5E+3	3.60E-3	32.4E-3
2.6E+3	3.46E-3	31.2E-3
2.7E+3	3.33E-3	30.0E-3
2.8E+3	3.21E-3	28.9E-3
2.9E+3	3.10E-3	27.9E-3
3.0E+3	3.00E-3	27.0E-3
3.1E+3	2.90E-3	26.1E-3
3.2E+3	2.81E-3	25.3E-3
3.3E+3	2.73E-3	24.5E-3
3.4E+3	2.65E-3	23.8E-3
3.5E+3	2.57E-3	23.1E-3
3.6E+3	2.50E-3	22.5E-3



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**LAB 3**

## Lab 3 – Series Resistors

Names: Aaron Sprunger, Raphaël Wolff

Date: 5 September 2013

The purpose of this lab is to:

Experiment with series circuits and verify that the simulation, analysis (calculations) and test results all agree.

From the resistor kit select 3 resistors (10K, 2.2K, and 4.7K)

Measure and record the value of each resistor. Connect the resistors as shown in Figure 1. Measure and record the total resistance,  $R_T$ . Then connect the resistors as shown in Figure 2, the 9V come from the Elvis II (Modular Engineering Educational Laboratory Platform). Then measure and record with the Digital Multimeter the current and voltages of the series circuit.

Equipment needed:

- 1 – Digital Multimeter
- 1 – Elvis II
- 3 – Resistors

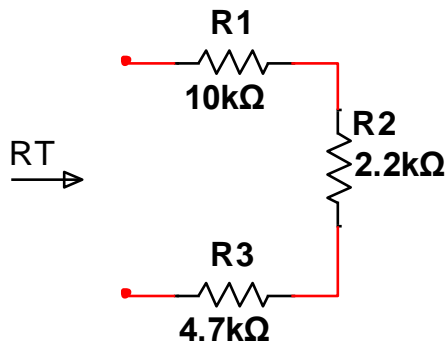


Figure 1

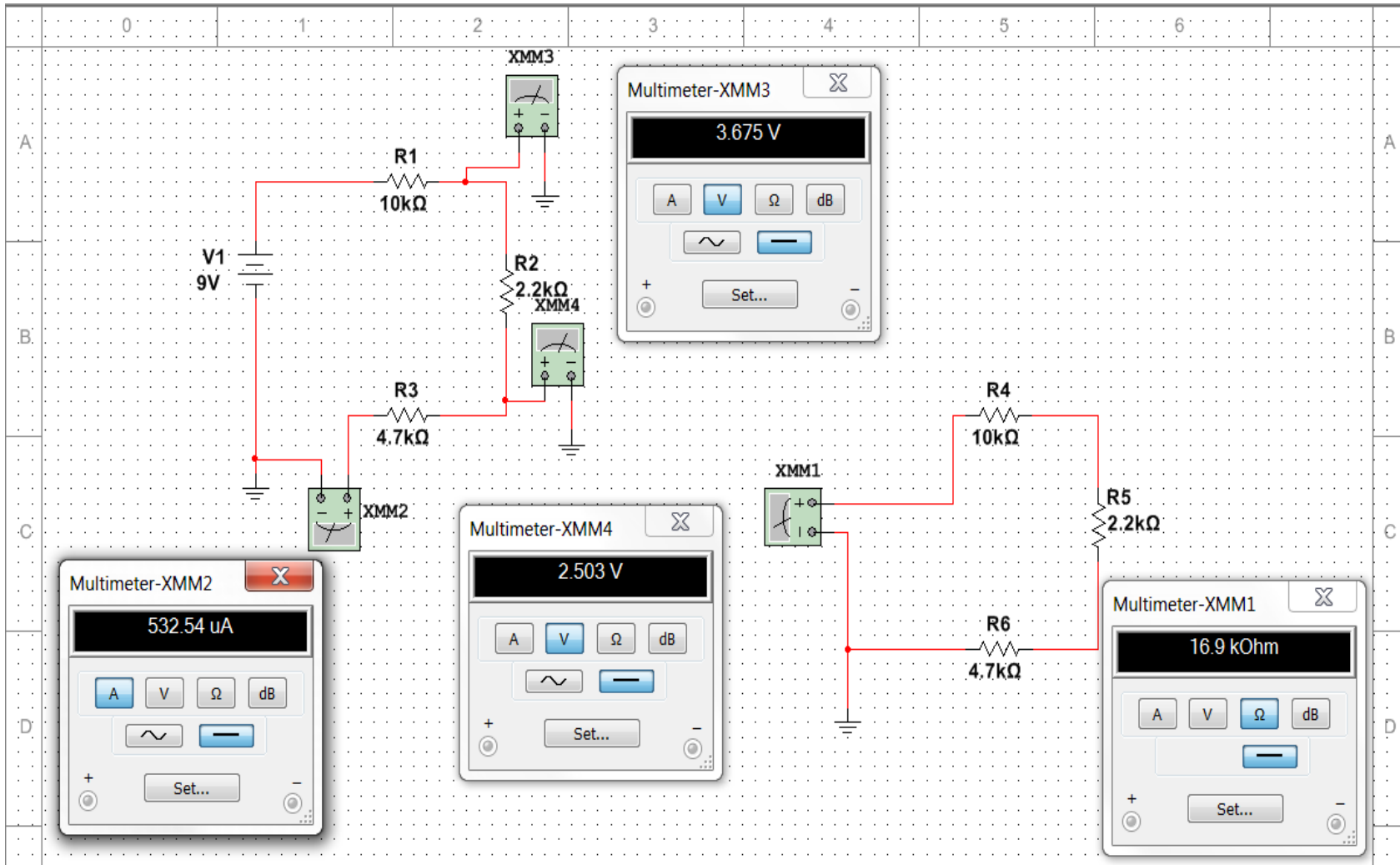
	Measured	Calculated	Simulated
R1 =	9.84E+3Ω	10.0E+3Ω	10.0E+3Ω
R2 =	2.3E+3Ω	2.2E+3Ω	2.2E+3Ω
R3 =	4.7E+3Ω	4.7E+3Ω	4.7E+3Ω
$R_T$ =	16.752E+3Ω	16.9E+3Ω	16.9E+3Ω

Measured = using Digital Multimeter

Calculated = based on color code and Excel values

Simulated = Multisim simulation

Simulated





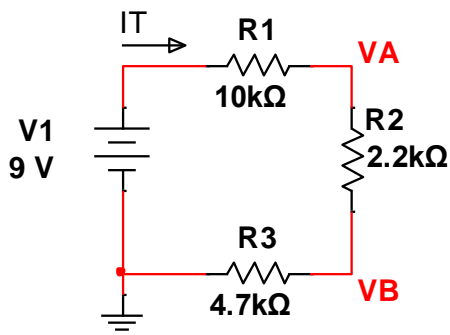


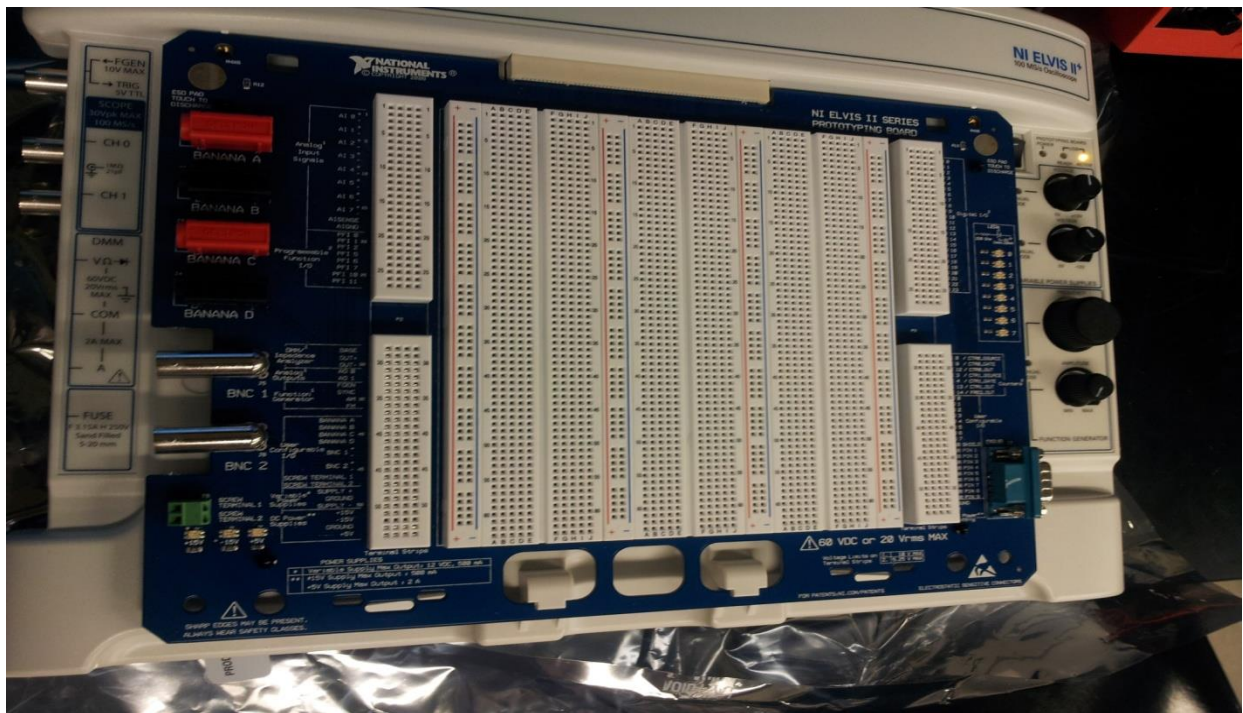
Figure 2

	Measured	Calculated	Simulated
$I_T =$	550.5E-6A	532.5E-6A	532.5E-6A
$V_1 =$	9V	9V	9V
$V_A =$	3.72V	3.674556V	3.675V
$V_B =$	2.54V	2.502959V	2.503C

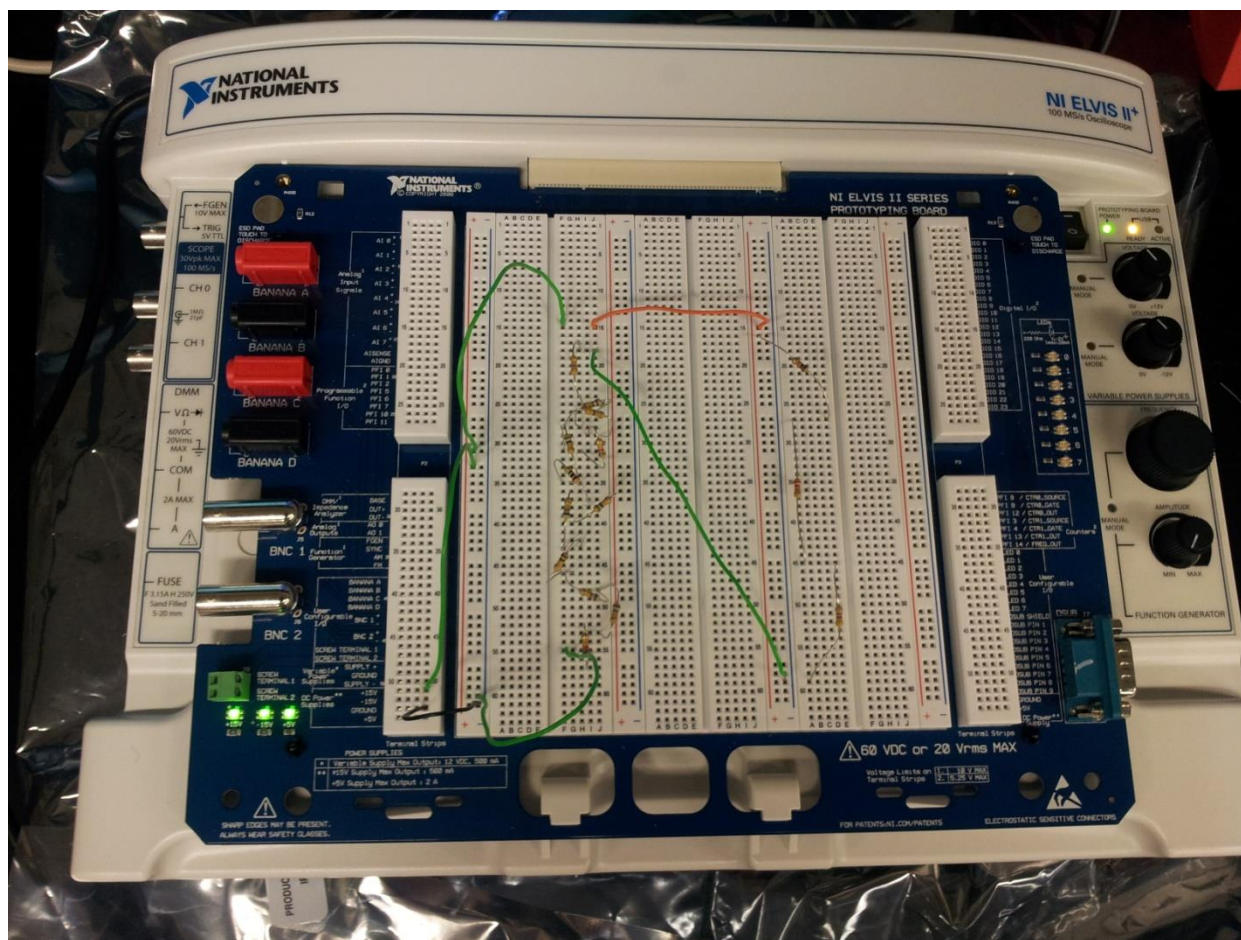
Measured = using Digital Multimeter  
 Calculated = based on color code and Excel values  
 Simulated = Multisim simulation

### Calculated Values

$V_1 =$	9 V
$R_1 =$	10.0E+3 Ω
$R_2 =$	2.2E+3 Ω
$R_3 =$	4.7E+3 Ω
$R_T =$	16.9E+3 Ω
$I_T$	532.5E-6 A
$V_A =$	3.674556 V
$V_B =$	2.502959 V



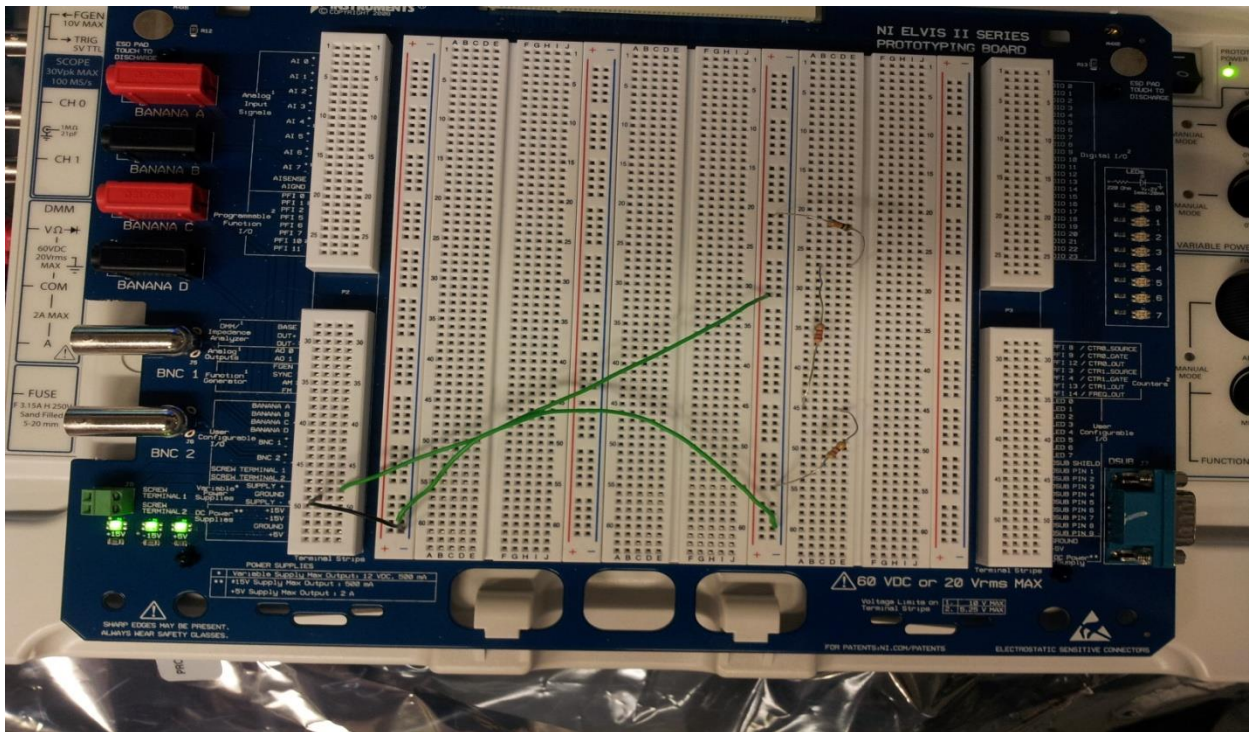
# Elvis



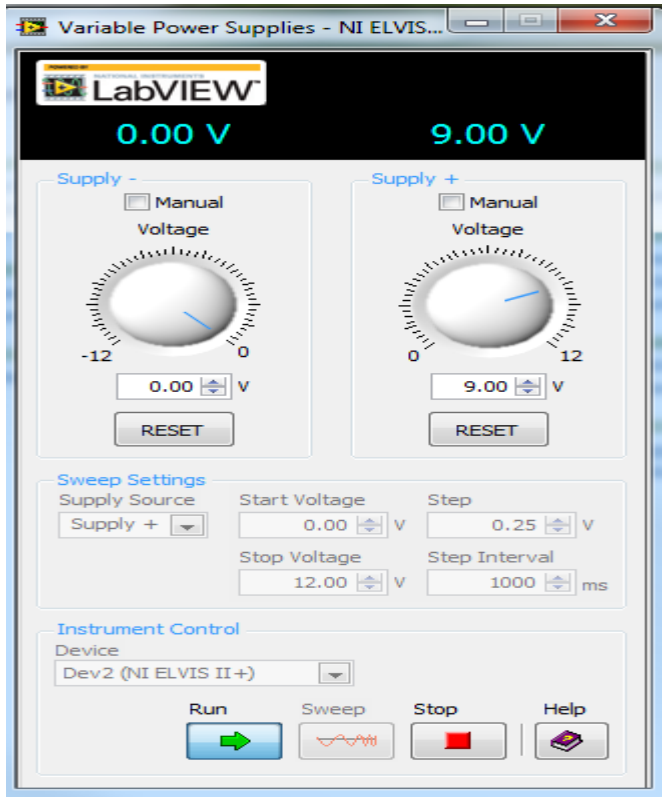
Elvis and the 42 Resistors Step-Down Voltage



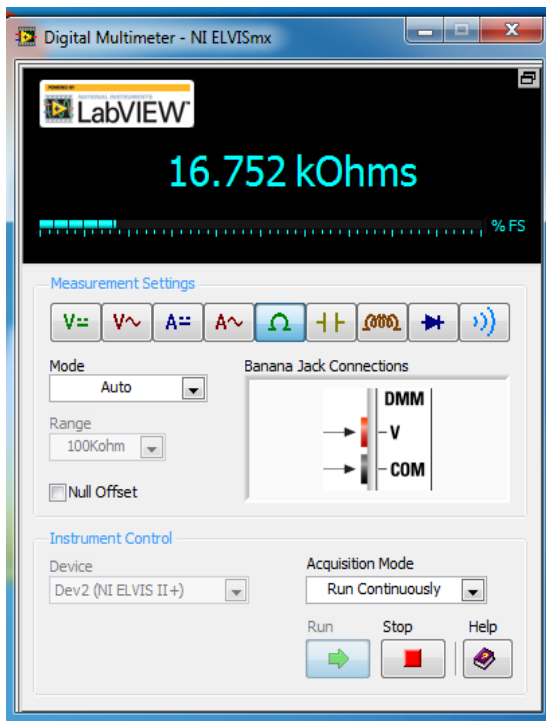
Instructor Questions the Method of 42



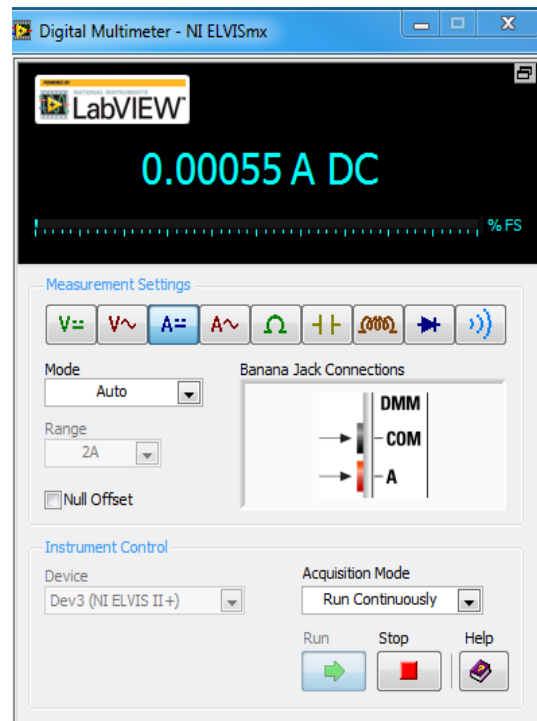
Elvis Correctus



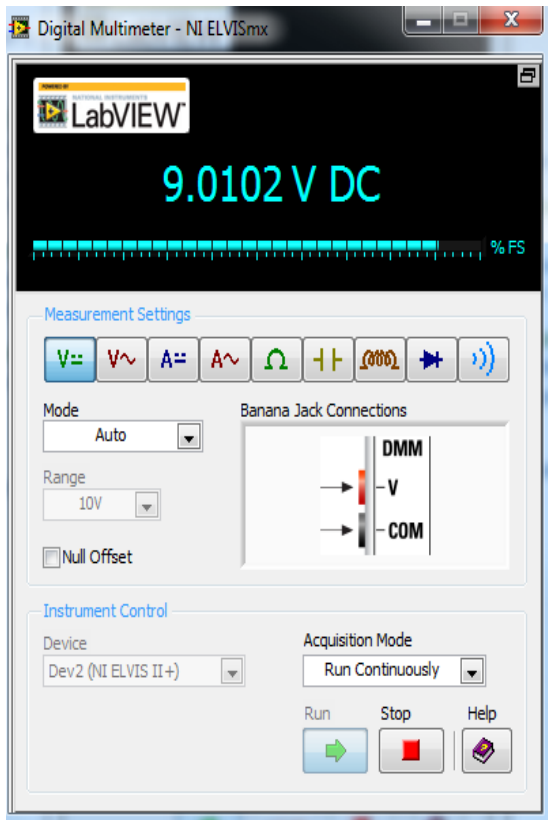
Verification of Elvis 9v Setting



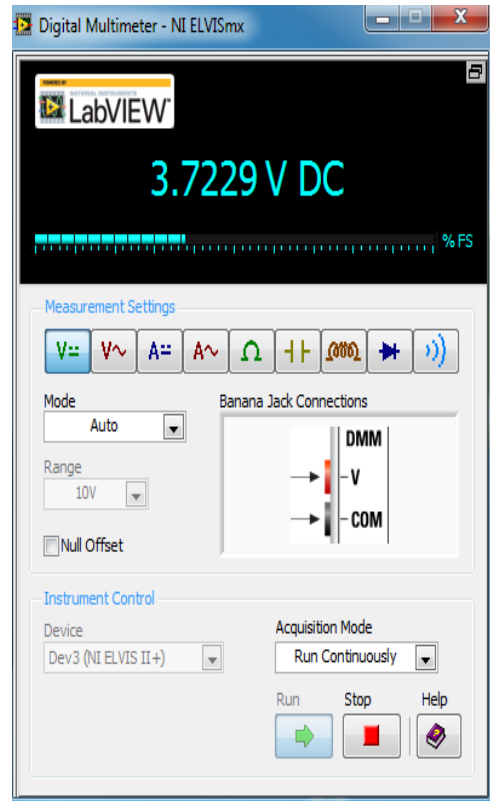
RT



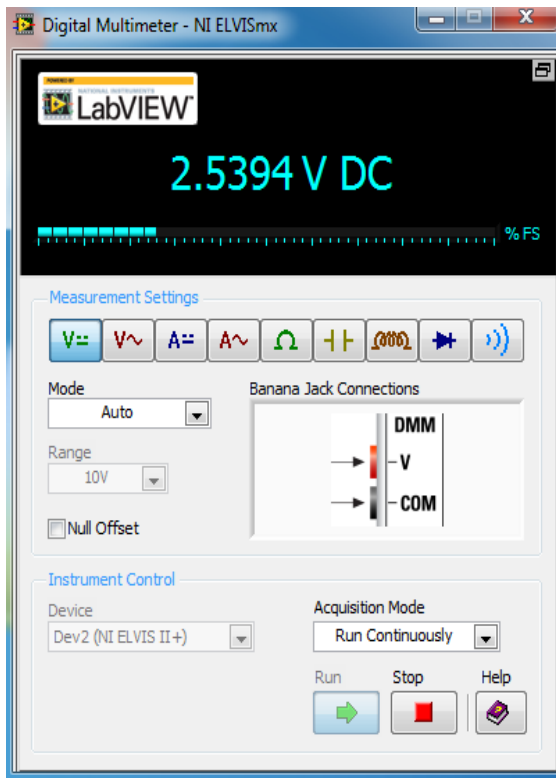
IT



V1



VA



VB

Observations: Learned more about Elvis and the ability of the software to read fine graduations such as milliamps. Elvis performed as expected replicating calculated and simulated results.

National Instruments Elvis II Serial Number 1677D1e, Software version number NT2012.

GW Instel Multimeter Model Number: GDW-8245, Serial Number CL860259

Dell PC running MS Windows 7. Asset tag number A242461.

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**LAB 4**

Names: Aaron Sprunger, Raphaël Wolff  
Date: September 12 and 19

# Pressure Sensor Model Activity

## Shareable Content Object (SCO)

Initial measurements

- $R_1 = 1.228 \text{ k}\Omega$
- $R_2 = 1.46 \text{ k}\Omega$
- $R_3 = 13.42 \text{ k}\Omega$
- $R_3 = 1.491 \text{ k}\Omega$

R1



R4

R2

R3

R1





R2



R3



R4



## Post-Activity Questions

1. In the above procedure, what factors could have an effect on the outcome (the resistivity of the bridge circuit)?

The amount of graphite in the mixture would affect the outcome as well as how much pressure is put on the bridge.

2. What is meant by the “reference” voltage or reference resistance of the Wheatstone bridge?

Reference voltage refers to the output by a DC power source.

Does this stay consistent? Why or why not?

Our guess is that it would not stay constant as pressure is applied to the bridge.

3. What determines the reference voltage / resistance?

When pressure is applied to the bridge, the space between the graphite molecules increases and the resistance would change with it. Output voltage would change.

4. What causes a change in resistance or voltage?

Current demand causes a change in the resistance or voltage.

5. Describe three (3) MEMS (Micro-electromechanical systems) that use a diaphragm pressure sensor.

HARMEMS Technology -- high aspect ratio micro-electromechanical systems technology is a proven technology for airbag sensing applications.

Surface Micromachining -- In surface micromachining, the MEMS sensors are formed on top of the wafer using deposited thin film materials. These deposited materials consist of structural materials that are used in the formation of the sensors and sacrificial layers that are used to define gaps between the structural layers.

Bulk Micromachining -- In bulk micromachining, the single crystal silicon is etched to form three-dimensional MEMS devices. This is a subtractive process in which the silicon in the wafer is specifically removed using anisotropic chemistries.

<http://www.freescale.com/webapp/sps/site/overview.jsp?code=SNSMEMSOVERVIEW>

6. How could this pressure sensor model be improved upon?

Better materials -- graphine instead of graphite for example.

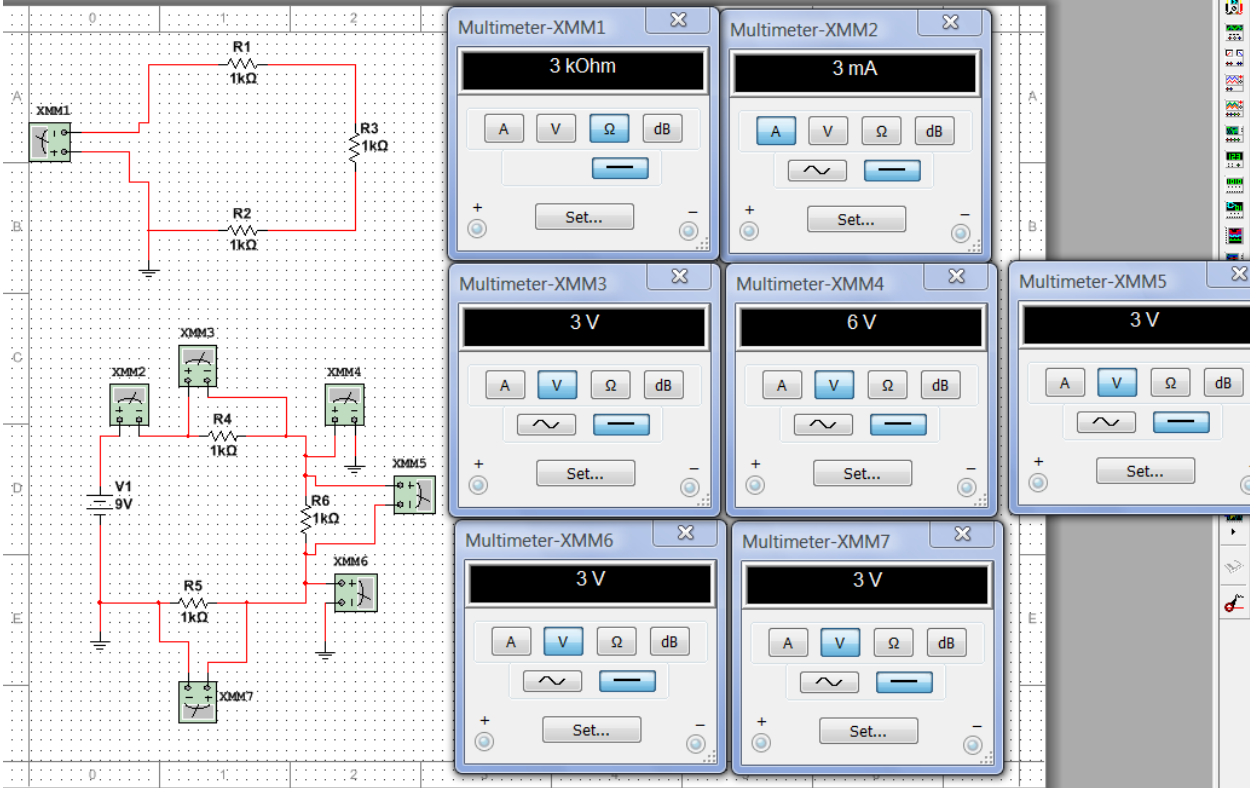
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**LAB 5**

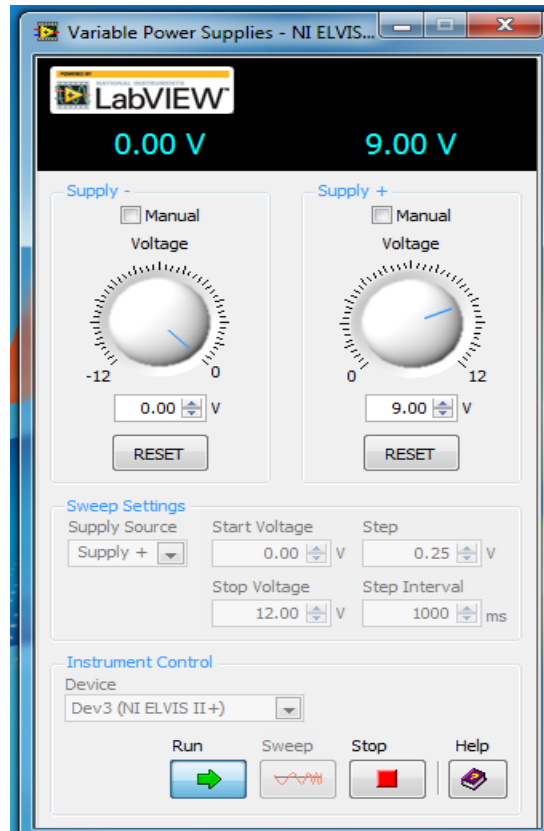
Names: Aaron Sprunger, Raphaël Wolff

Date: September 26

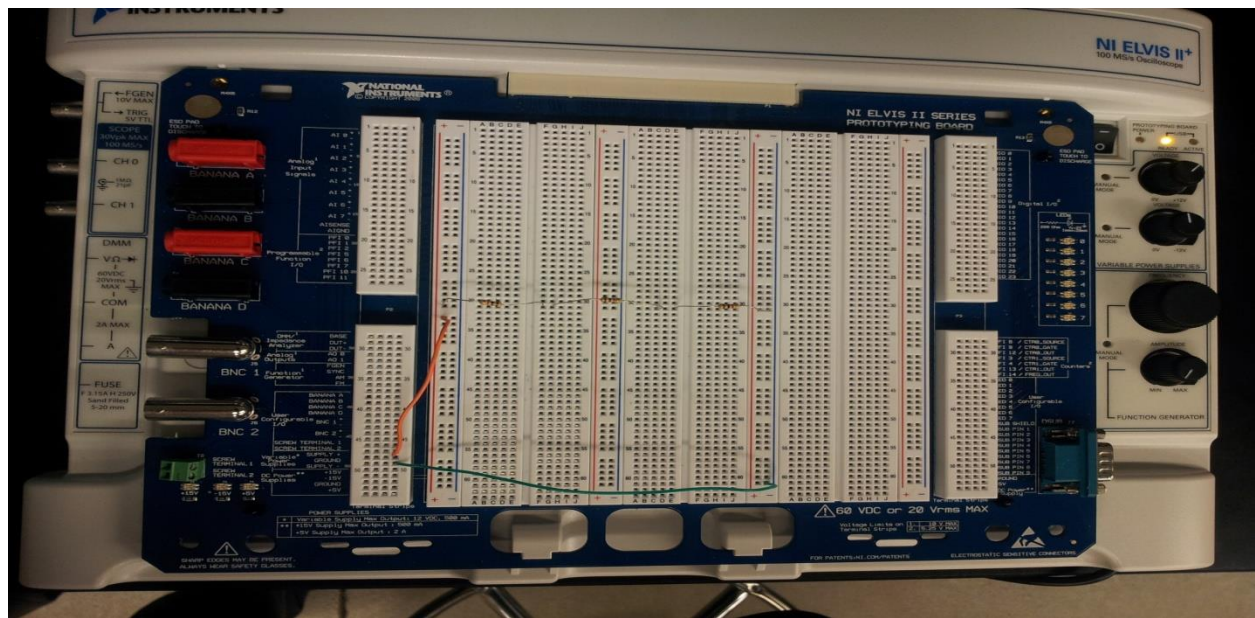
### Three Resistors in Series

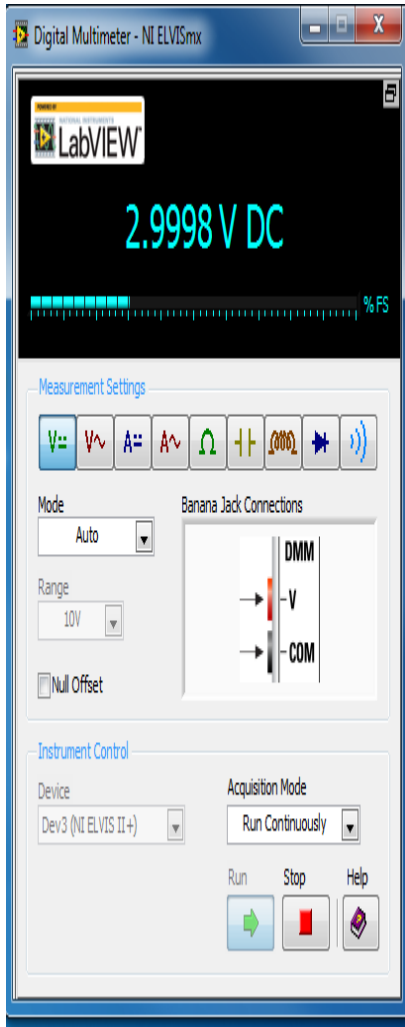


	A	B	C
1			
2	V1		9 V
3	R1	1.00E+03	$\Omega$
4	R2	1.00E+03	$\Omega$
5	R3	1.00E+03	$\Omega$
6	IT	3.0E+3	mA
7	ER1		3 V
8	ER2		3 V
9	ER3		3 V
10	VA	6.0E+0	V
11	VB	3.0E+0	V

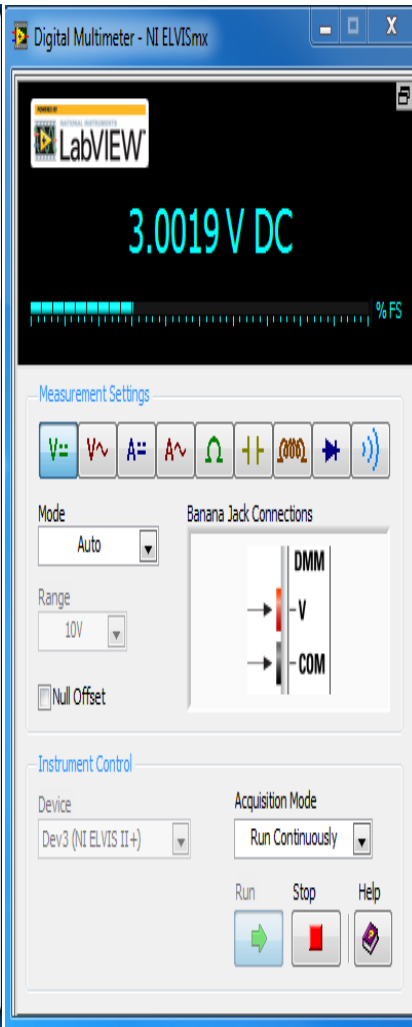


V1

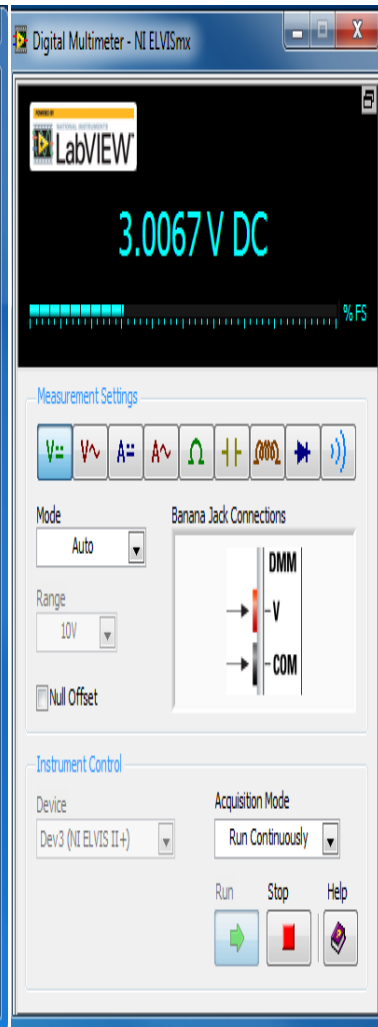




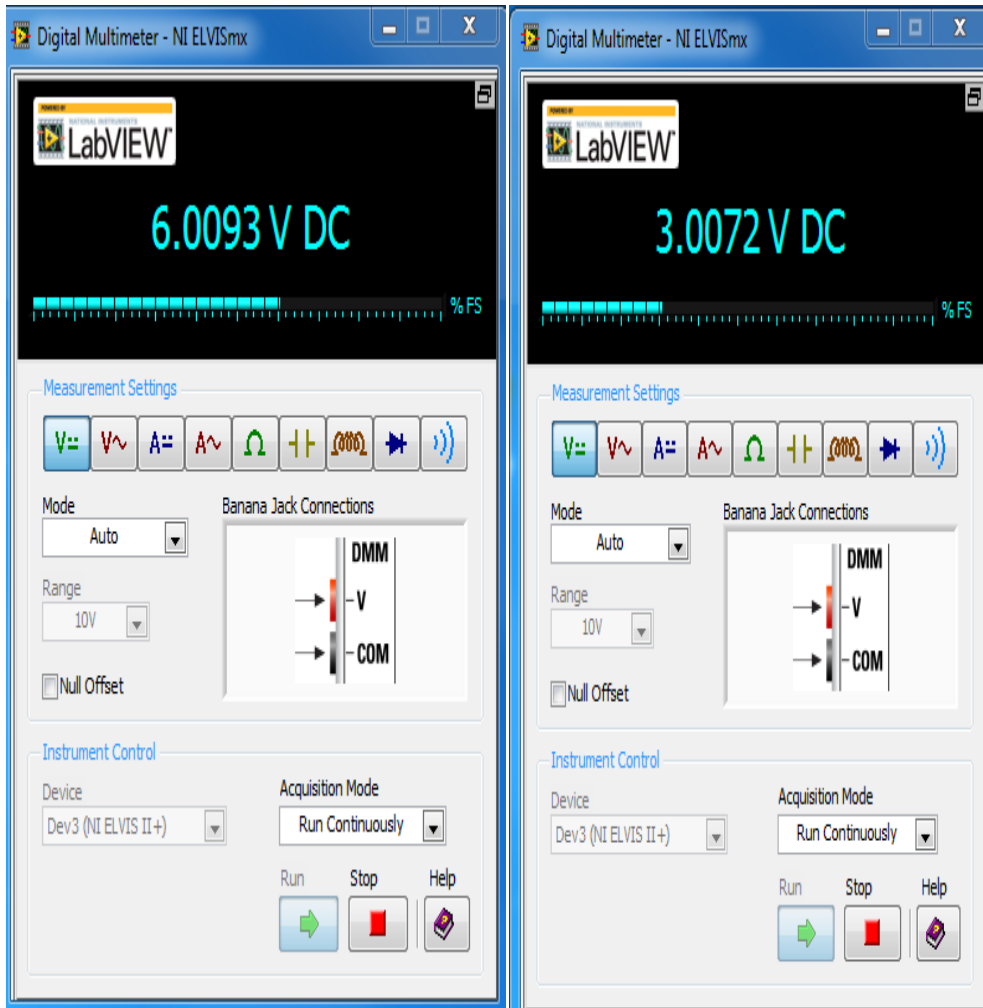
ER1



ER2



ER3



VA

VB

Observations: This lab illustrates how to calculate equal value resistors in series and total current.

Equipment Used:

National Instruments Elvis II Serial Number 1677D1e, Software version number NT2012.

GW Instel Multimeter Model Number: GDW-8245, Serial Number CL860259

Dell PC running MS Windows 7. Asset tag number A242461.



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**LAB 6**

## Lab 6 – Series and Parallel Resistors

Names: Minh Mai, Aaron Sprunger, Raphaël Wolff

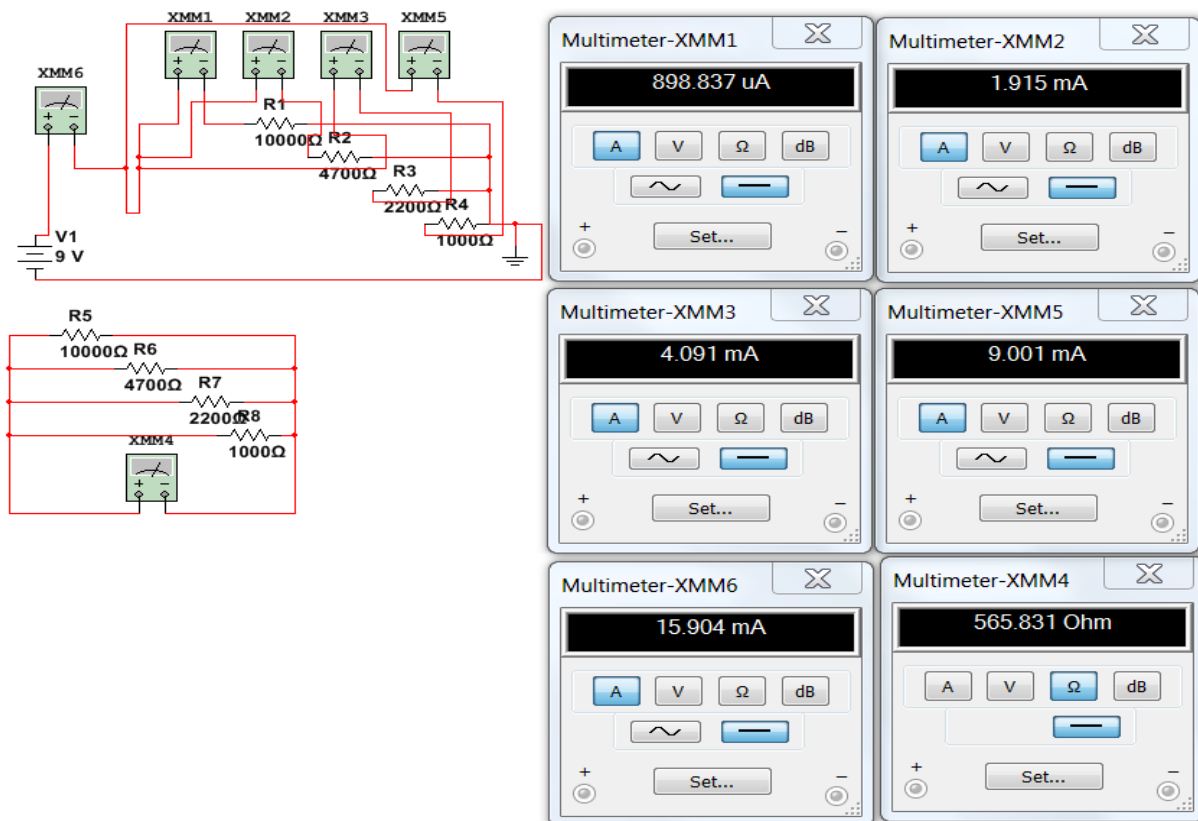
Date: 19 September 2013

The purpose of this lab is to:

Experiment with series circuits and verify that the simulation, analysis (calculations) and test results all agree.

From the resistor kit select 4 resistors (1K, 2.2K, 4.7K, and 10K)

Measure and record the value of each resistor. Connect the resistors as shown in Figure 1. Measure and record the total resistance,  $R_T$ . Then connect the resistors as shown in Figure 2, the 9V come from the Elvis II (Modular Engineering Educational Laboratory Platform). Then measure and record with the Digital Multimeter the current and voltages of the series circuit.



	Calculated	Measured	Simulated	
V1=	9	9	9.0029	V
R1=	1.0E+3	996.6	1.0E+3	Ω
R2=	2.2E+3	2290	2.2E+3	Ω
R3=	4.7E+3	4735	4.7E+3	Ω
R4=	10.0E+3	10026	10.0E+3	Ω
RT=	<b>565.8E+0</b>	563.9	<b>565.8E+0</b>	Ω
IT	<b>15.9E-3</b>	0.01594	<b>0.0159</b>	A
I1	<b>0.009</b>	0.00903	<b>0.0090</b>	A
I2	<b>4.1E-3</b>	0.0039191	<b>0.0041</b>	A
I3	<b>1.9E-3</b>	0.0019009	<b>0.0019</b>	A
I4	<b>900.0E-6</b>	0.000898837	<b>0.0009</b>	A
Check Sum			0.0159	A

	Calculated	Measured	Simulated	
V1=	9	9	9.0029	V
R1=	1000	996.6	1000	Ω
R2=	2200	2290	2200	Ω
R3=	4700	4735	4700	Ω
R4=	10000	10026	10000	Ω
RT=	<b>=1/((1/B3)+(1/B4)+(1/B5)+(1/B6))</b>	563.9	<b>565.831</b>	Ω
IT	<b>=B2/B7</b>	0.01594	<b>0.015904</b>	A
I1	<b>=(B7/B3)*B8</b>	0.00903	<b>0.009001</b>	A
I2	<b>=(B7/B4)*B8</b>	0.0039191	<b>0.0041</b>	A
I3	<b>=(B7/B5)*B8</b>	0.0019009	<b>0.001915</b>	A
I4	<b>=(B7/B6)*B8</b>	0.000898837	<b>0.000898837</b>	A
Check Sum			<b>=SUM(D9:D12)</b>	A

Measured using Digital Multimeter

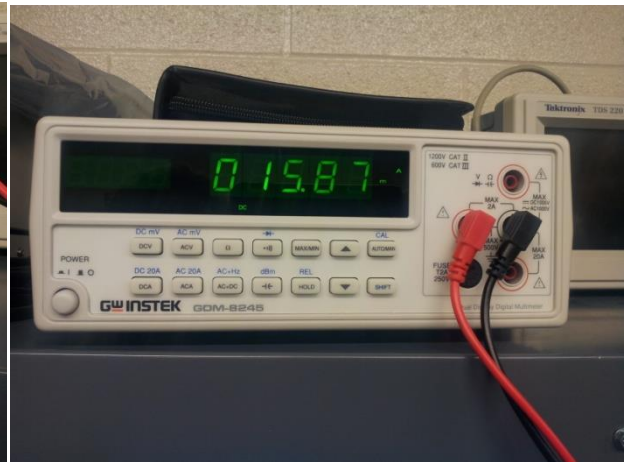
Calculated based on color code and Excel values

Simulated using Multisim

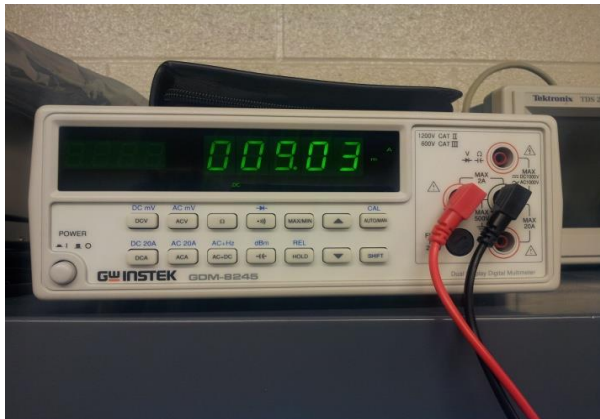
RT



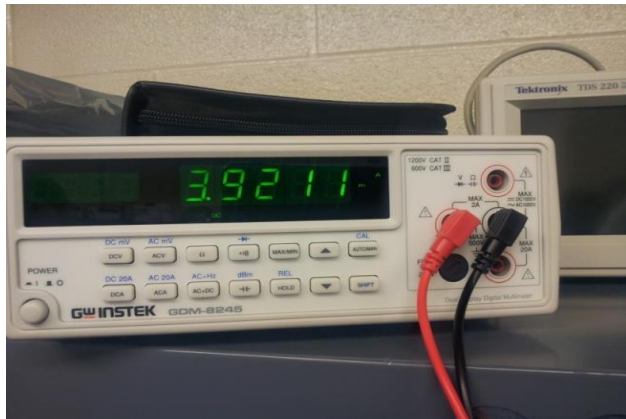
IT



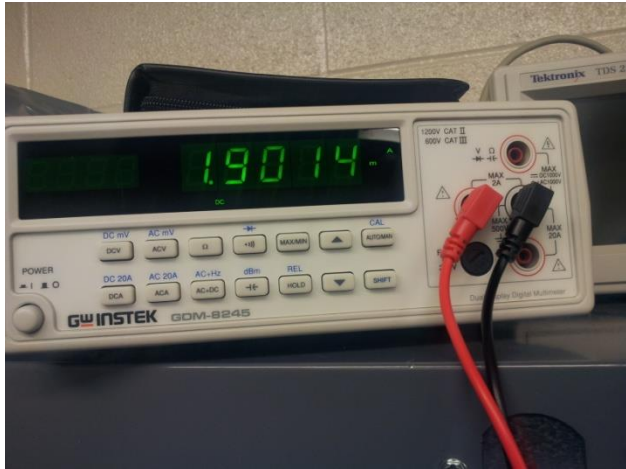
V



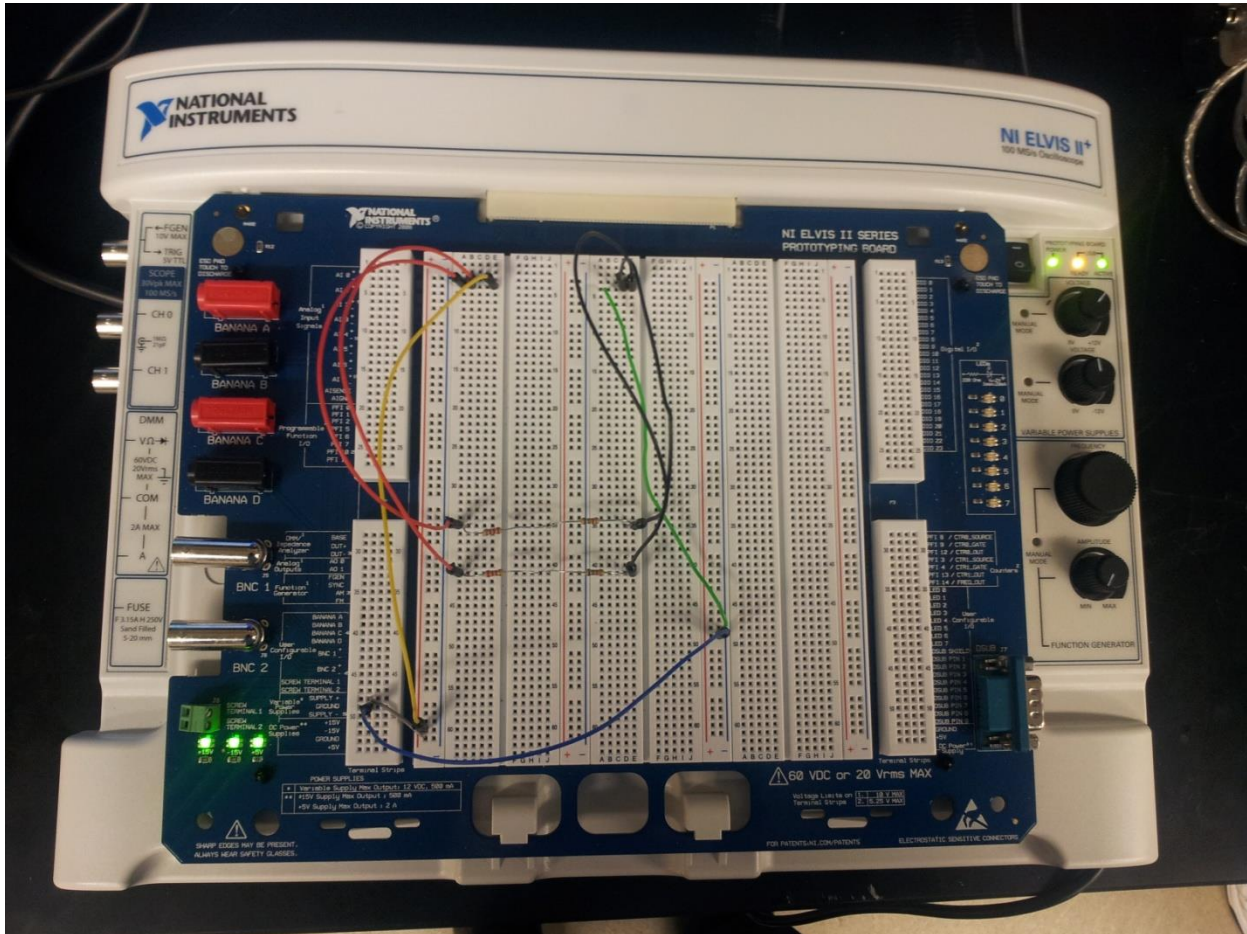
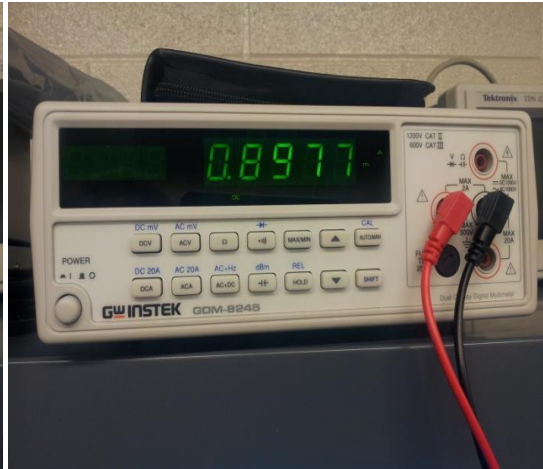
I2



13



14



Observations: We were able to utilize the assumed voltage approach, everything worked out as planned.

National Instruments Elvis II Serial Number 1677D1e, Software version number NT2012.

GW Instel Multimeter Model Number: GDW-8245, Serial Number CL860259

Dell PC running MS Windows 7. Asset tag number A242461.

In class activity:

Names: Aaron Sprunger, Raphaël Wolff

Date: 24 October 2013

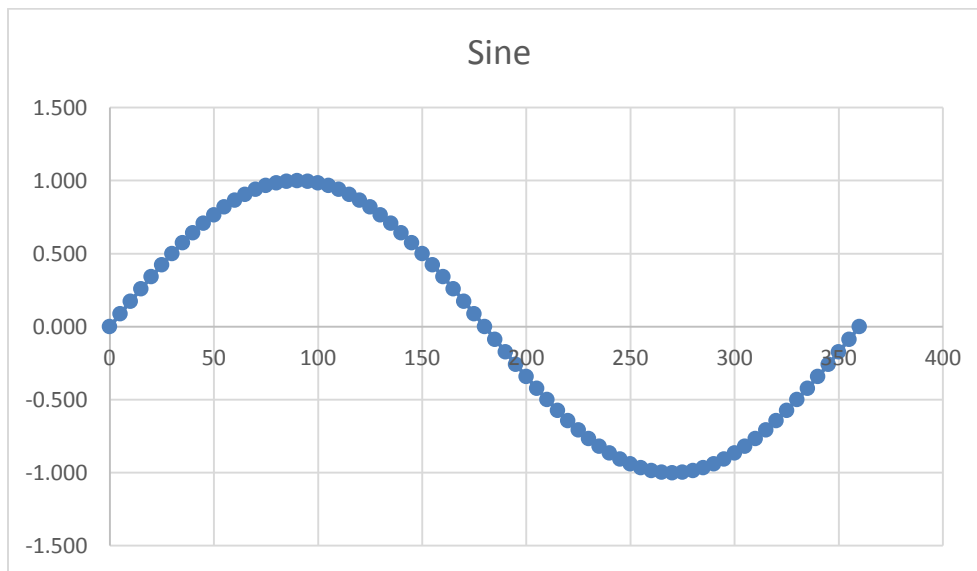
Degrees	Magnitude	Cosine	Sine
0	0.000	1.00	0
5	0.087	1.00	
10	0.174	0.98	
15	0.259	0.97	
20	0.342	0.94	
25	0.423	0.91	
30	0.500	0.87	0.5
35	0.574	0.82	
40	0.643	0.77	
45	0.707	0.71	0.707
50	0.766	0.64	
55	0.819	0.57	
60	0.866	0.50	0.866
65	0.906	0.42	
70	0.940	0.34	

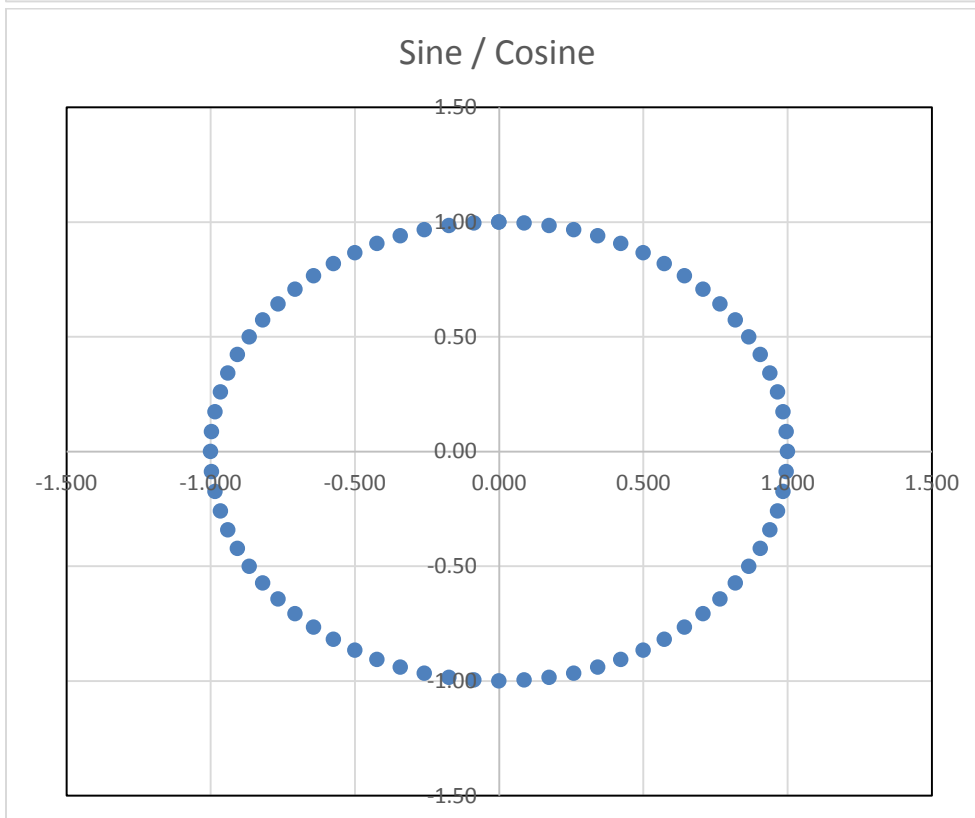
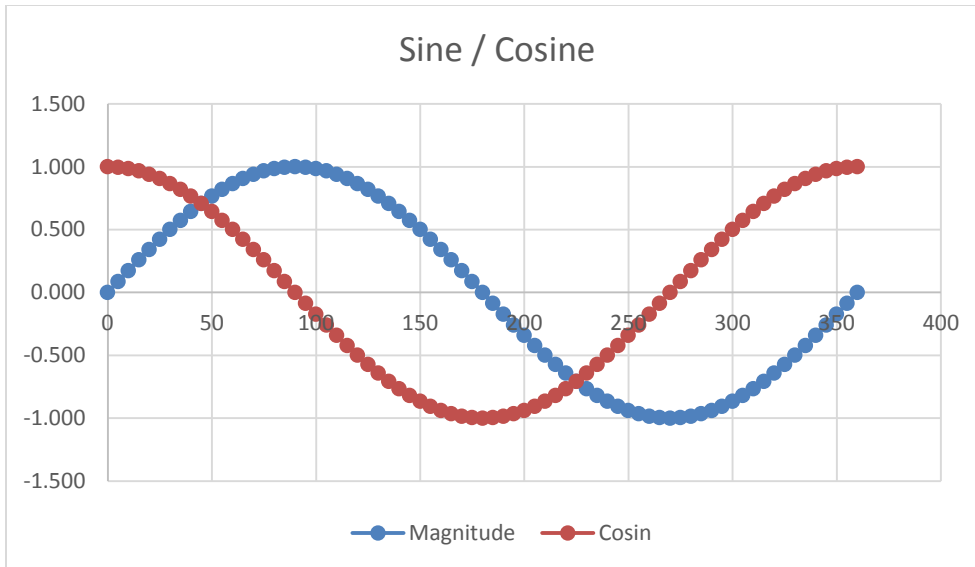
75	0.966	0.26	
80	0.985	0.17	
85	0.996	0.09	
90	1.000	0.00	1
95	0.996	-0.09	
100	0.985	-0.17	
105	0.966	-0.26	
110	0.940	-0.34	
115	0.906	-0.42	
120	0.866	-0.50	
125	0.819	-0.57	
130	0.766	-0.64	
135	0.707	-0.71	
140	0.643	-0.77	
145	0.574	-0.82	
150	0.500	-0.87	
155	0.423	-0.91	
160	0.342	-0.94	
165	0.259	-0.97	
170	0.174	-0.98	
175	0.087	-1.00	
180	0.000	-1.00	
185	-0.087	-1.00	
190	-0.174	-0.98	
195	-0.259	-0.97	

200	-0.342	-0.94
205	-0.423	-0.91
210	-0.500	-0.87
215	-0.574	-0.82
220	-0.643	-0.77
225	-0.707	-0.71
230	-0.766	-0.64
235	-0.819	-0.57
240	-0.866	-0.50
245	-0.906	-0.42
250	-0.940	-0.34
255	-0.966	-0.26
260	-0.985	-0.17
265	-0.996	-0.09
270	-1.000	0.00
275	-0.996	0.09
280	-0.985	0.17
285	-0.966	0.26
290	-0.940	0.34
295	-0.906	0.42
300	-0.866	0.50
305	-0.819	0.57
310	-0.766	0.64
315	-0.707	0.71
320	-0.643	0.77



325	-0.574	0.82
330	-0.500	0.87
335	-0.423	0.91
340	-0.342	0.94
345	-0.259	0.97
350	-0.174	0.98
355	-0.087	1.00
360	0.000	1.00





Observations: This lab illustrates the relationship of sine and cosine and how cosine is 90 degrees out of phase.

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**LAB 7**

## Lab 7 – Series/Parallel Resistors

Names: Aaron Sprunger, Raphaël Wolff

Date: 3 October 2013

The purpose of this lab is to:

Experiment with series circuits and verify that the simulation, analysis (calculations) and test results all agree.

From the resistor kit select 8 resistors: 2 each  $470\Omega$ , 2 each  $1k\Omega$ , and 1 each of the following:

$2.2k\Omega$ ,  $3.3k\Omega$ ,  $4.7k\Omega$ ,  $10k\Omega$

Measure and record the value of each resistor. Connect the resistors as shown in Figure 1. Measure and record the total resistance,  $R_T$ . Then connect the resistors as shown in Figure 2, the 9V come from the Elvis II (Modular Engineering Educational Laboratory Platform). Then measure and record with the Digital Multimeter the current and voltages of the series circuit.

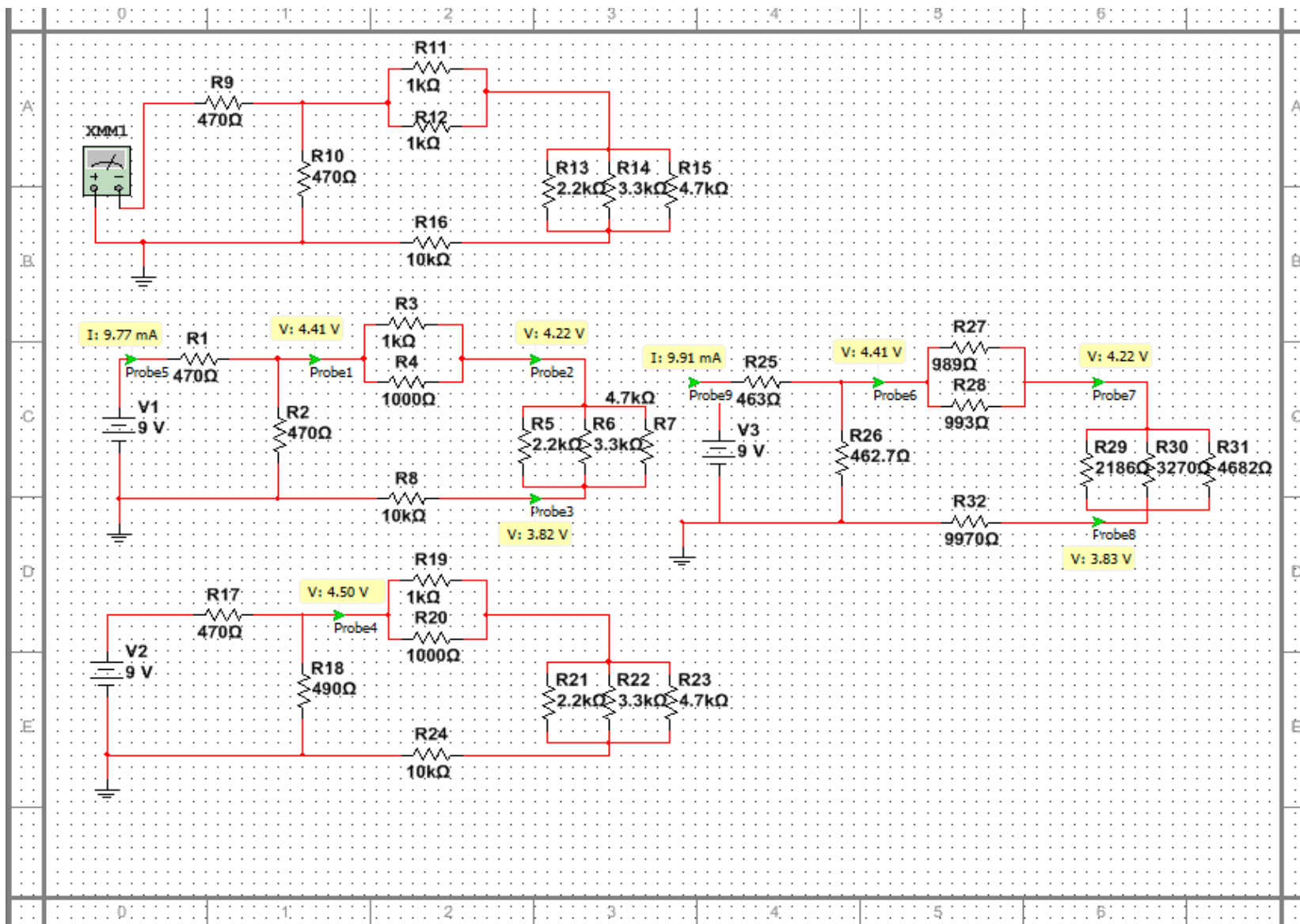
Equipment needed:

1 – Digital Multimeter

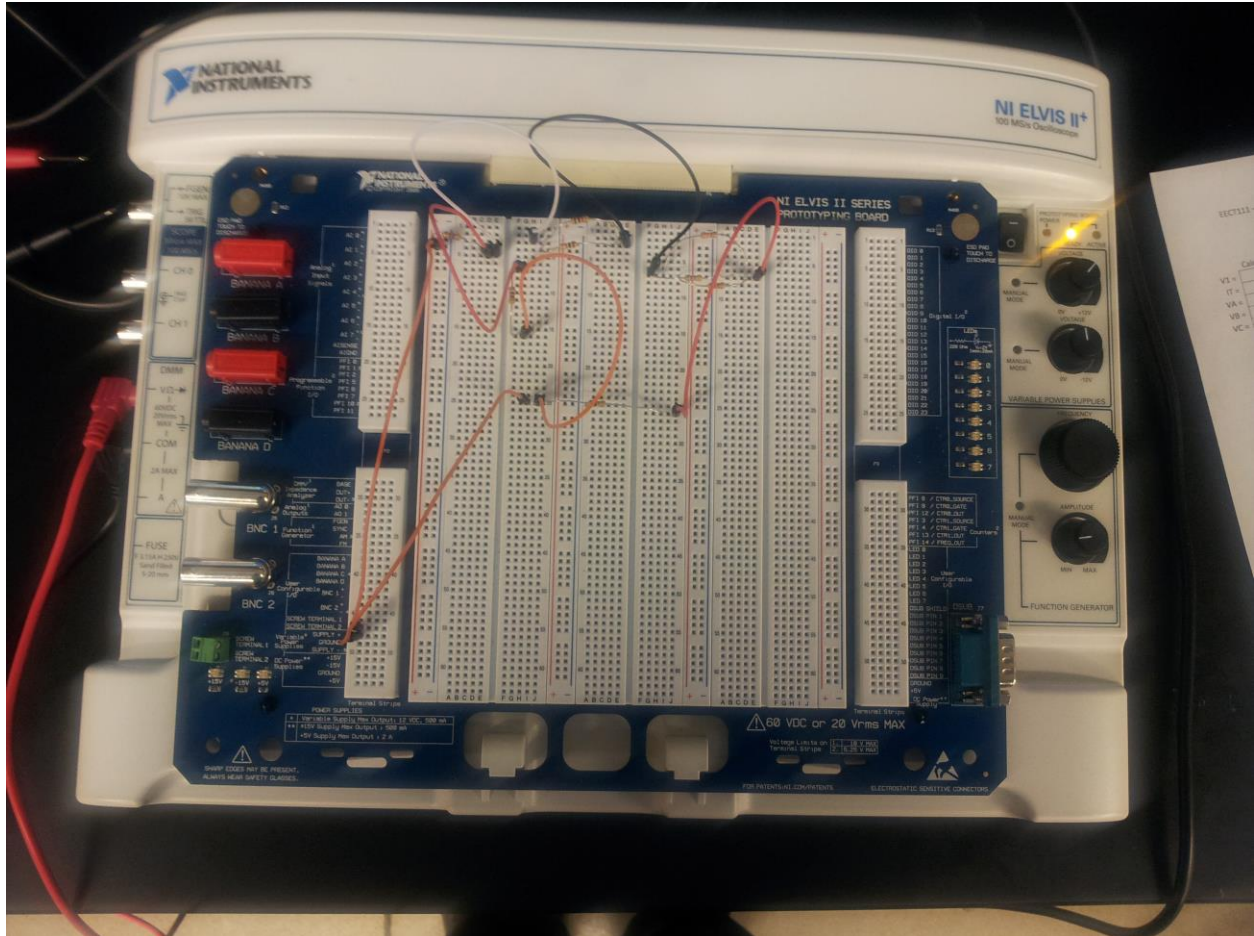
1 – Elvis II

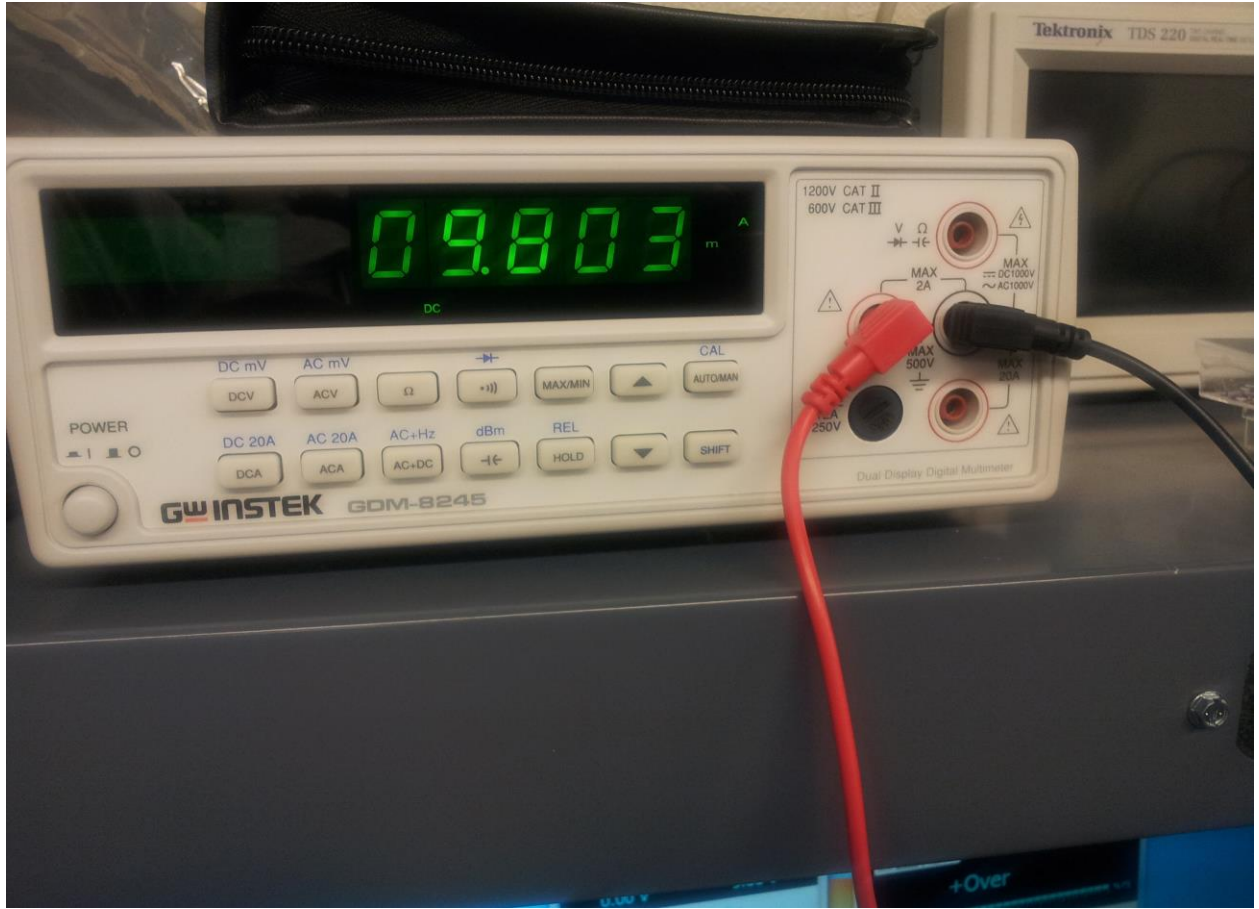
8 – resistors.

Adjust  $R_2$  so that the  $V_A$  voltage is equal to 4.5V. Then measure the value of the new  $R_2$  and calculate and simulate a value that would produce the 4.5V.



# Elvis Wired

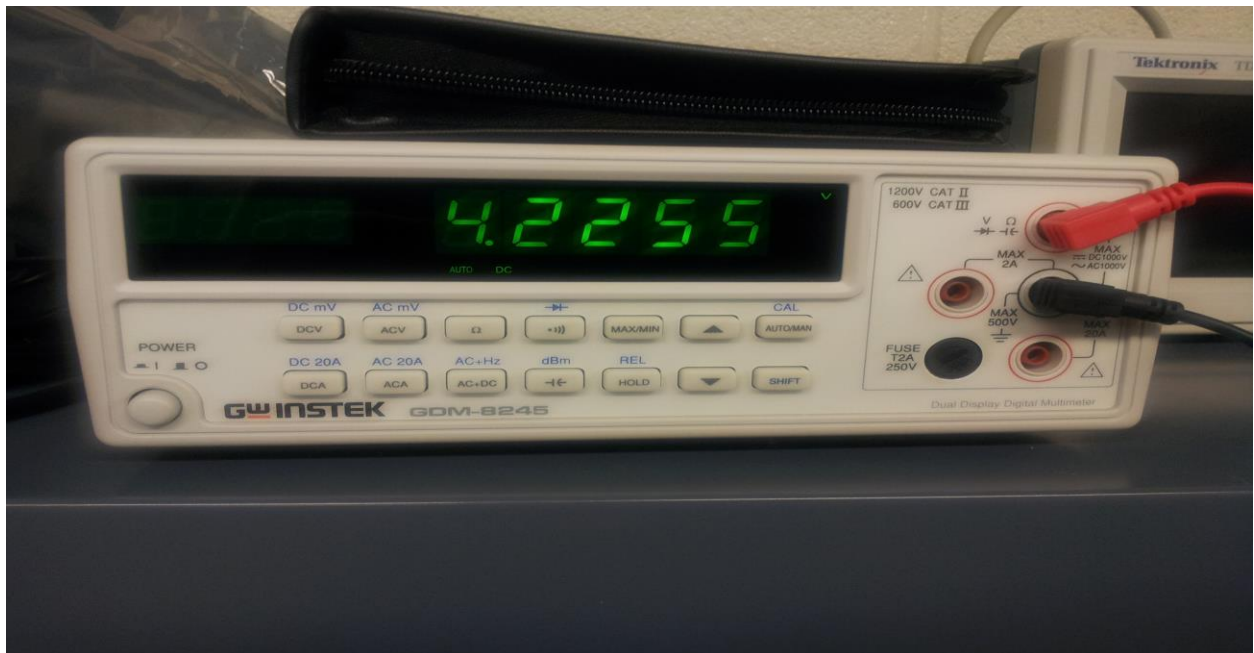




VA

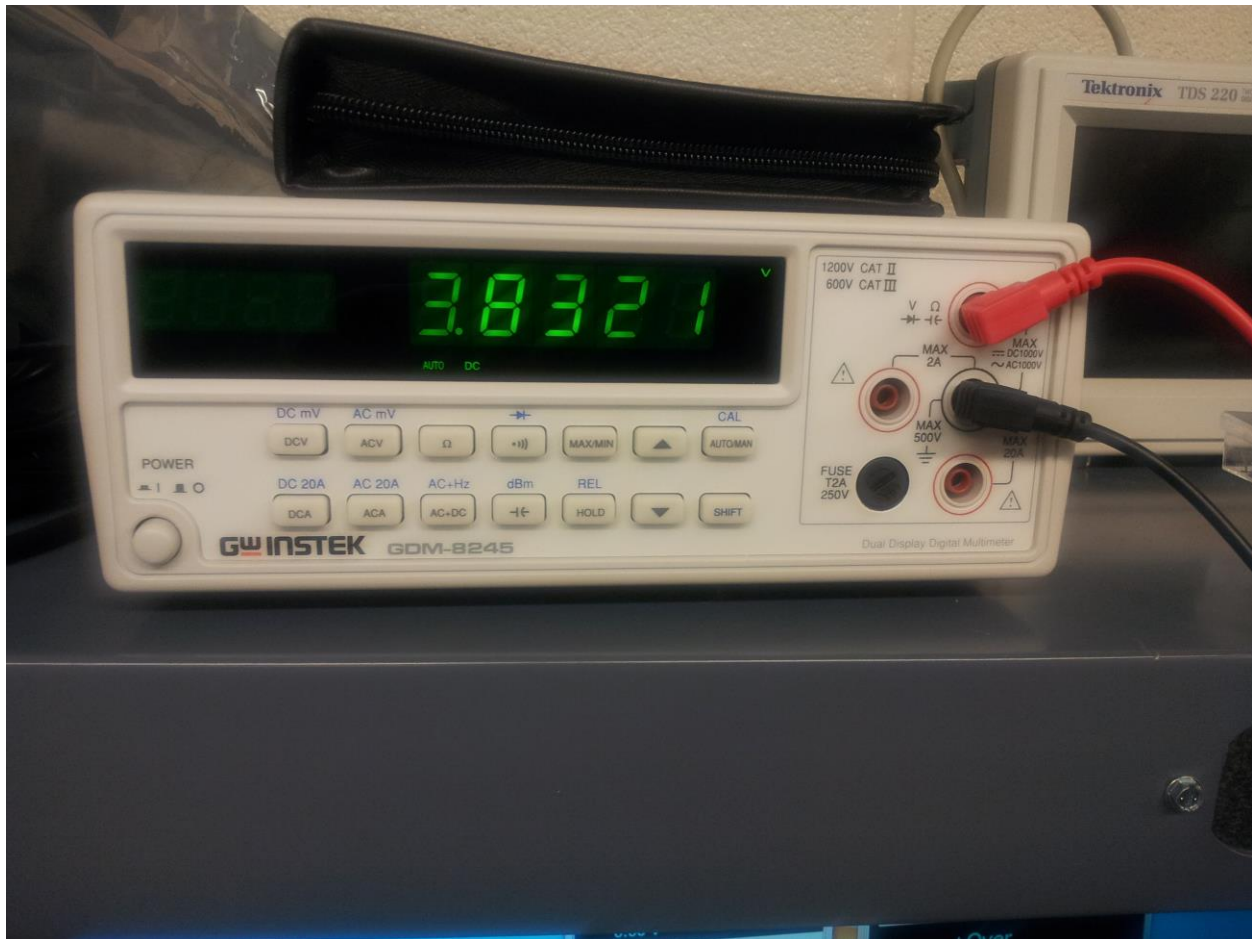


VB





VC



Observations: It was interesting to watch the voltage step-down as it moved through the various parallel and series circuits.

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**LAB 8**

EECT111 – 51C

## Capacitance Lab

Aaron Sprunger and Raphaël Wolff

Date: 14 November 2013

The purpose of this lab is to:

Experiment with a resistive/capacitive circuit. In particular, its relationship to capacitance and frequency will be investigated, including a plot of capacitive reactance versus frequency. We verified our lab results by comparing our findings in the lab to those that we calculated and simulated.

Equipment needed:

1- Digital Multimeter: Instek GDM-8254

1- Function Generator: Instek GFG-8210

1- Oscilloscope: Tektronix TDS 220

1- LCR Meter: Instek LCR-819

National Instruments Elvis II Serial Number 1677D1e, Software version number NT2012.

GW Instek Multimeter Model Number: GDW-8245, Serial Number CL860259

Dell PC running MS Windows 7. Asset tag number A242461.

1- Resistor

3- Capacitors of different value

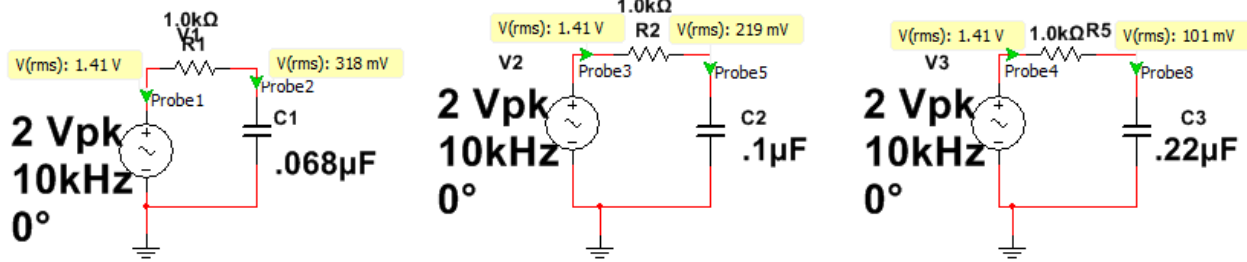
### Components

(1) .068  $\mu\text{F}$  measured capacitive value: .07100  $\mu\text{F}$

(1) .1  $\mu\text{F}$  measured capacitive value: .10079  $\mu\text{F}$

(1) .22  $\mu\text{F}$  measured capacitive value: .22911  $\mu\text{F}$

We modeled and constructed our in-lab RC circuits as simulated below with MultiSim.



Theory:

The current /voltage characteristic of inductors is unlike that of typical resistors. While resistors show a constant resistance value over a wide range of frequencies, the equivalent ohmic value for a capacitor, known as capacitive reactance, is directly proportional to frequency. The capacitive reactance can be computed via the formula:

$$X_C = \frac{1}{2\pi fC}$$

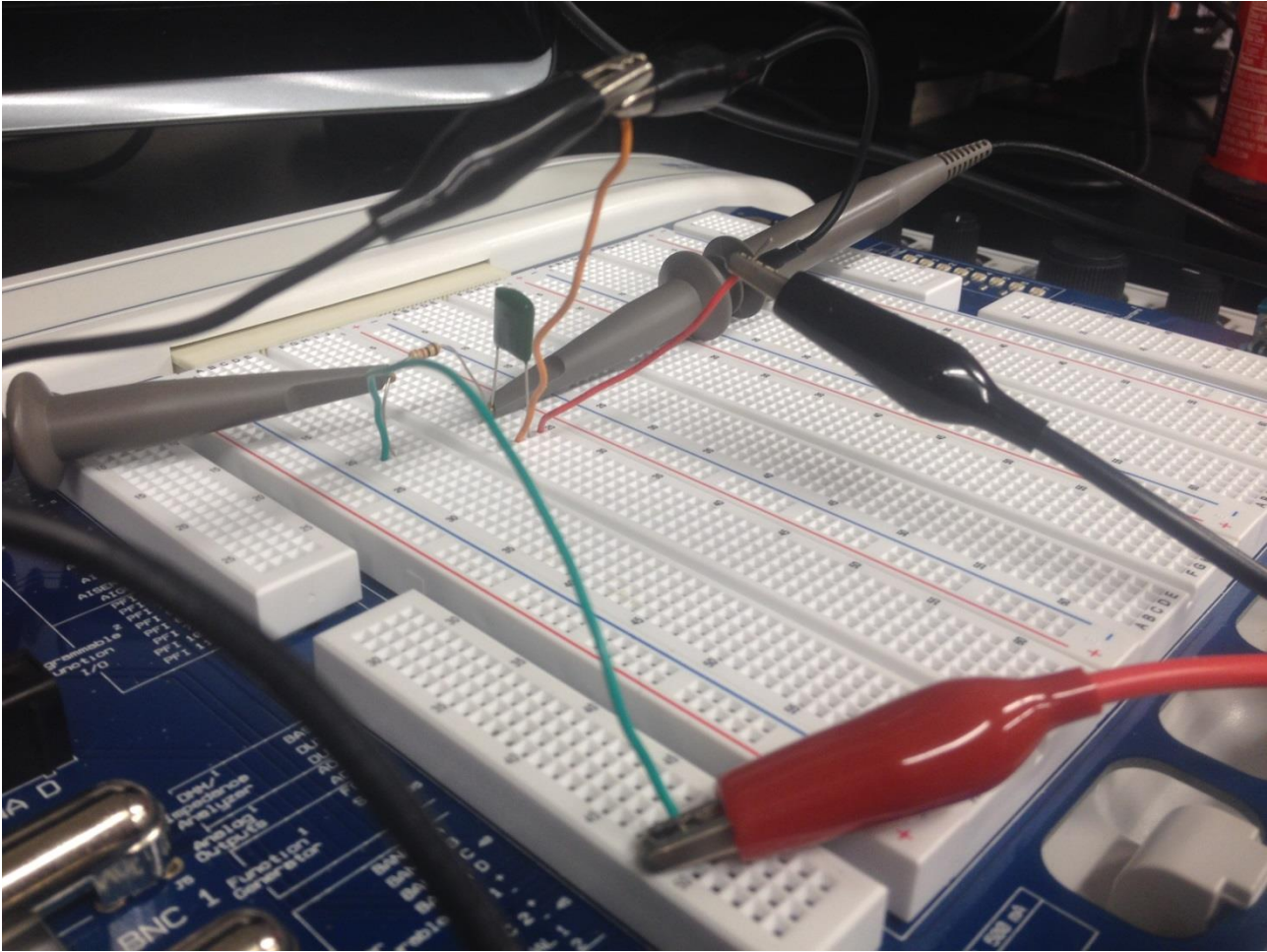
Procedure:

The magnitude of capacitive reactance may be determined experimentally by feeding a capacitor a known current, measuring the resulting voltages, and dividing the two following Ohm's Law. We can then repeated this process across a range of frequencies in order to obtain a dataset that can then be used to plot capacitive reactance versus frequency.

1. Build the 3 circuits as shown above. Place one probe before the resistor and another across the capacitor. We then set the function generator to make a sine wave and produce 2 Vp-p.
2. Record both the voltage in and voltage out at the frequencies listed for all 3 different capacitors.
3. Use the source current and the measured capacitor voltages to determine the experimental capacitive reactance and dB attenuation for each frequency.

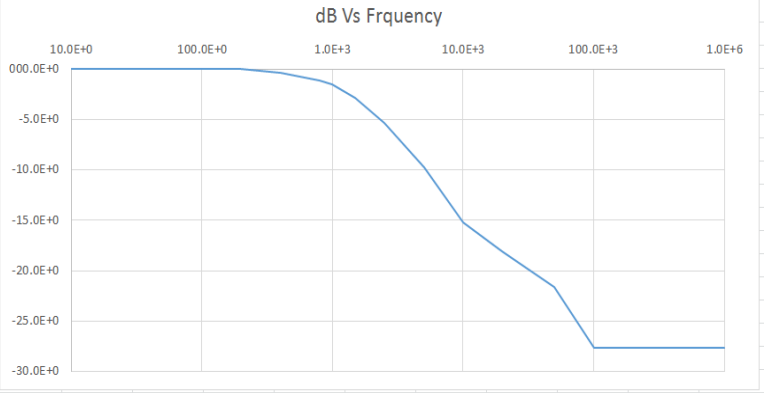
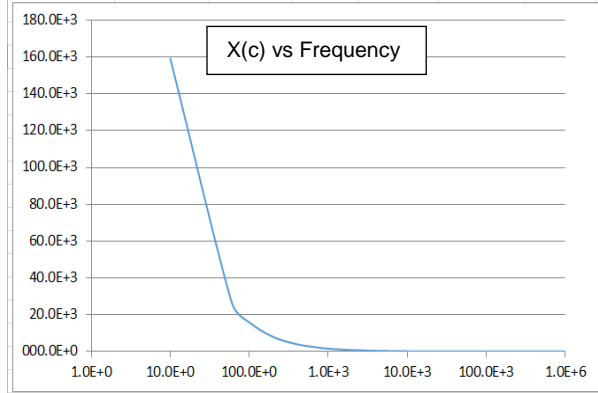
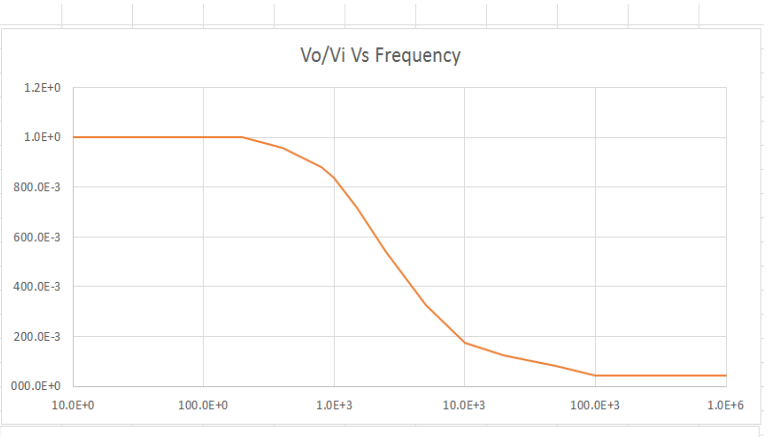
Results and Supporting Data:

Circuit Design Utilizing the ELVIS II



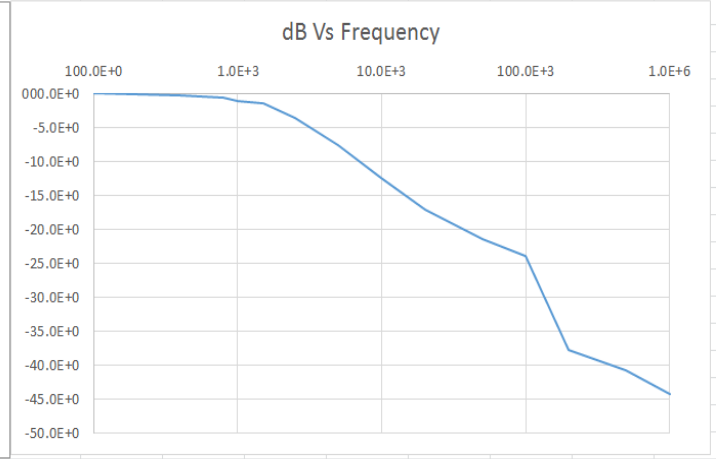
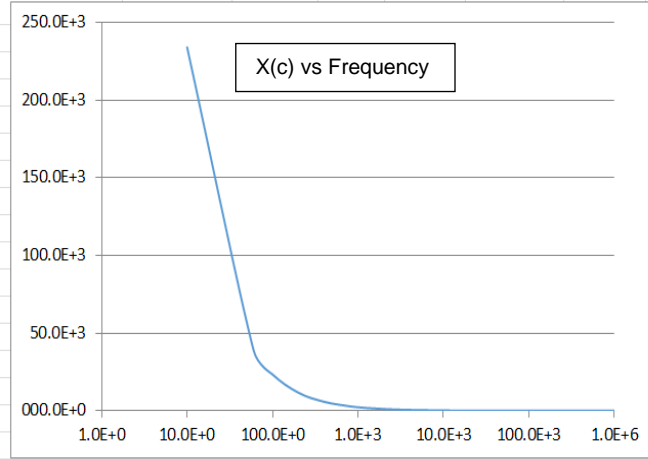
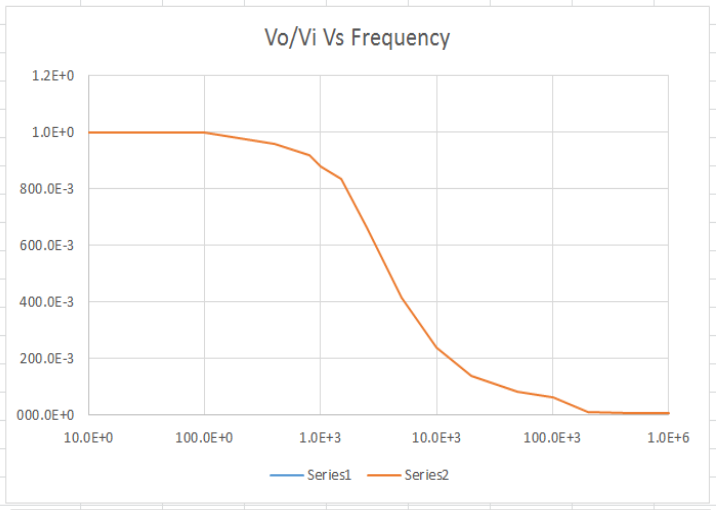
.068μF

Voltage Output	Voltage Input	Frequency	100.0E-9 Vo/Vi	dB	Xc
500.0E-3	500.0E-3	10.0E+0	1.0E+0	000.0E+0	159.2E+3
2.0E+0	2.0E+0	60.0E+0	1.0E+0	000.0E+0	26.5E+3
2.0E+0	2.0E+0	100.0E+0	1.0E+0	000.0E+0	15.9E+3
2.0E+0	2.0E+0	200.0E+0	1.0E+0	000.0E+0	8.0E+3
1.9E+0	2.0E+0	400.0E+0	960.0E-3	-354.6E-3	4.0E+3
1.8E+0	2.0E+0	800.0E+0	880.0E-3	-1.1E+0	2.0E+3
1.7E+0	2.0E+0	1.0E+3	840.0E-3	-1.5E+0	1.6E+3
1.4E+0	2.0E+0	1.5E+3	720.0E-3	-2.9E+0	1.1E+3
1.1E+0	2.0E+0	2.5E+3	540.0E-3	-5.4E+0	636.6E+0
640.0E-3	2.0E+0	5.0E+3	326.5E-3	-9.7E+0	318.3E+0
320.0E-3	1.8E+0	10.0E+3	173.9E-3	-15.2E+0	159.2E+0
240.0E-3	1.9E+0	20.0E+3	125.0E-3	-18.1E+0	79.6E+0
160.0E-3	1.9E+0	50.0E+3	83.3E-3	-21.6E+0	31.8E+0
80.0E-3	1.9E+0	100.0E+3	41.7E-3	-27.6E+0	15.9E+0
80.0E-3	1.9E+0	200.0E+3	41.7E-3	-27.6E+0	8.0E+0
80.0E-3	1.9E+0	500.0E+3	41.7E-3	-27.6E+0	3.2E+0
80.0E-3	1.9E+0	1.0E+6	41.7E-3	-27.6E+0	1.6E+0



# .1 $\mu$ F

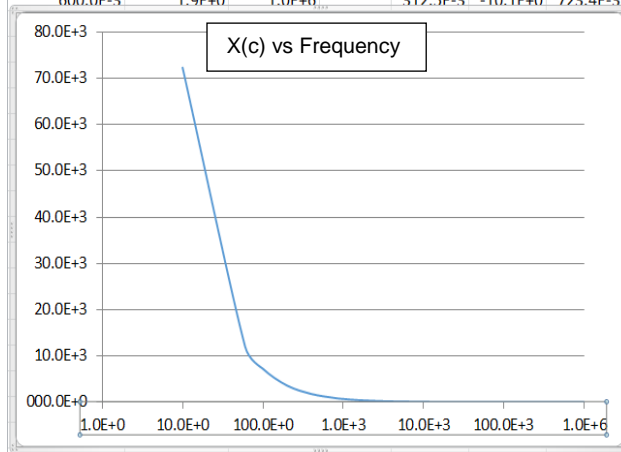
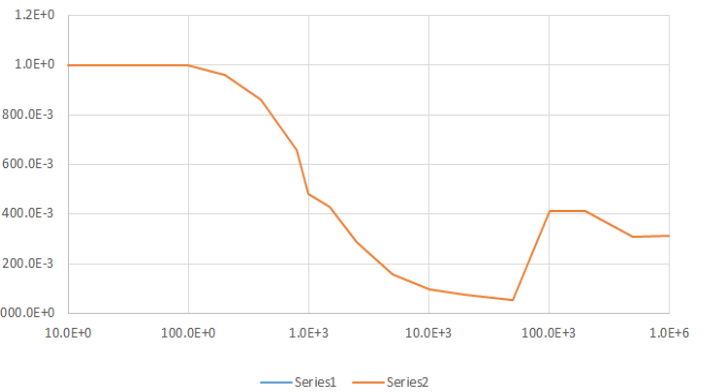
Voltage Output	Voltage Input	Frequency	68.0E-9	Vo/Vi	dB	X <sub>c</sub>
0.4800	480.0E-3	10.0E+0		1.0E+0	000.0E+0	234.1E+3
1.9600	2.0E+0	60.0E+0		1.0E+0	000.0E+0	39.0E+3
1.9600	2.0E+0	100.0E+0		1.0E+0	000.0E+0	23.4E+3
1.9600	2.0E+0	200.0E+0		980.0E-3	-175.5E-3	11.7E+3
1.9200	2.0E+0	400.0E+0		960.0E-3	-354.6E-3	5.9E+3
1.8400	2.0E+0	800.0E+0		920.0E-3	-724.2E-3	2.9E+3
1.7600	2.0E+0	1.0E+3		880.0E-3	-1.1E+0	2.3E+3
1.6400	2.0E+0	1.5E+3		836.7E-3	-1.5E+0	1.6E+3
1.3000	2.0E+0	2.5E+3		663.3E-3	-3.6E+0	936.2E+0
0.8000	1.9E+0	5.0E+3		416.7E-3	-7.6E+0	468.1E+0
0.4400	1.8E+0	10.0E+3		239.1E-3	-12.4E+0	234.1E+0
0.2600	1.9E+0	20.0E+3		138.3E-3	-17.2E+0	117.0E+0
0.1600	1.9E+0	50.0E+3		85.1E-3	-21.4E+0	46.8E+0
0.1200	1.9E+0	100.0E+3		63.8E-3	-23.9E+0	23.4E+0
0.0248	1.9E+0	200.0E+3		12.9E-3	-37.8E+0	11.7E+0
0.0180	2.0E+0	500.0E+3		9.2E-3	-40.7E+0	4.7E+0
0.0120	2.0E+0	1.0E+6		6.1E-3	-44.3E+0	2.3E+0



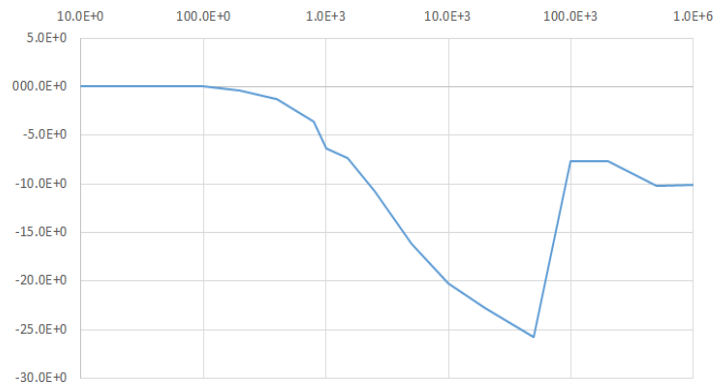
## .22μF

Voltage Output	Voltage Input	Frequency	220.0E-9	Vo/Vi	dB	X <sub>c</sub>
480.0E-3	480.0E-3	10.0E+0		1.0E+0	000.0E+0	72.3E+3
2.0E+0	2.0E+0	60.0E+0		1.0E+0	000.0E+0	12.1E+3
2.0E+0	2.0E+0	100.0E+0		1.0E+0	000.0E+0	7.2E+3
1.9E+0	2.0E+0	200.0E+0		960.0E-3	-354.6E-3	3.6E+3
1.7E+0	2.0E+0	400.0E+0		860.0E-3	-1.3E+0	1.8E+3
1.3E+0	2.0E+0	800.0E+0		656.6E-3	-3.7E+0	904.3E+0
940.0E-3	2.0E+0	1.0E+3		479.6E-3	-6.4E+0	723.4E+0
840.0E-3	2.0E+0	1.5E+3		428.6E-3	-7.4E+0	482.3E+0
560.0E-3	1.9E+0	2.5E+3		288.7E-3	-10.8E+0	289.4E+0
300.0E-3	1.9E+0	5.0E+3		156.3E-3	-16.1E+0	144.7E+0
180.0E-3	1.9E+0	10.0E+3		96.8E-3	-20.3E+0	72.3E+0
140.0E-3	1.9E+0	20.0E+3		72.9E-3	-22.7E+0	36.2E+0
100.0E-3	1.9E+0	50.0E+3		51.5E-3	-25.8E+0	14.5E+0
800.0E-3	1.9E+0	100.0E+3		412.4E-3	-7.7E+0	7.2E+0
800.0E-3	1.9E+0	200.0E+3		412.4E-3	-7.7E+0	3.6E+0
600.0E-3	1.9E+0	500.0E+3		309.3E-3	-10.2E+0	1.4E+0
600.0E-3	1.9E+0	1.0E+6		312.5E-3	-10.1E+0	723.4E-3

Vo/Vi Vs Frequency



dB Vs Frequency



### Observations:

This lab has proven to us that capacitors oppose change in voltage, and they accomplish this by producing a current. A capacitor will pass a greater amount of AC current, given the same AC voltage, as the frequency increases. This effect is what allows capacitors to be very effective low-pass filters.

### Equipment Used:

National Instruments Elvis II Serial Number 1677D1e, Software version number NT2012.

GW Instel Multimeter Model Number: GDW-8245, Serial Number CL860259

Dell PC running MS Windows 7. Asset tag number A242461.



Function Generator: Instek GFG-8210

Oscilloscope: Tektronix TDS 220

LCR Meter: Instek LCR-819

**THE  
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**LAB 9**

Inductance Lab

Aaron Sprunger and Raphaël Wolff

Date: 21 November 2013

The purpose of this lab is to:

Experiment with a resistive/inductive circuit. In particular, its relationship to inductance and frequency will be investigated, including a plot of inductive reactance versus frequency. We verified our lab results by comparing our findings in the lab to those that we calculated and simulated.

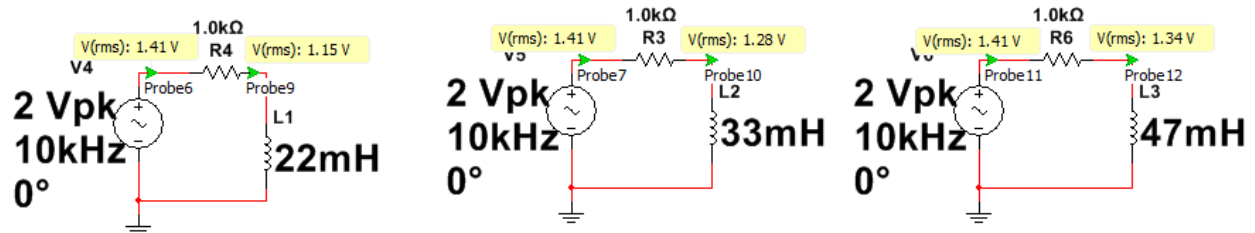
Equipment needed:

- 1- Digital Multimeter: Instek GDM-8254
- 1- Function Generator: Instek GFG-8210
- 1- Oscilloscope
- 1- LCR Meter: Instek LCR-819
- 1- Resistor
- 3- Inductors of different value

Components

- (1) 22 mH measured inductive value: 19.626 mH
- (1) 33 mH measured inductive value: 29.874 mH
- (1) 47 mH measured inductive value: 40.213 mH

We modeled and constructed our in-lab RL circuits as simulated below by MultiSim



### Theory:

The current /voltage characteristic of inductors is unlike that of typical resistors. While resistors show a constant resistance value over a wide range of frequencies, the equivalent ohmic value for an inductor, known as inductive reactance, is directly proportional to frequency. The inductive reactance can be computed via the formula:

$$X_L = j2\pi fL$$

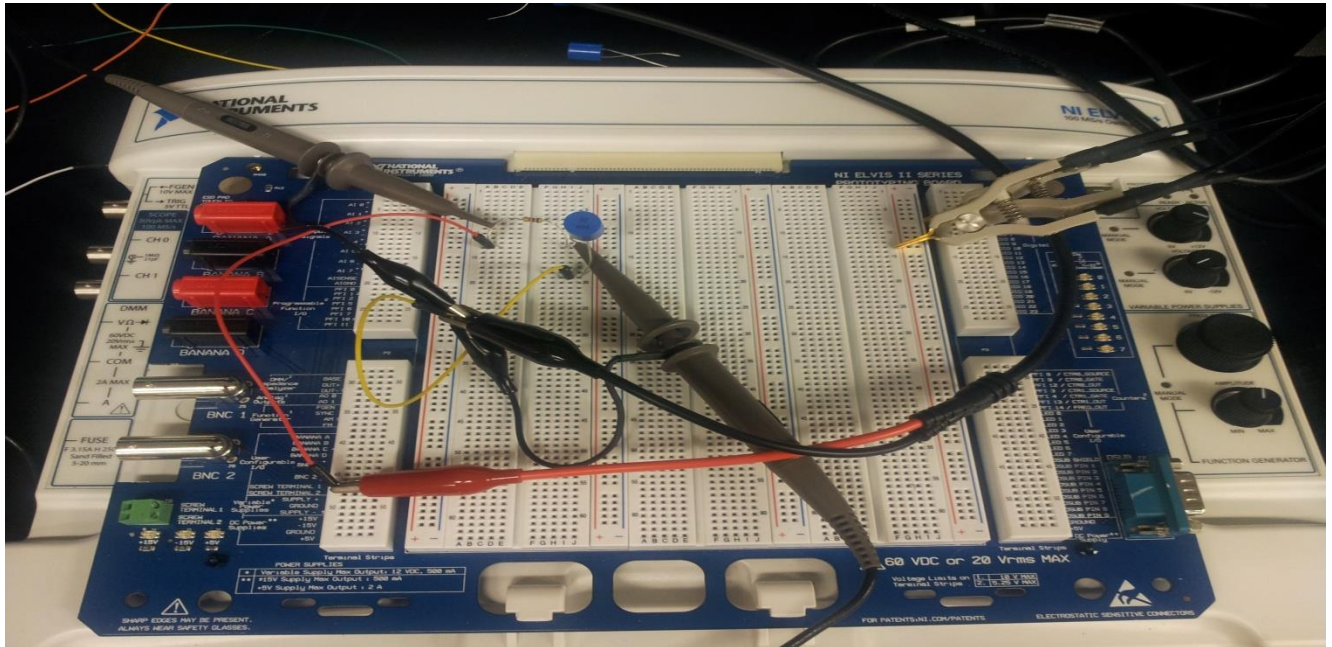
### Procedure:

The magnitude of inductive reactance may be determined experimentally by feeding an inductor a known current, measuring the resulting voltage, and dividing the two, following Ohm's Law. We then repeated this process across a range of frequencies in order to obtain a dataset that can then be used to plot inductive reactance versus frequency.

4. Build the 3 circuits as shown above. Place one probe before the resistor and another across the inductor. We then set the function generator to make a sine wave and produce 2 Vp-p.
5. Record both the voltage in and voltage out at the frequencies listed for all 3 different inductors.
6. Use the source current and the measured inductor voltages to determine the experimental inductive reactance and dB attenuation for each frequency.

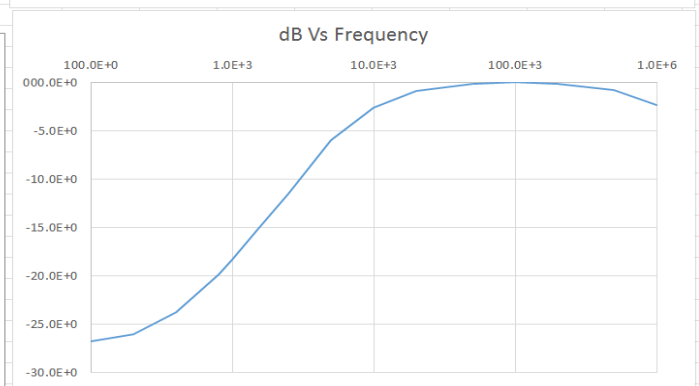
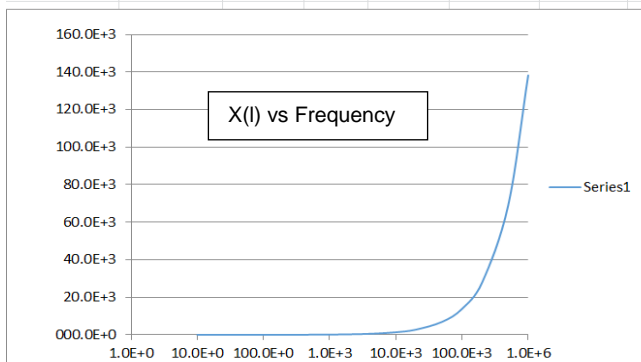
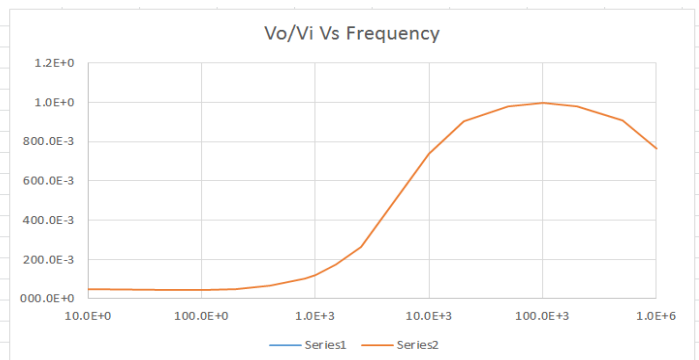
## Results and Supporting Data:

### Circuit Design Utilizing the ELVIS II



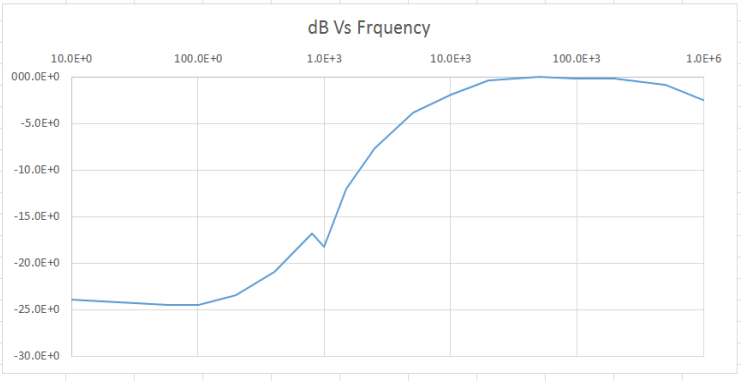
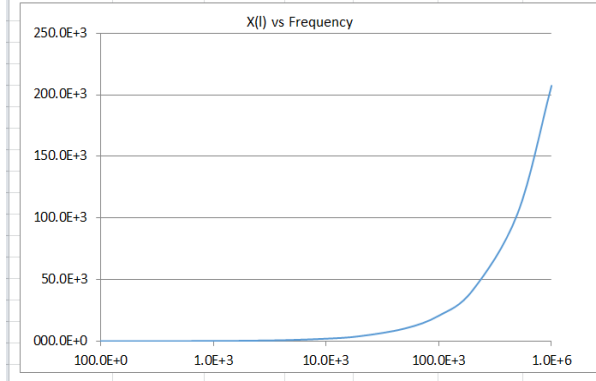
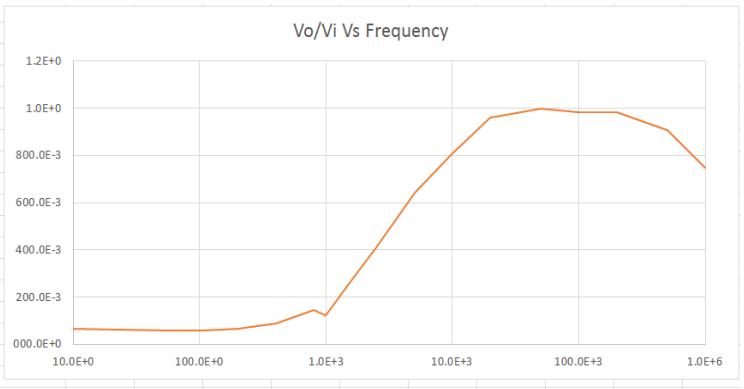
## 22mH Inductor

Voltage Output	Voltage Input	Frequency	0.0220 Vo/Vi	dB	X(l)
28.0E-3	550.0E-3	10.0E+0	50.9E-3	-25.9E+0	1.4E+0
84.0E-3	2.0E+0	60.0E+0	42.9E-3	-27.4E+0	8.3E+0
90.0E-3	2.0E+0	100.0E+0	45.9E-3	-26.8E+0	13.8E+0
100.0E-3	2.0E+0	200.0E+0	50.0E-3	-26.0E+0	27.6E+0
130.0E-3	2.0E+0	400.0E+0	65.0E-3	-23.7E+0	55.3E+0
202.0E-3	2.0E+0	800.0E+0	101.0E-3	-19.9E+0	110.6E+0
242.0E-3	2.0E+0	1.0E+3	121.0E-3	-18.3E+0	138.2E+0
352.0E-3	2.0E+0	1.5E+3	172.5E-3	-15.3E+0	207.3E+0
552.0E-3	2.1E+0	2.5E+3	265.4E-3	-11.5E+0	345.6E+0
1.0E+0	2.1E+0	5.0E+3	500.0E-3	-6.0E+0	691.2E+0
1.5E+0	2.1E+0	10.0E+3	740.4E-3	-2.6E+0	1.4E+3
1.9E+0	2.1E+0	20.0E+3	905.7E-3	-860.7E-3	2.8E+3
2.1E+0	2.1E+0	50.0E+3	981.1E-3	-165.5E-3	6.9E+3
2.2E+0	2.2E+0	100.0E+3	1.0E+0	000.0E+0	13.8E+3
2.1E+0	2.2E+0	200.0E+3	981.5E-3	-162.4E-3	27.6E+3
2.0E+0	2.2E+0	500.0E+3	907.4E-3	-844.0E-3	69.1E+3
1.6E+0	2.1E+0	1.0E+6	764.2E-3	-2.3E+0	138.2E+3



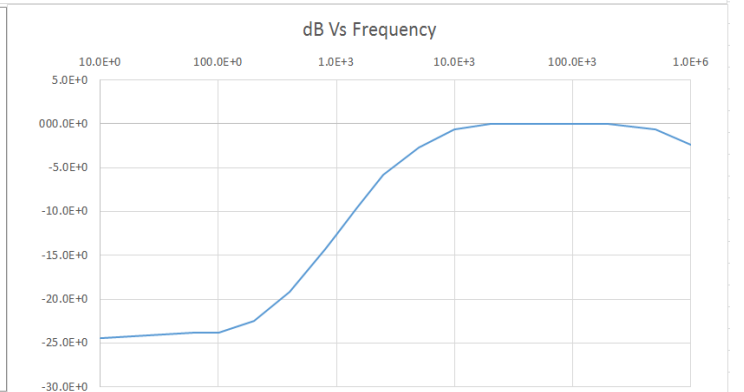
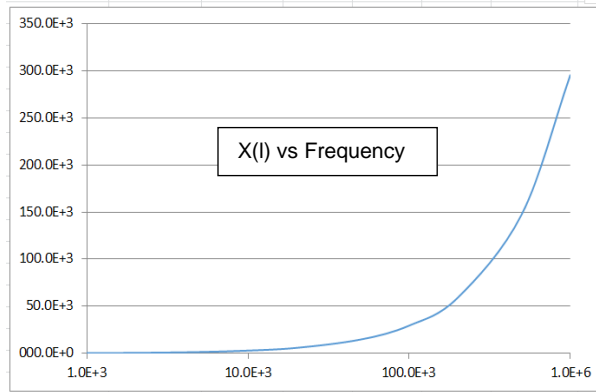
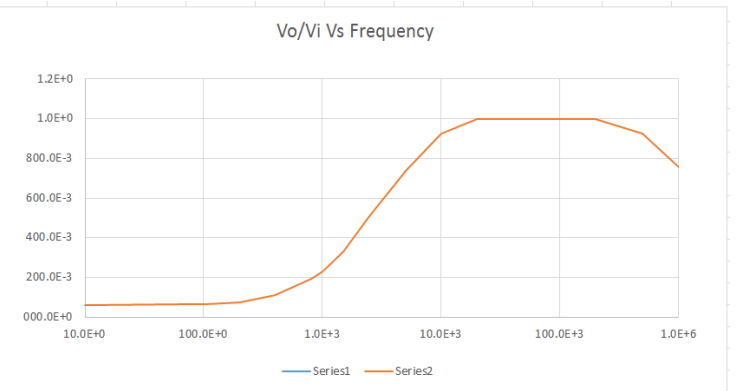
### 33mH Inductor

Voltage Output	Voltage Input	Frequency	0.033 Vo/Vi	dB	X(l)
32.0E-3	500.0E-3	10.0E+0	64.0E-3	-23.9E+0	2.1E+0
120.0E-3	2.0E+0	60.0E+0	60.0E-3	-24.4E+0	12.4E+0
120.0E-3	2.0E+0	100.0E+0	60.0E-3	-24.4E+0	20.7E+0
136.0E-3	2.0E+0	200.0E+0	67.3E-3	-23.4E+0	41.5E+0
184.0E-3	2.0E+0	400.0E+0	90.2E-3	-20.9E+0	82.9E+0
296.0E-3	2.0E+0	800.0E+0	145.1E-3	-16.8E+0	165.9E+0
256.0E-3	2.1E+0	1.0E+3	123.1E-3	-18.2E+0	207.3E+0
512.0E-3	2.0E+0	1.5E+3	251.0E-3	-12.0E+0	311.0E+0
840.0E-3	2.0E+0	2.5E+3	411.8E-3	-7.7E+0	518.4E+0
1.4E+0	2.1E+0	5.0E+3	641.5E-3	-3.9E+0	1.0E+3
1.8E+0	2.2E+0	10.0E+3	807.3E-3	-1.9E+0	2.1E+3
2.0E+0	2.1E+0	20.0E+3	962.3E-3	-334.1E-3	4.1E+3
2.2E+0	2.2E+0	50.0E+3	1.0E+0	000.0E+0	10.4E+3
2.1E+0	2.2E+0	100.0E+3	981.5E-3	-162.4E-3	20.7E+3
2.1E+0	2.2E+0	200.0E+3	981.5E-3	-162.4E-3	41.5E+3
2.0E+0	2.2E+0	500.0E+3	907.4E-3	-844.0E-3	103.7E+3
1.6E+0	2.2E+0	1.0E+6	750.0E-3	-2.5E+0	207.3E+3



### 47mH Inductor

Voltage Output	Voltage Input	Frequency	0.047 Vo/Vi	dB	X(l)
30.0E-3	500.0E-3	10.0E+0	60.0E-3	-24.4E+0	3.0E+0
128.0E-3	2.0E+0	60.0E+0	64.0E-3	-23.9E+0	17.7E+0
128.0E-3	2.0E+0	100.0E+0	64.0E-3	-23.9E+0	29.5E+0
150.0E-3	2.0E+0	200.0E+0	75.0E-3	-22.5E+0	59.1E+0
220.0E-3	2.0E+0	400.0E+0	110.0E-3	-19.2E+0	118.1E+0
384.0E-3	2.0E+0	800.0E+0	192.0E-3	-14.3E+0	236.2E+0
464.0E-3	2.0E+0	1.0E+3	232.0E-3	-12.7E+0	295.3E+0
664.0E-3	2.0E+0	1.5E+3	332.0E-3	-9.6E+0	443.0E+0
1.1E+0	2.1E+0	2.5E+3	509.6E-3	-5.9E+0	738.3E+0
1.6E+0	2.1E+0	5.0E+3	735.8E-3	-2.7E+0	1.5E+3
2.0E+0	2.1E+0	10.0E+3	924.5E-3	-681.6E-3	3.0E+3
2.1E+0	2.1E+0	20.0E+3	1.0E+0	000.0E+0	5.9E+3
2.2E+0	2.2E+0	50.0E+3	1.0E+0	000.0E+0	14.8E+3
2.2E+0	2.2E+0	100.0E+3	1.0E+0	000.0E+0	29.5E+3
2.2E+0	2.2E+0	200.0E+3	1.0E+0	000.0E+0	59.1E+3
2.0E+0	2.2E+0	500.0E+3	925.9E-3	-668.5E-3	147.7E+3
1.6E+0	2.1E+0	1.0E+6	754.7E-3	-2.4E+0	295.3E+3



### Observations:

This lab has proven to us that inductors oppose change in current, this is opposition to change is its reactance. Inductors must accomplish this task by producing a voltage. An inductor will drop a greater amount of AC voltage, given the same AC current, as the frequency increases. This effect is what allows inductors to be very effective high-pass filters.

### Equipment Used:

National Instruments Elvis II Serial Number 1677D1e, Software version number NT2012.

GW Instel Multimeter Model Number: GDW-8245, Serial Number CL860259

Dell PC running MS Windows 7. Asset tag number A242461.

Function Generator: Instek GFG-8210

Oscilloscope: Tektronix TDS 220

LCR Meter: Instek LCR-819