Lab Notebook

EECT111-50C

Circuit Analysis

Spring 2015

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5/7/15

CONTENTS

Lab 1

Resistor Variability

Lab 1: Resistor Variability (1)

Objective:

Learn how resistors vary using 10 resistors with the same color code.

Equipment/Materials:

	Brand	Model	S/N
Digital Multimeter	GW INSTEK	GDM-8245	CL860260
10 x 1kΩ resistors	N/A	N/A	N/A

Digital Multimeter

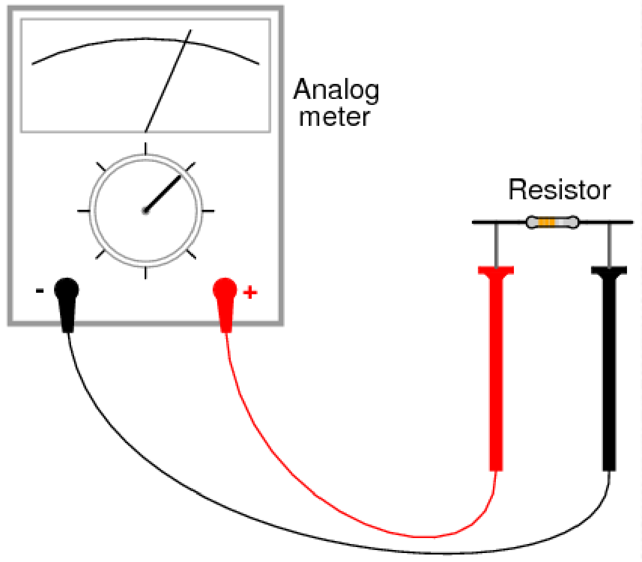
Lab 1: Resistor Variability (2)

Procedures:

Connect a resistor to the red and black ends of a Digital Multimeter to measure the resistors' value.

Calculation:

Mean	982.6	= AVERAGEA(C12:C81)
Std. Dev	5.8	= STDEV(C12:C81)
Median	981	= MEDIAN(C12:C81)
Mode	980	= MODE(C12:C81)
Smallest	975	= MIN(C12:C81)
Largest	1002	= MAX(C12:C81)
Range	27	= C88-C87



Lab 1: Resistor Variability (3)

Measured Data:

	A	B	C	E	F	G
10			Measured Value	Resistor Tolerance		
11			Resistance (Ω)	Low Tolerance	High Tolerance	Nominal
12	Group1	1	982	950	1050	1000
13		2	980	950	1050	1000
14		3	981	950	1050	1000
15		4	984	950	1050	1000
16		5	978	950	1050	1000
17		6	980	950	1050	1000
18		7	980	950	1050	1000
19		8	980	950	1050	1000
20		9	981	950	1050	1000
21		10	982	950	1050	1000
22	Group2	11	979	950	1050	1000
23		12	982	950	1050	1000
24		13	978	950	1050	1000
25		14	979	950	1050	1000
26		15	999	950	1050	1000
27		16	987	950	1050	1000
28		17	987	950	1050	1000
29		18	982	950	1050	1000
30		19	980	950	1050	1000
31		20	1000	950	1050	1000

	A	B	C	E	F	G
10			Measured Value	Resistor Tolerance		
11			Resistance (Ω)	Low Tolerance	High Tolerance	Nominal
32	Group3	21	980	950	1050	1000
33		22	979	950	1050	1000
34		23	978	950	1050	1000
35		24	977	950	1050	1000
36		25	978	950	1050	1000
37		26	979	950	1050	1000
38		27	977	950	1050	1000
39		28	979	950	1050	1000
40		29	981	950	1050	1000
41		30	983	950	1050	1000
42	Group4	31	977	950	1050	1000
43		32	985	950	1050	1000
44		33	996	950	1050	1000
45		34	977	950	1050	1000
46		35	983	950	1050	1000
47		36	981	950	1050	1000
48		37	994	950	1050	1000
49		38	979	950	1050	1000
50		39	975	950	1050	1000
51		40	978	950	1050	1000

Lab 1: Resistor Variability (4)

Measured Data:

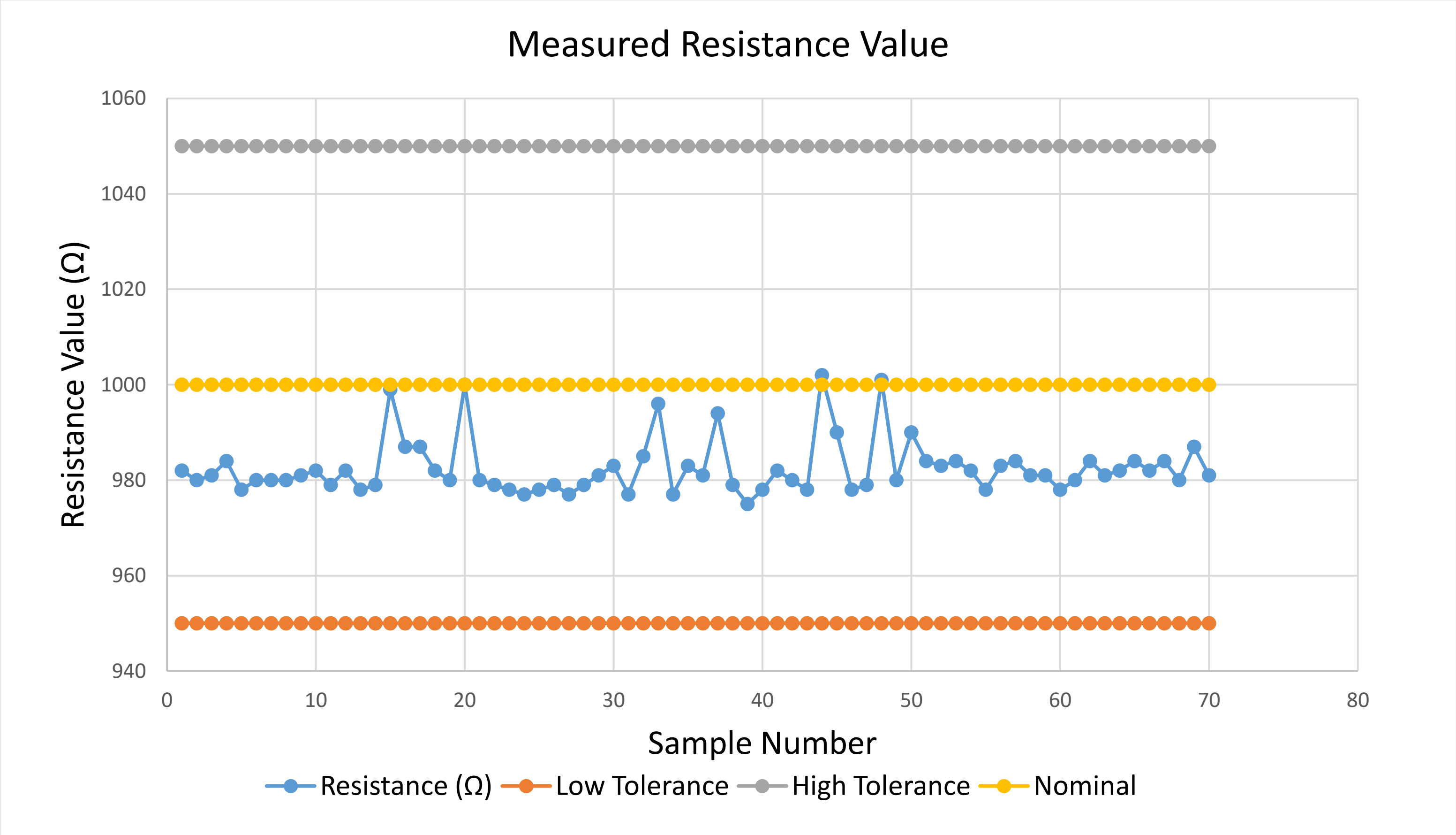
	A	B	C	E	F	G
10			Measured Value	Resistor Tolerance		
11			Resistance (Ω)	Low Tolerance	High Tolerance	Nominal
52	Group5	41	982	950	1050	1000
53		42	980	950	1050	1000
54		43	978	950	1050	1000
55		44	1002	950	1050	1000
56		45	990	950	1050	1000
57		46	978	950	1050	1000
58		47	979	950	1050	1000
59		48	1001	950	1050	1000
60		49	980	950	1050	1000
61		50	990	950	1050	1000
62	Group6	51	984	950	1050	1000
63		52	983	950	1050	1000
64		53	984	950	1050	1000
65		54	982	950	1050	1000
66		55	978	950	1050	1000
67		56	983	950	1050	1000
68		57	984	950	1050	1000
69		58	981	950	1050	1000
70		59	981	950	1050	1000
71		60	978	950	1050	1000

	A	B	C	E	F	G
10			Measured Value	Resistor Tolerance		
11			Resistance (Ω)	Low Tolerance	High Tolerance	Nominal
72	Group7	61	980	950	1050	1000
73		62	984	950	1050	1000
74		63	981	950	1050	1000
75		64	982	950	1050	1000
76		65	984	950	1050	1000
77		66	982	950	1050	1000
78		67	984	950	1050	1000
79		68	980	950	1050	1000
80		69	987	950	1050	1000
81		70	981	950	1050	1000

Mean	982.6	= AVERAGEA(C12:C81)
Std. Dev	5.8	= STDEV(C12:C81)
Median	981	= MEDIAN(C12:C81)
Mode	980	= MODE(C12:C81)
Smallest	975	= MIN(C12:C81)
Largest	1002	= MAX(C12:C81)
Range	27	= C88-C87

Lab 1: Resistor Variability (5)

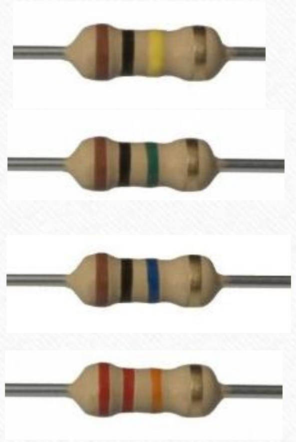
Graph Result:



Lab 1: Resistor Variability (6)

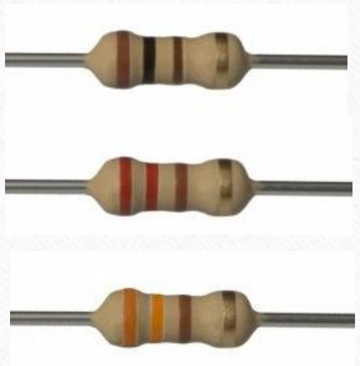
Conclusion:

All measured data were lower than nominal value. When we switch around resistance code, the value of resistance didn't change.
We observed that standard resistors do not have the exact value as the color code value.



Lab 2

Reading and Sorting Resistors



Lab 2: Reading and Sorting Resistors (1)

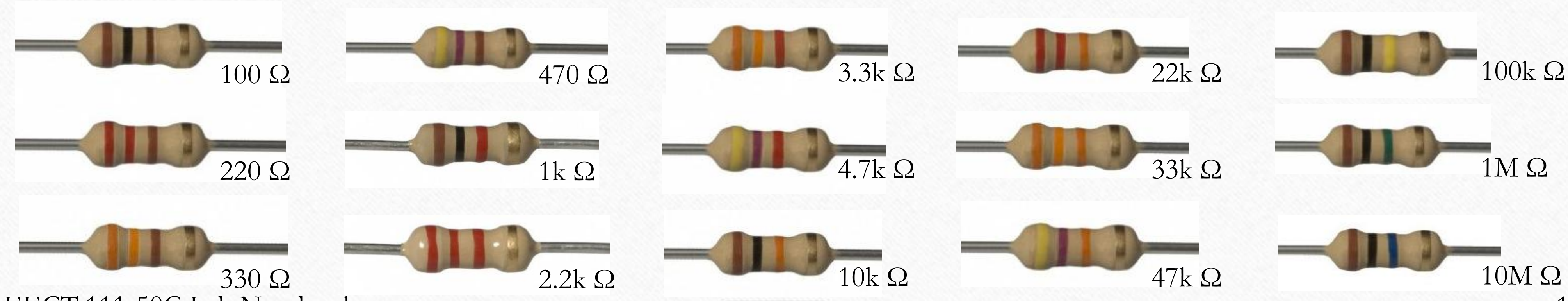
Objective:

Learn the resistor color code using 15 resistors.

Equipment/Materials:

	Brand	Model	S/N
Digital Multimeter	**GW INSTEK**	**GDM-8245**	**CL860260**

15 Different Resistor	**100, 220, 330, 470, 1k, 2.2k, 3.3k, 4.7k, 10k, 22k, 33k, 47k, 100k, 1M, 10M**



Lab 2: Reading and Sorting Resistors (2)

Procedures:

Build a specified resistor using color code and sort resistors based on color codes from smallest to largest and measure the resistance of each resistor and verify sorting.

Lab 2: Reading and Sorting Resistors (3)

Calculation:

The colored bands together give information about the resistance value, the tolerance as well as other parameters. The resistor can have from 3 to 6 bands. With the color code chart, the meaning of each band can be determined.

Color	Signficant figures			Multiply	Tolerance (%)
black	0	0	0	x 1	
brown	1	1	1	x 10	1 (F)
red	2	2	2	x 100	2 (G)
orange	3	3	3	x 1K	
yellow	4	4	4	x 10K	
green	5	5	5	x 100K	0.5 (D)
blue	6	6	6	x 1M	0.25 (C)
violet	7	7	7	x 10M	0.1 (B)
grey	8	8	8	x 100M	0.05 (A)
white	9	9	9	x 1G	
gold			3th digit only for 5 and 6 bands	x 0.1	5 (J)
silver				x 0.01	10 (K)
none					20 (M)

http://electricalengineeringbasics.weebly.com/resistor-color-code.html

Lab 2: Reading and Sorting Resistors (4)

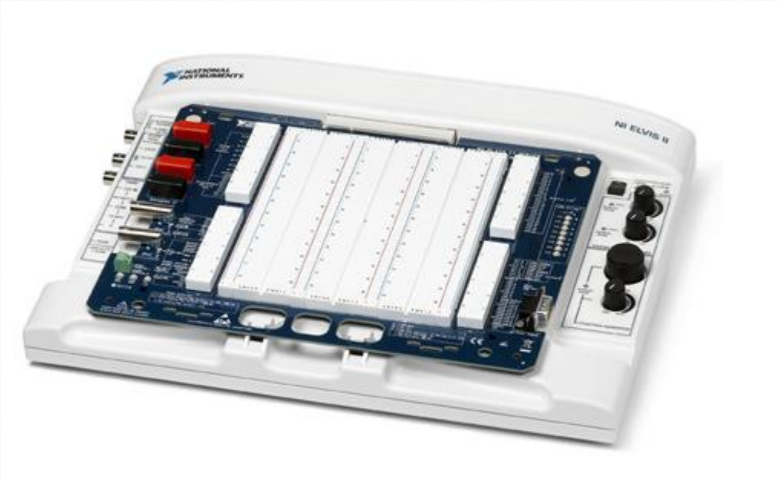
Measured Data:

	Nominal [Ω]	Color Code			Tolerance [%]	Measured Value [Ω]	Low [Ω]	Max [Ω]	In Tolerance?	Too Low?	Too High?
1	100	Brown	Black	Brown	5	**99**	95	105	Yes	No	No
2	220	Red	Red	Brown	0.05	**216**	209	231	Yes	No	No
3	330	Orange	Orange	Brown	0.05	**322**	314	347	Yes	No	No
4	470	Yellow	Violet	Brown	0.05	**462**	447	494	Yes	No	No
5	1,000	Brown	Black	Red	0.05	**980**	950	1,050	Yes	No	No
6	2,200	Red	Red	Red	0.05	**2,170**	2,090	2,310	Yes	No	No
7	3,300	Orange	Orange	Red	0.05	**3,250**	3,135	3,465	Yes	No	No
8	4,700	Yellow	Violet	Red	0.05	**4,620**	4,465	4,935	Yes	No	No
9	10,000	Brown	Black	Orange	0.05	**9,750**	9,500	10,500	Yes	No	No
10	22,000	Red	Red	Orange	0.05	**21,600**	20,900	23,100	Yes	No	No
11	33,000	Orange	Orange	Orange	0.05	**32,900**	31,350	34,650	Yes	No	No
12	47,000	Yellow	Violet	Orange	0.05	**45,670**	44,650	49,350	Yes	No	No
13	100,000	Brown	Black	Yellow	0.05	**100,100**	95,000	105,000	Yes	No	No
14	1,000,000	Brown	Black	Green	0.05	**998,000**	950,000	1,050,000	Yes	No	No
15	10,000,000	Brown	Black	Blue	0.05	**10,220,000**	9,500,000	10,500,000	Yes	No	No

Lab 2: Reading and Sorting Resistors (5)

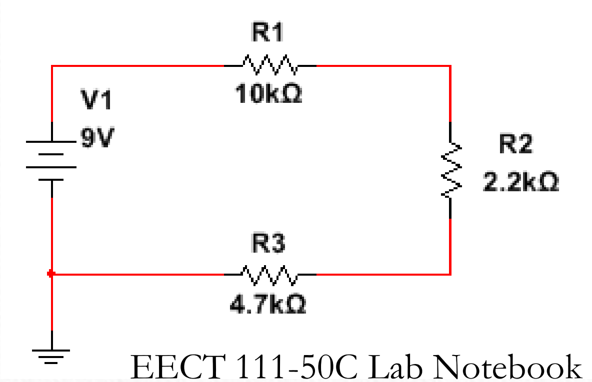
Conclusion:

We found that the different combinations of color showed different measured values. All measured values were within 5 % tolerance.



Lab 3

Series Resistors Current and Voltage



Lab 3: Series Resistors Current and Voltage (1)

Objective:

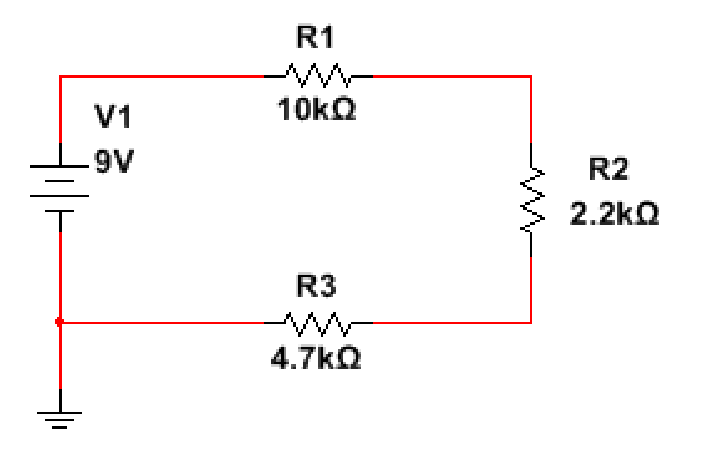
Experiment with series circuits and verify that the simulation, analysis (calculations) and measured test results all agree.

Equipment/Materials:

	Brand	Model	S/N
Digital Multimeter	GW INSTEK	GDM-8245	CL860260
Elvis II	National Instruments	NI Elvis II+	1677D5B
Resistors	10K, 2.2K, and 4.7K Ω.		

Lab 3: Series Resistors Current and Voltage (2)

Schematic:



Lab 3: Series Resistors Current and Voltage (3)

Procedures:

Measure and record the value of each resistor. Connect the resistors in series in the following order; 10K, 2.2K, and 4.7K Ω and measure each resistor and total resistor.

Then, apply 9 V to the circuit using Elvis II and measure and record with the Digital Multimeter the current and voltages of the series circuit.

Lab 3: Series Resistors Current and Voltage (4)

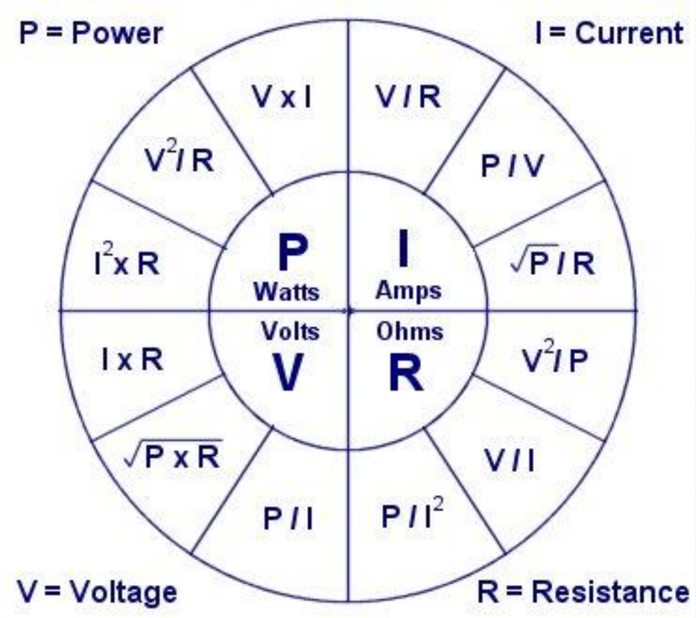
Calculation:

Resistor Color Codes

R1	Brown	Black	Orange	10k	Ω
R2	Red	Red	Yellow	2.2k	Ω
R3	Yellow	Violet	Red	4.7k	Ω

Ohm's Law

$$I_T = \frac{V_T}{R_T}$$

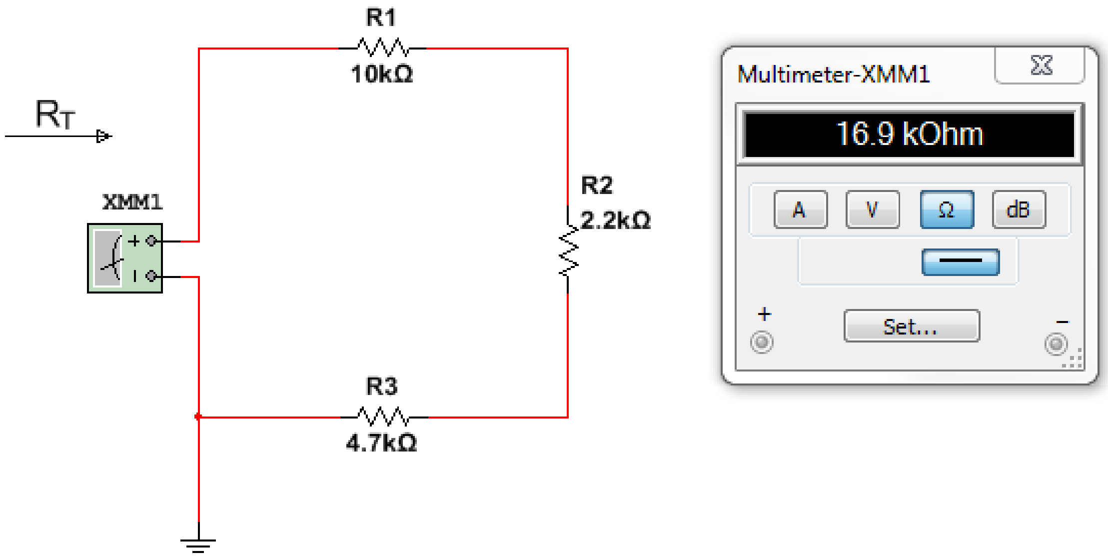


http://www.rmcybernetics.com/science/cybernetics/electronics_volts_amps_watts.htm

Lab 3: Series Resistors Current and Voltage (5)

Multisim – Resistance:

	B	C	D	E	F
10		Unit	Calculated	Measured	Simulated
11	V	V	9.000E+0	9.086E+0	9.000E+0
12	R1	Ω	10.000E+3	9.750E+3	10.000E+3
13	R2	Ω	2.200E+3	2.170E+3	2.200E+3
14	R3	Ω	4.700E+3	4.620E+3	4.700E+3
15	RT	Ω	16.900E+3	16.570E+3	16.900E+3
16	IT	A	532.544E-6	548.340E-6	532.544E-6
17	IT Equation		= D11 / D15	= E11 / E15	= F11 / F15

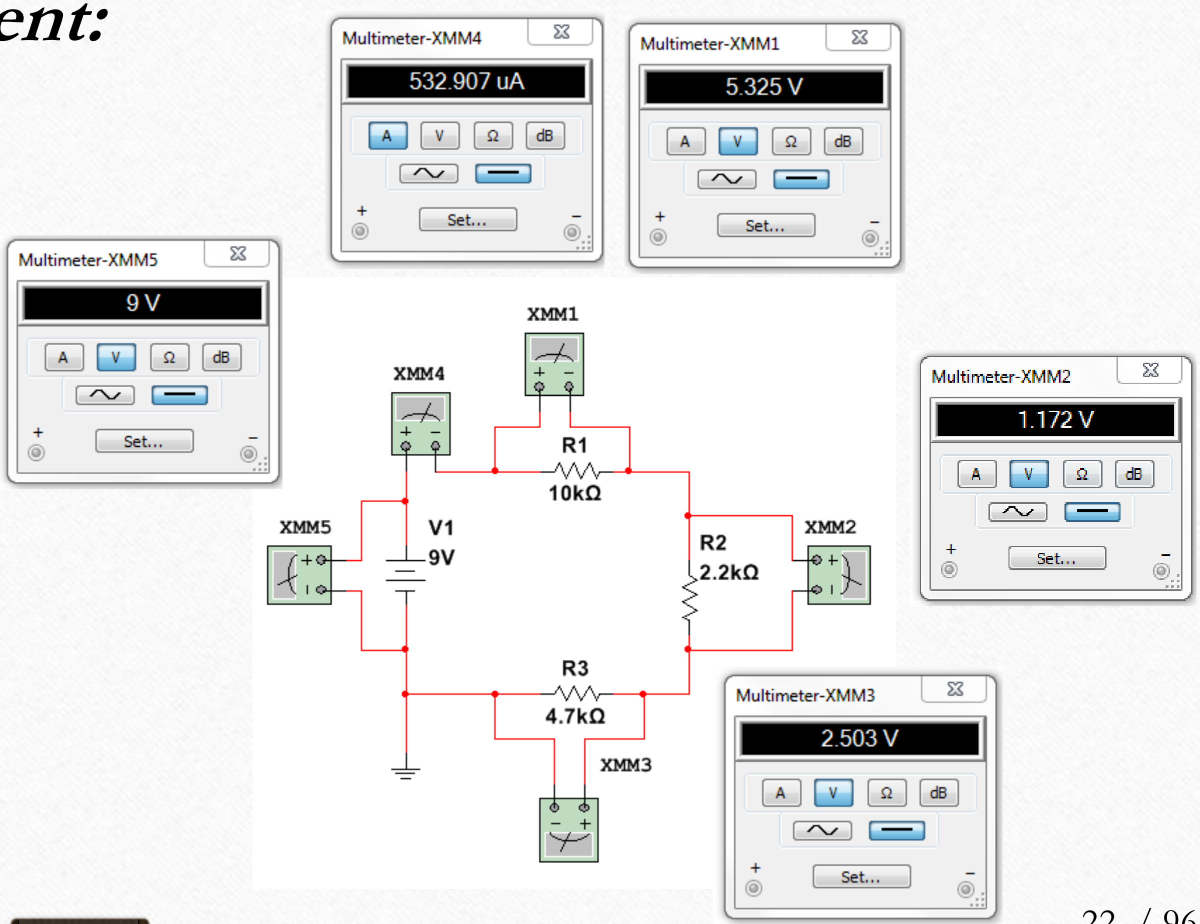


Lab 3: TOTAL RESISTANCE

Lab 3: Series Resistors Current and Voltage (6)

Multisim – Voltage and Current:

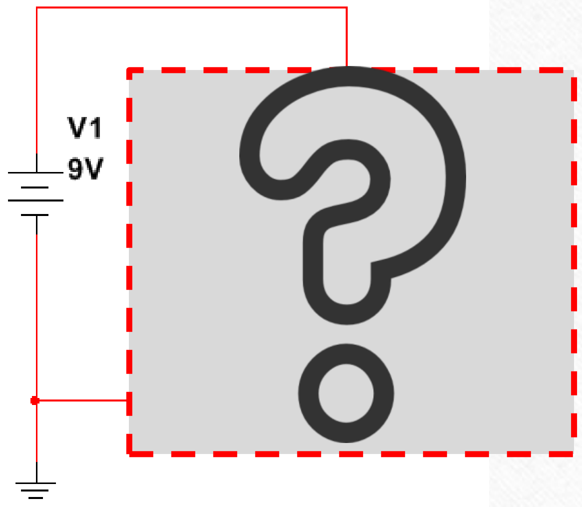
	B	C	D	E	F
18		Unit	Calculated	Measured	Simulated
19	V	V	9.000E+0	9.086E+0	9.000E+0
20	R1	Ω	10.000E+3	9.750E+3	10.000E+3
21	R2	Ω	2.200E+3	2.170E+3	2.200E+3
22	R3	Ω	4.700E+3	4.620E+3	4.700E+3
23	RT	Ω	16.900E+3	16.570E+3	16.900E+3
24	IT	A	532.544E-6	548.340E-6	532.544E-6
25	V1	V	9.000E+0	9.086E+0	9.000E+0
26	VA	V	5.325E+0	3.703E+0	5.325E+0
27	VB	V	1.172E+0	2.520E+0	1.172E+0
28	VC	V	2.503E+0	2.502E+0	2.503E+0
29	VA Equation		= D20 * D24	N/A	N/A
30	VB Equation		= D21 * D24	N/A	N/A
31	VC Equation		= D22 * D24	N/A	N/A



Lab 3: Series Resistors Current and Voltage (7)

Conclusion:

We found that measured values were similar to the expected values.
Also, the results of simulations were similar to the measured values.
We observed that a series circuit has the same current throughout the series.
Total voltage in a series circuit was the sum of the voltage that is lost through each resistor.



Lab 4

Black Box Design, Series Resistors

Lab 4: Black Box Design, Series Resistors (1)

Objective:

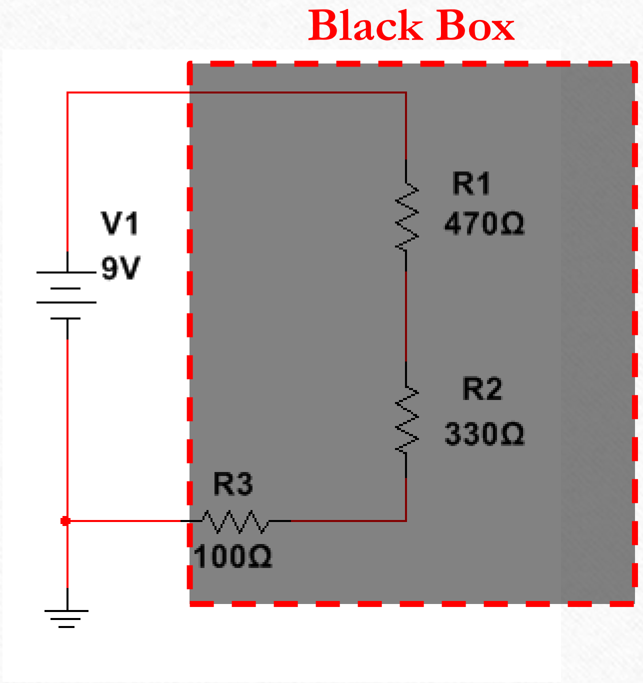
Learn about series circuits.

Equipment/Materials:

	Brand	Model	S/N
Digital Multimeter	GW INSTEK	GDM-8245	CL860260
Elvis II	National Instruments	NI Elvis II+	1677D5B
Resistors	470, 330, and 100 Ω.		
Wires			

Lab 4: Black Box Design, Series Resistors (2)

Schematic:



Lab 4: Black Box Design, Series Resistors (3)

Procedures:

Measure each resistor using Digital Multimeter and set them on the Elvis II in series.

Set three wires to connect source voltage and series resistors.

Apply 9 V to the circuit using Elvis II and determine what combination of three resistors making the current draw is 10 mA.

Lab 4: Black Box Design, Series Resistors (4)

Calculation:

<u>Total Resistance in Series</u>

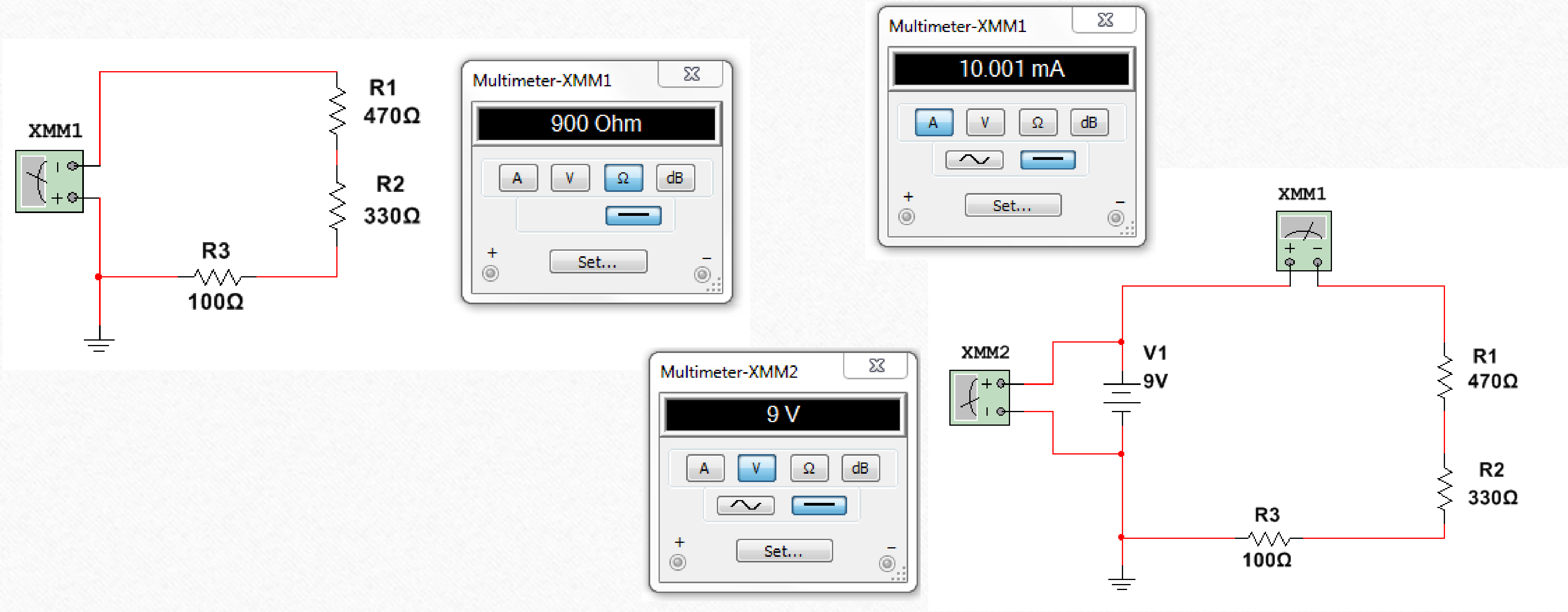
$$R_T = \frac{V_T}{I_T}$$

$$R_T = R_1 + R_2 + R_3$$

	B	C	D	E	F	G	H
7		Unit	Design	Measured	Calculated (Measured)	Simulated	% Error (Design vs. Measured)
8	V1	V	9.000E+0	9.004E+0	8.896E+0	9.000E+0	0.04
9	IT	A	10.000E-3	10.029E-3	10.151E-3	1.001E-3	0.29
10	RT	Ω	900.000E+0	886.990E+0	886.990E+0	900.000E+0	1.45
11	R1	Ω	470.000E+0	464.120E+0	464.120E+0	470.000E+0	1.25
12	R2	Ω	330.000E+0	324.410E+0	324.410E+0	330.000E+0	1.69
13	R3	Ω	100.000E+0	98.460E+0	98.460E+0	100.000E+0	1.54
14	RT Equation		= D8 / D9	N/A	= F11 + F12 + F13	= G11 + G12 + G13	

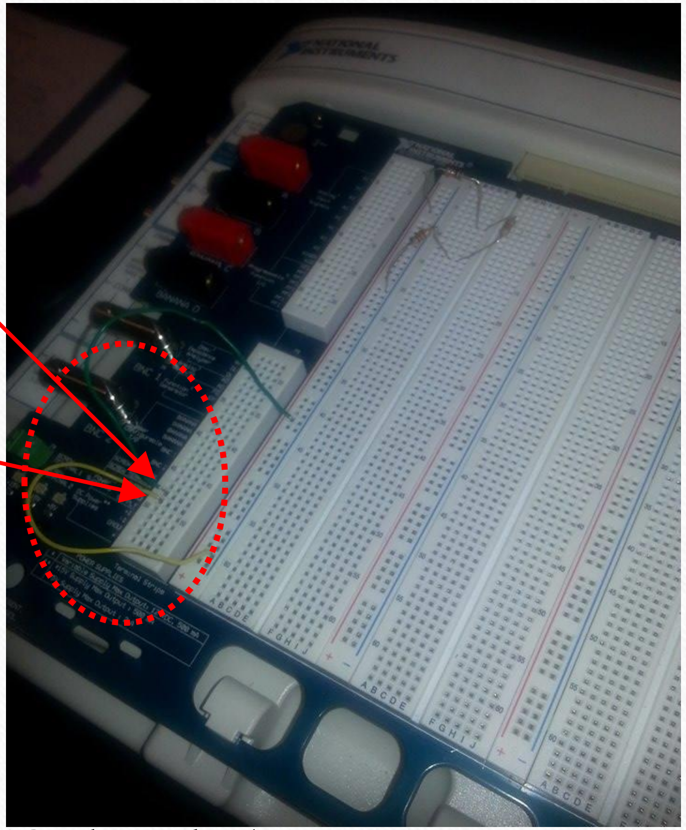
Lab 4: Black Box Design, Series Resistors (5)

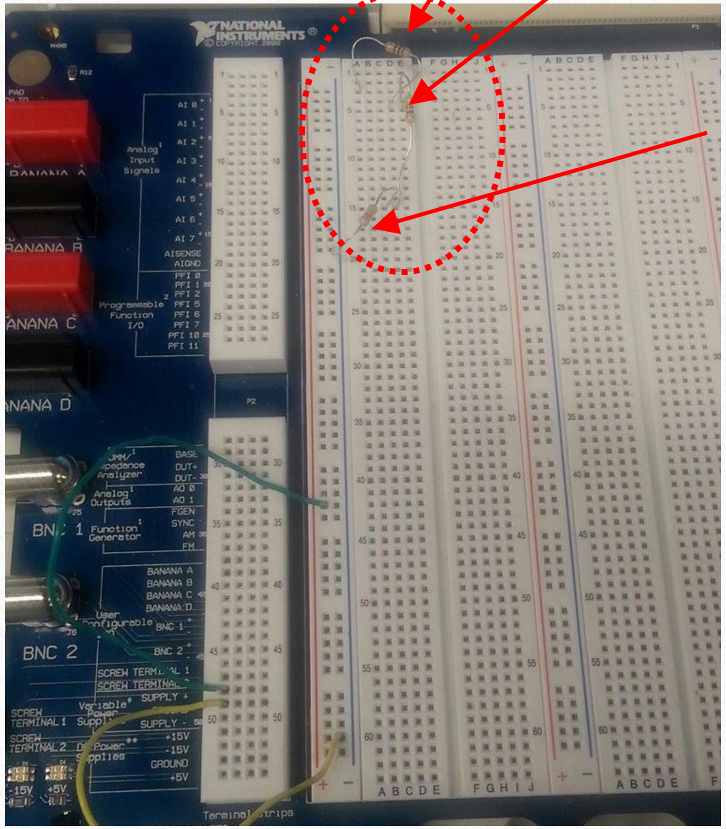
Multisim – Voltage, Resistance, and Current:



Lab 4: Black Box Design, Series Resistors (6)

Settings of Elvis II:





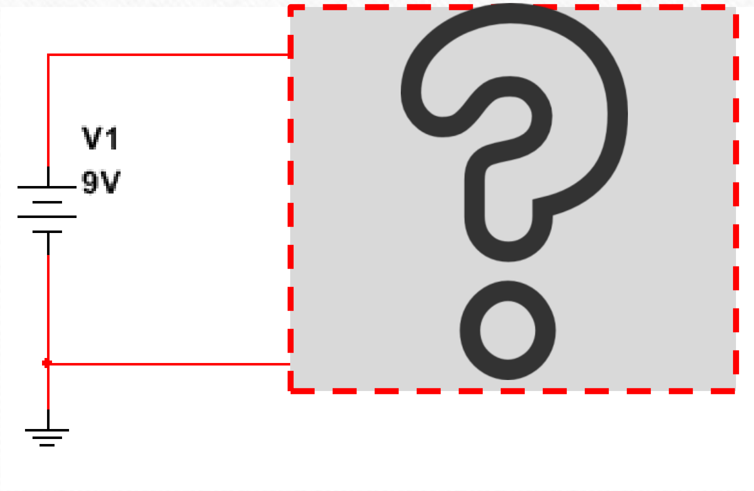
Lab 4: Black Box Design, Series Resistors (7)

Conclusion:

We designed a series circuit using knowledge that a series circuit has same current throughout the series.

Total current was within 5% tolerance and we proved that our design was correct.

Lab 5



Black Box Design, Parallel Resistors

Lab 5: Black Box Design, Parallel Resistors (1)

Objective:

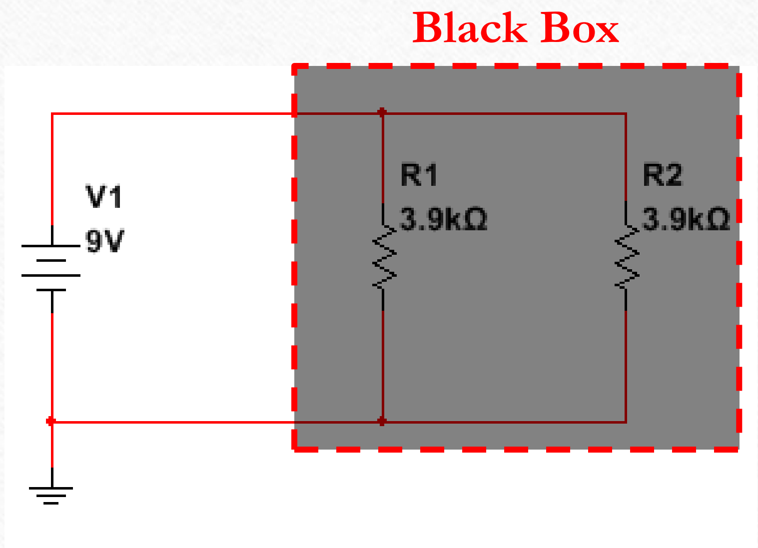
Learn about parallel circuits.

Equipment/Materials:

Brand	Model	S/N	
Digital Multimeter	GW INSTEK	GDM-8245	CL860333
National Instruments	NI Elvis II+	1677D5B (A242480)	
Standard Resistors (Ω)	2 x 3.900E+3		

Lab 5: Black Box Design, Parallel Resistors (2)

Schematic:



Lab 5: Black Box Design, Parallel Resistors (3)

Procedures:

Measure each resistor using Digital Multimeter and set them on the Elvis II in parallel.

Set two wires to connect source voltage and parallel resistors.

Apply 9 V to the circuit using Elvis II and determine what combination of two resistors making the current draw is 4.9 mA.

Lab 5: Black Box Design, Parallel Resistors (4)

Calculation:

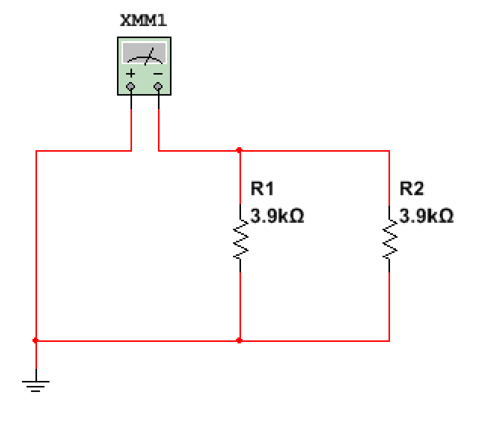
Total Resistance in Parallel (2 Resistors)

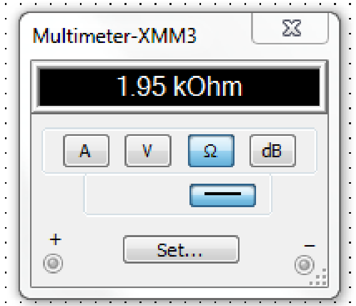
$$R_T = \frac{R_1 \times R_2}{R_1 + R_2} \quad \text{or} \quad R_T = \frac{1}{(\frac{1}{R_1}) + (\frac{1}{R_2})}$$

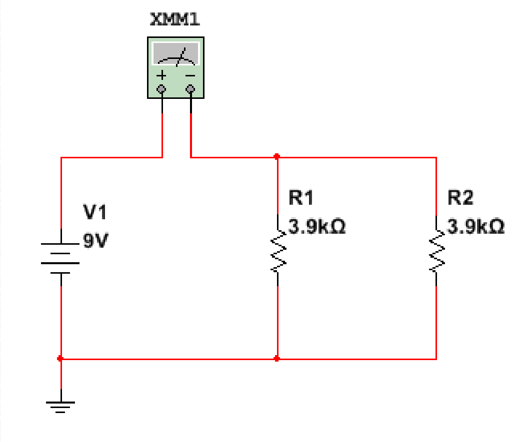
	C	D	E	F	G	H	I	J
10		Unit	Design	Calculated (Design)	Measured	Calculated (Measured)	% Error	Simulated
11	V1	V	9.000E+0	9.052E+0	9.004E+0	8.554E+0	0.04	9.000E+0
12	IT	A	4.642E-3	4.615E-3	4.415E-3	4.647E-3	4.89	4.617E-3
13	**RT**	Ω	1.950E+3	1.950E+3	1.938E+3	1.925E+3	0.64	19.500E+3
14	R1	Ω	3.900E+3	3.833E+3	3.833E+3	3.833E+3	1.72	3.900E+3
15	R2	Ω	3.900E+3	3.869E+3	3.869E+3	3.869E+3	0.79	3.900E+3
16	**RT Equation**		= (E14 * E15) / (E14 + E15)	= (F14 * F15) / (F14 + F15)	N/A	= (H14 * H15) / (H14 + H15)	N/A	N/A

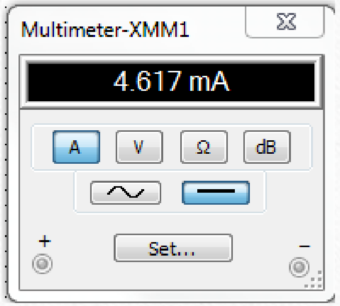
Lab 5: Black Box Design, Parallel Resistors (5)

Multisim – Resistance and Current:





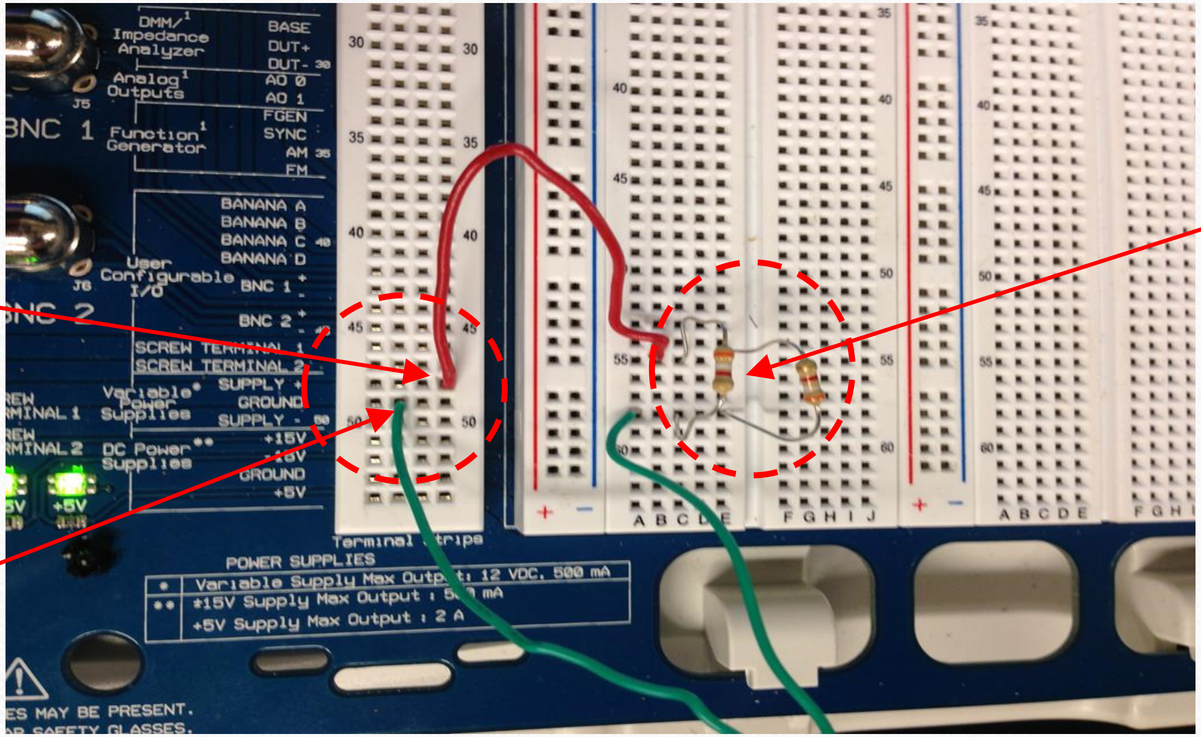




	C	D	E	F	G	H	I	J
10		Unit	Design	Calculated (Design)	Measured	Calculated (Measured)	% Error	Simulated
11	V1	V	9.000E+0	9.052E+0	9.004E+0	8.554E+0	0.04	9.000E+0
12	**IT**	A	4.642E-3	4.615E-3	4.415E-3	4.647E-3	4.89	4.617E-3
13	**RT**	Ω	1.950E+3	1.950E+3	1.938E+3	1.925E+3	0.64	19.500E+3
14	R1	Ω	3.900E+3	3.833E+3	3.833E+3	3.833E+3	1.72	3.900E+3
15	R2	Ω	3.900E+3	3.869E+3	3.869E+3	3.869E+3	0.79	3.900E+3

Lab 5: Black Box Design, Parallel Resistors (6)

Settings of Elvis II:



Source

Ground

Resistor in Parallel

R1 = 3.9k Ω

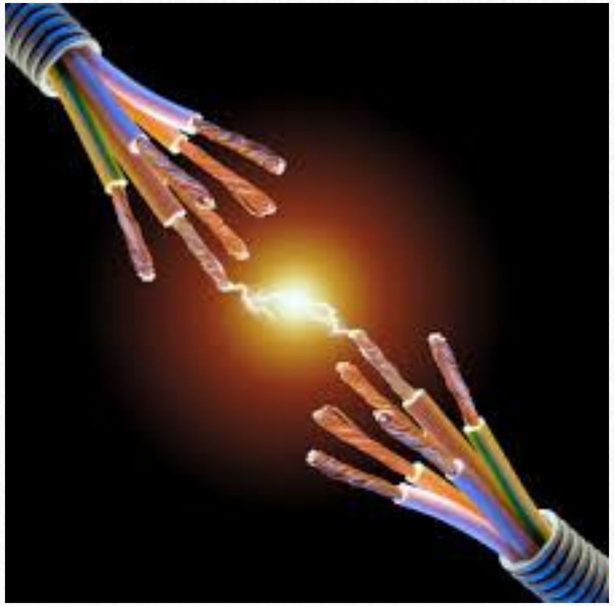
R2 = 3.9k Ω

Lab 5: Black Box Design, Parallel Resistors (7)

Conclusion:

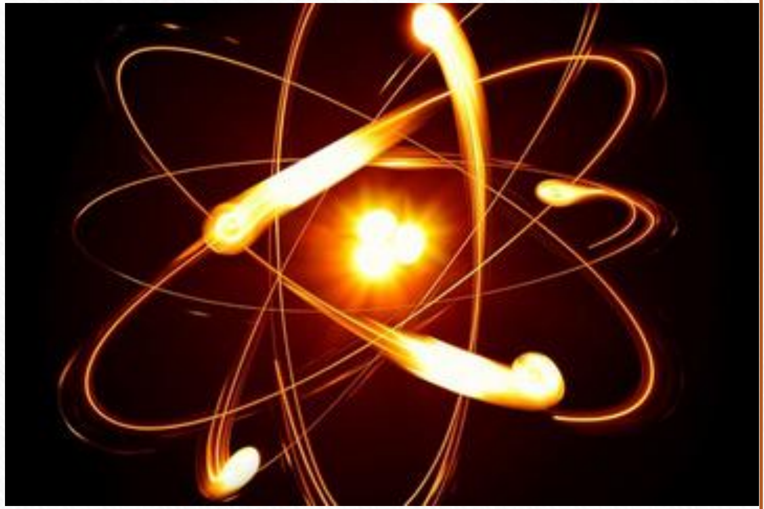
We designed a parallel circuit using a knowledge that a parallel circuit has the same voltage, and different current depending on the resistor through the parallel route.

Total current was within 5% tolerance and we proved that our design was correct.



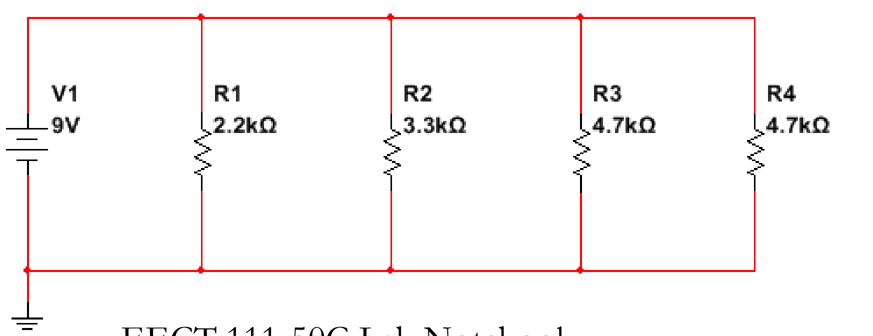
Lab 6

N/A



Lab 7

Resistor Parallel Circuit



Lab 7: Resistor Parallel Circuit (1)

Objective:

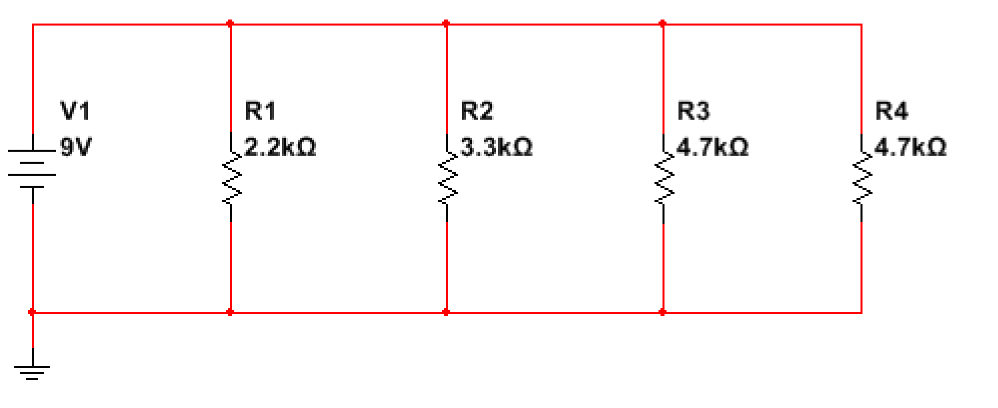
Learn about parallel circuits.

Equipment/Materials:

Brand	Model	S/N	
Digital Multimeter	GW INSTEK	GDM-8245	CL860333
National Instruments	NI Elvis II+	1677D5B (A242480)	
Standard Resistors (Ω)	2.2k	3.3k	2 x 4.7k

Lab 7: Resistor Parallel Circuit (2)

Schematic:



Lab 7: Resistor Parallel Circuit (3)

Procedures:

Measure each resistor using Digital Multimeter and set them on the Elvis II in parallel.

Set four wires to connect source voltage and parallel resistors.

Apply 9 V to the circuit using Elvis II and measure total current and current through each of the branches.

Lab 7: Resistor Parallel Circuit (4)

Calculation:

Total Resistance in Parallel (Any Number of Resistors)

$$R_T = \frac{1}{(\frac{1}{R_1}) + (\frac{1}{R_2}) + (\frac{1}{R_3}) + (\frac{1}{R_4})}$$

Total Current

$$I_T = \frac{V_T}{R_T}$$

Current through Each Resistor

$$I_n = \frac{V_n}{R_n}$$

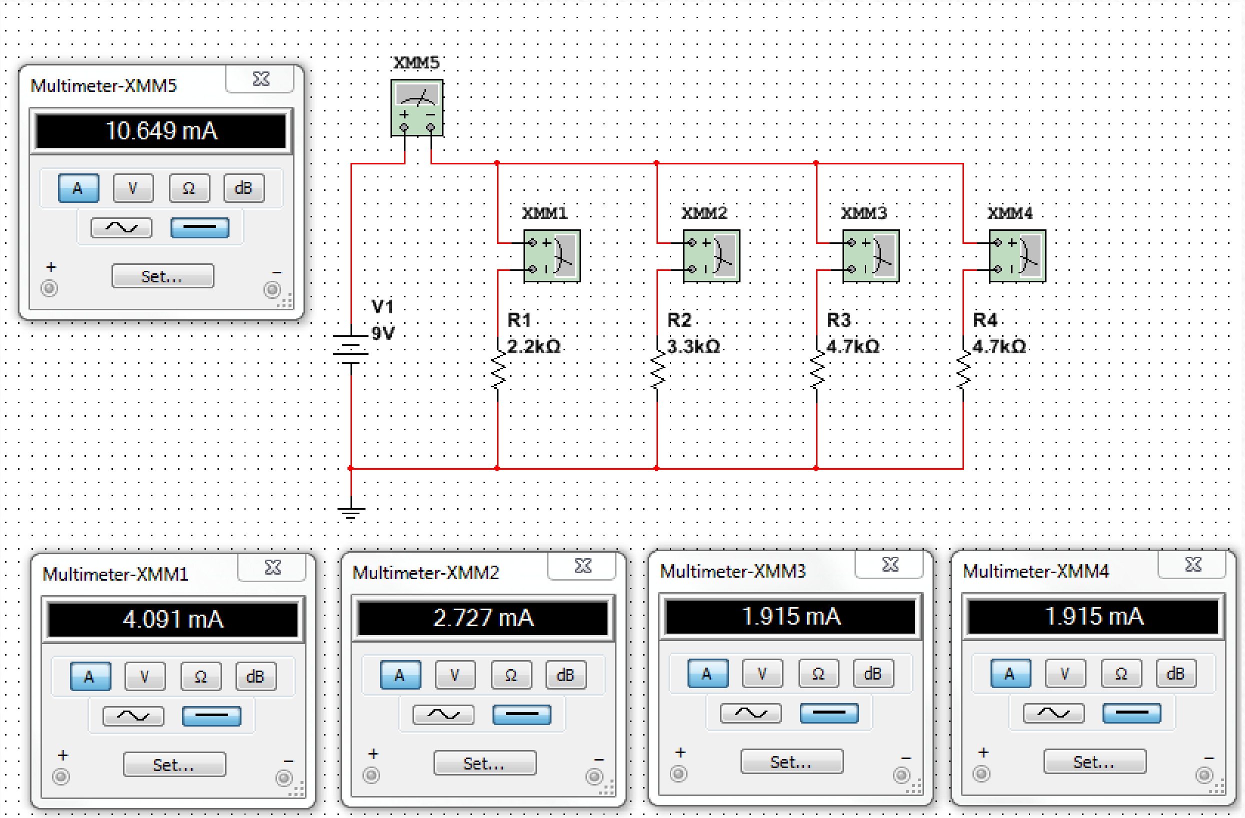
Lab 7: Resistor Parallel Circuit (5)

Calculation:

	C	D	E	F	G	H	I	J
9		Unit	Design	Calculated (Design)	Measured	Calculated (Measured)	% Error	Simulated
10	V1	V	9.000E+0	9.000E+0	9.003E+0	9.138E+0	0.03	9.000E+0
11	**IT**	A	10.648E-3	10.648E-3	10.665E-3	10.812E-3	0.16	10.649E-3
12	I1	A	4.091E-3	4.091E-3	3.986E-3	4.176E-3	2.56	4.091E-3
13	I2	A	2.727E-3	2.727E-3	2.691E-3	2.778E-3	1.33	2.727E-3
14	I3	A	1.915E-3	1.915E-3	1.864E-3	1.907E-3	2.66	1.915E-3
15	I4	A	1.915E-3	1.915E-3	1.917E-3	1.962E-3	0.11	1.195E-3
16	**RT**	Ω	845.232E+0	845.232E+0	832.700E+0	845.232E+0	1.48	844.859E+0
17	R1	Ω	2.200E+3	2.200E+3	2.156E+3	2.200E+3	2.00	2.200E+3
18	R2	Ω	3.300E+3	3.300E+3	3.241E+3	3.300E+3	1.79	3.300E+3
19	R3	Ω	4.700E+3	4.700E+3	4.722E+3	4.700E+3	0.47	4.700E+3
20	R4	Ω	4.700E+3	4.700E+3	4.589E+3	4.700E+3	2.36	4.700E+3
21	**IT Equation**		= E10 / E16	= E10 / E16	N/A	= E10 / E16	N/A	N/A
22	**RT Equation**		= (1 / ((1/E17) + (1/E18) + (1/E19) + (1/E20)))	= (1 / ((1/F17) + (1/F18) + (1/F19) + (1/F20)))	N/A	= (1 / ((1/H17) + (1/H18) + (1/H19) + (1/H20)))	N/A	N/A

Lab 7: Resistor Parallel Circuit (6)

Multisim – Current:

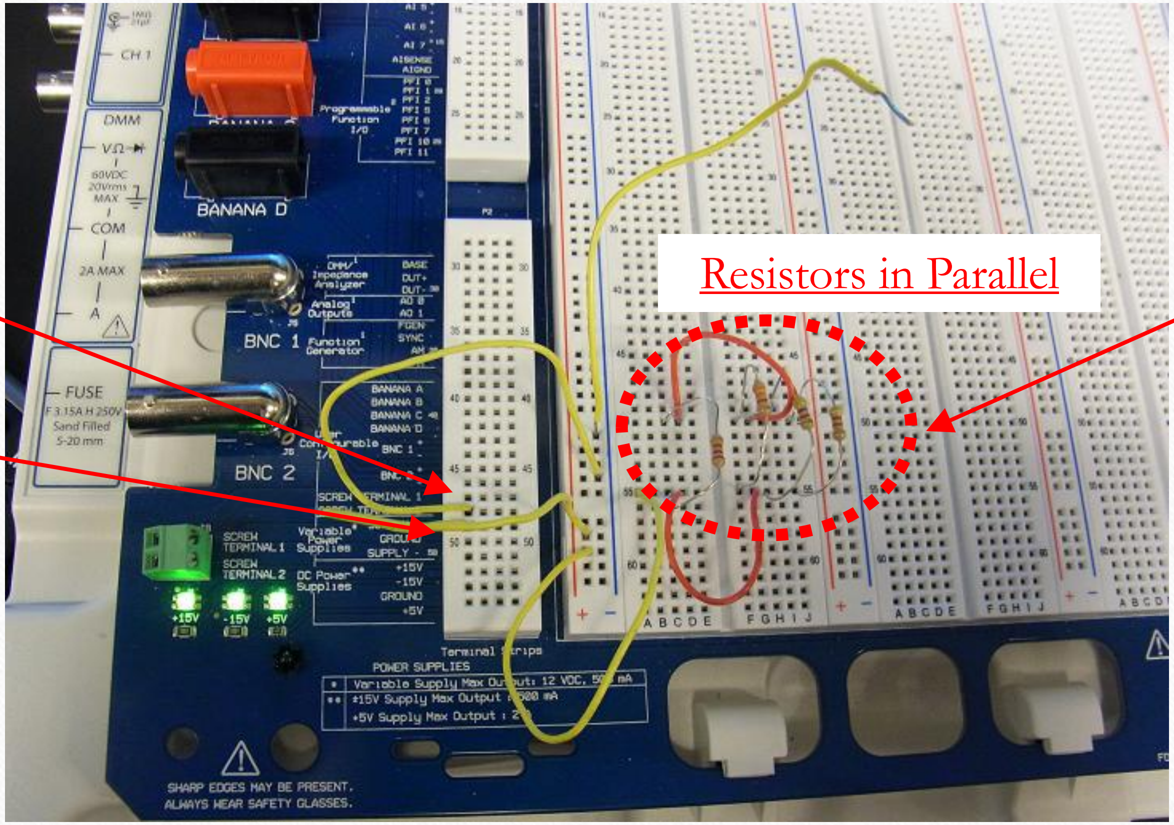


Lab 7: Resistor Parallel Circuit (7)

Settings of Elvis II:

Source

Ground



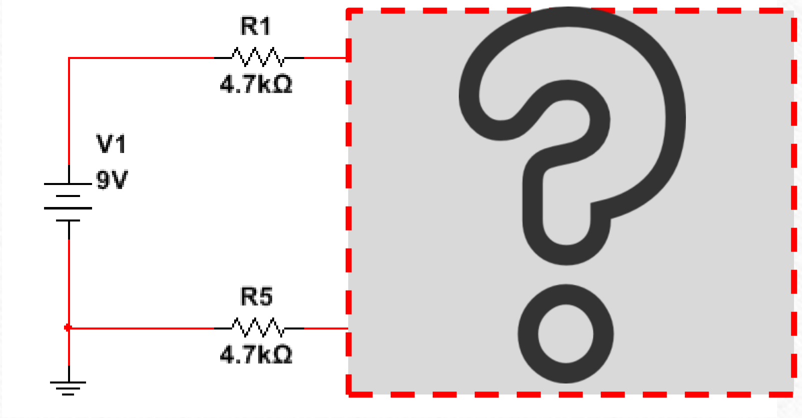
From the left
R1 = 2.2k Ω
R2 = 3.3k Ω
R3 = 4.7k Ω
R4 = 4.7k Ω

Lab 7: Resistor Parallel Circuit (8)

Conclusion:

We observed that the higher the resistance in parallel path, the lower the current, and total current was equivalent to the sum of the current through all parallel paths.

Current and voltage were within 5% tolerance.



Lab 8

Black Box Design, Equal Value Resistors

Lab 8: Black Box Design, Equal Value Resistors (1)

Objective:

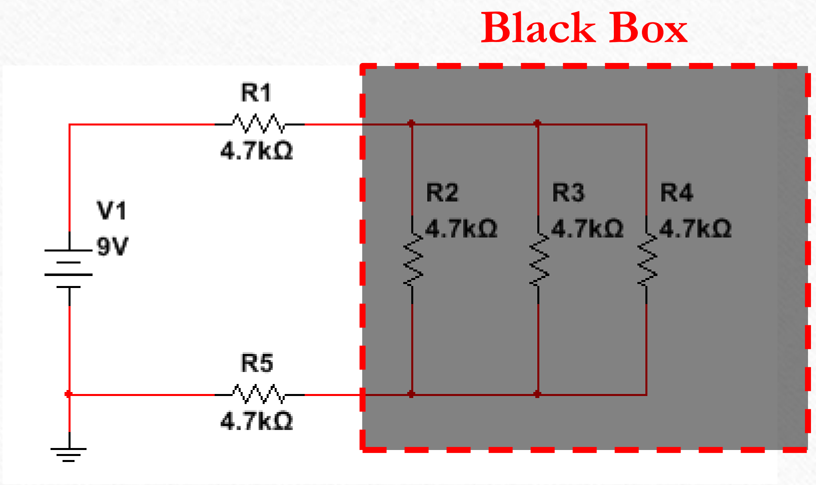
Learn about building a circuit that produces exactly 1.3V.

Equipment/Materials:

Brand	Model	S/N
Digital Multimeter	GW INSTEK	GDM-8245
Elvis II	National Instruments	1677D5B (A242480)
10k Ω pot		
Standard resistor	5 X 4700Ω	

Lab 8: Black Box Design, Equal Value Resistors (2)

Schematic:



Lab 8: Black Box Design, Equal Value Resistors (3)

Procedures:

Measure each resistor using Digital Multimeter.

Determine three equal resistors, R_2, R_3, and R_4, that are parallel or series with the two 4.7k Ω resistors, R_1 and R_5, in series in order to design a circuit that V_{234} would be 1.286 V.

Apply 9 V to the circuit using Elvis II and measure loss of voltage in V_{234}.

Then, replace R_1 to a 10k Ω pot and adjust it so that the output voltage is exactly 1.3 V using 10k Ω pot.

Lab 8: Black Box Design, Equal Value Resistors (4)

Calculation:

Total Current

$$I_{234} = I_1 = I_5 = I_T = \frac{V_T}{R_T}$$

Since R_1 is in series.

Total Resistance R2, R3, and R4 in Parallel

$$R_{234} = \frac{1}{(\frac{1}{R_2})+(\frac{1}{R_3})+(\frac{1}{R_4})} = \frac{1}{(\frac{1}{R_2})+(\frac{1}{R_2})+(\frac{1}{R_2})} = \frac{R_2}{3}$$

Since R_2, R_3, and R_4 are equal value.

$$R_{234} = \frac{V_{234}}{I_T}$$

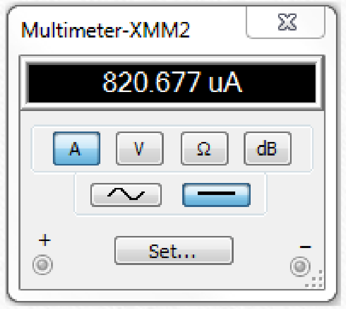
Lab 8: Black Box Design, Equal Value Resistors (5)

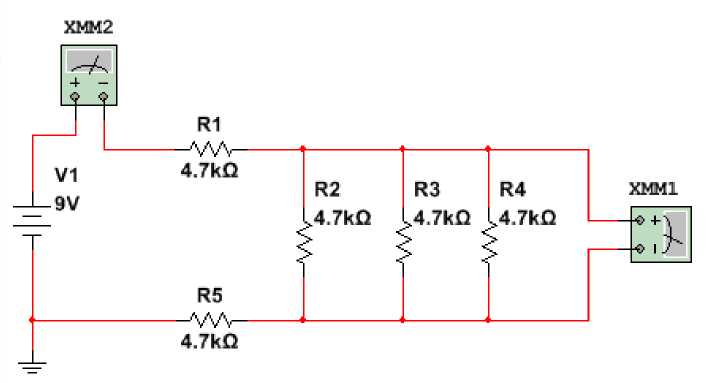
Calculation:

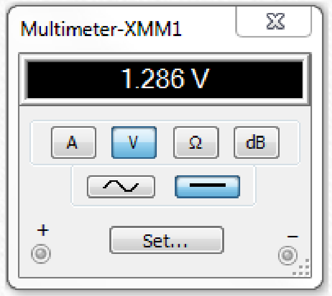
	Unit	Design	Calculated (Design)	Measured	Measured (Adjusted)	% Error	Simulated
V1	V	9.000E+0	9.000E+0	9.020E+0	9.020E+0	0.22	9.000E+0
VA	V	5.143E+0	5.143E+0	5.149E+0	5.149E+0	0.12	5.143E+0
VB	V	3.857E+0	3.857E+0	3.858E+0	3.858E+0	0.02	3.857E+0
VA-VB	V	1.286E+0	1.286E+0	1.291E+0	1.291E+0	0.41	1.286E+0
(VA-VB)adj	A	1.300E+0	1.300E+0	N/A	1.301E+0	N/A	1.300E+0
IT	A	820.669E-6	820.669E-6	1.530E-3	N/A	N/A	820.677E-6
R1	Ω	4.700E+3	4.700E+3	4.604E+3	N/A	2.04	4.700E+3
R2	Ω	4.700E+3	4.700E+3	4.690E+3	4.690E+3	0.21	4.700E+3
R3	Ω	4.700E+3	4.700E+3	4.608E+3	4.608E+3	1.96	4.700E+3
R4	Ω	4.700E+3	4.700E+3	4.579E+3	4.579E+3	2.57	4.700E+3
R5	Ω	4.700E+3	4.700E+3	4.604E+3	4.604E+3	2.04	4.700E+3
R234	Ω	1.567E+3	1.567E+3	1.545E+3	1.545E+3	1.38	1.567E+3
RT	Ω	10.967E+3	10.967E+3	N/A	N/A	N/A	10.967E+3
R1adj	Ω	N/A	N/A	N/A	4.520E+3	N/A	4.580E+3

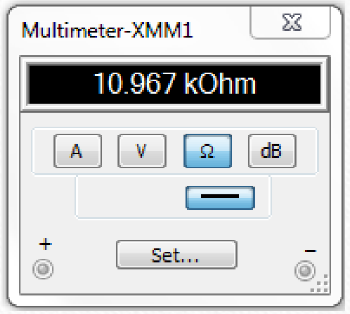
Lab 8: Black Box Design, Equal Value Resistors (6)

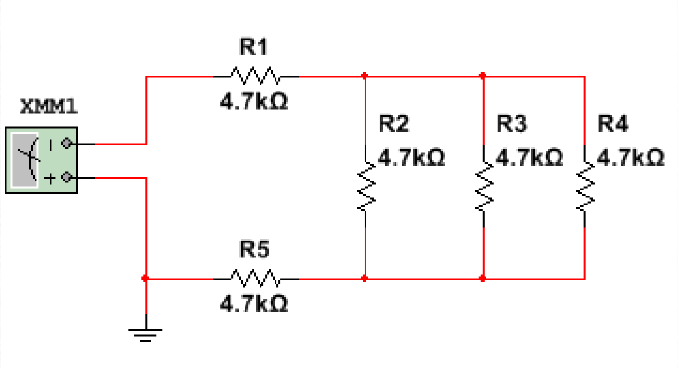
Multisim – Current, Voltage, and Resistance:

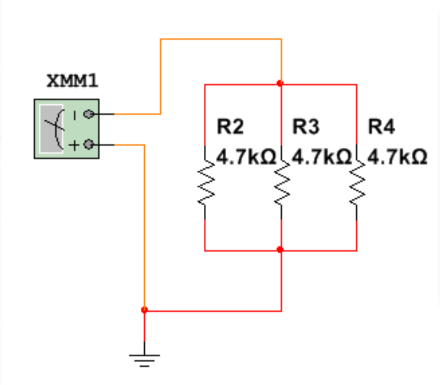


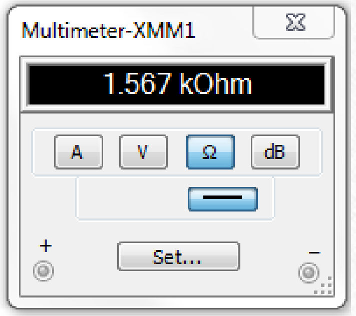






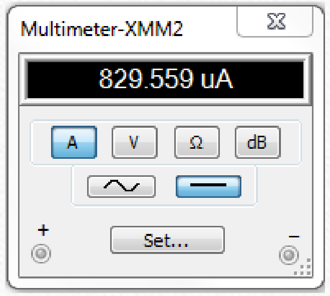


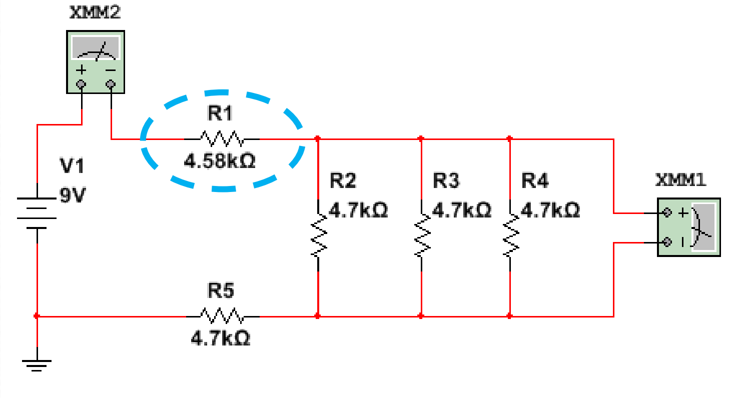


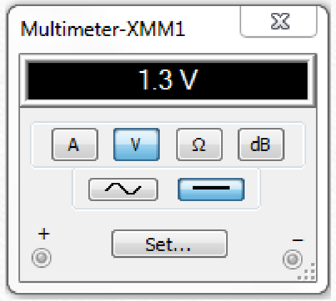


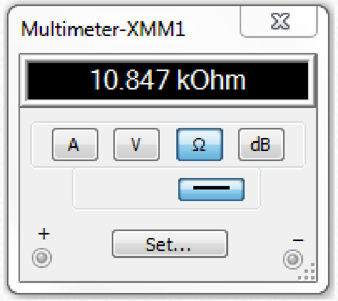
Lab 8: Black Box Design, Equal Value Resistors (7)

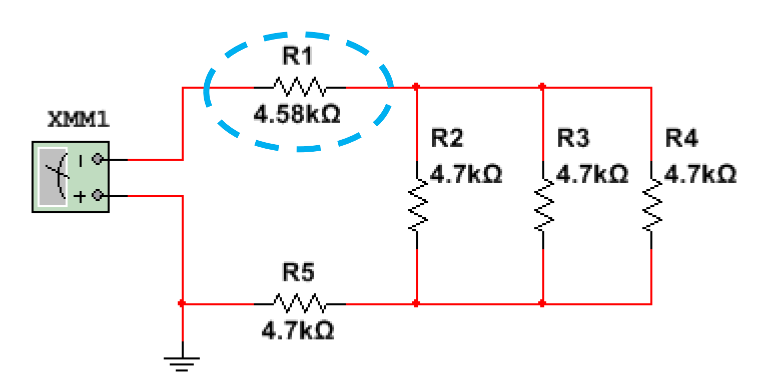
Multisim – Current, Voltage, and Resistance (Adjusted):









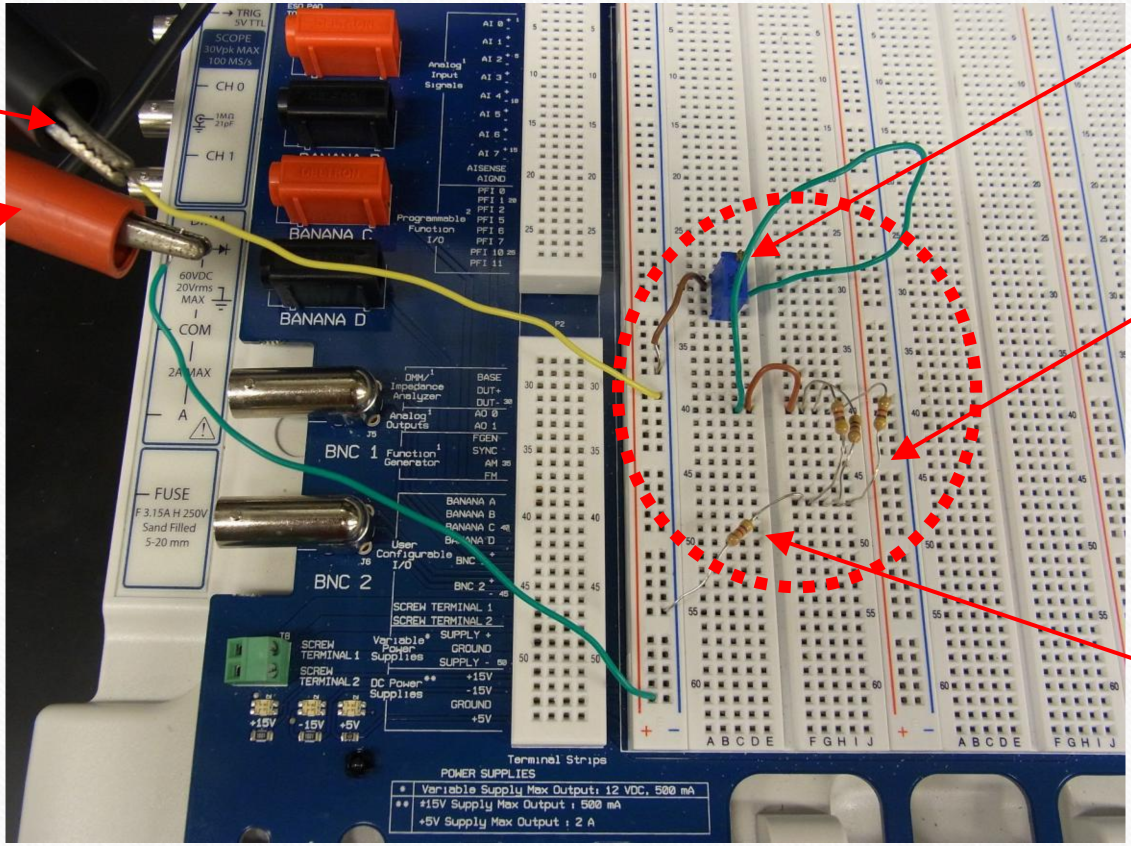


Lab 8: Black Box Design, Equal Value Resistors (8)

Settings of Elvis II:

Source

Ground



10k Ω adjuster pot

Resistors in Parallel

R2 = 4.7k Ω

R3 = 4.7k Ω

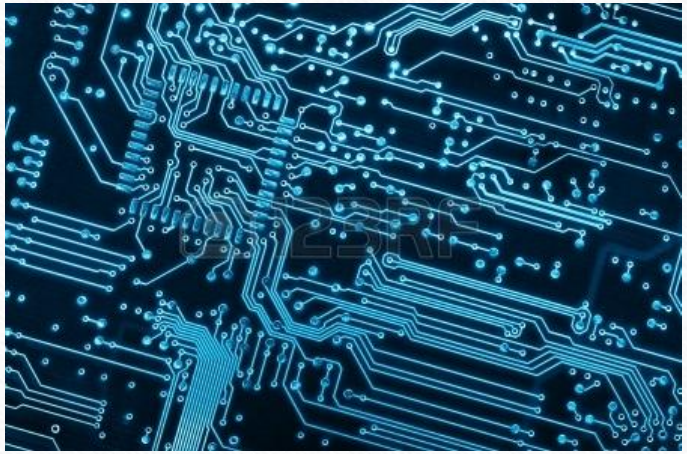
R4 = 4.7k Ω

R5 = 4.7k Ω

Lab 8: Black Box Design, Equal Value Resistors (9)

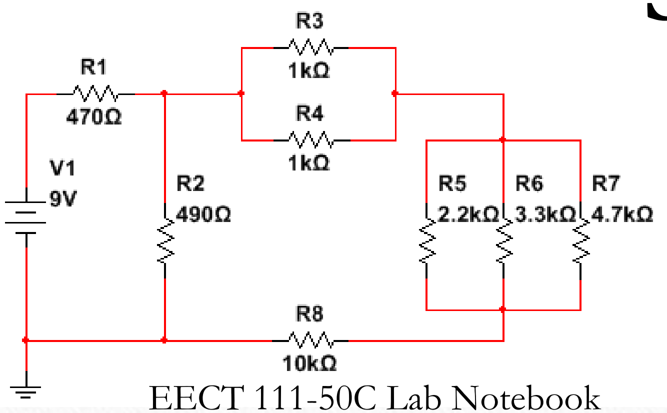
Conclusion:

The resistors in the black box could be derived by the calculation using Ohm’s law. The calculated value and measured value in the black box were very similar. This means that we proved Ohm’s law to be true.



Lab 9

Series/Parallel Resistors



Lab 9: Series/Parallel Resistors (1)

Objective:

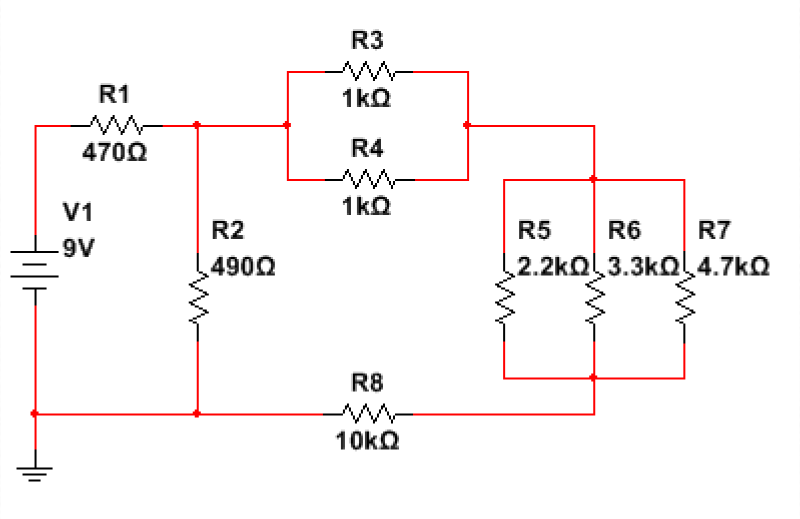
Experiment with series/parallel circuits and verify that the simulation, analysis (calculations) and test results all agree.

Equipment/Materials:

Brand	Model	S/N
Digital Multimeter	GW INSTEK	GDM-8245 CL860333
RSR	HY1802D (60Hz, 110V/2A)	22510028
Standard Resister	2-470, 2-1K, 2.2K, 3.3K, 4.7K, 10K Ω	
Breadboard		
Wires		
10k Ω pot		

Lab 9: Series/Parallel Resistors (2)

Schematic:



Lab 9: Series/Parallel Resistors (3)

Procedures:

Build series and parallel circuit as specified and measure the total resistance. Then connect the resistors to the 9 V source. Then measure and record the current and voltages of the circuit.

Adjust R2 so that the VA voltage is equal to 4.5 V. Then measure the value of the new R2 and calculate and simulate a value that would produce 4.5 V.

Lab 9: Series/Parallel Resistors (4)

Calculation:

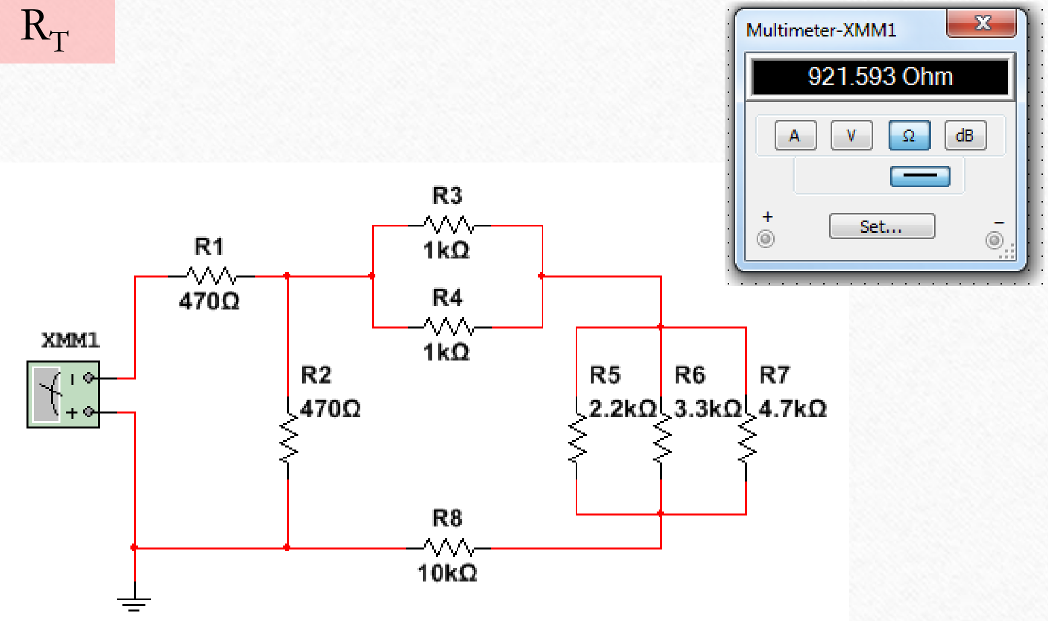
IT	A	= D12 / D19
I2	A	= D13 / D21
I345678	A	= E13 / D30
RT	Ω	= D20 + D31
R34	Ω	= 1 / ((1/D22) + (1/D23))
R567	Ω	= 1 / ((1/D24) + (1/D25) + (1/D26))
R345678	Ω	= D28 + D29 + D27
R2345678	Ω	= 1 / ((1/D30) + (1/D21))

	B	C	D	E	F	H	I
11		Unit	Design	Calculated (Design)	Measured	% Error	Simulated
12	VT	V	9.000E+0	9.000E+0	9.026E+0	0.29	9.000E+0
13	VA	V	4.410E+0	4.410E+0	4.434E+0	0.54	4.410E+0
14	VB	V	4.219E+0	4.219E+0	4.241E+0	0.52	4.219E+0
15	VC	V	3.825E+0	3.825E+0	3.843E+0	0.48	3.825E+0
16	IT	A	9.766E-3	9.766E-3	9.964E-3	2.03	9.766E-3
17	I2	A	9.383E-3	9.383E-3	N/A	N/A	N/A
18	I345678	A	382.472E-6	382.472E-6	N/A	N/A	N/A
19	**RT**	Ω	921.593E+0	921.593E+0	905.900E+0	1.70	921.593E+0
20	R1	Ω	470.000E+0	470.000E+0	460.650E+0	1.99	470.000E+0
21	R2	Ω	470.000E+0	470.000E+0	463.240E+0	1.44	470.000E+0
22	R3	Ω	1.000E+3	1.000E+3	979.000E+0	2.10	1.000E+3
23	R4	Ω	1.000E+3	1.000E+3	977.000E+0	2.30	1.000E+3
24	R5	Ω	2.200E+3	2.200E+3	2.156E+3	2.00	2.200E+3
25	R6	Ω	3.300E+3	3.300E+3	3.245E+3	1.67	3.300E+3
26	R7	Ω	4.700E+3	4.700E+3	4.631E+3	1.47	4.700E+3
27	R8	Ω	10.000E+3	10.000E+3	9.780E+3	2.20	10.000E+3
28	R34	Ω	500.000E+0	500.000E+0	488.800E+0	2.24	500.000E+0
29	R567	Ω	1.031E+3	1.031E+3	1.012E+3	1.77	1.031E+3
30	R345678	Ω	11.531E+3	11.531E+3	11.278E+3	2.19	11.531E+3
31	R2345678	Ω	451.593E+0	451.593E+0	444.840E+0	1.50	451.593E+0

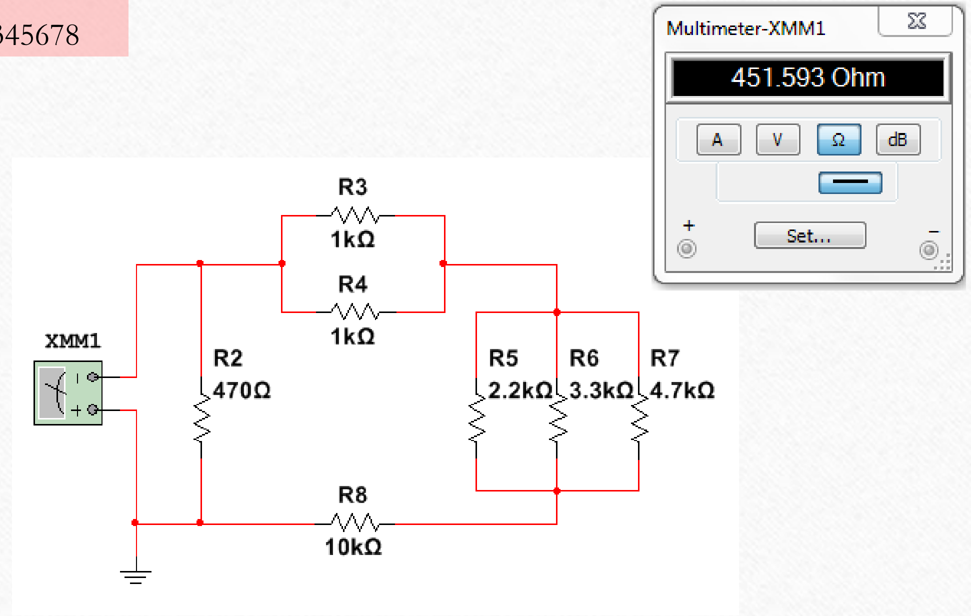
Lab 9: Series/Parallel Resistors (5)

Multisim – Resistance:

R_T



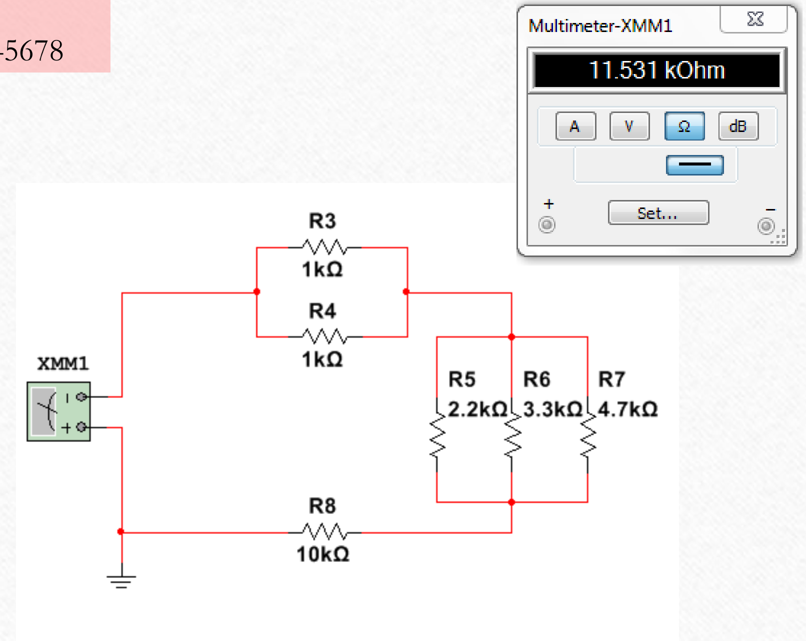
$R_{2345678}$



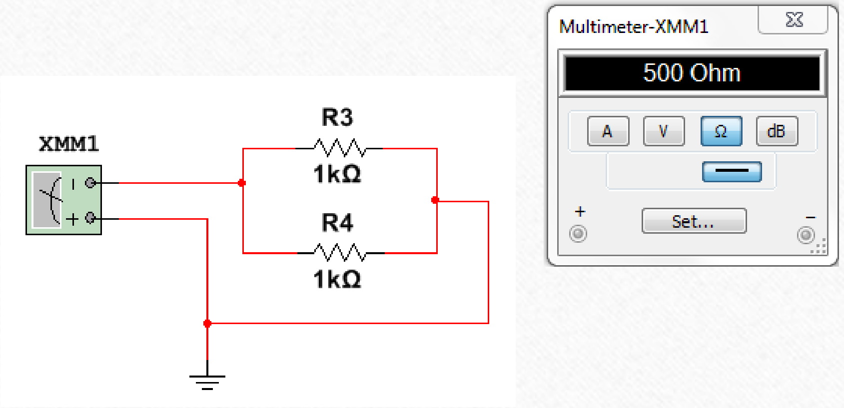
Lab 9: Series/Parallel Resistors (6)

Multisim – Resistance:

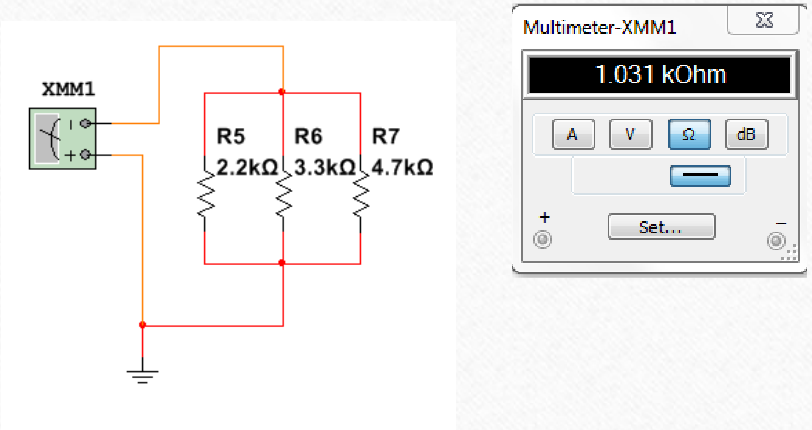
R_{345678}



R_{34}



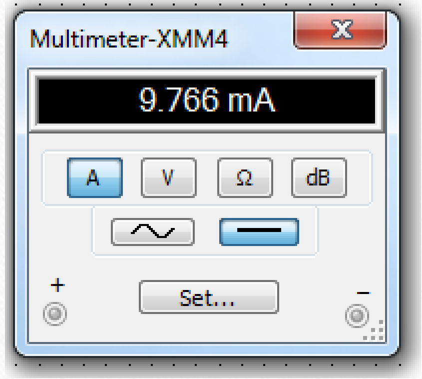
R_{567}

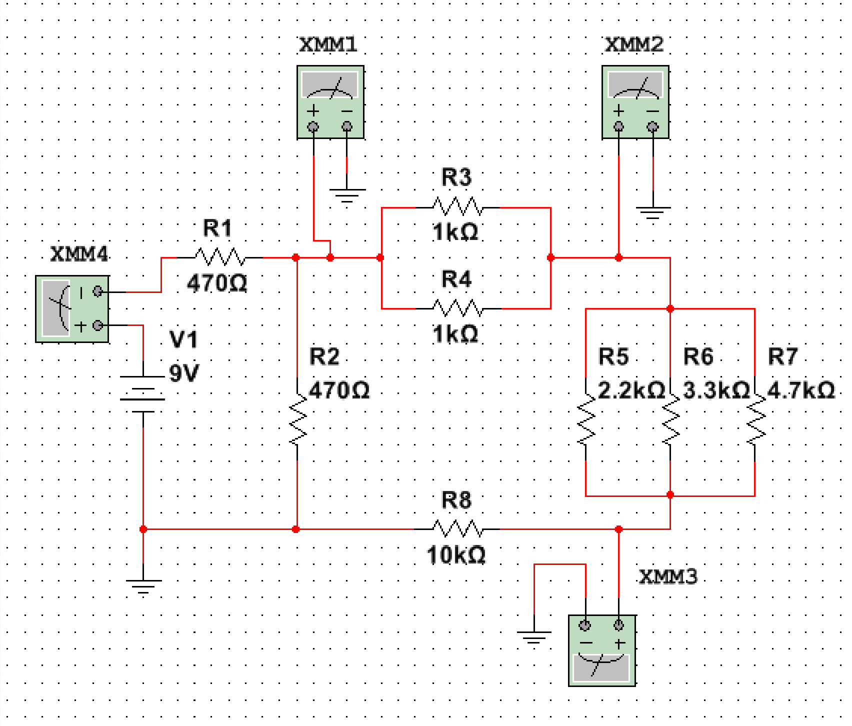


Lab 9: Series/Parallel Resistors (7)

Multisim – Current:

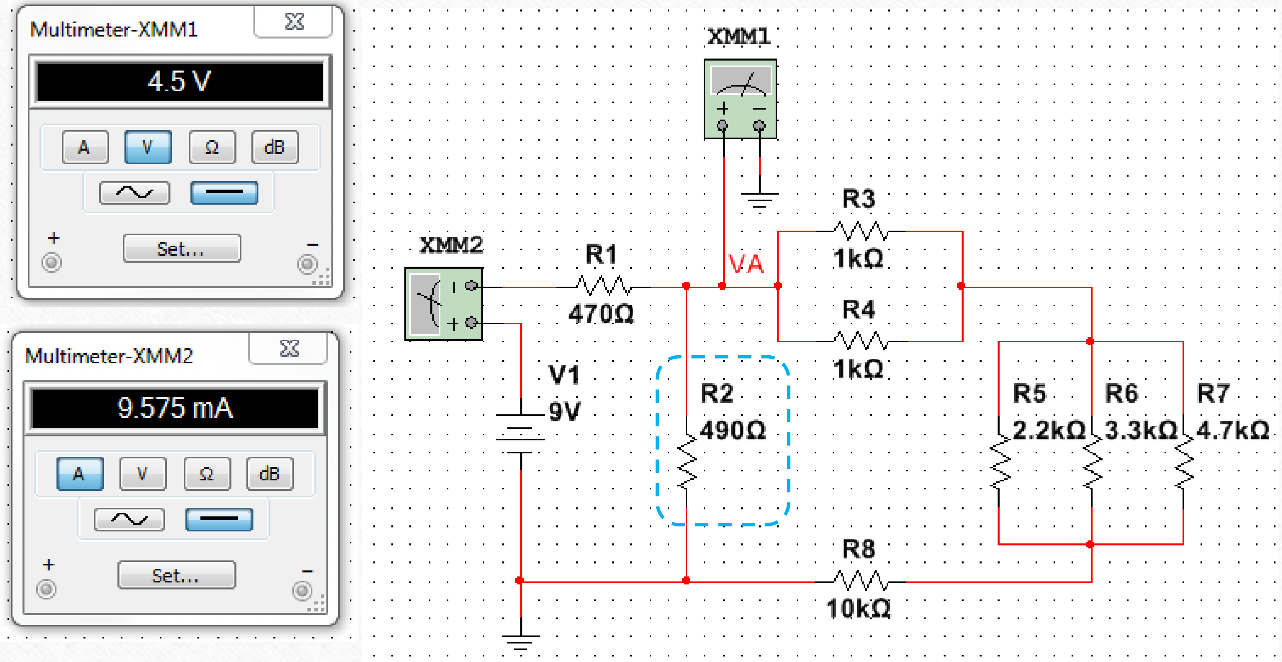
I_T





Lab 9: Series/Parallel Resistors (8)
Adjust R2 to get 4.5V at VA

Multisim – Current and Voltage:



	Unit	Calculated	Measured	Simulated	% Error
VA	V	4.500E+0	4.501E+0	4.500E+0	0.02
R2	Ω	**490.210E+0**	477.200E+0	490.000E+0	2.65

Calculation for adjusted R2 to get 4.5 V at VA

V_A = 4.5 V

V_T – 4.5 V = V_2 → 9 - 4.5 = 4.5 V

I_T = I_1 = V_1/R_1 = 4.5V / 470Ω = 9.574 mA

R_{345678} = 11530 Ω

I_{345678} = V_A / R345678 = 4.5V / 11530 Ω

= 3.9 * 10^{-4} A

I_2 = I_T - I_{345678} = 0.009179 A

R_2 = V_2 / I_2 = 4.5V / 0.009179 A = **490.21 Ω**

Lab 9: Series/Parallel Resisters (9)

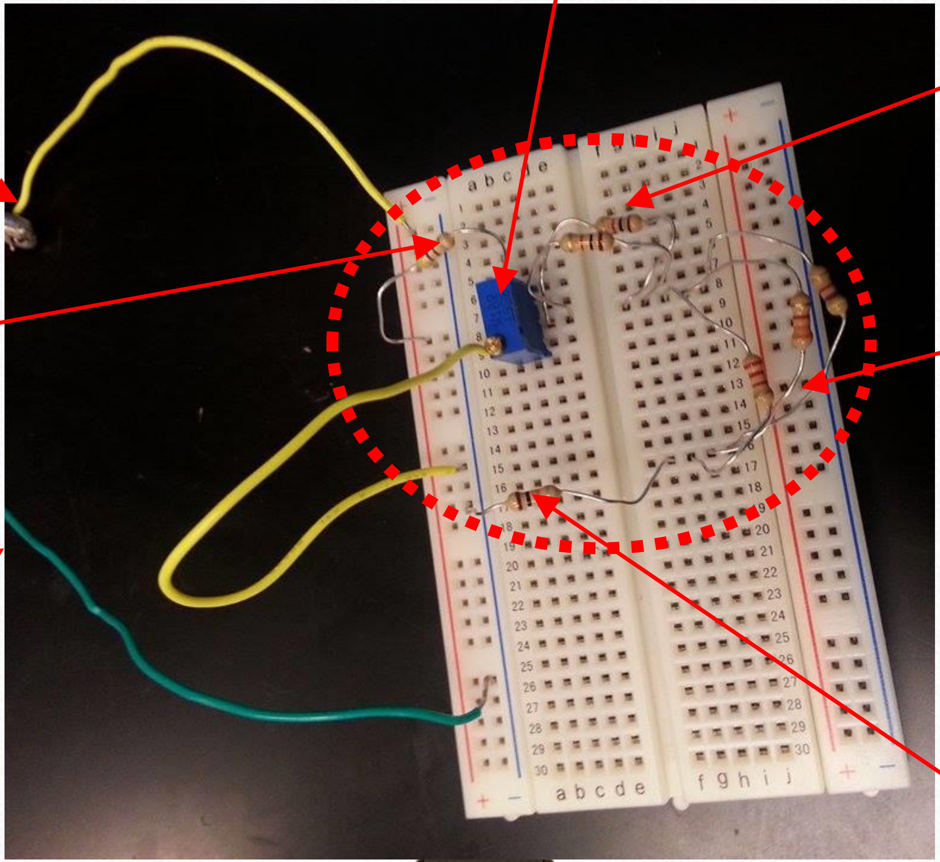
Settings of Breadboard:

Source

R1 = 470 Ω

Ground

10k Ω adjuster pot



Resistors in Parallel

R3 = 1k Ω
R4 = 1k Ω

Resistors in Parallel

R5 = 2.2k Ω
R6 = 3.3k Ω
R7 = 4.7k Ω

R8 = 10k Ω

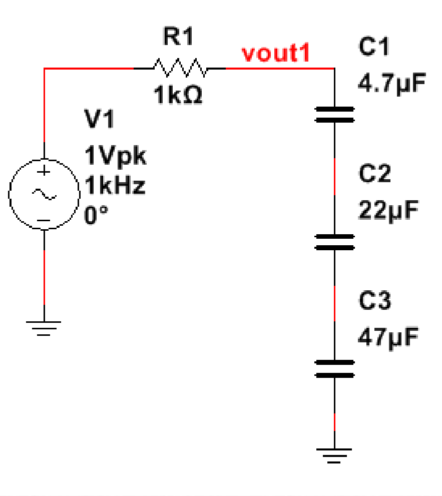
Lab 9: Series/Parallel Resisters (10)

Conclusion:

Measured resistance value was within 5% deviation compared to the designed value.

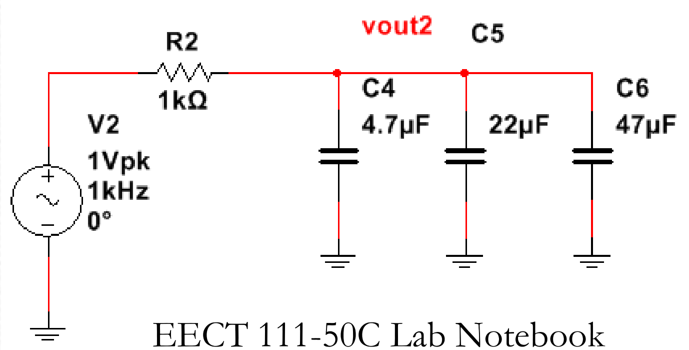
When voltage as VA changed, the total resistance changed. This means that total current also changes.

We observed those changes through this experiment and our percentage error of calculated value and measured data was 2.65%.



Lab 10

Series/Parallel Capacitors



Lab 10: Series/Parallel Capacitors (1)

Objective:

Experiment with series/parallel circuits and combination of capacitors.

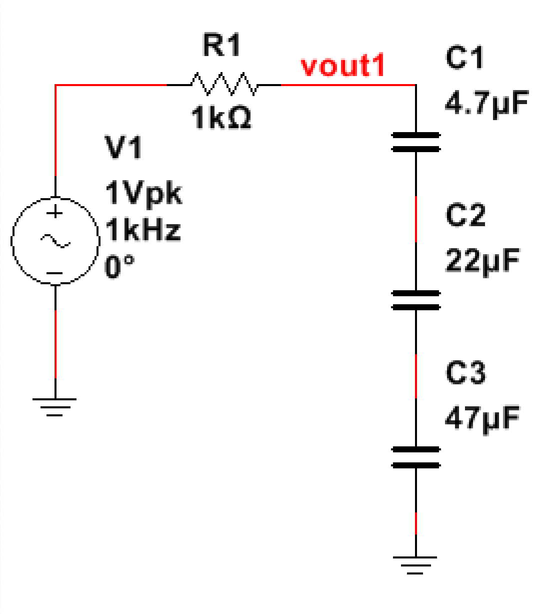
Equipment/Materials:

Brand	Model	S/N
LCR Meter	INSTEC LRC Meter	E121001
Capacitors	4.7µF, 22µF, 47µF	
Bread Board	Table 4	

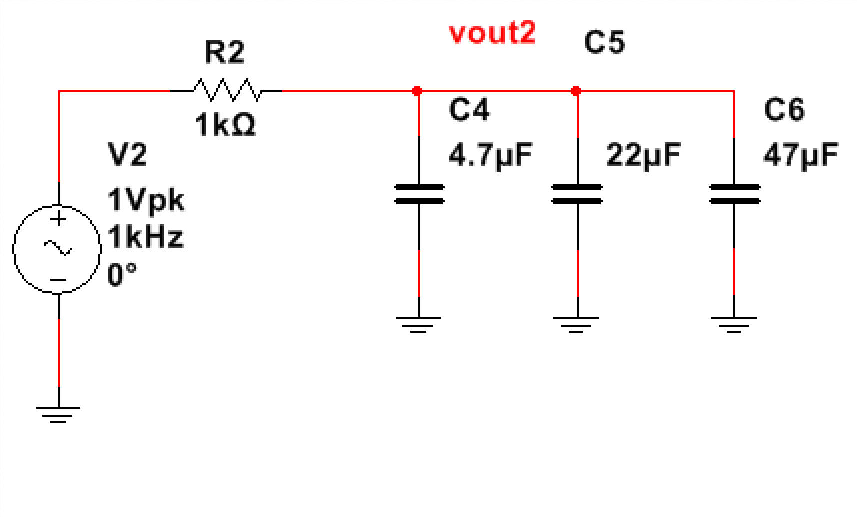
Lab 10: Series/Parallel Capacitors (2)

Schematic:

Capacitors in series



Capacitors in parallel



Lab 10: Series/Parallel Capacitors (3)

Procedures:

Measure and record the capacitance of each capacitor using the LCR meter. Connect all capacitors in series and measure and record the total capacitance. Then, connect all capacitors in parallel and measure and record the total capacitance.

Lab 10: Series/Parallel Capacitors (4)

Calculation:

Total Capacitance in Series

$$C_T = \frac{1}{(\frac{1}{C_1}) + (\frac{1}{C_2}) + (\frac{1}{C_3})}$$

Total Capacitance in parallel

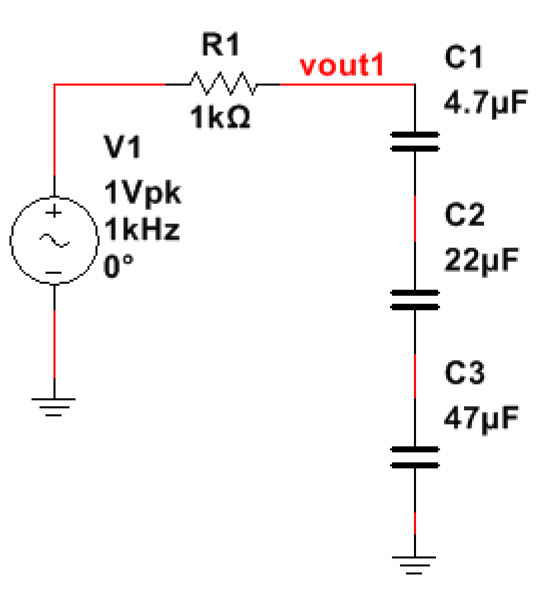
$$C_T = C_1 + C_2 + C_3$$

	Unit	Design	Calculated (Design)	Measured	Calculated (Measured)	% Error	Simulated
C1	µF	4.700E+0	4.700E+0	4.240E+0	4.240E+0	9.79	N/A
C2	µF	22.000E+0	22.000E+0	18.381E+0	18.381E+0	16.45	N/A
C3	µF	47.000E+0	47.000E+0	36.139E+0	36.139E+0	23.11	N/A
CT (Series)	µF	3.578E+0	3.578E+0	3.049E+0	3.145E+0	12.09	3.578E+0
CT (Parallel)	µF	73.700E+0	73.700E+0	54.420E+0	58.760E+0	20.27	73.700E+0

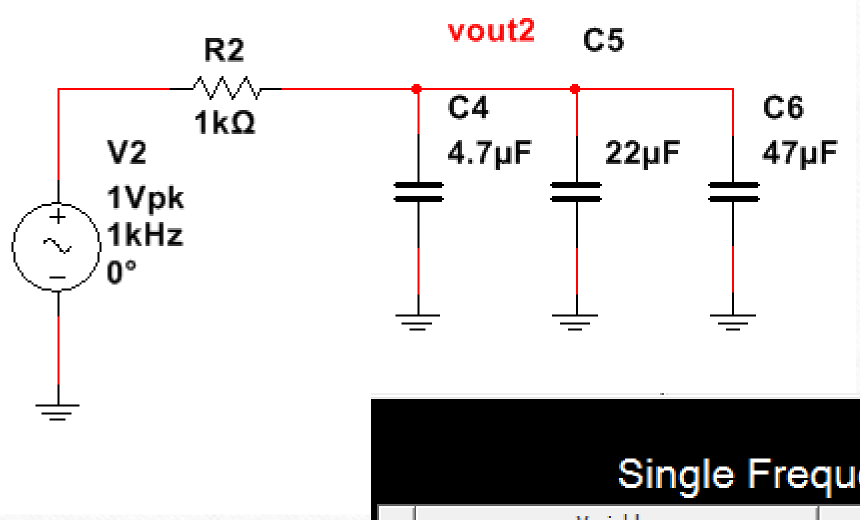
Lab 10: Series/Parallel Capacitors (5)

Multisim – Total Capacitance:

<u>Capacitors in series</u>



<u>Capacitors in parallel</u>



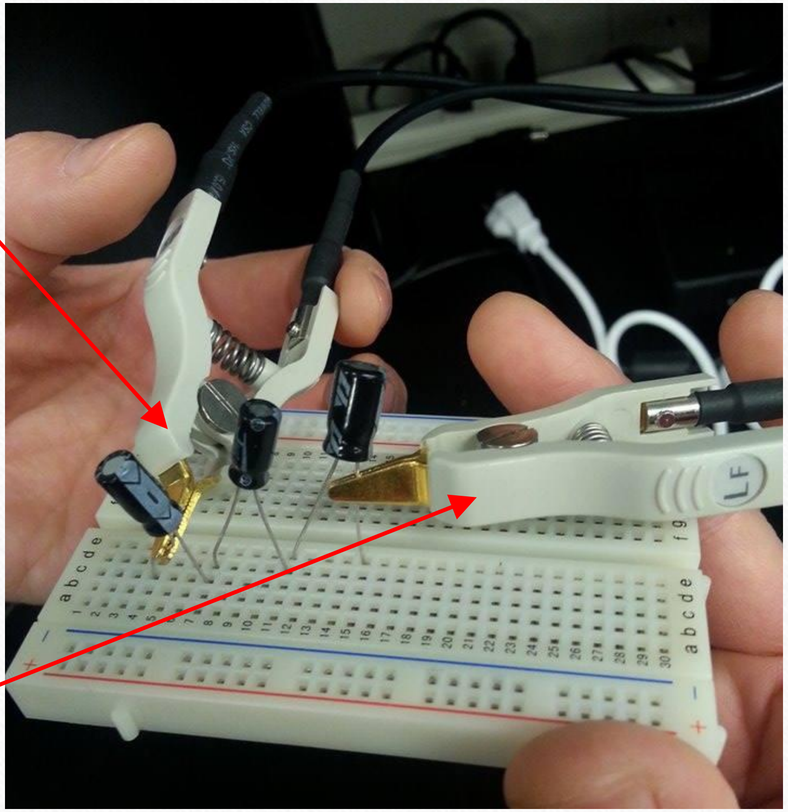
Lab10
Single Frequency AC Analysis @ 1000 Hz

	Variable	Real	Imaginary
1	1/(abs(imag(V(vout1)/I(R1)))*1000*2*pi)	3.57785 u	0.00000
2	1/(abs(imag(V(vout2)/I(R2)))*1000*2*pi)	73.70000 u	0.00000

Lab 10: Series/Parallel Capacitors (6)

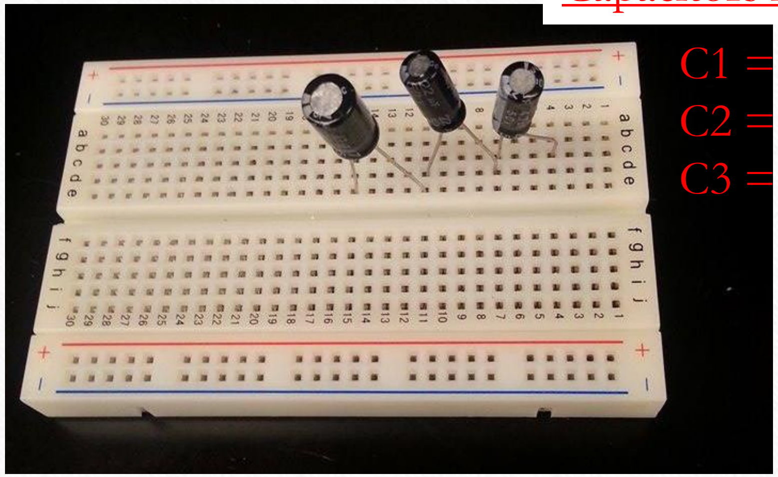
Settings of Breadboard:

Source

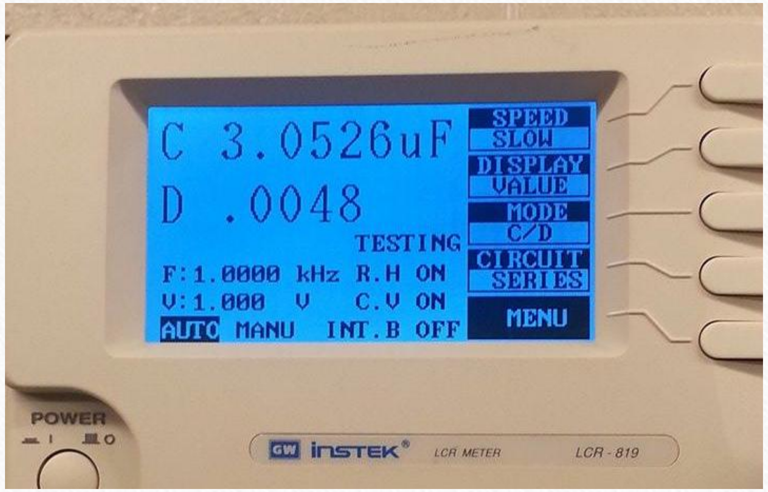


Ground

Capacitors in Series



C1 = 4.7 μF
C2 = 22 μF
C3 = 47 μF



LCR Meter Screen

Lab 10: Series/Parallel Capacitors (7)

Conclusion:

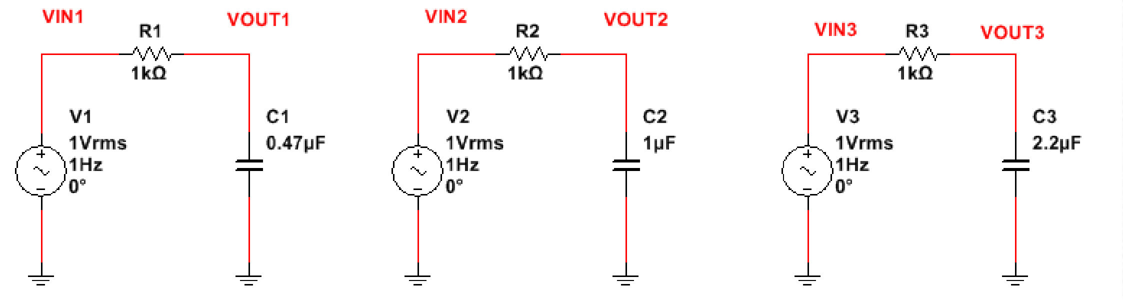
As we predicted, total capacitance in series was smaller than the total capacitance in parallel.

Percentage error was greater compared to the other experiment, such as measuring resistance, voltage, or current.

(We used a 4.7μF capacitor instead of 10 μF which the instruction specified because there weren't enough numbers of 10 μF capacitors for all students.)

Lab 11

RC Lab



VIN1
R1
1kΩ
VOUT1
V1
1Vrms
1Hz
0°
C1
0.47µF
VIN2
R2
1kΩ
VOUT2
V2
1Vrms
1Hz
0°
C2
1µF
VIN3
R3
1kΩ
VOUT3
V3
1Vrms
1Hz
0°
C3
2.2µF

Lab 11: RC Lab (1)

Objective:

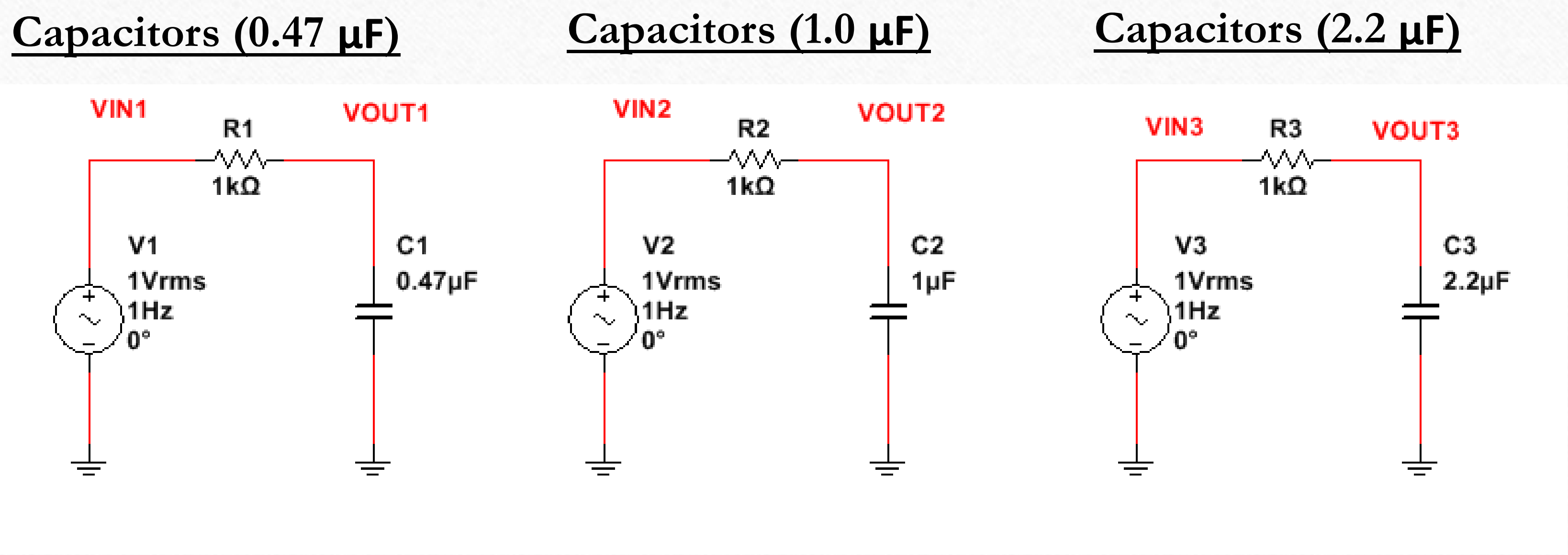
Experiment with RC (Resistor & Capacitor) circuits.

Equipment/Materials:

Brand	Model	S/N	
Digital Multimeter	GW INSTEK	GDM-8245	CL860333
LCR Meter	INSTEC LRC Meter	E121001	
Oscilloscope	Tektronix TDS 220	TDS220	B083259
Function Generator	Tektronix GFG 8210	C705254	
Capacitors	0.47µF, 2.2µF, 1.0µF		
Resistor	1000Ω		

Lab 11: RC Lab (2)

Schematic:



Lab 11: RC Lab (3)

Procedures:

Measure and record the resistor value using the DMM and measure and record the capacitor values using LCR meter.

Connect all resistors and one capacitor in series and connect Channel 1 of the Oscilloscope to the input and Channel 2 to the output.

Adjust the voltage of the function generator to 1Vpp at the frequencies 10 through 10,000.

Measure the input and output voltages using the Oscilloscope for each frequency. Repeat this measurement procedure for the each capacitor and record the value.

Lab 11: RC Lab (4)

Calculation:

Capacitive Reactance (X_C)

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

Impedance (Z)

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

Current through Capacitance (I_C)

$$I_C = \frac{V_S}{Z}$$

Output Voltage (V)

$$V_{out} = Z \times I_C$$

Lab 11: RC Lab (5)

Calculation:

	A	B	C	D
12		Unit	Design	Measured
13	C1	F	470.000E-9	432.000E-3
14	C2	F	2.200E-6	2.036E+0
15	C3	F	1.000E-6	1.024E+0
16	R1	Ω	1.000E+3	978.700E+0
17	V_s	V	1.000E+0	1.020E+0

Output Voltage [V]	= E22 * C22
X_C [Ω]	= 1 / (2 * PI() * A22 * C13)
Z [Ω]	= SQRT (C16 ^2 + C22 ^2)
I_C [A]	= C17 / D22

	A	B	C	D	E	F	G
19		Output Voltage C = 0.47 μF					
20		Expected				Measured	
21	Frequency [Hz]	Output Voltage [V]	X_c [Ω]	Z [Ω]	I_c [A]	Input Voltage [V]	Output Voltage [V]
22	10	999.564E-3	33.863E+3	33.878E+3	29.518E-6	1.020E+0	1.040E+0
23	50	989.274E-3	6.773E+3	6.846E+3	146.071E-6	984.000E-3	968.000E-3
24	100	959.055E-3	3.386E+3	3.531E+3	283.218E-6	976.000E-3	920.000E-3
25	200	861.036E-3	1.693E+3	1.966E+3	508.544E-6	968.000E-3	816.000E-3
26	300	748.508E-3	1.129E+3	1.508E+3	663.125E-6	960.000E-3	715.000E-3
27	400	646.127E-3	846.569E+0	1.310E+3	763.230E-6	952.000E-3	608.000E-3
28	500	560.755E-3	677.255E+0	1.208E+3	827.982E-6	944.000E-3	528.000E-3
29	600	491.504E-3	564.379E+0	1.148E+3	870.875E-6	944.000E-3	464.000E-3
30	700	435.475E-3	483.754E+0	1.111E+3	900.201E-6	944.000E-3	416.000E-3
31	800	389.802E-3	423.284E+0	1.086E+3	920.899E-6	936.000E-3	376.000E-3
32	900	352.151E-3	376.253E+0	1.068E+3	935.943E-6	936.000E-3	336.000E-3
33	1000	320.737E-3	338.628E+0	1.056E+3	947.168E-6	936.000E-3	312.000E-3
34	2000	166.938E-3	169.314E+0	1.014E+3	985.967E-6	928.000E-3	168.000E-3
35	3000	112.164E-3	112.876E+0	1.006E+3	993.690E-6	936.000E-3	120.000E-3
36	4000	84.355E-3	84.657E+0	1.004E+3	996.436E-6	936.000E-3	104.000E-3
37	5000	67.571E-3	67.726E+0	1.002E+3	997.714E-6	928.000E-3	88.000E-3
38	6000	56.348E-3	56.438E+0	1.002E+3	998.411E-6	928.000E-3	72.000E-3
39	7000	48.319E-3	48.375E+0	1.001E+3	998.832E-6	928.000E-3	72.000E-3
40	8000	42.291E-3	42.328E+0	1.001E+3	999.105E-6	926.000E-3	42.200E-3
41	9000	37.599E-3	37.625E+0	1.001E+3	999.293E-6	926.000E-3	38.400E-3
42	10000	33.843E-3	33.863E+0	1.001E+3	999.427E-6	928.000E-3	34.400E-3

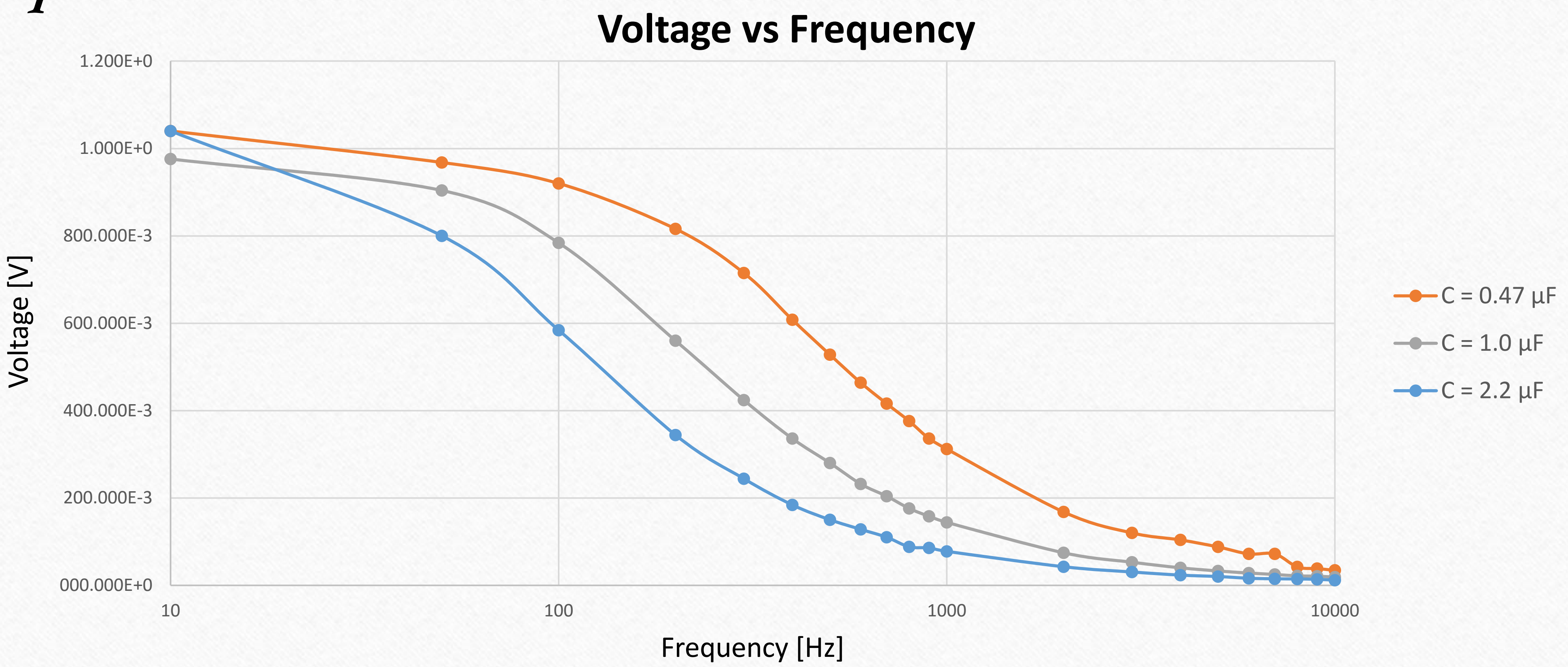
Lab 11: RC Lab (6)

Calculation:

	A	H	I	J	K	L	M	N	O	P	Q	R	S
19		Output Voltage C = 1.0 μF						Output Voltage C = 2.2 μF					
20		Expected				Measured		Expected				Measured	
21	Frequency [Hz]	Output Voltage [V]	X_c [Ω]	Z [Ω]	I_c [A]	Input Voltage [V]	Output Voltage [V]	Output Voltage [V]	X_c [Ω]	Z [Ω]	I_c [A]	Input Voltage [V]	Output Voltage [V]
22	10	990.581E-3	7.234E+3	7.303E+3	136.928E-6	984.000E-3	976.000E-3	998.032E-3	15.915E+3	15.947E+3	62.708E-6	1.020E+0	1.040E+0
23	50	822.637E-3	1.447E+3	1.759E+3	568.566E-6	976.000E-3	904.000E-3	954.028E-3	3.183E+3	3.336E+3	299.717E-6	1.010E+0	800.000E-3
24	100	586.134E-3	723.432E+0	1.234E+3	810.214E-6	968.000E-3	784.000E-3	846.733E-3	1.592E+3	1.880E+3	532.018E-6	1.020E+0	584.000E-3
25	200	340.147E-3	361.716E+0	1.063E+3	940.372E-6	944.000E-3	560.000E-3	622.677E-3	795.775E+0	1.278E+3	782.479E-6	1.010E+0	344.000E-3
26	300	234.424E-3	241.144E+0	1.029E+3	972.134E-6	944.000E-3	424.000E-3	468.650E-3	530.516E+0	1.132E+3	883.384E-6	1.000E+0	244.000E-3
27	400	177.971E-3	180.858E+0	1.016E+3	984.036E-6	944.000E-3	336.000E-3	369.698E-3	397.887E+0	1.076E+3	929.152E-6	1.000E+0	184.000E-3
28	500	143.195E-3	144.686E+0	1.010E+3	989.694E-6	936.000E-3	280.000E-3	303.314E-3	318.310E+0	1.049E+3	952.891E-6	1.000E+0	150.000E-3
29	600	119.705E-3	120.572E+0	1.007E+3	992.810E-6	936.000E-3	232.000E-3	256.391E-3	265.258E+0	1.035E+3	966.573E-6	1.000E+0	128.000E-3
30	700	102.800E-3	103.347E+0	1.005E+3	994.702E-6	936.000E-3	204.000E-3	221.706E-3	227.364E+0	1.026E+3	975.114E-6	1.000E+0	110.000E-3
31	800	90.061E-3	90.429E+0	1.004E+3	995.936E-6	928.000E-3	176.000E-3	195.120E-3	198.944E+0	1.020E+3	980.779E-6	1.000E+0	88.000E-3
32	900	80.123E-3	80.381E+0	1.003E+3	996.785E-6	928.000E-3	158.000E-3	174.137E-3	176.839E+0	1.016E+3	984.721E-6	1.000E+0	85.600E-3
33	1000	72.155E-3	72.343E+0	1.003E+3	997.393E-6	928.000E-3	144.000E-3	157.177E-3	159.155E+0	1.013E+3	987.570E-6	1.000E+0	77.600E-3
34	2000	36.148E-3	36.172E+0	1.001E+3	999.346E-6	928.000E-3	74.400E-3	79.327E-3	79.577E+0	1.003E+3	996.849E-6	1.000E+0	42.400E-3
35	3000	24.107E-3	24.114E+0	1.000E+3	999.709E-6	928.000E-3	52.800E-3	52.977E-3	53.052E+0	1.001E+3	998.596E-6	1.010E+0	30.400E-3
36	4000	18.083E-3	18.086E+0	1.000E+3	999.836E-6	928.000E-3	40.000E-3	39.757E-3	39.789E+0	1.001E+3	999.209E-6	1.010E+0	23.200E-3
37	5000	14.467E-3	14.469E+0	1.000E+3	999.895E-6	928.000E-3	32.800E-3	31.815E-3	31.831E+0	1.001E+3	999.494E-6	1.010E+0	20.000E-3
38	6000	12.056E-3	12.057E+0	1.000E+3	999.927E-6	928.000E-3	28.000E-3	26.516E-3	26.526E+0	1.000E+3	999.648E-6	1.010E+0	16.000E-3
39	7000	10.334E-3	10.335E+0	1.000E+3	999.947E-6	928.000E-3	24.800E-3	22.731E-3	22.736E+0	1.000E+3	999.742E-6	1.010E+0	14.800E-3
40	8000	9.043E-3	9.043E+0	1.000E+3	999.959E-6	928.000E-3	21.600E-3	19.890E-3	19.894E+0	1.000E+3	999.802E-6	1.000E+0	14.400E-3
41	9000	8.038E-3	8.038E+0	1.000E+3	999.968E-6	928.000E-3	20.800E-3	17.681E-3	17.684E+0	1.000E+3	999.844E-6	1.000E+0	13.600E-3
42	10000	7.234E-3	7.234E+0	1.000E+3	999.974E-6	1.000E+0	18.800E-3	15.913E-3	15.915E+0	1.000E+3	999.873E-6	1.000E+0	11.600E-3

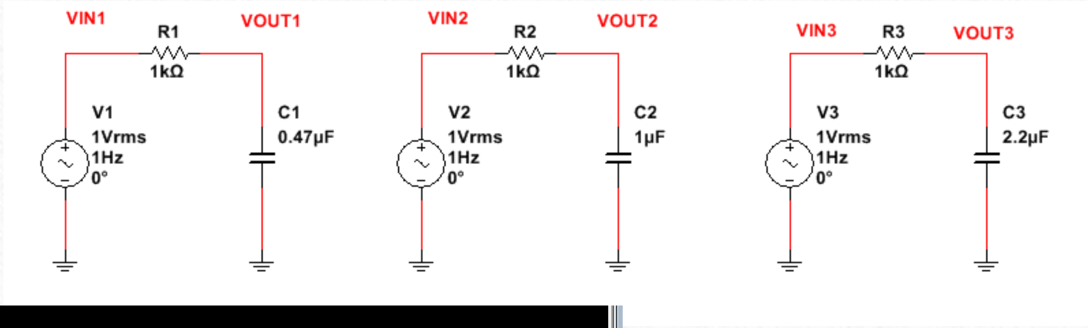
Lab 11: RC Lab (7)

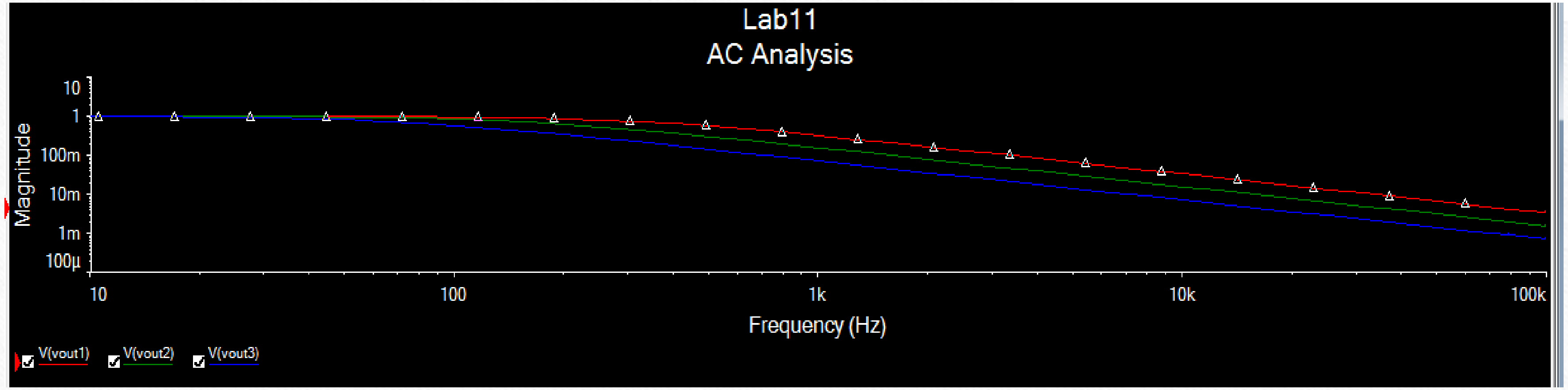
Graph:



Lab 11: RC Lab (8)

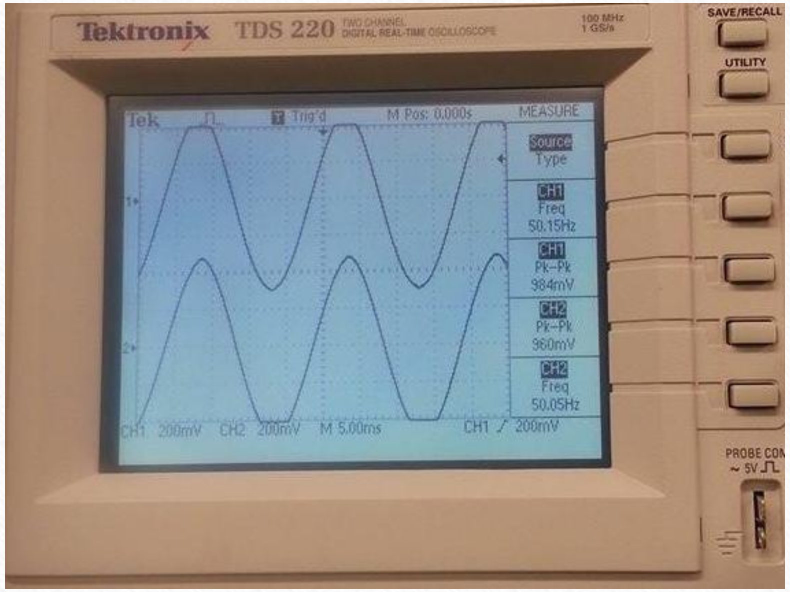
Multisim – Voltage vs Frequency:



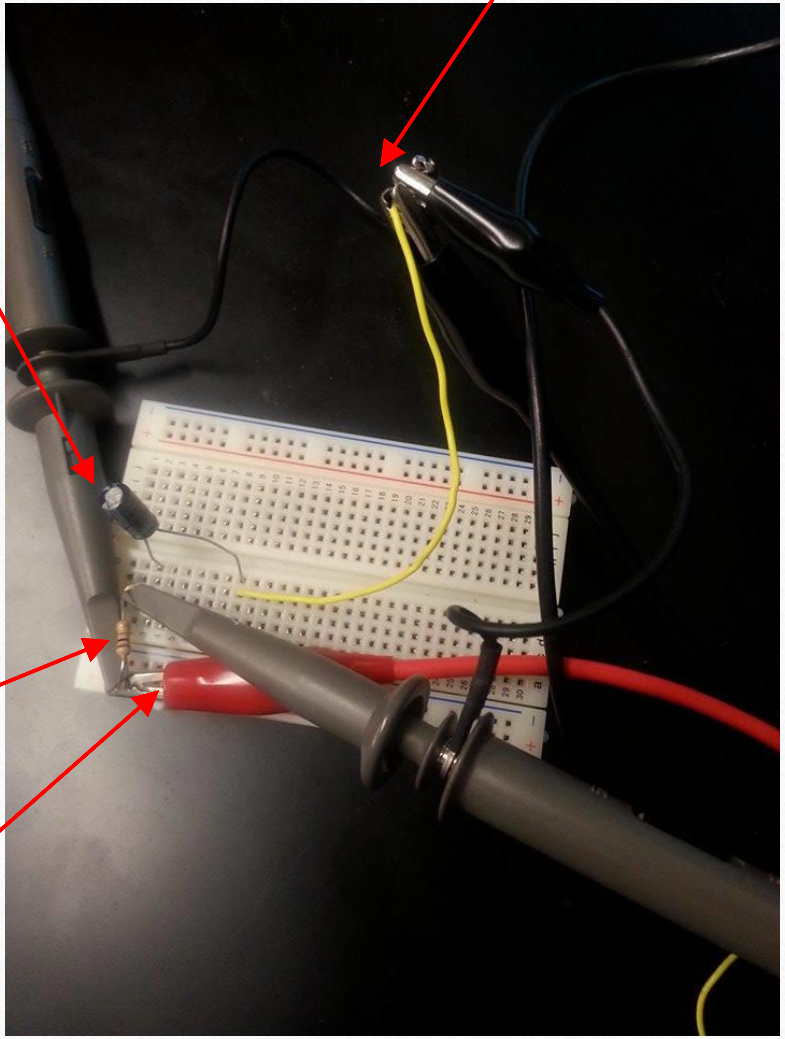


Lab 11: RC Lab (9)

Settings of Breadboard:



Oscilloscope Screen

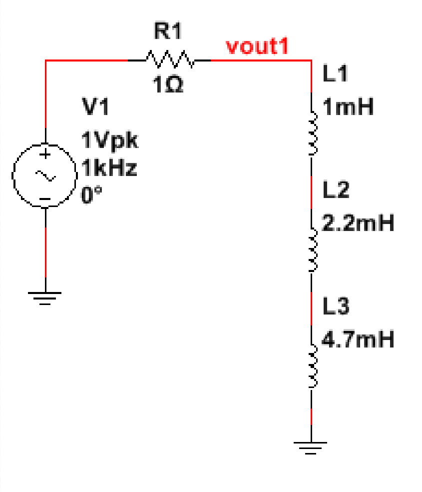


Lab 11: RC Lab (10)

Conclusion:

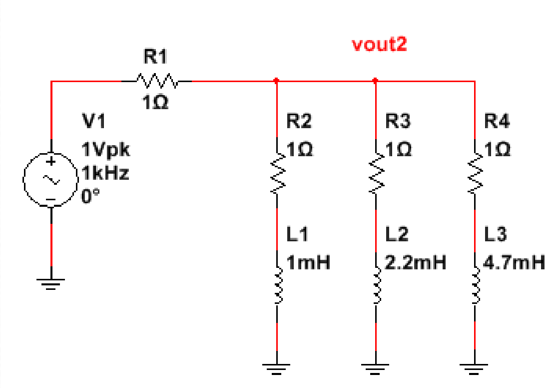
The higher the frequency, the lower the voltage output. The input voltage did not change.

The smaller capacitor exhibited a higher voltage compared to the larger capacitor.



Lab 12

Series/Parallel Inductors



Lab 12: Series/Parallel Inductors (1)

Objective:

Experiment with series circuit and parallel combinations of inductors.

Equipment/Materials:

Brand	Model	S/N
Bread Board	Table 4	
LCR Meter	INSTEC LRC Meter	E121001
Inductors	1mH, 2.2mH, 4.7mH	

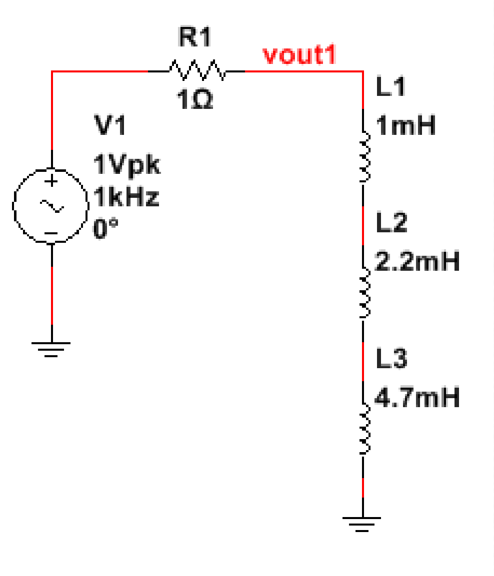
Procedures:

Measure and record the inductance of each inductor using the LCR meter. Connect all inductors in series and measure and record the total inductance.

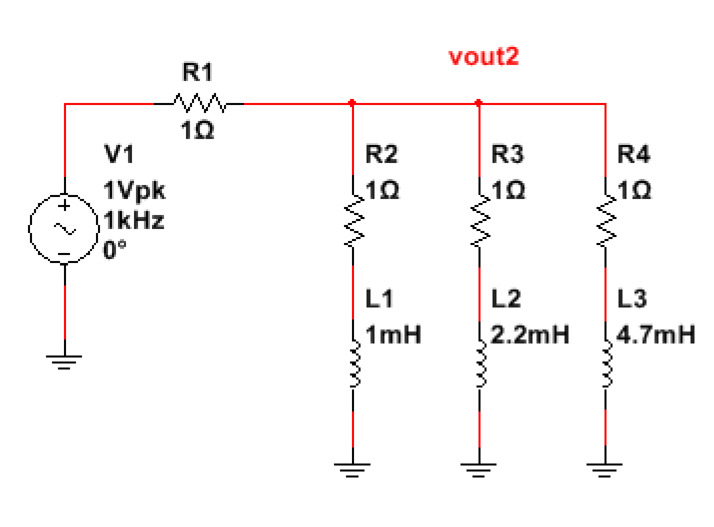
Lab 12: Series/Parallel Inductors (2)

Schematic:

Inductors in series



Inductors in parallel



Lab 12: Series/Parallel Inductors (3)

Calculation:

Total Inductors in Series

$$L_T = L_1 + L_2 + L_3$$

Total Inductors in parallel

$$L_T = \frac{1}{(\frac{1}{L_1}) + (\frac{1}{L_2}) + (\frac{1}{L_3})}$$

Series	unit	Design	Measured	Simulated	% Error
L1	H	1.000E-3	990.850E-6	N/A	0.92
L2	H	2.200E-3	2.180E-3	N/A	0.91
L3	H	4.700E-3	4.310E-3	N/A	8.30
LT	H	7.900E-3	7.280E-3	7.900E-3	7.85
Parallel	**unit**	**Design**	**Measured**	**Simulated**	**% Error**
L1	H	1.000E-3	990.850E-6	N/A	0.92
L2	H	2.200E-3	2.180E-3	N/A	0.91
L3	H	4.700E-3	4.310E-3	N/A	8.30
LT	H	599.768E-6	558.000E-6	601.246E-6	6.96

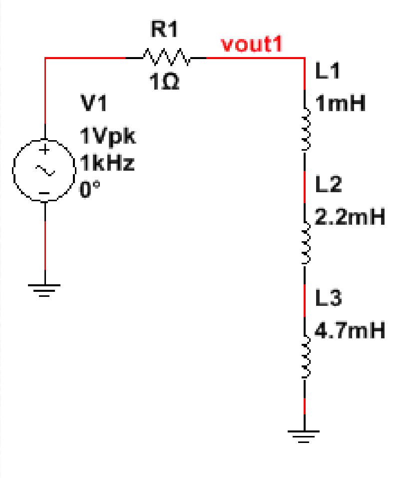
Lab 12: Series/Parallel Inductors (4)

Multisim – Voltage vs Frequency:

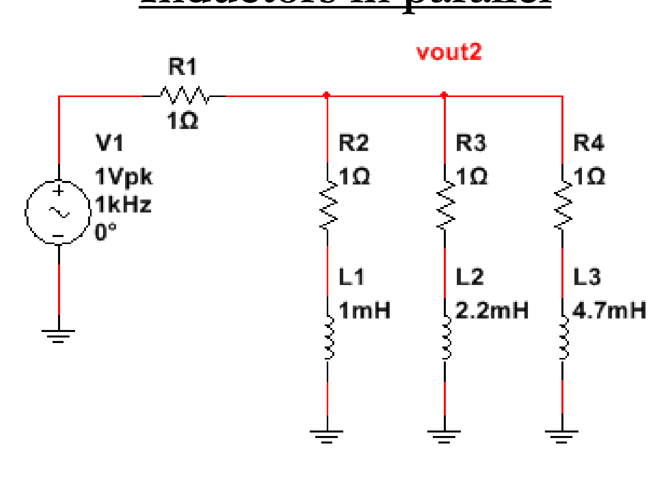
Design1
Single Frequency AC Analysis @ 1000 Hz

	Variable	Real	Imaginary
1	abs(imag((V(vout1)/I(R1))/(2*pi*1000)))	7.90000 m	0.00000
2	abs(imag((V(vout2)/I(R2))/(2*pi*1000)))	601.24552 u	0.00000

Inductors in series

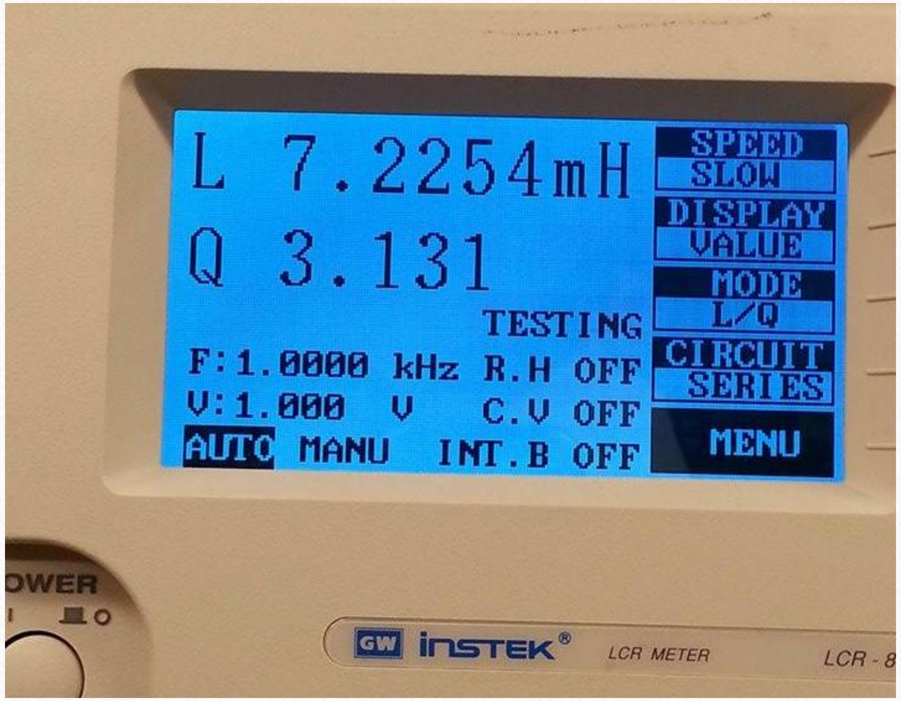


Inductors in parallel

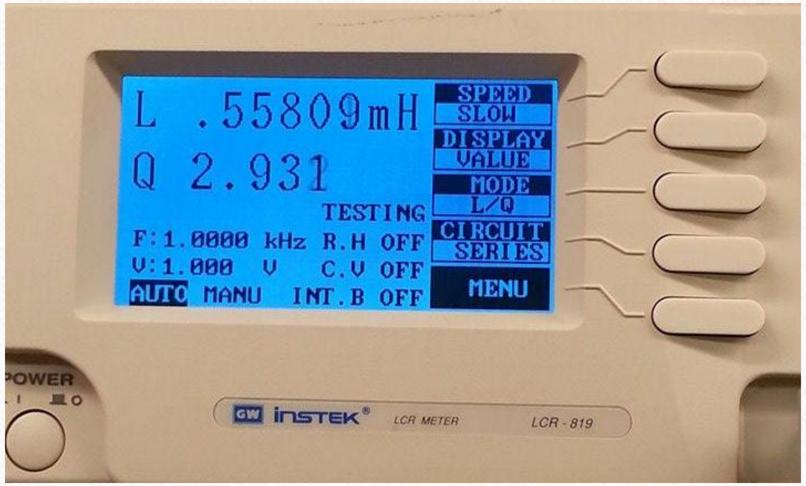


Lab 12: Series/Parallel Inductors (5)

Measured value of inductance:



LCR Meter Screen



Lab 12: Series/Parallel Inductors (6)

Conclusion:

All measurements were lower than expected.

Both series circuit and parallel circuit showed total inductance that were expected.

The inductance of measurement value increased quickly at first, then gradually it became slowly increased.

We observed calculated value and measured data were within 10 % tolerance.