University of Cincinnati
College of Engineering and Applied Science
Department of Mechanical & Materials Engineering

Course Code : **20-MECH-4071C**
Course Title : **Measurements & Instrumentation Lab**

Experiment Number : **#1**
Experiment Title : **MEASUREMENT CONSIDERATIONS**

Date(s) Performed : **August 29, 2022 – September 12, 2022**
Date Submitted : **Month Day, Year**

Group Code : **002-13**
Group Members : **ROYER, Zane**
: **YI, Hongrui**

Instructor : **Dr. Aimee M. Frame**

Deductions by TA:

Initials	Content	Form/Writ
SJ	4	0
LB	7	1.5
DP	17.5	0

TOTAL SCORE = 170 **/200**

ABSTRACT

The reason for this set of experiments was to reacquaint with the lab equipment while exploring some common measurement issues. Topics covered in this lab included loading induced by measurement devices, the use of AC coupling and chassis grounding issues.

For the measurement uncertainty experiment, variations in measurement systems and other external influences that affect the precision of calculations were explored. The number of significant digits of measurements using ELVIS EMM was more than that using Fluke DMM, which showed that ELVIS EMM was more precise than Fluke DMM. For the measurement loading experiment, the error due to accidental loading of the system by the measurement device and its effect on the accuracy of the measurements were analyzed. It was useful for telling whether the measurements were reliable or not. For AC vs DC coupling experiment, the influence of AC coupling on various measurements were studied. AC coupling would block the DC offset and eliminate the steady-state response. For grounding issue experiment, the output of the RLC circuit and series circuit with oscilloscope was measured and the influence of the chassis ground was analyzed. Parts of the system might be intentionally shorted out due to the "ground" connection. Therefore, multiple channels are needed to measure the voltage drop across the circuit branch with oscilloscope.

-1 Not appropriate conclusion for grounding issues

Table of Contents

1. Objectives

Note: do not use bullet points

The purpose of this lab is to:

- Reintroduce the lab equipment while showing the basic measurement errors that can occur with them.
- Illustrate how to identify and correct the common measurement errors with the tools given.
- Observe the results that occur when measurement loading is apparent in the system.
- Compare and Contrast systems when AC coupling is on and off.
- Analyze and system that has common grounding issues then revise the system to correct the issue.

2. Theoretical Background

2.1 Measurement Uncertainty & Loading

1. **Ohm's Law:**

$$I = \frac{V}{R} \qquad (1)$$

2. **Kirchhoff's voltage law (KVL):**

$$\sum_{i=1}^{N} V_i = 0 \qquad (2)$$

The sum of voltages around a closed loop or path is zero.

3. **Kirchhoff's current law (KCL):**

$$\sum_{i=1}^{N} I_i = 0 \qquad (3)$$

The sum of currents flowing into a closed surface or node is zero.

4. **Series Resistance Circuit:**

Equivalent Resistance Calculation:

$$R_{eq} = \sum_{i=1}^{N} R_i = R_1 + R_2 + \ldots + R_N \qquad (4)$$

Voltage Calculation by Voltage Dividers:

$$V_{R_i} = \frac{R_i}{R_{eq}} V_s = \frac{R_i}{\sum_{j=1}^{N} R_j} V_s \qquad (5)$$

5. Parallel Resistance Circuit:

Equivalent Resistance Calculation:

$$\frac{1}{R_{eq}} = \sum_{i=1}^{N} \frac{1}{R_i} \tag{6}$$

Current Calculation by Current Dividers:

$$I_{R_i} = \frac{R_{eq}}{R_i} I_s \tag{7}$$

6. Power in Electrical Circuits:

$$P = IV = I^2 R = \frac{V^2}{R} \tag{8}$$

7. Uncertainty calculation:

$$E_{rms} = \sqrt{\left(\tfrac{\partial X}{\partial v_1} \mathrm{V} v_1\right)^2 + \left(\tfrac{\partial X}{\partial v_2} \mathrm{V} v_2\right)^2 + \ldots + \left(\tfrac{\partial X}{\partial v_n} \mathrm{V} v_n\right)^2} \tag{9}$$

2.2 System Response

1. 1st Order System:

System can be modeled as:

$$A_1 \frac{dX_{out}}{dt} + A_0 X_{out} = B_0 X_{in} \tag{10}$$

Step Response:

$$X_{out}(t) = KA_{in}\left(1 - e^{-t/\tau}\right) \tag{11}$$

Static Sensitivity:

$$k = \frac{B_0}{A_0} \tag{12}$$

Time Constant:

$$\tau = \frac{A_1}{A_0} \tag{13}$$

For the RC circuit, the time constant is:

$$\tau = RC \tag{14}$$

Frequency Response Function:

$$H(\omega) = \frac{X_{out}(\omega)}{X_{in}(\omega)} = \frac{B_0}{j\omega A_1 + A_0} \tag{15}$$

2. 2nd Order System:

System can be modeled as:

$$A_2\ddot{X}_{out} + A_1\dot{X}_{out} + A_0 X_{out} = B_0 X_{in} \tag{16}$$

Frequency Response Function:

Percent Overshoot:

$$PO = \frac{max\,overshoot}{KA} \times 100\% = e^{-\zeta\pi/\sqrt{1-\zeta^2}} \tag{17}$$

Frequency Response Function:

$$H(\omega) = \frac{X_{out}(\omega)}{X_{in}(\omega)} = \frac{1}{k - m\omega^2 + j\omega c} = \frac{1/k}{1 - \left(\frac{\omega}{\Omega}\right)^2 + 2\zeta\left(\frac{\omega}{\Omega}\right)j} \tag{18}$$

2.3 AC vs DC Coupling

When using AC coupling, the unwanted DC component of the system will be blocked. All low frequency components will be attenuated with AC coupling. If you want to have the offset voltage, namely the DC component, DC coupling should be selected.

2.4 Grounding Issues

Oscilloscope is frequently used with measuring the system output like the voltage, current and so on. Unlike measurement devices, the "-" signal reference of each channel is attached to chassis ground, which is attached to the AC line ground. Under this circumstance, a two-channel signal difference feature must be used to measure the differential voltage, using the "+" leads of each channel to measure. For DC circuits, the voltage across each component can be calculated by subtracting the voltage readings of each nodes.

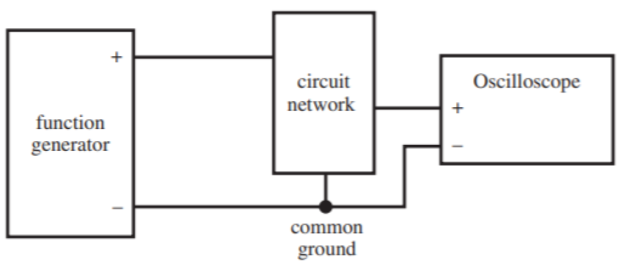


Figure 1. Real ammeter with input impedance

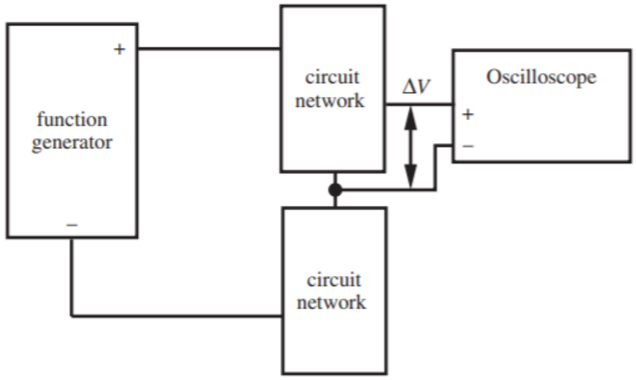


Figure 2. Real ammeter with input impedance

3. Experimentation

3.1 Measurement Uncertainty

3.1.1 Procedure Objectives

-0.5; Provide more details, at least 3-5 sentences

The objective of this part of the experiment was to explore the variation in measurements that occur in measurement devices due to uncontrollable factors. The variation in measurements affect precision when using the collected data to make calculations.

3.1.2 Experimental Results

The circuit seem in Figure 2 was built on the Elvis prototype board. Then each resistor value was measured.

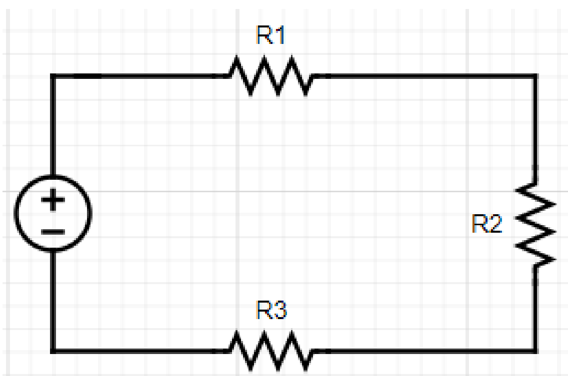


Figure 2: 3.1 Circuit Diagram

Resistors are not their exact nominal values due to external factors, so the resistances needed to be measured with the NI Elvis III and Fluke DMM to find the actual resistances. The values in Table 1: Resistor Values show that the Ni Elvis measuring device is acuate to two decimals while the Fluke is only accurate to 1 decimal place. While taking the data there was a lot of small fluctuations in measurements, also called "noise", while measuring the data making it hard to know the correct number to write down.

Table 1: Resistor Values

	Nominal Value	NI Elvis III (+/- 0.01)	Fluke DMM (+/- 0.1)
R1 (Ω)	220	216.70	216.6
R 2 (Ω)	220	216.10	216.0
R3 (Ω)	220	217.10	217.0

Below is Table 2 which is the values for voltage in, voltage across resistor 3, and the current across resistor 3. Like Table 1, this table also shows that the NI Elvis is more accurate than the Fluke.

Table 2: Values from Figure 2 Circuit

	Theoretical Value	NI Elvis III	Fluke DMM
Voltage In (V)	6	6.012 +/- 0.001	6.003 +/- 0.001
R3 Voltage (V)	2	2.0097 +/- 0.0001	2.006 +/- 0.001
R3 Current (A)	0.009091	0.00932 +/- 0.00001	0.009 +/- 0.001

3.1.3 Analysis Questions

2.4.A. Compute the power through the output resistor and its uncertainty using your measured values and each of the following three equations.

-1; Wrong uncertainty calculation

Answer:

-12; missing uncertainty calculation process

Table 3: Uncertainty of Power

	NI Elvis III		Fluke DMM	
Power Formula Used	Nominal (W)	Uncertainty (W)	Nominal (W)	Uncertainty (W)
IV	0.0187	0.00002	0.02	0.002
I^2R	0.0189	0.00004	0.02	0.004
$\frac{V^2}{R}$	0.018604	0.000002	0.01854	0.002

The uncertainty formula used was equation (9), the Excel worksheet equations used to calculate these values can be found in Figure 20. Table 3 shows that the NI Elvis III is much more precise than the Fluke DMM since the uncertainty of the Elvis is much lower than the Fluke.

-1; provide more explanation

2.4.B. Theoretically, the different measurement devices (ELVIS vs Fluke) should not affect the overall accuracy (i.e. nominal value) of the calculated power value. Do the results obtained in analysis question A confirm this assumption? Why or why not?

Answer:

The data confirms the assumption that the different measurement devices do not affect the overall accuracy. The accuracy is not affected because all the measurement devices have random error which causes small variations in measurements.

2.4.C Theoretically, the different measurement devices (ELVIS vs Fluke) will likely affect the overall precision (i.e. uncertainty value) of the calculated power value. Do the results obtained in analysis question A confirm this assumption? Why or why not?

Answer: -1; provide more explanation

The data confirms that the assumption that the different measurement devices affect the overall precision of the calculated power value. The precision is affected because the devices read with different precisions (i.e. decimal places) which changes the precision of the calculated values.

3.1.4 General Discussion

The measurement uncertainty of devices comes from various factors, in this part of the lab the factors observed included precision of measurement devices and small random error fluctuations of the measurement devices. The precision of the NI Elvis III is much better than the Fluke DMM because it can read one more decimal place for resistor values (See Table 1), one more decimal place for voltage (See Table 2), and two more decimal places for current (See Table 2). The small random error fluctuations were more apparent in the larger values, in this case the resistor values, because the number is larger making it hard for the devices to read as accurate as the smaller number.

3.2 Measurement Loading

3.2.1 Procedure Objectives

The objective of this part of the lab is to explore how measurement devices used can cause measurement loading on the circuit and cause errors in measurements. A pair of large resistors (2.2MΩ) and a pair of small resistors (10Ω) are used to see which pair will cause the measurement loading and yeild inaccurate results.

3.2.2 Experimental Results

Again, like mentioned for Table 1, resistors are not their exact nominal values due to external factors. This time we are only measuring used the Elvis DMM since the objective of this part of the experiment does not include the accuracies of different devices. R1 and R2 are considered R_a in the lab procedure while R3 and R4 are considered R_b.

Table 4: Resistance Values

	Nominal	NI Elvis III
R1(Ω)	10	10.095
R2(Ω)	10	10.093
R3(Ω)	2,200,000	2,232,200
R4(Ω)	2,200,000	2,222,800

The parallel circuit was made using the two 10Ω resistors then multiple measurements were made across the circuit and then compared to their theoretical value in Table 5.

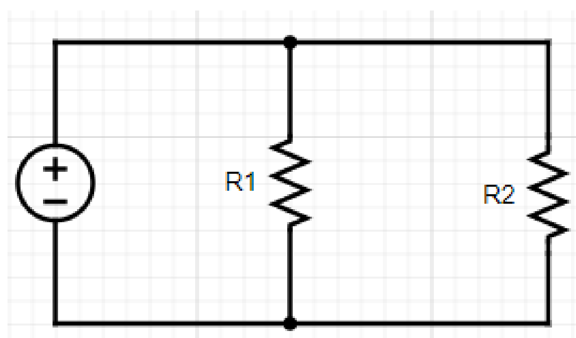


Figure 3: 3.2 Parallel Circuit Diagram

When comparing the numbers measured to their theoretical values, the Voltage in measurement and the Current from the power supply is much smaller than the theoretical due to a type of error called measurement loading which will be discussed in section 3.2.4.

Table 5: Parallel Circuit Values

	Theoretical Value	NI Elvis III
Voltage In (V)	2	1.8939
Current From Power Supply (A)	0.4	0.31239
R1 Current (A)	0.2	0.18774

R2 Current (A)	0.2	0.19031

The series circuit was made using the two 2.2MΩ resistors then multiple measurements were again taken and compared to their theoretical values.

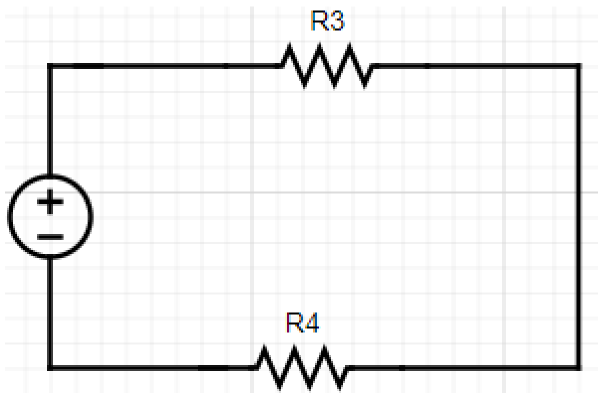


Figure 4: 3.2 Series Circuit Diagram

Like the comments of Table 5, this table also has values not closely aligning with the theoretical values with the Voltage thought R3 and R4 being much lower than the theoretical and the total current being much higher than the theoretical value.

Note: be careful with your layout

Table 6: Series Circuit Values

	Theoretical Value	NI Elvis III
Voltage In (V)	12	12.021
R3 Voltage (V)	6	5.425
R4 Voltage (V)	6	5.402
Total Current (A)	0.0000027	0.00005

The current though the circuit was also measured using the Fluke DMM and showed a value of 0.000A, this value is not actually 0 but the Fluke does not have the accuracy to correctly measure the current though the circuit since it is such a small number.

3.2.3 Analysis Questions

3.4.A. Calculate the percent error between the expected and actual current measurements through each resistor taken in Procedures 3.3.C.

Answer:
The percent error formula used to calculate the values is:

$$\left|\frac{Actual\,Value - Theoretical\,Value}{Theoretical\,Value}\right| * 100\% \quad (19)$$

-2; missing recalculated currents

An example of this calculation can be seen below:

$$\frac{0.18774-0.2}{0.2} * 100\% = 6.13\%$$

The values for the table below were calculated based off the data in Table 5.

Table 7: Percent Error of Current Through 10Ω Resistors

	R1	R2
Percent Error	6.1300%	4.8450%

3.4.B. Theoretically, the addition of an ammeter in the parallel circuit should create measurement loading. Do the results from the previous question confirm this assumption?

do not use personal pronouns

Answer:
My results do confirm that there is measurement loading because the results differ from the theoretical values. When measuring with an ammeter it is connected in series with the circuit, since ammeters have small input impedances, the device affects the measurement when measuring across something with a small resistance. Equation (4) is the reason for this, since the resistances are added the small resistance of the ammeters affects small resistors.

3.4.C. Calculate the percent error between the expected and actual voltage measurements across each resistor taken in Procedures 3.3.E.

Answer:
Equation (19) was used to calculate the values based off Table 6. See question 3.4.A to see an example of how the calculation was made.

Table 8: Percent Error of Voltage Through 2.2MΩ Resistors

layout

	R3	R4

-2; missing recalculated voltages, %error formula

Percent Error	9.583%	9.967%

Note: relist all of the used equations for each part, don't simply refer

3.4.D. Based on the results from the previous question, what contributed to the inaccuracy of your voltage measurements?

Answer:

do not use personal pronouns

Measurement loading contributed to the inaccuracy to my voltage measurements. The measurement loading is occurring because the voltmeter connects in parallel with the circuit and has a very high impedance. Equation (6) is the reason for this type of loading. Since the Resistances are added by their inverses large resistances in the measurement devices affect systems with large resistances.

3.4.E. For the parallel circuit, 2V was the given value for the ELVIS Variable Power Supply. However, the measured voltage to the circuit was less than this value. However, there is not a similar significant difference in the 12V supplied to the series circuit. What does this difference indicate about the measurement system?

Answer:

The difference indicates that measurement loading affects the low voltage system more than higher voltage system. The reason for this is because, when measuring the voltage drop across the entire circuit, the measurement device affects the outcome since the 2V circuit's resistors were very low values compared to the large resistor values of the 12V circuit. If the device has an internal resistance of 5Ω in a circuit with 10Ω resistors it will affect the system much more than if the system had 2.2MΩ resistors.

3.4.F. In non-academic situations, the theoretical values may not be known. Therefore, what can be done to determine if there might be accuracy issues with measurements taken in these situations?

Answer:

To determine if there might be accuracy issues, test the resistors on a known circuit, if the resistor is a large value, then the voltage readings may be inaccurate, if the resistors are small values, then the current reading may be inaccurate.

<u>3.2.4 General Discussion</u>

Measurement loading can affect the outcome when measuring voltage and currents depending on the resistance of your circuit and if your circuit is in parallel or series. If measurement loading occurs, it can lead to inaccurate results without any way of knowing that they are not accurate. A voltmeter measures in parallel and has a very large input impedance which can cause measurement loading across a circuit branch with a high impedance. An ammeter measures in series and has a very low input impedance which can cause measurement loading across a circuit branch with a small impedance.

-1; missing issue with fluke

3.3 AC vs DC Coupling

-0.5; provide more detail, different frequencies and input functions were used

3.3.1 Procedure Objectives

The objective of this part of the lab is to examine the affects that AC coupling, that acts as a hgih pass filter, has on a circuit. This procrdure with also show how to use tools within the NI Elvis III program, including how to use the funtion generator and oscilloscope.

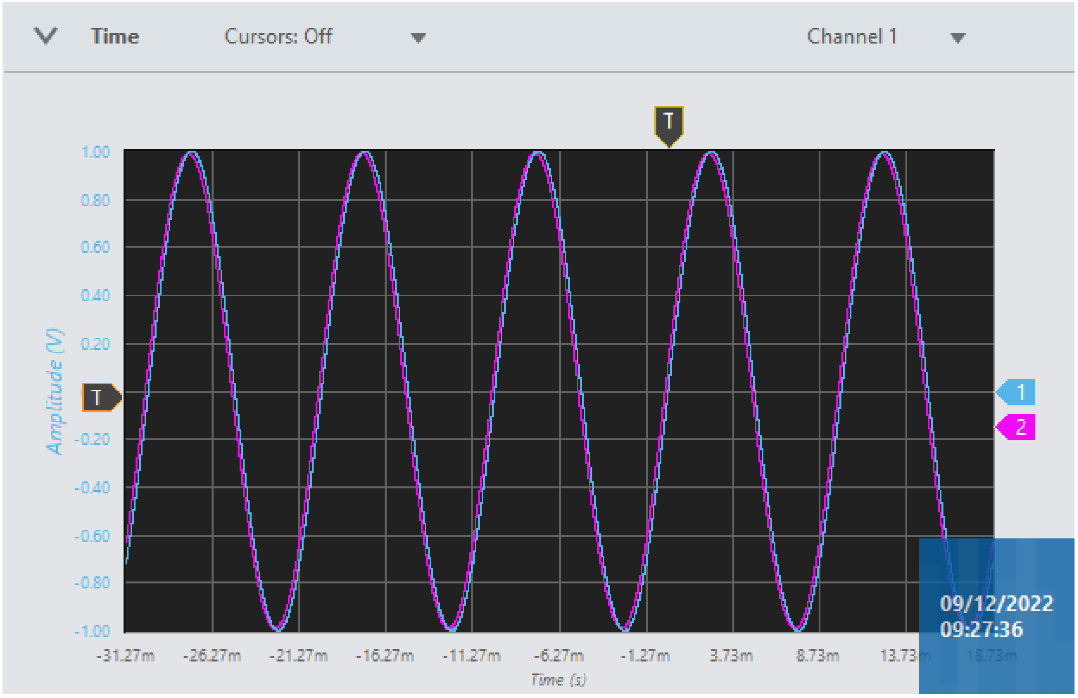
3.3.2 Experimental Results

Table 9 shows the peak-to-peak voltages at different frequencies with AC coupling on with Channel 2 and AC coupling off with Channel 1.

Table 9: 3.3 Peak-to-Peak Voltage Measurements

Frequency	Peak-to-Peak Voltage (V)	
	Channel 1	Channel 2
100 Hz	2.006	1.986
50 Hz	2.006	1.949
25 Hz	2.005	1.825
5 Hz	2.007	0.842153

Figure 5 - Figure 8 each show two different sine waves, channel 1 (Blue line) has AC coupling off while channel 2 (Pink line) has AC coupling on.



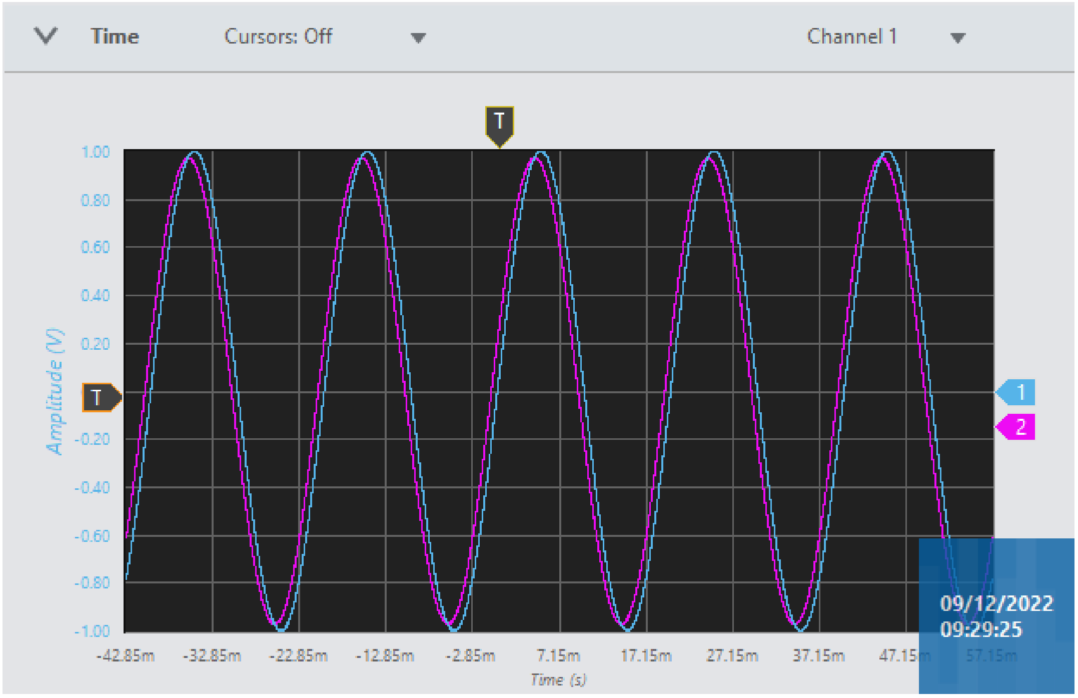
Measurements				
	Volts peak - peak	RMS	Frequency	Period
Channel 1	2.006V	707.431mV	100.004Hz	10ms
Channel 2	1.986V	700.167mV	99.972Hz	10.003ms

Trigger settings	Values
Mode	Auto
Type	Analog edge
Source	Channel 1
Level	0V
Slope	Rising
Acquisition delay	Disabled
Position	-6.272ms

Horizontal & acquisition settings	Values
Time per division	5ms
Acquisition	Decimate
Sampling	637 kS/s

Channel settings	Channel 1 values	Channel 2 values
Volts per division	200mV	200mV
Coupling	DC	AC
Probe attenuation	1x	1x
Vertical offset	0V	0V
Vertical position	0V	0V

Figure 5: 100 Hz Sine Wave



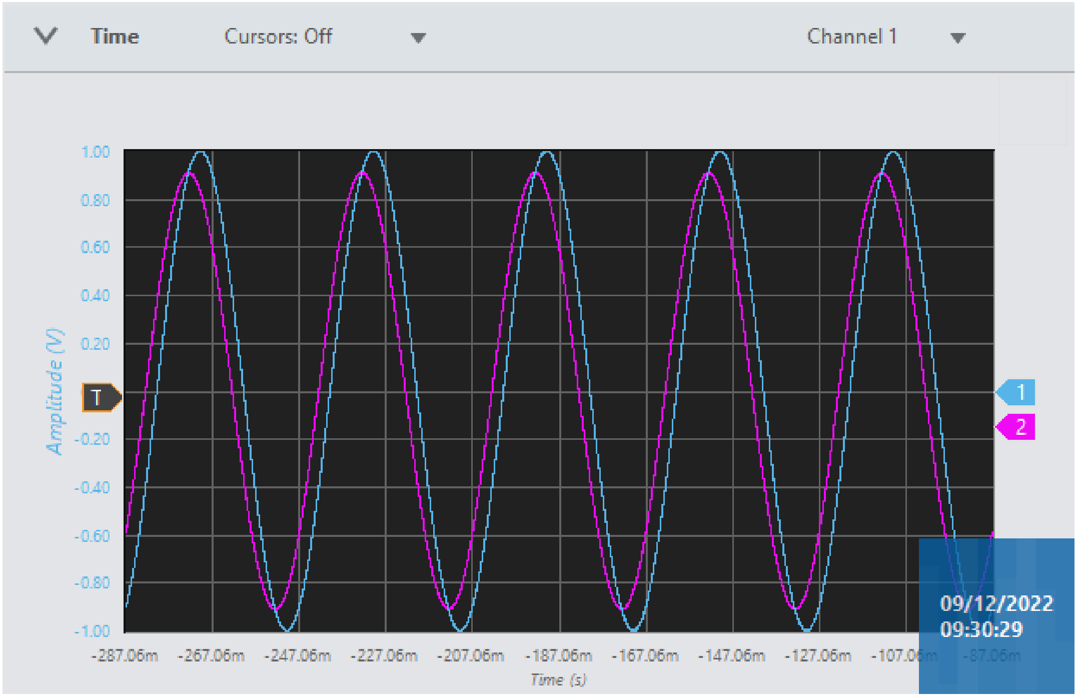
Measurements				
	Volts peak - peak	**RMS**	**Frequency**	**Period**
Channel 1	2.006V	707.747mV	50.008Hz	19.997ms
Channel 2	1.949V	687.534mV	50.001Hz	20ms

Trigger settings	Values
Mode	Auto
Type	Analog edge
Source	Channel 1
Level	0V
Slope	Rising
Acquisition delay	Disabled
Position	7.151ms

Horizontal & acquisition settings	Values
Time per division	10ms
Acquisition	Decimate
Sampling	319 kS/s

Channel settings	Channel 1 values	Channel 2 values
Volts per division	200mV	200mV
Coupling	DC	AC
Probe attenuation	1x	1x
Vertical offset	0V	0V
Vertical position	0V	0V

Figure 6: 50 Hz Sine Wave



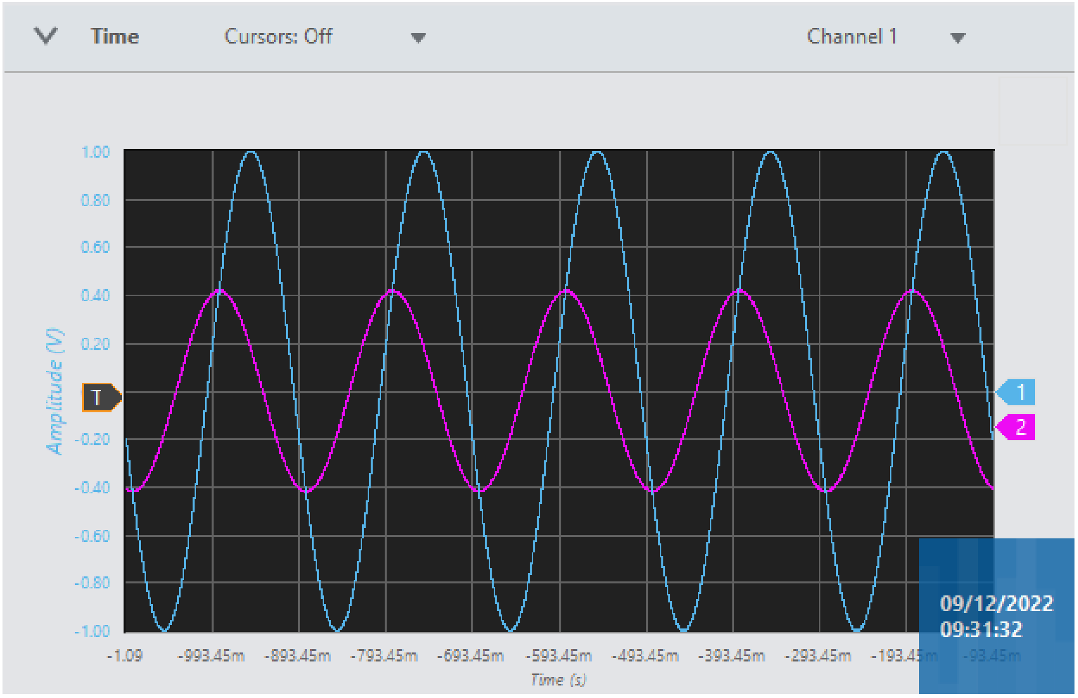
Measurements				
	Volts peak - peak	RMS	Frequency	Period
Channel 1	2.005V	704.198mV	25.002Hz	39.997ms
Channel 2	1.825V	637.43mV	25.001Hz	39.998ms

Trigger settings	Values
Mode	Auto
Type	Analog edge
Source	Channel 1
Level	0V
Slope	Rising
Acquisition delay	Disabled
Position	-187.061ms

Horizontal & acquisition settings	Values
Time per division	20ms
Acquisition	Decimate
Sampling	111 kS/s

Channel settings	Channel 1 values	Channel 2 values
Volts per division	200mV	200mV
Coupling	DC	AC
Probe attenuation	1x	1x
Vertical offset	0V	0V
Vertical position	0V	0V

Figure 7: 25 Hz Sine Wave



Measurements				
	Volts peak - peak	**RMS**	**Frequency**	**Period**
Channel 1	2.007V	709.501mV	4.999Hz	200.042ms
Channel 2	842.153mV	295.729mV	4.997Hz	200.112ms

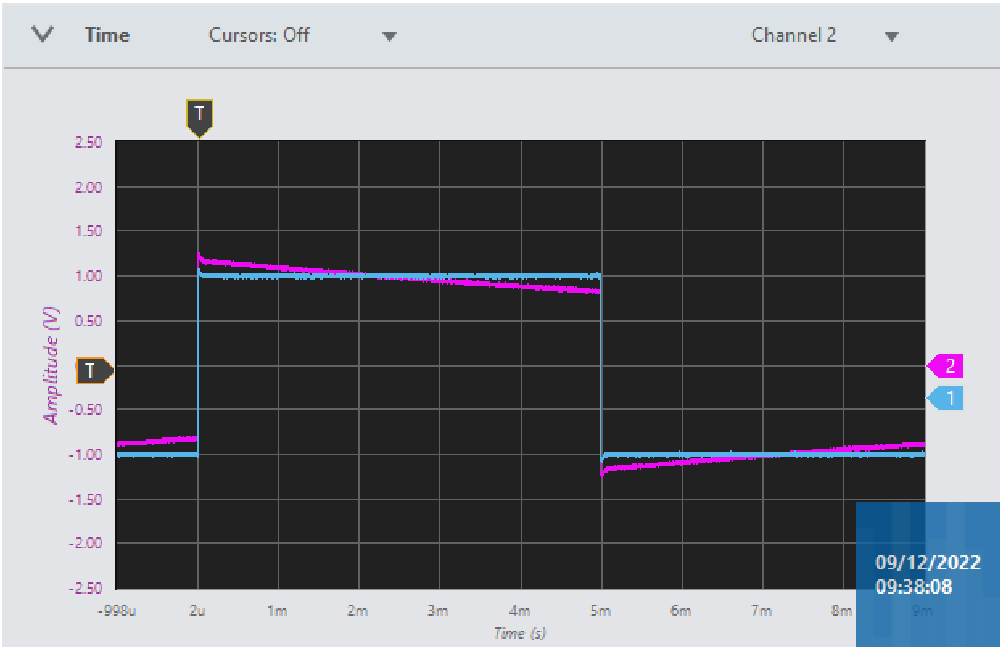
Trigger settings	Values
Mode	Auto
Type	Analog edge
Source	Channel 1
Level	0V
Slope	Rising
Acquisition delay	Disabled
Position	-593.448ms

Horizontal & acquisition settings	Values
Time per division	100ms
Acquisition	Decimate
Sampling	29.3 kS/s

Channel settings	Channel 1 values	Channel 2 values
Volts per division	200mV	200mV
Coupling	DC	AC
Probe attenuation	1x	1x
Vertical offset	0V	0V
Vertical position	0V	0V

Figure 8: 5 Hz Sine Wave

Figure 9 and Figure 10 show a square wave with two different frequencies. The AC coupling with the square wave makes the peak voltage higher with lowering frequencies compared to lower peak voltages with lower frequencies with the sine waves.



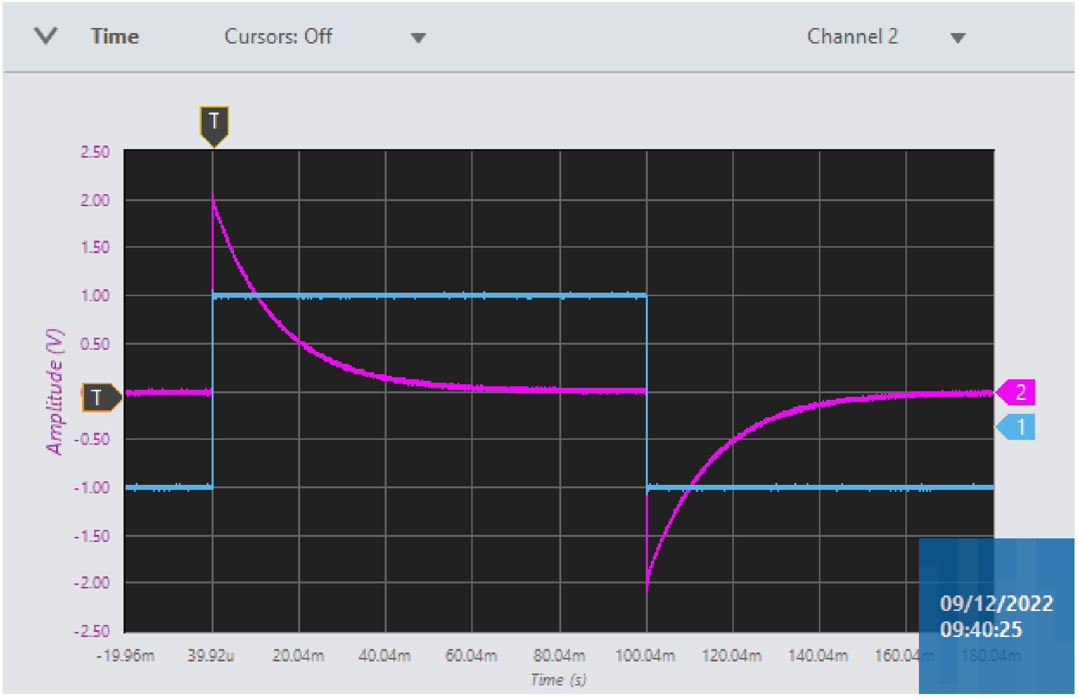
Measurements				
	Volts peak - peak	RMS	Frequency	Period
Channel 1	2.002V	1V	- - -	- - -
Channel 2	2.504V	990.529mV	- - -	- - -

Trigger settings	Values
Mode	Auto
Type	Analog edge
Source	Channel 1
Level	0V
Slope	Rising
Acquisition delay	Disabled
Position	4.002ms

Horizontal & acquisition settings	Values
Time per division	1ms
Acquisition	Decimate
Sampling	3.13 MS/s

Channel settings	Channel 1 values	Channel 2 values
Volts per division	500mV	500mV
Coupling	DC	AC
Probe attenuation	1x	1x
Vertical offset	0V	0V
Vertical position	0V	0V

Figure 9: 100 Hz Square Wave



Measurements				
	Volts peak - peak	**RMS**	**Frequency**	**Period**
Channel 1	1.994V	1V	- - -	- - -
Channel 2	4.137V	541.555mV	- - -	- - -

Trigger settings	Values
Mode	Auto
Type	Analog edge
Source	Channel 1
Level	0V
Slope	Rising
Acquisition delay	Disabled
Position	80.04ms

Horizontal & acquisition settings	Values
Time per division	20ms
Acquisition	Decimate
Sampling	160 kS/s

Channel settings	Channel 1 values	Channel 2 values
Volts per division	500mV	500mV
Coupling	DC	AC
Probe attenuation	1x	1x
Vertical offset	0V	0V
Vertical position	0V	0V

Figure 10: 5 Hz Square Wave

3.3.3 Analysis Questions

4.3.A. Note that the same signal was measured on both channels with the only difference being the use of AC Coupling (which acts as a high pass filter). Comment on the effect that AC coupling has on steady-state measurements (like the sine waves in Steps C & D). Be sure to look at both the magnitude and time delay differences as they relate to the frequency of the signal.

Answer:

By observation of the results, the average peak to peak voltage of the AC coupled signal is lower than the DC coupled signal. Hence, it could be concluded that the magnitude of AC coupled signal attenuates with the decreasing of frequency. This is because the AC coupling simulates a high-pass filter, the low-frequency signal is eliminated. In addition, the time delay increases - the AC peak phase shift occurs later than the DC signal peak.

4.3.B. Note that the same signal was measured on both channels with the only difference being the use of AC Coupling (which acts as a high pass filter). Comment on the effect that AC coupling had on the static portion of a measurement signal in steps E & F.

Answer:

As the frequency decreases, the AC coupled signal stabilizes to its final value at an exponentially faster rate. At 100hz the AC signal drops linearly, while at 5hz the signal stabilizes exponentially to 0. This is another example of AC coupling attenuation. At 5hz, the signal has more time to drop before the next peak, so the attenuation is exponentially worse.

4.3.C. Would you use AC coupling when recording the transient response of a system to a step input (signal measured in steps E & F)? Why or why not?

Answer:

do not use personal pronouns

We would not use AC coupling because it cannot remain stable when a stable input is applied when recording the response of a system to a step input. If the natural response of the system to a step input is fixed at the input voltage, then AC coupling may simulate attenuation that is not actually present in the system.

4.3.D. Using the .csv file from step F, estimate the time constant of the AC coupling setting of the ELVIS oscilloscope. Note that this is similar to a first order system response discussed in the "Modeling First & Second Order Systems" module located on the class lecture Canvas page.

Answer:

By extracting .csv data to Matlab, Figure 11: 5 Hz Square Wave presents the system response. Time constant is the time taken by system to reach 63% of its steady-state value. This is equivalent to the time between the spike and the voltage reaching 37% of its maximum value. By estimation of the figure, V_{max} = 2.04998 V, which is reached at t_1 = 0.01998s. 37% of the maximum value is about 0.7585 V, reached at t_2 = 0.0344s. $\boldsymbol{\tau = t_2 - t_1 = 0.01442}$. The result could also be checked by applying the same calculation to the second spike. The maximum absolute voltage is 2.03238 V, which is reached at t_3 = 0.11994s. And at t_4 = 0.1341s, 37% of the maximum absolute voltage that is 0.75198V is reached. $\tau = t_4 - t_3 = 0.01416$.

-1, no units at final final answer

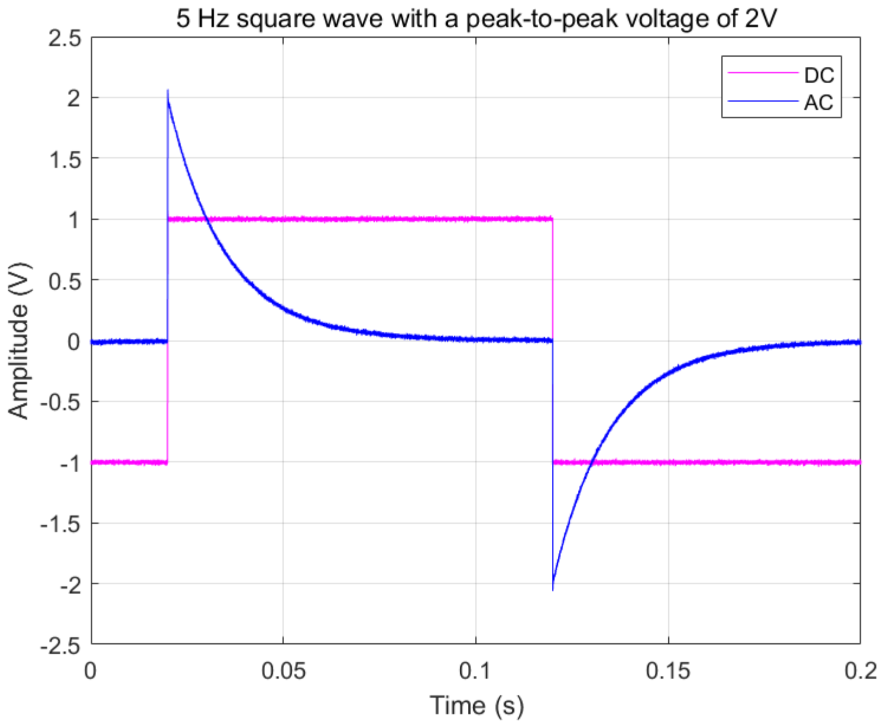


Figure 11: 5 Hz Square Wave by Matlab

3.3.4 General Discussion

-0.5; AC acts as high pass filter

By observing figures and results, after adding 2 V DC offset to the DC coupling, the curves move upward. Switching the mode to AC coupling, the system shape reverts to be the same as DC coupling without DC offset.

DC coupling is useful in modeling 1st order system and 2nd order system. The AC coupling can block the DC offset signal and eliminate the steady-state response.

3.4 Grounding Issues

-1 Did not mention comparison between Elvis DMM and oscilloscope nor the types of grounding each measurement device uses (chassis and floating ground)

3.4.1 Procedure Objectives

The objective of this part of the experiment is to show that the common ground that measurment devices share with circuit conponents may cause measurement problems. The procedure will examine how to connect the measurement devices in such a way that certain components being mesured do not get shorted out and appropriate measurments can be taken.

3.4.2 Experimental Results

The circuit in was made then the voltage drop was measured across each circuit. The circuit was then changed to have a AC voltage source with channel 1 measuring peak-to-peak drop across the input voltage and channel 2 measuring the voltage drop across each resistor. Channel 1 in Table 11 had the clips connected to the same points the entire time "measuring" the same thing. The ground issue that causes this error in measurement will be discussed in section 3.4.4.

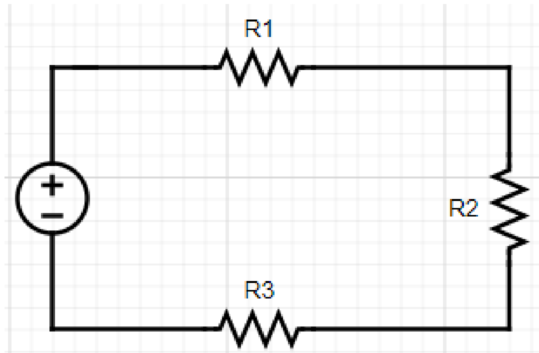


Figure 12: Resistor Circuit

Table 10: DC 3 Resistor Circuit Measurements

	R1	R2	R3
Voltage Drop (V)	2.9798	3.0466	2.9862

Table 11: AC Peak-to-Peak Voltage Measurements

	Channel 1	Channel 2
Peak- to-Peak Voltage of R1 (V)	5.92	5.906
Peak- to-Peak Voltage of R2 (V)	7.189	3.628
Peak- to-Peak Voltage of R3 (V)	7.663	2.552

The circuit shown in Figure 13 was made then the peak-to-peak voltage was taken across each component using an oscilloscope with channel 1 on the input voltage signal and channel 2 measuring each component. Like Table 11, Table 12 shows similar results with channel 1 always "measuring" the same thing but yielding different results depending on where channel 2 is located.

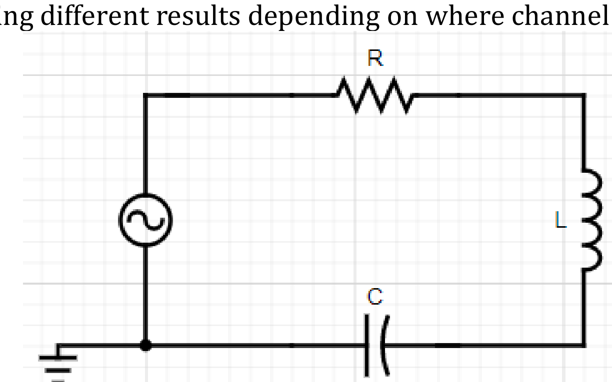
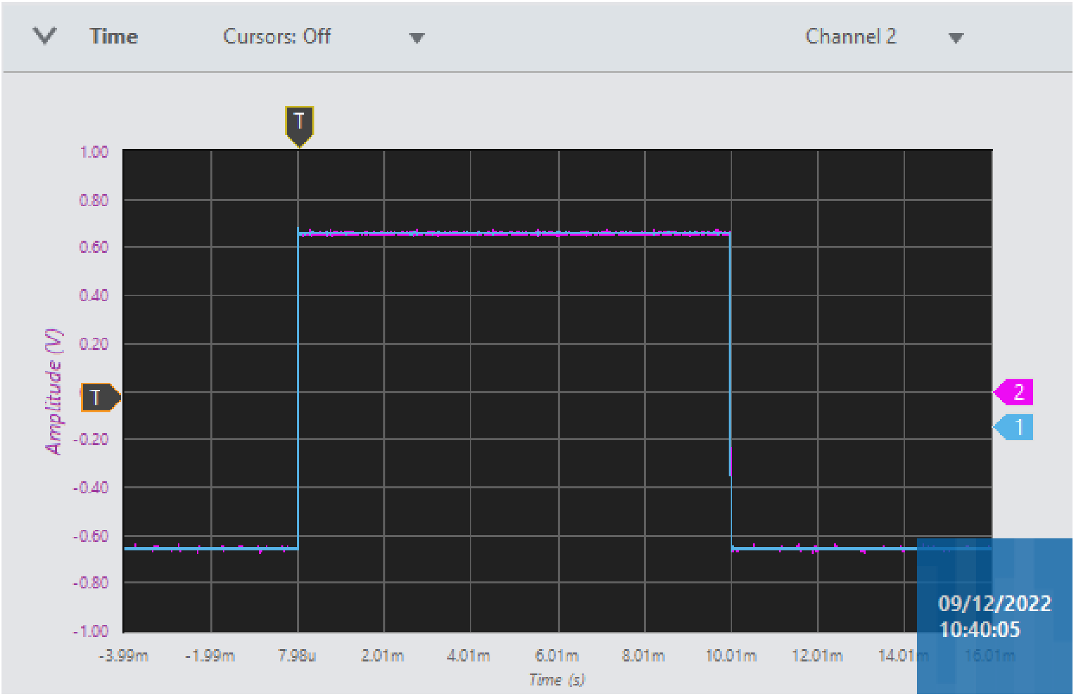


Figure 13: RLC Circuit

Table 12: RLC Circuit Measurements

	Channel 1	Channel 2
Peak- to-Peak Voltage of R (V)	5.92	5.906
Peak- to-Peak Voltage of L (V)	7.189	3.628
Peak- to-Peak Voltage of C (V)	7.663	2.552

-2 incorrect



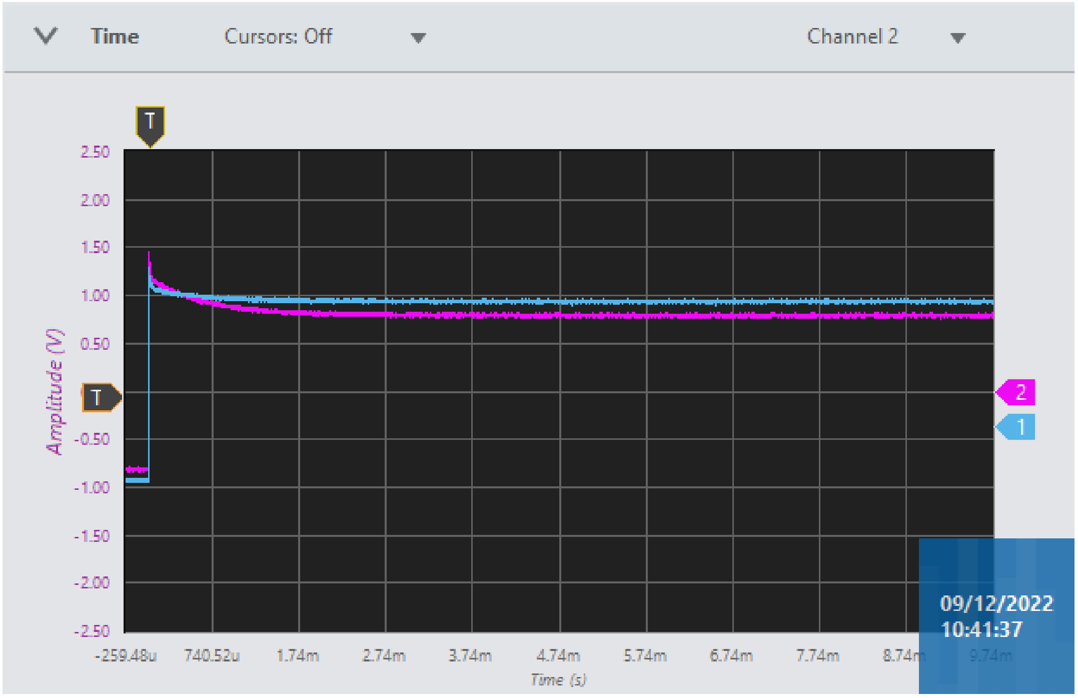
Measurements				
	Volts peak - peak	**RMS**	**Frequency**	**Period**
Channel 1	1.313V	658.967mV	- - -	- - -
Channel 2	1.316V	658.508mV	- - -	- - -

Trigger settings	**Values**
Mode	Auto
Type	Analog edge
Source	Channel 1
Level	0V
Slope	Rising
Acquisition delay	Disabled
Position	6.008ms

Horizontal & acquisition settings	**Values**
Time per division	2ms
Acquisition	Decimate
Sampling	1.59 MS/s

Channel settings	**Channel 1 values**	**Channel 2 values**
Volts per division	200mV	200mV
Coupling	DC	DC
Probe attenuation	1x	1x
Vertical offset	0V	0V
Vertical position	0V	0V

Figure 14: RLC Voltage Across the Resistor



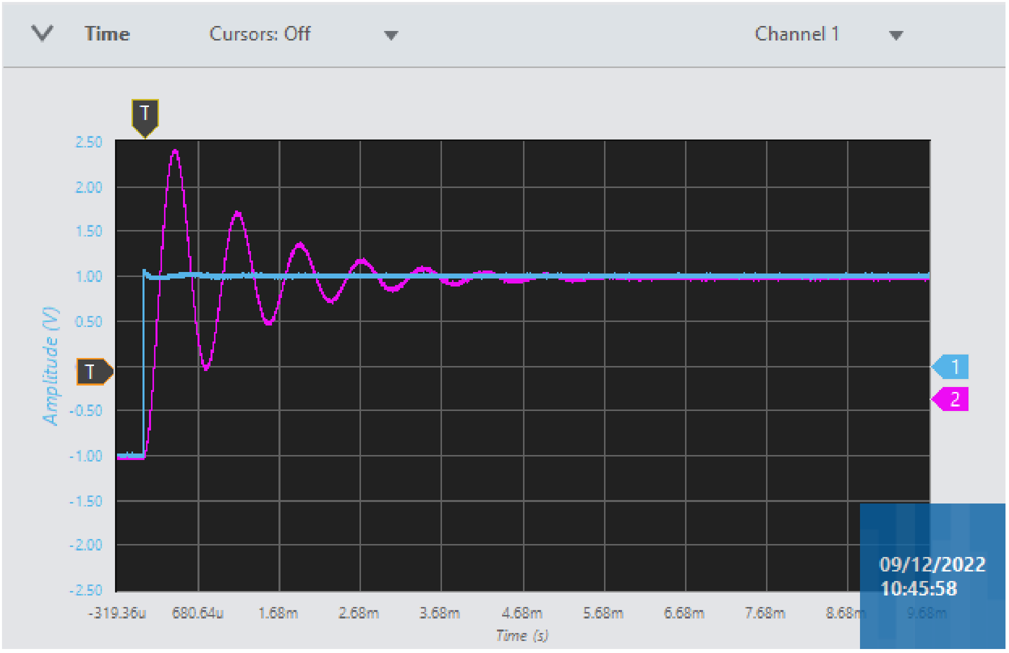
Measurements				
	Volts peak - peak	**RMS**	**Frequency**	**Period**
Channel 1	1.872V	941.97mV	- - -	- - -
Channel 2	1.61V	831.724mV	- - -	- - -

Trigger settings	**Values**
Mode	Auto
Type	Analog edge
Source	Channel 1
Level	0V
Slope	Rising
Acquisition delay	Disabled
Position	4.741ms

Horizontal & acquisition settings	**Values**
Time per division	1ms
Acquisition	Decimate
Sampling	3.13 MS/s

Channel settings	**Channel 1 values**	**Channel 2 values**
Volts per division	500mV	500mV
Coupling	DC	DC
Probe attenuation	1x	1x
Vertical offset	0V	0V
Vertical position	0V	0V

Figure 15: RLC Voltage Across the Inductor



Measurements				
	Volts peak - peak	**RMS**	**Frequency**	**Period**
Channel 1	2.108V	1.002V	- - -	- - -
Channel 2	3.455V	1.037V	- - -	- - -

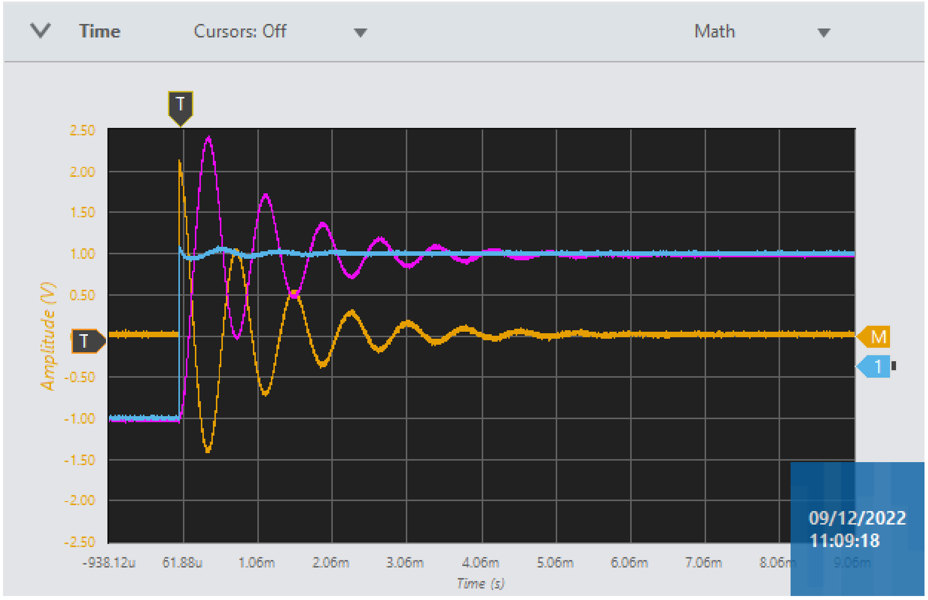
Trigger settings	**Values**
Mode	Auto
Type	Analog edge
Source	Channel 1
Level	-7.886mV
Slope	Rising
Acquisition delay	Disabled
Position	4.681ms

Horizontal & acquisition settings	**Values**
Time per division	1ms
Acquisition	Decimate
Sampling	3.13 MS/s

Channel settings	**Channel 1 values**	**Channel 2 values**
Volts per division	500mV	500mV
Coupling	DC	DC
Probe attenuation	1x	1x
Vertical offset	0V	0V
Vertical position	0V	0V

Figure 16: RLC Voltage Across the Capacitor

To account for the measurement device error that has been occurring in the previous parts of this section of the lab, there is a function in the oscilloscope that allows you to correct these errors. The orange line in Figure 17 and Figure 18 show the actual voltage drop across the inductor and resistor respectively.



Measurements				
	Volts peak - peak	RMS	Frequency	Period
Channel 1	2.111V	1.003V	- - -	- - -
Channel 2	3.484V	1.04V	- - -	- - -
Math	3.555V	338.476mV	- - -	- - -

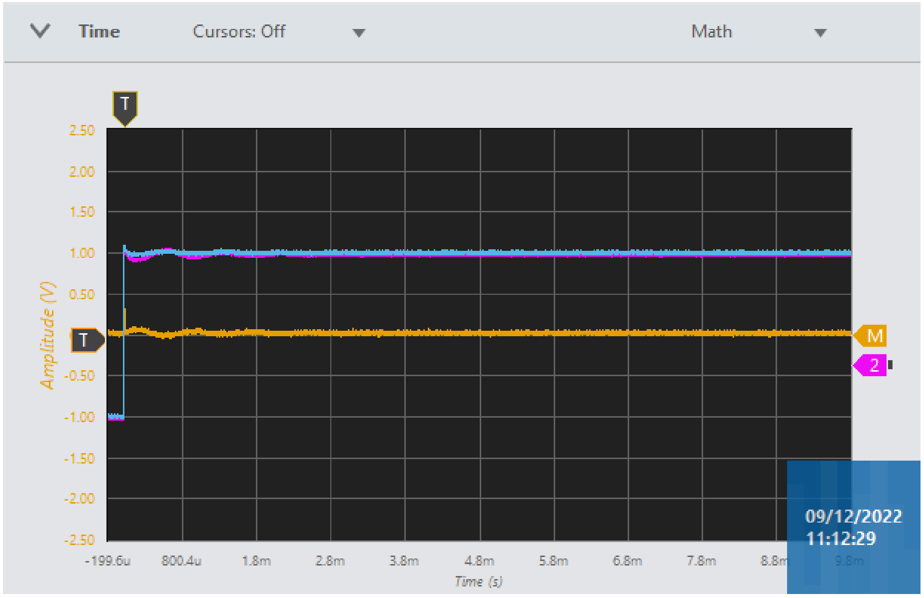
Trigger settings	Values
Mode	Auto
Type	Analog edge
Source	Channel 1
Level	-7.886mV
Slope	Rising
Acquisition delay	Disabled
Position	4.062ms

Horizontal & acquisition settings	Values
Time per division	1ms
Acquisition	Decimate
Sampling	3.13 MS/s

Channel settings	Channel 1 values	Channel 2 values
Volts per division	500mV	500mV
Coupling	DC	DC
Probe attenuation	1x	1x
Vertical offset	0V	0V
Vertical position	0V	0V

Math settings	Math values
Function	A - B
A Source	Channel 1
B Source	Channel 2
Volts per division	500mV
Vertical position	0V

Figure 17: Actual Voltage Drop Across Inductor



Measurements	Volts peak - peak	RMS	Frequency	Period
Channel 1	2.163V	1.007V	- - -	- - -
Channel 2	2.163V	983.257mV	- - -	- - -
Math	694.226mV	29.276mV	- - -	- - -

Trigger settings	Values
Mode	Auto
Type	Analog edge
Source	Channel 1
Level	-7.886mV
Slope	Rising
Acquisition delay	Disabled
Position	4.8ms

Horizontal & acquisition settings	Values
Time per division	1ms
Acquisition	Decimate
Sampling	3.13 MS/s

Channel settings	Channel 1 values	Channel 2 values
Volts per division	500mV	500mV
Coupling	DC	DC
Probe attenuation	1x	1x
Vertical offset	0V	0V
Vertical position	0V	0V

Math settings	Math values
Function	A - B
A Source	Channel 1
B Source	Channel 2
Volts per division	500mV
Vertical position	0V

Figure 1819: Actual Voltage Drop Across Resistor

3.4.3 Analysis Questions

5.3.A. For Procedure A (resistors in series), what differences did you observe between the ELVIS DMM and Oscilloscope voltage measurements?

i. Explain why the DMM measurements and some of the Oscilloscope measurements were accurate.

Answer:
The voltage drop measurement of the DMM is accurate because the ground of the DMM is (obviously) not connected to the ground of the variable power supply. It is essentially an isolated measurement device, similar to the way the Fluke DMM works.

ii. Describe the impact that chassis grounding had for each of the incorrect Oscilloscope measurements (i.e. how was the original circuit changed, does the measurement make sense based any shorts in the system, etc).

Answer:
When R2 was measured, the voltage drop was incorrectly measured as higher than it should have been. This is because due to the location of the ground wire, R1 was shorted out and the circuit was changed to a two-resistor circuit. Similarly, the voltage drop of R3 was incorrect because both R1 and R2 were shorted out, creating a single-resistor circuit with a much higher voltage drop than a three-resistor circuit.

5.3.B. Compare the measured responses of the voltage drop across the capacitor taken in Procedure B and Procedure C. Are the responses the same? If so, why? If not, which measurement is correct and what does the incorrect measurement actually represent?

Answer:
The voltage output of procedure B and procedure C are the same when measuring the capacitance in the RLC circuit. This is because the circuit ground is connected to the same circuit node as the oscilloscope ground, so there is no short in any part of the circuit during the measurement. Chassis ground is not an issue when measuring circuit components that are in contact with power supply ground.

5.3.C. Compare the measured responses of the voltage drop across the inductor taken in Procedure B and Procedure C. Are the responses the same? If so, why? If not, which measurement is correct and what type of system does the incorrect measurement actually represent?

Answer:
When measuring the voltage across the inductor, procedure C is correct and B is incorrect. In program B, the capacitor is shorted out and the circuit represented is a first order R-L circuit. In program C, two channels are used to ensure that the entire circuit is measured and no short circuit occurs.

5.3.D. Compare the measured responses of the voltage drop across the resistor taken in Procedure B and Procedure C. Are the responses the same? If so, why? If not, which measurement is correct and what type of system does the incorrect measurement actually represent?

Answer:

When measuring resistance, procedure C is correct and B is incorrect. In program B, the inductor and capacitor are shorted out, creating a single resistive circuit that drops the entire input voltage. In program C, two channels are used to ensure that the entire circuit is measured and no shorts occur.

3.4.4 General Discussion

The measurements with the ELVIS DMM are very different from those with the ELVIS oscilloscope. The underlying reason for this is that the ELVIS oscilloscope's chassis ground intentionally shorts some components in the system, so we need to use multiple channels of the oscilloscope to measure the voltage output of each component in the system.

Do not use bullet points. For each experiment, provide a paragraph of conclusion.

4. Conclusions

-2, provide more detail discussion, for example causation of observed phenomenon

Having performed the experiment, and after a thorough analysis of the data, the following points are therefore concluded:

- ELVIS DMM has a smaller uncertainty than that of Fluke DMM. Precision of ELVIS DMM and Fluke DMM is different, while ELVIS DMM has a higher precision.
- In some cases, the internal loading of the measurement devices can lead to significant error to the measured values. For instance, the measurements with voltmeter are not so reliable when measuring the voltage drop across very large resistance.
- Compared with DC coupling, AC coupling will block the DC components of the signal and attenuate the low frequency components. Hence, it will eliminate the steady-state response of the system, which is not useful for modeling both the 1st order system and 2nd order system.
- The chassis ground of ELVIS Oscilloscope will intentionally short out some components of the system, so we need to use multiple channels with oscilloscope to measure the voltage output of every component in the system.

APPENDICES

A – EQUIPMENT LIST

Table 13: Equipment List

Equipment Description	Model Number	Serial Number
Digital Multimeter	Fluke 115	30112965WS
Prototyping Base	NI ELVIS III	3169FFF
Prototyping Board	NI ELVIS III	316811A

Note: list lab equipment for both sessions

B – MATLAB Code (or Excel, other computational software, etc)

Excel Code for 2.4.A

2.4.A.						
Fluke	IV	I^2*R	V^2/R	R3	V	I
Nominal num of P	=H3*G3	=H3^2*F3	=G3^2/F3	217	2.006	0.009
Uncertainty of P	=SQRT((B6*H5)^2+(B8*G5)^2)	=SQRT((C6*H5)^2+(C8*F5)^2)	=SQRT((D6*G5)^2+(D8*F5)^2)	deltaR	deltaV	deltaI
	dP/dI	dP/dI	dP/dV	0.1	0.001	0.001
	=G3	=2*H3*F3	=2*G3/F3			
	dP/dV	dP/dR	dP/dR			
	=H3	=H3^2	=-(G3^2)/F3^2			
ELVIS	IV	I^2*R	V^2/R	R3	V	I
Nominal num of P	=H14*G14	=H14^2*F14	=G14^2/F14	217.1	2.0097	0.00932
Uncertainty of P	=SQRT((B17*H16)^2+(B19*G16)^2)	=SQRT((C17*H16)^2+(C19*F16)^2)	=SQRT((D17*G16)^2+(D19*F16)^2)	deltaR	deltaV	deltaI
	dP/dI	dP/dI	dP/dV	0.01	0.0001	0.00001
	=G14	=2*H14*F14	=2*G14/F14			
	dP/dV	dP/dR	dP/dR			
	=H14	=H14^2	=-(G14^2)/F14^2			

Figure 20: 2.4.A Excel Sheet

MATLAB Code for 4.3.D:

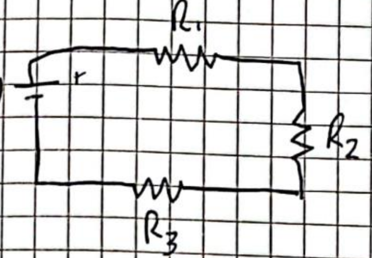
```
%% Section 4.3.D
clc;
clear;
close all;
% Read all the csv files
data = csvread('4.2_F.csv',1,0);

% Time data
t = data(:,1);

% Output voltage measurement
DC = data(:,2);
AC = data(:,5);

% Figure
plot(t,DC,'m',t,AC,'b');
grid on;
set(gca,'XLim',[0 0.2]);
set(gca,'YLim',[-2.5 2.5]);
set(gcf,'color','white');
xlabel('Time (s)');
ylabel('Amplitude (V)');
title('5 Hz square wave with a peak-to-peak
voltage of 2V');
legend('DC','AC')
```

C – Scanned Lab Notes

Prelab #1:

$R_1 = R_2 = R_3 = 220\,\Omega$

2.2A



$V = IR$

$R_t = R_1 + R_2 + R_3 = 660\,\Omega$

$I = V/R = 6/660 = 0.009091\,A = 9.091\,mA$

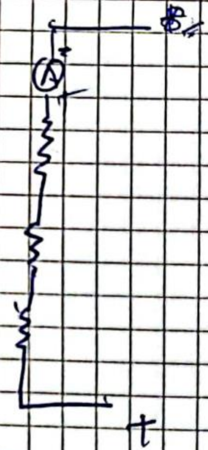
3.2A

$\frac{1}{R_t} = 1/10 + 1/10$

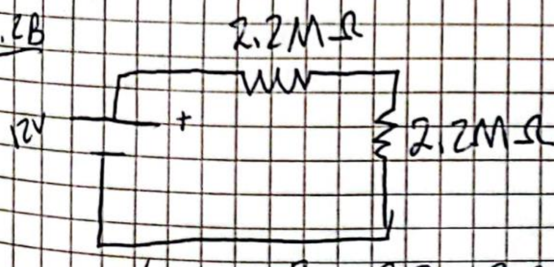
$R_t = 5\,\Omega$

$I = 2V/5\Omega = 0.4A = 400\,mA$

$I_{Branch} = 2V/10\Omega = 0.2A = 200\,mA$



3.2B

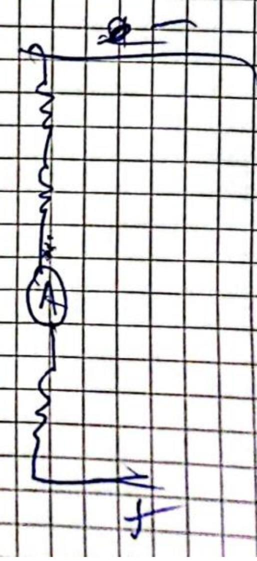


$I = \frac{12V}{4.4M\Omega}$

$R_t = 2.2 + 2.2 = 4.4M\Omega$

$I = 0.00027\,mA$

$V = 0.0000027 \cdot 2.2M\Omega = 6V$



2.3 A

$R_1 = 216.70\,\Omega \pm 0.01\,\Omega$

$R_2 = 216.10\,\Omega \pm 0.01\,\Omega$

$R_3 = 217.18\,\Omega \pm 0.01\,\Omega$

Variable Power Supply:

Name: NI Elvis III

Serial: 3169FFF

Breadboard:

Serial: 316811A

$R_1 = 216.\cancel{8}6 \pm 0.1\,\Omega$

$R_2 = 216.0 \pm 0.1\,\Omega$

$R_3 = 217.0 \pm 0.1\,\Omega$

Name: Fluke 115 DMM

Serial: 30112965 WS

2.3.C

Fluke

$V_{in} = 6.003V \pm 0.001V$

$V_{R3} = 2.006V \pm 0.001V$

$I_{R3} = 0.009 \pm 0.001A$

Elvis:

$V_{in} = 6.012V \pm 0.001V$

$V_{R3} = \cancel{2.00}\ 2.0097 \pm 0.0001V$

$I_{R3} = 0.00932A \pm 0.00001A$

Aalya

3.3.A

~~**Fluke**~~

~~$R_{a_1} =$~~

~~$R_{a_2} =$~~

~~$R_{b_1} =$~~

~~$R_{b_2} =$~~

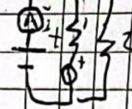
Elvis

$R_{a_1} = 10.095\,\Omega \cancel{\pm 0.001\Omega}$

$R_{a_2} = 10.093\,\Omega \cancel{\pm 0.001\Omega}$

$R_{b_1} = \cancel{2.2297}\ 2.2322\,M\Omega \cancel{\pm 0.001}$

$R_{b_2} = 2.2228\,M\Omega \cancel{\pm 0.0001 M\Omega}$



3.3.C. Elvis:

$V_{in} = 1.8939\,V$ ~~± 0.0001 V~~

$I =$ ~~0.36~~ $0.31239\,A$ ~~± 0.00001 A~~

$I_{R_{a1}} = 0.18774$ ~~± 0.00001 A~~

$I_{R_{a2}} =$ ~~0.189~~ 0.19031 ~~± 0.00001 A~~

3.3.~~D~~ E

Elvis

$V_{in} =$ ~~12.018 V ± 12~~ $12.021\,V$ ~~± 0.001 V~~

$V_{R_{b1}} = 5.425\,V$ ~~± 0.001 V~~

$V_{R_{b2}} = 5.402\,V$ ~~± 0.001 V~~

$I = 0.00005\,A \pm$ ~~0.00004 A~~

3.3.F

$I = 0.000\,A \pm 0.001\,A$

not measurable

Satya
08/29

2.4.A

$P = IV$ $\quad P = I^2 R$ $\quad P = V^2/R$

$\frac{\partial P}{\partial I} = V$ $\quad \frac{\partial P}{\partial I} = 2IR$ $\quad \frac{\partial P}{\partial V} = 2V/R$

$\frac{\partial P}{\partial V} = I$ $\quad \frac{\partial P}{\partial R} = I^2$ $\quad \frac{\partial P}{\partial R} = -V^2/R^2$

4.2.A.C Volts Peak-to-Peak NI ElVis

Channel 1: ~~2.06V~~ ~~2.004V~~ 2.006V

Channel 2: ~~2.048V~~ ~~1.999V~~ 1.986V

4.2.1.i. C1: 2.006V

~~C2~~ C2: 1.949V] 50 Hz

ii. C1: 2.005V

C2: 1.825V

iii) C1: 2.007V

C2: 842.153 mV

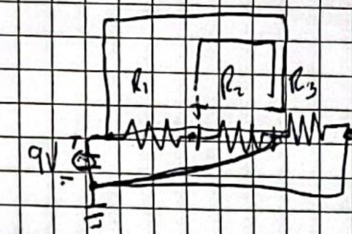
Satya 09/12

5.2.A.i

$V_{R_1} = 2.9798V$

$V_{R_2} = 3.0466V$

$V_{R_3} = 2.9862V$



5.2.A.ii

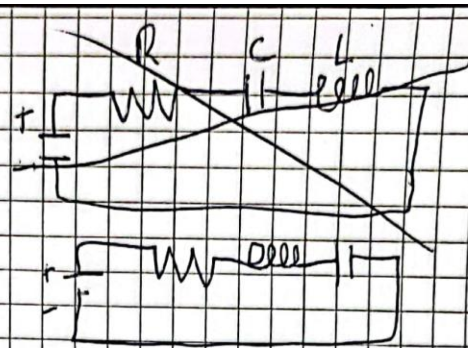
	C1	C2
$V_{pp}R_1$	5.92V	5.906V
$V_{pp}R_2$	7.189V	3.628V
$V_{pp}R_3$	7.663V	2.552V

5.2.B

V_R = ~~1.318V~~

V_C = ~~2.005V~~

V_L = ~~3.539V~~



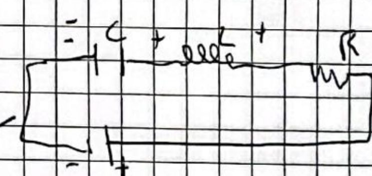
	C1	C2
V_R	1.313V	1.316V
V_L	1.872V	1.61V
V_C	~~2.111V~~ 2.108V	3.455V

5.C.B

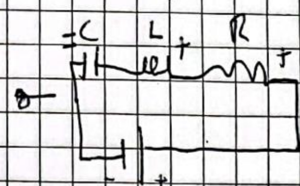
A-B

i. T/div = 1ms V/div = 500mV

ii. T/div = 1ms V/div = 500mV



iii. T/div = ~~[illegible]~~ 1ms V/div = 500mV



[illegible] 09/12