Oscilloscope

Equipment:

- Computer with PASCO ScienceWorkshop 850 Interface and PASCO Capstone
- Signal Generator
- Voltage Sensor (Round DIN to two Banana plugs)
- Signal Generator cable (BNC plug to Alligator clips)
- 3 alligator wires
- Multimeter
- 6 V Lantern Battery
- 100 Ω Resistor
- 470 Ω Resistor (Yellow, Purple, Brown, Gold)
- 2.2 μF mylar Capacitor

Introduction

A traditional instrument to display the electrical signals is the oscilloscope. Capstone software allows the PASCO Interface to function as an oscilloscope. When PASCO Voltage sensor is connected to the source of an electrical signal, the Interface monitors the voltage, while the Capstone software displays the values of voltage as a function of time.
Voltage of DC source doesn't change with time; therefore, when Voltage Sensor is connected to DC power supply (battery), the software displays a flat line either below or above the time axis depending on the direction of the voltage.
However, when Voltage Sensor is connected to AC powers supply (socket), the resulting graph of voltage vs. time, takes the form of a sin function:

$$V(t) = V_{max} \sin(2\pi f t)$$

The voltage varies sinusoidally from $+V_{max}$ to $-V_{max}$ with frequency f. Because of this oscillation, the direction of the voltage, and hence the direction of the current, changes back and forth.

Oscilloscope displays instant values of the AC voltages but not RMS values of the voltage needed to assess energy provided by the AC power supply. RMS values of the voltage should be measured with a voltmeter. The biggest difference between an oscilloscope and an AC voltmeter is that the oscilloscope displays the variations the voltage, while the voltmeter measures the RMS voltage. With the oscilloscope, a "peak voltage" or max magnitude of the voltage could be measured and RMS value could be calculated from it.
Alternatively, with the voltmeter, RMS value could be measured and V_{max} could be calculated from it

$$V_{RMS} = \frac{V_{max}}{\sqrt{2}} \text{ or } V_{max} = \sqrt{2}V_{RMS}$$

. Objective:

- *To compare AC and DC voltage signals displayed by the oscilloscope*
- *To compare AC voltages (MAX and RMS) measured with a Multimeter and an Oscilloscope*

Part #1: Displaying a DC Signal

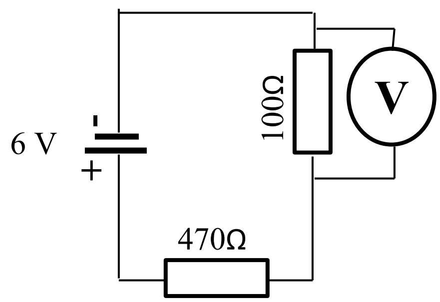

Figure 1. Schematic diagram of series circuit using DC power source.

1. Construct a series circuit with the 6 V battery, a 100 Ω resistor, and a 470 Ω resistor as shown in Figure 1.
2. Set the Multimeter as a DC Voltmeter.
3. Measure the voltage across each resistor and the terminal voltage of the battery. (Refer to Lab #2).
4. Place alligator clips on the end of the voltage sensor cable. ***Very carefully*** insert Voltage Sensor cable into analog input A of the PASCO interface. (Make sure the notch is at the top.)
5. Open "Oscilloscope Set Up" from http://physlab.tamucc.edu/ (Lab 7 line).
6. For each resistor, and then for the battery, connect the Voltage Sensor's clips across the component, take data briefly in Capstone, stop Capstone, then use the Coordinate Tool (cross wire) to measure the voltage.
7. How do the voltage measurements compare between the two instruments? Include your findings in the report.

Voltage	Voltmeter	Oscilloscope	% Difference
$V_{100\,\Omega}$ (V)			
$V_{470\,\Omega}$ (V)			
V_{batt} (V)			

Table 1. DC Voltage Measurements.

Part# 2: Measuring AC Signals

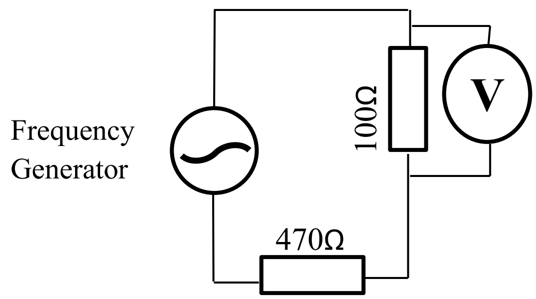

Figure 2. Schematic diagram of series circuit using AC power source.

1. Attach a BNC cable to Channel 1 (CH1) of the Frequency Generator.
2. Construct a series circuit with the Frequency Generator, a 100 Ω resistor, and a 470 Ω resistor as shown in Figure 2. (It's the same circuit, with the frequency generator replacing the battery.)
3. Ground the circuit. Connect the Output of PASCO (⏚) to the 470 Ω resistor with a banana cable.
4. Connect the Voltage Sensor's clips across the 100 Ω resistor.
5. Set the Frequency Generator to:
    - Frequency (FREQ) = 1200 Hz
    - Amplitude (AMPL) = 10 V
6. Press FREQ button to change frequency. Use the knob to increase/decrease frequency. Use the left/right arrows to alter precision (e.g. to change from thousands of Hz to hundreds of Hz).
    - Make sure to Press FREQ button again after the frequency has been set.
    - Change the amplitude in a similar manner using AMPL button.
7. Monitor the signal using Capstone's virtual oscilloscope. While monitoring the signal, adjust the frequency above and below 1200 Hz (± 1000 Hz), then return the frequency to 1200 Hz. Similarly, adjust the amplitude above and below 10 V, then return the amplitude to 10 V.
8. Notice how changes to frequency and amplitude affected the appearance of the graph.
    - Include the description of the observed changes in the report.
    - Describe differences between AC and DC signals in the report.
9. Stop monitoring. If the display doesn't look like a nice sine wave, you may have to stretch or compress the time axis, then monitor again for a brief time.
10. Measure the Period of the signal with the aid of Coordinate Tool and enter the measured values in Table 2. **Hint:** The Period is the time between two consecutive maximums.
    1. Increase the precision of the coordinate tool before calculating the Period.
        - Right click on the coordinate tool, then select *Tool Properties*.
        - Select *Numerical Format*, then select *Horizontal Coordinate*.
        - Increase *Number of Decimal Places* to 5.

11. Calculate the frequency of the signal from the measured value of Period.
12. Compare the calculated frequency with the one shown on Frequency Generator Display.

Measured Period (s)	Calculated frequency (Hz)	Displayed frequency (Hz)	% Difference

Table 2. Measured and Calculated values of AC frequency.

13. Measure MAX voltage of signal with Coordinate Tool. Record MAX in Table 3 for 100 Ω resistor.
14. Connect the Voltage Sensor across the 470 Ω resistor to measure the MAX voltage of that circuit element. Do the same for the Frequency Generator. Record the values in Table 3.
15. For both DC and AC circuits, investigate if the voltages for each resistor add up to the power supply voltage. Include your findings in the report.

Voltage	Voltmeter (RMS Voltage)	Oscilloscope (MAX Voltage)	Ratio (Voltmeter / Oscilloscope)	$V(t) = V_{max}\sin(2\pi f t)$
$V_{100\,\Omega}$ (V)				
$V_{470\,\Omega}$ (V)				
V_{EMF} (V)				

Table 3. AC Voltage Measurements in a series circuit consisting of a 100 ohm resistor and a 470 ohm resistor, using a frequency generator to provide the EMF.

16. Set the Multimeter as an AC Voltmeter.
17. Measure the voltage across each resistor and the terminal voltage of the Frequency Generator. Record the values in Table 3.
18. For each element of the circuit, compose a function V(t) using V_{max} and the displayed frequency from Table 2. **Hint:** $V(t) = V_{max}\sin(2\pi f t)$
19. Comment on the ratios observed in Table 3 and how they compare to the expected ratio.
20. Disconnect the Voltage Sensor from the circuit. Adjust the voltage scale to millivolts (click on the vertical axis and scroll). Similarly, adjust the time scale to hundredths of a second. While monitoring the signal, hold the one of the metal ends of the voltage sensor and bring it in proximity to various electrical devices. Notice where you see a signal roughly resembling a sin wave.
21. For the signal with the largest amplitude, measure peak voltage and period. (Increase precision of coordinate tool). Calculate the frequency of the signal. What is the link between the frequency and the source?

Part# 3: Displaying different AC Signals

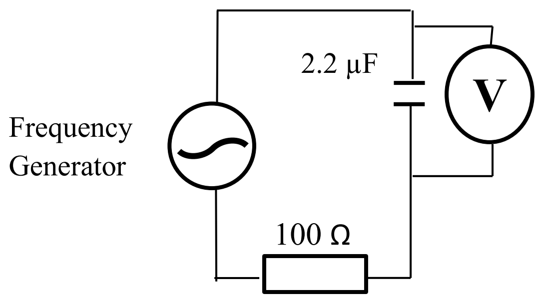

Figure 3. Schematic diagram of an AC circuit with a resistor and capacitor in series.

1. Set up the circuit depicted in Figure 3. (One resistor has been replaced by a capacitor.)
2. Set the Frequency Generator to 500 Hz and 10 V. Make sure circuit is grounded to the PASCO (⏚).
3. Connect the Voltage Sensor across the capacitor and monitor the AC signal. Stop monitoring and record the MAX voltage of the capacitor.
4. Using the same technique, record the MAX voltage of the resistor and the Frequency Generator.
5. Repeat all 3 measurements for frequencies ranging from 500 – 5500 Hz in increments of 1000 Hz.
6. Check the effect of the frequency on the values V_R, V_C, and V_{EMF} by plotting each parameter against frequency on the same graph (V_R vs freq, V_C vs freq, V_{EMF} vs freq).

Frequency (Hz)	500	1500	2500	3500	4500	5500
Peak V_c (V)						
Peak V_r (V)						
Peak V_{emf} (V)						

Table 4. Measurements for voltage of an AC circuit consisting of a resistor and a capacitor in series.

7. How does the increase in frequency affect the voltage across the capacitor compared to the resistor?
8. For 500 Hz, add voltage of the capacitor and resistor ($V_C + V_R$), and calculate the Pythagorean addition of voltage of the capacitor and resistor ($\sqrt{V_C^2 + V_R^2}$).
9. Identify which type of addition of V_R and V_C (regular sum or Pythagorean addition) matches better with V_{EMF} of the power supply. Give a reason why. **Hint:** Do V_R and V_C peak at the same time?

Frequency (Hz)	Peak V_c (V)	Peak V_r (V)	Peak V_{emf} (V)	$V_c + V_r$	$\sqrt{(V_c^2 + V_r^2)}$

Table 5. Calculations of AC voltage for 500 Hz signal in RC circuit.

Requirements for the Report:

The report must contain a **Header** at the top (Title of Lab, Authors, and Date)

Abstract Section must contain the following in paragraph form:

- Brief Introduction that includes objectives and basic theory of the lab.
- Methodology describing broadly what was done, using what tools, and what was measured/recorded.
- Data Summary including quantities worked into sentences. Describe the importance of each Table and Graph.
    - Compare DC voltage measurements between multimeter and oscilloscope in Table 1.
    - Describe difference between DC and AC. How does AC signal change when you change frequency? Amplitude?
    - In Table 2, how does calculated frequency compare with frequency displayed on Function Generator? Discuss reasons for differences between the two frequencies.
    - For both AC and DC circuits, state if sum of the resistor voltages matches the power supply voltage. Do both AC and DC sources obey the rules of voltage in series circuits?
    - How do ratios in Table 3 (Voltmeter/Oscilloscope) compare against expected ratio $V_{RMS}/V_{MAX} = 1/\sqrt{2}$? Discuss reasons for differences between the measured and expected ratios.
    - For the chosen background signal (when sensor was disconnected), state your decision on the link between the measured frequency and the source. Discuss your reasoning.
    - What does the data in Table 4 and the graph illustrate about the effect of frequency on voltage across the capacitor? Resistor? State the difference in the effect that frequency has on each voltage.
    - Discuss which type of addition of V_R and V_C (regular sum or Pythagorean addition) matches better with the V_{EMF}. Why?
- The lab manual contains questions and/or imperatives throughout that will guide you with the conclusions. **Always incorporate the questions and/or imperatives from the lab manual**.

Data Section must contain the following:
[Each table and graph should be labeled and descriptively captioned]

- 5 Tables
- 1 Graph (V_R vs freq, V_C vs freq, V_{EMF} vs freq.)