## INTRODUCTION:

In this laboratory the student will investigate the operation of a series AC circuit. An Agilent 33120A Function Generator will be used to produce AC time varying waveform.

## PRELAB – PART A – PSPICE SIMULATION:

1. Using PSpice, build the circuit shown in Figure 10.1. The parts needed are: **VSIN**, **r**, **L**, **C**, and **GND_Earth**. Configure the **VSIN** component's parameters:

**DC=0**, **AC=0**, **VOFF=0**, **VAMPL=1**, and **Freq=10k**.

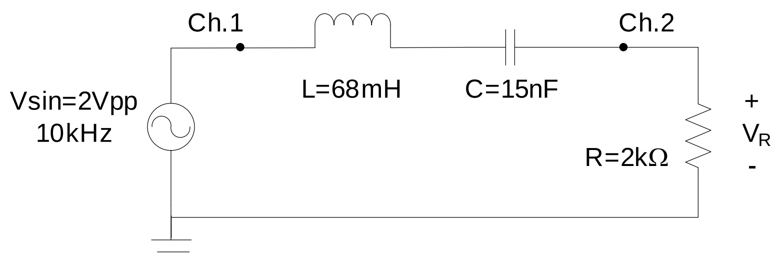
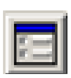



**Figure 10.1: AC Series Circuit.**

2. Label the wire attached to the positive terminal of the source "**Ch.1**" and the wire connected to the top of the resistor "**Ch.2**" as shown in the figure.

3. Place voltage markers  at Ch.1 (source voltage) and Ch.2 (resistor voltage).

4. Choose **Analysis→Setup**… or click  and enable a "**Transient**" analysis.

5. Set the **Print Step** to **0**, the **Final Time** to **0.5ms**, the **Step-Ceiling** to **10ns**, and check the box to "**Skip initial transient solution**".

6. Choose **Analysis→Simulate**… or click  to simulate the circuit's operation.

7. A Probe Plot will automatically pop up displaying the AC voltages, with respect to ground, as a function of time at each marker location. Note that the Ch.2 (resistor) voltage does not reach steady-state conditions until after the 3$^{rd}$ cycle of the waveform. (I.e. – the 4$^{th}$ cycle)

   Record the (steady-state) **peak values** of the Ch.1 and Ch.2 node voltages in Table 10.1.

8. Assuming that the phase angle of the source is 0$^o$, determine the (steady-state) **phase angle** of the resistor voltage and record the value in Table 10.1.

9. Capture and save the PSpice schematics plot on a USB flash drive.

## PRELAB – PART B – CALCULATIONS:

1. Calculate the impedance of each circuit element and the phasor value of the current that will flow in the circuit shown in Figure 10.1 assuming that the **phase angle** of the source is **0º** and that the source **frequency** is **10kHz**. Record the results in Table 10.1.

## LABORATORY PROCEDURE:

1. Use an LCR meter to measure the actual values of the resistor, the capacitor, and the inductor. Record the values in Table 10.2.

2. Construct the circuit shown in Figure 10.1. Utilize an Agilent 33120A (or 33220A) Function Generator as the sinusoidal source.

3. Configure the function generator for a high-impedance load by pressing the following softkey sequence: **Utility→Output Setup→High Z→Done**.

4. Choose a sinusoidal output by pressing the **Sine** button. Configure the waveform for a frequency of **10kHz** and a **2Vpp** amplitude, and then press the **Output** button to "turn on" the supply.

5. Use the multimeter to measure the RMS voltages across the inductor, capacitor, and resistor. Set the multimeter up for AC current measurement and measure the series current. Record the results in Table 10.3.

6. Utilize a GW Instek GDS-2064 Digital Storage Oscilloscope to display the source and resistor voltages as a function of time. Connect the red lead from CH1 of the scope to node Ch.1 in the circuit and the red lead from CH2 of the scope to node Ch.2 in the circuit.

7. Turn on the scope and press the lighted yellow CH1 button to select CH1. Configure the channel for DC Coupling by pressing the F1 key repeatedly until the DC symbol ⎓ is displayed.

8. Press the F4 key repeatedly until the Probe setting is x1. Both the Invert and BW Limit options should be off. Press the lighted blue CH2 and set it up the same as CH1. Both the Invert and BW Limit options should be off.

9. Press the blue **Auto Set** button to the lower right of the power button. This causes the DSO to search for the signals on both channels. The yellow and blue lighted CH1 and CH2 button should be on. On the screen should be displayed two horizontal lines: the top line is the yellow CH1 trace and the bottom line is the blue CH2 trace.

10. Rotate the **VOLT/DIV** knob below the CH1 so that the display setting in the lower left of the screen is set at **CH1** ⎓ **500mV**. Likewise, set CH2 to the **500mV** per division setting.

11. Rotate the CH1 **POSITION** knob so that the **Position(1)=0.00V** is displayed in the lower left of the screen. Do the same for the CH2 trace. The 1 and 2 arrow on the left of the screen will overlap in the center of the display.

12. Save the screen image to a USB flash drive by pressing **Save/Recall→Save Waveform (F4)→ Save Waveform (F1)→Destination USB (F3)**.

**13.** Press the **Cursor** button to the right of the power button. On the right of the screen is a gray pop up menu with the title of CURSOR at the top. Cycle the **F1** key so that the **Source** is **CH1**. Note that CH1 of the scope is connected across the voltage source (**$V_S$**) in the circuit.

**14.** Cycle the **F3** Vertical key so that the lower line is solid and the upper line is dashed. Use the **VARIABLE** knob just below the power button to move the lower cursor line to the center grid of the screen. Doing so will display **$V_2$:0.00V** in the lower right of the screen.

**15.** Cycle the **F3** key again so the top line is now solid and the lower line is dashed. Adjust the **VARIABLE** knob so the upper cursor line at the peak of the yellow CH1 horizontal trace. The peak voltage level of the upper cursor will be displayed in the lower left of the screen. Record the peak voltage for **$V_S$** in Table 10.4.

**16.** Now cycle the **F1** key to **CH2**. Note that, as configured, CH2 of the scope is connected across the resistor (**$V_R$**) in the circuit.

**17.** Repeat the cursor measurement for the blue horizontal CH2 trace and record the peak voltage for **$V_R$** in Table 10.4.

**18.** Press the Cursor button again this time selecting the Horizontal cursors. Measure the time difference between the peak of Ch.1 and the peak of Ch. 2. Record the time difference in Table 4.

**19.** Press the **Cursor** button again this time selecting the **Horizontal** cursors. Measure the time difference **Δt** between the zero-crossing of Ch.1 (the source voltage) and the zero-crossing of Ch.2 (the resistor voltage) and record the result as **Δt** for the resistor voltage $V_R$ in Table 10.4.

**20.** Calculate the phase shift between the resistor and source voltages in degrees and state whether the resistor voltage is lagging or leading the source voltage. Record the results for $V_R$ in Table 10.4.

Note that the phase shift in degrees can be calculated by multiplying the time difference both by the frequency and by 360°. ( $\angle\theta = \Delta t \cdot f \cdot 360^\circ$ ) Furthermore, if the trace of Ch.2 is behind in time (to the right) of Ch.1 then it is ***lagging*** or it has a negative phase-shift, and if the trace of Ch.2 is ahead in time (to the left) of Ch. 1 then it is ***leading*** or it has a positive phase-shift.

**21.** On the oscilloscope, press the **Measure** button right beside the Cursor button. In the gray pop up menu area MEASURE should be displayed.

**22.** Press the **F1** key repeatedly to select **CH1** and Press the **F2** key repeatedly to select **CH2**.

**23.** Press the **F3** key repeatedly to select **Voltage**.

**24.** Press the **F4** key repeatedly to measure **Vpp**. The press **F5** to go back to the **Previous Menu**.

**25.** Press the **F2** button and repeat the process so that **Vamp** is selected and press **F5** to go back.

**26.** Press the **F3** button and repeat the process so that **$V_{RMS}$** is selected.

**27.** Press the **Run/Stop** button just below the blue Auto Set and the screen will freeze at that time instant. Record in Table 10.4 the peak-to-peak and RMS voltages displayed both for the source voltage $V_S$ (Ch.1) and the resistor voltage $V_R$ (Ch.2).

**28.** Press the **Run/Stop** button again and the scope will go back to the Run mode.

**29.** Rearrange the circuit so that the capacitor is the last series component (i.e. – swap the resistor and the capacitor while leaving all other connections the same). By doing, Ch.2 of the scope is now configured to measure the capacitor voltage $V_C$.

**30.** Repeat the previous measurements to determine the peak, peak-to-peak and RMS values of the capacitor voltage along with the time-delay and phase-shift for the capacitor voltage compared to the source voltage and record the results in Table 10.4.

**31.** Rearrange the circuit again so that the inductor is the last series component (i.e. – swap the capacitor and the inductor while leaving all other connections the same). By doing, Ch.2 of the scope is now configured to measure the inductor voltage $V_L$.

**32.** Repeat the previous measurements to determine the peak, peak-to-peak and RMS values of the θinductor voltage along with the time-delay and phase-shift for the inductor voltage compared to the source voltage and record the results in Table 10.4.

**33.** Remember that the oscilloscope only measures voltages. If a current measurement is desired, the easiest way to measure current magnitudes is to measure a resistor's voltage and divide the magnitudes by the resistance value. Additionally, since the current flowing through a resistor is in-phase with the resistor's voltage, the phase angle of the current will be the same as the voltage.

Thus, based on the previous results for the resistor voltage, determine the peak, peak-to-peak and RMS values of the current along with the time-delay and phase-shift for the current compared to the source voltage and record the results in Table 10.5.

## POSTLAB:

Use the measured data in Table 10.4 in polar form ($V_p\angle\,\phi°$) for each component voltage and the series current $I_p\angle\,\delta°$ to calculate the impedances $Z_R$, $Z_L$, and $Z_C$. Enter the results on Table 10.6. Compare the impedance values obtained during the prelab to those calculated based from the measured voltages and currents.

## REPORT GUIDE:

1. Draw the measured impedances of Table 10.6 as vectors in the complex plane. Add the vectors together to determine the total impedance, $Z_T$.

2. Confirm whether or not the KVL equation for the AC series circuit holds true by summing the voltages across all three circuit elements and comparing the summed values to the source voltage. Remember to include phase angles in the calculation. Do your results confirm the KVL equation? Discuss your results.

3. Use the measured voltage and current magnitudes (Tables 10.4 and 10.5) along with the frequency to determine the Ohm, Henry, and Farad component values. Compare the calculated values to the values measured using the LCR meter (Table 10.2).

4. Discuss any differences between the calculated and measured component values.

## DATA / RESULTS:

**Table 10.1: Prelab Simulated and Calculated Values**

| | $V_{peak\,Ch.1}$ | $V_{peak\,Ch.2}$ | Phase Angle $_{Ch.2}$ | $Z_R$ | $Z_L$ | $Z_C$ | $\tilde{I}$ |
|---|---|---|---|---|---|---|---|
| **Calculated** | | | | | | | |

**Table 10.2: Measured Circuit Components using LCR Meter**

| | R (Ω) | L (H) | C (F) |
|---|---|---|---|
| **Measured** | | | |

**Table 10.3: RMS Measured Values using Multimeter**

| | $V_S$ | $V_L$ | $V_C$ | $V_R$ | $I_S$ |
|---|---|---|---|---|---|
| **Measured** | | | | | |

**Table 10.4: Phasor Voltage Values Measured using Oscilloscope**

| | $V_{Peak}$ | $V_{Peak\text{-}to\text{-}Peak}$ | $V_{RMS}$ | Δt | Phase Angle | Lagging or Leading |
|---|---|---|---|---|---|---|
| $V_S$ | | | | -------------- | 0° | -------------- |
| $V_R$ | | | | | | |
| $V_C$ | | | | | | |
| $V_L$ | | | | | | |

**Table 10.5: Phasor Current Values Measured using Oscilloscope**

| | $I_{Peak}$ | $I_{Peak\text{-}to\text{-}Peak}$ | $I_{RMS}$ | Δt | Phase Angle | Lagging or Leading |
|---|---|---|---|---|---|---|
| $I_S$ | | | | | 0° | |

**Table 10.6: Prelab Simulated and Calculated Values**

| | $Z_R = \|Z_R\| \angle \theta^\circ$ | $Z_L = \|Z_L\| \angle \theta^\circ$ | $Z_C = \|Z_C\| \angle \theta^\circ$ |
|---|---|---|---|
| **Prelab Calculated** | | | |
| **Calculated from Measured** | | | |
| **% error** | | | |

Approved by: ______________________________ Date: _________________