ECE 2100 Experiment V

AC Circuits

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# Introduction

In this laboratory exercise you will apply techniques learned in class to solve circuits in which the inputs are sinusoidal. This technique makes use of transforms and involves complex arithmetic, but is generally much easier to use than techniques that directly solve differential equations. Remember, these are really just shortcuts for solving the differential equations that arise from Kirchhoff's laws and the current-voltage relationships for the resistor, capacitor, and inductor.

 Take care in this laboratory to interpret your readings correctly. There are three ways in which we refer to sinusoidal amplitudes. One way is to refer to the amplitude of a sinusoid, that is, the coefficient of a sinusoidal operator like the sine or cosine. This is also referred to as the zero-to-peak value. The second way is called the "peak-to-peak" value, and is twice the zero-to-peak value. The peak-to-peak value is what is usually read off the oscilloscope, since this is the most accurate measurement you can make on the display. The "rms" (root-mean-square) value refers to the square root of the mean value of the squared waveform. This is very useful for power calculations, and for sinusoids it is equal to the zero-to-peak value divided by. Most meters will read RMS values when measuring ac signals.

# Research Question

How can we understand the connection between phasor domain calculations and actual circuit response?

## Components Required

 1/4 watt Resistors (number required in parentheses):

1[k] (2) 2.2[k] (2)

2.7[k] (1) 3.9[k] (1)

Capacitors:

0.01[F] (1) 150[pF] (1) 0.022[F] (1)

0.1[F] (2) 1[F] (1) 0.033[F] (1

# Method

# To understand the connection between phasor domain calculations and actual circuit response, we will analyze circuits containing capacitors and having sinusoidal inputs. These circuits are most easily solved using phasor domain techniques. We will compare the results of calculation with measurements made using the oscilloscope.

# *Data*

# Our data will be measurements taken using the oscilloscope and the multimeter.

# *Data Analysis*

# We will compare our phasor domain calculations with measurements made using the oscilloscope.

# Pre-Lab Assignment

1. Step 1: Find the output vout(t) of the circuit in Figure 1, as explained in that step. Use phasor domain techniques, but then convert to the time domain to get vout(t).

2. Step 6: Find the ac and dc components of the output vout(t) of the circuit in Figure 2, as explained in that step. Use phasor domain techniques, but then convert to the time domain to get vout(t).

# Procedure and Results

***Circuit 1: Calculation***

1. Examine the circuit in Figure 1. Assume that a signal source with a 50[] Thévenin resistance is applied to the input. The signal at the input will be a sinusoid with a frequency of 3[kHz] and an amplitude of 10[Vpp]. Calculate, using phasor techniques, the magnitude and the phase shift of the output signal with an open circuit at the output.

Remember that the frequency given here is *f*, and is not the angular frequency, **. You will need to convert to angular frequency to use the phasor technique. Record these values in Table 1. Note that the phase shift refers to that phase measured with respect to the signal at the input.

**Table 1.** Output signal measurements for circuit 1

|  |  |  |
| --- | --- | --- |
|  | Magnitude | Phase shift |
| Calculation |  |  |
| Measurement with 10X probe |  |  |
| Measurement with 1X probe |  |  |
| Measurement with multimeter |  | ////////////////////////////////////////////////// |



**Figure 1.** First of Two AC Circuits.

***Circuit 1: Measurements***

The scope probes need to be calibrated to make accurate measurements. The procedure will be explained in class, and is available on the course web site in the PowerPoint presentation *Phase\_Measurement.pptx*.

2. Calibrate the probes by connecting them to the calibrating signal on the front of the oscilloscope. Adjust the probes so that the square wave on the screen is indeed square.

3. Build the circuit in Figure 1. Connect the signal generator to the oscilloscope and set the signal generator for a sinusoidal signal with a frequency of 3[kHz] and an amplitude of 10[Vpp]. Now remove the signal generator from the oscilloscope and connect it to the circuit input *vin*. Use the 10X probes to measure the magnitude and phase shift of the output signal using the oscilloscope. Repeat this measurement with the oscilloscope probe in the 1X position. Record your measured values in Table 1.

4. Compare your measurements, with and without the 10X probe, to your calculations. Which measurements were more accurate? Calculate the impedance of the 150[pF] capacitor at this frequency. Use this information to explain your results.

5. Repeat the magnitude measurements with the multimeter instead of the oscilloscope. Record your measured values in Table 1. Compare with your previous measurements and explain any discrepancies.

***Circuit 2: Calculation***

6. Examine the circuit in Figure 2. Assume that the combination of the voltage source *v1* and the 50[] resistor is a signal source with a 50[] Thévenin resistance, and *v2* is a dc power supply set to –7[V]. Assume that *v1* has a frequency of 10[kHz] and an amplitude of 5[Vpp]. Solve for the magnitude and phase shift of the ac component and the dc component of the signal with an open circuit at the output. You will need to use superposition to complete this step. Remember that for dc sources, capacitors are open circuits. Record your answers in Table 2.

***Circuit 2: Measurements***

7. Build the circuit in Figure 2. Note that the 50[] resistor should not be added with a discrete component. That is, do not use a resistor from your kit since this is an internal characteristic of the signal generator. Also, note that the dc source must be included as a floating supply. The dc source contained within the signal generator cannot be used as a floating supply, which means you need to use the dc power supply, and not the function generator offset feature

If you are using electrolytic capacitors, it is important that you observe the proper biasing polarity: connect the positive side of the capacitor towards ground since *v2* is negative.

Use the 10X probes to measure *vout*. Use *v1* as your phase reference. Repeat this measurement with the oscilloscope probe in the 1X position. Record your results Table 2.

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**Table 2.** Output signal measurements for circuit 2

|  |  |  |  |
| --- | --- | --- | --- |
|  | Magnitude | Phase | DC Component |
| Calculation |  |  |  |
| Measurementwith 10X probe |  |  |  |
| Measurementwith 1X probe |  |  |  |

8. The output of the circuit in Figure 2 has both a dc and an ac component. That is, your output waveform will be a sinusoid added to a constant value; the constant value is the dc component. Measure the dc component of the output. To do this you may want to make use of the ac/dc coupling feature of the oscilloscope.

# Conclusion

1. The input to the oscilloscope can be modeled as a 1[M] resistor in parallel with a capacitor in the range of about 20[pF]. When the scope probe is properly calibrated, it can be modeled as a 9[M] resistor in parallel with a capacitor having a capacitance 1/9th that of the oscilloscope input capacitance. When you calibrate the probe, you are in fact adjusting the probe capacitance so that it has the correct value. If the scope probe is not properly calibrated, is an error introduced into your measurement? What is the nature of the error? Is there also an error in dc measurements made using the scope probe?
2. Repeat the calculation of the output voltage of the circuit in Figure l assuming that the oscilloscope is connected to the circuit output. Repeat this calculation again assuming that the oscilloscope ***and the scope probe*** are connected to the circuit output. In which case is the circuit loading more of a problem? Why?
3. Assume that the scope probe is connected to the oscilloscope. Calculate the impedance of the scope probe and oscilloscope combination at the terminals of the scope probe. Do this calculation for a signal frequency of 3[kHz] and 10[kHz]. If the probe and oscilloscope were connected to a circuit output, for which frequency would the circuit loading be more of a problem? Why?
4. Devise an experiment for determining the capacitance of an unmarked capacitor. Do not use time constant methods.