Lab: AC Circuits

OBJECTIVES:

EQUIPMENT:

- Universal Breadboard (Archer 276-169)
- 2 Simpson Digital Multimeters (464)
- Function Generator (Global Specialties 2001)*
- Resistor (between 5 kΩ and 50 kΩ, ¼ watt)
- Capacitor (between .005 and .1 μF)
- Inductor (between 5 and 200 mH)
- Diode

INTRODUCTION

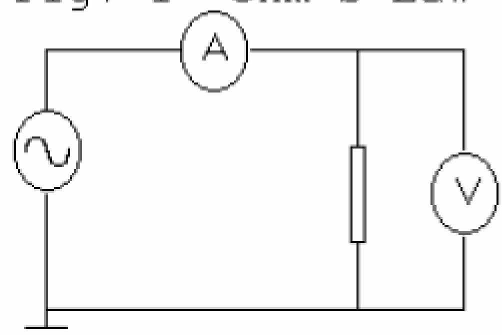
In the earlier lab on the DC behavior of electrical components, you applied varying voltages to each device and measured the resulting current. In this lab, you will repeat similar procedures using a function generator as an AC voltage source. The topic gets complex, because there are many variables to keep straight, but it is very important. All large-scale electrical power is AC, as are all non-digital electrical communication systems. AC voltages and currents are constantly varying. We will use v and i to represent the voltage and current at any particular instant. V and I represent the peak voltage and peak current. Voltmeters and ammeters (unless they tell you otherwise) measure V_{rms} and I_{rms}, where "$_{rms}$" stands for "root mean square." This is also knows as the "effective voltage," Veff, and "effective current," I_{eff}. A later lab will concentrate on the instantaneous and peak values; this week we will concentrate on the root-mean-square measurements as provided by a standard multimeter.

Part I. VOLTAGE VS. CURRENT

Note: Do not turn on the function generator until your circuit has been approved by the instructor. Always turn off the function generator before changing devices or working with the circuit.

* This function generator has an output impedance of 600 Ω, enough to protect it from short circuits. Do not substitute a different generator without checking that it is similarly protected.

Fig. 1 Ohm's Law



For each of the 4 components, use the circuit shown to determine if V_{rms} is proportional to I_{rms} when AC voltages are applied to the component.

1. Record the manufacturer's specifications for the resistor, capacitor and inductor.

Manufacturer's Specifications:

Resistor: __________ Ω

Capacitor: __________ μF

Inductor: __________ mH

2. Use the HI output of the generator, set the MODE to a sine wave, and turn off the DC OFFSET.

3. Initially, set the RANGE to 1K and the FREQUENCY to ".5" thereby giving a frequency of .5 x 1 kHz = 500 Hz. The AMPLITUDE knob will control the output voltage.
4. Set the multimeters to measure AC current and AC voltage, respectively.
5. Record rms current values for voltage steps from 0 to 1.2 V. Note: Root-mean-square values can never be negative, so make all measurements in steps of no more than 0.2 V from 0 to 1.2 V.
6. Record current values in the data table.
7. Change the RANGE and FREQUENCY controls to obtain a frequency of 10 kHz.
8. Repeat steps 5 & 6 *{Note: convince yourself that changing the frequency has little or no effect with the resistor and diode}*.
9. Repeat the full set of measurements for the capacitor and inductor for both 500 Hz and 10 kHz.

	rms Current in:					
Applied V_{rms} (V)	**Resistor 500 Hz (mA)**	**Diode 500 Hz (mA)**	**Capacitor 500 Hz (mA)**	**Inductor 500 Hz (mA)**	**Capacitor 10 kHz (mA)**	**Inductor 10 kHz (mA)**
0						
0.2						
0.4						
0.6						
0.8						
1.0						
1.2						
Slopes from graphs (or enter "not ohmic"):						
Theoretical values for slopes (or enter "not ohmic"):						
	R		**X_C**	**X_L**	**X_C**	**X_L**
Percent difference:						

Analysis

1. Using Graphical Analysis, plot the graph of voltage vs. current for each set of measurements.
2. Use "Curve Fit" to obtain the best curve fit for each data set. *For all devices which appear ohmic, find the slope of the best line.*

	Resistor 500 Hz	**Diode 500 Hz**	**Capacitor 500 Hz**	**Inductor 500 Hz**	**Capacitor 10 kHz**	**Inductor 10 kHz**
Fit equation (type)						
Slope (if applicable)						

3. For the resistor, the slope is, of course, called the "resistance." For the capacitor, the slope is called "capacitive reactance" and symbolized by X_C. For the inductor, the slope is called the "inductive reactance" and symbolized by X_L.

Calculate the capacitive reactance for each frequency from the manufacturer's specified capacitance, using the formula below.

$$\mathbf{X_C = 1/(2\pi fC)}$$

X_C (500 Hz) = _______________

X_C (10 kHz) = _______________

Record values in the data table above.

4. Similarly, calculate the inductive reactance for each frequency from the manufacturer's specified inductance, using the formula below.

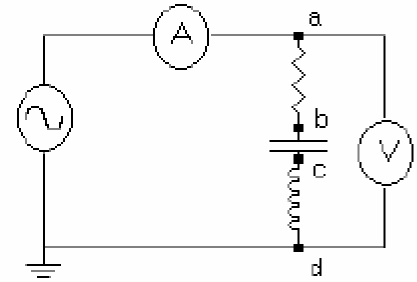
$$\mathbf{X_L = 2\pi fL}$$

Record values in the data table above.

5. Compare each of these calculated values to the slope of the corresponding graph. Also compare the manufacturer's value for the resistor to the slope of that graph. Calculate the % Error for these values and record in the above table.

Part II. LRC CIRCUIT

Fig. 2 LRC Series Circuit



Turn off the function generator then connect the resistor, capacitor and inductor in series as shown. Set the function generator to 2 kHz and maximum amplitude.

1. Measure the rms current for this circuit.

I_{rms} ______________ mA

2. Connect the voltmeter leads at points a and d to measure the total voltage, V_{rms}, for the circuit.

V_{rms} (V_{ad} for the 3 elements combined) _____________ V

3. Measure the rms voltage (V_{Rrms}) between points a and b of the circuit.

V_{Rrms} (V_{ab} for the resistor) _____________ V

4. Measure the rms voltage (V_{Crms}) between points b and c of the circuit.

V_{Crms} (V_{bc} for the capacitor) _____________ V

5. Measure the rms voltage (V_{Lrms}) between points c and d of the circuit.

V_{Lrms} (V_{cd} for the inductor) _____________ V

Analysis

1. Find the value of R within the LRC circuit using $V_{Rrms} = I_{rms} R$.

R = _______________

2. Similarly, find the value of X_C within the LRC circuit using $V_{Crms} = I_{rms} X_C$.

X_C = _______________

3. Find the value of X_L within the LRC circuit using $V_{Lrms} = I_{rms} X_L$.

X_L = _______________

4. Find the total impedance, Z using $V_{Rrms} = I_{rms} Z$.

Z (measured) = _______________

5. Calculate the value of Z using the formula below:

$$Z = [R^2 + (X_L - X_C)^2]^{1/2}$$

Z (calculated) = _______________

6. Find the phase angle from the formula, $\tan \phi = (X_L - X_C) / R$.

ø = ______________

7. Does the sum of the rms voltages on each component in the LRC circuit equal the total rms voltage. Can you explain why not?

8. Does the sum of the rms voltages on each component in the LRC circuit equal the total rms voltage? Can you explain why not?