Lab 27. REACTANCE AND RESONANT CIRCUITS

1. Guiding Questions

- How are are an inductor's or capacitor's current and voltage related in an ac circuit?
- How is an inductor's or capacitor's behavior affected by ac frequency?
- How do LC and RLC circuits resonate?

2. Equipment

Inductor, capacitor, resistor box, variable-frequency ac source (signal generator), electric multimeter, breadboard, connecting wires

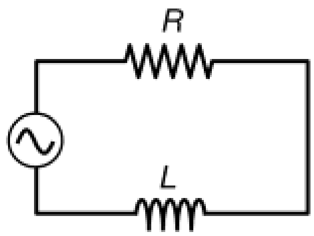
3. Background

Circuits containing capacitors and inductors in series exhibit resonance at or near the frequency at which $X_L - X_C = 0$, which is $\omega_0 = 1/\sqrt{LC}$. Increasing resistance R in the circuit damps the resonance, with critical damping occurring when $2R^2 = L/C$.

4. Activities

In this lab, you will determine the reactance of an inductor and capacitor and measure the properties of resonant circuits. Your measurements of voltage will be on *alternating* current, so your multimeter should be set to AC voltage. The readings will be rms voltages.

1. Inductor

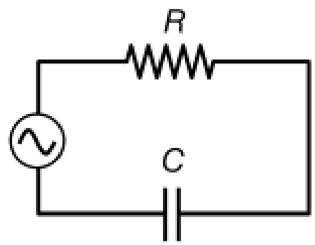


First, use the ohmmeter to measure the resistance R_L of the inductor as if it were a resistor and record it in your notebook. Place the inductor in series with a resistor and the signal generator. Power the circuit with sine waves at a varietyof source frequencies. At each frequency, find a resistor (resistance R) that gives $V_{Rrms} \approx V_{Lrms}$. Record the measured values of R, V_{rms}, V_{Rrms}, and V_{Lrms}. Be sure to include the units with your measurements.

Use the appropriate formulas to calculate the current, the angular frequency, and the reactance. Estimate the inductance of the inductor.

Capacitor

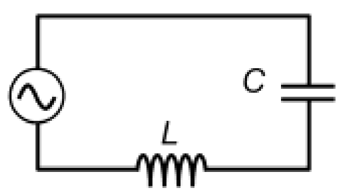
You need a capacitor to go with your inductor to make a resonant circuit. Select a capacitor that should give you a fairly large capacitance, or connect several capacitors in parallel to give you a high capacitance. Describe the capacitor or capacitors in your notebook. If your multimeter has a setting to measure capacitance, you may as well use it and record the measurement in your notebook as well. (I still want you to measure the reactance at different frrequencies.) Place the capacitor in series with a resistor and the signal generator. Power the circuit using sine waves at a variety of source frequencies. At each frequency, find a resistor (resistance R) that gives $V_{\text{Rrms}} \approx V_{\text{Crms}}$. Record the measured values of R, V_{rms}, V_{Rrms}, and V_{Crms}.



Use only dielectric capacitors. Do not use an electrolytic capacitor, as they are ruined by currents of the wrong polarity.

Use the appropriate formulas to calculate the angular frequency and the capacitive reactance. Estimate the capacitance of the capacitor (or set of capacitors in parallel).

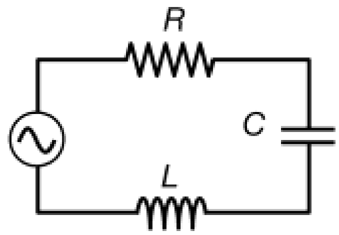
LC Circuit



Connect the inductor and capacitor in series with the signal generator. Place the AC voltmeter in parallel with the capacitor, so that you measure the rms voltage V_{Crms} across it. Scan the frequency of the signal generator to find the frequency giving the maximum voltage. This is the resonant frequency of the circuit. You may need to decrease the sensitivity of the voltmeter as you get close to the resonant frequency.

Record the value of this resonant frequency $f_0$and also the voltage across the capacitor V_C, the inductor V_L, and the and source V_S at this frequency. Repeat the measurements for other frequencies in the same order of magnitude. (For instance, if the resonant frequency is 500 Hz, you might want to measure the values also at 100 Hz, 250 Hz, 400Hz, 450 Hz, 550 Hz, 660 Hz, 1000 Hz, and 2500 Hz.) Calculate I_{rms} as $\omega C V_{\text{Crms}}$. Also calculate the theoretical resonant frequency $f_0 = \omega_0/(2\pi)$ where $\omega_0 = 1/\sqrt{LC}$ and the characteristic resistance $R_0 = \sqrt{L/C}$.

RLC Circuits



If time permits, add some resistance to the circuit (in addition to the intrinsic resistance of the inductor) by placing a resistor in series with the inductor and capacitor. Again, find the resonant frequency of the circuit by adjusting the source frequency to give the greatest V_C or V_L. Use three different resistances, one near the characteristic resistance $R_0 = \sqrt{L/C}$ and the other two below it. Measure V_{rms}, V_{Rrms}, V_{Crms}, and V_{Lrms} at a variety of frequencies near f_0. Calculate I_{rms} as V_{Rrms}/R.

5. Group Lab Report

Abstract, Purpose

What quantities did you measure of what system? What quantities, relationships, or insights did you derive from your observations?

Theory

How should current and voltages be related to each other and to source frequency, resistance R, capacitance C, and inductance L in ac RC, RL, LC, and RLC circuits?

Experimental

As always, tell how you conducted the measurements. For the sake of my sanity, please report the manufacturer and model of all commercial equipment used in your data collection.

Observations and Data

The data tables with measured and calculated quantities (this can be transcribed or photocopied from your notebook).

Analysis and Discussion

Display and discuss

- A plot of $\frac{V_R}{RV_C}$ vs. ω for the RC circuit. (*Hint:* use this to determine C.)
- A plot of $\frac{RV_L}{V_R}$ vs. ω for the RL circuit. (*Hint:* use this to determine L.)
- A single graph of $V_L V_C / V_S^2$ vs f with a separate plot line for each of the different resistances used in the LC and RLC circuits. Label each curve with the resistance.

Conclusions

What did you find or demonstrate about the behavior of ac RC, RL, LC, and RLC circuits?