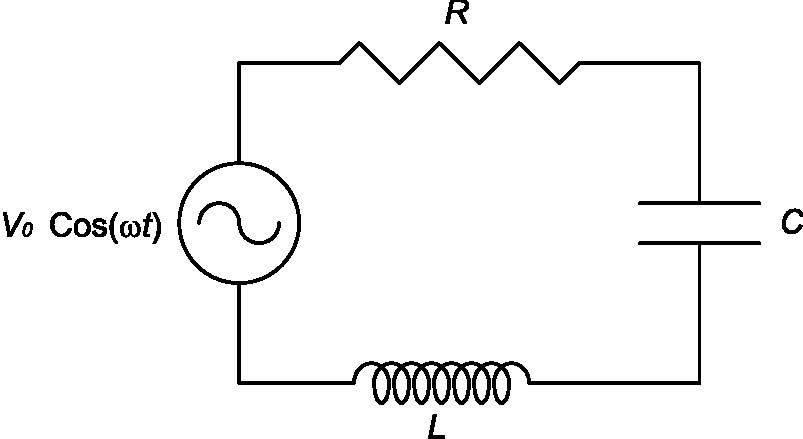
AC CIRCUITS

***BACKGROUND*:**

The *LRC* circuit is an electrical circuit consisting of an inductor , a resistor , and a capacitor , connected in series. The and components of the circuit form a harmonic oscillator for current and will resonate. The effect of the resistor is produces damping.

There are many applications for this circuit. They are used in many different types of oscillator circuits. Another important application is for tuning, such as in radio receivers or television sets, where they are used to select a narrow range of frequencies from the ambient radio waves. In this role the circuit is often referred to as a tuned circuit. An *LRC* circuit can be used as a band-pass filter or a band-stop filter. The tuning application, for instance, is an example of band-pass filtering. The *LRC* filter is described as a second-order circuit, meaning that any voltage or current in the circuit can be described by a second-order differential equation in circuit analysis.

The series *LRC* circuit is shown below:



In this circuit the power supply () provides energy that drives the oscillations, the capacitor stores charge that further drives the circuit, the inductor *L* stores magnetic field energy that drives the circuit further still, the resistor impedes the current that converts these energies into heat. The equation governing this circuit is:

We define the following:

|  |  |  |
| --- | --- | --- |
| Inductive Reactance |  | (Eqs. 1) |
| Capacitive Reactance |  |
| Impedance |  |
| Phase Angle |  |

The solution to this equation is:

The current is thus given by:

The voltages across the capacitor, resistor and inductor are respectively:

Often we will ignore the time dependence of the component voltages, namely:

|  |  |  |  |
| --- | --- | --- | --- |
|  | where |  | (Eqs. 2) |
|  |  |
|  |  |

***Impedance***

junk.wmfCapacitors and inductors act like resistors in that they react to the power supply voltage and have the units of Ohms. However, resistance and reactance add like vectors, called phasors. Consider *R* to be a vector in the +*x* direction, *XL* to point in the +*y* direction and *XC* to point in the -*y* direction. The sum of these three vectors gives us *Z*. The illustration to the right shows the impendence *Z* for *L* = 10 mH, *R* = 5 Ω, *C* = 100 µF, and ω = 1200 rad/s. For these values we get:

= 12 Ω (at + 90°)

= 5 Ω (at 0°)

= 8.33 Ω (at - 90°)

=

= 6.20 Ω

= = 36.6°

If the phase angle is positive, the circuit is said to be more inductive than capacitive, and the current lags the power supply voltage (ELI). If the phase angle is negative, the circuit is said to be more capacitive than inductive, and the current leads the power supply voltage (ICE)[[1]](#footnote-1)\*.

***PROCEDURE:***

***Part 1: Analyzing AC Circuits***

1. **Introduction**
   1. Show algebraically that 

Hints:

1. **Waveforms**
   1. For the remainder of this lab we will assume values for the inductor as = 10 mH, the resistor as = 5 Ω, the capacitor as = 100 µF, and the power supply as = 10 V. We will allow to remain as an independent variable.
   2. If = 500 rad/s, calculate the values for , , , , , , and . Enter your results into the Theoretical column in Table 1.
   3. An oscilloscope is a type of electronic test instrument that allows observation of constantly varying signal voltages, usually represented as a two-dimensional plot of one (or more) the signals on the *y*-axis, with time on the *x*-axis. Since voltages are always measured with respect to some arbitrary reference, it is only differences in measurements along the vertical axis that have any meaning.
   4. Suppose you connected an oscilloscope to a series *LRC* circuit (with = 500 rad/s), and measured the waveforms as shown in the first plot. The uppermost wave is for the voltage across the power supply, the next one down is for the voltage across the capacitor, the third one down is for the voltage across the resistor, and the one on the bottom is for the voltage across the inductor. On this image the horizontal axis has 5 ms/div and the vertical axis has 20 V/div. A division is one of the larger 5 x 5 squares.
   5. To measure the period of a given waveform, count the number of divisions for a complete wave and multiply by the scale factor (5 ms/div for this case).
      1. What is the period of the above waveforms?
      2. What is the frequency of the waves?
      3. Do you have 500 rad/s? If so, you have done this part correctly.
   6. Measure the zero-to-peak amplitude of the power supply waveform. Do you get 10 V? If so, you have done this part correctly.
   7. Measure the zero-to-peak amplitude of the capacitor, resistor, and inductor waveforms. Enter your , , values into the Measured column in Table 1 (and calculate the percent errors).
   8. It can be shown from Eqs. 2 that , , and . Using your measured values from the previous step and = 5 Ω, calculate , , and (and the percent errors).
   9. The phase angle refers to the phase angle between the power supply voltage and the current. Since the current can be found from the phase angle is easily measured. To measure the phase angle, proceed as follows: Measure the time difference, , between the zero-crossing of the power supply voltage and the zero-crossing of the resistor voltage (at the same point in phase). Multiply by 360°/ (which you measured earlier). Enter your value into Table 1 (and calculate the percent error).
2. **Impedance**
   1. In the plot provided, draw your phasors with = 10 mH, = 5 Ω, = 100 μF, and = 500 rad/s. Measure the length of and the phase angle between and . Do your results agree with your previous values?
   2. For = 500 rad/s, do you have a more capacitive or a more inductive circuit? Does the current lead or lag the voltage?
3. **Resonance**
   1. Suppose you have collected the data in Table 2 from the series *LRC* circuit, where is the power supply frequency, , and are respectively the zero-to-peak voltages across the capacitor, resistor and inductor, and is the phase angle.
   2. Make semi-log plots of the Table 2 data in the plots provided.
   3. For what value of do , and have a maximum? This value is called the resonant frequency, and at this frequency, the circuit is said to be in resonance. Compare your value to .
   4. What is the value of at resonance? Would you say that is at a masteximum, minimum or neither?
   5. What is the value of at resonance? Would you say that is at a maximum, minimum or neither?
   6. Show algebraically from Eqs. 1 and 2, that at resonance the following:

= ; = = ; = ; = 0°

* 1. At low frequencies (), the circuit is more capacitive. Show algebraically from Eqs. 1 and 2 the following:

≈ ; ≈ ; ≈ ; ≈ 0 ; ≈ -90°

* 1. At high frequencies (), the circuit is more inductive. Show algebraically from Eqs. 1 and 2 the following:

≈ ; ≈ ; ≈ ; ≈ ; ≈ 90°

\*NOTE: Include all screenshots, drawings, schematics, tables, and graphs in your lab report.

Equipment:

1. “Lab 08 – Tables.docx”
2. “Lab 08 – Plots.pdf”

1. \* Many electronics engineers use the mnemonic “ELI the ICE man”. [↑](#footnote-ref-1)