

Physics 251 Laboratory

AC Circuits Part 1 - Implementation

Pre-Lab: Please do the lab prep exercise on the web.

Introduction

This week we will set up a series RLC circuit driven by an ac voltage source, and use an oscilloscope and a digital voltmeter to study its behaviors. For reference, here are the equations we have discussed in lecture.

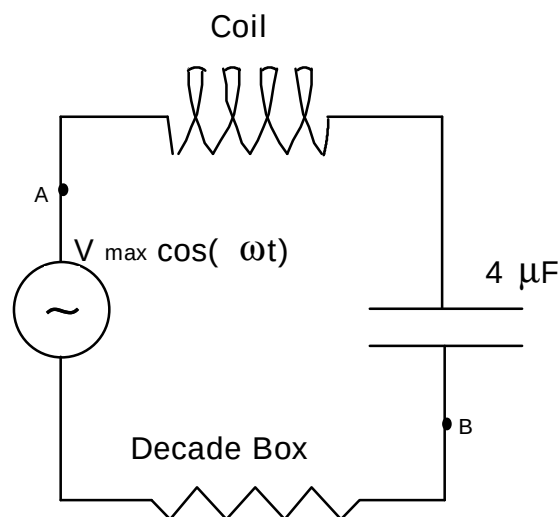
$$\begin{aligned} V &= V_{\max} \cos(\omega t) & I &= I_{\max} \cos(\omega t - \phi) & I_{\max} &= V_{\max} / Z \\ Z &= \sqrt{R^2 + (X_L - X_C)^2} & \tan \phi &= \frac{X_L - X_C}{R} \\ V_L &= I_{\max} X_L \cos\left(\omega t + \frac{\pi}{2}\right) & V_R &= IR & V_C &= I_{\max} X_C \cos\left(\omega t - \frac{\pi}{2}\right) \\ P &= \frac{I_{\max} V_{\max} \cos \phi}{2} = \frac{I_{\max}^2 Z \cos \phi}{2} = \frac{I_{\max}^2 R}{2} \end{aligned}$$

You will be supplied with the following equipment:

1. Signal generator
2. Large coil with removable iron core
3. 4 μF capacitor
4. Resistance decade box
5. Cables, clips, connectors, etc.
6. Oscilloscope
7. Digital voltmeter (DVM)

Section 1

Set up the circuit as it is shown in the figure. Because of the way we will make measurements, **it is important that the resistance box be “last” attached to the ground side of the signal generator.**



Initially, set the decade resistance box for 50 Ω , and set the signal generator to produce a 2500 Hz sine wave. Set the amplitude of the sine wave to its maximum value. Do not use the iron core in the coil.

Once everything is set up, do a few measurements.

1. Use the DVM to measure the voltage produced by the signal generator.
2. Set up the oscilloscope and look at the voltage waveform (measure at point A). Does the voltage you see agree with what the DVM said?

3. Try varying the frequency and amplitude; make sure you understand what the oscilloscope is doing.
4. Now, move the DVM to measure the voltage across the resistor. Set the scope to measure at point B. Do these voltages agree? Should they?

Section 2

In this section, we will measure the inductance of the coil both with and without the iron core in place. This can be done because we know the capacitance of our capacitor and we can measure the resonant frequency of the circuit. The amplitude of the current (and hence of V_R) is a maximum at resonance.

1. With the circuit set up as above, turn the frequency adjust knob all the way down (to 0.3) while staying on the 1 kHz scale.
2. Measure the voltage across the resistor (point B) vs. the frequency all the way to the top of the scale. You may wish to “scan” the frequency range first and plan to take more closely spaced data near resonance.
3. Plot your results and determine the resonance frequency as best you can. Is it easier to use the oscilloscope or the voltmeter to find resonance?
4. Calculate the inductance of the coil.
5. Repeat this process with the iron core in place. You may need to go to a different frequency range.

Section 3

Now, get a second set of leads and use the scope to measure at points A and B simultaneously. Use Channel 1 to measure at A and Channel 2 at B. You should be able to see the phase angle ϕ directly with this setup. Can you? Try setting the frequency far below resonance then scanning the frequency through resonance. Does the phase behave as you expect? We can also find resonance by looking for the frequency where $\phi = 0$.

1. With the iron core removed set the signal generator to 3 kHz. Measure the phase shift.
2. Calculate what phase shift you expect. Does your result make sense?
3. Set your ‘scope to trigger on channel 1 at zero voltage. Your waveform should cross zero in the middle of the screen (indicated by a little “T”). Shift this waveform up from the center, and shift channel 2 down so they don’t overlap.
4. Look at channel 2. Does it cross its own x-axis (indicated at the left of the screen) at the trigger point? This is your phase shift again.
5. Watch the phase shift as you cross resonance. Determine the resonant frequency with and without the core using this method. Do your results agree with the ones from before? Which way is more accurate?

Name _____ Data _____

Lab Partners _____

AC Circuits Part 1 - Implementation Results

Please use the back of this page or attach another sheet if you need more room.

Section 1

1. Source voltage as measured by DVM _____
2. Source voltage as measured by oscilloscope _____
3. Do your voltage measurements agree? If not, why? _____

4. Voltage across resistor as measured by DVM _____
5. Voltage across resistor as measured by oscilloscope _____
6. Do your voltage measurements agree? If not, why? _____

Section 2

Without Core		With Iron Core	
f(Hz)	V _R (Volts)	f(Hz)	V _R (Volts)

Resonance frequency will be at the maximum of the graph.

Plot Results in Excel and attach to this sheet.
Using your plotted results, find:

Without Iron Core

Resonance frequency _____

L= _____

Calculated Impedance _____

With Iron Core

Resonance frequency _____

L= _____

Calculated Impedance _____

Section 3**Without Core**

Phase shift _____ Resonance frequency _____

With Core

Phase shift _____ Resonance frequency _____

How closely do the results for resonance frequency in section 2 and section 3 agree?
Which method do you think is most accurate _____

Overall

Why is the resonant frequency important in electric circuits? How does the inductance of the coil change when the iron core is in place? _____

What was good about this lab and what would you do to improve it?

Physics 251 Laboratory

AC Circuits Part 2 – Simulation

Pre-lab: Please do the lab prep exercise on the web.

Introduction

We have recently been studying ac circuits. As you have undoubtedly noticed, this is an area in which any given problem can have a great deal of complexity. Thus, there is often a tendency to write down dozens of equations and attempt to mix and match them as needed while ignoring the basic phenomena that occur. In this lab, we will construct a spreadsheet that reproduces the behavior of a series RLC Circuit. By using the equations to generate graphs we will gain a bit more insight into what happens in the circuit. To more realistically simulate what happens in a real circuit, we will assume the source generates a fixed voltage $V = V_{\max} \cos(\omega t)$ and that the current responds with an appropriate phase.

$$V = V_{\max} \cos(\omega t) \quad I = I_{\max} \cos(\omega t - f) \quad I_{\max} = \frac{V_{\max}}{Z}$$

$$Z = \sqrt{R^2 + (X_L - X_C)^2} \quad \tan f = \frac{X_L - X_C}{R}$$

$$V_L = I_{\max} X_L \cos(\omega t + \frac{p}{2}) \quad V_C = I_{\max} X_C \cos(\omega t - \frac{p}{2}) \quad V_R = IR$$

$$P = IV \quad X_L = \omega L \quad X_C = \frac{1}{\omega C}$$

$P=IV$ is true at each instant in each component of the circuit. That is, for example, $P_L(t) = V_L(t)I(t)$ (recall that I is the same in all parts of the circuit).

Equipment and Supplies

Macintosh computer with Microsoft Excel software

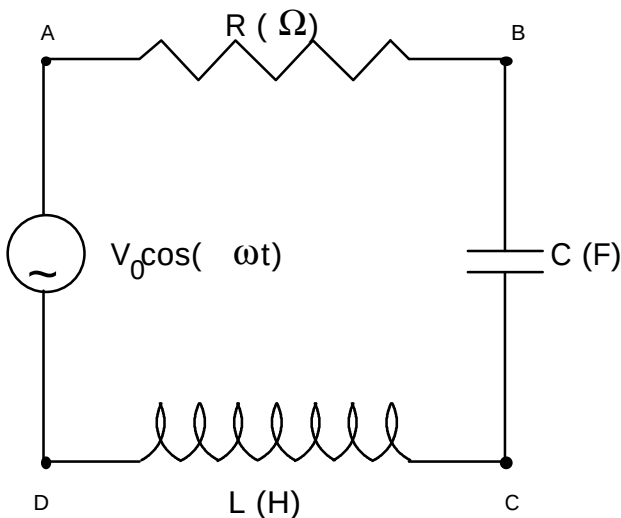
Simulation is in the 251 folder in a file labeled: "AC Circuit Simulation"

Section 1

In the 251 folder there is a file called AC Circuit Simulation. This file contains an outline of how to begin. Ultimately, you will develop a spreadsheet that analyzes the series RLC circuit, and displays graphs of many important parameters.

Initially, the spreadsheet has spaces for values of R , L , C , $V_{\max}$, ω , and Δt . The first five are values that represent the circuit at the right, while Δt is a time step that you will use in calculating values of the various voltages, powers etc. that occur in the circuit. We have also calculated values of the voltage as a function of time, and included a graph of V vs. t . Just below the area for input values, we have calculated the frequency corresponding to the input ω , and the resonance frequency corresponding to the input L and C .

Recall that by clicking on a cell and looking up to the header bar you can see what was typed into that cell. If it is a number, then that value is an "input" if it is an equation (beginning with an equals sign '=') then it is calculated from other values in the sheet.



Section 2

In addition to the few "pre-calculated" columns and numbers, we have left a bit of work for you to do.

1. Put equations into cells B24 through B28 to calculate the reactances, impedance, phase and $I_{\max}$. You can use your values for reactances to calculate impedance, phase and $I_{\max}$.
2. Have a look at the values for the reactances X_L and X_C . If you change the angular frequency ω do they change in a sensible way? If you set ω equal to the resonance value, what happens?
3. Type an equation for I into cell F3. Your equation should use the time in cell D3 and values from column B. You will be "filling down" in column F to calculate I vs. t with your formula. Don't forget to use dollar signs "\$" to indicate values that should not change as a function of time (for instance, use $\$B\19 for ω). You can have a look in cell E3, the first line of the formula for V , as an example. Finally, "pull down" the square box in the lower right of F3 until it matches the length of the data in columns E and F.
4. Now highlight all the data in columns D, E and F and use the "Plot Wizard" to graph V and I on the same plot. (Use XY scatter with smooth line). Try changing the values of R , L , C and ω . The phase difference calculated in B27 should show up on your graph.
5. Put in calculations for the voltages, V_R , V_L , V_C in columns G, H and I. Try making a plot with I and V_R on the same graph. Are they in phase? How about a graph of I and V_C and V_L ? You may need to change the values of L , C , R and ω to get all of the data visible on a single vertical scale. (try decreasing R first). Unfortunately, excel does not have a way to plot two data sets on one horizontal axis using different vertical scales.

6. Now, put in formulas for the power dissipated in each of the three components and for the source. In each case, it is just $V \cdot I$ for that component.
7. Make graphs of the Power and V on the resistor as a function of time. Notice that the power is always positive. Do the same for the inductor. Does it look like the power dissipated in the inductor averages to zero?
8. Graph the power output of the source vs. time. Note the effects of changing the values of R , L , C , and ω . Can you get the power to be all positive?

NAME _____ DATE _____

LAB PARTNERS _____

AC Circuits Part 2 - Simulation Results

Please use the back of this page or attach another sheet if you need more room

Section 2

Do the reactances X_L and X_C change if you change the angular frequency? _____

If you set the angular frequency equal to the resonance frequency, what happens? _____

Plot a graph of source voltage vs. current.

What is the phase angle ϕ between the source voltage and the current? _____

Plot graphs of the power dissipated through the resistor, inductor and capacitor as functions of time.

Does it look like the power dissipated through the inductor averages to zero? _____

Plot the power output of the source vs. time. Can you get the power to be all positive by changing the values of R, L and C? How?

Overall

Describe to “the boss” why you can save him/her money by simulating this LRC circuit before you build it?

What was good about this lab and what would you do to improve it?
