LABORATORY 10

RLC Circuits

Guide

Introduction

When an AC signal is input to an RLC circuit, voltage across each element varies as a function of time. The voltage will oscillate with a frequency of the AC signal. Likewise, the current will also oscillate with the same frequency. Nevertheless, the voltage and current may not rise and fall at the same time. The voltage and current is said to be out of phase as shown below.

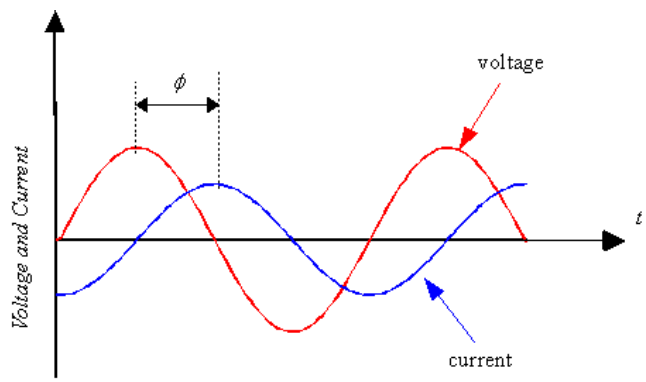


Figure 1: Voltage and current in an AC circuit

The phase angle ϕ represents the difference between the maximum voltage and the maximum current. The phase angle will depend on the nature of the circuit.
Consider a circuit consisting of a resistor, capacitor, and an inductor in series

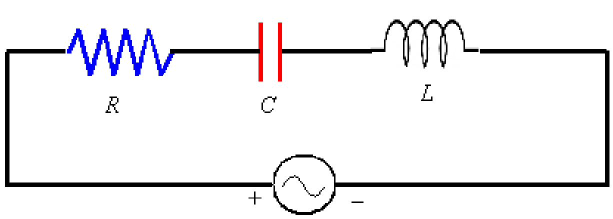


Figure 2: RLC series circuit

In an AC circuit, the Ohm's law cannot be directly applied. However, the law can be applied for maximum values of current and voltages. The maximum voltage across the resistor is given by

$$V_R = I_{\max} R \tag{1}$$

and the maximum voltage across the capacitor is given by

$$V_C = I_{\max} X_C \tag{2}$$

where X_C is known as the **capacitive reactance** and measures the effective resistance of the capacitor. The value of the capacitance reactance is defined as

$$X_C = \frac{1}{2\pi f C} \tag{3}$$

Likewise, the maximum voltage across the inductor is given by

$$V_L = I_{\max} X_L \tag{4}$$

where X_L is the **inductive reactance** and is defined as

$$X_L = 2\pi f L \tag{5}$$

The maximum voltage of the AC signal is given by

$$V_{\max} = I_{\max} Z \tag{6}$$

where Z is the known as the **impedance** of the circuit.

$$Z = \sqrt{R^2 + \left(X_L - X_C\right)^2} \tag{7}$$

The minus sign in front of the capacitive reactance reflects the 180° phase difference between the voltage across the inductor and the voltage across the capacitor. At a unique single frequency, $X_L = X_C$. This frequency is known as the **resonant frequency**. At resonant frequency, the current will be in phase with the source voltage. Setting the inductive and capacitive reactance equal to each other gives the resonant frequency to be

$$f_r = \frac{1}{2\pi\sqrt{LC}} \tag{9}$$

At resonant frequency, the impedance will be a minimum and the current in the circuit will be a maximum. The voltage across the inductor-capacitor combination will also be zero at resonant frequency.

The resonant frequency can be readily observed by using the XY mode on the oscilloscope. In the XY mode, the display will measure the voltage from one channel as a function of the voltage from the second channel. The resonance condition will be given by a single diagonal line on the oscilloscope display.

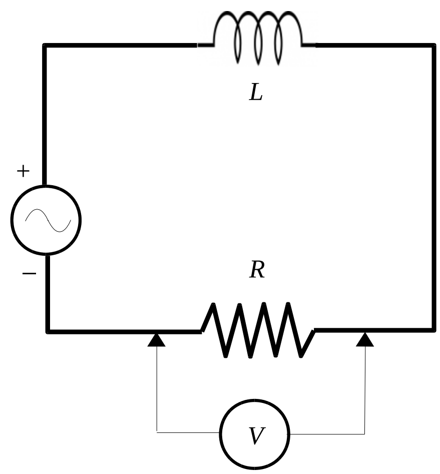
By measuring the half-life, either the inductance of an unknown inductor or the resistance of an unknown resistor can be found.

Lab10 Prelab

Name ______________________ TA Checkoff ______________________

Teammate ______________________ Score ______________________

1. Power supply output voltage is $V_S = V_{\max}\sin(\omega t)$, $V_{\max} = 10V$, $R = 100\Omega$, $L = 10mH$, $f = 20Hz$.



What is oscilloscope voltage expression?

__/6pt

2. Power supply output voltage is $V_S = V_{\max}\sin(\omega t)$, $V_{\max} = 10V$, $R = 100\Omega$, $L = 10mH$, $f = 15Hz$, $C = 330\mu F$.

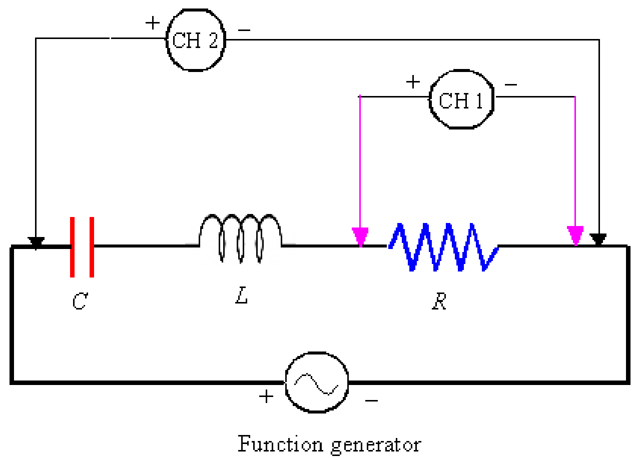


Figure 3: Oscilloscope connections for the RLC circuit

What are CH1 and CH2 expression?

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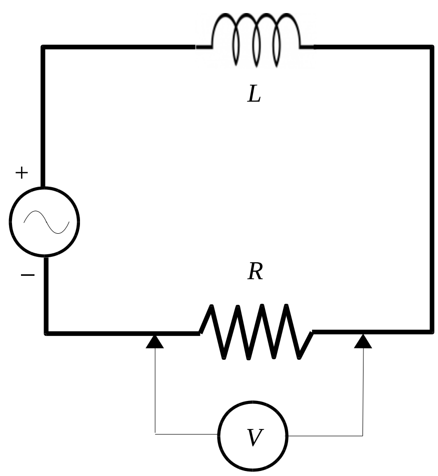
Lab10 Report

Name ______________________ TA Checkoff ______________________

Teammate ______________________ Score ______________________

Part I: Resistance of the Function Generator

1. Use multimeter to measure and record the actual resistances of the 100 Ω resistor and that of the 10 mH inductor.
2. Use 100 Ω resistor and the 10 mH inductor on the BREAD board to create the RL circuit shown below.

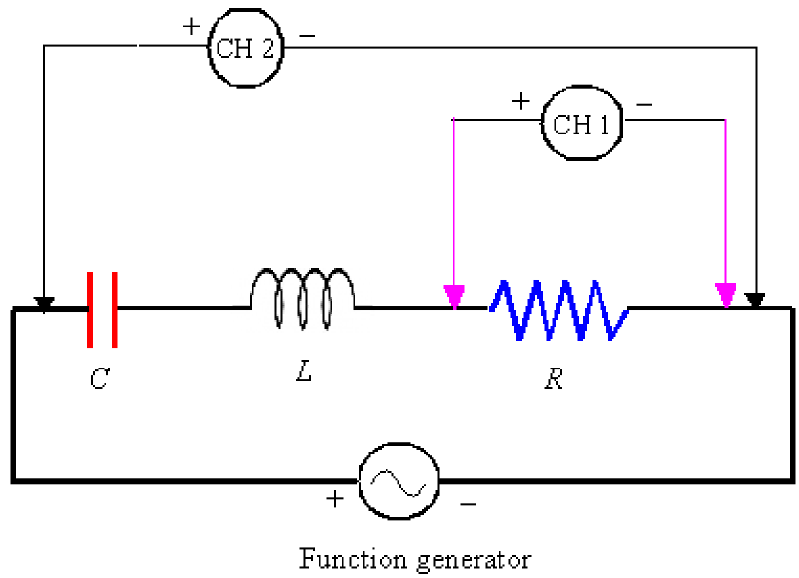


Oscilloscope

3. Attach the oscilloscope probe between the inductor and resistor and the oscilloscope ground between the square wave generator ground and resistor
4. Set the function generator to sinusoidal wave.
5. Use the function generator output knob to set the peak-to-peak voltage to be about ±10 V.
6. Adjust the oscilloscope voltage and horizontal time scale to obtain a single trace similar to either an exponential decay or growth diagram.
7. Measure the half-life from the oscilloscope display.

Part II: Phase Measurement

1. Use multimeter to measure and record the actual resistances of the 100 Ω resistor and that of the 10 mH inductor.
2. Use a 330 μF capacitor, 100 Ω resistor, and 10 mH inductor in the BREAD circuit board to create an RLC circuit shown below.



3. Set the function generator to sinusoidal mode with a frequency of 15 Hz and the peak-to-peak voltage to be about ±10 V.
4. Connect the alligator clip of the oscilloscope probe to the ground of the function generator.
5. Use vertical controls and set the coupling for CH 1 and CH 2 to AC.
6. Obtain simultaneous displays of the voltage across the resistor, i.e. current, and the voltage across the source.
7. Turn the sec/div knob to obtain about two complete cycles on the display.
8. Use the time cursors to measure the phase, Δt, between the current and the voltage across the source. Record the phase in the data table.
9. Measure and record the amplitude of the resistor and source voltage.
10. Repeat the phase and amplitude measurements for frequencies of 1500 Hz and 2000 Hz.

Part III: Resonance

1. Adjust the frequency until the current and the voltage across the source are in phase.
2. Record the resonant frequency of the RLC circuit.
3. Replace the 330 μF capacitor with 100 μF capacitor and determine the resonant frequency.

4. Use a breadboard and create a RLC circuit using a 300 Ω resistor, 470 μF capacitor, and unknown inductor.
5. Measure and record the resonant frequency.
6. Replace the 470 μF capacitor with a 1000 μF capacitor and again measure the resonant frequency.

Data Sheet:

Part I: Resistance of the Function Generator

Resistance of the inductor, R_L = _______________

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Trial	**Frequency (in Hz)**	**Resistance of the Resistor (in Ω)**	**Half-life (in s)**
1	10		
2	15		
3	20		

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Part II: Phase Angle Measurement

Resistance of the resistor = _________________________

Resistance of the inductor = _________________________

Capacitance of the capacitor = _________________________

__/4pt

Trial	**Frequency (in Hz)**	**Phase, Δt (in)**	**Maximum V_R (in)**	**Maximum V_{RLC} (in)**
1	**15**			
2	**1500**			
3	**2000**			

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Part III: Resonant Frequency

	Resistance (in Ω)	Capacitance (in μF)	Resonant Frequency (in Hz)
Circuit I – Bread Board		330	
Circuit II – Bread Board		100	
Circuit III – Bread Board		470	
Circuit IV – Bread Board		1000	

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Calculations:

1. Compare the value of half-life to the actual half-life.
2. From the phase measurement, calculate the phase angle.
3. Calculate the theoretical phase angle for each frequency.
4. Determine the % difference between the expected and the actual resonant frequency.

Results:

Part I: Resistance of the Function Generator

Trial	Experimental Half-life	Theoretical Half-life
1		
2		
3		

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Part II: Phase Angle Measurement

Trial	Experimental Phase Angle	Theoretical Phase Angle
1		
2		
3		

__/10pt

Part III: Resonant Frequency Measurement

	Theoretical Resonant Frequency (in Hz)	Experimental Resonant Frequency (in Hz)	% Error
Circuit I – Bread Board			
Circuit II – Bread Board			
Circuit III – Bread Board			
Circuit IV – Bread Board			

__/10pt

TA: ______________________

Part One: _____________of 19 Pt.
Part Two: _____________of 22 Pt.
Part Three: _____________of 42 Pt.
Prelab: _____________of 17Pt.
Total: _____________of 100Pt.