Lab1. Observation, Modeling, and Communication

In this lab, you will learn about RLC circuits. These circuits consist of a resistor (R), inductor (L) and capacitor (C) wired in series, parallel, or any combination of the two. RLC circuits are oscillators, meaning that they produce a periodic, oscillating electronic signal. Each RLC circuit has its own resonant frequency. This is an input frequency at which the circuit exhibits distinctive behavior.

For this module, you will be given an RLC circuit and asked to calculate its resonant frequency. Then, you will build the circuit with the NI ELVIS III to observe how it behaves. Finally, you will confirm its resonant frequency using the Bode analyzer.

Learning Objectives

After completing this lab, you will be able to complete the following activities:

1. Become familiar with ECE 3313 course procedures
2. Become familiar with NI ELVIS instruments
3. Discuss the purpose and behavior of RLC circuits
4. Calculate the resonant frequency of an RLC circuit
5. Measure and confirm the resonant frequency using instrumentation
6. Observations about the purpose and behavior of an RLC circuit

Required Tools and Technology

Platform: NI MultiSim	View User Manual: http://www.ni.com/pdf/manuals/374483d.pdf Components used in this lab: • (1) 22 mH inductor • (1) 10 Ω resistor • (1) 47 µF capacitor
Hardware: N/A	View Breadboard Tutorial: http://www.ni.com/tutorial/54749/en
Hardware: N/A	

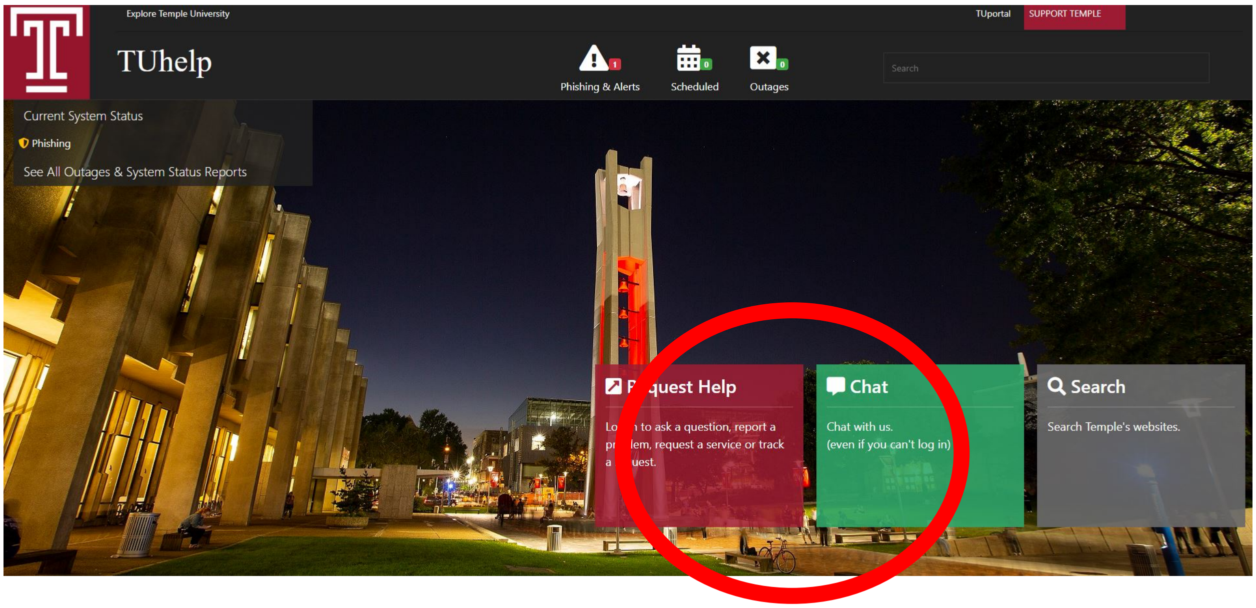
Multisim access code though Temple:

Install MultiSim here: https://www.ni.com/en-us/support/downloads/software-products/download.multisim.html#312060

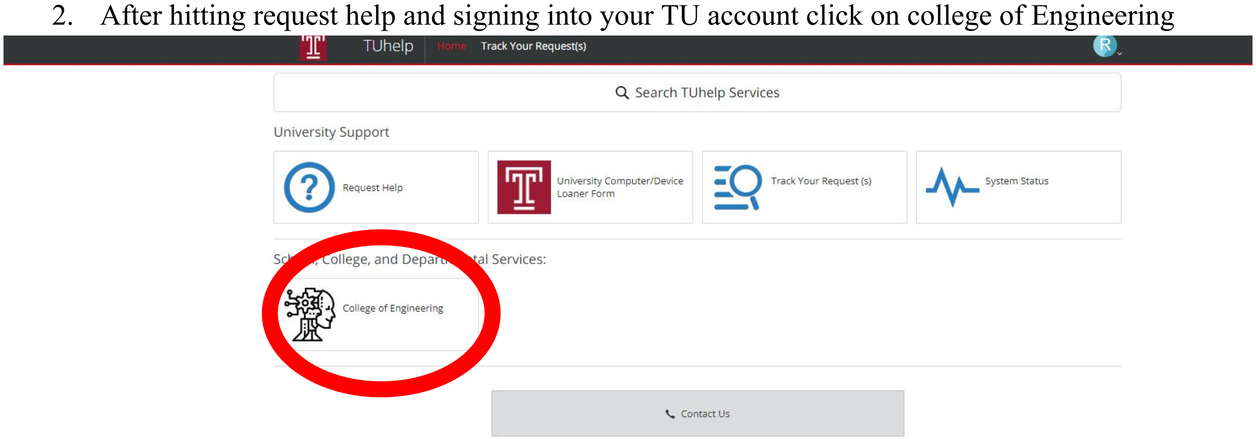
Note: There is no Multisim for Mac OS, please contact IT for help in installing the software or remote accessing a Temple computer running Windows.

Go to https://tuhelp.temple.edu/

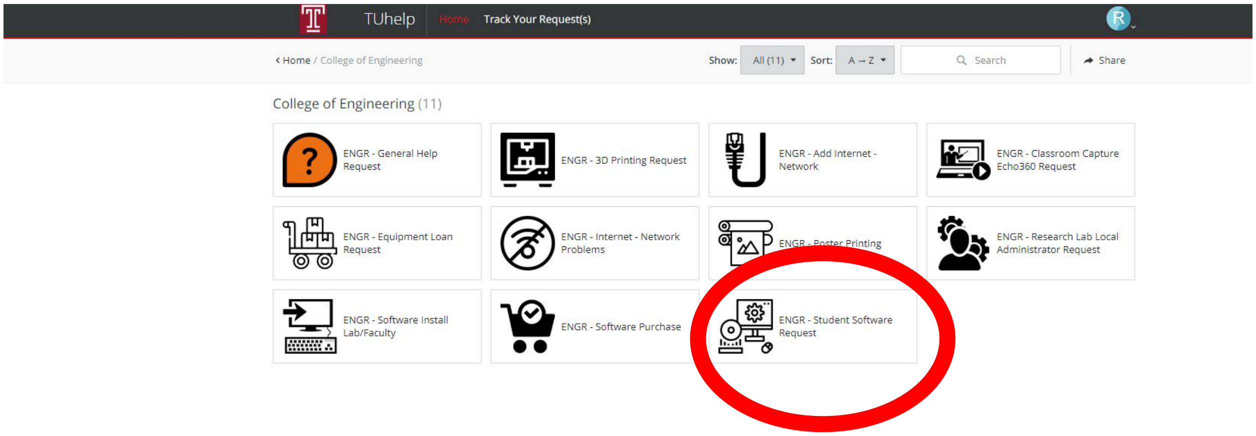
1. On the screen below click request help



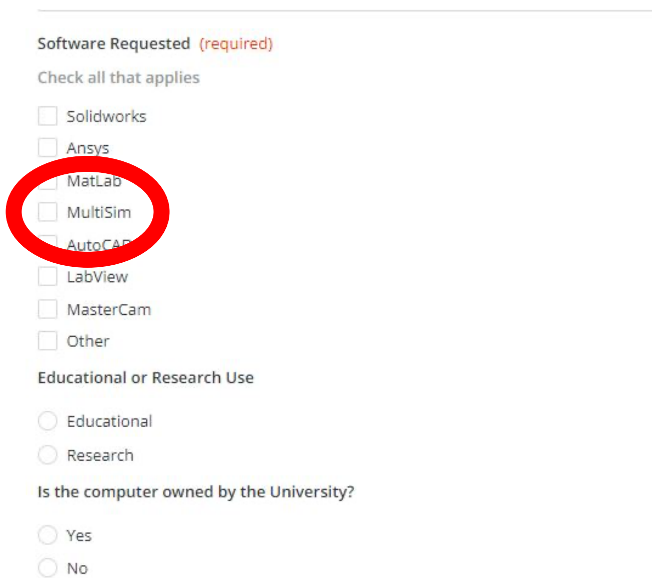
2. After hitting request help and signing into your TU account click on college of Engineering



3. Now select ENGR Student software Request



4. Fill out the form and select Multisim



5. IT will send you and email with the access code within a few days.

1. Background Information

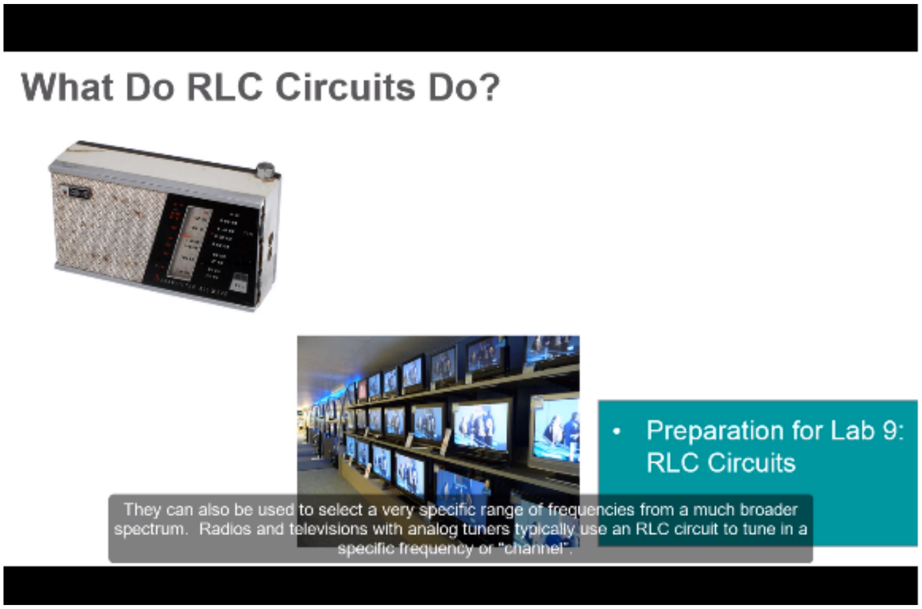


Figure 1. Video Screenshot. View the video here: https://bit.ly/2QB7w5W

Video Summary

- RLC circuits contain the following: a resistor (R), an inductor (L), and a capacitor (C)
- Harmonic oscillator—produces resonating/oscillating signal that is damped (reduced) by resistor
- Used in oscillator circuits, filters:
    1. Allow you to select signals (e.g. radio, Wi-Fi) from all those being broadcast
    2. E.g. analog tuner in radio using variable capacitance or inductance

1.1. Fundamentals of RLC Circuits

Also known as resonant, tuned, and LCR circuits, RLC circuits consist of a resistor (R), inductor (L), and capacitor (C). Like an LC circuit, an RLC circuit forms a harmonic oscillator for current. It produces a periodic, oscillating signal, creating AC current from DC input. RLC circuits resonate similarly to LC circuits, but the resistor in the circuit damps the oscillation (causes it to die down) unless more energy is continually provided by a power supply. RLC circuits are second-order circuits, because their underlying equations are second-order differential equations.

Commonly, RLC circuits are used in filter circuits and can serve as different types of filters depending on the configuration of their components. One example is bandpass filters: filters that block out most signals but transmit those within a specific range of frequencies. RLC bandpass filters are common in analog tuning circuits such as those found in radios and televisions.

RLC circuits are also used in:

- Oscillators
- Voltage multipliers such as those in cathode ray televisions and particle accelerators
- Pulse discharge circuits such as those in microwaves and radio transmitters

1.2. RLC Circuit Behavior

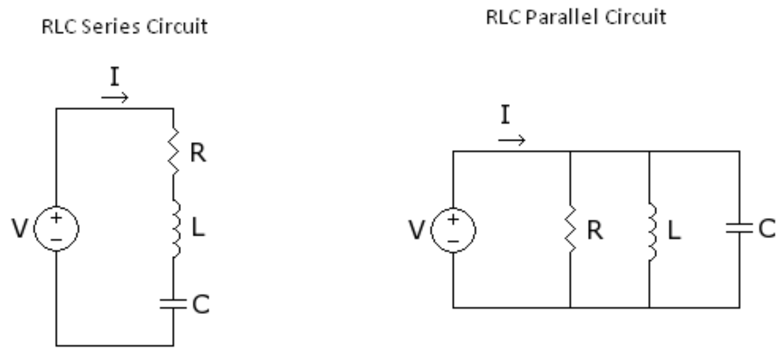


Figure 3. RLC circuits

An RLC circuit behaves as an electronic oscillator. As energy shifts back and forth between the electrostatic field of the capacitor and the magnetic field of the inductor, a periodic signal is produced. The resistor gradually damps (decreases the amplitude of) the oscillations, which leads the signal to attenuate to zero unless more power is supplied. Depending on the resistance provided, the system's behavior may be *under-damped* (sub-attenuated–allowing oscillation), *over-damped* (over-attenuated–no oscillation) or *critically damped* (attenuated–minimal resistance to avoid oscillation).

The frequency response of a circuit is comprised of two relationships: the relationship between gain and input signal frequency, and the relationship between phase and input frequency. In electronics, gain denotes the magnitude of a circuit's output signal compared to its input signal. The frequency response of an RLC circuit is characterized by a peak gain, and the input frequency at which this peak gain occurs is known as the circuit's resonant (or resonance) frequency.

The resonant frequency f_0 of an RLC circuit, in Hz, is:

$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$

(Equation 1)

In series RLC circuits, impedance is minimized at the resonant frequency. In parallel circuits, impedance is more or less maximized.

1.3. Applications of RLC Circuits

Filters are a key set of applications of RLC circuits. One relevant example is audio systems. Consider a speaker system consisting of a midrange speaker, a woofer for bass (low-frequency) sounds, and a tweeter for treble (high-frequency) sounds. An RLC high-pass filter transmits the treble sounds to the tweeter while attenuating lower-frequency sounds that could damage the sensitive speaker. Meanwhile, a low-pass filter passes low-frequency sounds to the woofer to be amplified. Although simple high- and low-pass filters can be made with just a capacitor and resistor, RLC circuits make for much more refined solutions.

RLC circuits can also make bandpass filters, which transmit certain ranges of frequencies, and bandstop filters, which block out certain ranges. Bandpass filters are used for transmitting and receiving signals. Bandstop filters are used in applications such as reducing audio feedback in instrument amplifiers.

RLC circuits have countless applications outside of being filters. For example, RLC circuits are used for voltage magnification and parallel RLC circuits can be used for current magnification. Another use for RLC circuits is in induction heating.

2. Experiments

2.1. Implement: Observe Attenuation Behavior

You will require to calculate the resonant frequency of the circuit below using Equation 1.

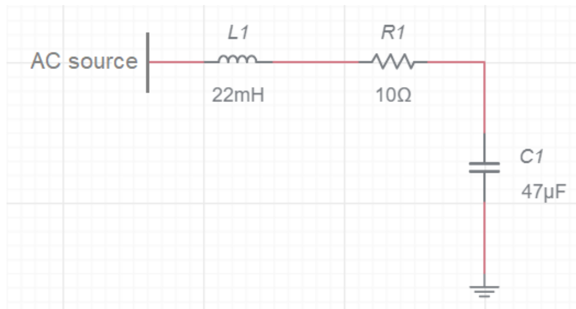


Figure 6. Calculate f_0

You will use the NI MultiSim to simulate the RLC circuit. You will need to use transient and AC sweep mode to plot the signal in time and frequency response (i.e., Bode plot) to observe the attenuation (dampening) of various frequencies of input signal.

Instructions:

Set up the Circuit

1. Build a circuit shown in Figure 6, which you analyzed theoretically in the exercise.
2. Example can be found in the online version Multisim
   a. https://bit.ly/2YW9K3G

   Note: the voltage source will need to be changed to a Clock Voltage source for this Section (to get the square wave)

3. Configure the input voltage with the following settings:

Table 1-1 Function generator Settings

Output signal waveform	Square
Frequency	20 Hz
Amplitude	1 Vpp
DC Offset	0 V

- These settings will cause the function generator to input DC voltage to the circuit that alternates between +0.5 V and -0.5 V. The LC oscillator will produce an alternating current that will be damped by the resistor.

Observe the Circuit

1. **Run** the simulation in interactive mode and observe the pattern of attenuation.
2. Try changing the signal frequency to values both higher and lower than your theoretically calculated resonant frequency. Notice how the patterns change.
3. Describe your observations of the circuit's attenuated response.
4. When you are done, **stop** the function generator and oscilloscope.

Implement: Observe Frequency Response

1. First, you will use the AC sweep to run the circuit through a wide range of frequencies and observe its frequency response. Finally, you will identify the actual resonant frequency of the circuit.
2. Example can be found from the online version Multisim listed above,
    a. Change the source back to the AC Voltage source, and run an AC Sweep
3. Configure the Bode analyzer with the following settings:

Table 1-3 Bode Analyzer Settings

Stimulus channel	
Start frequency	10 Hz
Stop frequency	10 kHz
Steps per decade	10
Peak Amplitude	1 V
Response channels	
Response 1	Active
Response 2	Inactive
Response 3	Inactive
Other	
Cursors	Manual

Determine Resonant Frequency

1. Press **Run**.
2. Use the cursors to find the frequency at which the system's gain is highest, which is the resonant frequency.
3. What is the measured resonant frequency, in Hz?

3. Experimental Questions

These questions will help you review and interpret the concepts learned in this lab.

- In your own words, describe what an RLC circuit is and what it is used for.
- What is the effect of adding a resistor to an LC oscillator (making it an RLC oscillator)?

APPENDIX

The following is the template of the ECE 3313 report. Note that the report must be typed using Microsoft Words/Excel. Please download the template from the Canvas website.

ECE 3313 Lab X Report | Your Name

Title: Lab 1: Observation, Modeling, and Communication

NAME: **Partner:**

General Objective: One or two sentences that describe the objective of this specific lab.

1.0 Prelab Activities: If there is any

2.0 Background Activities: Read background information and summarize important theory, equation, etc.

3.0 Procedure: Describe step-by-step procedure, including circuit schematic, calculation, and etc.

4.0 Results: A lab often includes questions. Please include your answer under the result sections.

- **4.1 Simulation Results:** Make sure to fully discuss about the results, figure, etc.
- **4.2 Experimental Results:** Make sure to fully discuss about the results, figure, etc.

5.0 Conclusions

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