PHYS245 Lab: RLC circuits

Purpose:

- Understand the resonance in and RLC circuit.
- Observe underdamped and overdamped oscillations in RLC circuits
- Construct a band pass filter.

Equipments: ELVIS II, 10 mH inductor, 4.7 nF capacitor, and 10 Ω and 330 Ω resistors, jump wires, two coaxial cables with BNC connectors, banana-to-minigrabber cables.

The combination of resistor (R), inductor (L), and capacitor (C) are commonly used for resonance circuits and filter circuits. You have seen RC and RL circuits previously. In this Lab, a circuit will be constructed with a resistor (R), a capacitor (C) and an inductor (L) in series. In experiment I, you will observe the oscillatory signals in a RLC resonant circuit. In experiment II, you will construct a band pass filter circuit using R, L, and C.

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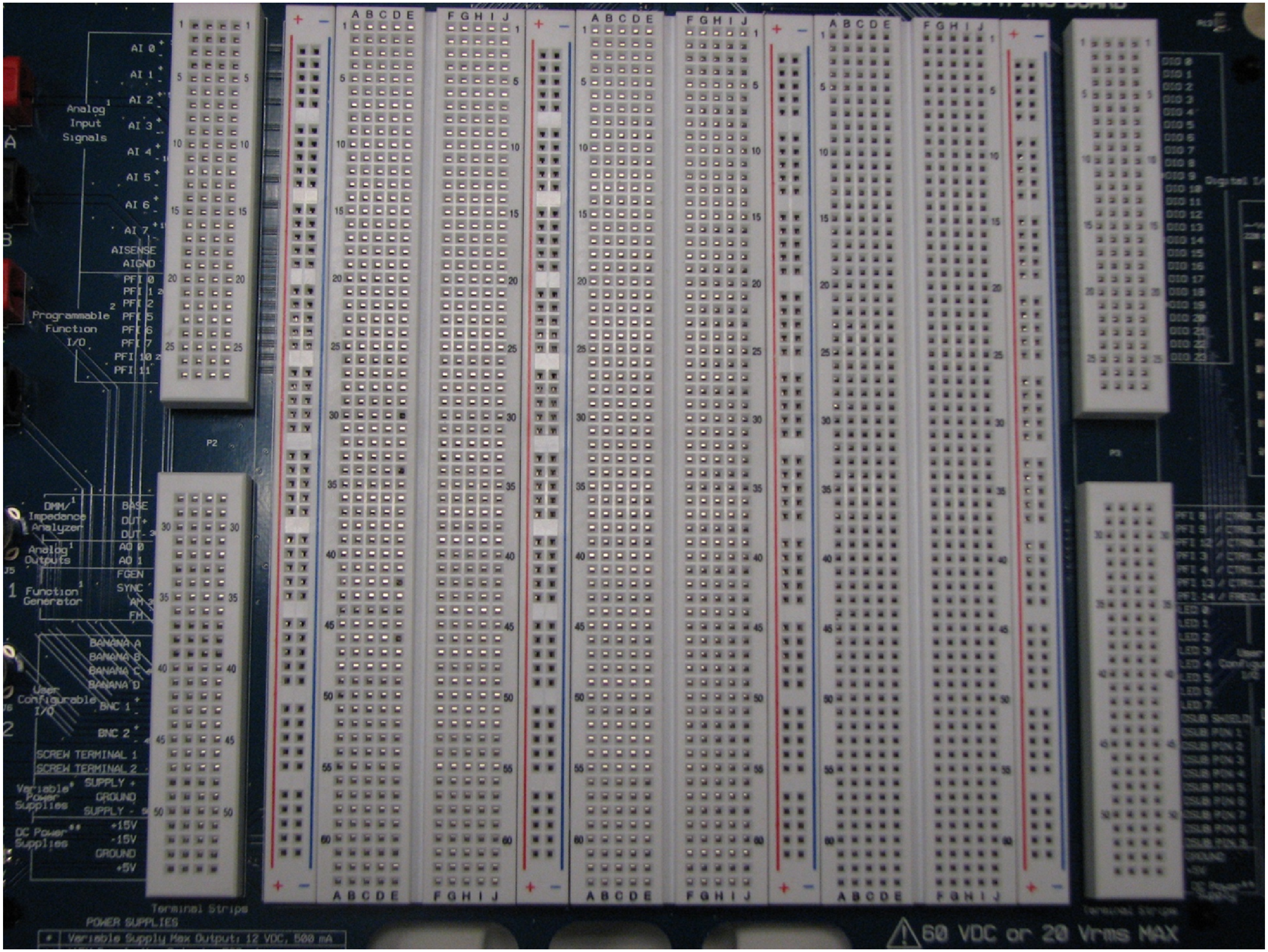
Pre-Lab exercises

Practice the construction of circuits in the prototyping board picture on next page.

Calculate the resonance frequency for a circuit with a resistor ($R = 10\Omega$), a capacitor ($C = 4.7$ nF) and a an inductor ($L = 10$ mH) in series.

In experiment I, suppose you have to choose the frequency of the square wave yourself. A student said that he would choose the frequency of the square wave as the frequency of the RLC resonance calculated above. Do you think this is a wise decision for the experiment? If yes, explain why. If no, briefly describe how you would choose the frequency.

Roughly sketch what you would expect for the transfer function (H) as a function of frequency (f) in experiment II.



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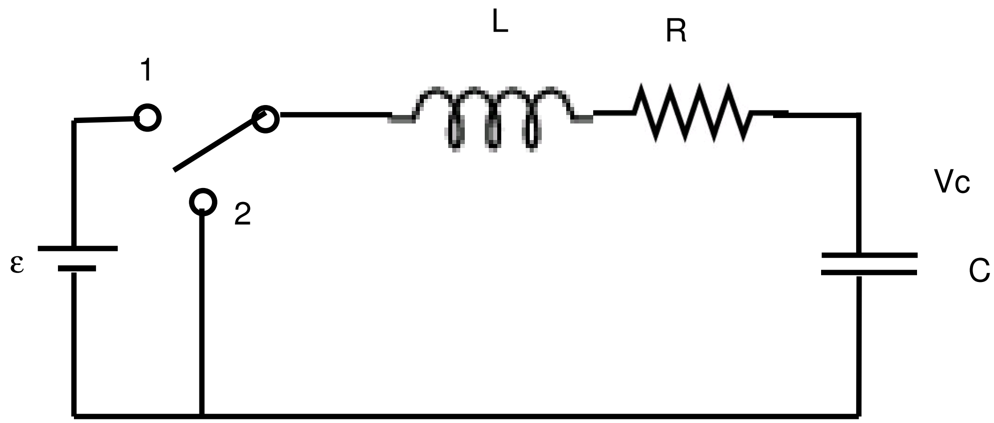
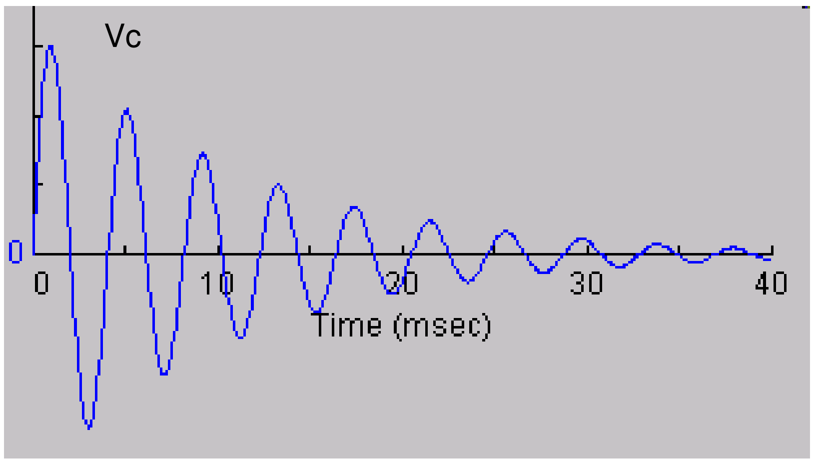
Experiment I: RLC resonance circuit

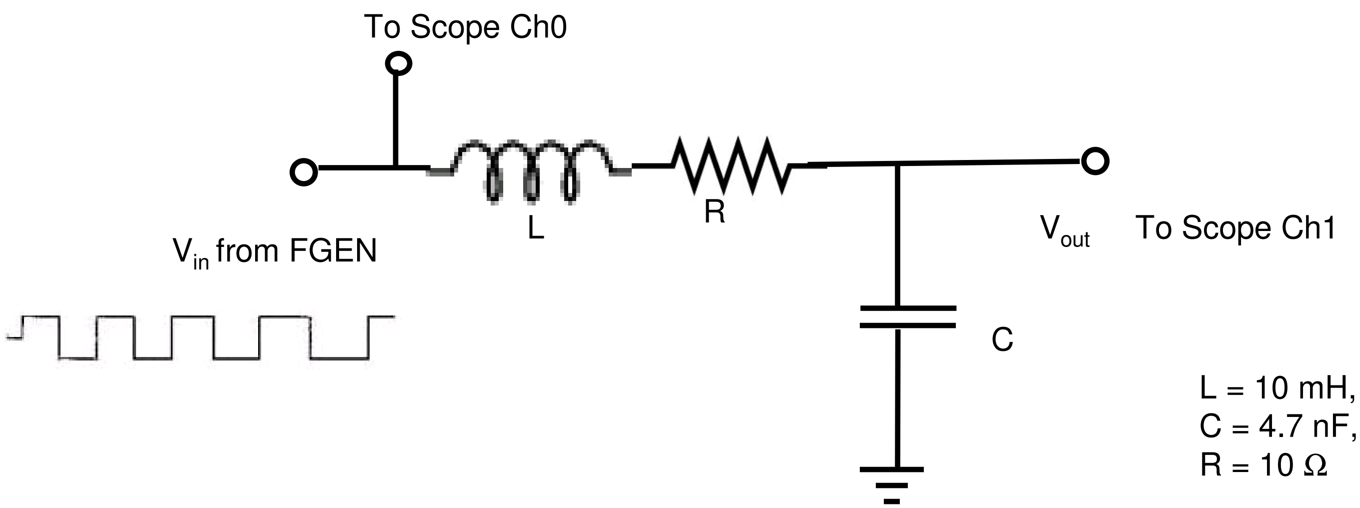


Switch to 1: charge the RLC circuit
Switch to 2: Discharge the RLC circuit

If the resistor R is small enough, The voltage across the capacitor Vc will oscillate, instead of approaching the final voltage monotonically, during the charging or discharging processes. These oscillation is a result of the resonance in the RLC circuit. It is a indication that electromagnetic energy goes back and forth between the capacitor and the inductor.



Use a square wave to "turn on and off" the RLC circuit. The square wave produces the same effect as a battery being switched on and off periodically. Construct the circuit on the prototyping board. Route the square wave from the FGEN to the input of the circuit. Direct the output to the Scope Ch1. The square wave from FGEN can be routed to Scope ch0 as a reference.

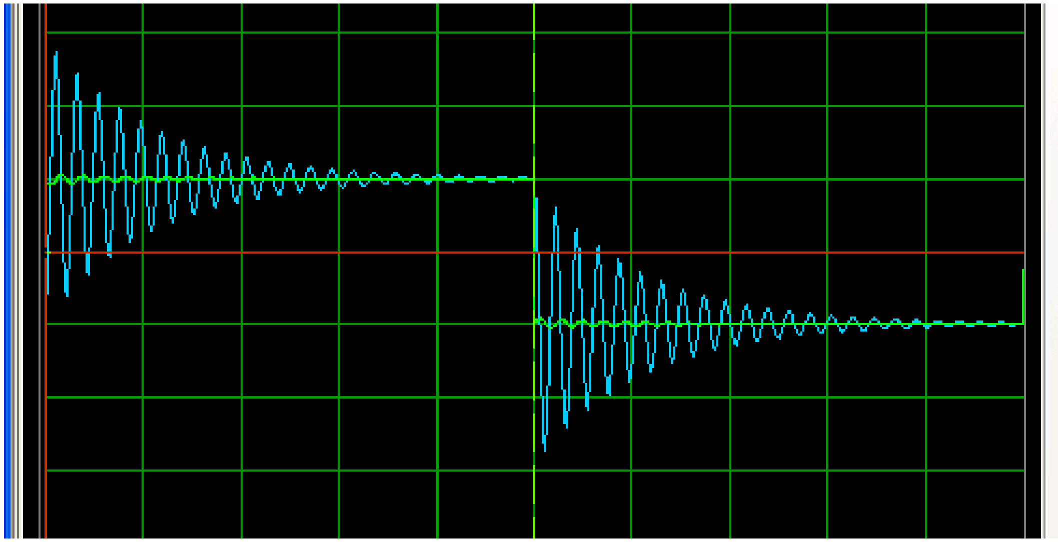


Set the frequency of the square wave to 500 Hz. The period the square wave is 2 ms, much larger than the period of oscillation of the RLC circuit. This allows for the observation of many oscillations in the RLC circuit.

Use "Edge" Trigger for the channel 0 signal (square wave) to obtain a stable waveform in the Scope. Adjust the vertical scale (Volts/Div) and horizontal scale (Time/Div) for clear view of RLC oscillations.

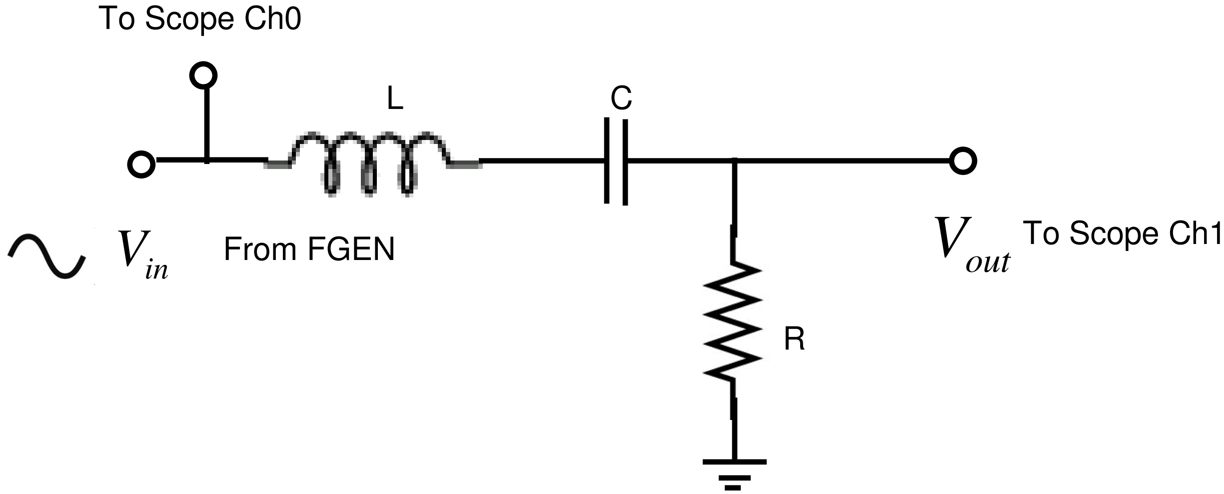
The following screen shot is an example of the waveform of the RLC underdamped oscillation. The green line is the square wave in channel 0. The blue line is the voltage on the capacitor (channel 1), and it oscillates as a function of time. This means that the energy in the capacitor oscillates as a function of time, because the electromagnetic energy goes back and forth between the inductor and the capacitor. The magnitude of the oscillation decays as a function of time, because the energy dissipates on the resistor, and the total energy gradually decreases.

The oscillation exists for both the "on" and "off" state of the circuit, or the "high" and "low" state of the square wave. The frequency of the oscillation should be the resonance frequency of the RLC circuit. From waveform of your Scope, estimate the oscillation frequency. To make the estimate accurate, you can measure the time elapse t_N associated with many (N) oscillations. The period of the oscillation is $T_0 = t_N/N$. The frequency is $f_0=1/T_0$. Compare with the resonance frequency calculated in the Pre-Lab.



Replace the 10 Ω resistor with the 330 Ω resistor. Observe the waveform again. The oscillatory features should disappear. Instead capacitor voltage vary monotonically as a function of time during the charging and discharging processes. A larger resistor dissipates energy faster. The electromagnetic energy in the circuit quickly decreases and the oscillation can not be observed. This is known as overdamped RLC oscillation.

Experiment II: RLC band pass filter



L = 10 mH
C = 4.7 nF
R = 330 Ω

Construct the filter circuit as shown in the diagram. Use 330 Ω resistor. Feed a sine wave (V_{pp} = 2V) signal from the FGEN to the input of the circuit.

Route the input signal V_{in} to the channel 0 of the Scope. Route the output signal to the channel 1 of the Scope. Enable both channels.

Start with the resonance frequency(f= 23 kHz) calculated in the Pre-Lab. Compare the magnitudes of V_{in} and V_{out}. Then move away from the resonance frequency, and observe how the magnitude of V_{out} changes.

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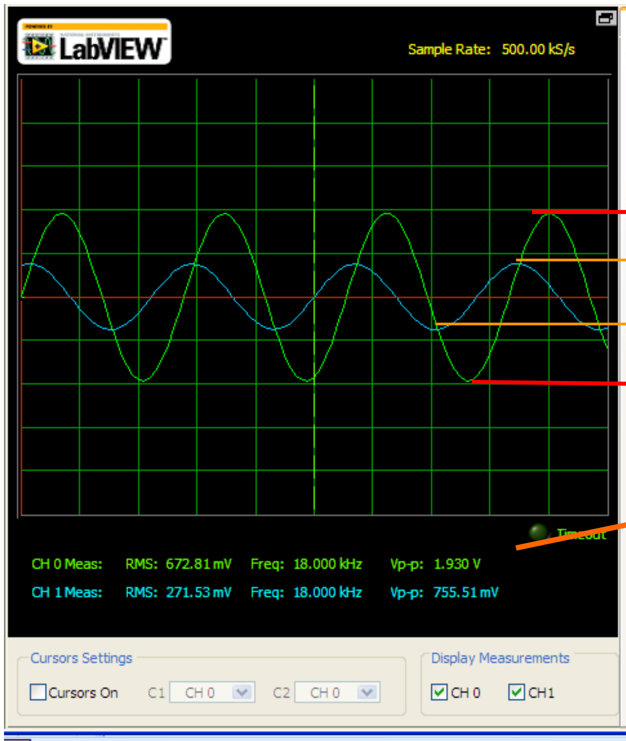
Transfer function is defined as $$\left|H_V\right| = \frac{\left|V_{out}\right|}{\left|V_{in}\right|}$$

Measure Hv as a function of frequency f



V_{out} V_{in}

This picture illustrates how to measure V_{in} and V_{out} on the Scope

The peak-to-peak voltage values for channels 0 and 1 are also automatically calculated by the Scope and displayed at the bottom of the screen

Make sure you choose the vertical (Volt/Div) and horizontal (Time/Div) scale properly for bettering viewing and easy measurement of the input and output signal.

Measure the transfer function at f = 1, 10, 15, 17, 20, 21, 22, 23, 24, 25, 26, 29, 32, 35, 40, 50, 60 kHz. Then plot $H_v - f$ in Origin

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Print out the $H_v - f$ plot and include it in your Lab report. Pay attention to the shape of the $H_v - f$ curve you have plotted. Is it consistent with the concept of "band pass filter". Briefly comment in your Lab report. Determine the resonance frequency from the $H_v - f$ plot. Compare it with the calculation in the Pre-Lab.