CMPE 306

Lab X: Frequency Selective RLC Circuits

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1. Purpose and Introduction

The purpose of this lab is to study second-order frequency-selective circuits consisting of resistors, capacitors and inductors. These circuits are *frequency-selective* because the outputs due to input sinusoidal signals at certain frequencies have larger amplitude than the outputs due to input signals at other frequencies. Thus the circuit *selects* certain frequencies (the high amplitude ones) in preference to other frequencies (the low amplitude ones). Such frequency selective circuits are the most common use for RLC designs. The addition of the second energy storage device, that is, adding the inductor to an RC circuit or the capacitor to an RL circuit permits us to design a frequency selective circuit that has a *bandpass* characteristic, in addition to the low pass and high pass characteristics demonstrated in Lab IX.

By the end of this lab session, students will be able to perform the following tasks:

1. Simulate and analyze prototype RLC circuits.
2. Predict circuit performance using complex impedances.
3. Construct low pass and band pass filters with series RLC circuits forms.
4. Collect and analyze data illustrating that the circuits have the desired frequency selective characteristics.

2. Pre-Lab

Lab partners are expected to participate fully in the simulation and analysis/derivation exercises thown in the lab.

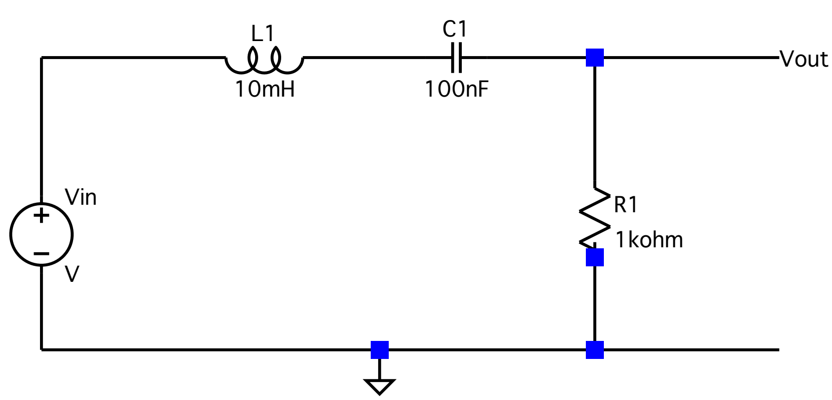

Figure 1 LTSPICE Circuit #1 for Bandpass Filter

1. Using the complex impedance of the capacitor and the resistor, write an expression for the gain of this passive circuit, $G(\omega) = \frac{V_{out}}{V_{in}}$. Determine the resonance frequency, where the imaginary part of the complex impedance is zero and the frequency(ies) where the output power is 50% of the input power.
2. Create the simple circuit shown in Figure 2 in LTSPICE. Using the notation used in Lab IX, set the voltage source Vin to be an AC source with 5 volt amplitude and 0 volte offset. Using Lab IX, Figure 1 as a guide, create the SPICE directive to sweep the input frequency from 10 Hz to 1 MHz with 20 frequency steps per decade. Verify that your center frequency and half power points agree with the predictions made in Step 1.
3. From plotting window (which should come up immediately), select the Add Traces option. When you add the traces, select V(Vout), then type "/", then select V(n001V). This will plot the ratio $G(\omega) = \frac{V_{out}}{V_{in}}$. You should see a plot that looks like **Error! Reference source not found.**.

   Collaborate with your lab partner to answer the following questions. Notice that the x-axis (the frequency scale) is logarithmic in nature, and the y-axis (the amplitude scale) is in decibels (dB).[1] Double click on the y-axis and change the representation to **Bode** with amplitude. The solid green curve is the magnitude of the (complex) gain, and the dotted line is the phase. Does this make sense, given the DC characteristics of the capacitor and the high frequency characteristic of the inductor? Does the curve match your expression derived in Step 1, above? This curve represents a *band pass* circuit. Explain why this terminology makes sense.
4. Modify the LTSPICE circuit to match the circuit shown in Figure 2.
5. Repeat Step 2 and Step 3. Remember to find the center frequency and the related power gain.
6. Show the plots and computations required in Steps 1-5 to the Teaching Assistant. Include this information in your lab report.

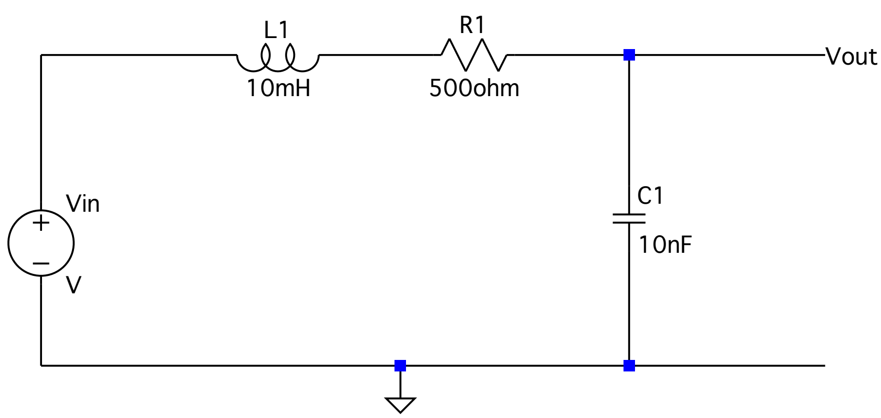

Figure 2 LTSPICE Circuit #2

[1] A decibel (dB) is *also* a logarithmic unit. For voltages, $[v]_{\text{dB}} = 20\log_{10}\left(\frac{v}{v_{\text{ref}}}\right)$, where $[v]_{\text{dB}}$ is the value of the amplitude of the voltage v given in decibels, and v_{ref} is some reference voltage. For the case of

3. Equipment

This lab exercise uses the following equipment:

1) Tektronix AFG310 Arbitrary Function Generator
2) Tektronix 2012 Digital Storage Oscilloscope
3) BNC-to-BNC cable
4) Two BNC-to-alligator cables.
5) 500Ω, 1kΩ resistors, 10nF, 100nF capacitors, 10mH inductor
6) Multimeter

4. .Procedure

Before starting, use your multimeter to measure the resistance of the inductor. Record this value; you will need it in 4.3 and 4.4, below.

4.1. Series LRC Circuit #1

1. Construct the circuit shown in Figure 1
2. Use a 5V amplitude sinusoidal output (peak-to-peak 10V, offset 0V) of the function generator as the input voltage source.
3. Measure the output voltage for frequencies from 100Hz to 300kHz. Take at least eight points to plot a smooth curve. Make sure that the half-power frequency(ies) and the resonance frequency, as computed in the pre-lab, is (are) among the points measured.
4. Using MATLAB or EXCEL, plot the measured ratio of the amplitudes of the output sine wave to the input sine wave, $\frac{|V_{out}|}{|V_{in}|}$ (voltage ratio, not decibels!) on the y-axis vs. $\log_{10}(f)$ on the x-axis.

   The vertical magnitude should be from 0 to 1. Locate the half-power point(s) calculated and identify it(them) with a square on the plot.
5. Using your knowledge of the low frequency and high frequency characteristics of inductors and capacitors, discuss why your plot makes sense.

4.2. Series LRC Circuit #2

1. Construct the filter shown in Figure 2.
2. Repeat steps 2) to 5) of part 4.1.

4.3. Preparation for Next Lab

Congratulations! You have completed the ten lab exercises for CMPE306. Next week you will have a practice period for the lab final. You will select a circuit at random from among several candidates and will be asked to construct and measure the circuit performance without guidance from a lab description such as this. The lab final is worth 50% of your laboratory grade and will be taken *individually*, not with your partner! Students will have one hour to complete the lab final.

Lab X is also the final lab report of the semester. For the lab report for this week, please include all of the plots that you were asked to create, and all of the values you were asked to record, and the computations you were asked to make. Partners should participate in the derivations. Please indicate in your report if your partner participated or not.

5. Tear Down and Clean Up

1. Turn off the power supply, AFG, and oscilloscope and set the multimeter to the OFF position. Return the multimeter to your TA for storage.
2. Save your images or data to your memory stick. Then close the program and sign off of the computer.
3. Put your resistors and capacitors chip back in your lab kit. Return your lab kit to the TA for storage.
4. Return the BNC cables and BNC-to-alligator cables and hang them neatly in their proper rack.
5. Police your lab area: leave it neat and clean.
6. If you're using your own laptop, there's nothing else to clean up.
7. If you're using the lab computer, save whatever work you want to your USB drive. Close LTSPICE if necessary. Eject your drive.