SAMPLE: EXPERIMENT 2
Series RLC Circuit / Bode Plot

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Experiment 2: Series RLC Circuit Sinusoidal Response

Introduction

Since inductive and capacitive reactances are a function of frequency, the sinusoidal response of a series RLC circuit will vary with the applied frequency. Inductive reactance is directly proportional to the frequency, and the capacitive reactance is inversely proportional to frequency. There is a frequency, fo, where the reactances cancel out ($X_L - X_C = 0$) and the circuit becomes resistive ($Z = R + j(X_L - X_C)$. This phenomenon is called resonance. Below the "resonant" frequency the impedance is capacitive. Above the resonant frequency the impedance is inductive. In this laboratory experiment, the measured response of the RLC circuit will be compared to analysis and simulation.

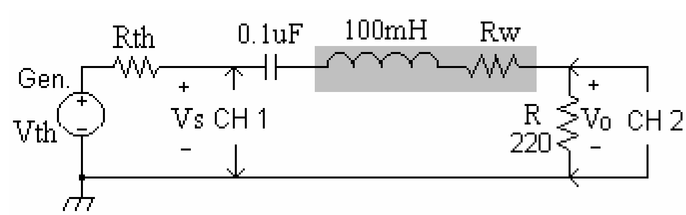
The series resonant circuit has two important parameters, resonant frequency, fo, and bandwidth, BW. The bandwidth is the difference between the two frequencies where the current in the circuit is 0.707 of its' maximum value. These two parameters are related to the parameters of the circuit's "step" response. One objective of this lab exercise is to become more familiar with the response of "oscillatory" circuits. Oscillation is a common natural phenomenon, and in electrical circuits it may be desired or undesired. For example, we don't want digital signals to oscillate when the voltage level changes, but oscillation may occur because of inductance in wires and capacitance between wires and within logic gates. Understanding resonance is important for engineers in general. Resonance can destroy mechanical systems, or be desired, as in a musical instrument.

Equipment Required

Function Generator and Oscilloscope.
L = 100mH, 5%, C = 0.1uF capacitor, R = 220 ohms.
(Use the components whose values you determined in experiment 1, measure R)

Procedure Part 1: Resonant Frequency and Bandwidth

1. Connect C, L, and R directly together, with no wires in between. Connect the function generator and oscilloscope leads directly to the components.



2. Connect channel 1 of the oscilloscope to measure Vs, the output of the function generator and connect channel 2 of the oscilloscope to measure the voltage, Vo, across R. Set the oscilloscope to trigger on channel 1.

4. Set the function generator to produce a 5 volt, peak to peak, 1600 Hertz sine wave, with no offset (this is Vs). Fine-tune the function generator to get the maximum voltage, Vo. This will occur at the circuit's resonant frequency, fo.

5. Measure and record the peak to peak magnitude of the voltage, Vo, and the frequency, fo (make sure that Vs is still 5 volts peak to peak). Also measure and record the phase angle, θ_0, of Vo with respect to Vs.

6. Tune the function generator to a frequency below fo where the voltage, Vo, is 0.707 of it's maximum value. Make sure that Vs is still 5 volts peak to peak. Measure the phase angle of Vo with respect to Vs. Record the frequency as f1, and the phase angle as θ_1.

7. Tune the function generator to a frequency above fo where the voltage, Vo, is 0.707 of it's maximum value. Again, make sure that the function generator voltage is still 5 volts peak to peak. Measure the phase angle of Vo with respect to Vs. Record the frequency as f2, and the phase angle as θ_2.

   Organize your data into a table such as the one below:

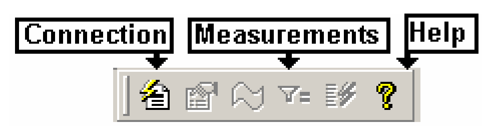
	Frequency	Vo Magnitude	Vo Phase angle
fo, Resonant frequency			θ_0 =
f1, Lower frequency			θ_1 =
f2, Upper frequency			θ_2 =

Procedure Part 2: Frequency Response Plot

This procedure requires a function generator capable of generating a frequency sweep and an oscilloscope connected to a computer. The procedure in this part uses an Agilent 33120A function generator, a Tektronix TDS1002 oscilloscope, a PC with Microsoft Excel, and Tek Open Choice software.

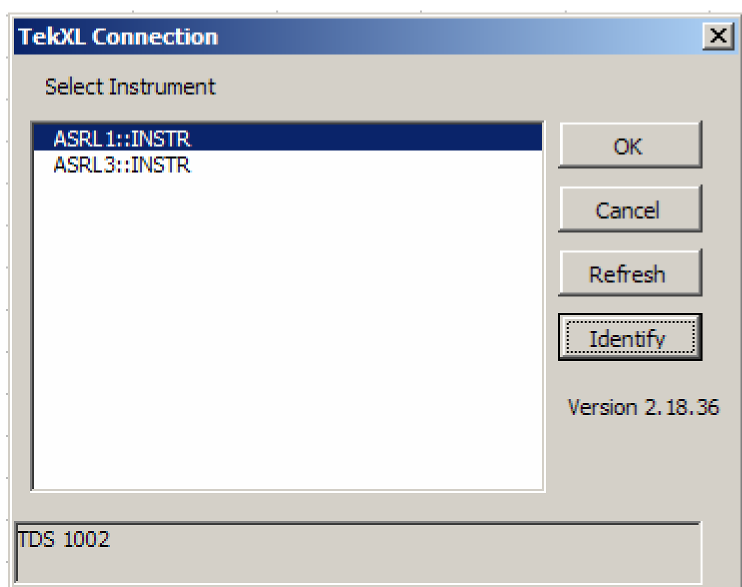
1. Use the same setup as in part 1 (repeat part 1, steps 1 and 2).

2. Open Excel. You should see the TekXL tool bar as shown on the right. Click on "connection".

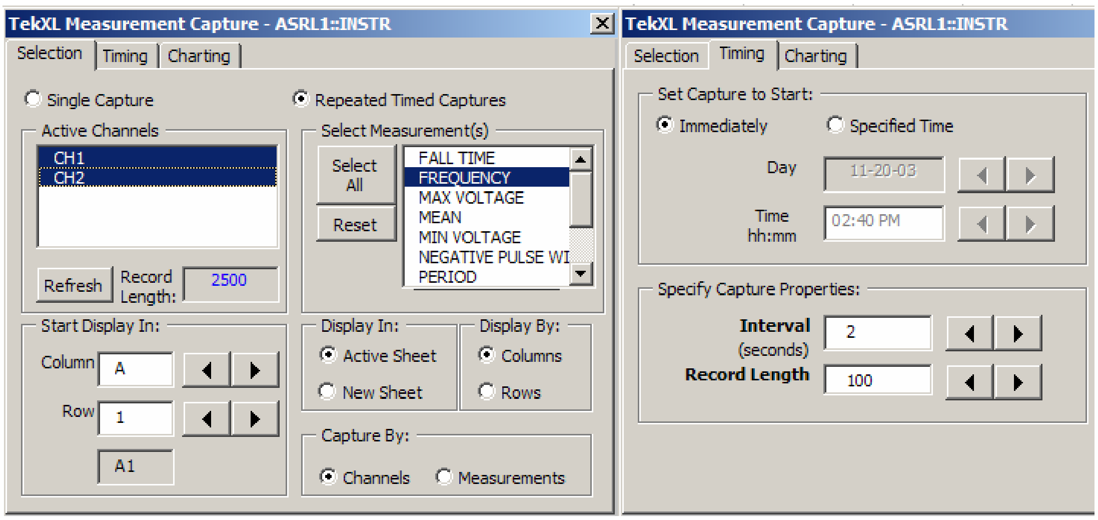


3. Select an instrument, usually the first one, and click on "identify". The instrument ID should appear at the bottom of the window, in this case, "TDS1002".

   Click "OK". If there is a problem with this part of the procedure, you may need to ask the instructor or lab assistant for help. Also, you may click on the "Help" in the TekXL tool bar.



4. Click on "Measurements" in the TekXL tool bar. Click the "Selection" tab and select both channels 1 and 2. Select the measurements: FREQUENCY and ROOT MEAN SQUARE, as shown below. Click on the "Timing" tab.



5. The timing settings depend on the capability of the function generator and oscilloscope interface. The example frequency response plot shown on the next page was done using an Agilent 33120A function generator set to logarithmic sweep from 100Hz to 10KHz in 400 seconds. If you need help setting the function generator, ask the lab instructor or assistant for help. You can also refer to the function generators user manual.

   The sampling interval was set to 2 seconds so one would expect 200 measurements in 400 seconds. However, only 95 measurements were actually made in that time, due to a slow serial interface. So the record length was set to 100.

6. The oscilloscope time base needs to be set so that one cycle is displayed at the lowest frequency, in this case, 1mS/Div. At the highest frequency there will be 100 cycles displayed. Since the oscilloscope takes 2500 samples per screen, one cycle of 100Hz would consist of 2500 samples and one cycle of 10KHz would consist of 25 samples.

7. Set the function generator to produce a 1 volt rms sine wave. Set both vertical channels of the oscilloscope to 500mV/Div. You should now be ready to start the sweep.

8. The Agilent function generator starts the sweep when the "Single/TRIG" button is pressed. TekXL Measurement starts when the start button is clicked. Click the start button and immediately after push the "Single/TRIG" button on the function generator.

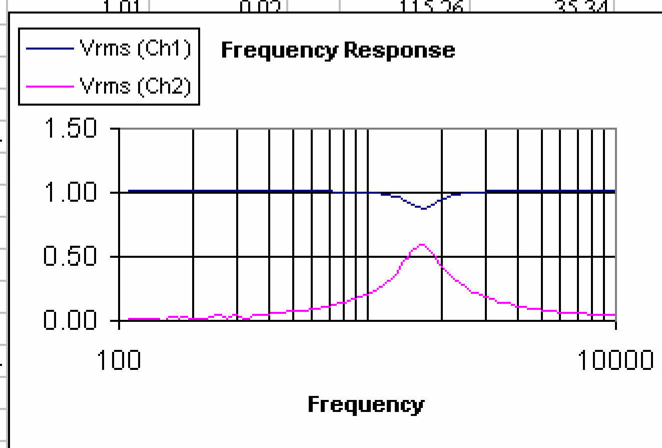
   You should observe the frequency increase on the oscilloscope screen and in Excel. Channel 2 frequency will be way off most of the time due to the low amplitude of the channel 2 signal. Stop the acquisition at 10KHz. You can delete the channel 2 frequency column and format the columns for better readability. See the sample result on the next page.

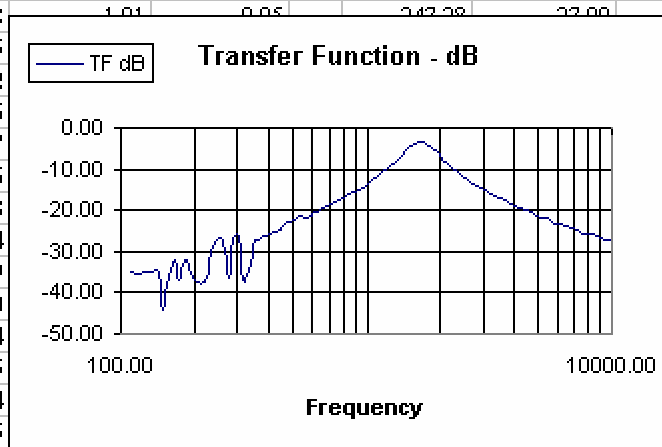
Sample Acquisition

The first 35 of 95 rows of the acquired measurements are shown below. The columns and graphs have been formatted. Note the dip in the function generator output at the resonant frequency in the first graph. This is due to the generator's 50-ohm internal resistance. This internal resistance would need to be included in calculating the Q and bandwidth for the response curve in the top graph.

The second graph was generated by plotting the actual "Transfer Function" of the filter. The ratio of the filters output to its input is plotted. The internal resistance of the function generator would not be included in calculating the Q and bandwidth for the response curve in the bottom graph. Cell F3 has the equation: =20*LOG10(C3/B3). A linear plot could be generated by writing in cell F3: =(C3/B3).

	A	B	C	D	E	F	G
1	Frequency	Vrms (Ch1)	Vrms (Ch2)		Frequency	TF dB	
3	109.41	1.01	0.02		109.41	-34.88	
4	115.26	1.01	0.02		115.26	-35.34	
5	121.07						
6	127.68						
7	134.55						
8	141.64						
9	149.16						
10	156.89						
11	165.02						
12	173.61						
13	182.75						
14	192.01						
15	201.94						
16	212.59						
17	223.61						
18	234.52	1.01	0.03		234.52	-30.79	
19	247.28	1.01	0.05		[illegible]	[illegible]	
20	260.15						
21	273.52						
22	287.36						
23	301.57						
24	317.26						
25	333.33						
26	350.14						
27	368.19						
28	386.70						
29	405.84						
30	427.35						
31	449.64						
32	471.25						
33	495.05	1.01	0.07		495.05	-22.76	
34	520.83	1.01	0.08		520.83	-22.08	
35	547.05	1.01	0.08		547.05	-21.59	





Analysis, Part 1

1. Calculate the theoretical resonant frequency of your RLC circuit. What is the percent difference between the measured and the calculated resonant frequency?

2. Calculate the theoretical bandwidth of your RLC circuit from your data in part 1 (remember to include Rw). Does the internal resistance of the function generator need to be included in the calculations? Why or why not? What is the percent difference between the measured and the calculated bandwidth?

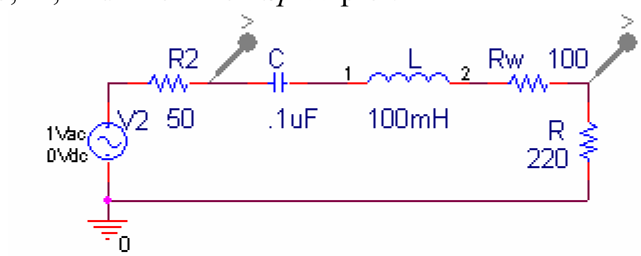
3. Simulate the RLC circuit with *PSpice*. Use "AC Sweep" analysis to plot the magnitude and phase response of the circuit from 100 Hertz to 10,000 Hertz. See below. Be sure to use your measured component values.

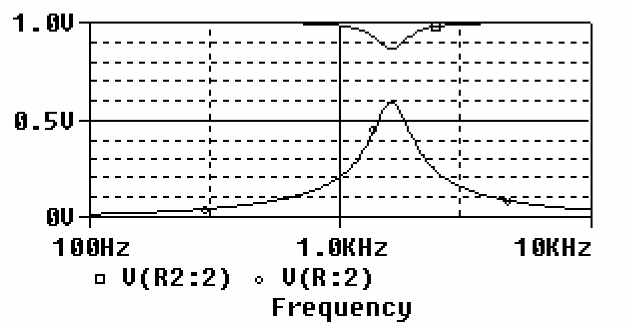
4. Use the cursors in *PSpice* to locate fo, f1, and f2 on the *PSpice* plot.

5. Note the circuit and simulation results on the right and the simulation settings below.

6. Compare your simulation results with your calculations. They should be in close agreement.

7. Record your measured resonant frequency and measured bandwidth. Save these results for the next experiment. (Also save the parts and measured values for the next set of experiments.)





fo = ________________

BW = ________________

R = ______________ Rw =_____________ L = ___________ C = ______________