Experiment 25 - Modified

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Objectives:
1. Observe the characteristics of a series RLC circuit.
2. Demonstrate resonance.

Pre-Lab Information:
- Resonant frequency occurs when the capacitance reactance (XC) is equivalent to the inductive reactance(XL)
- $Gain[dB] = 20log_{10}(Gain[\frac{V}{V}])$
- $w_r = \frac{\mathbf{1}}{\sqrt{\boldsymbol{LC}}} = \frac{\boldsymbol{rad}}{\boldsymbol{s}}$
- $f_r = \frac{1}{2\pi\sqrt{LC}} = Hz$
- $I = \frac{V}{R}$
- $x_C = \frac{1}{jwC}\ (capacitive\ reactance)$
- $x_L = jwL\ (inductive\ reactance)$

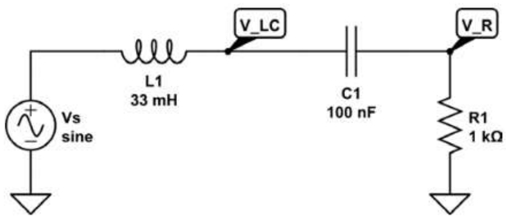

Figure 1. The default set-up for Experiment 25.

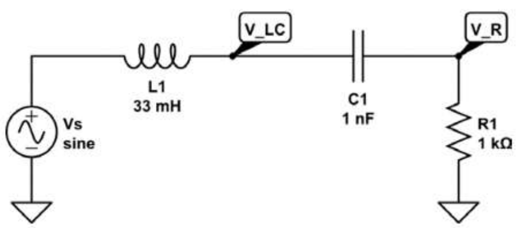

Figure 2. The additional set-up for Experiment 25.

Procedure:

Step 1 (Handout):

Table 1: Component Values for figure 1-2	R [ohm]	C1 [uF]	C2 [uF]	L [mH]	L Winding Resistance [ohm]
Expected	1000	0.1	1	33	n/a
Measured	990	0.102	1.07	32.44	22.59

Insert circuit diagram figure 3

Step 2 (Handout):

Table 2: Resonant frequency for figure 3	wr [rad/s]	fr [Hz]
Calculated	17384.4	2766.81
Measured	13854.4	2205

Table 3: Measured impedance and current for figure 3	Zeq [k ohm]	Io [mApp < Θ]
Fr/10	0.99 - j44.46	.045 < 88.72
Fr	0.99 - j4.375	.548 < 68.7

Fr*10	0.99 - j.270	0.487 < 64.71

Step 3 (Handout):
CH1 1 Vs, CH2 = VLC, CH3 = VR

Table 4: Measured values for various frequencies for figure 3	Frequency [Hz]	Frequency [rad/s]	Vs [Vpp]	VLC [Vpp < Ө]	VR [Vpp < Ө]	VLC/Vs [V/V]	VLC/Vs [dB]	VR/Vs [V/V]
	100	628.3	2	2 < 0	0.2 < 80	1	0	0.1
	200	1256.6	2	2 < 0	0.3 < 70	1	0	0.15
f_r/10	220.5	1385.4	2	2 < 0	0.3 < 70	1	0	0.15
	300	1885.0	2	2.1 < 0	0.4 < 70	1.05	0.42	0.2
	400	2513.3	2	2.1 < -0.5	0.6 < 70	1.05	0.42	0.3
	1000	6283.2	2	2.2 < -4	1.2 < 51	1.1	0.83	0.6
	2000	12566	2	2.3 < -17	1.9 < 21	1.15	1.21	0.95
f_r	2205	13854	2	2.4 < -20	1.9 < 15	1.2	1.58	0.95
	3000	18850	2	2.3 < -32	2.0 < 4	1.15	1.21	1
	4000	25133	2	2.1 < -44	1.9 < -22	1.05	0.42	0.95
	10000	62832	2	1.1 < -73	1.1 < -63	0.55	-5.19	0.55
	20000	125664	2	0.6 < -85	0.6 < -80	0.3	-10.46	0.3
f_r*10	22050	138544	2	0.5 < -80	0.5 < -80	0.25	-12.04	0.25
	30000	188496	2	0.4 < -90	0.4 < -90	0.2	-13.98	0.2
	40000	251327	2	0.3 < -95	0.3 < -93	0.15	-16.48	0.15

Note for figures 4-6:

- the magnitude of the phase shifts for the following figures are swapped
- CH1 (yellow) = Vi, CH2 (green) = VLC, CH3 (orange) = VR

Figure 4: Oscilloscope image of fr (resonant frequency)

Figure 5: Oscilloscope image of fr/10 (resonant frequency divided by 10)

Figure 6: Oscilloscope image of fr*10 (resonant frequency times 10)

Step 4 (Handout)
Insert circuit diagram figure 7

Table 5: Resonant frequency for figure 7	wr [rad/s]	fr [Hz]
Calculated	169734	27013
Measured	169395	26960

Table 6: Measured impedance and current for figure 7	Zeq [k ohm]	Io [mApp < ϴ]
Fr/10	0.99 - j5.279	0.465 < -77.38
Fr	0.99 - j33.79	0.319 < 22.32
Fr*10	0.99 - j346.6	0.00016 < 134.8

CH1 1 Vs, CH2 = VLC, CH3 = VR

Table 7: Measured values for various frequencies for figure 7	Frequency [kHz]	Frequency [rad/s]	Vs [Vpp]	VLC [Vpp < ϴ]	VR [Vpp < ϴ]	VLC/Vs [V/V]	VLC/Vs [dB]	VR/Vs [V/V]
	1	6283.2	2	2.3 < 0	0.4 < 0	1.15	1.21	0.2
	2	12566	2	2.4 < 0	0.4 < 0	1.2	1.58	0.2
f_r/10	2.696	16940	2	2.5 < 2	0.4 < 0	1.25	1.94	0.2
	3	18850	2	2.5 < 2	0.45 < 0	1.25	1.94	0.225
	4	25133	2	2.5 < 3	0.45 < 1	1.25	1.94	0.225
	10	62832	2	2.8 < 3	0.5 < 1	1.4	2.92	0.25
	20	125664	2	4.6 < 5	0.9 < 3	2.3	7.23	0.45
f_r	26.96	169395	2	10.8 < -66	2.1< 3	5.4	14.65	1.05
	30	188496	2	7.8 < -115	1.7 < -45	3.9	11.82	0.85
	40	251327	2	2.3 < -155	0.8 < -80	1.15	1.21	0.4
	100	628320	2	0.5 < -150	0.2 < -98	0.25	-12.04	0.1
	200	1256640	2	0.2 < 20	0.2 < 50	0.1	-20	0.1
f_r*10	269.6	1693950	2	0.075 < 45	0.065 < 70	0.0375	-28.52	0.0325
	300	1884960	2	0.08 < 50	0.07 < 75	0.04	-27.96	0.035
	400	2513270	2	0.12 < 60	0.110 < 80	0.6	-4.44	0.055

Note for figures 8-10:

- the magnitude of the phase shifts for the following figures are swapped
- CH1 (yellow) = Vi, CH2 (green) = VLC, CH3 (orange) = VR

Figure 8: Oscilloscope image of fr (resonant frequency)

Figure 9: Oscilloscope image of fr/10 (resonant frequency divided 10)

Figure 10: Oscilloscope image of fr*10 (resonant frequency times 10)

Step 5 (Handout):

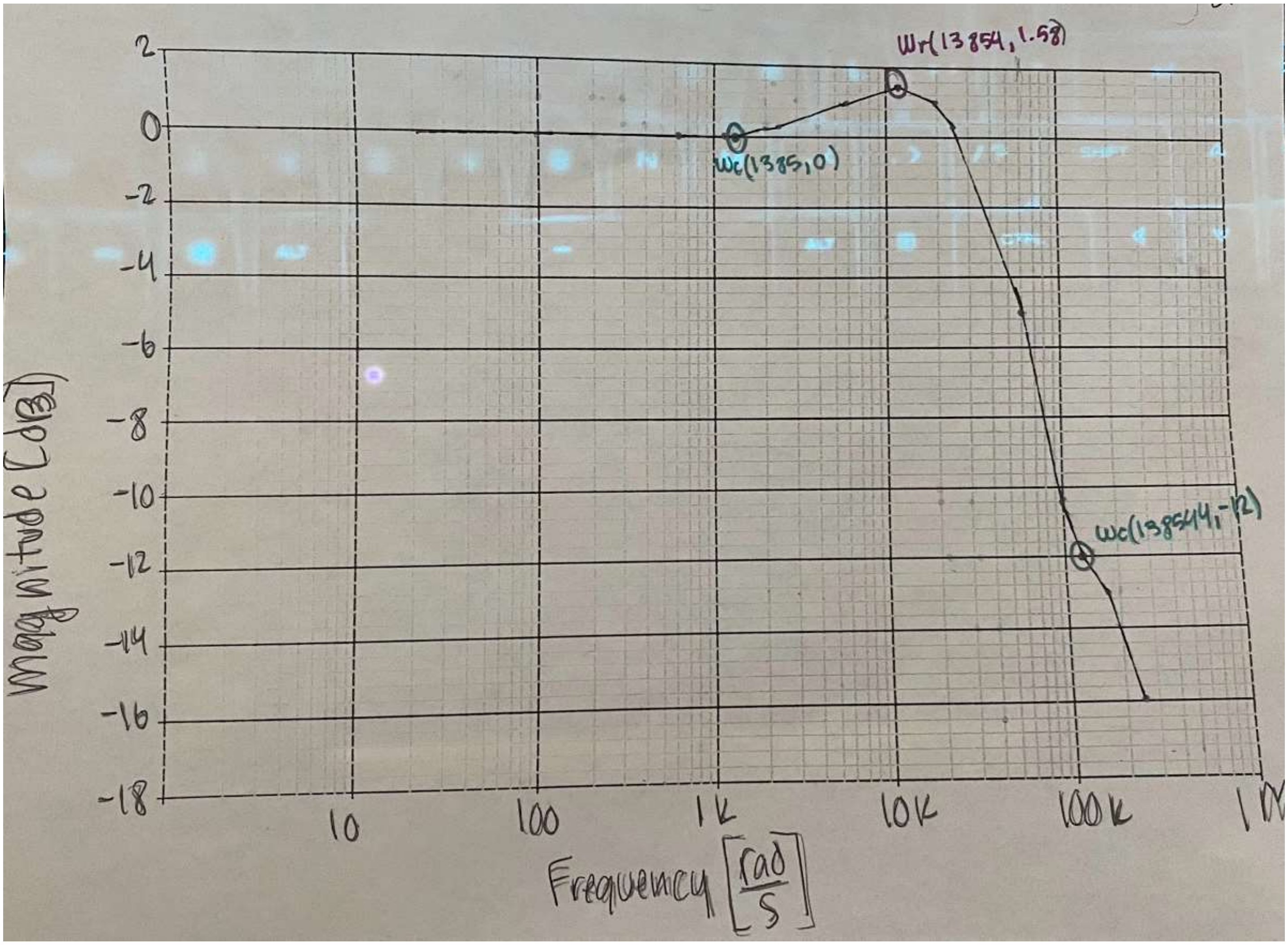

Figure 11: Hand drawn bode plot of figure 3 and table 4

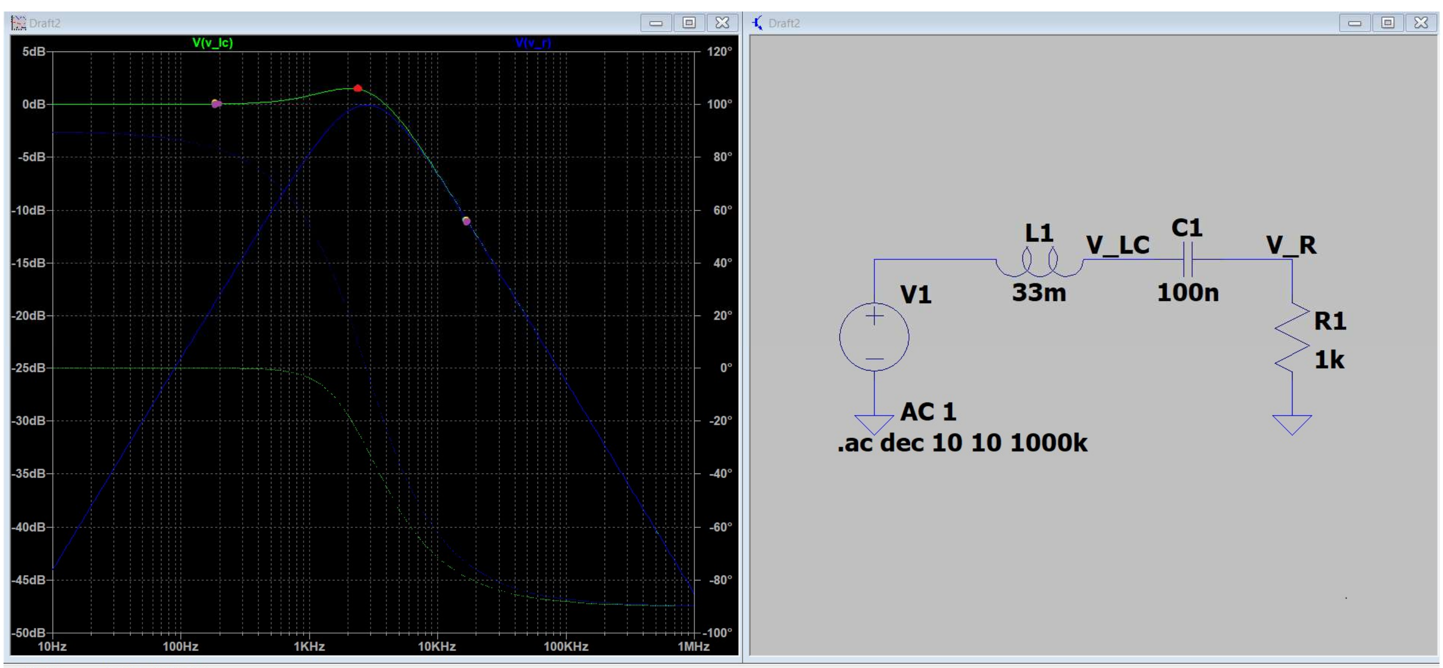

Figure 12: LTSpice Bode Plot for figure 3

Looking at figure 11 and figure 12, we can conclude that our simulations are the "same" as our real experiment. On figure 11, our resonant frequency occurs at 13854 Hz and 1.58 dB. On figure 12, our resonant frequency occurs at 1591.55 Hz and 2 dB. fr/10 occurs at 1358 Hz and 0 dB and fr*10 occurs at 138544 Hz and -12 dB on figure 11. fr/10 occurs at 159 Hz and 0 dB and fr*10 occurs at 15915.5 Hz and -10 dB. Other than the scale of the frequency (which could have been an error on my recording but not on my consistency), the resonant frequencies and the dB gain correspond between figure 11 and 12 as well as the shape of the bode plots.

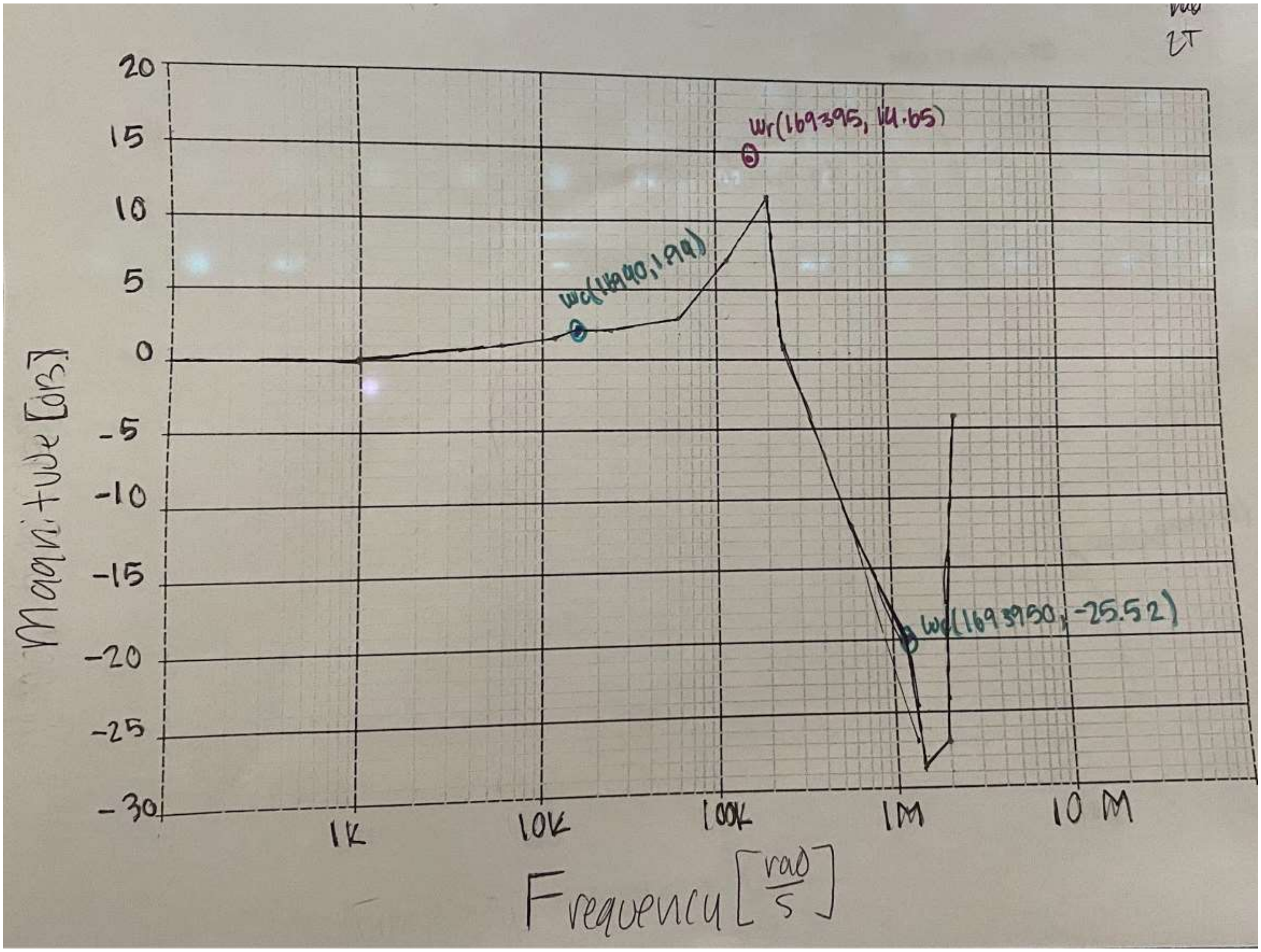

Figure 13: Hand drawn bode plot for figure 7 and table 7

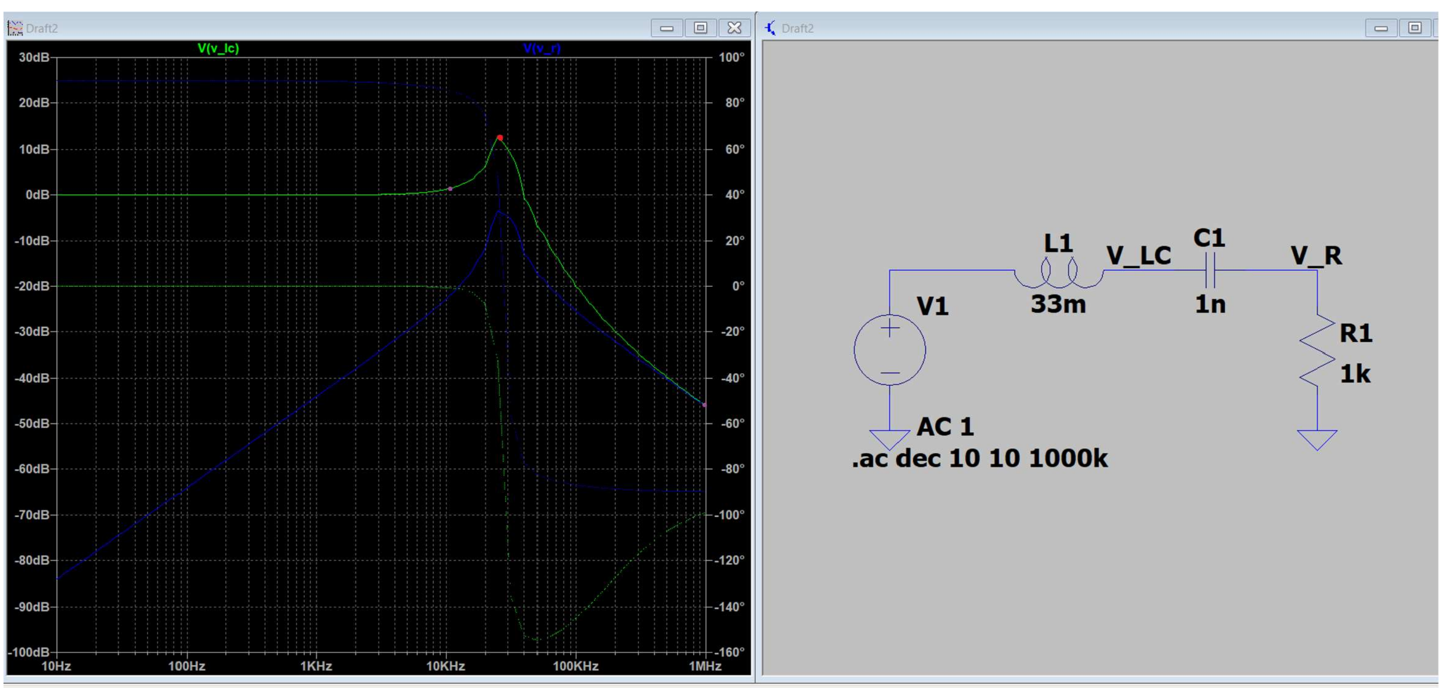

Figure 14: LTSpice Bode Plot for figure 7

Looking at figure 13 and figure 14, we can conclude that our simulations are the "same" as our real experiment. On figure 13, our resonant frequency occurs at 169395 Hz and 14.65 dB. On figure 14, our resonant frequency occurs at 15915.5 Hz and 13 dB. fr/10 occurs at 16940 Hz and 1.94 dB and fr*10 occurs at 1693950 Hz and -25.52 dB on figure 13. fr/10 occurs at 1591.55 Hz and 2 dB and fr*10 occurs at 159155 Hz and -30 dB. Other than the scale of the frequency (which could have been an error on my recording but not on my consistency), the resonant frequencies and the dB gain correspond between figure 13 and 14 as well as the shape of the bode plots.

Step 6 (Handout):
At higher frequencies, XL dominates XC and is higher. At lower frequencies, XC dominates and is higher. This can be shown by the voltage readings on the oscilloscope through different frequencies and ohms law. At lower frequencies, our voltage is larger which means our Zeq is positive so our XL is dominating. At higher frequencies, our voltage is smaller which means our Zeq is negative so our XC is dominating. When increasing or decreasing the frequency from the resonant frequency, the magnitude of the gain decreases regardless of V/V or dB. Immediately beside the resonant frequency, there is a drastic difference in magnitude. As the frequency gets larger/smaller, the difference is less drastic and can eventually level out in terms of dB. When decreasing the capacitance, it took a higher frequency to reach resonant frequency. The resonant frequency also increased. The capacitance increased by a scale of 100, the resonant frequency increased by a scale of approximately 10, and the resonant gain increased by a scale of approximately 7. A possible source of error in this experiment could have been the tolerance of the components used (resistors, capacitors, and inductors). By limiting the difference in values we limit discrepancies between real and simulated values although it is impossible to get the exact component values needed because all electrical components have tolerance error including sources. These discrepancies become more noticeable and drastic when approaching resonant frequency.