Physics 219_2018 - Nick Pun/Exp. 2 (LCR Resonance Circut)/Exp 2 LCR Resonance

SIGNED by Nick Pun Oct 19, 2018 @03:07 PM PDT

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4.1

Measured R: 0.9877k +- 0.1 ohms

Used 4 * 5 mH inductors in series to achieve 20 mH

Low frequency in this context means a frequency low enough that the function has enough time to dampen to zero. Low frequency in this case would be around 1.5 kHz and lower. However, we don't want to pick a frequency too low that the voltage stays at zero longer than it needs to be.

V_output appears to be a damped negative sine function (or cosine shifted left by pi/2), it's peaks and valleys come closer and closer together until they reach zero. The damping appears to follow an exponential decay. This is related to Eqn1 in that Eqn1 is a cosine function that is shifted left by pi/2 and multiplied by an exponential decay function.

We can improve the accuracy of our measurements on the oscilloscope by increasing the horizontal and vertical scales until we can see only one full damped oscillation. This will make each increment on the graph smaller and thus more precise. We were able to fit one oscillation using a vertical scale of 50 mV and a horizontal scale of 20 us. Discussed with Ray's group. They had the same scales with the same reasons.

Fitting the data:

First we removed all the data points that were not part of the damped oscillating function (zeros at the start).

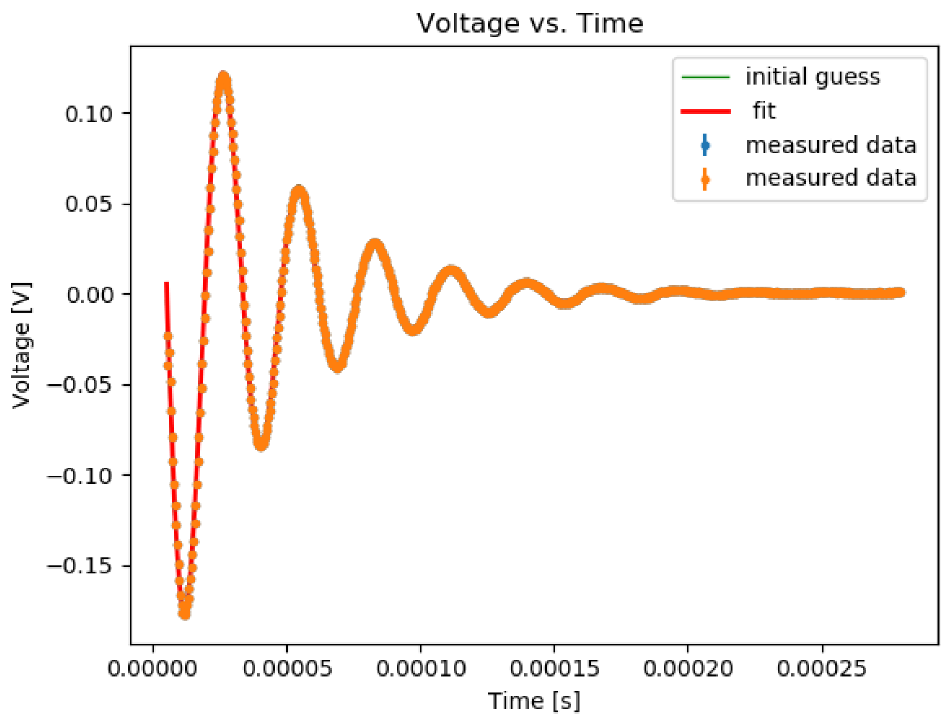
The fitting parameters we used was guesses = (0.235,4e-5,35000,np.pi/7) and y_sigma = 0.000666.

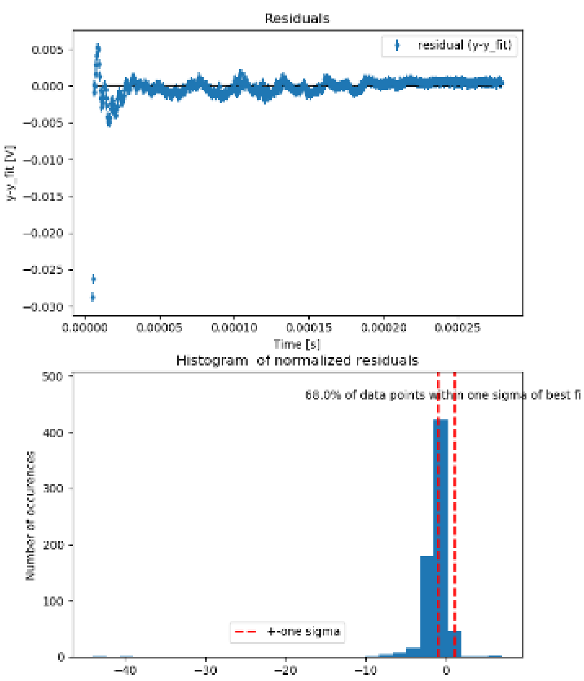
This created a good quality graph for the majority of the function, but was not very good for the first 0.00003 seconds. This is because the input square function isn't perfectly square, it fluctuates for a short amount of time (about the same time as the duration of the bad fit).

Goodness of fit - chi square measure:
Chi2 = 4862.61444165848, Chi2/dof = 7.119494058065125

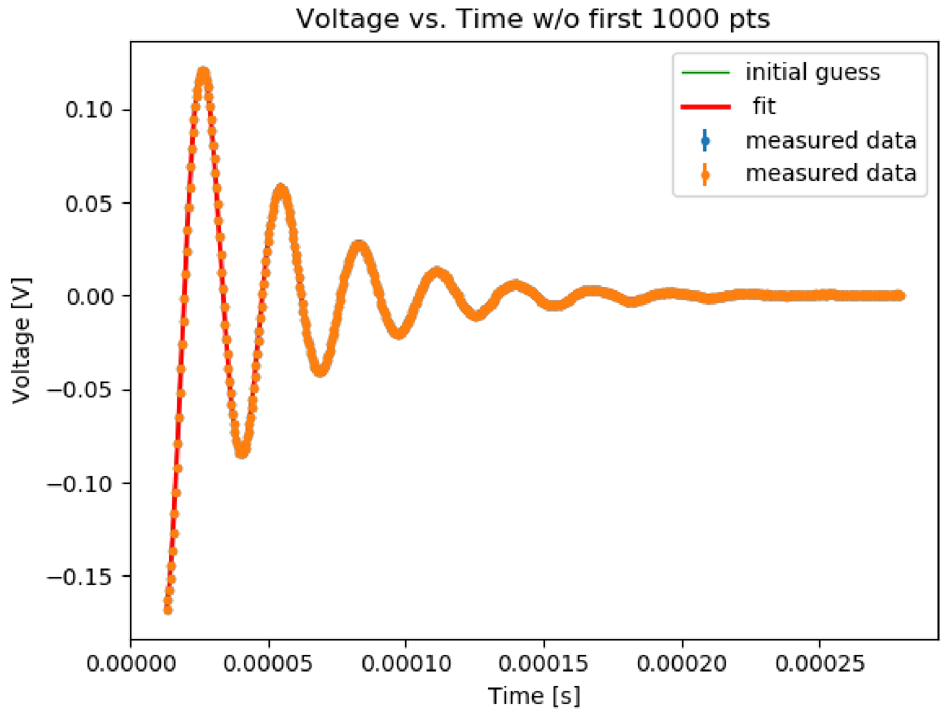
Fit parameters:
amplitude = 2.398e-01 +/- 2.636e-04
relaxation time = 3.892e-05 +/- 5.186e-08
frequency = 3.519e+04 +/- 5.164e+00
phase = 3.975e-01 +/- 1.011e-03

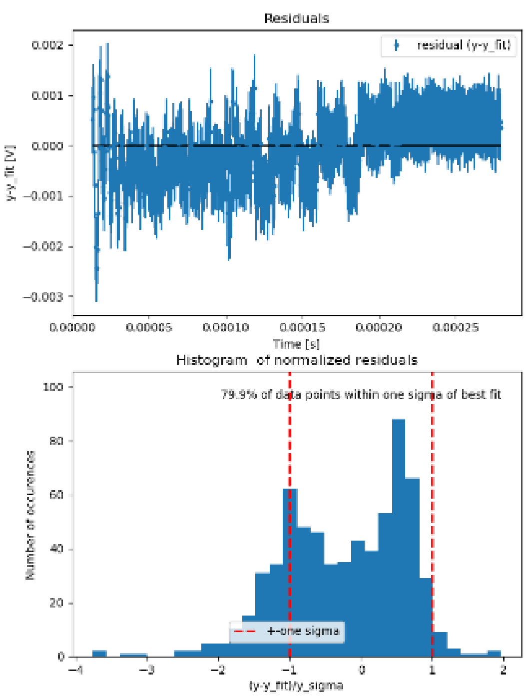
Residual information:
68.0% of data points agree with fit to within 1 sigma





We should use data points that happen after the square function stabilizes.

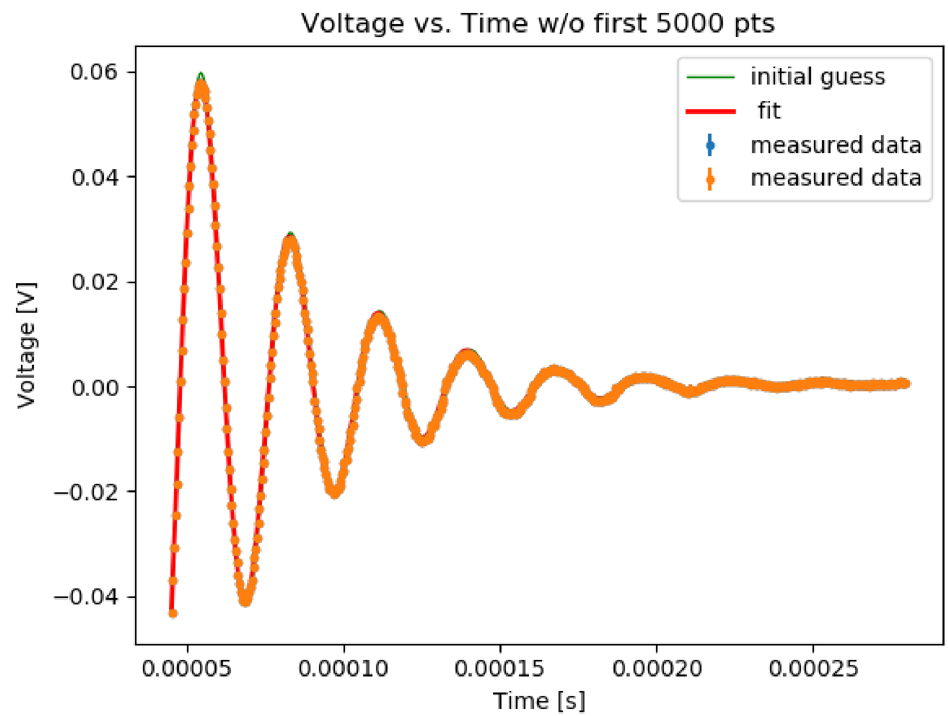


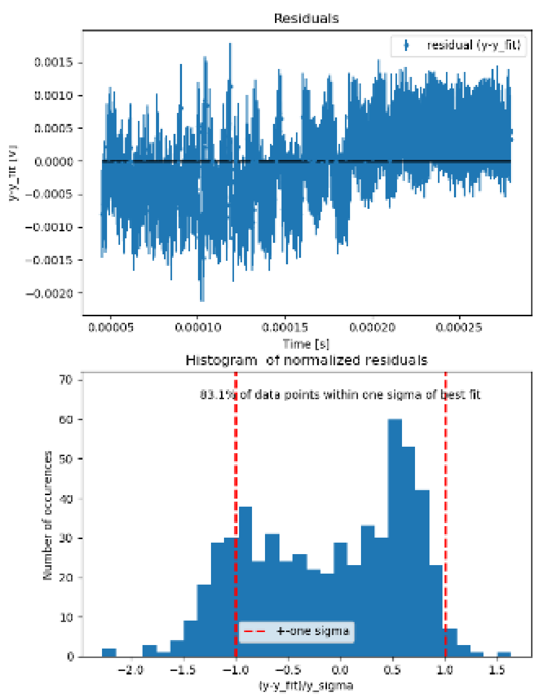


Goodness of fit - chi square measure:
Chi2 = 497.4199207570819, Chi2/dof = 0.7502562907346635

Fit parameters:
amplitude = 2.393e-01 +/- 3.733e-04
relaxation time = 3.896e-05 +/- 6.166e-08
frequency = 3.532e+04 +/- 6.572e+00
phase = 3.587e-01 +/- 1.579e-03

Residual information:
79.9% of data points agree with fit to within 1 sigma





Goodness of fit - chi square measure:
Chi2 = 326.0115972765055, Chi2/dof = 0.5591965647967504

Fit parameters:
amplitude = 2.306e-01 +/- 1.568e-03
relaxation time = 3.971e-05 +/- 1.528e-07
frequency = 3.532e+04 +/- 1.377e+01
phase = 3.555e-01 +/- 5.700e-03

Residual information:
83.1% of data points agree with fit to within 1 sigma

4.2

Input freq = 1.5 khz

Input pk-pk = 1.98V

Output pk-pk = 19.2 mV

Amplitude uncertainty is 2% according to manual except for small amplitudes where fuzziness is more than 2%.

Took rough measurements first then went back and took more data points around resonance frequency.

freq	amplitude (V)
10hz	1.53mV +/- 280uV
500hz	8mV
1khz	14.9mV
5khz	63.2mV
10khz (input v dropped to 1.94)	133mV
20khz	348mV
25khz	570mV
27khz	700mV
28kz	790mV
29khz	900mV
30khz	1.03V
31khz	1.20V
31.5khz	1.25V
32khz	1.32V
32.5khz	1.43V
33khz	1.52V
33.5khz	1.61V
34khz	1.68V
34.5khz	1.75V
35khz	1.79V
36khz (input v @1.9V)	1.79V
36.5khz	1.75V
37khz	1.68V
37.5khz	1.61V
38khz	1.56V
38.5khz	1.47V
39khz	1.43V
39.5khz	1.32V
40khz(input v @1.94V)	1.24V
41khz	1.11V
42khz	1.02V
43khz	900mV
44khz	840mv
45khz	770mV
50khz	540mV
60khz	354mV
70khz	264mV
80khz	208mV
100khz	136mV
120khz	96mV
140khz	68mV

150khz	56mV

@ freq = 35.588127 khz, amplitude = 1.80V (resonance)

Set Vr = sqrt(2) V, freq is then = 32.35 khz and 38.95 khz

Bandwith = 38.95 - 32.35 = 6.6 khz

We must investigate frequencies far away from resonance frequency in case there are other resonance frequencies that could contribute to the overall shape of the graph.

Phase shift investigation (used cursors):

below resonance: freq = 1 khz, shift = 748 us

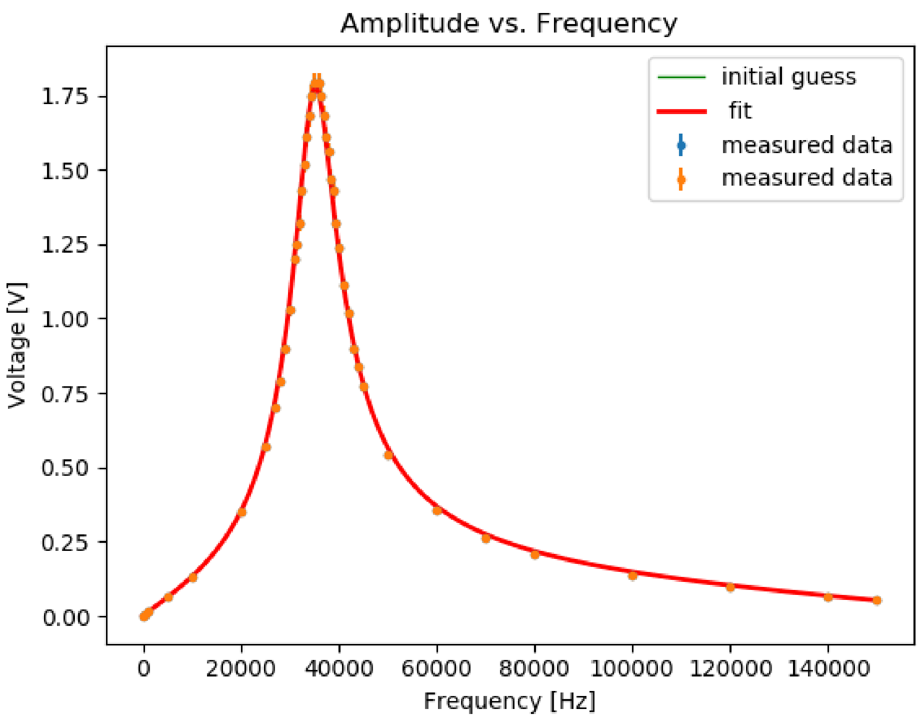
above resonance: freq = 70 khz, shift = 3.32 us

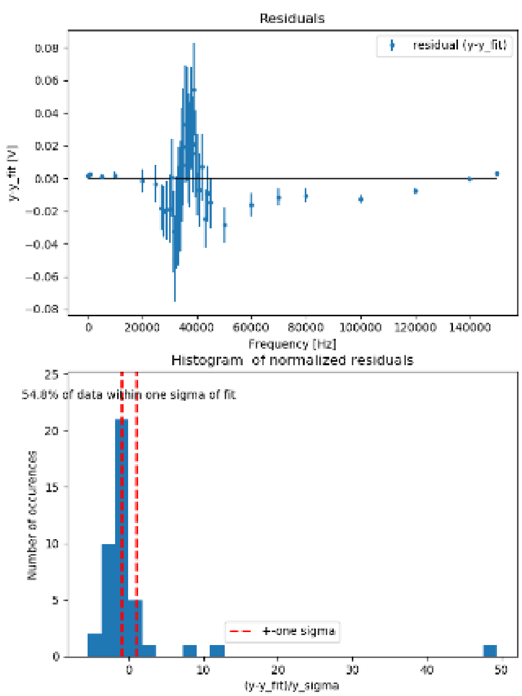
on resonance: freq = 35.588127 khz, shift = 100 ns (almost non existent)

On resonance, the phase shift is little to none. However, when moving away from the resonance frequency, it appears that the output function shifts rapidly when we are going below the resonance frequency and shifts slowly when we are going above the resonance frequency.

Data fitting:

initial guesses = (1.78,3.535e+4,5.359e+4,-2.408e-12)





Goodness of fit - chi square measure:
Chi2 = 2853.626639484454, Chi2/dof = 75.09543788116984

Fit parameters:
amplitude = 1.780e+00 +/- 1.151e-02
resonant frequency = 3.535e+04 +/- 3.710e+01
gamma width = 5.359e+04 +/- 5.269e+02
backgraound = -2.408e-12 +/- 5.014e-14

Residual information:
54.8% of data points agree with fit

The fit is not ideal, as the Chi^2 is big (75) and only 54.8% of the data fits within one sigma. The background term I used was back*x*x because it does look like a square exponential towards the end of the graph. I tried to improve the fit by changing the exponent of x in the background term, however, other choices of the exponent of x other than 2 increased Chi^2 and decreased the % of data within 1 sigma. Hence, I settled with back*x*x as the background term.

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4.3

T-Score between resonance frequency estimates: 134.08

By T-Score, we are not confident that these two estimates are the same. It seems as though one method is a more accurate measurement of the actual value. This could be because of some errors in calculations or some defects in the equipment that may have affected one method more than the other.

There is slight disagreement in the ratios R/L of the two methods. The first is calculated to be 49385, whereas the second is found during the fitting to be 53590. There is a difference of 4205 between them. However, they are both around 50000, which is what is hypothetically supposed to be the value for R/L when R = 1000 and L = 20e-3.

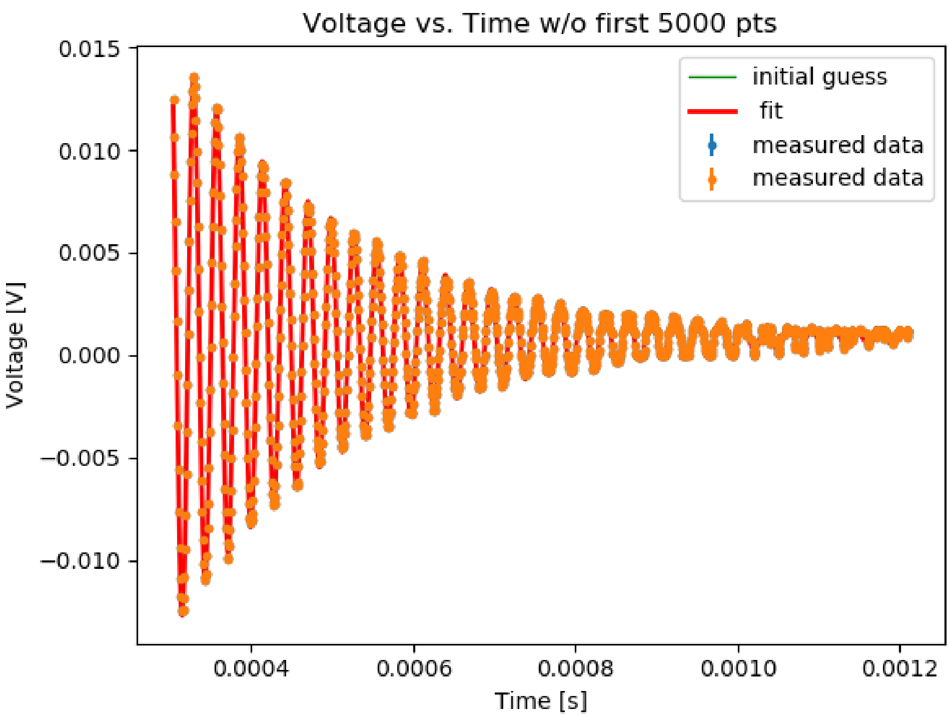
4.4

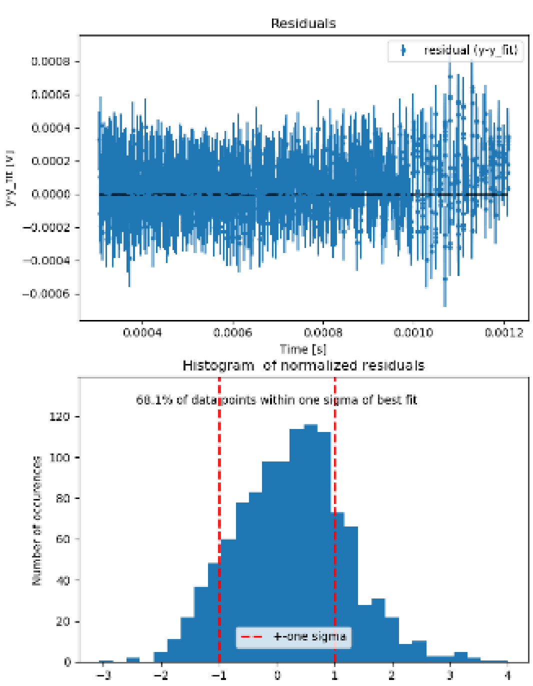
Resistor: 98.20 +/2 0.01

Freq: 500hz

First, I removed all data points that did not correspond to one decay. I also added a small voltage offset in the function as my fitting seemed to have a consistent effect where all points were above the fit line by about 0.0008 V.

Initial guesses = (0.05635,2.209e-4,35440,2.074)





Goodness of fit - chi square measure:
Chi2 = 1225.650520689878, Chi2/dof = 1.0798683001672935

Fit parameters:
amplitude = 5.630e-02 +/- 3.247e-04
relaxation time = 2.208e-04 +/- 6.544e-07
frequency = 3.544e+04 +/- 2.095e+00
phase = 2.066e+00 +/- 5.608e-03

Residual information:
68.1% of data points agree with fit to within 1 sigma

This fit is good because Chi2/dof is low (around 1).

The ratio of the resistors is: R1/R2 = 10.058, and all the fitted parameters have decreased by a factor of roughly 10 except for frequency and amplitude. Frequency is not dependent on R so I expected that it would be unneffected. However, I did not expect that the amplitude would also decrease by a factor of 2 in addition to the 10. This could be because at lower R's, different terms in the formula become more prevailent. This could also be due to internal resistances of the circuit affecting the reading differently for lower values of R.

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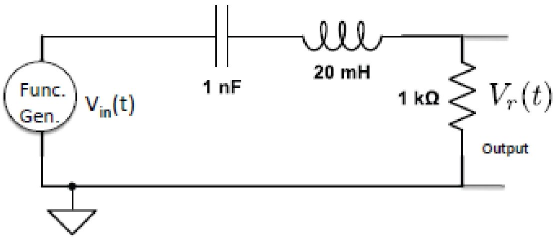
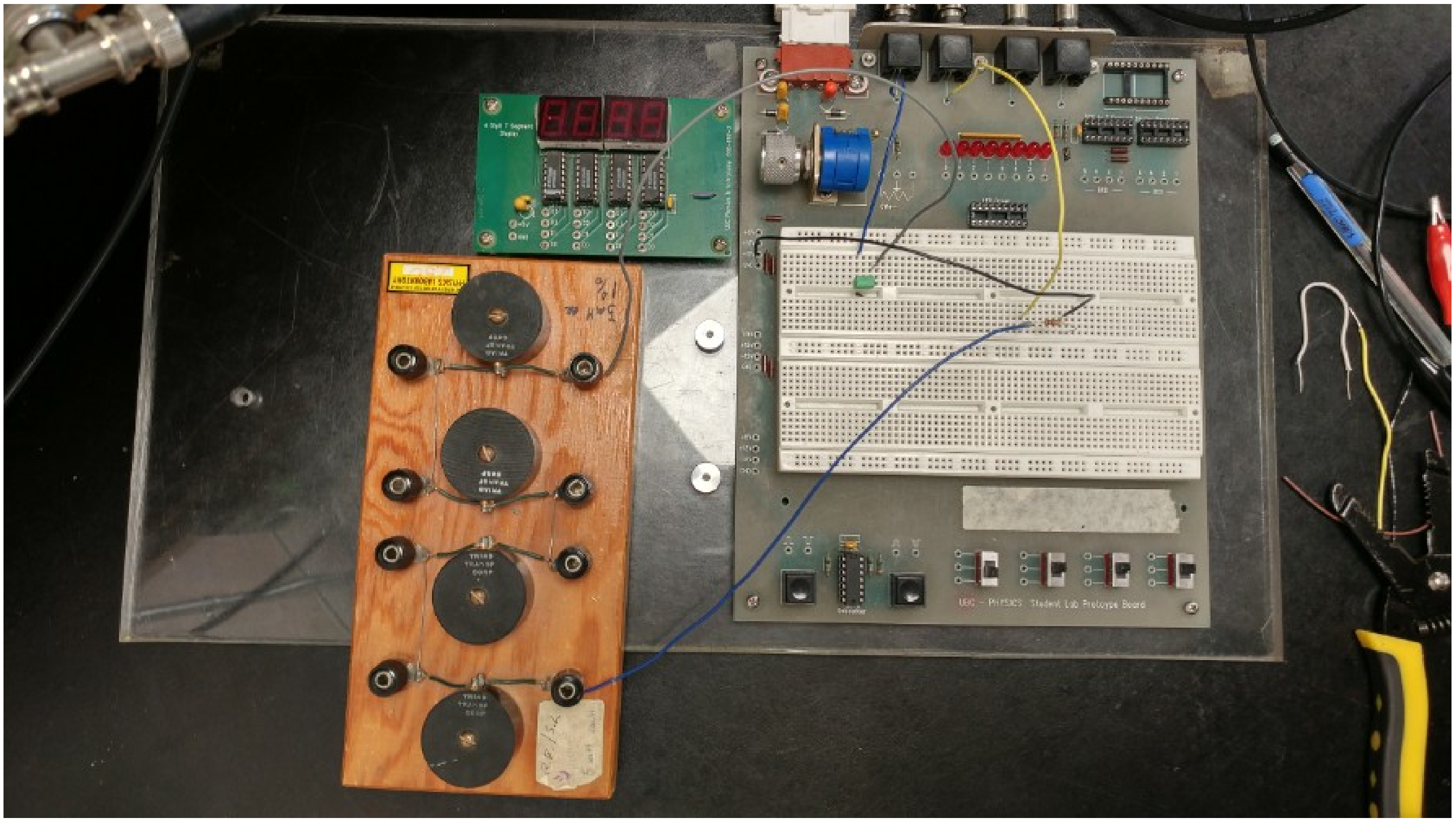
Discussion





This is the circuit design and actual circuit build that we used.

The expected value for the resonance frequency is 35.588127 khz, at an amplitude of 1.80V. However, the first was higher by 0.281873 +/- 0.005164 khz, and the second was lower by 0.238127 +/- 0.0371 khz. This tells me that they both have about the same level of accuracy for the measurement of the resonance frequency, but the first method is more precise as it has lower uncertainty.

The two measurements, although they are close to the theoretical value of the resonance frequency, disagree with eachother. As evident from their T-Score, we are not confident that the numbers are the same.

In the future, I would find a way to properly remove the data points that are not a part of the decays as I may have accidently removed too much or too little when eyeballing it. I would also use a lower input frequency in order to be even more certain that the amplitude dampens to 0.