Fitting Circuits for Capacitance

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Overview

In this project, I explored a method of fitting the frequency response of a circuit for capacitance. I set up three different circuits with the same capacitor and recorded the voltage as a function of frequency at the designated location for each. I then used Ohm's law to solve for the voltage at that location as a function of frequency to obtain a model for how the voltage should respond. Once I had the theoretical model for the voltage, I used python, specifically SciPy, to fit the data with the model keeping the capacitance free.

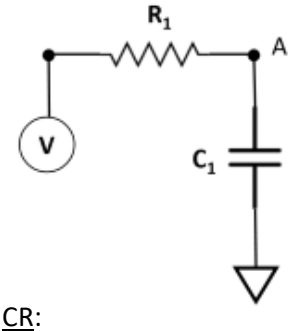
Circuits:

Circuit Parameters:

The input voltage differed each run even though I never changed its value:

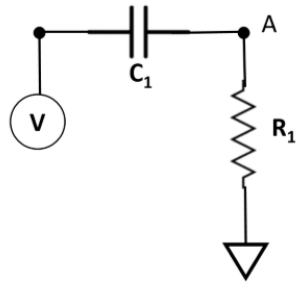
V_{RC} = 3.535v
V_{CR} = 3.543v
V_{RCR} = 3.477v
R_1 = 1475 ohms
R_2 = 1197 ohms
C = 100 nF capacitor in my circuits and then fit the data to see if I got that value.

RC:



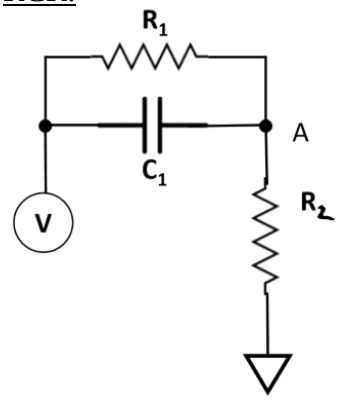
$$V_{A_1} = v\sqrt{\frac{1}{1+(wcR_1)^2}}$$

CR:



$$V_{A_2} = v\sqrt{\frac{1}{1+\frac{1}{(wcR_1)^2}}}$$

RCR:

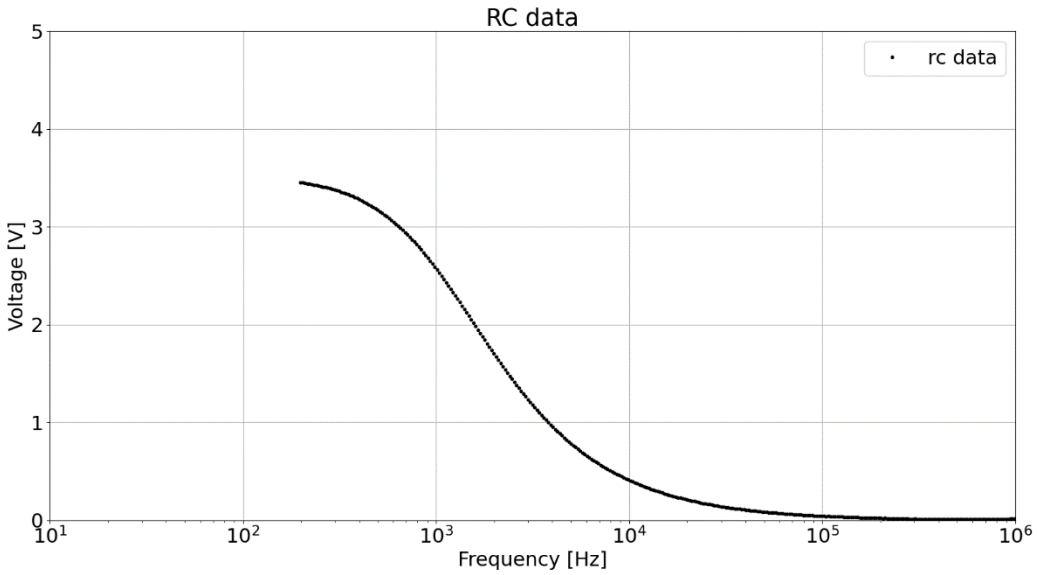


$$V_{A_3} = v\sqrt{\frac{{R_1}^2+\frac{1}{(wc)^2}}{(R_1R_2)^2+\frac{(R_1+R_2)^2}{(wc)^2}}}$$

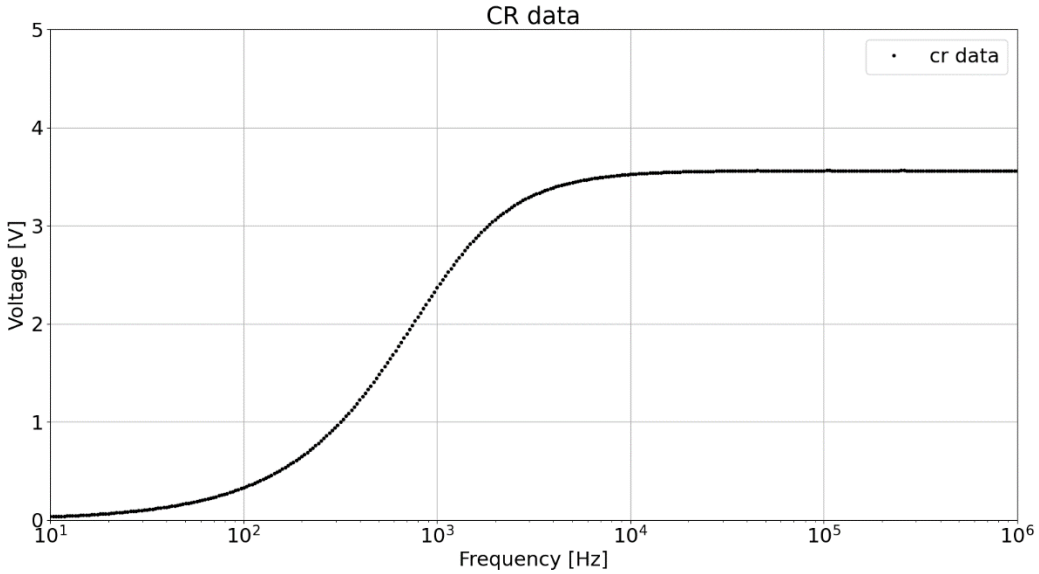
Frequency Response Data:

This is the recorded voltages at A in the circuits described above as the frequency was varied. The RC is a low pass filter (it only passes lower frequency signals) the CR is a high pass filter and the RCR appears to amplify signals at higher voltages.

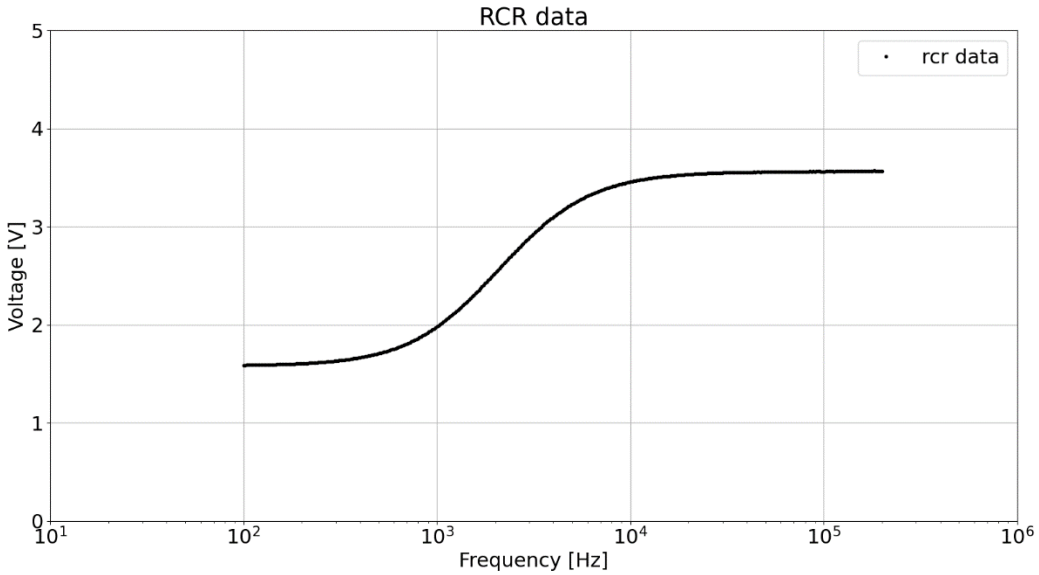
RC:



CR:



RCR:

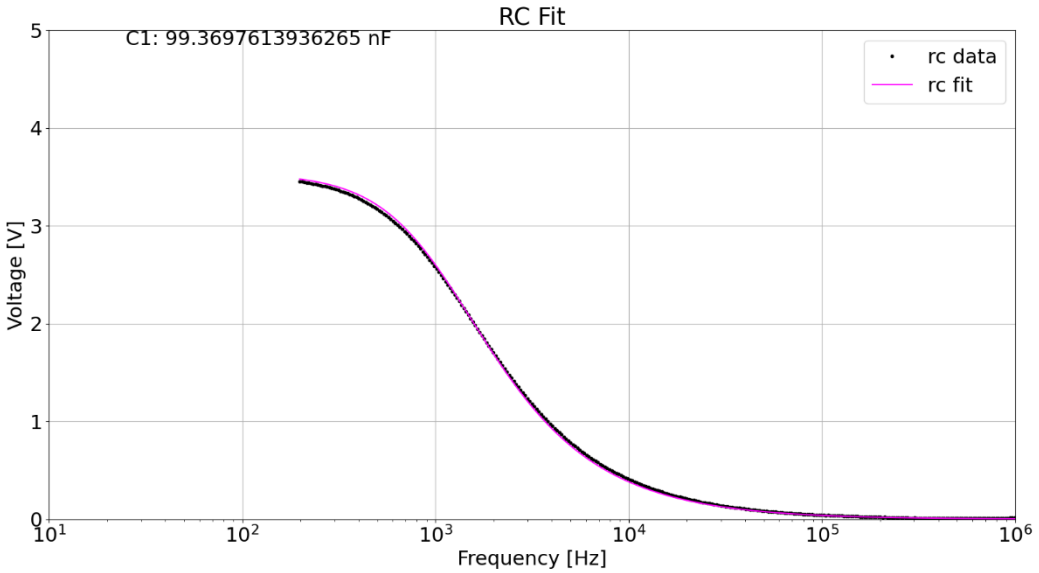


Data Fit with Model:

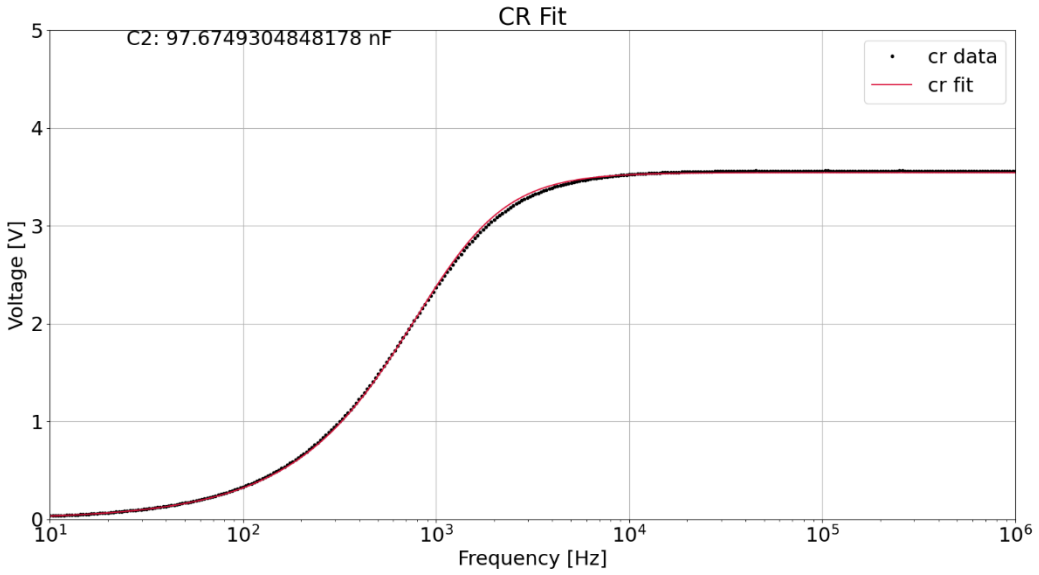
Using the SciPy library in python, more specifically the curve_fit() function, I was able to fit the collected data with the theoretical model.

In the end, the returned values for capacitance were close to the accepted value of 100nF, with an average of 99.95 nF over the three circuits. I had to refine my bounds for the capacitance though because my curve fitting function was spitting out some infeasible numbers. Once I put some bounds on the fitting function ([0, 1] for the RC and CR and [0, 1*10^-6] for the RCR), reasonable values were returned as fit parameters

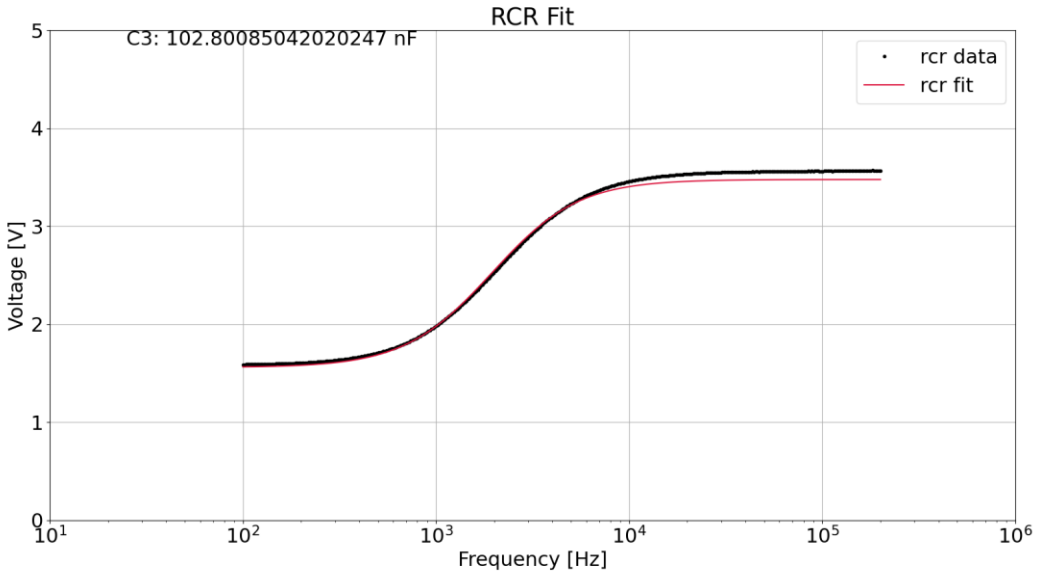
RC:



CR:


CR Fit
C2: 97.6749304848178 nF
cr data
cr fit
Voltage [V]
Frequency [Hz]
0
1
2
3
4
5
10^1
10^2
10^3
10^4
10^5
10^6

RCR:


RCR Fit
C3: 102.80085042020247 nF
rcr data
rcr fit
Voltage [V]
Frequency [Hz]
0
1
2
3
4
5
10^1
10^2
10^3
10^4
10^5
10^6

Conclusion:

I set out to fit collected data to a theoretical model to return some free parameter, in this case capacitance. That was achieved, but unfortunately this process is not entirely complete for a general case. Due to the restrictive bounds that I had to put onto my fitting function, a frequency response data from a circuit with a capacitance at or above 1 μF would not be able to be fit for capacitance with my code how it is now. However, the method that I did use returned consistent and reliable values for capacitance and I would trust my current code for any circuit with a capacitance value beneath 1μF.