Physics 219_2018 - Nick Pun/Exp. 1 (RC Circuit)/Exp 1 RC Circuit

SIGNED by Nick Pun Oct 05, 2018 @02:04 PM PDT

Nick Pun Oct 04, 2018 @12:20 PM PDT

Introduction

Lab Partners: Abenezer Sewagegn, Mourad Ahmed

Materials:

- Function Generator
- Ohmmeter
- Oscilloscope
- Resistors (10k ohm + 1M ohm)
- Capacitors (2x 1 μF)
- Electrical Wires

If a power supply is held constant at some value V_{in} for $t < 0$ for a long time, then $V_c(0) = V_{in}$.

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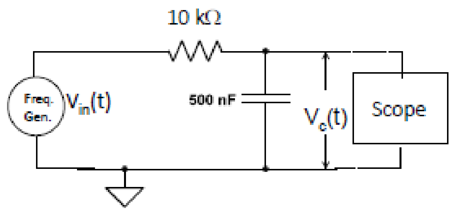
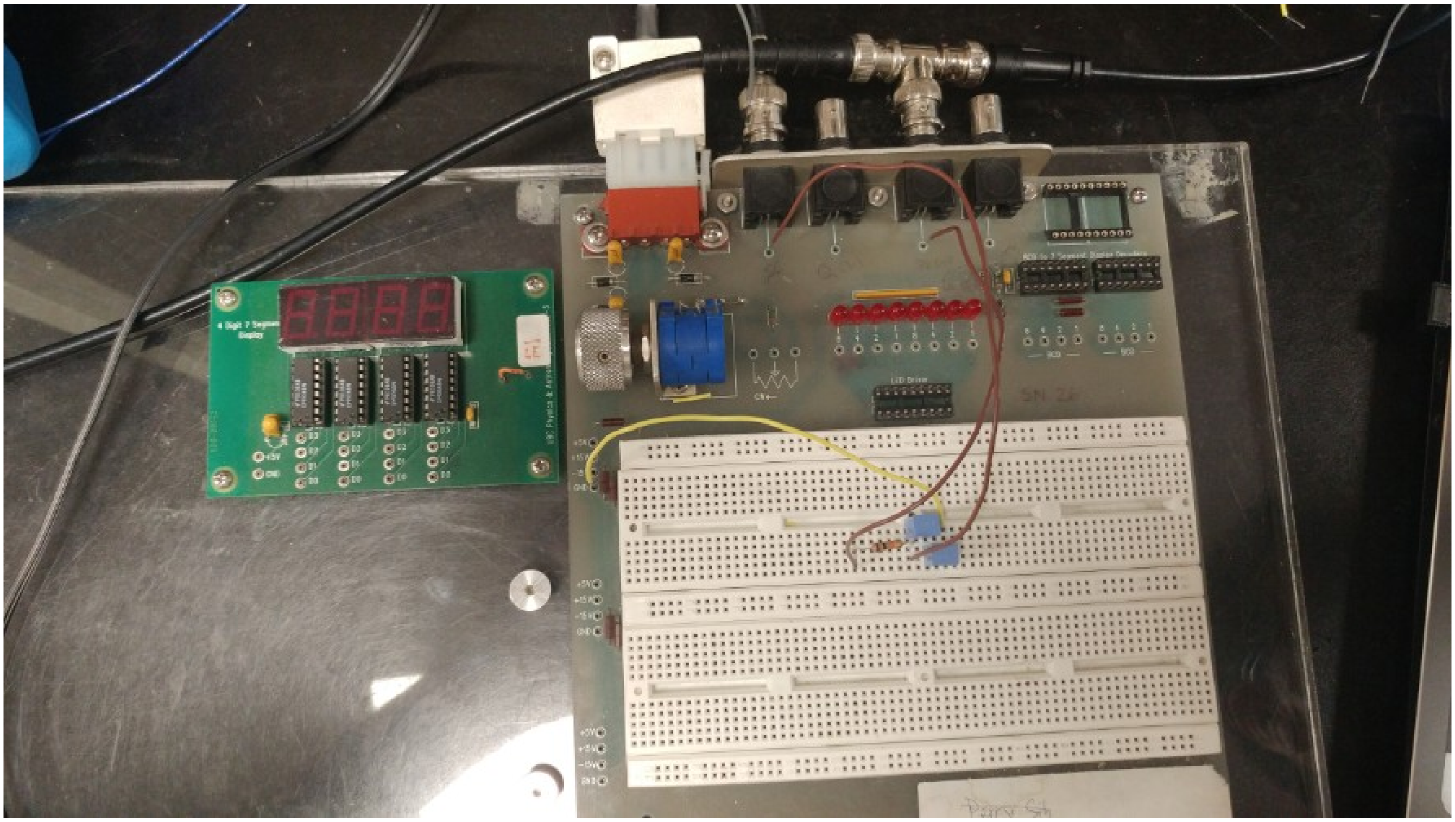
Measurement of the RC time constant in the time domain





We measure the actual resistance of the 10k ohm resistor:

R_{10k} = 9.81*10^3 +/- 10 ohms

To choose a frequency:

We want a frequency not too big that the capacitor won't have enough time to discharge, but also a frequency not too small that the capacitor will stay at 0V for longer than it needs to be.

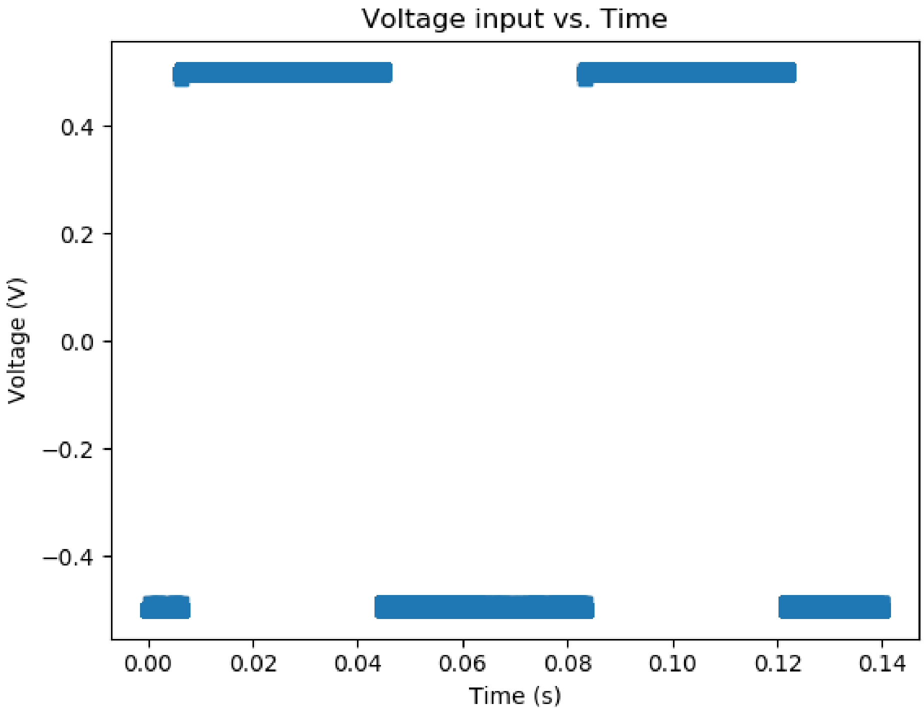
We chose a frequency of 13 Hz.

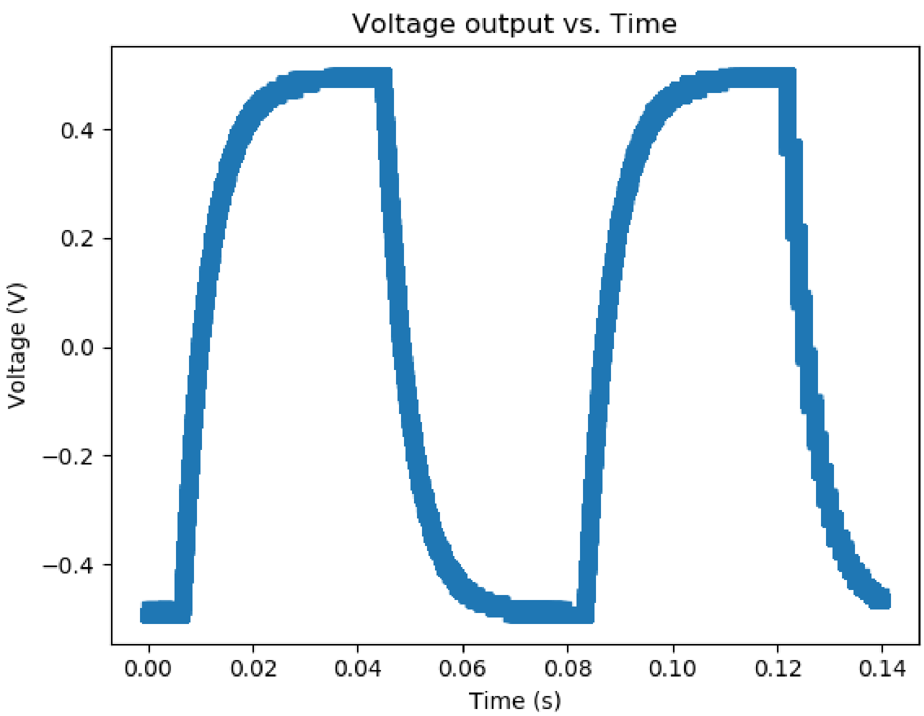
$V_c(t)$ behavior:

- has the same frequency as the square graph

- rises when V changes to +1 following a function similar to y=ln(x)

- decays when V changes to 0 following a function similar to y=e^2





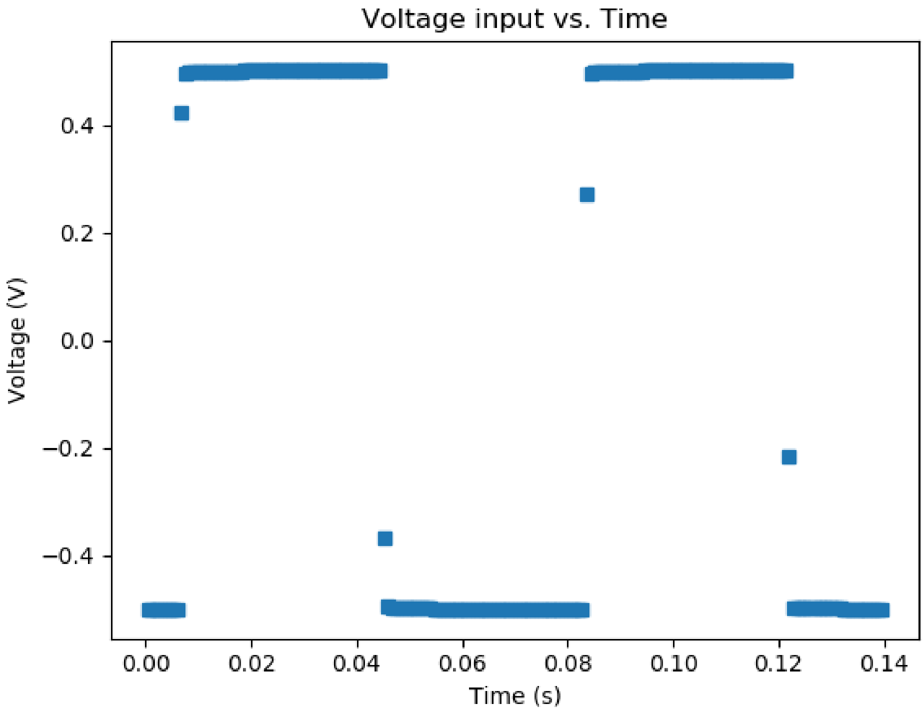
To choose a packing factor:

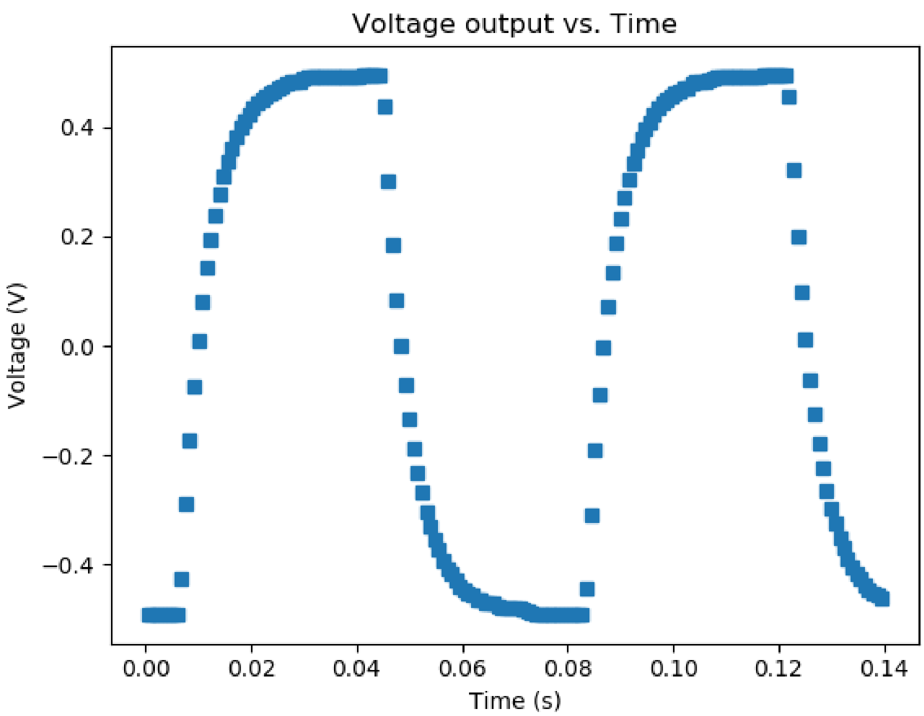
We have 87500 data points and about 2.5 complete oscillations so there are about 17500 data points per decay curve.

- we need to choose a packing factor that is not too large that we will no be able to distinguish between the curve and the increase

- we need to choose a packing factor that is not too small that we will not be able to distinguish between data points

- I chose a packing factor of 500 to give me around 35 data points per decay curve, this lets me distinguish between the point and still be able to see the trend of the curve clearly





Tau estimate:

- V_o = 500mV

- V_f = 1000mV*(1/e) -500 = -132.121mV (set this as y2 cursor on scope)

- deltaV = 632 mV

- Vc(0) = 1

- Vc(t) = 1-0.632 = 0.368

- deltaT = 5.14ms

- time to drop by factor 1/e = 5.14 ms (measured)

Tau = $5.14 * 10^{-3}$ s

Scaling of scope

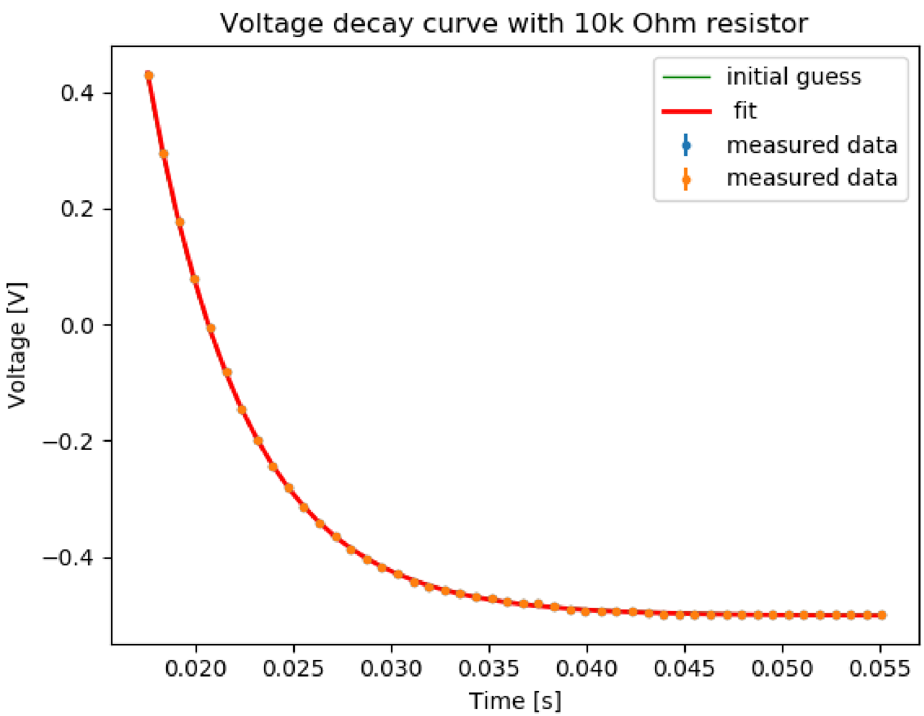
- We chose 400us and 200mV as scale in order to maximize the graph such that we could still see the point where the curve starts decreasing and the point where the V has dropped by a factor of 1/e.

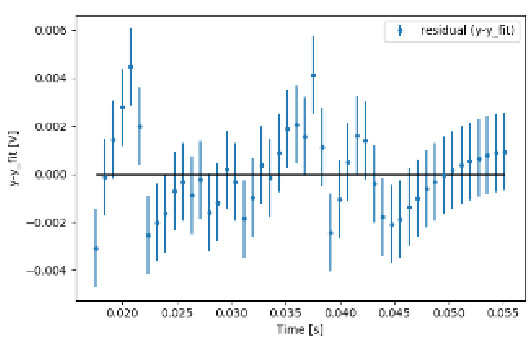
Single decay analysis:

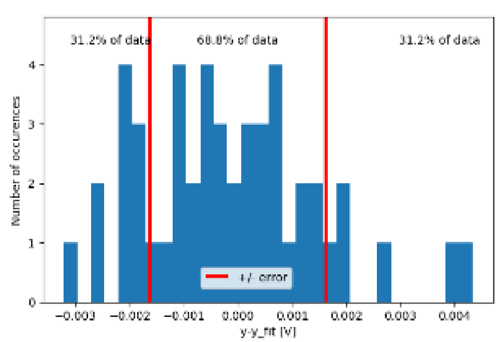
npac = 1000

guesses = (31,0.005,-0.5)

y_sigma = 0.00162







Goodness of fit - chi square measure:
Chi2 = 47.83142952840124, Chi2/dof = 1.0629206561866942

Fit parameters:
amplitude = 3.145e+01 +/- 2.692e-01
relaxation time = 4.992e-03 +/- 1.126e-05
V_offset = -5.015e-01 +/- 3.364e-04

Residual information:
68.8% of data points agree with fit

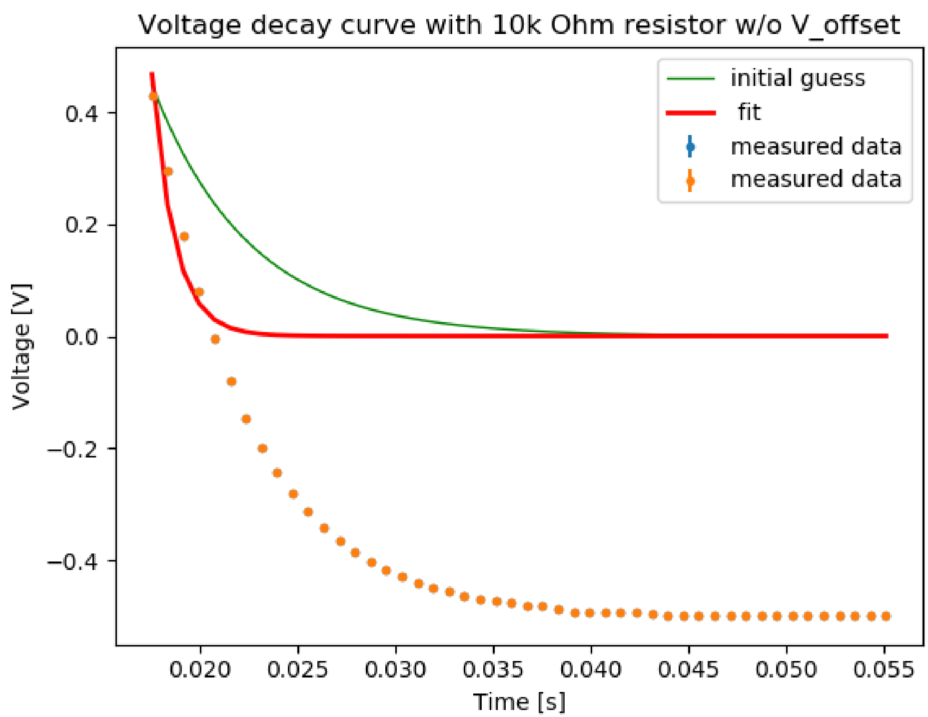
This is a good fit because Chi^2/dof is around 1.

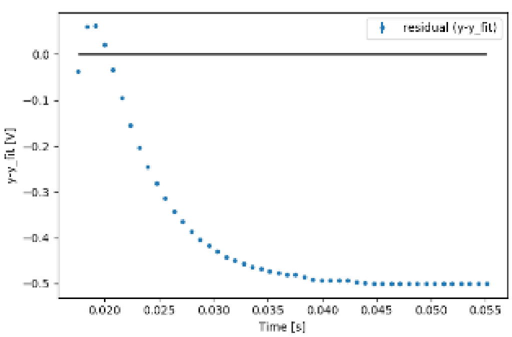
V_offset exclusion:

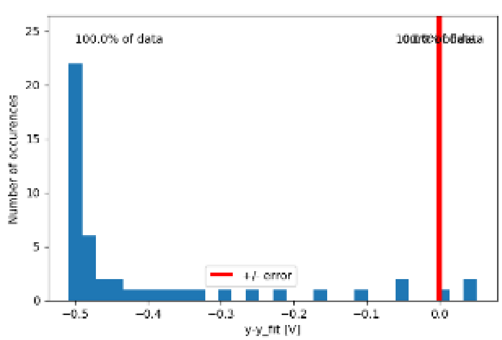
Fitting the data without a V_offset forces the fit function to level out at V = 0, because it doesn't return negative values for V. This causes the vast majority of the residuals to be below the 0 and 100% of the them to be outside of the 68% y_sigma range. This means the fit is a very low quality fit.

guesses = (15,0.005)

y_sigma = 0.00162







Goodness of fit - chi square measure:
Chi2 = 3291177.7393058944, Chi2/dof = 71547.34215882378

Fit parameters:
amplitude = 1.855e+06 +/- 1.847e+05
relaxation time = 1.155e-03 +/- 7.501e-06

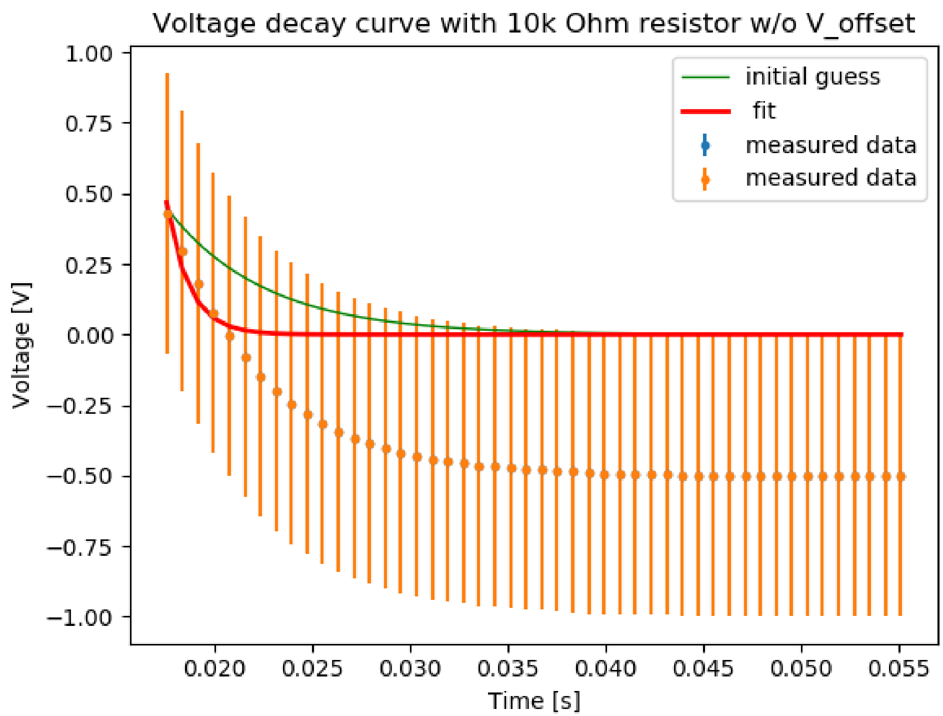
Residual information:
0.0% of data points agree with fit

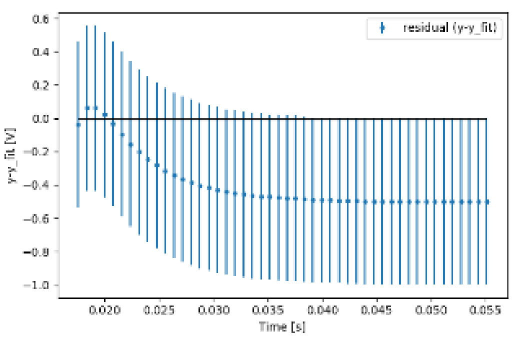
This is a very bad fit because Chi^2/dof is 71547 which is very high.

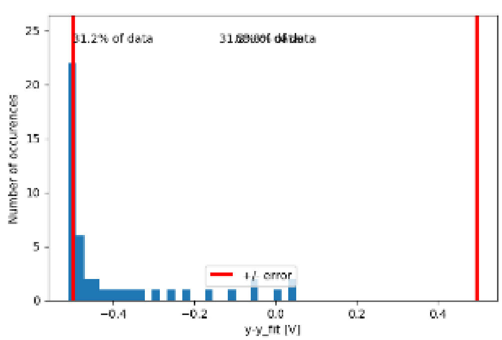
We can increase the quality by increasing the y_sigma but that results with very large uncertainties.

guesses = (15,0.005)

y_sigma = 0.497







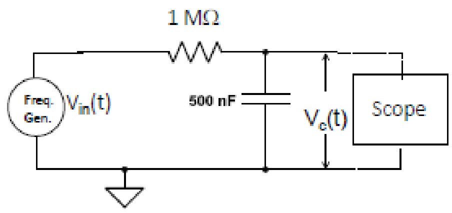
Goodness of fit - chi square measure:
Chi2 = 34.96782246376287, Chi2/dof = 0.7601700535600624

Fit parameters:
amplitude = 1.855e+06 +/- 5.666e+07
relaxation time = 1.155e-03 +/- 2.301e-03

Residual information:
68.8% of data points agree with fit

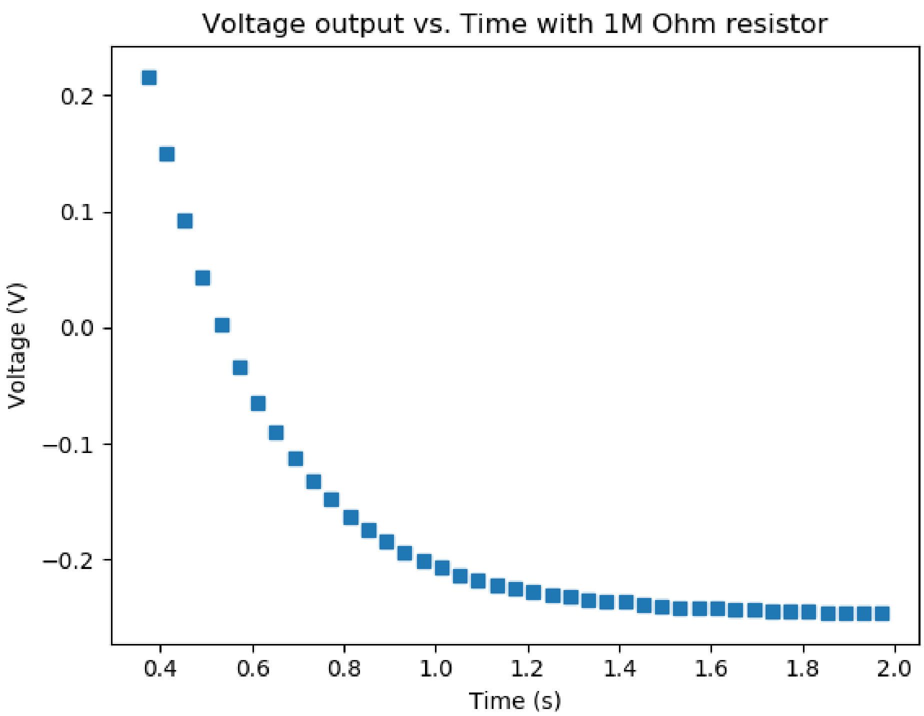
This is a good fit because Chi^2/dof is around 0.76 which is low but the data points have a very high uncertainty.

1M ohm resistor:



R_{1M} = 1.0031*10^6 +/- 0.0001 ohm (measured)

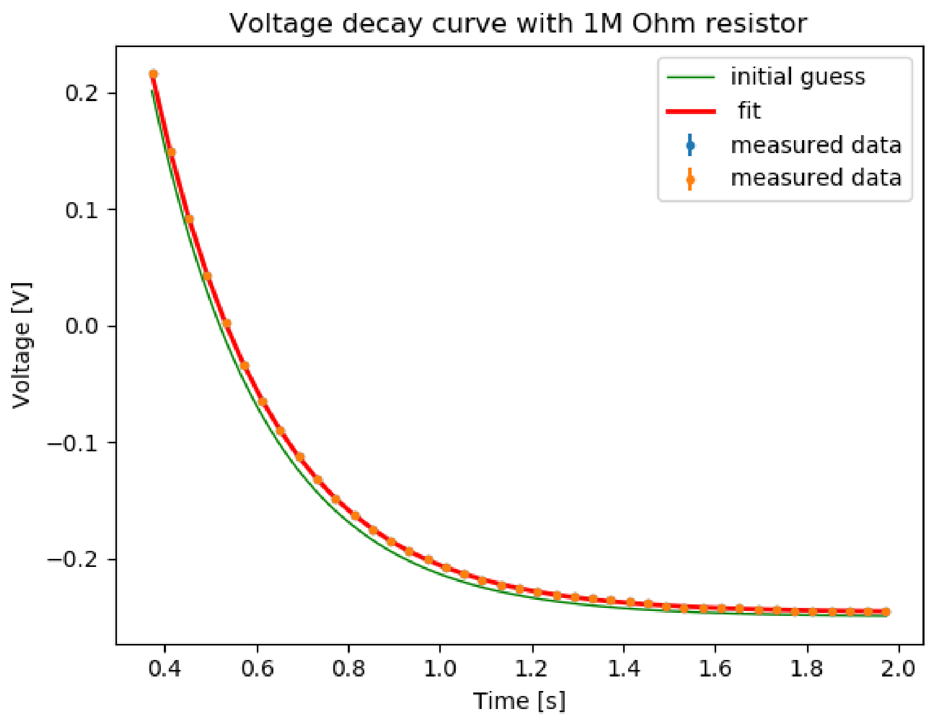
npac = 500

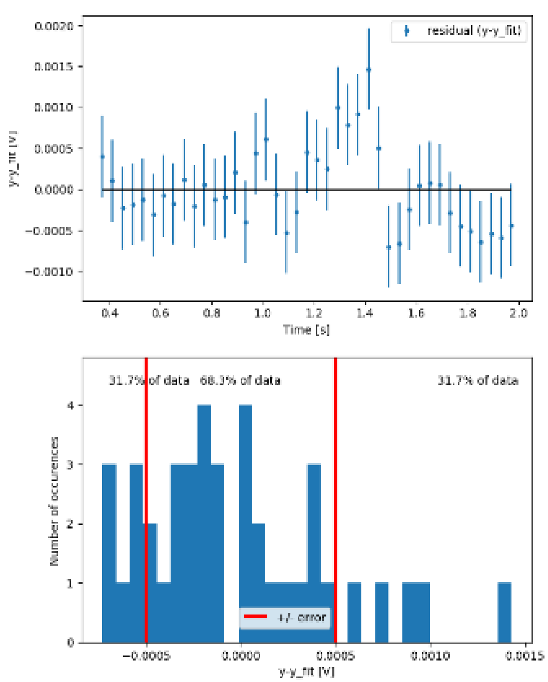


npac = 500

guesses = (2,0.25,-0.25)

y_sigma = 0.0005





Goodness of fit - chi square measure:
Chi2 = 38.551403439488595, Chi2/dof = 1.0145106168286473

Fit parameters:
amplitude = 1.960e+00 +/- 5.019e-03
relaxation time = 2.577e-01 +/- 3.861e-04
V_offset = -2.462e-01 +/- 1.257e-04

Residual information:
68.3% of data points agree with fit

This is a good fit because Chi^2/dof is around 1.

- 1M ohm resistor increases tau.

- deltax1M = 101.6ms

Comparison of calculations for C:

R_{10k} = 9.81e03 +/- 1e01 Ohm

R_{1M} = 1.0031e06 +/- 1e04 Ohm

Tau_{10k} = 4.992e-03 +/- 1.126e-05 s

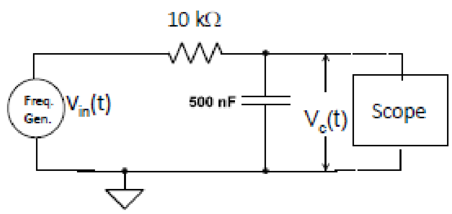
Tau_{1M} = 2.577e-01 +/- 3.861e-04 s

C_{10k} = 5.09e-07 +/- 1.260e-09 F

C_{1M} = 2.57e-7 +/- 2.591e-09 F

Although both calculated values are to the same degree of the theoretical value of the capacitance, C_{1M} is approximately half the theoretical value whereas C_{10k} is much closer. This like likely because there is a 1M Ohm internal resistance of the oscilloscope. When added to the 10k Ohm circuit in parallel, there is a large difference between the resistor and the internal resistance, meaning that most of the voltage is applied across the resistor and hence the internal resistance does not affect the RC time constant as much. However, with a 1M ohm resister in parallel, there is not very much difference, and so the voltage is split in half between the resistor and the oscilloscope and hence the internal resistance will have a non-negligible affect on the RC time constant by a decrease in a factor of approximately 2.

Measurement of the RC time constant in the frequency domain

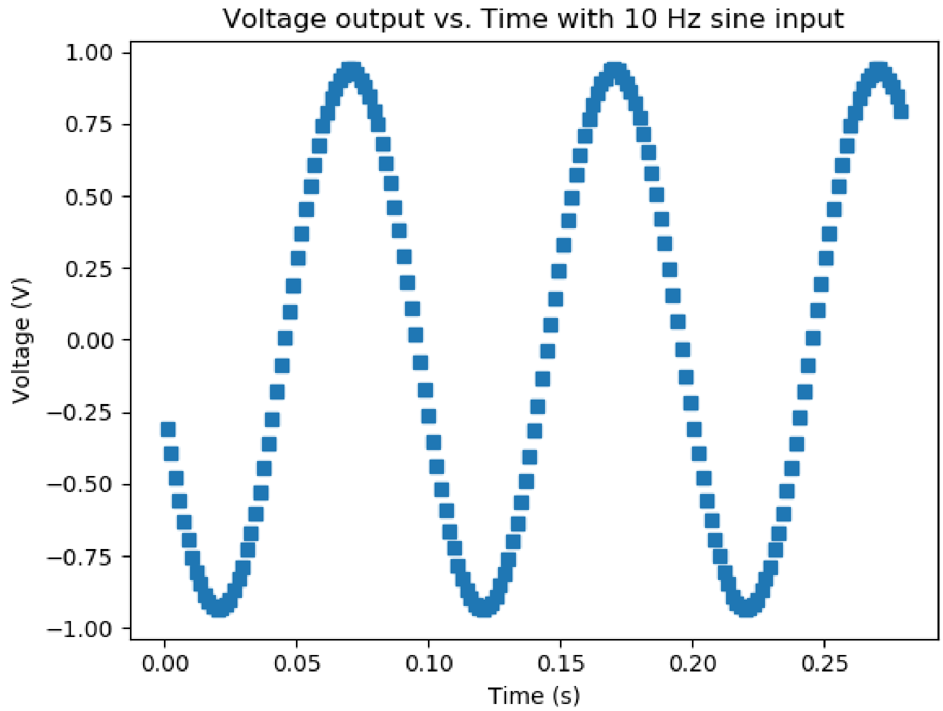


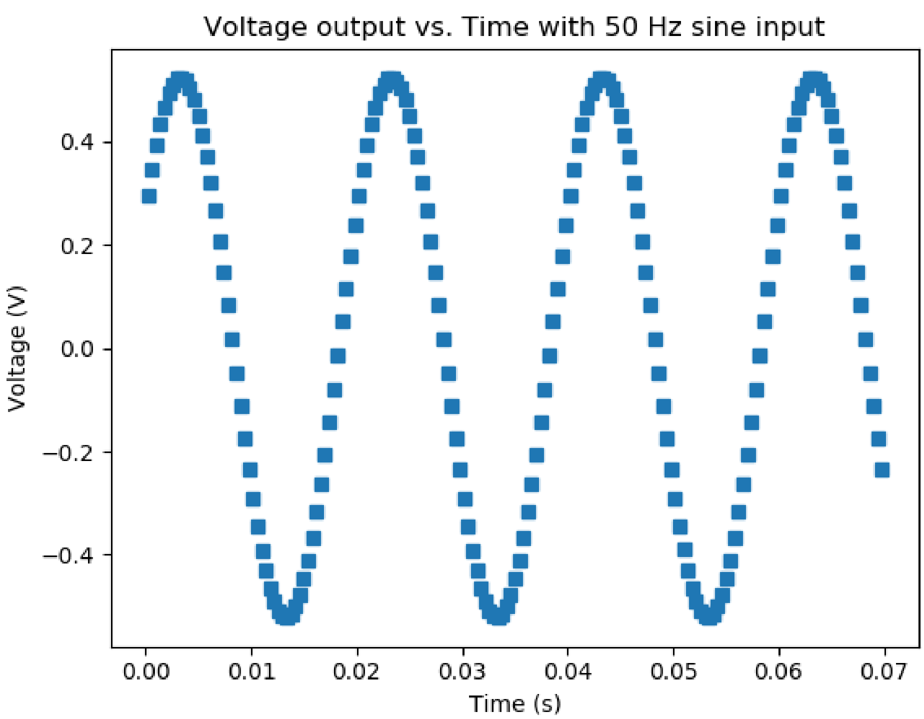
Resistor used: 9.86k +-10ohms (measured)

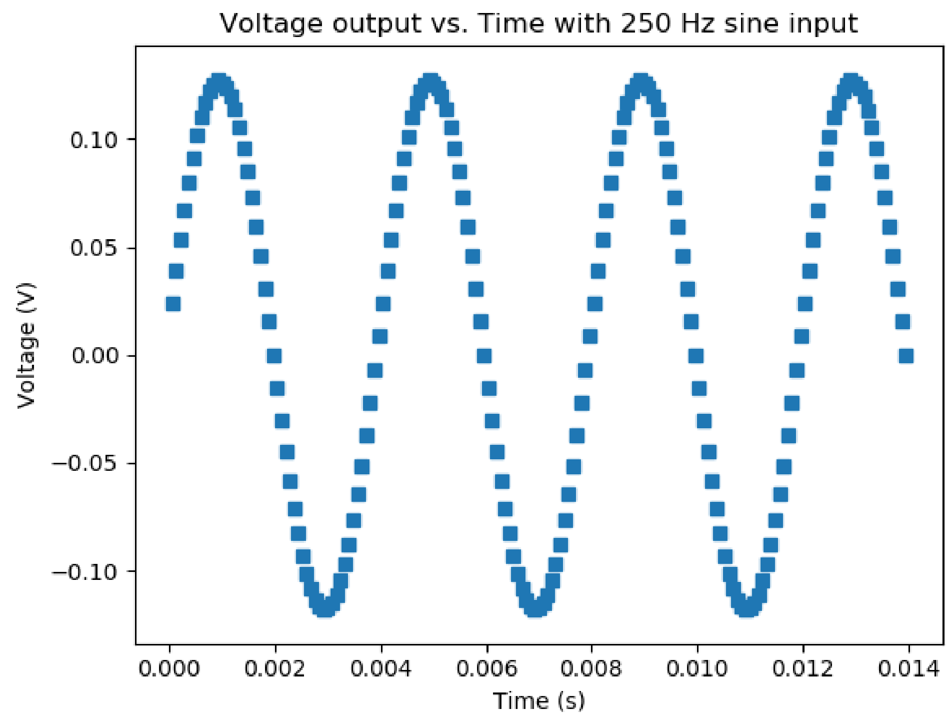
We measured the amplitudes using the auto-measure-amplitude tool.

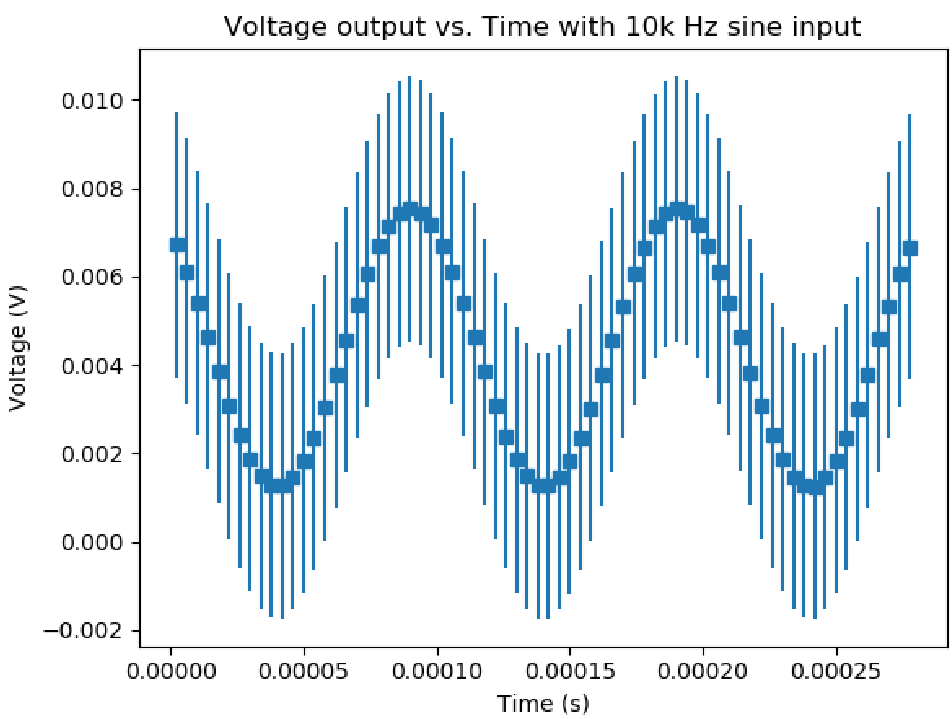
We used manufacturer's specified uncertainty for the oscilloscope vertical uncertainty = +/- 2%.

Frequency (hz)	Amplitude of output (V)
10	1.86/2
20	1.64/2
30	1.42/2
40	1.20/2
50	1.04/2
70	0.804/2
90	0.648/2
110	0.540/2
150	0.402/2
200	0.304/2
250	0.242/2
500	0.124/2
1000	0.0620/2
5000	0.0123/2
10000	0.00622/2


Voltage output vs. Time with 10 Hz sine input
Voltage (V)
Time (s)
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00
0.00
0.05
0.10
0.15
0.20
0.25


Voltage output vs. Time with 50 Hz sine input
Voltage (V)
Time (s)
0.4
0.2
0.0
−0.2
−0.4
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07

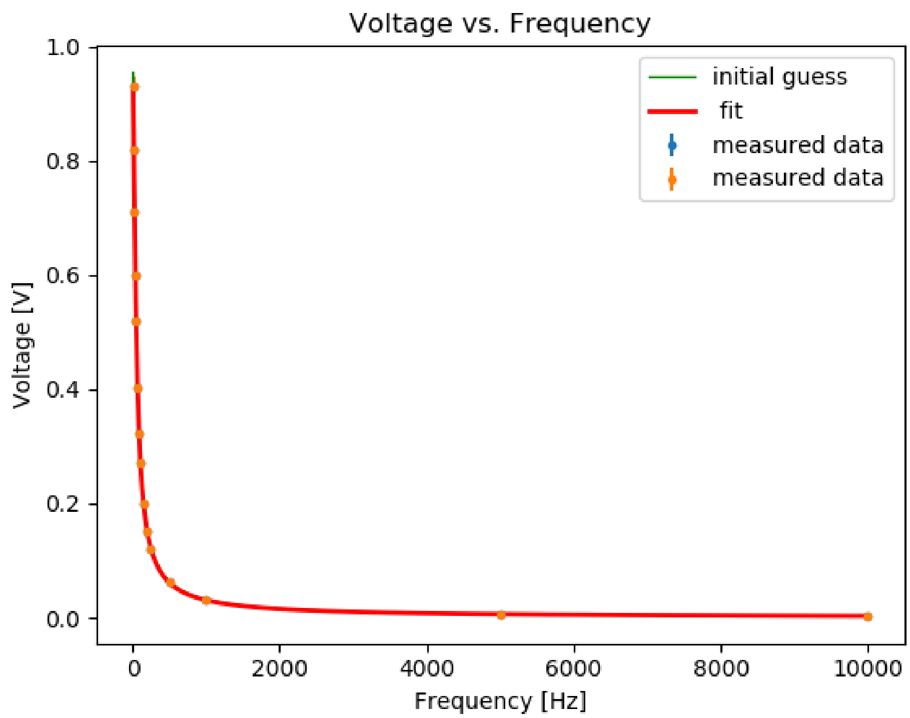


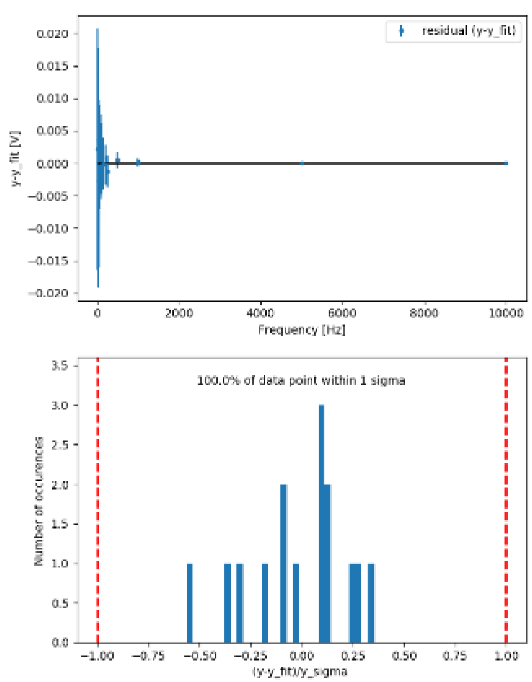


Clearly, the amplitude of the output function decreases as the frequency increases, and appears to decrease according to an inverse exponential relationship. The 10k Hz function has very large uncertainties because the fluctuations where so small that the oscilloscope may have had a hard time nullifying the random uncertainties when averaging the data points.

Curve fitting the trend:

guesses = (1.0,.005,0.0)





Goodness of fit - chi square measure:
Chi2 = 0.890188511853397, Chi2/dof = 0.07418237598778309

Fit parameters:
amplitude = 9.730e-01 +/- 1.508e-02
relaxation time = 5.024e-03 +/- 9.783e-05
V_offset = 2.105e-05 +/- 6.385e-05

Residual information:
100.0% of data points agree within 1 sigma of fit

The fit of the curve is very good as the Chi^2 is 0.074 which is very low.

Calculation for C:

R_{10k} = 9.86e03 +/- 1e01 Ohm

Tau_{10k} = 5.024e-03 +/- 9.783e-05 s

C = 5.10e-07 +/- 9.9e-09 F

I believe the time domain method with a small resistor is the best way to measure C as it has the smallest uncertainty. The frequency domain is less accurate because we used some data points in the very high frequency range (10 Hz) for this experiment which had a lot of fluctuations. This could have thrown off the estimation of Tau during the curve fitting and thus increased the uncertainty in C during the calculations. The uncertainties for C were calculated by multiplying C by the square-root of the sum of the squares of the relative uncertainties in R and Tau. The frequency method has the potential to be a more accurate measurement if we use only lower frequencies during the measurement. This will reduce the amount of data points that have large fluctuations.

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Discussion

The lab taught me two different methods of determining the value of the C. The first method is using time as the domain, and the second is in the frequency domain. The time domain method involved closely examining a single decay at of the voltage across a resistor, which we did for two different resistors. We concluded that using a smaller resistor results in a more accurate measurement of Tau and thus C. The second method involved taking multiple measurements of amplitude for different frequencies. This is good as random errors in measurements has the potential to be reduced since we are taking multiple measurements. However, we found that the fluctuations of the amplitude became increasingly problematic as we entered higher frequency ranges.

The $V_c(f)$ graph shows that for a given input signal, the output signal of this circuit will produce a function that is the same as the input function but with a smaller amplitude and a phase shift. The case where this does not happen is in square graphs, as capacitors cannot discharge all their stored energy instantaneously.

This type of circuit can be used in a sound system that has noise at frequencies by dampening the fluctuations, which are usually quick changes in the input voltage. The circuit would release the stored energy slowly as opposed to instantaneously.