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Low Pass RC Lab Final Notebook

Advanced Lab I

Introduction

For this lab, we set up a low pass RC circuit and attempted to predict the output voltage measured based on the input voltage, resistor and capacitor values and the finite difference modeling technique. Finite difference modeling is a method used to model trickier differential equations on a computer and estimate a result when solving them analytically is particularly burdensome. The goal of this experiment is to measure the accuracy of an output voltage model produced by finite difference modeling compared to the actual measured voltage. Comparison will involve contrasting attenuation, functional similarity and a chi-square fit.

$$\frac{V_{in}(t) - V_{out}(t)}{R} = C\,\frac{V_{out}(t) - V_{out}(t-\Delta t)}{\Delta t}$$

Solving for $V_{out}(t)$:

$$\boxed{V_{out}(t) = \frac{V_{in}(t) + RC/_{\Delta t}\left(V(t-\Delta t)\right)}{RC/_{\Delta t} + 1}}$$

This is the model produced for the output voltage of a low pass RC circuit.

Hypotheses

Based on a cursory analysis of comparable finite difference modeling already published, we have made the following projections:

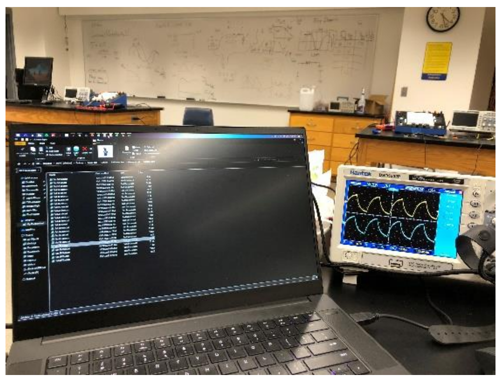
- We expect our model to match the attenuation (amplitude for the sine waves) of the actual measured voltage with a 25% margin of error.
- We expect the model to fully match the functional model of the actual measured voltage (i.e if the measured voltage is triangular, we expect the model to be triangular)
- We expect the model to fit the data at a 50% significance level

Experiment

1. We built the RC circuit on a protoboard, connecting the oscilloscope to the Vin and Vout terminals
    a. The resistor and the capacitor in the circuit had the following values:

Resistance: 11970.0 ohms
Capacitance: 1e-08 farads

2. We then connected the oscilloscope to the computer and exported the Vin and Vout data from the oscilloscope directly to a text file saved locally on the computer.



3. Data formatting was necessary due to inconsistences in units of the output produced by the oscilloscope and this was done with a Python script parsing the data after reading in the files.
4. A total of 18 datasets were extracted from the oscilloscope. We observed the Vin and Vout varying the frequency of the input voltage in three ways: below the cut-off, near the cut-off and above the cut-off. We did this for three different wave types (sine, square and triangular) for a grand total of 9 datasets, multiplied by two for measurements of both Vin and Vout.

Data Analysis

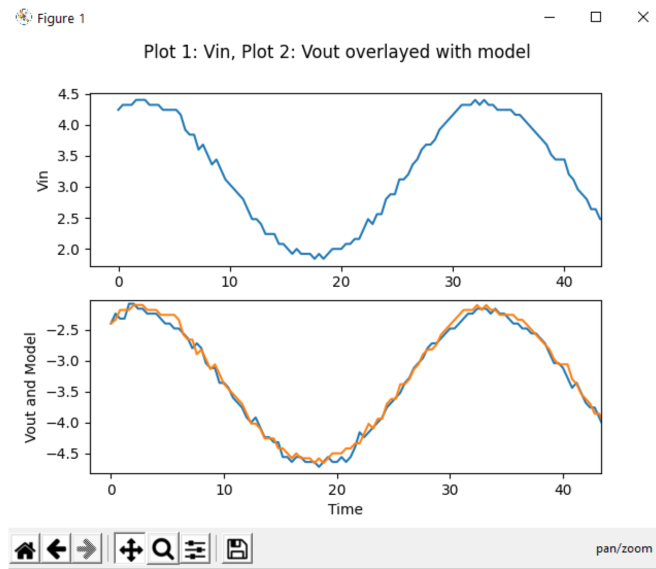
From the 9 pairs of datasets collected, only the sine wave near the cut-off and the triangular above the cut-off were salvaged as usable for data analysis. This occurred due to a systematic error in the way the oscilloscope exported the data.

Data analysis was done in Python utilizing the Matplotlib, SciPy and NumPy libraries. The following are the specific results of the dataset where Vin was a sine wave at a frequency near the cut-off:

```
Resistance: 11970.0 ohms
Capacitance: 1e-08 farads
Cut-off Frequency: 1329.615230508733 Hz
delta T: 0.01 milliseonds
RCoverdeltaT: 0.01197

==> Low Pass Filter Data Visualization and Finite Difference Modeling <==
```

```
--- Model Parameters ---
Enter wave type (sine, square, triangular):sine
Enter frequency region (below cut-off, near cut-off, above cut-off):near cut-off
Chi-square = 3165540.159513248
Reduced Chi-square = 990.7793926489039
Chi-Square Probability = 0.0
```



Results

Our data analysis shows the model (in orange) overlayed over the measured voltage, structurally matching the measured voltage. They are both sine functions, confirming the hypothesis that the model will match the functional type of the measured voltage. However, because of the systematic error mentioned earlier, we had to manually correct for an offset and therefore could not determine a reasonable chi-square probability or a margin of error for the attenuation.

Conclusion

We were not able to arrive on concrete assertions regarding the accuracy of the finite difference model due to the systematic error produced by the oscilloscope. However, regardless of the errors produced in execution, our model matched our measured data in terms of functional type and observable attenuation/structural similarity. For more reassuring results, this experiment needs to be repeated with better datasets from which can be determined an actual chi-square probability and a percent difference in amplitude and attenuation.