Lab 5: Fourier Series

Preamble

Associated Class Notes

This lab supports the materials covered in Chapter 4 Fourier Series (https://cpjobling.github.io/eg-247-textbook/fourier_series/index) of the course notes. You may wish to refer to worksheet 9 (https://cpjobling.github.io/eg-247-textbook/worksheets/worksheet9) and worksheet 10 (https://cpjobling.github.io/eg-247-textbook/worksheets/worksheet10) for additional examples to try.

Other formats

This document is available in HTML (https://cpjobling.github.io/eg-247-textbook/labs/lab05/index) format for online viewing and PDF (https://cpjobling.github.io/eg-247-textbook/labs/lab05/lab05.pdf) for printing.

Acknowledgements

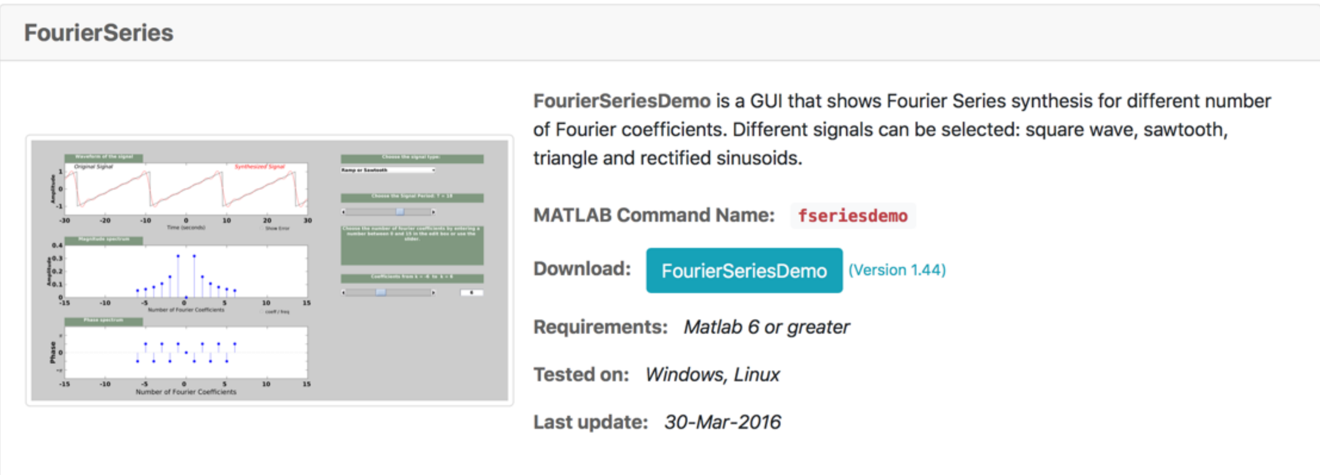
These examples have been adapted from Chapter 7 of Stephen Karris, Signals and Systems : With MATLAB Computing and Simulink Modeling (5th Edition) (http://site.ebrary.com/lib/swansea/docDetail.action?docID=10547416).

The Simulink model used in Lab Exercise 16 was developed by Third Year EEE Student Fahad Alqahtani as part of his Level 3 Project in 2013-2014.

Preparation

Before we start today's lab you will need to download and install the **Fourier series demo app**, that was demonstrated in class, from Georgia Tech's Educational Matlab GUIs (https://dspfirst.gatech.edu/matlab) page.

To install, visit the page and scroll down to find the Fourier Series Demo app (see image below)



Right-click on the Blue Button labelled **FourierSeriesDemo** and save to your `lab05` folder.

Open and run `fseriesdemo/fseriesdemo.m`.

If MATLAB issues a message about the need to change the working directory or add a folder to the MATLAB path. Accept the choice given.

Spend some time playing with the settings and obderving the results. We will use this as a check of results of the labs to follow.

Lab Exercise 9: Computation of the coefficients of the Trig. Fourier Series

In this lab exercise we will review the Fourier series for a square wave with odd and even symmetry before going on to compute and plot the Fourier series for the *triangular* waveform.

We will also explore and confirm the stated results of even-, odd- and half-wave symmetries.

Before you Start

Download attached files:

- TrigFourierSeries.m (TrigFourierSeries.m)
- FourierSeries.m (FourierSeries.m)
- trig_fseries.m (trig_fseries.m)

and store them in your `lab05` folder.

Part 1

Open the script `trig_fseries.m` as a MATLAB Live Script. Run the script and read through the results. Note that the script calls the `TrigFourierSeries` function, defined in the file `TrigFourierSeries.m`, which in turn calls the `FourierSeries` function, defined in `FourierSeries.m`, to calculate the trigonometric Fourier series for the square wave with odd-symmetry. In other words, it reconstructs the a_k and b_k Coefficients from the exponential Fourier series coefficients C_k.

Part 2

Save the m-file `trig_fseries.m` as an MATLAB Live Script `ex9_1`. Change the script so that it computes and plots the trig. Fourier series for the square-wave waveform with even symmetry (Section 7.4.1 in the textbook).

Note that the limits of the integration in `trig_fseries.m` start at 0, so you will need to construct the square wave over the period $[0, T]$ using unit step functions.

Part 3

Copy the script `trig_fseries.m` and save it as `ex9_2`. Change the copy so that it computes and plots the trig. Fourier series for the Triangular waveform (Section 7.4.3 in the textbook).

Note

Parts 2 and 3 can be added to `trig_fseries` and the whole submitted as a single Live Script file `ex9.mlx` providing that you use section headings to separate the parts and edit/add to the textual comentary to match the exercise descriptions.

Exercise 10: Simulating Wave Anaysis

Downoad and open the Simulink model fourier_example.slx (fourier_example.slx). Examine the settings for the sine terms and compare the amplitudes and frequencies of the settings with the results of running `trig_fseries.m`. Run the simulation and view the reconstructed signal and the spectrum.

Part 4

Change the settings so that the Simulink model uses the coefficients from the square-wave even-symmetry result. Simulate and capture the time and spectrum plots. Save your model as `ex10_1.slx`.

Hint: Be careful to evaluate which set of coefficients are present in the Fourier series. Are they a_k or b_k? What do you need to change in the sine wave generators to get the right results?

Attach a screen capture of the spectrum plot and the Simulink model to the Lab 5 page your lab submission.

Part 5

Change the settings so that the Simulink model uses the coefficients from the triangular wave result. Simulate and capture the time and spectrum plots. Save your model as `ex10_2.slx`.

Lab Exercise 11: Computation of the coefficients of Exponential Fourier Series

In this lab exercise we will review the Fourier series for a square wave with odd and even symmetry before going on to compute and plot the Fourier series for the `triangular` waveform.

We will also explore and confirm the stated results of even-, odd- and half-wave symmetries.

Before you Start

Download the attached file:

- exp_fseries.m (exp_fseries.m)

Part 6

Open the script `exp_fseries.m` as a Live Script, run it and examine the results. Note that the script calls the `FourierSeries` function defined in `TrigFourierSeries.m` to calculate the exponential Fourier series for the square wave with odd-symmetry.

Part 7

Copy the script `exp_fseries.m` and save it as `ex11_1`. Change the copy so that it computes and plots the exponential Fourier series for the square-wave waveform with even symmetry (Section 7.4.1 in the textbook). *Hint*: Use the same definition of f(t) that you used in Exercise 9.

The Simulink model plots the *Power Spectrum* of the simulated reconstructed signal. To plot the power spectrum of a exponential Fourier series we need to produce a stem plot. Each stem in the power spectrum is computed using $\sqrt{C_k C_K^*}$ (see **Parseval's Theorem** in the notes). In MATLAB this would be `C(k)*conj(C(k))`.

Plot the Power Spectrum of the signal from exponential Fourier series coefficients computed in this section. Compare the computed power spectrum with the simulated power spectrum. \emph{Note}: expect dome differences!

Part 8

Copy the script `exp_fseries.m` and save it as `ex11_2`. Change the copy so that it computes and plots the exponential Fourier series for the full-wave rectified sinusoidal waveform (**Note**: `f(t) = abs(sin(t))` (Section 7.4.5 in the textbook).

Note

As for Exercise 9, parts 7 and 8 can be added to `exp_fseries` and the whole submitted as a single Live Script file `ex11.mlx`.

What to turn in

You should attach your modified versions of the example file as a single Live Script or separate scripts to the Lab 5 submission page in OneNote. Marks will be awarded according to how many parts of Exercises 9-11 have been completed. You should attach a copy of your MATLAB Live Scripts named `ex9_1`, `ex9_2`, `ex11_1`, `ex11_2`, copies of your Simulink models `ex10_1.slx` and `ex10_2.slx` plus screen shots of the harmonic waveforms generated.

If you wish, you can submit all parts of Exercises 9 and 11 in single Live Script files (I suggest that you name these `ex9.mlx` and `ex11.mlx` respectively) providing that each part is separated by properly titled sections.

Remember, whichever method you use, you should ensure that you use the Live Script editor's text features to add emplanatory text to your MATLAB code.

When you have finished attaching your work, complete the claim form and turn-in your assignment through Teams.

Claim

Up to 2 marks can be claimed if you complete Exercise 9, 1 mark for Exercise 10 and an addition 2 marks Exercise 11.

See [Assessment and Feedback: Labwork Assessment (https://docs.google.com/spreadsheets/d/1U-O2hu_Th369EHp6mdc1_j_7ARew2WosE93cjsW012c/edit?usp=sharing)](https://docs.google.com/spreadsheets/d/1U-O2hu_Th369EHp6mdc1_j_7ARew2WosE93cjsW012c/edit?usp=sharing) for a detailed marking scheme.

The deadline for claims and submission is **Midnight, 22nd March**.

Optional Additional Tasks: Review and Change the Code.

A problem with the scripts as provided is that the limits on the integrals are set in the range $[0, T]$. It would be convenient if this could be changed, for example when computing FS for even signals, the limits could be adjusted to $[-T/2, T/2]$.

In MATLAB we can achieve this by adding extra arguments to the function definition.

Part 9

Examine the code for the `FourierSeries` function that is defined in `FourierSeries.m`. Adapt the function definition so that the user can define the range of the Fourier Series integral. If you succeed, use the modified function to compute the Fourier series of the triangular wave form by exploiting half-wave symmetry. Save the script that does this as `ex11_3`.

Part 10

Examine the code that is defined in `TrigFourierSeries`. Note that it calls `FourierSeries` then computes `ak` and `bk` from the `Ck` coefficients. Why did I do that do you think?

If you made the suggested change to `FourierSeries`, provide compatible changes to your copy of `TrigFourierSeries`. Test it on a square wave with even symmetry (Lab 9 Part 2). Save the resulting calling script as `ex9_3`.

Compute the FS of the half-wave rectified cosine function. Save the resulting calling script as `ex11_4`.

Bonus