Lab 10: Fourier Series Matlab - Answer Sheet

Follow the procedures in the document "Lab 10 – Fourier Series Matlab - Procedure" and prepare a report on your ePortfolio. The report should include the following sections (Note: all figures must be labelled correctly):

Introduction:

The purpose of this lab was to explore the Fourier series and how it is used to approximate periodic functions such as a square pulse and sawtooth pulse.

Procedures:

This section should be written to describe the steps taken for each part of the lab. The report should include answers to the following questions:

A.1) What happens to the overall signal when harmonics are added?

- The added harmonics introduces more sine waves to the signal, creating an overall signal that's composed of several sine wave superimposed on one another.

A.2) Observe each plot, listen to the associated sound and explain the relationship you notice between plot and corresponding sound.

- As more sine waves are added which have higher frequencies the pitch of the corresponding sound increases. That is the final signal with the higher frequency sine waves has the highest sound.

B.1) Write a brief description of how CODE 2 implements the Fourier series described by Equation (1).

- In CODE 2, the Fourier series approximation of a square wave is implemented by calculating Fourier coefficients based on the user-specified number of terms (N_TERMS). First, the code computes the constant term a0, representing the average value of the function. Then, it calculates the an and bn coefficients, which correspond to the contributions of cosine and sine terms for each harmonic. Using a loop, these terms are summed to construct the Fourier series, where each term in the series is a sinusoidal component multiplied by a harmonic frequency n. The final approximation is plotted to show how closely it resembles a square wave, accuracy improving as more terms are included.

B.2) Using the command hold on, plot the graph produced by CODE 1 and CODE 2 on the same picture. Consider the number of terms N_TERMS = 7. Insert a legend on your plot describing the two signals: name the ideal square wave f(x) and the approximation f'(x).

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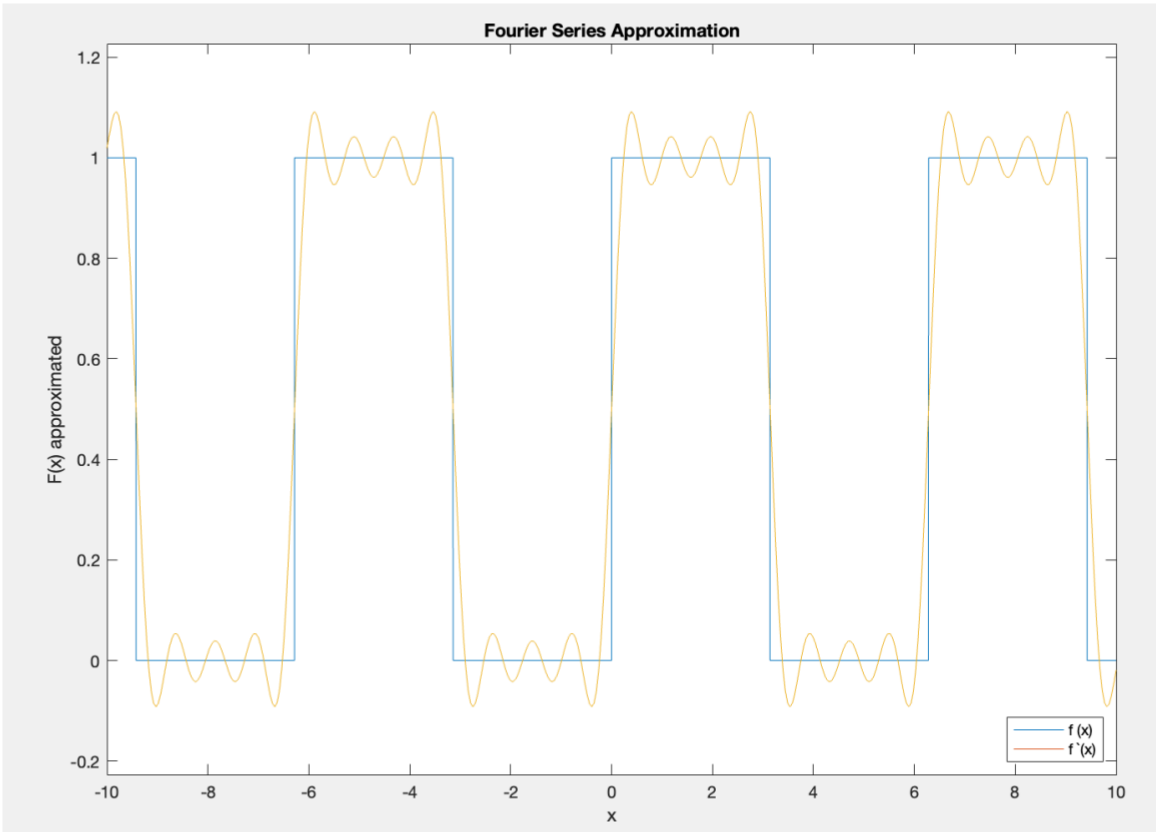

• Figure 1. Fourier Series of Square Wave with 7 terms

B.3) Run the code that results from B.2 for N_TERMS = 10,20 and 30 without closing the Figure each time you run. This way you will have multiple plots on Figure 1. Include the plot on your report and answer the following question: considering the ideal square wave f(x) as a reference, where in the signal wave do the approximations of f(x) have the greatest error/oscillation?

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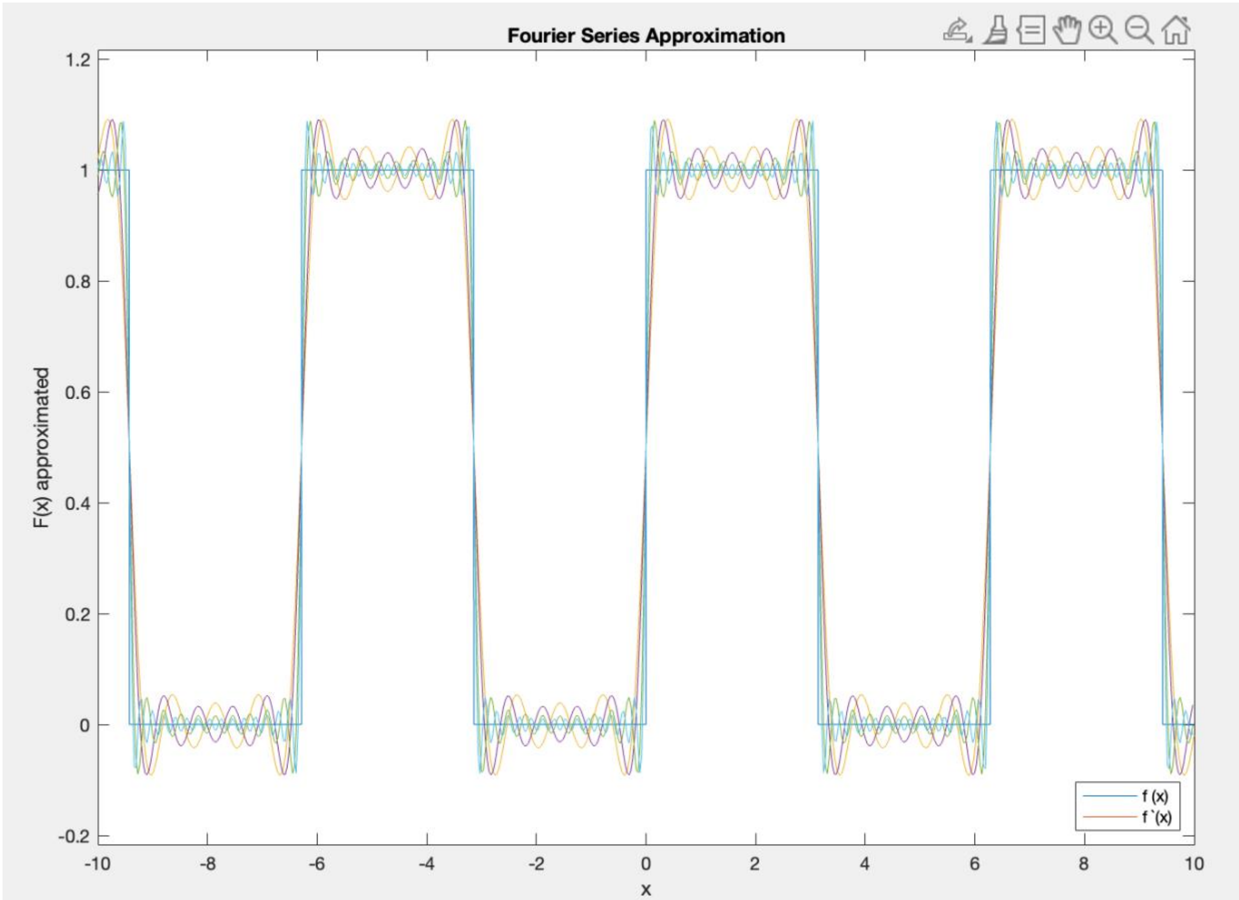

- Figure 2. Fourier Series of Square Wave with 10, 20, & 30 terms

- From the above figure, it is clear that the greatest error occurs during the transitions from high to low or low to high.

B.4) The Gibbs phenomenon is an overshoot (or "ringing") of the Fourier series. Defining the overshoot as the difference in amplitude between the highest point of the approximation and the reference function, record the overshoot values in Table 1 associated with each of the following number of terms. What is the relationship between the overshoot and the number of terms in the series?

Table 1 – Overshoot for different number of terms of the FS.

Number of terms	Overshoot
7	0.092
20	0.089
30	0.083
50	0.082

As the number of terms increases, the overshoot decreases.

B.5) Run CODE 2 multiple times (for N_TERMS = 7,20,30,50 and 100.) and, using the command tic toc, record in Table 2 the time MATLAB takes to perform the approximation of f(x). Notice that you can uncomment % tic and % toc to perform the required task.

Table 2 – Computational time for different number of terms of the FS.

Number of terms	Computational time
7	0.050211
20	0.074222
30	0.08622
50	0.115431
100	24.483018

B.6) From the previous problems it could be noticed that, the higher number of terms of the series is, more precise the approximation will be; however, the computational time cost increases. In practice, we must find a balance between precision and computational cost when using Fourier series. What determines this balance?

- The balance comes from finding a number of terms that can accurately simulate a square wave (or whatever function is desired), that is there are minimal overshoots and distortions. However, there can be so many terms such that it drastically slow the computational time.

C.1) CODE 2 implements the approximation of a square wave using Fourier series. Modify this code so that it will produce the approximation of a triangular wave (more specifically, a sawtooth wave) similar to the one shown in Figure 1. In your report, include, on the same figure, plots of the approximated sawtooth function considering N_TERMS = 10,20 and 30.

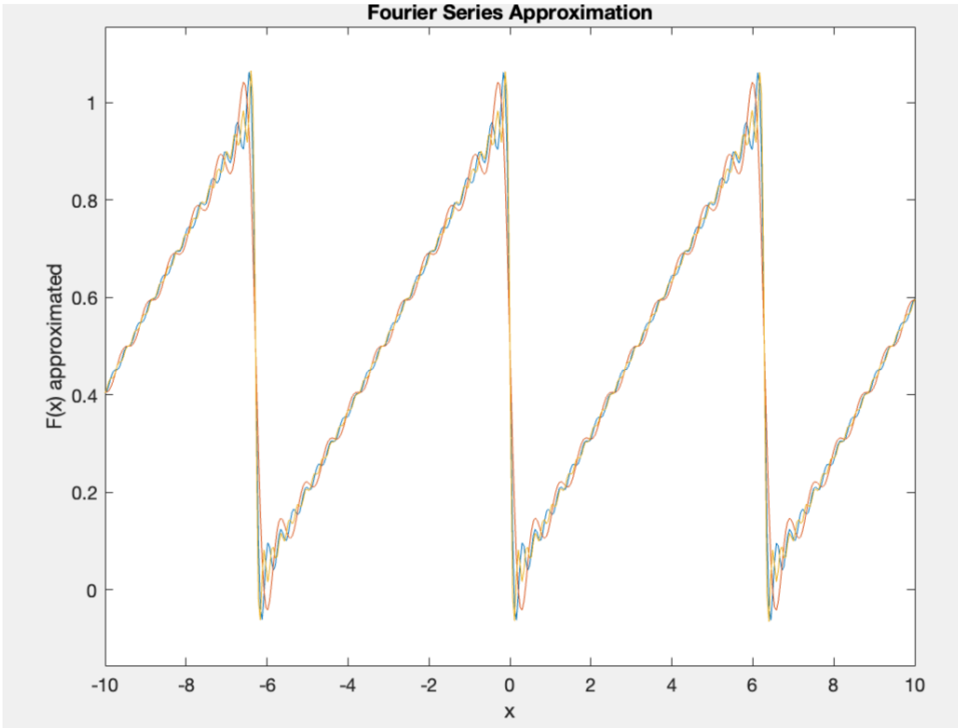

Figure 3. Fourier Series of Sawtooth with 10, 20, & 30 terms

Conclusions:

This section should include the conclusions to the lab and should answer the following questions.

What did you enjoy about this lab?

- I enjoyed seeing the Fourier series represented graphically. It helped with my understanding.

What didn't go well in this lab?

- I had some issues getting the required toolboxes to run

How would you improve the lab experiment for future classes?

- No major improvements.