EEE 391
Basics of Signals and Systems
MATLAB Mini Project 1
due: 14 November 2023, Tuesday by 23:55 on Moodle

In this assignment, you will get hands-on experience with MATLAB by using Fourier series representation of periodic signals and by using Fourier series coefficients in a real life example.

1 Fourier Series Representation of Periodic Signals

Periodic signals can be written as a summation of harmonically related complex exponential numbers as in the equation 1. Hence, only the knowledge of frequency components and corresponding complex amplitudes of a periodic signal gives us all the information about the signal.

$$x(t) = \sum_{k=-\infty}^{\infty} a_k e^{jk2\pi f_0 t} \tag{1}$$

So, how do we derive the coefficients, a_k's, for the harmonic sum? The answer is that we use the Fourier Series integral to perform Fourier analysis. The complex amplitudes for any periodic signal can be calculated with the Fourier integral:

$$a_k = \frac{1}{T_0}\int_0^{T_0} x(t)e^{-j(2\pi/T_0)kt}\,dt \tag{2}$$

(a) Assume that you are given a periodic square wave signal as in Fig. 1 with the formula given in 3. You will use Fourier series representation to get this signal. Calculate the Fourier series coefficients a_k's for the k values between -2 and 2. Plot your signal on the square wave and observe the similarities and differences. Then, repeat this procedure for k values between -4 and 4. Increase the k value until your signal looks like a square wave. Plot all your trials and comment on the effect of k value on the convergence.

$$x(t) = \begin{cases} 1, & \text{if } -1 \le x < 0 \\ -1, & \text{if } 0 \le x < 1 \end{cases} \tag{3}$$

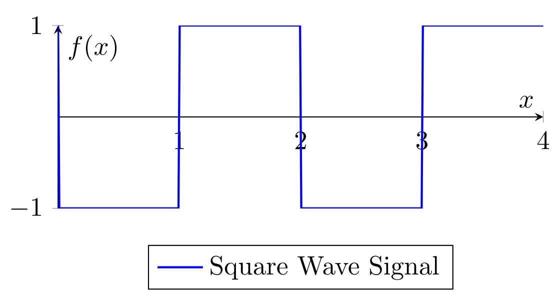

Figure 1: Square Wave Signal with Period 2

(b) Now, assume that you are given a periodic triangle wave signal as in Fig. 2 with the formula given in 4. You will use Fourier series representation to get this signal. Calculate the Fourier series coefficients a_k's for the k values between -2 and 2. Plot your signal on the square wave and observe the similarities and differences. Then, repeat this procedure for k values between -4 and 4. Increase the k value until your signal looks like a square wave. Comment on the effect of k value on the signal approximation error.

$$x(t) = \begin{cases} -x, & \text{if } -2 \leq x < 0 \\ x, & \text{if } 0 \leq x < 2 \end{cases} \tag{4}$$

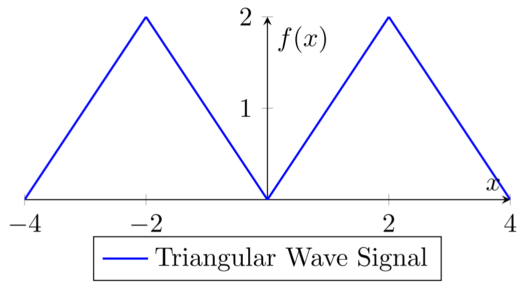

Figure 2: Triangular Wave Signal

2 A Real Life Example

Mathematically sound can be represented as sum of different sinusoids. In this part of the assignment each of the following Fourier series expansions stands for a note.

(a) First find the closed form of these signals by using their Fourier series coefficients. Do this by hand.

$$signal_1 = \frac{1}{2}e^{j(2\pi*220*2^{10/12})t8} + \frac{1}{2}e^{-j(2\pi*220*2^{10/12})t8} \tag{5}$$

$$signal_2 = \frac{1}{2}e^{j(2\pi*220*2^{6/12})t2} + \frac{1}{2}e^{-j(2\pi*220*2^{6/12})t2} \tag{6}$$

$$signal_3 = \frac{1}{2}e^{j(2\pi*220*2^{8/12})t8} + \frac{1}{2}e^{-j(2\pi*220*2^{8/12})t8} \tag{7}$$

$$signal_4 = \frac{1}{2}e^{j(2\pi*220*2^{5/12})t2} + \frac{1}{2}e^{-j(2\pi*220*2^{5/12})t2} \tag{8}$$

(b) Write these closed form signals in MATLAB.

(c) Define the following by writing the lines given. (fs for sampling frequency, n1 for note length, t8 for eight note, t2 for half note, sd for short duration and rest for long duration)

fs = 8000
n1 = 2
t8 = 1/fs: 1/fs:n1/8
t2 = 1/fs: 1/fs:n1/2
sd = zeros(1,round(length(t8)/10))
rest = zeros(1,length(t8))

(d) By using these notes which are found in part (b) and the parameters which are given in part (c), create an array according to this order:

signal1, sd, signal1, sd, signal1, sd, signal2, sd, rest, sd, signal3, sd, signal3, sd, signal3, sd, signal4

(e) Listen to this combination of notes by using the command sound.