

Fourier Series MATLAB GUI Documentation

INTRODUCTION

The Fourier series GUI is designed to be used as a tool to better understand the Fourier series. The GUI allows the user to sum up to five sine waves using a Simulink model, change their frequency, amplitude, and phase, and plot the resulting signal. It also allows the user to plot various sample signals which can then be approximated using the sine waves.

This document explains the operation of the GUI. Other documents are available which provide more details on the Fourier series itself.

FILES NEEDED TO RUN FOURIER SERIES GUI

fourier.mdl
fourierGUI.p

Place these two files in the same directory, and make this your working directory in MATLAB.

SIMULINK MODEL

The foundation of the GUI is a simple Simulink model, shown in Fig. 1.

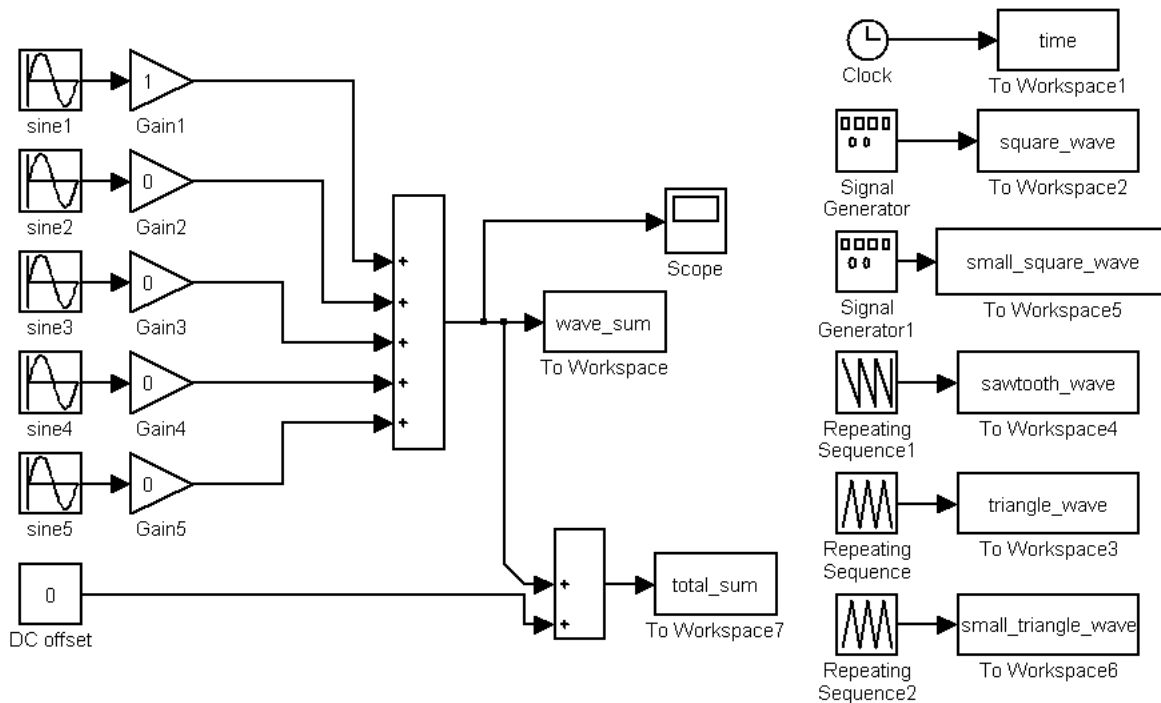


Fig. 1. Simulink model controlled by GUI.

This model sums up to five sine waves along with a DC offset. The gain block next to each sine wave acts as an “on/off” switch for the signal. The frequency, amplitude, and phase shift of each sine wave can be set manually in the Simulink model, but these parameters can be controlled more easily using the GUI.

The Simulink model also outputs five sample signals and a time vector, seen on the right side of the model.

RUNNING THE GUI

With the proper working directory selected, type 'fourierGUI' in the MATLAB command window.

OPERATING THE GUI

When you initially open the GUI, it will look as shown in Fig. 2.

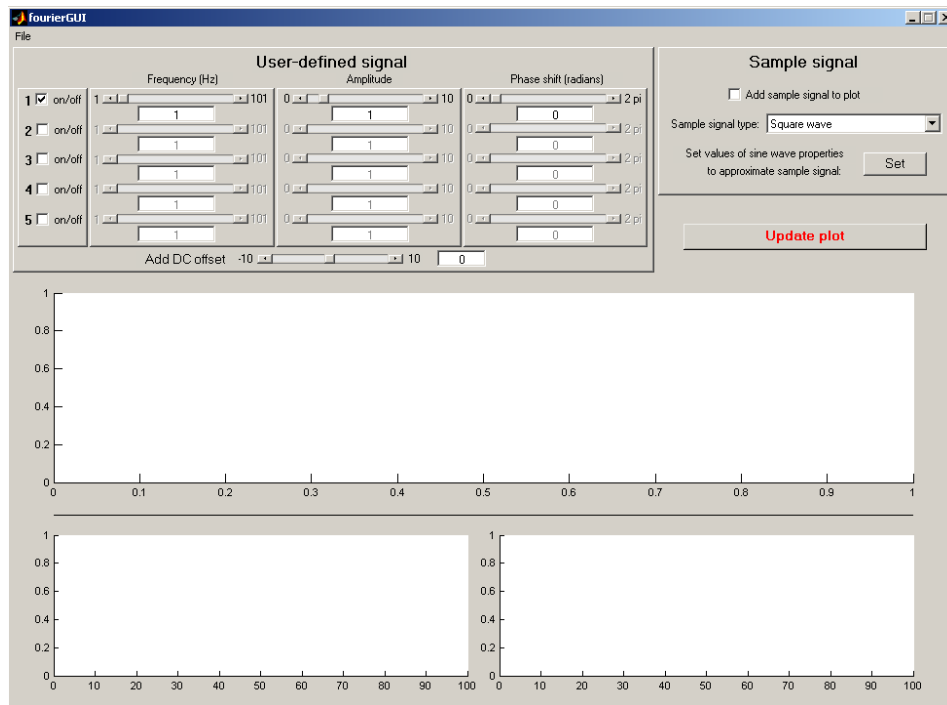


Fig. 2. Fourier series GUI.

Summing and Altering Sine Waves

The portion of the GUI which allows you to vary the parameters of the sine waves in the Simulink model is shown in Fig. 3.

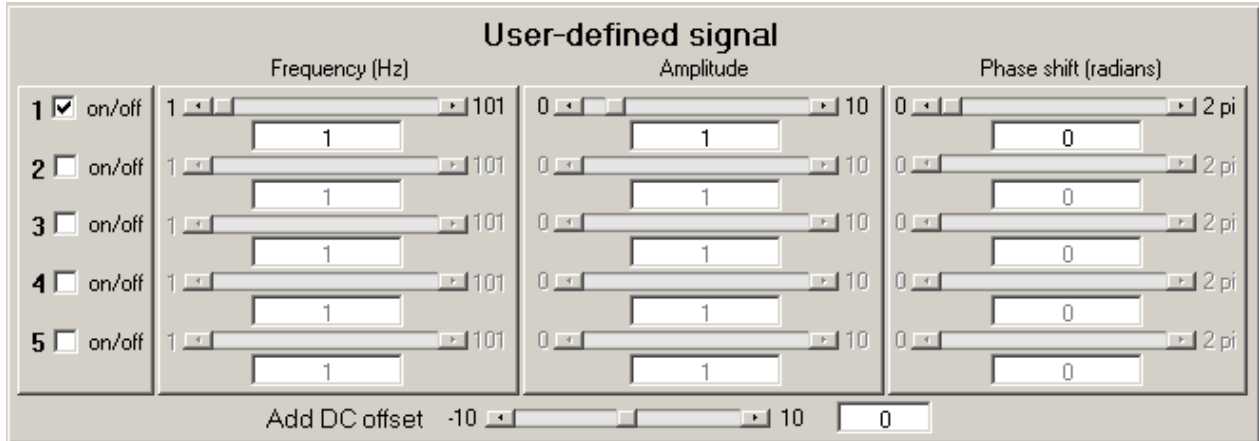


Fig. 3. Controls for user-defined signal.

Checking the “on/off” box for a sine wave will activate its controls; all of the controls except those for sine wave 1 are initially inactive when the model is opened.

For each sine wave, you can set the frequency in Hertz, the amplitude, and the phase shift in radians. You can also add a DC offset. When you have defined the desired values for each parameter, click “Update plot” to see the resulting signal.

Sample Signals

The GUI allows you to plot a sample signal on the axes along with the user-defined signal. This gives you the option of attempting to replicate a particular type of signal by adjusting the properties of the sine waves until the user-defined signal and the sample signal match. The controls for these sample signals are shown in Fig. 4.

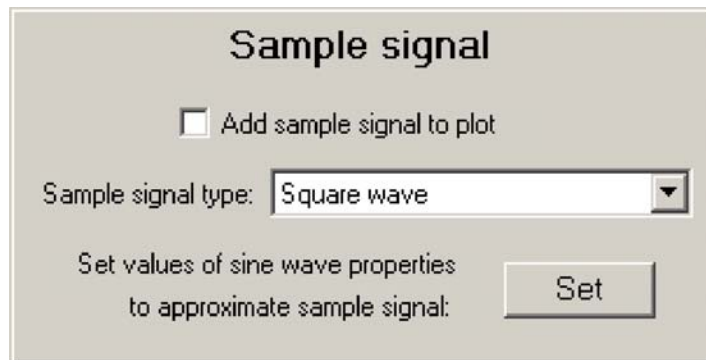


Fig. 4. Controls for sample signal.

Check the “Add sample signal to plot” box to plot the sample signal along with the user-defined signal on the large axes. There are five sample signals to choose from. They have varying frequencies, amplitudes, and shapes, as shown in Fig. 5. For details on the properties of these signals, see Table A-1 in Appendix A.

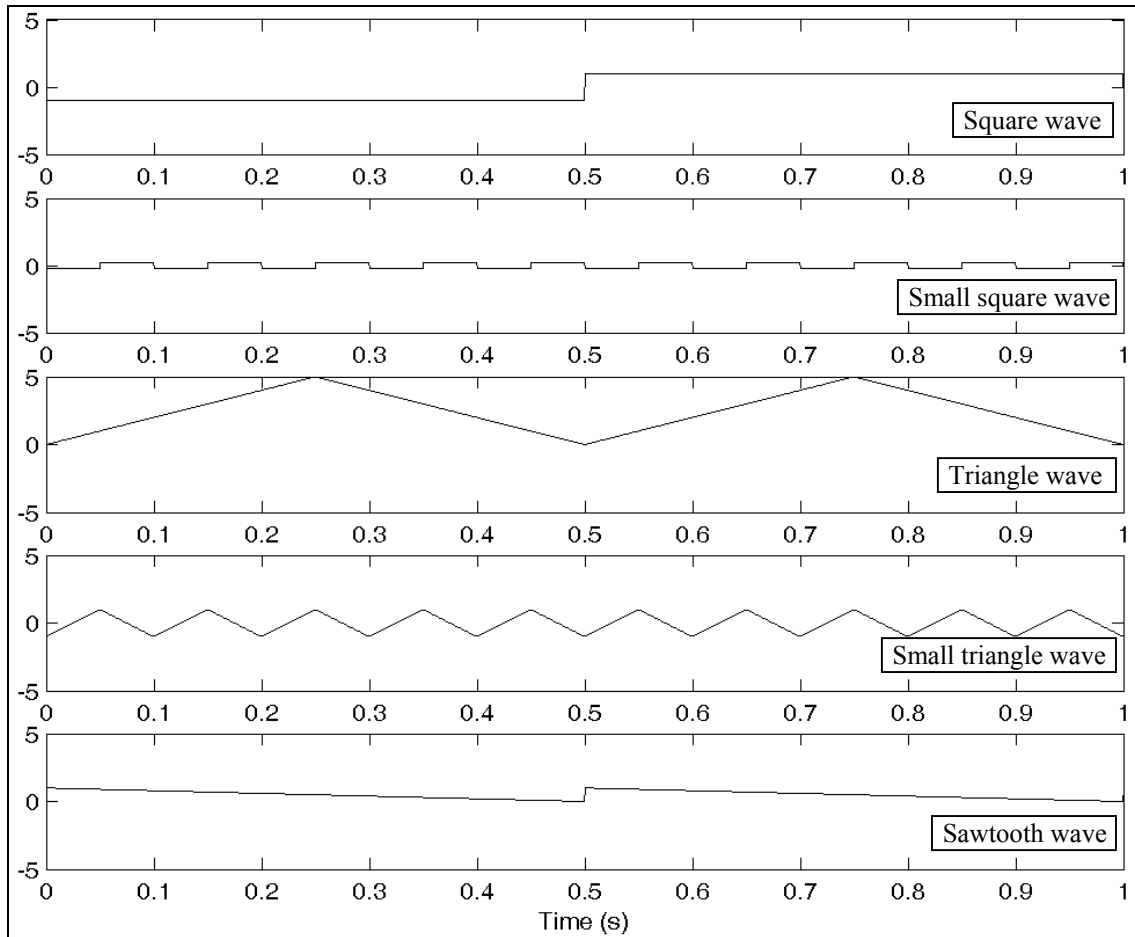


Fig. 5. Sample signals.

Select the signal you would like to plot using the drop-down menu shown in Fig. 6.

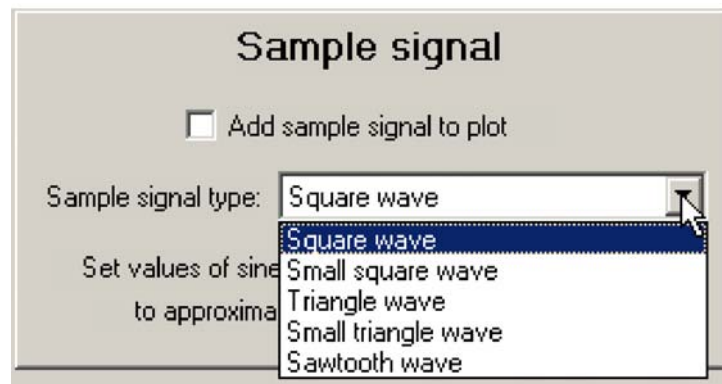


Fig. 6. Sample signal drop-down menu.

As it is difficult to manually adjust the sine waves and find the correct values to approximate a given signal, you also have the option of letting the GUI fill in the correct values for you. When you click the “Set” button, the values for frequency, amplitude, phase shift, and DC offset will be filled in to approximate the currently selected sample signal. Then click “Update plot” to see this five-term Fourier series approximation of the signal. For details on the values used for

each sample signal, see Table A-2 in Appendix A. Fig. 7 shows the GUI being used to approximate the square wave sample signal.

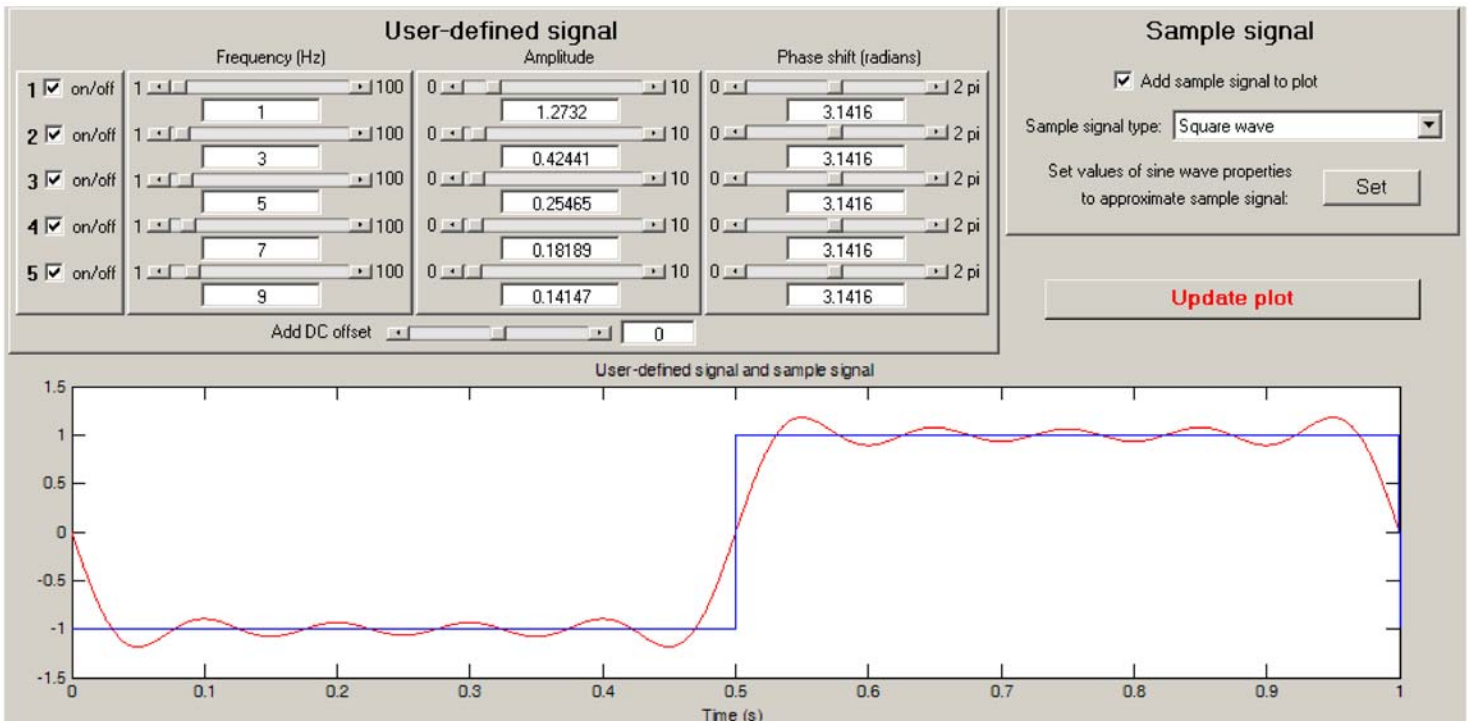


Fig. 7. Use of the GUI to approximate the sample square wave.

Frequency Content of Signals

As an additional tool to understand the signal you are viewing, the GUI also displays the frequency content of the sample and user-defined signals. This is a measure of the power of the signal at various frequencies. For example, Fig. 8 shows the frequency spectrum for the square wave approximation in Fig. 7.

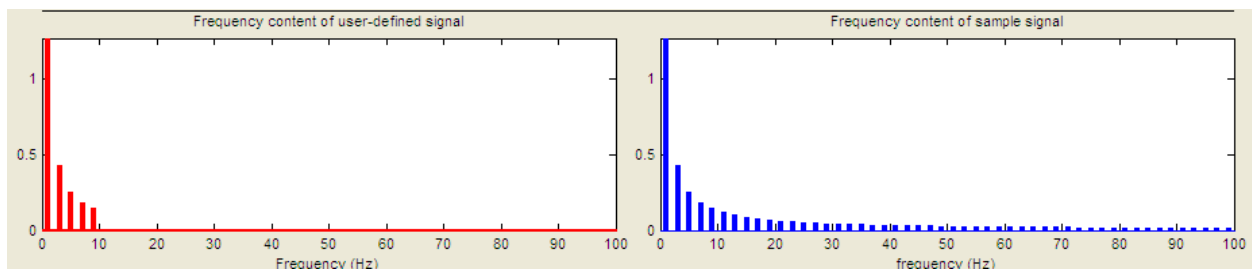


Fig. 8. Frequency content of square wave sample signal and its approximation.

You can clearly see that the user-defined signal's frequency spectrum consists of five peaks, corresponding to the five sine waves. The sample signal, on the other hand, has peaks continuing on to infinity. These plots are produced by taking the Fast Fourier Transform (FFT) of each signal and plotting the magnitude of the result versus frequency.

APPENDIX A Sample Signals

Table A-1 lists the properties of the sample signals.

Table A-1. Properties of sample signals.

Signal name	Minimum value	Maximum value	Frequency (Hz)
Square wave	-1	1	1
Small square wave	-0.25	0.25	10
Triangle wave	0	5	2
Small triangle wave	-1	1	10
Sawtooth wave	0	1	2

Table A-2 gives the values of frequency, amplitude, and phase shift which are automatically filled in when a user has the GUI automatically approximate the selected sample signal. f_0 is the fundamental frequency of the signal, and x_0 is either the peak amplitude or peak-to-peak amplitude, depending on the signal. Note that the signals are all approximated using only sine waves, therefore some signals require that the sine waves be phase-shifted.

Table A-2. Fourier series constants used to approximate sample signals.

	f_0 (Hz)	x_0	Sine wave	Frequency (Hz)	Amplitude	Phase shift (rad)	DC offset
Square wave	1	1	1	$f_0 \cdot 1 = 1$	$\frac{4x_0}{\pi \cdot 1} = 1.273$	$\pi = 3.142$	0
			2	$f_0 \cdot 3 = 3$	$\frac{4x_0}{\pi \cdot 3} = 0.424$	$\pi = 3.142$	
			3	$f_0 \cdot 5 = 5$	$\frac{4x_0}{\pi \cdot 5} = 0.255$	$\pi = 3.142$	
			4	$f_0 \cdot 7 = 7$	$\frac{4x_0}{\pi \cdot 7} = 0.182$	$\pi = 3.142$	
			5	$f_0 \cdot 9 = 9$	$\frac{4x_0}{\pi \cdot 9} = 0.141$	$\pi = 3.142$	
Small square wave	10	0.25	1	$f_0 \cdot 1 = 10$	$\frac{4x_0}{\pi \cdot 1} = 0.318$	$\pi = 3.142$	0
			2	$f_0 \cdot 3 = 30$	$\frac{4x_0}{\pi \cdot 3} = 0.106$	$\pi = 3.142$	
			3	$f_0 \cdot 5 = 50$	$\frac{4x_0}{\pi \cdot 5} = 0.064$	$\pi = 3.142$	
			4	$f_0 \cdot 7 = 70$	$\frac{4x_0}{\pi \cdot 7} = 0.045$	$\pi = 3.142$	
			5	$f_0 \cdot 9 = 90$	$\frac{4x_0}{\pi \cdot 9} = 0.035$	$\pi = 3.142$	

Triangle wave	2	5	1	$f_0 \cdot 1 = 2$	$\frac{4x_0}{\pi^2 \cdot 1^2} = 2.026$	$\frac{3\pi}{2} = 4.712$	2.5
			2	$f_0 \cdot 3 = 6$	$\frac{4x_0}{\pi^2 \cdot 3^2} = 0.225$	$\frac{3\pi}{2} = 4.712$	
			3	$f_0 \cdot 5 = 10$	$\frac{4x_0}{\pi^2 \cdot 5^2} = 0.081$	$\frac{3\pi}{2} = 4.712$	
			4	$f_0 \cdot 7 = 14$	$\frac{4x_0}{\pi^2 \cdot 7^2} = 0.041$	$\frac{3\pi}{2} = 4.712$	
			5	$f_0 \cdot 9 = 18$	$\frac{4x_0}{\pi^2 \cdot 9^2} = 0.025$	$\frac{3\pi}{2} = 4.712$	
Small triangle wave	10	2	1	$f_0 \cdot 1 = 10$	$\frac{4x_0}{\pi^2 \cdot 1^2} = 0.811$	$\frac{3\pi}{2} = 4.712$	0
			2	$f_0 \cdot 3 = 30$	$\frac{4x_0}{\pi^2 \cdot 3^2} = 0.090$	$\frac{3\pi}{2} = 4.712$	
			3	$f_0 \cdot 5 = 50$	$\frac{4x_0}{\pi^2 \cdot 5^2} = 0.032$	$\frac{3\pi}{2} = 4.712$	
			4	$f_0 \cdot 7 = 70$	$\frac{4x_0}{\pi^2 \cdot 7^2} = 0.017$	$\frac{3\pi}{2} = 4.712$	
			5	$f_0 \cdot 9 = 90$	$\frac{4x_0}{\pi^2 \cdot 9^2} = 0.010$	$\frac{3\pi}{2} = 4.712$	
Sawtooth wave	2	1	1	$f_0 \cdot 1 = 2$	$\frac{x_0}{\pi \cdot 1} = 0.318$	0	0.5
			2	$f_0 \cdot 2 = 4$	$\frac{x_0}{\pi \cdot 2} = 0.159$	0	
			3	$f_0 \cdot 3 = 6$	$\frac{x_0}{\pi \cdot 3} = 0.106$	0	
			4	$f_0 \cdot 4 = 8$	$\frac{x_0}{\pi \cdot 4} = 0.080$	0	
			5	$f_0 \cdot 5 = 10$	$\frac{x_0}{\pi \cdot 1} = 0.064$	0	