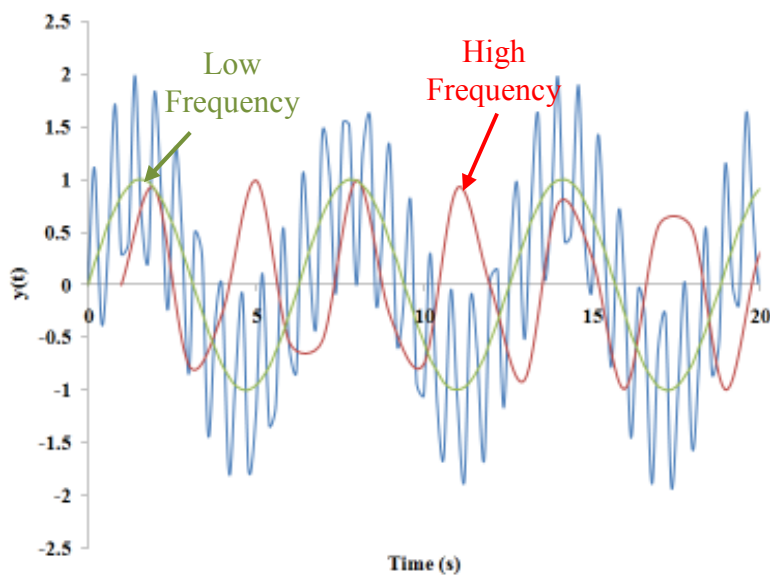
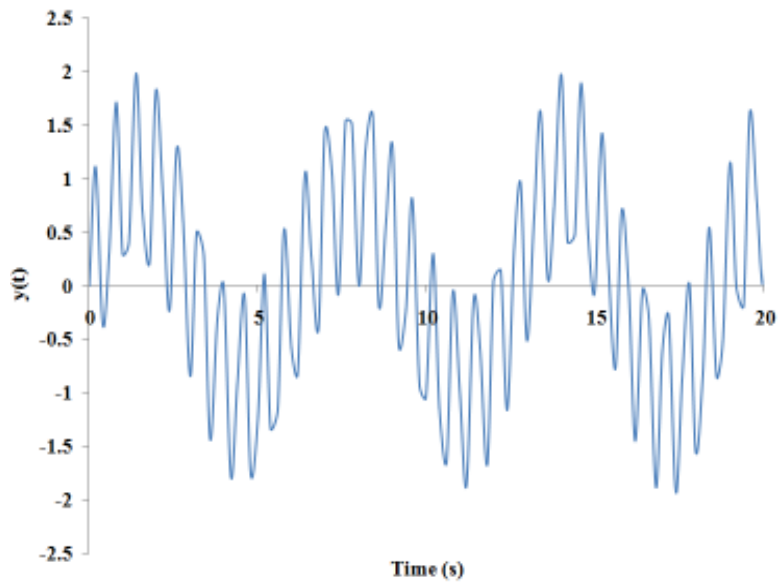


Fast Fourier Transform Tutorial

Fast Fourier Transform (FFT) is a tool to decompose any deterministic or non-deterministic signal into its constituent frequencies, from which one can extract very useful information about the system under investigation that is most of the time unavailable otherwise. Engineers and scientists often resort to FFT to get an insight into a system or a process.

By examining the following signal one can observe a high frequency component riding on a low frequency component. The question what are these frequencies? In this example, FFT will be used to determine these frequencies.



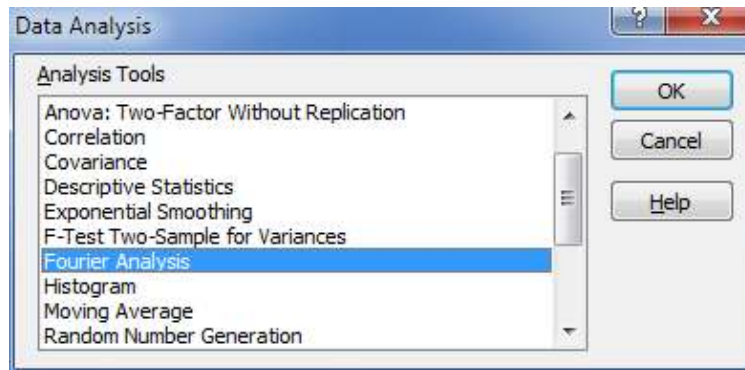
Fourier Analysis is part of the **Data Analysis ToolPak**. If you cannot find the *Data Analysis ToolPak*, please refer to [Appendix 1](#) of this tutorial to enable the Analysis ToolPak.

First, you need to insert the following five labels: **Time**, **Signal**, **Frequency**, **Magnitude**, and **Complex Fourier**, which should corresponds to the cells A1:E1, respectively. Note that the time and signal are stored in column A and column B.

A	B	C	D	E
Time	Signal	Frequency	FFT Magnitude	Complex FFT
0	0			
0.2	1.107966758			
0.4	-0.367384153			
0.6	0.285226975			
0.8	1.706714338			

Labels

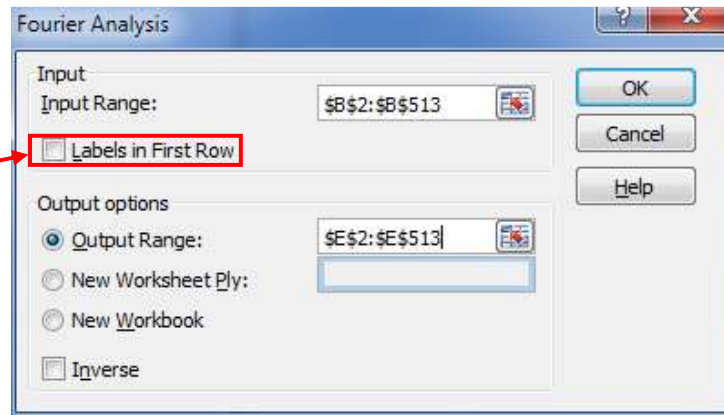
Select Cell E2 and access Fourier Analysis by click **Data/Data Analysis** and select **Fourier Analysis**.



Excel will prompt you with Fourier Analysis dialog box, in which you must enter the following information:

- **Input Range:** select the range where the signal data is stored. The number of cells must be 2^n number of samples.
- **Output Range:** select the range where the complex FFT will be stored. In our example, select the corresponding range in **column E**.
- After enter the information, as shown in the figure below, click OK. Excel will populate **column E** with the complex FFT results.

Check if you included cell B1 in the input range



Note: if you included **cell B1** in the input range, you must click the check box to indicate that the **Labels in First Row**.

Second, calculate the FFT magnitude by using **IMABS(ref)** function in column D, where **ref** refers to cells in **column E** where the complex FFT data stored. Recall from our Fourier Transform formulation discussed in class that the integral was double-sided (i.e. integral bounds from $-\infty$ to ∞). Also, the Fourier Integral was divided by the number of samples N (i.e. number of data points). Therefore, the magnitude calculation has to be adjusted for the number of samples and the double-sided properties of the transform by multiplying **IMABS(ref)** by $2/N$. in this example $N=512$. Fill in column D with this formula in the range corresponding to the range where FFT complex data is stored.

A	B	C	D	E
Time	Signal	Frequency	FFT Magnitude	Complex FFT
0	0		$=(2/512)*IMABS(E2)$	
0.2	1.107966758			6.07745482567079-0.294653600084316i
0.4	-0.367384153			6.15192115817672-0.596058308419429i
0.6	0.285226975			6.27990097870396-0.911491422910109i

Third, fill in the frequency column by performing the following steps:

- 1- Insert 0 in cell B2.
- 2- Calculate the sampling frequency such that

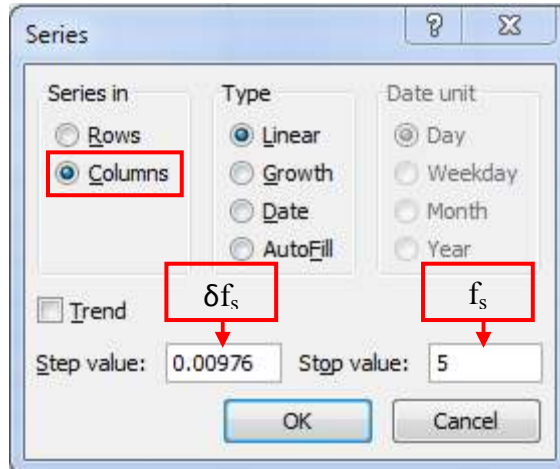
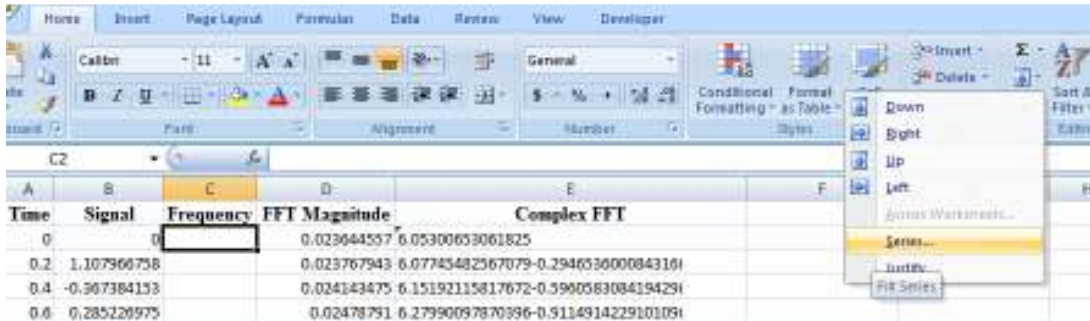
$$f_s = \frac{1}{\Delta t}$$

where, f_s is the sampling frequency and Δt is the time step (i.e. the number stored in cell A3).

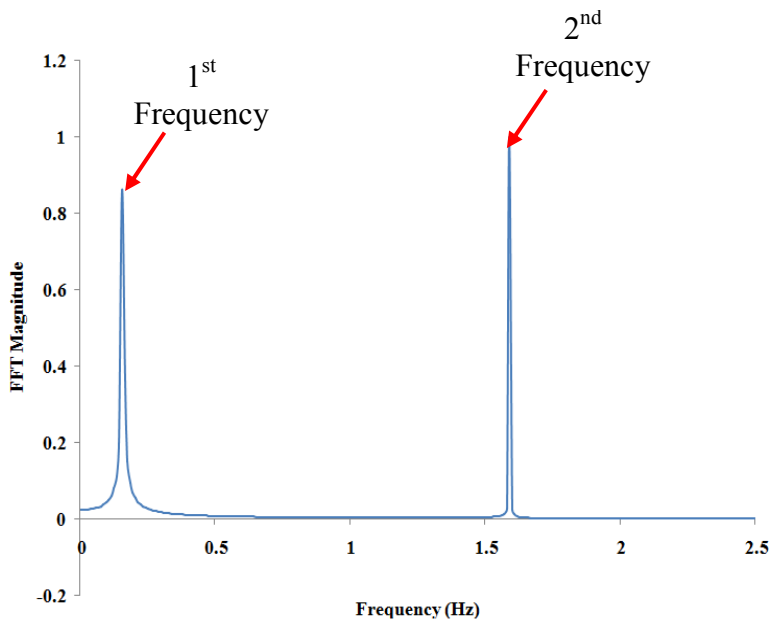
- 3- Calculate δf_s which will be used to fill in series

$$\delta f_s = \frac{f_s}{N}$$

4- Fill in a series column C by clicking Home/Fill (in Cells Tab)/Series



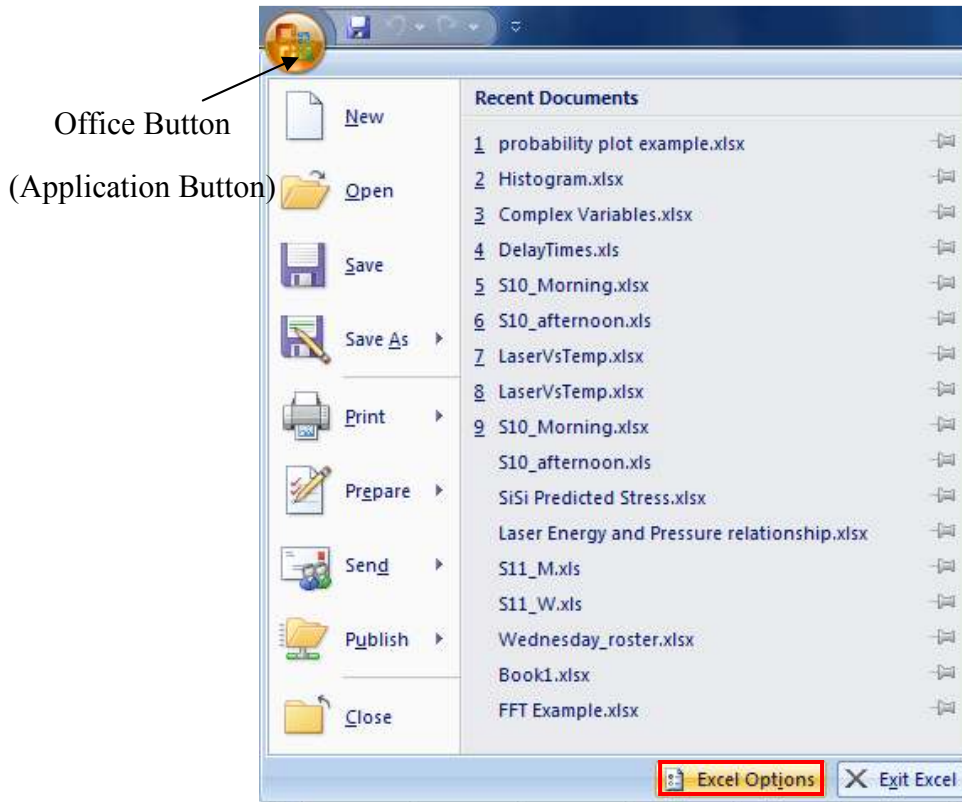
Last, plot FFT Magnitude vs Frequency to display the transformed spectra. Note due the symmetry properties of Fourier Transform don't plot more than N/s data points, failing to do so the FFT spectra will duplicate itself.



Appendix 1: Data Analysis ToolPak

By default, this add-in is not activated. Therefore the first step is to activate the Analysis ToolPak.

Go to **Office Button** (application Button)/**Excel Options**



Select the **Add-Ins** Tab, then select **Excel Add-Ins** from the **Manage** dropdown menu located at the bottom of the dialog box and click **Go**.

Excel will prompt you with another dialog box “**Add-Ins**” to select the analysis tools you want to activate. Check the box beside **Analysis ToolPak** and **Analysis ToolPak-VBA** and click **OK**.

You don't have to perform these steps every time you use the data analysis tools. You follow these steps if you can't access the Data Analysis tools, which usually is the first time you use PC with freshly installed Office or the first time you use the ToolPak.

