

Practical Lab Class: Electronic, Signal and Measurement – Experiment 3

Fourier Synthesis, Sampling, and DFT

**Questions to prepare before the lab.**

1. Draw a sinusoidal waveform of your choice and explain the meaning of the frequency of the signal, amplitude, phase angle, and wavelength.
2. Write Fourier series of saw tooth (for positive slope and negative slope separately) waves up to 10 harmonics and explain the common difference between both series.
3. Draw a sine wave of amplitude = 1, frequency = 1y, phase shift = 0°, and for duration of 2 seconds. Then draw the same waveform with phase shift of +90° and explain the difference in both the waveforms.
4. If a complex signal is generated by combining the fundamental signal (first harmonic) of 200 Hz and next 4 harmonics. Then what is the maximum frequency available in that signal? How one can find those frequencies if fundamental frequency is not known in the time domain?
5. In question 4, above, if we want to sample the signal, then what is the minimum sampling frequency required as per Nyquist Sampling Theorem?

ATTENTION:

1. All the above stated questions must be prepared and written properly before coming to the lab.
2. All the labs must be implemented using Python 3. You can use the built-in function to generate sin, cos, and sawtooth waveform (if required) but for Fourier synthesis (DFT, IDFT, and others) direct use of built-in functions is not allowed.

3.1 Sine-signal and sampling

A test signal is to be generated with the frequency and sampled with the defined sampling frequency . A sinusoidal signal is to be examined. For continuous-time systems, the following applies: angular frequency .

Thus, the sinusoidal oscillation is defined by:

.

Sampling in discrete systems occurs in periods of duration .

Thus, the discrete-time points can be described by the time index *k* = 0, 1, 2, .... Accordingly, it follows:

.

1. Generate a sinusoidal oscillation for k= 0...60 with , A0=1 and .

Plot the oscillation with the matplotlib *stem()* function and label your graph accordingly.

1. Change your fundamental frequency to and plot the oscillation in a new plot using the matplotlib *stem ()* function. Describe the change in the period of the oscillation.

1.2 Fourier Synthesis

1. Create a sawtooth signal with and amplitude = 2 for 5 periods sampled with . Define it for one period using the slope. For the rest of the signal, i.e. the other periods use the condition of periodicity. Plot the signal starting with 0 by adjusting the initial phase angle.
2. Create the sawtooth signal using the Fourier synthesis below.

Plot the sawtooth developed until “first”, “second”, “third”, “fourth”, and “fifth” harmonic frequency order together with the original sawtooth (from a) in a diagram and label your graph accordingly.

1. Create a time shift for the sawtooth signal generated above (in b). The signal shall be shifted t=0.0015 sec in time. Plot the shifted and unshifted signals separately and explain the difference.

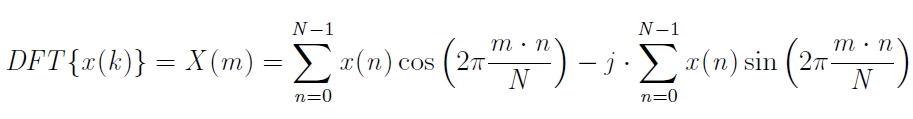
1.3 DFT

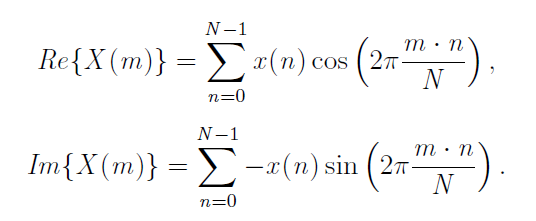
The discrete Fourier transform (DFT) can be used to transform a sampled signal from the time domain to the frequency domain (spectral domain). Signal processing, e.g. filtering (e.g. high pass, low pass, band pass to remove interfering frequencies), can be performed either in the time domain or in the frequency domain.

In this task, we will now transform between the time domain and the frequency domain and investigate.

DFT:

or after inserting:





with

Inverse DFT:

1. Create a function to calculate the DFT in Python. The function should be able to take any signals, whereby the output of the function should be the DFT result.
2. Calculate the DFT of a sawtooth (developed to the 4th harmonic) of fundamental frequency,

when sampling with

Calculate the DFT for the sawtooth sampled once for 400 values and sampled once for 16000 values. Plot the amplitude response. What frequency range do you need to plot to represent the full information. What is the difference in the amplitude response for 400 values and 16000 values?

1. Generate a periodic square wave signal (period 400Hz) and calculate the DFT (sampling frequency 8000 Hz, 2000 readings sampled). Plot the amplitude response.