# Signals & Systems Laboratory

# CSE- 301L

# Lab # 09

# OBJECTIVES OF THE LAB

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This lab aims at the understanding of:

- Power of Continuous & Discrete time Signals
- Application of Fourier Series
- Synthesis of Square Wave
- Synthesis of Triangular Wave

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## 9.1 SIGNAL POWER

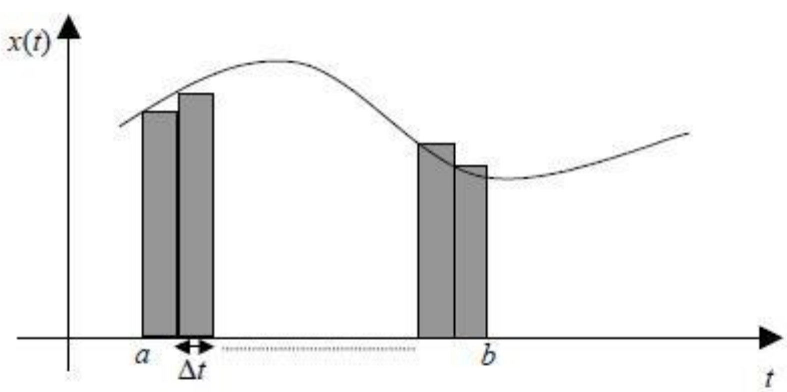
Average power of continuous time signal can be calculated using the formula:

$$P = \frac{1}{T}\int_{-T/2}^{T/2} |x(t)|^2 \, dt$$

To carry out the integral, Euler Approximation can be used. It simply tells that a definite integral can be approximated using a sum i.e.

$$\int_a^b x(t)dt \cong \sum_{n=0}^{N-1} x(a+n\Delta t)\Delta t, \quad \Delta t = \frac{b-a}{N}$$

In this method, the region over which integral is carried out is divided into N parts or intervals, each of duration t, such that function stays constant over those short intervals. Approximating function in this way is shown below. Note that as the number of intervals N is increased, the approximation gets better.

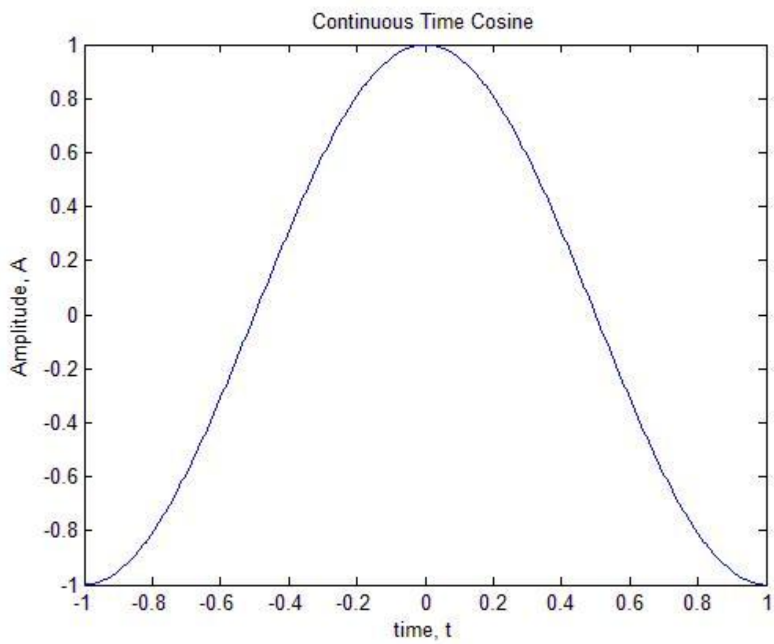



Approximating integrals using sums is a deep subject of numerical analysis by itself; therefore its further detail is out of scope. It is enough to know that Euler's formula is easy to implement and produces good results for almost all the signals that will be studied here as long as N is selected large enough.

**Example – Power of Continuous Time Cosine**

```
clc
clear all
close all
t = -1:0.005:0.995;       % time duration of given signal;
xt = cos(2*pi*t/2);       % generate signal
```

```
plot(t, xt);                              % plot signal
 xlabel('time, t');
ylabel('Amplitude, A');
title('Continuous Time Cosine');
abs_xt_2 = abs(xt).^2;                    % take absolute square of signal
T = 2;                                    % length of interval
delta_t = 0.005;                          % interval duration
pxt = sum(abs_xt_2)*delta_t/T             % power of given signal
```




```
pxt =
          0.5000
```

## ---------------------------TASK 1---------------------------

Calculate the power of discrete-time cosine signal with period 20, defined over interval 0:19 using the following formula:

$$P = \frac{1}{N}\sum_{0}^{N-1} | x[n] |^2$$

## 9.2 FOURIER SERIES

Fourier series theory states that a periodic wave can be represented as a summation of sinusoidal waves with different frequencies, amplitudes and phase values.

### 9.2.1 Synthesis of Square wave

The square wave for one cycle can be represented mathematically as:

$$x(t) = \begin{cases} 1 & 0 \le t < T/2 \\ -1 & T/2 \le t < T \end{cases}$$

The Complex Amplitude is given by:

$$X_k = \begin{cases} (4/j*pi*k) & \text{for} \quad k=\pm1, \pm3, \pm5..... \\ 0 & \text{for} \quad k=0,\pm2, \pm4, \pm6..... \end{cases}$$

#### i. Effect of Adding Fundamental, third, fifth, and seventh Harmonics

**Example**

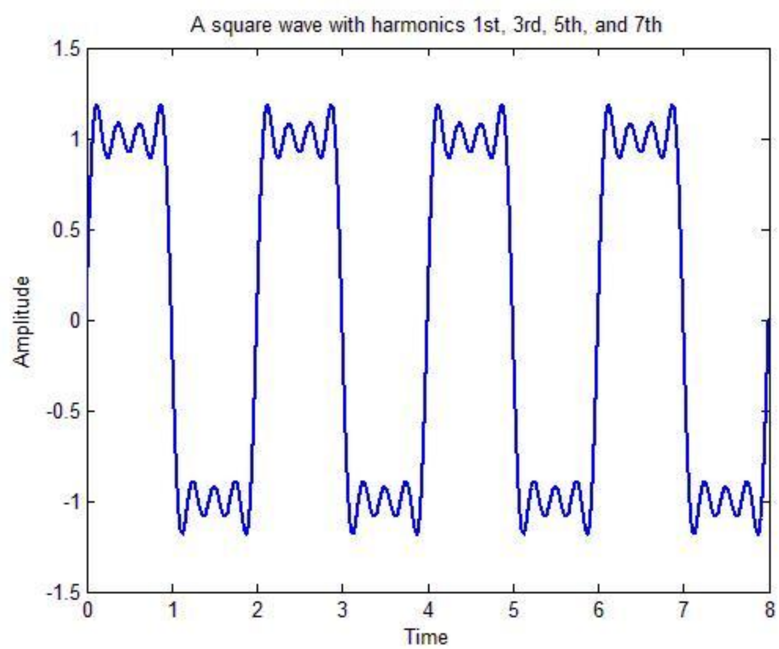
```
clc
clear all
close all

t=0:0.0001:8;
ff=0.5;

% WE ARE USING SINE FUNCTION BECAUSE FROM EXPONENTIAL FORM OF FOURIER
% SERIES FINALLY WE ARE LEFT WITH SINE TERMS
y = (4/pi)*sin(2*pi*ff*t);
% COMPLEX AMPLITUDE = (4/(j*pi*k))
for k = 3:2:7
   fh=k*ff;
```

```
    x = (4/(k*pi))*sin(2*pi*fh*t); y=y+x;
end

plot(t,y,'linewidth',1.5);
title('A square wave with harmonics 1st, 3rd, 5th, and 7th'); xlabel('Time');
ylabel('Amplitude');
```




## ---------------------------TASK 2---------------------------

Analyze the effect of Adding 1st to 17th harmonics and the effect of Adding 1st to 27th harmonics in above example.

## ---------------------------TASK 3---------------------------

Write a program that plots the signal s(t).

$$s(t) = \sum_{n=1}^{N} \frac{\sin(2\pi\ nt)}{n} \qquad \text{where n = 1, 3, 5, 7, 9} \qquad \text{and N = 9}$$

OR

$$s(t) = \sin(2\pi * t) + \frac{\sin(6\pi * t)}{3} + \frac{\sin(10\pi * t)}{5} + \frac{\sin(14\pi * t)}{7} + \frac{\sin(18\pi * t)}{9}$$

What do you conclude from TASKS 2 & 3?

## 9.2.2 Synthesis of Triangular wave

The signal can be represented by complex exponential signal:

x(t)= xk* exp(2*pi*f *k *t * j)

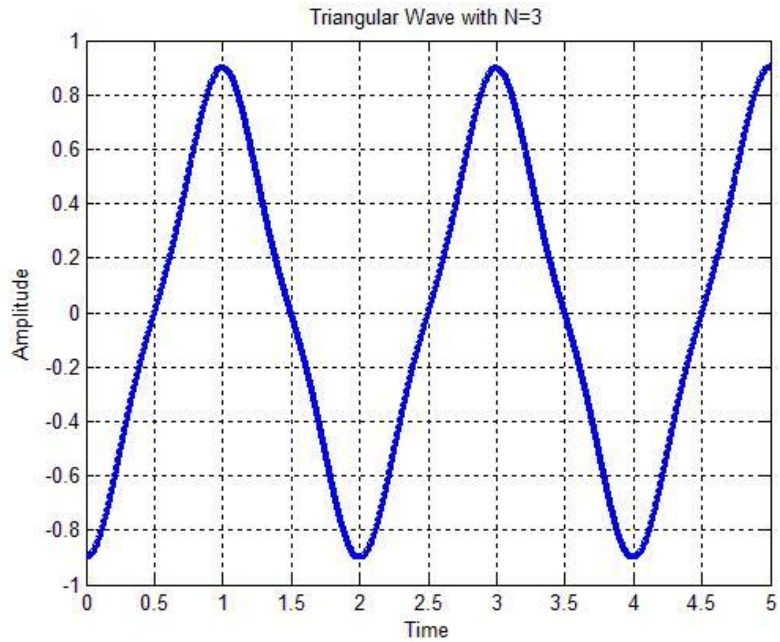
With the Complex Amplitude is given by:

$$xk = \begin{cases} (-8/*pi^2*k^2) & \text{for k is an odd integer} \\ 0 & \text{for k for k is an even integer} \end{cases}$$

**Example: Triangular wave with N=3**

```
clc; clear all; close all
t=0:0.001:5;
x=(-8/(pi*pi))*exp(i*(2*pi*0.5*t));
y=(-8/(9*pi*pi))*exp(i*(2*pi*0.5*3*t));
s=x+y;
plot(t,real(s),'linewidth',3);
title('Triangular Wave with N=3');
ylabel('Amplitude');
xlabel('Time')
```

grid;




## ---------------------------TASK 4---------------------------

Generate a **triangular wave with N=11**

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