Experiment 5: Signal Operations & Synthesis of signals using Fourier Series

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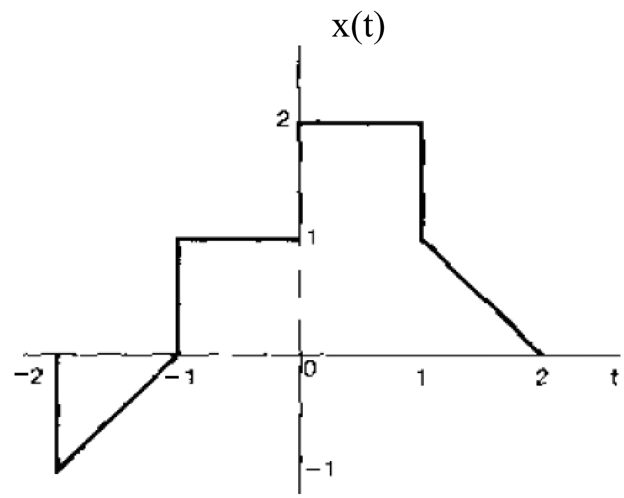
This experiment is intended to make the student to learn about Signal operations and Fourier Series (FS) of Continuous-time Signals by using MATLAB as a tool for computations. In Run #1, the student understands the time operations on signals. In Run #2, the student is expected to perform FS expansion and obtain the FS coefficients and reconstruct the given piece (non-periodic) of signal from the FS coefficients and the harmonic terms. In Run #3, for given periodic signals, plot the Fourier Spectra (magnitude and phase angle spectra) and also observe the Gibbs phenomenon while reconstructing the signal.

<u>Run #01: Signal operations</u>

Q1. (i) Write the expression for the given signal x(t) in your notebook. Write a MATLAB code for this expression using relational / logical operators and plot it

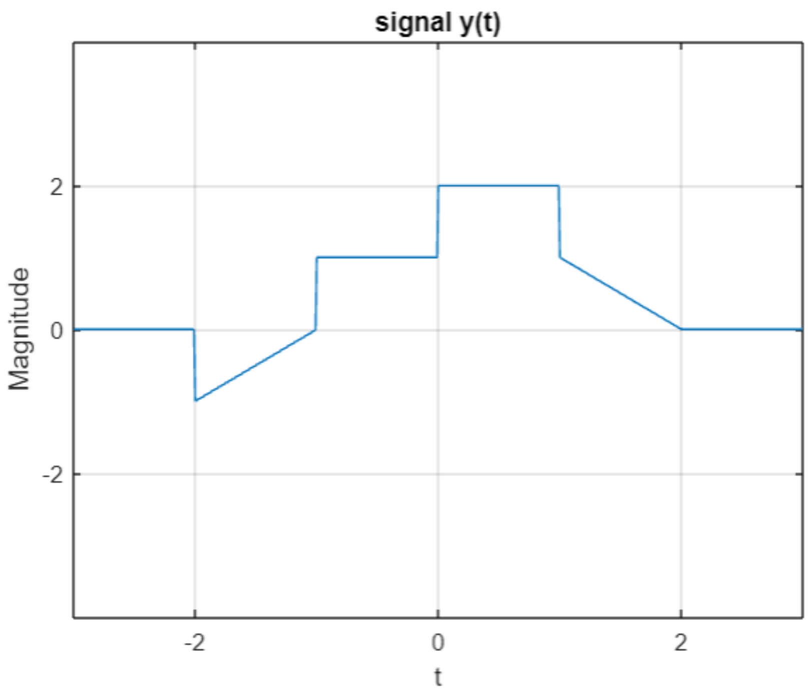
(ii) Perform the given operations on the generated signal x(t) . Plot them, give x,y labels, title, grid on

(i) x(t - 1)   (ii) x(2 - t)   (iii) x(2t + 1)   (iv) x(4 - t/2)



Answer (paste the written code and plots):
(i)

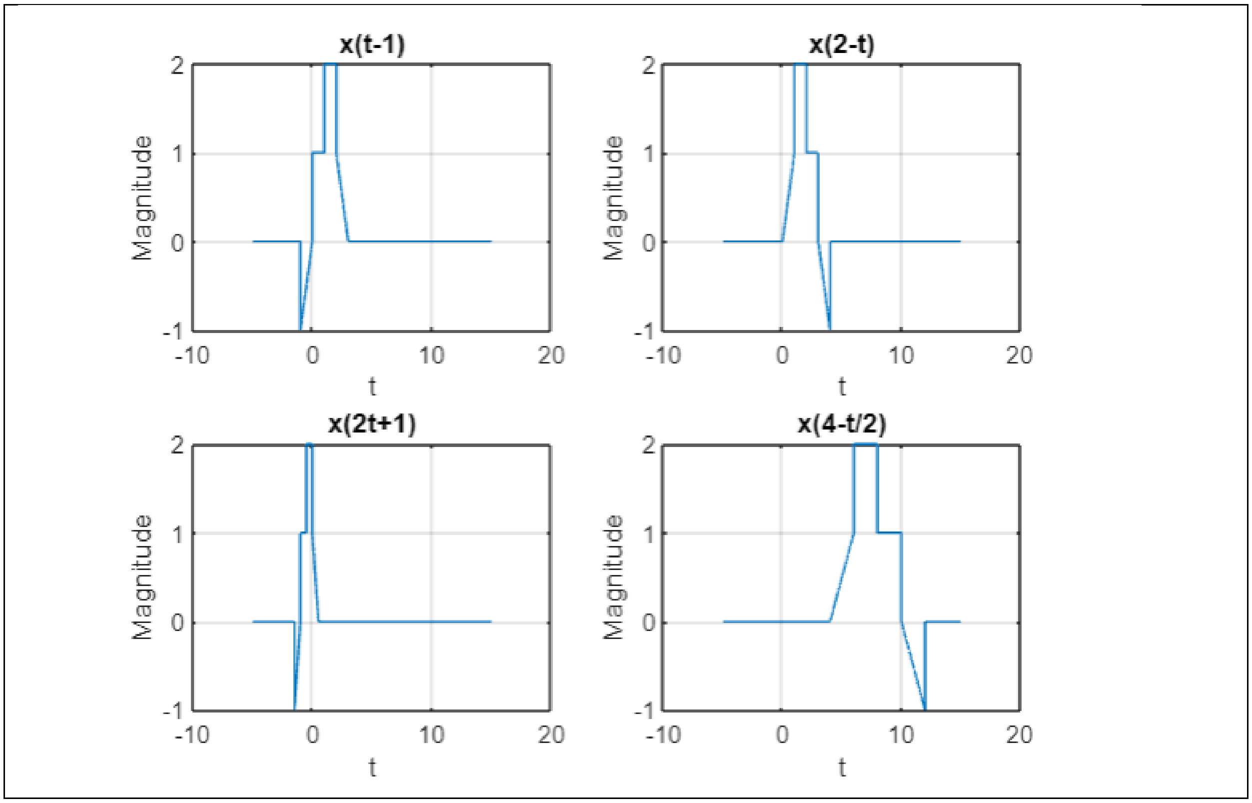
```
clc
clear all
close all
t = -3:0.01:3;
x1 = t+1;
x2 = 1;
x3 = 2;
x4 = 2-t;
y1 = x1.*(t>=-2 & t <-1) + x2.*(t>=-1 & t < 0) + x3.*(t >=0 & t<1) + x4.*(t>=1 & t<=2);
plot(t,y1); grid on
axis([-3,3,-4,4]);
xticks([-2,0,2]);
yticks([-2,0,2]);
title('signal y(t)')
xlabel('t');
ylabel('Magnitude');
```



(ii)

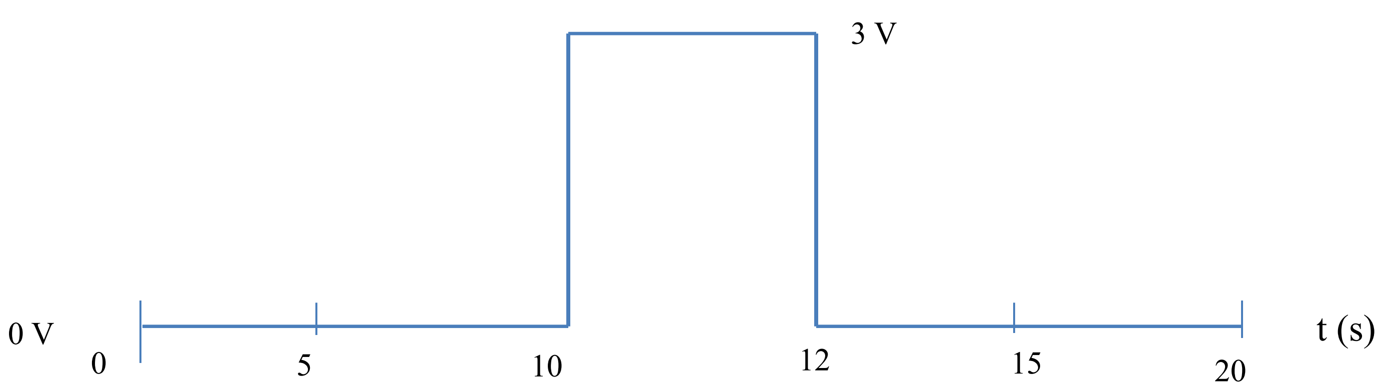
```
clc;
clear all;
t=-5:0.001:15;
y = 0.*(t>-10 &t<-2)+(t+1).*(t>-2 &t<-1)+1.*(t>=-1 &t<0)+2.*(t>=0 &t<1)+(-
t+2).*(t>=1&t<2)+0.*(t>2);
t1=t-1;
y1= 0.*(t1>-10 &t1<-2)+(t1+1).*(t1>-2 &t1<-1)+1.*(t1>=-1 &t1<0)+2.*(t1>=0&t1<1)+(-
```

```
t1+2).*(t1>=1 &t1<2)+0.*(t1>2);
subplot(2,2,1);
plot(t,y1);
xlabel('t');
ylabel('Magnitude');
title('x(t-1)');
grid on;
t2=2-t;
y2=0.*(t2>-10 &t2<-2)+(t2+1).*(t2>-2 &t2<-1)+1.*(t2>=-1 &t2<0)+2.*(t2>=0&t2<1)+(-
t2+2).*(t2>=1 &t2<2)+0.*(t2>2);
subplot(2,2,2);
plot(t,y2);
xlabel('t');
ylabel('Magnitude');
title('x(2-t)');
grid on;
t3=(2*t)+1;
y3=0.*(t3>-10 &t3<-2)+(t3+1).*(t3>-2 &t3<-1)+1.*(t3>=-1 &t3<0)+2.*(t3>=0&t3<1)+(-
t3+2).*(t3>=1 &t3<2)+0.*(t3>2);
subplot(2,2,3);
plot(t,y3);
xlabel('t');
ylabel('Magnitude');
title('x(2t+1)');
grid on;
t4=4-(t/2);
y4=0.*(t4>-10 &t4<-2)+(t4+1).*(t4>-2 &t4<-1)+1.*(t4>=-1 &t4<0)+2.*(t4>=0&t4<1)+(-
t4+2).*(t4>=1 &t4<2)+0.*(t4>2);
subplot(2,2,4);
plot(t,y4);
xlabel('t');
ylabel('Magnitude');
title('x(4-t/2)');
grid on;
```



Run #02: Fourier Series and reconstruction of a signal

(2) For the signal 'f (t)' shown below



a) Write MATLAB code using relational operators and plot the above signal ‘f(t)’ between 0 to 20s

b) Now, obtain the expressions for Trigonometric Fourier series coefficients $\mathbf{a_0}$, $\mathbf{a_n}$, and $\mathbf{b_n}$ for the above signal considering the signal of duration from $t_1 = 9$ and $t_2 = 13$ (Time period, $T_0 = 4$)

NOTE : (1) Solve all the integrals and obtain the final expressions for $\mathbf{a_o}$, $\mathbf{a_n}$ and $\mathbf{b_n}$

(2) Do all these calculations in your observation book only

(3) Plot the *original signal* and *reconstructed signal* on a single graph only. Explore **hold on** & **hold off** matlab plot commands

c) Write Matlab code for computing $\mathbf{a_0}$, $\mathbf{a_n}$, and $\mathbf{b_n}$ using the expressions you have derived in your observation notebook as a function of **n (**no. of harmonics / no. of terms**) by** using **for loop**

d) Write MATLAB code for reconstructing the signal using **FS coefficients** $\mathbf{a_o}$, $\mathbf{a_n}$ **and** $\mathbf{b_n}$. The reconstruction should be limited to the duration $t_1 = 9$ and $t_2 = 13$. ($T_0 = 4$) and no. of harmonics (n) = 5.

e) Consider n (no. of harmonics) = 10 and use the above code to reconstruct the signal during $t_1 = 9$ and $t_2 = 13$. ($T_0 = 4$). Comment on your observations on how closely the reconstructed signal is following

   a. at the rising and falling edges, b. at the flat portion (3V region) and

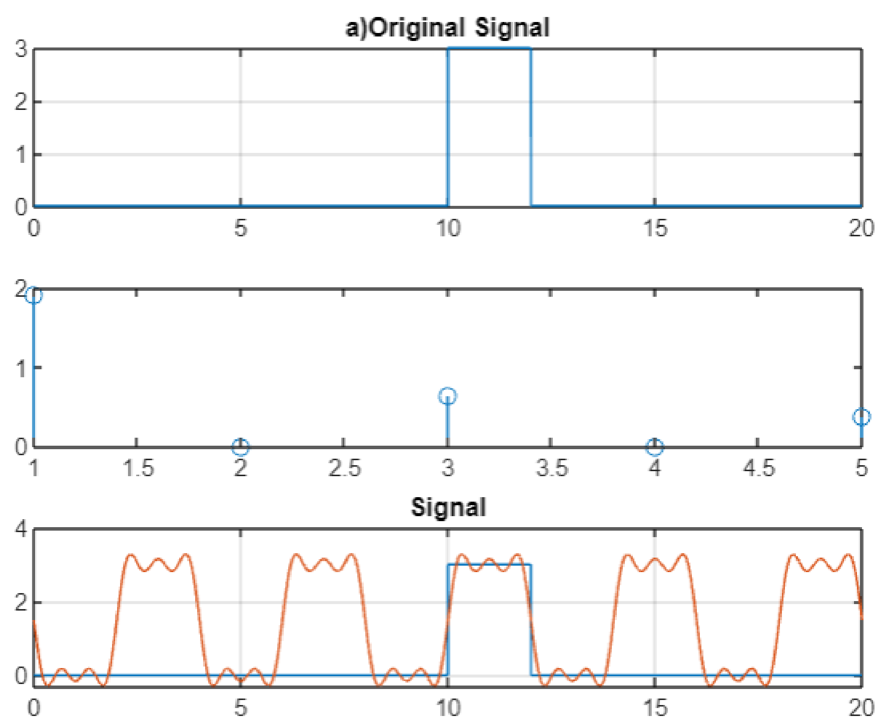
   c. at the flat portion (0 V region) of the original signal

f) For n = 10, evaluate the reconstructed signal for a time duration t = 0 to 20 (To = 4) and plot. How is this different from original f(t)? Comment on your observation.

Answer (paste the written code and plots):

b) c)

```
t=0:0.00001:20;
f=3.*(t>=10 & t<12) +0.*(t<10 & t>=12);
N=5;
n=1:N;
a0=1.5;
an=0;
ft=1.5.*ones(1,length(t));
bcoeff = [];
for n=1:N
    bn=((-3)./(pi.*n)).*(1-((-1).^n));
    ft=ft+ bn.*sin((pi*t.*n)./2);
    bcoeff(n) = bn ;
end
subplot(3,1,1);
plot (t,f);
grid on
title('a)Original Signal');
subplot (3,1,2);
n = 1:N;
stem(n,abs(bcoeff));
subplot(3,1,3);
plot(t,f)
hold on
plot(t,ft);
title('Signal')
hold off
grid on
```



```
d)
t=9:0.00001:13;
f=3.*(t>=10 & t<12) +0.*(t<10 & t>=12);
N=5;
n=1:N;
a0=1.5;
ft=a0*ones(1,length(t));
for n=1:N
   b(n)=((-3)./(pi.*n)).*(1-((-1).^n));
   ft=ft+ b(n).*sin((pi*t.*n)./2);
end
```

e)

1)rising and falling edge of original signal and reconstructed signal are much closely related in this case(n=10) than the case of n=5.

2)the middle portion of reconstructed signal and the original signal are merging at the portion between 10.5 and 11.5.

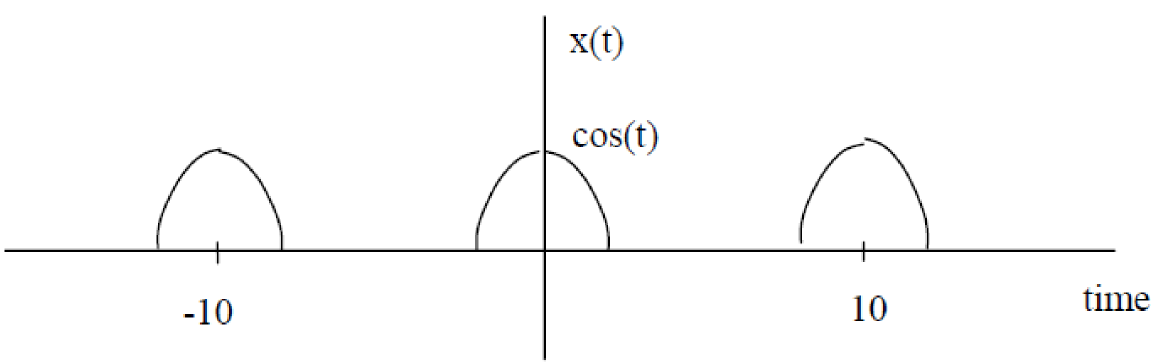
3)the edges i.e., just more than 9 and close to 12 are somewhat merging into the original signal.

f)

The 3V part of the reconstructed signal still has some sine waves that are clearly visible.
The reconstructed signal has 3V as amplitude 5 times i.e., at even intervals.
This is not observed in the original signal.

Run #03 : Fourier Series and Fourier Spectra.

Q3. For the following signal



a) Obtain the exponential Fourier series expression between the limits (- π /2 to + π / 2) for the above signal

b) Find the exponential Fourier series coefficients using matlab program for n = 15

c) Plot the spectra versus frequency (explore ***abs*** and ***angle*** Matlab commands)

d) Generate the original signal from the Fourier components and observe Gibbs Phenomena for n = 10, 20 and 50

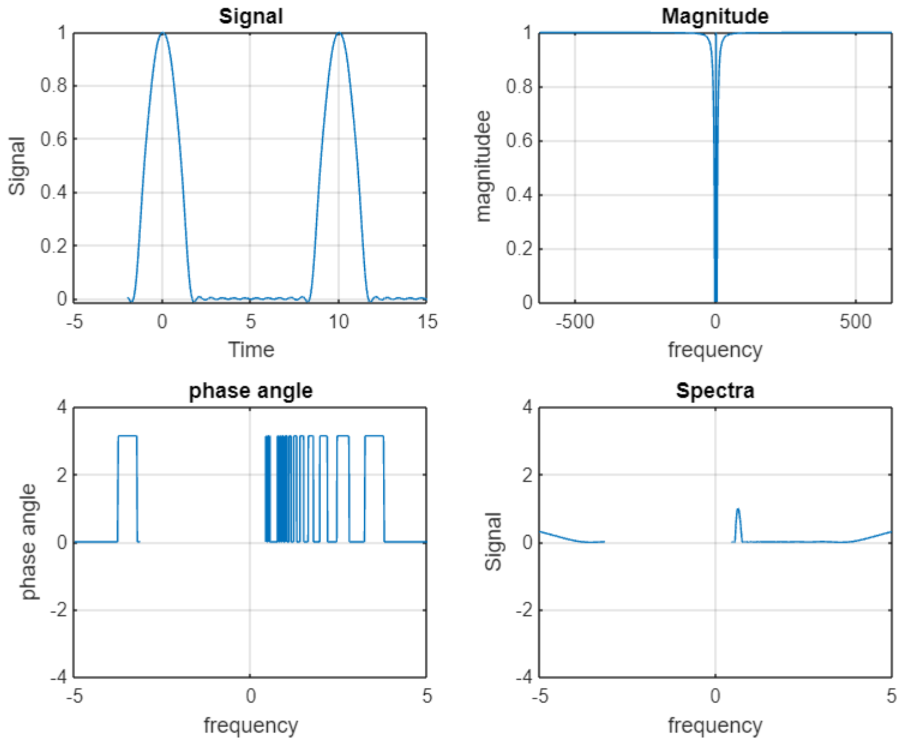
Answer (paste the written code and plots):

a)

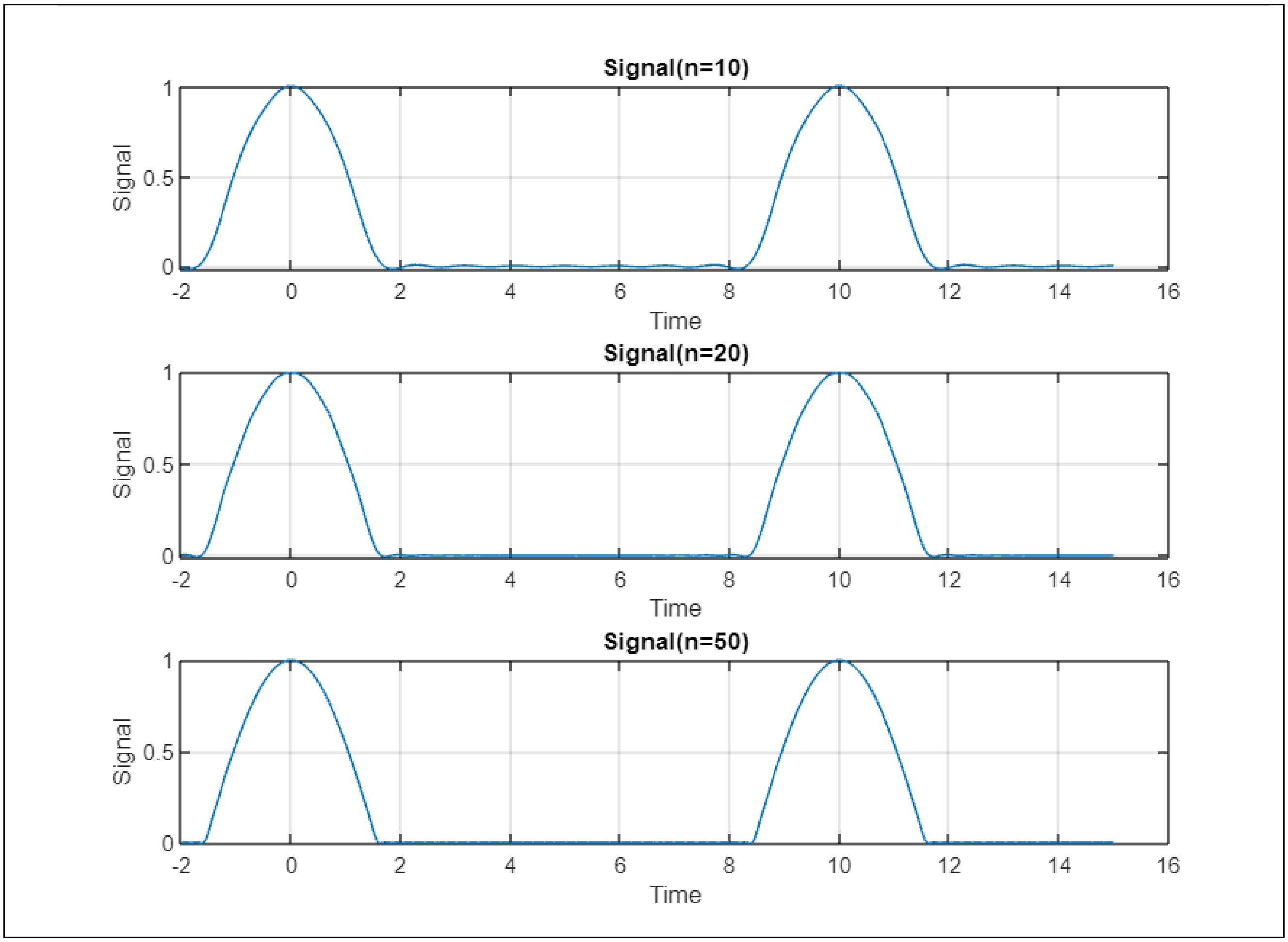
b) , c)

```
clc
close all;
clear all;
T = 10;
w0 = -2*pi/T;
t = -2:T/1000:15;
N = input('number of harmonics :');
Co = 1/5;
ft = Co*ones(1,length(t));
for n = 1:N
    cn = cos(pi*n*w0/2)*(1/(5*(1-(n*w0)^2)));
    c_n = cn;
    ft = ft + cn*exp(j*n*w0*t) + c_n*exp(-j*n*w0*t);
end
subplot(2,2,1)
plot(t,ft)
title('Signal');
xlabel('Time');
ylabel('Signal');
grid on
subplot(2,2,2)
f = (1./t)*2*pi; %frequency
plot(f,abs(ft));
title('Magnitude');
xlabel('frequency');
ylabel('magnitudee');
grid on
subplot(2,2,3)
plot(f,angle(ft));
title('phase angle');
xlabel('frequency');
ylabel('phase angle');
axis([-5,5,-4,4])
grid on
subplot(2,2,4)
plot(f,ft);
```

```
title('Spectra');
xlabel('frequency');
ylabel('Signal');
axis([-5,5,-4,4])
grid on
```



d)



<u>Link to upload files</u>

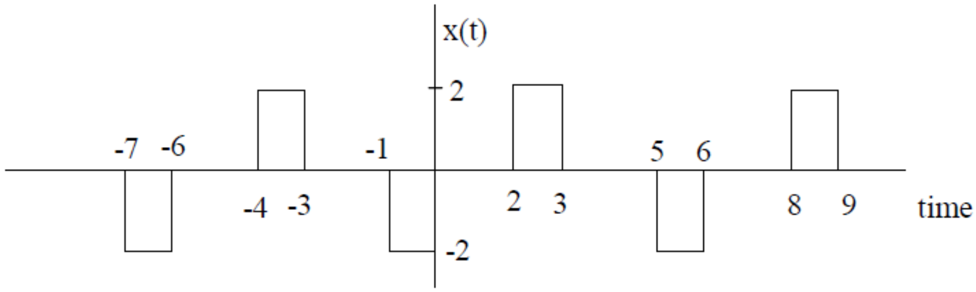
<u>Tuesday Batch https://forms.gle/sCPCiG8tTrEHKqry7</u>

Sunday of the week in which you perform this experiment mostly March 21 5 PM

<u>Thursday batch Link https://forms.gle/cngagDXrHMZiLXQu9</u> Due on Feb 28th 5 PM

Try Yourself

Q4. For the following signal



(i) Find the exponential Fourier series coefficients using matlab program for n = 15

(ii) Plot the Magnitude spectra versus frequency

(iii) Generate the original signal from the Fourier components and observe Gibbs Phenomena for n = 10, 20 and 50