Lab 1

Introduction to MATLAB for Signals and Systems

EECS3451

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1. Introduction:

Using MATLAB to answer questions provided. Questions leads to create formulas and graphs plots to get a better understanding of signals and systems. This report is mainly answering the provided questions using MATLAB. Results will demonstrate the use of MATLAB properly in analysing signals and systems.

2. Equipment: MATLAB

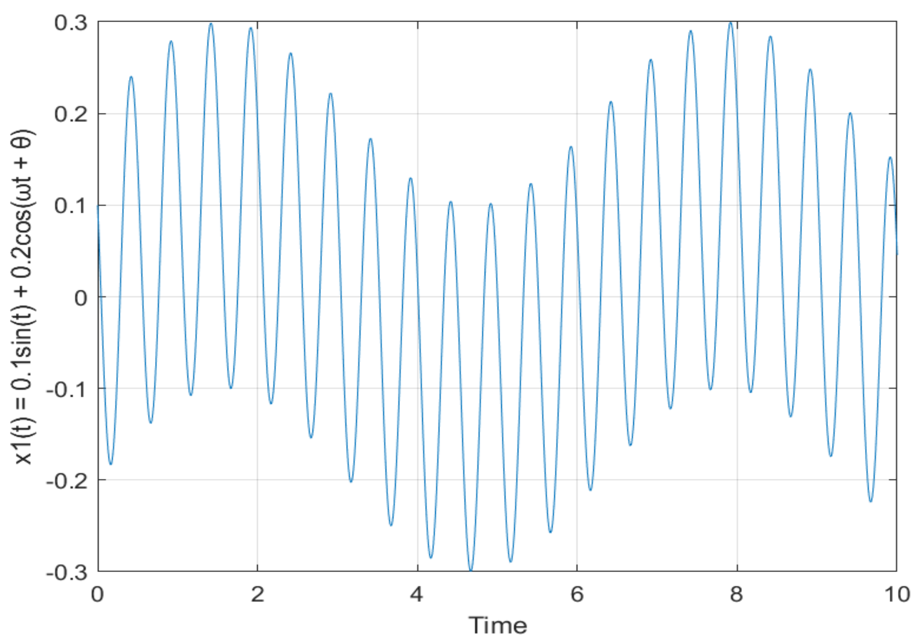
3. Results and discussion:

The answers to provided question are as follows,

Q1) Consider the CT signal: x1(t) = 0.1sin(t) + 0.2cos(ωt + θ)

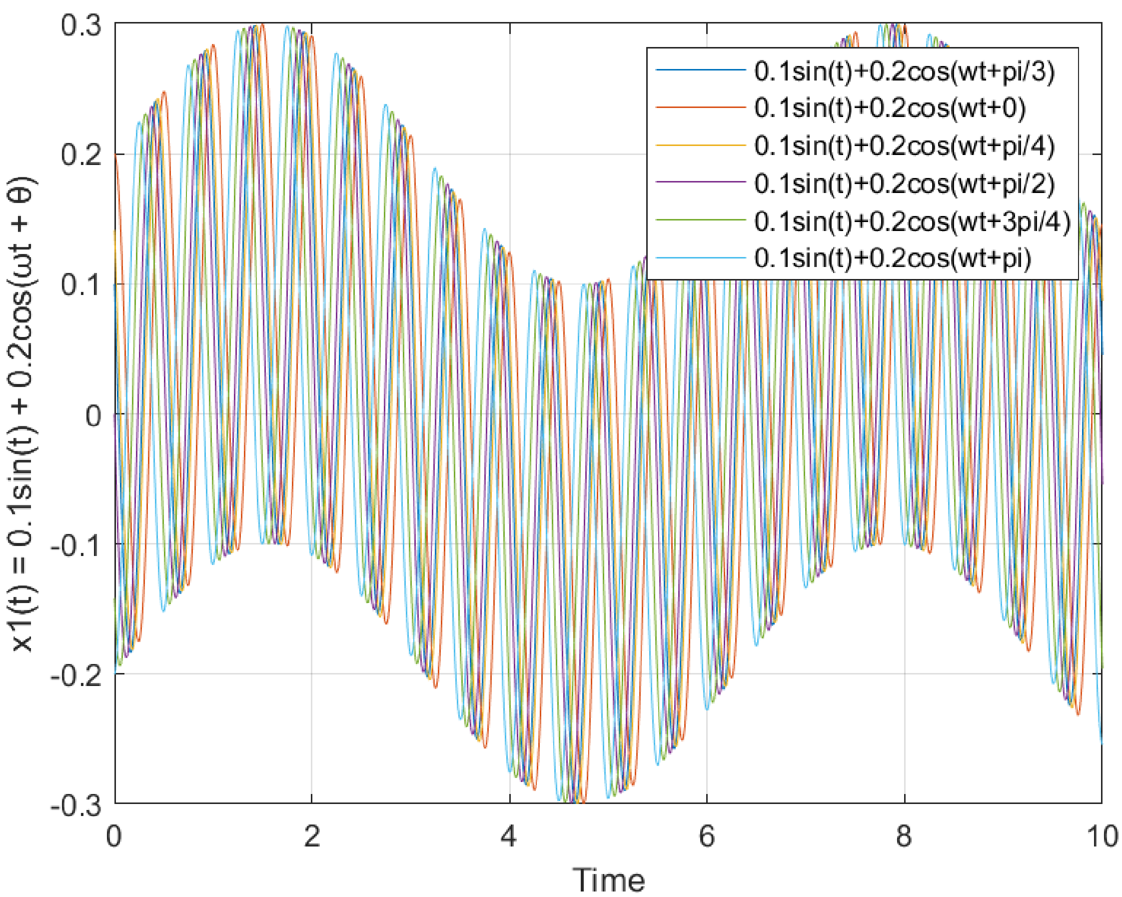
a) Plot x1(t) with θ = 60◦ for 0 ≤ t ≤ 10 and f = 2Hz. Label the x- and y-axis properly

```
t1 = 0:0.01:10; % 0<= t <=10
theta = pi/3; % 60 degrees = pi/3 rad
f = 2; % w = 2*pi*f, f=  2Hz
x1 = 0.1*sin(t1) + 0.2*cos( 2*pi*f*t1 + theta);
plot(t1,x1);
xlabel('Time');
ylabel('x1(t) = 0.1sin(t) + 0.2cos(ωt + ?)');
grid;
```



b) Investigate the waveforms by varying θ in x1(t) from 0◦ to 180◦ with an increment of 45◦ . Plot these waveforms on the same graph and provide a legend for these waveforms. Label the axes. You should investigate how to make multiple plots on the same graph.

```
for theta = 0:pi/4:pi % ? from 0 to 180 degrees(pi rad) with
increments of 45 degrees (pi/4 rad)
    hold on;
    t1 = 0:0.01:10; % 0<= t <=10
    f = 2; % w = 2*pi*f
    x2 = 0.1*sin(t1) + 0.2*cos( 2*pi*f*t1 + theta);
    plot(t1,x2);
end
legend('0.1sin(t)+0.2cos(wt+pi/3)','0.1sin(t)+0.2cos(wt+0)','0.1
sin(t)+0.2cos(wt+pi/4)','0.1sin(t)+0.2cos(wt+pi/2)',
'0.1sin(t)+0.2cos(wt+3pi/4)', '0.1sin(t)+0.2cos(wt+pi)' );
hold off;
```



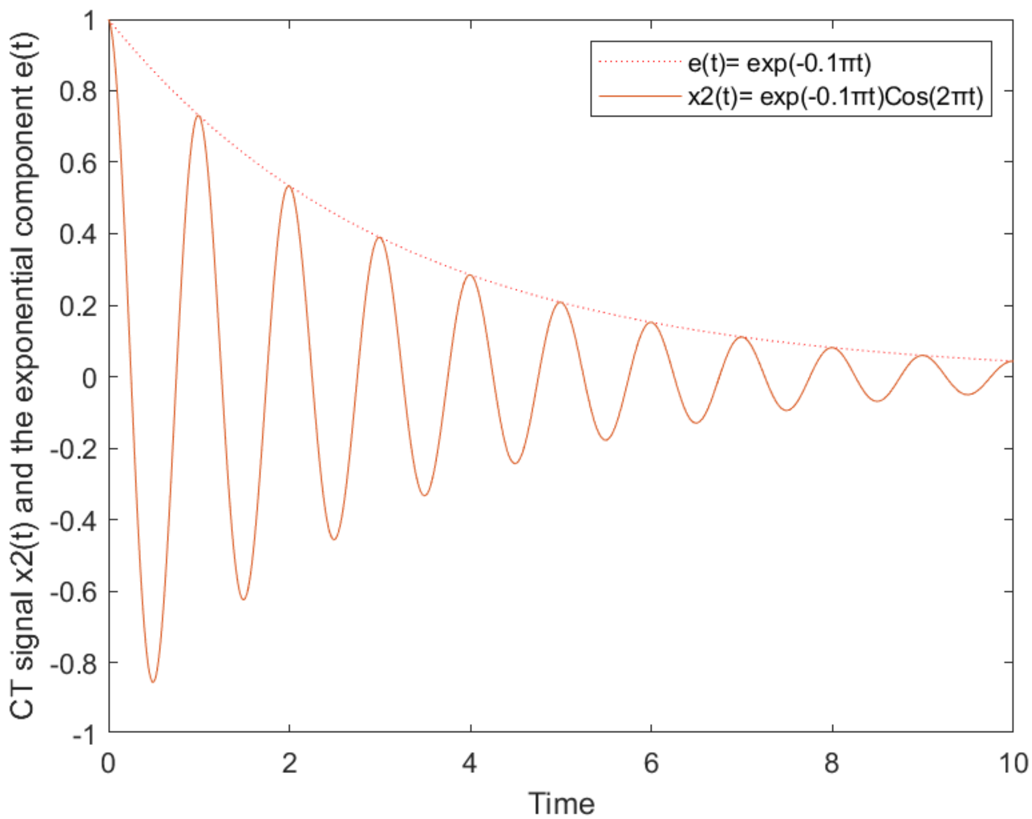
c) Is x1(t) a periodic signal? Explain.

Yes, X1(t) is a periodic signal because the plot above shows that the signal has a fundamental period To = 1/f = 1/2 = 0.5;

Q2) Consider the CT signal: x2(t) = e-0.1πtcos(2πt)

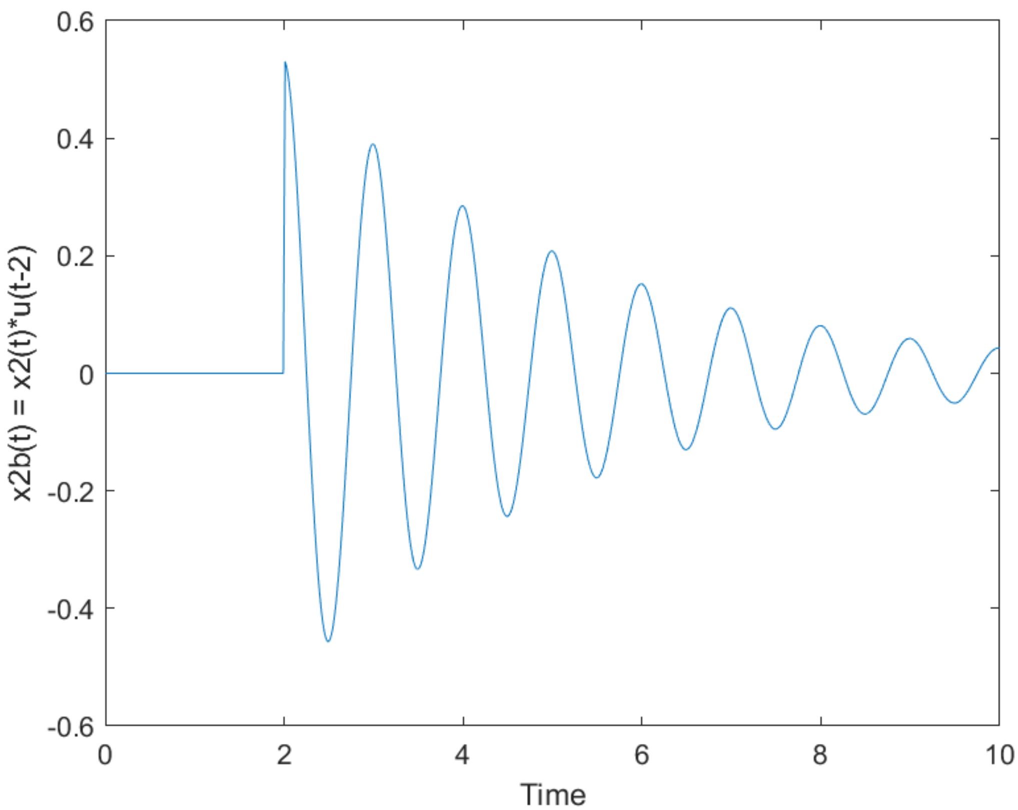
a) The exponential component in x2(t) is called the positive envelope of x2(t), call this function e(t). Plot both e(t) and x2(t) on the same graph for $0 \leq t \leq 10$ with e(t) displayed in red dotted line. Label the x axis and y axis properly. Provide a legend for these waveforms

```
t2 = 0:0.01:10; % 0 <= t <= 10
e = exp(-0.1*pi*t2);
plot(t2,e,'r:');

hold on;
x2 = e.*cos(2*pi*t2);
plot(t2, x2)

hold off;
legend('e(t)= exp(-0.1πt)', 'x2(t)= exp(-0.1πt)Cos(2πt)');
xlabel('Time');
ylabel('CT signal x2(t) and the exponential component e(t)');
```



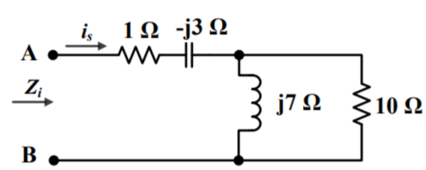
b) A new signal x2b(t) is now obtained by multiplying x2(t) with the time-shifted unit-step function u(t-2). Plot x2b(t) for $0 \leq t \leq 10$. (Hint: you may want to use the Heaviside function in MATLAB to implement the unit-step function)

```
t3 = 0:0.01:10; % 0 <= t <= 10
u = heaviside(t3-2); % time-shifted unit-step function
x2b = x2.*u;
plot(t3,x2b);
xlabel('Time');
ylabel('x2b(t) = x2(t)*u(t-2)');
```



Q3)

a) Calculate the equivalent impedance Zi in the following circuit, express your final answer in polar form.




```
Zi = 1 - 3j + 70j/(10+7j);
Zi = 4.2886 + 1.6980i;
polar form of a+jb -> re^j*theta
a =real(Zi)=rx= 4.2886 , b =imag(Zi)=ry=1.6980
r = sqrt(real(Zi)^2 + imag(Zi)^2) = 4.6125
```

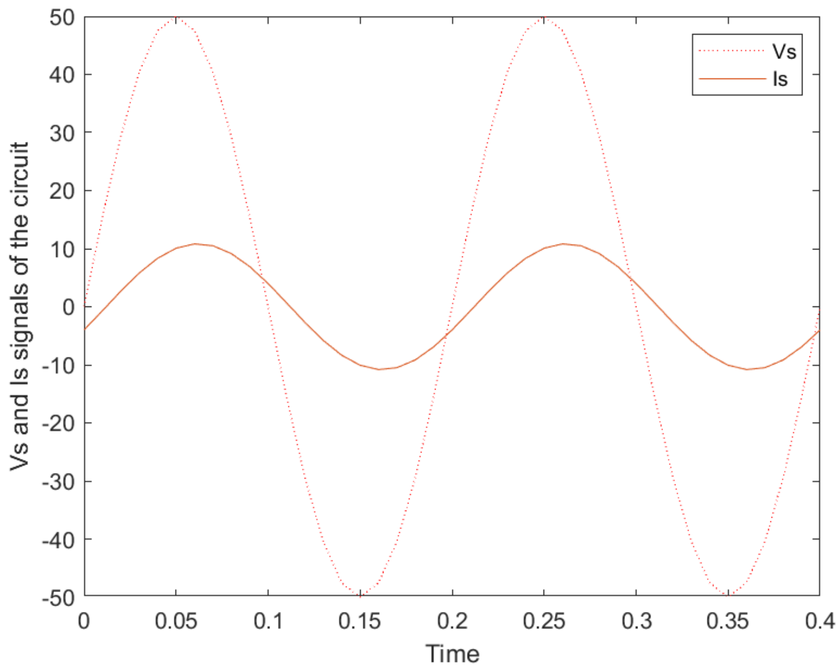
```
[phase_angle, magnitude] = cart2pol(real(Zi), imag(Zi))
phase_angle = theta = 0.3770
magnitude = r = 4.6125
```
Polar form of Zi = 4.6125e^(0.377j)

b) Suppose a sinusoidal voltage signal (vs) with an amplitude of 50V and a period of 0.2s is connected to the terminal A-B of the above circuit. Find is and express your final answer in polar form? Plot both vs and is on the same graph for 2 periods. Provide a legend for these waveforms and label the axes.

```
sinusoidal function -> x(t) = A sin(2*pi*f*t + theta) , T= 1/f
Given A = 50, T = 0.2, f = 1/0.2
```
Vs = 50*sin(2*pi/0.2)

```
polar form given Theta = 0, r = magnitude = 50
     -> Vs = 50e^(0j) = 50

V= IZ -> Is = Vs/Zi
Zi = 4.2886 + 1.6980i;
Is = vs/Zi;
```
Is = vs/Zi = 10.0788 - 3.9905i
```
[phase_angle, magnitude] = cart2pol(real(Is), imag(Is))
phase_angle = -0.3770
magnitude = 10.8401
```
Polar form of Is = 10.84e^(-0.377j)

```
% Plotting
t2 = 0:0.01:0.4;
Vs = 50*sin(2*pi*t2/0.2);
plot(t2,Vs,'r:');

hold on;
Is = 10.84*sin(2*pi*t2/0.2 - 0.377);
plot(t2, Is)

hold off;
legend('Vs', 'Is');
xlabel('Time');
ylabel('Vs and Is signals of the circuit');
```



Q4) A symmetrical square wave signal with amplitude V and frequency f can be described by the following series:

$$x_{sq}(t) = \frac{4V}{\pi} \sum_{n=1,3,5}^{\infty} \frac{1}{n} \sin(n2\pi ft)$$

Write a user-defined function “squarewave” in MATLAB that displays both the square waveform and its fundamental component. The function will also output the maximum instantaneous power of the fundamental component of xsq(t). The function will allow users to input the frequency of the square wave signal (f), the amplitude V, the number of terms to be used in the series in (1), and the time array. Your output display must include a legend and a title.

Inside squarewave.m

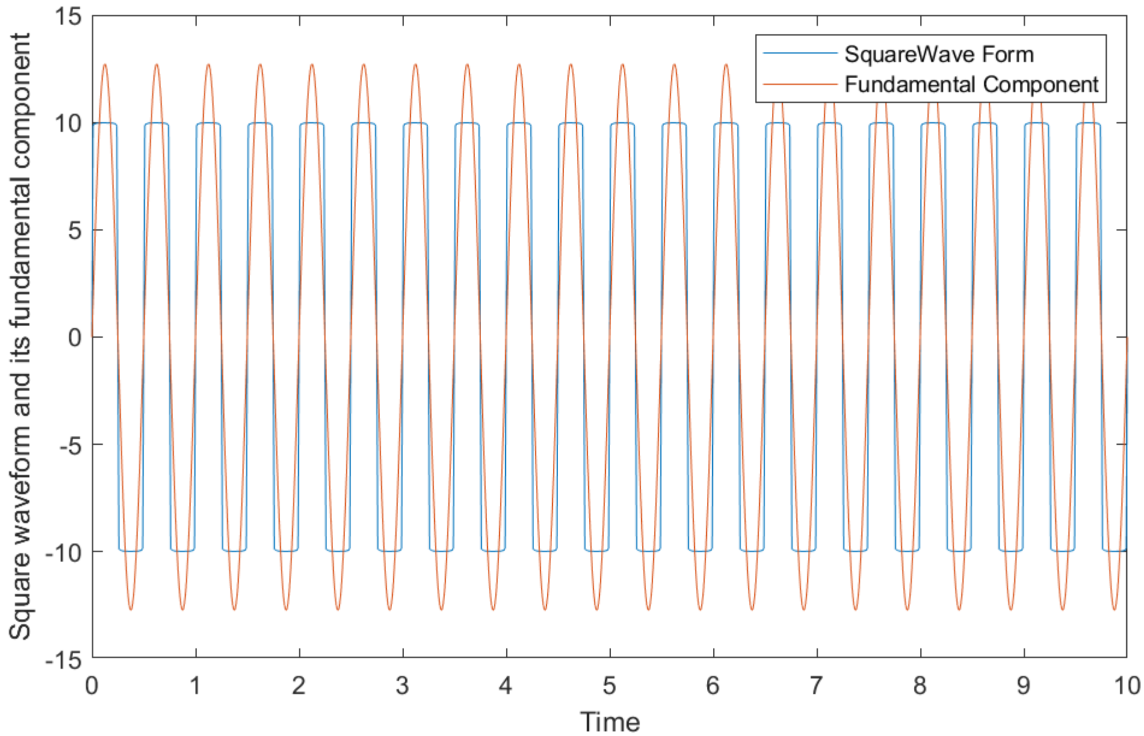
```
function [out, power] = squarewave(f, V, n, t)

% Frequency[f], Amplitude[v], Number of Terms[n], Time Array[t]
max_array = 1:n*2; %1:double the number required(because we only need odd #s)
odd_terms =  max_array(rem(max_array,2)==1); % getting n odd numbers
out = zeros(1,length(t)); % empty array of all zeros

for i=1:length(odd_terms) % summation of all the terms
        tmp= 1/odd_terms(i) * sin(odd_terms(i)*2*pi*f*t);    % a term of a n
at a time
        out=out+tmp;                                  % adding terms
end

%e= sin(1*2*pi*f.*t);
out = out*4*V/pi; % complete xsq(t) function
```

```
plot(t,out);

hold on;

fundamental = 4*V/pi * 1/1 * sin(1*2*pi*f*t); % Fundamental component n =1 of
xsq(t)

plot(t,fundamental);

% maximum instantaneous power of the fundamental component of xsq(t)
fundamental_power = fundamental.^2;
power = fundamental_power;

fprintf('maximum instantaneous power of the fundamental component of xsq(t)
is %s.\n',max(power));

plot(t, power);

hold off;
legend('SquareWave Form', 'Fundamental Component', 'instantaneous power of
the fundamental component');
xlabel('Time');
ylabel({'Square waveform, its fundamental component(fc),';'and instantaneous
power of fc'})

end
```

Test your function by calling squarewave.m in your main M-file, and using the following parameters: V = 10, f = 2Hz and 150 terms of the series.

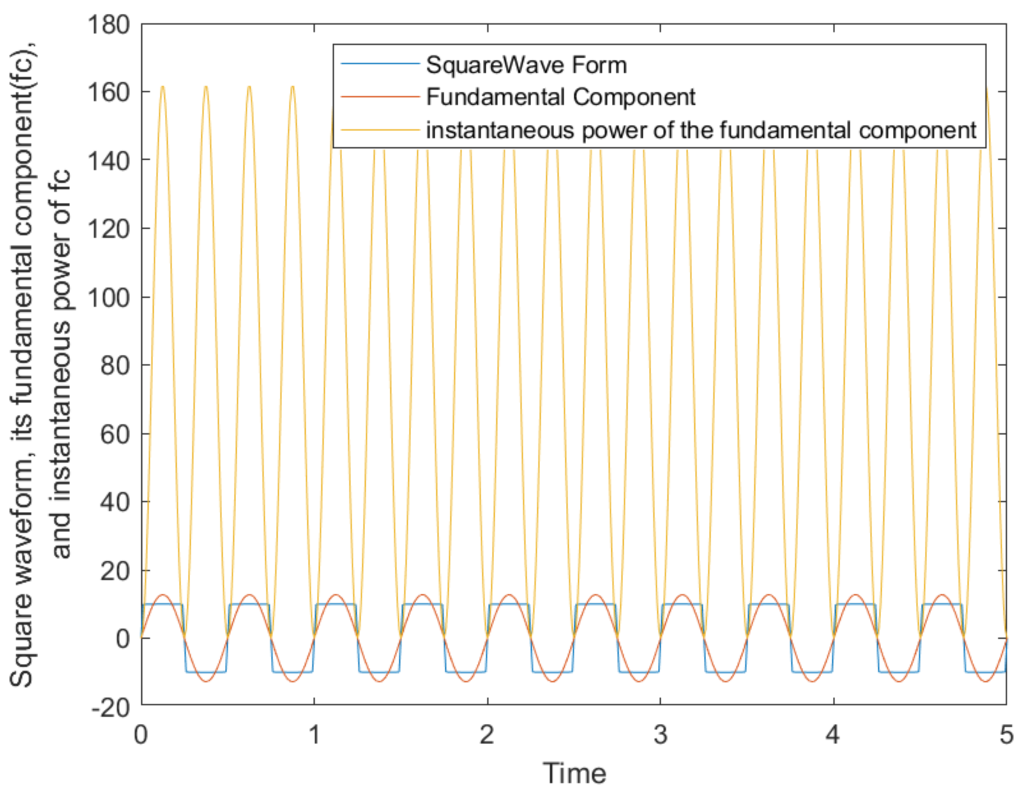
```
%squarewave(f, V, n, t)
squarewave(2,10,150, 0:0.01:10);
```

maximum instantaneous power of the fundamental component of xsq(t) is 1.614747e+02.



With instantaneous power signal

```
squarewave(2,10,150, 0:0.01:5);
```

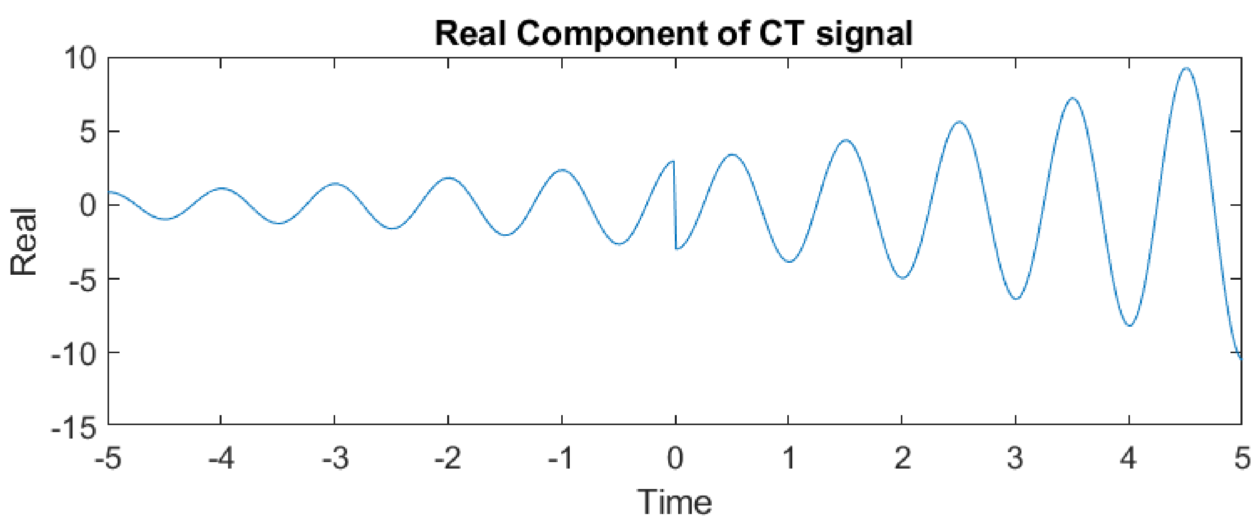


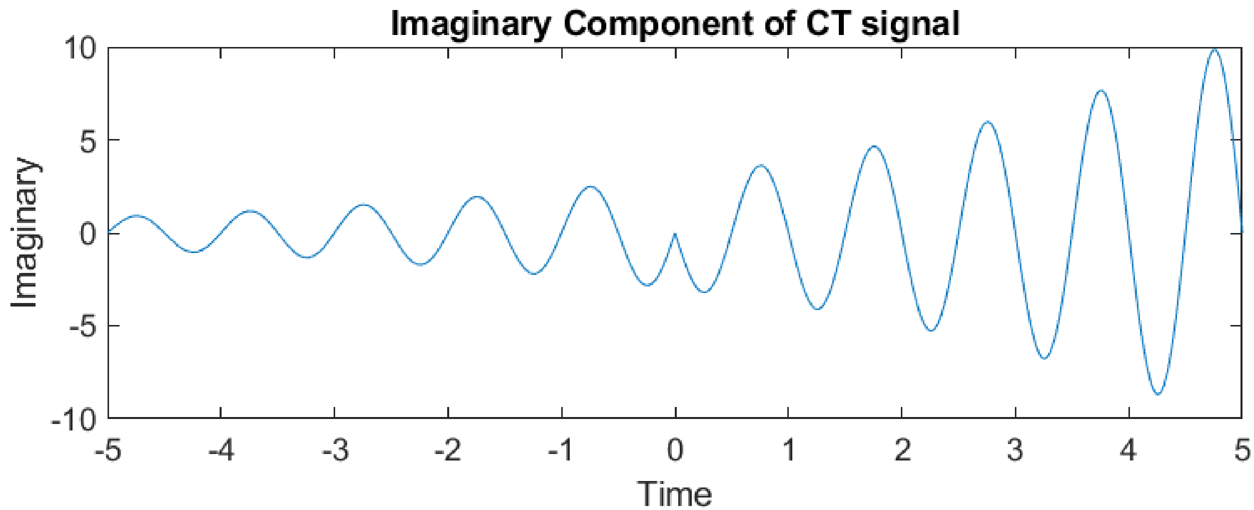
Q5)

a) Sketch the following CT signal with respect to the time variable from -5 to 5 with a suitable time step. Sketch the real and imaginary components separately (i.e. use subplot() function in MATLAB). Provide a title for each plot. Label the axes. (Hint: look for sgn(t) in MATLAB)

$$x(t) = -3\,\text{sgn}(t) \cdot e^{j2\pi t + 0.25t}$$

```
t5 = -5:0.01:5; %-5 to 5 with a time step of 0.01
f = -3*sign(t5).*exp(1j*2*pi*t5 + 0.25*t5); % sgn() => sign()

realf = real(f); % real component
imagf = imag(f); % imaginary component
subplot(2,1,1); % 2 rows, 1 column, 1st spot
plot(t5,real(f));
xlabel('Time');
ylabel('Real');
title('Real Component of CT signal');

subplot(2,1,2); % 2 rows, 1 column, 2nd spot
plot(t5,imag(f));
xlabel('Time');
ylabel('Imaginary');
title('Imaginary Component of CT signal');
```





b) Suppose a new signal xnew(t) is now created by multiplying x(t) with a rectangular pulse signal as shown below:

$$x_{new}(t) = x(t) \cdot rect\left(\frac{t}{4}\right)$$

Sketch the real and imaginary components of xnew(t) separately with respect to the time variable from -5 to 5 with a suitable time step. Provide a title for each plot. Label the axes. Any if-loops, for-loops and while-loops are NOT allowed for question 5.

```
t5 = -5:0.01:5; %-5 to 5 with a time step of 0.01
f = -3*sign(t5).*exp(1j*2*pi*t5 + 0.25*t5); % sgn() => sign()
fnew = f.*(-2<t5 & t5<2); % multiply by rectangular pulse signal
rect(t/T), where T = 4
% rect(t/T), T=4
% rect(t/4) = f -> |t5| <= T/2 =2 and otherwise 0 -> |t5| > 2

realf = real(fnew);% real component
imagf = imag(fnew);% imaginary component
subplot(2,1,1); % 2 rows, 1 column, 1st spot
plot(t5,real(fnew));
xlabel('Time');
ylabel('Real');
title('Real Component of new CT signal');

subplot(2,1,2); % 2 rows, 1 column, 2nd spot
plot(t5,imag(fnew));
xlabel('Time');
ylabel('Imaginary');
title('Imaginary Component of new CT signal');
```

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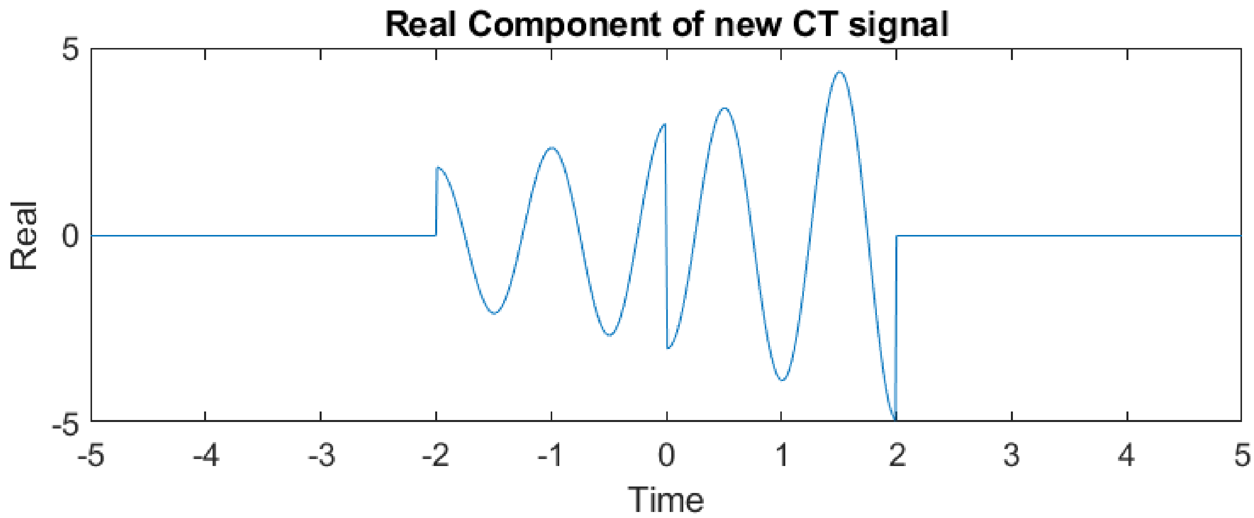
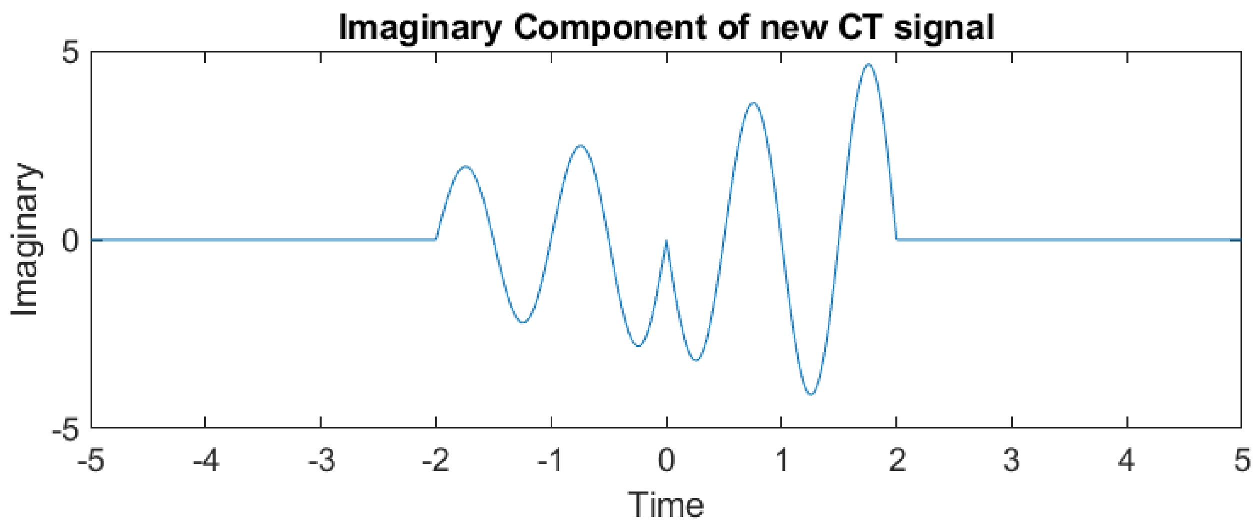




Q6) If x(t) is given by the following piecewise signal, plot x(t) and 2x(t+1) on separate plots but on the same graph.

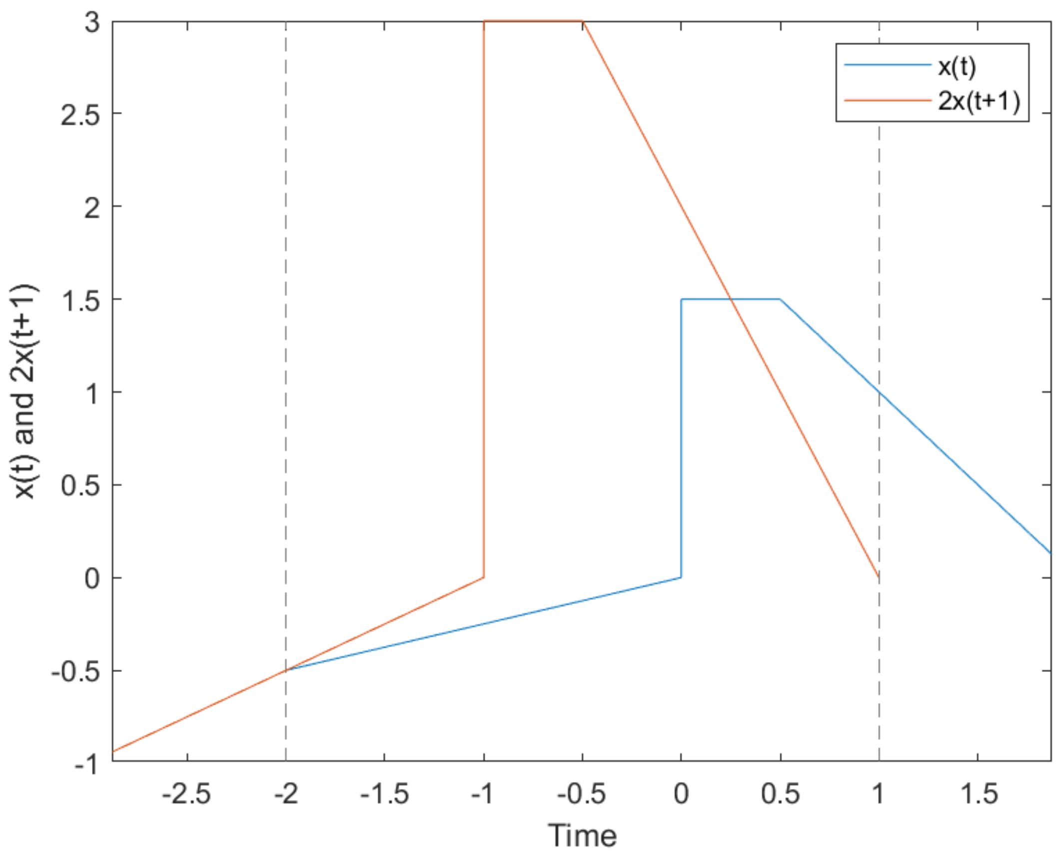
$$x(t)=\begin{cases}0.25t & -2\le t<0\\ 1.5 & 0\le t<0.5\\ -t+2 & 0.5\le t\le 2\end{cases}$$

```
syms x(t)
x(t)=piecewise(-2<=t<0, 0.25*t, 0<=t<0.5, 1.5, 0.5<=t<=2, -t+2);
% plotting x(t)
fplot(x(t));

hold on;

fplot(2*x(t+1)); % plotting transformed x(t) into 2*x(t+1)
```

```
hold off;
legend('x(t)', '2x(t+1)');
xlabel('Time');
ylabel('x(t) and 2x(t+1)');
```



Future analysis:

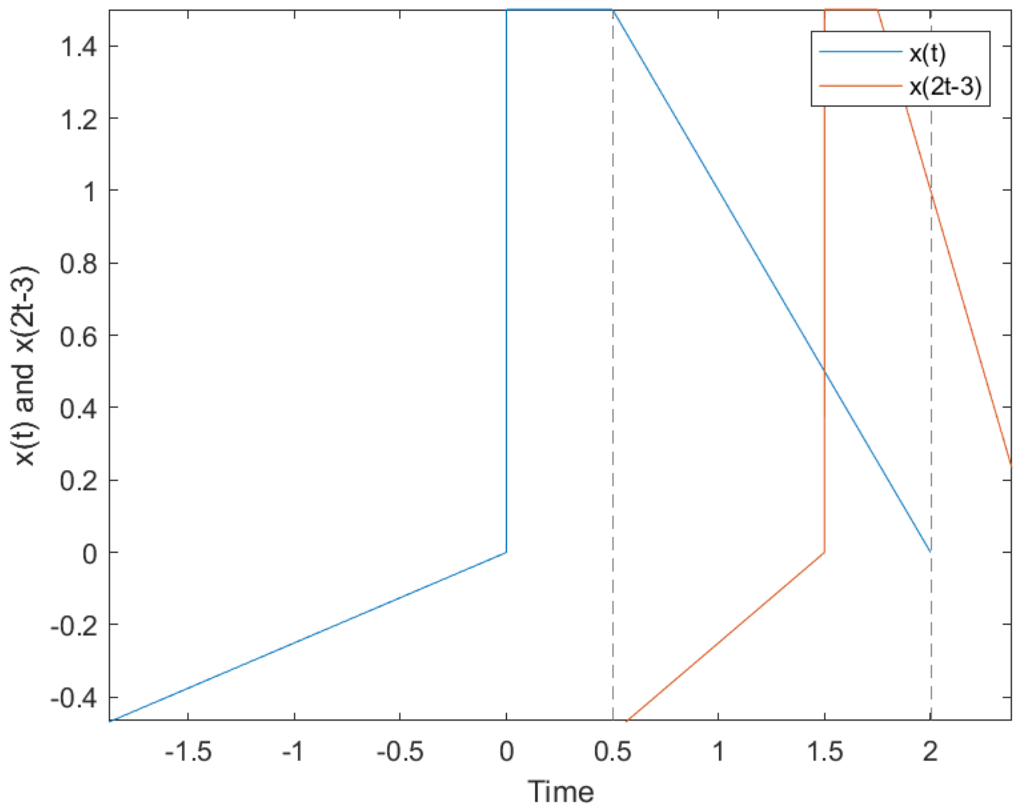
```
syms x(t)
x(t)=piecewise(-2<=t<0, 0.25*t, 0<=t<0.5, 1.5, 0.5<=t<=2, -t+2);
% plotting x(t)
fplot(x(t));

hold on;

fplot(x(2*t-3)); % plotting transformed x(t) into x(2t-3)

hold off;

legend('x(t)', 'x(2t-3)');
xlabel('Time');
ylabel('x(t) and x(2t-3)');
```



Q7) Consider a DT signal given by:

$$x(n) = (1 - e^{-0.01n})\cos\left(\frac{\pi n}{10}\right) \text{ for } 0 \leq n \leq 100$$

(1) Write a Matlab code to plot the DT signal.

```
n = [0:100];
x = (1-exp(-0.01*n)).*cos(pi*n/10);
stem(n,x,'filled'), grid
title('x(n)')
xlabel('n');
ylabel('x(n)');
```

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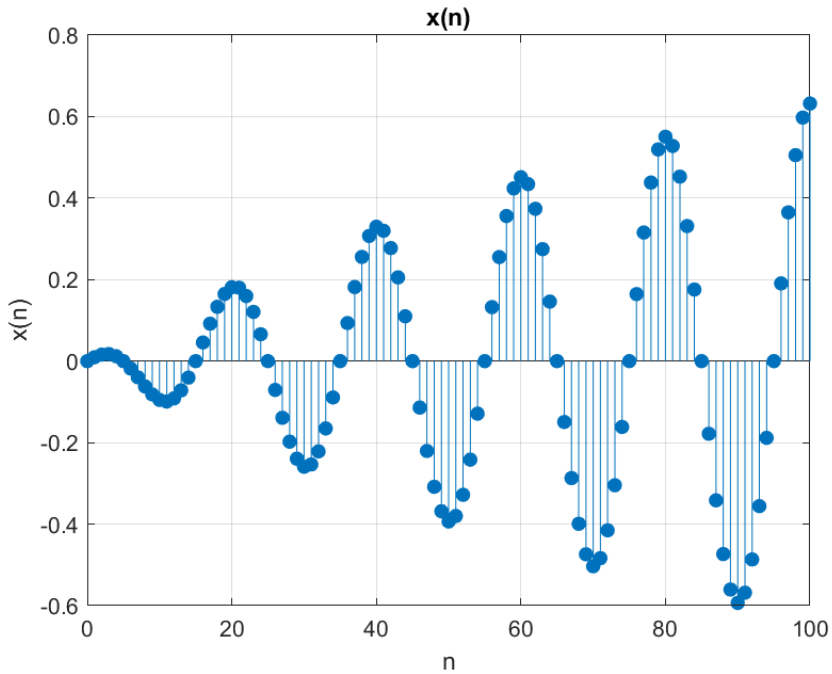
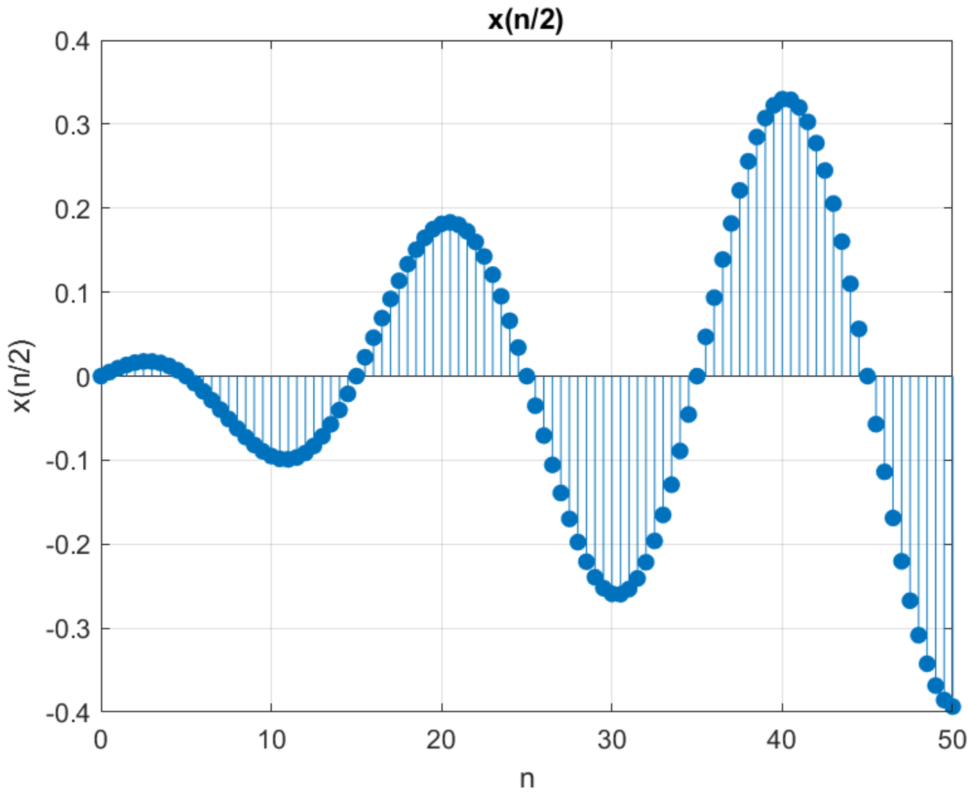


(2) Write a Matlab code to plot the signals y(n)=x(n/2) and z(n)=x(4n).

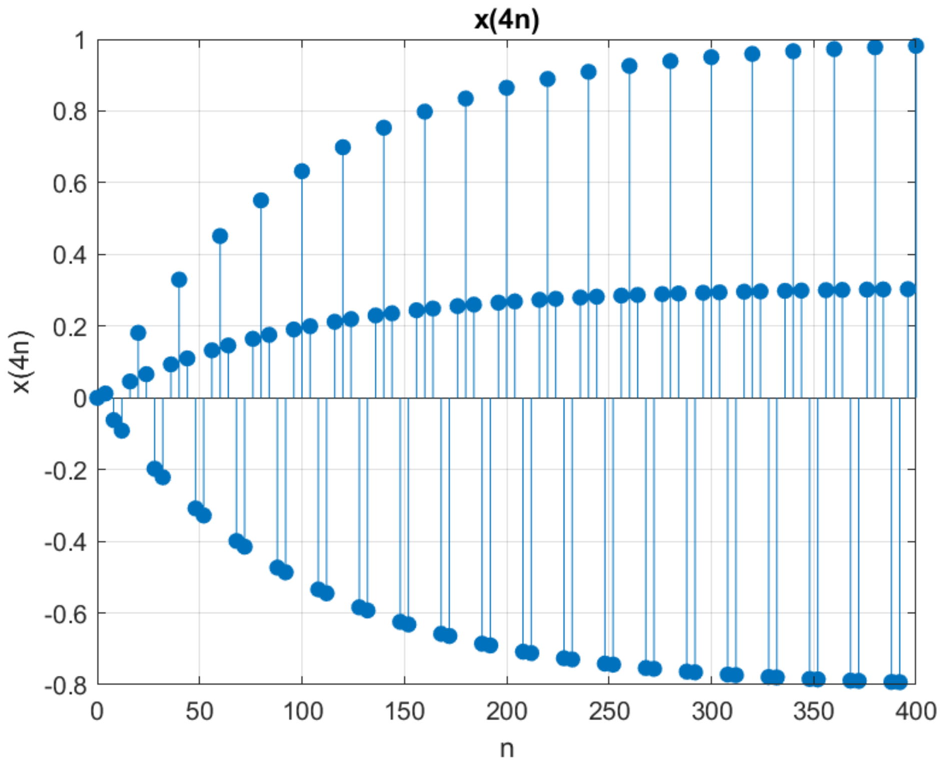
y(n)=x(n/2)

```
n2_1 = [0:100]./2; % x(n/2)
x2_1 = (1-exp(-0.01*n2_1)).*cos(pi*n2_1/10);
stem(n2_1,x2_1,'filled'), grid
title('x(n/2)');
xlabel('n');
ylabel('x(n/2)');
```



z(n)=x(4n)

```
n2_2 = [0:100].*4; % x(4n)
x2_2 = (1-exp(-0.01*n2_2)).*cos(pi*n2_2/10);
stem(n2_2,x2_2,'filled'), grid
title('x(4n)')
xlabel('n');
ylabel('x(4n)');
```



(3) Write a Matlab code to generate two signals: y(n)=x(n/4) and z(n)=y(4n). Plot both y(n) and z(n). What is the relationship between x(n) and z(n)?

y(n)=x(n/4)

```
n3_1 = [0:100]./4; % x(n/4) = y(n)
y = (1-exp(-0.01*n3_1)).*cos(pi*n3_1/10);
stem(n3_1,y,'filled'), grid
title('x(n/4)')
xlabel('n');
ylabel('x(n/4)');
```

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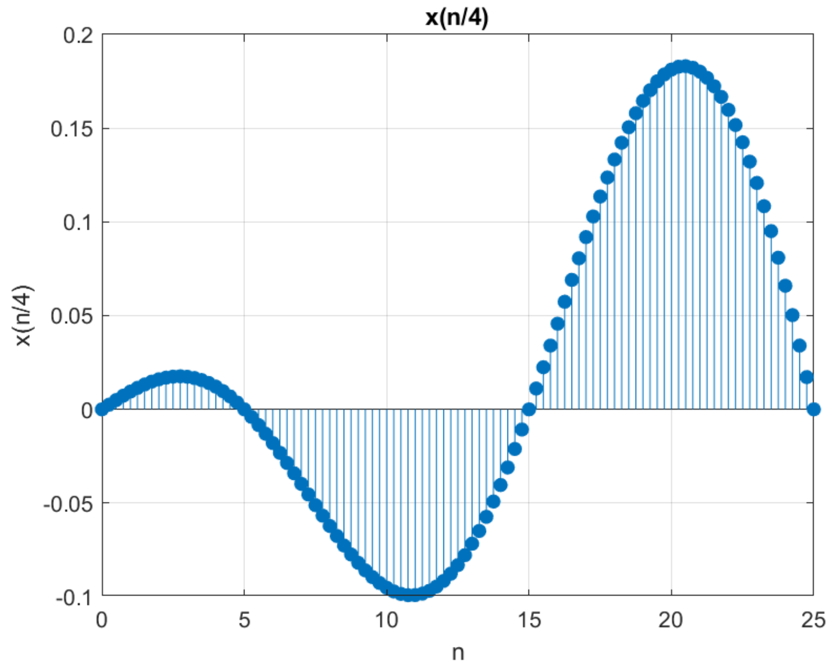
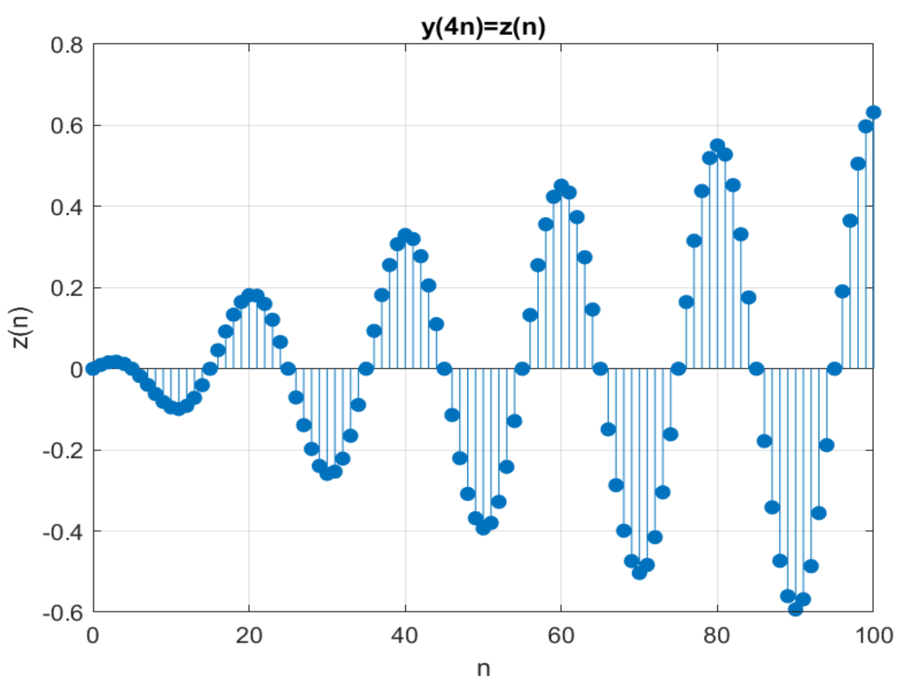


z(n)=y(4n)

```
n3_2 = n3_1.*4; % y(4n)
z = (1-exp(-0.01*n3_2)).*cos(pi*n3_2/10);
stem(n3_2,z,'filled'), grid
title('y(4n)=z(n)')
xlabel('n');
ylabel('z(n)');
```

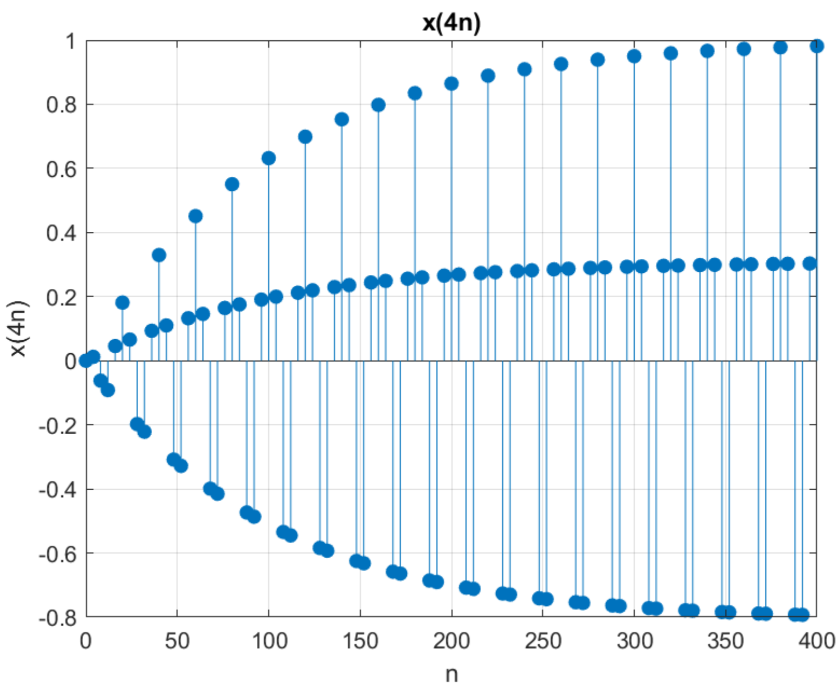


x(n) and z(n) are equal

(4) Repeat (3) with y(n)=x(4n) and z(n)=y(n/4). What is the relationship between x(n) and z(n)?

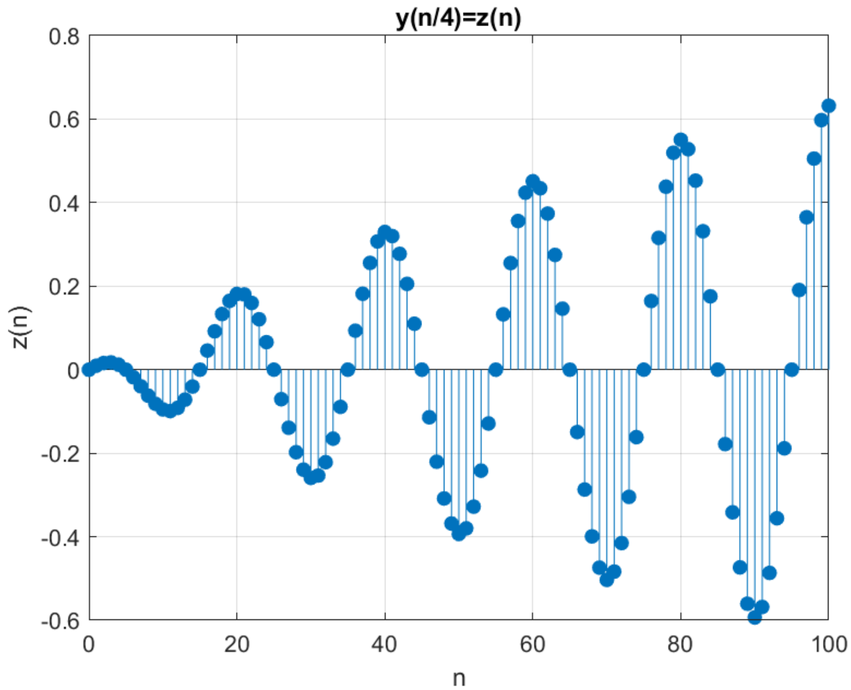
y(n)=x(4n)

```
n4_1 = [0:100].*4;
y = (1-exp(-0.01*n4_1)).*cos(pi*n4_1/10);
stem(n4_1,y,'filled'), grid
title('x(4n)')
xlabel('n');
ylabel('x(4n)');
```



z(n)=y(n/4)

```
n4_2 = n4_1./4;
z = (1-exp(-0.01*n4_2)).*cos(pi*n4_2/10);
stem(n4_2,z,'filled'), grid
title('y(n/4)=z(n)')
xlabel('n');
ylabel('z(n)');
```



x(n) and z(n) are equal

4. Conclusion: state what you learn from this lab, lab objectives you achieved, and any difficulties you met.

Learned how to plot CT signals, DT signals, rectangular pulse functions, Unit step functions, sign functions, sinusoidal functions, exponential functions in MATLAB using pre defined functions such as real(), imag(), etc.

All the questions were answered using MATLAB and was able to get a better understanding of signals and systems by observing the generated plots.

Had a hard time to find how to plot a rectangular pulse function. In addition, had to review formulas related to circuits and waveforms.