INSTITUTO TECNOLÓGICO DE ESTUDIOS

SUPERIORES DE MONTERREY

Analysis of Signals and Systems (Group 01)

-Project #1, MATLAB exercises-

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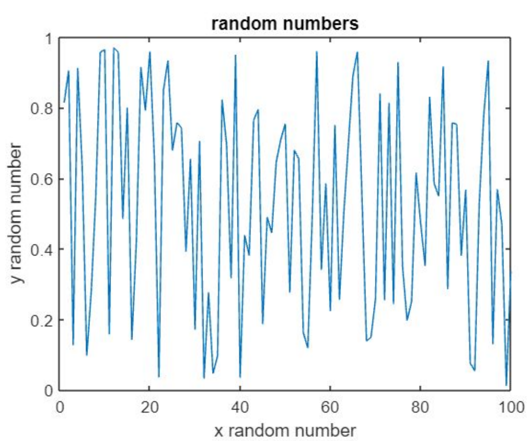
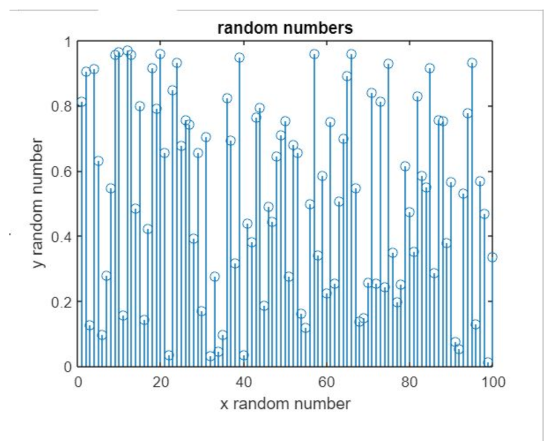
Exercise #1 (Isabella Dubon A00824441)

> *Exercise 1.* Fort the vector x = rand(1,100), graph plot(x) y stem(x). Do not forget to put the name and units to all the axes of your graph.
> -What can you say about each of the signals obtained? Reason your answer.
> -Explain a real example where you can use the vector x (in a similar way than the example before but think in a different application).

The first signal generated is the plot(x) signal, this signal is periodic and continuous. Meanwhile the second signal corresponding to stem(x) is an aperiodic signal and discrete. In the graphs shown below we can see the difference between each of the signals. A vector x can be used in real life to measure an earthquake. This device is called a seismograph and it detects and records earthquakes.



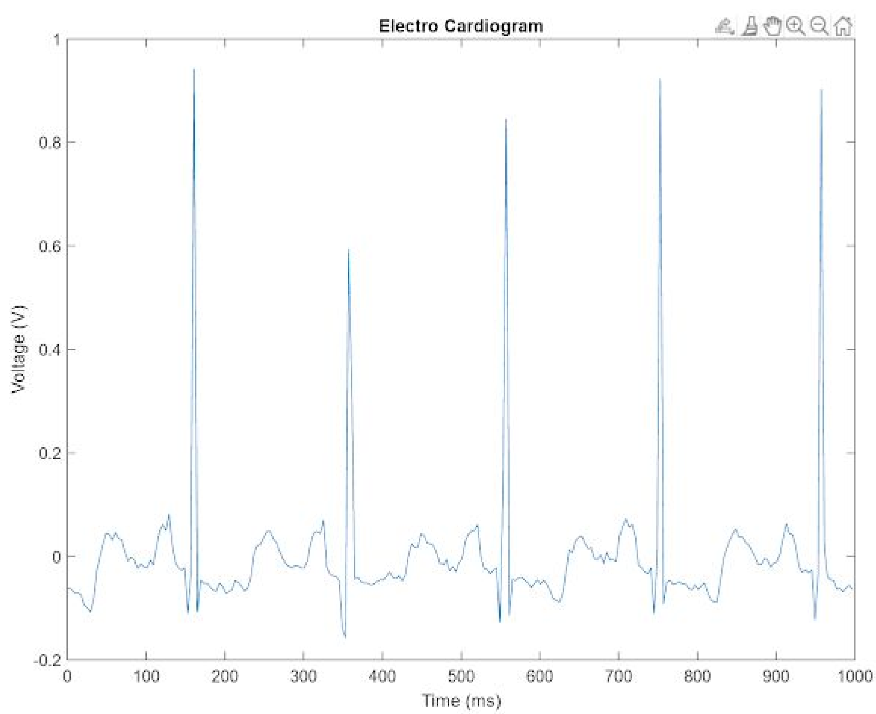



```
code:
x=rand(1,100)
figure(1)
plot(x)
title('random numbers')
xlabel('x random number')
ylabel('y random number')
figure(2)
stem(x)
title('random numbers')
xlabel('x random number')
ylabel('y random number')
```

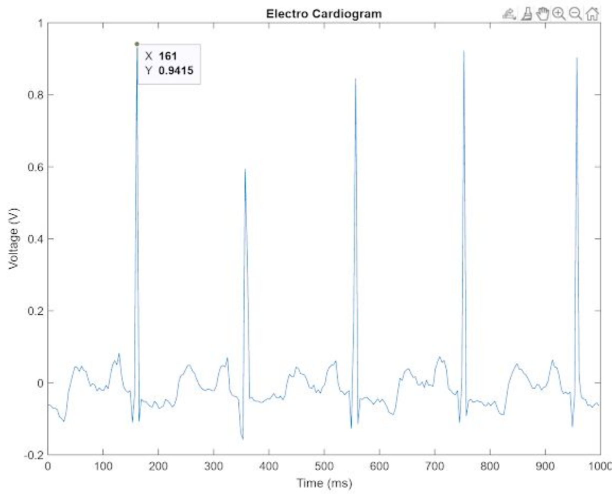
Exercise #2 (Hector J. Pequeno Chairez, A01246364)

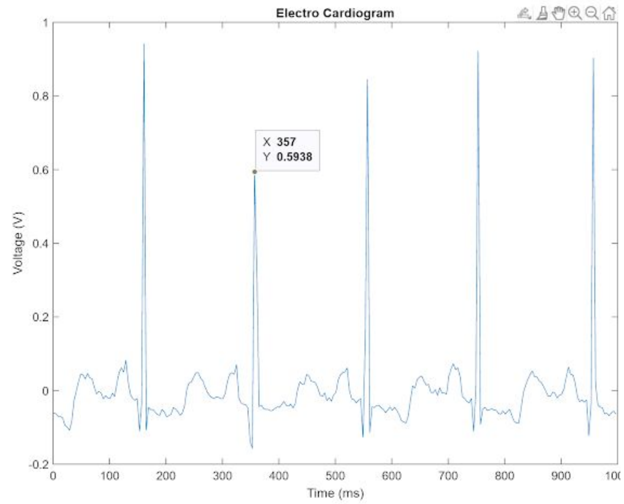
> ***Exercise 2.*** Read the ecg.txt file that you can find in Blackboard, which contains the values of an ECG signal captured every *X* ms.
> -Consider the value of *X* as (2 + 2*nº of group) ms, that is, for example, group # 1 should take the value of X as (2 + 2 * 1) = 4ms, for group # 2, X will be (2 + 2 * 2) = 6ms, for group # 3 it will be (2 + 2 * 3) = 8ms, etc.
> - Explain and justify the choice of the chosen values.
>
> -Visualize the values of the signal in the corresponding times, for that, draw the signal as a function of time with the **plot** function. Do not forget to put the name and units to all the axes of your graph. What can you say about the signal obtained? Justify your answer.
> - Looking at your signal, which is the value of the Heart Rate Variability of your ECG signal?

The signal generated by the code and using the number of team =1, looks like the signal is periodical, but if you look closer into the graph, there are so many little variations, and this doesn't match with the meaning of the word, so the graph is aperiodical. Also if we categorize the signal as a Power or Energetical signal, match with the definition of the power signal, because it never ends, but this is just a part of an entire lifetime of a person, and someday if the heart stops, also the signal will disappear, for that reason and in that context, this signal will be considered as an Energetical signal.

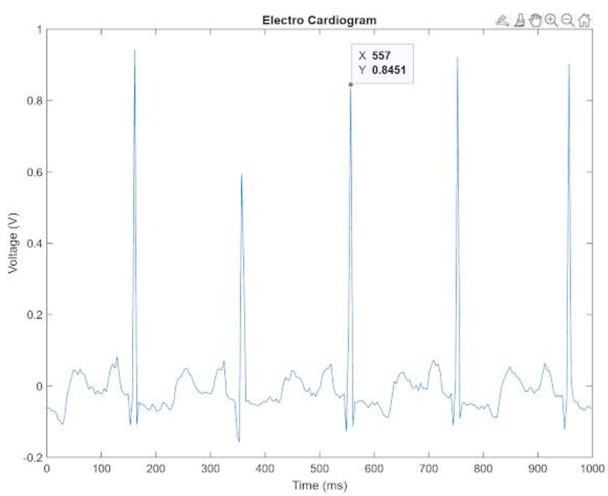


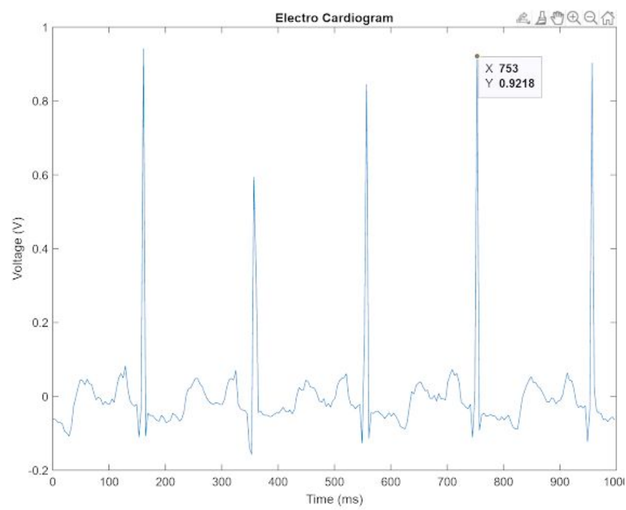
Finally, in these graphs we can measure the RR intervals, these intervals help us to detect the HRV (Heart Ratio Variation) between every rate (time interval).





HRV= RR = 357 - 161 = 196 [ms].





HRV = RR = 753 - 557 = 196 [ms].

Finally, as we can notice, the HRV is equal to 196 ms.

Code:

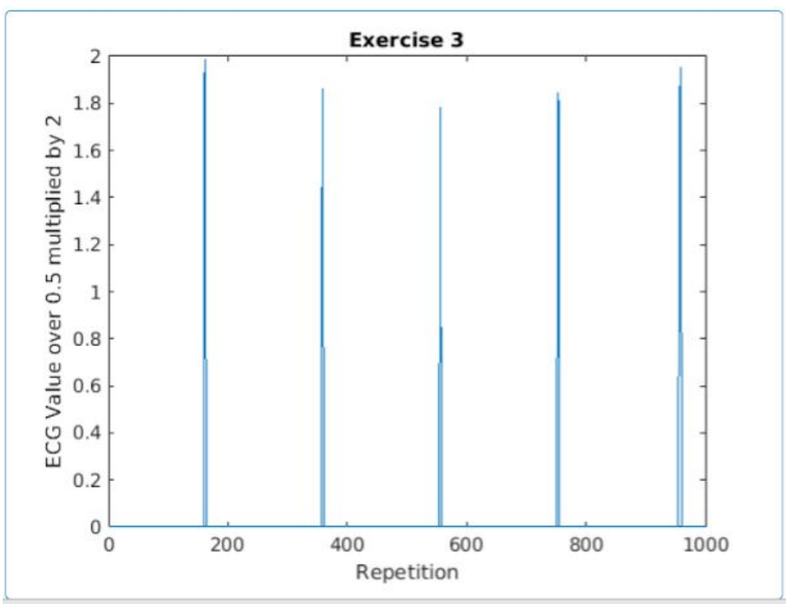
```
clear % Clean program info

HR = textread('ecg.txt', '%f'); % We read and save the information of the
ECG, to the HR (Heart Rate) variable

prompt = 'Introduce the group number'; % Communicate to the user an input,
related to the group
```

```
aux = input(prompt); % Received the user input to use in the formula "(2+
2*aux)"
x = 1:(2 + 2*aux):1000; % Define and save the X axis = Time(ms) from 1 to
1000 (ms)
y = HR(x,1); % Define and save the HR info to be displayed on the graph
plot(x,y); % Display the Graph
xlabel('Time (ms)'); % Label the x-axis on the graph
ylabel('Magnitude'); % Label the y-axis on the graph
title('HRV'); % Create a title for the graph
```

Exercise #3 (Mauricio Aguilar)

> ***Exercise 3.*** Load the ecg.txt file and zero the vector values below 0.5. Values greater than or equal to 0.5 multiply them by 2. Plot the vector obtained. Do not forget to put the name and units to all the axes of your graph. What can you say about the signal obtained? Justify your answer.

The signal obtained looks like a Dirac single impulses. The impulses look very far apart from one another, which make sense given the variations of the HR and the fact that all impulse below 0.5 were converted to zeros.



```
I= VarName1>0.5;  %Identify all numbers below 0.5
y=VarName1.*I; %multiply them by 0

E= VarName1<=0.5; %identify all number equal or above 0.5
z=y*2          %multiply them by 2

plot(z)
title('Exercise 3')
ylabel('ECG Value over 0.5 multiplied by 2')
xlabel('Repetition')
```

Exercise #4 (Isabella Dubon A00824441)

Exercise 4. Create and visualize a causal sinusoidal signal of length 100, period X and amplitude Y.

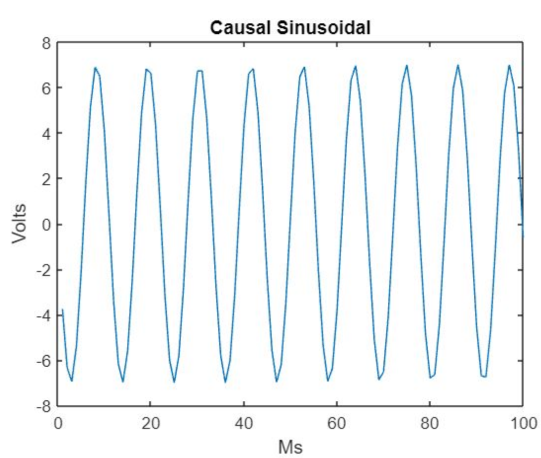
Take the value of X as (8 + 2 * group no.), for example, group # 1 must take the value of X as (8 + 2 * 1) = 10ms, for group # 2, X will be (8 + 2 * 2) = 12ms, for group # 3 it will be (8 + 2 * 3) = 14ms, etc.

Take the value of Y in Volts as (3 + 2 * group number), that is, for example, group # 1 must take the value of Y as (3 + 2 * 1) = 5, for group # 2, Y will be (3 + 2 * 2) = 7, for group # 3 it will be (3 + 2 * 3) = 9, etc.

- Explain and justify the choice of the chosen values. Do not forget to put the name and units to all the axes of your graph.

-What can you say about the signal obtained? Justify your answer.

The code was written in a way for the user to input their group number in order to calculate the causal sinusoidal. In our case, since we are group 1, the value for X would be 12 and the value for Y would be 7. The signal obtained appears to be periodic and continuous. This signal portrays a causal sinusoidal and it looks like this:



The following code used for the signal would be:

```
groupnum = input('Type your group number');
L=100; %length
X = 8 + 2 * groupnum; %Value for the period
w = (2*pi)/X; %Value for the frequency
phi = 0; %phi is not mentioned, so it's assumed its value is 0
A = 3 + 2 * groupnum; %Value for the amplitude
%sinudoidal signal equation
n = 1:L;
x = A*sin((2*pi/w)*n+phi);
plot(x)
title('Causal Sinusoidal')
xlabel('Ms')
ylabel('Volts')
```

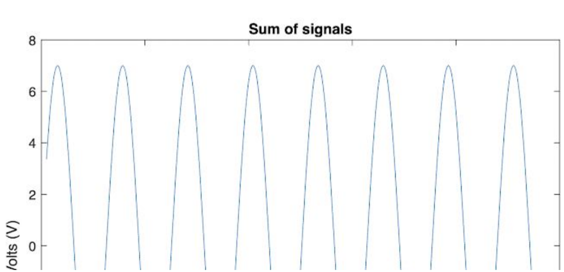
Exercise #5 (Hector J. Pequeno Chairez, A01246364)

> ***Exercise 5.*** Create 3 sinusoidal signals with length 100 and periods (1 + group number), (2 + group number) and (4 + group number), respectively. Visualize the signal generated by the sum of the 3 sinusoidal signals.
>
> That means, the group nº 1, will take the values of the periods of 2ms, 3ms and 5ms, respectively.
>
> Explain and justify the choice of the chosen values. Do not forget to put the name and units to all the axes of your graph.
>
> -What can you say about the obtained signal? Justify your answer.

Answers:

To select the different values we must consider some parameters, for example the amplitude it's not defined by an instruction, so we decide to compute the amplitude by the past instruction in exercise #4 (Take the value of Y in Volts as (3 + 2 * group number), that is, for example, group # 1 must take the value of Yas (3 + 2 * 1) = 5, for group # 2,Y will be (3 + 2 * 2) = 7, for group #3 it will be (3 + 2 * 3) = 9, etc.), then to compute this value we must select a Nº of the group first, the selected value is the number '1', because it's our team number.

Nº of groups = 1



For this reason and applying the formulas, the amplitude of the signals are the following:

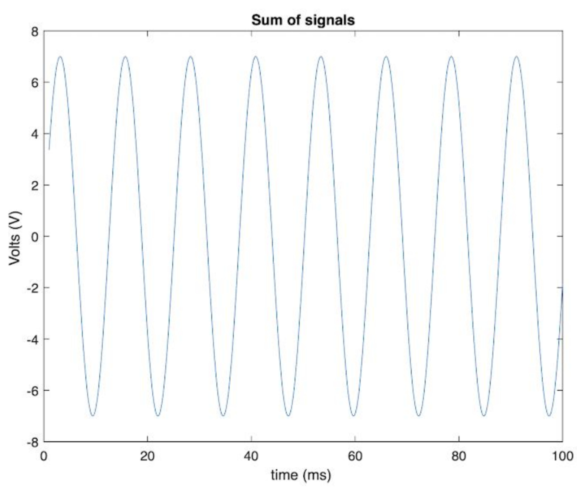
Signal 1: 7 volts

Signal 2: 9 volts

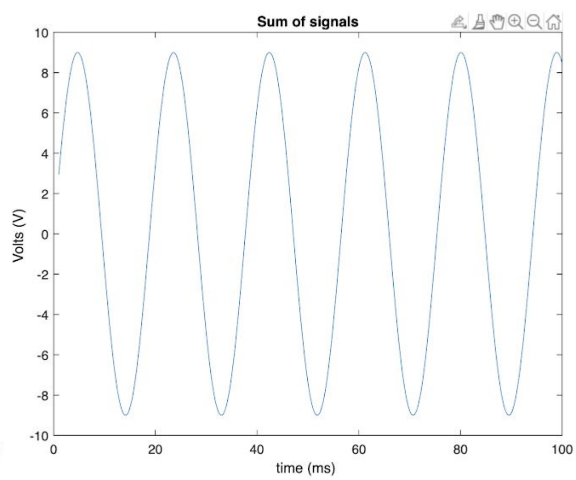
Signal 3: 11 volts

The final signal is the sum of all the other 3 signals, this means that the area under the curve of each signal is represented with one last signal, in the program you have the option to represent the signal 1, 2, 3, the sum of all the signals or the final signal, this controlled by a menu.

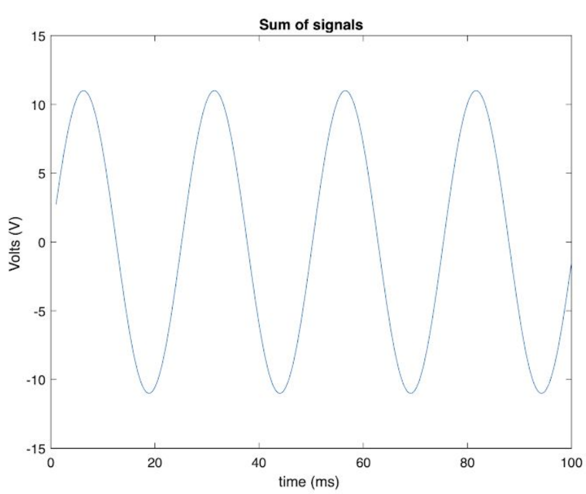
Signal 1:



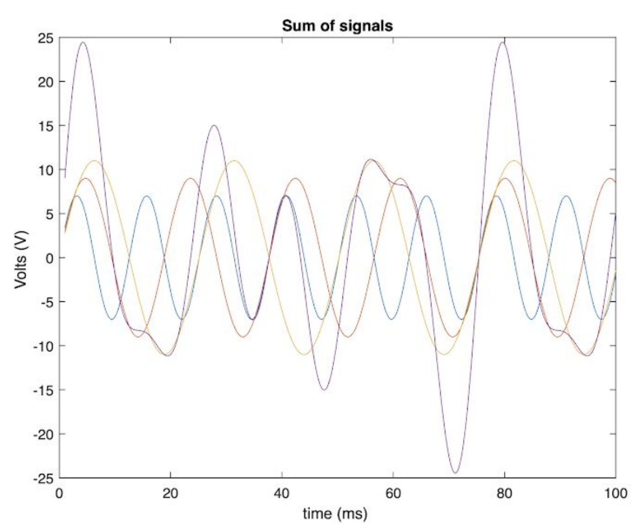
Signal 2:



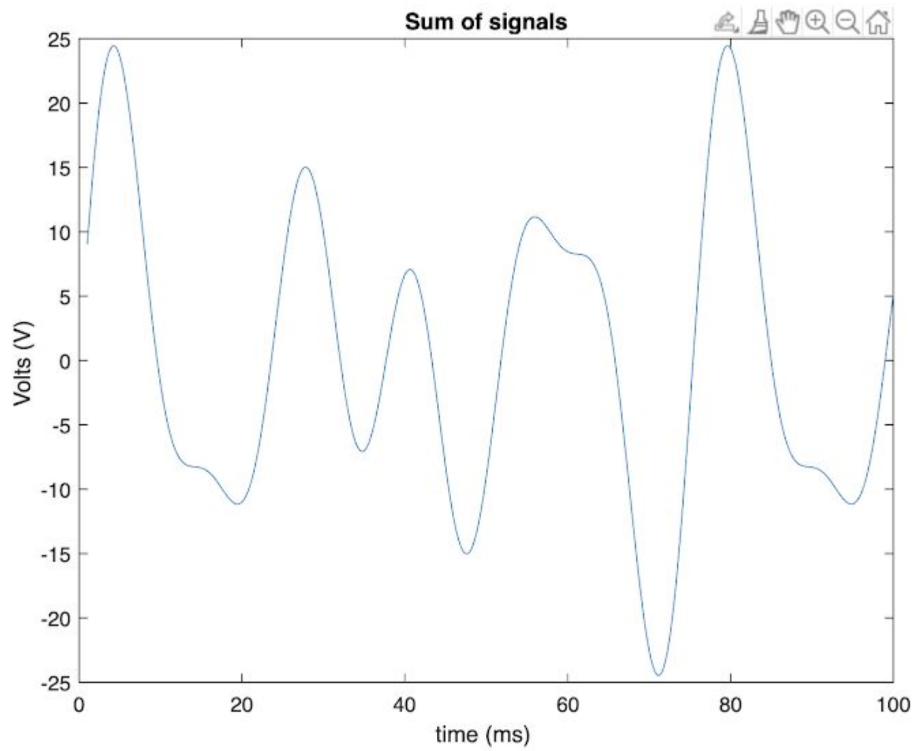
Signal 3:



All Signals (including the final signal):



This is the final Signal:



This signal is aperiodical because it doesn't have any symmetrical shape and also the signal is a Power one, this is because we can't see the final of the graph and it tends to increase and decrease without showing any signal of tendency to 0.

Code:

```
clear % Clear console

% Signal 1, variables:

double Y1; % Amplitude of the signal 1
double X1; % Period1
double group1; % Group Number
double signal1; % Auxiliar to display the signal
double group1; % Variable to calculate the group

% Signal 2, variables:

double Y2; % Amplitude of the signal 2
double X2; % Period signal 2
```

```
double group2; % Variable to calculate the group
double signal2; % Auxiliar to display the signal


% Signal 3, variables:

double Y3; % Amplitude of the signal 3
double X3; % Period signal 2
double group3; % Variable to calculate the group
double signal3; % Auxiliar to display the signal

% Program setup
prompt = "Introduce the number of the group"; % Solicit the group
group = input(prompt); % We read the group
group1 = 1  + group; % Compute group of signal 1
group2 = 2  + group; % Compute group of signal 2
group3 = 3  + group; % Compute group of signal 3
X = 1:.1:100; % Create de X-axis of the signal

% Signal 1 - Operation
disp("This is the amplitude of the signal 1"); % We display the message
Y1 = (3 + 2*group1); % Compute the amplitude of the signal by A = Y = (3 +
2*GROUP)
disp(Y1); % We display the amplitude
signal1 = Y1*sin(X/group1); % Asing the created signal to a variable, just
to have controlled the signals


% Signal 2 -Operation
disp("This is the amplitude of the signal 2"); % We display the message
Y2 = (3 + 2*group2); % Compute the amplitude of the signal by A = Y = (3 +
2*GROUP)
disp(Y2); % We display the amplitude
signal2 = Y2 * sin(X/group2);% Asing the created signal to a variable, just
to have controlled the signals


% Signal 3 -Operation
disp("This is the amplitude of the signal 3"); % We display the message
Y3 = (3 + 2*group3); % Compute the amplitude of the signal by A = Y = (3 +
2*GROUP)
disp(Y3); % We display the amplitude
signal3 = Y3 * sin(X/group3); % Asing the created signal to a variable, just
to have controlled the signals
```

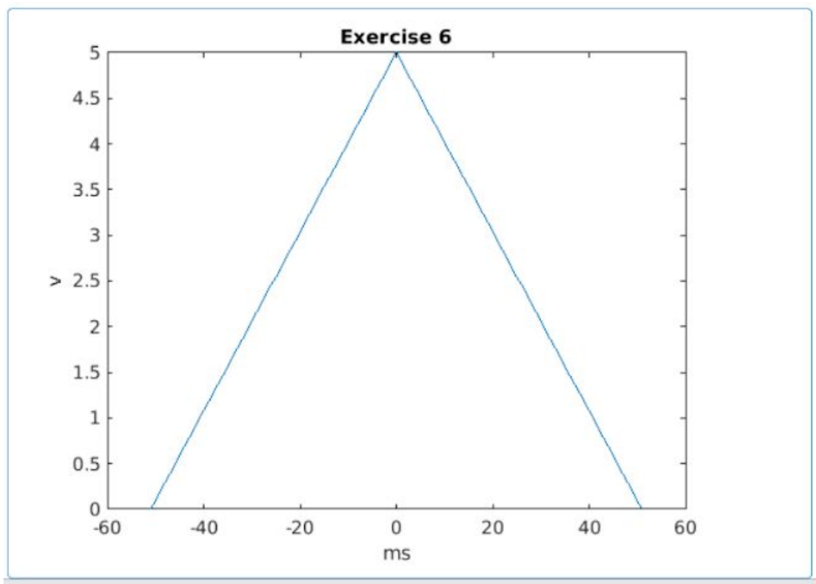
```
  TotalSignal = signal3 + signal2 + signal1; % Compute the summatory of the
  signal

  % Display the menu in the console
  disp("Introduce the corresponding # for your interest option");
disp("1 - Display the signal 1 into the graph");
disp("2 - Display the signal 2 into the graph");
disp("3 - Display the signal 3 into the graph");
disp("4 - Display the summatory of signals into the graph");
disp("5 - Display the all the signals into the graph");
prompt = "If you select other option the program will end";
sel = input(prompt); % Read the input of the user

% Select what to display, following the "sel" variable
if (sel==1) % Display first graph
plot(X,signal1); % Display the signal 1 into the graph
xlabel("time (ms) "); % Label the x-axis
ylabel("Volts (mV) "); % Label the y-axis
title("Sum of signals"); % We name our graph
elseif(sel == 2) % Display second graph
plot(X,signal2); % Display the signal 2 into the graph
xlabel("time (ms) "); % Label the x-axis
ylabel("Volts (mV) "); % Label the y-axis
title("Sum of signals"); % We name our graph

elseif(sel == 3) % Display the third graph
plot(X,signal3); % Display the signal 3 into the graph
xlabel("time (ms) "); % Label the x-axis
ylabel("Volts (mV) "); % Label the y-axis
title("Sum of signals"); % We name our graph
elseif(sel == 4) % Display the summatory graph
plot(X,TotalSignal); % Display the summatory of the signal
xlabel("time (ms) "); % Label the x-axis
ylabel("Volts (mV) "); % Label the y-axis
title("Sum of signals"); % We name our graph
elseif(sel == 5) % Display all the graphs graph
plot(X,signal1); % Display the signal 1 into the graph
hold on; % Maintain the signal in the graph
plot(X,signal2); % Display the signal 2 into the graph
hold on; % Maintain the signal in the graph
plot(X,signal3); % Display the signal 3 into the graph
hold on; % Maintain the signal in the graph
plot(X,TotalSignal); % Display the summatory of the signal
hold on; % Maintain the signal in the graph
xlabel("time (ms) "); % Label the x-axis
ylabel("Volts (mV) "); % Label the y-axis
title("Sum of signals"); % We name our graph
else
disp("Invalid option"); % Display error message
end
```

Exercise #6 (Mauricio Aguilar)

Exercise 6. Create and display a triangular signal with support in [(-50-group number), (50+ group number)] ms. The support of a function is defined as the domain subset within which the function takes non-zero values. Assign values to the axis command so that the graph can be seen in the intervals [(-60-group number), (60+group number)] in "t" in ms, and [-0.5, 6] in the y-axis. Consider an amplitude of 5 Volts.

Do not forget to put the name and units to all the axes of your graph.
Tip: You can use the Matlab function "*tripuls*".

- What can you say about the obtained signal? Justify your answer.




```
r=(50+1)*2; %create the width
p=-51:51; %create the support
signal=5*(tripuls(p,r)); %create the triangular signa
                         %with an amplitude of 5


plot(p,signal)
title('Exercise 6')
xlabel('ms')
ylabel('v')
```

The graph obtained is a single triangle that reaches the amplitude of 5. The tripuls function was crucial for the making of this exercise. The support can be found in 51 with a width of 51.

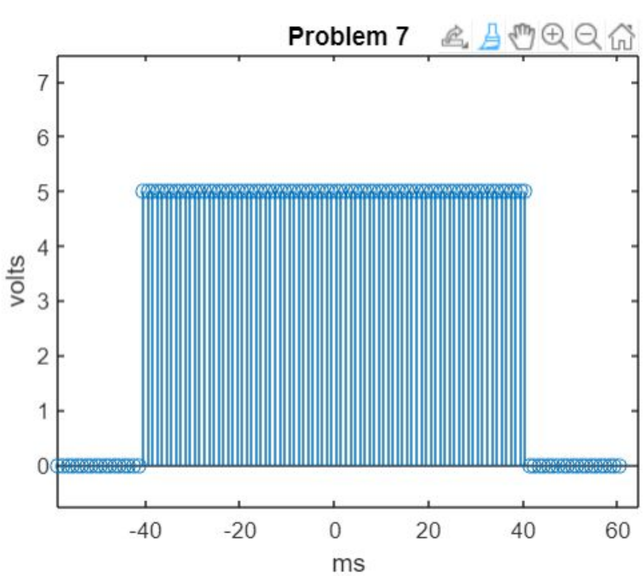
Exercise #7 (Isabella Dubon A00824441)

> ***Exercise 7.*** Create and visualize a pulse signal in the interval [(-40-group number), (40+group number)] in "t" in ms and [-0.5, 6] in the y-axis, with support in [(-20-group number),(20+group number)] and length 121. Use the command "*stem*" to plot your graph. Consider an amplitude of 5 Volts.
>
> Do not forget to put the name and units to all the axes of your graph.
> Tip: You can use the Matlab function "*rectpuls*".
>
> Now, create two copies of the previous pulse signal, the first one delayed 10 ms and the second one delayed 20 ms and a quarter wide. Do not forget to put the name and units to all the axes of your graph.
>
> - What can you say about the obtained signals? Justify your answer.

For this exercise, it was necessary to create three signals, all of which were aperiodic and discrete. For the first signal, the graph looked like the following image:

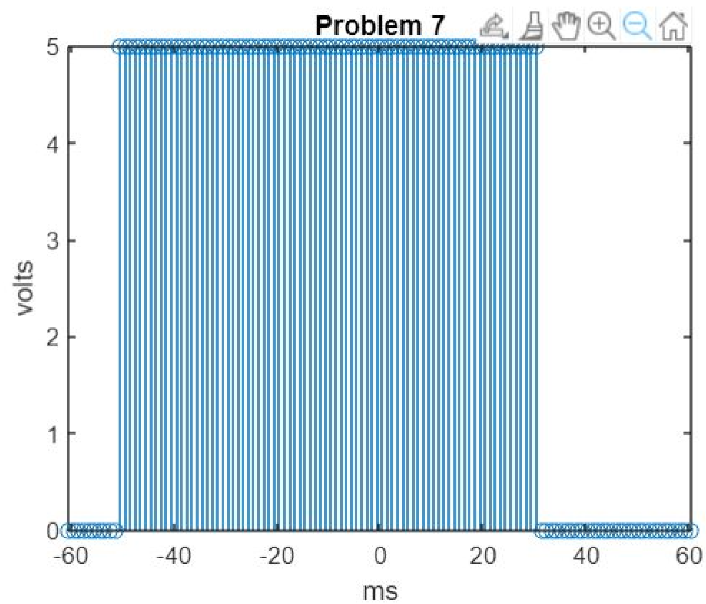
Followed by the code:

```
%a.
```




```
clear %Clear the console
groupnum=input('Enter your group number: '); %Ask the user for their group #
l= -121/2:121/2 %length of the signal
w = (40+groupnum)*2 %width of the signal
y=5*rectpuls(l,w) %rectangular pulse
figure(1)
stem(l,y) %plot of the signal
xlim([(-40-groupnum) (40+groupnum)]) % x limits
ylim([0.5,6]) %y limits
title('Problem 7') %title of the graph
xlabel('ms') %x label for the graph
ylabel('volts') %y label for the graph
```

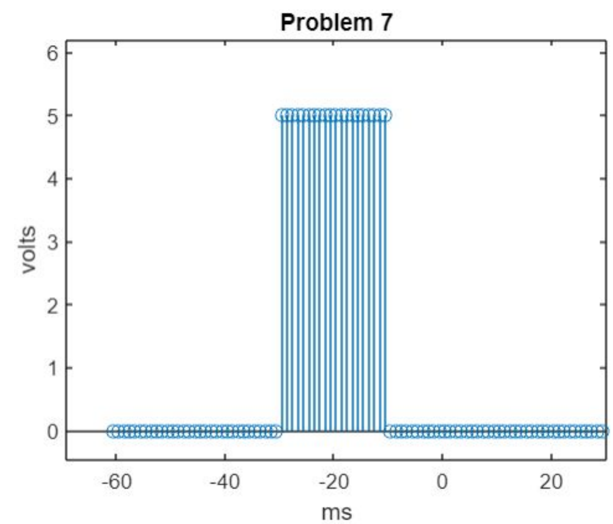
For the second signal, it was necessary to apply a delay to the x-axis. To create this delay, a variable for delay was created and it was added to the existing code, adding it to the rectplus function as part of the length. The figure below shows the resulting graph:



The code for the previous graph was:

```
%b.
l1= -121/2:121/2 %length of the signal
w1 = (40+groupnum)*2 %width of the signal
delay=10
y1=5*rectpuls(l1+delay,w1) %rectangular pulse
figure(2)
stem(l1,y1) %plot of the signal
xlim([(-40-groupnum) (40+groupnum)]) % x limits
ylim([0.5,6]) %y limits
title('Problem 7') %title of the graph
xlabel('ms') %x label for the graph
ylabel('volts') %y label for the graph
```

At last, a final modification was made to the signal. This time, the delay was for 20ms and the width was narrowed to ¼ of the original size. To create this effect, the delay was just replaced with the new given value and the width was divided by 4, to reduce its size to the requested new figure. The following figure shows the new signal created:



The new code were these modifications were implemented was the following:

```
%c.
l2= -121/2:121/2 %length of the signal
w2 = ((40+groupnum)*2)/4 %width of the signal
delay1=20
y2=5*rectpuls(l2+delay1,w2) %rectangular pulse
figure(3)
stem(l2,y2) %plot of the signal
xlim([(-40-groupnum) (40+groupnum)]) % x limits
ylim([0.5,6]) %y limits
title('Problem 7') %title of the graph
xlabel('ms') %x label for the graph
ylabel('volts') %y label for the graph
```

Exercise #8 (Hector J. Pequeno Chairez, A01246364)

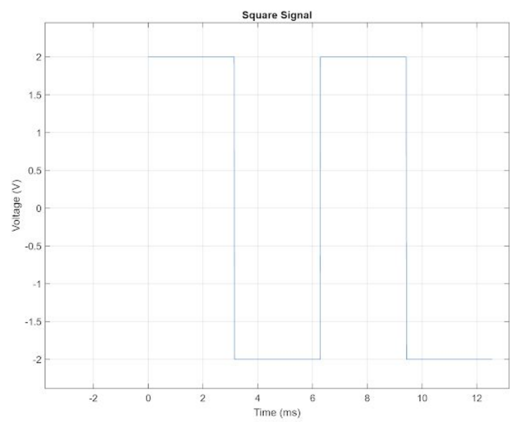
Exercise 8. A square signal can be generated in MATLAB with the "*square*" function and a sawtooth signal is generated with the "*sawtooth*" function. Check the MATLAB help to understand how these functions are used and generate a figure for each function in the time interval [0, 4 * pi * group number] with increment of 0.01. The amplitude of each signal will be [-2 , 2] Volts. Each figure must be gridded (with grid). Assign values to the axis command so that the graph can be seen in the intervals [-1, (4 * pi * group number) + 1] in "t" in ms. Place titles to the axes and to the graph according to whether said graph is "square function" or "sawtooth function", respectively.

-What can you say about the obtained signal? Justify your answer.

First, we have the square signal, this is generated by the function square, this function receive as parameter the range of values to cover (time in ms), in this case we have that the limit goes from 0 to 4*pi*1 ms (approximately 12.5637 ms) and the magnitude is from -2 to 2 (Volts).

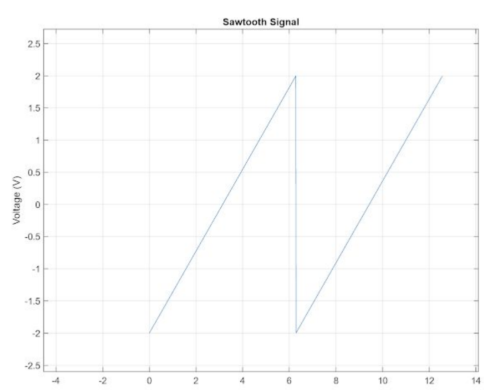
This can be seen as a energetical signal, because it tends to 0, when the signal goes to the final time, but this is generated only because our range of interest makes this effect, but this it's just an square signal.

The graph is the following:



Then, we have the second signal, the sawtooth, this signal also goes from 0 to 12.56 ms and the magnitude is from -2 to 2 Volts. This looks like a Power graph because we can't see a tendency to 0 at the final of the graph, but also as the last one, it is just an effect generated by the interval that we use. This is just a Sawtooth signal.

The signal is the following:



Code:

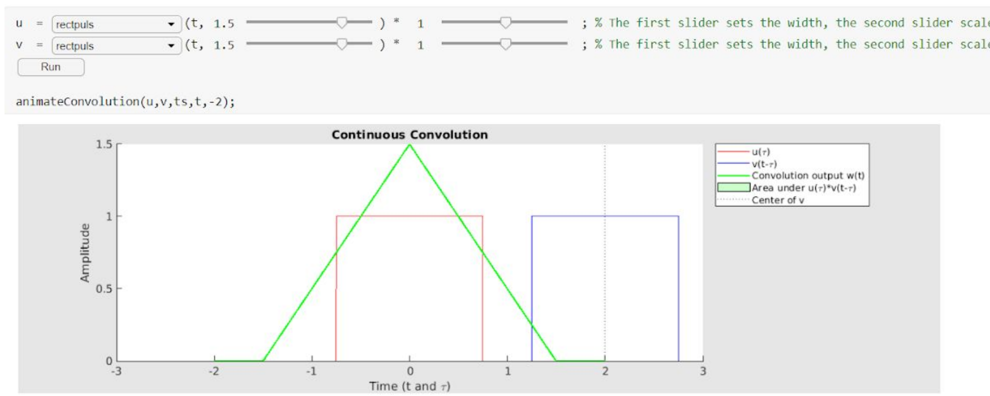
```
clear % Clear trash values
group = 1; % Number of our group
disp("Select the number with the option of your interest:"); % Display the
menu
disp("1 - Square function"); % Display option 1
prompt = "2 - Display sawtooth graph"; % Display option 2
sel = input(prompt); % Read the input of the menu
x=0:.01:4*pi*group; % Create a range for the signals


if(sel==1) % Condition to select our interest option

   plot(x,2*square(x)); % Display the square  graph
   xlabel("Time (ms)"); % Label for x-axis
   ylabel("Voltage (V)"); % Label for y-axis
   title("Square Signal"); % Title for the graph

elseif(sel==2) % Second option selected

   plot(x,2*sawtooth(x)); % Display the sawtooth graph
   xlabel("Time (ms)"); % Label for x-axis
   ylabel("Voltage (V)"); % Label for y-axis
   title("Sawtooth Signal"); % Title for the graph

else % Last option selected
   disp("No valid option selected"); % Display error message

end % End of the If Status
```

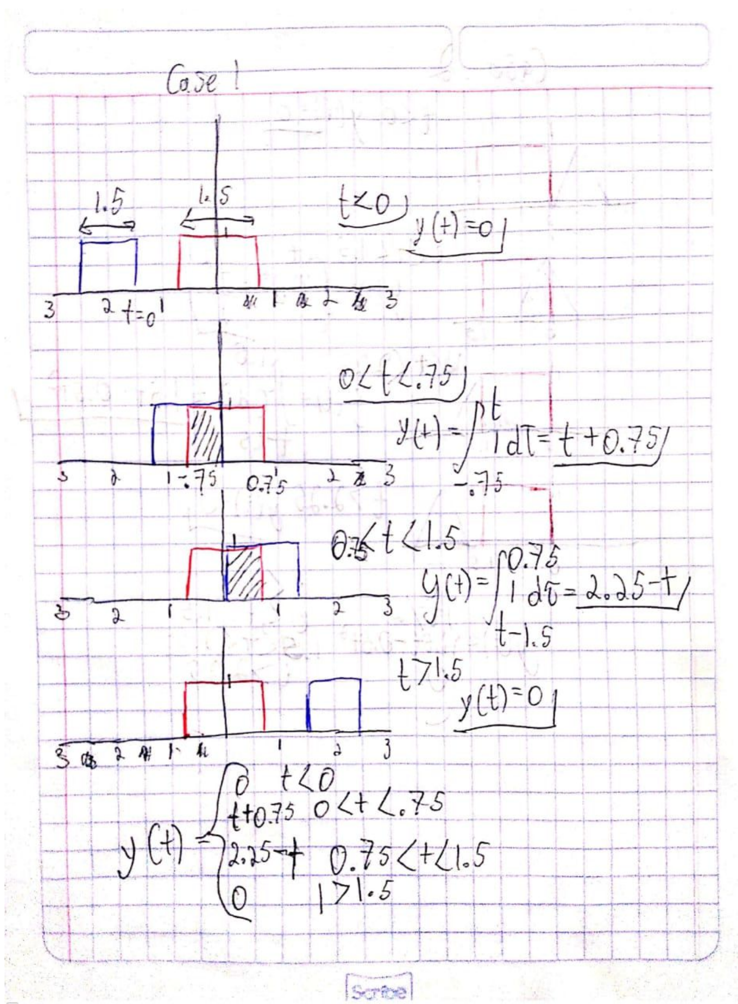
Exercise #9 (Mauricio Aguilar)

Exercise 9. Open the script **Convolution.mlx** you have in Canvas in Matlab. In this script you will find an animated code for the convolution operation.
Consider the following cases and perform the convolution of two signals analytically (i.e., with the corresponding mathematical operations) and validate your solution with the Matlab code. You need to include the mathematical analysis as well as the Matlab graph for your solution.
-**Case 1:** consider u and v as rectangular pulses of width 1.5 and amplitude 1.
-**Case 2:** consider u as a rectangular pulse of width 1.5 and amplitude 1 and v as a triangular pulse of width 1.5 and amplitude 1.
- Does the order of inputs matter? Is convolution commutative?
- Describe your general observations about the convolution output w compared to the inputs u and v?

After a short time playing with the Matlab code, no, the order of inputs does not matter. We can conclude that convolution is indeed commutative. In the first case, the result is a triangular signal and in case 2 is a sinusoidal signal. This makes sense given the inputs, which in the first case are 2 squares and in the second case is a square and a triangle.

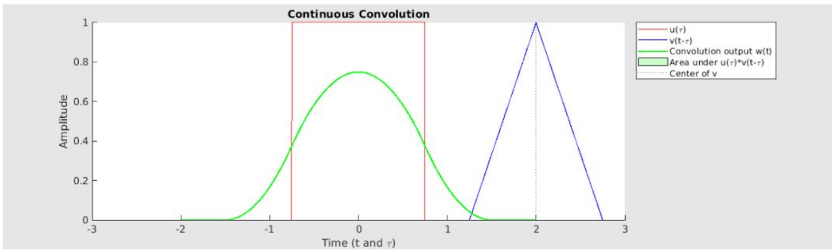
Case 1



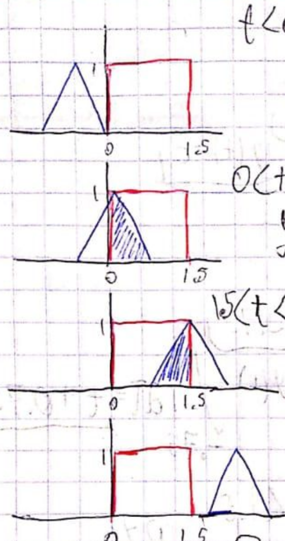


Case 2

```
u = rectpuls ▾ (t, 1.5 ———○——— ) * 1 ———○——— ; % The first slider sets the width, the second slider sc
v = tripuls  ▾ (t, 1.5 ———○——— ) * 1 ———○——— ; % The first slider sets the width, the second slider sc
Run

animateConvolution(u,v,ts,t,-2);
```



Caso 2



$t<0 \quad y(t)=0$

$0<t<1.5$

$y(t)=\int_0^t \tau\, d\tau = \frac{t^2}{2}$

$1.5<t<2.25$

$y(t)=\int_{t-1.5}^{1.5} \tau\, d\tau = 1.5t-0.5t^2$

$t>2.25 \quad y(t)=0$

$$y(t)=\begin{cases} 0 & t<0 \\ t^2/2 & 0<t<1.5 \\ 1.5t-0.5t^2 & 1.5<t<2.25 \\ 0 & t>2.25 \end{cases}$$

Each team member performed 3 exercises each, as labeled in every one of them. However, we helped each other through difficulties and did every exercises in some way to understand how Matlab works.