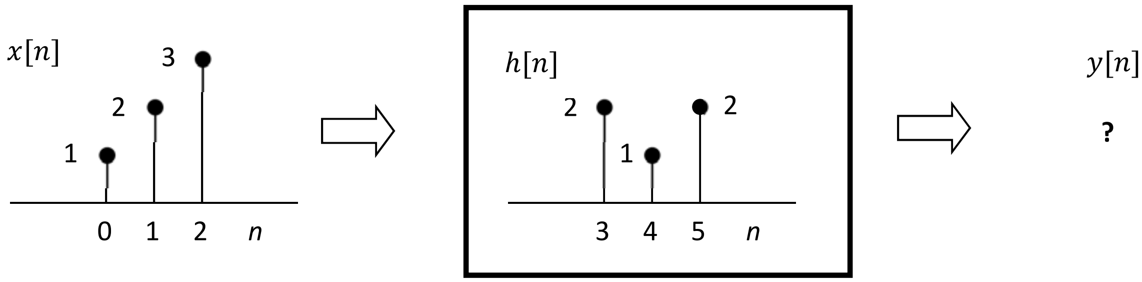
ELEC2100 **Prelab #2**

<u>Objective</u>

- To be familiar with impulse response and convolution

<u>Ex.1</u> Convolution




```
x=[1 2 3];                                  % input x
nx=0:2;                                     % n index of x

h=[2 1 2];                                  % impulse response h
nh=3:5;                                     % n index of h

y=conv(x,h)                                 % obtain the output y using convolution
ny=3:7;                                     % n index of y

% min(ny) = min(nx) + min(nh)        →      3 = 0 + 3
% max(ny) = max(nx) + max(nh)        →      7 = 2 + 5
% Each time-shifted impulse of the impulse response can be regarded as a delay unit.

figure(1);
subplot(311); stem(nx,x); ylabel('x[n]'); grid; axis([-1 8 0 4]);
subplot(312); stem(nh,h); ylabel('h[n]'); grid; axis([-1 8 0 4]);
subplot(313); stem(ny,y); ylabel('y[n]'); grid; axis([-1 8 0 11]);
xlabel('n');
```

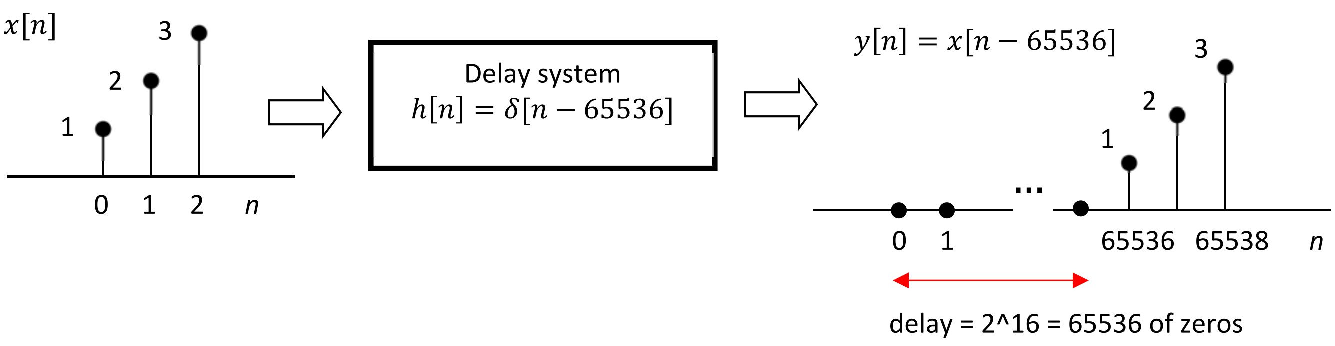
Self-check :

- Write down the mathematical expression of $x[n]$ as the sum of impulses.
- Write down the mathematical expression of $h[n]$ as the sum of impulses.
- Obtain the output sequence y by hand calculation.
- Check your answer with the Matlab result.

Ex.2 Impulse Response (Audio)

Read the audio file (**song2.wav**) using "**audioread**".
Use "**zeros**" to introduce delay to the audio file.

e.g.



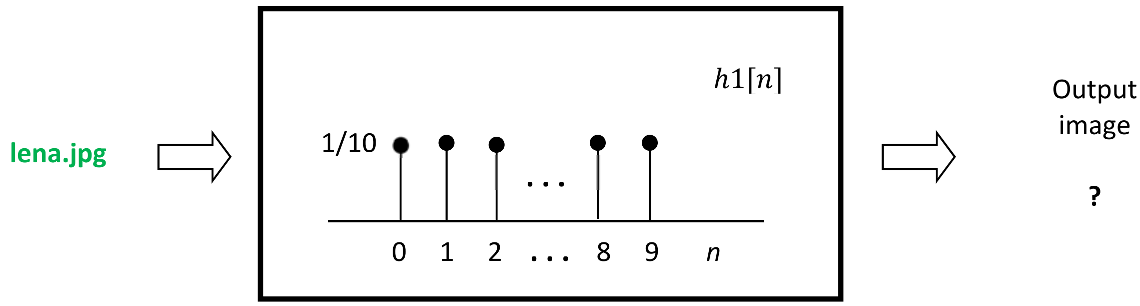

```
[x,fs] = audioread('song2.wav');        % read audio file and sample rate
x=x';                                   % transpose of x

delay=2^16;                             % delay (in terms of points with zero magnitude)
y=[zeros(1,delay) x];                   % delayed version by adding zeros in front of x

tx=[0:length(x)-1]/fs;                  % time index of x
ty=[0:length(y)-1]/fs;                  % time index of y

figure(2);
plot(tx,x); grid;                       % plot x
hold on;
plot(ty,y,'r');                         % plot y in the same figure(2)
xlabel('time (sec)');
legend('Original','Delayed');
hold off;

z=[x zeros(1,delay)] + y;               % original and delayed are added together

% Two matrices must have the same length before adding them together.
% Certain number of zeros are added to original x so as to make it have the same length as y.

sound(x, fs);                           % hear the original
sound(y, fs);                           % hear the delayed
sound(z, fs);                           % hear the sum of x and y
```

Self-check :

- Is x a row matrix or column matrix ?
- Why is it necessary to obtain the transpose of x ?
- Can you modify the given Matlab code so that it is not necessary to do transpose of x ?
- What is the time interval between two consecutive sample points ?
- What is the actual delay time (in seconds) ?
- Can you hear any difference between the original and the delayed version ?
- What is the mathematical expression of the impulse response $h[n]$ to generate $z[n]$?
- Can you define the impulse response h and use "**conv**" to generate z ?

Ex.3 Impulse Response (Image)

Display the image file (**lena.jpg**) using “**imread**”.
Apply the image file to system $h1[n]$ using “**conv2**” (i.e. perform 2-D convolution).




```
i2=imread('lena.jpg');                % read the file
figure(3); imshow(i2);                % display the image

h1=ones(1,10)/10                      % impulse response (1-by-10, 1-D filter)

y1=conv2(h1, h1, i2, 'same');         % perform 2-D convolution using 1-D filter
figure(4); imshow(uint8(y1));         % map values into [0:255] before showing the figure


h2=ones(10,10)/100                    % impulse response (10-by-10, 2-D filter)

y2=conv2(i2, h2, 'same');             % perform 2-D convolution using 2-D filter
figure(5); imshow(uint8(y2));         % map values into [0:255] before showing the figure
```

For color image, use the Matlab command “**convn**” to perform N-dimensional convolution.

Self-check :

- Compare i2 and y1.
- What is the difference on y2 between with ‘same’ and without ‘same’ ?
- Why is it necessary to use the command “uint8” for showing the image after convolution ?
- Any difference on the convolution between using 1-D filter and 2-D filter in this example ?
- What do the above systems (h1 and h2) do ?