7. Sampling rate conversion

1. Using D = 2 and x(n) = {1, 2, 3, 4, 3, 2, 1} write a MATLAB program to verify that the downsampler is time varying.

```
clc;

clear all;

x = [1,2,3,4,3,2,1];
y = downsample(x,2)

% y= 1     3     3     1

x = [1,2,3,4,3,2,1];
y = downsample(x,2,1)

%y= 2     4     2
```

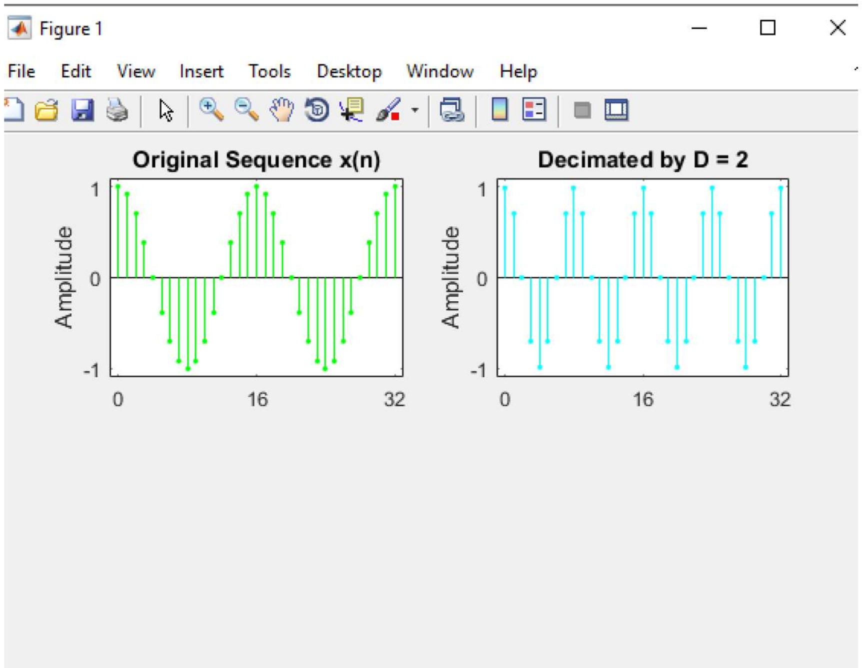
---

2. Let $x(n) = \cos(0.125\pi n)$. Write a MAT LAB program to generate a large number of samples of $x(n)$ and decimate them using $D = 2$, 4, and 8 to show the results of decimation

---

```
%%
clc;
clear all;
n = 0:2048; k1 = 256; k2 = k1+32; m = 0:(k2-k1);
Hf1 = figure('units','inches','position',[1,1,6,4],...
'paperunits','inches','paperposition',[0,0,6,4]);
% (a) Original signal
x = cos(0.125*pi*n); subplot(2,2,1);
Ha = stem(m,x(m+k1+1),'g','filled'); axis([-1,33,-1.1,1.1]);
set(Ha,'markersize',2); ylabel('Amplitude');
title('Original Sequence x(n)');
set(gca,'xtick',[0,16,32]); set(gca,'ytick',[-1,0,1]);
% (b) Decimation by D = 2
D = 2; y = decimate(x,D); subplot(2,2,2);
Hb = stem(m,y(m+k1/D+1),'c','filled'); axis([-1,33,-1.1,1.1]);
set(Hb,'markersize',2); ylabel('Amplitude');
title('Decimated by D = 2');
set(gca,'xtick',[0,16,32]); set(gca,'ytick',[-1,0,1]);
```

Output:



---

3. Let I = 2 and x(n) = {1, 2, 3, 4}. Write a MATLAB program to verify that the upsampler is time varying

---

```
clc;
clear all;
x = [1,2,3,4];
v = upsample(x,3);

% v =1    0    0    2    0    0    3    0    0    4    0    0

v = upsample(x,3,1);

%v = 0    1    0    0    2    0    0    3    0    0    4    0

v = upsample(x,3,2)

% v= 0    0    1    0    0    2    0    0    3    0    0    4
```

---

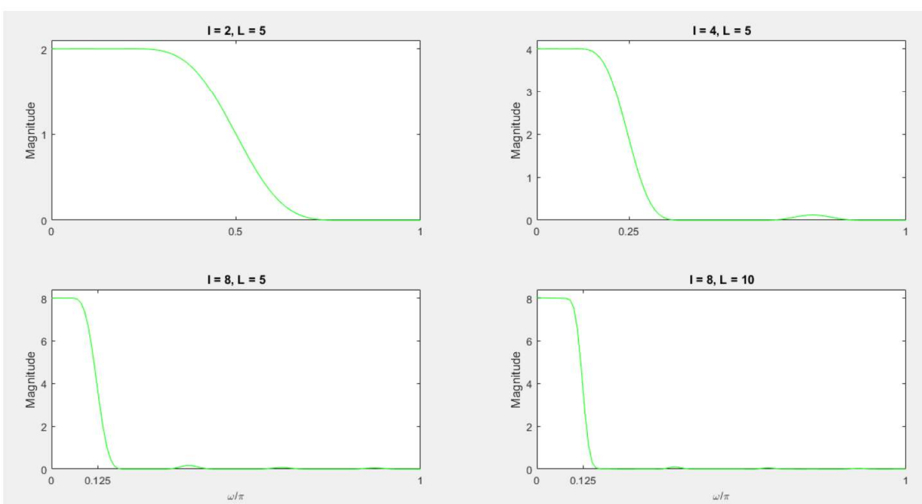
4. Let x(n) = cos(πn).Write a MATLAB program to generate samples of $x(n)$ and interpolate them using I = 2, 4, and 8 to show the results of interpolation.

---

5. Write a MATLAB program to examine the frequency response of the lowpass filter used in the interpolation of the signal $x(n) = \cos(\pi n)$.

```
clc;
clear all;
n = 0:256; x = cos(pi*n); w = [0:100]*pi/100;
Hf1 = figure('units','inches','position',[1,1,6,4],...
'paperunits','inches','paperposition',[0,0,6,4]);
% (a) Interpolation by I = 2, L = 5;
I = 2; [y,h] = interp(x,I); H = freqz(h,1,w); H = abs(H);
subplot(2,2,1); plot(w/pi,H,'g'); axis([0,1,0,I+0.1]); ylabel('Magnitude');
title('I = 2, L = 5');
set(gca,'xtick',[0,0.5,1]); set(gca,'ytick',[0:1:I]);
% (b) Interpolation by I = 4, L = 5;
I = 4; [y,h] = interp(x,I); H = freqz(h,1,w); H = abs(H);
subplot(2,2,2); plot(w/pi,H,'g'); axis([0,1,0,I+0.2]); ylabel('Magnitude');
title('I = 4, L = 5');
set(gca,'xtick',[0,0.25,1]); set(gca,'ytick',[0:1:I]);
% (c) Interpolation by I = 8, L = 5;
I = 8; [y,h] = interp(x,I); H = freqz(h,1,w); H = abs(H);
subplot(2,2,3); plot(w/pi,H,'g'); axis([0,1,0,I+0.4]); ylabel('Magnitude');
title('I = 8, L = 5'); xlabel('\omega/\pi','fontsize',10)
set(gca,'xtick',[0,0.125,1]); set(gca,'ytick',[0:2:I]);
% (d) Interpolation by I = 8, L = 10;
I = 8; [y,h] = interp(x,I,10); H = freqz(h,1,w); H = abs(H);
subplot(2,2,4); plot(w/pi,H,'g'); axis([0,1,0,I+0.4]); ylabel('Magnitude');
title('I = 8, L = 10'); xlabel('\omega/\pi','fontsize',10)
set(gca,'xtick',[0,0.125,1]); set(gca,'ytick',[0:2:I]);
```

Output:



----

6. Design a linear-phase FIR interpolation filter to interpolate a signal by a factor of 4, using the bandlimited method.

```
%%
I = 4; L = 5;
Hf1 = figure('units','inches','position',[1,1,6,4],...
'paperunits','inches','paperposition',[0,0,6,4]);
% (a) Full signal bandwidth: alpha = 1
alpha = 1; h = intfilt(I,L,alpha);
[Hr,w,a,L] = Hr_Type1(h); Hr_min = min(Hr); w_min = find(Hr == Hr_min);
H = abs(freqz(h,1,w)); Hdb = 20*log10(H/max(H)); min_attn = Hdb(w_min);
subplot(2,2,1); plot(w/pi,Hr,'g','linewidth',1.0); axis([0,1,-1,5]);
set(gca,'xtick',[0,1/I,1],'ytick',[0,I]); grid; ylabel('Amplitude');
title('Amplitude Response: alpha = 1');
subplot(2,2,3); plot(w/pi,Hdb,'m','linewidth',1.0); axis([0,1,-50,10]);
set(gca,'xtick',[0,1/I,1],'ytick',[-50,round(min_attn),0]); grid
ylabel('Decibels'); xlabel('\omega/\pi', 'fontsize',10);
title('Log-mag Response: alpha = 1')
% (b) Partial signal bandwidth: alpha = 0.75
alpha = 0.75; h = intfilt(I,L,alpha);
[Hr,w,a,L] = Hr_Type1(h); Hr_min = max(Hr(end/2:end)); w_min = find(Hr == Hr_min);
H = abs(freqz(h,1,w)); Hdb = 20*log10(H/max(H)); min_attn = Hdb(w_min);
subplot(2,2,2); plot(w/pi,Hr,'g','linewidth',1.0); axis([0,1,-1,5]);
set(gca,'xtick',[0,1/I,1],'ytick',[0,I]); grid; ylabel('Amplitude');
title('Amplitude Response: alpha = 0.75');
subplot(2,2,4); plot(w/pi,Hdb,'m','linewidth',1.0); axis([0,1,-50,10]);
set(gca,'xtick',[0,1/I,1],'ytick',[-50,round(min_attn),0]); grid
ylabel('Decibels'); xlabel('\omega/\pi', 'fontsize',10);
title('Log-mag Response: alpha = 0.75');
```

Output: