DUBLIN CITY UNIVERSITY

ELECTRONIC AND COMPUTER ENGINEERING

EE515 - Real Time Digital Signal Processing

Assignment 2

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Signed: ___________________ Date: 13/12/2019

Michael Lenehan

Contents

1 Question 1

All code for this section can be found within the appendices.

1.1 Part 1

$$y[n] = 2x[n] - 3x[n-1] + 2x[n-2]$$

$$y[n] \text{ in the range } 0 \leq n \leq 10 \text{ for:}$$

$$x[n] = \begin{cases} 0 & n < 0 \\ n+1 & n = 0,1,2 \\ 5-n & n = 3,4 \\ 1 & n \geq 5 \end{cases}$$

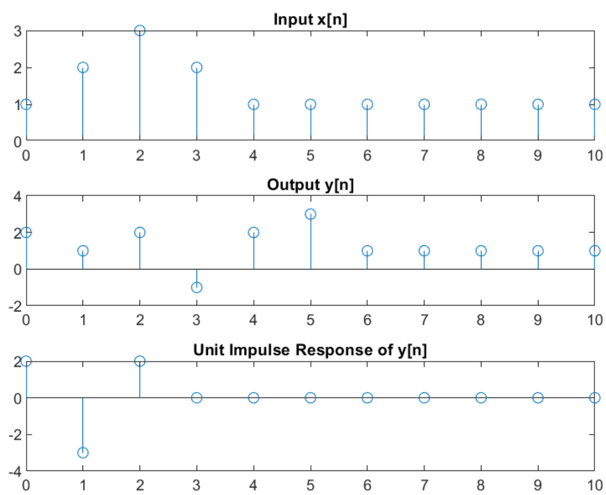

Figure 1: Output for Question 1 Parts 1, 2, and 3

From Figure 1 it can be seen that the values for $y[n]$ are $\{2, 1, 2, -1, 2, 3, 1, 1, 1, 1, 1\}$.

1.2 Part b

The stem plot in 1 shows the stem plot containing both $y[n]$ and $x[n]$. The values of $x[n]$ are shown to be $\{1,2,3,2,1,1,1,1,1,1,1\}$.

1.3 Part c

The unit impulse response for y[n] is shown in 1, with output values of $\{2,-3,2,0,0,0,0,0,0,0,0\}$.

2 Question 2

All code for this section can be found within the appendices.

2.1 Part a

The frequency response of the filter is given by the following:

$$y[n] = \frac{1}{11}\sum_{k=0}^{10} x[n-k]$$

Converting to the Frequency Domain

$$H(j\hat{\omega}) = \frac{1}{11}\sum_{k=0}^{10} e^{-j\hat{\omega}k}$$

Sum of a Geometric Series

$$\sum_{k=0}^{L-1} a^k = \frac{1-\alpha^L}{1-\alpha}$$

$$H(j\hat{\omega}) = \frac{1}{L}(\frac{1-e^{-j\hat{\omega}L}}{1-e^{-\hat{\omega}}})$$

Taking out a factor of $e^{\frac{-j\hat{\omega}L}{2}}$ from the numerator

and $e^{\frac{-j\hat{\omega}}{2}}$ from the denominator:

$$H(j\hat{\omega}) = \frac{1}{L}(\frac{e^{\frac{-j\hat{\omega}L}{2}}(e^{\frac{j\hat{\omega}}{2}} - e^{\frac{-j\hat{\omega}L}{2}})}{e^{\frac{-j\hat{\omega}}{2}}(e^{\frac{jom\hat{e}ga}{2}} - e^{-\frac{j\hat{\omega}}{2}})})$$

$$H(j\hat{\omega}) = (\frac{\sin(\frac{\hat{\omega}L}{2})}{L\sin(\frac{\hat{\omega}}{2})})e^{\frac{-j\hat{\omega}(L-1)}{2}}$$

As in the code shown, the Dirichlet function is used for the computation of the magnitude. The output plot can be seen in the first plot in Figure 2, found below.

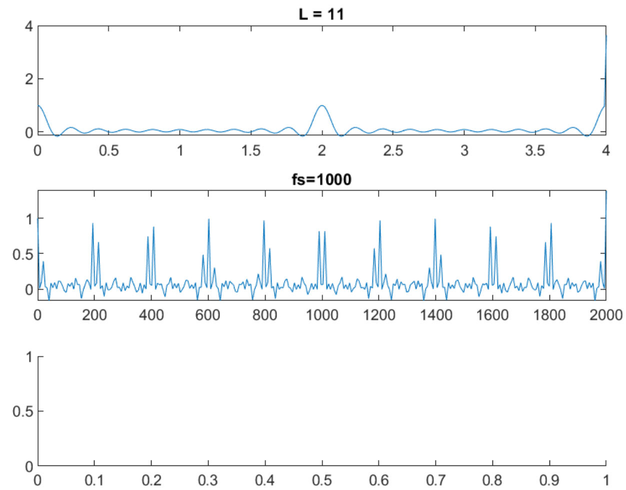

Figure 2: The output from Q2 Part 1, Part 2, and Part 3

2.2 Part B

The frequency response of the system with $f_s = 1000$ is given in the second plot of Figure 2.

2.3 Part C

As no correct implementation could be completed for this section, there is no correct plot found in Figure 2. The code implementation can be found above this section.

2.4 Part D

This system can be described as a Rectangular Window FIR Filter.

3 Question 3

3.1 Part a

There are 3 loops within this DFG. These loops are indicated below:

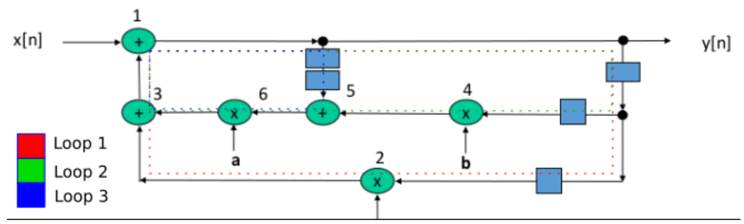

Figure 3: DFG with Loops labelled

Each of these loops can be seen to begin and end at the addition node after the input $x[n]$.

3.2 Part b

The smallest loop, labelled Loop 3 has an iteration period of 5/2. The next smallest loop, labelled Loop 2 has an iteration period of 7/2. Finally, the largest loop, labelled Loop 1 has an iteration period of 4/2. Therefore, the iteration period bound has a value of 7/2.

3.3 Part c

The computation times for each path, with no delay, are as follows:

- Loop 1: 1 Multiplication, 2 Additions
  - $2+(2*1)=4$

- Loop 2: 2 Multiplications, 3 Additions
  - $(2*2)+(3*1)=7$
- Loop 3: 1 Multiplication, 3 Additions
  - $2+(3*1)=5$

Therefore, the critical path is found in the path labelled “Path 2” in Figure 3. This path has a length of 7 time units.

3.4 Part d

By shifting the register before the addition node “5” to between addition node “5” and multiplication node “6”, the following iteration periods are achieved:

- Loop 1:
  - 4/2
- Loop 2:
  - 7/3
- Loop 3:
  - 5/2

Therefore, the iteration period bound has been reduced. The changes to be made can be seen in Figure 4, found below.

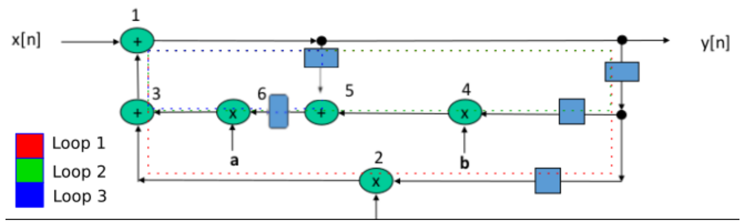

Figure 4: Retimed DFG

4 Appendix

4.1 Question 1

```
clc
clear all

%% Part a

x = zeros(1,11)
n=0:10;

i=0;
while i<11
    if(i==0 || i==1 || i==2)
        x(i+1)=i+1;
    end
    if(i==3 || i==4)
        x(i+1)=5-i;
    end
    if(i>=5)
        x(i+1)=1;
```

```
    end
    i=i+1;
end

Hz = [2 -3 2];
y=conv(x,Hz);

%% Part b

fig=figure;
subplot(3,1,1);
stem(n,x);
title('Input x[n]');
subplot(3,1,2);
stem(n,y(1:11));
title('Output y[n]');

%% Part c

x=zeros(1,11);
x(1)=1;
h=conv(Hz,x);
subplot(3,1,3)
stem(n,h(1:11));
title('Unit Impulse Response of y[n]');
saveas(fig, 'Q1.png')
```

4.2 Question 2

```
clc
clear all
```

```
%% Part a

% L=11;
% omega=linspace(0,2*pi,300);
% aliasSinc=((sin((omega*L)/2))/(L*sin(omega/2)))
% h=exp((-j*omega*(L-1))/2).*aliasSinc
%
% plot(omega/pi,h)

L=11
x = linspace(0,4*pi,300);
h = diric(x,L).*exp((-j*x*(L-1)/2));

fig=figure
subplot(3,1,1)
plot(x/pi,h)
title('L = 11')

%% Part b

fs=1000
L=11
x = linspace(0,2*pi*fs,300);
h = diric(x,L).*exp((-j*x*(L-1)/2));

subplot(3,1,2)
plot(x/pi,h)
title('fs=1000')
```

```matlab
%% Part c

t=0:1
xfunc = cos(2*pi*25*t) + sin(2*pi*250*t)
out = conv(xfunc, h)

% subplot(3,1,3)
% plot(t,out)
% title('x(t) input')
saveas(fig, 'Q2.png')
%% Part d

% Rectangular Window FIR Filter
```