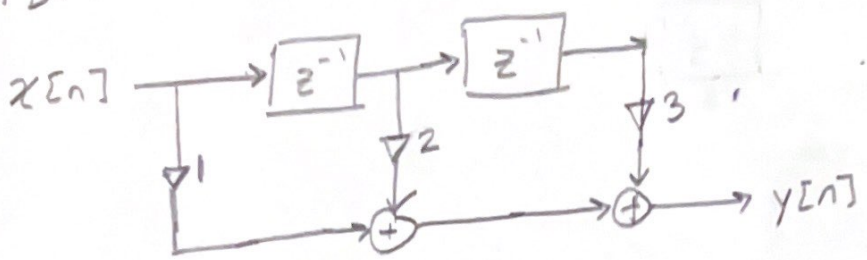
DSP HW #8

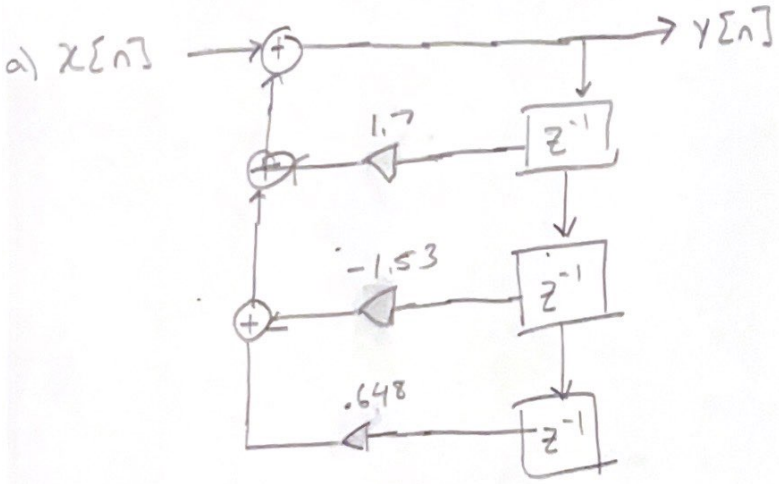
1) $y[n] = x[n] + 2x[n-1] + 3x[n-2]$ $\quad H(z) = \frac{Y(z)}{X(z)} = 1 + 2z^{-1} + 3z^{-2}$

a) Draw Direct Form

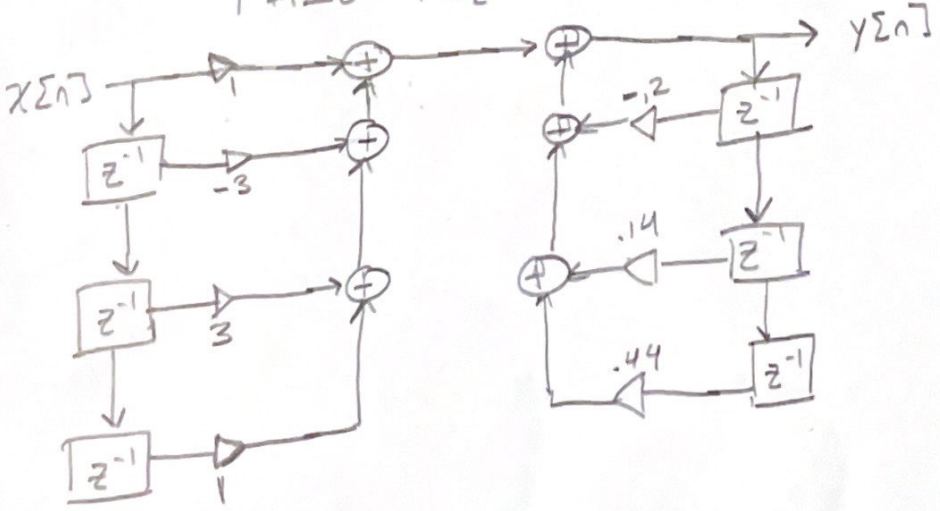


2) $H(z) = \frac{1}{1 - 1.7z^{-1} + 1.53z^{-2} - .648z^{-2}}$

a)



3) $H(z) = \frac{1 - 3z^{-1} + 3z^{-2} + z^{-3}}{1 + .2z^{-1} - .14z^{-2} + .44z^{-3}}$



Filter Designer - [untitled.fda *]

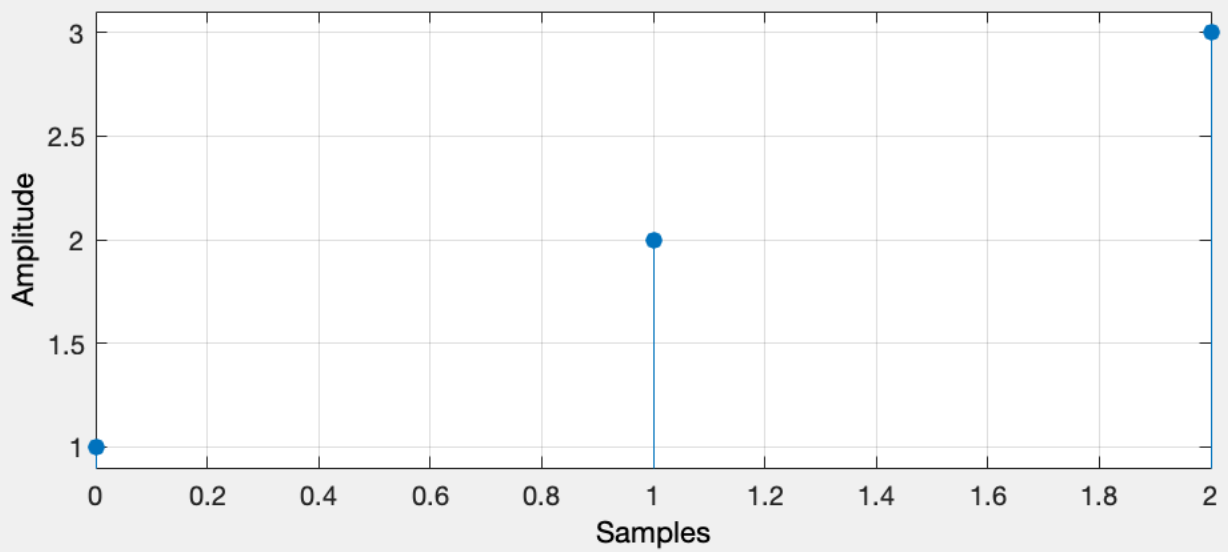
File Edit Analysis Targets View Window Help

Current Filter Information

Structure: Direct-Form I
Order: 2
Stable: Yes
Source: Imported

Store Filter ...
Filter Manager ...

Impulse Response



Filter Coefficients

Filter Structure:
Direct-Form I

Import as second-order sections

Numerator [1, 2, 3] Clear

Denominator 1 Clear

Sampling Frequency:
Units: Normalized ...
Fs: Fs

Import Filter

Importing Filter ... Done

Filter Designer - [untitled.fda *]

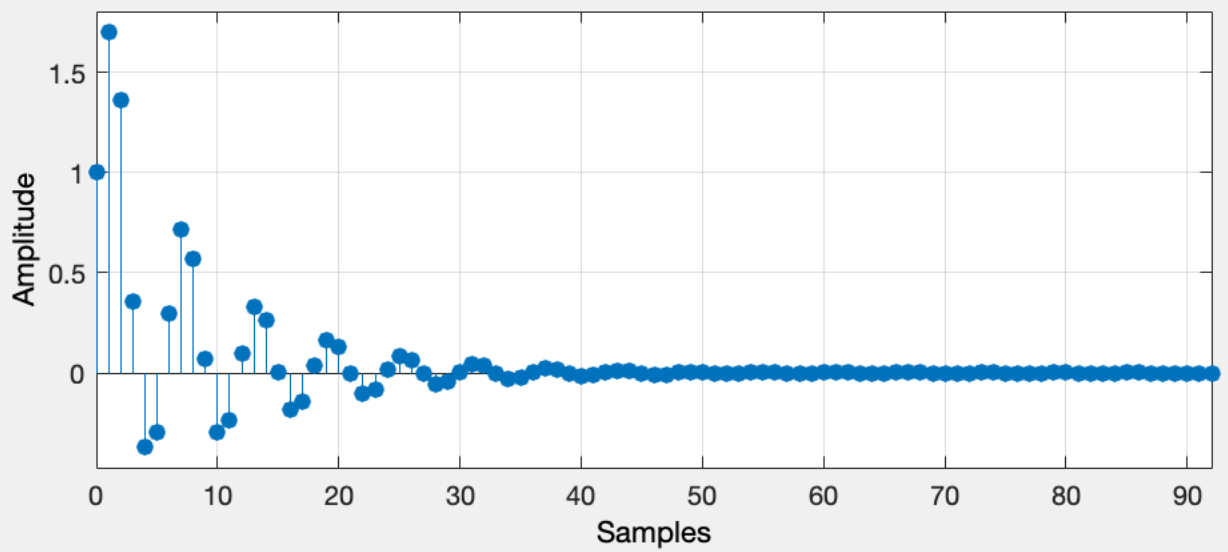
File Edit Analysis Targets View Window Help

Current Filter Information

Structure: Direct-Form I
Order: 3
Stable: Yes
Source: Imported

Store Filter ...
Filter Manager ...

Impulse Response



Filter Coefficients

Filter Structure:
Direct-Form I

Import as second-order sections

Numerator 1 Clear
Denominator [1, -1.7, 1.53, -.648] Clear

Sampling Frequency:
Units: Normalized ...
Fs: Fs

Import Filter

Importing Filter ... Done

Filter Designer - [untitled.fda *]

File Edit Analysis Targets View Window Help

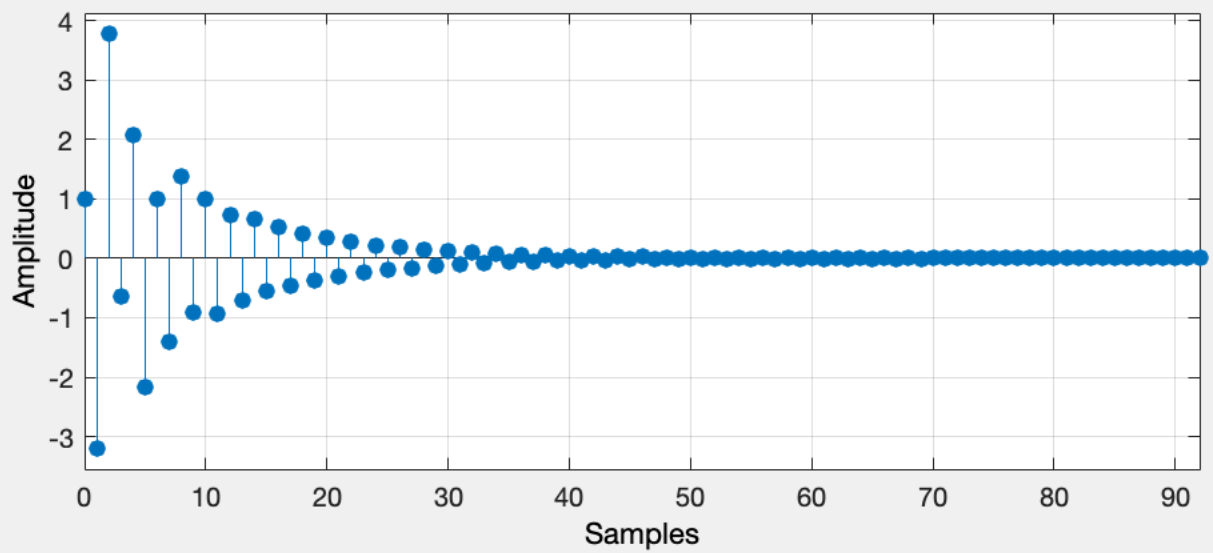
Current Filter Information

Structure: Direct-Form I
Order: 3
Stable: Yes
Source: Imported

Store Filter ...

Filter Manager ...

Impulse Response



Filter Coefficients

Filter Structure:

Direct-Form I

Import as second-order sections

Numerator [1, -3, 3, 1] Clear

Denominator [1, .2, -.14, .44] Clear

Sampling Frequency:

Units: Normalized ...

Fs: Fs

Import Filter

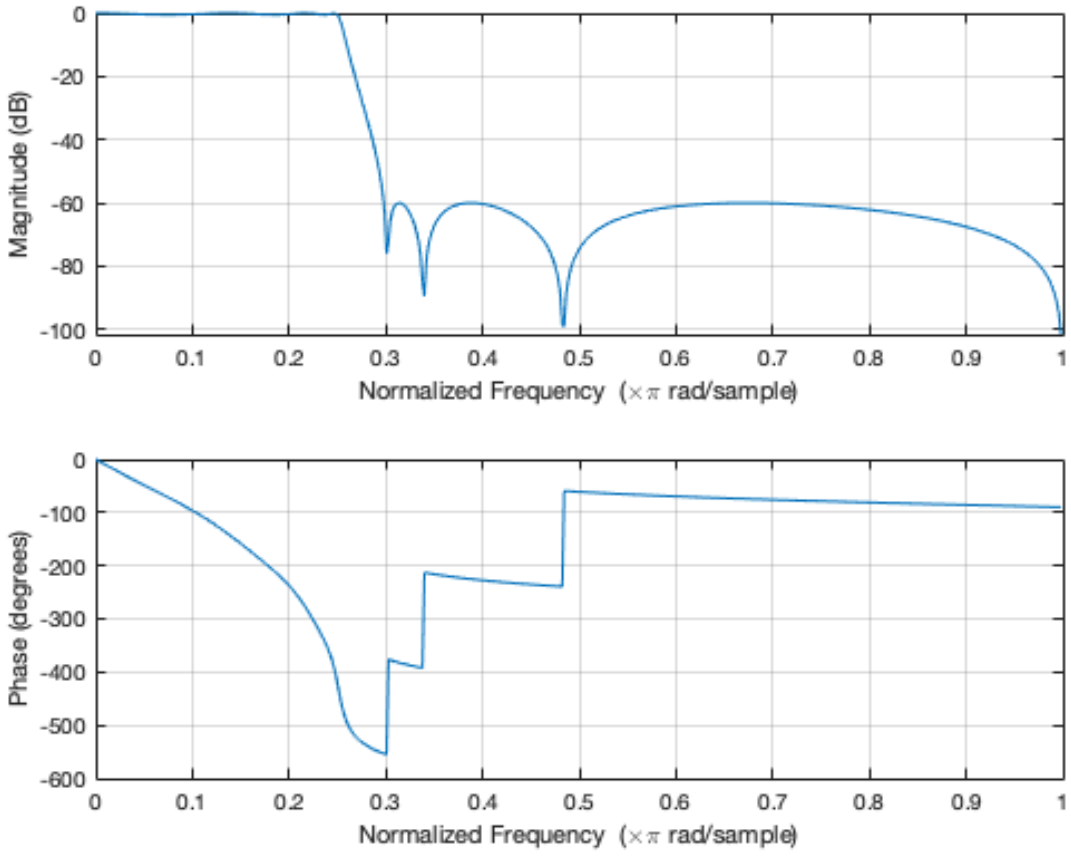
Importing Filter ... Done

```
%!-------------------------------------------------------------------------
%! DSP HW8 #4a
%!  - Create filter with .5dB ripple in passband, 60dB ripple in stopband,
%!      a passband edge freq of .25pi and a stopband edge freq of .3pi
%!  - Document the coefficients and plot the log magnitude with freqz.m
%!-------------------------------------------------------------------------

%! Enviorment
wp = .25*pi;
ws = .3*pi;
ripple_pb = .5;
ripple_sb = 60;

%! Create filter
[N, Wn] = ellipord(wp/pi, ws/pi, ripple_pb, ripple_sb);
[b, a] = ellip(N, ripple_pb, ripple_sb, Wn);

%! Plot
freqz(b, a)
```



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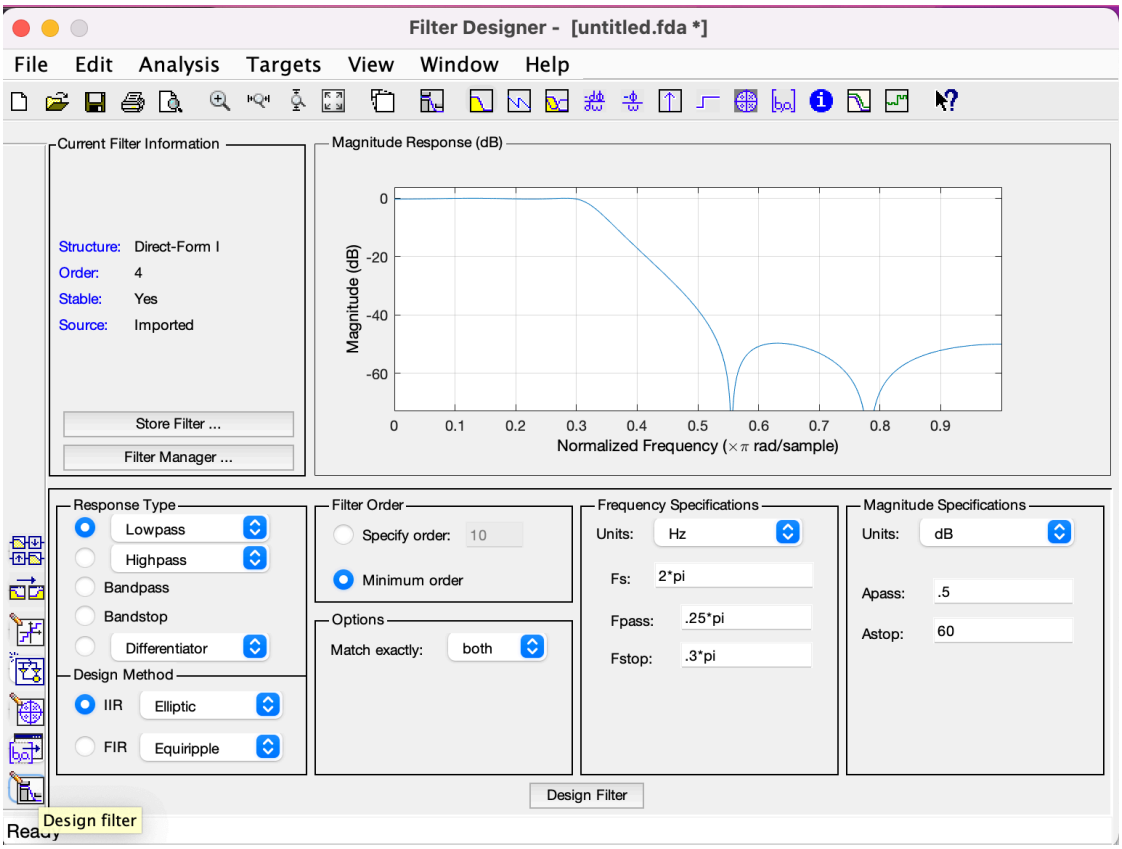
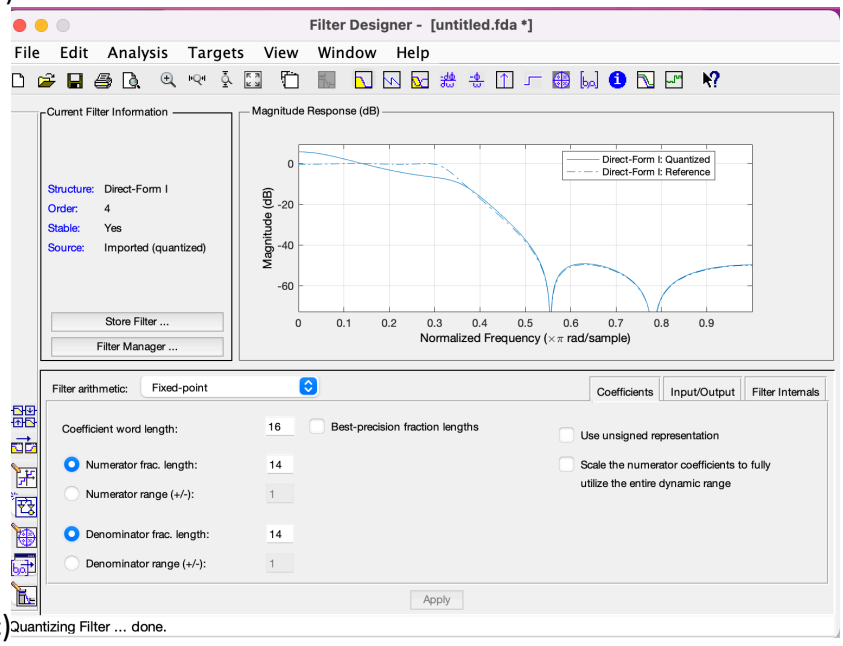
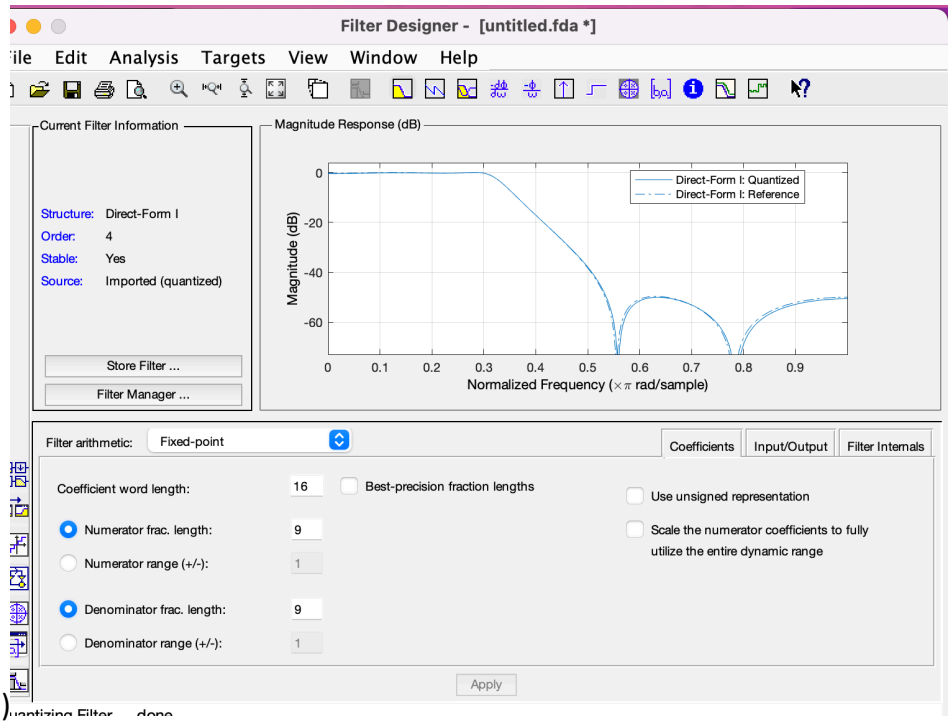

Filter Designer - [untitled.fda *]
File Edit Analysis Targets View Window Help
Current Filter Information
Structure: Direct-Form I
Order: 4
Stable: Yes
Source: Imported
Store Filter ...
Filter Manager ...
Magnitude Response (dB)
Magnitude (dB)
Normalized Frequency (×π rad/sample)
Response Type
Lowpass
Highpass
Bandpass
Bandstop
Differentiator
Design Method
IIR
Elliptic
FIR
Equiripple
Filter Order
Specify order: 10
Minimum order
Options
Match exactly: both
Frequency Specifications
Units: Hz
Fs: 2*pi
Fpass: .25*pi
Fstop: .3*pi
Magnitude Specifications
Units: dB
Apass: .5
Astop: 60
Design Filter
Design filter
Ready

4b)


Filter Designer - [untitled.fda *]
File Edit Analysis Targets View Window Help
Current Filter Information
Structure: Direct-Form I
Order: 4
Stable: Yes
Source: Imported (quantized)
Store Filter ...
Filter Manager ...
Magnitude Response (dB)
Direct-Form I: Quantized
Direct-Form I: Reference
Magnitude (dB)
Normalized Frequency (×π rad/sample)
Filter arithmetic: Fixed-point
Coefficients
Input/Output
Filter Internals
Coefficient word length: 16
Best-precision fraction lengths
Use unsigned representation
Numerator frac. length: 14
Numerator range (+/-): 1
Scale the numerator coefficients to fully utilize the entire dynamic range
Denominator frac. length: 14
Denominator range (+/-): 1
Apply
Quantizing Filter ... done.

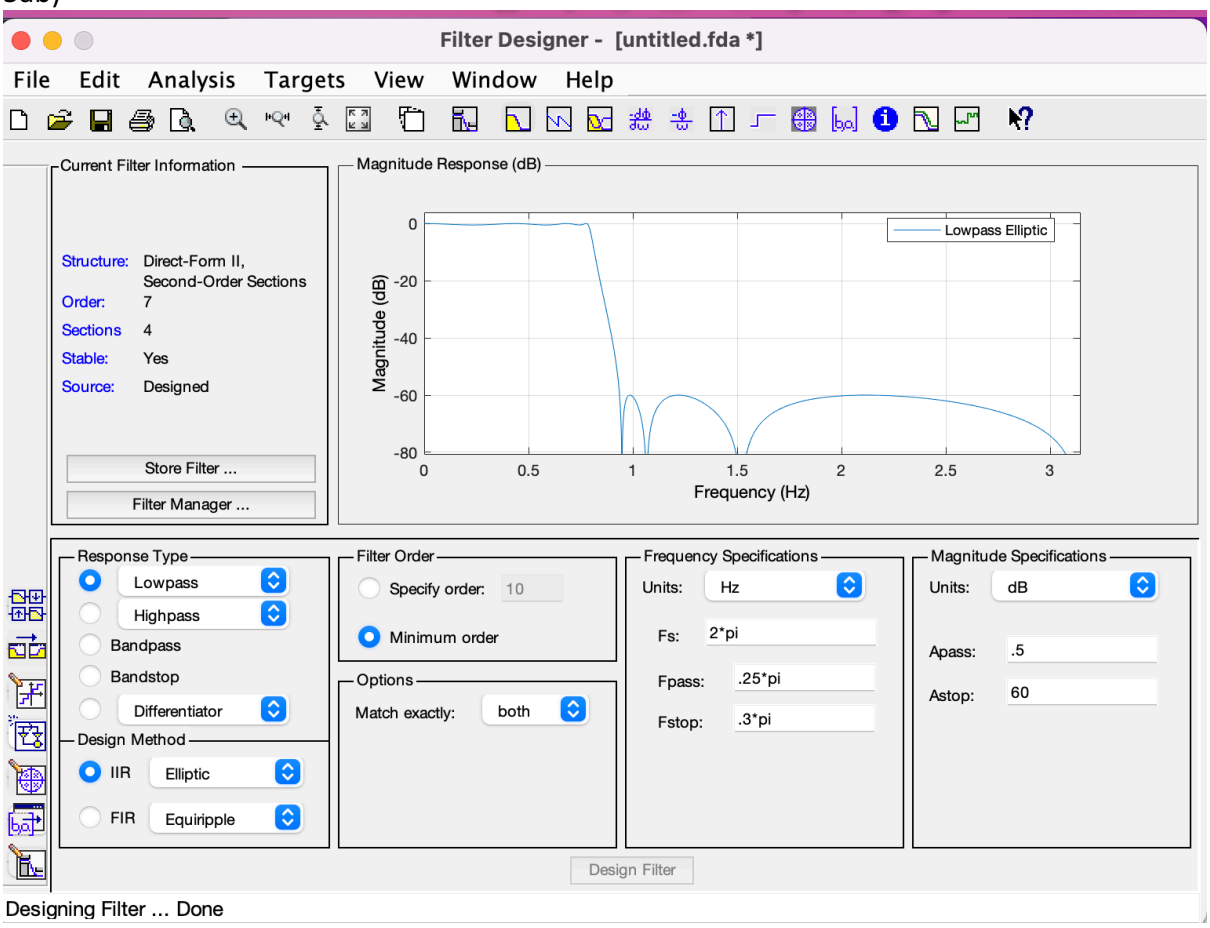
4c)

4d)

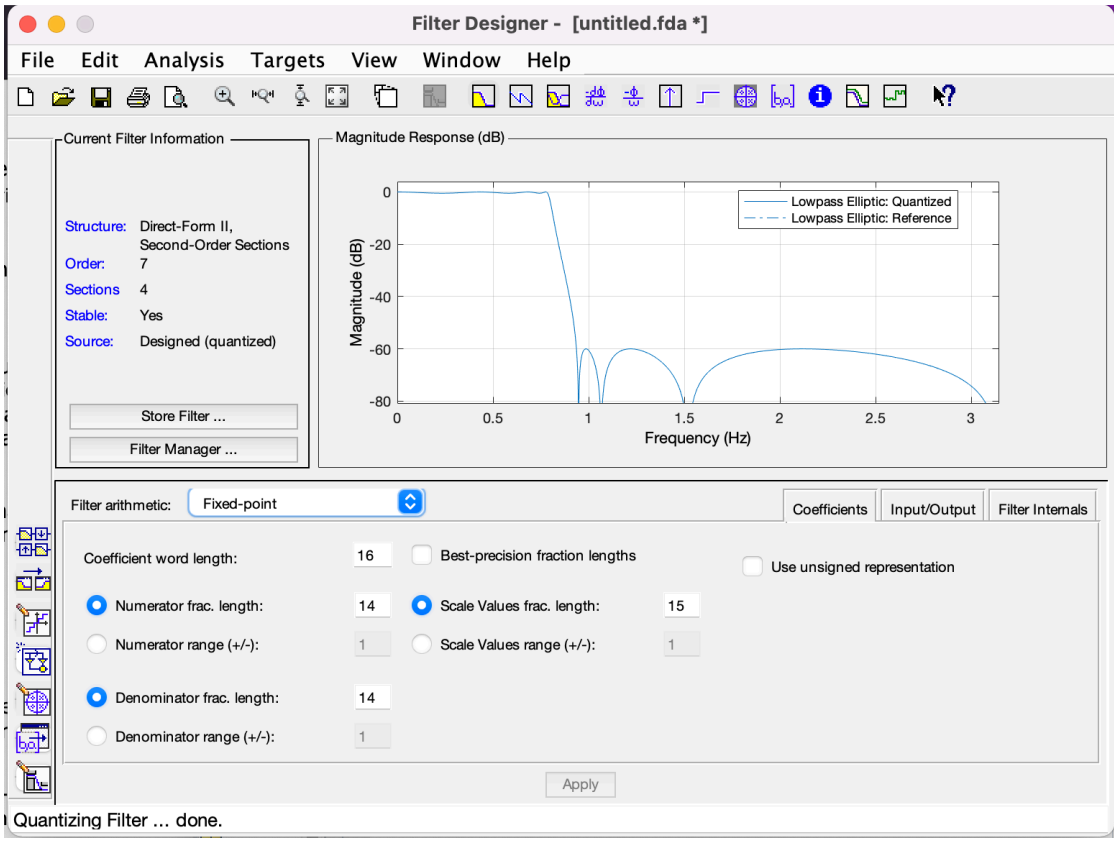


4e) The figure in 4b doesn't match 4a. I think this is because the matlab function doesn't defult to Direct Form 1. Comparing 4c to 4b you can see that the curve diverges. I think this is because it only has 2 binary digits for the integer values. When you use 9 bits as fraction in 4d there are more bits for the integer part. I experimented a little with increasing the integer bits with 14 decimal bits and it matched the curve much better.

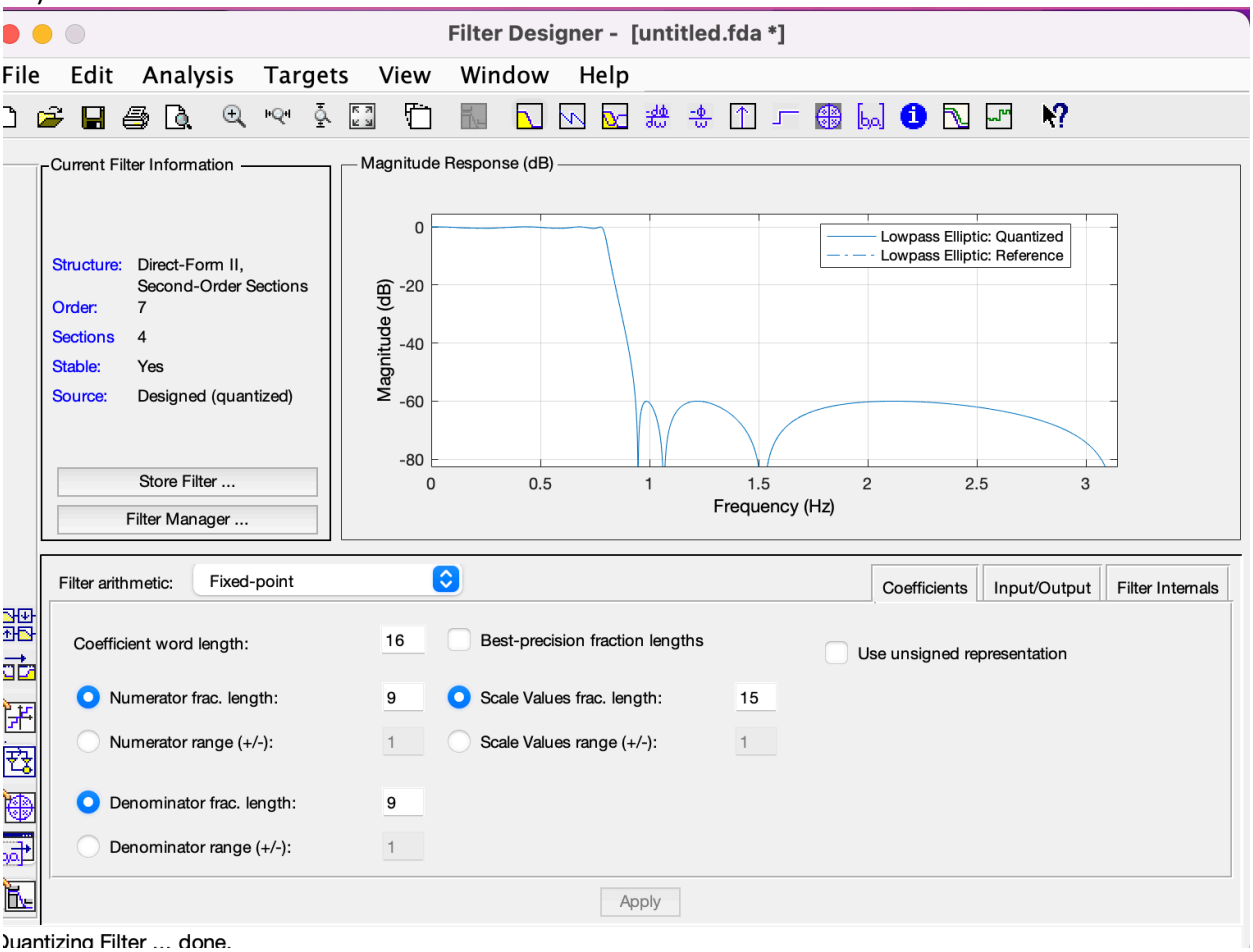
5ab)


Filter Designer - [untitled.fda *]
File Edit Analysis Targets View Window Help
Current Filter Information
Structure: Direct-Form II, Second-Order Sections
Order: 7
Sections 4
Stable: Yes
Source: Designed
Store Filter ...
Filter Manager ...
Magnitude Response (dB)
Lowpass Elliptic
Magnitude (dB)
0
-20
-40
-60
-80
0
0.5
1
1.5
2
2.5
3
Frequency (Hz)
Response Type
Lowpass
Highpass
Bandpass
Bandstop
Differentiator
Design Method
IIR
Elliptic
FIR
Equiripple
Filter Order
Specify order: 10
Minimum order
Options
Match exactly: both
Frequency Specifications
Units: Hz
Fs: 2*pi
Fpass: .25*pi
Fstop: .3*pi
Magnitude Specifications
Units: dB
Apass: .5
Astop: 60
Design Filter
Designing Filter ... Done

5c


Filter Designer - [untitled.fda *]
File Edit Analysis Targets View Window Help
Current Filter Information
Structure: Direct-Form II, Second-Order Sections
Order: 7
Sections 4
Stable: Yes
Source: Designed (quantized)
Store Filter ...
Filter Manager ...
Magnitude Response (dB)
Lowpass Elliptic: Quantized
Lowpass Elliptic: Reference
Magnitude (dB)
0
-20
-40
-60
-80
0
0.5
1
1.5
2
2.5
3
Frequency (Hz)
Filter arithmetic: Fixed-point
Coefficients
Input/Output
Filter Internals
Coefficient word length: 16
Best-precision fraction lengths
Use unsigned representation
Numerator frac. length: 14
Scale Values frac. length: 15
Numerator range (+/-): 1
Scale Values range (+/-): 1
Denominator frac. length: 14
Denominator range (+/-): 1
Apply
Quantizing Filter ... done.

5d)



5e) All of the curves are virtually the same when quantizing the coefficients. In SOS cascade form the quantization doesn't have much of a effect on the filter as opposed to the Direct Form 1 implementation, so SOS cascade is much more robust.