Task 1:

$$H(e^{iw}) = 1 + e^{-2iw} = e^{-iw}(e^{iw} + e^{-iw}) = e^{-iw}(2\cos(w))$$

So. the phase response is $-w$

The Grap delay : $T(w) = -\frac{d\theta(w)}{dw} = -(-1) = 1$

Task 2. (a) $f_p = \frac{4000}{16000} = \frac{1}{4}$ $\quad f_s = \frac{5000}{16000} = \frac{5}{16}$

$\Delta f = \frac{5}{16} - \frac{1}{4} = \frac{1}{16}$

So Normalized pass frequency is $\frac{1}{4}$, stop is $\frac{5}{16}$

the width of transition band is $\frac{1}{16}$

(b) i : as formula. $\Delta f = \frac{0.9}{N}$.

$\therefore N = \frac{0.9}{\Delta f} = \frac{0.9}{\frac{1}{16}} = 15.$

ii : $N = \frac{3.1}{\frac{1}{16}} = 51$

iii : $N = \frac{3.3}{\frac{1}{16}} = 53$

iv : $N = \frac{5.5}{\frac{1}{16}} = 89.$

Task3: $f_p = \frac{12}{32} = \frac{3}{8}$ $f_s = \frac{13.5}{32} = \frac{27}{64}$

$\Delta f = \frac{27}{64} - \frac{24}{64} = \frac{3}{64}$

$f_c = \frac{f_p + f_s}{2} = \frac{51}{128}$

$$h(n) = \begin{cases} 2f_c \operatorname{sinc}(n \cdot 2\pi f_c) & n \neq 0 \\ 2f_c & n = 0 \end{cases}$$

$$= \begin{cases} \frac{51}{64} \times \operatorname{sinc}\left(\frac{51\pi}{64} \cdot n\right) & n \neq 0 \\ \frac{51}{64} & n = 0 \end{cases}$$

For Hamming: $N = \frac{3.3}{\Delta f} = 71$

$$w(n) = \begin{cases} 0.54 + 0.46 \cos\left(\frac{2\pi \cdot n}{71}\right) & |n| \leq \frac{N-1}{2} = 35 \\ 0 & \text{otherwise.} \end{cases}$$

$$h_t(n) = w(n)h(n)$$

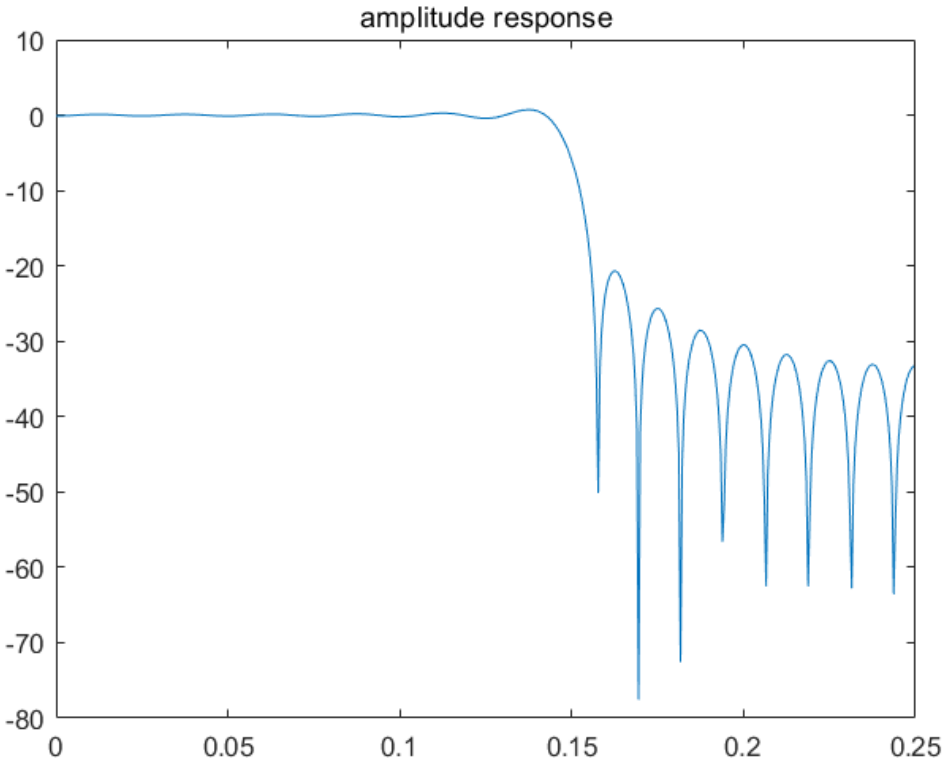
$$= \begin{cases} \frac{51}{64} \times \left(0.54 + 0.46 \cos\left(\frac{2\pi n}{71}\right)\right) \times \operatorname{sinc}\left(\frac{51\pi}{64} \cdot n\right); & 0 < n \leq 35 \\ \frac{51}{64}; & n = 0 \\ 0; & \text{otherwise.} \end{cases}$$

For Blackman: $N = \frac{5.5}{\Delta f} = 119$

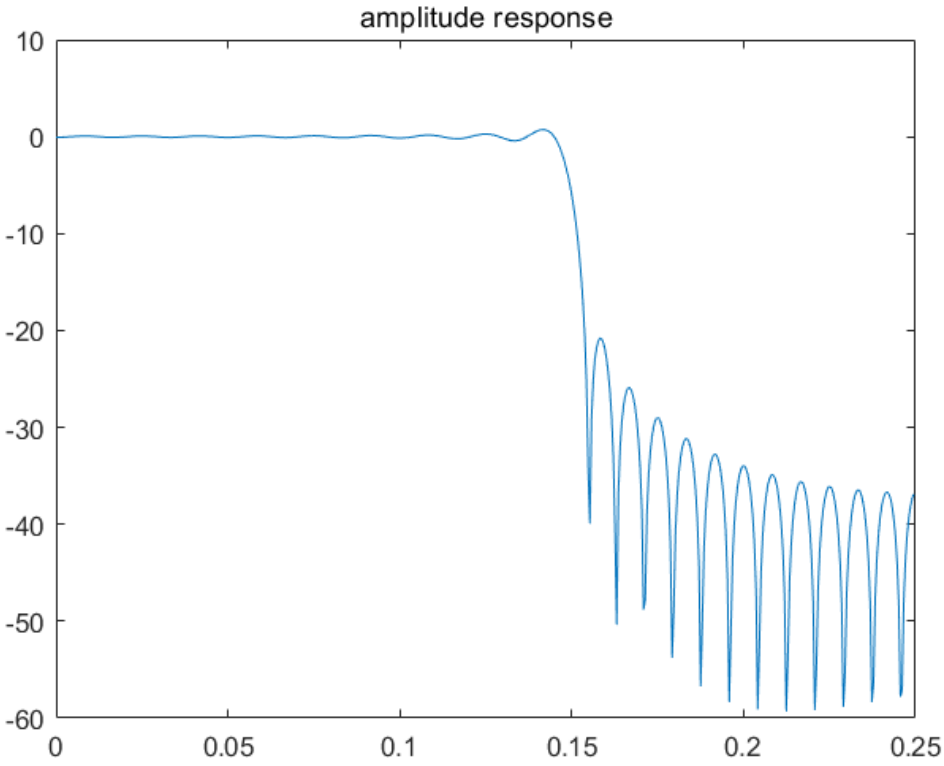
$$w(n) = \begin{cases} 0.42 + 0.5 \cos\left(\frac{2\pi n}{119}\right) + 0.08 \cos\left(\frac{4\pi n}{119}\right); & |n| \leq 59 \\ 0; & \text{otherwise.} \end{cases}$$

$$h_t = w(n)h(n) = \begin{cases} \frac{51}{64} \times \left(0.42 + 0.5 \cos\left(\frac{2\pi n}{119}\right) + 0.08 \cos\left(\frac{4\pi n}{119}\right)\right) \\ \quad \times \operatorname{sinc}\left(\frac{51}{64} \cdot \pi \cdot n\right); & 0 < n \leq 59 \\ \frac{51}{64}; & n = 0 \\ 0; & \text{otherwise} \end{cases}$$

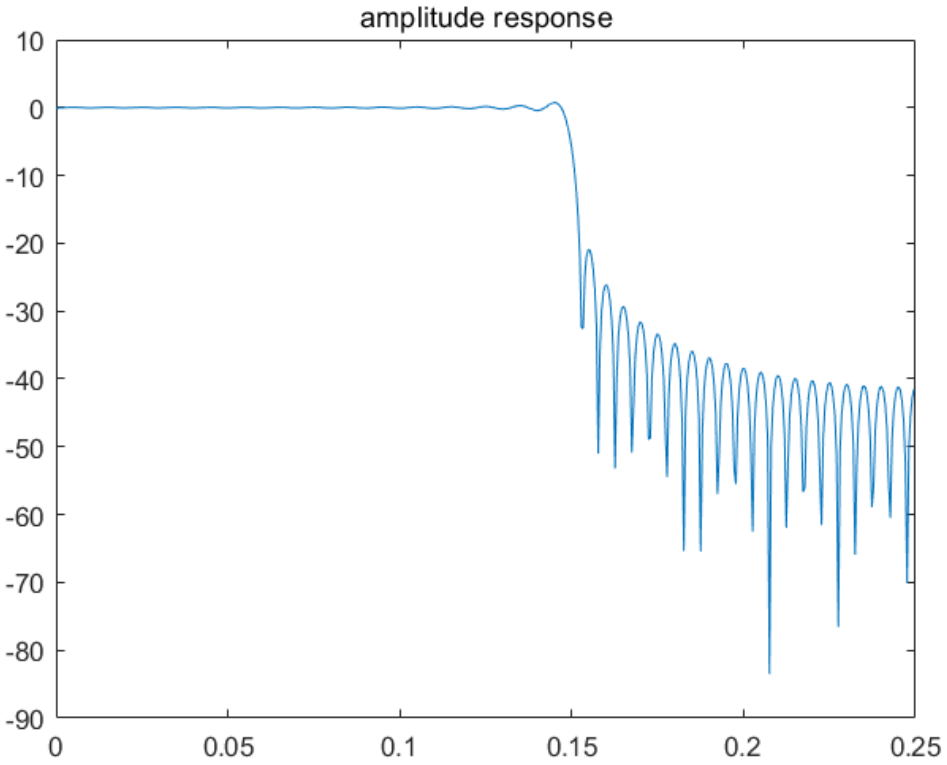
task4



a) The attenuation of the first (the leftmost) oscillatory peak inthe stopband is -20

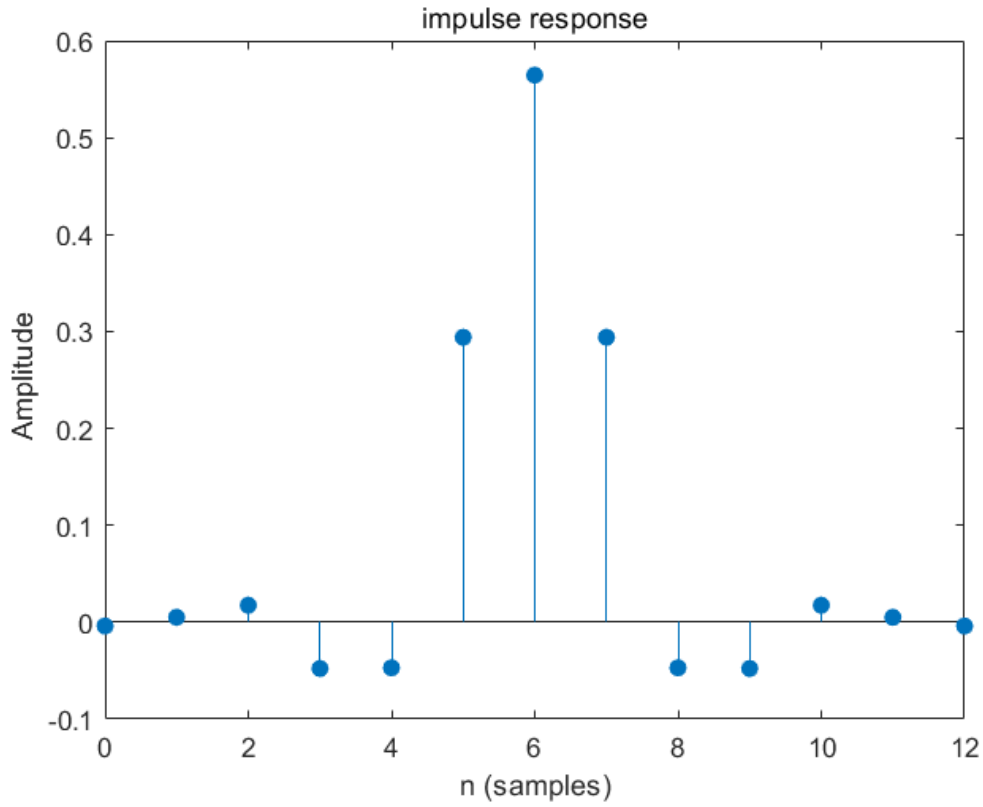


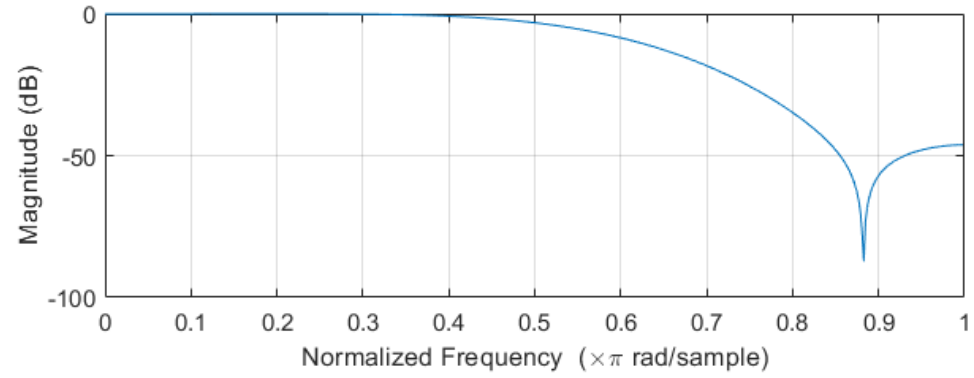
b) The first peak value is still -20,but it get a little bit eraly on x axis

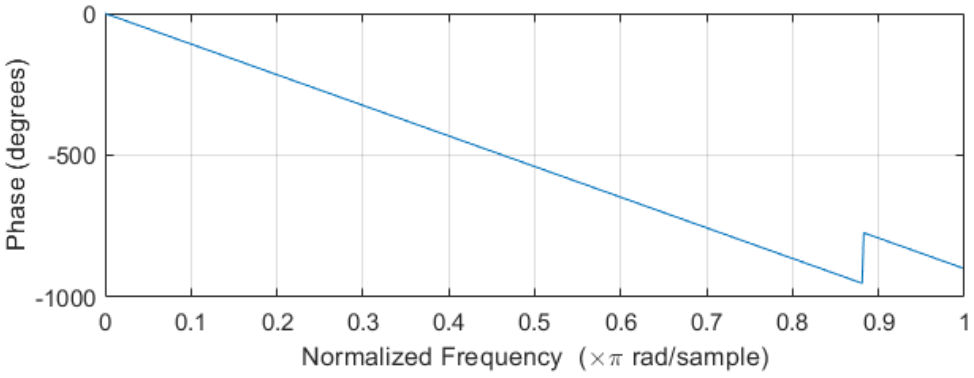


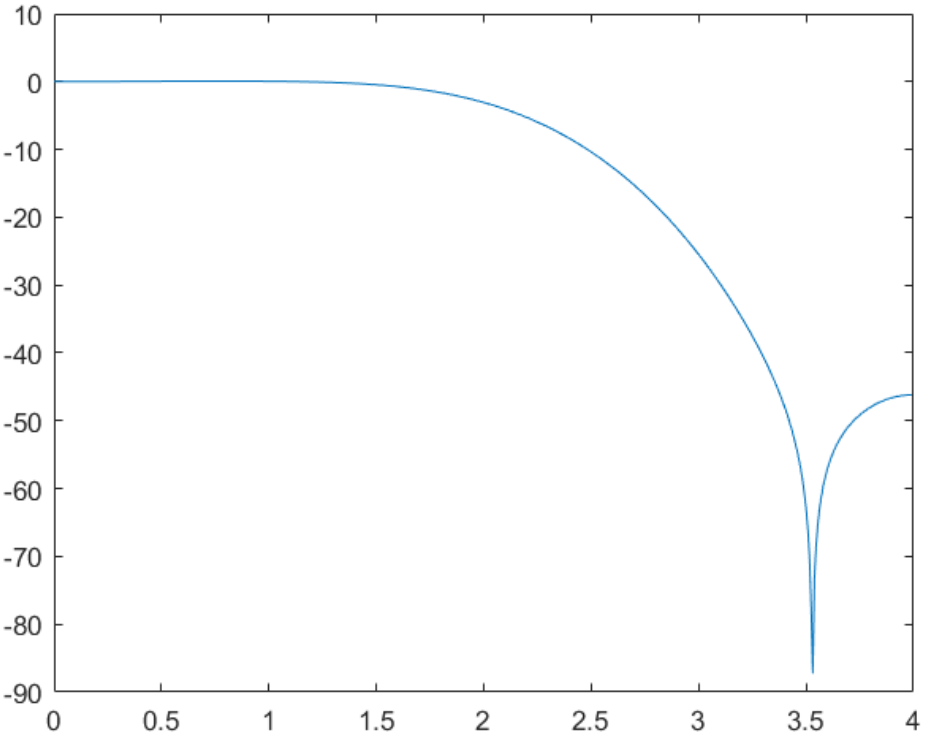
c) The first peak value is still -20,but it get a little bit eraly on x axis.Change N cannot change the stopband attenuation

task5

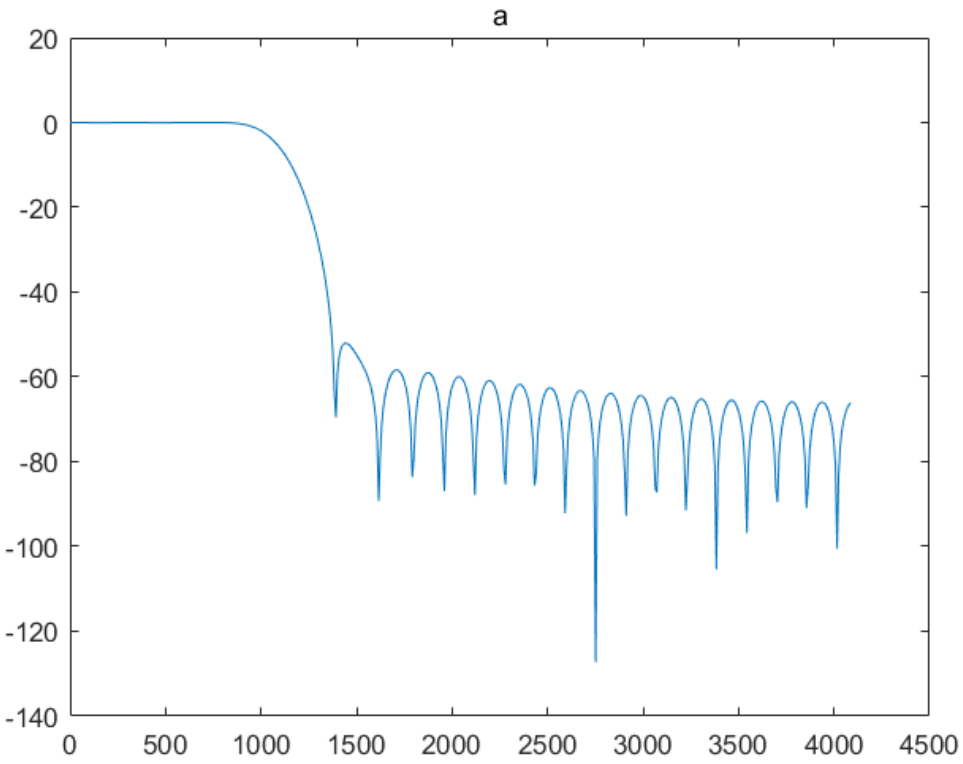

impulse response
Amplitude
n (samples)
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
0
2
4
6
8
10
12

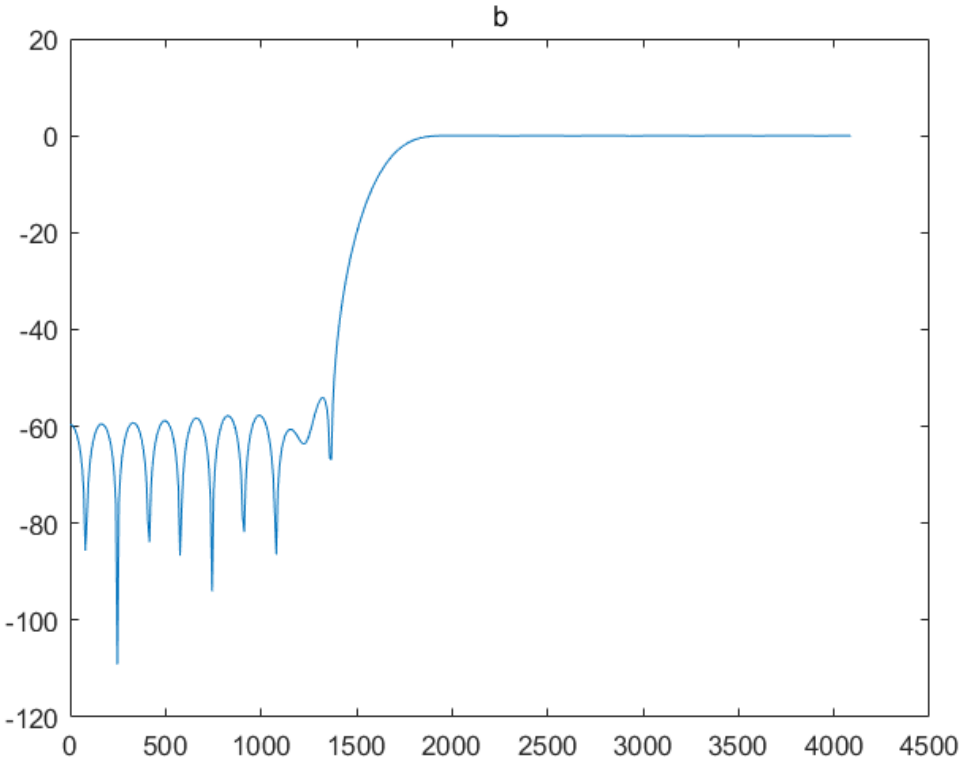

Magnitude (dB)
Normalized Frequency (×π rad/sample)
0
-50
-100
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

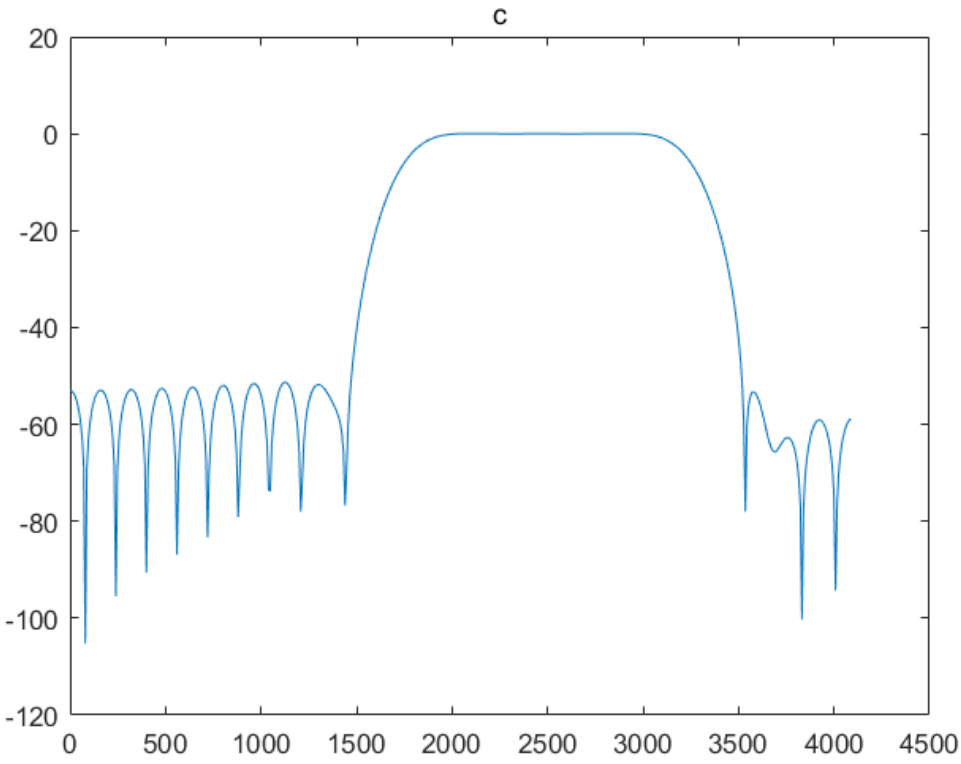

Phase (degrees)
Normalized Frequency (×π rad/sample)
0
-500
-1000
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

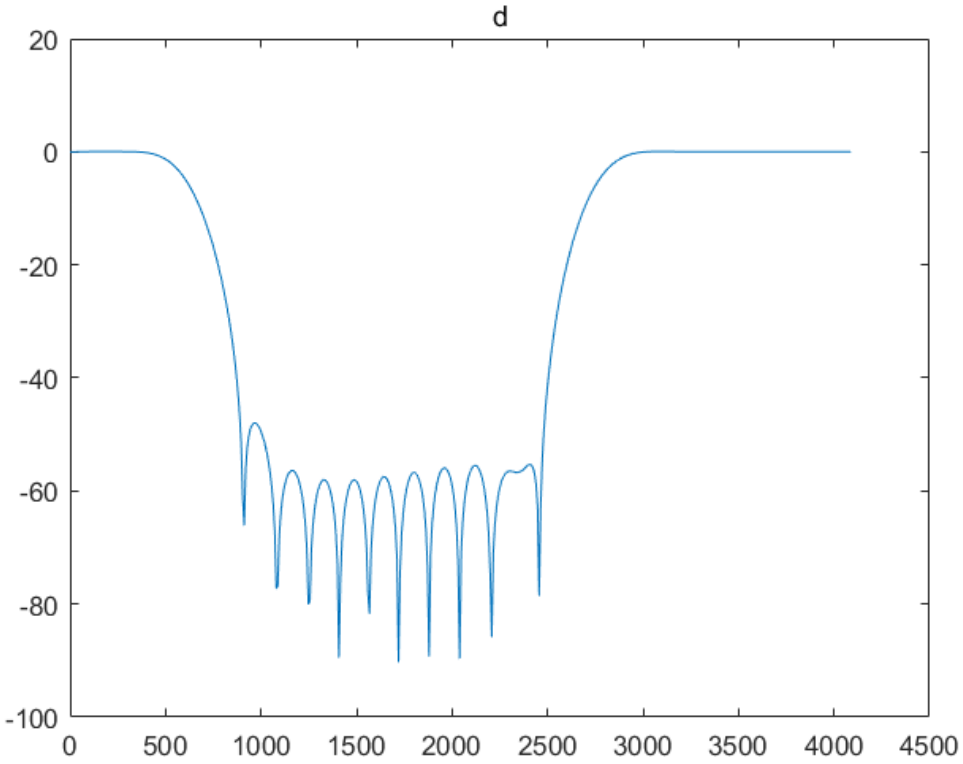

10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
0
0.5
1
1.5
2
2.5
3
3.5
4

task6

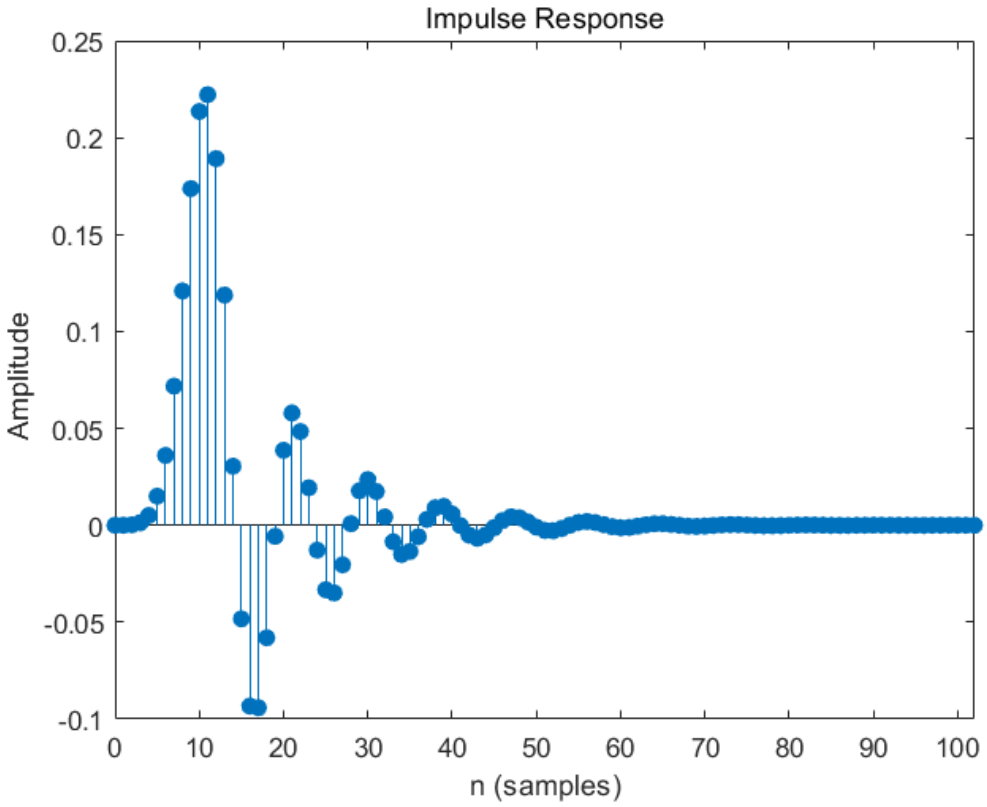

a
20
0
-20
-40
-60
-80
-100
-120
-140
0
500
1000
1500
2000
2500
3000
3500
4000
4500

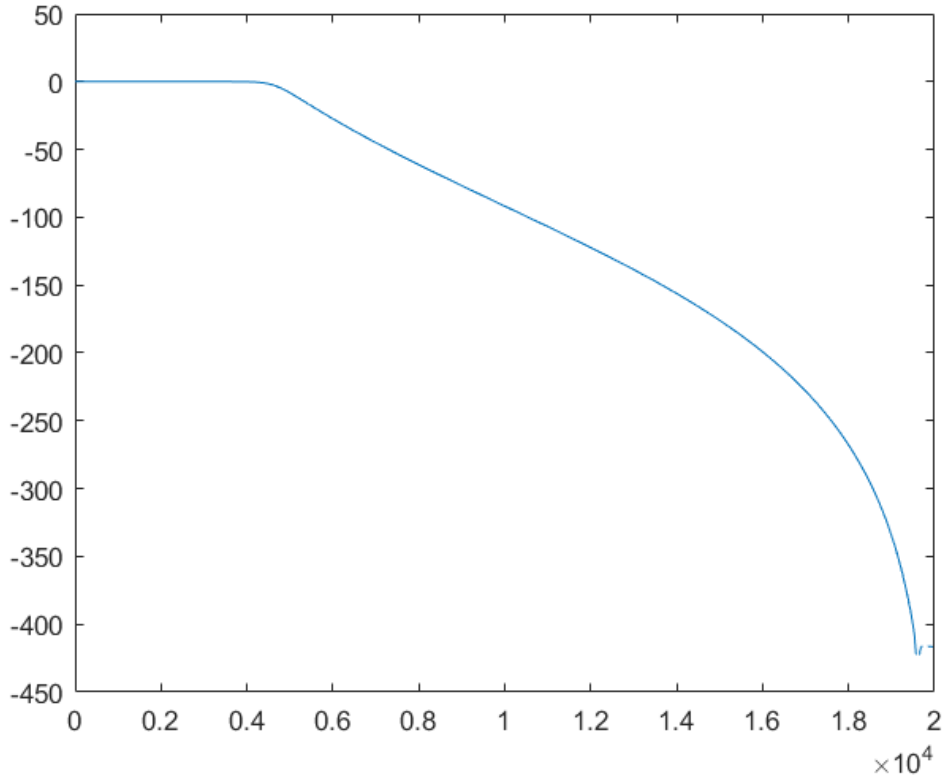

b
20
0
-20
-40
-60
-80
-100
-120
0
500
1000
1500
2000
2500
3000
3500
4000
4500


c
20
0
-20
-40
-60
-80
-100
-120
0
500
1000
1500
2000
2500
3000
3500
4000
4500


d
20
0
-20
-40
-60
-80
-100
0
500
1000
1500
2000
2500
3000
3500
4000
4500

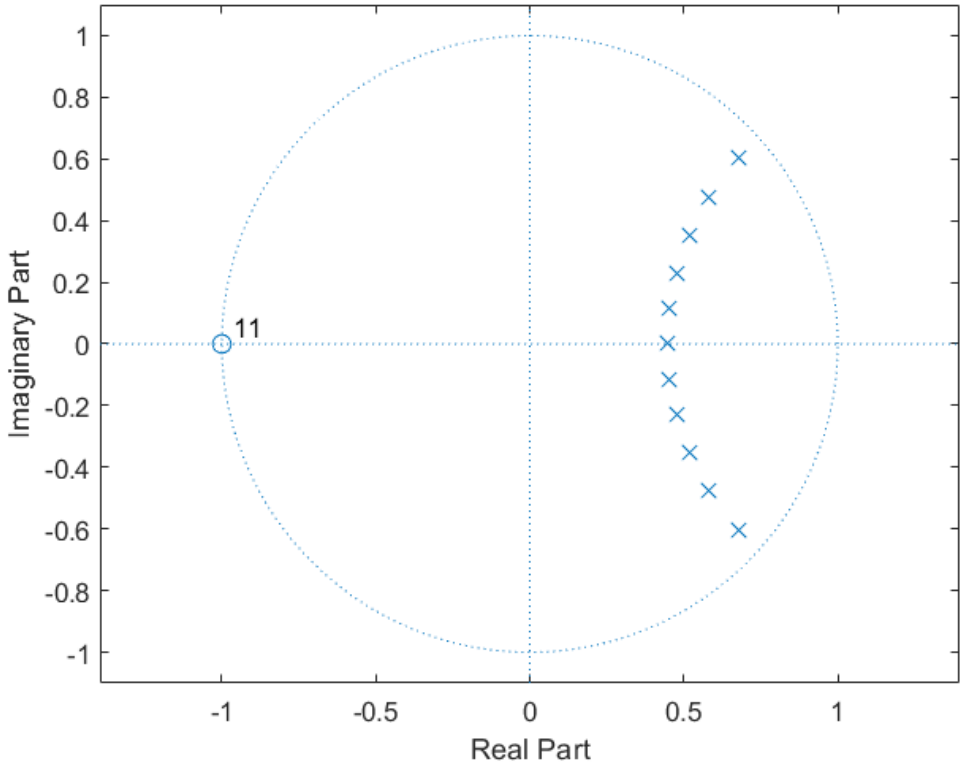
task7


Impulse Response
Amplitude
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
0
10
20
30
40
50
60
70
80
90
100
n (samples)



-1
-1
-1
-1
-1
-1
-1
-1
-1
-1
-1

0.6800 + 0.6034i
0.6800 - 0.6034i
0.5829 + 0.4754i
0.5829 - 0.4754i
0.5181 + 0.3510i
0.5181 - 0.3510i
0.4768 + 0.2311i
0.4768 - 0.2311i
0.4539 + 0.1146i
0.4539 - 0.1146i
0.4465 + 0.0000i



task8 & task9, see the code in design_low_pass.m

task10

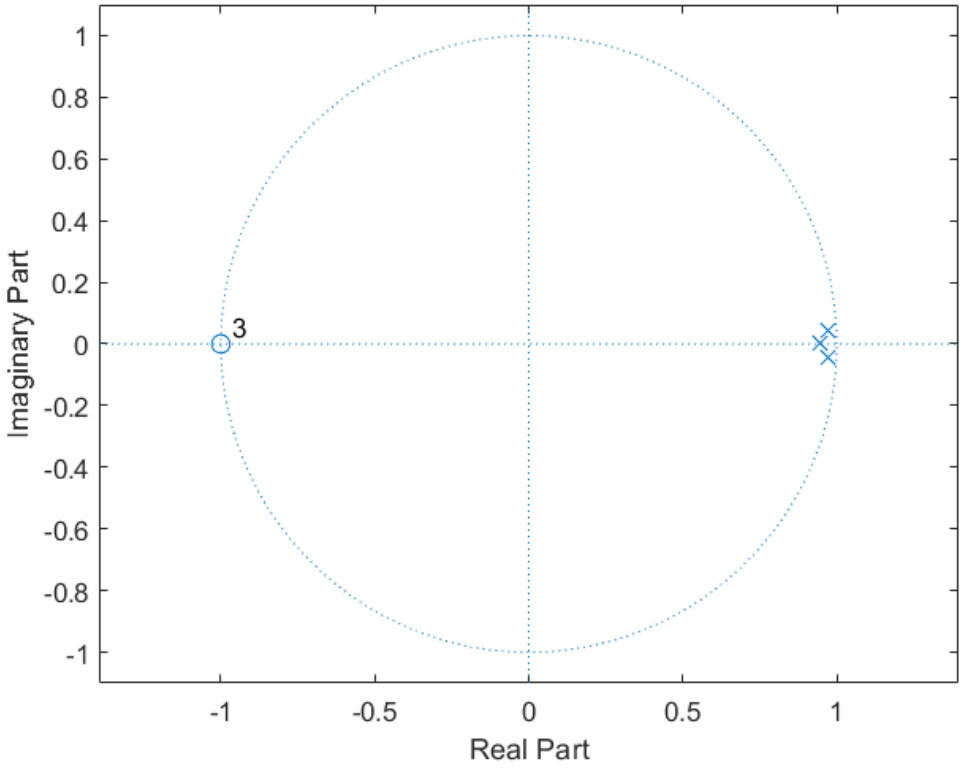
N = 1×4

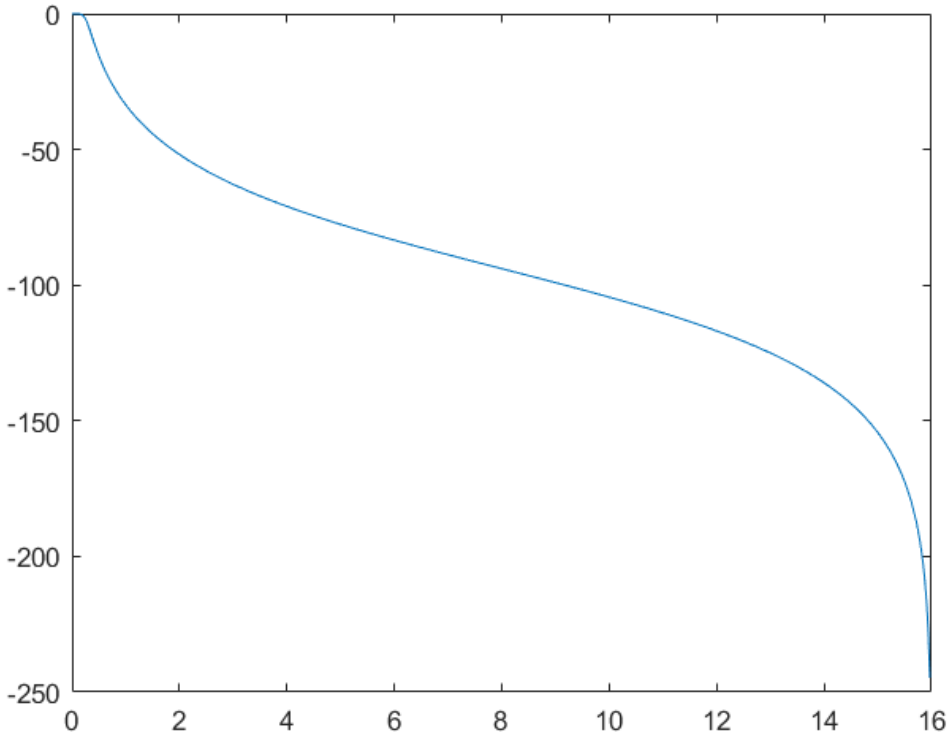
10^{-4} ×

0.1903 0.5708 0.5708 0.1903

D = 1×4

1.0000 -2.8913 2.7884 -0.8970


Imaginary Part
Real Part
3
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-1
-0.5
0
0.5
1


0
-50
-100
-150
-200
-250
0
2
4
6
8
10
12
14
16