CSP Lab | Assignment 2 Report
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Aim: Design of digital filters such as Low Pass Filter (LPF), Band Pass Filter (BPF).

Designs Given:

1. LPF or Half band filter with fc = 400 Hz, ωc = π/2, N = 39

$$h_d[n] = \begin{cases} \dfrac{Sin(\omega_c\, n)}{\pi\, n}, & -(N-1)/2 \le n \le (N-1)/2 \\ \dfrac{\omega_c}{\pi}, & n = 0 \end{cases}$$

2. LPF with fc = 400 Hz, ωc = π/4, N = 39
3. BPF with fc1 = 500 Hz, fc2 = 1200 Hz, fs = 6000 Hz, N = 39

$$h_d[n] = \begin{cases} \dfrac{Sin(\omega_{c2} n)}{\pi\, n} - \dfrac{Sin(\omega_{c1}\, n)}{\pi\, n}, & -(N-1)/2 \le n \le (N-1)/2 \\ \dfrac{\omega_{c2} - \omega_{c1}}{\pi}, & n = 0 \end{cases}$$

Window function to be used : **Hamming Window**

$$W_H[n] = \begin{cases} 0.54 - 0.46\cos\left(\frac{2\pi n}{N-1}\right), & if\ 0 \le n \le N-1 \\ 0, & otherwise \end{cases}$$

Understanding:

We know the conversion between analog & digital frequency is given below relation:

Digital frequency = 2π(analog frequency)/(sampling frequency)

Using above relationship, we can infer following for given designs:

Design 1: (LPF, wc = pi/2)

- Sampling frequency = 1600 Hz

Design 2: (LPF, wc = pi/4)

- Sampling frequency = 3200 Hz

Design 3: (BPF, fc1 = 500 Hz, fc2 = 1200 Hz)

- wc1 = π/6
- wc2 = 2π/5

C functions have been written in a common_functions header file which contains implementation for hamming window design, low pass filter design and band pass filter design. Functions take in parameters as below :

- Window Function : **float* hammingWindow(int N)** | N : No. of filter taps
- LPF Function : **float* lpf(int fc, int fs, int N)**
- BPF Function : **float* bpf(int fc1, int fc2, int fs, int N)**

Output:

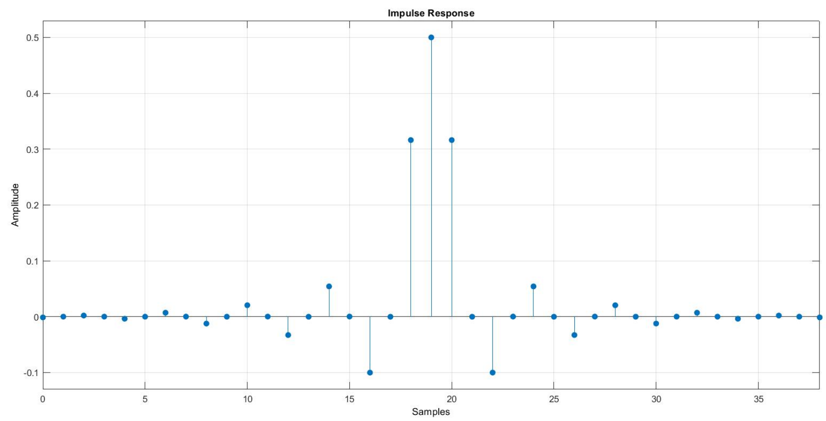
Low Pass Filter (wc = pi/2) Output:
-0.001340, -0.000017, 0.001964, 0.000027, -0.003756, -0.000046, 0.007062, 0.000072, -0.012360, -0.000101, 0.020444, 0.000131, -0.032960, -0.000159, 0.054209, 0.000182, -0.100205, -0.000196, 0.316214, **0.500000**, 0.316153, -0.000196, -0.100146, 0.000182, 0.054155, -0.000159, -0.032911, 0.000131, 0.020403, -0.000101, -0.012327, 0.000071, 0.007039, -0.000046, -0.003741, 0.000027, 0.001957, -0.000017, -0.001340,

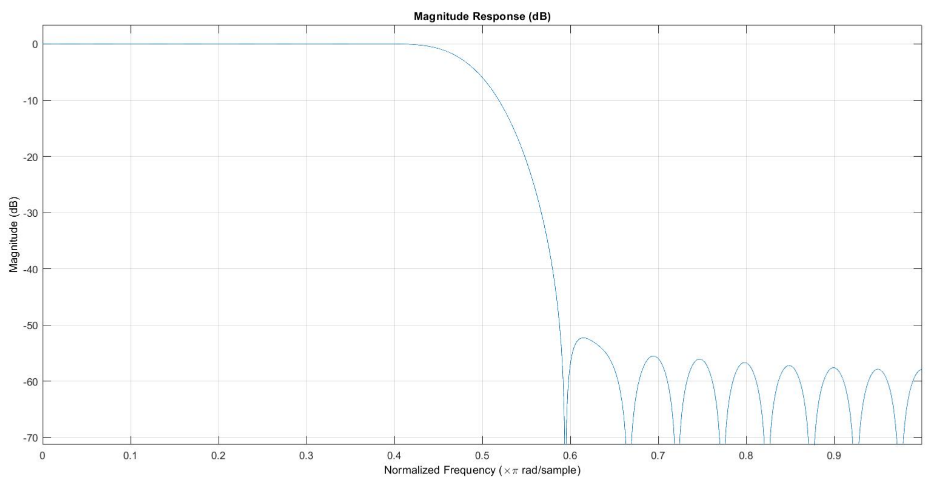
Low Pass Filter (wc = pi/4) Output:
0.000942, 0.001525, 0.001396, 0.000014, -0.002643, -0.005195, -0.005014, -0.000036, 0.008710, 0.015982, 0.014498, 0.000066, -0.023254, -0.041996, -0.038392, -0.000091, 0.070788, 0.155153, 0.223668, **0.250000**, 0.223625, 0.155092, 0.070747, -0.000091, -0.038354, -0.041945, -0.023220, 0.000066, 0.014469, 0.015945,
0.008687, -0.000036, -0.004998, -0.005175, -0.002633, 0.000014, 0.001391, 0.001522, 0.000942,

Band Pass Filter (fs = 6000) Output:
-0.000596, -0.000902, 0.000165, 0.000240, -0.003728, -0.009435, -0.007737, 0.005469, 0.017932, 0.013905, 0.001030, 0.007166, 0.035801, 0.040033, -0.026918,
-0.130486, -0.159227, -0.043329, 0.142622, **0.233333**, 0.142595, -0.043313, -0.159134, -0.130383, -0.026891, 0.039984, 0.035748, 0.007154, 0.001027, 0.013873, 0.017884, 0.005453, -0.007711, -0.009400, -0.003713, 0.000239, 0.000164, -0.000900, -0.000596,

Results:

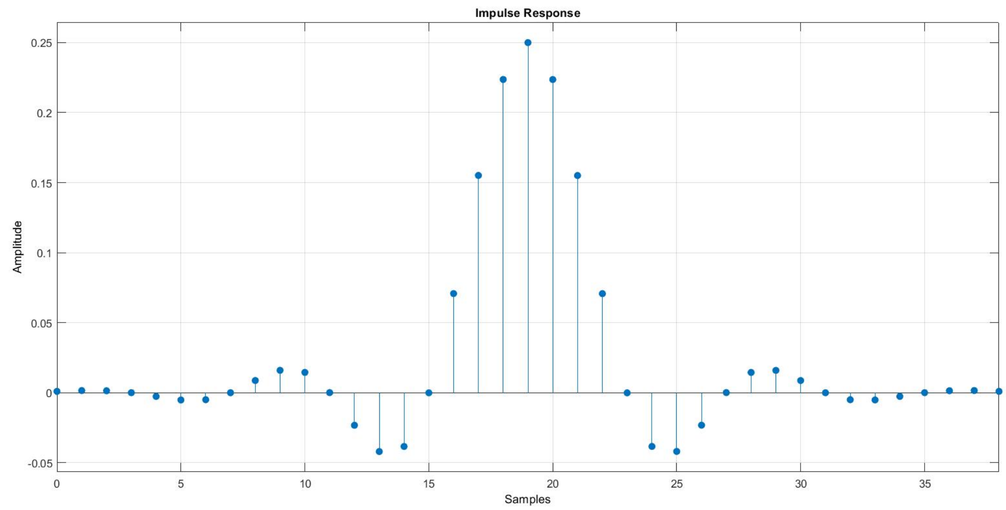
1. Wc = pi/2 , LPF Design

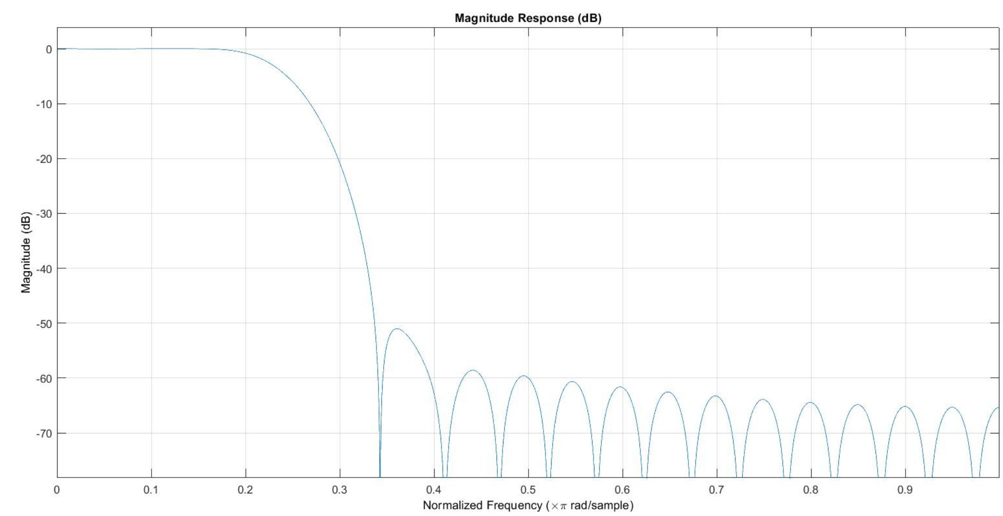




We can observe that cutoff frequency in magnitude response is inline with wc parameter i.e. **0.5*pi**

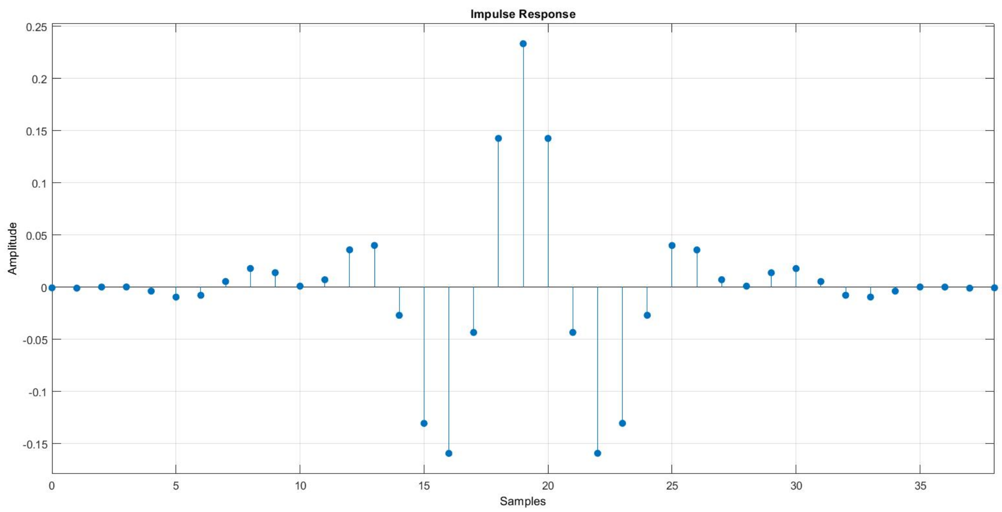
2. Wc = pi/4, LPF Design

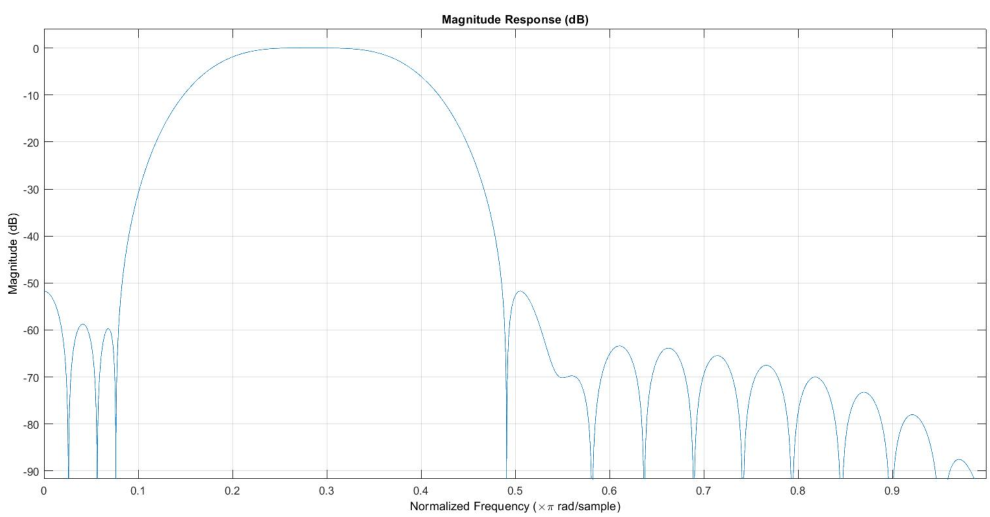




We can observe that cutoff frequency in magnitude response is inline with wc parameter i.e. **0.25*pi**

3. BPF Design, wc1 = pi/6, wc2 = 2*pi/5





We can observe that cutoff frequencies in magnitude response is inline with wc1 & wc2 parameter i.e. **wc1 = 0.167*pi & wc2 = 0.4*pi**