# Filter Design Assignment-II

## EE338 - 2023
## Chebyshev Bandpass Filter Review Report

Ojas Karanjkar
210070040

# Contents

# 1 Student Details

- Name : Ojas Karanjkar
- Roll No: 210070040
- Filter number assigned: 103

# 2 Chebyshev Bandpass Filter Details

## 2.1 Un-normailzed Discrete time specifications

- 1. m = 23
  2. q(m) = [2.3] = 2
  3. r(m) = 23 - 10*2 = 3
  4. BL(m) = 20 + 3*2 + 11*3 = 59
  5. BH(m) = 59 + 75 = 134
- Passband = 59 kHz to 134 kHz.
- Transition Band Width = 5 kHz.
- Stopband = 0 to 54 kHz and 139 to 300 kHz.
- Tolerance = 0.15.
- Nature of Passband = Equiripple.
- Nature of Stopband = Monotonic.

## 2.2 Normailzed discrete filter specifications

Sampling frequency = $600kHz$

$$\omega = \frac{\Omega * 2\pi}{\Omega_{sampling}} \tag{1}$$

- Passband = $0.1967\pi$ to $0.4467\pi$ .
- Transition Band Width = $0.0167\pi$ .
- Stopband = 0 to 0.18 and $0.4633\pi$ to $\pi$ .
- Tolerance = 0.15.
- Nature of Passband = Equiripple.
- Nature of Stopband = Monotonic.

## 2.3 Converting to Analog Low-pass filter

We have the following transformation for converting into analog low-pass filter:

$$\Omega = tan(\frac{\omega}{2}) \tag{2}$$

Using the above Bilinear Transformation, the passband and stopband specifications are updated as follows:

- Passband = 0.3191 to 0.8451 .
- Transition Band = 0.2905 to 0.3191 and 0.8451 to 0.8910 .
- Stopband = 0 to 0.2905 and 0.8910 to $\infty$ .
- Tolerance = 0.15.
- Nature of Passband = Equiripple.
- Nature of Stopband = Monotonic.

## 2.4 Frequency Transformation for Band-Stop Filter

The frequency transformation for converting a bandpass filter to low pass filter are as follows:

$$\Omega_L = \frac{\Omega_0^2 - \Omega^2}{B\Omega} \tag{3}$$

$$B = \Omega_{p2} - \Omega_{p1} \tag{4}$$

$$\Omega_0 = \sqrt{\Omega_{p1}\Omega_{p2}} \tag{5}$$

According to the above transformation, we can tabulate the updated value of passband and stopband edges:

| $\Omega$ | $\Omega_L$ |
|---|---|
| $0^+$ | $-\infty$ |
| $0.3191(\Omega_{p1})$ | $-1$ |
| $0.2905(\Omega_{s1})$ | $-1.2127$ |
| $0.5193(\Omega_0)$ | 0 |
| $0.8910(\Omega_{s2})$ | 1.1185 |
| $0.8451(\Omega_{p2})$ | 1 |
| $\infty$ | $\infty$ |

- Passband edge = 1 ($\Omega_{lp}$)
- Stopband edge = 1.1185 ($\Omega_{ls}$)

- Tolerance = 0.15.
- Nature of Passband = Equiripple.
- Nature of Stopband = Monotonic.

## 2.5 Analog Lowpass Transfer Function

Tolerance = 0.15

$$D_1 = \frac{1}{(1-\delta)^2} - 1 = 0.3844 \tag{6}$$

$$D_2 = \frac{1}{\delta^2} - 1 = 43.44 \tag{7}$$

We take $\epsilon$ to be equal to $\sqrt{D_1}$ and calculate N as follows:

$$N \geq \lceil \frac{cosh^{-1}\sqrt{\frac{D_2}{D_1}}}{cosh^{-1}\frac{\Omega_{Ls}}{\Omega_{Lp}}} \rceil \tag{8}$$

Substituting the values in above equation gives N to be equal to 7.

### 2.5.1 Finding Poles of the transfer function

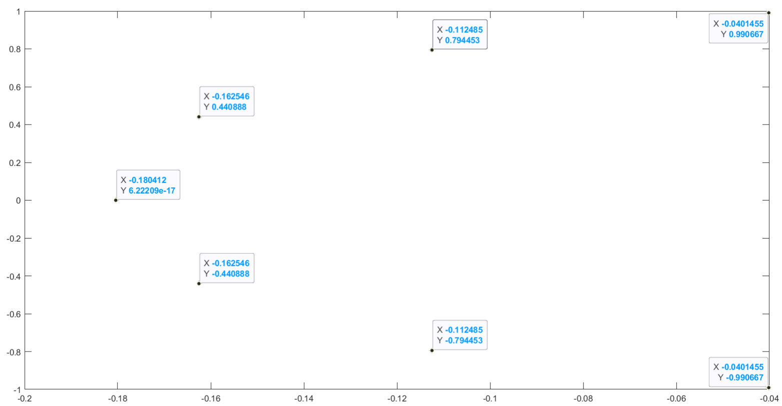
Poles can be found using the following expression:

$$1 + 0.3841cosh^2(7cosh^{-1}()\frac{s}{\iota}) = 0 \tag{9}$$

Upon solving the above equation we get the following value of poles in open left half complex plane:

$$\begin{gathered} \text{p1} = -0.1625 + \iota 0.4409 \\ \text{p2} = -0.1625 - \iota 0.4409 \\ \text{p3} = -0.0.401 + \iota 0.9907 \\ \text{p4} = -0.0.401 - \iota 0.9907 \\ \text{p5} = -0.1125 + \iota 0.7945 \\ \text{p6} = -0.1125 - \iota 0.7945 \\ \text{p7} = -0.1804 \end{gathered}$$

The plot of the poles of the magnitude response of the Analog Lowpass filter plotted in python is as follows:-




Poles of Magnitude response

The Transfer Function of the Analog Lowpass Filter:

$$H_{analog,LPF}(s_L) = \frac{(-1)^N p_1 p_2 p_3 p_4 p_5 p_6 p_7}{\Pi_{i=1}^{7}(s - p_i)}$$

## 2.6 Analog Bandstop Transfer Function

Now we need to transform the Analog Lowpass filter back to Analog Bandpass filter using the same transformation we used earlier.

$$s_L = \frac{\Omega_0^2 + s^2}{Bs}$$

Thus

$$s_L = \frac{0.2697 + s^2}{0.5259s}$$

Substituting this value of $s_L$ into the above Analog Lowpass Filter Tranfer Function to get the Analog Bandpass Filter Tranfer function i.e $H_{analog,BPF}(s)$. Numerator and Denominator coefficients are as follows:

| Powers of s in Denominator | Coefficients |
|---|---|
| $s^{14}$ | 1 |
| $s^{13}$ | 0.4264 |
| $s^{12}$ | 2.4628 |
| $s^{11}$ | 0.8688 |
| $s^{10}$ | 2.3978 |
| $s^{9}$ | 0.6767 |
| $s^{8}$ | 1.1857 |
| $s^{7}$ | 0.2556 |
| $s^{6}$ | 0.3198 |
| $s^{5}$ | 0.0492 |
| $s^{4}$ | 0.0470 |
| $s^{3}$ | 0.0046 |
| $s^{2}$ | 0.0035 |
| $s^{1}$ | 0.0002 |
| $s^{0}$ | 0.0001 |

| Powers of s in Numerator | Coefficients |
|---|---|
| $s^{7}$ | 0.2806 |

| Powers of z in Denominator | Coefficients |
|---|---|
| $z^{-14}$ | 1 |
| $z^{-13}$ | -7.1112 |
| $z^{-12}$ | 27.3168 |
| $z^{-11}$ | -71.8033 |
| $z^{-10}$ | 142.5073 |
| $z^{-9}$ | -224.0436 |
| $z^{-8}$ | 286.1419 |
| $z^{-7}$ | -300.7474 |
| $z^{-6}$ | 261.3445 |
| $z^{-5}$ | -186.8610 |
| $z^{-4}$ | 108.5512 |
| $z^{-3}$ | -49.8857 |
| $z^{-2}$ | 17.3512 |
| $z^{-1}$ | -4.3110 |
| $z^{0}$ | 0.5295 |

| Powers of s in Numerator | Coefficients |
|---|---|
| $z^{-12}$ | -0.0002 |
| $z^{-10}$ | 0.0006 |
| $z^{-8}$ | -0.0010 |
| $z^{-6}$ | 0.0010 |
| $z^{-4}$ | -0.0006 |
| $z^{-2}$ | 0.002 |

## 2.7 Peer Review

I have reviewed the chebyschev filter design of Kushal Gajbe, Roll No. 210070048. I have gone through his matlab code for chebyshev bandpass filter. I have observed that, he made functions for calculating the values of the parameters for the filter and transformation as well. I have checked the correctness of those functions and can say that the values he got are correct.I have cross checked the value of poles and those are correct as well. Finally, he has correctly written the transfer functions and the magnitude and phase response plots are correct as well. Hence, I certify the chebyschev bandpass filter, that Kushal Gajbe has designed to be correct.