Filter Design Assignment-I

EE338 - 2023
Filter Review Report

Ojas Karanjkar
210070040

Contents

1 Student Details

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

2 Butterworth Bandstop 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 + 40 = 99
- Stopband = 59 kHz to 99 kHz.
- Transition Band Width = 5 kHz.
- Passband = 0 to 54 kHz and 104 to 212.5 kHz.
- Tolerance = 0.15.
- Nature of Passband and Stopband : Both monotonic.

2.2 Normailzed discrete filter specifications

Sampling frequency = $425kHz$

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

- Stopband = 0.27π to 0.46π .
- Transition Band Width = 0.0235π .
- Passband = 0 to 0.25 and 0.48π to π .
- Tolerance = 0.15.
- Nature of Passband and Stopband : Both monotonic.

2.3 Converting to Analog Low-pass filter

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

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

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

- Stopband = 0.451 to 0.88 .
- Transition Band = 0.414 to 0.4509 and 0.88 to 0.939 .
- Passband = 0 to 0.414 and 0.939 to ∞ .
- Tolerance = 0.15.
- Nature of Passband and Stopband : Both monotonic.

2.4 Frequency Transformation for Band-Stop Filter

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

$$\Omega_L = \frac{B\Omega}{\Omega_0^2 - \Omega^2}$$
$$\text{B} = \Omega_{p2} - \Omega_{p1}$$
$$\Omega_0 = \sqrt{\Omega_{p1}\Omega_{p2}}$$

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

Ω	Ω_L
0^+	0^+
$0.414(\Omega_{p1})$	1.00
$0.451(\Omega_{s1})$	1.28
$0.623^-(\Omega_0)$	$-\infty$
$0.623^+(\Omega_0)$	$+\infty$
$0.88(\Omega_{s2})$	-1.19
$0.939(\Omega_{p2})$	-0.99
∞	0^-

- Passband edge = 1 (Ω_{lp})
- Stopband edge = 1.19 (Ω_{ls})
- Tolerance = 0.15.
- Nature of Passband and Stopband : Both monotonic.

2.5 Analog Lowpass Transfer Function

Tolerance = 0.15

$$D_1 = \frac{1}{(1-\delta)^2} - 1 = 0.3844$$
$$D_2 = \frac{1}{\delta^2} - 1 = 43.44$$
$$N \geq \lceil \frac{log(\frac{D_2}{D_1})}{2log(\frac{\Omega_s}{\Omega_p})} \rceil$$
$$N = 14$$
$$\frac{\Omega_p}{D_1^{\frac{1}{2N}}} \leq \Omega_c \leq \frac{\Omega_s}{D_2^{\frac{1}{2N}}}$$
$$1.03467 \leq \Omega_c \leq 1.040042$$
$$\Omega_c = 1.037$$

2.5.1 Finding Poles of the transfer function

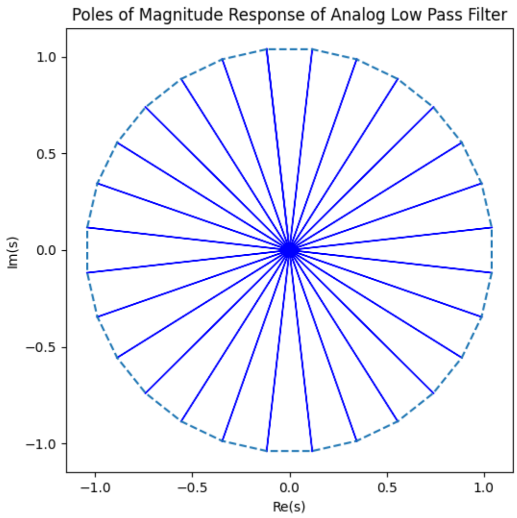
Poles can be found using the following expression:

$$1 + (\frac{s}{j\Omega_c})^{2N} = 0$$

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

p1 = -0.1161 - 1.0305i
p2 = -0.3425 - 0.9788i
p3 = -0.5517 - 0.8781i
p4 = -0.7333 - 0.7333i
p5 = -0.8781 - 0.5517i
p6 = -0.9788 - 0.3425i
p7 = -1.0305 - 0.1161i
p8 = -1.0305 + 0.1161i
p9 = -0.9788 + 0.3425i
p10 = -0.8781 + 0.5517i
p11 = -0.7333 + 0.7333i
p12 = -0.5517 + 0.8781i
p13 = -0.3425 + 0.9788i
p14 = -0.1161 + 1.0305i

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:

$$H_{analog,LPF}(s_L) =$$

$$\frac{\Omega_c^N}{(s_L-p_1)(s_L-p_2)(s_L-p_3)(s_L-p_4)(s_L-p_5)(s_L-p_6)(s_L-p_7)(s_L-p_8)(s_L-p_9)(s_L-p_{10})(s_L-p_{11})(s_L-p_{12})(s_L-p_{13})(s_L-p}$$

2.6 Analog Bandstop Transfer Function

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

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

Thus

$$s_L = \frac{0.525s}{0.6234 + s^2}$$

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

2.7 Peer Review

I have reviewed the assignment of Kushal Gajbe, Roll No. 210070048. His phase response is too smooth to be that of real life filter. Also it does not match (atleast the nature of his phase response) of the assignment which was given as reference. Magnitude response is fine. There seems to be calculation error in order and passband/stopband edges.

Powers of s in Denominator	Coefficients
s^{28}	1
s^{27}	4.5216
s^{26}	15.6636
s^{25}	38.1214
s^{24}	78.2437
s^{23}	133.00100
s^{22}	198.57304
s^{21}	258.8133
s^{20}	302.5689
s^{19}	316.1823
s^{18}	299.8353
s^{17}	257.2226
s^{16}	201.52
s^{15}	143.6732
s^{14}	93.8095
s^{13}	55.8353
s^{12}	30.4367
s^{11}	15.09
s^{10}	6.8393
s^{9}	2.8028
s^{8}	1.0423
s^{7}	0.3465
s^{6}	0.1033
s^{5}	0.0268
s^{4}	0.00614
s^{3}	0.001164
s^{2}	0.0001859
s^{1}	2.08e-05
s^{0}	1.79e-05

Powers of s in Numerator	Coefficients
s^{28}	1
s^{26}	5.44
s^{24}	13.7438
s^{22}	21.3649
s^{20}	22.8332
s^{18}	17.7472
s^{16}	10.34
s^{14}	4.5949
s^{12}	1.5625
s^{10}	0.404
s^{8}	0.07866
s^{6}	0.01111657
s^{4}	0.00108005
s^{2}	6.45e-05
s^{0}	1.79e-06

Powers of s in Denominator	Coefficients	Powers of s in Numerator	Coefficients
z^{-28}	1	z^{-28}	1
z^{-27}	9.57	z^{-27}	12.32
z^{-26}	50.54	z^{-26}	84.5647
z^{-25}	187.8297	z^{-25}	408.8093
z^{-24}	544.4017	z^{-24}	1539.5987
z^{-23}	1297.2673	z^{-23}	4755.4093
z^{-22}	2625.6999	z^{-22}	12439.4012
z^{-21}	4611.614	z^{-21}	28134.1051
z^{-20}	7134.3600	z^{-20}	55891.89107
z^{-19}	9826.3641	z^{-19}	98477.3500
z^{-18}	12143.8409	z^{-18}	155140.5032
z^{-17}	13542.3158	z^{-17}	219772.7785
z^{-16}	13681.73244	z^{-16}	28109.5449
z^{-15}	12555.8230	z^{-15}	325473.9455
z^{-14}	10482.1612	z^{-14}	281090.54498
z^{-13}	7964.1211	z^{-13}	219772.7785
z^{-12}	5503.5802	z^{-12}	155140.5032
z^{-11}	3453.45056	z^{-11}	98477.35009
z^{-10}	1962.1101	z^{-10}	155140.5032
z^{-9}	1004.2234	z^{-9}	219772.778
z^{-8}	461.69327	z^{-8}	281090.54498
z^{-7}	188.60517	z^{-7}	325473.9455
z^{-6}	67.7939	z^{-6}	12439.40124
z^{-5}	21.1230	z^{-5}	4755.4093
z^{-4}	5.58500	z^{-4}	1539.5987
z^{-3}	1.12327	z^{-3}	408.8093
z^{-2}	0.20558	z^{-2}	84.5647
z^{-1}	0.0245	z^{-1}	12.32868
z^{0}	000163	z^{0}	1.0000887