$\begin{array}{c} {\bf School\ of\ Engineering\ and\ Applied\ Science\ (SEAS)}\\ {\bf Ahmedabad\ University} \end{array}$

BTech(ICT) Digital Signal Processing (Section 1)

Laboratory Assignment-7 Question 2

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AIM: Design an IIR filter using impulse in-variance method using Chebyshev

- 1. Solution Problem-1
 - (a) Handwritten Analysis:

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Atso. Some more details over provided. Wi = locuses CutOff frequency = 0.37 Wh = Higher Cutoff frequency = 0.671 T = Sampling Time = 0.1 Sp = Penshand Ripple = 0.11	major	Calculating Major & Minor Axis, $Y_1 = \begin{pmatrix} B^2 + 1 \\ 2p \end{pmatrix} = \begin{pmatrix} (2.0347)^2 + 1 \\ 2x & 2.0347 \end{pmatrix}$ $Y_2 = \begin{pmatrix} p^2 - 1 \\ 2p \end{pmatrix} = \begin{pmatrix} (2.0347)^2 - 1 \\ 2x & 2.0347 \end{pmatrix}$
: $\&P = 1 - 1$: $\&P$		Finding the angular positions of poles, using this aquation, $ Q_{k} = (2k+N+1)\pi \text{where } k=0,1 $
NOW onwards, the order will be ansidered as N=2, as we are initally calculating for low pass filter,		for $k=0$
Parameter $B = \sqrt{1+\ell^2 + 1}$ $= \sqrt{(1+(0.5130)^2 + 1)} = \sqrt{2.0347}$ 0.5130	Step	Finding xis and y's for poles' equation, using those equation, $x_k = \frac{1}{2} \cos \varphi_k \qquad q_k = \frac{1}{2} \sin \varphi_k$
	AURUNUS In the questial, It is given that the order of the filter is 4. Also, some more details are provided. When I tigher Cutoff frequency = 0.37 When I tigher Cutoff frequency = 0.671 I = Sampling Fine = 0.11 Peck - to-Peck Passband Ripple = 1 - 1 Peck - to-Peck Passband Ripple = 1 - 1 Itte? (1-6)2 : &= 1 - 1 = 0.2625 (1-0.11)2 NOW onwards, the order will be considered as N=2, as we are initally calculating for low pass filter. Passmeter R = VIte2 + 1 // N E	AURUNUS In the questial, It is given that the order of the filter is 4. Also, some more details are provided. When I tigher Cutoff frequency = 0.57 When I tigher Cutoff frequency = 0.67 I = Sampling Time = 0.1 Sp = Pansband Pipple = 0.11 Peak - to-Peak Passband Pipple = 1 - 1 Ite? (1-6)2 : &= 1 - 1 = 0.2625 (1-0.11)2 NOW onwards, the order will be considered as N=2, as we are initally calculating for low pass filter, Parameter P = Vite? + 1 // N Creg.:

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	: b. 70.2977 + 0.7976 = 0.9748
For k=0, For k=1	1.1239
X.= 0.9716 cos (37) 71 = 0.7716 cos (57)	[: bo = 0.9745]
y. = 1.2630 sin(37) 24y = 1.2630 sin(57)	
0 (4) 0 (4)	: H(s) = b0 = 0.9745
	: H(S) = bo = 0.9745 (S-So)(S-SI)
from the above equation,	11 12 12 12 12 12 12 12 12 12 12 12 12 1
y = 0.8931 y = -0.8931	Simplifying the above equation,
	4(c) = A 9AUC -0
	H(S) = 0.9AUS () 82-(S1+S0)S+S0.S1
Graff Equation of Poles: Sk = 2x+ j/2k	
	$S_{1+S_{0}} = -0.5456 + j(0.8931) - 0.5456$ - $j(0.8931)$ = -1.0912 - (2)
$\begin{array}{c} \therefore S_0 = -0.5456 + j(0.8931) \\ S_1 = -0.5456 + j(-0.8931) \end{array}$	-j(0.8931)
31= 0.3936 1	=-1.0912
573 System function:	S, S = (-0.5456 + j(0.8931)) (-0.5456 - j(0.8931))
System function: H(S) = bo	1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
(S-So) (S-S1)	(Hexe's the form of (a-b)(a+b) = a2-b2)
Cohere, $b_0 = S_0 \cdot S_1$ $\sqrt{1+\epsilon^2}$	C. C (0 EUEC)2 - (-1) (0.8931)2
VITEZ	$S_1 \cdot S_0 = (0.5456)^2 + (-1)(0.8931)^2$ = 0.2978 + 0.3936 - 3
: bo = (-0.5456+10.8781)) x (-0.5456	= 1.0953
$\frac{1 + (0.8730)^{L}}{(-0.8731)} \times (-0.5456 + j(-0.8731))$ $= 0.2933 + j(-0.4832) + j(0.4832) + (+(0.8731)^{2})$	= 1.0953 Putting Ans. of 28 3 into equation (1),
VI+ (0.5730) ^L	: H(S) = 0.9745 - (9)
= 0.2977+ j(-0.4872)+ j(0.4872)	52+(1.0912)5+1.0953
+ (+(o.8931)2)	
1.1239	

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		MCS)= 86.56545
al Course of the City of		S4+10.284653+452.60252+1827.08965
grel/ Conversion of locapeas filter to Bandposs filter,		+31560.5529
Ismaless +1 Hez!		
From the question,		
0 I_ = W_ = 0.37 = 37 rad/see		= 86.5654 S ² (32+3.56968+944377)
7 0.1		
2) Ru = Wh = 0.67 = 67 red/sec		(82+6.7158 +334.194)
7 0.1		
		- 60 005 2
Replacing S to (52+ RIDH in the S(DH-NL)		= 86.565452
		(S+1.785 + 91.25)
equation (a) $\Rightarrow = S^2 + 187^2$		
375		[\$ +3.36] ² +322.9
$= S^2 + 177.6529$		
9.4285	Note:	AS I'm not able to find H(Z) from this way I have tried 2nd approach hese.
Other countries and	0/2	
:. H(s) = 0.9745		
$\frac{\left(S^{2}+177.6529\right)^{2}+\left(1.0912\right)\left(S^{2}+177.6529\right)}{9.4256}$		H(s) = 0.9745 (s.s.)(5-s.)
9.4250 / 9.4255 /		((S-S0)(S-S1))
A STANDARD TO SEA TO SE		
= 0.9745 x (9.4255)2		= 0.9945 A + B L 5-S0 S-S1
$(S^2+177.6529)^2+(1.0912)(S^2+177.6529)$ (9.4253)+		
		Milliana A + R = 1
(9.425 S) ² (1.0153		Where $A + B = 1$ $S-S_0$ $S-S_1$ $(S-S_0)(S-S_1)$
= 0.9745 × 88.8306 S ²		20 21 (2.38)(3.31)
54+355.305852+31560.5529		: (S-S1) A + B(S-S0) =1
+ 10.284653+ 1827.08905 + 92.296252		
T 97.29628		and the state of t

3	Page No.: Date: YOUVA
	When S=S,
	B = 1 $4 = 1$ $5 = 5$
	: A = -B
	A = 1 = -0.5598j $2 \times (0.8931)j$
	:. B = 0.5598j
	:. H(S) = 0.9745 x 0.5598 1 - 1 S-S, S-So)
	$= 0.5455$) $\begin{bmatrix} 1 & -1 \\ S-S_1 & S-S_0 \end{bmatrix}$
	Replacing S to S2 + 177.6529 9.425 x S This S = So. S1
	PRISE 084550 (1.0953) + 177.6529 9.425 × 8
	From eq (g) = [18.9764]
	:. H(s) = 0.5455) \$ - \$ [8.9764-SS, [8.9764-SS] This also Seens can't Solvable for H(z). (Manually)
7	This also seems can't solvable for H(z). (manually)

(b) Matlab Script:

```
1 % Name : Samarth Shah
2 % Roll No: AU1841145
_{3} % Lab7 ( Question_2 ) From the given transfer function co-efficients, get a plot
      of the
4 % IIR bandpass Chebyshev Prototype-1 Filter
5 clc ;
6 clear all;
7 close all ;
{\bf 8} %Cutoff low and high frequencies
9 Low_cut=0.3*pi;
10 High_cut=0.6*pi;
11 %Sampling Time T
12 S_time=0.1;
13 %Order of the filter, was given in the question
14 order = 4;
15 %Passband Ripple
16 p_ripple = 0.11;
17 %Converting Passband Ripple to db values
p_ripple_db=-20*log10(1-p_ripple);
20 W=sqrt(Low_cut * High_cut)/S_time;
Bandwidth=(High_cut - Low_cut)/S_time;
_{22} %Using Inbuilt function of Chebyshev Type I filter design. This will return
^{\rm 23} %Transfer function co-efficients a and b of H(s).
24 [b,a]=cheby1(order,p_ripple_db,1,'s');
25 %Converting Low-pass filter to band-pass filter
26 [d,c]=lp2bp(b,a,W,Bandwidth);
27 %Converting analog to digital domain (S->Z)
28 [f,e]=impinvar(d,c,10);
29 figure;
30 freqz(f,e); %Plotting the Magnitude and Phase response
31 figure;
32 zplane(f,e); %Plotting Zeros and poles
33
_{34} %From Handwritten analysis, defining co-efficients a and b of H(s):
35 %Transfer function co-efficients a and b.
a = [1, 1.0912, 1.0953];
b = [0, 0, 0.9745];
38 %Converting Low-pass filter to band-pass filter
39 [d,c]=lp2bp(b,a,W,Bandwidth);
40 %Converting analog to digital domain (S->Z)
41 [f,e]=impinvar(d,c,10);
42 figure;
43 freqz(f,e); %Plotting the Magnitude and Phase response
44 figure;
45 zplane(f,e); %Plotting Zeros and poles
```

(c) Simulation Output:

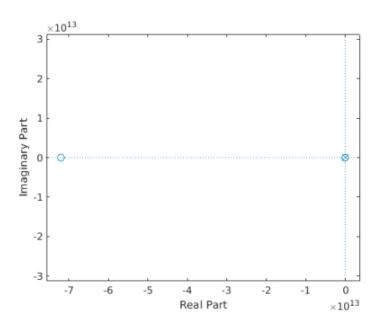


Figure 1: The image shows the value of poles. $\,$

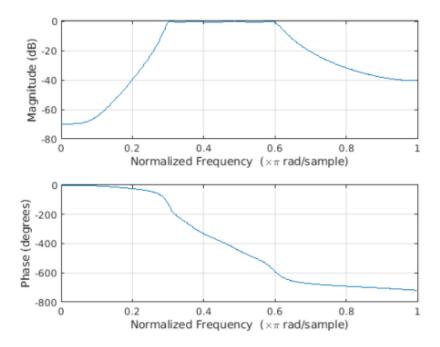


Figure 2: IIR lowpass Chebyshev Prototype-1 Filter (Magnitude and Phase Response)

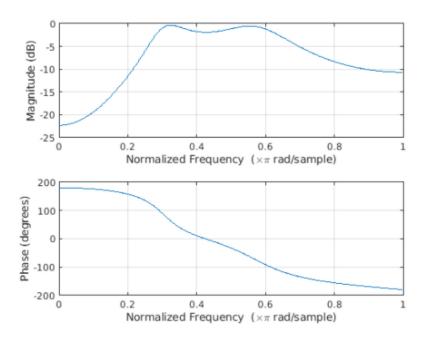


Figure 3: IIR lowpass Chebyshev Prototype-1 Filter from Handwritten Analysis (Magnitude and Phase Response)