Name: Nimra Naslv  Reg No: 19-CP-35  Section: Alpha  Submitted to: Str Majid  Date: 28-January-2022	
Digital Signal Processing	
Assignment: 04	
Questions:  Question: I  Determine the system function of the following signal flow graphs:  a)  x(n) wi(n) , wi(n) , wi(n) , wi(n) , wi(n) , y(n) , y(n) y(n)	
Solution: $w_1[n] = n[n] + \frac{1}{2} w_2[n-1]$	
$W_{2}[n] = W_{1}[n]$ $W_{3}[n] = W_{2}[n] - W_{2}[n-1] - 1 W_{4}[n-1]$ $W_{4}[n] = W_{3}[n]$ $Y[n] = W_{4}[n] = W_{3}[n]$	

In z-Hansform: $W_1(2) = X(2) + \frac{1}{2} = W_2(2) \rightarrow \mathbb{O}$
$W_{2}(z) = W_{1}(z) \longrightarrow \textcircled{2}$ $W_{3}(z) = W_{1}(z) - z' W_{2}(z) - \frac{1}{4} z' W_{4}(z) \longrightarrow \textcircled{3}$ $W_{4}(z) = W_{3}(z) - \textcircled{9}$ $Y(z) = W_{3}(z) - \textcircled{9}$
N Put eq (1) in eq (1) $W_1(z) = X(z) + \frac{1}{2} z^1 W_2(z) \rightarrow \mathbb{A}$
$W_3(z) = W_1(z) \left\{ 1 - z^{-1} \right\} - \left[ 1 - z^{-1} \right] W_3(z) - \boxed{B}$
By using Equation (A) ue get
$X(z) = W_1(z) - \frac{1}{2} z^{-1} W_1(z)$
$X(z) = W_1(z) \left\{ 1 - \frac{1}{2} - \frac{1}{2} \right\}$
$W_2(z) = \frac{X(z)}{\left(1 - \frac{1}{2}z^{-1}\right)}$
Put $w_{2}(2)$ in eq (B) $W_{3}(2) = X(2) (1-z^{-1}) - 1 z^{-1} w_{3}(2)$ $(1-1z^{-1}) \qquad \qquad$

As

$$W_3(z) = Y(z)$$
 $W_3(z) + \frac{1}{2} = \frac{1}{2} W_3(z) = X(z) (1-z^2)$ 
 $W_3(z) + \frac{1}{2} = \frac{1}{2} W_3(z) = X(z) (1-z^2)$ 
 $Y(z) = \frac{1}{2} = \frac{1}{2} \frac{1}{2$ 

	$W_{1}(z) = W_{1}(z) - \frac{1}{4}z^{-1} W_{3}(z) - 0$ $W_{1}(z) = W_{1}(z) + \frac{1}{2}z^{-1} W_{5}(z) - 0$ $W_{1}(z) = W_{1}(z) + \frac{1}{2}z^{-1} W_{5}(z) - 0$ $W_{2}(z) = W_{1}(z) + \frac{1}{2}z^{-1} W_{2}(z) - 0$ $Y(z) = W_{3}(z) + W_{3}(z) - 0$ $W_{1}(z) = X(z) - \frac{1}{2}z^{-1} W_{1}(z)$
	$W_{2}(z) = X(z) / (1 + 1 + 1 + 2)$ $W_{2}(z) = X(z) / (1 + 1 + 2)$ $W_{2}(z) = W_{3}(z)$
	$W_3(2) = W_3(2)$ $W_3(2) = X(2) / (1 + \frac{1}{4} z^{-1}) - B$ $W_5(2) = W_1(2) + \frac{1}{2} z^{-1} W_5(2)$
	$W_{5}(2) \left\{ 1 - \frac{1}{2} z^{-1} \right\} = W_{1}(2)$ $W_{5}(2) \left\{ 1 - \frac{1}{2} z^{-1} \right\} = X(2) \qquad W_{1}(2) = X(2)$
	$W_5(2) = \times (2) / (1 - 1/2 = 1) - B$
	put the value of $\bigcirc$ and $\bigcirc$ in eq $\bigcirc$ $(z) = W_5(z) + W_3(z)$
	$Y(z) = X(z) \begin{cases} 1 & 1 \\ 1 - \frac{1}{2}z^{-1} \end{cases} + X(z) \begin{cases} 1 & 1 \\ 1 + \frac{1}{2}z^{-1} \end{cases}$ $Y(z) = X(z) \begin{cases} 1 & 1 \\ 1 - \frac{1}{2}z^{-1} \end{cases} + \frac{1}{2}z^{-1} $
H	$\frac{(2) = Y(2)}{X(2)} = 2 - \frac{1}{4} z^{-1}$ $\frac{1 - \frac{1}{2} z^{-1}}{(1 - \frac{1}{2} z^{-1})(1 + \frac{1}{2} z^{-1})}$

Question: 2
Design IIR Filters using Impulse Invariance And Bilinear
bansformation based on Butterworth Approximation
Solution
IIR Filter Design Using Impulse Invariance based on
Butterworth Approximation:
Given: $0.23306 \le H(e^{jw}) \le 1$ $0 \le  w  \le 0.47$
0-23306 =  M(e) / -  H(e)w)  ≤ 0.17782 0.5x ≤  w  ≤x
[H[e-]] - 011102
Discrete Time specification convert into, continuous Time specification
Role of To is cancel out by the Impulse invaviance
method so we assume
Td = 1 W = ATd W = A
0.23306 5 H. (in) 61 0 6 12 5 0.4x
H(jr)  ≤ 0.17782 0.5x ≤  2  ≤ x
By using Butterworth Approximation:
$\left H_{c}(j_{n})\right ^{2}=1$
1+ (ja )2N
1+ (in) 1 (in)
(0.23306)2 = 1
1+ / YA 12 N 0-23306
(Jac) 0.17782 -
1+ D2 12N = 1
(nc) (0.23306)2
10.4 x 1 2N = 1 -1
(326)

(042)2N = 17.416 -> A
(0-17782)2 =
1+ (32)
1+/1 /2N = 1
$\frac{1+(-1)^{2N}-1}{(0.17782)^2}$
10.5x \2N = 1 -1
$(2c)$ $(0.17782)^2$
(0.5 x \2N = 30,6256 → B
(se)
Divide Equation $\Theta$ by Equation $\Theta$ $(0.4 \times)^{2N} / (\Omega_{c})^{2N} = 17.410$
(0.4x) /(1c) = 17.410
(0.5 x)2N/(De)2N 30.6256
(0.4 x)2N = 0.5884
(0.5 **)
$(0.8)^{2N} = 0.5684$
Taking log10 on b/s
Log10 (0.8) = Log10 (0.5684)
2N log16 (0.8) = log16 (0.5684)
2N(-0.0969) = -0.2453 2N = 2.5314
N = 1.2657 $N = 2$

When we put N= 12657 in eq @ and eq @ we get
the same answer of he
In Equation A.
(0.4x)2(1.2657) = 17.410
(0.42)2.5314 = 17.410
( Ac )
(0.4x) = (17.410) 1/2.5314
\\\ \Lambda_{\alpha}\)
0.47 = 1c
3.0914
Ac = 0.4064
In Equation B:
$(0.5\pi)^2(1.2657) = 30.6256$
\ \De /
(0.57)2-5314 = 30.6256
( se )
(0.52) = (30.6256) 1/2.5314
· \ \\ \alpha_c \\ \
0.57 = 3.864
Ac
nc = 0.4064
when we put N=2 in eq (a) and eq (b), we get
the different answer of re.
In Equation A:
(0.4x)2×2 = 17.410
( ne)
10.4x )4 = 17.410
( 1c)

	THE OWNER WHEN		
0.4x (17.410)14	***************************************		1
		***************************************	
To C 1: 0		***************************************	
In Equation B: (0.5x)2x2 = 30.6256		***************************************	
$(\lambda_c)$		***************************************	
(0.5x) = 30-6256			****
(se)		***************************************	
(0.57) = (30.6256) 1/4			
( ne )		***************************************	
$-\Omega_{c} = 0.6677$			
Now, we choose $n_c = 0.61519$ , $N = 2$		A < 1	
Angular Distance b/w poles = 7		Jing 759	
- 7 1 Co.	135	XY	5
= \( \tau = 180 \) = 90			····
N=2 = even = No pole on 71-anis			Res
Number of poles = 2N			1
= 2×2 = 4	225	× 2	15
for casual and stable system	******************************		
choose those poles which lies on		***************************************	*******
the left side of s- plane			********
. The resulting transfer function has the	folla	uina poles	5
		) /	
S1 = 0.61519 e (135°)			
= 0.61519 \ (135) + j sin (135)}			
2 0.61519 { -0.9960 + 10.08836})			
2 - 0.6127 + j 0.05435			
82 = -0.6127 - 10.05435			

Resulting in:			
H(s) =	(-2c)"		
	(s-si) (s-	S <sub>1</sub> )	The state of the s
H(s) =	10.615	12	
	· 6127 + 10.0542	ss)) (s-(-0.6127-jo	1(28020.
		77 (	- State of the sta
H(s) =	0.61519		
(S+0.6	127-10.05435	) (s+0.6127 + jo.0	5435)
2	0.3784		
	52 + 1.22548	+ 0.3774	
Mapping to	z-domain ;		
	A	transform into pole	at
Z = e sk Tol in		and the same of th	***************************************
H(z) =	0.3784		
	e <sup>51</sup> z-1) (1-	(1- ,20	
	- 204	<u> </u>	
F -0	-6127+10-05435	-1) (1-e-0-6127-10-05435	
(1-e	<u>Z</u>	)(I-e	2,)
=	0.378	4	
(1-0:541	8 e 30.05435 z-1)	(1-0.5418 e-10.05435	z1)
H(z) = I		+ B	-0
	1186,002432 =1)	(1-0.5418e-j0.05	435 -1)
(103	105 2	(1-0.24186	2)
n / 545 36	1 - 22420	***************************************	
A= (1-0.5418 e)	The state of the s	0.3784	
(1-	0.5418 e Joie 5435 21	) (1-0.5418e-10.05435	2=0.54188
		***************************************	(-d
= 0.378	4	***************************************	***************************************
1	65435		***************************************
(1-0.5418 e-10.	×		
	0.5418 e	10.05435	
		***************************************	NAME OF TAXABLE PARTY.

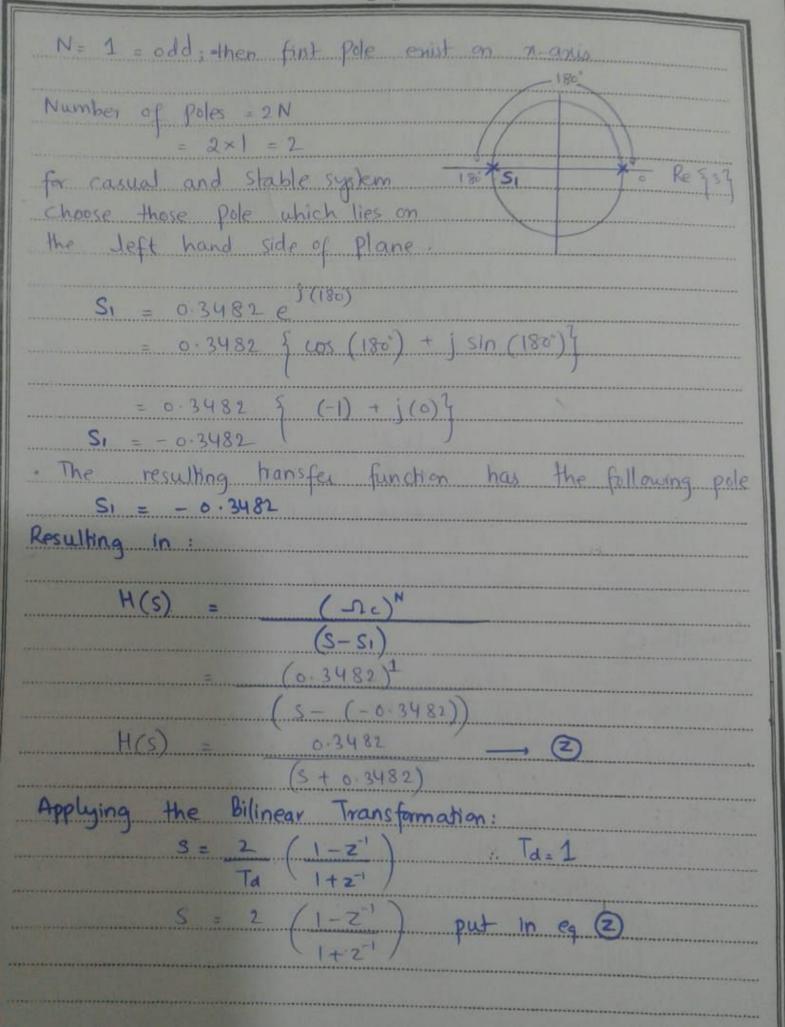
A = 0-3184
1-0.5418 (cos (-0.05435) + j sin (-0.05435))
0.5418 (cor (0.05435) + 151n (0.05435))
A = 0.3784
1- (0.99-j9.48×164)
0.99 + j 9.48×104
= 0.3784
1×163 +1.91511
A = 1.0317 ×164 - 0.1975;
B = (1-0.5418e-j0.05435 21) 0.3784
B = 0.3784 (1-0.5418 e 10.05435-1) (1-0.5418 e 2-1) = 0.5418e 30.05
= 1-0.8418e10.05435 x 1
A STATE OF THE STA
0.5418 6_10.02432
13 = 0.3784
1- 0.5418 (cos(0.05435) + jsin (0.05435))
0.5418 (cos (-0.05435) + jsin (-0.05435))
B = 0.3784
1 - (0.999 + 1.897)
B = 1.0515 × 10-4 + 0.199 j
Put the value of A and B in eq ®
11/ 3 / 01/2 / - 4
H(z) = 1.0317 × 164 -0.1975 + 1.0515 × 164 + 0.199 j
(1-05418 e 10.05435 z-1) (1-0.5418 e-10.05435 z-1
***************************************

IIR Filter Design using Bilinear Transformation based on Butter- worth approximation:
Given: $0.23306 \le  H(e^{j\omega})  \le 1 \qquad 0 \le  \omega  \le 0.4\pi$ $ H(e^{j\omega})  \le 0.17782 \qquad 0.5\pi \le  \omega  \le \pi$
Solution:  Discrete Time Specification Convertinto Continous Time specification $a = 2$ ton $\left(\frac{\omega}{2}\right)$
When $w = 0.4z$ $-\Omega = \frac{2}{Td} + \tan\left(\frac{w}{2}\right)$ $T_d = 1$
$= 2 + \tan (0.47)$ $= 1.4530$ $= 1.4530$ $= 1.4530$ $= 23306$ $= 1.4530$
When $w = 0.5 \times$ $-2 = 2$ fan $(w)$ $-17182$ $-1930 = 2$ $-2 + 4$ $-2 +$
-2 = 2
$0.23306 \leq  H(3A)  \leq 1 \qquad 0 \leq  \Omega  \leq 1.4530$ $ H(3A)  \leq 0.17782 \qquad 2 \leq  \Delta  \leq \infty$
By using Butterworth Approximation: $ H_{c}(j_{2}) ^{2} = 1$ $ H_{c}(j_{2}) ^{2} = 1$ $ H_{c}(j_{2}) ^{2}$

	(0.23306)2 = 1
	1+ (3(1.4530))2N
	(3 10)
1	
	( ne / (6-23306) <sup>2</sup>
	1.4530)24 = 1 _1
-	(12c) <sup>20</sup> . (6.23306) <sup>2</sup>
	·4530)2N = 17.410 - 1
	Se /
	(0·17782) <sup>2</sup> = (
	$1+\left(\frac{1}{2}\left(\frac{2}{2}\right)\right)^{2n}$
	1+/2\1N = 1
	(ne) = (0.17782) <sup>2</sup>
	$/2 \ ^{2N} = 1 -1$
	(se) (0.17782)°
	( 1 ) 1 = 30.6256 - B
	(se)
Divid	de Equation (B) by Equation (B)
(	(4530) = 17.410,
(	2) 1 / (sic) 2N 30-6256
	(1.4530)2N = 0.5684
	2 /
	(0.7265)2N = 0.5684 .
7	aking logue on b/s
-	

•	
	Logie (0-7265)2N = Logie (0-5684)
	2N logie (07265) = logie (0.5684)
	$2N \left(-0.1387\right) = \left(-0.2453\right)$
	N = 1.7688
	2_
	N = 0.8844
	$N \simeq 1$
	when we put N = 0.8844 in eq (B) and eq (B) we get the same answer of re
	In Equation A:
	(1.4530)2(0.8844) = 17.410
-	( ne
-	(1.4530) 1.7658 = 17.410
	( ne /
***	(1.4530)1.7688/13688 (17.410)1/1.7688
****	1.4530 = 5.0291
10153	7,735 = 3.027
*****	Ac = 0.2889
L	Equation B:
******	( 2 )2(0.8844 = 30.6256
	(ne) - 30.0250
	12 1.7888 = 30.6256
	(ne)
	(2) 17885 /1.7685 = (30.6256) 1/1.7685
	(20) = (30.6256)
	(10) 3 6.9209

nc = 6.2889
When we put N=1 in eq (1) and eq (18) 2 we get
the different answer of no.
In Equation A. (1.4530)2x1 = 17.410
$\left(\begin{array}{c} 1 \\ 0 \end{array}\right)$
(1.4530) = 17-410
( Ac )
(1.4530)2/L = (17.410)1/2
1.452
1.4530 = 4.1725
$\Omega c = 0.3482$
In Fourther B:
(2) <sup>2×1</sup> = 30.6256
( ne )
$(2)^2 = 30.6256$
( Ac )
$\frac{1}{2} \int_{-\infty}^{\pi/2} = (30.6256)^{1/2}$
(sac)
2 = S· \$340
0 02/10
No - above - 0.3613
Now, we choose $r_c = 0.3482$ , $N=1$
Angular Distance b/w poles = 7
= 7 = 180 = 180°
1
***************************************



H(z) =	0.3482	
	(2(1-2-1)+0.34	182
	( (1+z1)	
12	(2-2-1 + 0.348	201
		1
461	0.3482	
H(z) =	2-2=1 + 0.3482 (1	+ z <sup>-1</sup> )
***************************************	\+ z <sup>-1</sup>	
H(z) =	0.3482	***************************************
	2-2-1 +0.3482 +	0.3482 z"
	(+2"	1
H(z) =	(0.3482) (1+2	
11/2) -	-1.6518 z' + 2.348 0.3482 + 0.3482	***************************************
H(z) =	2.3482 - 1.6518	
	2.3102	***************************************
Question: 3	•••••••••••	
	ers using impulse li	nvaliance and bilinear
	based on Butterwarth	
0.78166	≤   H (e ju)   ≤ 1	0 \le   \w  \le 0.52
H (ejw)	) < 0.34409	0.62 =  W  = 2
Solution:		
11R filler Des	ign Using Impulse	Invariance based on
Butterworth A		
	<   H (e³") ≤1	0 4 W 60.5x
IH(ein	·) = 0.34409	0.6x <  w  < x

Discrete Time Specification Convert into	Continuous Time Sp.	elfication
Role of To is cancel out by the	impuse invaria	unce
method so we assume:  Ta=1 W= 177d W=1		***************************************
1d=1 W= 42 19		
- 0.78166 4 H (JA) 41 0 4	=   A   5 0.5x	
[H(Jr)] < 0.34409 0.67	( 4   2   4 ×	
By using Butterworth Approximation	13	
		***************************************
$ Hc(jn) ^2 = 1$		***************************************
1+ (jr) 2h		
$(6.78166)^2 = 1$		(H(()))
1+ (80 )2N	0.78166	tucks 1
(3nc)		1
$\frac{1+(2)^{2N}=1}{(0.78166)^{2}}$	0.34464	0.67
(nc) (0.78166)2		***************************************
(0.52 )2N = 1 -1		
(nc) (0.78166)2		
10.5 x 2N = 0.6366 - A		
( ne )		
(0.34409)2 = 1		
1+ (jr)2N		
1 + / 2 /2m = 1	***************************************	***************************************
(ne) (0.34409)		
10.67 J2N = 1		
(ne) (0.34409)		

$(0.6x)^{2N} = 7.4460 - (3)$
Divide Equation (B) by Equation (B)
Divide Equation ( by Equation ( ) (0.5 x) 2N (crc) 2N = 0.6366
(0.6x)2r/(-2c)2n 7.4460
(0.5x) 2N = 0.0854
$(0.8333)^{2N} = 0.0854.$
Taking log on b/s
Taking $\log_{10}$ on $b/s$ $\log_{10} (0.8333)^{2N} = \log_{10} (0.0854)$
2N log10 (0.8333) = log10 (0-0854)
2N (-0.0791) = -1.0685
2N = 13.508
N = 6.754
$N \approx 7$
When we put N = 6.754 in eq (1) and eq (1), we get
the same ansuer of re
In Equation Ai
$(0.5\pi)^2(6.754) = 0.6366$
$(0.5 \times )^{13.508} = 0.6366$
- 0/1
0.5x = 0.9671
-2c = 1.624
In Equation B:
(0.6x)2(6.754) = 7.4460
In Equation B: $(0.67)^{2}(6.754) = 7.4460$

L 172
(0-67) 13508 - 7.4460
262 = 1.1602
10 = 1.624
When we put N=7 in eq (B) and eq (B) , we get the
different answer of se.
In Equation A:
(0.57)2×7 - 0.6366
120
(0.5 x) = 0.6366
0.57 = 0.9682
A.
1.6223
In Equation B:
(0.67 )27 = 7.4460
\100
(0.62) = 7.4460
(· se )
1. C = 1.6331
Now we choose Ic= 1.6331, N=7 51.85 1 759
10 10
Angular Distance blu poles = 7 55 51 1 + 11.425
= 7 = 180 = 25.714 54 7
7 7 54 \$ 179.99
×c ×c
N=7 = odd = pole exist on x-onis 55 + 205.712 Reg
Number of Poles = 2N
= 2×7=14 Sc 231.42 × × 308.56
257-14 282.85
Sq.

Choose those poles which lies on the left side of s-plane.  The reculting transfer function has the following poles: $SI = 1.6331 \text{ p}^{3}(102.85)$ $= 1.6331 \text{ f}^{3}(03.(102.85) + \text{j} \sin (102.85))^{2}$ $SI = -0.3625 + \text{j} \cdot \sin (0.2.85) + \text{j} \sin (102.85)^{2}$ $SI = -0.3625 + \text{j} \cdot \sin (0.2.85) + \text{j} \sin (102.85)^{2}$ $SI = -0.3625 + \text{j} \cdot \sin (0.2.85) + \text{j} \sin (0.2.85)^{2}$ $SI = -0.3625 + \text{j} \cdot \sin (0.2.85) + \text{j} \sin (0.2.85)^{2}$ $SI = 1.6331 \text{ p}^{3}(03.(128.57) + \text{j} \sin (0.2.85)^{2}$ $SI = 1.6331 \text{ p}^{3}(03.928)$ $SI = 1.6331 \text{ p}^{3}(03.92$
The resulting transfer function has the following poles: $SI = 1.6331 \text{ p}(102.85)$ $= 1.6331 \text{ f}(53)(102.85) + \text{j} \sin(102.85)$ $SI = -0.3625 + \text{j} \cdot \text{S} = 906$ $SI = 1.6331 \text{ p}(128.57)$ $= 1.6331 \text{ f}(53)(128.57) + \text{j} \sin(128.57)$ $SI = -1.0181 + \text{j} \cdot \cdot$
$S_{1} = -0.3625 + j \cdot S906$ $S_{2} = j \cdot 6331 e^{j(128.57)}$ $= 1 \cdot 6331 \int (0.5 (128.57) + j \cdot Sin (128.57) \int (128.57) $
$S_{1} = -0.3625 + j1.5906$ $S_{2} =  .6331  e^{j(128.57)}$ $=  .6331  f^{2}(05) (128.57) + j sin (128.57) f^{2}$ $S_{3} =  .6331  e^{j(159.28)}$ $=  .6331  f^{2}(05) (159.28) + j sin (159.28) f^{2}$ $S_{3} = -1.471 + j 0.708$ $S_{4} =  .6331  e^{j(179.99)}$ $=  .6331  f^{2}(05) (179.99) + j sin (179.99) f^{2}$ $S_{5} =  .6331  f^{2}(05) (179.99) + j sin (179.99) f^{2}$ $S_{5} =  .6331  e^{j(205.712)}$ $=  .6331  f^{2}(205.712) + j sin (205.712) f^{2}$
$S_{2} = 1.6331 e^{3(128.57)}$ $= 1.6331 e^{3(128.57)} + j sin (128.57)^{\frac{1}{2}}$ $S_{2} = -1.0181 + j1.2768$ $S_{3} = 1.6331 e^{3(154.28)}$ $= 1.6331 f cos (154.28) + j sin (154.28)^{\frac{1}{2}}$ $S_{3} = -1.471 + j o.708$ $S_{4} = 1.6331 e^{3(174.94)}$ $= 1.6331 f cos (174.94) + j sin (174.94)^{\frac{1}{2}}$ $S_{5} = 1.6331 e^{3(205.712)}$ $S_{7} = -1.6331 e^{3(205.712)} + j sin (205.712)^{\frac{1}{2}}$
$S_{1} = -1.6331 \left\{ \cos \left( 128.57 \right) + \int \sin \left( 128.57 \right) \right\}$ $S_{2} = -1.0181 + \int 1.2768$ $S_{3} = 1.6331 \left\{ \cos \left( 154.28 \right) + \int \sin \left( 154.28 \right) \right\}$ $= 1.6331 \left\{ \cos \left( 154.28 \right) + \int \sin \left( 154.28 \right) \right\}$ $S_{3} = -1.471 + \int 0.708$ $S_{4} = 1.6331 \left\{ \cos \left( 174.99 \right) + \int \sin \left( 174.99 \right) \right\}$ $= 1.6331 \left\{ \cos \left( 174.99 \right) + \int \sin \left( 174.99 \right) \right\}$ $S_{5} = 1.6331 \left\{ \cos \left( 205.712 \right) + \int \sin \left( 205.712 \right) \right\}$ $= 1.6331 \left\{ \cos \left( 205.712 \right) + \int \sin \left( 205.712 \right) \right\}$
$S_{3} = \frac{1.6331}{6331} \frac{e^{3}(154.28)}{6331} = \frac{1.6331}{6331} \frac{e^{3}(154.28)}{6331} + \frac{1}{3} $
$S_3 = -1.471 + jo.708$ $S_4 = 1.6331                                 $
$S_3 = -1.471 + j 0.708$ $S_4 = 1.6331 e^{j(179.99)}$ $= 1.6331 \int cos(179.99) + j sin(179.99)^2$ $S_4 = -1.6330 + 2.85 \times 10^9 \text{ s}$ $S_5 = 1.6331 e^{j(205.712)}$ $= 1.6331 \int cos(205.712) + j sin(205.712)^2$
$S_{4} = 1.6331 e^{3(179.99)}$ $= 1.6331 e^{3(179.99)} + i sin (179.99)^{2}$ $S_{5} = 1.6331 e^{3(205.712)}$ $= 1.6331 e^{3(205.712)} + i sin (205.712)^{2}$
$= \frac{1.6331}{.} \left\{ \frac{(05)(179.99) + j \sin(179.99)}{3} \right\}$ $= \frac{1.6331}{.} \left\{ \frac{(205.712)}{.} \right\}$ $= \frac{1.6331}{.} \left\{ \frac{(205.712)}{.} \right\} + j \sin(205.712) \right\}$
$S_{4} = -1.6330 + 2.85 \times 10^{4} \text{ s}$ $S_{5} = 1.6331 \text{ e}^{3(205.712)}$ $= 1.6331 \text{ f}^{3(205.712)} + 3 \sin(205.712) \text{ f}^{3(205.712)}$
$S5 = 1.6331 e^{j(205.712)}$ $= 1.6331 e^{j(205.712)} + j sin(205.712) f$
= 1.6331 { cos (205.712) + 1 sin (205.712)}
S= = -1.4714 - jo.708
S6 = 1.6331 e)(231.41)
= 1.6331 \ (os (231.42) + \ \sin(231.42)4
S6 = -1.0184 - j1.2734

```
S7= 1-6331 e
      1.6331 & cos (257-14) + Isln (257-14) 4
Sa = -0.3634 - 11.5921
 Resulting in:
                           (12c)N
      H(s) =
               (5-2) (5-2) (5-2) (5-2) (5-2) (5-2)
                      (1.6331)7
       (s-(-0.3625+11.5906)) (s-(-1.0181+11.2768)
 (S-(-1.471+10.708)) (S-(-1.6330+2.85x164)) (S-(-1.4714-j0.708)
      (5-(-1.0184-11.2734))(5-(-0.3634-11.592))
                 30,980
H(S) =
    (S+0.3625-11.5906) (S+1.0181-11.2768) (S+1.471-j0.708)
(S+1.6330+2.85 x10) (S+1.4714+10.708) (S+1.0184+11.2734) (S+0.3634+11.592)
Mapping in z-domain:
Poles S= Sk in S-domain transform into pole at Z=e Sktd
in z-domain.
H(2) =
        1- 0-0.3625+)1.5906 z-1 1-0-1.0181+)1.2768 z-1
-1.471 + jo.708 -1 1-e-1.6330 + j2.85×164 -1 1-e-1.4714 - jo.708 z-1
    1-e-1.0184-j1.2734 -1 1-e-0.3634-j1.5921 -1
```

IIR Filter Design in Dily T C
IIR Filter Design using Bilinear Transformation based on Butterworth Approximation:
Given:
0.78166 < [H(esu)] <1 0 < [w] < 0.5x
1 2 / (
H(e)   ≤ 0.34409 0.6x ≤   w  ≤ x
Discrete Time Specification Convert, Continuous Time specification
2 = 2 to (W)
$\frac{-2}{T_d} = \frac{2}{T_d} + \tan\left(\frac{\omega}{2}\right)$
When w= 0.5x
$\Omega = \frac{2}{1} + \tan\left(\frac{\omega}{2}\right)$
70 (2)
= 2 tan (0.52)
2
= 2
When w= 0.62
$\Omega = 2 \tan(\omega)$
Td. (2)
= 2 tan (0.6x)
1 2
= 2.7527
0.78166 < H(jn) <1 0 < 10 < 2
11/10/16 0 24400
2. 0 # 0 # 0
By using Butterworth Approximation:
Hc(in) = 1
1+ ( in )2N
- JULE/

(078166) = 1
The state of the s
1+ ( Y 2 2 N
1+ ( -Q ) LN = 1
ne) (0.78166)2
$\left(\frac{2}{2}\right)^{2N} = \frac{1}{2}$
$(2)^{2N} = 0.6366 \longrightarrow \triangle$
$\begin{pmatrix} 2 \\ -\alpha_c \end{pmatrix} = 0.6366 \longrightarrow (A)$
(0.34409)2 - 1
1+ ( X/2 )2N
(xnc)
1+ ( 1 ) LN = 1
(0.34409) <sup>2</sup>
(2.7527) = 1
$(2.7527)^{2N} = 7.4460$
(2-7527) = 7-4460 → B
Divide Sourtie M 1 5 + 0
Divide Equation (A) and Equation (B)  (2) 1 (12) 1 2 0.6366
(2.7527)2N/(Dc)2N 7.4460
$(2)^{2N} = 0.08549$
(2.7527)
Taking Logio on b/s
) 2N
log10 (0.7265) = log10 (0.08549)
$2N \log_{10}(0.7265) = \log_{10}(0.08549)$ 2N(-0.1387) = -1.0680
2N (-0.1387) = -1.0680

2N = 7.700
N = 3.850
N ≅ 4
the same put N=3.850 in eq (A) and eq (B), we get
and any of the
Hauen Hi
_ 0000
(Ac)
(2 ) 7.700 = 0.6366
(se)
2 = (0.6366) 17.700
120
-12c = 2.1208
In Equation B:
(2-7527)2×3-350 = 7.4460
(Sc)
(2.7527)7.700 = 7.4460
(ne)
2.7527 = (7.4460) 1/7.700
-i c
Sc = 2.1209
When we put N= 4 In eq (A) and eq (B), we get
the different values of se
In Equation A:
(2) = 0.6366
( -Le )
(2) = 0.6366
( nc)
2 = 0.6366.78
De = 0.8300

To 6 1: 0
In Equation B: (2.7527)244 = 7.4460
12-7527)8 = 7.4460 .
- ( De
2-7527 = 7-44601/8
No
Ac = 2.1417
Now, we choose 12c = 2.1161, N=4
Angular Distance b/w poles = 2 si 3m 959
N 1125 6215
= 7 = 180 = 45° Sh 5
4 4
N=4= even; then No pole on n-anis
Number of poles = 2N 202.5
= 2x4=8 241.5 292.5
for casual and Stable system. SI
choose those poles which lies
on the left side of plane
. The resulting hansfer function has the following pole
Si= 2.1161 e 3(112.5)
= 2.1161 \( \los \left( 112.5 \right) + \( \jets \right) \right) \( \left( 112-5 \right) \right) \)
S1 = -0.8083 + j 1.9548
Sy = 2-1161 e)(157.5)
= 2.1161 \( \cos(157.5) + \) \( \sin\) (157.5) \( \) = -1.9548 + \( \) \
2000 1000 1000 1000 1000 1000 1000 1000

SI = -0.8083 + j1.9548
$S_{2} = -0.8083 - 11.9548$ $S_{3} = -1.9548 + 10.8083$
Sy = -1.9548 - jo. 8083
Resulting in: H(s) = (_ac)"
H(S) = (S-S1)(S-S3)(S-S4)
(S-(-0.8083+j1.9548)) (S-(-0.8083-J1.9548))
(S-(-1.9548+j0.8083)) (S-(-1.9548-j0.8083))
H(s) = 20.0514
(5+0.8083-)1.9548)(5+0.8083+)1.9548)
(S+1.9548-j 0.8083) (S+1.9548+j0.8083)
H(s) = 20.0514
(s2+ 0.80 83 s + js1.9548 + 0.8083 s + 0.6533 +
11.5860-js 1.9548-j1.5860+3.8212)(5++ 1.95485+
Sj 0.8883 + 1.9548 5 + 3.8212 + j 1.5866 - Js 0.8683
-11.5800 + 0.6533)
4(s)= 20.0514 → 3
(s2+1,6166 s + 4,4745) (s2+3,9096 s + 4,4745)

Applying the Bilinear Transformation: $S = \frac{2}{Td} \left( \frac{1-z^{-1}}{1+z^{-1}} \right) \qquad \text{if } Td = 1$ $S = 2 \left( \frac{1-z^{-1}}{1+z^{-1}} \right) \qquad \text{put in eq } \textcircled{2}$
$= \frac{3^{2} + 1.6166 + 4.4745}{4 \left(1-z^{-1}\right)^{2} + 1.6166 + 2 \left(1-z^{-1}\right) + 4.4745}$ $= \frac{4 \left(1-z^{-1}\right)^{2} + 1.6166 + 2 \left(1-z^{-1}\right) + 4.4745}{(1+z^{-1})^{2}}$ $= \frac{4 \left(1-2z^{-1}+z^{-2}\right) + 3.2332 + (1-z^{-2}) + 4.4745 + (1-2z^{-1}+z^{-1})}{(1+z^{-1})^{2}}$ $= \frac{4-8z^{-1} + 4z^{-2} + 3.2332 - 3.2332z^{-2} + 4.4745 - 8.949z^{-1} + 4.4745z^{-1}}{(1+z^{-1})^{2}}$
$\frac{2 \cdot 5 \cdot 2413 z^{-2} + 0.949 z^{-1} + 11.707}{(1+z^{-1})^{2}} \longrightarrow \bigcirc$
$S^{2} + 0.39096 S + 4.4745$ $= 4 \left( 1 - z^{-1} \right)^{2} + 0.39096 \left( 2 \left( 1 - z^{-1} \right) \right) + 4.4745$ $= 4 \left( 1 - 2z^{-1} \right)^{2} + 7.892 \left( 1 - z^{-1} \right) + 4.4745 \left( 1 + 2z^{-1} + z^{-2} \right)$ $= 4 \left( 1 - 2z^{-1} + z^{-2} \right) + 7.892 \left( 1 - z^{-1} \right) + 4.4745 \left( 1 + 2z^{-1} + z^{-2} \right)$
$= \frac{4 - 8z^{-1} + 4z^{-2}}{(1 + z^{-2})^2} + 7.8192 - 7.8192 z^{-2} + 4.4745 + 8.949z' + 4.4745$
= $0.6553 z^{2} + 0.949 z^{1} + 16.2937 \longrightarrow \textcircled{9}$ $(1+z^{1})^{2}$
Put the value of eq @ and eq @ in eq @

H(z) = 20.0514
$(5.2413z^{-1} + 0.949z^{-1} + 11.707)(0.6553z^{-1} + 0.949z^{-1} + 16)$ $(1+z^{-1})^{2}$
$(1+z^{-1})^{\perp}$ $(1+z^{-1})^{2}$
H(2)= 20.0514 (1+z')4
$ \left( 5.2413 z^{2} + 0.949 z^{1} + 11.707 \right) \left( 0.6553 z^{2} + 0.949 z^{1} + 16.293 \right) $
( 0.0335 Z + 0.999 Z + 16.293)
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