a) transfer function in s domain

$$H(s) = \frac{Ks^3}{\left(1+\frac{s}{2\pi f_{cL}}\right)^3\left(1+\frac{s}{2\pi f_{cH}}\right)^3}$$

slope decreasing points $f_{cL}$ and $f_{cH}$

written in terms of s and omega

$$w = 2\pi f$$

to write the pseudo code, we need to perform a bilinear transformation to convert to z-domain then do direct programming

For bilniear transform, we substitute

$$s = \frac{2}{T}\frac{(z-1)}{(z+1)}$$

$$T = \frac{1}{f} = \frac{1}{44100} \quad \text{(given)}$$

we acquire

$$\frac{K\left(\frac{2}{T}\frac{(z-1)}{(z+1)}\right)^3}{\left(1+\frac{\frac{2}{T}\frac{(z-1)}{(z+1)}}{2\pi f_{cL}}\right)^3\left(1+\frac{\frac{2}{T}\frac{(z-1)}{(z+1)}}{2\pi f_{cH}}\right)^3}$$

For ease of calculation, I will use many coefficients

Let's say

$$A = \pi T f_{cL}$$

$$B = \pi T f_{cH}$$

K calculation

$$H(s) = \frac{Ks^3}{\left(1+\frac{s}{2\pi f_{CL}}\right)^3 \left(1+\frac{s}{2\pi f_{CH}}\right)^3}$$

$w = 2\pi f$

$$|H(jw)| = 20\log_{10}K + 60\log_{10}|jw| - 60\log\left|1+\frac{jw}{2\pi f_{CL}}\right| - 60\log\left|1+\frac{jw}{2\pi f_{CH}}\right|$$

$$20\log_{10}K + 60\log_{10}(w) - 60\log\sqrt{1+\left(\frac{w}{2\pi f_{CL}}\right)^2}$$

$$-60\log\sqrt{1+\left(\frac{w}{2\pi f_{CH}}\right)^2}$$

$w = 2\pi f_{CL}$

$$20\log_{10}K = 60\log_{10}\sqrt{2} + 60\log_{10}\sqrt{1+\left(\frac{f_{CL}}{f_{CH}}\right)^2} - 60\log_{10} 2\pi f$$

$$K^{\frac{2}{3}} = \frac{(f_{CL}{}^2 + f_{CH})^2)}{2\sqrt{2}(f_{CL} f_{CH}\pi)^3}$$

$$\frac{8K}{T^3} A^3 B^3 \frac{(z-1)^3 \, (z+1)^3}{\left(A(z+1)+(z-1)\right)^3 \left(B(z+1)+(z-1)\right)^3}$$ ②

$$\frac{(z-1)^3 \, (z+1)}{AB(z^2+2z+1) + A(z+1)(z-1) + B(z+1)(z-1) + (z-1)(z-1)}$$

$$\qquad\qquad Az^2 - A \qquad Bz^2 - B \qquad + z^2 - 2z + 1$$

$$= \frac{z^2-1}{ABz^2 + 2ABz + AB + Az^2 - A + Bz^2 - B + z^2 - 2z + 1}$$

$$= \frac{(z^2-1)}{(AB+A+B+1)z^2 + (2AB-2)z + (AB-A-B+1)} \qquad \frac{8K(AB)^3}{T^3}$$

$AB+A+B+1 = D$

$2AB-2 = E$

$AB-A-B+1 = F$

$$= \frac{8KA^3B^3}{T^3} \frac{(z^2-1)^3}{(Dz^2+Ez+F)^3}$$

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$$D^2z^4 + \cancel{DEz^3} + \cancel{DFz^2}$$
$$\cancel{DEz^3} + E^2z^2 + EFz$$
$$\cancel{DFz^2} + EFz + F^2$$

$$\left(D^2z^4 + 2DEz^3 + (2DF+E^2)z^2 + 2EFz + F^2\right)$$

$$D^3z^6 + 2D^2Ez^5 + (2D^2F + DE^2)z^4 + 2DEFz^3 + DFz^2$$
$$D^2Ez^5 + 2DE^2z^4 + (2DEF + E^3)z^3 + 2E^2Fz^2 + EF^2z$$
$$D^2Fz^4 + 2DEFz^3 + (2DF^2 + E^2F)z^2 + 2EF^2z + F^3$$

simplifies to:

$$D^3z^6 + 3D^2Ez^5 + (3D^2F + 3DE^2)z^4$$
$$(6DEF + E^3)z^3 + (3E^2F + 3DF^2)z^2$$
$$3EF^2z + F^3$$

we acquire

$$\frac{8KA^3B^3}{T^3}\,\frac{(z^6 - 3z^4 + 3z^2 - 1)}{\left[D^3z^6 + 3D^2Ez^5 + (3D^2F + 3DE^2)z^4 + (6DEF + E^3)z^3 + (3E^2F + 3DF^2)z^2 + 3EF^2z + F^3\right]}$$

$\pi$ take as 3.14

$A = \pi T f_{cL} = 7.12\times10^{-5} f_{cL}$ $\qquad T = \frac{1}{f} = \frac{1}{44100}$ s

$B = \pi T f_{cH} = 7.12\times10^{-5} f_{cH}$

$D = AB + A + B + 1 = 5.06\times10^{-9} f_{cL} f_{cH} + 7.12\times10^{-8}(f_{cL} + f_{cH}) + 1$

$E = 2AB - 2 = 10^{-8} f_{cL} f_{cH} - 2$

$F = AB - A - B + 1 = 5.06\times10^{-9} f_{cH} f_{cL} - 7.12\times10^{-5}(f_{cL} + f_{cH}) + 1$

$$\frac{8KA^3B^3}{T^3} = 2.36$$

$$\frac{8KA^3B^3}{T^3} = C$$

Pseudo code

$$\frac{C\left(1-3z^{-2}+3z^{-4}-z^{-6}\right)}{D^3+3D^2Ez^{-1}+(3D^2F+3DE^2)z^{-2}+(6DEF+E^3)z^{-3}+(3E^2F+3DF^2)z^{-4}+3EF^2z^{-5}+F^3z^{-6}}$$

$b_0 = C$ $\quad a_0 = D^3$ $\quad a_4 = 3E^2F+3DF^2$

$b_2 = -3C$ $\quad a_1 = 3D^2E$ $\quad a_5 = 3EF^2$

$b_4 = 3C$ $\quad a_2 = 3D^2F+3DE^2$ $\quad a_6 = F^3$

$b_6 = -C$ $\quad a_3 = 6DEF+E^3$

$b_1, b_3, b_5 = 0$

$$\frac{b_0}{a_0} = \frac{C}{D^3} \qquad \frac{1}{a_0} = \frac{1}{D^3}$$

$$\frac{b_1}{a_0} = 0 \qquad \frac{-a_1}{a_0} = -\frac{3E}{D}$$

$$\frac{b_2}{a_0} = \frac{-3C}{D^3} \qquad \frac{-a_2}{a_0} = -\frac{3DF+3E^2}{D^2}$$

$$\frac{b_3}{a_0} = 0 \qquad \frac{-a_3}{a_0} = \frac{-(6DEF+E^3)}{D^3}$$

$$\frac{b_4}{a_0} = \frac{3C}{D^3} \qquad \frac{-a_4}{a_0} = \frac{-(3E^2F+3DF^2)}{D^3}$$

$$\frac{b_5}{a_0} = 0 \qquad -\frac{a_5}{a_0} = -\frac{3EF^2}{D^3}$$

$$\frac{b_6}{a_0} = \frac{-C}{D^3} \qquad -\frac{a_6}{a_0} = -\frac{F^3}{D^3}$$

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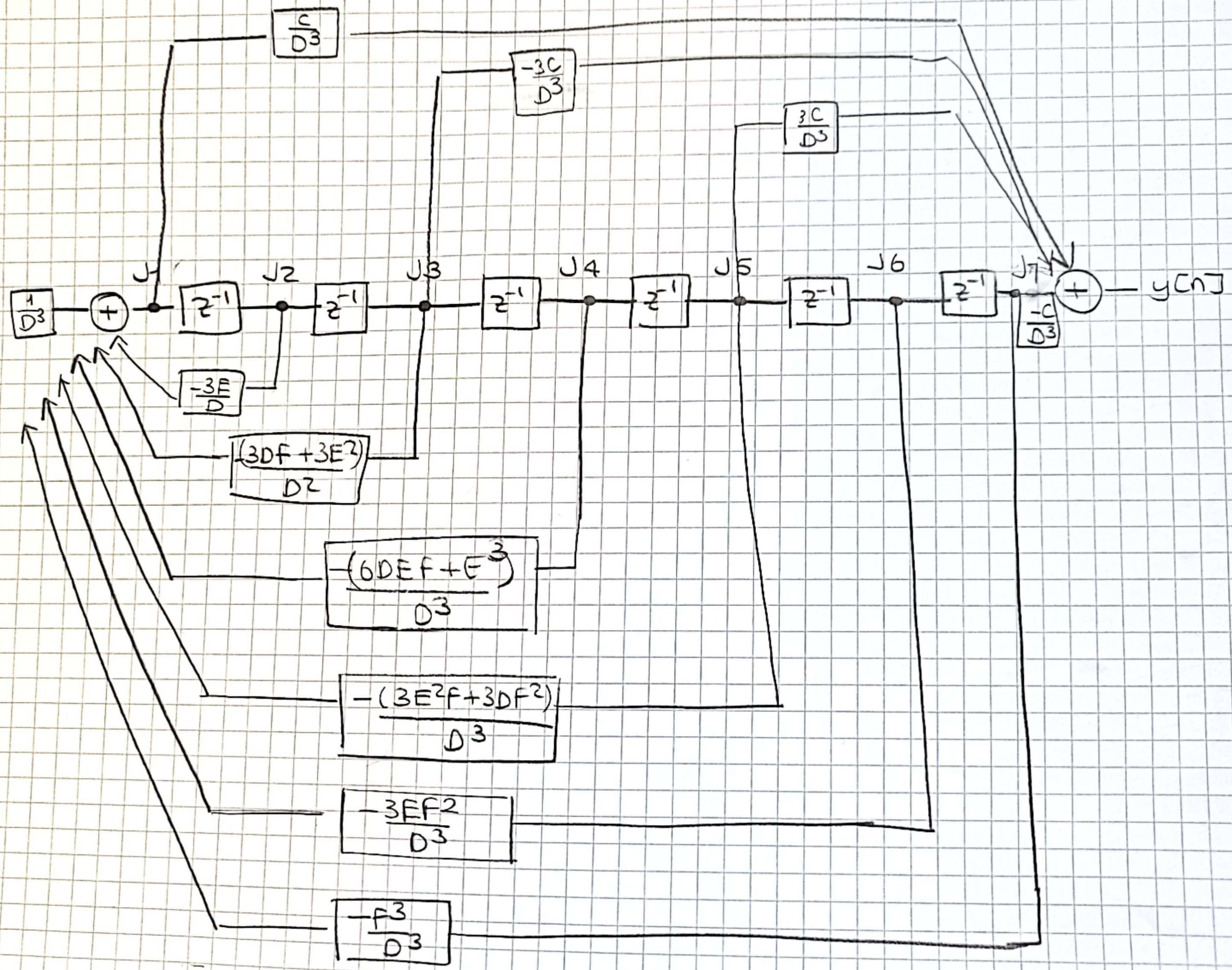

C/D3
-3C/D3
3C/D3
1/D3
J1
J2
J3
J4
J5
J6
J7
z-1
y[n]
-C/D3
-3E/D
(3DF+3E2)/D2
-(6DEF+E3)/D3
-(3E2F+3DF2)/D3
-3EF2/D3
-F3/D3

Pseudo code @TS t=n.S

input x

$$J1 = \frac{x}{D\wedge\wedge 3} - \frac{3E}{D} J2 - \frac{(3DF+3E^2)}{D^2} J3 - \frac{(-6DEF+E^3)}{D^3} J4$$

$$- \frac{(3E^2F+3DF^2)}{D^3} J5 - \frac{3EF^2}{D^3} J6 - \frac{F^3}{D^3} J7$$

$$y = \frac{C}{D^3} J1 - \frac{3C}{D^3} J3 + \frac{3C}{D^3} J5 - \frac{C}{D^3} J7.$$

output y

J7 = J6

J6 = J5

J5 = J4

J4 = J3

J3 = J2

J2 = J1

Return