Filter (Digital Filter)

i) Comparison between Analog and Digital filter.

(2)

Digital Filter

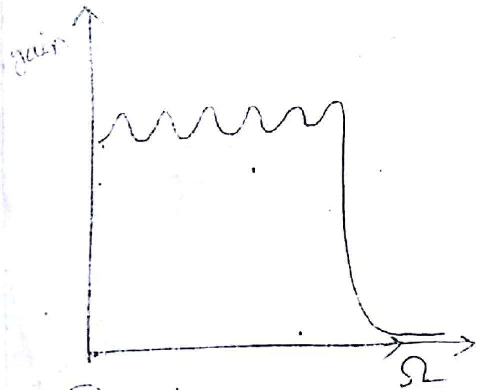
- Infinite impulse response filter. (IIR)
  $h(n) = \{1, 2, -2, 3, \dots\}$
- Finite impulse response filter. (FIR)
  $h(n) = \{1, 2, 3, 4\}$.

VVI. Comparison between IIR & FIR? (From book).

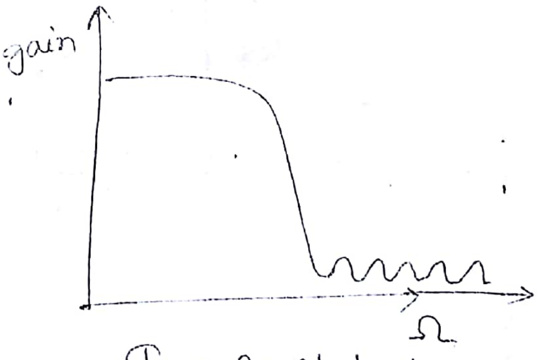
(FIR ⟷ Linear phase)

Digital filter

- Butterword filter
  (Here transfer characteristics are smooth for both pass bands and stopband)
- Chebyshev filter.
  (Equiripples are present either in the stop band or in the pass band.)



Type 1
Chebyshev



Type 2. Chebyshev.

VVI :- Comparison between these two.

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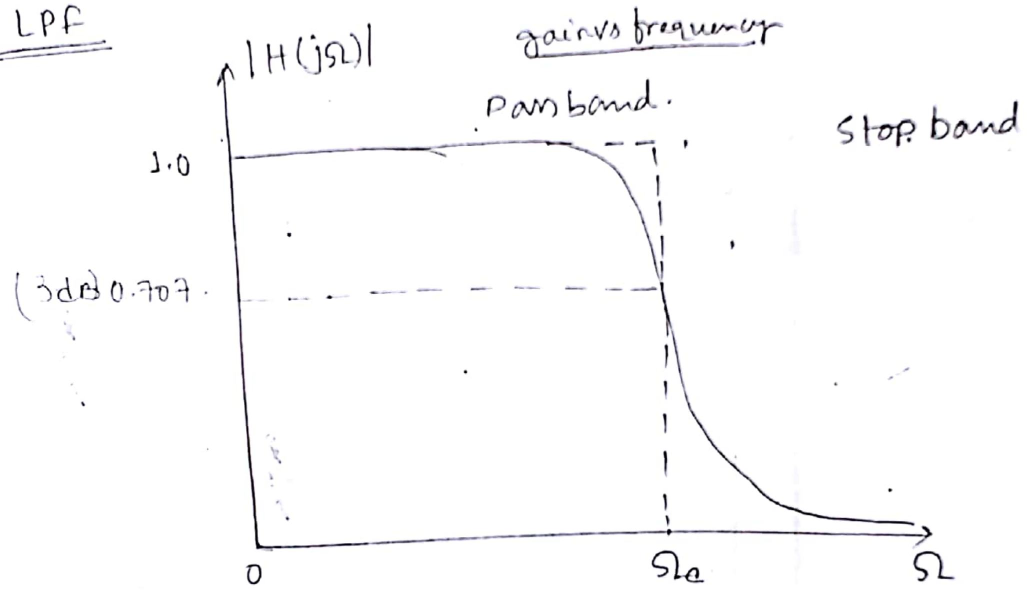
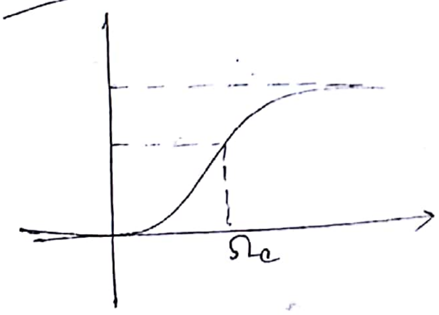
(*) Filter classification based on characteristics :-

- Low pass filter (LPF)
- HPF (High pass filter)
- BPF (Band pass filter)
- Band stop / reject filter

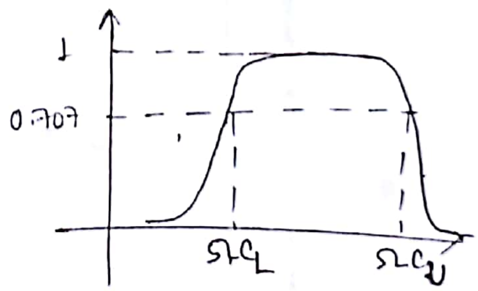
LPF



HPF



BPF

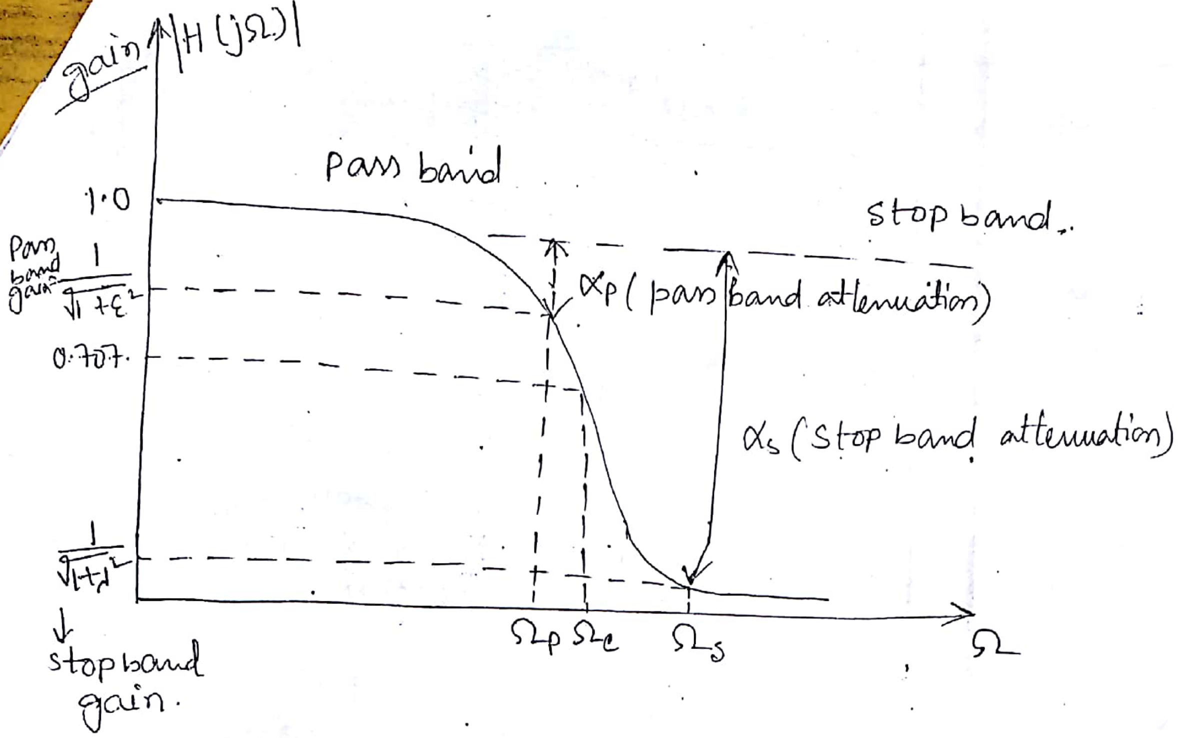


(*) IIR filter design :-

Butterword low pass filter design :-

Digital (Digital from analog) :-

step 1 :-



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⊛ Difference betⁿ IIR and FIR :-

IIR	FIR
1) IIR stands for infinite impulse response system.	1) finite impulse response system.
2) Less powerful than FIR filters, requires less processing power and less work to set up the filters.	2) FIR filters are more power-ful than IIR, but also require more processing power and more work to set up the filters.
3) They are more easy to change "On the fly"	3) They are less easy to change "On the fly" as you can by
4) These are less flexible.	4) Their, greater power means more flexibility and ability to finely adjust.
5) Cannot implement linear-phase filtering.	5) Can implement linear-phase filtering.
6) More efficient	6) Less efficient
7) Used as notch (Band stop), band pass function.	7) used as anti-aliasing, low pass baseband filters.
8) Higher sensitivity.	8) lower sensitivity.
9) Delay is less.	9) Delay is more than IIR filter.

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Analog filter transfer fun^n

Step 1 :- From the given specifications find order of the filter.

$\Omega_s , \Omega_p \rightarrow$ Given.

α_s & α_p or $\frac{1}{\sqrt{1+\varepsilon^2}}$ & $\frac{1}{\sqrt{1+\lambda^2}} \longrightarrow$ Given.

$$N = \frac{\log \sqrt{\frac{10^{0.1\alpha_s} - 1}{10^{0.1\alpha_p} - 1}}}{\log \left(\frac{\Omega_s}{\Omega_p} \right)} \quad \text{or,} \quad N = \frac{\log \left(\frac{\lambda}{\varepsilon} \right)}{\log \left(\frac{\Omega_s}{\Omega_p} \right)}$$

where, $\lambda = \sqrt{10^{0.1\alpha_s} - 1}$, $\varepsilon = \sqrt{10^{0.1\alpha_p} - 1}$.

Step 2 :- From the value of N equate it to the next higher integer

Step 3 :- From the value of N, find the transfer function of filter $\boxed{\cancel{hs}}$ H(S) from table no - 5.1 (5.9)
when ~~Ω~~ $\Omega_c = 1$ rad/sec.

Step 4 :- $\Omega_c = \Omega_p / (10^{0.1\alpha_p} - 1)^{\frac{1}{2N}}$

$$= \frac{\Omega_s}{(10^{0.1\alpha_s} - 1)^{\frac{1}{2N}}}$$

$$\Omega_c = \frac{\Omega_p}{(\varepsilon)^{1/N}} = \frac{\Omega_s}{(\lambda)^{1/N}}$$

Step 5 :-
From the calculated value of Ω_c we obtained analog filter transfer function -

- $H_a(s)$ by replacing $s \rightarrow \frac{s}{\Omega_c}$

(For HPF it will be $\frac{\Omega_c}{s}$)

From $H_a(s)$ find $H(z)$ by using anyone of the following method. $\longrightarrow$

a) Approximation of Derivative.

b) Impulse ~~invariation~~ invariance method. (II)

c) Bi-linear transformation method. (BT)

d) Matched Z-transform.

short note.

Step-7:-

From H(z) realize the filter.

H.W :- 5.2, 5.4,

Ex:- 5.5.

$\boxed{0 \rightarrow \text{Low pass filter}}$

II method :-

Here relation between analog angular frequency (Ω) and digital angular frequency (ω)

(5.5)

$$\omega = \Omega T.$$

where T is the sampling period. If not mentioned consider T=1.

Now, In II method 1st find Ha(S) interms of sum of single pole.

$$Ha(S) = \sum_{K=1}^{N} \frac{C_K}{S - P_K}$$

Then H(z) can be obtained by

$$H(z) = \sum_{K=1}^{N} \frac{C_K}{1 - e^{P_K T} z^{-1}}$$

(VVI)
Ex: 5.11 , 5.13, 5.15(VVI), PP-5.17, 5.8

* Bilinear transformation :-

Here s is replaced by $s = \frac{2}{T}\frac{(1-z^{-1})}{(1+z^{-1})}$

· Ex - 5.16 (Imp), 5.18 (Imp).

Ex - 5.5 :-

$$0.9 \le |H(j\Omega)| \le 1 \longrightarrow 0 \le \Omega \le 0.2\pi.$$

$$|H(j\Omega)| \le 0.2 \longrightarrow 0.4\pi \le \Omega \le \pi.$$

$$\frac{1}{\sqrt{1+\varepsilon^2}} = 0.9 \longrightarrow \varepsilon =$$

$$\frac{1}{\sqrt{1+\lambda^2}} = 0.2 \longrightarrow \lambda =$$

$$\Omega_p = 0.2\pi, \quad \Omega_s = 0.4\pi$$

$$N = \frac{\log(\lambda/\varepsilon)}{\log\left(\frac{\Omega_s}{\Omega_p}\right)} = 4$$

$$\Omega_c = \frac{\Omega_p}{(\varepsilon)^{1/N}}$$

Ex:- 5.1

Given, $\alpha_p = 1\text{dB}$, $\alpha_s = 30\text{dB}$, $\Omega_p = 200$ rad/sec

$\Omega_s = 600$ rad/sec.

$$\Rightarrow N = \frac{\log\sqrt{\frac{10^{0.1\alpha_s}-1}{10^{0.1\alpha_p}-1}}}{\log\left(\frac{\Omega_s}{\Omega_p}\right)}$$

$$= \frac{\log\sqrt{\frac{10^{3}-1}{10^{0.1}-1}}}{\log(3)}$$

$$= \cancel{0}.\ 3.758$$

$$N = 4$$

$$= \frac{\log\sqrt{\frac{10^{0.1\times 600}-1}{10^{0.1\times 200}-1}}}{\log\left(\frac{600}{200}\right)}$$

$$= \frac{\log\sqrt{\frac{10^{60}-1}{10^{20}-1}}}{\log(6/2)}$$

$$= \frac{\log\left(\sqrt{1\times 10^{40}}\right)}{\log(3)}$$

$$= \frac{20}{0.477} = 41.9 \simeq 42.$$

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S.2

$\alpha_p = 3dB, \quad \Omega_p = 2 \times \pi \times 500 = 1000\pi \text{ rad/sec}$

$\alpha_s = 40dB, \quad \Omega_s = 2 \times \pi \times 1000 = 2000\pi \text{ rad/sec}.$

$$N = \frac{\log \sqrt{\frac{10^{0.1\alpha_s} - 1}{10^{0.1\alpha_p} - 1}}}{\log\left(\frac{\Omega_s}{\Omega_p}\right)}$$

$$= \frac{\log\left(\sqrt{\frac{10^{0.1 \times 40} - 1}{10^{0.1 \times 3} - 1}}\right)}{\log\left(\frac{2000}{1000}\right)}$$

$$= \frac{\log(100.23)}{\log(2)}$$

$$= 6.64 = 7.$$

~~Butterworth filter pole:~~

S.4)

$\alpha_p = -2dB, \quad \Omega_p = 20 \text{ rad/sec}$

$\alpha_s = -10dB, \quad \Omega_s = 30 \text{ rad/sec}.$

$$\cancel{\boxed{N = \frac{\log \sqrt{\frac{10^{0.1 \times 20} - 1}{10^{0.1 \times 20} - 1}}}{\log\left(\frac{10}{2}\right)} = \frac{\log \sqrt{\frac{10^{3} - 1}{10^{2} - 1}}}{\log(5)} = \frac{\log(3.176)}{\log(5)}}}$$

$= 1$

$$N = \frac{\log \sqrt{\frac{10^{0.1 \times 10} - 1}{10^{0.1 \times 2} - 1}}}{\log\left(\frac{30}{20}\right)} = \frac{\log \sqrt{\frac{10^{1} - 1}{10^{0.2} - 1}}}{\log(3/2)}$$

$= 3.36$

$= 4.$

from table 5.1,

$$H(s) = \frac{1}{(s^2+0.76537s+1)(s^2+1.84773s+1)}$$

$$\Omega_c = \frac{\Omega_p}{(10^{0.1\alpha_p}-1)^{\frac{1}{2N}}}$$

$$= \frac{20}{(10^{0.1\times2}-1)^{\frac{1}{2\times4}}}$$

$$= \frac{20}{(10^{0.2}-1)^{1/8}} = 21.3867.$$

$s \rightarrow \frac{s}{21.3867}$ in $H(s)$

i.e; $$H(s) = \frac{1}{\left[\left(\frac{s}{21.3867}\right)^2 + 0.76537\times\frac{s}{21.3867}+1\right]}$$

$$\times \frac{1}{\left(\frac{s}{21.3867}\right)^2 + 1.8477\times\frac{s}{21.3867}+1}$$

$$= \frac{1}{\left(\frac{s}{2.186\times10^{-3}}\right)^2}$$

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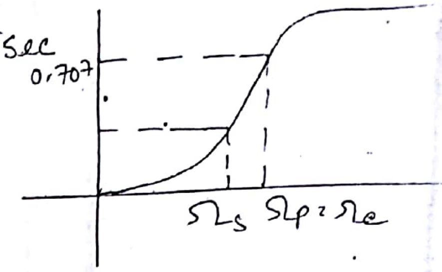
1) Using BT design a high pass filter with cuttof frequency 100Hz and down ~~3dB~~ 10 dB at 350Hz. sampling frequency is 5000Hz

⇒

$T = \frac{1}{F_s} = \frac{1}{5000} = 0.0002$ sec



$\alpha_s = 10\,dB$ $f_c = 1000\,Hz$.

$\alpha_p = 3\,dB$. $\Omega_p = \Omega_c$.

$f_s = 350\,Hz$. $\omega_p = 2\pi \times 1000$

$= 2000\pi$.

$= \cancel{6283.1}$

$\omega_s = 2\pi \times 350$

$= \cancel{2199.11}\ 700\pi$

$$N = \frac{\log\left(\sqrt{\frac{10^{0.1\alpha_s}-1}{10^{0.1\alpha_p}-1}}\right)}{\log\left(\frac{\Omega_s}{\Omega_p}\right)} = \frac{\log\left(\sqrt{\frac{9}{0.995}}\right)}{\log\left(\frac{700\pi}{2000\pi}\right)}$$

$$= \frac{\log\left(\sqrt{\frac{10^{0.1\times10}-1}{10^{0.1\times3}-1}}\right)}{\log\left(\frac{2199.11}{6283.1}\right)} \qquad = \frac{\log(3.007)}{}$$

$$= \frac{\log\left(\sqrt{\frac{9}{0.995}}\right)}{\log(0.35)} = \frac{\log(3)}{\log(0.35)}$$

$\omega_s = 2\pi \times 350 = 700\pi$, $\omega_p = 2000\pi$

Using BT method

$\Omega_s = \frac{2}{T} \tan \frac{\omega_s}{2}$

$= \frac{2}{2\times10^{-4}} \tan(350\pi)$

$= 3552.46$

$\Omega_p = \frac{2}{2\times10^{-4}} \cdot \tan(1000\pi)$

$= 67659.8$.

$$N = \frac{\log\left(\sqrt{\frac{10^{0.1\times10}-1}{10^{0.1\times3}-1}}\right)}{\log\left(\frac{3552.46}{67659.83}\right)}$$

$$= \frac{\log(3.007)}{\log(0.525)} = \cancel{-1.279}\ |-0.373| = 1.$$

$$\boxed{= \cancel{|-1.708|} = \cancel{1.708} \simeq 2}.$$

$$S \rightarrow \frac{\Omega_c}{S}.$$

$$H(s) = \frac{1}{s^2+\sqrt{2}s+1} = \frac{1}{\left(\frac{67659.8}{s}\right)^2 + \sqrt{2}\times\frac{67659.8}{s}+1}$$

$$= \frac{1}{\left(\frac{\Omega_c}{s}\right)^2+\sqrt{2}\frac{\Omega_c}{s}+1}$$

Now as the filter is high pass filter s is replaced by $\frac{\Omega_c}{s}$.

i.e; $S \rightarrow \frac{\Omega_c}{S} = \frac{67660}{S}.$

$$H_a(s) = \cancel{\frac{1}{\left(\frac{67660}{s}\right)^2+\sqrt{2}}}\ \frac{1}{\frac{67660}{s}+1} = \frac{S}{67660+S}$$

Now, in BT method $s = \frac{2}{T}\frac{(1-z^{-1})}{(1+z^{-1})}$

$$H(z) = \frac{\frac{2}{T}\frac{(1-z^{-1})}{(1+z^{-1})}}{67660+\frac{2}{T}\frac{(1-z^{-1})}{(1+z^{-1})}} = \frac{\frac{2}{T}\left(\frac{z-1}{z+1}\right)}{67660+\frac{2}{T}\frac{(z-1)}{(z+1)}}$$

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Q $H(s) = \frac{2}{(s+1)(s+2)}$ find $H(z)$ using BT method where $T = 1$ sec.

$\Rightarrow$

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

$$H(z) = \frac{2}{\left[\frac{2}{T}\frac{(1-z^{-1})}{(1+z^{-1})}+1\right]\left[\frac{2}{T}\times\frac{(1-z^{-1})}{(1+z^{-1})}+2\right]}$$

$$= \frac{2}{\left(2\frac{(z-1)}{(z+1)}+1\right)\left(2\cdot\frac{(z-1)}{(z+1)}+2\right)}$$

$$= \frac{\cancel{2}}{\left[2\cdot\frac{(z-1)}{(z+1)}+1\right]\cdot\cancel{2}\left[\frac{z-1}{z+1}+1\right]}$$

$$= \frac{1}{\frac{2z-2+z+1}{z+1}\times\frac{z\cancel{-1}+z\cancel{+1}}{z+1}}$$

$$= \frac{1}{\frac{z-1}{z+1}\times\frac{2z}{z+1}}$$

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

$$= \cancel{\frac{(1+z^{-1})^2}{2z}}$$

$$= \frac{2}{\frac{2(1-z^{-1})+(1+z^{-1})}{(1+z^{-1})}\times\frac{2(1-z^{-1})+2(1+z^{-1})}{(1+z^{-1})}}$$

$$= \frac{2}{\frac{2-2z^{-1}+1+z^{-1}}{(1+z^{-1})}}\times\frac{1}{\frac{2-\cancel{2z^{-1}}+2+\cancel{2z^{-1}}}{(1+z^{-1})}}$$

$$= \frac{2}{\frac{3-z^{-1}}{(1+z^{-1})}\times\frac{4}{(1+z^{-1})}} = \frac{2(1+z^{-1})^2}{4(3-z^{-1})} =$$

$\frac{z-1}{z+1}$

⊛ Bilinear transformation method:-

Here s is replaced by $= \frac{2}{T}\frac{(1-z^{-1})}{(1+z^{-1})}$

relation between ω and Ω:-

$$s = \frac{2}{T}\frac{(1-z^{-1})}{(1+z^{-1})} = \frac{2}{T}\frac{(re^{j\omega}-1)}{(re^{j\omega}+1)} = \frac{2}{T}\left[\frac{r\cos\omega + jr\sin\omega - 1}{r\cos\omega + jr\sin\omega + 1}\right]$$

$$= \frac{2}{T}\left[\frac{r\cos\omega - 1 + jr\sin\omega}{r(\cos\omega + 1) + jr\sin\omega}\right]$$

$$= \frac{2}{T}\frac{\{(r\cos\omega - 1) + jr\sin\omega\}\{(r\cos\omega+1) - jr\sin\omega\}}{(r\cos\omega+1)^2 + (r\sin\omega)^2}$$

$$= \frac{2}{T}\times\frac{(r\cos\omega-1)(r\cos\omega+1) - jr\sin\omega(r\cos\omega-1) + jr\sin\omega(r\cos\omega+1) + r^2\sin^2\omega}{r^2\cos^2\omega + 2r\cos\omega + 1 + r^2\sin^2\omega}$$

$$= \frac{2}{T}\times\frac{(r\cos\omega)^2 - (1)^2 - jr^2\sin\omega\cancel{\cos\omega} + jr\sin\omega + jr^2\cancel{\sin\omega\cos\omega} + jr\sin\omega + r^2\sin^2\omega}{r^2(\cos^2\omega + \sin^2\omega) + 2r\cos\omega + 1}$$

$$= \frac{2}{T}\times\frac{r^2\cos^2\omega - 1 + jr\sin\omega + jr\sin\omega + r^2\sin^2\omega}{r^2 + 2r\cos\omega + 1}$$

$$= \frac{2}{T}\times\frac{r^2(\cos^2\omega + \sin^2\omega) - 1 + 2jr\sin\omega}{r^2 + 2r\cos\omega + 1}$$

$$\sigma + j\Omega = \frac{2}{T}\times\frac{r^2 - 1 + 2jr\sin\omega}{r^2 + 1 + 2r\cos\omega} = \frac{2}{T}\left[\frac{r^2-1}{r^2+1+2r\cos\omega} + j\frac{2r\sin\omega}{r^2+1+2r\cos\omega}\right]$$

Equate Imaginary

$$\Omega = \frac{2}{T}\left[\frac{2r\sin\omega}{r^2+1+2r\cos\omega}\right] = \frac{2}{T}\left[\frac{2\sin\omega}{2+2\cos\omega}\right] \quad \text{when } r=1$$

$$= \frac{2}{T}\left[\frac{\sin\omega}{1+\cos\omega}\right] = \frac{2}{T}\frac{\cancel{2}\sin\frac{\omega}{2}\cancel{\cos\frac{\omega}{2}}}{\cancel{2}\cos^{\cancel{2}}\frac{\omega}{2}}$$

$$\boxed{\Omega = \frac{2}{T}\tan\frac{\omega}{2}} \qquad \boxed{\omega = 2\tan^{-1}\frac{\Omega T}{2}}$$

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(*) In case of II method the relation of ω and Ω is linear. But for BT method it is non-linear. Due to this non-linear effect the distortion ~~and~~ or error is known as <u>Warping effect</u> (5.46 to 5.48).

To minimize the distortion pre-warping is used.

<u>H.W</u>:- 5.18,

PP – 5.9

<u>Ex</u> – 5.30, 5.32,

PP → 5.17.

—o—

<u>Step-7</u>

Realization of filter :-

1) Direct form 1 (DF1)
2) Direct form 2 (DF2)
3) Cascade form
4) parallel form.

<u>1) DF1</u> :-

Delay ⇒ $x(n) \longrightarrow \boxed{z^{-1}} \longrightarrow x(n-1)$

Adder ⇒

Multiplier ⇒

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DFI :-

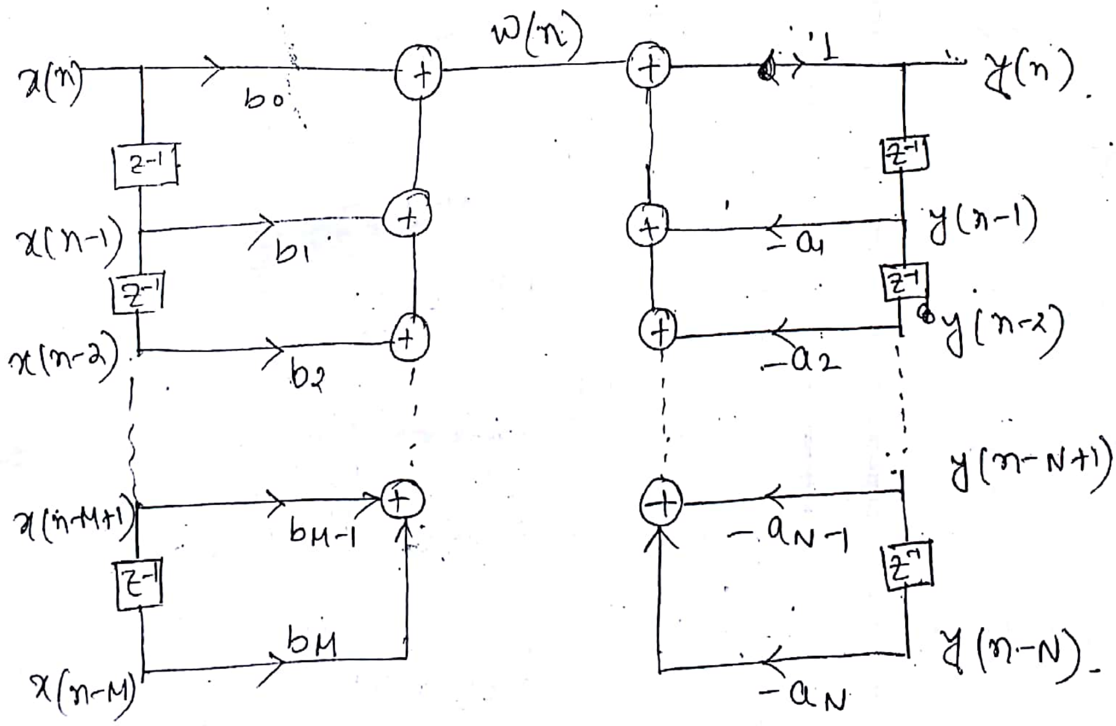
we know,

$$y(n) = -\sum_{k=1}^{N} a_k y(n-k) + \sum_{k=0}^{M} b_k x(n-k)$$

$$= -a_1 y(n-1) - a_2 y(n-2) \cdots - a_N y(n-N) + \underbrace{b_0 x(n) + b_1 x(n-1) \cdots + b_M x(n-M)}_{w(n)}$$

$$w(n) = b_0 x(n) + b_1 x(n-1) + b_2 x(n-2) \cdots + b_M x(n-M) \quad \text{--- (1)}$$

$$y(n) = -a_1 y(n-1) - a_2 y(n-2) \cdots - a_N y(n-N) + w(n) \quad \text{--- (2)}$$



DF2 We know,

$$y(n) = -\sum_{k=1}^{N} a_k y(n-k) + \sum_{k=0}^{M} b_k x(n-k)$$

$$Y(z) = -\sum_{k=1}^{N} a_k z^{-k} Y(z) + \sum_{k=0}^{M} b_k z^{-k} X(z).$$

$$\Rightarrow Y(z)\left[1+\sum_{k=1}^{N} a_k z^{-k}\right] = \sum_{k=0}^{M} b_k z^{-k} X(z)$$

$$\Rightarrow H(z) = \frac{Y(z)}{X(z)}$$

$$= \frac{\sum_{k=0}^{M} b_k z^{-k}}{\left[1+\sum_{k=1}^{N} a_k z^{-k}\right]} = \frac{Y(z)}{W(z)} \cdot \frac{W(z)}{X(z)}$$

$$\frac{Y(z)}{W(z)} = \sum_{k=0}^{M} b_k z^{-k} \Rightarrow Y(z) = \sum_{k=0}^{M} b_k z^{-k} W(z)$$

So, $y(n) = \sum_{k=0}^{M} b_k w(n-k).$

$$y(n) = b_0 w(n) + b_1 w(n-1) \cdots + b_M w(n-M) \quad \text{— (2)}.$$

Now,

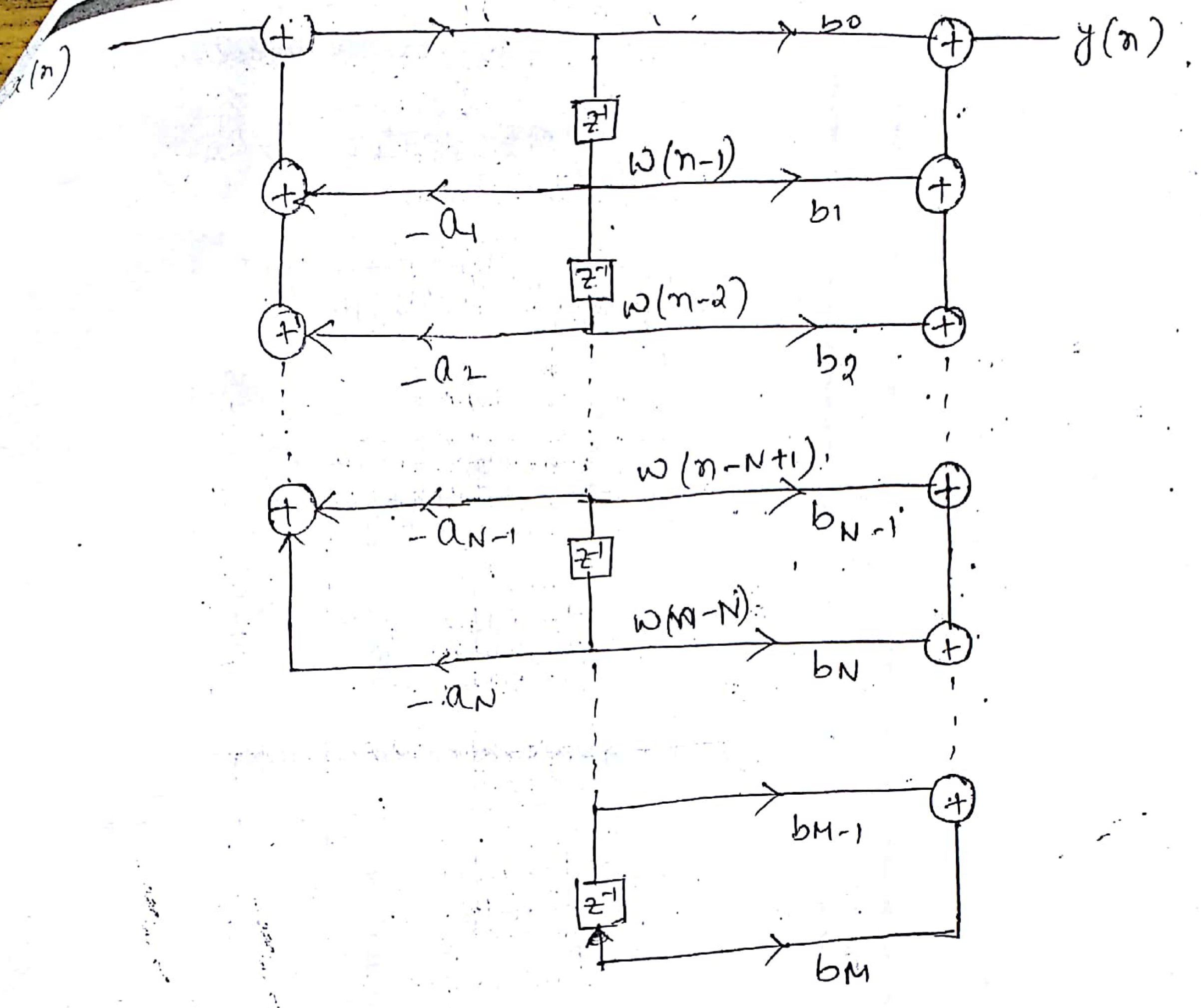
$$\frac{W(z)}{X(z)} = \frac{1}{1+\sum_{k=1}^{N} a_k z^{-k}} \Rightarrow X(z) = \cancel{W(z)+\ldots}$$

$$= W(z) + \sum_{k=1}^{N} a_k z^{-k} \cdot W(z).$$

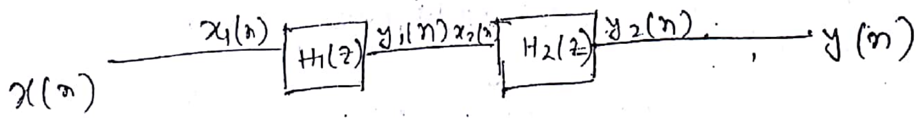
$$x(n) = w(n) + \sum_{k=1}^{N} a_k w(n-k)$$

$$\Rightarrow w(n) = x(n) - a_1 w(n-1) - a_2 w(n-2) \cdots a_N w(n-N)$$

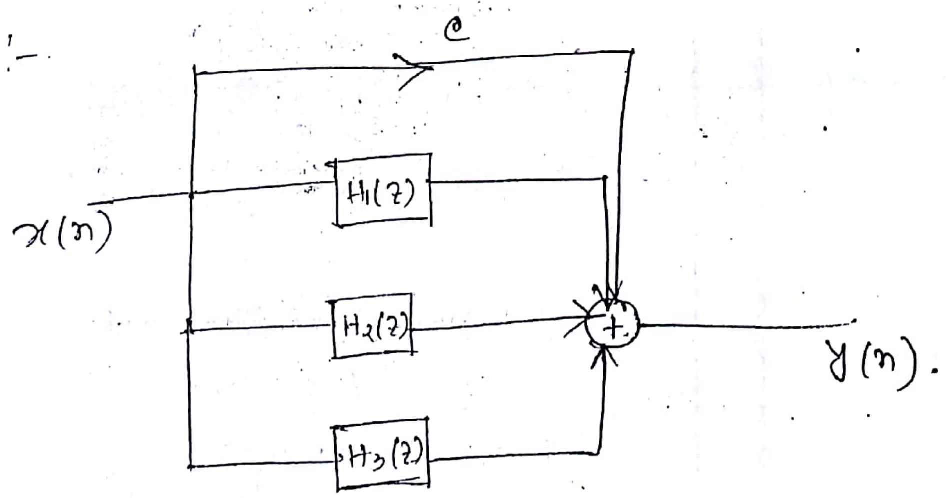
— (1).



Cascade :-



Parallel :-



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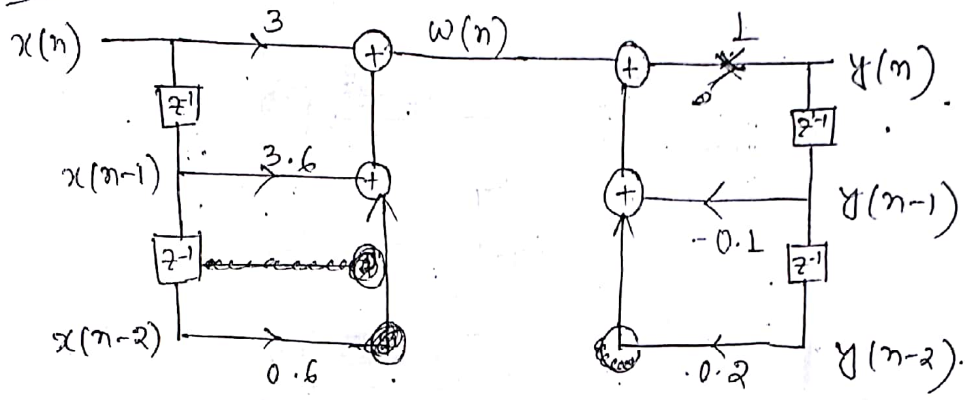
Q) $y(n) = -0.1y(n-1) + 0.2y(n-2) + 3x(n) + 3.6x(n-1) + 0.6x(n-2)$

Realize using DF1, DF2, Cascade, parallel.

$\Rightarrow$ DF1:-

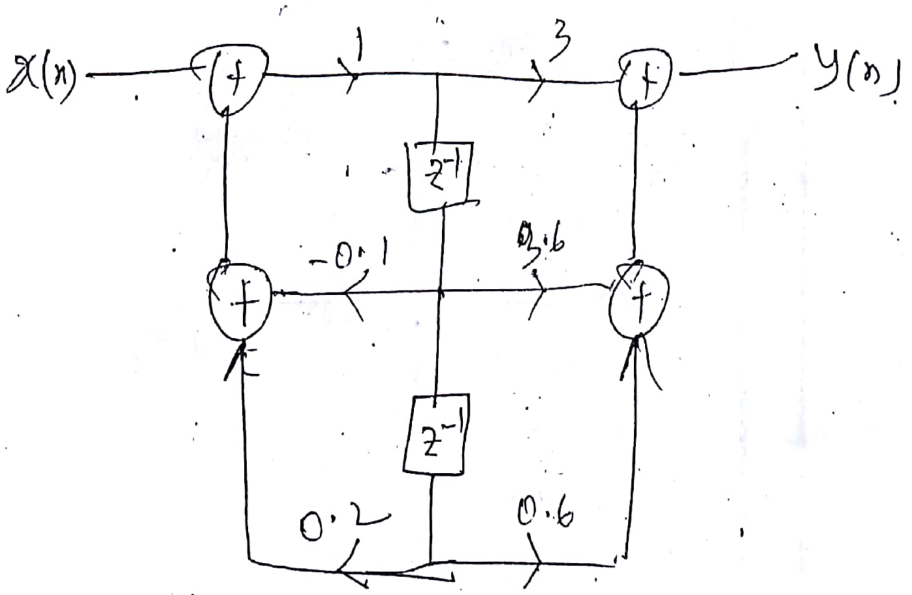


DF2:-

$$Y(z) = -0.1z^{-1}Y(z) + 0.2z^{-2}Y(z) + 3X(z) + 3.6z^{-1}X(z) + 0.6z^{-2}X(z)$$

$$\Rightarrow Y(z)\left[1 + 0.1z^{-1} - 0.2z^{-2}\right] = 3X(z) + 3.6z^{-1}X(z) + 0.6z^{-2}X(z)$$

$$\Rightarrow H(z) = \frac{Y(z)}{X(z)} = \frac{3 + 3.6z^{-1} + 0.6z^{-2}}{1 + 0.1z^{-1} - 0.2z^{-2}}$$



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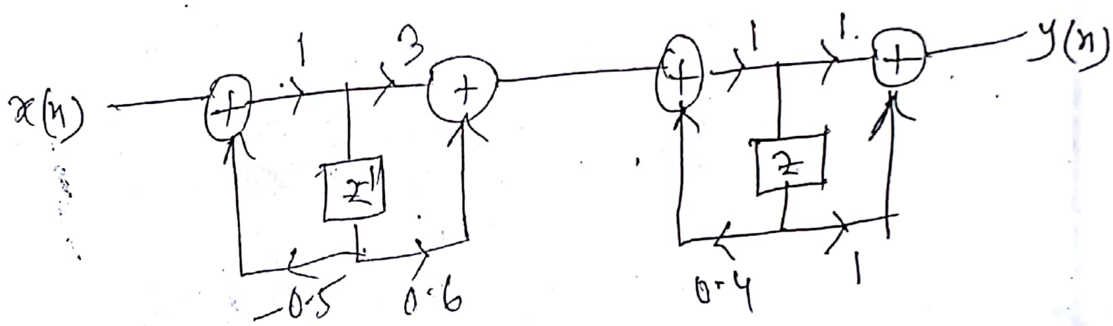
Cascade

$$H(z) = \frac{3 + 3.6z^{-1} + 0.6z^{-2}}{1 + 0.1z^{-1} - 0.2z^{-2}}$$

$$= \frac{(3 + 0.6z^{-1})(z^{-1} + 1)}{(1 + 0.5z^{-1})(1 - 0.4z^{-1})}$$

$$= H_1(z)\, H_2(z)$$

$$H_1(z) = \frac{3 + 0.6z^{-1}}{1 + 0.5z^{-1}}, \quad H_2(z) = \frac{1 + z^{-1}}{1 - 0.4z^{-1}}$$



Parallel

$$H(z) = \frac{3 + 3.6z^{-1} + 0.6z^{-2}}{1 + 0.1z^{-1} - 0.2z^{-2}}$$

$$-0.2z^{-2} + 0.1z^{-1} + 1 \,\overline{\big)\, 0.6z^{-2} + 3.6z^{-1} + 3}\; -3$$

$$\underline{0.6z^{-2} - 0.3z^{-1} - 3}$$

$$3.9z^{-1} + 6$$

$$H(z) = -3 + \frac{3.9z^{-1} + 6}{1 + 0.1z^{-1} - 0.2z^{-2}}$$

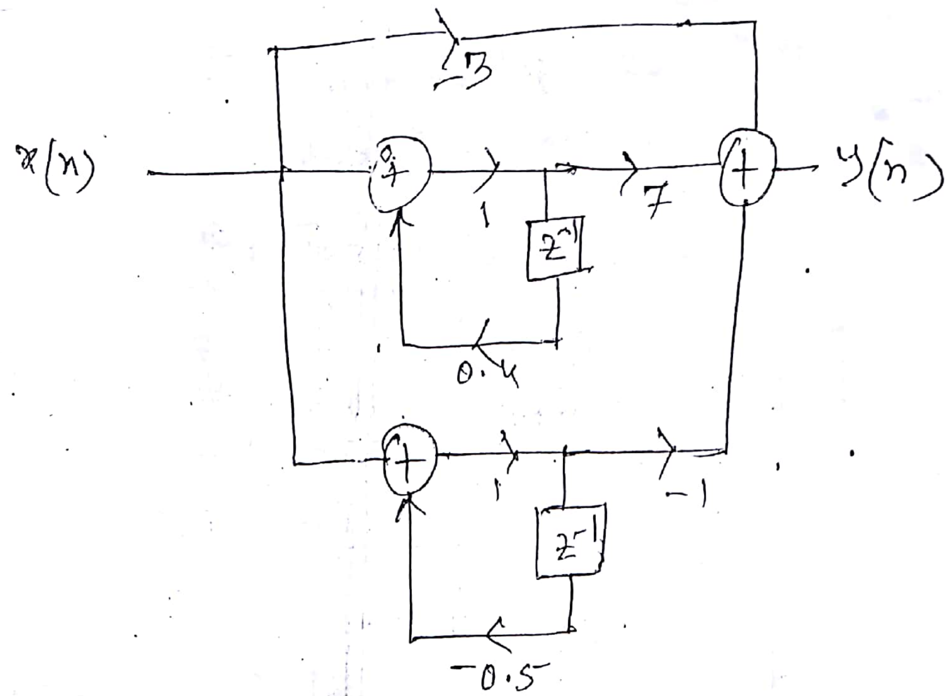
$$= -3 + \frac{A}{1 - 0.4z^{-1}} + \frac{B}{1 + 0.5z^{-1}}$$

$$= -3 + \frac{7}{1 - 0.4z^{-1}} - \frac{1}{1 + 0.5z^{-1}}$$

$$\Downarrow \qquad\qquad \Downarrow \qquad\qquad \Downarrow$$

$$C \qquad\quad H_1(z) \qquad\quad H_2(z)$$

Scanned by CamScanner



<u>H.W</u> :- Ex - 5.21, 5.23, 5.26, 5.25, 5.28,
WI, VVI, (I)

Filter design - Organizer.

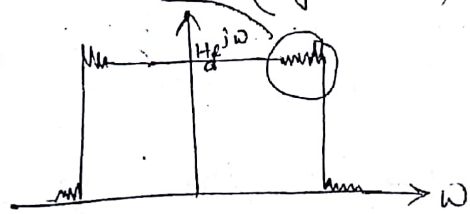
(*) <u>FIR filter</u> :-

1> Explain the linear phase of FIR filter. (Pg - 6.2, 6.3)

2> Short note: fourier series designing FIR method (Pg - 6.16, 6.17)

3> WI <u>Window technique / Windowing</u> :- (Pg: 6.29, 6.31)

4> Gibbs phenomenon :- (Pg - 6.29)



5> Rectangular window :- Pg (6.33)

6> Triangular "

(*) DSP processor (Pg no - 11.17)