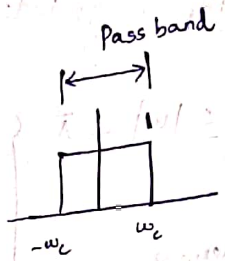
17/09/2021

$$\boxed{w_c = \frac{2\pi f_c}{f_s}}$$

(1) Using a rectangular window technique design a low pass filter with pass band gain of unity, cut off freq. of 1000 Hz & working at a sampling freq. of 5kHz. The length of the impulse response should be 7.

→ LPF, $N = 7$

Pass band gain — unity

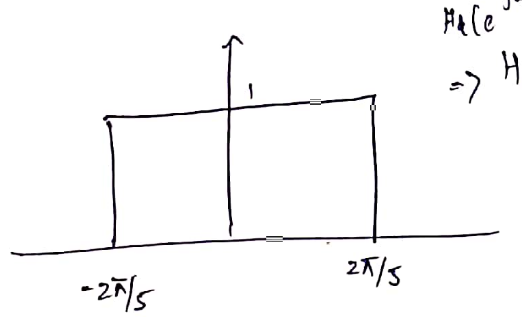


$f_c = 1000\,Hz$

$f_s = 5\,kHz$

$$\Rightarrow w_c = \frac{2\pi \times 1000}{5000} = \boxed{2\pi/5}$$

$\Rightarrow$



$H_d(e^{jw})$

$$\Rightarrow H_d(w) = \begin{cases} 1, & -2\pi/5 \le w \le 2\pi/5 \\ 0, & \text{elsewhere} \end{cases}$$

Step 1:

$$h_d(n) = IFT\left[H_d(w)\right]$$

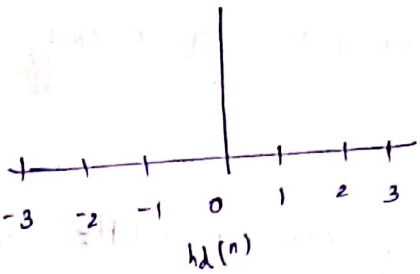
$$h_d(n) = \frac{1}{2\pi} \int_{-2\pi/5}^{2\pi/5} 1 \cdot e^{jwn}\, dw.$$

$$\Rightarrow \frac{1}{2\pi}\left[\frac{e^{jwn}}{jn}\right]_{-2\pi/5}^{2\pi/5}$$

$$\boxed{h_d(n) \Rightarrow \frac{1}{\pi n}\left(\sin\left(\tfrac{2\pi}{5}\right)n\right)}$$

$\alpha = \frac{N-1}{2} \Rightarrow \frac{7-1}{2}$

$\boxed{\alpha = 3}$



$h_d(\alpha) = 0/0$

$h(1) = h(-1)$

$h(2) = h(-2)$

$h(3) = h(-3)$

$$\boxed{P_W = 1W \cdot 10^{(P_{dBW}/10)}}$$

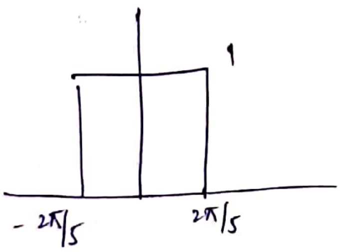
---

(2) Design a FIR filter (low pass) using rectangular window with passband gain of 0 dB, cutt off freq. of 200 Hz, sampling frequency of 1 KHz. Assume the length of the impulse response as 7.

→ 0 dB = 1 W

$f_c = 200 Hz$

$f_s = 1 kHz$



$$\Rightarrow \omega_c = \frac{2\pi f_c}{f_s} = \frac{2\pi \times 200}{1000} = 2\pi/5$$

$$H_d(e^{j\omega}) = \begin{cases} 1 & -2\pi/5 < \omega < 2\pi/5 \\ 0 & \text{otherwise} \end{cases}$$

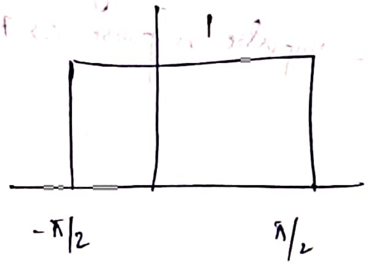
③ Design a LPF FIR with 11 coefficients for the foll. specifications:

Passband freq. edge = 0.25 kHz & sampling freq. = 1 KHz.

Use rectangular, hamming & hanning window in the design.

→ $\omega_c = \frac{2\pi f_c}{f_s}$

$\Rightarrow \frac{2\pi \times 250}{1000} \Rightarrow \boxed{\pi/2}$



$$H_d(e^{j\omega}) = \begin{cases} 1 & -\pi/2 < \omega < \pi/2 \\ 0 & \text{otherwise} \end{cases}$$

$$\boxed{h_d(n) = \frac{1}{2} \frac{\sin(n\pi/2)}{n\pi/2}}$$

Substitute n = 0

$\Rightarrow h_d(n) = 0/0$ $\boxed{N = 7}$

$\Rightarrow h(1) = h(-1)$

$h(2) = h(-2)$

⋮

$h(5) = h(-5)$

$h(6) = h(-6)$

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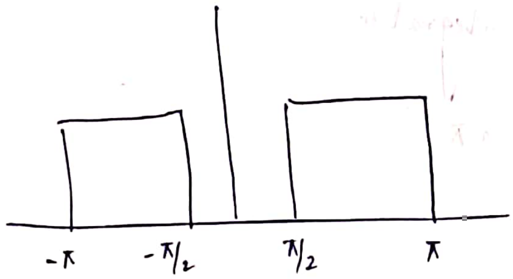
(4) Design a HPF FIR with 7 coefficients for the following specifications.

Cut off freq. = 250Hz & sampling frequency = 1kHz.
Use rectangular, hamming & hanning window in the design.

→ $w_c = \pi/2$



$$\int_{-\pi}^{-\pi/2} (\qquad) \, dw + \int_{\pi/2}^{\pi} (\qquad) \, dw$$

$h_d(n) = \dots\dots$

$\boxed{-3 \le n \le 3}$

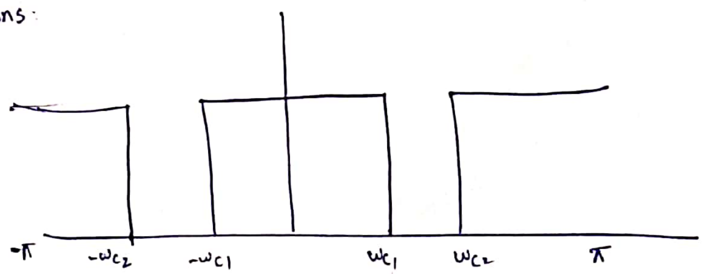
(5) Design a band stop pass filter for the foll. specifications :

$f_{c_1} = 100 Hz$, $f_{c_2} = 200 Hz$, $F_s = 1000 Hz$, filter length = 9.

→ Band stop pass filter = 3 integration.

⇒ $w_{c_1} = 0.2\pi$ | $w_{c_2} = 0.4\pi$

Filter specifications:



$$\Rightarrow \int_{-\pi}^{-\omega_{c2}} + \int_{-\omega_{c1}}^{\omega_{c1}} + \int_{\omega_{c2}}^{\pi}$$

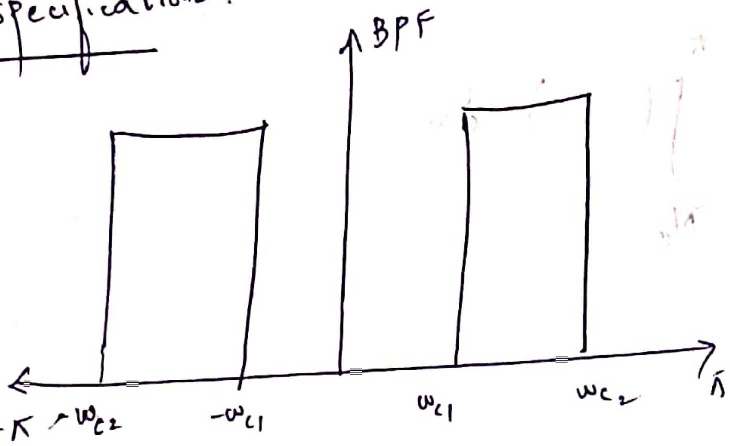
⑥ Design a band ~~stop~~ pass filter for the foll. specifications.

$f_{c1} = 100$ Hz ; $f_{c2} = 200$ Hz , $F_s = 1000$ Hz, filter length = 9

→ Band pass filter ⇒ 2 integration.

$\omega_{c1} = 0.2\pi$ | $\omega_{c2} = 0.4\pi$

Filter specifications :



$$\Rightarrow \int_{-\omega_{c2}}^{-\omega_{c1}} (\quad) + \int_{\omega_{c1}}^{\omega_{c2}} (\quad)$$

23/04/2021

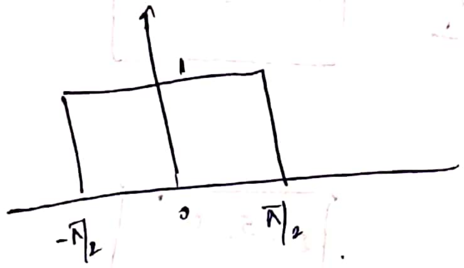
(B) Design of FIR filter ~~with~~ by frequency sampling method.

(1) Find out the filter coefficients $h(n)$ obtained by sampling & the desired freq. response:

$$H_d(e^{jw}) = \begin{cases} e^{-j3w}, & 0 \le |w| \le \pi/2 \\ 0, & \pi/2 \le |w| \le \pi \end{cases}$$

for $N=7$ } Low pass filter

$\Rightarrow$



Step 1: To find $H(K)$ $\to$ Magnitude, Phase

$H(K) \Rightarrow DFT\,[H_d(e^{jw})]$ ~~to~~ be sampled at,

$$w = \frac{2\pi}{N} k.$$

$\to$ Magnitude of $|H(k)|$

~~Here~~ $w = \frac{2\pi}{N} k$; $k = 0, 1, \ldots N-1$

Here; $\boxed{w = \frac{2\pi}{7} k}$, $k = 0, 1, \ldots, 6$

$k=0$,

$|H(k)| = \omega_0 = 0^\circ = \boxed{0}$

$k=1$,

$|H(k)| = \omega_1 = \frac{2\pi}{7} \cdot 1 \Rightarrow \frac{2\times180}{7} = \boxed{51.4^\circ}$

$(\pi = 180)$

$k=2$,

$|H(k)| = \omega_2 = \frac{2\pi}{7} \cdot 2 = \frac{2\times180\times2}{7} = \boxed{102.8^\circ}$

$k=3$,

$\omega_3 = \frac{2\pi}{7} \cdot 3 = \frac{2\times180\times3}{7} = \boxed{154.8^\circ}$

$k=4$,

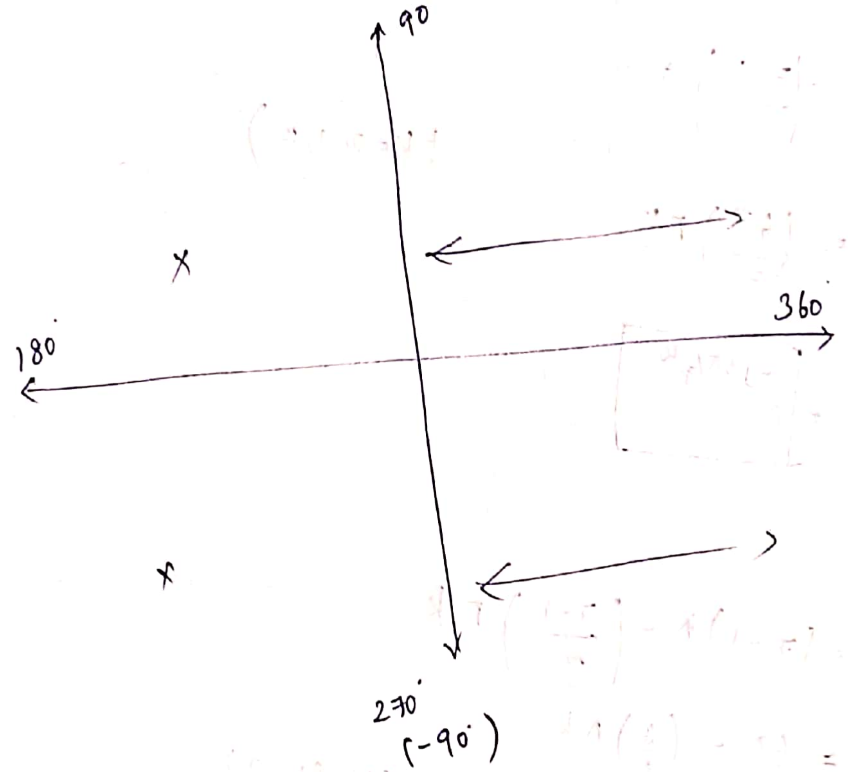
$\omega_4 = \frac{2\pi}{7} \cdot 4 = \frac{2\times180\times4}{7} = \boxed{205.7^\circ}$

$k=5$,

$\omega_5 = \frac{2\pi}{7} \cdot 5 = \frac{2\times180\times5}{7} = \boxed{257.14^\circ}$

$k=6$,

$\omega_6 = \frac{2\pi}{7} \cdot 6 = \frac{2\times180\times6}{7} = \boxed{308.5^\circ}$



$$\Rightarrow \quad \begin{array}{l|l} w_0 = 1 & w_3 = 0 \\ w_1 = 1 & w_4 = 0 \\ w_2 = 0 & w_5 = 0 \\ & w_6 = 1 \end{array}$$

$$|H(k)| = \begin{cases} 1 & k = 0, 1, 6 \\ 0 & \text{otherwise} \end{cases}$$

$\angle H(k) \rightarrow$ Phase information of $H(k)$

$$\theta(k) = -\left(\frac{N-1}{N}\right)\pi k \qquad k = 0, 1, \dots, \frac{N-1}{2}$$

(or)

$$\theta(k) = \cancel{(N-1)}\ (N-1)\pi - \left(\frac{N-1}{N}\right)\pi k \qquad k = \frac{N+1}{2} \dots (N-1)$$

Here,

$$\theta(k) = -\left(\frac{7-1}{7}\right)\pi k \qquad (k = 0, 1, 2)$$

$$\theta(k) = -\left(\frac{6}{7}\right)\pi k$$

$$= \boxed{e^{-j6\pi/7\, k}}$$

(or)

$$\theta(k) = (7-1)\pi - \left(\frac{7-1}{7}\right)\pi k$$

$$= 6\pi - \left(\frac{6}{7}\right)\pi k$$

$$= -\frac{6\pi}{7}(k-7) \Rightarrow e^{-j\frac{6\pi}{7}(k-7)}$$

$$H(k) = \begin{cases} e^{-j\frac{6\pi}{7}\pi k}, & k = 0, 1, 6 \\ 0, & k = 2, 3, 4, 5 \end{cases}$$

Step 2: To find $h(n)$

$N \to$ odd

$$h(n) = \frac{1}{N}\left\{ H(0) + 2\sum_{k=1}^{\frac{N-1}{2}} \mathrm{Re}\left[H(k)\, e^{j\frac{2\pi kn}{N}} \right] \right\}$$

$$h(n) = \frac{1}{7}\left\{ \cancel{H(0)}\ 1 + 2\sum_{K=1}^{3} Re\left[H(K)e^{j\frac{2\pi kn}{7}}\right]\right\}$$

$$= \frac{1}{7}\left\{ 1 + 2\sum_{K=1}^{3}\left[e^{-j\frac{6\pi}{7}k} \cdot e^{j\frac{2\pi kn}{7}}\right]\right.$$

$$= \frac{1}{7}\left[1 + 2\,Re\left[e^{-j\frac{6\pi}{7}} \cdot e^{\frac{2\pi n}{7}}\right]\right]$$

$$= \frac{1}{7}\left[1 + 2\,Re\left[e^{j\frac{2\pi}{7}(n-3)}\right]\right]$$

$$\boxed{h(n) = \frac{1}{7}\left\{ 1 + 2\left[\cos\frac{2\pi}{7}(n-3)\right]\right\}}$$

$$\boxed{\pi = 180^\circ}$$

$$h(0) = \frac{1}{7}\left\{ 1 + 2\cos\frac{2\pi}{7}(-3)\right\}$$

$$= \frac{1}{7}\left\{ 1 + 2(-0.9009)\right]$$

$$= \frac{1}{7}\left[1 - 1.8\right] \Rightarrow \frac{-0.8}{7} = \boxed{-0.114} = h(6)$$

$$h(1) = \frac{1}{7}\left\{ 1 + 2\left[\cos\left(\frac{2\pi}{7}(-2)\right)\right]\right\}$$

$$= \boxed{0.0793} = h(5)$$

$$h(2) = \frac{1}{7}\left\{ 1 + 2\left[\cos\frac{2\pi}{7}(-1)\right]\right\} \Rightarrow \frac{1}{7}\left\{1 + 2(0.623)\right\}$$

$$= \boxed{0.321} = h(4)$$

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$$h(3) = \frac{1}{7}\left\{ 1+2\left[\cos 0\right]\right\}$$

$$= \frac{1}{7}\left[1+2 \right] \Rightarrow \frac{3}{7}$$

$$\boxed{h(3) = 0.428}$$

$$h(n) = \{-0.114,\ 0.0793,\ 0.321,\ 0.428,\ 0.321,\ 0.0793,\ -0.114\}$$

Step 3 :

To find $|H(z)|$

---

(2) Design a linear phase low pass filter with a cutoff freq of $\pi/2$ radian per sec.

Take N=17.

Find out the magnitude, phase diff.

→ K=0 :

$$w_0 = \frac{2\pi}{N} K = \boxed{0}$$

K=1:

$$w_1 = \frac{2\pi}{17} \cdot 1 = \boxed{21.176}$$

K=2 :

$$w_2 = \frac{2\pi}{17} \cdot 2 = \boxed{42.352}$$

K=3 :

$$w_3 = \frac{2\pi}{17} \cdot 3 = \boxed{63.51}$$

K=4 :

$$w_4 = \frac{2\pi}{17} \times 4 = \boxed{84.68}$$

K=5 :

$$w_5 = \frac{2\pi}{17} \times 5 = \boxed{105.85}$$

$\underline{K=6}$:

$$\omega_6 = \frac{2\pi}{17} \times 6 = 127.02$$

$\underline{K=7}$:

$$\omega_7 = \frac{2\pi}{17} \times 7 = 148.19$$

$\underline{K=8}$:

$$\omega_8 = \frac{2\pi}{17} \times 8 = 169.36$$

$\underline{K=9}$:

$$\omega_9 = \frac{2\pi}{17} \times 9 = 190.53$$

$\underline{K=10}$:

$$\omega_{10} = \frac{2\pi}{17} \times 10 = 211.7$$

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$$|H(k)| = \begin{cases} 1 & k = 0 \text{ to } 3, \quad k = 13 \text{ to } 16 \\ 0 & k = 4 \text{ to } 12 \end{cases}$$

$$H(k) = \begin{cases} e^{-j\frac{16}{17}\pi k}, & k = 0 \text{ to } 4. \\ 0, & k = 5 \text{ to } 12 \\ e^{-j\frac{16\pi}{17}(k-17)}, & k = 13 \text{ to } 16 \end{cases}$$

$$\cancel{h(n) = \frac{1}{17}\left\{1+2\left[\cos\frac{2\pi}{17}(n-3)\right]\right\}^2}$$

$$h(n) = \frac{1}{N}\left[H(0) + 2\sum_{k=1}^{\frac{N-1}{2}} \text{Re}\left[H(k)\,e^{j\frac{2\pi kn}{N}}\right]\right]$$

$$= \frac{1}{17}\left[1+2\sum_{k=1}^{8} \text{Re}\left[H(k)\,e^{j\frac{2\pi kn}{N}}\right]\right]$$

$$= \frac{1}{17}\left[1+2\sum_{k=1}^{4} \text{Re}\left[H(k)\,e^{j\frac{2\pi kn}{17}}\right]\right]$$

$$= \frac{1}{17}\left[1+2\sum_{k=1}^{4} \text{Re}\left[e^{-j\frac{16\pi k}{17}} \cdot e^{j\frac{2\pi kn}{17}}\right]\right]$$

$$= \frac{1}{17}\left[1+2\sum_{k=1}^{4} \text{Re}\left[e^{j\frac{2\pi k}{17}(n-8)}\right]\right]$$

$$= \frac{1}{17}\left[1+2\left[\sum_{k=1}^{4} \cos\frac{2\pi k}{17}(n-8)\right]\right]$$

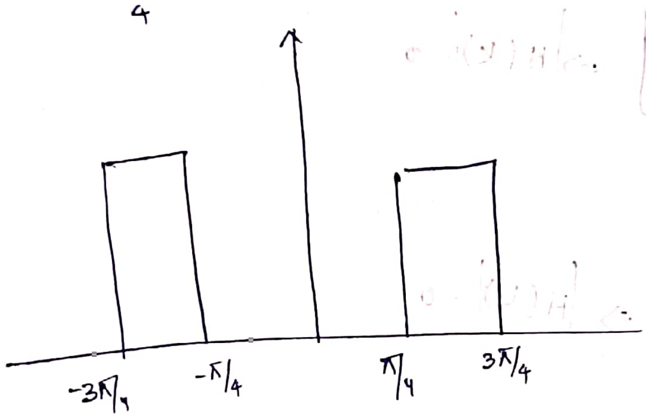
$$h(n) = \frac{1}{17}\left[1+2\left[\cos\frac{2\pi}{7}(n-8) + \cos\frac{4\pi}{17}(n-8) + \cos\frac{6\pi}{17}(n-8) + \cos\frac{8\pi}{17}(n-8)\right]\right]$$

24/09/2021

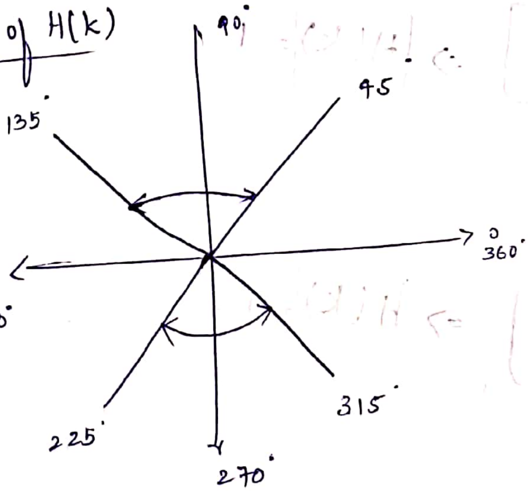
① Use of frequency sampling method to design a band pass FIR filters with foll. specifications.
Sampling frequency 8000Hz, cut off freq. $f_{c_1} = 1000 Hz$; $f_{c_2} = 3000 Hz$. Determine the filter coefficients for N = 7.

→ $\boxed{w_{c_1} = \frac{2\pi F_s}{f_{c_1}}}$ $\boxed{w_{c_2} = \frac{2\pi F_s}{f_{c_2}}}$

⇒ $w_{c_1} = \frac{\pi}{4} = 45°$ $w_{c_2} = \frac{3\pi}{4} \Rightarrow \boxed{135°}$



Step 1: Magnitude of H(k)



$w = \frac{2\pi}{7} \times k$ k = 0 to 6

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$\underline{k=0:}$

$$\omega = \frac{2\pi}{7} \cdot 0 = \boxed{0^\circ} \Rightarrow |H(k)| = 0$$

$\underline{k=1:}$

$$\omega = \frac{2\pi}{7} \cdot 1 = \boxed{51.4^\circ} \Rightarrow |H(k)| = 1$$

$\underline{k=2:}$

$$\omega = \frac{2\pi}{7} \cdot 2 = \boxed{102.8^\circ} \Rightarrow |H(k)| = 1$$

$\underline{k=3:}$

$$\omega = \frac{2\pi}{7} \cdot 3 = \boxed{154.2^\circ} \Rightarrow |H(k)| = 0$$

$\underline{k=4:}$

$$\omega = \frac{2\pi}{7} \cdot 4 = \boxed{205.6^\circ} \Rightarrow |H(k)| = 0$$

$\underline{k=5:}$

$$\omega = \frac{2\pi}{7} \cdot 5 = \boxed{257.14^\circ} \Rightarrow |H(k)| = 1$$

$\underline{k=6:}$

$$\omega = \frac{2\pi}{7} \times 6 = \boxed{308.4^\circ} \Rightarrow |H(k)| = 1$$

$$|H(k)| = \begin{cases} 1 & k = 1, 2, 5, 6 \\ 0 & k = 3, 4 \end{cases}$$

$$\text{Phase of } H(k) = \begin{cases} e^{-j\frac{6\pi}{7}k}, & k = 0 \text{ to } 2 \\ e^{-j\frac{6\pi}{7}(k-7)}, & k = 5 \text{ to } 6 \end{cases}$$

$$h(n) = \frac{1}{N}\left\{H(0) + 2\sum_{k=1}^{\frac{N-1}{2}} Re\left[H(k)e^{\frac{j2\pi kn}{N}}\right]\right\}$$

$$= \frac{1}{7}\left\{0 + 2\sum_{k=1}^{3} Re\left[e^{-j\frac{6\pi}{7}k} e^{\frac{j2\pi kn}{7}}\right]\right\}$$

$$= \frac{1}{7}\left[0 + 2\sum_{k=1}^{3} Re\left[e^{\frac{j2\pi k}{7}(n-3)}\right]\right]$$

$$= \frac{1}{7}\left[0 + 2\sum_{k=1}^{3} Re\left[\cos\left(\frac{2\pi k}{7}(n-3)\right)\right]\right]$$

$$= \frac{1}{7}\left[0 + 2\left[\cos\left(\frac{2\pi.1}{7}(n-3)\right) + \cos\left(\frac{2\pi.2}{7}(n-3)\right)\right]\right]$$

$$\Rightarrow h(n) = \frac{1}{7}\left[0 + 2\left[\cos\left(\frac{2\pi}{7}(n-3)\right) + \cos\left(\frac{4\pi}{7}(n-3)\right)\right]\right]$$

$h(0) = h(6) = -0.07928$

$h(1) = h(5) = -0.321$

$h(2) = h(4) = 0.11456$

$h(3) = 4/7 = 0.5714$

27/09/2021

Characteristics of FIR filters : Linear phase filters

Q: What is the condition for filters to act as linear phase FIR filters?

Methods : Designing of FIR filters

(i) Windowing technique :

$$h(n) = h_d(n) \cdot w(n), \text{ where } h_d(n) = IFT[H_d(w)]$$

(ii) Fourier series technique : $\Rightarrow H_d(e^{jw}) \rightarrow h_d(n)$

$\Rightarrow h(n) = h_d(n)$

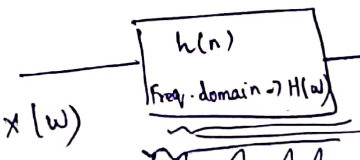
(iii) Freq. sampling method :

FIR filters :

(i) FIR filters are an LTI systems performs a filtering operations on various freq. component at its I/P.

(ii) The nature of this filtering action is determined by "freq. response characteristics $\boxed{H(w)}$ → X. (critical parameter)

[Impulse response of the filter ⇒ h(n)]



$Y(w) = X(w) \cdot H(w)$ | $h(n) = h(N-1-n)$

→ System act as a filter.

(iii) An LTI system modifies the I/P spectrum $X(w)$ according to its freq. response $H(w)$ to produce an O/P signal with spectrum, $\boxed{Y(w) = X(w) \cdot H(w)}$

(iv) Hence $H(\omega)$ is the weighting function / spectral shaping function to different freq. components of i/p signal.

$H(\omega)$ is a complex quantity,

$$H(\omega) = |H(\omega)| \angle H(\omega)$$

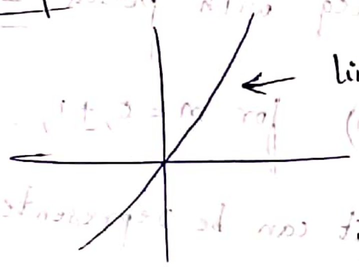
$$\angle H(\omega) = \theta(\omega) - \alpha(\omega)$$

Here $|H(\omega)|$ = constant 'c'.

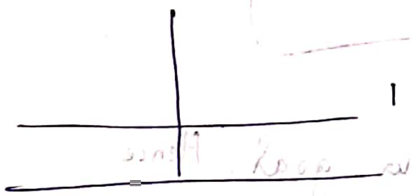
$\boxed{\theta(\omega) \text{ proporitional to } \omega}$

Main characteristics of FIR filters $\Rightarrow$ Linear phase
$\Rightarrow$ Constant / Uniform magnitude

Condition for linear phase:



Condition for constant / uniform magnitude:



Derivative of phase is equal to group delay,

$$\boxed{T_g = \frac{d\,\theta(\omega)}{d\omega)}} \longrightarrow \text{Group delay.}$$

$\therefore$ Linear phase filter delay is constant & indept. of freq.

Characteristics of FIR filter

(i) Linear phase:

We will only care abt $h(n)$ [Impulse response]

Let $h(n)$ be a causal finite duration seq. in the interval $0 \le n \le N-1$ & the samples of $h(n)$ are real.

(ii) FT of $h(n)$ is,

$$\boxed{H(\omega) = \sum_{n=0}^{N-1} h(n) e^{-j\omega n}}$$

$H(\omega)$ is periodic in freq. with period 2π.

i.e. $H(\omega) = H(\omega + 2\pi m)$ for $m = 0, \pm 1, \ldots$

$\because H(\omega)$ is complex, it can be represented as magnitude & phase function:

$$\boxed{H(\omega) = \pm |H(\omega)| e^{j\theta(\omega)}}$$

(iii) For FIR filter, Linear phase is our goal. Hence $\theta(\omega)$ is directly $\propto$ to ω.
(proportional)

$$\Rightarrow \boxed{\theta(\omega) = -\alpha(\omega)}$$

α - constant.

$$H(\omega) = \sum_{n=0}^{N-1} h(n) e^{-j\omega n} \quad \text{—— (1)} \quad \Rightarrow \text{F.T of } h(n)$$

$$H(\omega) = \pm |H(\omega)| e^{j\theta(\omega)}$$

$|H(\omega)|$ - magnitude

$e^{j\theta(\omega)}$ - phase info.

$$H(\omega) = \pm |H(\omega)| e^{-j\alpha\omega} \quad \text{--- (2)}$$

ξ (1) & (2)

$$\Rightarrow \sum_{n=0}^{N-1} h(n)\, e^{-j\omega n} = \pm |H(\omega)| e^{-j\alpha\omega}$$

$$\Rightarrow \sum_{n=0}^{N-1} h(n)\left[\cos\omega n - j\sin\omega n\right] = \pm |H(\omega)| \left[\cos\alpha\omega - j\sin\alpha\omega\right]$$

Equating real & imaginary part,

$$\pm |H(\omega)| \cos\alpha\omega = \sum_{n=0}^{N-1} h(n)\cos\omega n \quad \text{--- (3)}$$

$$\pm |H(\omega)| \sin\alpha\omega = \sum_{n=0}^{N-1} h(n)\sin\omega n \quad \text{--- (4)}$$

Divide (4) ÷ (3)

$$\frac{\sin\alpha\omega}{\cos\alpha\omega} = \frac{\sum_{n=0}^{N-1} h(n)\sin\omega n}{\sum_{n=0}^{N-1} h(n)\cos\omega n} \quad \text{--- (5)}$$

$$\sin\alpha\omega \sum_{n=0}^{N-1} h(n)\cos\omega n = \cos\alpha\omega \sum_{n=0}^{N-1} h(n)\sin\omega n$$

$$\sum_{n=0}^{N-1} h(n)\sin\alpha\omega\cos\omega n = \sum_{n=0}^{N-1} h(n)\cos\alpha\omega\sin\omega n$$

$$\Rightarrow \sum_{n=0}^{N-1} h(n)\sin\alpha\omega\cos\omega n - \sum_{n=0}^{N-1} h(n)\cos\alpha\omega\sin\omega n = 0$$

$$\Rightarrow \boxed{\sum_{n=0}^{N-1} h(n)\sin(\alpha - n)\omega = 0} \quad \text{--- (6)}$$

Fourier series.

Only soln for eqn (6) exists when,

$\boxed{\alpha = \frac{N-1}{2}}$ & $\boxed{h(n) = h(N-1-n)}$

for $0 \leq n \leq N-1$

condition for filters to act as a linear phase FIR filters

→ Linear phase filter requires the filter to have both constant group delay & phase delay.,

$\boxed{\alpha = \frac{N-1}{2}}$; $h(n) = h(N-1-n)$

⇒ If only constant group delay is required, in this case the condition is,

$\boxed{\alpha = \frac{N-1}{2}}$; $h(n) = -h(N-1-n)$

Here impulse response h(n) is antisymmetric around the centre of sequence

Frequency response of Linear Phase FIR filter.

CASE 1 : h(n) is symmetric & N - odd.

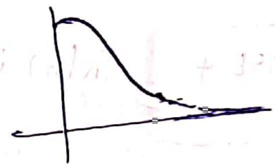
Magnitude fn :

$$|H(w)| = h\left(\frac{N-1}{2}\right) + \sum_{n=1}^{\frac{N-1}{2}} 2h\left(\frac{N-1}{2} - n\right) \cos wn$$

Phase fn :

$$\angle H(w) = -\alpha w = -\left(\frac{N-1}{2}\right) w$$

LPF:



HPF:

CASE 2 : h(n) is symmetric & N - even

Magnitude fn :

$$|H(w)| = \sum_{n=1}^{N/2} 2h\left(\frac{N}{2} - n\right) \cos\left(w\left(n - 1/2\right)\right)$$

Phase fn :

$$\angle H(w) = -\alpha w = -\left(\frac{N-1}{2}\right) w$$

CASE 3 : $h(n)$ is antisymmetric & N-odd :

$\longrightarrow h(n) = -h(N-1-n)$

$h(1) = -h(-1)$

$h(2) = h(-2)$

Magnitude f^n :

$$|H(\omega)| = \sum_{n=1}^{\frac{N-1}{2}} 2h\left(\frac{N-1}{2} - n\right) \sin \omega n$$

Phase f^n :

$$\angle H(\omega) = \frac{\pi}{2} - \alpha\omega = \frac{\pi}{2} - \left(\frac{N-1}{2}\right)\omega$$

CASE 4 : $h(n)$ is antisymmetric & N-even :

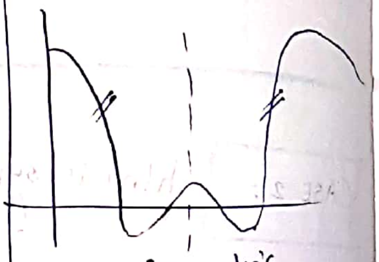
Magnitude f^n :

$$|H(\omega)| = \sum_{n=1}^{N/2} 2h\left(\frac{N}{2} - n\right) \sin\left(\omega(n-1/2)\right)$$

Phase f^n :

$$\angle H(\omega) = \frac{\pi}{2} - \alpha\omega = \frac{\pi}{2} - \left(\frac{N-1}{2}\right)\omega$$

LPF :



[Same pattern is repeated]

~~Coeff~~ h(n)	N	Magnitude Response
Symmetric	Odd	Symmetric
Symmetric	Even	Antisymmetric
Antisymmetric	Odd	Antisymmetric
Antisymmetric	Even	Symmetric

DIGITAL FILTER

FIR - Finite
Response

(i) $h(n) \rightarrow$

becoz
(ii) Non-recur
present &
only

cont.

$y(n) = x(n)$

Freq. domain, $Y(z) =$

$Y(z) = X(z$

$H(z) = Y$
X

$X(z)$ $H(z)$

$\Rightarrow H(z) = [1$

(iii) No feed

(iv) Uncondit
(Always
phase

$\Rightarrow$ FIR filter