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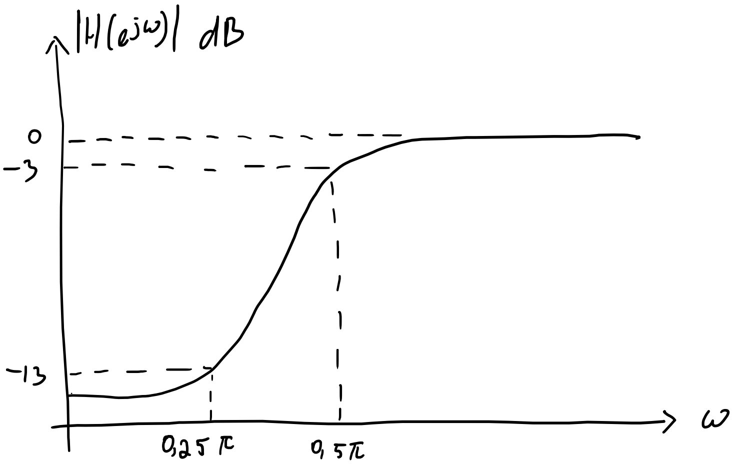
1. $f_p = 2000\ Hz$ $\qquad F_s = 8\ kHz = 8000\ Hz$

$f_s = 1000\ Hz$ $\qquad R_p = -3\ dB$

$f_o = 4000\ Hz$ $\qquad R_s = -13\ dB$

a. $\omega_p = \dfrac{2\pi f_p}{F_s} = \dfrac{2\pi \cdot 2000}{8000} = 0{,}5\pi$ rad/sampel

$\omega_s = \dfrac{2\pi f_s}{F_s} = \dfrac{2\pi \cdot 1000}{8000} = 0{,}25\pi$ rad/sampel

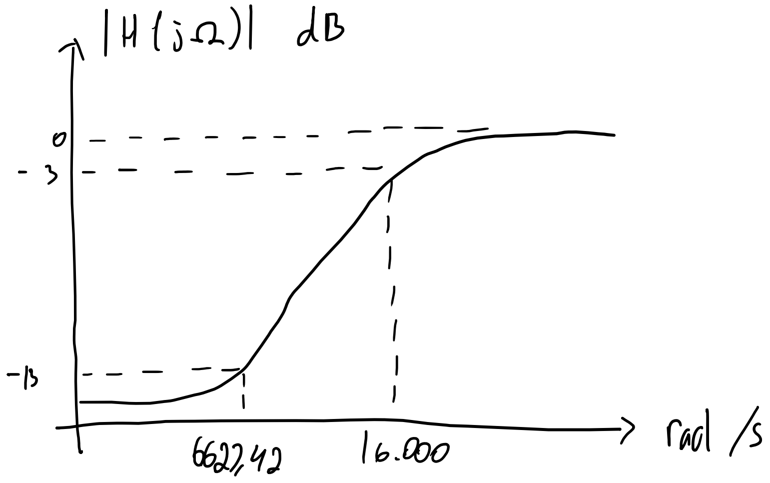


b. $T = \dfrac{1}{F_s} = \dfrac{1}{8000}$

$\Omega_p = \dfrac{2}{T}\tan\left(\dfrac{\omega_p}{2}\right) = \dfrac{2}{1/8000}\tan\left(\dfrac{0{,}5\pi}{2}\right) = 16.000$ rad/s

$\Omega_s = \dfrac{2}{T}\tan\left(\dfrac{\omega_s}{2}\right) = \dfrac{2}{1/8000}\tan\left(\dfrac{0{,}25\pi}{2}\right) = 6627{,}42$ rad/s

c.



d.

$$\Omega_c = \frac{\Omega_p}{\Omega_s} = \frac{16.000}{6627,42} = 2,41$$

$$n = \left\lceil \frac{\log\left[\frac{10^{-\frac{R_p}{10}} - 1}{10^{-\frac{R_s}{10}} - 1}\right]}{2\log\left(\frac{1}{\Omega_c}\right)} \right\rceil = \left\lceil \frac{\log\left[\frac{10^{3/10} - 1}{10^{13/10} - 1}\right]}{2\log\left(\frac{1}{2,411}\right)} \right\rceil = \lceil 1,67 \rceil = 2$$

$$H(s) = \frac{1}{s^2 + \sqrt{2}\,s + 1}$$

e. $H(s)$ filter Butterworth karena tidak ada ripple

f. HPF : $s \to \frac{\Omega_p}{s} \to \frac{16.000}{s}$

$$H(s)\Big|_{s \to \frac{16.000}{s}} = \frac{1}{\left(\frac{16.000}{s}\right)^2 + \sqrt{2}\left(\frac{16.000}{s}\right) + 1}$$

$$= \frac{s^2}{s^2 + 16.000\sqrt{2}\,s + 16.000^2}$$

$$H(z) = H(s)\Big|_{s \to 2F_s \frac{(1-z^{-1})}{(1+z^{-1})}} = \frac{\left(16.000\left(\frac{1-z^{-1}}{1+z^{-1}}\right)\right)^2}{\left(2.000 \cdot \frac{(1-z^{-1})}{(1+z^{-1})}\right)^2 + 16.000\sqrt{2}\left(2.0000 \cdot \frac{(1-z^{-1})}{(1+z^{-1})}\right) + 16.000^2}$$

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

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

$$H(z) = \frac{1 - 2z^{-1} + z^{-2}}{3{,}414 + 0{,}586\, z^{-2}}$$

g. $n = \underline{2}$

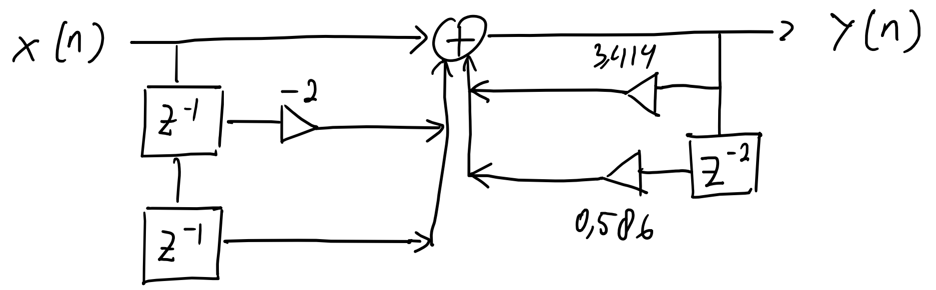
h.

$$H(z) = \frac{Y(z)}{X(z)} = \frac{1 - 2z^{-1} + z^{-2}}{3{,}414 + 0{,}586\, z^{-2}}$$

$$Y(z)\left(3{,}414 + 0{,}586\, z^{-2}\right) = X(z)\left(1 - 2z^{-1} + z^{-2}\right)$$

$$3{,}414\, Y(z) + 0{,}586\, z^{-2}\, Y(z) = X(z) - 2z^{-1}X(z) + z^{-2}X(z)$$

$$3{,}414\, Y(n) + 0{,}586\, Y(n-2) = X(n) - 2X(n-1) + X(n-2)$$



i. $x(t) = 2\cos(2000\pi t)$

$$X(n) = 2\cos\left(\frac{2000\pi}{8000} n\right) = 2\cos(0{,}25\pi n)$$

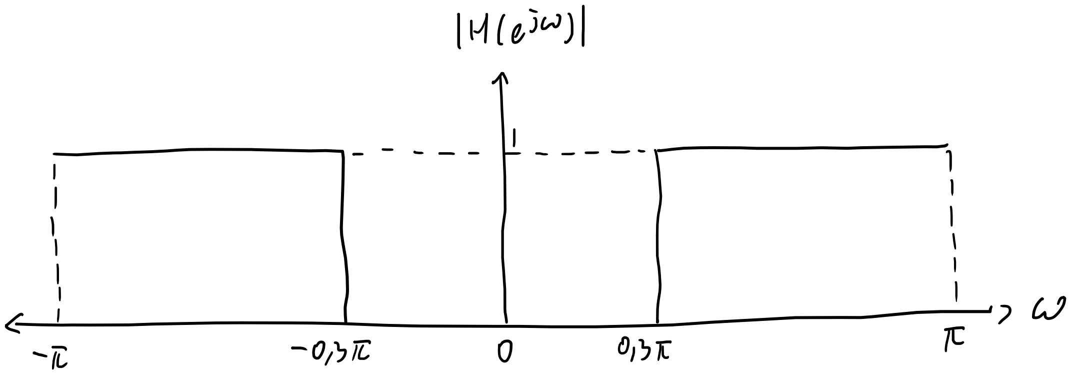
2.

$$H(e^{j\omega}) \begin{cases} e^{-j2\omega}, & -\pi \le \omega \le -0{,}3\pi \\ 0, & -0{,}3\pi < \omega < 0{,}3\pi \\ e^{-j2\omega}, & 0{,}3\pi \le \omega \le \pi \end{cases}$$

$$w[n] = 0{,}54 - 0{,}46 \cos\left(\frac{2\pi n}{M-1}\right), \quad 0 \le n \le M-1$$

$$F_s = 8 \text{ kHz}$$

a.



b. $\alpha = 2$

Jumlah koef. filter : $M = 2\alpha + 1 = 2.2 + 1 = 5$

Orde filter : $N = M - 1 = 4$

c. $\omega_c = 0{,}3\pi$

$$h_d[n] = \frac{\sin[\pi(n-\alpha)] - \sin[\omega_c(n-\alpha)]}{\pi(n-\alpha)}, \quad 0 \le n \le N$$

$$h_d[n] = \frac{\sin[\pi(n-2)] - \sin[0{,}3\pi(n-2)]}{\pi(n-2)}, \quad 0 \le n \le 4$$

$$h_d[n] = [\,h_d(0) \quad h_d(1) \quad h_d(2) \quad h_d(3) \quad h_d(4)\,]$$

$$h_d[n] = [\,-0{,}151 \quad -0{,}258 \quad 0{,}7 \quad -0{,}258 \quad -0{,}151\,]$$

d. $w[n] = [w(0) \quad w(1) \quad w(2) \quad w(3) \quad w(4)]$

$w[n] = [0{,}08 \quad 0{,}54 \quad 1 \quad 0{,}54 \quad 0{,}08]$

e. $h[n] = h_d[n] . w[n]$

$= [-0{,}012 \quad -0{,}139 \quad 0{,}7 \quad -0{,}139 \quad -0{,}012]$

f. Filter stabil dan kausal karena jenis filter FIR yang non-rekursif dan BIBO

g. $\omega_c = \dfrac{2\pi f_c}{F_s}$

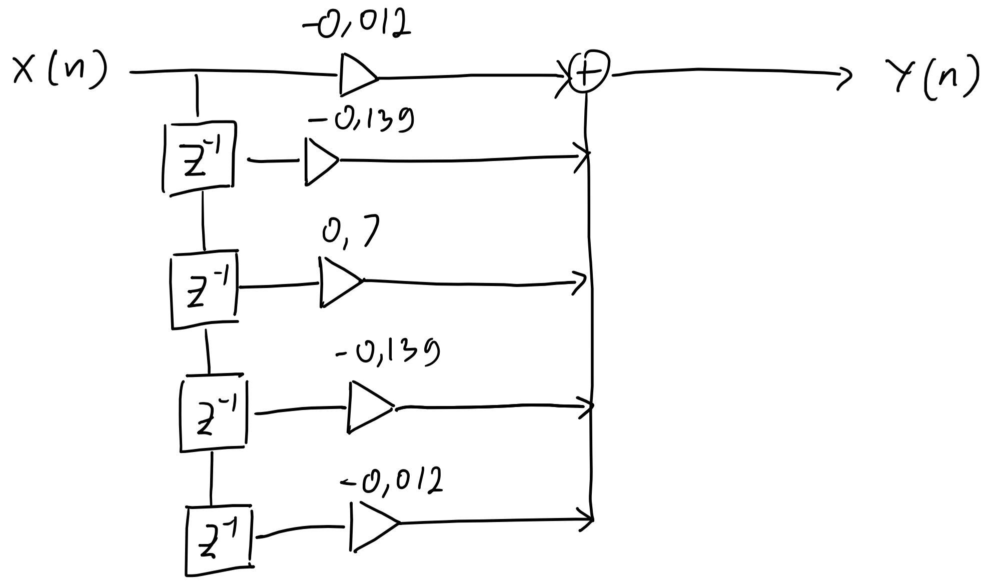
$0{,}3\cancel{\pi} = \dfrac{2\cancel{\pi} f_c}{8000}$

$f_c = 1.200 \text{ Hz}$

Rentan frekuensi yang dilewatkan : $f \geq f_c$

$f \geq 1.200 \text{ Hz}$

h.



i. $h[n] = [-0{,}012 \quad -0{,}139 \quad 0{,}7 \quad -0{,}139 \quad -0{,}012], \quad 0 \leq n \leq 4$

$h[n] = [-0{,}012 \quad -0{,}139 \quad 0{,}7 \quad -0{,}139 \quad -0{,}012 \quad 0 \quad 0 \quad 0], \quad 0 \leq n \leq 7$

$$f[n] = h[2n] = \{h[0], h[2], h[4], h[6]\}$$

$$= \begin{bmatrix} -0{,}012 & 0{,}7 & -0{,}012 & 0 \end{bmatrix}$$

$$g[n] = g[2n+1] = \{h[1], h[3], h[5], h[7]\}$$

$$= \begin{bmatrix} -0{,}139 & -0{,}139 & 0 & 0 \end{bmatrix}$$

$$W_4 = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & -j & -1 & j \\ 1 & -1 & 1 & -1 \\ 1 & j & -1 & -j \end{bmatrix}$$

$$F_4 = W_4 \cdot f[n]$$

$$\begin{bmatrix} F[0] \\ F[1] \\ F[2] \\ F[3] \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & -j & -1 & j \\ 1 & -1 & 1 & -1 \\ 1 & j & -1 & -j \end{bmatrix} \begin{bmatrix} -0{,}012 \\ 0{,}7 \\ -0{,}012 \\ 0 \end{bmatrix} = \begin{bmatrix} 0{,}676 \\ -0{,}7j \\ -0{,}724 \\ 0{,}7j \end{bmatrix}$$

$$G_4 = W_4 \cdot g[n]$$

$$\begin{bmatrix} G[0] \\ G[1] \\ G[2] \\ G[3] \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & -j & -1 & j \\ 1 & -1 & 1 & -1 \\ 1 & j & -1 & -j \end{bmatrix} \begin{bmatrix} -0{,}139 \\ -0{,}139 \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} -0{,}278 \\ -0{,}139 + 0{,}139j \\ 0 \\ -0{,}139 - 0{,}139j \end{bmatrix}$$

$$H[0] = F[0] + W_8^0 . G[0] = 0{,}676 + 1.(-0{,}278) = 0{,}398$$

$$H[1] = F[1] + W_8^1 G[1] = -0{,}7j + \left(\frac{1}{\sqrt{2}} - \frac{1}{\sqrt{2}}j\right)\left(-0{,}139 + 0{,}139j\right)$$

$$= -0{,}504i$$

$$H[2] = F[2] + W_8^2 G[2] = -0{,}724 + (-j).0 = -0{,}724$$

$$H[3] = F[3] + W_8^3 G[3] = 0{,}7j + \left(-\frac{1}{\sqrt{2}} - \frac{1}{\sqrt{2}}j\right)\left(-0{,}139 - 0{,}139j\right)$$

$$= 0{,}896j$$

$$H[4] = F[0] - W_8^0 G[0] = 0{,}676 - (1).(-0{,}278) = 0{,}954$$

$$H[5] = F[1] - W_8^1 G[1] = -0{,}7j - \left(\frac{1}{\sqrt{2}} - \frac{1}{\sqrt{2}}j\right)\left(-0{,}139 + 0{,}139j\right)$$

$$= -0{,}896j$$

$$H[6] = F[2] - W_8^2 G[2] = -0{,}724 - (-j).0 = -0{,}724$$

$$H[7] = F[3] - W_8^3 G[3] = 0{,}7j - \left(-\frac{1}{\sqrt{2}} - \frac{1}{\sqrt{2}}j\right)\left(-0{,}139 - 0{,}139j\right)$$

$$= 0{,}504i$$

j. $|H[0]| = 0{,}398$ $\quad |H[1]| = 0{,}504$ $\quad |H[2]| = 0{,}724$ $\quad |H[3]| = 0{,}896$

$|H[4]| = 0{,}954$ $\quad |H[5]| = 0{,}896$ $\quad |H[6]| = 0{,}724$ $\quad |H[7]| = 0{,}504$