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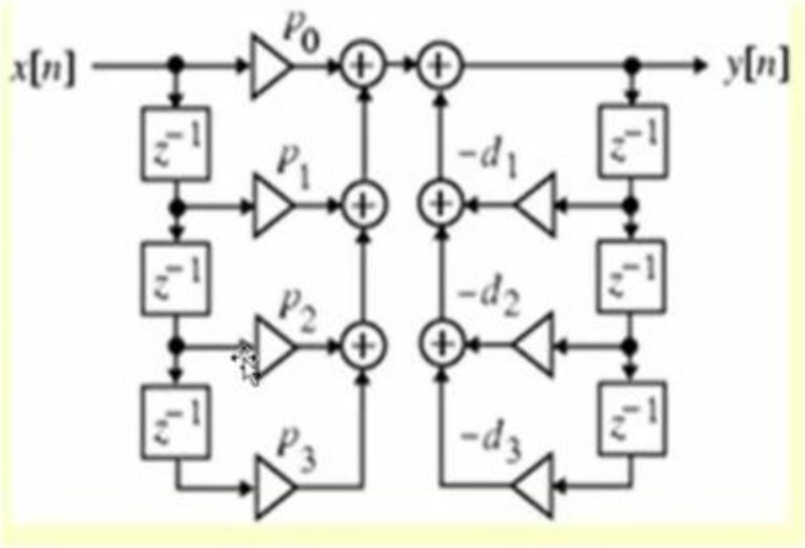
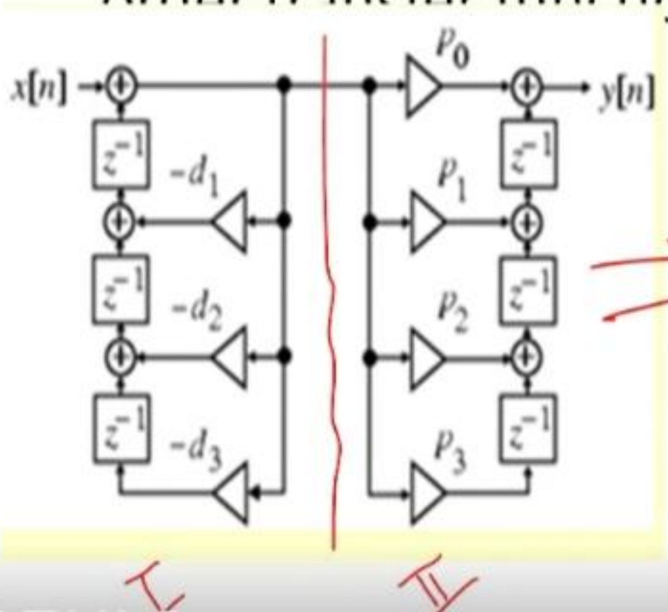
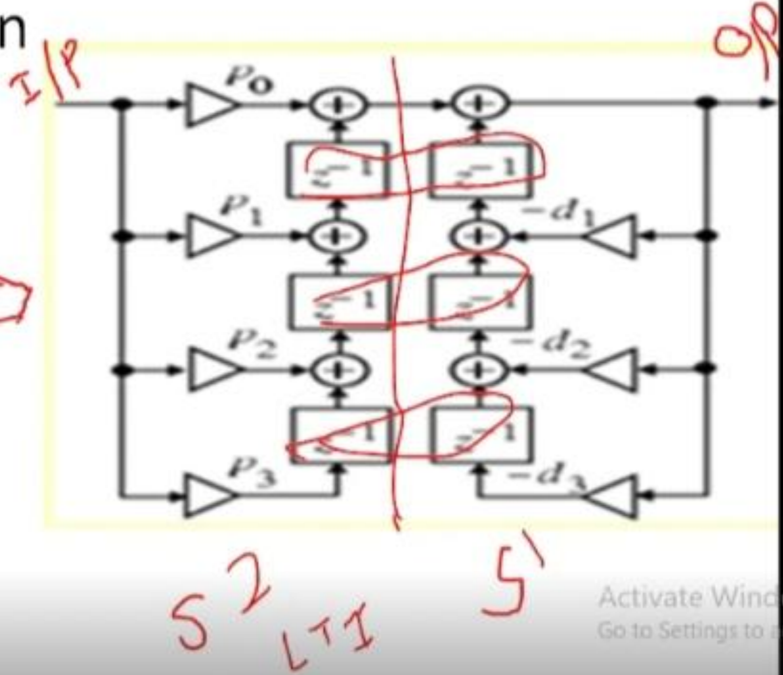


Contd...

- The direct form-I structure is non canonical as it requires 6 delay elements to realize a 3rd order transfer function





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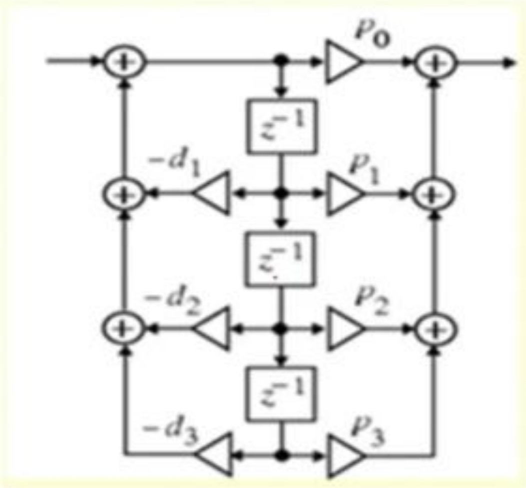
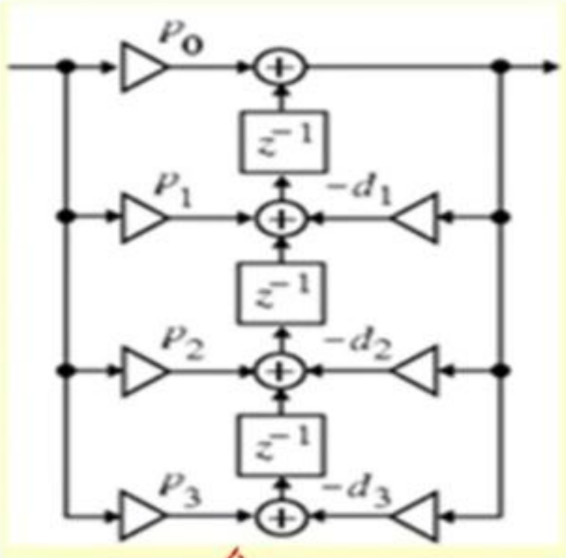
- Non canonical to canonical- By reducing the delays



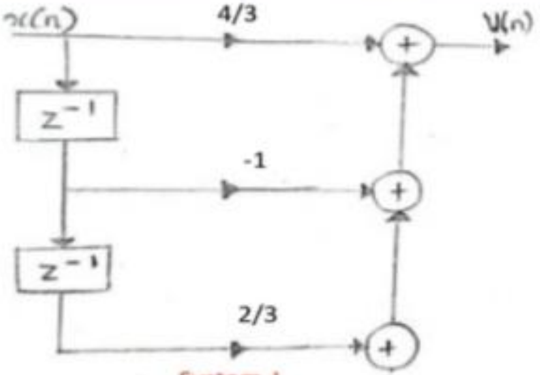


DF -II

Solved Examples

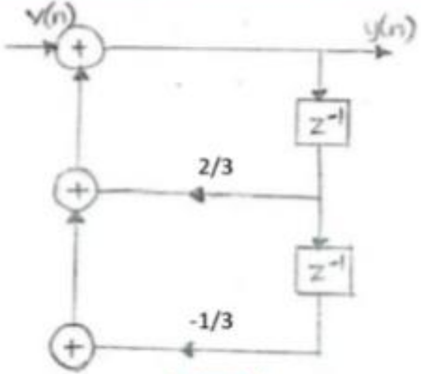
$$y(n)=\frac{4}{3}x(n)-x(n-1)+\frac{2}{3}x(n-2)+\frac{2}{3}y(n-1)-\frac{1}{3}y(n-2)$$

$$v(n)=\frac{4}{3}x(n)-x(n-1)+\frac{2}{3}x(n-2)$$



System-I

$$y(n)=v(n)+\frac{2}{3}y(n-1)-\frac{1}{3}y(n-2)$$



System-II

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Contd…

$$H(z) = \frac{P(z)}{D(z)} = \frac{p_0 + p_1 z^{-1} + p_2 z^{-2} + p_3 z^{-3}}{1 + d_1 z^{-1} + d_2 z^{-2} + d_3 z^{-3}}$$

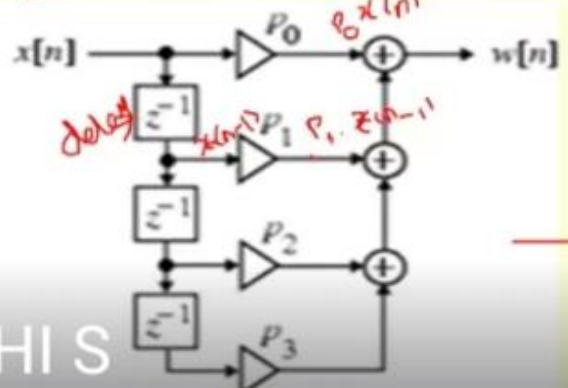
$$H_1(z) = \frac{W(z)}{X(z)} = P(z) = p_0 + p_1 z^{-1} + p_2 z^{-2} + p_3 z^{-3} = W(z)$$

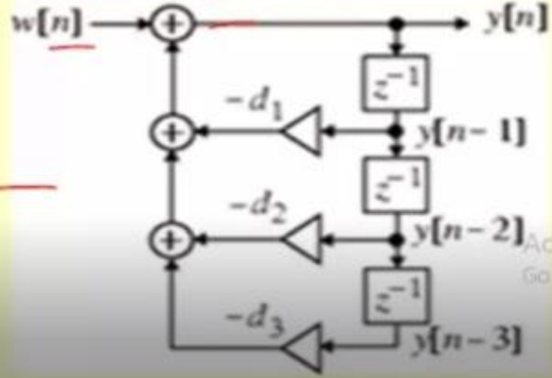
$$H_2(z) = \frac{Y(z)}{W(z)} = \frac{1}{D(z)} = \frac{1}{1 + d_1 z^{-1} + d_2 z^{-2} + d_3 z^{-3}} =$$

$$w[n] = p_0 x[n] + p_1 x[n-1] + p_2 x[n-2] + p_3 x[n-3]$$

$$y[n] = w[n] - d_1 y[n-1] - d_2 y[n-2] - d_3 y[n-3]$$

$w(n) = y(n)$





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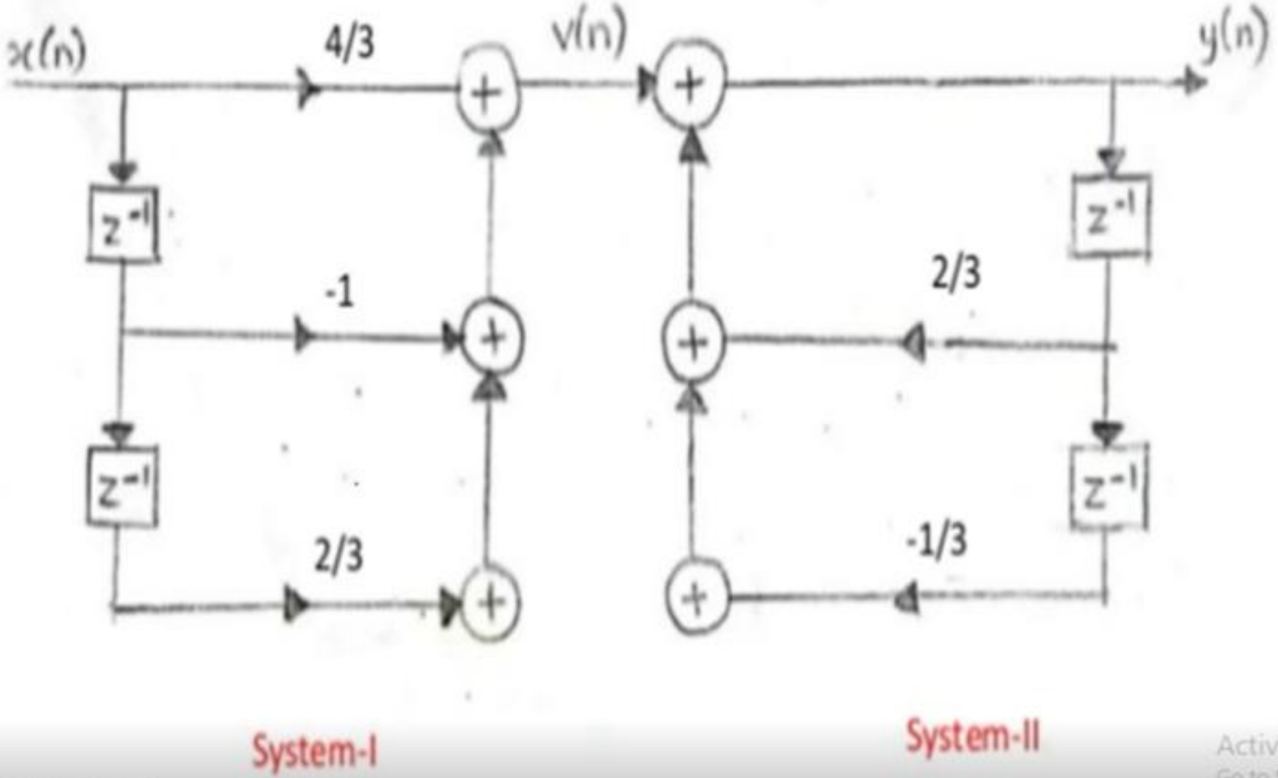
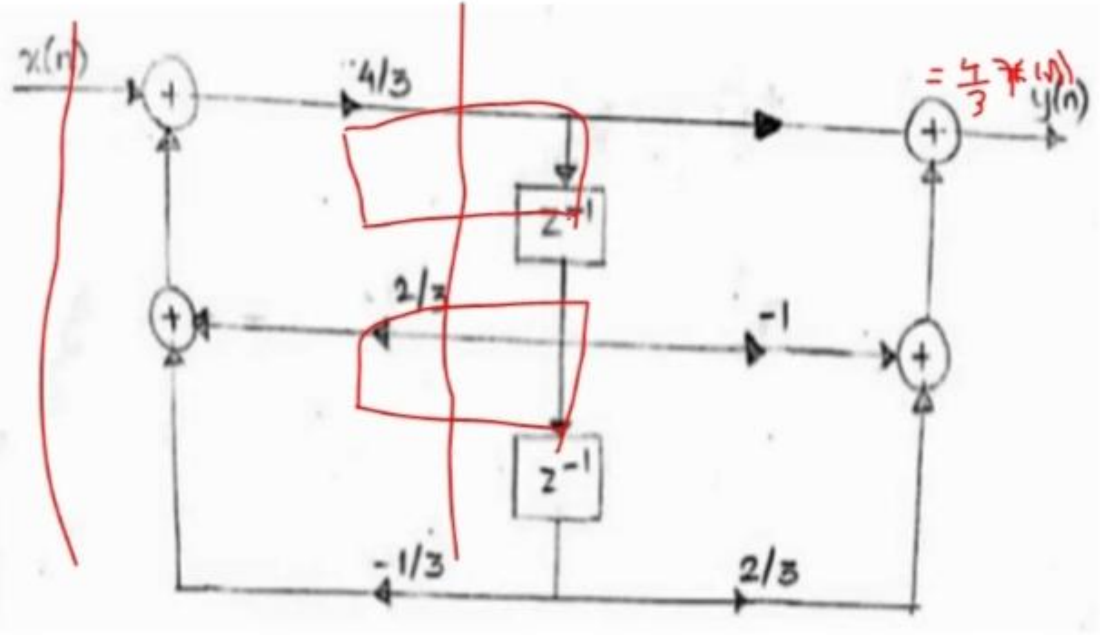


Direct Form II



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Contd...

Implement the filter represented by following transfer function

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

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

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

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

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

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

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Cascade form Structure

By expressing the numerator and the denominator polynomials of the transfer function as a product of polynomials of lower degree, a digital filter can be realized as a cascade of low-order filter sections

Consider, for example, $H(z) = P(z)/D(z)$ N
expressed as

N $= H_1(z) \cdot H_2(z)$
N_1 N_2

$$H(z) = \frac{P(z)}{D(z)} = \frac{P_1(z)P_2(z)P_2(z)}{D_1(z)D_2(z)D_3(z)}$$

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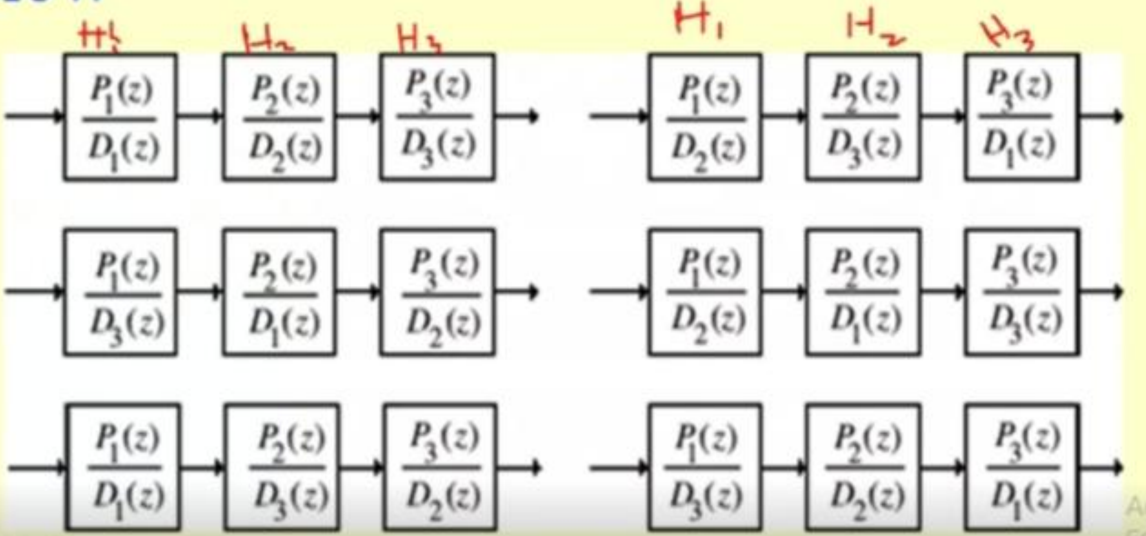
Contd...

Examples of cascade realizations obtained by different pole-zero pairings are shown below



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Contd...

There are altogether a total of 36 different cascade realizations of

$$H(z) = \frac{P_1(z)P_2(z)P_2(z)}{D_1(z)D_2(z)D_3(z)}$$

based on pole-zero-pairings and ordering

Due to finite wordlength effects, each such cascade realization behaves differently from others

$$H(z) = \frac{1+\frac{1}{5}z^{-1}}{\left(1-\frac{1}{2}z^{-1}+\frac{1}{3}z^{-2}\right)\left(1+\frac{1}{4}z^{-2}\right)}$$

$$H(z) = H_1(z) \cdot H_2(z)$$

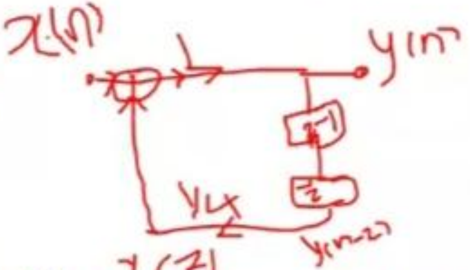
$$H_1(z) = \frac{1}{\left(1+\frac{1}{4}z^{-2}\right)}$$

$$H_2(z) = \frac{1+\frac{1}{5}z^{-1}}{1-\frac{1}{2}z^{-1}+\frac{1}{3}z^{-2}}$$

$$H_1(z) = \frac{Y_1(z)}{X_1(z)} = \frac{1}{1+\frac{1}{4}z^{-2}}$$

$$Y_1(z) + \frac{1}{4}z^{-2}Y_1(z) = X_1(z)$$

$$y_1(n) + \frac{1}{4}y_1(n-2) = x_1(n)$$



$$H_2(z) = \frac{Y_2(z)}{X_2(z)} = \frac{1+\frac{1}{5}z^{-1}}{1-\frac{1}{2}z^{-1}+\frac{1}{3}z^{-2}}$$

$$Y_2(z) - \frac{1}{2}z^{-1}Y_2(z) + \frac{1}{3}z^{-2}Y_2(z) = X_2(z) + \frac{1}{5}X_2(z)z^{-1}$$

$$y_2(n) - \frac{1}{2}y_2(n-1) + \frac{1}{3}y_2(n-2) = x_2(n) + \frac{1}{5}x_2(n-1)$$

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