SNS COLLEGE OF TECHNOLOGY

Coimbatore-35
An Autonomous Institution

Accredited by NBA – AICTE and Accredited by NAAC – UGC with 'A+' Grade
Approved by AICTE, New Delhi & Affiliated to Anna University, Chennai

DEPARTMENT OF BIOMEDICAL ENGINEERING

19BMB302 - BIOMEDICAL SIGNAL PROCESSING

III YEAR/ V SEMESTER

UNIT III INFINITE IMPULSE RESPONSE FILTERS

INFINITE IMPULSE RESPONSE FILTERS

Characteristics of practical frequency selective filters. characteristics of commonly used analog filters - Butterworth filters, Chebyshev filters. Design of IIR filters from analog filters (LPF, HPF, BPF, BRF) - Approximation of derivatives, Impulse invariance method, Bilinear transformation. Frequency transformation in the analog domain. Structure of IIR filter - direct form I, direct form II, Cascade, parallel realizations.

Example 5.25 Realize the system with difference equation $y(n) = \frac{3}{4}y(n-1) - \frac{1}{8}y(n-2) + x(n) + \frac{1}{3}x(n-1)$ in cascade form.

Solution

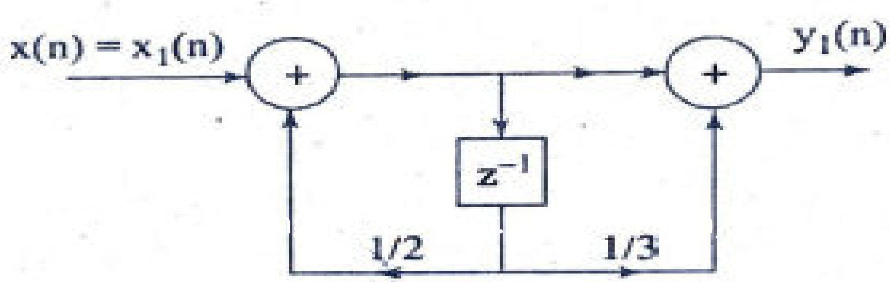
From the difference equation we obtain

$$H(z) = \frac{Y(z)}{X(z)} = \frac{1 + \frac{1}{3}z^{-1}}{1 - \frac{3}{4}z^{-1} + \frac{1}{8}z^{-2}}$$

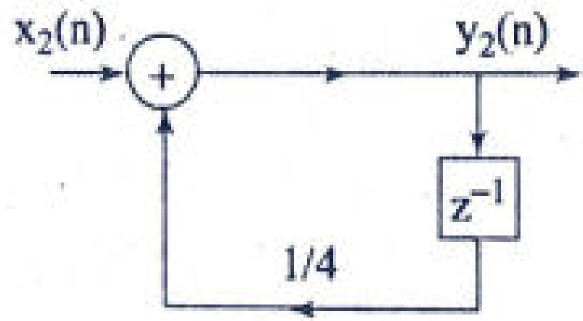
$$= \frac{1 + \frac{1}{3}z^{-1}}{(1 - \frac{1}{2}z^{-1})(1 - \frac{1}{4}z^{-1})} = H_1(z)H_2(z)$$

where $H_1(z) = \dfrac{1 + \frac{1}{3}z^{-1}}{1 - \frac{1}{2}z^{-1}}$ and $H_2(z) = \dfrac{1}{1 - \frac{1}{4}z^{-1}}$.

$H_1(z)$ can be realized in direct form II as



Similarly, $H_2(z)$ can be realized in direct form II as



Cascading the realization of $H_1(z)$ and $H_2(z)$ we have

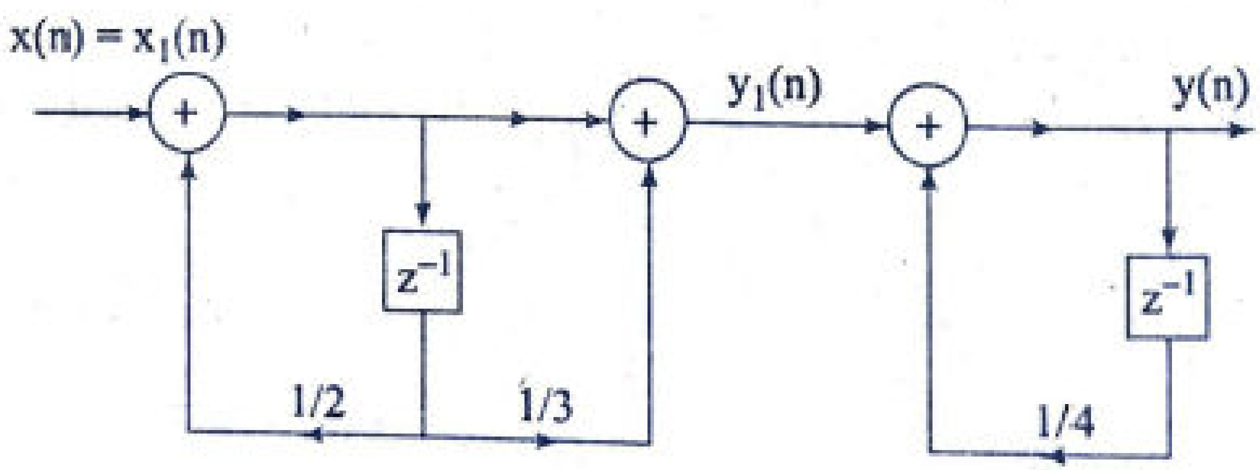


Fig. 5.48 Cascade realization of Example 5.25

5.14.6 Parallel form structure

A parallel form realization of an IIR system can be obtained by performing a partial expansion of

$$H(z) = c + \sum_{k=1}^{N} \frac{c_k}{1 - p_k z^{-1}} \tag{5.123}$$

where $\{p_k\}$ are the poles

The Eq. (5.123) can be written as

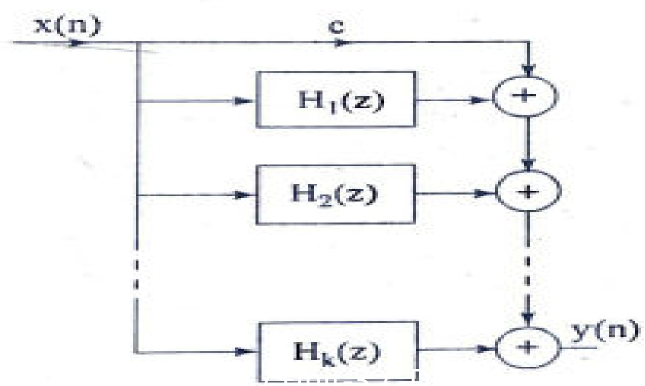
$$H(z) = c + \frac{c_1}{1 - p_1 z^{-1}} + \frac{c_2}{1 - p_2 z^{-1}} + \ldots + \frac{c_N}{1 - p_N z^{-1}} \tag{5.124}$$

$$H(z) = \frac{Y(z)}{X(z)} = c + H_1(z) + H_2(z) + \ldots + H_N(z) \tag{5.125}$$

Now

$$Y(z) = cX(z) + H_1(z)X(z) + H_2(z)X(z) + \ldots + H_N(z)X(z) \tag{5.126}$$

The Eq. (5.126) can be realized in parallel form as shown in Fig. 5.49.



Example 5.26 Realize the system given by difference equation $y(n) = -0.1y(n-1) + 0.72y(n-2) + 0.7x(n) - 0.252x(n-2)$ in parallel form.

Solution

The system function of the difference equation is

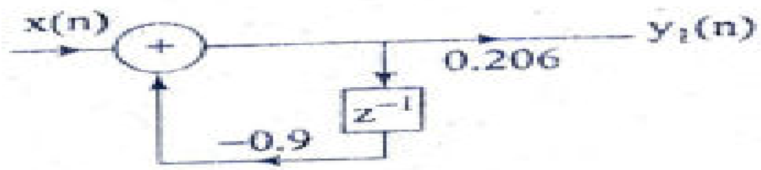
$$H(z) = \frac{0.7 - 0.252z^{-2}}{1 + 0.1z^{-1} - 0.72z^{-2}}$$

$$= 0.35 + \frac{0.35 - 0.035z^{-1}}{1 + 0.1z^{-1} - 0.72z^{-2}}$$

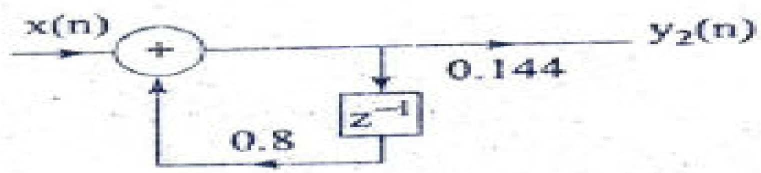
$$= 0.35 + \frac{0.206}{1 + 0.9z^{-1}} + \frac{0.144}{1 - 0.8z^{-1}}$$

$$= c + H_1(z) + H_2(z)$$

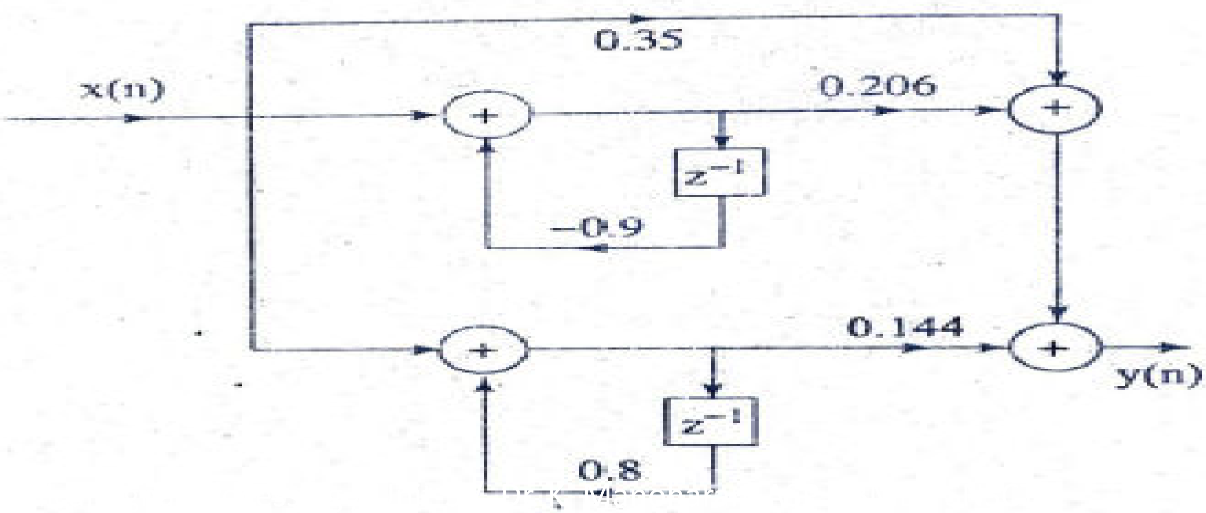
$H_1(z)$ can be realized in direct form II as



$H_2(z)$ can be realized in direct form II as



Now the realization of $H(z)$ is shown in Fig. 5.50.



Example 5.27 Obtain the direct form I, direct form II, cascade and paralle realization for the system $y(n) = -0.1y(n-1) + 0.2y(n-2) + 3x(n) + 3.6$ $1) + 0.6x(n-2)$

Solution

Direct form I

Let $3x(n) + 3.6x(n-1) + 0.6x(n-2) = w(n)$

$y(n) = -0.1y(n-1) + 0.2y(n-2) + w(n)$

By inspection, The direct form I realization is shown in Fig. 5.51.

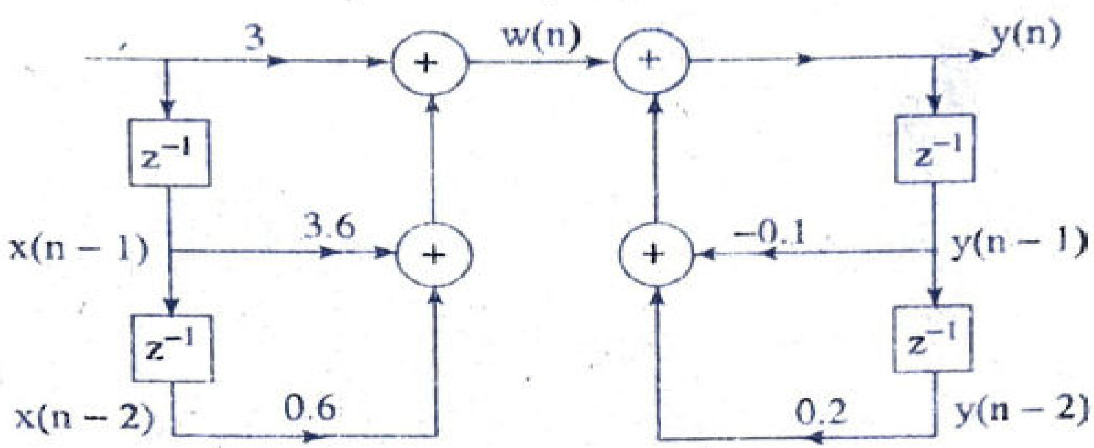


Fig. 5.51 Direct form I realization of example 5.27

Direct form II

From the given difference equation we have

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

The above system function can be realized in direct form II as shown in Fig. 5.52.

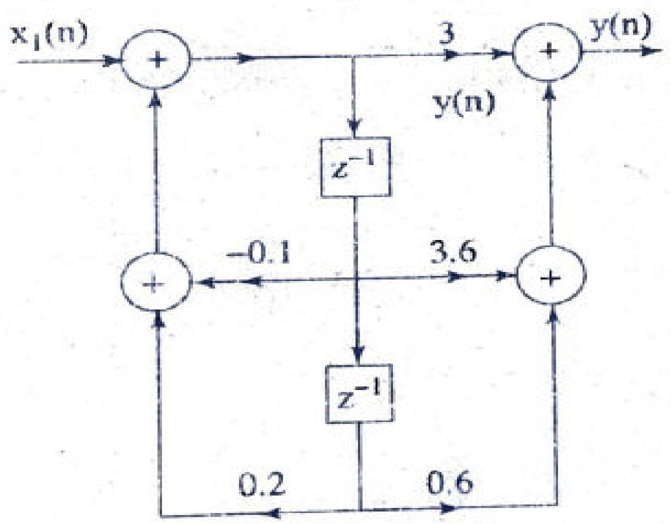


Fig. 5.52 Direct form II realization of example 5.27

Cascade form

$$\text{we have} \quad \frac{Y(z)}{X(z)} = \frac{3 + 3.6z^{-1} + 0.6z^{-2}}{1 + 0.1z^{-1} - 0.2z^{-2}}$$

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

$$\text{Let} \quad H_1(z) = \frac{3 + 0.6z^{-1}}{1 + 0.5z^{-1}} \quad \text{and}$$

$$H_2(z) = \frac{1 + z^{-1}}{1 - 0.4z^{-1}}$$

Now we realize $H_1(z)$ and $H_2(z)$ and cascade both to get realization of $H(z)$

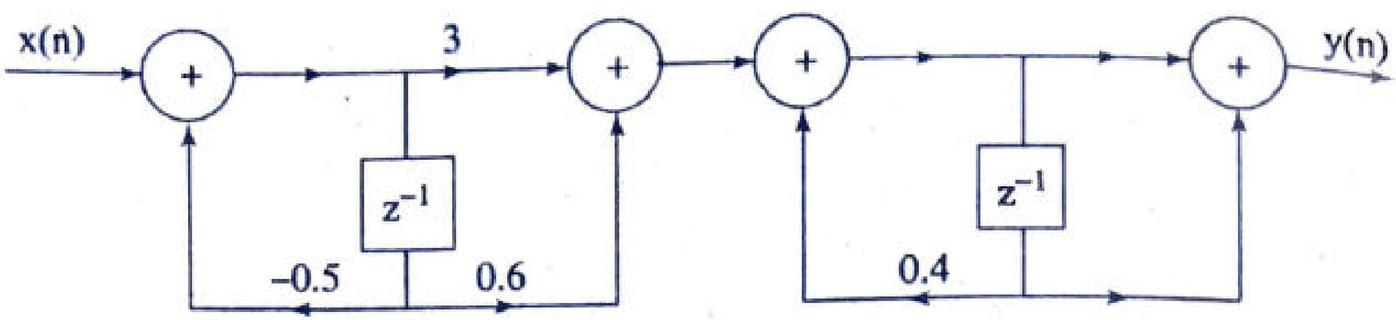


Fig. 5.53 Cascade form realization of example 5.27