



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.



5.14.6 Parallel form structure

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

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

where $\{p_k\}$ are the poles

The Eq. (5.123) can be written as

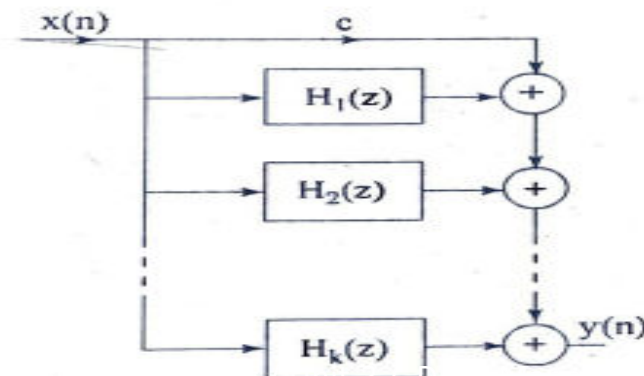
$$H(z) = c + \frac{c_1}{1 - p_1 z^{-1}} + \frac{c_2}{1 - p_2 z^{-1}} + \dots + \frac{c_N}{1 - p_N z^{-1}} \quad (5.124)$$

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

Now

$$Y(z) = cX(z) + H_1(z)X(z) + H_2(z)X(z) + \dots + H_N(z)X(z) \quad (5.126)$$

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.

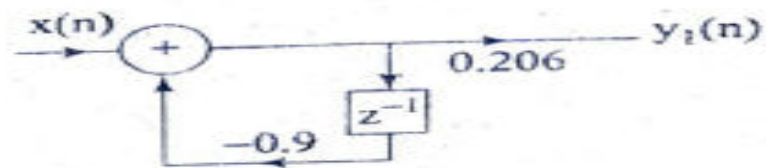
Solution

The system function of the difference equation is

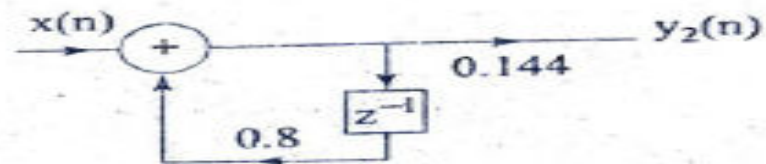
$$\begin{aligned} H(z) &= \frac{0.7 - 0.252z^{-2}}{1 + 0.1z^{-1} - 0.72z^{-2}} \\ &= 0.35 + \frac{0.35 - 0.035z^{-1}}{1 + 0.1z^{-1} - 0.72z^{-2}} \\ &= 0.35 + \frac{0.206}{1 + 0.9z^{-1}} + \frac{0.144}{1 - 0.8z^{-1}} \\ &= c + H_1(z) + H_2(z) \end{aligned}$$



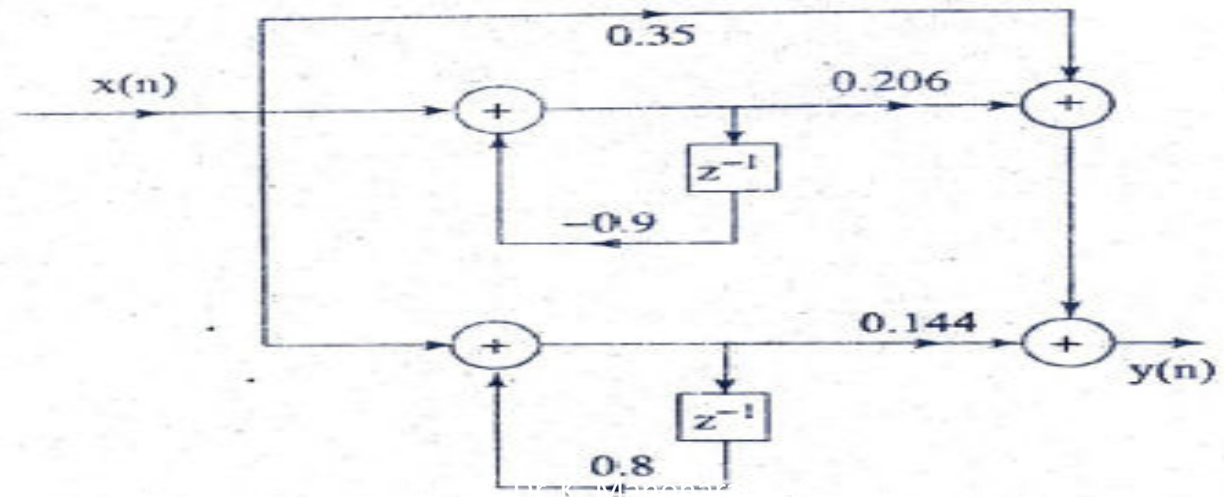
$H_1(z)$ can be realized in direct form II as



$H_2(z)$ 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 parallel realization for the system $y(n] = -0.1y(n - 1) + 0.2y(n - 2) + 3x(n) + 3.6x(n - 1) + 0.6x(n - 2)$

Solution

Direct form I

$$\text{Let } 3x(n) + 3.6x(n - 1) + 0.6x(n - 2) = w(n)$$

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

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

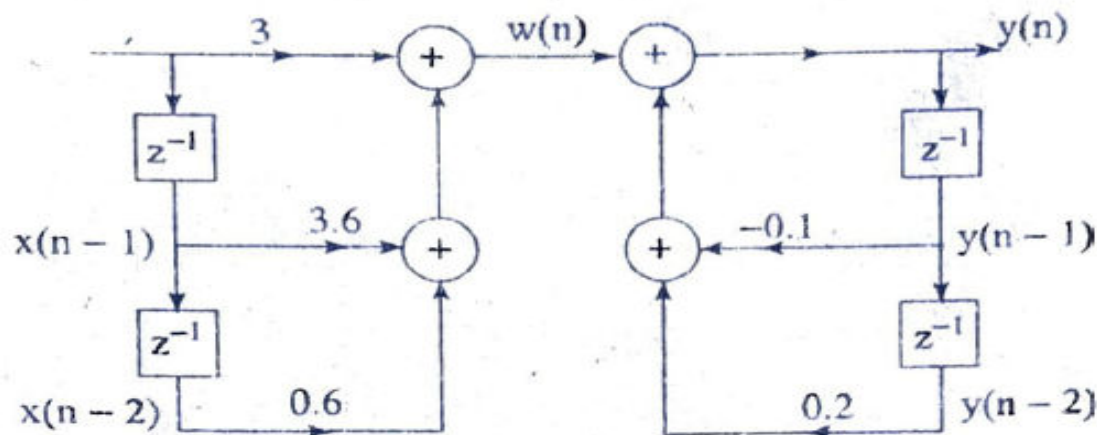


Fig. 5.51 Direct form I realization of example 5.27



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.

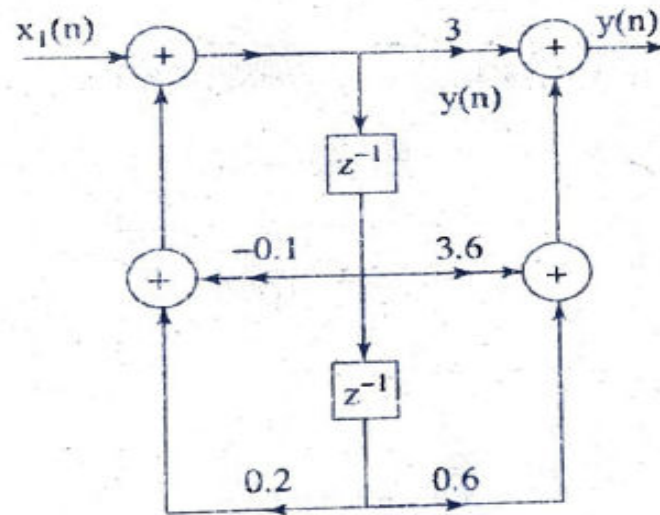


Fig. 5.52 Direct form II realization of example 5.27



Cascade form

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

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

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

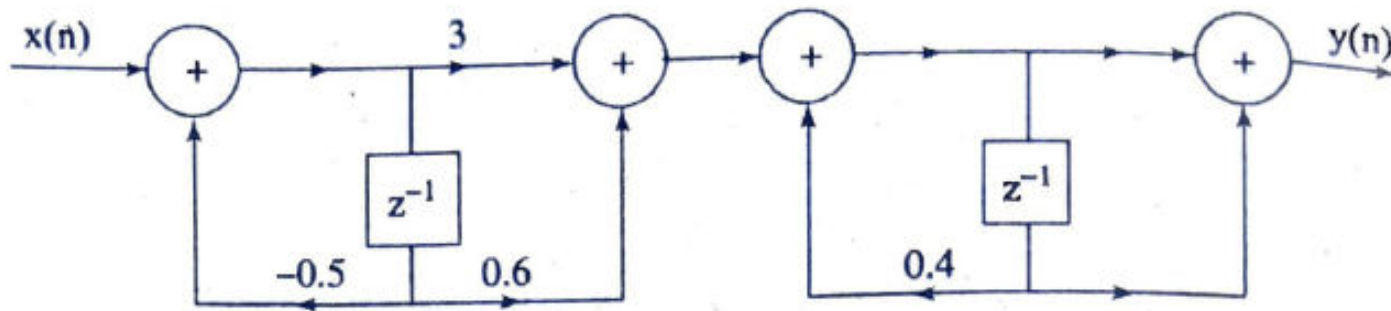


Fig. 5.53 Cascade form realization of example 5.27



Parallel form

$$\begin{aligned}
 H(z) &= \frac{3 + 3.6z^{-1} + 0.6z^{-2}}{1 + 0.1z^{-1} - 0.2z^{-2}} \\
 &= -3 + \frac{7}{1 - 0.4z^{-1}} - \frac{1}{1 + 0.5z^{-1}} \\
 &= c + H_1(z) + H_2(z)
 \end{aligned}$$

$$\begin{array}{r}
 -0.2z^{-2} + 0.1z^{-1} + 1 \quad \begin{array}{l} -3 \\ \hline 0.6z^{-2} + 3.6z^{-1} + 3 \\ 0.6z^{-2} - 0.3z^{-1} - 3 \\ \hline 3.9z^{-1} + 6 \end{array} \\
 \rightarrow H(z) = -3 + \frac{3.9z^{-1} + 6}{1 + 0.1z^{-1} - 0.2z^{-2}} \\
 = -3 + \frac{A}{1 - 0.4z^{-1}} + \frac{B}{1 + 0.5z^{-1}} \\
 \text{where } A = 7, B = -1
 \end{array}$$

Now we realize $H(z)$ in parallel form as shown in Fig. 5.54.

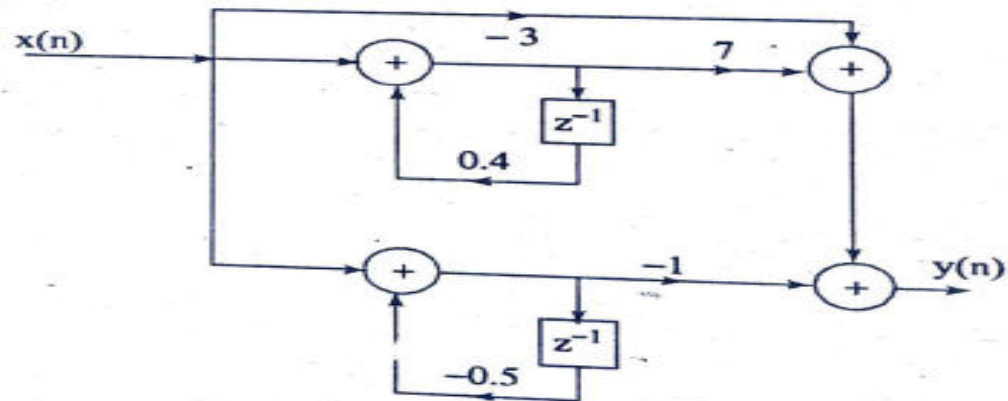


Fig. 5.54 Parallel form realization of example 5.27