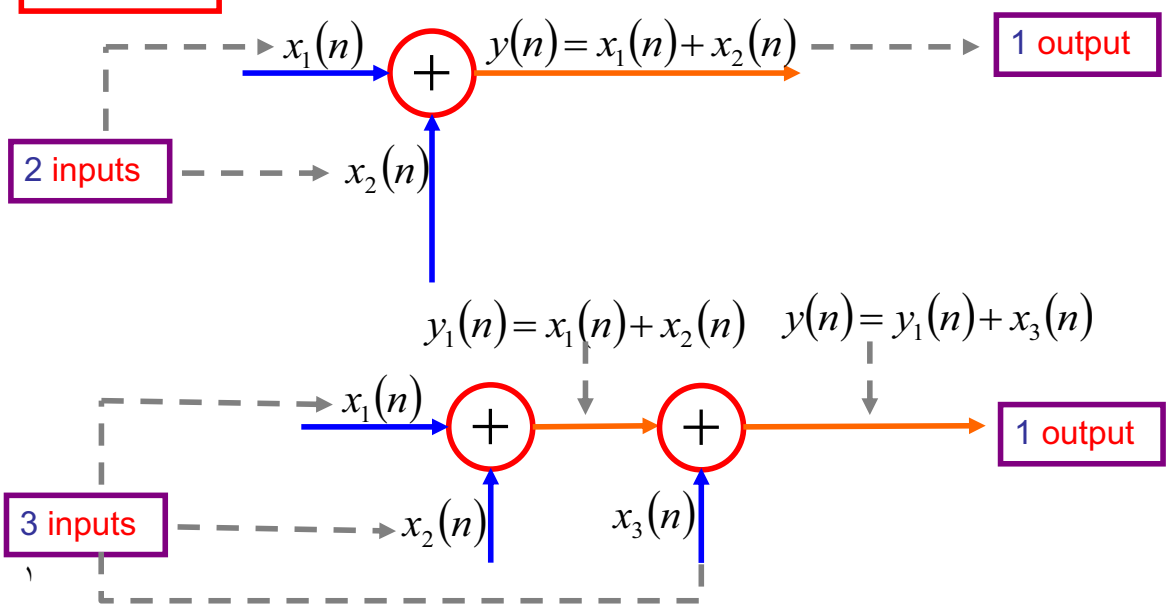
CHAPTER 6 : DIGITAL FILTER STRUCTURES

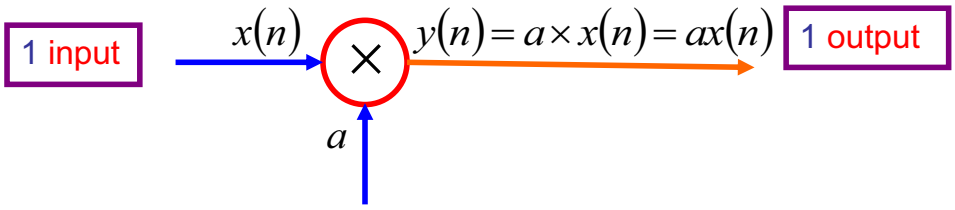
6.1 BASIC ELEMENTS

❖Three basic building blocks are used to describe the LTI systems and digital filters

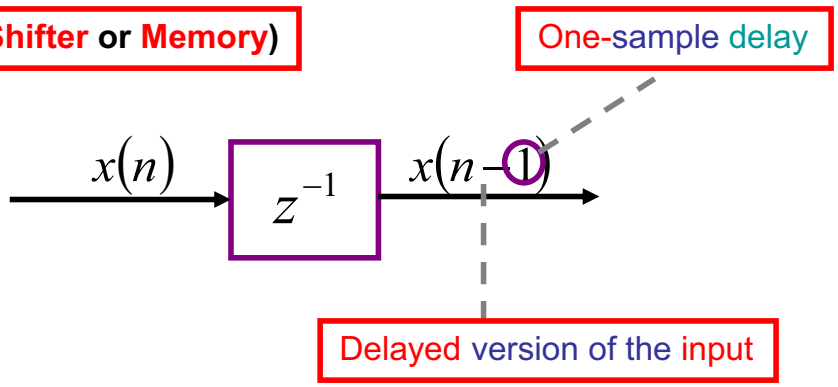
1. ADDER



2. MULTIPLIER (Gain)



3. Delay Element (Shifter or Memory)



It is implemented using a shift register

6.2 FIR FILTER STRUCTURE

❖The Finite Impulse Response (FIR) filter is described by :

A . DIFFERENCE EQUATION

$$y(n)=\sum_{i=0}^{M} b_i x(n-i)$$

$$=b_0 x(n)+b_1 x(n-1)+.....+b_M x(n-M)$$

where $b_i's$ are the coefficients of the filter

B . TRANSFER FUNCTION

$$H(z)=\sum_{n=0}^{M} b_n z^{-n}$$

$$=b_0+b_1 z^{-1}+.....+b_M z^{-M}$$

6.2 FIR FILTER STRUCTURE (Contd.)

C . THE IMPULSE RESPONSE

$$h(n)=\begin{cases} b_n & 0\le n\le M \\ 0 & otherwise \end{cases}$$

✓ The order of the filter is ***M*** .

✓ The length (the number of coefficients) of the filter is ***M+1*** .

6.2 FIR FILTER STRUCTURE (Contd.)

ADVANTAGES OF THE FIR FILTER

- ✓ They are always stable .
- ✓ They are relatively simple compared to the IIR structures .
- ✓ They can be designed to linear phase response that is desirable in some applications

DISADVANTAGES OF THE FIR FILTER

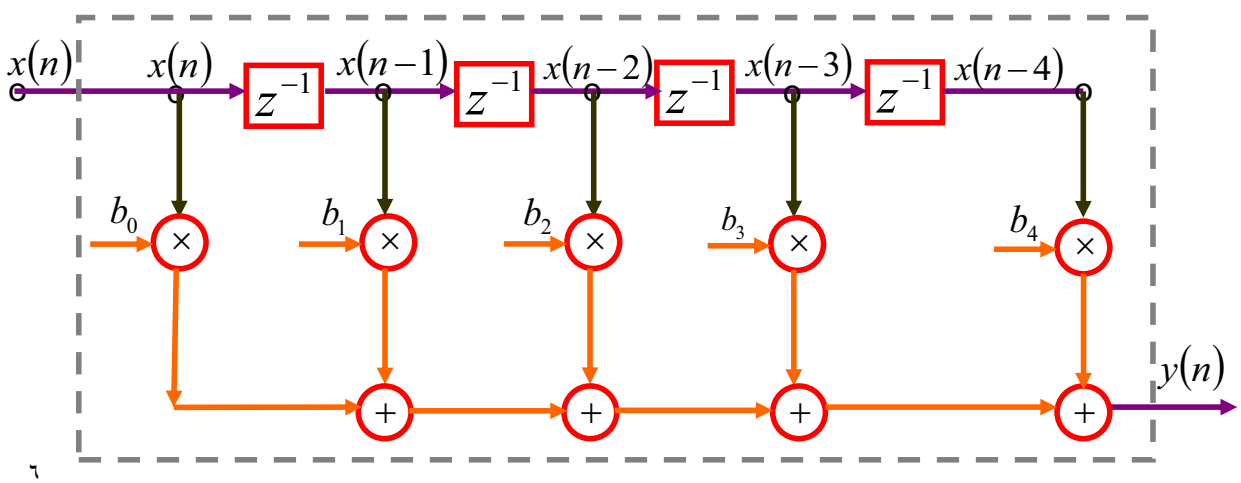
- ✓ A large value of ***M*** (the order of the filter) is required to adequately approximate sharp cut-off frequencies.
- ✓ The delay of non recursive linear phase filter can be non integer number of samples, which leads to a complication in the realization.

STRUCTURES OR REALIZATIONS

1. DIRECT FORM STRUCTURE

- ✓ The difference equation is implemented as a tapped delay line.
- ✓ For ***M = 4*** the difference equation is implemented as tapped delay line.

$$y(n)=b_0x(n)+b_1x(n-1)+b_2x(n-2)+b_3x(n-3)+b_4x(n-4)$$



ADVANTAGE OF THE LINEAR PHASE STRUCTURE

✓ This structure requires 50% fewer multiplication than the direct form.

EXAMPLE 6.1

A FIR is given by the transfer function

$$H(z)=1+16.0625z^{-4}+z^{-8}$$

REQUIRED

Determine and draw the direct and the linear phase

SOLUTION

$$H(z)=\frac{Y(z)}{X(z)}=1+16.0625z^{-4}+z^{-8}$$

$$Y(z)=\left(1+16.0625z^{-4}+z^{-8}\right)X(z)$$

$$\Downarrow$$

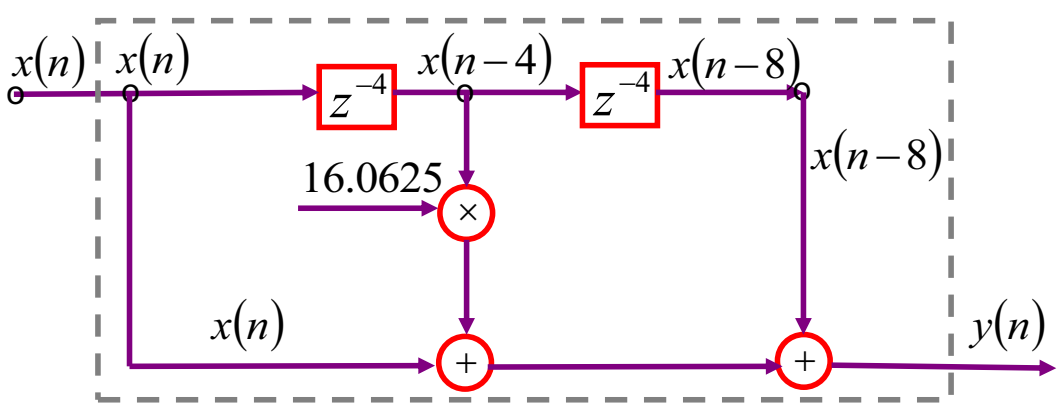
$$Y(z)=\left(1+16.0625z^{-4}+z^{-8}\right)X(z)$$

EXAMPLE 6.1 (Contd.)

Then the difference equation is given by

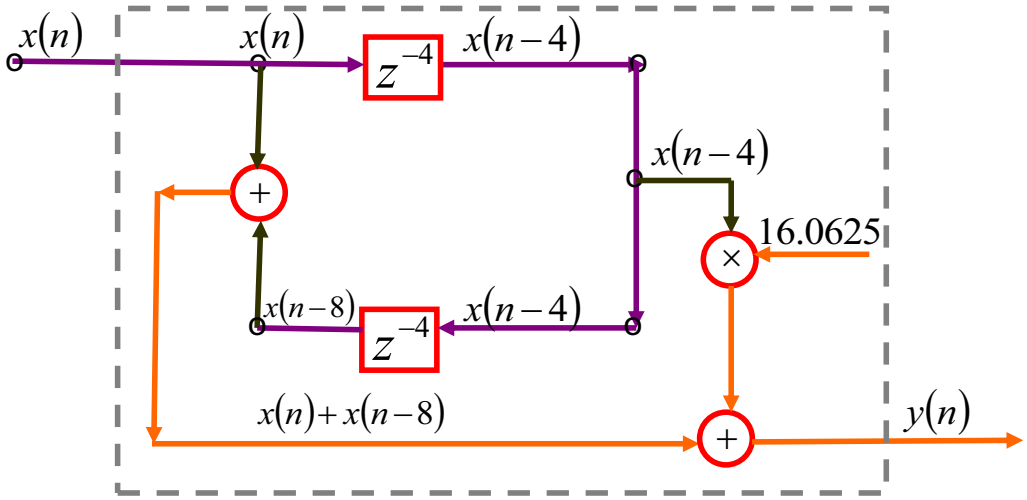
$$y(n)=x(n)+16.0625x(n-4)+x(n-8)$$

The direct form structure



EXAMPLE 6.1 (Contd.)

the difference equation can be rewritten in the form

$$y(n)=[x(n)+x(n-8)]+16.0625x(n-4)$$

The linear phase structure