EEE328
Digital Signal Processing

Ankara University

Faculty of Engineering

Electrical and Electronics Engineering Department

Structures for Discrete-Time Systems

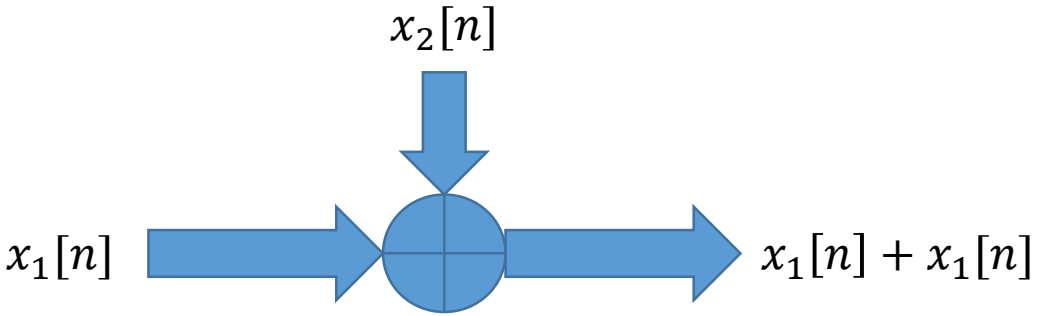
EEE328 Digital Signal Processing

Lecture 13

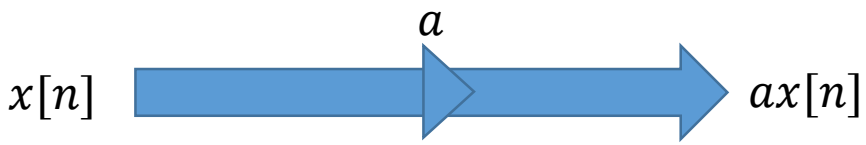
Agenda

- Blocks Diagrams of Linear Constant-Coefficient Difference Equations
- Signal Flow Graph Representation of Linear Constant-Coefficient Difference Equations
- Basic Structures for IIR Systems
- Transposed Forms
- Basic Network Structures for FIR Systems
- Quantization

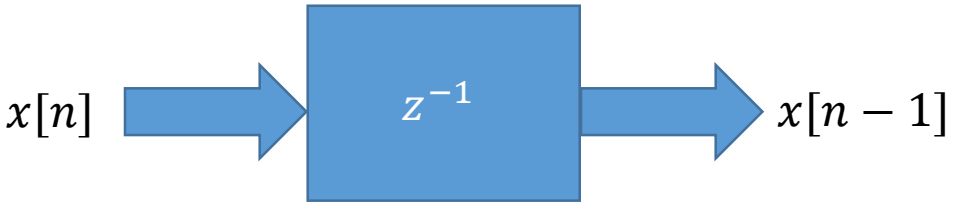
Blocks Diagrams of Linear Constant-Coefficient Difference Equations



Addition of two sequences

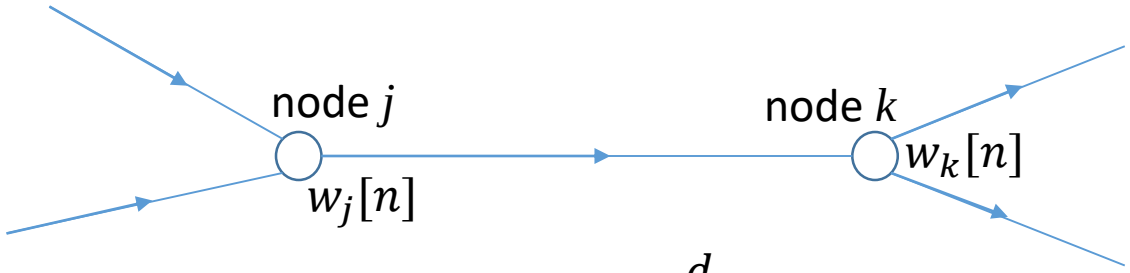


Multipl. of a seq. by a const.

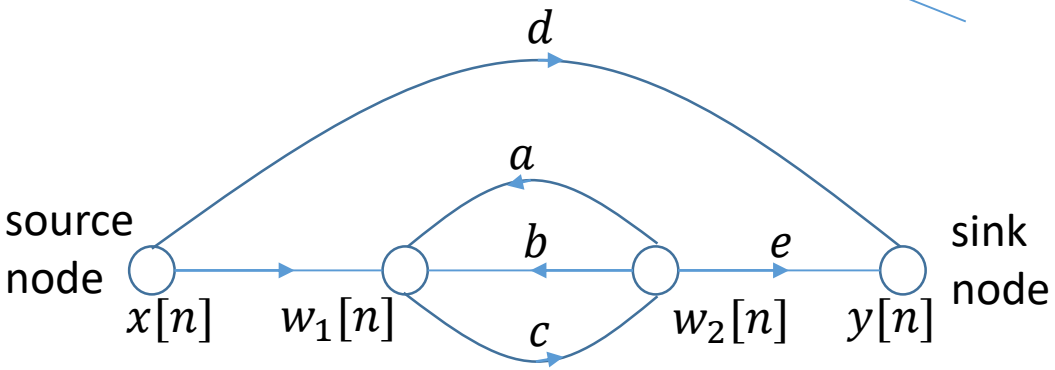


Unit delay

Signal Flow Graph Representation of Linear Constant-Coefficient Difference Equations



Nodes and branches in a signal flow graph



Signal flow graph with source and sink nodes

$$w_1[n] = x[n] + aw_2[n] + bw_2[n]$$
$$w_2[n] = cw_1[n]$$
$$y[n] = dx[n] + ew_2[n]$$

Basic Structures for IIR Systems

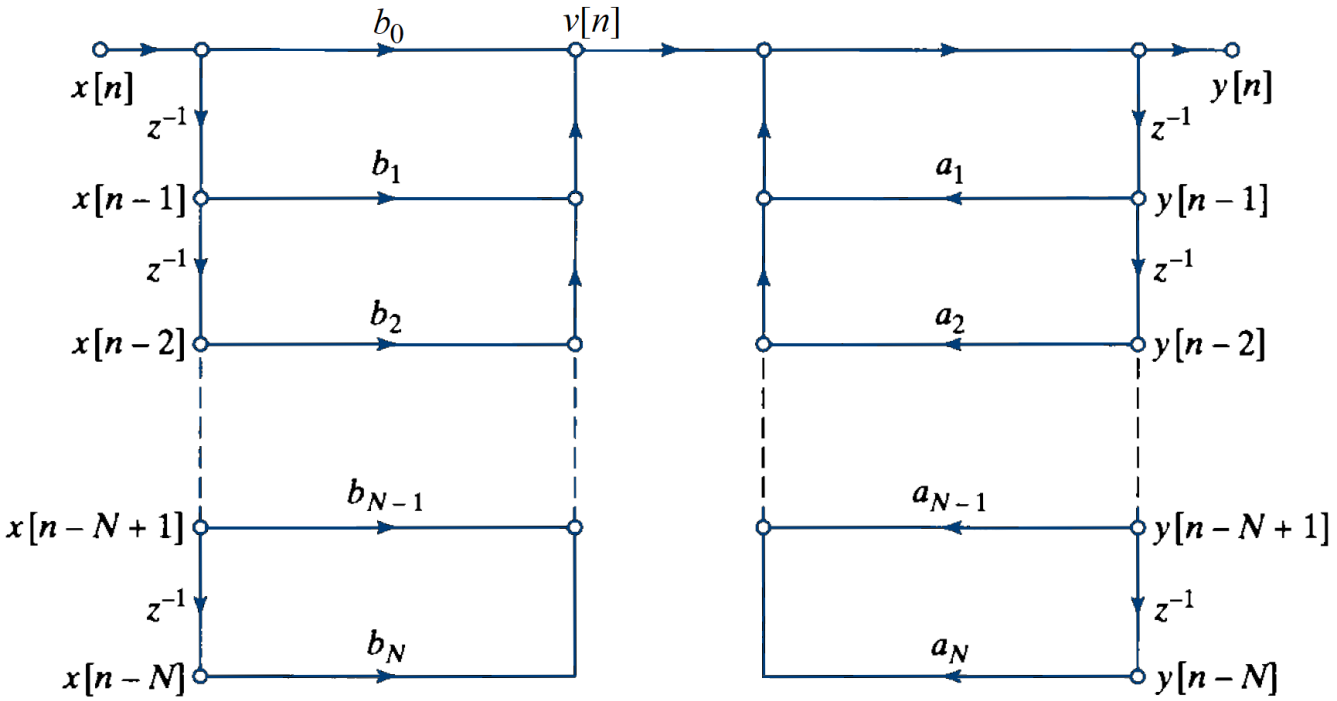
Direct Forms

$$y[n] - \sum_{k=1}^{N} a_k y[n-k] = \sum_{k=1}^{N} b_k x[n-k]$$

$$H(z) = \frac{\sum_{k=0}^{M} b_k z^{-k}}{1 - \sum_{k=1}^{N} a_k z^{-k}}$$

Basic Structures for IIR Systems

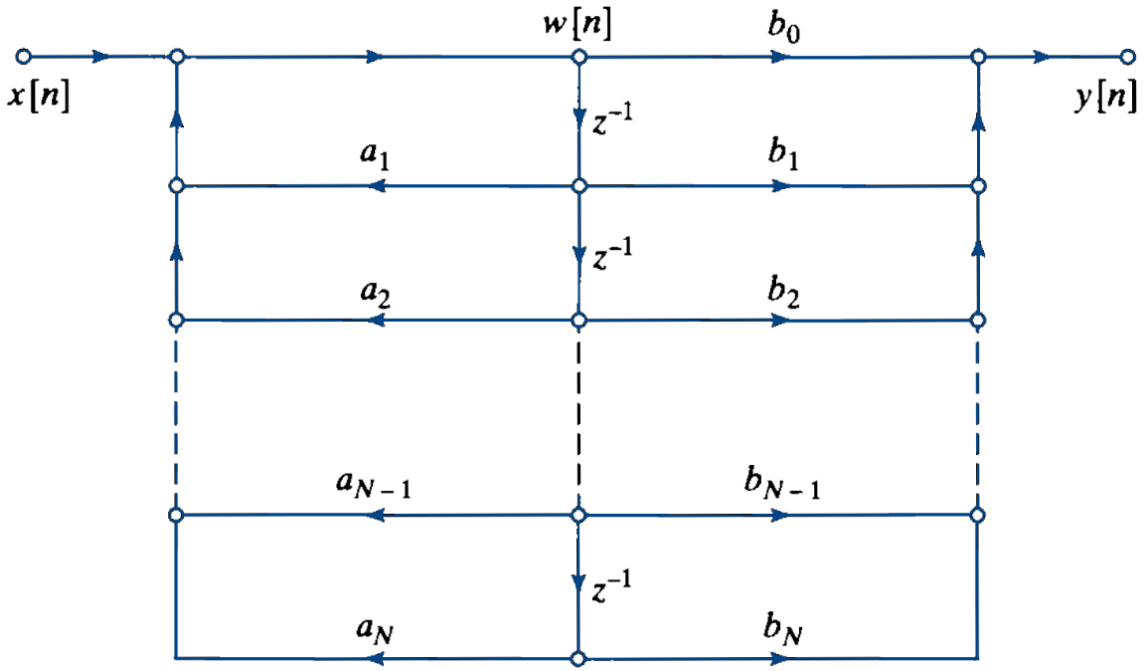
Direct Forms



Signal flow graph of direct form I structure for an N^{th}-order system

Basic Structures for IIR Systems

Direct Forms

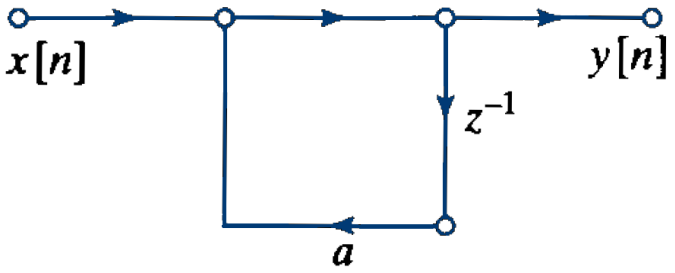


Signal flow graph of direct form II structure for an N^{th}-order system

Transposed Forms

Transposed Form for a First-Order System with No Zeroes

$$H(z) = \frac{1}{1 - az^{-1}}$$

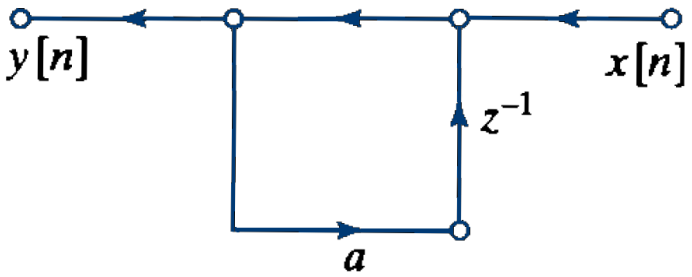


Flow graph of simple first-order system

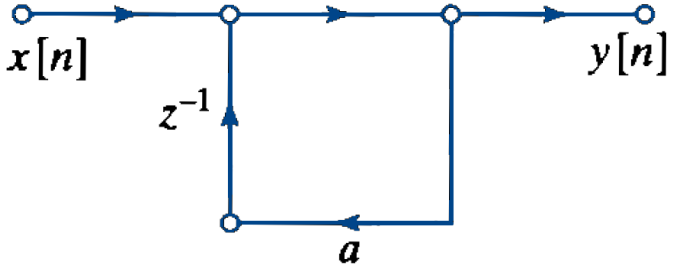
Transposed Forms

Transposed Form for a First-Order System with No Zeroes

$$H(z) = \frac{1}{1 - az^{-1}}$$

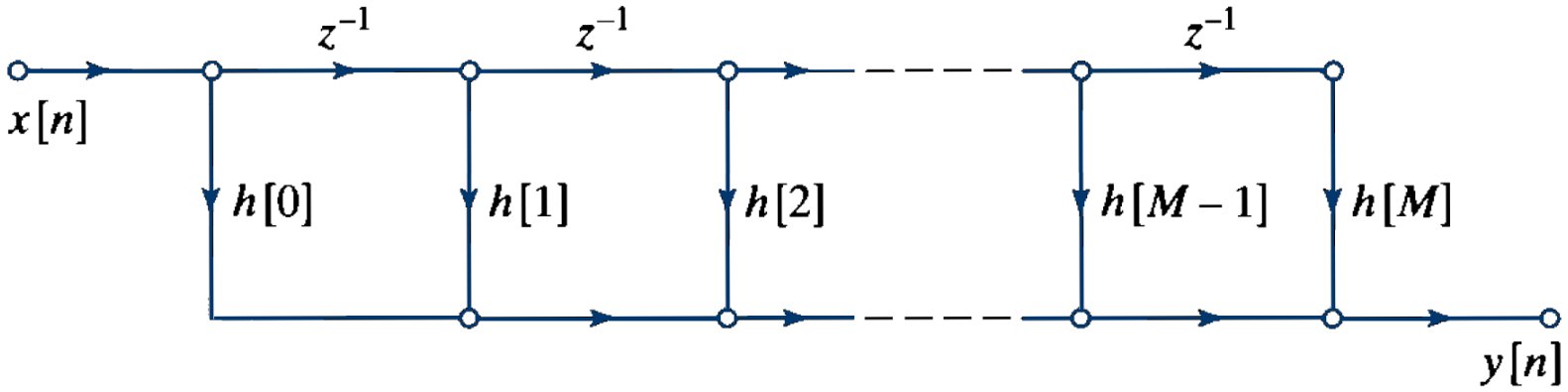


Transposed form of simple first-order system

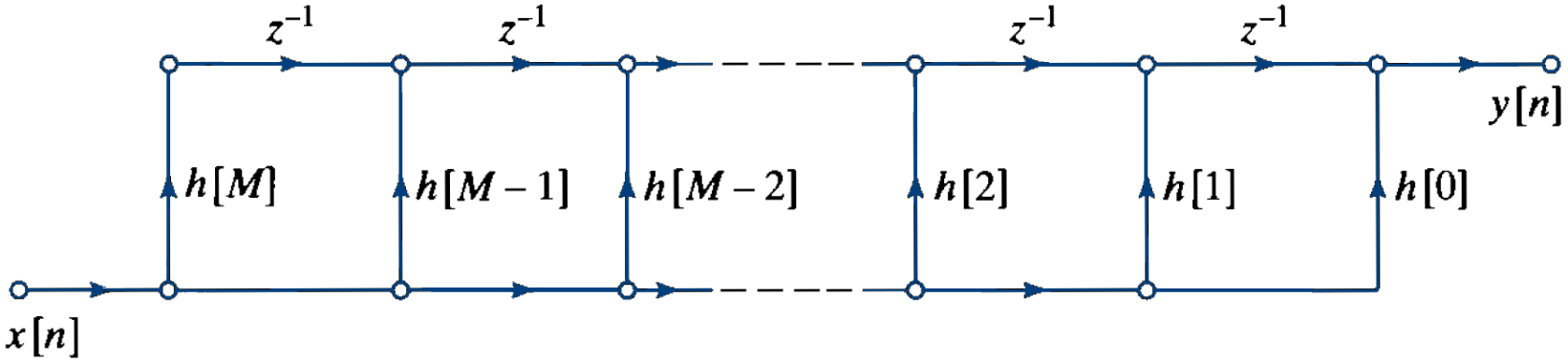


Transposed form of simple first-order system
Input on the left

Basic Network Structures fo FIR Systems



FIR System – Direct Form



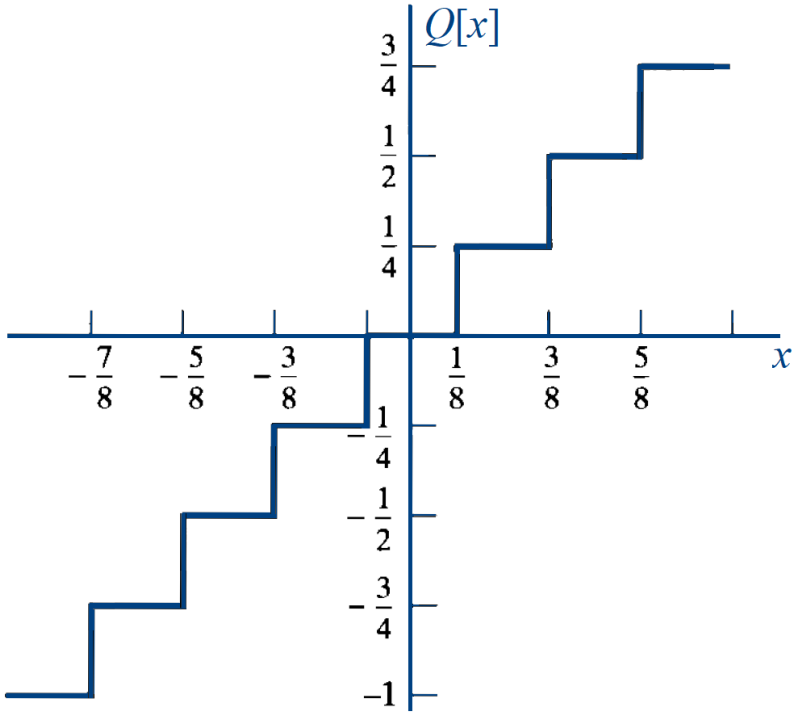
FIR System – Transposition

Quantization

$$x = X_m\left(-b_0 + \sum_{i=1}^{\infty} b_i 2^{-i}\right)$$

$$\hat{x} = Q_B[x] = X_m\left(-b_0 + \sum_{i=1}^{B} b_i 2^{-i}\right) = X_m \hat{x}_B$$

$$\Delta = X_m 2^{-B}$$

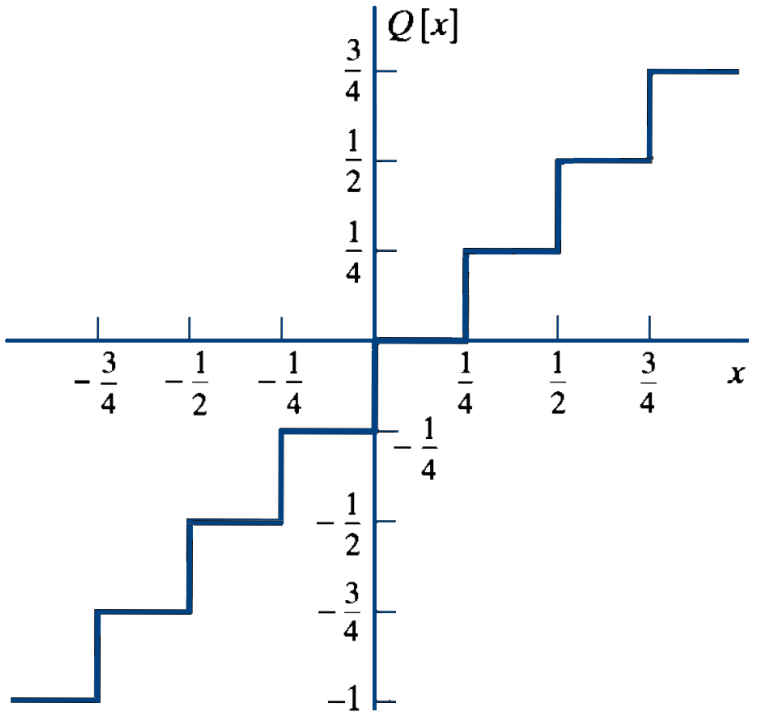


Rounding

Quantization

Quantization Error:

$e = Q_B[x] - x$



Truncation

References

- Signals & Systems, Second Edition, A. V. Oppenheim, A. S. Willsky with S. H. Nawab, Prentice Hall, 1997
- Discrete-Time Signal Processing, Second Edition, A. V. Oppenheim, R. W. Schafer with J. R. Buck, Prentice Hall, 1999