İşaret İşleme
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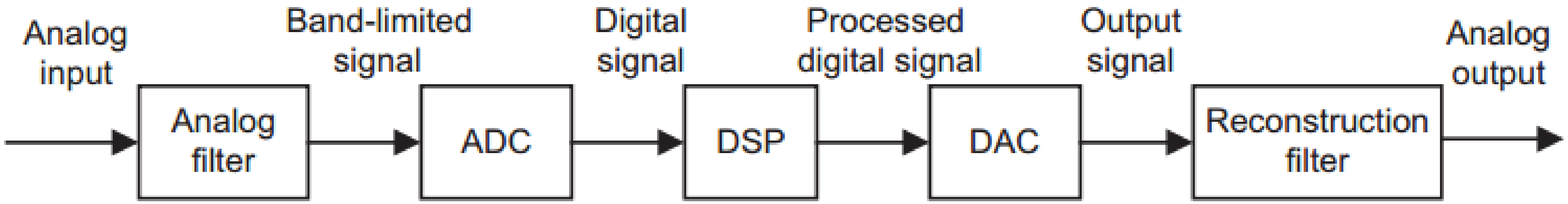
BASIC CONCEPTS OF DIGITAL SIGNAL PROCESSING

Digital signal processing (DSP) technology and its advancements have dramatically impacted our modern society everywhere. Without DSP, we would not have digital/Internet audio and video; digital recording; CD, DVD, and MP3 players; iPhone and iPad; digital cameras; digital and cellular telephones; digital satellite and TV; or wired and wireless networks.



A digital signal processing scheme.

As shown in the diagram, the analog input signal, which is continuous in time and amplitude, is generally encountered in the world around us. Examples of such analog signals include current, voltage, temperature, pressure, and light intensity. Usually a transducer (sensor) is used to convert the nonelectrical signal to the analog electrical signal (voltage).

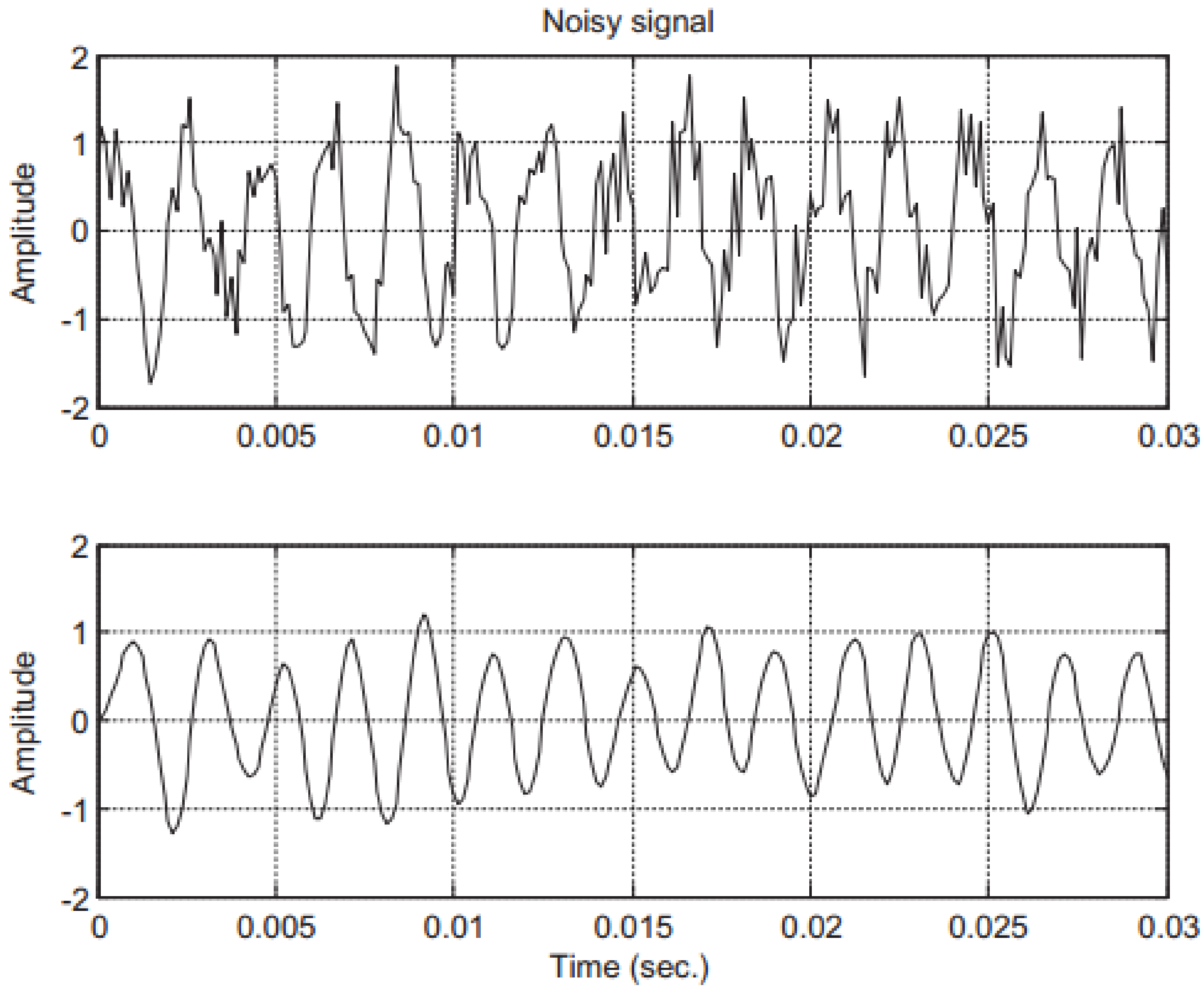
The band-limited signal at the output of the analog filter is then sampled and converted via the ADC unit into the digital signal, which is discrete both in time and in amplitude. The DS processor then accepts the digital signal and processes the digital data according to DSP rules such as lowpass, highpass, and bandpass digital filtering, or other algorithms for different applications. Notice that the DS processor unit is a special type of digital computer and can be a general-purpose digital computer, a microprocessor, or an advanced microcontroller; furthermore, DSP rules can be implemented using software in general.

With the DS processor and corresponding software, a processed digital output signal is generated. This signal behaves in a manner according to the specific algorithm used. The next block in Figure 1.1, the DAC unit, converts the processed digital signal to an analog output signal. As shown, the signal is continuous in time and discrete in amplitude

BASIC DIGITAL SIGNAL PROCESSING EXAMPLES IN BLOCK DIAGRAMS

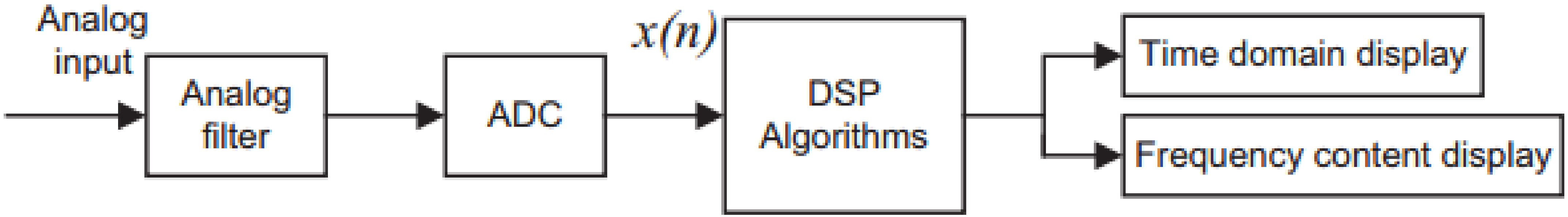
Digital Filtering

Digital Filtering

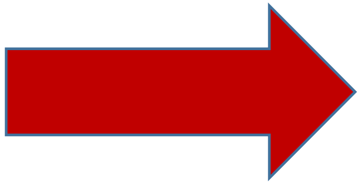


(Top) Digitized noisy signal. (Bottom) Clean digital signal using the digital lowpass filter.

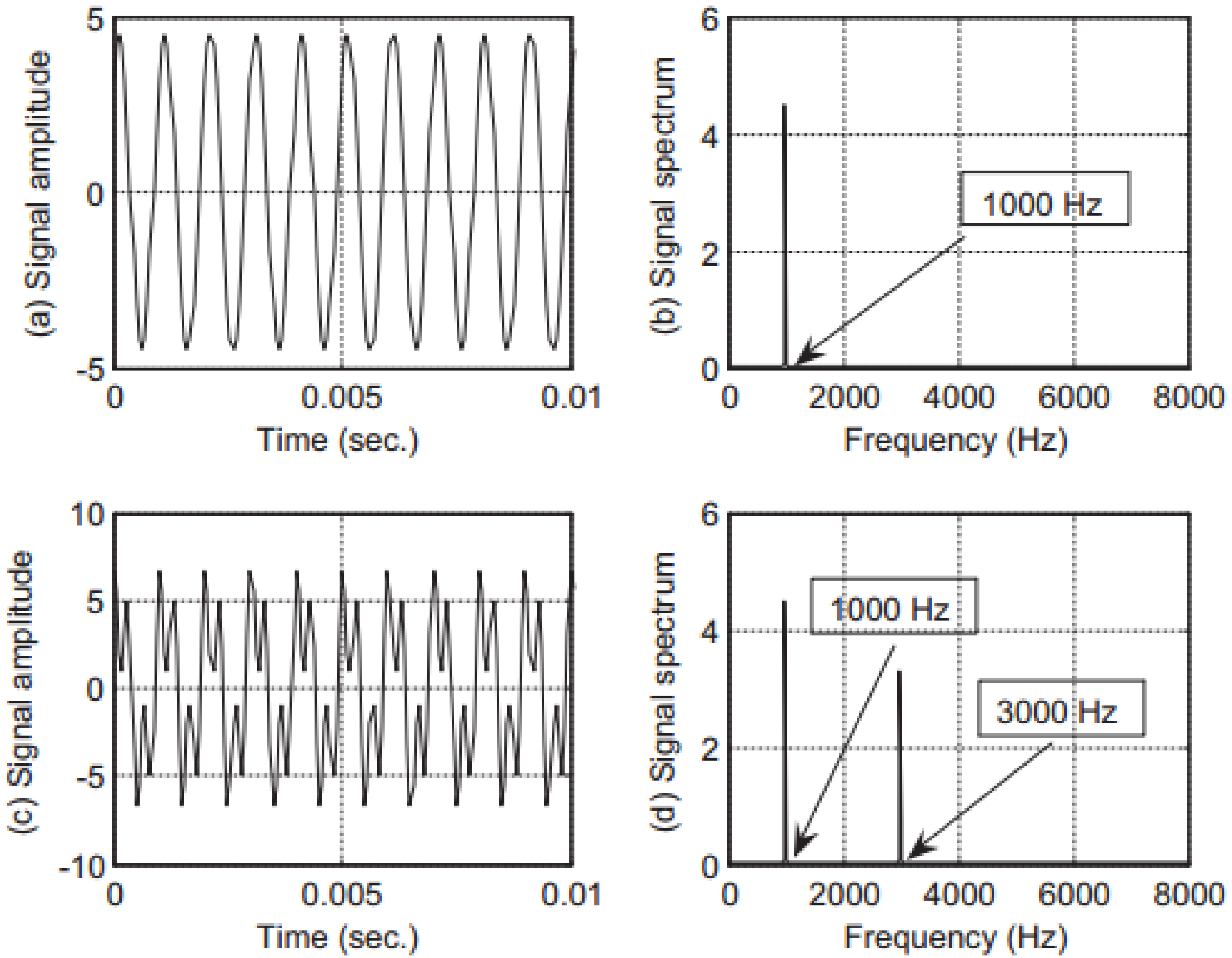
Signal Frequency (Spectrum) Analysis



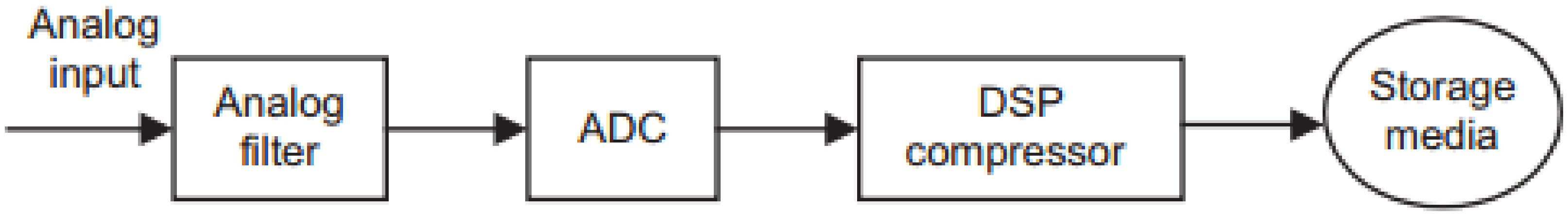
Signal spectral analysis.



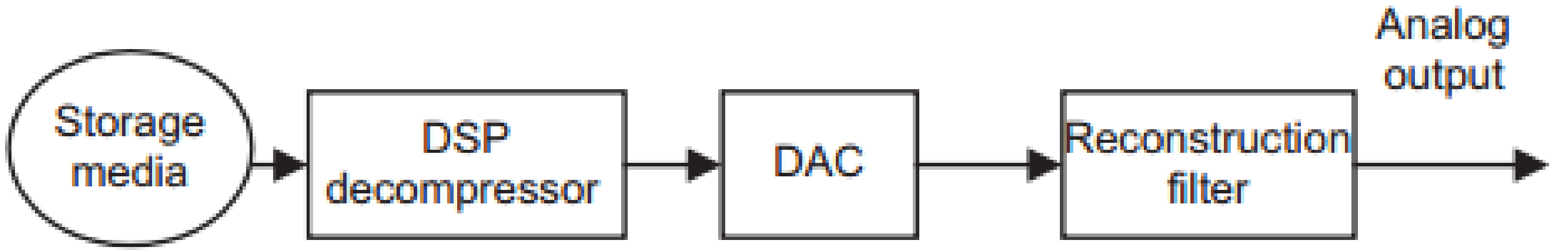
Signal Frequency (Spectrum) Analysis



Audio signals and their spectrums.



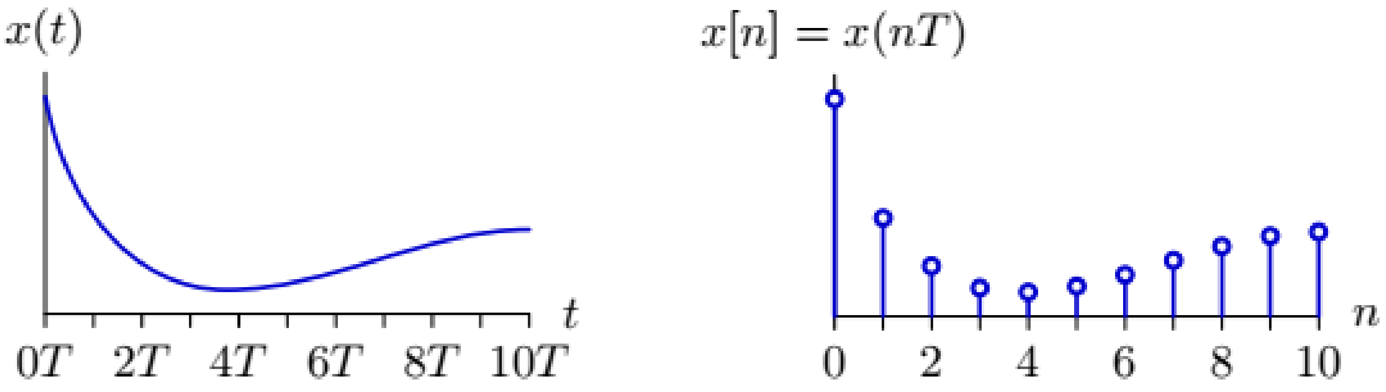
Simplified data compressor.



Simplified data expander (decompressor).

Signals and Systems

Sampling: converting CT signals to DT



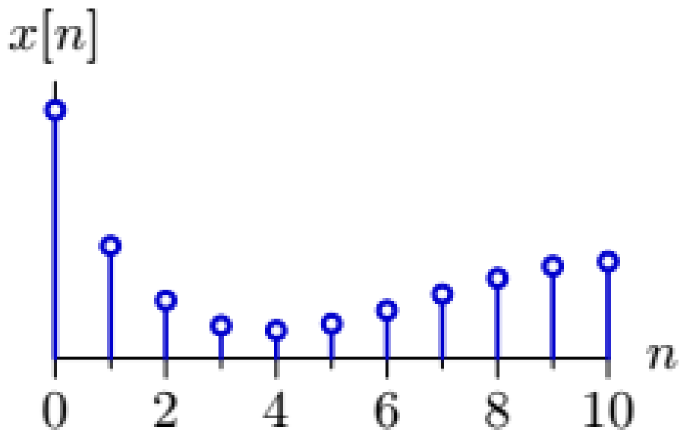
$T =$ sampling interval

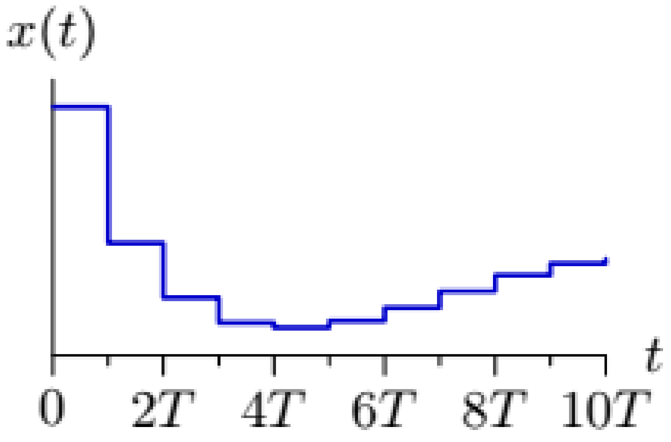
Important for computational manipulation of physical data.

- digital representations of audio signals (e.g., MP3)
- digital representations of images (e.g., JPEG)

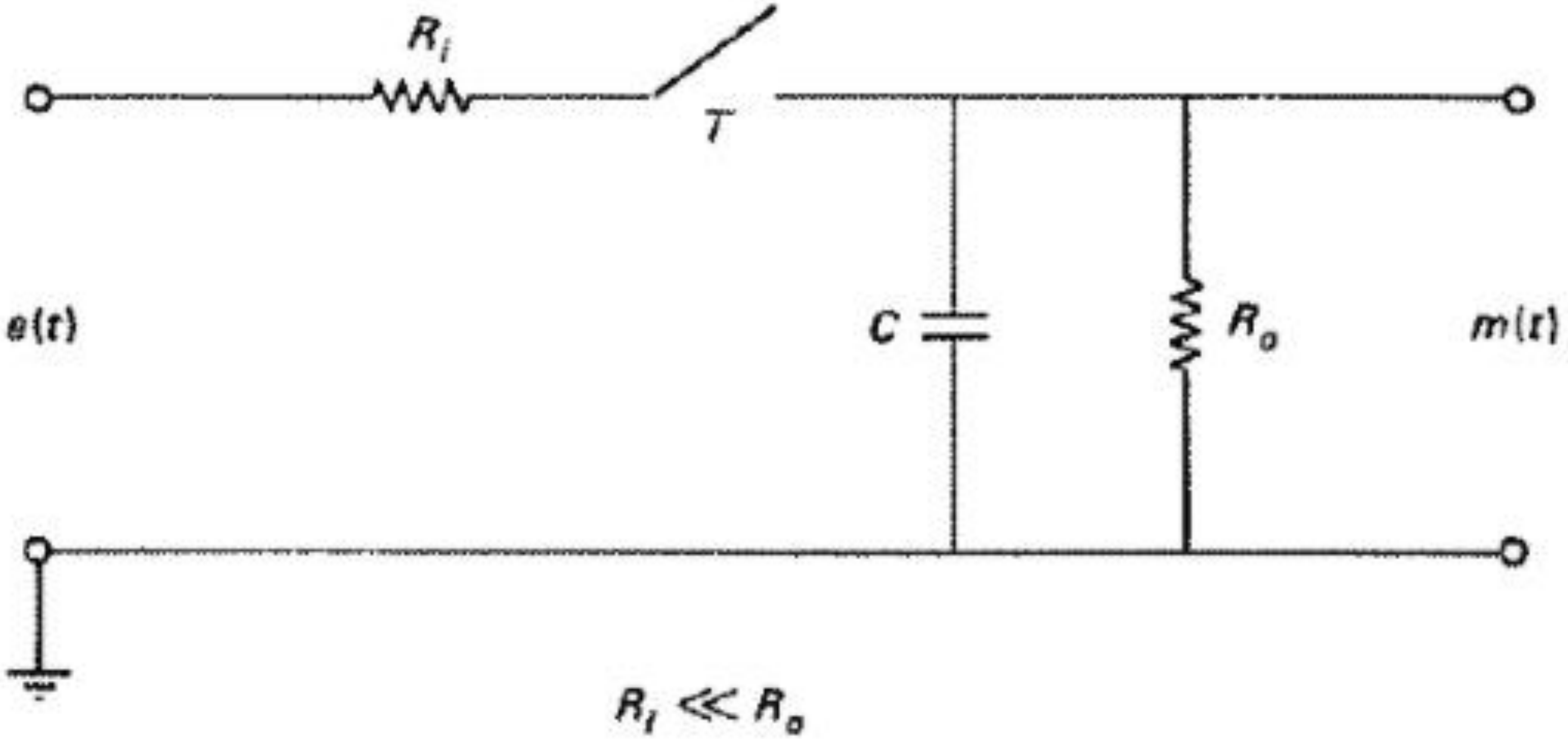
Reconstruction: converting DT signals to CT

zero-order hold





$T =$ sampling interval



Circuit approximating a zero-order hold.

Discrete-Time Systems

We start with discrete-time (DT) systems because they

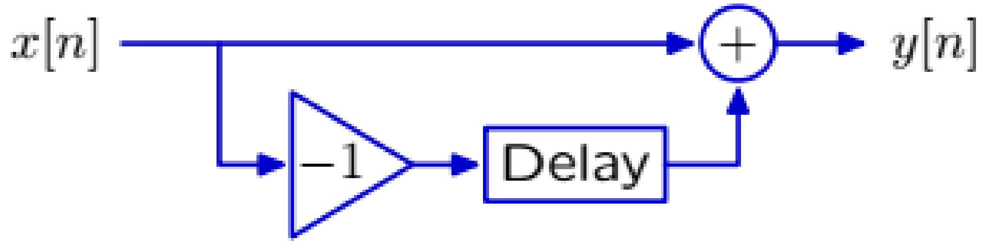
- are conceptually simpler than continuous-time systems
- illustrate same important modes of thinking as continuous-time
- are increasingly important (digital electronics and computation)

Representations of Discrete-Time Systems

Difference equation:

$$y[n] = x[n] - x[n-1]$$

Block diagram:

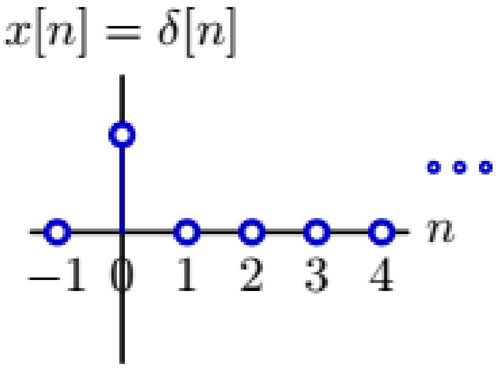


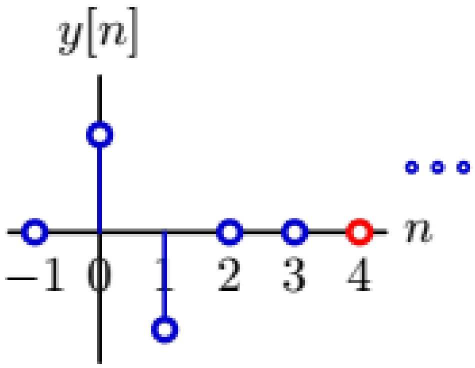
Step-By-Step Solutions

Difference equations are convenient for step-by-step analysis.

Find $y[n]$ given $x[n] = \delta[n]$: $\quad y[n] = x[n] - x[n-1]$

$$\begin{aligned}
y[-1] &= x[-1] - x[-2] && = 0 - 0 = 0 \\
y[0] &= x[0] - x[-1] && = 1 - 0 = 1 \\
y[1] &= x[1] - x[0] && = 0 - 1 = -1 \\
y[2] &= x[2] - x[1] && = 0 - 0 = 0 \\
y[3] &= x[3] - x[2] && = 0 - 0 = 0 \\
&\cdots
\end{aligned}$$

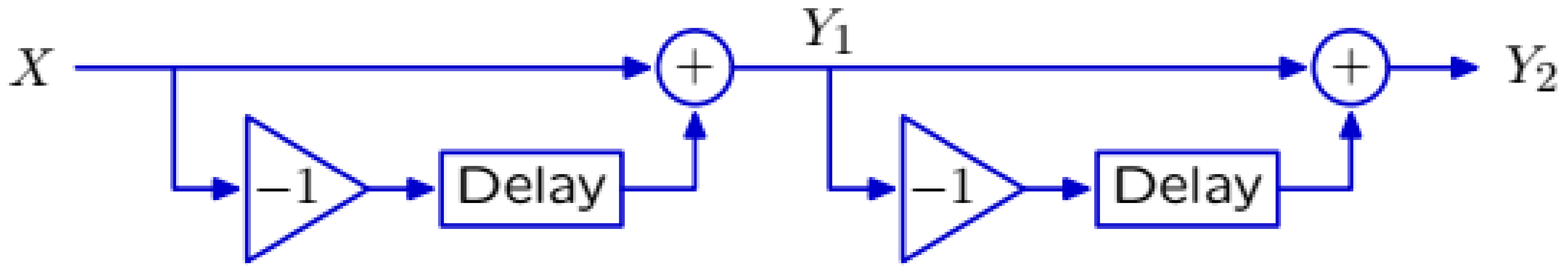




Operator Representation of a Cascaded System

System operations have simple operator representations.

Cascade systems $\rightarrow$ multiply operator expressions.



Using operator notation:

$$Y_1 = (1 - \mathcal{R})\, X$$

$$Y_2 = (1 - \mathcal{R})\, Y_1$$

Substituting for Y_1:

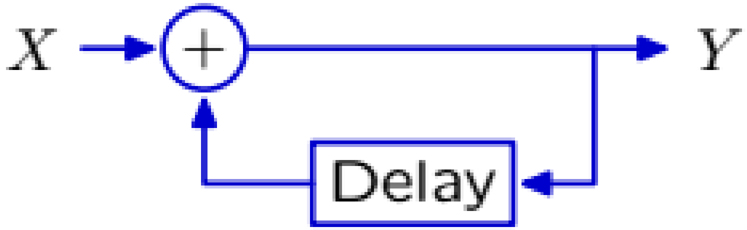
$$Y_2 = (1 - \mathcal{R})(1 - \mathcal{R})\, X$$

R: X ve Y_1 işaretlerinin 1 örnek geciktirilmiş hali (R:x[n-1], R:y[n-1] gibi) olarak düşünülmelidir !!

Feedback

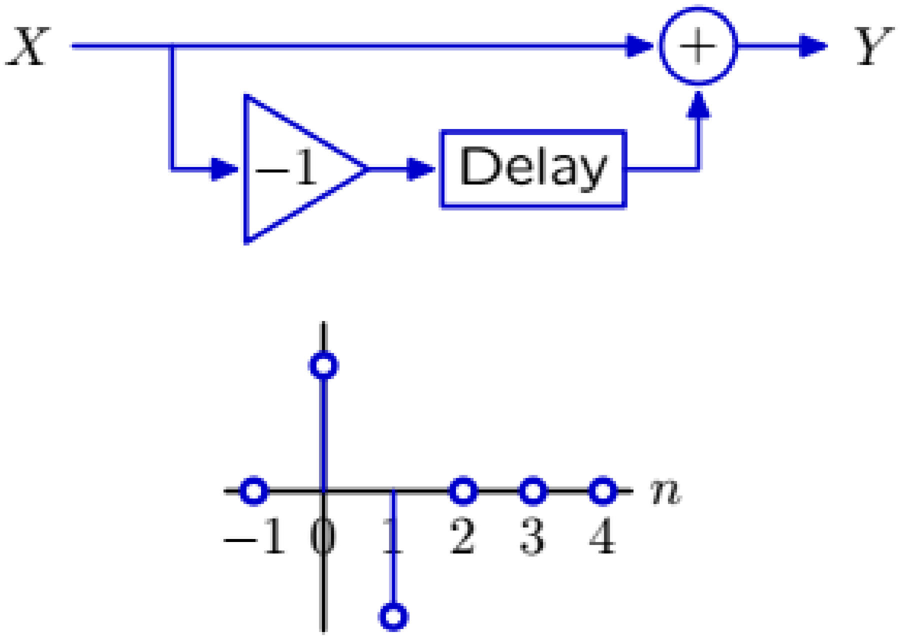
Systems with signals that depend on previous values of the same signal are said to have **feedback**.

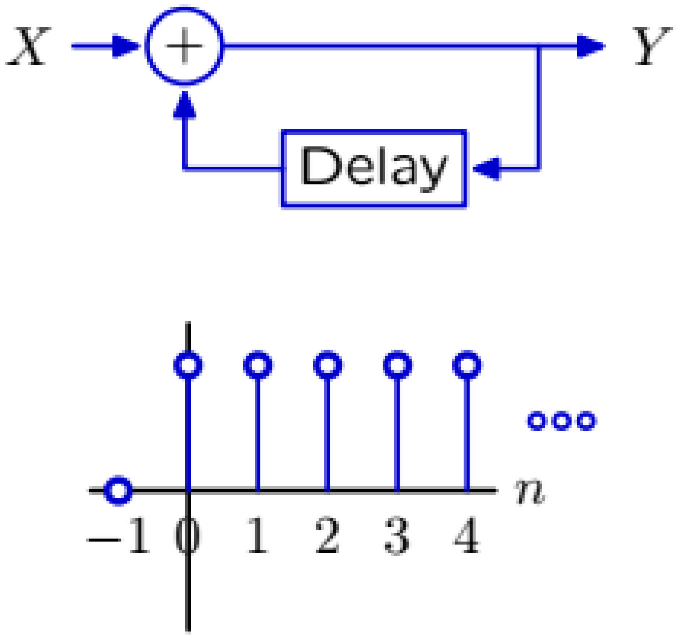
Example: The accumulator system has feedback.



Finite and Infinite Impulse Responses

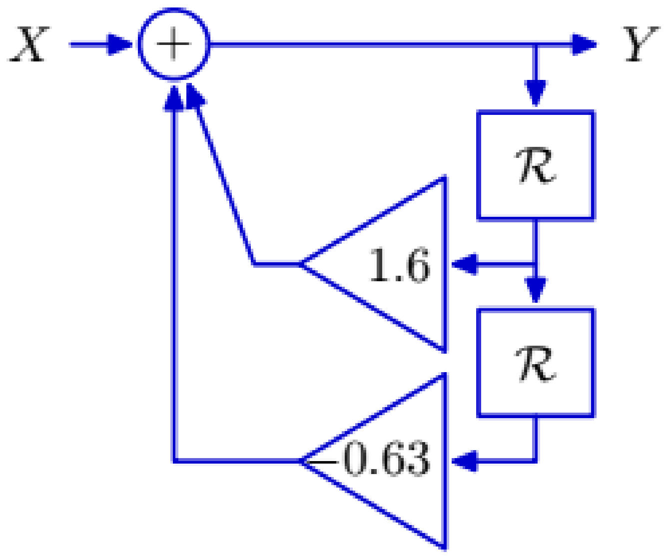
The impulse response of an acyclic system has finite duration, while that of a cyclic system can have infinite duration.





Factoring Second-Order Systems

Factor the operator expression to break the system into two simpler systems (divide and conquer).



$$Y = X + 1.6\mathcal{R}Y - 0.63\mathcal{R}^2 Y$$

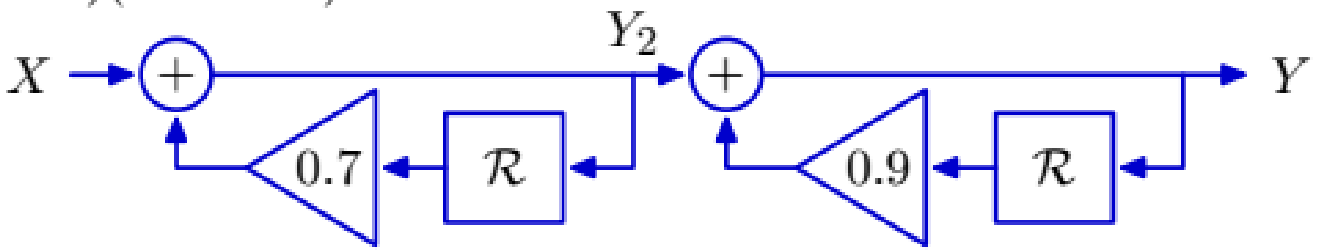
$$\left(1 - 1.6\mathcal{R} + 0.63\mathcal{R}^2\right) Y = X$$

$$(1 - 0.7\mathcal{R})(1 - 0.9\mathcal{R})\, Y = X$$

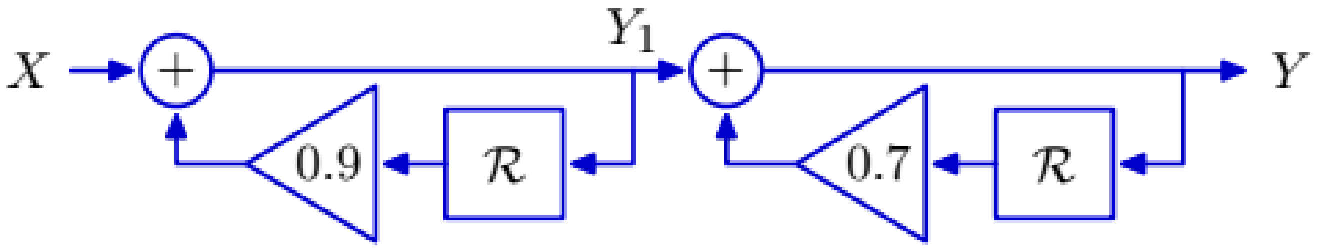
Factoring Second-Order Systems

The factored form corresponds to a cascade of simpler systems.

$$(1 - 0.7\mathcal{R})(1 - 0.9\mathcal{R})\,Y = X$$

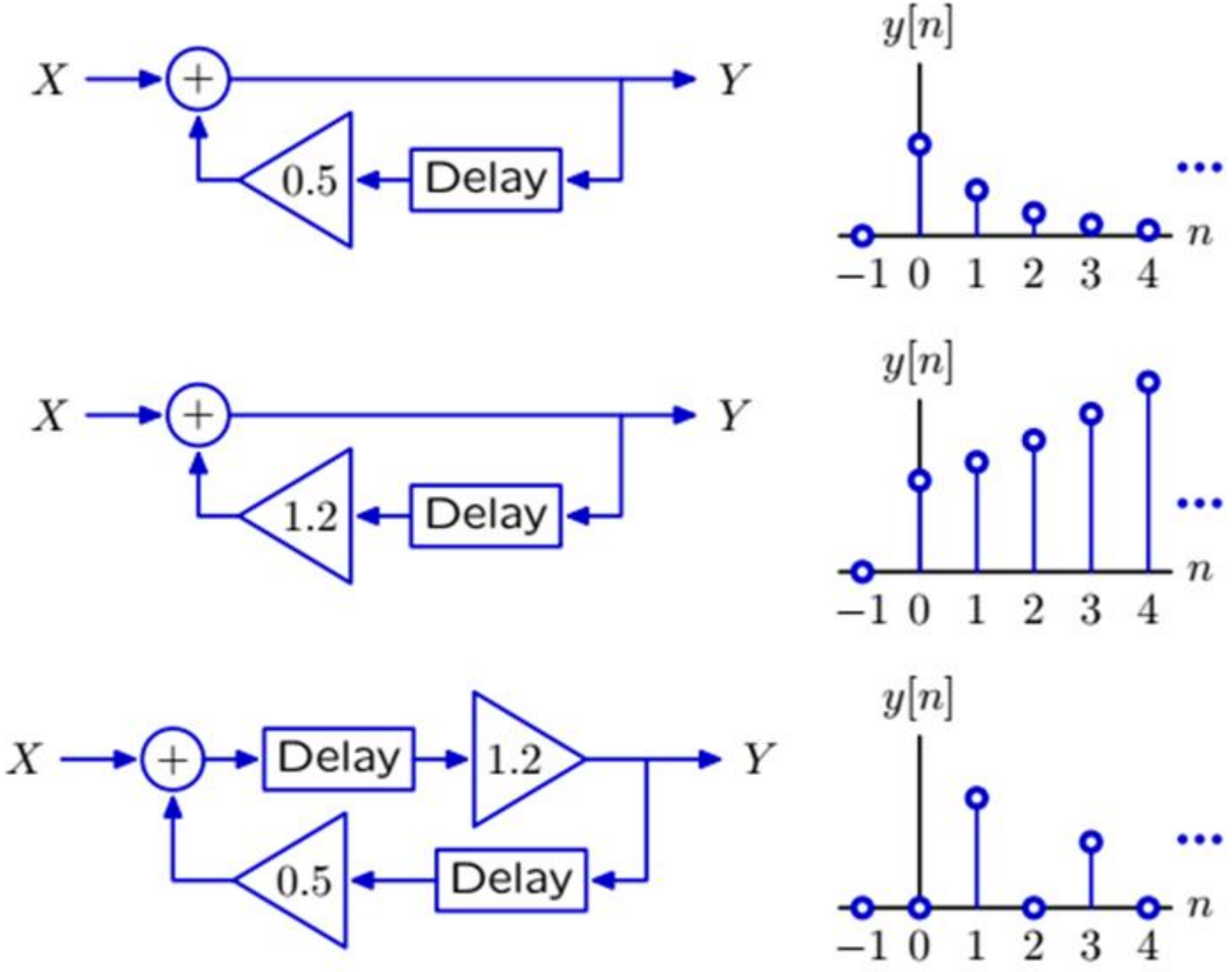


$$(1 - 0.7\mathcal{R})\,Y_2 = X \qquad (1 - 0.9\mathcal{R})\,Y = Y_2$$



$$(1 - 0.9\mathcal{R})\,Y_1 = X \qquad (1 - 0.7\mathcal{R})\,Y = Y_1$$

Check Yourself



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6.003 Signals and Systems
Fall 2011

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