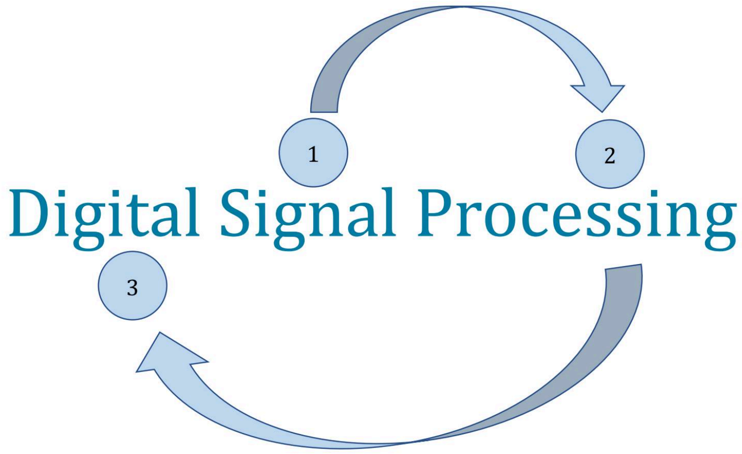
What is DSP?



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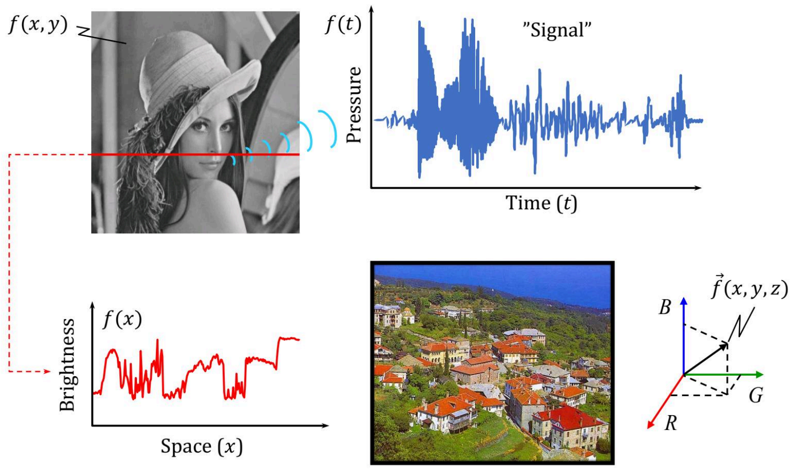
Signals



Signals are physical quantities which vary with time, space, or some other variable(s) and convey information in their patterns of variation.

Signals are mathematically represented by functions of one or more independent variables. In general

$f_k(v_1, \dots, v_M), k = 1, \dots, K$

K = number of channels

M = number of dimensions

We focus on $K = M = 1 \Rightarrow$

Scalar signals

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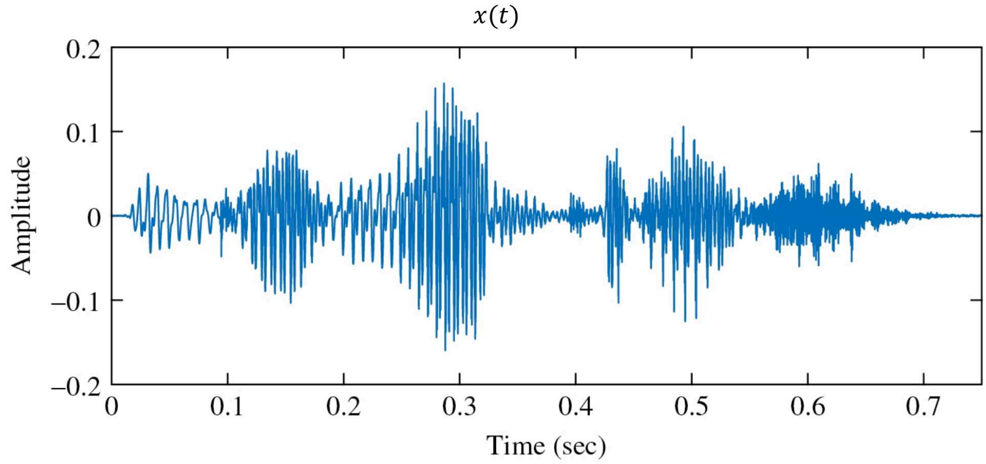
Scalar Continuous-Time Signals



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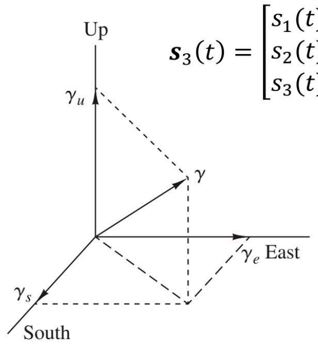
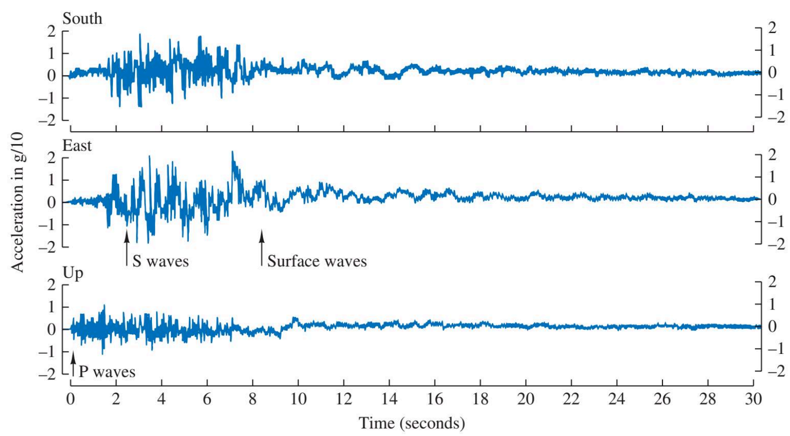
Vector or Multichannel Signals



$$\boldsymbol{s}_3(t) = \begin{bmatrix} s_1(t) \\ s_2(t) \\ s_3(t) \end{bmatrix}$$



Three components of ground acceleration measured a few kilometers from the epicenter of an earthquake.

(From *Earthquakes*, by B. A. Bold, ©1988 by W. H. Freeman and Company. Reprinted with permission of the publisher.)

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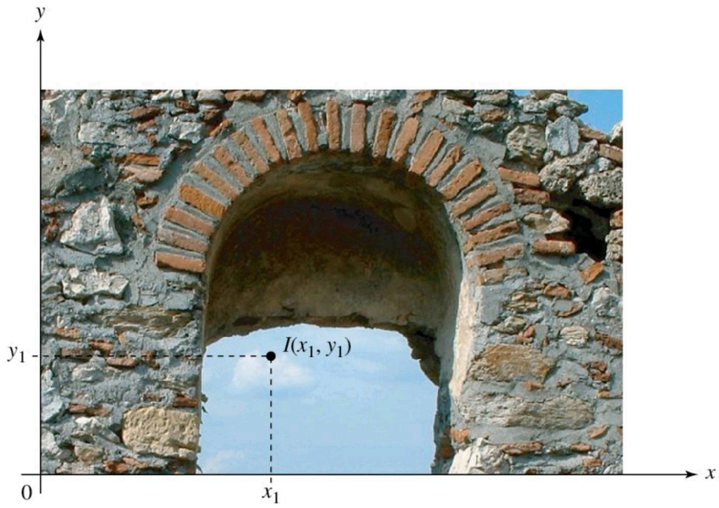
Example of a Two-Dimensional Vector Signal



Gray-scale image

$I(x, y)$

Color image

$$\boldsymbol{I}(x, y) = \begin{bmatrix} I_r(x, y) \\ I_g(x, y) \\ I_b(x, y) \end{bmatrix}$$

Color video

$$\boldsymbol{I}(x, y, t) = \begin{bmatrix} I_r(x, y, t) \\ I_g(x, y, t) \\ I_b(x, y, t) \end{bmatrix}$$

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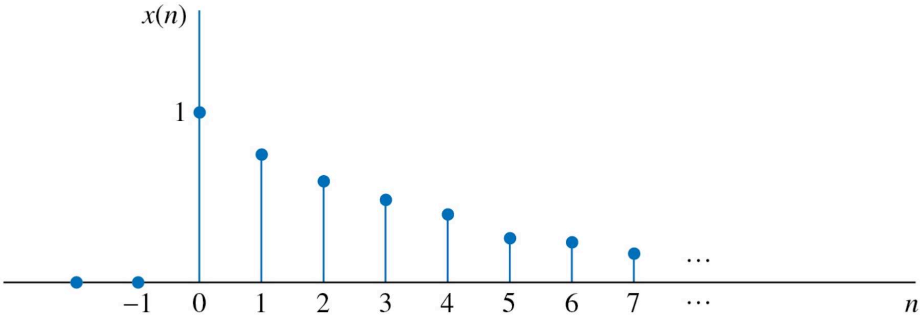
Example of Discrete-Time Signal

$$x(n) = \begin{cases} 0.8^n, & n \geq 0 \\ 0, & n < 0 \end{cases}$$



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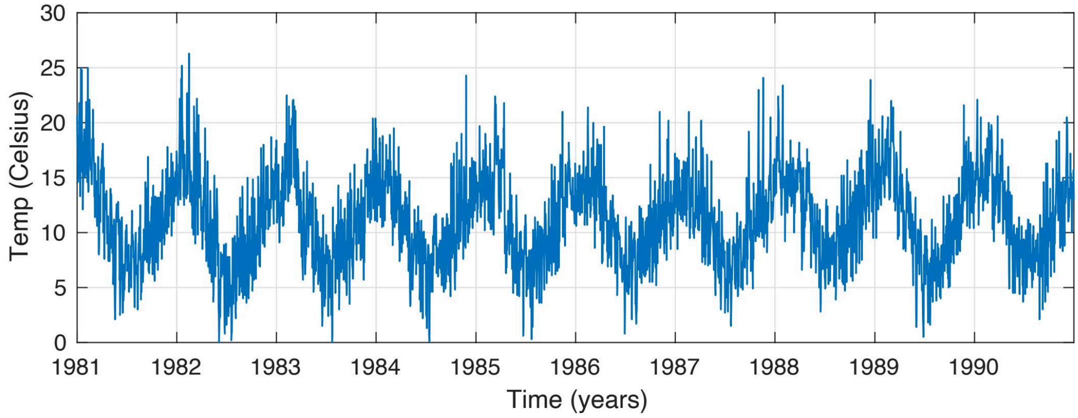
Discrete-Time Signals with Continuous Amplitude



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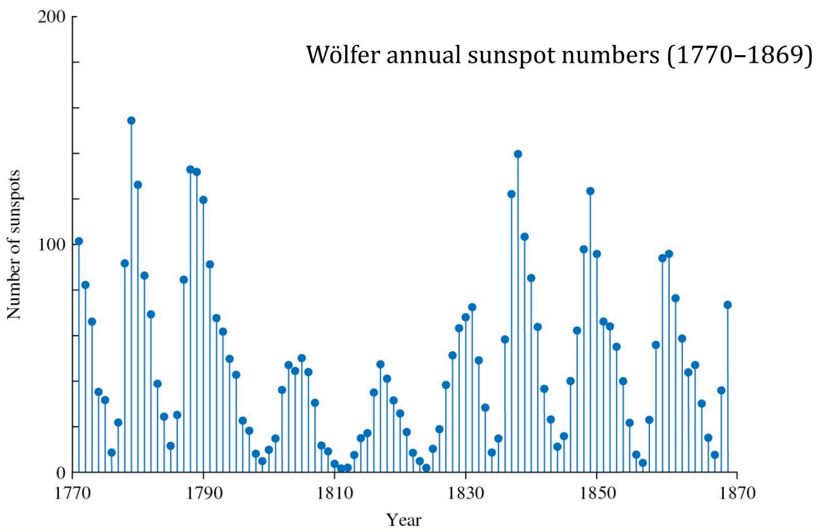
Discrete-Time Signals with Discrete Amplitude



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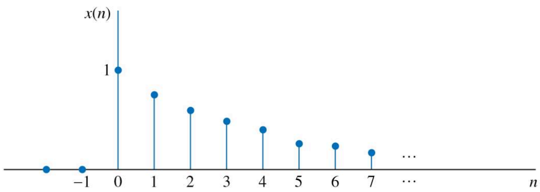
Deterministic Versus Random Signals

Deterministic Signals

Consider the signal $s(n) = 0.8^n u(n)$

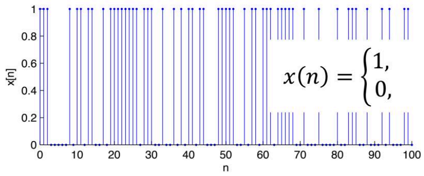


The value of $s(n)$ is specified by the formula for each value of n ⇒ There is only one signal!

Randomness ⇔ Unpredictability

Random Signals

Consider a signal $x(n)$ generated by flipping a fair coin (Bernoulli sequence)



$$x(n) = \begin{cases} 1, & \text{Heads Up} \\ 0, & \text{Tails Up} \end{cases}$$

Each time we repeat the random experiment we obtain a different sequence ⇒ Signal ensemble!

- We develop algorithms to analyze and process $x(n)$ using average properties of the ensemble
- We apply the developed algorithms to the available single signal realization

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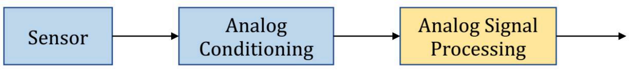
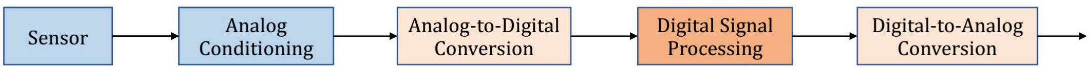
Signal Processing: Analog versus Digital

Signal processing is concerned with the acquisition, representation, transformation, and manipulation of signals to improve their quality or extract useful information



Analog (or Continuous-Time) signal processing is concerned with the conversion of analog signals into electrical signals by special transducers (sensors) and their processing by analog electrical and electronic circuits



Digital (or Discrete-Time) Signal Processing is concerned with the representation of analog signals by sequences of numbers, the transformation of these sequences or the extraction of information from them by numerical computation techniques, and the conversion of such sequences into analog signals

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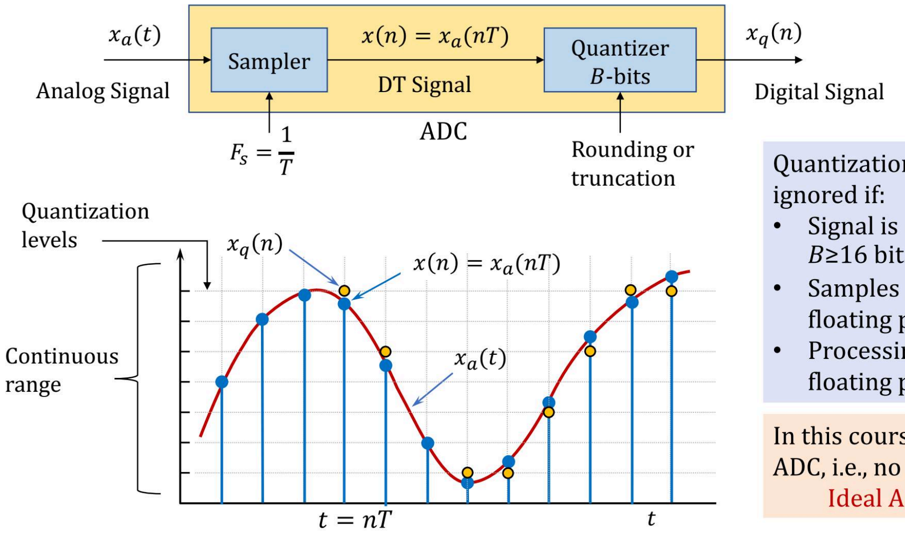
Analog-to-Digital Conversion

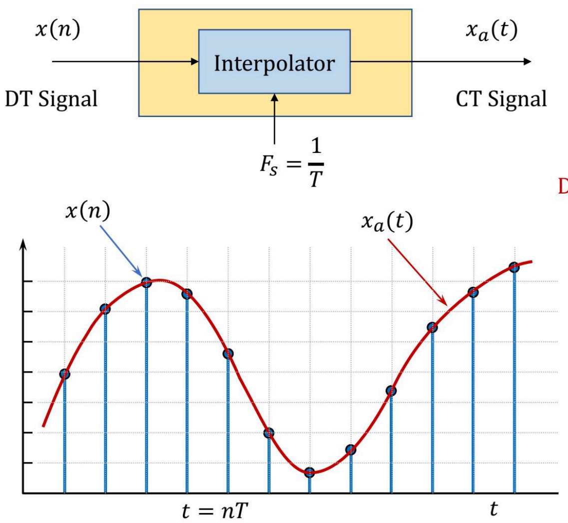


Quantization effects can be ignored if:

- Signal is quantized with $B \geq 16$ bits
- Samples are converted to floating point
- Processing is done with floating point arithmetic

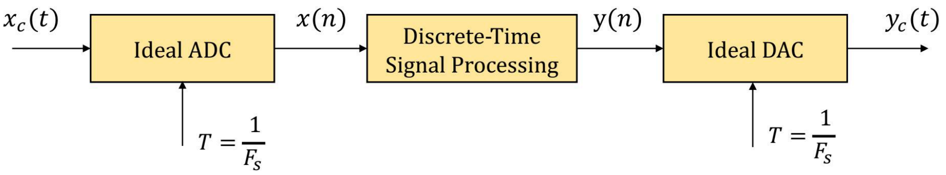
In this course we assume ideal ADC, i.e., no quantization!
Ideal ADC ⇔Sampler

Digital-to-Analog Conversion



DAC ⇔ Interpolator

Discrete-Time or Digital Signal Processing



- After the samples of a discrete-time signal have been stored in memory, time-scale information is lost
- The DAC reintroduces time-scale information
- Discrete-time systems can be implemented in real-time or off-line
- ADC and DAC always operate in real-time

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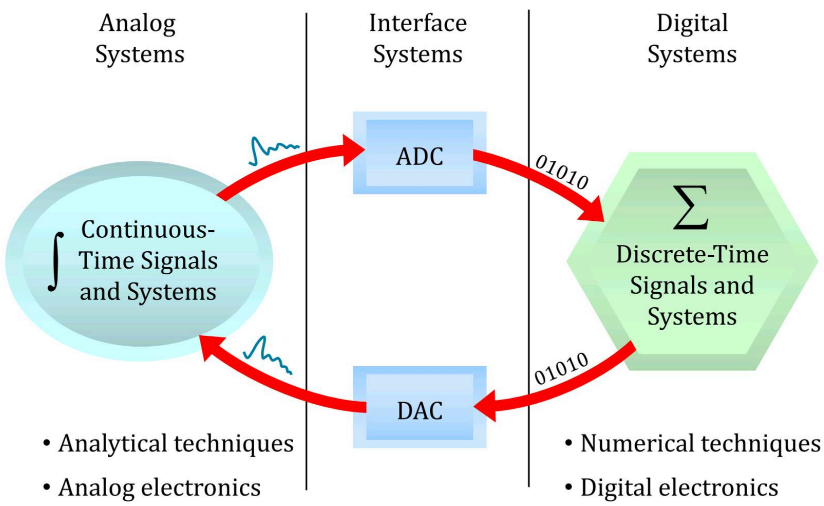
The Three System Classes



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Why DSP?

- Sophisticated signal processing functions can be implemented using digital techniques
- Important signal processing techniques are difficult or impossible to implement using analog electronics
- Digital systems are inherently more reliable, more compact, and less sensitive to environmental conditions and component aging than analog systems
- The digital approach allows the possibility of time-sharing a single processing unit among a number of different signal processing functions

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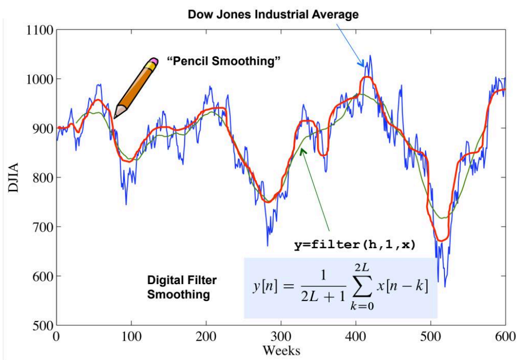
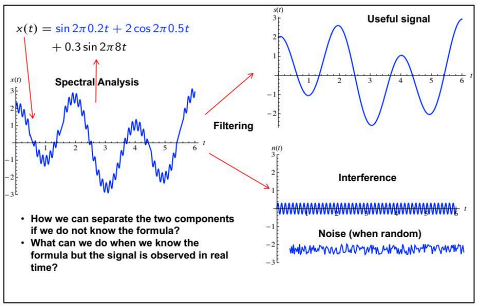
Signal Filtering and Signal Analysis

Signal Filtering The main objective of signal filtering is to improve the quality of a signal according to an acceptable criterion of performance. Signal filtering can be subdivided into the areas of frequency selective filtering, adaptive filtering, and array processing.

Signal Analysis The primary goal is to extract useful information that can be used to understand the signal generation process or extract features that can be used for signal classification purposes. Key areas of signal analysis include spectral analysis and signal modeling.





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