Chapter 1
INTRODUCTION TO DIGITAL SIGNAL PROCESSING
1.1 Introduction
1.2 Signals

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July 14, 2018

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- To start with, a classification of the various types of signals encountered in today's technological world is provided.
- Then the *sampling process* is described as a means of converting analog into digital signals.

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  A radio signal represents the strength of an electromagnetic wave that depends on one independent variable, namely, time.

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- Some signals arise naturally, others are man-made.

Natural signals are found, for example, in:

- Acoustics, e.g., speech signals, sounds made by dolphins and whales

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- Physical sciences, e.g., signals produced by lightnings, the room temperature, the atmospheric pressure

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- Politics, e.g., the popularity ratings of a political party
- Economics, e.g., the price of a stock at the TSX, the TSX index, the gross national product

Signals *Cont'd*

Two general classes of signals can be identified:

- Continuous-time signals
- Discrete-time signals

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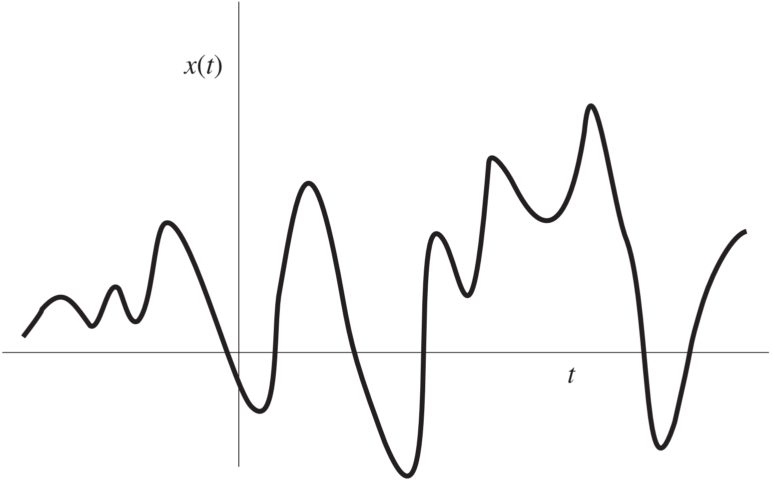
- A continuous-time signal can be represented by a function

$$x(t) \quad \text{where} \quad -\infty < t < \infty$$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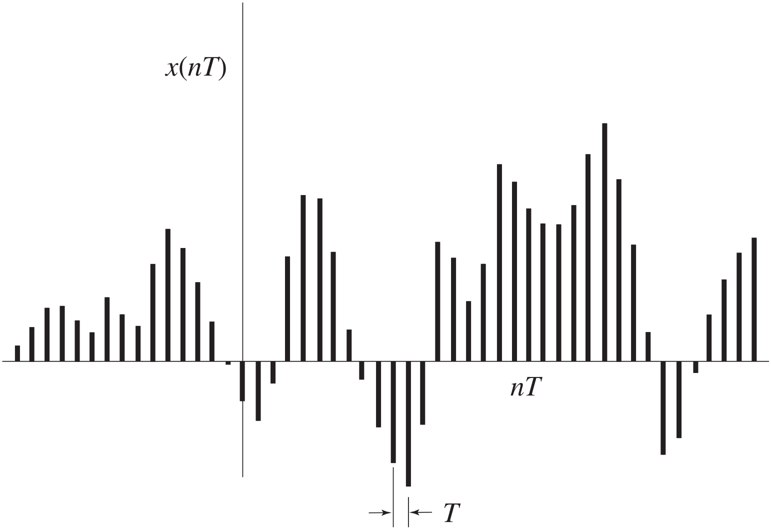
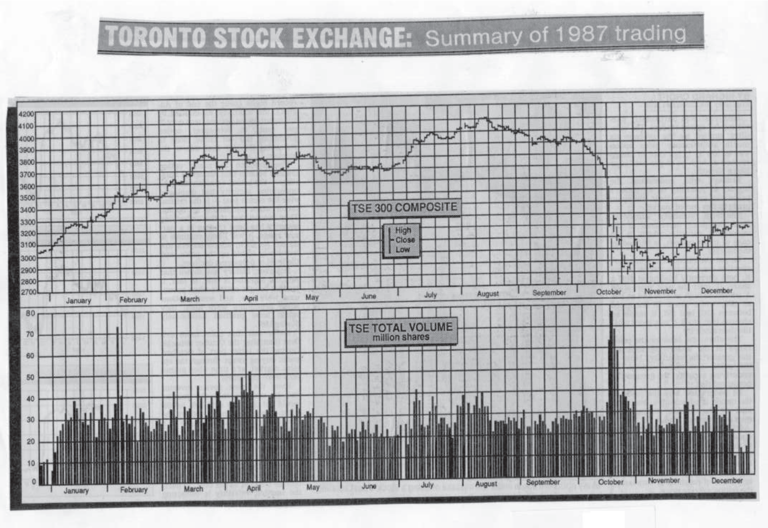
- Constant T usually represents time but it could be any other physical quantity depending on the application.

Discrete-Time Signals *Cont'd*



Discrete-Time Signals *Cont'd*



Discrete-Time Signals *Cont'd*

Note:

The signals in the previous two slides are discrete-time signals since a mutual fund or the TSX index has only one closing value per day.

They are plotted as if they were continuous-time signals for the sake of convenience.

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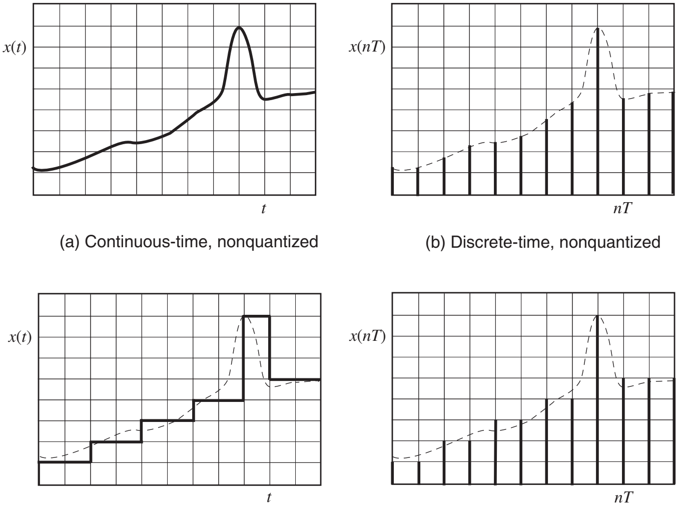
- A *nonquantized signal* is a signal that can assume any value within a given range, e.g., the ambient temperature.
- A *quantized signal* is a signal that can assume only a finite number of discrete values, e.g., the ambient temperature as measured by a digital thermometer.

Nonquantized and Quantized Signals *Cont'd*



(a) Continuous-time, nonquantized

(b) Discrete-time, nonquantized

(c) Continuous-time, quantized

(d) Discrete-time, quantized

Alternative Notation

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- In later presentations, the more economical notation $x(n)$ will be used where appropriate.

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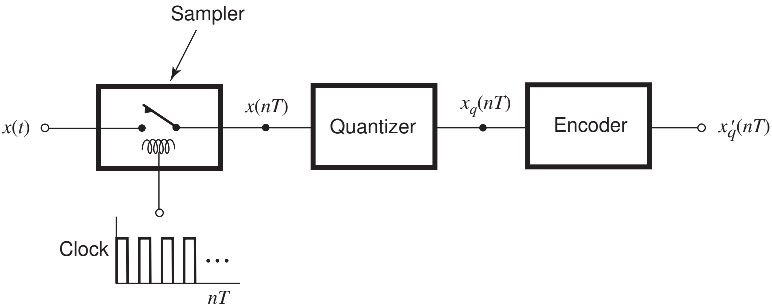
- We must then quantize it to get a quantized discrete-time signal.
- That way, we can generate a numerical representation of the signal that entails a finite amount of information.

A sampling system comprises three essential components:

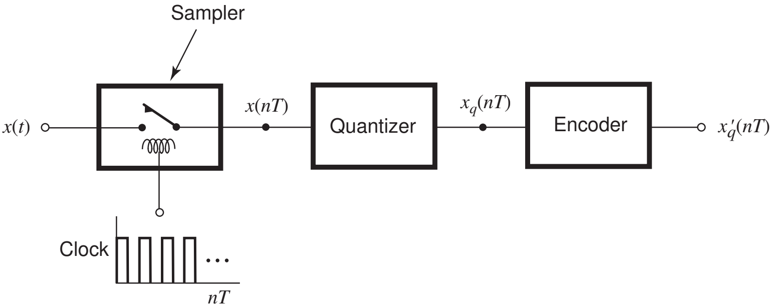
- sampler
- quantizer
- encoder

Sampling Process *Cont'd*



Sampling system

- A *sampler* in its bare essentials is a switch controlled by a clock signal which closes momentarily every T seconds thereby transmitting the level of the input signal $x(t)$ at instant nT, i.e., $x(nT)$, to its output.



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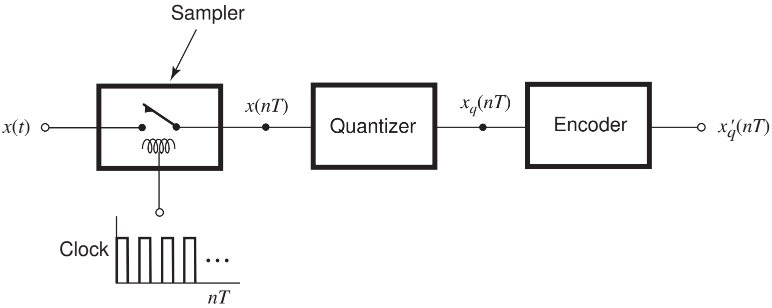
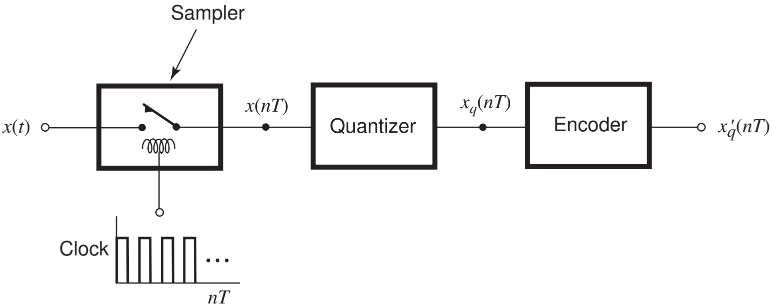
- Parameter T is called the *sampling period*.



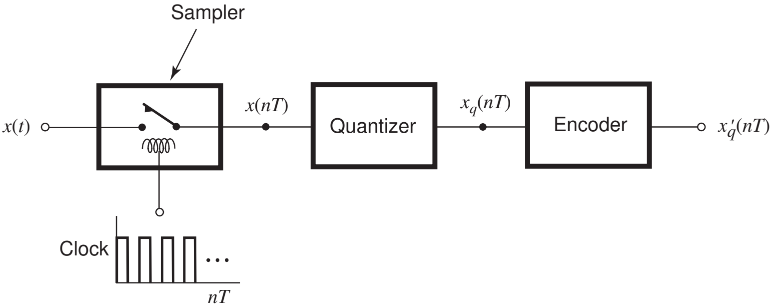
Sampling system

- A *quantizer* is a device that will sense the level of its input and produce as output the nearest available level, say, $x_q(nT)$, from a set of allowed levels, i.e., a quantizer will produce a quantized continuous-time signal.



Sampling system

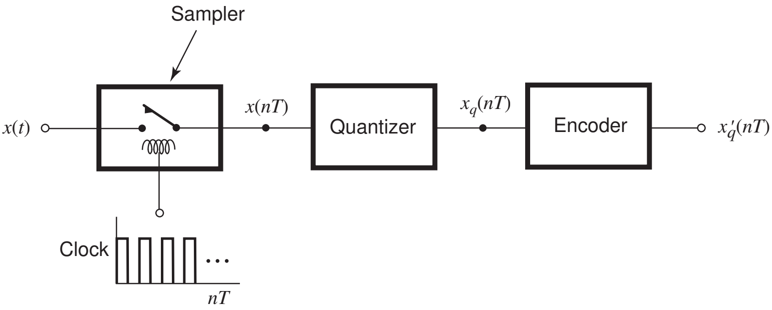
- An *encoder* is essentially a digital device that will sense the voltage or current level of its input and produce a corresponding binary number at its output, i.e., it will convert a quantized continuous-time signal into a corresponding discrete-time signal in binary form.



Sampling system

Sampling Process *Cont'd*

- The sampling system described is essentially an *analog-to-digital converter* and its implementation can assume numerous forms.



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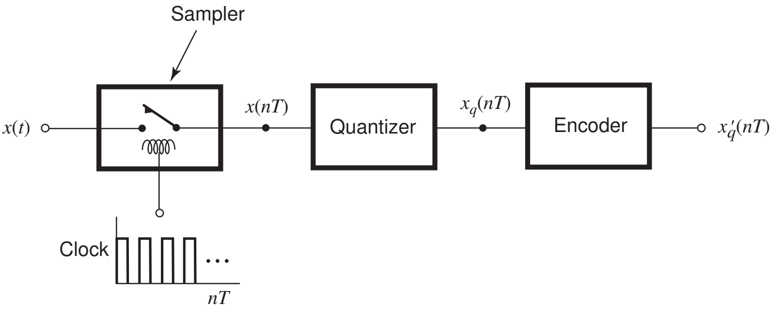
- These devices go by the acronym of A/D converter or ADC and are available in VLSI chip form as off-the-shelf devices.



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- The accuracy of the representation can be improved by increasing
  - the sampling rate, and/or
  - the number of allowable quantization levels in the quantizer
- The sampling rate is simply $1/T = f_s$ in Hz or $2\pi/T = \omega_s$ in radians per second (rad/s).

Sampling Process *Cont'd*

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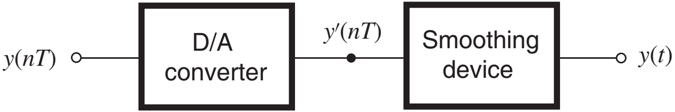
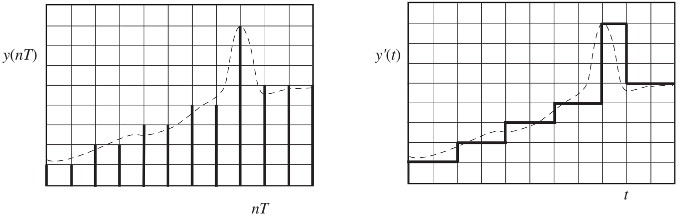
- Just like the sampling process, the conversion from a discrete- to a continuous-signal requires a suitable *digital-to-analog interface*.

- Typically, the digital-to-analog interface requires a series of two cascaded modules, a *digital-to-analog (or D/A) converter* and a *smoothing device:*

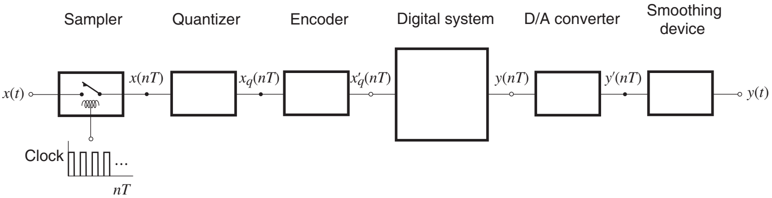


- A D/A converter will receive an encoded digital signal in binary form like that in Fig. (a) as input and produce a corresponding quantized continuous-time signal such as that in Fig. (b).
- The stair-like nature of the quantized signal is, of course, undesirable and a D/A converter is normally followed by some type of smoothing device, typically a lowpass filter, that will eliminate the uneveness in the signal.



(a) (b)

Complete DSP system



- The quality of the conversion from a continuous- to a discrete-time signal and back to a continuous-time signal can be improved
  - by understanding the processes involved and/or
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Sampling Process *Cont'd*

- The quality of the conversion from a continuous- to a discrete-time signal and back to a continuous-time signal can be improved
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- This subject will be treated at a higher level of sophistication in Chap. 6.

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- If the filtering is carried out by digital means, then it is referred to as *digital filtering*.

This slide concludes the presentation.

Thank you for your attention.