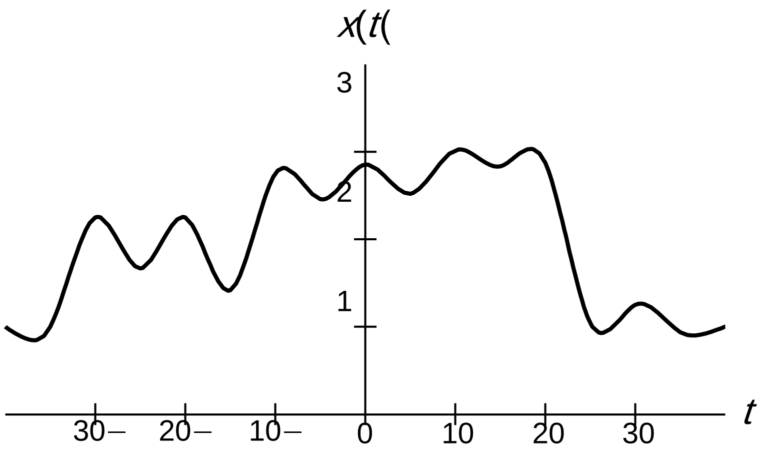
Part 1

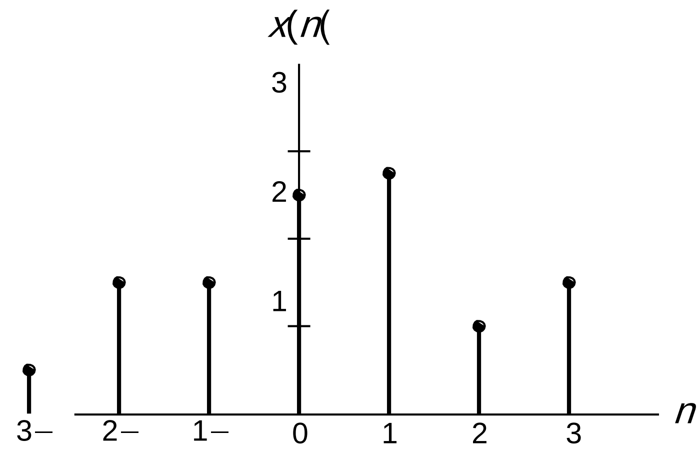
Introduction

- A signal is a function of one or more variables that conveys information about some (usually physical) phenomenon.
- For a function f, in the expression $f(t_1, t_2, \ldots, t_n)$, each of the $\{t_k\}$ is called an independent variable, while the function value itself is referred to as a dependent variable.
- Some examples of signals include:
  - a voltage or current in an electronic circuit
  - the position, velocity, or acceleration of an object a
  - force or torque in a mechanical system
  - a flow rate of a liquid or gas in a chemical process a
  - digital image, digital video, or digital audio
  - a stock market index

- Number of independent variables (i.e., dimensionality:(
  - A signal with *one* independent variable is said to be one dimensional (e.g., audio.(
  - A signal with *more than one* independent variable is said to be multi-dimensional (e.g., image.(
- Continuous or discrete independent variables:
  - A signal with *continuous* independent variables is said to be continuous time (CT) (e.g., voltage waveform.(
  - A signal with *discrete* independent variables is said to be discrete time (DT) (e.g., stock market index.(
- Continuous or discrete dependent variable:
  - A signal with a *continuous* dependent variable is said to be continuous valued (e.g., voltage waveform.(
  - A signal with a *discrete* dependent variable is said to be discrete valued)e.g., digital image.(
- A *continuous-valued CT* signal is said to be analog (e.g., voltage waveform.(
- A *discrete-valued DT* signal is said to be digital (e.g., digital audio.(

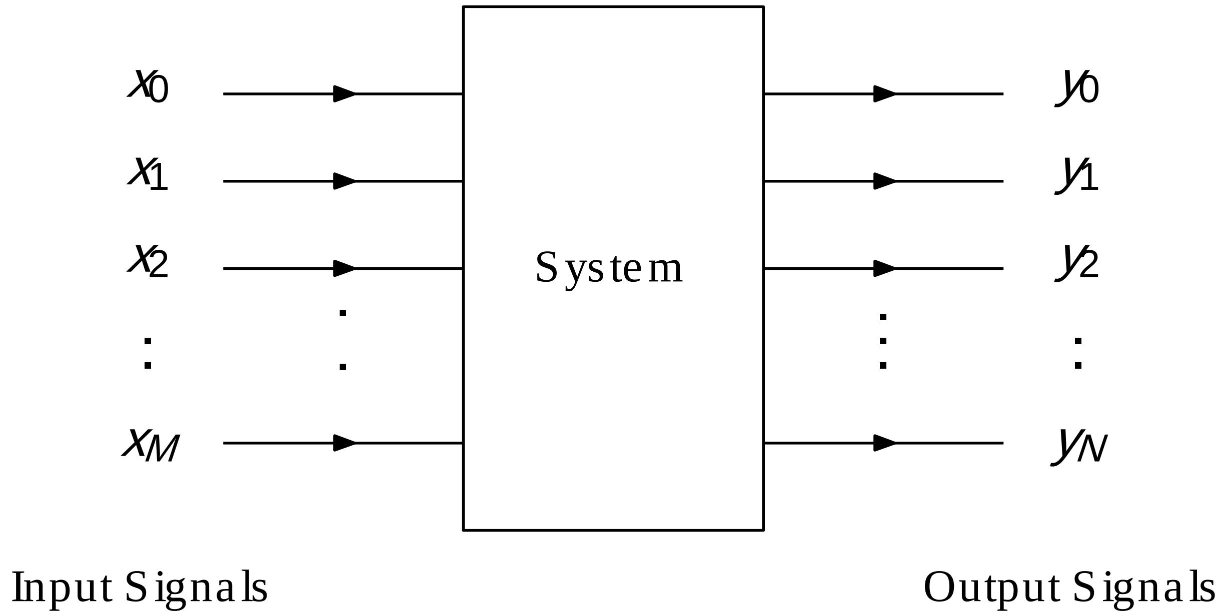


Continuous-Time (CT) Signal

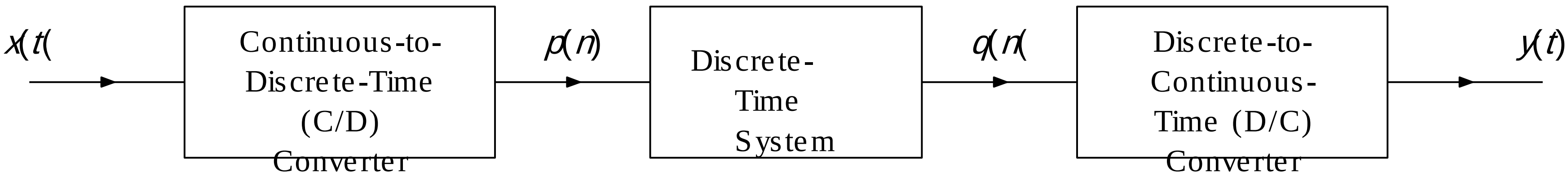


Discrete-Time (DT) Signal

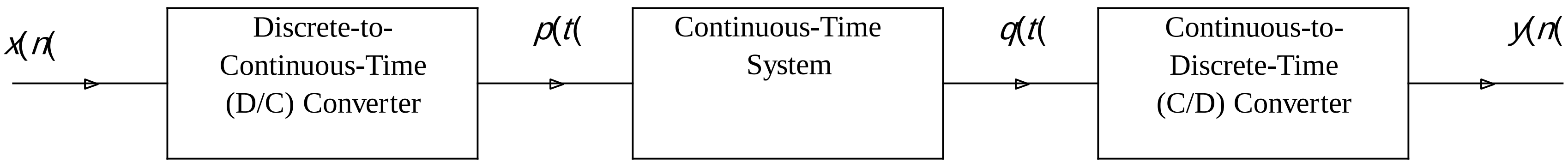
- A system is an entity that processes one or more input signals in order to produce one or more output signals.



- Number of inputs:
  - A system with *one* input is said to be single input (SI.(
  - A system with *more than one* input is said to be multiple input (MI.(
- Number of outputs:
  - A system with *one* output is said to be single output (SO.(
  - A system with *more than one* output is said to be multiple output (MO.(
- Types of signals processed:
  - A system can be classified in terms of the *types of signals* that it processes.
  - Consequently, terms such as the following (which describe signals) can also be used to describe systems:
    - one-dimensional and multi-dimensional,
    - continuous-time (CT) and discrete-time (DT), and
    - analog and digital.
  - For example, a continuous-time (CT) system processes CT signals and a discrete-time (DT) system processes DT signals.

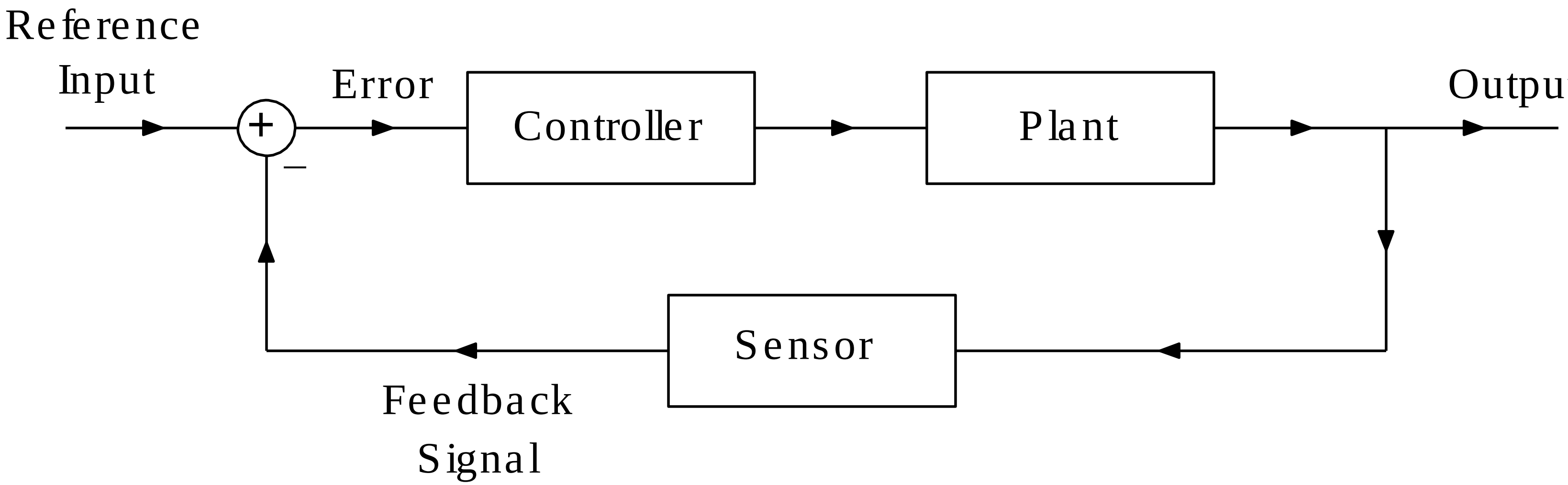


Processing a Continuous-Time Signal With a Discrete-Time System



Processing a Discrete-Time Signal With a Continuous-Time System

General Structure of a Communication System



General Structure of a Feedback Control System

- Engineers build systems that process/manipulate signals.
- We need a formal mathematical framework for the study of such systems.
- Such a framework is necessary in order to ensure that a system will meet the required specifications (e.g., performance and safety.(
- If a system fails to meet the required specifications or fails to work altogether, negative consequences usually ensue.
- When a system fails to operate as expected, the consequences can sometimes be catastrophic.

- The (original) Tacoma Narrows Bridge was a suspension bridge linking Tacoma and Gig Harbor (WA, USA).
- This mile-long bridge, with a 2,800-foot main span, was the third largest suspension bridge at the time of opening.
- Construction began in Nov. 1938 and took about 19 months to build at a cost of $6,400,000.
- On July 1, 1940, the bridge opened to traffic.
- On Nov. 7, 1940 at approximately 11:00, the bridge collapsed during a moderate (42 miles/hour) wind storm.
- The bridge was supposed to withstand winds of up to 120 miles/hour.
- The collapse was due to wind-induced vibrations and an *unstable mechanical system*.
- Repair of the bridge was not possible.
- Fortunately, a dog trapped in an abandoned car was the only fatality.

System Failure Example: Tacoma Narrows Bridge)Continued(

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Section 1.1

Signals

- Earlier, we were introduced to CT and DT signals. A
- CT signal is called a function.
- A DT signal is called a sequence.
- Although, strictly speaking, a sequence is a special case of a function (where the domain of the function is the integers), we will use the term function exclusively to mean a function that is not a sequence.
- The nth element of a sequence x is denoted as either $x(n)$ or x_n.

- Strictly speaking, an expression like "$f(t)$" means the *value* of the function f evaluated at the point t.
- Unfortunately, engineers often use an expression like "$f(t)$" to refer to the *function* f (rather than the value of f evaluated at the point t), and this sloppy notation can lead to problems (e.g., ambiguity) in some situations.
- In contexts where sloppy notation may lead to problems, one should be careful to clearly distinguish between a function and its value.
- Example (meaning of notation:(
  - Let f and g denote real-valued functions of a real variable.
  - Let t denote an arbitrary real number.
  - Let H denote a system operator (which maps a function to a function). The
  - quantity $f+g$ is a *function*, namely, the function formed by adding the functions f and g.
  - The quantity $f(t)+g(t)$ is a *number*, namely, the sum of: the value of the function f evaluated at t; and the value of the function g evaluated at t. The
  - quantity Hx is a *function*, namely, the output produced by the system represented by H when the input to the system is the function x.
  - The quantity $Hx(t)$ is a *number*, namely, the value of the function Hx evaluated at t.