Digital Signal Processing

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Signal and System

- A signal is a function of independent variables that carry some information that contains some information about the behavior of a natural or artificial system.
- A signal is a physical quantity that varies with time, space or any other independent variable by which information can be conveyed.

A **system** is any physical set of components that takes a signal, and produces a signal.

- respond to signals and produce new signals
- process (extract, modify, transform, or manipulate) input signals to produce output signals.
- Excitation signals are applied at system inputs and response signals are produced at system outputs

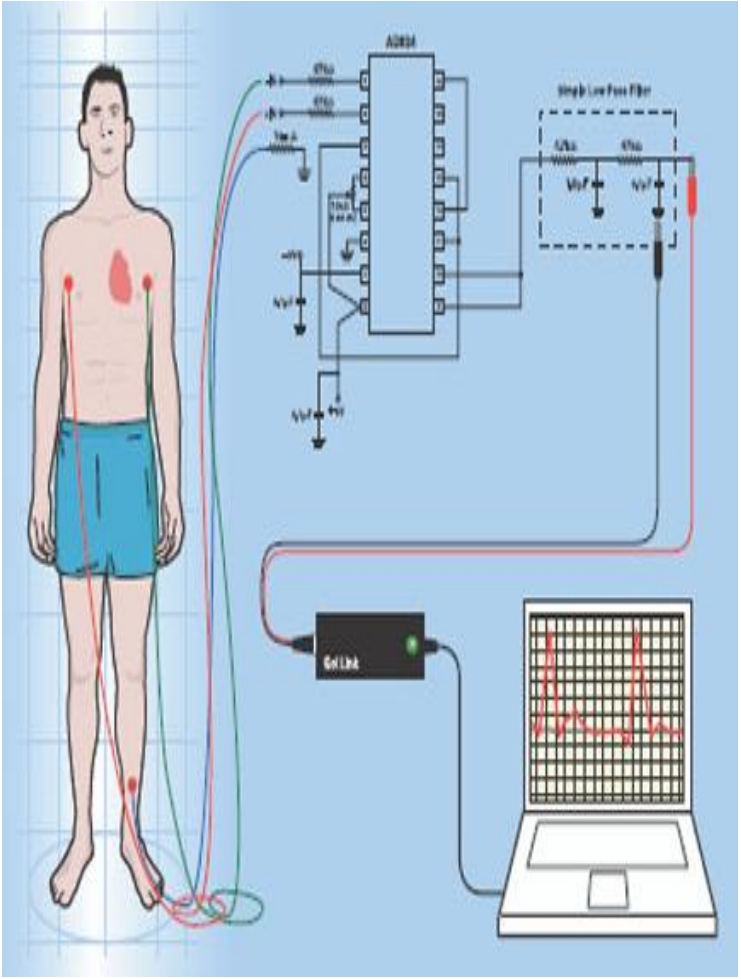
Block diagram of a simple system

Biomedical Signal and System

- The generation of many biological signals found in the human body is traced to the electrical activity of large group of nerve cells or muscle cells.
- A biomedical signal is generally acquired by a sensor, a transducer or/and electrode, and it is converted to a proportional voltage or current for processing and storage.

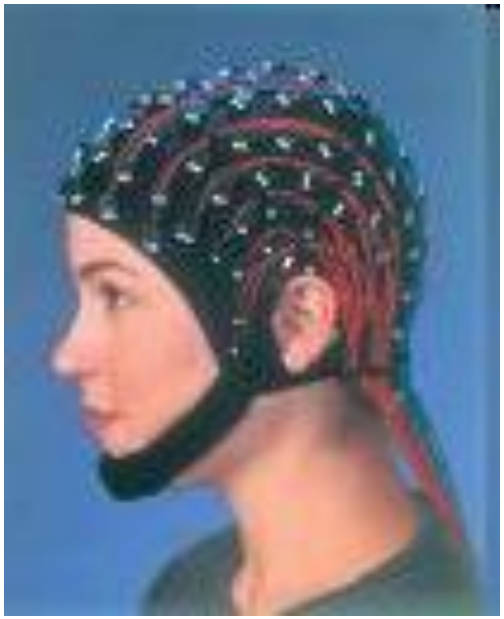
Example of Biomedical Signals

1. Electrocardiogram (ECG)
   - A record of the electrical activity of the heart.
   - To measure the rate and regularity of heartbeats as well as the size and position of the chambers, the presence of any damage to the heart, and the effects of drugs or devices used to regulate the heart (such as a pacemaker).
   - Represents changes in the potential (voltage) due to electrochemical processes involved in the formation and spatial spread of electrical excitations in the heart cells.



2. Electroencephalogram (EEG)

- a record of fluctuations in the electrical activity of large groups of neurons in the brain.
- Measures the electrical fields associated with the current flowing through a group of neurons.



To record EEG or ECG, at least two electrodes are needed.

- an active electrode is placed over the particular site of neuronal activity that is of interest

- a reference electrode is placed at some remote distance from this site

❖ EEG or ECG is measured as the voltage or potential difference between the active and the reference electrodes

Because of biomedical signals are generally contaminated with noise; their signal noise ratios (SNRs) can be improved by filtering (analog or discrete filters).

Biomedical Systems

- In biology and medicine, many systems can be identified. Example of biomedical systems:
  - ✓ nervous system
  - ✓ immune system
  - ✓ digestive system
  - ✓ respiratory system

Classification of Signals

There are several broad classification of signals :

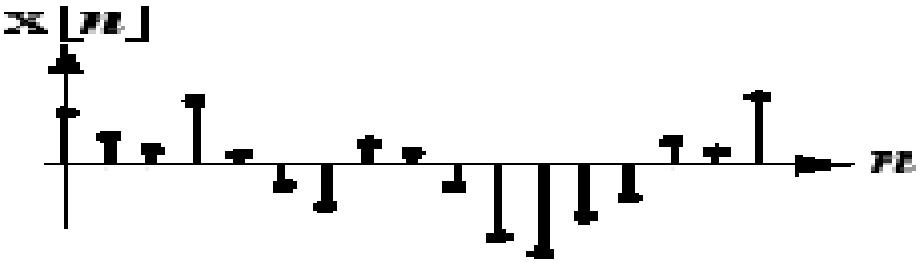
1. Continuous-time and Discrete-time Signal
2. Even and Odd Signals
3. Periodic Signals, Nonperiodic Signals
4. Deterministic Signals, Random Signals
5. Causal, Anti-causal and Noncausal Signals
6. Right-Handed and Left-Handed Signals

1. Continuous-time and discrete-time signal

- A signal, *x(t)* is said to be a continuous-time signal if it is defined for all time *t*.
- A discrete-time signal, *x[n]* is defined only at discrete instants of time.
- A discrete-time signal is often derived from a continuous-time signal by sampling it at a uniform rate.

Continuous-time signal

Disrete-time signal

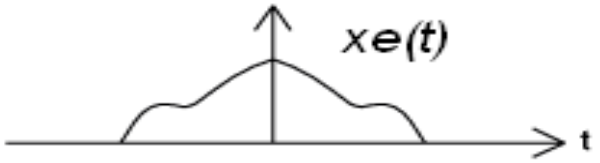


2. *Even and odd signals*

- A continuous-time signal,

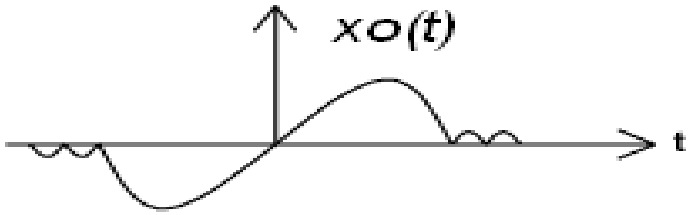
✓ $x(t)$ is said to be an even signal if it satisfies the condition below:

$$x(-t) = x(t) \text{ for all } t$$



✓ x be an odd signal if it satisfies the condition below:

$$-x(-t) = x(t) \text{ for all } t$$



– even signals are symmetric about the vertical axis or time origin, whereas odd signals are antisymmetric (asymmetric) about the time origin.

3. *Periodic signals, nonperiodic signals*

- A periodic signal $x(t)$ is a function that satisfies the condition below:

$$x(t) = x(t+T) \text{ for all } t \qquad (1)$$

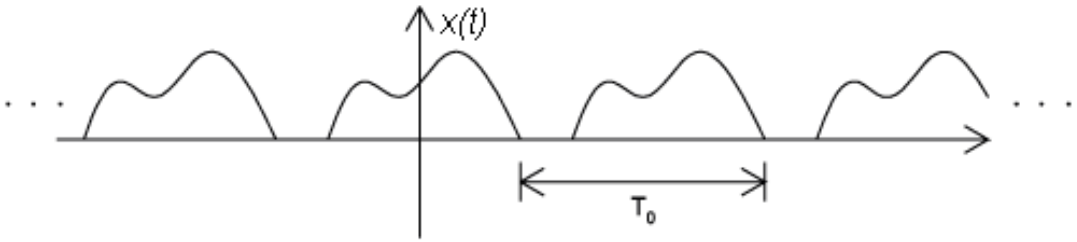
- T that satisfied the above equation is called fundamental period of $x(t)$.

- The reciprocal of fundamental period is called fundamental frequency.

$$f = 1/T$$

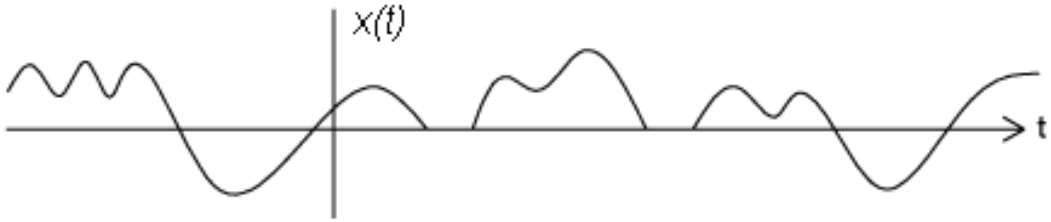
- The frequency f is measured in hertz (Hz) or cycles per second.
- The angular frequency is measured in radians per second.

$$\omega = 2\pi/T$$



A Periodic signal with period T

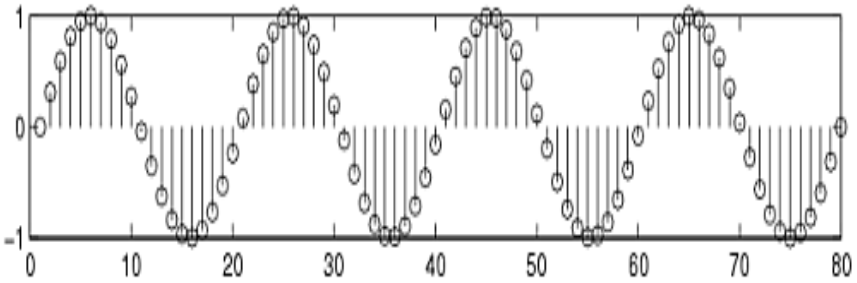
Any signal *x(t)* for which there is no value of *T* to satisfy the condition of equation [*x(t)* = *x(t+T)* for all *t]* is called aperiodic or nonperiodic signal.



A nonperiodic signal

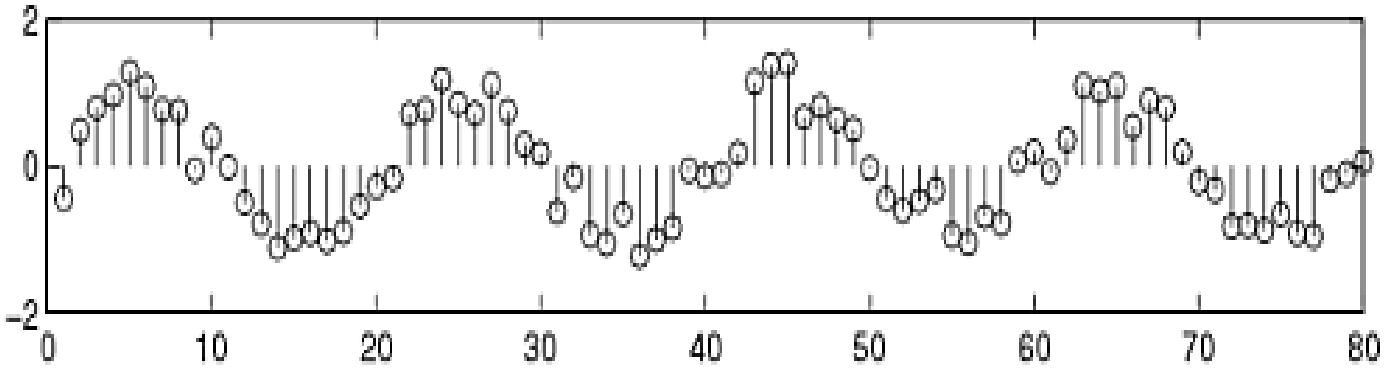
4. Deterministic signals, random signals

- A deterministic signal is a signal in which each value of the signal is fixed and can be determined by a mathematical expression, rule, or table.
- Because of this the future values of the signal can be calculated from past values with complete confidence.



Deterministic signal

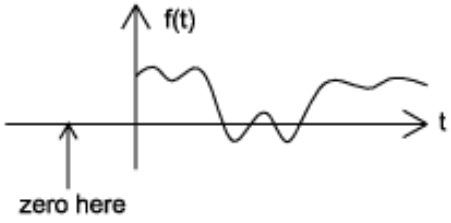
– A random signal has a lot of uncertainty about its behavior.
– The future values of a random signal cannot be accurately predicted and can usually only be guessed based on the averages of sets of signals.



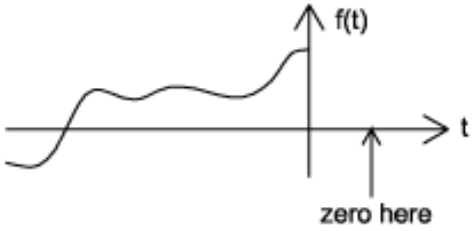
Random signal

5. *Causal, anti-causal and noncausal signals*

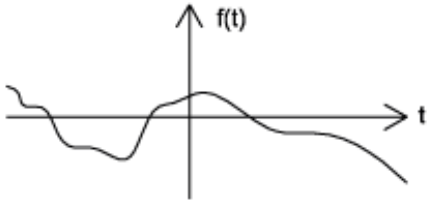
- Causal signals are signals that are zero for all negative time.
- Anticausal are signals that are zero for all positive time.
- Noncausal signals are signals that have nonzero values



A causal signal



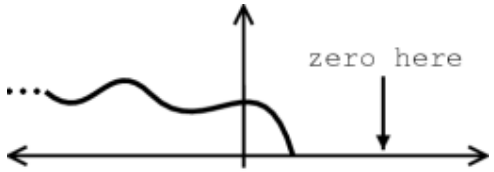
An anticausal signal



A noncausal signal

6. Right-Handed and Left-Handed Signals

Right-handed signal



Left-handed signal