Real Time System

Third Level

Lecture Four

Signals

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Goals

Up-on completing this lecture, the student should be able to:

1- Identify the various types of signals and their application domains.
2- Classify the signals according to their parameters.

Data is collection of information, usually formatted in a special way. All software is divided into two general categories: data and programs. Programs are collections of instructions for processing data.

Data can exist in a variety of forms such as numbers or text on pieces of paper, as bits and bytes stored in electronic memory, or as facts stored in a person's mind.

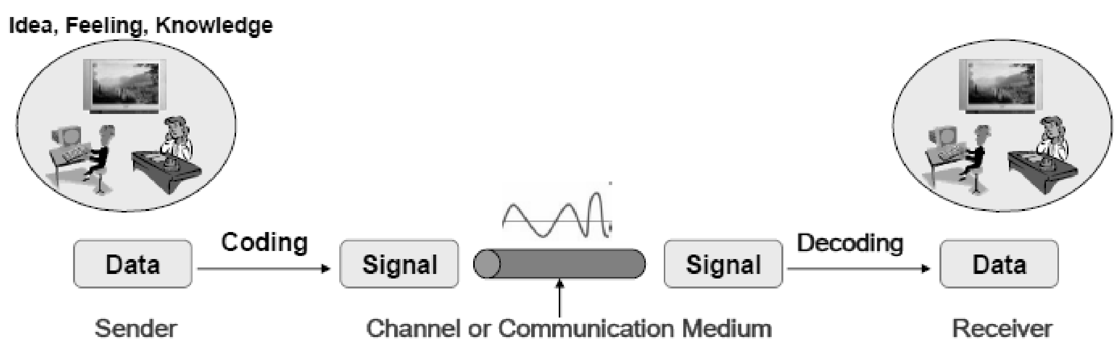
Data – information formatted in human/machine readable form.

Signal – electric or electromagnetic representation of data.

The fundamental quantity of representing some information is called a **signal**. It doesn't matter what the information is (Analog or digital information). In mathematics, a signal is a function that conveys some information. In fact any quantity measurable through time over space can be taken as a signal.

When information needs to be transmitted, data must be turned into energy in the form of electro-magnetic signals**.**

Transmission – communication of data through propagation and processing of signals.



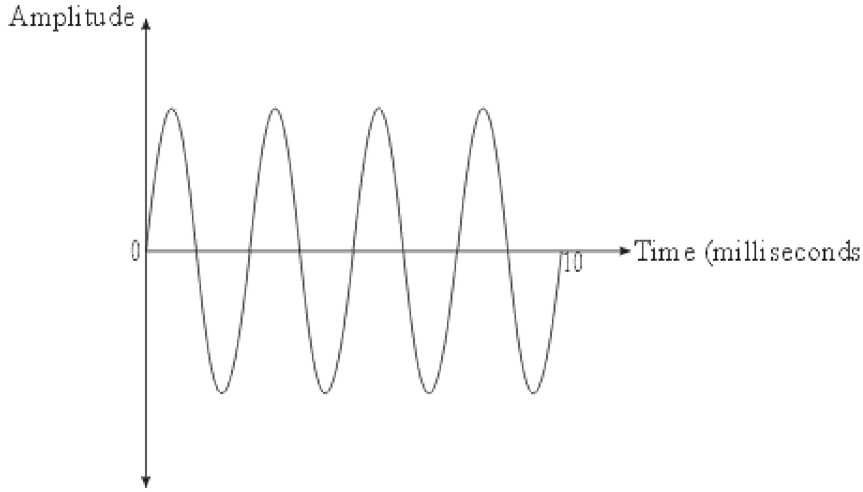
Signal Representation

Signals can be represented as Time domain and frequency domain. Time domain and frequency domain are two modes used to analyze data. Both time domain analysis and frequency domain analysis are widely used in fields such as electronics, acoustics, telecommunications, and many other fields.

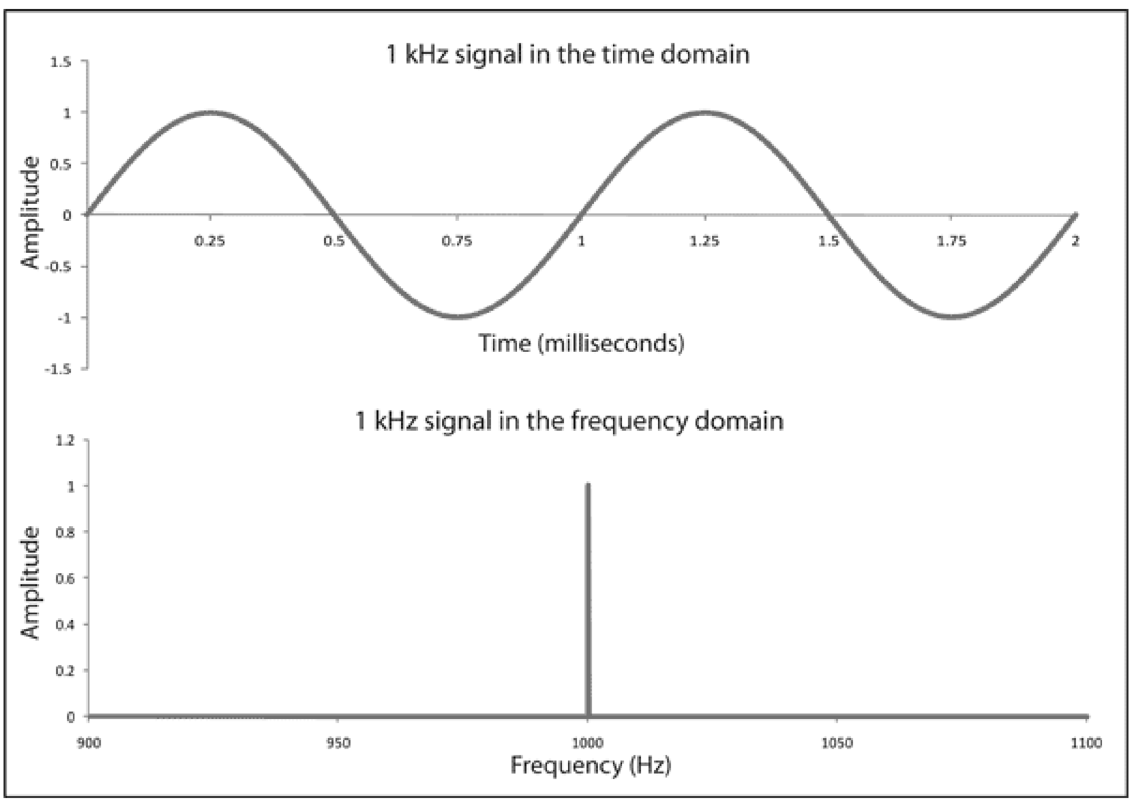
Time domain analysis is analyzing the data over a time period.

Frequency domain is a method used to analyze data. This refers to analyzing a mathematical function or a signal with respect to the frequency.

Most of the signals in practice are **TIME-DOMAIN** signals. That is, whatever that signal is measuring, is a function of time. In other words, when we plot the signal one of the axes is time and the other is usually the amplitude. When we plot time-domain signals, we obtain a time-amplitude representation of the signal.



This representation is not always the best representation of the signal for most signal processing related applications. In many cases, the most distinguished information is hidden in the frequency content of the signal. The frequency SPECTRUM of a signal is basically the frequency components of that signal. The frequency spectrum of a signal shows what frequencies exist in the signal. The below represents a signal in time domain and frequency domain.



Signaling is the way data is communicated. This type of signal used can be either analog or digital.

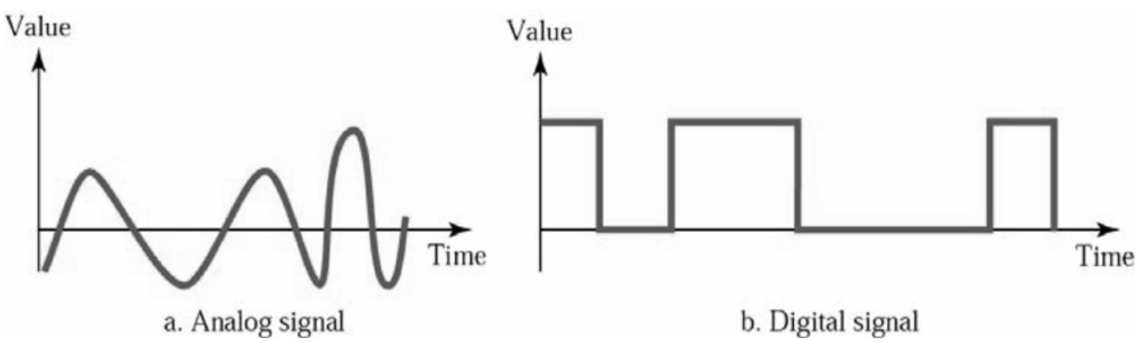
Analog vs. Digital Data

• **Analog data** – representation variable takes on continuous values, e.g. voice, temperature, etc.

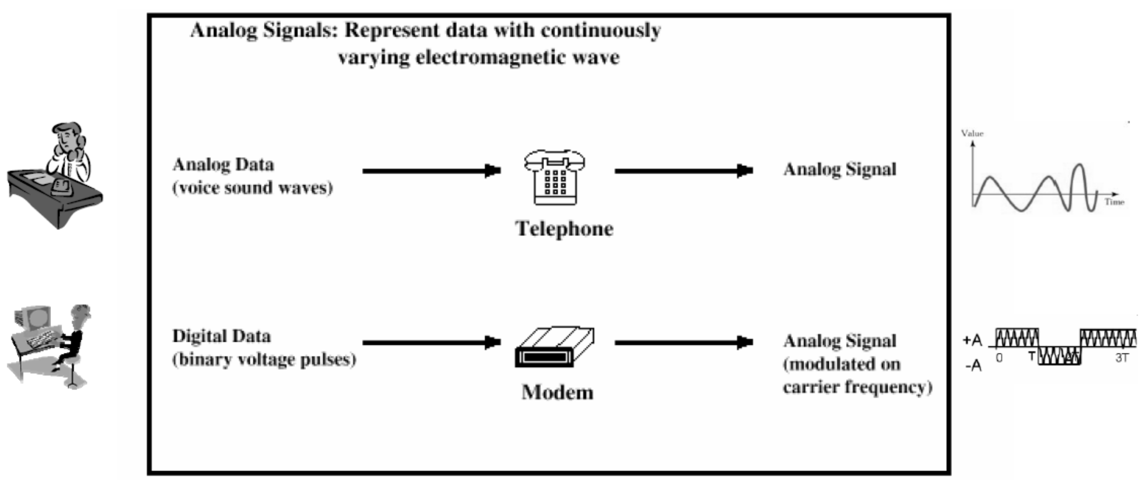
• **Digital data** – representation variable takes on discrete values, e.g. text, digitized images, etc.

Analog signal – signal that is continuous in time and can provide an infinite number of values in a given range (continuous in time and value).

Discrete (digital) signal – signal that is discrete in time and assumes only a limited number of values in a given range (discrete in time and value).



Both analog and digital data can be transmitted using either analog or digital signals.



In the natural world communication signals are generally analog for example:

–Hearing with sound waves.

–Sight with light waves.

In the manmade world communication signals are generally digital for example:

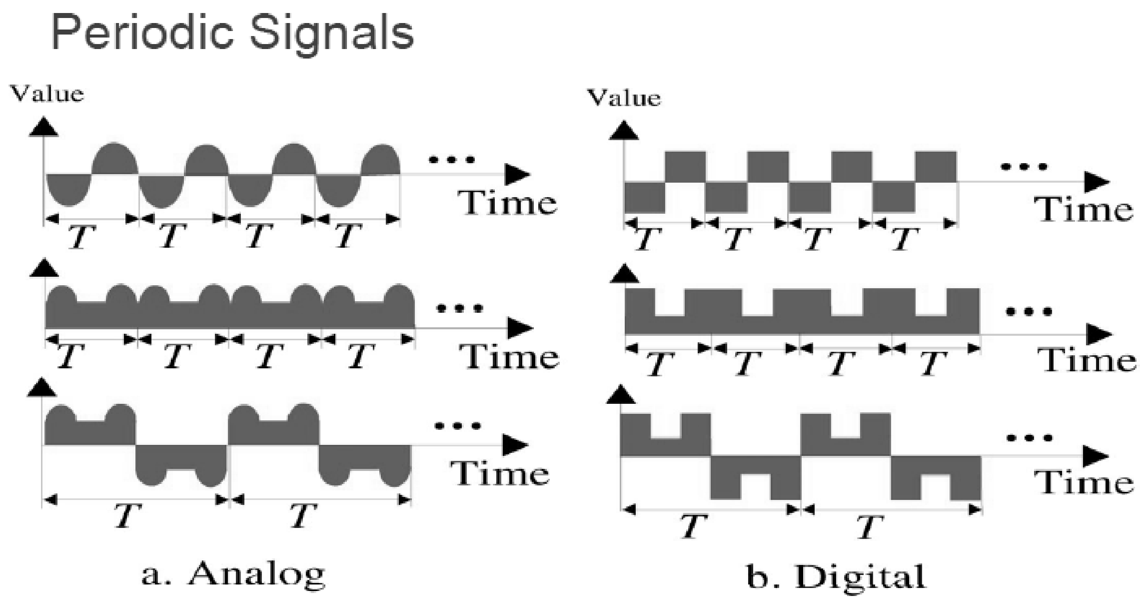
–Sound: telephone, radio, CD

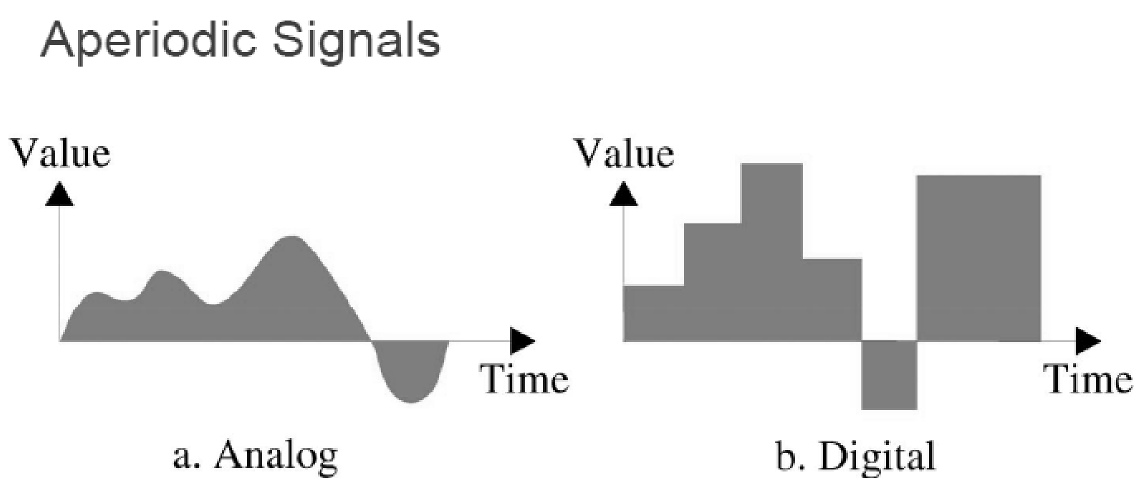
– Light: television, computer monitor.

Any information can be represented as an analog or a digital signal.

Periodic signal – completes a pattern within some measurable time frame, called a period, and then repeats that pattern over subsequent identical periods.

Aperiodic signal – changes without exhibiting a pattern that repeats over time.





Analog signals are those which are naturally occurring. Any analog signal can be converted to a digital signal. How?

Classification of Analog Signals:

1. **Simple Analog Signal** – cannot be decomposed into simpler signals

Sine wave – most fundamental form of periodic analog signal, mathematically described with 3 parameters:

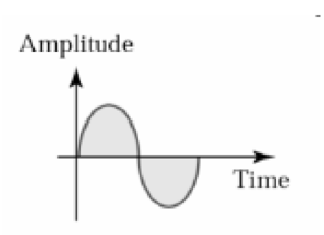
$$s(t) = A*\sin(2\pi ft + \phi)$$

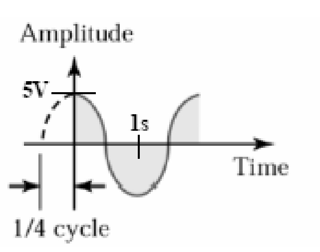
- **Peak amplitude (A)** – absolute value of signal's highest intensity.
  Unit: volts [V]
- **Frequency (f)** – number of periods in one second
  Unit: hertz [Hz] = [1/s] – inverse of period (T)!
- **Phase (φ)** – absolute position of the waveform relative to an arbitrary origin –
  Unit: degrees [º] or radians [rad].

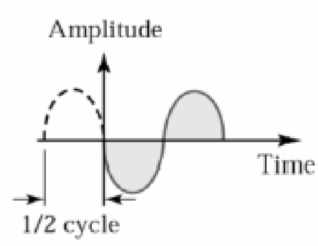
2. **Composite Analog Signal** – composed of multiple sine waves.

Phase in Simple Analog Signals – **measured in degrees or radians**

- **$360^o = 2\pi$ rad**
- **$1^o = 2\pi/360$ rad**
- **1 rad = $(360/2\pi)^o$** = 57.29578°
- **phase shift of 360^o = shift of 1 complete period**
- **phase shift of 180^o = shift of 1/2 period**
- **phase shift of 90^o = shift of 1/4 period**







φ = 0º or 360º

Example [period and frequency]

Unit	Equivalent	Unit	Equivalent
seconds (s)	1 s	hertz (Hz)	1 Hz
milliseconds (ms)	10^{-3} s	kilohertz (KHz)	10^{3} Hz
microseconds (μs)	10^{-6} s	megahertz (MHz)	10^{6} Hz
nanoseconds (ns)	10^{-9} s	gigahertz (GHz)	10^{9} Hz
picoseconds (ps)	10^{-12} s	terahertz (THz)	10^{12} Hz

units of period and respective frequency

(a) Express a period of 100 ms in microseconds.

100 ms = 100×10^{-3} s = $100 \times 10^{-3} \times 10^{6}$ μs = 10^{5} μs

(b) Express the corresponding frequency in kilohertz.

100 ms = 100×10^{-3} s = 10^{-1} s

$f = 1/10^{-1}$ Hz = 10×10^{-3} KHz = 10^{-2} KHz

Frequency in Simple Analog Signals:

Rate of signal change with respect to time

• Change in a short span of time ⇒ high freq.

• Change over a long span of time ⇒ low freq.

• Signal does not change at all ⇒ zero freq.

• Signal changes instantaneously ⇒ ∞ freq.

Digital Signals

Sequence of voltage pulses (DC levels) – each pulse represents a signal element.

• Binary data are transmitted using only 2 types of signal elements (1 = positive voltage, 0 = negative voltage)

• Key digital-signals terms:

 Bit interval – time required to send a single bit, unit: [sec].

 Bit rate – number of bit intervals per second – unit: [bps].