

## 1. Introduction

There is a significant interest in digital signal processing area with the rapid development in integrated-circuit technology.

Inexpensive and relatively fast digital circuit have made it possible to construct highly sophisticated digital systems capable of performing complex digital signal processing functions and task.

Some signals with extremely wide bandwidths or real-time processing requiring. Analog or optical signal processing is the only possible solution for such signals.

### Advantages:

- Digital circuits are cheaper and more reliable
- Digital processing hardware allows programmable operations, so be can easily modify and flexibility in system design.

## Signals, Systems, and Signal Processing

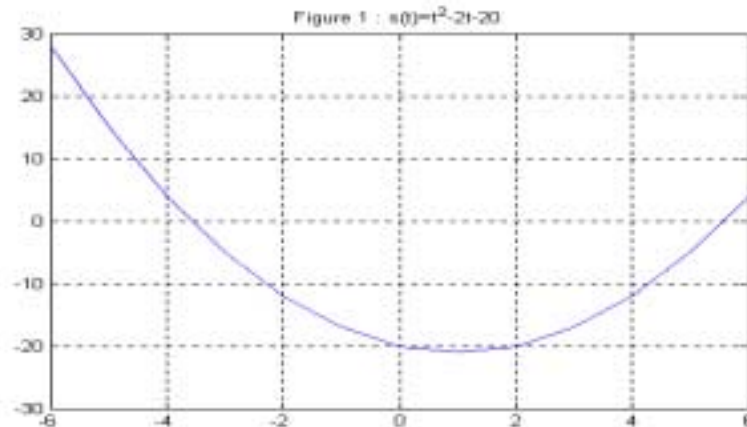
**A signal** is defined as any physical quantity that varies with time, space, or any other independent variable(s).

A signal as a function of one or more independent variables.

Example:

$$s(t) = t^2 - 2t - 20$$

where t is called independent variable (time) and s(t) is dependent variable.

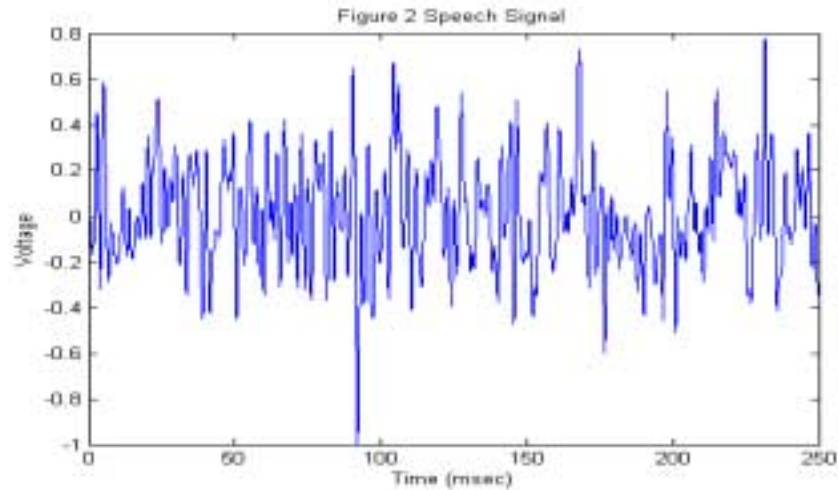


```
>> x=-6:6;  
>> y=x.^2-2*x-20;  
>> plot(x,y)  
>> grid on  
>> title('Figure 1 :  
s(t)=t^2-2t-20')
```

There are some signals that functional relationships are unknown or too complicated. Such a *speech signal*. It may be represented to a high degree of accuracy as a sum of several sinusoidal of different amplitudes and frequencies.

$$\sum_{i=1}^N A_i(t) \sin [2\pi f_i(t)t + \theta_i(t)]$$

where  $A_i(t)$ ,  $f_i(t)$ , and  $\theta_i(t)$  are the set of amplitude, frequencies, and phases.



An example of a signal with two independent variables is an image signal.

$$I(x, y)$$



A system can be defined as a physical device that performs an operation on a signal.

Example:

A filter is used to perform some operation(s) on the signal to reduce the noise and interface corruption from the desired information-bearing signal.

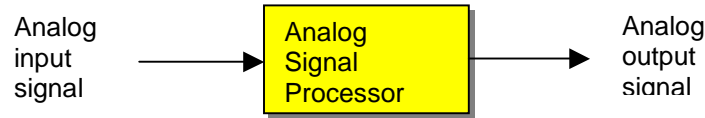
Such operations are usually referred to as signal processing.

- If the operation on the signal is linear, the system is called linear.
- If the operation on the signal is nonlinear, the system is called nonlinear

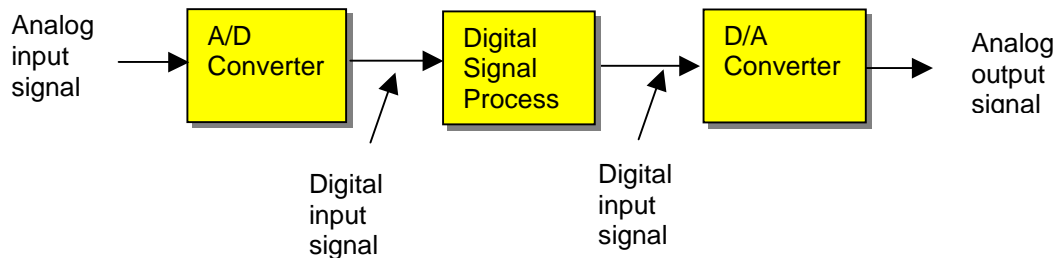
The digital signal processing on the signal may be performed by a digital hardware, a software program, or a combination of digital hardware and software with each of performs its own set of specified operations.

## Basic Elements of a Digital Signal Processing

Most of the cases signals are analog in nature. It may be processed directly by appropriate analog system



An analog signal may be processed by digital signal processor using interface between the analog signal and the digital processor. This interface is called an *analog-to-digital (A/D) converter*. An other interface may be required after the processing to convert from digital signal to the analog signal, which is called a *digital-to-analog (D/A) converter*.



## Advantages of Digital over Analog Signal Processing

- A digital programmable system allows flexibility in reconfiguring the digital signal processing operations simply by changing the program
- Reconfiguration of an analog system requires redesign of hardware.
- Digital signal processor provides much better control of accuracy requirements. Accuracy requirement in the A/D Converting.
- Tolerance in analog circuit components make it extremely difficult for the system designer to control the accuracy of an analog processing system
- Digital signals are easily stored on magnetic media without distortion or loss of signal fidelity.
- Analog signal may lose signal quality.
- Digital signal processing can allow more sophisticated signal processing algorithms.
- It is difficult to perform precise mathematical operations on signals in analog operations
- In some cases a digital implementation of the signal processing system is cheaper than analog implementation.

Some examples of digital signal processing are:

- The application of digital signal processing techniques in speech processing and signal transmission on digital telephone channels

- Image processing and transmission in seismology and geophysics, in oil exploration, in the detection systems

## Signal Types

The different types of signals:

Simple Signals - Single Channel – One Dimensional

- Analog Signal
- Discrete Signal
- Digital Signal

Higher Order Signals

- Single Channel and Multidimensional Signals
- Multi Channel and Single Dimensional Signals
- Multi Channel and Multidimensional Signals

The value of the signal can be a real-valued scalar quantity,

$$s_1(t) = A \sin 4\pi t$$

A complex-valued quantity

$$s_2(t) = Ae^{j4\pi t} = A \cos 4\pi t + jA \sin 4\pi t$$

Or vector form

$$S_3(t) = \begin{bmatrix} s_1(t) \\ s_2(t) \\ s_3(t) \end{bmatrix}$$

A vector form signal is referred as a multi-channel signal.

An example of 3-leads electrocardiogram (ECG).

- If the signal is a function of a single independent variable, the signal is called a one-dimensional signal
- On the other hand, a signal is called M-dimensional if its value is a function of M independent variables.

An example of a two-dimensional signal is a picture. The intensity of brightness at each point is

$$I(x, y).$$

For a black-and-white TV picture may be treated as a three-dimensional signal.

$$I_b(x, y, t)$$

A color TV picture may be described by three intensity function of the form by the vector

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