Digital Signal Processing - Fundamentals

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- We are all immersed in a sea of signals. All of us from the smallest living unit, a cell, to the most complex living organism (humans), receive signals all the time and continue to process them. Survival of any living organism depends upon its ability to process the signals appropriately.

What is a Signal?

- *Anything which carries information is a signal.* e.g. human voice, chirping of birds, smoke signals, gestures (sign language), fragrances of the flowers.

- Many of our body functions are regulated by chemical signals, blind people use sense of touch. Bees communicate by their dancing pattern.

- Modern high speed signals are: voltage changer in a telephone wire, the electromagnetic field emanating from a transmitting antenna, variation of light intensity in an optical fiber.

- Thus we see that there is an almost endless variety of signals and a large number of ways in which signals are carried from on place to another place.

Signals: The Mathematical Way

- **A signal is a real (or complex) valued function of one or more real variables**. When the function depends on a single variable, the signal is said to be one-dimensional and when the function depends on two or more variables, the signal is said to be multidimensional.

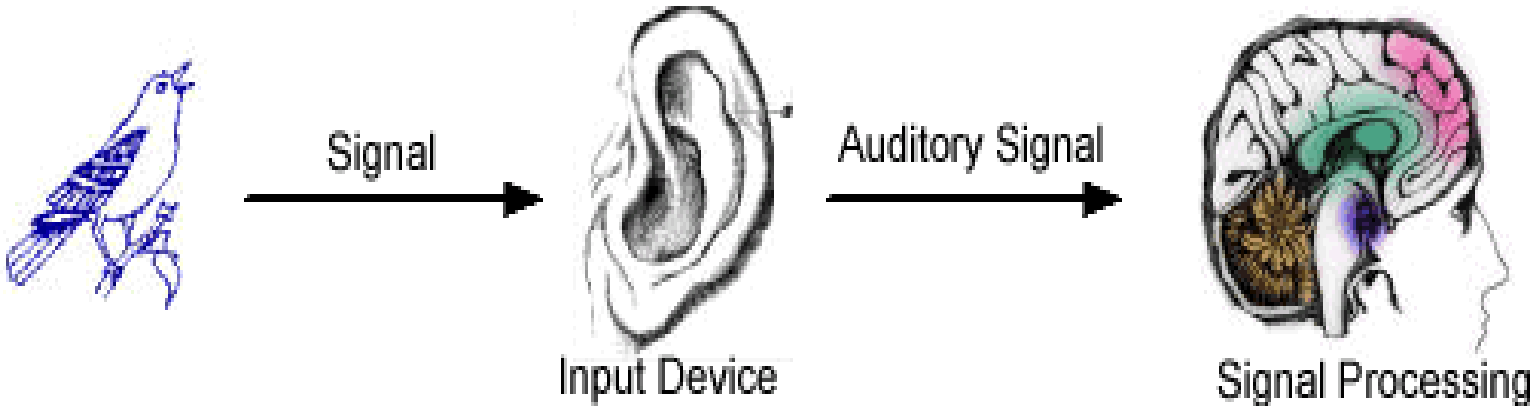
- **Examples of a 1-D signal:** A speech signal, daily maximum temperature, annual rainfall at a place.

- **Example for 2-D signal:** An image is a two dimensional signal, vertical and horizontal coordinates representing the two dimensions.

- **Four Dimensions:** Our physical world is four dimensional (three spatial and one temporal).

What is Signal processing?

- Processing means operating in some fashion on a signal to extract some useful information e.g. we use our ears as input device and then auditory pathways in the brain to extract the information. The signal is processed by a **system**. In the example mentioned above the system is biological in nature.



The signal processor may be an electronic system, a mechanical system or even it might be a computer program.

Analog versus digital signal processing

- The signal processing operations involved in many applications like communication systems, control systems, instrumentation, biomedical signal processing etc. can be implemented in two different ways

  - Analog or continuous time method
  - Digital or discrete time method..

Analog signal processing

- Uses analog circuit elements such as resistors, capacitors, transistors, diodes etc
  - Based on natural ability of the analog system to solve differential equations that describe a physical system
  - The solutions are obtained in real time...

Digital signal processing

- The word digital in digital signal processing means that the processing is done either by a digital hardware or by a digital computer.
  - Relies on numerical calculations
  - The method may or may not give results in real time..

Comparison of DSP over ASP

Advantages

- Developed Using Software on Computer
- Working Extremely Stable
- Easily Modified in Real Time
- Low Cost and Portable

Disdvantages

- Lower Speed and Lower Frequency

Advantages of digital approach over analog approach

Flexibility: Same hardware can be used to do various kind of signal processing operation, while in the case of analog signal processing one has to design a system for each kind of operation

Repeatability: The same signal processing operation can be repeated again and again giving same results, while in analog systems there may be parameter variation due to change in temperature or supply voltage.

- The choice of choosing between analog or digital signal processing depends on the application. One has to compare design time, size and the cost of the implementation.

Classification of signals

We use the term signal to mean a real or complex valued function of real variables and denote the signal by x(t). The variable t is called independent variable and the value x of t as dependent variable.

When t takes a vales in a countable set the signal is called a discrete time signal. For example

$$t \in \{0, T, 2T, 3T, 4T,...\}$$

$$t \in \{....-1, 0 ,1,...\}$$

$$t \in \{1/2, 3/2, 5/2, 7/2,...\}$$

- For convenience of presentation we use the notation x[n] to denote discrete time signal. When both the dependent and independent variables take values in countable sets (two sets can be quite different) the signal is called **Digital Signal.**

- When both the dependent and independent variable take value in continuous set interval, the signal is called an **Analog Signal**.

- **Notation:** When we write x(t) it has two meanings. One is value of x at time t and the other is the pairs (x(t), t) allowable value of t.

- **Notation for continous time signal**: {x(t)} denotes the continuous time signal. Here {x(t)} is short notation for {x(t), t ε I} where I is the set in which t takes the value.

- **Notation for discrete time signal**: Similarly for discrete time signal we will use the notation {x(n)}, where {x(n)} is short notation for {x(n), n ε I }.

- Note that in {x(t)} and {x[n]} are dummy variables. Some books use the notation x [.] to denote {x[n]} and x[n] to denote value of x at time n.

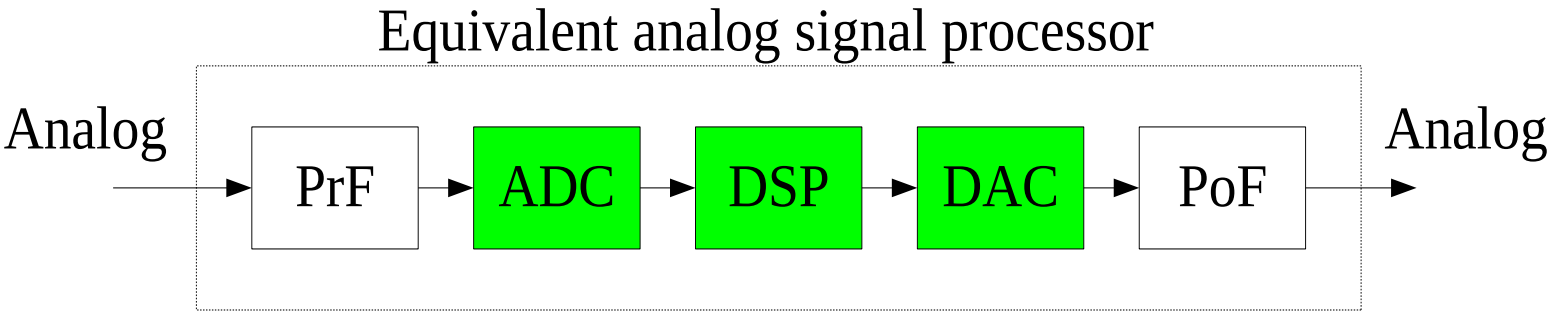
- **{x(t)} refers to the whole waveform, while x[n] refers to a particular value.**
  - Most of the books do not make this distinction clean and use x[n] to denote signal and x[n0] to denote a particular value.

Discrete Time Signal Processing and Digital Signal Processing

- When we use digital computers to do processing we are doing digital signal processing. But most of the theory is for discrete time signal processing where dependent variable generally is continuous. This is because of the mathematical simplicity of discrete time signal processing.

- Digital Signal Processing tries to implement this as closely as possible. Thus what we study is mostly discrete time signal processing and what is really implemented is digital signal processing.

Block Diagram of DSP



PrF: antialiasing filtering

PoF: smooth out the staircase waveform