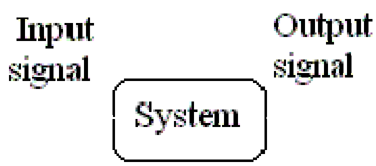
Introducton of signals and systems

First of all we will try to look into the formal definitions of the terms '**signals**' and '**systems**' and then go on further to introduce to you some simple examples which may be better understood when seen from a signals and systems perspective.

Signals are functions of one or more variables .

Systems respond to an input signal by producing an output signal .



1.**A voltagesignal:** voltage across two points varying as a function of time.
2.**A force pattern:** force varying as a function of 2-dimensional space.
3. **A photograph***:* color and intensity as a function of 2-dimensional space.
4 . **A video signal:** color and intensity as a function of 2-dimensional space and time.

Examples of systems include :

1. **An oscilloscope:** takes in a voltage signal, outputs a 2-dimensional image characteristic of the voltage signal.
2. **A computer monitor:** inputs voltage pulses from the CPU and outputs a time varying display.
3. **An accelerating mass :** force as a function of time may be looked at as the input signal, and velocity as a function of time as the output signal.
4. **A capacitance:** terminal voltage signal may be looked at as the input, current signal as the output.

Examples of mechanical and electrical systems

You are surely familiar with many of these signals and systems and have probably analyzed them as well, but in isolation . For instance, you must have studied accelerating masses in a mechanics course (see Fig (a)), and capacitances in an electrostatic course (see Fig (b)), separately.

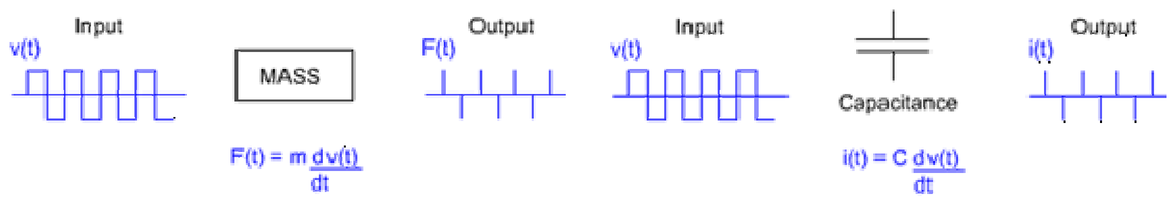


Figure 4.1

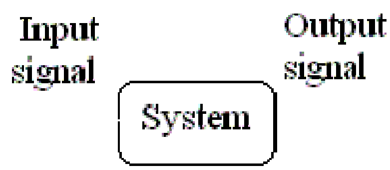
As you can see, there is a similarity in the way the input signal is related to the output signal. These similarities will interest us in this course as we may be able to make inferences common to both these systems from these similarities.

We will develop very general tools and techniques of analyzing systems, independent of the actual context of their use. Our approach in this course would be to define certain properties of signals and systems (inspired of course by properties real-life examples we have), and then link these properties to consequences. These "links" can then be used directly in connection with a large variety of systems: electrical, mechanical, chemical, biological… knowing only how the input and output signal are related! Thus, our focus when dealing with signals and systems will be on the relationship between the input and output signal and not really on the internals of the system.

Issues that will concern us in signals and systems include

1. Characterization (description of behavior) of systems and signals.
2. Design of systems with certain desired properties.
3. Modification of existing systems to our advantage.

A signal was defined as a mapping from a set of the independent variable (domain) to the set of the dependent variable (co-domain). **A system is also a mapping, but across signals, or across mappings** . That is, the domain set and the co-domain set for a system are both sets of signals, and corresponding to each signal in the domain set, there exists a unique signal in the co-domain set.



In **signals and systems** terminology, we say; **corresponding to every possible input signal, a system "produces" an output signal.**

In that sense, realize that a system, as a mapping is one step hierarchically higher than a signal. While the correspondence for a signal is from one element of one set to a unique element of another, the correspondence for a system is from one whole mapping from a set of mappings to a unique mapping in another set of mappings!

Examples of systems

Examples of systems are all around us. The speakers that go with your computer can be looked at as systems whose input is voltage pulses from the CPU and output is music (audio signal). A spring may be looked as a system with the input , say, the longitudinal force on it as a function of time, and output signal being its elongation as a function of time. The independent variable for the input and output signal of a system need not even be the same.

In fact, it is even possible for the input signal to be continuous-time and the output signal to be discrete-time or vice-versa. For example, our speech is a continuous-time signal, while a digital recording of it is a discrete-time signal! The system that converts any one to the other is an example of this class of systems.

As these examples may have made evident, we look at many physical objects/devices as systems, **by identifying some variation associated with them as the input signal and some other variation associated with them as the output signal** (the relationship between these, that essentially defines the system depends on the laws or rules that govern the system) . Thus a capacitance with voltage (as a function of time) considered as the input signal and current considered as the output signal is not the same system as a capacitance with, say charge considered as the input signal and voltage considered as the output signal. Why?

The mappings that define the system are different in these two cases.

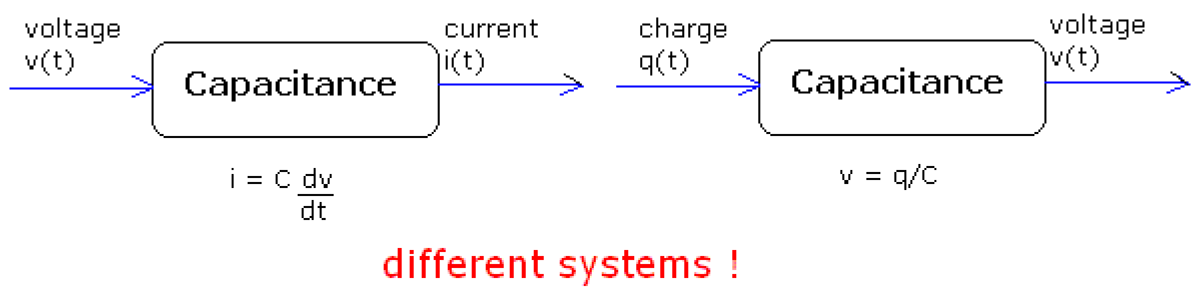


Figure 4.2

The system description specifies the transformation of the input signal to the output signal. In certain cases, a system has a closed form description. E.g. the continuous-time system with description $\mathbf{y(t) = x(t) + x(t-1)}$; where $\mathbf{x(t)}$ is the input signal and $\mathbf{y(t)}$ is the output signal. Not all systems have such a closed form description. Just as certain "pathological" functions can only be specified by tabulating the value of the dependent variable against all values of the independent variable; some systems can only be described by tabulating the output signal against all possible input signals.

Explicit and Implicit Description

When a closed form system description is provided, it may either be classified as an **explicit** description or an **implicit** one. For an **explicit** description, it is possible to express the output at a point, purely in terms of the input signal. Hence, when the input is known, it is easily possible to find the output of the system, when the system description is Explicit. In case of an Explicit description, it is clear to see the relationship between the input and the output.

e.g. $\mathbf{y(t) = \{ x(t) \}^{2} + x(t-5)}$.

In case the system has an **Implicit** description, it is harder to see the input-output relationship. An example of an Implicit description is $\mathbf{y(t) - y(t-1)\, x(t) = 1}$. So when the input is provided, we are not directly able to calculate the output at that instant (since, the output at 't-1' also needs to be known). Although in this case also, there are methods to obtain the output based solely on the input, or, to convert this implicit description into an explicit one. The description by itself however is in the implicit form. With this introduction, let us go on to formally defining signals and systems.

Signals are functions of one or more independent variables.
Systems are physical models which gives out an output signal in response to an input signals.
Trying to identify real-life examples as models of signals and systems, would help us in understanding the subject better