BGS INSTITUTE OF TECHNOLOGY

Signals & System basic concepts

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- **Signal:**

  A signal is defined as a function of one or more variables which conveys information on the nature of a physical phenomenon. The value of the function can be a real valued scalar quantity, a complex valued quantity, or perhaps a vector.

- **System:**

  A system is defined as an entity that manipulates one or more signals to accomplish a function, thereby yielding new signals.

- **Continuos-Time Signal:**

  A signal x(t) is said to be a continuous time signal if it is defined for all time t.

- **Discrete-Time Signal:**

  A discrete time signal x[nT] has values specified only at discrete points in time.

- **Signal Processing:**

  A system characterized by the type of operation that it performs on the signal. For example, if the operation is linear, the system is called linear. If the operation is non-linear, the system is said to be non-linear, and so forth. Such operations are usually referred to as "Signal Processing".

Classification of Signals

•Deterministic Signals

A deterministic signal behaves in a fixed known way with respect to time. Thus, it can be modeled by a known function of time t for continuous time signals, or a known function of a sampler number n, and sampling spacing T for discrete time signals.

• Random or Stochastic Signals:

In many practical situations, there are signals that either cannot be described to any reasonable degree of accuracy by explicit mathematical formulas, or such a description is too complicated to be of any practical use. The lack of such a relationship implies that such signals evolve in time in an unpredictable manner. We refer to these signals as random.

Even and Odd Signals

A continuous time signal x(t) is said to an even signal if it satisfies the condition

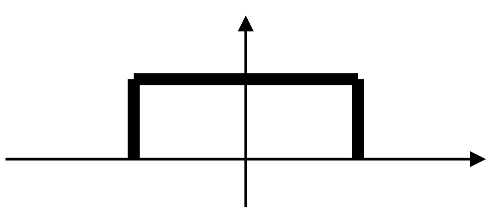
$x(-t) = x(t)$ for all t

The signal x(t) is said to be an odd signal if it satisfies the condition

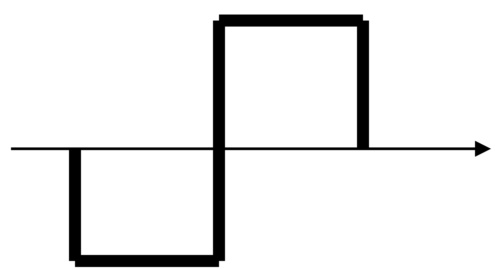
$x(-t) = -x(t)$

In other words, even signals are symmetric about the vertical axis or time origin, whereas odd signals are antisymmetric about the time origin. Similar remarks apply to discrete-time signals.

Example:



even



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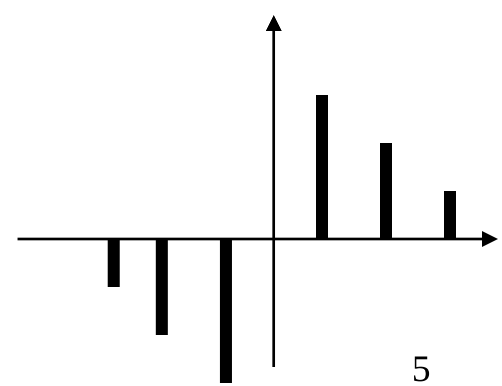


odd

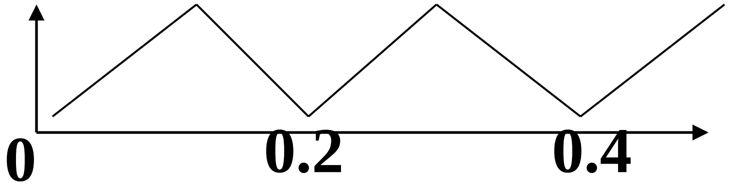
Periodic Signals

A continuous signal x(t) is periodic if and only if there exists a T > 0 such that
$x(t + T) = x(t)$
where T is the period of the signal in units of time.

$f = 1/T$ is the frequency of the signal in Hz. $W = 2\pi/T$ is the angular frequency in radians per second.

The discrete time signal x[nT] is periodic if and only if there exists an N > 0 such that
$x[nT + N] = x[nT]$
where N is the period of the signal in number of sample spacings.

Example:



Frequency = 5 Hz or 10π rad/s

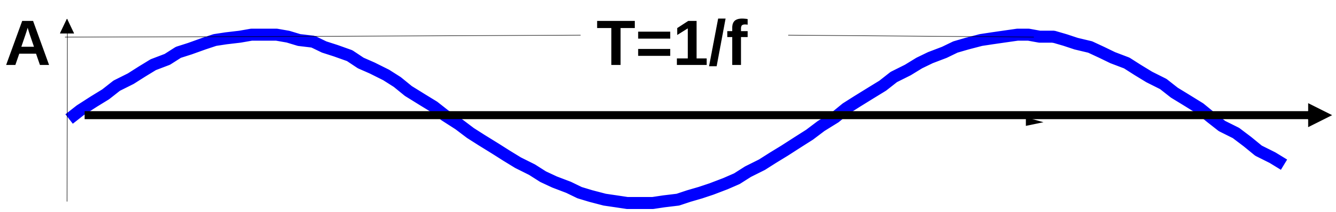
Continuous Time Sinusoidal Signals

A simple harmonic oscillation is mathematically described as

$x(t) = A\cos(wt + \theta)$

This signal is completely characterized by three parameters:

A = amplitude, $w = 2\pi f$ = frequency in rad/s, and θ = phase in radians.



Discrete Time Sinusoidal Signals

A discrete time sinusoidal signal may be expressed as

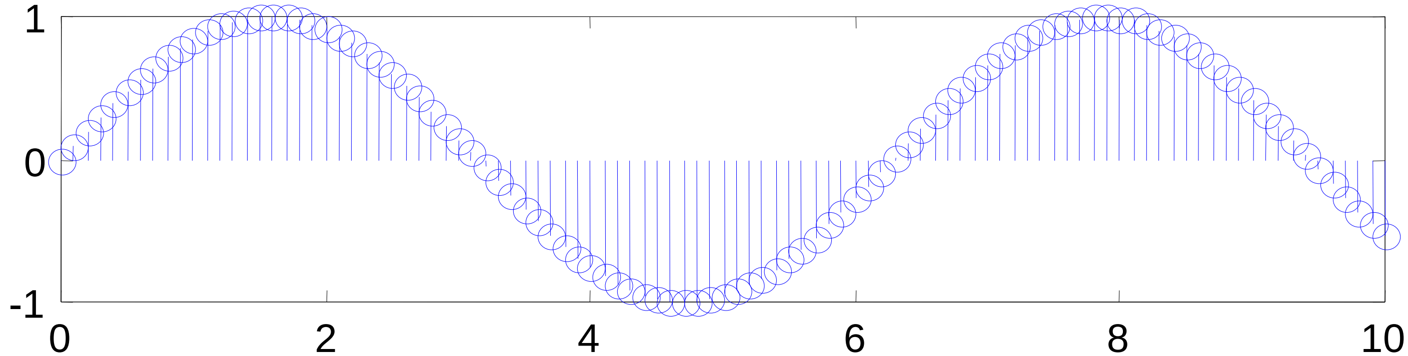
$x[n] = A\cos(wn + \theta)$ $\quad -\infty < n < \infty$

Properties:

- A discrete time sinusoid is periodic only if its frequency is a rational number.

- Discrete time sinusoids whose frequencies are separated by an integer multiple of 2π are identical.

- The highest rate of oscillation in a discrete time sinusoid is attained when $w = \pi$ (or $w = -\pi$), or equivalently $f = 1/2$ (or $f = -1/2$).



Energy and Power Signals

- **A signal is referred to as an energy signal, if and only if the total energy of the signal satisfies the condition**
  $0 < E < \infty$

- **On the other hand, it is referred to as a power signal, if and only if the average power of the signal satisfies the condition**
  $0 < P < \infty$

- **An energy signal has zero average power, whereas a power signal has infinite energy.**

- **Periodic signals and random signals are usually viewed as power signals, whereas signals that are both deterministic and non-periodic are energy signals.**

Basic Operations on Signals

(a) Operations performed on dependent variables

1. Amplitude Scaling:

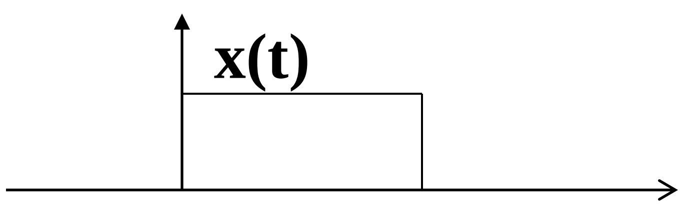
let x(t) denote a continuous time signal. The signal y(t) resulting from amplitude scaling applied to x(t) is defined by

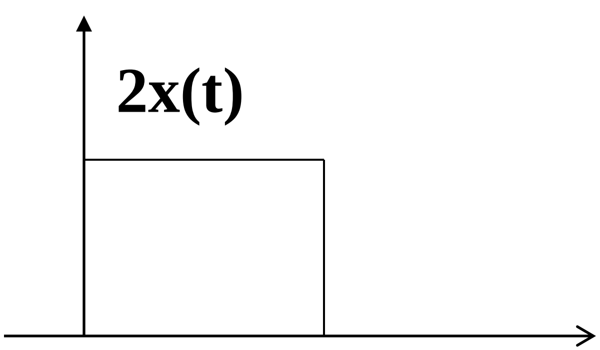
$$y(t) = cx(t)$$

where c is the scale factor.

In a similar manner to the above equation, for discrete time signals we write

$$y[nT] = cx[nT]$$





2. Addition:

Let x_1 [n] and x_2[n] denote a pair of discrete time signals. The signal y[n] obtained by the addition of x_1[n] + x_2[n] is defined as

$y[n] = x_1[n] + x_2[n]$

Example: audio mixer

3. Multiplication:

Let x_1[n] and x_2[n] denote a pair of discrete-time signals. The signal y[n] resulting from the multiplication of the x_1[n] and x_2[n] is defined by

$y[n] = x_1[n].x_2[n]$

Example: AM Radio Signal

(b) Operations performed on independent variable

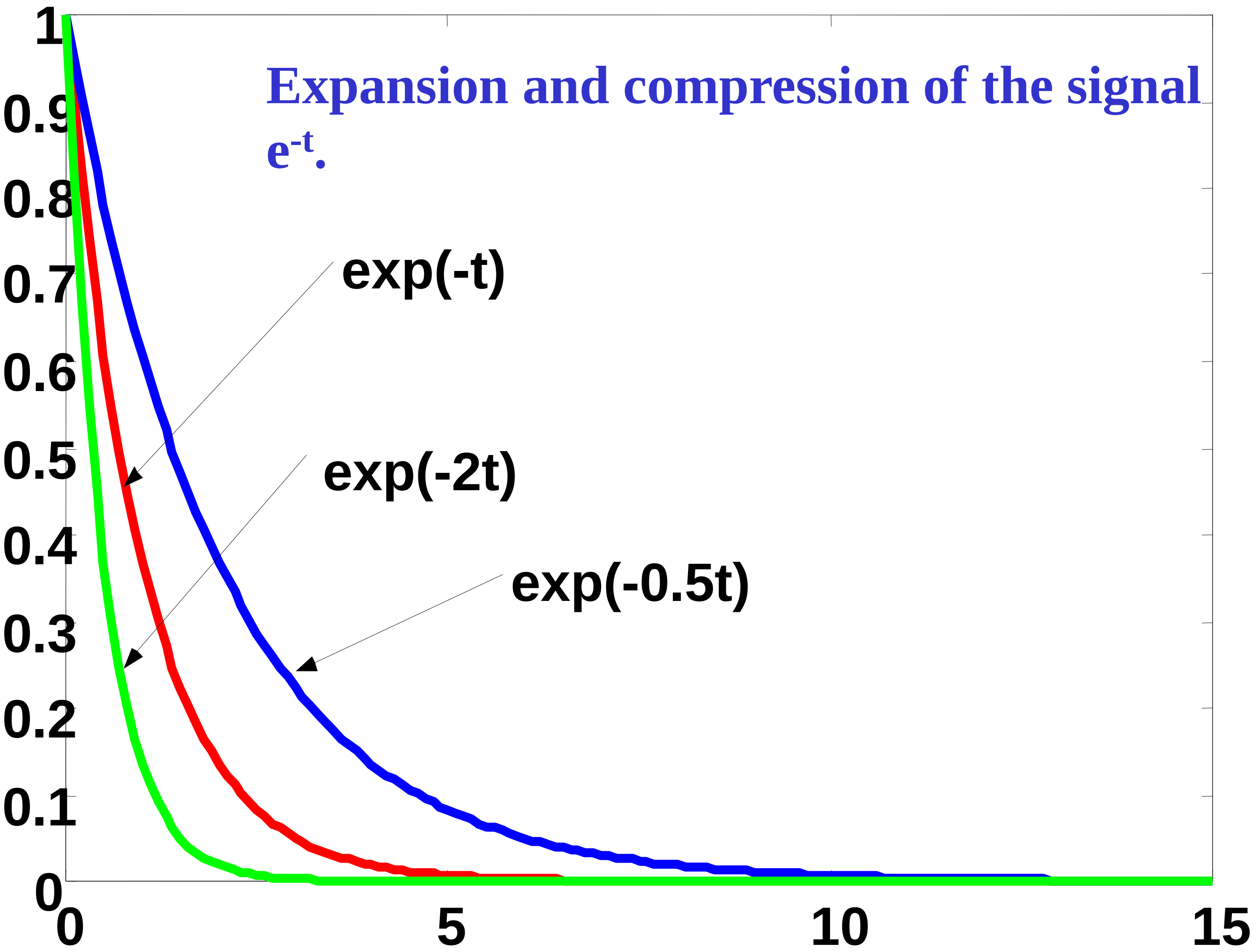
- **Time Scaling:**

  Let y(t) is a compressed version of x(t). The signal y(t) obtained by scaling the independent variable, time t, by a factor k is defined by

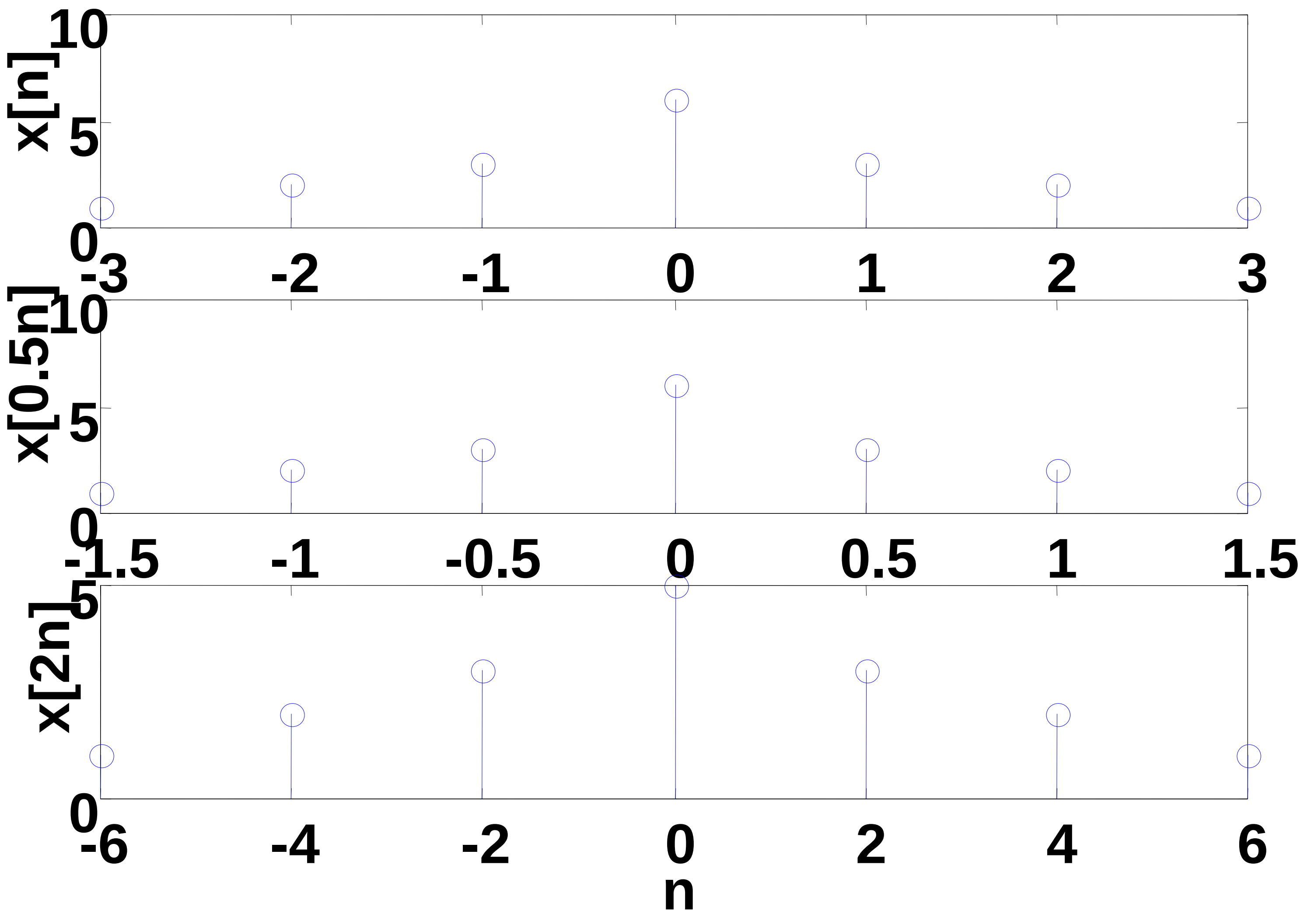
  $y(t) = x(kt)$

  - if $k > 1$, the signal y(t) is a compressed version of x(t).
  - If, on the other hand, $0 < k < 1$, the signal y(t) is an expanded (stretched) version of x(t).

Example of time scaling

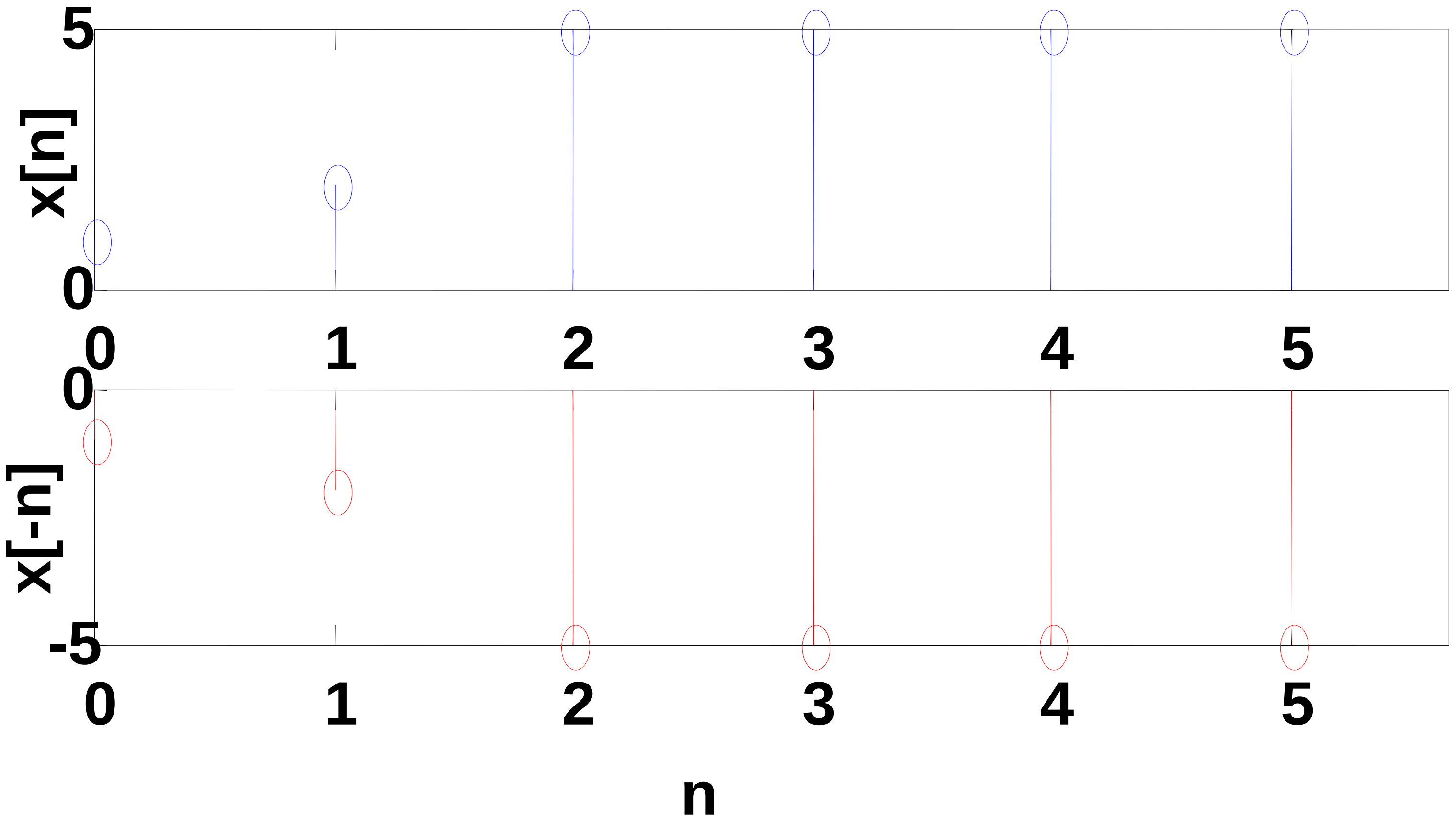


Time scaling of discrete time systems



Time Reversal

- This operation reflects the signal about t = 0 and thus reverses the signal on the time scale.



Time Shift

A signal may be shifted in time by replacing the independent variable n by n-k, where k is an integer. If k is a positive integer, the time shift results in a delay of the signal by k units of time. If k is a negative integer, the time shift results in an advance of the signal by |k| units in time.