Signal & Systems
Lecture #1

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Course Assessment

- Total assessment 100 %
  - Midterm : 30%
  - Final Exam : 50%
  - Internal Evaluation : 20%
- Internal Evaluation 20%
  - Quizzes : 10%
  - Assignment : 10%

Internal Evaluation Details

- Total Quizzes 5 — Total Assignments 5

  Best of 4 Quizzes — Best of 4 Assignments

- Semester Project will be conducted in the form of groups.
  - Evaluation will be equal to 1 quiz and 1 assignment

  Total 5 Quizzes — Total 5 Assignments

Course Book

- Signal & Systems, By Alan V. Oppenheim, Alan S. Willsky with S.Hamid Nawab

Introduction

What is a Signal?

- If a function represents a physical quantity or variable containing information about the behavior and nature of the phenomenon.
- Signals are functions of one or more variables.

Examples of Signals

- Examples of signals include:
  - **A Voltage signal**: voltage across two points varying as a function of time.
  - **A photograph**: color and intensity as a function of 2-dimensional space.
  - **A Video Signal**: color an intensity as a function of 2-dimensional space and time.

What is a System?

- Systems are operator that accept a given signal (the input) and produces a new signal (the output).
- Systems respond to an input signal by producing an output signal.

Examples of Systems

- Examples of system includes:
  - **An Oscilloscope:** takes in a voltage signal, outputs a 2-dimensional image characteristic of the voltage signal.
  - **A computer monitor:** inputs voltage pulses from the CPU and outputs a time varying display.
  - **A capacitance:** terminal voltage signal may be looked at as the input, current signal as the output.

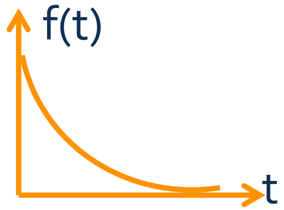
Classification of Signals

Classification

- Two main broad classification of signals are:
  - Continuous time signal
  - Discrete time signal

Continuous Time Signals

- Is is an infinite and uncountable set of numbers.
- There are infinite possible values from the time t and instantaneous amplitude x(t) between start and end point.
- If a signal at all values of t is a countinous variable:

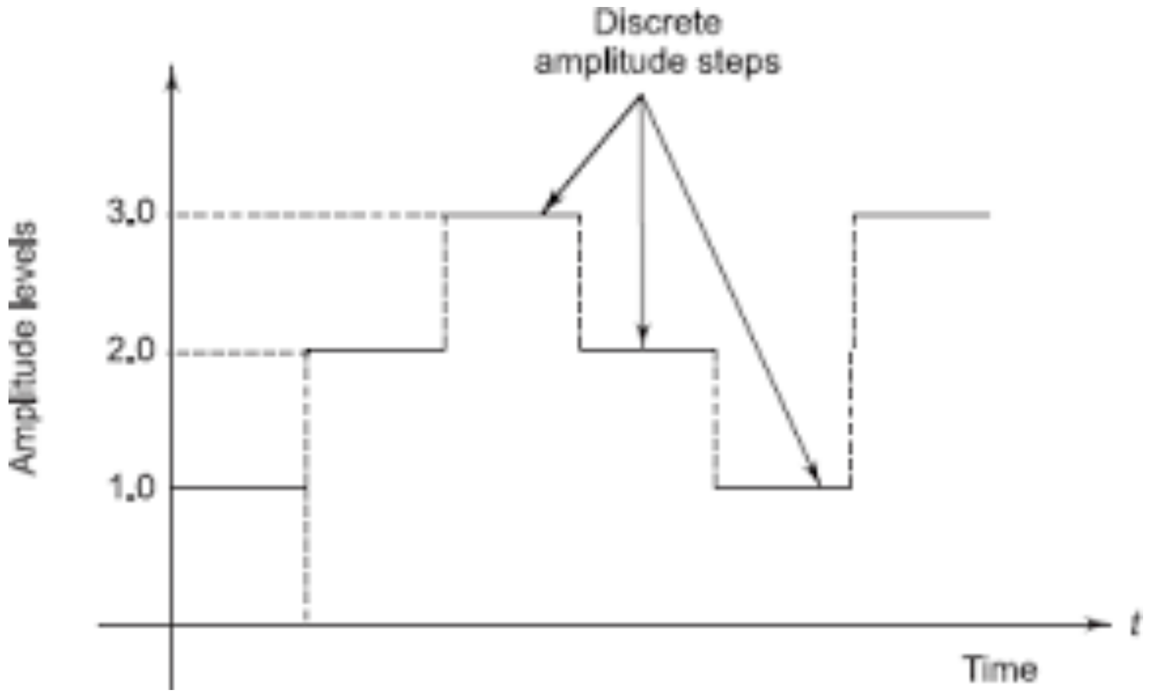


Exponential Function

- This signal is continuous in time as well as in amplitude.
  - Another example is Sinusoidal Signal.

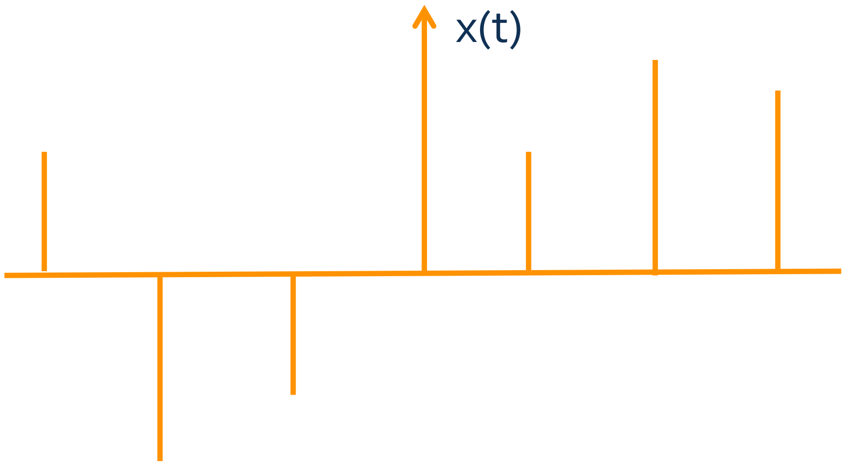
Continuous Time Signals (cont.)

- The signal shown below is continuous in time but discrete in amplitude.



Discrete Time Signals

- The number of elements in the set as well as possible values of each element is finite and countable.
- It can be represented with computer bits and stored on a digital storage medium.



Basic Operations

Elementary Operations on Signals

- There are several basic operation by which new signals are formed from given signals:
  - Amplitude Scale: $y(t) = ax(t)$, where a is a real (or possibly complex) constant.
  - Amplitude Shift: $y(t) = x(t) + b$, where b is a real = (or possibly complex) constant
  - Addition: $y(t) = x(t) + z(t)$
  - Multiplication: $y(t) = x(t)z(t)$

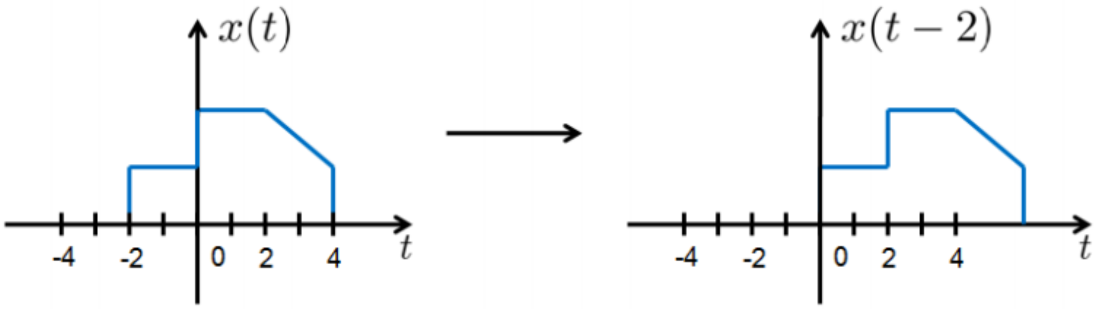
Time Shift

- For any $t_0 \in R$ and $n_0 \in Z$ time shift is an operation defined as:

$$x(t) \rightarrow x(t - t_0)$$

$$x[n] \rightarrow x[n - n_0]$$

- If $t_o > 0$, the time shift is known as "delay".
- If $t_o < 0$, the time shift is known as "advance".
- For example:



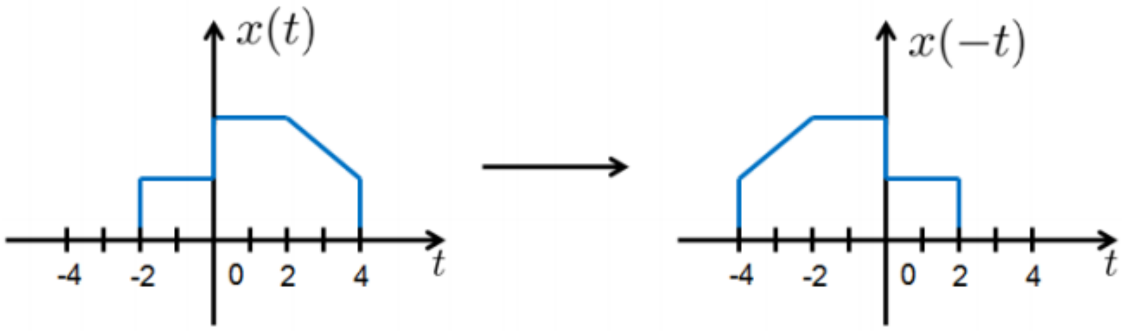
Time Reversal

- Time reversal if defined as:

$$x(t) \rightarrow x(-t)$$

$$x[n] \rightarrow x[-n]$$

- Which can be interpreted as the “flip over the y-axis”.
- For example:

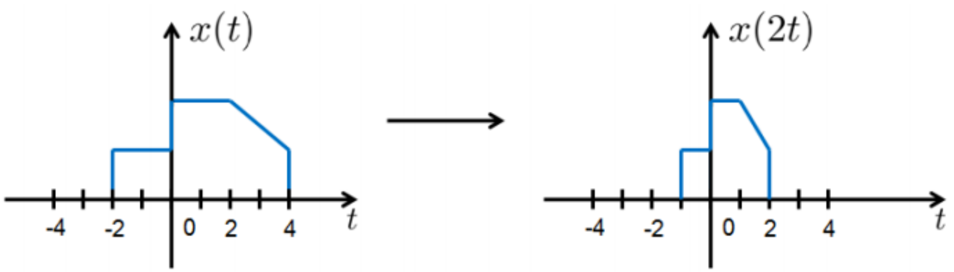


Time Scaling

- Time scaling is the operation where the time variable t is multiplied by a constant a:

$$x(t) \rightarrow x(at), \quad a > 0$$

- If a > 1, the time scale of the resultant signal is "decimated" (speed up).
- If 0 < a < 1, the time scale of the resultant signal is "expanded" (slowed down).
- For example:



Combination of Operations

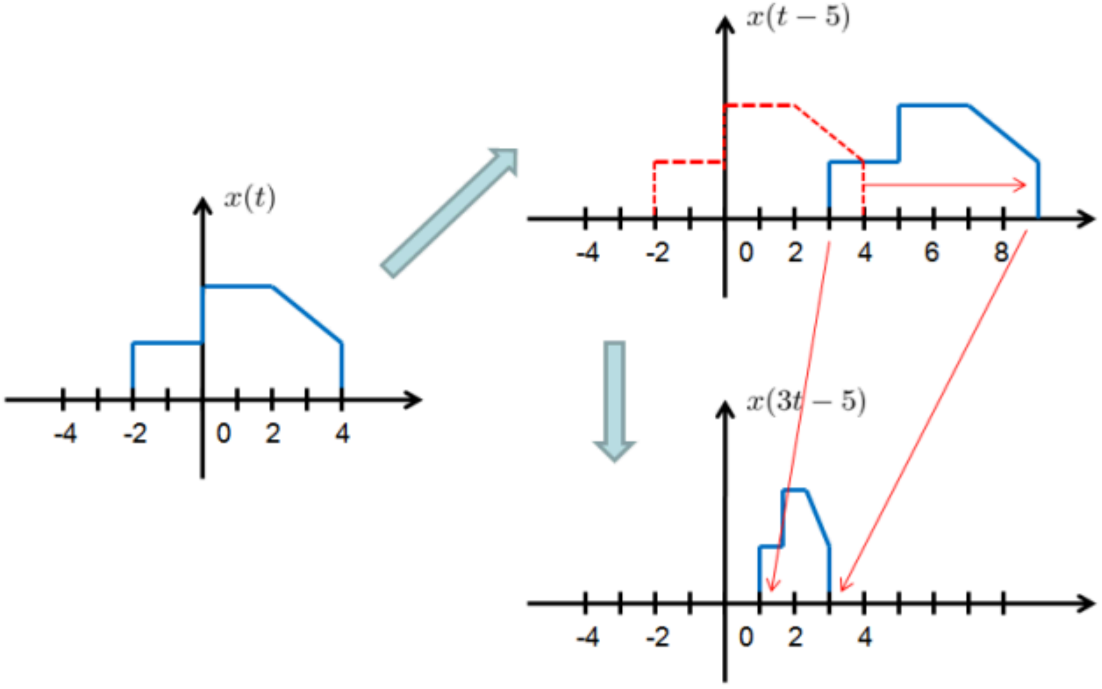
- Linear operation in time on a signal x(t) can be expressed as:

$$y(t) = x(at - b), \quad a, b \in R$$

- There are two methods to describe the output signal:
  - Method A: “shift, then scale”
    - Define v(t)= x(t-b)
    - Define y(t) = v(at) = x(at-b)
  - Method B: “Scale, then shift”
    - Define v(t) = x(at)
    - Define y(t) = x(t-b/a) = x(at-b)

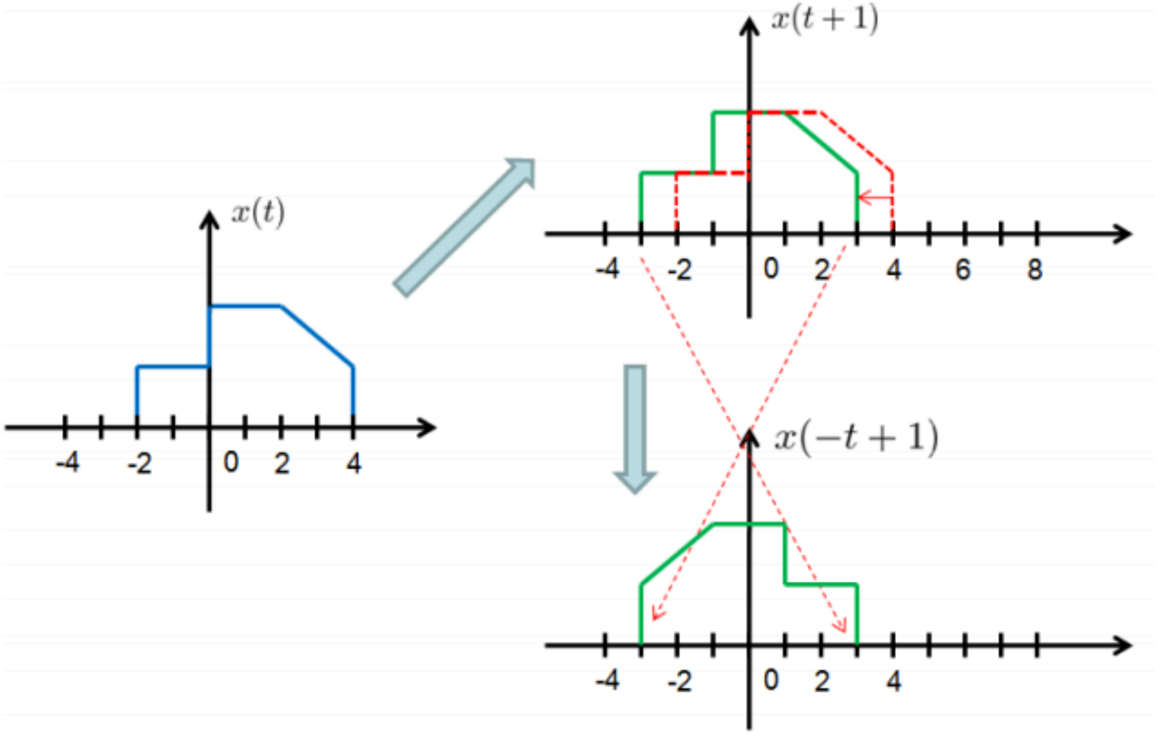
Combination of Operations (cont.)

- Example 1:



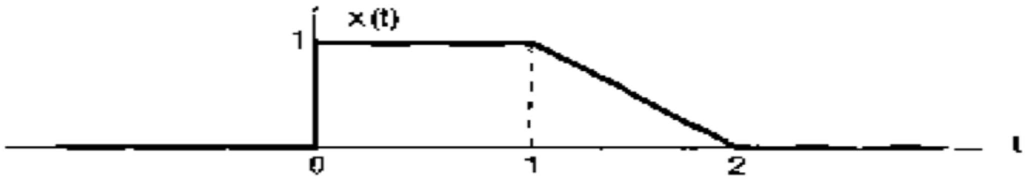
Combination of Operations (cont.)

- Example 2:



Example #1

- Given the signal x(t) as shown below:



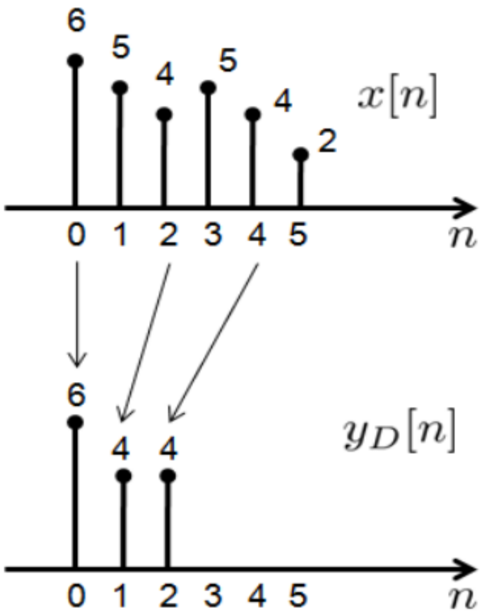
(a)

- (a): Draw the signal x(t+1)
- (b): Draw the signal x(-t+1) obtained by a time shift and a time reversal.
- (c): Draw the time scaled signal x(3/2t)
- (d): Draw the signal x (3/2t+1) obtained by a time shift and scaling.

Decimation & Expansion

Decimation

- Decimation is defined as: $y_D[n] = x[Mn]$
- For some integers M. M is called the decimation factor.
- When M=2.

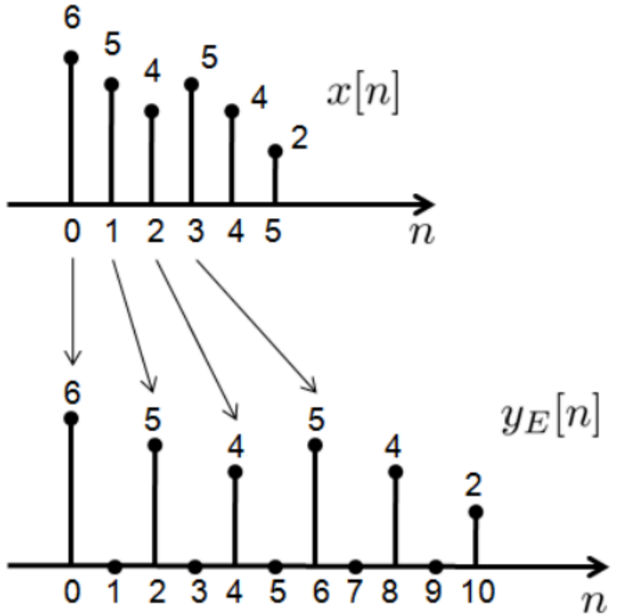


Expansion

- Expansion is defined as:

$$y_E[n] = \begin{cases} x\left[\frac{n}{L}\right], & n = \text{integer} \quad \text{multiple} \quad \text{of} \quad L \\ 0, & \text{otherwise} \end{cases}$$

- L is called the expansion factor.
- When L=2.



Classification of Signals

Periodic vs Aperiodic

- Definition-1: A continuous time signal x(t) is periodic if there is a constant T > 0 such that:

$$x(t) = x(t+T), \quad for \quad all \quad t \in R$$

- Definition-2: A discrete time signal x[n] is periodic if there is an integer constant N > 0 such that:

$$x[n] = x[n+N], \quad for \quad all \quad n \in Z$$

- Signals do not satisfy the periodicity conditions are called aperiodic signals.

- T_0 is called the fundamental period of x(t) if it is the smallest value of T >0 satisfying the periodicity condition. The number $\omega_0 = \frac{2\pi}{T_0}$ is called the fundamental frequency of x(t).

Periodic vs Aperiodic (cont.)

- N_o is called the fundamental period of x[n] if it is smallest value of N > o where N ε Z satisfying the periodicity condition. The number $\frac{\Omega_0}{2\pi} = \frac{m}{N}$ is called the fundamental frequency of x[n].

Example #2

- Determine the fundamental period of the following signals:

$$(a): \quad e^{j3\pi t/5}$$

$$(b): \quad e^{j3\pi n/5}$$

Even & Odd Signals

- An even signal is any signal f such that f(t) = f(-t).
- A signal x(t) or x[n] is referred to as an even signal if it is identical to its time-reversed counterpart, i.e., with its reflection about the origin.
- An odd signal on the other hand is a signal f such that f(t) = -(f(-t)).
- Any signal can be written as a combination of an even and odd signal, i.e., every signal has an odd-even decomposition.

$$f(t) = \frac{1}{2}\left(f(t) + f(-t)\right) + \frac{1}{2}\left(f(t) - f(-t)\right)$$

Even & Odd Signals (cont.)

- The all-zero signal is both even and odd. Any other signal cannot be both even and odd, but may be neither.

Thank You