Signals and Systems

EC241

Indian Institute of Information Technology Guwahati

Syllabus

EC241 **Signals and Systems** **3-0-0-6**

Syllabus :

Signals: Signal Basics, Elementary signals, classification of signals; signal operations: scaling, shifting and inversion; signal properties: symmetry, periodicity and absolute integrability; Sampling and Reconstruction, Sampling and Nyquist theorem, aliasing, signal reconstruction: ideal interpolator, zero-order hold, first-order hold; Sinc function, Practical reconstruction. Systems: classification of systems; Time-Domain Analysis of Continuous-Time Systems; system properties: linearity, time/shift-invariance, causality, stability; continuous-time linear time invariant (LTI) and discrete-time linear shift invariant (LSI) systems: impulse response and step response; response to an arbitrary input: convolution; circular convolution; system representation using differential equations; Eigen functions of LTI/ LSI systems, frequency response and its relation to the impulse response. Signal representation: signal space and orthogonal basis; continuous-time Fourier series and its properties; continuous-time Fourier transform and its properties; Parseval's relation, time-bandwidth product; discrete time fourier series; discrete-time Fourier transform and its properties; relations among various Fourier representations. Linear Convolution using DFT. Fast Fourier Transform (FFT); Laplace transform and properties, Inverse Laplace Transform by Partial Fraction and Z-transform: definition, region of convergence, properties; transform-domain analysis of LTI/LSI systems, system function: poles and zeros; stability, inverse Z-Transform by Partial Fraction.

Text:

1. M. J. Roberts, ”Fundamentals of Signals and Systems”, 1st Edition, Tata McGraw Hill, 2007.

References:

1. A.V. Oppenheim, A.S. Willsky and H.S. Nawab, ”Signals and Systems”, 2nd Edition Prentice Hall of India,2006.

2. B. P. Lathi,”Signal Processing and Linear Systems”, 1st Edition , Oxford University Press, 1998.

3. R.F. Ziemer, W.H. Tranter and D.R. Fannin, ”Signals and Systems - Continuous and Discrete”, 4th Edition, Prentice Hall, 1998.

4. Simon Haykin, Barry van Veen, ”Signals and Systems”, 2nd Edition, John Wiley and Sons, 1998.

Evaluation

- Assignment/Mini Project/Quiz: 20
- Mid Semester: 30
- Attendance: 5
- End Semester: 45
- **Total: 100**

Introduction

Introduction to Signals

Examples of Real-world signals:

- Human speech
- Light from a light-house
- Microwave from a TV or mobile transmission tower
- Image projected by a projector
- Video projected by a projector

- **Functions of independent variables** be it **time, space etc.**
- Convey **information about certain phenomenon**
- **Definition: Signals are physical functions of independent variables that convey information about certain phenomenon**

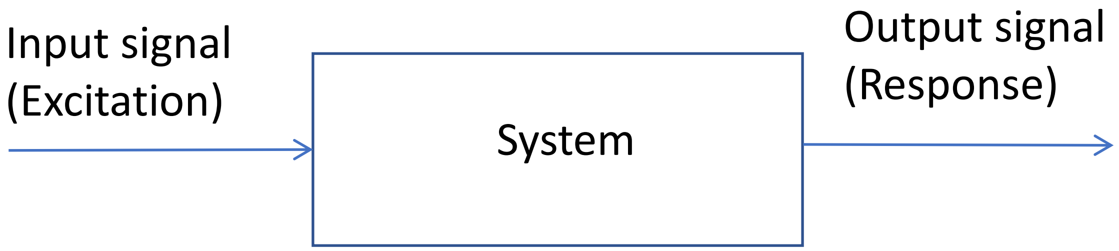
Introduction to Systems

Examples of Systems:

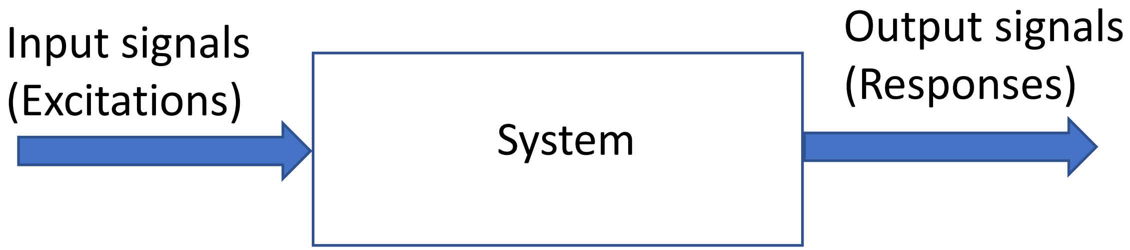
- Cellular phone, Television, Projector
- Measuring instruments
- Control mechanisms of Automobiles, Aircrafts and other machines
- Living beings
- Weather
- Stock Market

- Transforms one or more forms of signal (excitations) into one or multiple forms (responses)
- **Definition: System is an entity that acts upon one or more input signals (excitations) to produce one or more output signals (responses)**

Relationship between Signals and Systems - A Block Diagrammatic Representation



Single input single output system



Multiple inputs multiple outputs system

Classification of Signals

Classification of signals can be done based on whether they are

- Continuous-time or Discrete-time (CT or DT)
- Continuous-value or Discrete-value (CV or DV)
- Random or Nonrandom (RD, NRD)

Classification of Signals - Examples

- Let us consider some signals to understand the different classification
  - **Example 1:** Human Speech Signal without any processing
  - **Example 2:** Recorded human speech stored in a computer hard drive
  - **Example 3:** A record of annual rainfall at a location over 10 years
  - **Example 4:** A record of annual car sales of a company over 10 years
  - **Example 5:** Periodic Pulsating Light signal from a light house
  - **Example 6:** Light signal from a Indicator that glows each time a person enters a shopping mall

Classification of Signals - Examples

- Let us consider some signals to understand the different classification
  - **Example 1:** Human Speech Signal without any processing (CT, CV, RD)
  - **Example 2:** Recorded human speech stored in a computer hard drive (DT, DV, RD)
  - **Example 3:** A record of annual rainfall at a location over 10 years (DT, CV, RD)
  - **Example 4:** A record of annual car sales of a company over 10 years (DT, DV, RD)
  - **Example 5:** Periodic Pulsating Light signal from a light house (CT, DV, NRD)
  - **Example 6:** Light signal from a Indicator that glows each time a person enters a shopping mall (CT, DV, RD)

Overview of MATLAB, SCILAB

Continuous-Time Signals

Continuous-Time Signals

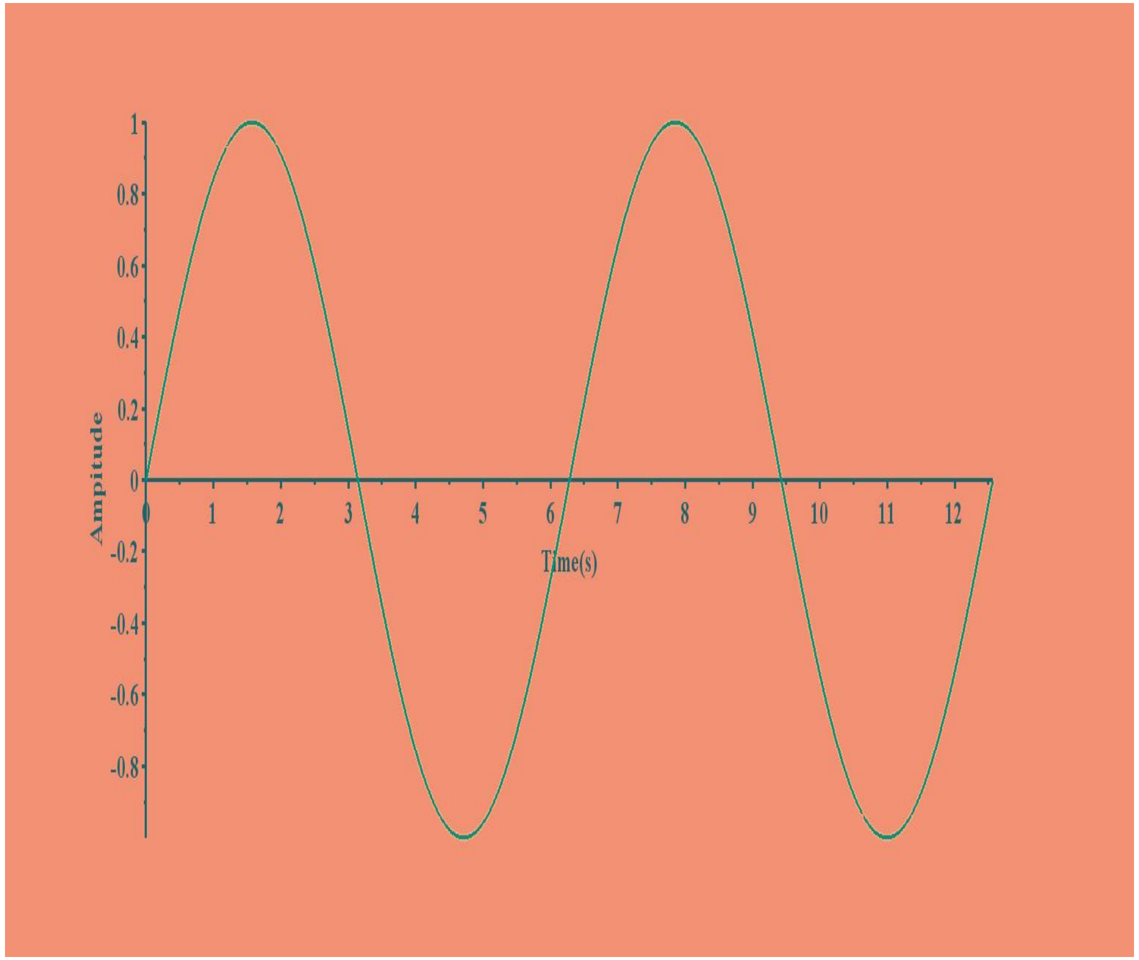
- Continuous-time signals are functions of the independent variable, *time*
- The domain of such functions is all real numbers
- **Definition: A continuous-time signal is function of the independent variable time, *t*, i.e. *g(t)* and has defined values for every real value of *t*.**

Continuous function and Continuous-Time Signals

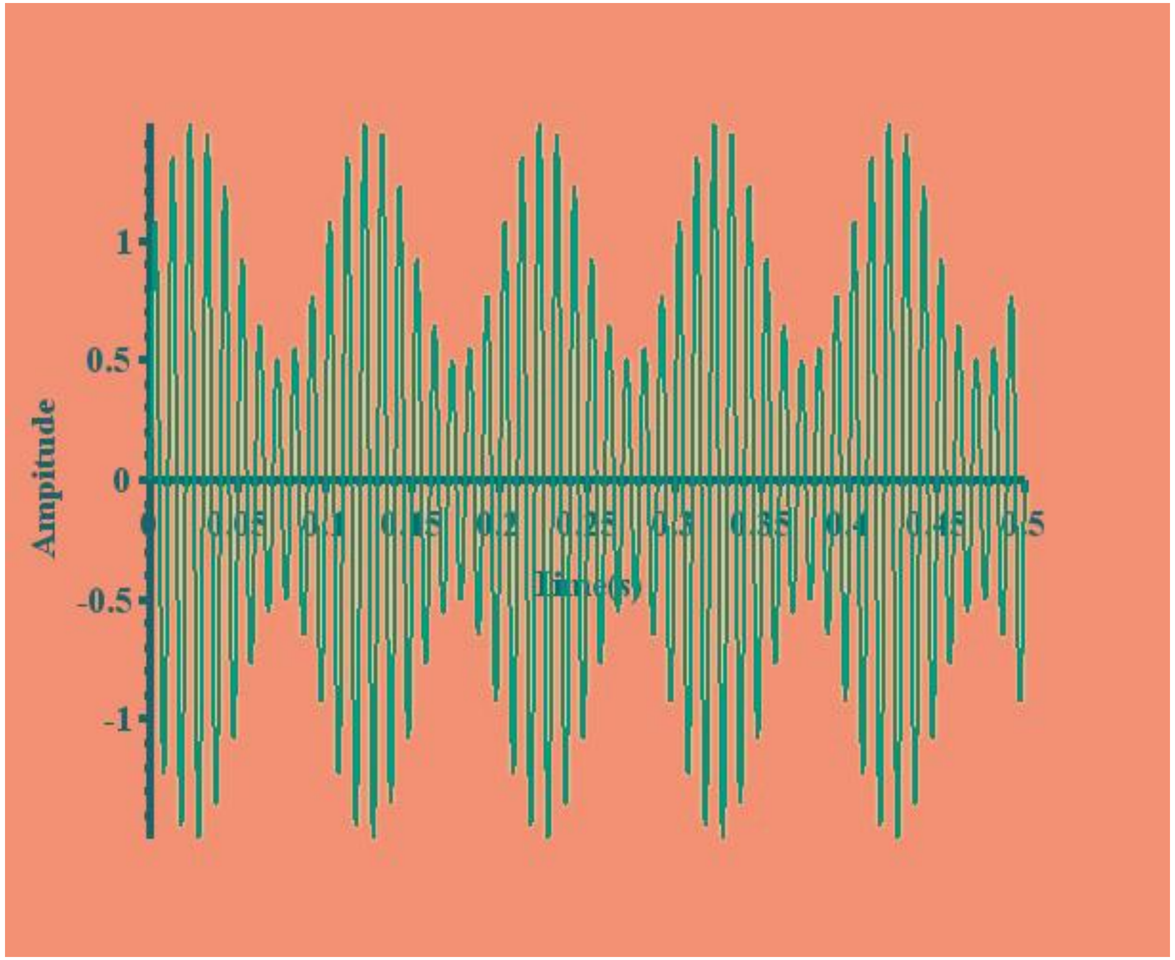
- A function $g_1(t)$ is classified as a discontinuous function if at some time t_0

$$\lim_{\in \to 0} g_1(t_0 + \in) \neq \lim_{\in \to 0} g_1(t_0 - \in)$$

Some Continuous-Time Signals

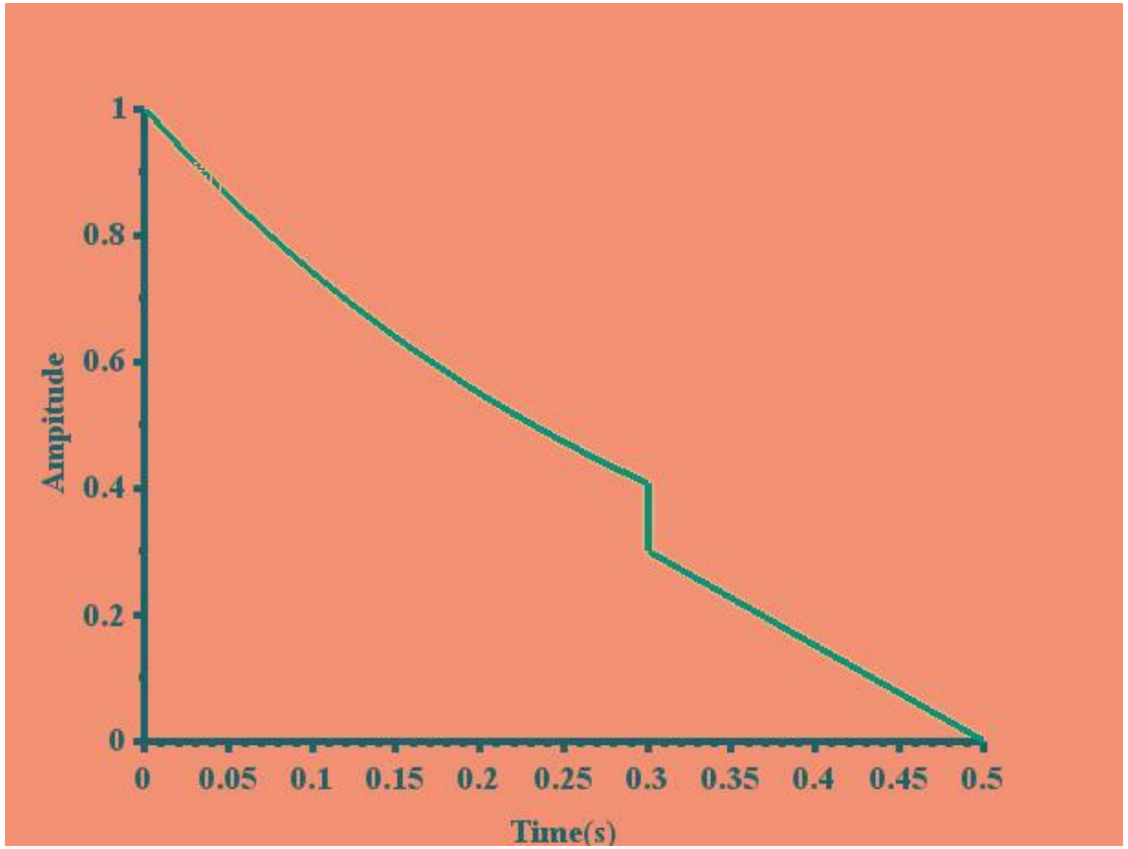


Sine Signal

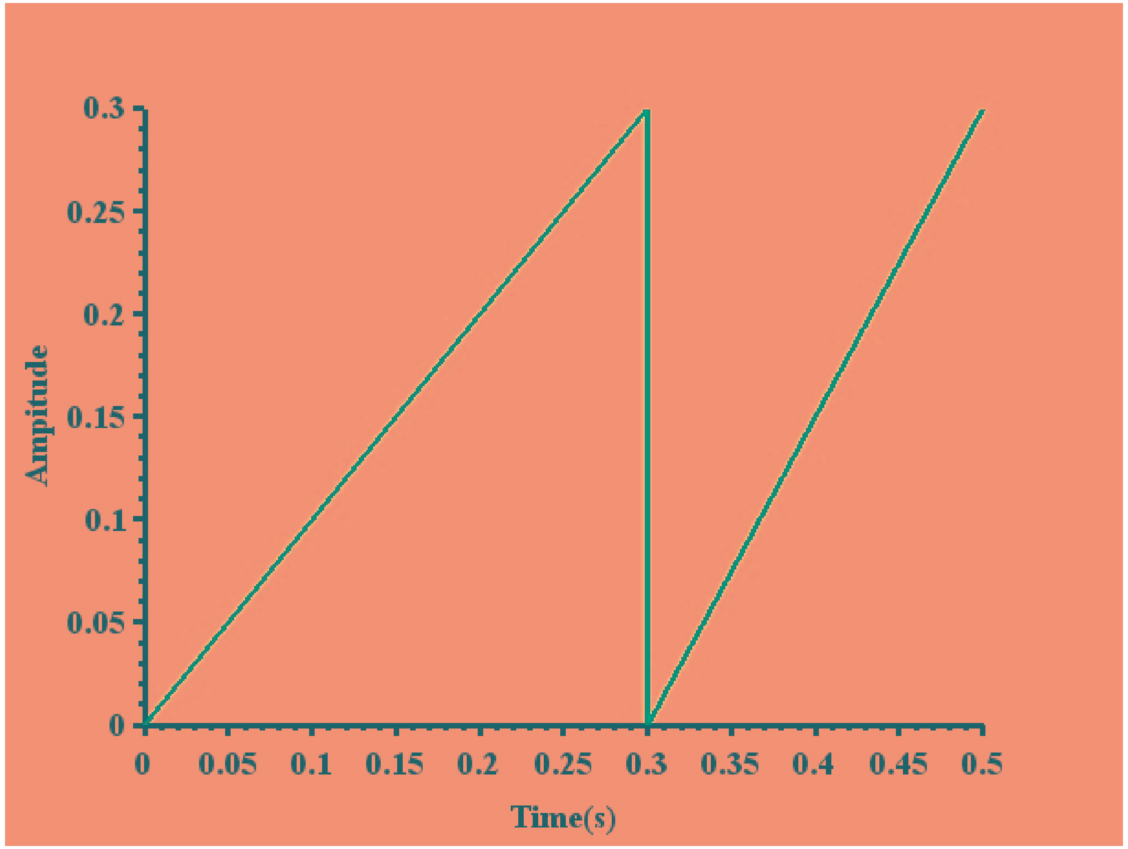


AM Signal

Some Continuous-Time Signals



Arbitrary Signal



Sawtooth Signal

Notations for Continuous and Discrete-Time Signals

- For functions whose domain is a continuum of real or complex number the argument is enclosed in parentheses (.).
- For functions whose domain is integers, the argument is enclosed in square brackets [.]
- The domain of continuous-time (CT) signals is a continuum of real numbers. E.g. of representation of a CT signal is $x(t)$
- The domain of discrete-time (DT) signals is integers. E.g. of representation of a DT signal is $x[n]$

Some Important CT Signals

- Sinusoids:

$$g(t) = A\cos\left(\frac{2\pi t}{T_0} + \theta\right) = A\cos(2\pi f_0 t + \theta) = A\cos(\omega_0 t + \theta)$$

- Complex exponentials:

$$g(t) = A\, e^{(\sigma_0 + j\omega_0)t} = A\, e^{\sigma_0 t}[\cos(\omega_0 t) + j\,\sin(\omega_0 t)$$

- Unit step function:

$$u(t) = \begin{cases} 1, t > 0 \\ \frac{1}{2}, t = 0 \\ 0, t < 0 \end{cases}$$

Some Important CT Signals (cont…)

- Signum function

$$\operatorname{sgn}(t) = \begin{cases} 1, & t > 0 \\ 0, & t = 0 \\ -1, & t < 0 \end{cases}$$

- Unit Ramp function

$$\operatorname{ramp}(t) = \begin{cases} t, & t > 0 \\ 0, & t \leq 0 \end{cases} = \int_{-\infty}^{t} u(\tau)d\tau$$

Some Important CT Signals (cont…)

- Unit Rectangle function

$$\mathrm{rect}(t) = \begin{cases} 1, & |t| < \dfrac{1}{2} \\ \dfrac{1}{2}, & |t| = \dfrac{1}{2} \\ 0, & |t| > \dfrac{1}{2} \end{cases}$$

- Unit Triangle function

$$\mathrm{tri}(t) = \begin{cases} 1 - |t|, & |t| < 1 \\ 0, & |t| \geq 1 \end{cases}$$

Some Important CT Signals (cont…)

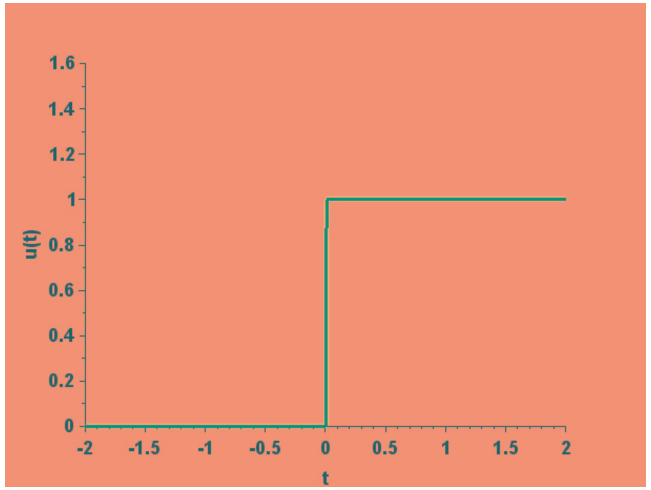
- Unit Sinc function

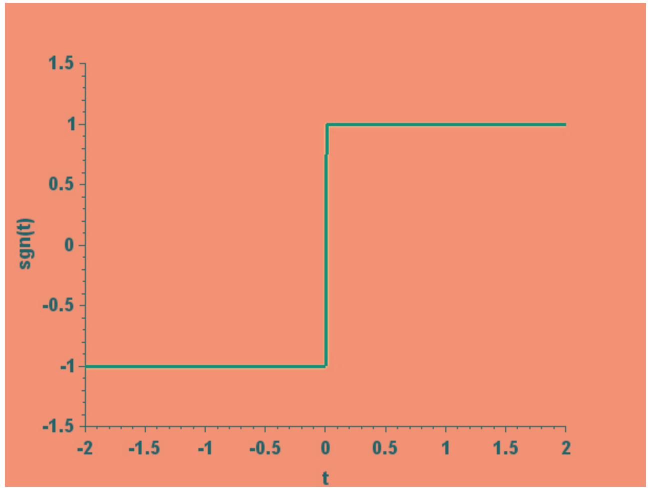
$$\mathrm{sinc}(t) = \frac{\sin(\pi t)}{\pi t}$$

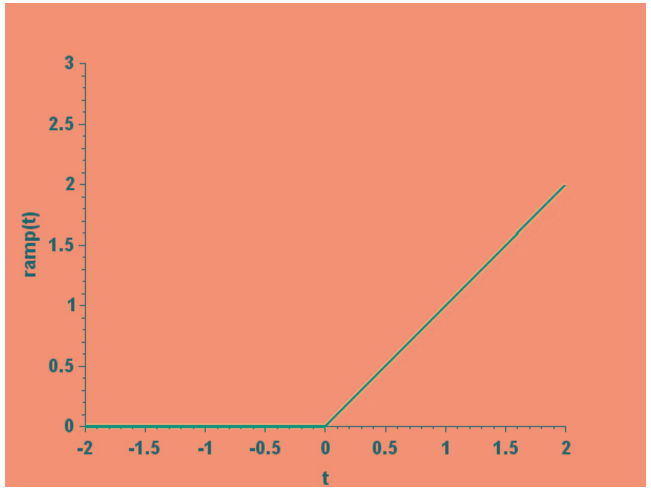
Sketch

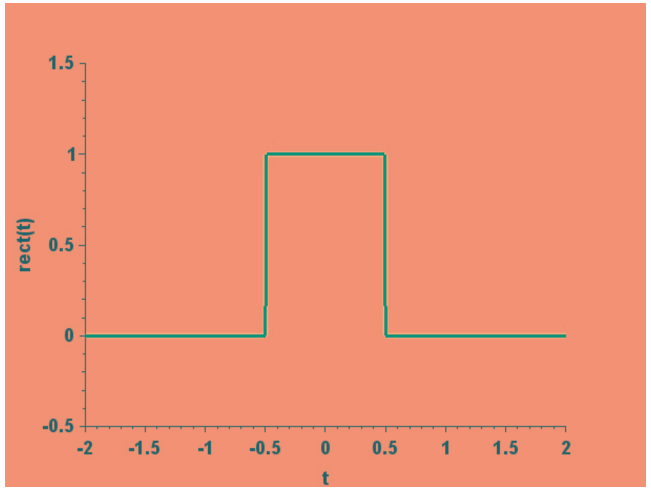
$u(t), \mathrm{sgn}(t)\ , \mathrm{ramp}(t), \mathrm{rect}(t), \mathrm{tri}(t), \mathrm{sinc}(t)$

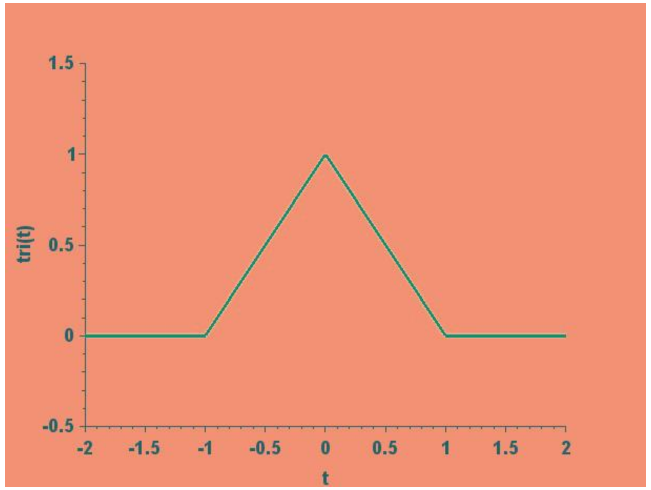
Sketch $u(t), \mathrm{sgn}(t), \mathrm{ramp}(t), \mathrm{rect}(t), \mathrm{tri}(t), \mathrm{sinc}(t)$

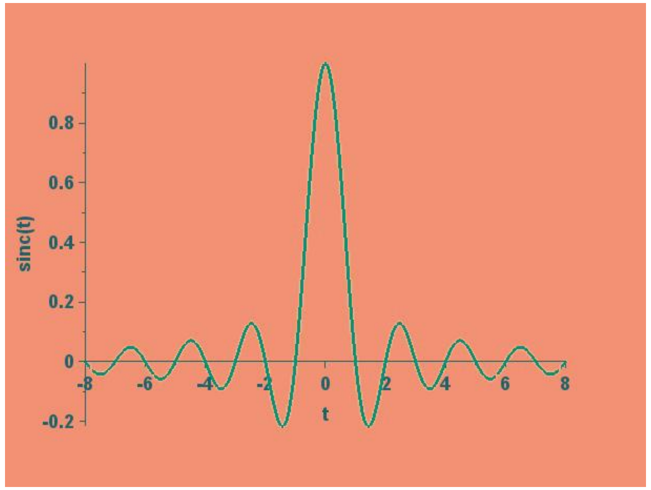












Some Important CT Signals – Unit Impulse Function

- Consider the functions:

$$\delta_a(t) = \begin{cases} \frac{1}{a}, & |t| < \frac{a}{2} \\ 0, & |t| \geq \frac{a}{2} \end{cases}$$

$$\delta_b(t) = \begin{cases} \frac{1}{b}\left(1 - \left|\frac{t}{b}\right|\right), & |t| < b \\ 0, & |t| \geq b \end{cases}$$

Sketch the functions $\delta_a(t)$ and $\delta_b(t)$

Sketch the functions $\delta_a(t)$ and $\delta_b(t)$