Signal Processing Fall 2021

- Canvas – for all communications
- 1 midterm exam 50 %
  1 final ″ 50 %
- Textbook –
  Haykin and Van Veet, "Signals and Systems", 2nd edition, Wiley, 2003

  Supplemental Textbook
  Oppenheim et. al, "Signals and Systems", Pearson, 2014
  2nd Ed.

  {→ Türkçe Tercümesi Var}

- Read the Book – You WILL not pass unless you read the book.!!
  + Solve the exercises.

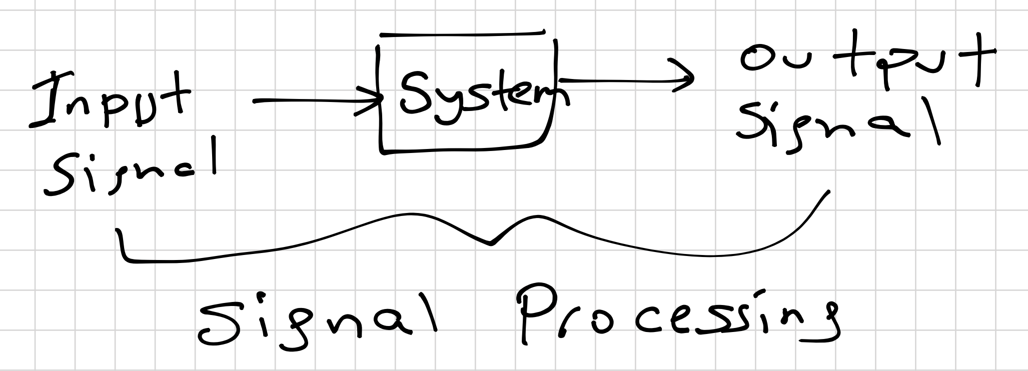
What is a signal

~ Speech
~ Emails
~ Heartbeat
~ Radio waves

"A signal is a function of one or more variables that conveys information on the nature of a physical phenomenon"

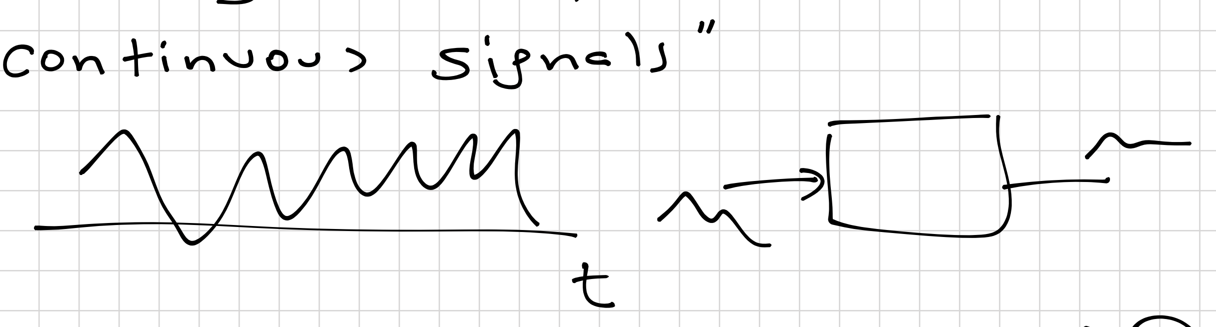
What is a system

A system is an entity that manipulates one or more signals to accomplish a function therefore yielding new signals.

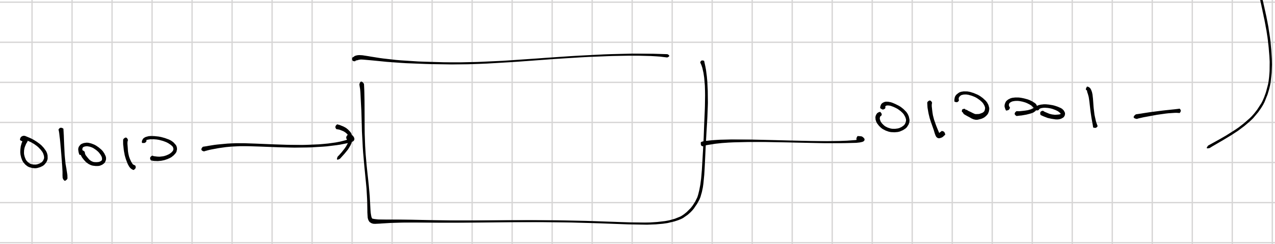


Analog and Digital Signal Processing

- Analog signal processing involves "continuous signals"



- Digital Signal Processing (DSP)
  - it involves discrete and quantized



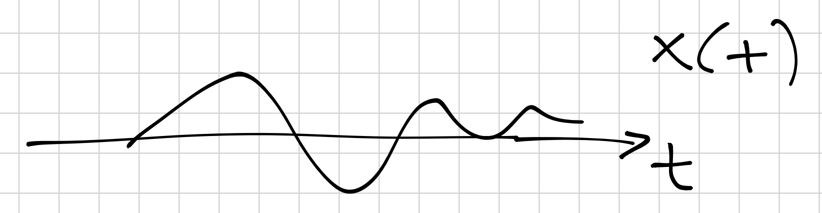
- Mixed Signal Processing ?

Classification of Signals

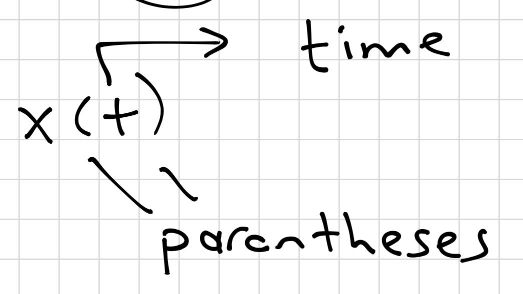
- In this course we will focus on one dimensional single valued signals.
- We will represent the signals as functions of time

① Continuous-Time (CT) signals vs Discrete-Time (DT) signals

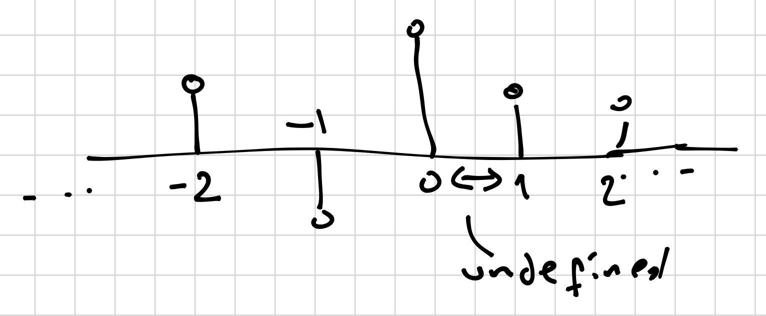
$x(t)$ → dependent variable
 ↳ independent variable (time)



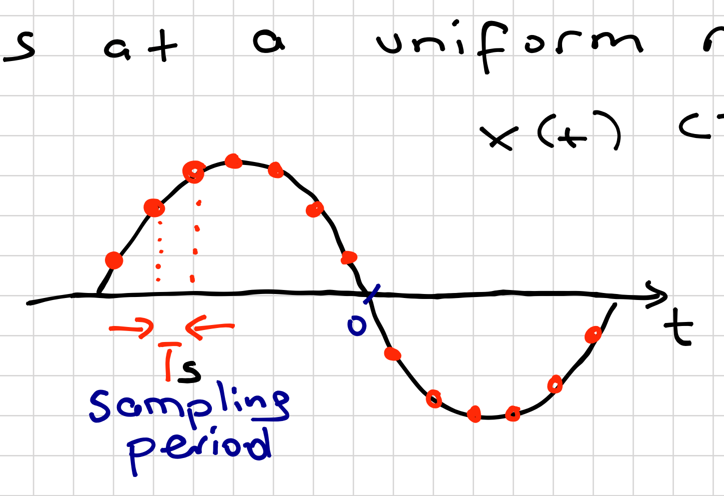
A CT signal $x(t)$ is defined for all time (t)

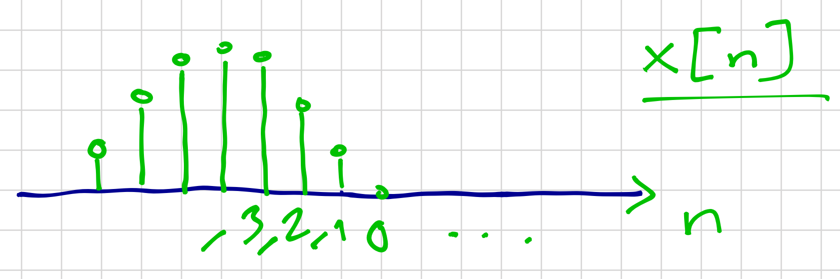


A DT signal is defined only on discrete instants of time



Sampling – is used to derive a DT signal from a CT signal by taking the values at a uniform rate.



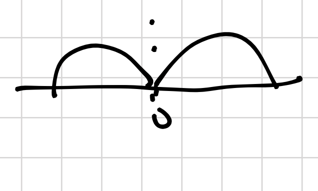


$x[n] = x(n \cdot T_s)$ $n = 0, \mp 1, \mp 2 \ldots$

(n → independent variable; $x[n]$ → signal (dependent variable))

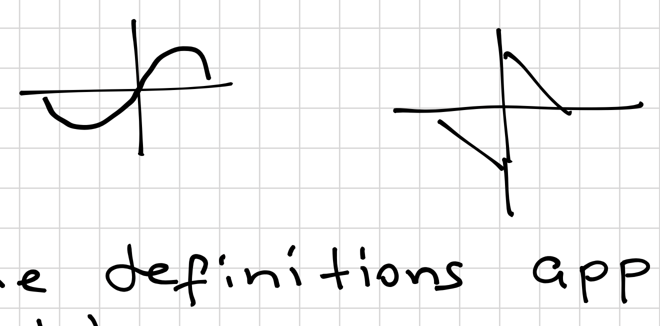
② Even and Odd Signals.

Even signal : $x(t) = x(-t)$



symmetric around origin !

Odd signal $x(-t) = -x(t)$



(– Same definitions apply to discrete signals)

- Some signal may be neither!

$x(t) = 0$

Ex

$$x(t) = \begin{cases} \sin(\pi t/T), & -T \leq t \leq T \\ 0, & \text{otherwise} \end{cases}$$

$$x(-t) = \begin{cases} \sin(-\pi t/T), & -T \leq t \leq T \\ 0, & \text{otherwise} \end{cases}$$

$$x(-t) = \begin{cases} -\sin(\pi t/T), & -T \leq t \leq T \\ 0, & \text{otherwise} \end{cases}$$

$$= -x(t)$$

$x(t)$ is an ODD signal.

Even/Odd Decomposition.

$$x(t) = \underbrace{x_e(t)}_{\text{even}} + \underbrace{x_o(t)}_{\text{odd signal}}$$

$$x_e(-t) = x_e(t)$$

$$-x_o(-t) = x_o(t)$$

$$x_e(-t) - x_o(-t) = x(t)$$

$$x(-t) = x_e(-t) + x_o(-t)$$

$$x_e(t) = \frac{1}{2}\left[x(t) + x(-t)\right]$$

$$x_o(t) = \frac{1}{2}\left[x(t) - x(-t)\right]$$

Ex $x(t) = e^{-2t} \cdot \cos(t)$

Find the even and odd components of $x(t)$

$$x(t) = e^{-2t} \cdot \cos(t)$$

$$x(-t) = e^{2t} \cdot \cos(-t)$$

$$= e^{2t} \cos(t)$$

$$x_e(t) = \frac{1}{2}\left[e^{2t}\cos(t) + e^{-2t}\cos(t)\right]$$

$$x_e(t) = \cosh(2t)\cos(t)$$

$$x_o(t) = -\sinh(2t)\cdot\cos(t)$$

/* $\cosh(x) = \frac{1}{2}\left(e^{2t} + e^{-2t}\right)$

$\sinh(x) = \frac{1}{2}\left(e^{2t} - e^{-2t}\right)$ */

Symmetry for complex signals

A complex-valued signal, $x(t)$, is said to be "conjugate-symmetric" if

$$x(-t) = x^*(t)$$

/* $x(t) = a(t) + j\,b(t)$ (Real: $a(t)$, Imaginary: $b(t)$)

$x^*(t) = a(t) - j\,b(t)$ */

If $x(t)$ is conjugate symmetric:

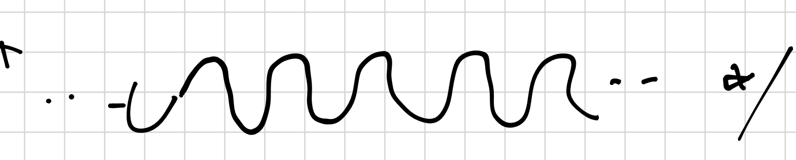
$$a(-t) + j\,b(-t) = a(t) - j\,b(t)$$

∴ The real part of $x(t)$, $(a(t))$ is EVEN

∴ The imaginary part of $x(t)$, $(b(t))$ is odd

③ Periodic and non-periodic signals.

CT If $x(t)$ is a periodic signal then $x(t) = x(t+T)$, for all t where T is a positive constant.

/*  */

If this condition is satisfied for, let's say $T = T_0$, then it will also be satisfied for $T = 2T_0, 3T_0, \ldots$

$$x(t) = x(t+T_0) = x(t+2T_0) + \ldots$$

- The smallest value of T that satisfies the condition is called "the fundamental period"!,

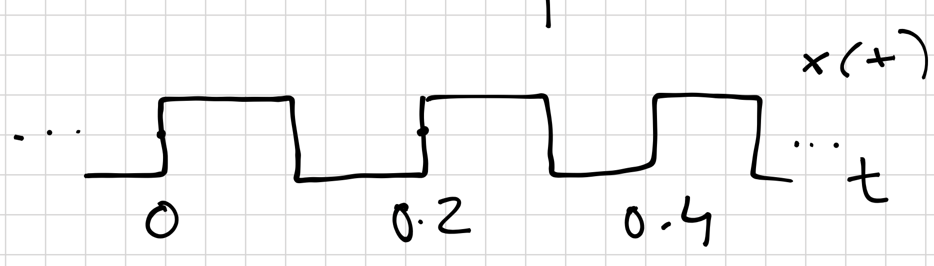
T : (seconds)

(Fundamental Frequency: $f = \frac{1}{T}$ (Hertz) Hz

Angular Frequency.

$$\omega = 2\pi \cdot f = \frac{2\pi}{T} \quad \text{(radians/sec)}$$

Ex



$T = 0.2$ s.

$$f = \frac{1}{0.2} = 5\text{ Hz}$$

$$\omega = 2\pi \cdot 5 = 10\pi \text{ rad/sec.}$$

Ex non-periodic