Fondamenti di Comunicazioni

Corso: Fondamenti di comunicazioni e Internet (canale I e II)
E Telecomunicazioni

Lezione 1: Introduzione (segnali continui e discreti)

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SAPIENZA
UNIVERSITÀ DI ROMA

Materiale didattico: Tiziana Cattai, Stefania Colonnese, Roberto Cusani

Informazioni generali

Fondamenti di Comunicazioni (circa 15 ore)

Obiettivo: Fondamenti sulle comunicazioni, uso dei segnali digitali e loro elaborazione

- Lezioni
  - Lunedì 12-13.30 (Aula 108, Marco Polo) per Fondamenti di comunicazioni ed Internet (canale II)
  - Lunedi 16:00-17:00 (Aula 108, Marco Polo+ Altra aula) per Fondamenti di comunicazioni ed Internet (canale I) e Telecomunicazioni
  - Eventuali modifiche saranno comunicate durante il corso
- Le giornate dedicate alle esercitazioni e agli homework saranno stabilite durante il corso
- Riferimenti: Tiziana Cattai email: tiziana.cattai@uniroma1.it

  Per ricevimento contattare il docente

Informazioni generali

- Materiale Didattico:

  Tutto il corso è interamente coperto dai Lucidi delle lezioni disponibili su Moodle

- Modalità di esame (appelli gennaio e febbraio)
  - Degli homework durante il corso sulla parte pratica (10 punti)
  - Una prova scritta a gennaio o febbraio
  - Una parte con domande a risposta multipla (15 punti)
  - 1 Esercizio (5 punti)
  - Delle prove intermedie su moodle durante il corso: quiz che rilasciano un massimo di 4 punti da utilizzare come punti bonus esclusivamente nell'appello di Gennaio o Febbraio 2024

- Modalità di esame (appelli da marzo in poi)

  Una prova scritta
  - Una parte con domande a risposta multipla (vale 15 punti)
  - 1 Esercizio (vale 5 punti)

  Una prova orale a valle della correzione dello scritto (Vale +10 (-5) punti)

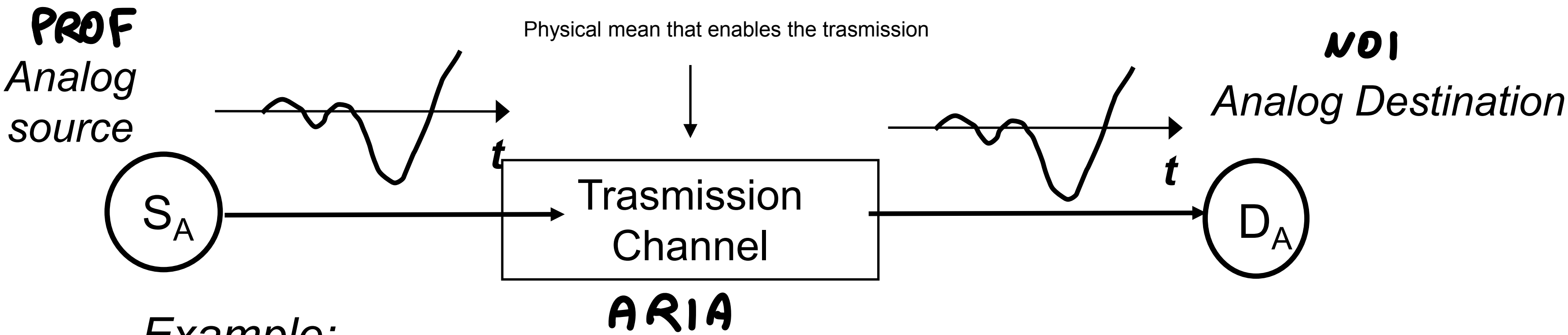
Programma

- Introduzione (segnali continui e discreti)
- Segnali notevoli, operazioni sui segnali
- Energia e potenza
- Correlazione ed impulso
- Convoluzione e filtraggio

Homework

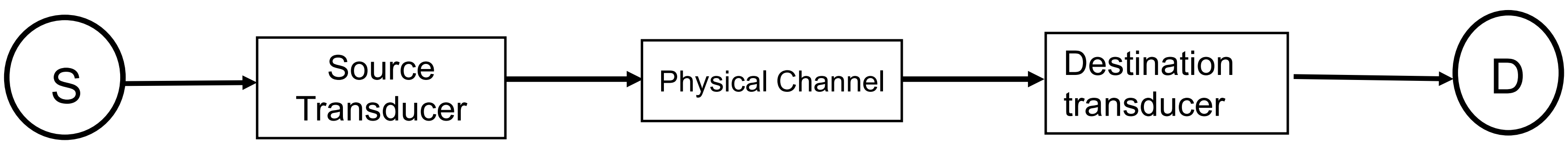
- Serie e trasformata di Fourier
- Correlazione e spettro
- Campionamento e quantizzazione
- Mezzi fisici di trasmissione

Continuous signals



Example:

Voice → signal of acustic pression
Telephone → Electrical signal
Video → optical signal

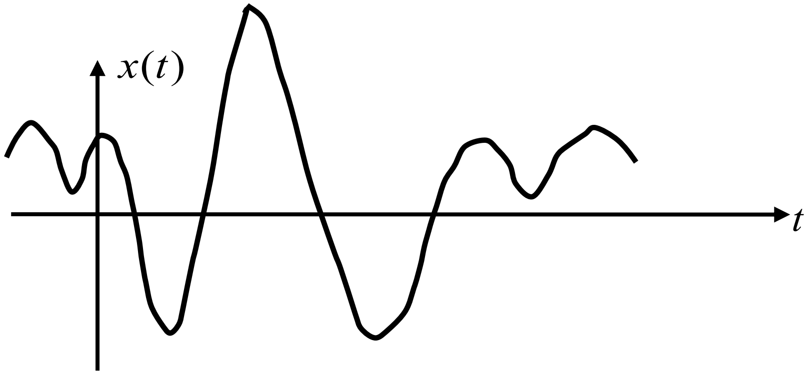


GRANDEZZA FISICA CHE TRASMETTE INFORMAZIONI

Continuous signals

Signal: physical quantity that varies in time and carry the information

$$x(t), \qquad -\infty < t < +\infty$$

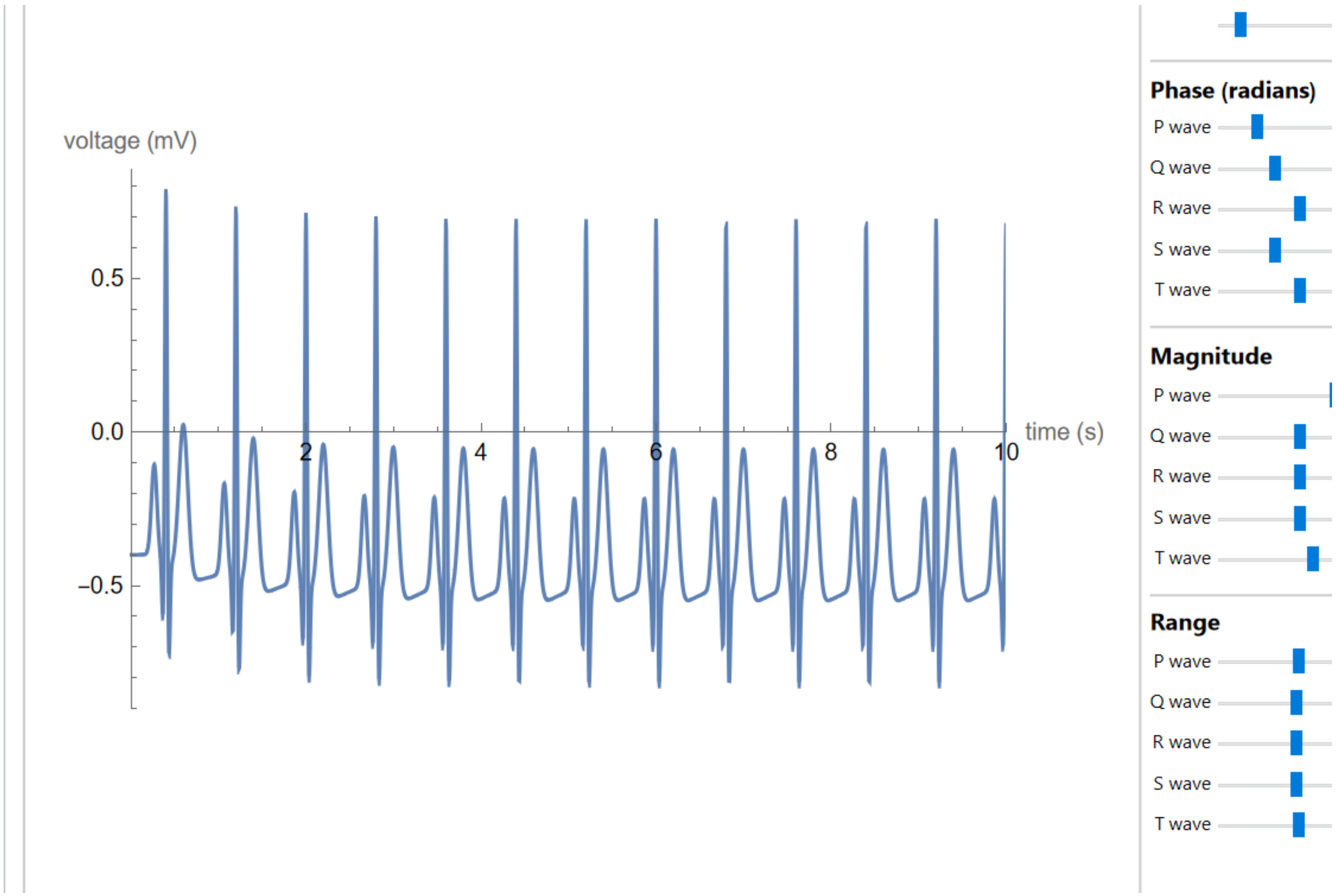


Example of continuous time signal: voice, temperature, music

Study of signals through real or function mathematical functions

Example of signals

- https://demonstrations.wolfram.com/SyntheticECG/



Classification of signals and elementary signals

A signal can be expressed by a real or complex mathematical function f(x). It can be written as:

$$\boxed{x(t) = x_R(t) + j\, x_I(t)}$$

Complex signals: couple of two real signals, that are a real signal $x_R(t)$ and an imaginary signal $x_I(t)$.

In alternative, it can be seen as a couple of real signals, associated to module $|x(t)|$ and phase arg(x(t))

$$x(t) = |x(t)| \cdot \exp[j \cdot \arg(x(t))]$$

$$|x(t)| = \sqrt{x_R^2(t) + x_I^2(t)}$$

$$\arg(x(t)) = arctg\left(\frac{x_I(t)}{x_R(t)}\right)$$

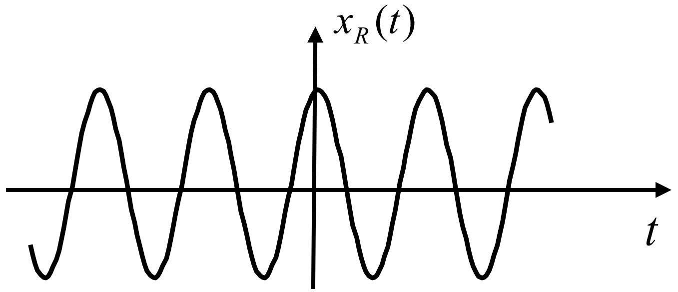
Classification of signals and elementary signals

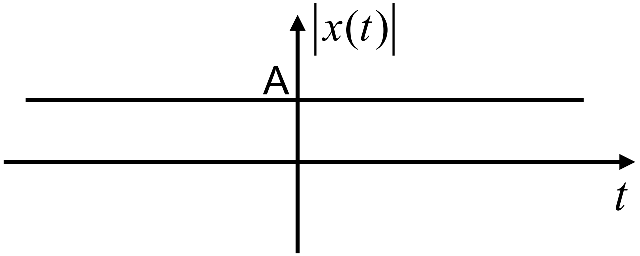
Complex exponential

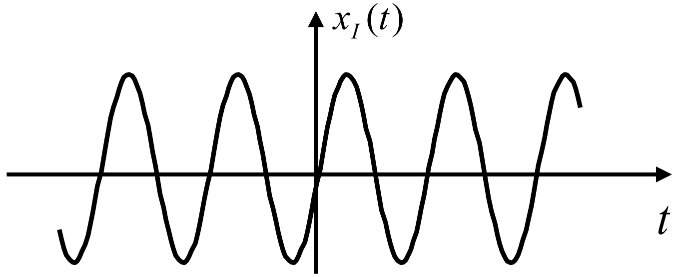
$$x(t) = Ae^{j(2\pi f_0 t+\varphi)} = A\cos(2\pi f_0 t + \varphi) + jA\sin(2\pi f_0 t + \varphi)$$

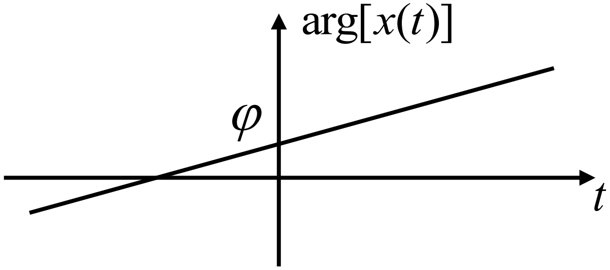
$$\begin{cases} x_R(t) = A\cos(2\pi f_0 t + \varphi) \\ x_I(t) = A\sin(2\pi f_0 t + \varphi) \end{cases}$$

$$\begin{cases} |x(t)| = A \\ \arg[x(t)] = 2\pi f_0 t + \varphi \end{cases}$$



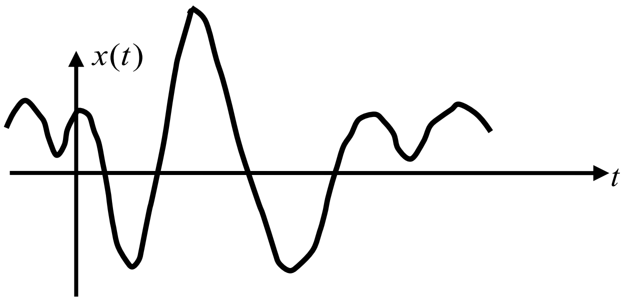






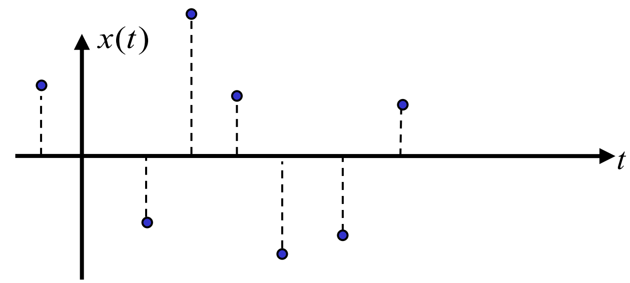
Classification of signals and elementary signals

Analogic signal



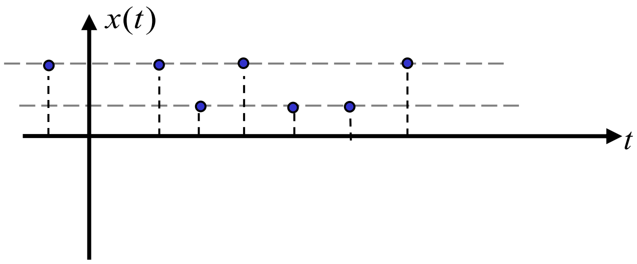
The signal is a continuous function (real or complex) of a continuous vaariable

Sampled signal



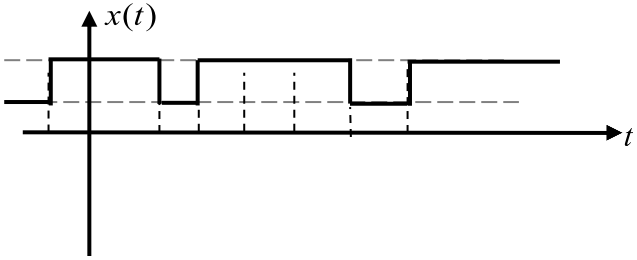
The signal is represented by a continuous function but the t-variable can have only discrete values

Digital signal



t is a discrete variable and it can have only discrete values

Discrete signal

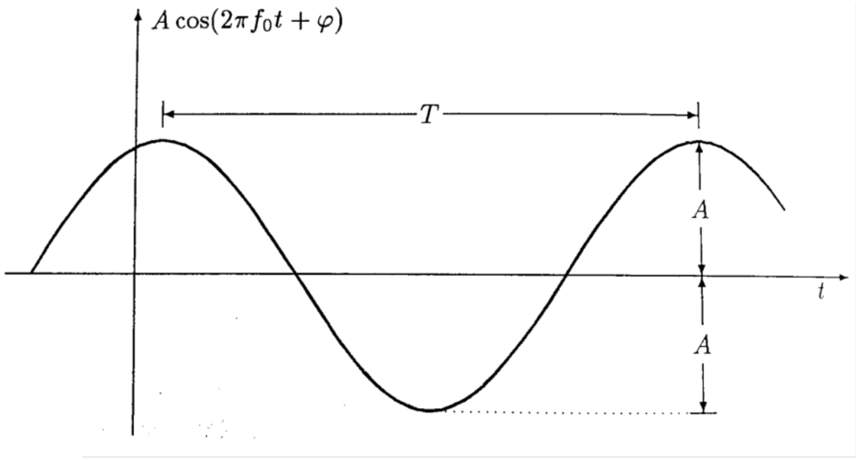


t is a continuous variable but it can have only discrete values

Example of signals

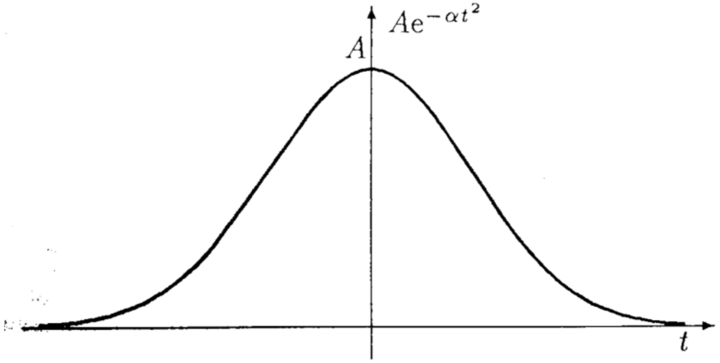
- Sine wave

$$x(t) = A cos(\frac{2\pi}{T} t + \varphi)$$



- Gaussian signal

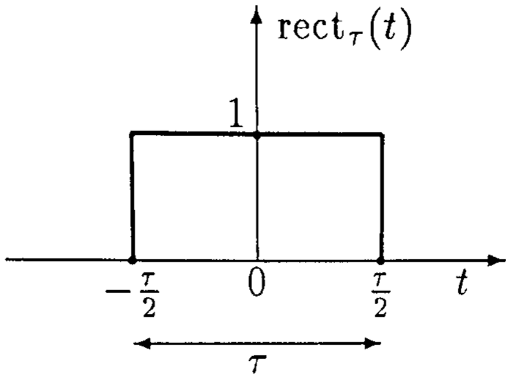
$$x(t) = Ae^{-\alpha t^2}$$



Example of signals

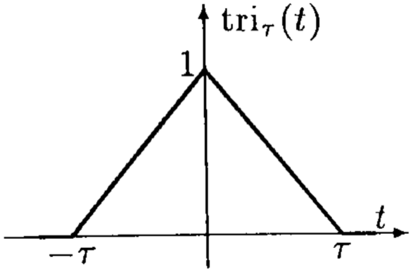
- Rettangolo

$$x(t) = rect(t) = \begin{cases} 1 \; if \; |t| \le \frac{\tau}{2} \\ \frac{1}{2} \; if \; |t| = \frac{\tau}{2} \\ 0 \; otherwise \end{cases}$$



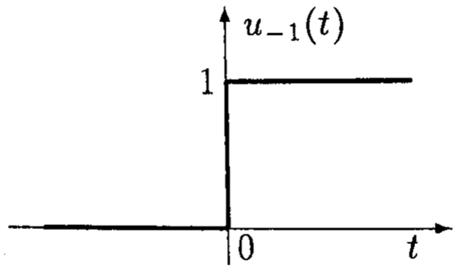
- triangolo

$$x(t) = tri(t) = \begin{cases} \frac{t}{\tau} + 1 \; if \; t \in [-\tau, 0] \\ -\frac{t}{\tau} + 1 \; if \; t \in [0, \tau] \\ 0 \; otherwise \end{cases}$$



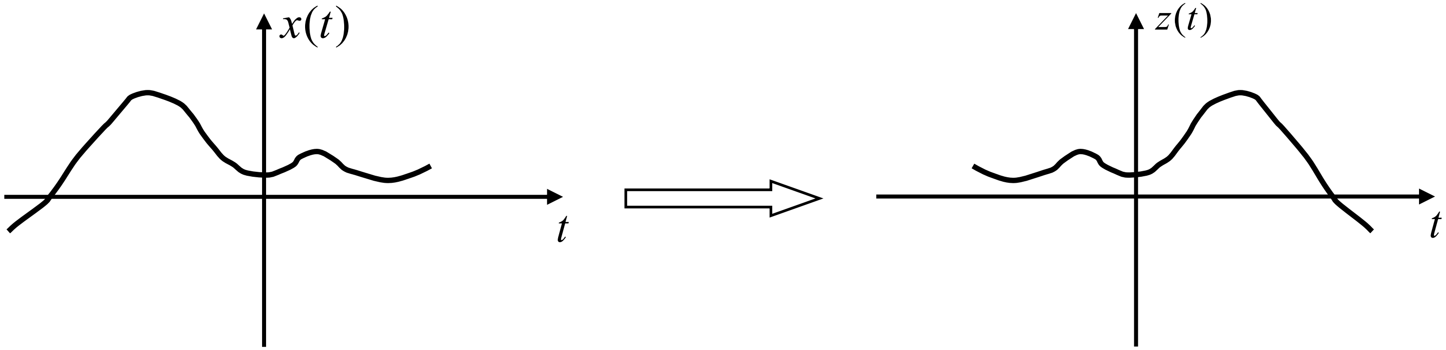
- Gradino unitario

$$x(t) = u_{-1}(t) = \begin{cases} 1 \; if \; t \ge 0 \\ 0 \; otherwise \end{cases}$$



Operations with signals

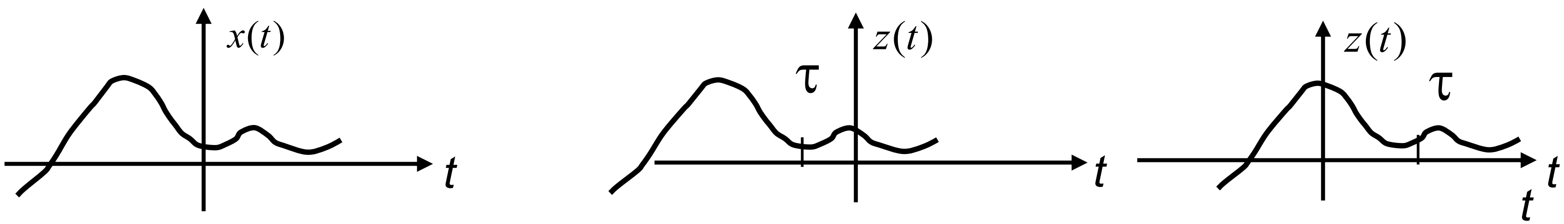
- Sum, Product: $z(t) = x(t) + y(t)$, $z(t) = x(t) \cdot y(t)$
- Product with a constant: $z(t) = cx(t)$ (Amplification, Attenuation)
- Flipping: $z(t) = x(-t)$



Operation with signals

Translation

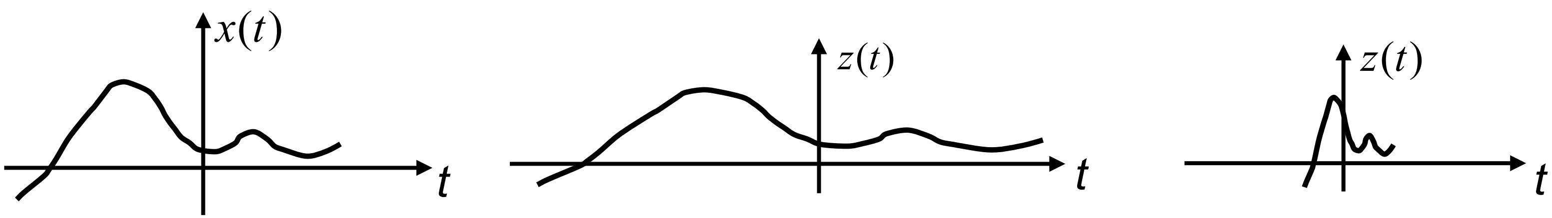
$$z(t) = x(t - \tau)$$



$\tau < 0$ anticipo $\qquad$ $\tau > 0$ ritardo

Axis warping

$$z(t) = x(\alpha t), \alpha > 0$$



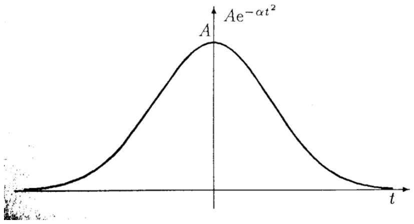
$\alpha < 1$ dilatazione $\qquad$ $\alpha > 1$ contrazione

Esempi : $x(t) = tri(2t)$, $x(t) =$ tri(1/3 t), $x(t) = \mathrm{rect}\left(\frac{1}{2t}\right)$, $x(t) = rect(t-1)$, $x(t) = \mathrm{rect}(t+1)$

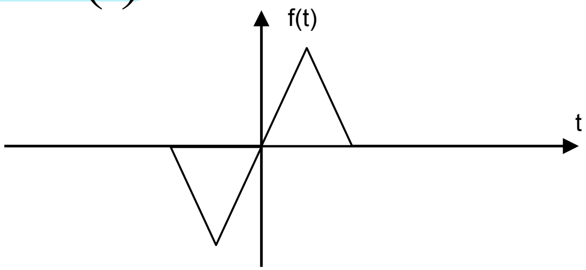
Symmetry

Given a real signal (or sequence)

- Even symmetry (simmetria pari) $f(-t)=f(t)$



- Odd symmetry (simmetria dispari) $f(-t)=-f(t)$



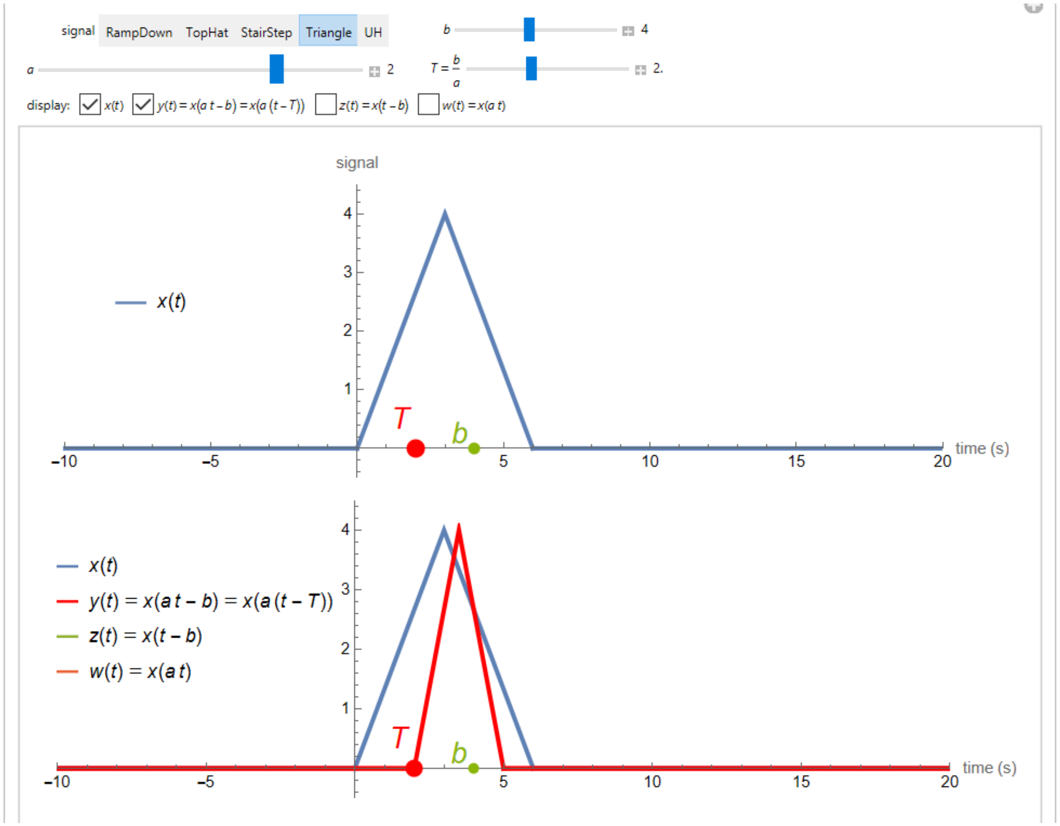
Given a complex signal (or sequence)

- Hermitian symmetry: real part and module: even symmetry and imaginary part and phase: odd symmetry

Example of signals

[Time Shifting and Time Scaling In Signal Processing]

https://demonstrations.wolfram.com/TimeShiftingAndTimeScalingInSignalProcessing/



Matlab example

+4 main_SWSS_epanet_demandvalues_01.m | convolution.m | examplees_quant_sampl.m | convolution.m | main_toy_SWSS_02.m | plot_sinewave.m | +

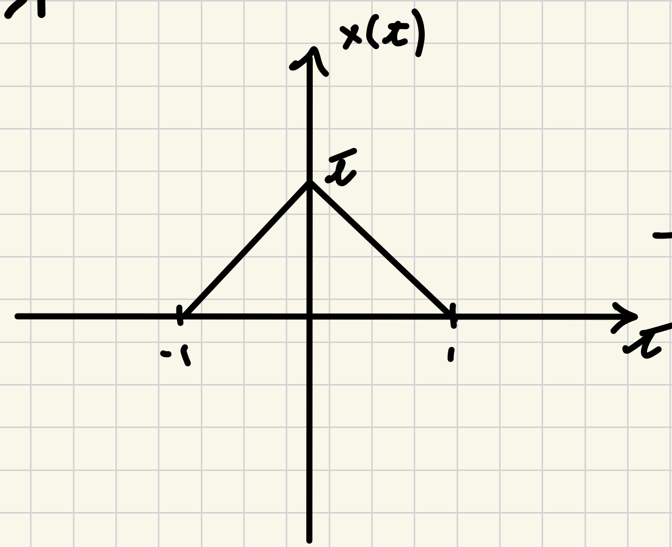
```
close all
clear
clc

% Creare una sinusoide
t = 0:0.05:2*pi; % Intervallo di tempo da 0 a 2*pi
A = 1; % Amplitude
f = 1; % Frequenza
phi = 0; % Fase
sinusoide = A * sin(2*pi*f*t + phi);

% Grafico della sinusoide originale
subplot(2, 1, 1);
stem(t, sinusoide);
title('Sinusoide Originale');
xlabel('Tempo');
ylabel('Amplitude');

% Trasla la sinusoide
t_shifted = t + 2; % Trasla di 1 secondo (puoi cambiare il valore a tuo piacimento)
sinusoide_shifted = A * sin(2*pi*f*t_shifted + phi);

% Grafico della sinusoide traslata
subplot(2, 1, 2);
stem(t_shifted, sinusoide_shifted);
title('Sinusoide Traslata');
xlabel('Tempo');
ylabel('Amplitude');

```

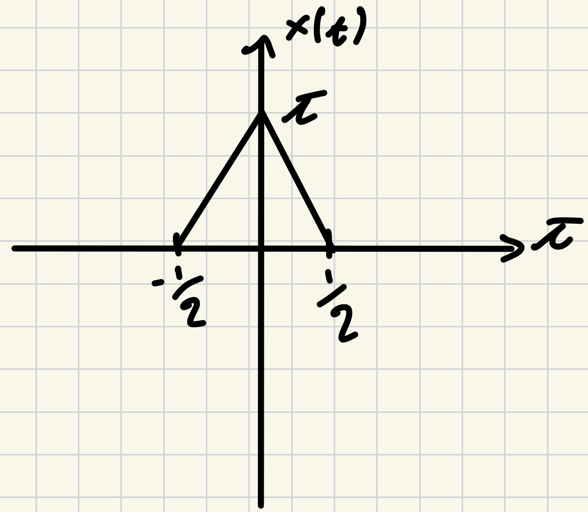
Examples

- $x(t) = rect\left(\frac{t}{3}\right)$
- $x(t) = 2rect\left(\frac{t}{3}\right)$
- $x(t) = tri(2t - 3)$
- $x(t) = rect\left(t + \frac{1}{2}\right) \cdot 3tri\left(\frac{t}{2}\right)$
- $x(t) = 2rect\left(\frac{t}{2} - 4\right) + tri(t + 2)$

$z(t) = \text{tri}(2t)$ $\quad x(t) = \text{tri}(t) = \begin{cases} 1 - |t| & -1 \leq t \leq 1 \\ 0 & \text{ALTRIMENTI} \end{cases}$

$\alpha = 2 > 1$



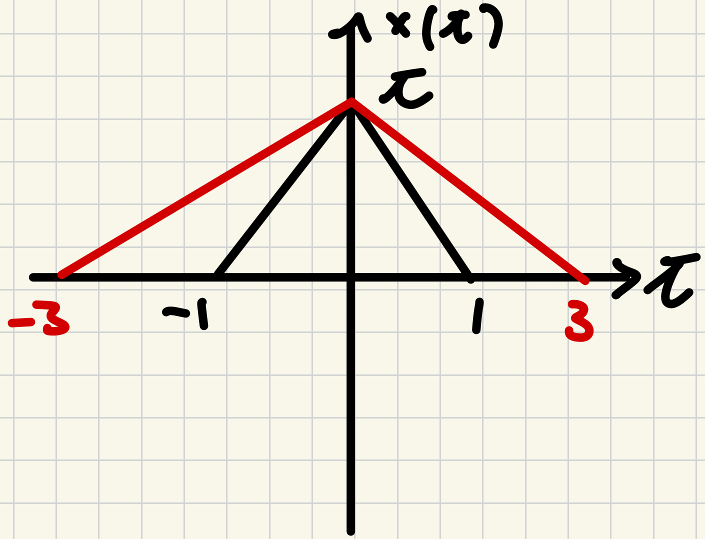


PROVE:

$z\left(-\frac{1}{2}\right) = \text{tri}\left(2 \cdot \left(-\frac{1}{2}\right)\right) = \text{tri}(-1) = 0$

$z(0) = \text{tri}(2 \cdot 0) = \text{tri}(0) = 1$

$x(\tau) = \mathrm{Tri}\left(\frac{1}{3}\tau\right) \quad \alpha = \frac{1}{3} < 1$

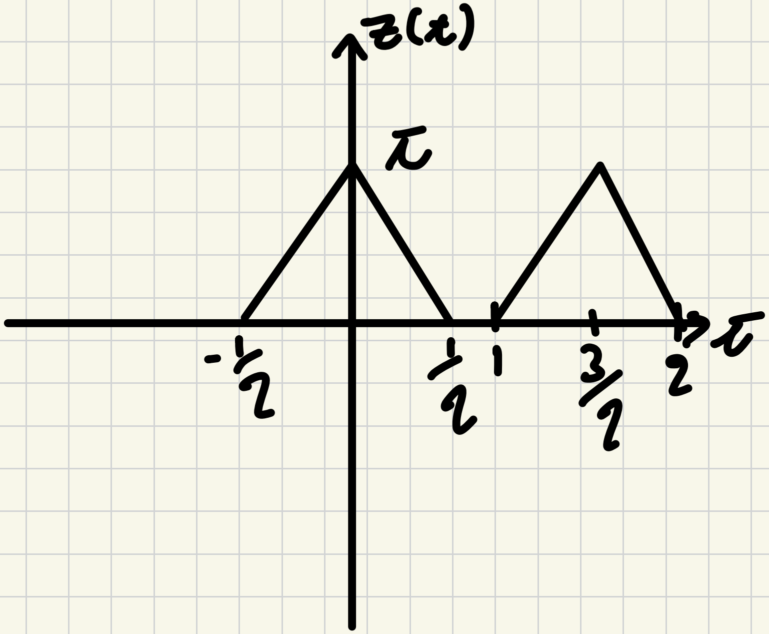


PROVE

$z(-1) = \mathrm{Tri}\left(-\frac{1}{3}\right) > 0$

$z(t) = \text{tri}(2t - 3)$

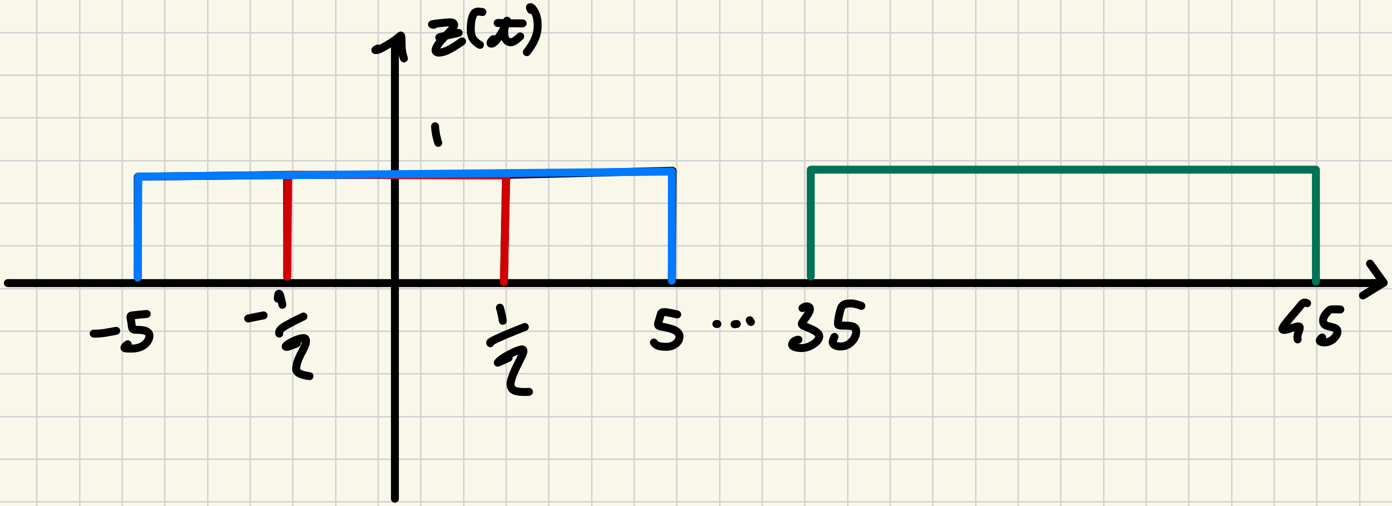
$\text{tri}(2(t - 3/2)) \Rightarrow \quad z(t) = \text{tri}(2t')$



$z(3) = \text{tri}(3) = 0$

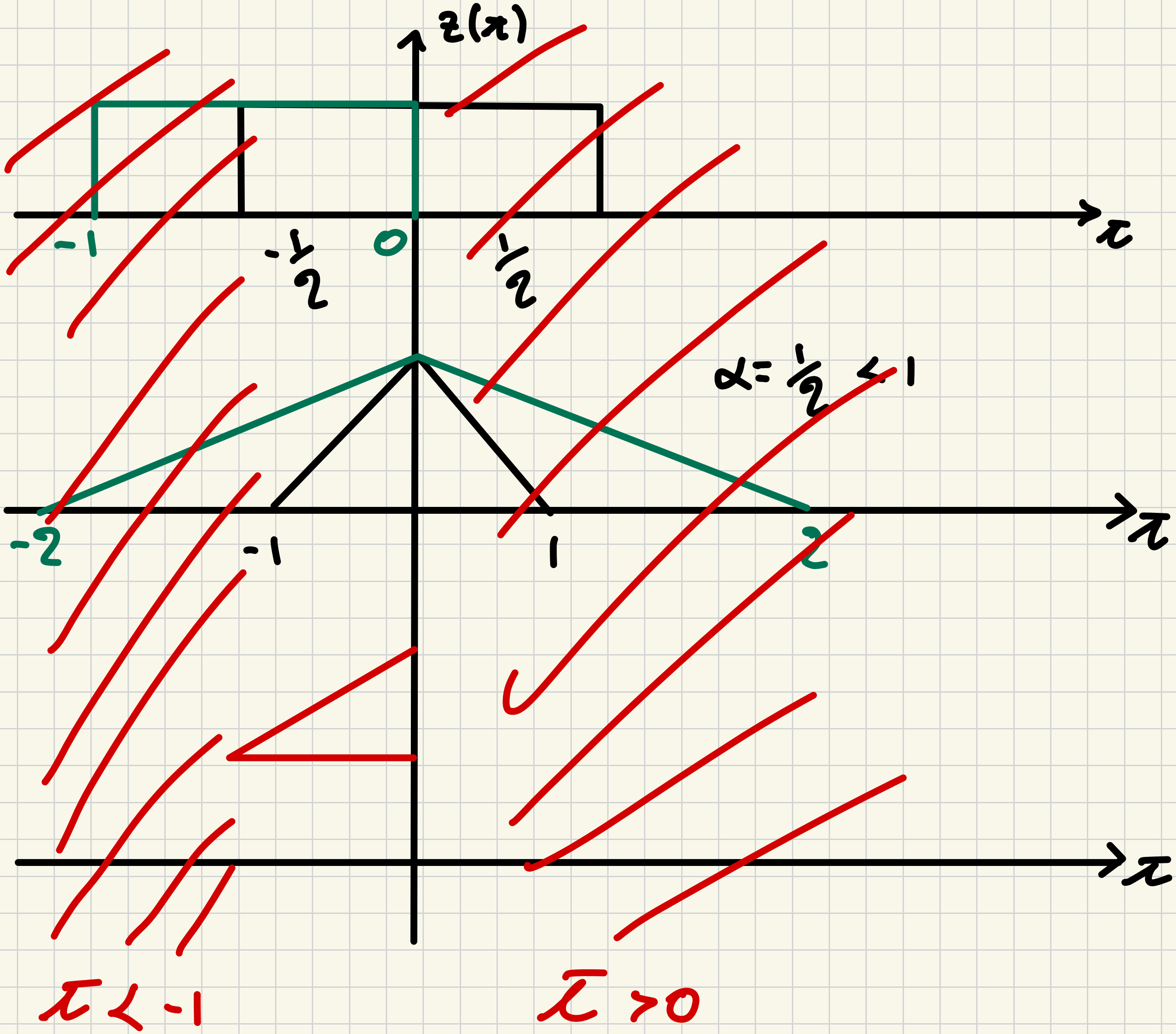
$z\left(\frac{3}{2}\right) = \text{tri}(0) = 1$

$$z(t) = \mathrm{rect}\left(\frac{t}{10} - 4\right) = \mathrm{rect}\left(\frac{1}{10}(t - 40)\right)$$



$z(t) = \mathrm{rect}\left(t + \frac{1}{2}\right) \cdot 3\,\mathrm{tri}\left(\frac{t}{2}\right)$

$x(t)$ $y(t)$



$$z(x) = \mathrm{rect}\left(\frac{x}{2} - 4\right) + \mathrm{tri}\,(x + 2)$$