08/31/20

Digital Signal Processing

DSP is the use of digital processing (such as by computers or more specialized digital signal processors) to perform a wide variety of signal processing operations.

Digital signals processed in this manner are a sequence of numbers that represent samples of a continuous variable in a domain (such as time, space, frequency)

Signal Processing

- Analog SP
- Digital SP
  - audio, speech, sonar, radar, sensor array processing
  - statistical signal processing
  - data compression, video coding
  - SP for communications, control, biomedical engineering

DSP can involve linear and nonlinear operations.

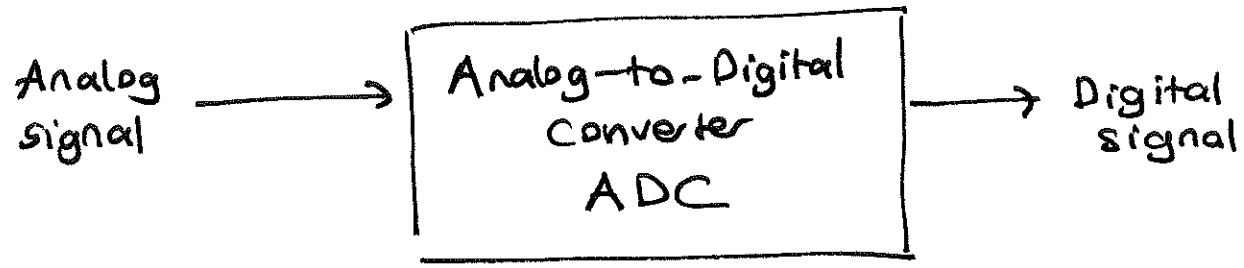
in time, frequency, spatial-temporal domains, wavelet.

Digital Filtering

Linear digital filter (time invariant) : Output = Input * Impulse Response.

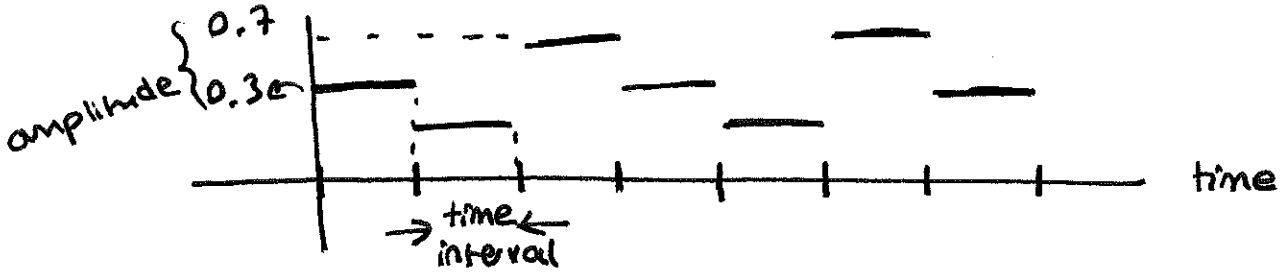
Z-plane : z transform provides a tool for analyzing stability of digital filters.

Signal Sampling



sampling is done in 2 stages : discretization and quantization

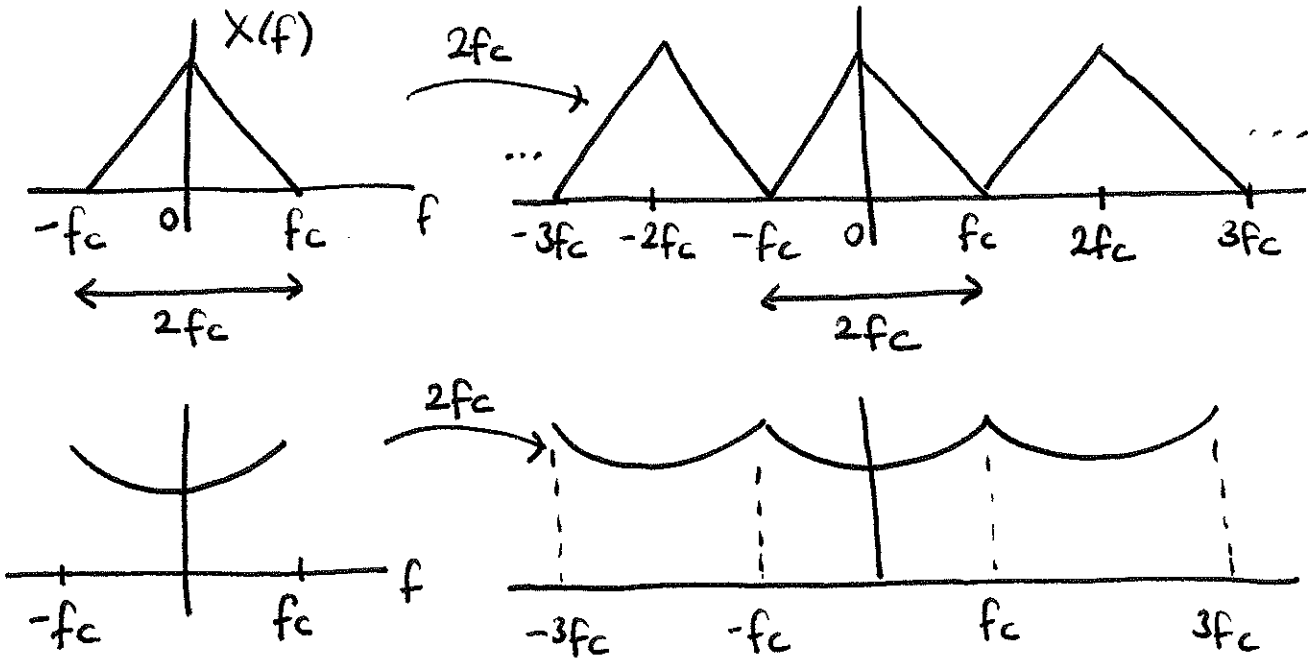
Discretization :



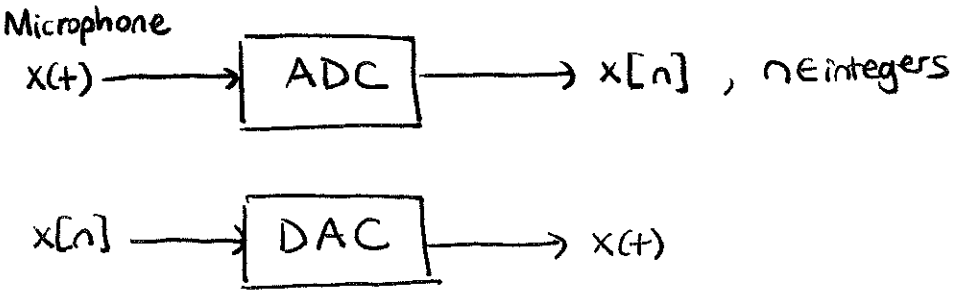
Quantization : Each amplitude is approximated by a value from a finite set of values (e.g., rounding numbers to integers)

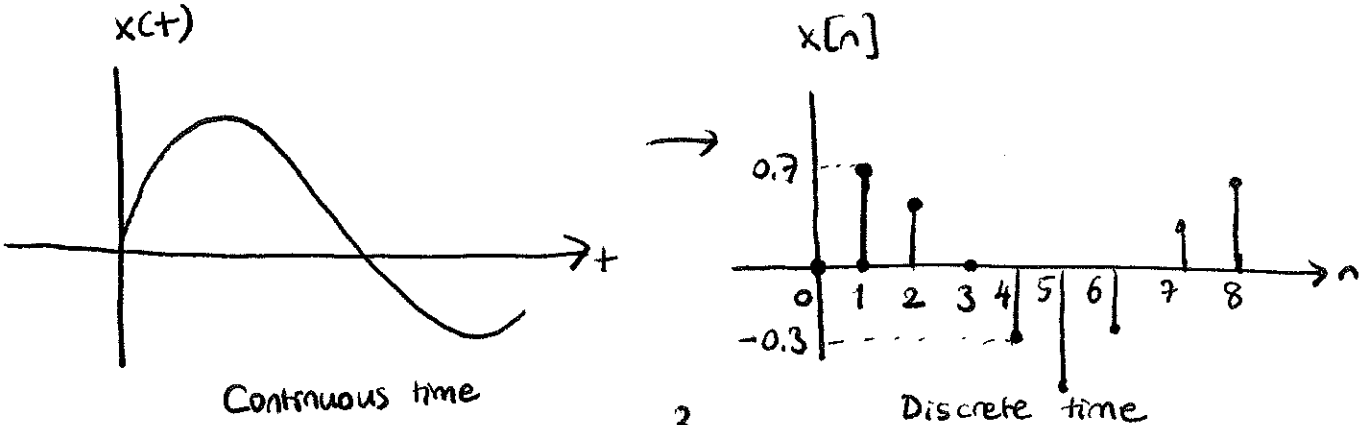
The Nyquist - Shannon Sampling Theorem

This theorem states that a signal can be reconstructed from its samples if the sampling rate is greater than twice the highest frequency component in the signal.



Example



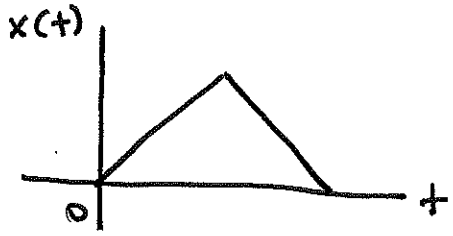


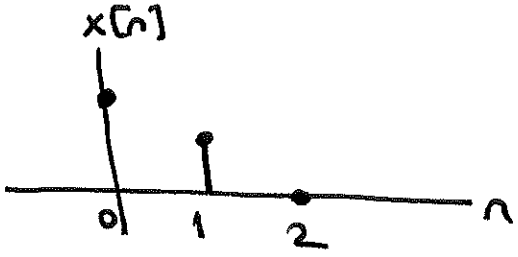
Example Human ear can hear between

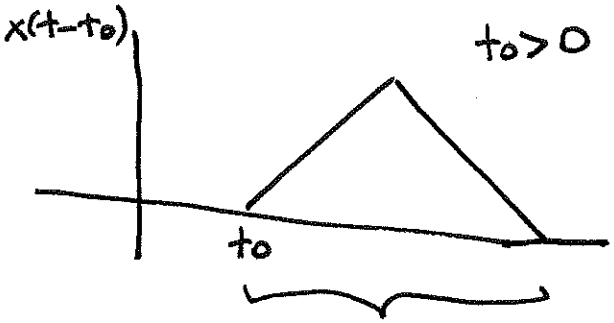
20 Hz — 20 kHz

Sampling rate $\approx$ 40 kHz

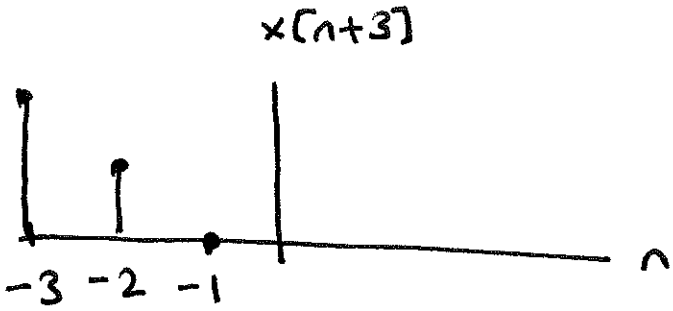
Time shift



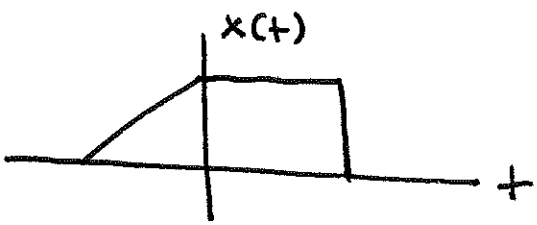


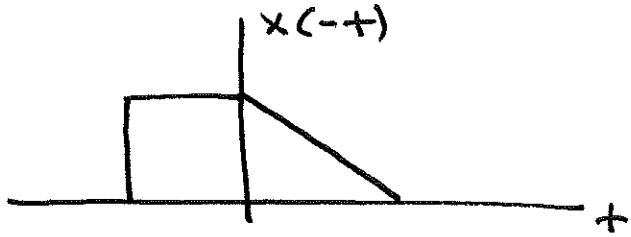


delayed version

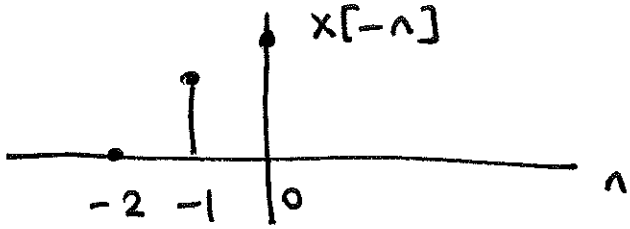


Flipping

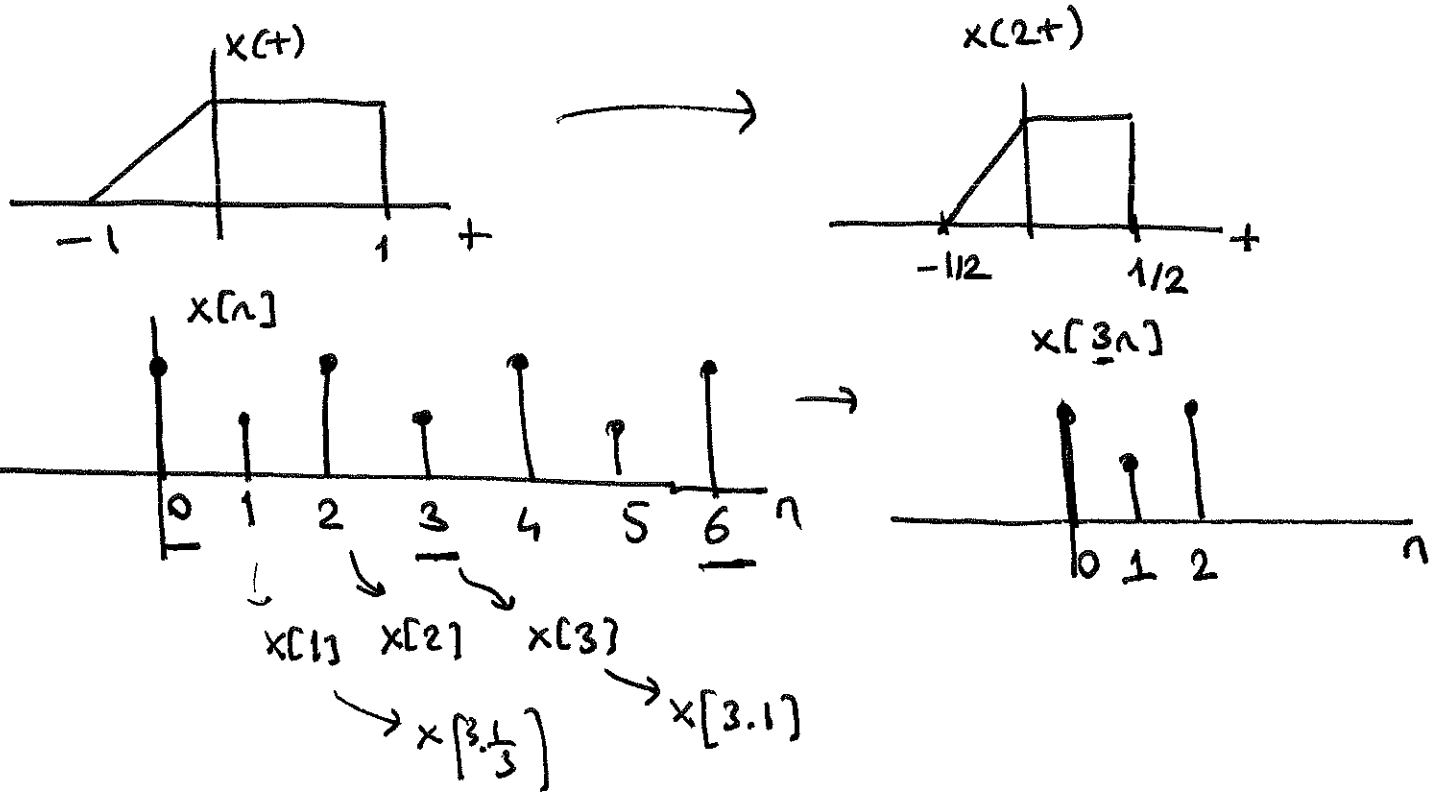




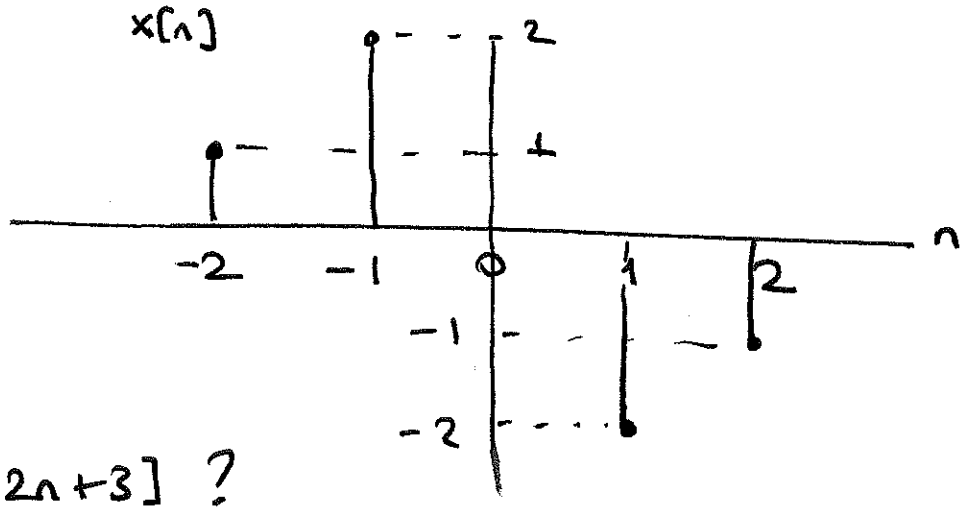
(playing backwards)



Scaling



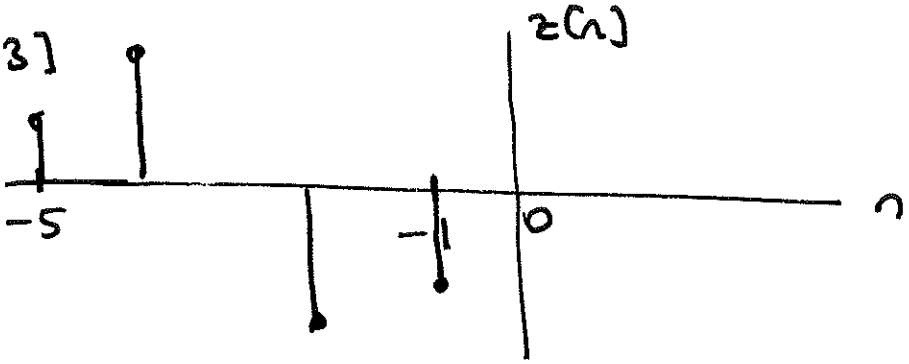
Example



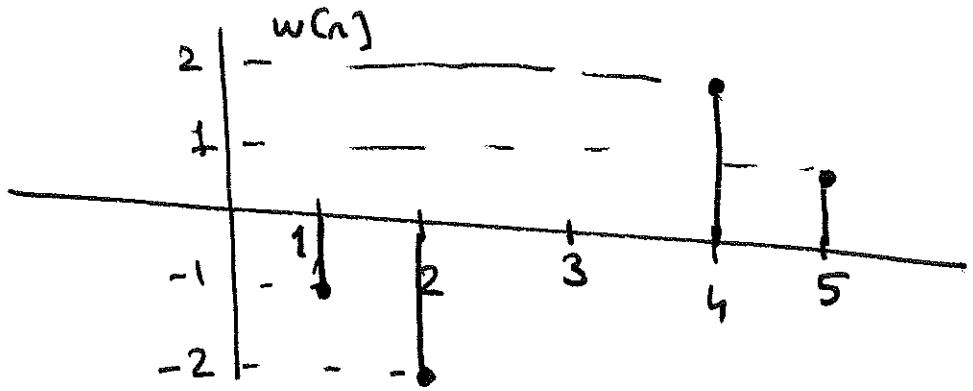
$x[-2n+3]$?

order of operations: Shift → flip → Scale

$z[n] = x[n+3]$



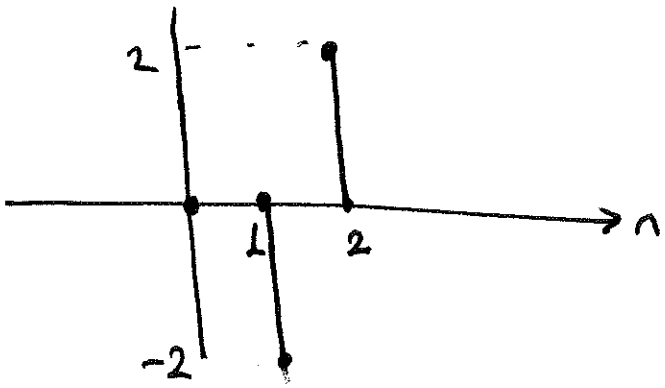
$w[n] = z[-n] = x[-n+3]$



Scaling: $x[-2n+3]$

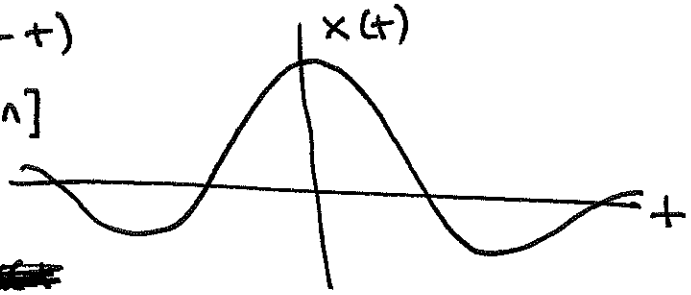
$w[n] = x[-n+3]$

$w[2n] = x[-2n+3]$



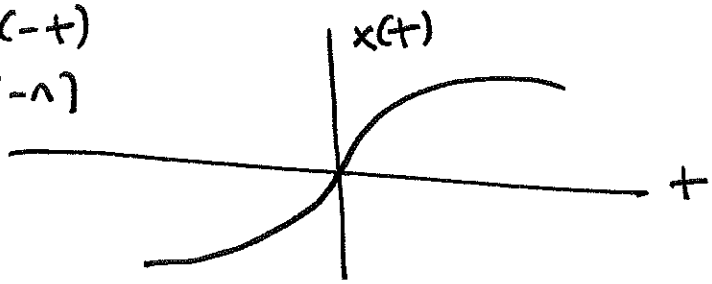
Even signals : $x(t) = x(-t)$

$x[n] = x[-n]$



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

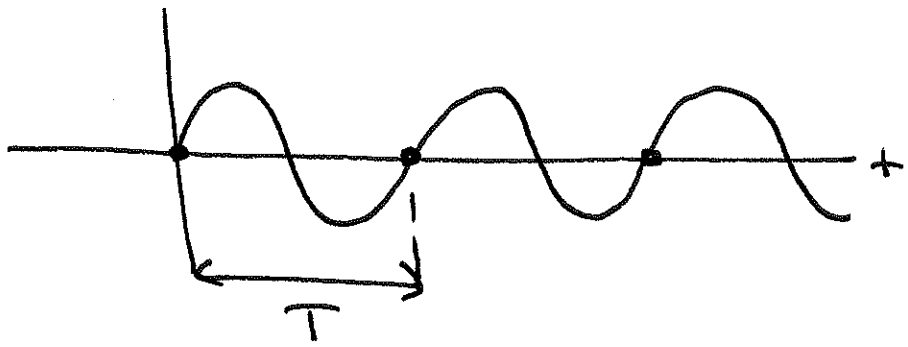
$x[n] = -x[-n]$



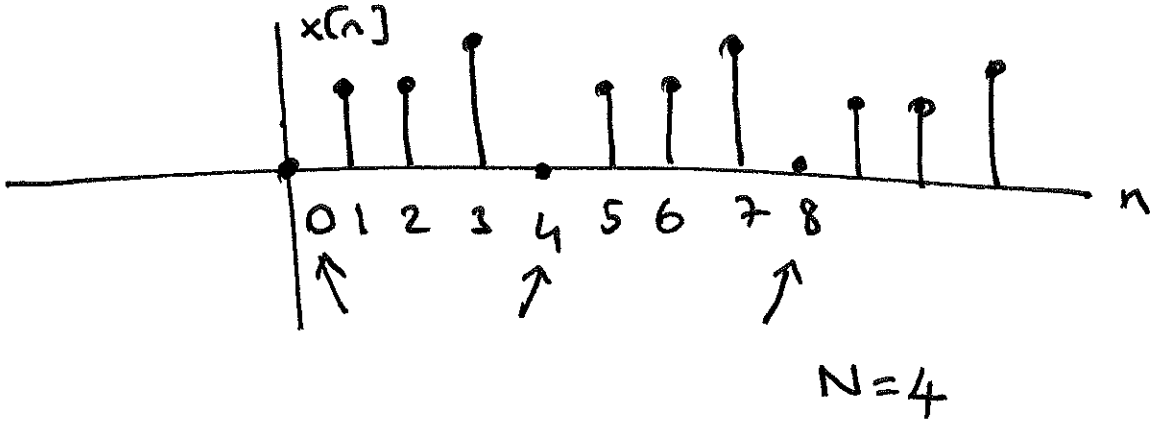
$x[n] = \text{even}(x[n]) + \text{odd}(x[n])$

Periodicity

$x(t) = x(t + T)$, for all t

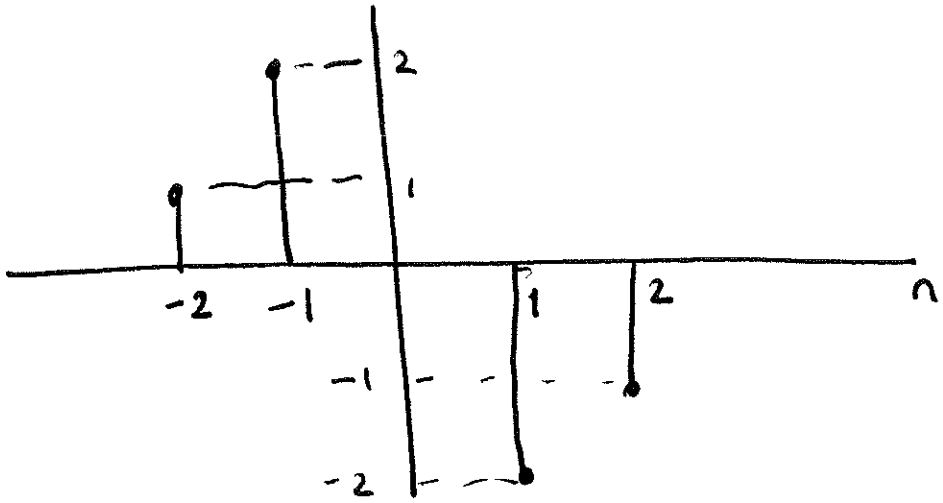


$x[n] = x[n+N]$, $N \in$ integer , for all n

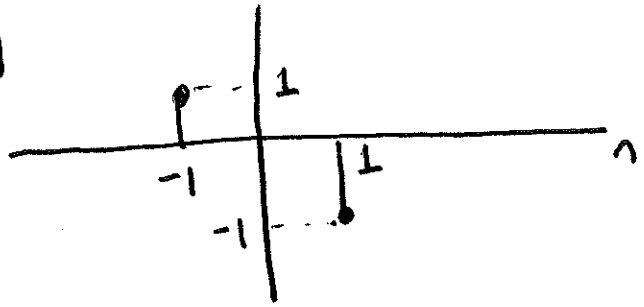


Scale → Flip → Shift & Why it does not work in our example!

$x[n]$



$z[n] = x[2n]$



$w[n] = z[-n] = x[-2n]$

$x[-2n+3] \neq w\left[n \mp \frac{3}{2}\right]$

not possible in discrete time

(Extra)

Digital Signal Processing

5G
MIMO,
Compression,
Digital commun.,
Noise cancelling

Communications

Storage, data
compression,
ADC/DAC,
Sonar,
Radar

Systems

Digital
signal
controllers,
Process
control

Control

Medical

Imaging
(ECG,
EEG,
MRI)

Practical
implementation
of maximum
likelihood
decoding

Optimization

Machine
Learning

Principle
components,
Classification

Computing

Data compression,
Cloud computing,
Computer vision

Physics
& Math.

Wavelet
transforms,
Compressive
Sensing,
Group
testing

Biology

Cell signaling,
DNA sequencing,
Metabolic
pathways,