SIGNALS AND SYSTEMS

COE150

SIGNALS

Signal can be something that conveys information.

The information in a signal is represented as variations in the patterns for some quantity that can be manipulated, stored, or transmitted by a physical process.

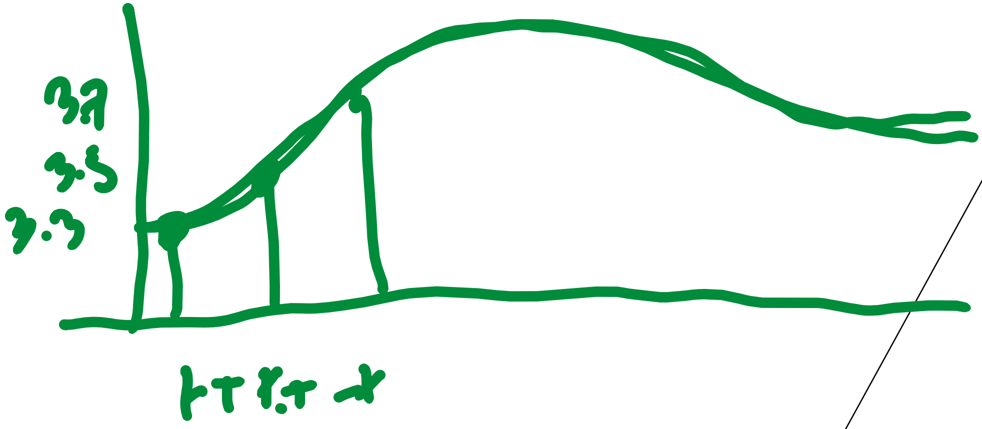
communication digital format

DIGITAL SIGNAL PROCESSING

The processing of signals using computers and other digital systems.

input sound mic → DSP computer → 0.1 → output

Digital signal processing involves the **sampling**, **quantization** and **processing** of these signals for many applications.



3.3
3.5
3.7

DETERMINISTIC AND RANDOM SIGNALS

A **deterministic signal** is a function of one or more independent variables such as time, distance, position, temperature, and pressure.

Ex. $s(t) = 3\sin(2.1\pi t + 0.3198)$

! specific value

A signal that is determined in a random way and cannot be predicted ahead of time is a **random signal**.

level

speech recognition

repetitive

TYPICAL SIGNAL PROCESSING OPERATIONS

1. The continuous time signal is converted to a digital signal (analog to digital converter – ADC)

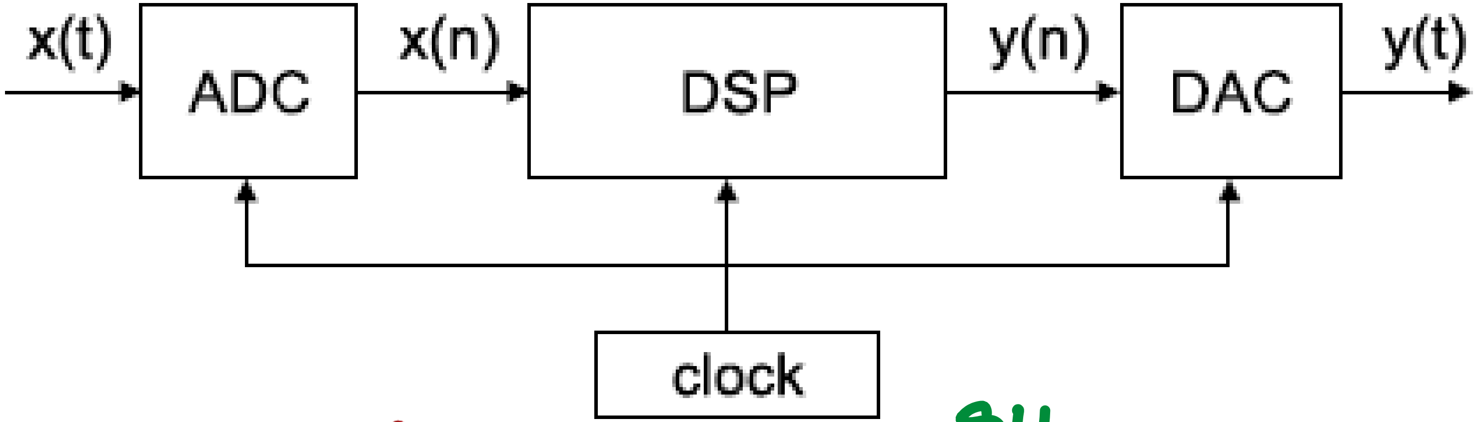
2. The digital signal is processed with a digital system (such as a digital signal processor – DSP) to meet the requirements of some practical application

computer system

3. The digital output signal is converted to a continuous time output signal (digital to analog converter – DAC).

speaker

CONCEPTUAL BLOCK DIAGRAM OF A TYPICAL SYSTEM



speaker
analog
input

sig
discr.
discrete time signal $x[n]$

CTS $x(t)$

BASIC TIME DOMAIN OPERATIONS

1. Scaling
2. Delay
3. Addition

1. SCALING

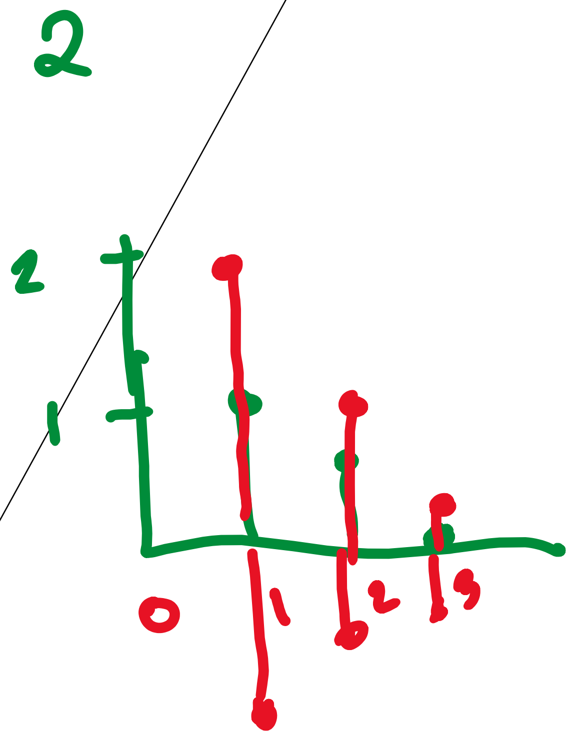
The **scaling operation** involves amplification or attenuation for continuous time signals and multiplication for digital signals.

Continuous Time Signal:

$$y(t) = \alpha x(t)$$

Discrete Time Signal:

$$y(n) = \alpha x(n)$$

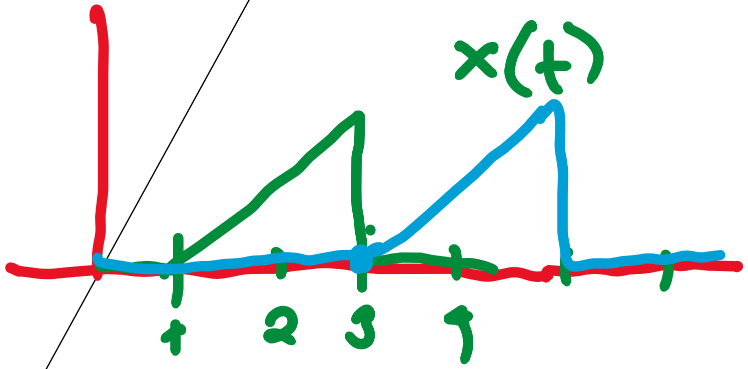


DELAY

The delay operation generates a signal that is a delayed replica of the original signal.

Continuous Time Signal:

$$y(t) = x(t - t_0)$$



$y(t) = x(t-2)$

$t=2$

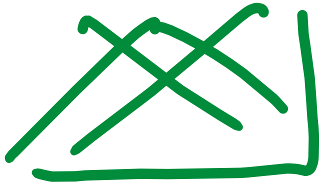
Discrète Time Signal:

$$y(n) = x(n - m)$$

FILTERING

It involves passing a certain range of frequencies in the signal to the output and blocking the others.

The range of frequencies allowed to pass is called the **pass band** and the range of frequencies blocked is called the **stop band**.



30Hz → 50Hz

stop band < 30Hz

30Hz - 50Hz

> 50Hz

band stop filter

band pass filter

range

30Hz high pass filter

30Hz low pass filter

REPRESENTING DISCRETE TIME SIGNALS

1. Table
2. Functional representation
3. Sequence representation

n	-3	-2	-1	0	1	2	3
$x(n)$	5	7	3	-5	2	8	0

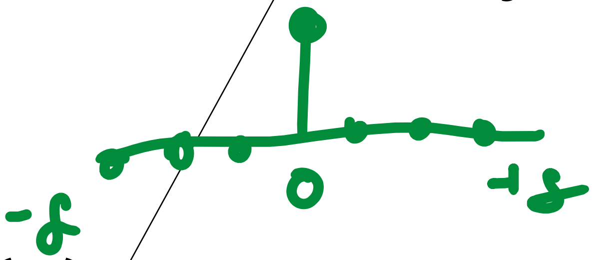
$$x(n) = \begin{cases} 1 & n < 0 \\ 0 & n = 0 \\ 2 & 0 < n \leq 5 \\ 3 & n > 5 \end{cases}$$

$$x(n) = \{5, 7, 3, \underset{\uparrow}{-5}, 2, 8, 0\}$$

BASIC DISCRETE TIME SIGNALS

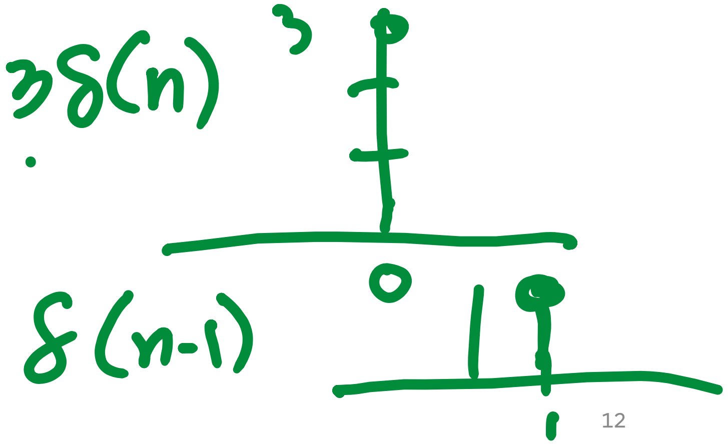
Unit Impulse

An ideal impulse function is a function that is zero everywhere but at the origin, where it is infinitely high.



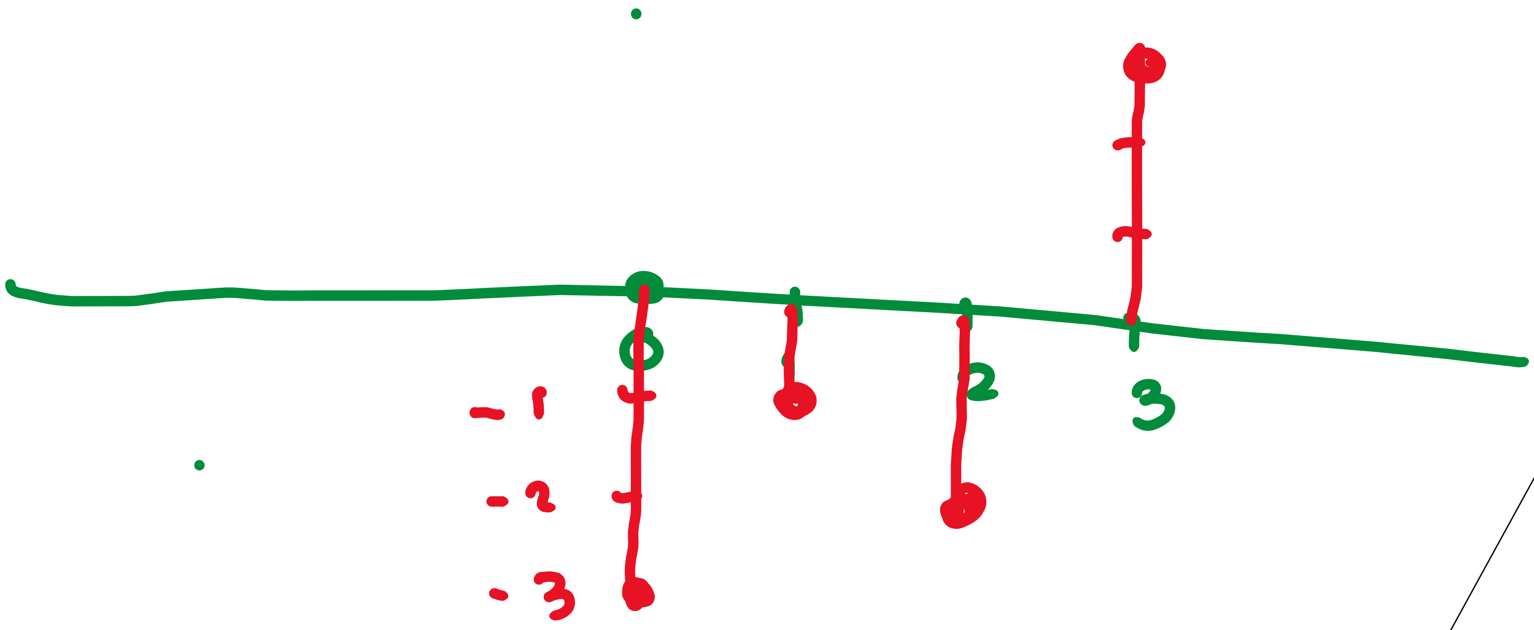
The **unit impulse sequence** is denoted as $\boldsymbol{\delta(n)}$ and is defined as

$$\delta(n-m) = \begin{cases} 1 & \text{for} \quad n = m, \\ 0 & \text{for} \quad n \neq m. \end{cases}$$



impulse sequence

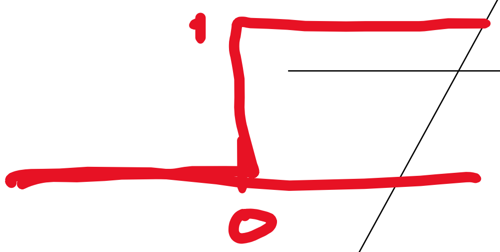
$$S_i(n) = -3\,\delta(n) - \delta(n-1) - 2\delta(n-2) + 3(n-3)$$



BASIC DISCRETE TIME SIGNALS

Unit Step

$u(n) = \begin{cases} 0, & n < 0 \\ 1, & n \geq 0 \end{cases}$



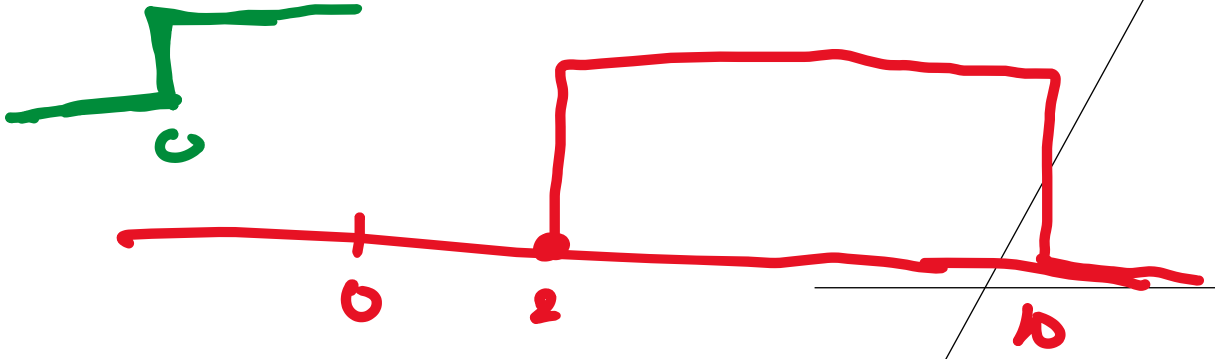
The **unit step sequence** is denoted $\boldsymbol{u(n)}$ and is defined as

5

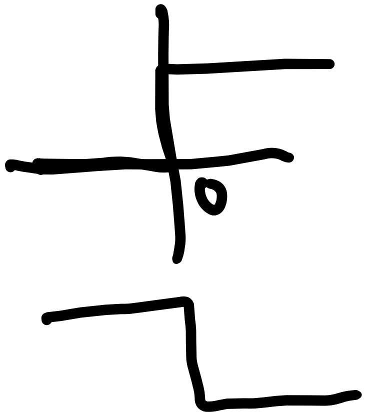
$$u(n - m) = \begin{cases} 0 & \text{for} \quad n < m, \\ 1 & \text{for} \quad n \geq m. \end{cases}$$

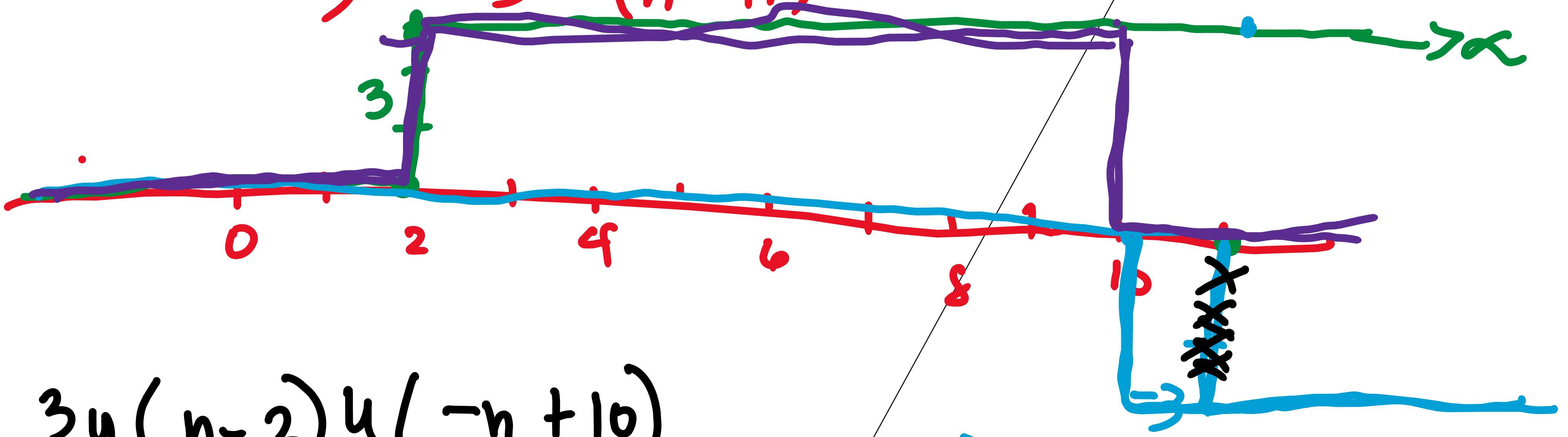
$u(n-5)$

$$S_2(n) = \begin{cases} 0, & n<2 \\ 3, & 2\le n\le 10 \\ 0, & n>10 \end{cases}$$



$$S_2(n) = 3u(n-2) - 3u(n-11)$$





$$S_2(n) = 3u(n-2)u(-n+10)$$

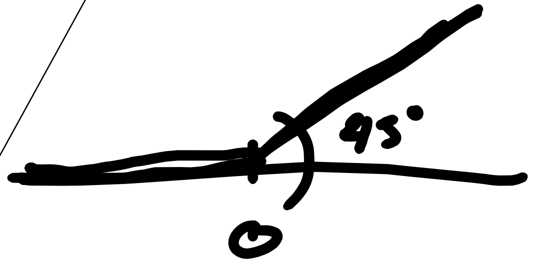
$3+(-3)=0$

BASIC DISCRETE TIME SIGNALS

Unit Ramp

The **unit ramp sequence** is denoted $\boldsymbol{u_r(n)}$ and is defined as

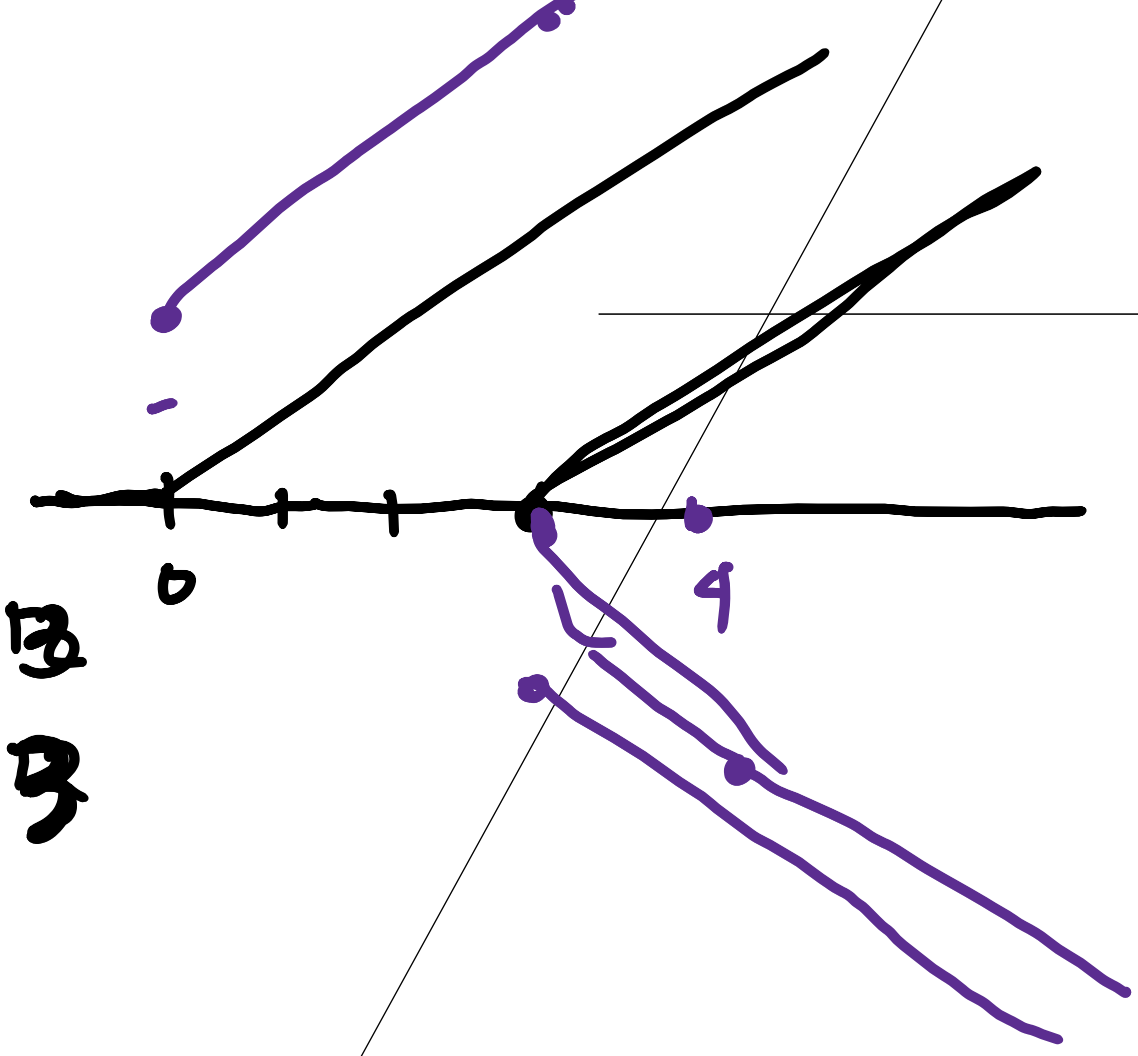
$$u_r(n-m) = \begin{cases} 0 & \text{for} \quad n < m, \\ (n-m) & \text{for} \quad n \geq m. \end{cases}$$



$$s_3(n) = 2u_r(n) - 2u_r(n-3)$$

$$u_r(n) = \begin{cases} 0, & \forall n < 0 \\ n, & \forall n \geq 0 \end{cases}$$

$$u_r(n-3) = \begin{cases} 0, & \forall n < 3 \\ n-3, & \forall n \geq 3 \end{cases}$$



$$2(4) - 2(4-3)$$

$$= 8 - 12 = -4$$

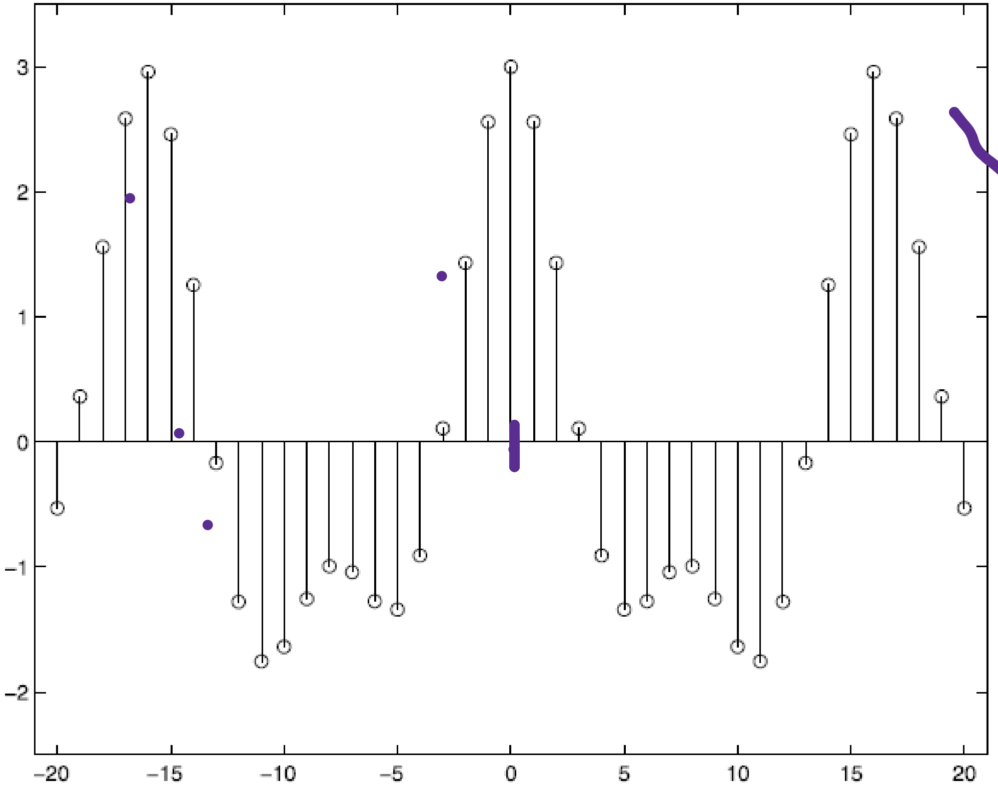
EVEN AND ODD SIGNALS

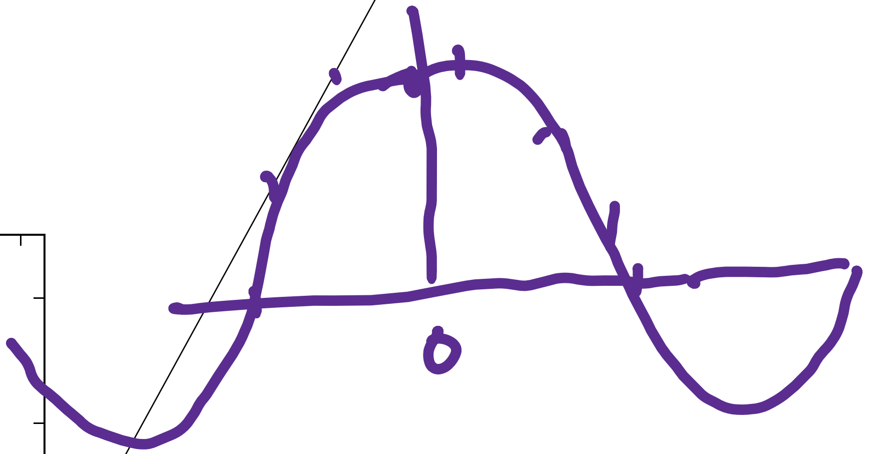
A signal is even if

$$x(-n) = x(n)$$

even signal symmetry at 0

$y = \cos\theta$

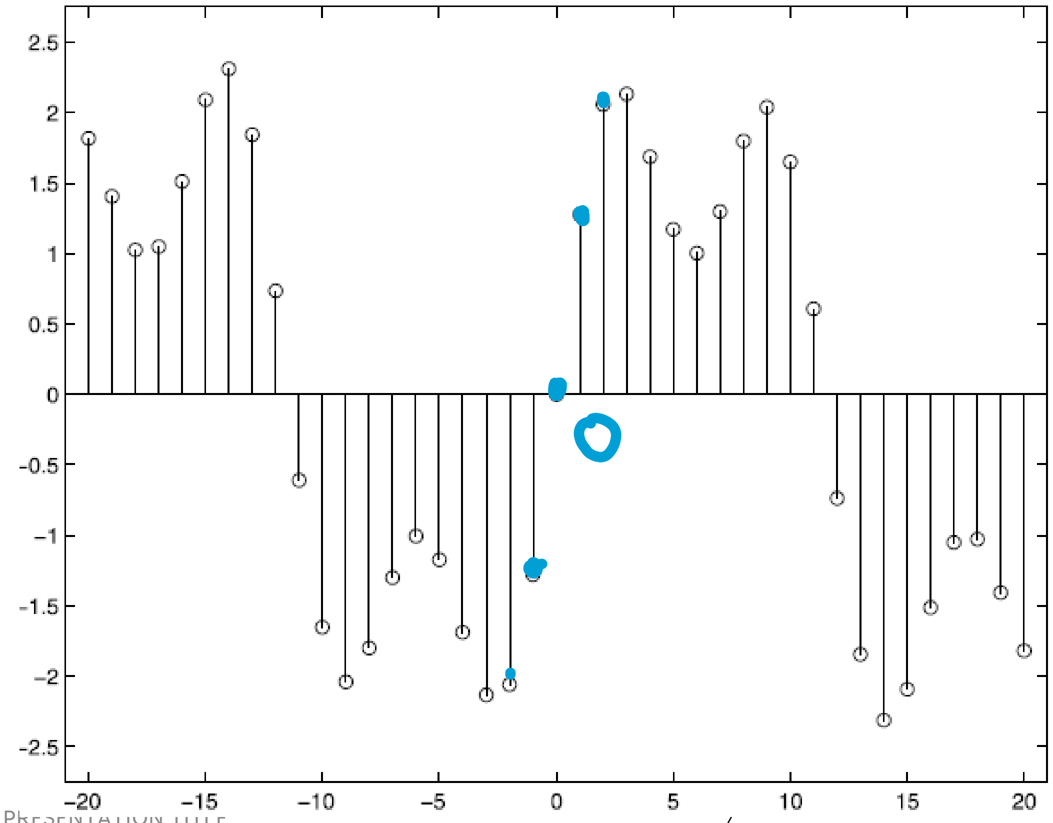


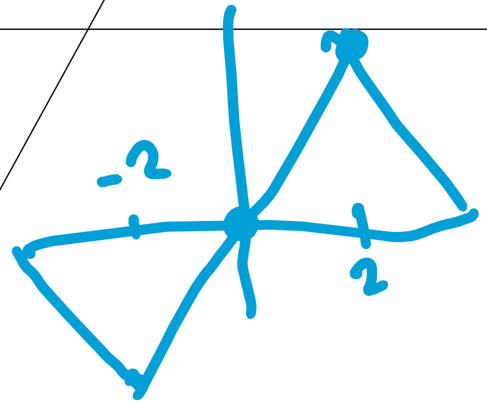


EVEN AND ODD SIGNALS

A signal is odd if

$$x(-n) = -x(-n)$$



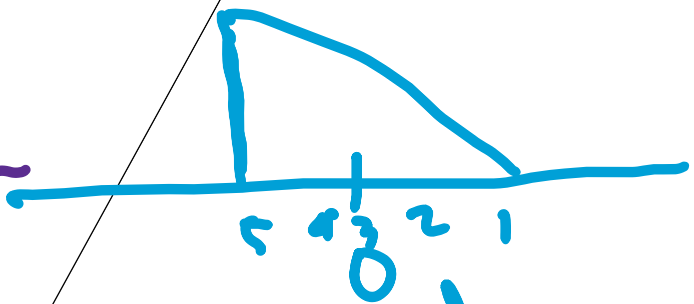


EVEN AND ODD SIGNALS

$x(-n) =$ flipping the signal from left to right

An arbitrary signal, $\boldsymbol{x(n)}$, can be separated into its even and odd parts using the following equations:

$$
\begin{aligned}
x(n) &= x_e(n) + x_o(n), \\
x_e(n) &= 0.5\,[x(n) + x(-n)], \\
x_o(n) &= 0.5\,[x(n) - x(-n)].
\end{aligned}
$$

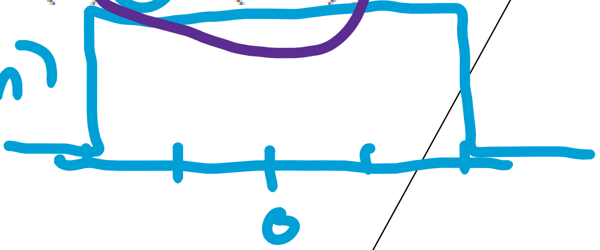


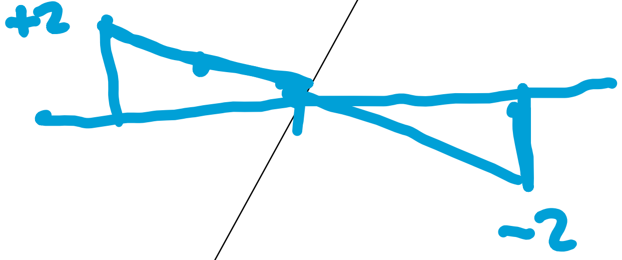
$$
\begin{array}{ccccc}
-2 & -1 & 0 & 1 & 2 \\
\end{array}
$$

$x(n) = \{5, 4, \underset{\uparrow}{3}, 2, 1\}$

$x_e(n) =$
(-2) $0.5(5+1) = 3$
(-1) $0.5(4+2) = 3$
0 $0.5(3+3) = 3$
1 $0.5(2+4) = 3$
2 $0.5(1+5) = 3$

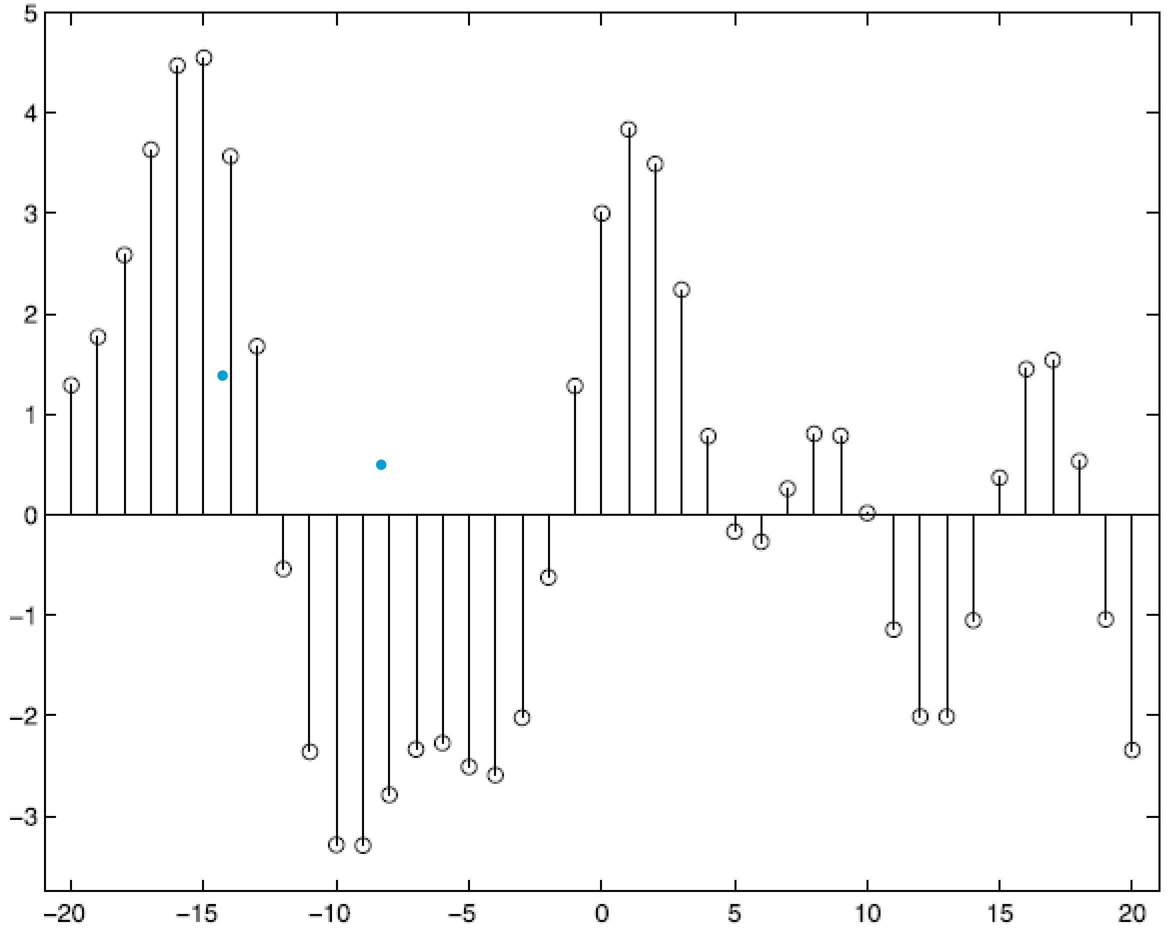
$x_e(n)$





$x_o(n)$
$(-2) = 2$
$(-1) = 1$
$(0) = 0$
$(1) = -1$
$(2) = -2$

FIG 1. SIGNAL THAT IS NEITHER ODD OR EVEN
FIG 2. PLOT OF FLIPPING THE SIGNAL



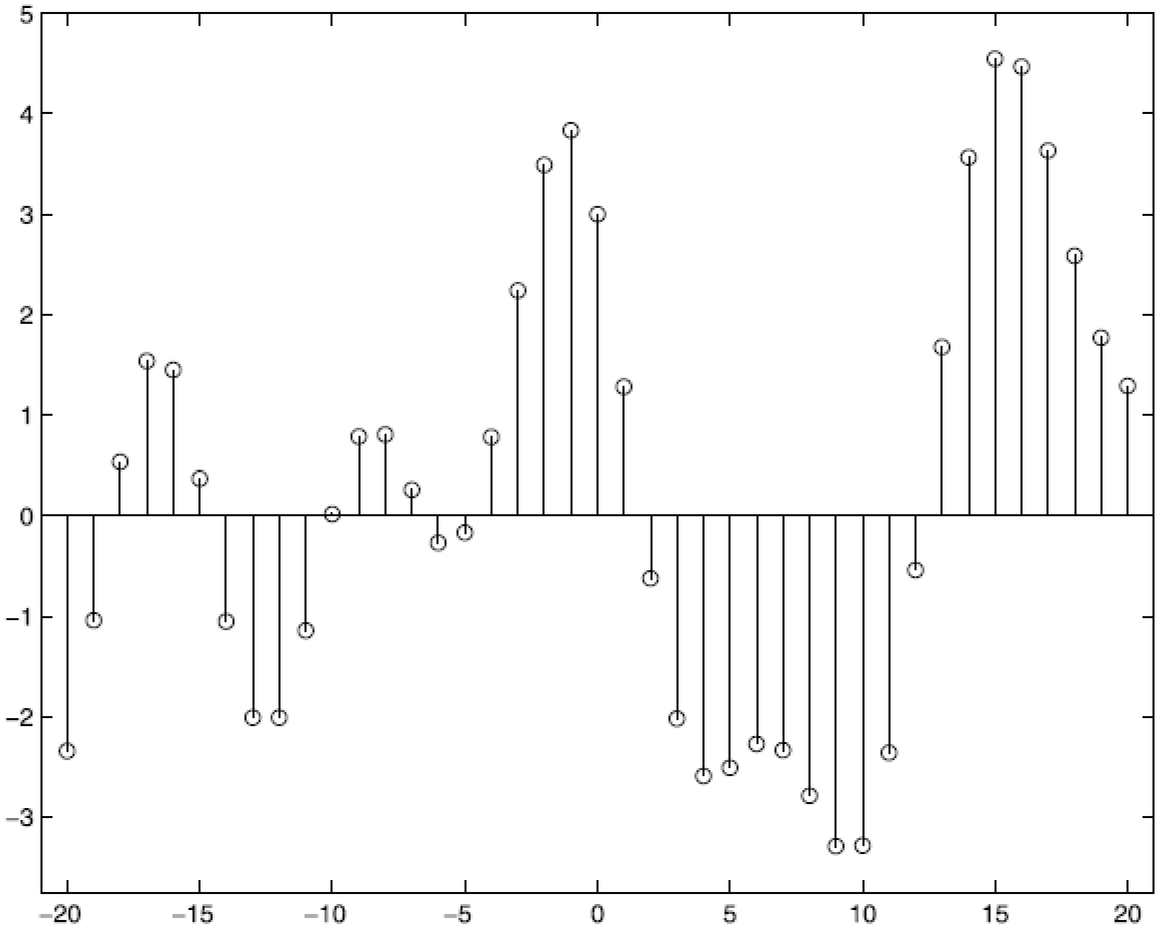


FIG 3. EVEN PLOT
FIG 4. ODD PLOT