SIGNAL CLASSIFICATION AND BASIC SIGNALS

MODULE 1

CLASSIFICATION OF SIGNALS

SINGLE CHANNEL & ONE DIMENSIONAL SIGNALS

Real valued & scalar

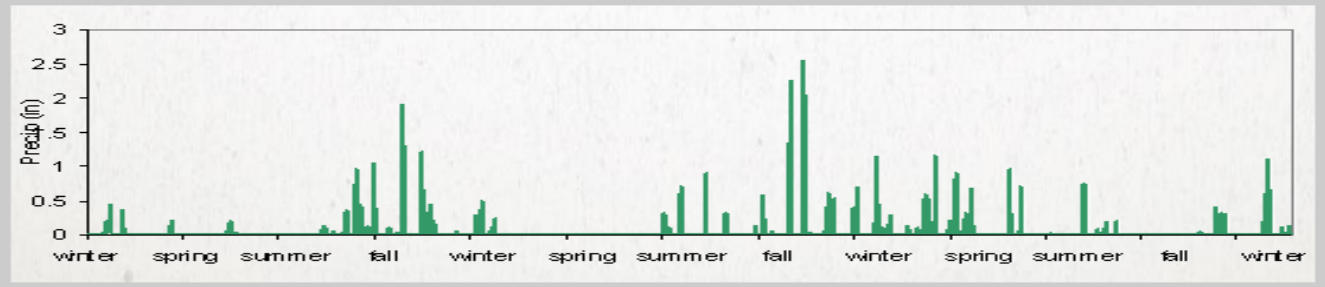
$$s_1(t) = A\sin 3\pi t$$

Independent variable

Single channel, One dimensional signal

complex valued & scalar

$$s_2(t) = A\cos 3\pi t + jA\sin 3\pi t$$



MULTI CHANNEL & MULTI DIMENSIONAL SIGNALS

VERY LARGE ARRAY

MULTI CHANNEL SIGNALS

Multi channel signal represented as a vector

$$\mathbf{s}(t) = \begin{bmatrix} s_1(t) \\ s_2(t) \\ s_3(t) \end{bmatrix}$$

Source 1

Source 2

Source 3

Channels

Examples

3 channel signal due to an Earth quake

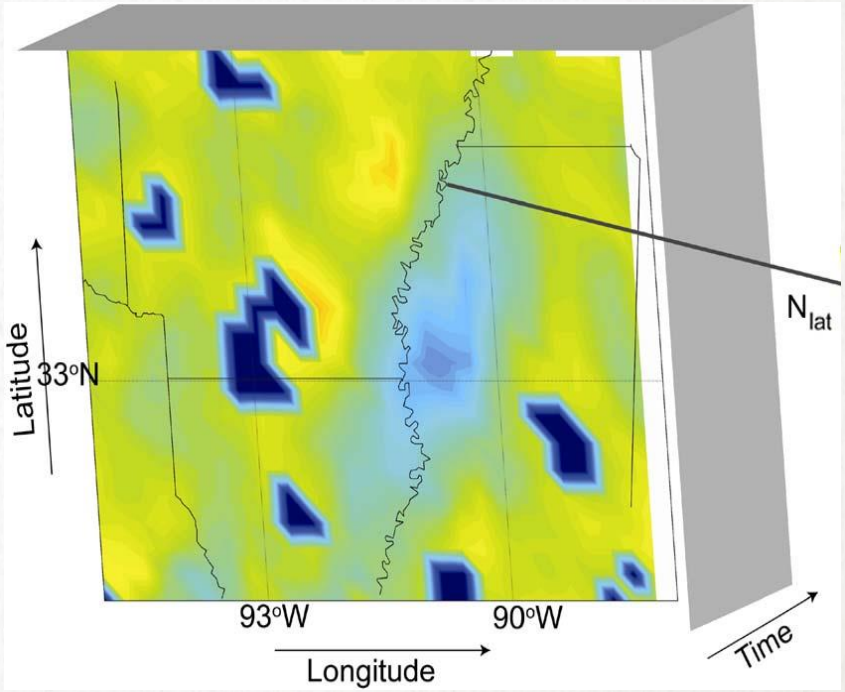
ECG Signals via 12 electrode sensor

MULTI DIMENSIONAL SIGNALS

2-D Signal (Image)

WorldView-2 Sensor: digital image

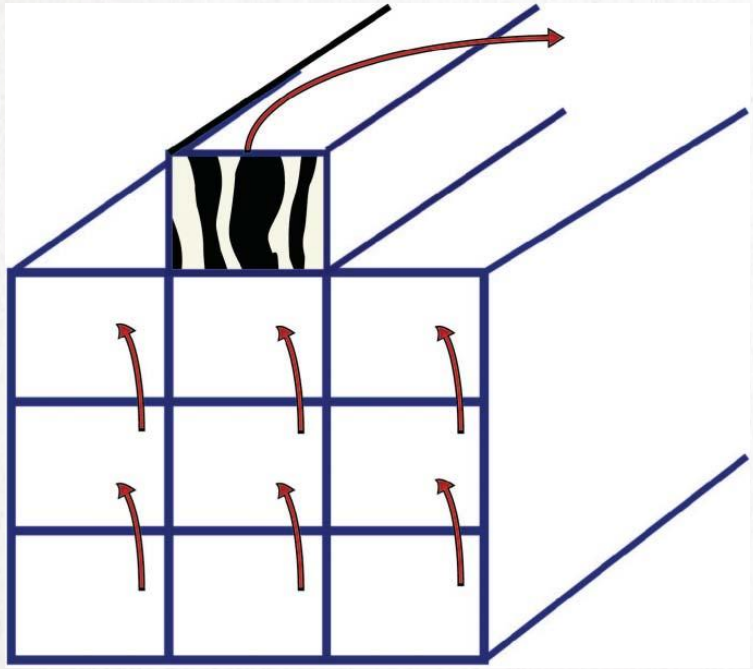
3-D Signal (Spatio-temporal data)



AMSR-E based Soil Moisture Dataset

ILLUSTRATION OF A 3D SIGNAL

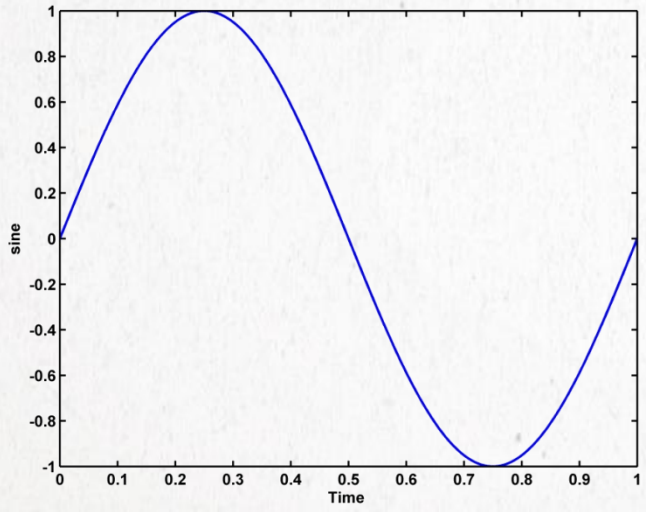
$$I(x, y, t)$$



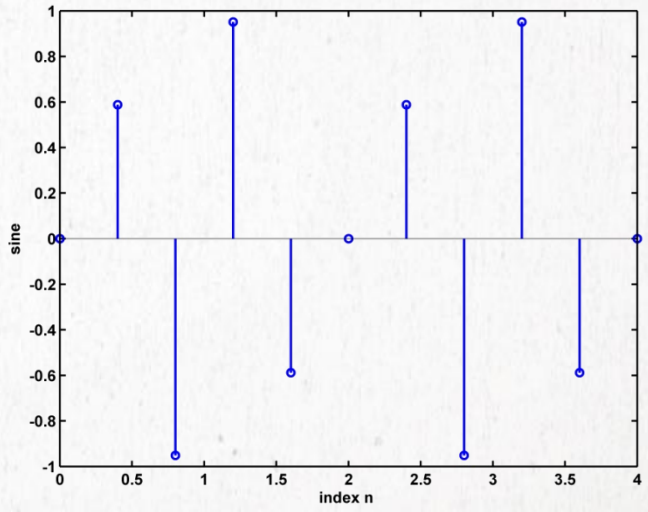
x – cells (along columns)
y – cells (along rows)
t – time (along 3rd dim)
Each cell (x,y)
X & Y can be
(1) Latitude & longitude values
(2) Integers representing uniform sized grid cells
(3) Key: Image or 2 D signal is a function of X & Y
(4) Nature of function changes with time

CONTINUOUS VS. DISCRETE SIGNALS

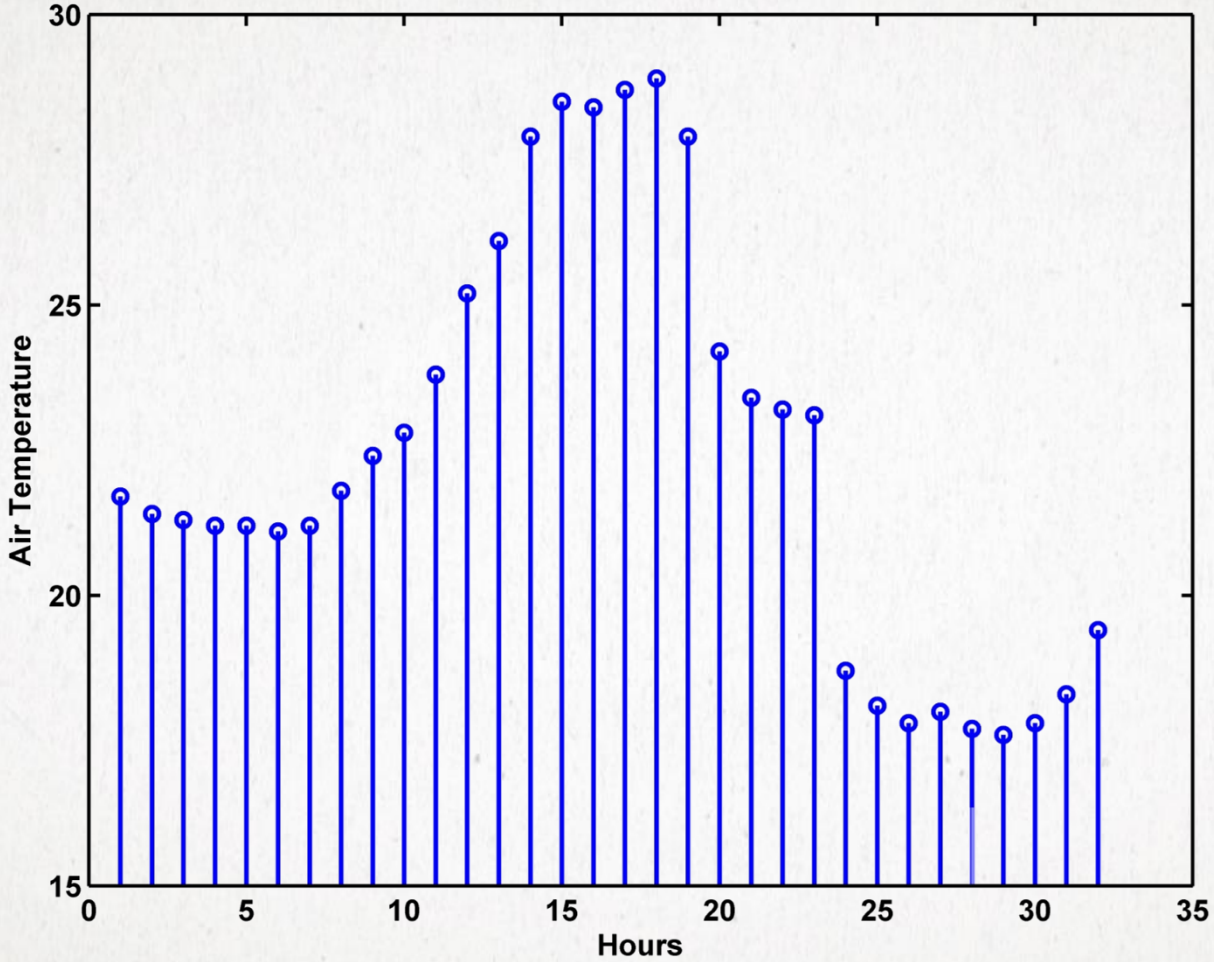
Continuous Signal



Discrete Signal



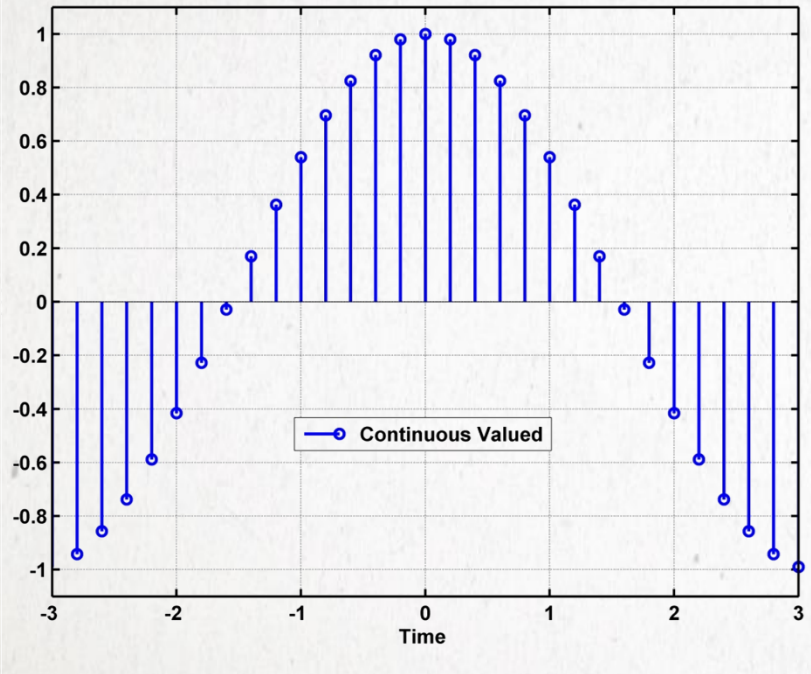
A REAL WORLD DISCRETE SIGNAL REPRESENTING A PHYSICAL PROCESS



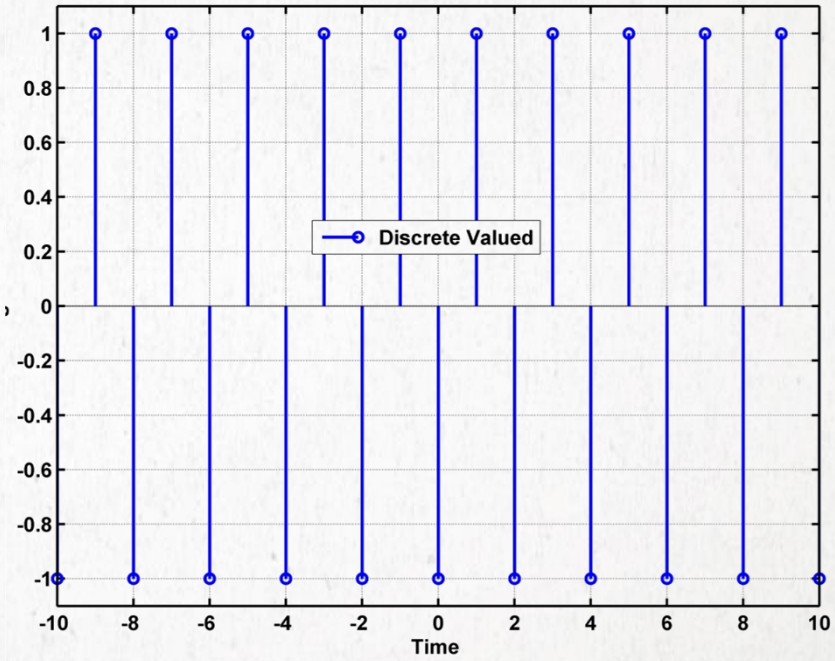
Hourly air temperature (deg Celsius) from a data site (climate analysis) at Mississippi SCAN Site Perthshire (2046)

CONTINUOUS VS. DISCRETE VALUED SIGNALS

DISCRETE SINUSOID

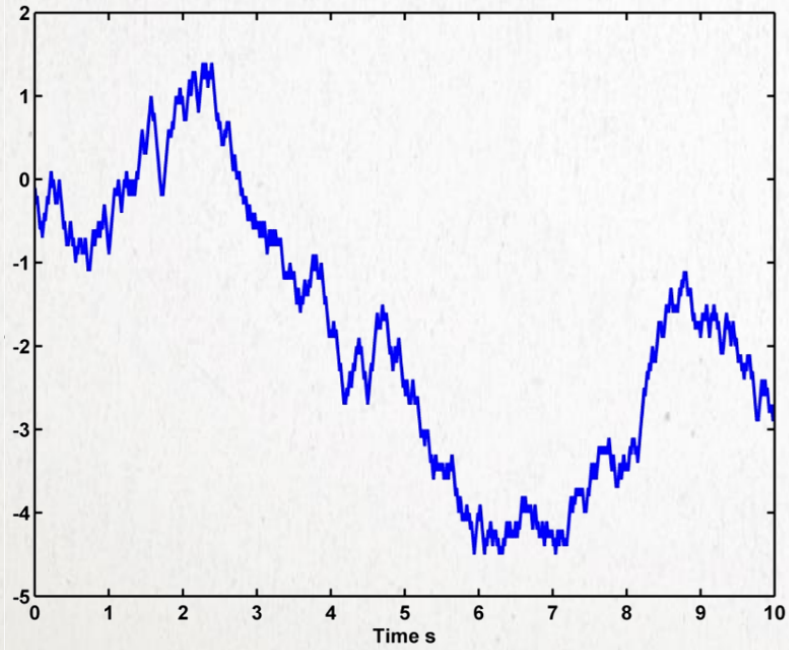


DIGITAL SIGNAL

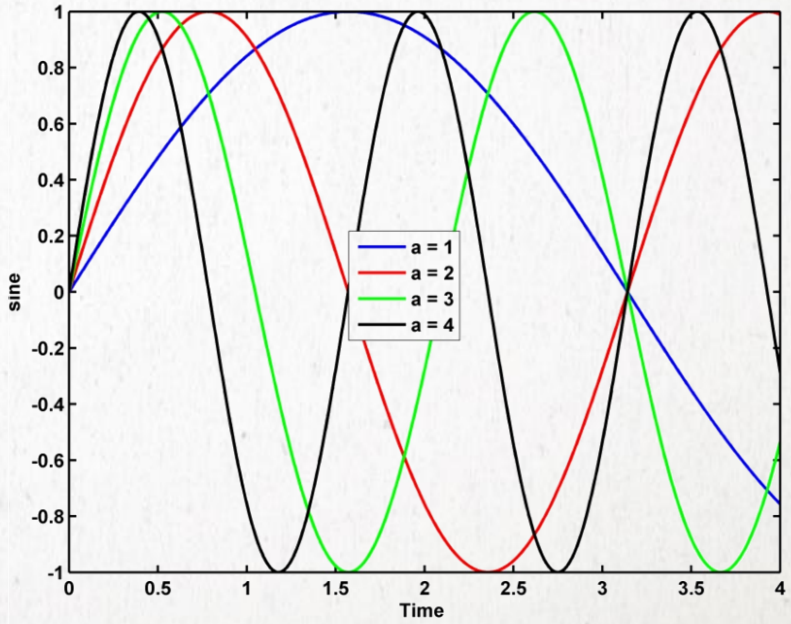


RANDOM VS. DETERMINISTIC SIGNALS

RANDOM SIGNAL (WEINER PROCESS)

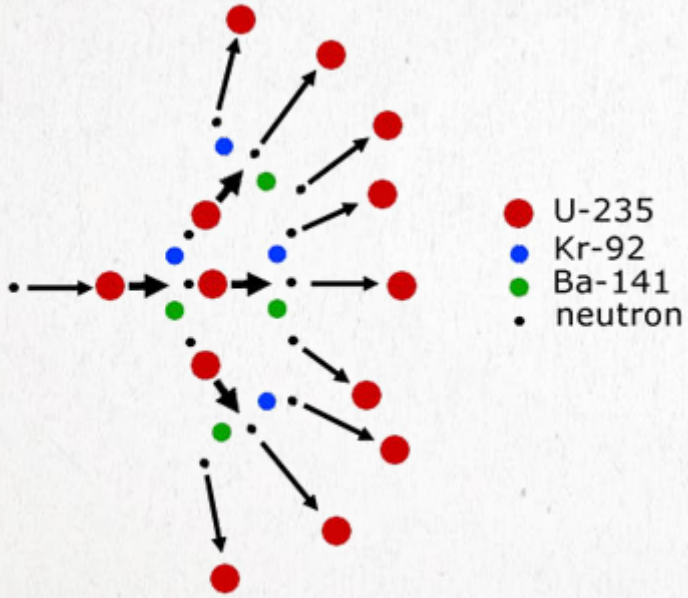


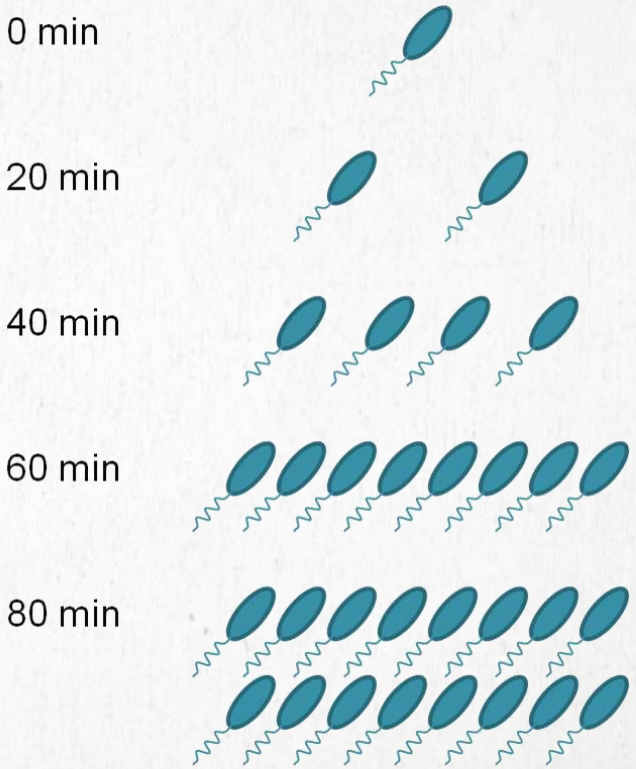
SINUSOIDS (DETERMINISTIC)



EXPONENTIAL AND SINUSOID SIGNALS

POSITIVE EXPONENTIAL PROCESSES

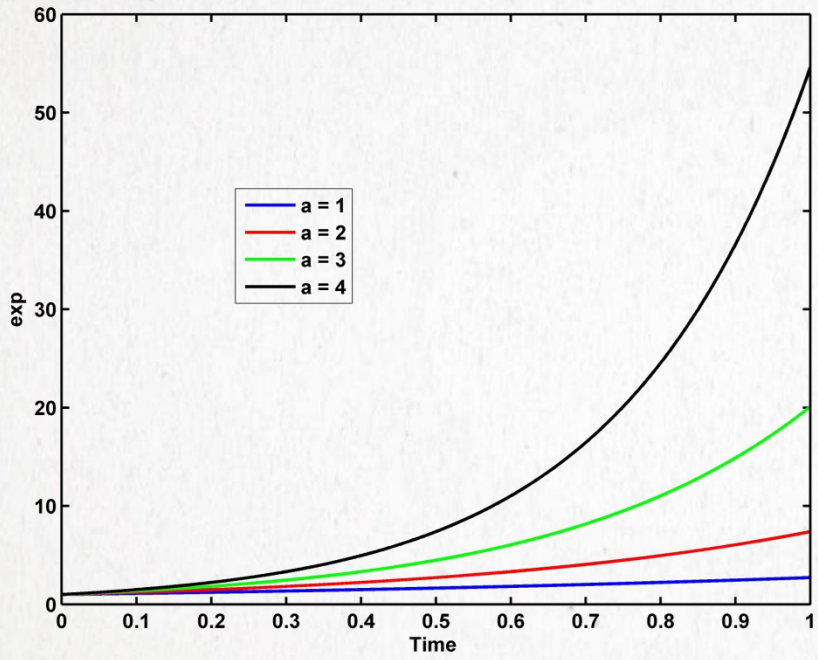




10 hours growth = > 1 Billion cells!

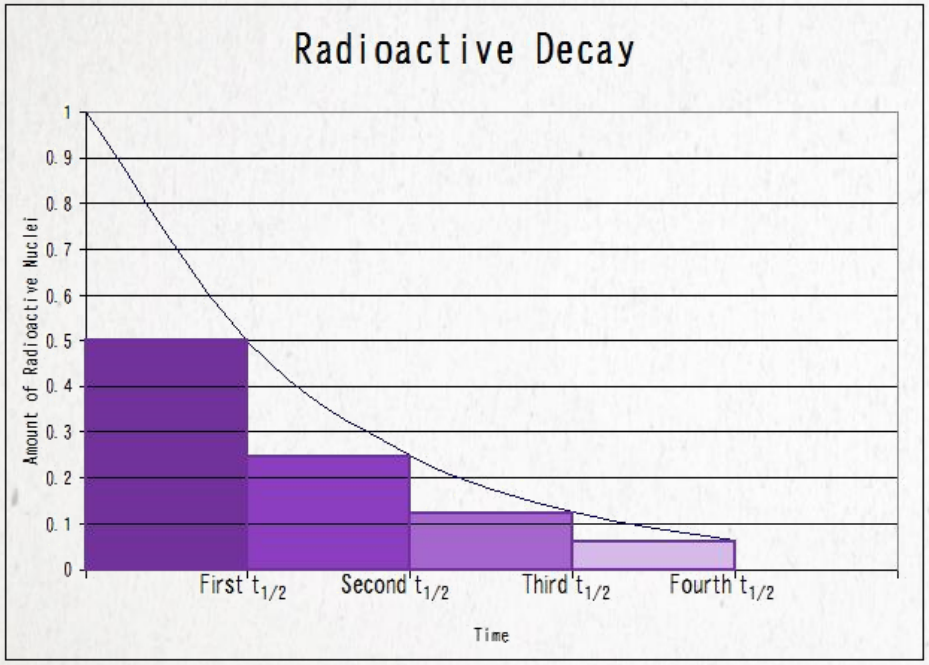
$$s(t) = \exp(at)$$

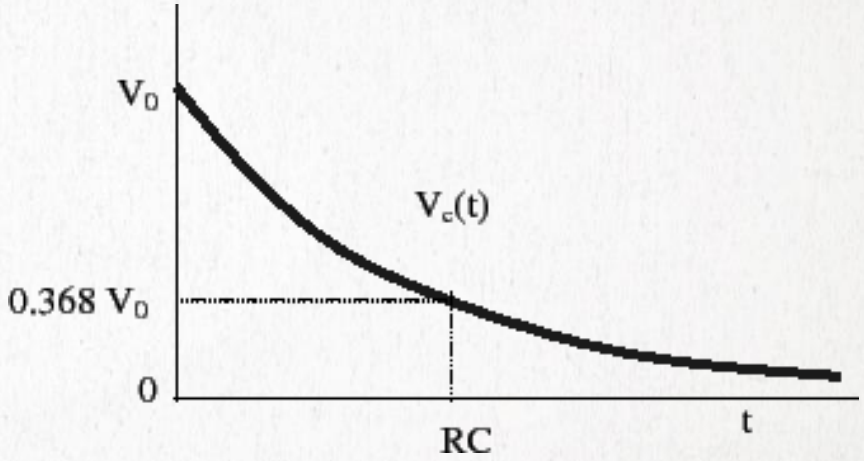
$$a > 0$$



REAL GROWING EXPONENTIAL

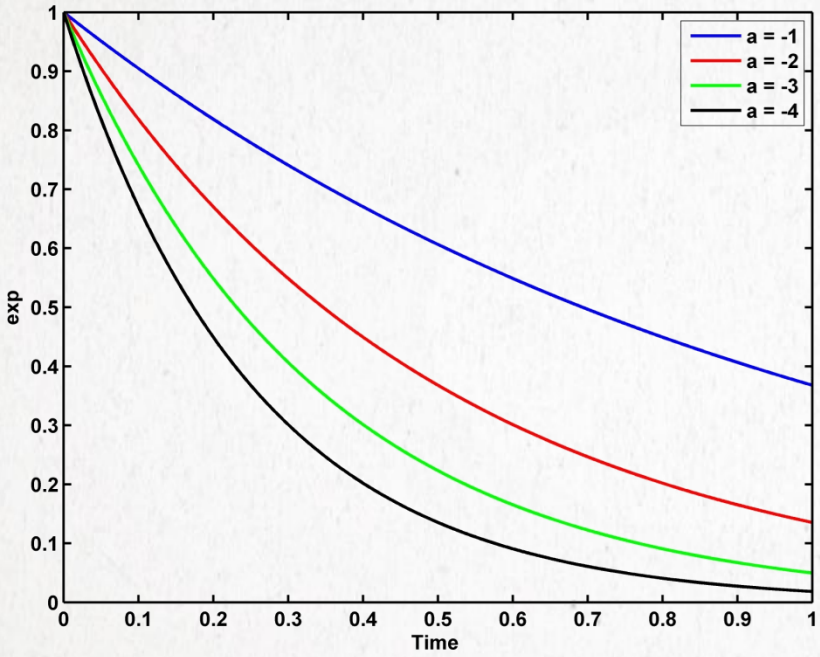
NEGATIVE EXPONENTIALS





$$s(t) = \exp(at)$$

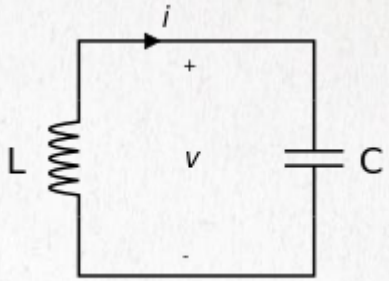
$$a < 0$$



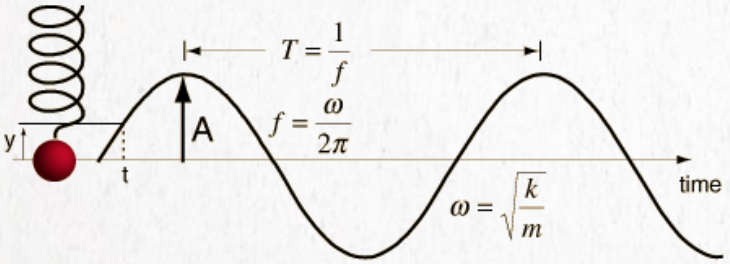
REAL DECAYING EXPONENTIAL

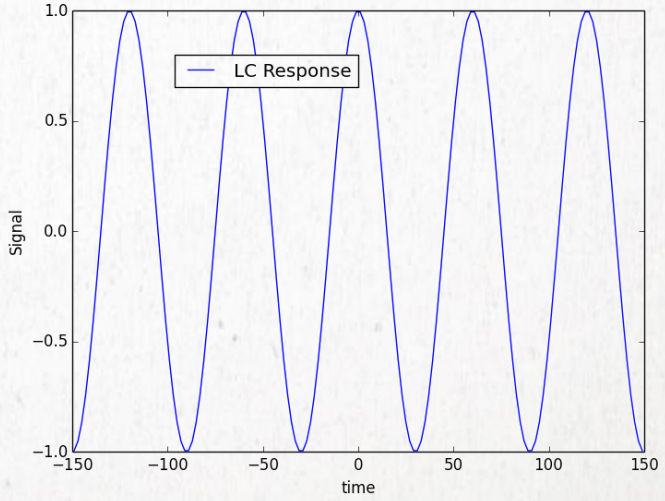
PURE SINUSOIDS

LC circuit response



SIMPLE HARMONIC MOTION

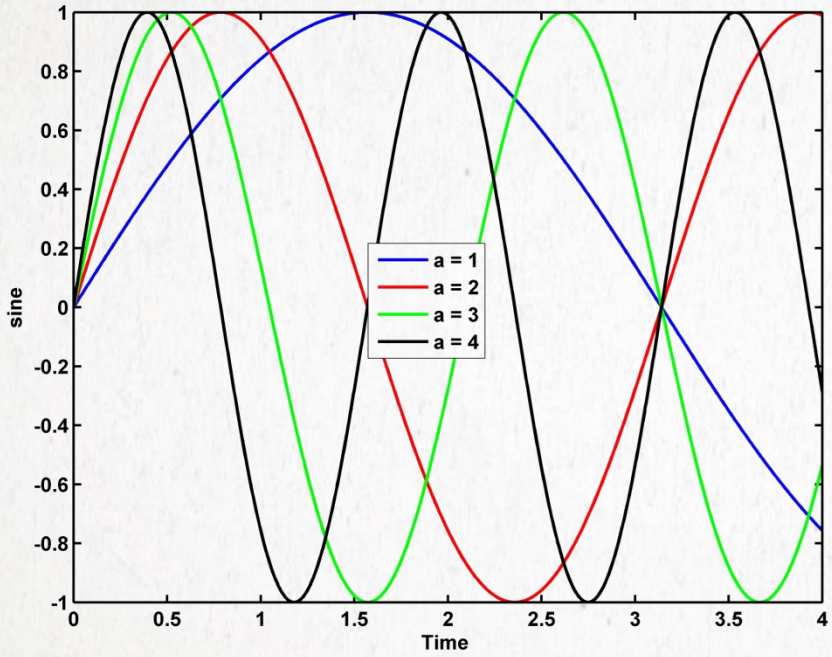




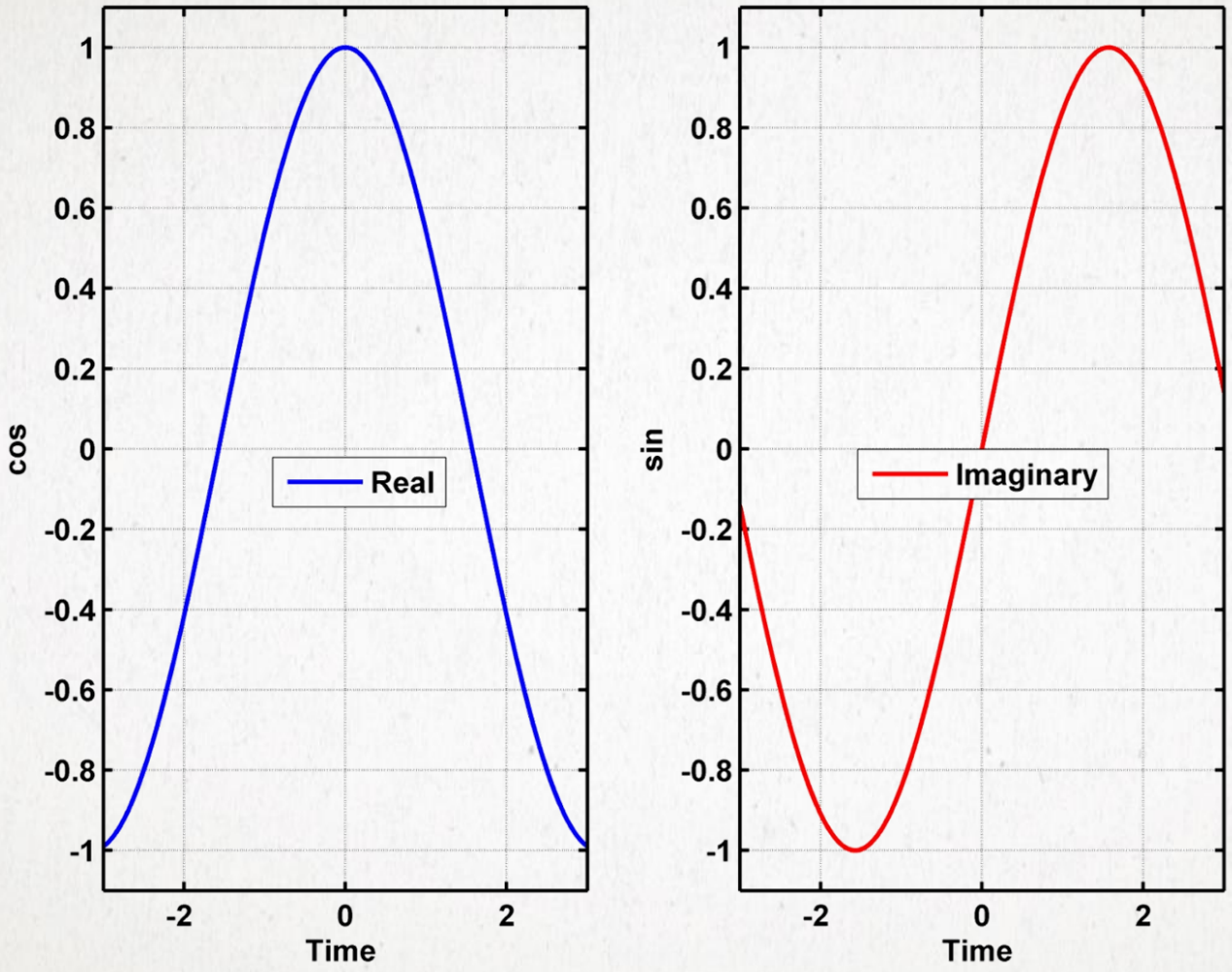
PURE SINUSOIDS

$$s(t) = \sin(at)$$

$$a > 0$$

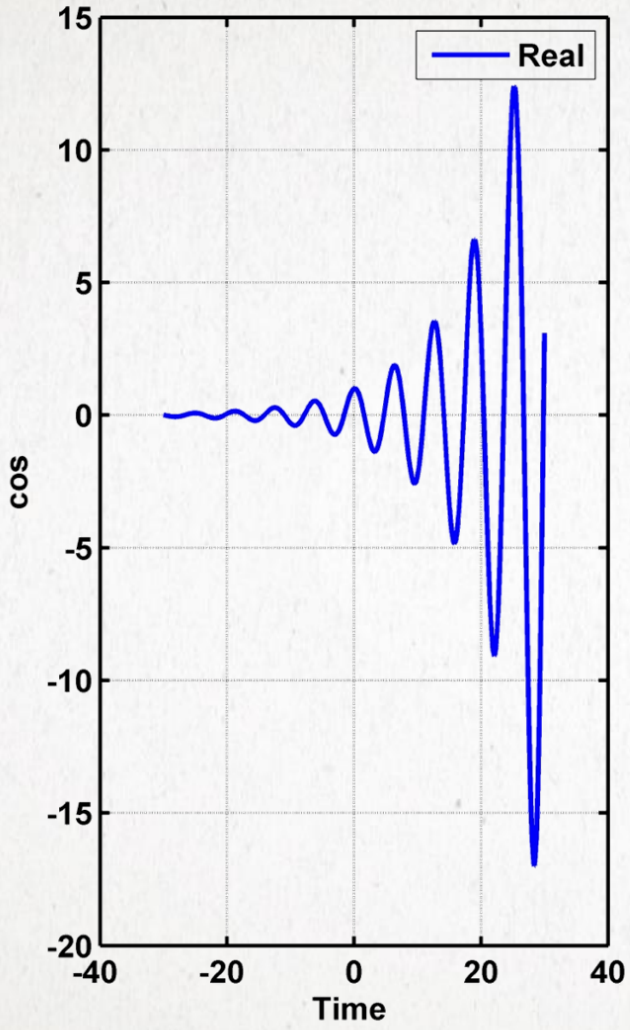


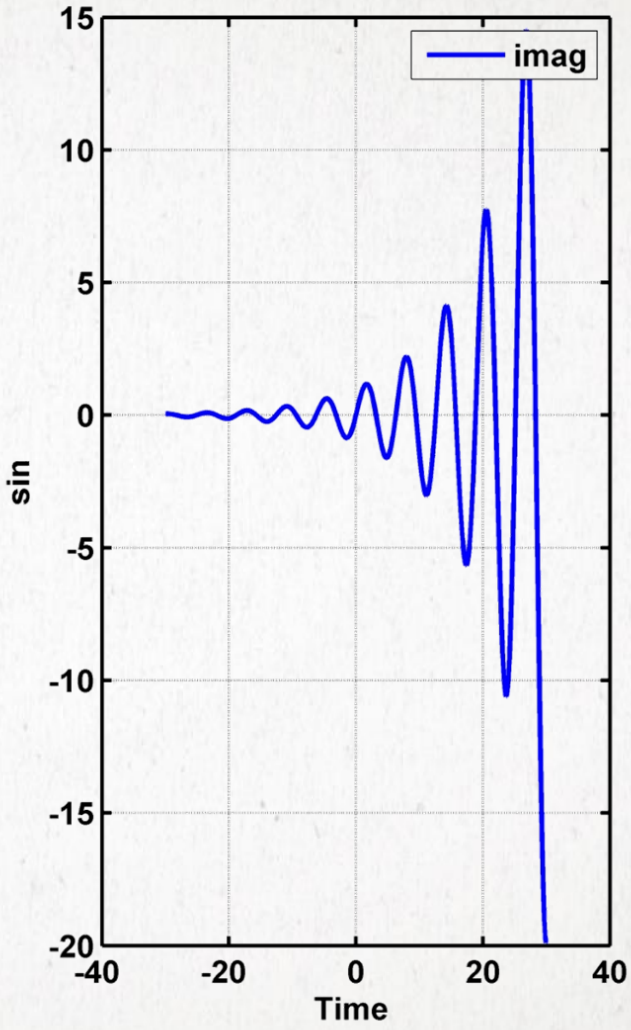
COMPLEX EXPONENTIAL



$$x(t) = \exp(jt) = \cos(t) + j\sin(t)$$

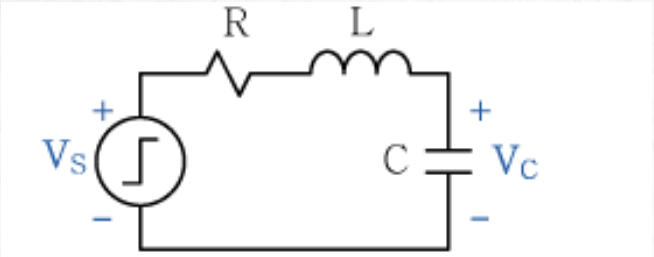
GROWING COMPLEX EXPONENTIAL





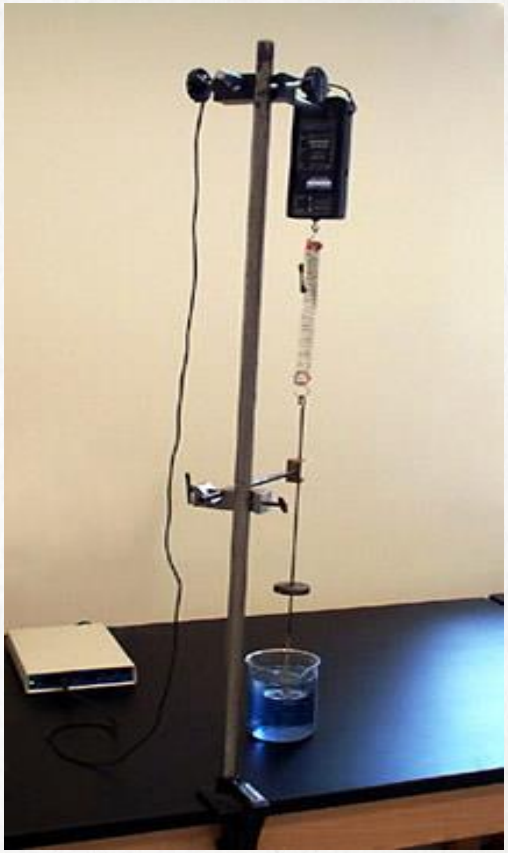
$$x(t) = \exp(at + jt) = \exp(at)\cos(t) + \exp(at)\, j \sin(t)$$

DECAYING COMPLEX EXPONENTIALS

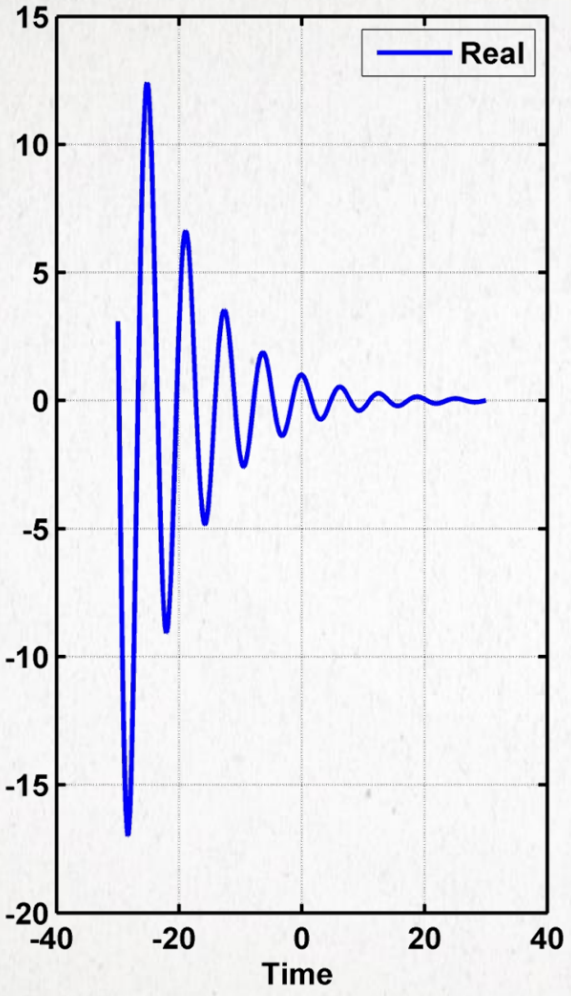


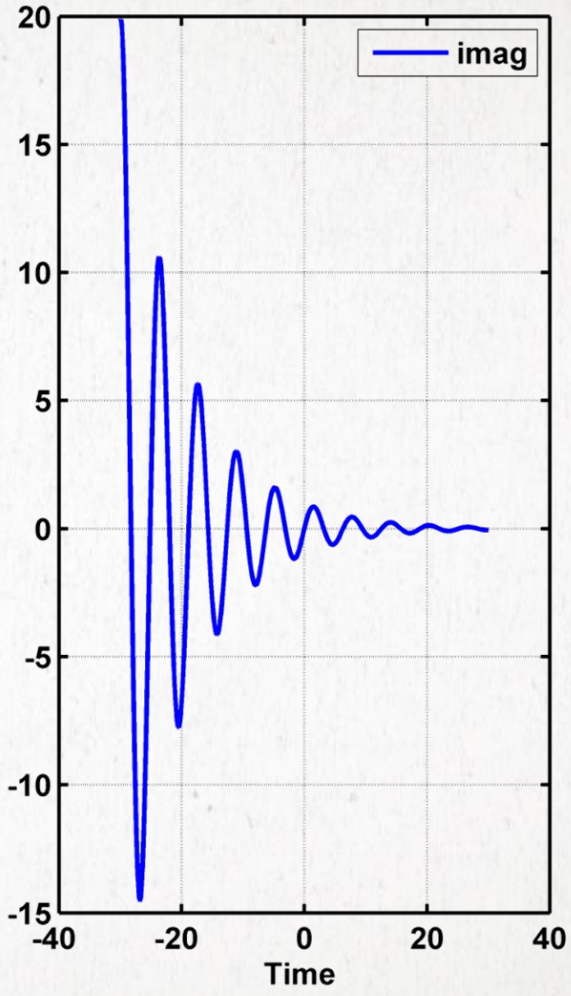
Transfer function: $\frac{V_C(s)}{V_S(s)} = \frac{1}{LCs^2 + RCs + 1}$

$f_r = \frac{1}{2\pi\sqrt{LC}}$ $Q_f = \frac{1}{R}\sqrt{\frac{L}{C}}$



DECAYING COMPLEX EXPONENTIAL

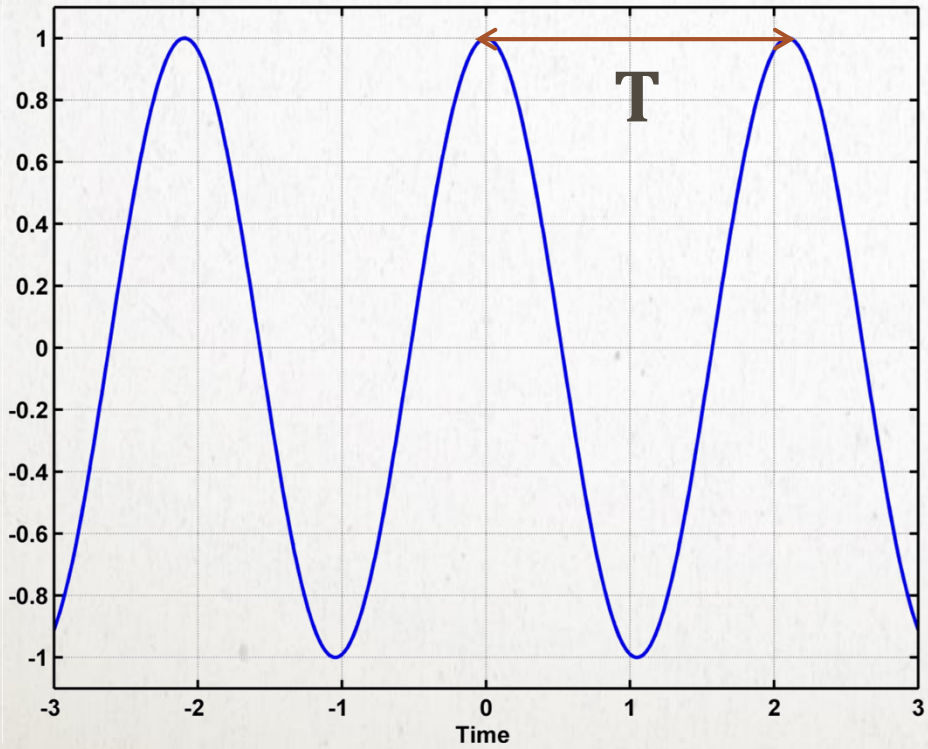




$$x(t) = \exp(at + jt) = \exp(at)\cos(t) + \exp(at)\, j \sin(t)$$

FREQUENCY

- Popular in radio receivers hi-fi systems, or spectral filters.
- In physics frequency is related to harmonic motion
- In fact frequency is related to time
- Periodic signals with one harmonic have frequency $f = \frac{1}{T}$



T – Period
f - frequency

CONTINUOUS & DISCRETE SINUSOIDS

$$x(t) = A\cos(\Omega t + \theta)$$

Analog frequency in radians

$$\Omega = 2\pi F$$

Frequency in Hertz

$$x[n] = A\cos(\omega n + \theta)$$

frequency in radians

$$\omega = 2\pi f$$

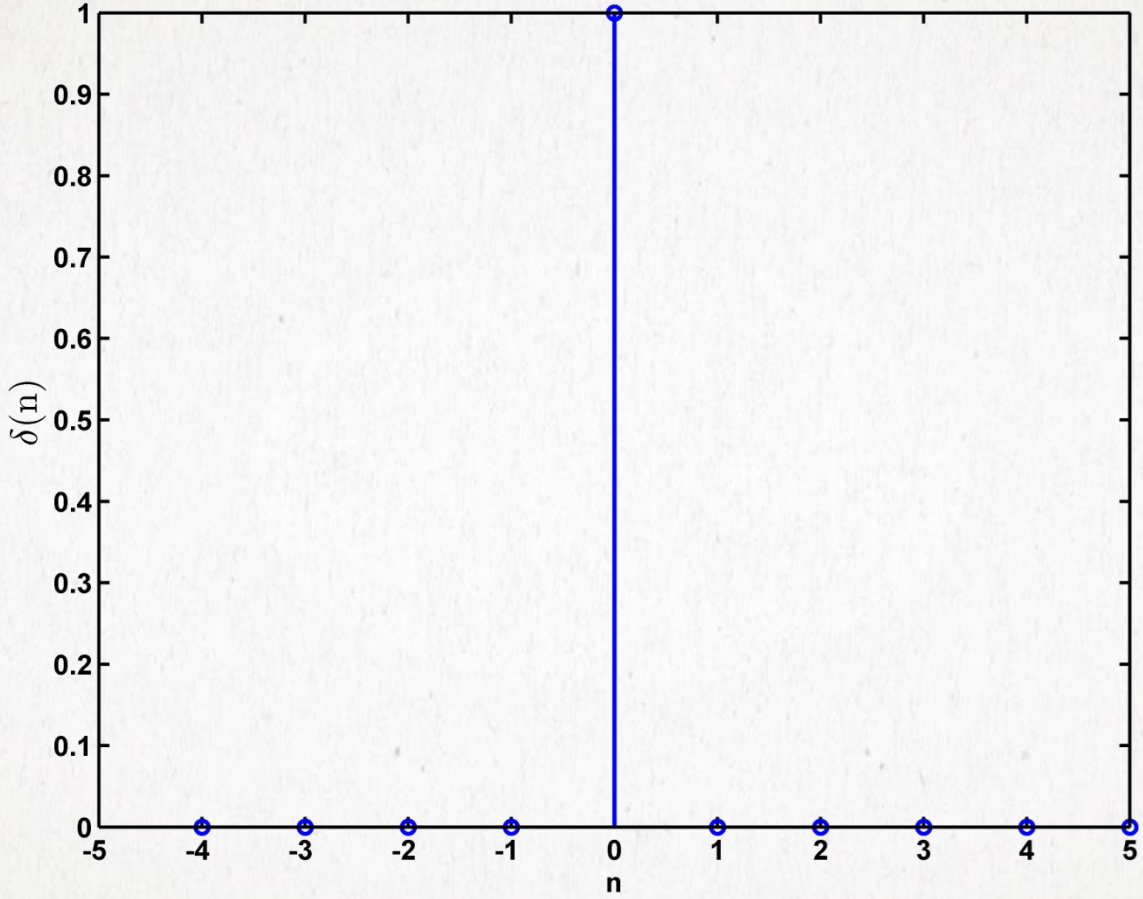
Frequency in cycles per sec

Analog Frequency

$$-\infty < F < \infty$$

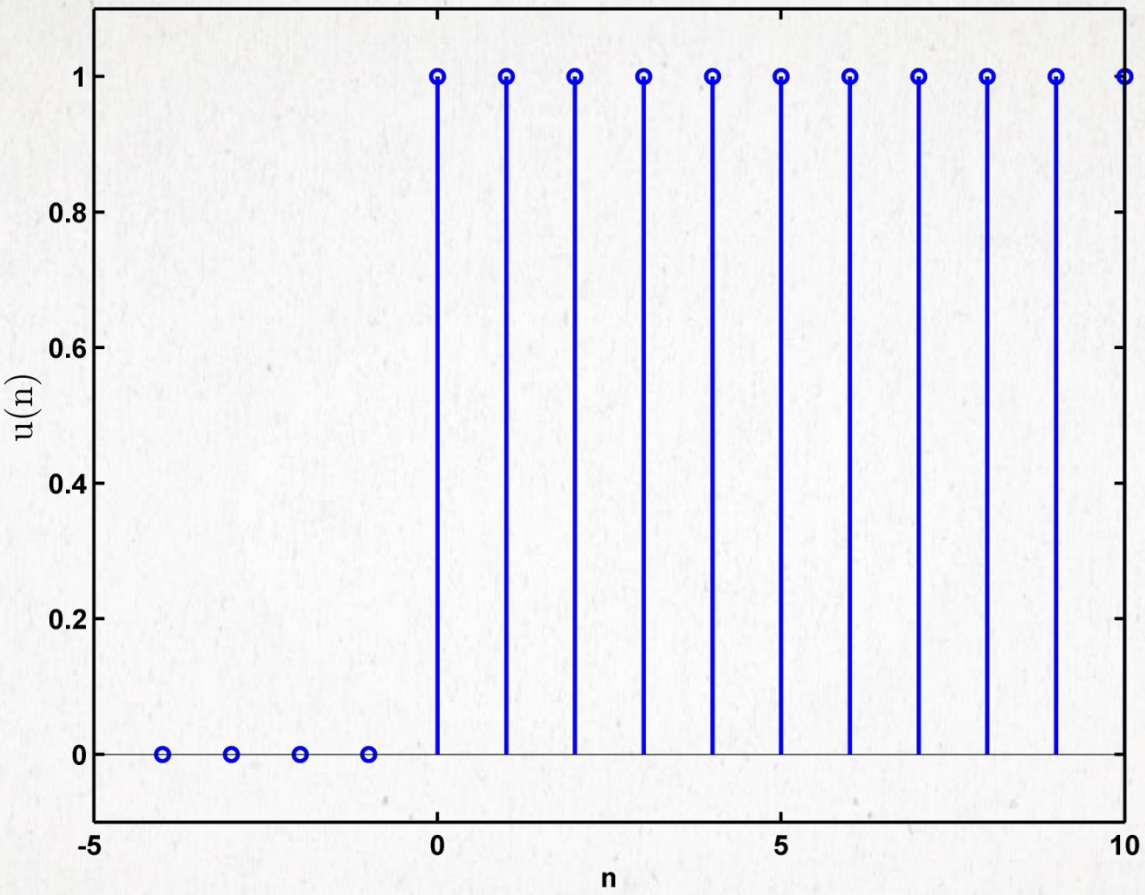
$$-\frac{1}{2} < f < \frac{1}{2}$$

UNIT IMPULSE



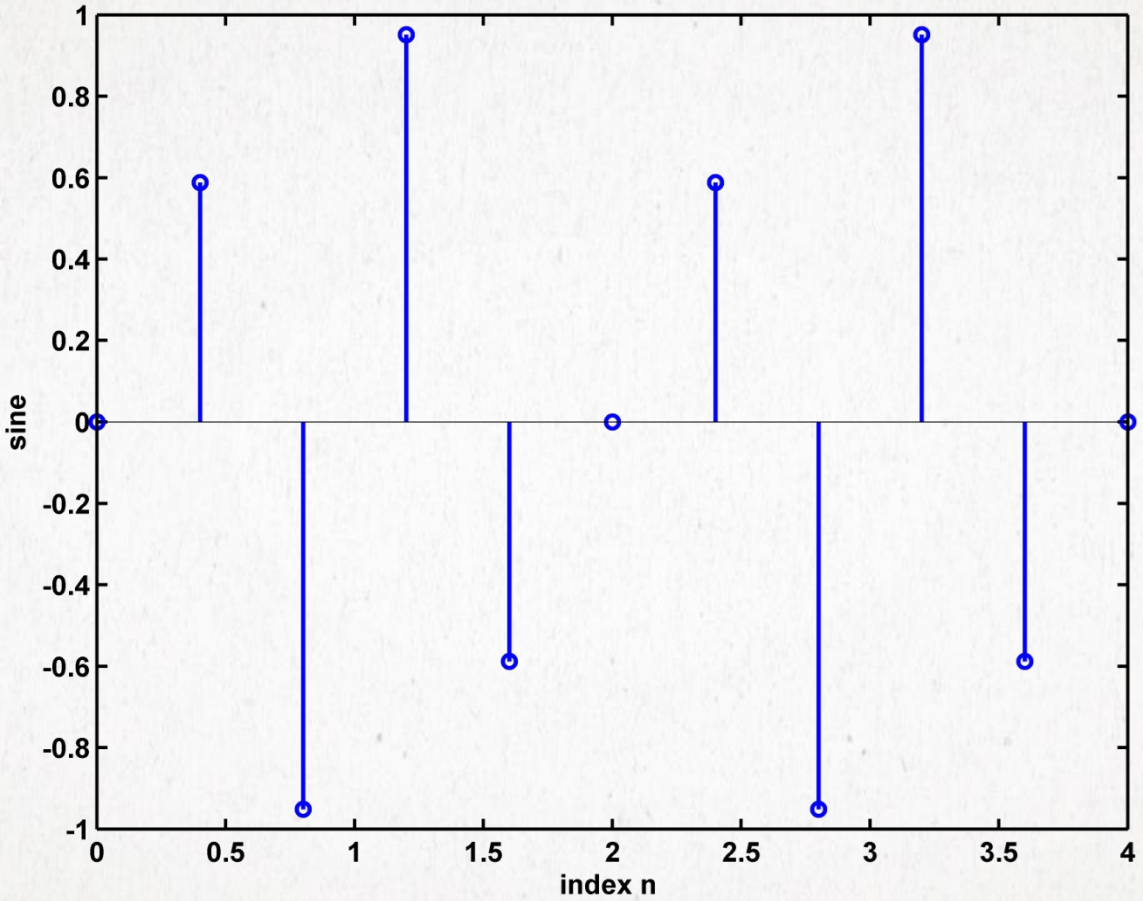
$$\delta(n) = \begin{matrix} 1 & n = 0 \\ 0 & n \neq 0 \end{matrix}$$

UNIT STEP SEQUENCE



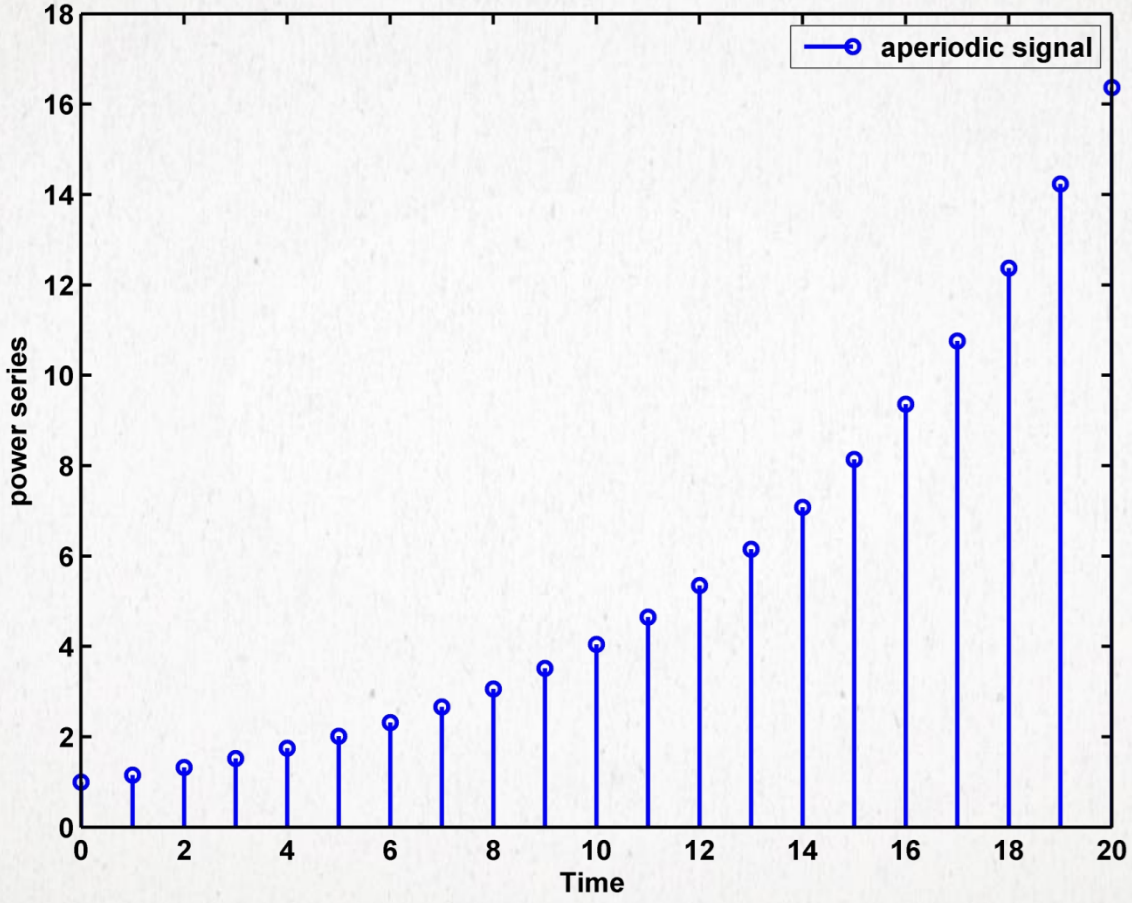
$$u(n) = \begin{matrix} 1 & n \geq 0 \\ 0 & n < 0 \end{matrix}$$

DISCRETE TIME PERIODIC SIGNAL



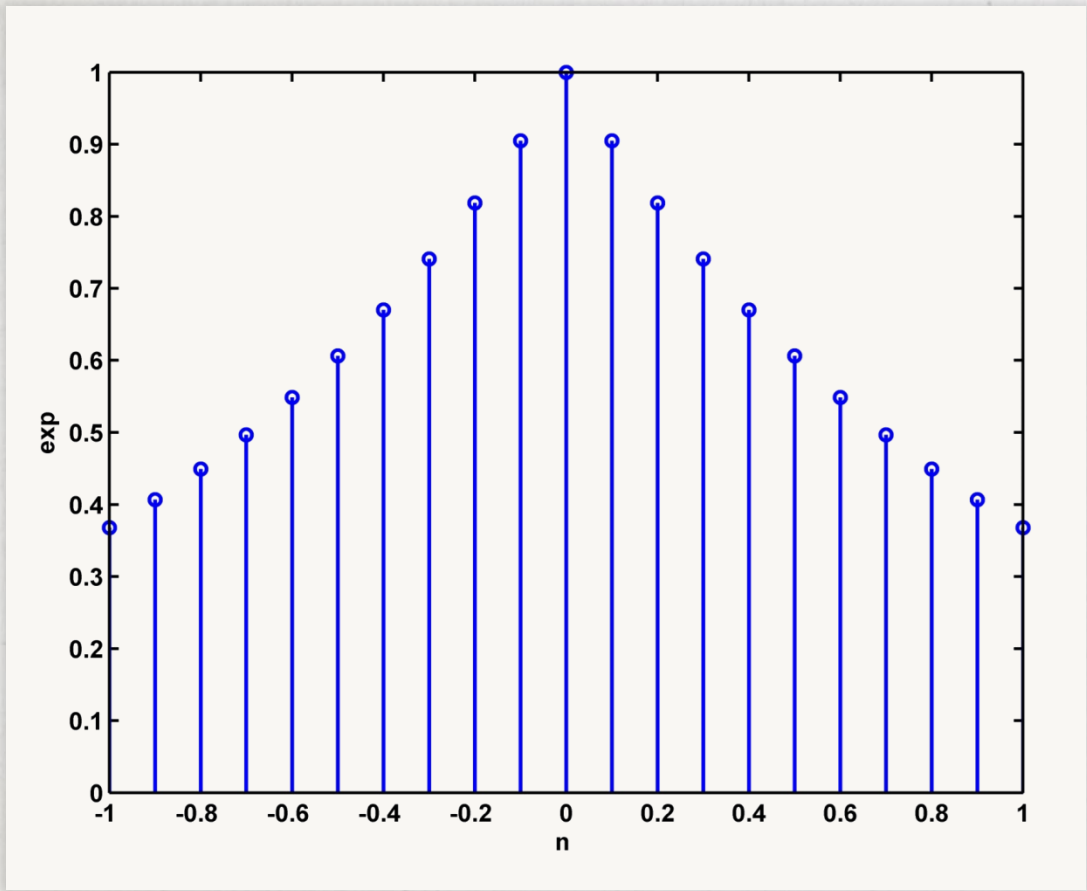
$$x(n+N)=x(n)$$

APERIODIC SIGNAL



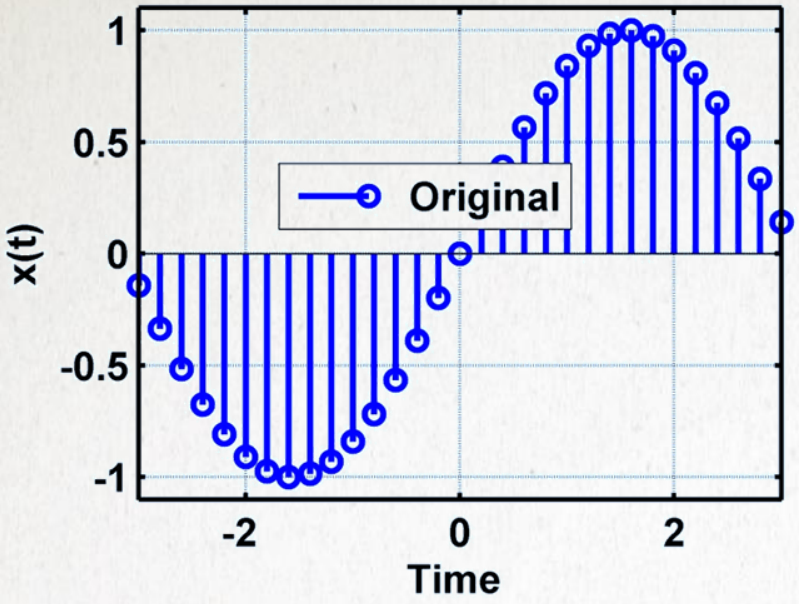
$$x(n+N) \neq x(n)$$

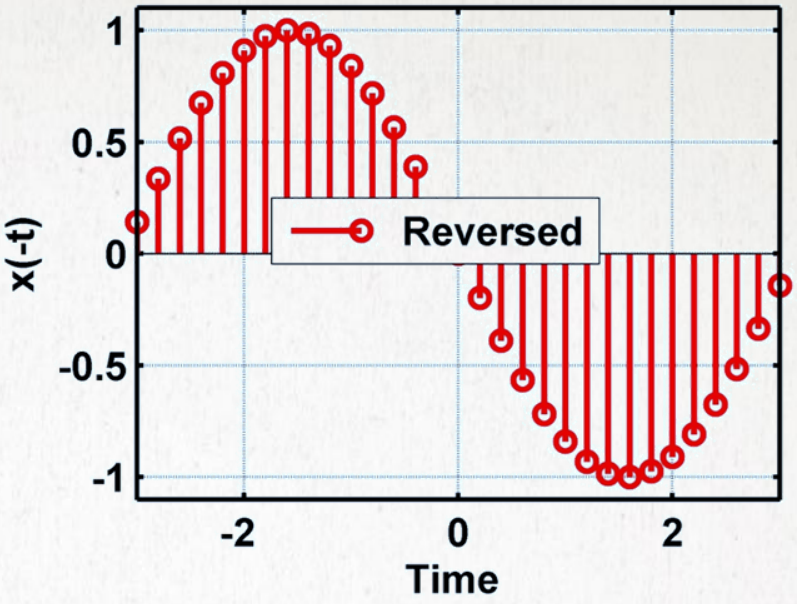
$$\exp(a|n|)$$

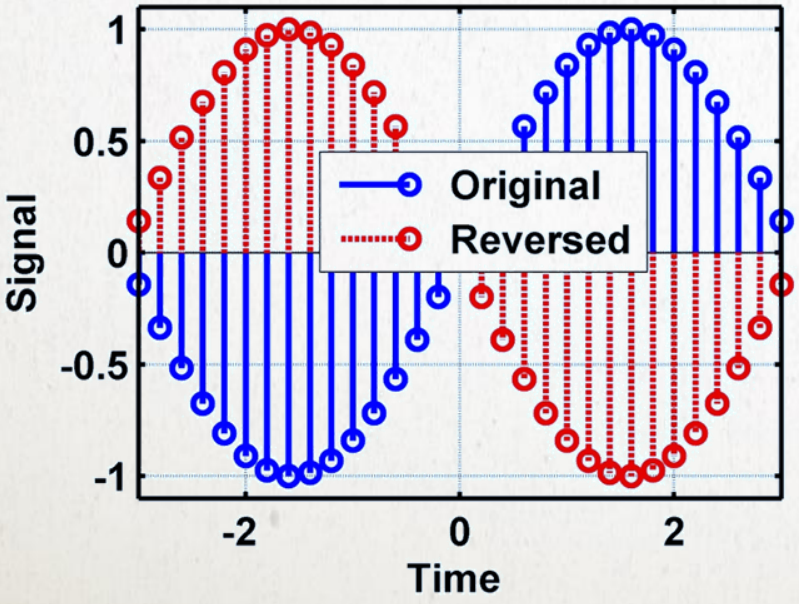


$$x(-n) = x(n)$$

DISCRETE EVEN SIGNAL



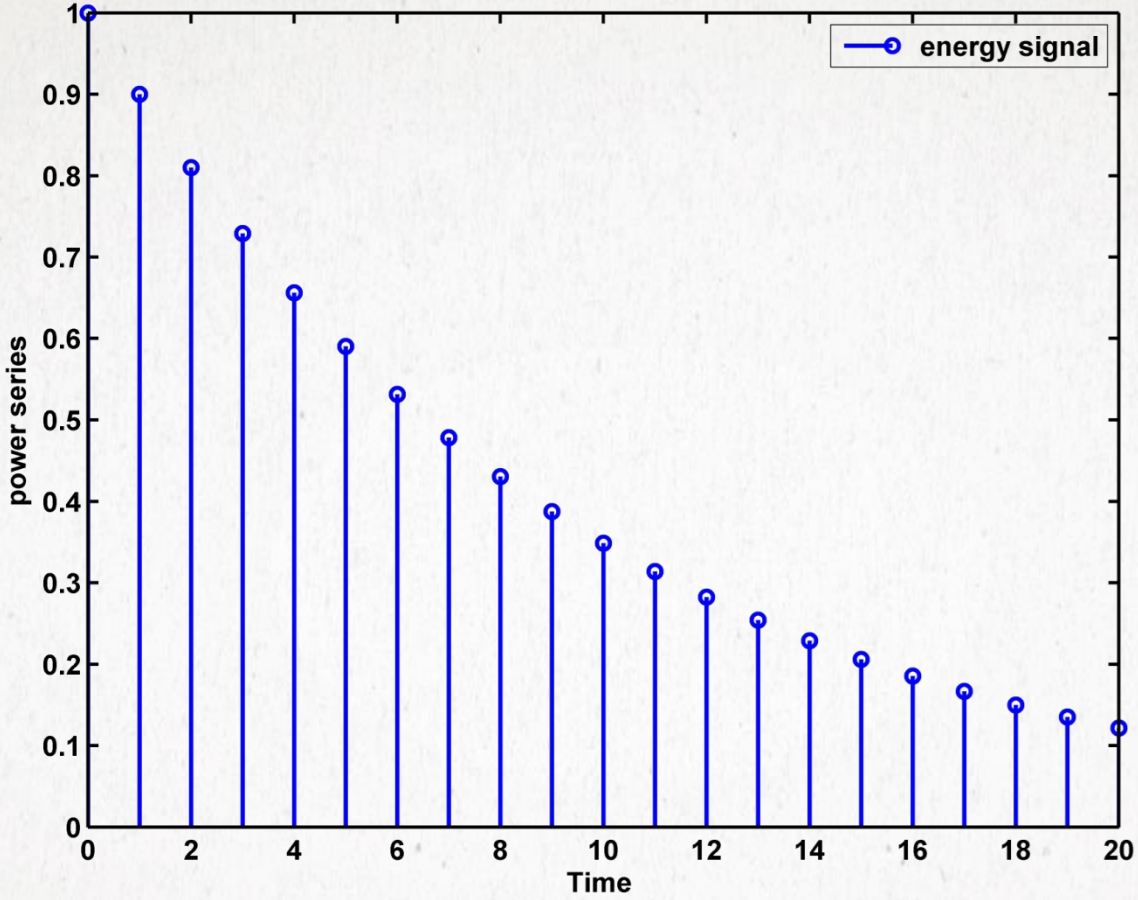




$$x(-n) = -x(n)$$

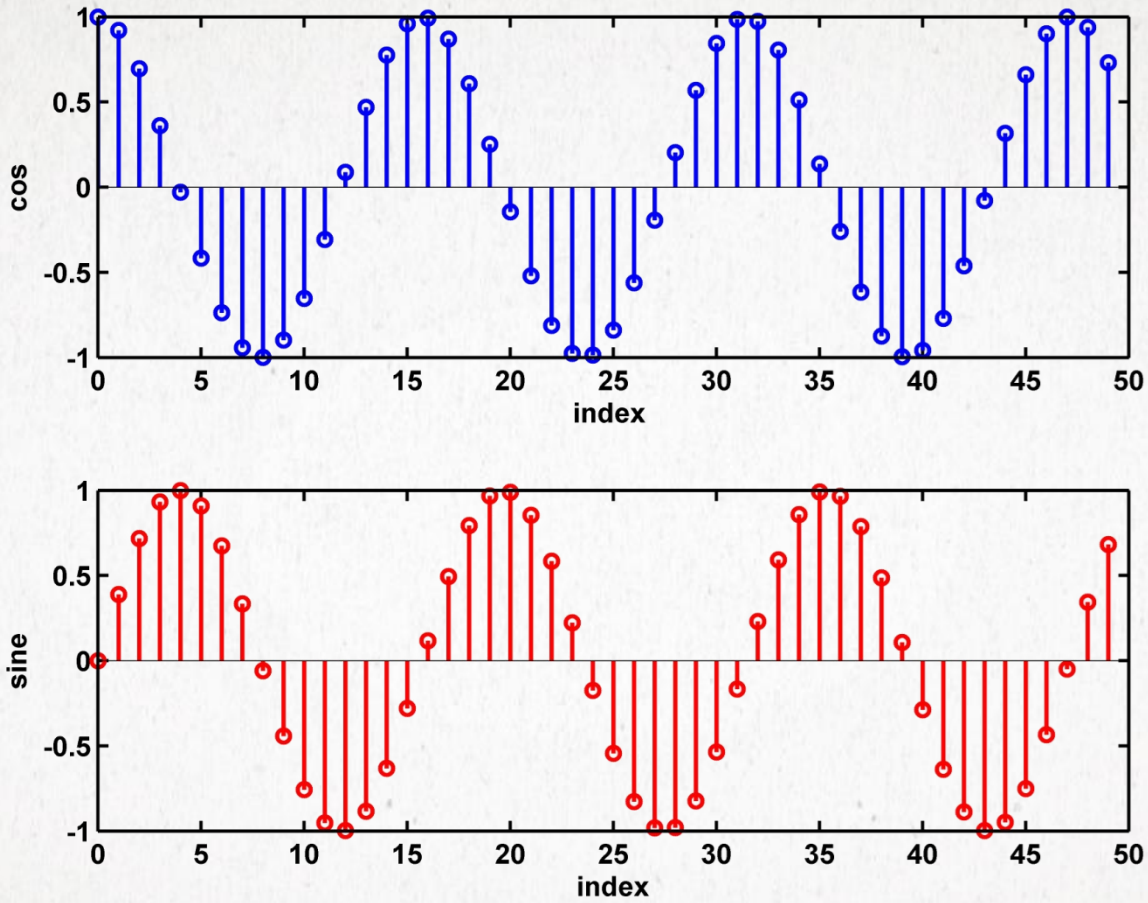
DISCRETE
ODD
SIGNAL

ENERGY SIGNAL



$$E = \lim_{N \to \infty} \sum_{n} \left| x(n) \right|^2 < \infty$$

POWER SIGNAL



$$P = \lim_{N\to\infty} \frac{1}{2N+1} \sum_{n} \left|x(n)\right|^2 < \infty$$