Introduction

Objective/What?

In this course, we will study different signals, systems, and networks.

Motivation/Why?

Signals (set of information or data) are widely present around us and provide us meaningful knowledge, such as monthly sales of a company or average price of a stock.

Systems help us analyze signals by processing inputs and producing outputs. This processing helps us understand how a signal behaved in the past and predict its future behaviour.

To realize these systems using electrical components, we need networks such as circuits with passive and active components.

Hence, we shall study signals, systems, and networks.

Methodology / How?

We will study different types of signals, their properties, and their Fourier representation. We will also study different systems, their stability, and the Laplace Transform. Next, using network analysis, network theorems, and two-port networks, we will realize our systems. Finally, we will study network functions, stability criterion, and realize passive and active filters.

Textbooks

We will be closely following the following textbooks.

1. Principles of Signal Processing and Linear Systems – B. P. Lathi
2. Networks and Systems – D. Roy Choudhary.

Signals

A signal is a set of information or data. In this course, we will deal almost exclusively with signals that are functions of time.

To measure the size of a signal, we define the signal energy of a signal as:

$$E_f = \int_{-\infty}^{\infty} |f(t)|^2 \, dt$$

(where $f(t)$ is a complex valued signal)

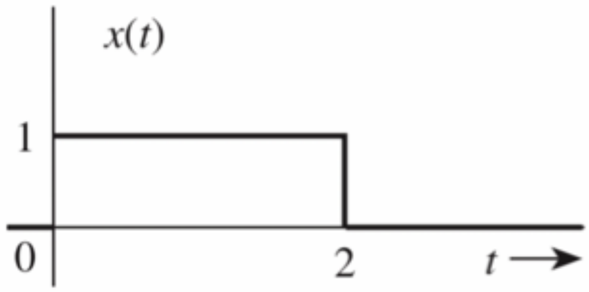
In some cases, the signal energy may not be finite. For such signals, a more meaningful measure of the signal size is the time average of the energy, which is called as the power of the signal:

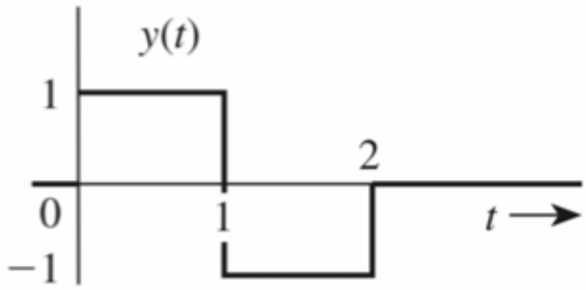
$$P_f = \lim_{T \to \infty} \frac{1}{T} \int_{-T/2}^{T/2} |f(t)|^2 \, dt = \frac{1}{T} \int_{-T/2}^{T/2} |f(t)|^2 \, dt$$

(for periodic signals with period T)

Note: The terms energy and power we have defined here are used to indicate the signal size. They are not used in the conventional sense with SI units Joules and Watts.

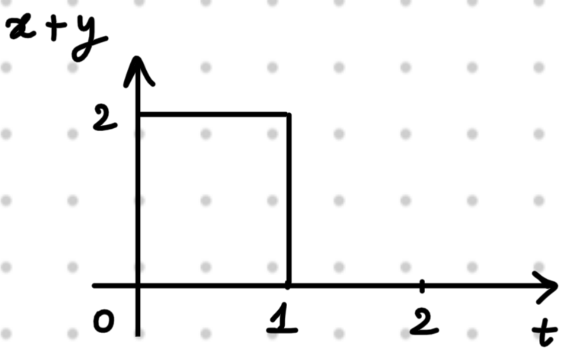
Q. Find the energies of the pair of signals $x(t)$ and $y(t)$ shown below. Sketch and find the energies of signals $x(t) + y(t)$ and $x(t) - y(t)$?

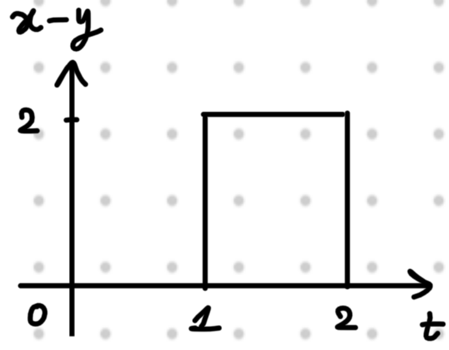




A. $$E_x = \int_0^2 1^2 \, dt = 2$$

$$E_y = \int_0^1 1^2 \, dt + \int_1^2 (-1)^2 dt = 2$$

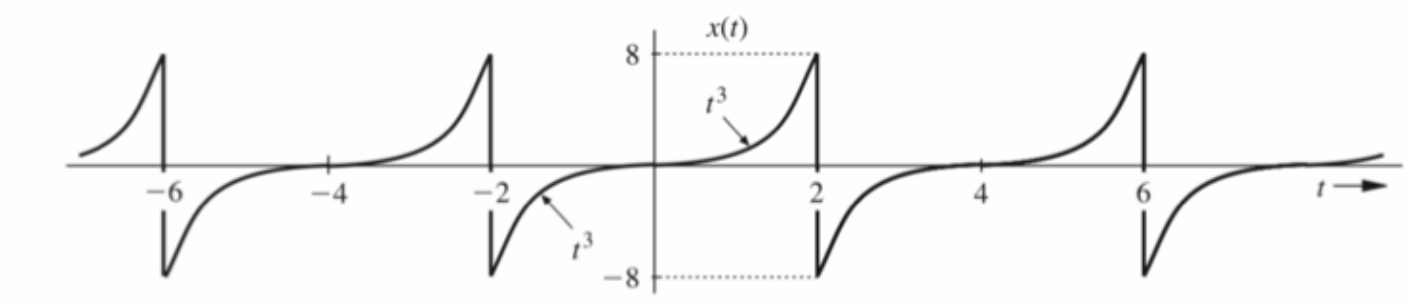




$$E_{x+y} = \int_0^1 2^2 \, dt = 4 \quad , \quad E_{x-y} = \int_1^2 2^2 \, dt = 4$$

Note: In general, $E_{x \pm y} \neq E_x + E_y$

Q. Find the power of the periodic signal $x(t)$ shown in the figure below. Find also the powers and the rms values of: $-x(t)$, $2x(t)$, and $c\,x(t)$.



A. $$P_x = \frac{1}{4}\int_{-2}^{2}(t^3)^2\,dt = \frac{64}{7} \Rightarrow RMS_x = \frac{8}{\sqrt{7}}$$

$$P_{-x} = \frac{1}{4}\int_{-2}^{2}(-t^3)^2\,dt = \frac{64}{7} \Rightarrow RMS_{-x} = \frac{8}{\sqrt{7}}$$

$$P_{2x} = \frac{1}{4}\int_{-2}^{2}(2t^3)^2\,dt = \frac{256}{7} \Rightarrow RMS_{2x} = \frac{16}{\sqrt{7}}$$

$$P_{cx} = \frac{1}{4}\int_{-2}^{2}(ct^3)^2\,dt = 64\,\frac{c^2}{7} \Rightarrow RMS_{cx} = \frac{8c}{\sqrt{7}}$$

Signal Classification : Signals can be classified as

1. Continuous - time and Discrete - time : A signal that is specified for every value of time t is a continuous - time signal, and a signal that is specified only at discrete values of time t is a discrete - time signal.

2. Analog and Digital : A signal whose amplitude can take on any value in a continuous range (i.e. an infinite number of values) is an analog signal. A digital signal is one whose amplitude can take on only a finite number of values.

3. Periodic and Aperiodic : A signal is said to be periodic if for some constant T_0

$$f(t) = f(t+T_0) \quad \text{for all } t$$

The smallest value of T_0 that satisfies this condition is the period of $f(t)$.

A signal is aperiodic if it does not obey this property.

4. Causal and Noncausal: A signal that does not start before $t=0$ is a causal signal (i.e. $f(t)=0$ for $t<0$). A signal that starts before $t=0$ is a noncausal signal (i.e. $f(t) \neq 0$ for $t<0$).

5. Energy and Power: A signal with finite energy is an energy signal. A signal with finite nonzero power is a power signal.

   Note: A signal with finite energy has zero power, and a signal with finite power has infinite energy.

6. Deterministic and Random: A signal whose physical description is completely known is a deterministic signal. A signal whose values cannot be predicted precisely but are known only in terms of probabilistic description is a random signal.