

Signals and Systems

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SIGNAL ENERGY AND POWER

If $v(t)$ and $i(t)$ are respectively the voltage and current across a resistor with resistance R , then the instantaneous power is

$$p(t) = v(t)i(t) = \frac{1}{R} v^2(t)$$

The total energy expended over the time interval $t_1 \leq t \leq t_2$ is

$$\int_{t_1}^{t_2} p(t) dt = \int_{t_1}^{t_2} \frac{1}{R} v^2(t) dt$$

And the average power over this time interval is

$$\frac{1}{t_2 - t_1} \int_{t_1}^{t_2} p(t) dt = \frac{1}{t_2 - t_1} \int_{t_1}^{t_2} \frac{1}{R} v^2(t) dt$$

We use similar terminology for power and energy for any continuous-time signal $x(t)$ or any discrete-time signal $x[n]$. Moreover we can consider signals that take on complex values. In this case the total energy:

$$\int_{t_1}^{t_2} |x(t)|^2 dt \quad \text{where } |x| \text{ = magnitude of complex } x$$

The total energy in a discrete-time signal $x[n]$ over $n_1 \leq n \leq n_2$ is defined as:

$$\sum_{n=n_1}^{n_2} |x[n]|^2$$

Average power:

$$\frac{1}{n_2 - n_1 + 1} \sum_{n=n_1}^{n_2} |x[n]|^2$$

When examining energy and power in signals over an infinite time interval, we define the total energy as:

$$E_x \triangleq \lim_{T \rightarrow \infty} \int_{-T}^T |x(t)|^2 dt = \int_{-\infty}^{\infty} |x(t)|^2 dt \quad (\text{in continuous time})$$

$$E_x \triangleq \lim_{N \rightarrow \infty} \sum_{n=-N}^N |x[n]|^2 = \sum_{n=-\infty}^{\infty} |x[n]|^2 \quad (\text{in discrete time})$$

We define the time-averaged power over an infinite interval as:

$$P_x \triangleq \lim_{T \rightarrow \infty} \frac{1}{2T} \int_{-T}^T |x(t)|^2 dt \quad (\text{in continuous time})$$

$$P_x \triangleq \lim_{N \rightarrow \infty} \frac{1}{2N+1} \sum_{n=-N}^N |x[n]|^2 \quad (\text{in discrete time})$$

We identify three classes of signals

1. Signals with finite total energy $E_x < \infty$

Such a signal must have zero average power as $P_x = \lim_{T \rightarrow \infty} \frac{E_x}{2T} = 0$.

Fundamentals Of Signals And Systems Solutions

Lingsheng Yao



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