Signals and Systems

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 $t_1 \le t \le t_2$ 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:

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

The total energy in a discrete-time signal $x[n]$ over $n_1 \le n \le n_2$ 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:

$$E_\infty \triangleq \lim_{T \to \infty} \int_{-T}^{T} |x(t)|^2 \, dt = \int_{-\infty}^{\infty} |x(t)|^2 \, dt \qquad (\text{in continuous time})$$

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

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

$$P_\infty \triangleq \lim_{T \to \infty} \frac{1}{2T} \int_{-T}^{T} |x(t)|^2 \, dt \qquad (\text{in continuous time})$$

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

We identify three classes of signals

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

Such a signal must have zero average power as $P_\infty = \lim_{T \to \infty} \frac{E_\infty}{2T} = 0$.

Signals And Systems Solution

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of systems

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