UNIT - 1

How Are Signal & Systems Related ?

How to design a system to process a signal in particular ways?

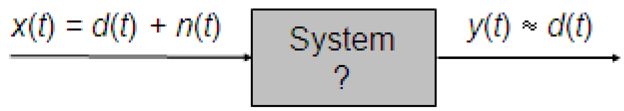
Design a system to restore or enhance a particular signal

1. Remove **high frequency** background communication noise
2. Enhance **noisy** images from spacecraft

Assume a signal is represented as

$$x(t) = d(t) + n(t)$$

Design a system to remove the unknown "noise" component n(t), so that y(t) ≈ d(t)



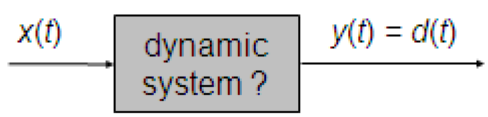
How to design a (dynamic) system to modify or control the output of another (dynamic) system

1. Control an aircraft's altitude, velocity, heading by adjusting throttle, rudder, ailerons
2. Control the temperature of a building by adjusting the heating/cooling energy flow.

Assume a signal is represented as

$$x(t) = g(d(t))$$

Design a system to "invert" the transformation g(), so that y(t) = d(t)



"Electrical" Signal Energy & Power

It is often useful to characterise signals by measures such as **energy** and **power**

For example, the **instantaneous power** of a resistor is:

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

and the **total energy** expanded over the interval [t_1, 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 energy** is:

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

How are these concepts defined for any continuous or discrete time signal?

- Generic Signal Energy and Power

Total energy of a continuous signal x(t) over [t_1, t_2] is:

$$E = \int_{t_1}^{t_2} |x(t)|^2 dt$$

where |.| denote the magnitude of the (complex) number.

Similarly for a discrete time signal x[n] over [n_1, n_2]:

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

By dividing the quantities by (t_2-t_1) and (n_2-n_1+1), respectively, gives the **average power**, P

Note that these are similar to the electrical analogies (voltage), but they are different, both value and dimension.

Energy and Power over Infinite Time:

For many signals, we're interested in examining the power and energy over an infinite time interval (-∞, ∞). These quantities are therefore defined by:

$$E_\infty = \lim_{T\to\infty} \int_{-T}^{T} |x(t)|^2 dt = \int_{-\infty}^{\infty} |x(t)|^2 dt$$

$$E_\infty = \lim_{N\to\infty} \sum_{n=-N}^{N} |x[n]|^2 = \sum_{n=-\infty}^{\infty} |x[n]|^2$$

If the sums or integrals do not converge, the energy of such a signal is infinite

$$P_\infty = \lim_{T\to\infty} \frac{1}{2T}\int_{-T}^{T} |x(t)|^2 dt$$

$$P_\infty = \lim_{N\to\infty} \frac{1}{2N+1}\sum_{n=-N}^{N} |x[n]|^2$$

Two important (sub)classes of signals

1. Finite total energy (and therefore zero average power)
2. Finite average power (and therefore infinite total energy)

Signal analysis over infinite time, all depends on the "tails" (limiting behaviour)

- Time Shift Signal Transformations

A central concept in signal analysis is the transformation of one signal into another signal. Of particular interest are simple transformations that involve a transformation of the time axis only.

A linear **time shift** signal transformation is given by:

$$y(t) = x(at + b)$$

where b represents a signal offset from 0, and the a parameter represents a signal stretching if |a|>1, compression if 0<|a|<1 and a reflection if a<0.