Introduction: Signals

→ flow of information

→ measured quantity that varies with time (or position)

→ electrical signal received from a transducer
(microphone, thermometer, accelerometer, antenna, etc.)

→ electrical signal that controls a process

Continuous-time signals: voltage, current, temperature, speed, ...

Discrete-time signals: daily minimum/maximum temperature, lap intervals in races, sampled continuous signals, ...

Electronics can only deal easily with time-dependent signals, therefore spatial signals, such as images, are typically first converted into a time signal with a scanning process (TV, fax, etc.)

Signal processing

Signals may have to be transformed in order to

- ⟶ amplify or filter out embedded information
- ⟶ detect patterns
- ⟶ prepare the signal to survive a transmission channel
- ⟶ prevent interference with other signals sharing a medium
- ⟶ undo distortions contributed by a transmission channel
- ⟶ compensate for sensor deficiencies
- ⟶ find information encoded in a different domain

To do so, we also need

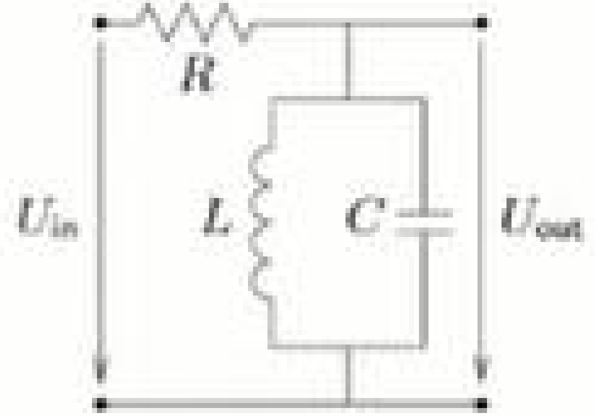
- ⟶ methods to measure, characterise, model and simulate transmission channels
- ⟶ mathematical tools that split common channels and transformations into easily manipulated building blocks

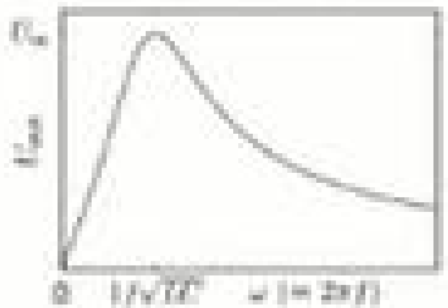
Analog electronics

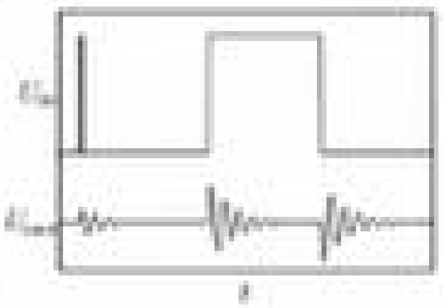
Passive networks (resistors, capacities, inductivities, crystals, SAW filters), non-linear elements (diodes, ...), (roughly) linear operational amplifiers

Advantages:

- passive networks are highly linear over a very large dynamic range and large bandwidths
- analog signal-processing circuits require little or no power
- analog circuits cause little additional interference







$$\frac{U_{in} - U_{out}}{R} = \frac{1}{L}\int_{-\infty}^{t} U_{out}\,d\tau + C\frac{dU_{out}}{dt}$$

Digital signal processing

Analog/digital and digital/analog converter, CPU, DSP, ASIC, FPGA.

Advantages:

- $\longrightarrow$ noise is easy to control after initial quantization
- $\longrightarrow$ highly linear (within limited dynamic range)
- $\longrightarrow$ complex algorithms fit into a single chip
- $\longrightarrow$ flexibility, parameters can easily be varied in software
- $\longrightarrow$ digital processing is insensitive to component tolerances, aging, environmental conditions, electromagnetic interference

But:

- $\longrightarrow$ discrete time processing artifacts (aliasing)
- $\longrightarrow$ can require significantly more power (battery, cooling)
- $\longrightarrow$ digital clock and switching cause interference

Typical DSP applications

- → communication systems
  modulation/demodulation, channel equalization, echo cancellation
- → consumer electronics
  perceptual coding of audio and video on DVDs, speech synthesis, speech recognition
- → music
  synthetic instruments, audio effects, noise reduction
- → medical diagnostics
  magnetic-resonance and ultrasonic imaging, computer tomography, ECG, EEG, MEG, AED, audiology
- → geophysics
  seismology, oil exploration
- → astronomy
  VLBI, speckle interferometry
- → experimental physics
  sensor-data evaluation
- → aviation
  radar, radio navigation
- → security
  steganography, digital watermarking, biometric identification, surveillance systems, signals intelligence, electronic warfare
- → engineering
  control systems, feature extraction for pattern recognition