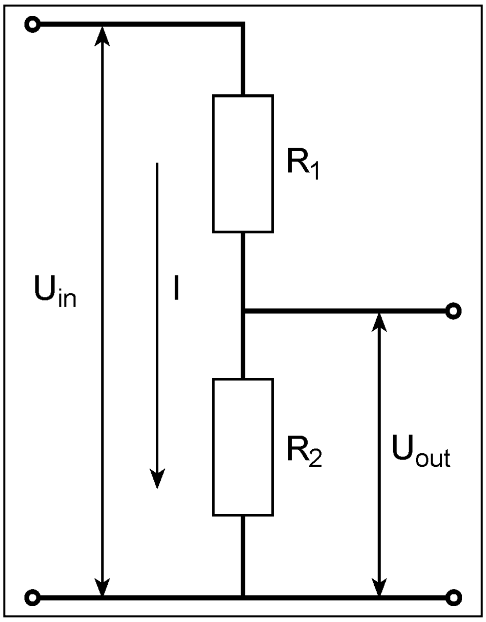
# Basic electronic units and circuits

## Voltage divider

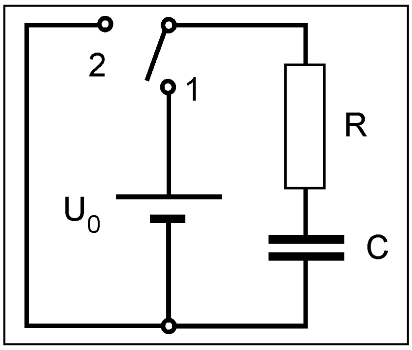



The simplest basic electric circuit, which consists of two resistors connected in series. The ratio of the resistances determines what fraction of the input voltage will appear on the output electrodes.

$$U_{out} = U_{in}\frac{R_2}{R_1 + R_2}$$

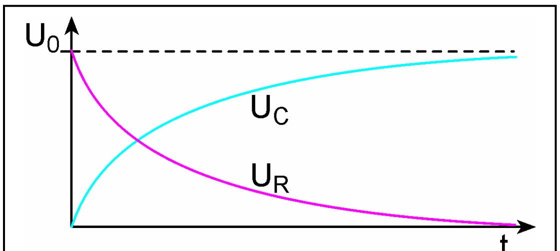
## RC circuit-elements in DC circuits

## Charging (1) and discharging (2) a serial RC circuit

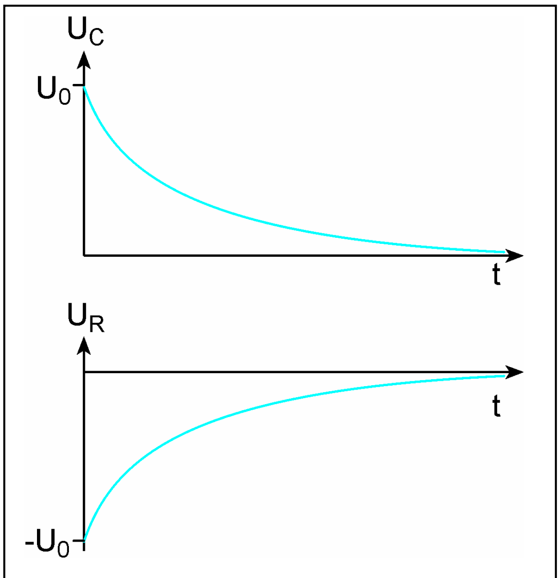



So called "transient" phenomena take place
From Kirchhoff's 2nd law: $U_0 = U_R + U_C$.

$$U_R = U_0 e^{-\frac{t}{RC}} \quad , \quad U_C = U_0(1 - e^{-\frac{t}{RC}})$$




charging

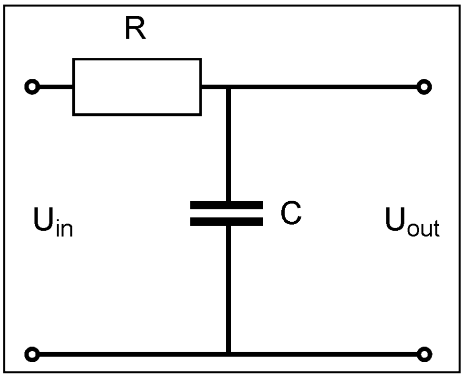


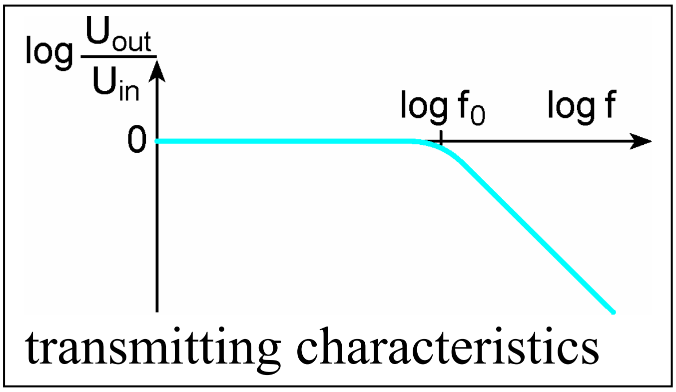

discharging

From Kirchhoff's 2nd law:
$U_R + U_C = 0$

$$U_R = -U_0 e^{-\frac{t}{RC}} \quad , \quad U_C = U_0 e^{-\frac{t}{RC}}$$

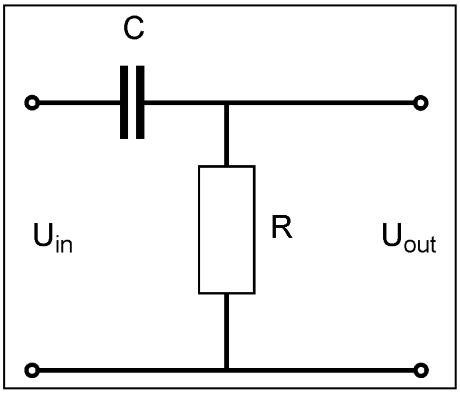
## Low pass filter

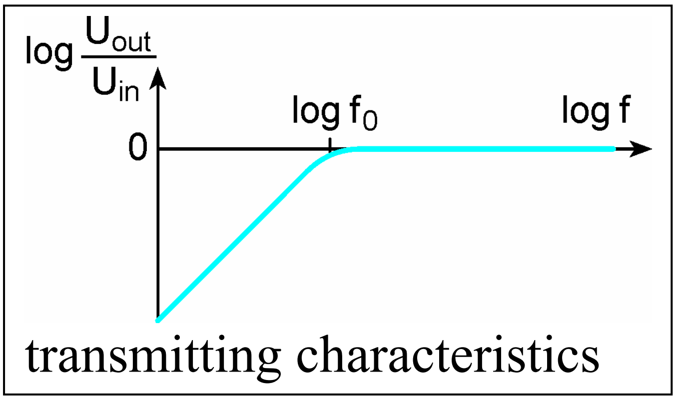



$$U_{out} = U_{in} \frac{1}{\sqrt{1+(2\pi fCR)^2}}$$

## High pass filter




$$U_{out} = U_{in} \frac{2\pi fCR}{\sqrt{1+(2\pi fCR)^2}}$$

## AC filter circuits

Filter circuits are practically voltage dividers, the only difference is that one of the resistors is replaced by a capacitor. This small difference, however, essentially changes the properties of the voltage divider, since the AC resistance (impedance) of the capacitor depends on the frequency ($f$).

$$X_C = \frac{1}{2\pi fC}$$

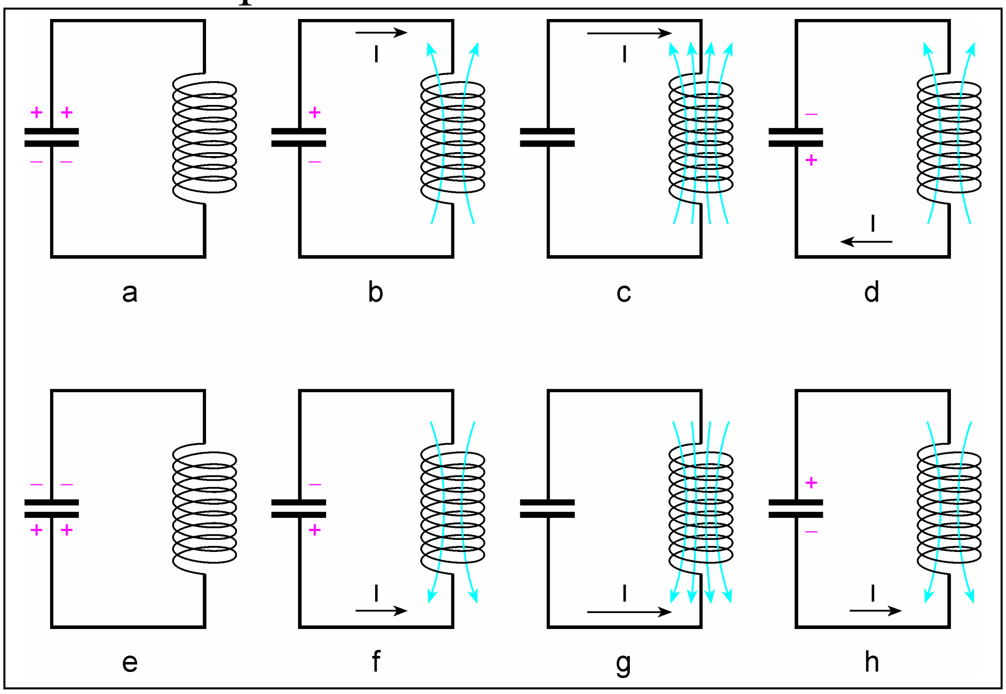
Hence the voltage division becomes frequency dependent.

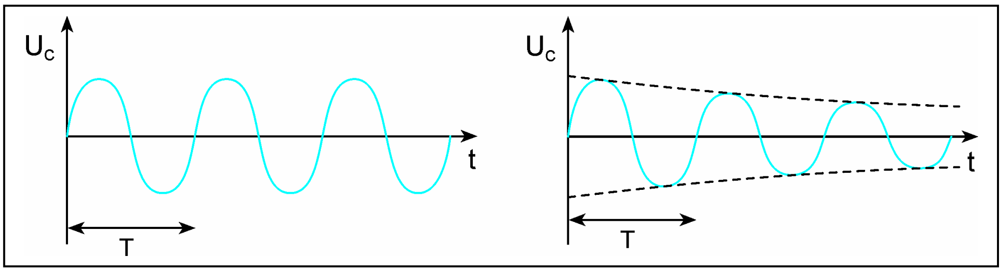
$$U_{out}(1) = U_{in} \frac{X_C}{\sqrt{R^2 + X_C^2}} \quad , \quad U_{out}(2) = U_{in} \frac{R}{\sqrt{R^2 + X_C^2}}$$

**LC circuit (oscillating circuit)**

A circuit consisting of a capacitor and a coil is called an oscillating circuit, or LC circuit.

If the capacitor of the LC circuit is charged to a certain voltage and left undisturbed, the voltage on the capacitor will undergo sinusoidal oscillation. Because of the ohmic resistance of the coil, the amplitude of this oscillation will decrease exponentially, i.e. the oscillation is damped.

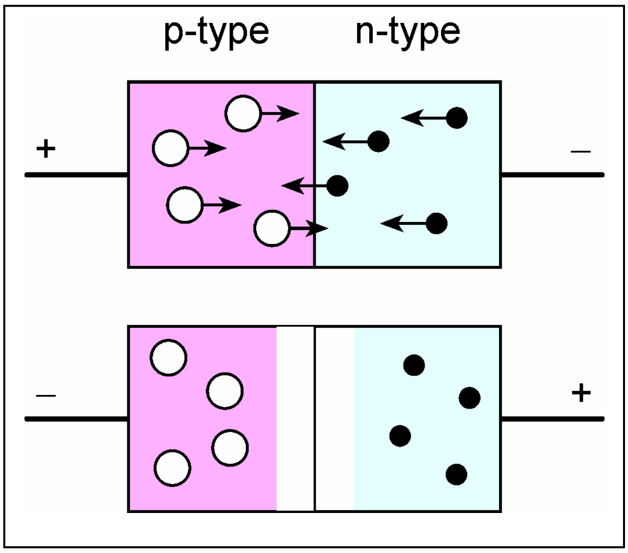



The voltage on the capacitor of an ideal and a realistic oscillator is constant amplitude and damped sinusoidal, respectively

## Semiconductor electrical elements

### Semiconductor diode

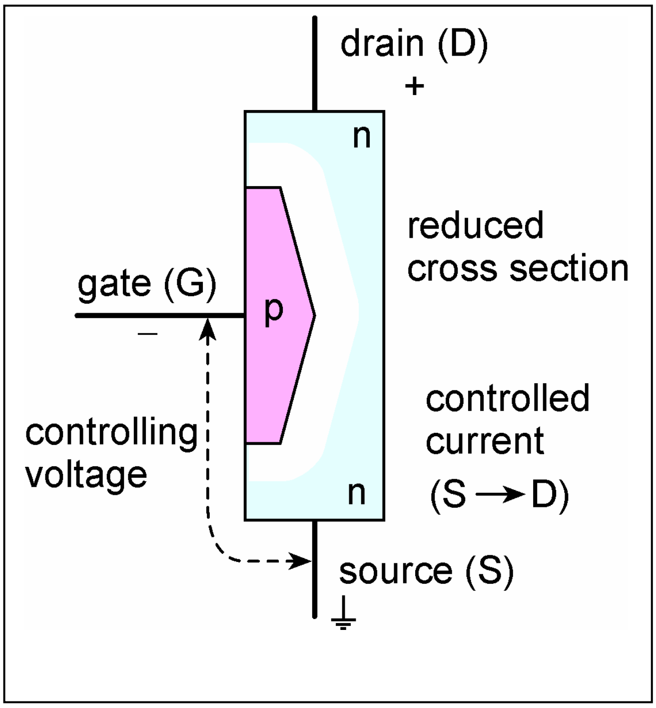



The semiconductor diode consists of an n-type and a p-type semiconductor. It allows the electric current to flow only in one direction.

### Transistors

The first transistor was invented in 1949 (Nobel Prize in 1956).

### FET (Field Effect Transistor)




The controlling voltage sets the thickness of the empty layer, which can be seen in a diode. Changing the cross section area of a conductor can be used to regulate the current. The great advantage of the FET is that, practically, there is no current on the controlling electrode, so the input power is very low. This became a very important respect as the integrated circuits spread. The more transistors are squeezed into an integrated circuit, the less heat can be produced by one transistor.

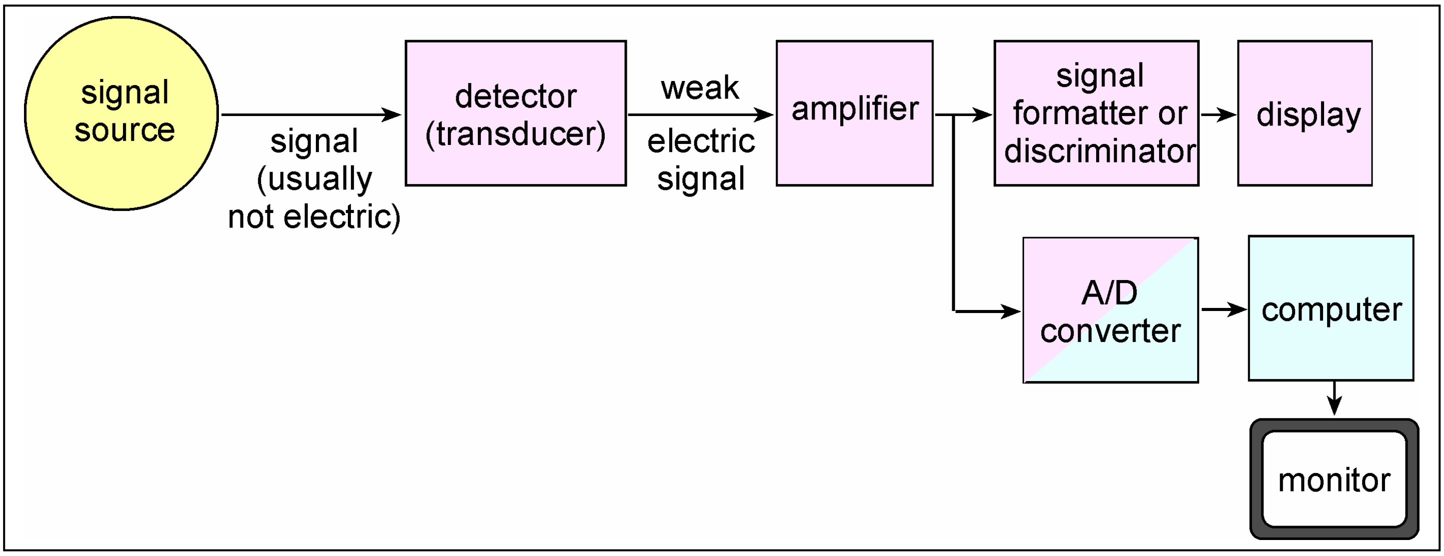
## Signals, signal processing

Any physical quantity or its change, which carries information, is called a signal (i.e. temperature, pulse rate, cardiac sound intensity).
Most of signals are not electric in nature. These signals need to be transformed into electric ones in order to simplify their processing. Different types of detectors and transducers serve this purpose.

## Classification of signals

1. non periodic, quasiperiodic (almost periodic), stochastic
2. analog, digital
3. continuous, pulse

## Scheme of the signal-processing chain



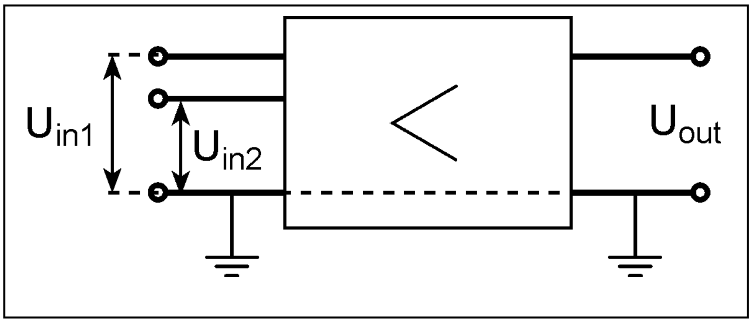

## Electrical amplifier

An electrical amplifier is required to produce an output signal whose shape is (possibly) identical with that of the input signal, but its power is greater.
Of course, an amplifier is operated by a power supply whose energy is used for the output signal.
(Fourier decomposition of signals) See in the manual! (AMPLIFIER)

## Differential mode amplifier

$U_{out} = (U_{in1} - U_{in2})A_U$

Application: for example ECG (see in the manual!)




## Feedback

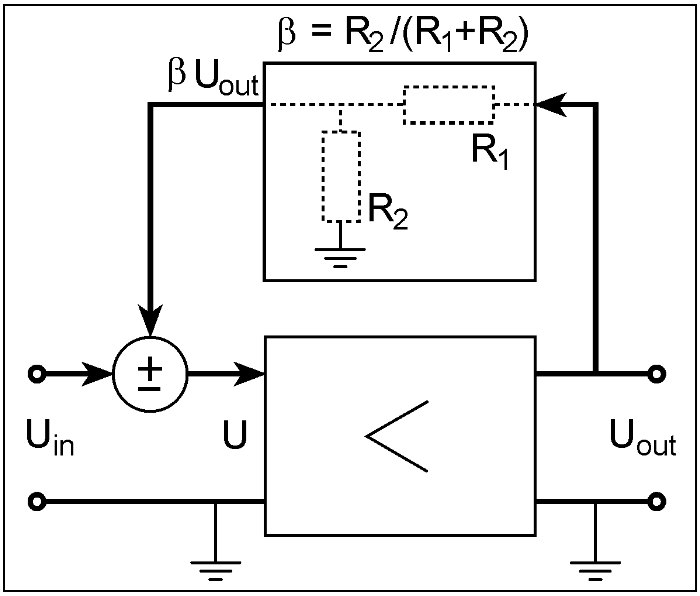
The properties of an amplifier can be changed radically if a portion of the output signal is led back to the input.

positive feedback:

$$A_{U,fb} = \frac{U_{out}}{U_{in}} = \frac{A_U}{1 - A_U\beta}$$

negative feedback:

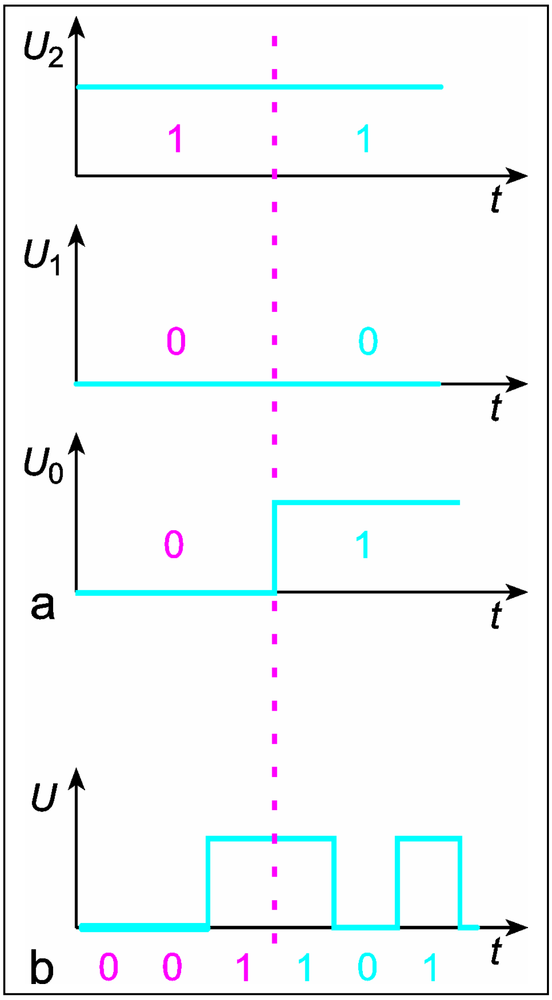
$$A_{U,fb} = \frac{U_{out}}{U_{in}} = \frac{A_U}{1 + A_U\beta}$$




Loop gain: $A_U\beta$

## Signal conversion and signal selection

### Analog-digital (A/D) conversion

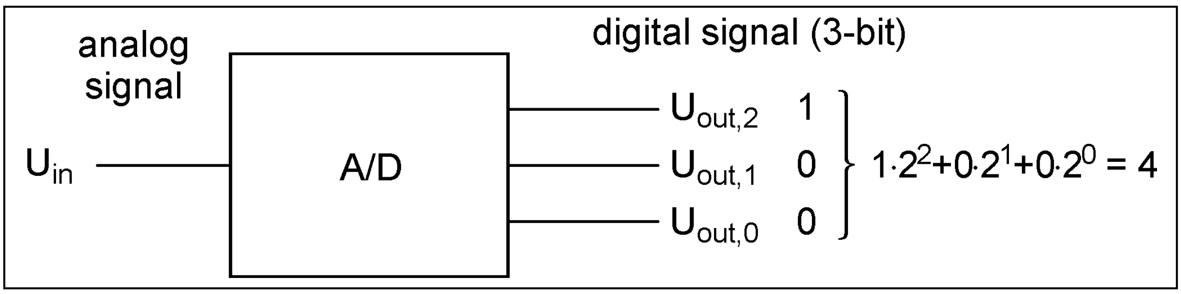



In the case of the simplest binary digital (BD) signal the voltage can take two values:
low, denoted with 0, and high, denoted with 1. This represents a one-digit number in binary (2-base) numeral system.

(multivibrators see in the manual: PULSE GENERATOR)

To display a greater number with this method, we need more parallel or consecutive BD voltage signals.

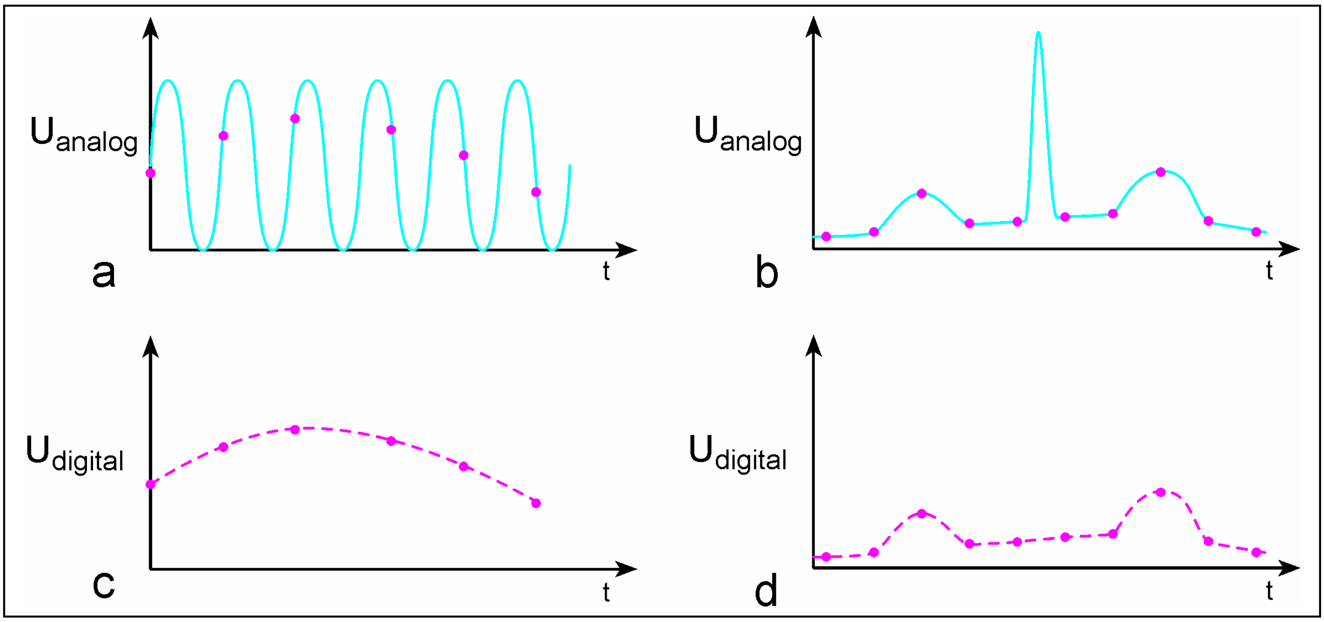
For example, 3 parallel BD voltage signals have altogether $2^3 = 8$ different configurations, hence we can display numbers from 0 to 7.



Important parameters of the A/D converter:

1. range of the input voltage that it can convert
2. resolution of the converter that is number of bits that the converter has

3. frequency of the sampling (Usually, the input voltage changes continuously, so the converter always measures its value after a certain period of time (it samples the signal). It is crucial that the sampling frequency is adjusted to the signal.) (**Bad sampling**!)

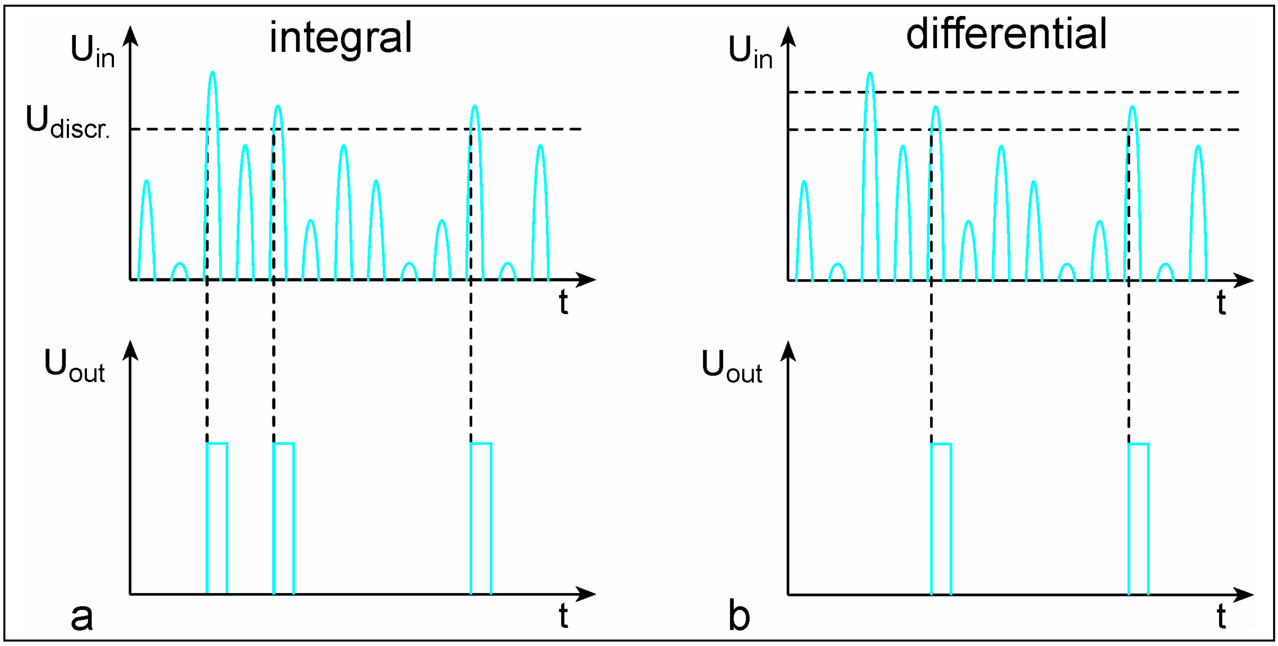


## Noise filtering

With a combination of high pass and low pas filters.

## Pulse selection

The selecting circuit is called integral or differential discriminator.



**Displays**

displays the number (analog, digital)
mechanical writer

Liquid Crystal Display (LCD):
Main advantage is the flat design and that they are free of harmful radiation.

The optic properties of liquid crystals can be influenced by electric field (electro-optic phenomenon), so they can be applied directly to alter the transparency of a pixel. The LCD displays do not emit light, so if necessary, they are enlightened by white fluorescent background light emitted from behind the panel.

Twisted Nematic (TN) or cholesteric liquid crystal