Medical signal processing

Signal?

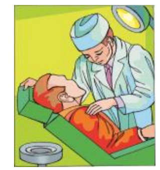
signal: contains information (information: new knowledge, that decreases the uncertainty).

signal

noise: everything, that is not signal.

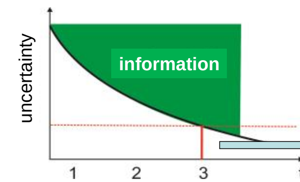
Relative!

Information



information:

1. Enters.	1. A patient.
2. Complaint?	2. I've a toothache.
3. Which?	3. Third molar.



diagnosis → therapy

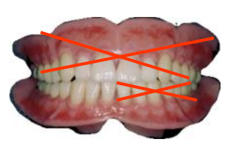
Information content

Which tooth is ill?

<u>32</u> possible answers! The uncertainty is enough large.

1. Upper? - not. Only 16 possible places. Decreasing uncertainty.

2. On the left? - not. 8 possible places.



Five right questions are necessary to indentify the place!

<u>Information content</u>: 5 *bit* ($2^5 = 32$)

Bit: unit of the information.

Classification of the signals 1.

Electric signals (e.g. ECG, EEG, EMG, etc.)

Non electric signals (e.g. blood pressure, temperature, etc.)

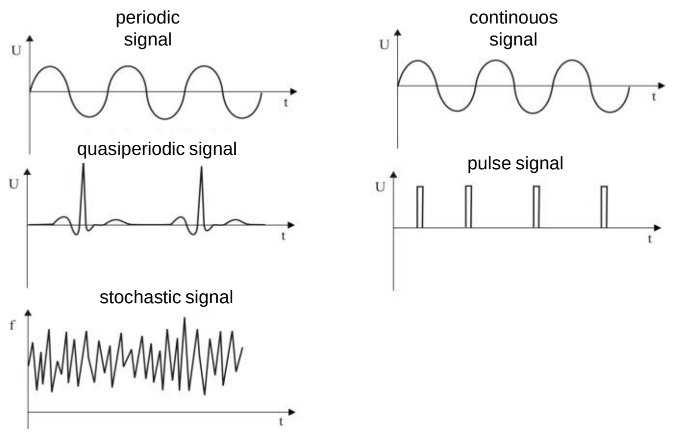
transformation

Equipments are based on electricity!.

electric signal

processing

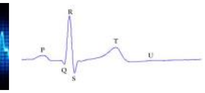
Classification of the signals 2.



Classification of the signals 3.

analog signal

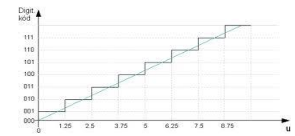
sound



ecg

In a certain range every value is possible.

digital signal



Only a finite no. of values are possible.

height:

analog signall

measurement

height:
175 cm

(only discret values)

Signal and noise

Noise is random normally!

Ideal case: there is no noise!

Real measurements: noise is always present!

Signal to noise ratio:

The ratio of the quantity used to characterize the strength of the signal and the noise.

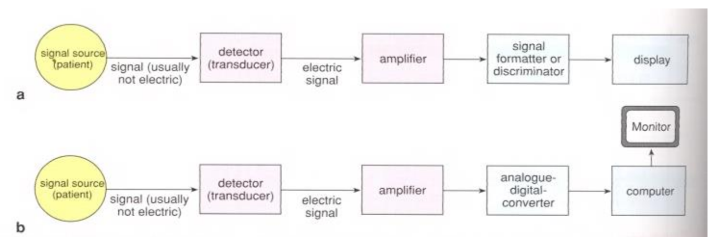
Higher value is better!

How can we increase?

increasing the signal

decreasing the noise

Signal processing



Elements in a electric circuit

passive


resistor


capacitor


inductivity

active



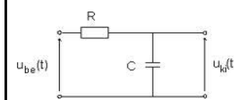
diode


transistor

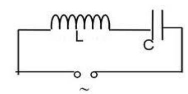
Electric circuits

A unit consists of elements.

simple
(consists of passive elements)



RC circuit



LC circuit

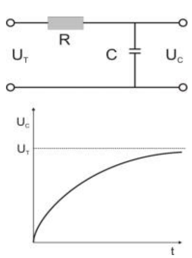
complex
(consists of passive and active elements)

integrated circuit


amplifier

DC behavior of a RC-circuit

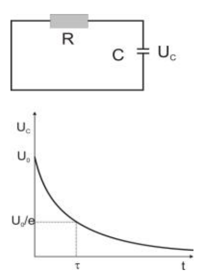
charging



$U_C = U_T \cdot \left(1 - e^{-\frac{t}{RC}}\right)$

$\tau = RC$

discharging

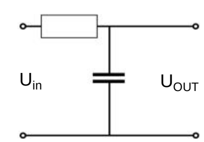


τ = time constant

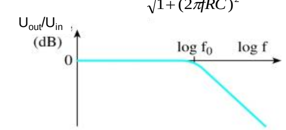
$U_C = U_0 \cdot e^{-\frac{t}{RC}}$

AC behavior of a RC-circuit

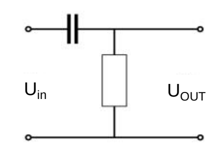
Lowpass filter



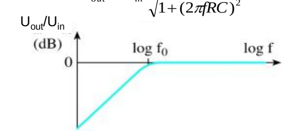
$$U_{out} = U_{in} \frac{1}{\sqrt{1+(2\pi fRC)^2}}$$



Highpass filter

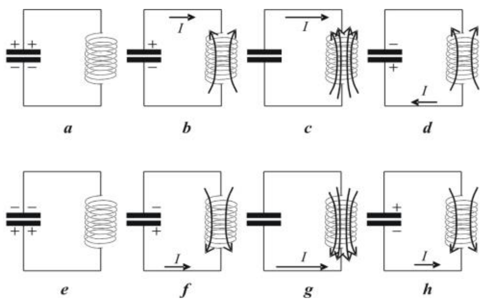


$$U_{out} = U_{in} \frac{2\pi fRC}{\sqrt{1+(2\pi fRC)^2}}$$



Resonant circuit (LC-circuit)

Electric (in the capacitor) and magnetic (in the coil) field



The electric and the magnetic field peridically are built up and destroyed.

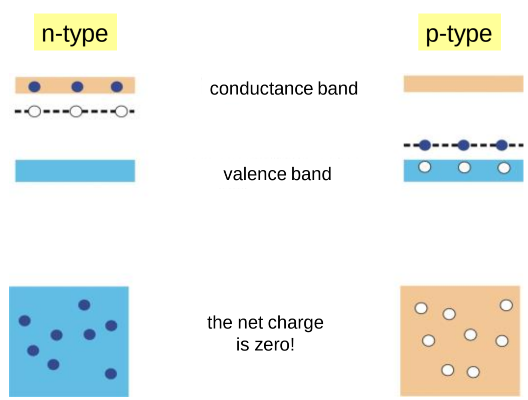
$$f = \frac{1}{2\pi\sqrt{LC}}$$

Resonance

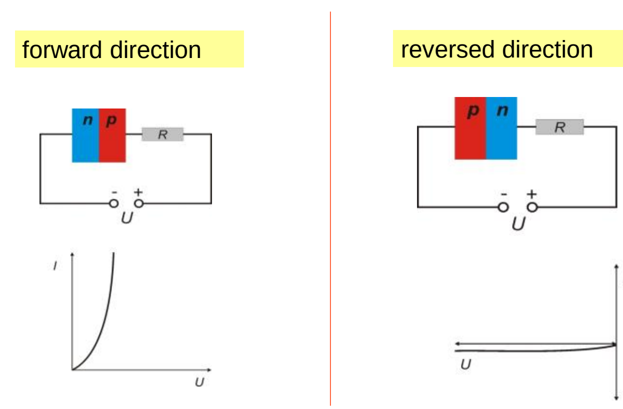
Energy excange between two oszcillating systems is possible only if the resonant frequency of the two systems is enough close to each other.

Tacoma bridge (1940)

Semiconductors

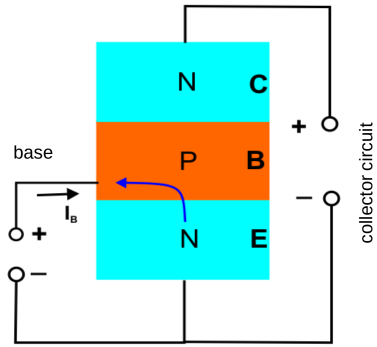


Working of a diode



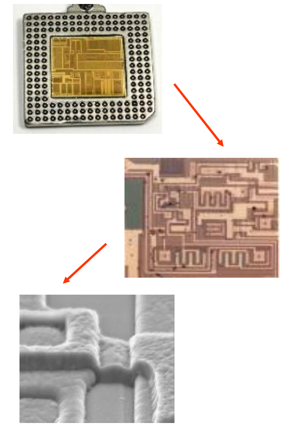
The transistor

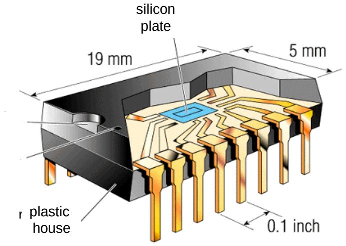
It is built up from 3 layers.



NPN transistor (there is PNP too)

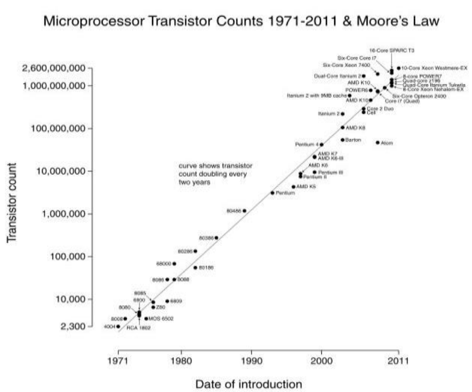
Integrated circuits (IC)





Transistors, diodes, resistors and capacitors are formed on a semiconductor plate producing a complicated electric circuit.

The development



There are about 10^{11} neurons in the brain.

Detectors

sound

microphone

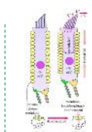
pressure

blood pressure monitor

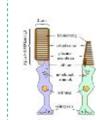
light

photodiode

elektric signal



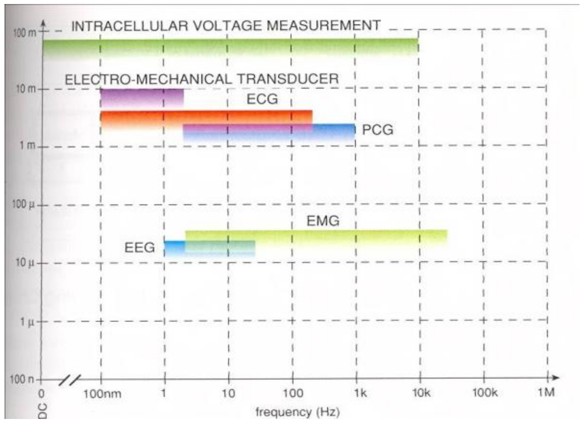
hair cells



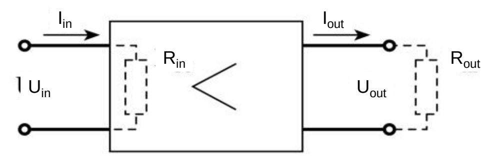
cones and rods

szcintillation head

Biological signals



Amplifier



Amplifier if
$P_{out} > P_{in}$

Power gain: (A_P)

Voltage gain: (A_U)

$$A_P = \frac{P_{out}}{P_{in}}$$

$$A_U = \frac{U_{out}}{U_{in}}$$

The decibel scale

Instead of the simple proportion we use frequently the logaritmic of them. This is the decibel-scale.

$$n = 10 \cdot \lg \frac{P_{out}}{P_{in}} \text{ (dB)}$$

$$P = \frac{U^2}{R}$$

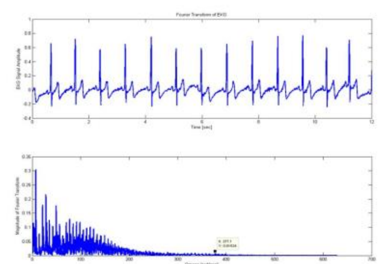
$$A_P = \frac{U_{out}^2 / R_{out}}{U_{in}^2 / R_{in}} = \frac{U_{out}^2}{U_{in}^2} \cdot \frac{R_{in}}{R_{out}} = A_U^2 \cdot \frac{R_{in}}{R_{out}}$$

$$n(dB) = 10 \cdot \lg A_U^2 + 10 \cdot \lg \frac{R_{in}}{R_{out}} = 20 \cdot \lg A_U \left(+ 10 \cdot \lg \frac{R_{in}}{R_{out}} \right)$$

Fourier theoreme

$$y(t) = \sum_k a_k \sin(k \cdot \omega_0 \cdot t + \Phi_k)$$

Every periodic signal may be decomposed into the sum of sinusiodal signals.

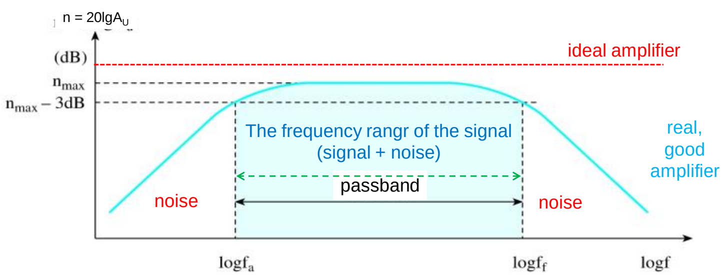


An ecg signal and it's frequency components.

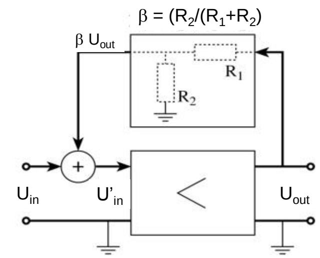
Transfer characteristics

The amplification (in decibel) as the function of the frequency.

In the presence of the noise the real amplifier is better.

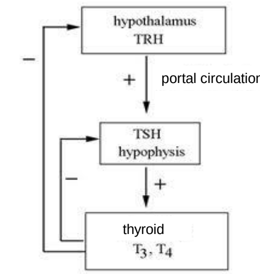


Feed-back



$$U_{in}^{'} = U_{in} \pm \beta \cdot U_{out}$$

$$A_{U,F} = \frac{U_{out}}{U_{in}} = \frac{A_U}{1 \pm \beta \cdot A_U}$$

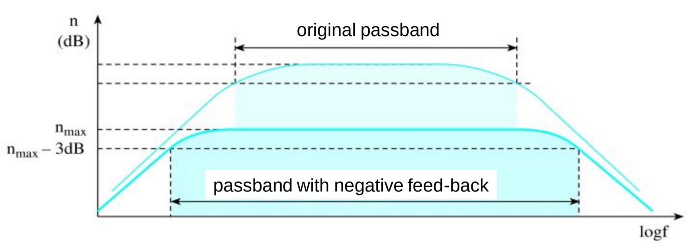


feed-back in the body

Negative feed-back

The feed-backed part of the output is added to the input after inversion.

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



Advantage of the negative feed-back

$$A_{U,F} = \frac{U_{out}}{U_{in}} = \frac{K_U}{1 + \beta \cdot K_U} \text{ usually } \beta \cdot K_U >> 1, \text{ so } K_{U,F} \approx \frac{K_U}{\beta \cdot K_U} = \frac{1}{\beta}$$

The properties (gain, transfer band) depend on feed-back elements only.

Consueqencies:

1. The parameters (gain, transfer band) are well defiinied.
2. Noise level decreases on the output.
3. Stability increases.

Pozitive feed-back

The feed-backed part of the output is added to the input.

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

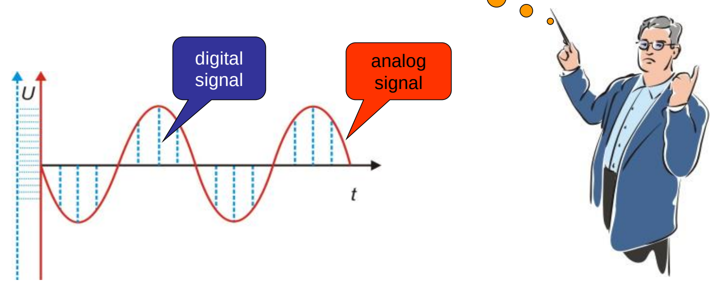
if $\beta A_U = 1$ the system is unstable, oscillation.

↓

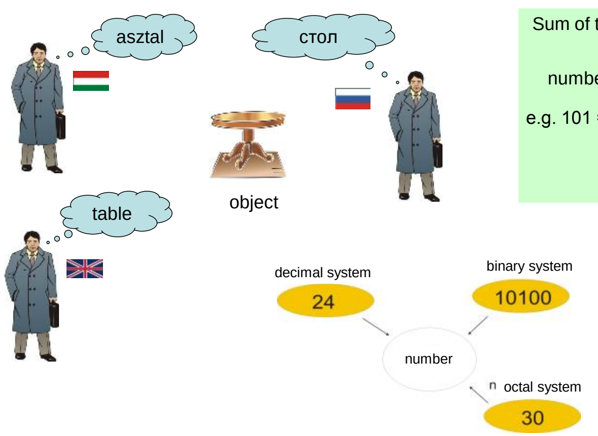
Oscillators: used to produce electric signal.

Digitazing the signal

Digital signal: a signal characterized by digital value and determined at a given time peridically (sampling).



Binary system of the numbers



Sum of the powers op 2.

numbers: 0 and 1.

e.g. 101 = $1\cdot2^2$

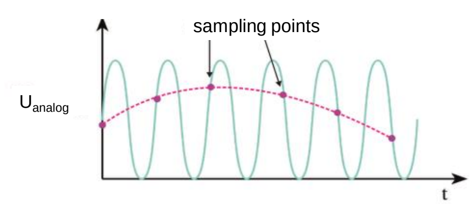
$+ 0\cdot2^1$

$+ 1\cdot2^0$

Shannon principle

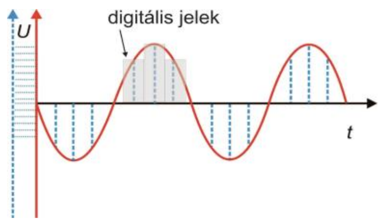
$f_{sampling} \geq 2\cdot f_{signal}$

If the sampling doesn't fulfill this requirement, false frequncies appear.



Role of the resolution

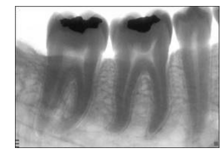
quantization noise:
noise due to the quantization.



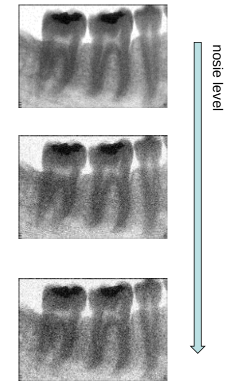
Due to the quantization series of squere pulses appear. The fequency range of them is different from the original one. Higher resolution decreases this noise.

Role of the noise level

original image



Richly detailed images, sufficient information.

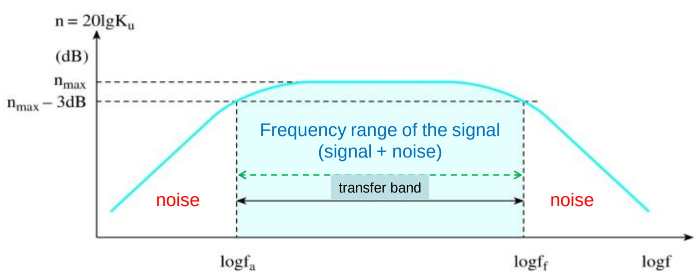


Increasing noise level decreases the information obtained from the image.

To decrease the noise level is an important part of the signal processing.

Planning a good amplifier

Base: Noise is present in the whole frequency range.

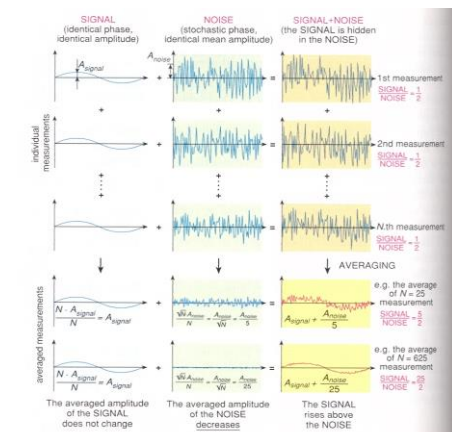


The signal to noise ratio increases
due to the decreasing amplification out of the transfer band.

Decreasing the noise by averaging

Base:

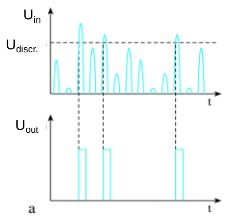
Noise is random while the signal is not.



Pulse signals

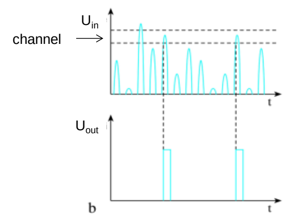
Base: The amplitude of the noise pulses is different in average.

Integral discriminator (ID)



Signal is produced only over a certain level.

Differential discriminator (DD)



Signal is produced if the amplitude is in the channel.

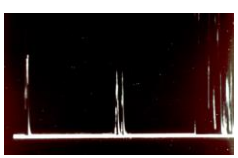
Displays

CRT (not frequenty used nowadays)

LCD

OLED

Displaying a time process



Time is on the horizontal axis and amplitude of the signal is on the vertical axis.

Information in an image

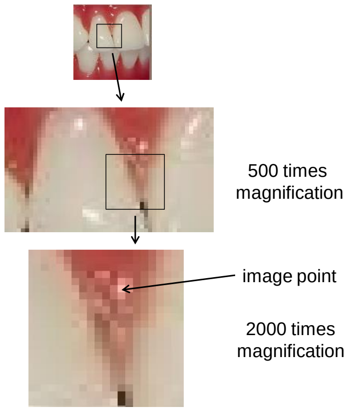
What is on the photo?

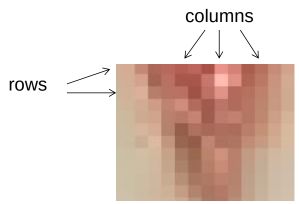
„ A landscape, a beautiful garden."

In fact:

How much is the absorption ability and the reflectivity of the different objects.

Structure of an image

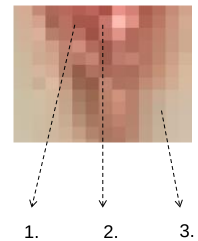




A digital image consist of image points ordered in columns and rows. They have different colors and intensities.

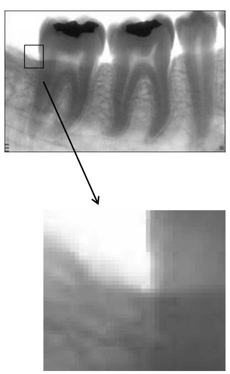
Physical content of an image

Every image point corresponds to a small part of the body. This part normally is a square. This is a ***pixel***. The pixel is cosidered to be homogeneous.
The properties of an image point are related to some physical characteristics of the pixel.



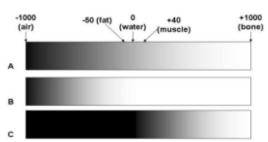
The 1. and the 2. pixel have the same absorption ability, but the reflectivity is different.
The absorption ability of the 3. pixel is diferrent, too.

X-ray image

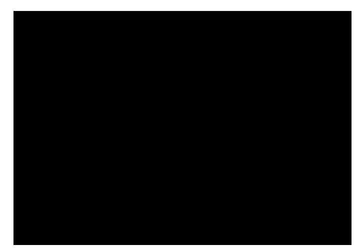


What information is in this image?
The x-ray absorption ability of the pixel is recorded in the image point.
Practically the μ value.

Gray scales of a CT image at different „windows”.



3D image

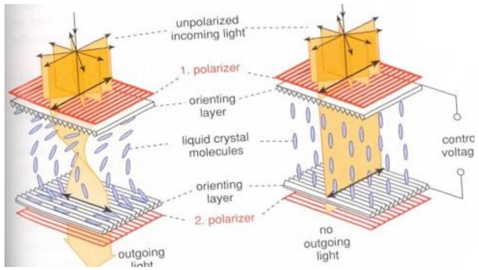


Every image point corresponds to a certain volume of the body. This volume normally a cube. this is the ***voxel***.

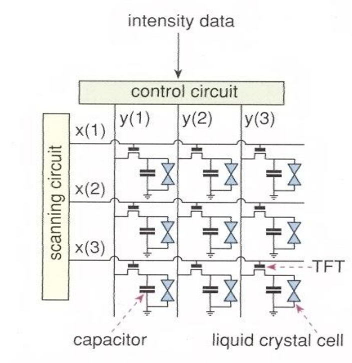
The properties of an image point are related to some physical characteristics of the voxel.

LCD (Liquid Crystal Display)

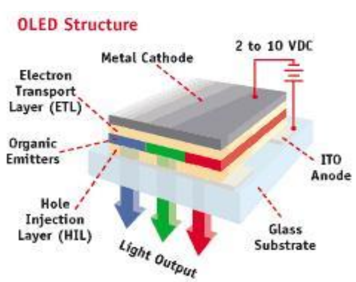
Structure and working of a single pixel (cell)



TFT (-LCD) display



A very thin (transparent) transistor layer switches each pixel. This improves the speed.



O(rganic)LED displays

This is the structure of a unit cell (an image point) of the display.
The recombination of the electrons and holes produces the light. The color corresponds to the energy difference of them.
(Of cource one of the electrodes must be transparent.)

LED: Light Emitting Diode

Comparison of displays

	CRT	LCD	TFT-LCD (LED)	Plasm	OLED
brightness (cd/m²)	~100	200-300	200-300	400-1000	A few 100
Contrast ratio	> 1000:1	~ 600:1	600:1 (but LED: 1000000:1)	> 1000:1	> 1000:1
Viewing angle	whole range	~140-160 degree	~140-160 degree	~160 degree	whole range
Frame rate	<1 ms	8-20 ms	<8 ms	<1 ms	<1 ms

Flexible displays

Transparent displays

Application of the CCD

Unit cell of a CCD