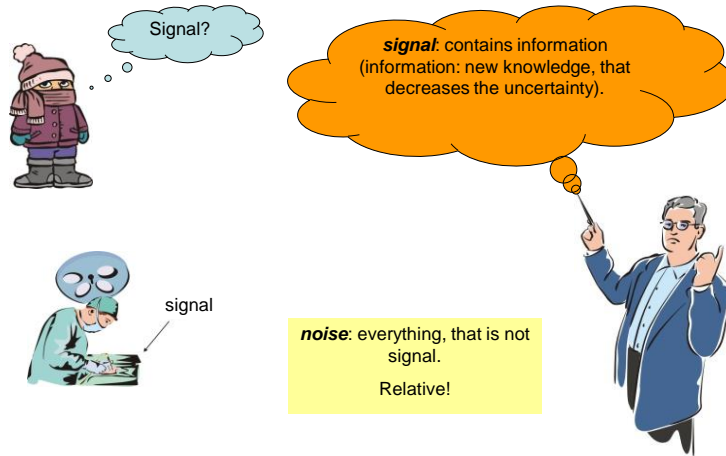


Medical signal processing



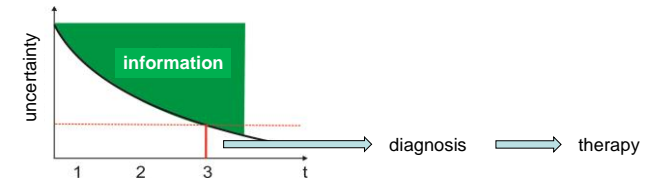
Information



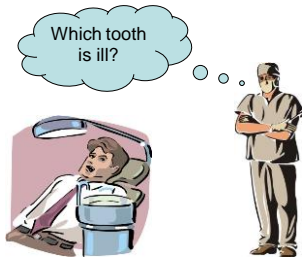
1. Enters.
2. Complaint?
3. Which?

information:

1. A patient.
2. I've a toothache.
3. Third molar.



Information content



32 possible answers! The uncertainty is enough large.

1. Upper? - not. Only 16 possible places. Decreasing uncertainty.
2. On the left? - not. 8 possible places.

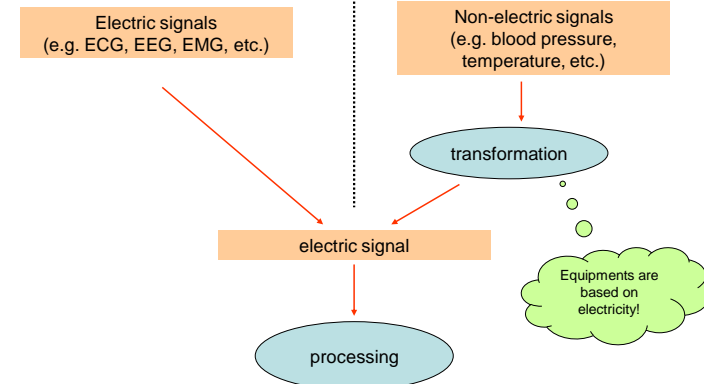


Five right questions are necessary to identify the place!

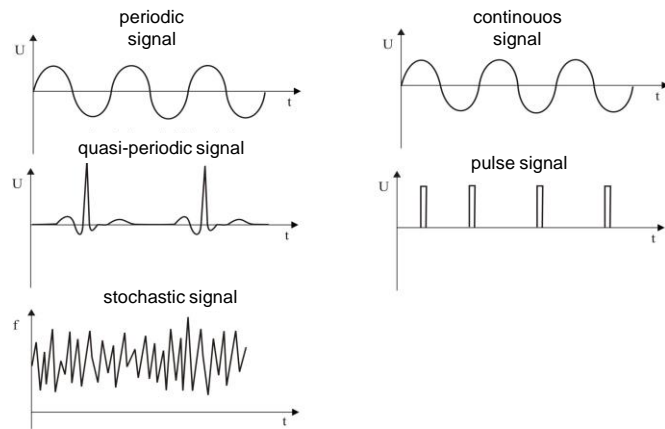
Information content: 5 bit ($2^5 = 32$)

Bit: unit of the information.

Classification of the signals 1.



Classification of the signals 2.

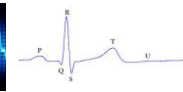


Classification of the signals 3.

analog signal



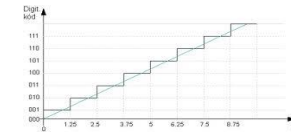
sound



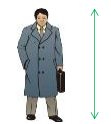
ecg

Every value is possible in a certain range .

digital signal



Only a finite no. of values are possible.



height:
analog signal

measurement



height:
175 cm
(only discrete 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 quantity used to characterize the strength of the signal and the noise.

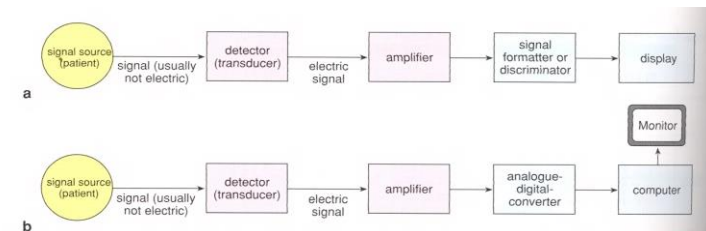
Higher value is better!

How can we increase?

increasing the signal

decreasing the noise

Signal processing



Elements in electric circuit

passive



resistor



capacitor



inductivity

active



diode

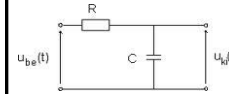


transistor

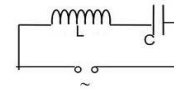
Electric circuits

A unit that consists of elements.

simple
(consists of passive elements only)



RC circuit



LC circuit

complex
(consists of passive and active elements)



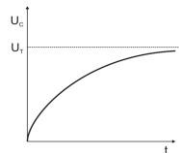
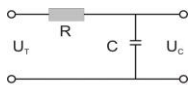
integrated circuit



amplifier

DC behavior of a RC-circuit

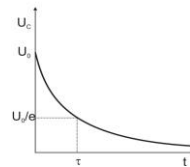
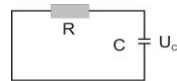
charging



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

$$\tau = RC$$

discharging

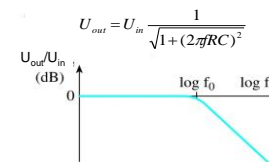
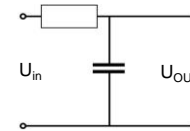


τ = time constant

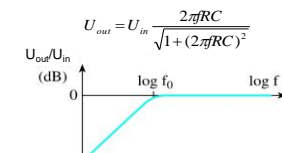
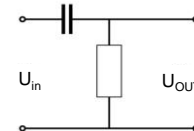
$$U_c = U_0 \cdot e^{-\frac{t}{RC}}$$

AC behavior of a RC-circuit

Lowpass filter

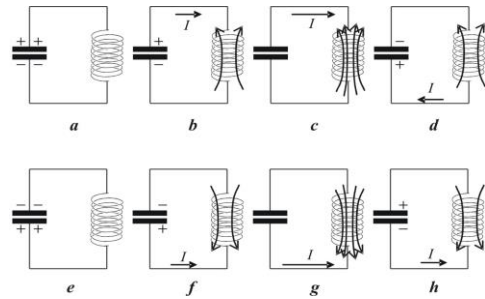


Highpass filter



Resonant circuit (LC-circuit)

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



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

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

Resonance

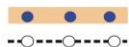
Energy exchange between two oscillating systems is possible only if the resonant frequency of the two systems is enough close to each other.

Tacoma bridge (1940)



Semiconductors

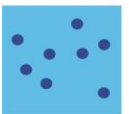
n-type



conductance band

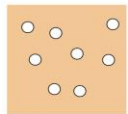
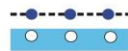


valence band



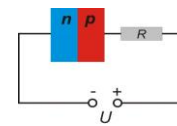
the net charge
is zero!

p-type

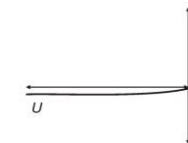
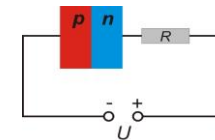


Working of a diode

forward direction

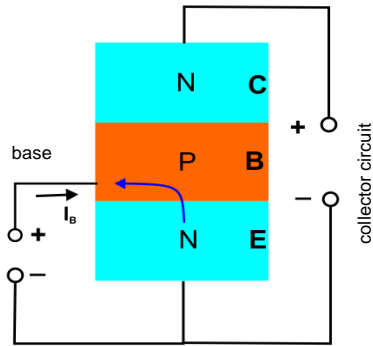


reversed direction



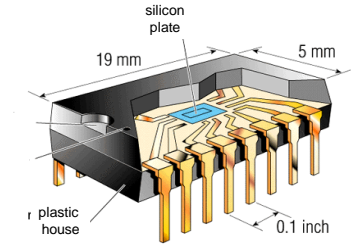
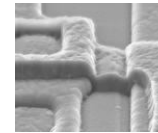
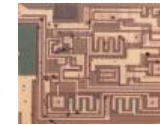
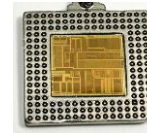
The transistor

It is built up from 3 layers.



NPN transistor (there is PNP too)

Integrated circuits (IC)

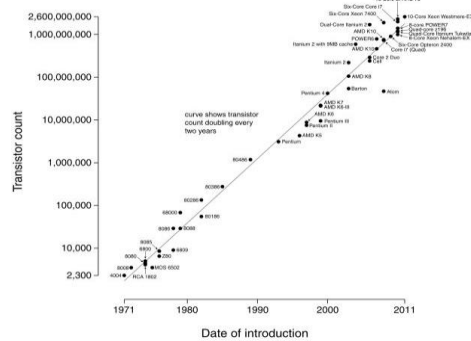


Transistors, diodes, resistors and capacitors are formed on a semiconductor plate producing a complicated electric circuit.

The development

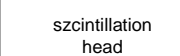


Microprocessor Transistor Counts 1971-2011 & Moore's Law



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

Detectors

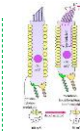


microphone

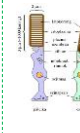
blood pressure monitor

photodiode

electric signal

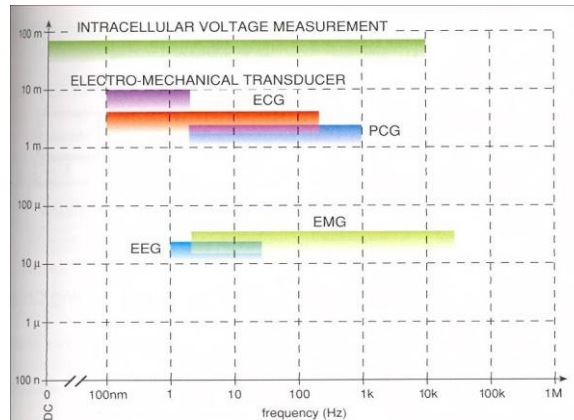


hair cells

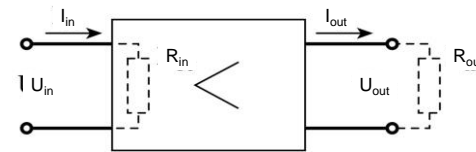


cones and rods

Biological signals



Amplifier



**Amplifier
only 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 logarithmic of them. This is the decibel-scale.

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

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

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

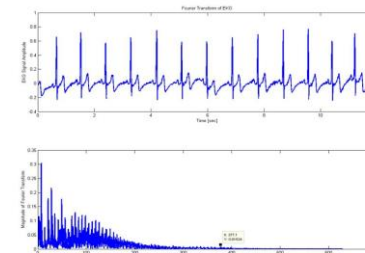
$$n(\text{dB}) = 10 \cdot \lg A_U^2 + 10 \cdot \lg \frac{R_{in}}{R_{out}} = 20 \cdot \lg A_U + 10 \cdot \lg \frac{R_{in}}{R_{out}}$$



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 sinusoidal signals.

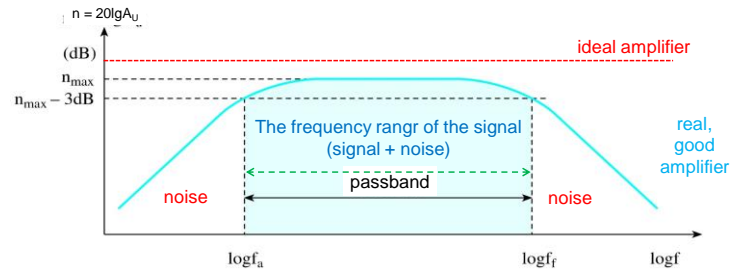


An ecg signal and its frequency components.

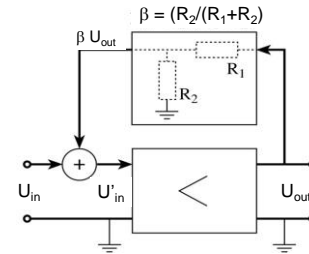
Transfer characteristics

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

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

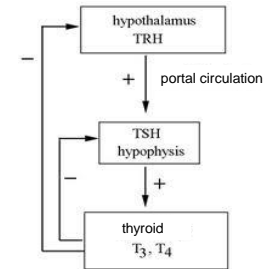


Feed-back



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

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

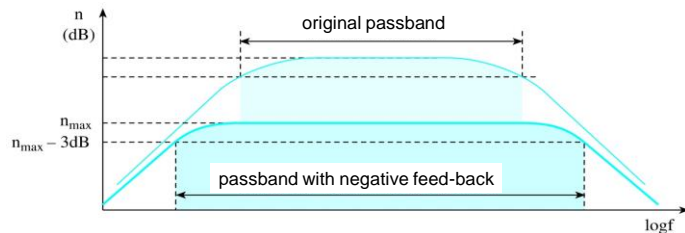


feed-back
in the body

Negative feed-back

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

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



Advantage of the negative feed-back

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

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

Consequences:

1. The parameters (gain, transfer band) are well defined.
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.

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

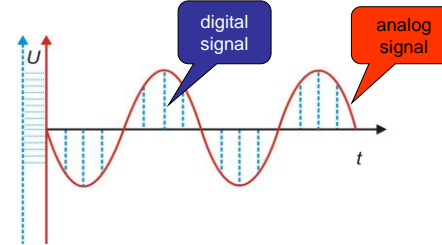
if $\beta A_U = 1$ the system is unstable, oscillation.



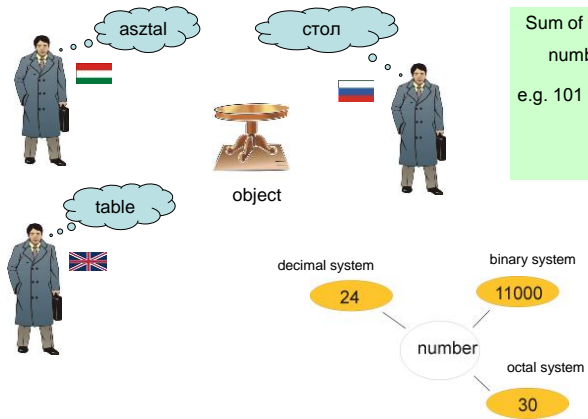
Oscillators: used to produce electric signal.

Digitizing the signal

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



Binary system of the numbers



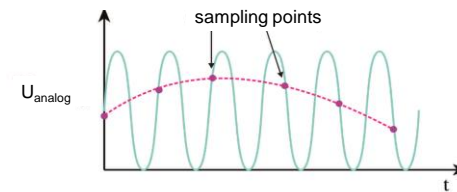
Sum of the powers of 2.
numbers: 0 and 1.

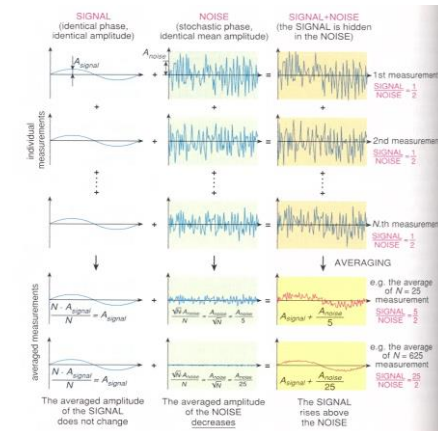
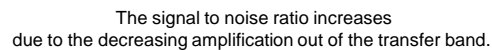
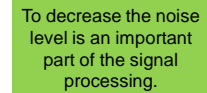
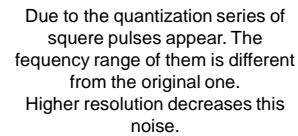
$$\begin{aligned} \text{e.g. } 101 &= 1 \cdot 2^2 \\ &+ 0 \cdot 2^1 \\ &+ 1 \cdot 2^0 \end{aligned}$$

Shannon principle

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

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

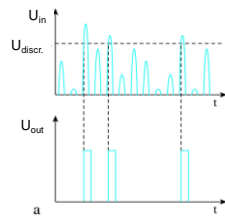




Pulse signals

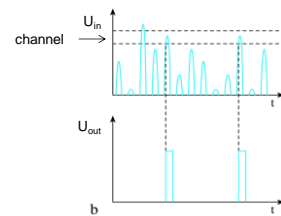
Base: The amplitude of the noise pulses is different in average.

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 frequently used nowadays)



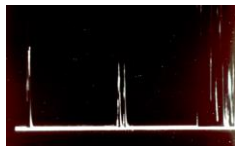
LCD

OLED



XEL-1

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?

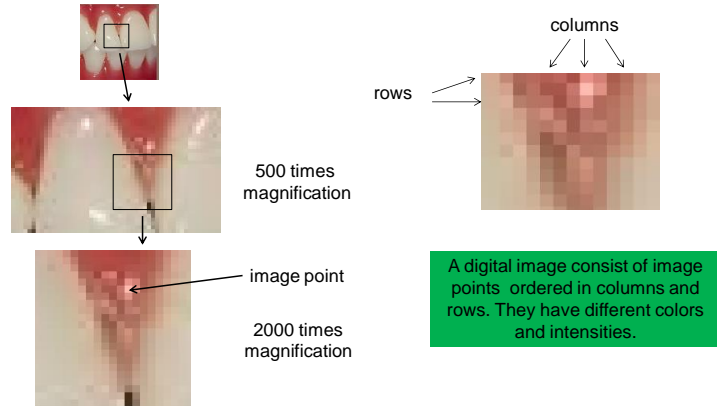
„A landscape, a beautiful garden.“



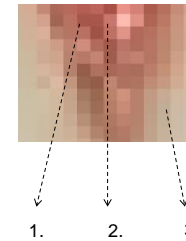
In fact:

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

Structure of an image



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 considered 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 different, too.

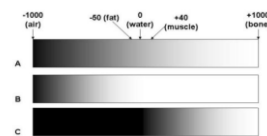
X-ray image



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“.

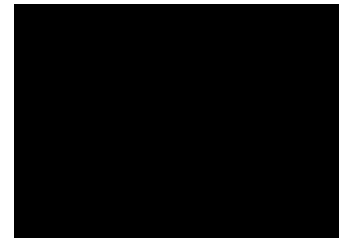


3D image



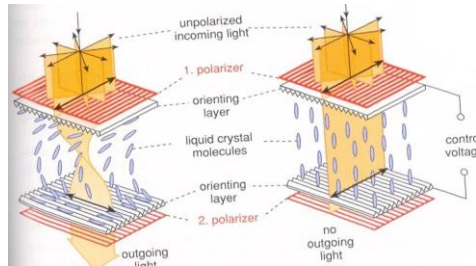
Every image point corresponds to a certain volume of the body. This volume normally a cube. this is the **voxel**.

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

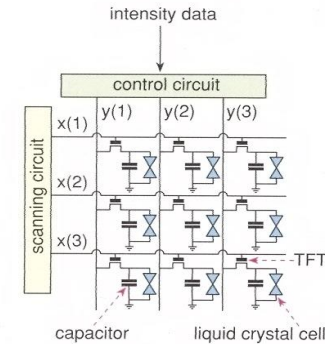


LCD (Liquid Crystal Display)

Structure and working of a single pixel (cell)

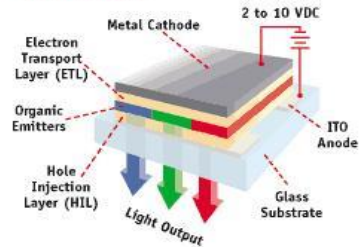


TFT (-LCD) display



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

OLED Structure



LED: Light Emitting Diode

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 course one of the electrodes must be transparent.)

Comparison of displays

	CRT	LCD	TFT-LCD (LED)	Plasm	OLED
brightness (cd/m ²)	~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

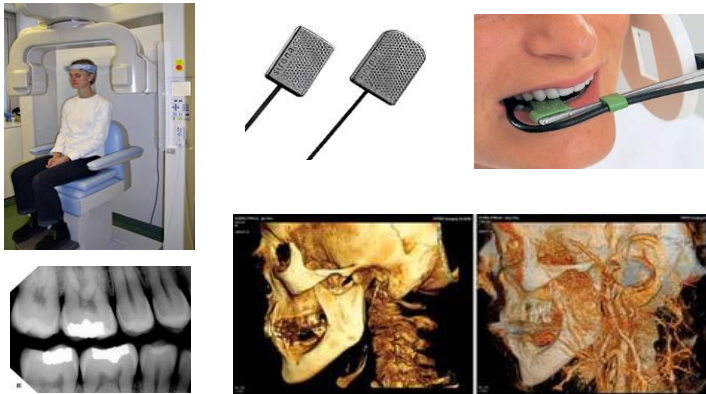
Flexible displays



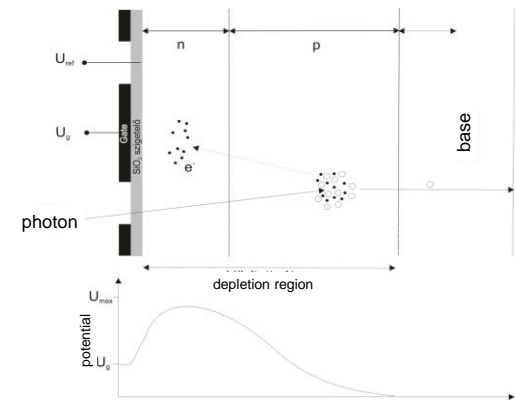
Transparent displays



Application of the CCD



Unit cell of a CCD



Which amplifier is the ideal one and
what is the reason that it is not the best solution?