Sensor Design II♪

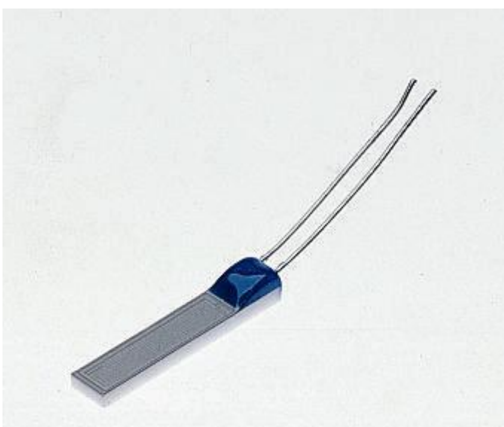
ME 490B Fall 2014

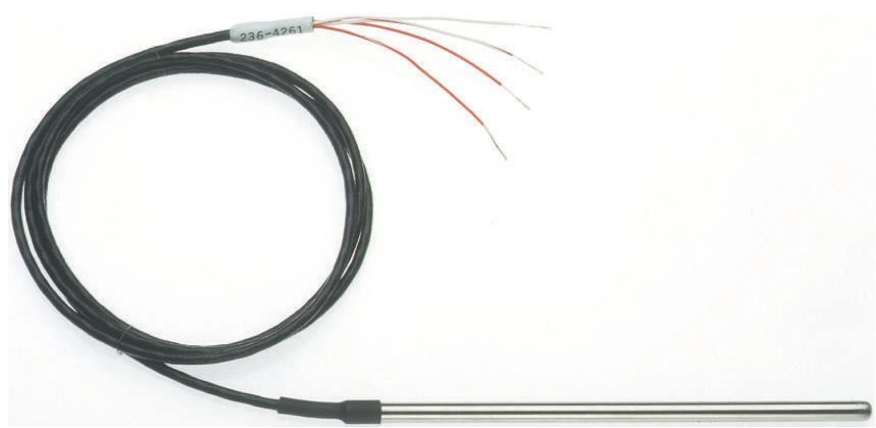
Sensors

- Temperature Sensors
- Light Sensors
- Force Sensors
- Displacement Sensors
- Motion Sensors
- Sound Sensors
- Biomedical Sensors
- Sensor Interfacing

Temperature sensors

- **Resistive thermometers**
  - typical devices use platinum wire (such a device is called a platin um resistance thermometers or PRT)
  - *linear* but has poor *sensitivity*





Temperature sensors-Thermisto rs♪

Use materials with a high thermal coefficient of resistan ce

– *sensitive* but highly *non-linear*

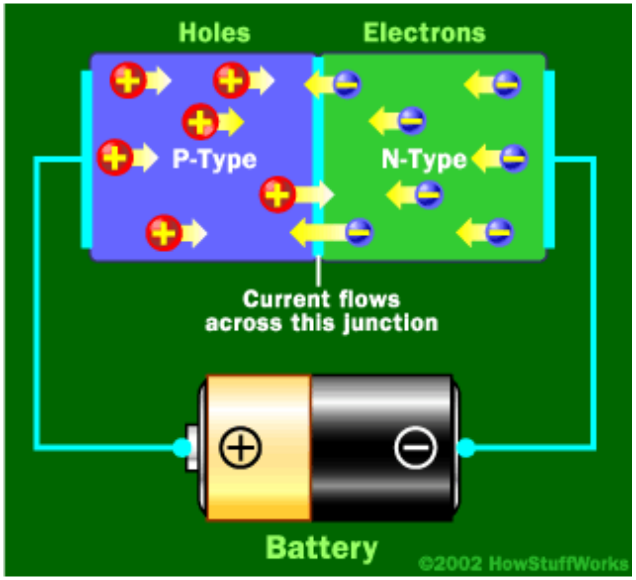
♪

Temperature sensors-Transistor

- ***pn* junctions**
  - a semiconductor device with the properties of a diode (we will consider semiconductors and diodes later)
  - *inexpensive*, *linear* and *easy to use*
  - *limited temperature range* (perhaps -50°C to 150 °C) due to nature of semiconductor material

pn-junction sensor

Diode



When the negative end of the circuit is hooked up to the N-type layer and the positive end is hooked up to P-type layer, electrons and holes start moving and the depletion zone disappears.

Light-emitting Diode (LED) ♪

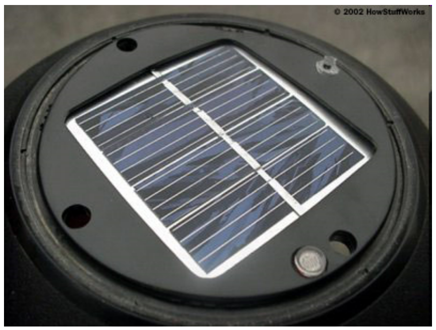
LEDs are just tiny light bulbs that fit easily into an electrical circuit. LEDs are specially constructed to release a large number of photons outward.

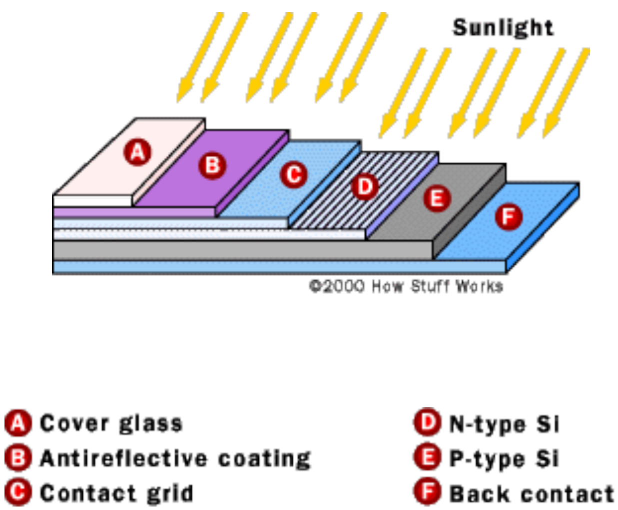
Light Sensors

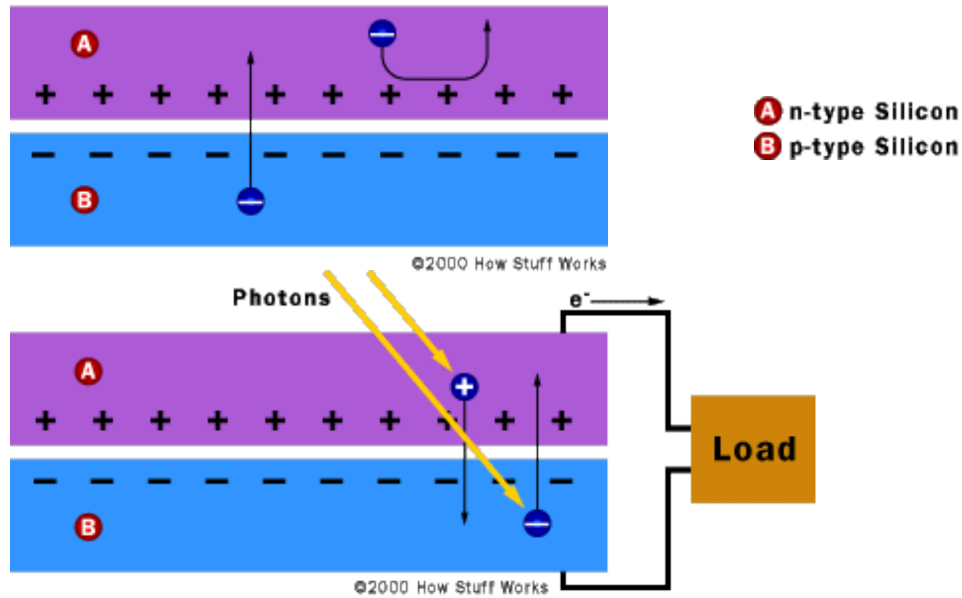
- Photovoltaic
  - light falling on a *pn*-junction can be used to generate electricity from ligh t energy
    (as in a solar cell)
  - small devices used as sensors are c alled photodiodes
  - fast acting, but the voltage produced is *not* linearly related to light intensit y

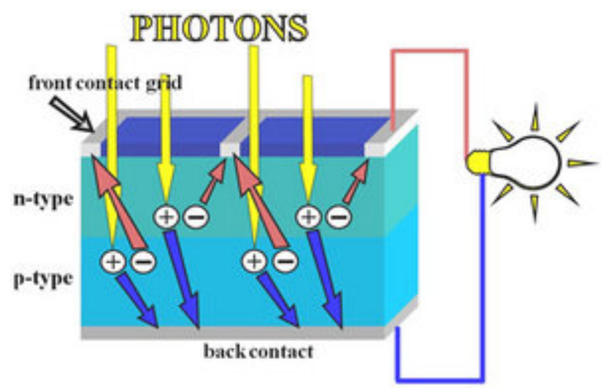
A typical photodiode

Basic structure of a generic silicon solar cell



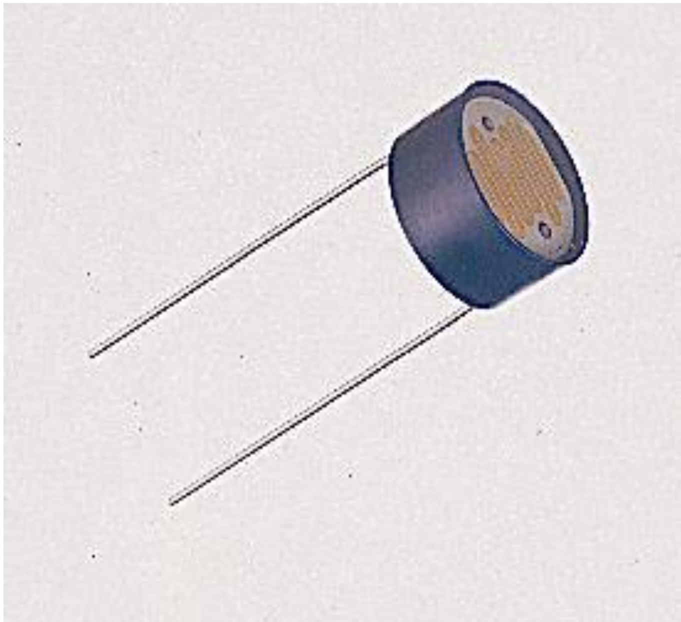






Light Sensors-Photoconductive

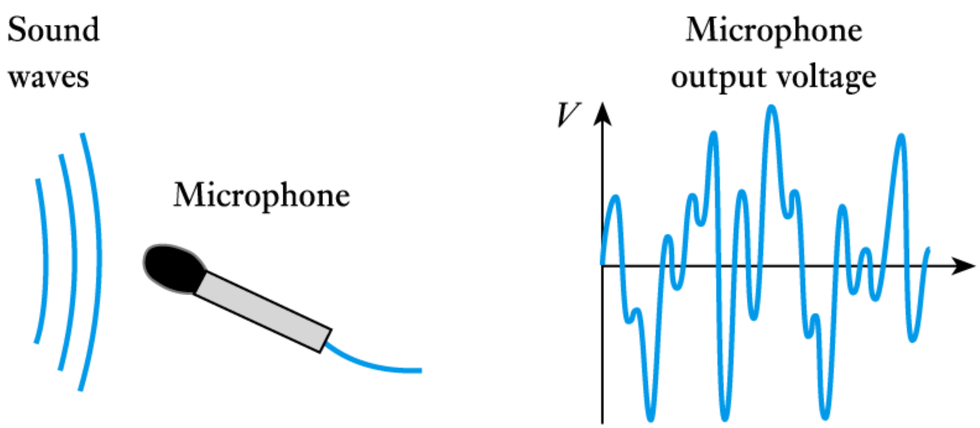
- **Photoconductive**
  - such devices do not produce elec tricity, but simply change their res istance
  - photodiode (as described earlier) can be used in this way to produ ce a linear device
  - phototransistors act like photodio des but with greater sensitivity
  - light-dependent resistors (LDRs) are slow, but respond like the hu man eye



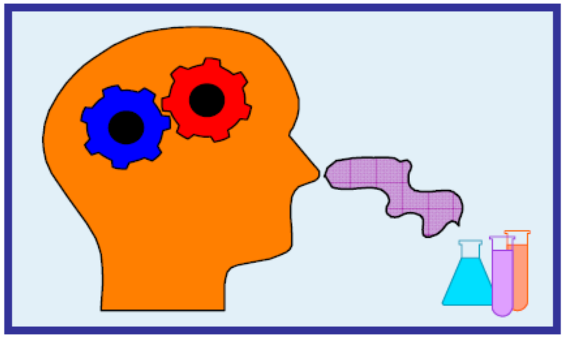
A light-dependent resistor (LDR)

Sound Sensors

- **Microphones**
  - a number of forms are available
    - e.g. carbon (resistive), capacitive, piezoelectric and moving-coil microphones
    - moving-coil devices use a magnet and a coil attached to a diaphrag m – we will discuss electromagnetism later



Biochemical sensors - Electric Nose



HUMAN NOSE

- array of hundreds of sensors
- organic sensors
- broad band capability
- trainable to new odors
- data acquisition in the brain
- analysis by true Neural Network processing; pattern recognition

LIMITS ON HUMAN NOSE

- fatigue
- odor adaptation
- insensitivity to some species
- toxicity of some contaminants

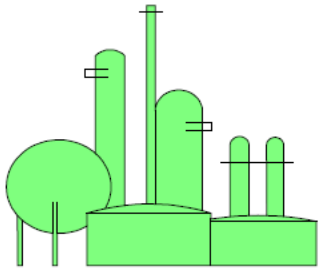
JPL ELECTRONIC NOSE

- array of a few tens of sensors
- thin film polymer based sensors
- broad band capability
- polymers selected to respond to particular compounds
- trainable to new analytes
- data acquisition by computer
- data analysis by computational methods and pattern recognition

LIMITS ON ENOSE

- insensitivity to some species
- good only for a limited set of analytes

SPACE STATION ENVIRONMENTAL MONITORING



INDUSTRIAL MONITORING AND PROCESS CONTROL

Identity and condition of raw materials, leaks and buildup of toxic compounds; Monitor food processing

OTHER ENVIRONMENTAL MONITORING

Air quality in buildings, aircraft. Presence of toxic materials in enclosed spaces (mines, tunnels, e

SECOND GENERATION ELECTRONIC NOSE

MILITARY APPLICATIONS

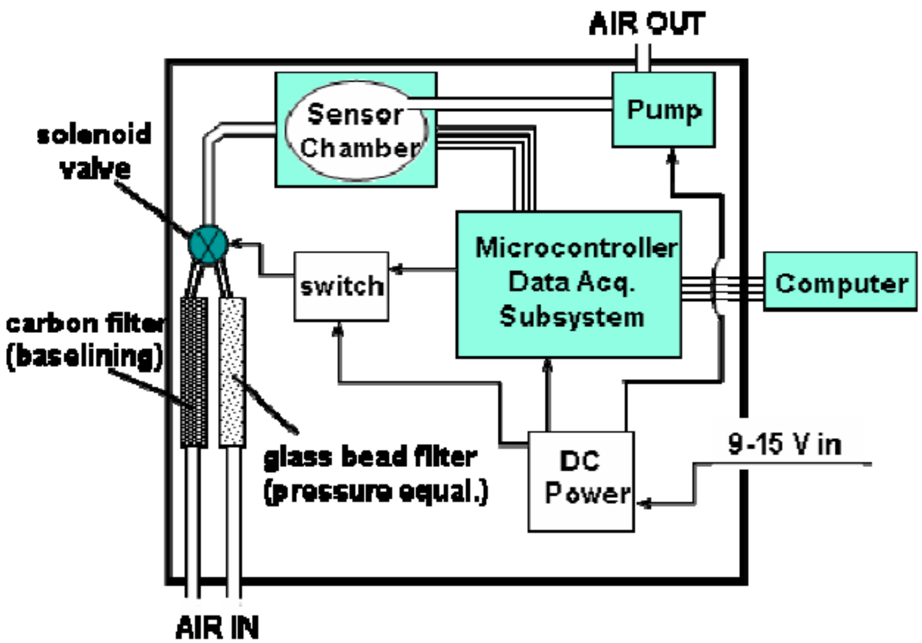
air quality monitor, detection of explosives and other hazards

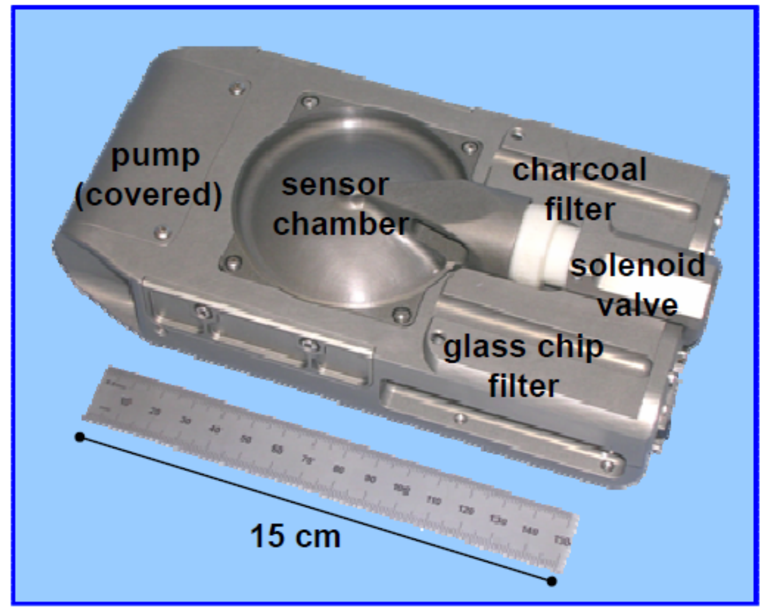
MEDICAL APPLICATIONS

Diagnosis through breath or body fluid analysis; remote monitoring of patient condition

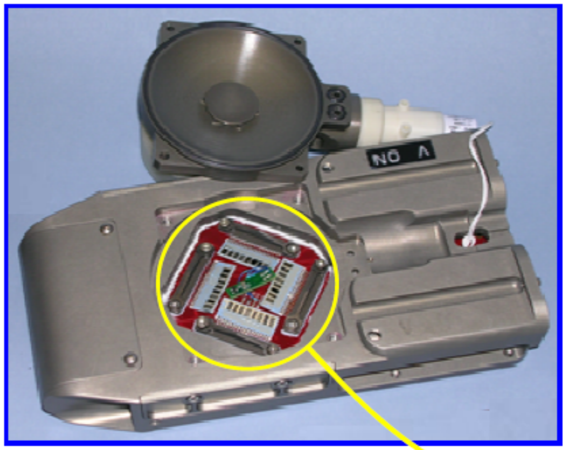
PLANETARY EXPLORATION

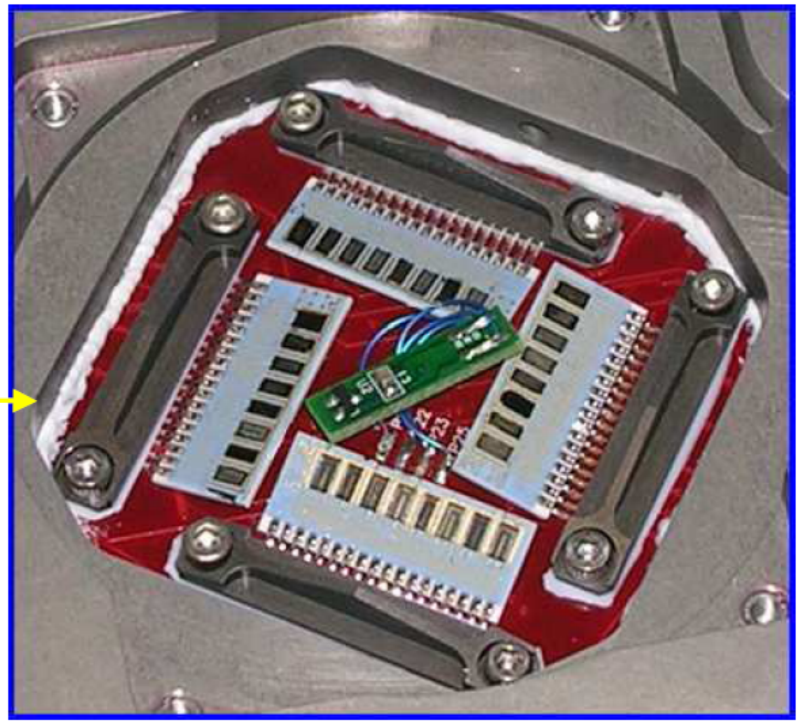
Study planetary atmosphere to determine constituents and fluctuations





The JPL Electronic Nose

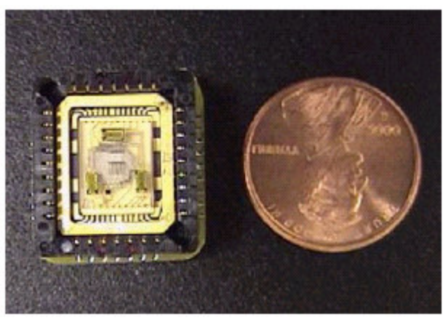
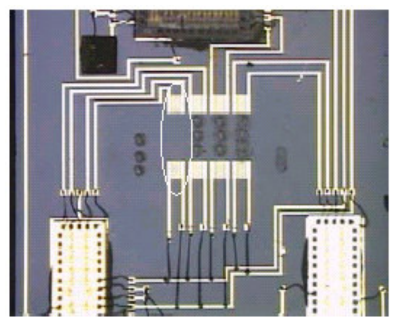




- Polymer loaded with carbon black for electronic conductivity
- Operate at 28-36 °C
- Sensor set selected to detect 20 organic and a few inorganic compounds

Acoustic bio-chemical sensors

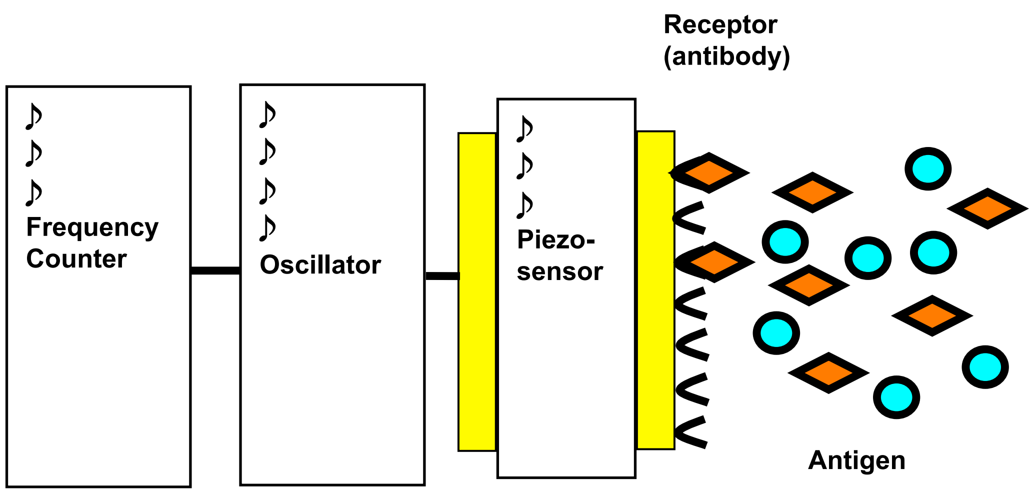
- Acoustic waves in materials at ultrasonic frequencies
- Involve piezoelectric substrates to generate acoustic fields
- Extremely sensitive gravimetric detectors
- Coated with an receptor probe to collect biochemical species of interest
- Bind bacterium, virus, toxin, or chemical and generate a measurable signal
- Typically measures changes in frequency/phase of oscillation

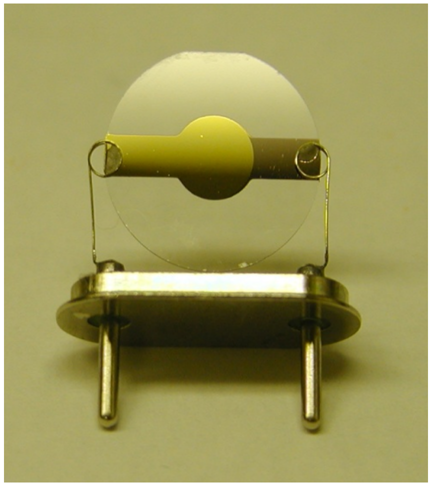



Sandia Lab SAW sensor

Acoustic bio-chemical sensors-QCM (Quartz Crystal Microbalance)

- Capable of measuring surface mass changes on a sensitive surface area
- Large molecules (proteins, viruses and bacteria) can be measured directly after binding to the receptor (e.g. antibody)
- Limited in the sensitivity





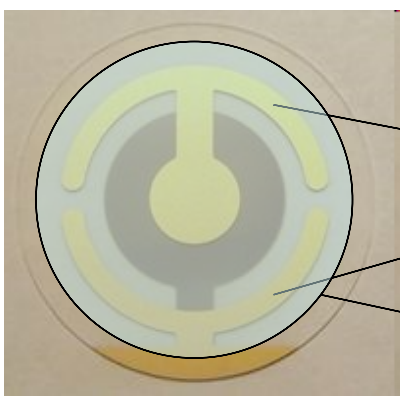
Quartz vs. PMN-PT

Quartz = SiO_2

http://www.mineralminers.com/html/phantom_quartz_crystal.htm

PMN-PT = $(1\text{-}x)Pb(Mg_{1/3}Nb_{2/3})O_3\text{-}xPbTiO_3$

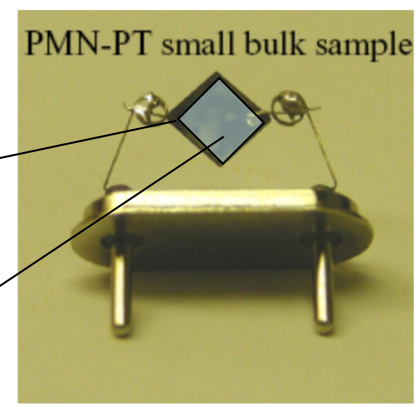
http://www.trstechnologies.com/Products/Single_Crystal/piezo_crystals.php



http://www.tangidyne.com/liquid_monitoring_crystals.html

Au electrode
(Non-functionalized layer)

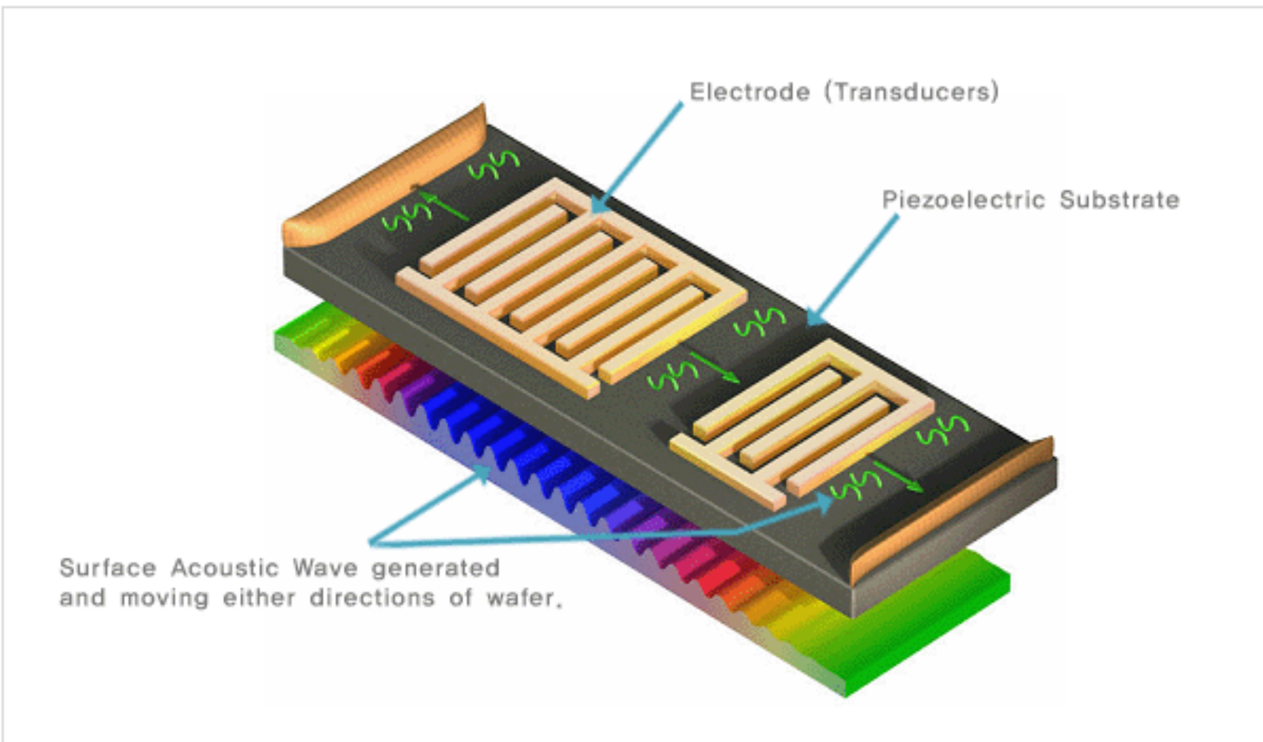
Polymethylmethacrylate (PMMA)
(Functionalized layer)



Hong, Y.K.. et al. (2004)

surface acoustic wave (SAW) devices

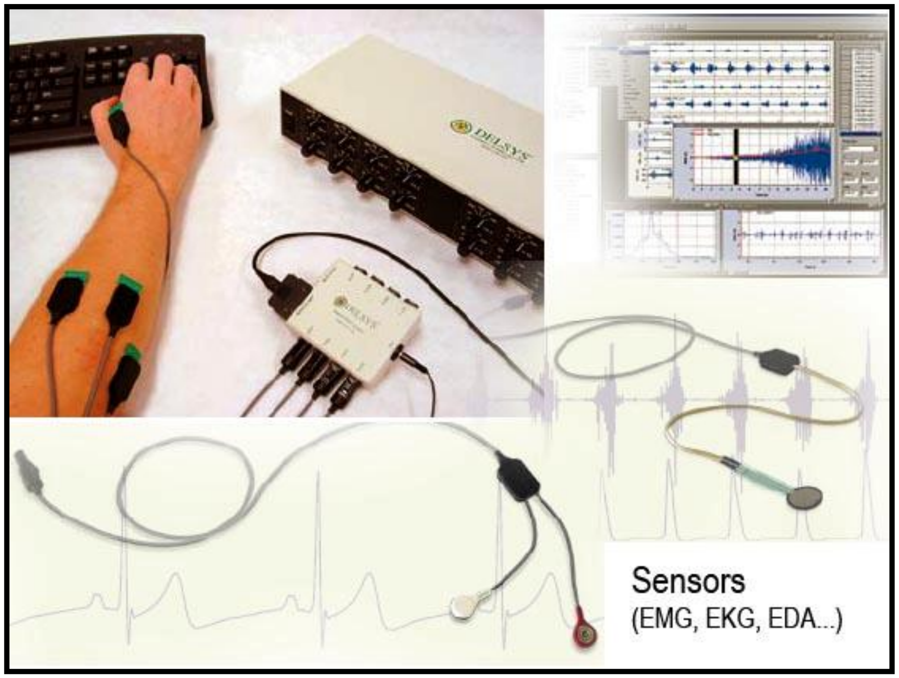
- When chemical vapor molecules come in contact with and are adsorbed by the plate the mass per unit area of plate increases significantly.
- The Vp of the propagating wave is decreased ♪



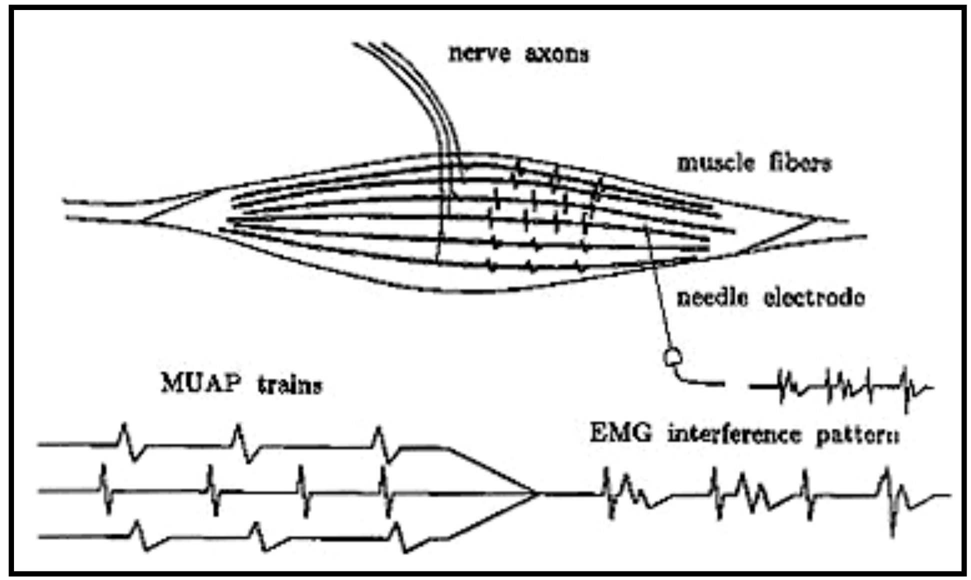
Electromyogram (EMG)

- Electromyogram (EMG) is a technique for evaluating and recording the activation signal of muscles.
- EMG is performed by an **electromyograph**, which records an **electromyogram**.
- Electromyograph detects the electrical potential generated by muscle cells when these cells contract and relax.

Electromyogram (EMG)



EMG Apparatus♪



Muscle Structure/EMG♪

Electromyogram (EMG)

- The electrical source is the muscle membrane potential of about -70mV.
- Measured EMG potentials range between

  < 50 µV up to 20 to 30 mV, depending on the muscle under observation.
- Typical repetition rate of muscle unit firing is about 7−20 Hz.
- Damage to motor units can be expected at ranges between 450 and 780 mV

Electromyogram (EMG)

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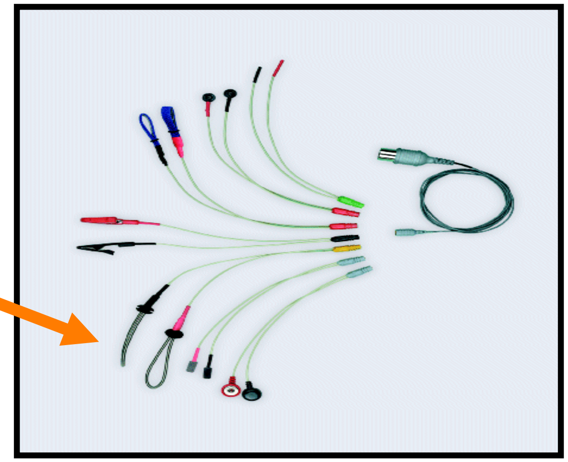
Intramuscular – ♪
Needle Electrodes♪



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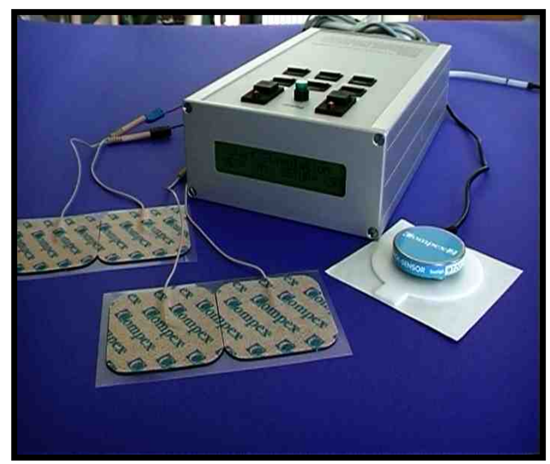
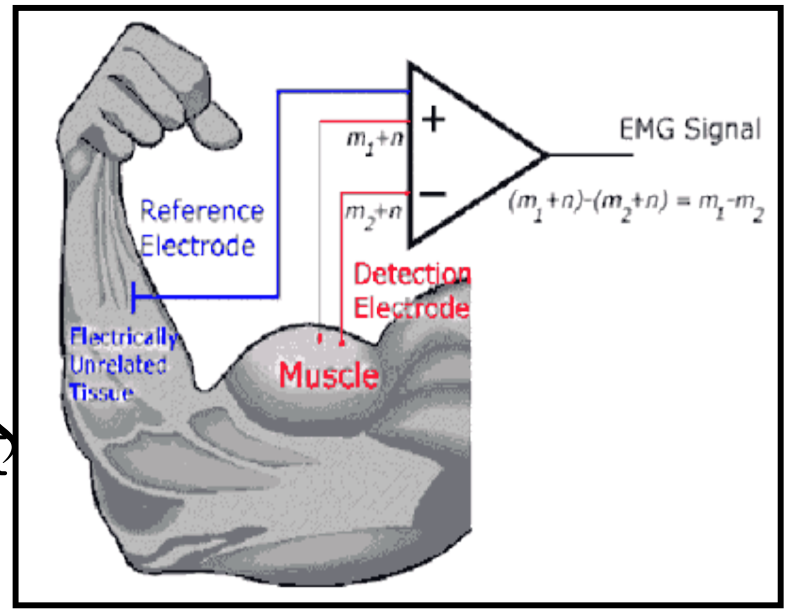
♪
Extramuscular – Surface
Electrodes♪



Electromyogram (EMG)

- Clean the site of application of electrode♪
- Insert needle/place surface electrodes at muscle group♪
- Record muscle activity at rest♪
- Record muscle activity upon voluntary contraction of the muscle♪



Electromyogram (EMG)

EMG processing:♪

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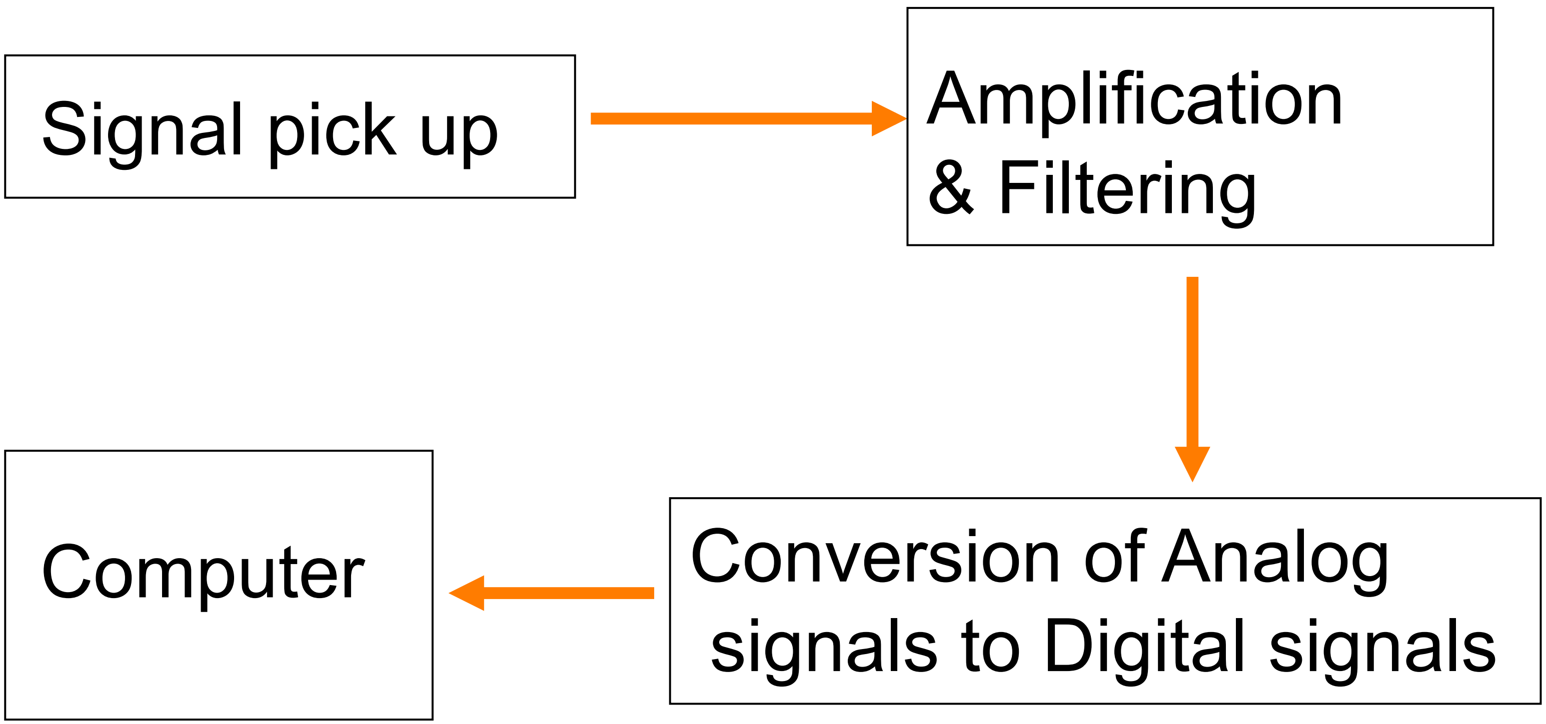
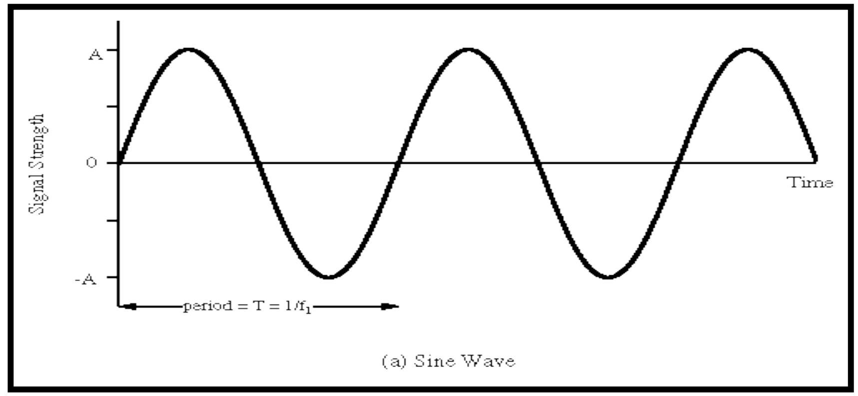


Electromyogram (EMG)

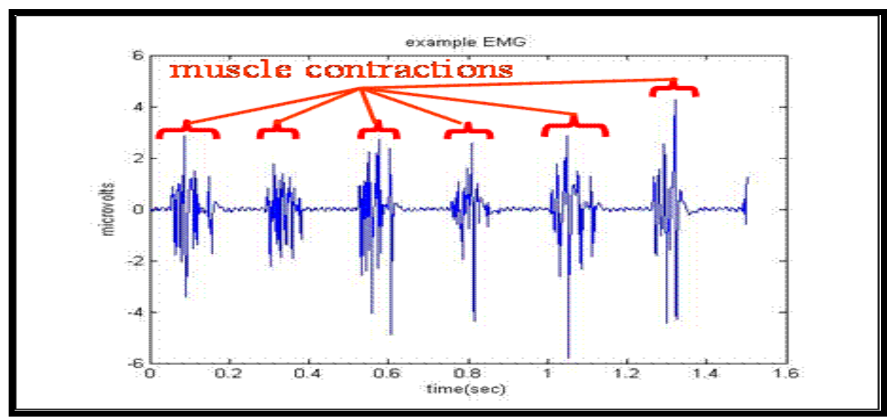
- Muscle Signals are Analog in nature. ♪

♪

- EMG signals are also collected over a specific period of time.♪



Analog Signal♪



Reading

- Gravimetric detectors
  - http://www.sciencedirect.com/science/article/pii/S0925400511007891
- EMG/EEG
  - http://en.wikipedia.org/wiki/Electromyography
  - http://en.wikipedia.org/wiki/Electroencephalography
- Temperature sensors
  - Mouser, digikey
  - http://pdfserv.maximintegrated.com/en/an/AN4679.pdf
  - http://www.analog.com/static/imported-files/tutorials/temperature_sensors_chapter7.pdf