

Sensor Design II♪

ME490A♪

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Adapted from a presentation by
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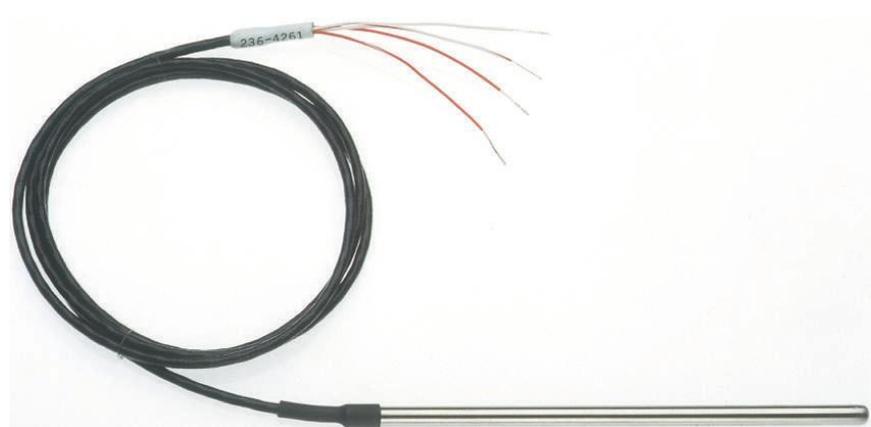
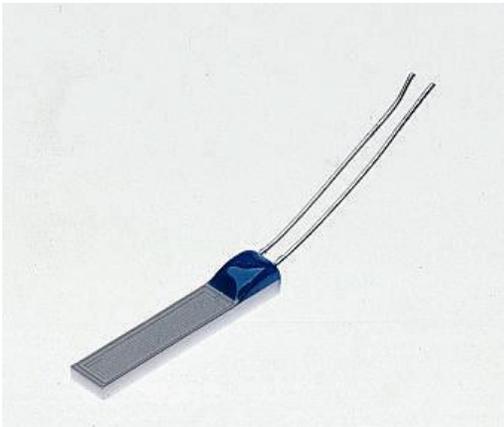
Sensors

- 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 platinum resistance thermometers or PRT)
- *linear* but has *poor sensitivity*



Temperature sensors-Thermisto

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Use materials with a high thermal coefficient of resistance

– *sensitive* but highly *non-linear*

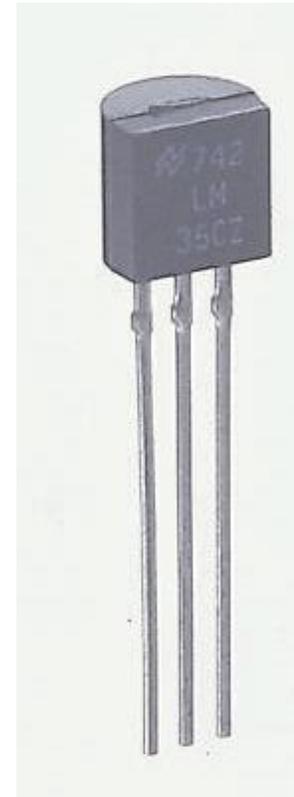
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Temperature sensors-Transistor

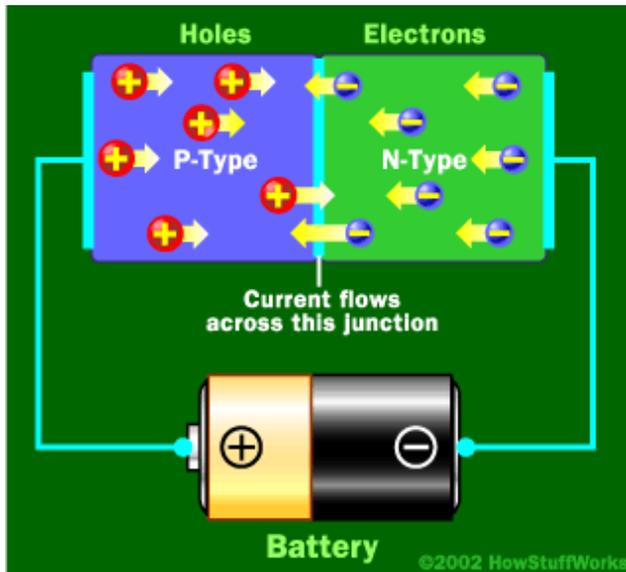


- ***pn junctions***
 - a semiconductor device with the properties of a diode (we will consider semiconductors and diodes later)
 - *inexpensive, linear and easy to use*
 - *limited temperature range* (perhaps -50°C to 150°C) due to nature of semiconductor material



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.

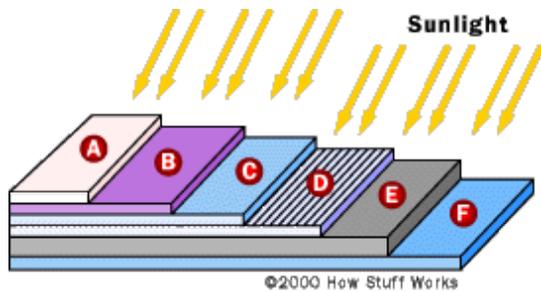
Light Sensors

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

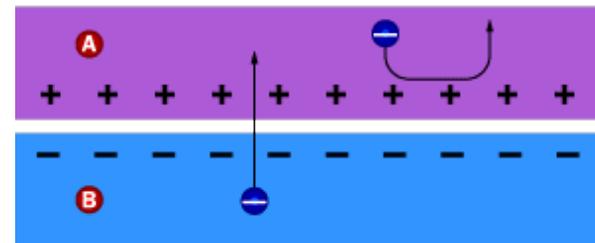


A typical photodiode

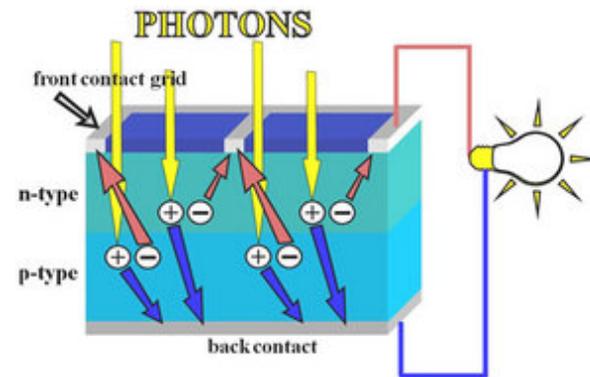
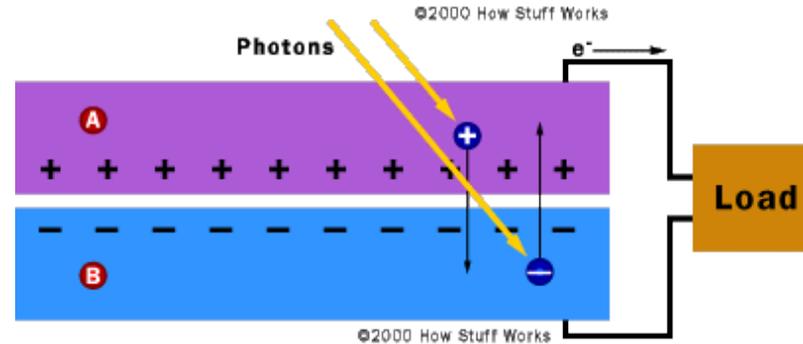
Basic structure of a generic silicon solar cell



- A** Cover glass
- B** Antireflective coating
- C** Contact grid
- D** N-type Si
- E** P-type Si
- F** Back contact



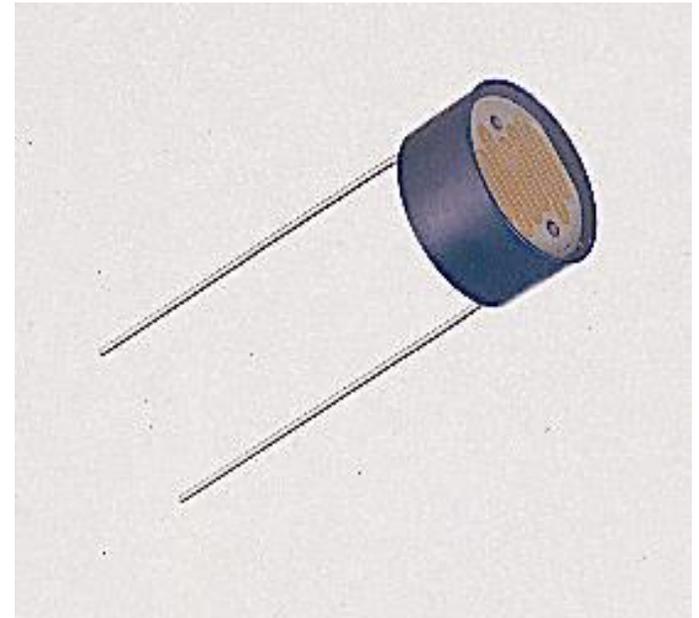
- A** n-type Silicon
- B** p-type Silicon



Light Sensors-Photoconductive

- **Photoconductive**

- such devices do not produce electricity, but simply change their resistance
- photodiode (as described earlier) can be used in this way to produce a linear device
- phototransistors act like photodiodes but with greater sensitivity
- light-dependent resistors (LDRs) are slow, but respond like the human eye



A light-dependent resistor (LDR)

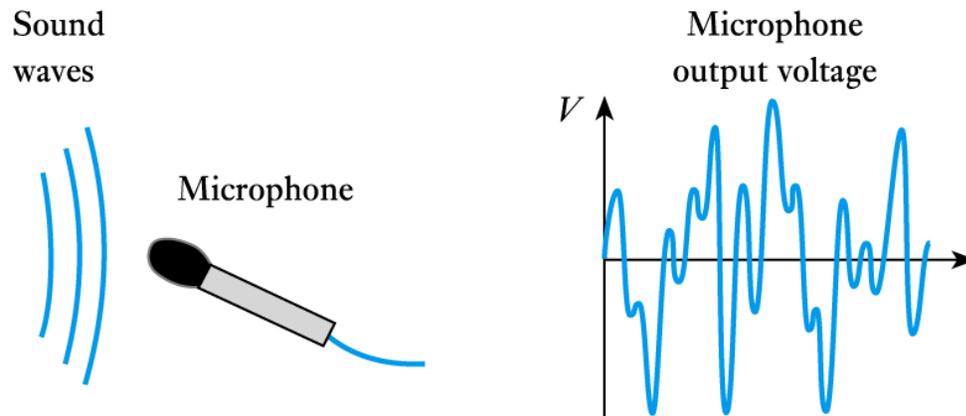
Sound Sensors

- **Microphones**

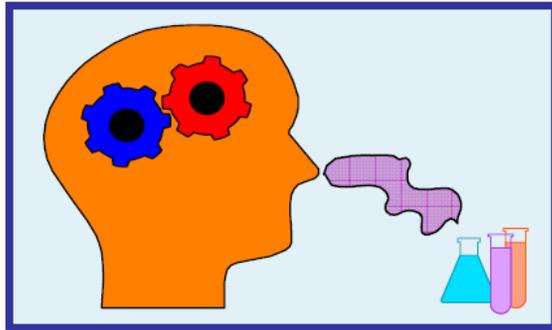
- a number of forms are available

- e.g. carbon (resistive), capacitive, piezoelectric and moving-coil microphones

- moving-coil devices use a magnet and a coil attached to a diaphragm – 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

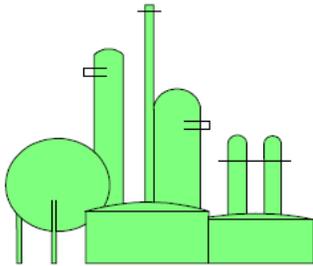


JPL ELECTRONIC NOSE

- ◆ 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



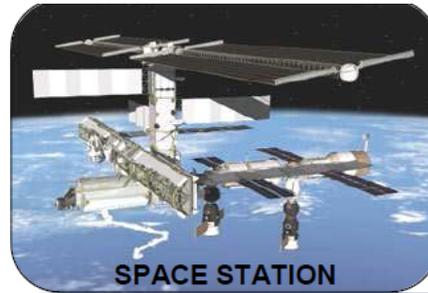
INDUSTRIAL MONITORING AND PROCESS CONTROL

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

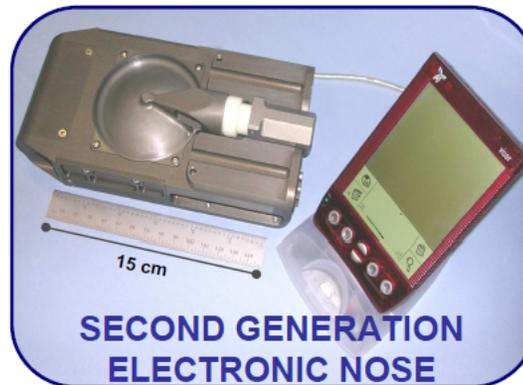


MILITARY APPLICATIONS

air quality monitor, detection of explosives and other hazards



SPACE STATION ENVIRONMENTAL MONITORING



SECOND GENERATION ELECTRONIC NOSE



PLANETARY EXPLORATION

Study planetary atmosphere to determine constituents and fluctuations



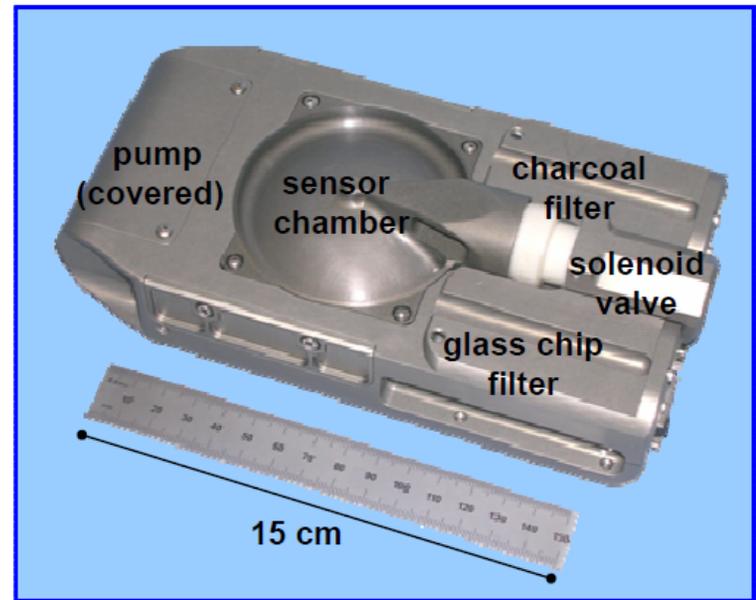
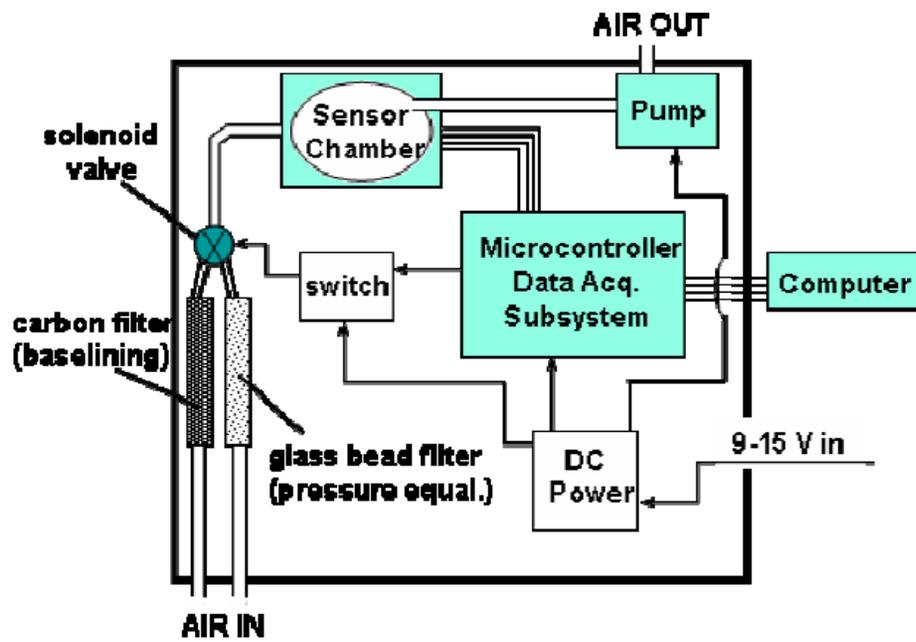
OTHER ENVIRONMENTAL MONITORING

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

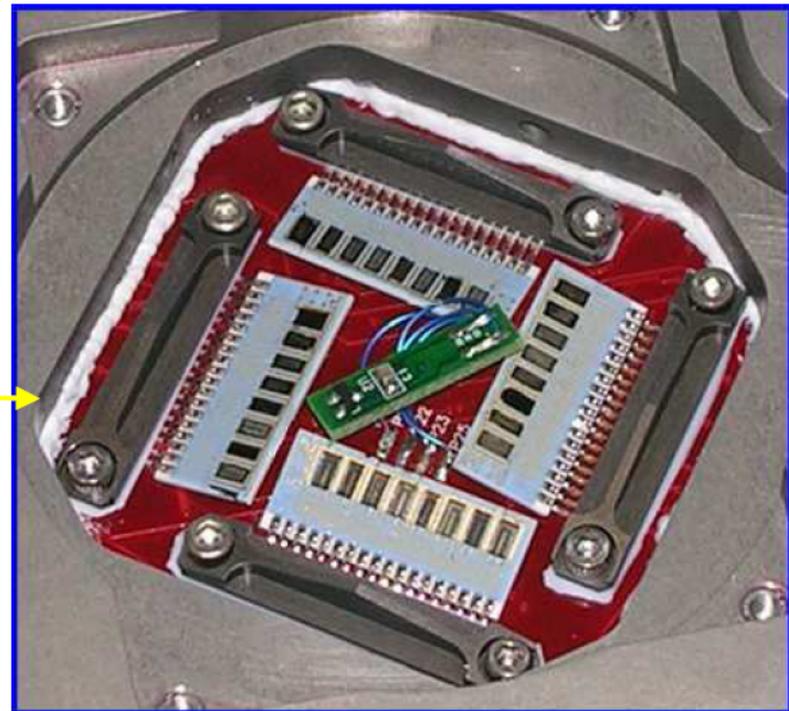
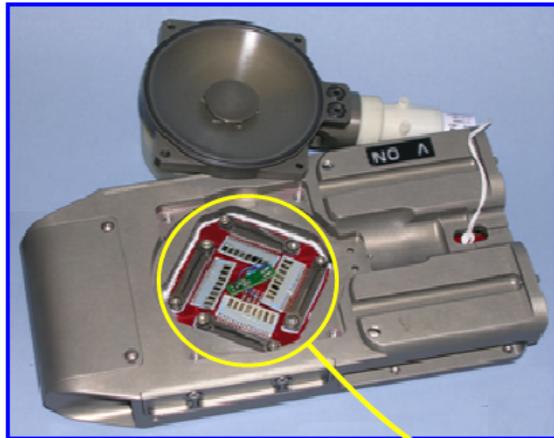


MEDICAL APPLICATIONS

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



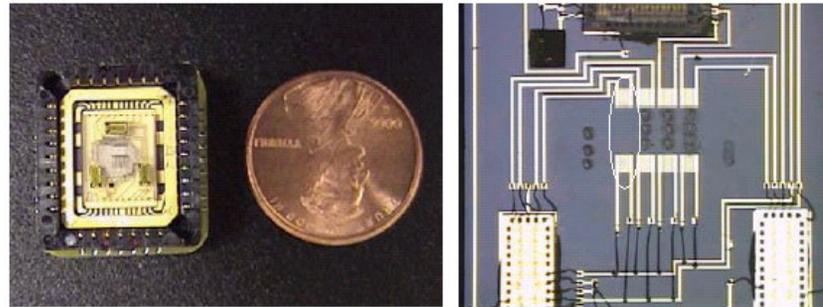
The JPL Electronic Nose



- ❖ 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

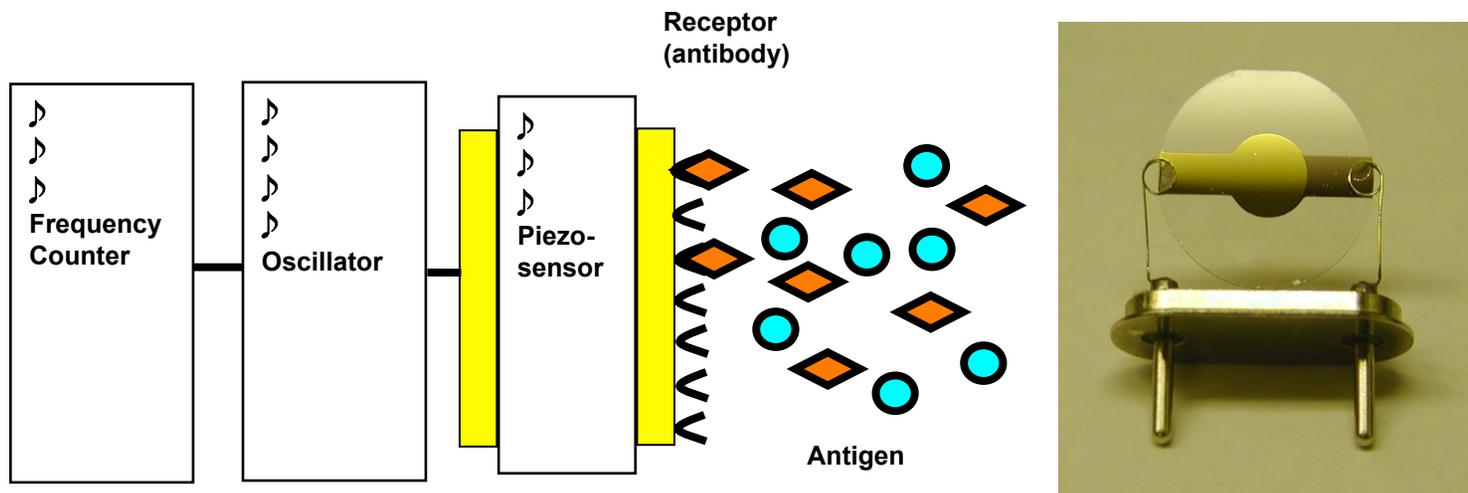
- Acoustic waves in materials at ultrasonic frequencies
- Involve piezoelectric substrates to generate acoustic fields
- Extremely sensitive gravimetric detectors
- Coated with an receptor probe to collect biochemical species of interest
- Bind bacterium, virus, toxin, or chemical and generate a measurable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

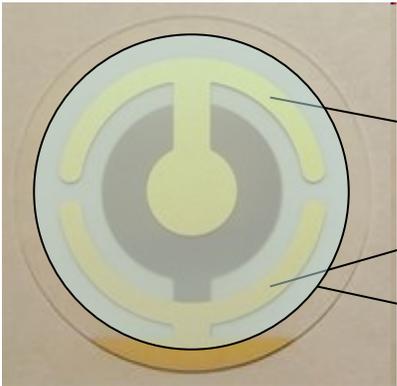


http://www.mineralminers.com/html/phantom_quartz_crystal.htm

PMN-PT = $(1-x)\text{Pb}(\text{Mg}_{1/3}\text{Nb}_{2/3})\text{O}_3-x\text{PbTiO}_3$

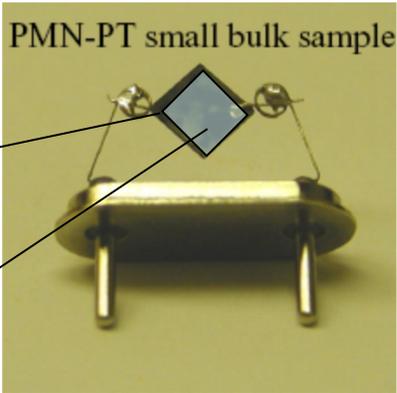


http://www.trstechnologies.com/Products/Single_Crystal/piezo_crystals.php



Au electrode
(Non-functionalized layer)

Polymethylmethacrylate (PMMA)
(Functionalized layer)

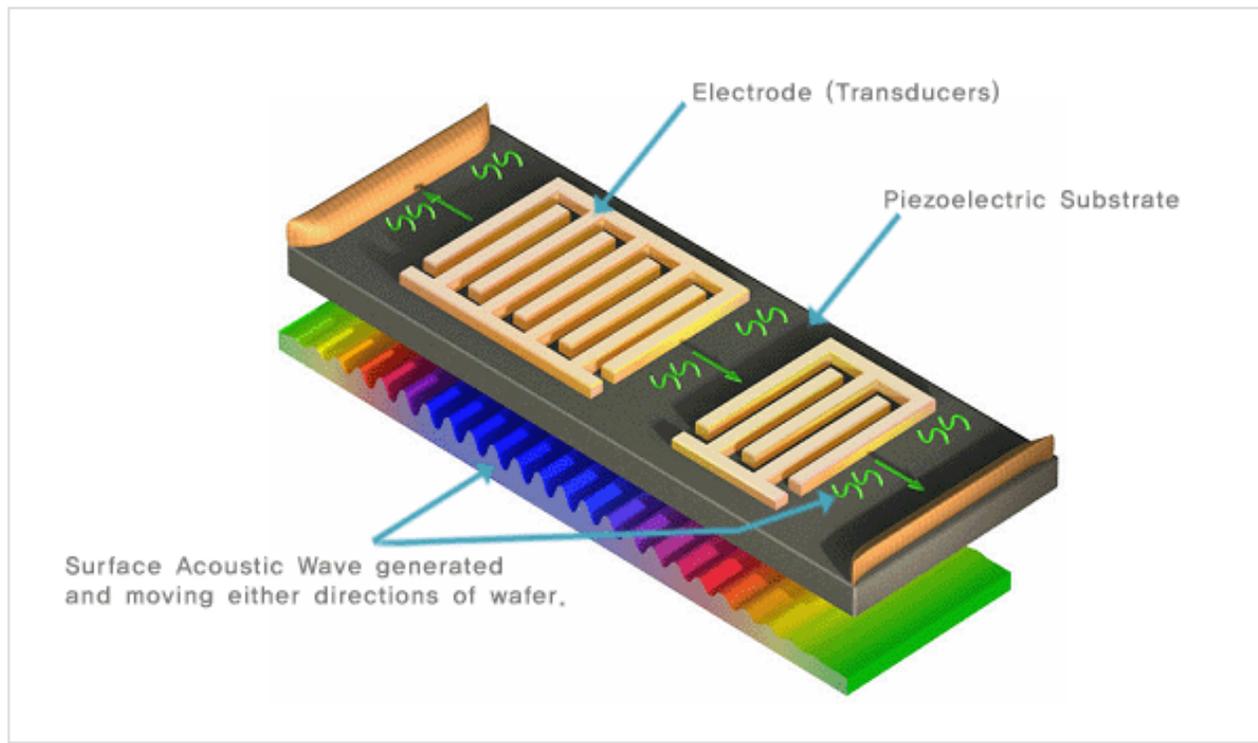


Hong, Y.K.. et al. (2004)

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

surface acoustic wave (SAW) devices

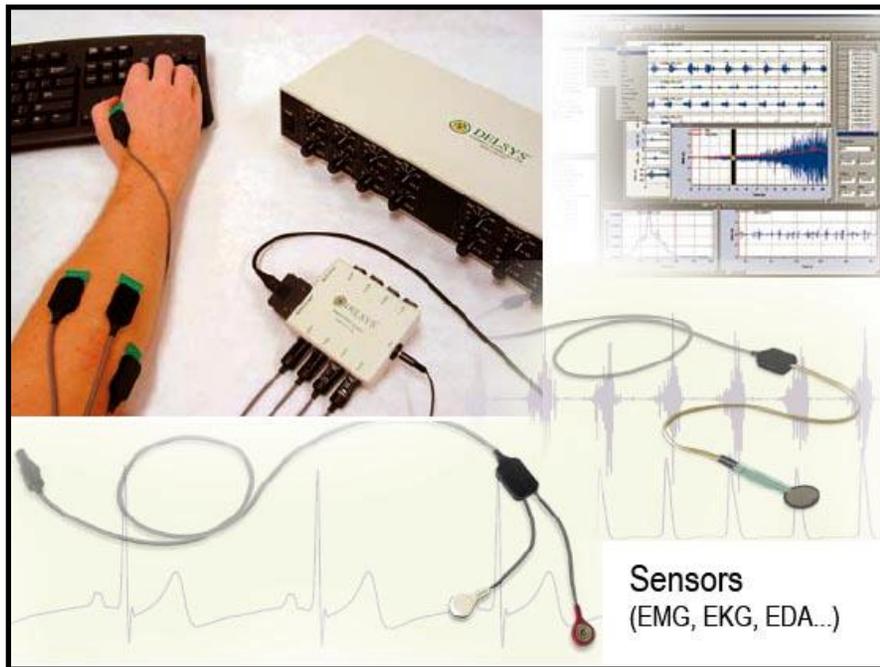
- When chemical vapor molecules come in contact with and are adsorbed by the plate the mass per unit area of plate increases significantly.
- The V_p of the propagating wave is decreased 🎵



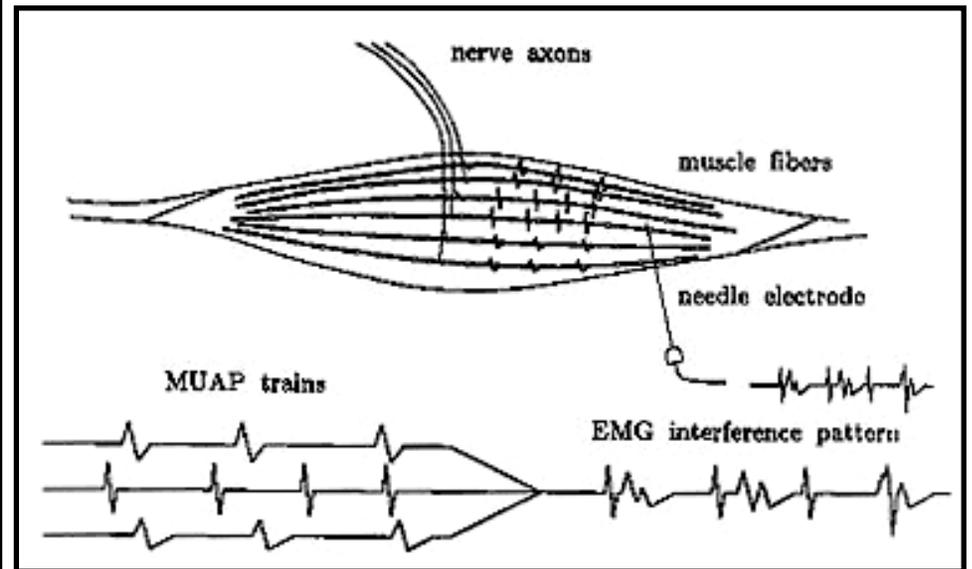
Electromyogram (EMG)

- 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

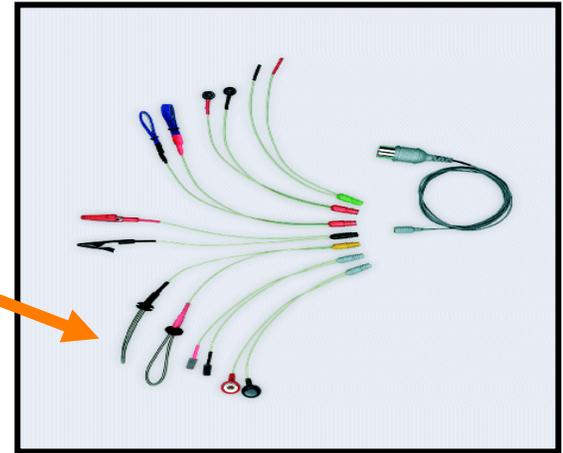
Electromyogram (EMG)

- The electrical source is the muscle membrane potential of about -70mV .
- Measured EMG potentials range between $< 50 \mu\text{V}$ 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

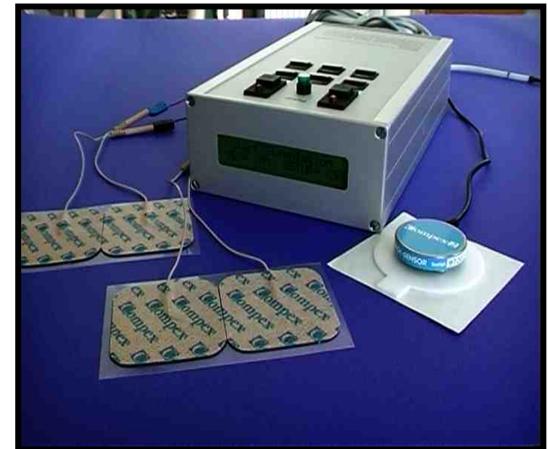
Electromyogram (EMG)



Intramuscular –
Needle Electrodes

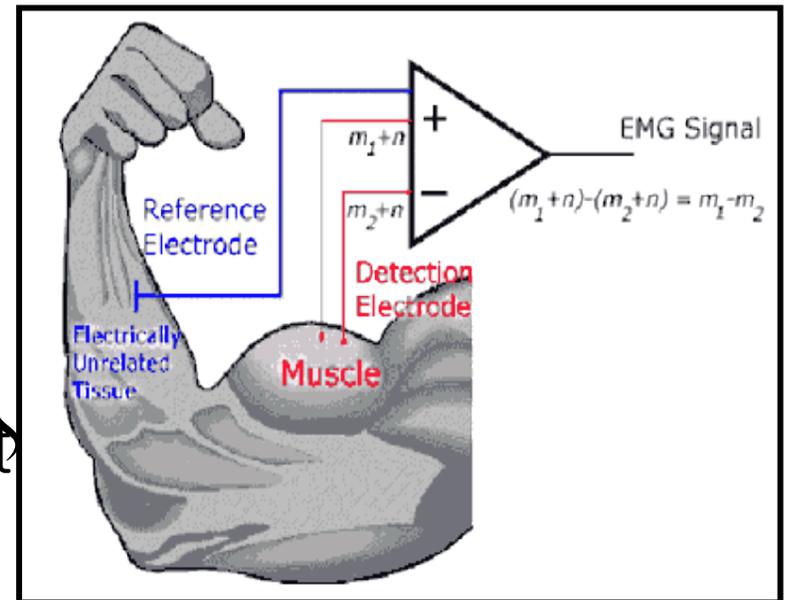


Extramuscular – Surface
Electrodes



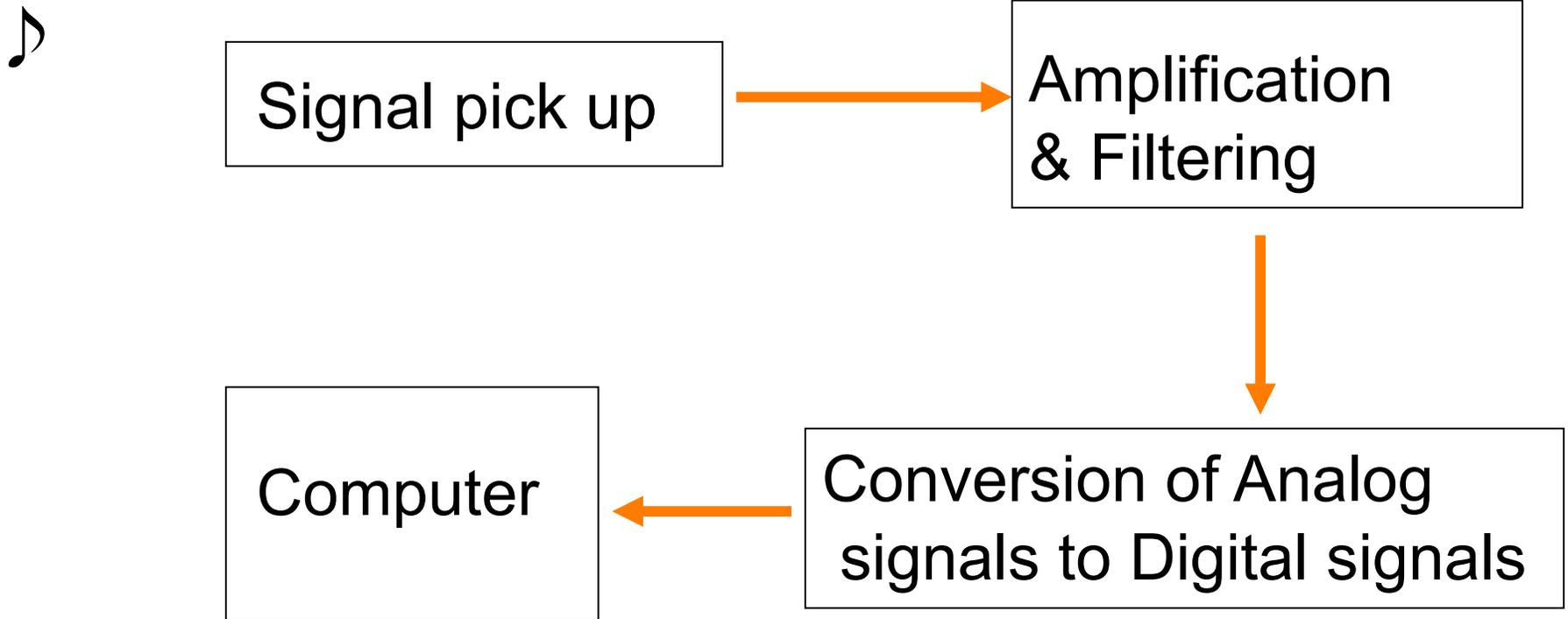
Electromyogram (EMG)

- 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:♪

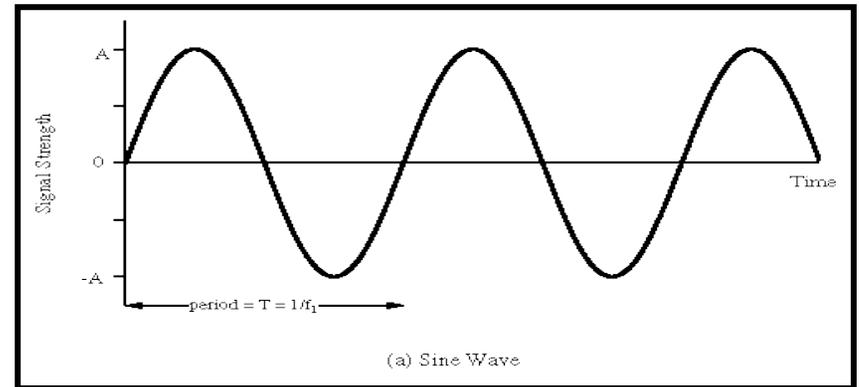


Electromyogram (EMG)

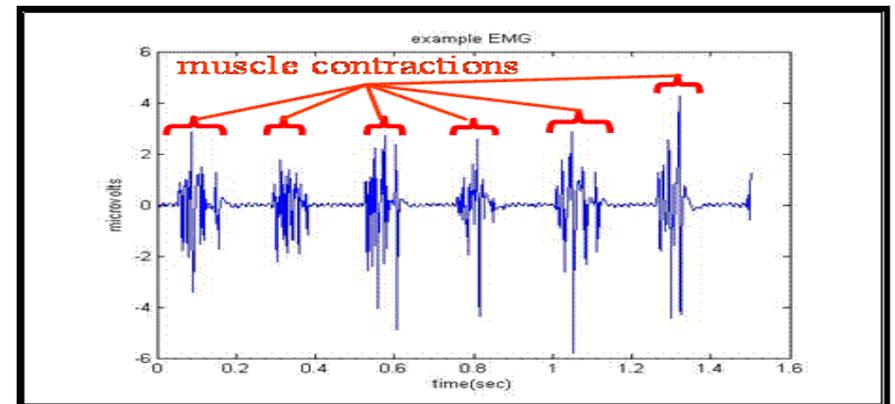
- Muscle Signals are Analog in nature. 🎵



- 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