Mobile Applications

HI1033

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Multi-Sensor Data Synchronization using Mobile Phones

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Digital Doping is Legal

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Outline

- Introduction and scientific purpose
- Mobile sensor platform
- Bluetooth performance
- Single clock algorithm
- Synchronizing the clocks
- Summary and future works

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Wireless Wearable

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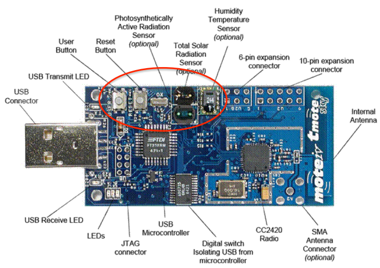
Tmote Sky (TelosB)



Sensors

- What to sense?
- How to sense/measure?
- Available sensors
  - Technology
- Medical
  - ECG
  - Analys

Applications

- Smart Grid
- Industrial Automation
- Smart Cities and Urban Networks
- Home Automation
- Building Automation
- Structural Health Monitoring
- Body Sensor Networking
  - Health: monitor & assist disabled
  - Military: command, control, communications and computing.

Sensors according to wiki

- A sensor is a device which measures a physical quantity and converts it into a signal which can be read and observer or by an instrument
- For example a mercury thermometer converts the temperature into expansion and contraction of a liquid which can be read on a calibrated glass tube

Classification of sensors

- Thermal – temperature, heat
- Electromagnetic – electrical, magnetism
- Mechanical – pressure, flow, viscosity, density, mechanical, humidity
- Chemical – oxygen, ion, pH, redox, carbon monoxide
- Optical radiation – light sensors, infra-red, proximity sensors, interferometry

Classification of sensors

- Ionizing radiation – radiation (geiger), subatomic particles
- Acoustic – acoustic (ultrasound), sound

Sensing

- As this course is named wireless sensor network, we need to convert any *physical* value to an *electrical* value
- **From:** temperature, humidity, light, ... (none electrical)
- **To:** current, voltage, resistance, time interval or frequency

Property

- **Input range**: the operating range to which the sensor is sensing
  - E.g. Temperature sensor operating reliably from -5°C to 40°C.
  - Outside this range the sensor's fault tolerance is exceeded.
- **Output range**: range of the output value
  - E.g. Temperature sensor returns voltage between 0 and 5V

Property

- **Sensitivity**: How is a change in input signal mapped to the output signal?
  - E.g. an inclination sensor produces in output voltage of 1mv for every 2.30°.
- **Latency**: Speed with which sensor reacts to change
  - E.g. A temperature sensor having a latency of 14s per 10°C

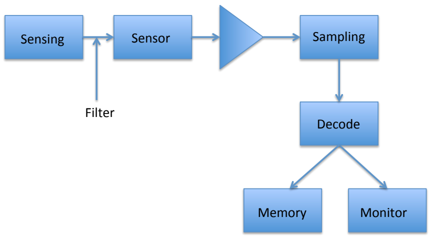
Property

- **Stability**: insensitivity to factors other then measured physical quantity.
  - Noise: undesired change from ideal output value. E.g. thermal noise in the
  - Distortions. E.g. radioactive radiation influencing the sensor.
  - Environmental influences. E.g. temperature, air pressure, …

Noise

- Anything that obscures the desired signal
- External noise
  - Part of the environment
  - E.g. temperature, electromagnetic interference (power lines, combustion engines, electrical motors, radio & TV), sun light, gravitational flux, …
- Internal noise
  - White noise (uniform), Pink noise (1/f)

Sensor



Sampling

- What is sampling?
  - Discrete reading of sensors values.
- Why sample?
  - Converting to digital value, Very obvious: needed for digital processing by computer.

Sampling rate

- Nyquist theorem
  - The sampling rate has to be at least twice as fast as the fastest **change**. If not, you are going to miss relevant information.
  - E.g. If sound signal changes at 3 kHz, you have to sample at at least 6 kHz to not miss anything of the signal.

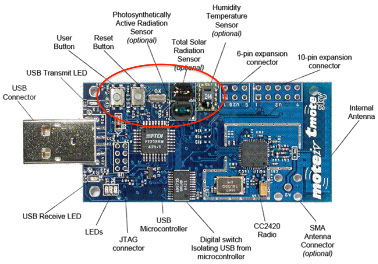
Bit depth

- An 8-bit sampling (quantization) gives an resolution of 256 levels.
- If a signal varies from 0 to 10V, using a 8 bit resolution. Given the sampling value of 3.1415.... V after coding 3.1372 V
  - 10/255 = 0.0392 V/level
  - 80*0.0392 = 3.1372 V

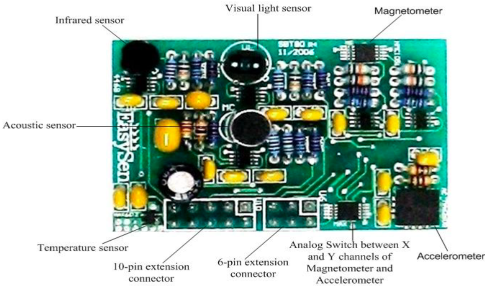
Sensor technologies

- Contact sensor
- Force sensors
- Light sensing
- Gyroscope
- Accelerometers

Tmote Sky (TelosB)



EasySen SBT80

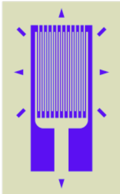


Contact sensor

- Binary or analog
  - Binary sensors are just switches. Either pressed or not
  - Analog sensors are often spring-loaded. A force F is needed for pressing the switch, the force translates into a value
- Size: from micro switch to power switch
- Can be mechanically extended to get whiskers

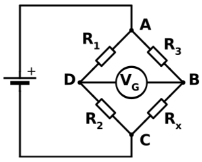
Force sensors

- Strain sensor and pressure sensors. Operates on principle expressed in Kelvin's law. Resistance of a conductor depends on lengh *l* and area *A*, and conductivity *r*.
- 120 Ohm is industry standard
- Changes are in micro ohm



Wheatstone bridge

- Measuring instrument to measure the unknown resistance Rx
- Measure the voltage between B and D using a galvanometer Vg
- Rx = (R2/R1)*R3



Light sensors

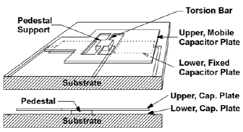
- Photo diode
  - Diode embedded in translucent plastic package
  - Conductivity influenced by photons hitting the n-p junction
- Photo transistors
  - Transistors embedded in translucent plastic package
  - Transistors amplifies (100 to 1000 times), can be hooked to a AD converter
- Light dependent resistors (LDR)
  - Resistance decrease when light falls on it
  - Not sensitive to infrared light
- Light to frequency converter
  - Diode combined with a IC to convert current to pulse
  - Accurate, light intensity on one wire

Other sensors

- Proximity sensors
  - Mechanical: contact sensor
  - Optical: consists of a light source (LED) and light detector (phototransistor)
- Potentiometer – displacement
- Linear variable differential transformer (LVDT) – movement
- Capacitance sensor, dependent on distance between the electrodes
- Piezoelectric sensors generates electrical potential when stressed

Accelerometers

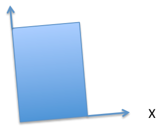
- Spring-mounted mass
- Newton's law and spring-mass relation



- Simplest micro electro-mechanical system (MEMS) device possible
- The widespread use of accelerometers have pushed the cost down dramatically

Exam question

Estimate the speed in the direction of the accelerometer's x-axis 5 seconds after the measurement started, which is the error due to incorrect mounting.



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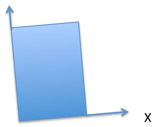


Speed = time * acceleration

5 * 9.81 * sin(5) = 4.27m/s

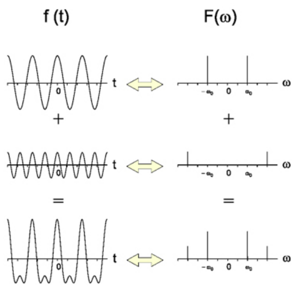
Gyroscopes

- Several types exist (mechanical and optical)
- Mechanical examples: flywheel gyroscope
  - Conservation of angular momentum Gy
  - Torques on axes depends on T=I, w, O
- Gyroscopes are no longer rotating wheels. Solid state gyroscopes are sturdier and smaller. (piezoelectric)
- 9DoF (acc, gyro and magnetometer)

Analyze of acceleration

- Low-pass filer
  - Isolate constant acceleration
  - Used to find the device orientation
- High-pass filter
  - Show instantaneous moves only
  - Used to identify user-initial moves

Fourier Transform



Filter

- Engineering function for Low-pass filter
  - FilterFactor = 0,1
  - lvalue = (newAcce * FilterFactor) + (preAcc * (1,0 – FilterFactor))
  - preAcce = lvalue
- High-pass filter
  - hvalue = newAcce - lvalue

Medical analyze

- Diagnose
  - Ocular
  - Audible
- Tele metric
  - Electrical
  - Chemical
- Information about
  - Skin
  - Heart
  - Lungs

Coff
Blood
Skin

What to sense

- Mechanical quantity (force, displacement)
- Pressure, flow, volume
- Thermic sensors
- Ultrasound
- Electrodes for bio potential
- Chemical sensors
- Optical sensors

Medical values

- Example on things to measure on humans
  - Mechanical – muscle, bone mass
  - Thermic – infection, metabolism
  - Electrical – muscle, nerves
  - Chemical – blood gases, blood glucose, enzymes

Medical sensors

- ECG
  - (Electrocardiogram)
  - Monitor the heart
- Pulse oximeter
  - Pulse and oxygen level
  - surveillance
- Pressure measurement
  - Blood pressure
  - Lung capacity
- Accelerometer
  - Stroke, alzheimers

Pressure measurement

- Pressure sensors for
  - Blood pressure
  - Pressure in eye globe
  - Inter cranial pressure
  - Measurement of respiration

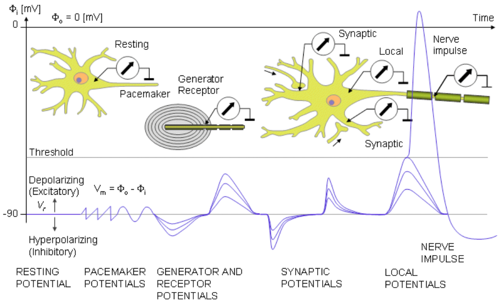
Invasive blood pressure measurement

- Strain sensor physical connected with a membrane
  - Blood lumps, air bubbles
  - Changes in the cannulas cross section area
  - The position of the cannula
  - High different between the measure point and the pressure sensor
- Cannula needle point sensor

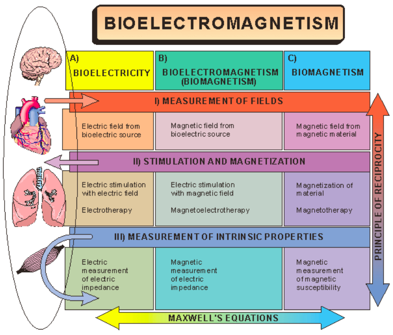
Non-invasive pressure measurement

- Systolic and diastolic blood pressure, hence the arterial pressure
- Korotokow-sound using a stethoscope
  - Subjective
  - Artifacts
  - High different

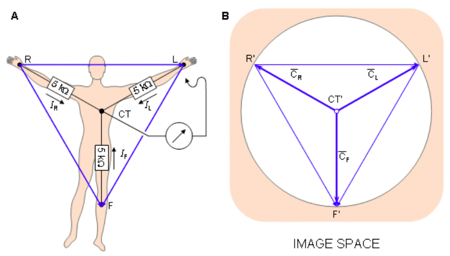
Bioelectric function of the nerve cell



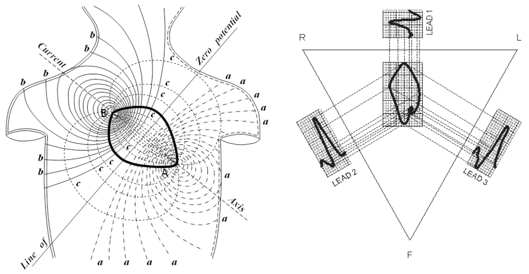
Bioelectromagnetism



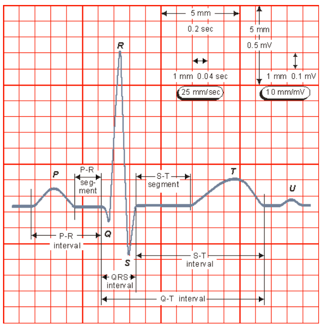
The Wilson central terminal (CT)



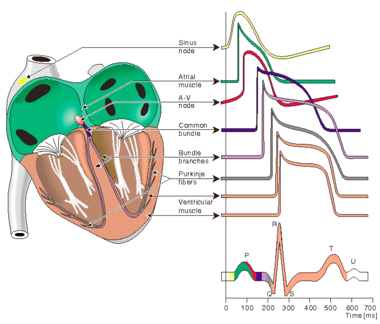
Human electrocardiogram



A normal electrocardiogram

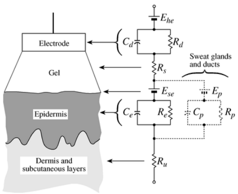


Monitor of the heart



Connect electrodes to tissue

- Silver chloride (AgCL) – Silver metal
- Easy to get distortions
- Ag0(s) + Cl– <-> AgCl(s) + e-

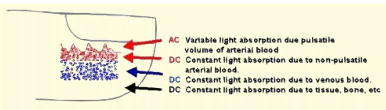


Pulse oximetry

- A non-invasive method to monitor oxygenation of a patient's hemoglobin
- That is fast
  - under 90% = new red blood cells are created
  - under 70% = increase risk of heartarytmier
  - under 30% = risk for life

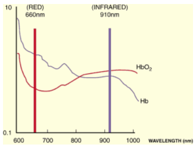
Pulse oximetry

- Clinical use
  - Lung diseases
  - Operation (anestesi, surveillance)
  - Neonatal care
  - Surveillance in ambulance



Pulse oximetry

- Pulse oximetry – Two LED with wavelength 660nm and 910nm
- Two different absorption for Hb and $Hb0_2$
- Built on reference values



Learning goals

- After this lecture and studies you should be able to read data sheet about a sensor an be able to translate it to physical values.
- Given a physical signal figure out an appropriate sensor to use, and be able to choice an appropriate conversion to an digital signal