IoT. IE 2307

École d'ingénieurs du numérique

Biblio

IoT Concept

- The Internet of Things: Connecting Objects, by Hakima Chaouchi (Editor) Wiley, 2013
- Internet of Things - Global Technological and Societal Trends From Smart Environments and Spaces to Green ICT, Ovidiu Vermesan & Peter Friess, River Publishers, 2011
- The Emerging Domain of Cooperating Objects: Definitions and Concepts, Pedro José Marrón, Daniel Minder, Stamatis Karnouskos, Springer 2012
- Architecting the Internet of Things, Dieter Uckelmann, Mark Harrison, Florian Michahelles, Springer 2011

IoT legal aspects

- Internet of Things: Legal Perspectives, Rolf H. Weber, Romana Weber, Springer, 2010

IoT and Arduino

- Programming Arduino Next Steps: Going Further with Sketches, Simon Monk, 2013
- Making Things Talk: Using Sensors, Networks, and Arduino to See, Hear, and Feel your World, By Tom Igoe, O'Reilly Media, 2011

1. DEFINITION
2. CLASSIFICATION AND TERMINOLOGY
3. BASIC SENSOR SIGNAL PROCESSING SCHEME
4. SENSOR – ACTUATOR
5. BASICS OF MEASUREMENTS
   > noise, repeatability, sensitivity, accuracy, drift, range, offset, saturation, reaction time (dead time)
6. FOCUS ON SOME EXAMPLES OF IOT SENSORS
   > MEMS, Heart rate, localization
7. IOT SENSOR (quantified self, wearable sensors)
8. READING A SPEC SHEET
9. HOW TO CHOOSE AND WHERE TO BUY A SENSOR

Assignments to do at home

Linear function
Most simple function, 2 parameters f(x)=a*x+b
If you zoom enough, all functions become linear

Polynomial function
Always fits perfectly to your curve (Taylor approximation)
But might need high order polynomial -> many parameters
f(x)=a_n*x^n +a_n-1*x^(n-1) +…a_0, n+1 parameters
Normally not a physical solution

Functions without saturation
Power function x^a (a>0) / exponential function exp(ax) a>0 / logarithmic function log(x)
Goes up to infinitly (no saturation)

Saturation
Power function -x^a (a<0) 1/x, exponential function -exp(ax) a<0

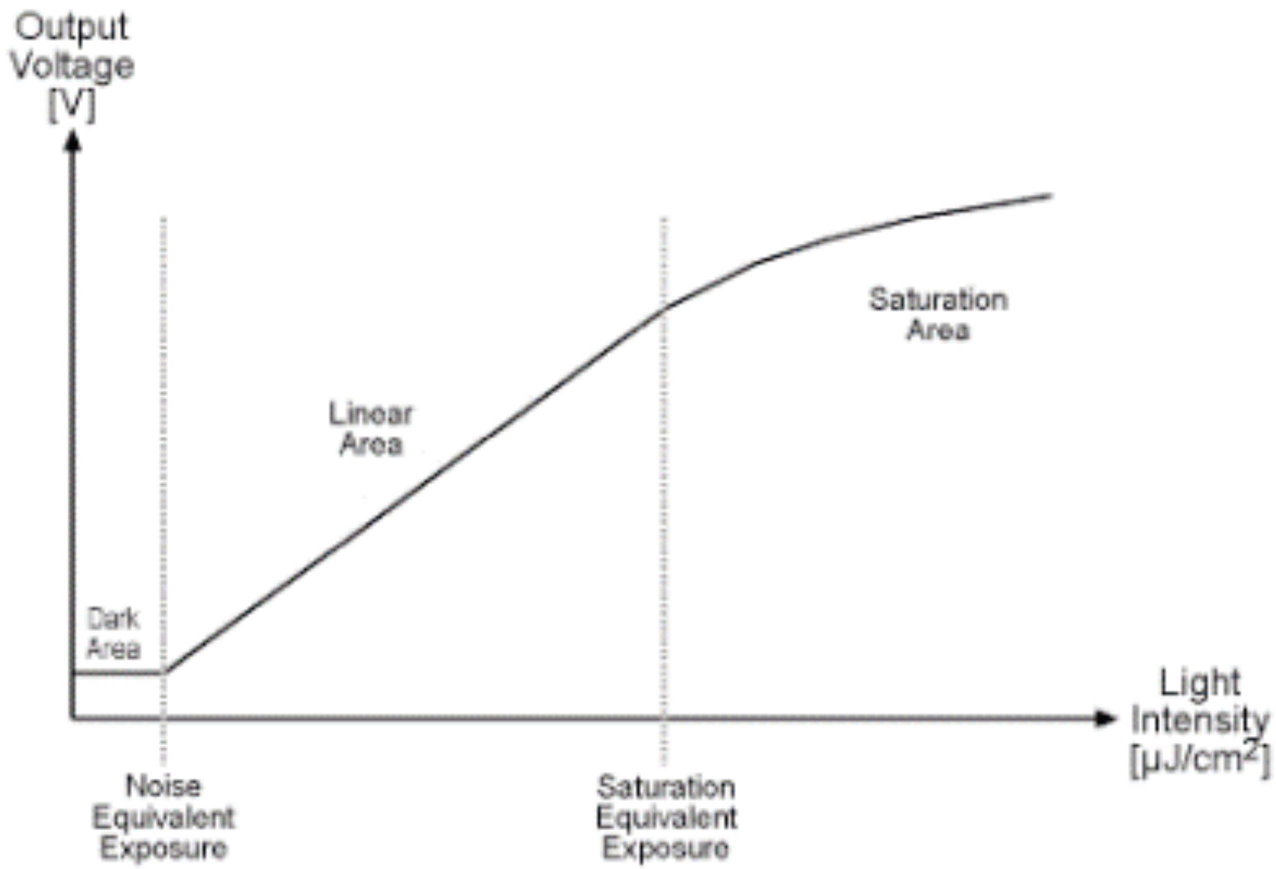
Mathematical functions

> spreadsheets. Estimation of parameters.

> http://fooplot.com
(simple and easy)

> https://www.wolframalpha.com
(even complex problems can be solved)

Saturation


Output Voltage [V]
Dark Area
Linear Area
Saturation Area
Light Intensity [µJ/cm2]
Noise Equivalent Exposure
Saturation Equivalent Exposure

Range

The measurement range is the valid measurement interval of the physical quantity (within the proposed accuracy).

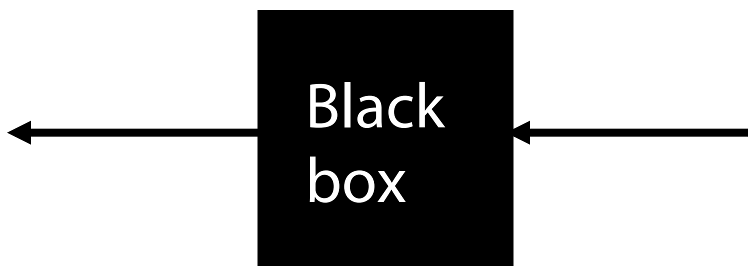
The range is given
> As minimum and maximum of the interval
> In dB with $dB=10*\log_{10}(max/min)$

Actuator Definition

A sensor transform a variable into a physical quantity

Physical quantity

> temperature
> humidity
> volume
> concentration



variable

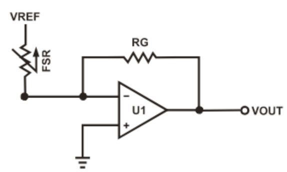
SENSORS signal processing scheme

In order to connect a sensor to a computer, we need to transform his physical response into a digital value

steps

T

R



V

8bit

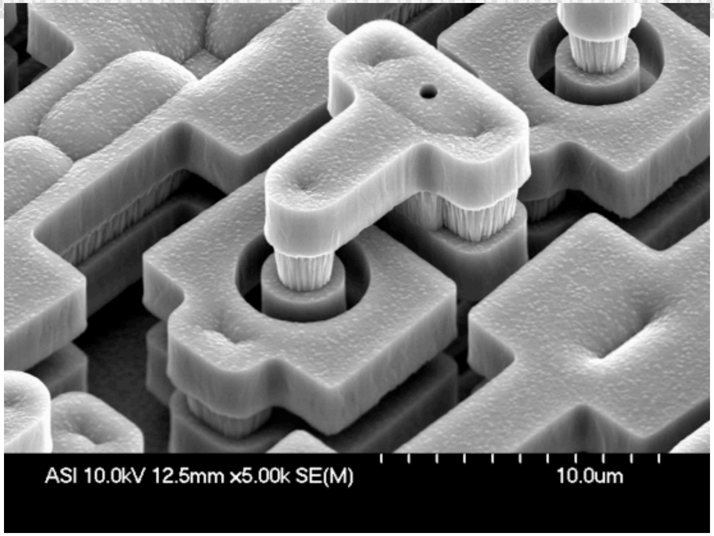
variable T, float

Sensor resistance varies with temperature → Conversion into an electrical tension → ADC → computer

Sensors and actuators in mobile phones

- accelerometer 3 axes
- gyroscope
- GPS
- magnetometer
- 2 camera (QRCode, image analysis,…)
- RFID / NFC
- BT
- luminosity
- IR, proximity
- Tactile
- microphone

- Screen
- loud speakers
- vibration
- flash

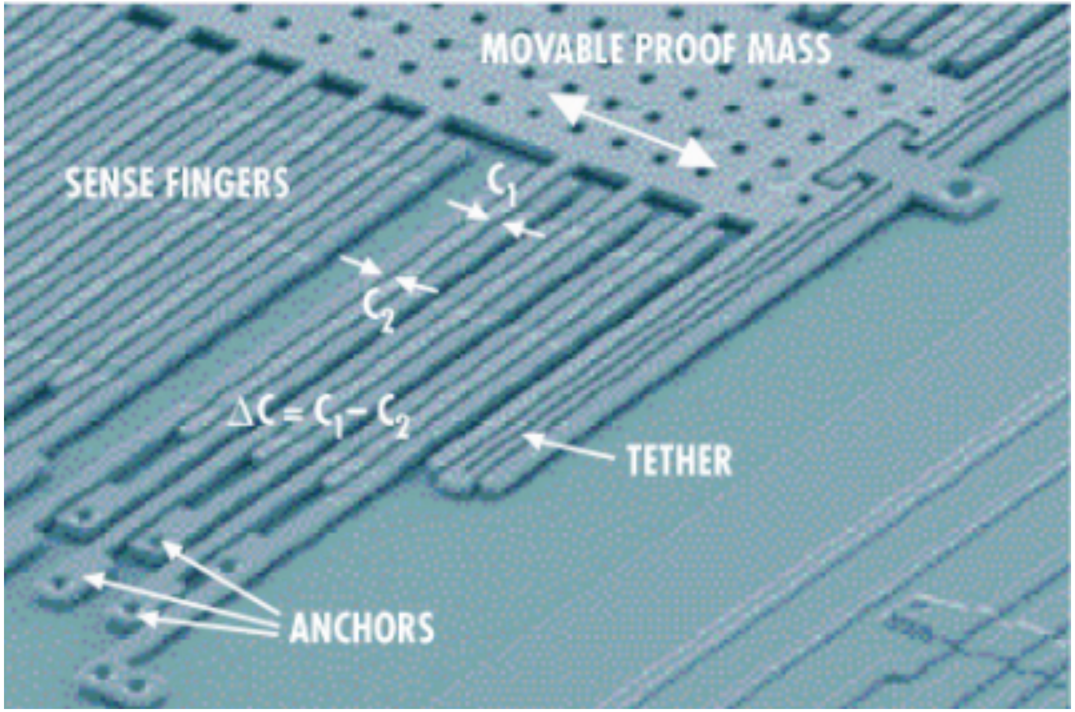


MEMS : micro-electro-**mechanical** systems
NEMS : nano-eletro-**mechanical** systems

> Processor + sensor
> Complex properties : electrical + physical + chemical + mechanical

Beyond Semiconductor basis : deposition + etching on semiconductor (silicon) wafer

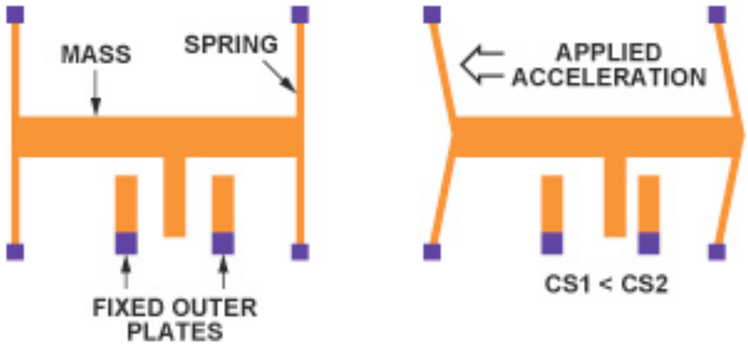
Single axis accelerometer, MEMS
Cost 1€, size 1mm^3

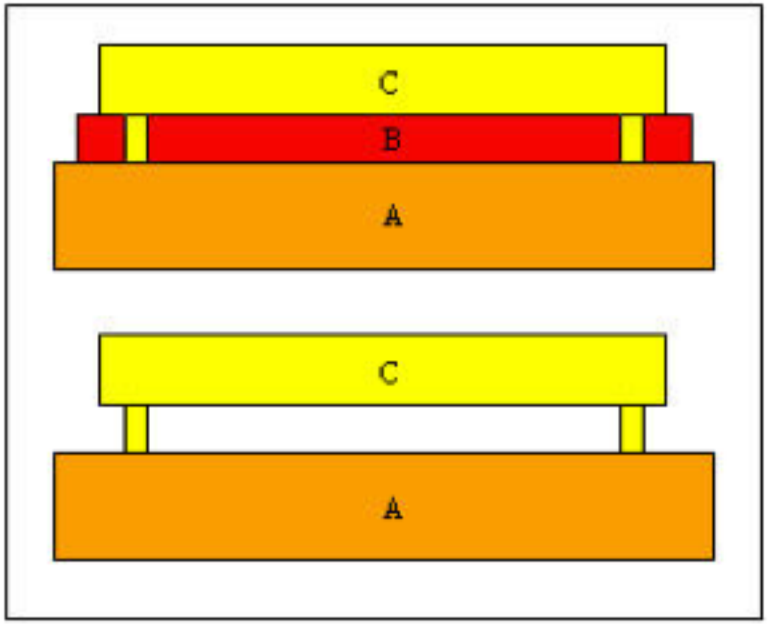


Accelerometer

Functioning : capacitive sensing

process : lost material etching



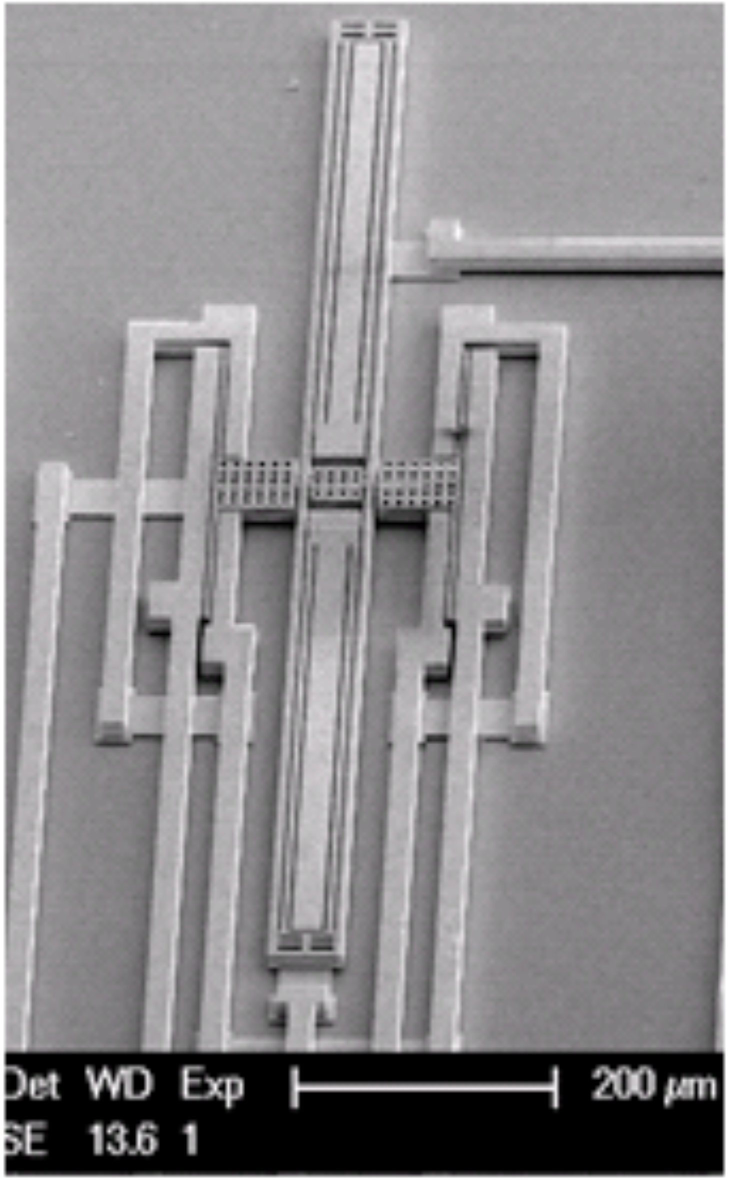


Capacitance between two plates : **C** = ε*A/d

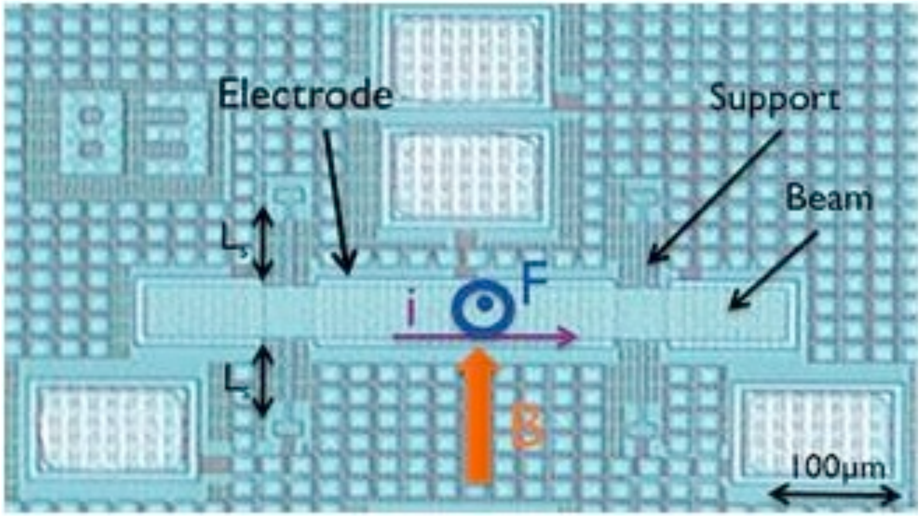
SENSORS

MEMS : magnetometer
size 1 mm^3, cost 1€

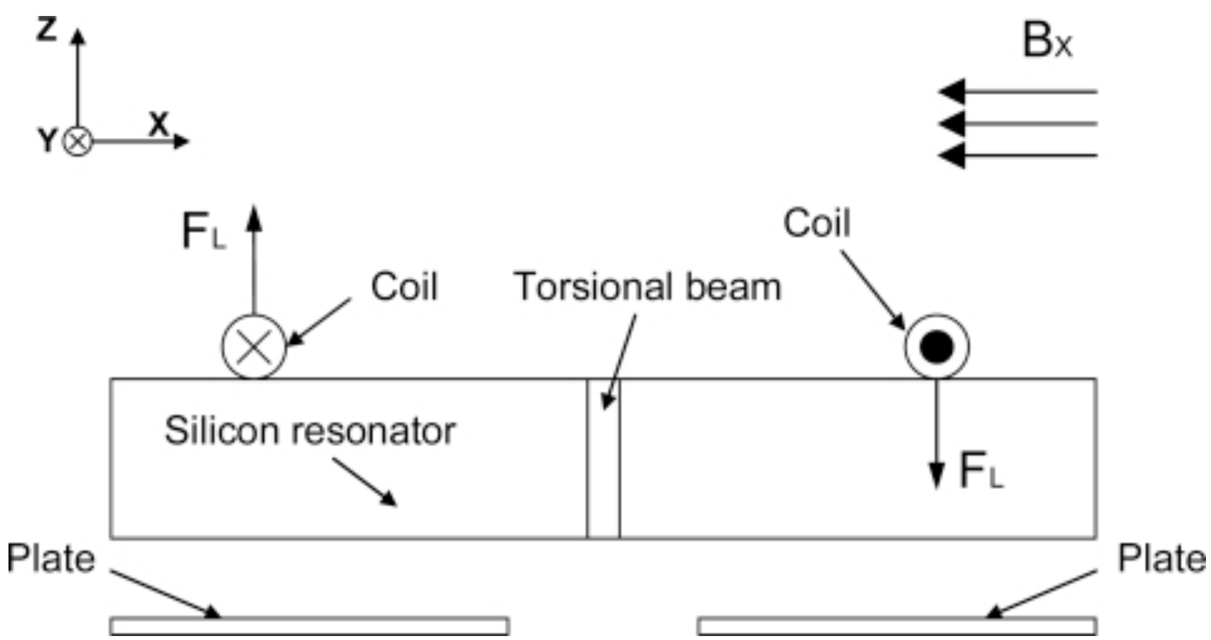
- Electronic magnetometer



E-magnetometer



Lorenz Force **F** = q (**v** x **B**)



IoT sensor example : Measuring human body heartrate

SENSORS heart rate measurements

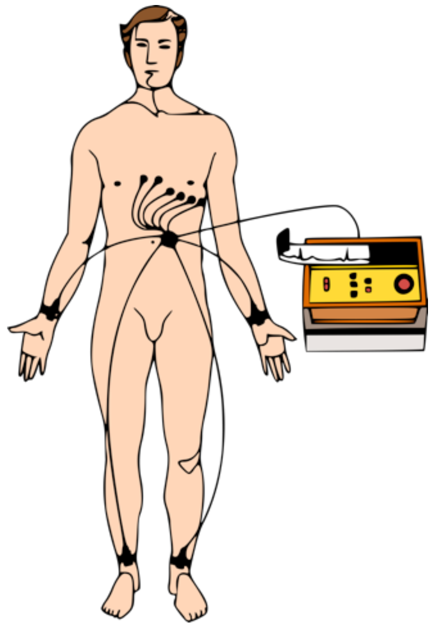
Electrocardiogram measurements

- Medical measurement
- Sports application device

Seismocardiogram

Measurements on mobile phone

- **Light absorption** measurement
- **Sound analysis**
- **Acceleration analysis**

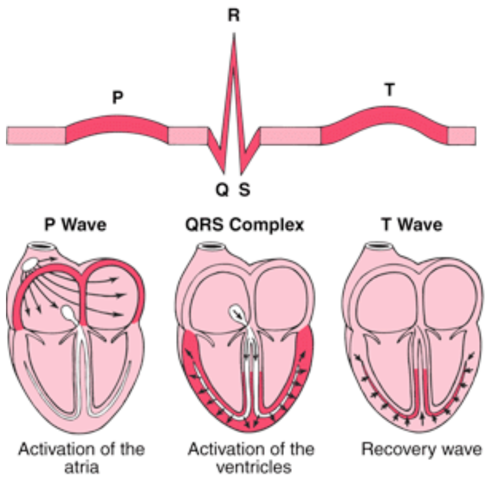


Physical phenomenon

The ECG device detects and amplifies the tiny electrical changes on the skin that are caused when the heart muscle depolarizes during each heartbeat. At rest, each heart muscle cell has a negative charge, called the membrane potential, across its cell membrane. Decreasing this negative charge toward zero, via the influx of the positive cations, Na+ and Ca++, is called depolarization, which activates the mechanisms in the cell that cause it to contract.

More than just the heart rate

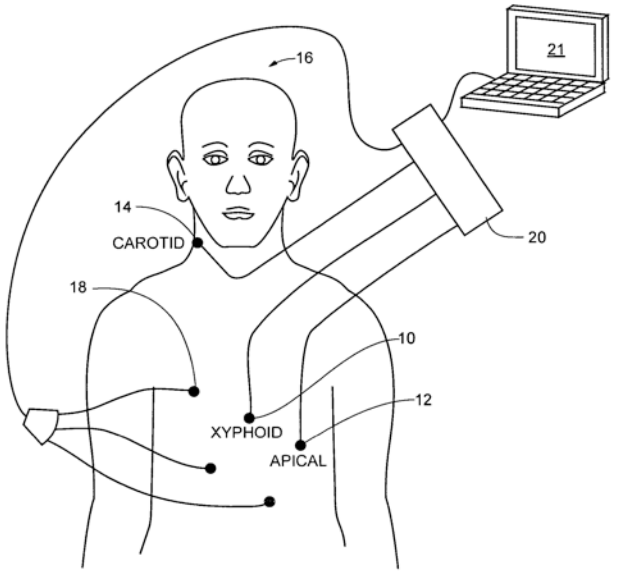
During each heartbeat, a healthy heart will have an orderly progression of a wave of depolarisation. This is detected as tiny rises and falls in the voltage between two electrodes placed either side of the heart, which is displayed as a wavy line either on a screen or on paper. This display indicates the overall rhythm of the heart and weaknesses in different parts of the heart muscle.



Simplified, sports version, heart rate only
2 electrodes
Make shure electric contact is guaranteed

B1

Seismocardiography (SCG) is a non-invasive measurement of the vibrations of the chest caused by the heartbeat. SCG signals can be measured using a miniature accelerometer attached to the chest, and are thus well-suited for unobtrusive and long-term patient monitoring.



Same idea, but beyond

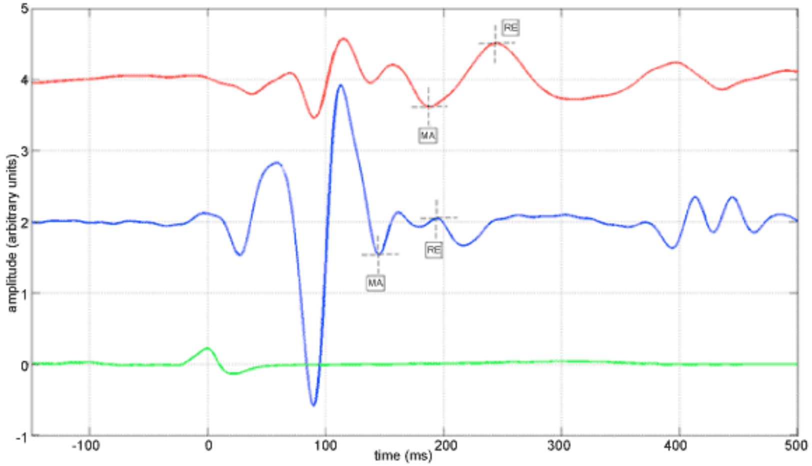


Figure 4: Measurements of the inhalation phase while the subject is supine. The annotated superior-inferior axis SCG signal (red, on top), the annotated dorsoventral SCG signal (blue, in the middle), and the ECG signal (green, in the bottom). Annotations: maximum acceleration of blood in the aorta (MA) and onset of rapid ejection of blood into the aorta (RE).

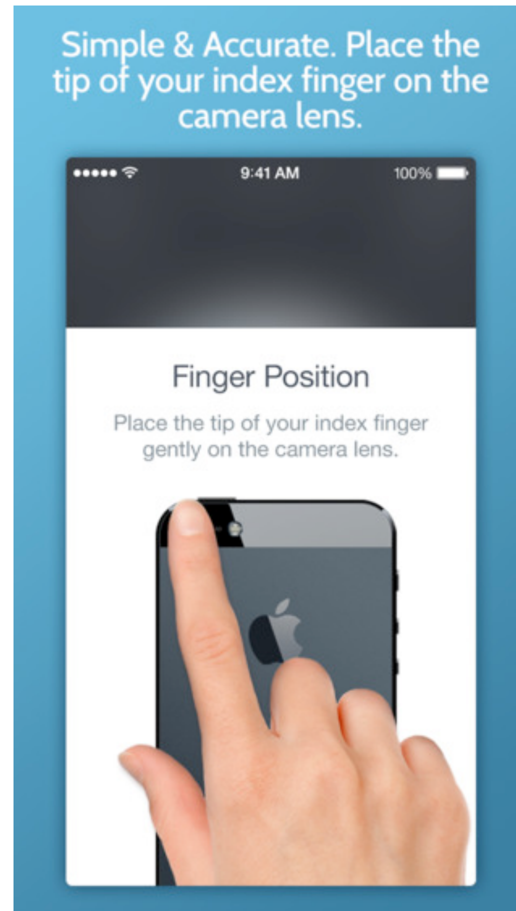
SENSORS heart rate measurements : mobile phone : light absorption

Instant Heart Rate - Heart Rate Monitor by Azumio for Free featuring workout training programs from Fitness Buddy

Use your smartphones' camera to measure your heart rate.

The applications detects how the colour of your finger changes when blood flows into it. Similar to the way that a medical pulse oximeter works.

Please note, this app is intended to be used for fun only and should not be used for any medical purposes.

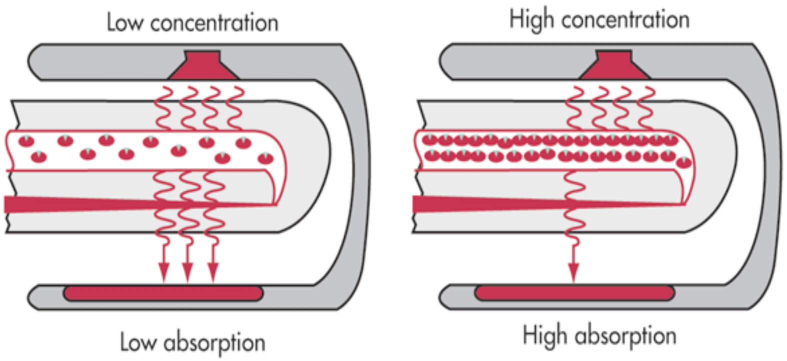


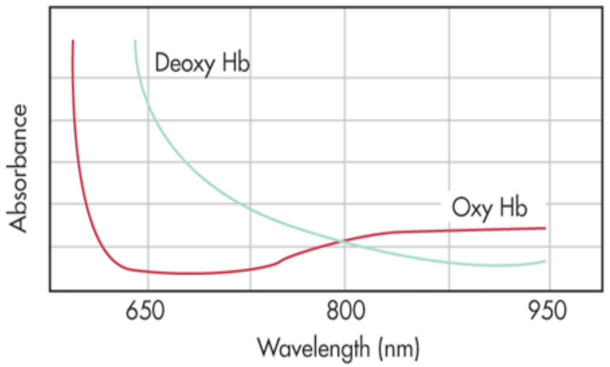
Physical basis

Pulse oximetry is a noninvasive photo-based technique that measures the light absorption and reflection properties of deoxygenated and oxygenated hemoglobin.

By illuminating a tissue bed with LEDs and measuring the amount of light absorbed by the tissue using a light-sensitive photodiode (PD), the concentration of oxygen in the arterial blood, heart rate, and blood flow can be estimated. The LEDs typically shine visible red (650 nm) and infrared (IR) light (940 nm).

PPG signals can be measured by either transmittance or reflectance mode optical sensors.





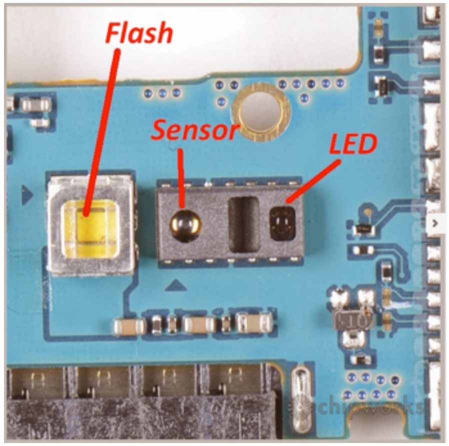
SENSORS heart rate measurements : mobile phone : light absorption

Galaxy S5

Implementation :

Separate light sources

And light detection



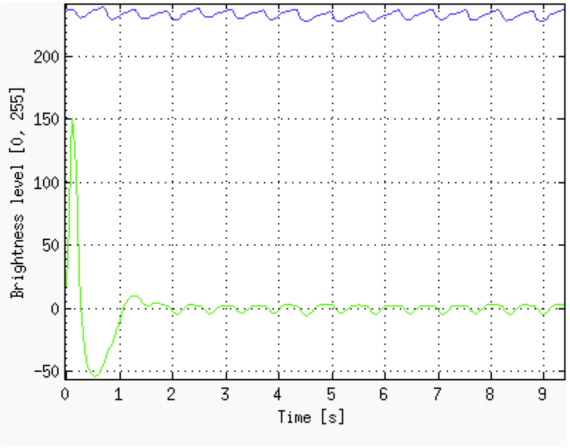
iPhone

Implementation:

Flash as illumination

Camera (red channel)

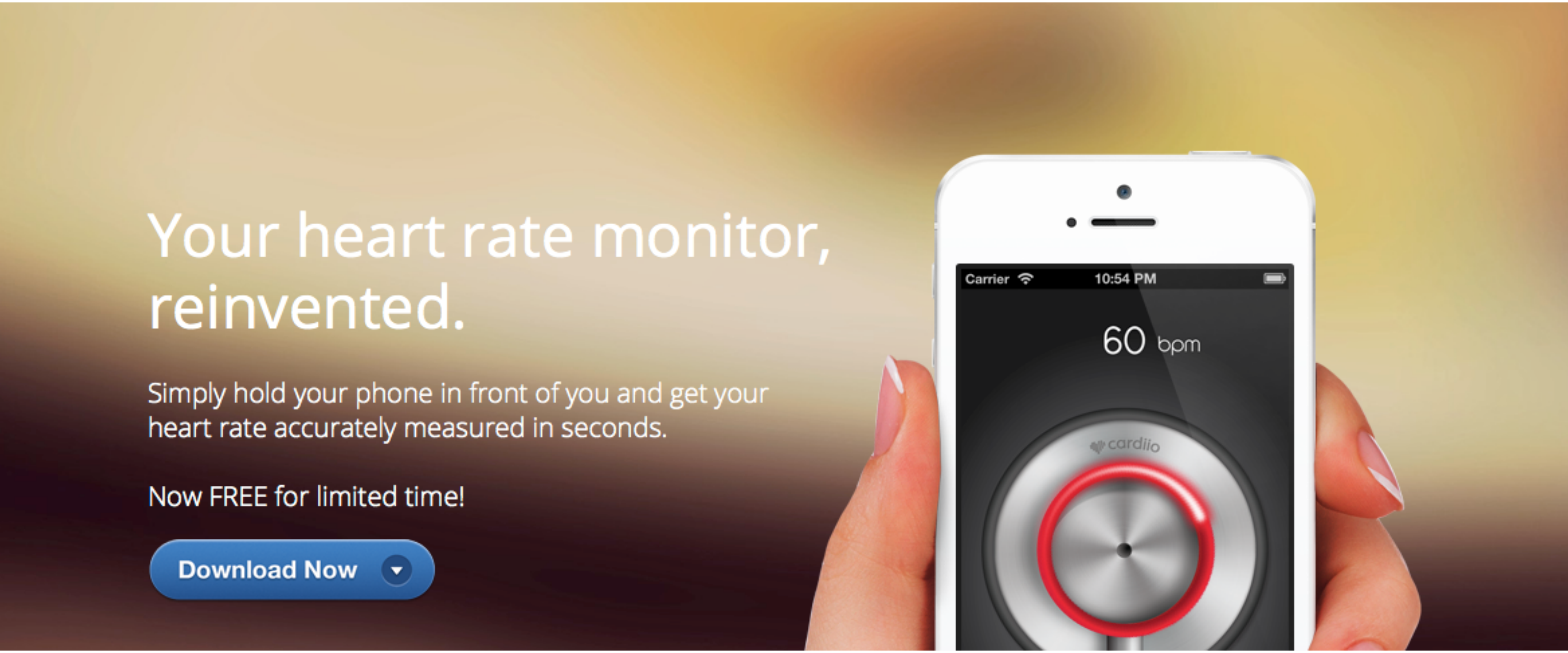
as sensor



SENSORS heart rate measurements : mobile phone : light absorption

cardiio

Every time your heart beats, more blood is pumped into your face. This slight increase in blood volume causes more light to be absorbed, and hence less light is reflected from your face. Cardiio uses your camera to track these tiny changes in reflected light that are not visible to the human eye and calculate your heart beat!



SENSORS heart rate measurements : mobile phone : sound

Heart Monitor

Because Heart Monitor uses sound to detect heart rates, you can use the iPhone 3G directly over your heart or directly on the pulse in your neck or wrist. Heart Monitor works best in quiet areas. You can get excellent results when using the microphone on your headphone cable.

Before buying heart monitor check to see if you can find a pulse point located:
* In your neck just below the start of your jaw.
* Your chest directly over your heart.
* Your wrist inline with the base of your thumb.

SENSORS heart rate measurements : mobile phone : acceleration

seismoCardiograph

IoT : user localization

Different methods are used for user localization

- GPS
- Cell ID
- WiFi
- BTL

User localization can be

- Absolute
- Relative

GPS

- 31 NAVSTAR satellites rotate around earth (since 1978)
- height ≈ 20’000km
- 1 orbit ≈ 12hours,
- Use solar energy
- signal UHF 1575.42 MHz
- signal power < 50W
- Every satellite contains an ultra-precise atomic clock
- Position on earth is determined by triangulation : longitude, latitude, altitude
- Deliberate signal degradation was removed in 2000

- GLONASS is already in use too (24 satellites)
- Soon we will have GALILEO and BEIDOU

Sensor signal are : GPS Coordinates

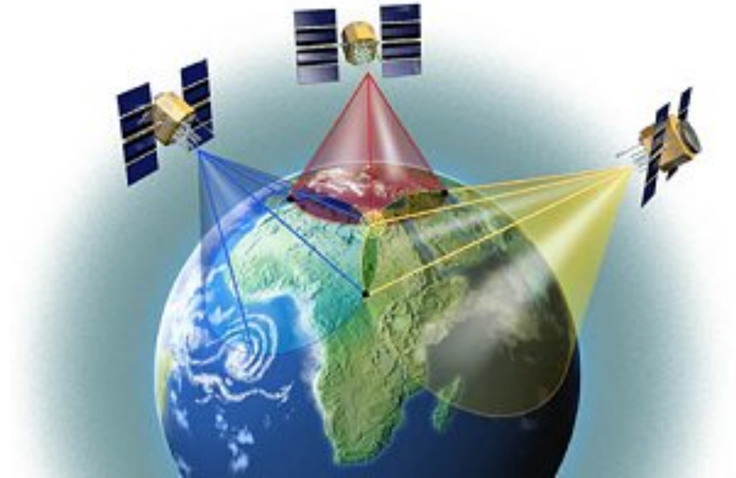
> Longitude
    in degrees, min, sec
    0° (Greenwich) to 360°

> Latitude
    in deg, min, sec
    -90° to 0° (equator) to +90° (north pole)

> Paris
    2.35 longitude
    48.89 latitude

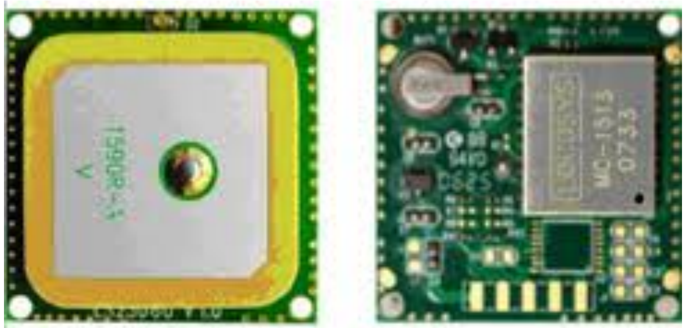
> Altitude

Position determination by triangulation



GPS

Sensor accuracy depends on
> number of satellites in vision
> density variations in ionosphere and in the troposphere
> orbital variations
> multi-path signals


Top View LS20030

> typical accuracy 20m
> coverage all over the globe
> does not work indoors

> A-GPS to get satellite *almanach* + *ephemeris (correction tables)*
Better accuracy / lower response time

Cell ID

Methodology

> Your GSM connection knows the antenna cell ID
> Having a correspondence table between the cell ID and their location, you can estimate the user localization

Correspondence tables

Telecom operators

Mobile phone constructors / operating systems (Apple / Google)

Open Source projects : https://opencellid.org/

> typical accuracy 200m - 2000m
> good coverage on land
> works indoors too

Methodology

> Your WiFi connection knows the Mac-address of the Wifi routers
> Having a correspondence table between the Mac-addresses and their location, you can estimate the user localization

Correspondence tables
(method of collection is called wardriving)
(is done unintendently by all mobile phone users)
Mobile phone constructors / operating systems (Apple / Google)
Open Source projects : https://openwifi.su/

> typical accuracy 20m
> many regions are not covered
> works indoors too

BTLE localization

Indoor localization

> Place beacons indoors at relevant places
> Having a correspondence table between the Beacon-ID and their location, you know that the user is near the target

> Any indoor region to target has to be specifically prepared
> tradeoff between beacon size and beacon life-time
> BTLE is BT variant using low energy
> many mobile phones are BTLE compliant
> cheap, 10€
> lifetime : a few years

> Binary (near – not near) (3m-100m)
> most regions are not covered
> targetd for indoors use

Quantified self

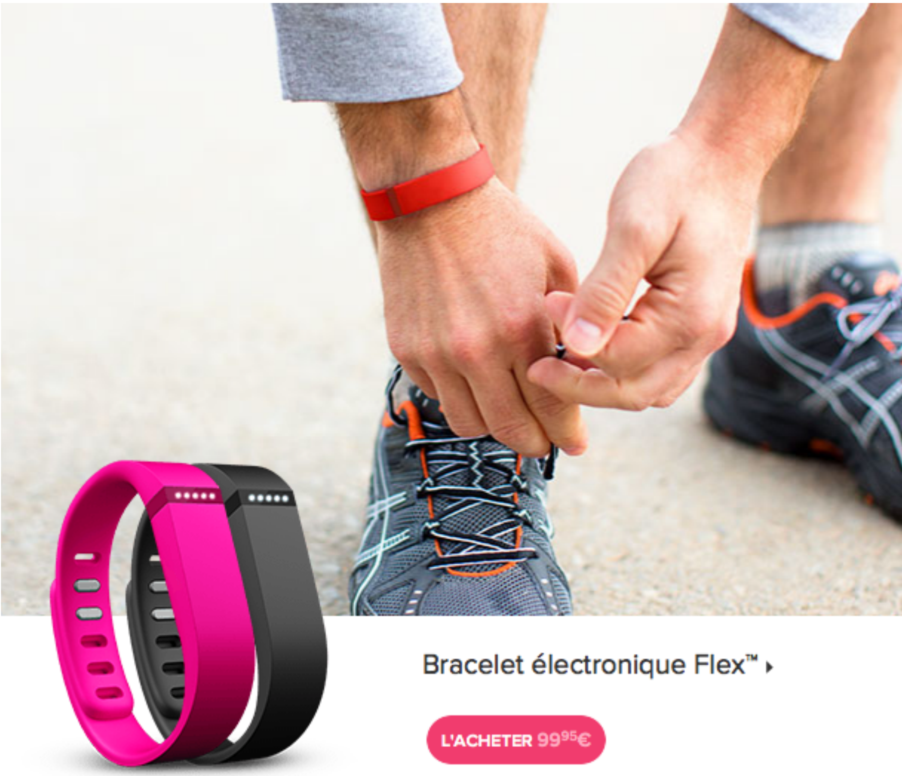
Movement to incorporate technology into data acquisition on aspects of a person's daily life.

→ self-tracking / life logging / wearable computing

4 examples :
> Fitbit
> Kapture
> HAPIFork
> Withings

Fitbit

Fitbit is a small device to track your physical activity or sleep. You can wear the device all day because it easily clips in your pocket, pants, shirt, bra, or to your wrist when you are sleeping. The data collected is automatically synched online when the device is near the base station. After uploading, you can explore visualizations of your physical activity and sleep quality on the web site. You can also view your data using their new mobile web site. You can also track what you eat, other exercises that you do, and your weight.



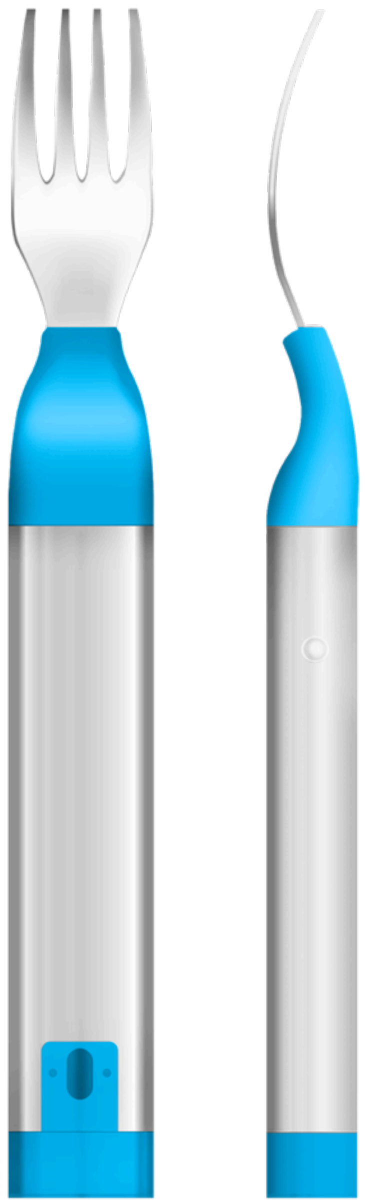
Kapture

Bracelet, which continuously registers the last 60 seconds of ambient sound. If you lived en exceptional sound moment, you tap on the bracelet and the last 5 seconds are sent and logged on to internet. (If you pay for it, the last 60 seconds are sent up)

HAPIFork

Connected fork, which logs your meals and proposes more healthy eating habits.

Measures
> Meal duration
> Number of fork usages
> Time between fork usages



Withings

Measures body health parameters (weight, heart rate) and aggregates the data on internet. You can access them by a mobile application.

Prototyping platforms

> Arduino
> Raspberry Pi

Low barrier for entrance
> Simple to start and test
> low financial cost (10-30€)
> large community for support

Prototyping

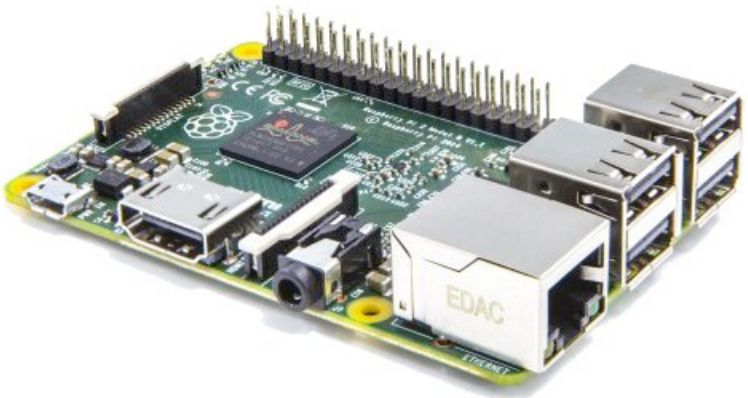
Arduino Uno
http://arduino.cc/
Micro-controller board
no full OS, if powered up it starts running
developer code code
16MHz clock, ATmega328
2kB RAM
32kB storage memory
Programming language : Arduino, simplified set of C / C++ commands

Sensor input / output
14 GPIO, (6 PWM enabled)
Analog Input : 6 entrances 10bit

Power supply
Power input 5V usb or battery (7-12V) power jack
minimum power 42mA

Communication
SPI / I2C / UART
no network connectivity (only with additional shields)

Prototyping



Raspberry Pi 2
900 MHz, ARM Cortex
RAM : 1GB
Needs micro SD memory stick
Linux based
Multi-tasking
Programming languages :
Python, C, C++, Java, Ruby..

Sensor input / output
no analog sensor input
8 GPIO

Power supply
Input 5V USB, minimum power 700mA

Communication
SPI / I2C / UART
Ethernet, HDMI output, 2 USB masters

Arduino
Easier to use
Best for simple, repetitive task
More sensor input/output ports
More robust in experimental conditions
Miniature version available
-> Our choice for IoT

Raspberry Pi
Full fledged computer, with very low price
Needed for multimedia applications
Needed for use as Web server
Web connection integrated

Criteria to choose a sensor

Characteristics to be considered when you choose a sensor

1. Error, Precision / Accuracy
2. Environmental condition - usually has limits for temperature/ humidity
3. Range
4. Power consumption
5. Type of signal (analogue voltage, digital, communication bus)
6. Physical Dimension
7. Cost

Measures light intensity

Bias voltage is applied to a semiconductor p-n junction.
With light falling on to the junction, electron-holes are created and swept towards the electrodes, creating a photocurrent.

The photocurrent is proportional to the light intensity.