ULB

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ECOLE POLYTECHNIQUE DE BRUXELLES

ECAM

BRUSSELS ENGINEERING SCHOOL

Smart Wound Care: Device design

Active Medical Device (ELEC-H424)

1. **Introduction**
2. Biomarkers
3. Sensors
4. PCB
5. Prototype

- Chronic wounds :
  - Result from variety of medical conditions (obesity, hypertension, …)

- Crucial to monitor the progression of a wound
- Nowadays = visual inspection of the skin
- Goal = use smart bandages

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• Biochemical markers

pH

- Infection indicator marker
- Normal skin : pH alkaline (≈7)
- Wound : pH between 5.5 and 6.5
- pH>6 ➔ appearance of human-pathogenic bacteria
- Incidence on the effectiveness of antibiotics and antiseptics

Advantage(s)	Disadvantage(s)
• Precise information	• Very expensive sensor • Length of the sensor (10 cm minimum)

Physical markers

Temperature

- Infection indicator marker
- Increasing temperature around a wound associated to the presence of an infection

Advantage(s)

- Very easy to measure
- Associated to a defence mechanism
- Cheap sensor

Disadvantage(s)

- Depends on the environment's temperature
- Could vary a lot during the day (exercise,…)

Oxygen

- Slow recovery monitoring marker
- Concentration around a wound = important factor for healing
- Helps eliminate bacteria and debris in the wound

Advantage(s)	Disadvantage(s)
• Constant value • Small sensor	• $sp0_2$ sensor • More expensive than other sensors

Humidity

- Slow recovery monitoring marker
- Wound moisture balance = critical for optimum healing conditions

Advantage(s)

- Easy to measure
- Small & cheap sensor

Disadvantage(s)

- Sensor must be placed closed to the wound

Pressure

- Slow recovery monitoring marker
- Exerted pressure ranges from 14 to 40 mmHg in the bandages

Advantage(s)

- Easy to measure
- Improves the healing speed
- Cheap sensor

Disadvantage(s)

- Sensor must be placed closed to the wound

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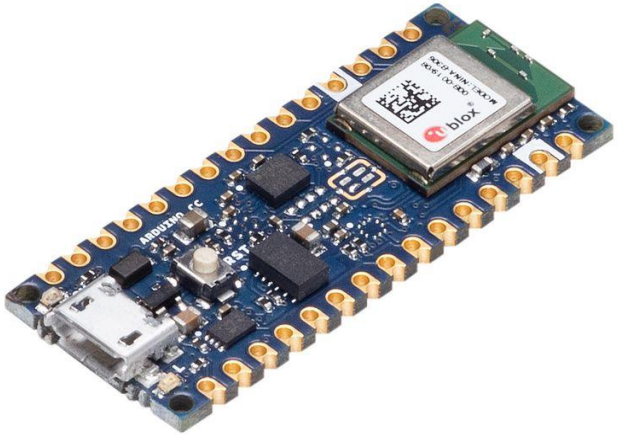
Sensors

Control board – *Arduino Nano 33 BLE*



- **Voltage output :** 5V and 3.3V
- **Communication protocol :** I2C capable, Bluetooth serial communication
- **Coding language :** C++ based
- **Accessibility :** fast delivery, relatively cheap
- **Improved performanceq :** enables to treat all the data needed

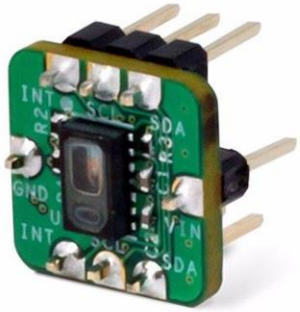
Sensors

Humidity and temperature sensor – SHT40-AD1B-R2

- **Accuracy on the humidity :** ± 1%
- **Accuracy on the temperature :** ± 0.1°C (@25°C)
- **Power supply :** 1.08V to 3.6V, *Ultra-low-power*
- **Accessibility :** available by 1
- **Ease of use :** Library available and I2C capable

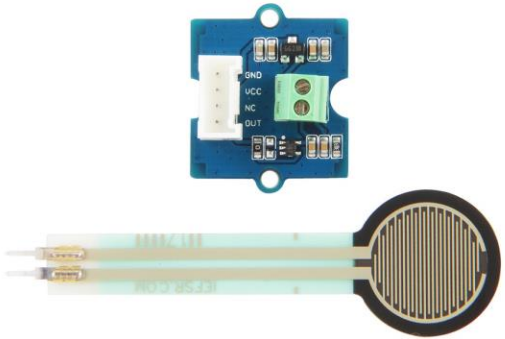
Sensors

Oxygen level sensor – MAXREFDES117



- **Accuracy :** ± 2% (for saturation levels ranging from 70% to 100%
- **Power supply :** 2V to 5.5V
- **Accessibility :** available by 1
- **Ease of use :** Open source library available and I2C capable

Pressure sensor – Round Force Sensor FSR402



- **Accuracy :** Continuous (analog)
- **Power supply :** 3.3V or 5V
- **Accessibility :** available by 1
- **Ease of use :** Value directly read using the µC (Analog input pin)

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4. **PCB**
5. Prototype

PCB

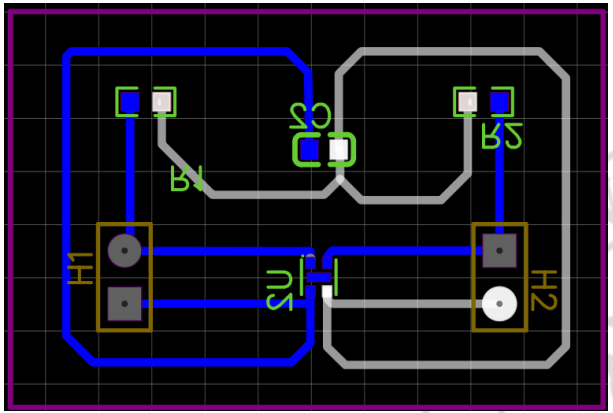
Why was it important ?

- Good connection between the components
- Simplify wiring and reduced short-circuit risks
- Space optimisation
- Improved comfort and discretion for patients

PCB

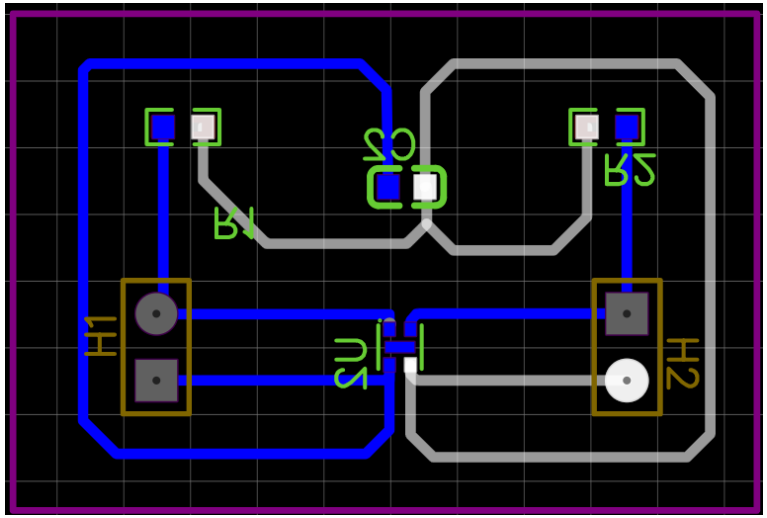
Issues :

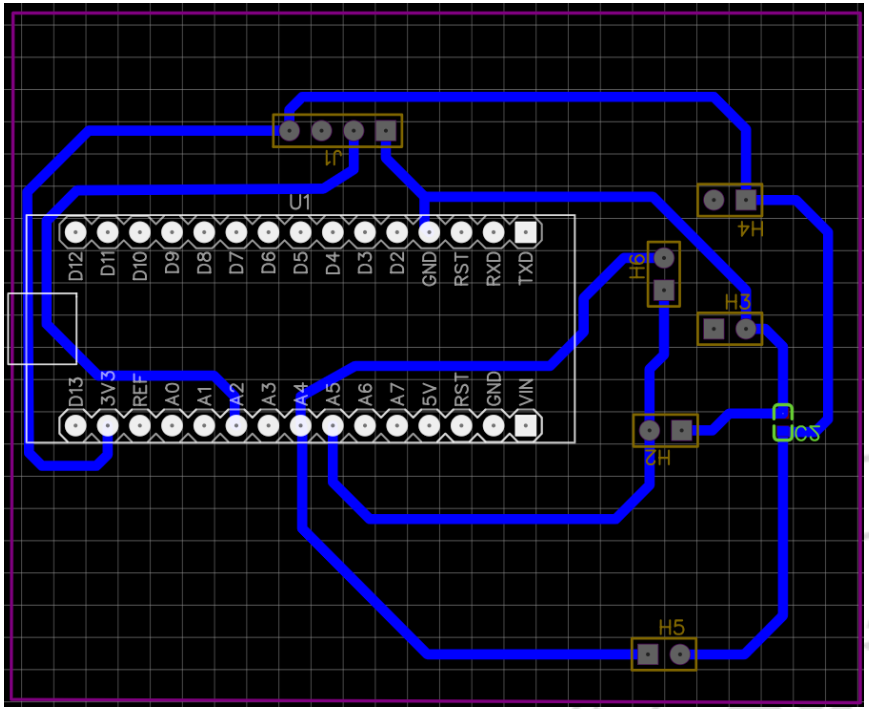
- Pin → 0,3mm ø
- Road as wide as possible (1mm)
- Create a PCB for the humidity sensor



PCB

Humidity and T° sensor





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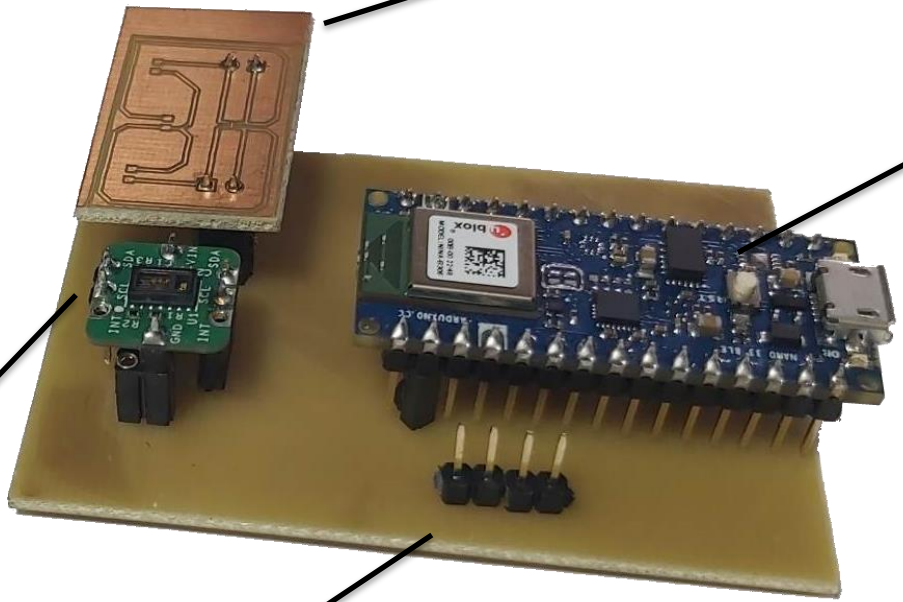
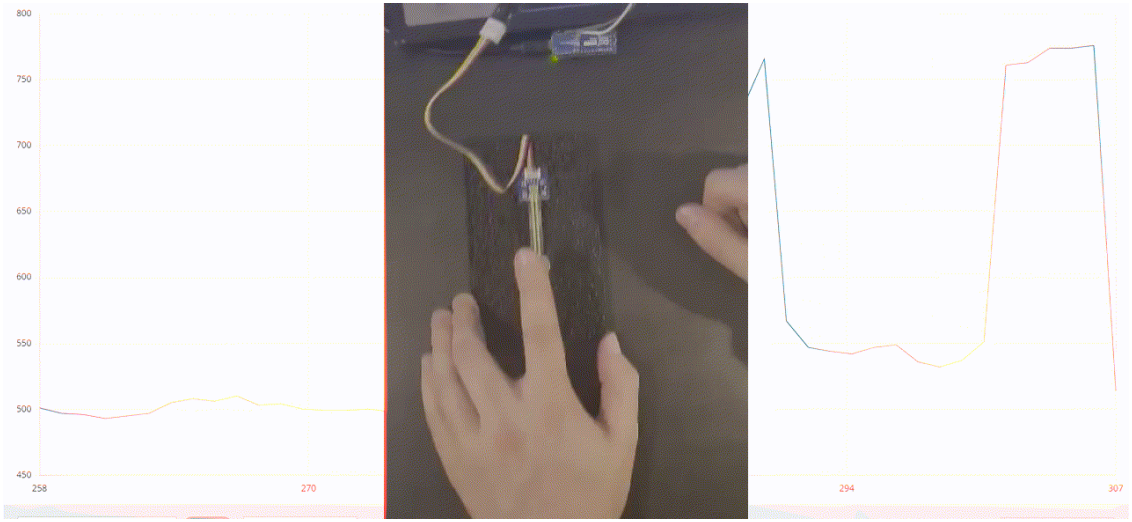
Prototype


Secondary PCB
Arduino Nano
spO2 sensor
Connection for the FSR402

Prototype : current state

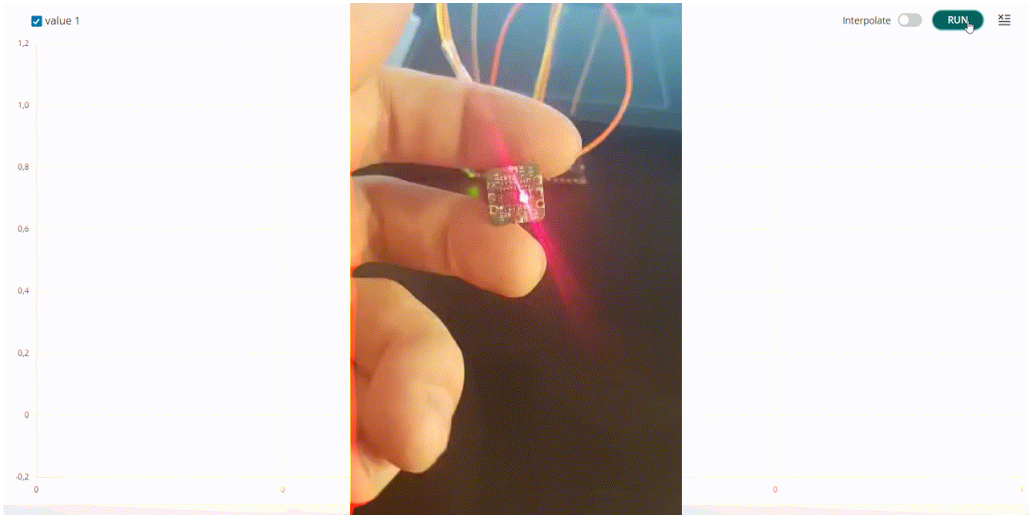
- Measuring the pressure



- Validation step proposed:
  - Using balance weights placed on the sensor

Prototype : current state

- Measuring the temperature



- Validation steps performed :
  - Placing a finger on the sensor raises the temperature
  - Placing a cooled finger on the sensor decreases the temperature

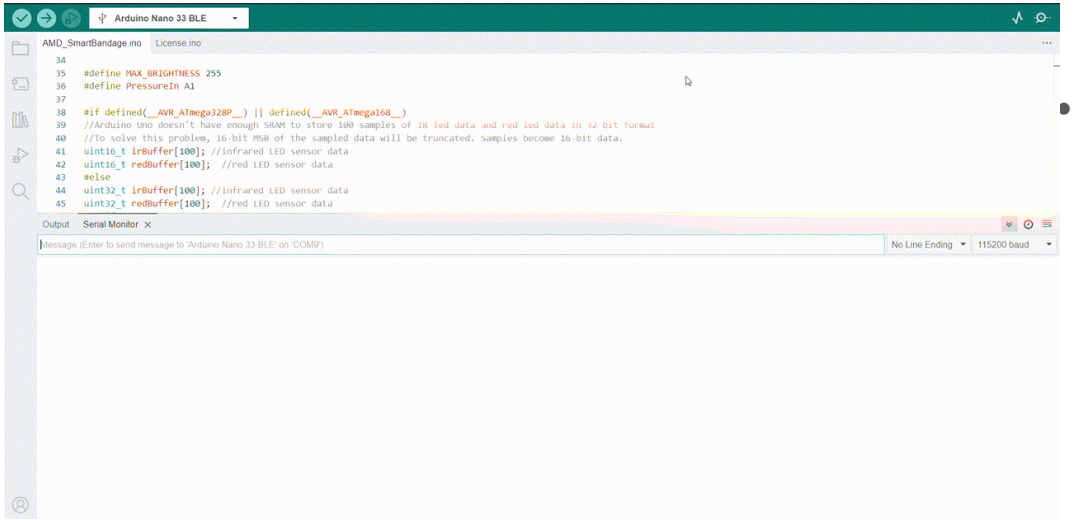
Prototype : current state

- Measuring the BPM and spO2

- Validation steps performed :
  - Compared with an hospital-grade oxymeter
  - BPM value measured by hand

Prototype : current state

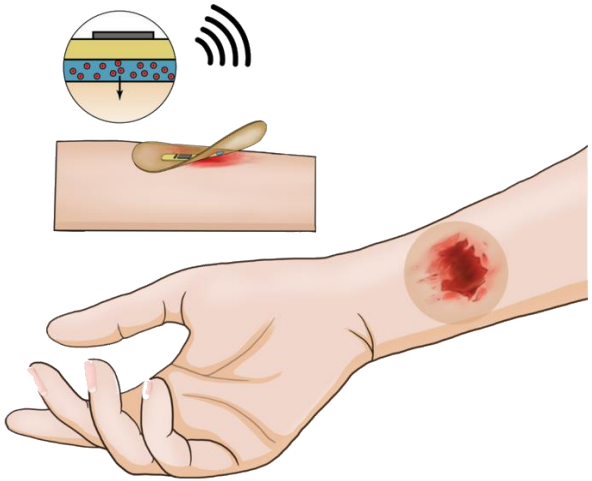
- Measuring the BPM and spO2



- Validation steps performed :
  - Compared with an hospital-grade oxymeter
  - BPM value measured by hand

Prototype : next steps

What remains to be done to test it in real conditions?



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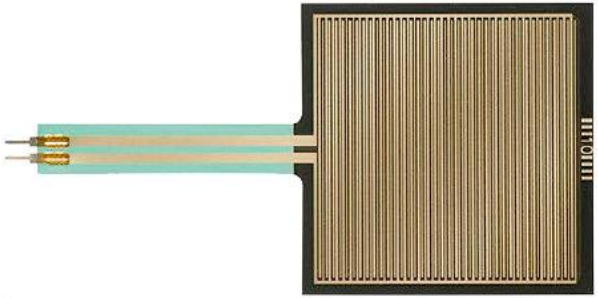
Prototype : next steps

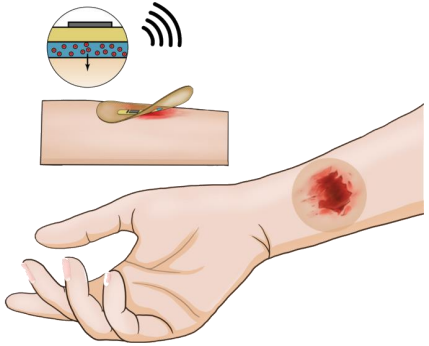
- Using the SHT40
- Test both PCBs
- Choosing a more adequate shape for the pressure sensor



FSR® 406
38mm Square x 83mm

Prototype : next steps

- Stabilise the sensors
- Develop a wearable circuit
  - Using a flexible PCB
  - Reducing the size of the components
  - Apply safety standards
  - Allow wireless communication



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Thank you for your attention!

Any questions?

Other non-selected Markers

- Nitric oxide
  - Promotes cell growth, cell migration, new blood vessel formation and stimulation of collagen production
  - Concentration between 50 and 500 nM
  - **No sensor for aqueous environment**
- Uric acid
  - Waste product
  - Indicator of oxidative stress and bacterial infection
  - Chronic wounds = hypoxic ➔ increase of purine metabolites concentration
  - **Too large**
- Proteases
  - responsible for the balance between extracellular matrix (ECM) degradation and deposition
  - Disrupt in the balance ➔ state of chronic inflammation
  - **Too complex** (colorimetric or fluorescent study ➔ need of light and camera)

Markers

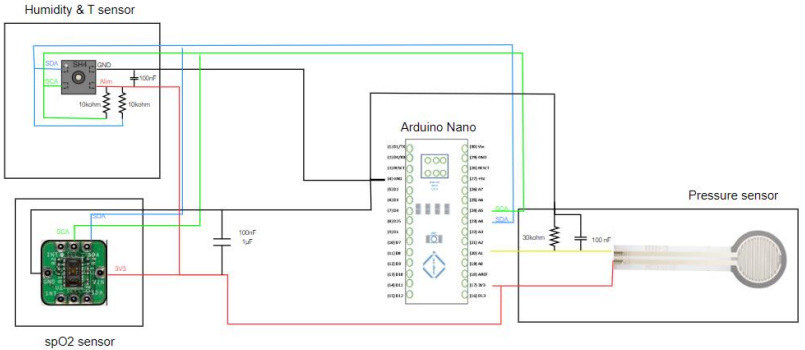
- Summary of the different markers proposed

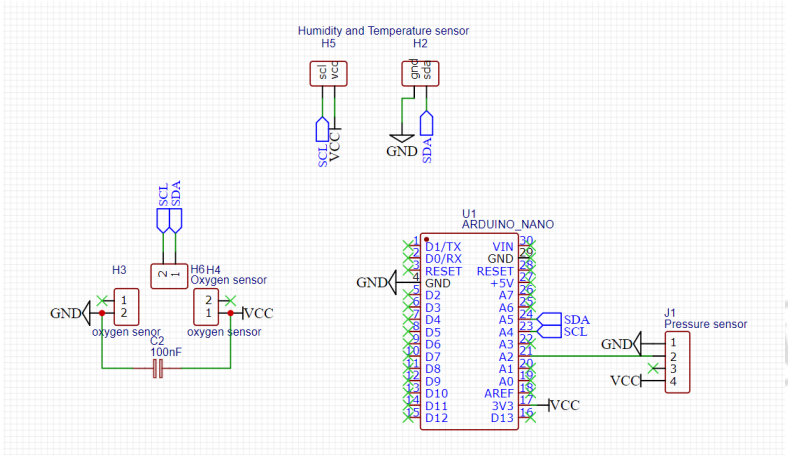
Bio-marker	Type of marker	Litterature review	Sensor review	Price
pH	Infection	Very positive	Negative	Negative
Nitric oxide	Slow recovery	Positive	Negative	/
Uric acid	Slow recovery & infection	Positive	Negative	/
Proteases	Slow recovery	Positive	Very negative	/
Temperature	Infection	Very positive	Very positive	Very positive
Oxygen	Slow recovery	Very positive	Positive	Positive
Humidity	Slow recovery	Very positive	Positive	Very positive
Pressure	Slow recovery	Positive	Very positive	Positive

Depending on the review, the characteristic's review will either be "Very positive " (The review encourages the use of this marker), "Positive", "Neutral", "Negative" (The review raises important issues) and "Very negative" (One point in the review prevents the use of this sensor).

PCB

Wiring diagram





Arduino Libraries

- The SparkFun library used for most of the measures taken.