INTRODUCTION TO ESIPAP COMPUTING SESSIONS

WEDNESDAY 8 – THURSDAY 9 FEBRUARY 2023

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GOALS OF THE COMPUTING SESSIONS

- Computing is required for instrumentation purposes:
  - Simulation of sensor
  - Data acquisition
  - Data analysis
  - Algorithm and reconstruction of physics objects

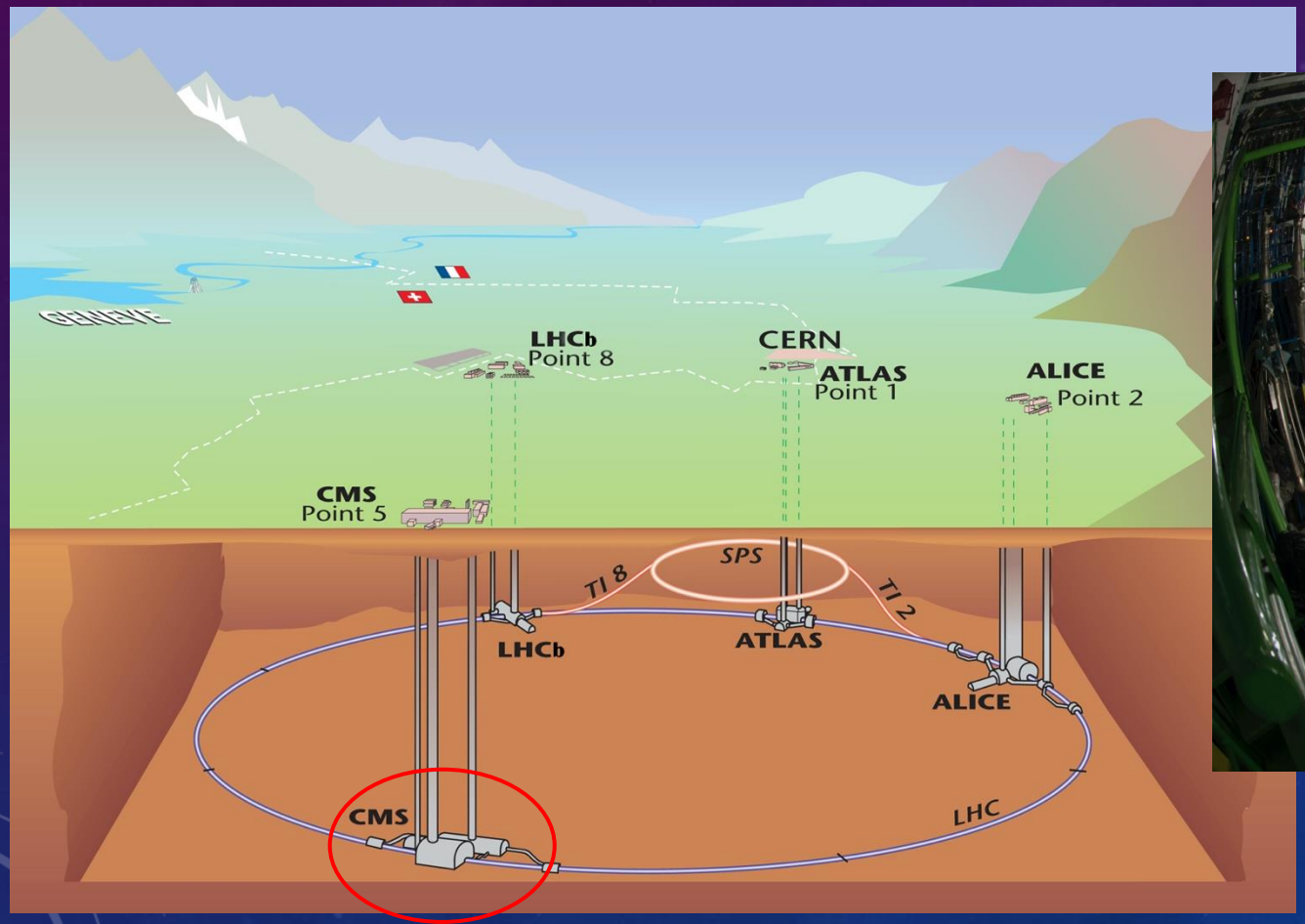
- Computing sessions target to apply your theoretical knowledge:
  - Instrumentation
  - Software programming in C++
  - Using specific tools of high energy physics: ROOT

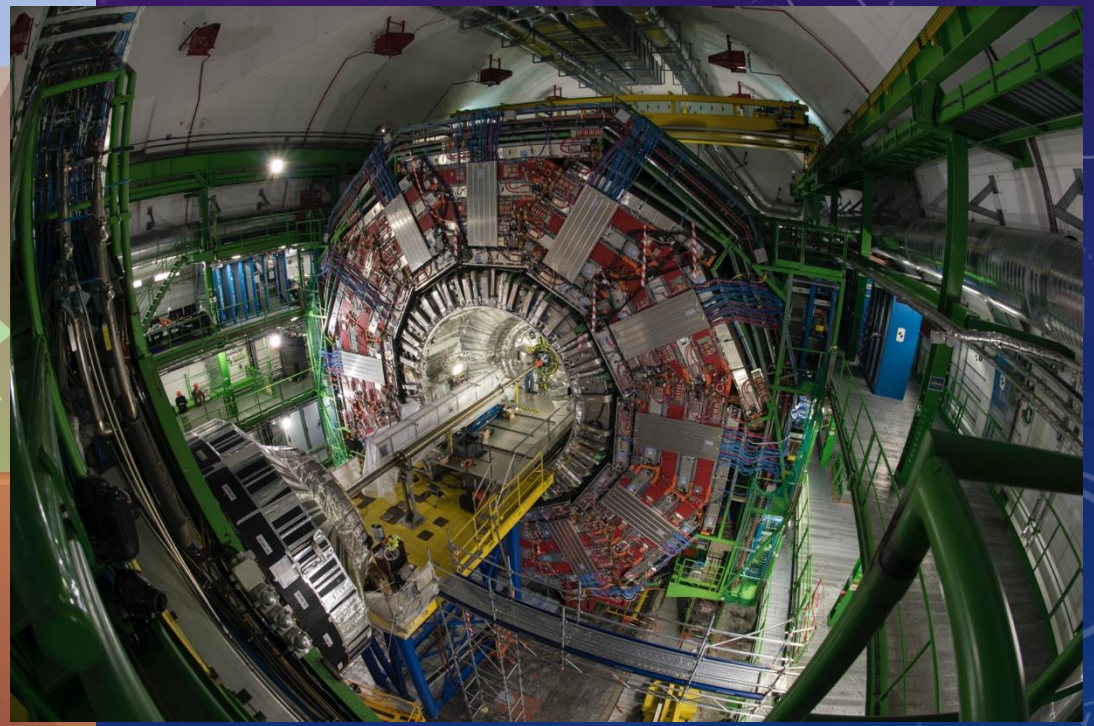
- Working by yourself and experimenting

- Getting the good practice

PHYSICS CONTEXT

THE CMS (COMPACT MUON SOLENOID) DETECTOR





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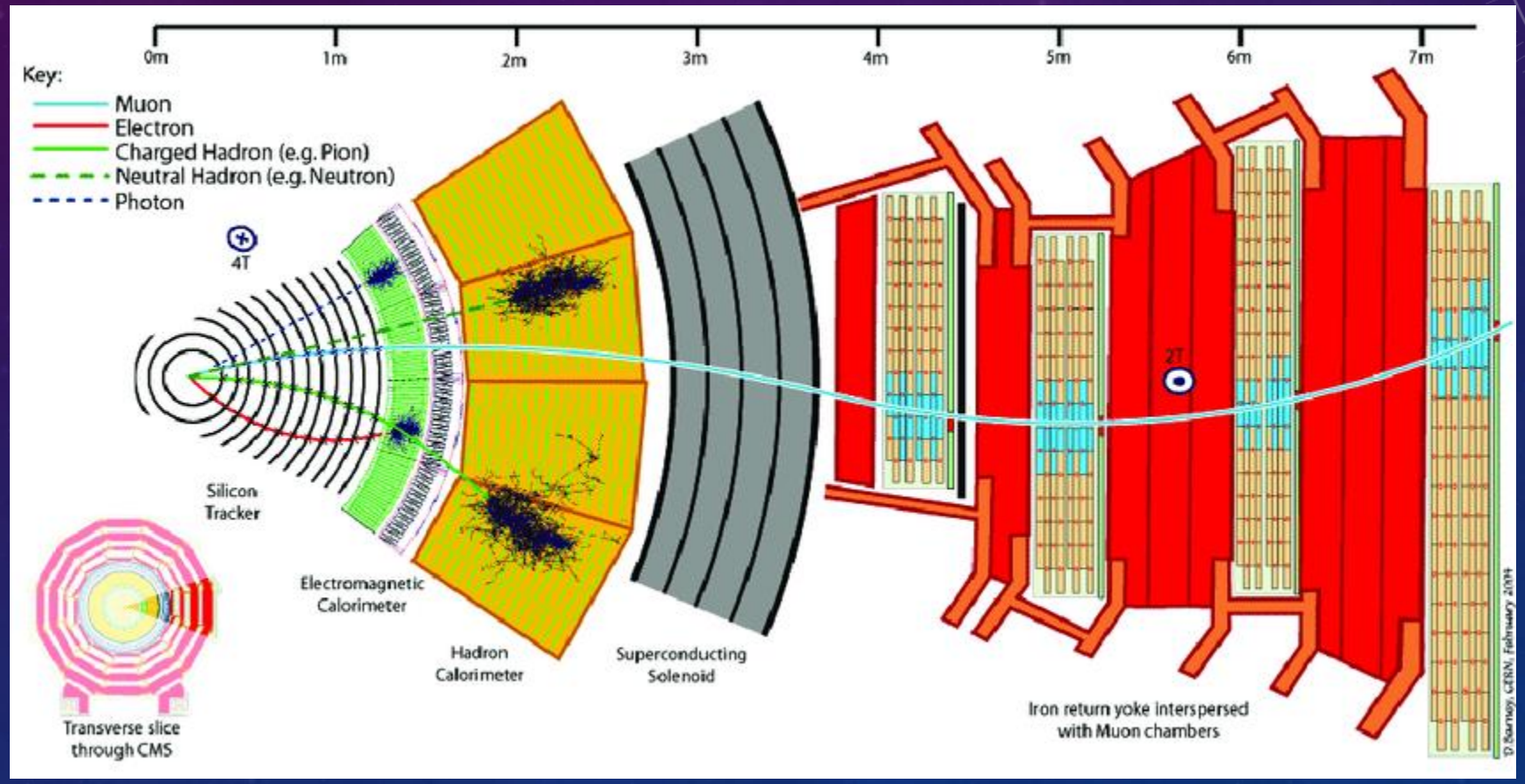
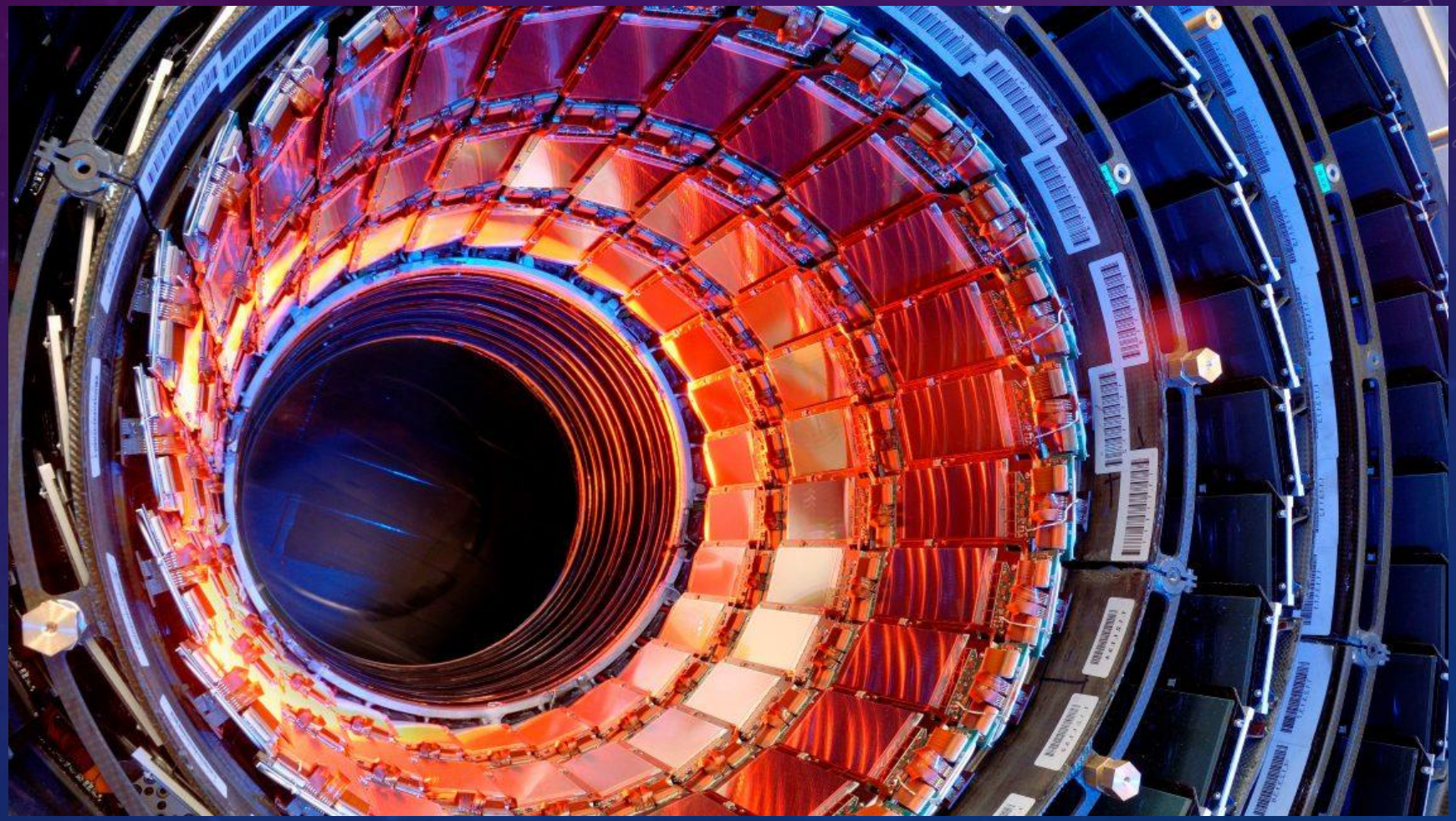


SILICON STRIP TRACKER



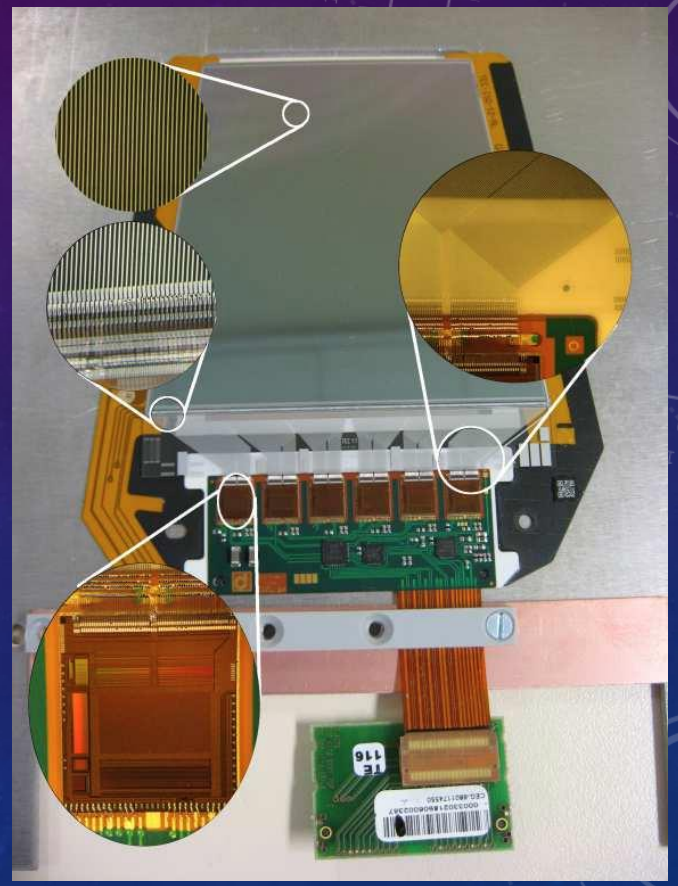
SILICON STRIP TRACKER

Instrumental activities

- R&D
- Construction
- Operation (online)
- Alignment & calibration
- Offline analyses
- Simulation
- Radiation damages evaluation
- …

CMS silicon strip tracker in few numbers:

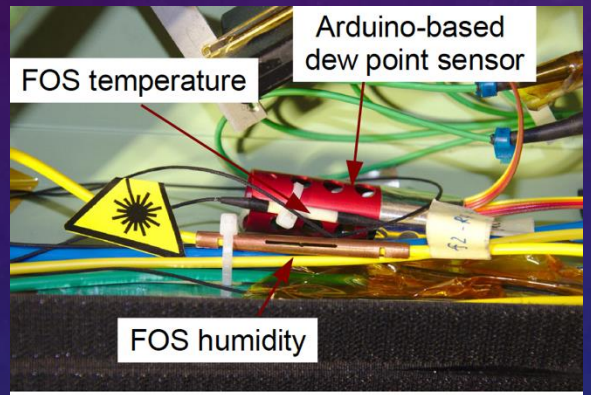
- 15 000 modules
- Surface: ~ 200 m^2
- 10^6 channels

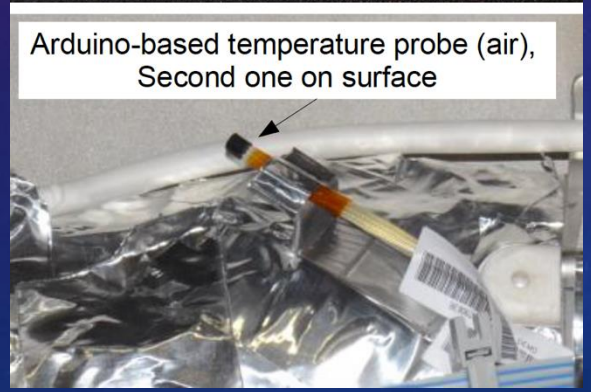


Performances:

- Hit resolution: 20-40 µm
- Hit efficiency > 98% (at high Pile-Up)
- Timing alignment accuracy: 1ns
- …

SILICON STRIP TRACKER





During its operation it is important to monitor environment conditions:

- Temperature
  - Leakage current
  - Noise
  - Thermal dissipation
  - Radiation damages
  - …
- Humidity
  - Dew points & condensation
  - Front End electronics
  - …

Monitoring tools

Several probes are used to monitor that:

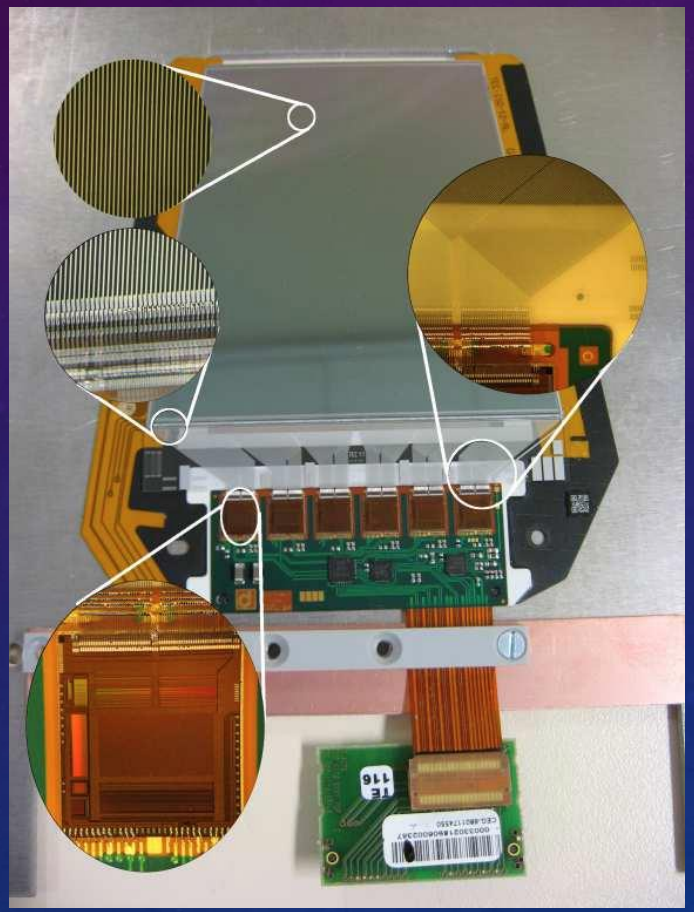
- On-board sensors
- External sensors

→ Some are ARDUINO-based!

COMPUTING SESSION AIMS

Instrumental activities

- R&D
- Construction
- **Operation (online)**
- Alignment & calibration
- **Offline analyses**
- **Simulation**
- Radiation damages evaluation
- …



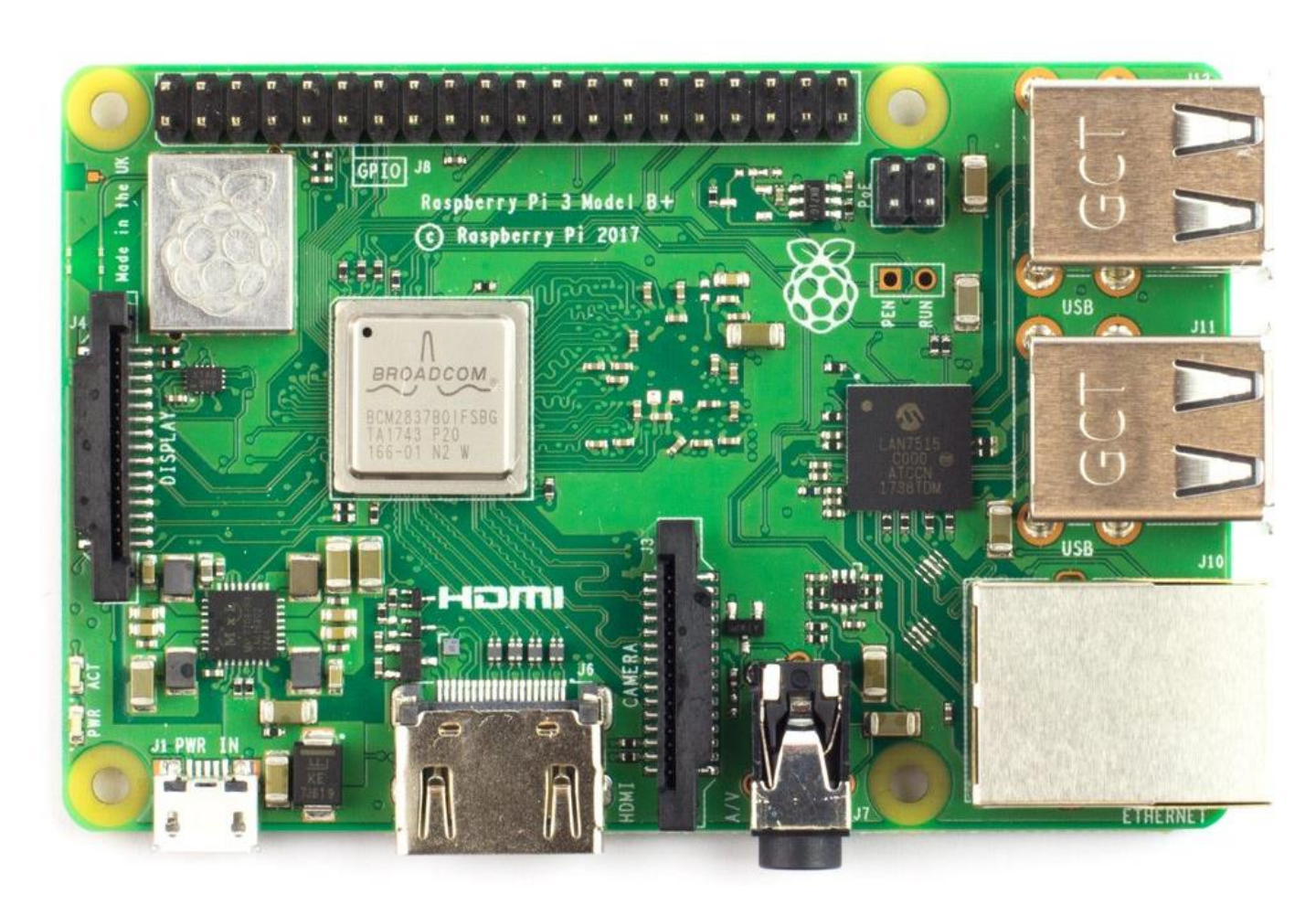
1. **Slow control**
   - Using a dedicated electronic board (Sense Hat) read by a Raspberry
     - Monitor the temperature & humidity
     - Send warning when conditions are not fulfilled

2. **Offline analyses**
   - Calibration of the temperature sensors
   - Evaluation of the sensor resolution

3. **Simulation**
   - Basic simulation with the GEANT4 package of a CMS silicon strip sensor

SETUP

THE RASPBERRY BOARD



Raspberry Pi 3 B+ motherboard

- Quad-core 64 bits processors @ 1,4 GHz
- ARM (Acorn Risc Machine) architecture used mainly in smartphones, tablets, robotics, automation

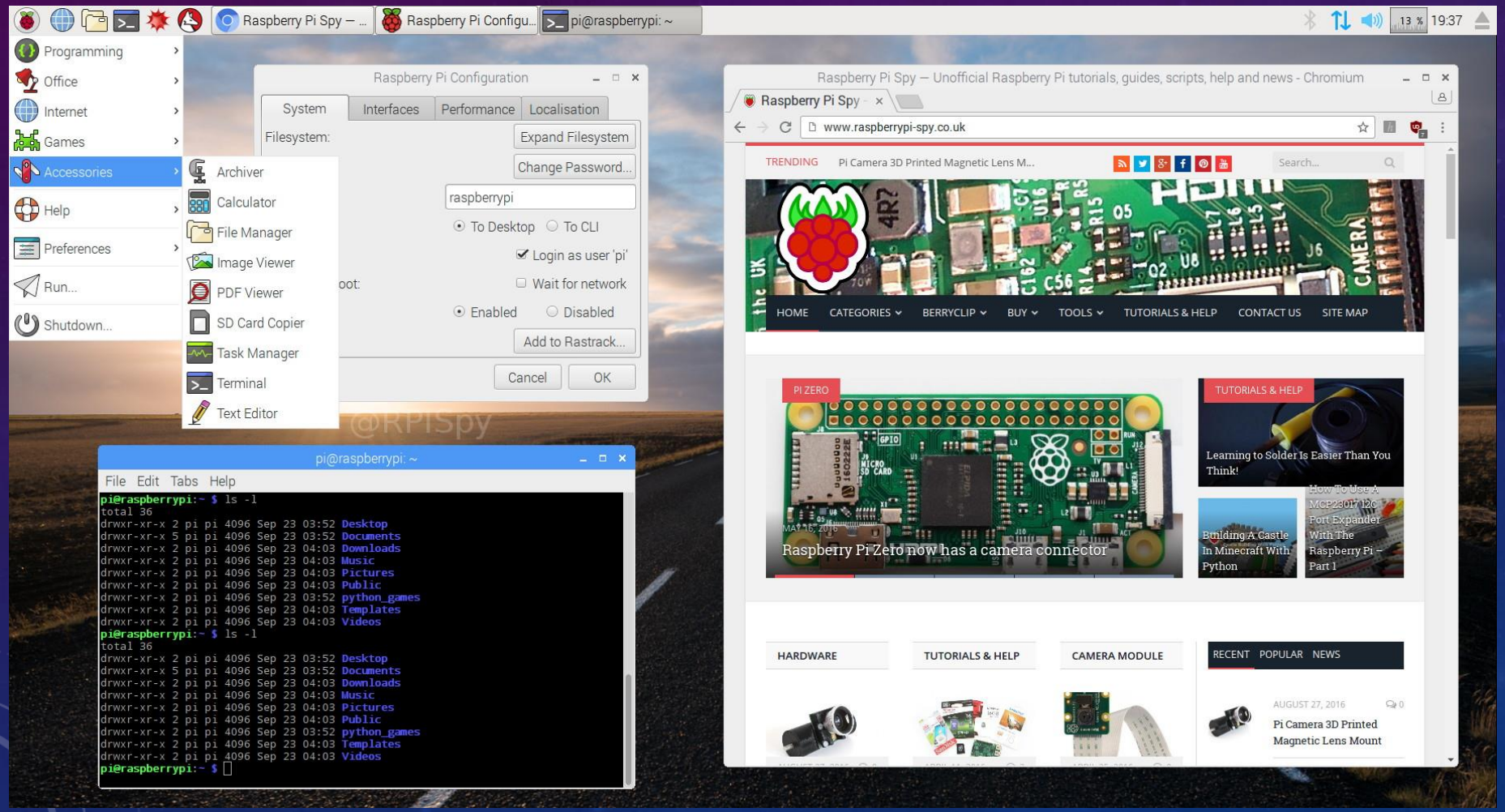
  Advantages : price, flexibility, performances

CONNECTIONS TO PERIPHERICAL DEVICES

- 4 USB ports
- 1 ethernet port
- 1 HDMI plug
- 1 GPIO (General Purpose Input/Output) port for connecting sensors
- Powered by micro USB (5V, 2.5A min)

+ WIFI
+ Bluetooth

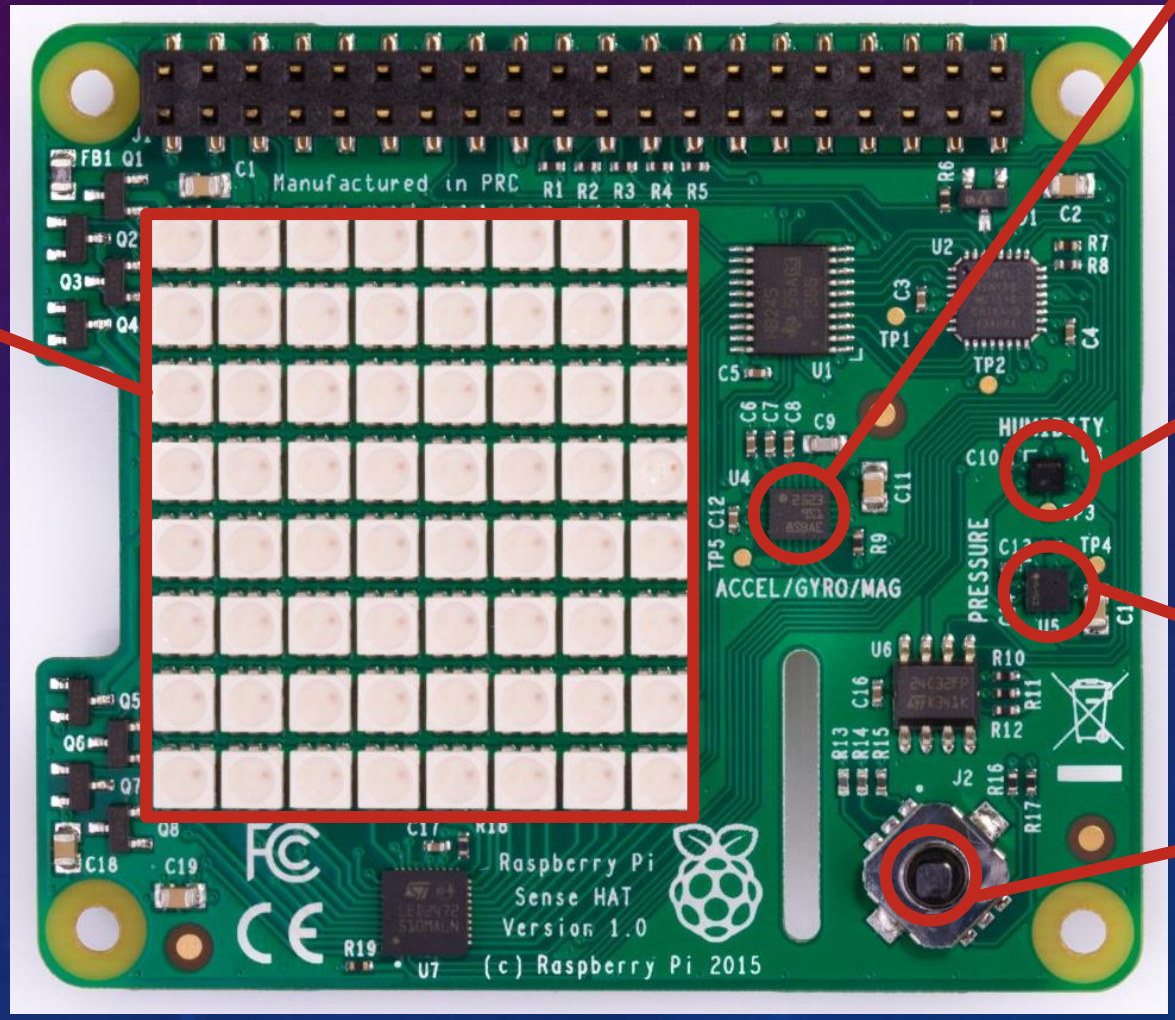
LINUX DISTRIBUTION: RASPBERRY PI OS (PREVIOUSLY RASPBIAN)



Stored on a micro SD card

SENSE HAT BOARD

8x8 LEDs for display



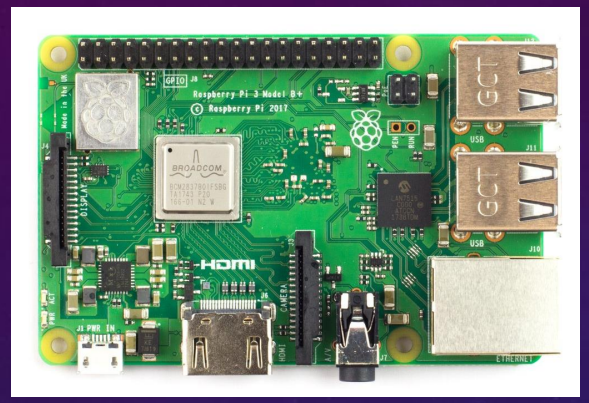
3D accelerometer, 3D gyrometer and 3D magnetometer sensor

Humidity / Temperature sensor

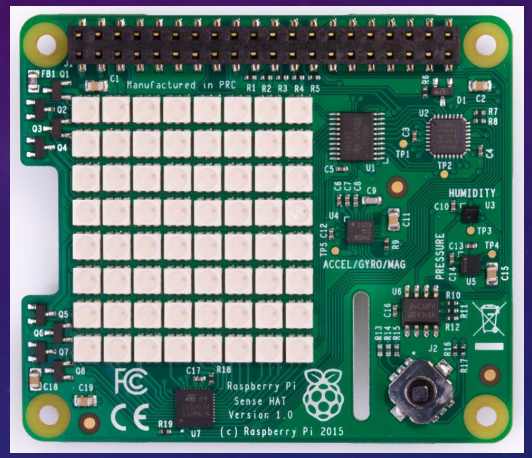
Pressure / Temperature sensor

Joystick

PRICE



Raspberry Pi 3 B+
~ 40 €



Sense Hat
~ 30 €

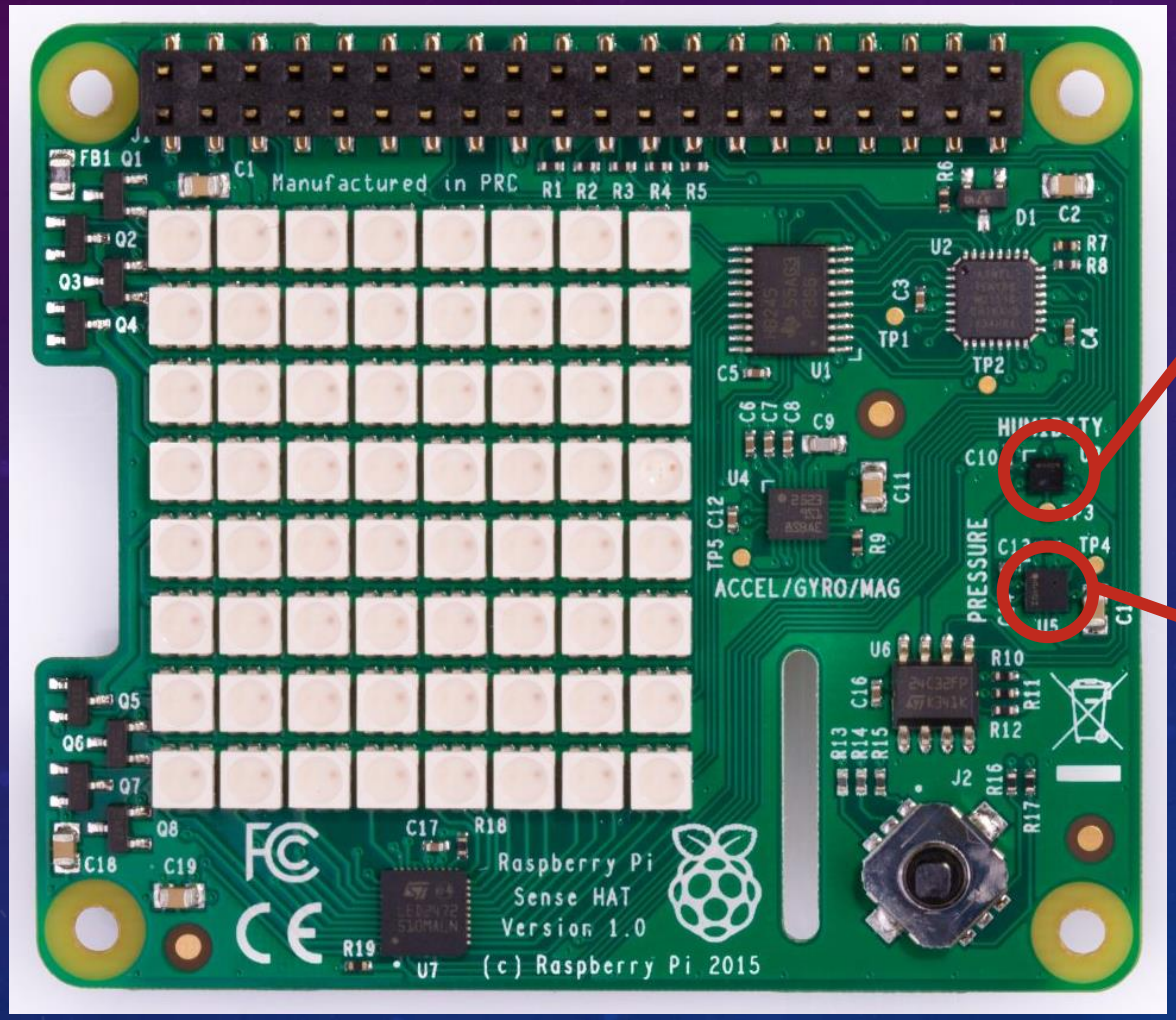
Connectors
~ 15 €

Micro SD
~ 10 €

Total: ~ 100€
(good gift for Saint-Valentin's day)

SENSORS AND SIGNAL CONDITIONING

SENSORS TO STUDY

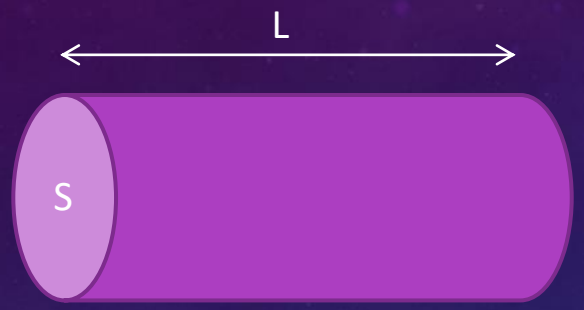


Humidity / Temperature sensor

Pressure / Temperature sensor

HOW TO MEASURE ….?

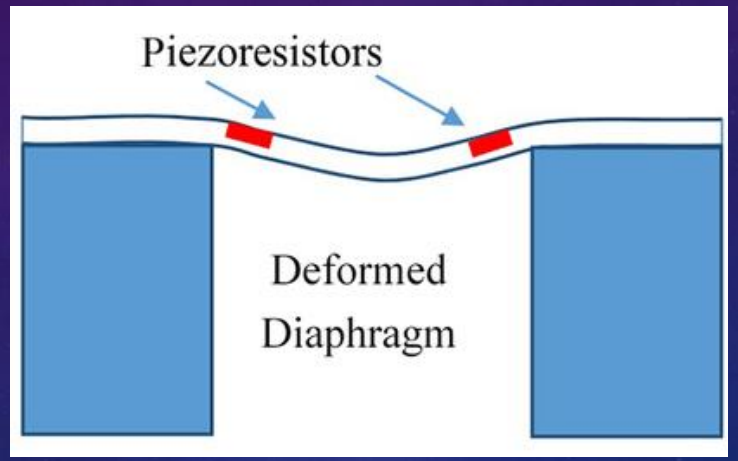
Temperature



$$R = \rho \frac{S}{L}$$

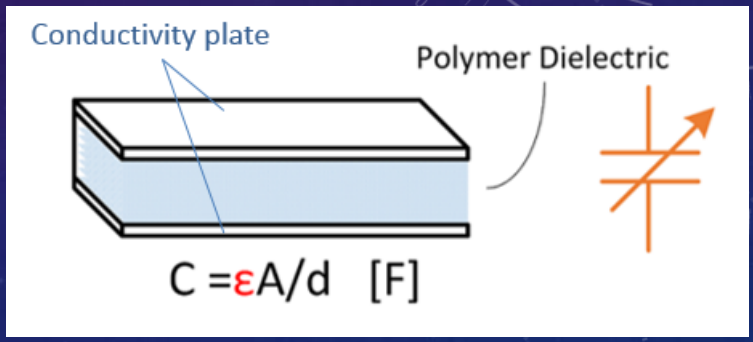
Material resistivity ρ depends on temperature.

Pressure



Piezoresistive effect:
a change in resistivity when a stress is applied.

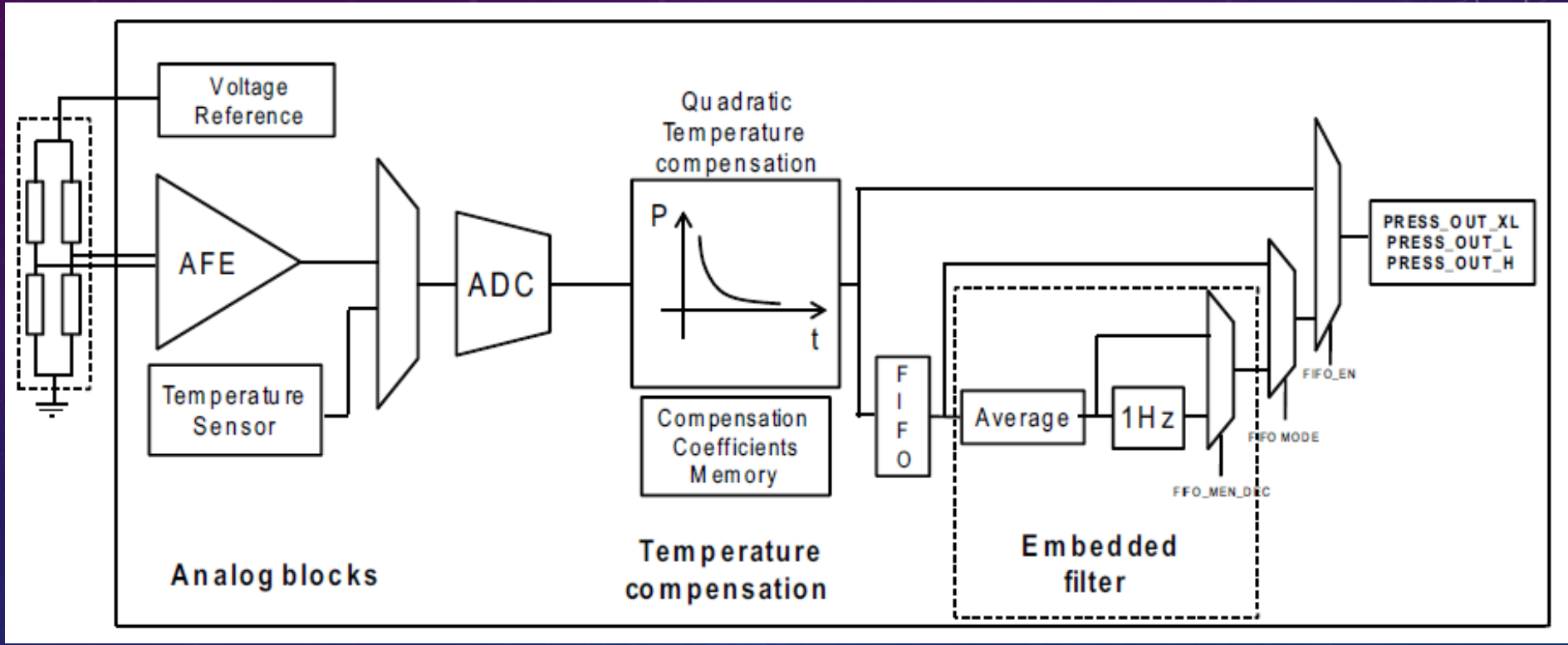
Humidity



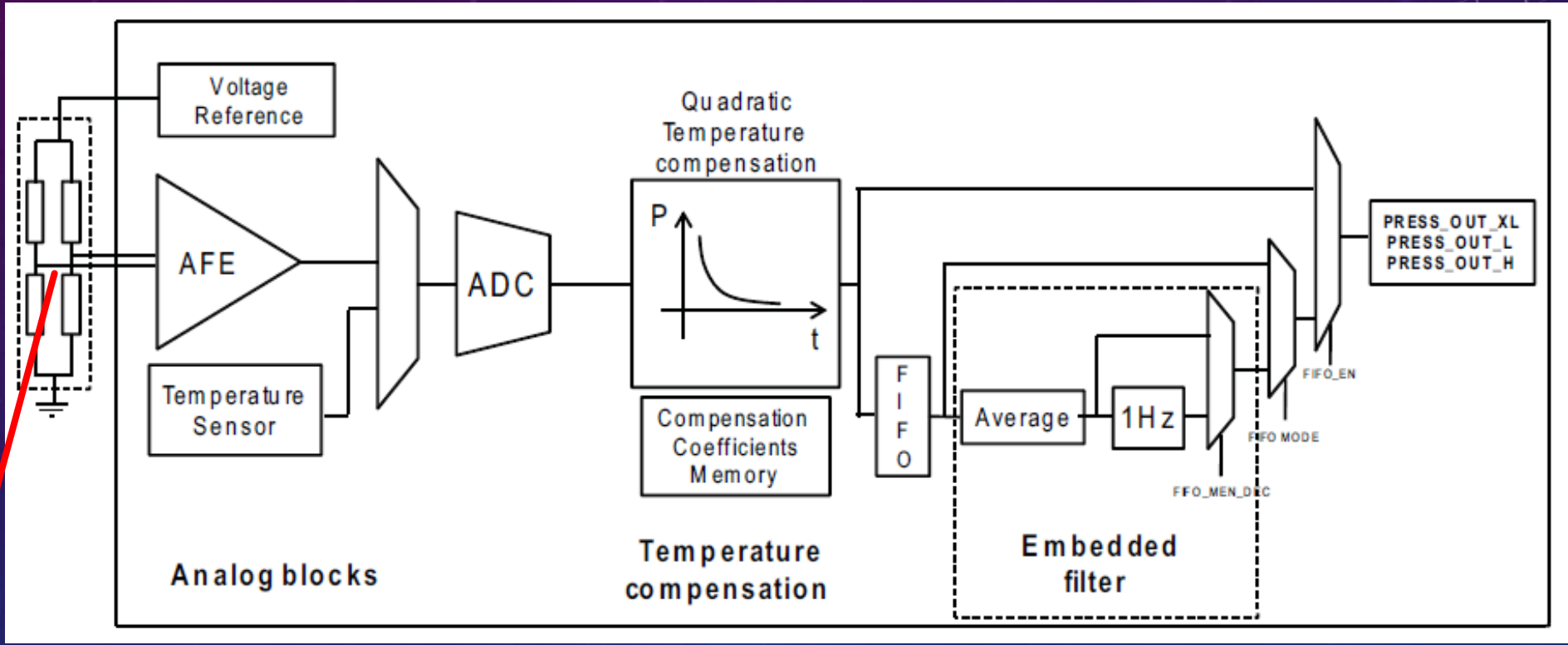
Dielectric material absorbs water molecules until equilibrium

→ change the electrical conductivity ε [in S/m]

PRESSURE / TEMPERATURE SENSOR PROCESS

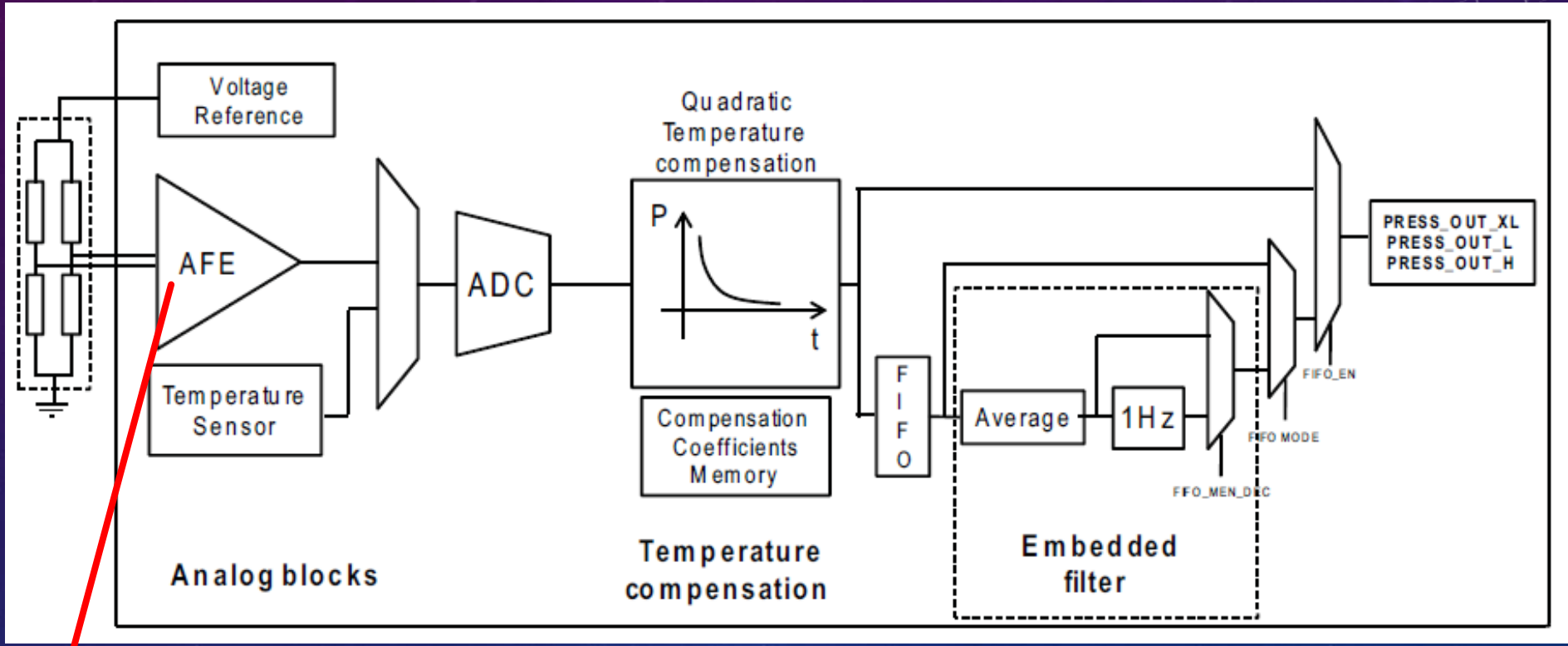


PRESSURE / TEMPERATURE SENSOR PROCESS



Wheatstone bridge
for translating change of resistance into change of tension

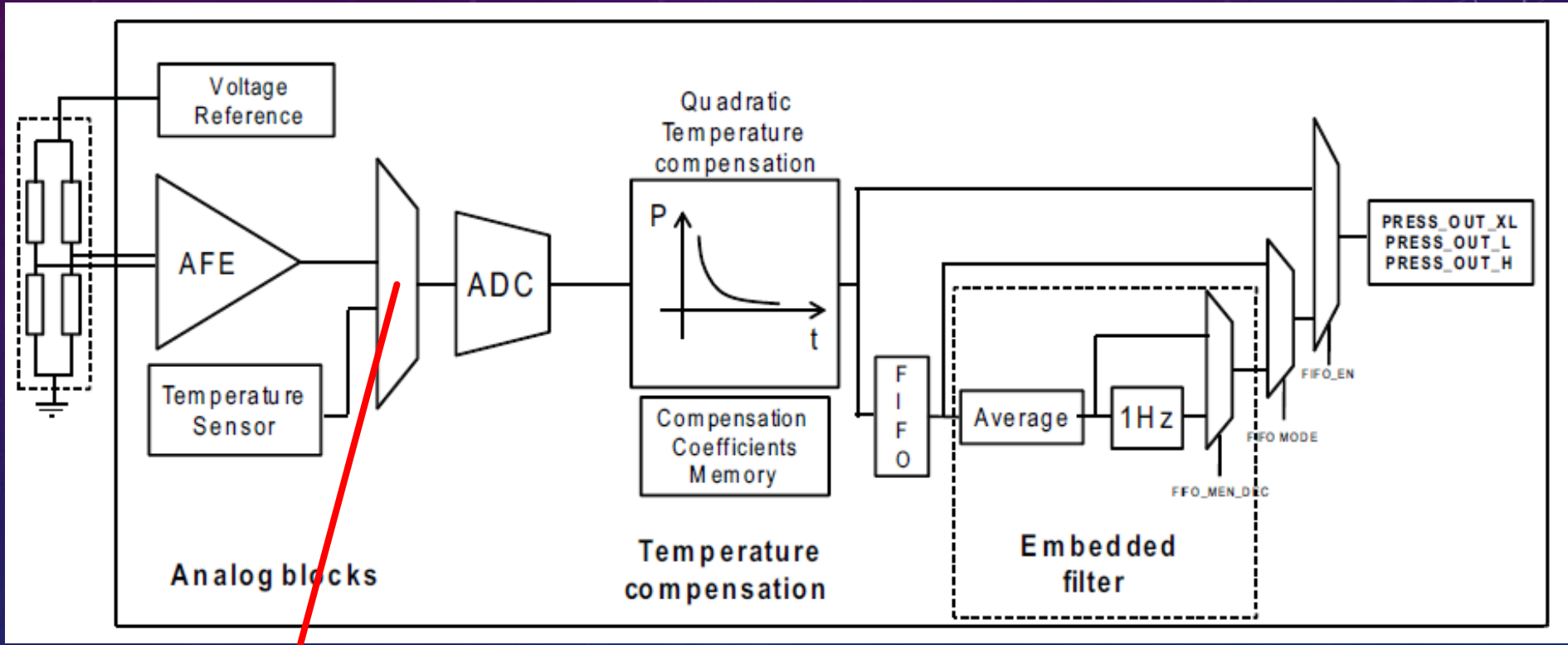
PRESSURE / TEMPERATURE SENSOR PROCESS



Analogic Front-End

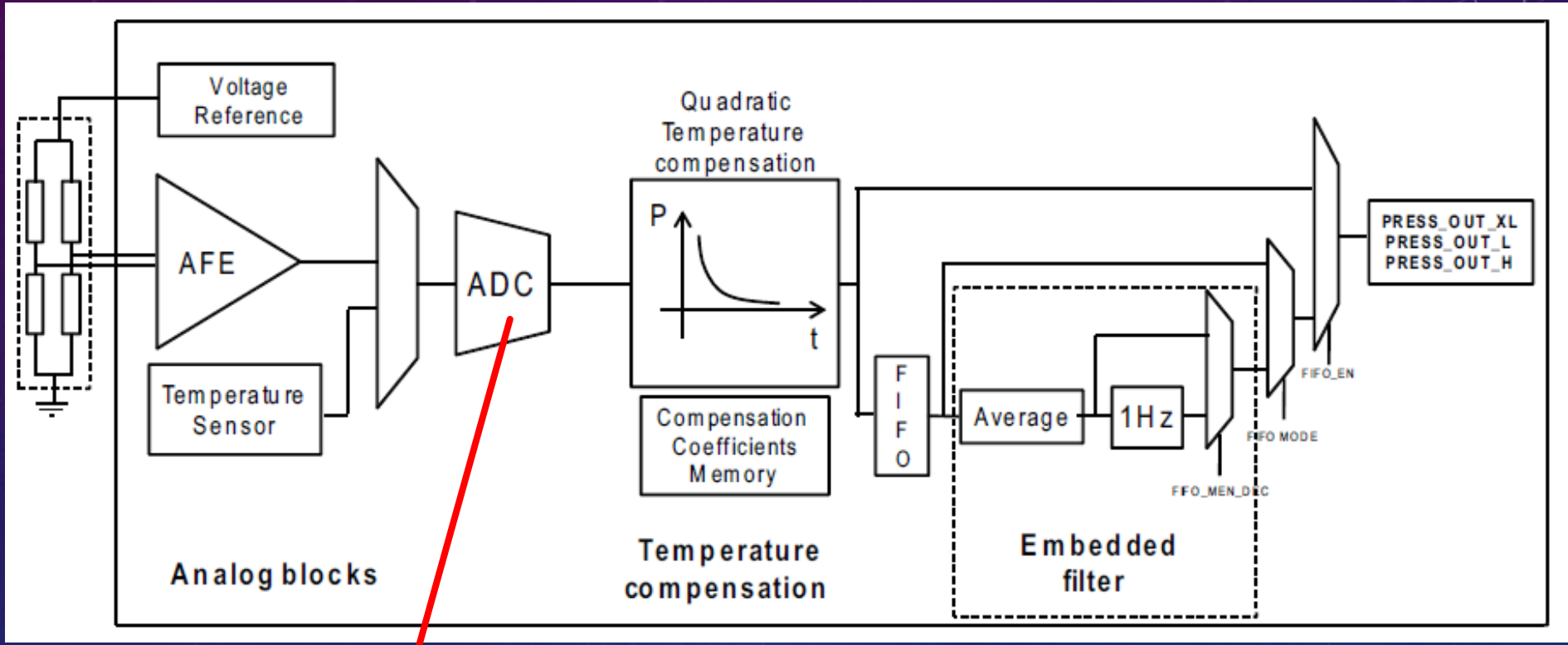
- Small signal voltages vs noise floor
- Amplifying signal and removing noise

PRESSURE / TEMPERATURE SENSOR PROCESS



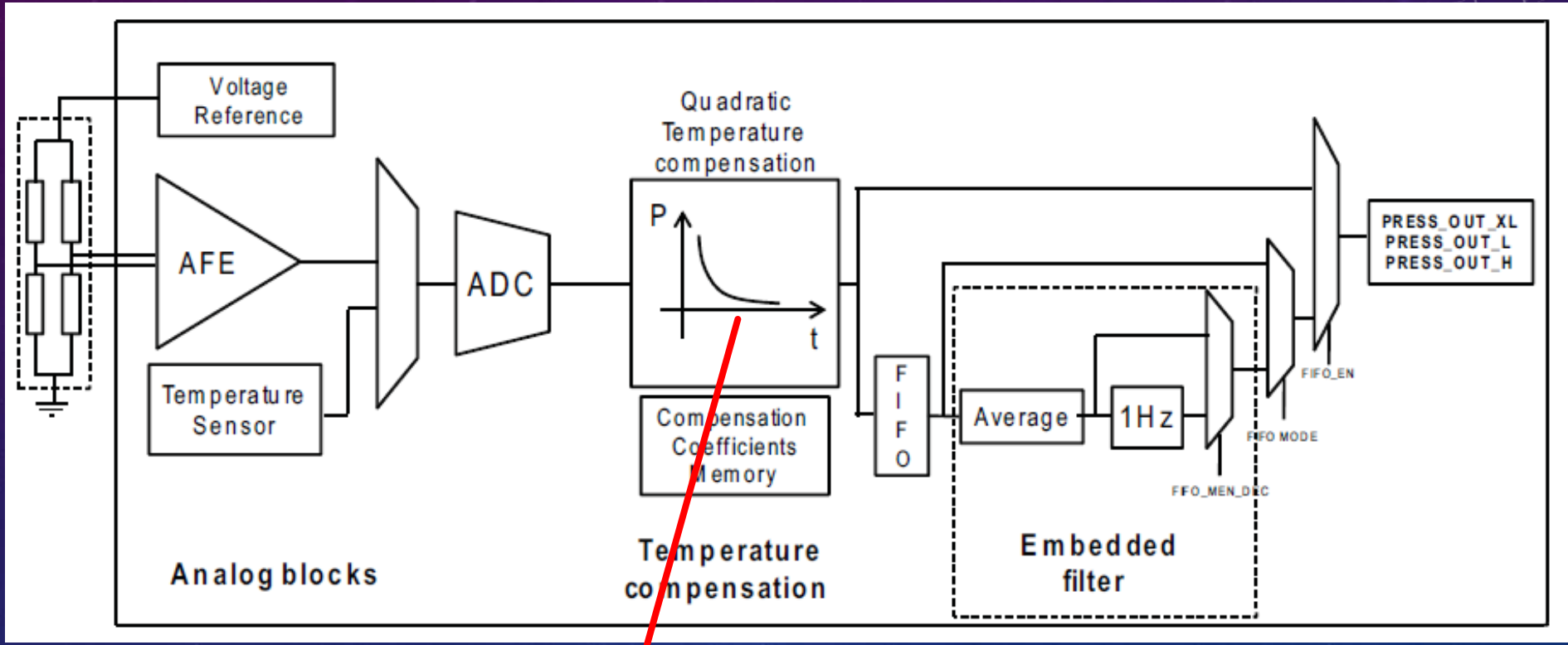
Multiplexer
Treating pressure and temperature measures by the same channel

PRESSURE / TEMPERATURE SENSOR PROCESS



Analogic to Digital converter
Digitalization of the measure

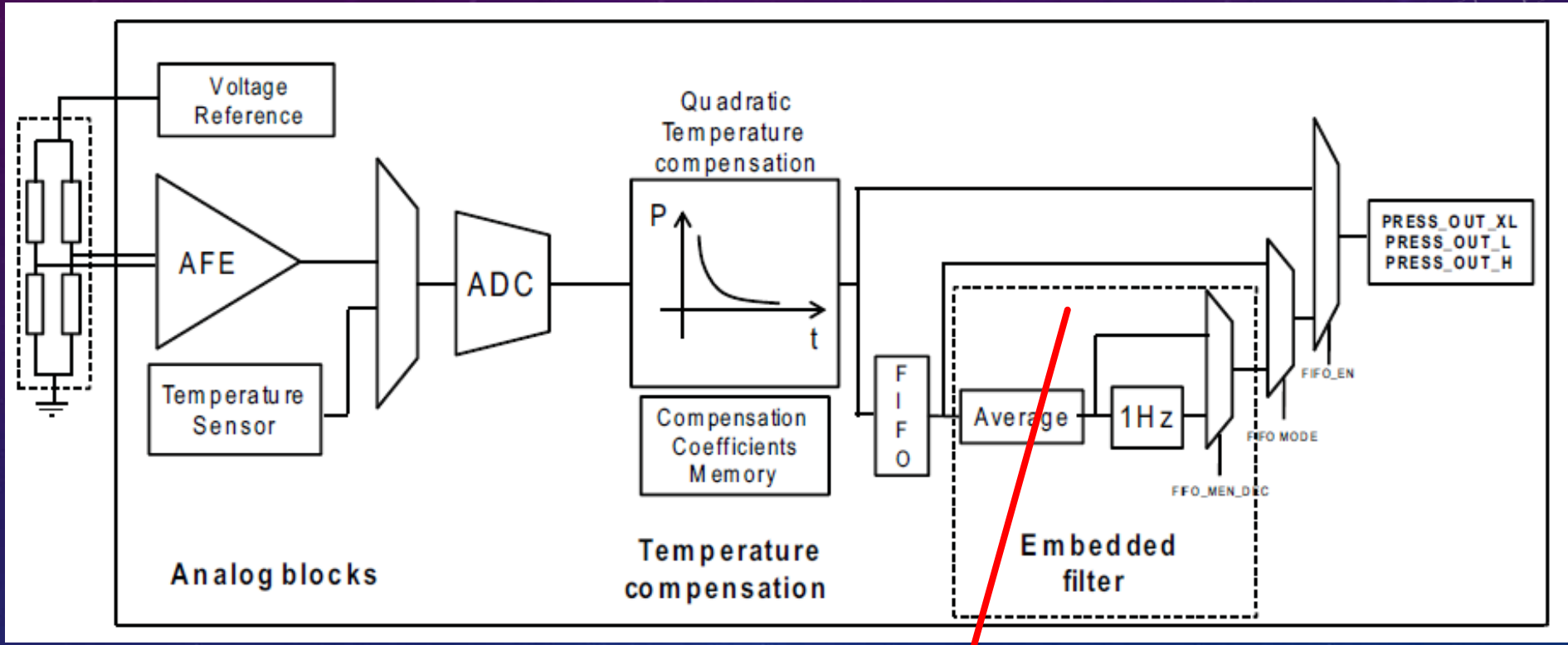
PRESSURE / TEMPERATURE SENSOR PROCESS



Temperature compensation
Piezoresistivity depends on T
→ Need to compensate this effect

Calibration settings

PRESSURE / TEMPERATURE SENSOR PROCESS

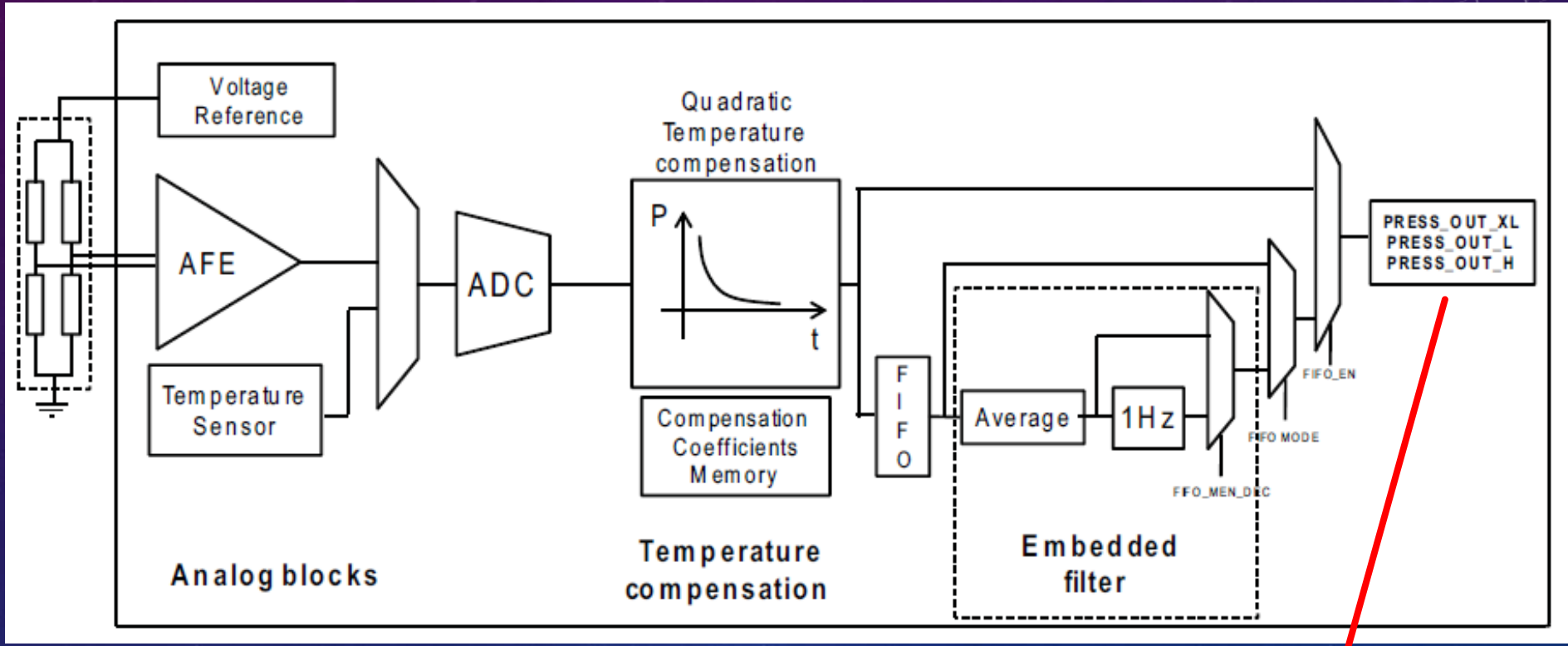


Calibration settings

Average

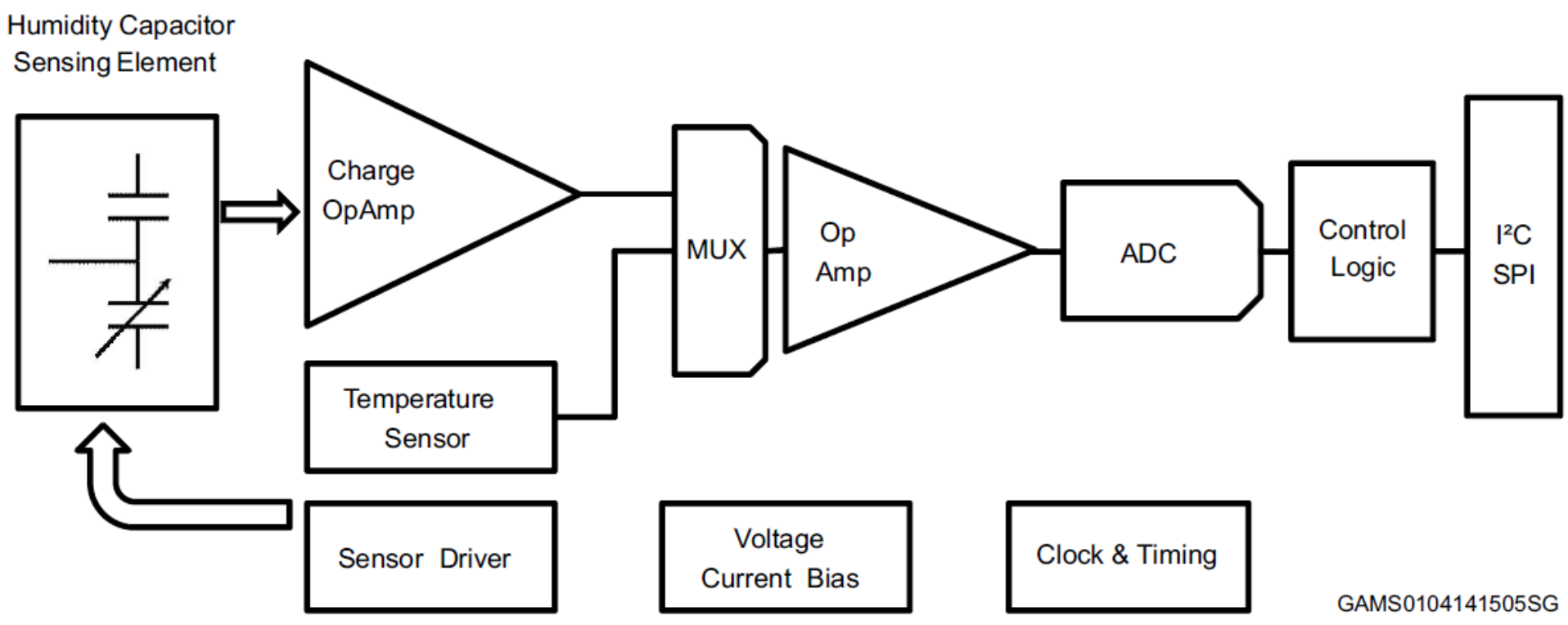
A maximum of 32 successive measurements are done (~1s) and an average value is computed.

PRESSURE / TEMPERATURE SENSOR PROCESS



Data transfer
Data are sent to the Raspberry via the GPIO port with the protocol I2C

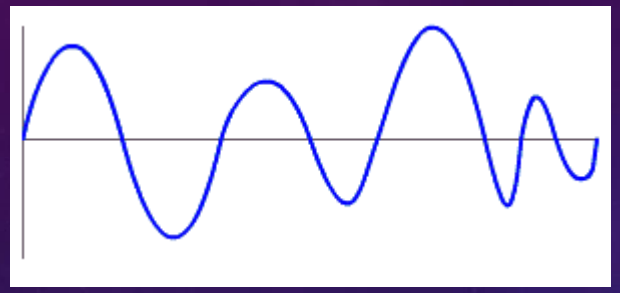
HUMIDITY / TEMPERATURE SENSOR PROCESS



One logic part is missing in this schema:
Translation of the tension to temperature and relative humidity.

Calibration settings

ADC RESOLUTION FOR PRESSURE SENSOR



analogic

ADC

24 bits

0	1	0	1	1	1	0	1	0	0

digital

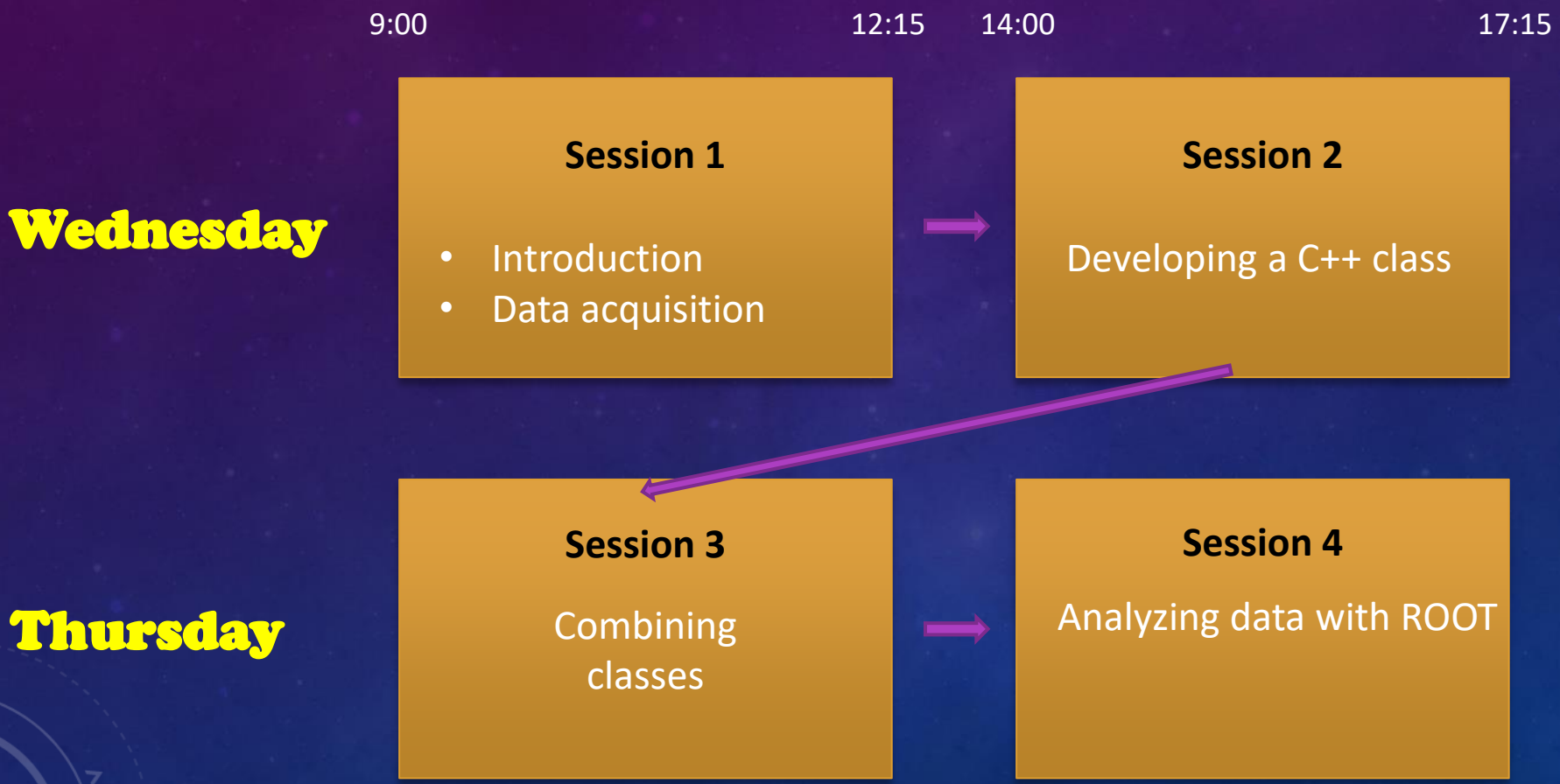
- Operating range of the sensor: [260 hPa to 1260 hPa] where the sensor is relevant and reliable
- Conversion pressure to measure: measure = pressure × 4096
- Number of bits for coding the maximum value 1260 hPa → measure = 5 160 960
  → N = 23 bits because $2^{22}-1 <$ measure $< 2^{23}-1$ …. but not standard: using 24 bits – ADC
- Full range : [0 hPa to 4096 hPa]
- Sensitivity : 4096 hPa / $2^{24}-1$ = 0,00024 hPa

SUMMARY ON ADC SENSITIVITY

	Pressure - Temperature sensor		Humidity - Temperature sensor	
	Pressure	Temperature	Humidity	Temperature
Operating range	260 hPa to 1260 hPa	-30°C to +105°C	0% to 100%	-40°C to +120°C
Full scale	0 hPa to 4096 hPa	-30°C to +110°C	Linear interpolation, depending of the calibration coefficients	
ADC resolution	24 bits	16 bits	16 bits	16 bits
Sensitivity	0,00024 hPa	0,002 °C	0,004 %	0,016 °C

ORGANIZATION

ORGANIZATION IN SESSIONS

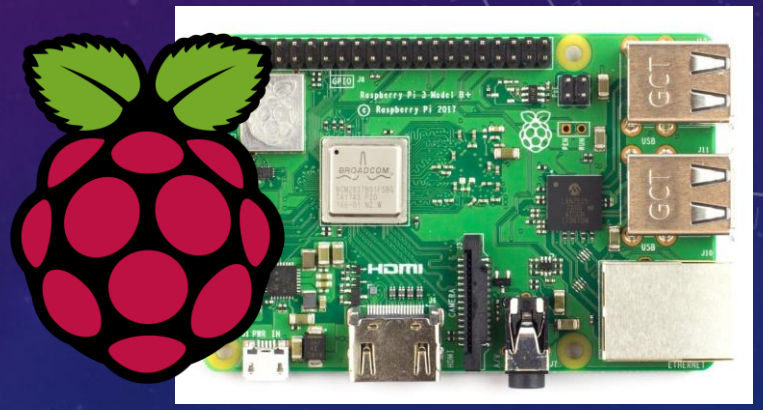


MULTI-PLATFORM DEVELOPMENT

Windows

Linux

Mac OS X



Raspberry board
(ARM architecture)

TOOLS TO USE

Generating automatically documentation of your code (in HTML and LaTex)

Building a C++ project witch several files (Linux / MacOSX only)

SKILL ASSESSMENT

Computing sessions 2023: assessment skill list

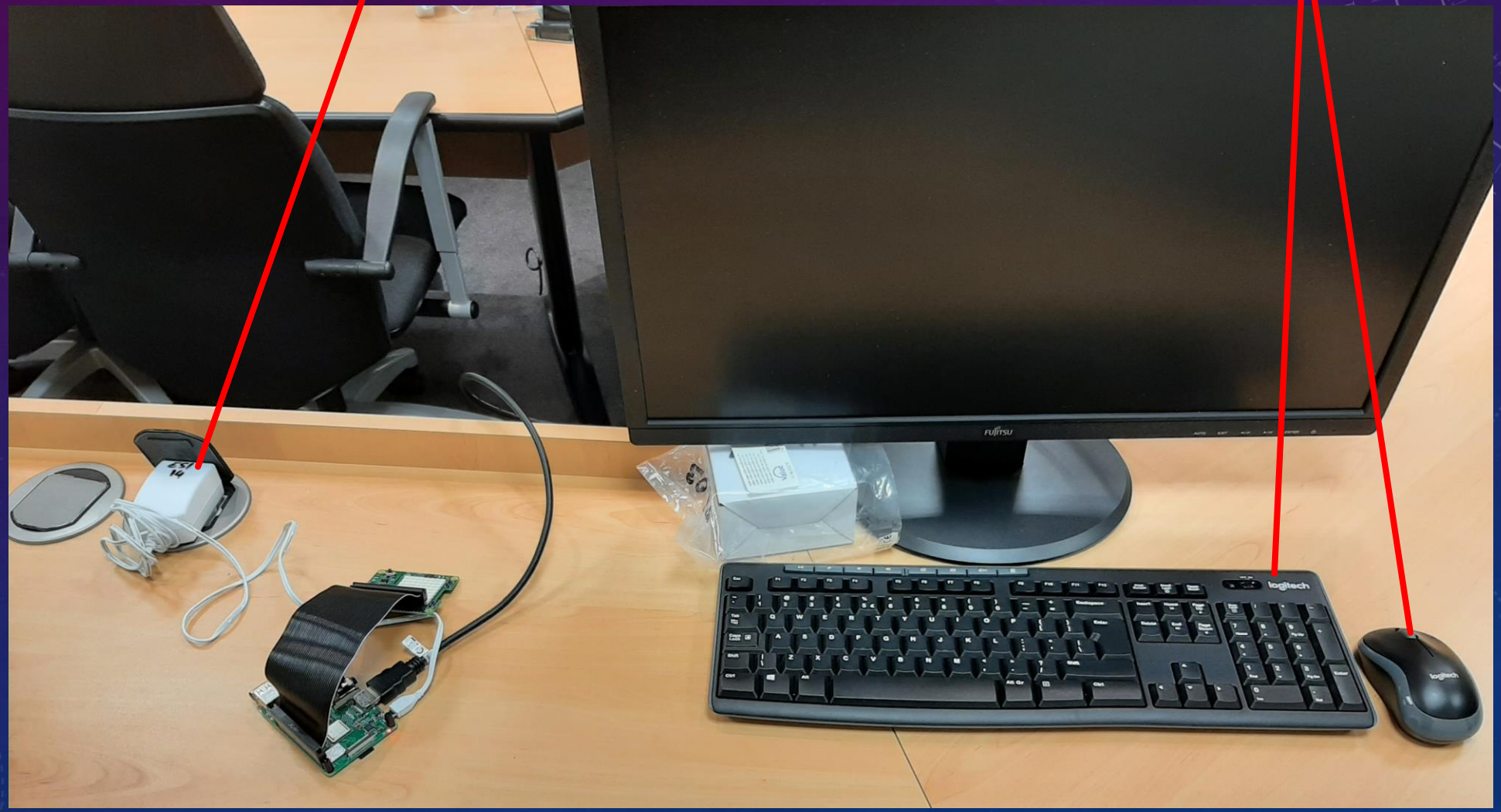
Skill category	Minimum	Satisfying	Very satisfying
1. Knowing C-programming basics	• Writing a "Hello World!" program • Asking questions to the user • Writing functions		
2. Using the standard library	• Using std::cout, std::string, std::fstream	• Using std::vector, std::stringstream and cmath.	• Using algorithms, iterators and manipulators.
3. Writing a C++ class	• Writing a simple class with: constructor without and with arguments, destructor, mutators, accessors and "print" function. • Instantiating and testing the implemented class.	• The class contains all the functionalities required by the specifications.	• Implementing operator overloading and copy constructor. • Using properly the reserved keywords "const" and "static".

1 / 2

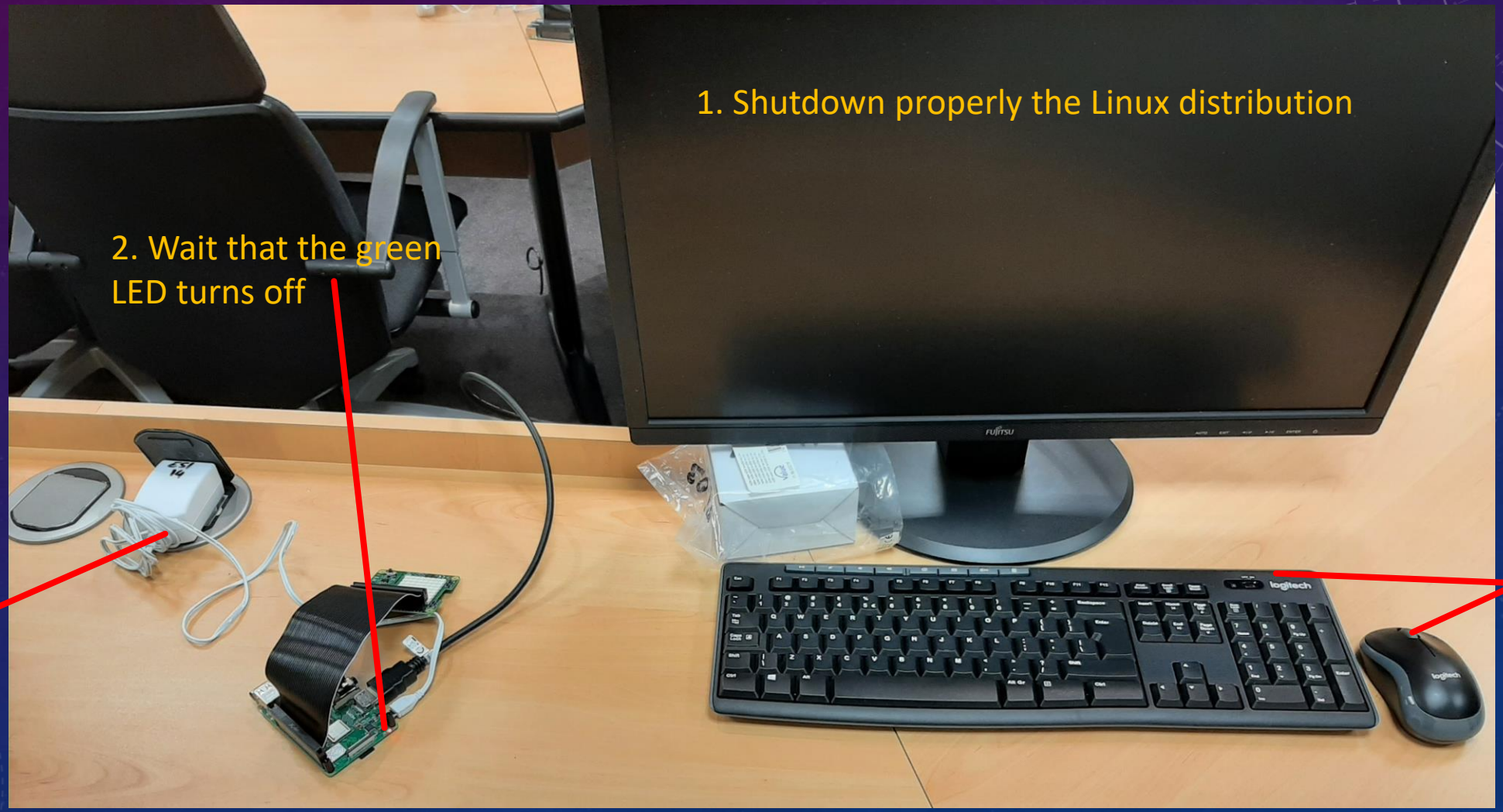
- Individual work is required
- Evaluation over 8 categories
- For validating the module
  - Minimum level must be reached for all the 8 categories
  - Satisfying level for at least 4 categories

BOOTING / TURNING OFF YOUR RASPBERRY

BOOT


1. Connecting the power supply
2. Switching on the keyboard and mouse

SHUTDOWN


1. Shutdown properly the Linux distribution
2. Wait that the green LED turns off
3. Withdraw the power supply
4. Switch off the keyboard and mouse