INTRODUCTION TO ESIPAP COMPUTING SESSIONS

WEDNESDAY 12 – THURSDAY 13 FEBRUARY 2020

ERIC CONTE – ERIC CHABERT

GOALS OF THE COMPUTING SESSIONS

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

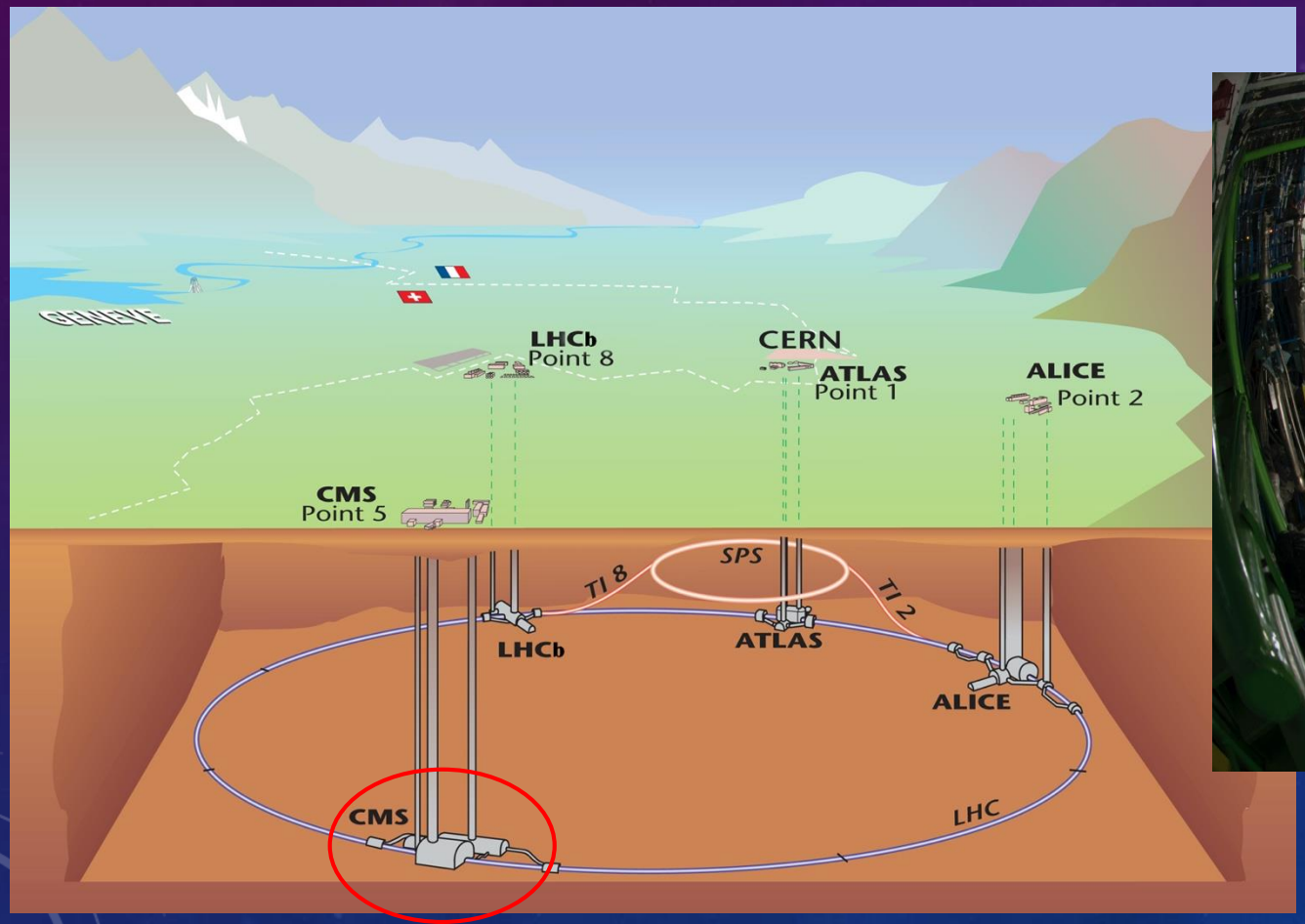
- Computing sessions target to apply your theoretical knowledge:
  - Instrumentation
  - Software programming in C++
  - Using specfic tools of high energy physics: ROOT and Geant4

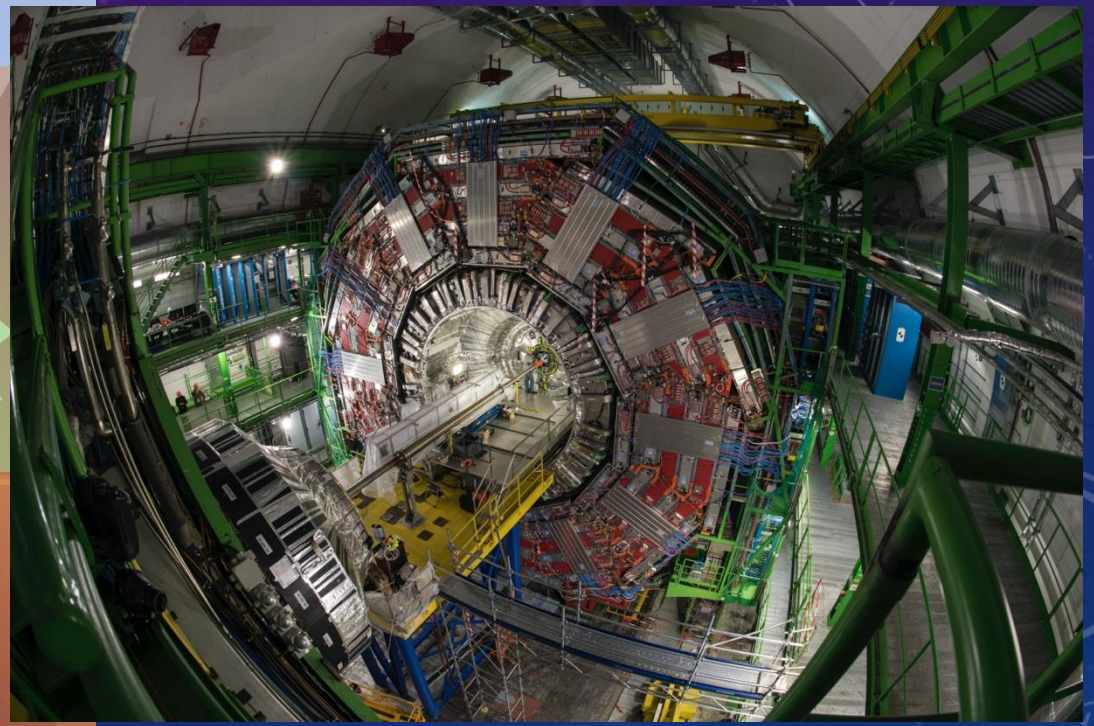
- Working by yourself and experimenting

- Getting the good practice

PHYSICS CONTEXT

THE CMS (COMPACT MUON SOLENOID) DETECTOR





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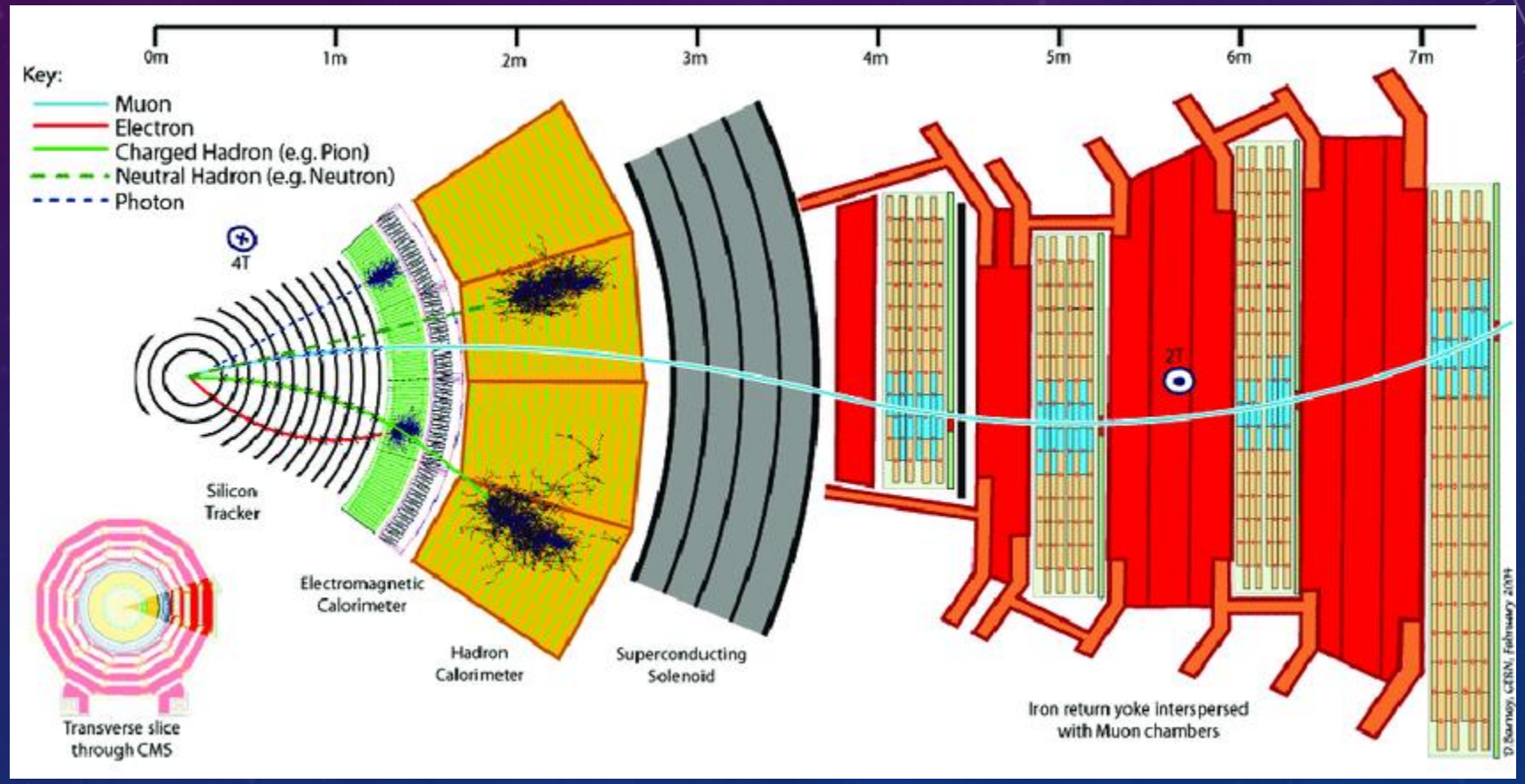
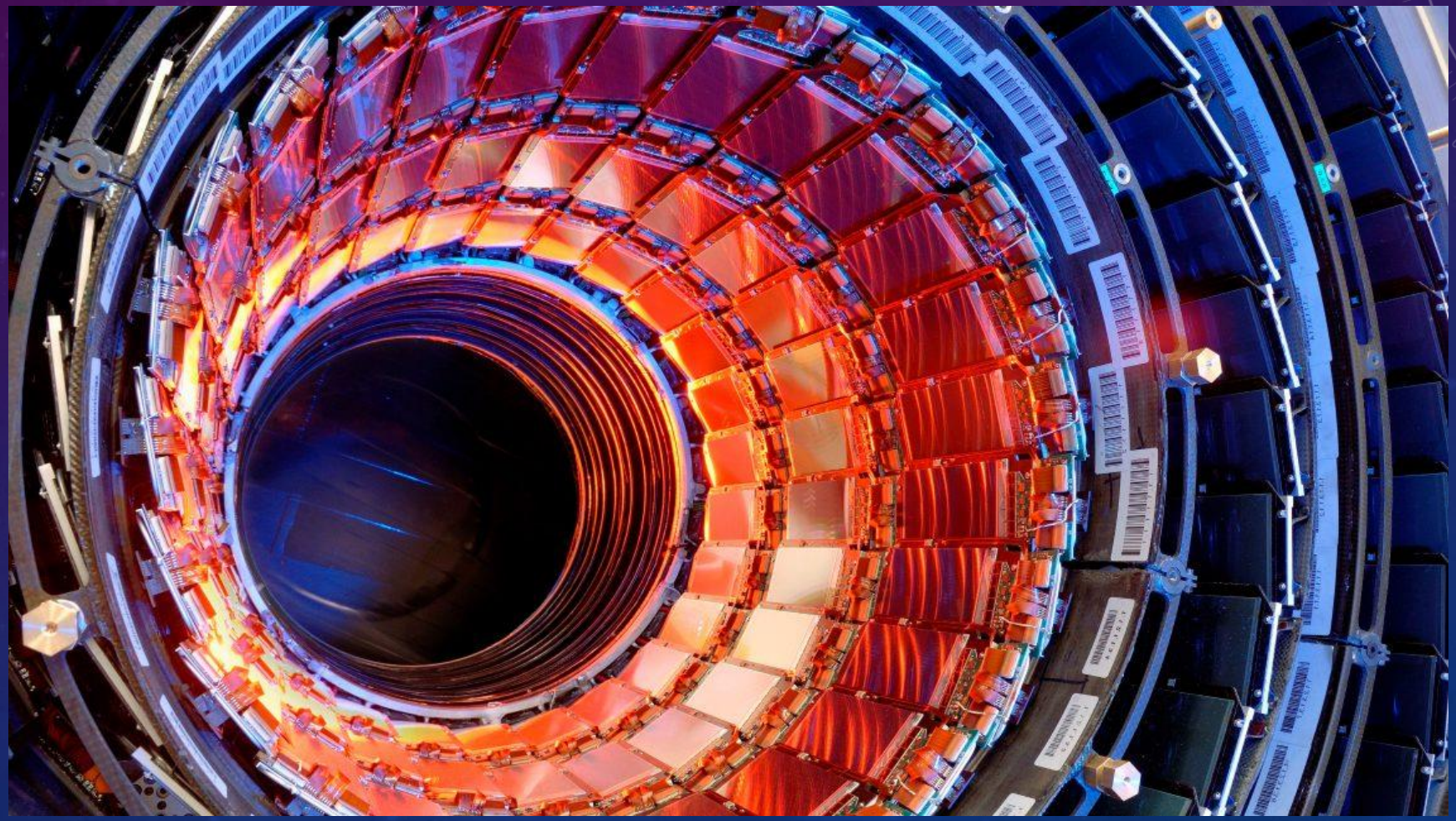


SILICON STRIP TRACKER



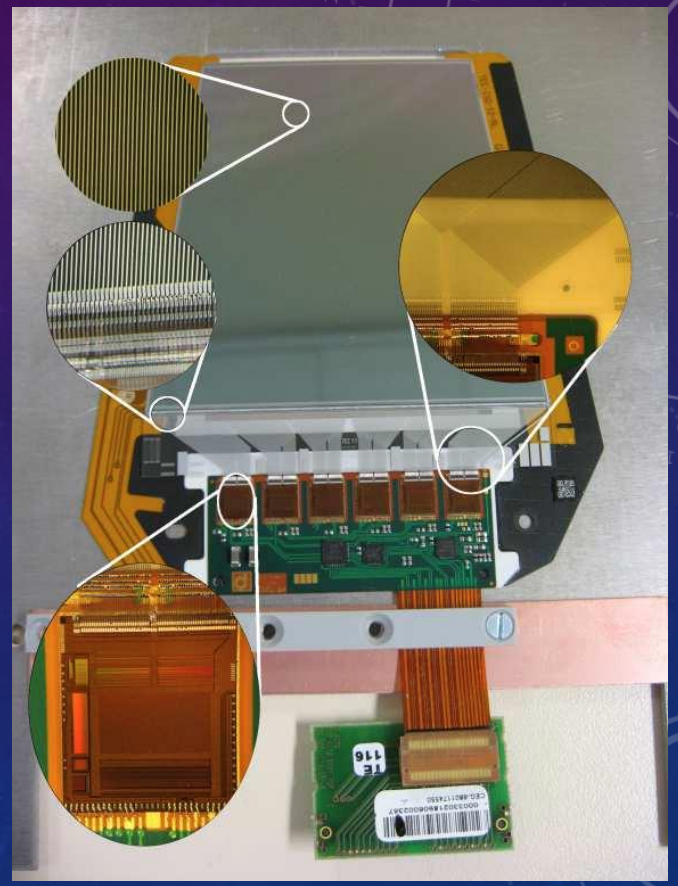
SILICON STRIP TRACKER

Instrumental activities

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

CMS silicon strip tracker in few numbers:

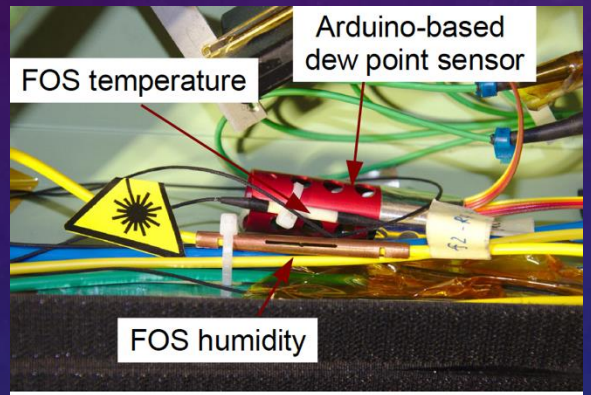
- 15 000 modules
- Surface: ~ 200 m^2
- 10^6 channels

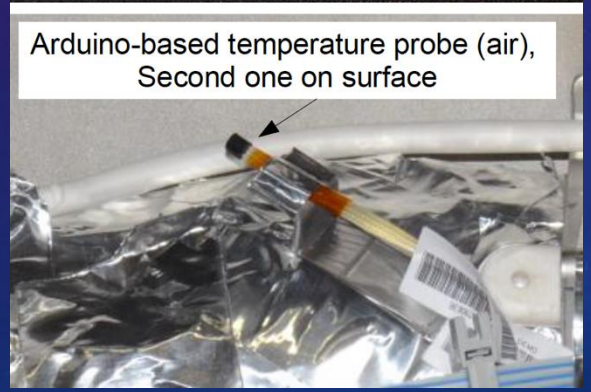


Performances:

- 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:

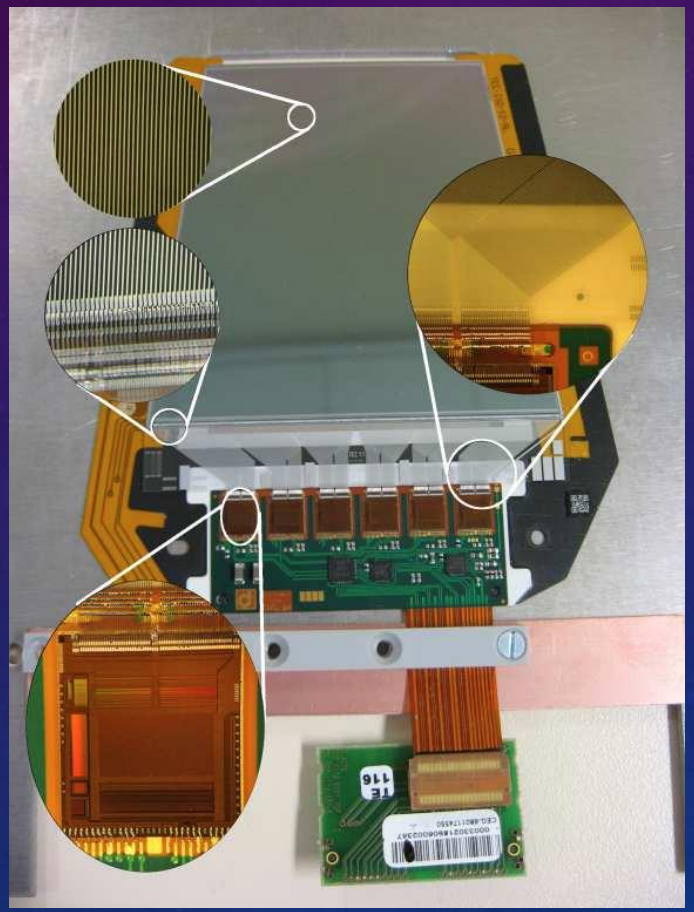
- On-board sensors
- External sensors

→ Some are ARDUINO-based!

COMPUTING SESSION AIMS

Instrumental activities

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



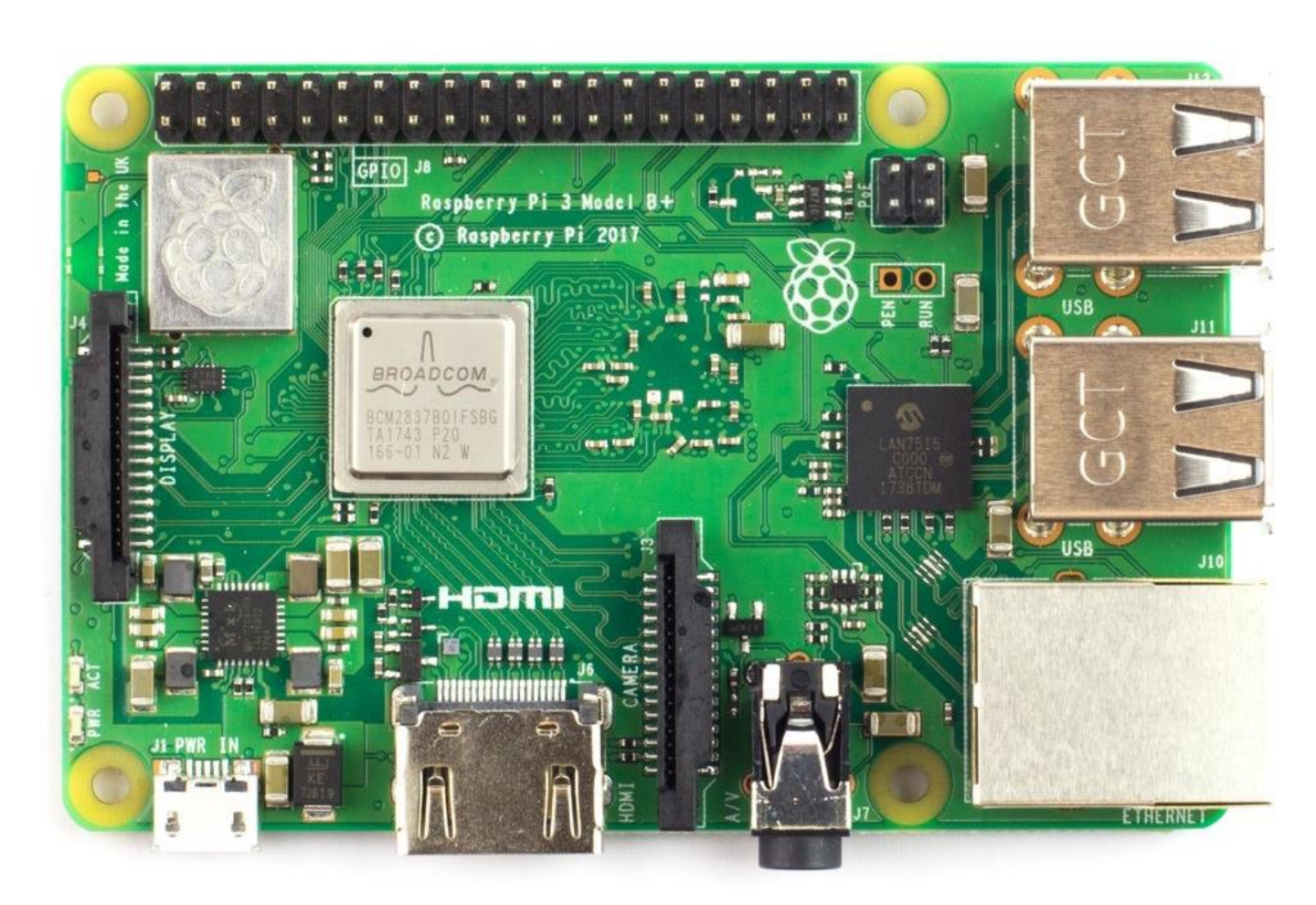
1. **Slow control**
   - Using a dedicated electronic board (Sense Hat) read by a Raspberry
     - Monitor the temperature & humidity
     - Send warning when conditions are not fulfilled

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
- RAM: 1 Go
- “Hard Disk”: 16 Go SD card

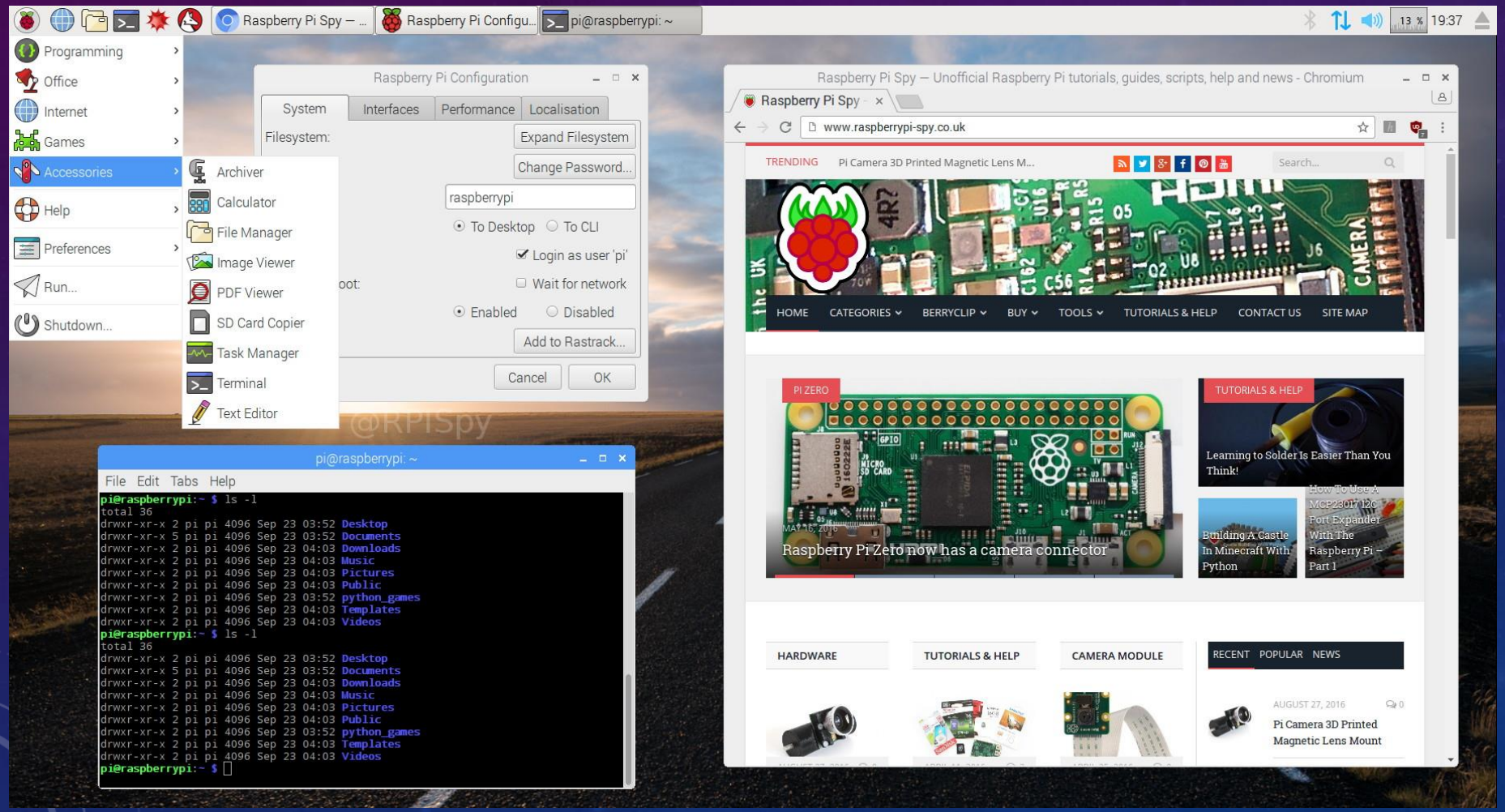
Advantages : price, flexibility, performances

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

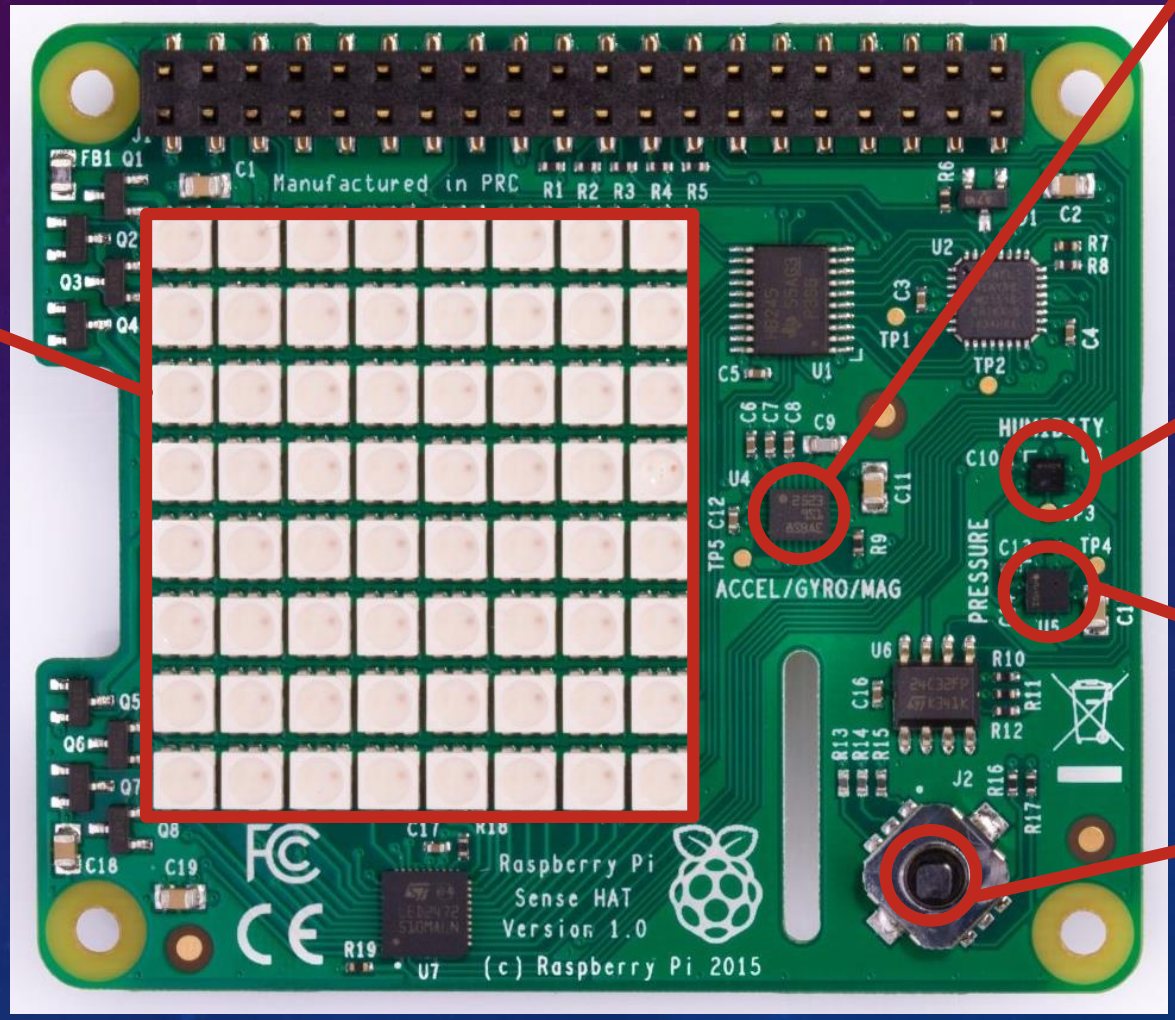
LINUX DISTRIBUTION: RASPBIAN



Stored on a micro SD card

SENSE HAT BOARD

8x8 LEDs for display



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

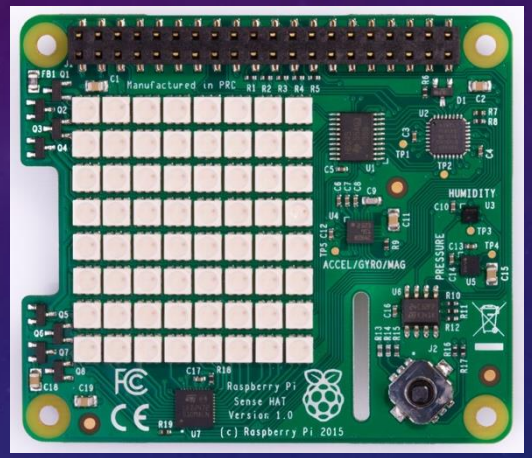
Humidity / Temperature sensor

Pressure / Temperature sensor

Joystick

PRICE

Raspberry Pi 3 B+
~ 40 €



Sense Hat
~ 30 €

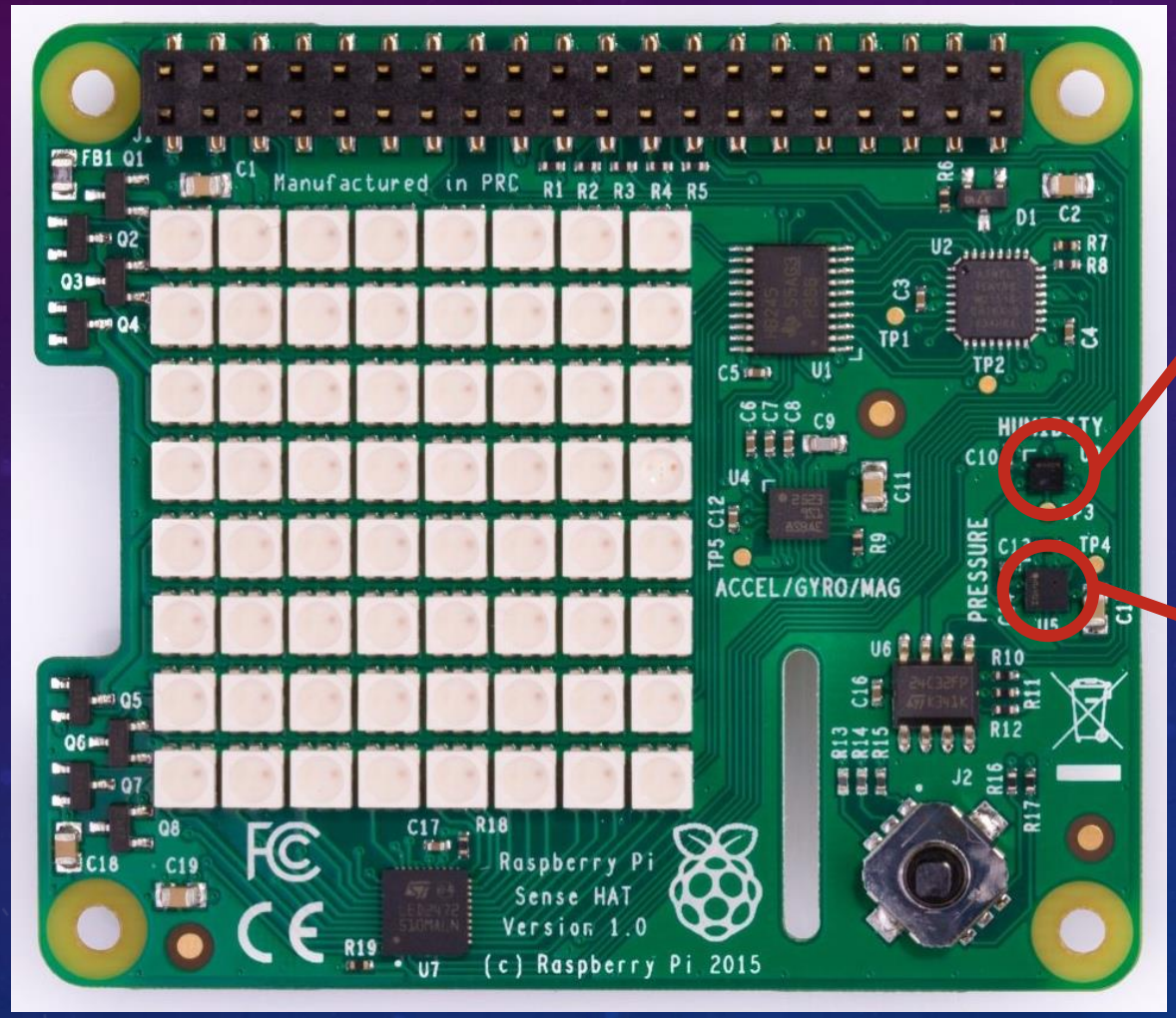
Connectors
~ 15 €

Micro SD
~ 10 €

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

SENSORS AND SIGNAL CONDITIONING

SENSORS TO STUDY

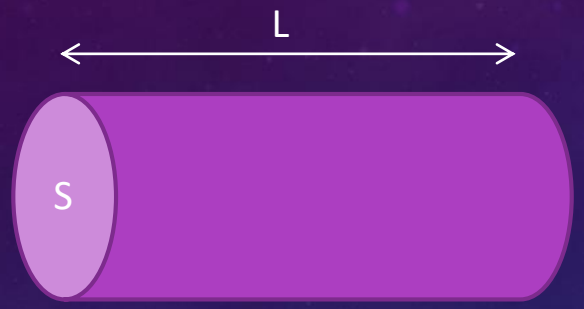


Humidity / Temperature sensor

Pressure / Temperature sensor

HOW TO MEASURE ….?

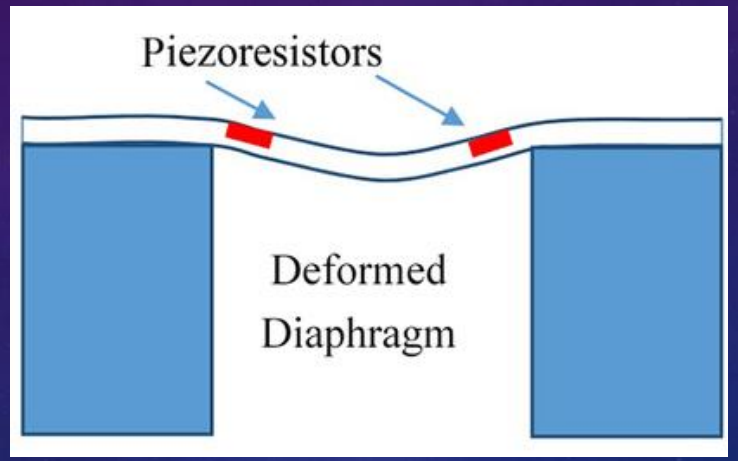
Temperature



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

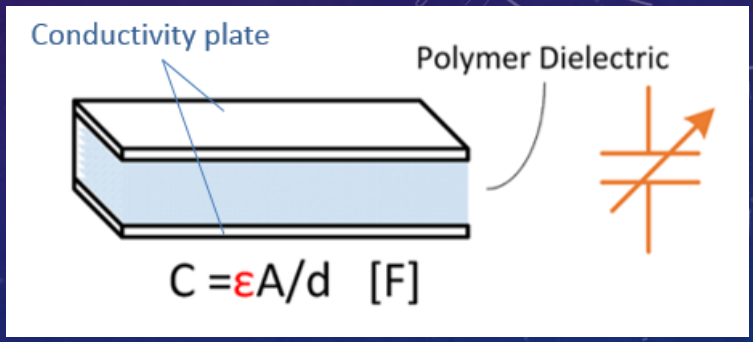
Material resistivity ρ depends on temperature.

Pressure



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

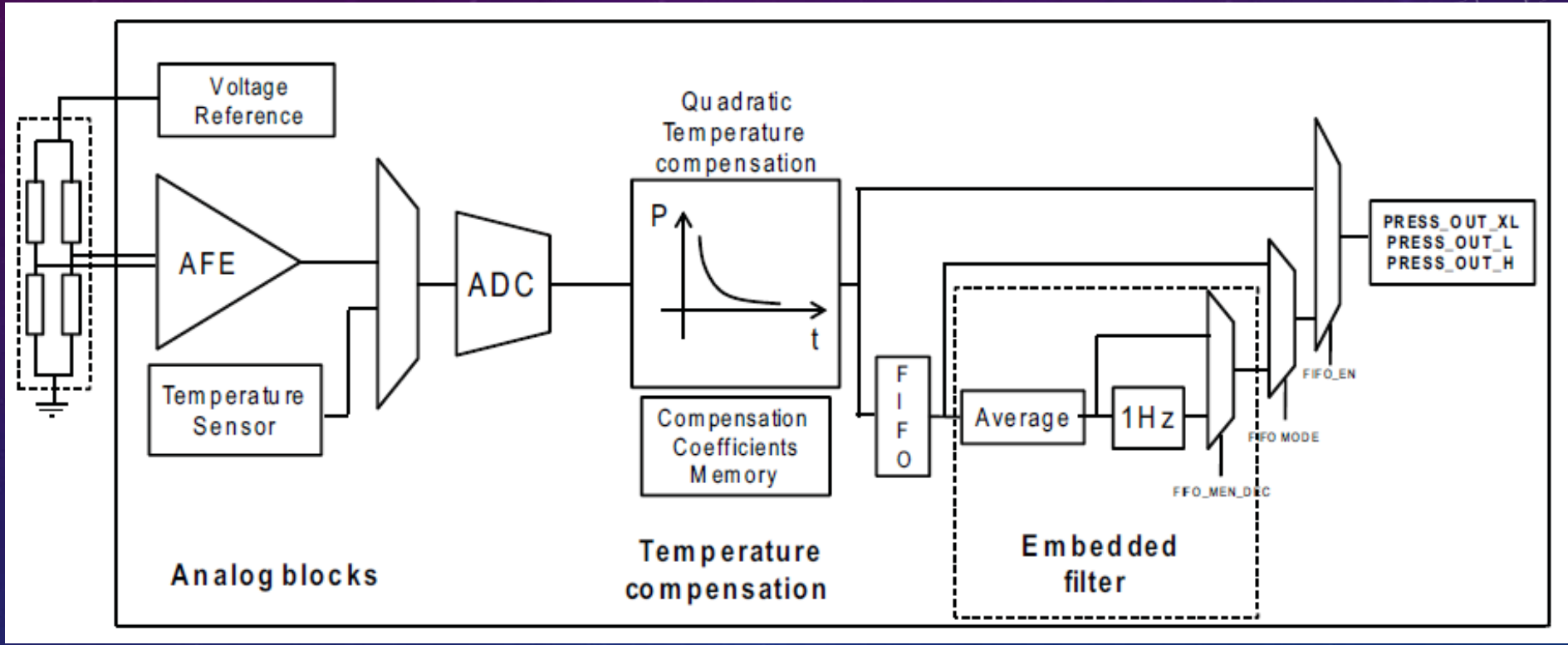
Humidity



Dielectric material absorbs water molecules until equilibrium

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

PRESSURE / TEMPERATURE SENSOR PROCESS



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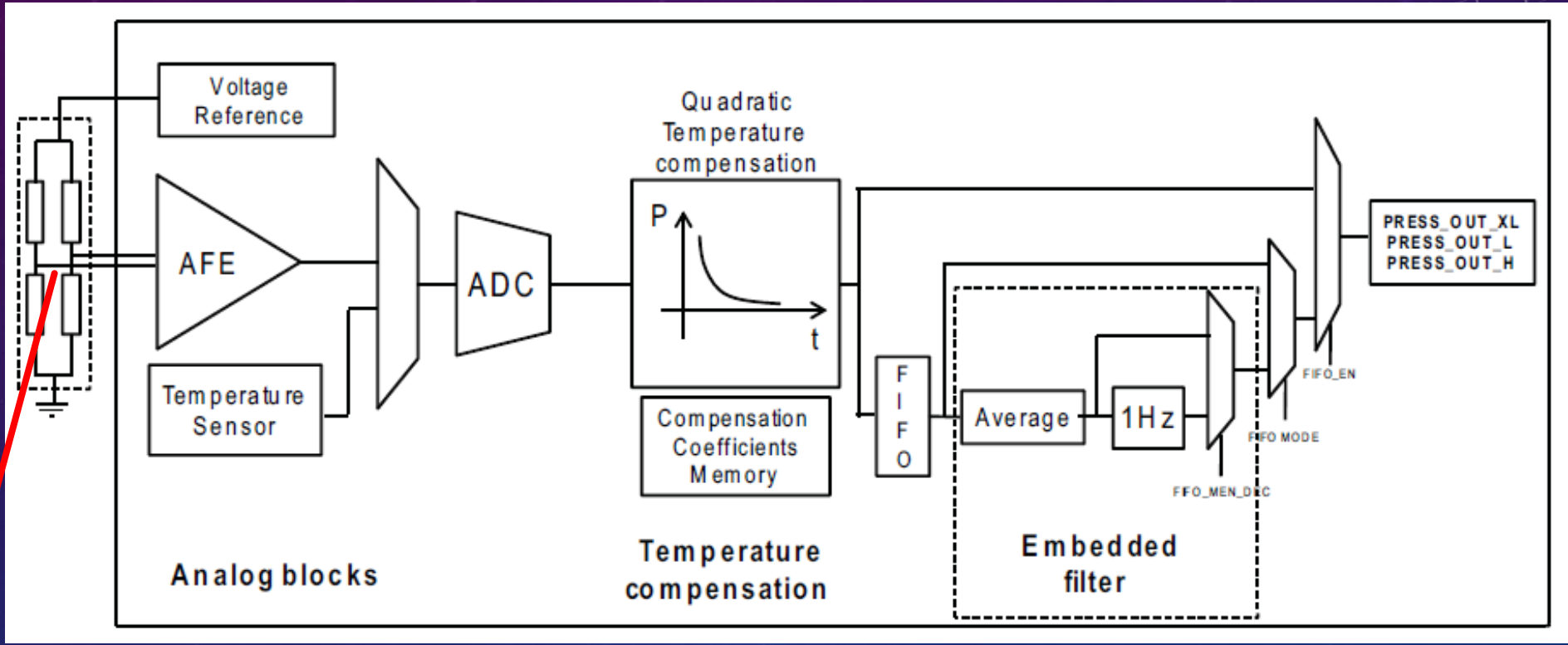
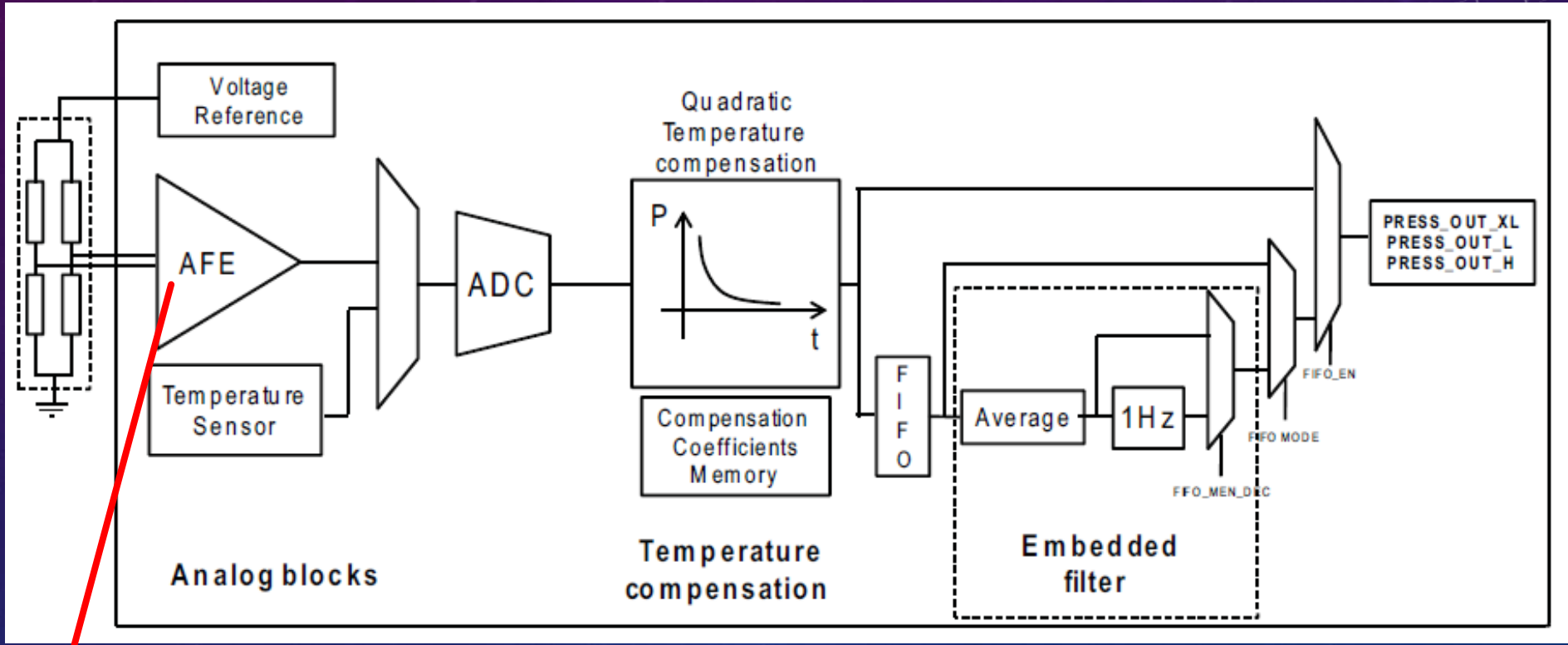


Wheatstone bridge
for translating change of resistance into change of tension

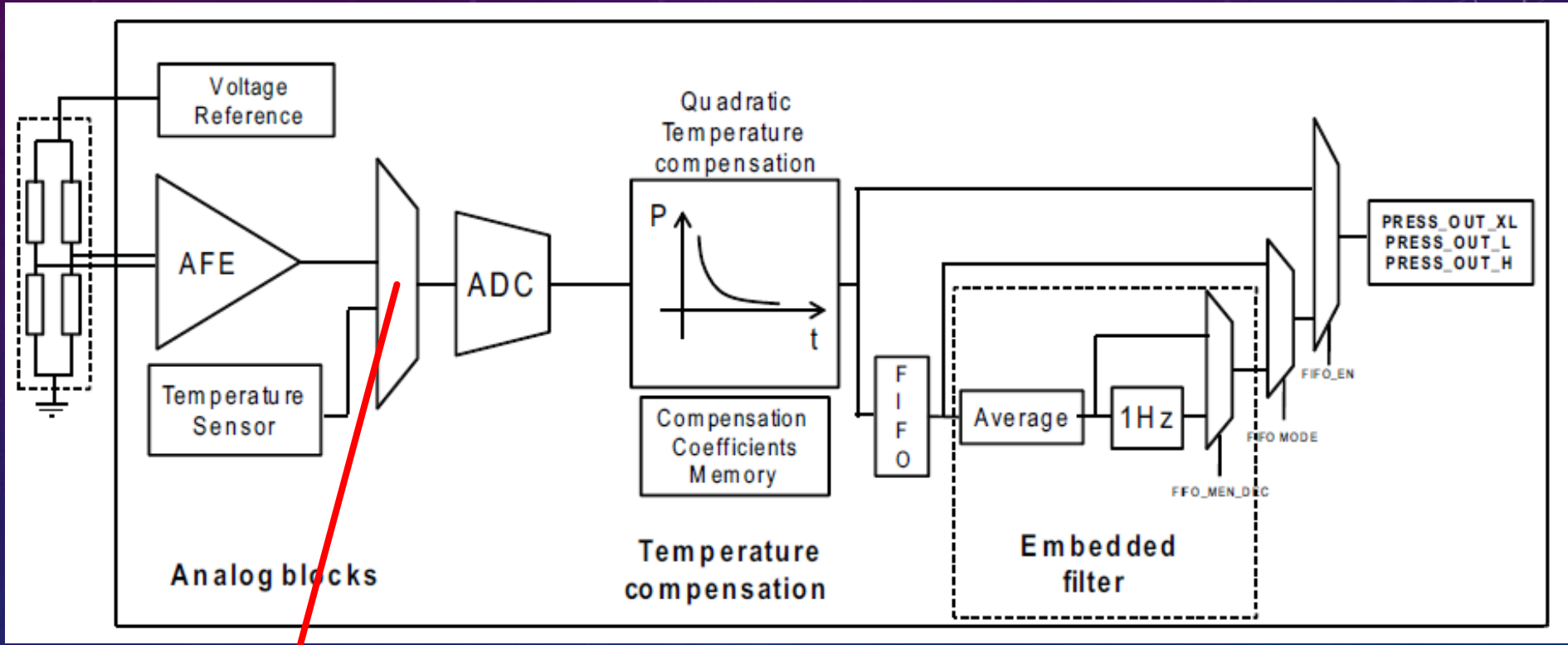
PRESSURE / TEMPERATURE SENSOR PROCESS



Analogic Front-End

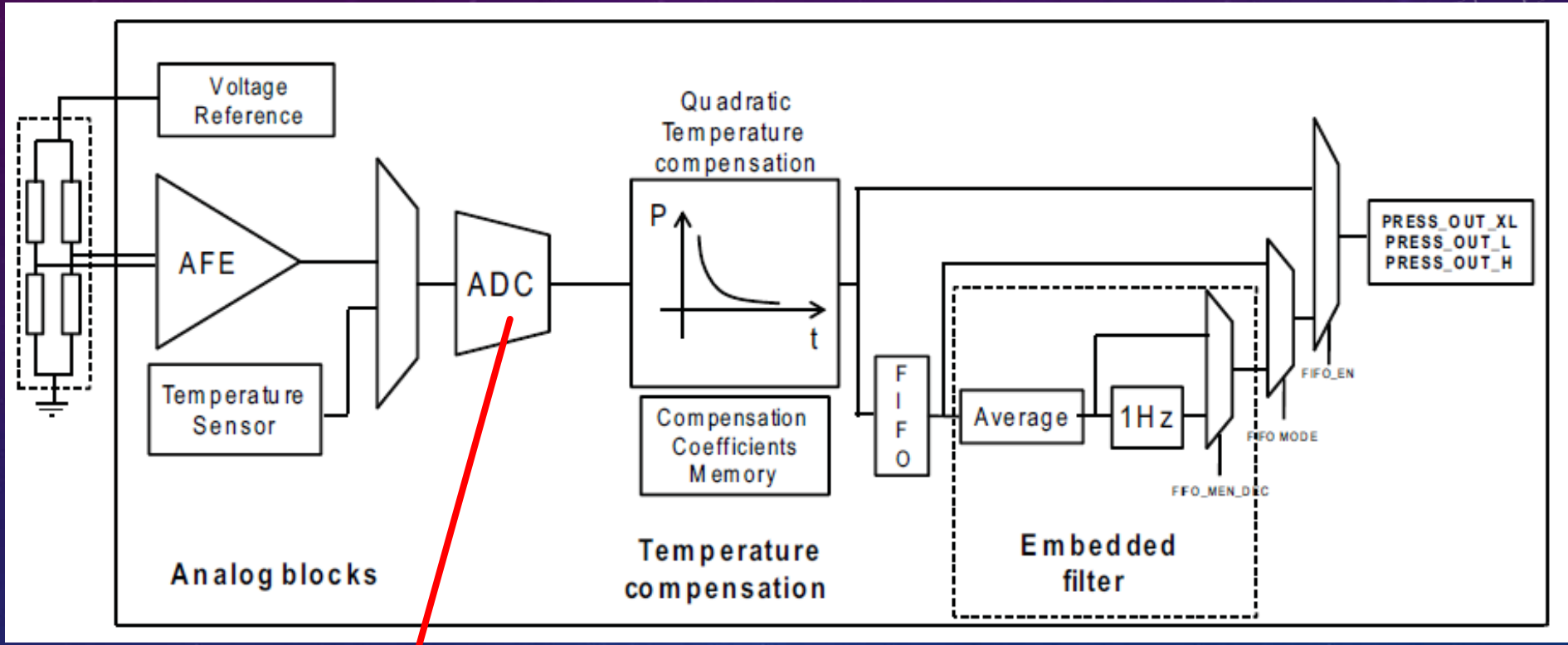
- Small signal voltages vs noise floor
- Amplifying signal and removing noise

PRESSURE / TEMPERATURE SENSOR PROCESS



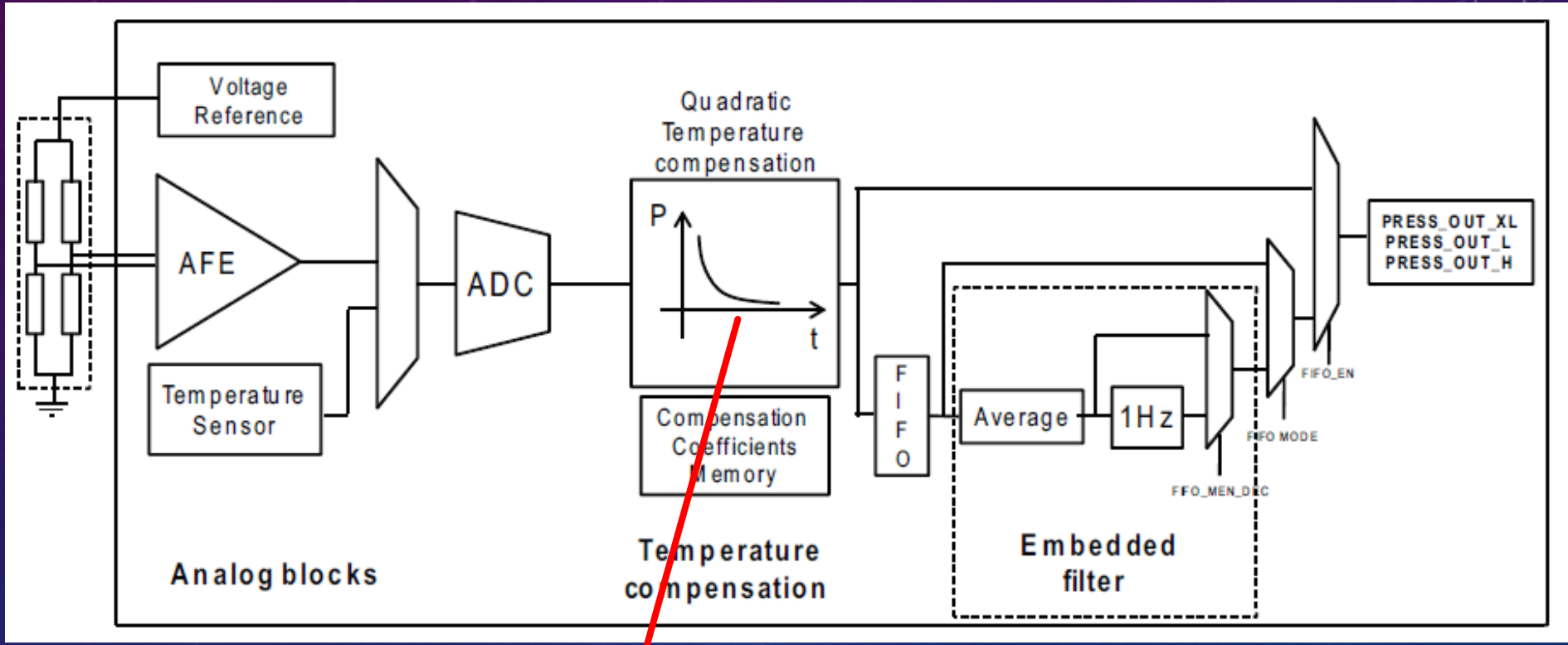
Multiplexer
Treating pressure and temperature measures by the same channel

PRESSURE / TEMPERATURE SENSOR PROCESS



Analogic to Digital converter
Digitalization of the measure

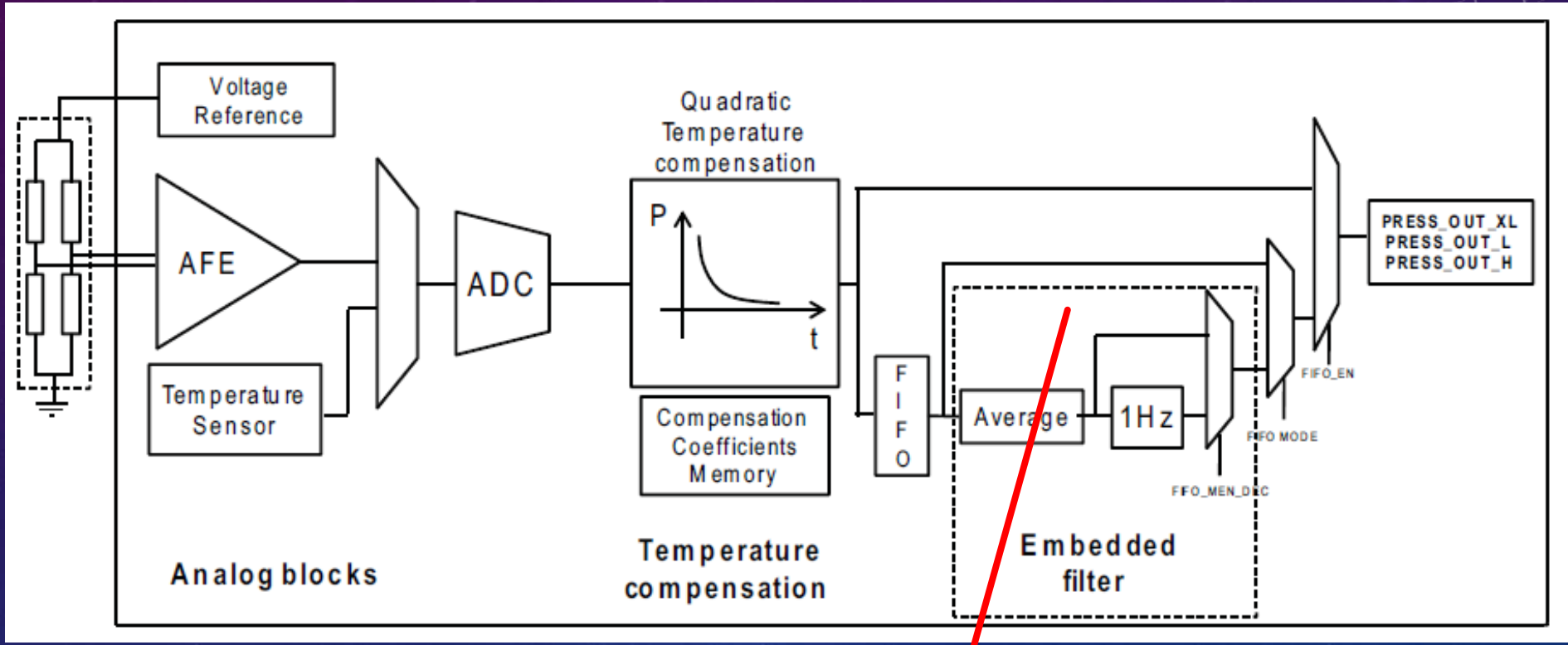
PRESSURE / TEMPERATURE SENSOR PROCESS



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

Calibration settings

PRESSURE / TEMPERATURE SENSOR PROCESS

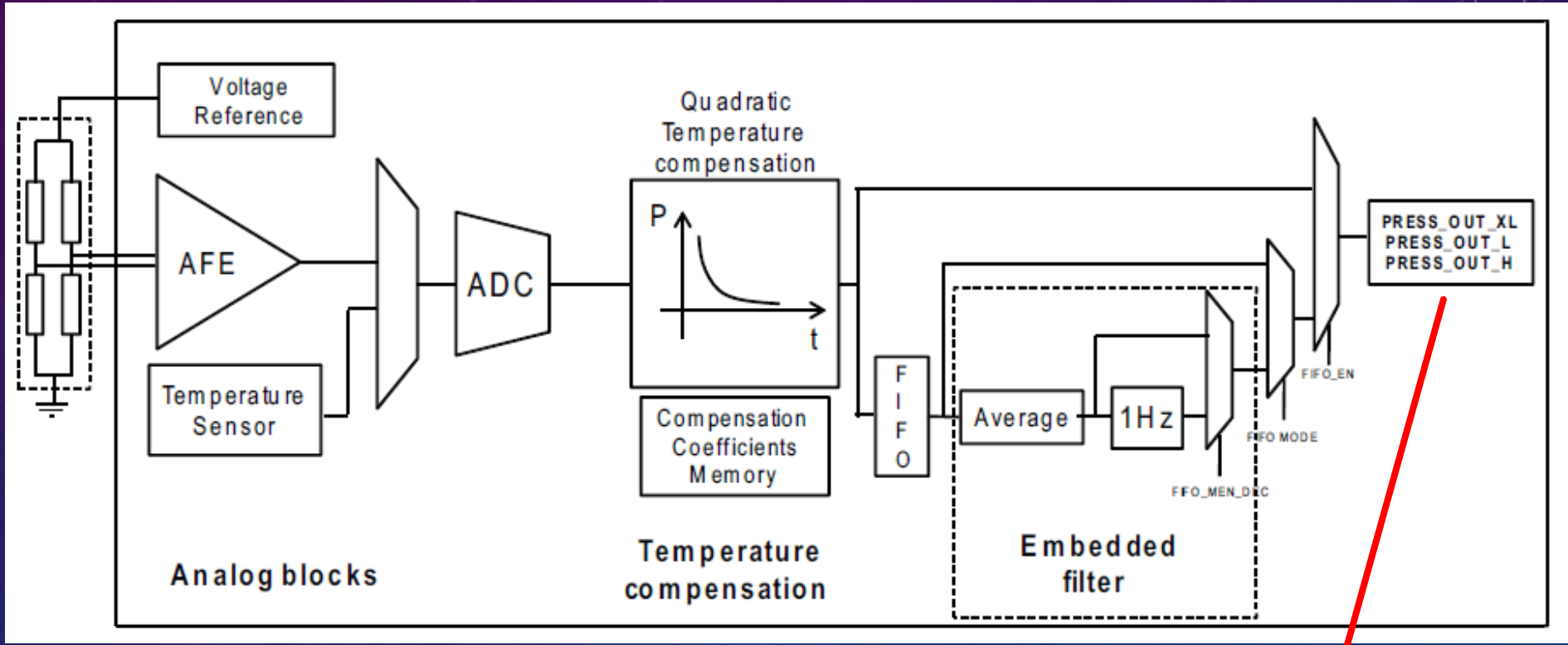


Calibration settings

Average

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

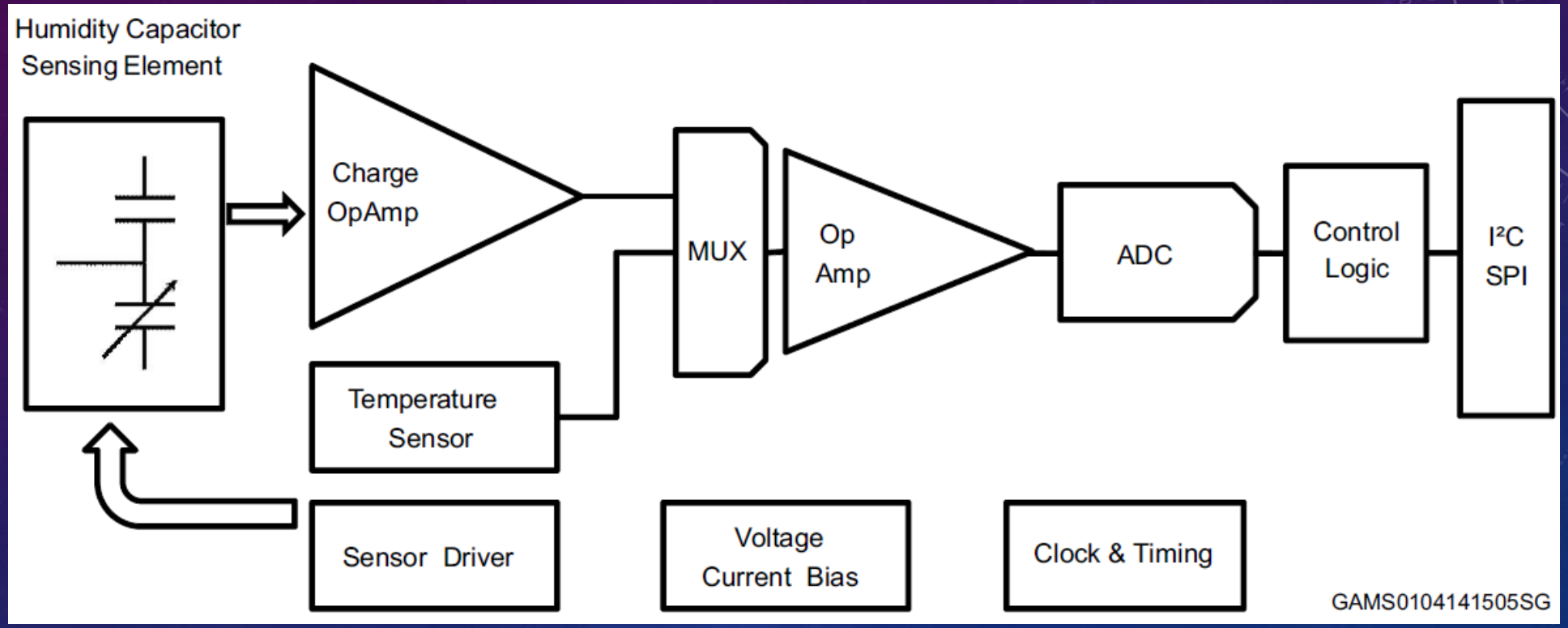
PRESSURE / TEMPERATURE SENSOR PROCESS



Data transfer

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

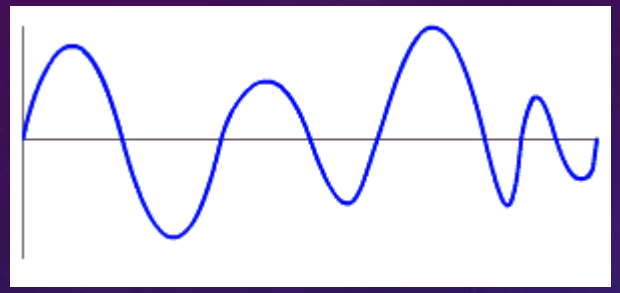
HUMIDITY / TEMPERATURE SENSOR PROCESS



One logic part is missing in this schema: Conversion 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 scale : [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

9:00 12:15 14:00 17:15 17:20 18:50

Wednesday

Session 1

- Introduction
- Data acquisition

Session 2

Developing a C++ class

Session 3

Combining classes

Thursday

Session 4

Analyzing data with ROOT

Session 5

- Simulating particle interaction with GEANT4
- Summary

ONE STUDENT, ONE RASPBERRY, ONE PC

First Name	Family Name	Email address	Raspberry ID	PC ID

https://docs.google.com/spreadsheets/d/1eV3puo4oWPzxkYC97-okWV9AYgx1TvQB_VAZEdYo-FQ/edit?usp=sharing

SAVING YOUR PRODUCTION

- End of session 2
- End of session 4

Sending your code to the supervisors for assessment

- Create on folder per session to ease the review
- How to create an archive:

```
tar –cvzf name.tar.gz directory
```

- Using a web service: www.wetransfer.com
  - destination: eric.conte@iphc.cnrs.fr
  - author: filling your address email
- A URL link is created: put it on the following spreadsheet

https://docs.google.com/spreadsheets/d/1UKm_ru84b0pMdHv--8WfJ5mx6NpKm6bGwDjhFNYkqsA/edit#gid=0

SKILL ASSESSMENT

Computing sessions 2020: 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

- Evaluation over 8 categories
- For validating the module
  - Minimum level must be reached for all the 8 categories
  - Satisfying level for at least 3 categories