INTRODUCTION TO ESIPAP COMPUTING SESSIONS

WEDNESDAY 8 – THURSDAY 9 FEBRUARY 2023 ERIC CHABERT - ERIC CONTE

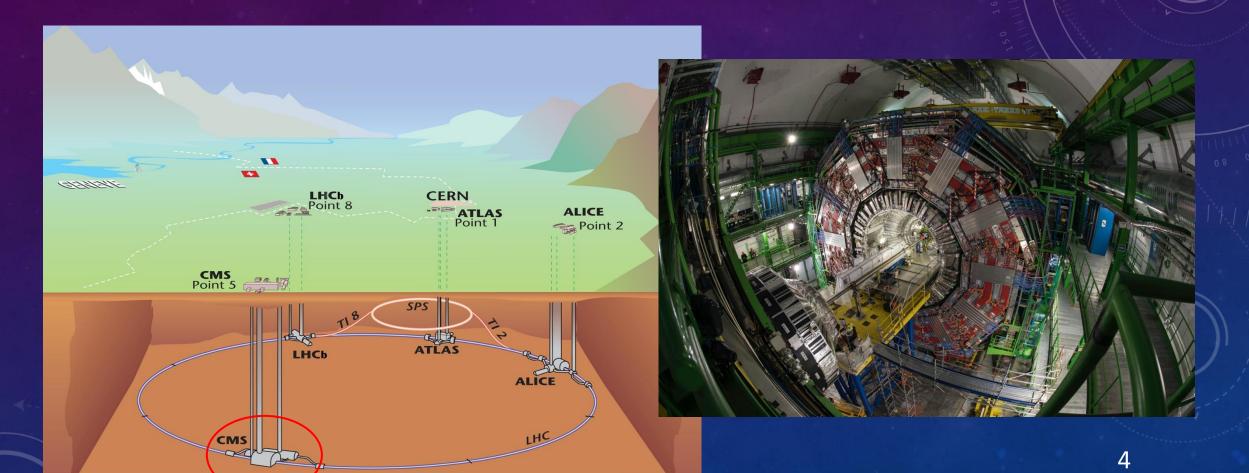
GOALS OF THE COMPUTING SESSIONS

- 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

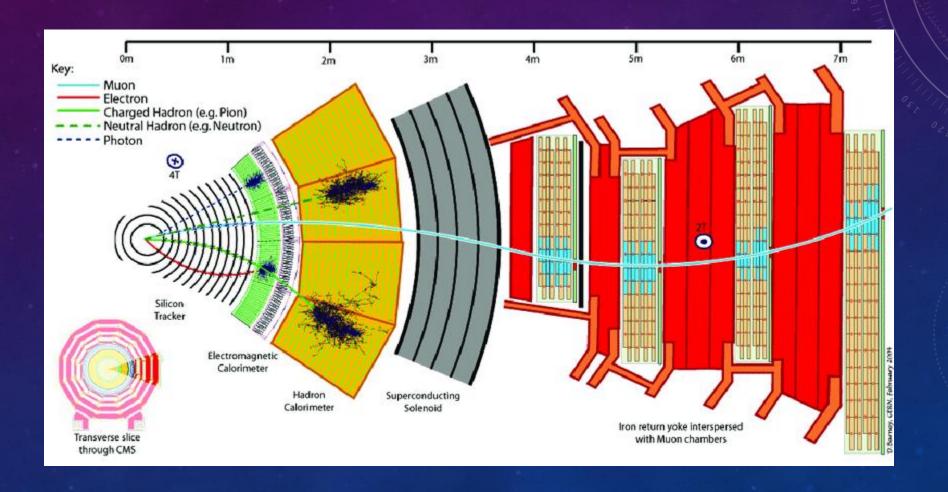


PHYSICS CONTEXT

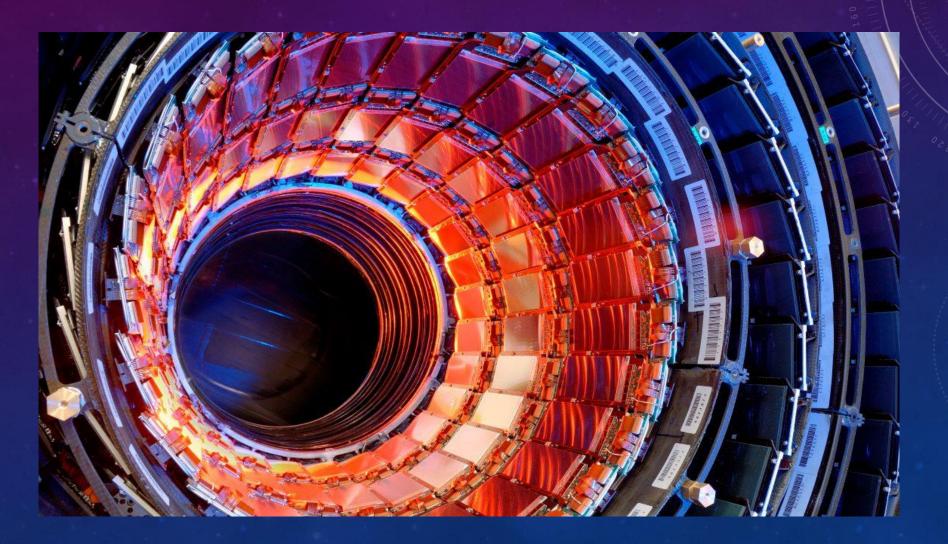
THE CMS (COMPACT MUON SOLENOID) DETECTOR



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SILICON STRIP TRACKER



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Instrumental activities

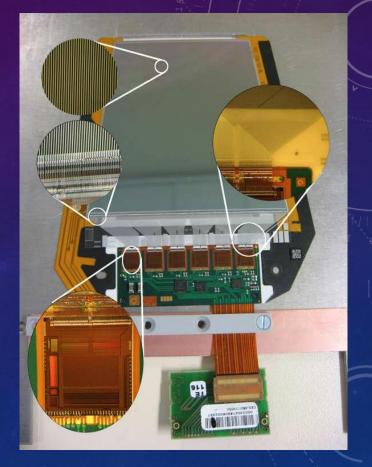
- R&D
- Construction
- Operation (online)
- Alignment & calibration
- Offline analyses
- Simulation
- Radiation damages evaluation

CMS silicon strip tracker in few numbers:

15 000 modules

• Surface: ~ 200 m²

• 10⁶ channels



Performances:

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

• ...

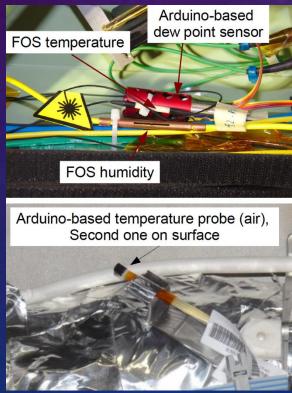
racy: 1ns

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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

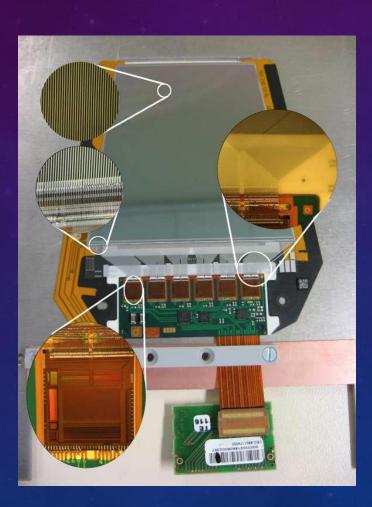
Several probes are used to monitor that:

- 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



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

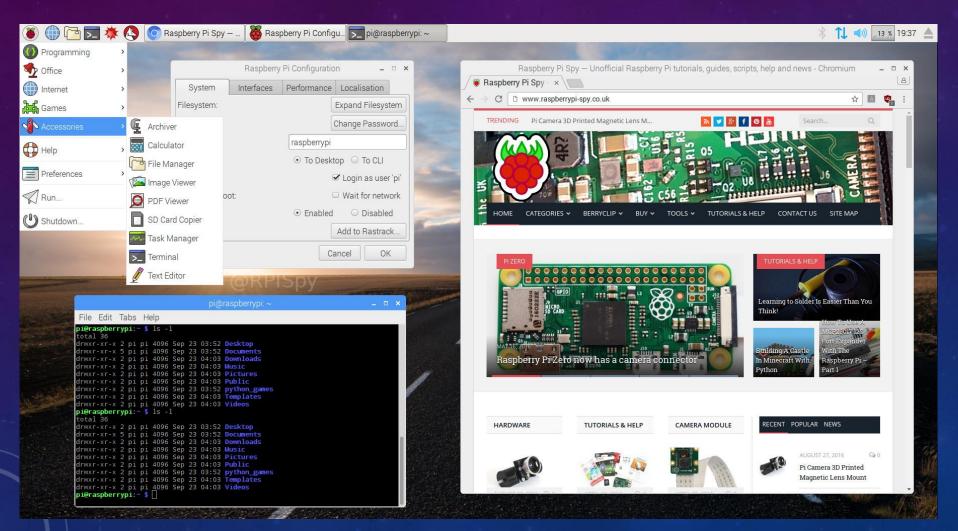
Advantages: price, flexibility, performances

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)

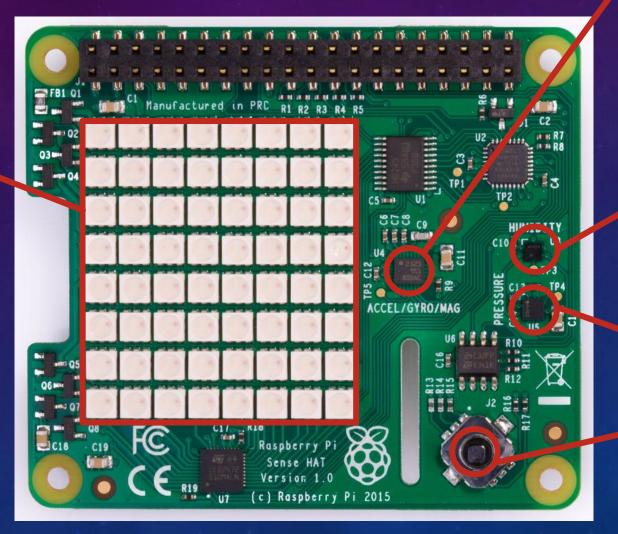




Stored on a micro SD card

SENSE HAT BOARD

8x8 LEDs for display



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

Humidity / Temperature sensor

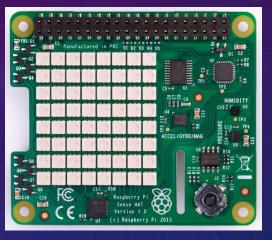
Pressure / Temperature sensor

Joystick

PRICE



Raspberry Pi 3 B+ ~ 40 €



Sense Hat of a 30 €



Connectors ~ 15 €

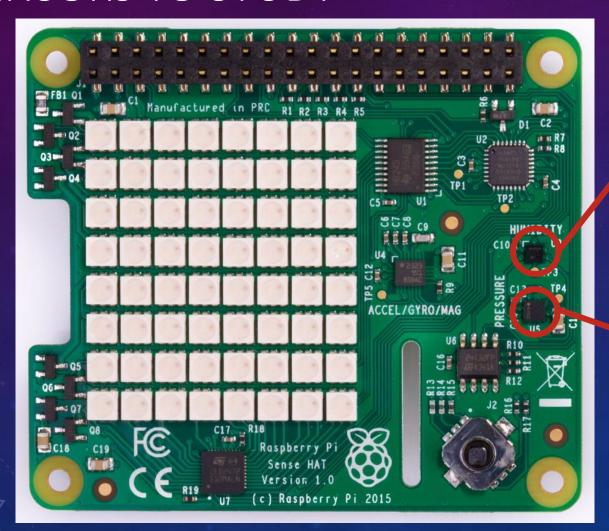
Micro SD ~ 10 €



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

SENSORS AND SIGNAL CONDITIONING

SENSORS TO STUDY



Humidity / Temperature sensor

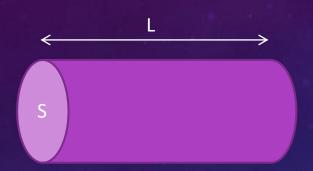


Pressure / Temperature sensor



HOW TO MEASURE?

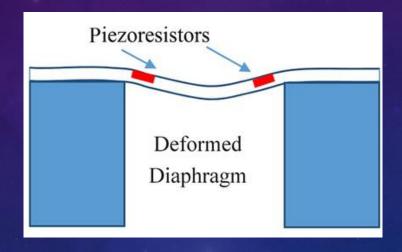
Temperature



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

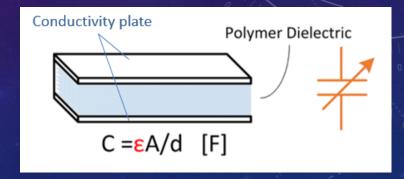
Material resistivity ρ depends on temperature.

Pressure



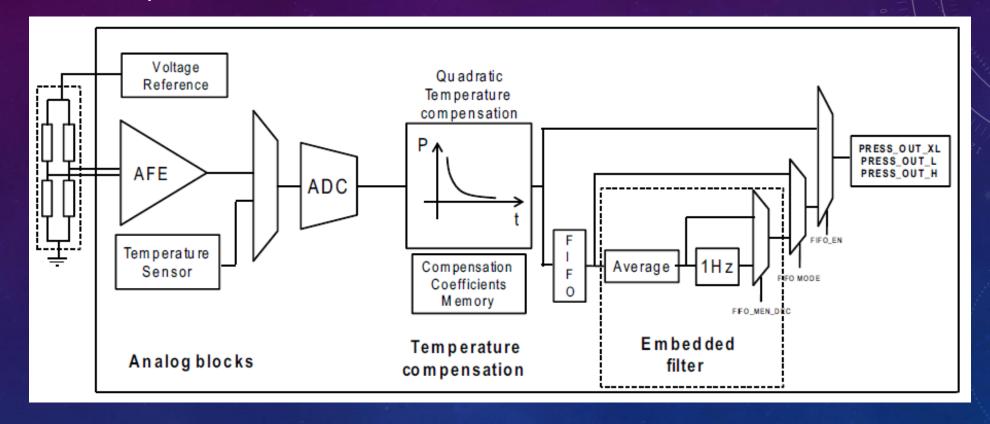
Piezoresistive effect:
a change in resistivity when
a stress is applied.

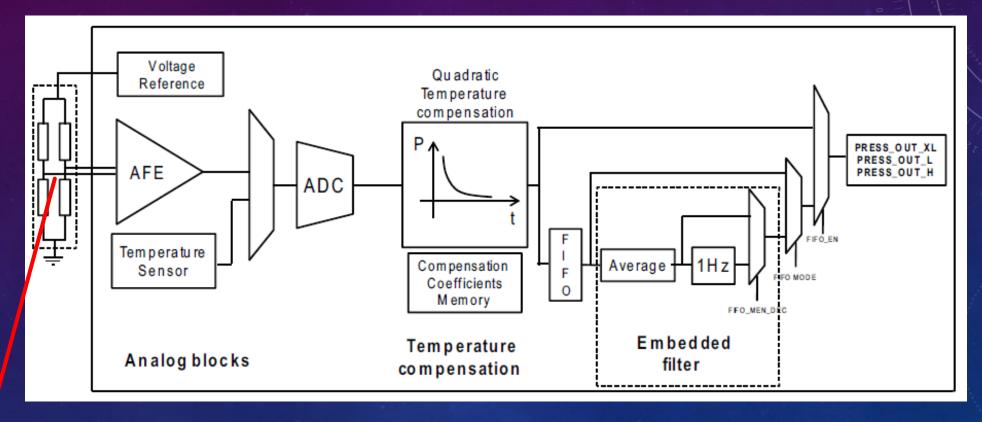
Humidity

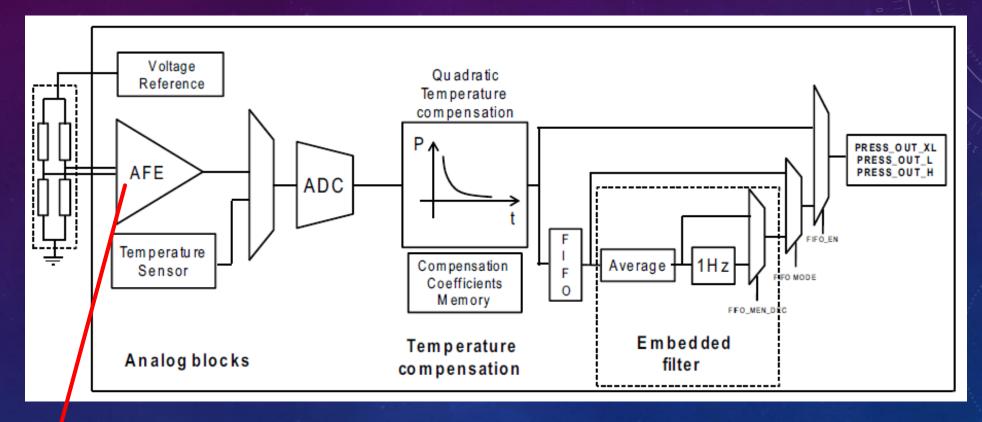


Dielectric material absorbs water molecules until equilibrium

change the electrical conductivity ε [in S/m]

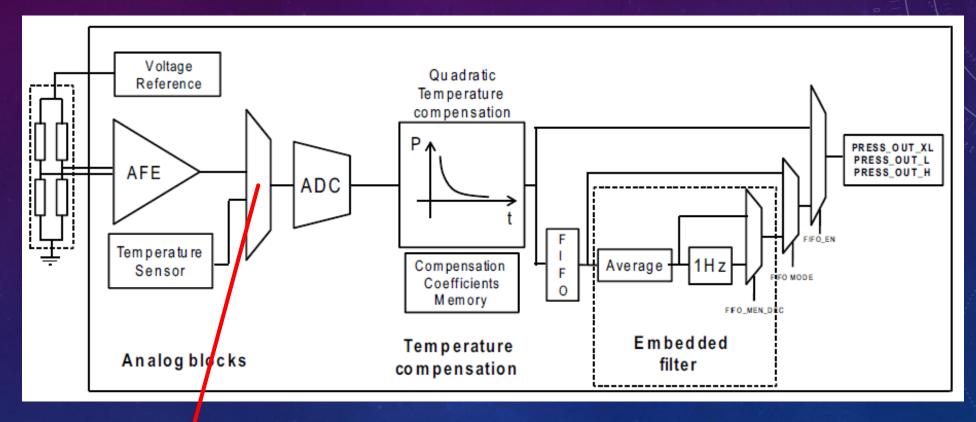






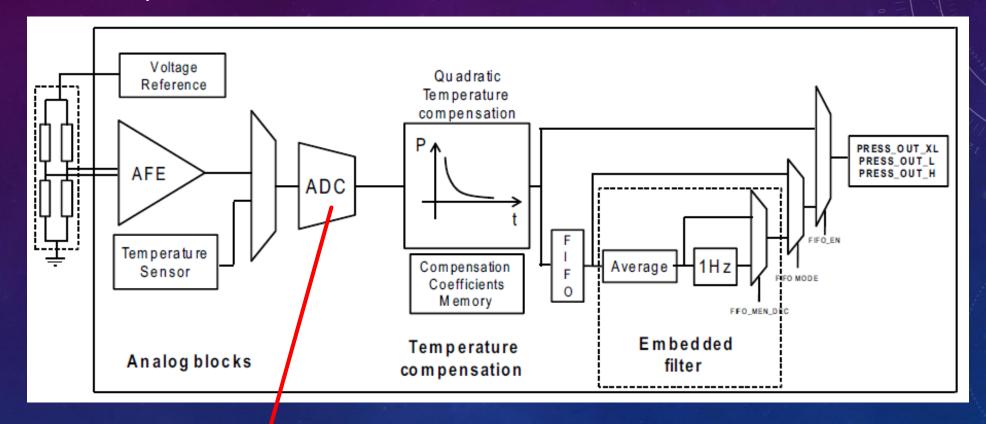
Analogic Front-End

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

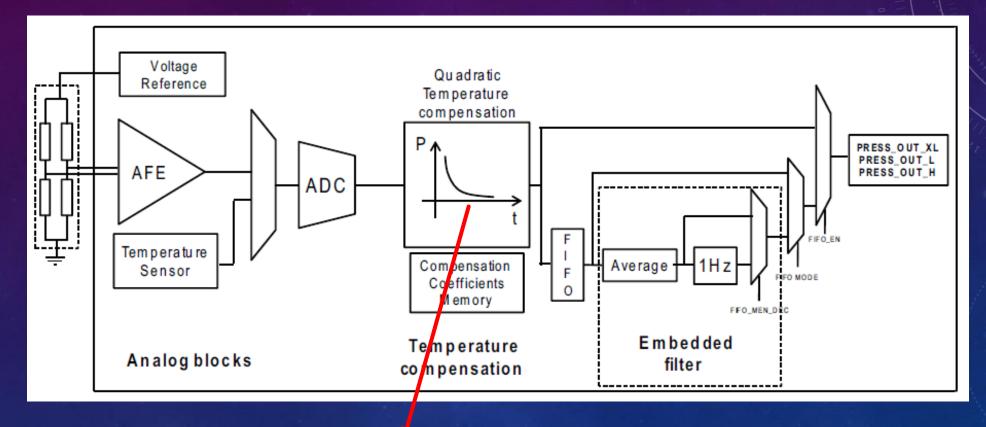


Multiplexer

Treating pressure and temperature measures by the same channel

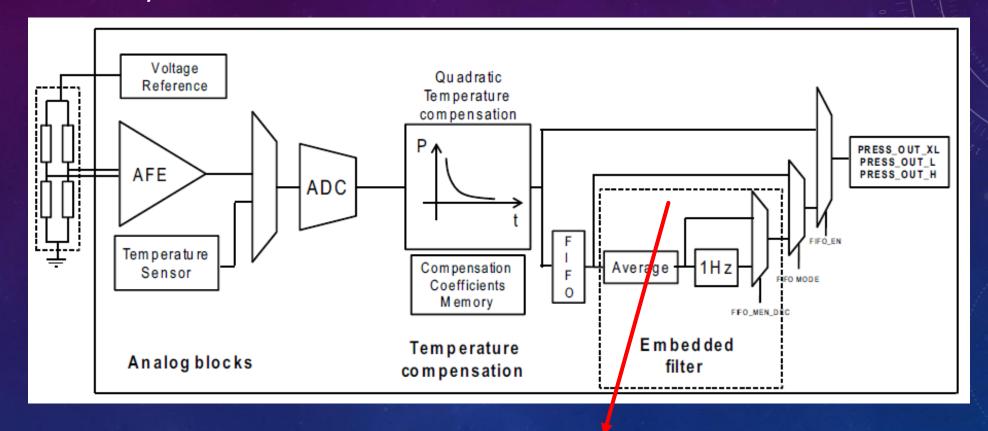


Analogic to Digital converter Digitalization of the measure



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



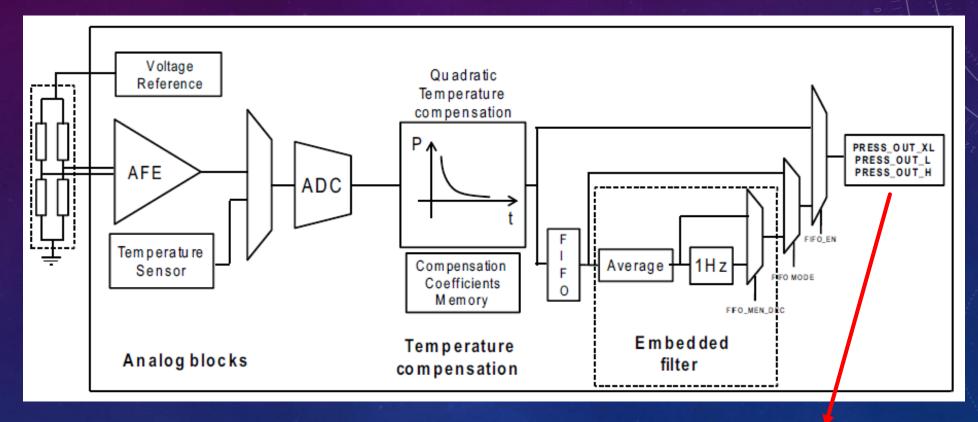


Calibration settings



Average

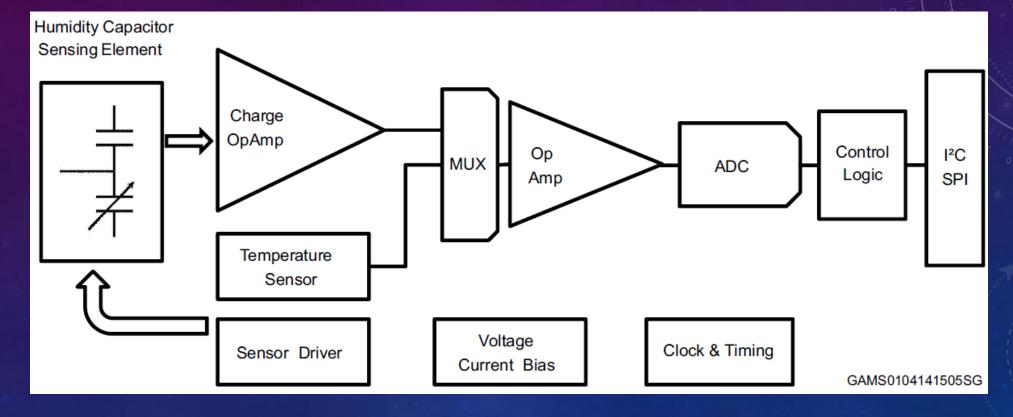
A maximum of 32 successive measurements are done (~1s) and an average value is computed.



Data transfer

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

HUMIDITY / TEMPERATURE SENSOR PROCESS

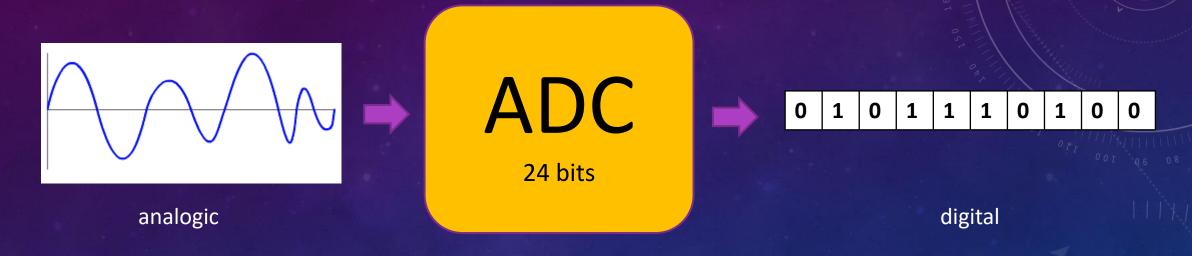


One logic part is missing in this schema:

Translation of the tension to
temperature and relative humidity.



ADC RESOLUTION FOR TEMPERATURE SENSOR



- 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 \rightarrow measure = 5 160 960 \rightarrow 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 / 2²⁴-1 = 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 30

ORGANIZATION IN SESSIONS

9:00 12:15 14:00 17:15

Wednesday

Session 1

- Introduction
- Data acquisition

Session 2

Developing a C++ class

Thursday

Session 3

Combining classes

Session 4

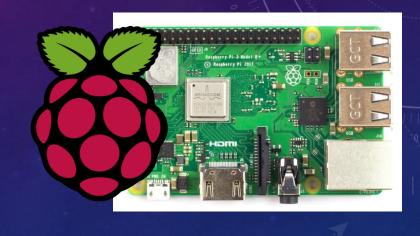
Analyzing data with ROOT

MULTI-PLATFORM DEVELOPMENT









Windows

Linux

Mac OS X

Raspberry board (ARM architecture)

TOOLS TO USE







- Saving and preserving code on the internet: site github
- Sharing codes with others.



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



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

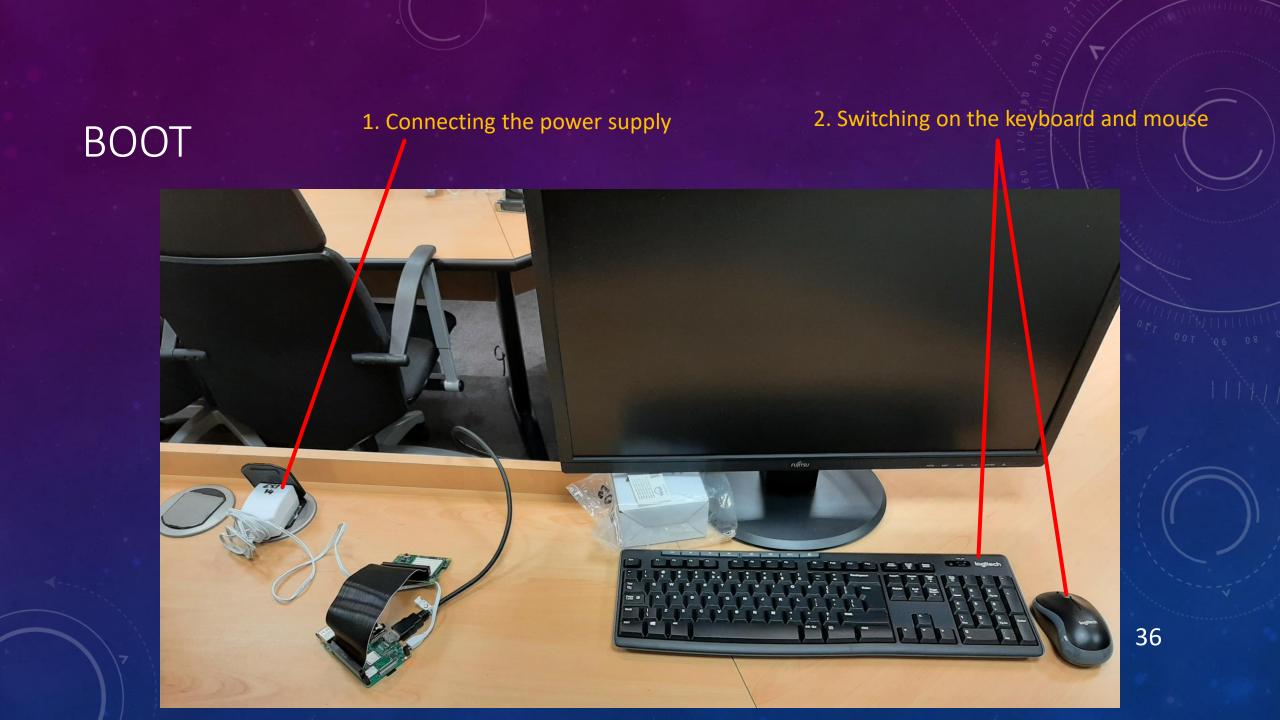
SKILL ASSESSMENT

Computing sessions 2023: assessment skill list

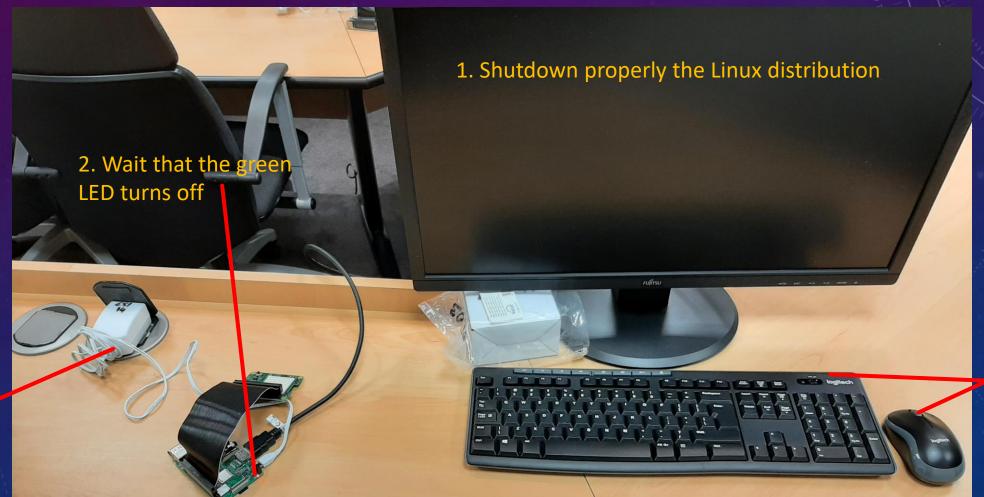
Skill category	Minimum	Satisfying	Very satisfying
1. Knowing C- programming basics	 Writing a "Hello World!" program Asking questions to the user Writing functions 		
2. Using the standard library	Using std::cout, std::string, std::fstream	Using std::vector, std::stringstream and cmath.	Using algorithms, 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".

- 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



SHUTDOWN



3. Withdraw the power supply

4. Switch off the keyboard and mouse

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