Jonathan David
Clément Le Marquis
Mickael Renault

POLYTECH NICE-SOPHIA

Building a vertical motion seismometer

with

Geo AZUR
TERRE - OCÉAN - ESPACE

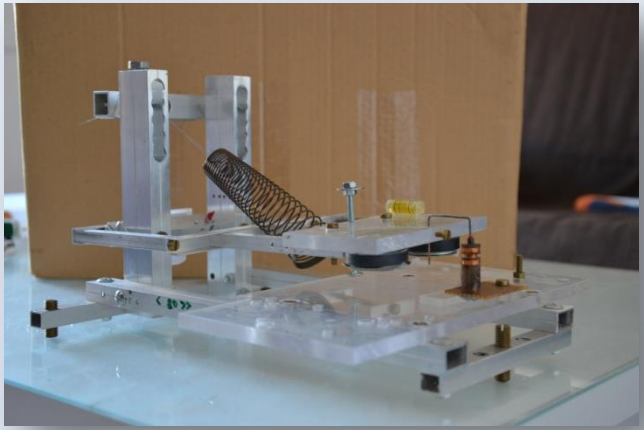
European Commission | Erasmus+

Summary

- I) Project management
- II) Seismic sensor and analog acquiring system
- III) Digital data transmission and user interaction
- IV) Future directions
- V) Conclusion

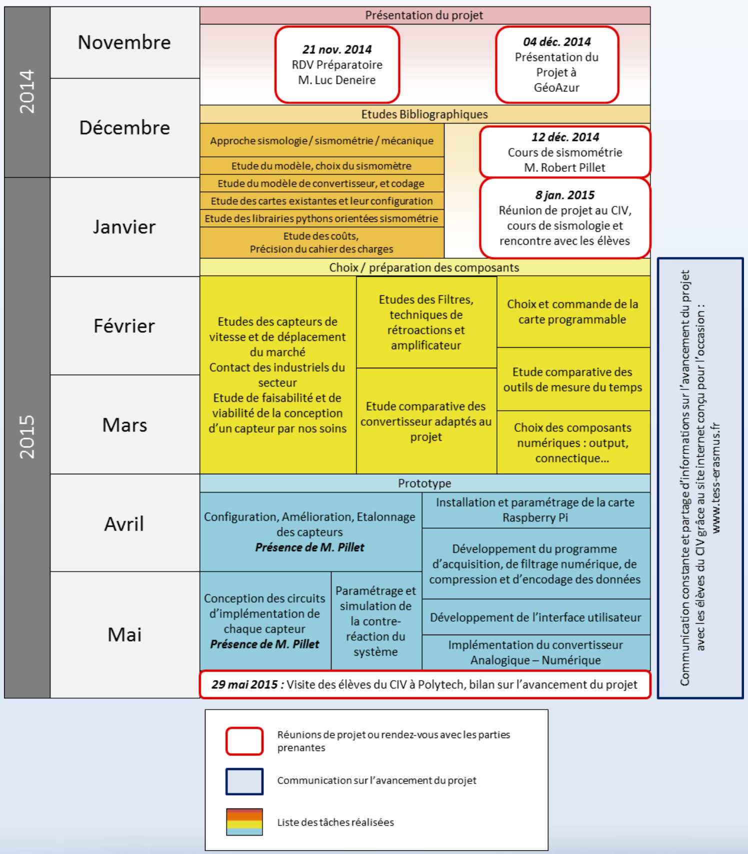
Introduction

- Erasmus+ Project
- Low cost seismometer
- Existing mechanical part
- Digital processing with a Raspberry Pi B+



I) Project Management

- Timing plan (Schedule)



- Working Plan :
  - Analog part :
    - Sensor
    - Control loop feedback
  - Numeric part :
    - Data acquisition
    - User interface

I) Project Management

Cost analysis

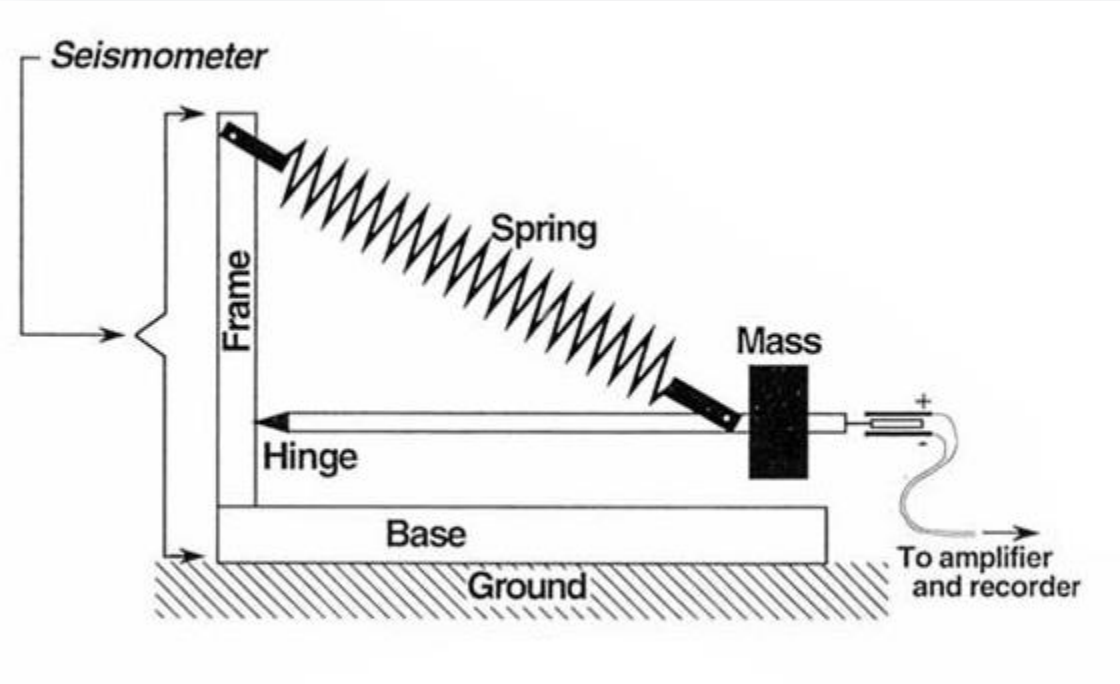
Objective budget : about 200€.

Estimated budget : 180€

We have worked with a handmade sensor. Professional sensor with high sensitivity costs at least 1000€.

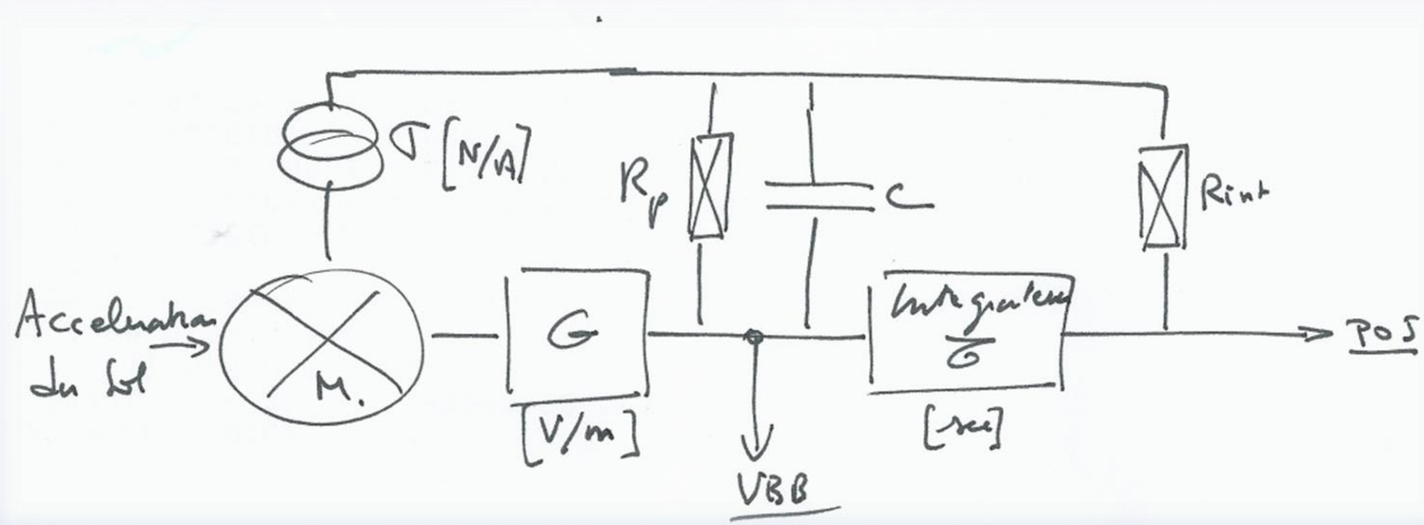
The seismometer

A. Mechanical part



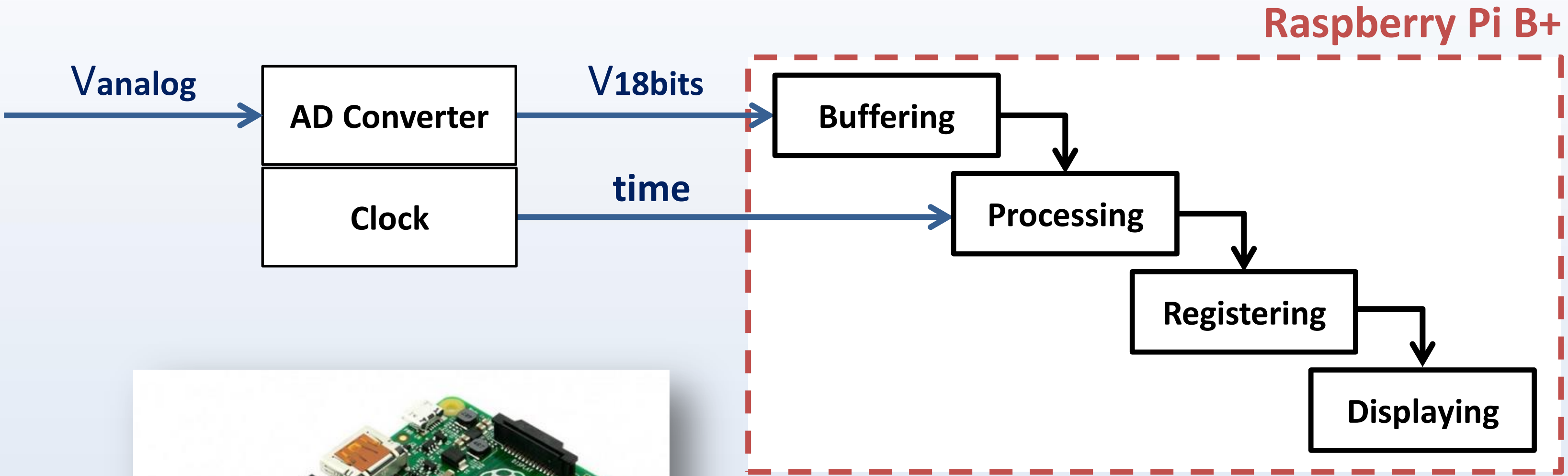
The seismometer

B. Analog Part



The seismometer

C. Numeric part

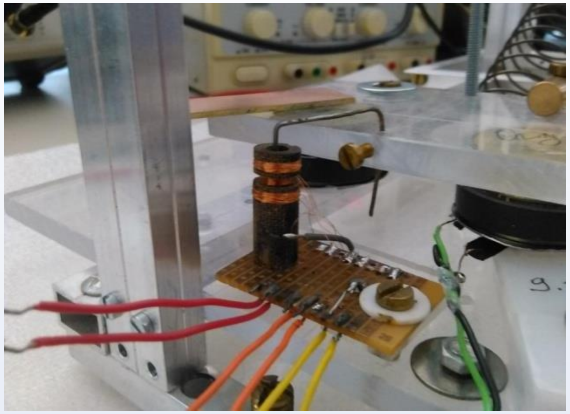


II) Seismic sensor and analog acquiring system

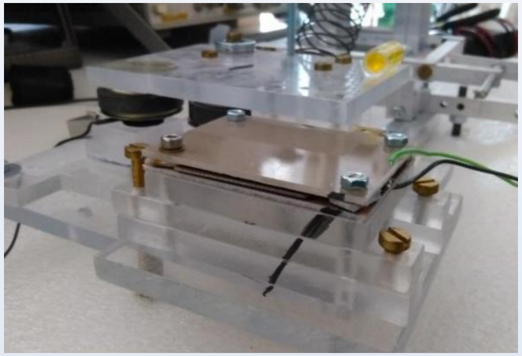
A. Seismic sensor

Using Displacement sensors :

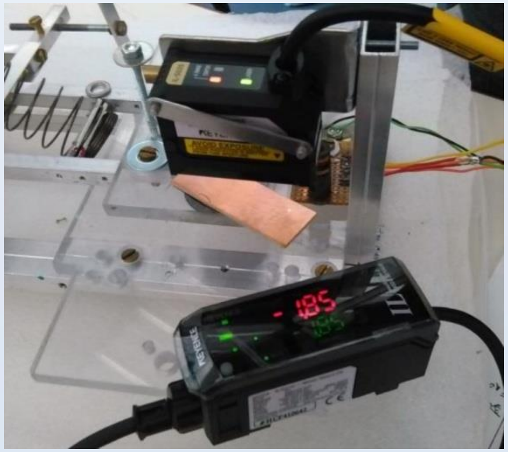
- Inductive (LVDT) :



- Capacitive :

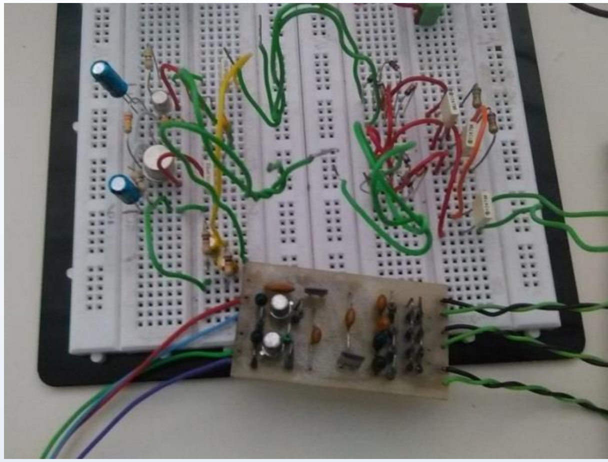


- Optical :



II) Seismic sensor and analog acquiring system

B. Implementation



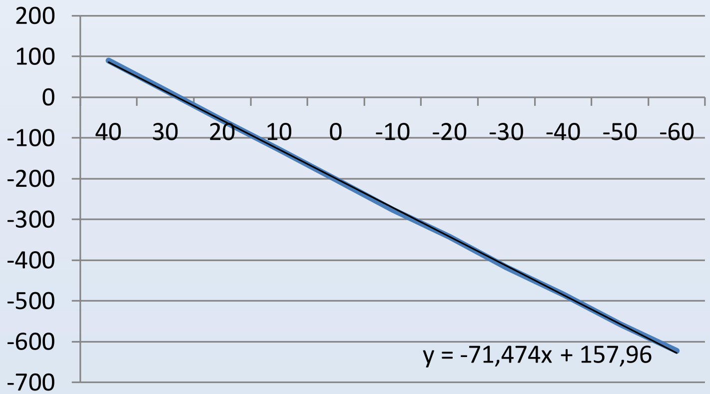
LVDT :

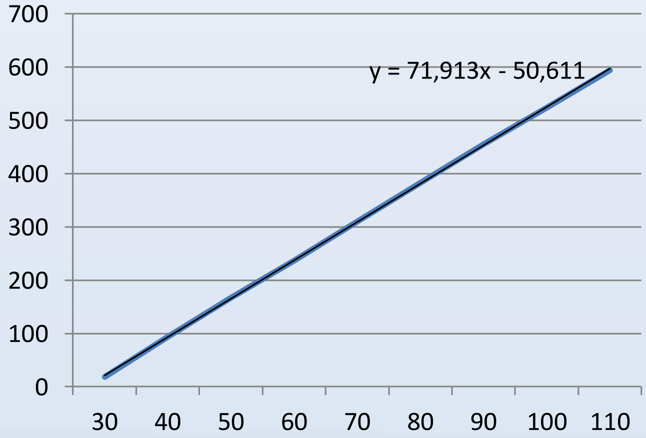
Left part creates current injected in the primary

Right part acquires the position of the mass

Characteristics :

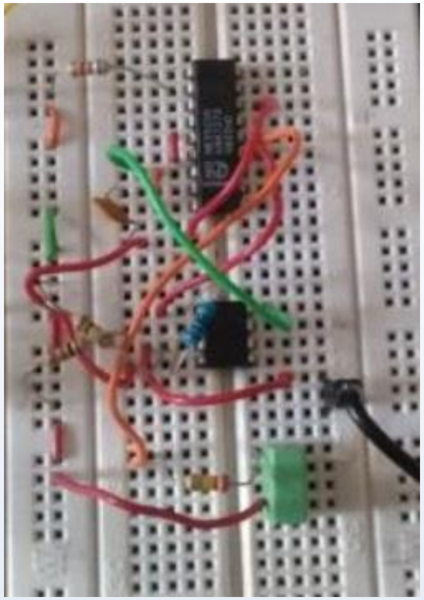
Linearity : 1cm





II) Seismic sensor and analog acquiring system

B. Implementation

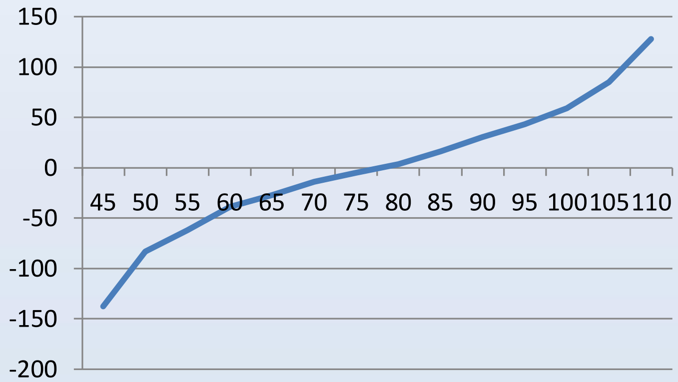


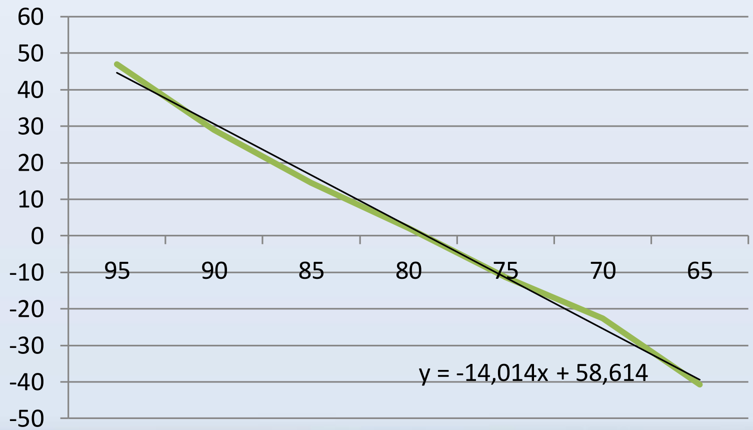
Capacitive :

Using a NE5521 microchip

Characteristics :

Linearity : 3mm



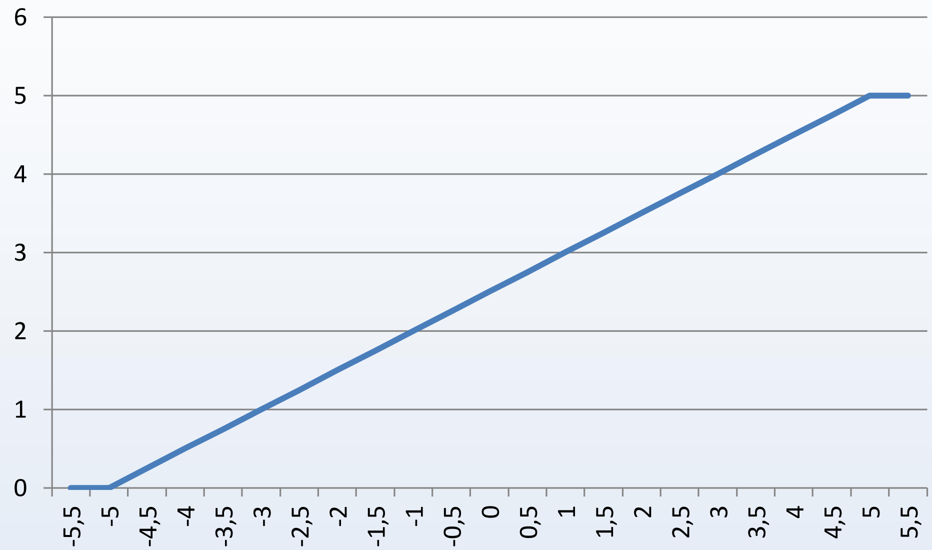


II) Seismic sensor and analog acquiring system

C. Comparison

Optical :

Linearity : 1 cm



Measure : capacitive < LVDT

Linearity : capacitive < LVDT ~ optical

Cost : capacitive = LVDT

=> LVDT is the best solution

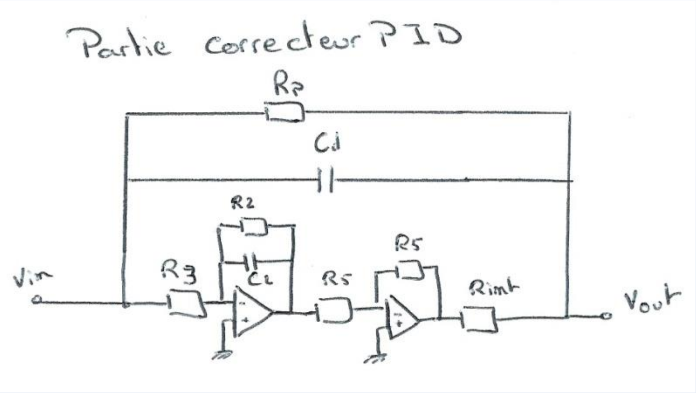
II) Seismic sensor and analog acquiring system

D. Control loop feedback

- Objective

 - Avoid intempestive oscillations of the mass

We have created a PID controller :



Effects of *increasing* a parameter independently[13]

Parameter	Rise time	Overshoot	Settling time	Steady-state error	Stability[11]
K_p	Decrease	Increase	Small change	Decrease	Degrade
K_i	Decrease	Increase	Increase	Eliminate	Degrade
K_d	Minor change	Decrease	Decrease	No effect in theory	Improve if K_d small

- Modeling

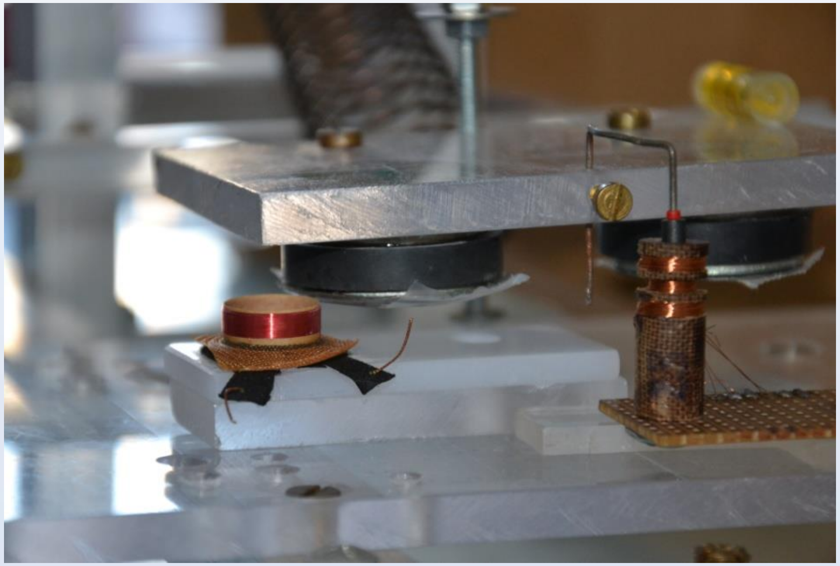
 - Hand schema , Math simulation (Matlab) , Electrical simulation (Cadence)

D. Control loop feedback

- Forcer

Transform current in movement.

Function on the principe of magnetism.



Characteristic :

Sigma = 1.1 N/A

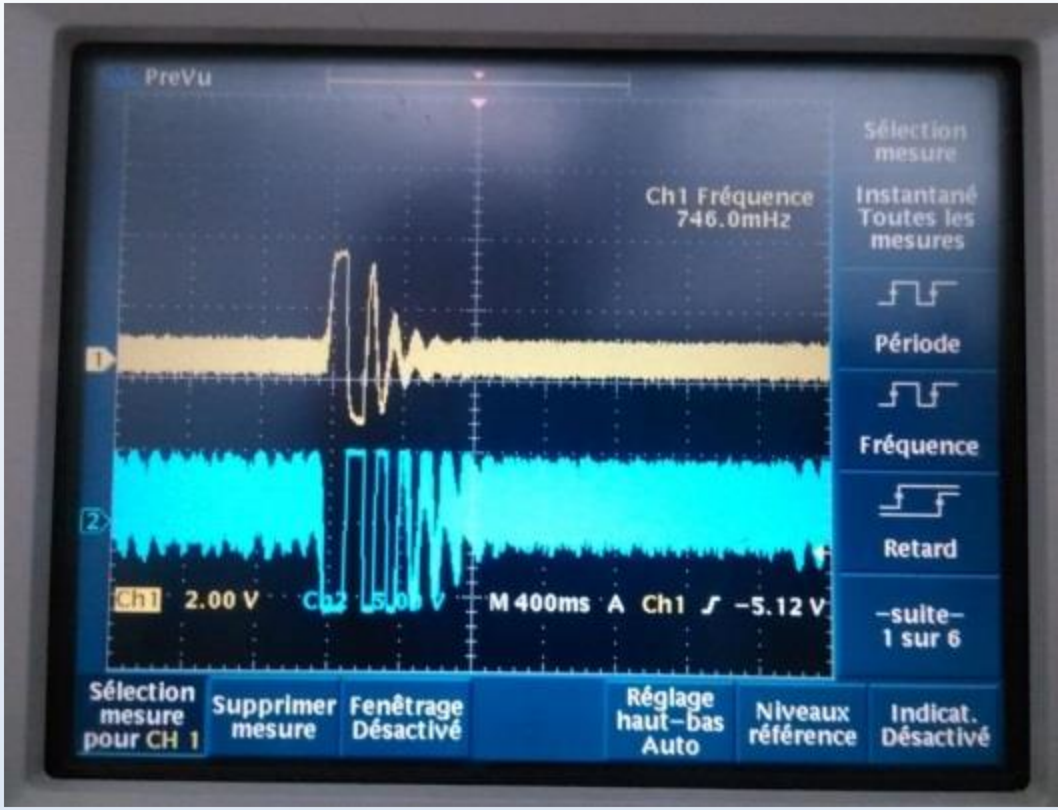
E. Complete analog part test

We have put each part of the seismometer together (mechanical sensor and control loop feedback) and run a test.

We have punched the table and monitoring the time response of the seismometer

In yellow the position mass signal

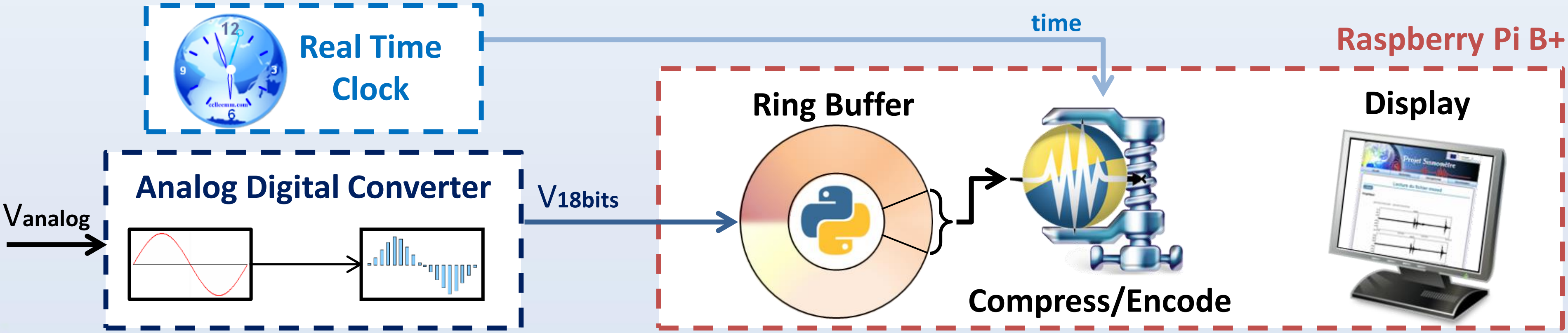
In blue the equivalent of the current injected in the forcer



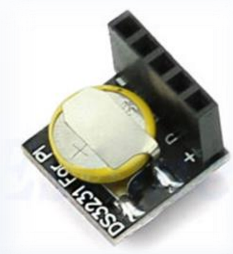
III) Digital data transmission and user interaction

A. Digital process

- Analog Digital Converter
- Real Time Clock
- Raspberry Pi B+

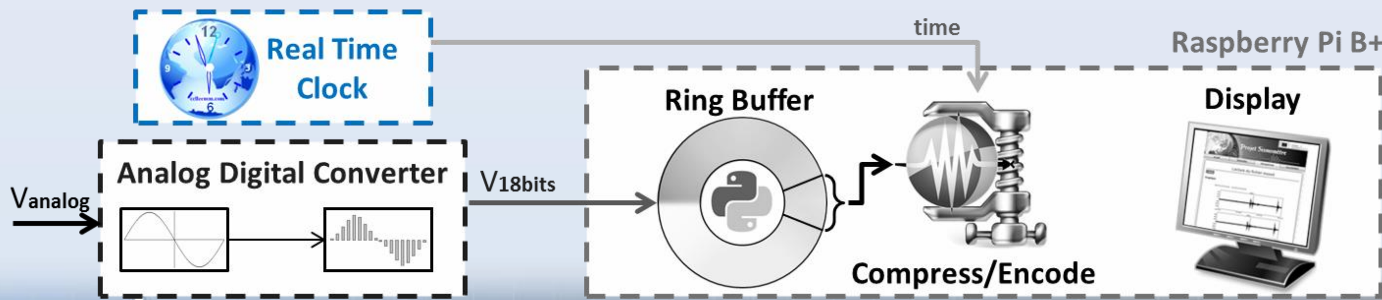


B. Real Time Clock



- Solution to keep time while system is off
- Choice between GPS module or RTC module
  - GPS gives time and location, auto-adjusted
  - RTC cheap and accurate : DS3231 ± 2ppm → max 2,6s/month

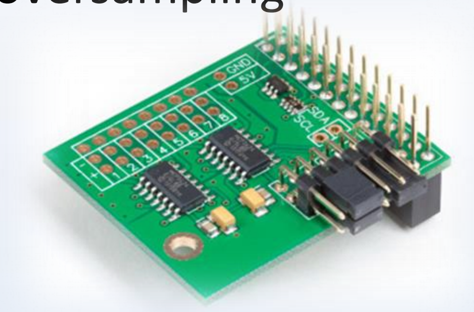
→ Best compromise : RTC with DS3231 chip (1,73€ with shipping)



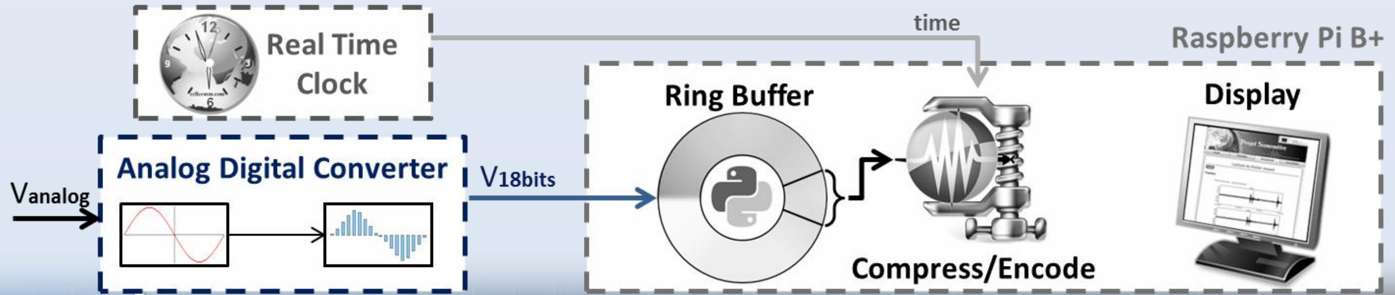
C. Analog Digital Converter

- Why choose a Sigma Delta converter ?
  - Oversampling and averaging for best estimations
  - Wen can use low resolution ADC if we use enough oversampling

16+ bits resolution
At least 2 channels
Minimal data rate : 125 SPS
Transmission protocol : I2C or SPI

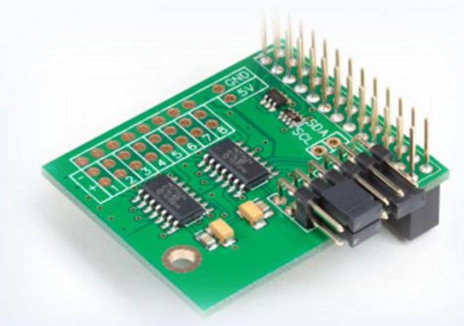


→ AB Electronics Delta Sigma Pi (33€ with shipping)

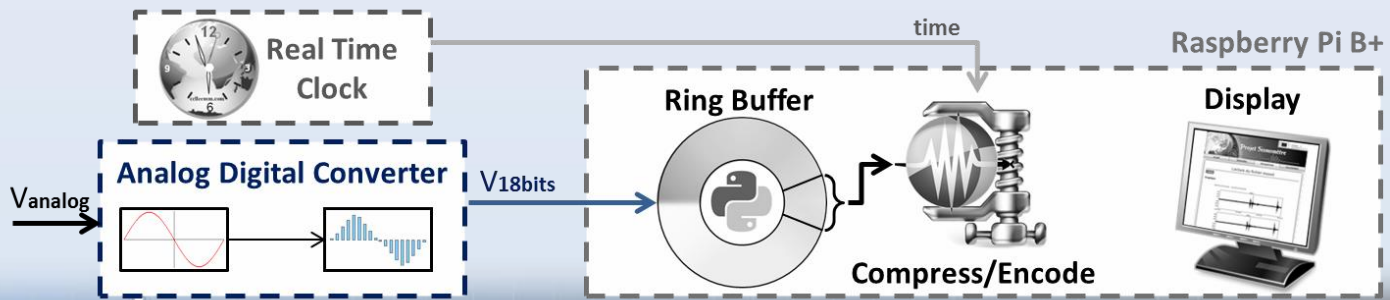


C. Analog Digital Converter

AB Electronics Delta Sigma Pi : Features



	Minimal specifications	Delta Sigma Pi
Resolution	16 bits	18 bits
Channels	2	8
Data rate	125 SPS	260 SPS
Transmission protocol	I2C or SPI	I2C (5V 100mA)
Additionnal features		- Integrated Programmable Gain amplifier (1,2,4, or 8) - One-shot or continuous conversion options



III) Digital data transmission and user interaction

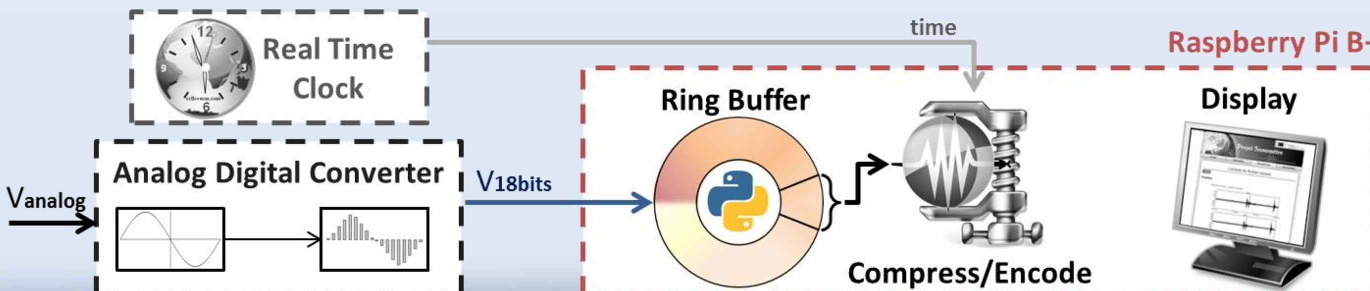
D. Ring Buffer

- Continuous reception
- Limited space
- Python 2.7 script for data acquisition on Raspberry Pi B+
  - Best compatibility with seismological tools
  - Integrated in Raspberry Pi : GPIO and I2C control

→Ring Buffer

with NumPy

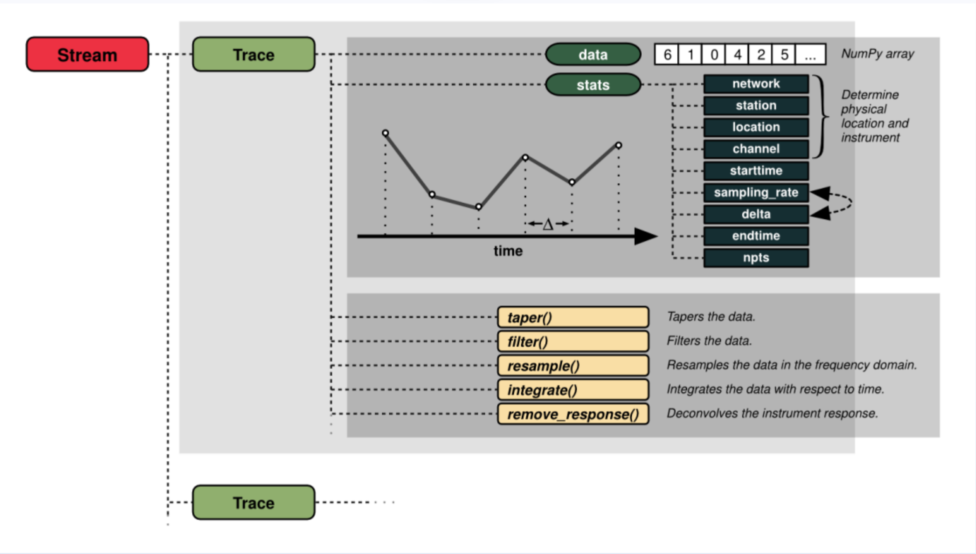
Data rate	Resolution	Duration	Allocated memory
125 SPS	18 bits	24 H	48,6 MB

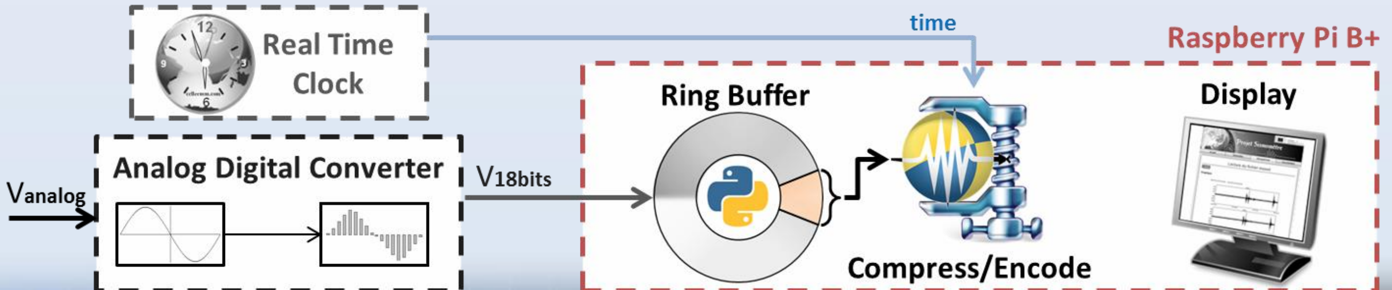


E. Compress and encode

ObsPy
A Python Framework for Seismology

- Register data stream every 30s
- Trace object : [data, metadata]
  - RTC time (of start / end)
  - Characteristics of record
  - Characteristics of seismometer
  - Various filtering functions
- Stream object : [Trace1, Trace2]
  - Position and speed of mass
- Save Stream to MSEED and PNG





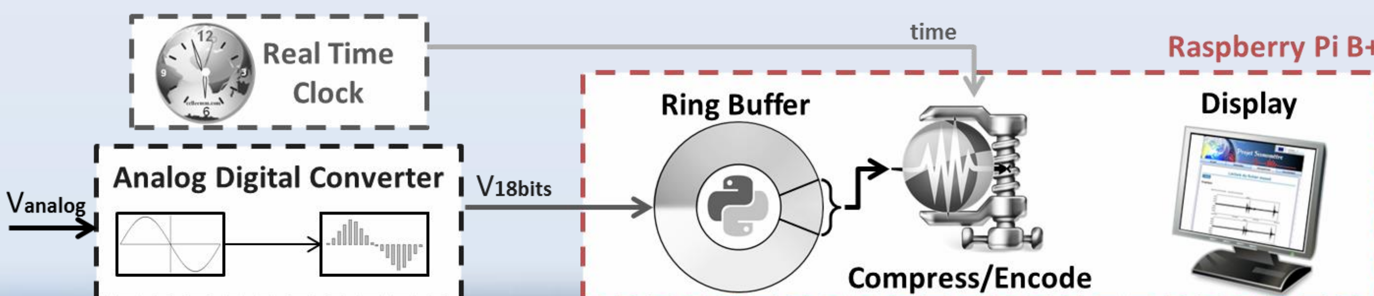
III) Digital data transmission and user interaction

F. User Interface

Objective : Avoid misunderstanding instruction and unsafe manipulation

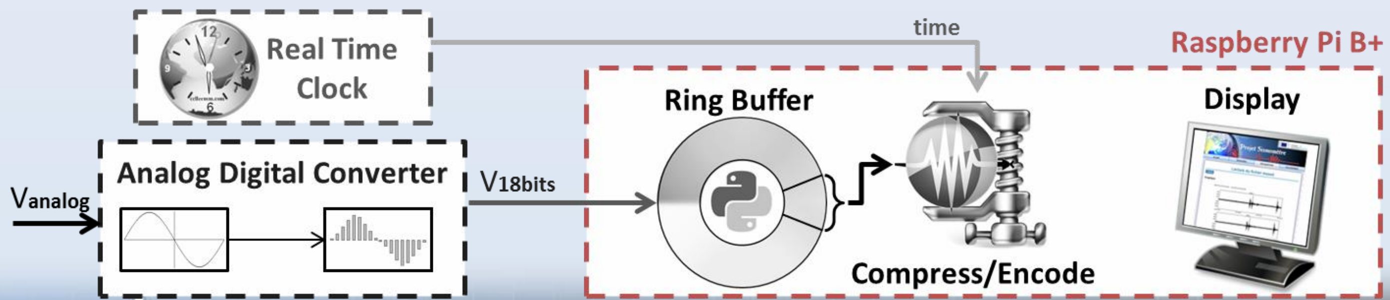
Web Application Interface to replace LXTerminal :

- PHP scripts, HTML and CSS rendering
- PHP call to Python recording script
- Enlarge local server accesses to execute our program
- Display seismograms, system informations, documentation



III) Digital data transmission and user interaction

F. User Interface



IV) Future directions

A. Improve feedback circuit

- Maybe developp a numeric feedback on the seismometer. This has never been done because of the time of conversion A/D and D/A
- Give the feedback more adaptative, with different choice of gain.
- Improve the work done on the modelisation of the seismometer.

IV) Future directions

B. Reduce instrument self noise

- Decrease the impact of noise : Filtering , Better choice of component
- Optimisation of the placement of the component (E.M.C)

C. Switch to Raspberry Pi 2

	Raspberry Pi B+	Raspberry Pi 2
Released	July 2014	February 2015
SOC	Broadcom BCM2835	Broadcom BCM2836
CPU	700MHz Single-Core ARM11	900MHz Quad-Core ARMv7
SDRAM	512 Mo	1 Go
Price	35€ (found now with a discount)	35€

IV) Future directions

D. Working with threats

- Threats : Advantage of multiple cores systems
- Smoother multitasking : Recording script and web interface
- More efficience with I2C data transmission
- 900MHz → a faster Python 2.7 script execution

Conclusion

- Diversity of working areas
  - High accuracy sensor
  - Feedback circuit
  - Analog to Digital Conversion
  - Data processing
  - User interface through Web Application

- Organisation :
  - Working Plan
  - Timing Plan
  - Team work and tasks division

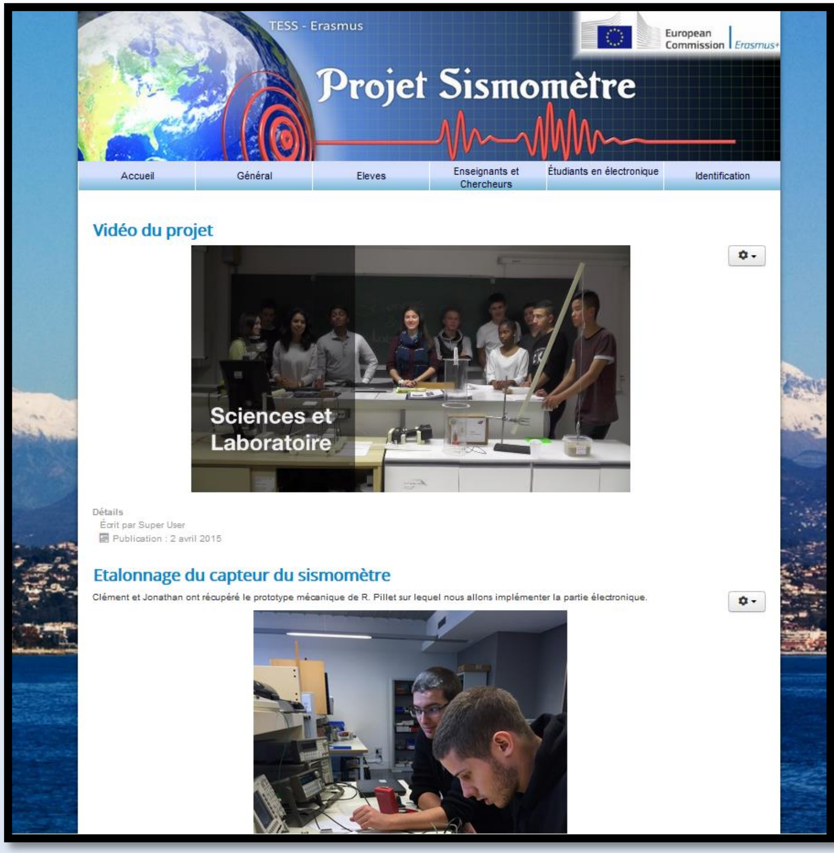
Conclusion

Communication

- Web platform to share the progresses :

www.tess-erasmus.fr

  - CIV student access
  - Teacher access
  - Electronic student access
  - Public access



Thanks for your attention

Do you have any questions ?