

Mikheil Kalantarovi

- Completed Bachelor's and pursuing Master's Degree in Electrical Engineering at Agricultural University of Georgia.
- Participating in projects at SMART|EDM_lab since 2024
 - Under the guidance of David Mchedlishvili.





Design of Thermostatic chambers

Mikheil Kalantarovi

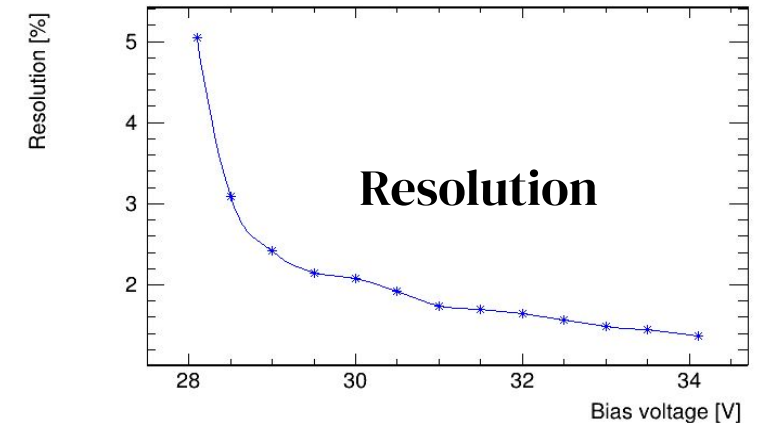
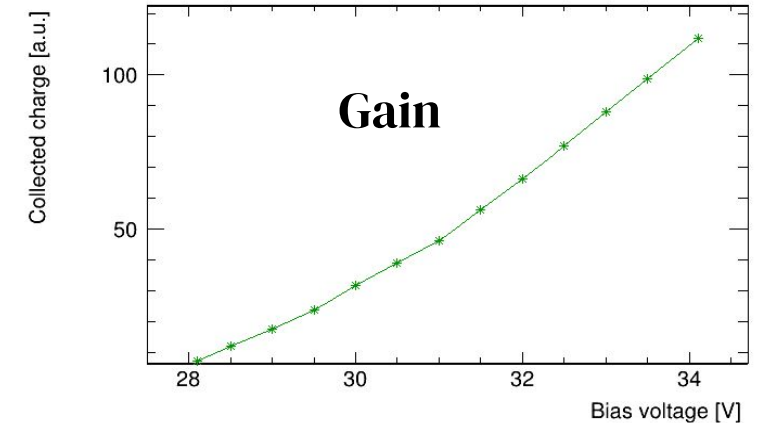
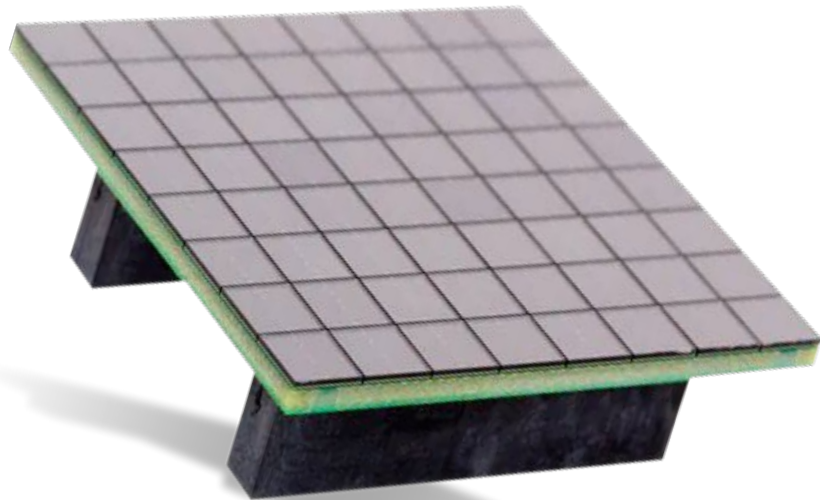
Thermostatic chamber

- **What is thermostatic chamber**
 - a device used to create and maintain a specific, stable temperature environment.
- **Applications**
 - used to examine temperature dependence in devices.



Project held at SMART|EDM_LAB

Main **SiPM** characteristics, such as Gain and Resolution, are highly dependent on voltage.



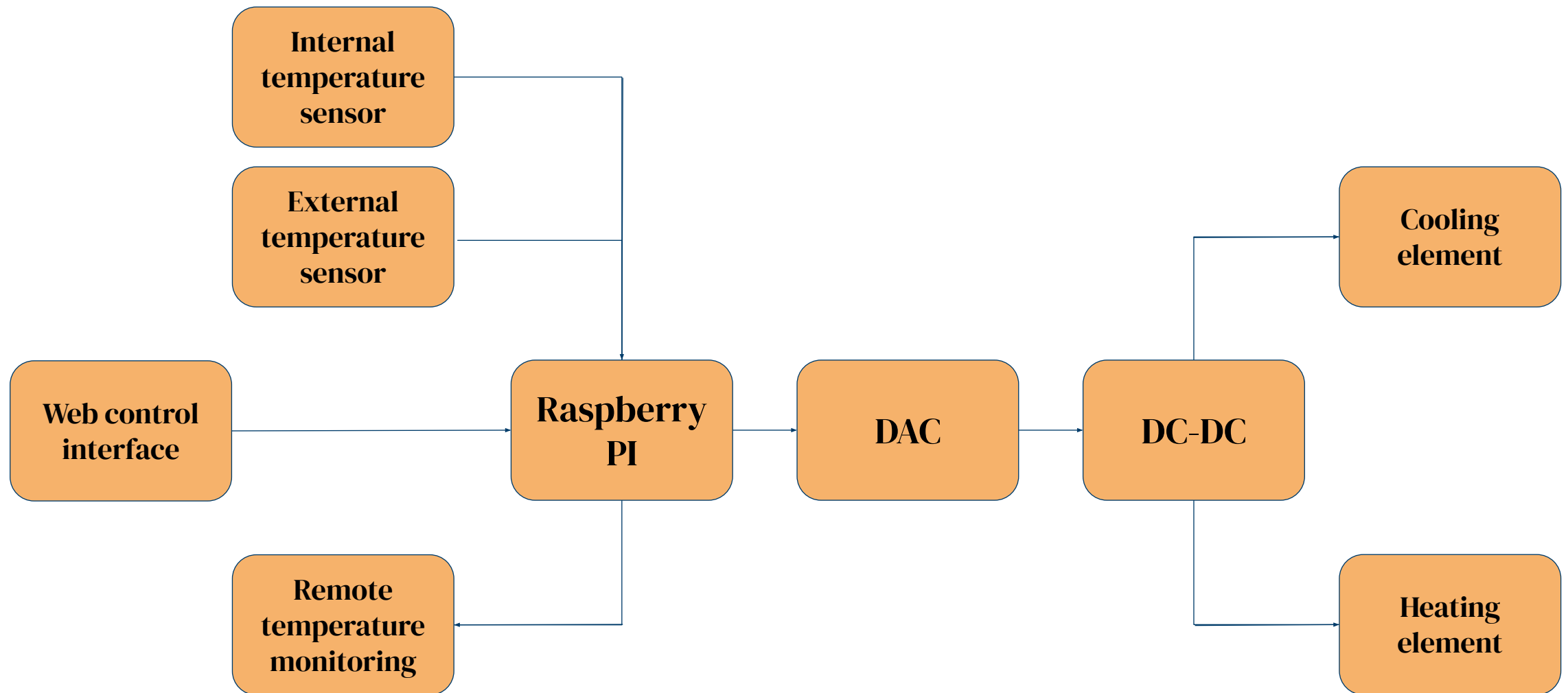
Project overview

System contains:

- Thermally isolated box;
- Heater(power resistor) and cooler(Peltier element);
- Digital sensors for internal and ambient temperature measurements;
- Adjustable power supply for heating and cooling;
- Raspberry Pi: main component of the system;
- Web interface for real-time control and monitoring.



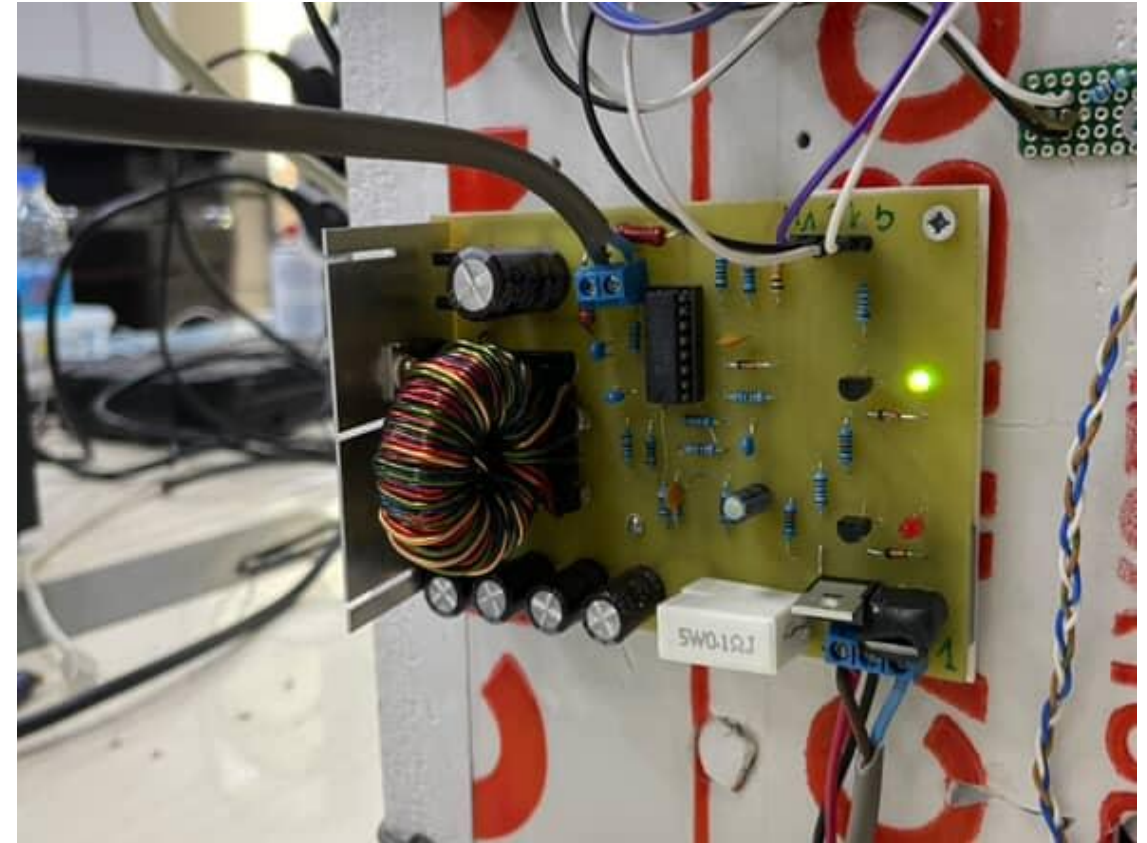
Block diagram



Power supply overview

Converts 24VDC input to a variable output

- Custom made;
- Based on DC-DC buck converter topology;
- Operating frequency: ≈ 100 kHz;
- Max. output current: 6 A(current limiting);
- Output voltage: 0 – 23 V.



Software overview

Main program code is written on Python. It contains:

- Temperature readout
- Heating/Cooling control using PID algorithm
- Web control interface, based on Flask framework
- Remote temperature monitoring
 - CERN ROOT framework(external)
 - WebSockets

Graphical User Interface(GUI)

Real-time Temperature Monitor

Sensor Readings

Internal Temperature: 11.062°C
Ambient Temperature: 22.062°C

Set Wanted Temperature

Set Temperature

Current Wanted Temperature

Wanted Temperature: 11°C

PID Control

P Coefficient:

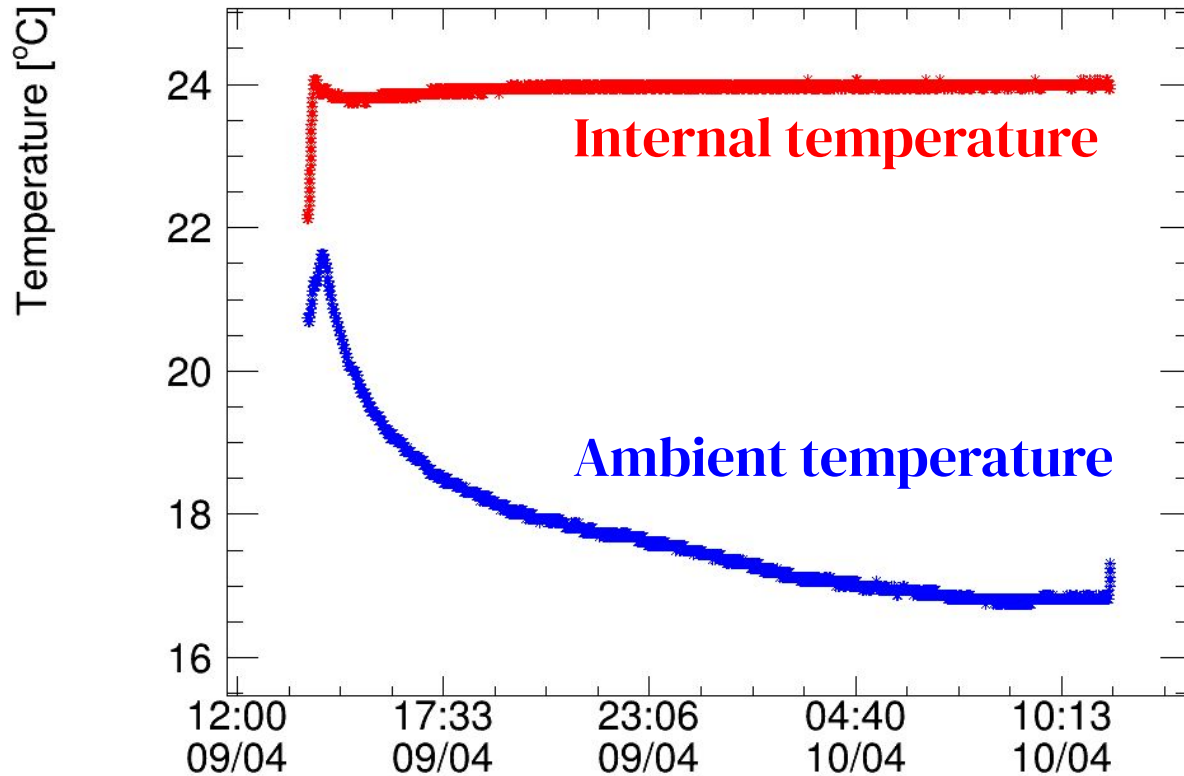
I Coefficient:

D Coefficient:

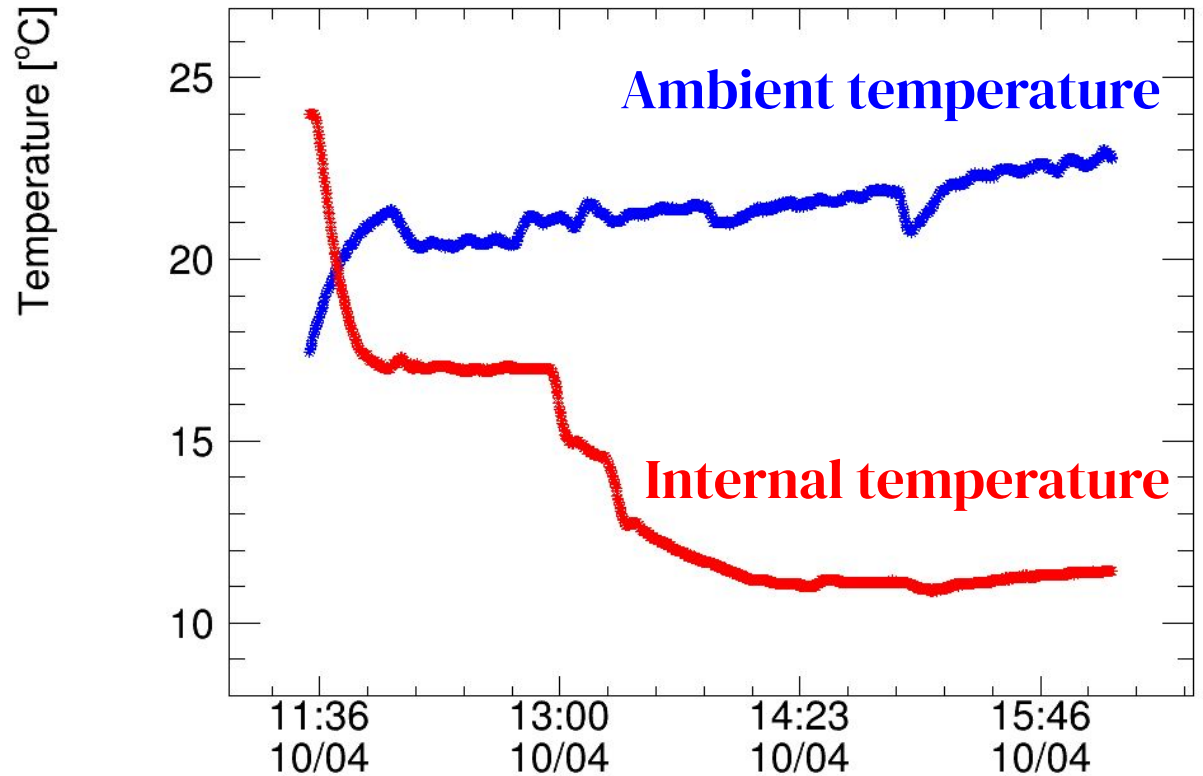
Update PID Coefficients

Disable PID

Tests



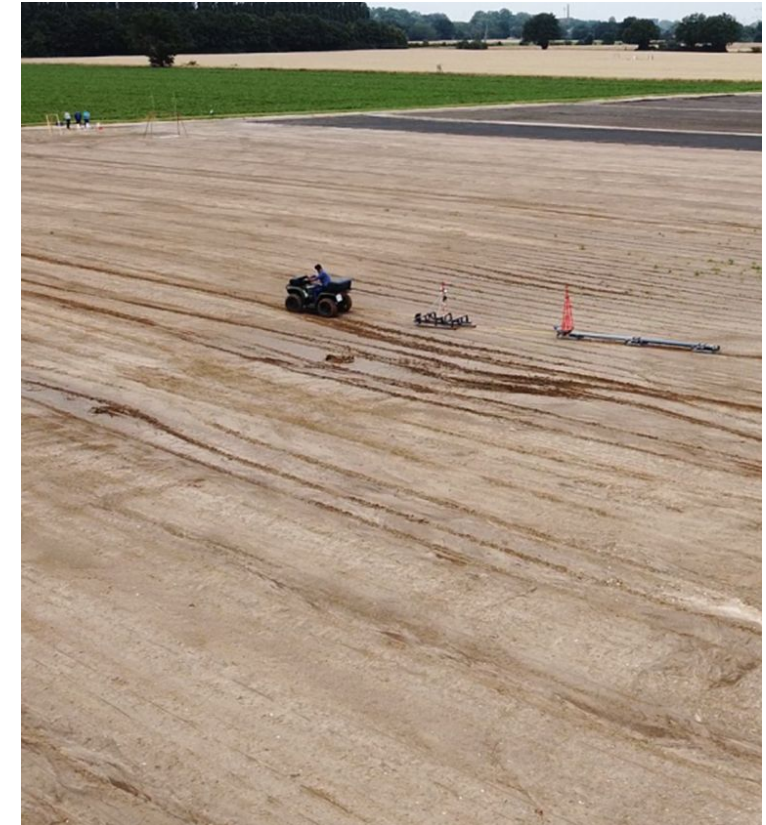
$$t_{\max} > 45^{\circ}\text{C}$$



$$t_{\min} = t_{\text{ambient}} - 11^{\circ}\text{C}$$

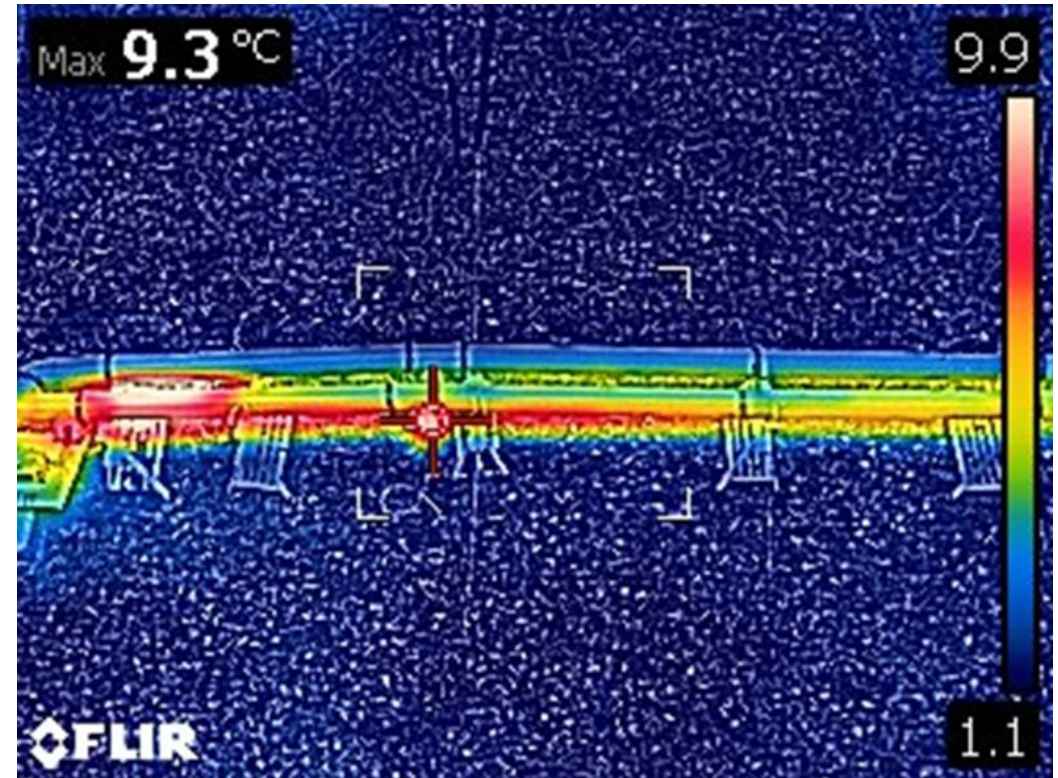
Project held at Forschungszentrum Jülich

SELMA is an electromagnetic multi-coil induction system, which evaluates the soil by measuring magnetic field. It uses multiple sensors that are dependant on temperature.



Requirements

- **The Thermostatic chamber must have:**
 1. Heating source with automated power adjustment.
 2. User-friendly interface for the remote control.
 3. Graphing tool for visualizing results.
- **Challenges:**
 - Chamber should fit inside the tube.
 - Constantly changing environment.
 - Delayed control.



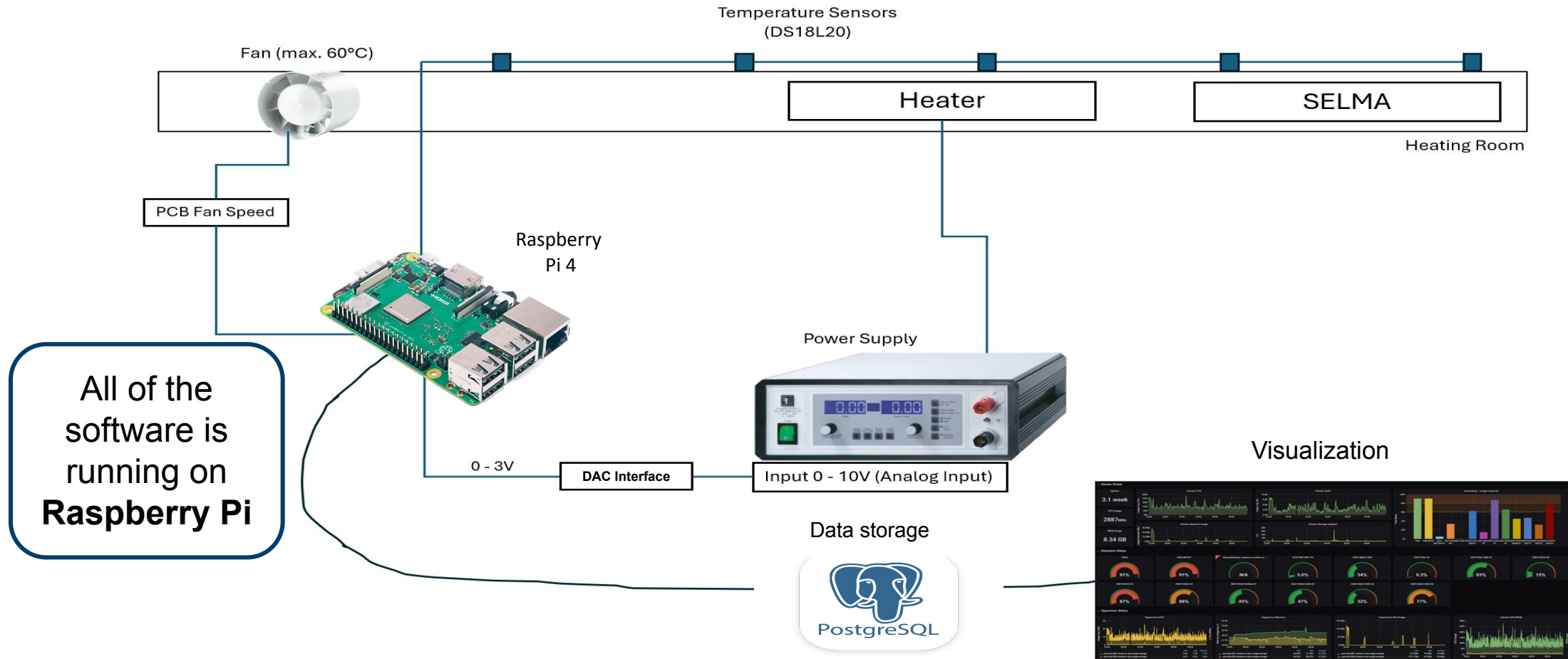
Project overview

System contains:

- Isolated pipe.
- Heating elements(power resistors).
- Digital sensors for internal temperature measurements.
- Adjustable power supply for heating.
- Raspberry Pi: main component of the system.
- Web interface for real-time control and monitoring.
- Grafana plots for the visualization.



System diagram



Software overview

Main program code is written on Python. It contains:

- Temperature readout
- Heating control using synchronized PID algorithm
- Web control interface, based on Flask framework
- Communication between devices using MQTT
- Remote temperature monitoring
 - PostgreSQL
 - Grafana

Synchronized PID algorithm

- Continuously observes system behavior
- Adjusts PID coefficients in real time
- Predicts future temperature using delay

PID for delayed system

$$u(t) = K_p e(t) + K_i \int e(t) dt + K_d \frac{de(t)}{dt}$$

$$e(t) = T_{target} - T_{air}(t)$$

$$T_{air}(t) = G \cdot u(t - \tau)$$

Rate of change

$$r = \frac{dT}{dt}$$

$$\Delta r = r - r_{target}$$

Synchronized control

$$K_p \leftarrow K_p \cdot (1 - \alpha \cdot \Delta r)$$

$$K_i \leftarrow K_i \cdot (1 - \beta \cdot \Delta r)$$

Synchronized PID algorithm

GOAL

Find τ such that:

$$T_{air}(t) \approx T_{heater}(t - \tau)$$

4) FIND BEST DELAY

Compute $score(d)$ for $d = 1, 2, \dots, 14$



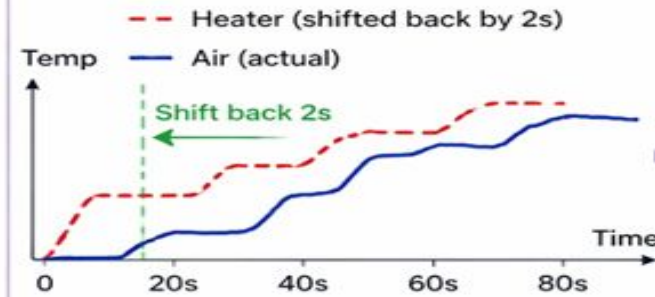
Best delay = 5 s (highest score)

5) SMOOTH UPDATE

To avoid jumping, the delay is updated slowly:

$$\begin{aligned} \text{THERMAL_DELAY}_{new} \\ = 0.9 \times \text{THERMAL_DELAY}_{old} + 0.1 \times \text{best_delay} \end{aligned}$$

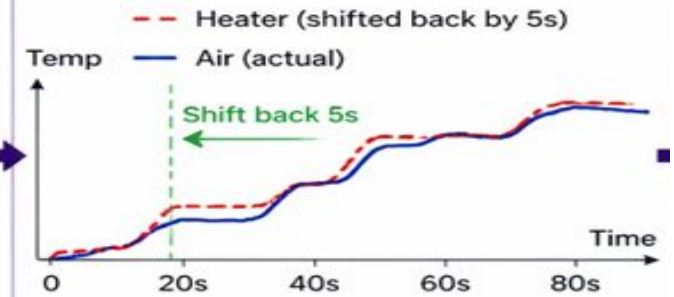
Test delay $d = 2$ s (too small)



Poor alignment → low score



Test delay $d = 5$ s (just right)



Good alignment → high score



6) HOW IT IS USED

The estimated delay τ is used to predict future air temperature:

$$T_{predicted} = T_{airnow} + (dT/dt) \times \tau$$

If $T_{predicted} \geq T_{target} \rightarrow$ reduce/stop heating early

This prevents overshoot.

Graphical User Interface(GUI)

Real-time Temperature Monitor

Sensor Readings

Temperature Sensor 1: 29
Temperature Sensor 2: 41.75

Set Wanted Temperature

Current Wanted Temperature

Wanted Temperature: 30°C

PID Control

P Limit: (Kp: 8)

I Limit: (Ki: 0.1)

D Limit: (Kd: 0)

System State

Error: -5.375

Integral: 254.124

Tests

- Final configuration.



Sensor at the end of the tube



Sensor on the heater

Accomplishments

- ❑ Heating source with automated power adjustment.
- ❑ User-friendly interface for the remote control.
- ❑ Graphing tool for visualizing results.





Institute of Technology and Engineering (ITE) FORSCHUNGSZENTRUM JÜLICH GMBH

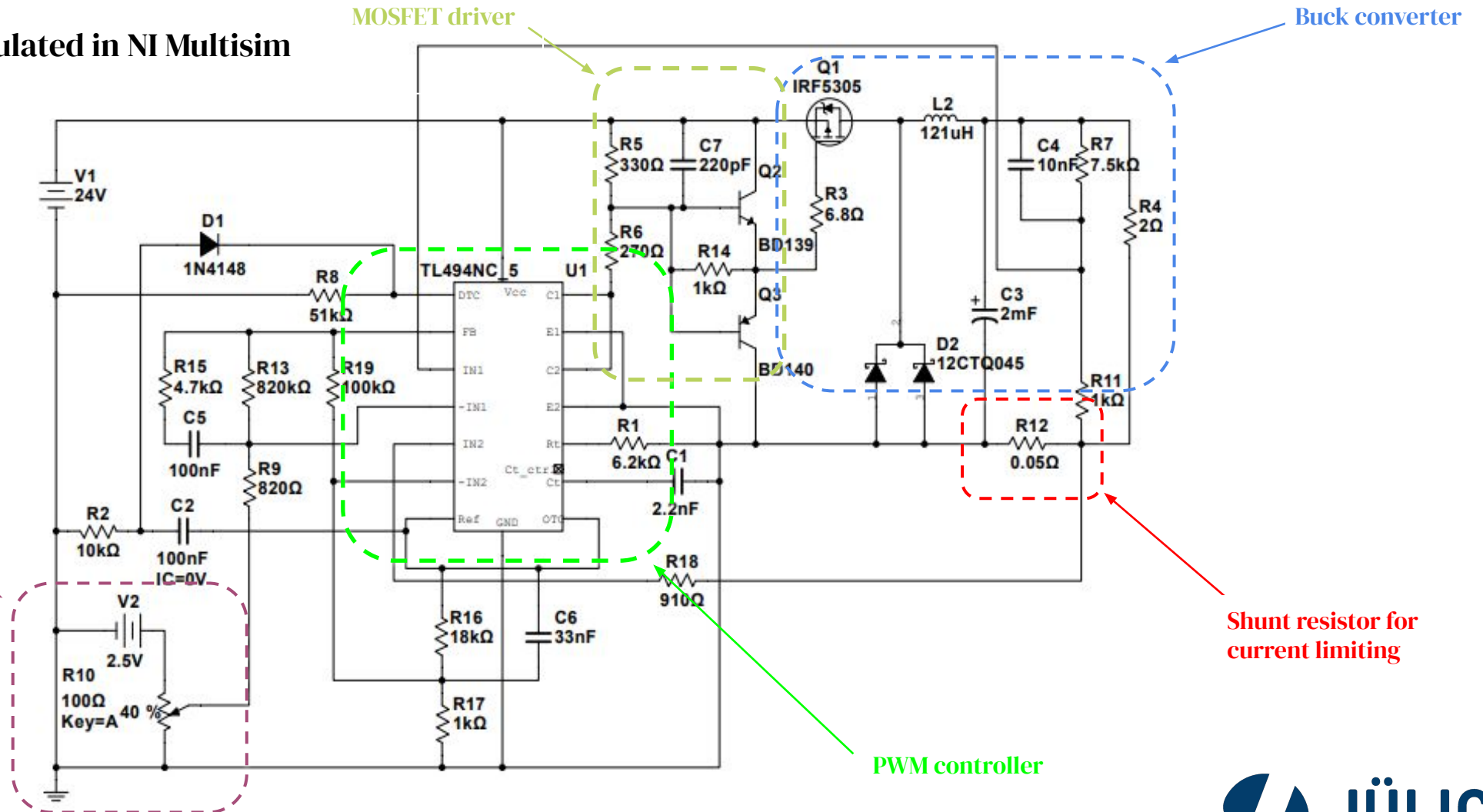
Thank you

Member of the Helmholtz Association



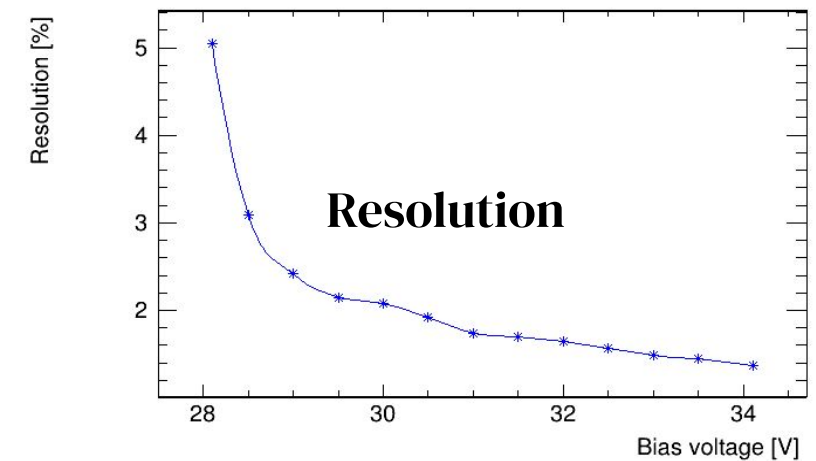
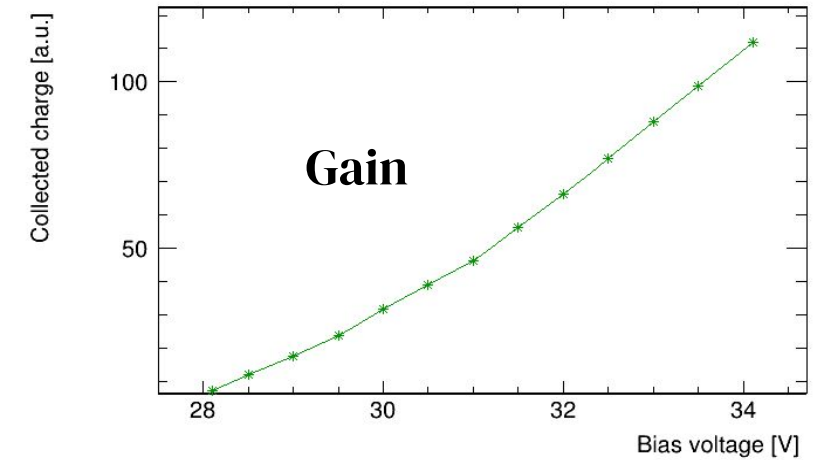
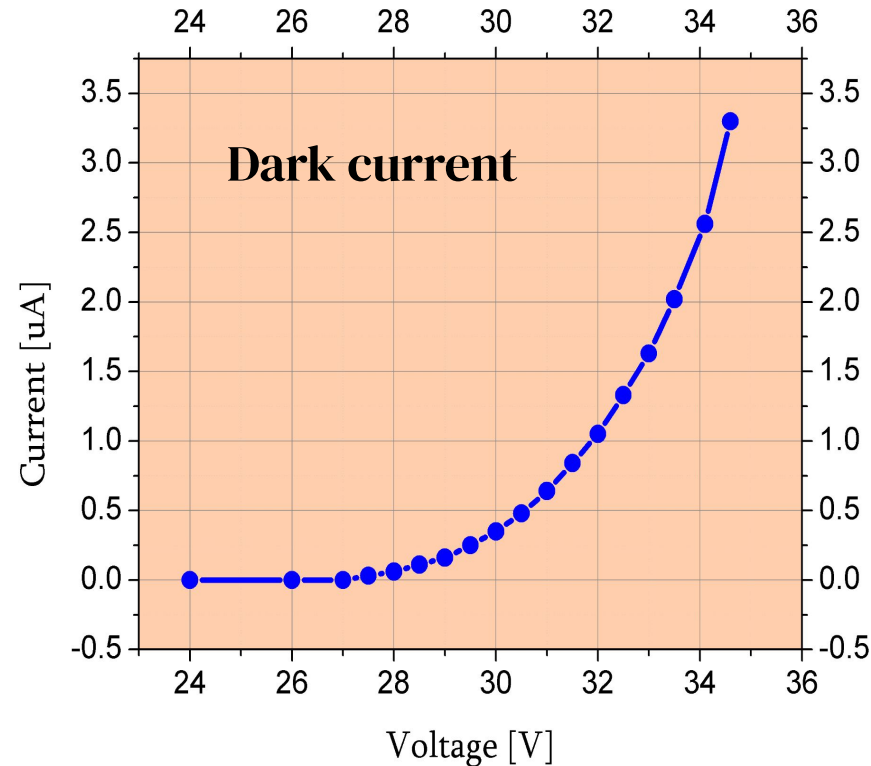
Power supply circuit

Designed and simulated in NI Multisim



Typical SiPM characteristics

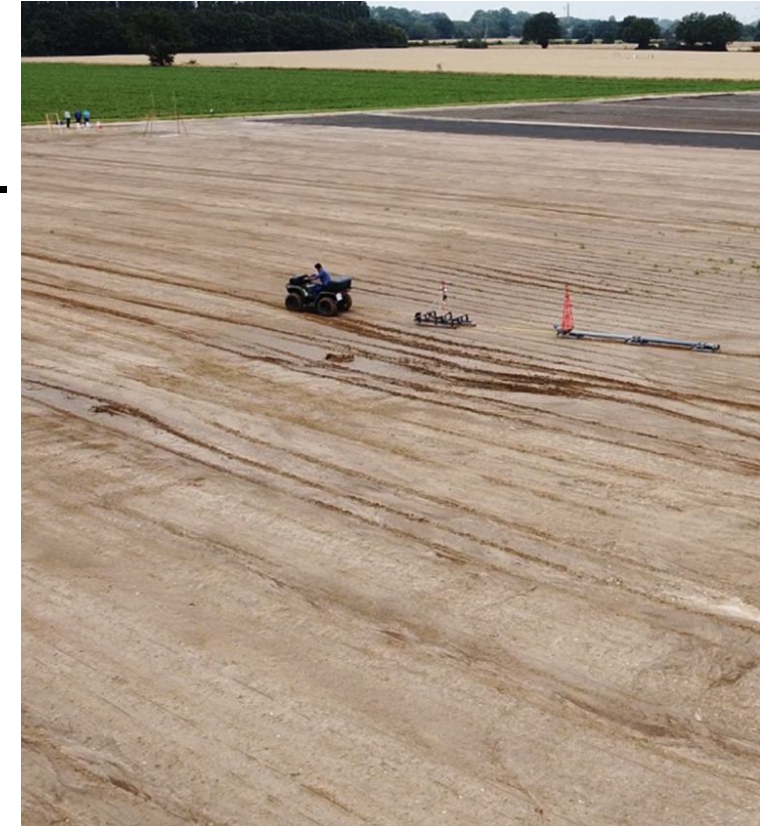
Measured SiPM sample: AFBR-S4N33C013



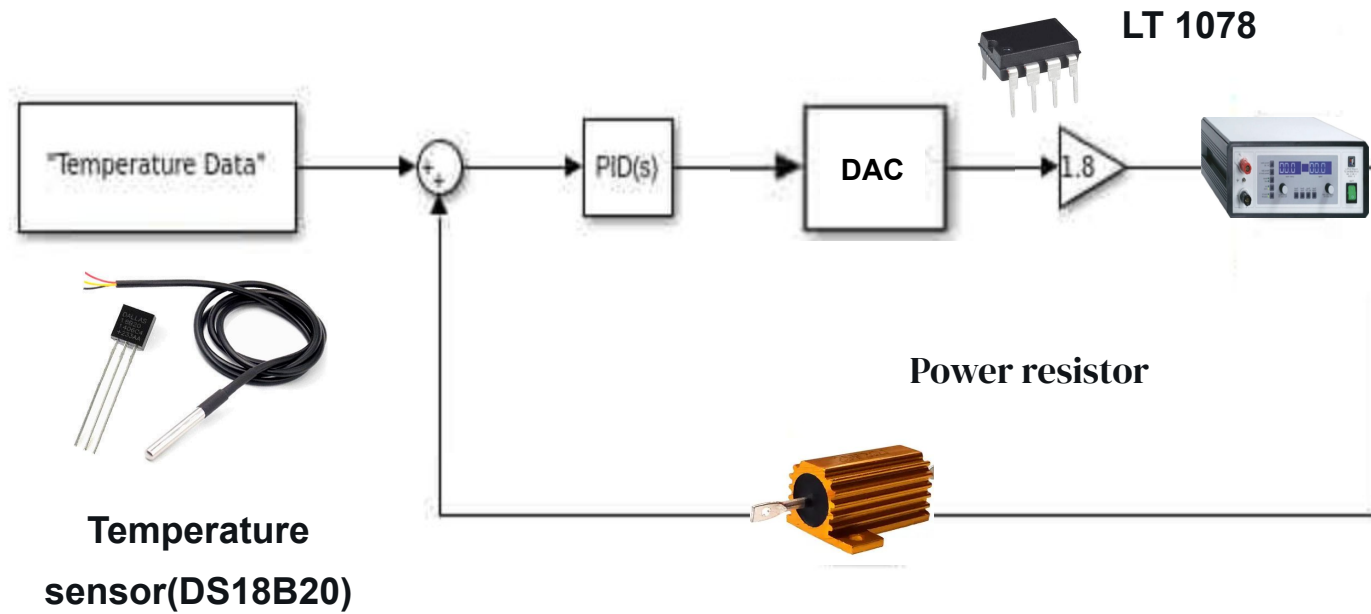
Main characteristics are highly dependent on voltage.

SELMA

- Evaluates the soil by measuring the magnetic field.
- Uses multiple sensors that are dependant on temperature.
- Requires a calibration to ensure consistent results.

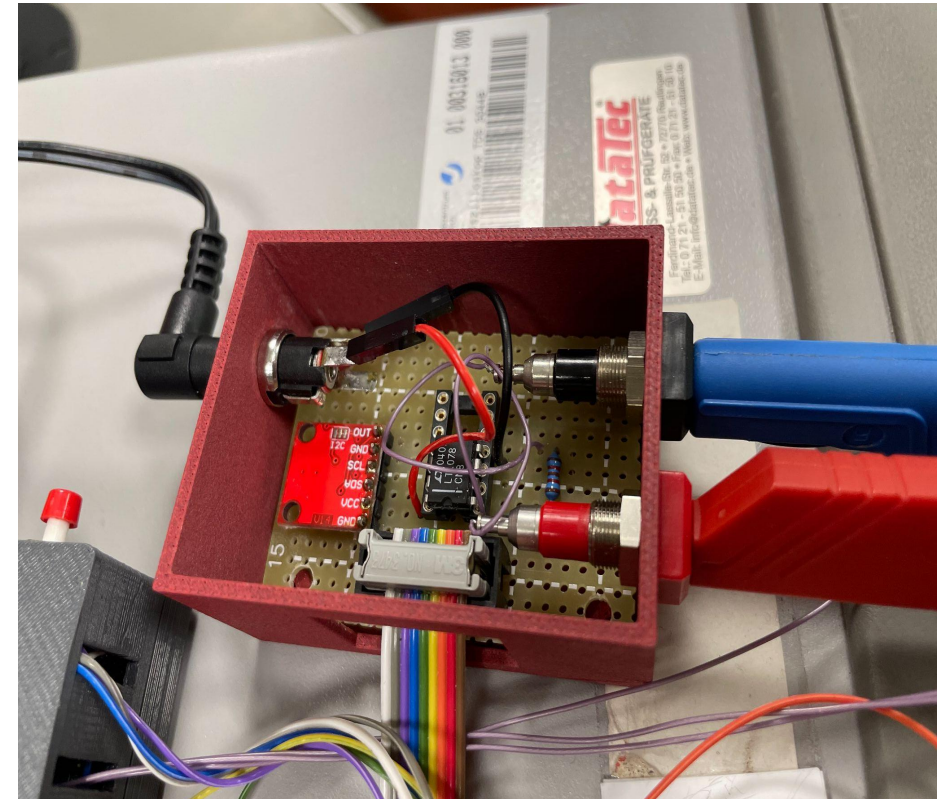


Practical realization



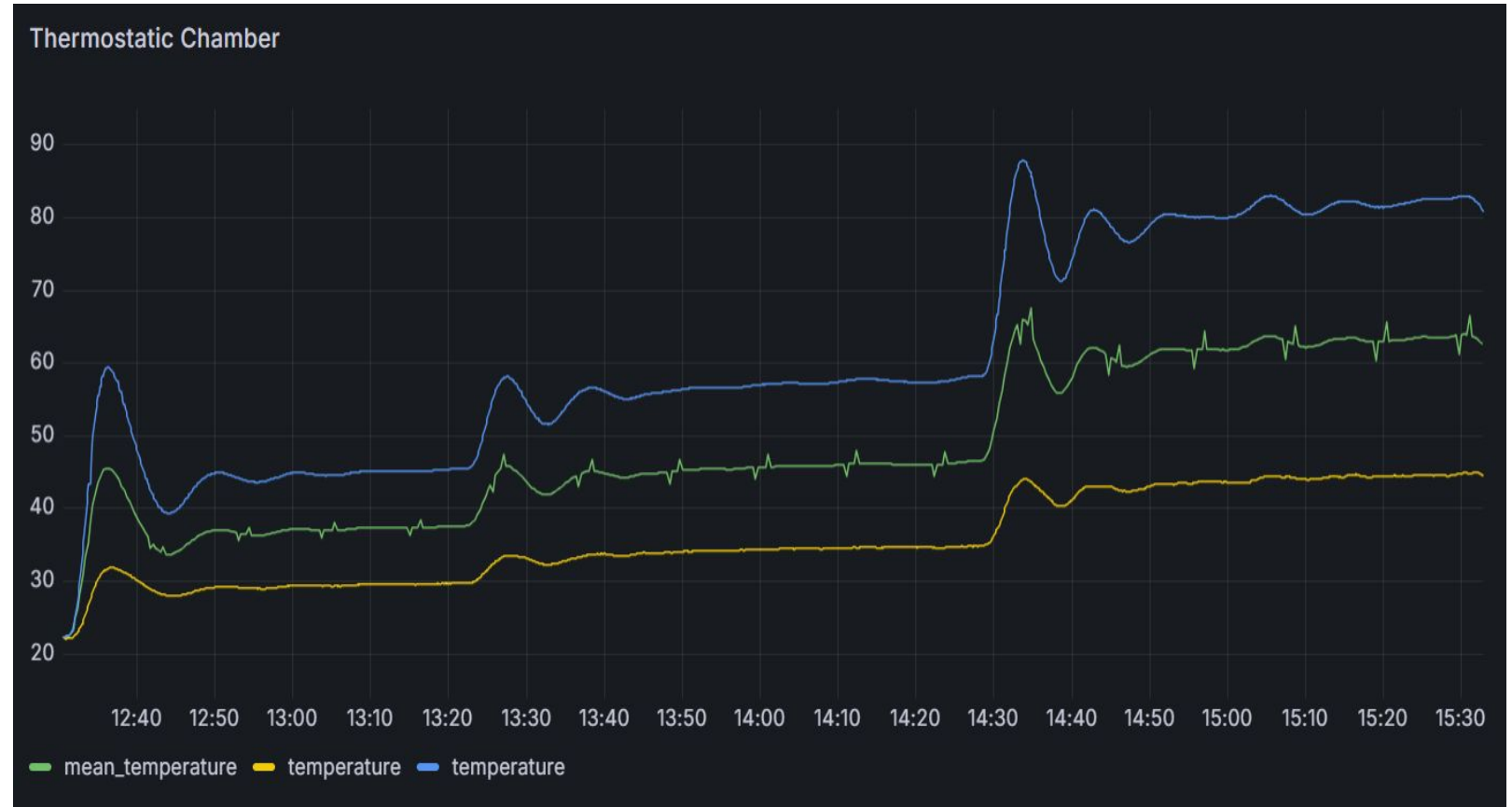
- Accuracy: ± 0.5 °C (from -10°C to +85°C)
- Resolution: 0.0625 °C (at 12 bit internal ADC resolution)

DAC Interface



Tests

- Integral resets after each successful step.
- Delay computing.



Sensor at the end of the tube



Sensor on the heater

Tests

- System was moved into the tube, to create a similar environment to an actual experiment.
- Introduction to the delay.
- Still no limit on the integral, but the output limit was removed.



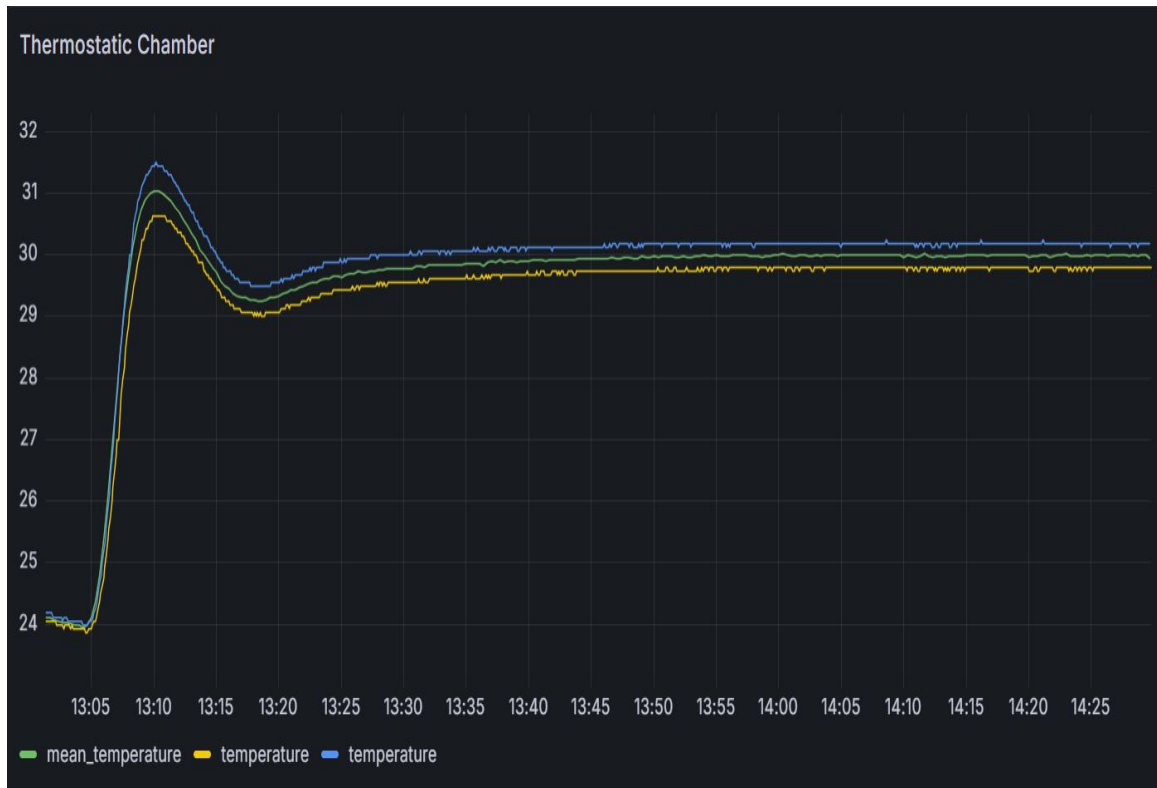
Sensor at the end of the tube



Sensor on the heater

Tests

Final configured version of automatic PID

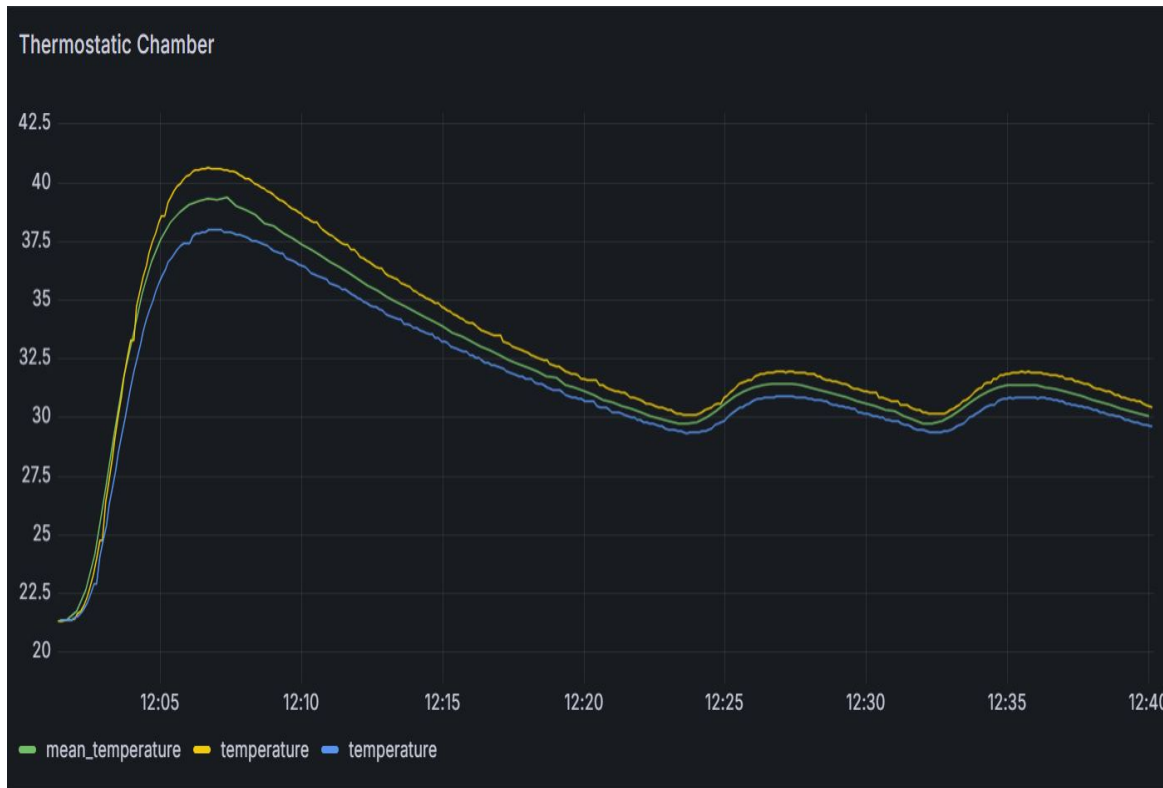


Tests with multiple steps, unlimited integral



Tests

First test of automatic PID with no limits



Limiting the output and the coefficients

