Thermal Feedback Device

HHRI 2025 – Lab Specialization

Jonathan Muheim

The MiniTouch

Translational Neural Engineering

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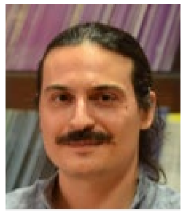
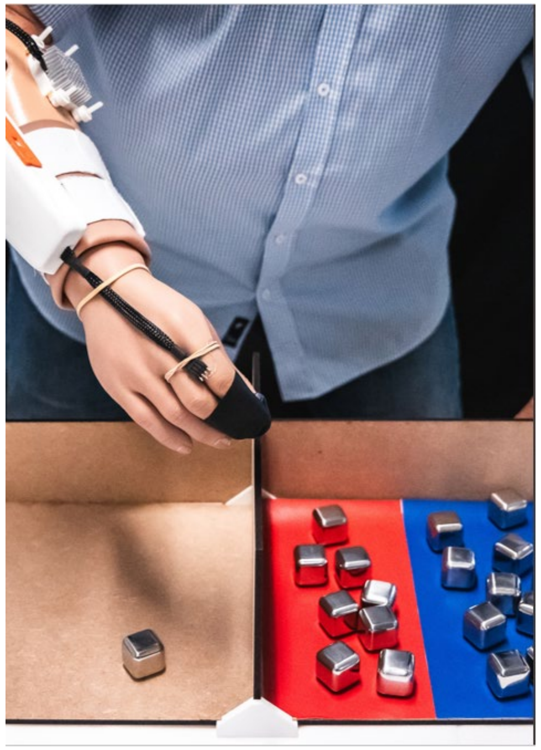
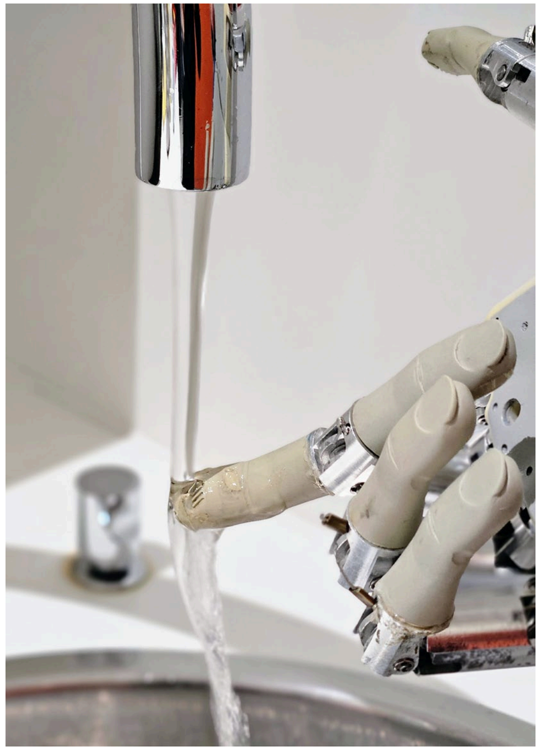

Dr Francesco Iberite

Dr Outman Akouissi

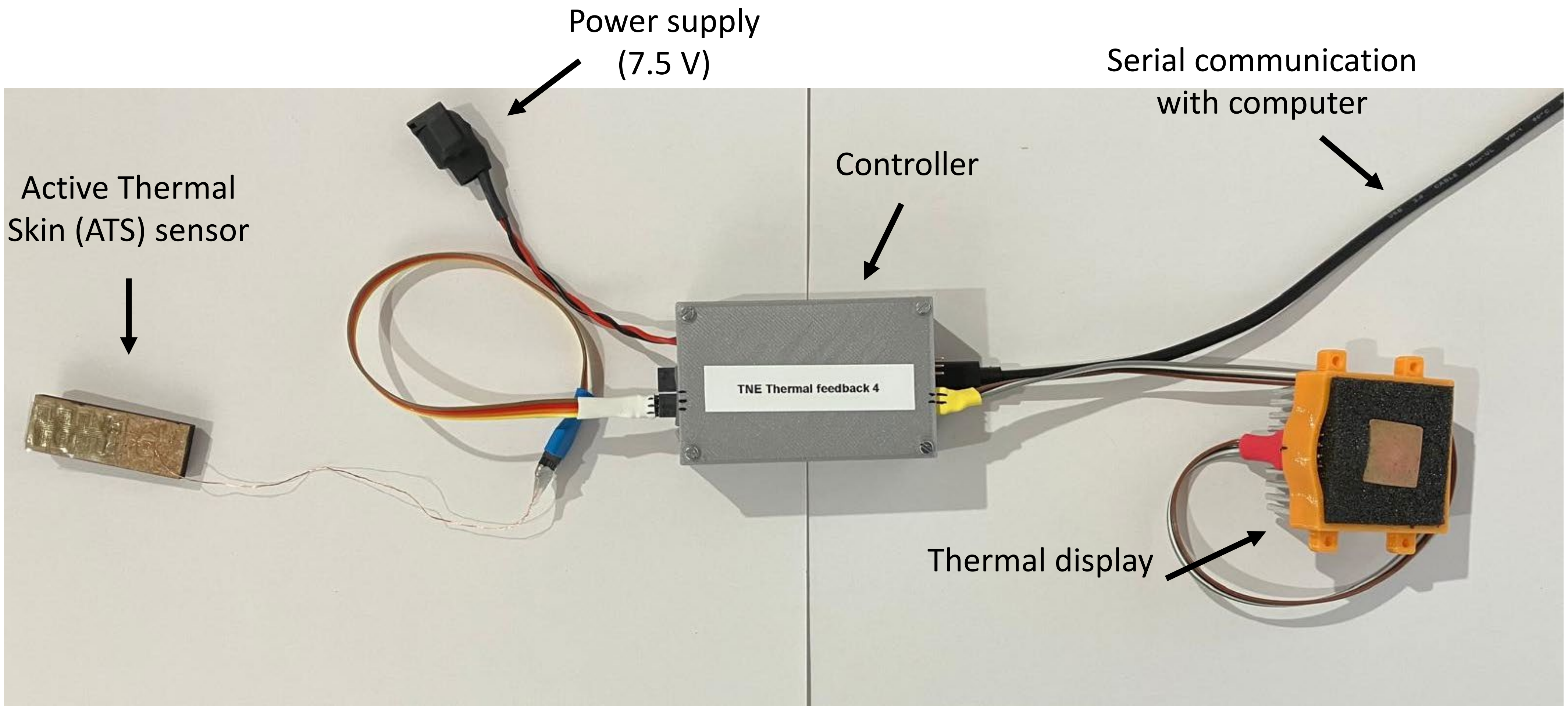



[Restoration of phantom thermal sensations in amputees]()

[Functional prosthesis integration]()

[Wetness perception]()

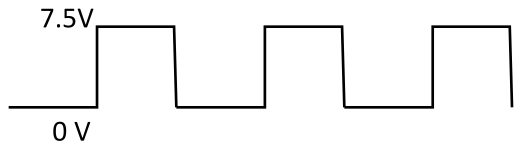
Hardware

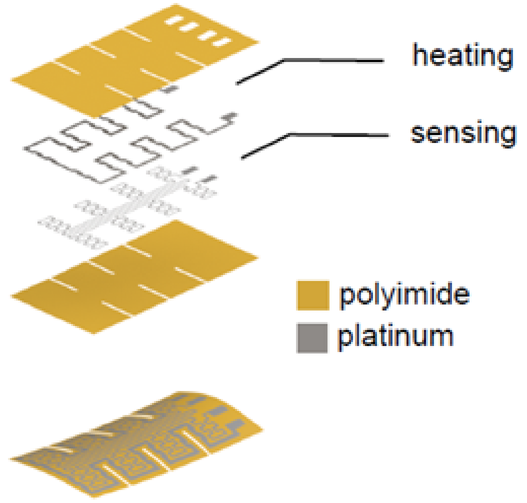


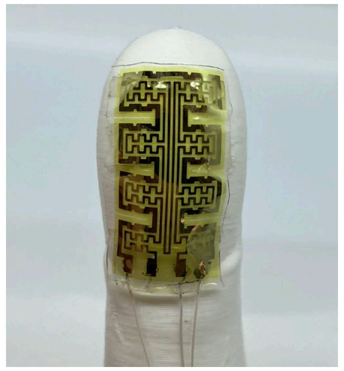
Take care of the hardware! The ATS sensor must be handled with caution

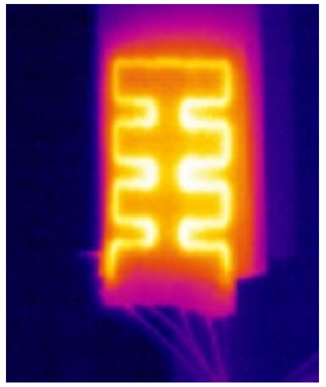
Hardware – ATS sensor

- The electronic skin is composed of 2 Pt tracks integrated into Polyimide
  - Heating track ($R_H \cong 300\ \Omega$)
  - Sensing track ($R_S \cong 1'000\ \Omega$)









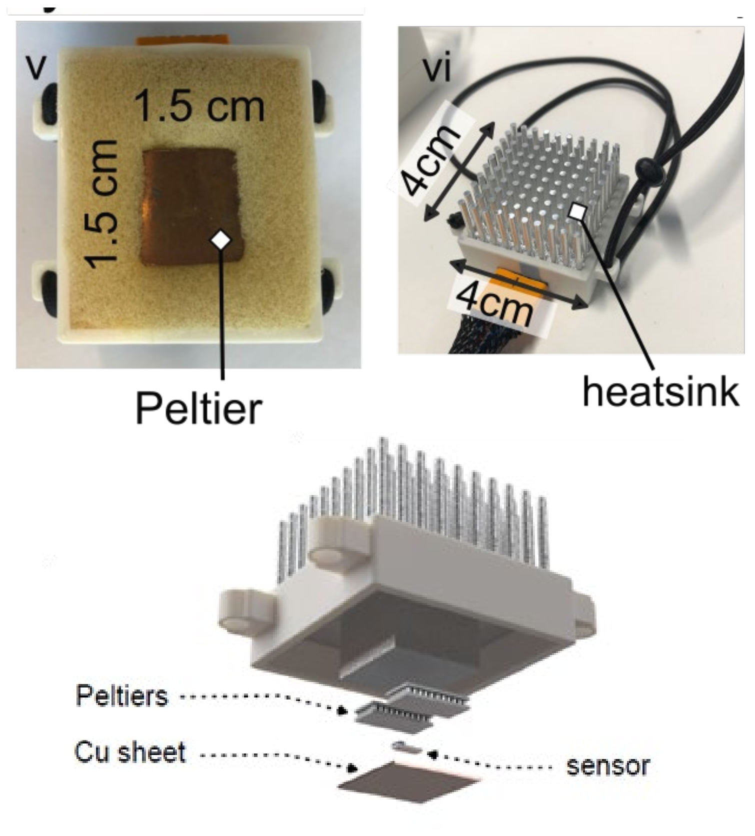
ATS: Active Thermal Skin sensor

Which track is thinner? Why?
How do you expect the resistance to change with temperature? (equation, order of magnitude)
What is the benefit of having an integrated heater?
What is the power dissipated in the heater?

Hardware – Thermal display

- The thermal display is composed of:
    - two Peltier cells connected in series
    - a temperature sensor (Pt1000)

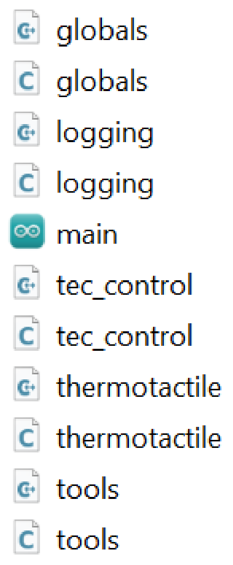
What is a Peltier module?
How can we control the delivered thermal stimuli?
Why do we need a heatsink?



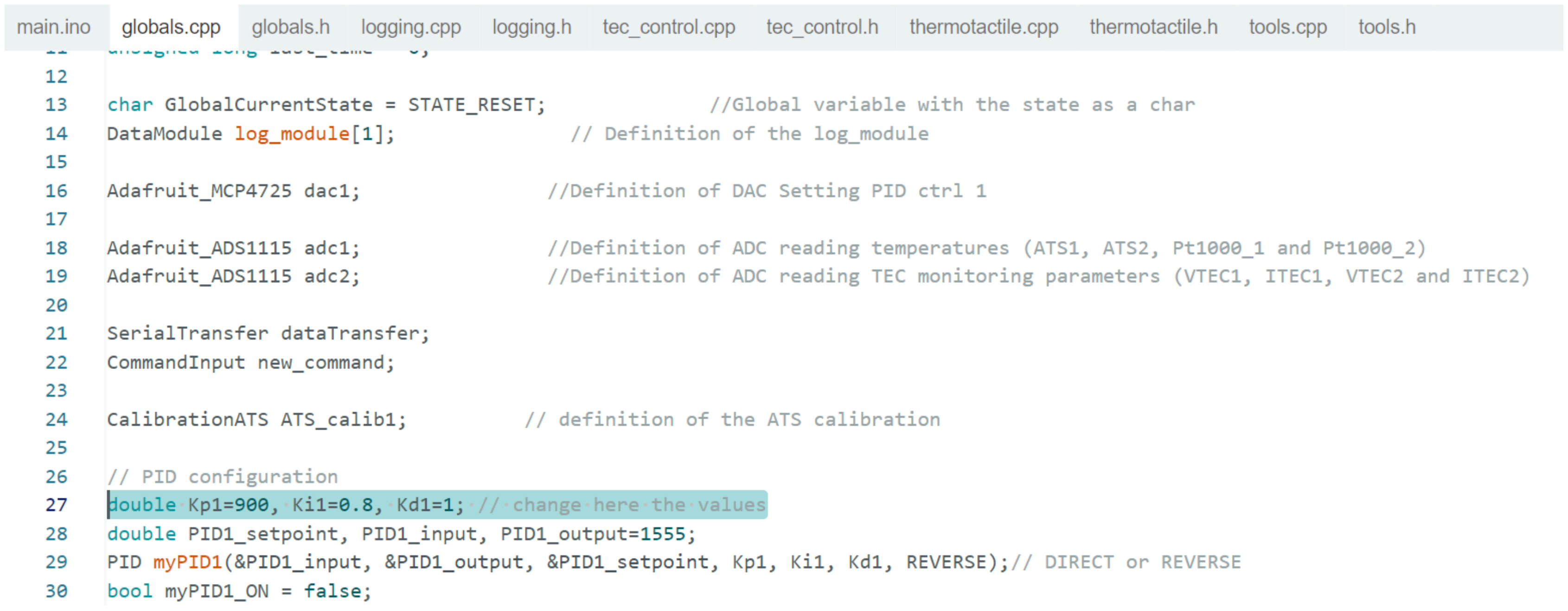
Thermal Display

Firmware

- Based on Arduino MKR Wifi 1010 microcontroller



globals
globals
logging
logging
main
tec_control
tec_control
thermotactile
thermotactile
tools
tools

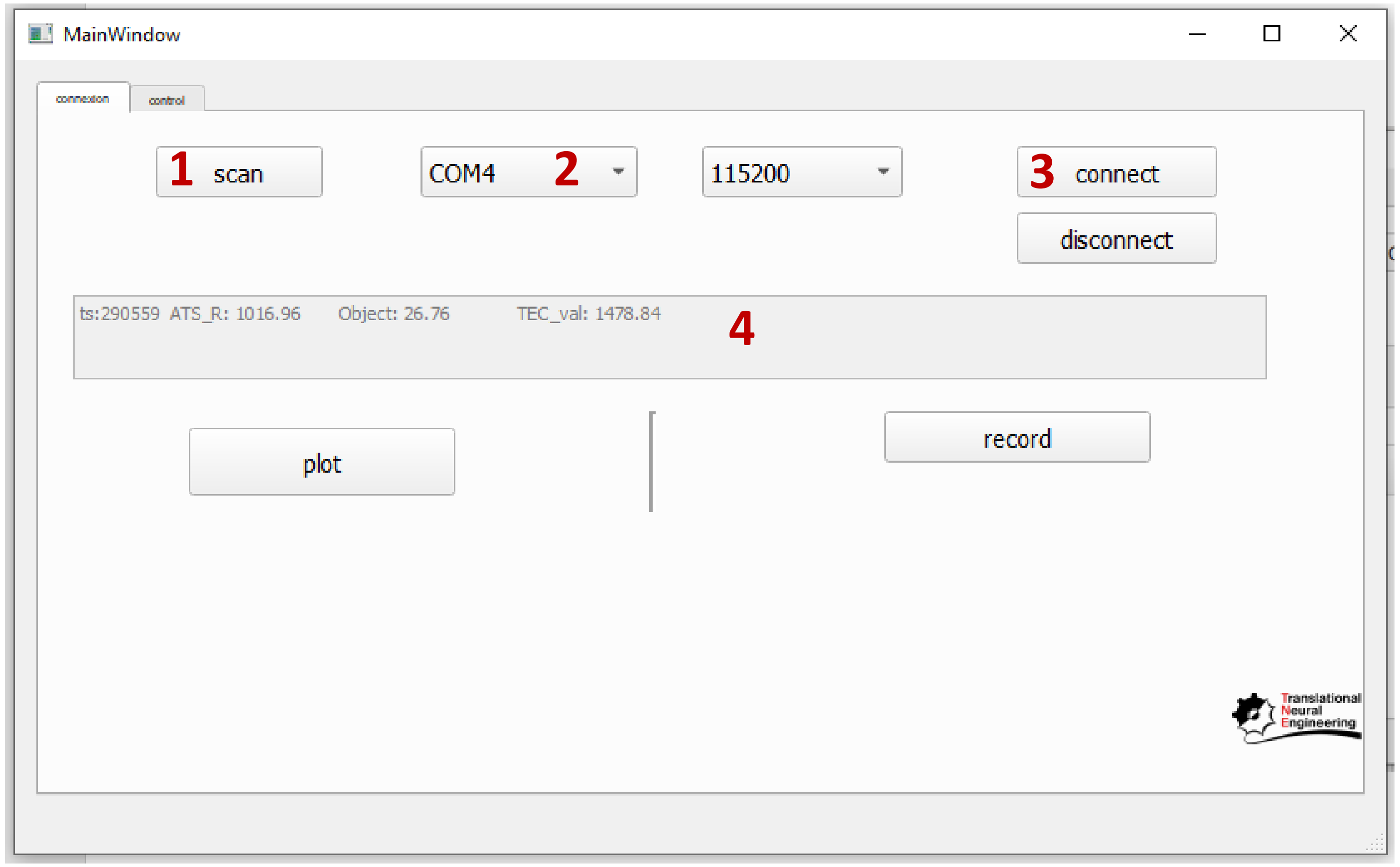


```

char GlobalCurrentState = STATE_RESET;              //Global variable with the state as a char
DataModule log_module[1];                     // Definition of the log_module

Adafruit_MCP4725 dac1;                      //Definition of DAC Setting PID ctrl 1

Adafruit_ADS1115 adc1;                      //Definition of ADC reading temperatures (ATS1, ATS2, Pt1000_1 and Pt1000_2)
Adafruit_ADS1115 adc2;                      //Definition of ADC reading TEC monitoring parameters (VTEC1, ITEC1, VTEC2 and ITEC2)

SerialTransfer dataTransfer;
CommandInput new_command;

CalibrationATS ATS_calib1;          // definition of the ATS calibration

// PID configuration
double Kp1=900, Ki1=0.8, Kd1=1; // change here the values
double PID1_setpoint, PID1_input, PID1_output=1555;
PID myPID1(&PID1_input, &PID1_output, &PID1_setpoint, Kp1, Ki1, Kd1, REVERSE);// DIRECT or REVERSE
bool myPID1_ON = false;
```

In principle, you should be able to do the project without modifying the Arduino code **except for the PID tuning phase**

Software

- Built with PyQT



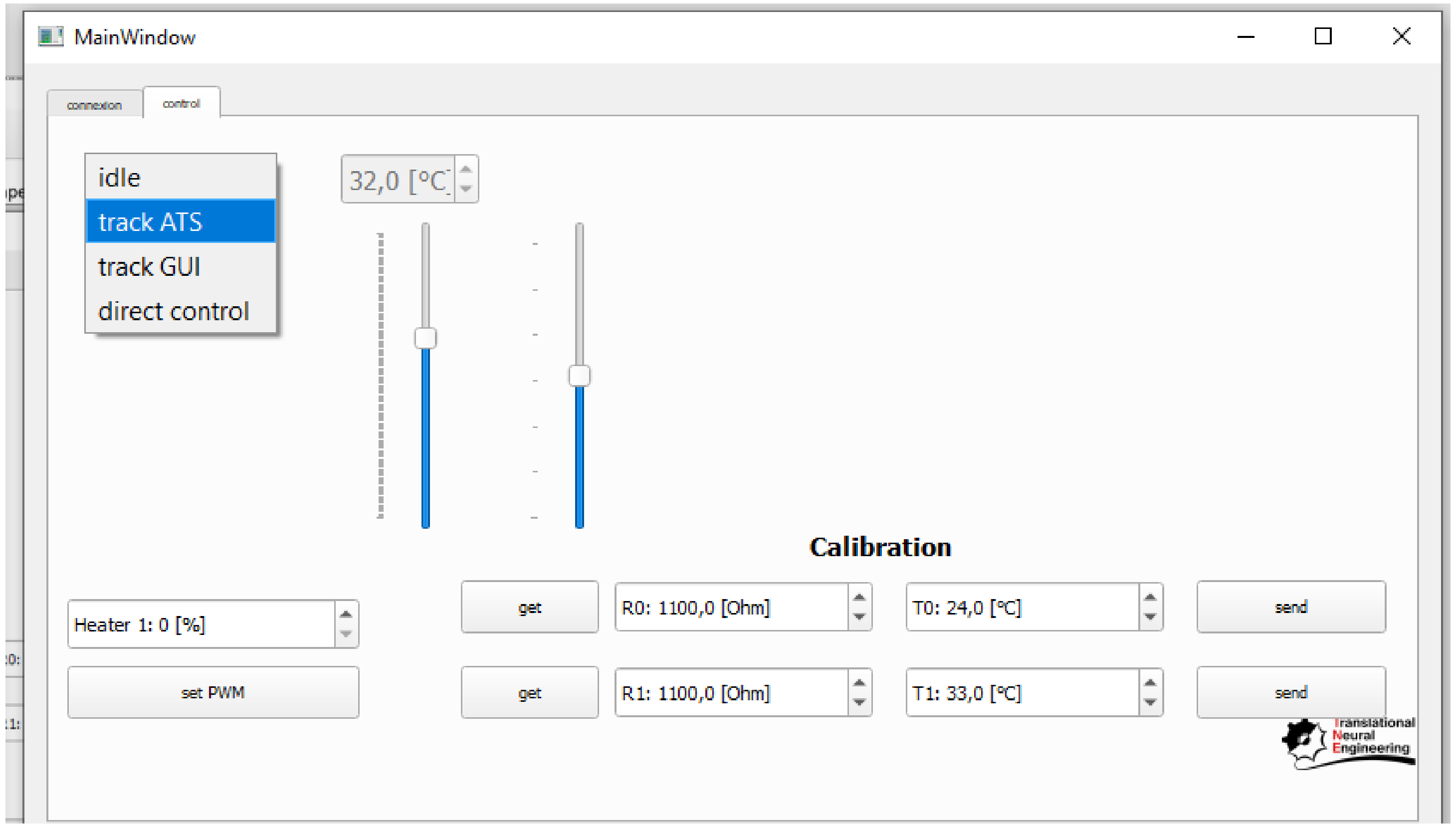
ts:290559 ATS_R: 1016.96 Object: 26.76 TEC_val: 1478.84

1. Scan for available ports
2. Select the port corresponding to the MiniTouch
3. Press the connect button
4. Verify that the data displayed is updating

Press the disconnect button to close the serial port!

ts= timestamp [ms]
ATS_R = Resistance of the ATS sensor [Ohm]
Object = thermal display [°C]
TEC_val = control value to the TEC controller [-]

Software


MainWindow

connexion | control

32,0 [°C]

Calibration

Heater 1: 0 [%]

R0: 1100,0 [Ohm]

T0: 24,0 [°C]

R1: 1100,0 [Ohm]

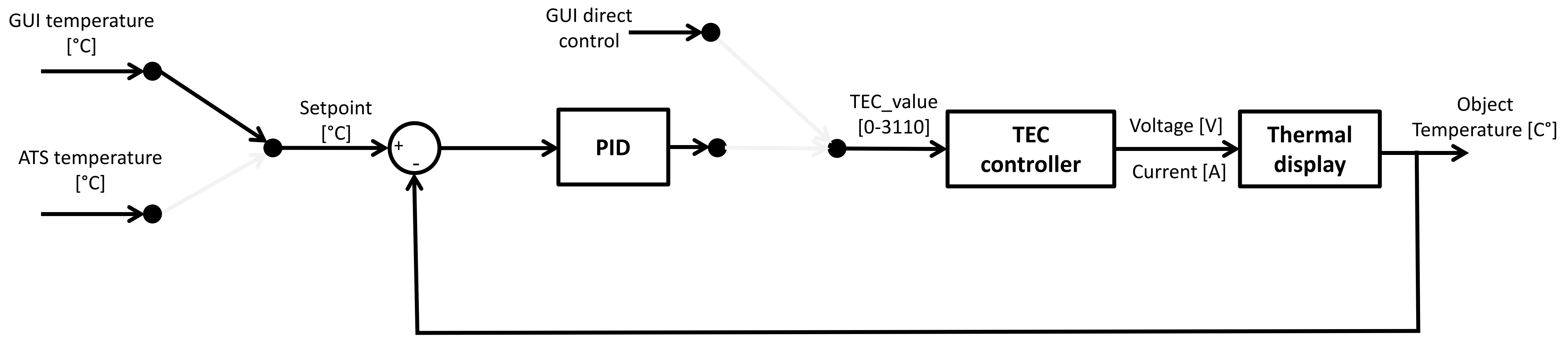
T1: 33,0 [°C]

The MiniTouch has 4 control modes:

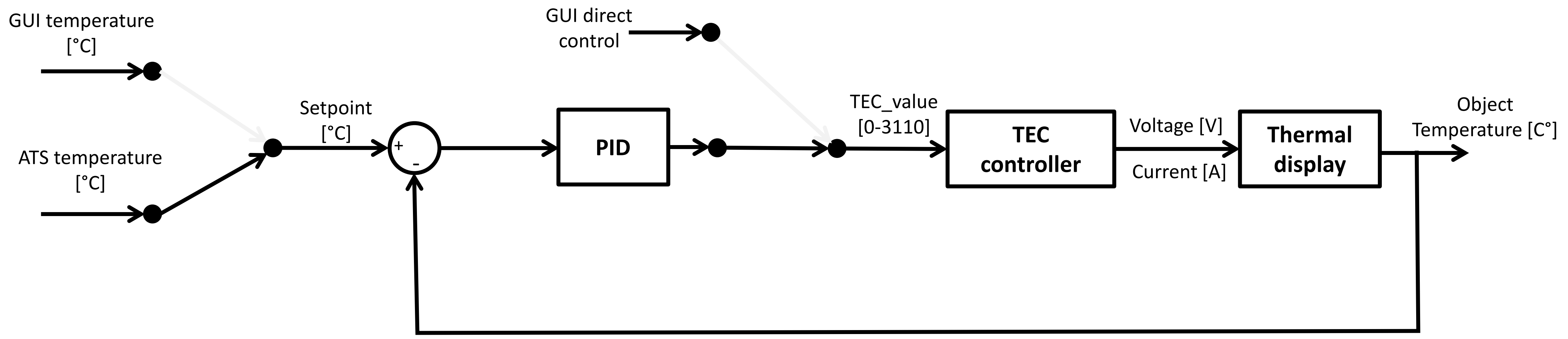
- Idle: the thermal display is disabled
- Track ATS: the temperature measured by the ATS is used as the setpoint
- Track GUI: the vertical slider on the GUI is used as the setpoint
- Direct control: the vertical slider drives directly the Peltier inputs

To pass from one mode to another, you need to go back to « idle »
Careful, in direct control mode, the thermal display can get dangerously hot (above 42°C and below 15°C)

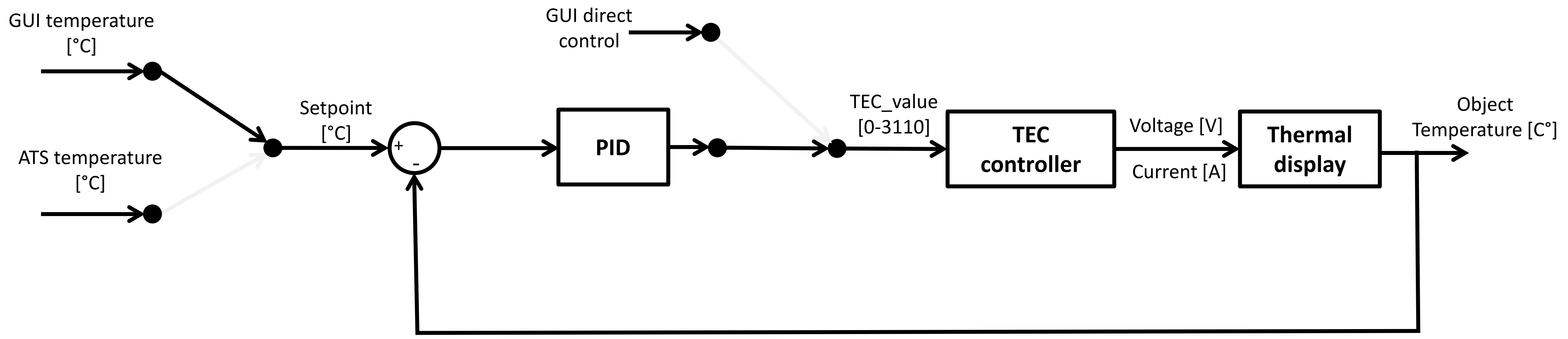
Control modes - **idle**



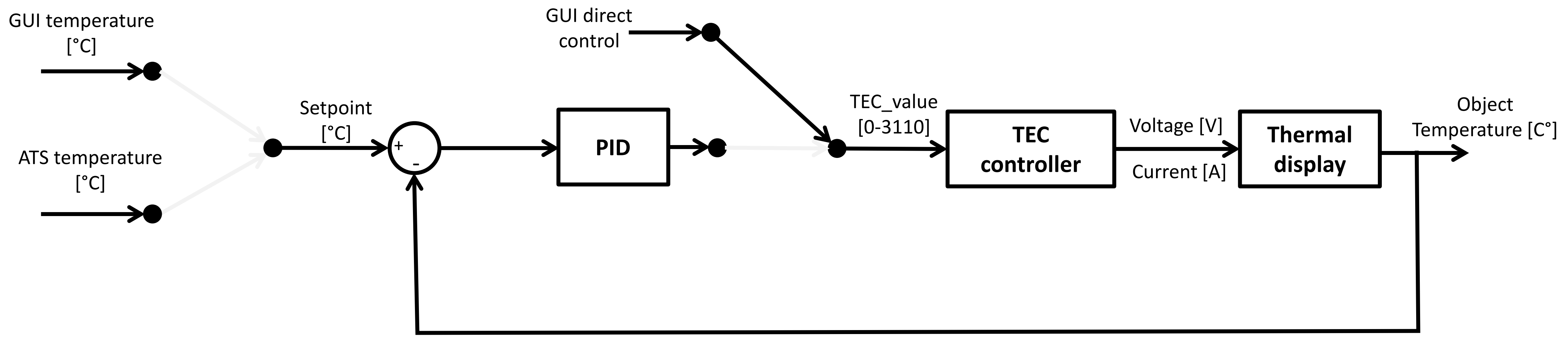
Control modes – **track ATS**



Control modes – **track GUI**



Control modes – **direct control**



Setting up

- Install the Arduino IDE
  - Install the SAMD board package (Tools > Boards > Boards Manager…)
  - Install the following libraries (Tools > Manage libraries…):
  - Adafruit_ADS1X15
  - Adafruit_MCP4725
  - FlashStorage
  - PID (by Brett Beauregard)
  - SerialTransfer

- Select the Arduino MKR Wifi 1010 board and verify the provided code
- Upload the code on your MiniTouch

Step 0 - Getting started

Not expected in the report

- Run the MiniTouch_app and connect to your device
- Use the different control modes of the MiniTouch
  - What do they correspond to?
  - Record about 2 minutes playing with the « track GUI » mode (in the full temperature range)
  - How is the file saved? (filename, file type)
  - Open the recorded file with Matlab (or python) and plot the setpoint temperature and the thermal display temperature over time.

Step 1 – Characterization of the ATS sensor

- Measure the resistance of the sensing track in contact with three object at different temperatures (heater *OFF*). Repeat the measurement 5 times for each temperature.
- Find the formula of the temperature T(R)
- Turn the heater ON (50%). How does the temperature of the sensor change when it is left in the air (contact with nothing)?
- Characterize the stabilizing temperature as a function of the power dissipated.
- Define a constant power so that the sensor stabilizes at a human skin baseline temperature.
- What are the limitations of this approach? What external factors could influence the stabilizing temperature? How does the ATS sensor behaves compared to our skin?
- *BONUS*: implement a control routine on the Arduino to modulate the power dissipation in the heating track.

Step 2 – Tuning the PID controller

- Change the PID parameters (Arduino code) to obtain a good performance. What is a good performance?
- Decide of a test condition (initial temperature and step amplitude) to tune the PID parameters
- Does the controller behaves the same way for cooling down and heating up? On different body parts? Why?
- Characterize the controller performance (rise time, max heating/cooling rate, overshoot…)
- How could the controller be further improved?

Make sure to have the thermal display mounted on the skin for this!

Step 3 – Functional validation of your implementation

- Using the MiniTouch in the *track ATS* mode perform a discrimination task (different materials, glasses at different temperature, wetness, …) to validate your implementation. Compare the performance you can achieve mediating the stimuli through the MiniTouch and with direct contact on your skin.

Step 4 – Psychophysical tests

- Propose and run a psychophysical test (cold versus warm detection thresholds, temperature thresholds on different body parts, JND from different baseline temperatures or any other psychophysical test you decide)
- Each group must run a different test