Setup of a cooling system in the production of new pixel modules for the HL-LHC ATLAS experiment

2022/12/22 (Thu)

Aoki Lab and Yamanaka Lab Joint Year-end Meeting

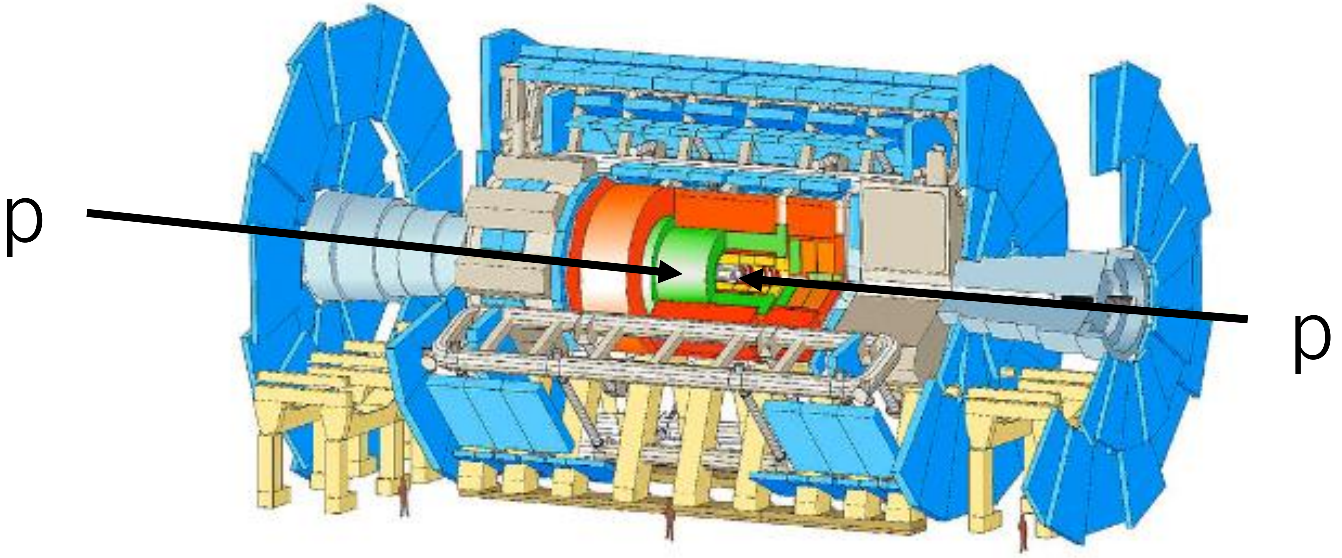
Yamanaka Group

M1 Rikuto Arakida

ATLAS experiment

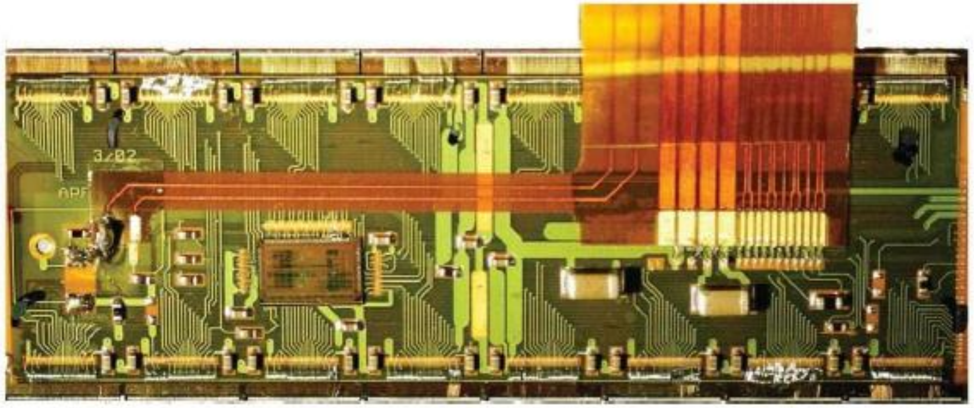
- Proton-proton (p-p) collisions:
  - Center-of-mass energy: $\sqrt{s} = 13.6\ \mathrm{TeV}$ (2022)
  - Peak luminosity: $2 \times 10^{34}\ \mathrm{cm^{-1}s^{-1}}$
  - Bunch crossing rate: $40\ \mathrm{MHz}$
- Study Higgs properties
- New particle search

ATLAS detector

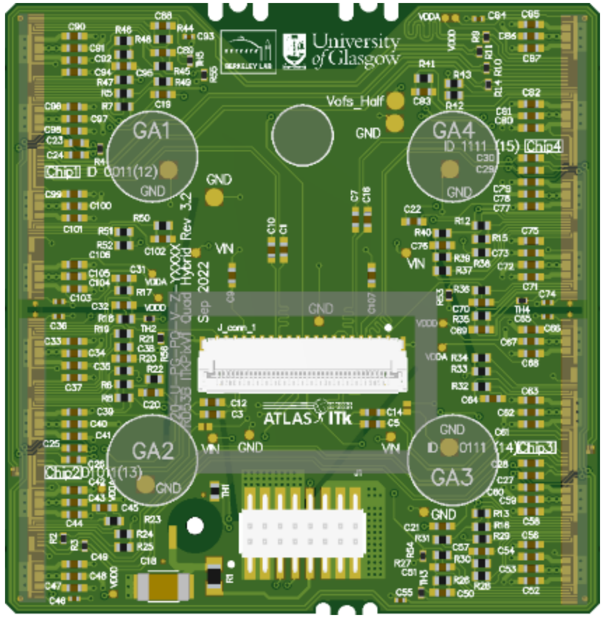


HL-LHC ATLAS experiment

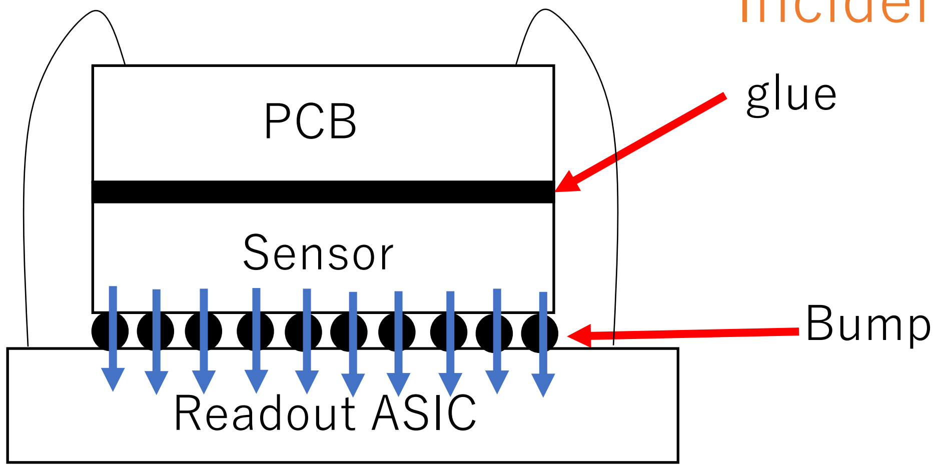
- Planned to be operational from 2029
- Peak luminosity : $\times 5 - 7$
  → Higher rate of secondaries
  → Severe radiation damage on detectors
  → Upgrade of the inner tracker

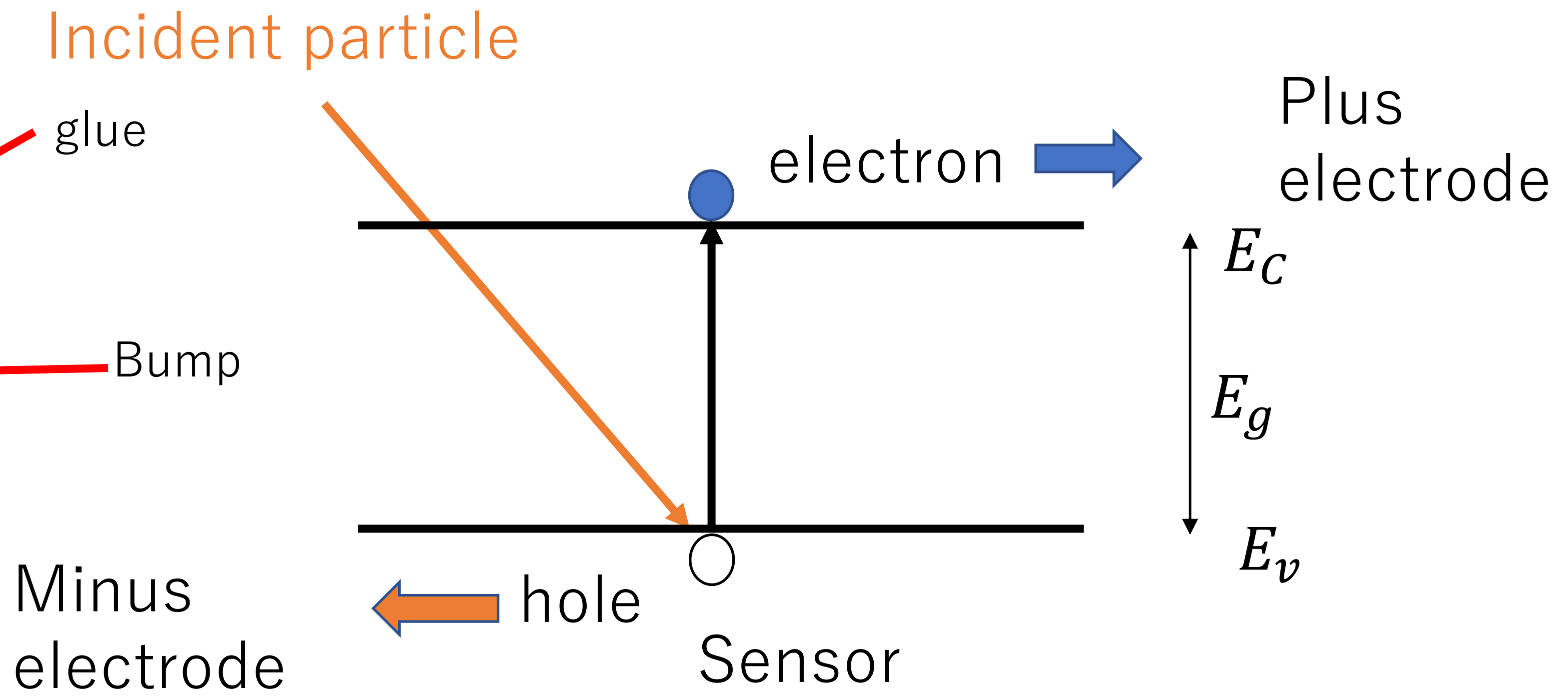


Upgrade!



Silicon pixel module

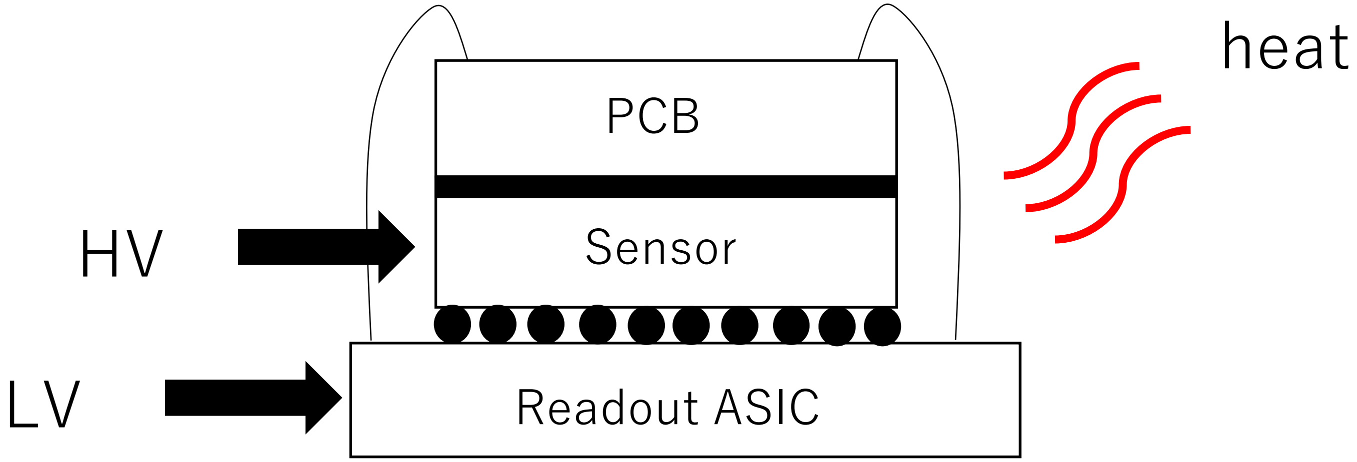




Generated electrons are sent to the readout ASIC through bumps

QA/QC test in the production of new pixel modules

Tests:
- **Visual inspection**
- **Electrical test**

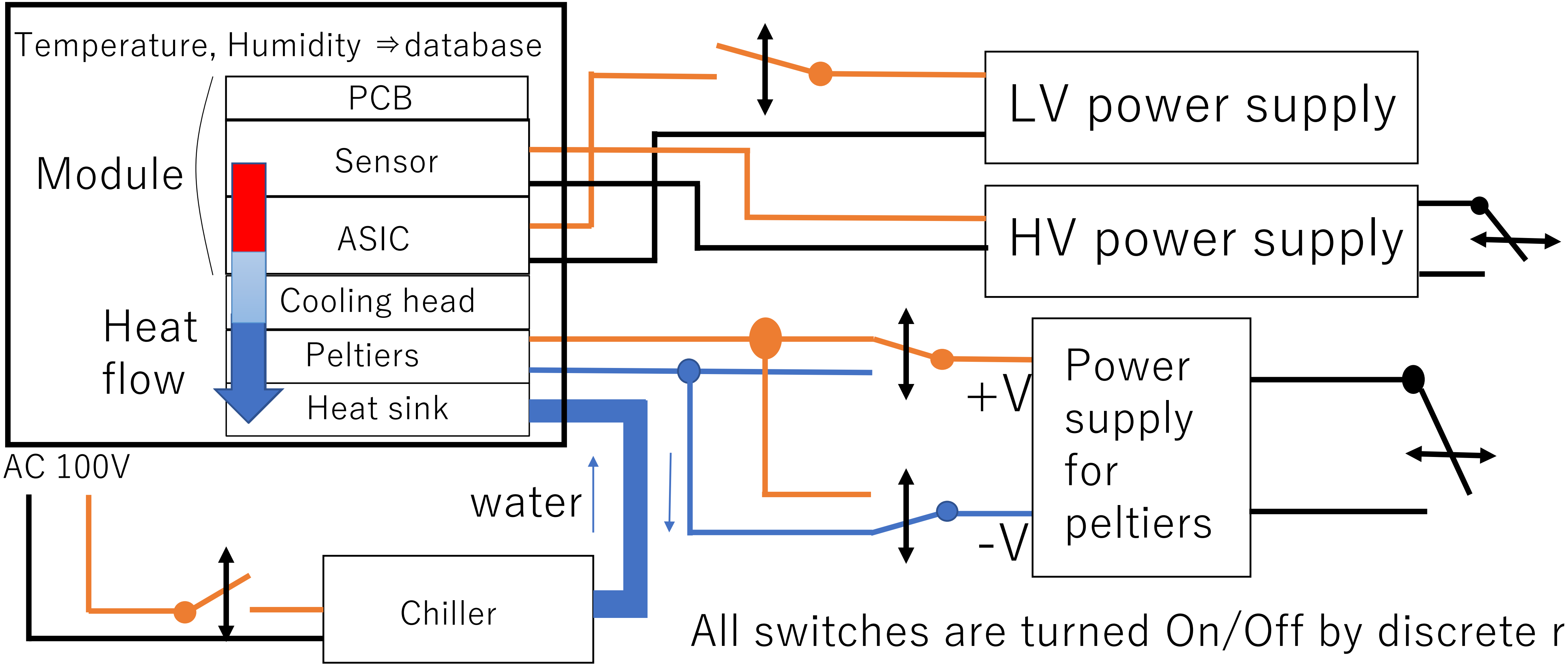


- Heat generated from the module should be evacuated

- Condensation could lead damage on the module

→ need to set up a system for cooling and sending avid air to module (my work)

Schematic picture of the system



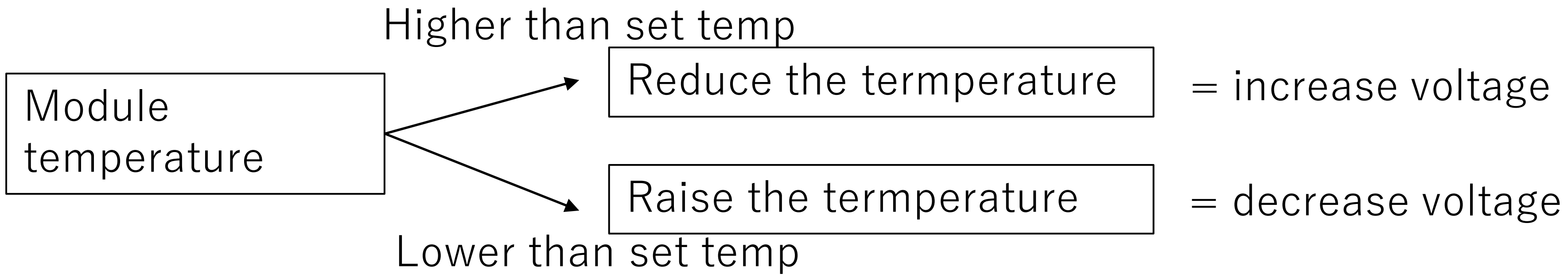
All switches are turned On/Off by discrete relays

Design of the system was derived by J.Hashimoto @ Tokyo-tech

Cooling principle and PID control of Peltiers

1. Read module temperature using Arduino
2. Operate PID control
   ⇒ determine voltage applied to peltiers
3. Module temperature are regulated

Firmware for Arduino was provided by H.Oide @ KEK



Current status of the Cooling Box at Osaka

I've finished 80% of all tasks for the setup of the system

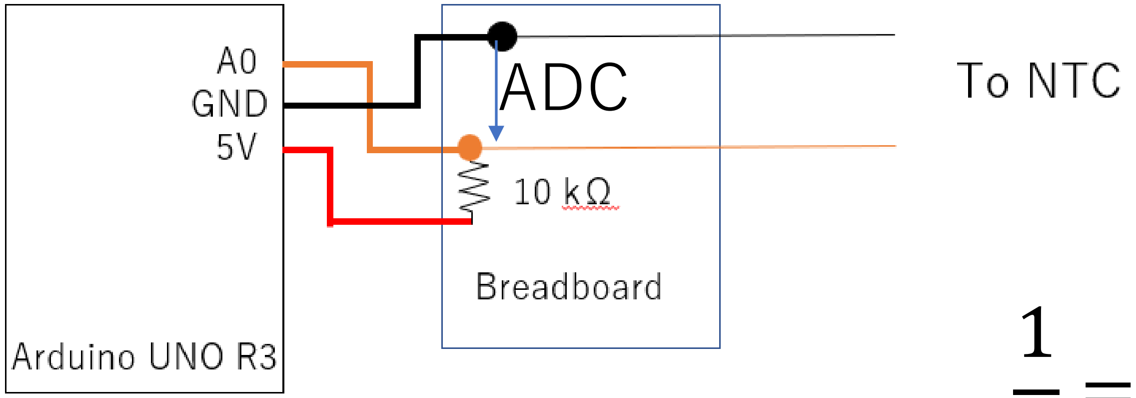
Done:

- Wiring
- Temperature measurement
- Humidity measurement
- Relay operation

To do next:

- Upload data to database
- Test PID control of Peltiers' voltage to control module temperature

Temperature readout using Arduino



NTC resistance R(T):

$$R(T) = 10\ k\Omega\ \times \frac{\text{ADC}}{1024 - \text{ADC}}$$

$$\frac{1}{T} = \frac{1}{298.15} + \frac{1}{B} \times \ln\left(\frac{R(T)}{R(T = 25℃)}\right)$$

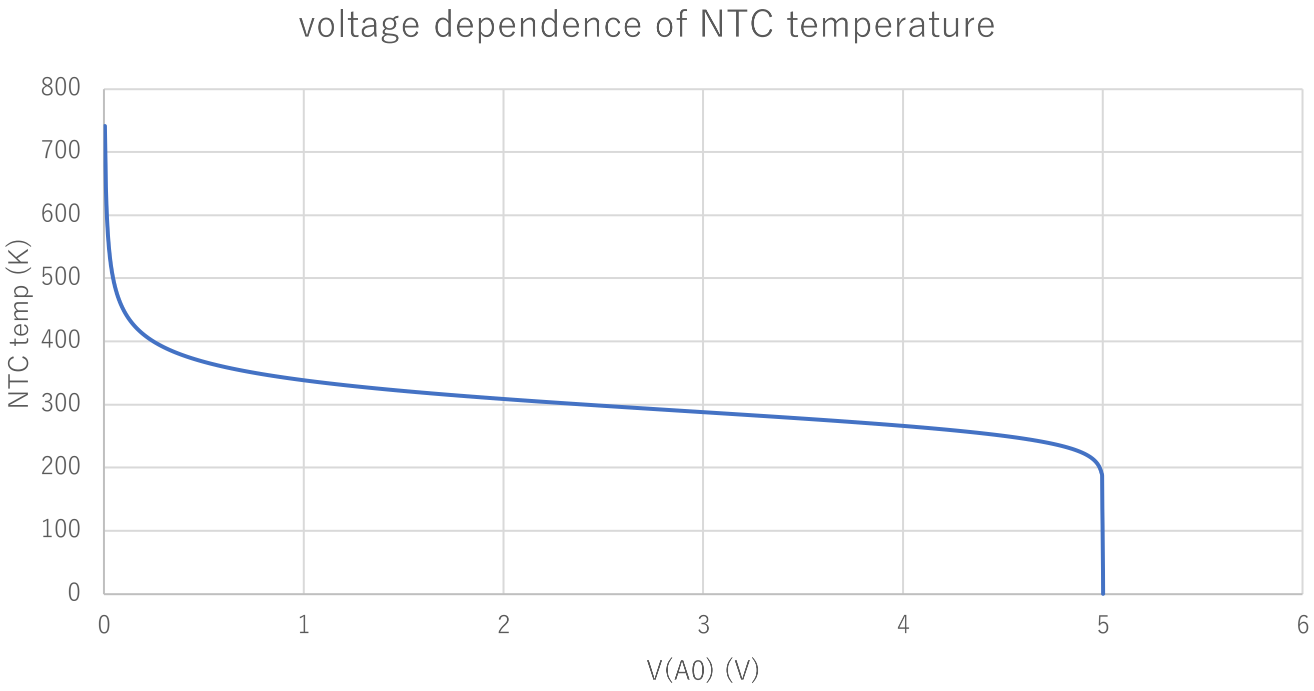
Spec:

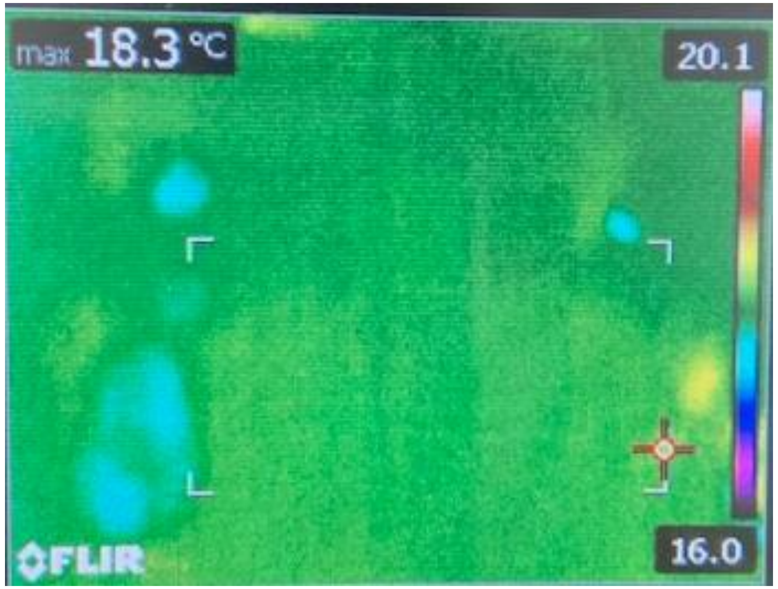
ADC resolution: 5V/1024

R(T=25°C)=10 kΩ

B=3455

Temperature resolution corresponding to the ADC resolution is about 0.1 °C near the room temperature 25°C





Thermo-camera

Message (Enter to send message to 'Arduino Mega or Mega 2560' on 'COM3')

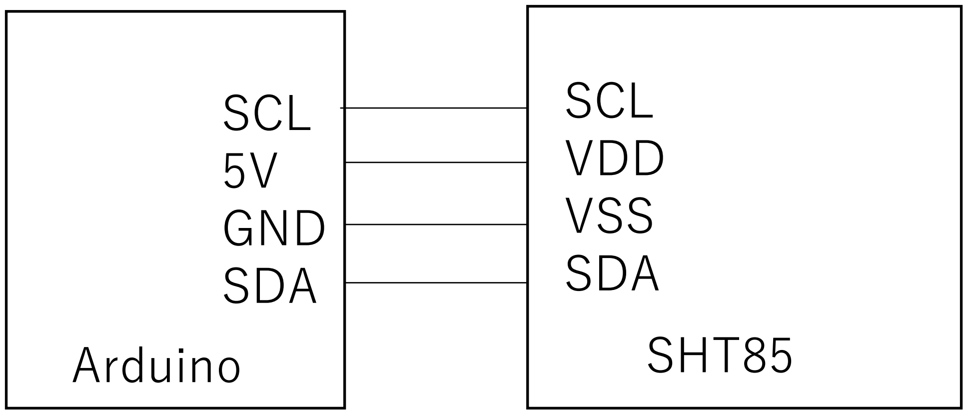
NTCResistance: 13.14 kΩ
18.13

Consistent with the range taken by a thermo-camera

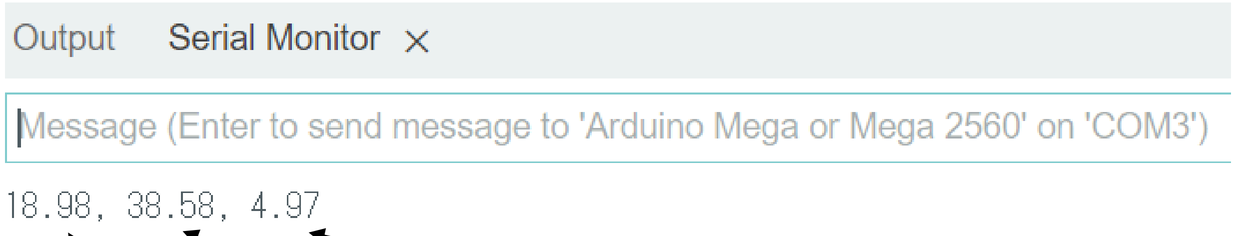
Humidity and Dew-Point readout

Sensirion_Humidity_Sensors_SHT85_Datasheet.pdf

Receive data output from SDA to measure temperature and humidity



Results on Serial Monitor



Temperature, Relative humidity, Dew point

℃ % %

Resolution: 0.01 °C 0.01 %

Relay’s performance

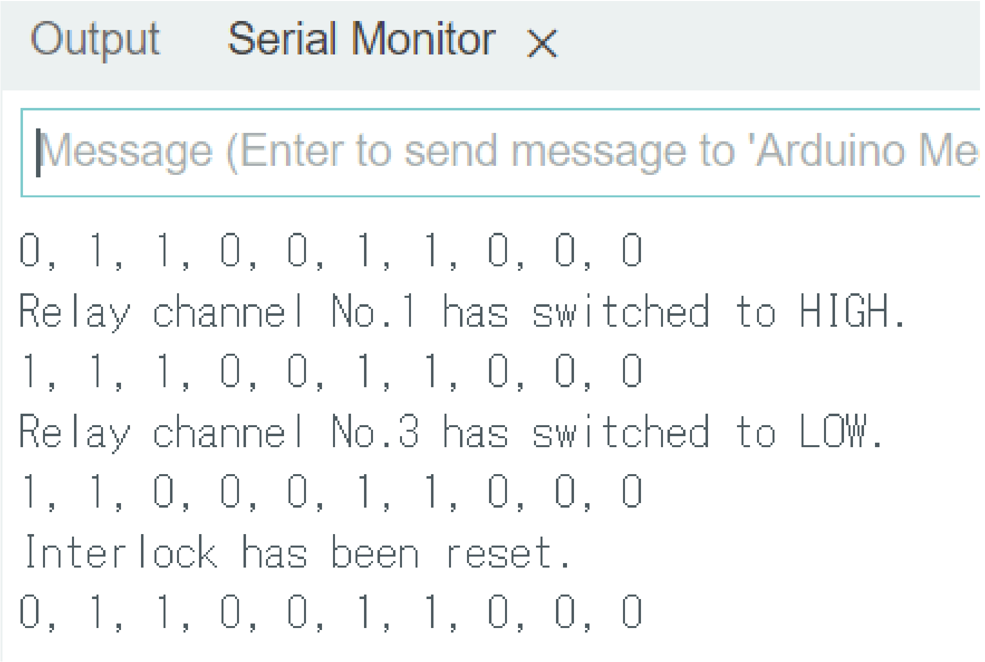
Checked the relay’s performance

Relay state

Arduino digital pin state

- 0 ⇒ off
- 1 ⇒ on

When a relay turns on, the associated LED glows



Summary and Future Plan

- Setup of the cooling box has been completed and the relays' performance, temperature and humidity readout are confirmed to be OK

- Try PID control of the peltiers and uploading temperature and humidity data to database

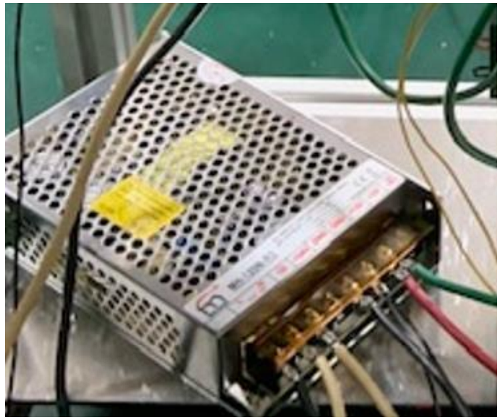
Backup

Power supply (PS)

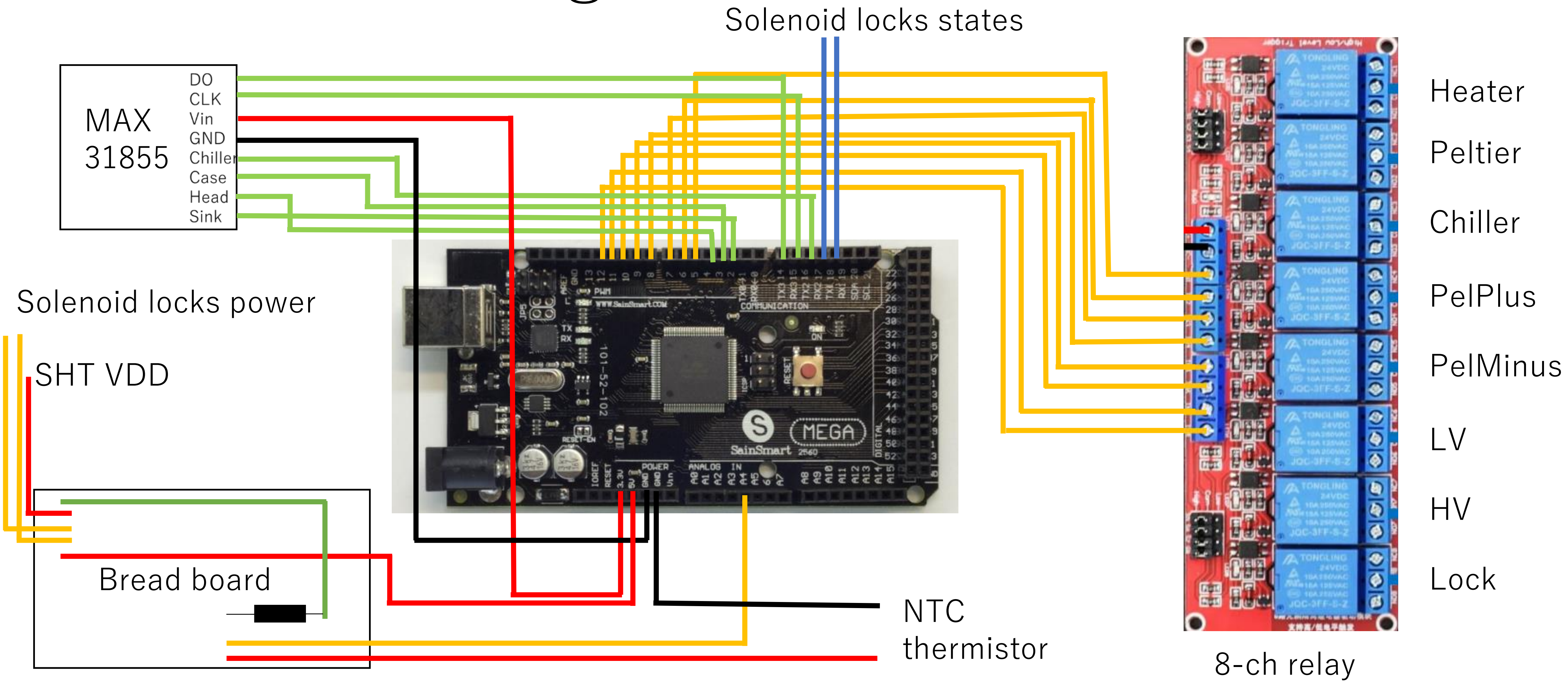
There are two PSs for 5VDC and 12VDC, respectively.

5VDC output: TEXIO PW18-1.3ATS (+6V, 5A)

12VDC output: MH-120N-R3 (+12V, 7A)



Detail of wiring around Arduino



Temperature readout accuracy

0.00, 18.00, 17.50, 18.00 0.00, 18.81, 18.19, 18.69

Consistent with the temperature range
taken by using a thermo-camera

Interlock conditions

- Module temperature (NTC temp) >= 40 °C
  - Measure:
    - 1. Turn off the LV → module temperature drops by about 15 K
    - 2. Turn off the peltiers →module temperature gradually approaches the chiller temperature
    - 3. Turn off the chiller→slowly approaches the room temperature

- Dew point > Module temperature – 2 °C
  - Measure:
    - 1. Turn off the peltiers→ module temperature gradually approaches the chiller temperature
    - 2. Turn off the chiller →slowly approaches the room temperature
    - 3. Turn off the LV

Temperature measurement using NTC thermistor

Principle

$$R(T) = R(T = 25℃)e^{B(\frac{1}{T} - \frac{1}{273.15+25})}$$

$$\Rightarrow \quad \frac{1}{T} = \frac{2}{298.15} + \frac{1}{B} \times \ln(\frac{R(T)}{R(T = 25℃)})$$

For NTC thermistor B57230V2103+260,

B=3455 (for 25/100)

R(T=25°C)=10 kΩ

By measuring the resistance of the NTC, we can obtain temperature