An I²C Control System for High Voltage Regulation of the APDs in the PANDA EMC Forward Endcap

PANDA Collaboration Meeting
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Presented by:
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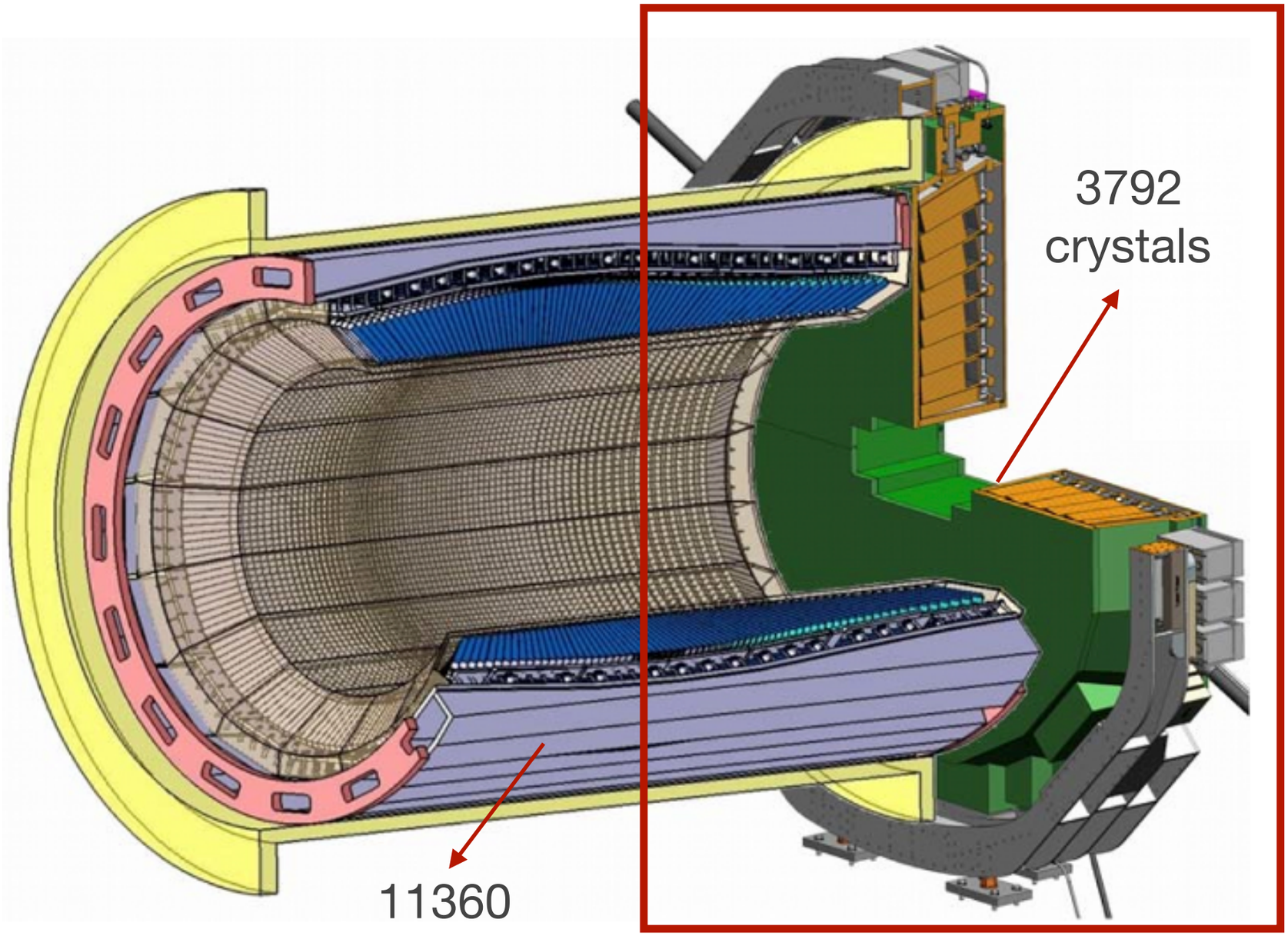
AG Thoma, Universität Bonn

Outline

- Introduction
- High Voltage Regulation for APDs
- I^2C Control System for High Voltage Regulation

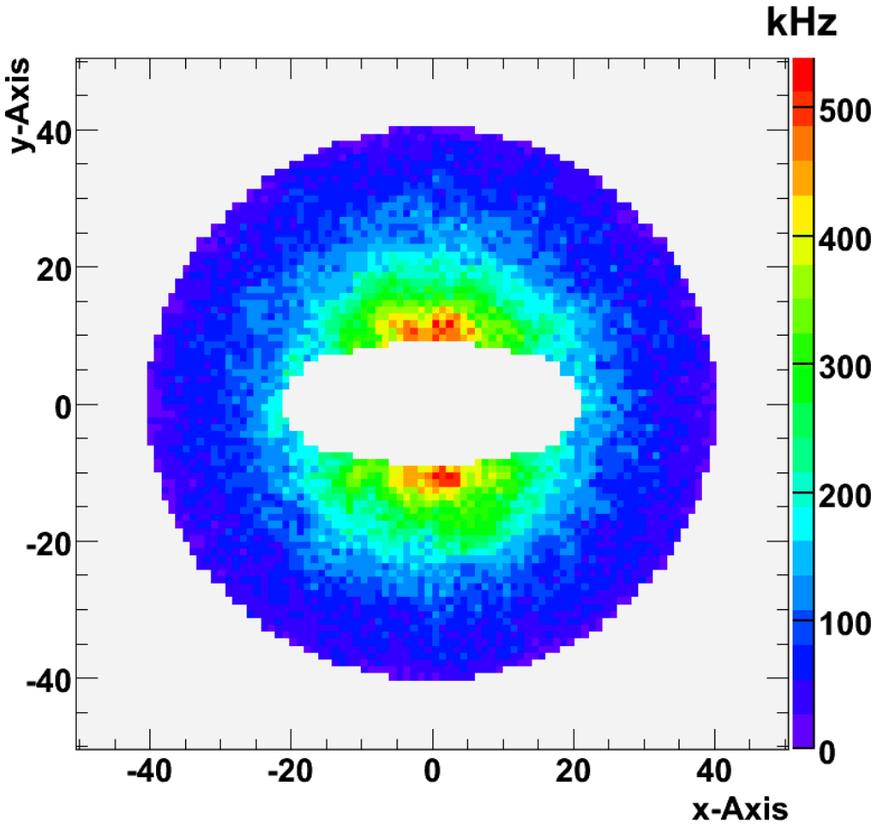
ElectroMagnetic Calorimeter (EMC)



In total: 15744 lead tungstate crystals

EMC Forward Endcap

Integrated single crystal rate for the forward endcap for an energy threshold of E>3 MeV at 15 GeV/c incident beam momentum.



- **In outer region**: event rate 10 kHz to 100 kHz expected.

- **In inner region**: event rate upto 500 kHz.

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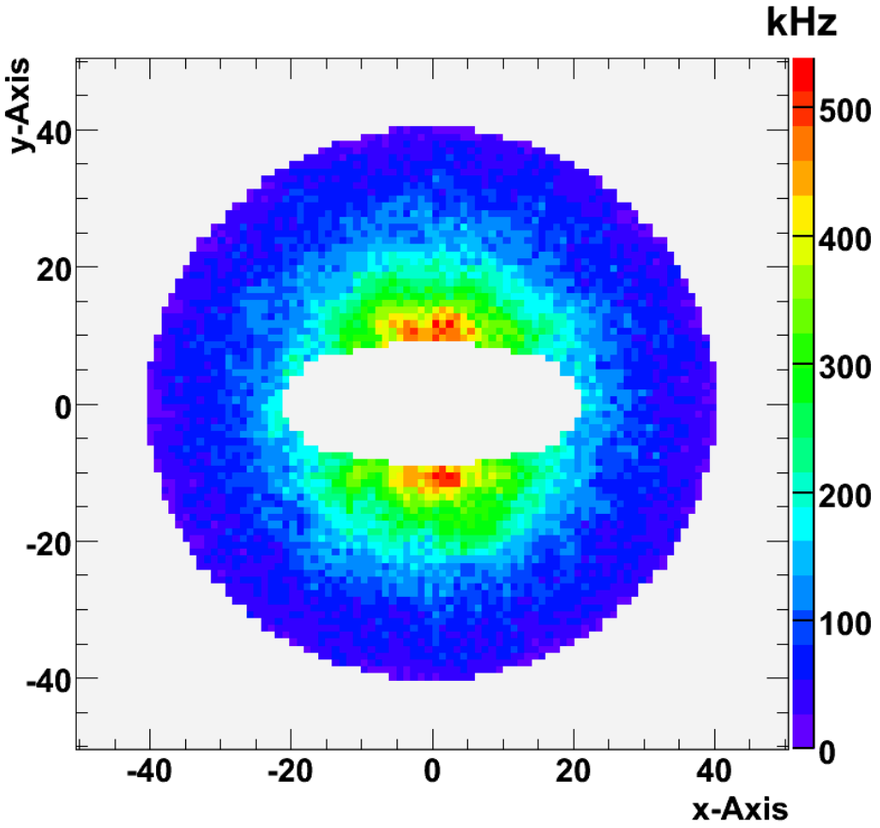
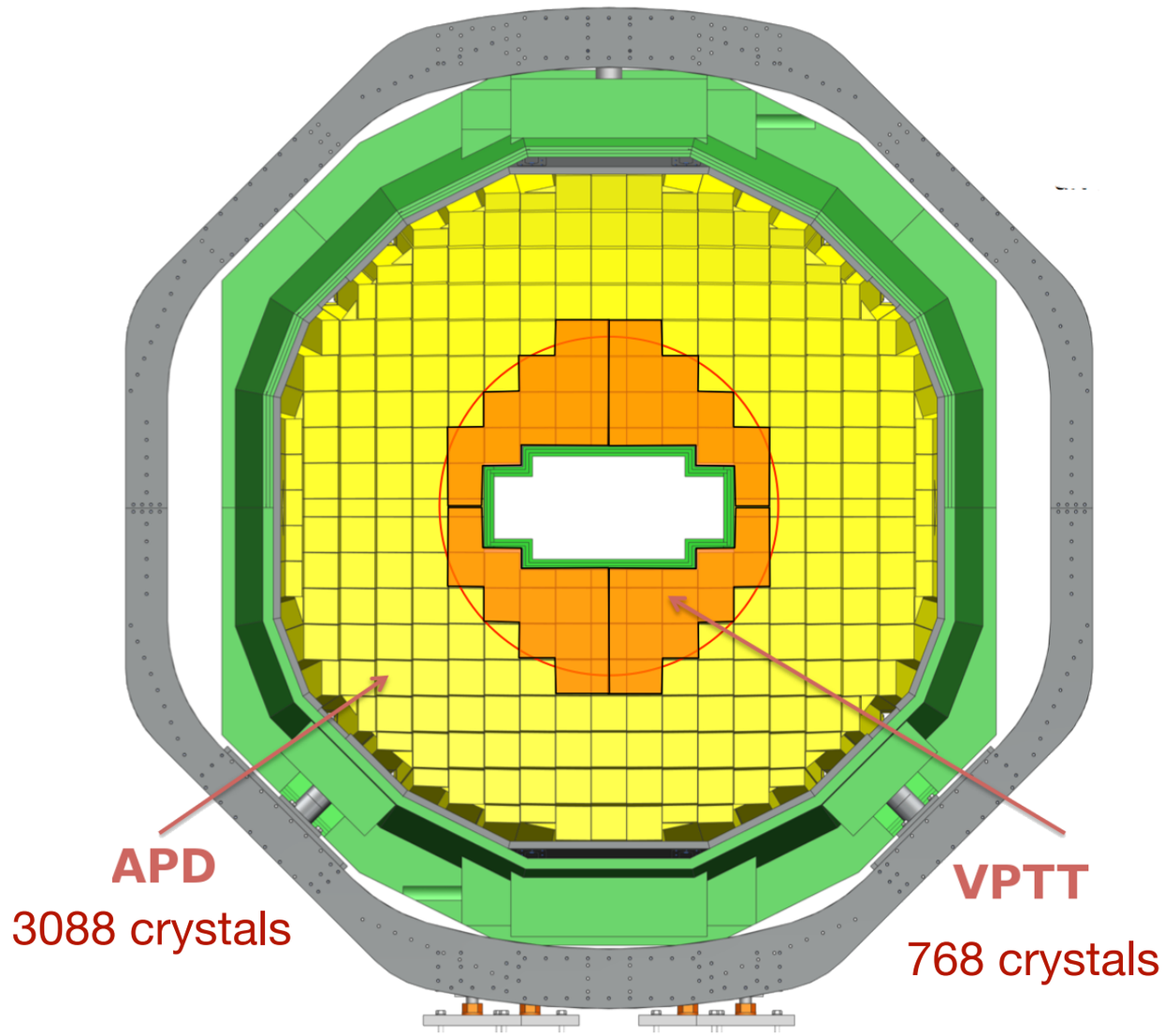
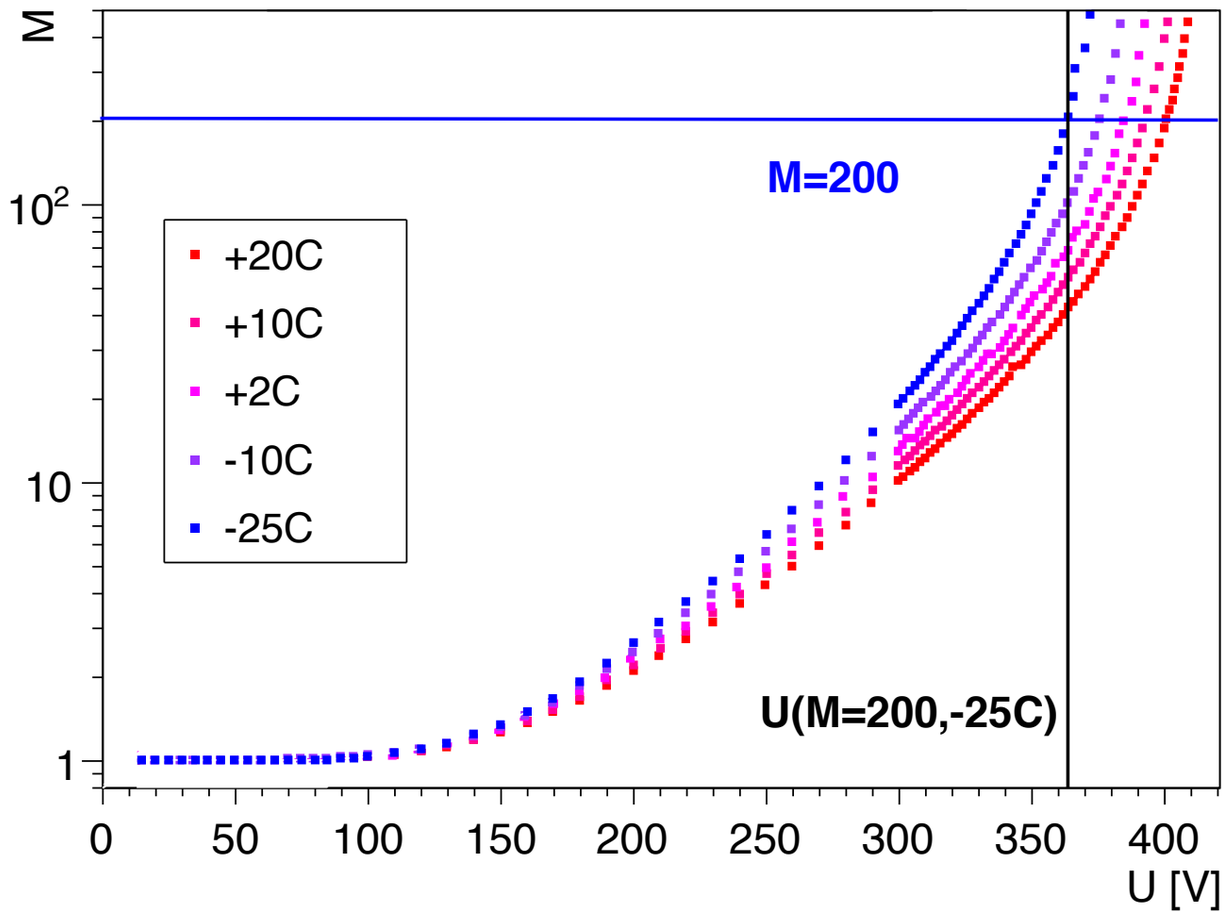


- **In outer region**: event rate 10 kHz to 100 kHz expected.
- **In inner region**: event rate upto 500 kHz.



Each crystal is equipped with 2 APDs.
→ 6176 APDs

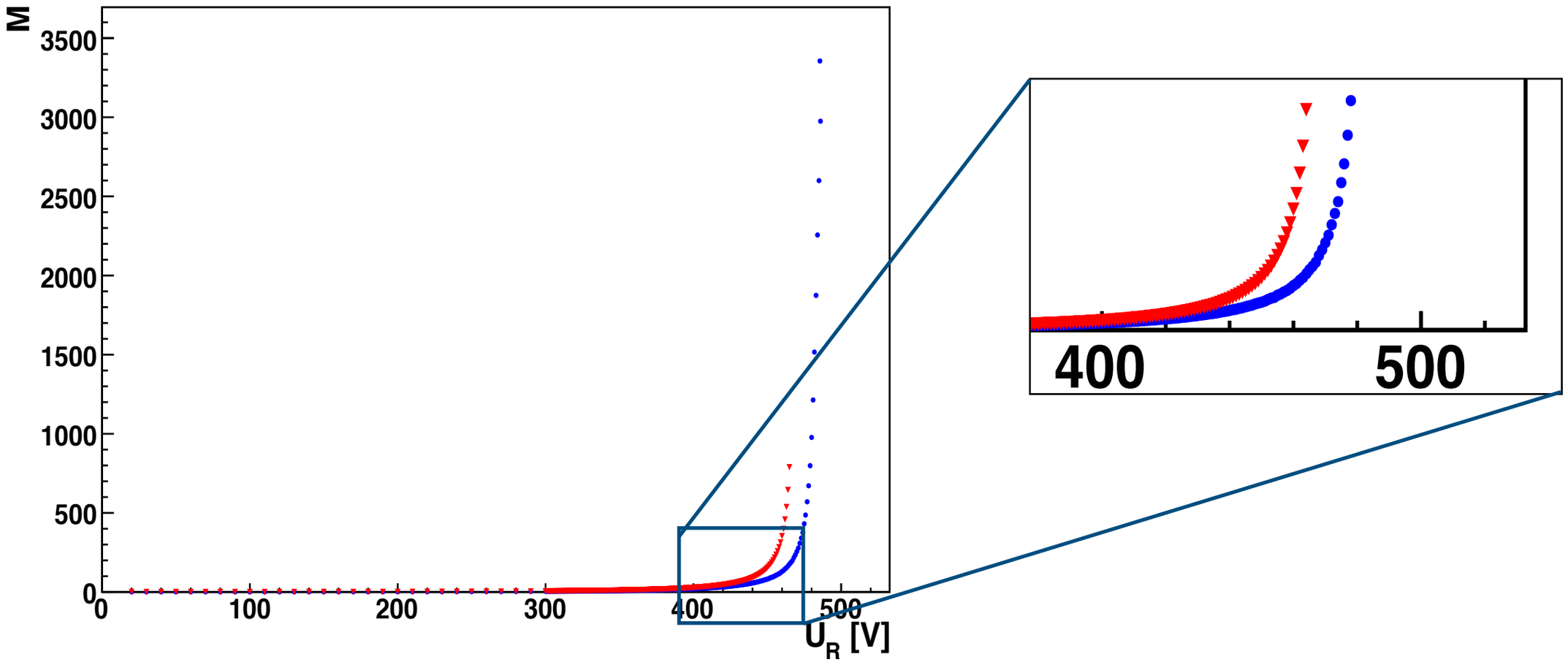
APDs



- APDs have internal gain mechanism and the gain (M) of APDs shows dependency on the temperature and the input high voltages.
- For constant gain M=200, high voltage of ~370 V required.

APDs

Determined gain values M of the APD before shown in blue and after shown in red exposure with a ^{60}Co source.



Radiation exposure causes shift in the high voltages of ~20 V for M=200.

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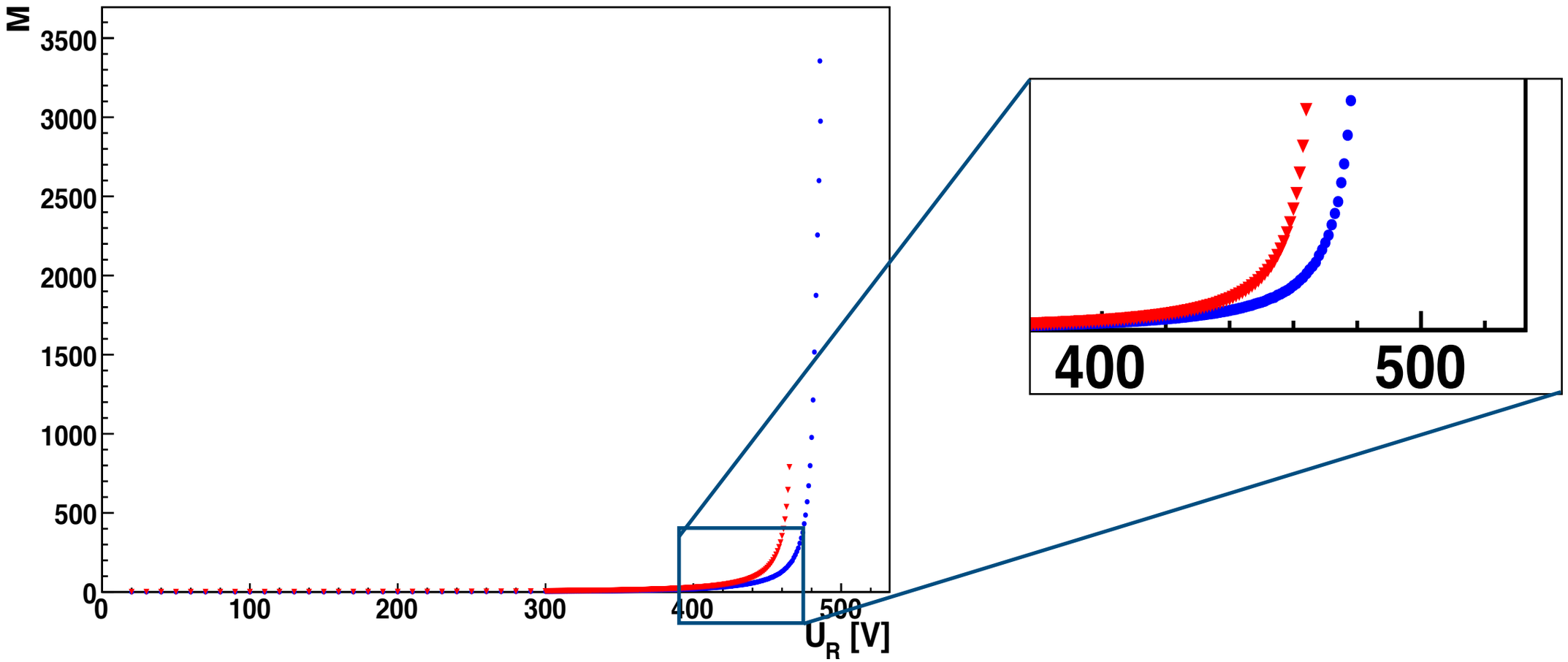

Radiation exposure causes shift in the high voltages of ~20 V for M=200.

For a constant gain, the high voltages need to be regulated!

High Voltage Regulation

6176 high voltage lines → Not feasible.

High Voltage Regulation

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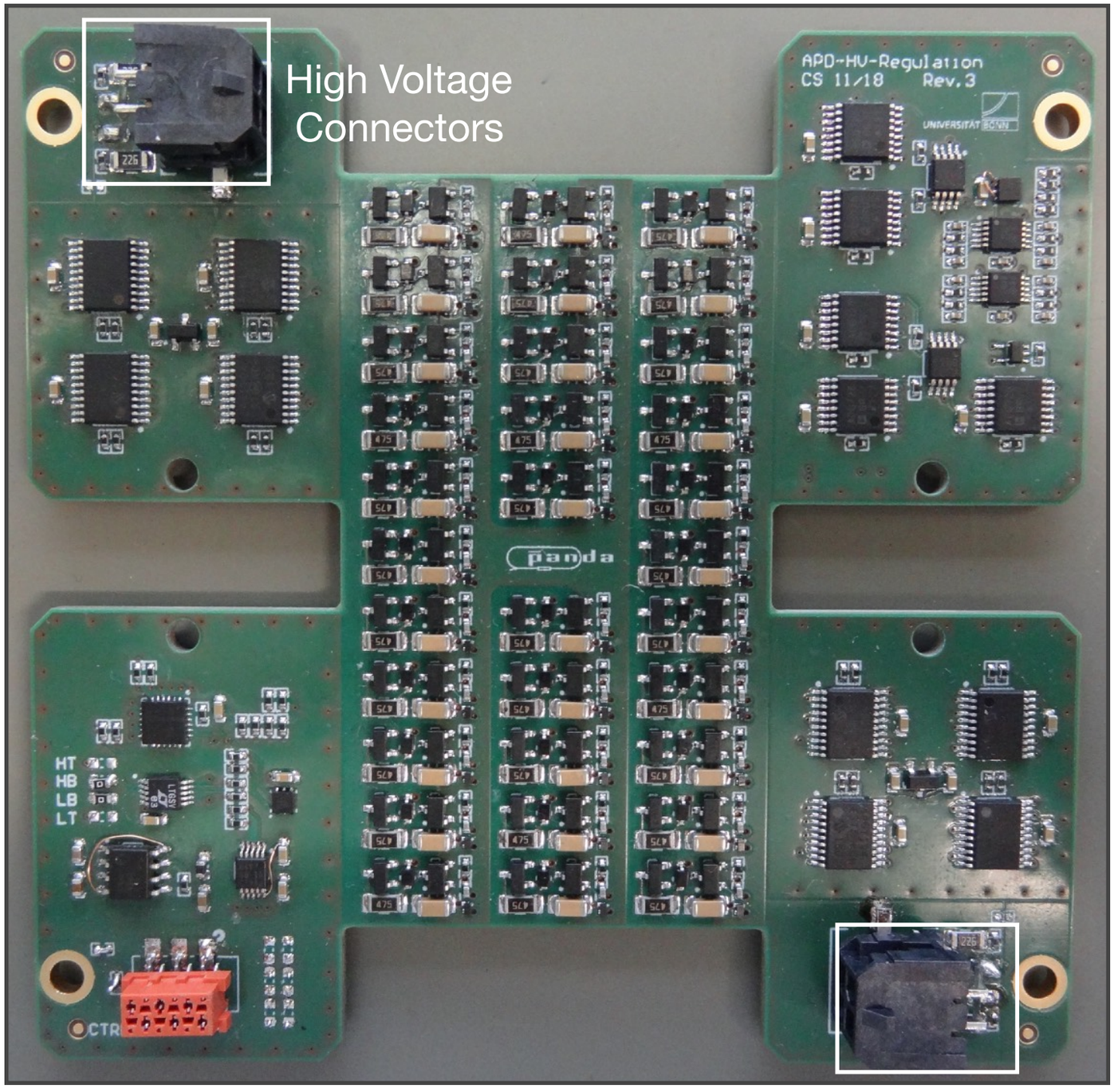
Solution:

- 8 APDs grouped together with $\Delta V = 7$ V.

→ realised by a High Voltage Board.

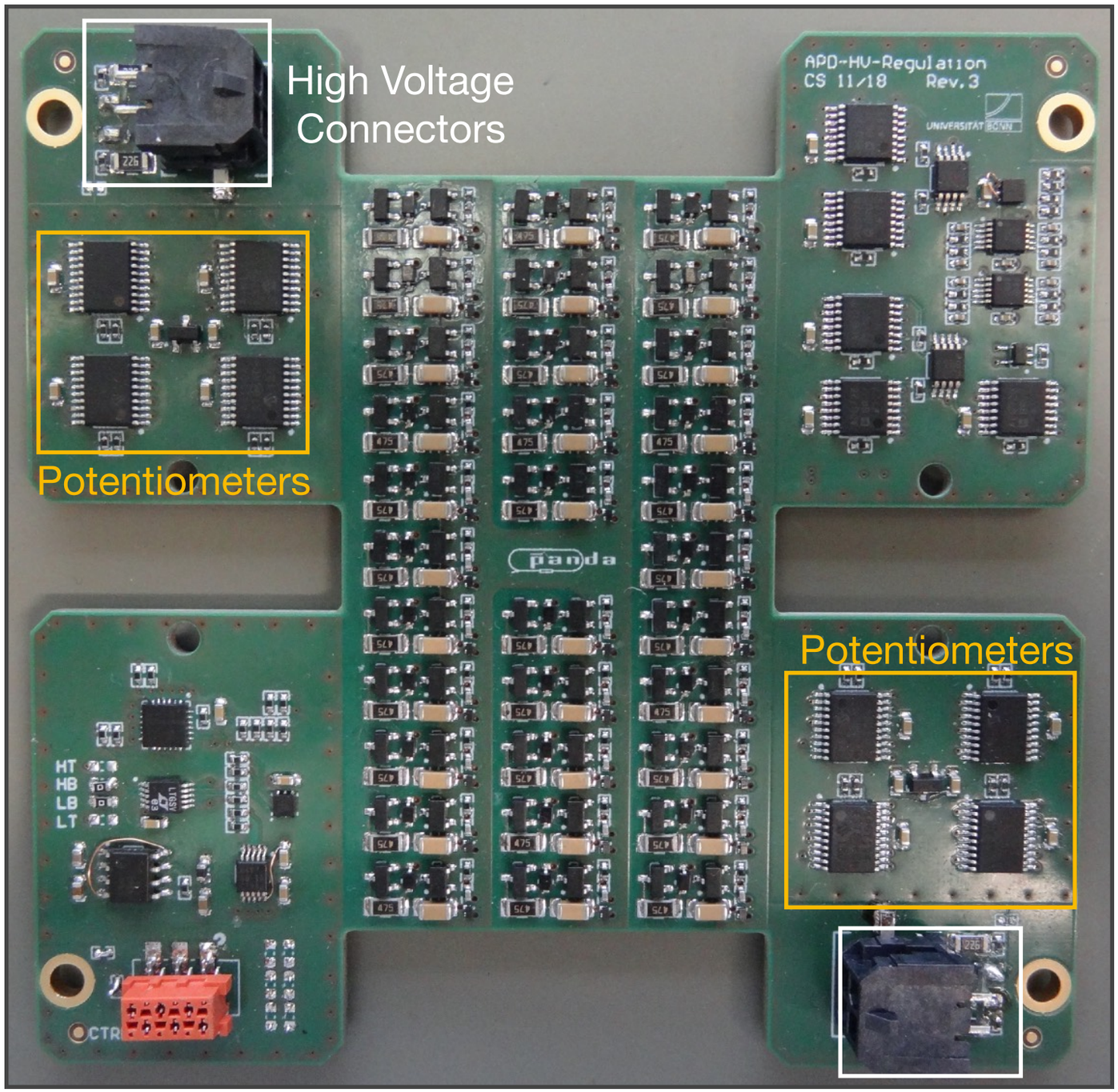
High Voltage Board



- 4 input high voltages → 32 output high voltage channels.

Developed by F. Grifka and upgraded by Dr. C. Schmidt

High Voltage Board



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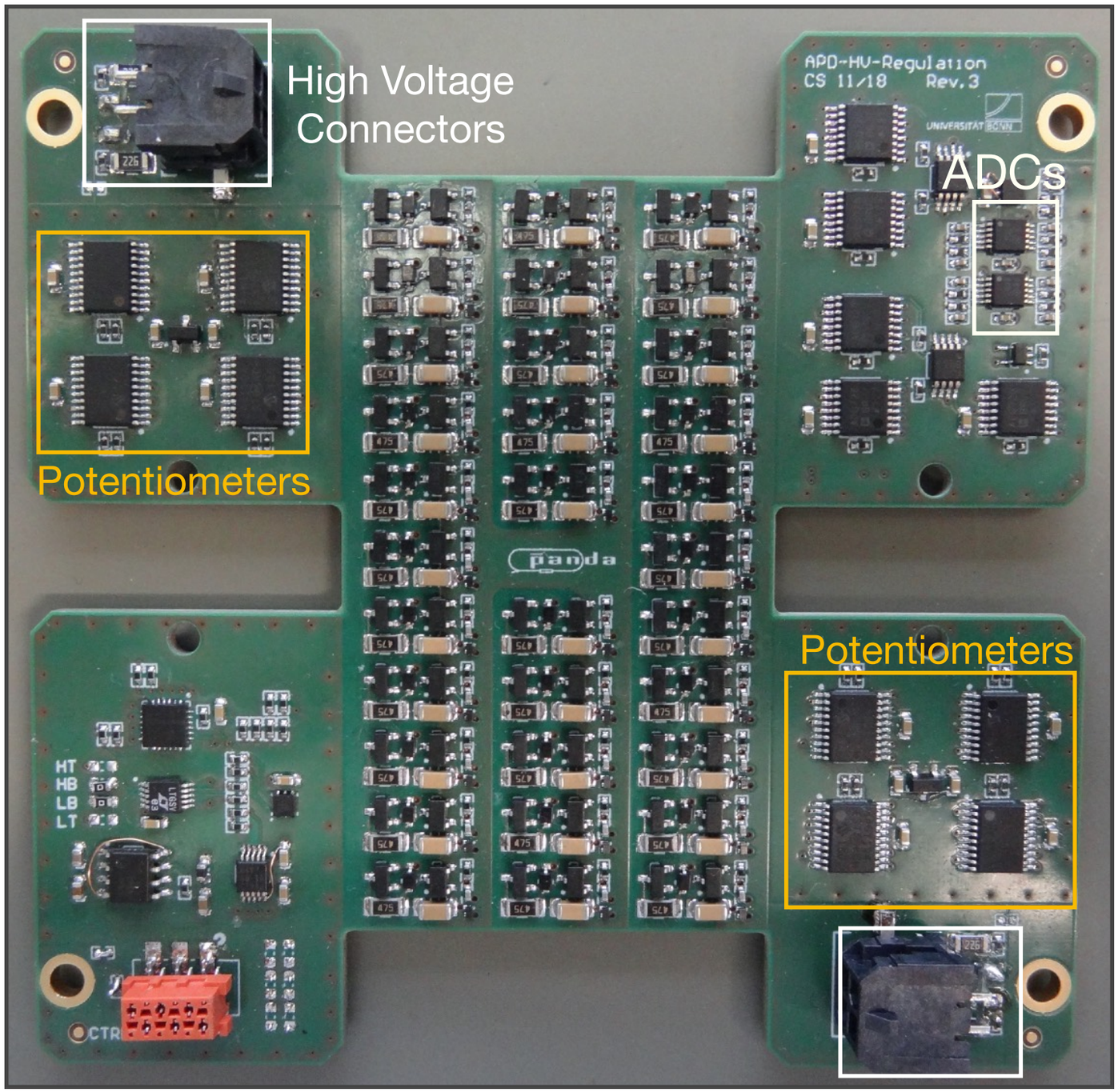

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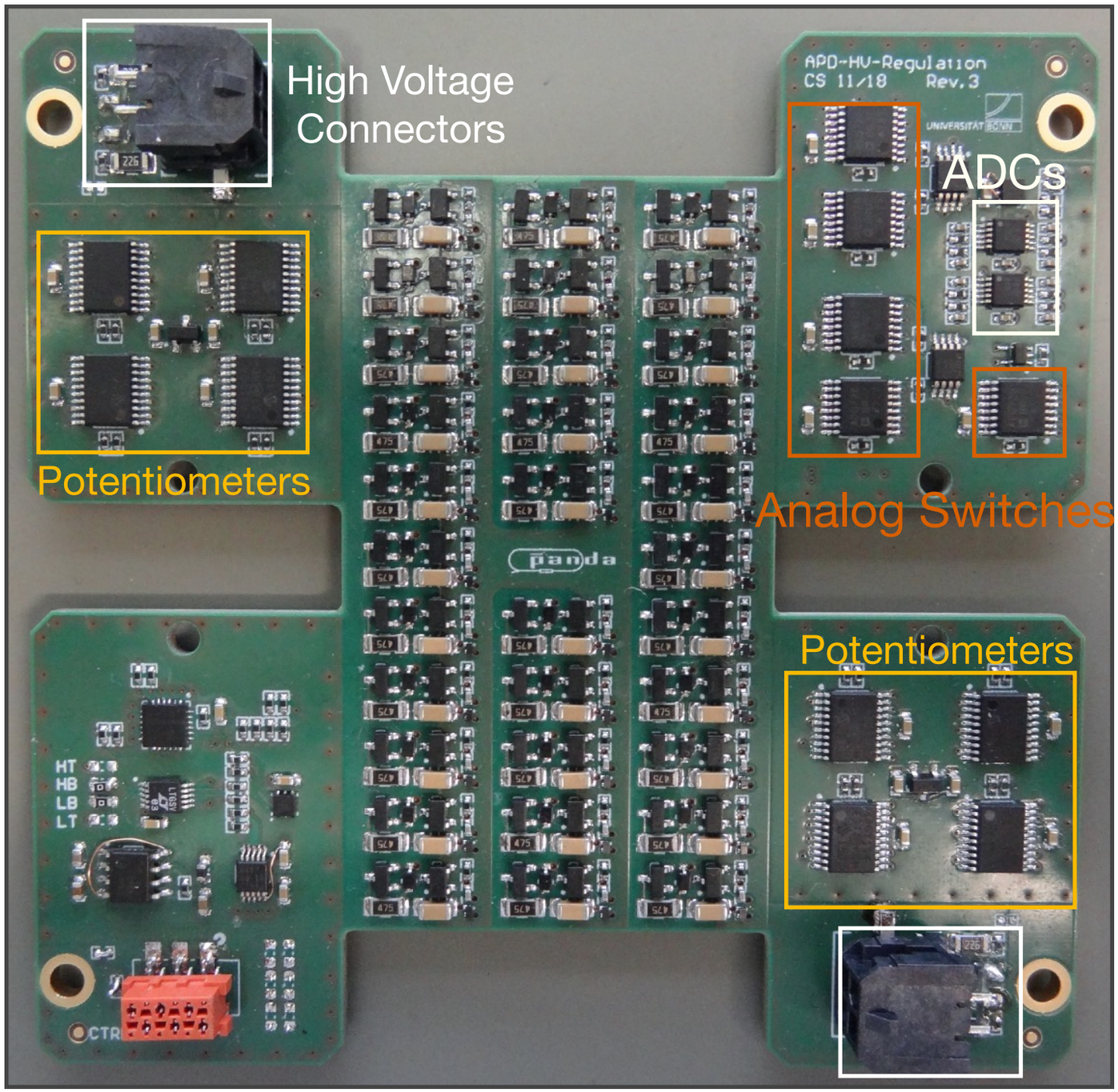

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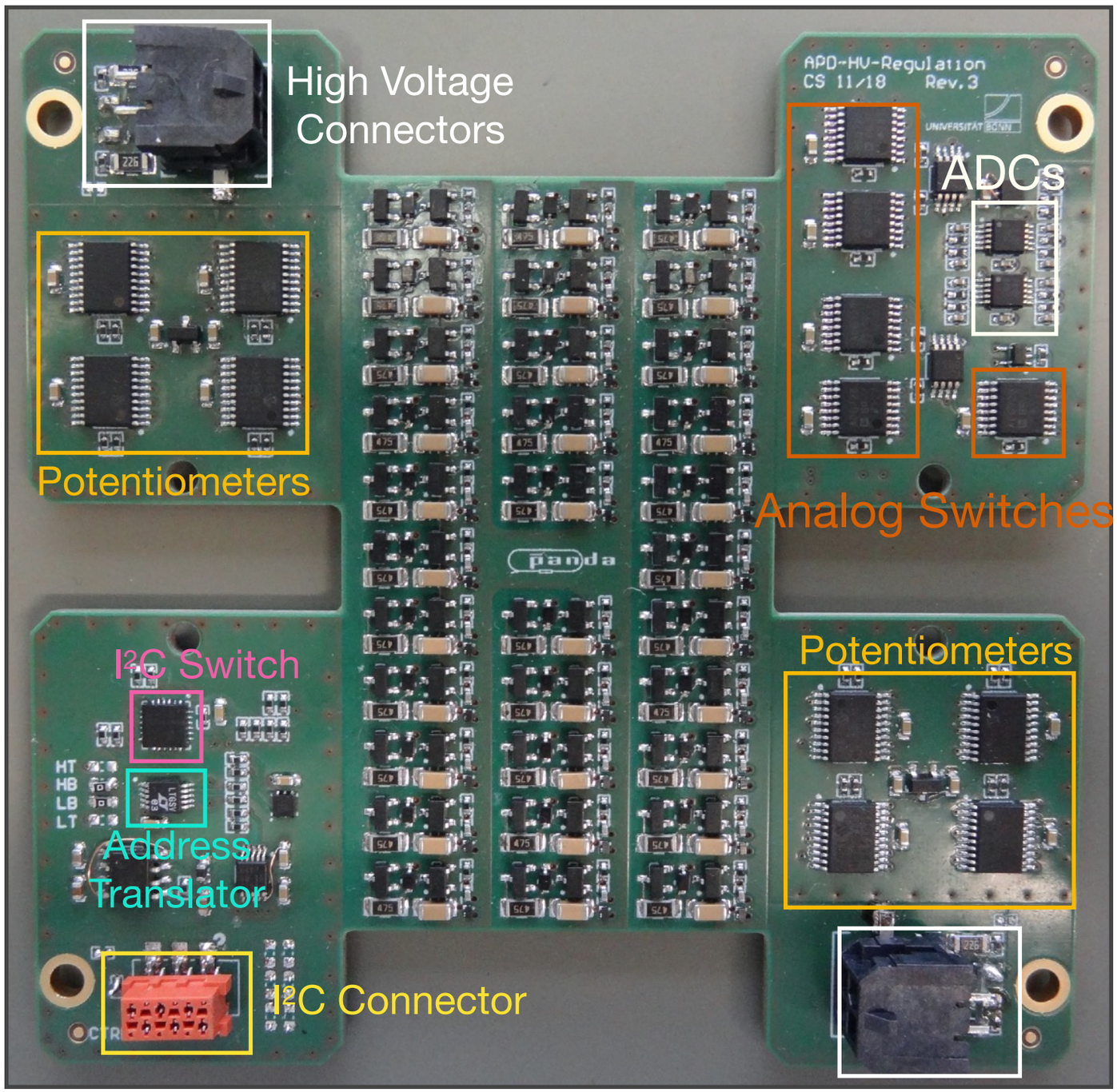

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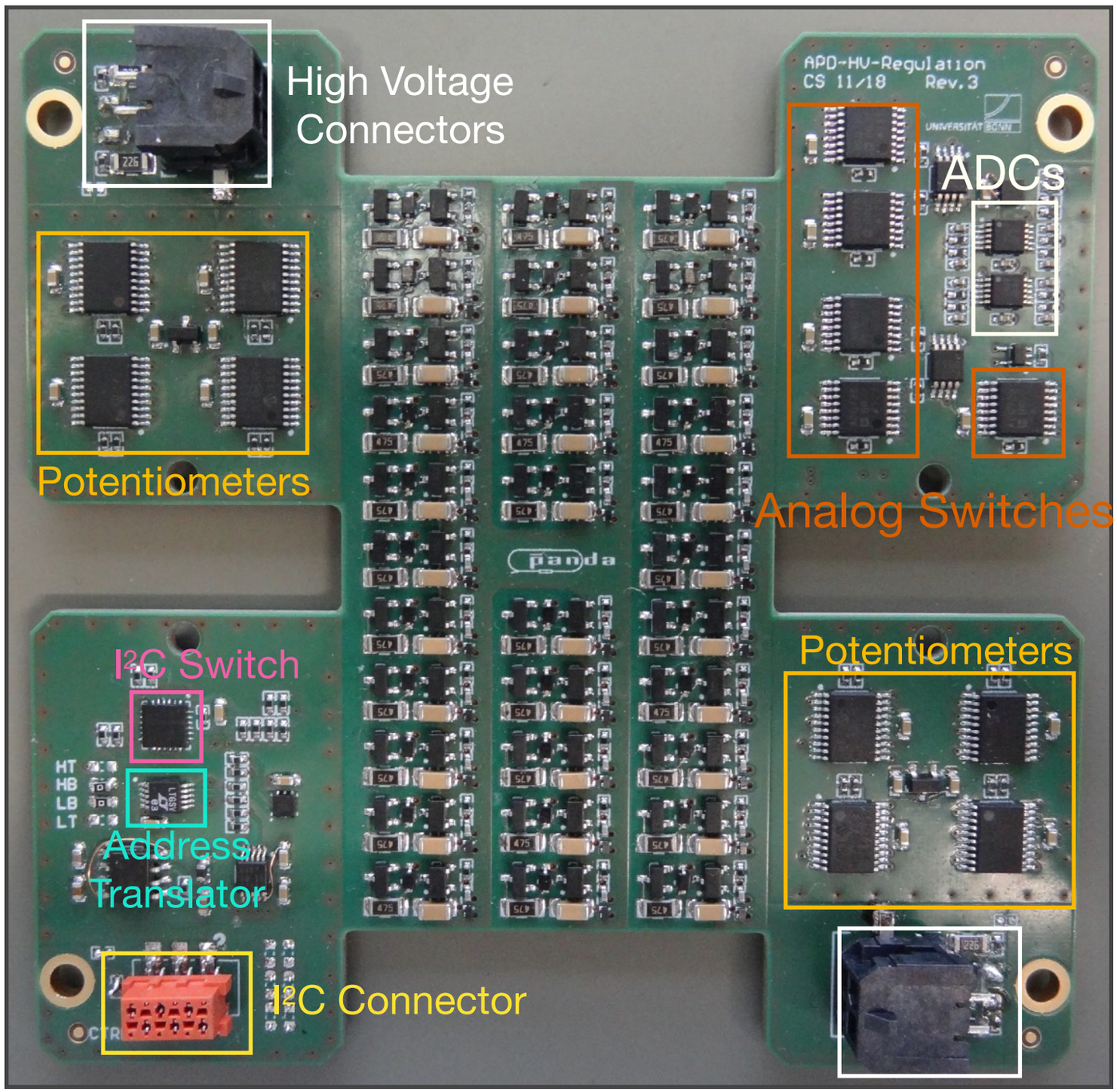
High Voltage Board



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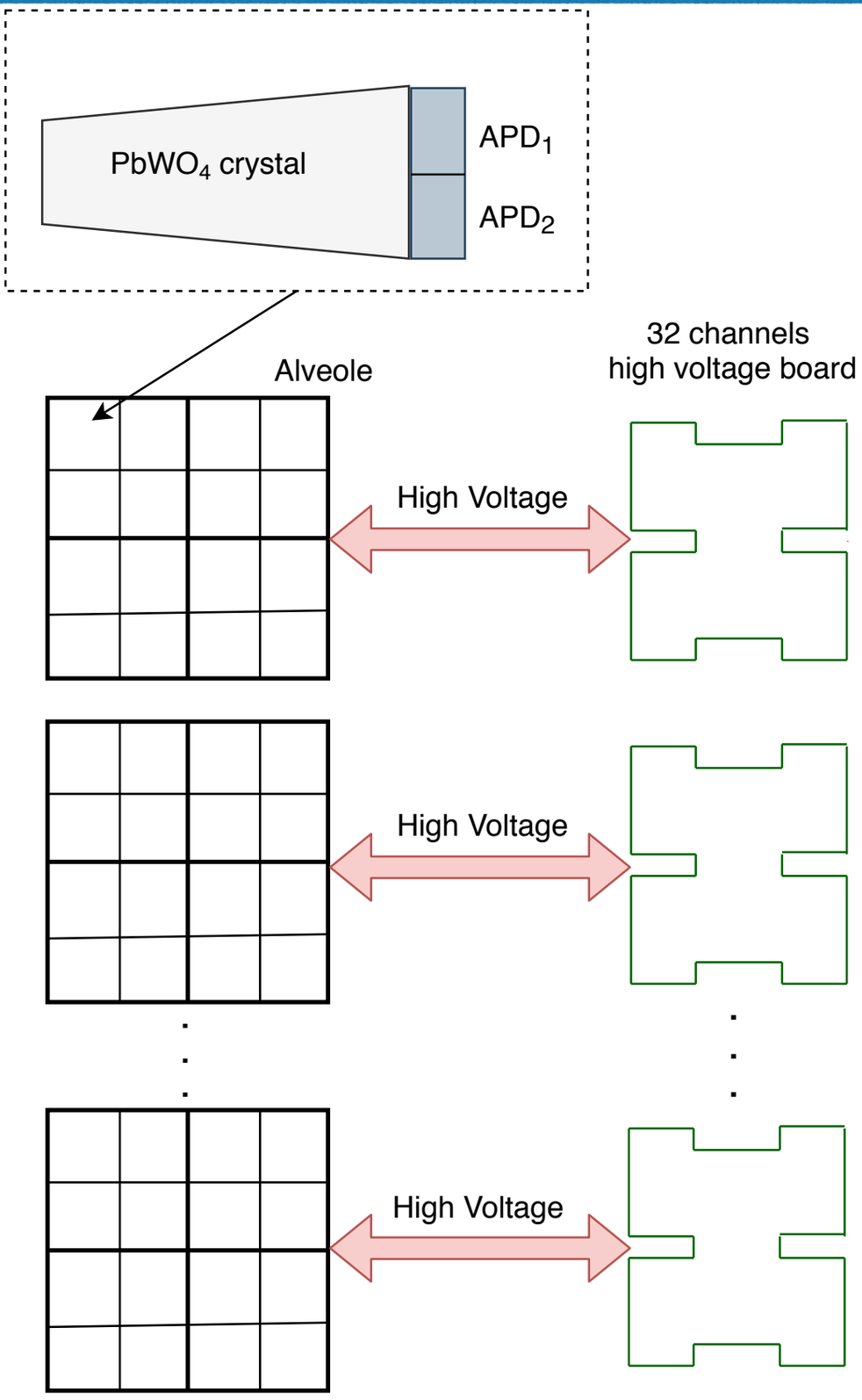
- 4 input high voltages → 32 output high voltage channels.
- High voltages of each channel are regulated by the potentiometers.
- ADCs: monitors high voltages.
- Components are I²C bus compatible
- For all APDs, 772 high voltage lines are required.

EMC Forward Endcap



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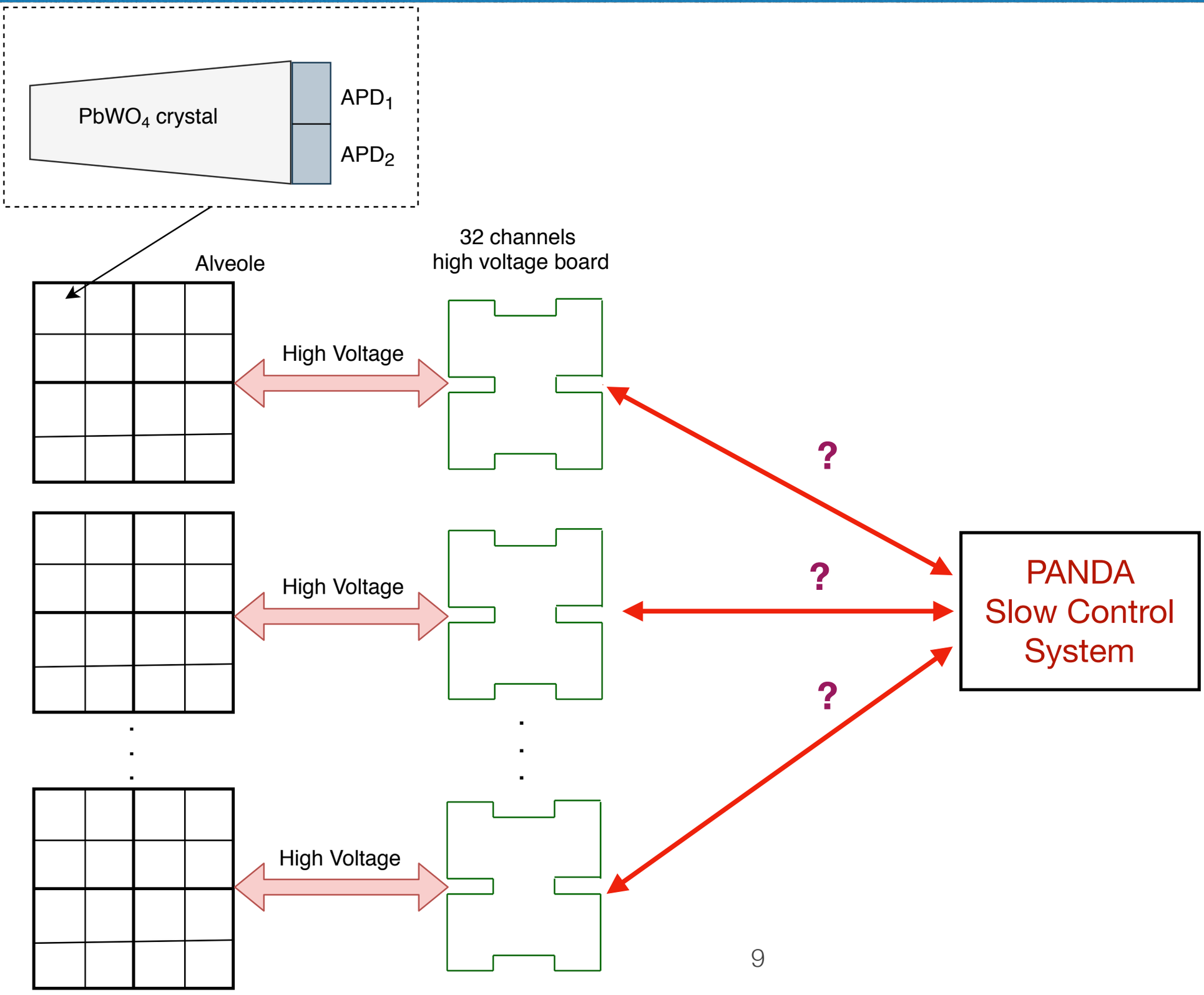

Goal

- Build the interface between the PANDA Experiment Slow Control (based on the CAN bus) and the High Voltage Boards (based on the I^2C bus).

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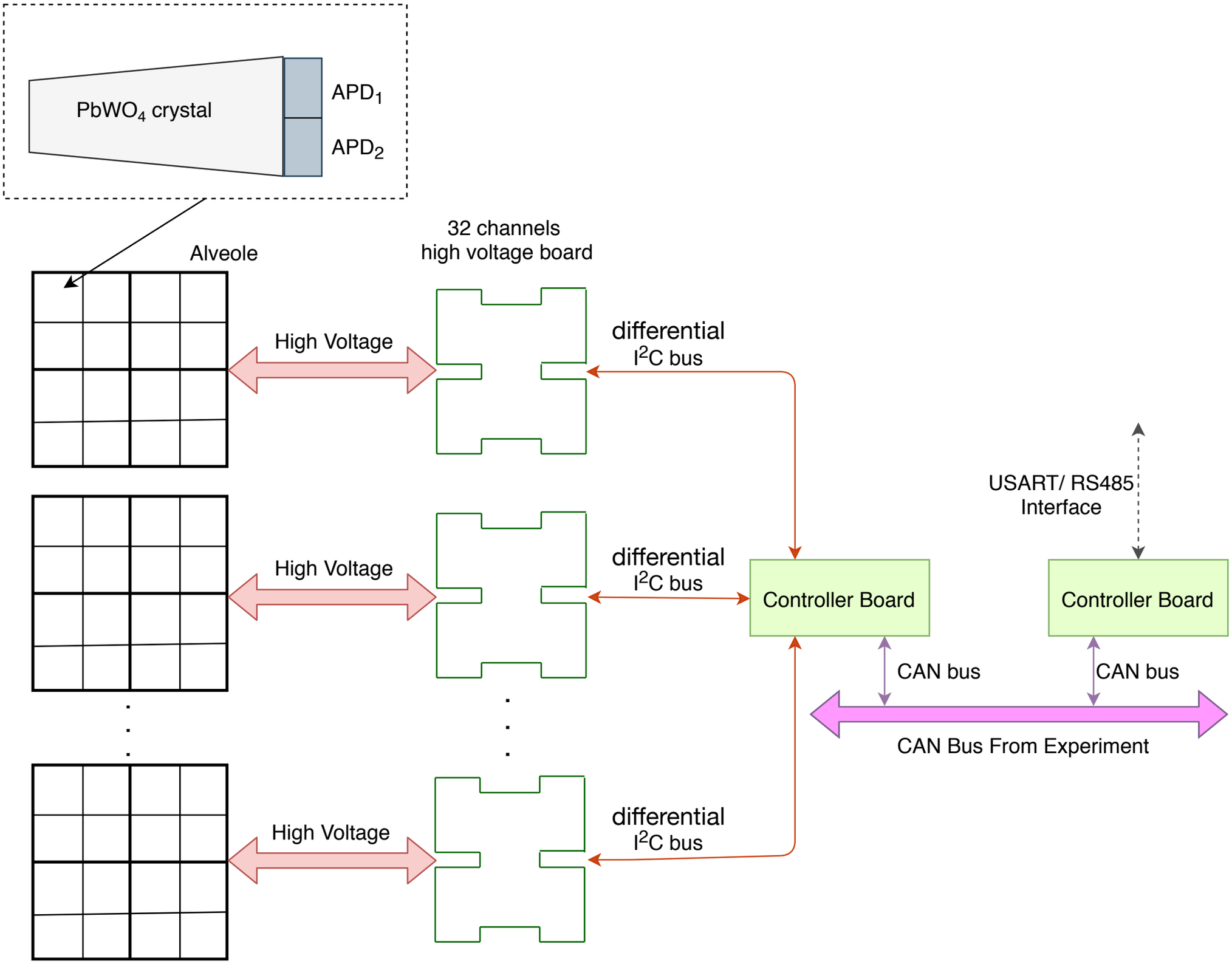
- Inspiration from Temperature and Humidity Monitoring board for PANDA (THMP) module.

  - Microcontroller provides I^2C and CAN bus interface.

  - Microcontroller, CAN transceiver and voltage regulators tested for radiation hardness.

→ Controller Board

EMC Forward Endcap



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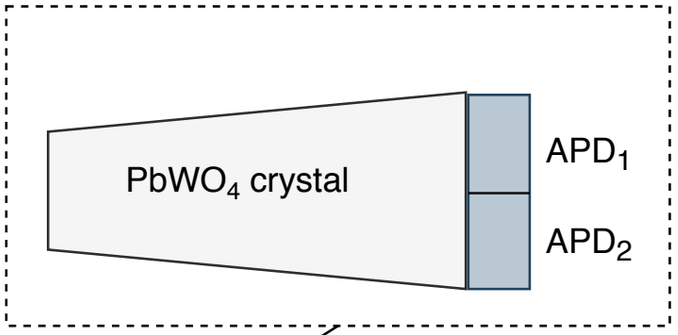
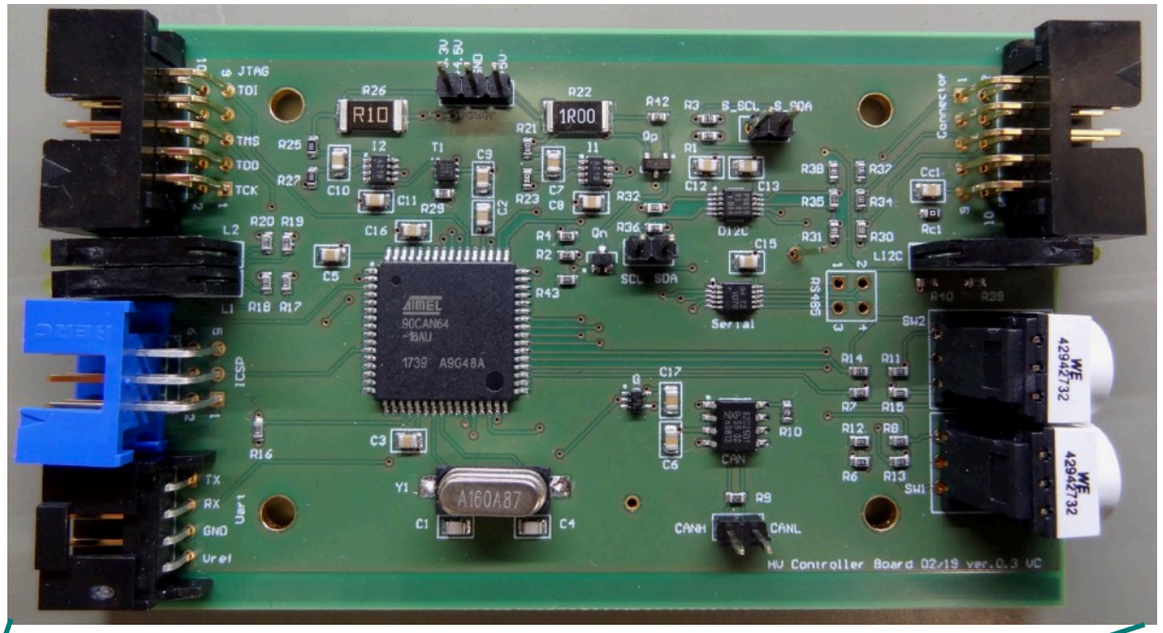




Alveole

32 channels
high voltage board

High Voltage

differential
I^2C bus

High Voltage

differential
I^2C bus

High Voltage

differential
I^2C bus

USART/ RS485
Interface

Controller Board

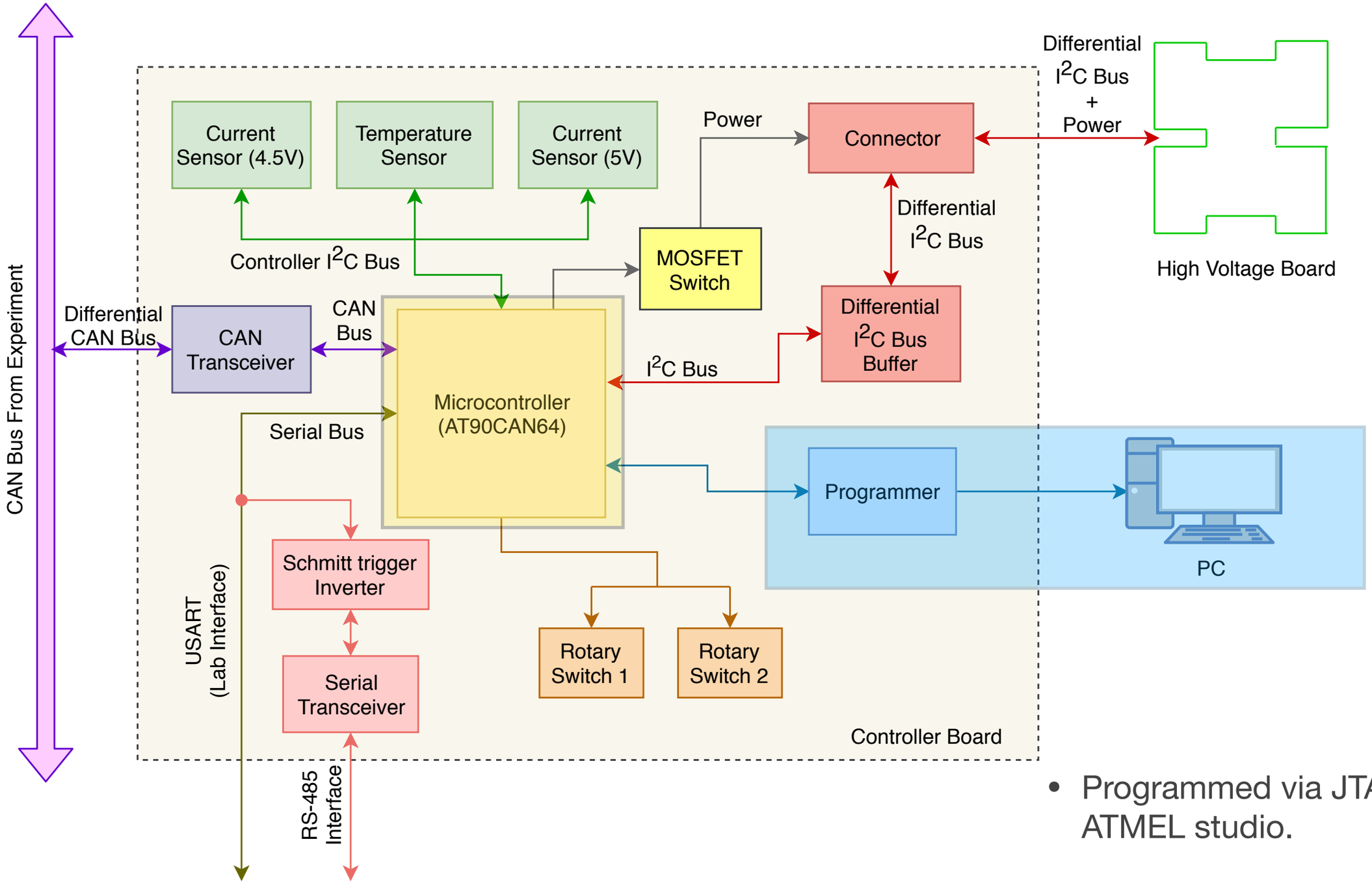
Controller Board

CAN bus

CAN bus

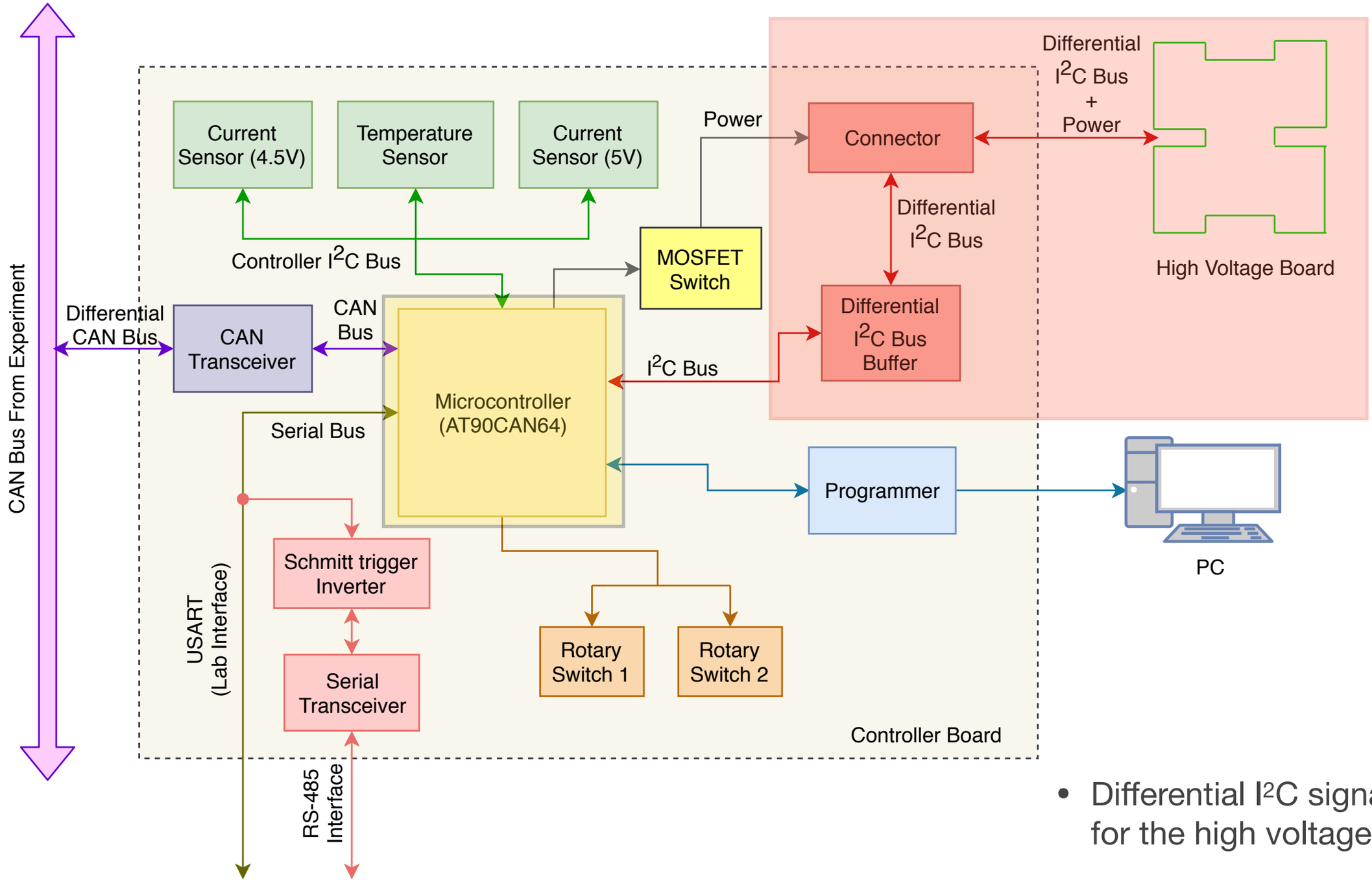
CAN Bus From Experiment

Controller Board



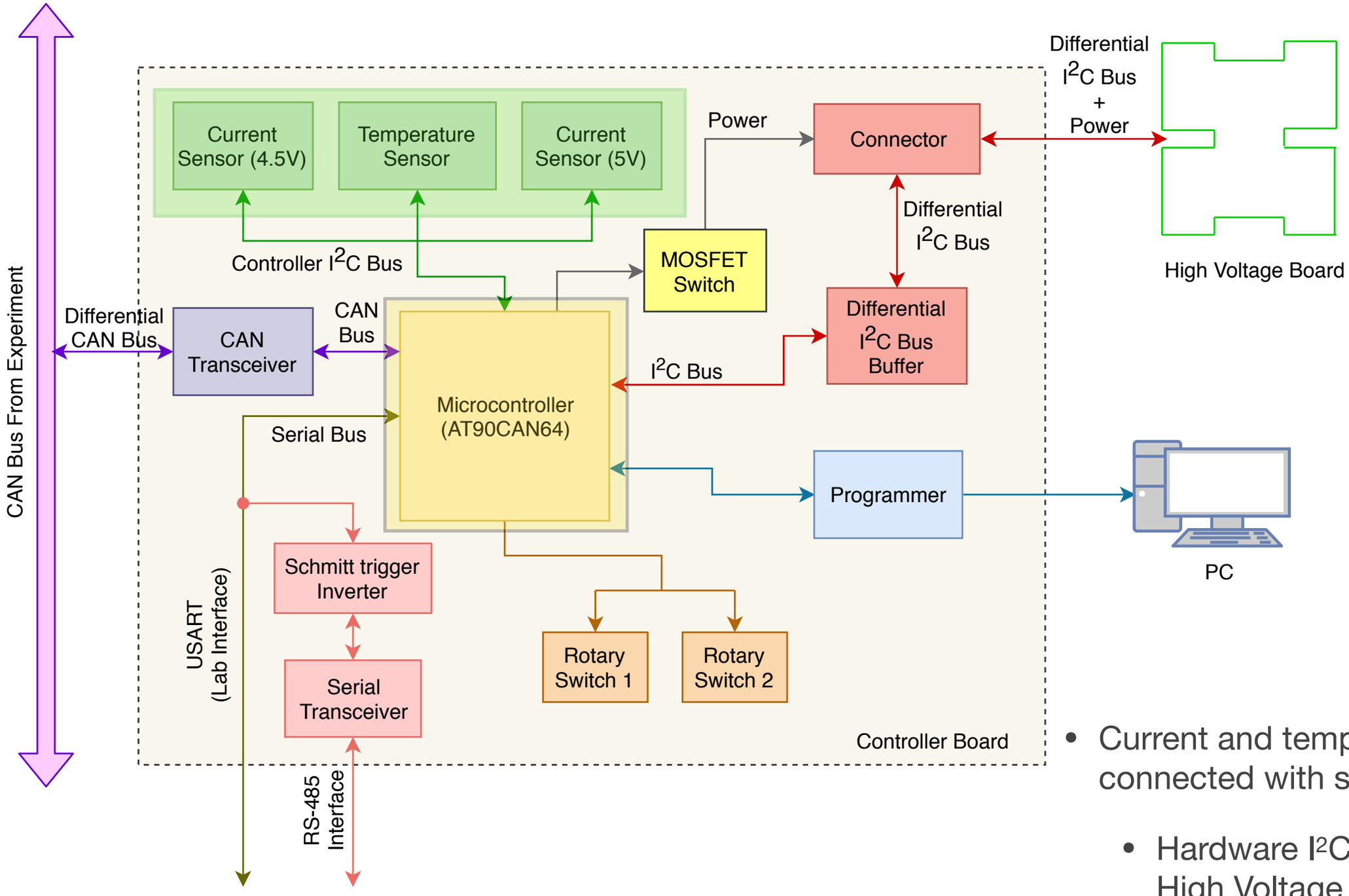
- Programmed via JTAG or ISP using ATMEL studio.
- Microcontroller operates at 16MHz.

Controller Board



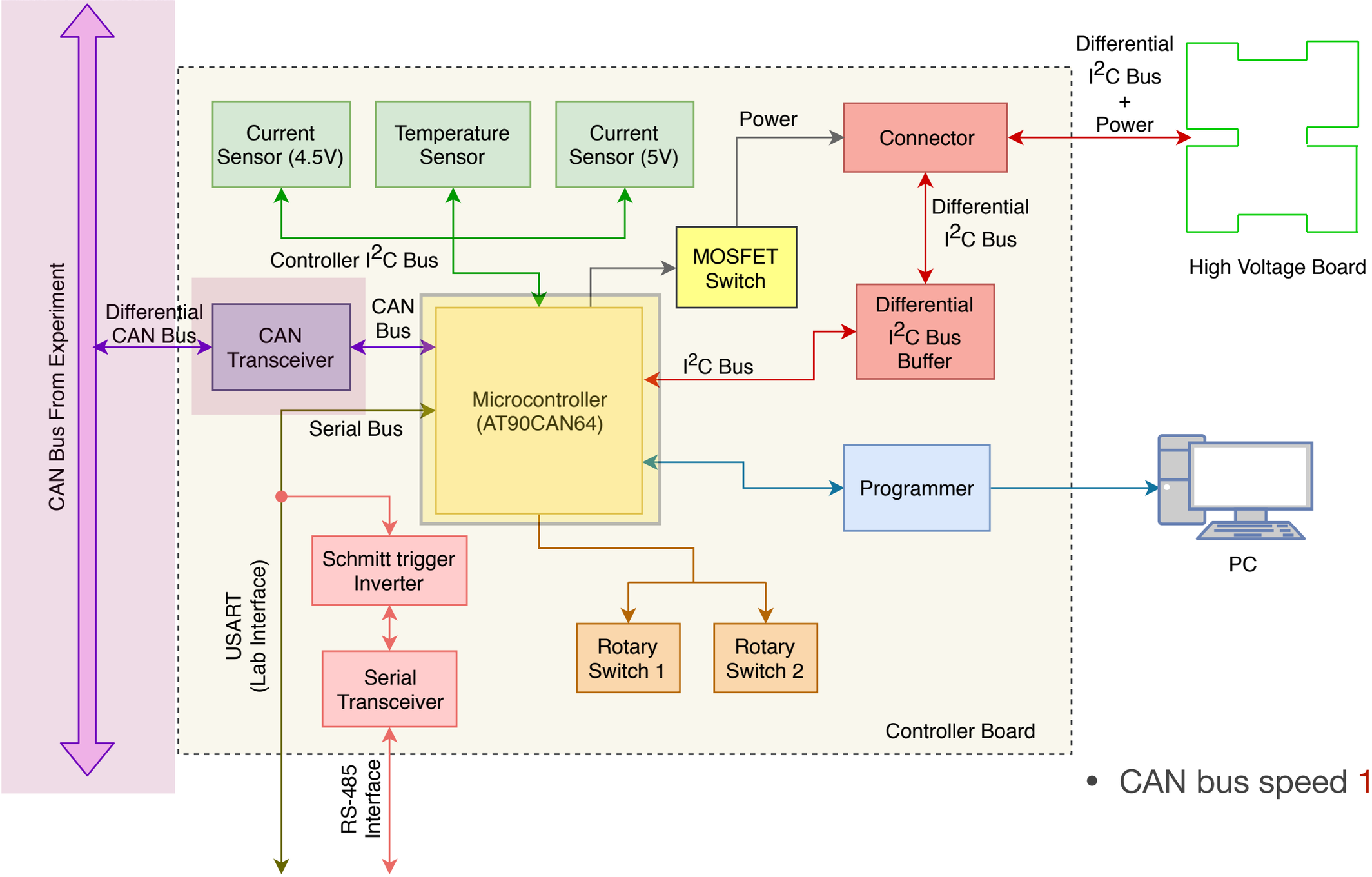
- Differential I²C signal and power for the high voltage boards.
- I²C bus speed 400kHz.

Controller Board



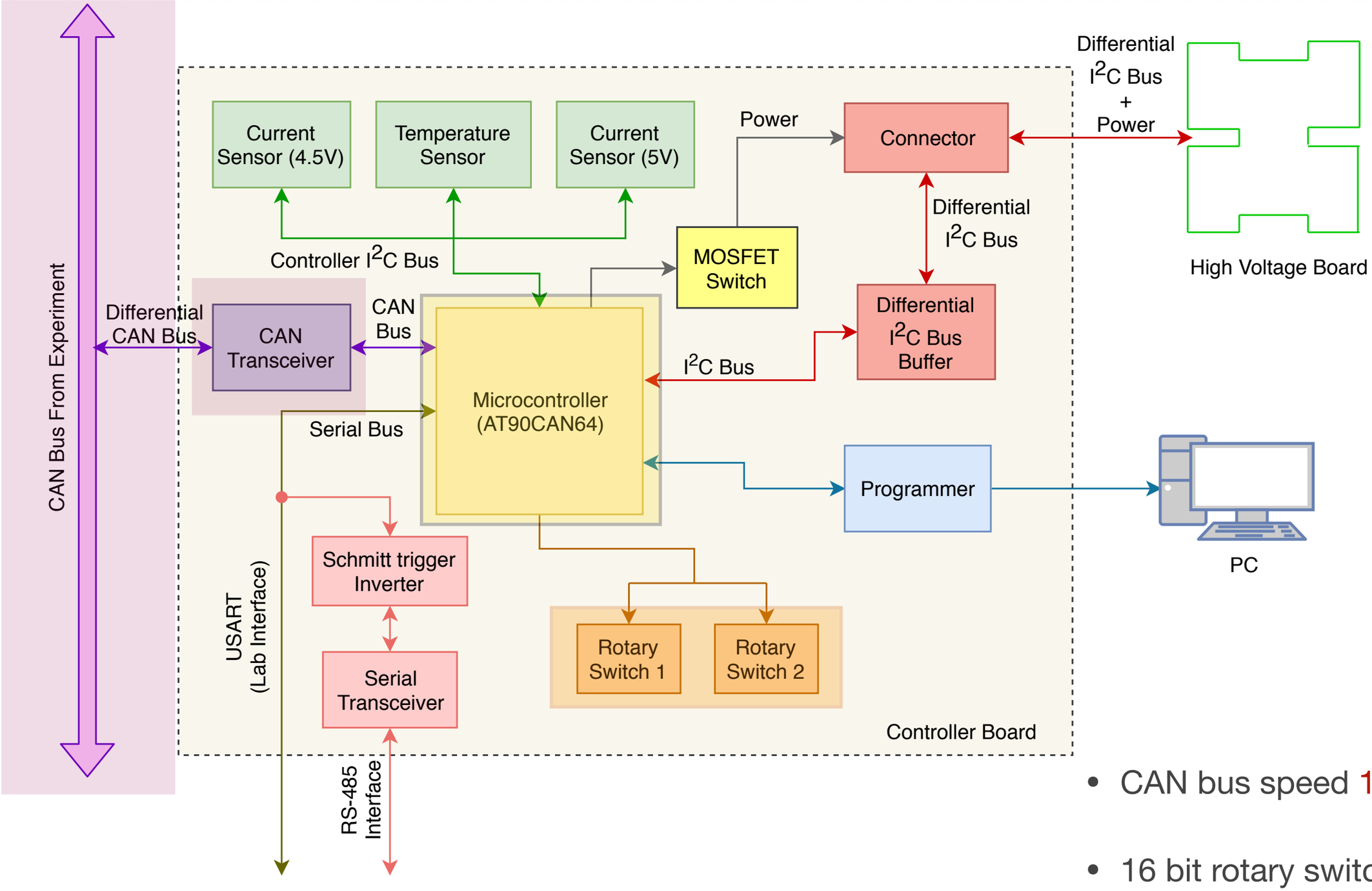
- Current and temperature sensors connected with software I²C bus.
  - Hardware I²C bus solely for High Voltage board.
- Controller I²C bus speed 27kHz.

Controller Board



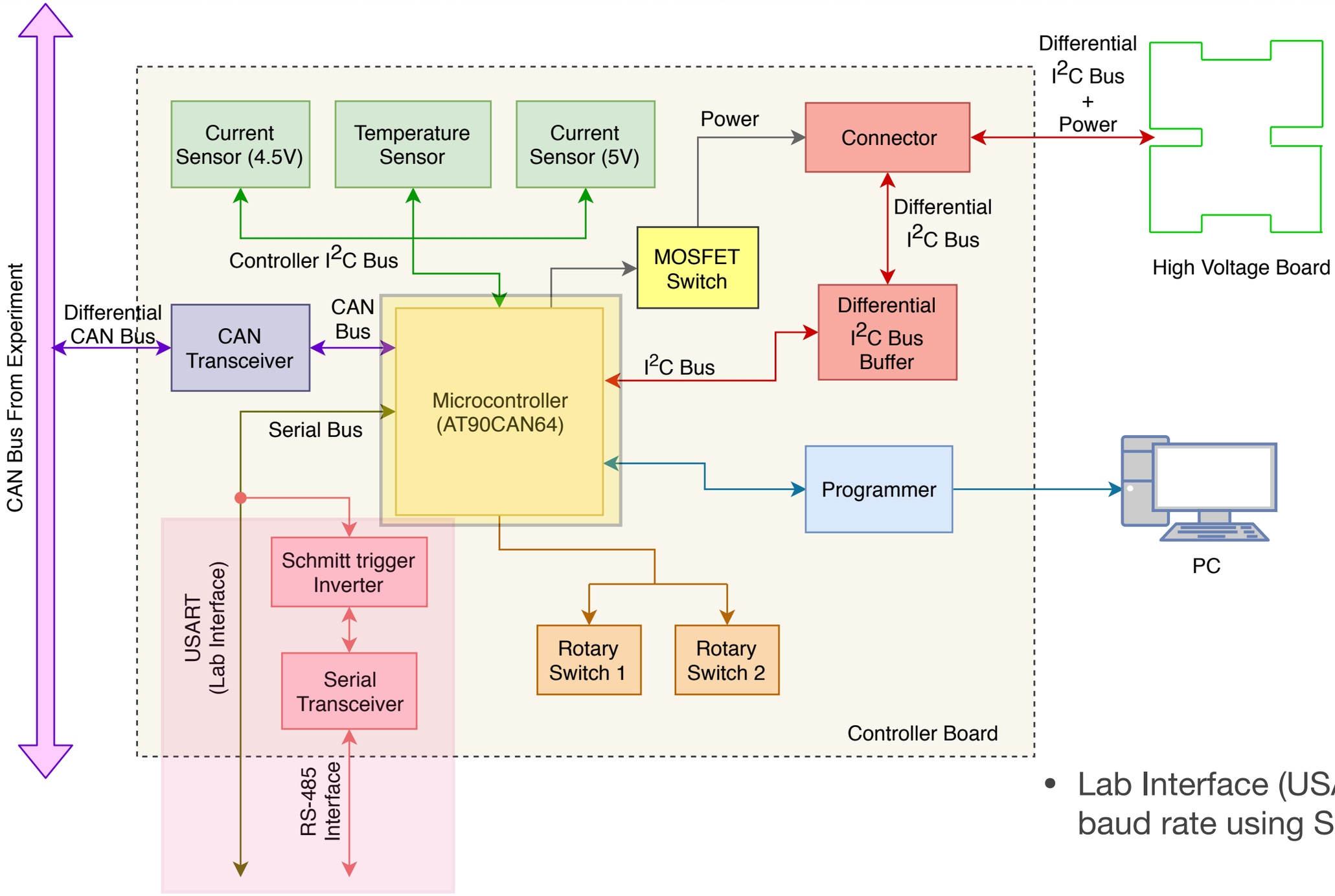
- CAN bus speed 125kbps.

Controller Board



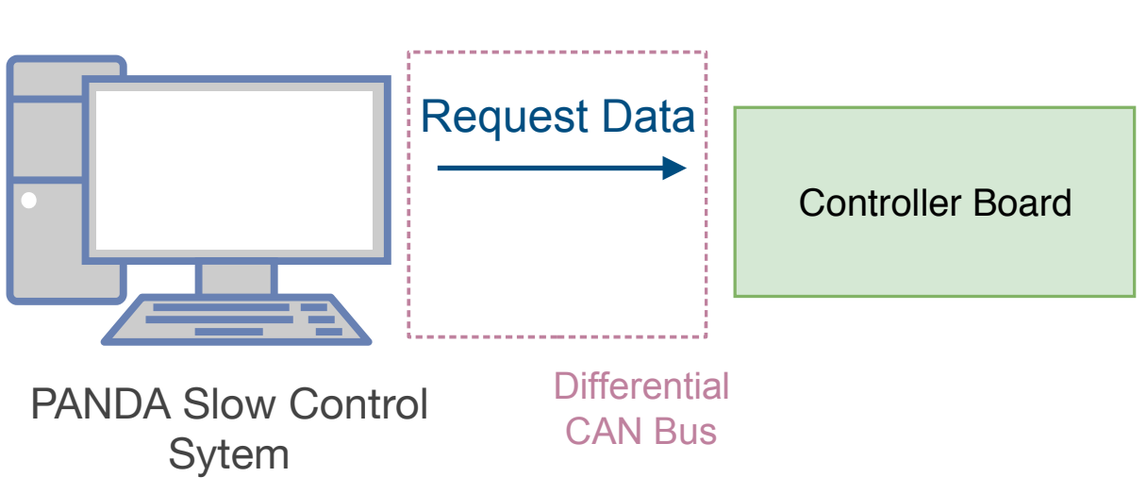
- CAN bus speed 125kbps.
- 16 bit rotary switches for providing unique identity to controller board.

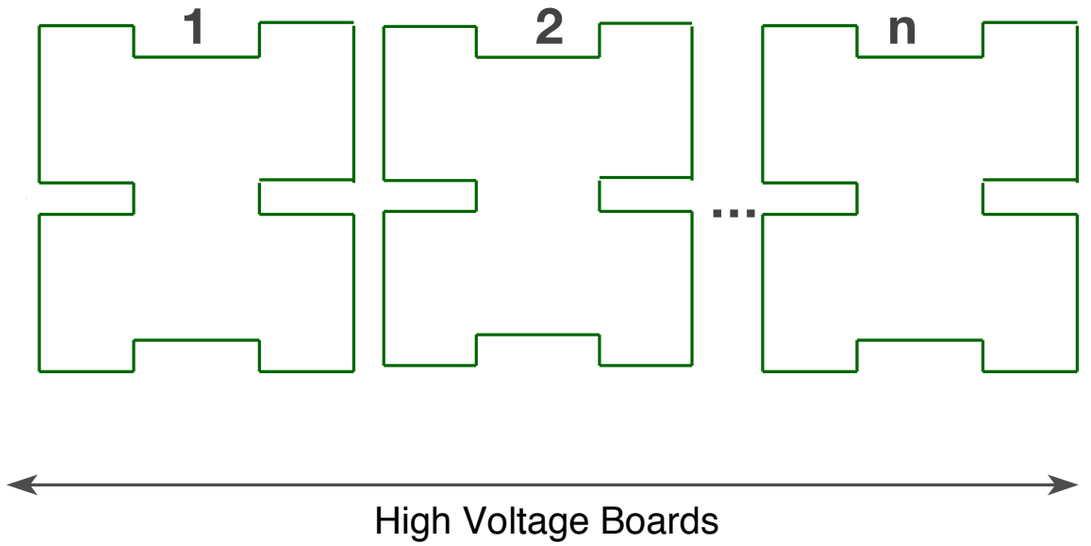
Controller Board



- Lab Interface (USART) with 115200 baud rate using SCPI commands.
- RS-485 for future purposes.

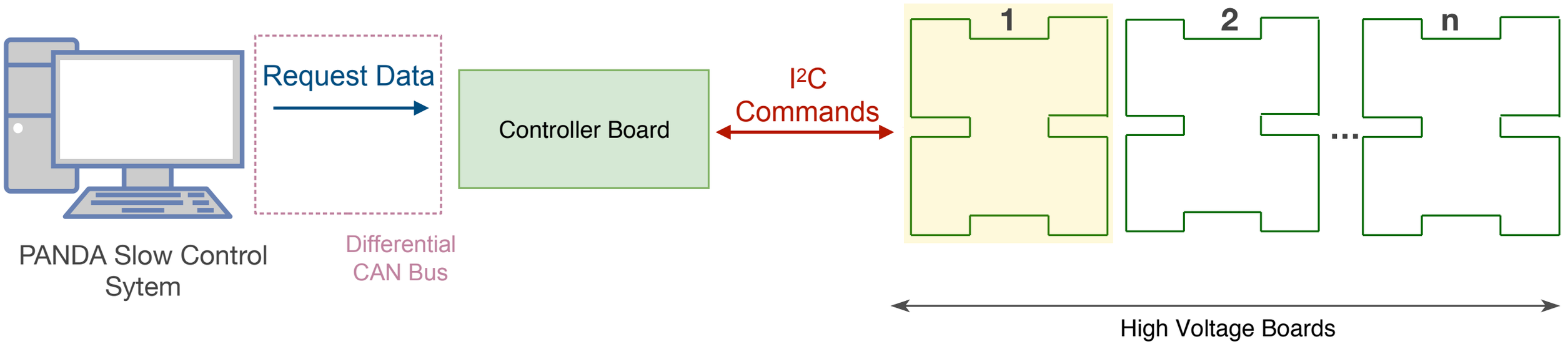
Readout Scheme





- The PANDA Slow Control system issues readout request via Can Bus .

Readout Scheme



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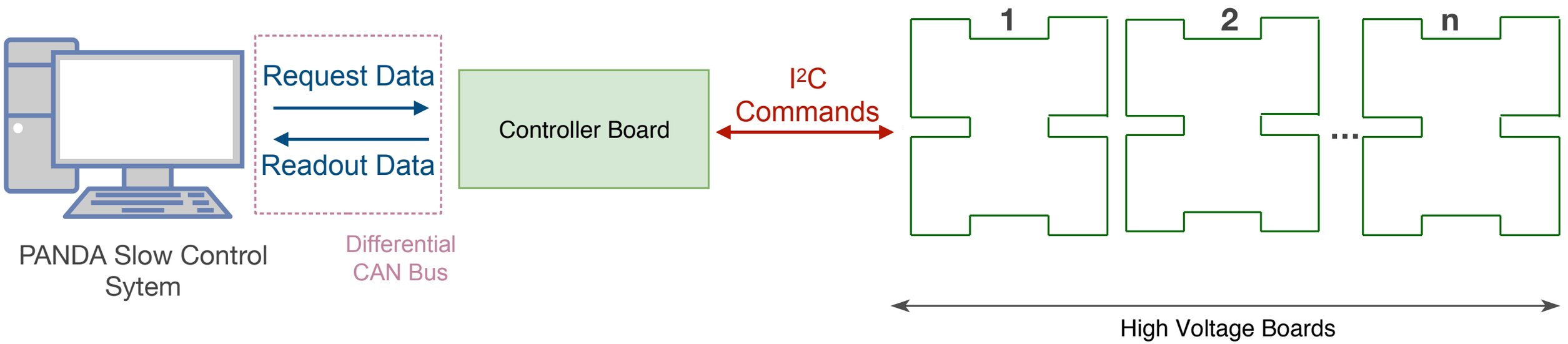

- The PANDA Slow Control system issues readout request via Can Bus .
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- The readout value is sent back to the microcontroller which is processed and sent further to the Detector Slow Control.

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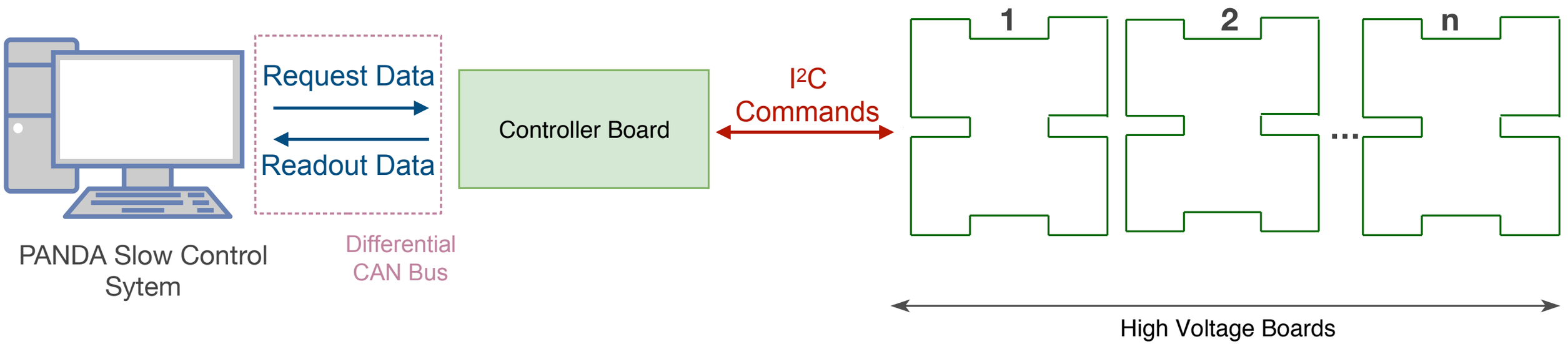

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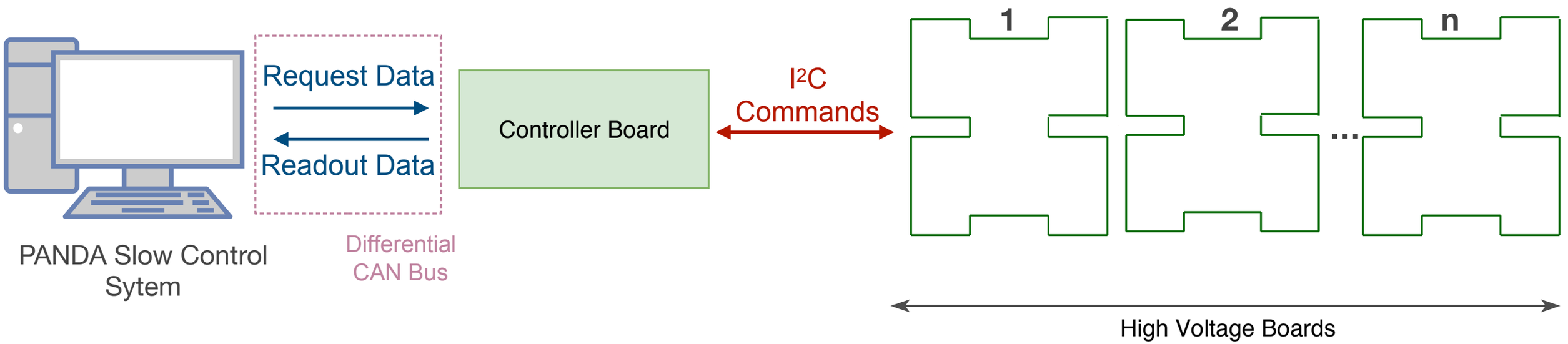

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- Can also be set as a background task (Similar to THMP) → Read ADC values from the mentioned High Voltage boards every N minutes.

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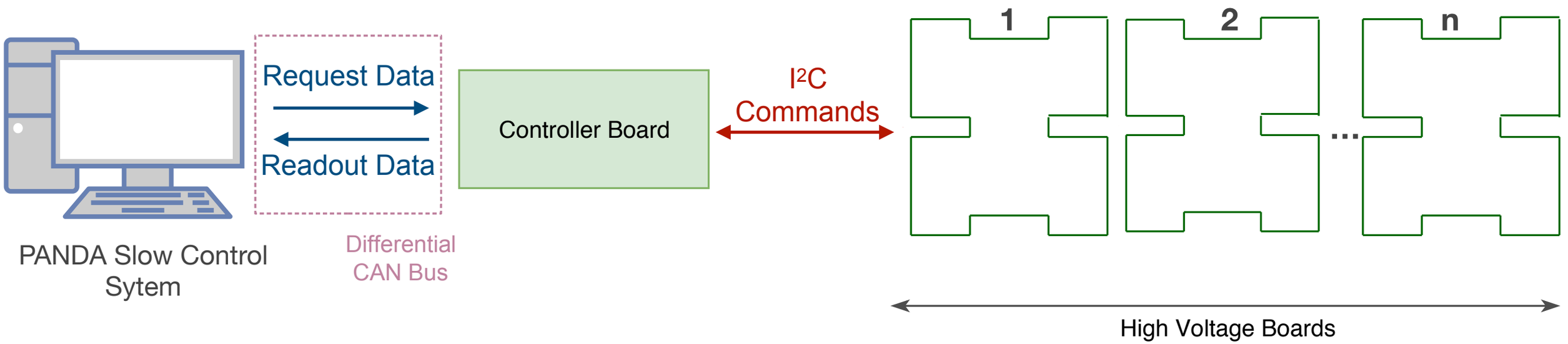

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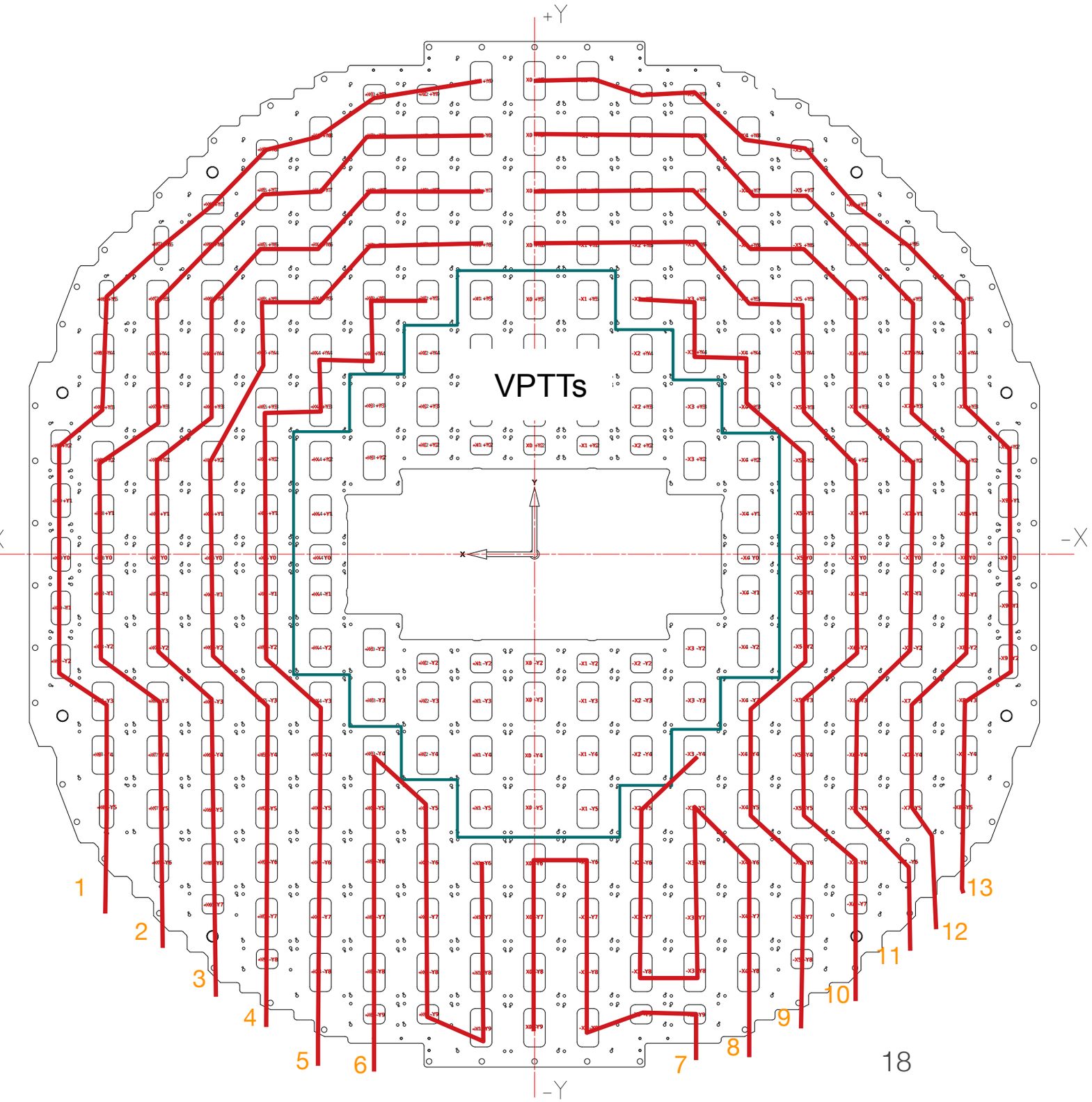
- Can also be set as a background task (Similar to THMP) → Read ADC values from the mentioned High Voltage boards every N minutes.
    - For CAN bus speed 250kbps, the total readout time for one High Voltage board is 105.833 ms.

Preliminary Connection Scheme for the High Voltage Regulation Boards



- In total, 13 controller boards required.
- Upto 20 high voltage boards can be connected to one I^2C bus.

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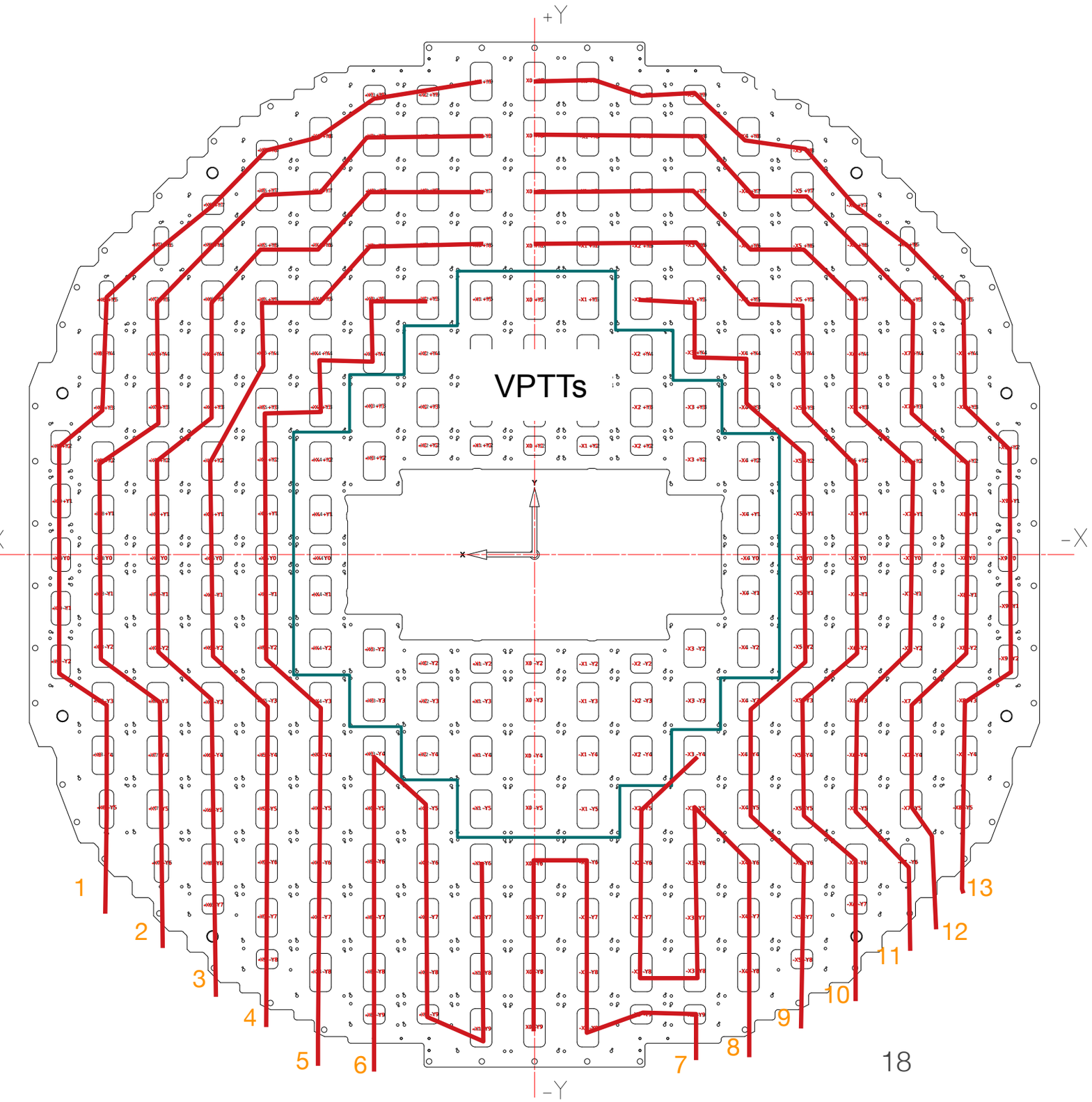

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- A controller board box can hold 4 controller boards + 1 power board (for powering all controller boards).
    - Power Board utilises similar power connectors like THMP.

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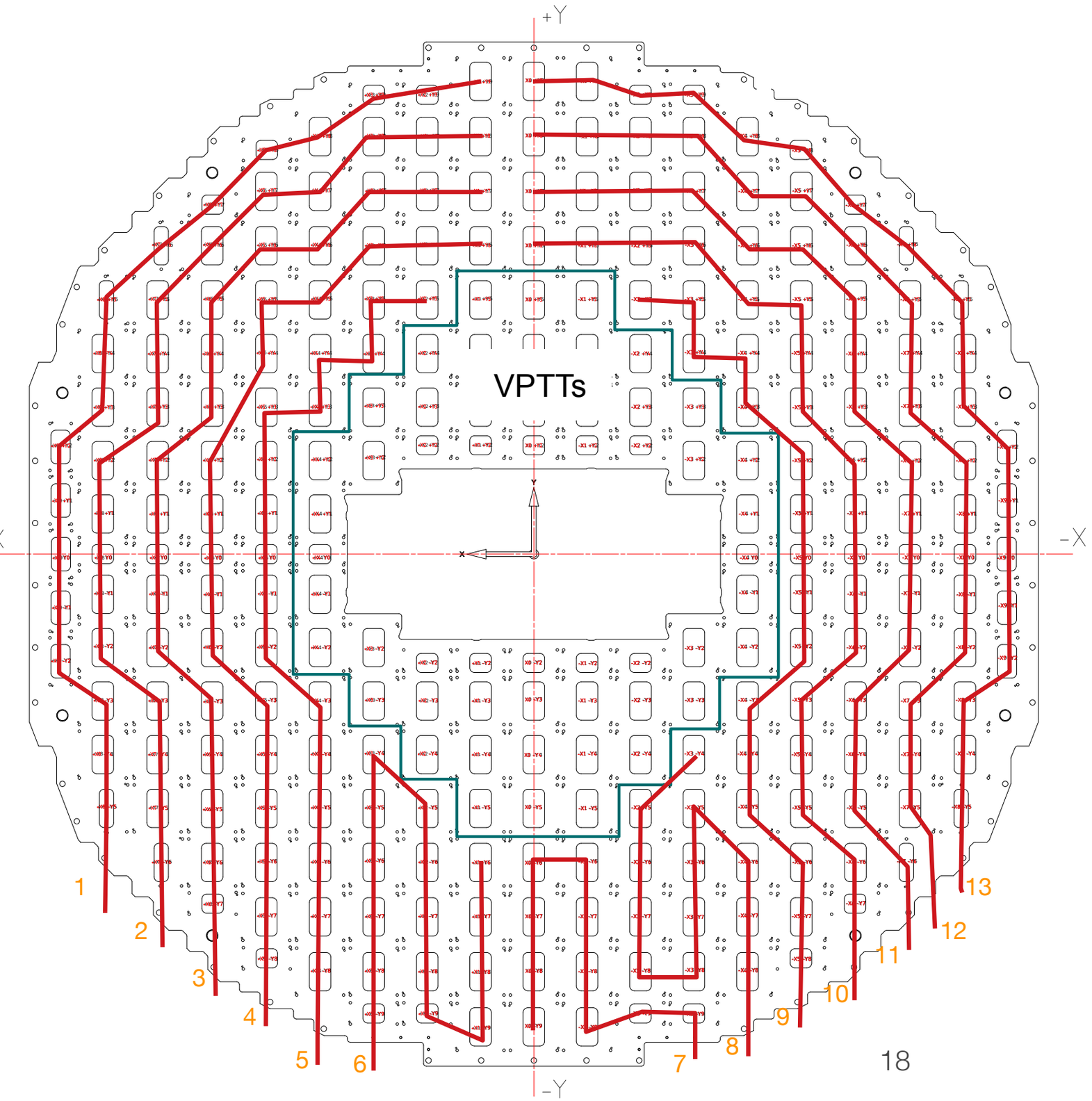

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- A controller board box can hold 4 controller boards + 1 power board (for powering all controller boards).
    - Power Board utilises similar power connectors like THMP.
- Require 2.12 seconds for reading ADC values of all channels of 20 boards.

Summary And Outlook

Summary

- High voltages provided to APDs need to be regulated → High voltage board.
- The controller board provides interface between the PANDA Experiment Slow control and the High Voltage boards.
- Approx. 20 high voltage boards can be connected to one controller board.
- Require 2.12 seconds for reading ADC values of all channels of 20 boards.

Outlook

- Tests need to be performed with the controller board in order to monitor its performance of the I^2C signals under radiation.

  → being performed, waiting for results. → Mass Production.

- In order to check for I^2C address conflicts, tests need to be performed with the full chain of high voltage boards connected to the controller board.
- Controller readout needs to be integrated into EPICS framework of the PANDA experiment's Slow Control.

References

- E. PANDA, Technical Design Report, arXiv preprint arXiv:0810.1216 (2008)

- M. Albrecht, Partial Wave Analysis of the Decay J/ψ → γωω at BESIII and Developments for the Electromagnetic Calorimeter of the PANDA Detector,
  PhD thesis: Ruhr-Universität Bochum, 2016

- F. Feldbauer and P. Friedel, Temperature and Humidity Monitoring Board for PANDA (THMP)

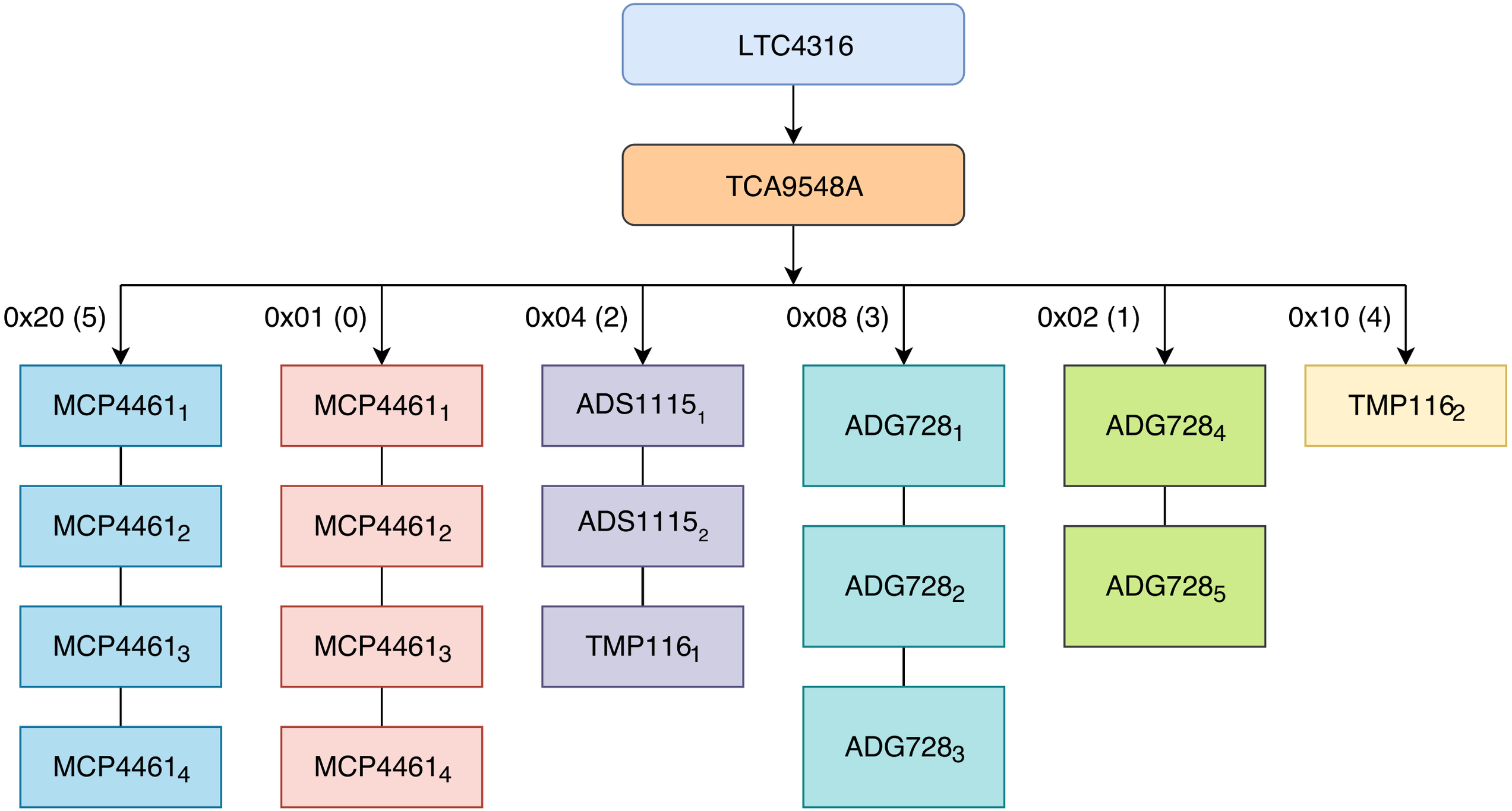
- R. Veenstra, Mountingplate/Numbering, Kernfysisch Versneller Instituut, Groningen, 2012

- F. Grifka, Entwurf und Test einer Platine zur HV-Regelung der APDs der Vorwärtsendkappe des PANDA-Experimentes, Bachelor Thesis: Rheinische Friedrich-Wilhelms-Universität Bonn, 2016

Thank You!

Extras

Address Mapping for the High Voltage Board



I²C Bus Address Translation

Original I²C address = 0x70 ,

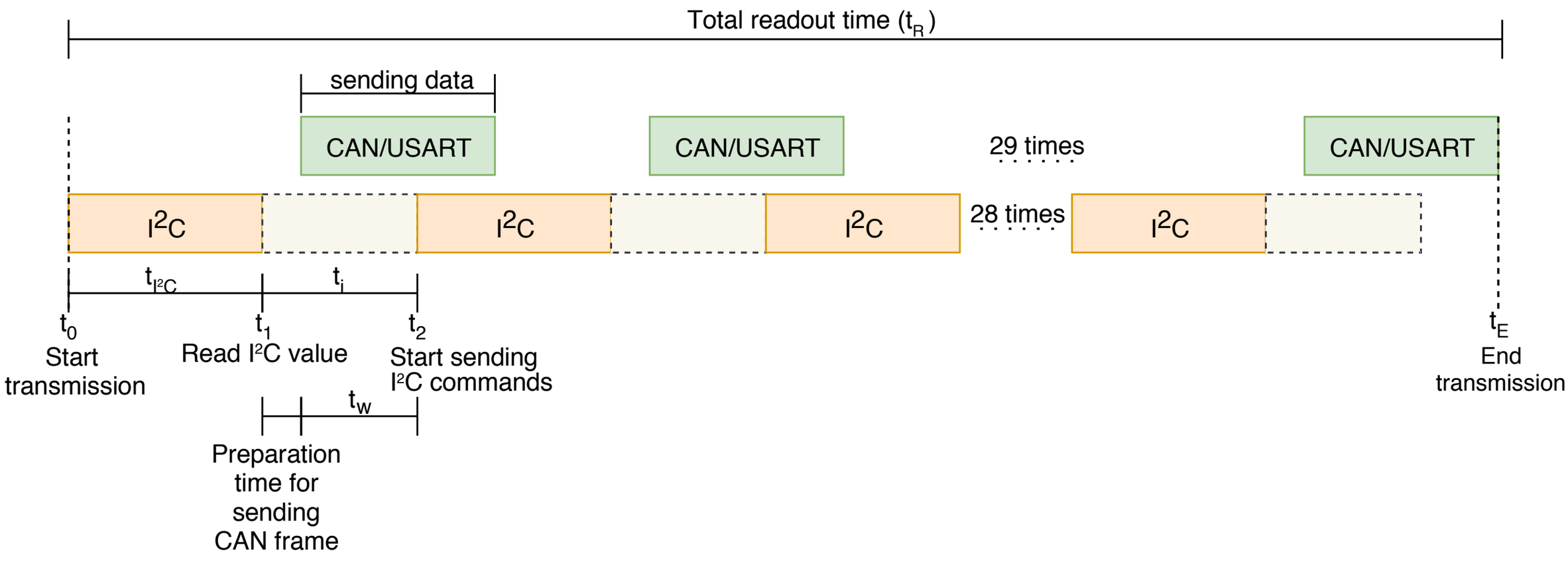
Modifier byte = 0x10 ,

New I²C address = (Original I²C address) ^ (Modifier byte)

= (0111 0000) ^ (0001 000)

= 0110 0000 (0x60) .

Readout


Total readout time (t_R)
sending data
CAN/USART
CAN/USART
29 times
CAN/USART
I²C
I²C
I²C
28 times
I²C
t_{I^2C}
t_i
t_0
Start transmission
t_1
Read I²C value
t_2
Start sending I²C commands
t_w
Preparation time for sending CAN frame
t_E
End transmission

Total Readout Time

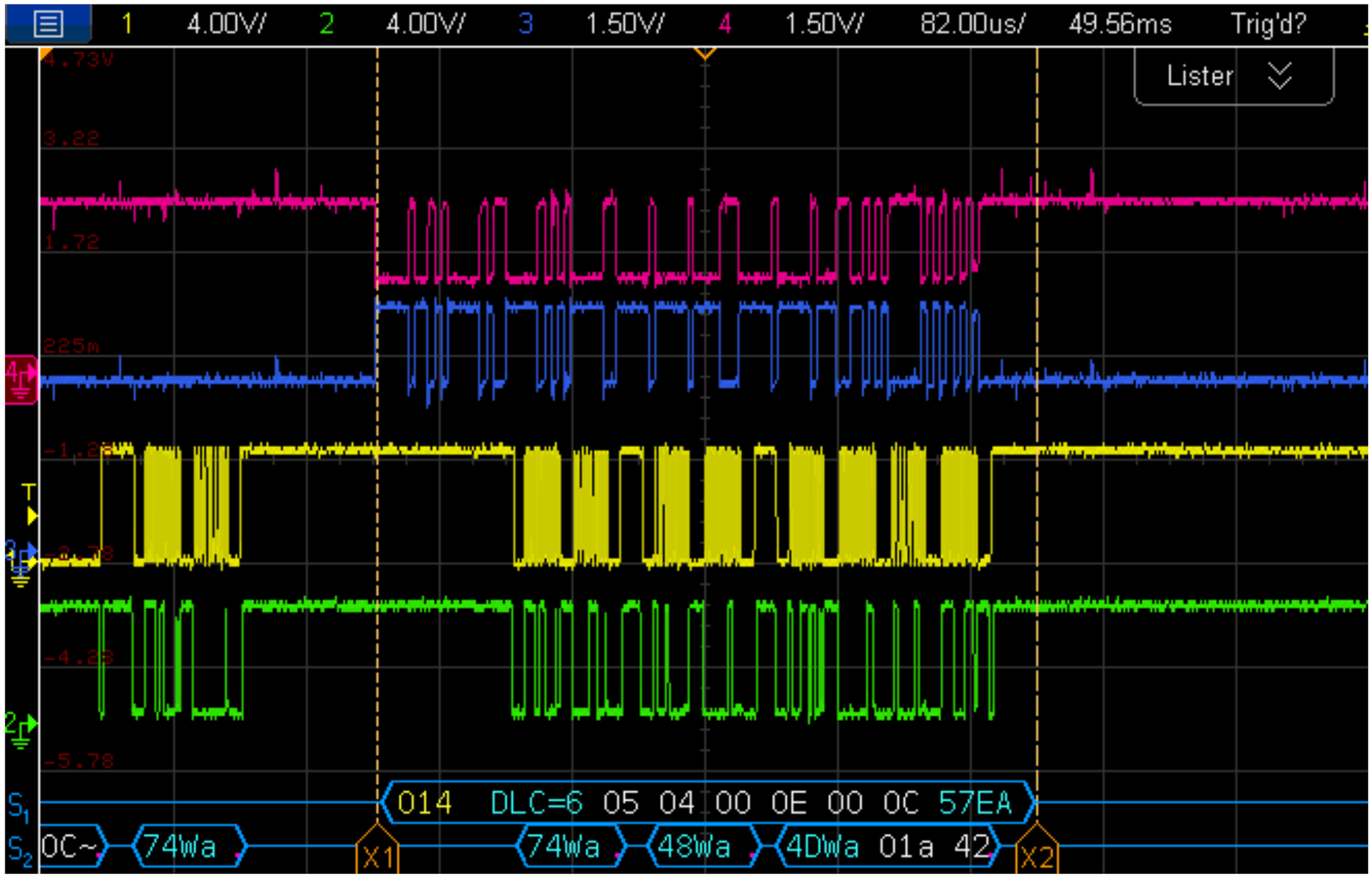
CAN bus speed [kbps]	t_{R1} [ms]
125	106.265
250	105.853
500	105.442
1000	105.157

Total readout time for varying CAN bus speeds.

USART baud rate [Baud]	t_{R2} [ms]
9600	339.85
14400	260.799
38400	163.648
57600	143.294
115200	124.105

Total readout time for varying USART baud rates.

Reading ADC Value of One Channel



Controller Board Box