Thermal compensation of the optical RF delay line for the SPS transverse damper

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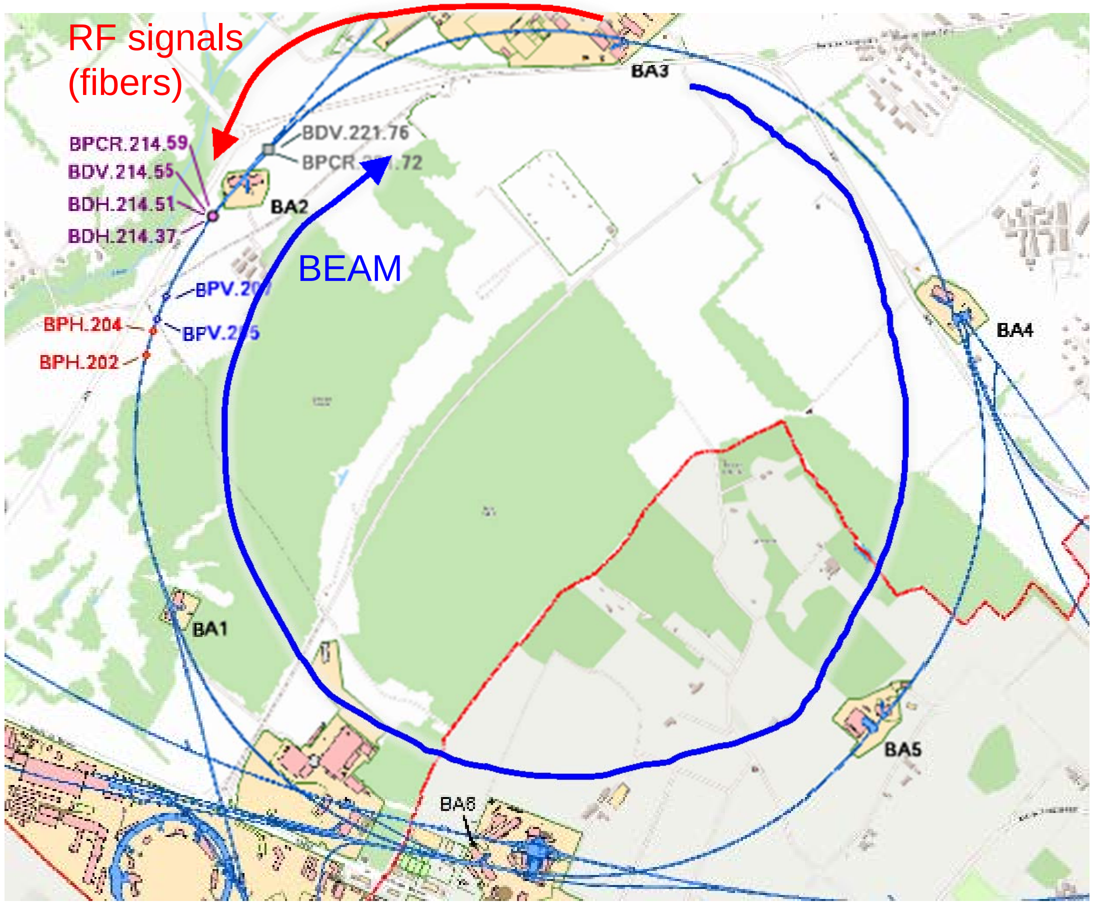
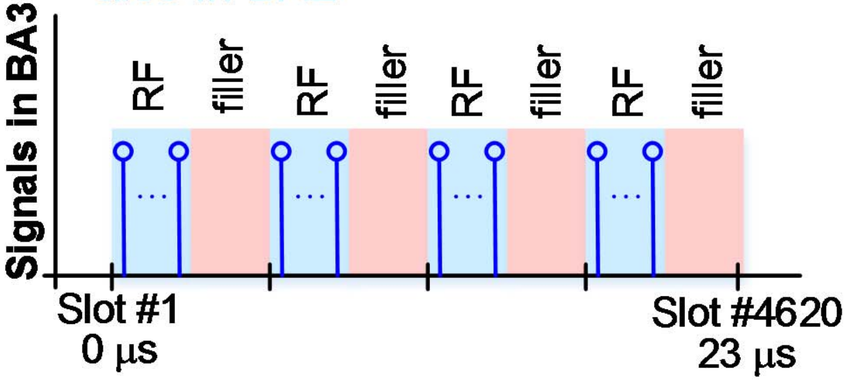
Motivation

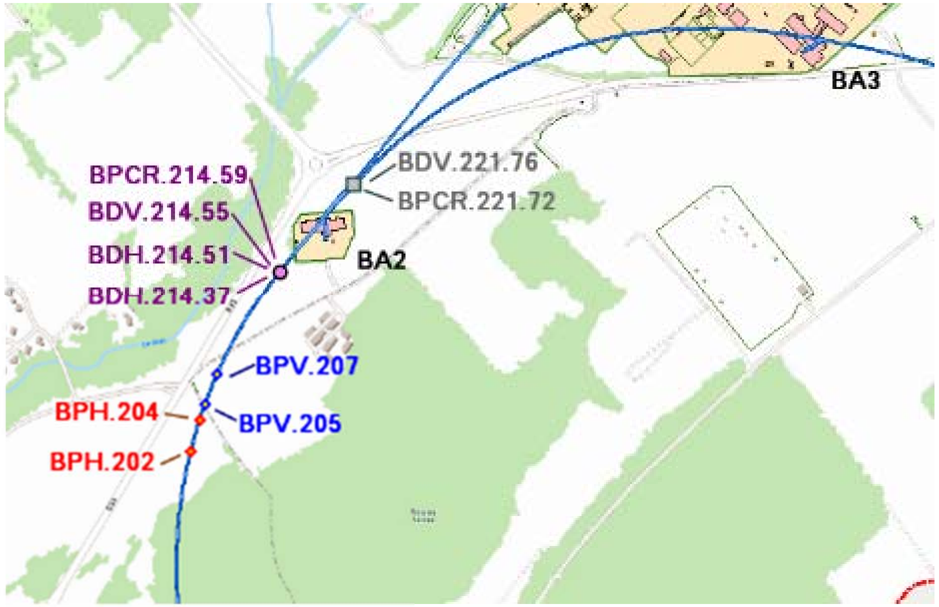
- SPS reference RF signals are generated in BA3
- SPS damper installed in BA2 (opposite direction than the beam is circulating)
- Ions use a sophisticated RF modulation scheme to accelerate "fixed frequency acceleration"
- Reference RF signals and the beam pickup signals have to arrive to the electronics at the same time

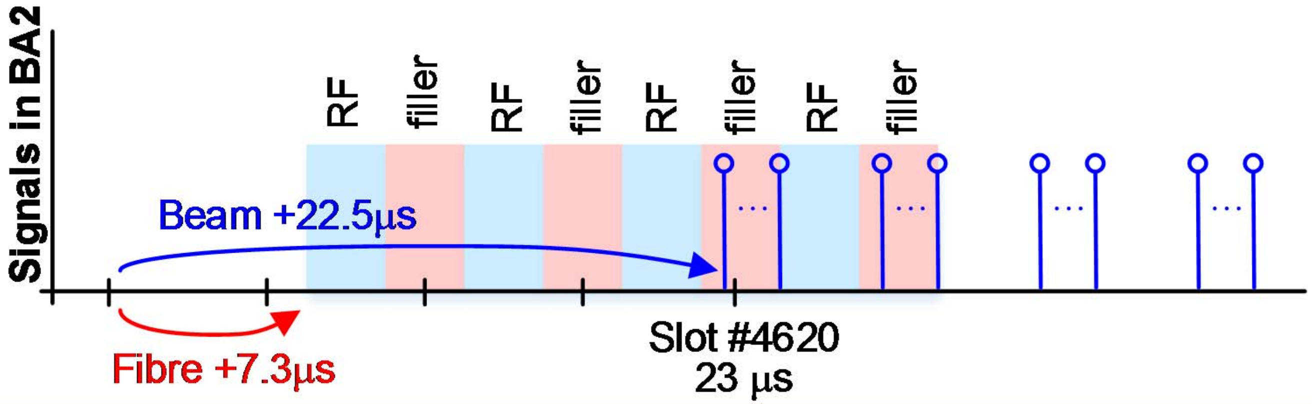


Motivation

- RF signals and the beam are synchronous in BA3
- They have to be made synchronous also in BA2

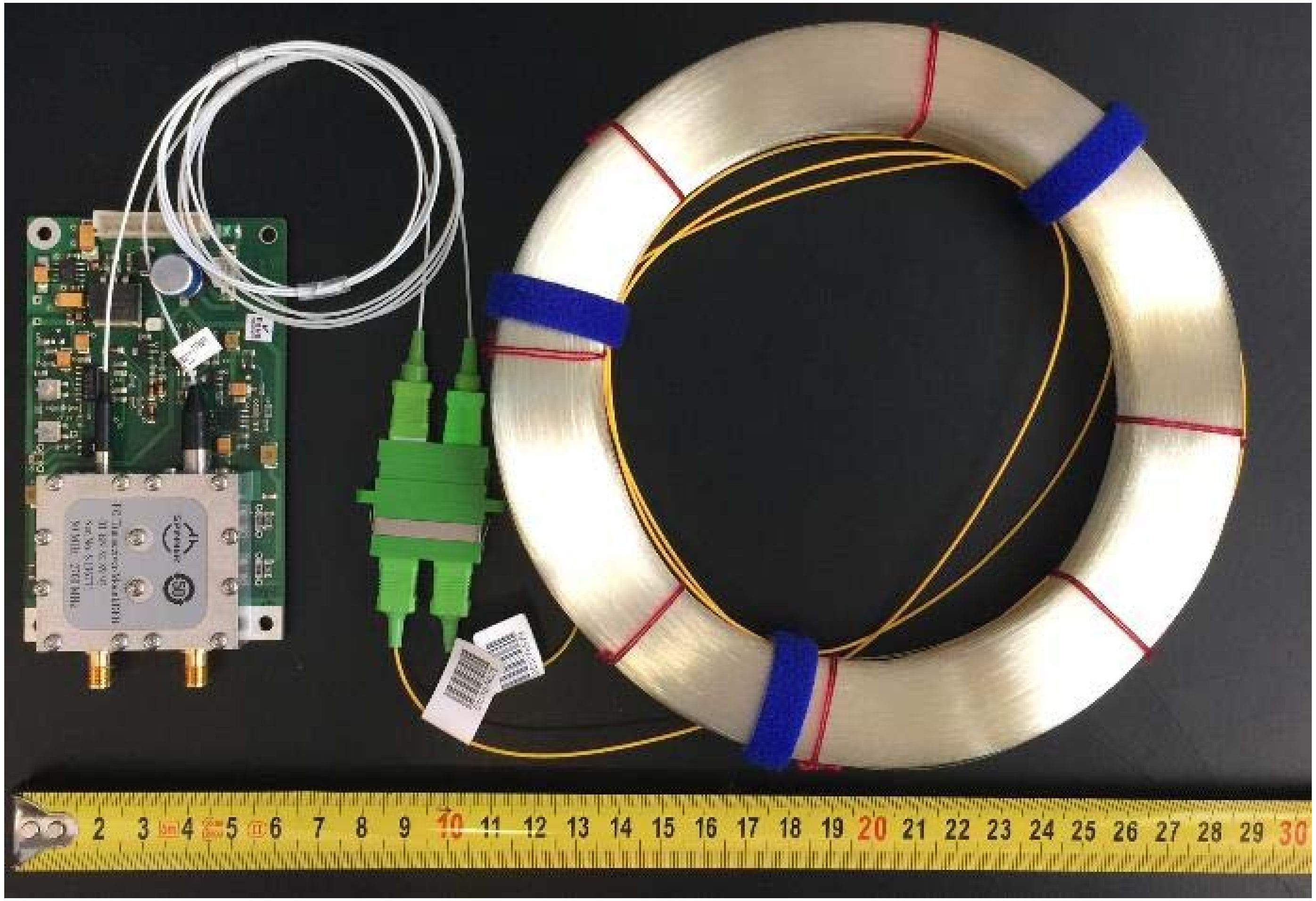






Fibre RF delay line

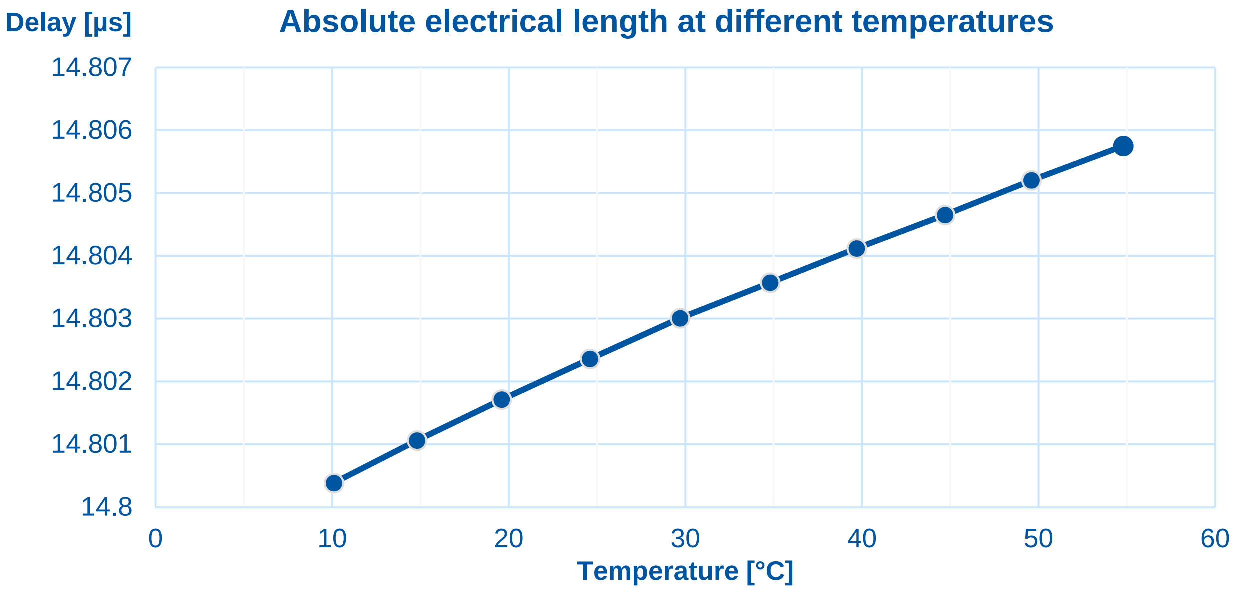
- Delays of several tens of μs can be easily obtained using analogue optical transceivers and single mode optical fibres



14.8 μs fibre coil (3 km) with analogue Spinner optical transceiver

Purpose of fibre thermal compensation

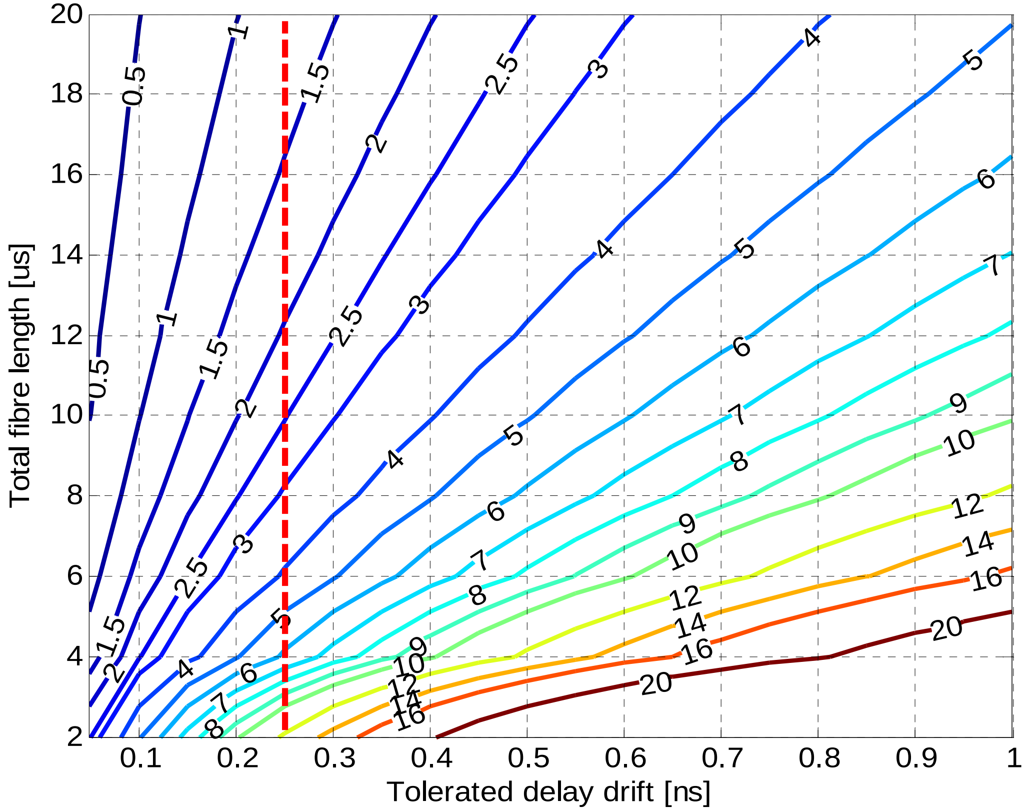
- Fibre thermal drift is too large for our application, temperature effects have to be compensated
- Group delay of 3 km long (~14.8 μs) optical fibre was measured in a thermal chamber

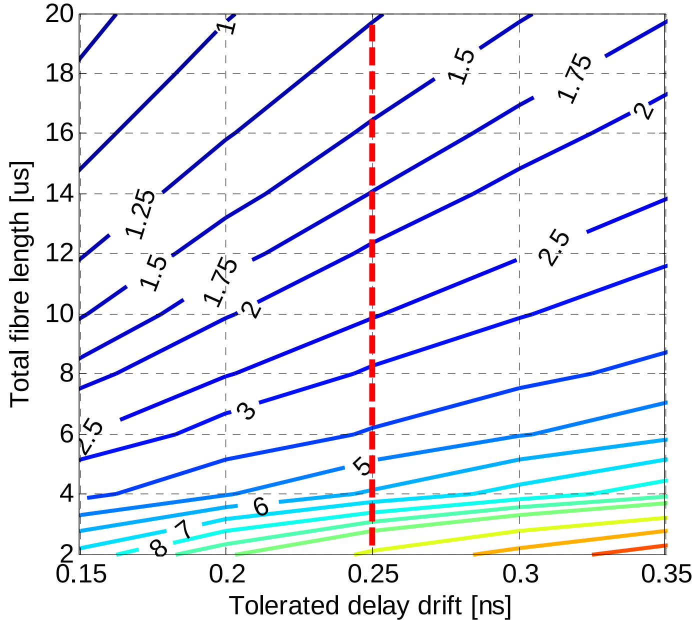


- Normalized polynomial fit:
  τ_{dNORM} = $-3.265197\mathrm{x}10^{-8}\, t^2$ + $\boldsymbol{1.015301\mathrm{x}10^{-5}\, t}$ + $9.997133\mathrm{x}10^{-1}$ [1; °C]

Requirements for temperature stability

- To meet the desired stability of group delay, temperature control must be very tight.
- Tolerated delay drift for correct damper operation is typically ±125 ps.

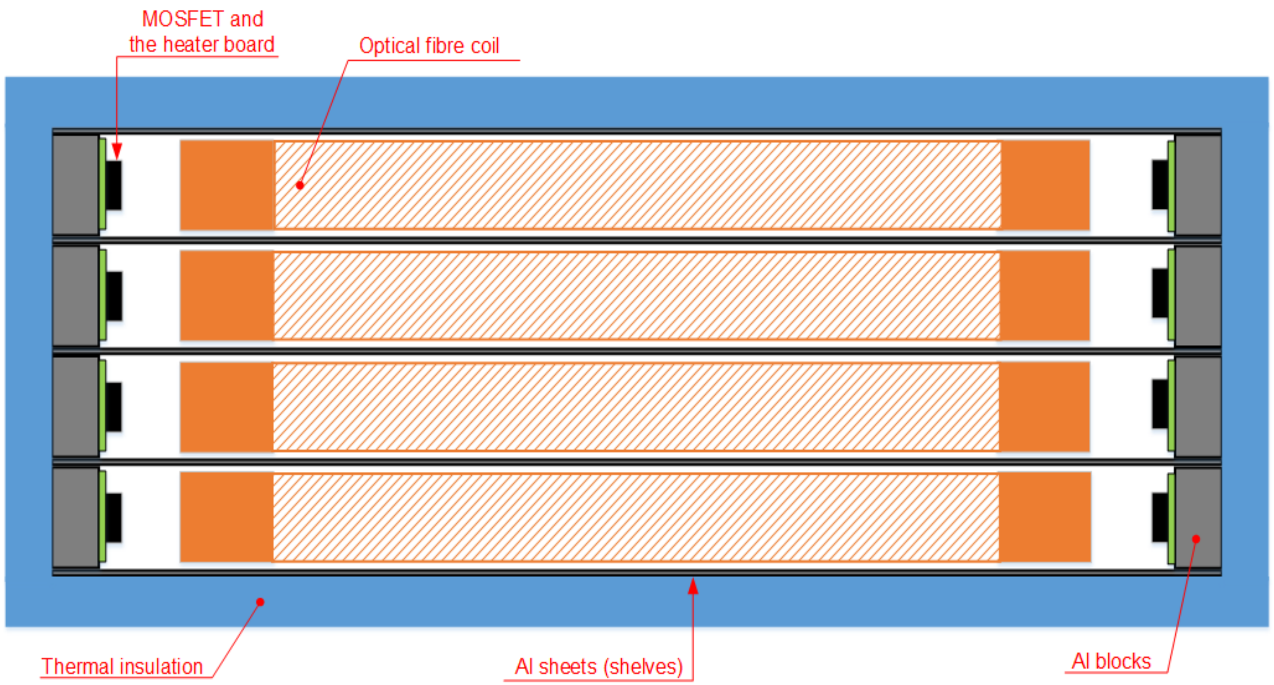




Maximum fibre temperature variation as a function of total fibre delay and tolerated delay drift.

Design of thermally insulated enclosure

- For practical reasons the fibre temperature is stabilized above the ambient
- Thermally insulated enclosure, housing 4 fibre coils have been designed
- To increase the thermal mass (and inertia), the enclosure is made of aluminium bars



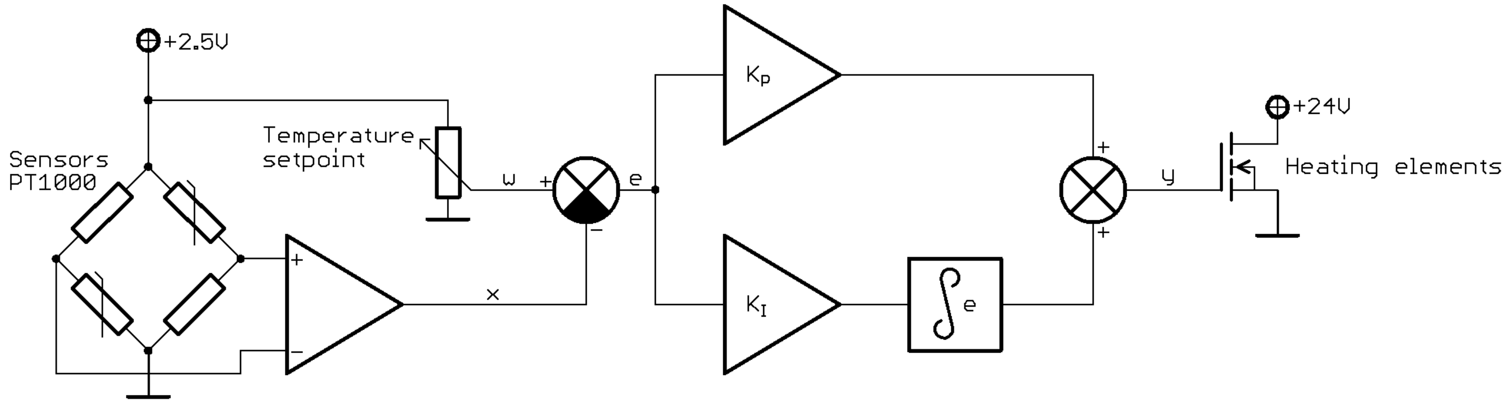
Design of thermally insulated enclosure

- Heating is provided by power MOSFETs mounted to the aluminium bars
- Each fibre slot has a heater board mounted on both sides
- Total 8 heater elements

- Each heater boards is equipped by a PT1000 temperature probe

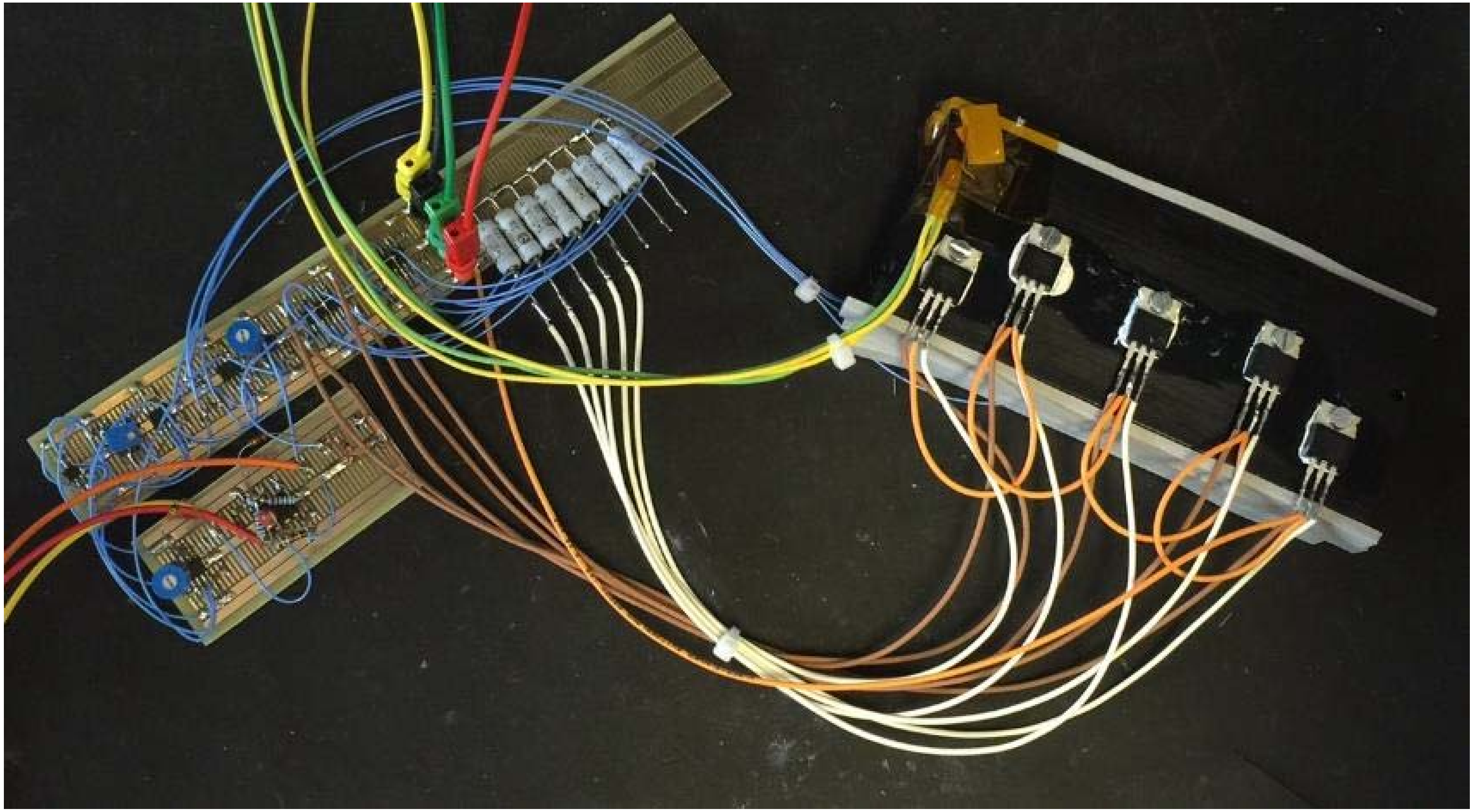
Temperature controller

- Design goal was to reach a temperature stability better than ±0.25 °C
- Controller is build as a fully analogue circuit
- Precision parts are used, such as PT1000, instrumentation amplifiers, voltage reference…
- To meet this requirements PI topology was used
- The topology was carefully designed such that temperature drifts in various parts of the circuit are cancelling-out



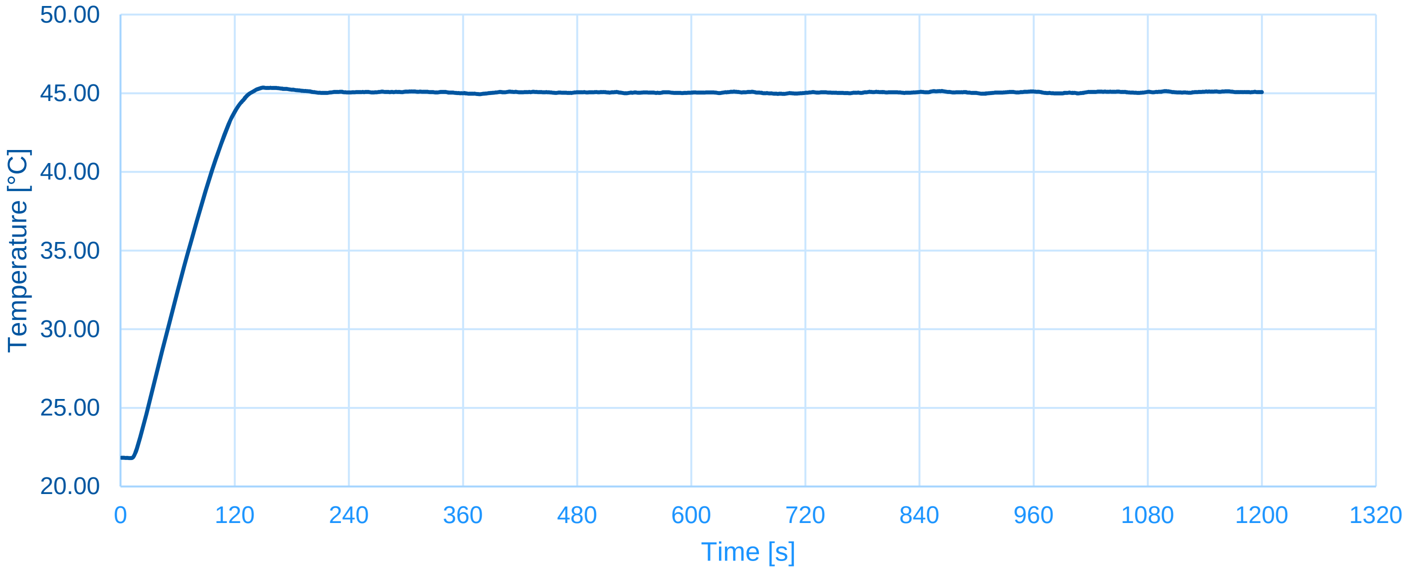
Controller test circuit

- For testing the performance of design controller prototype was build



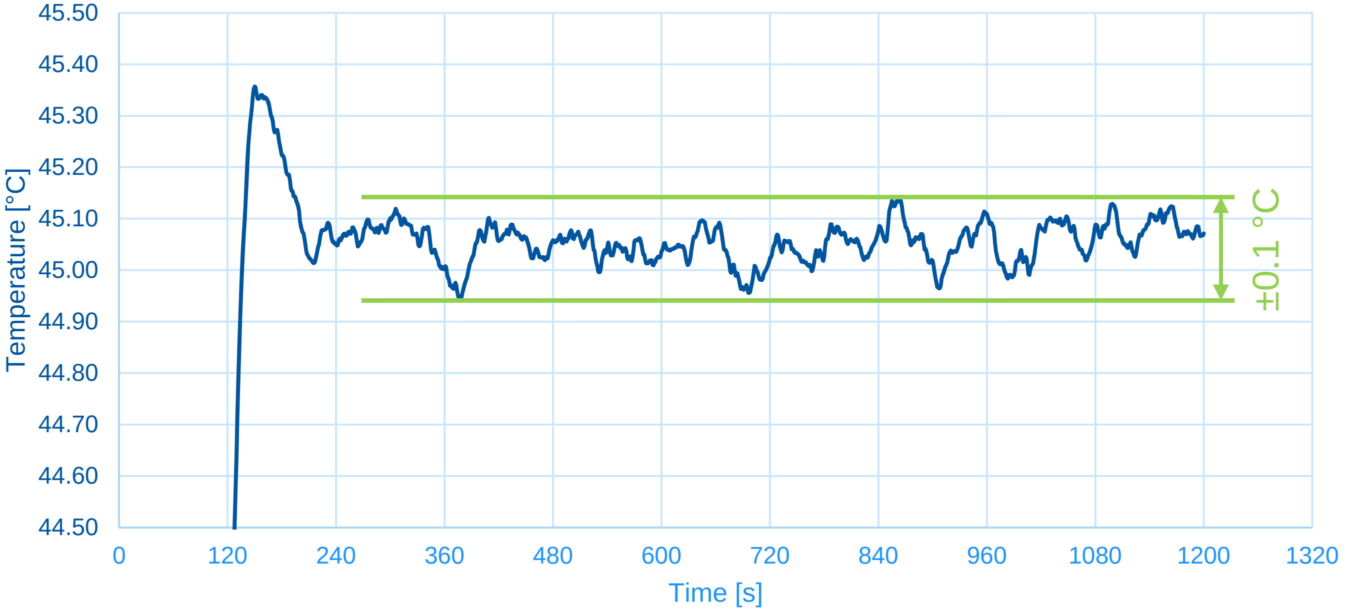
Performance of the controller

- Step response (switch on transient)
- Constant ambient temperature of 22 °C
- Setpoint temperature of 45 °C



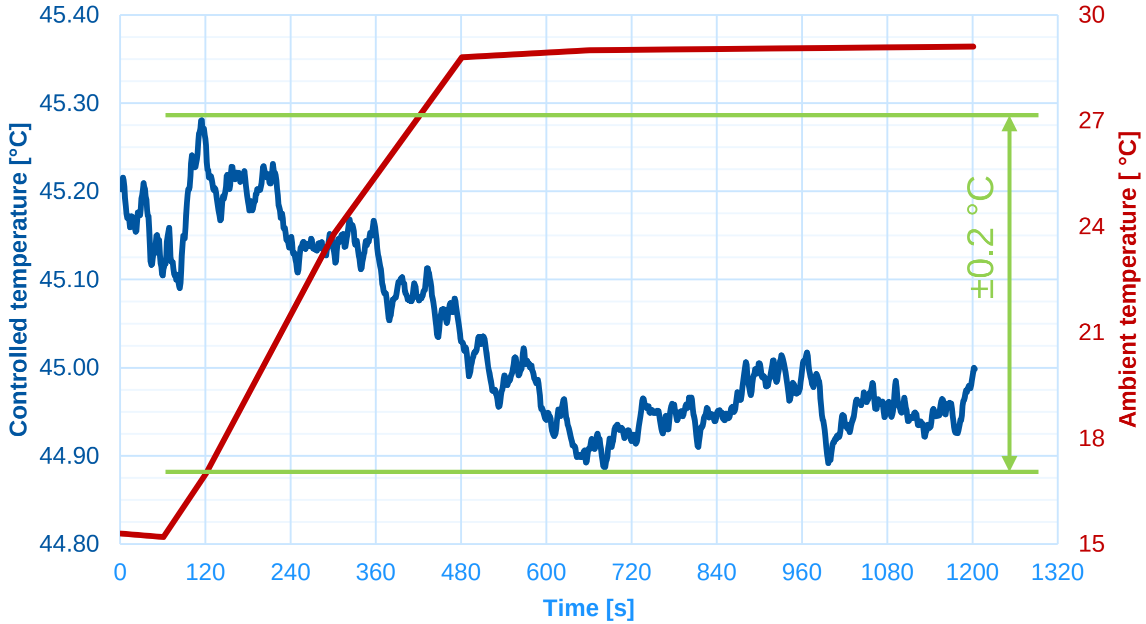
Performance of the controller

- Stability at constant ambient temperature 22 °C



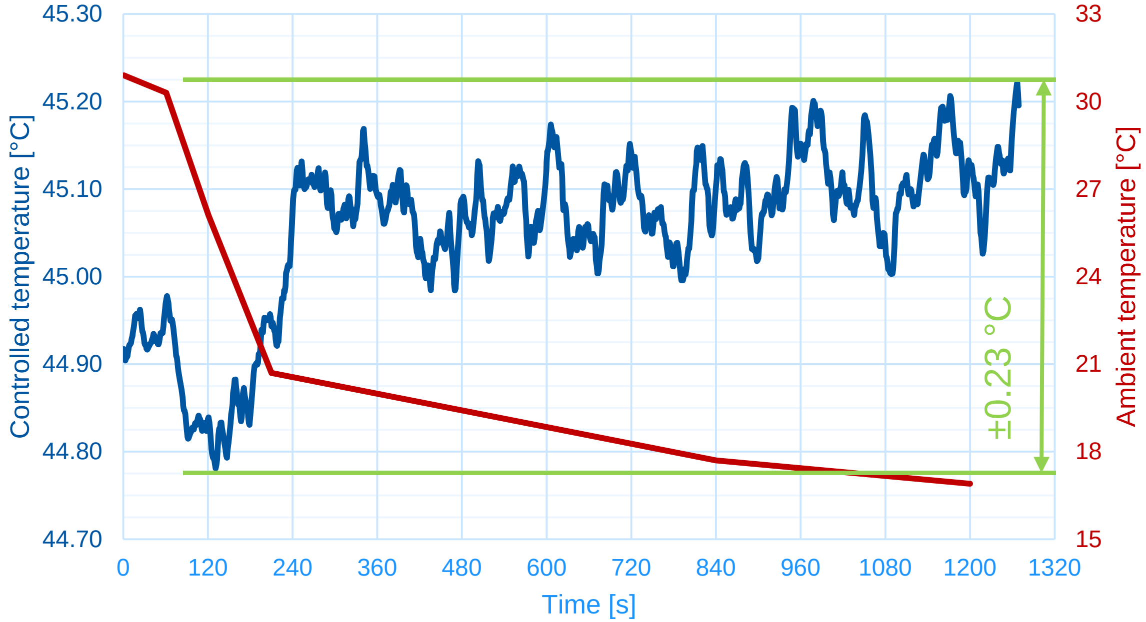
Performance of the controller

- Response to a large external perturbation
- Setpoint temperature 45 °C
- Variation of ambient temperature from 15 to 29 °C when the thermal chamber was heating up



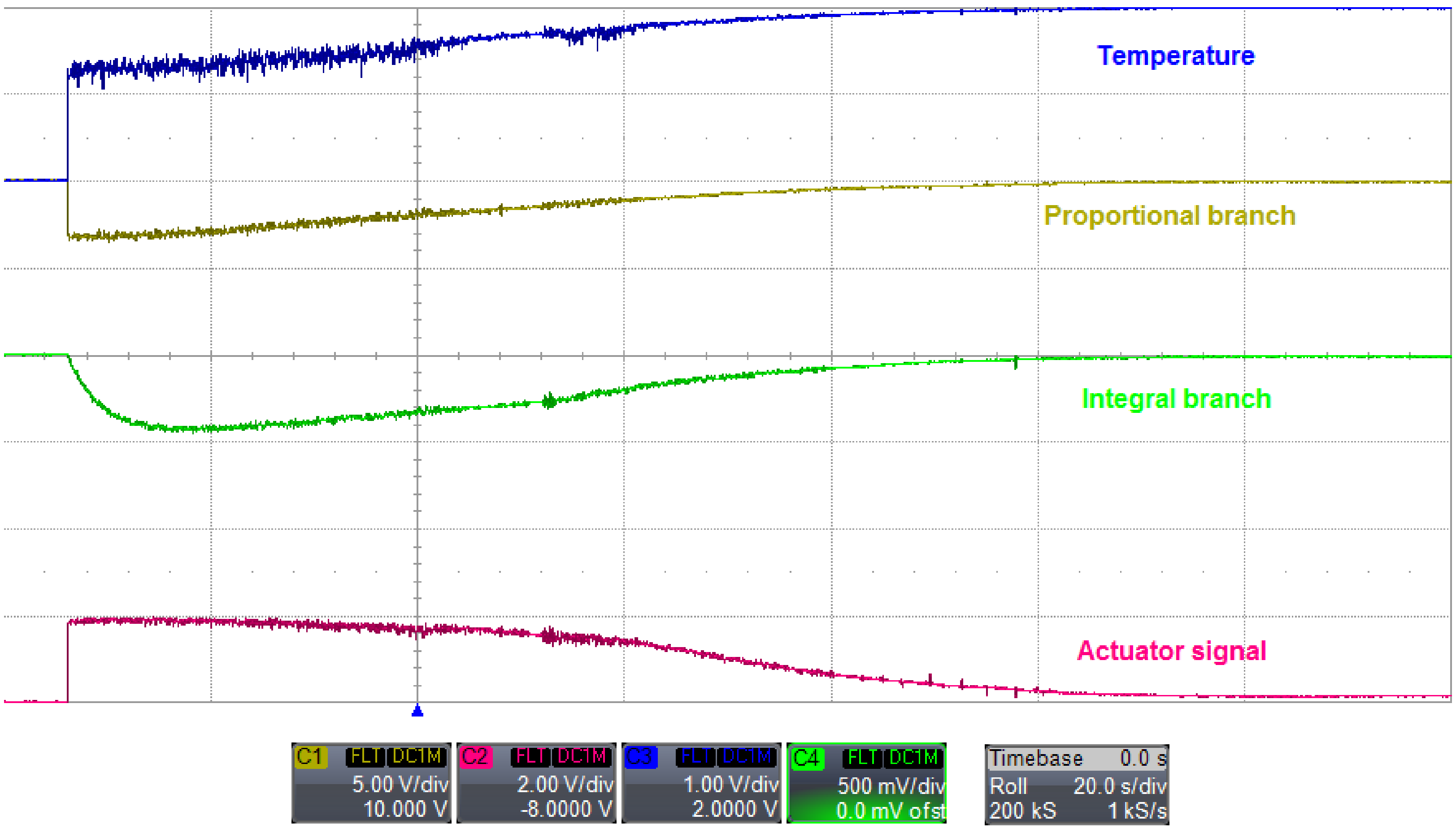
Performance of the controller

- Response to a large external perturbation
- Setpoint temperature of 45 °C
- Variation of ambient temperature from 31 to 17 °C when the thermal chamber was cooling down



Performance of the controller

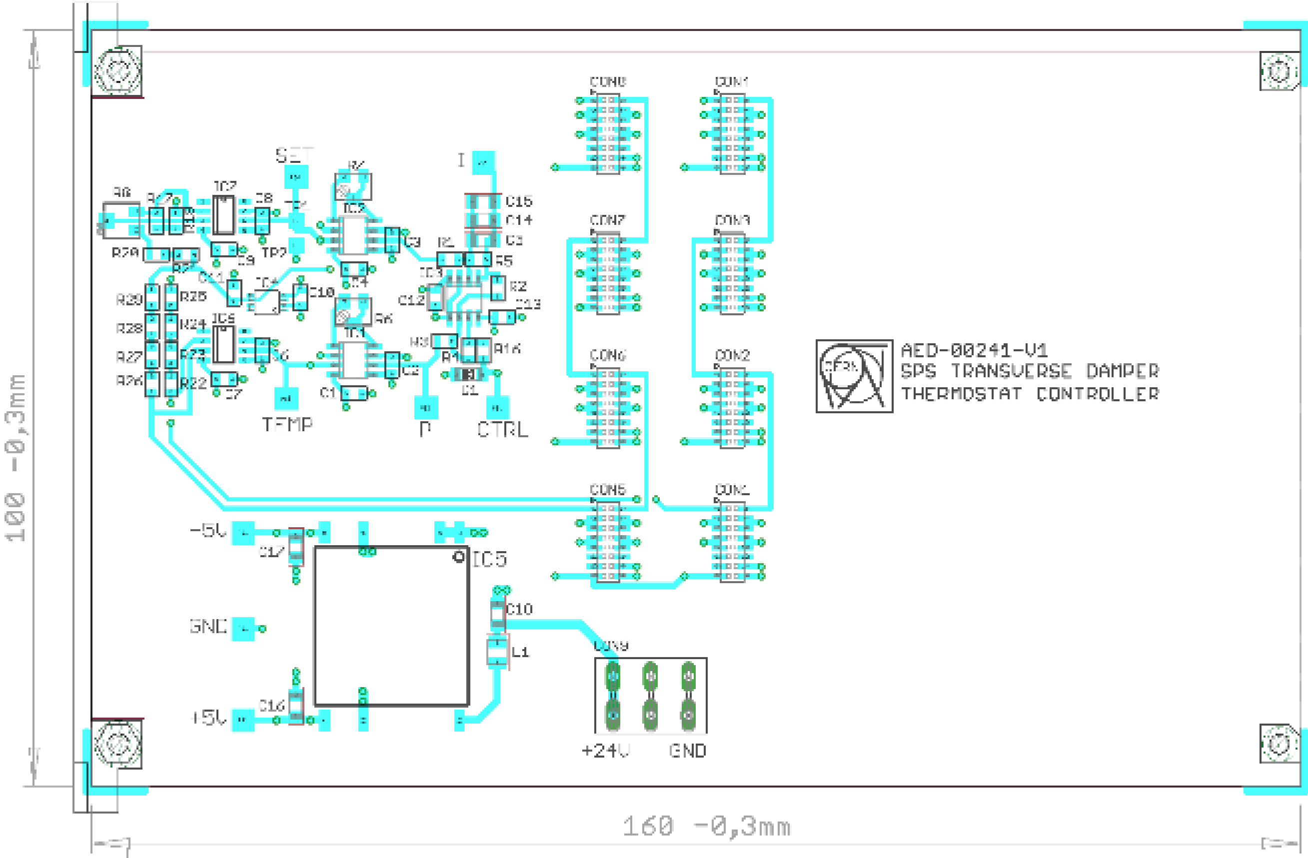
- Captured analogue regulator signals during initial heat up from 23 to 45 °C

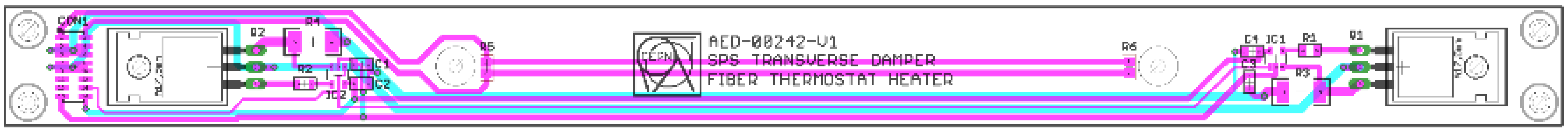


Project status

- Controller prototype successfully tested
- Final PCB designed and production file ready to sent out
- Mechanical design – drawings being finalized by P. Hofer
- Whole unit ready to be sent for production and installation in BA2

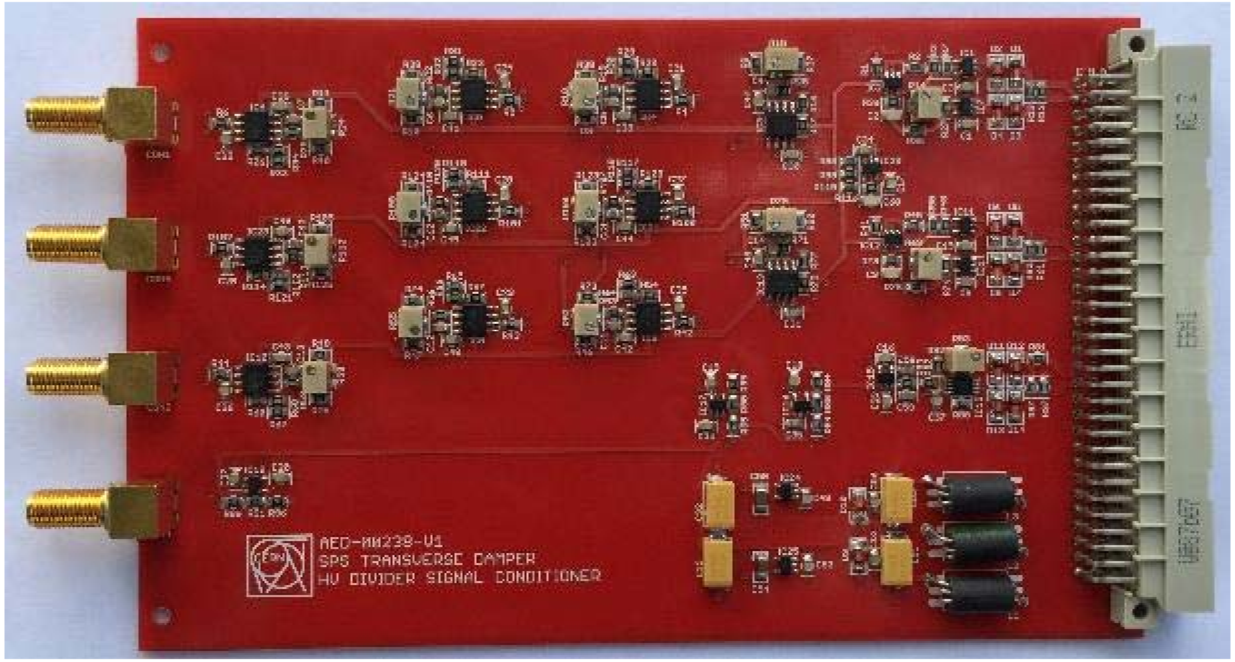
Project status



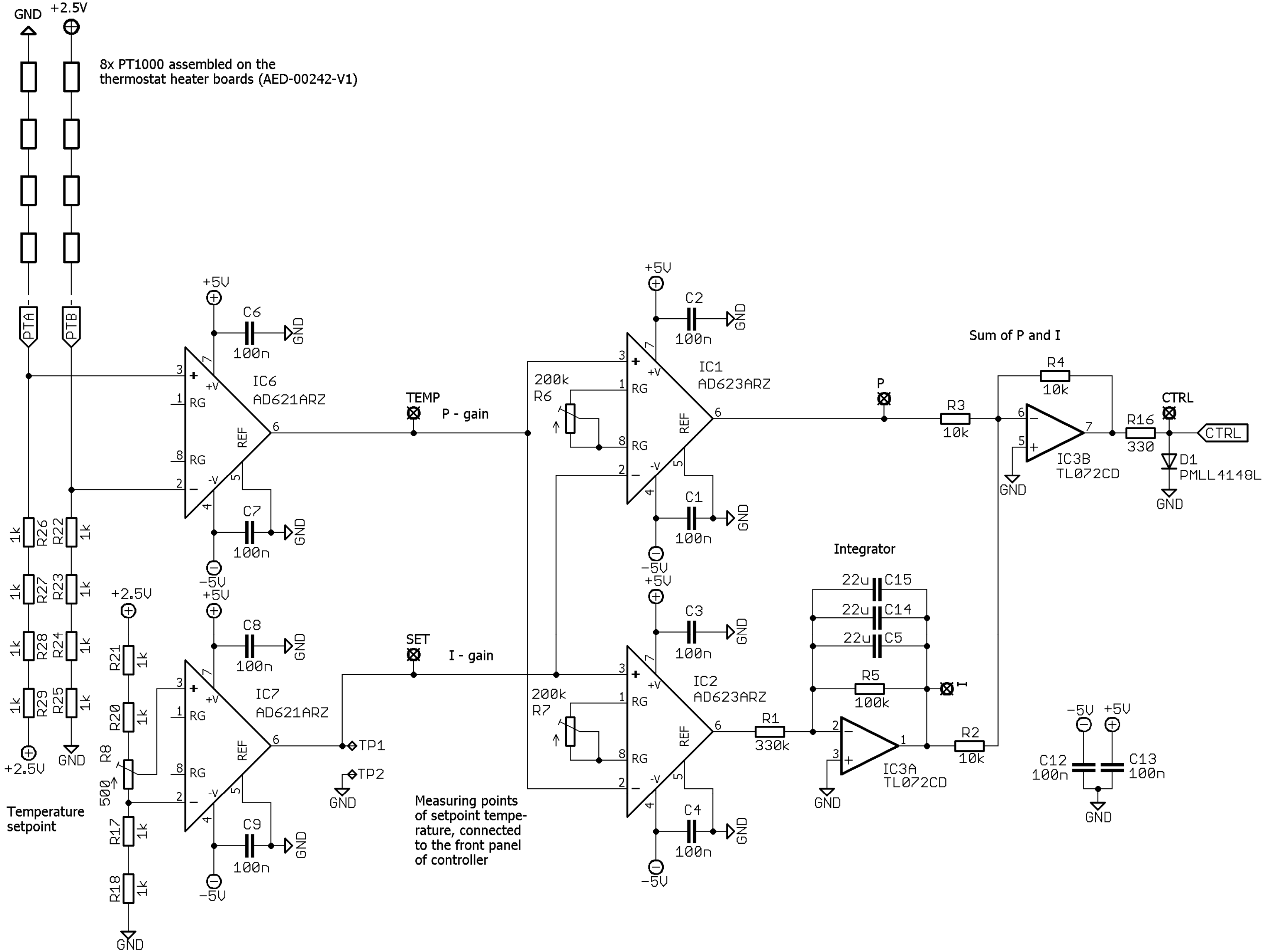


High voltage divider signal conditioner

- Second project I was working on during my stay
- Conditioning of RF-divider signals of the SPS transverse damper tetrode amplifier. Analogue and RF circuitry, 20 MHz bandwidth, fan-out, multiple 50 Ω line drivers.
- Prototype assembled, ready for tests




Questions ?
Thank you for your attention


8x PT1000 assembled on the
thermostat heater boards (AED-00242-V1)
GND
+2.5V
PTA
PTB
R26 1k
R27 1k
R28 1k
R29 1k
R22 1k
R23 1k
R24 1k
R25 1k
Temperature
setpoint
R21 1k
R20 1k
R8 500
R17 1k
R18 1k
IC6
AD621ARZ
IC7
AD621ARZ
C6 100n
C7 100n
C8 100n
C9 100n
+5V
-5V
TEMP
P - gain
SET
I - gain
TP1
TP2
Measuring points
of setpoint tempe-
rature, connected
to the front panel
of controller
IC1
AD623ARZ
IC2
AD623ARZ
200k
R6
200k
R7
C1 100n
C2 100n
C3 100n
C4 100n
P
Sum of P and I
R3 10k
R4 10k
IC3B
TL072CD
R16 330
CTRL
D1
PMLL4148L
Integrator
22u C15
22u C14
22u C5
R5 100k
I
R1 330k
IC3A
TL072CD
R2 10k
C12 100n
C13 100n