HV regulation board for the forward endcap
- Status -

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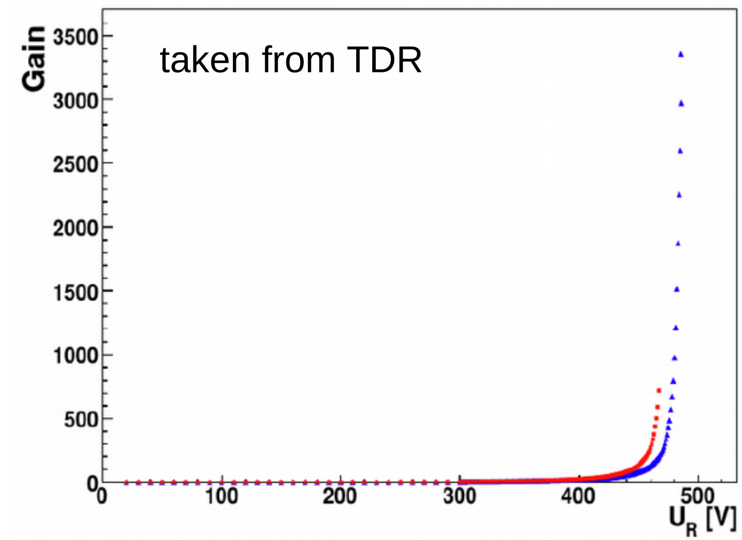
Introduction

Motivation

- Reach gain spread of max. 1%
- More freedom in matching procedure (less strict), G(U) very steep @200
- Be able to compensate different gain drifts of APDs due to radiation damage on long term

Irradiation ^{241}AmBe Source



Original idea voltage distribution

Due to very limited cross section for HV cables

→ One HV is fed to 8 APDs

Power distribution concept

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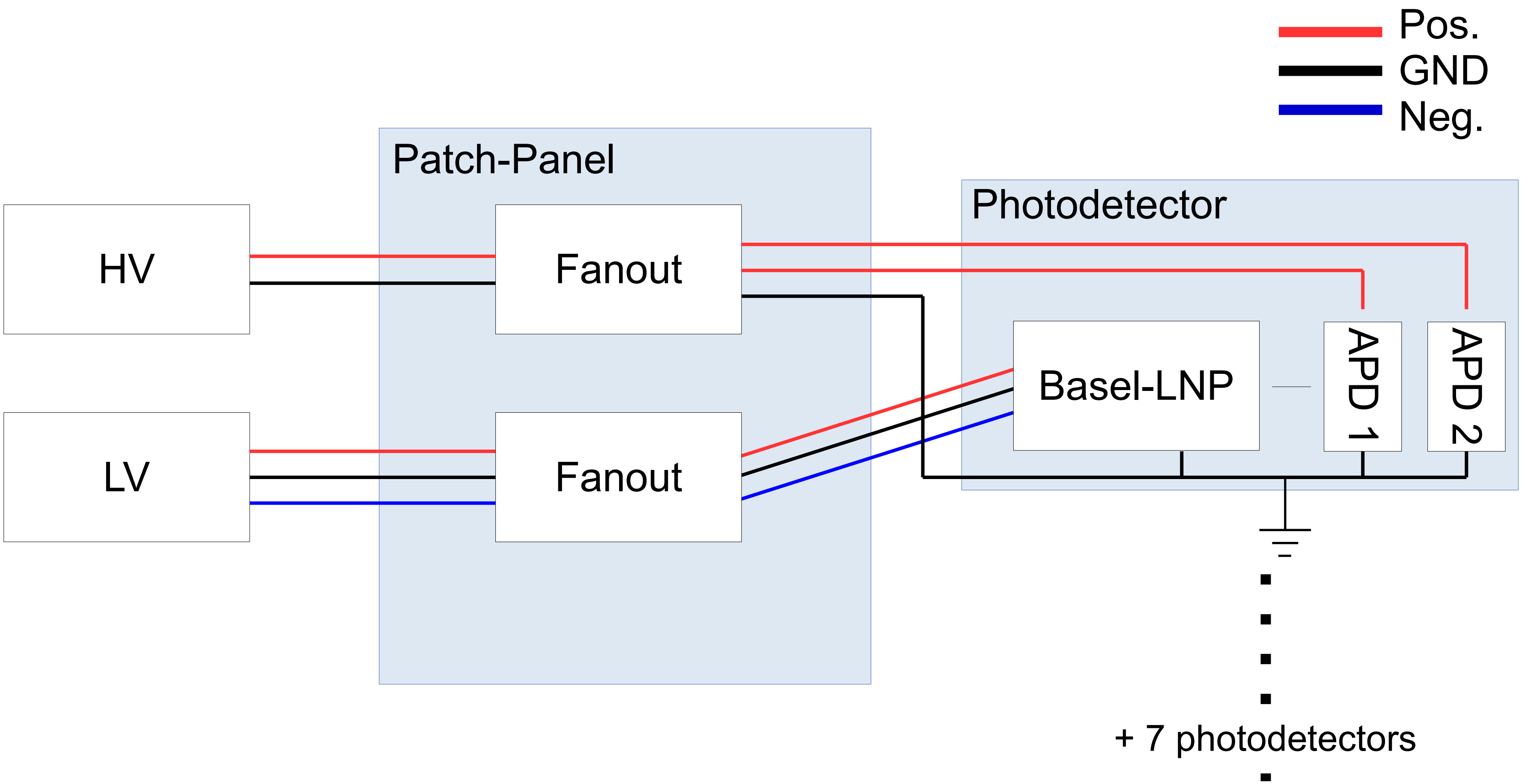
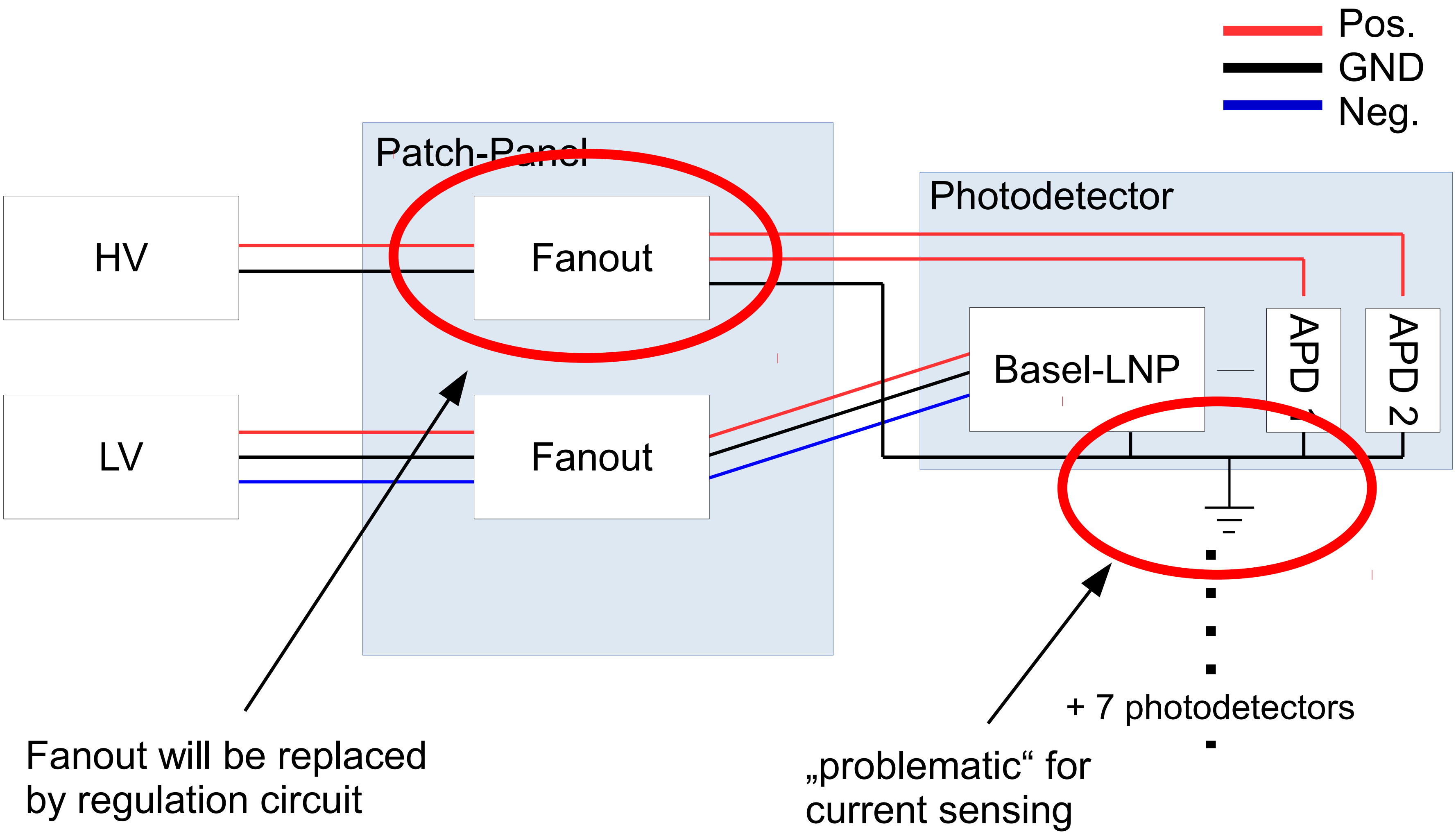
Voltage distribution



Power distribution concept

Voltage distribution



Starting point

Reuse HV regulation circuit from the Crystal Barrel Exp.@ELSA (also used in the barrel part)

- Regulation range 10Bit (100-500V)
- Temp. compensation
- I²C controlled

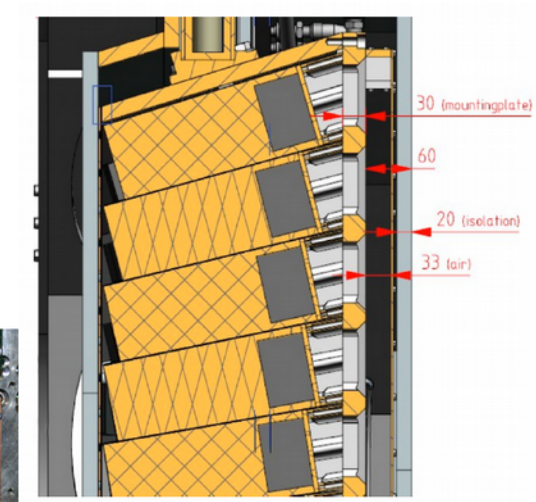
Special adaption for forward endcap

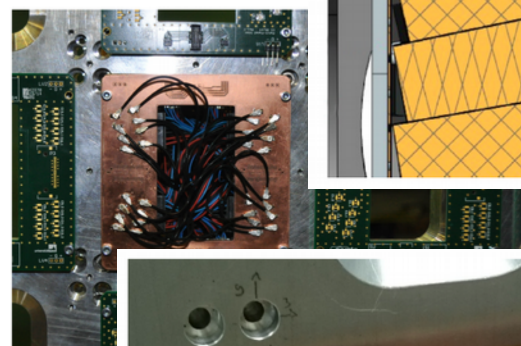
- 8%/V @ gain 200 → ~ 0,1V Voltage resolution
- Resonably regulation span (~25-40V)
- Accurate HV voltage measurement
- (Current measurement)

Mechanics – space constraints

Extrem dense situation behind the backplate

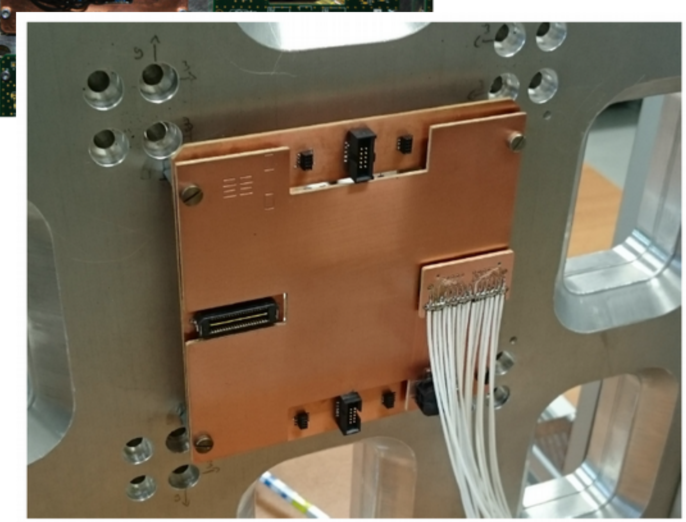
- All cables have to fit in a depth of 3.3cm
- Patch panel is interconnection of alveole to „outside“ cables





Add piggyback board

- As close as possible to existing patch panel
- Adds space for components of about 73 cm²

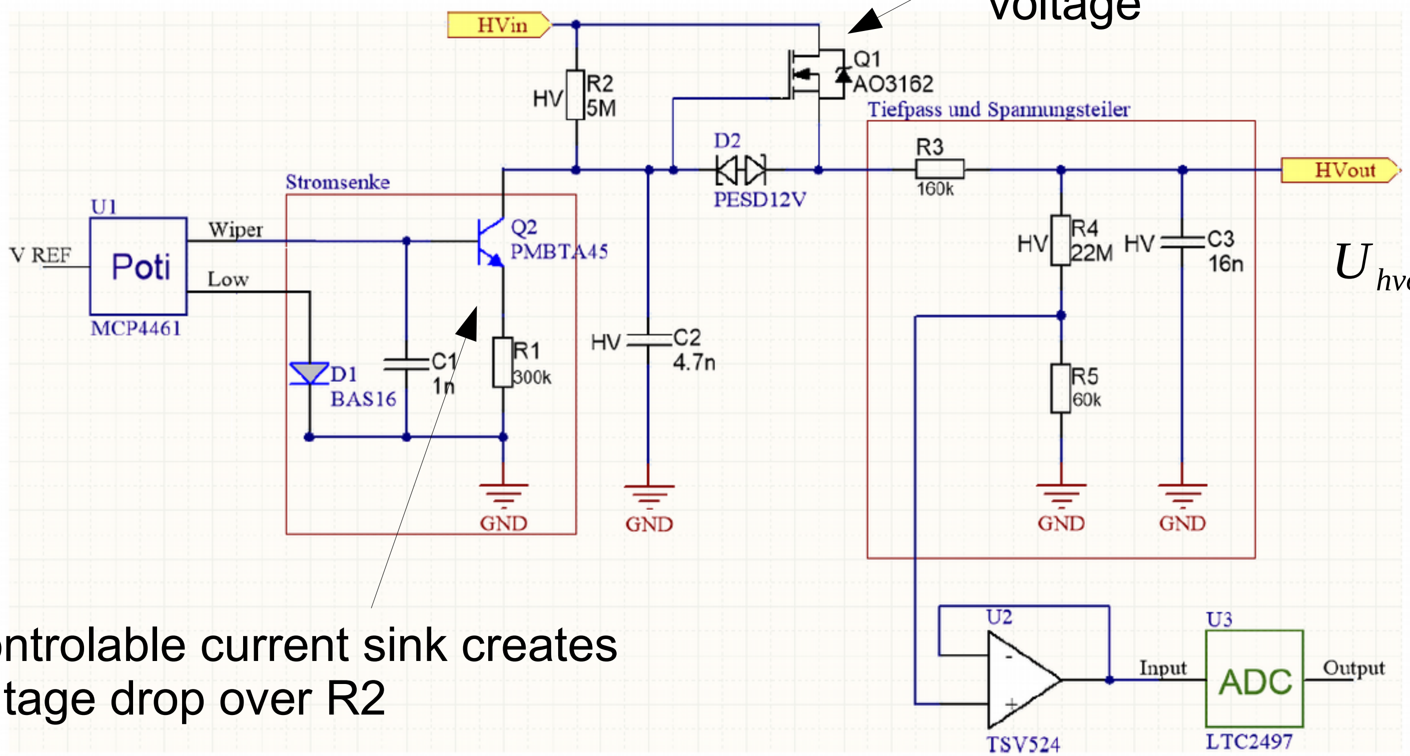


Piggyback board helps in mounting procedure

Voltage regulation

Schematic of basic curcuit

Voltage follower to tap off voltage



$$U_{hvout} = U_{hvin} - U_{R2}$$

Controlable current sink creates voltage drop over R2

Whole basic circuit is needed 32x for 16er and 16x for 8er alveole

Voltage regulation

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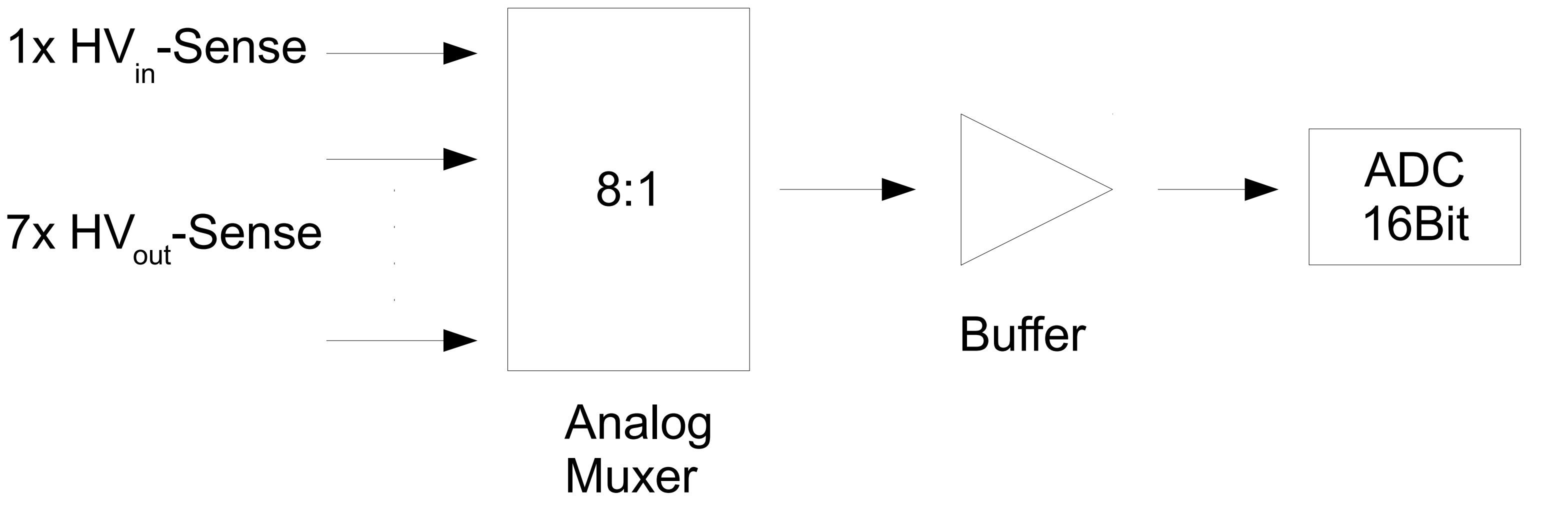
Instead of 32 OP-amps and 2 ADCs, sense voltages switched by muxer



Pros

- Monitoring of input voltage
- Recalibration of ADC channels possible after mounting

Cons

- Only 4/5 channels can be converted at once

Space constraints

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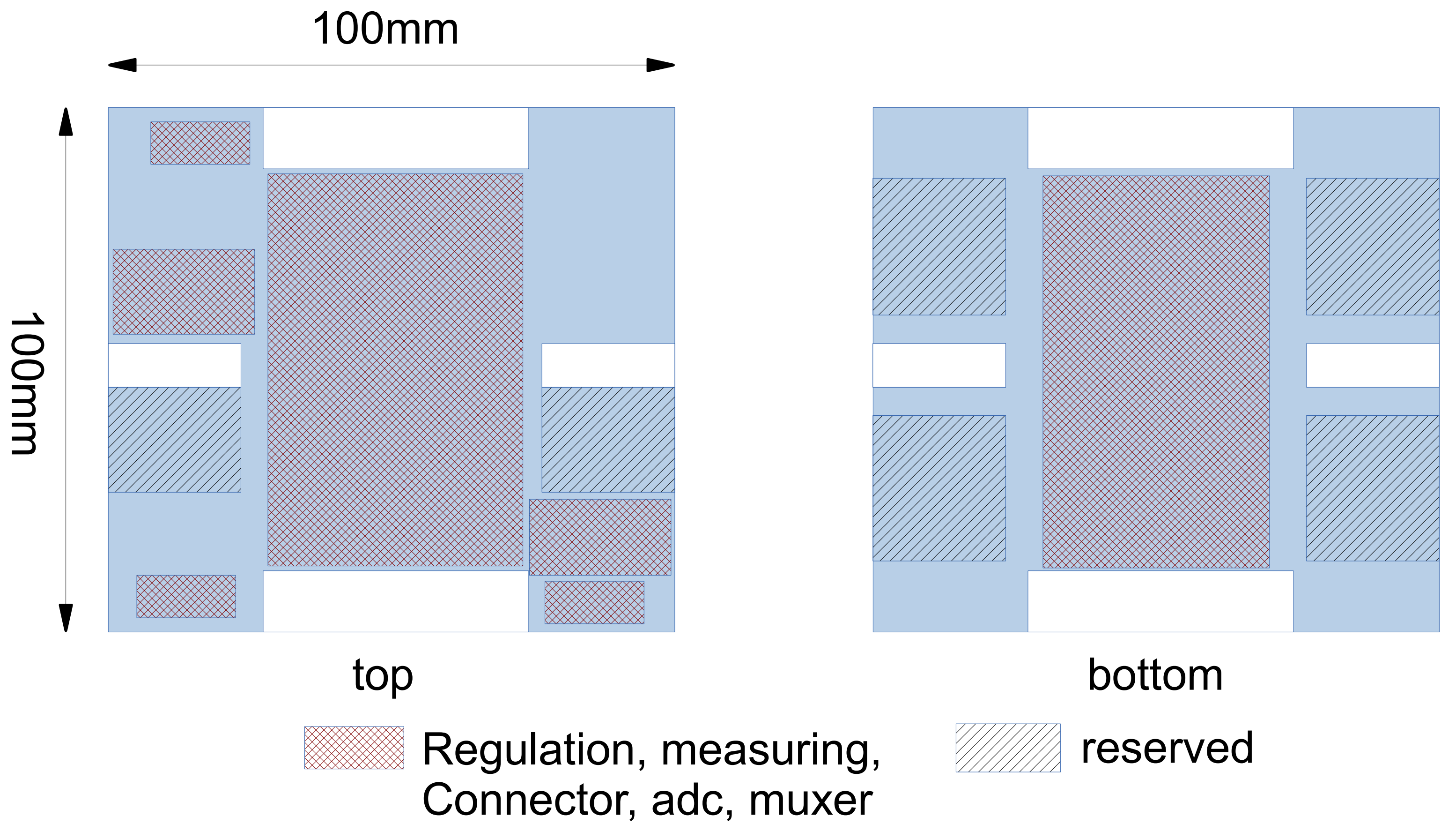
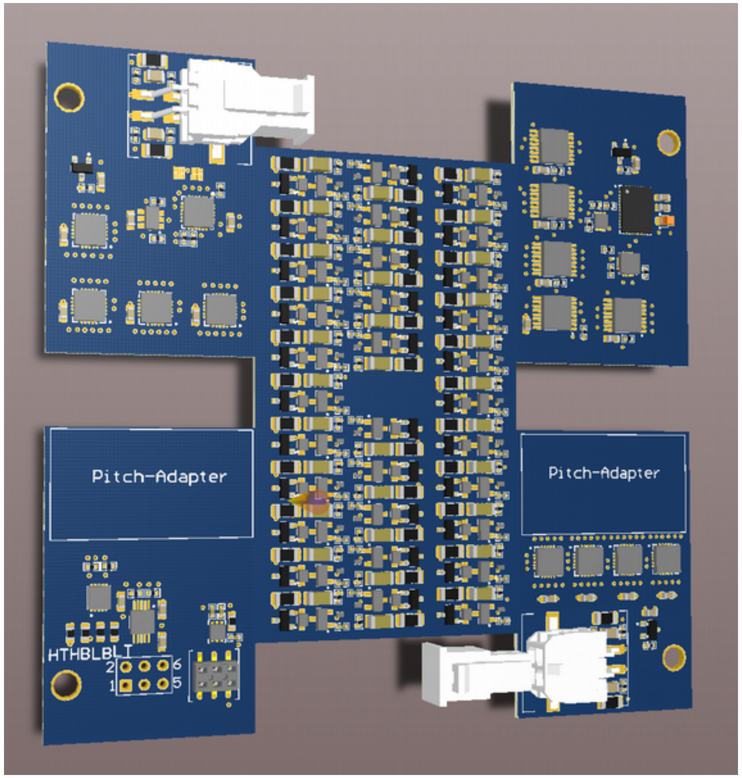
Almost all space used by regulation, measurement and connectors
high side current sensing needs more components



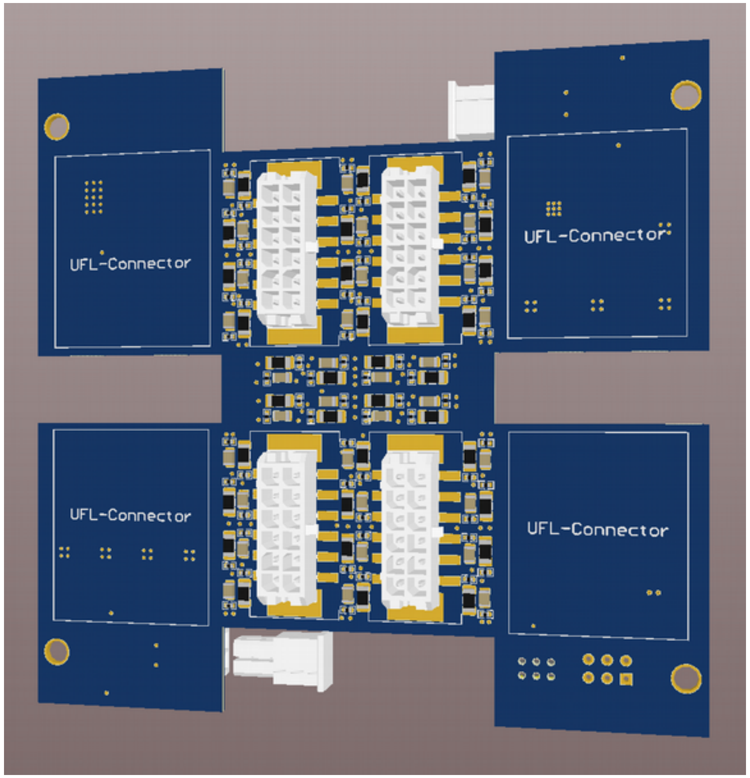
Not enough space → omited current measurement

Board layout

Current design

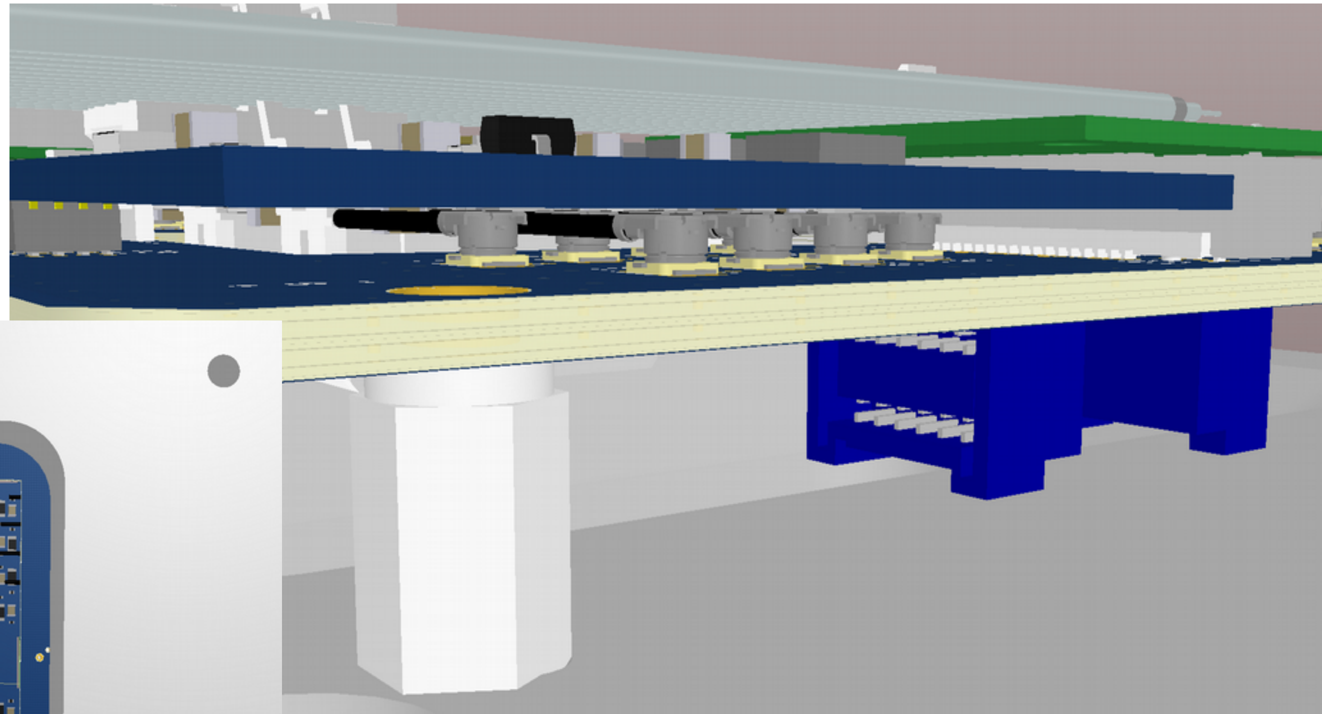


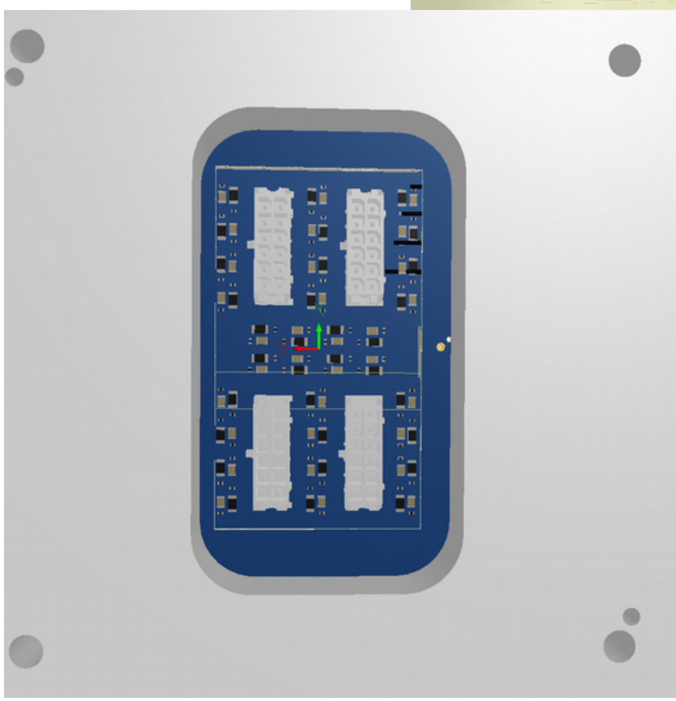
Top side



Bottom side

Board layout





Cable „problem“

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264 patch panel boards (16er/8er size) on each, one HV board

No room for 264 cables from available cross section.

→ In maximum ~32 cables possible

I²C

- 2 pairs via differential I²C (Data, CLK)
- chainable

SPI

- 4 single ended lines (SS, MOSI, MISO, CLK)
- chainable

To reduce cable count boards needs to be cascaded

16 boards → ~ 16 cables
8 boards → ~ 32 cables

Dangerous:
If data- or clock-lines get stuck, one loses control of connected boards

Test boards

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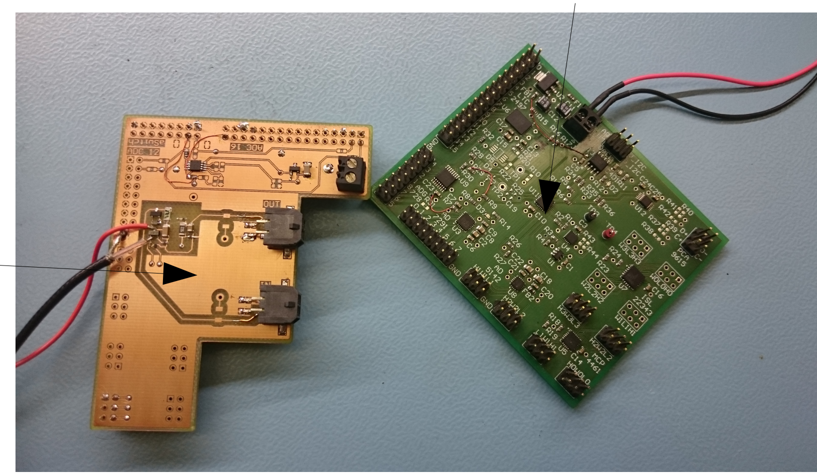
Due to different chip selection (dig. Poti, ADC) from original design, tests are needed

Test parameter of chips under different conditions

- Radiation
  - Test chips (I²C, ADC, Poti,...) up to a radiation dose of 500Gy
  - 4 runs of 125 Gy
- Temperature-cycles / dependence
- Longterm stability of voltage

I2C components test board

1-Channel prototype



Radiation tests

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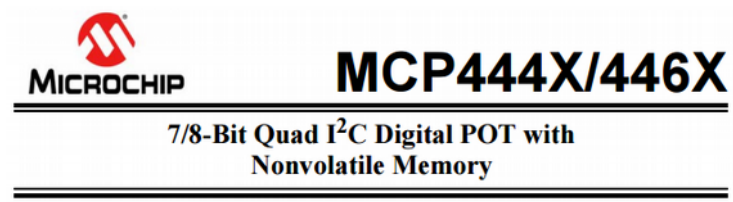
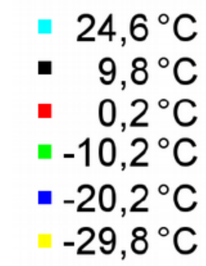
Test of digital potentiometer by measuring Resistance by 6,5digit multimeter

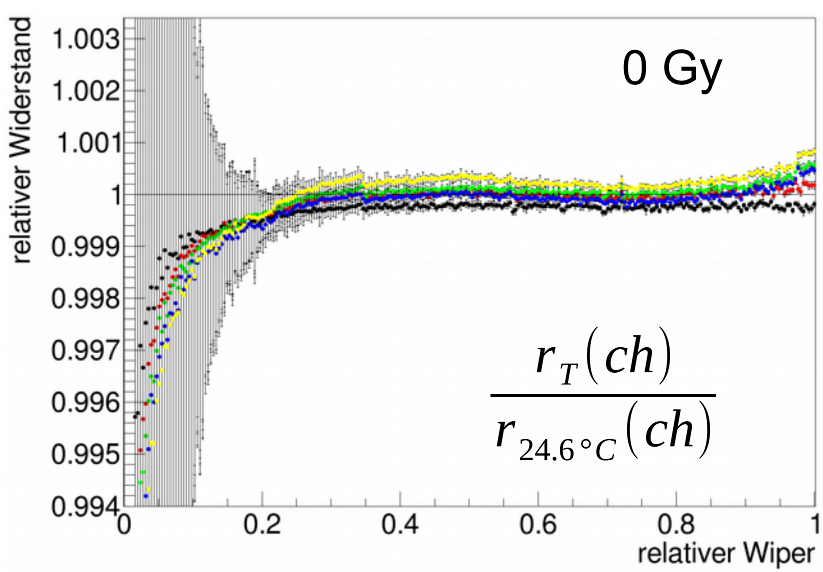

MICROCHIP MCP444X/446X

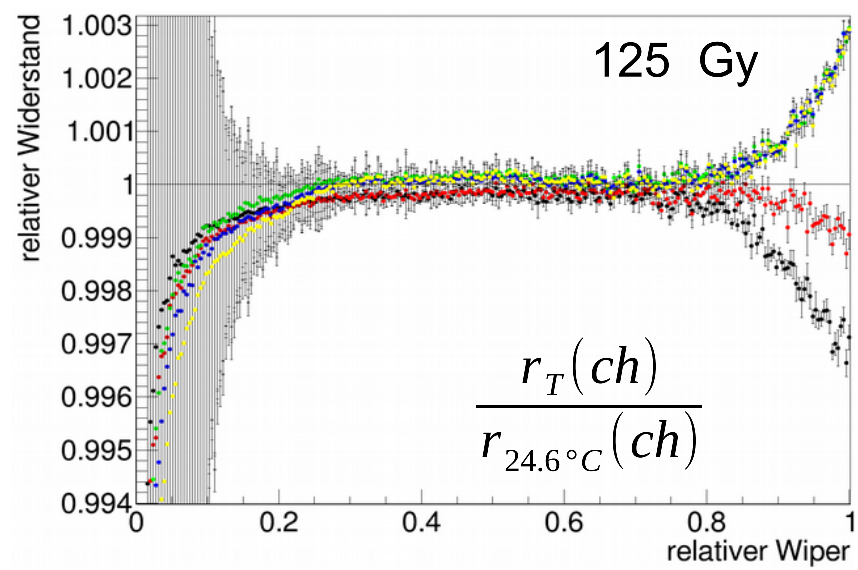
7/8-Bit Quad I^2C Digital POT with Nonvolatile Memory

Comparing the voltage divider factor for different radiation doses:

$$r_T(ch) = \frac{R_T(ch)}{R_T^{max}}$$







Radiation tests

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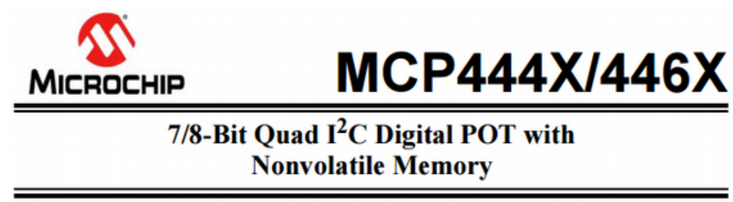
Test of digital potentiometer by measuring
Resistance by 6,5digit multimeter


MICROCHIP **MCP444X/446X**

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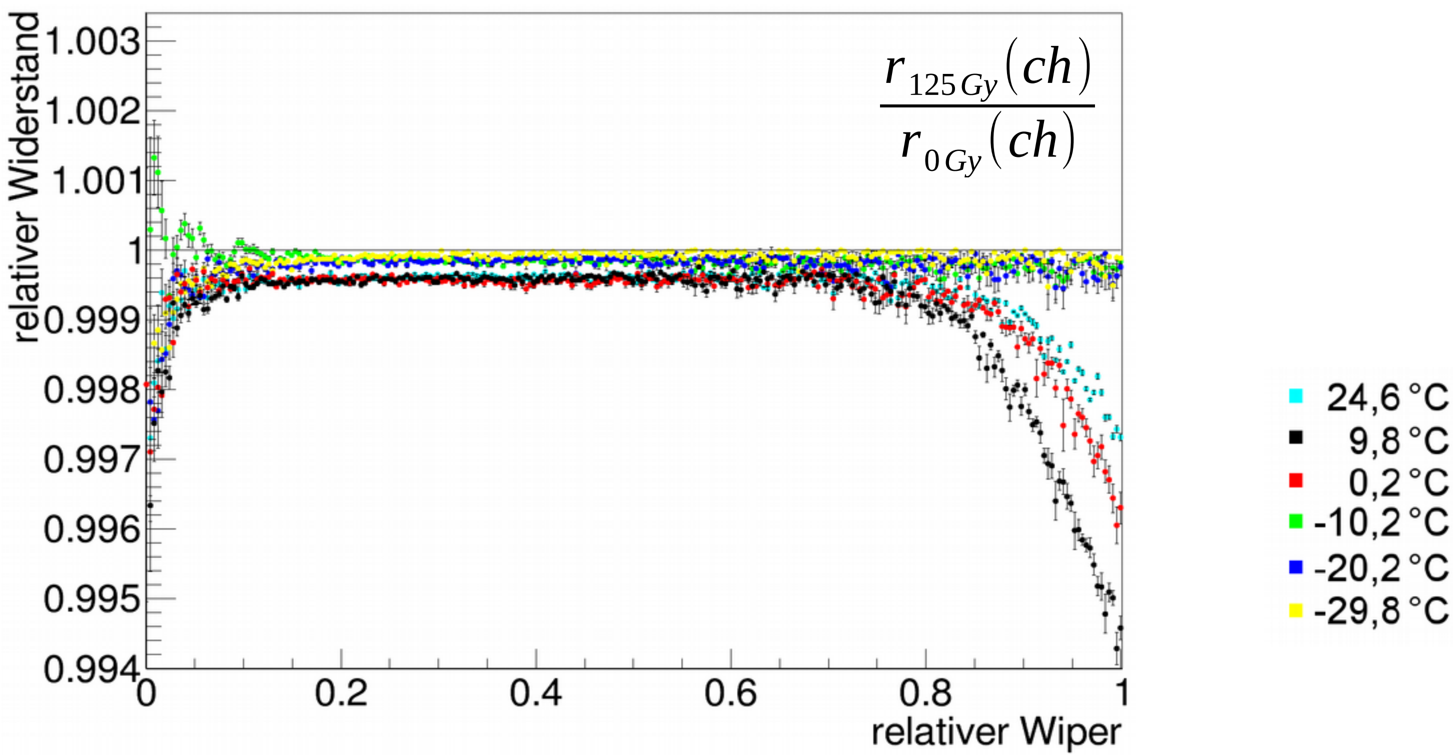
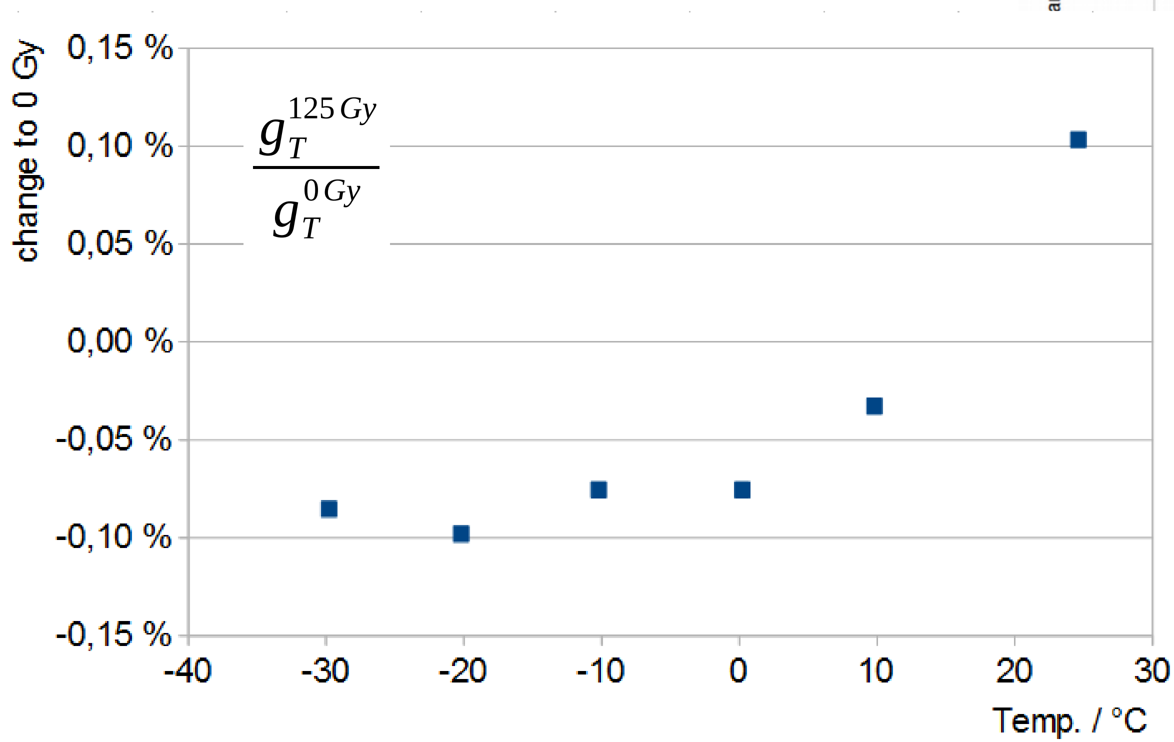


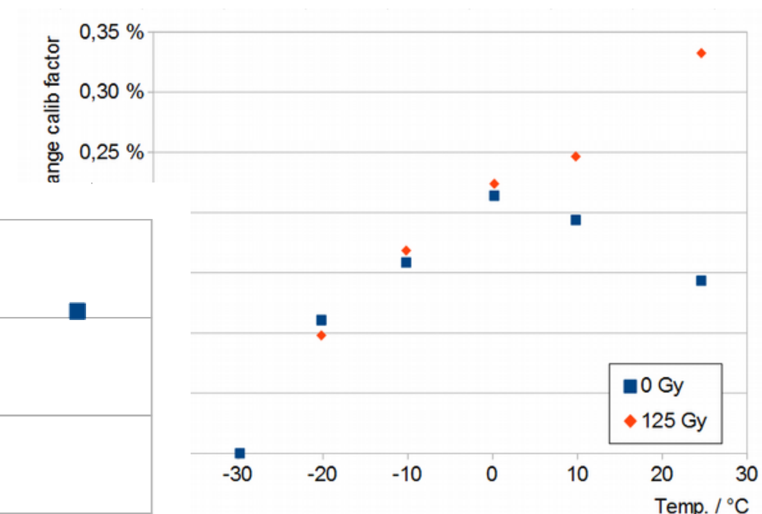
Radiation tests

Stimulate ADC input with external voltage source (0-1.5V)

LINEAR TECHNOLOGY LTC2497 16-Bit 8-/16-Channel

Fit of $U_T(c) = o + g_T \cdot c$





1-Channel Prototype

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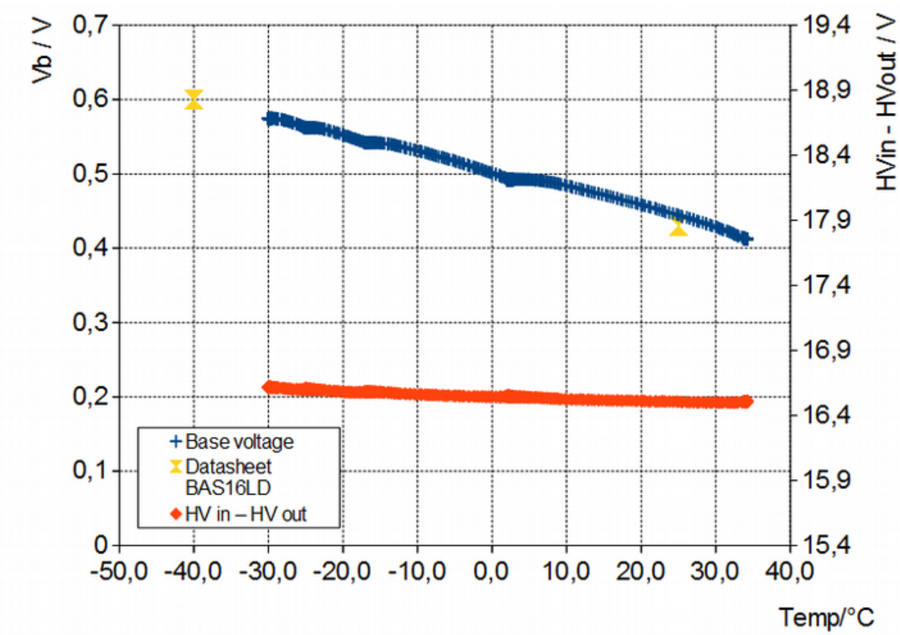
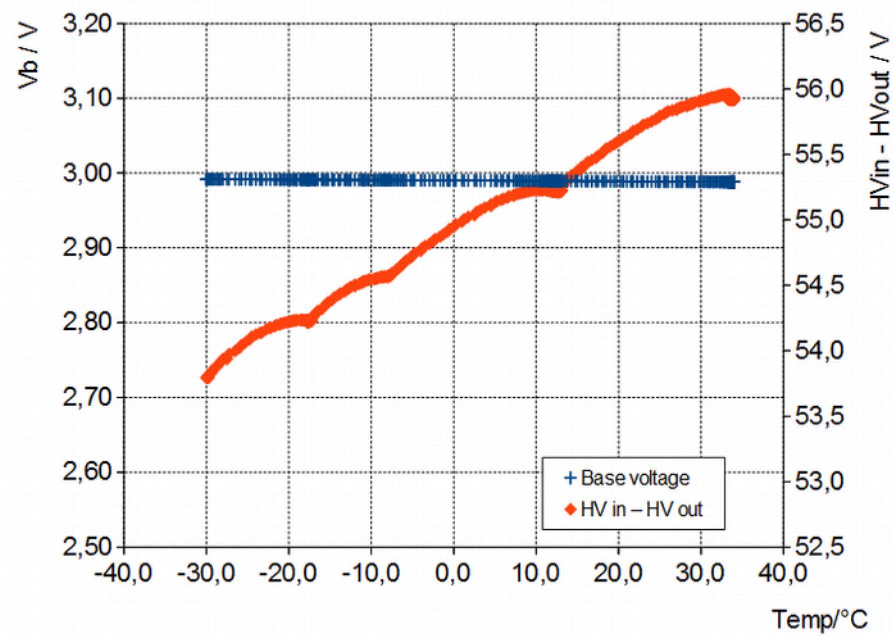
High voltage output - temperature dependence



~ 2mV/°C drift @Wiper=0



~ 33mV/°C drift @Wiper=255

- Current design compensates temp. dependence only partly
- If temp. is stable below 0.5°C, temp. dependence will be max. 16mV

Ref. Voltage 3V

~ 60µV/°C temp. dependence (datasheet max. 80ppm/°C)

1-Channel Prototype

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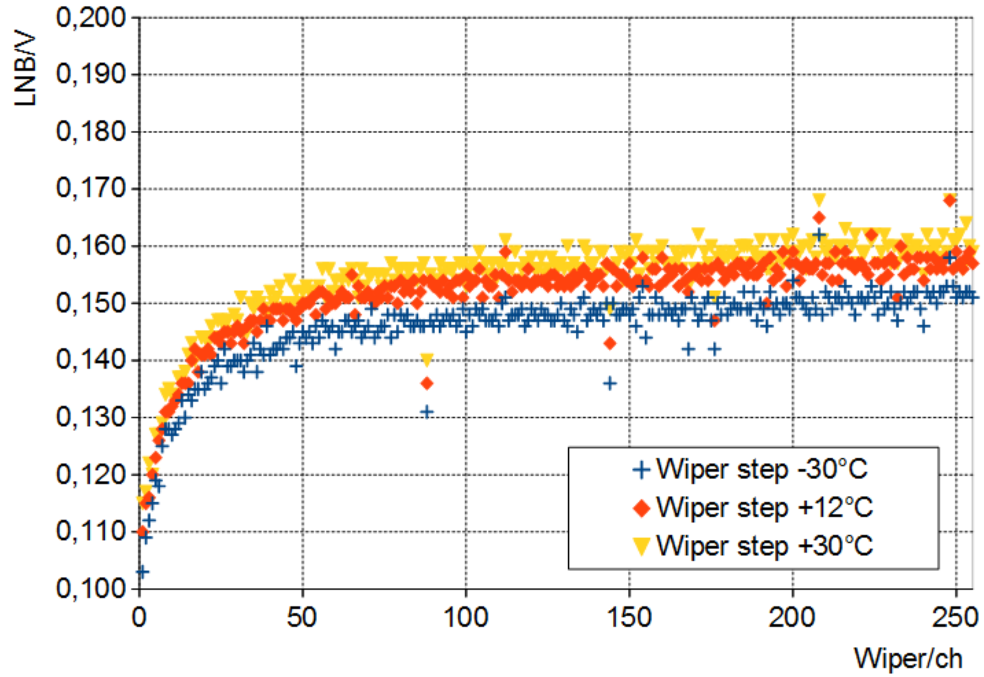
High voltage output - step size (LNB)

Digital potentiometer (MCP446X) with 8Bit resolution

@40V → 100 – 160 mV
(8%/V: ~1%)

@20V → 50 – 80 mV
(8%/V: ~0,5%)



Alternative to MCP 446x:

Serial adapter chip (integrated 10bit DAC) see talk H. Flemming
can increase the range by factor of 3 → 40V to 120V
or the resolution by factor 3 → 150mV to 50mV

1-Channel Prototype

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High voltage output - long term stability

Measurement at a fixed temperature in comparison to a 6,5digit multimeter (Keysight 34465A)

HV_{in}, HV_{out} 6,5digit DMM

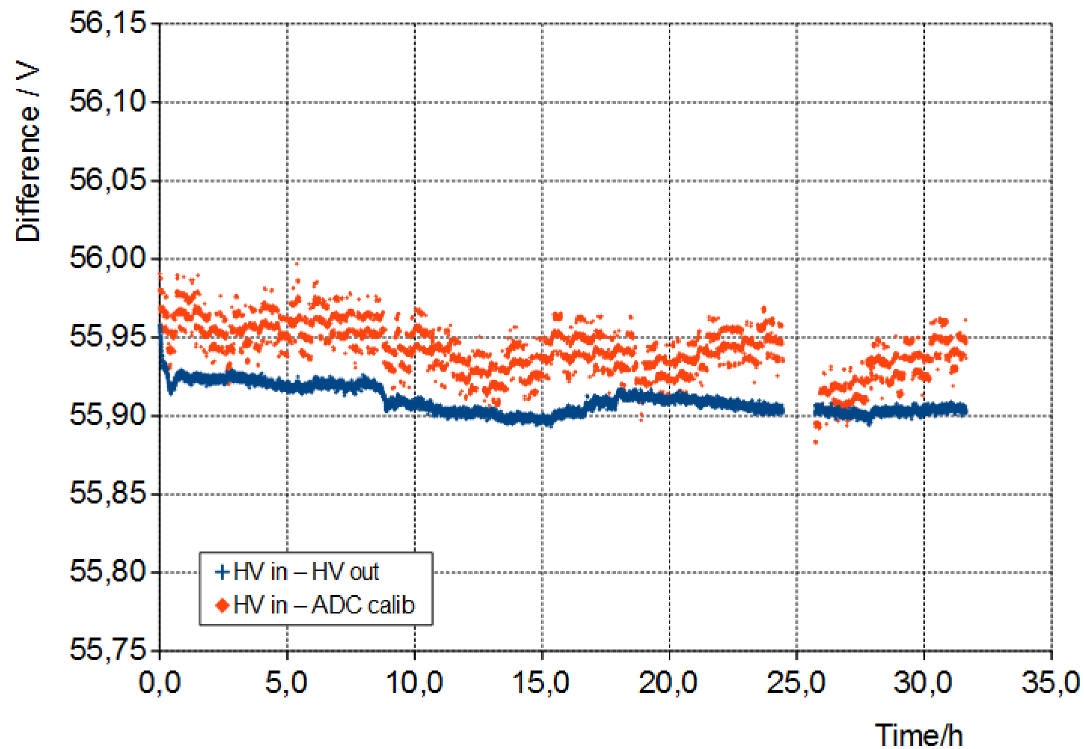
ADC calib onboard ADC

To be independent of Hvin fluctuations use difference

Std. deviation:

HV_{in} - ADC → 25mV

HV_{in} - HV_{out} → 10mV



1-Channel Prototype

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High v

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Hvin, H

ADC ca

To be in
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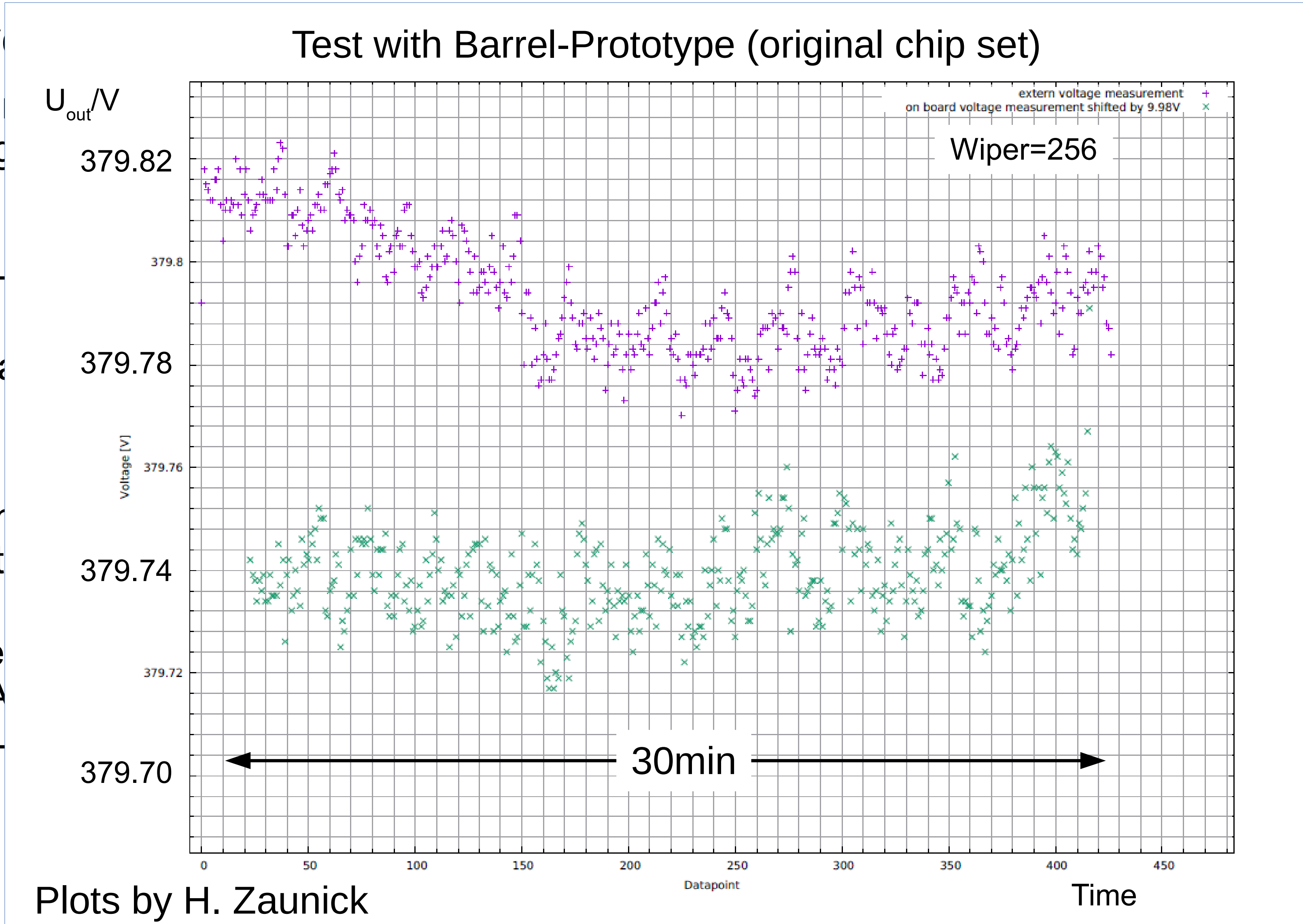
Std. de
HV_{in} - A
HV_{in} - H



1-Channel Prototype

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High v

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Std. de
HV_{in} - A
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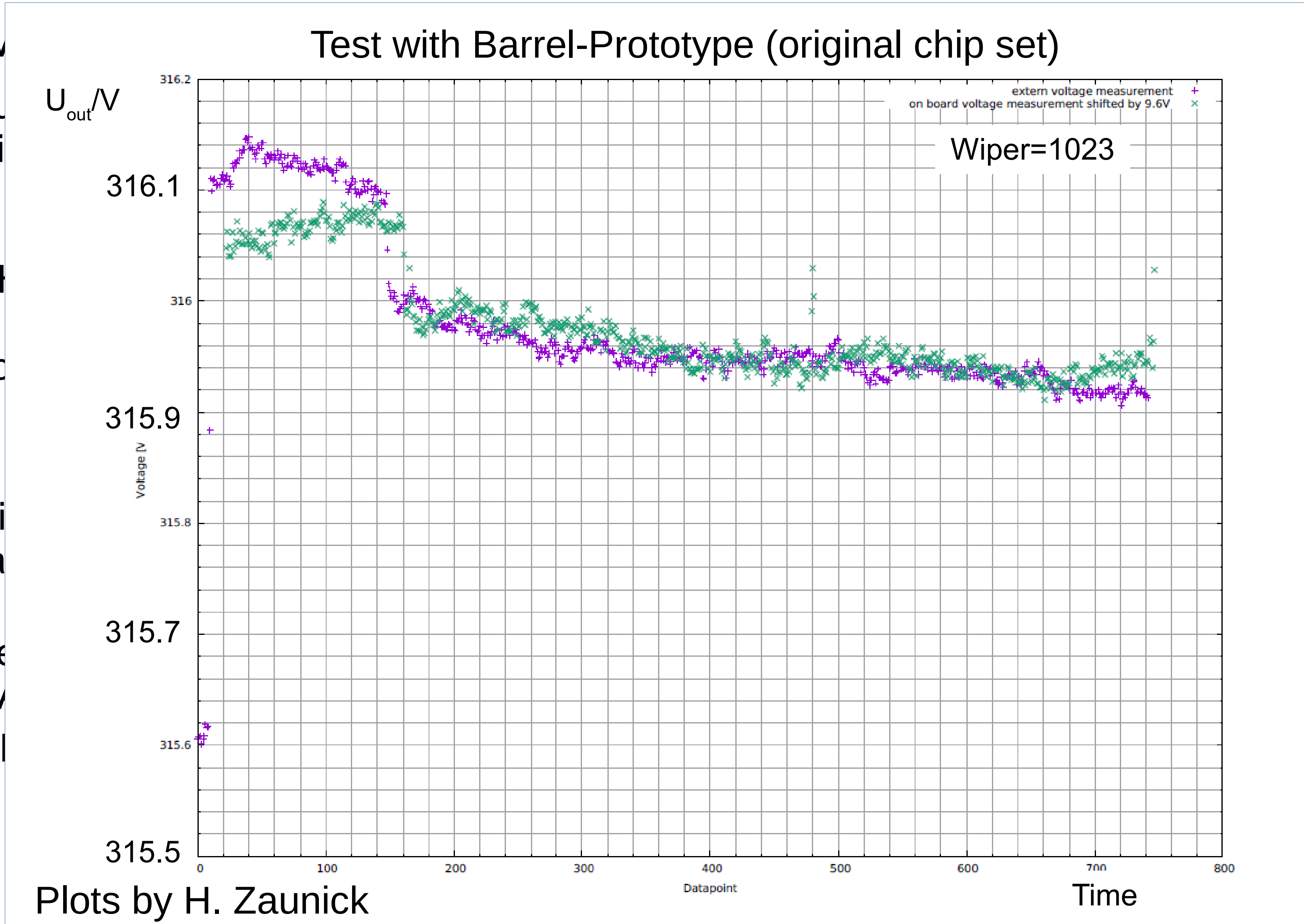

Next steps

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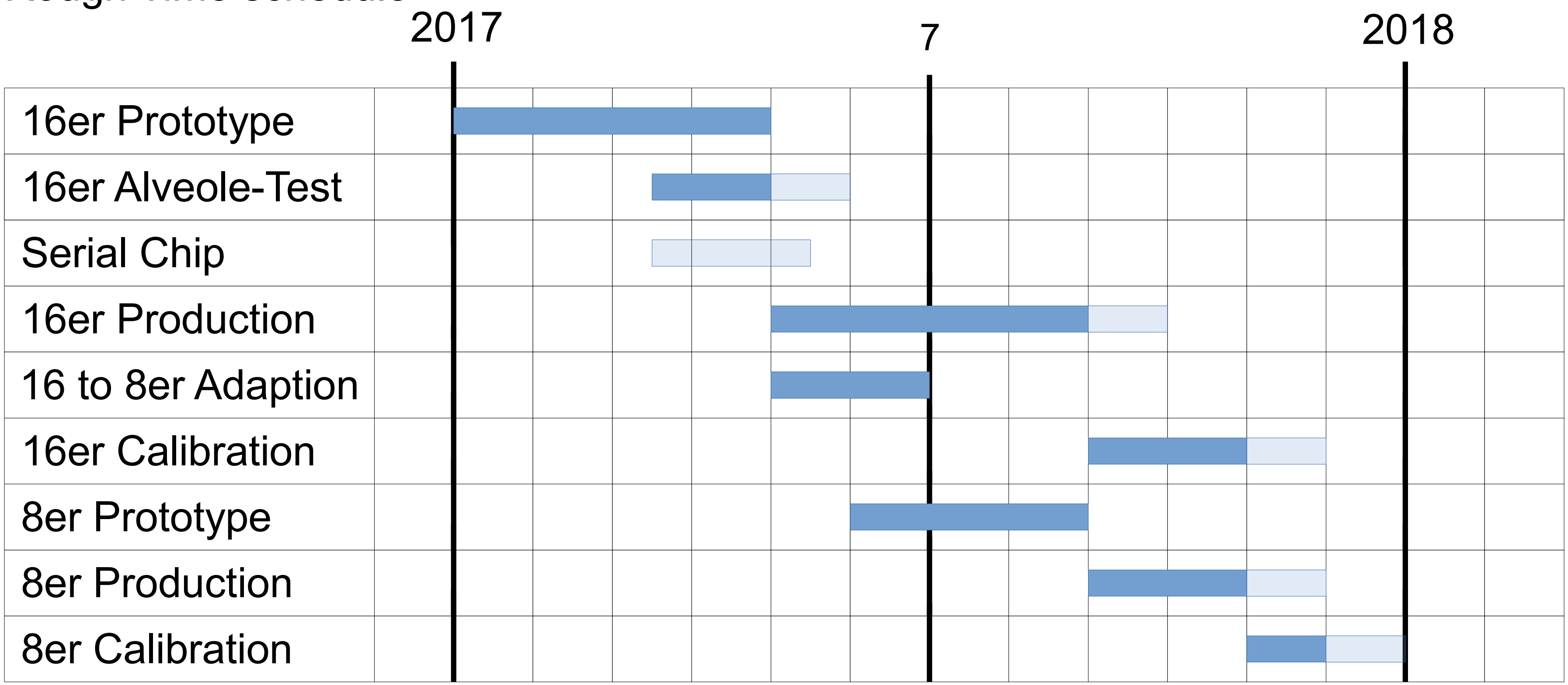
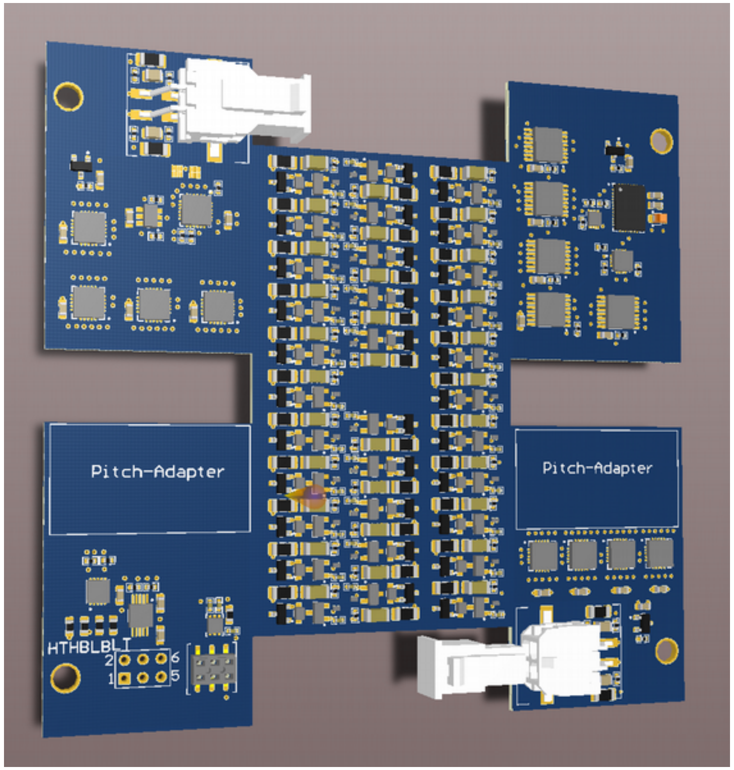
Rough Time schedule



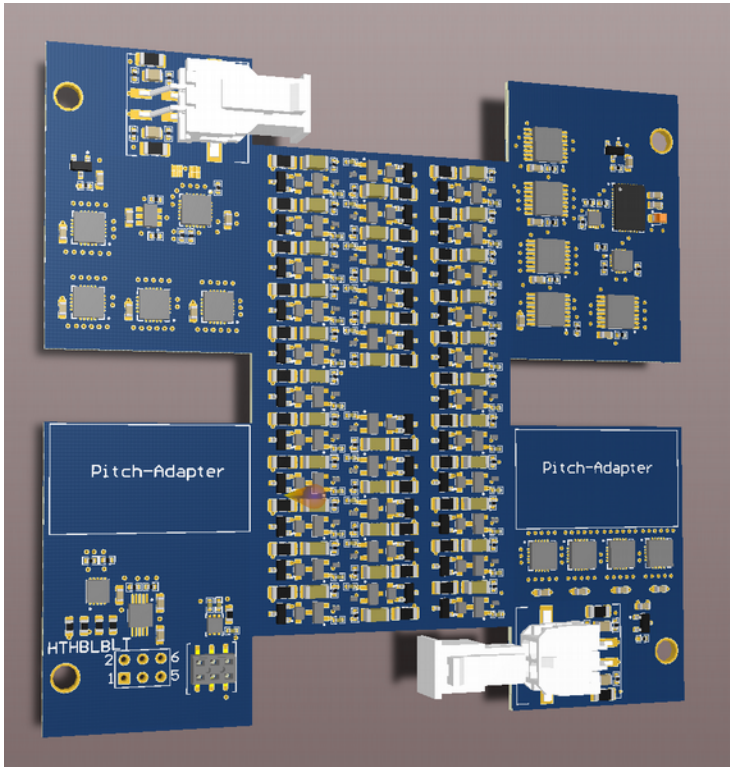
Near future steps

- Finalize layout 16er
- Build prototype
- Test 16er with APD Alveole

Thank you for your attention



Backup slides



Space consumption

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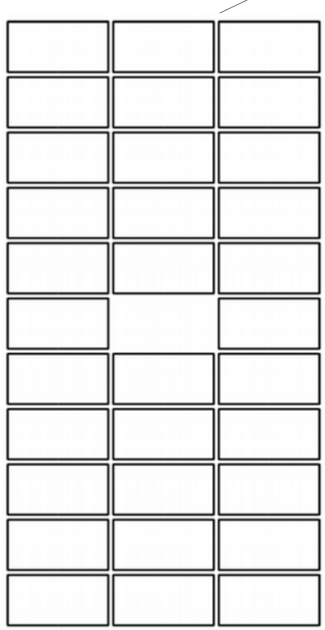
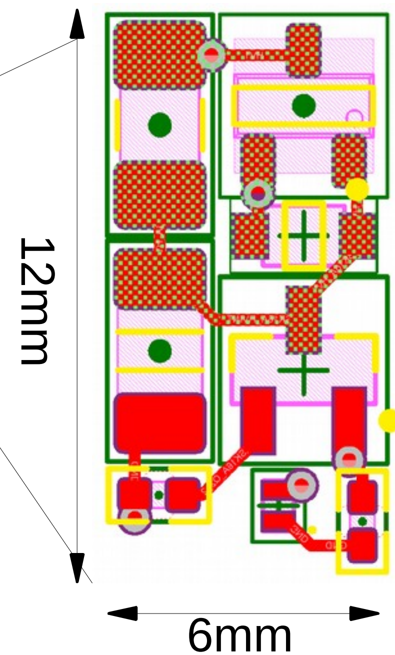
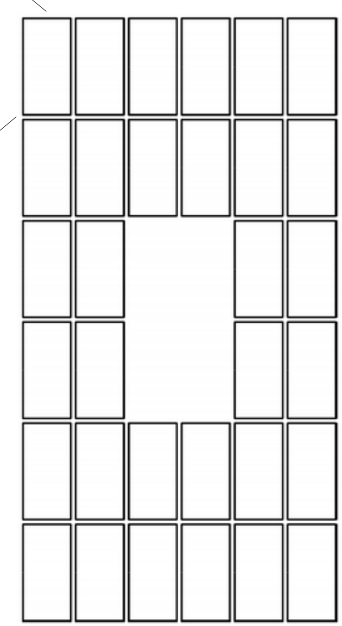
Current sink and voltage follower on top, Voltage divider near connector on bottom







$72mm^2 = 0{,}72cm^2$

$0{,}72cm^2 * 32 = 23{,}04cm^2$

$40mm * 68mm = 27{,}2cm^2$

Basic principle

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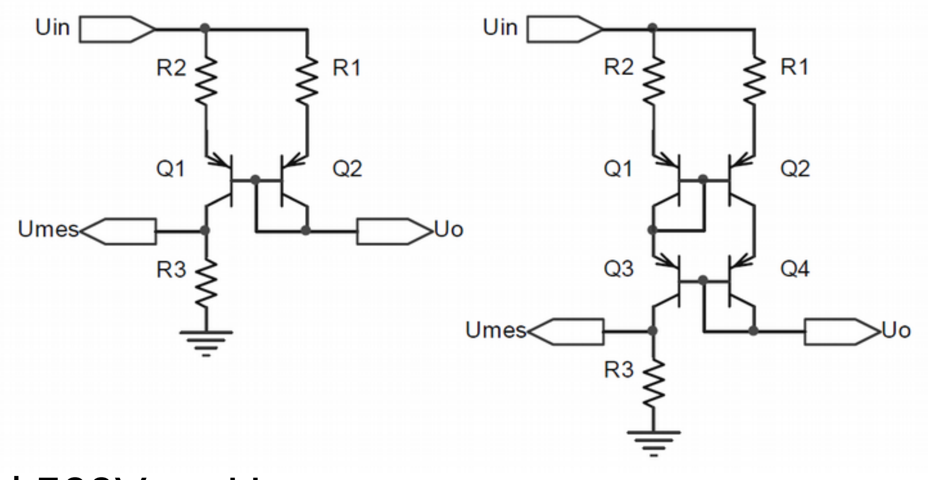
Current measurement circuit

Grounding concept in photodetector needs a highside current measuring circuit

Wilson Current Mirrors
mirrors current from the high side to a low side, where measuring can be done via a shunt resistor



Problems
Find FETs that can with stand 500V on U_{DS}
Needs much space (+additional parts to convert digital)

→ Current sensing omited

1-Channel Prototype

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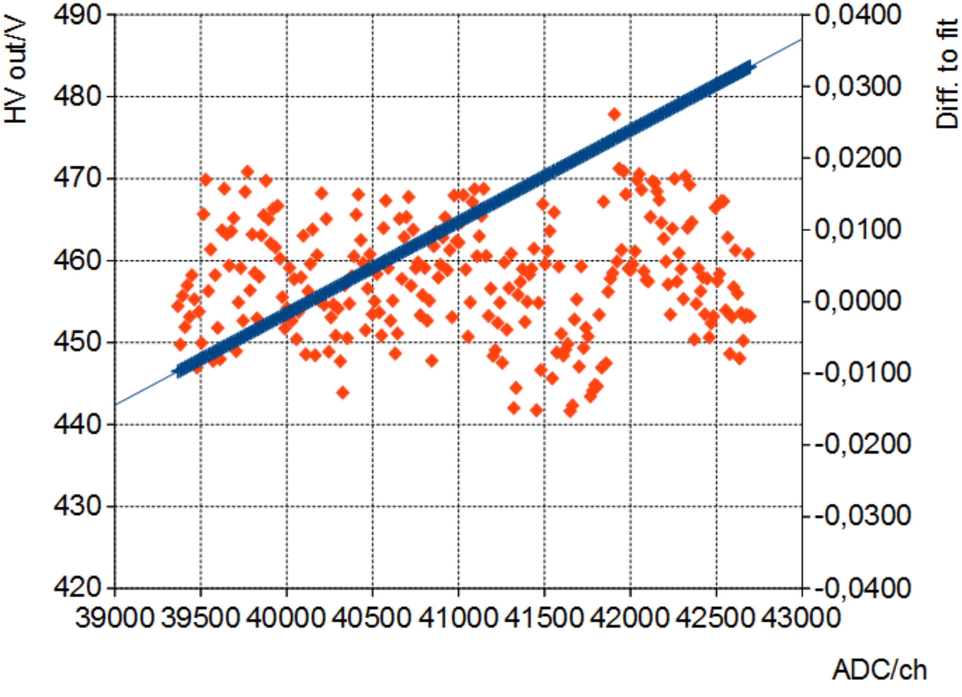
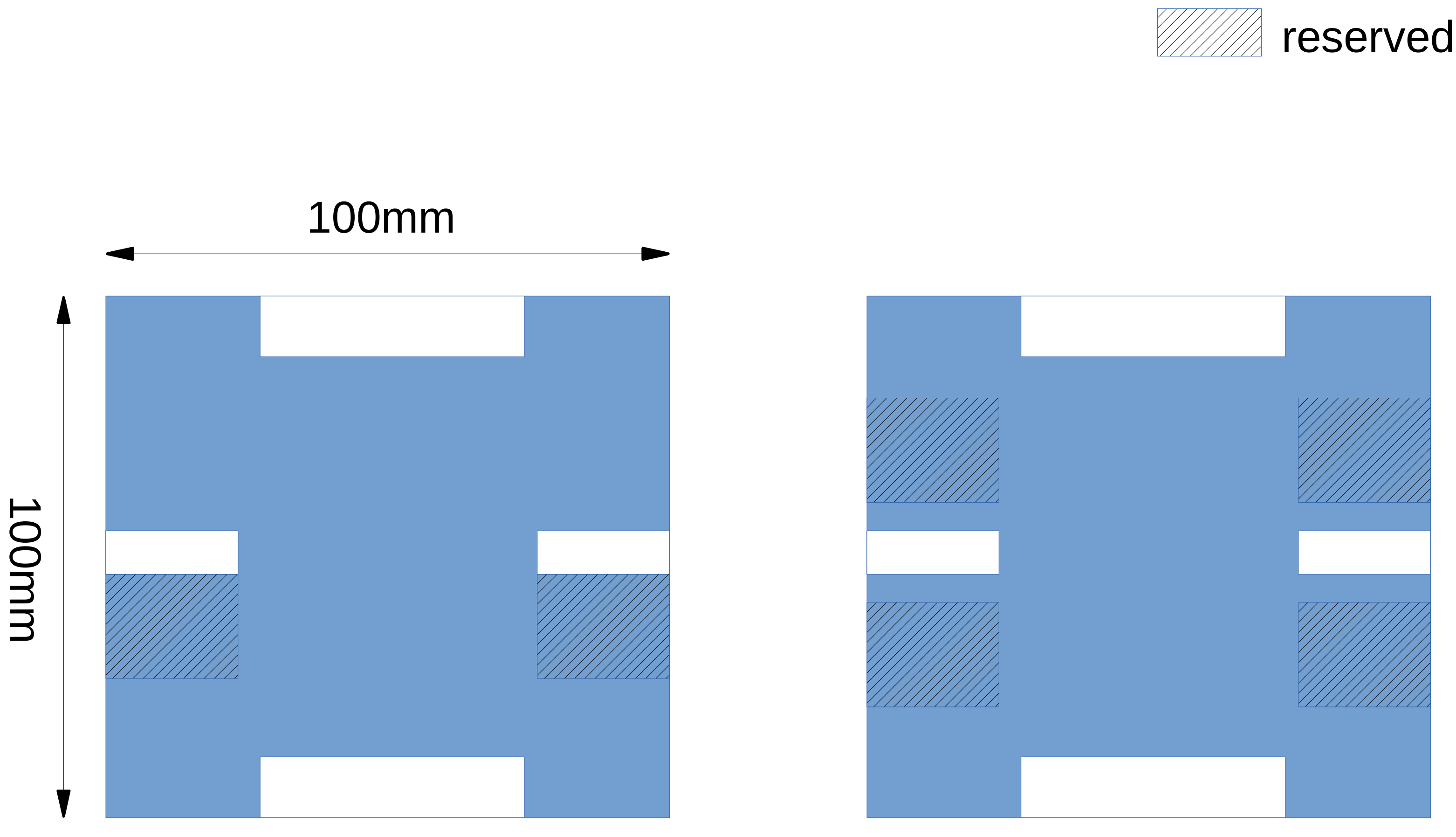
High voltage output - voltage measurement

Output measured by 6,5digit DMM and sweep of potentiometer from 0 to 255.
3mV over Calibration

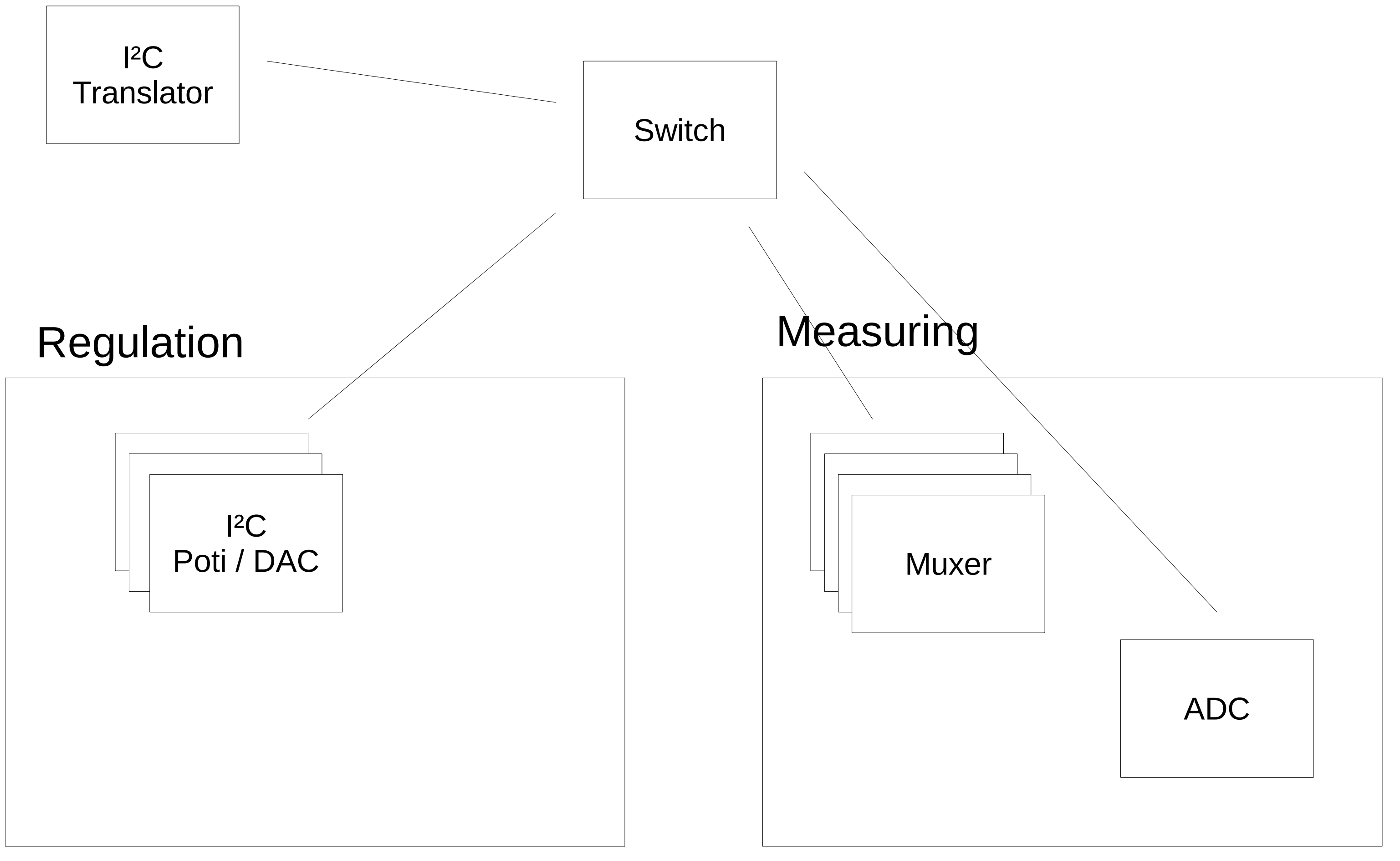


Maximal variation from a linear calibration ~+/-20mV

Space constraints



I²C structure



I²C structure

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I²C standard allows 7 or 10 bit adr.

- 7 bit commonly used, 10 bit not on every chip
- 128 – 16 = 112 adr.
- I²C switches, adr. translation
- Diff. I²C

Chip selection for current sink control

- Microchip MCP4464, 8Bit dig. Poti
- GSI chip, 10Bit DAC