Development of a new Revision for floating, high voltage Picoamperemeters

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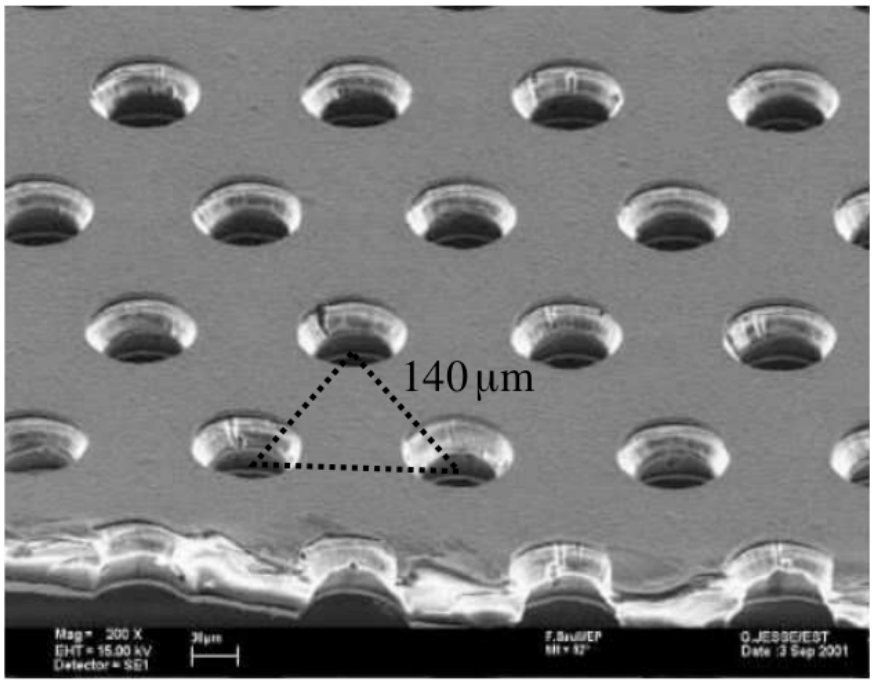
June 9, 2020

GEM-foil I



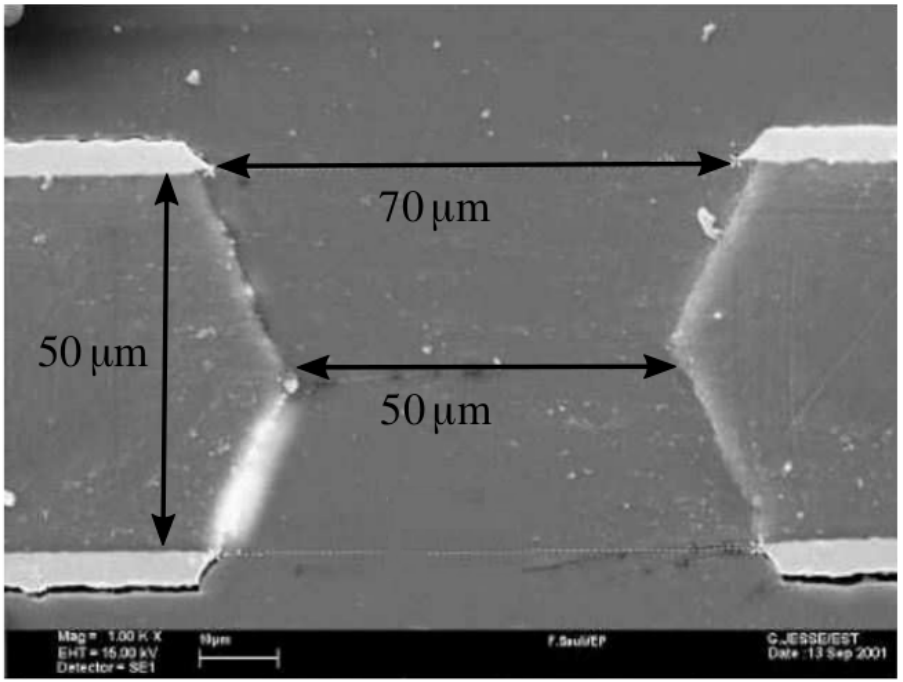


Figure: Photograph of a GEM-foil. From [4].

GEM-foil II

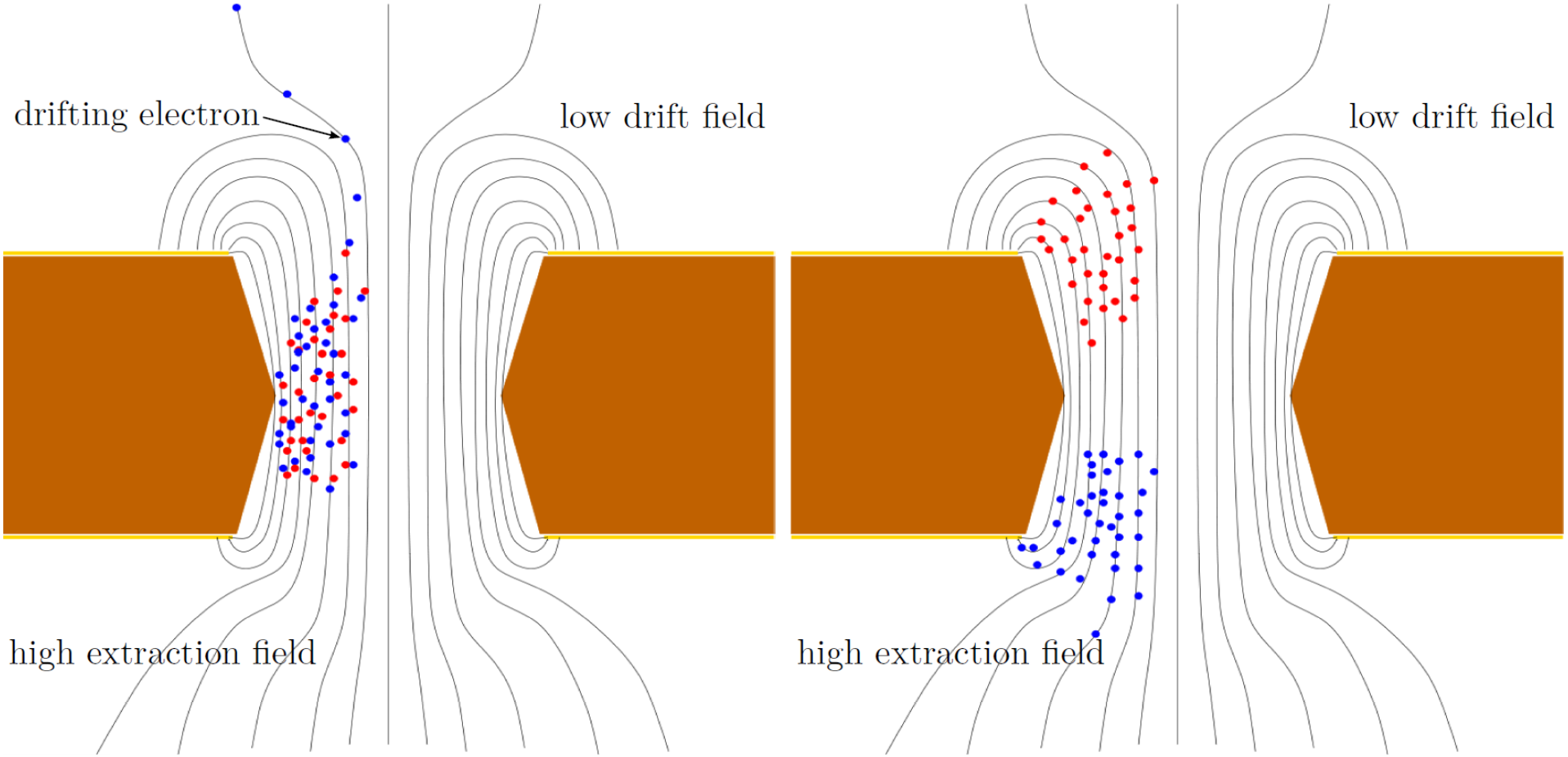
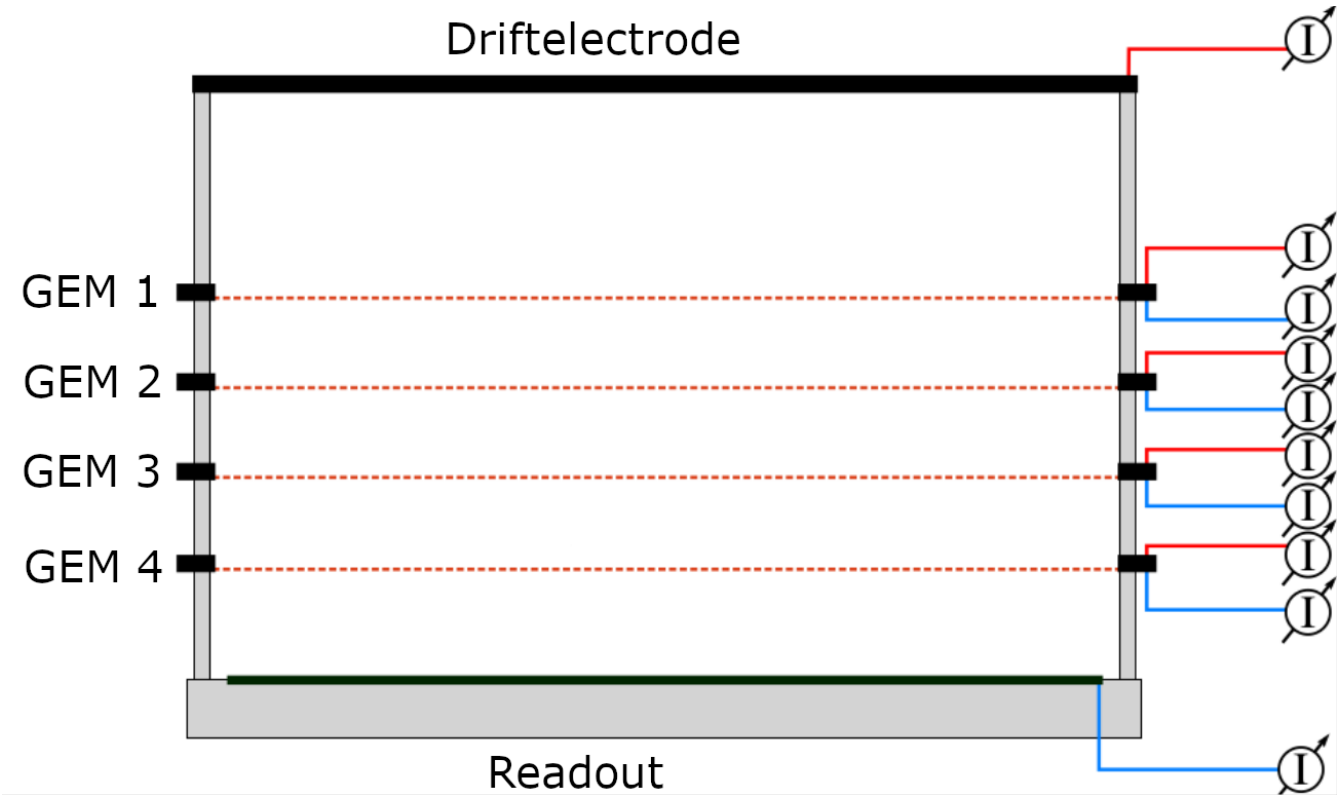


Figure: GEM-foil amplification. From [1].

Operation



Basic Principle

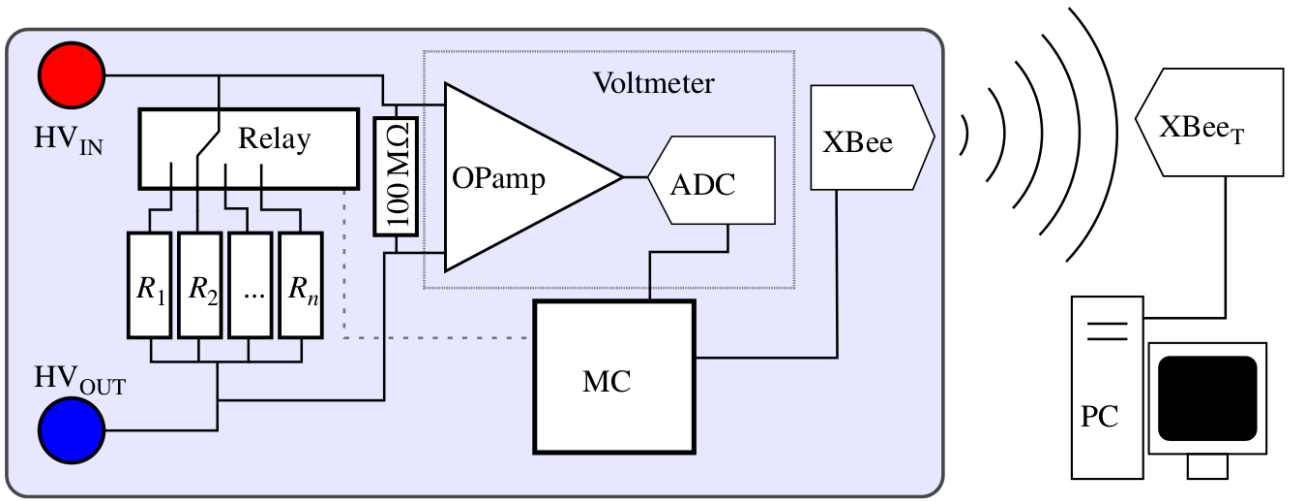


Figure: Picoamperemeter basic principle. From [3], modified.

A picoamperemeter

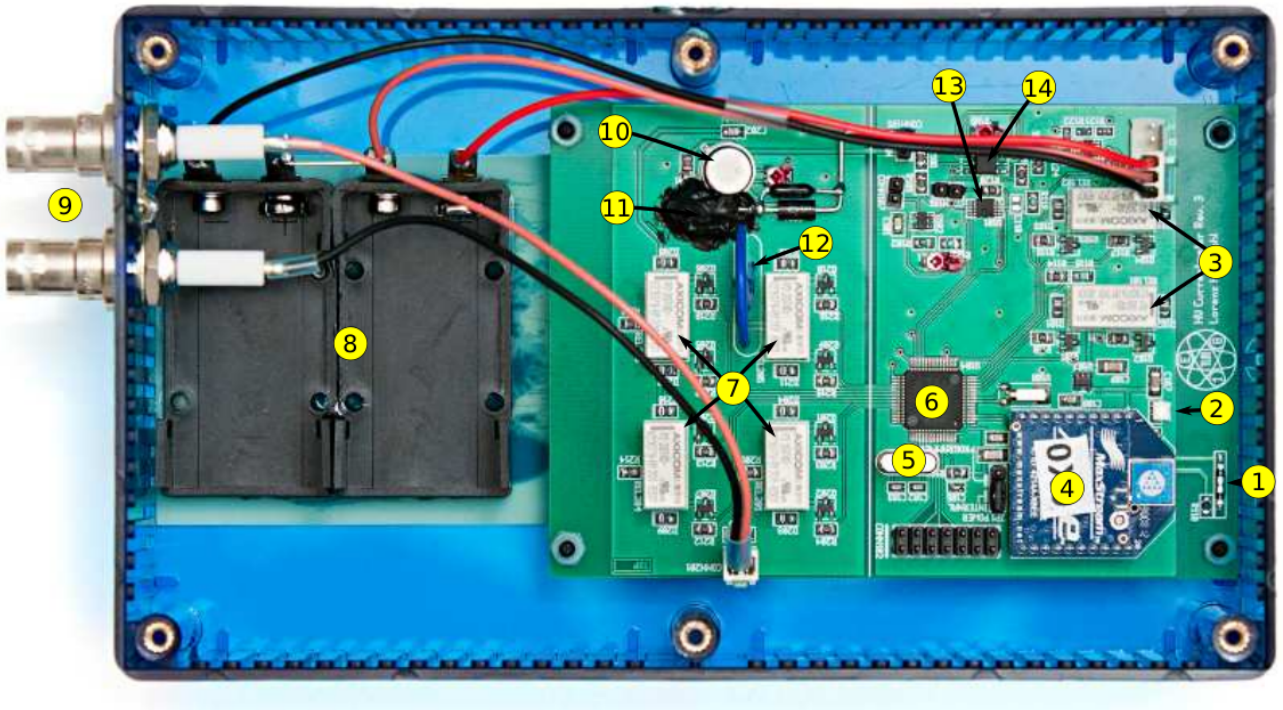


Figure: Picoamperemeter revision 3. From [2].

Design Characteristics

Measurement Range	$\pm 16.4\,\mathrm{mA}$ to $\pm 16.4\,\mathrm{nA}$
Lowest Possible Resolution	$0.625\,\mathrm{pA}$
Achieved Resolution	$\approx 1\,\mathrm{pA}$
Readout Frequency	$\approx 0.125\,\mathrm{Hz}$
Power Consumption	$\approx 2\,\mathrm{mA}$

Issues of the Design

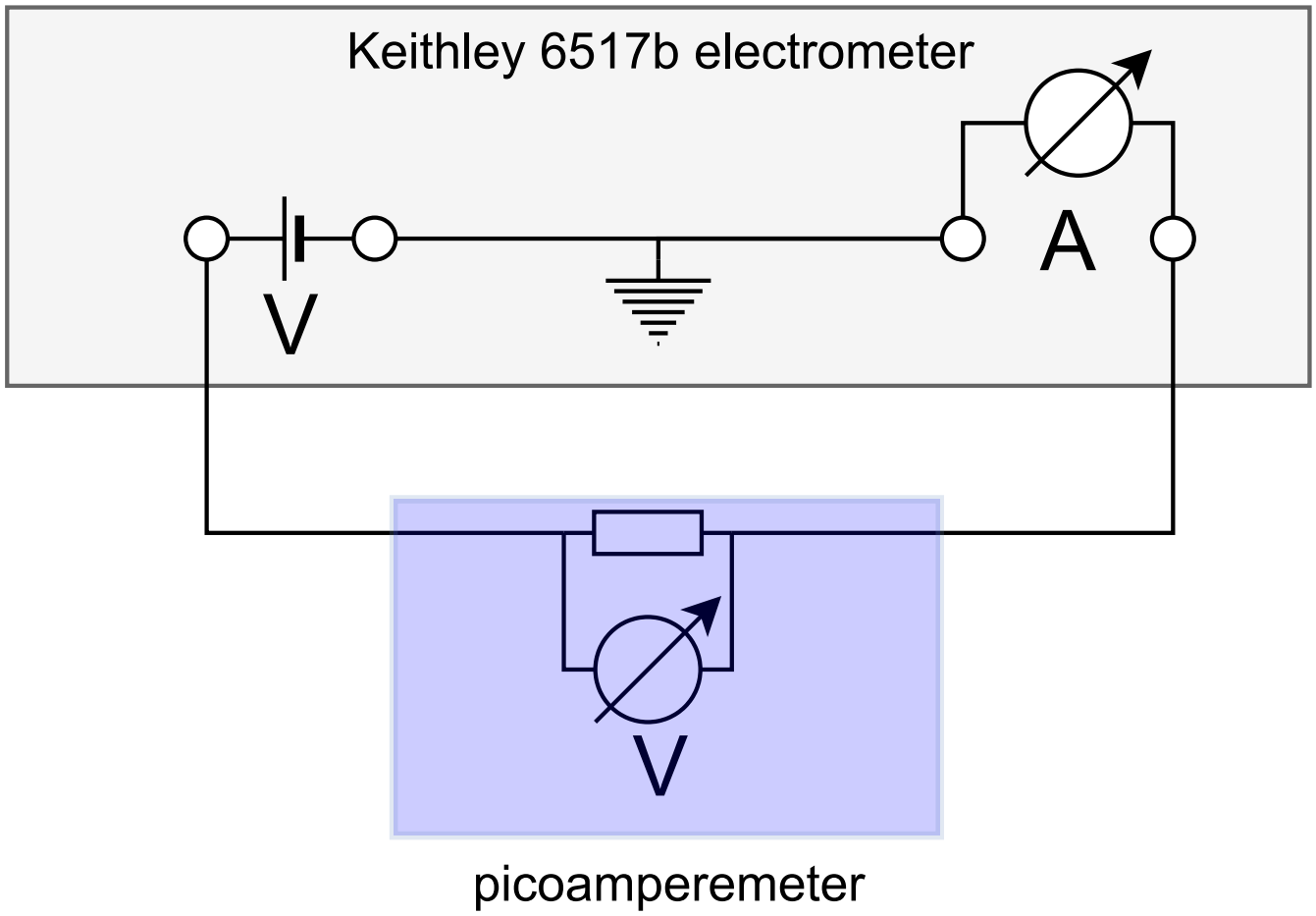
- Firmware only compiles on older machines
- Re-flashing firmware for receiver change necessary

} Software related

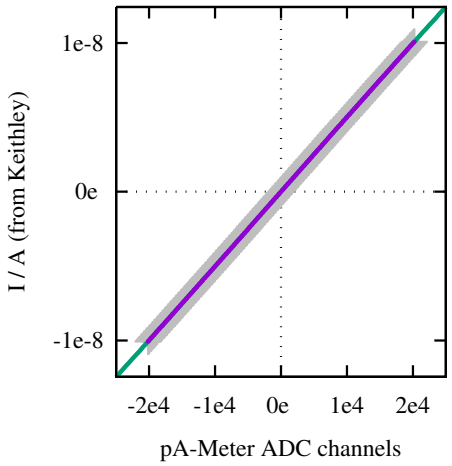
- Non-linear behaviour
- Temperature dependence
- Amplifier breaks down due to over-voltage
- Slow readout, ca 0.125 Hz

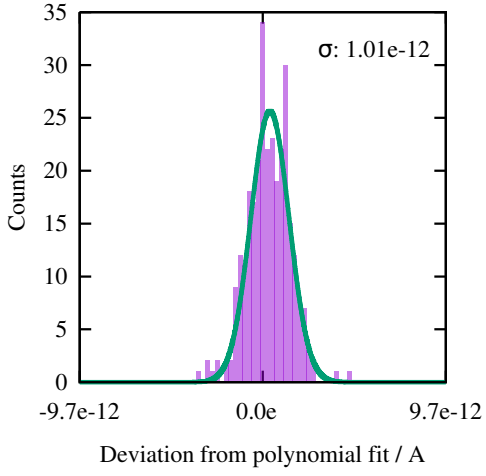
} Hardware related

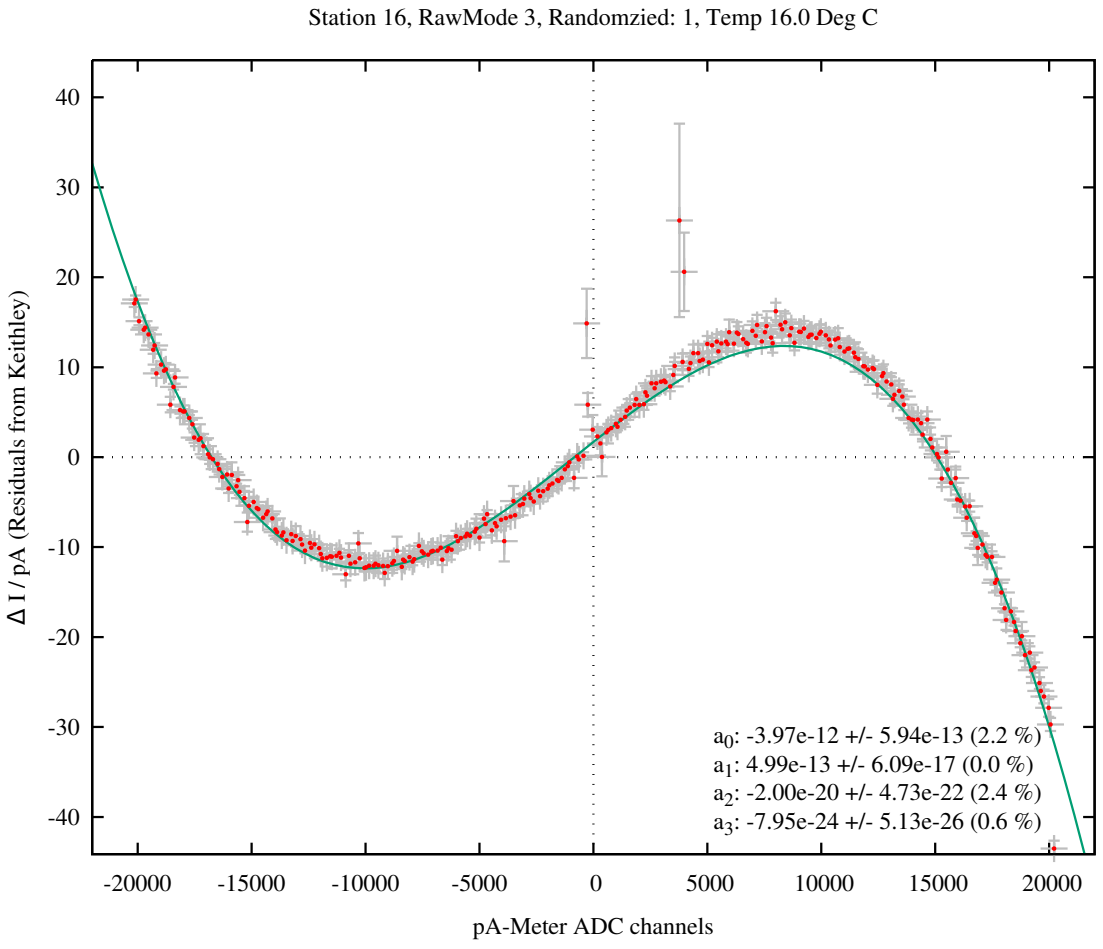
Calibration



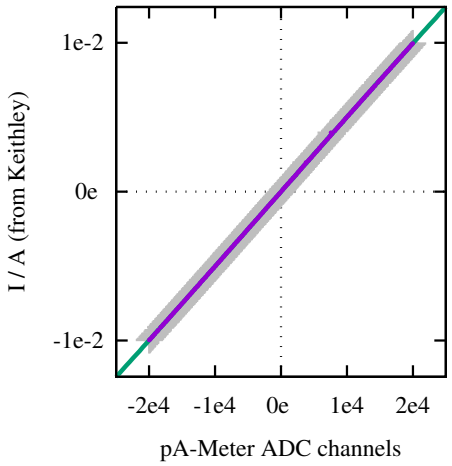
Calibration Result I

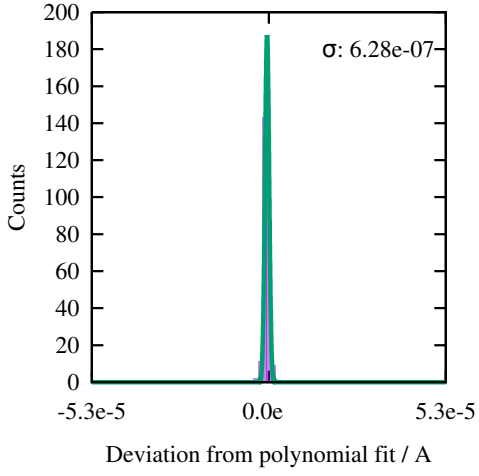


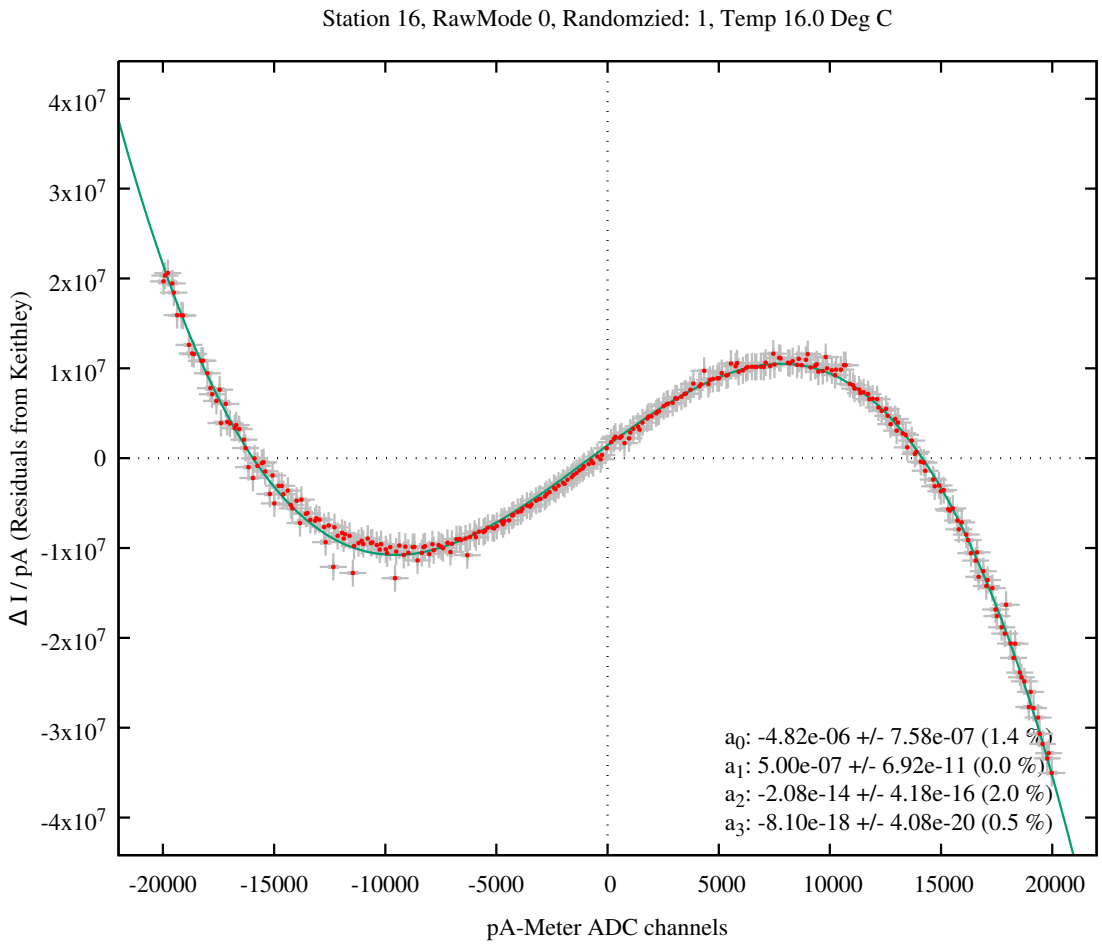




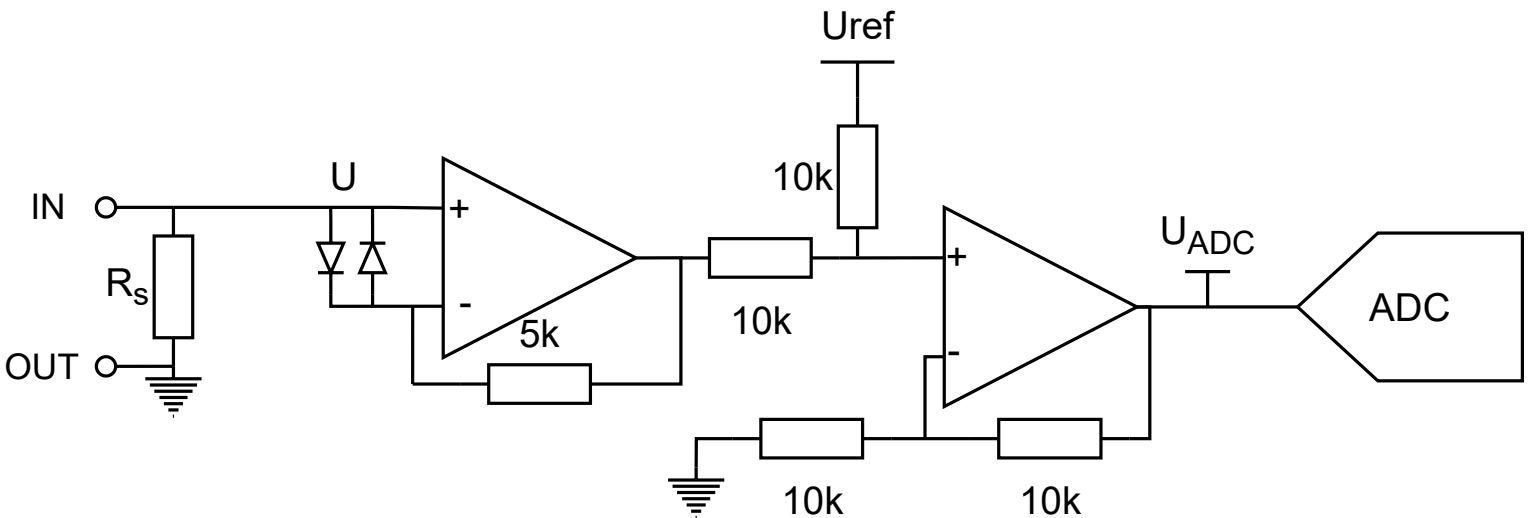
Calibration Result II





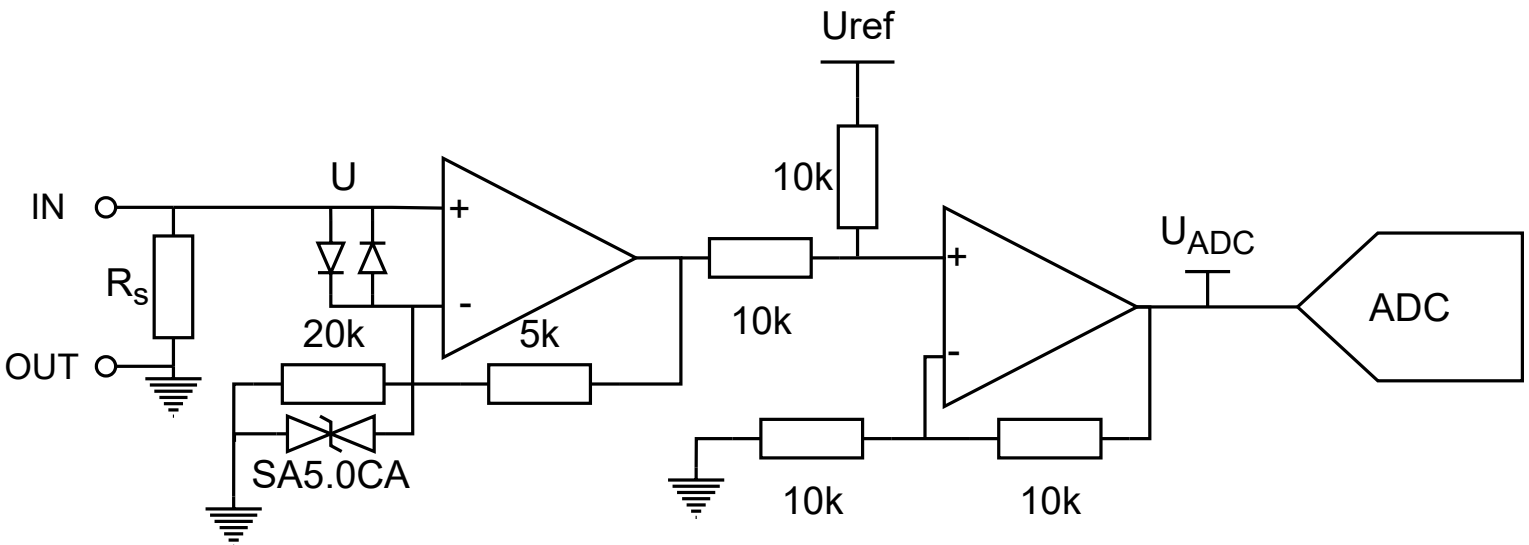


Measurement Circuit



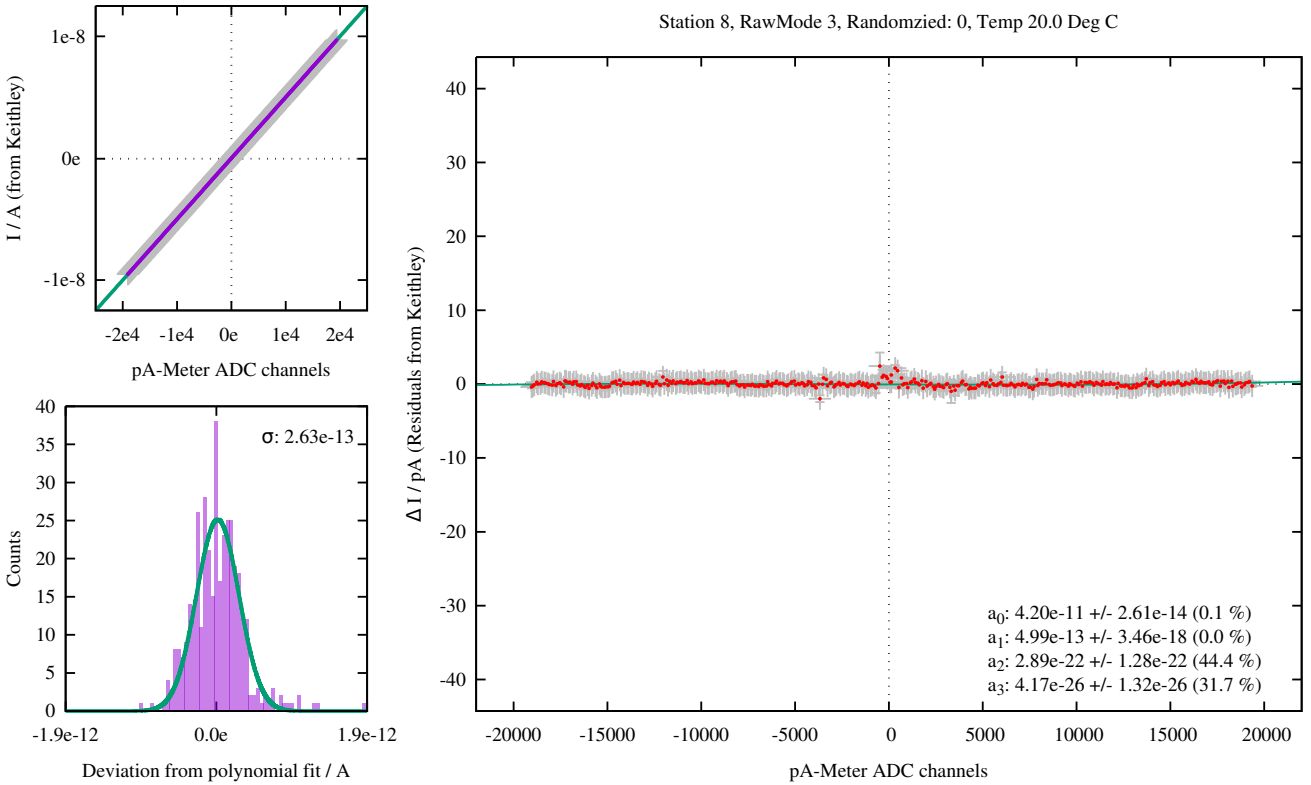
$$U_{\mathrm{ADC}} = R_{\mathrm{shunt}} I + U_{\mathrm{ref}} \tag{1}$$

Measurement Circuit

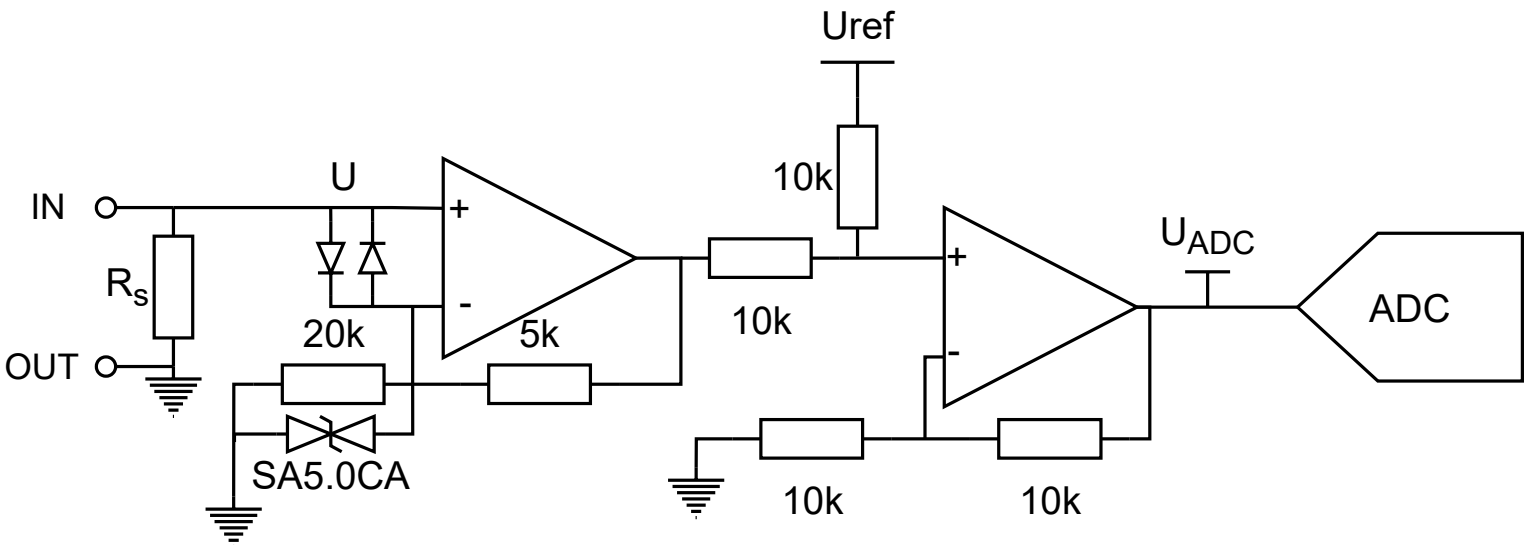


$$U_{\mathrm{ADC}} = 1.25 \cdot R_{\mathrm{shunt}} I + U_{\mathrm{ref}} \tag{2}$$

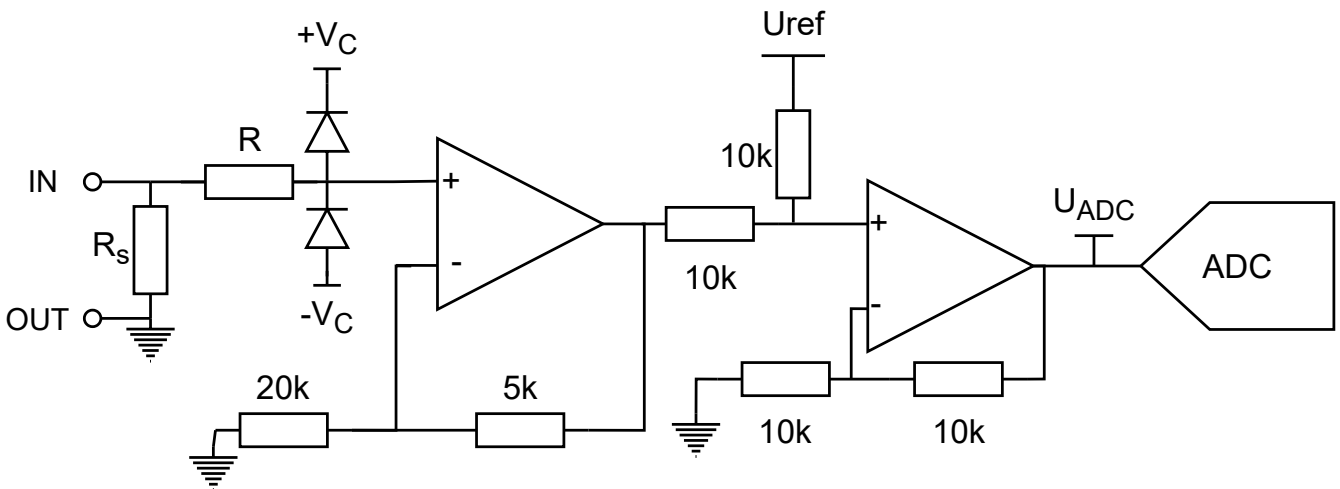
Diodes Removed



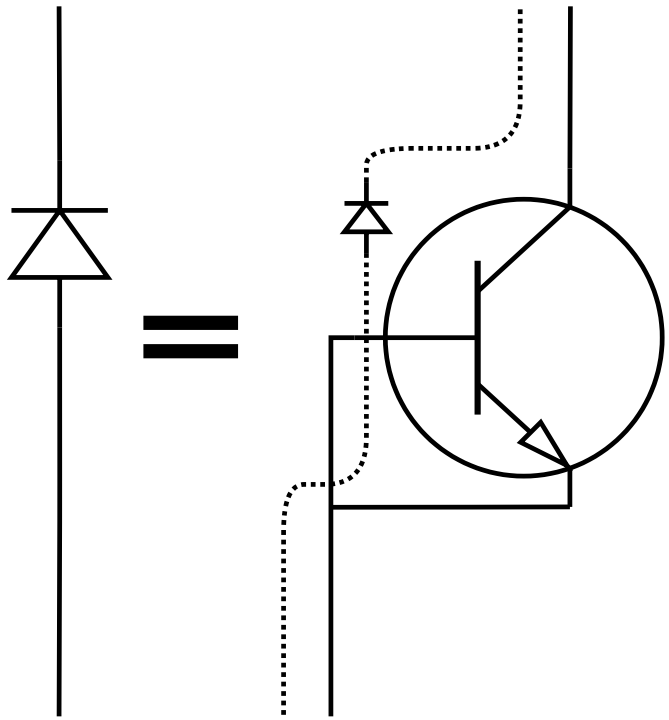
Measurement Circuit



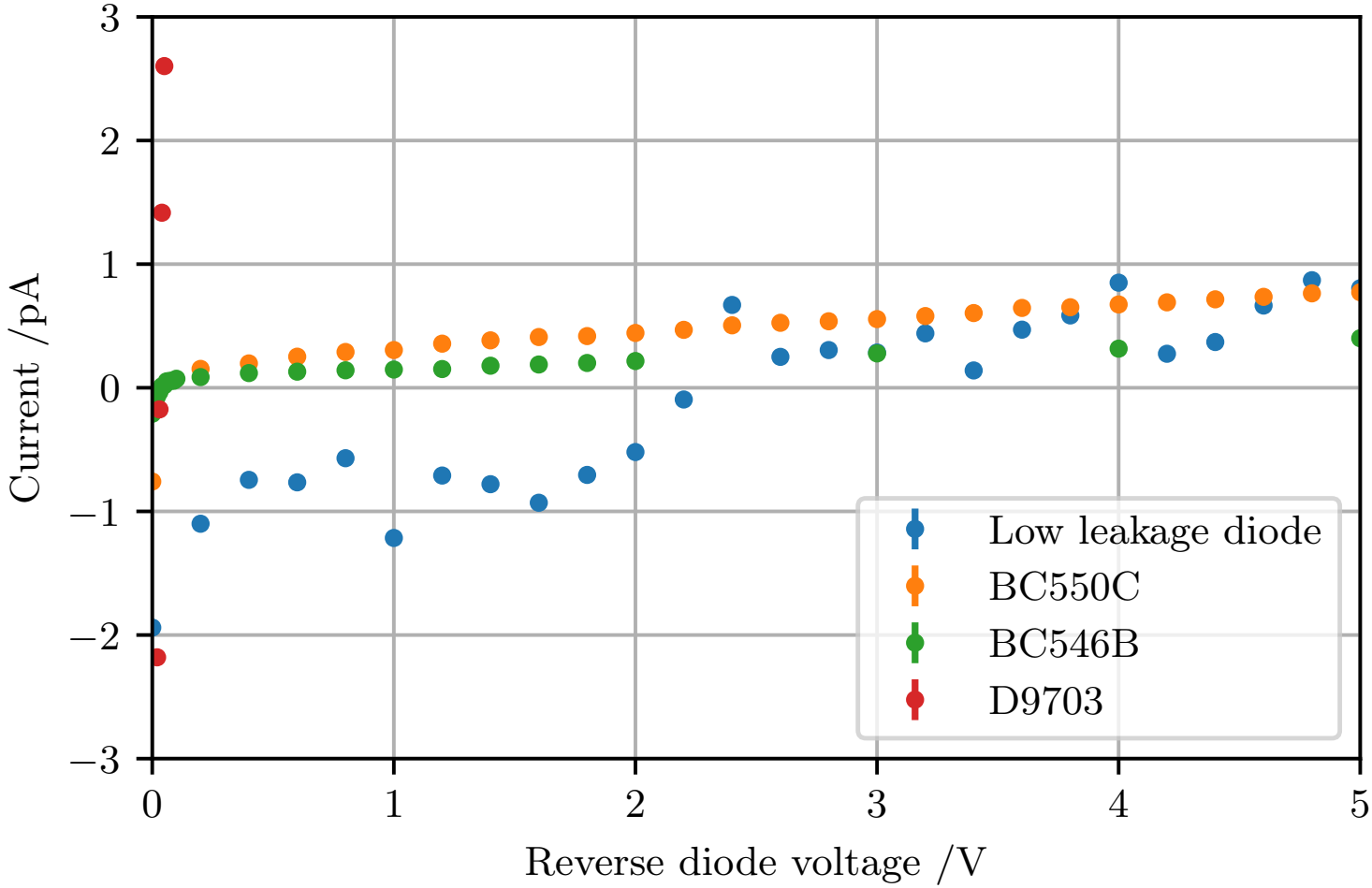
Improved OVP



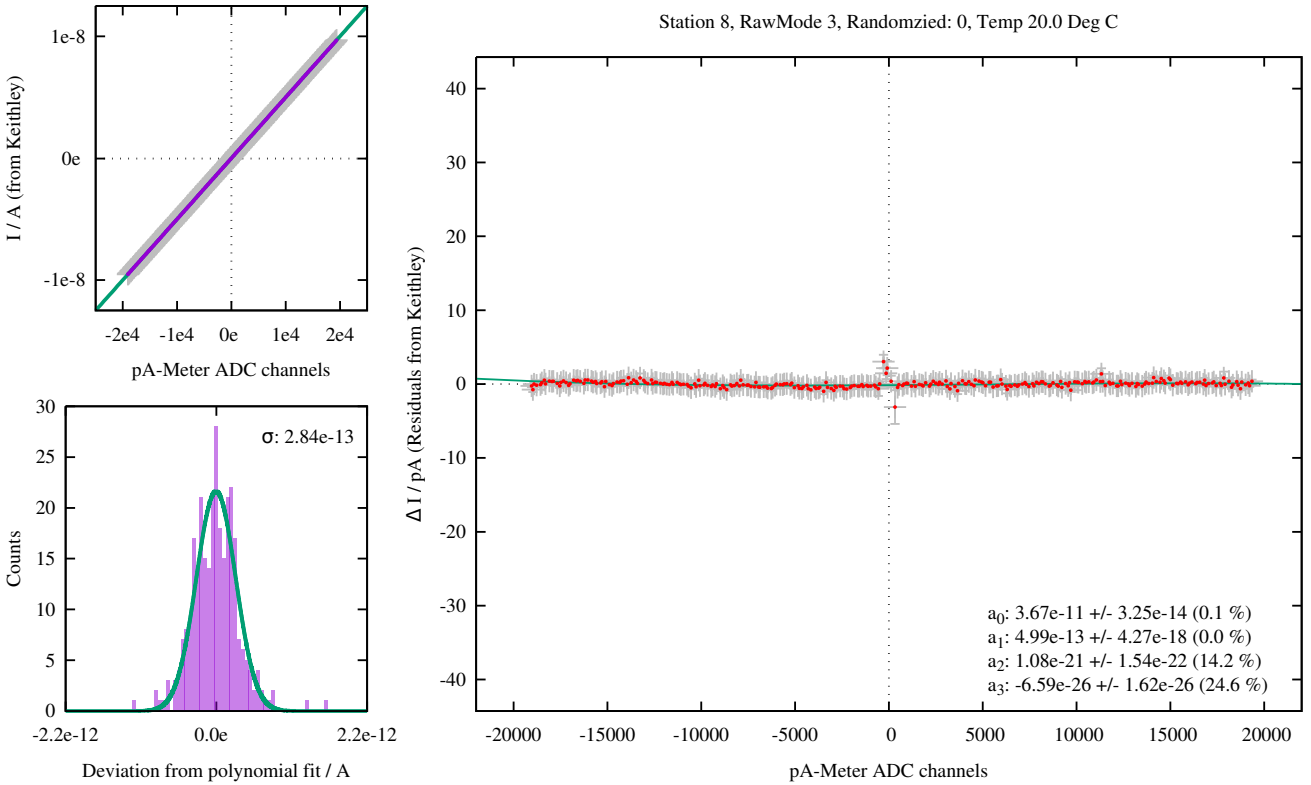
Transistor as Diode I



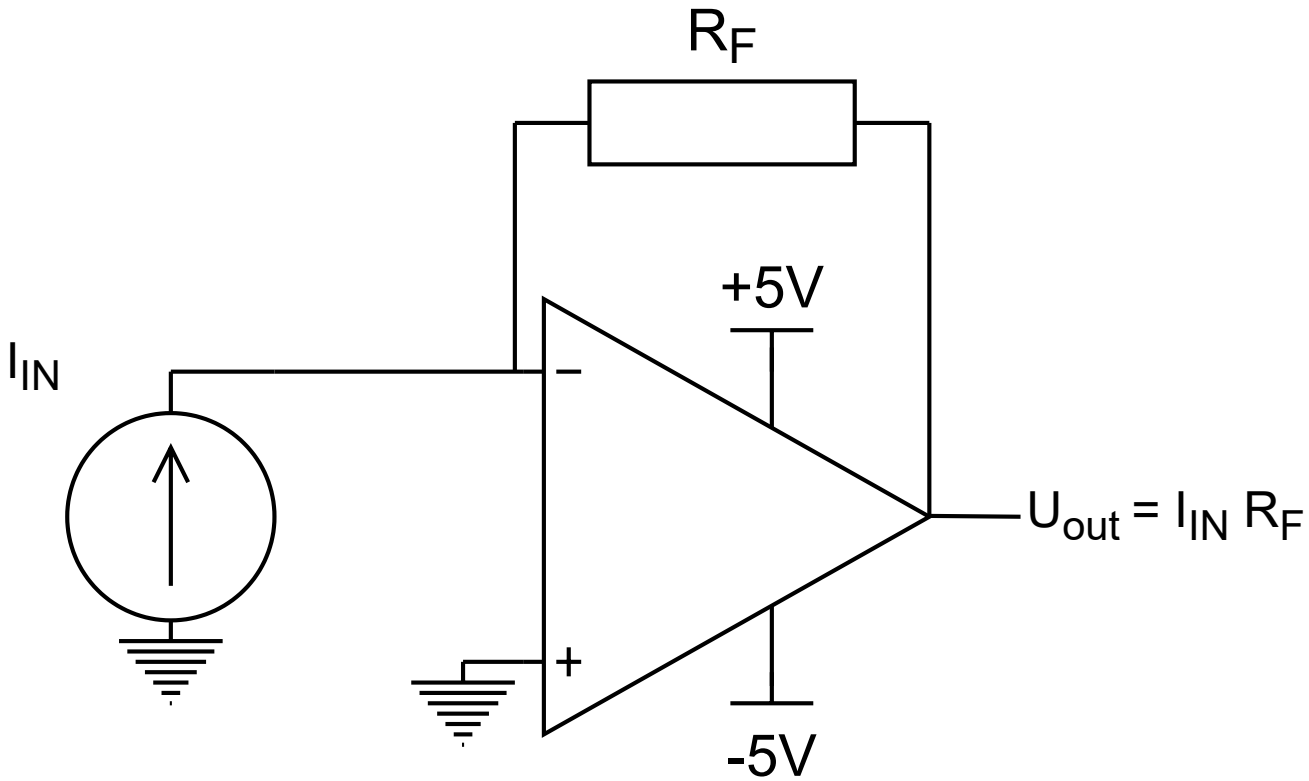
Transistor as Diode II



Improved OVP



New Front-end



Component Choice

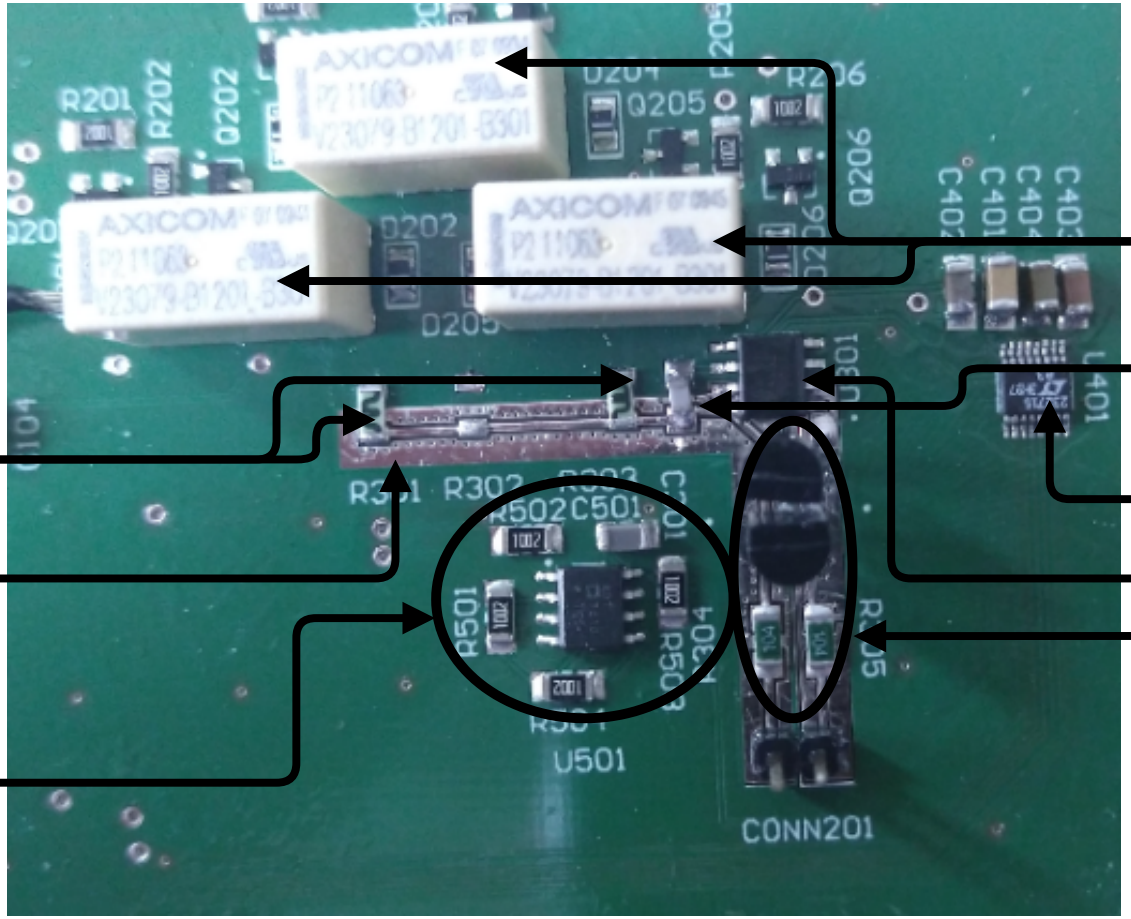
Op-Amp: ADA4530:

- 20 fA input bias current
- Specially desigend for TIA
- Offers guard ring buffer

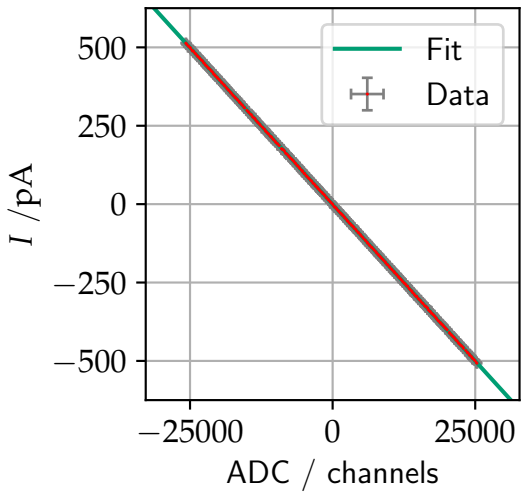
ADC: LTC2327

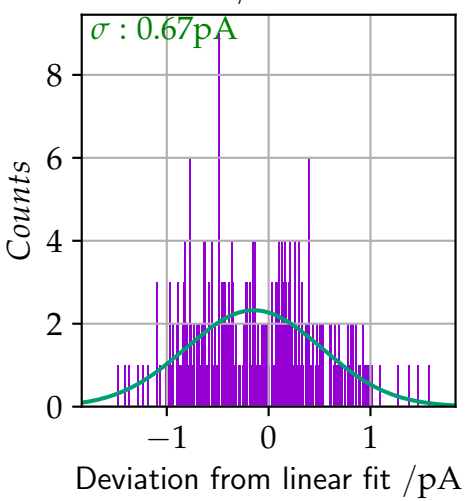
- True bipolar
- Low Error, low non-linearity
- Fast: 500 ksps

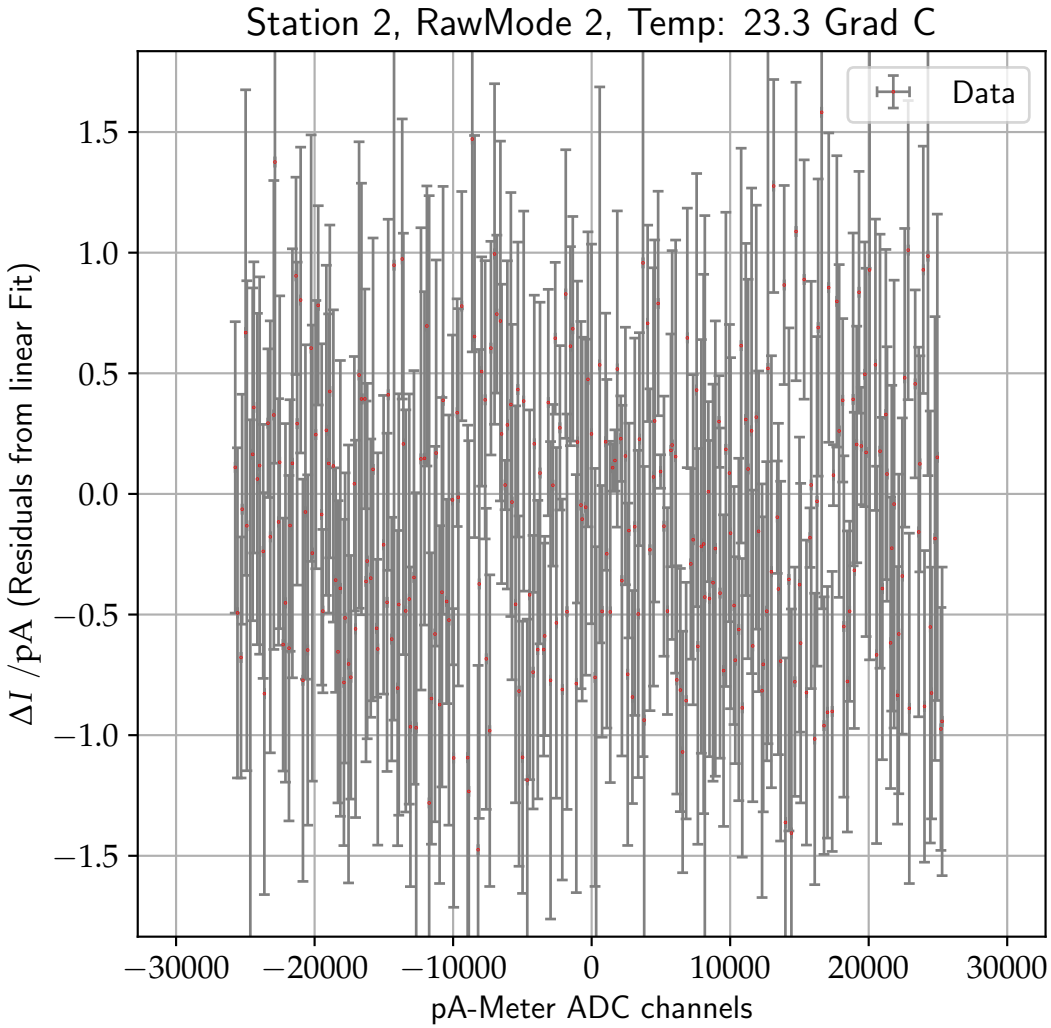
Prototype Layout



Measurements







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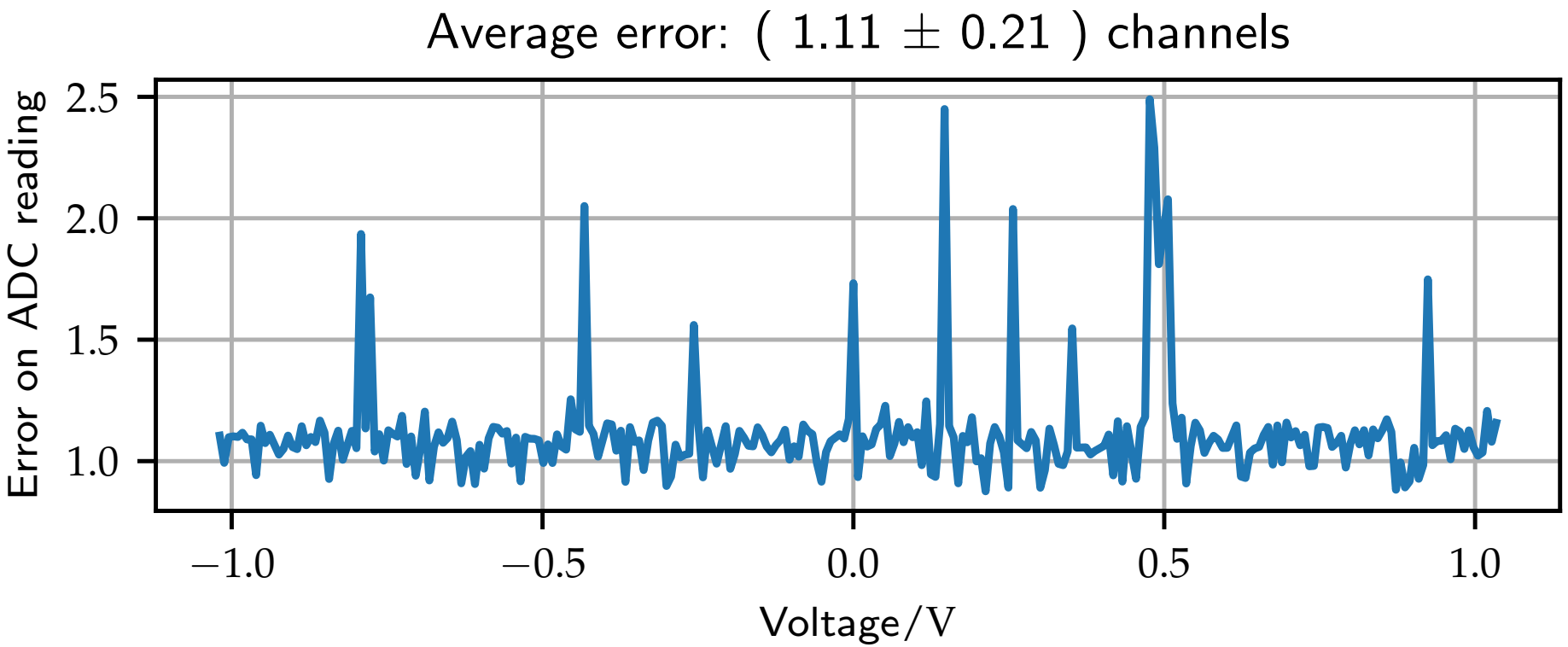

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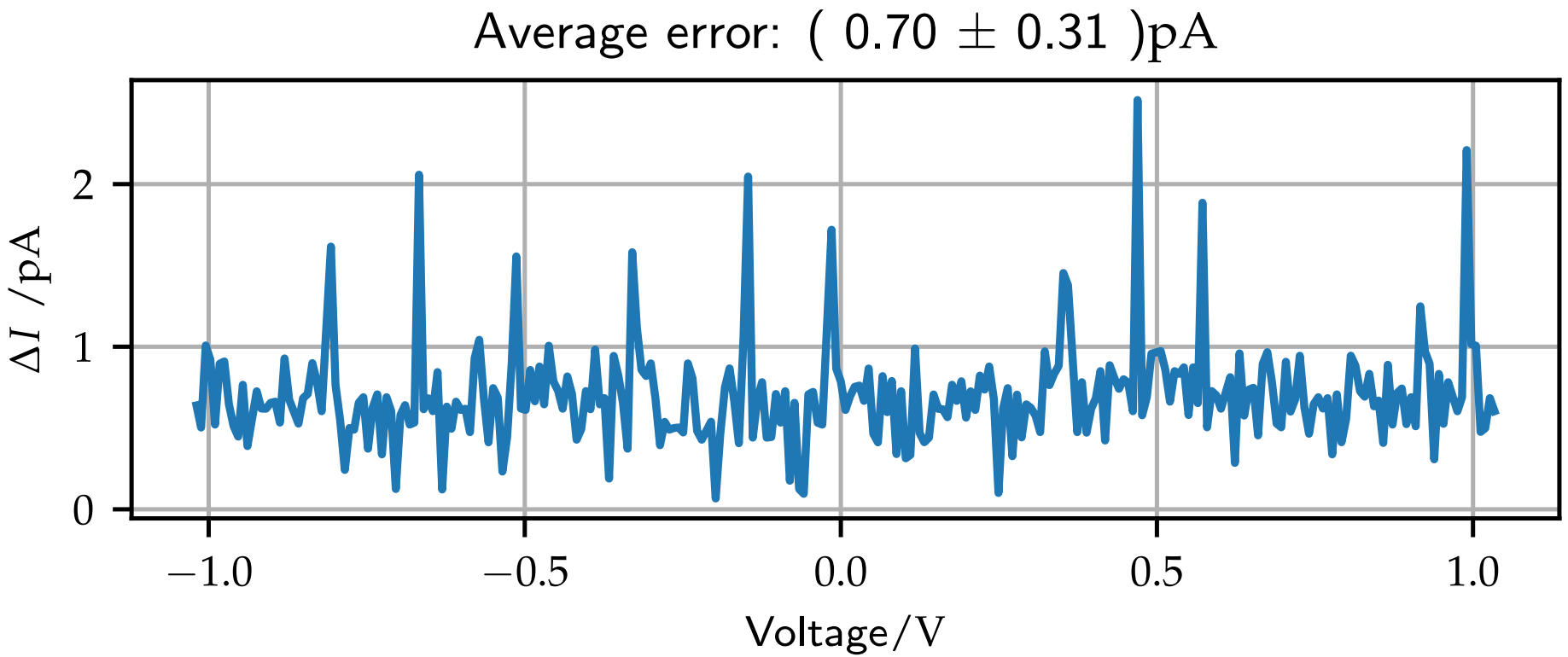

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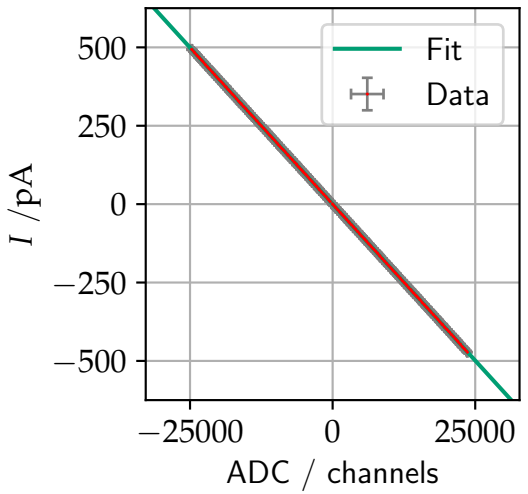

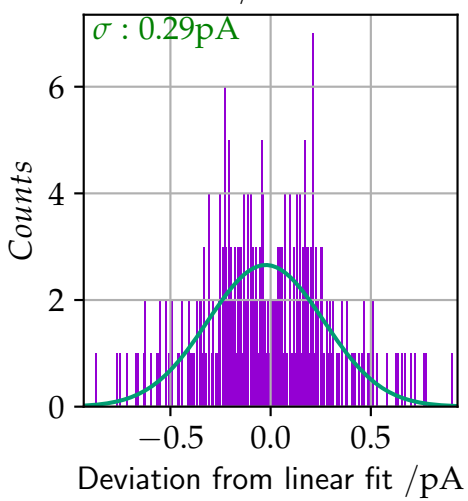

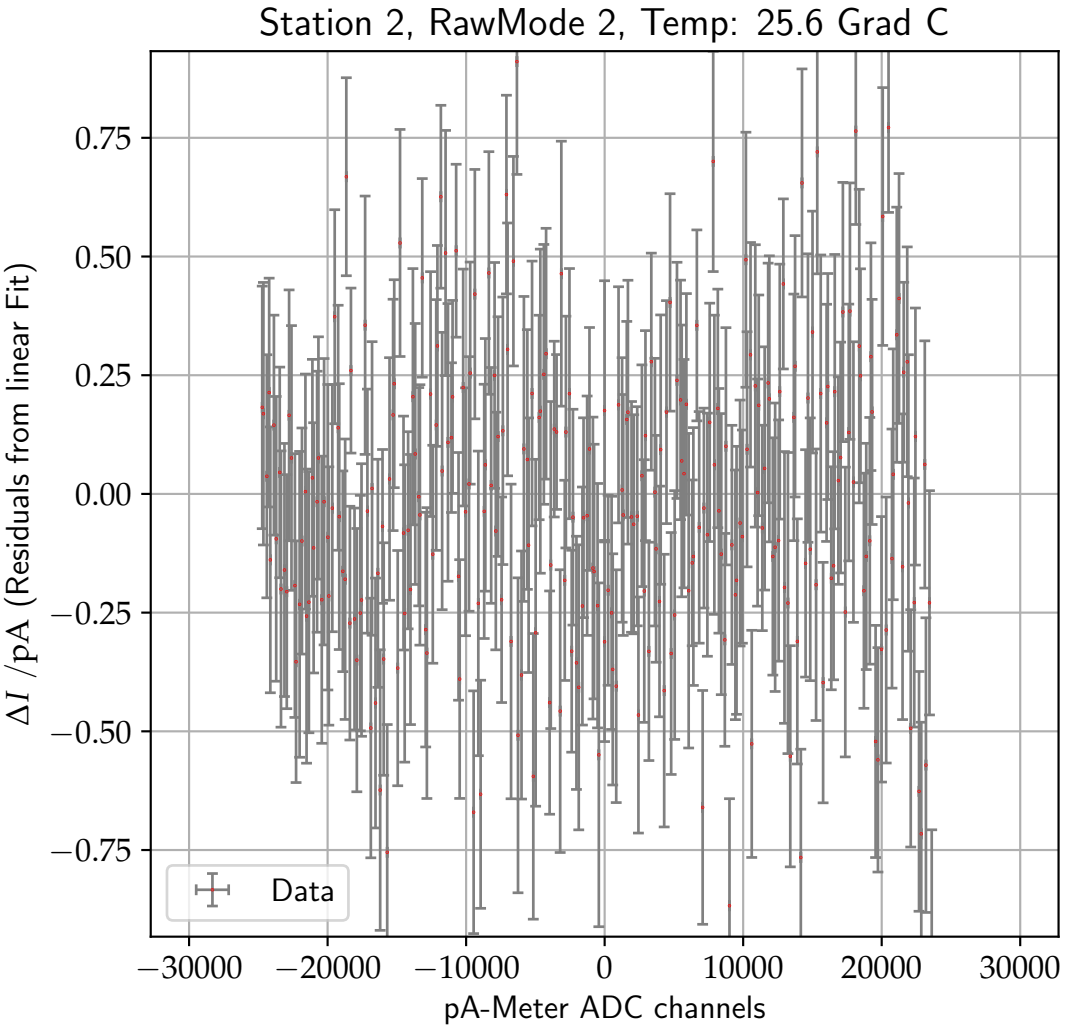

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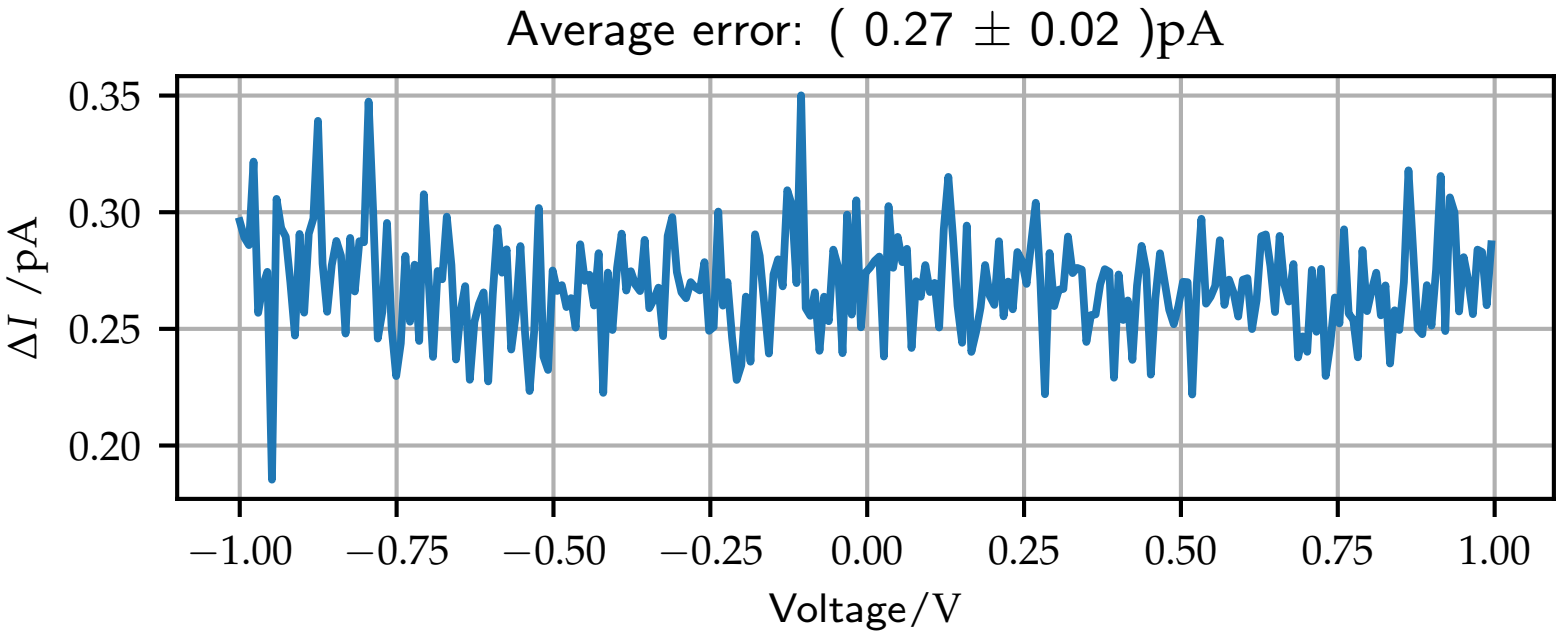

Characteristics

Measurement Range	$\pm 50\,\mathrm{nA}$ to $\pm 500\,\mathrm{pA}$
Lowest Possible Resolution	$19\,\mathrm{fA}$
Achieved Resolution	$\approx 40\,\mathrm{fA}$
Bandwidth	$\approx 20\,\mathrm{Hz}$
Readout Frequency	$\approx 7\,\mathrm{Hz}$
Power Consumption	$\approx 11\,\mathrm{mA}$

Bibliography

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