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# An ASIC Preamplifier for Germanium Detectors.

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# Overview

- Motivation for project
- Problems migrating preamp to ASIC
- Our solution to ASIC difficulties
- ASIC description
- Simulated performance
- First test results

# Why do we need an ASIC preamp?

We need much higher signal density in our Germanium detectors for 2 reasons:

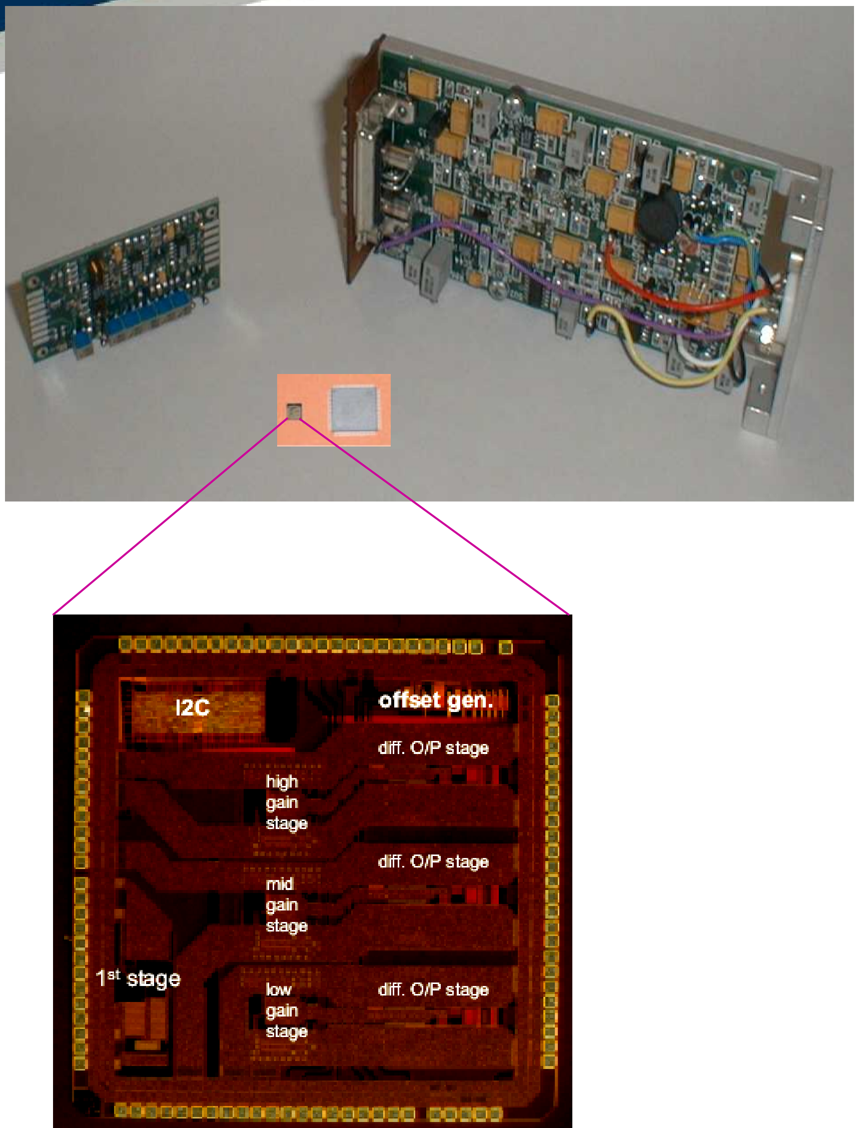
1. To handle high beam flux (multi-element)
   - DIAMOND *(Andy Dent, XAS-3)*
   - Nuclear Physics *(High intensity beams)*
   - SRS *(XHIO: XSTRIP upgrade with 1000 Ge pixels)*

2. For imaging (position and energy)
   - Nuclear Physics *(gamma-ray tracking)*
   - Medical Imaging *(SPECT, PET)*
   - Other applications: Waste monitoring, security

To achieve higher density we must have ASIC preamplifiers to reduce space and to cut power consumption.

# Saving space- shrinking preamps

- 2 generations of typical Germanium preamps.
- ASIC preamp on the same scale (MGPA)




- A typical preamplifier ASIC- the MGPA preamplifier for an electromagnetic calorimeter in the CMS experiment on LHC at CERN.

# Why is a Ge preamp ASIC difficult?

## ASIC problems

- Low voltage rails (3V)
- Hard to make large value resistors (For Rfb)

## Solution:

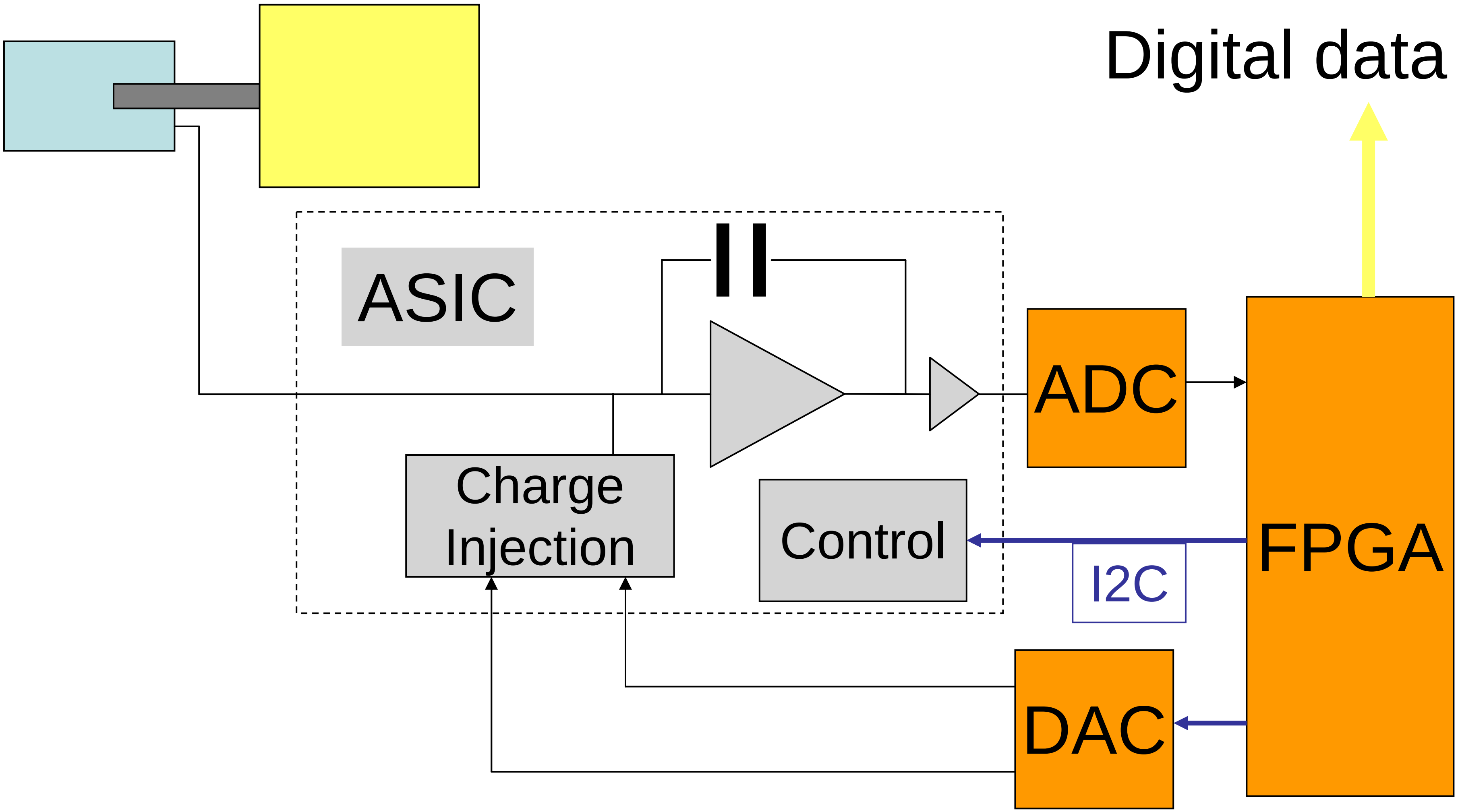
Continuously inject current to charge loop.

- Stops large voltages across Cfb
- Avoids the need for a feedback resistor.

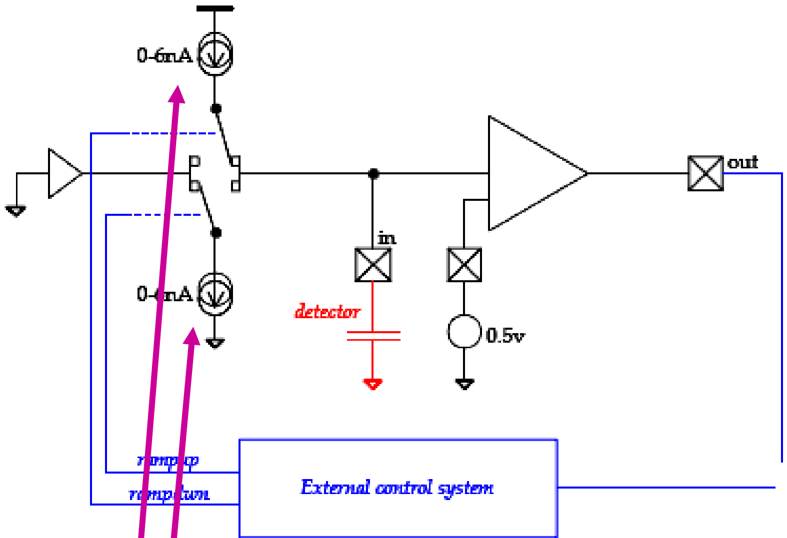
## Question:

Does injected charge cause too much noise?

# Schematic diagram

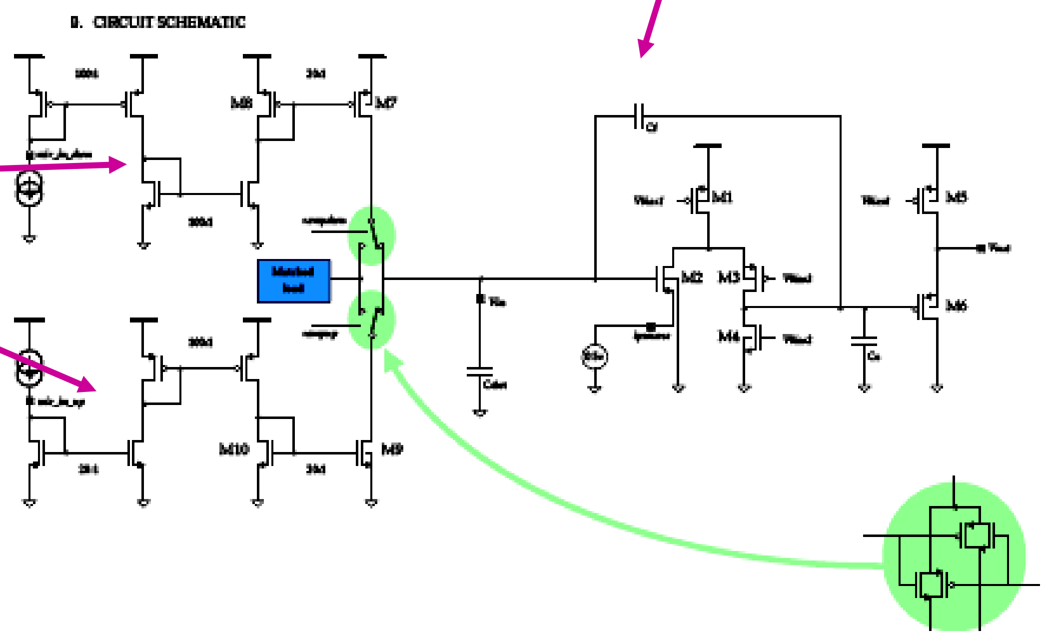


# Schematic diagram




Gain set by $C_{fb}$
200fF or 4pF

Inject charge
to discharge
Cfb. Either as
ramp or analogous
to transistor reset.



# ASIC Input FET

Tabulated Results

| Symbol | Name | Hand-Calculated value | | Simulation value | Units |
|---|---|---|---|---|---|
| g[illegible] | MOS transconductance | 68.06m | | 61.95m | S |
| $\bar{i}_{nth}^2$ | Thermal Noise density | 7.5 x10[illegible] | 6.8 x10[illegible] | - | $A^2/Hz$ |
| e[illegible] | Equivalent input noise voltage | 1.62 x10[illegible] | 1.77 x10[illegible] | | $V^2/Hz$ |
| e[illegible] | (referred using g[illegible]) | 4.02 x10[illegible] | 4.21 x10[illegible] | | $V/\sqrt{Hz}$ |
| $\bar{i}_{nf}^2$ | Flicker Noise density | 2.1 x10[illegible]/f | | | $A^2/Hz$ |

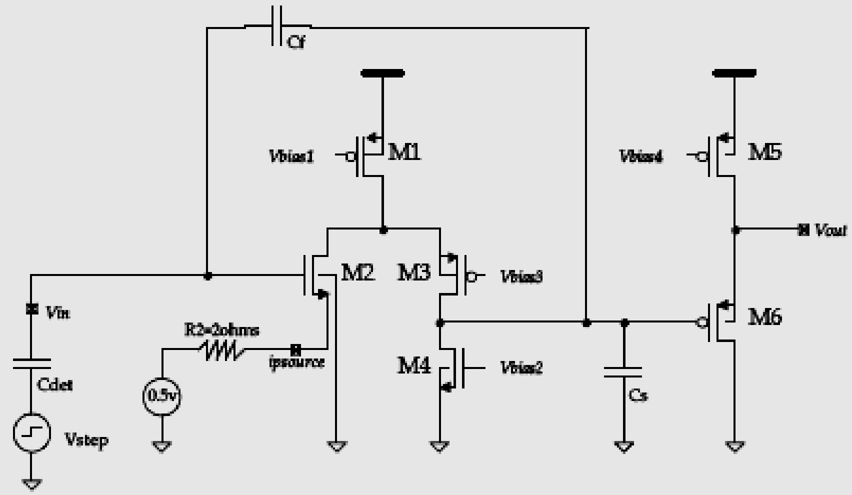
Comparison:

1) BF862 f=100kHz en = 0.8 nv/√Hz
2) IF1331 f=1kHz en = 2.5 nv/√Hz

Considering only the (dominant) thermal noise component, which is flat across all frequencies, the new ASIC design input FET seems to offer an improved noise performance at 0.4 nv/√Hz

# Simulation of performance:

# Rise time <=15ns

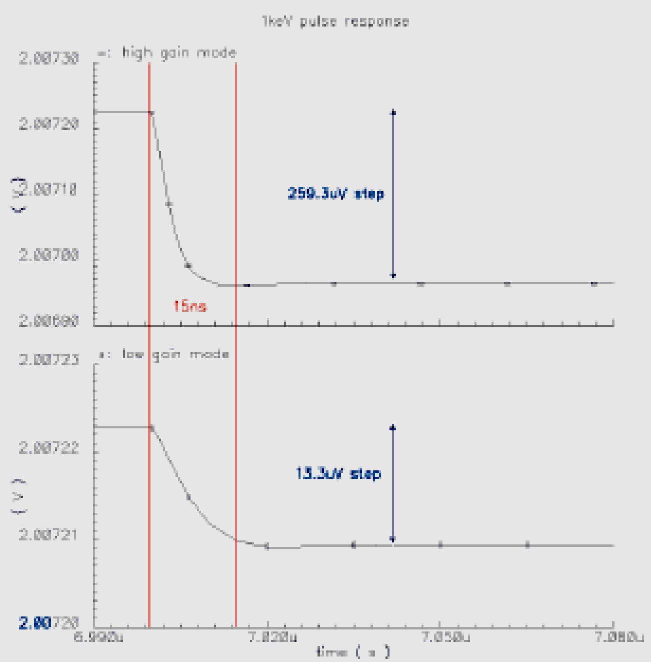



| | Cdet | Vstep (1keV) | Output voltage step | |
|---|---|---|---|---|
| *High Gain* | 2pF | 27 uV | 259.3 uV | |
| *Low Gain* | 30pF | 1.8 uV | 13.3 uV | |

1keV = 338e- = $5.4 \times 10^{-17}$ C

Q=CV

Vertical markers indicate the specified 15ns edge requirement.



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# Simulation of noise performance (6us shaping).

## No ramp current

| | Output voltage peak for a 1keV input | Total output noise (rms) | Input referred noise (rms) | Input referred (fwhm) | Spec. value (fwhm) |
|---|---|---|---|---|---|
| High Gain | 94 uV | 8.2 uV | 0.9 keV | 0.21 keV | < 180 eV |
| Low Gain | 4.9 uV | 1.5 uV | 0.3 keV | 0.72 keV | < 960 eV |

## 1nA ramp current (high rate)

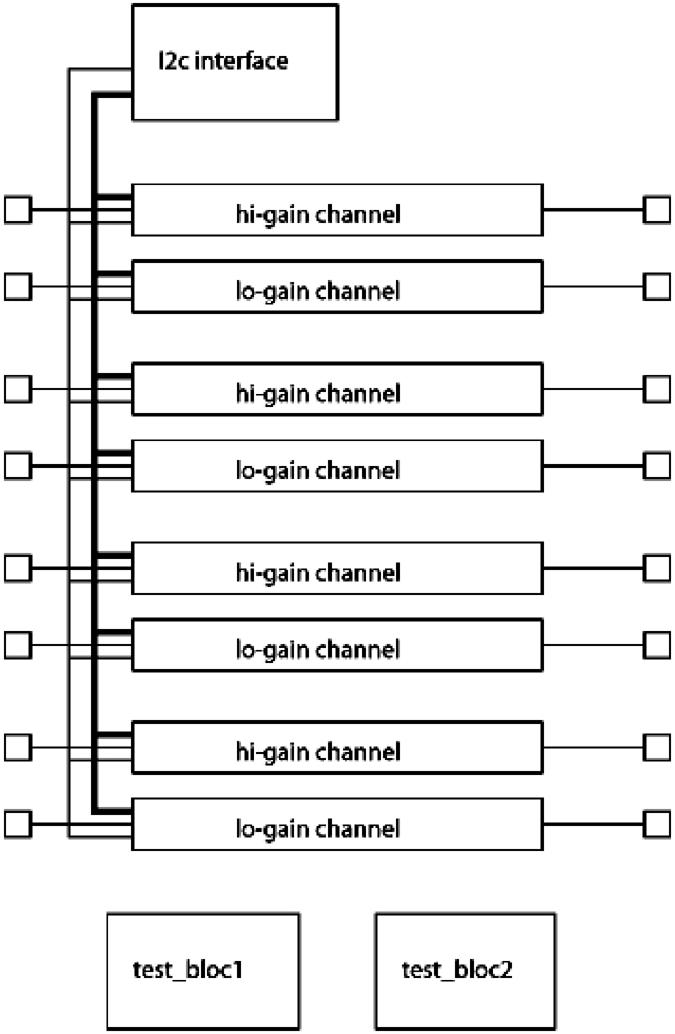
| | Output voltage peak for a 1keV input | Total output noise (rms) | Input referred noise (rms) | Input referred (fwhm) | Spec. value (fwhm) |
|---|---|---|---|---|---|
| High Gain | 94 uV | 79.2 uV | 0.84 keV | 1.98 keV | < 180 eV |
| Low Gain | 4.9 uV | 4.32 uV | 0.88 keV | 2.1 keV | < 960 eV |

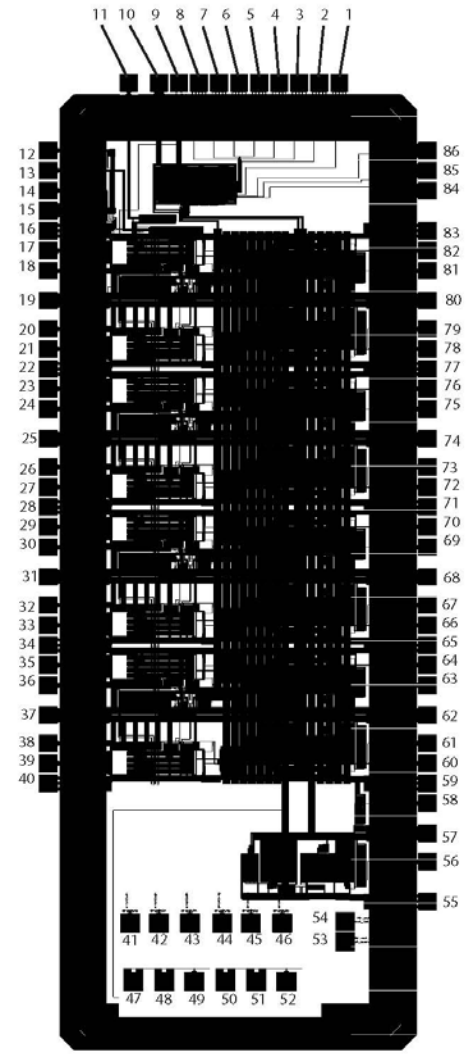
## 10pA ramp current (low rate)

| | Output voltage peak for a 1keV input | Total output noise (rms) | Input referred noise (rms) | Input referred (fwhm) | Spec. value (fwhm) |
|---|---|---|---|---|---|
| High Gain | 94 uV | 11.6 uV | 123 eV | 290 eV | < 180 eV |
| Low Gain | 4.9 uV | 1.5 uV | 306 eV | 719 eV | < 960 eV |

# Prototype ASIC layout

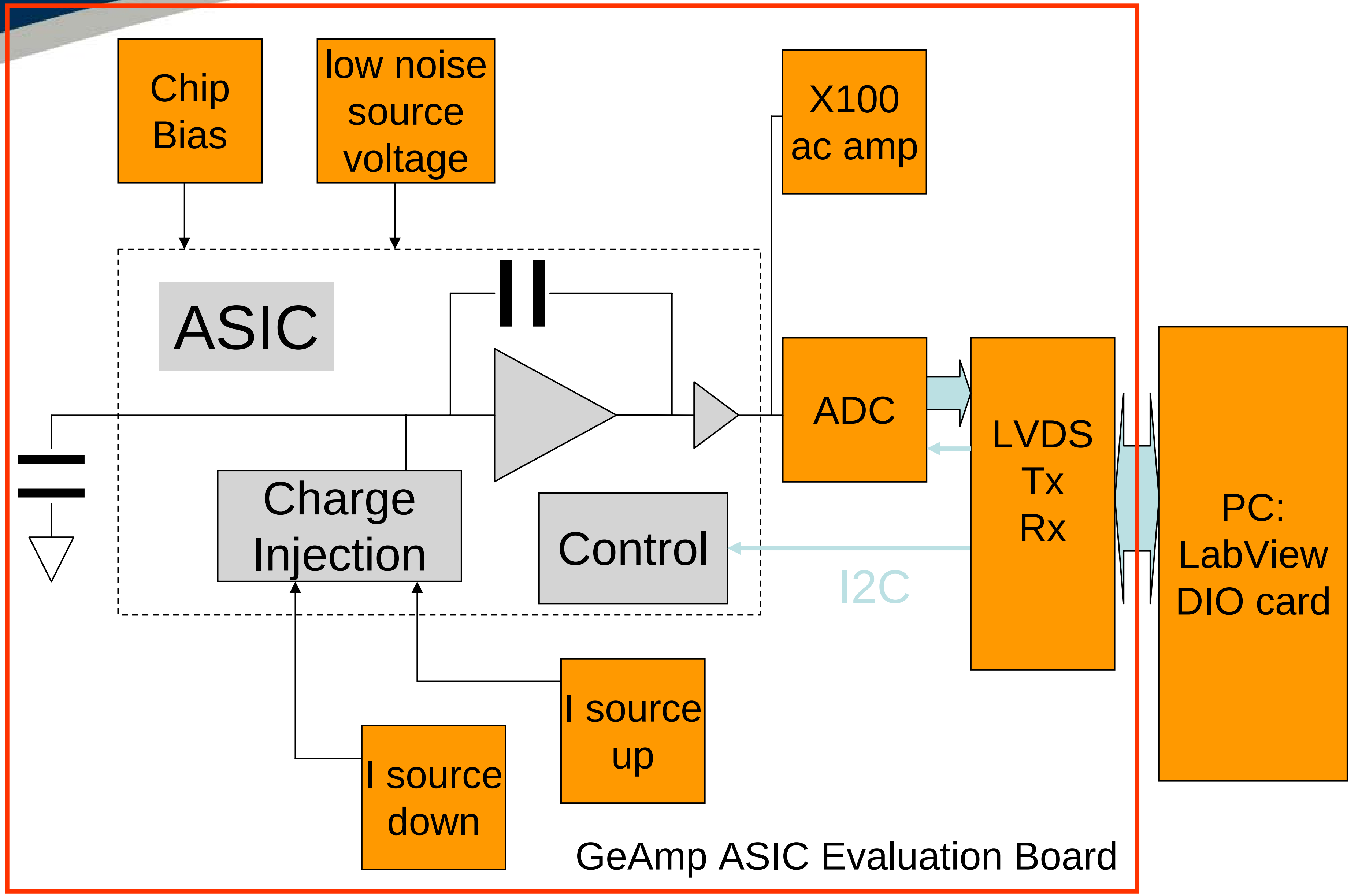
Fig1



2mm x 5mm

# ASIC testing



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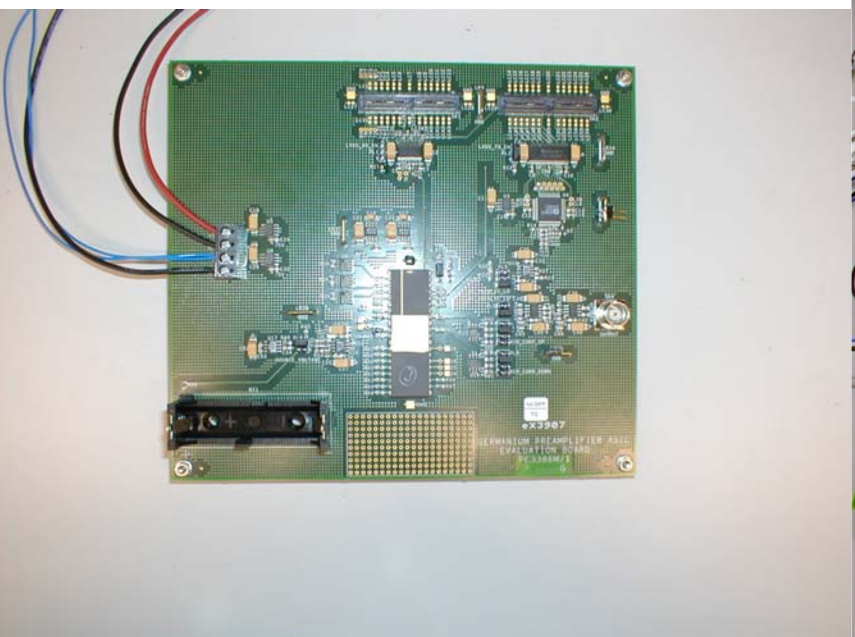
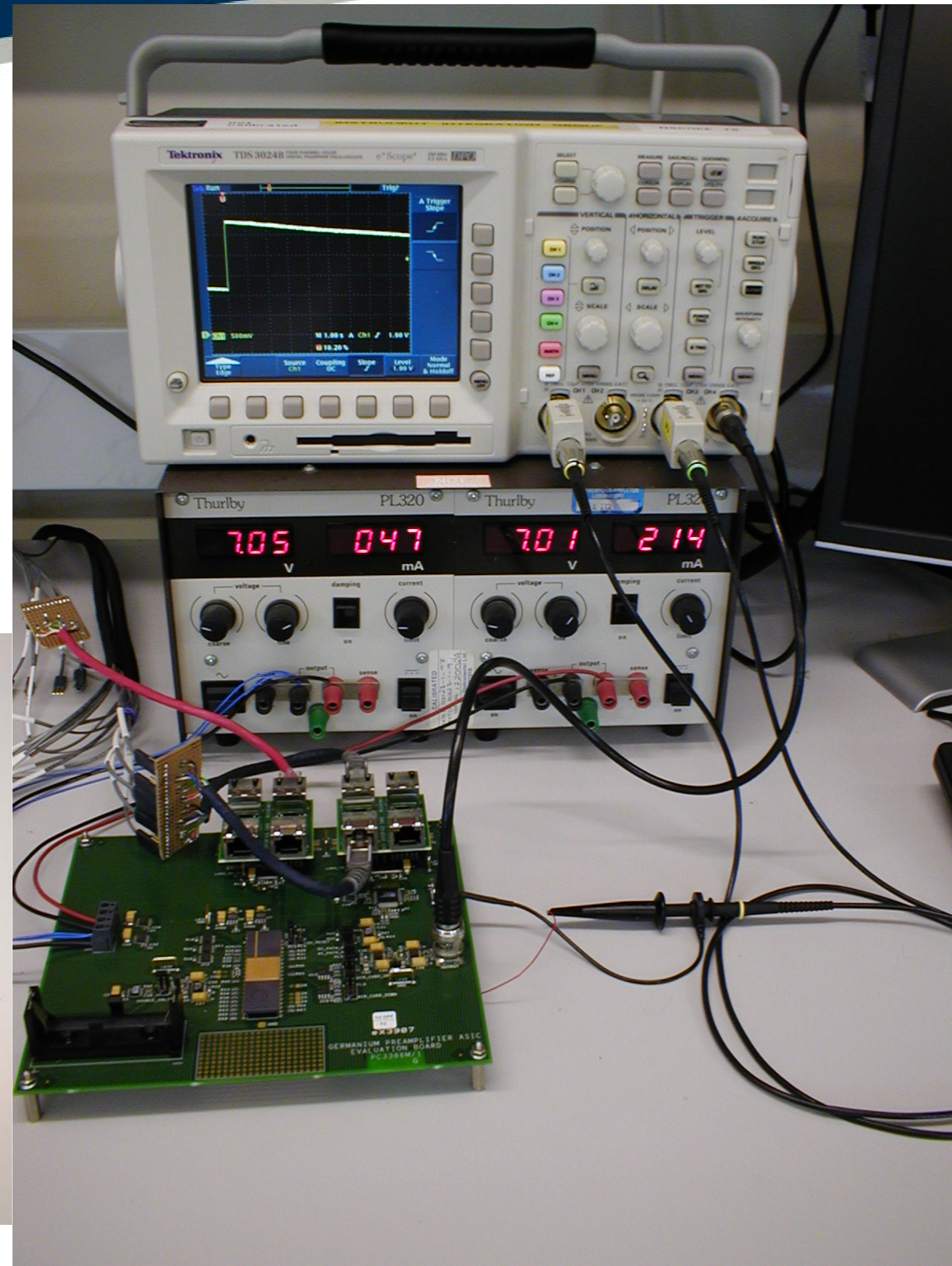
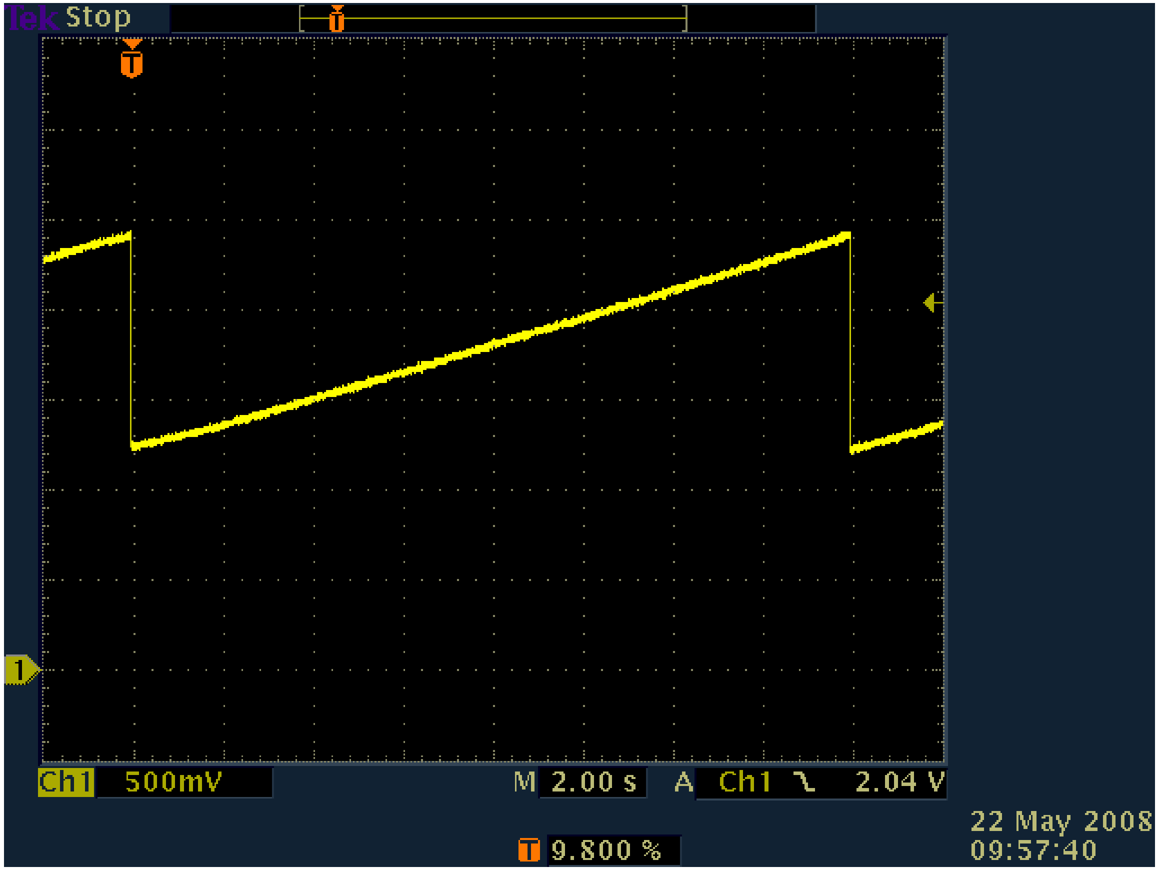
# Test card and Test System



# Initial tests show that ASIC functions as expected.

Input leakage raises output to 2.5v; control circuit detects over threshold and then ramps down to 1.25v.



# Tests under way now

- Compare ramp slope to injected current (check for linearity).
- Measure noise

# Conclusions

- A novel architecture proposed
- ASIC design successfully completed
- First tests show ASIC functionally correct.
- Crucial measurements of noise under way.