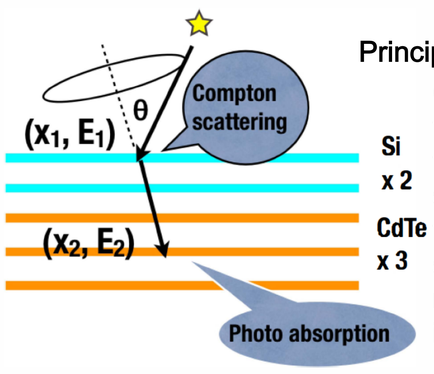
Development of ASIC for Si/CdTe detector in radioactive substance visualizing system

Atsushi Harayama , Shin'ichiro Takeda, Goro Sato, Hirokazu Ikeda, Shin Watanabe and Tadayuki Takahashi
Institute of Space and Astronautical Science (ISAS) / Japan Aerospace eXploration Agency (JAXA) , Japan
harayama@astro.isas.jaxa.jp

1.Introduction

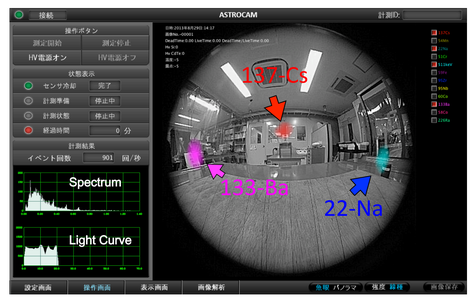
- We report on the recent development of a 64-channel analog front-end ASIC for a new gamma-ray imaging system to visualize radioactive substance. The imaging system employs a novel Compton camera which consists of silicon and cadmium telluride (CdTe) detectors. The ASIC aims for the readout of pixel/pad detectors utilizing Si/CdTe as detector materials, and the dynamic range from 100 keV to a few MeV.

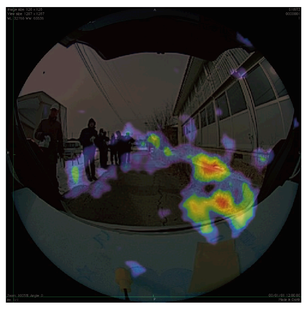


Principle of Si/CdTe Compton Camera

Si x 2
CdTe x 3

Gamma ray are scattered through the Si semiconductor detector and then absorbed by the CdTe semiconductor detector. Based on the values measured by semiconductor detectors, we can retrace the initial direction of incoming gamma rays.



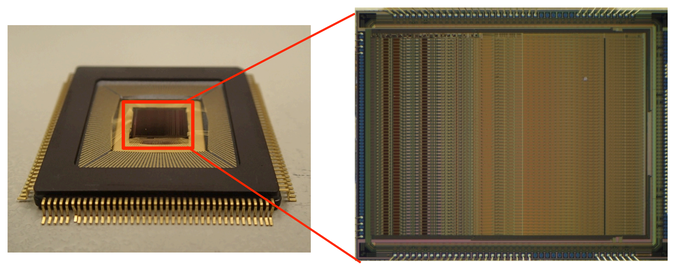


An example of imaging results obtained in Fukushima by using prototype Si/CdTe Compton camera. Air radiation level was about 2-3 μSv/h at 1 m from the ground. The accumulation of radioactive substances were visible with an exposure of around 40 – 60 minutes.

Based on the prototype, a commercial version of Si/CdTe Compton camera was released by Mitsubishi Heavy Industry Ltd in early 2013. Right figure shows a screen shot of the GUI software for operation and real-time radiation monitoring. Measured performances by using the prototypes are summarized as follows:

- Sensitivity; 0.16 – 1.1 cps/MBq (137-Cs, 662 keV)@ 1 m
- Energy resolution; 2.2 % (FWHM) @ 662 keV
- Angular resolution (ARM); 5° (FWHM) @ 662 keV
- Field of view; 180° x 180°
- Simultaneous imaging of multiple isotopes

This Work



KW04D64

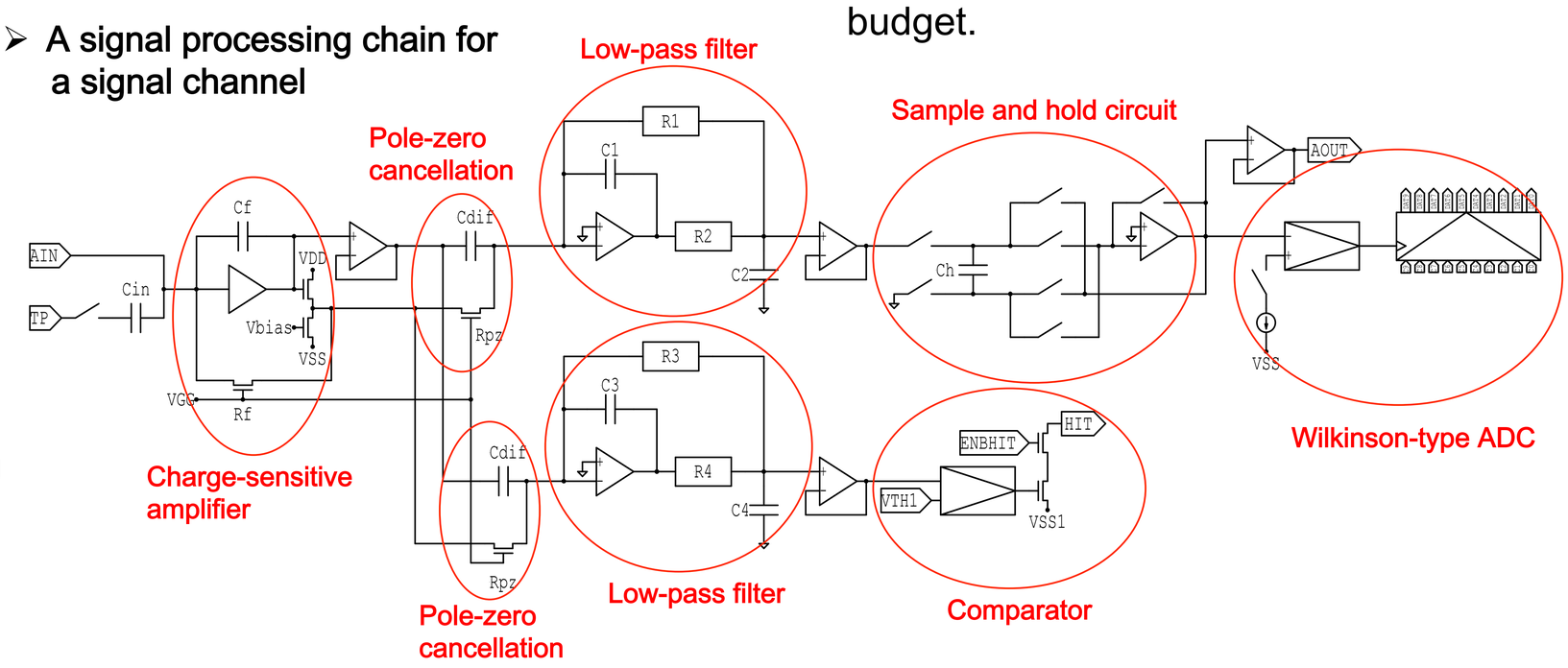
Our goals

- ✓ The dynamic range from 100 keV to a few MeV.
- ✓ Chip size of about 8 mm x 8 mm to assemble with Si/CdTe pixel detectors, which have high stopping power and good energy resolution.
- ✓ Low noise performance better then 300 e^- (r.m.s) with self-trigger capability .
- ✓ Low power consumption of about 0.6 mW per channel to comply with a limited power budget.

2. Circuit Description

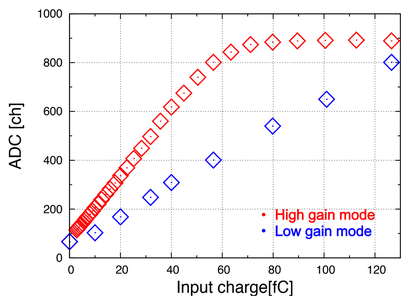
- Chip size of 7.8 mm x 7.1 mm.
- The readout chip consists of 64 identical signal channels and was implemented with the X-FAB 0.35 μm CMOS technology.
- Each channel contains a charge-sensitive amplifier, pole-zero cancellation circuit, low-pass filter, comparator, and sample-hold circuit together with a Wilkinson-type A-to-D converter.
- The circuit has a capability of common mode noise (CMN) subtraction on the chip.
- There are two trigger modes: one is ordinary analog trigger mode, the other is a digital trigger mode which employ the common mode corrected A/D data.
- There is an optional mode, the so-called sparse readout mode, where one can read out triggered channels.

➢ **A signal processing chain for a signal channel**

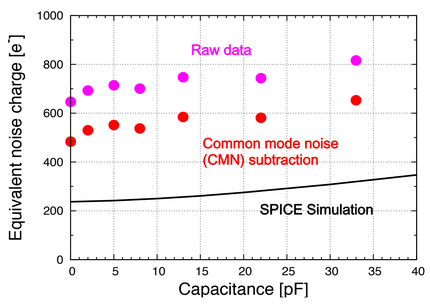


3.Circuit Properties

➢ We observed an equivalent noise charge (ENC) of 500 e^- + 5e^- / pF (r.m.s) with power consumption of 2.1 mW per channel. The large difference of the ENC between the SPICE simulation and the experimental data is considered as due to interference the environmental noise.

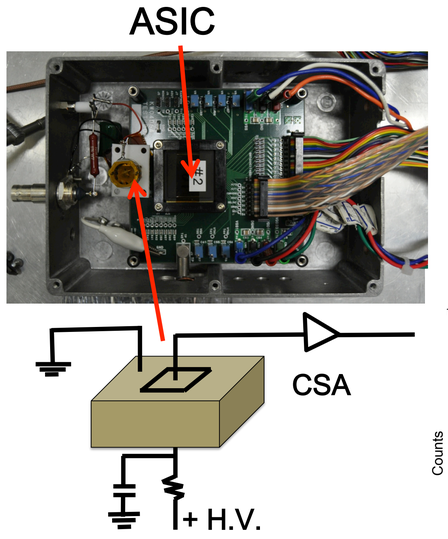


Linearity curves for high and low gain mode. (The chip has two gain mode.)



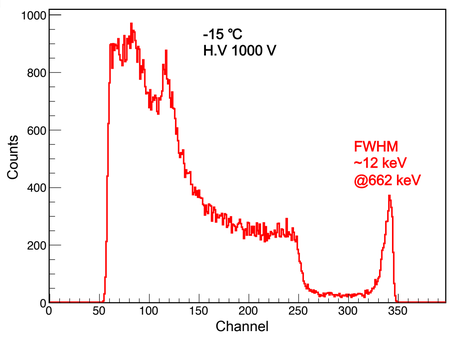
Noise level (ENC) against input capacitance

4.Performance test with a Schottky CdTe Diode

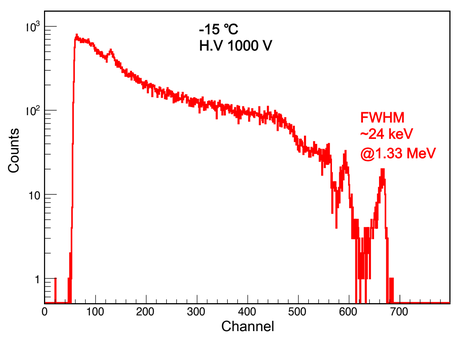


Schottky CdTe diode (ACRORAD)
3.45 mm x 3.45 mm
1 mm thickness
Guard ring 1mm

➢ The chip works fine when connected to Schottky CdTe diodes, and obtained spectra with good energy resolution, e.g. ~12 keV @662 keV, ~24 keV @ 1.3 MeV.



^{137}Cs Spectrum obtained in the high gain mode



^{60}Co Spectrum obtained in the high gain mode

5.Summary & Future Plans

✓We developed a 64-channel analog front-end ASIC for a new gamma-ray imaging system to visualize radioactive substances.
✓We observed an equivalent noise charge of ~500 e^- + 5 e^-/pF (r.m.s.) with power consumption of 2.1 mW per channel.
✓The chip works fine when connected to Schottky CdTe diodes,and obtained spectra with good energy resolution, e.g. ~12 keV @662 keV, ~24 keV @ 1.33 MeV.
✓ The upgrade version is now in a design phase. The new ASIC (KW04F64) will be delivered in a few month.

Reference

- T. Takahashi, S. Takeda, S. Watanabe and H.Tajima, IEEE NSS/MIC 4199 – 4204, 2012
- H. Ikeda, Nucl. Instr. Meth. A, 569, 98, 2006
- T. Kishishita et al., Nucl. Instr. Meth. A 578, 218, 2007
- T. Kishishita et al., Nucl. Instr. Meth. A 598, 591, 2009
- T. Kishishita et al., IEEE Trans. Nucl. Sci., 57, 2971, 2010
- G. Sato et al., IEEE Trans. Nucl. Sci, 58, 1370, 2010

9th International "Hiroshima" Symposium on the Development and Application of Semiconductor Tracking Detectors, Hiroshima, Japan (01-5 September 2013)