Characterisation of an ASIC for Small Satellite Space Radiation Monitors

T. A. Stein[a,b], D. Meier[a], and K. Røed[b]

[a]Integrated Detector Electronics AS (IDEAS), Oslo, Norway; [b]Department of Physics, University of Oslo, Oslo, Norway.

OVERVIEW

In this work we characterise the electronic and temperature performance of a detector readout circuit designed for the Radiation-hard Electron Monitor (RADEM) aboard ESA's JUpiter ICy moons Explorer (JUICE). RADEM uses a custom-made application-specific integrated circuit (ASIC, model: IDE3466) to measure energy deposition and coincidence patterns in up to 36 silicon radiation sensors. Using the ASIC along with COTS parts allows for cost effective payloads that are capable of delivering relevant operational space weather data. The overall payload complexity is greatly reduced f.i. requiring an external microcontroller instead of a FPGA to configure and interface the ASIC. A first prototype CubeSat instrument known as the Norwegian Radiation Monitor (NORM) is briefly discussed.

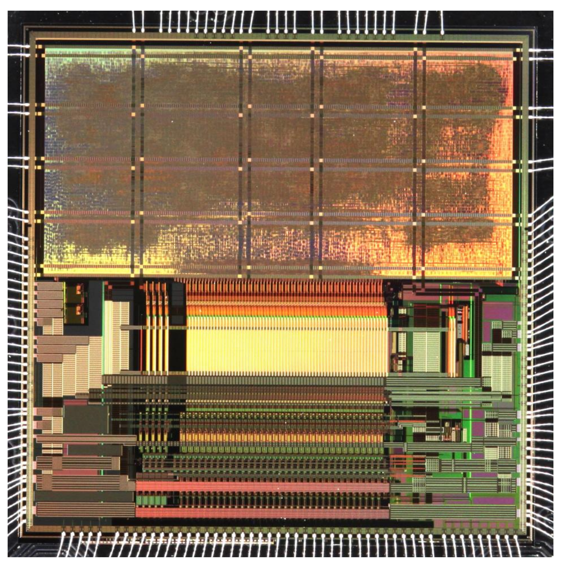

Fig. 1: Image of the ASIC top-layer (not to scale, die size: 16 mm x 16 mm, thickness: 450 µm).

MOTIVATION: NORM PAYLOAD CONCEPT

Miniaturisation is achieved by integrated circuit technology enabling next generation space instruments. For improved operational space weather now- and forecasting capabilities, a fleet of compact radiation monitors is inevitable for success. The deployment of a large number of simple radiation monitors reflects a Big Data approach to space weather monitoring and modelling. At present, only a limited number of science-grade instruments provide data, and often not in real-time. Our proposed, compact instrument concept shall conform with small satellite and CubeSat platform requirements, follow the New Space paradigm and improve access to relevant real-time space weather data.

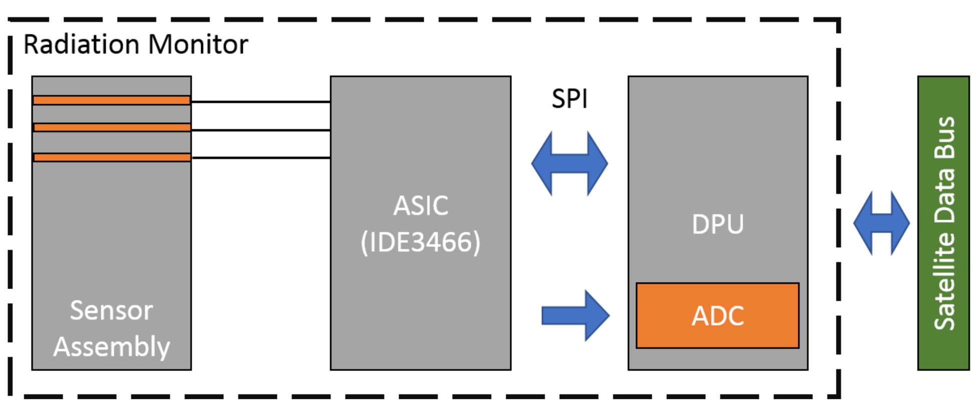

Fig. 2: Simplified system diagram of an IDE3466-based radiation monitor of the NORM instrument with only three detectors shown.

The NORM radiation monitor concept is currently under development at the University of Oslo (UiO) and shown in Fig. 2. NORM shall use a stack of 8 silicon sensors interleaved with absorbers to measure differential and integral flux of energetic electrons, protons and heavier ions. The silicon sensor assembly connects to the ASIC via AC-coupling capacitors. The ASIC is interfaced to a data processing unit (DPU) f. i. a microcontroller. The DPU pre-processes the data and interfaces the payload to the satellite data bus. Pulse-height spectroscopy is possible with an external ADC. Once the sensors are reverse-biased, the instrument is operational and re-configurable to address different applications or compensate for radiation effects. A future IDE3466 iteration may incorporate more trigger thresholds per channel and increase the number of available counters and patterns to allow for improved particle species identification, more attached sensors increase the number of energy bins.

ASIC FEATURES

4 low-gain channels (LG), charge-sensitive inputs:
- + Spectroscopy up to +20.8 pC, ENC ≈ 33000 e + 3 e/pF
- + 1 threshold, 10-bit linear prg. from +260 fC to +22.8 pC, 260 fC lowest threshold above noise
- + 1 trigger logic OR digital output

32 high-gain channels (HG), charge-sensitive inputs:
- + Spectroscopy up to +2.2 pC, ENC ≈ 3320 e + 9 e/pF
- + 1 low threshold (HGLT), 10-bit linear prg. from 1.2 fC to +0.1 pC, 2.2 fC lowest threshold above noise
- + 1 high threshold (HGHT), 10-bit linear prg. from 15 fC to +1 pC, 15 fC lowest threshold above noise
- +1 trigger logic OR digital output

Energy-resolved counting:
- + 36 digital counters read out via serial peripheral interface (SPI)
- + 22-bit Gray code counters
- + 1 Mcps / HG-channel count rate for 600 fC input charge
- + 100 kcps / LG-channel count rate for 10 pC input charge
- + 68-to-1 programmable coincidence pattern logic per counter

Pulse-height (charge) spectroscopy:
- + Analogue mux. output from all channels

Power consumption:

150 mW (typical operation), 240 mW (worst-case register settings)

SEL/SEU radiation hardened (triple-modular redundant, parity check, enclosed layout structures).

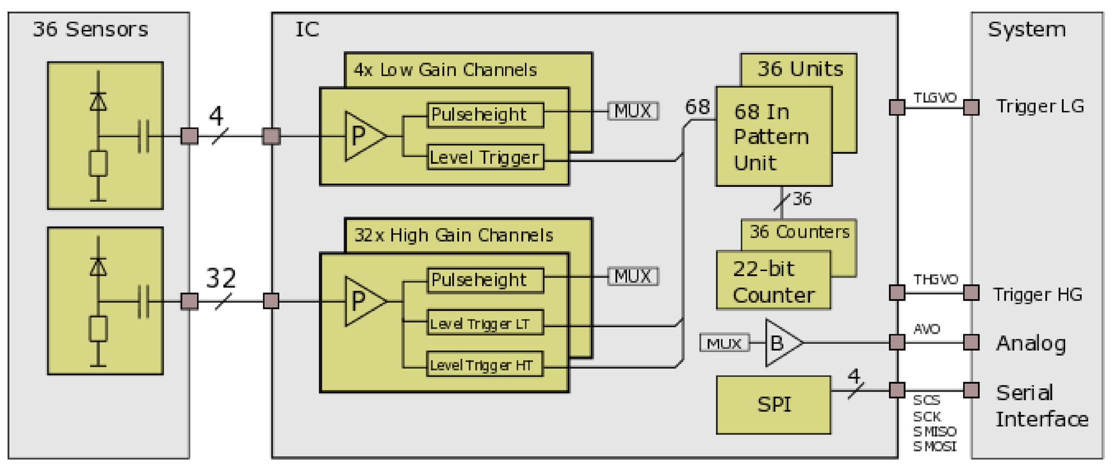

Fig. 3: Block diagram of ASIC (centre) in a typical application with detectors (left) and readout system (right).

You want to get a copy of this poster or learn more on the IDE3466 ASIC?
Use the QR-code to the right
or visit the product page:
http://www.ideas.no/products/ide3466/

ASIC APPLICATIONS

Instruments:	**Fields**:
Compact radiation monitor,	Space, High-Energy / Astro
Dosimeter,	/ Atmospheric Physics,
Particle spectrometer,	Medicine, Nuclear Industry,
Directional particle monitor.	Aerospace.

Detector type: optimised for silicon diodes (p-side, Si).

ASIC PERFORMANCE GRAPHS

Selected performance graphs are shown below.

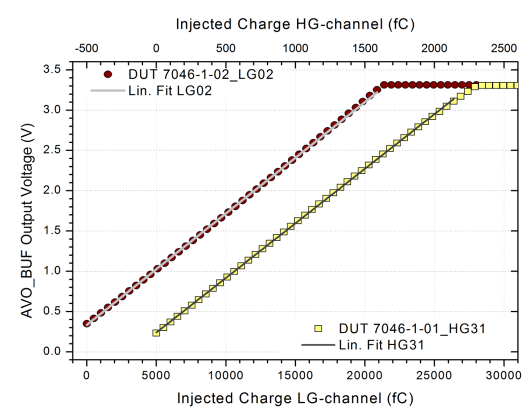

Fig. 4: Pulse-height spectroscopy.

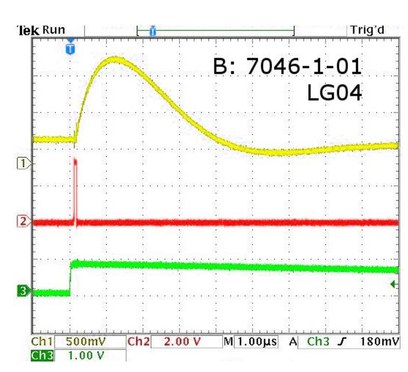

Fig. 5: Analogue, trigger output.

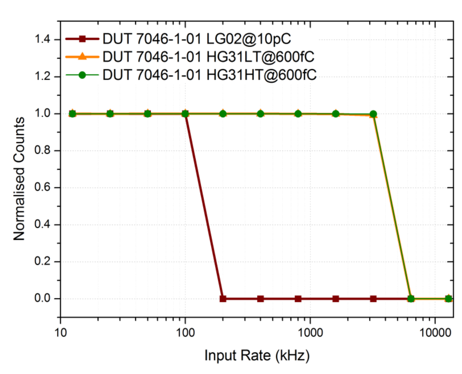

Fig. 6: Count rate capability.

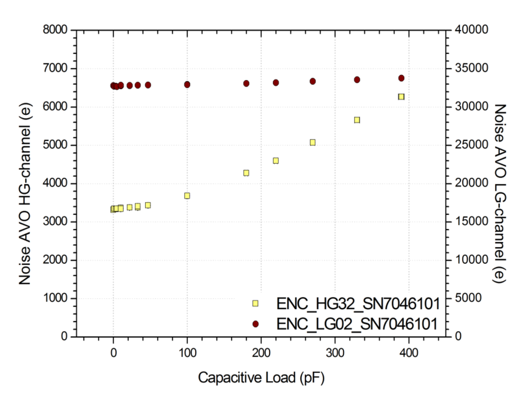

Fig. 7: ENC over load capacitance.

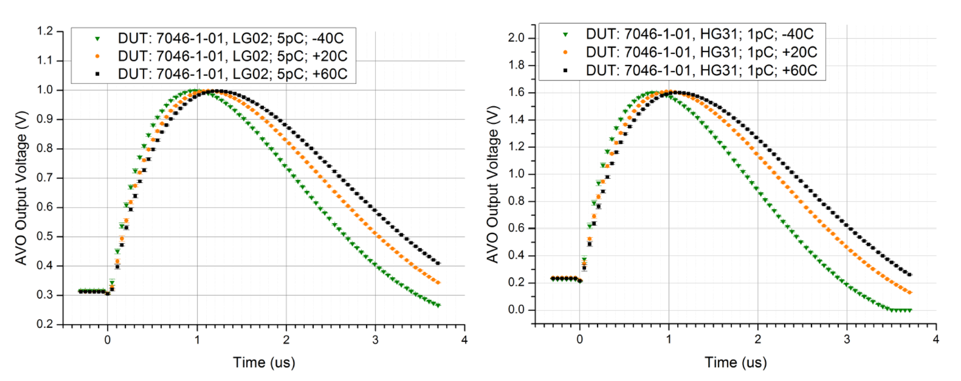

Fig. 8: LG (left) and HG (right) slow shaper analogue voltage output (AVO) for each temperature value.

ASIC PERFORMANCE REPORT

The IDE3466 ASIC was mounted on a test card when characterised using a NI PXI system and a CTS temperature chamber. One test device was used (S/N: 7046-1-01) with parameter setting DAC_GLOBAL_GAIN = 864 and with an external shunt resistor (0.2 Ω). Three temperature points were studied, namely -40, +20 and +60 C. The measured electronic performance over the temperature range was within specifications as provided by the RADEM collaboration. The main results are summarised in the tables below (Tab. 1-3). Additional figures can be found in the IEEE NSS/MIC 2017 proceedings and our previous paper (Stein et al., 2016). Selected graphs are shown on this poster (Fig. 4-8).

	Temperature			Unit
Parameter	**-40**	**+20**	**+60**	°C
Peaking Time	1.00	1.10	1.20	µs
Max. AVO Input Charge	-	20800	-	fC
AVO Slope	138.9	139.7	139.8	mV / pC
Min. Trigger Threshold	253	255	257	fC
Max. Trigger Threshold	-	20800	-	fC
Trigger Threshold Slope	28	30	30	fC / LSB
Counting rate capability	> 200			kHz
ENC	-	33000	-	e^-
ENC slope	-	3	-	e^-/pF

Tab. 1: Temperature-dependent performance parameters for the IDE3466 LG channels.

	Temperature			Unit
Parameter	**-40**	**+20**	**+60**	°C
Peaking Time	0.85	1.00	1.10	µs
Max. AVO Input Charge	2340	2290	2240	fC
AVO Slope	1320	1350	1350	mV / pC
Min. Trigger Threshold (HGLT)	1.8	1.9	2.1	fC
Max. Trigger Threshold (HGLT)	101	109	114	fC
Trigger Threshold Slope (HGLT)	0.098	0.106	0.111	fC / LSB
Min. Trigger Threshold (HGHT)	14.8	14.8	14.8	fC
Max. Trigger Threshold (HGHT)	983	1012	1220	fC
Trigger Threshold Slope (HGHT)	0.95	0.97	1.11	fC / LSB
Counting rate capability (HGLT)	> 400			kHz
Counting rate capability (HGHT)	> 800			kHz
ENC	-	3320	-	e^-
ENC slope	-	9	-	e^-/pF

Tab. 2: Temperature-dependent performance parameters for the IDE3466 HG channels.

	Temperature			Unit
Parameter	**-40**	**+20**	**+60**	°C
CALV offset	1.0489	0.97668	0.93055	V
CALV slope	1.16	1.21	1.25	mV / LSB

Tab. 3: Temperature-dependent performance parameters for the IDE3466 on-chip gain calibration unit's voltage step DAC (CALV).

CONCLUSIONS

The IDE3346 ASIC remains fully functional and within specifications over the design operating temperature range of -40 and +60 C. We conclude that the IDE3466 is an ideal readout circuit for a compact radiation monitor, in particular for use aboard small satellites. Currently, the IDE3466 is used for the RADEM instrument aboard the ESA JUICE mission, and towards the development of a compact radiation monitor (NORM) that is suitable for CubeSats.

ACKNOWLEDGEMENTS

We gratefully acknowledge the RADEM project partners EFACEC Aerospace, Paul Scherrer Institute (PSI), and the Laboratory of Instrumentation and Experimental Particle Physics (LIP). We also acknowledge the support from ESA (contract numbers 4000110643 and 4000104778; NPI programme), the Norwegian Space Centre (contract number BAS.13.1) and the Research Council of Norway for their support under the Industrial-PhD scheme (project number: 254678). At IDEAS we would like to thank in particular T. M. Johansen, P. Øya, P. Påhlsson, D. Steenari, and W. Dang for their support during the ASIC characterisation.

Find a detailed description of the IDE3466 ASIC in our 2016 open-access paper:

Timo A. Stein et al., "Front-end readout ASIC for charged particle counting with the RADEM instrument on the ESA JUICE mission", SPIE Proceedings, 2016. Paper ID: 9905-119, DOI: 10.1117/12.2231901

Any more questions? Get in touch!

Timo A. Stein
Integrated Detector Electronics AS
e-mail: timo.stein@ideas.no
URL: www.ideas.no
General enquiries: contact@ideas.no

Presented at 2017 IEEE NSS/MIC in Atlanta, USA.