

Using the SIPHRA ASIC with an SiPM array and scintillators for gamma spectroscopy

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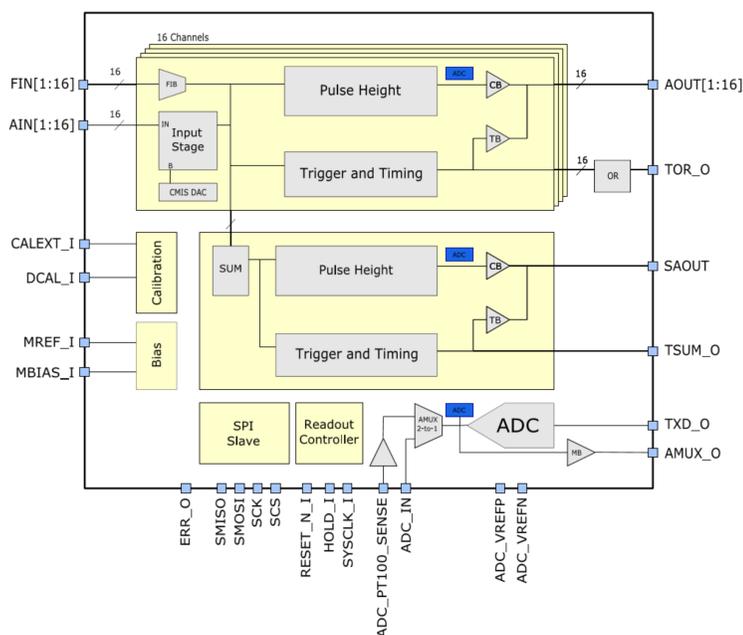
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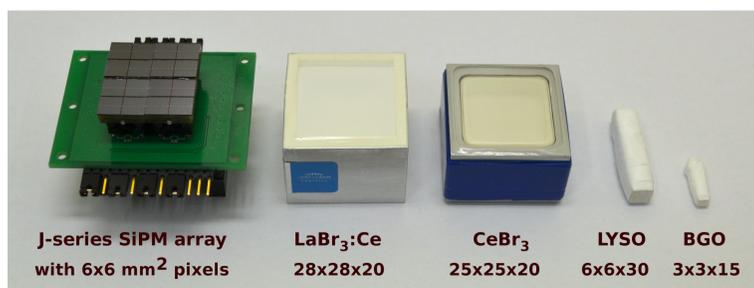
SIPHRA features

The Silicon Photomultiplier Readout ASIC (SIPHRA) is an integrated circuit recently developed by IDEAS for SiPM readout in space applications with particular attention to low-power design and radiation tolerance. It is a versatile ASIC that can also be used for readout of scintillation detectors equipped with SiPMs or photomultiplier tubes in many terrestrial applications, such as nuclear science, medical imaging and homeland security.

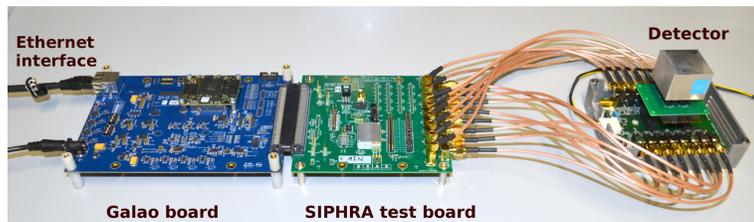
- 16 readout channels + 1 summing channel (DC or AC coupled)
- Programmable attenuation (10, 100, 200 or 400 for a maximum input charge of -0.4 nC, -4 nC, -8 nC or -16nC)
- Programmable shaping time (200 ns, 400 ns, 800 ns, 1600 ns)
- Programmable offset voltage at each input
- Pulse height spectroscopy for each channel: 17 charge integrators and shapers followed by track-and-hold
- 12-bit digital readout (3 ksp/s/channel) or analogue readout
- Timing outputs
- External voltage readout (e.g. PT100 sensor)
- Low power (30mW)
- Radiation resistant by design: SEU LETth = 50 MeV·cm²/mg, SEL LETth > 135 MeV·cm²/mg



Experimental setup



A 16-pixel array was assembled using four 2x2 SiPM arrays from SensL (ArrayJ-60035-4P-EVB). A number of different scintillator crystals were tested: the small LYSO and BGO crystals were coupled to one pixel, while the LaBr₃:Ce and CeBr₃ crystals covered the entire array.

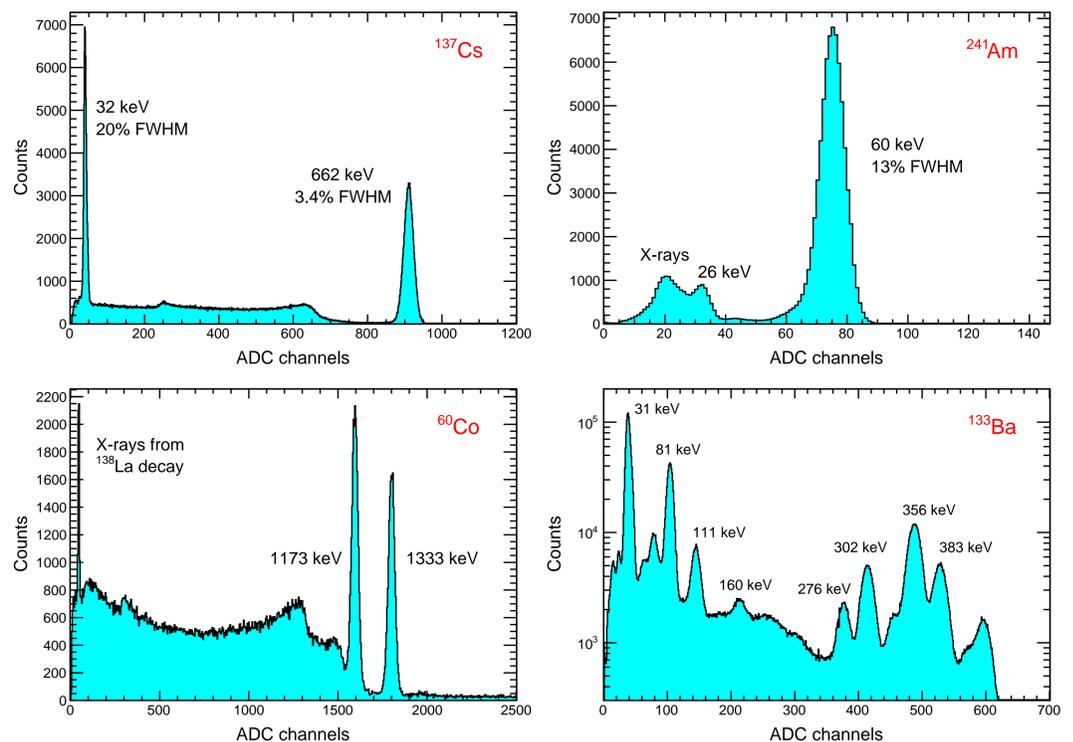


The SiPM outputs were DC-connected to SIPHRA inputs using 30 cm long coaxial cables. Three readout configurations were examined: all 16 SiPM pixels connected to one SIPHRA input, 16 pixels connected to 4 SIPHRA inputs (4 pixels per input), and one single pixel connected to one SIPHRA input. The measurements were performed using the Galao system, a commercially available ASIC evaluation kit from IDEAS. The shaping time was set to 800 ns for BGO and to 200 ns for the other scintillators.

Acknowledgements

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Spectral measurements with gamma-ray sources



The spectra above were obtained with the LaBr₃:Ce crystal and with all 16 SiPMs connected to one SIPHRA input using the input stage attenuation of 400. The table below summarises the energy resolution (FWHM) measured with different scintillator crystals.

Energy (keV)	32	60	81	122	511	662	1173	1274	1333
LaBr ₃ :Ce	20%	13%	10%	7.8%	3.9%	3.4%	2.5%	2.5%	2.4%
CeBr ₃	29%	18%	14%	11%	5.5%	4.8%	3.6%	3.6%	3.5%
LYSO	50%	29%	23%	-	10%	9.4%	-	6.0%	-
BGO	-	45%	32%	28%	13%	12%	-	8.6%	-

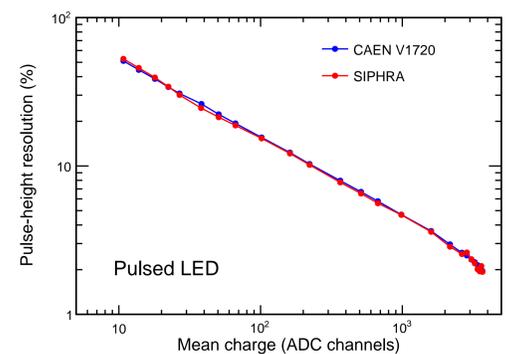
The energy range of the detector was estimated by extrapolating the detector response to 10 ADC channels above the baseline for the minimum detectable energy and to 3500 ADC channels for the maximum detectable energy. A signal of 10 ADC channels approximately corresponds to the minimum trigger threshold in SIPHRA.

Scintillator	Used attenuation	Detector energy range
LaBr ₃ :Ce	400	8 keV – 2.6 MeV
CeBr ₃	400	12 keV – 3.7 MeV
LYSO	400	26 keV – 7.5 MeV
BGO	100	28 keV – 6.6 MeV

The energy range above is given for a single SIPHRA input and a bias voltage of 27.5 V. When an SiPM array is connected to a monolithic scintillator and read out using multiple SIPHRA channels, the minimum and maximum detectable energies for the full detector are increased accordingly. Using all 16 channels, SIPHRA is capable of handling signal from energies of tens of MeV absorbed in bright scintillators. Adjustments of the detector energy range can be accomplished using the four programmable attenuations in SIPHRA and to some extent by changing the SiPM bias voltage. No significant change in the energy resolution was observed between the measurements using one SIPHRA input and four SIPHRA inputs for the readout of the 16-pixel array connected to the LaBr₃:Ce crystal.

Comparison with other electronics

The SiPM array was uniformly illuminated by 30 ns light pulses from an LED. Four SiPM pixels were read out by SIPHRA and four other pixels were read out by a CAEN V1720 waveform digitizer which performed digital charge integration. Both readout methods demonstrated identical pulse-height resolution for a range of light intensities.



Readout rate

The maximum readout rate of SIPHRA is defined by the clock frequency supplied to the ASIC. Using a clock period of 140 ns, a rate of 6.5 kHz was achieved for readout of 17 channels, and a rate of 95 kHz was achieved for readout of one channel. Clock periods shorter than 140 ns resulted in incorrect ADC output. Higher readout rates might be achievable with analogue readout.

