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High Dynamic Range Front-End Circuit for SiPM-Based Readout of Large LaBr3 Crystals

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Lanthanium bromide is currently one of the best choices among scintillating crystals for high resolution gamma spectroscopy. Its fast output pulse (16 ns decay time) allows the minimization of parallel noise component in the detector readout chain, and its high output yield (63 ph/keV) contributes to the achievement of a better energy resolution (2.8% @662 keV) than classic NaI(Tl) scintillators (7% @662 keV [1]). Recent improvements in SiPMs have proven the possibility to implement the scintillator readout chain with these solid-state detectors, avoiding the use of high voltages or low temperature needed for respectively PMTs and SDDs, and obtaining similar energy resolution (3.7% @662 keV). High density SiPMs, exploiting a large number of microcells (˜10000 cells/mmˆ2) together with a low DCR (30 kHz/mmˆ2), high PDE (30%) and a fast decay time (50 ns), suit well the need for the scintillator light output high dynamic range front-end. SiPMs could be also tiled in large area arrays, and so are becoming a feasible choice for the readout of large LaBr3 crystals. The target of the project here presented is the design of an analog front-end capable of capturing the full dynamic range of a 3"LaBr3 scintillator coupled to SiPM tiles, with negligible degradation of the overall resulting energy resolution. In this work we will demonstrate how the ENC of the front end circuit heavily contribute to the resulting resolution at lower energies (200 keV- 600 keV) if large optical signals are also to be detected (e.g. from a 15 MeV photon impinging on the scintillator) without manual gain adjustments. These energy resolution calculations, resulting in a need for almost 14-bit resolution, brought us to the design of an automatic gain control (AGC) circuit composed by a current conveyor input stage (6 Ohm input impedance) and a self-triggered gated integrator with automatic signal-dependent multiple gain adjustment. In this work we will show the topology of the AGC and of the integrator circuit. From circuit simulations the ENC of the resulting system is 0.3 pC and the saturation charge is 5 nC, thus reaching 84 dB of dynamic range, significantly improved with respect to the current state of the art. Based on GEANT crystal optical simulations and on field measurements, the resulting energy resolution is almost unaffected by the readout chain noise from 200 keV to 15 MeV and it is expected to be lower than 3% @662 keV. The overall designed front-end was implemented in a first 8-channel prototype ASIC in AMS C35B4C3 technology submitted in January and whose experimental characterization will be presented at the conference.

References
[1] Saint Gobain, "BrilLanCeTM Scintillators Performance Summary (Revision: January, 2009)"
[2] A. Dawood Butt et al., "Comparison of SiPM and SDD based readouts of 1″ LaBr3:Ce scintillator for nuclear physics applications," 2015 IEEE Nuclear Science Symposium and Medical Imaging Conference (NSS/MIC), San Diego, CA, 2015, pp. 1-4.

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