Ph.D. in Information Technology: Thesis Defense

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Filippo MELE – XXXIII Cycle

Low-Noise Low-Power Integrated Circuits for High Resolution X and Gamma Ray Semiconductor Detectors

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Abstract:

The increasing demand for performance improvements in radiation detectors, driven by cutting-edge research in nuclear physics, astrophysics and medical imaging systems, is causing not only a proliferation in the variety of the radiation sensors, but also a growing necessity of tailored solutions for front-end readout circuits and for signal elaboration, storage and digital transmission. The aim of the presented work is to study novel solutions for the readout Application Specific Integrated Circuits (ASICs), defining new possible paths for improving the state-of-the-art in terms of energy resolution, speed and power consumption, that compose the most important tradeoffs in the design of the front-end electronics. In the first part of this work, a newly designed Charge Sensitive Amplifier (CSA), named SIRIO-6, for X-ray spectrometers, is presented, optimizing the noise performance - and thus the energy resolution - with specific focus on sub-microsecond signal processing time, addressing the growing interest in high-luminosity experiments. The preamplifier demonstrated excellent results when connected to Silicon Drift Detectors (SDDs) at moderate cooling, achieving an optimum noise of 3.4 electrons r.m.s., and with room temperature Cadmium-Telluride (CdTe) detectors, recording a state-of-the-art noise performance which improves by a factor of two the best energy resolution present in literature at the time of writing for comparable experimental conditions. The integration of the CSA and the experimental results obtained on two custom radiation detection instruments realized for the ELETTRA (Trieste, Italy) and SESAME (Allan, Jordan) synchrotrons is described and commented. In the second part of this work, an ASIC constellation designed for X-Gamma Imaging Spectrometer (XGIS) onboard of the THESEUS (Transient High Energy Sources and Early Universe Surveyor) space mission is described. The XGIS is composed by two cameras that operate as wide field-deep sky monitors, and are based on a position sensitive double detection mechanism for image reconstruction, in which each pixel is constituted by a Thallium activated cesium Iodide scintillator crystal and two SDDs glued at both ends of the crystal. The presented readout ASIC, named ORION, designed for XGIS instrument, has a highly customized distributed architecture constituted by a total of 25600 front-end chips and 1600 multi-channel back-end chips, and is capable of a complete on-chip signal filtering, acquisition and digitization.

PhD Committee

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