A Real-Time Digital Signal Processing Chain for SiPM Readout in Quantum Optics Experiments

S.Carsi[1], A. Abba[1], A.Pozzoli[2], A.Allevi[2]

[1]*Nuclear Instruments srl, 22045, Lambrugo, Italy*

[2]*Università degli Studi dell'Insubria, 22100, Como, Italy*

Silicon photomultipliers (SiPMs) are increasingly adopted in quantum optics experiments thanks to their high photon detection efficiency and low noise. In applications such as twin-beam quantum correlations, where per-pulse charge values on both channels must be individually recorded and correlated, the quality and reproducibility of the signal integration chain are as critical as the detector itself.

We present a fully digital readout and processing system for SiPM-based measurements, implemented on the DAQ141 digitizer by Nuclear Instruments. The instrument samples at 1 GSa/s with 14-bit resolution over a 2 V dynamic range, and is built on an Open-FPGA platform configurable via the Sci-Compiler toolchain, allowing the firmware to be tailored to specific experimental requirements without custom hardware development.

The signal processing pipeline operates entirely in real time at the full sampling rate and consists of three stages: a baseline estimation and compensation block; a digital deconvolution stage that restores the underlying pulse shape from the SiPM response; and a charge integration block (QDC) operating on the deconvolved signal. This replaces conventional analog NIM chains — in particular boxcar averager integrators — with a single, compact, software-defined unit.

Compared to analog boxcar integrators, the digital chain offers an extended dynamic range in both directions: the reduced noise floor enables single-shot measurements at signal levels otherwise buried in analog noise, while the 14-bit full scale delays saturation significantly. All parameters are software-controlled, ensuring full reproducibility across sessions and enabling automated acquisition scans — key advantages in systematic twin-beam characterization campaigns.