SiPM0 : An FPGA based DAQ System for the Readout of SiPM Matrices in PET Applications

ABSTRACT

Next generation PET scanners should fulfill very high requirements in terms of spatial, energy and timing resolution. Modern scanner performances are inherently limited by the use of standard photomultiplier tubes. The use of Silicon Photomultiplier (SiPM) matrices is proposed for the construction of a 4D PET module based on LYSO continuos crystals, which is envisaged to replace the standard PET block detector. The module will provide a submillimetric spatial resolution on the photon hit position, performing at the same time, the Depth Of Interaction (DOI) calculation and the Time Of Flight (TOF) measurement. The use of large area multi-pixel Silicon Photomultiplier (SiPM) detectors requires the development of a multichannel Digital Acquisition system (DAQ) as well as of a dedicated front-end in order not to degrade the intrinsic detector performances. We have developed a custom DAQ system (SiPM0) for the read-out of 2 modules in time coincidence for Positron Emission Tomography (PET) applications. The DAQ system is based on front-end ASICs (VAHDR11 and TA32CG2 chips by IDEAS) that allow to read-out SiPM matrices preserving their spectroscopy and timing capabilities.

TECHNOLOGY STAGE

- Prototype of the SiPM0 DAQ system available.
- PET scanner small system demonstrator

APPLICATIONS

- Small animal PET systems (DASiPM2 and 4DMPET, INFN R&D project)
- SiPM readout for fiber optic based tracking systems

SPECIFICATIONS

The SIPM0 DAQ system developed at INFN within the DASIPM2 Collaboration for the characterization of 4 x 4 matrices of SiPM pixels is based on “off-the-shelf” Application Specific Integrated Circuits (ASICs) for the Front-End (FE) and for the Trigger Generation (TG) and on a custom Printed Circuit Board (PCB) where the data acquisition process and the data transfer to the host PC through a standard USB port are controlled by one FPGA (Altera Stratix II).

Each SIPM0 board houses two FE-TG ASIC pairs; each pair handles data from one matrix of 4 x 4 SiPM detectors. Two SiPM matrices can be housed on the SIPM0 board or on custom daughter cards connected to the SIPM0 board through micro-coaxial cables. The two daughter cards equipped with SiPM detectors will implement the two heads of the

PET system demonstrator.

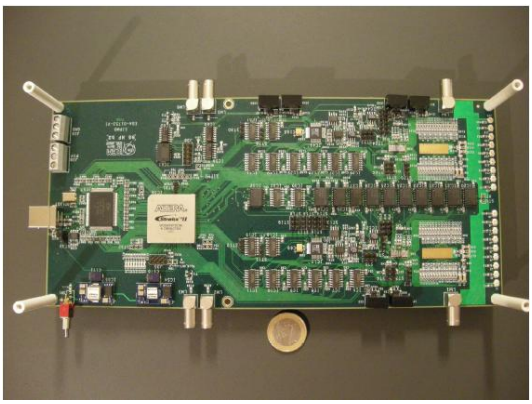

Figura 1. SIPM0 board top view

PERFORMACES

The SIPM0 DAQ system has been designed taking into account the estimated values for data rate, dynamic range and dark current rate. A maximum data rate of 2MHz is expected from a 4cm x 4cm SiPM array and scales down to 20 KHz for a 4 x 4 matrix of SiPM pixels. In the SIPM0 the readout bandwidth is dominated by the ADC conversion rate and by the memory readout time. The first (31.25KHz) is related to the conversion time (1μsec) and to the number of sampled data for event. The second (100 KHz) is related to the time required to download one memory bank in fast read mode (12.8μsec) and to the number of events stored in one memory bank. The values of both these parameters are therefore compatible fit the expected data rate.
The dynamic range is related to the charge generated by one photon in each SiPM pixel. With a Gain of 10^6, if all the 625 micro-cells are "on" the charge is 100pC, while in the more realistic assumption that only 200 micro-cells are "on" the charge is 32pC, below the extended dynamic range of the VA ASICs.
Finally the measured dark rate (2MHz) for a 1mm x 1mm SiPM is compatible with the VA peaking time (1μsec) since in PET applications the relevant events are high energy events with multiple photo-electrons.

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