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STiC - A Mixed Mode Silicon-Photomultiplier Readout ASIC for Time-of-Flight Applications

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STiC is a mixed mode readout ASIC for Silicon-Photomultipliers developed in the UMC 180nm CMOS technology. The chip has been designed for the EndoToFPET-US project and aims at providing a high timing resolution to high energy physics and medical imaging applications. The signal is read out and discriminated by a dual threshold method. A low threshold discriminator provides a high precision trigger signal while a linearized time-over-threshold method maintains a good energy resolution. An integrated TDC with 50ps bin size is used to digitize the trigger signals. A 16-channel prototype has been produced and measurements have been performed to quantize the performance of the ASIC.

Summary

The STiC chip is a mixed mode ASIC developed in 0.18um UMC CMOS technology for Silicon-Photomultiplier (SiPM) applications with very high timing resolution. It is designed for time-of-flight (ToF) measurements in high energy physics and medical imaging applications and dedicated in particular to the ENDOToFPET-US project, which aims at providing a powerful endoscopic time-of-flight PET system for early prostate and pancreas cancer diagnostics. The goal of this endoscopic system is to provide a spatial resolution in the order of 1 mm which necessitates a time-of-flight resolution of 200 ps FWHM.
In order to achieve this high timing resolution the STiC ASIC has a differential readout structure reducing the influence of noise sources. The connection scheme to the SiPMs can be either differential or single-ended. The timing and energy information, which are both required for a high resolution PET system, are encoded in two time stamps which are obtained by discriminating the signal with two different thresholds. A low threshold discriminator providing a high precision trigger signal is used as the timing trigger. A second discriminator with a higher threshold is used to implement a linearized time-over-threshold discrimination providing a good energy resolution. A combined signal of the trigger outputs is then processed by a TDC with a bin size of 50ps which has been developed at the ZITI Heidelberg. An integrated digital part stores the data and transfers
it over a LVDS serial link to the DAQ system. In order to compensate the high temperature dependence of SiPMs, the STiC ASIC is capable of tuning the sensor bias voltage.
A 16-channel prototype has been submitted in April 2012 and measurements have been carried out to quantify the chip performance. The SiPM bias DAC shows a linearity of 700mV, which exceeds the required 500mV tuning range for temperature and bias variations. An analog test channel has been used to characterize the performance of the analog input stage. A scan of the time-over-threshold output width with respect to the total injected signal charge shows a linear relationship for signal charges larger than 3pC maintaining the high
energy resolution of the charge measurement. In order to measure the single pixel time resolution of the chip a Hamamatsu MPPC (S10362-11-100) has been connected to this test channel and was illuminated by a fast laser system (PILAS PiL063SM) with a wavelength of 408nm. For the final trigger jitter after selecting the single pixel events and applying a time-walk correction using the time-over-threshold information a value of 180ps sigma was measured. This result is consistent with measurements using direct MPPC readout and is already close to the intrinsic time resolution of the sensor.
Preliminary coincidence measurements using the full system chain have been performed and verify the functionality of the chip. The results obtained from the characterization are used to improve the final 64 channel chip version which is currently being developed and will be submitted this year.

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