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Method of Signal Detection from Silicon Photomultipliers Using Fully Differential Charge to Time Converter and Fast Shaper

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The paper presents an implementation of fully differential readout method for Silicon Photomultipliers (SiPM). Front-end electronics consists of fast and slow path. The former creates the trigger signal while the latter produces a pulse width proportional to the input charge. One of the advantages of the circuit is its speed. The fast shaper generates unipolar pulse and utilizes the pole-zero cancelation circuit. The peaking time for single photoelectron is equal to 4.3ns and the FWHM is 6.4ns. The pulse width of the charge to time converter (QTC) depends on the number of photons entering the SiPM at the moment of measurement. The QTC response is nonlinear but it allows to work with signals in wide dynamic range. The pulse width for one photoelectron is equal to 10ns and can be modified. The proposed readout method is effective in measurements of random signals where frequent events tend to pile-up. The QTC provides the information on the total number of photons reaching SiPM during the integration time while the fast shaper generates a pulse each time a group of photons hit the detector. Thermal generation and afterpulses have a strong influence on the width of pulses from QTC. The proposed method enables to distinguish those overlapping signals and get the reliable information on the number of detected photons.

Summary

The front-end circuit consists of preamplifier with fast shaper and QTC. Fast shaper is based on pole-zero cancellation circuit and it is realized as a single stage pass-band active filter built on fully differential amplifier. It produces the most optimal signal in terms of pulse width (without overshoots and undershoots). Presented detection method utilizes the fast shaper output as a trigger source. The information on the amplitude and number of detected photoelectrons are not taken into account. The QTC contains fully differential integrating amplifier and comparator. Discharge resistor placed in the amplifier's feedback was tuned so as to obtain short pulses.

Another advantage of the proposed detection method is lack of a fast analog to digital converter (ADC) in the signal path. Time to digital converter (TDC) designed in FPGA can be used instead.

The fast shaper can be used in coincidence detection method. It allows to determine the origin of overlapping pulses that can appear due to incident light, thermal generation or afterpulses. The fully differential circuits, in comparison with single-ended circuits, have better parameters: swing, rejection of common-mode signals, signal to noise ratio, dynamic range, suppression of some harmonics.

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