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A novel feedback circuit for analogue time walk compensation

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Ever more precise time information is required to separate independent events at planned and proposed particle physics experiments. Typically, a combination of internal gain, very fast amplifiers and complex sampling circuitry are used to achieve this high time resolution. In this contribution a novel circuit to improve the time resolution of a depleted monolithic active pixel sensor (DMAPS) is presented. Its amplifier feedback is designed such that within its dynamic range the time walk of the trailing edge of the amplifier is compensated, making it the better estimate of the time of arrival (ToA).

Summary (500 words)

A novel approach to improve the time resolution of an analogue frontend of a depleted monolithic active pixel sensor (DMAPS) is presented. These sensors are implemented as a sensor diode housing isolated readout electronics. The typical structure consists of a charge sensitive amplifier (CSA) and a comparator which digitises the amplifier output. Commonly, a time stamp for the threshold crossing of the leading edge is stored as time-of-arrival (ToA). A second time stamp for the trailing edge can be sampled to calculate the time-over-threshold (ToT) to correct for the time walk effect on the leading edge. Due to the limited space for transistors within the pixel cell and limited power budgets, further improving the time resolution of these type of sensor is challenging. The speed of the amplifier is limited by the process as well as the available power density. Complex circuits for high resolution sampling need to be implemented outside the active matrix, reducing the fill-factor of the monolithic sensor while also adding additional power consumption.
In the presented work, a novel circuit has been developed and added to a preexisting design to achieve an analogue time walk compensation. The switching of the comparator on the leading edge is used to trigger and additional feedback current source of the amplifier which compensates the input dependence of the trailing edge. Thus, the trailing edge becomes the better estimate for the ToA within the dynamic range of the amplifier. For signals saturating the amplifier, the trailing edge is no longer compensated and instead the leading edge can be used. In saturation the leading edge has little time walk. A simple cut on the ToT to decide which edge is used allows for an absolute reduction of the time walk over a large signal range. Simulations and measurements show that over a range from 2k to over 10k electrons, the absolute maximum time walk of the frontend is limited to below 5 ns. Using only the leading edge, small charges can have a time walk of 15 ns or more. Similar DMAPS sensors have achieved time resolutions given by a Gaussian standard deviation of about 3 ns. The circuit also allows to relax the requirements on the amplifier power consumption, requiring only 20 uW for a 60 um x 60 um pixel compared to the 25 uW of the original design. The required area for the feedback circuit is 66 um^2.
Simulation results and measurements of the performance of this circuit will be presented.
The novel approach taken in this circuit should be presented at the TWEPP workshop to communicate the idea and find other possible applications as well finding new collaborators to develop the concept further.

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