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A front-end ASIC for ionising radiation monitoring with femto-amp capabilities

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An ultralow leakage current Application Specific Integrated Circuit (ASIC) called Utopia (Ultralow Picoammeter) has been designed and fabricated in AMS 0.35 μm CMOS, in order to be used as the front-end for ionising radiation monitoring at CERN. It is based on the topology of a Current to Frequency Converter (CFC) and demonstrates a wide dynamic range of almost 7 decades without range changing. Because of its design aiming in ultralow input leakage current and the ESD protection leakage current compensation, input currents as low as 50 fA can be measured.

Summary

Several readout systems for radiation detectors like ionisation chambers have been proposed in the bibliography and they all demonstrate a wide dynamic range of more than 5 decades. However, they are all limited in the lower input current range because of the leakage currents. This research focuses on the low range in order to provide an ultralow leakage current ASIC that can measure currents starting from less than 50 fA. The system is required to measure rates from 50 nSv/h up to 0.1 Sv/h. Using the typical conversion factor for γ rays that is $1.6\text{E-}6$ A/Sv/h for a specific detector that is used from the Radiation Protection group at CERN, the output current range spans from 80 fA to 160 nA. Measuring an input current of 80 fA is not feasible with the existing systems, due to the leakage currents. However, the proposed Utopia (Ultralow Picoammeter) ASIC shifts the dynamic range to the fA currents after leakage current compensation and is able to measure up to 500 nA.

The Utopia architecture is based on the topology of a synchronous Current to Frequency Converter (CFC). The integrator integrates the input current, including the leakage currents and provides an output voltage that is compared to a threshold by a discriminator. When the threshold is crossed, a fixed amount of charge is injected to the input through a stray insensitive switched capacitor circuit. The digitisation is made by counting the number of discharges in a reference time window from which the mean current can be calculated.

The design parameters and the design procedure will be presented along with the results of the first tests that were achieved with Utopia ASIC. The different leakage current sources were identified. The subthreshold leakage from the switches that are connected to the input, the ESD protection leakage current and the PCB leakage current were measured and their respective current values are presented. The parameters that affect the dominant leakage current that is coming from the ESD protection are addressed. Finally, the leakage current is subtracted and input currents as low as 50 fA have been measured. The limitations that arose after the first tests and the proposal for the second run that is currently under development and will include auto-calibration for leakage current and wider dynamic range in order to cover also the pulsed radiation fields, will be discussed.

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