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Characterization of a 9-Decade Femtoampere ASIC Front-End for Radiation Monitoring

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An ultra-low current sensing digitizer circuit for radiation monitoring for personnel and environmental safety was designed.
The ASIC includes some key functionalities like on-chip active leakage current compensation and multi-range charge balancing. The calibration procedure and the measurements of the Ultralow Picoammeter 2 (Utopia 2) ASIC are presented. This chip can measure input current over a wide dynamic range of 9 decades starting from a few femtoamperes. The ASIC has been characterized for its ultra-low current performance in the Swiss Federal Institute of Metrology. Radiation measurements when the front-end was connected to the ionization chambers used at CERN are presented.

Summary

The existing detectors used at CERN for background environmental radiation monitoring and radiation protection, provide an output current that varies from a few femtoampere up to the microampere range. A demonstrator ASIC named Utopia 1 [1], gave us the possibility to investigate the effect of the different leakage current sources present at the input of the front-end. This front-end is based on the current to frequency converter architecture and is designed for ultra-low leakage current behavior. The dominant leakage current in the input of the ASIC proved to be the leakage related to the ESD protection diodes.

The Utopia 2 ASIC is based on a two-channel compensating principle and charge balancing. The compensating channel whose input structures are matched to the measuring channel can subtract the leakage current that it is measuring from the first channel's input. Thus, by active on-chip leakage current compensation, channel 1 can measure the input current that is related only to the radiation detector's output.

This approach offers many advantages for ultra-low current measurements, since the leakage current of the ESD diodes is susceptible to temperature variations. Provided an initial calibration has been performed, the Utopia 2 ASIC is able to measure current over a wide dynamic range of 9 decades. Due to the current to frequency architecture, sufficient time has to be allocated for the sub-picoampere current measurements. This is compatible with the application since lower radiation can be accompanied by slower measuring time.

This article presents the characterization of the Utopia 2 ASIC. The testbench and the calibration procedure of the most important parameters of the ASIC are discussed. The measurement results, when various currents were injected using standard laboratory current sources are presented. The characterization in the ultralow currents range was performed in the Swiss Federal Institute of Metrology (METAS), where an accurate calibrated current source was used to inject current as low as 1 fA [2].

The Utopia 2 ASIC is able to digitize currents from 1 fA up to 5 μA and fulfills the specifications that are required for the new radiation monitoring system for personnel safety at CERN. Finally, the background radiation measurements when the front-end was connected to the detector and measurements with sources are shown.

References:
[1] Voulgari, E., Noy, M., Anghinolfi, F., Perrin, D., Krummenacher, F., & Kayal, M. (2016). A front-end ASIC for ionising radiation monitoring with femto-amp capabilities. Journal of Instrumentation, 11(02), C02071.

[2] Mortara, A., Jeckelmann, B., Hurni, A., & Probst, P. A. (2007). Accurate sub-picoampere source used to calibrate electrometers. 13e Congrès International de Métrologie.

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