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Review of the doctoral dissertation by Aleksandra Krzyżanowska, M.Sc. entitled "Digitally-Assisted Analog Circuits for Hybrid Pixel X-Ray Detectors" prepared under the supervision of Grzegorz Deptuch, Ph.D., D.Sc.

The dissertation presented by the Ph.D. candidate has been directed for review by the decision of the Board of the Faculty of Electrical Engineering, Automatics, Computer Science and Biomedical Engineering of the AGH University of Science and Technology at the meeting on 1 March 2018 in order to commence the procedure that leads to obtaining a doctoral degree in the field of Electronics.

The dissertation concerns a number of issues related to integrated circuits that constitute reading circuits in hybrid pixel detectors used for recording photons of X-radiation. The dissertation with bibliography has 151 pages and has been divided into seven basic parts (the eighth part is the bibliography). It has been written in English.

Four main theses of the dissertation have been defined in its introduction:

- the first one concerns the purpose of the dissertation and it states that the negative effects related to sharing charge by adjacent pixels can be compensated by appropriate circuit solutions using communication between pixels and by appropriate data processing algorithms;
- the second one focuses on the necessity to use a methodology that is significantly different than the one for circuits operating in the standard mode of counting individual photons and it points to the significant role of the effects related to dispersion of parameters of individual channels;
- the third thesis concerns the necessity to build appropriate simulation models of the reading circuit, taking into account the necessary elements using a behavioral representation of functional blocks;
- the fourth thesis points to the necessity to use the architecture indicated by the author in order to avoid technological limitations related to dispersion of parameters; these solutions are also to ensure correct reading of both the place and the energy of an incident photon.

The dissertation has many threads and includes theoretical solutions and simulations as well as measurements. It should be noted that the studied reading circuits are difficult to analyze because they include a digital part and an analog part, and that the signal source in hybrid technology is a separate sensor having its own specific properties dependent on the material and construction of a single pixel.

The essential (authorial) part of the dissertation is preceded by an extensive description introducing the necessary concepts. It is written very well and it prepares the reader to more difficult fragments of the dissertation. Then the author presents algorithms and circuit implementations, focusing mainly on the undesirable effects related to sharing the charge generated by interaction of a detector with a single photon and adjacent pixels. The algorithm C8P1, proposed by a group of scientists from the AGH, is extensively presented. Statistical and dynamic models taking into account circuit noises and their technological dispersion - i.e. parameters of fundamental significance for operation of the analog part of reading - have been proposed in the dissertation. In the experimental part the Ph.D. candidate is using the integrated circuit Chase Jr. with the mentioned algorithm implemented. It is assembled with a silicon pixel detector using the flip-flop method, thus creating a relatively small (18x18) test matrix.

Experimental works are complex, from constructing a testbed, through choosing the elements and methods, to creating the measurement software. Various experiments have been performed, also using X-radiation, and various correction procedures aimed at minimization of circuit dispersions have been compared. The experimental works are characterized by high scrupulousness, which can be seen especially in the context of signal reconstruction in cases of dividing charge between pixels. The simulation works, extending far beyond the simulations used by constructors of integrated circuits, also make a good impression.

It should be pointed out that the results of simulations and measurements point to correct operation of the implemented algorithm. The total energy of the photon is reproduced, and recording of signals in a corner between four pixels indicates that the compensation of charge division using the analog-digital architecture with inter-pixel communication is operating correctly. The author has also tackled a number of detailed problems in the scope of the influence of circuit noises and dispersions of parameters of the analog part.

If anything would worry the reviewer, it would be focusing the dissertation almost exclusively on the effects related to the reading circuit and the algorithm implemented in it. This is because the main axis of the dissertation are the considerations related to charge division between pixels potentially leading to false results. The effects related to the influence of non-homogeneity of responses of individual diodes of the sensor matrix, related to their individual differences caused e.g. by technological dispersions or possibly by local defects, however, have not been analyzed. The reviewer's experience in the scope of completely depleted matrixes used for imaging the trajectories of elementary particles indicates that dispersions between individual pixels can be incidentally significant. While large non-operational elements do not occur in mature sub-micron technologies, matrixes (especially made of materials other than silicon) are not so homogenous. It would be interesting to simulate a damaged matrix pixel and to observe how it influences the results of measurements obtained using adjacent pixels. This subject has been barely signaled in the dissertation in chapter 6.1.2, although the reviewer admits that considerations of this kind would extend beyond the scope of the dissertation defined by the theses and the title.

This remark does not reduce the very high evaluation of the dissertation, which certainly distinguishes itself among other experimental works, also those performed at CERN. This is a very scrupulous approach to the experiment, appropriately documented and described. All theses indicated in the introduction to the dissertation have been proved, the author exhibited her knowledge of technology, references have been chosen appropriately, and conclusions are convincing. The dissertation is also characterized by scrupulous editing. The reviewer has been reading the dissertation with pleasure and is hoping for its essential parts to be published in an international journal.

The reviewer has no doubts that the dissertation submitted for evaluation satisfies the requirements of relevant regulations for doctoral dissertations and it deserves a distinction. The dissertation not only documents the fulfilment of its stated goals but also proves an essential contribution of its author in the development of her scientific field - electronics.

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