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A Plugin-Based Architecture for Onboard Data Processing in Katherine Readout Systems for Timepix Detectors

The Katherine readout system for Timepix3 (and to a smaller extent, Timepix2) is widely used within the scientific Medipix community. Timepix3, in particular, is a popular readout chip offering a resolution of 256×256 pixels with a 55 µm pitch, capable of measuring both energy and timestamps (with 1.56 ns time binning) simultaneously. It has already demonstrated excellent performance and brought significant benefits to numerous projects [2, 3, 4]. For example, it has been employed as a radiation monitor in the ATLAS Experiment at CERN [5, 6], and its efficient operation in various low-power modes has also been shown [7].

Recently, the Katherine readout for the new Timepix4 chip has been finished and introduced to Medipix scientific community. Timepix4 [8] represents another leap forward in the capabilities of Timepix-class detectors. It features a resolution of 512×448 pixels, superior time binning (195 ps), and supports extremely high hit rates —up to 2.5 Ghits/s per chip.

All Katherine devices implement on-the-fly raw data decoding, which minimizes the need for data processing in the control software. However, since their architecture is based on SoC FPGA devices, there remains an opportunity to utilize this computational power in even more effective ways.

For this reason, we present a software plugin architecture designed for Katherine readout devices, enabling onboard data processing directly on the device's CPU. The goal of this work is to provide users with a C++ framework that supports the development of custom plugins or the use of pre-defined ones. The presented approach makes it possible to implement data-processing routines—previously handled by the acquisition software—directly in the hardware of the readout system. This capability can be used, for example, for data clustering, noisy pixel detection, or real-time processing for imaging applications.

The system has been successfully implemented on the Katherine readout platform for Timepix3 Gen2, based on the Cyclone V SoC, as well as on the new generation Katherine readout system for Timepix4, which utilizes the Arria 10 SoC. To demonstrate the capabilities and performance of the architecture, we present example plugins running on both Timepix3 and Timepix4 detectors. Additionally, we provide simple examples and documentation to guide users in developing and integrating their own custom plugins.

References:

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Workshop topics

Front-end electronics and readout

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