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FLAME SoC readout ASIC for electromagnetic calorimeter

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The design and measurement results of a SoC readout ASIC, called FLAME, developed for the electromagnetic calorimeter at the future linear collider are presented. The FLAME consists of 32 channels with variable gain front-end, fully differential shaper, and a 10-bit SAR ADC, working at 20 MSps, in each channel. All ADC samples are streamed out by two 5.2 Gbps serializers. Two testbeam campaigns with FLAME-based readout have been conducted successfully. The testbeam results as well as detailed characterization of the FLAME performed with a dedicated test setup are presented and discussed.

Summary (500 words)

For a future linear collider, a dedicated sandwich-type calorimeter, LumiCal, for luminosity measurements is under development. Currently, the LumiCal design is being adopted for the electromagnetic calorimeter ECAL in the LUXE experiment, an electron - laser collider planned for construction at DESY, Hamburg. The LumiCal will consist of 30 to 40 layers of segmented silicon sensors for the linear collider or 20 layers of silicon or GaAs sensors for ECAL in the LUXE experiment, with tens of thousands of channels per detector, and dedicated readout electronics, in each case. FLAME is a 32-channel SoC readout ASIC developed in CMOS 130 nm technology for LumiCal. Each readout channel is composed of an analogue front-end with two gain modes, a differential CR-RC shaper, and a 10-bit SAR ADC. The ASIC is equipped with high speed data serializers, biasing and trimming DACs, calibration injection circuitry, and an SPI-based slow control circuitry. As a result, the number of external components is reduced to the absolute minimum. The die size is 4170 um x 3700 um.

Under experimental conditions, the charge deposition per channel varies from few fC (for MIP) to few pC at the electromagnetic shower maximum. To cover this wide deposition range, two gain modes was foreseen in the front-end, one optimized for a 5 GeV electrons used at the DESY testbeam facility, and the second designated for the larger depositions. For the pedestal stabilization and to accommodate for the sensor leakage current, the Krummenacher feedback is used. Its circuitry was modified to allow for coarse pedestal setting, whereas the fine-tuning feature is provided in each channel by the trimming DACs. The front-end is followed by a pole-zero cancellation circuit, and a CR-RC shaper with 50 ns peaking time and a fully differential architecture, matching the SAR ADC input without need of an additional single-ended signal conversion. The ADC samples the shaper output with the nominal 20 MSps rate, with the possibility of increasing the rate up to 50 MSps. The channel layout occupies 2780 um x 80 um (1350 um x 80 um is used for decoupling of the reference voltage).

The ADC output is encapsulated with the front-end gain information and 8-bit timestamp counter value. This data package is encoded in the 8b/10b scheme, serialized based on multi-phase PLL, and sent out by two 5.2 Gbps serial links using SST drivers. Data links are designed to work directly with the Xilinx FPGA gigabit receivers.

The FLAME has been characterized with a dedicated test setup, and the results will be presented in this contribution.

The complete readout system for a multi-layer calorimeter prototype, including also FPGA-based DAQ system, has been developed and successfully used in two testbeam campaigns conducted at DESY with the 5 GeV electron beam, with the main purpose of verifying the performance of a calorimeter and commissioning the

GaAs sensors foreseen for the LUXE experiment. The testbeams results will be presented and discussed, mainly in terms of the FLAME performance.

Primary authors: MORON, Jakub (AGH University of Science and Technology (PL)); SWIENTEK, Krzysztof Piotr (AGH University of Science and Technology (PL)); IDZIK, Marek (AGH University of Science and Technology (PL)); FIRLEJ, Miroslaw (AGH University of Science and Technology (PL)); BUGIEL, Roma (Centre National de la Recherche Scientifique (FR)); BUGIEL, Szymon (Centre National de la Recherche Scientifique (FR)); FIUTOWSKI, Tomasz Andrzej (AGH University of Science and Technology (PL))

Presenter: MORON, Jakub (AGH University of Science and Technology (PL))

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