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A Micropower Readout ASIC for Pixelated Liquid Ar TPCs

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The Liquid Argon Pixel (LArPix) prototype ASIC implements 32 channels of analog front end circuitry and backend digitizers at a power consumption of less than 50 uW/channel. LArPix is envisioned as a component of a potential DUNE near detector TPC module. Demanding noise, power, and dynamic range requirements are imposed by myriad particle interaction scenarios. Widely varying track signatures with charge depositions of 1-20 MIP (15k e-/MIP) per pixel at burst rates of up to 500 kHz must be accommodated. A unique design solution for these competing requirements will be presented, including initial functionality of the June 2017 tapeout.

Summary

The motivation for LArPix is to enable large liquid Argon TPC operation in high-rate environments. In addition to increased hit rate capability, another primary enabling factor is the reduced trajectory ambiguity achievable with a pixel-based detector. The feasibility of the pixel sensor array approach has been demonstrated by the LHEP group at U. Bern. The LArPix ASIC seeks to evolve that initial proof of concept towards a working detector system by using a full-custom, micropower ASIC solution.

The 32-channel prototype IC will be submitted for fabrication in a mixed-signal 0.18 um CMOS process in June 2017. The IC will be integrated onto a detector pixel array operating at 88K in liquid Argon. These detector planes will be part of a demonstrator TPC envisioned for neutrino experiments, e.g. as a component of the DUNE near detector.

The LArPix IC analog channel is comprised of a charge readout Analog Front End (AFE) and Successive Approximation ADC (SAR). The digital backend logic provides timing, control, hit buffering, and serial communication with daisy-chain readout. The devices themselves will be assembled onto the detector PCB plane, physically over top of the communication and power buses. The arrangement is such that the devices form a track over the service buses, with 16 detector elements connecting to each side of a LArPix IC.

The AFE nominal power consumption is ˜18-24 uW per channel, with the balance of power in the SAR and backend at less than 25 uW per channel. A total power of <50 uW per channel is compatible with operation in LAr. The AFE implements a pure charge integrator, comparator, threshold trim DAC, analog buffer, and low-power Schmitt trigger to condition the comparator output. The time resolution of the analog channel is 2 us, while limiting the ENC to <500 e- RMS at room temperature. The ENC of the AFE decreases to <300 e- RMS at 88K. These values are at or less than 1/3rd the 1500 e- RMS noise requirement, which is 1/10th MIP. The CSA operates with a switched reset, which is derived as the OR'ed combination of a periodic reset and a hit detection reset. The reset signal is generated by the ADC sampling and control engine, with the programmable periodic reset allowing for the clearing of leakage current and spurious background charge.

Other features of the AFE include a trim DAC per channel, test pulse input, and high gain mode. The 5-bit trim DAC provides a fine tuning of the 8-bit, 6 mV resolution global DAC to accommodate severe channel mismatch at LAr temperature. The SAR will digitize the nominal AFE dynamic range of 20 MIP to a resolution of 8 bits. A high gain mode of 3 MIP dynamic range is available as a configuration setting in the AFE.

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