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A Readout Network for High-Density Electrode Array Targeting Neutrinoless Double-Beta Decay Search in TPC

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Among the current and planned experiments of neutrinoless double-beta decay ($0\nu\beta\beta$), the high-pressure gaseous Time Projection Chamber (TPC) stands out for its excellent energy resolution, very low radioactive background level and good scalability. Moreover, high position resolution can be maintained with an appropriate charge readout scheme for gaseous TPC to further suppress the background through ionization imaging. A pixelated charge readout plane without gas-electron avalanche is desirable. Based on a 0.35um CMOS process, a low noise sensor, Topmetal-S, is being developed which, even without gas gain, the energy resolution requirement could be met. Since $0\nu\beta\beta$ tracks are extended to tens of cm in length in high-pressure gas, Topmetal-S is designed to have mm-sized charge collection electrode, followed by a charge sensitive amplifier and an ADC in the first prototype. To realize a ton-scale high-pressure gaseous TPC, approximately 1×10^5 Topmetal-S sensors need to be laid on a meter-sized plane. The greatest challenge is a reliable high-density channels readout.
This paper proposed a distributed, self-organizing and fault-tolerance readout network. As a node of the network, each Topmetal-S integrates a router. The scheme establishes local connection between nearby sensors to form a sensor network. Each sensor not only generates and transmits their own data, but also forwards data from nearby sensors, and data packet is finally received by a computer that is connected at the edge of the network. In order to simplify the complexity of router, 2D-Mesh is chosen as the topology of the network. A distributed routing algorithm, extended-XY, is implemented. The routing algorithm is also fault-tolerant. Failed sensors will not disable a large section of the network. Faulty node detection is implemented by sending test packets by the computer. After fault detection, through configuration the computer will form a set of rectangular region called faulty blocks to contain detected faults. The extended X-Y routing follows the regular X-Y routing until the packet reaches a boundary node of a faulty block. At that point, the packet is routed around the block clockwise to pass through. The design of the router is complete. The whole network performance is being simulated. The details of the routing algorithm, the fault detection scheme, the micro-architecture of the router, the throughput, and latency of the network will be presented.

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