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High-Speed Electronics for PET Systems

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Abstract. Positron Emission Tomography (PET) cameras provide a real-time data acquisition challenge. A PET camera typically has several hundred detector modules, each servicing about 150 scintillator crystals. Each detector module must identify 511 keV gamma ray interactions (Singles Events) at sustained rates of up to 1 MHz, and for each interacting gamma ray, measure the interaction position, deposited energy, and time (with ˜4 mm, ˜100 keV, and ˜1 ns accuracy respectively). For a subset of these cameras (time-of-flight PET cameras), the required timing accuracy is ˜100 ps. A commonly used approach for processing Singles Events in real time is to send a high-bandwidth version of the analog signal from each detector module to a constant fraction discriminator. A time to digital converter (TDC) then records an arrival time that is referenced to a common, master clock. The amplitudes of these analog signals are also digitized to obtain an estimate of the amount of signal observed in each channel. The deposited energy is obtained by summing the analog signals, and the interaction position is obtained using various sums, differences, and ratios of analog signals. The control of the analog digitization and TDC, computations used to measure the energy and position, and additional tasks (such as calibration corrections, Compton scatter rejection, event word formatting, and diagnostics) are performed by a field-programmable gate array (FPGA), often assisted by look-up tables stored in RAM. While there are hundreds of parallel circuits for processing Singles Events, their outputs are usually multiplexed. This enables Coincident Events to be identified by tens of coincidence detection circuits, which are realized in additional FPGAs. These Coincidence Events, which are positron annihilations (identified by finding pairs of Singles Events in different detector modules that occur within ˜10 ns of each other) are identified, formatted, and stored at sustained rates up to 10 MHz.

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