A Correlation-based Pulse Detection Technique for Gamma/Neutron Detectors

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Accurate pulse detection and pulse-height discrimination (PSD) is required in many applications such as nuclear nonproliferation, homeland security, and international safeguards. Recently, significant research efforts have been focused on utilizing digital techniques for fast pulse detection and PSD in gamma/neutron detectors. Most of these techniques use a fast digitizer unit to digitize the pulse data coming from a photo-multiplier tube (PMT), and the data acquisition is initialized when incoming waveform crosses a set threshold voltage/energy. The captured waveforms are then post-processed (online or offline) extract pulse characteristics such as the pulse height and the time-of-arrival. This technique has some limitations. First, the finite amount of available storage limits the throughput of the offline systems, and the online systems require constant adjustments prior to taking measurements which makes it unsuitable for portable detector applications. Second, the fixed threshold limits the lowest energy pulses that can be correctly detected. Ideally, the threshold amplitude should be set close to the amplitude of noise generated by the electronics; however, 'false' detections are then likely to occur.

In this work, we present a new correlation-based detection technique that significantly improves the probability of detection for low signal-to-noise ratio (SNR) pulses. We propose performing a normalized cross-correlation (NCC) of the incoming pulse data to a predefined pulse template, and using a threshold correlation value to trigger the detection of a pulse. The template pulse can be an average of high energy pulses measured from a particular detector which then can be used as a template for detecting low energy pulses. Simulations of correlation-based detection show approximately 2x improvement in the probability of detection for a given SNR pulse. Furthermore, the NCC can be computed on a field programmable gate array (FPGA) using correlator hardware accelerators, so that the pulses may be detected in real-time as opposed to after post-processing of the acquired data. The correlator implemented on an FPGA will also allow recognition of the pulse peaks and time-of-arrival in real-time. Therefore, only the relevant information such as pulse peak and time-of-arrival are required to be stored—resulting in substantial reduction in the required storage space.

In the full paper, results from an FPGA implementation will be shown and discussed to illustrate the improved ability to accurately detect low energy pulses using the proposed technique.