A Correlation Based Pulse Detection Technique for Gamma/Neutron Detectors

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I. INTRODUCTION

Recently, significant research efforts have been focused on utilizing digital techniques for fast pulse detection and pulse shape discrimination (PSD) for gamma/neutron detectors. Figure 1(a) illustrates a typical experimental setup and pulse detection technique that uses a fast digitizer unit to digitize the pulse data coming from a photo-multiplier tube (PMT), and the pulse data acquisition is initialized when the incoming waveform crosses a predefined threshold voltage which is equivalent to the minimum detectable pulse energy. In nuclear proliferation applications, accurate detection of the low energy pulses is useful for robust material identification. However, in typical detection techniques, the threshold voltage must be set higher than the amplitude of the noise generated by the PMT, otherwise, false pulse detections are likely to occur.

In this work, we propose performing a normalized cross correlation (NCC) of incoming data with a predefined pulse template, and using the correlation result to trigger the detection of a pulse. An implementation of this technique is shown in Figure 1(b). The template pulse is an average of previously recorded high energy pulses, which then is used to detect low energy pulses through the NCC. The NCC can be computed and analyzed in real-time on a field programmable gate array (FPGA). Also, the peak amplitude and arrival time can be detected in real-time on an FPGA which means we are only required to store relevant information as opposed to complete waveforms.

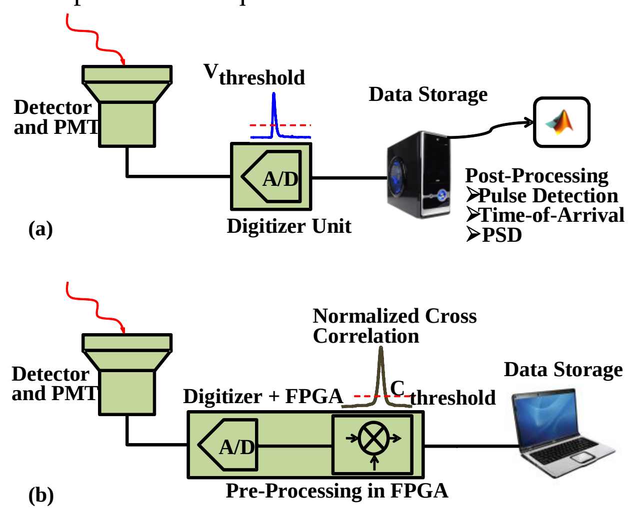

Figure 1: Block diagrams of (a) amplitude thresholding and (b) correlation based pulse detection technique

II. NORMALIZED CROSS CORRELATION (NCC)

Normalized correlation has been used extensively as a metric to evaluate the degree of similarity between two signals in a wide variety of applications such as radar target identification, fingerprint matching, image processing, and wireless communication [1-2]. In this work, we will be using template matching ability of NCC to improve flexibility and robustness of data acquisition in particle detectors. The NCC of signal *f(x)* with template *t* can be computed as follows [1].

$$C(u) = \frac{\sum_x[f(x)-\overline{f_u}][t(x-u)-\bar{t}]}{\sqrt{\left\{\sum_x[f(x)-\overline{f_u}]^2 \sum_x[t(x-u)-\bar{t}]^2\right\}}} \quad (1)$$

Where $\overline{f}(x)$ and $\bar{t}$ refer to averages of the signal and the template, respectively. The value of NCC ranges from -1 to 1, and provides flexibility to measure a wide range of energies without requiring adjustments to the digitizer settings when measuring different energy levels.

III. SIMULATION RESULTS

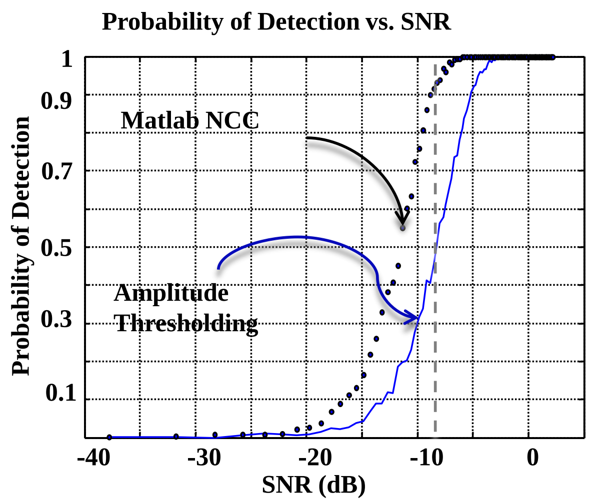

Figure 2: SNR vs. Probability of detection plot

Simulations were conducted to verify the feasibility of the proposed technique. Measured data was used to model the incoming pulses and the template pulse was computed by averaging these pulses. Moreover, random White Gaussian Noise (WGN) was added to the pulses to emulate realistic detector behaviour. The figure of merit used to compare amplitude thresholding technique with the correlation-based technique is the probability of correct detection for a given signal-to-noise ratio (SNR) pulse. For a given SNR, the NCC technique approximately doubles the probability of correct detection as illustrated in Figure 2. Therefore, the minimum detectable energy when using NCC is 2x lower than that of amplitude thresholding techniques. For example, as shown in Figure 2, for a pulse with SNR of -8 dB, the amplitude thresholding technique correctly detects the presence of a pulse 50% of the time, while the correlation based technique improves this probability to 92%.

IV. HARDWARE IMPLEMENTATION

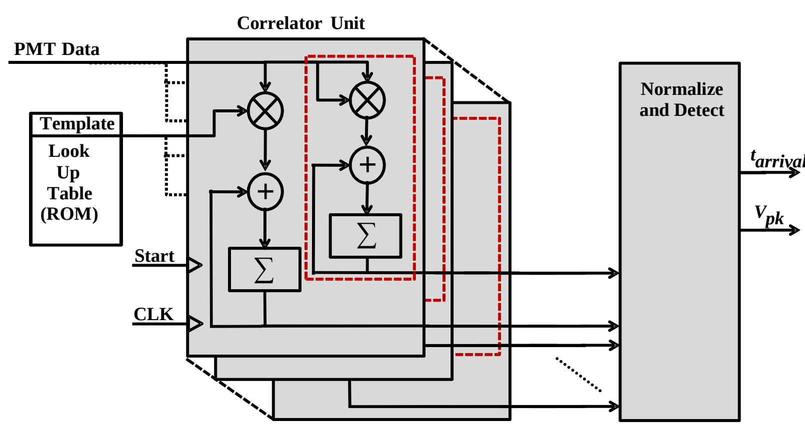

Figure 3: Hardware implementation of the correlator

The normalized cross correlation algorithm can be realized on a field programmable gate array (FPGA) device that is usually integrated within the digitizer units of scintillation detector systems. We will pursue the hardware implementation illustrated in Figure 3. This implementation consists of N parallel correlator units where N is the length of the template pulse pre stored on the FPGA. Each correlator unit consists of multiply and accumulate functions required for calculating individual correlation coefficients. The individual correlation coefficients are then passed to the normalize-and-detect block which normalizes correlation coefficients so that NCC value is between -1 and 1. This block is also responsible for detecting the arrival of a pulse, recording the time-of-arrival, and the peak amplitude.

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

REFERENCES

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