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Title: Analysis of Pulse-Shape Discrimination Techniques for BC501A Using GHz Digital Signal Processing

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Analysis of Pulse-Shape Discrimination Techniques for BC501A
Using GHz Digital Signal Processing

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Abstract

A comparison study of pulse-shape analysis techniques was conducted for a BC501A scintillator using digital signal processing (DSP). In this study, output signals from a preamplifier were input directly into a 1 GHz analog-to-digital converter. The digitized data obtained with this method was post-processed for both pulse-height and pulse-shape information. Several different analysis techniques were evaluated for neutron and gamma-ray pulse-shape discrimination. It was surprising that one of the simplest and fastest techniques resulted in some of the best pulse-shape discrimination results. This technique, referred to here as the Integral Ratio technique, was able to effectively process several thousand detector pulses per second. This paper presents the results and findings of this study for various pulse-shape analysis techniques with digitized detector signals.

Summary

Advances in digital signal processing (DSP) instrumentation have resulted in faster and higher resolution digitizers that are commercially available, easy to use, and support analog-to-digital conversion in excess of one GHz (one billion samples per second). This faster digital technology may now open up some new applications in detector pulse analysis. One such application is neutron spectrometry using BC501A (or NE-213) scintillators that requires the simultaneous evaluation of pulse-shape and pulse-height signals. In this study, a comparison of pulse-shape analysis techniques was conducted on the digitized data from a BC501A liquid organic scintillator.

The equipment setup used the anode output from the photomultiplier tube as input into a fast preamplifier. The preamplifier output was split and fed directly into both channels of a GAGE Applied Science Inc. 8 bit Analog to Digital (A/D) computer card, model 82G. One channel's gain was set to maximum and used for triggering the digitizer board. The other channel was used to record both pre-trigger and post-trigger signals digitized at a rate of one GHz (one billion samples per second). After a fixed number of digitized samples were recorded for each trigger, the data was saved to computer memory and the A/D digitizer board was reset for another detector pulse. This sequence was conducted until an adequate number of detector pulses were recorded.

The saved data was post-analyzed for both pulse-height and pulse-shape information. Pulse-height analysis was accomplished using a charge (or data) integration technique, converting the 8 bit digitized data to a 10 bit pulse height spectrum. However, the main focus of this research was to explore various pulse-shape analysis techniques for neutron and gamma-ray discrimination.

The pulse-shape analysis techniques evaluated in this research include: 1) fitting the DSP data to various equations; 2) using various integration techniques; 3) using differential analysis techniques; and 4) rise time determination with data filtering techniques. It was surprising that one of the simplest and fastest techniques resulted in some of the best results. This technique, which will be called the Integral Ratio technique, is similar to some charge integration techniques that has been successfully used with analog electronics. This Integral Ratio technique was able to process digitized data at several thousand detector pulses per second. This demonstrates that real time processing of digitized pulses may be possible up to moderate count rates. One example of the data processed by the Integral Ratio technique is shown in Figure 1. The data in Figure 1 was generated with a Cf-252 neutron source and covers the neutron energy range of about 400 keV to a few MeV. Another interest of this research is the ability to discriminate neutrons from gamma-ray interactions at energies below 1 MeV. This paper will present a comparative study of different pulse-shape analysis techniques for BC501A as applied to digitized data.

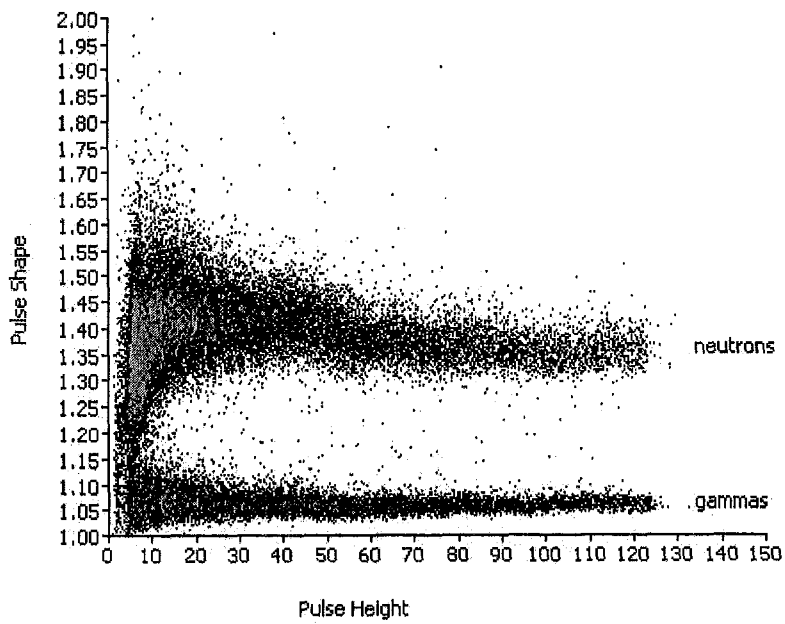

Figure 1. Analyzed pulses from a BC501A scintillator and Cf-252 source are plotted as Pulse-Shape versus Pulse-Height using the Integral Ratio Technique.