NE 204: Advanced Concepts in Radiation Detection and Measurement

Experiment 1: Digital Signal Processing for Gamma-Ray Spectroscopy in HPGe

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Purpose

In this experiment, an HPGe detector is used to study digital signal processing techniques for gamma-ray spectroscopy. A trapezoidal shaping filter will be implemented in software and optimal parameters for the filter will be determined experimentally. The performance of the digital shaping filter will be evaluated for non-rate-limited applications of gamma-ray spectroscopy. The first portion of the experiment is dedicated to setting up a specific digital acquisition system to enable the taking and saving of digitized signals originating from preamplifier electronics in coaxial HPGe detectors. Once the acquisition system is prepared, various procedures are proposed for determining the optimum filter parameters for maximizing energy resolution, without any consideration for rate or pile-up effects. The optimized digital filter is then used to determine the Fano factor and charge collection properties of the detector.

Approach

A range of standard gamma-ray calibration sources (i.e. "check sources") will be used to evaluate the spectroscopic performance of the digital filter. A digitization system from Struck Innovative Systems (SIS) will be used to collect and store digitized waveforms from coaxial HPGe detectors. The SIS3302 module provides 8 input channels (only one needed for this experiment) with 16-bit resolution and up to 100 MHz sampling rate. The SIS3150 module provides a USB 2.0 interface to the digitized data. Software for configuring and controlling the digitization system will be provided. Digitized waveforms will be stored in HDF5 format to facilitate the design and implementation of digital shaping filters in software (i.e. python or C++). You must implement a trapezoidal shaping filter with configurable parameters for peaking time and gap time. Rate and timing effects should not be considered in this lab: focus only on gamma-ray spectroscopy for low count rate scenarios. The tradeoffs between rate characteristics and spectroscopic performance of various filters will be examined in the next lab.

Required

- Study the effect of ballistic deficit as a function of the gap time of the trapezoidal filter. Consider the peak position, shape, and width as a function of gap time. Experimentally determine the optimum gap time for your detector.

- Evaluate the contributions of the various electronic noise components (series, parallel, $\frac{1}{f}$) by measuring the width of full-energy peaks as the peaking time of the filter is varied. Experimentally determine an optimum peaking time for your detector at low count rates (do not consider pile-up/rate effects).

- Using your experimentally determined optimum filter parameters, measure the energy resolution for gamma-ray energies ranging from 60 keV to 1332.5 keV.

Optional

- Use the peak width measurements to determine the Fano factor and estimate the effects of charge trapping in your detector.

- Compare your software implementation of the trapezoidal filter to that implemented in the firmware of the SIS3302 card. Quantitatively compare the spectroscopic performance of the two implementations.

- Set up an analog signal processing chain and collect spectral data from multiple gamma-ray check sources. Determine the Fano factor and estimate the effects of charge trapping using the spectra acquired by the analog system. Compare the results with those obtained for the digital system.

- Investigate other digital shaping filters such as Gaussian or cusp filters.

- Study the impact of digitizer sampling rate on energy resolution. Evaluate spectral performance as a function of configured sampling rate.