NE 204: Advanced Concepts in Radiation Detection and Measurement

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

## Purpose

In this experiment, an HPGe detector is calibrated and used to study digital signal processing techniques for gamma-ray spectroscopy. A 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, the students will determine appropriate calibration approaches for the HPGe detector system, and then 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 calibrate the HPGe detector and 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 SIS3316 module provides 8 input channels (only one needed for this experiment) with 14-bit resolution and up to 250 MHz sampling rate and an Ethernet interface to the digitized data. Old UCB nuclear engineering software for configuring and controlling the digitization system is available, be we will first need to customize this software to acquire data in the most useful form. You will implement a shaping filter with configurable parameters for peaking time and gap time. The trapezoidal filter is a logical starting point, but exploration of other filter shapes is encouraged. 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**

* Develop software to quickly calibrate your HPGe detector that:
  + Creates a relation between channel and energy; and
  + Creates a functional relation between peak energy and resolution.

You may pre-specify which peak energies you will use to calibrate. You will use this software multiple times in this lab as we manipulate filter parameters and likewise in subsequent labs.

* Study the effect of ballistic deficit as a function of the gap time of the 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, 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).

**Optional**

* Study the impact of digitizer sampling rate on energy resolution. Evaluate spectral performance as a function of configured sampling rate. (You may also down-sample your data in post processing – is there a difference?).
* Use the peak width measurements to determine the Fano factor and estimate the effects of charge trapping in your detector. Before attempting this, evaluate whether your detector is sufficiently performant to make this determination.
* 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.
* Compare your digital filter with alternative designs (trapezoid, cusp, Gaussian…).
* Make a friend in another group and compare detectors.