Development of a High-Speed Data Acquisition System For Nuclear Physics Measurements

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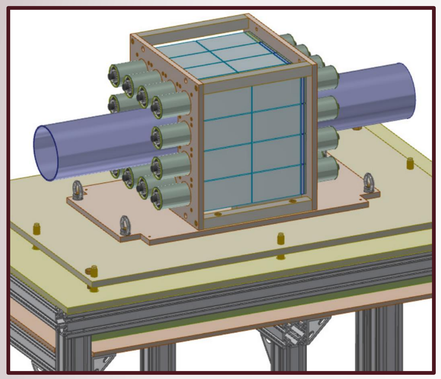
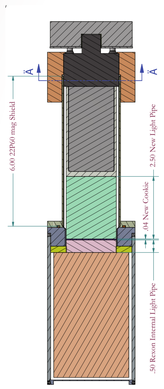
Modular NaI(Tl) Array

The NOPTREX collaboration is currently developing an array of modular NaI(Tl) scintillation detectors to be used in fundamental neutron-gamma measurements. This array will consist of 24 NaI(Tl) crystals arranged in a square ring, each coupled to a Hamamatsu R550 PMT and an electronics board custom made at IU Bloomington. These detectors will be capable of operating in both pulse and current mode. To process the signals from these detectors, we will use the CAEN DT5560SE digitizer and a custom firmware. This firmware will allow for high-speed processing of the signal without differentiating individual pulses.





CAEN DT5560SE and SciCompiler

The CAEN DT5560SE:

- Xilinx Zynq-7000 SoC Z-7030 FPGA
- 125Ms/s Internal Clock
- 32 Analog input channels

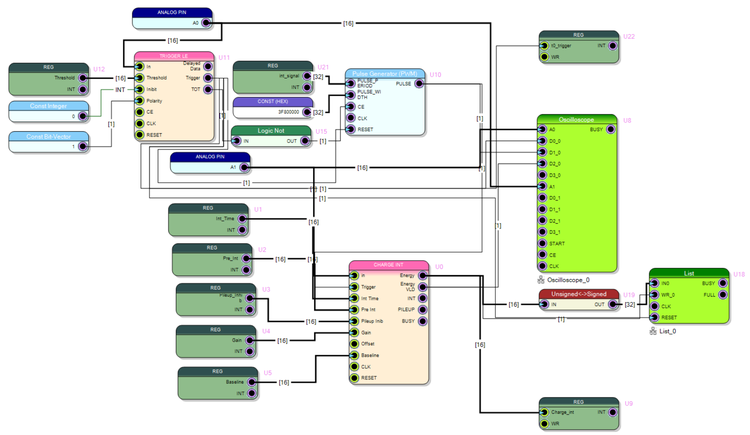
The DT5560SE digitizer is a desktop digitizer that allows for real time signal digitization and processing. It uses a Xilinx FPGA and custom firmware to be adaptable to any data acquisition application. For the NOPTREX NaI(Tl) array, we will use the charge integration firmware to efficiently process the detector signals.

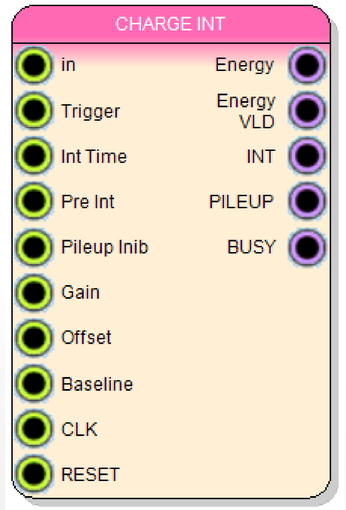
The DT5560SE includes a license for the CAEN SciCompiler software. This software simplifies the FPGA firmware design process by using a high-level block diagram coding environment and premade modules for nuclear physics applications. SciCompiler uses Vivado to compile the firmware and produce a bitstream for the FPGA.

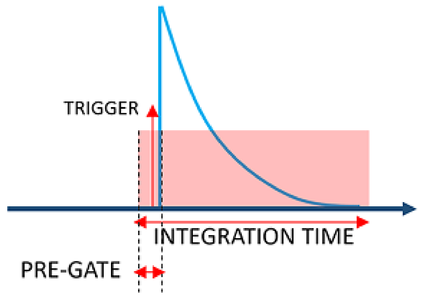
Charge Integration Firmware

In order to process the detector signals, we have developed a charge integration firmware using the SciCompiler software. This firmware centers on the charge integration module provided in SciCompiler that finds the area under the signal over a given time period following an input signal pulse. The module provides as an output a single word for the integration value.

For the purposes of the NOPTREX experiment, the firmware is required to trigger on a 20Hz external signal to mimic the proton accelerator signal, which starts the neutron pulse. Following this trigger, the firmware then executes the charge integration over multiple shorter windows, ranging from 1us to 100 us in length. When the next t0 signal is received, these integration windows are reset and the data for the 20Hz cycle is saved to the list module, which produces a list of the integration values for each window.



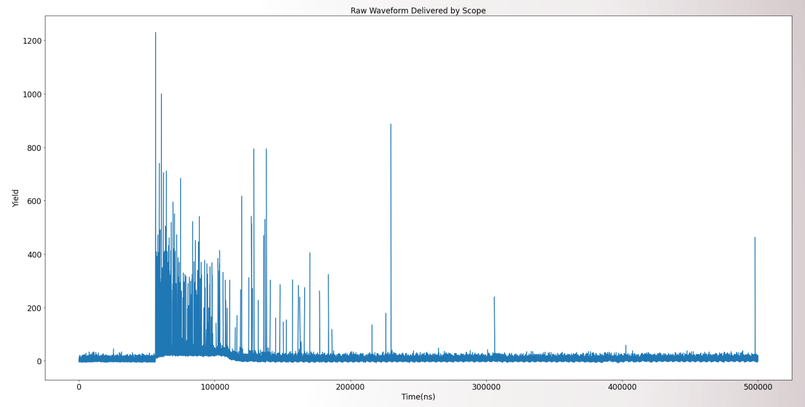


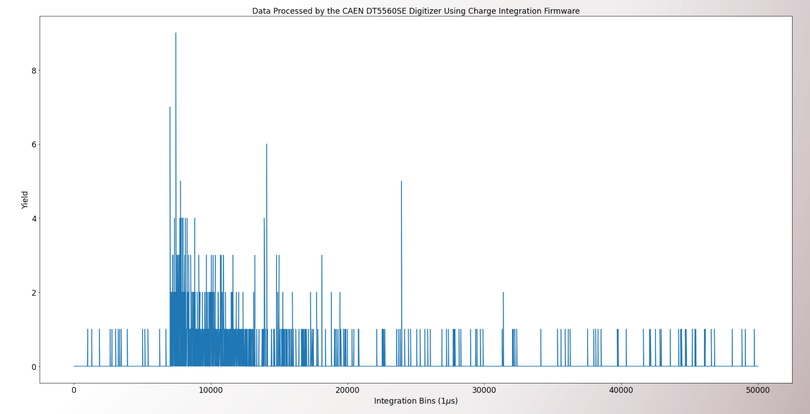


Images Courtesy of https://www.caen.it

Firmware Testing

To test the firmware, we used raw waveforms from a previous experiment conducted by the NOPTREX collaboration at Los Alamos National Lab. The waveforms were converted to a .csv file and loaded into a Rohde & Schwarz RTA4004 oscilloscope/waveform generator. Using the arbitrary waveform tool, we then delivered these waveforms to the DT5560SE digitizer and used the charge integration firmware to create a list of the integration values over the 20Hz cycle for an integration time of 1us per window. The following graphs demonstrate the raw waveform given to the digitizer and the resulting data from the firmware.





As a future task, we will be delivering a long chain of multiple neutron event waveforms to the digitizer to further evaluate the firmware. The resulting charge integration data will be used to construct a time-of-flight histogram of the neutron events, and this will be compared to the previously analyzed data.
In addition, we must develop a readout software to interface with the firmware that provides a view of the oscilloscope output and controls the list module. The SciCompiler software provides a software develop kit upon firmware compilation to assist in the software development process.