A Scalable FPGA-Based Digitizing Platform for Radiation Data Acquisition

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Regulating the proliferation of nuclear materials has become an important issue in our society. In order to detect the radiation given off by nuclear materials, systems implementing detectors connected to data processing modules have been developed. We have implemented a scalable, portable detection platform with a data processing module about the size of an external DVD hard drive. The data processing component of our system utilizes real-time data handling, the potential for growth, and behavior modifications through custom FPGA code editing. The scalability of the system is dynamic, so additional input channels can be implemented if necessary. In this work, we present a scalable, portable detection system capable of transmitting streaming data from its local X5-210m digitizer. The data arrives at the ends of the data capturing module, is processed in real time by the onboard FPGA and then is transferred to a computer via a PCIe card in discrete packets. The maximum transfer rate from the FPGA to the PC is 2 Gbps. The Detection for Non-Proliferation Group at the University of Michigan will use the detection platform to achieve pre-processing of radiation data in real time. Such pre-processing includes pulse shape discrimination, pulse-height distributions, and particle time of arrival.

Objectives and Advantages

Detection of special nuclear materials is the ultimate objective of this study. Here are some of the applications stemming from the ability of such detection:

- Nuclear non-proliferation
- Safeguards
- National security

An FPGA-based data detection platform has highly beneficial qualities, including:

- Scalability
- Portability
- Can be easily reprogrammed to achieve desired handling of the incoming data

Measurement System and Analysis

The scalability of our data capturing platform is beneficial in case there is ever a need to correlate times of pulse arrivals from multiple detectors, or if multiple data sources need to be processed at the same time.

- Expanding the system only requires the addition of more data processing modules.
- The X5-210 module connects to the back of a PC or laptop through a PCIe expansion card, so additional PCIe slots can be added to a PC or laptop to accommodate multiple PCIe expansion cards.
- By adding more modules, more channels can be included.
- The dimensions of the FPGA-based data processing module are 28.5 x 106 x 160 mm, which makes transportation of the system easy.

Figure 1. Overall data capture system.

Figure 2. The measurement threshold was set to 130 keV electron equivalent.

Figure 3. The University of Michigan developed a measurement system capable of acquiring the data on particles given off by radiation sources (left) with standard liquid scintillation detectors (bottom right) and a 250-MHz Innovative Integration (II) X5-210m digitizer (right).

Figure 4. FPGA Architecture.

FPGA Pre-Trigger

When a trigger event occurs, if we began capturing the incoming data at that exact moment in time, we would miss the beginning of the overall waveform.

- A pre-trigger on the FPGA buffers the incoming data for a programmable number of samples.
- When a trigger event occurs, the start time of the data acquisition becomes the trigger time minus the pre-trigger interval.

Figure 5. Pulses measured with the FPGA and a Cf-252 neutron source. The pulses were digitized with the X5-210m digitizer at 250 MHz.

Conclusions

The FPGA will eventually be able to process incoming data streams in real time, discriminate detected particles based on their pulse shape and send the identification results to the PC without having to store the data values of the entire waveform.

- The method of identifying pulses and their associated particles by use of correlation algorithms implemented on the FPGA will be further explored. This work will result in a more accurate particle identification scheme.

Future Work