A Scalable FPGA-Based Digitizing Platform for Radiation Data Acquisition

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INTRODUCTION

Digitizing discrete, fixed length data pulses from organic scintillation detectors allows for the determination of the types of particles being emitted by a certain material. This knowledge in turn reveals information about the type of material under examination. We are using a four channel, 250 MHz analog-to-digital data detection platform from Innovative Integration [1] which is scalable, portable and reprogrammable. The system captures discrete data pulses based on comparisons of the values of the streaming data against a user-specified threshold value. Every time the comparison asserts itself, a new window of data is captured. In this paper, we focus on the advantages of using an FPGA-based digitizer for such data detection platforms. This system is being developed for nuclear-nonproliferation measurements that will employ multiple organic scintillation detectors.

SCALABLE MEASUREMENT PLATFORM

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. All that is required to expand the system is 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. A layout of the system is shown in Fig.1. By adding more modules, more channels can be included and so streaming data from additional sources can be processed. The dimensions of the FPGA-based data processing module are 28.5x 106x 160mm, which make transportation of the system easier.

FPGA ARCHITECTURE

A key component of this system is the Virtex 5 FPGA [2] housed inside the Innovative Integration X5-210 module [1]. A block diagram of the FPGA architecture is shown in Fig. 2. This FPGA processes the incoming ADC (Analog-to-Digital Converter) data stream and can be programmed to achieve the desired handling of the information. As data streams from the ADC channels, the data values are synchronously compared to a programmable trigger threshold value and when the input values achieve the user-specified comparison, a

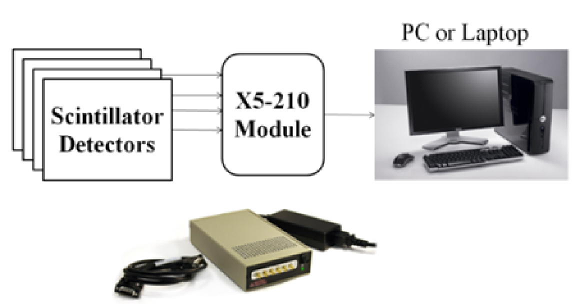

Figure 1. Overall data capture system.

trigger event occurs and data capture begins. The data acquisition rate is limited by three factors: 1) The memory on the FPGA module is 512 MB of DRAM and 4 MB of SRAM, 2) Transfer rate over the PCIe link from FPGA to PC of 2000 MB/s, 3) Memory on the PC [1]. The number of data samples to be captured every trigger event is user-specified.

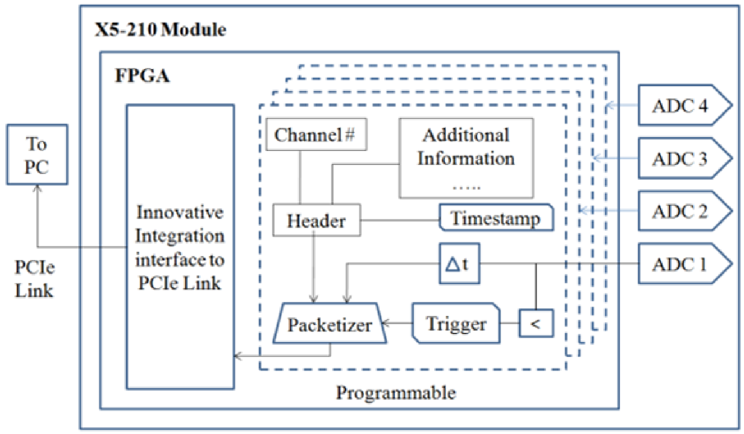

Figure 2. FPGA architecture.

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. Therefore, in order to capture the entire waveform, we implement a pre-trigger on the FPGA that buffers the incoming data for a programmable number of samples. In this manner, when a trigger event occurs, the start time of the data acquisition becomes the trigger time minus the pre-trigger interval.

Every trigger event, a specified number of samples (usually 256) are captured and sent to the PC or laptop. We reserve the first four of these data samples for header information specific to the pulse. The header information includes a timestamp of the trigger event, the channel number of the channel which triggered, plus supplementary, unused bits available for future expansion. More than four samples can be used in the header and so additional information can also be included, if needed. Fig.3 shows a processed plot of data taken by the detection system. A clear distinction can be seen between neutrons and gamma rays in this plot of the tail-to-total integrals of captured waveforms. Fig. 3 shows the measurement results obtained with a Cf-252 source placed 30 cm from an EJ-309 liquid scintillation detector. Neutrons produce larger tail integrals than gamma rays which can be clearly seen in Fig. 3. The measurement threshold was set to 130 keVee (keV electron equivalent).

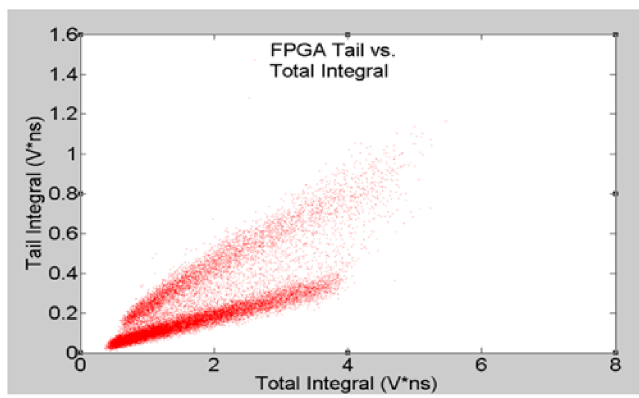

Figure 3. FPGA measurements.

The eventual goal of this system is to pre-process liquid scintillater detector data in real time through custom modifications to the FPGA for identifying special nuclear materials.

References

1. "X5-210M User's Manual," Innovative Integration, Feb 5, 2009. [online] http://www.innovative-dsp.com/support/docs.htm
2. "Virtex-5 FPGA User Guide", Xilinx Inc., November 2009. [online] http://www.xilinx.com/support/documentation/virtex-5.htm