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A Scalable FPGA-based 64 Channel Data Acquisition System of X-ray Cargo Inspection

Hyojeong Choi , Young Soo Kim , Jang Ho Ha, Chang Goo Kang, Ah Hyun Park, Jeong Min Park and Han Soo Kim*
Korea Atomic Energy Research Institute, Jeongeup-si, Jeollabuk-do, Korea
** Corresponding author : khsoo@kaeri.re.kr*

1. Introduction

Field-programmable gate array (FPGA) devices are widely used in many fields such as medical and industrial fields because of their properties of the cost-effective, field-reprogrammable and stabilities. In nuclear instruments applications, particularly, these are typically used for large amounts of data acquisitions from multi-channel radiation sensors array and image processing.

Recently, advanced security inspection systems capable of 3-D image recognition, and simultaneously obtaining the information of the material of shape and composition have been studied [1, 2]. We are currently developing a multi-radiation inspection system to obtain high resolution images and the material composition of air cargo. In this study, we developed a scalable FPGA-based data acquisition system (DAS) board equipped with 64 channels of X-ray sensors. 16 DAS boards can be connected to a control unit, therefore, total of 1,024 channels of X-ray sensors can be used for X-ray image acquisition.

2. Methods and Results

2.1. Design and Fabrication of the data acquisition system

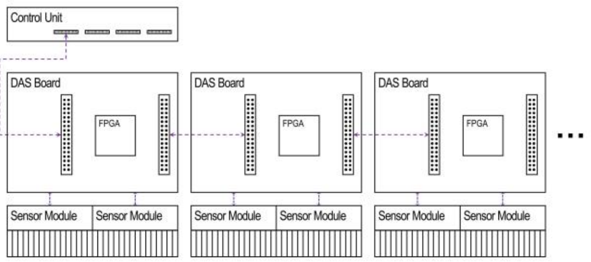

Fig. 1. Block diagram of the scalable DAS boards.

The development of a 64-channel DAS board was discussed in Ref. [3]. By connecting these boards, more X-ray sensors can be used for image acquisition with high-resolution. Fig. 1 shows the block diagram of the linked X-ray detector modules including DAS boards and sensor modules. The sensor module consists of 32-channel readout boards designed at Korea Atomic Energy Research Institute (KAERI) [4], pixelated $CdWO_4$ scintillator and silicon photodiode.

First, the DAS board receives the signal from the control unit. The DAS board directly connected to the control unit acts as the master which reprocesses the timing signals from the control unit. The DAS sends these signals to the next DAS board which acts as the slave. Each DAS board generates timing signals to be transmitted to the next DAS board.

Conversely, the X-ray data from each sensor module are transferred to the previous DAS board. Analog X-ray signals from each sensor module are digitized by using 18-bit high speed analog to digital converter (ADC) and stored into the 256k SRAM. All of the local timing signals are designed to control the devices in the DAS boards and acquire the X-ray data.

To acquire the X-ray data from all DAS boards at the same time, signals such as clocks and X-ray integration trigger signals required for the sensor modules should be directly transmitted from the control unit because it is necessary to prevent delay and unwanted distortion caused by connecting multiple DAS boards. Fig. 2 shows the timing diagram of the enable signal of the data out. In the data out enable phase, each slave DAS board transfers eighty 8-bit data stored in SRAM to the previous DAS board. The master receives all of this data and sends it to the control unit at a period of 500 ns per data. The time for each DAS board to transmit data is 40 us and the data out enable time of the master is 640 us.

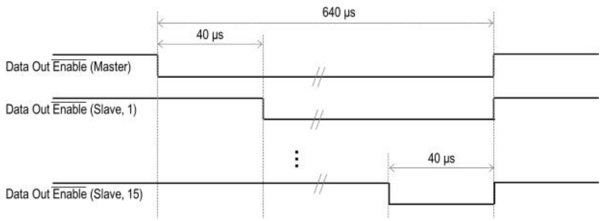

Fig. 2. Timing diagram of the designed DAS board.

The detector module consists of a DAS board and a sensor module. X-ray acquisition in this detector module is a multi-step process. First, the scintillators convert X-rays into visible light. Then Si-based photodiodes convert this visible light to electrical currents, which are integrated by the charge-sensitive preamplifiers. The voltage signals from these preamplifiers are sampled and held so that they are digitized by ADC sequentially. The digitized data are processed in the FPGA and saved to the SRAM.

2.2. Experimental Setup

Fig. 3 shows the connection of multiple detector modules. Three detector modules were used. A detector module includes a DAS board and two 32-channel readout boards. A master DAS board was connected to the control unit, and each DAS board was connected with a 34-pin data cable.

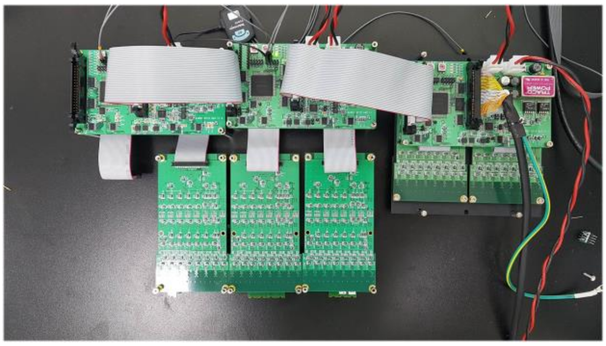

Fig. 3. Connected three detector modules.

Fig. 4 shows the experimental setup. Tektronix TLA6403 logic analyzer and DPO 3034 oscilloscope to verify timing of the signals and analog output voltages from the X-ray sensors were used. The computer and the control unit were connected by Ethernet to send and receive the data. Control unit, data acquisition software and power supply are supplied by Detection Technology.

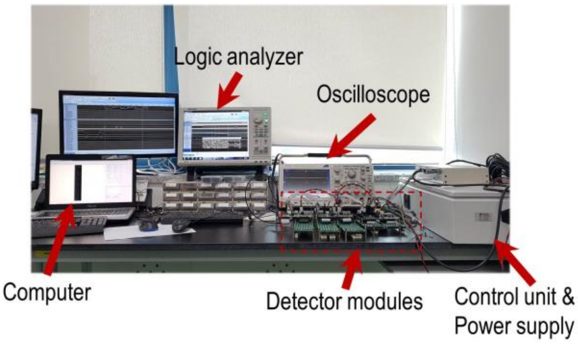

Fig. 4. Experimental setup.

2.3. Results of Experiments

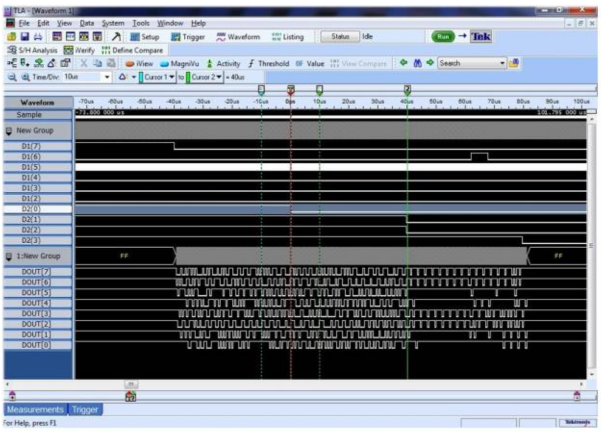

Fig. 5. Some timing signals observed by logic analyzer.

To verify the control signals and data generated by FPGA in the DAS board was analyzed by using a logic analyzer, shown in Fig. 5. Image was captured using data acquisition software by Detection Technology. Photodiodes were randomly mounted on readout boards, and then they were exposed to visible light. The result of the image capture is shown in Fig. 6.

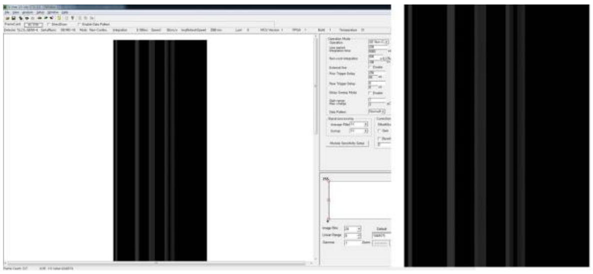

Fig. 6. An image acquired by exposing the visible light.

3. Conclusions

A scalable DAS board for air cargo inspection systems was developed. The DAS board can be connected with up to 16 other DAS boards. This makes it possible to use 1,024 X-ray detector channels and acquire high resolution images.

ACKNOWLEDGEMENT

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