Design and Development of a Prototype Low-Cost Data Acquisition Readout Electronics Board for Medical Imaging System

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Introduction

Medical imaging is growing popularity in recent times due to the increased rates of cancer. Conventional X-ray mammography is not suitable for detection of small lesions and hence there is thrust in designing scintillation-mammography devices like Gamma Camera. These positional sensitive imaging devices demand a multi-channel Data Acquisition System (DAQ) with parallel processing. In this paper, we have proposed a low-cost DAQ which may be used as the Readout electronics in medical imaging systems. This multi-channel DAQ system consists of a 16-Channel, current-input ADC chip (ie. DDC316). A low-cost FPGA is used for the interfacing DDC316 as a readout controller and communicating with PC over a serial interface. The DDC316 PCB board, FPGA firmware and Software GUI are developed in-house and tested in the laboratory using Silicon Photomultiplier (SiPM) and a red Light Emitting Diode (LED) light source.

Hardware

The DAQ system contains an FPGA board and a DDC316 IC with a charge integration time of 20 μs [1]. FPGA is used to generate control signals for DDC316 chip, acquire data from DDC316 and transfer it to PC. The architecture of the FPGA firmware is shown in Fig. 1.

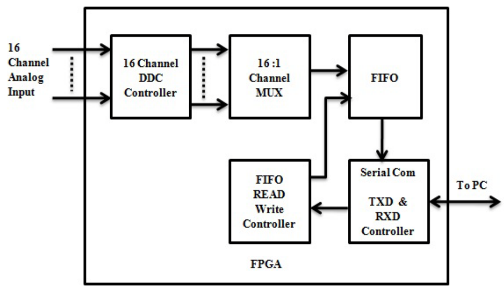

Fig. 1 FPGA Firmware Architecture

The features of the board are as follows.

- Detector Read-Out : SiPM / SiPM array
- Number of Channel:16
- Signal Polarity: Positive
- Trigger generated by external NIM module for testing.
- Dynamic Range 3-12pC
- Energy measurements by charge integration
- Power consumption: 32 mW/channel
- Resolution: 0.18fC
- Dimension: 10cm X 12 cm.

The readout board is shown in Fig. 2.

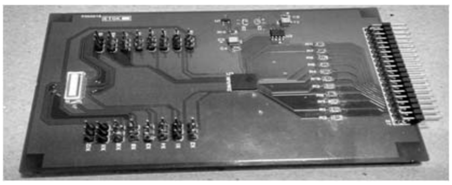

Fig. 2 Readout Board

Experimental setup

This DAQ has been tested using a SiPM detector and a light source from an LED. The scintillation photon of the wavelength range from 400 to 700 nm is replaced by a red LED light source (λ = ~650nm). The SiPM signal is amplified to 20x times using a high bandwidth fast amplifier. A TTL trigger and shaped output are generated using a 16 channel shaper NIM module (MSCF16) with adjustable shaping time from 250 to 1000ns. The SiPM detector is shown in Fig. 3. The block diagram of the experimental setup is shown in Fig. 4.

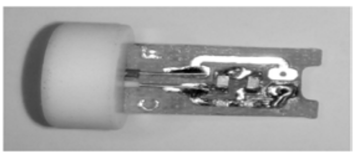

Fig. 3: SiPM detector

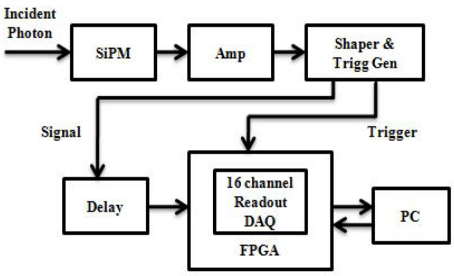

Fig. 4: Block diagram of the experimental setup.

Experimental results

The TTL trigger and the shaped SiPM output generated by MSCF16 are fed to readout board for acquisition. Fig. 5 shows the oscilloscope screenshot of those signals. The intensity of the Light Output was changed by varying the LED forward bias voltage. The calibration was found linear within the full input range of DDC316. Table 1 shows the results of the calculated and measured charge on four channels. Fig. 6 shows the screenshot of Data Acquisition software developed in Visual Basic.

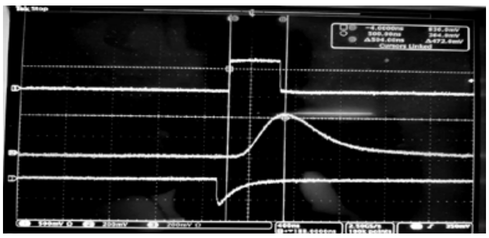

Fig. 5 SiPM output Signal & Trigger

Red LED	LED voltage	Measured value pC	Calculated value pC
Ch1	2.4	0.45	0.33
	2.8	0.77	0.57
	3.2	0.96	0.74
Ch5	2.4	0.36	0.33
	2.8	0.69	0.57
	3.2	0.88	0.74
Ch9	2.4	0.36	0.33
	2.8	0.64	0.57
	3.2	0.86	0.74
Ch13	2.4	0.42	0.33
	2.8	0.69	0.57
	3.2	0.88	0.74

Table 1: Test Results

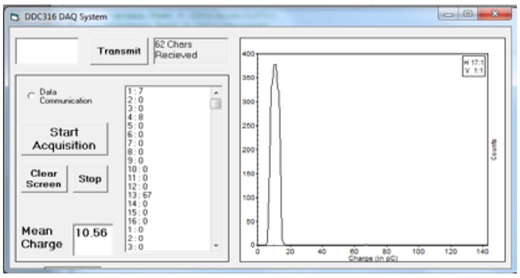

Fig. 6: Data Acquisition GUI in VB.

Conclusion

We have developed a low-cost 16 channel DAQ system for γ ray Imaging System. We have used DDC316 IC for data acquisition which gives a cost-effective solution for multi-channel charge measurement. An alternative to DDC316 is dedicated ASICs designed for SiPM readouts like CITIROC 1A and EASIROC [2][3]. These ASICs gives a better dynamic range and linearity for energy measurement but are not economical. We have proposed a compact low-cost solution for read-out electronics of Medical Imaging System.

Future Scope

For testing purpose, we have used a NIM module to generate the trigger signal and delayed shaped pulse from SiPM output. This needs to be integrated with the readout board using fast comparator and analog shaping circuit. This will help us to develop a self-triggered compact read-out unit for Medical Imaging System [4].

References

[1] www.ti.com, “DDC316” Datasheet.
[2] N.Dinu, et al., “ SiPM arrays and miniaturized readout electronics for compact gamma camera”, Nucl. Instrum. Method Phys. Res A 787(2015) 367-372.
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[4] R. Massari, et al., “A novel fully integrated handheld gamma camera”. Nuclear Instruments and method in physics Research A 832 (2016) 271-278.