Prototype development of Digital Pulse processing system & its Data Acquisition system for nuclear physics experiments

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Introduction

The traditional nuclear spectrometry systems employ analog front-end electronics for signal processing of radiation detectors. The output signals from pre-amplifier or photo multiplier tube are processed through a chain of analog devices before being digitalized. These front-end devices perform various operations like filtering, shaping, amplification, trigger generation etc.

The digital pulse processing approach replaces the traditional analog chain with equivalent digital algorithms. The pre-amplifier signal is digitized with a very fast sampling ADC and filtering, shaping, triggering activities are carried out in digital domain [1]. Various filter algorithms like CR-RC, trapezoidal are implemented and tested [2], [3]. This paper will describe the detail plan for implementation of a multichannel digital data acquisition system as an augmentation of the existing VECC DAQ system.

Pulse Processing Electronics

The digital DAQ electronics schematic is given below in Fig.1.

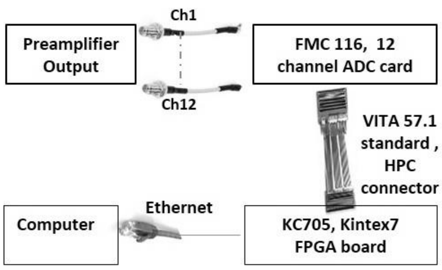

Fig. 1: Electronics block schematic.

FMC 116 from M/s 4DSP is a 16 channel VITA 57.1 standard HPC daughter card. The current board has 12 active input channels. This card captures the analog input at a sampling frequency of 125 MHz and sends the 16-bit digital data to Kintex 7 FPGA via serial LVDS interface.

A threshold value is used to trigger the filtering process. The digital filter is implemented into the FPGA with fixed point arithmetic. It eliminates the processing delay. The peak is detected automatically inside the FPGA and only the peak value is sent to the computer via Ethernet.

Digital Pulse Processing Firmware

We have taken CR-RC shaper along with pole zero cancellation circuit and the analog transfer function is given by

$$G_{filter}(S) = \frac{\tau(\tau_i+1)}{\tau_i(\tau s+1)^2}$$

Where τ is filter shaping time and τ_i is the preamplifier fall time. We have applied bilinear transformation for corresponding digital equivalent. Filter coefficients have been calculated for second order IIR filter for input parameters as sampling frequency 125 MHz, shaping time 5us and preamplifier fall time 50us - 100us. The VHDL code for the digital filter, peak search and ethernet communication to PC has been developed and tested. The digital filter response is given in Fig. 2.

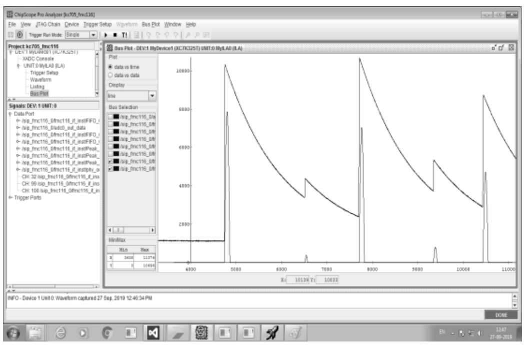

Fig. 2: Digital filter response captured by Chipscope

Ethernet based readout software & data acquisition system

The architecture of the data acquisition system is decoupled into client and server processes communicating via TCP socket on 127.0.0.1 local IP address. The server process is responsible for the Ethernet readout from the KC705, FMC116 card. The client is reading from the server and updates the GUI. The readout was developed by using the SPIIF API which is a wrapper API providing Open, Close, ReadSystemRegister, WriteSystemRegisters, ReadData, WriteData as functions to communicate with FMC116, KC705 device using "INTEL(R) 82579LM Gigabit Network Connection" device driver. The buffer of each channel is read and converted into a data format(.lst), which specifies the total number of channels, channel number along with the data, and a timestamp (currently constant) for every event registered.

Experimental results

The filter response and linearity of the system was studied with different amplitudes, rates, fall times of the input signals from periodic pulsar and a random pulsar. The spectrum response is given below Fig. 3.

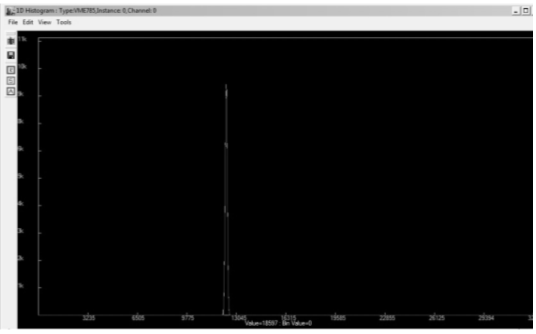

Fig. 3: Pulsar Spectrum from Digital DAQ

Gamma energy spectroscopy experiment has been carried out with CAEN make digital detector emulator module, DT5800 with digital DAQ and a CAMAC DAQ for comparative study. The experimental result is given in below Fig. 4.

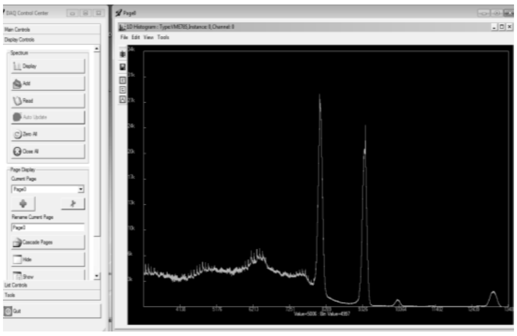

Fig. 4: Co-60 Spectrum from Digital DAQ

Conclusions & future scope

We have achieved 1.18% energy resolution in digital DAQ. There are scopes for improvement in the design and algorithm of the system to improve the resolution. This is the beginning of multichannel digital data acquisition system. Timestamp based correlation is in the future scope of this project.

References

[1] L. Bardelli and G. Poggi. "Digital-sampling systems in high-resolution and wid dynamic-range energy measurements: Comparison with peak sensing ADCs" ,NIM in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, 560(2):517–523, 2006

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[3] Payal Singhai et al., "Digital pulse processing techniques for high resolution amplitude measurement of radiation detector", proceedings of PCAPAC 2012, Kolkata, India, page no 279-281.