FPGA based low noise front end electronics board for radiation detection and measurement

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Introduction

Radiation pulse processing is the spine of nuclear physics experiments. The emitted radiation contains various information about particle properties and undergoes different nuclear reactions. In nuclear experiments, especially for particle detection it is very important to get the best possible energy resolution and precise time measurement [1] in extremely noisy environment. This requires high quality noise reduction techniques in radiation detection and measurement [2].

Proposed digital pulse processing scheme reduces the dead time of the system, considerably as it runs continuously in trigger-less mode. Use of digitizer operating at sampling frequency of 1Msps for fairly good energy measurement gives better and economical alternative compare to traditional analog scheme with very expensive peak sensing ADC. Algorithms for triangular and trapezoidal shaping were written in such a way that it provides inherent Pole-Zero compensation and Baseline Restoration. Block diagram of the proposed digital approach for nuclear pulse processing is shown in Fig.1.

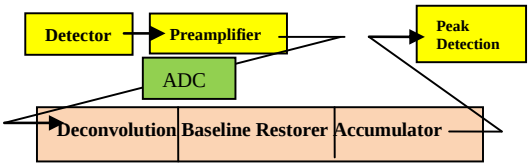

Fig.1 Schematic for trapezoidal/triangular shaping

For triangular and trapezoidal shaping, output of detector fed to preamplifier which gives exponential pulses of fixed time constant and variable amplitude (amplitude of preamplifier pulse is directly proportional to charge deposited by radiation). Preamplifier output chopped by ADC and then processed by three filters successively as shown in Fig.1. De-convolution filter, baseline restorer, accumulator and finally peak detection algorithm were implemented on Spartan-6 FPGA via Xilinx platform. Ideal response of above mentioned filters are shown in Fig.2.

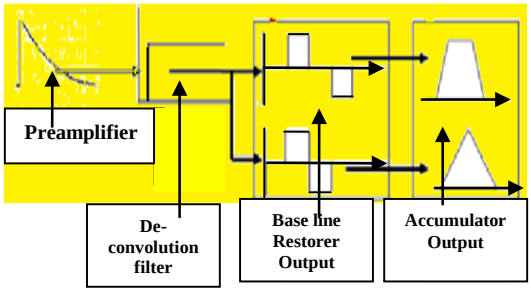

Fig.2 Ideal response of different filters for exponential pulse

Simulation Work

Simulation of digital pulse processing chain was done using simulink software available in Mat-lab version 2012a. This simulation gives better understanding and analysis of signals at every stage in both frequency and time domain respectively. Different types of shaping techniques (semi-Gaussian, trapezoidal and triangular) were simulated as shown in Fig.3. On the basis of signal to noise ratio, pile up rejection and count rate, a fair comparison and optimization had been studied among semi-Gaussian, trapezoidal and triangular shapings. Successful simulation of pile-up rejecter scheme adds strong possibility to use the concerned design for high count rate without losing any information. On the basis of signal to noise ratio, triangular shaping is found as the best option. Moreover, triangular shaping has least pile up, compared to other shapings for the same rise time.

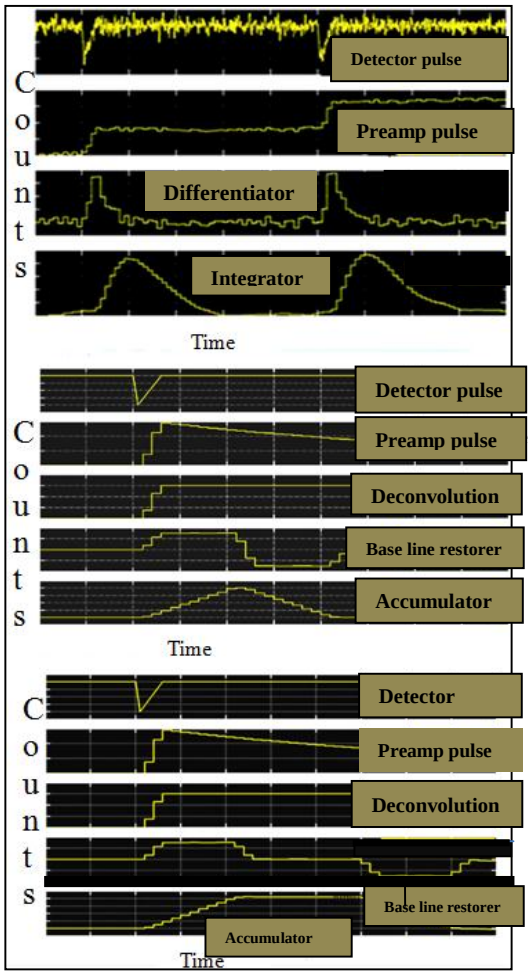

Fig.3 Simulation of different type of shaping
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Detector Assembly and Setup

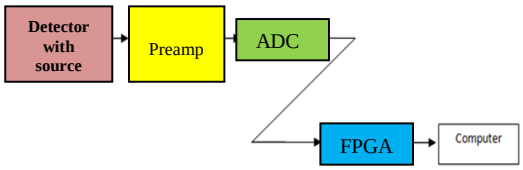

Fig.4 Block diagram showing electronic set up

Detector assembly set up is shown in Fig 4. Digital filters i.e. the de-convolution filter, baseline restorer, accumulation and peak detection were implemented on FPGA. Digital pulse processing chain was calibrated in the test bench of a radiation detection system. The energy spectrums were obtained for the beta (Sr-90) and alpha (Am-241) are shown in Fig.5.

Results and Conclusion

It is observed that implemented digital pulse processing system with low cost 1 Msps ADC

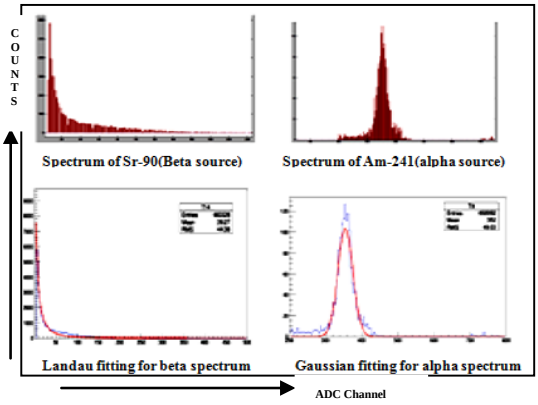

Fig. 5 Experiment result
Resolution obtain (with Alpha source) = 7.9%

gives energy resolution of 7.9% with alpha source mounted on 1cm ×1cm silicon pad (manufactured at BEL Bangalore). This resolution is comparable with other digital pulse processing schemes where high speed digitizer (40-125Msps) was used. This resolution is also compared to available conventional analog system, thus suggests the strong economical alternative of traditional analog scheme with very expensive amplifiers and peak sensing ADC module. Moreover unlike traditional pulse processing scheme proposed digital approach is much more dynamic, less spacious with better repeatability and reliability.

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References

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[2]H.Spieler. Radiation detectors and signal processing.