Digital system for signal processing from a position-sensitive detector based on Open FPGA digitizer.

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Signal preprocessing plays an important role in the interpretation of experimental data from detectors. Since most experiments collect information digitally, FPGAs are increasingly being used as part of the data acquisition system for signal processing. The work demonstrates three methods of signal processing from a linear position-sensitive detector (LPSD) with a ^{3}He-based resistive wire using the Open FPGA digitizer DT5560SE unit.

The detector is based on a proportional counter design and is made in cylindrical geometry. Its shell is the cathode, and an anode wire with high resistance is stretched inside its volume. The detector is filled with a high-pressure neutron converter gas, most often ^{3}He. When a neutron enters the working volume of the detector, the gas is ionized, resulting in a charge being collected at the anode. This charge is divided between the two ends of the detector and collected by the preamplifiers. The position is determined by dividing the charge at one end by the total charge [1]. In Figure 1 shows the principle of position calculation [2].

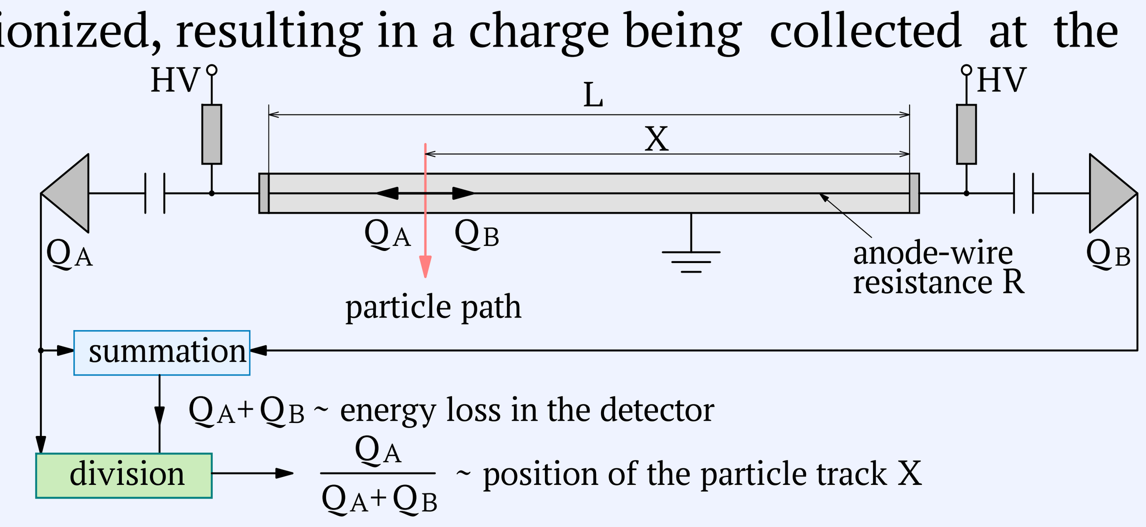


Fig.1. Principle of position measurements.

Tubes from the Consensus company were used in this work [3]. The processing algorithms are executed by a programmable logic integrated circuit (FPGA) as part of the SoC (system on a chip) Z-7030 digitizer **DT5560SE** from CAEN. The DT5560SE digitizer consists of four main sections, as shown in Figure 2. Below is a comparison of three methods of processing input signals - QDC, PSD and MCA HP. To implement these methods, the Sci-Compiler development environment was used [4], which includes a set of IP blocks libraries.

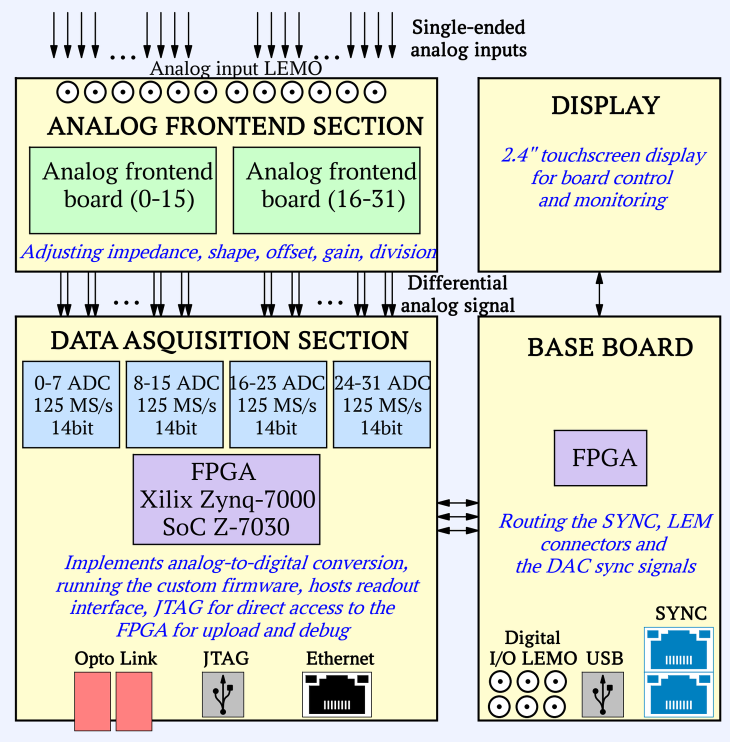


Fig.2. Block diagram of the DT5560SE digitizer device.

QDC (charge-to-digital conversion) is a method based on the measurement of energetic particles based on charge integration.

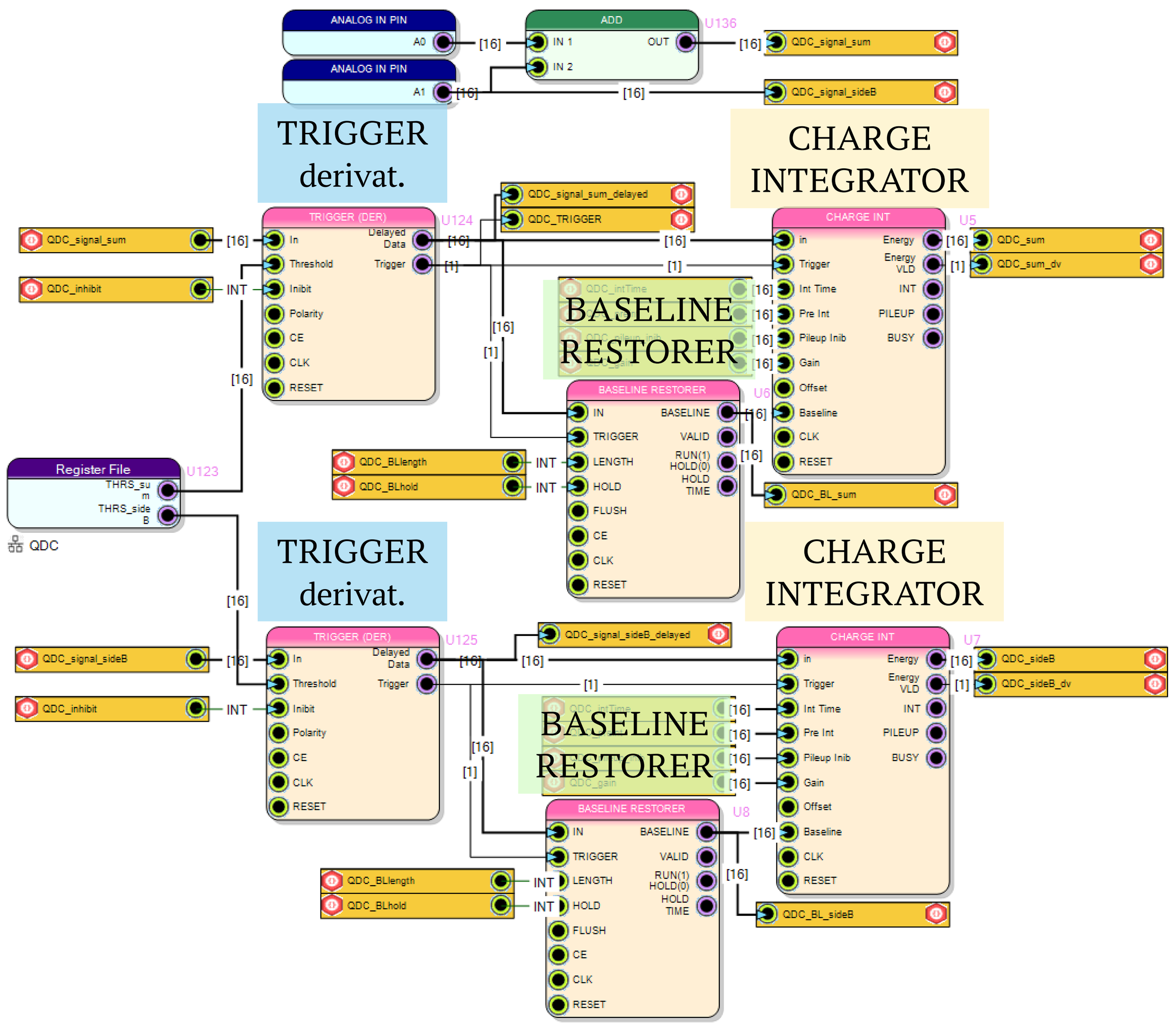


Fig.3. Implementation of the QDC method in program workspace Sci-Compiler.

The input signals are summed and fed to the input of the derivative TRIGGER block. Next, the delayed sum input signal and trigger are fed to the BASELINE RESTORER block to calculate the baseline. The CHARGE INT block subtracts the baseline from the input signal and then integrates the signal into a window. Similar processing is carried out for the second side of the tube.

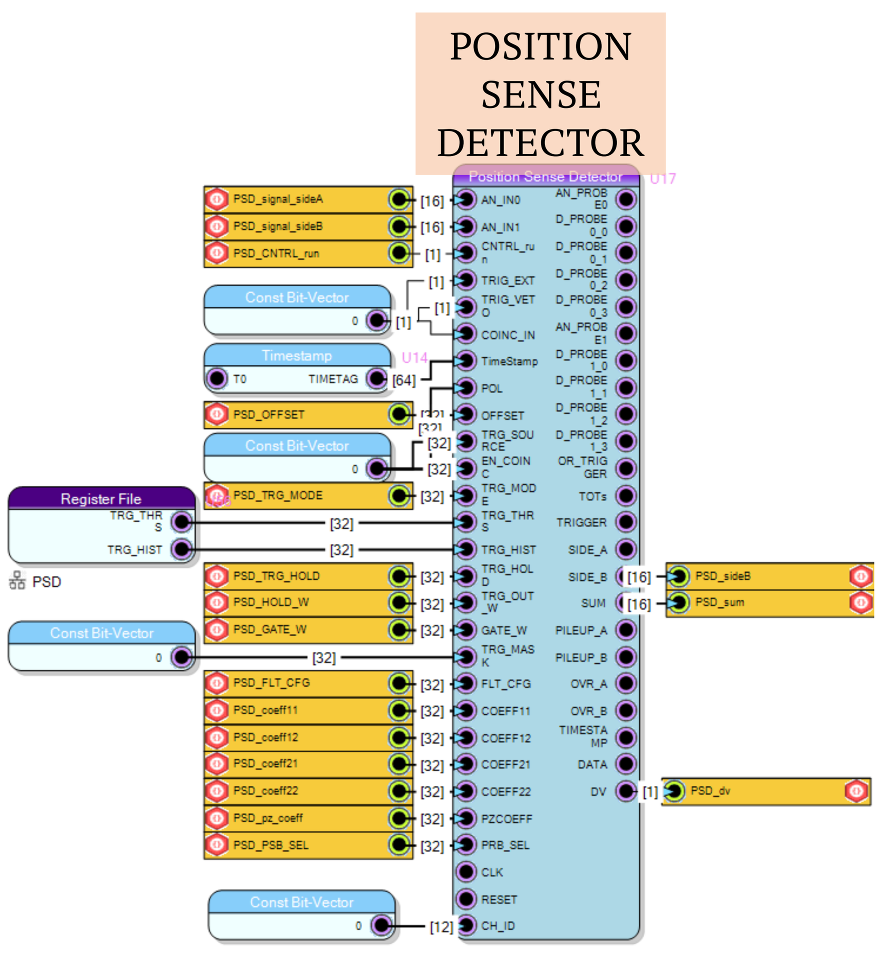


Fig.4. PSD block diagram.

The **PSD** (position sense detector) block is specially designed for position sensitive tubes. This IP-block uses two 2nd order quasi-Gaussian shaping filters. During the filter formation process, the Pick Finder search algorithm continuously works, which at the end of the work produces the value of the maximum amplitude of the filter. This IP block includes pole-zero compensation, baseline calculation, trigger circuit, and data packet generator. The standard data package includes energy value on both sides, timestamp, handset number and flags, and can be transferred to personal computer.

The **MCA HP** (multi channel analyzer for high resolution detector) block implements spectrometric signal processing and contains the following basic functions: receiving signals of both polarities, deconvolution of an exponential signal, a fast trapezoidal filter for a trigger, a slow trapezoidal filter for energy calculations, and baseline restoration. The output of a trapezoidal filter is a flat-topped trapezoid whose height is proportional to the amplitude of the output pulse.

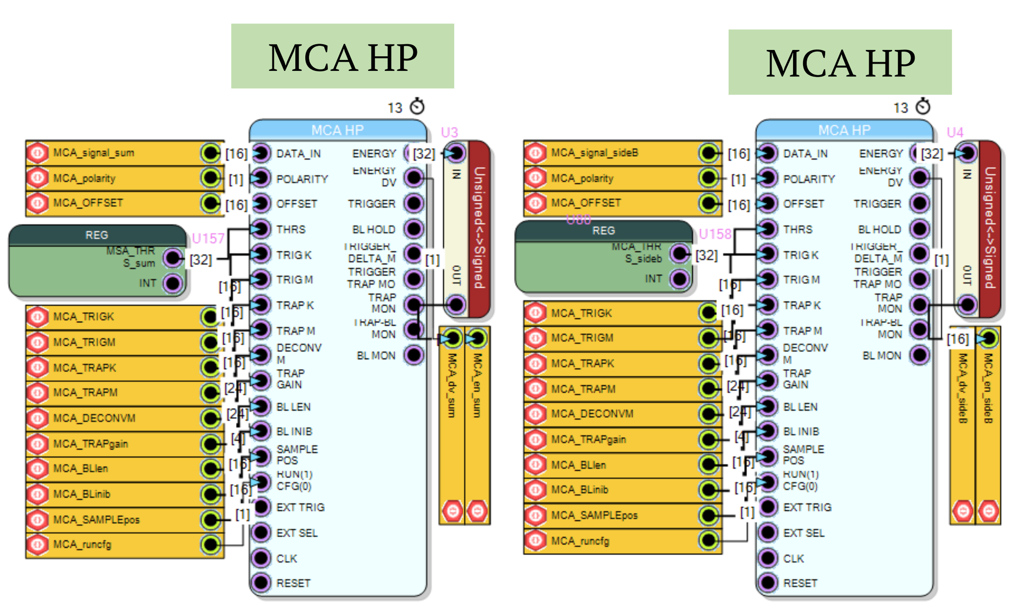


Fig.5. MCA HP block diagram.

To determine the coordinate of the neutron interaction, it is necessary to use the DIVIDER (Pipelined) block. The results of energy calculations on one side, the total energy and a trigger are supplied to its input. The result of the division is fed into the Spectrum block to obtain a histogram. This procedure is shown in Fig.6 and is common to all three methods.

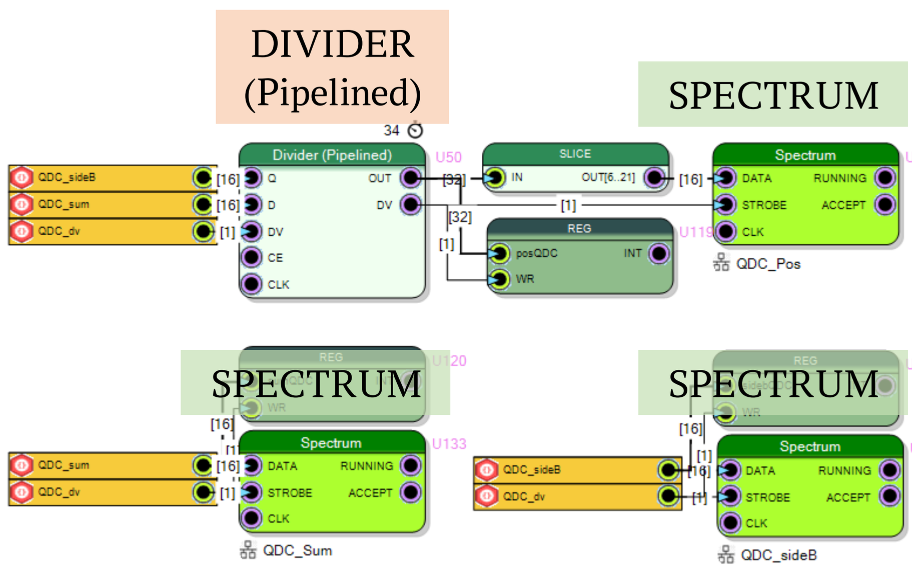
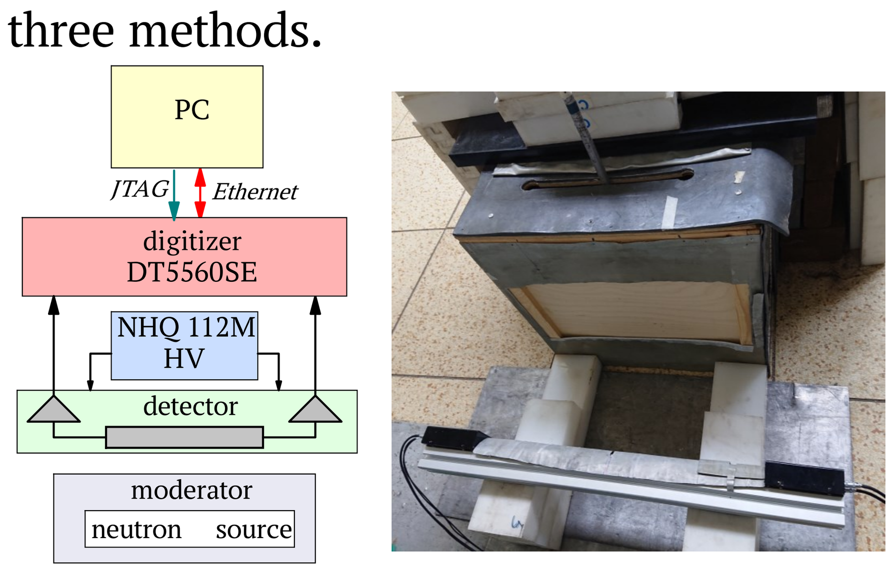


Fig.6. Division block diagram.



a) b)

Fig.7 a) block diagram of the test bench, b) part of the setup with a source, moderator and detector.

A test setup with two Helium-PSD-8/600-12,5L counters used as a neutron detector was developed at FLNP JINR. The ^{252}Cf neutron source in a polyethylene moderator was placed at a distance of approximately 0,3 m from the counters. The CAEN DT5560SE digitizer is used as the data acquisition system in the test system, which is connected to a personal computer via an Ethernet interface.

Data were obtained using the Resource Explorer software included in the Sci-Compiler development environment. Figure 8 shows the first measurement results of the test system using the three methods described. The shift in the slit position is explained by the lack of detector calibration.

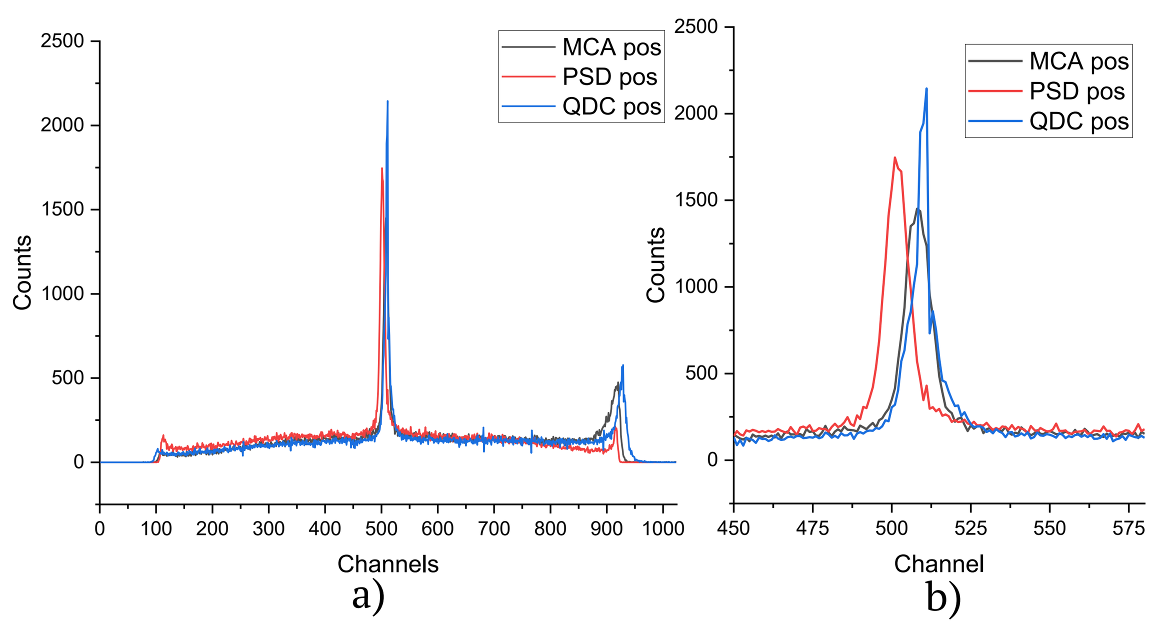


Fig. 8 a) general view of the measured position spectrum with a 5 mm slit, b) an enlarged fragment of the slit position spectrum

The processing time of the MCA HP method (4 us) is determined by the shaping time of the slow energy trapezoidal filter; the position resolution was about 0.81% of the tube length. The PSD method processing time was about 0.8 us and is determined by a shaping time of the quasi-Gaussian filter. The positional resolution of this method is about 0.75% of the tube length. The QDC method processing time determines the integration window of the input signal and is 1.2 us, while the position resolution was about 0.59%. Using the given parameters, the QDC method was judged to be more suitable.

Conclusion. Three methods for processing position-sensitive detector signals are presented, implemented as firmware for an open FPGA as part of the DT5560SE block from CAEN. Based on the results of the first measurements with a ^{252}Cf neutron source, preliminary estimates of the position resolution for three processing methods were carried out. In the future, the system is planned to be calibrated and optimized to build a multichannel data acquisition system to launch a large-area detector in the reactor beam.

[1] Glenn F. Knoll, Radiation Detection and Measurement, fourth ed.. — USA: John Wiley & Sons, Inc., 2010

[2] B.E. Fischer, A digital processor for position sensitive detectors // Nuclear instruments and methods. — 1977. — № 141. — p. 173-181.

[3] Helium-PSD-8/600-12,5L / URL: https://consensus-group.ru/katalog/neutron-counters/pozitsionno-chuvstvitelnye/520-gelij-psd-8600-1251#

[4] Sci-Compiler URL: https://www.sci-compiler.com/