Method and unit for dynamic control of conversion characteristics of spectrometric paths for multichannel charged particle registration systems

Yu V Tuboltsev¹, A A Bogdanov¹, Yu V Chichagov¹, I V Eremin¹, V K Eremin¹ and E M Verbitskaya¹

¹ Ioffe Institute, St. Petersburg, 194021 Russia

E-mail: tuboltsev@mail.ioffe.ru

Abstract. A method and unit for dynamic control of conversion characteristics of spectrometric paths of multichannel charged particle registration systems based on specialized microchip with a large degree of integration similar to IDE1140 in structure is proposed. The conversion characteristics are controlled during operation of the device by auto-adjusting the offset and gain of the scaling amplifier. The proposed method allows to use the entire dynamic range of the analog-to-digital converter and adjust the temperature drift for each channel at the hardware level during operation of the device.

1. Introduction

Position-sensitive systems are now widely used in nuclear physics, astrophysics, and high-energy physics to record the trajectories and energies of charged particles. In the field of nuclear physics there are many developing and already operating factories producing intense beams of radioactive isotopes such as FRIB (USA), GSI – Germany, RIBF (Japan), SPIRAL2 (France), ISOLDE (Switzerland), HIAF (China) and others. These factories are equipped or upgraded with powerful detecting apparatus comprising a position-sensitive detectors (Super-FRS) [1]. Multichannel charged particle registration systems are used at the new fragment separator ACCULINNA-2 [2] for the profile measurement of radioactive isotope beams [3,4].

Multichannel readout electronics for silicon detectors are also used in cosmic-ray study [5, 6]. Strip detectors and Application Specific Integrated Circuits (ASICs) VA140 and IDE1140 [7] manufactured by IDE are core elements in such multichannel systems. This article describes the method and the example unit of subsequent development of these systems.

VA140 (or IDE1140) ASIC include 64 spectrometric paths and two analog multiplexers (MUX). Each spectrometric path contains a charge sensitive preamplifier (CSPA) and a shaping amplifier (SA). To capture the maximum amplitude from the output of the SA a sample and hold circuit (S&H) is used. The voltage is readout from it through the analog multiplexer at the ASIC output. Signals generated at the ASIC output are amplified by an instrumentation amplifier and digitized by an analog-to-digital converter (ADC). Data from the ADC go to the Field-Programmable Gate Array (FPGA), the task of which is to generate control signals to the ASIC, buffer the data received from the ADC and transfer them to the computer (PC).

As shown by the analysis of such systems carried out in [5], spectrometric paths have different conversion characteristics. The difference in the path transfer coefficients is 4.40 - 5.24 keV per one
ADC quantization level for signals from the p-side detector strips. The readout signal is located at some initial level (pedestal), due to the internal features of the ASIC. Therefore, the amplitude range (figure 1) of the readout signals is determined on the one hand by different pedestals on which the signals are located, on the other hand, by different path conversion coefficients.

![Figure 1](image)

**Figure 1.** Illustration of the difference in amplitude ranges of spectrometric paths.

When processing, data normalization is required, i.e., scaling of the data obtained from all spectrometric paths to a single energy range. Data normalization is carried out at the software level by appropriate computer processing. Thus, in the considered devices, the signals are digitized in different amplitude ranges for the ADC. Pedestals and transmission coefficients can change during operation, since the detectors, ASIC, instrumentation amplifier and ADC are analog semiconductor devices, the heating of which due to the variation of ambient temperature or as a result of their operation leads to a change in their characteristics.

### 2. Description of the method

In this paper, we describe a solution that consists in creating an ASIC-based ionizing radiation registration system in which the normalization and stabilization of conversion characteristics is done at the hardware level by dynamic controlling the conversion characteristics. Figure 2 shows the structure of the system.

![Figure 2](image)

**Figure 2.** Block diagram of the multichannel charged particle registration system with dynamic control of the conversion characteristics at the hardware level.

This is achieved by applying the scaling amplifier. The initial position of the conversion characteristic is controlled by shifting the initial voltage at its output. The control of the “slope” of the conversion characteristic is performed by changing the gain of the scaling amplifier. Digital-to-analog
converters (offsetting and amplifying DACs) are used to control the corresponding inputs. The process of controlling the zero offset and transmission coefficient is illustrated in figure 3.

![Figure 3](image)

**Figure 3.** The diagrams illustrating the zero offset and gain control.

To adjust the pedestals and channel transfer coefficients, digital codes are put into the FPGA during calibration. In the process, FPGA performs the following functions. The signal from an external trigger generates clock pulses by which the signals are output sequentially from each spectrometer path of the ASIC. The signals are digitized by ADC, buffered in FPGA memory, and transmitted to a computer. At the moment of reading the signal from the ASIC corresponding to the certain path, the FPGA corrects the pedestal and transmission coefficient of this path using digital-to-analog converters, by applying voltage to compensate for the initial level of the pedestal and bringing the transmission coefficient to the maximum for this amplitude range. The reference values used to offset and amplify the signal from the ASIC are stored in the FPGA memory for each path. They have to be obtained during the calibration. The stabilization of the conversion characteristics of each spectrometric path is carried out either using an external generator of stable amplitude, the signal from which is fed to the ASIC calibration input, or by reference energy peaks. To stabilize the conversion characteristic, two reference signals can be selected, one at the beginning of the conversion range and another at its end. The stabilization process consists in comparing the digital code received from the reference source with the reference code stored in memory in advance, that allows to make the correction of zero offset or the conversion characteristic coefficient.

### 3. Fast scaling amplifier unit and main characteristics

Figure 4 shows the structure of the fast scaling amplifier. It is implemented on a broadband multiplier-adder - AD835 chip. The transient process for adjusting the signal from ASIC is no more than 30 ns, which allows it to be read both with the maximum speed for these ASICs for 100 ns, and with the optimum for 300 − 500 ns.

![Figure 4](image)

**Figure 4.** An example of the scaling amplifier unit.
The transient process with signal correction based on the AD835 is shown in figure 5 and is no more than 20 ns, which is significantly less than the minimum signal duration (100 ns), and thus allows the application of such chips to correct the signal even at the maximum readout speed.

![Figure 5. Pulse waveforms, from top to bottom: ASIC output, amplifying DAC output, final signal, and offsetting DAC output.](image)

4. Conclusion
The proposed method and unit for dynamic control of the conversion characteristics of spectrometric paths included in the ASIC allow to normalize these characteristics at the hardware level and thereby utilize the entire dynamic range of the analog-to-digital converter used to readout signals from the spectrometric paths, as well as adjust the temperature drift of the conversion characteristics during operation.

References
[1] Facility for Antiproton and Ion Research in Europe (FAIR) http://www.fair-center.eu
[2] Fomichev A S et al. 2019 The First Experiments with the New ACCULINNA-2 Fragment Separator Bulletin of the Russian Academy of Sciences: Physics 83 385–91
[3] Tuboltsev Yu V et al. 2019 A Multichannel Spectrometric Readout System for Strip Semiconductor Detectors Instrum. Exp. Tech. 62 6 764-70
[4] Bogdanov A A et al. 2019 Two-dimensional position-sensitive spectrometer for registration of ionizing radiation International Conference PhysicA.SPb.Phy.: Conf. Ser. 1400 5 055050
[5] Zhang Fei et al. 2013 Readout electronics of silicon detectors used in space cosmic-ray charges measurement Chinese Phys. C 38 066101
[6] Da-Li Zhang et al. 2017 Beam test of CSES silicon strip detector module Chinese Phys. C 41 056101
[7] IDE1140: 64 Channel sample-and-hold and multiplexer output https://ideas.no/products/ide1140/