ELECTRONIC SIMULATOR OF SIGNALS DERIVED FROM SCINTILLATION DETECTORS IN SPECTROMETRIC IDENTIFICATION OF HIGH-ENERGY CHARGED PARTICLES

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Development of the high-energy charged particles small-caliber spectrometer, which is planning to be launched into near-Earth orbit to study the nature of electron microbursts requires tests to adjust the nanosatellite payload. It will need access to the ionizing radiation sources, scintillation detectors, large-area silicon photodiodes, which convert the particle burst in the detector from passing through the detector into an electrical impulse and other modules. In other words, to the control and test equipment. The current economic situation might not allow providing all tests due to various reasons. Therefore, elaboration of hardware modules while the absence of both sensors and converters of the weak analog signals is an optimal solution to solve the task of testing the digital module of the particle recorder-analyzer.

Accumulation of the database on the particle flux densities for a certain period within 15 energy ranges from the two spatial mutual opposite directions is the main task of the spectrometer. The circuit multiplexing structure of microcontroller pins has chosen during a search for the solution of electronic simulation of the anti-coincidence logic in the method of measuring specific energy losses and total energy, fig. 1. With the help of which makes a decision on the assignment of the type and energy range of particles.

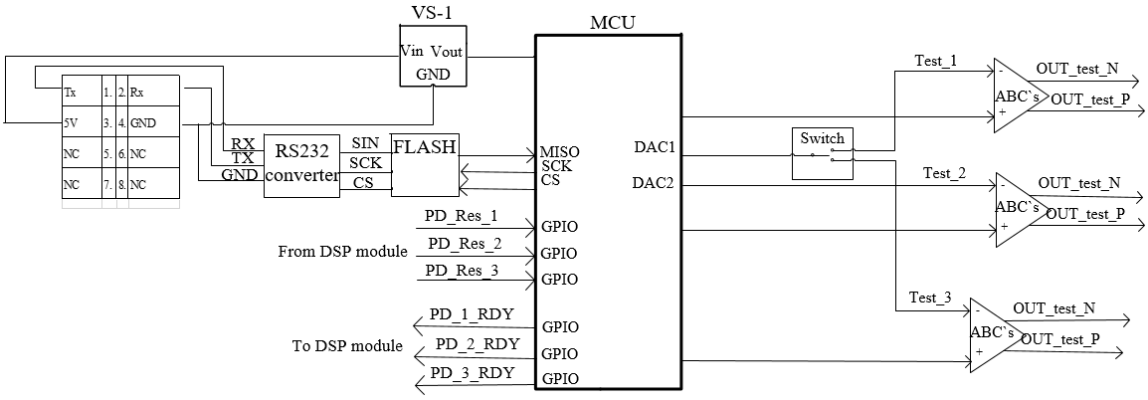

Figure 1. Simplified block diagram of the charged particles signals simulator with a circuit multiplexing of the MCU microcontroller outputs.

The second channel should manage one digital-to-analog converter (DAC), having respect to that it can work with both the first and the third detectors. The triggering of the first and third detectors simultaneously is a false combination

and is excluded from the statistical set of particle types and energies. It requires a switcher because general-purpose microcontrollers typically have two DACs. The switching time is tens of nanoseconds for a well-known CMOS switcher like the CD4066. It does not introduce significant signal propagation delays regarding the aim of the current task. At that, arrays for testing will be kept in the SPI Flash memory, firstly generated in PC. An operating from the side of a PC performs via a virtual COM-port, which is physically a USB port. To interact with the microcontroller, a logic level converter and an interface converter are added to the circuit. There are three instrumentation amplifiers in inverted configuration at the output of the module. They convert unipolar voltage to bipolar one (ABC blocks, fig. 1). Such a schematic solution is a consequent effect of the requirement of increasing interference immunity during communication between analog and digital signal processing modules.

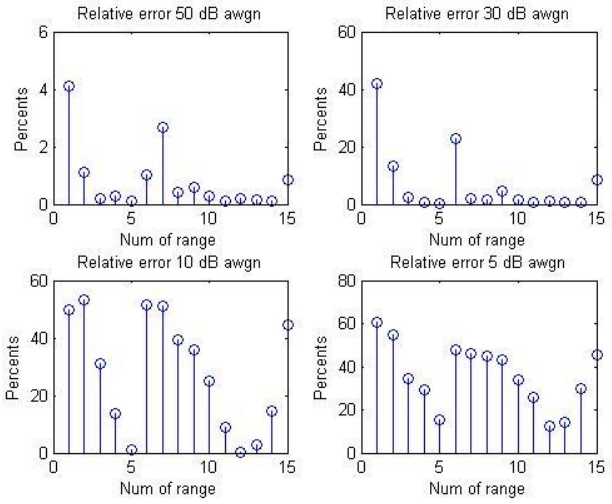

Figure 2. A relative change in the quantity of counted particles in the energy ranges in one direction (in percentage).

After signal passage across all the scheme circuits, a task arises whether particles with energies close to boundaries of "energy gates" can be interpreted as particles of other energy ranges. After the measurements, it can find the validity of the assorted particles with a certain probability or deviation from the Gaussian distribution. For example, let's add a random white Gaussian noise to the signal with a signal-to-noise ratio of 5, 10, 30, 50 dB. In such a way, we can define the particle quantity that will get to the wrong energy ranges. The simulation for the signal-to-noise ratio equals approximately 10 dB or smaller has shown that particles with energies close to the middle of the energy range also may be interpreted as units of other energy ranges (fig. 2, 3). An input test sequencing, derived from Figs. 9, 10 in [1] will be strongly distorted.

It may conclude from the sample shown in figs 2, 3, that the greater the signal-to-noise ratio, the more particle count rate in the first range (low-energy electrons) comparatively with other energy ranges. The error becomes so large at signal-to-noise ratios of 10 dB or smaller that it can raise the issue of the reliability of the digitized data.

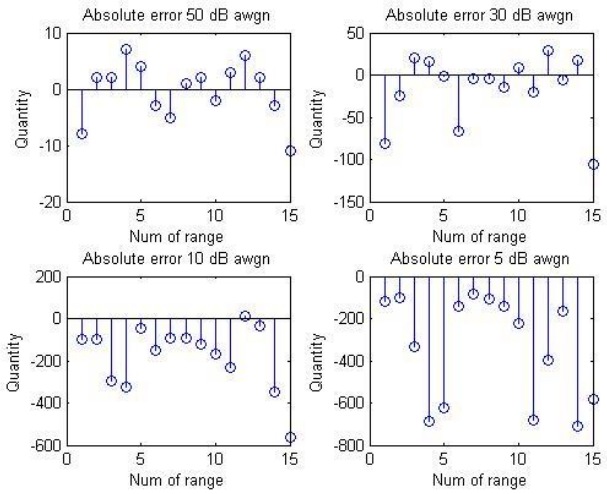

Figure 3. Variation of counted particles quantity in the energy ranges from one direction (in absolute units, the sample is 25000 particles)

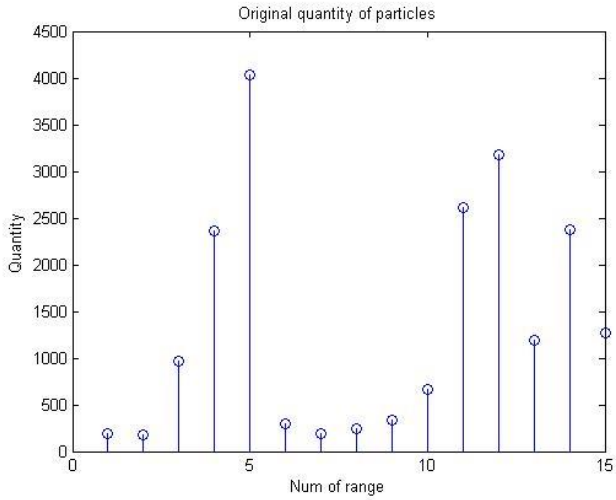

Figure 4. The number of particles in energy ranges without noise addition

References

1. J. Barylak, O.V. Dudnik, T. Woźniczak, V.O. Adamenko, R.V. Antypenko, N.V. Yezerskyi. Simulation of CubeSat caliber particle detector "MiRA_ep" response to energetic electrons and protons using GEANT4 package. Proc. SPIE, Vol. 11176. 2019. p. 111763C-1 - 111763C-10; https://doi.org/10.1117/12.2536748.

Анотація

Представлено концепцію електронного імітатора сигналів зі сцинтиляційних детекторів для заміщення системи, розміщеної у камері з джерелом іонізуючого випромінювання при випробуваннях електронних систем спектрометра-аналізатора заряджених частинок високих енергій, що проектується.

Abstract

The concept of an electronic simulator of signals derived from scintillation detectors elaborating instead of the system located in a chamber with an ionizing radiation source during testing of electronic systems of the analyzer-spectrometer of high energy charged particles presented.