

Digital signal processing in High Energy Physics

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December 15, 2015

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Modern tasks

In the modern era of hyper technical progress occurs more and more tasks which can be handled only by using robotized platform or software. To these problems we can attribute the preliminary data processing in high energy physics (HEP) and nuclear physics experiments.

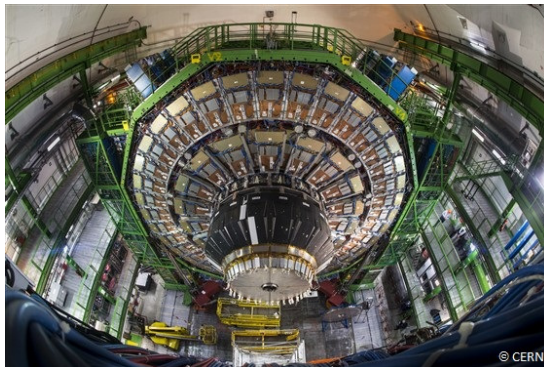


Figure : Modern detector system in HEP.

To perform the tasks set before the scientists: as quickly as possible to process the output signals from the detection device and transferred to storage devices, is necessary to develop the most optimal algorithms and create over fast electronics. A section of scientific work that deals with digital signal processing (DSP) needs to develop algorithms and methods for the high speed processing of the output signals from the electronics using a Fourier transform, convolutions, etc. Very often, there is no possibility for testing electronics with existing software for signal processing in the real detectors, so there is a need for a new type of electronics that could simulate the response of a real recording device. The subject of this presentation is the development of such device.

In experimental and applied particle physics, nuclear physics, and nuclear engineering, a particle detector, also known as a radiation detector, is a device used to detect, track, and/or identify high-energy particles, such as those produced by nuclear decay, cosmic radiation, or reactions in a particle accelerator. Modern detectors are also used as calorimeters to measure the energy of the detected radiation. They may also be used to measure other attributes such as momentum, spin, charge etc. of the particles.

Scheme of particle detectors

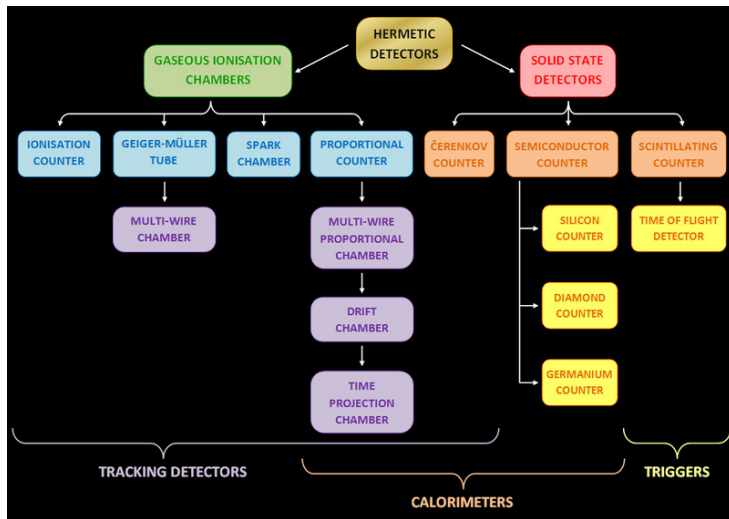


Figure : Scheme of modern particle detectors.

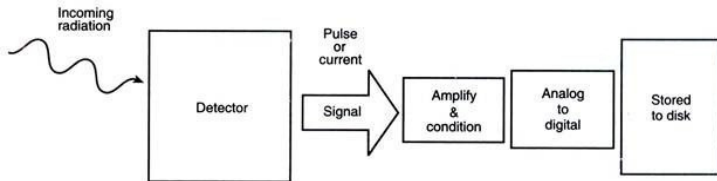


Figure : Scheme of basic radiation detector system.

Modelling of the detector response

The main goal of this DSP project is to simulate the response of the semiconductor Germanium detector. Other words to replace the chain:

Incoming radiation $\Rightarrow$ Detector $\Rightarrow$ Amplifier



A simple electronic board (maximum two)
(with the same output characteristics)

Hardware:

- 1 PC (laptop).
- 2 Signal source.
- 3 Amplifier.

Software:

- 1 Friendly GUI.
- 2 Internal software.

The main idea is the next: using microcontroller create signals which will correspond a real spectrum, then amplify the signals with using amplifier board and readout by signal analyser (counter).

Electronic block-scheme

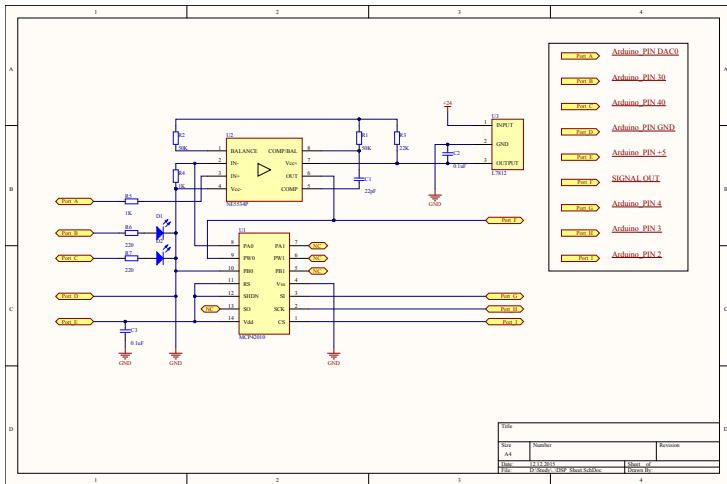


Figure : Electronic block-scheme (*AltiumDesigner [www.altium.com]*)

Hardware specification

Microcontroller

Arduino DUE. Based on a 32-bit ARM core microcontroller (Atmel SAM3X8E ARM Cortex-M3 CPU). A 84MHz clock. 2 DAC (digital to analog, 12 bit). Flash Memory 512KB. SRAM 96KB. [www.arduino.cc]

Amplifier

NE5534P. High-performance operational amplifiers combining excellent DC and AC characteristics. Unity-Gain Bandwidth 10MHz. $V_{cc\pm} = \pm 3V$ to $\pm 20V$ and $R_L = 600\ \Omega$. [www.ti.com/lit/ds/symlink/sa5534.pdf]

Digital potentiometer

MCP42010. Dual digital potentiometer. Value 10k Ω . Single supply operation (2.7V - 5.5V). 256 taps for each potentiometer. SPI interface communication. [www.microchip.com/downloads/en/DeviceDoc/11195c.pdf]

Pictures

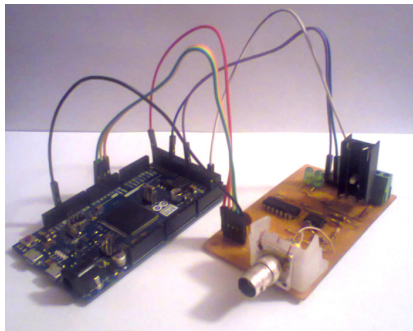


Figure : Arduino & amplifier boards.

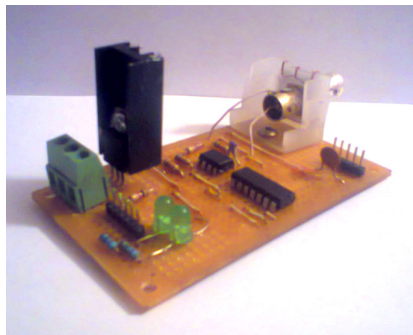


Figure : Amplifier board.

Correspondences

Channel number $\leftrightarrow$ Signal amplitude

Counts $\leftrightarrow$ Signal frequency

Signal shape

$$S(\tau) = A \times \exp(-\rho \times \tau)$$

Signal probability

The probability $P(t)$ that an event will occur at time t to $t+dt$ with no events occurring between $t = 0$ and time t is given by the exponential distribution:

$$P(t)dt = \exp(-f \times t)dt, dt \rightarrow 0$$

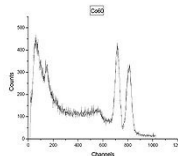


Figure : Energy spectrum of ionisation radiation.

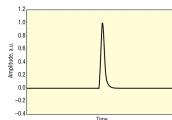


Figure : Detector signal.

Friendly GUI

Pressing the button Create Spectrum user can create spectrum with different parameters (intensity of the peaks, energy, number of channels, with/without Compton scattering etc.). Also it is possibility to adjust the probability constant and gain of the amplifier. Button Start can be used for sending the data (spectrum parameters) to the Arduino board via USB. Stop button is to stop pulses generation. All signals (spectrum) are stored on Flash memory of the Arduino board and can be read in any time.

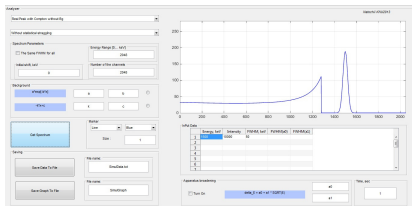


Figure : Create spectrum GUI.

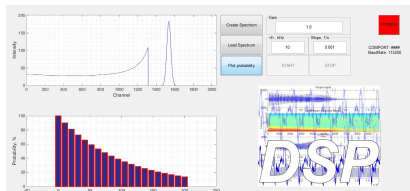


Figure : Signal generator GUI.

Conclusion

In progress of the DSP-Project was developed electronics and software for the task. The highest frequency of the pulse generator is not more than 100 *kHz*, 4096-point discrete amplitude. Unfortunately there are some problems with the output signals but the solving is in process.

Thus in future one can use the device like pulse generator for the calibration of readout electronics in HEP.

Thanks for attention!