**Preliminary processing of the signals in a nuclear physics experiment**

**1. Introduction.**

The amplitude of a signal from a detector is not sufficient, as a rule, to guarantee the properly working of the registering and analyzing devices. For example, signal amplitude from an ionization chamber or semiconductor detector is just ten to hundreds micro Volts. At the same time input dynamical range for such device as ADC (analog-to-digital-converter) is usually 0-10 V. That is why it is needed to amplify the signal in $10^2$-$10^7$ times before one will be processed and analyzed. For this preamplifier and then main amplifier are used. The principal aim for preamplifier is to force and to transform a signal from detector (for ex., see fig.1, Si multi-strip detector used in low energy nuclear physics) with the highest possible ratio signal/noise. Further amplification and shaping is performed in main amplifier which can be apart from the detector enough. Main amplifier has opportunities for amplitude, shape and pole-zero adjustments, which are especially important in the experiments aimed at the research of the properties of new nuclei. The third “prior” device suggested to consider is fast amplitude discriminator commonly used to give a logical signal for following triggering or analyzing system after the input signal exceeds some threshold.

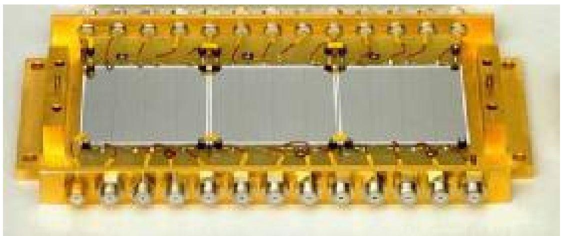

Fig.1. Position-sensitive 12-strip focal plane detector array of the Dubna gas-filled recoil separator.

**2. Principle of operation.**

When a semiconductor detector such as Si one is used for the measurement of charge particles (α, e, p, X-rays) operational amplifier mode integrators using feedback capacitance are commonly used. Because of this operation, this type of amplifier is called a “charge amplifier”. The first stage of a charge amplifier is usually a low-noise FET and its open-loop gain is set sufficiently high (≥1000) so that that the amplification is not influenced by the detector capacitance. The open-loop gain for a particle produced charge Q in a detector is given as following:

$$Q = Q_e + Q_1,$$

$$Q_e = C_e U_{in},$$

$$Q_1 = C_1(U_{in} - U_{out}),$$

$$U_{out} = kU_{in}.$$

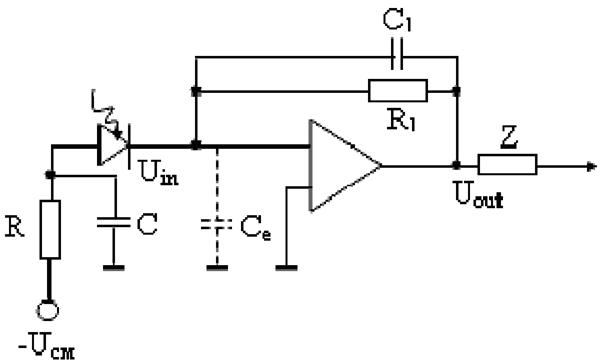


Fig.2. Simplified scheme of charge-sensitive preamplifier.

Considering according to $U_{out}$, will get $U_{out} = Q/[(C_e + C_1)/k + C_1]$.

Due to k >> 1 and $(C_e + C_1)/k << C_1$ get

$U_{out} \approx Q/ C_1$.

So, output signal amplitude is determined by a charge Q formed by an ion in the detector and the feedback capacitance $C_1$. And almost does not depend on detector capacitance.

The other characteristics (including high gain) required of charge preampl are:

• low noise

• excellent integration linearity

• high-speed rise time

• high temperature stability

The main amplifier in nuclear electronics solve the next problems:

• further signal amplification to the range 0 – 10 V

• getting better signal/noise ratio

• the pulse shaping

**3. The exercise.**

The goal of the project is to give a probationer the foundation of analog nuclear electronics and methods of the measurements and analog circuit construction in nuclear physics. Everyone can get more skill in analog module design, measurement of the parameters of the devices and applying of the devices with the radiation detectors usage. Students will get the practical knowledge in analog circuit design, PCB layout and soldering of planar chip components, modules mounting and further testing and tuning designed devices such as multi-channel charge-sensitive preamplifiers, amplifiers and fast amplitude discriminator (see fig.3), which are used in the experiments on synthesis and decay properties studying at the FLNR JINR.

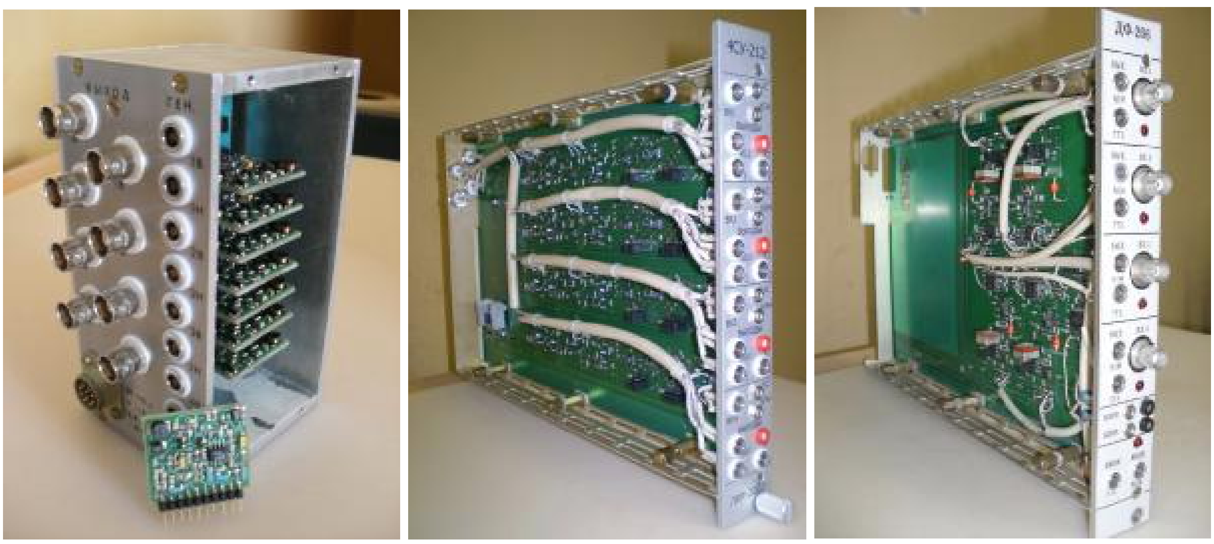

Fig.3. The 8-channel charge-sensitive preamplifier; the 4-channel spectroscopic amplifier; the 4-channel fast amplitude discriminator with common threshold level setting.

## 4. Desirable level of knowledge.

Foundations of electricity and analog circuits (desirable but not necessary).

## 5. References


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2. Radeka V; "Low-Noise Techniques in Detectors", Ann. Rev. Nucl. Part. Sci., 38, p.217, (1988).
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4. Subbotin V.G. *et al.*, Acta Physica Polonica B **34**, 2159-2162 (2003).
5. Tsyganov Yu.S. *et. al.*, Nuclear Instr.and Meth. in Phys. Res. A **525**, 213-216 (2004).


## 6. Number of students

2-4.

## 7. Head of project

Dr. Alexey Voinov, head of measuring equipment group of sector N 1 “Synthesis and decay properties of superheavy nuclei”, Flerov Laboratory of Nuclear Reactions.

Scientific interests: Synthesis and decay properties of the heaviest nuclei, nuclear electronics, charge particles detectors.

Scientific results: During last ten years we synthesized 38 new nuclides with proton numbers *Z*=104-118 and neutron numbers *N*=161-177 in the complete-fusion reactions of $^{238}$U, $^{237}$Np, $^{242,244}$Pu, $^{243}$Am, $^{245,248}$Cm, $^{249}$Bk and $^{249}$Cf targets with $^{48}$Ca beams. Six new superheavy elements 113-118 were observed for the firs time. Decay energies and lifetimes of the neutron-rich superheavy nuclei as well as their production cross sections indicate a considerable increase in the stability of nuclei with the approach to the theoretically predicted nuclear shells with *N*=184 and *Z*=114 and can be considered the experimental proof of the existence of enhanced stability in the region of superheavy elements.

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