JOINT INSTITUTE FOR NUCLEAR RESEARCH

Veksler and Baldin laboratory of High Energy Physics

FINAL REPORT ON THE SUMMER STUDENT PROGRAM

Design of dual-channel scheme spectrometric amplifier-discriminator

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Abstract

Various types of scintillators, one of which are single crystals of cesium iodide (CsI) are used for the detection of the ionizing radiation. Silicon photomultipliers (SiPM) can be used to collect light emitted per scintillation. These semiconductor devices convert light incident on them into electrical signals. The report presents the results of an eight-week work to study ways to strengthen and shaping signal, which is produced with SiPM pixels for later processing by the sampling and spectrometry.

1. Introduction

The study is aimed at the selection of the small amplitude signals from the noise and an acquisition of the required gain and the temporary output characteristics.

Preamplifiers are for amplification and shaping of various electrical signals. In what follows, we consider the signals, having a form of biexponential pulse produced with pixels SiPM (Fig. 1).

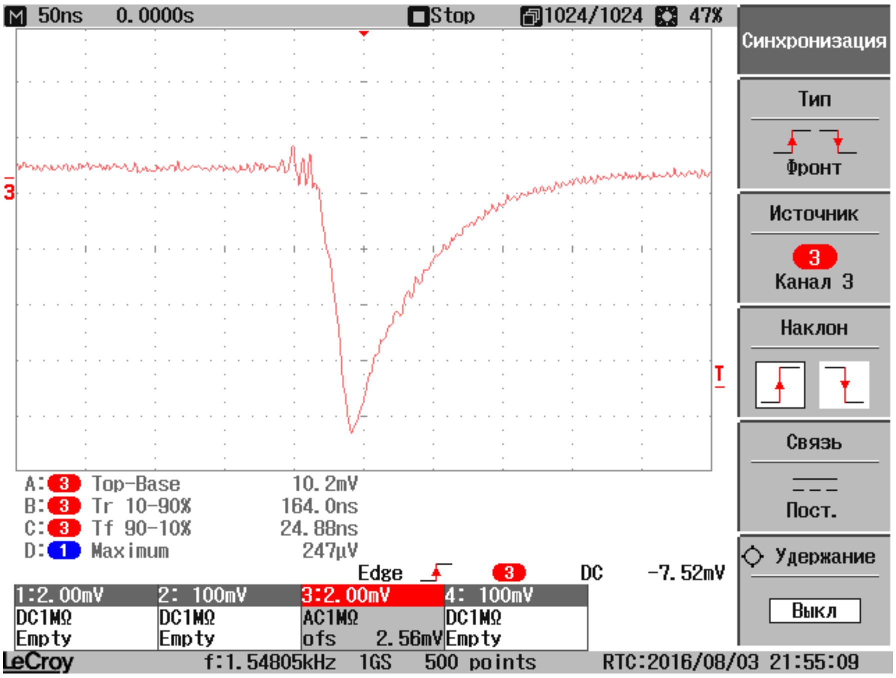

Figure 1. The biexponential impulse arbitrary amplitude

In the present work, SiPM SensL C-series 60035 are applied as a detector of the luminous flux with sensor size 6x6 mm and 35 microns' microcells size. During the experiments, light collection was performed with CsI crystal size 15x15x100 mm, as well as Lanthanum- Bromine (LnBr) of cylindrical shape and the size of 24x6 mm and 10x10x10 mm plastic scintillator with a gamma-ray source based on americium (Am).

The result of the experimental work was receiving of the circuit with sufficient sensitivity and output parameters required for further processing. In the future development of the module we plan to sample the received signal and accumulating of amplitude spectrum, as well as the control parameters of thermal stabilization of sensing elements based on the microcontroller with low power consumption and heat dissipation.

2. Circuit design

SiPM standard connection to a source of bias voltage and receiving of signal is shown in Fig. 2. The circuit R1-C1-C2 is a high-pass filter, the resistor R2 limits the current SiPM, the useful signal is taken from the resistor R3.

The voltage bias Vbias for used SiPM is 24.2-29.4 V and overvoltage up to 5 V to increase the sensitivity of pixels. [1]

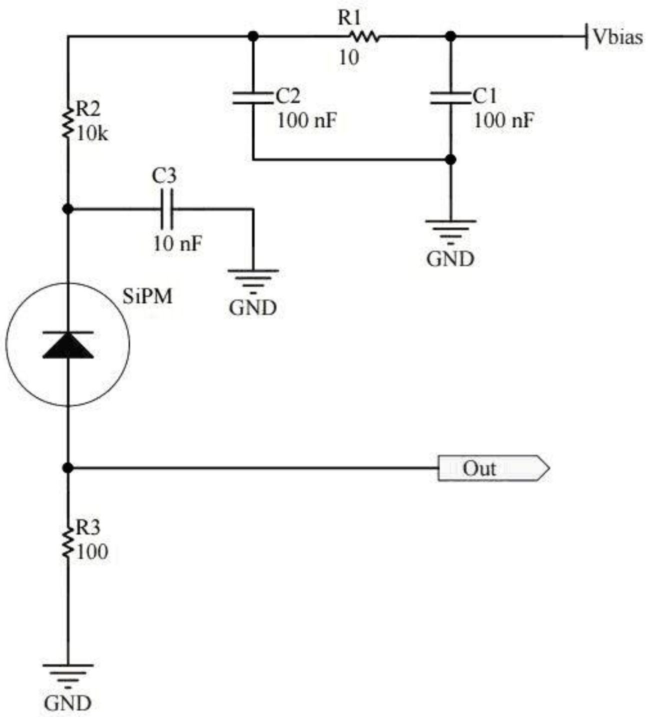

Figure 2. The applicable wiring diagram SiPM pixel

2.1. Amplification path

In a preamplifier, the scheme with the normally inverting charge sensitive amplifier has been selected. It was built on the basis of an operational amplifier with a capacitor of low capacitance in the feedback path and pull to the ground non-inverting input (Fig. 3). To ensure the required slew rate and separation of the useful signal, the fast (1.6 GHz), low-noise, FET-input operational amplifier OPA657[2] were used.

Resistor R2 is paired with a capacitor C2 forming the elementary integrator, that is needed for the formation of a sufficient slew rate of the forward front for subsequent signal processing. R2-R3 form a feedback path of the defining gain.

The capacitor C4 is a high-pass filter and is it used for remove DC component in the input. Chain C3-R7-C4 and C5-R8-C6 are lower frequency filters and arranged on the board as close as possible to the amplifier to remove spurious noise affecting the circuit board paths.

Resistor R4 by the same way as the resistors R5-R6 for matching is loaded when The detector elements of 50-phm coaxial cable is connecting.

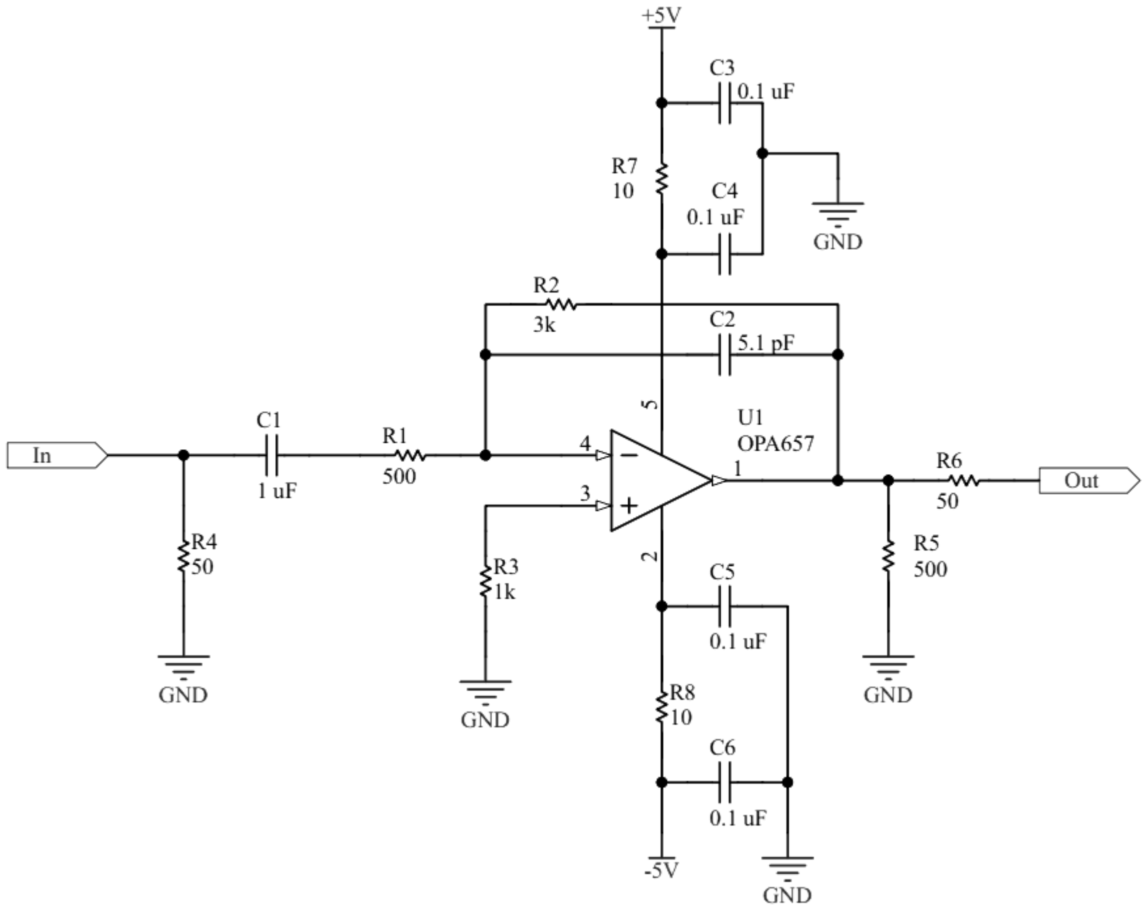

Figure 3. Amplification path based on the OPA657 op amp

The gain of the amplification path K is determined by based on the ratio of resistors:

$$K = \frac{R_2}{R_1}.$$

The values of feedback resistors path are selected in such a way as to ensure $K \approx 6$ and the time constant of the integrating circuit of the same order with the signal rising time from the pixel SiPM (about 10 ns) $\tau = 3 \times 10^3 \times 5.1 \times 10^{-12} =$ 15.3 ns.

2.2. Power supply

To supply SiPM and operational amplifiers, the following power system has been chosen, as it is in Figures 4-7. In the scheme of power SiPM, the multi-trimmer R40 is applied for the possibility the bias voltage regulation and correspondingly the sensitivity SiPM.

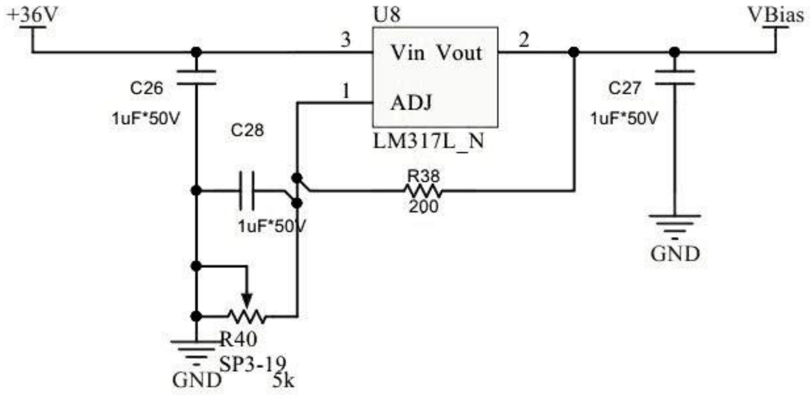

Figure 4. Stabilizer bias power SiPM

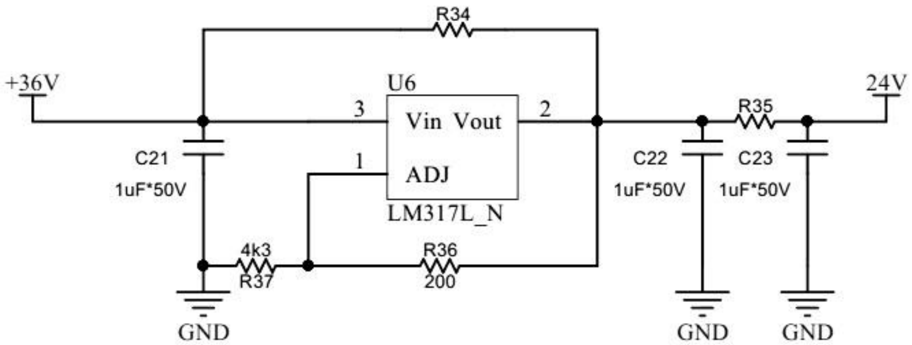

Figure 5. Voltage stabilizer 36V to 25V

Resistors R36-R37 are selected according to the calculation [3]:

$$V_{out} = 1.25 \times \left(1 + \frac{R36}{R37}\right) + I_{adj}(R2)$$

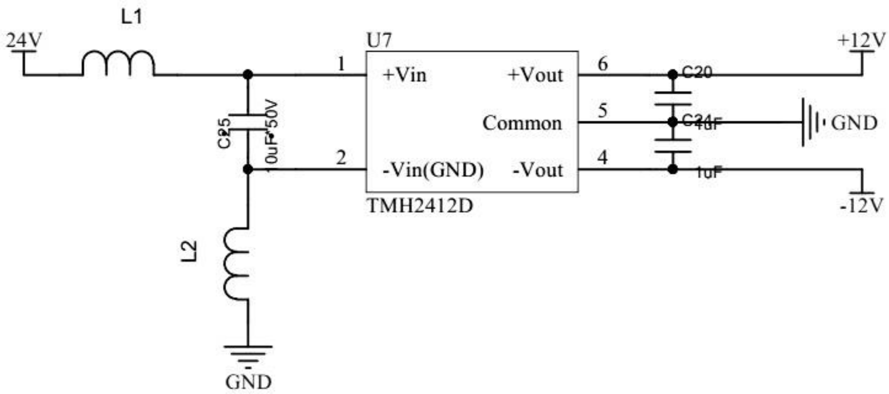

Figure 6. Step-down converter 24V to ± 12V

The unipolar voltage bipolar convertor (Fig. 6) is required to power operational amplifiers for operation the signals on both positive and negative values. Subsequently, the same scheme can be applied to a differential amplifier output.

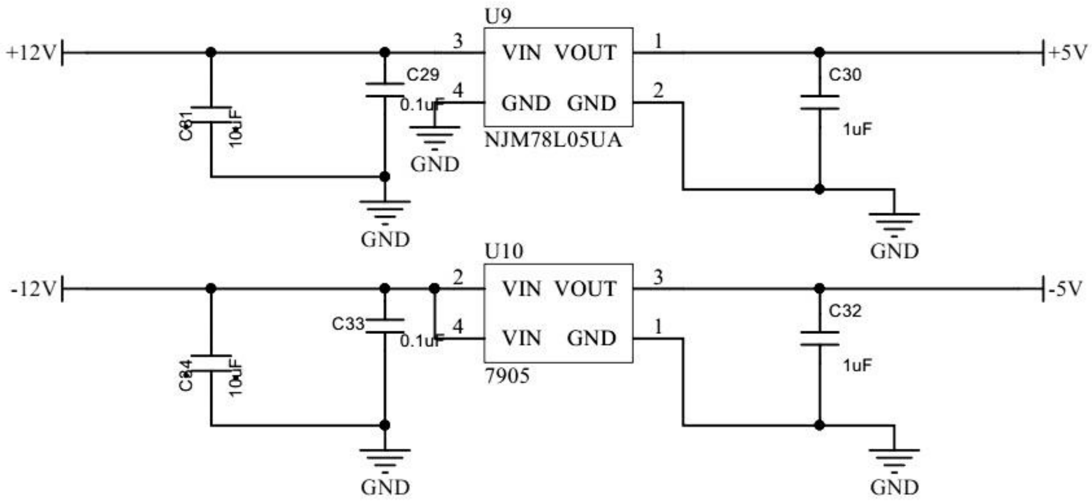

Figure 7. The stabilizer of ± 5V to power operational amplifiers

3. Test results

In the original version of the amplifier circuit supposed an absence of the resistor R1 in feedback path. If the circuit tests on different scintillators the following waveforms are obtained:

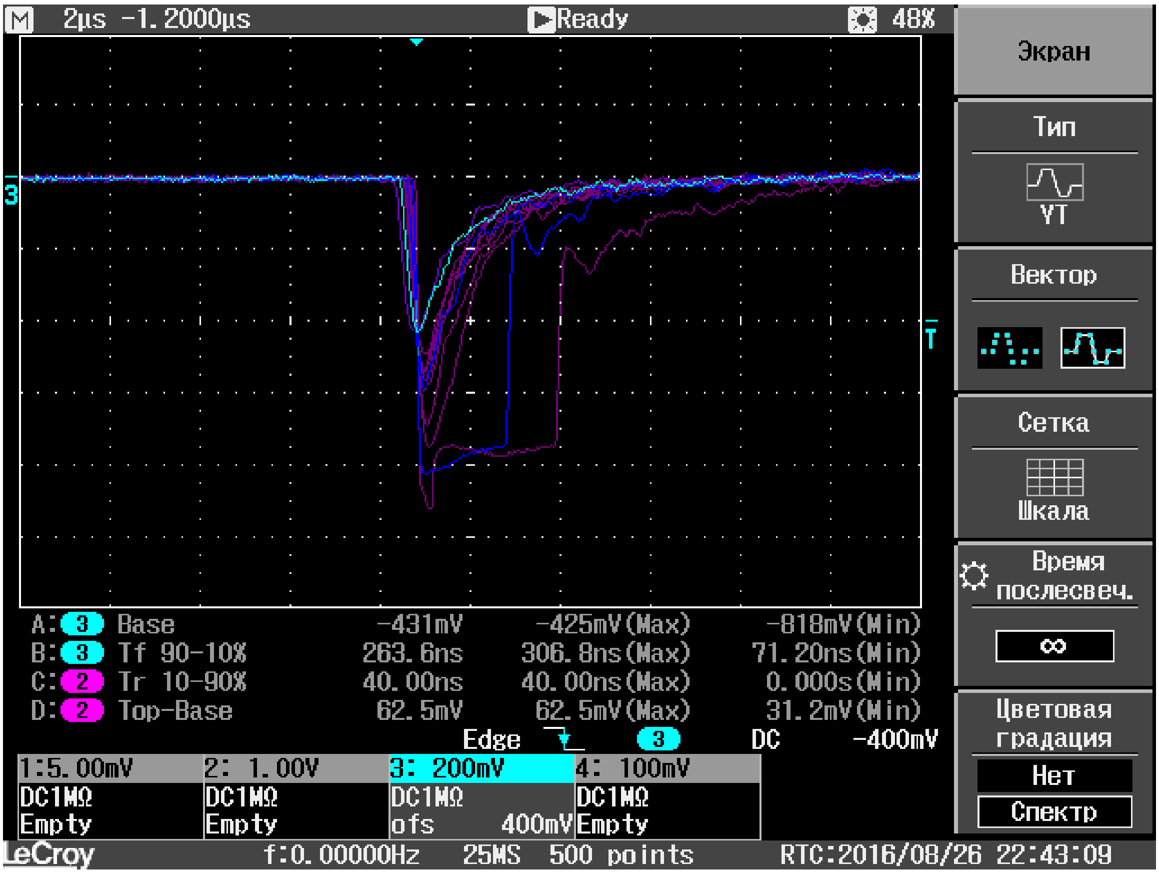

Figure 8. The output of the amplifier signal to the OPA657 in the CsI crystal signal

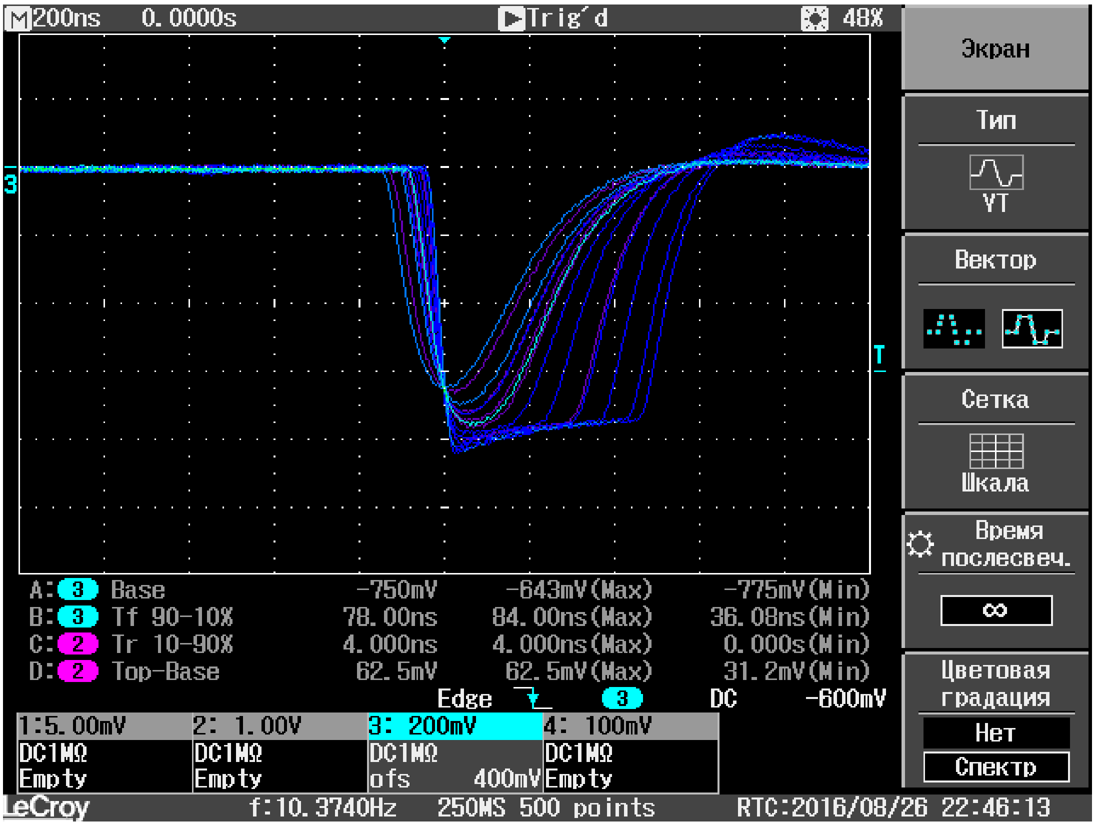

Figure 9. The output of the amplifier OPA657 a crystal on LnBr

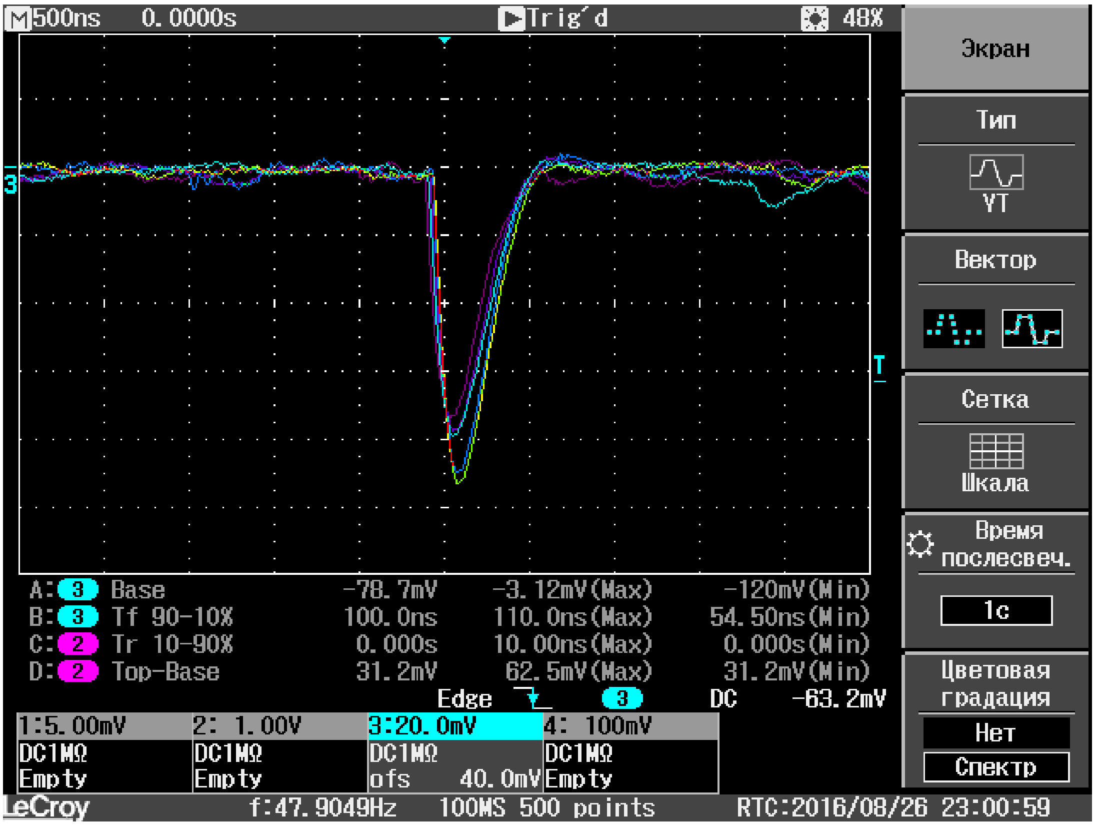

Figure 10. The output of the amplifier OPA657 on a plastic scintillator with the radiation source on the basis of americium

In accordance with Figures 8-9 which are shown that at the large input pulse amplifier reaches the saturation, we decided to install resistors R2 = 1.78 ohms and R1 = 500 ohms. waveforms were obtained on the scintillator LnBr:

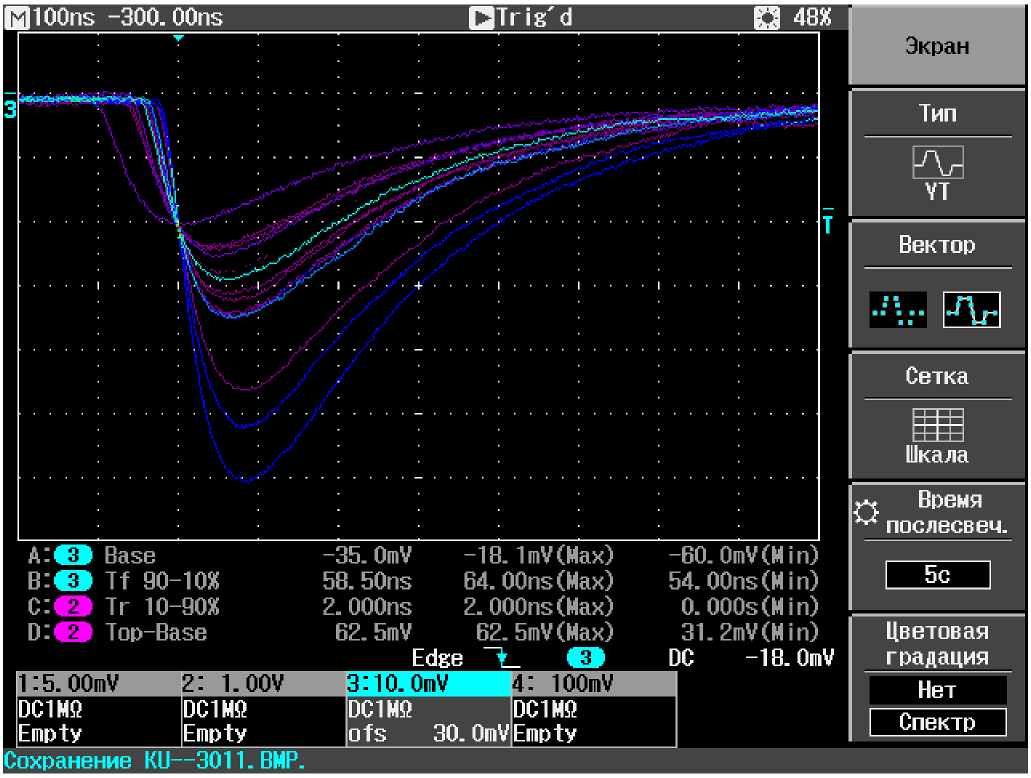

Figure 11. The output of the amplifier with a gain K≈3

During experiments with different denominations, the obtained feedback circuit elements having optimum characteristics of signal are presented in Figure 3.

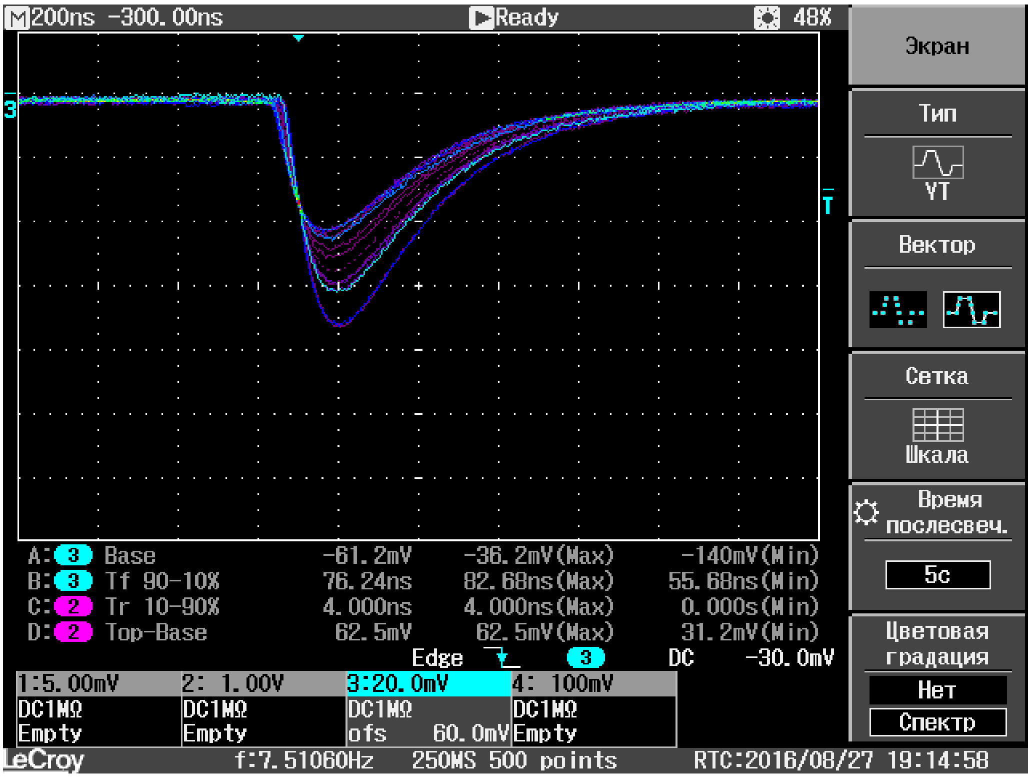

Figure 11. The output of the amplifier of the final version

Also this amplifier has been tested a part of the spectrometric channel when a the crystal scintillator CsI, and Cobalt-60 source as γ-quantum. The received is a magnitude spectrum (Fig. 12) with two distinct peaks corresponding to energies 1173,24 keV and 1332.5 keV, characteristic for Co-60 [4].

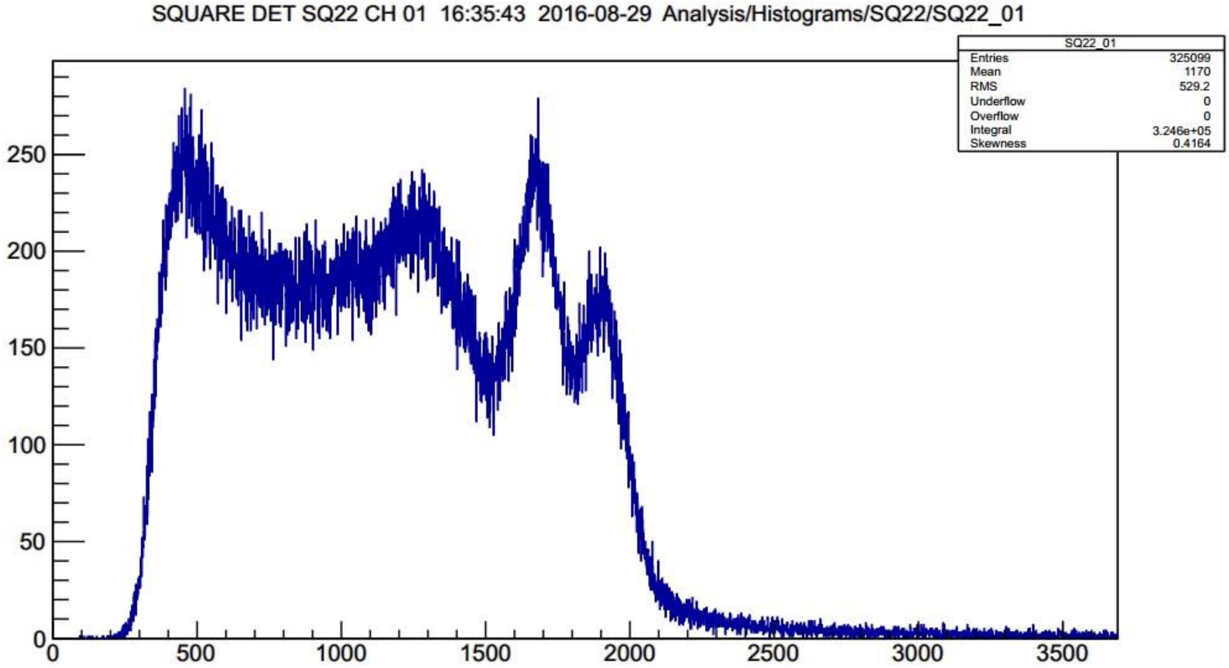

Figure 12. The energy spectrum of Cobalt-60, obtained by using the designed circuit as the preamplifier in the composition of spectrometric channel

In pulse mode, the accumulation was measured of the power characteristic of cesium-137. There is the visible peak on the waveform corresponding to the energy of 662 keV[4](Fig. 13)

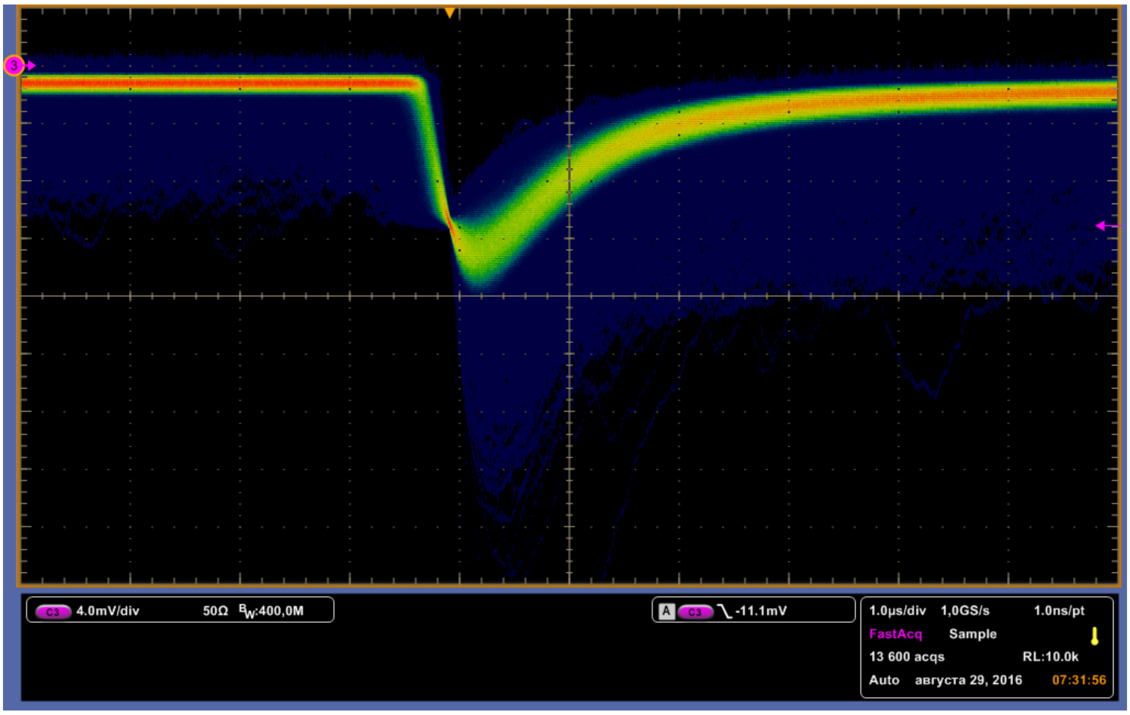

Figure 13. The energy characteristic of Cesium-137

Dark current level measurements have shown that it is within the allowable level, there is no any significant significant effect on the determination of the amplitude spectrum.

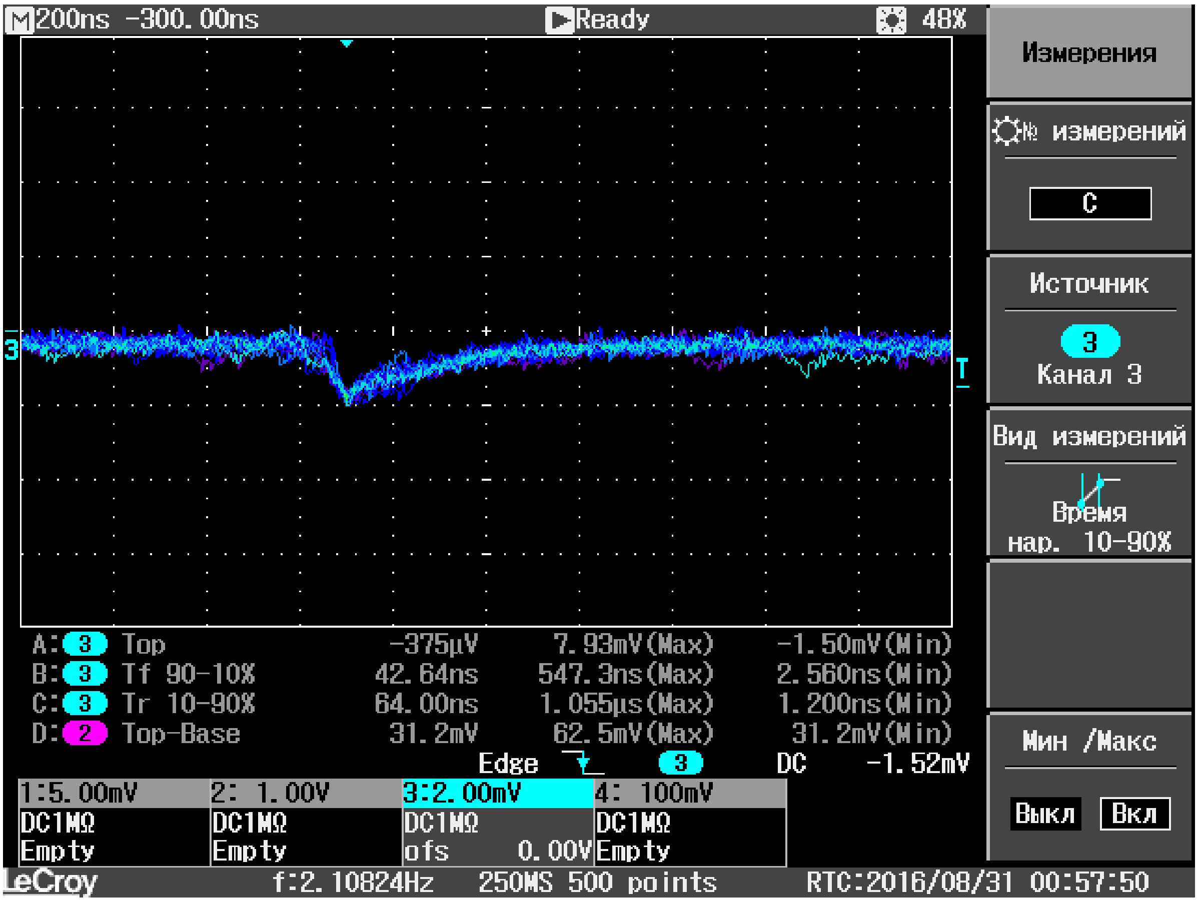

Figure 14. SiPM dark current after passing the path of the amplifier.

4. Summary

According to the results of this work, it was designed and debugged spectrometric amplifier circuit. These time and amplitude characteristics suggest the possibility of using of this scheme as a pre-amplifier in the particle detection systems with a some work - in the future, it is necessary explore the different variants for powering SiPM, we will also investigate the circuit of the output stages of the amplifier to the load on the twisted pair cable.

The next step will be to developing of the microcontroller received signal processing systems and the thermal stabilization control.

References

[1] Documentation of SensL C-Series Family: http://sensl.com/products/c-series/

[2] Documentation of OPA657: http://www.ti.com/product/opa657

[3] Documentation of LM317L-N: http://www.ti.com/product/LM317L-N

[4] HyperPhysics, Georgia State University: http://hyperphysics.phy-astr.gsu.edu/hbase/hframe