The XXVI International Scientific Conference of Young Scientists and Specialists
(AYSS-2022)

Development of the JINR CSA-1 charge-sensitive preamplifier and comparison with the CANBERRA model 2018EB preamplifier in terms of its main characteristics

Head of research group

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Scientific adviser

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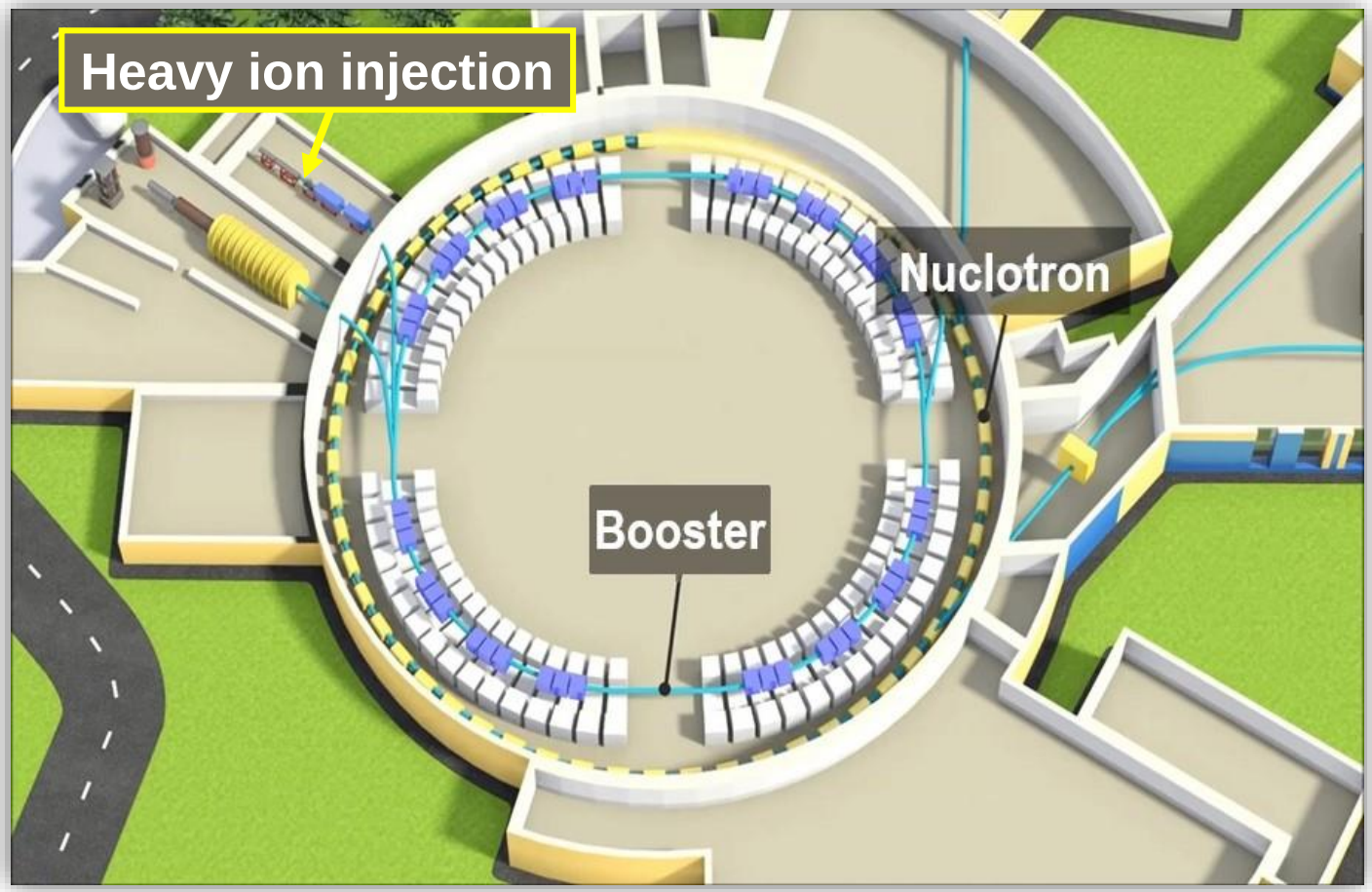
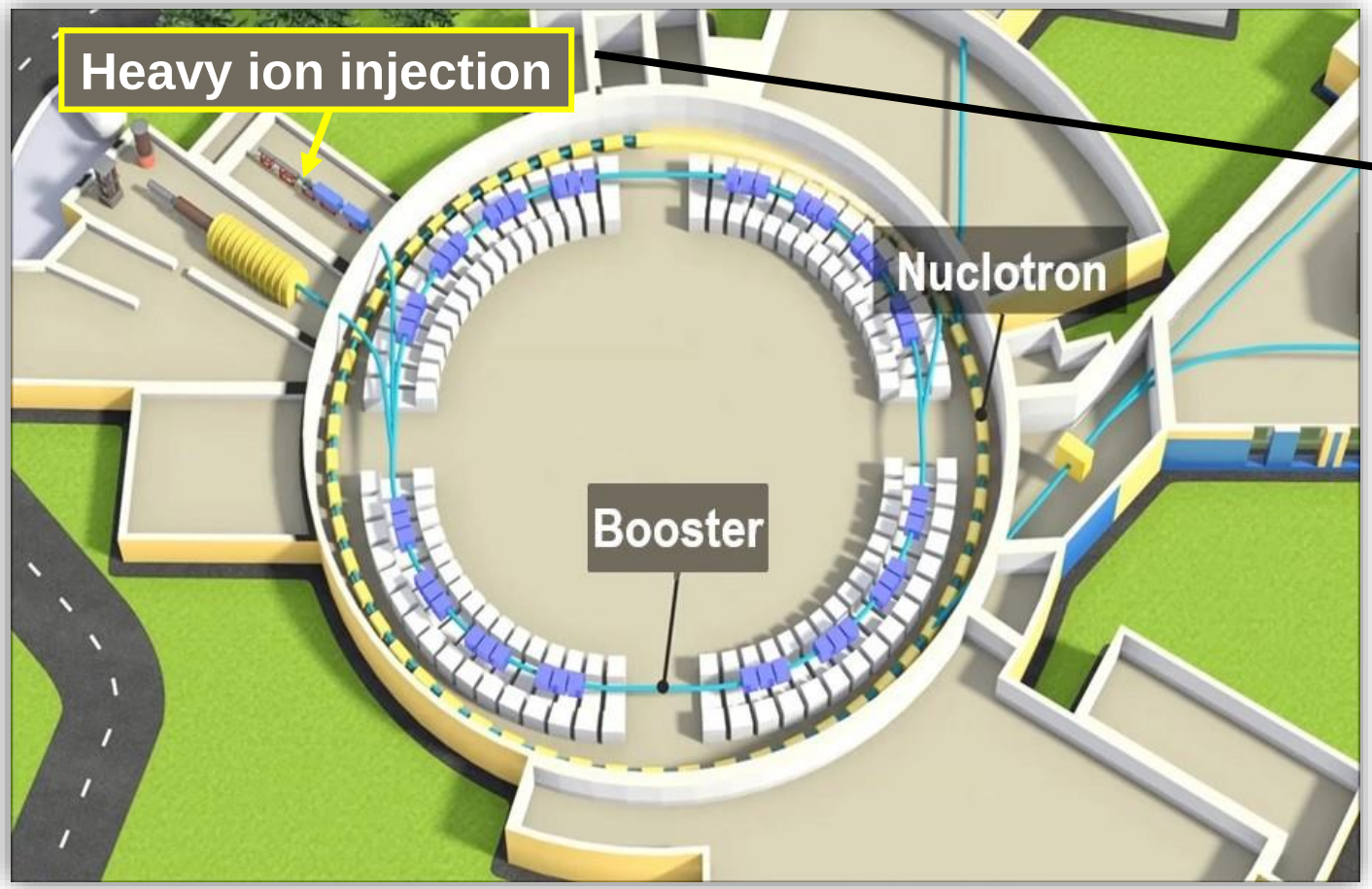
Dubna, 24-28 October 2022

NICA injection complex



NICA injection complex



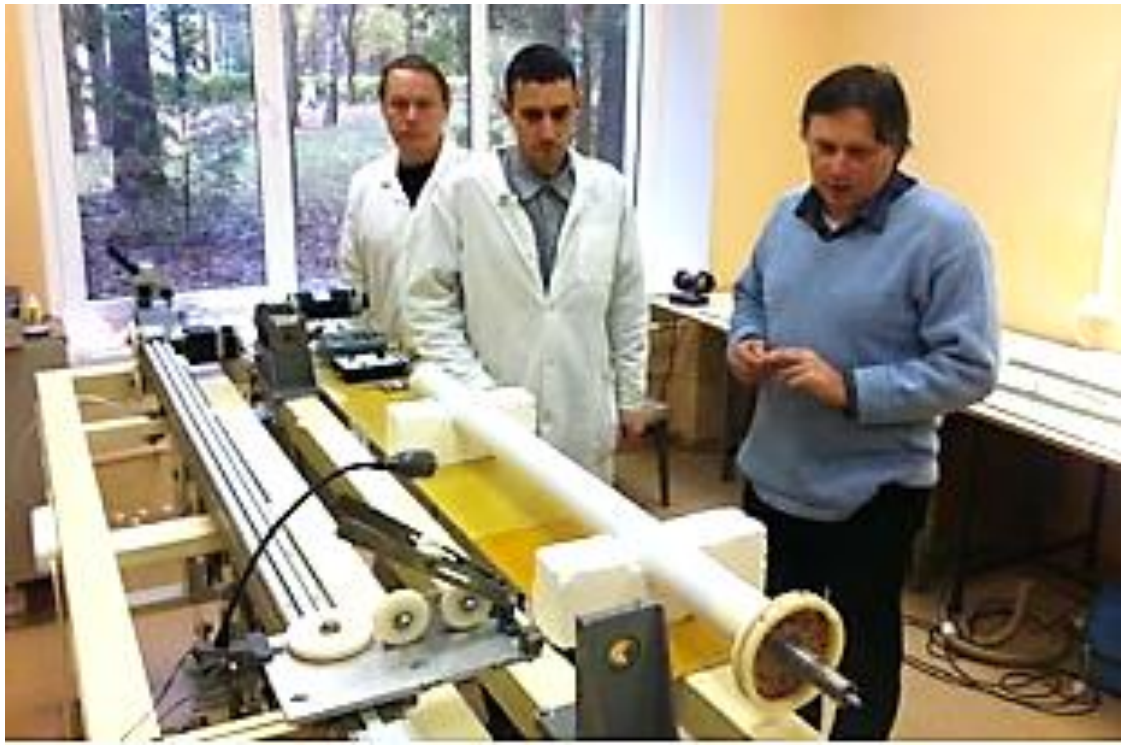
Heavy ion source KRION 6T

Ions produced and injected:

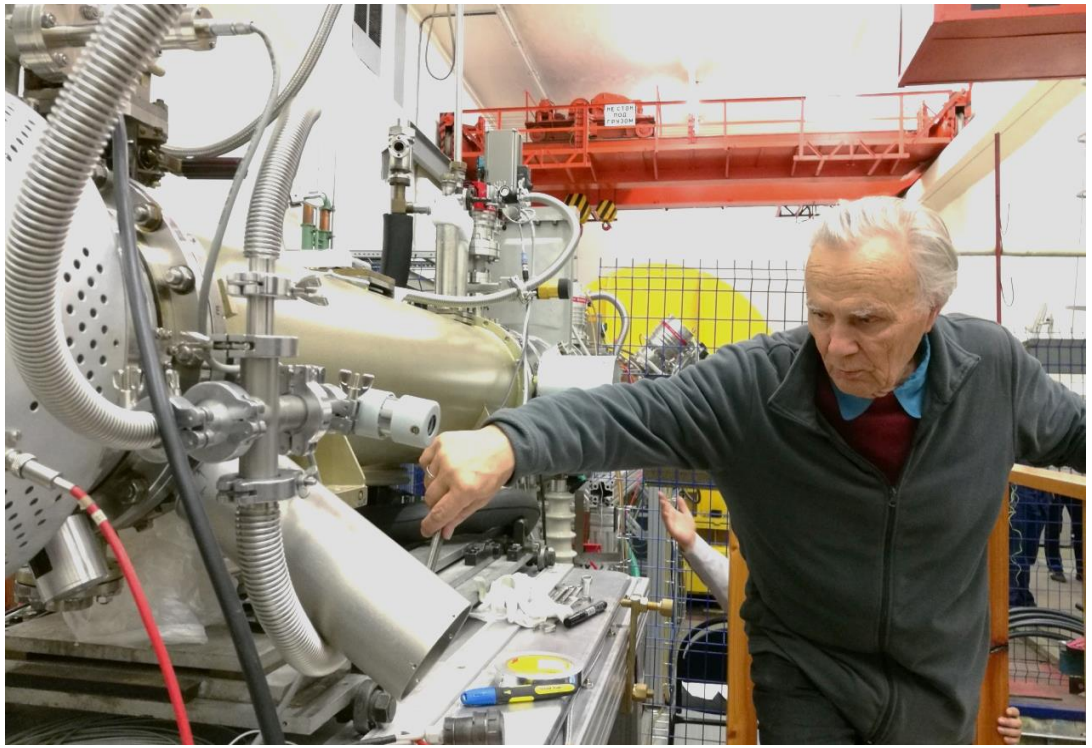
$^{78}Kr^{17+}$ $^{40}Ar^{16+}$

$^{124}Xe^{41+}$ $^{12}C^{6+}$

NICA injection complex

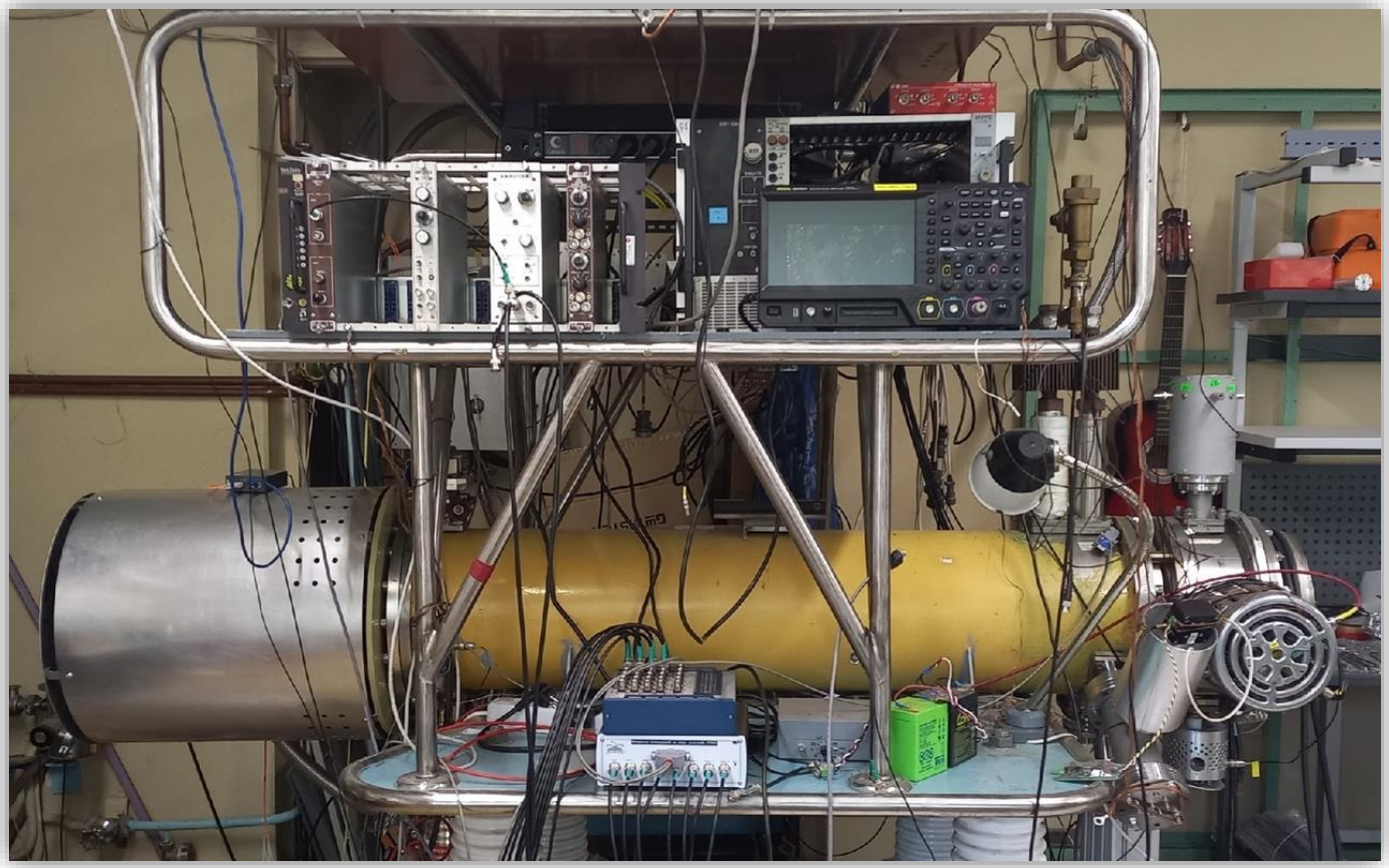


6T solenoid fabrication, 2012



Prof. E.D. Donets near Krion-6T ESIS, 2018

NICA injection complex



Krion-2M ESIS, 2022

KRION was invented by prof. E.D. Donets at JINR, Dubna, in 1968.

1970-1985, Dubna, cryogenic version of EBIS KRION-1,2, bare ions C, N, O, Ne, Ar, Kr, Xe.

Purpose and objectives

Purpose:

- To develop the charge-sensitive preamplifier for the alpha spectrometry investigations – JINR CSA-1;
- To calibrate and compare main parameters with the CANBERRA Model 2018EBTM.

Objectives:

- To develop a circuit for a charge-sensitive preamplifier JINR CSA-1, use modeling the operation of the device;
- To calibrate the CANBERRA Model 2018EBTM preamplifier and JINR CSA-1, determine their gain and noise;
- To compare JINR CSA-1 with the CANBERRA model 2018EB preamplifier in terms of its main characteristics.

The main requirements for the CSP

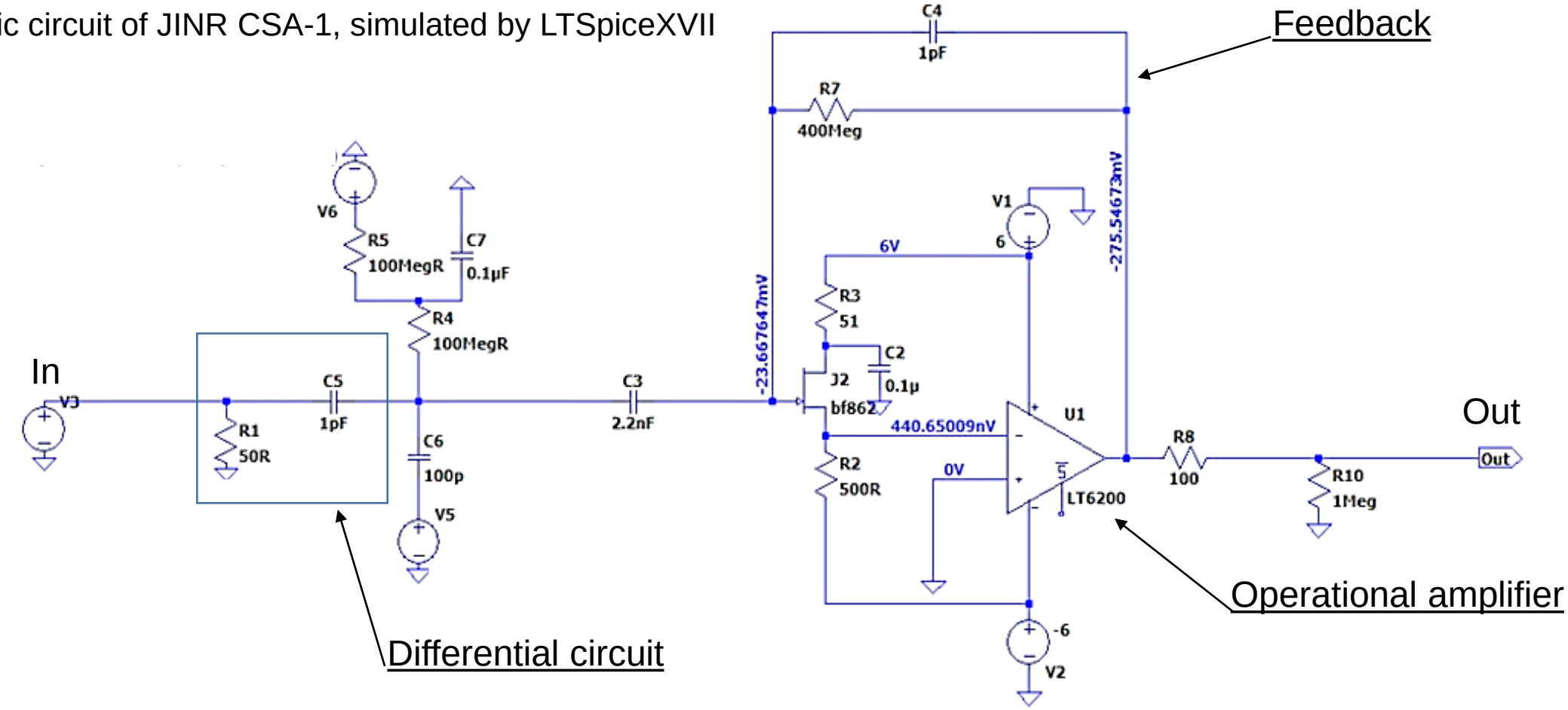
The main requirements for the charge-sensitive preamplifiers are:

- optimal gain;
- low equivalent noise charge;
- stability of parameters in the operating temperature range;
- matching the bandwidth of the preamplifier to the signal spectrum;
- optimal price-quality ratio for the task.

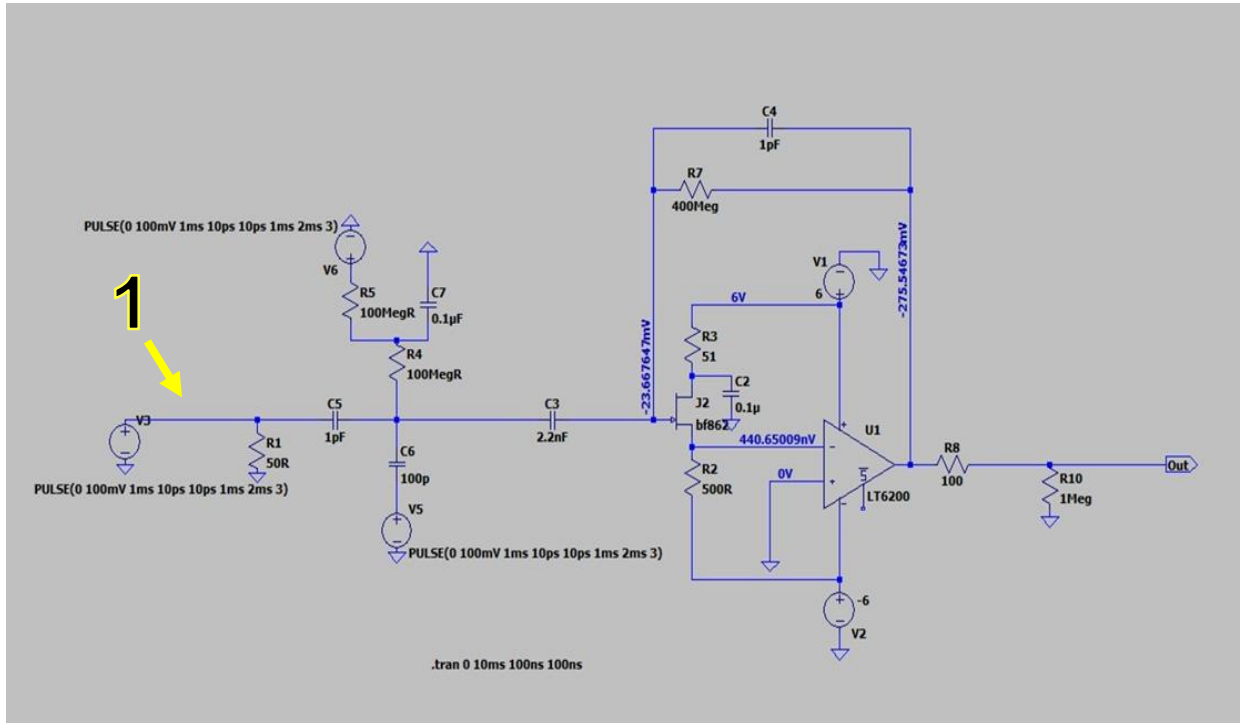
The main parameter of preamplifiers in the spectrometry tract is maximization the signal-to-noise ratio (the ratio of the most probable signal amplitude to the standard deviation of the noise).

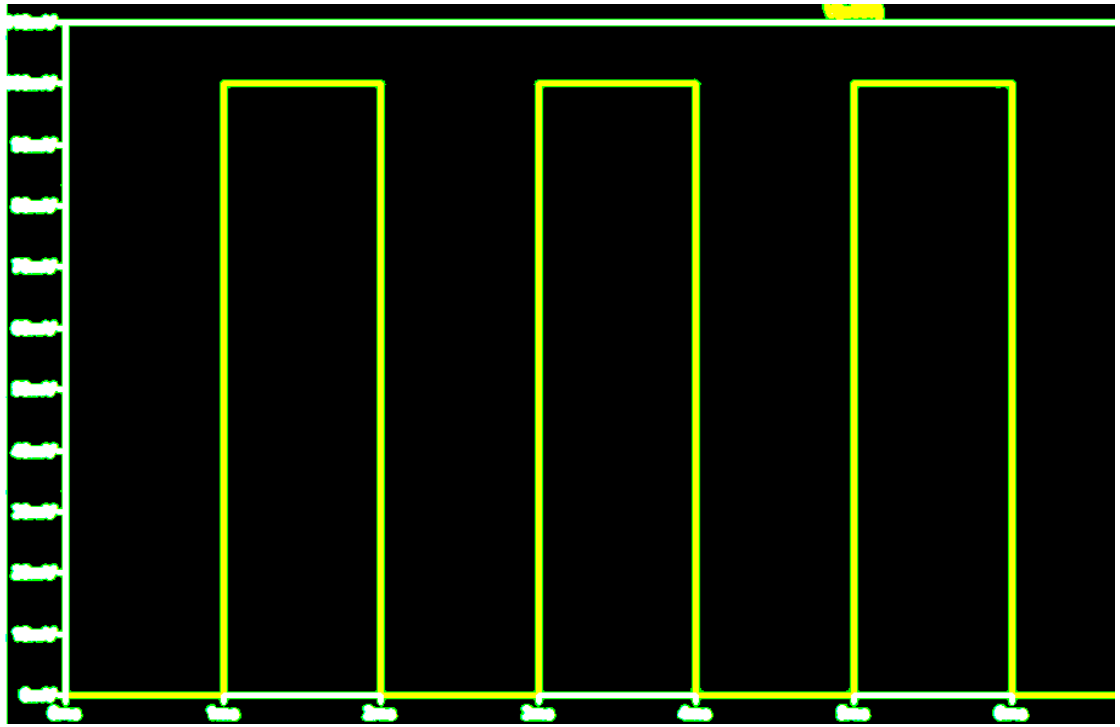
Modeling JINR CSA-1

Electric circuit of JINR CSA-1, simulated by LTSpiceXVII



Modeling JINR CSA-1

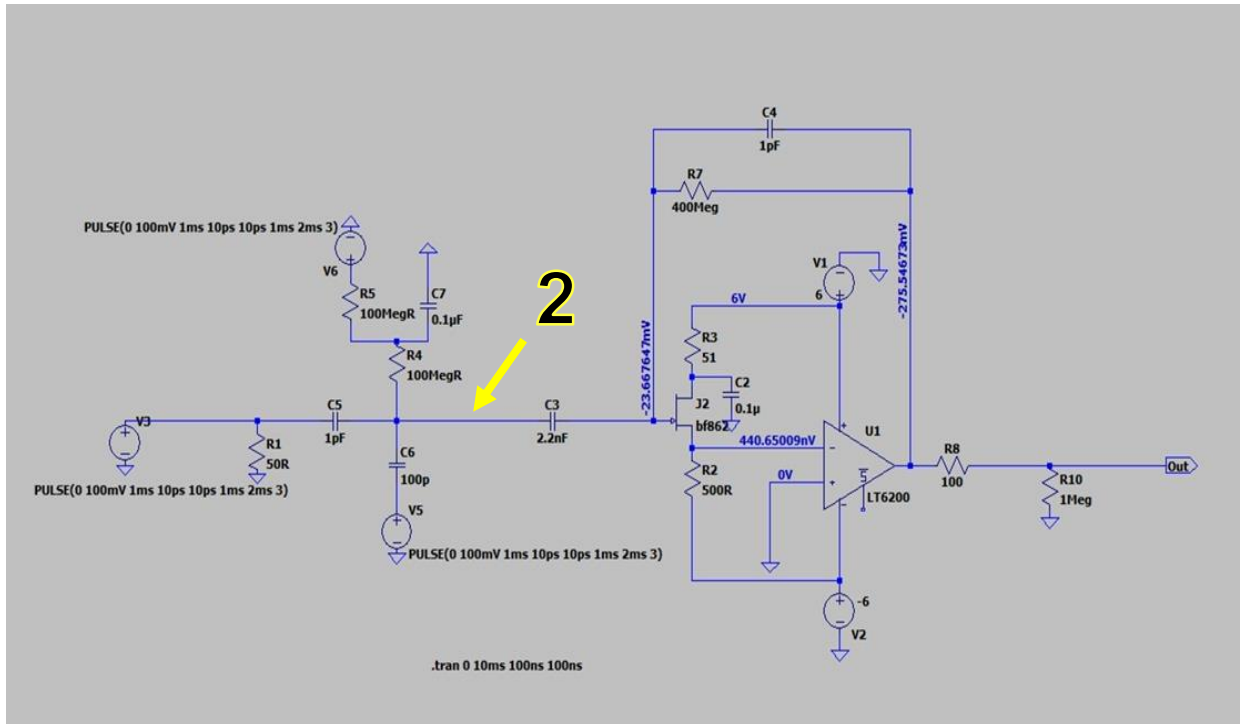




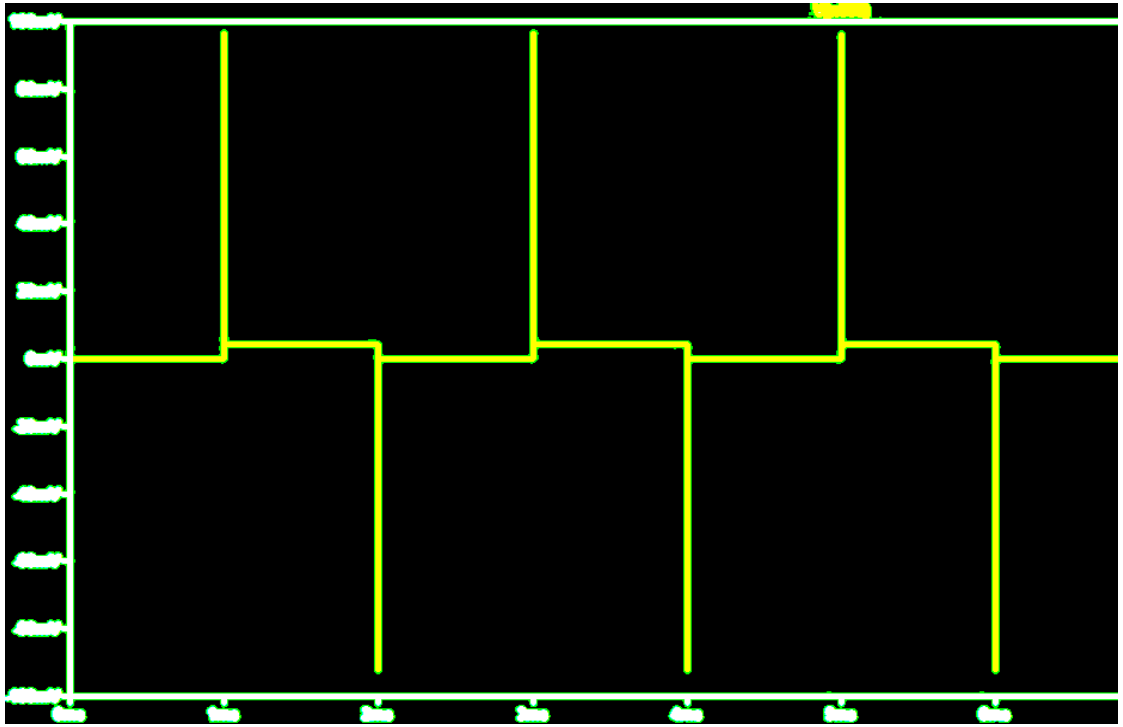
Electric circuit of JINR CSA-1, simulated by LTSpiceXVII

1 — pulses from the generator

Modeling JINR CSA-1

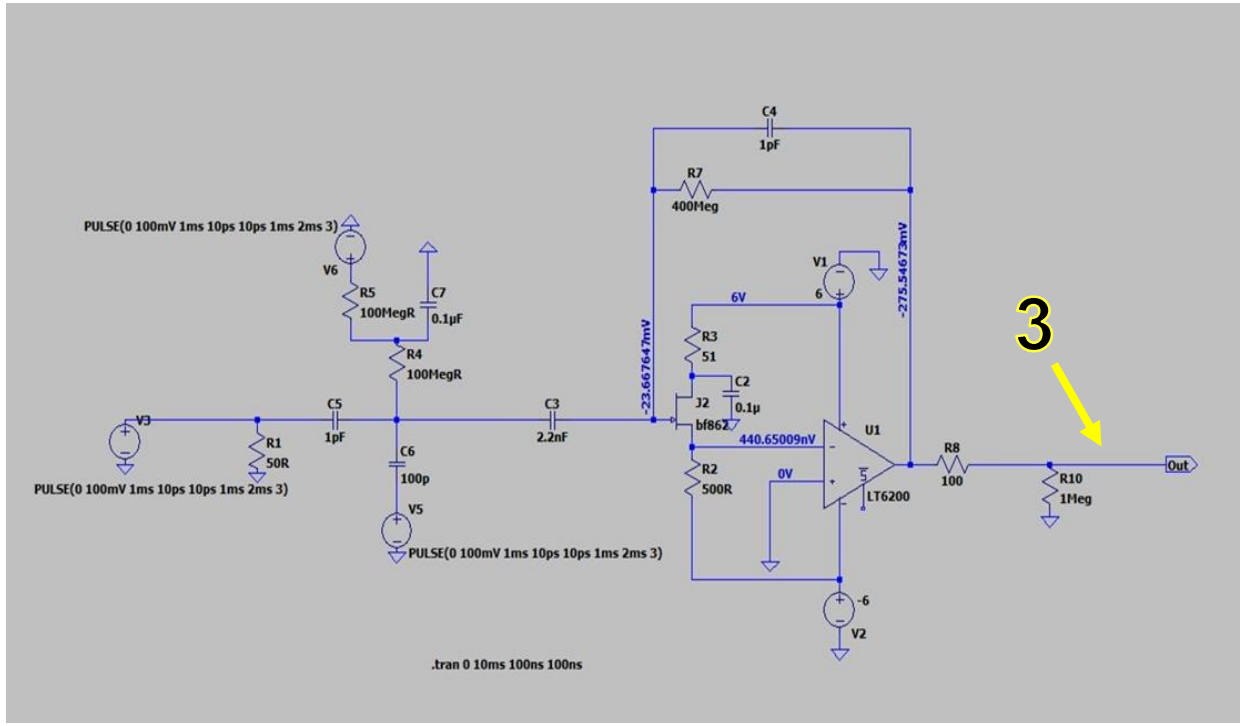


Electric circuit of JINR CSA-1, simulated by LTSpiceXVII

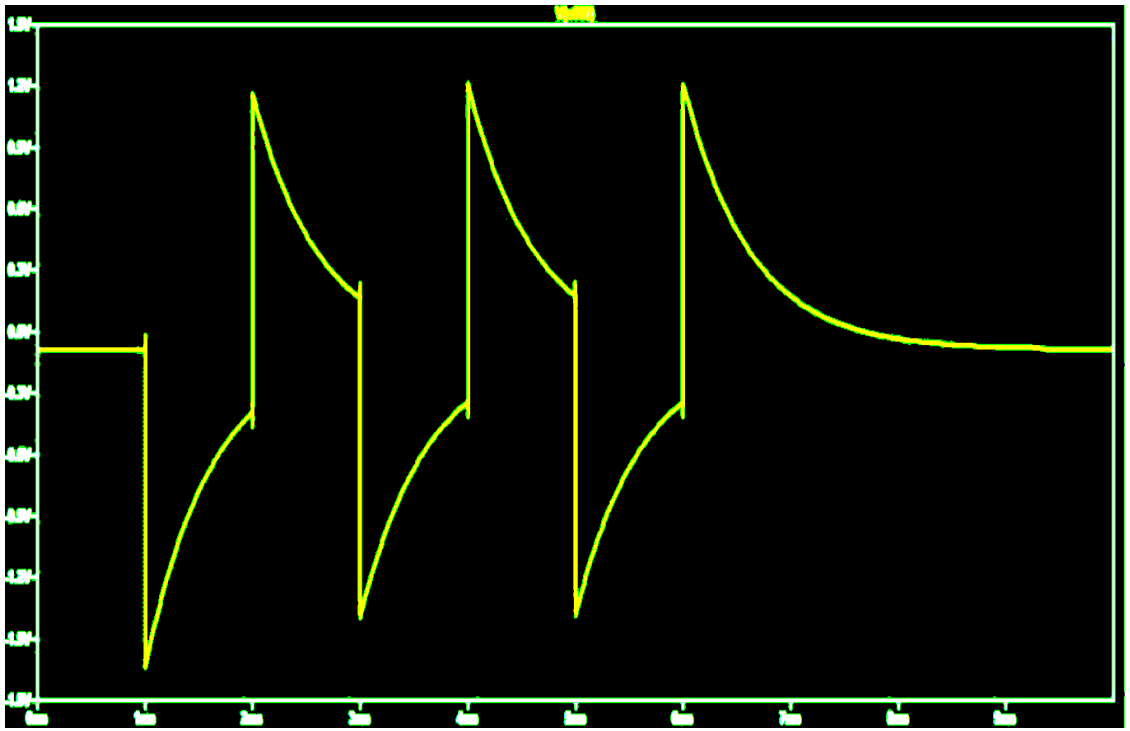


2 — differentiated signal on the input of the operational amplifier

Modeling JINR CSA-1



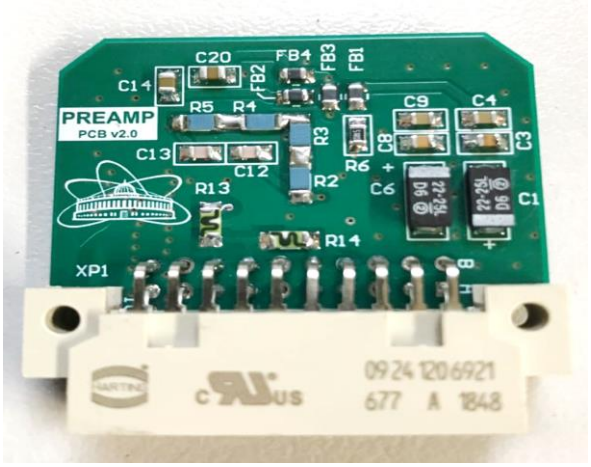
Electric circuit of JINR CSA-1, simulated by LTSpiceXVII



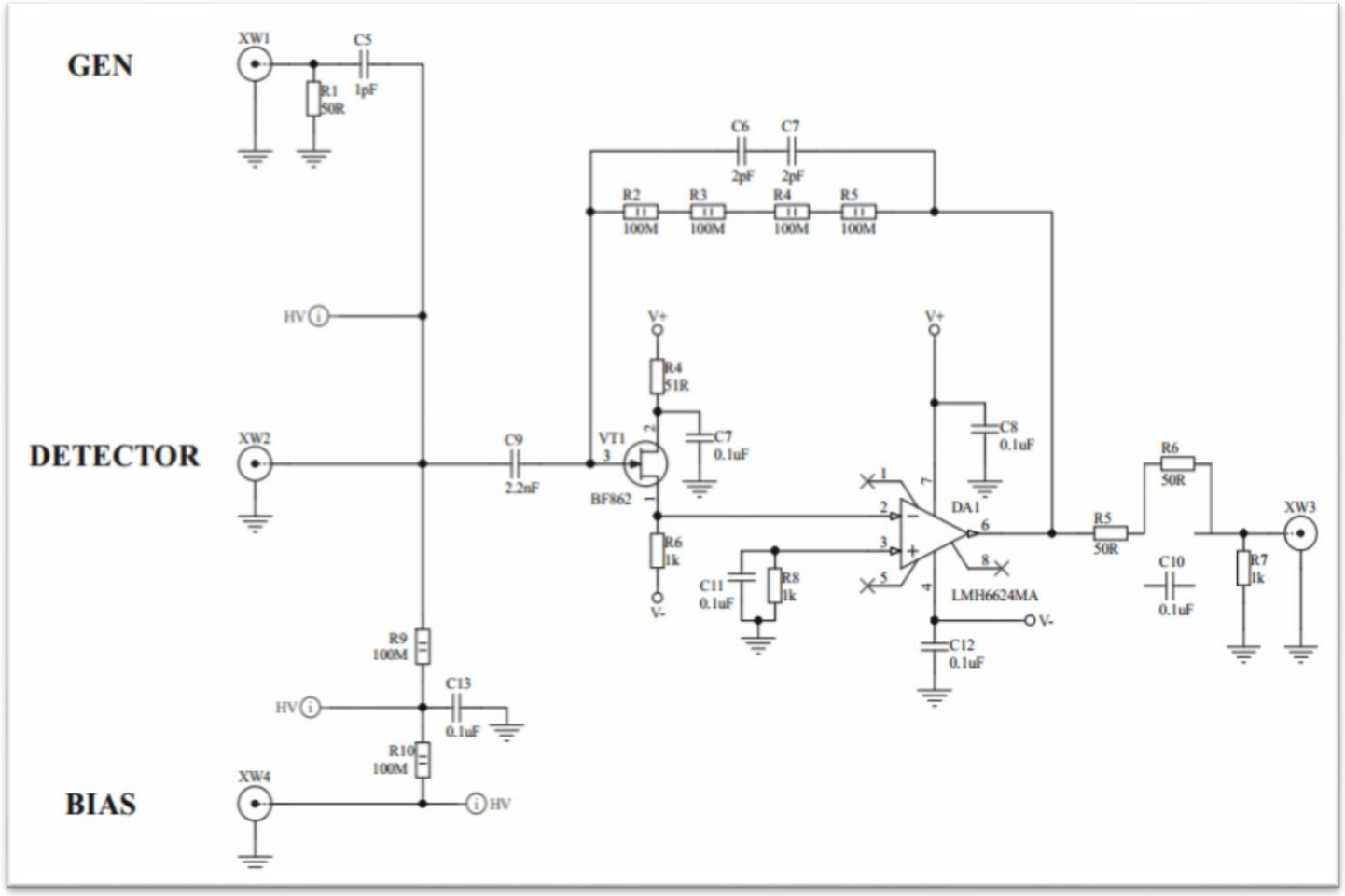
3 — output signal from the preamplifier on the output of the operational amplifier

Charge-sensitive preamplifiers

Preamplifier CANBERRA Model 2018EB

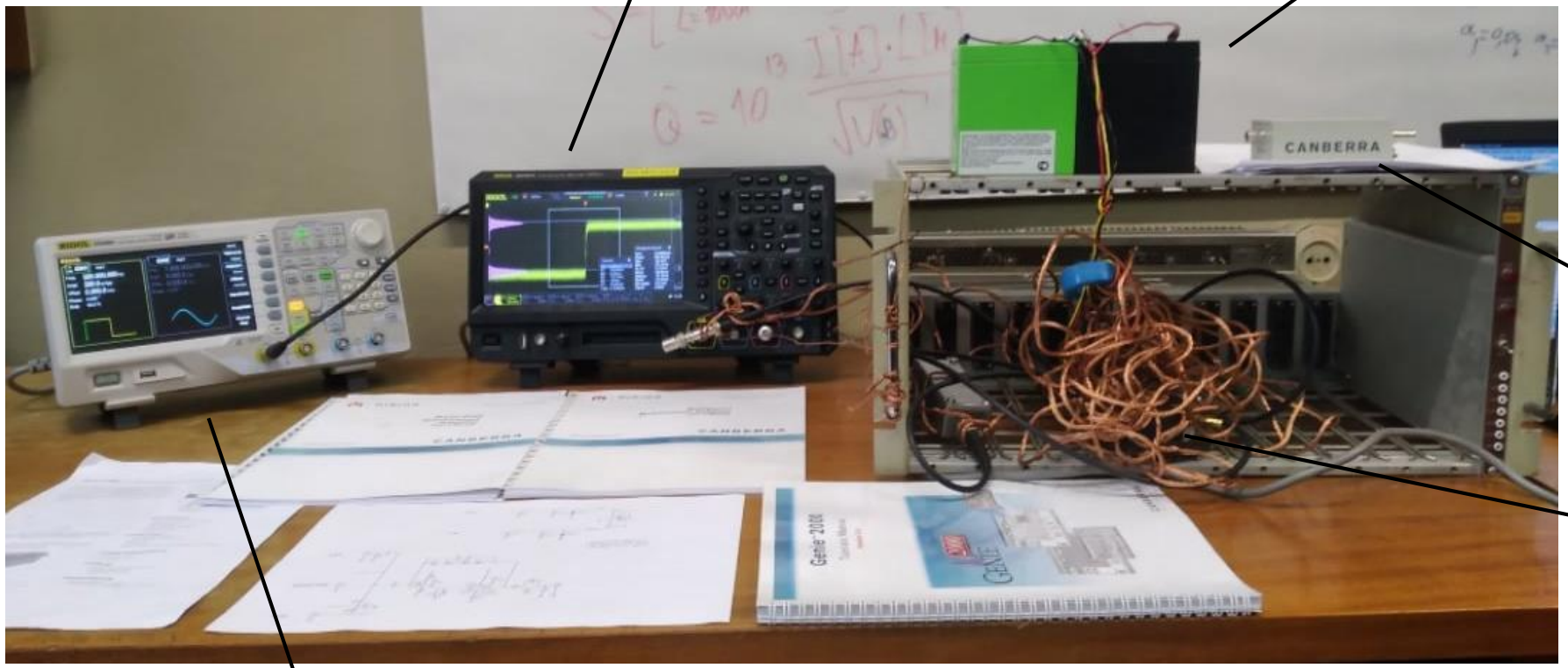


Preamplifier JINR CSA-1



Preamplifier Functional Diagram JINR CSA-1

Preamplifier calibration principle



oscilloscope Rigol MS5074

batteries Delta DT 1207

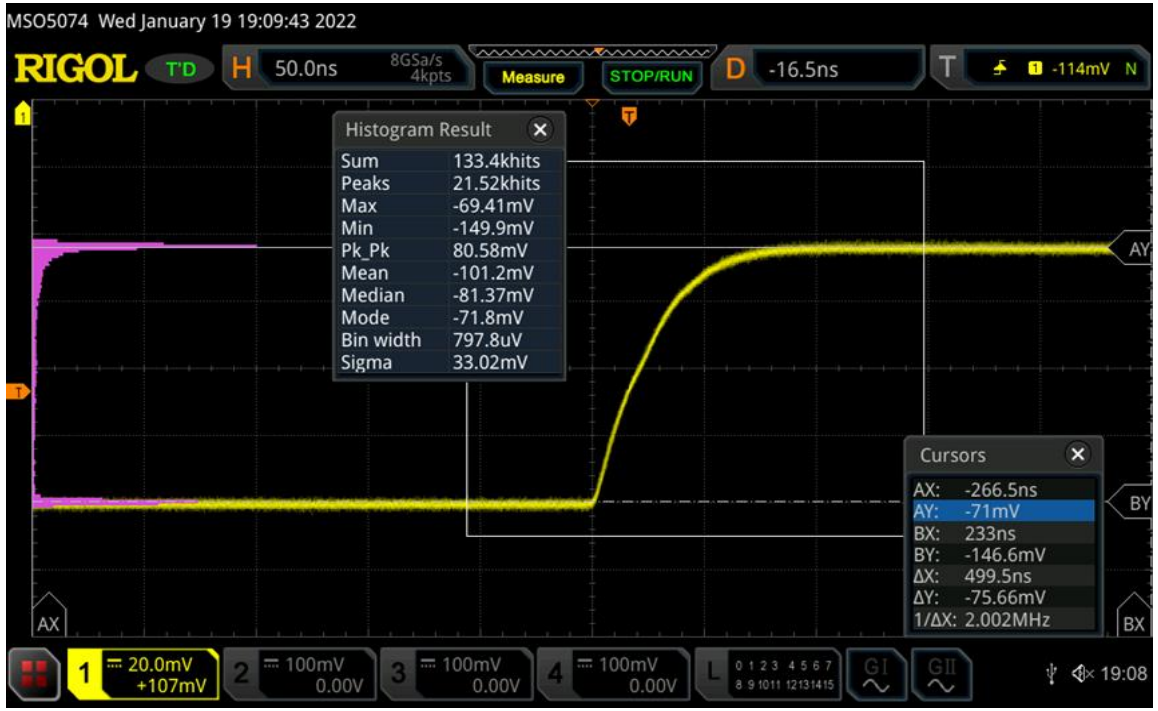
preamplifier CANBERRA Model 2018EB in an insulated case

preamplifier JINR CSA-1 in an insulated case

Pulse generator Rigol DG4062

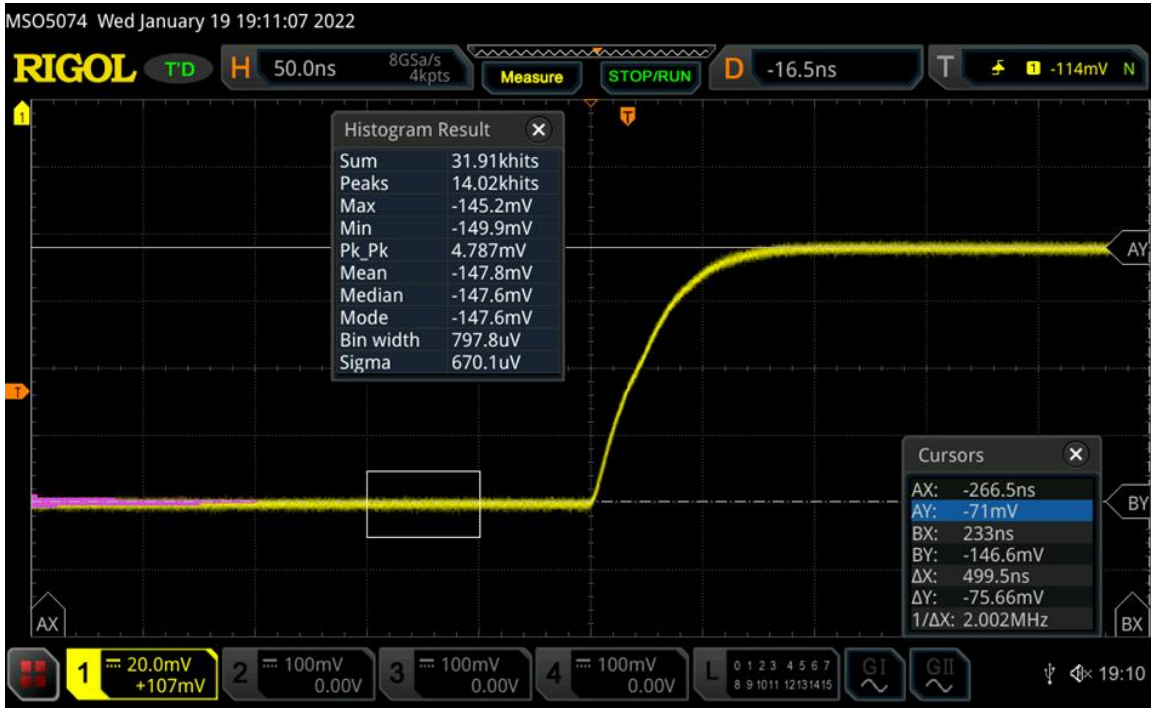
Analysis of calibration data

Output signal from the preamplifier CANBERRA Model 2018EB



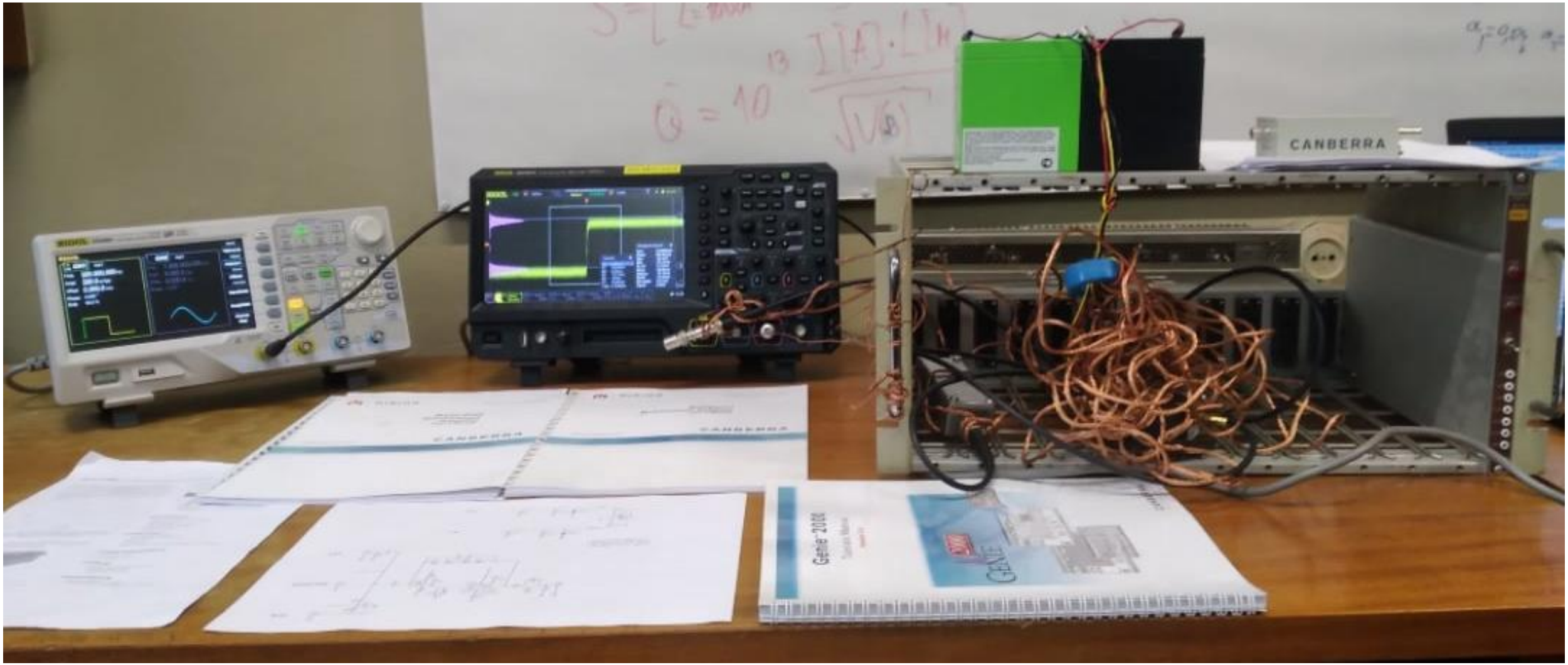
f = 500Hz
U_{in} = 50mV
C_{source} = 0pF

Noise of the preamplifier CANBERRA Model 2018EB

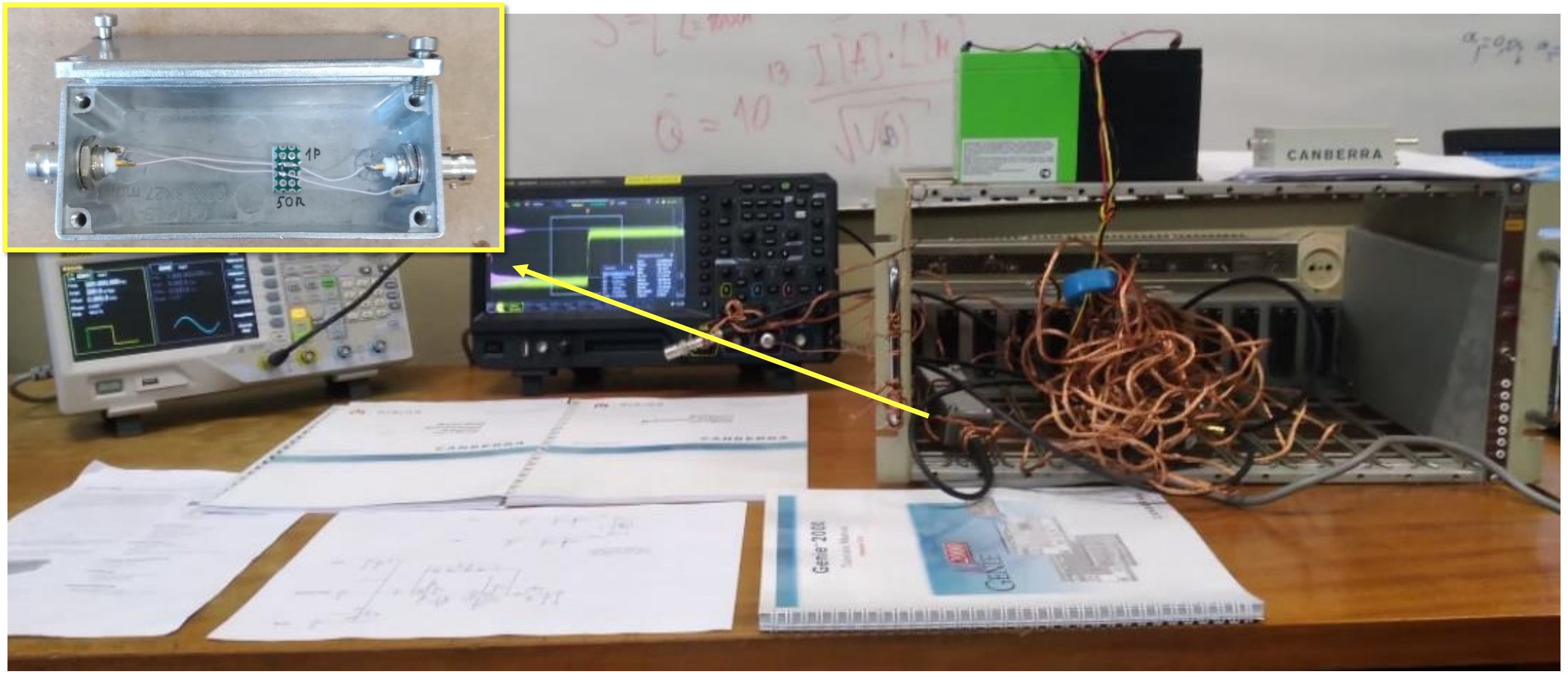


f = 500Hz
U_{in} = 50mV
C_{source} = 0pF

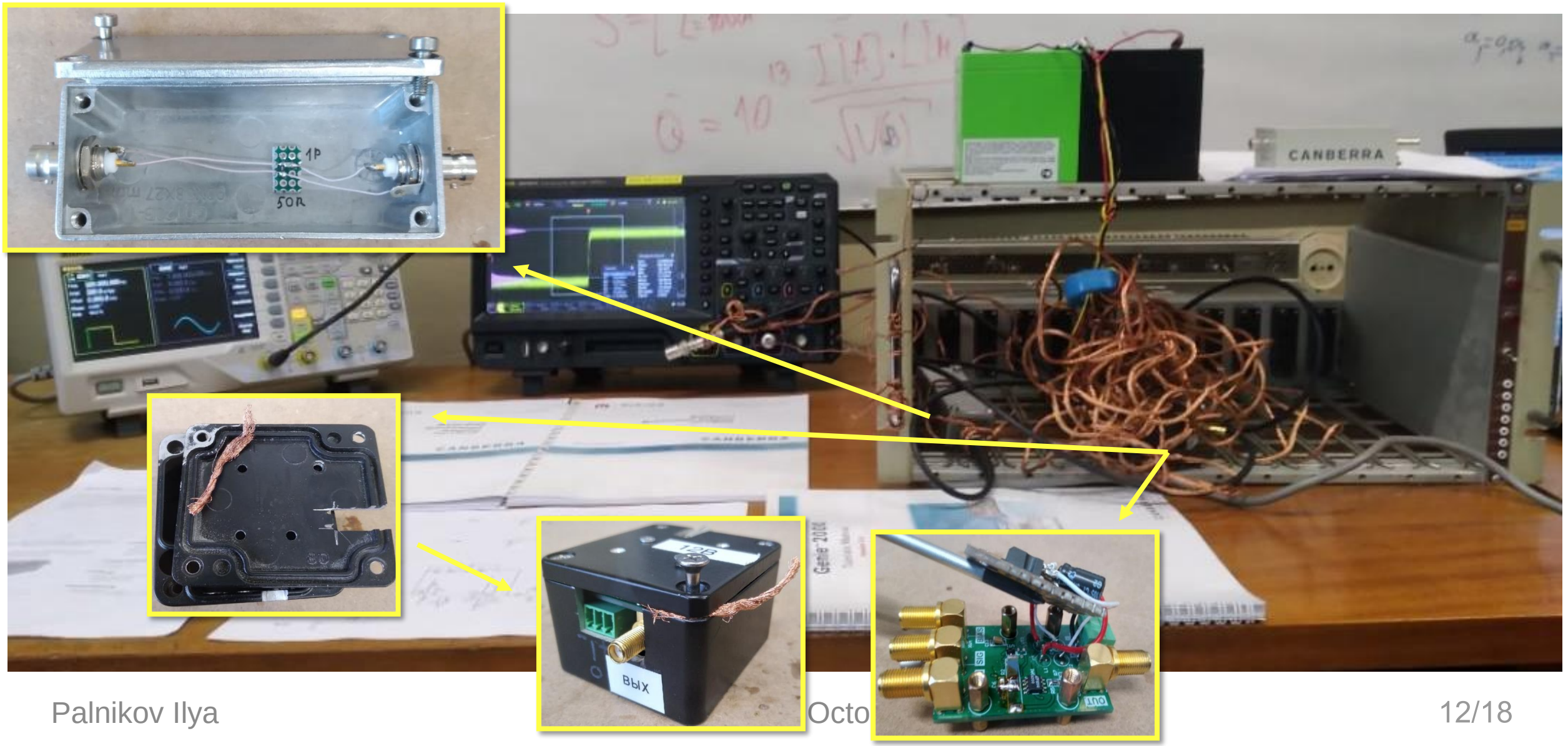
Optimization of the calibration circuit



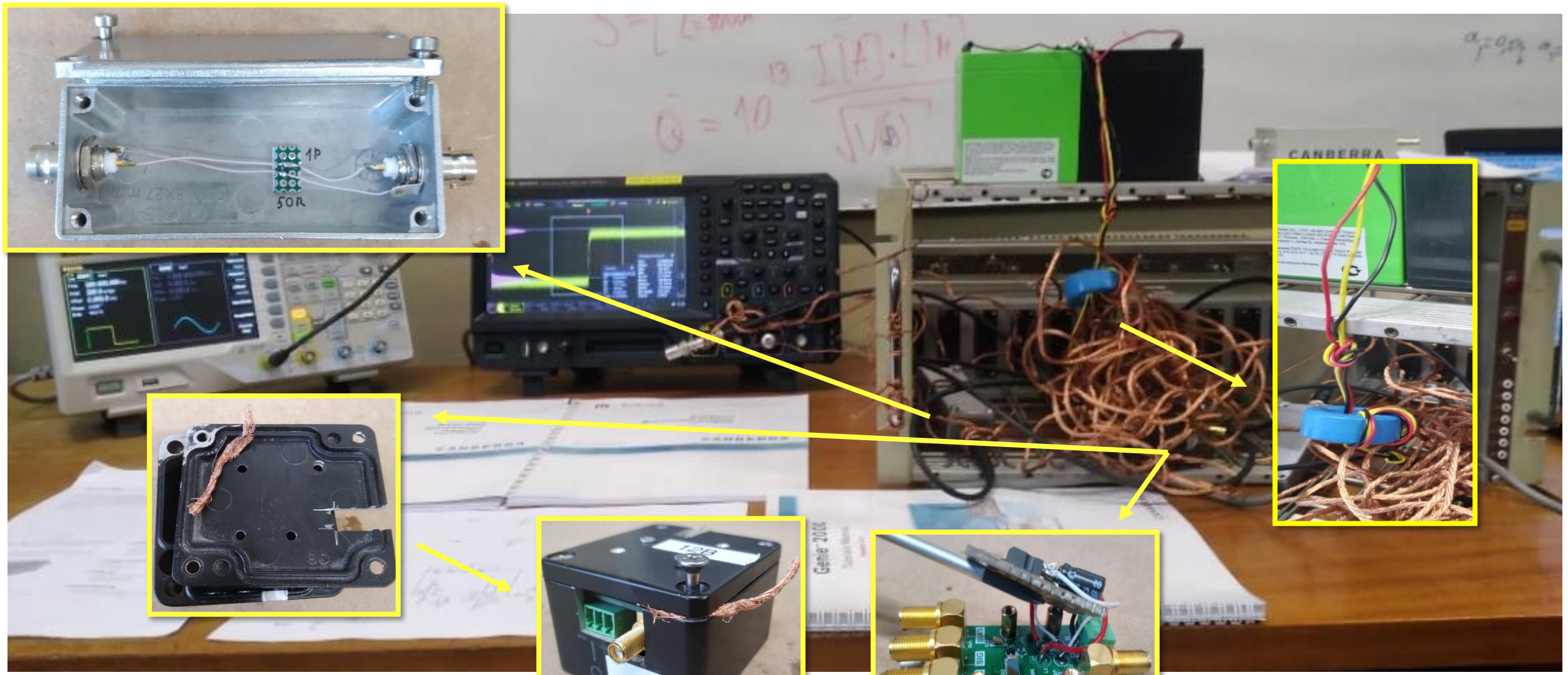
Optimization of the calibration circuit



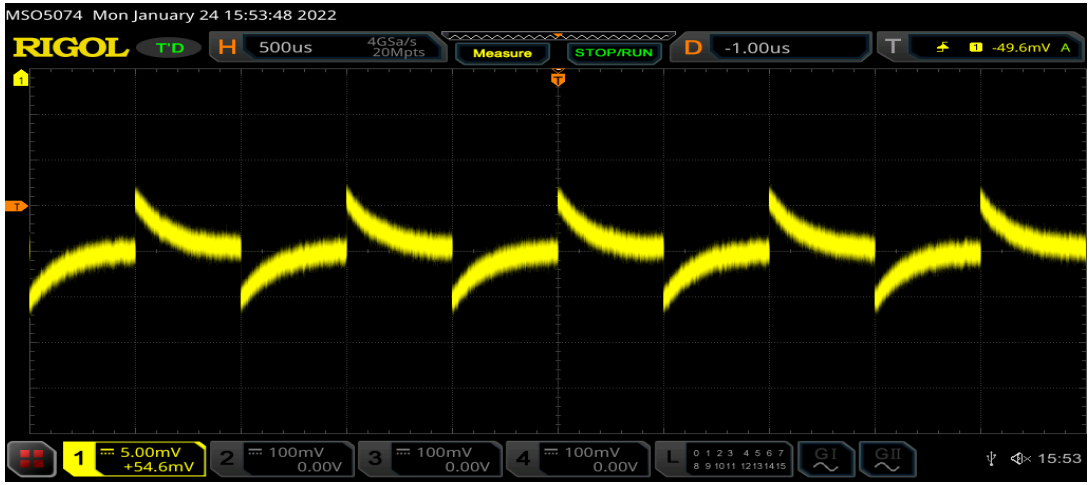
Optimization of the calibration circuit



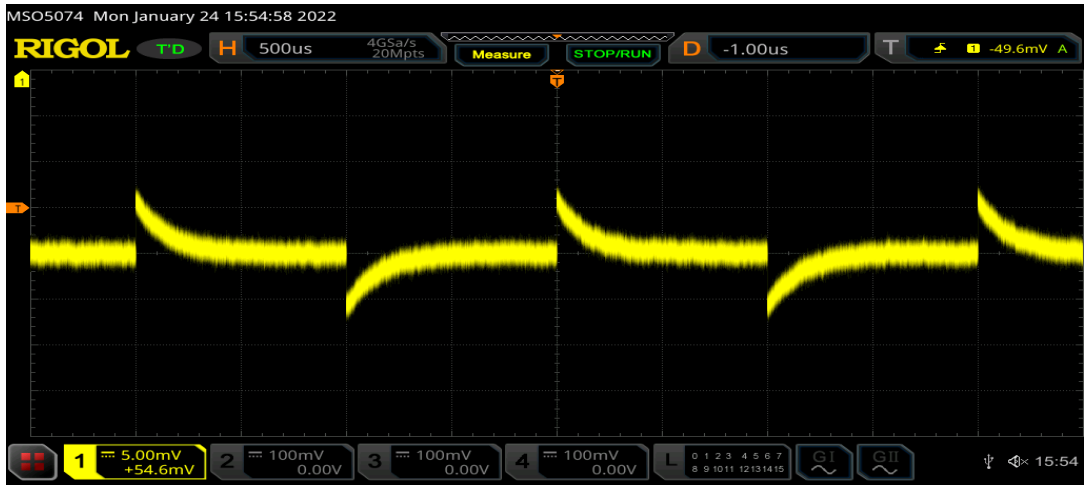
Optimization of the calibration circuit



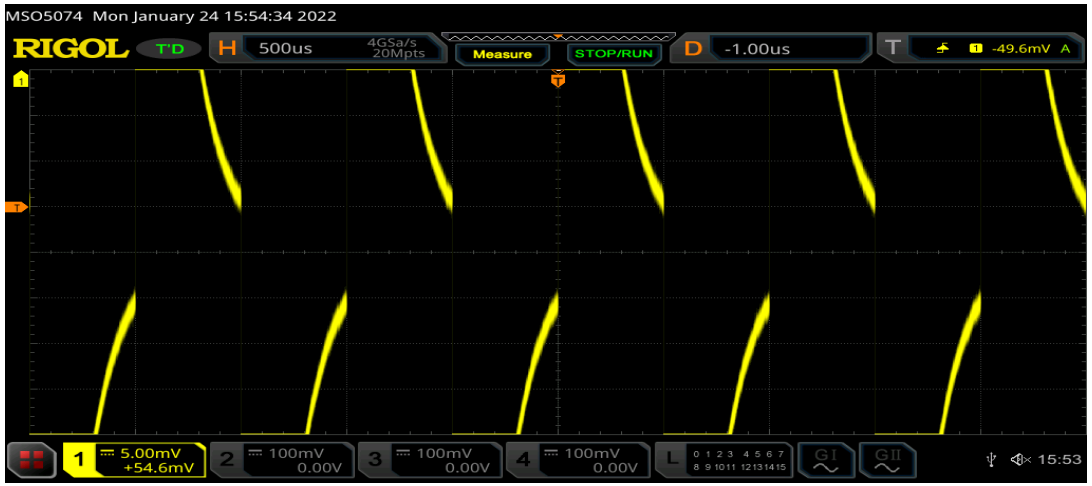
Optimization of the calibration circuit



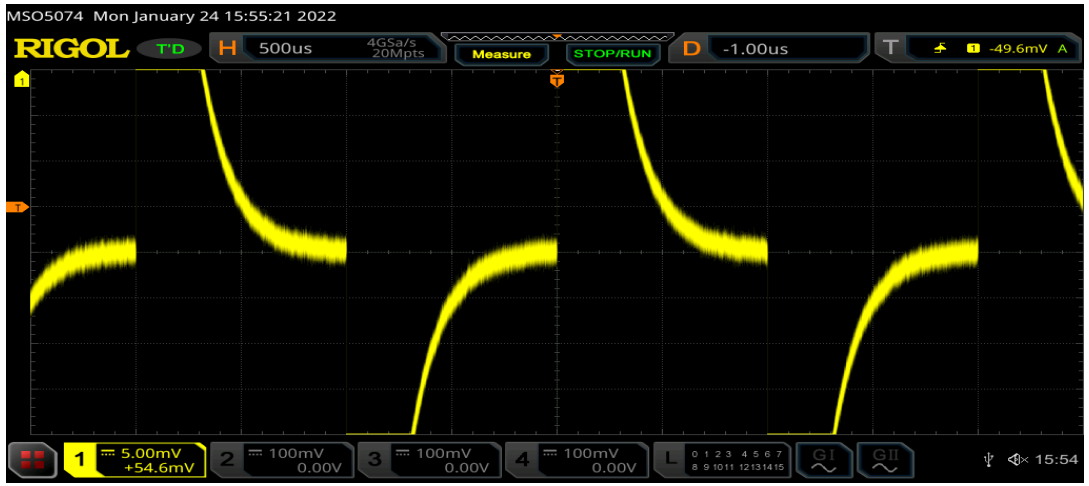
Output signal at **1kHz** frequency and **10mV** input amplitude



Output signal at **500Hz** and **10mV** input amplitude

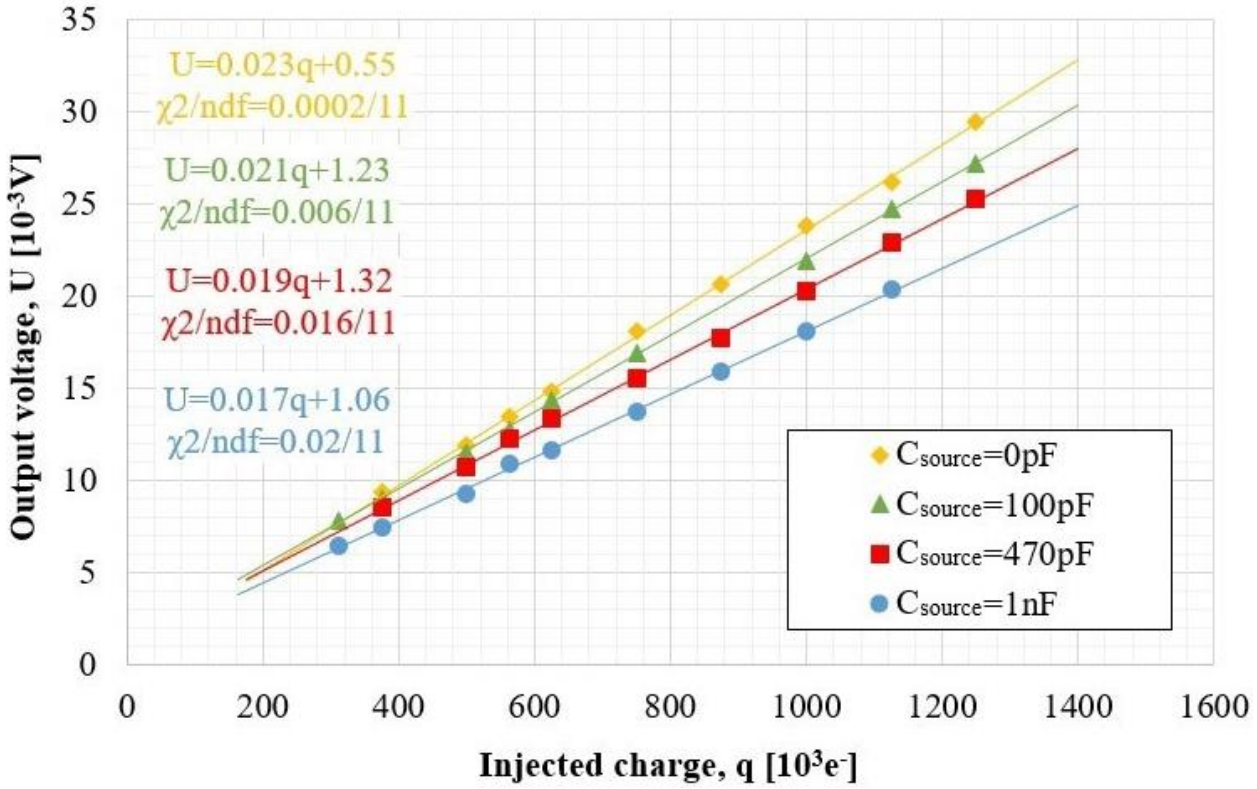


Output signal at **1kHz** frequency and **300mV** input amplitude

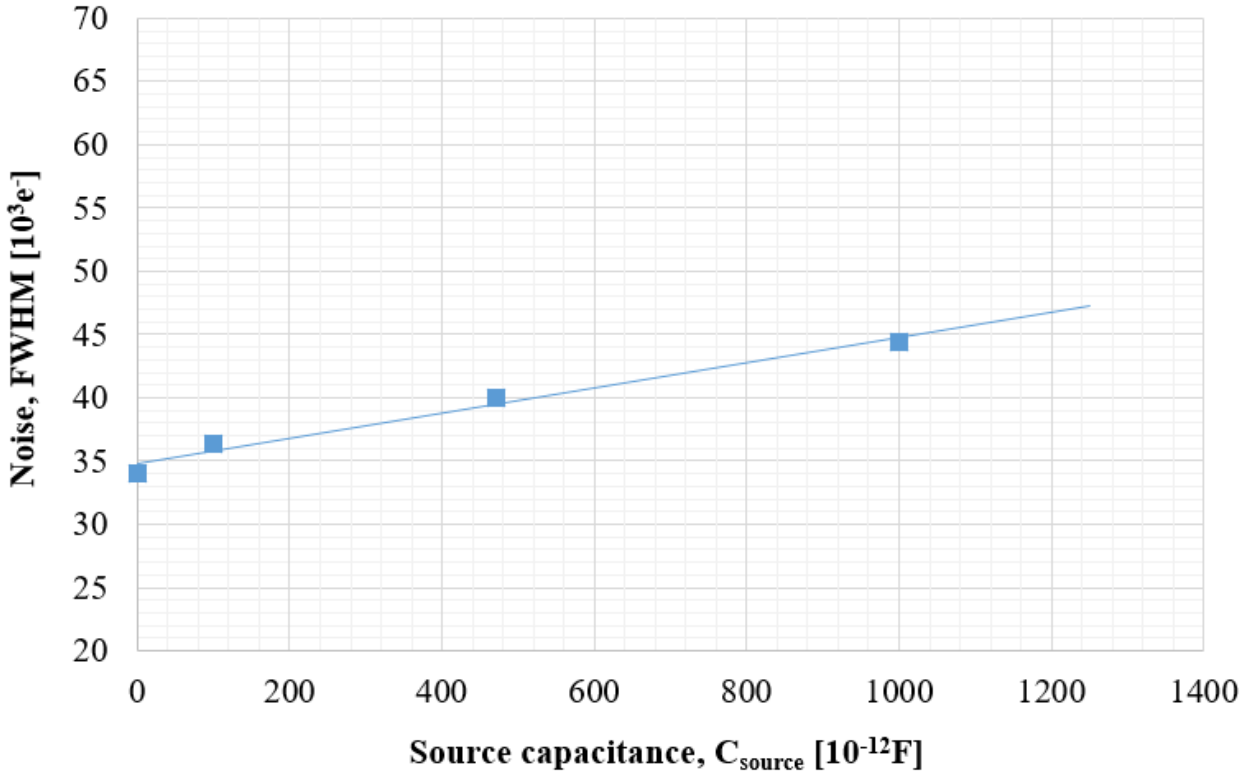


Output signal at **500Hz** and **300mV** input amplitude

Calibration of CANBERRA Model 2018EB

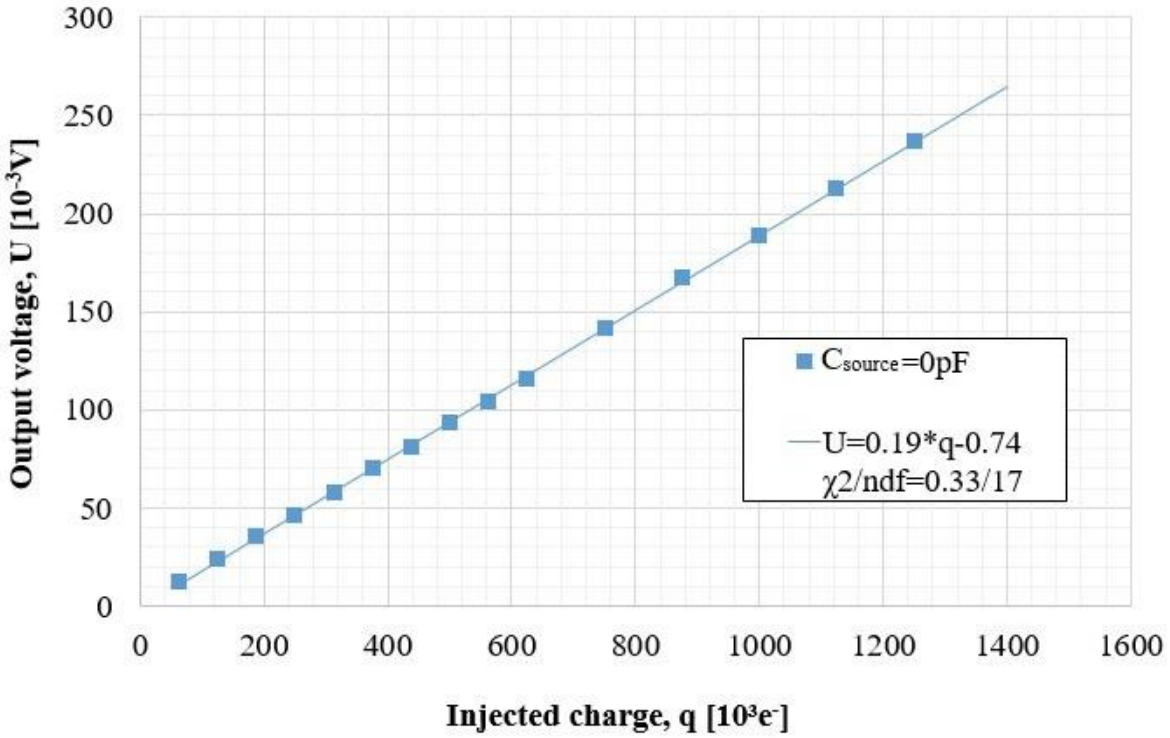


Gain functions of the CANBERRA Model 2018EB for the different loaded capacitance

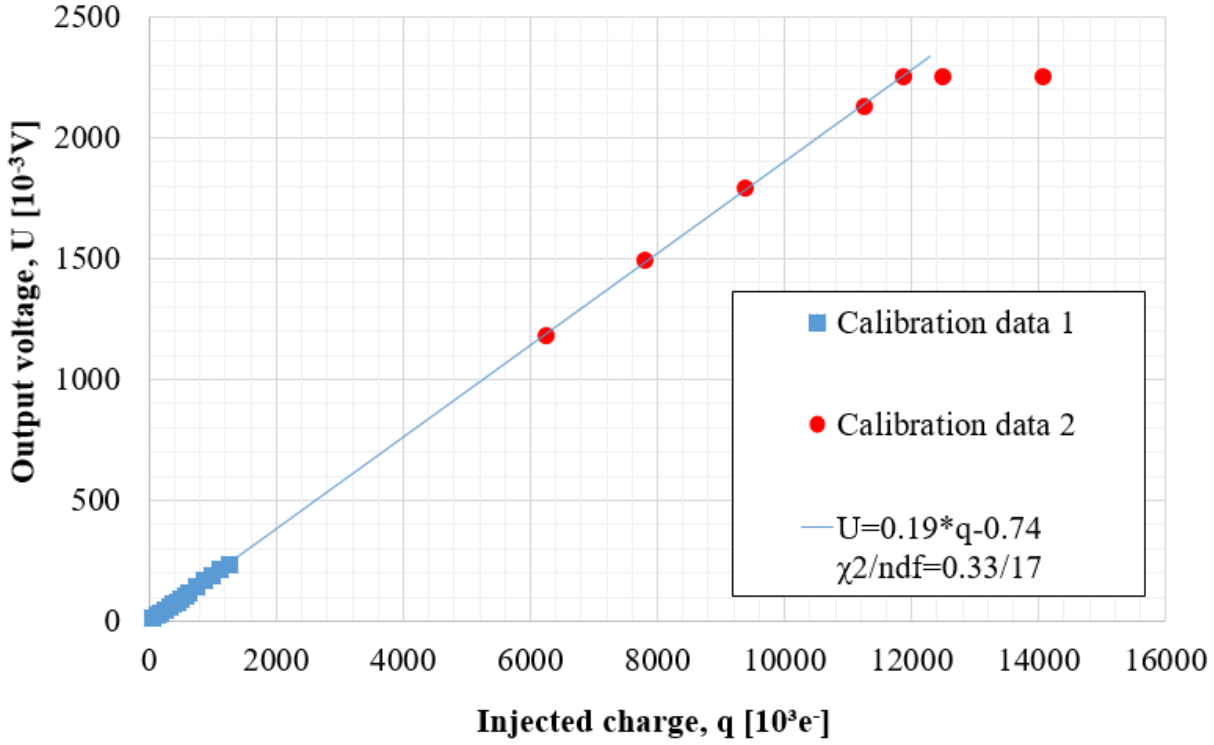


Noise of the CANBERRA Model 2018EB as a function of loaded parallel capacitance

Gain linearity for JINR CSA-1

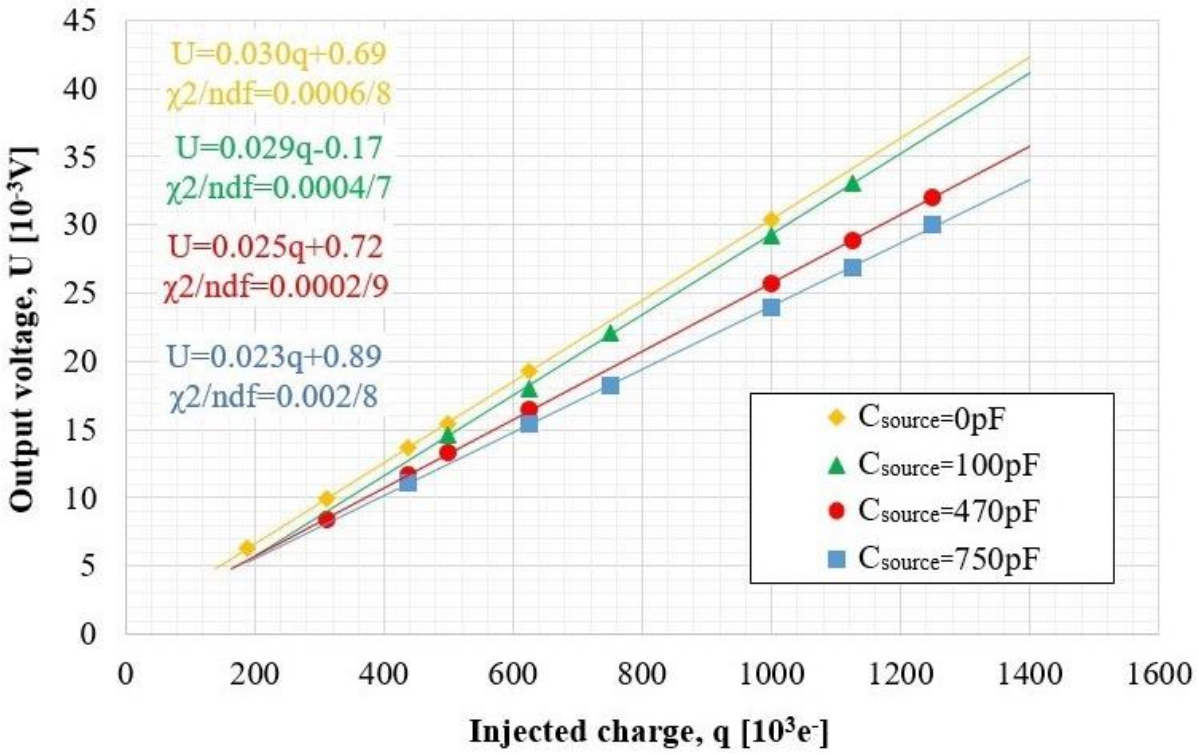


Fit of JINR CSA-1 gain for 1pF feedback capacitance and 0pF parallel loaded capacitance

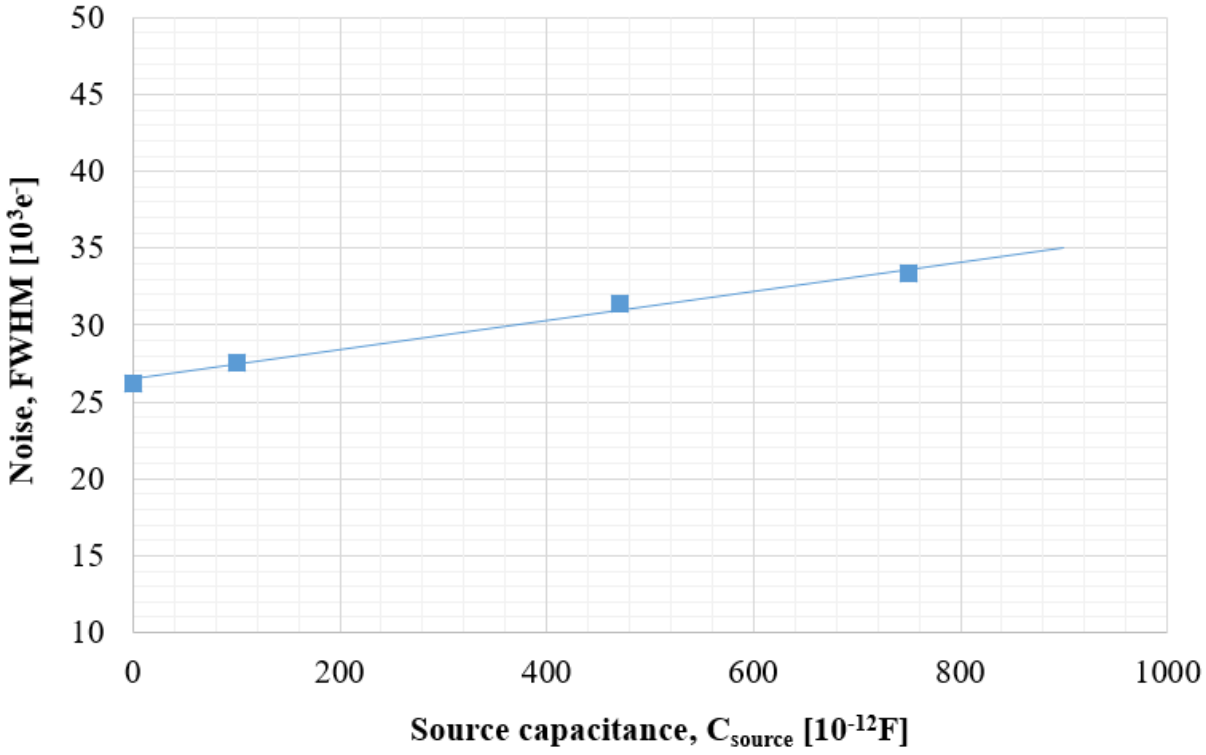


Fit extrapolation of JINR CSA-1 gain for 1pF feedback capacitance and 0pF source capacitance of extended data range

Calibration of JINR CSA-1

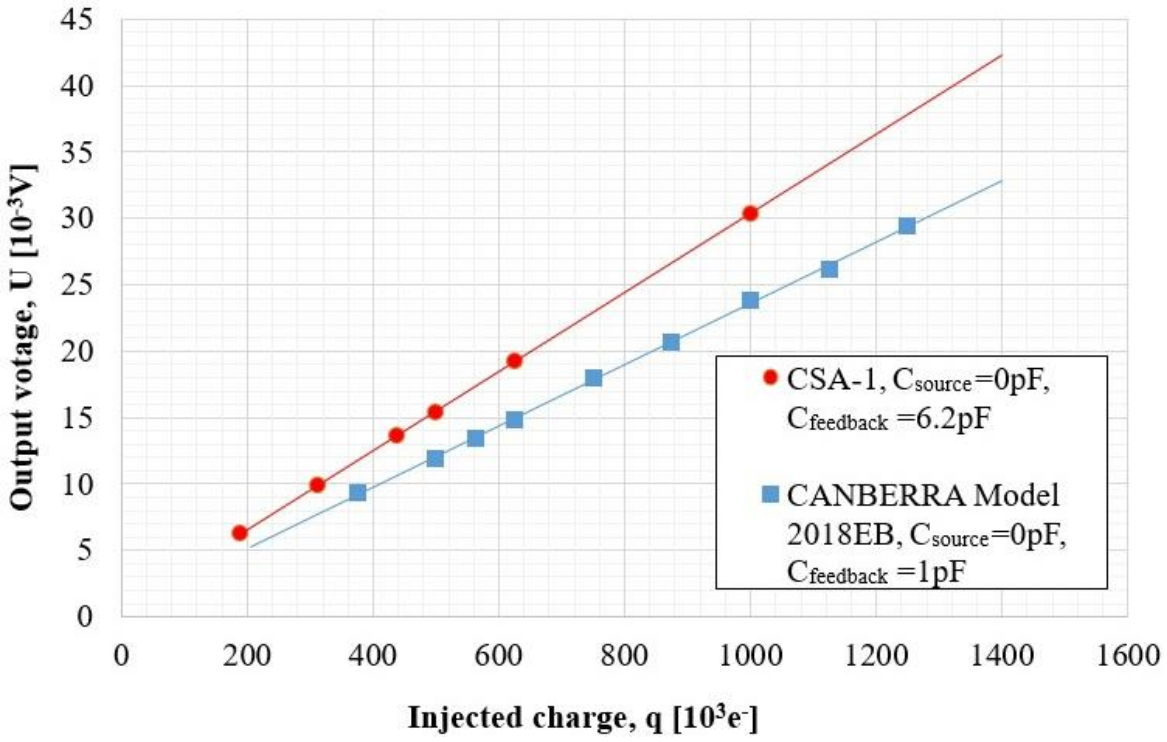


Gain functions of the JINR CSA-1 for the different loaded capacitance

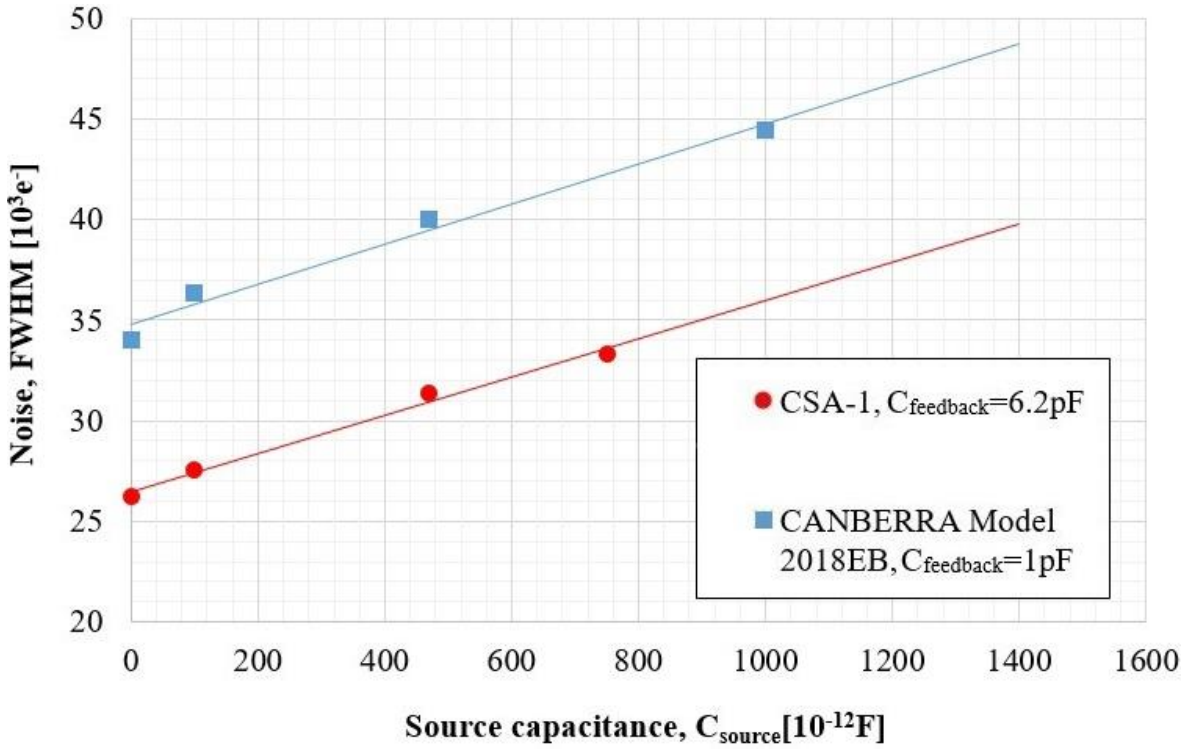


Noise of the JINR CSA-1 as a function of loaded parallel capacitance

CANBERRA Model 2018EB vs JINR CSA-1



Gain of the JINR CSA-1 with 6.2pF feedback and gain of the CANBERRA Model 2018EB with 1pF feedback at 0pF loaded capacitance



Noise of JINR CSA-1 with 6.2pF feedback and CANBERRA Model 2018EB noise with 1pF feedback as a function of parallel loaded capacitance

Conclusions

1) The main characteristics of the investigated CSA were measured:

- Gain of the preamplifiers
- Noise figures

2) Simulation of the electrical circuit of the JINR CSA-1 was carried out:

- Signal-to-noise ratio optimization
- Bandwidth correction respectively to the task

3) The main parameters of the JINR CSA-1 have been optimized:

- Capacitance and feedback resistor values
- Impedance matching of electrical circuits and loadings
- Optimal grounding point of the amplifier box and common ground rail was defined to avoid creation of grounding loops

Thank you for your attention!

Head of research group

Evgeny Donets

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Dubna, 24-28 October 2022