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Electron Gun Control System for Electron String Ion Sources

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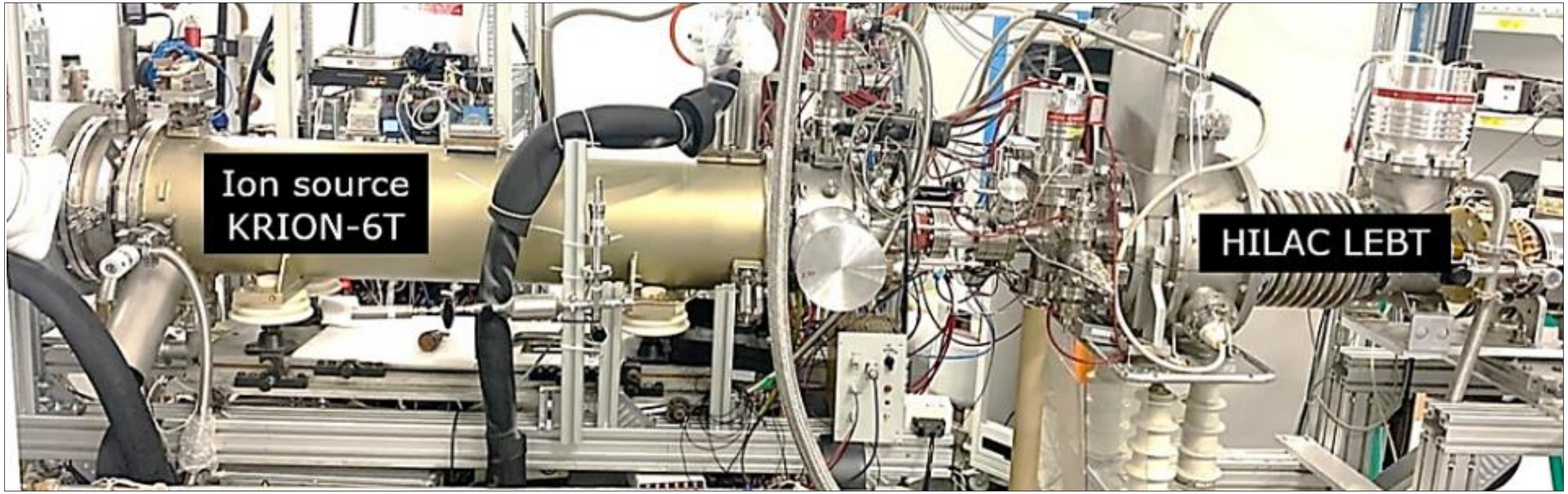
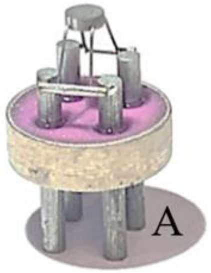
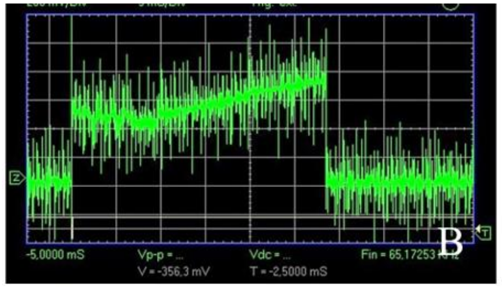
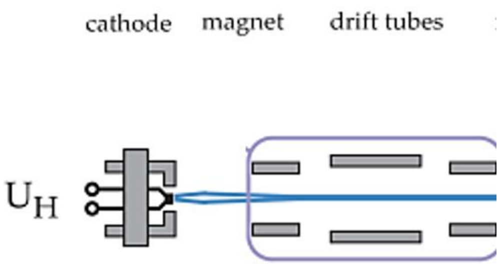


IrCe
Катод
0.8 – 2 мм







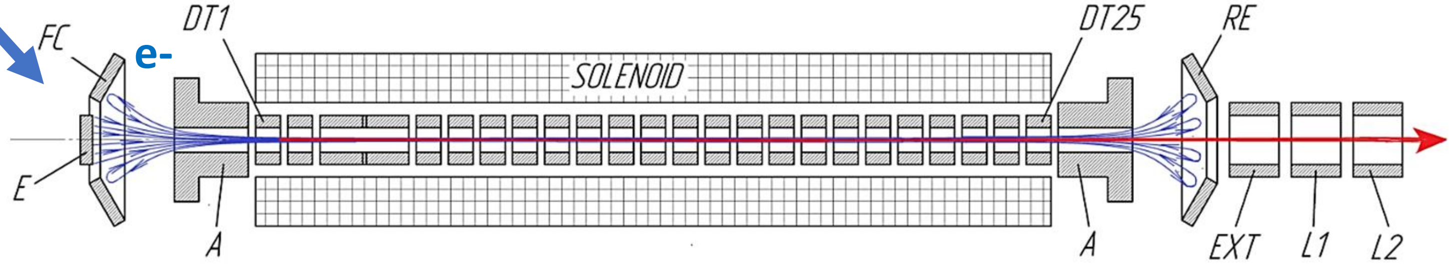


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FIGURE 3. Krion-6T ESIS schematic: FC – false cathode; E – electron emitter; A – anodes; DT – ion drift tubes (25 separate drift tubes); RE – electron reflector; EXT – ion extraction electrode; L1, L2 – lenses; Produced ions are pulsely extracted from the source to the right side towards the red arrow.

***Abstract*—Electron impact is the main process responsible for the ionization of atoms to high charge states in Electron beam/string ion sources. Corresponding energy electron beam, compressed in an external strong magnetic field (up to 6 Tesla), is produced by an electron gun. As its key element the electron gun contains a thermionic electron emitter made of IrCe. Electron string ion source KRION-6T designed and created in LHEP JINR as the prototype of a heavy ion source for the NICA accelerator complex contains an electron gun with the cathode located at a high-voltage negative potential up to -10 kV. A feature of the electron gun control circuit is a number of factors, namely, the fact that the cathode assembly of the electron gun is located at a negative high-voltage potential and the need to accurately establish and measure the electron emission current. The article describes methods, circuits, electronic devices and the details of ESIS electron gun control system electronic devices.**

Keywords—NICA, particle accelerator, EBIS, ESIS, ion source, electron gun, electron beam, cathode, control system

I. Introduction

Since 1994 at VBLHEP JINR began experiments on obtaining ion beams using Electron Beam Ion Source (EBIS) [1] operating in the reflective electron beam mode. The discovery of a special state of electron plasma called an «electron string» created the direction of new Electron String Ion Sources (ESIS) creation [2], [3], [4], [5].

The new KRION-6T ESIS was created and commissioned in 2012 at VBLHEP JINR. In the 55th Nuclotron run (February - April 2018), C^{6+}, Ar^{16+} and Kr^{26+} ion beams were produced, accelerated and used for physics experiments. In April 2022, the KRION-6T ESIS was installed on an HV platform of a new HILAC (Heavy Ion Linac) injector (Fig. 1). The injector is a part of the NICA/MPD assembly [6] which

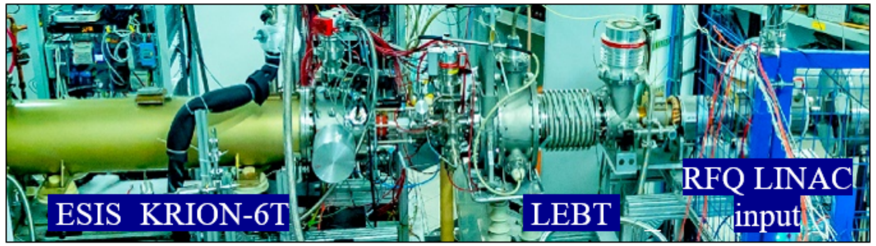


Fig. 1. HV platform of a HILAC-NICA injector with KRION-6T ESIS.

II. ESIS Electron Gun

A complex control system of the ESIS electron gun contains an emitter itself (the cathode), false cathode, anode, power supply unit, control and measurement electronic modules. The IrCe electron emitter described in detail in [8] is typically 0.8 - 2.0 mm in diameter (Fig. 2A) and it produces a typical emission current of 5 - 30 mA in the electron string operation mode (Fig. 2B). Thermionic emission current is provided by filament with applied AC 20 kHz 0 – 1.5 V voltage with the maximum current up to 10 A; as a result, the required temperature of about 1800 °C is maintained on the cathode surface.

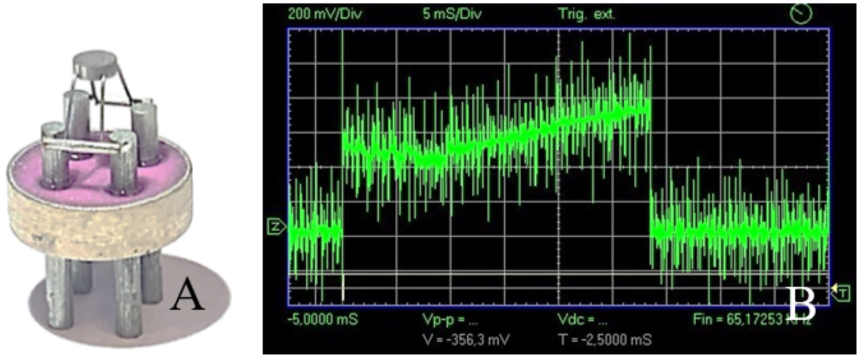
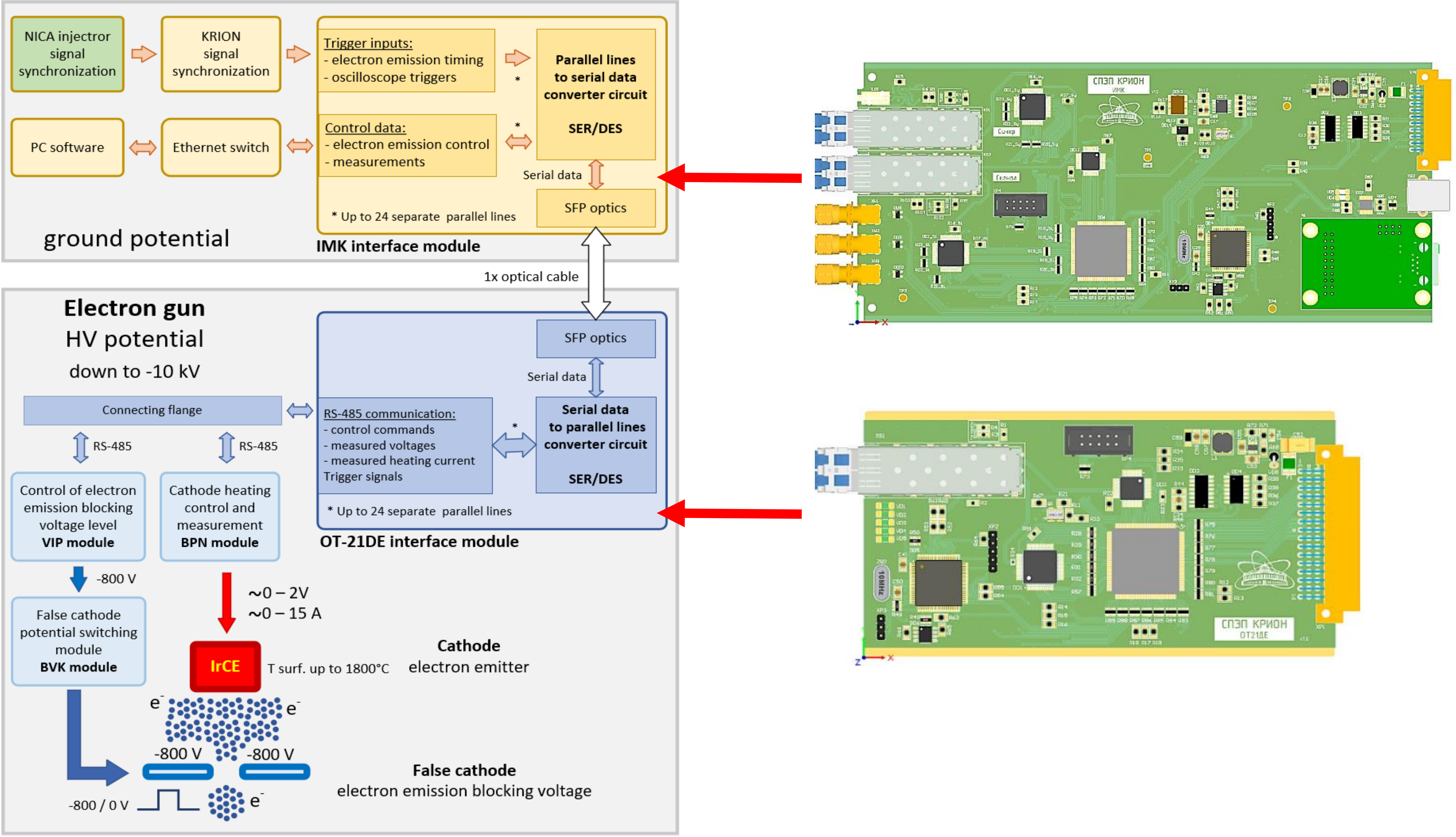


Fig. 2. ESIS KRION-6T IrCe electron emitter: A) emitter view;
B) measured electron emission pulse: 5 – 7 mA, pulse duration – 30 ms.

The electron emission is a pulsed process in ESIS pulsed beam ion source, but according to the IrCe cathode operation



NICA injectror signal synchronization
KRION signal synchronization
Trigger inputs:
- electron emission timing
- oscilloscope triggers
Parallel lines to serial data converter circuit
SER/DES
PC software
Ethernet switch
Control data:
- electron emission control
- measurements
Serial data
SFP optics
* Up to 24 separate parallel lines
ground potential
IMK interface module
1x optical cable
Electron gun
HV potential
down to -10 kV
Connecting flange
SFP optics
Serial data
RS-485 communication:
- control commands
- measured voltages
- measured heating current
Trigger signals
Serial data to parallel lines converter circuit
SER/DES
* Up to 24 separate parallel lines
OT-21DE interface module
RS-485
RS-485
Control of electron emission blocking voltage level
VIP module
Cathode heating control and measurement
BPN module
-800 V
~0 – 2V
~0 – 15 A
False cathode potential switching module
BVK module
IrCE
T surf. up to 1800°C
Cathode
electron emitter
-800 V
-800 V
False cathode
electron emission blocking voltage
-800 / 0 V

directly to the emitter. The BPN module allows to smoothly adjust the primary coil regulator power via a Modbus register, measure the transformer primary coil current and regulator output voltage. The power regulator is based on an ARM 32-bit microcontroller (MCU) controlled a 16-bit digital-to-analog converter connected to the SET input of the LT3081 chip.

The schematic presented in Fig. 5 and simulated in LTspice [9] shows V1 = 3 V control voltage on the input (LT3081 SET input) implements 21.75V on the output of the programmable regulator. MCU built-in 12-bit ADC measures regulator load current and output voltage and places measured values into the BPN module Modbus register.

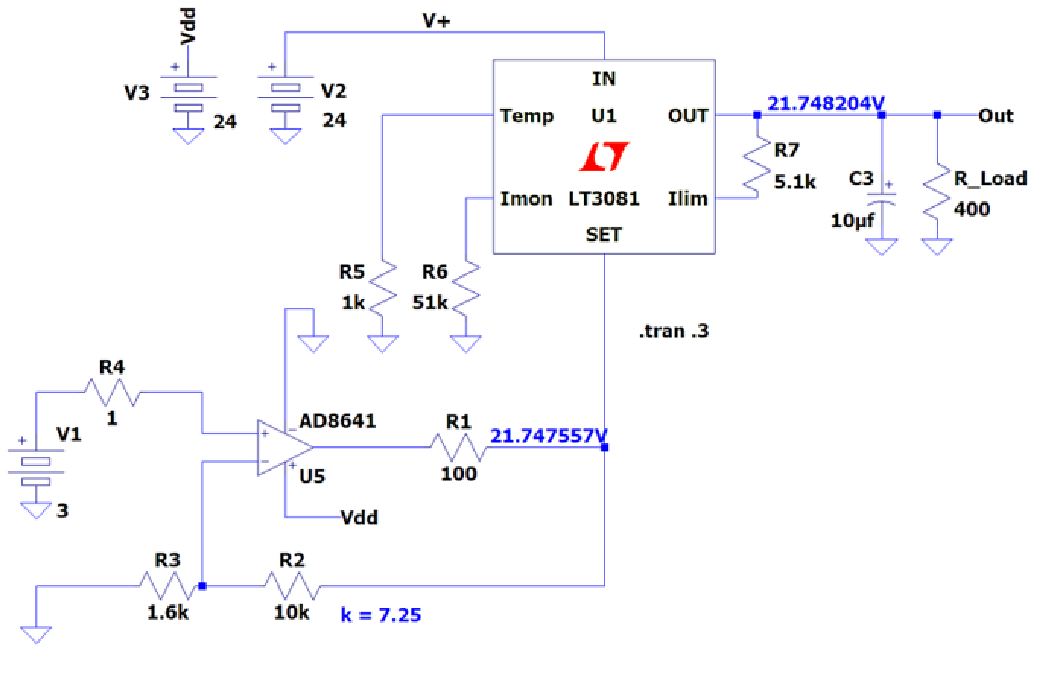


Fig. 5. Linear power regulator simulation schematic.

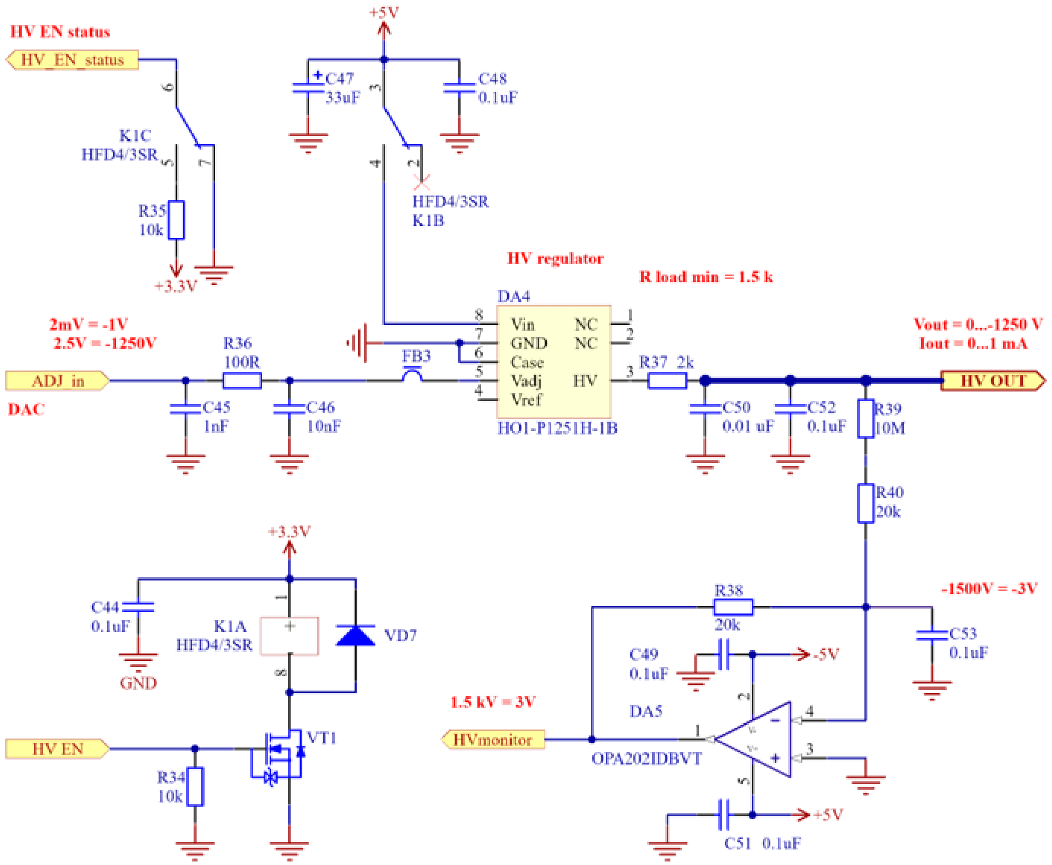


Fig. 7. Negative high-voltage potential control circuit.

The HV potential in the VIP module is controlled and monitored by a 32-bit ARM microcontroller, external SPI DAC and built-in 12-bit ADC. In Fig. 7, the input control voltage Vcont. <= +2.5 V ensures the output high voltage of the DA4 programmable module, Vout <= -1250 V. The output voltage is monitored by the R39, R40 and R38 HV-dividers and DA5 opamp voltage invertor circuit. The DA5 output voltage alternates in the range of the MCU bult ADC module measurement range, measured secondary Vout_p = +3 V

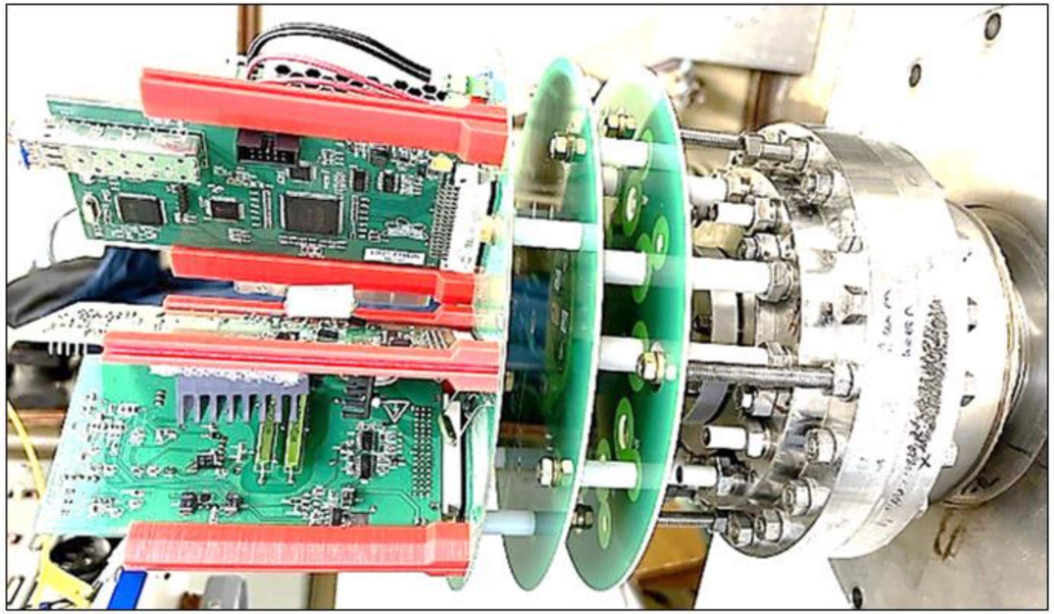


Fig. 8. ESIS electron gun control system electronics assembly view.

The developed electron gun control system ensured the operation of the Electron String Ion Sources during bench tests and at accelerator sessions of the NICA complex. The results of the ion source commissioning are described in [7]. As part of development pulsed ADC modules are under creation to ensure monitoring the shape of the electron emission current pulse.

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