Programmable High-Voltage Power Supply Unit

Version 1.01

User Manual

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CGC Instruments
Hübschmannstr. 18 | D–09112 Chemnitz
Tel.: +49 (371) 355 098–55
Fax: +49 (371) 355 098–60
internet: www.cgc-instruments.com
e–mail: info@cgc-instruments.com

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Safety Information

- The device may be installed and used by authorized and instructed personnel only. Read this manual carefully before installing and using the device. Always follow the safety notes and warnings in this manual.
- The device is designed for indoor dry laboratory use only. Before powering the device on, the device temperature must accommodate to the ambient temperature to avoid moisture condensation. This is especially relevant after transportation.
- Do not operate the device if it is damaged or not functioning properly. Never use damaged cables or accessories.
- Do not open the device case, install replacement parts, or perform modifications to the device. There are no user serviceable parts inside.
- To avoid damage, connect the line cord to a properly wired and grounded receptacle only. Be sure that the mains voltage and the fuse rating match the device specification. Never operate the device during thunderstorms.
- Never use corrosive or abrasive cleaning agents or polishes, avoid the usage of organic solvents. If necessary, clean the device with a soft moist cloth. Make sure that the device is completely dry and free from contaminants before powering it on.

! **Warning:** The programmable high-voltage power supply unit is an electronic device that is sensitive to electrostatic electricity. While manipulating with the device and the plug-in modules, the ESD (*Electro-Static Discharge*) protection rules must be kept in mind.

Technical Data

Characteristics

- four high-precision high-voltage amplifiers
- one dual high-voltage switching converter
- 19" case, bench top or rack mount
- interlock loops
- digital controller with remote control via USB

Device Modules

Voltage Controller

- label: PSU-CTRL
- control of four amplifiers and a dual switching converter
- integrated power supply unit:
  technology: switching mode with input rectifier
  current limiter, over-voltage and over-temperature protection
  output voltages:
  12 V, 5 A max., voltage tolerance ±2%, efficiency >90%
  5 V, 3 A max., voltage tolerance ±1%, efficiency >90%
  3.3 V, 3 A max., voltage tolerance ±1%, efficiency >95%
- supply voltage supervising
- output voltage and temperature monitoring, fan controller
- controller of an inrush-current limiter (ICL)
- serving of two independent interlock loops
  terminals: BNC socket at front and rear panel
  (selectable per software)
- 16-bit RISC microcontroller running at 16 MHz
- non-volatile memory, data space: 1 MB
- user-friendly graphical interface
- USB data interface
- 19" plug-in module, width: 28 HP, height: 3 U, front mount

Dual High-Voltage Switching Converter

- label: HV-SMPS2
- dual, digitally-controlled, serially connected, floating high-voltage switching converter
- temperature sensor
- control: digital by a 16-bit RISC microcontroller running at 16 MHz
- voltage monitoring: 16-bit analog-to-digital converter

- output voltages:
  100 V...2 kV, 0.5 mA max.
  200 V...4 kV, 0.1 mA max.
- output noise and ripple: <100 mV_{p-p}
- connectors:
  output 2 kV (HV Output MCP): SHV (5-kV SHV) receptacle
  output 4 kV (HV Output Screen): HC51 (10-kV SHV) receptacle
- 19" plug-in module, width: 20 HP, height: 3 U, front mount

High-Voltage Output
- label: HV-OUT
- output connector:
  ITT Cannon receptacle KPT02E14-5SA71
  (panel receptacle with 5 female contacts)
- four output voltages, analog ground and sensing wire
- voltage monitoring: 16-bit analog-to-digital converters
- 19" plug-in module, width: 8 HP, height: 3 U, front mount

Dual Negative High-Voltage Amplifier
- label: HVA100-2ND
- dual, digitally-controlled, precise high-voltage amplifier
- output voltages: 2x 0..-100 V, 5 mA max.
- temperature sensor
- built-in output capacitance: 10 µF
- control: dual 16-bit digital-to-analog converter
- voltage resolution: 2 mV nominal
- output noise and ripple: <100 μV_{p-p}
- voltage stability: 1 ppm typ.
- 19" plug-in module, width: 8 HP, height: 3 U, front mount

Bipolar High-Voltage Amplifier
- label: HVA700-1DH
- digitally-controlled, precise high-voltage amplifier
- temperature sensor
- output voltage: -100...+700 V, 5 mA max.
- built-in output capacitance: 10 µF
- control: 18-bit digital-to-analog converter
- voltage resolution: 3.33 mV (10/3 mV) nominal
- output noise and ripple: <100 μV_{p-p}
- voltage stability: 1 ppm typ.

- 19" plug-in module, width: 8 HP, height: 3 U, front mount

Negative High-Voltage Amplifier
- label: HVA100-1NDH
- digitally-controlled, precise high-voltage amplifier
- temperature sensor
- output voltage: 0...-100 V, 5 mA max.
- built-in output capacitance: 20 µF
- control: 20-bit digital-to-analog converter
- voltage resolution: 0.1 mV nominal
- output noise and ripple: <100 μV_{p-p}
- voltage stability: 1 ppm typ.
- 19" plug-in module, width: 8 HP, height: 3 U, front mount

Power-Supply Unit ±15 V
- label: LV-PSU
- rectifier and adjustable linear regulators, temperature sensor
- output voltages: ±15 V, 1 A max.
- 19" plug-in module, width: 9 HP, height: 3 U, rear mount

High-Voltage Rectifier 100 V
- label: HV-RECT100
- high- and low-voltage rectifiers with filter capacitors
- output voltages: >120 V, 20 mA max., >18 V, 20 mA max.
- 19" plug-in module, width: 10 HP, height: 3 U, rear mount

High-Voltage Power-Supply Unit 100 V
- label: HV-PSU100
- adjustable high-voltage linear regulator, temperature sensor
- output voltage: -115 V, 20 mA max.
- 19" plug-in module, width: 12 HP, height: 3 U, rear mount

High-Voltage Rectifier 700 V
- label: HV-RECT700
- high- and low-voltage rectifiers with filter capacitors
- output voltages: >720 V, 20 mA max., >18 V, 20 mA max.
- 19" plug-in module, width: 10 HP, height: 3 U, rear mount

High-Voltage Power-Supply Unit 700 V
- label: HV-PSU700

- adjustable high-voltage linear regulator, temperature sensor
- output voltage: +715 V, 20 mA max.
- 19" plug-in module, width: 12 HP, height: 3 U, rear mount

Main Device

Security

- two interlock loops (short circuit enables the voltage output):
  BNC sockets at the front and rear panels
- overcurrent protection: output current limit of all supply voltages
- overtemperature protection:
  temperature sensors at heatsinks and in ICs
  (shutdown and restart temperatures freely programmable)

Monitoring

- LEDs: Activated, Interlock, Failure
- supply voltage monitoring
- temperature monitoring
- high-voltage monitoring
- fan monitoring
- line monitoring

Human-Machine Interface (HMI)

- monochrome LCD display 128x64 pixel
  pixel size: 0.5 mm
  pixel color: yellow, background: blue
  background illumination: white LED
- keypad: 5 keys: 4x direction + 1x "enter"
- rotary encoder: 24 positions per revolution, integrated press button
- optional external shutdown button via the interlock loop

Power Supply

- rated voltage: 115/230 V ±10%, 50/60 Hz
- power consumption:
  standby (deactivated): <15 VA, 10 VA typ.
  maximum (activated with highest output voltages): 20 VA
- main fuses: T 1.25 A (slow acting, size ø5x20 mm)
- mains connection:
  IEC inlet with EMC filter and integrated fuse holder
- mains transformer: toroidal with inrush-current limiter (ICL)

General

- 3 U 19" bench-top case:
  height: 133 mm, width: 449 mm, depth: 435 mm,
  total depth with handles and connectors: 486 mm,
  total width with handles: 483 mm,
  total height with case feet: 140 mm,
  cover strips, horizontal rails: anthracite gray,
  cover, bottom, and side panels: white aluminum
  front and rear panels: clear anodized
- forced cooling:
  92-mm fan at the rear panel, temperature-dependent control,
  monitored fan operation, warning on fan failures
- allowable temperature range for device operation: +10...+40°C
- weight: 13.5 kg
- cleaning: use moist cloth only, avoid use of organic solvents

Shipment Contents

- programmable high-voltage power supply unit
  HV-SMPS2+HV-AMP2+1+1
- output cables:
  multipole high-voltage:
  connectors:
  ITT Cannon plug KPT06F14-5PA71
  Vacom PLUG-MPC5-4-DI-CUL
  cable type:
  assembled from single Teflon-isolated wires
  shielding: copper braid
  isolation: polyester braid
  length 5 m
  HV Output MCP (2 kV):
  connectors: SHV (5-kV SHV) cable plugs
  cable type: HRG58
  length 5 m
  HV Output Screen (4 kV):
  connectors: HC51 (10-kV SHV) cable plugs
  cable type: HRG58
  length 5 m
- line cord (universal IEC mains lead, length 1.8 m)
- control and diagnostic software
- user manuals in electronic form

Description

General

This document describes the programmable high-voltage power supply unit. The hardware for a complete measurement system suited for driving a Fermi-surface mapper (FeSuMa) spectrometer consists of the abovementioned device, a vacuum setup, and connection cables.

The device is a combination of four precise high-voltage amplifiers with power supply units, two high-voltage switching-mode power supply units, and a voltage controller. It is fitted into a metallic 19" case, the front and rear panels are shown in Fig. 1 and Fig. 2.

The voltage controller is described in its individual manual (see the device homepage at www.cgc-instruments.com/Miscellaneous/HVS2+HVA4). Beside its intrinsic function, the voltage controller contains also control and monitoring circuits of the whole device, i.e. all plug-in modules in the 19" case. The function is briefly described in this document, for further details, please consult the manual of the voltage controller.

Main Device

The main device HV-SMPS2+HV-AMP2+1+1 uses a modular construction. It consists of plug-in modules that can be easily removed for servicing purposes or when the device is transported. The modules are inserted from the front and also from the rear side of the housing. In this way, a 19" 3 U housing instead of a double-height 6 U case could be used.

The modules at the rear side produce the supply voltages for the analog part of the electronic circuits, i.e. ±15V, -115 V, and +715 V. The supply voltages for digital circuits (+12 V, +5 V, and +3.3 V) are provided by the voltage-controller module. They are galvanically connected to the device ground, i.e. to the protective earth (the PE wire). The supply voltages for analog circuits are galvanically isolated from the device ground, their ground is located at the multipole output connector and should be connected to spectrometer's chamber.

All power supplies for analog circuits are precise linear regulators, the supply for digital circuits are high-efficiency switching-mode regulators. The mains transformer is toroidal, to reduce the current spikes,

an inrush-current limiter (ICL) is used to minimize the mains current when the device is powered on.

At the front side, three amplifier modules (HVA100-2ND, HVA700-1DH, and HVA100-1NDH) with four high-voltage amplifiers are located (see Fig. 1). The amplifiers are driven by digital-to-analog converters controlled via a galvanically-isolated SPI interface from the FPGA in the voltage-controller module PSU-CTRL. The high-voltage amplifiers produce voltages for electrostatic lens and the front side of an MCP in the spectrometer, they are fed to the connector in the output module HV-OUT (see Fig. 3). In this module, analog-to-digital converters are located which monitor the output voltages and the potential of the analog ground.

The controller module PSU-CTRL contains an FPGA that integrates several SPI controllers for the communication with the digital-to-analog converters in the high-voltage amplifiers, with the switching converters HV-SMPS2, the analog-to-digital converters in the output module HV-OUT, and the non-volatile memory. Further, a PWM controller in the FPGA controls the fan speed and two counters measure the fan rotation period as well as the line frequency. The operation is controlled by a crystal oscillator, its frequency is multiplied by a PLL circuit in the FPGA to a 100 MHz clock, providing a time resolution of 10 ns. The FPGA is attached to a CPU implementing the user interface. The CPU controls the graphic LCD and serves the human-machine interface (HMI) consisting of the LCD, cursor keys, and a rotary encoder (see section "Human-Machine Interface").

The control software running on the main CPU implements an intuitive user interface with menus and dialog boxes. The user has the possibility to monitor the function of the device and set all working parameters. These are stored in a non-volatile memory (FRAM) so that the device keeps all setting after powering off.

The USB interface attached to the CPU can be used for remote controlling the device, the USB connector is located at the front side of the controller module PSU-CTRL. A Windows™ GUI application can be used at a remote PC to emulate the direct manual control at the front panel. By additional text-mode utilities, the device parameters can be set or read, the device function can be monitored, or the device firmware can be updated.

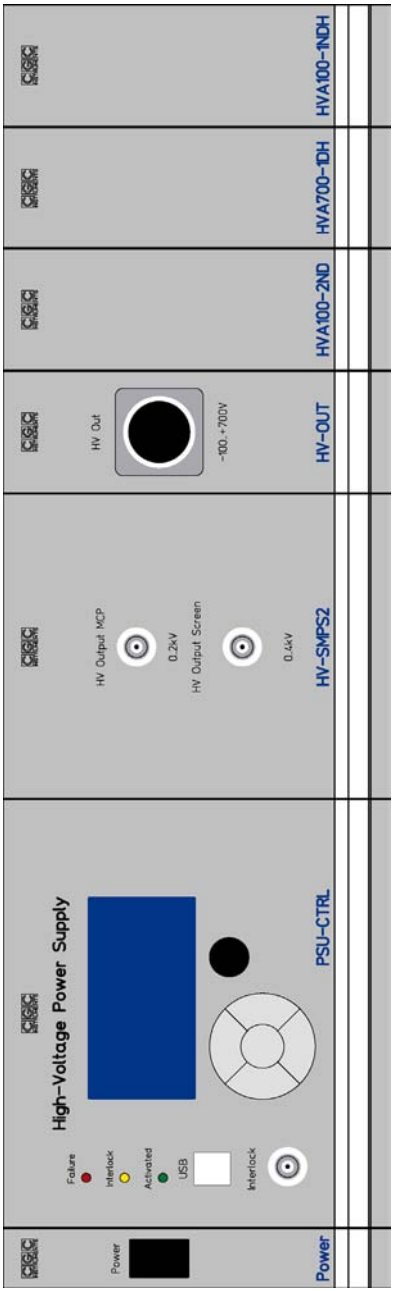

Fig. 1. The front panel of the programmable power supply unit.

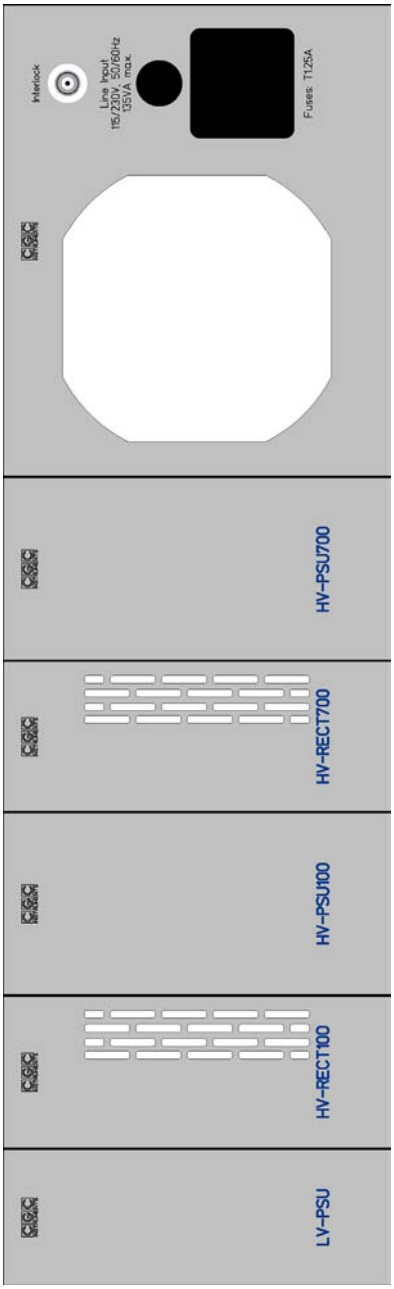

Fig. 2. The rear panel of the programmable power supply unit.

Embedded Safety Precautions

The system is equipped with two interlock loops that disable the output if any of the loops is opened. The terminals of the interlock loops are located at two BNC sockets. They are intended to be connected to a vacuum controller or another supervising device. The sensing of any of the interlock loops can be disabled in system settings if its function is not required (see the manual of the voltage controller for more details).

The power supplies of the device are cooled by several heatsinks located in the device housing. The heatsinks are actively cooled by a fan at the rear panel, the fan is controlled according to the heatsink temperature. Thus, in the standby state with disabled output, the device produces only minimal acoustic noise, since the fan is typically turned off. Under operation, the heatsink temperature increases and the fan is activated. Under certain conditions, the cooling power of the device is not sufficient and the device can overheat. This may happen if the device output is overloaded or even shorted, if the ambient temperature is high, or if the fan fails. To prevent this from happening, the device is deactivated if the temperatures exceed a preset level (see the manual of the voltage controller for more details).

Control and Indication Elements

All control elements are located at the front panel of the voltage controller (see Fig. 1).

Using the rocker switch "Power", you can power the device on or off. When powered on, the three LEDs at the front panel of the controller module PSU-CTRL ("Failure", "Interlock", and "Activated") light and the display turns on.

The LED "Interlock" shows the state of the interlock loops. It lights yellow, if the interlock loops are closed, i.e. if the corresponding contacts are shorted. When any of the loops is open, the LED "Interlock" is off and the device cannot be activated, unless the particular interlock loop is deactivated in system settings (see the manual of the voltage controller for more details).

The LED "Activated" lights green if the voltage output is active. This indicates that high voltages with a desired magnitude are present at the outputs and shows that no failure has occurred. If the device can-

not be activated or was unintentionally deactivated, check the dialog boxes for device monitoring (see the manual of the voltage controller for more details). The most probable reason for the deactivation is an opened interlock loop or a wrong setting of it.

The LED "Failure" lights red if any failure occurs, i.e. if the device overheats or the fan fails. You can identify the reason for the failure by inspecting the dialog boxes for monitoring the device function (see the manual of the voltage controller for more details). On a fan failure, the device indicates a failure but continues to operate. You should, however, replace the fan as soon as possible since the temperature inside the device may rise and the performance degrade. In extreme cases, the device may overheat, this is signalized if one of heatsinks in the device reaches the critical temperature. In such case, the device is deactivated and the output is turned off. The temperature threshold can be modified, you can also check the current temperatures by opening the dialog box for temperature monitoring on the LCD (see the manual of the voltage controller for more details).

Human-Machine Interface

The device is equipped with a graphic liquid crystal display (LCD), a set of keys (keypad), and a rotary encoder. The keys are arranged in a circle symbolizing the key function: There are four direction keys ("left", "right", "up", and "down") and a middle key for confirmation or selection ("enter").

The keys are used for menu navigation, for selecting dialog items, or for changing values. The function of the keypad in every device state is symbolized on the LCD immediately above the keypad. A text describes the function of the middle key, alternatively just the symbol "↵" is displayed showing that the middle key is functional. Similarly, arrows show which of the keys has an influence on the operation in the current state. When a menu is active, the vertical direction keys are used to change the current selection. The right direction key as well as the middle key opens a submenu, provided it is available. The left direction key closes the submenu or the main menu if there was no opened submenu. The middle key selects the menu item and launches the corresponding action.

The rotary encoder is used to change numerical values or select items. The function of the encoder is symbolized on the LCD immediately above the encoder knob in every device state. In most situations,

the encoder uses an enhanced speed control. This enables you to precisely set any desired value or quickly make large changes. You can change the corresponding value in small steps when you rotate the encoder slowly or make large changes when you spin the encoder knob rapidly. To set large numbers, the encoder speed can be further increased by pressing and holding the direction key "left". If this feature is available, the left arrow is shown above the keys.

In some situations, the encoder's push button is used to reset the selected value, set it to default, or switch the encoder function. In such cases, the symbol "⧈" is shown on the LCD above the encoder knob reporting that the encoder's push button is functional.

For more details about the operation, see the manual of the voltage controller.

Terminals

The output high-voltage terminals are located in the connector "HV Out" at the front panel of the output module HV-OUT (see Fig. 1). The connector is an ITT Cannon KPT receptacle with 5 pins, for the pin layout, see Fig. 3 and Tab. 1. The high-voltage outputs are connected to four pins. The last pin of the device connector is the analog ground of the device - this is the reference potential of the high voltages. The connector and cable screening is the sensing wire of the analog ground, it should be connected to the analog ground at the vacuum setup (see also section "Installation"), this compensates the

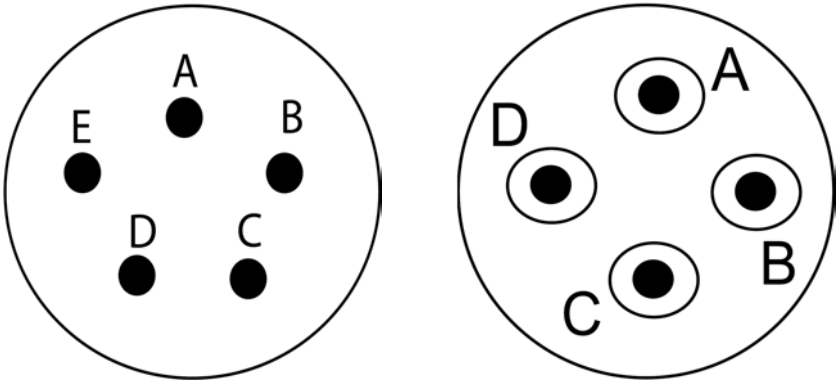

Fig. 3. The multipole high-voltage output connector.
Connector at the output module HV-OUT (left) and at the vacuum setup (right).

Tab. 1. Pin layout of the output connector at the module HV-OUT and at the vacuum setup.

Connector Pin		Signal	Description
Device	Vacuum		
Scr	Scr	AGnd-Sens	Analog-Ground Sense
A		AGnd	Analog Ground
B	A	V1	Output Voltage 1 (0...-100 V)
C	B	V2	Output Voltage 2 (-100...+700 V)
D	C	V3	Output Voltage 3 (0...-100 V)
E	D	V4	Output Voltage 4 (0...-100 V)

voltage drops in the ground wire.

The interlock loops are available at the BNC sockets located at the front panel of the controller module PSU-CTRL (see Fig. 1) and at the rear panel of the device (see Fig. 2). If the particular interlock loop is enabled, the contacts of the respective BNC socket must be shorted to enable the device. Since the shielding of the connector is connected to the device ground, i.e. the protective earth (the PE wire), you may short the inner contact of the connector to the PE wire to enable the device operation.

At the front panel of the controller module PSU-CTRL, a USB socket for remote control is located. The USB socket is the type B usual for peripheral devices. It can be connected to any compatible host by a USB cable with a maximum length of 5 m.

For the mains connection, an IEC inlet with an EMC filter and integrated fuse holder is located at the rear panel. Use a standard line cord with the universal IEC mains lead to connect the device to the mains. To replace the fuse, remove the line cord and open the fuse holder. Insert the new fuse, close the fuse holder, and connect the line cord back to the IEC inlet.

Installation

! Before powering on the system, read the user manual carefully.

For shipping the device, it was disassembled and the plug-in modules were packed separately. You have to insert all plug-in modules into the main chassis and fix them with the screws at their front panels to prepare the device for operation.

! Use gloves and avoid touching the modules with the fingers. Most modules have chromated side walls in order to improve the EMC shielding of the cassettes. The chromated surface is electrically conductive but is sensitive to chemical substances like the sweat on human skin. In most cases, the fingerprints at a chromated surface are permanent and cannot be cleaned.

Check the front and rear panels shown in Fig. 1 and Fig. 2 for the right order of the plug-in modules.

! Be sure that the plug-in modules are inserted properly at the correct position. Failing do this will most probably damage the device when it will be powered on.

To install the device, either a standard 19" rack can be used or the device can be placed on a stable table. Note that the device requires a space of at least 49 × 49 × 14 cm³ (width × depth × height) and weighs about 13.5 kg. The rack or the supporting surface must guarantee a sufficient mechanical stability under this load. The installation area must be kept dry and the temperature within the range specified in the section "Technical Data". Avoid exposing the device to direct sun light since this may substantially increase the device temperature and degrade the performance.

During operation, only the front panel of the device has to be accessible. Before installing the device in its final position, you should attach the line cord; it should be connected to the IEC inlet on the rear panel (see Fig. 2). To power the device, a power mains socket with proper grounding is required. Check the voltage selector at the rear panel before powering on the device.

! **Warning:** A wrong setting of the voltage selector may permanently damage the device.

The air inlet at the rear panel must not be covered or obstructed during device operation, it must be provided with sufficiently cool air for

active cooling of the device. Take necessary precautions to ensure a sufficient supply of cool air when installing the device in closed racks. Inspect and clean the fan regularly. Furthermore, use a vacuum cleaner to remove dust from the fan and from the modules in the device housing. Many modules use one of their side walls as heatsinks, large dust layers on them substantially lower the cooling power and the device may overheat if the heatsinks are extremely dirty. Also the lifetime of a dirty fan can be significantly shortened.

If already connected, disconnect the output cables and power on the device by toggling the rocker switch "Power". The display at the front panel of the controller module PSU-CTRL will turn on (see Fig. 1). During the startup, the three LEDs beside the LCD ("Failure", "Interlock", and "Activated") will light for 1-2 seconds. When the device startup completes, the LED "Interlock" indicates the state of the interlock loop. The other two LEDs ("Activated" and "Failure") should be inactive. Consult the section "Quick Setup Guide" in the manual of the voltage controller PSU-CTRL how to take the device in operation.

If the device behaves properly, connect it to the spectrometer hardware by the supplied cables. Pay a special attention to a proper grounding of the device. The grounding point should be the vacuum flange with the multipole vacuum connector for the high voltages (see Fig. 3). The enclosed 4.8-mm blade terminal for an M4 mounting should be mounted to the connector's flange by one of the flange screws and the grounding wire of the multipole cable should be connected to this terminal. The grounding wire is connected to the cable shielding (signal AGnd-Sens in Tab. 1) and to the analog-ground wire of the cable (signal AGnd in Tab. 1), this wire is plugged to the pin A of the connector at the device side (see Fig. 3). The analog-ground wire provides the power connection to the device, the cable shielding serves as a sensing terminal, i.e. senses the reference potential for the output voltages.

The high-voltage coaxial cables for the output voltages of the switching converter HV-SMPS2 should be connected to respective vacuum connectors. The used connectors are not intermateable - the cable for the 2-kV output (HV Output MCP) is equipped with SHV (5-kV SHV) plugs, the cable for the 4-kV output (HV Output Screen) uses the HC51 connectors (10-kV SHV). The shielding of both cables is grounded at the vacuum connectors, at the device side, the connector shielding is galvanically isolated from the device ground and is just terminated by small capacitances in order to provide a high-frequency

grounding. This grounding scheme should reduce ground loops and improve the noise values of the output voltages.

A properly connected device should be tested by applying the desired voltages on the device output. Please verify that the aimed voltages can be reached and are stable without any discharges or other unwanted phenomena. Finally, if no problems were observed, proceed with installing the control software and running test scans with the spectrometer.

In case of any discrepancy with this description, try to repeat the corresponding steps. If you cannot solve the issues, contact the distributor or the manufacturer of the device.