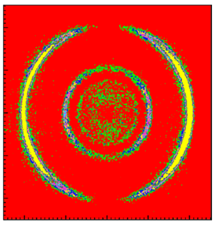
RoentDek

Handels GmbH

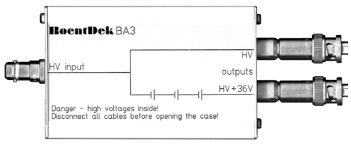
Supersonic Gas Jets
Detection Techniques
Data Acquisition Systems
Multifragment Imaging Systems



Power Supply Manual

BIASET3
HV2/4, HV2/6, HV2/8, HV2/10, HV3
SPS2 (mini)
BA3, HVZ and HVT/HVT4
USB-IO1

(Version 11.0.2511.1)



RoentDek Handels GmbH

Mail Addresses:

<u>Headquarter</u>

RoentDek Handels GmbH
Im Vogelshaag 8
D-65779 Kelkheim-Ruppertshain
Germany

<u>Frankfurt subsidiary</u>

RoentDek Handels GmbH
c/o Institut für Kernphysik
Max-von-Laue Str. 1
D-60438 Frankfurt am Main
Germany

Web-Site:

www.roentdek.com

WEEE:

DE48573152

The HV2/4 and HV2/6 were developed by

iseg Spezialelektronik GmbH

for

RoentDek Handels GmbH

Table of Contents

5 The RoentDek High Voltage Supplies

Safe and high-performance operation of **RoentDek** detectors requires adequate high voltage supplies and auxiliary passive bias units. In the following the standard units and accessory items are described. If you have received a different model, please refer to the respective manual.

The **RoentDek HV3** High Voltage power supply is the latest unit and offers three output channels. The form factor is 19"/3HU. In the standard configuration, it is equipped with one negative output and two positive output channels with a maximum voltage of 4 kV each. Variants with ±6 kV are also available. The **HV3** can be remote-controlled in various ways: either directly via a DC-input voltage or by software through the USB-port or over the Ethernet (Telnet or web browser interface). Thus, the **HV3** it is well suited for the integration into larger data acquisition-systems (e.g. Tango).

If you have received an **HV3** please refer to the separate manual and continue with Chapter 5.3 of the manual here to learn about **HV3** operation with accessory passive high voltage supply units such as **HVZ** or **HVT-3** that may be provided to operate a **RoentDek** detector. Otherwise continue with the following chapter, i.e. if you use a **HV2/4** or similar NIM unit as high voltage power supply

5.1 The HV2/4 (/6 /8 /10) dual High Voltage supply module

The **RoentDek** 2×4kV High Voltage power supply is especially designed for biasing multi-channel-plate detectors, featuring low ripple and regulated current limitation and protection. It is usually powered by a NIM crate or via the **RoentDek SPS2(mini)** mains adapter (through the 9-pin socket on the rear side panel). Special versions of this module for up to 6, 8 and 10 kV (**HV2/6**, **HV2/8**, …) are available, also for "pseudo-floating" operation mode (see Chapter 5.2).

The switches on the side panel will set the respective channels A and B to negative or positive output polarity (not for **HV2/10**, which has factory-fixed polarities). The polarity is indicated by an LED on the front panel. **Only change polarity when mains power is off.**

If a channel of the power supply is switched on (indicated by an LED), and the "DAC" switch is set to the upward position, the 10-turn potentiometers on the front panel can be used for manual setting of the output potential U_o, 10 turns corresponding to U_{max} (e.g. 4 kV in case of the **HV2/4**) with linear progression. The voltages can also be set externally via an analog voltage input to the LEMO-sockets on the rear panel (0-10 V positive input corresponds to 0-4 kV voltage output for **HV2/4** (1:400) or 1 kV progression for every 1 V analog input for **HV2/6**, **HV2/8** and **HB2/10** (1:1000) with linear progression). For this the "DAC" switch must be set to "DAC". Please contact **RoentDek** for adequate DC level remote controls (e.g. the **USB-IO1, see Chapter 5.10**).

The A/B switch will allocate the display to channel A or B, the V/I switch will enable voltage or current reading of the respective channel. The accuracy of the reading is within a few volts and a few µA (typically 1 µA), respectively.

If a channel is turned on, the "Inhibit" input can be used for enabling / disabling the voltage output with a TTL level. Specified operation modes are:

a) Input open (resistance to ground > 10 kΩ) or level > +2.5 V: high voltage output is enabled
b) Input shorted (resistance to ground < 1 kΩ) or level < +1 V: high voltage output is disabled

Do not use input voltages outside of the range from 0 V to +6 V.

The "Inhibit" input can be used for remote safe-guarding or actively enabling/disabling the voltage output by applying a TTL level as described above. Notice: if the "Enable" switch is on "Kill" position, high voltage output must be resumed manually.

The maximum current I_{max} delivered is 3 mA for the **HV2/4** (1 mA for **HV2/6** and **/8**, and 0.5 mA for **HV2/10**). Both I_{max} and U_{max} can be restricted in 10 % steps (e.g. from 0.3 mA/400 V to 3 mA/4 kV for the **HV2/4**, the latter corresponding to 100 %). Usually the current limiter should set to 10 %, i.e. 0.3 mA when using it with a **RoentDek** MCP detector (exception: biasing via an **HVT** device).

If a pre-set limit is exceeded (e.g. too high current) a red "Error" LED on the front flashes once and the high voltage "trips": it turns off when the "Enable" switch on the front table is in the "Kill" position (see Figure 5.1, on channel B). Re-engagement must be manually prompted by turning the channel off and on again via the red main switch.

If the "Enable" switch is **not** in "Kill" position (see Figure 5.1, on channel A) the unit will automatically try to resume the set value. **The latter is NOT a favorable operation condition if the tripping is caused by detector sparks and may cause damage if prolonged. We strongly advise to operate the power supply only in "Kill Enable" mode**. In case of an "Error", turn off the voltage to 0 Volts and switch the module off. Do not turn it on again before a proper state for safe operation has been verified.

Figure 5.1: 2x4kV Power Supply (front panel)

Important: The safest operation mode for MCPs is the "Enable Kill" position. If the current limitation is set low and the switch is on this position it can happen that an error is indicated when starting to increase the voltage on a certain detector part, although no problem of the hardware actually exists. This is due to the loading current of capacitors in the power supply itself or in the signal decoupling circuits. In that case set the switch to the other direction *when starting to increase voltage. You may switch to the "Enable Kill" position later after the voltage setting is finished.*

The hardware ramp speed is 500 V/s. (power switch or inhibit turned on/off.)

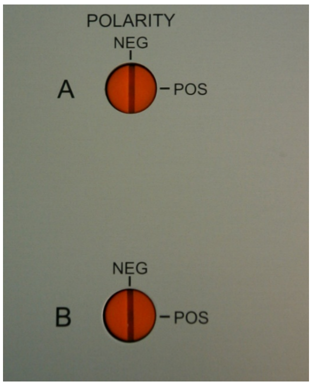
Figure 5.3: 2x4kV Power Supply (rear-panel)

For standard modules the 9-pin socket located on the rear panel can be used to alternatively receive power via a **SPS2(mini)** mains adapter (in absence of a NIM crate. Pin assignments are

Pin1/2: ground
Pin6: -24 V, Pin7 +24 V — for N24 modules (see Figure 5.9) and
Pin5: -6 V, Pin8: +6 V — additionally <u>for 6 V modules</u> (not with N24 label)*

Further specifications:

Operation/storing temperature:	0 ... +50 °C / -20 ... +60 °C
Ripple (peak-to-peak)	< 50 mV_{pp} for all frequencies (**HV2/4** and **/6**)
	HV2/8 and **/10**: for < 1 kHz up to 200 mV_{pp}
Display reading precision	±0.1% plus 1 digit
Stability	$\Delta U_o < 2 \times 10^{-4}$ of U_{max} or 5×10^{-5} of ΔU_o
Temperature coefficient	$< 1 \times 10^{-4}$/°C



Changing the Polarity:
To change the polarity of either channel A or B, locate the corresponding "red knobs" on the left side-panel (see Figure 5.2, here: negative polarity is selected for both channels). **Only if the mains power is off** adjust the slit of the "red knob" to the desired polarity using either an adequate screwdriver or a coin. **Do not press on the knob! Do not use force!** The channel is adjusted if you hear and feel the lock click into place.

Figure 5.2 (left side): 2x4kV Power Supply

Warning: the HV output of this power supply can be hazardous if not properly operated. Never operate the module with open housing. RoentDek denies any responsibility for accidents with their products and is protected by German laws. If you need special instructions how to handle high voltage power supplies please contact RoentDek.

Notice: **HV2/4** and similar units may need an adequate pull-up preventer circuit like the **RoentDek HVT** when operating two channels at the same polarity supplying resistive-coupled contacts such as the two sides of an MCP stack (see Chapter 5.5).

For optimal stability of the set values it is recommended to operate the **RoentDek** high voltage power supplies mainly between 2% and 100% of U_{max}, e.g. between 80 V and 4000 V for the **HV2/4**. Lower voltage settings are possible but specs are not guaranteed below 1% of U_{max}. If you want to achieve stable voltage outputs well below 100 V with a **HV2/4**, **RoentDek** can provide a voltage divider based on the **RoentDek HVT+** passive voltage dividing unit (see Chapter 5.9).

Module versions with the "KIB" label (see Figure 5.4) have an internal jumper switch that allows linking the "*Enable Kill*" function of both channels: If one of the channels experiences a current drain at the I_{max} set value (a "trip"), <u>both</u> channels will be turned off (<u>but only if both channels are set to "*Enable Kill*"</u>). The "kill both" (KIB) setting is of advantage when tripping of one channel

* Modules with 6 V operation (as displayed in Figure 5.3) can be used for routing voltages from a NIM ... t which acts then as a DC-output for ±6 V, ±24 V, +12 V (pin4) and -12 V (pin9) in order to bias ... e **DLATR6** and **ATR19-2**. Please observe the label next to the socket.

alone will result in a problematic bias situation while the other channel maintains its set potential*. This is especially relevant for high voltage units with higher than 4 kV output.

Unless otherwise indicated the factory setting of the jumper position does NOT support the "kill both" functionality (see in Figure 5.5). The jumper for enabling the "kill both" functionality can be accessed after opening the side panel with the polarity switches (**before opening the case switch off both channels, wait for one minute and then remove all cable connections to the module, otherwise there is risk of electro-hazard. Only touch the inside at the jumper position!**). To enable the "kill both" functionality set the jumper to the position as shown in Figure 5.5, lower picture).

Figure 5.4: Label on the side panel indicating availability of the "kill both" functionality:

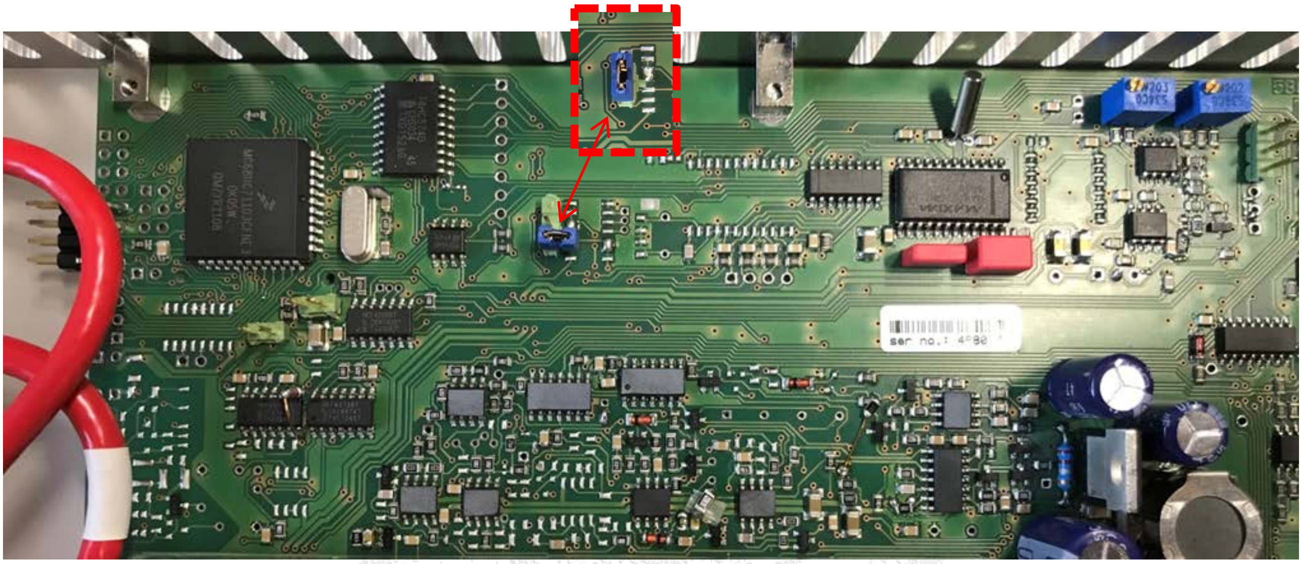


Figure 5.5: Photos of the internal circuit board (after opening the side panel).
In big picture: standard jumper position for not enabling the "kill both" function (blue jumper not set, only "parked on one of the pins).
Insert picture: Jumpers is set, bridging the pins for enabling "kill both" function.

* Such a potentially damaging bias scheme can for example occur when both channels bias an MCP stack on same polarities. Tripping of only one channel can then result in a situation that the other channel in function produces an excessive voltage across the MCP stack or between an intermediate MCP stack contact and front/back side.

5.2 The Pseudo-Floating power supply options PF+ and PF-

For some applications it is beneficial to operate a high voltage supply for detector bias in the so-called "Pseudo-Floating" mode. While the function of channel A corresponds to the standard high voltage supply version, channel B output is determined not only by the setting of channel B (via the corresponding dial or remote control) but also by the setting of channel A:

$$\mathbf{B'} = \mathbf{B} + \mathbf{A} \qquad \text{and} \qquad \mathbf{A'} = \mathbf{A} \qquad \text{(for PF+, same polarity)}$$

A' and **B'** are the actual output potentials U_o from the corresponding SHV sockets on rear panel, **A** and **B** are the set values, controlled by the dials or remote control inputs. If both channels are set to same polarity, **A** defines the "float potential" while the **B** setting defines the potential difference between the outputs (**A'** and **B'**). For detector operation, the **A'** output is used for MCP front or the anode bias while **B'** biases the opposing detector end. **B** then determines voltage across the detector while **A** defines the "float" potential of the respective detector part relative to ground: Changing **A** setting only will not affect the detector function, e.g. in terms of gain.

It is to note, however, that **B'** can never exceed the maximum rating U_{max} of the specific high voltage supply (4, 6, 8 or 10 kV), e.g. **B'** is always < 4 kV for **HV2/4PF+** even if (B + A) would mathematically yield a higher value.

It is also possible to operate the two channels of a PF+ high voltage power supply at alternating polarities. In this case, however, the voltage difference **B' = B +A** between the SHV output does not stay constant when **A** is varied due to the sign change.

For this reason a the HV2/4 version can be supplied as **PF**- version, internally set to

$$\mathbf{B'} = \mathbf{B} - \mathbf{A} \qquad \text{and} \qquad \mathbf{A'} = \mathbf{A} \ \text{ with } \ \mathbf{B} > \mathbf{A} \qquad \text{(for PF-, different polarities)}$$

correspondences between set values and outputs. This allows for an equivalent pseudo-floating operation scheme when the potentials at the detector ends have different sign.

For the **PF**- version the minimum value of **B'** is 0, i.e. the polarity of the output cannot change if (**B - A**) would mathematically yield a negative value. The versions **PF**- or **PF**+ are factory-fixed and cannot be changed

It is to note that the high voltage outputs of the **PF** high voltage supply versions are not physically floating, only the function of a floating power supply channel as simulated by special voltage control circuits inside the units. Therefore, it is not possible to reverse the output polarity of **B'** by changing set values from A < B to A > B.

The following table shows some examples. Channel B is set to the MCP voltage (here: 2700 Volts), while channel A can be varied.

Examples for **HV2/4PF+/-**	pol. **B**	**B** set (diff.)	pol. **A**	**A** set range and output	output on lower SHV socket **B' = B + A (PF+)**
electron mode	+	2700 V	+	0 V to 1300 V (front)	+2700 V to +4000 V (back)
pos. ion mode	-	2700 V	-	1300 V to 0 V (back)	- 4000 V to -2700 V (front)
					B' = B - A (PF-)
alternate mode	+	2700 V	-	2700 V to 0 V (front)	0 V to +2700 V (back)

Figure 5.6: HV2/4PF+ Power Supply

Note that also the operation the pseudo-floating **HV2/4** and similar units may need an adequate pull-up preventer circuit like the **RoentDek HVT** when operating two channels at the same polarity supplying resistive-coupled contacts such as the two sides of an MCP stack (see Chapter 5.5).

5.3 The BIASET3 with SPS2(mini)

The **BIASET3** consists of the 90-250 V_{AC} main power supply **SPS2 or SPS2mini** and 1 to 4 units of **HV2/4** (or **HV2/6**, **HV2/8** and **HV2/10**) modules (see Chapter 5.1) as a standalone power supply solution without the need for a NIM bin. It can also incorporate single channel high voltage (HV) modules like the **HV1/4** or any of the **EHQ 1xxx** series earlier **BIASET2** product. The **BIASET3** includes a stand for up to 4 HV modules. The HV modules and the **SPS2mini** are interconnected via 9-pin sub-D cables (included) on the rear panels*.

Figure 5.7: BIASET3 with SPS2 and one HV2/4 module (corresponds to BIASET3-2). Alternative mountings include adapter frames for placing several HV2/4 units in 6HU 19" rack or sideways in 3HU racks.

The **SPS2** mains adapter provides power via standard 9-pin sub-D cables for up to two HV modules or via twin-9-pin sub-D cables for up to four HV modules. It measures about 130×130 mm with a depth of approximately 250 mm (extra 100 mm free depth are needed for the cables on the rear panel).

The **SPS2** can be mounted to a 3-HU 19" rack (occupies 24 width units) or can be used as a table-top unit. The unit requires sufficient airflow and an ambient temperature < 40 °C. A spare main fuse (250 V 4 A, slow) is supplied within the AC-input socket. Separate fuses inside the housing (0.63 A "slow") secure the 6 V DC output lines. Lit LEDS on the rear panel indicate normal operation.

Always turn off the unit when connecting/disconnecting the mains power cable or the cables to the HV modules. Always turn off the unit AND remove the power cable when opening the case or changing fuses.

* The output from the **SPS2mini** cannot supply operation voltages for the **(N)DLATR** or **FAMP/CFD** modules.

Figure 5.8: SPS2 front and rear panel with connection cable to HV2/4 module (not shown).

High voltage modules of the type "N24" and **EHQ 1xxx** (e.g. **HV1/4**) can alternatively be supplied via the **SPS2mini** mains adapter which delivers only ±24 V. If you want to purchase a mains adapter for an existing **HV2/4** module, verify of which type it is. The "N24" units can be recognized by the respective label on the front panel or equivalent side-panel labelling:

Figure 5.9: SPS2mini mains adapter (left) and the specific label (red arrow) on the front side of a "N24"- type HV2/4 module which can be powered by it (those units with side panel labels will show the N24 indication there). The N24-type HV modules can also be operated with old-type NIM-crates that does not supply the ±6 V.

The **SPS2mini** comes with an external mains adapter, to be connected to the "*DC input*" socket. **Remove the mains power plug from the AC socket when connecting/disconnecting cables on DC input or output sockets of the SPS2mini**.

5.4 BA3 battery unit

The **BA3** battery unit is one of several specific "passive" units for biasing **RoentDek** detectors as an add-on device to a **HV2/4** or similar high voltage supply unit. Its typical application is to simplify helical wire delay-line anode bias but it can also be used whenever a floating battery device is needed for certain biasing schemes. Several **BA3** units can be cascaded and combined with other devices.

Usually it is sufficient to operate a helical wire delay-line anode with voltage difference of 20 to 50 V between the “reference” and the “signal” wires (for details please refer to the **RoentDek** Delay-line manual. To supply this constant voltage offset between the wires a battery can be used. The **RoentDek BA3** battery pack provides this offset with values between 35 and 40 V (nominally 36 V, without load 38-39 V).

For using the **BA3** to supply wire potentials you need to connect the SHV output “*HV +36 V*” to the U_{sig} input of the **FT12/16-TP** plug and the other SHV output “*HV*” to the U_{ref} input. The desired potential for the reference wire (U_{ref}) must be supplied to the SHV input. “*HV input*” of the **BA3**’s opposite side. The maximum potential for $\mathbf{U_{ref}}$ is specified as 4 kV, on demand units with up to 6 kV rating can be provided.

Please note that the battery is not discharged during normal operation as no current is flowing between U_{ref} and U_{in}. Even in the presence of a short on the delay-line anode, there is still a 10 kΩ resistance between the poles of the internal battery pack (this is only valid for **BA3** bought in or after 2014). The lifetime of the battery pack is therefore very long (several years). The individual batteries are standard 12 V cells which can be found for example in camera shops. If you need help in replacing the battery, please contact **RoentDek**. Before opening the case, make sure to turn off, discharge and disconnect the high voltage. Only open the side where the “*HV Input*” socket is located. The **BA3** circuits is also used as part of the **HVZ10** voltage dividing unit, see Chapter 5.4.

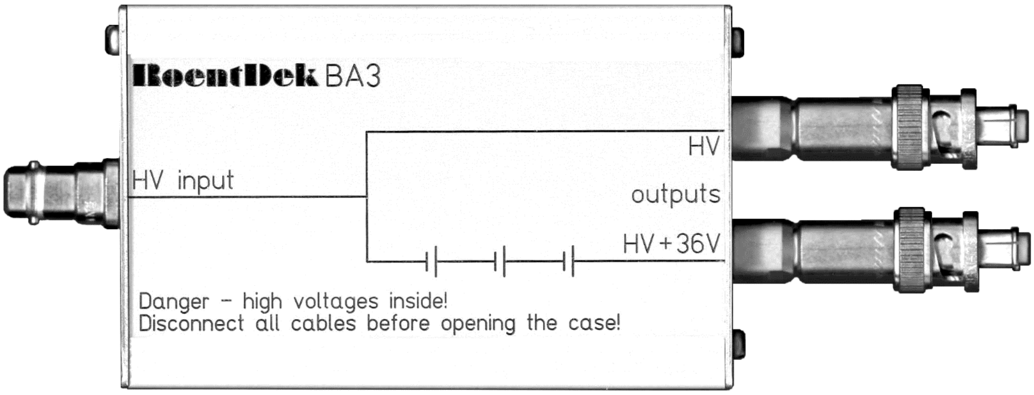


Figure 5.10: RoentDek BA3 battery box. The voltage input is on the left side, the output connectors (here as reserve SHV) on the right side. The input voltage is routed to the upper voltage output (for U_{ref})) and produces with the internal battery pack the signal voltage U_{sig} = U_{ref} + 36 V (nominally) on the lower output connector. Newer versions of the BA3 have SHV sockets as outputs (instead of plugs shown here) and in-line 10 kΩ resistors.

5.5 HVT and HVT4(+) High Voltage Terminators

If a micro-channel plate stack or similar semi-conducting devices with resistance in the MΩ to few GΩ range shall be biased with <u>same</u> polarity on both sides (e.g. positive, for electron detection), standard high voltage power supplies’ control circuits cannot stabilize the lower bias setting below a certain minimum voltage $\mathbf{U_L}$. The reason is that any biased device with non-infinite resistance (such as an MCP stack) must be described as a “load resistance” $\mathbf{R_L}$ for a high voltage supply which forms a resistor chain to ground with the internal resistance $\mathbf{R_{HV}}$ inside the high voltage supply: While the far end of $\mathbf{R_L}$ is biased to a certain higher voltage $\mathbf{U_H}$ by another power supply channel (with same polarity [*]) the other end of $\mathbf{R_L}$ will be pulled up to a certain potential $\mathbf{U_L}$, even if the dial setting of the their-connected high voltage supply channel is set to zero or to a lower output potential, see Figure 5.11. This effect prevails even if this channel is connected indirectly via a resistor/diode chain (e.g. through an **HVZ**, see Chapter 5.5.1). As a consequence, only higher voltages than $\mathbf{U_L}$ can be actively selected by the dial setting of the power supply channel in this case.

----------$\mathbf{R_L}$----------(-----$\mathbf{R_{HV}}$-----**ground**)   inside HV supply

↑ (MCP) ↑

$\mathbf{U_H}$ $\mathbf{U_L}$ (> ΔU) $\mathbf{U_L/U_H = R_{HV} / (R_{HV} + R_L)}$

Figure 5.11: Scheme of effective biasing circuit when both ends of a resistor load (e.g. an MCP stack) shall be set to same-polarity potentials U_L < U_H in absolute numbers. U_B is pulled to minimum potential ΔU determined by the resistor ratio R_{HV}/R_L.

[*] If the ends of R_L are biased at different polarity there is no such effect as described here.

For the RoentDek high voltage supplies $\mathbf{R_{HV}}$ is on the order of 100 MΩ. To prevent pull-up when biasing devices having $\mathbf{R_L}$ of same order a smaller "terminating" resistor $\mathbf{R_{HVT}}$ must be placed to ground, i.e. parallel to $\mathbf{R_{HV}}$, thus reducing $\mathbf{U_L}$. This can for example be achieved by a passive *pull-up preventer circuit*, the RoentDek *High Voltage Terminator* box (**HVT**). On the RoentDek **HV2/4** and similar units $\mathbf{U_L}$ can directly be observed on the voltage display (when the respective set voltage is zero or low enough). The novel RoentDek HV3 high voltage supply may contain a **HVT**-circuit internally for some output channels.

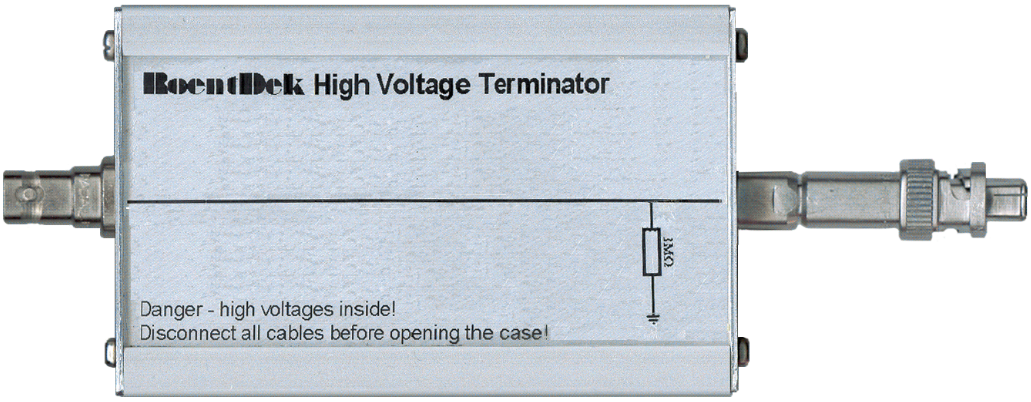


Figure 5.12: High Voltage Terminator, with 1MΩ resistor to ground and reverse SHV connector on one side. A special version (HVT+) is designed as voltage divider enlarging the output range of HV2/4 units (see Chapter 5.9).

The standard **HVT** contains a 1 MΩ resistor to "ground" and is optimized for electron detection purposes with MCP front potential near +200 V or higher. For typical MCP stack resistances (> 20 MΩ), i.e $\mathbf{R_L}$ in Figure 5.11. MCP front voltage ($\mathbf{U_L}$) due to the "pull-away" effect will be < 200 V and can actively be raised up to for example 1000 V with a high voltage supply (1400 V maximum rating). If the achievable $\mathbf{U_L}$ is still too high even in presence of an **HVT**, a parallel resistor can be placed inside the unit to reduce the effective $\mathbf{R_{HVT}}$.

Note, that the current drawn from the low-voltage power supply channel is then determined by $\mathbf{R_{HVT}}$ and may limit the maximum voltage that can be reached in presence of an **HVT** (especially if current limiter settings are engaged). In this case $\mathbf{R_{HVT}}$ must be increased, e.g. by adding an in-line resistor inside the **HVT** or replacing it (see **HVT4**, below). Only use resistors with sufficient voltage and power rating. Contact RoentDek if you need extra instruction how to change $\mathbf{R_{HVT}}$ and for supply of adequate resistors.

The minimum achievable lowest voltage **UL** in presence of a **HVT** is defined by the following formula:

$$\mathbf{U_L} = \mathbf{U_H} \cdot \mathbf{R_{HVT}} / (\mathbf{R_{HVT}} + \mathbf{R_L}) \qquad \text{with } \mathbf{R_L} = \mathbf{R_{MCP}} \text{ in this application.}$$

Note again, that these considerations are only valid when $\mathbf{U_L}$ and $\mathbf{U_H}$ have same polarity.

It is also possible to change the internal resistor to a customized value so that the desired voltage on MCP front (or back) is generated only by applying the bias on the other MCP side (passive **HVT** use). A special **HVT** version is available that eases the task of adjusting resistor sets. If you need help in determining $\mathbf{R_{HVT}}$ for passive **HVT** use or finding adequate resistors, please contact RoentDek. As an alternative the **HVZ-G** circuit can be used (see Chapter 5.6) which sets MCP front potential to a default (positive) value once MCP back potential to a higher positive potential.

It is important to note that the effective MCP front potential may still differ from the set voltage in case of a non-negligible in line resistor value (R_{Df}) in the biasing chain. Please refer to the RoentDek Delay-line manual for determining this effect.

The latest **FT12TP(z)** decoupling plugs can be equipped with an internal on-board **HVT** circuit, please refer to Chapter 5.8.

Readily available product variations of the **High Voltage Terminator** with different $\mathbf{R_{HVT}}$ are for example the **HVT4** (containing a 10 MΩ resistor rated for up to 4 kV) and the **HVT-3** (see Figure 5.13).

Figure 5.13: The HVT-3 can be directly connected to the output socket of a high voltage supply.

These are typically used for applications with MCP front at a high negative potential up to -6 kV via an SHV feedthrough and MCP back side thus being at a negative potential well beyond -1 kV (exceeding the standard **HVT** rating). In this case the MCP back side voltage may be pulled away unless connected through **High Voltage Terminator** (see Figure 5.14).

Electron detection (0 V < $U_{MCP\ front}$ < +1000 V)

MCP front ← **HVT** ← HV supply (+)

MCP back ← HV supply (++)

<u>**heavy**</u> **positive ion detection** ($U_{MCP\ back}$ with negative bias)

MCP front ← HV supply (- -)

MCP back ← **HVT4** ← HV supply (-) or via **HVZ**

MCP back ← **HVT4** (for operation with **FT12TPz**)

Figure 5.14: Typical voltage settings requiring an in-line HVT or HVT4 for pull-up prevention. When detecting negative ions (if having low kinetic energy) the MCP front potential must be increased to at least +2000V and an HVT4 is to be used in the left diagram. In this operation mode the necessary MCP back/anode voltages are beyond the rating of the standard feedthroughs typically used for delay-line detectors (see Chapter 5.7).

For applications with demands for slow heavy ion or negative ion detection please contact **RoentDek** for special detector mounting, signal decoupling and high voltage supplies rated up to 10 kV.

5.5.1 The HVT4+ matched mode

For MCP stacks with intermediate connection via a shim ring placed in between two MCPs **RoentDek** offers a modified **HVT4+** unit. It alternatively (or additionally) contains an in-line matching resistor (R_M) inserted for forcing a matched MCP stack operation (R_{HVT} is usually removed when the **HVT4+** is used in matching mode).

In this "matching mode" the resistor value R_M is selected so that it reduces the effective resistance on one side of the stack by placing R_M in parallel to the MCP with higher resistance. The **HVT4+** unit in combination with an **SHV-T** plug (also available from **RoentDek**) completes the necessary biasing scheme. The **HVT4+** unit connects between the corresponding high voltage inputs for the intermediate connection, e.g. "**X**" in case of an **FT12TP** plug, or any other SHV/MHV feedthrough connected to the shim ring (as in case of **FT4TP/FT16TP**) and either the MCP front SHV input or the MCP back SHV input (usually via **FT12TP** or **HFSD/HFST**), see Figure 5.16.

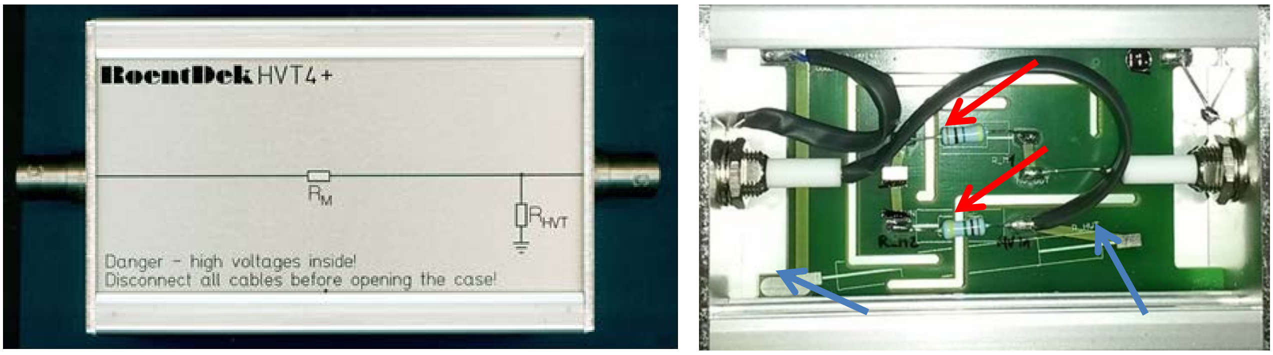
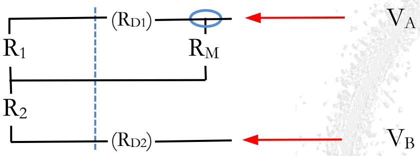


Figure 5.15: HVT4+ showing the circuit with resistors R_M (and optionally R_{HVT}), R_M internally formed by two serial resistors (red arrows), their sum equalling the value of R_M. A specific block digram on the top panel of each unit indicates the installed circuits on delivery. R_{HVT} can also be added later, to be soldered between the pads indicated by blue arrows (right picture). R_M must always be connected parallel to the MCP with higher resistance.

For an MCP stack containing individual MCP with resistances R_1 and R_2 the ratio between the voltages U_1 and U_2 across the respective MCP follow Kirchhoff's law as $U_1/U_2 = R_1/R_2$, with a total voltage across the MCP stack of $U = U_1 + U_2$. Blocking resistors in the signal decouplers can slightly change the effective potential on the MCPs so that V_A-V_B is not exactly equal to U. For a matched chevron MCP set R_1/R_2 is selected to be near unity and the individual MCPs the same voltage. If MCPs have different resistances a matching resistor R_M can be placed in parallel to the MCP with higher resistance (assumed to be R_1 in the following considerations).



$$\frac{U_1}{U_2} = \frac{R_M}{R_1+R_M}\,\frac{R_1}{R_2}$$ **Equation 5.1**

$R_1 > R_2$

$$\frac{U_1}{U_2} = 1: \quad R_M = \frac{R_1 R_2}{R_1 - R_2}\left(\frac{R_1+R_{D1}}{R_1}\right)$$ **Equation 5.2**

Figure 5.16: Connection scheme for the HVT4+ operated in matching mode and equations for determining R_M. The dashed vertical line indicates the vacuum wall with feedthroughs. The MCPs, separated by a shim ring with contact lug, have resistances of R_1 and R_2, respectively, with $R_1 > R_2$. If the resistance of the front MCP is larger than of the rear MCP (which is then R_2 in above equations), V_A denominates the front MCP stack bias (and V_B the rear bias). If the resistance of the front MCP is smaller than of the rear MCP (which is then R_1) V_A denominates the rear bias (and V_B the front bias). R_{D1} and R_{D2} denominate blocking resistors in the signal decouplers/terminators (inside HFSD, HFST or FT12TP) which can usually be neglected (term in parentheses) when determining R_M.

The same considerations hold for triple stack assemblies in which case the sum-resistance of the two unseparated MCPs enter Equation 5.1 as R_1 or R_2. Note, that in this (and in selected other) cases the targeted value of U_1/U_2 may differ from 1 so that the equation to determine R_M must be modified accordingly. In case you need help to find the ideal value of R_M and/or physically a resistor with desired properties please contact **RoentDek**. **It is mandatory to choose resistors with sufficient voltage and power ratings**.

For connecting the **HVT4+** in the biasing scheme for matching mode an additional **SHV-T** plug is required at the position of the blue oval in Figure 5.16. Note again that the **HVT4+** is always placed in parallel to the MCP stack stage that needs resistance reduction*. Typical connection schemes, also in combination with other passive voltage dividing boxes such as the **HVZ** (see Chapter 5.6) can be found on the **RoentDek** web site.

If you have received a non-matched MCP set and **HVT4+** from **RoentDek**, the **HVT4+** will usually be equipped with a resistor set that produces an effective R_M close to the desired value. The choice of the resistor set was then based on estimations about the MCP resistances from specifications values obtained from the manufacturer(s).

However, this does NOT guarantee sufficient matching since the real resistance values can significantly deviate from the specified numbers. Therefore, it is mandatory to verify MCPs resistances (e.g. by a method described in an Appendix of the detector manual) and then modify the resistance in the **HVT4+** accordingly.

An **HVT4+** unit operated in matching mode can only simultaneously be used as bias pull-up preventer on the MCP side with the larger resistance, otherwise R_{HVT} must be located in a separate **HVT** connected to the other MCP bias input. Please contact

* When using a **FT12TP** plug with internal **HVZ** voltage divider circuit (see Chapter 5.8) the plastic stopper on the MCPback SHV needs to be removed if the rear MCP is the one with higher resistance.

RoentDek for advice in case you are unsure about the proper connection scheme for combining both R_{HVT} and R_M for a certain MCP stack. If an **HVT4+** shall be operated only in the standard **HVT** terminating mode (with R_{HVT} in place), R_M must be set to zero, i.e. short-circuited with a bypass cable.

If you need help in modifying the **HVT4+** to improve matching conditions (i.e. by adding/exchanging resistors) please contact **RoentDek**.

The **HVT4+** unit can alternatively be used to place R_M as "backup resistor" parallel to the whole MCP stack. This can increase operation safety in application with biasing schemes beyond 4 kV detector potential and stabilize MCP bias when a resistor chain is applied for supplying detector voltages. Two **SHV-T** plugs are required for this biasing scheme.

5.6 HVZ voltage divider unit

The **RoentDek HVZ** is a passive voltage distributing box generating intermediate potentials in steps of 28 V or 56 V (±10 %) for all delay-line anode contacts and MCP back side of **RoentDek** delay-line detectors (and a **BA3**-equivalent voltage between the reference and signal wire). This is achieved by a chain of special diodes which are serially placed between the contact junctions to the respective detector parts.

The **HVZ** has one high voltage input socket (SHV) labeled "*HV In*" and four SHV output sockets for providing bias to the MCP back side ($U_{MCP\ back}$), "*Holder*" (U_H) and the delay-line anode wires (U_{ref}/U_{sig}). Thus, only two potentials are to be provided from high voltage supplies for biasing all detector contacts: U_{sig} (via the "*HV In*" socket) and $U_{MCP\ front}$, i.e. the MCP front potential. The latter may be produced by "terminating" MCP front via a **RoentDek HVT** (see Chapter 5.5). Other detectors like the **RoentDek DET40/75** can also be biased in this way using the **HVZ-T**.

The maximum potential for "*HV In*" is specified as 4 kV, units with up to 6 kV rating can be provided on demand. For operation of detectors at even higher voltage ("**XHV**") a special **HVZ10** can be provided (see Chapter 5.7).

Using the **HVZ** for detector bias distribution is equivalent to applying a resistor divider chain for this purpose. The **HVZ** using Z-diodes has the advantage that the relative voltages set between MCP back, Holder and delay-line wires do not depend on the absolute detector bias with respect to ground (i.e. are independent from the choice of MCP front potential). This ensures the proper voltage difference between the MCP back side and the anode (wires) and provides near-optimal voltage setting for the **DLD**'s or **Hex**' "*Holder*" bias: The voltage drop is generated as soon as a minimum current of few µA is flowing in the proper direction. The intermediate potential of the Holder can be selected in steps of about 28 V or 56 V (for older versions) by jumper settings. A battery box is not needed when using the **HVZ**, however, optional jumper positions also allow bias settings for the wires through a separate **BA3** or other floating battery units. The **BA3** can also be used in combination with the **HVZ** for further increasing the voltage difference between anode wires and MCP back.

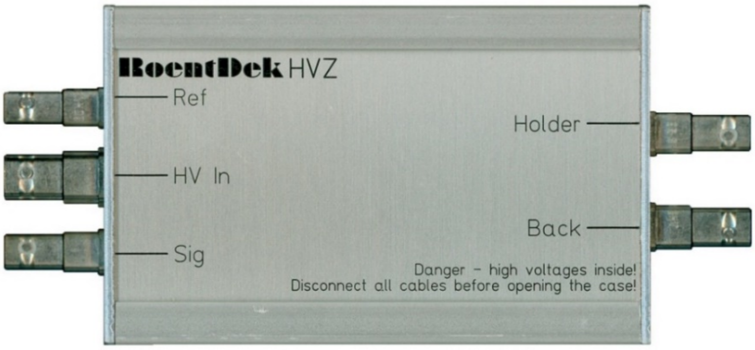


Figure 5.17: HVZ with the SHV connector sockets.

Inside the **HVZ** a total voltage drop of up to a maximum set value (nominally about 260 V) is generated as soon as appropriate electrical current flows through the unit from the input SHV socket labeled "*HV In*" to the "*Back*" socket. This current can only flow if there is an according potential difference maintained between the sockets and if the current is drained by a resistor load connected to the "*Back*" socket. During detector operation this resistor is formed by the microchannel plate stack. For this the **HVZ**' "*Back*" socket must be physically connected to the MCP stack's rear side input and must always be at the same or more positive ptotential than the MCP stack's front side, which is connected to the MCP front high voltage supply. Please insure that $U_{MCP\ front}$ < "*HV In*" at all times, i.e. during increases of the voltages toward normal detector operation and also when voltages are turn down from termination detector operation. **If the potential on the MCP back socket should become more positive than the potential on "*HV In*" the HVZ may be damaged!**

Never supply a separate potential to any other HVZ socket than the "*HV In*" socket. Never directly ground any socket in order to force this potential to zero. This may cause irrecoverable damage to the HVZ circuit.

It is important to note that the relation between the current through the MCP stack and the voltage between "*HV In*" and MCP front potentials is not linear as long as it is lower than the **HVZ'** set value. For calculating the nominal MCP back potential (i.e. on the voltage input of a signal decoupler on MCP back contact) the set voltage needs to be subtracted from the nominal "*HV In*" bias. This is important to note when considering the effective voltage across the MCP stack and when calculating the MCP resistance from the current flowing through the stack.

It is important to ensure that the voltage across the **HVZ** is never inversed and that "*HV In*" > "*Back*" > MCP front bias according to normal detector operation. The use of the **HVZ** requires the "*Back*" output always being connected to the MCP back side when applying voltage.

For operation in the standard configuration (as shipped) with all outputs sockets "*Ref*", "*Sig*", "*Holder*" and "*Back*" connected to the detector (e.g. via the **RoentDek FT12TP** or **FT16TP** decoupling circuits) the bias applied to "*HV In*" is directly connected with the "*Sig*" output socket, i.e. supplying the signal wire potential (U_{sig}). "*Ref*" output provides a 39 V more negative U_{ref} potential (i.e. with the same potential difference as obtained by a **RoentDek BA3** unit).

As described above the "*Back*" output provides the bias for $U_{MCP\ back}$ which is nominally 260 V more negative than "*HV In*". However, the effective bias on MCP back side may be lower (more negative) due to the voltage drop across the blocking resistor in the signal decoupling circuit (typically 1 MΩ, please refer to the delay-line detector manual for determining this additional bias shift).

The bias pickup from the **HVZ** for the Holder potential (U_H) can be adjusted between U_{ref} and $U_{MCP\ back}$ in steps of 56 V or 28 V by selecting a jumper position (default: $U_H = U_{MCP\ back} + 56$ V).* Before opening the **HVZ**, make sure to reduce all voltages to zero and then disconnect all cables from the **HVZ**. When removing the cables while still on high potential, there might still be hazardous voltages stored within the **HVZ**'s capacitors.

There are two different versions of the **HVZ**: the older version (with printed circuit board showing 'Rev. 1.0', 'Rev. 1.1' or 'Rev 1.2' labels) and the newer version ('Rev. 1.3' or higher). Their basic functionality is the same – the new versions just offers additional jumper settings (e.g. with 28 V steps) which might be helpful for special requirements. Please verify which version you own and follow the corresponding setting instructions below:

The latest **FT12TP** decoupling plugs can be equipped with an internal on-board **HVZ** circuit, please refer to Chapter 5.8.

For **DET** detectors a special **HVZ-T** (which includes a separate **HVT** circuit) and a simpler **HVZ-DET** version is available (see in the respective detector manual). Another variation is the **HVZ-G** for applications when the anode potential is set to ground potential, typically via an **SHV-G** plug.).

Figure 5.18 HVZ-G plug, here the version for negative bias of MCP back potential.

HVZ-DET and **HVZ-G** can be directly connected to the MCP back SHV socket of a signal feedthrough.
If the anode shall be operated at ground potential (0 V) a **HVZ-G** may be used on the MCP back socket while additionally placing a **SHV-G** plug on the respective anode connection socket (usually via **HFSD** or **HFST**) for setting the anode to ground potential. A **HVZ-DET** connected to the MCP back socket allows for setting a variable anode potential which has to be

* Note that the detector's Holder potential is not necessarily to be supplied through the **HVZ**. It can also be drawn from an independent high voltage supply if linearity near the MCP edge needs further optimization.

chained through the interconnected SHV sockets on the **HVZ-DET**. In both cases a voltage between anode and MCP back will be created as soon as MCP front bias is raised to a negative potential beyond the factory set potential difference.

This factory set potential difference between anode and MCP back potential may differ slightly from the default value due to chip tolerances. However, the real value, noted on the case (see Figure 5.18), will be close enough to the default value, allowing for proper functionality.

The default value of a specific **HVZ-G** can be factory-set to a variety of voltages depending on the choice of the internal diodes. The **HVZ-G** is specified for up to 500 V potential difference to ground.

The same unit with reverse polarity (positive) can be used to bias MCP front side of **DLD** or **DET** allowing for electron detection. In this case, a positive potential on the rear part of the detector will likewise draw MCP front potential close to the favourable value, e.g. +250 V in this case.

5.6.1 HVZ Revisions 1.3 and newer

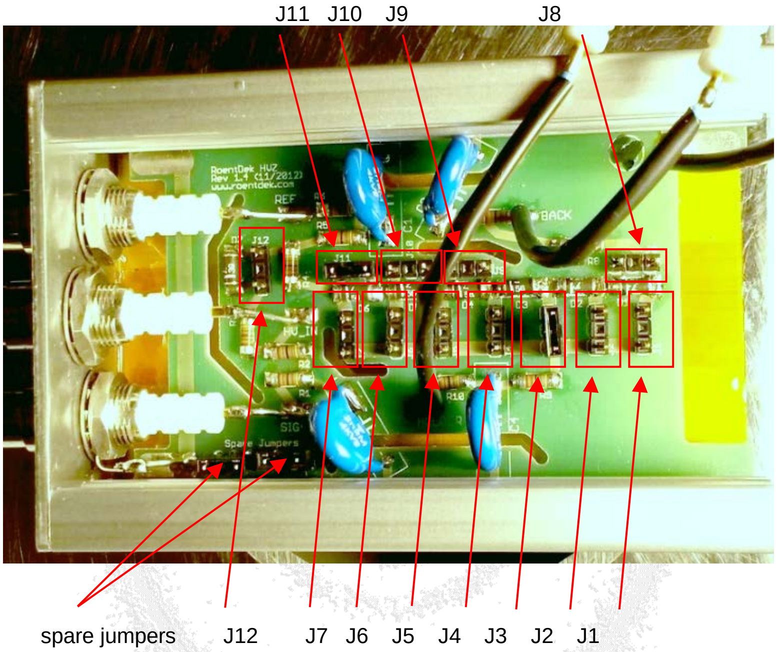


Figure 5.19: HVZ Revisions 1.3 and newer with jumper options.

The standard setting (as shown in Figure 5.19) sets $\mathbf{U_{ref} = U_{MCP\ back} + 224\ V}$ and $\mathbf{U_H = U_{MCP\ back} + 56\ V}$. For this, jumpers are set on positions J3 and J11. You may change U_H (without modifying U_{ref}) as following:

J1 to J7: jumper positions determining "*Holder*" potential. Only one jumper shall be set on J1 to J7.

jumper at J1:	Holder and Back outputs provide the same potential	$U_H = U_{MCP\ back}$
jumper at J2:		$U_H = U_{MCP\ back} + 28\ V$
jumper at J3:	default	$U_H = U_{MCP\ back} + 56\ V$
jumper at J4:		$U_H = U_{MCP\ back} + 112\ V$
jumper at J5:		$U_H = U_{MCP\ back} + 168\ V$
jumper at J6:		$U_H = U_{MCP\ back} + 224\ V\ (= U_{ref})$
jumper at J7:		$U_H = U_{MCP\ back} + 224\ V\ (= U_{ref})$

Changing this jumper position from the default setting can be beneficial for modified detector geometry (MCP holding plate at a non-standard position) or if the effective MCP back potential is significantly shifted (use J1 position). There are a numerous different settings possible, listed by the value of U_{ref}:

$\mathbf{U_{ref} = U_{MCP\ back} + 280\ V}$ - remove J11 and then follow this table instead of the one above:

J1 to J7: jumper positions determining "*Holder*" potential. Only one jumper shall be set on J1 to J7.

jumper at J1:	Holder and Back outputs provide the same potential	$U_H = U_{MCP\ back}$
jumper at J2:		$U_H = U_{MCP\ back} + 28\ V$
jumper at J3:	default	$U_H = U_{MCP\ back} + 56\ V$
jumper at J4:		$U_H = U_{MCP\ back} + 112\ V$

	jumper at J5:		$U_H = U_{MCP\ back} + 168$ V
	jumper at J6:		$U_H = U_{MCP\ back} + 224$ V
	jumper at J7:		$U_H = U_{MCP\ back} + 280$ V (= U_{ref})

$U_{ref} = U_{MCP\ back}$ + 252 V - remove J11 and set J8. Then follow this table instead of the one above:

J1 to J7:	jumper positions determining "*Holder*" potential. Only one jumper shall be set on J1 to J7.		
	jumper at J1:	Holder and Back outputs provide the same potential	$U_H = U_{MCP\ back}$
	jumper at J2:	Holder and Back outputs provide the same potential	$U_H = U_{MCP\ back}$
	jumper at J3:	default	$U_H = U_{MCP\ back} + 28$ V
	jumper at J4:		$U_H = U_{MCP\ back} + 84$ V
	jumper at J5:		$U_H = U_{MCP\ back} + 140$ V
	jumper at J6:		$U_H = U_{MCP\ back} + 196$ V
	jumper at J7:		$U_H = U_{MCP\ back} + 252$ V (= U_{ref})

$U_{ref} = U_{MCP\ back}$ + 196 V - set J11, J10 and J8. Then follow this table instead of the one above:

J1 to J7:	jumper positions determining "*Holder*" potential. Only one jumper shall be set on J1 to J7.		
	jumper at J1:	Holder and Back outputs provide the same potential	$U_H = U_{MCP\ back}$
	jumper at J2:	Holder and Back outputs provide the same potential	$U_H = U_{MCP\ back}$
	jumper at J3:	default	$U_H = U_{MCP\ back} + 28$ V
	jumper at J4:		$U_H = U_{MCP\ back} + 84$ V
	jumper at J5:		$U_H = U_{MCP\ back} + 140$ V
	jumper at J6:		$U_H = U_{MCP\ back} + 196$ V (= U_{ref})
	jumper at J7:		$U_H = U_{MCP\ back} + 196$ V (= U_{ref})

$U_{ref} = U_{MCP\ back}$ + 168 V - set J11 and J10. Then follow this table instead of the one above:

J1 to J7:	jumper positions determining "*Holder*" potential. Only one jumper shall be set on J1 to J7.		
	jumper at J1:	Holder and Back outputs provide the same potential	$U_H = U_{MCP\ back}$
	jumper at J2:		$U_H = U_{MCP\ back} + 28$ V
	jumper at J3:	default	$U_H = U_{MCP\ back} + 56$ V
	jumper at J4:		$U_H = U_{MCP\ back} + 112$ V
	jumper at J5:		$U_H = U_{MCP\ back} + 168$ V (= U_{ref})
	jumper at J6:		$U_H = U_{MCP\ back} + 168$ V (= U_{ref})
	jumper at J7:		$U_H = U_{MCP\ back} + 168$ V (= U_{ref})

$U_{ref} = U_{MCP\ back}$ + 140 V - set J11, J10 and J9. Then follow this table instead of the one above:

J1 to J7:	jumper positions determining "*Holder*" potential. Only one jumper shall be set on J1 to J7.		
	jumper at J1:	Holder and Back outputs provide the same potential	$U_H = U_{MCP\ back}$
	jumper at J2:	Holder and Back outputs provide the same potential	$U_H = U_{MCP\ back}$
	jumper at J3:	default	$U_H = U_{MCP\ back} + 28$ V
	jumper at J4:		$U_H = U_{MCP\ back} + 84$ V
	jumper at J5:		$U_H = U_{MCP\ back} + 140$ V (= U_{ref})
	jumper at J6:		$U_H = U_{MCP\ back} + 140$ V (= U_{ref})
	jumper at J7:		$U_H = U_{MCP\ back} + 140$ V (= U_{ref})

$U_{ref} = U_{MCP\ back}$ + 112 V - set J11, J10, J9 and J8. Then follow this table instead of the one above:

J1 to J7:	jumper positions determining "*Holder*" potential. Only one jumper shall be set on J1 to J7.		
	jumper at J1:	Holder and Back outputs provide the same potential	$U_H = U_{MCP\ back}$
	jumper at J2:		$U_H = U_{MCP\ back} + 28$ V
	jumper at J3:	default	$U_H = U_{MCP\ back} + 56$ V
	jumper at J4:		$U_H = U_{MCP\ back} + 112$ V (= U_{ref})
	jumper at J5:		$U_H = U_{MCP\ back} + 112$ V (= U_{ref})
	jumper at J6:		$U_H = U_{MCP\ back} + 112$ V (= U_{ref})
	jumper at J7:		$U_H = U_{MCP\ back} + 112$ V (= U_{ref})

These options can be beneficial if the effective MCP back potential is strongly shifted, or a lower anode voltage shall be used for some reason (i.e. different anode type). If a larger voltage drop (beyond 280 V between U_{ref} and $U_{MCP\ back}$) is required it is possible placing two **HVZ** units in series or combining a **HVZ** with a **BA3**.

For all HVZ revisions and settings above the following is valid:

J12:	no jumper:	$U_{sig} = U_{ref} + 36$ V (default)

if a jumper is set on J6: both Ref and Sig outputs provide the same potential as "*HV in*".

This option allows using a **BA3** or other floating battery device for producing the voltage difference between "*Ref*" and "*Sig*" for a delay-line anode.

If you use an **HVZ** with an older board (revision 1.2 or earlier) please contact **RoentDek** for information on jumper settings/functions).

5.7 HVZ10 voltage divider unit for XHV operation

For the **XHV** option (i.e. **RoentDek** delay-line detectors that can operate beyond the standard high voltage ratings) the **HVZ10** unit is available. It contains a flexible high voltage dividing circuitry in a box with (typically) four output lines rated to 10 kV and up to two input voltages.

Figure 5.21: Left picture: HVZ10 box with four-fold high voltage output cable which will be connected to an XHV feedthrough. Right picture: high voltage inputs on rear panel. Here, two SHV10 socket are provided for supplying two independent voltages. Other versions are available which operate with just one input voltage (MCP front or U_{ref}) and/or use other input socket standards

In the following, the basic **HVZ10** version is described. You may have received a separate add-on manual if your unit differs remarkably from the standard version. You will in any case receive specific information about the circuitry and tables for output voltages as function of input voltage(s) and MCP resistance. The **HVZ10** must be operated in combination with **RoentDek** -approved high voltage supplies and feedthroughs. It is important to verify whether the high voltage supply can deliver sufficient current for the **HVZ10** circuit as it is laid out.

Before using, please verify for which maximum input/output voltages and polarity your HVZ10 version is rated and never exceed this voltage or invert the polarity.

The **HVZ10** contains an exchangeable upper board to allow for different operational modes, e.g. the detector's initial startup procedure at low voltages and the final operation at high voltages. The boards can simply be interchanged after opening the case. Resistor values on the boards may have to be adjusted when the MCPs need replacement. **RoentDek** provides specific information, voltage tables (and adequate resistors, if needed) for this procedure or can completely service a board.

Only apply high voltage to the HVZ10 when the case is closed. Before opening the case, make sure to fully discharge your high voltage power supply and then disconnect it or disable it and secure it against being switched on again.

Once you have received the detector system it is recommended to first install the MCP dummy disc made from insulating material in place of the MCP stack for verifying the high voltage soundness of the whole assembly at first. For this test, the board for normal high-voltage operation should be installed in the **HVZ10**, as it is the case when you receive the setup. Although no MCP stack is installed the voltage should be increased very slowly to the design values (the vacuum within the chamber should be better than 10^{-5} mbar). Minor arcing incidents are not uncommon during this procedure. Once the setup sustains operation at the design potential without discharge, the MCP stack can be installed to the detector. At this point, the top-side board should be exchanged for the PCB designated for the initial startup procedure of the detector. The startup procedure itself is defined in the manual (see Chapter 2).

The PCB for the initial startup procedure will set one detector potential (MCP front or U_{ref}, depending on the polarity of the high voltage supply) to ground potential or near that, while the detector function is verified by raising the MCP bias to operational values as described in the initial startup procedure. General detector performance can thus be fully verified.

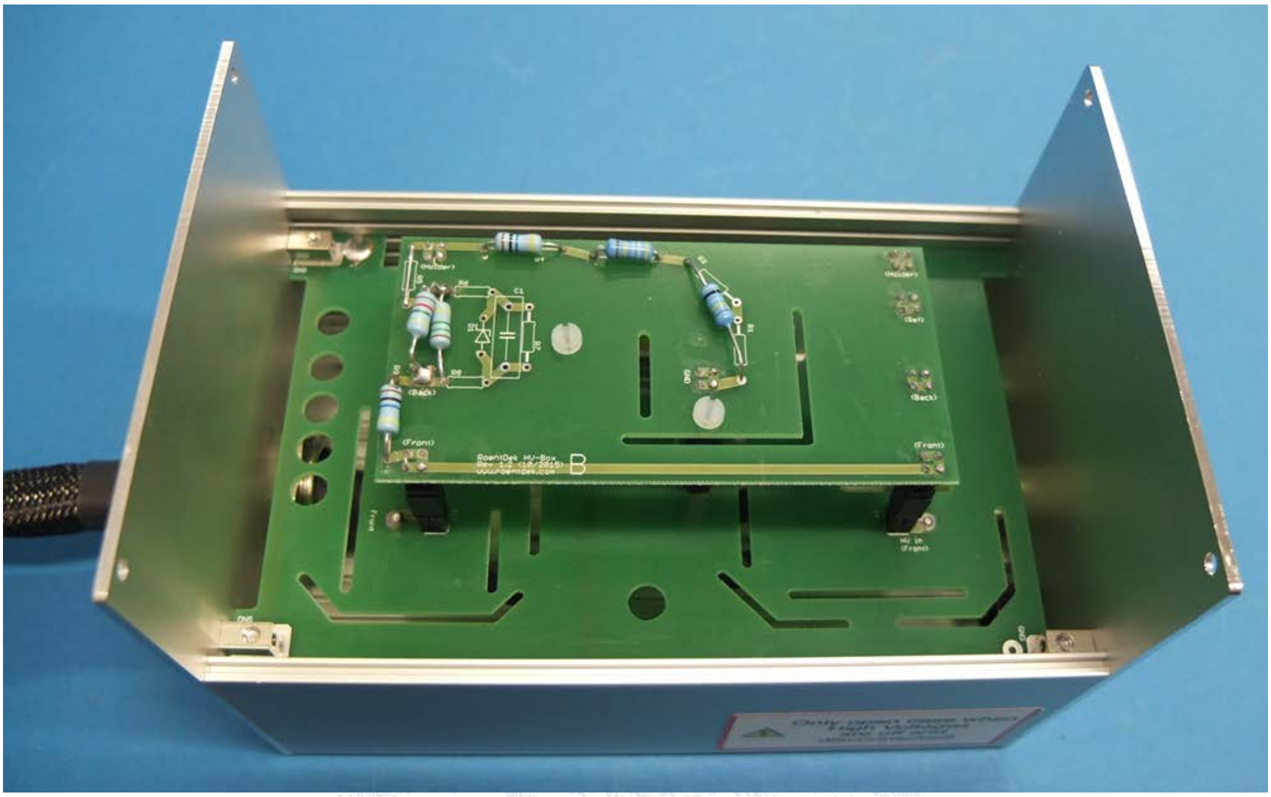


Figure 5.22: Open HVZ10 case with exposed top-side voltage divider PCB which can be reconfigured to allow for different biasing schemes. A BA3 circuit (not visible) is placed on the intermediate PCB plane and produces the differential delay-line wire potentials from U_{ref}. The values of the resistors within the chain are specifically selected for detector operation near the targeted MCP front voltage (here: -10 kV, operated with only one high voltage supply channel) and for the given MCP resistance. PCBs for operation at positive MCP potentials look very similar.

After that, the PCB for high voltage operation may be re-installed and voltage can be raised to the design potential. As a general safety precaution, raising voltages very slowly should be standard practice.

For replacing the PCB **turn off and fully discharge the high voltage** and open the case. Then remove the plastic screws that secure the board onto the back plane PCB. Retract the top-sided PCB and replace it by the desired one. Make sure that all connection posts are well met and then secure the board with plastic screws. **Close the case before applying high voltage**.

The safest operation mode for a detector biased to **XHV** voltages employs only one high voltage channel, which is either connected to "MCP Front" input (positive ion detection, negative polarity) or with positive polarity to the "*Ref*" input (i.e. the anode), for negative ion or electron detection on the positively biased MCP.

In case of operational problems (power failure, vacuum breakdown, etc.) a controlled voltage shut down may be maintained and guarantee safe relative detector voltages at all times, preventing damage from erroneous settings. In this biasing scheme, the counter-side of the detector must be bridged to ground potential via a "terminating resistor" of adequate resistance that may be formed as a chain of resistors (R1 to R4, see Figure 5.23, right picture).

The disadvantage of this scheme is that an optimal MCP bias cannot be set independently from the floating potential value: The terminating resistor bridge and the MCP stack resistance with its parallel resistor (R9) form a voltage dividing chain. The bias across the MCP stack and thus the gain will depend both on the resistor ratio and the floating voltage on MCP front.

Thus, the ideal bias voltage for the MCP stack must be determined before, e.g. during the startup procedure. Bias adjustment for the MCP stack requires changing of resistors R1 to R4 so that the chain yields the right resistance ratio to the parallel array of R9 and the MCP stack resistance. Operation at a different floating voltage will again require adjustments if the ideal MCP bias shall be maintained. Likewise, MCP replacement may also require resistor adjustments.

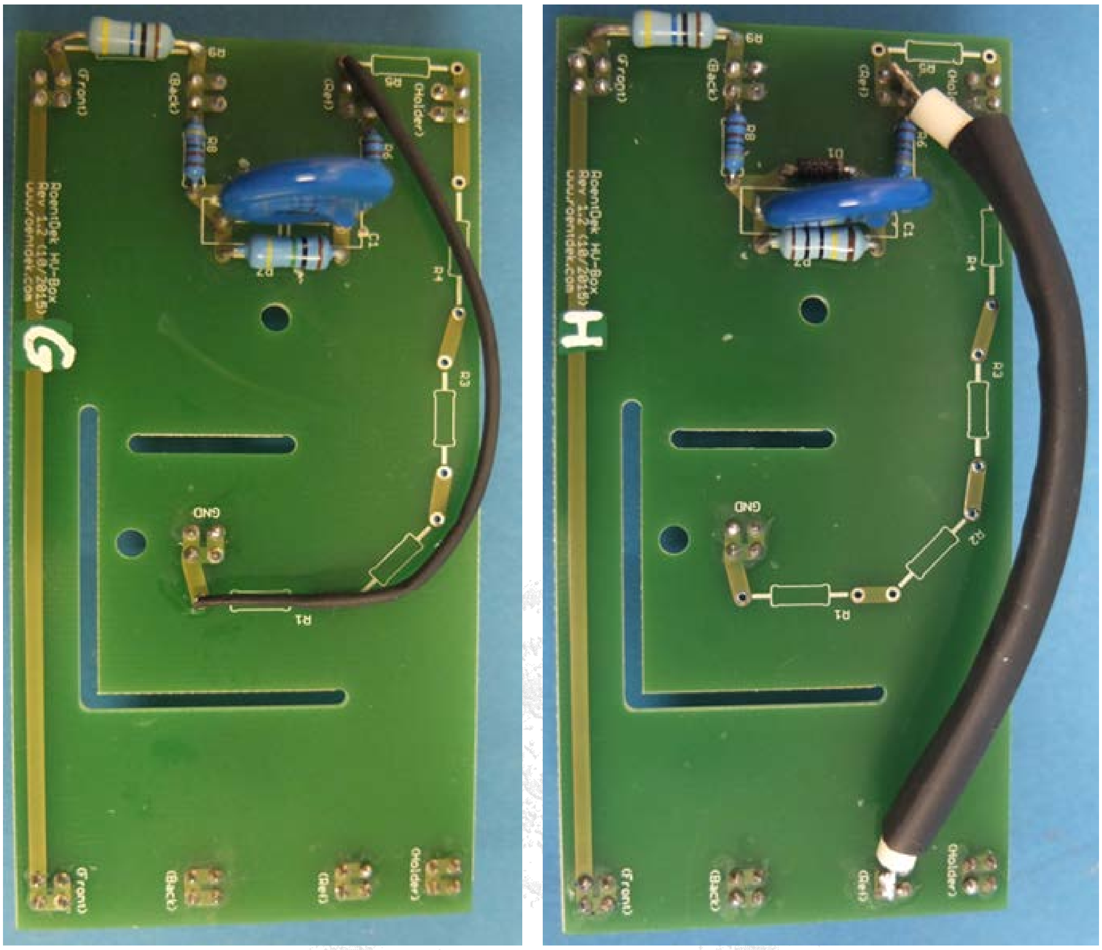


Figure 5.23: PCB for initial start-up procedure (left) for operation with negative polarity on "MCP front" input via HVZ10. U_{ref} potential is set to ground. As the voltage is raised to about -2500 V the detector operates in (positive) ion detection mode. Right picture: PCB for operation at high negative MCP potential using one high voltage power supply which provides U_{ref} plus a floating high voltage power supply that generates the voltage across the MCP stack. In both cases a Z-diode maintains a voltage drop of nominally 230 Volts between U_{ref} and U_{back}.

If two independent high voltage supplies are used, floating voltage and MCP bias can be independently adjusted. However, it is **strongly recommended to ensure that** during voltage increase/decrease and also in case of voltage tripping **both high voltage channels are always ramped in a coordinated and synchronized way** so that no **excessive potential differences** can occur **across the detector** which **will lead to uncontrolled discharge and damage**.

RoentDek can provide approved high voltage power supplies for all operation modes, such as the **HV2/10PF+** and **HV2/8PF+** units

It must also be noted that there are different types of high voltage supplies. Floating power supplies usually do not impose any problems. But when using two fully independent high voltage supplies it must be checked whether they are based on a diode cascade voltage multiplier. If this is the case, an additional resistor from the lower potential to ground must be implemented in order to prevent that the power supplies influence each other. When you plan to replace your power supplies by different ones, please contact **RoentDek** for advice

5.8 HVZ voltage divider circuit and internal HVT inside the FT12TPz

The latest version of the **FT12TP** plug for **DLD** can be upgraded to internally contain **HVZ** and/or **HVT** circuits by replacing PCBs inside the housing. If an **FT12TPz** is ordered, the according PCB set is included and may already be factory-mounted (then noted on a label found on the top lid of the housing).

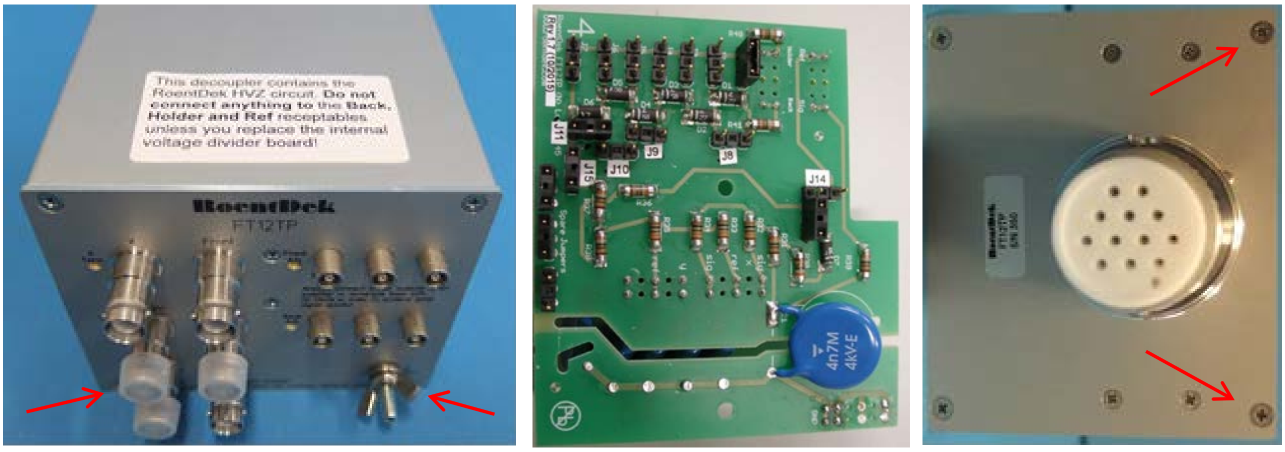


Figure 5.24: FT12TPz with internal HVZ board (#4) which is accessible after removing the bottom side of the case (loosen the four screws indicated by the red arrows). The rear detector potential is applied only via the U_{sig} input.

Before opening the **FT12TP**, make sure to first reduce applied voltages to zero and only then disconnect all **SHV** cables. When removing the cables while still on high potential, there might still be hazardous voltages stored within the **FT12TP's** capacitors.

If an internal **HVZ** board is in place only the (MCP) "*Front*" and the "*Sig*" (and optionally the "X") SHV sockets are used to provide voltage to the detector. Here, the "*Sig*" socket input corresponds to the "*HV in*" socket in the standard **HVZ** box, see Chapter 5.6 and also refer to the operation and safety instructions given there. The white plastic stoppers on the SHV sockets "*Back*", "*Holder*" and "*Ref*" prevent some common mistakes when connecting the high voltage cables. These plastic stoppers may be temporarily removed for connection testing purposes with an Ω-meter, or when a **HVT4(+)** unit is connected on "Back". While in the HVZ operation mode (actively biasing all detector contacts) only via "*HV in*" and "*Front*" sockets). **Neither of "*Back*", "*Holder*" and "*Ref*" sockets should be independently biased or grounded*. MCP front bias must always be more negative than the signal bias. Otherwise the internal HVZ circuits can be damaged.** Note generally that **MCP front bias must always be more negative than the signal bias**.

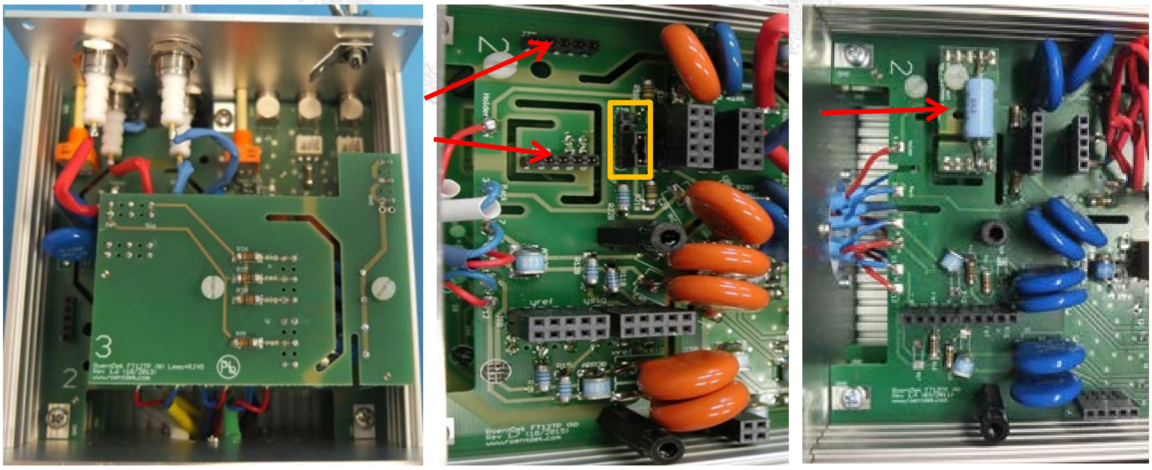


Figure 5.25: Inside view of a FT12TP plug with installed standard board #3 (no HVZ function, left picture) and with exposed base board (#2) when the upper board (#3, #4, or custom board) is removed (for that loosen the two plastic screws and retract the board). The red arrows in the middle picture indicate a bank pair where the optional HVT resistor board *HVTmini* can be placed, see in the right picture on a similar #2 board (description in Chapter 5.8.1). Also described there is the function of the J2B jumper bank (indicated by the yellow rectangle).

* Only MCP back socket may be terminated via an appropriate R_{HVT} (inside an **HVT4** box, one of its SHV sockets then remains unconnected), or connected to an intermediate MCP contact via an **HVT4+** box, see Figure 5.14 and Chapter 5.5.1.

In case you achieved an upgrade from a standard **FT12TP** to an **FT12TPz** by exchanging the PCB board #3 to #4 by yourself you should add the supplied label and insert the white stoppers to the SHV sockets for preventing common mistakes when connecting the high voltage cables. Likewise, if you place the internal **HVT** you should add the corresponding sticker supplied with it. The presence of an **HVT** bridge inside the plug can be verified by measuring the resistance between pin 2 and any screw on the plug's case: If 1 MΩ is measured the **HVT** is installed, otherwise there is infinite resistance (>10 MΩ).

The optional combinations of jumper settings for J1-J11 on the (internal) **HVZ** board as shown in Figure 5.25 (version 1.7 and newer)* result in exactly the same bias output functionalities as described for the (external) HVZ box boards (for version 1.3 as described in Chapter 5.6.1). The factory-set jumper positions are noted on the case of the **FT12TPz**. It is advisable to keep track of any modification at any time.

Since the internal **HVZ** board of the **FT12TPz** is directly supplying the voltages to its decoupling circuits, J12 on the external **HVZ** unit had to be replaced by a combination of jumpers J13-J15 (default: J13 and J15 are set) in order to maintain flexibility for alternative biasing schemes, e.g. during trouble shooting or verification procedures.

These (non-standard) options are summarized as followed:

J14 jumper is set <u>instead</u> of J13:

U_{ref} is separately biased through the "*Ref*" SHV socket.

<u>None</u> of jumpers J1-J7 being set:

Holder bias (U_H) is separately biased via the "*Holder*" SHV socket.

Jumpers from J1-J7, J13 <u>and</u> J15, are all removed (only J14 jumper must be set):

<u>All</u> voltages are supplied through the SHV sockets.

Thus, the **HVZ** function of the internal board can be stepwise reduced to the "standard" **FT12TP** plug (e.g. equipped with internal board #3) bias input scheme through the separate SHV sockets. Obviously, for this the white stoppers on the SHV sockets must be at least partially removed, only temporarily, i.e. as long as these non-standard settings are operated. Please put the stoppers back in place as soon as you reactivate the corresponding **HVZ** functions.

Further biasing options are enabled by changes on the base board (#2):

5.8.1 Internal HVT board and additional bias options of the latest FT12TP plugs for DLD

In the course of ongoing **FT12TP** upgrades further options have been implemented on the base board (#2) to allow for additional biasing functions after internal modifications by the user. These settings are independent from the piggy-back board selection #3 (standard bias through the SHV sockets), #4 (**HVZ**) or else. **FT12TP(z)** units with serial numbers of 360 and higher allow the following options:

Internal HVT functions: A special bridge circuit which can be obtained from **RoentDek** (see Figure 5.25) contains a R_{HVT} resistor and terminates MCP front input to ground via a 1 MΩ, exactly like the external **HVT** box as described in Chapter 5.5. However, there are no options defined of changing this resistor value or of connecting the internal R_{HVT} to any other bias contact.

If you are not sure (while the **FT12TP** plug case is closed) whether an *HVT* resistor bridge is placed on the internal base board (#2) or not you can verify its presence/absence with an **Ω** meter by checking the resistance to ground (i.e. the **FT12TP** case) of the "*Front*" SHV socket. This should take place while the **FT12TP** plug is removed from the feedthrough. Then you should either measure the 1 MΩ *HVT* resistance (i.e.: bridge in place) or find a near-infinity resistance (no bridge connected).

Internally connecting MCP back to Holder potential: by changing the jumper position J2B from its default position "down" (as shown in Figure 5.25, middle picture) to its upper position, the bias input to MCP back from the corresponding SHV socket (or **HVZ** circuit) is suspended. The "*Holder*" bias input (coming either through the corresponding SHV socket or the **HVZ** circuit) is then routed both to MCP back and "*Holder*", being on nearly the same potential. This mode is only for expert users, please contact RoentDek before modifying the J2B jumper from its default position.

Setting MCP back and Holder on a detector to the same potential cannot always be achieved simply by biasing the corresponding SHV sockets with the same nominal potential (i.e. by short-connecting the sockets "*Holder*" and "*Back*" via a **SHV-T** or by placing a jumper at J1 in case of operation with a **HVZ** circuit):

* If you have received an earlier board version, please refer to the descriptions obtained with the unit.

As soon as the MCP front side is set to a more negative bias during operation, the presence of the blocking resistor R_{Db} (usually 1 MΩ, see Chapter 5.5) in the MCP back connection line will change the effective MCP back bias on the detector. This can only be avoided if the jumper J2B in Figure 5.26 is changed to the "up" position.

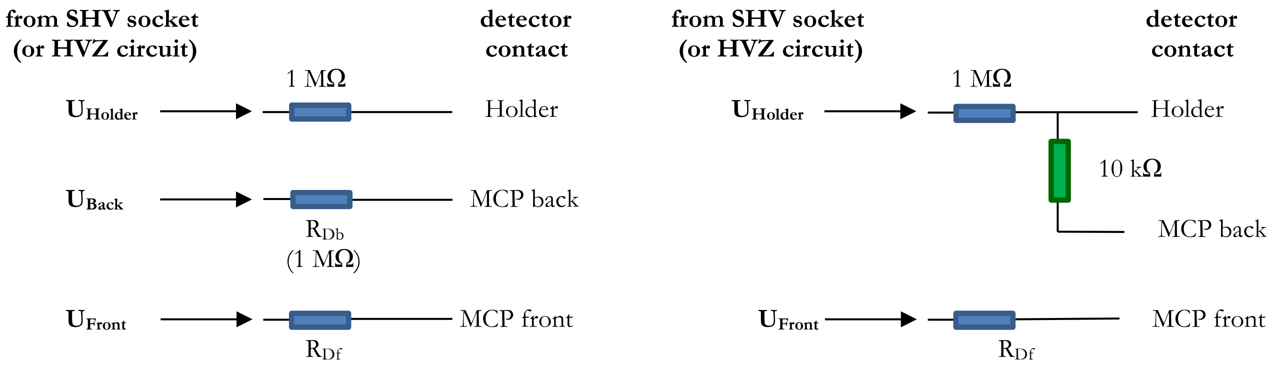


Figure 5.26: Connection circuits for the two J2B jumper settings, left scheme: the standard "down" setting (as in Figure 5.25), right scheme for the alternative "up" setting. The 10 kΩ resistance separating "*Holder*" and MCP back is low enough to not impose a remarkable voltage shift of MCP back compared to "*Holder*" even when MCP front is set to operational values. Note, that there is the 1 MΩ blocking resistor in the line to the MCP back (and "*Holder*") causing a corresponding (common) bias shift, as described earlier.

For detector assemblies without intermediate MCP carrier plate (e.g. **DLD120**, **HEX100** and **DLD40SL**) the Holder bias setting is not affecting the imaging properties on the outer diameter. For these detectors the factory-setting for the Holder potential (i.e. near MCP back potential) can be kept.

5.9 HVT+ and custom-designed voltage dividing circuit boxes

Based on the **HVT** **RoentDek** provides the passive voltage divider **HVT+** for increasing the operation range of the **RoentDek** high voltage supplies (e.g. the **HV2/4**) to voltages well below 100 V. Depending on the internal jumper position the output voltage is nominally reduced by a factor of 10 (jumper at J1 position, see Figure 5.28) or by a factor of 100 (jumper at J2 position). These scaling factors are only accurate within a few % due to resistor tolerances. The presence of an external resistor load (e.g. formed by a series of resistor-coupled spectrometer plates to ground) will alter the scaling factor systematically, see below. With maximum specified input voltage of 1000 V this allows to set stable output voltages between 1 V and 100 V with a **HV2/4**, e.g. for biasing spectrometers, meshes or lens elements.

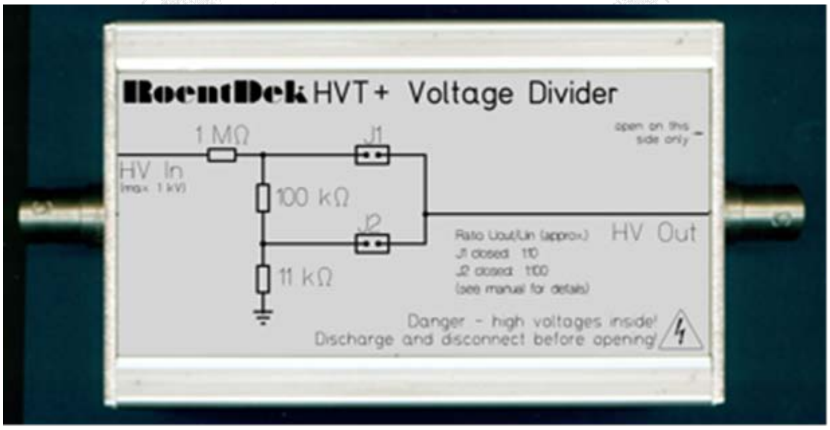


Figure 5.27: HVT+ with 100:10:1 resistor chain. Depending on the jumper the nominal scaling factor between output and input voltage is 1:10 (J1 set) or 1:100 (J2 set). The maximum input voltage is 1000 V. On demand the HVT+ can also come as a version equipped with a third jumper position J3 which enables the standard HVT functionality (see Chapter 5.5) with R_{HVT} having a nominal value of 1111kΩ.

Precision voltage setting via **HVT+** requires measuring the actual output voltage with an adequate instrument (while the output is connected to the resistor load R_L, if any). However, as long as R_L > 10 MΩ, the voltage reading on the **HV2/4** gives a fairly precise indication of the output voltage, taking into account the nominal scaling factor (depending on jumper setting). For smaller R_L the scaling factor deviates from the nominal values. It can be approximated for R_L > 100 kΩ by:

$U_o/U_{eff} = 10 + 1M\Omega/R_L$ (J1 set) or $Uo/U_{eff} = 100 + 1.1\ M\Omega/R_L$ (J2 set)

It is to note that the current drawn from the high voltage supply will be dominated by the "blind" current through the internal resistors to ground inside the **HVT+**. The effect of an external resistor load on this current can hardly be measured via the current display of the **HV2/4**.

For special biasing schemes of detectors RoentDek can provide custom-designed voltage dividing boxes. The following figures show a (not-complete) selection of circuits that have been provided to customers.

Figure 5.28: Set of voltage divider boxes for DET operated at high negative bias (MCP front up to -4800 V) with a mesh biased 200 V more negative than MCP front (lower box) and a resistor divider chain for biasing MCP back and Anode at adequate potential for single particle counting (upper box). The voltage drop between MCP back and Anode is 1/6 of the MCP back potential, here (can be altered by changing the 2 MΩ resistor, see Kirchhoff's laws).

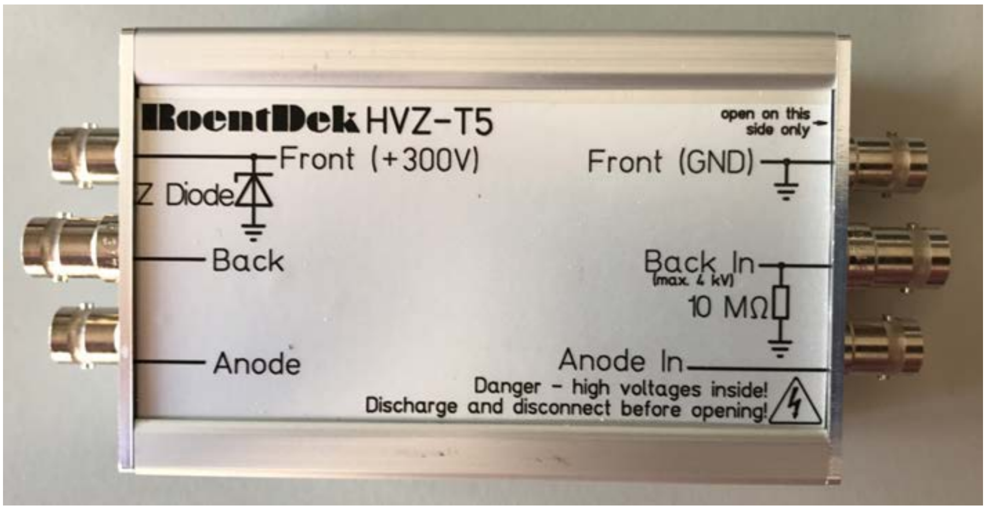


Figure 5.29: Voltage divider for DET operation with MCP front at +300 V (or ground), with MCP back and Anode at any set potentials between MCP front and +5 kV.

5.10 Remote Control of the RoentDek HV supply via USB-IO1

The voltage setting of the **HV2/4 (6/8/10)** units can be operated via the **RoentDek** **USB-IO1** DA/AD controller. If the control switches on a **HV2/4 (6/8/10)** unit is set to "DAC" (as upper channel in Figure 5.1), its high voltage output is proportional to the voltage input (0 -4 V or 0 -10 V) on the corresponding input socket on the rear panel. A **USB-IO1** can provide two individual voltage outputs up to 10 V for this purpose, controlled by software via USB, see Figure 5.30.

Figure 5.30: Front and rear panels of the USB-IO1 device with USB-port for the PC-connection and the two LEMO analogue out2 and out1 output sockets, suitable for remote-controlling the HV2/4 (6/8/10) units.

Control of the USB outputs is provided by *LabView*, CoboldPC and the *Iseg_control_USB_IO1.exe* GUI-program. Please contact **RoentDek** for details of advanced operation with LabView or CoboldPC.

For simple tasks of remote voltage setting the GUI program (see Figure 5.31) is usually sufficient, its operation self-explaining for most applications (otherwise please contact **RoentDek**).

The program interface has two sections for two independent output channels. Setting options for channel 2 (output from *out2* socket) are kept minimal while channel 1 (output from *out1* socket) control provides options to ramp the voltage automatically with selectable speed (in 10 V steps) or to change voltage settings after selectable delays (2 steps). Do not enter any set voltage above the maximum range of the connected high voltage supply.

It is very important to first enter the correct conversion factor which is independently selectable for the two channels. This value will determine the correspondence between set voltage and output voltage and depends on the used high voltage unit. For **HV2/4** the conversion is 4000 for **HV2/6 (8/10)** it has to be set to 10000.

False conversion factor setting will result in false output voltages which can cause damage to connected devices.

It is therefore recommended to verify proper output response on the **HV2/4 (6/8/10)** display before connecting any SHV socket.

Minor deviation between set voltage and real output voltage is possible and may be corrected by "fine-tuning" of the conversion factor, e.g. setting it to 3997 instead of 4000 for **HV2/4**.

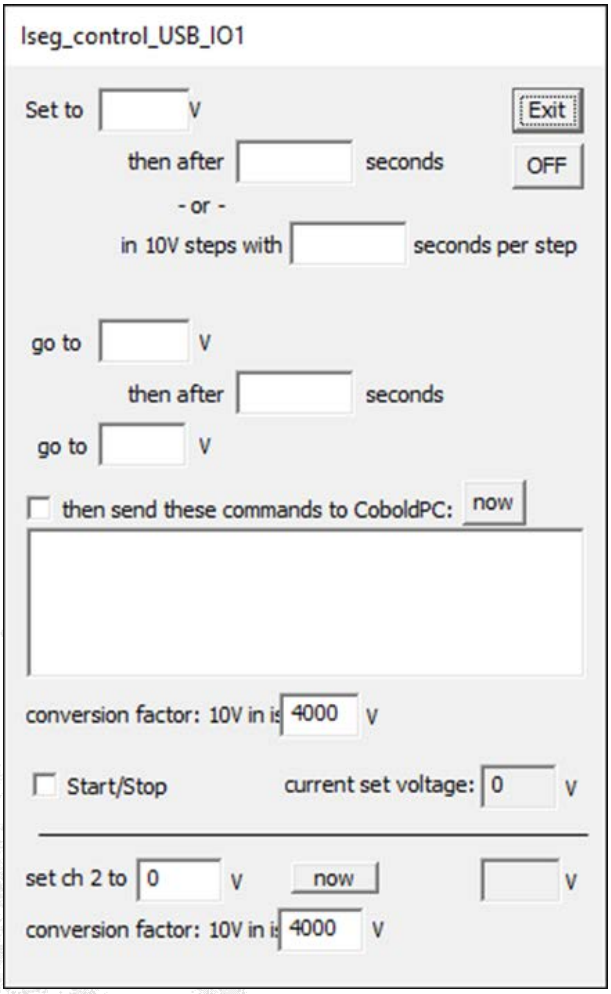


Figure 5.31: Input options of the GUI-program

List of Figures

List of Equations