Nanonis™

# Besocke interface AKBE

# User Manual

July 2012 (R3180)

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# Conventions

The following signal words and symbols appear in this manual:

**Warning:** Indicates a potentially hazardous situation which, if not avoided, could result in a malfunction of the instrument, damage to the instrument, injury, or death.

**High voltage:** Risk of electric shock. Lethal voltages present.

**Note:** Additional information to help you understand the internal function of the unit, or its applications, but is not essential for general operation.

*Italic* — *Commands, programs, menu items, functions, field names and product names are shown in italic characters.*

# Safety information

- Read this manual carefully and all related documents before installing and using the instrument.
- The safety notes and warnings have to be obeyed at all times.
- The AKBE may only be installed and used by authorized and instructed personnel who have read this manual.
- The AKBE is designed for indoors dry laboratory use only.
- Do not install substitute parts or perform modifications to this instrument. No user serviceable parts inside.
- Do not operate the AKBE if it is damaged or not functioning properly. Never use damaged accessories.
- Never use corrosive or abrasive cleaning agents or polishes. If necessary, clean the instrument with a soft and dry cloth, and make sure that it is completely dry and free from contaminant before returning it to service.

**Warning:** Lethal voltages are present inside the instrument and at the output connectors.

**Warning**: The power cord must be connected to a properly wired and earthed socket.

# About this Manual

This manual is intended as a reference tool for users of the Nanonis AKBE Besocke interface. It covers the functionality of the instrument and explains its installation and operation.

This manual is not a service manual for the AKBE.

## Revision history

July 2012 (R3180) Initial release of the AKBE manual

The SPECS order number for this manual is: 78 000 366

# Introduction

The Nanonis Besocke interface (AKBE) is the link between the high voltage instruments of a Nanonis SPM controller and a microscope using a Besocke-type (or Beetle-type) head. The AKBE distributes scanning, offset, and coarse motion high voltage signals to the various piezo electrodes of the microscope head, and switches between translational and rotational coarse motion.

The AKBE features two high voltage inputs for scanning and offset signals from up to two Nanonis HVA4 high voltage amplifiers. A high voltage loop to the Nanonis PMD4b allows the addition of coarse motion waveforms to the HVA4 signals. The microscope head is connected to a single output connector, which carries separate signals for each piezo electrode.

Interlock mechanisms in the piezo motor HV output connector and the high voltage output to the PMD4b guarantee that the high voltage output is disabled on these outputs as soon as a connector is disconnected from the unit. Additional safety is provided by a remote switch-on feature, which enables the high voltage output of the connected HVA4 and PMD4b only if the AKBE is powered on. These safety measures as well as the switching of the internal relays are controlled by an internal logic circuit.

The AKBE is controlled over a digital port connected to the PMD4b, and all of its configuration options can be conveniently set in the motor control software, without requiring any change of settings at the hardware. Handset operation is possible using the handset delivered with the PMD4b.

# Head compatibility and head geometry conventions

The AKBE works with Besocke-type SPM heads which have the piezo electrodes used for coarse motion oriented all in the same direction, as shown in the picture below. The AKBE is not compatible with heads that have a radial piezo electrode orientation. Both 5-quadrant and 4-quadrant piezos can be used, although using 4-quadrant piezos will limit the scanning and offset options available (see the sections below).

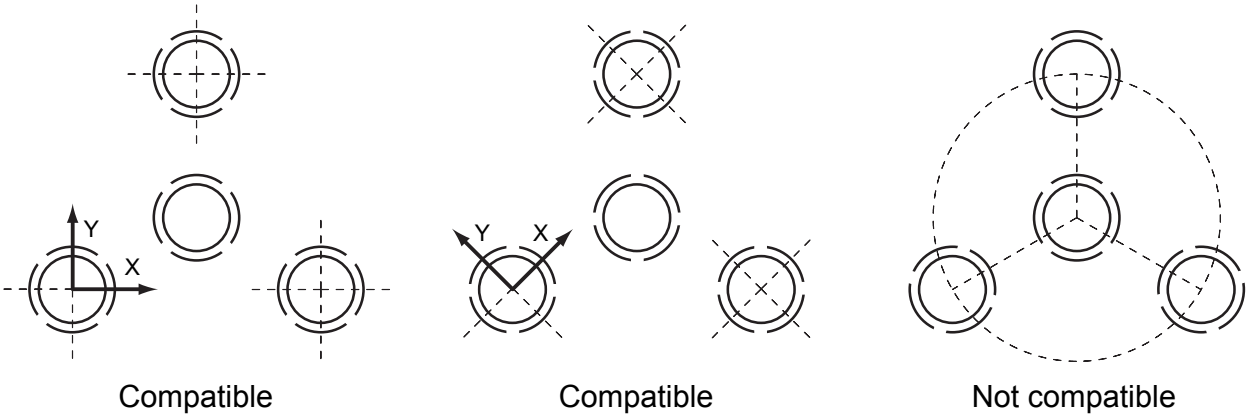


**Figure 1: Possible Besocke-type SPM head piezo electrode configurations: The AKBE can control the configurations shown on the left and in the center (all electrodes are oriented in the same direction), but not the configuration shown on the right (radial orientation).**

Throughout this manual, the piezo tubes and their electrodes will be named according to the following scheme:

- Numbers 1, 2, and 3 are used for the outer piezo tubes of the head, i.e. the piezo tubes used for coarse motion (and scanning in certain configurations).
- The letter "i" is used for the central piezo tube.
- ±X, ±Y and Z denote the piezo electrodes used for coarse and fine movement in X, and Y direction, as well as fine-Z motion. The coordinate system is as shown in the figure above. Coarse motion in Z-direction is achieved using the X and Y electrodes of the outer piezo tubes, denoted "+C" and "-C" depending on the polarity of the coarse motion driving waveform.

The naming scheme is shown in the picture below, for the two configurations compatible with the AKBE.

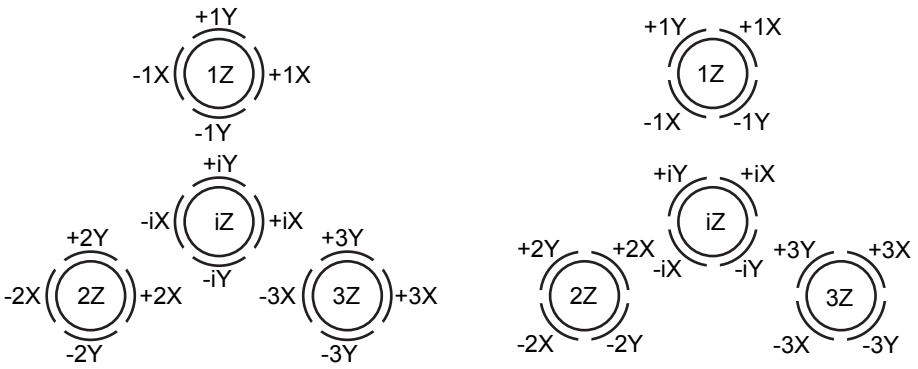


**Figure 2: Naming scheme for the piezo electrodes of a Besocke-type head, as used in this manual.**

Note that the 1Z, 2Z, and 3Z signals are connected together internally in the AKBE.

# Scanning and offset options with one Nanonis HVA4

The standard configuration for driving Besocke-type SPM heads is one Nanonis HVA4 high voltage amplifier in combination with a Nanonis PMD4b and the AKBE. When the microscope head is fitted with 5-quadrant piezo tubes, the outer piezo tubes can be used either for scanning and coarse motion, for Z-offset and coarse motion, or for coarse motion only. The AUX channel of the Nanonis HVA4 can be used for applying an offset in Z direction, either by using the central electrodes of the three outer piezo tubes, or the central electrode of the center piezo tube. With 4-quadrant piezo tubes, scanning must be done using the center piezo, and no Z-offset can be applied. The following table summarizes the options available when using one Nanonis HVA4, depending on the kind of center piezo tube used. The options can be selected by software, and do not require any hardware configuration once the instruments are connected together.

| Center Piezo | Scanning | Z-feedback | Z-offset | X-Y-offset |
|---|---|---|---|---|
| 5 quadrants | Using center piezo | On center piezo | On outer piezos | Not possible |
| | | On outer piezos | On center piezo | Not possible |
| 4 quadrants | Using center piezo | On center piezo | Not possible | Not possible |
| 2 quadrants | Using outer piezos | On center piezo | On outer piezos | Not possible |
| | | On outer piezos | On center piezo | Not possible |
| No center tube | Using outer piezos | On outer piezos | Not possible | Not possible |

**Table 1: Allowed scanning and offset configurations when using one Nanonis HVA4.**

## Notes on 4-Quadrant piezo tubes

The AKBE is compatible with 4-quadrant piezo tubes, but the following points should be considered:

- A 5-to-4 quadrant adapter is required, and must be connected between the X, Y, and Z outputs of the Nanonis SC4 and the X, Y, Z, and AUX inputs of the Nanonis HVA4.
- It is not possible to apply offsets in Z direction, since the required AUX channel of the Nanonis HVA4 is used for one of the four-quadrant signals.
- Only the central piezo tube can be used for scanning, the outer piezo tubes can be used for coarse motion only. If the outer piezos have 5 electrodes, the central electrode of each piezo must be connected to ground (GND of the AKBE *HV OUTPUT* connector (7))

The wiring of the microscope head also differs from the 5-quadrant wiring. The signal usually applied to the center electrodes of the outer piezo tubes (1Z, 2Z, 3Z) must be connected to one of the 4 quadrants of the central piezo tube, as shown below (1Z shown):

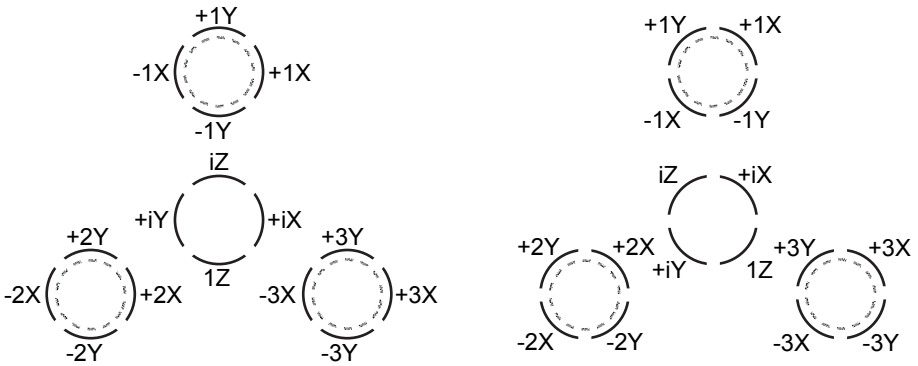


**Figure 3: Naming scheme for the piezo electrodes of a Besocke-type head when a 4-quadrant center piezo tube is used, and is connected to the AKEB output (and not directly to a Nanonis HVA4). The outer piezo tubes can be either 5 or 4 quadrant, but cannot be used for applying offsets in Z-direction.**

**Note:** This wiring configuration is required only for home-built microscopes using a 4-quadrant center piezo tube. For RHK STM microscopes, the signals for the center piezo tube are extracted directly from the Nanonis HVA4 (please see the *RHK STM microscopes* section below).

# Scanning and offset options with two Nanonis HVA4

The use of two Nanonis HVA4 high voltage amplifiers is necessary only when it is required to apply offsets in X-Y-direction, or if an offset in Z-direction is required when using a 4-quadrant center piezo tube, and 5-quadrant outer piezo tubes. With two Nanonis HVA4s, an additional HVS4 power supply is required. The following table summarizes the available options when using two Nanonis HVA4s (configurations requiring 1 HVA4 are not listed). The options can be selected by software, and do not require any hardware configuration once the instruments are connected together.

| Center Piezo | Scanning | Z-feedback | Z-offset | X-Y-offset |
|---|---|---|---|---|
| 5 quadrants | Using center piezo | On center piezo | On outer piezos | On outer piezos |
| | | On outer piezos | On center piezo | On outer piezos |
| | Using outer piezos | On center piezo | On outer piezos | On center piezo |
| | | On outer piezos | On center piezo | On center piezo |
| 4 quadrants | Using center piezo | On center piezo | Not possible* | On outer piezos |
| 4 quadrants (RHK) | Using center piezo | On center piezo | On outer Piezos | On outer piezos |
| *Except if connecting the center piezo to one HVA4 using a BNC adapter. | | | | |

**Figure 4: Allowed scanning and offset configurations when using two Nanonis HVA4s.**

# Coarse motion logic

The internal switching matrix of the AKBE distributes the coarse approach waveforms generated by the Nanonis PMD4b to the individual electrodes of the three outer piezo tubes for coarse motion. During Z-coarse motion, the SPM head moves in the rotational mode, requiring a more complex signal distribution than for the translational X- and Y- coarse motions.

For rotational motion, the AKBE can be configured for each one of the twelve external electrodes of the outer piezos individually, meaning that the following options are possible:

- The signal applied to the electrode has the same polarity as for translational motion
- The signal applied to the electrode has the opposite polarity as for translational motion
- The electrode is connected to GND

Generator 1 and 2 of the PMD4b output signals with same amplitude but opposite polarity. For more details, please refer to the PMD4 user manual.

The SPM heads compatible with the AKBE (as described above) will therefore be driven in coarse motion as shown in the pictures below:

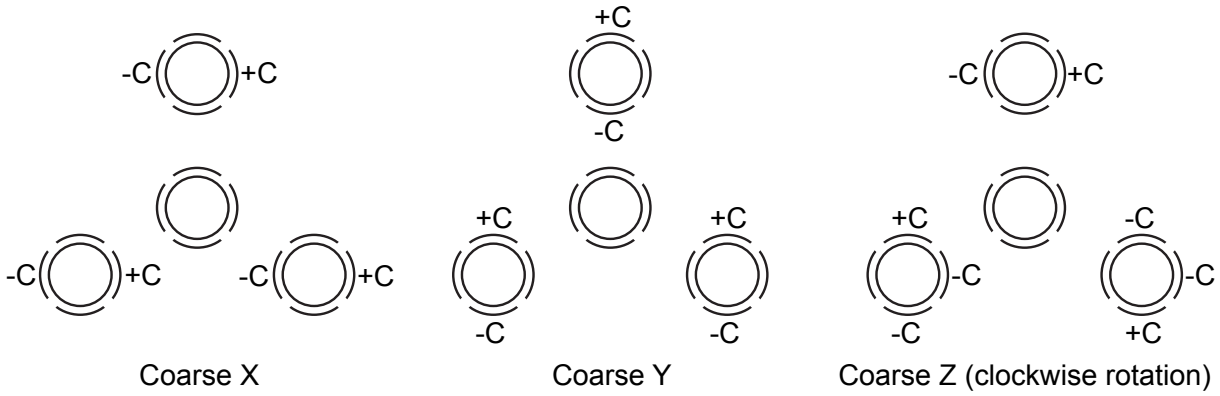


**Figure 5: Coarse motion signals for outer piezo tubes, 0° and 90° electrode orientation.**

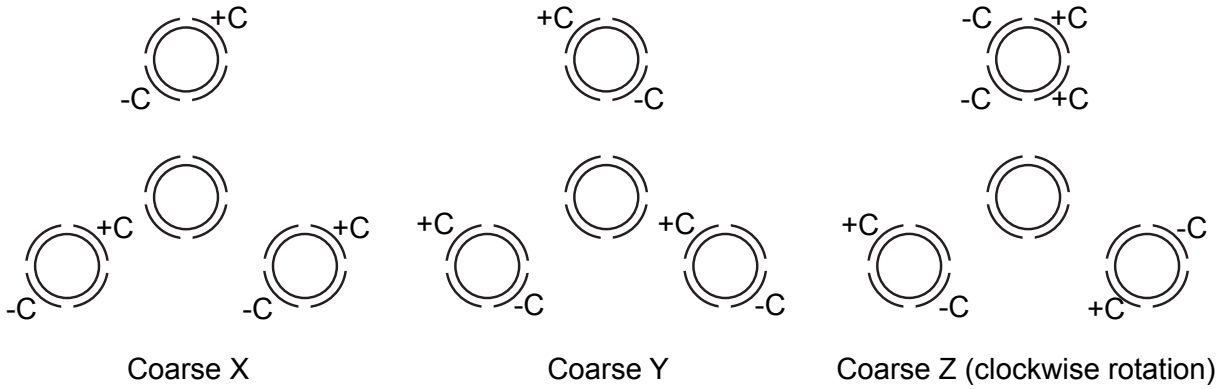


**Figure 6: Coarse motion signals for outer piezo tubes, 45° and -45° electrode orientation.**

## Coarse motion with optional signal attenuators

The coarse motion signals as shown in the above figures allow for a perfect coarse motion in X and Y direction, but the forces on the outer piezo tubes in rotational mode (coarse motion in Z direction) are not fully tangetial. Although the achieved movement in Z direction is precise enough, almost perfect rotational movement can only be achieved by adding signal attenuators to some of the coarse motion signals.

The attenuators are a built-to-order option, and the capacitance of the piezo motor electrodes must be specified before ordering the AKBE.

When using attenuators, the SPM heads will be driven in coarse motion as shown in the figures below:

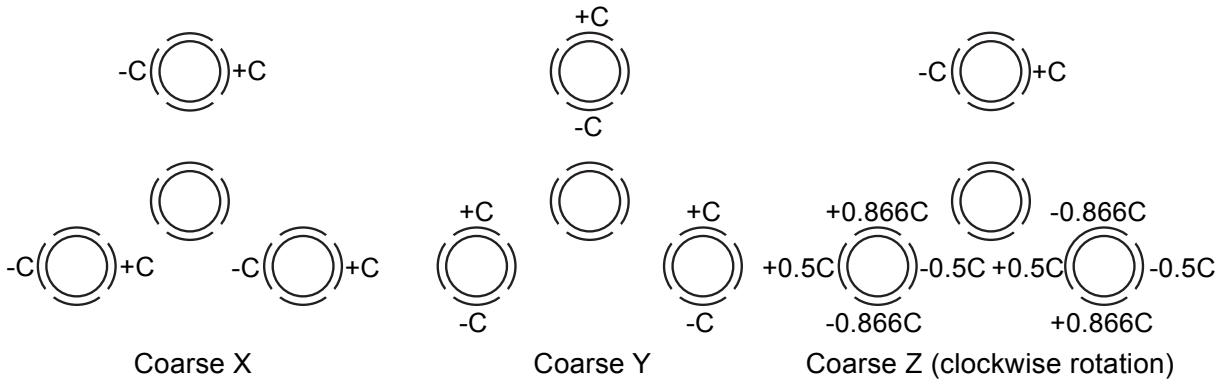


**Figure 7: Coarse motion signals for outer piezo tubes, 0° and 90° electrode orientation, using signal attenuators.**

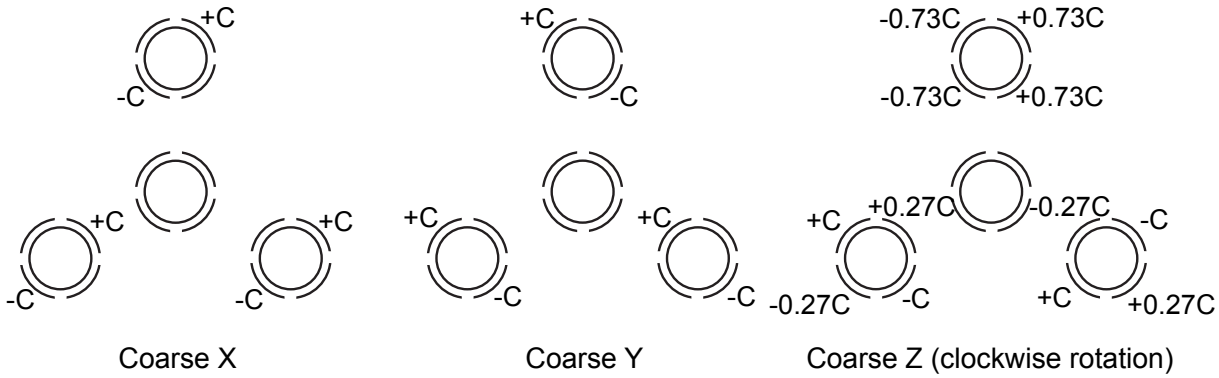


**Figure 8: Coarse motion signals for outer piezo tubes, 45° and -45° electrode orientation, using signal attenuators.**

# Instrument Overview

## Block diagram

The block diagram of the AKBE is shown in the picture below.

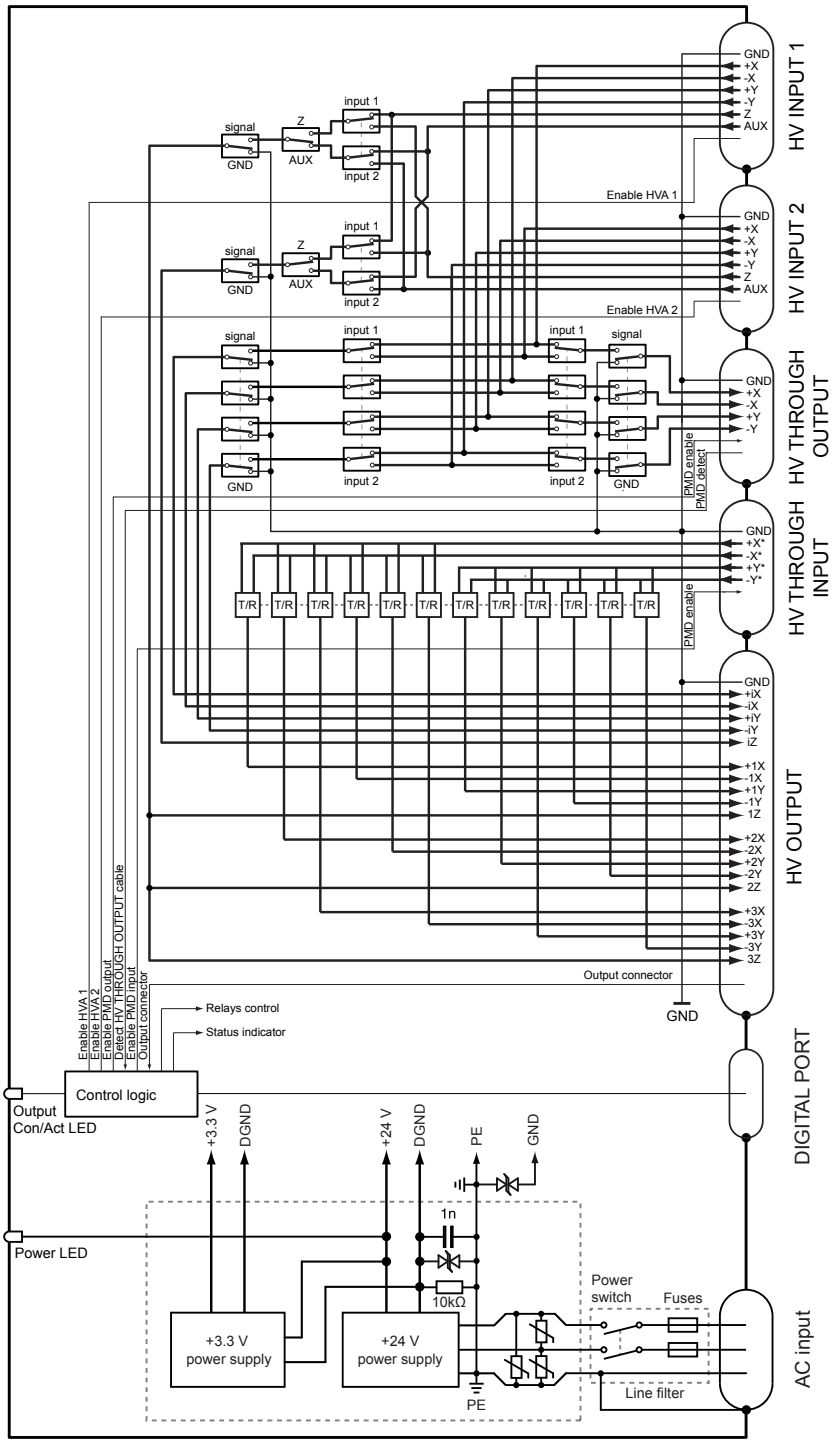


**Figure 9: Block diagram of the AKBE.**

High voltage signals for scanning and offset are applied to the *HV INPUT 1* (11) and *HV INPUT 2* (10) connectors. The X and Y channels are routed to the X and Y electrodes of the center piezo, or to the X and Y electrodes of the three outer piezos (over the PMD4b connected to the *HV THROUGH OUTPUT* connector (8)), or to both. By default, the signals of *HV INPUT 1* (11) are selected. The Z and AUX channels are routed to the Z electrodes of the center piezo, or the Z electrodes of the outer piezos. By default the Z channel of *HV INPUT 1* (11) is routed to the Z electrode of the center piezo, and the AUX channel of the same input is routed to the Z electrodes of the three outer piezos. The electrodes of the center piezo are connected to GND by default, when the AKBE is powered on.

The high voltage signals from *HV INPUT 1* (11) and *HV INPUT 2* (10) can be also routed to the PMD4b over the *HV THROUGH OUTPUT* (8). This is the case when scanning or offset is done using the three external piezos, and coarse approach signals must be applied to the same electrodes. By default, the signals of *HV INPUT 1* (11) are selected, but the connector is tied to GND if no cable is connected.

The output signals of the PMD4b (X* and Y*) are applied to the *HV THROUGH INPUT* connector (9), and are routed to the three external piezos over 12 Translation/Rotation (T/R) switches, one for each X or Y electrode of the outer piezos. X* and Y* can be either scan/offset signals coming from *HV INPUT 1* (11) or *HV INPUT 2* (10) and then routed to the PMD4b over *HV THROUGH OUTPUT* (8), or coarse approach signals generated by the PMD4b. Details of the T/R switches are explained below.

The relays are powered by an internal 24 V power supply, steered by a control logic powered by its own 3.3 V power supply. The control logic also monitors the output connectors' interlocks and enables the HV outputs of the HVA4 and PMD4b. The interlock and enable signals are protected against overvoltage, and there is no electrical connection between the control logic and high voltage signals in order to avoid noise injection.

There is only one electrical ground for the high voltage signals inside the AKBE, called GND, meaning that HVGND of the HVA4 and PMGND of the PMD4b are tied together at the AKBE. GND is not connected to PE (protection earth) or DGND (digital ground, the reference ground of the control logic) except for protection diodes.

## Translation/Rotation switches

The twelve T/R switches are identical, and all switch in parallel. The schematic of one of the switches is shown in the diagram below. The jumper contacts position in the drawing corresponds to the position of the jumpers on the AKBE circuit board (see the *Advanced instrument configuration* section for more details).

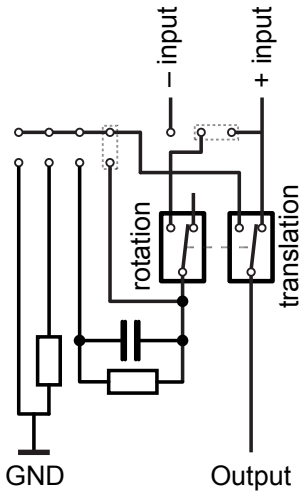


**Figure 10: Translation/rotation switch. Twelve of these switches are installed in the AKBE. The diagram shows the "translation" setting, and the jumpers are set such that during rotation the same signal is applied to the output as for translation. The resistors and capacitor forming the signal attenuator are optional and fitted only if required.**

# Front panel

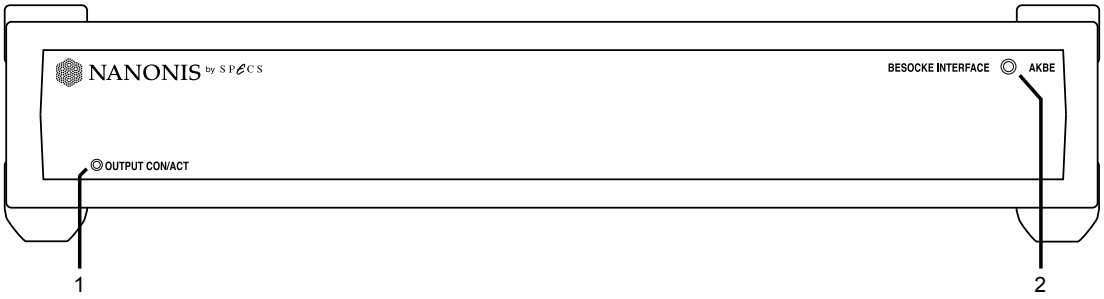


**Figure 11: AKBE front panel.**

1. **Connector/Active LED (green/orange):** Lights green if a plug is connected to the *HV OUTPUT* connector (7) and a PMD4b is connected to the *HV THROUGH OUTPUT* (8). Lights orange if a plug is connected to the *HV OUTPUT* connector (7) but no PMD4b is connected to the *HV THROUGH OUTPUT* (8). The LED is off, if none of the above conditions is met, or no plug is connected to the *HV OUTPUT* connector (7).
2. **Power LED (blue):** Indicates that power supply of the AKBE is turned on.

# Rear Panel

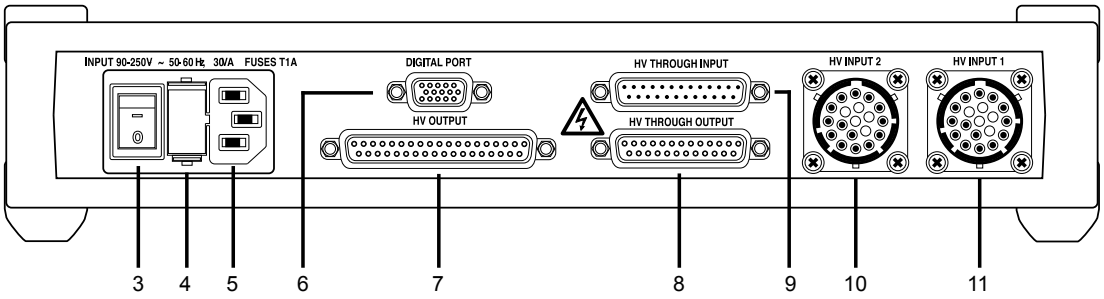


**Figure 12: AKBE rear panel.**

3. **Power switch:** Turns the AKBE on and off.
4. **Fuse holder:** Contains two identical fuses. Slow blowing 1A fuses (T1A) should be used independently from the line voltage
5. **IEC power socket.**
6. **DIGITAL PORT:** This HD D-sub15 female connector is used for controlling the AKBE over the *Extension port* of the PMD4b, using the serial protocol implemented over this interface. For more details, please refer to the *Digital port* section.
7. **HV OUTPUT:** This D-sub37 female connector carries up to 20 high voltage signals required by the microscope head, one for each piezo electrode. A blank plug for custom wiring to the microscope head, or adapters for commercial microscopes are provided with the AKBE. For more details, please refer to the *HV output* section.
8. **HV THROUGH OUTPUT:** This D-sub25 female connector supplies the high voltage signals applied to the outer piezos from either *HV INPUT 1* (11) or *HV INPUT 2* (10) to the *HV INPUT* of the PMD4b (“send”). For more details, please refer to the *HV through output* section.
9. **HV THROUGH INPUT:** This D-sub25 male connector receives the coarse motion signals generated by the PMD4b. If high voltage signals for scanning or X-Y offset need to be applied to the outer piezos, this input also acts as a “return” line of the signals sent to the PMD4b over the *HV THROUGH OUTPUT* (8) connector. For more details, please refer to the *HV through input* section.
10. **HV INPUT 2:** High voltage signals from a HVA4 are applied to this connector. Note that if only one HVA4 is used, it should be connected to *HV INPUT 1* (11). For more details, please refer to the *HV inputs 1 and 2* section.
11. **HV INPUT 1:** High voltage signals from a HVA4 are applied to this connector. This is the default connector for connecting one HVA4, and should always be used if only one HVA4 is connected to the AKBE. For more details, please refer to the *HV inputs 1 and 2* section.

# Installation Guide

This installation guide shows how to prepare and power-up the AKBE. Following these instructions ensures that the instrument is working correctly, and that it can be connected to the experiment. Further steps will be explained in detail in the chapters following this guide.

It will be assumed that a PMD4b and one or two HVA4 are used together with the AKBE.

## Contents of delivery

When first unpacking the AKBE, please check for the following items:

1. Nanonis AKBE
2. Blank output plug, or adapter cable for commercial microscopes
3. Cable for connection between AKBE and HVA4 (2, if 2 HVA4s are required)
4. 2 cables for connection between AKBE and PMD4b
5. Digital port cable
6. Power cable
7. User manual

This list is valid if the AKBE is used for home-built microscopes. If the AKBE is used with supported commercial microscopes, the contents of delivery will be different.

The items are shown in the picture below. Note that the power cable appearance will depend on the country where the AKBE is used (Type J power cable shown).

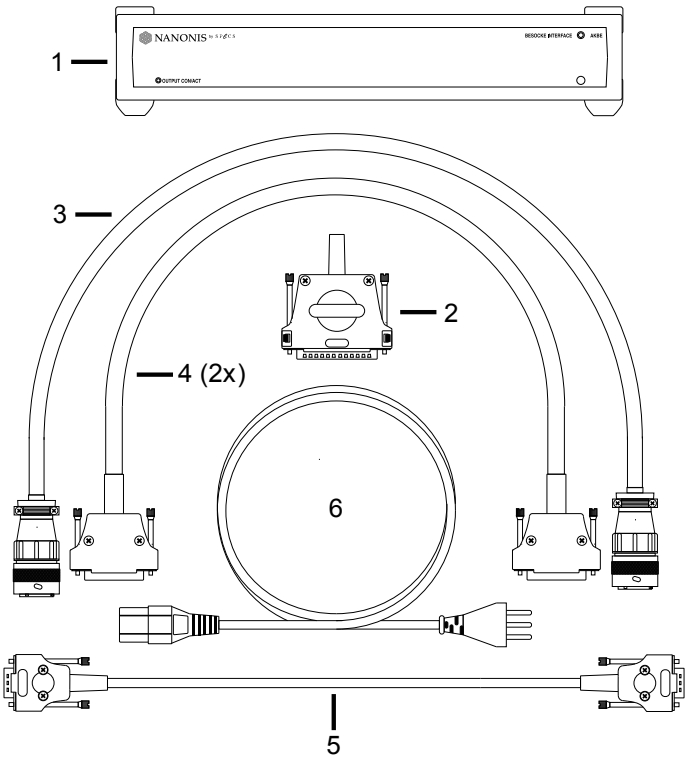


**Figure 13: Items delivered with the AKBE. Item 3 will be delivered twice if two Nanonis HVA4 are used with the AKBE. If the AKBE is used with commercial SPMs, specific adapter cables will be delivered instead of item 2.**

# Set-up

To properly set up the instrument, a square space of at least 40cm × 45cm × 15cm (W × D × H) is required. The AKBE weighs approx. 3.2 kg, and stability of its supporting table must be guaranteed. It must be possible to access the hardware from the front and the rear in order to connect all necessary cables. The space has to be dry and kept within the specified temperature range.

The AKBE requires one power socket (10 VA typical, 30 VA max at 90 - 253 V AC) with proper grounding. The AKBE is powered by a wide range power supply.

**Warning:** The power cord must be connected to a properly wired and earthed socket.

# Electrical ground

No particular care has to be taken when considering the electrical ground concept of the AKBE, since its internal circuits are not coupled to the GNDs of the instruments connected to it or to the microscope head, except for protection diodes. They are, however, connected to PE (and therefore the enclosure of the AKBE) over a 10 kΩ resistor.

The signal grounds of all instruments connected to the AKBE over the *inputs and outputs* (7-11) are tied together inside the AKBE.

# Powering

Switch on the AKBE with the power switch located at the back of the unit (see picture below). The *Power LED* (2) will turn on.

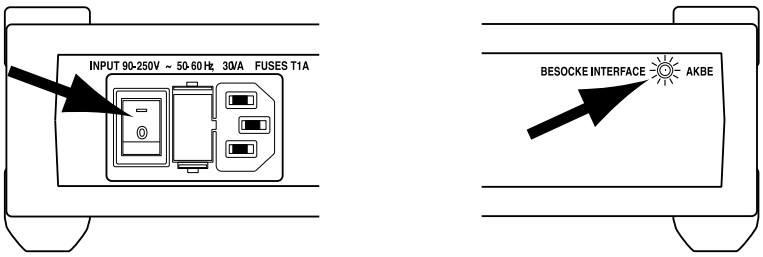


**Figure 14: Powering up the AKBE. Left side: location of the power switch at the back of the AKBE. Right side: LED which will turn on after powering the unit.**

The AKBE is now ready for use. Should the AKBE not turn on as described above, please refer to the *Troubleshooting* section before proceeding. If a solution to the unexpected behavior is not listed there, please contact SPECS before taking any further action.

## How to proceed

- Turn off the instrument
- Make sure that the HVA4 is switched off, then connect the HVA4 to *HV INPUT 1* (11), as described in the *HV INPUTS 1 and 2* section
- If a second HVA4 is required, make sure that also this HVA4 is switched off, and connect it to *HV INPUT 2* (10), as described in the *HV INPUTS 1 and 2* section.

- Make sure that the PMD4b is switched off, then connect the AKBE *HV THROUGH INPUT* (9) with the *PIEZO MOTOR HV OUTPUT* of the PMD4b, as described in the *HV through input* section
- Connect the AKBE *HV THROUGH OUTPUT* (9) with the *HV INPUT* of the PMD4b, as described in the *HV through output* section
- Connect the *DIGITAL PORT* (6) to the *EXTENSION PORT* of the PMD4b, as described in the *Digital port* section
- Connect the microscope to the *HV OUTPUT* (7), as described in the *HV output* section.
- Make sure that the HVA4 *HV switches* are in the off position, and that the PMD4b *HV output enable switch* is in the disable position. Then, switch on the AKBE first, and then the HVA4 and PMD4b using the power switch at the back of the HVS4. If two HVA4s are required, turn on the HVA4 not sharing the HVS4 power supply with the PMD4b at the end.

**Caution:** Please carefully read the HVA4 and PMD4 user manuals delivered with the respective instruments before proceeding!

# HV inputs 1 and 2

The AKBE has two HV input connectors, each one with 19 pins and a bayonet locking mechanism. The connectors are manufactured by Souriau (TRIM TRIO, series UTG, model UTG01619P). The corresponding cable plug (TRIM TRIO, series UTG, model UTG61619S) is mounted on the cable for the connection between AKBE and HVA4.

The HV stages of the HVA4s connected to the inputs are switched on remotely, once the AKBE is powered, using the HV enable signals. There is no interlock in these connectors, meaning that the AKBE cannot detect if a HVA4 is connected to it or not. When powering up the AKBE, the pins of the connectors are floating, with no connection to the PMD4b or the microscope. However, as soon as the AKBE receives a valid control signal at its *DIGITAL PORT* (6), the internal switches will reconfigure according to the configuration sent with the control signal, meaning that the connector pins could be connected to the microscope either directly or over the PMD4b. When using only one HVA4, the software configuration (based on a license file) makes sure that the pins of *HV INPUT 2* (10) are never connected to the microscope or to the PMD4b.

**Warning:** Always connect the HVA4s to the AKBE before powering the AKBE or the HVA4s.

The following sections of this chapter explain how to connect the AKBE high voltage inputs to a Nanonis HVA4, and explain in more detail the pin layout of the connector and the circuitry behind it.

## HV inputs connection

### Systems with one HVA4

Make sure that the HVA4 and the AKBE are switched off, and that the HV out switches of the HVA4 are in the off position. The *HV INPUT 1* (11) of the AKBE is connected to the Nanonis HVA4 using the cable delivered with the AKBE, as shown in the picture below. The *HV INPUT 2* connector (10) can be left open, the connector pins are floating and not connected internally if only one HVA4 is used.

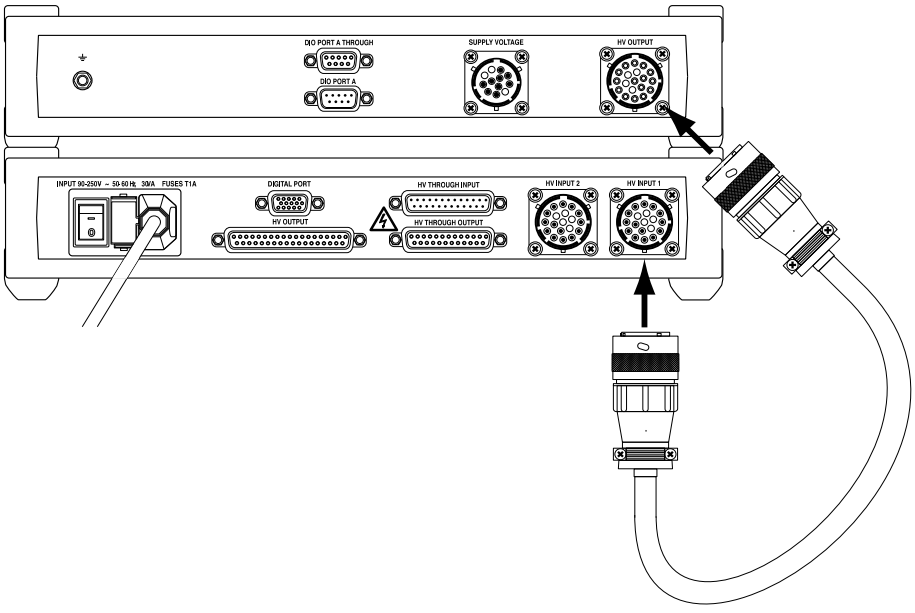


**Figure 15: Connection of a Nanonis HVA4 to the AKBE, when only one HVA4 is used.**

## Systems with two HVA4

Make sure that both HVA4s and the AKBE are switched off, and that the HV out switches of both HVA4s are in the off position. *HV INPUT 1* (11) of the AKBE is connected to the Nanonis HVA4 which drives the center piezo, while *HV INPUT 2* (10) of the AKBE is connected to the Nanonis HVA4 which drives the outer piezos.

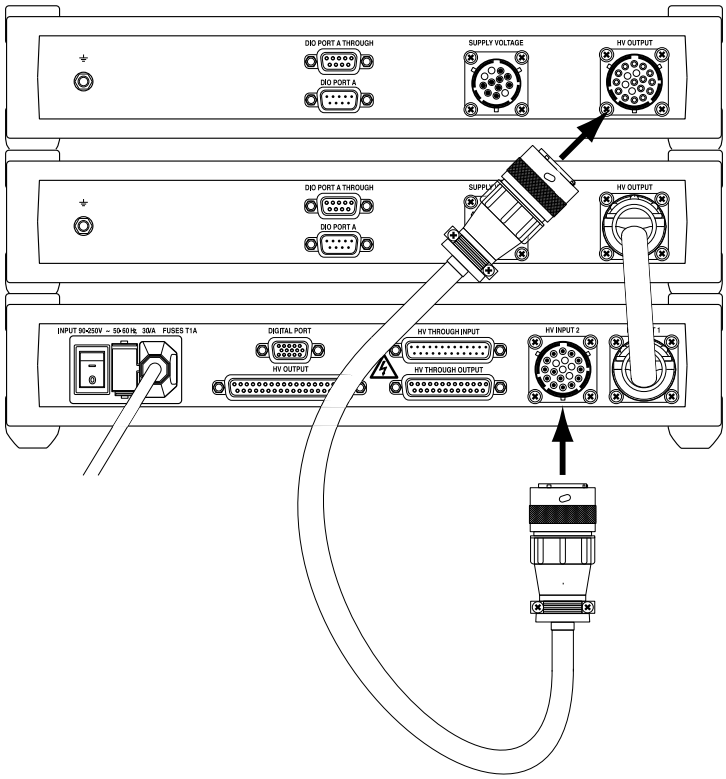


**Figure 16: Connection of a second Nanonis HVA4 to the AKBE. A first HVA4 is already connected.**

# HV inputs schematic

A schematic of the circuits related to the high voltage inputs (10, 11) is shown in the picture below.

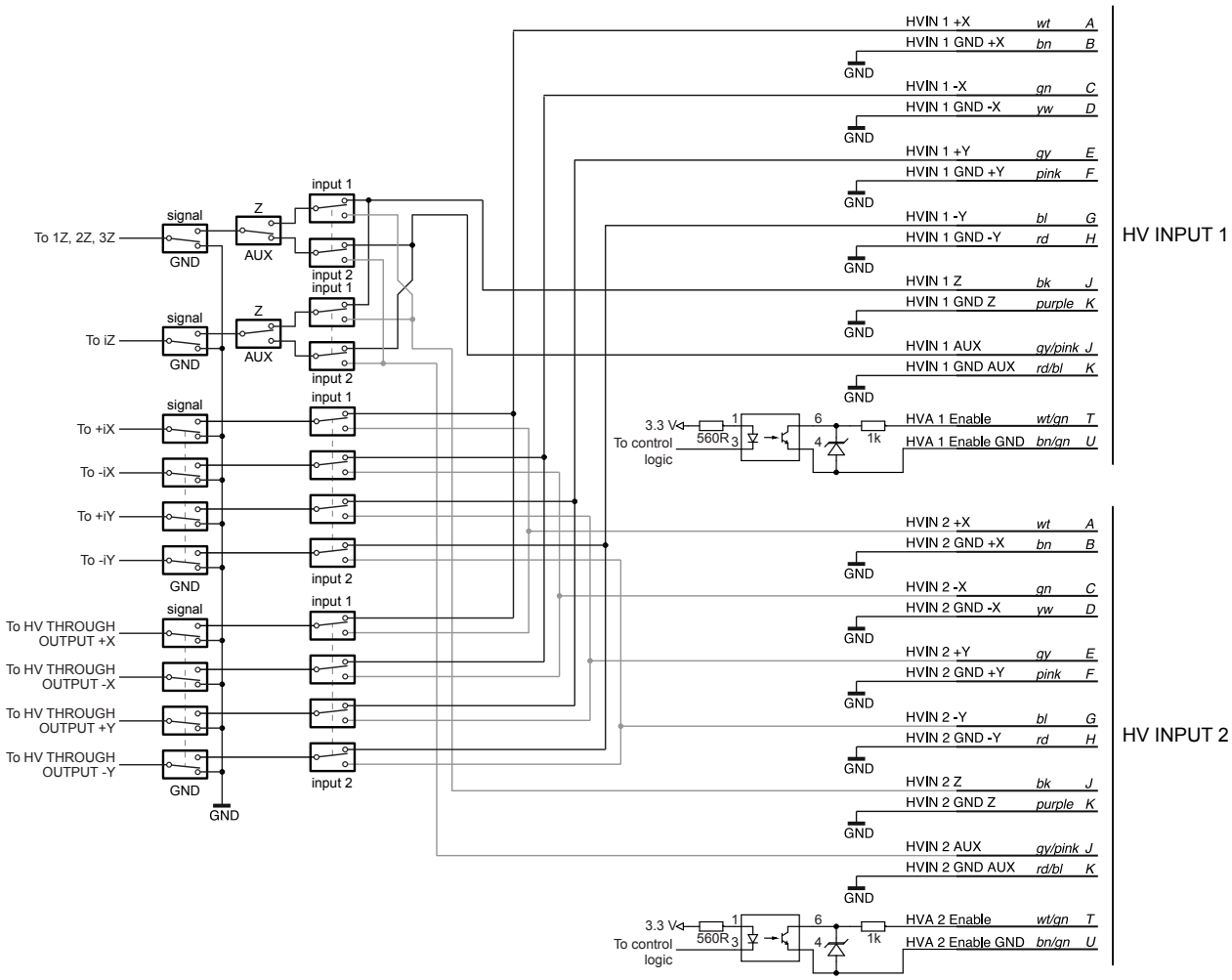


**Figure 17: Schematic of the high voltage inputs. Signal lines related to *HV INPUT 2* (10) are drawn in grey for clarity. The relays are shown in their default position.**

All input signals are routed directly to the input select relays, while the GNDs of the input signals are connected together to the internal GND of the AKBE. The selector relays decide which input is routed to the Z or X-Y electrodes of either the inner piezo or the three outer piezos. Two additional relays select whether the AUX or the Z channel of the HVA4 are used for the Z electrodes of the inner piezo and the outer piezos. For a full picture of the signal routing, please refer to the *block diagram*.

All electrodes can be connected to GND with an additional set of relays, which is the default configuration when the AKBE is switched off. Note that PE is not carried over the HV input connectors.

The HVA4s are enabled remotely by the AKBE control logic which shorts pins T and U of the HV input connectors over a photocoupler.

# HV inputs pin layout

The *HV INPUT 1* (11) and *HV INPUT 2* (10) connector pin layout is shown in the picture and table below. The pin layout is identical for both connectors.

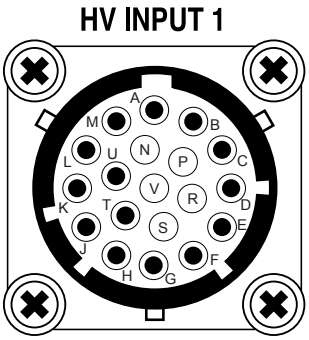


**Figure 18: HV input connectors pin configuration. HVINPUT 1 is shown, but *HV INPUT 1* (11) and *HV INPUT 2* (10) have the same pin configuration.**

| PIN | Signal | PIN | Signal | PIN | Signal |
|---|---|---|---|---|---|
| A | +X Signal | G | -Y Signal | N | NC |
| B | +X HVGND | H | -Y HVGND | P | NC |
| C | -X Signal | J | Z Signal | R | NC |
| D | -X HVGND | K | Z HVGND | S | NC |
| E | +Y Signal | L | AUX Signal | T | HV enable (signal) |
| F | +Y HVGND | M | AUX HVGND | U | HV enable (GND) |
| | | | | V | NC |

**Table 2: Pin assignment of the HV input connectors. The pin assignment is valid for both *HV INPUT 1* (11) and *HV INPUT 2* (10).**

# HV input cable

One cable for the connection between AKBE and HVA4, shown below, is delivered with the AKBE. If two HVA4s need to be used, the second cable is delivered with the second HVA4.

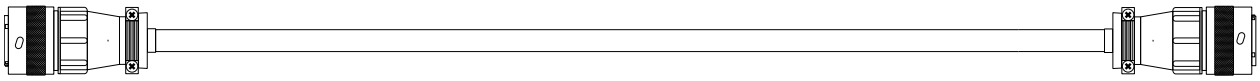

**Figure 19: Cable for connection between AKBE and HVA4.**

The wiring diagram of the cable is shown below.


**Figure 20: Wiring diagram of the cable for connection between AKBE and HVA4.**

# HV through output

One female D-sub 25-pin connector is used for the *HV THROUGH OUTPUT* connector (8). The signals on this connector are routed to the PMD4b using one of the two cables for the connection between AKBE and PMD4b delivered with the AKBE. The *HV THROUGH OUTPUT* (8) is used for scan or offset signals in X and Y direction, which have to be applied on the outer piezos of the microscope head. These signals are generated by the HVA4(s) connected to *HV INPUT 1* (11) and *HV INPUT 2* (10, only if 2 HVA4s are used), and then routed to the *HV THROUGH OUTPUT* (8) if the AKBE is configured accordingly. Scan and offset signals in Z direction are not routed to the *HV THROUGH OUTPUT* (8).

If no scan or offset signals in X and Y direction are needed for the experiment, the *HV THROUGH OUTPUT* (8) is not used and can be left disconnected.

The HV input of the PMD4b is remotely enabled, once the AKBE is powered on, using the PMD4b enable signals of the *HV THROUGH OUTPUT* (8). Therefore, if this output is not connected to the PMD4b, the HV input of the PMD4b will always be disabled. For more details about the PMD4b HV input, please refer to the PMD4 user manual.

An interlock mechanism makes sure that no high voltage will be applied at the *HV THROUGH OUTPUT* connector (8), if a PMD4b is not connected to it. In that case, the ±X and ±Y output pins are connected to GND inside the AKBE with relays, and it will not be possible to route HV signals to this connector using the Motor control software. High voltage output is enabled only if the two pins of the connector corresponding to the HV enable lines are shorted. The *Connector/Active LED* (1) will light orange, if no PMD4b is connected to the *HV THROUGH OUTPUT* connector (8), or if a PMD4b is connected but switched off. For details, please refer to the schematic below.

**Warning:** Always connect the PMD4b to the AKBE *HV THROUGH OUTPUT* (8) before powering the AKBE or the PMD4b.

## HV through output connection

Make sure that the PMD4b, the HVA4(s), and the AKBE are switched off, that the HV out switches of the HVA4 are in the off position, and that the HV output enable switch of the PMD4b is in the disable position. The *HV THROUGH OUTPUT* (8) of the AKBE is connected to the Nanonis PMD4b using the cable delivered with the AKBE, as shown in the picture below.

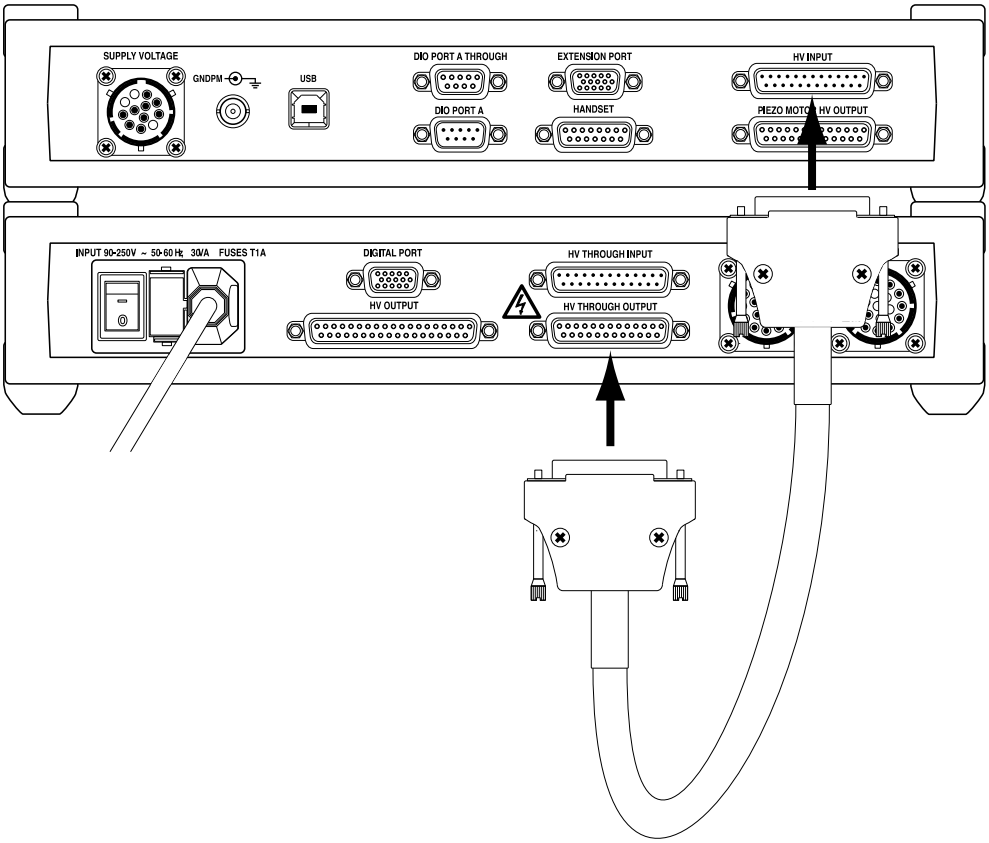


**Figure 21: Connection of a Nanonis PMD4b to the *HV THROUGH OUTPUT* (8) connector of the AKBE.**

**Warning:** Lethal voltages can be present at the *HV THROUGH OUTPUT* (8)!

# HV through output Schematic

A schematic of the circuits related to the *HV THROUGH OUTPUT* (8) is shown in the picture below.

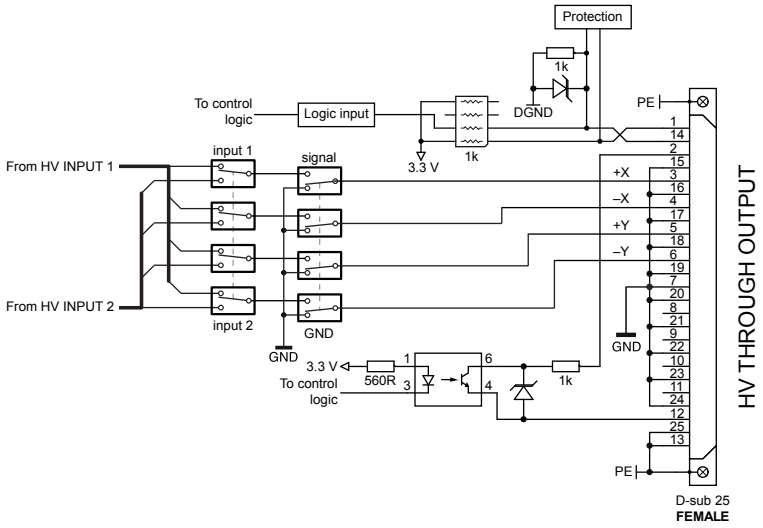


**Figure 22: Schematic of the *HV THROUGH OUTPUT* (8).**

The signals from *HV INPUT 1* (11) and *HV INPUT 2* (10) pass through the input selector relays and a set of relays which allows the output lines to be shorted to GND, before reaching the *HV THROUGH OUTPUT* connector (8). Note that the relays have already been drawn in the schematic of the *HV INPUTS* in the previous section. For a complete picture of the signal routing, please refer to the *block diagram*.

The interlock mechanism is shown in the upper part of the figure. The AKBE applies 3.3 V on pin 1. If a PMD4b is connected and powered on, pin 1 and 14 are shorted, and the control logic detects a voltage of 3.3 V on pin 14. The HV input of the PMD4b is enabled by shorting pins 2 and 12 over a phototransistor inside the AKBE.

# HV through output pin layout

The *HV THROUGH OUTPUT* (8) connector pin layout is shown in the picture and table below.

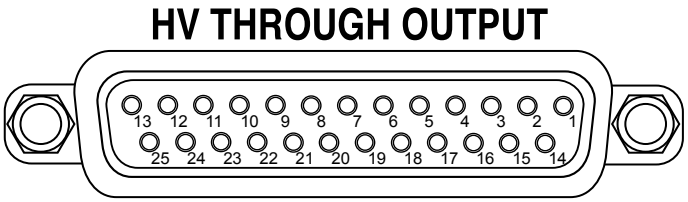


**Figure 23: *HV THROUGH OUTPUT* (8) connector pin layout.**

| PIN | Signal |
|---|---|
| 1 | HV through out enable (signal, +3.3V from AKBE) |
| 2 | PMD4b HV Input enable (signal, +5Vfrom PMD4b) |
| 3 | +X output |
| 4 | -X output |
| 5 | +Y output |
| 6 | -Y output |
| 7 | GND |
| 8-11 | NC |
| 12 | PMD4b HV Input enable (GND) |
| 13 | PE |
| 14 | HV through out enable (return line) |
| 15-24 | GND |
| 25 | PE |

**Table 3: Pin assignment of the *HV THROUGH OUTPUT* connector (8).**

# HV through output cable

Two identical cables for the connection between an AKBE and a PMD4b are delivered with the AKBE. One is used for the connection between the *HV THROUGH OUTPUT* (8) of the AKBE to the HV INPUT of the PMD4b, the other one for the connection between the *HV THROUGH INPUT* (9) of the AKBE and the PIEZO MOTOR HV OUTPUT of the PMD4b. The cable is depicted below.

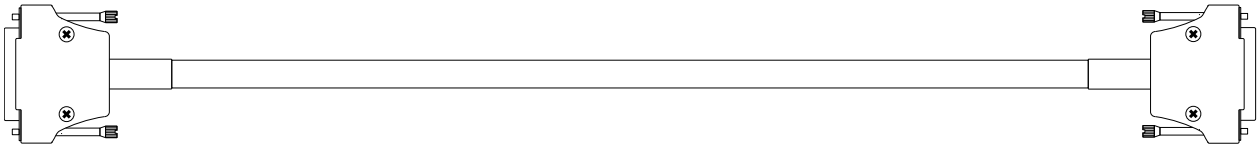

**Table 4: Cable for connection between AKBE and PMD4b.**

The wiring diagram of the cable for the connection between an AKBE and a PMD4b is shown below. The Z and AUX channels are connected within the cable, but are not used by the AKBE. Note that the shield of the cable is always connected to PE at the male connector side.

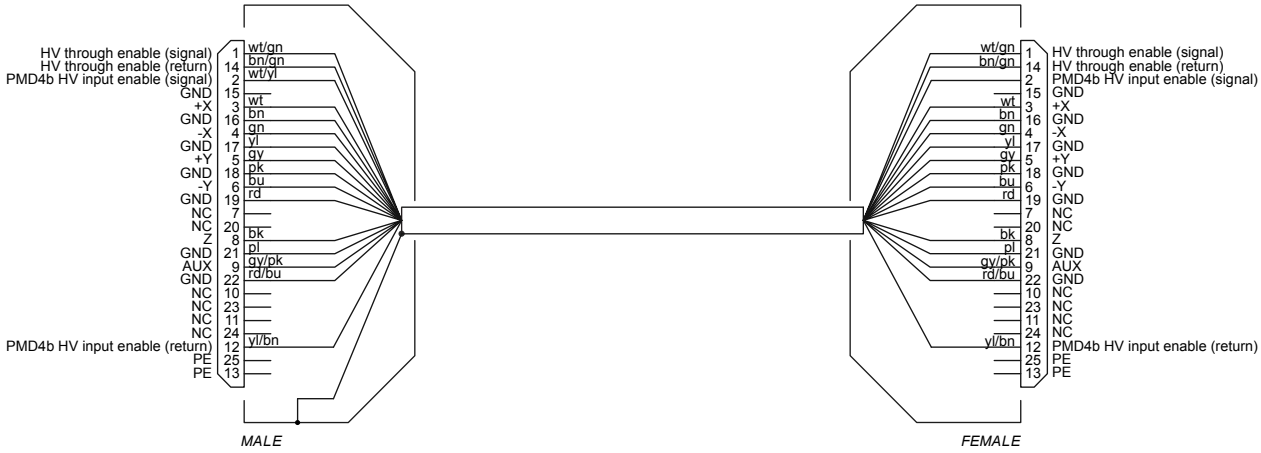


**Figure 24: Wiring diagram of the cable for the connection between AKBE and PMD4b. Both *HV THROUGH OUTPUT* (8) and *HV THROUGH INPUT* (9) cables have the same internal wiring. Note that the shield is connected to PE only at the male connector side.**

# HV through input

One male D-sub 25-pin connector is used for the *HV THROUGH INPUT* (9). The signals applied to this input are routed to the Translation/Rotation switches of the AKBE, and then to the outer piezos of the microscope head. They cannot be routed to the center piezo.

The HV stage of the PMD4b connected to the *HV THROUGH INPUT* (9) is remotely switched on using the HV enable signals, but only if a plug is detected at the *HV OUTPUT* connector (7). Therefore, if no microscope is connected to the *AKBE HV OUTPUT* (7), the PMD4b output will be disabled. There is no interlock in the connector, meaning that the AKBE cannot detect if a PMD4b is connected to the *HV THROUGH INPUT* (9) or not.

**Warning:** Always connect the PMD4b to the AKBE *HV THROUGH INPUT* (9) before powering the AKBE or the PMD4b.

**Warning:** Always connect the PMD4b to the AKBE *HV THROUGH INPUT* (9) before connecting the microscope to the AKBE.

## HV through input connection

Make sure that the PMD4b, the HVA4(s), and the AKBE are switched off, that the HV out switches of the HVA4 are in the off position, and that the HV output enable switch of the PMD4b is in the disable position. The *HV THROUGH INPUT* (9) of the AKBE is connected to the Nanonis PMD4b using the cable delivered with the AKBE, as shown in the picture below.

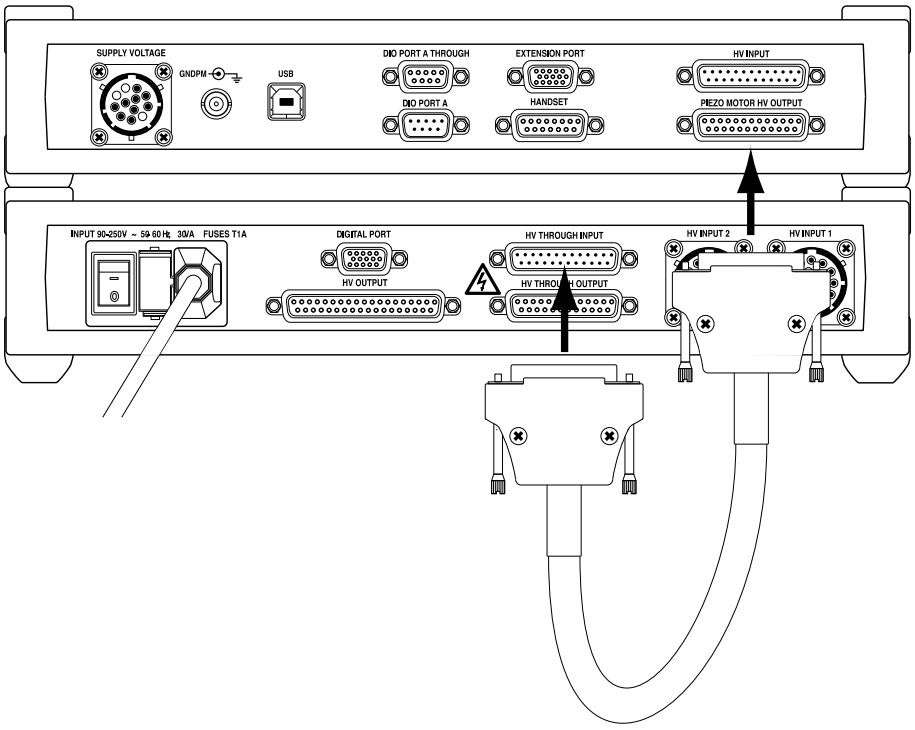


**Figure 25: Connection of a Nanonis PMD4b to the *HV THROUGH INPUT* (9) connector of the AKBE.**

# HV through input schematic

A schematic of the circuits related to the *HV THROUGH INPUT* (9) is shown in the picture below.

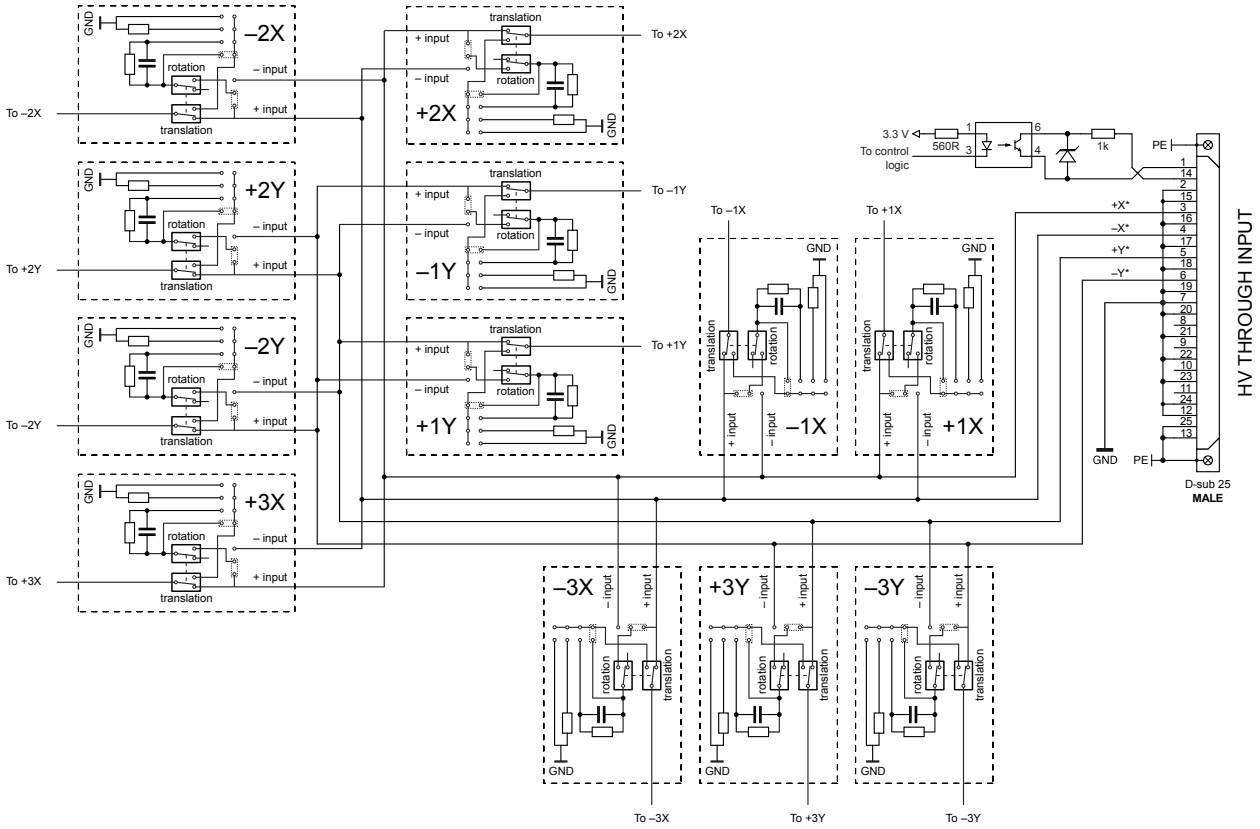


**Figure 26: Schematic of the *HV THROUGH INPUT* (9), showing the translation/rotation switches. The placement of the switches in the picture corresponds to the placement of the switches on the AKBE circuit board.**

All input signals are routed directly to the translation/rotation switches, and then to the three outer piezos of the microscope head.

The HV output of the PMD4b is enabled remotely by the AKBE control logic, which shorts pins 1 and 14 of the PIEZO MOTOR HV OUT connector over a phototransistor.

# HV through input pin layout

The *HV THROUGH INPUT* (9) connector pin layout is shown in the picture and table below.

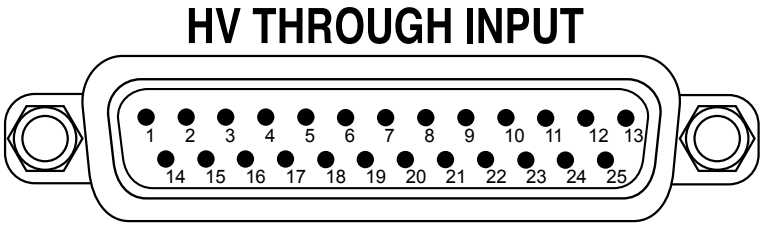


**Figure 27: *HV THROUGH INPUT* connector (9) pin layout.**

| PIN | Signal |
|---|---|
| 1 | PMD4b Piezo Motor HV Output enable (return line) |
| 2 | GND |
| 3 | +X input |
| 4 | -X input |
| 5 | +Y input |
| 6 | -Y input |
| 7 | GND |
| 8-11 | NC |
| 12 | GND |
| 13 | PE |
| 14 | PMD4b Piezo Motor HV Output enable (signal) |
| 15-24 | GND |
| 25 | PE |

**Table 5: Pin assignment of the *HV THROUGH INPUT* connector (9).**

# HV through input cable

The HV through input cable is identical to the HV through output cable, therefore it does not matter which one of the two cables delivered with the AKBE is used for connecting the *HV THROUGH INPUT* (9) or the *HV THROUGH OUTPUT* (8) to the PMD4b.

# HV output

One female D-sub 37-pin connector is used for the *HV OUTPUT* connector (7). The AKBE outputs all high voltage signals to the microscope head via this connector. Therefore, only a single cable to the microscope is required.

An interlock mechanism makes sure that high voltage will be applied at the output only if a plug is connected to the *HV OUTPUT* connector (7). Otherwise, the high voltage lines for the central piezo tube (±iX, ±iY, iZ) as well as the Z-signals for the outer piezo tubes (1Z, 2Z, 3Z) are connected to GND inside the AKBE, while the high voltage lines for the X- and Y-electrodes of the outer piezos are connected to GND inside the PMD4b. High voltage is enabled only if the two pins of the connector corresponding to the HV enable lines are shorted. This also allows for a remote disabling of the high voltage output, by connecting the two lines to an external switch or instrument (e.g. pressure gauge or thermometer), which opens the circuit under conditions where the high voltage should be disabled. Details are explained in the sections below.

## HV output connection

Make sure that the PMD4b, the HVA4(s), and the AKBE are switched off, that the HV out switches of the HVA4 are in the off position, and that the HV output enable switch of the PMD4b is in the disable position. The *HV OUTPUT* (7) of the AKBE is connected to the microscope as shown in the picture below. For a description of the output cable options, please see the sections below.

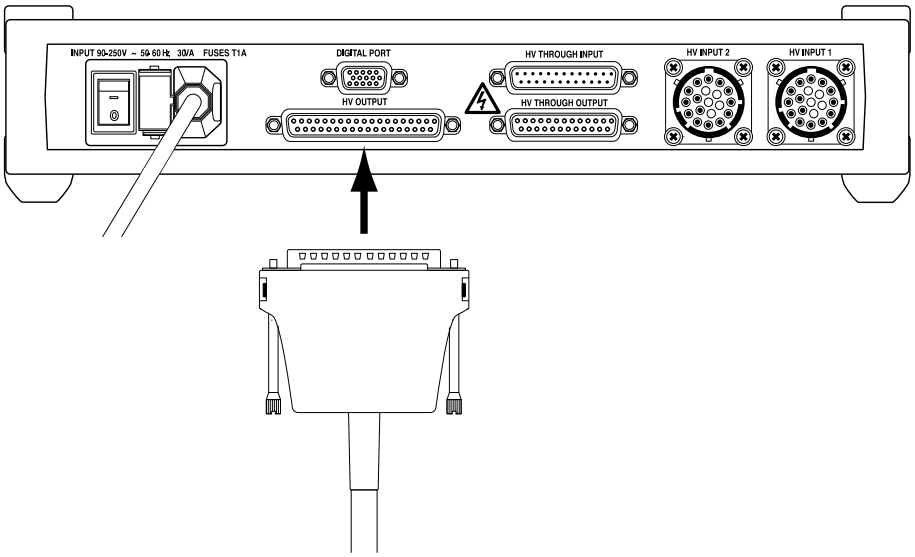


**Figure 28: Connection of the HV OUTPUT (7) of the AKBE.**

**Warning:** Lethal voltages can be present at the HV OUTPUT (7)!

**Attention:** If no plug is connected to the *HV OUTPUT* connector (7), the Connector/Active LED (1) will remain dark, and the output will be disabled.

# HV output schematic

A schematic of the circuits related to the *HV OUTPUT* (7) is shown in the picture below.

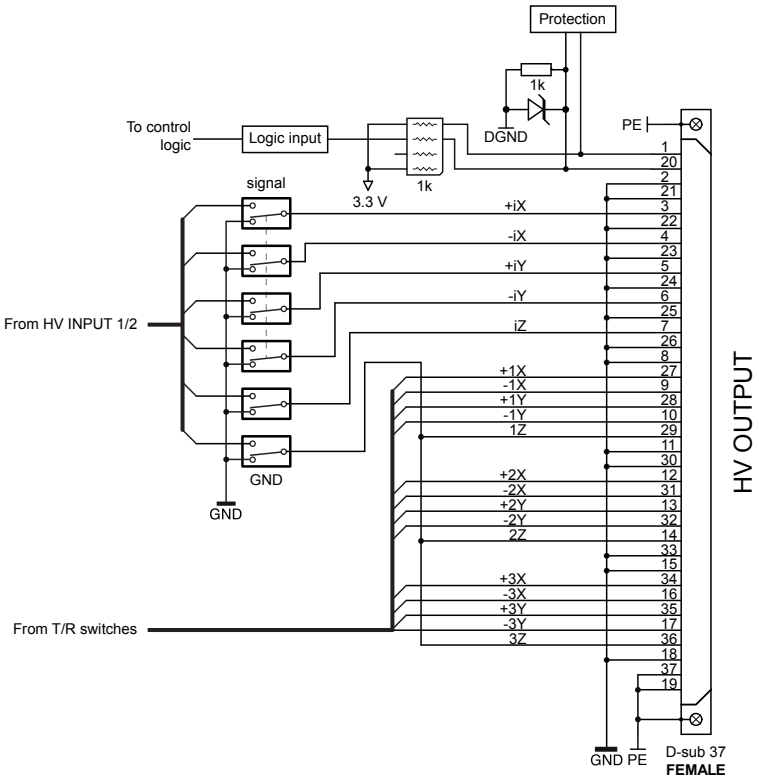


**Figure 29: Schematic of the *HV OUTPUT* (7) of the AKBE.**

Note that the relays have already been drawn in the schematic of the *HV INPUTS*. For a complete picture of the signal routing, please refer to the block diagram.

# HV output pin layout

The *HV OUTPUT* (7) connector pin layout is shown in the picture and table below.

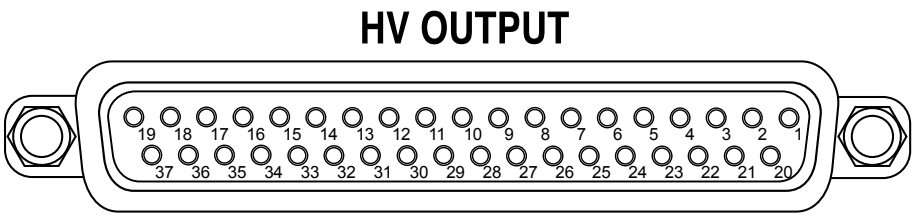


**Figure 30: HV OUTPUT connector (7) pin layout.**

| PIN | Signal | PIN | Signal |
|---|---|---|---|
| 1 | HV out enable (signal, +3.3V from AKBE) | 17 | -3Y |
| 2 | GND | 18 | GND |
| 3 | +iX | 19 | PE |
| 4 | -iX | 20 | HV out enable (return line) |
| 5 | +iY | 21-26 | GND |
| 6 | -iY | 27 | +1X |
| 7 | iZ | 28 | +1Y |
| 8 | GND | 29 | 1Z |
| 9 | -1X | 30 | GND |
| 10 | -1Y | 31 | -2X |
| 11 | GND | 32 | -2Y |
| 12 | +2X | 33 | GND |
| 13 | +2Y | 34 | +3X |
| 14 | 2Z | 35 | +3Y |
| 15 | GND | 36 | 3Z |
| 16 | -3X | 37 | PE |

**Table 6: Pin assignment of the *HV OUTPUT* connector (7).**

# HV output cable

If the AKBE is not used with the commercial microscopes listed below, wiring to the microscope head has to be done using the blank plug delivered with the instrument. The following diagram illustrates how the connections to the microscope head should be made; the diagram applies to the case when the central piezo tube is used for scanning and the outer tubes for coarse motion. It is recommended to use a multi-core shielded cable, containing coaxial cables at least for the scan and offset signals, with the shields connected to GND of the AKBE. Twisted-pair cables are an alternative, if coaxial cables cannot be used. For coarse positioning only signals, twisted pair cables should be used. The shield of the whole cable is connected to PE at the AKBE side, while the shields of the single coaxial cables (or the GND line of the twisted pair) are connected to the GND of the AKBE. Note that, if coaxial cables are used for wiring the electrodes of the outer piezo tubes, each signal should be carried over the core of the cable, while the shields are connected to GND. This requires fifteen coaxial cables.

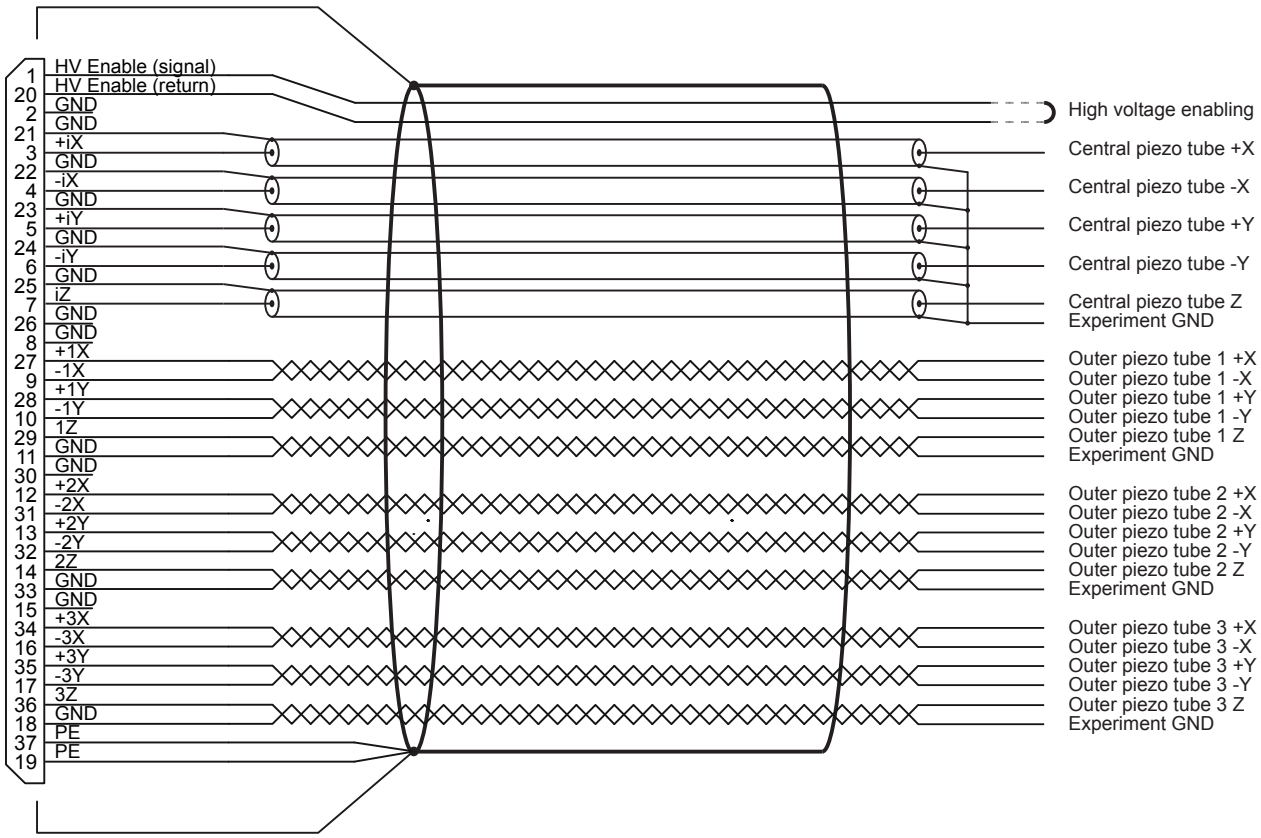


**Figure 31: HV output cable configuration for the connection of the AKBE to the microscope head. The cabling in the diagram uses coaxial cables for the scanning signals of the central piezo tube and twisted pair cables for the outer piezo tubes.**

**Warning:** Use only cables and plugs which are specified for voltages of at least 4 kV for the preparation of the high voltage cable. Only personnel trained to handle high voltages should prepare HV cables.

# HV output cable for Createc microscopes

The HV Output cable delivered with the AKBE for Createc microscopes completely replaces the original Createc HV cable. The cable is 5 m long, and is plugged to the *HV OUTPUT* (7) and the two UHV feedthroughs of the microscope. The two plugs at the microscope side are manufactured by *Amphenol*, and have model number *97-3106A-18-1S*. The Cryostat and STM temperature measurement diodes can be accessed over two BNC connectors. The cable is shown in the picture below.

For Createc AFM microscopes, where the center piezo tube is used only for the excitation of the AFM sensor, an additional adapter cable (shown on the right in the picture below) is delivered with the AKBE. The Z signals for the outer piezo tubes and the temperature measurement signals are then connected to the microscope using this adapter cable. A BNC input is used for applying the excitation voltage, and a 1/1000 divider is integrated inside the connector.

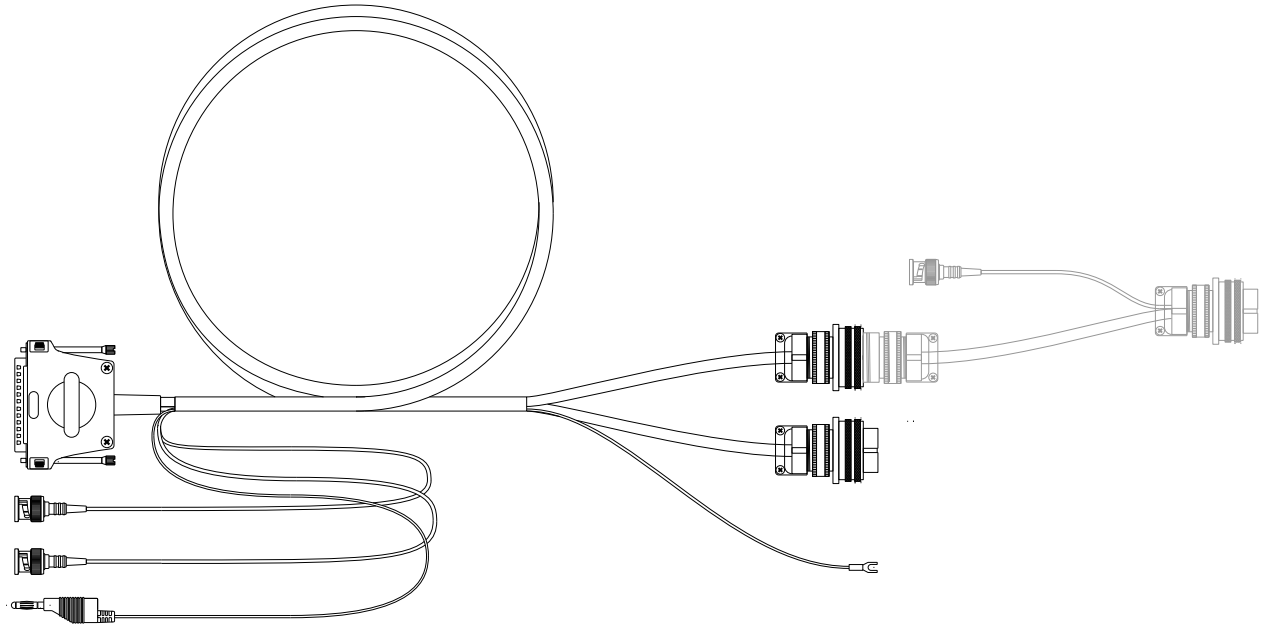

**Figure 32: Cable for the connection of the AKBE to Createc microscopes. The adapter drawn in grey on the right of the picture is only used for microscopes with AFM capability.**

The wiring diagram of the HV output cable for Createc microscopes is shown below.

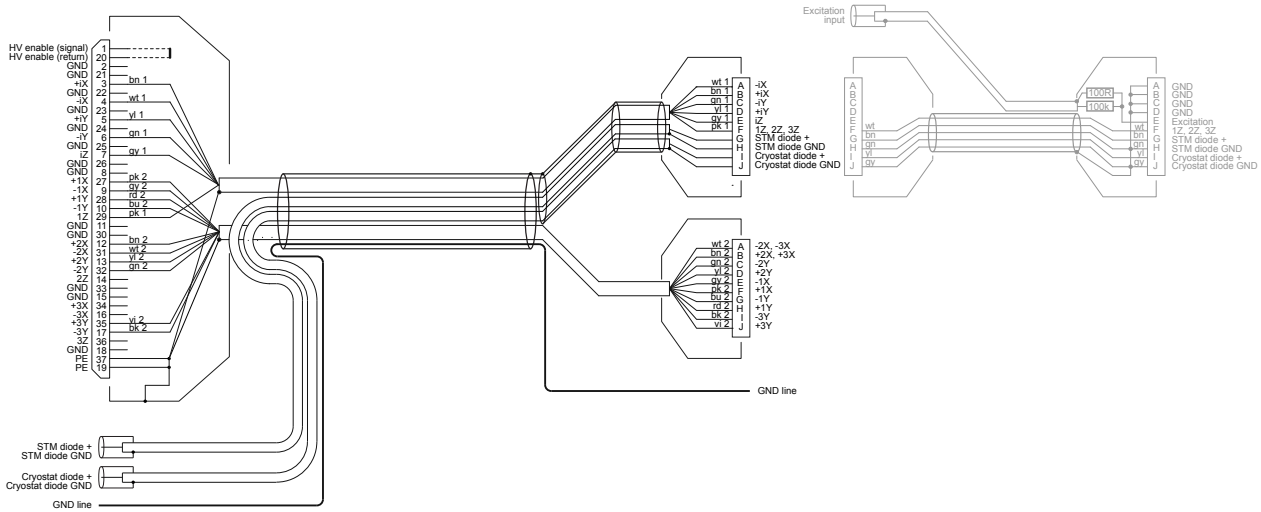


**Figure 33: Wiring diagram of the cable for the connection of the AKBE to Createc microscopes. Interlock signals are drawn with dotted lines. The adapter drawn in grey on the right of the picture is only used for microscopes with AFM capability.**

# HV output cable for RHK microscopes

The HV Output cable delivered with the AKBE for RHK STM microscopes is a short adapter cable. The cable is 20 cm long, and is plugged to the *HV OUTPUT* (7) and to the electronics side of the RHK microscope cable. The plug on the microscope side is manufactured by *Amphenol*. The cable is shown in the picture below.

**Figure 34: Adapter cable for the connection of the AKBE to RHK STM microscopes.**

The wiring diagram of the HV output adapter cable for RHK STM microscopes is shown below.

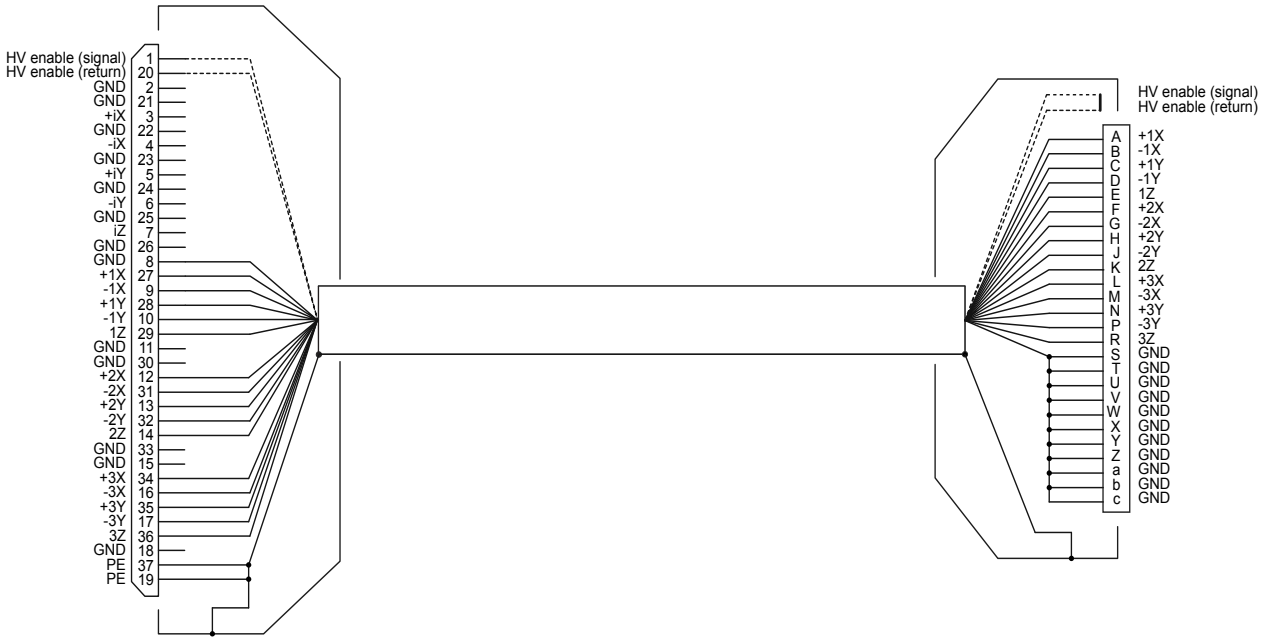


**Figure 35: Wiring diagram of the adapter cable for the connection of the AKBE to RHK microscopes. Interlock signals are drawn with dotted lines.**

# Digital port

The digital port of the AKBE is used to control the instrument and to read out its status information. Communication is done over a serial protocol running at a clock speed of 250 kHz and a signal level of 5 V. The connector is a high density D-sub connector with 15 pins, as used for VGA computer screens. The *DIGITAL PORT* (6) is connected to the Extension port of the PMD4b using the Digital port cable supplied with the AKBE.

All signal, power and GND lines of the digital port are isolated inside the PMD4b, therefore there is no galvanic connection between the AKBE and PMD4b digital circuits.

## Digital port connection

Make sure that the PMD4b, the HVA4(s), and the AKBE are switched off, that the HV out switches of the HVA4 are in the off position, and that the HV output enable switch of the PMD4b is in the disable position. The *DIGITAL PORT* (6) of the AKBE is connected to the Nanonis PMD4b using the cable delivered with the AKBE, as shown in the picture below.

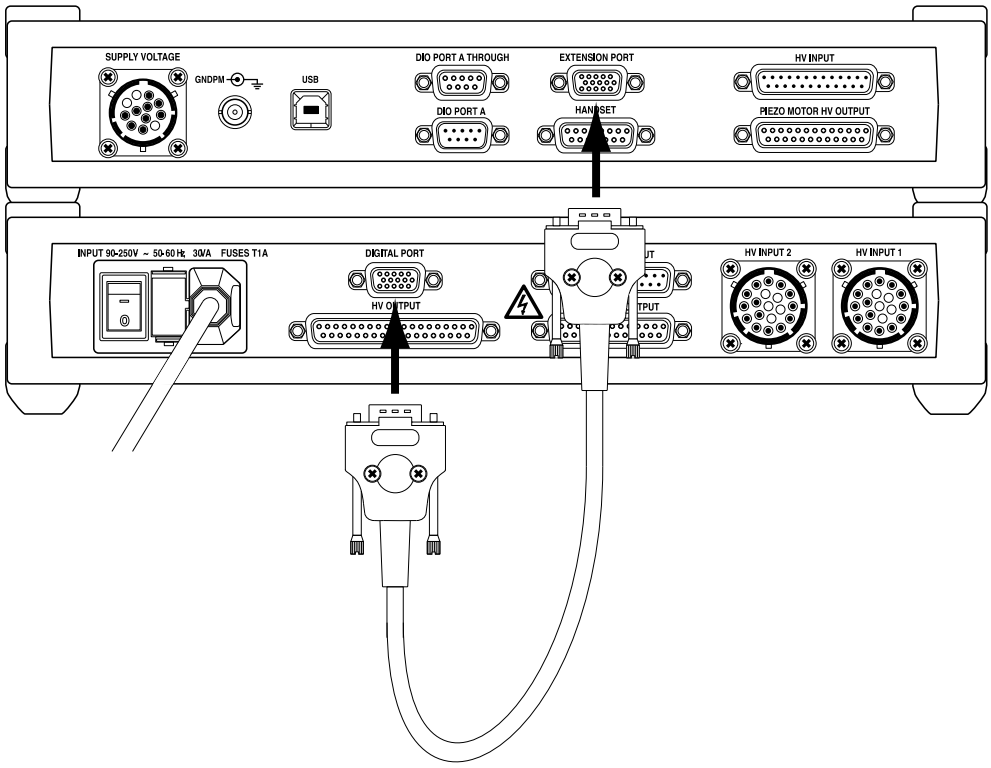


**Figure 36: Connection of the DIGITAL PORT (6) of the AKBE to the Extension port of the PMD4b.**

# Digital port schematic

A schematic of the circuits related to the *DIGITAL PORT* (6) is shown in the picture below.

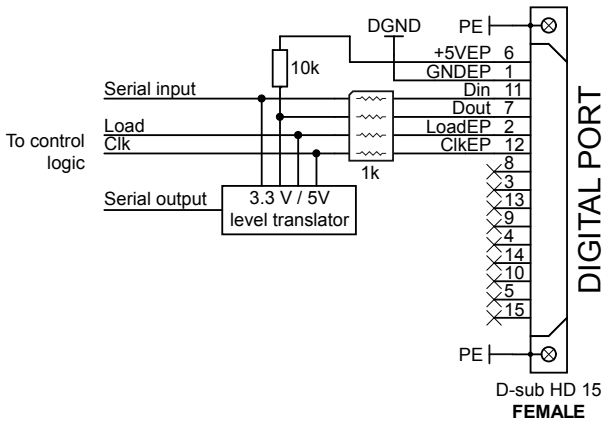


**Figure 37: Schematic of the *DIGITAL PORT* (6) of the AKBE.**

The AKBE logic works at a signal level of 3.3 V. Therefore the input signals from the PMD4b are attenuated prior to the control logic, while the serial output is converted to 5 V TTL level.

# Digital port pin layout

The *DIGITAL PORT* (6) connector pin layout is shown in the picture and table below.

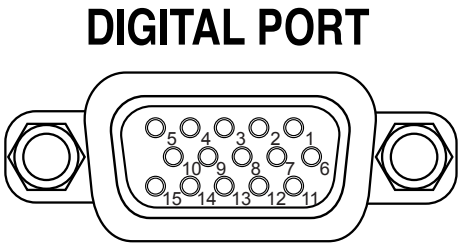


**Figure 38: *DIGITAL PORT* connector (6) pin layout.**

| PIN | Signal name | Signal description |
|---|---|---|
| 1 | GNDEP | Digital GND from extension port of PMD4b |
| 2 | LoadEP | Load shift register |
| 3-5 | NC | |
| 6 | +5VEP | +5 V supply from PMD4b |
| 7 | Dout | Serial interface digital output (16 data bits) |
| 8-10 | NC | |
| 11 | Din | Serial interface digital input (16 data bits) |
| 12 | ClkEP | Serial interface clock (250 kHz) from PMD4b |
| 13-15 | NC | |

**Table 7: Signal assignment of the *DIGITAL PORT* (6) of the AKBE.**

# Digital port cable

One digital port cable for the connection between AKBE and PMD4b, shown below, is delivered with the AKBE.

**Figure 39: Digital port cable of the AKBE.**

The wiring diagram of the cable is shown below.

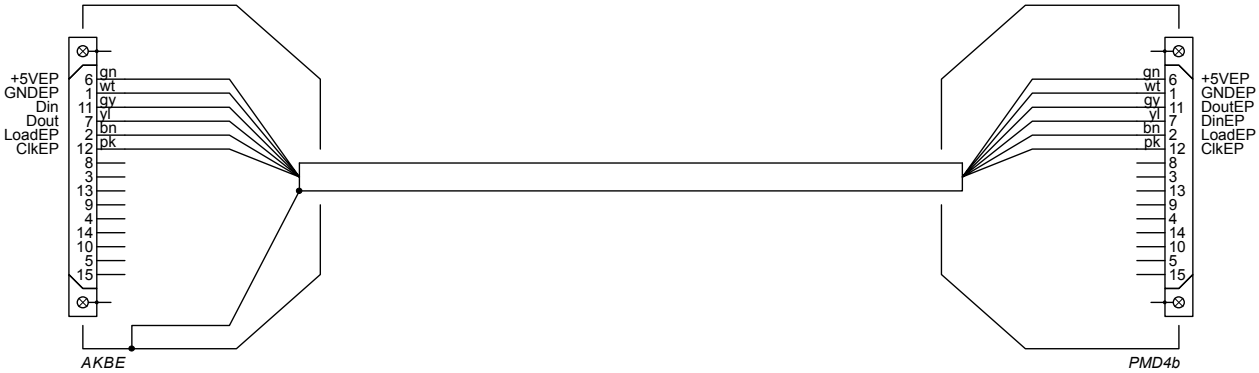


**Figure 40:Wiring diagram of the digital port cable of the AKBE. Signals at the PMD4b side are named after the signals definition in the PMD4 manual.**

# Digital port protocol

The serial interface of the extension port uses a bitstream of 16 bits, running at a clock speed of 250 kHz. Up to 16 data bits can be received on the serial input line, while 8 data bits can be sent using the serial output line. The 8 missing bits of the output datastream are reserved for the parallel inputs of the PMD4b. The timing diagram for the bitstream is shown in the figure below.

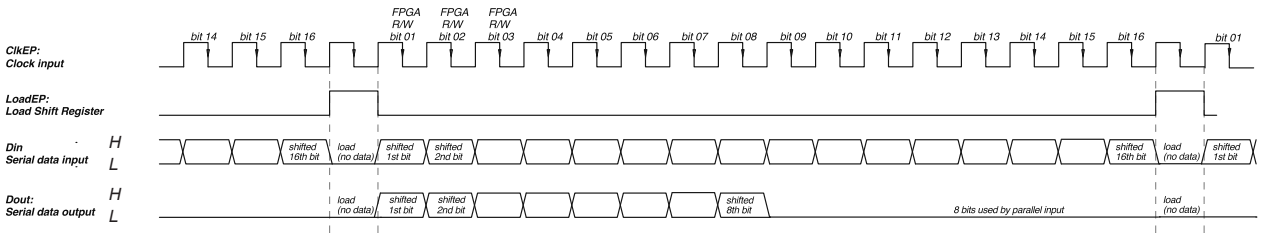


**Figure 41: Timing diagram of the serial protocol of the AKBE *DIGITAL PORT* (6).**

# Digital port register table

The register table contains the full register set of the Din and Dout lines of the serial protocol. The table is valid for firmware version V1.4 and higher of the AKBE, and firmware version V2009 or higher of the PMD4b.

**Warning:** The register table is added to this manual for information only. The AKBE is not designed to be controlled by other instruments than a Nanonis PMD4b. Any attempt to control the AKBE with other instruments will void the AKBE warranty. SPECS denies any liability in case of damage to other equipment.

| Din Bitstream | Information | "H" meaning |
|---|---|---|
| Bit 16 | HV input 1/2 selector (through) | HV input 2 to HV through output |
| Bit 15 | HV input 1/2 selector (±iX, ±iY) | HV input 2 to HV output (±iX, ±iY) |
| Bit 14 | HV input 1/2 selector (iZ) | HV input 2 to HV output (iZ) |
| Bit 13 | HV input 1/2 selector (1Z, 2Z, 3Z) | HV input 2 to HV output (1Z, 2Z, 3Z) |
| Bit 12 | Z/AUX selector (iZ) | AUX of HV input 1/2 to HV output (iZ) |
| Bit 11 | Z/AUX selector (1Z, 2Z, 3Z) | AUX of HV input 1/2 to HV output (1Z, 2Z, 3Z) |
| Bit 10 | ±iX, ±iY enable/GND | Enable ±iX, ±iY output |
| Bit 09 | iZ enable/GND | Enable iZ output |
| Bit 08 | 1Z, 2Z, 3Z enable/GND | Enable 1Z, 2Z, 3Z |
| Bit 07 | Translation/Rotation selector | Rotation |
| Bit 06 – Bit 01 | Not used | |

**Table 8: Digital port bitstream content for the Din data line.**

| Dout Bitstream | Information | "H" meaning |
|---|---|---|
| Bit 8 | HV through output interlock | PMD4b connected to HV through out |
| Bit 7 | HV output interlock | Output connector plugged |
| Bit 6 | HV input 1 enable/disable signal | HVA4 connected to HV input 1: HV output enabled |
| Bit 5 | HV input 2 enable/disable signal | HVA4 connected to HV input 2: HV output enabled |
| Bit 4 | HV through out enable/disable signal | PMD4b connected to HV through output: HV input enabled |
| Bit 3 | HV through in enable/disable signal | PMD4b connected to HV through input: HV output enabled |
| Bits 1, 2 , 9 – 16 | Not used | |

**Table 9: Digital port bitstream content for the Dout data line.**

# Specifications (digital port)

| | |
|---|---|
| Input lines (ClkEP, Din, LoadEP) | |
| Input impedance | > 10 kΩ |
| Low input threshold | 1.2 V |
| High input threshold | 3.0 V |
| Maximum input voltage | 5.0 V |
| Output lines (Dout) | |
| Output impedance | < 1 kΩ |
| High output voltage | > 4.5 V (@ 0.5 mA load) |
| Low output voltage | < 0.5 V (@ 0.5 mA load) |
| Clock | |
| Maximum clock frequency | 250 kHz |
| Signal risetime restrictions | <20% of clock period |
| Isolation | |
| Isolation between GND and DGND | 16V @ 10 mA, limited by TVS suppressors |
| EMC-Protection | According to EN61326-1 |

# Example: Nanonis SPM Control System

This section describes how the AKBE is connected to and used with a Nanonis SPM control system. Please make sure that you have read and understood the sections above before proceeding. All safety warnings are valid also for this section. For more information about the other instruments shown in the following paragraphs, please refer to the corresponding user manuals.

## Connections on the backside of the instruments

The following pictures show the appearance of a SPM control system with AKBE, PMD4b, and HVA4 installed and properly connected. Note that the Nanonis RC4, SC4, HVS4 and other cables than those needed for the operation of the AKBE are not shown.

### Systems with one HVA4

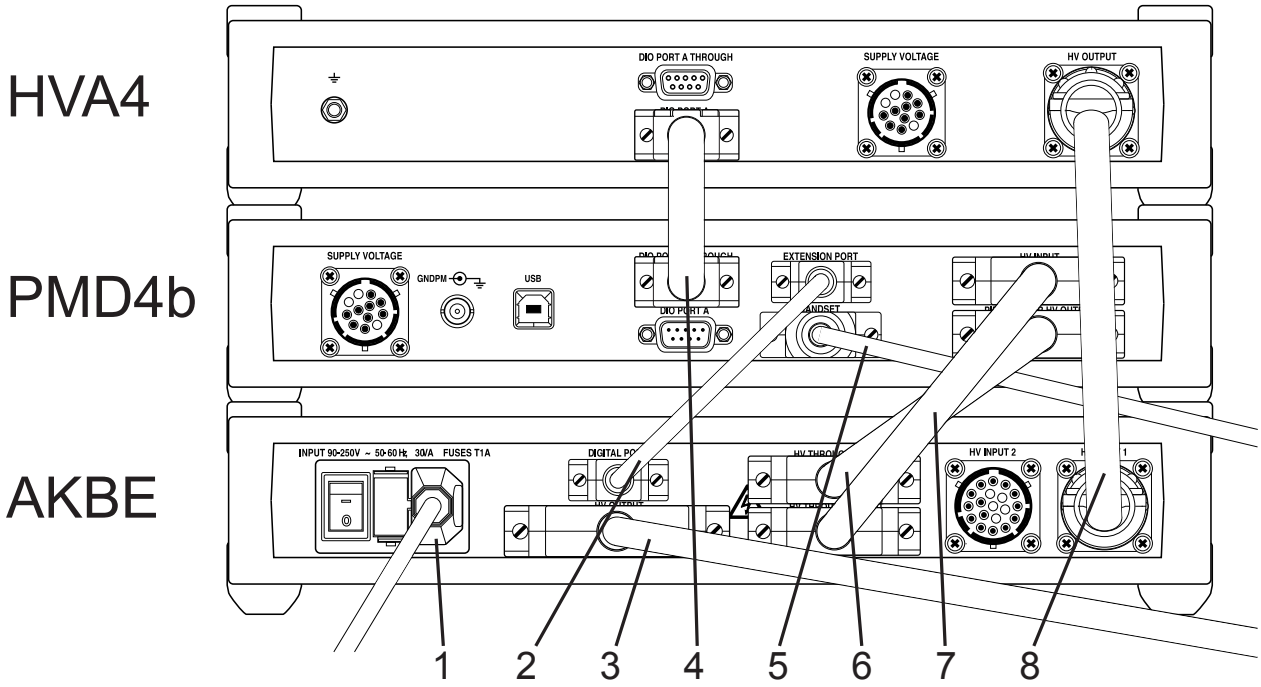


**Figure 42: Rear panel of a Nanonis SPM control system showing the connections needed for the operation of the AKBE with one HVA4. 1: Power cord, 2: Digital port cable, 3: AKBE HV OUTPUT cable to microscope head, 4: DIO cable between PMD4b and HVA4, 5: PMD4b handset cable, 6: Cable for connection between AKBE and PMD4b (between HV THROUGH INPUT of the AKBE and Piezo motor HV output of the PMD4b), 7: Cable for connection between AKBE and PMD4b (between HV THROUGH OUTPUT of the AKBE and HV input of the PMD4b), 8: Cable for connection between AKBE and HVA4. HV INPUT 2 of the AKBE is left open.**

## Systems with two HVA4s

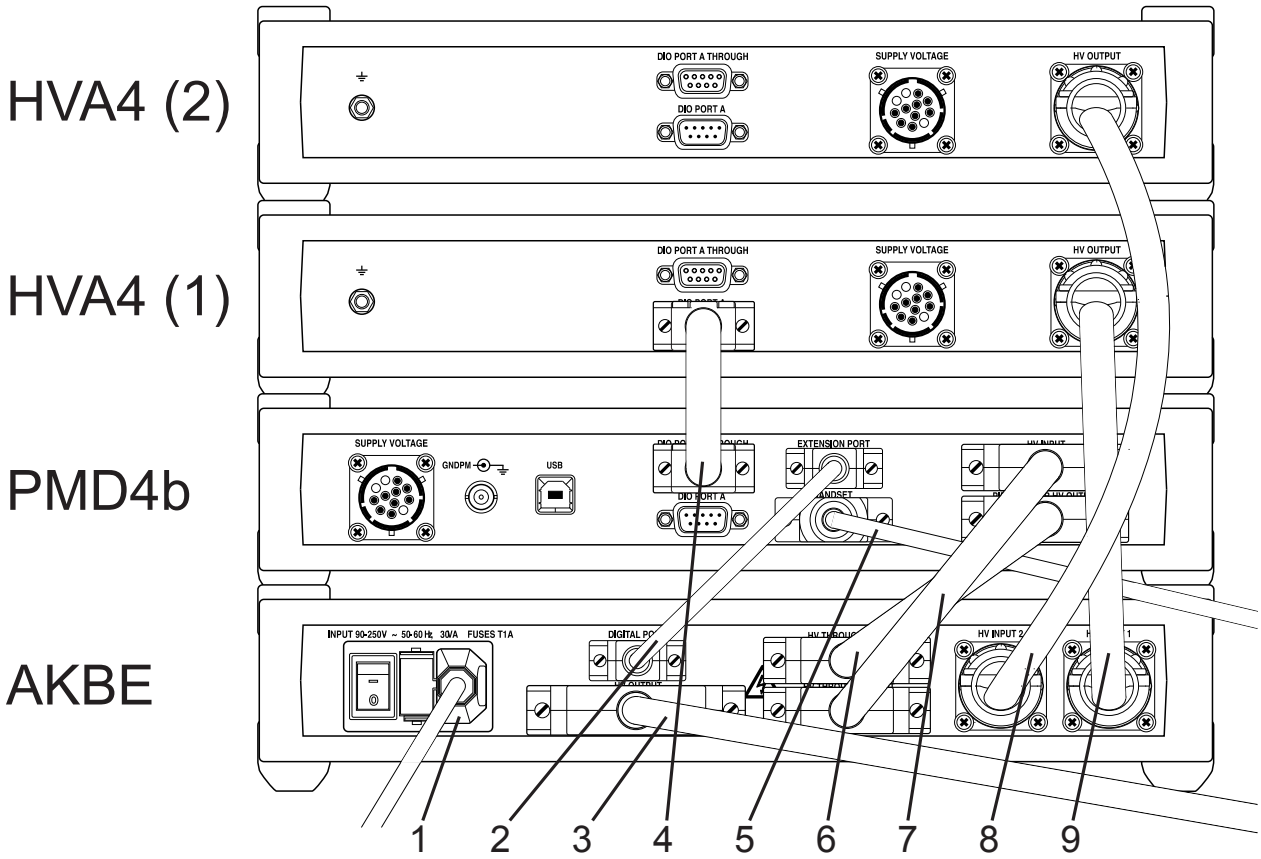


**Figure 43: Rear panel of a Nanonis SPM control system showing the connections needed for the operation of the AKBE with two HVA4s. 1: Power cord, 2: Digital port cable, 3: AKBE HV OUTPUT cable to microscope head, 4: DIO cable between PMD4b and HVA4, 5: PMD4b handset cable, 6: Cable for connection between AKBE and PMD4b (between HV THROUGH INPUT of the AKBE and Piezo motor HV output of the PMD4b), 7: Cable for connection between AKBE and PMD4b (between HV THROUGH OUTPUT of the AKBE and HV input of the PMD4b), 8: Cable for connection between AKBE and HVA4 number two, 9: Cable for connection between AKBE and HVA4 number one.**

# Software interface: PMD4b-AKBE Motor control module

The scope of this section is to explain the features of the software module necessary for the operation of the AKBE (*Motor control*) in combination with a Nanonis SPM Control System. For a more comprehensive explanation of the module as well as the complete control system software, please refer to the software online help.

The AKBE is controlled with a dedicated version of the Nanonis PMD4b *Motor control* module, which can be accessed under the *Modules* menu item. For all details about the PMD4 Motor control module, please refer to the PMD4 user manual, this section explains only features related exclusively to the AKBE.

The figures below show the PMD4b *Motor control* module used for controlling the AKBE. The configuration shown is for home-built microscopes using two HVA4s, the most complex configuration. For single-HVA4 configurations, some of the options are not available.

For settings used in combination with Createc or RHK microscopes, please refer to the following sections.

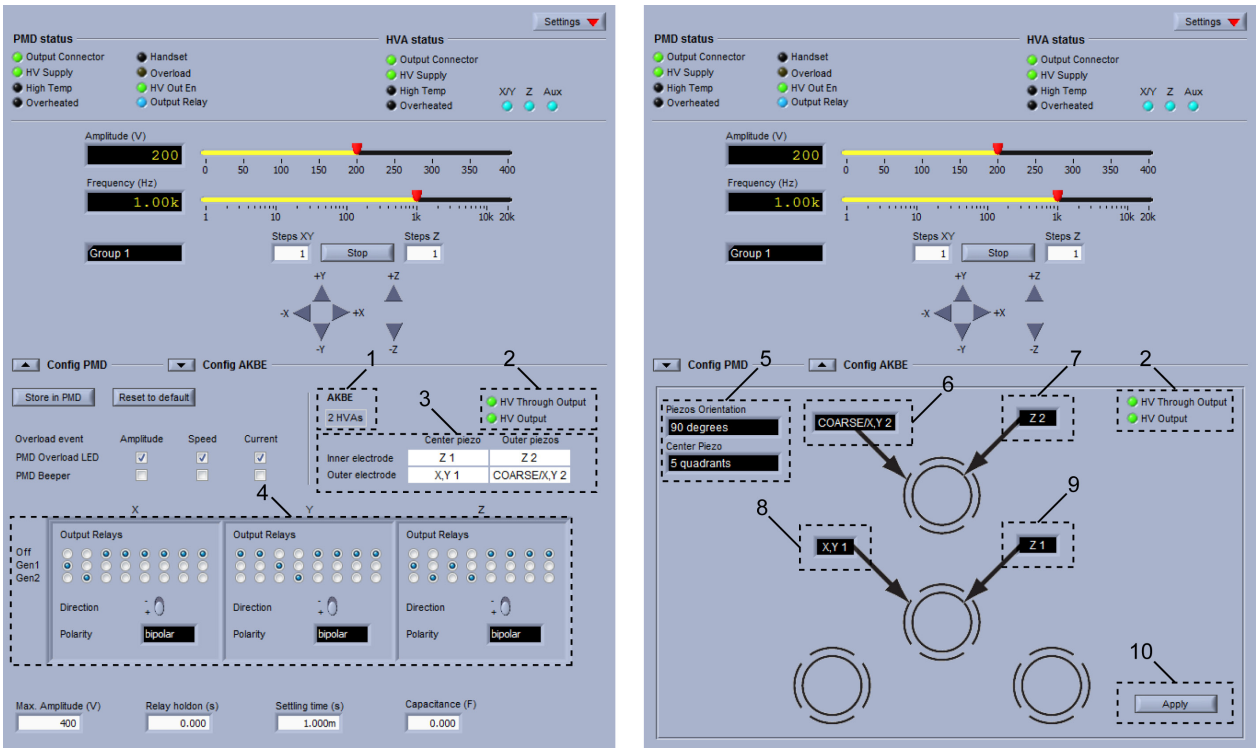


**Figure 44: AKBE version of the PMD4b motor control module. On the left is the configuration window of the PMD4b, on the right is the configuration window of the AKBE. The configuration shown is for homebuilt microscopes using two HVA4s.**

| | | |
|---|---|---|
| 1 | HVA4 configuration | This panel indicates whether if a configuration with one or two Nanonis HVA4s is being used. The configuration is set by license file and cannot be changed from the motor control module. |
| 2 | AKBE status LEDs | The *HV Through Output* LED indicates whether the *HV THROUGH OUTPUT* (8) is connected to the HV INPUT of the PMD4b. The HV Output LED indicates whether a plug is connected to the *HV OUTPUT* (7) of the AKBE. |
| 3 | AKBE configuration display | This panel shows the settings used in the piezo electrodes configuration of the AKBE configuration window. The settings cannot be changed from this panel, but need to be changed in the AKBE configuration window. |
| 4 | PMD4b channel configuration | Configures which output channel of the PMD4b is active when moving the corresponding axis, the kind of output waveform generated, and which waveform generator is routed to the PMD4b outputs. For details, please refer to the PMD4 user manual.<br>*Output Relays* defines which output channel(s) the high voltage waveform generated by the PMD4b should be applied.<br><br>**The configuration shown in the image above is the default configuration for the AKBE and should not be changed!**<br><br>*Direction* defines the waveform direction (forward/backward). "+" direction means that by pressing the +X, +Y, or +Z manual move buttons, the PMD4 generates a forward waveform.<br>*Polarity* defines if a bipolar or a unipolar (positive or negative) waveform is generated.<br>*Capacitance* is used to enter the capacitance of the piezo motor. The PMD4 will output a correct waveform only if the capacitance is set correctly in this input field. For Besocke-type microscope heads, the number inserted here is given by:<br><br>$(C_{1X} + C_{2X} + C_{3X} + C_{-1X} + C_{-2X} + C_{-3X} + C_{1Y} + C_{2Y} + C_{3Y} + C_{-1Y} + C_{-2Y} + C_{-3Y})/3$<br><br>The capacitance is measured with respect to the corresponding center electrode 1Z, 2Z or 3Z. |
| 5 | Piezo orientation and center piezo configuration | *Piezo orientation* defines the orientation of the piezo electrodes in the image of the AKBE configuration window. The setting does not affect the function of the AKBE or of the PMD4b.<br>*Center piezo configuration* defines the options available for the center piezo tube. The options are:<br>• *5 quadrants* (default): The center piezo has one inner electrode and four outer electrodes<br>• *4 quadrants*: The center piezo has one inner electrode and four outer electrodes, but the inner electrode is connected to GND<br>• *2 quadrants or stack*: The center piezo has one inner electrode and one outer electrode, or the center piezo tube is replaced by a piezo stack. In both cases only movement in Z-direction is possible<br>• *None*: No center piezo tube. Scanning is possible only with the outer piezo tubes.<br><br>Note that the selected configuration is applied only after pressing the *Apply* button |
| 6 | Outer piezos outer electrodes configuration | Configures the signal applied to the outer electrodes of the three outer piezos. The options available depend on the number of HVA4s available:<br><br>**1 HVA4:**<br>• *GND*: The outer electrodes are connected to GND. Coarse motion is disabled.<br>• *COARSE* (default): The outer piezo electrodes are used for coarse motion only.<br>• *COARSE/X,Y*: The outer piezo electrodes are used for coarse motion and for scanning. With this setting it is not possible to use the center piezo tube for scanning. Both *HV THROUGH INPUT* (9) and *HV THROUGH OUTPUT* (8) must be connected to the PMD4b, and a HVA4 must be connected to *HV INPUT 1* (11). This option is not available when a 4-quadrant geometry for the center piezo tube is selected.<br>**2 HVA4s:** |

| | | |
|---|---|---|
| | | • *GND*: The outer electrodes are connected to GND. Coarse motion is disabled.<br>• *COARSE/X,Y 2* (default): The outer piezo electrodes are used for coarse approach and for offset/scanning using the HVA4 connected to *HV INPUT 2* (10). Both *HV THROUGH INPUT* (9) and *HV THROUGH OUTPUT* (8) must be connected to the PMD4b, and a HVA4 must be connected to *HV INPUT 2* (10).<br>• *COARSE/X,Y 1*: The outer piezo electrodes are used for coarse approach and for offset/scanning using the HVA4 connected to *HV INPUT 1* (11). Both *HV THROUGH INPUT* (9) and *HV THROUGH OUTPUT* (8) must be connected to the PMD4b, and a HVA4 must be connected to *HV INPUT 1* (11). This option is not available when using a 4-quadrant geometry for the center piezo tube.<br><br>Note that the selected configuration is applied only after pressing the *Apply* button. |

| | | |
|---|---|---|
| 7 | Outer piezos inner electrode configuration | Configures the signal applied to the inner electrodes of the three outer piezos. The options available depend on the number of HVA4s available:<br><br>**1 HVA4:**<br>• *GND* (default): The inner electrodes are connected to GND. Offset and Z-feedback are not possible. When using a 4-quadrant geometry for the center piezo tube, this option is set automatically and cannot be changed.<br>• *AUX*: The inner electrodes are connected to the AUX channel of the HVA4. This setting is used for applying offsets in Z-direction, while the center electrode of the center piezo is used for Z-feedback. A HVA4 must be connected to *HV INPUT 1* (11). This option is not available when using a 4-quadrant geometry for the center piezo tube.<br>• *Z*: The inner electrodes are connected to the Z channel of the HVA4. This setting is used when the outer piezo tubes are used for Z-feedback. A HVA4 must be connected to *HV INPUT 1* (11). This option is not available when using a 4-quadrant geometry for the center piezo tube.<br>**2 HVA4s:**<br>• *GND*: The inner electrodes are connected to GND. Offset and Z-feedback are not possible.<br>• *Z 1*: The inner electrodes are connected to the Z channel of the HVA4 connected to *HV INPUT 1* (11). This setting is used when the outer piezo tubes are used for Z-feedback. A HVA4 must be connected to *HV INPUT 1* (11). This option is not available when using a 4-quadrant geometry for the center piezo tube.<br>• *Z 2:* (default): The inner electrodes are connected to the Z channel of the HVA4 connected to *HV INPUT 2* (10). This setting is used when the outer piezo tubes are used for offset in Z-direction. A HVA4 must be connected to *HV INPUT 2* (10). Operation with a 4-quadrant geometry center piezo tube is possible only if the center piezo is connected to the first HVA4 directly using a BNC adapter and not through the AKBE.<br>• *AUX 1*: The inner electrodes are connected to the AUX channel of the HVA4 connected to *HV INPUT 1* (11). This setting is used when the outer piezo tubes are used for offset in Z-direction. A HVA4 must be connected to *HV INPUT 1* (11). This option is not available when using a 4-quadrant geometry for the center piezo tube.<br>• *AUX 2*: The inner electrodes are connected to the AUX channel of the HVA4 connected to *HV INPUT 2* (10). This setting is used when the outer piezo tubes are used for offset in Z-direction. A HVA4 must be connected to *HV INPUT 2* (10). Operation with a 4-quadrant geometry center piezo tube is possible only if the center piezo is connected to the first HVA4 directly using a BNC adapter and not through the AKBE.<br><br>Note that the selected configuration is applied only after pressing the *Apply* button. |
| 8 | Center piezo outer electrodes configuration | Configures the signal applied to the outer electrodes of the center piezo tube. The options available depend on the number of HVA4s available:<br><br>**1 HVA4:**<br>• *GND*: The outer electrodes are connected to GND.<br>• *X,Y* (default): The outer electrodes are used for scanning. A HVA4 must be connected to *HV INPUT 1* (11). This option is not possible, if the three outer piezo electrodes are used for scanning.<br>**2 HVA4s:**<br>• *GND*: The outer electrodes are connected to GND.<br>• *X,Y 1* (default): The outer electrodes are used for scanning using the HVA4 connected to *HV INPUT 1* (11). A HVA4 must be connected to *HV INPUT 1* (11). This option is not possible, if the three outer piezo electrodes are used for scanning using the HVA4 connected to *HV INPUT 1* (11).<br>• *X,Y 2*: The outer electrodes are used for scanning using the HVA4 connected to HV INPUT 2 (10). A HVA4 must be connected to *HV INPUT 2* (10). This option is not possible, if the three outer piezo electrodes are used for scanning using the HVA4 connected to *HV INPUT 2* (10), or if a 4-quadrant geometry is |

| | | |
|---|---|---|
| | | used for the center piezo tube.<br><br>Note that the selected configuration is applied only after pressing the *Apply* button. |
| 9 | Center piezo inner electrode configuration | Configures the signal applied to the inner electrodes of the three outer piezos. The options available depend on the number of HVA4s available:<br><br>**1 HVA4:**<br>• *GND*: The inner electrode is connected to GND. Offset and Z-feedback are not possible. This option is not available when using a 4-quadrant geometry for the center piezo tube.<br>• *Z* (default): The inner electrode is connected to the Z channel of the HVA4. This setting is used when the center piezo tube is used for Z-feedback. A HVA4 must be connected to *HV INPUT 1* (11). This option is not available when using a 4-quadrant geometry for the center piezo tube.<br>• *AUX*: The inner electrode is connected to the AUX channel of the HVA4. This setting is used for applying offsets in Z-direction, while the center electrodes of the three outer piezo tubes are used for Z-feedback. A HVA4 must be connected to *HV INPUT 1* (11). This option is not available when using a 4-quadrant geometry for the center piezo tube.<br>**2 HVA4s:**<br>• *GND*: The inner electrodes are connected to GND. Offset and Z-feedback are not possible.<br>• *Z 1* (default): The inner electrode is connected to the Z channel of the HVA4 connected to *HV INPUT 1* (11). This setting is used when the center piezo tube is used for Z-feedback. A HVA4 must be connected to *HV INPUT 1* (11). This option is not available when using a 4-quadrant geometry for the center piezo tube.<br>• *Z 2*: The inner electrode is connected to the Z channel of the HVA4 connected to HV INPUT 2 (10). This setting is used when the center piezo tube is used for offset in Z-direction. A HVA4 must be connected to *HV INPUT 2* (10). This option is not available when using a 4-quadrant geometry for the center piezo tube.<br>• *AUX 1*: The inner electrode is connected to the AUX channel of the HVA4 connected to *HV INPUT 1* (11). This setting is used when the center piezo tube is used for offset in Z-direction. A HVA4 must be connected to *HV INPUT 1* (11). This option is not available when using a 4-quadrant geometry for the center piezo tube.<br>• *AUX 2*: The inner electrode is connected to the AUX channel of the HVA4 connected to *HV INPUT 2* (10). This setting is used when the center piezo tube is used for offset in Z-direction. A HVA4 must be connected to *HV INPUT 2* (11). This option is not available when using a 4-quadrant geometry for the center piezo tube.<br><br>Note that the selected configuration is applied only after pressing the *Apply* button. |
| 10 | *Apply* button | When pressing the *Apply* button, the options adjusted using the configuration tabs explained above are set in the AKBE hardware. If the *Apply* button is not pressed after a change of configuration, no change will occur, and the active configuration can be still seen in the *AKBE configuration* display. Please note that high voltage signals applied to the microscope might be re-routed instantaneously when pressing the *Apply* button, depending on the changes in the configuration. |

**Caution:** The relays of the AKBE can switch high voltage signals up to 400 V. However, in order to avoid a degradation of the contact quality and possible damage to the microscope head, it is recommended to set all voltages applied to the microscope head to 0 V before changing the head configuration.

# Hardware and software configuration for specific head types

This section describes how the AKBE is connected to and used with commercially available microscope heads. It will also describe how other instruments of a Nanonis SPM control system are connected to the AKBE and the microscope. Please make sure that you have read and understood the sections above before proceeding. All safety warnings are valid also for this chapter. For more information about the other instruments shown in the following sections, please refer to the corresponding user manuals.

**Warning:** The information provided in the following sections is believed to be correct as of the date of release, but is subject to change without notice. SPECS cannot be held responsible for inconsistent information resulting from changes in third-party hardware. SPECS cannot be held responsible for damage to third-party hardware resulting from the combination of SPECS instruments with third-party products.

## 4-Quadrant scan piezos: Operation with 5-to-4 quadrant adapter

The 5-to-4 quadrant adapter (see picture below on the left) is used to sum the Z scan signal into the X and Y signals, allowing the use of 4-quadrant piezo tubes with a Nanonis SPM controller. The adapter is an active device, and needs to be powered from an auxiliary power supply port of the Nanonis SC4 or OC4, as shown below on the right.

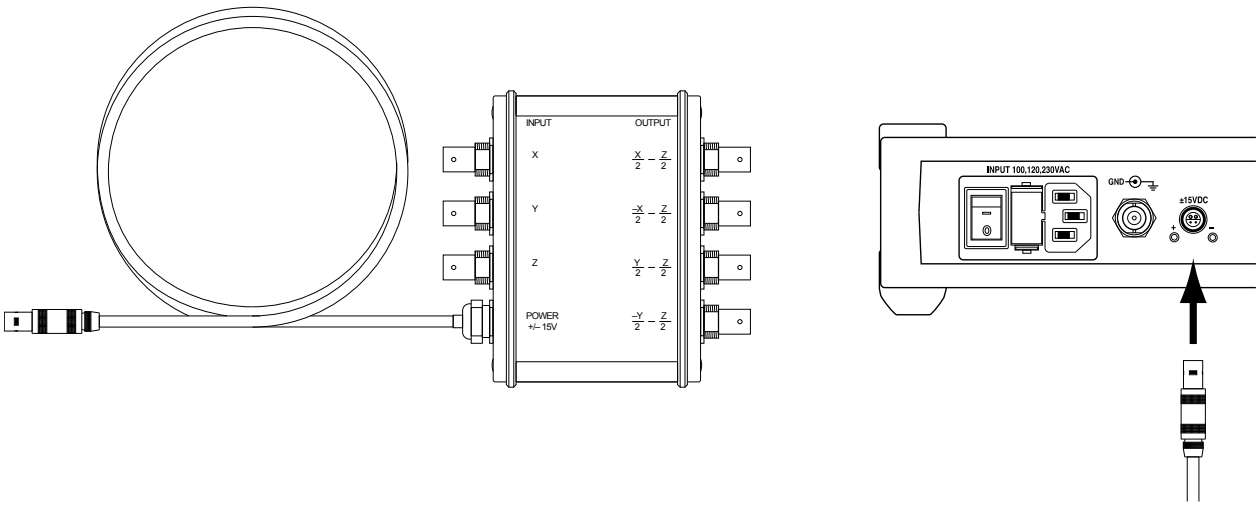


**Figure 45: Nanonis 5-4 quadrant adapter (left). The adapter is powered from the auxiliary power supply port of a Nanonis SC4 or OC4 (right).**

The 5-4 quadrant adapter is inserted between the Nanonis SC4 and the Nanonis HVA4. The SC4 outputs corresponding to the X, Y, and Z signals (AO5, AO6, and AO7) are connected to the X, Y, and Z inputs of the

adapter. The outputs of the adapter are connected to the X, Y, Z and AUX inputs of the HVA4. Since the Z signal is always summed with the same polarity, the inverting outputs of the HVA4 (-X and -Y) cannot be used. Therefore, the +X, +Y, Z, and AUX outputs must be used in combination with the 5-4 quadrant adapter. The following table summarizes the signal path from the outputs of the SC4 to the outputs of the HVA4.

| SC4 output (signal) | 5-4 quadrant adapter input | 5-4 quadrant adapter output | HVA4 input | HVA4 output (signal) |
|---|---|---|---|---|
| AO5 (X) | X | X/2 – Z/2 | X | +X (X/2 – Z/2) |
| AO6 (Y) | Y | -X/2 – Z/2 | Y | +Y (-X/2 – Z/2) |
| AO7 (Z) | Z | Y/2 – Z/2 | Z | Z (Y/2 – Z/2) |
| | | -Y/2 – Z/2 | AUX | AUX (-Y/2 – Z/2) |

**Table 10: Signal path from the outputs of the Nanonis SC4 to the output of the Nanonis HVA4 when using a 5-4 quadrant adapter.**

The following picture shows how the 5-4 quadrant adapter is connected between the Nanonis SC4 and HVA4.

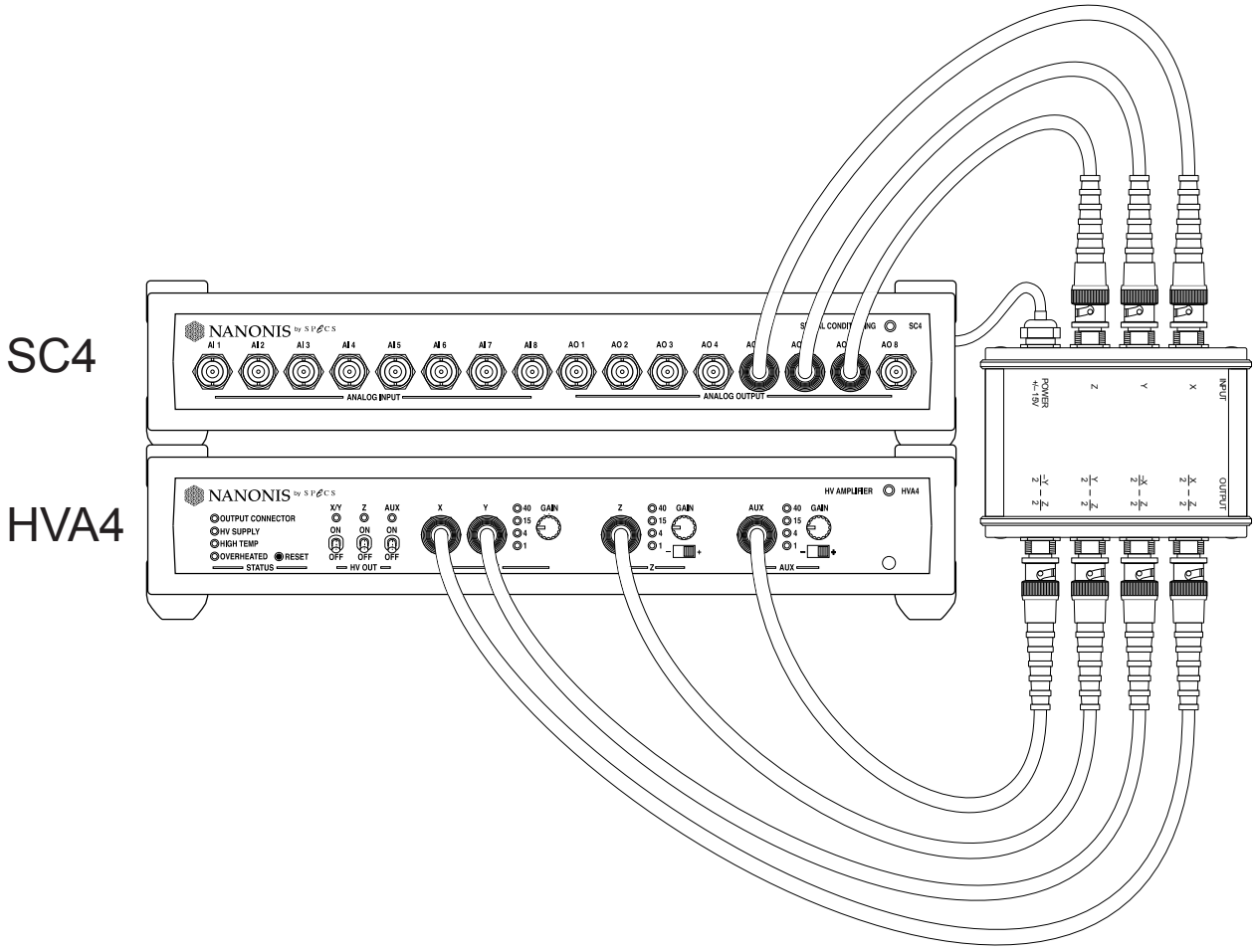


**Table 11:The 5-4 quadrant adapter is inserted in the signal path between Nanonis SC4 and HVA4.**

**Caution:** The polarity invert switch of the Z and AUX channels of the Nanonis HVA4 must be set to positive polarity (non-inverting) in order to obtain the correct signals for a 4-quadrant piezo tube.

# Createc STM microscopes

This section describes how the AKBE is connected to and configured for a Createc LT-STM without AFM capability. Please refer to the *Createc AFM microscopes* section for operation wth the combined Createc STM/AFM.

## Hardware configuration

The following pictures show the connections between the AKBE and other instruments of a Nanonis SPM control system. Note that the Nanonis RC4 and HVS4 and other cables than those delivered with or needed for the operation of the AKBE are not shown.

If a second HVA4 is used, the connections between the instruments are similar, with the exception of the second HVA4 connected to *HV INPUT 2* (10) of the AKBE. For the connection, please refer to the *Example: Nanonis SPM Control System* section above.

The temperature of the STM and of the Cryostat can be measured by applying a constant current to the temperature measurement diodes of the STM and of the Cryostat, and then by measuring the voltage drop. A constant current source is obtaind by applying a voltage to the 500 kΩ resistors provided with the AKBE for Createc microscopes. The resistors are connected to AO3(AO4) and to AI3(AI4). At the same time, AI3 and AI4 are connected to the STM temperature and Cryostat temperature BNC cables of the *HV output cable* provided with the AKBE, using a BNC T-piece. The connection is shown below.

The software module used for temperature measurement is explained in the next section.

### Connections on the front panel of the instruments

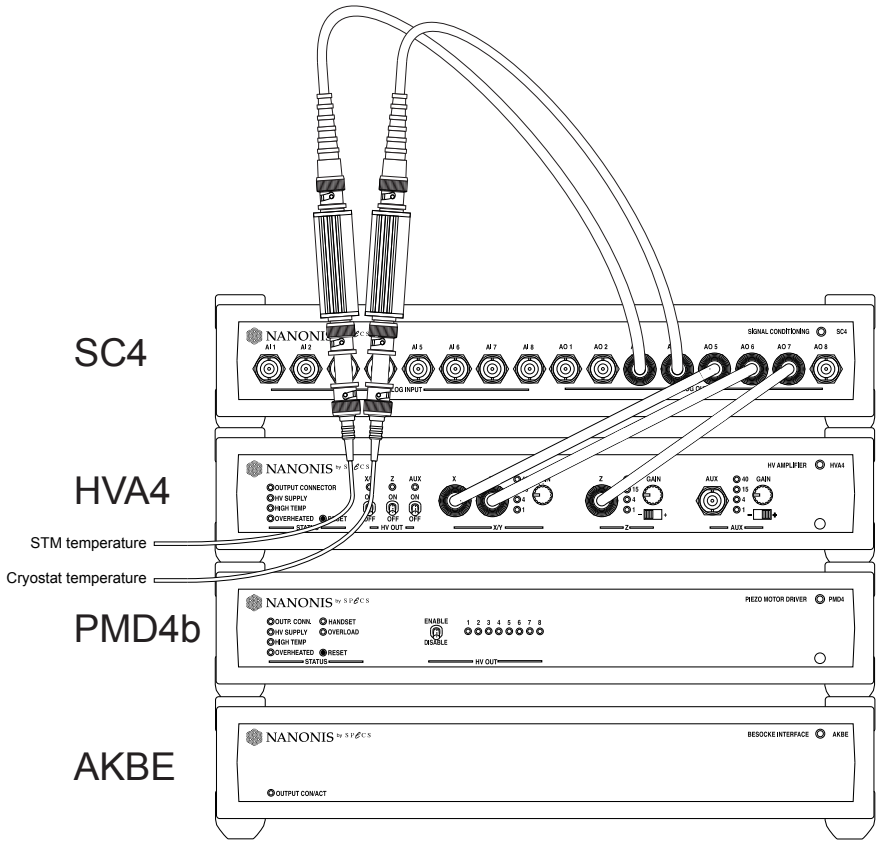


**Figure 46: Front panel connections of a Nanonis SPM control system with AKBE for a Createc STM system. Components not requiring a connection or not related to the AKBE are omitted. The two small boxes connected with a BNC T-piece to AI3 and AI4 of the Nanonis SC4 contain 500 kΩ resistors used as a current source for the temperature measurement diodes.**

### Connections on the backside of the instruments

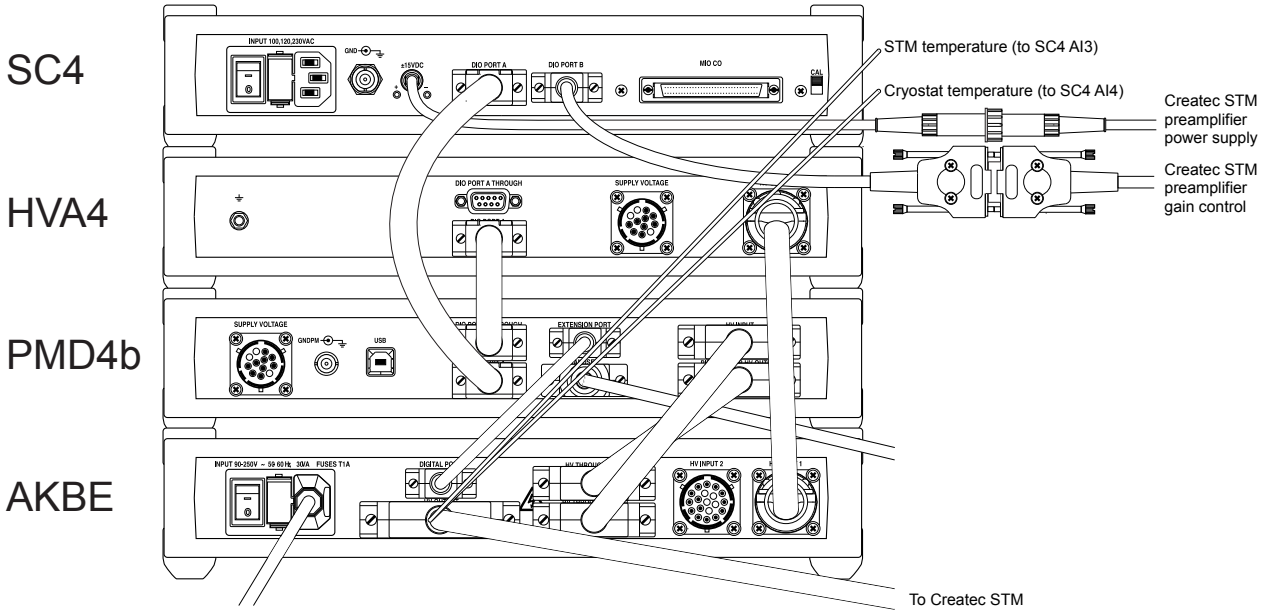


**Figure 47: Rear panel connections of a Nanonis SPM control system with AKBE for a Createc STM system. Components not requiring a connection to the microscope or not related to the AKBE are omitted.**

## Software configuration

The scope of this section is to explain the features of the software modules related to the operation of the AKBE in combination with a Nanonis SPM Control System and a Createc STM microscope. For a more comprehensive explanation of the modules as well as the complete control system software, please refer to the software online help. The software modules related to the operation of Createc microscopes with the AKBE are the motor control module and the temperature measurement module.

### Motor control

The *Motor Control Module* for the AKBE in combination with Createc STM microscopes and its configuration options are identical to the *Motor Control Module* for home-built microscopes discussed above, with the exception of the *Piezos orientation* and *Center Piezo* configuration: These are set by default to 90 degrees and 5 quadrants, and cannot be changed. For a general overview of the module, please refer to the *PMD4b-AKBE Motor Control Module* section above.

### Temperature measurement

The temperature measurement modules can be reached under *Modules/Temperature Module 1* and *Modules/Temperature Module 2*. They are identical, therefore the explanations listed below for *Temperature Module 1* are valid also for *Temperature Module 2*. The figure below shows the software module, its functions are explained in the following table.

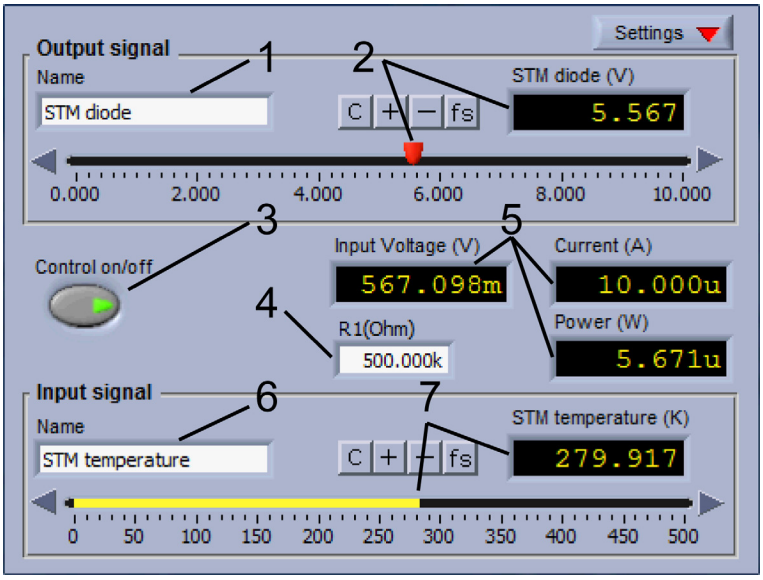


**Figure 48: Temperature measurement module for Createc microscopes.**

| | | |
|---|---|---|
| 1 | Output signal name | User-defined name for the output which acts as a current source for the temperature measurement diodes (AO3 for *Temperature Module 1* and AO4 for *Temperature Module 2*). "STM diode" has been used in the above example. The name set here will be used as a signal name throughout the Nanonis SPM Control System software. |
| 2 | Output voltage | When control is off, the voltage for the current source can be adjusted with the slider. When control is on, the voltage is automatically calculated to supply 10 µA to the temperature measurement diode. |
| 3 | Control on/off | When on, the output voltage is adjusted in order to supply 10 µA to the diode. The adjustment is done once and does not need to be repeated as long as the Nanonis SPM Control System software is running. |
| 4 | Series resistor (R1) | Value of the resistor used as a current source for the temperature measurement diode. The value is user adjustable, and set to a default resistance of 500 kΩ, corresponding to the resistance of the resistors supplied with the AKBE. |
| 5 | Input values | Display the measured voltage [V] over the temperature measurement diode, the calculated current [A] used to bias the diode, and the calculated dissipated power [W] in the diode. |
| 6 | Input signal name | User-defined name for the input used for the temperature measurement (AI3 for *Temperature Module 1* and AI4 for *Temperature Module 2*). "STM temperature" has been used in the above example. The name set here will be used as a signal name throughout the Nanonis SPM Control System software. |
| 7 | Temperature | Displays the calculated temperature based on a predefined look-up table with temperature calibration values of the temperature measurement diode. |

In order to set-up the temperature measurement, first make sure that the value for the series resistor corresponds to the actual resistor used. The default value is 500 kΩ, which corresponds to the resistance of the supplied resistors. If the resistors are replaced (e.g. if a larger or smaller bias current is required), the new value must be inserted in the Series Resistor (R1) tab. Then press the on/off button once. The temperature will then be displayed in the temperature display.

# Createc AFM microscopes

This section describes how the AKBE is connected to and configured for a Createc LT-STM/AFM. Please refer to the *Createc STM microscopes* section for operation wth the STM-only microscope.

## Hardware configuration

The following pictures show the connections between the AKBE and other instruments of a Nanonis SPM control system. Note that the Nanonis RC4 and HVS4 and other cables than those delivered with or needed for the operation of the AKBE are not shown.

The temperature of the AFM and of the Cryostat can be measured by applying a constant current to the temperature measurement diodes of the AFM and of the Cryostat, and then by measuring the voltage drop. A constant current source is obtaind by applying a voltage to the 500 kΩ resistors provided with the AKBE for Createc microscopes. The resistors are connected to AO3(AO4) and to AI3(AI4). At the same time, AI3 and AI4 are connected to the AFM temperature and Cryostat temperature BNC cables of the *HV output cable* provided with the AKBE, using a BNC T-piece. The connection is shown below. The software module used for temperature measurement is explained in the previous section.

The probe excitation signal is applied directly to the microscope using a BNC cable connected to the OUTPUT BNC of the Nanonis OC4.

### Connections on the front panel of the instruments

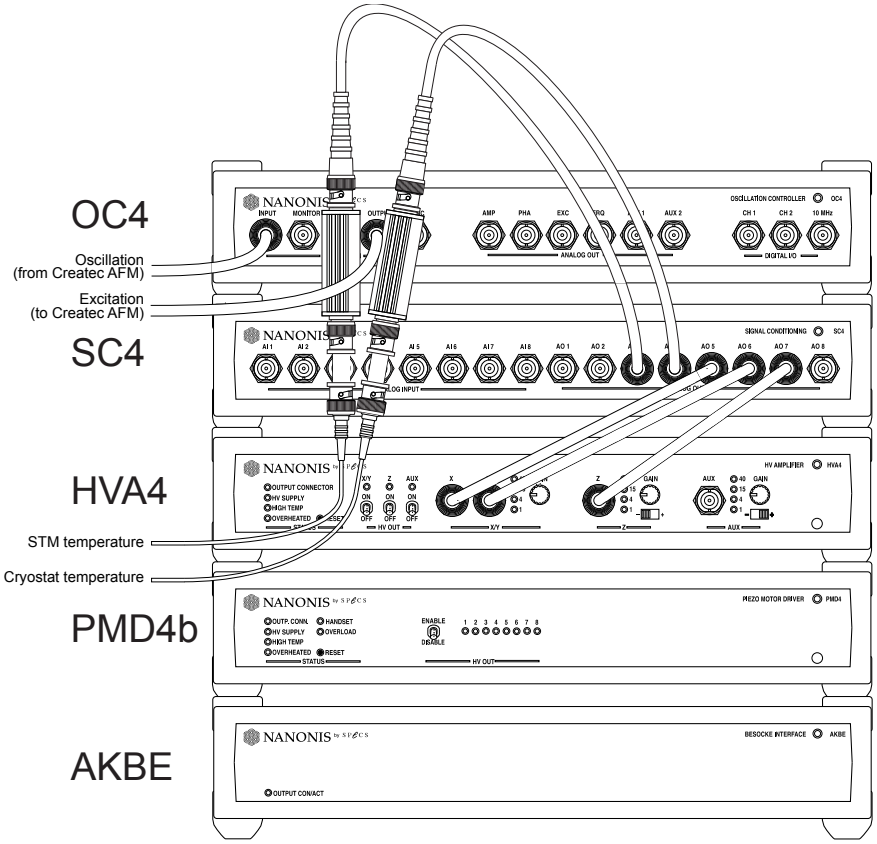


**Figure 49: Front panel connections of a Nanonis SPM control system with AKBE for a Createc AFM system. Components not requiring a connection or not related to the AKBE are omitted. The two small boxes connected with a BNC T-piece to AI3 and AI4 of the Nanonis SC4 contain 500 kΩ resistors used as a current source for the temperature measurement diodes.**

### Connections on the backside of the instruments

Connections at the backside of the instruments are identical to those of the STM system, with the addition of the Nanonis OC4.

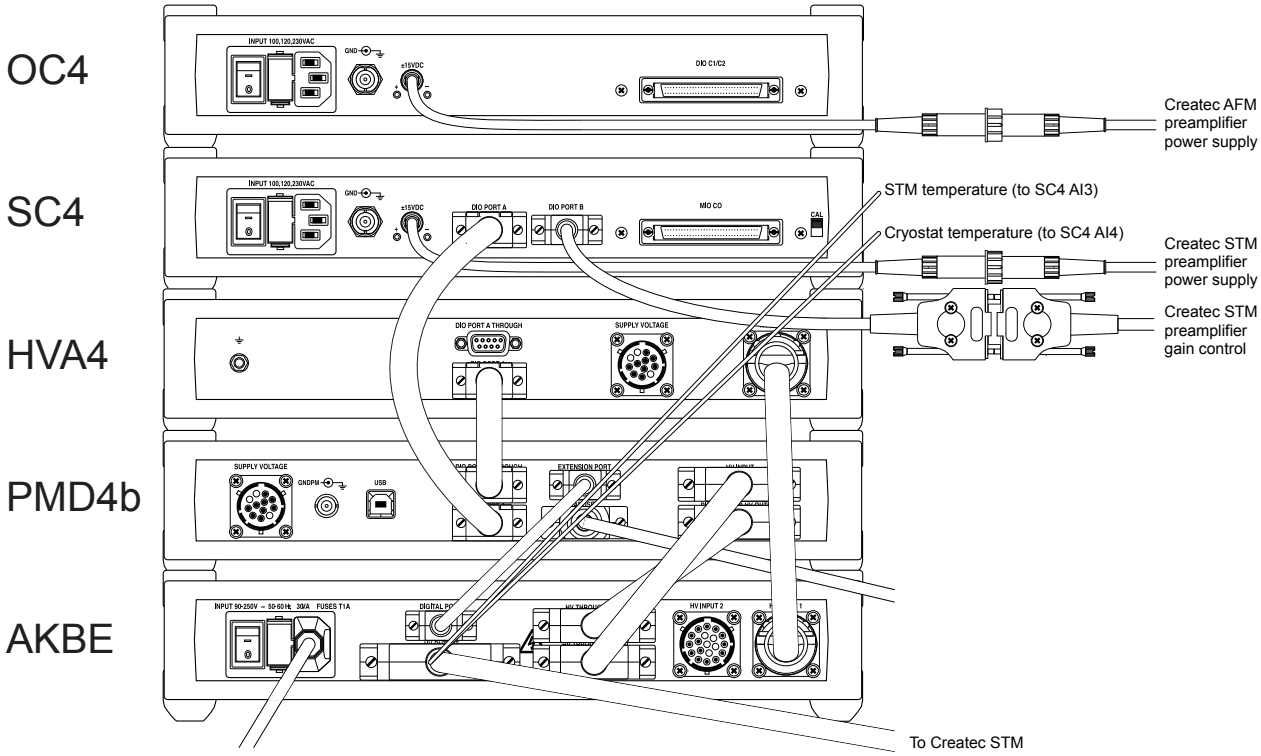


**Figure 50: Rear panel connections of a Nanonis SPM control system with AKBE for a Createc AFM system. Components not requiring a connection to the microscope or not related to the AKBE are omitted.**

## Software configuration

The scope of this section is to explain the features of the software modules related to the operation of the AKBE in combination with a Nanonis SPM Control System and a Createc AFM microscope. For a more comprehensive explanation of the modules as well as the complete control system software, please refer to the software online help. The software modules related to the operation of Createc microscopes with the AKBE are the motor control module and the temperature measurement module.

### Motor control

The *Motor Control Module* for the AKBE in combination with Createc AFM microscopes and its configuration options are slightly different from those of the STM microscopes, since the center piezo tube is used solely for the excitation of the AFM sensor. Note that only a single HVA4 can be used with Createc AFM microscopes.

The figure below shows the AKBE configuration window of the PMD4b *Motor control* module used for controlling the AKBE in combination with Createc AFM microscopes. Only options specific to these microscopes are discussed. For a general overview of the module, please refer to the *PMD4b-AKBE Motor Control Module* section above.

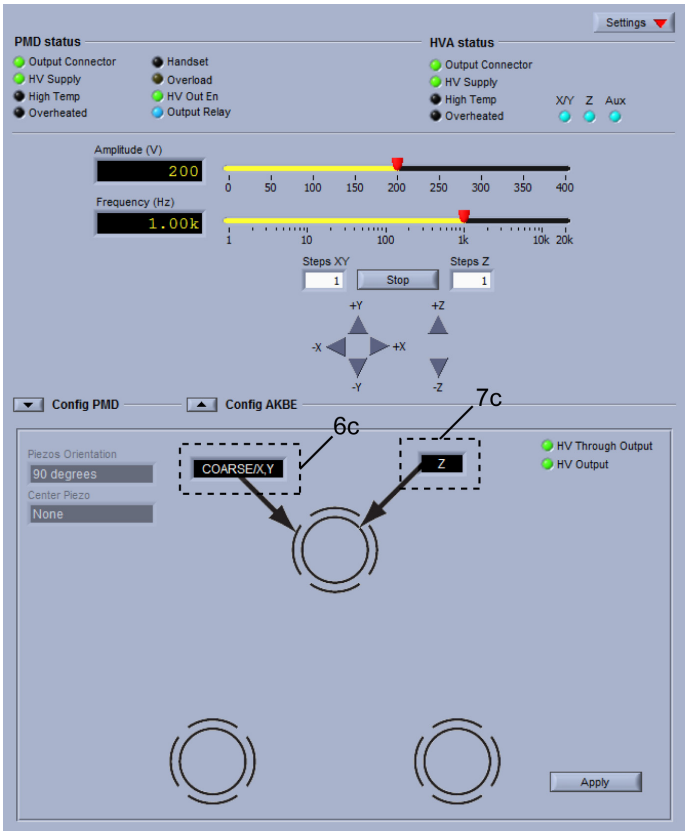


**Figure 51: AKBE version of the PMD4b motor control module (AKBE configuration window) for Createc AFM microscopes. Only single-HVA4 is possible, and the center piezo tube cannot be used for offset or scanning.**

| | | |
|---|---|---|
| 6c | Outer piezos outer electrodes configuration | Configures the signal applied to the outer electrodes of the three outer piezos:<br>• *GND*: The outer electrodes are connected to GND. Coarse motion and scanning are disabled.<br>• *COARSE/X,Y* (default): The outer piezo electrodes are used for coarse motion and for scanning. Both *HV THROUGH INPUT* (9) and *HV THROUGH OUTPUT* (8) must be connected to the PMD4b, and a HVA4 must be connected to *HV INPUT 1* (11).<br>Note that the selected configuration is applied only after pressing the *Apply* button. |
| 7c | Outer piezos inner electrode configuration | Configures the signal applied to the inner electrodes of the three outer piezos:<br>• *GND*: The inner electrodes are connected to GND. Offset and Z-feedback are not possible.<br>• *Z* (default): The inner electrodes are connected to the Z channel of the HVA4 and are used for Z-feedback. A HVA4 must be connected to *HV INPUT 1* (11).<br>• *AUX*: The inner electrodes are connected to the AUX channel of the HVA4. This setting is used if the HVA4 Z channel is not used for Z-feedback. A HVA4 must be connected to *HV INPUT 1* (11).<br>Note that the selected configuration is applied only after pressing the *Apply* button. |

# RHK STM microscopes

This section describes how the AKBE is connected to and configured for a RHK STM. RHK AFM microscopes cannot be operated with the AKBE.

## Hardware configuration

The following pictures show the connections between the AKBE and other instruments of a Nanonis SPM control system. Note that the Nanonis RC4 and HVS4 and other cables than those delivered with or needed for the operation of the AKBE are not shown.

The center piezo tube of the RHK STM is connected directly to the *Nanonis HVA4* over a *HVA4-BNC adapter*. Only the signals for the three outer piezos are routed through the AKBE. Therefore, the cable connecting the *HV THROUGH OUTPUT* (8) of the AKBE with the *HV INPUT* of the PMD4b, as well as the *HV INPUT cable* of the AKBE are not required.

The center piezo tube is operated with only 4 quadrants, therefore the +X, +Y, Z, and AUX BNCs of the *HVA4-BNC adapter* should be used, and a *5-to-4 quadrant adapter* should be used in front of the HVA4.

It is not possible to use the three outer piezos for applying offsets in X, Y, or Z direction using a single HVA4. If offsets using the three outer piezos should be required, a second Nanonis HVA4 (and also HVS4) needs to be connected to *HV INPUT 2* (10) of the AKBE.

### Connections on the front panel of the instruments

There are no microscope-specific connections on the front panel of the instruments. The tunneling current signal is connected to AI1 of the Nanonis SC4 using the adapter cable for the RHK tunneling current preamplifier provided with the AKBE. For the connections between Nanonis SC4 and HVA4, please refer to the *HVA4 user manual*, or the *5-to-4 quadrant adapter* section above.

### Connections on the backside of the instruments (1 HVA4)

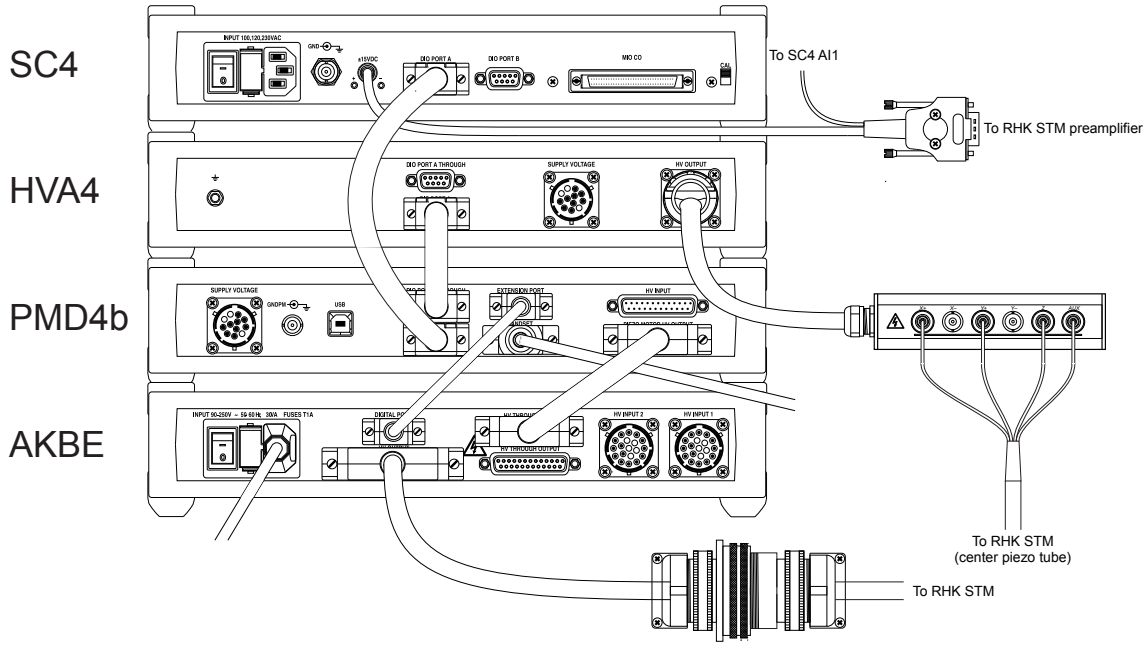


**Figure 52: Rear panel connections of a Nanonis SPM control system with AKBE for a RHK STM system. The center piezo tube is connected directly to the HVA4 with a HVA4-BNC adapter, and is wired for 4-quadrant operation, with only the +X, +Y, Z, and AUX BNCs of the *HVA4-BNC adapter* connected. Components not requiring a connection or not related to the AKBE are omitted.**

### Connections on the backside of the instruments (2 HVA4s)

This configuration differs slightly from the previous one, since the second HVA4 requires the AKBE to be connected to the PMD4b also over its *HV THROUGH OUTPUT* (8) connector. Also, the second HVA4 is connected to *HV INPUT 2* (10) of the AKBE, not *HV INPUT 1* (11). The configuration is displayed below.

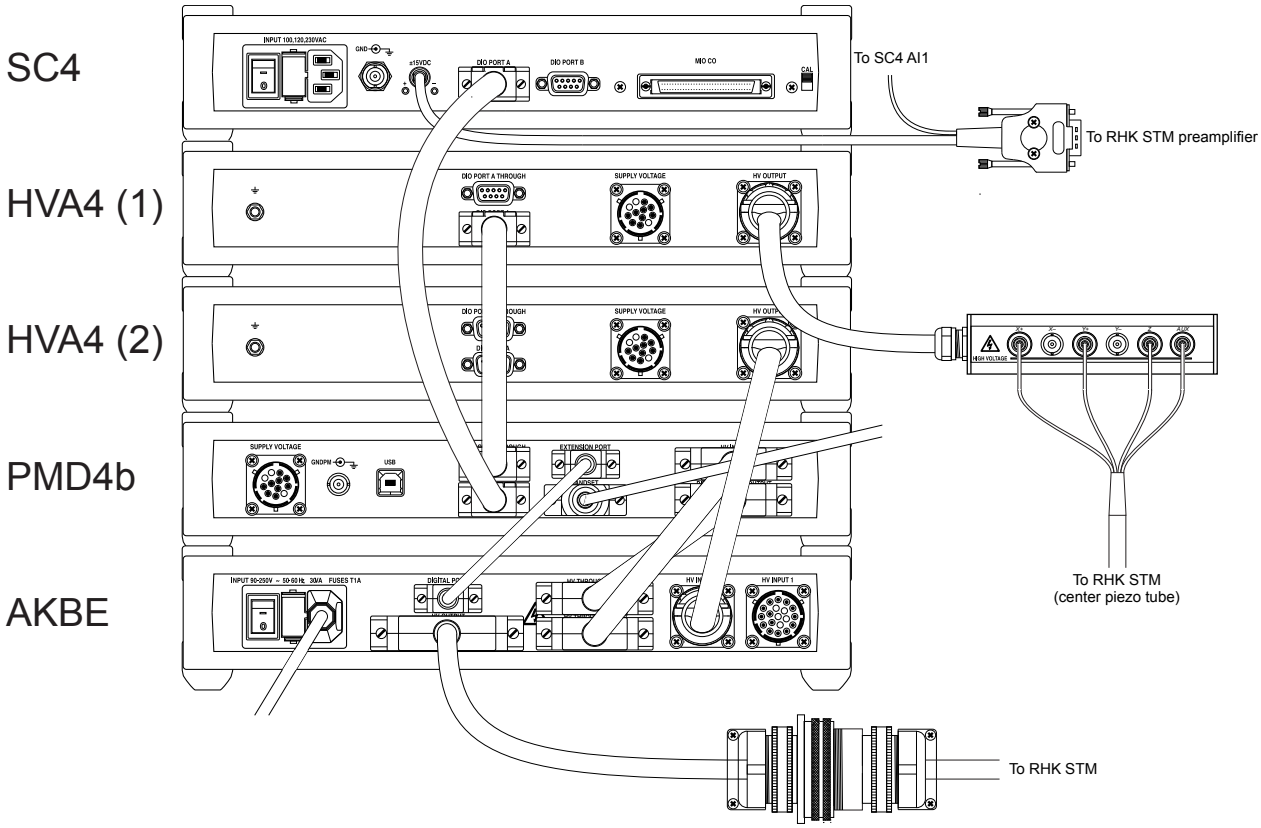


**Figure 53: Rear panel connections of a Nanonis SPM control system with two HVA4 high voltage amplifiers and AKBE for a RHK STM system. The center piezo tube is connected directly to the HVA4 with a HVA4-BNC adapter, and is wired for 4-quadrant operation, with only the +X, +Y, Z, and AUX BNCs of the *HVA4-BNC adapter* connected. Components not requiring a connection or not related to the AKBE are omitted**

## Software configuration

The scope of this section is to explain the features of the software modules related to the operation of the AKBE in combination with a Nanonis SPM Control System and a RHK STM microscope. For a more comprehensive explanation of the modules as well as the complete control system software, please refer to the software online help.

### Motor control

The *Motor Control Module* for the AKBE in combination with RHK STM microscopes and its configuration options are slightly different from those of home-built microscopes, since the center piezo tube is connected directly to the HVA4.

The figure below shows the AKBE configuration window of the PMD4b *Motor control* module used for controlling the AKBE in combination with RHK STM microscopes using 2 HVA4s. Single-HVA4 systems will lack some of the options. Only options specific to RHK STM microscopes microscopes are discussed. For a general overview of the module, please refer to the *PMD4b-AKBE Motor Control Module* section above.

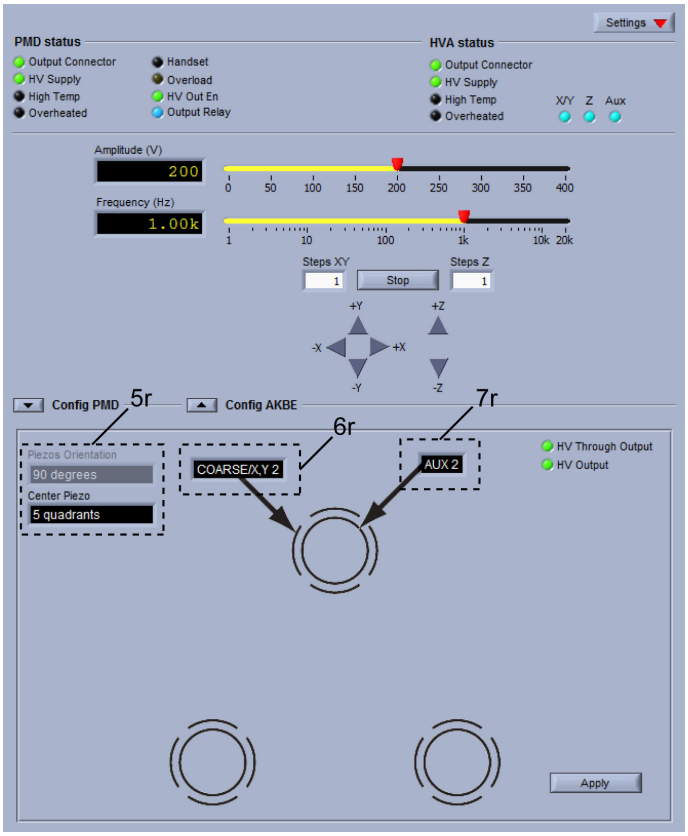


**Figure 54: AKBE version of the PMD4b motor control module (AKBE configuration window) for RHK STM microscopes. The center piezo tube is connected directly to the HVA4, therefore it cannot be configured over the Motor Control Module**

| | | |
|---|---|---|
| 5r | Piezo orientation and center piezo configuration | *Center piezo configuration* defines the options available for the center piezo tube. Since the center piezo tube is connected directly to the HVA4, the setting has no influence on any option of the AKBE, and is just a reminder for the user. |
| 6r | Outer piezos outer electrodes configuration | Configures the signal applied to the outer electrodes of the three outer piezos. The options available depend on the number of HVA4s available:<br><br>**1 HVA4:**<br>• *GND*: The outer electrodes are connected to GND. Coarse motion is disabled.<br>• *COARSE* (default): The outer piezo electrodes are used for coarse motion only.<br>**2 HVA4s:**<br>• *GND*: The outer electrodes are connected to GND. Coarse motion is disabled.<br>• *COARSE/X,Y 2* (default): The outer piezo electrodes are used for coarse approach and for offset using the HVA4 connected to *HV INPUT 2* (10). Both *HV THROUGH INPUT* (9) and *HV THROUGH OUTPUT* (8) must be connected to the PMD4b, and a HVA4 must be connected to *HV INPUT 2* (10).<br><br>Note that the selected configuration is applied only after pressing the *Apply* button. |
| 7r | Outer piezos inner electrode configuration | Configures the signal applied to the inner electrodes of the three outer piezos. Different options are only available with two HVA4s:<br><br>**2 HVA4s:**<br>• *GND*: The inner electrodes are connected to GND. Offset is not possible.<br>• *Z 2:* (default): The inner electrodes are connected to the Z channel of the HVA4 connected to *HV INPUT 2* (10). This setting is used when the outer piezo tubes are used for offset in Z-direction. A HVA4 must be connected to *HV INPUT 2* (10).<br>• *AUX 2*: The inner electrodes are connected to the AUX channel of the HVA4 connected to *HV INPUT 2* (10). This setting is used when the outer piezo tubes are used for offset in Z-direction. A HVA4 must be connected to *HV INPUT 2* (11).<br><br>Note that the selected configuration is applied only after pressing the *Apply* button. |

# Advanced instrument configuration

The AKBE is delivered preconfigured to fit the coarse motion logic of the microscope head it is intended to be used with. The logic can be modified by changing the position of the jumpers of the T/R switches on the AKBE main circuit board. This should be done only if absolutely required.

**Caution:** A modification of the coarse motion logic should be done only if absolutely required. Contact SPECS before starting the modification if there is any doubt about how the modification should be done.

Before proceeding with a modification of the jumper positions, please make sure that:

- *HV OUTPUT* (7) is disconnected from the microscope.
- *HV INPUT 1* (11) and *HV INPUT 2* (10) of the AKBE is disconnected from the HVA4(s).
- *HV THROUGH OUTPUT* (8), *HV THROUGH INPUT* (9), and the *DIGITAL PORT* (6) are disconnected from the PMD4b.
- The AKBE is disconnected from the mains.

Once the above conditions are fulfilled, put the AKBE on a stable and sufficiently large surface. Remove the four plastic caps covering the screws which hold the top cover of the instrument as shown in the figure below, and remove the screws by turning them CCW using a 3 mm hex screwdriver. Make sure not to lose the lock washers placed below the screws. The top cower can now be carefully lifted, and should be put on the side of the instrument. Note that there is a grounding wire connecting the top cover with the rest of the instrument, and therefore the top cover cannot be lifted by more than 10 cm and then removed completely.

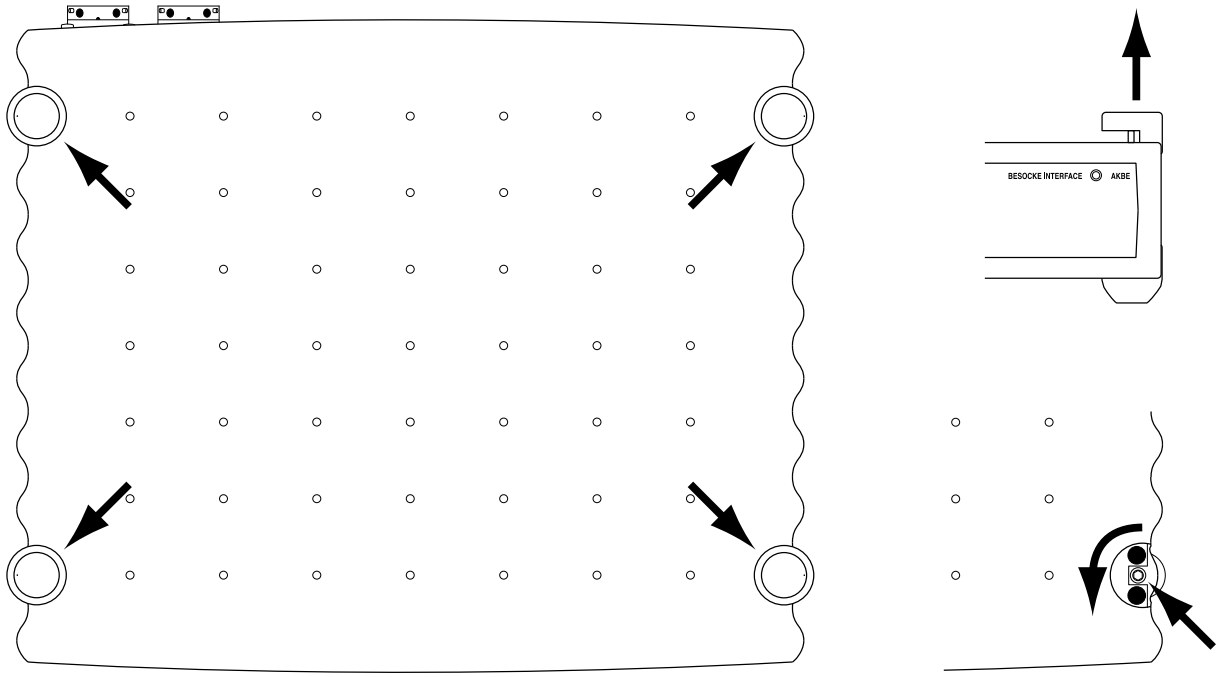


**Figure 55: Removing the top cover of the AKBE: First remove the four plastic caps covering the screws by lifting them, then remove the four screws by turning CCW with a 3 mm hex screwdriver.**

**Warning:** Failing to configure the T/R switches correctly will lead to uncontrolled coarse motion or even damage of the microscope head. SPECS denies any liability in case of damage to the microscope due to a wrong setting of the T/R switches..

**Warning:** Lethal voltages are present inside the AKBE. If a change of the jumper positions is required, make sure that the AKBE is disconnected from the mains, from the PMD4b, from the HVA4(s), and from the microscope.

There are twelve T/R switches inside the AKBE, which are located on the main circuit board at the positions indicated below within the dashed area. The outer piezo electrode addressed by each switch is also denoted in the image.

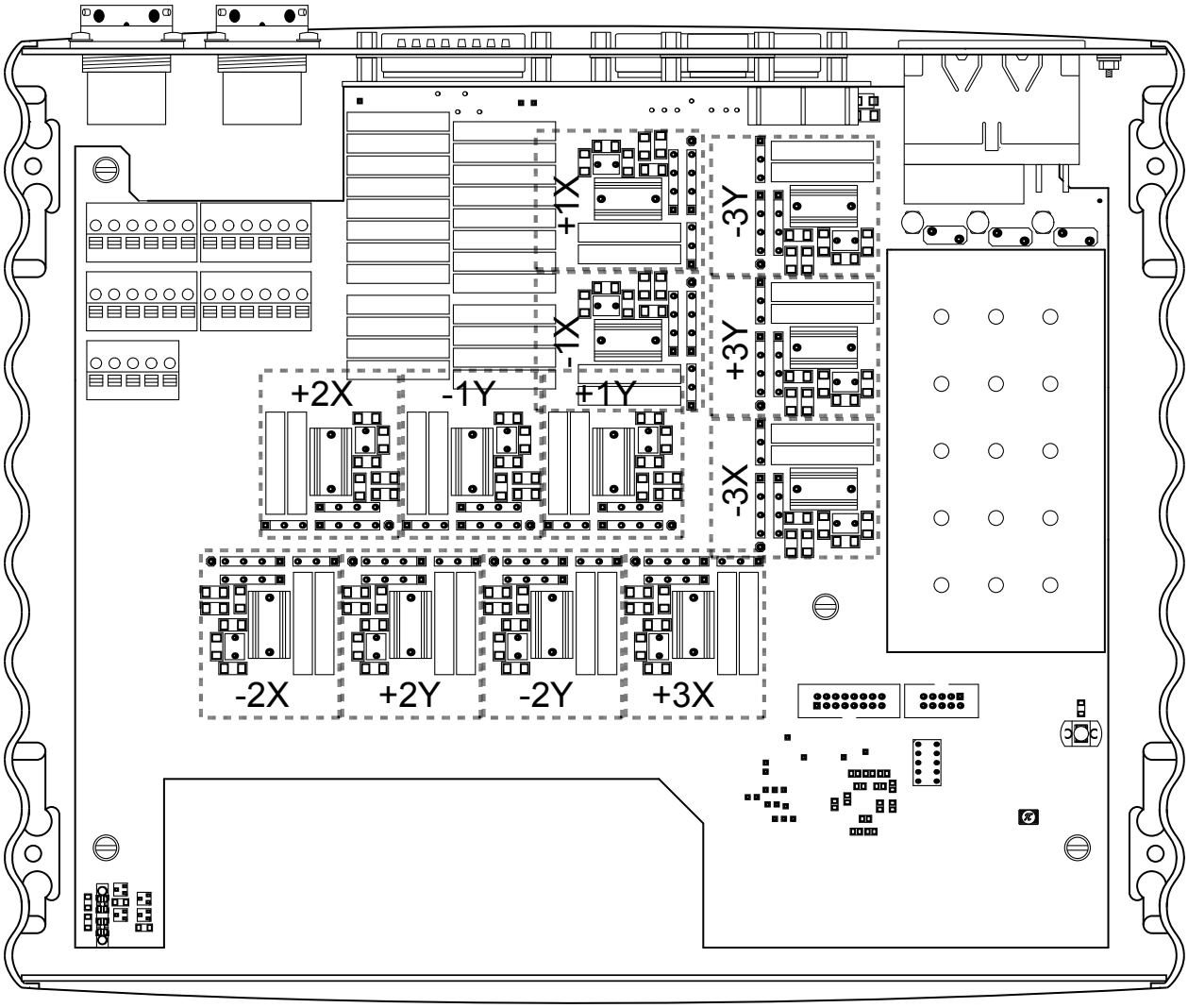


**Figure 56: Internal view of the AKBE showing the location of the T/R switches on the main circuit board (within the dashed areas). The corresponding outer piezo electrodes are indicated in the figure.**

# T/R switches configuration

The jumpers of each T/R switch are used for selecting how an electrode of the three outer piezos will be driven when the microscope head is set to rotation. The electrode can be driven with a signal with same polarity as during translational motion, with a signal of opposite polarity, or can be connected to GND. Additionally, the signal can be attenuated, if the optional signal attenuators are installed. The following table summarizes the possible options.

| Definition | Signal during translation | Signal during rotation |
|---|---|---|
| Same polarity | +C | +C |
| Opposite polarity | +C | -C |
| GND | +C | GND |
| Same polarity attenuated | +C | +aC ($0 \leq a \leq 1$) |
| Opposite polarity attenuated | +C | -aC ($0 \leq a \leq 1$) |

The following picture shows the corresponding jumper settings for the T/R switches. The jumpers are drawn as solid black rectangles. The simplified representation at the bottom of the picture will be used for the following section. For a schematic of the switches, please refer to the Block diagram.

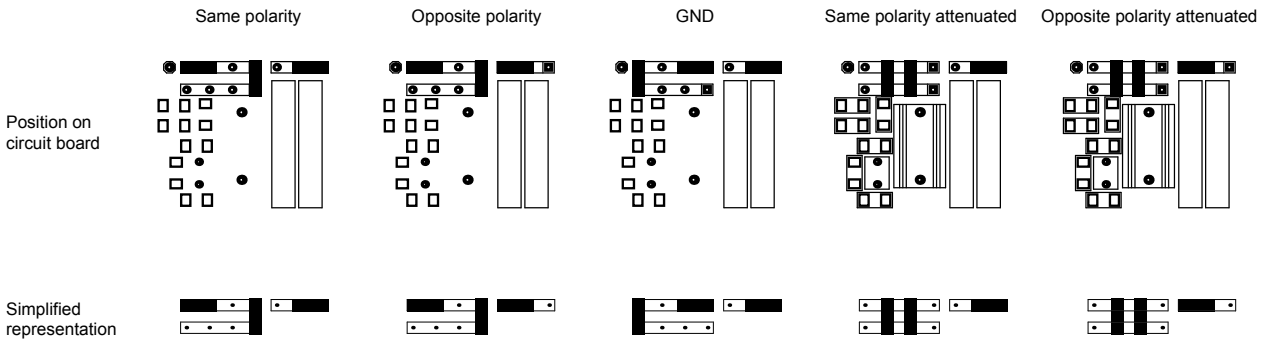


**Figure 57: Jumper settings of the T/R switches of the AKBE. Please refer to the text for details. The simplified representation is used in the following section.**

# Standard configurations

The standard configurations for the jumper settings of the T/R switches described below are valid for the configurations shown in the *Coarse motion logic* section at the beginning of this manual. In order to make the jumper setting easier to recognize, the simplified representation of the previous picture will be used.

## 0° and 90° electrode orientation

The following table outlines the signals used during coarse motion for 0° and 90° electrode orientation (see the Head compatibility and head geometry conventions section for details). This is also the default configuration for Createc and RHK microscopes. The signals are for positive direction, in the case of negative direction the sign has to be inverted. The figure below shows the corresponding jumper configuration.

| Electrode | +X motion | +Y motion | +Z motion |
|---|---|---|---|
| +1X | +C | GND | +C |
| -1X | -C | GND | -C |
| +1Y | GND | +C | GND |
| -1Y | GND | -C | GND |
| +2X | +C | GND | -C |
| -2X | -C | GND | GND |
| +2Y | GND | +C | +C |
| -2Y | GND | -C | -C |
| +3X | +C | GND | -C |
| -3X | -C | GND | GND |
| +3Y | GND | +C | -C |
| -3Y | GND | -C | +C |

**Table 12: Coarse motion signals applied on the outer piezo electrodes during coarse motion for 0° and 90° electrode orientation.**

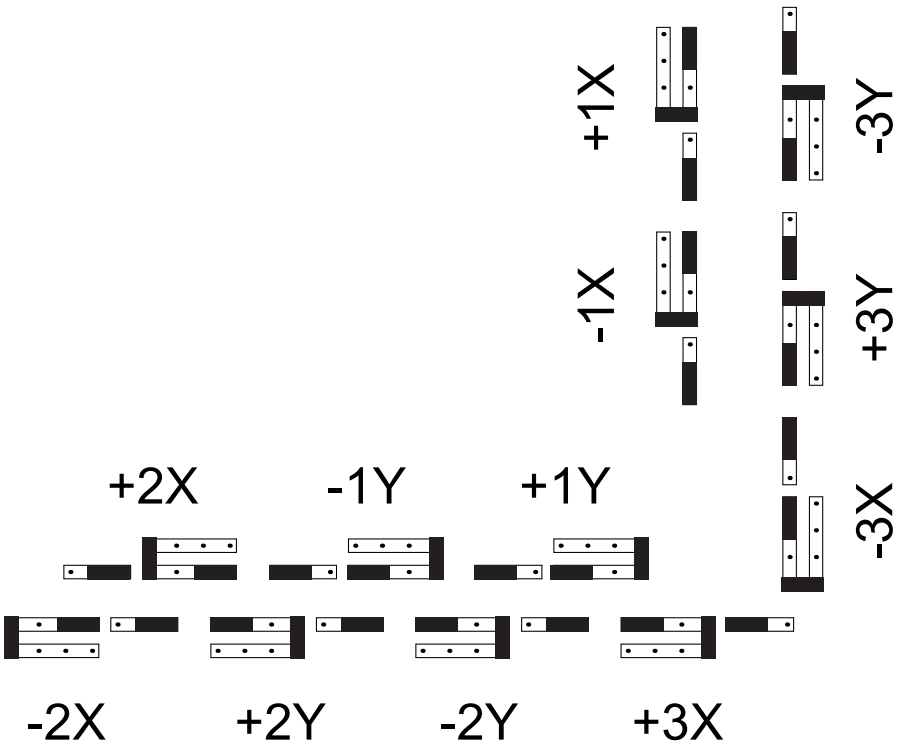


**Figure 58: Jumper configuration for rotational motion of a head with 0° and 90° electrode orientation. The arrangement of the jumpers corresponds to the arrangement on the main circuit board.**

## 45° electrode orientation

The following table outlines the signals used during coarse motion for 45° electrode orientation (see the head compatibility and head geometry conventions section for details). The signals are for positive direction, in the case of negative direction the sign has to be inverted. The figure below shows the corresponding jumper configuration.

| Electrode | +X motion | +Y motion | +Z motion |
|---|---|---|---|
| +1X | +C | GND | +C |
| -1X | -C | GND | -C |
| +1Y | GND | +C | -C |
| -1Y | GND | -C | +C |
| +2X | +C | GND | GND |
| -2X | -C | GND | GND |
| +2Y | GND | +C | +C |
| -2Y | GND | -C | -C |
| +3X | +C | GND | -C |
| -3X | -C | GND | +C |
| +3Y | GND | +C | GND |
| -3Y | GND | -C | GND |

**Table 13: Coarse motion signals applied on the outer piezo electrodes during coarse motion for 45° electrode orientation.**

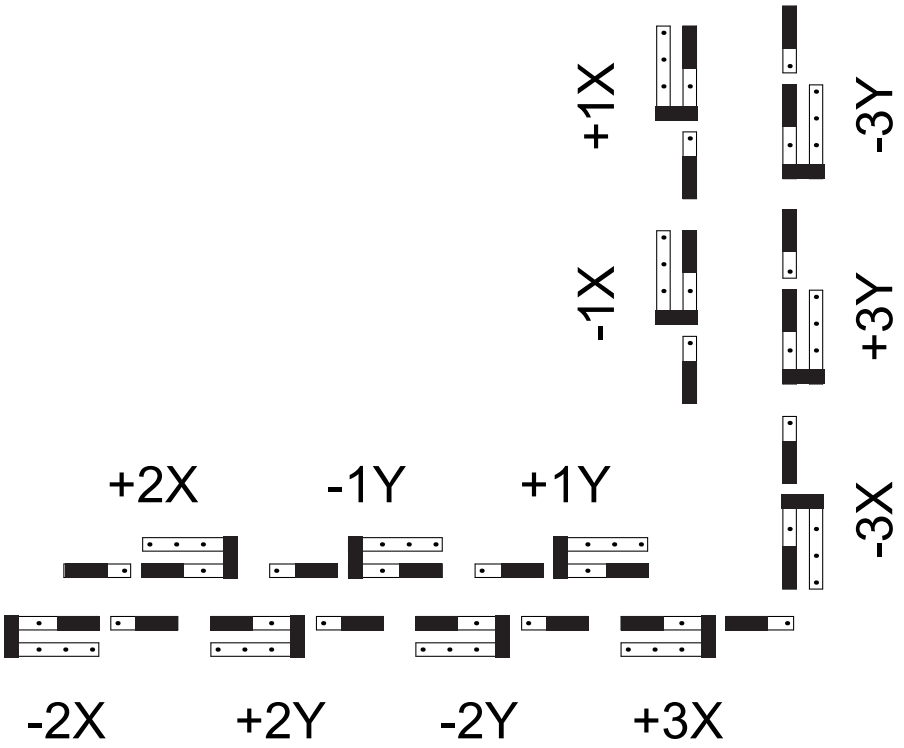


**Figure 59: Jumper configuration for rotational motion of a head with 45° electrode orientation. The arrangement of the jumpers corresponds to the arrangement on the main circuit board.**

## 0° and 90° electrode orientation with attenuation

The following table outlines the signals used during coarse motion for 0° and 90° electrode orientation (see the *Head compatibility and head geometry conventions* section for details), when the optional signal attenuators are installed. The signals are for positive direction, in the case of negative direction the sign has to be inverted. The figure below shows the corresponding jumper configuration.

| Electrode | +X motion | +Y motion | +Z motion |
|---|---|---|---|
| +1X | +C | GND | +C |
| -1X | -C | GND | -C |
| +1Y | GND | +C | GND |
| -1Y | GND | -C | GND |
| +2X | +C | GND | -0.5C |
| -2X | -C | GND | +0.5C |
| +2Y | GND | +C | +0.866C |
| -2Y | GND | -C | -0.866C |
| +3X | +C | GND | -0.5C |
| -3X | -C | GND | +0.5C |
| +3Y | GND | +C | -0.866C |
| -3Y | GND | -C | +0.866C |

**Table 14: Coarse motion signals applied on the outer piezo electrodes during coarse motion for 0° and 90° electrode orientation with installed signal attenuators.**

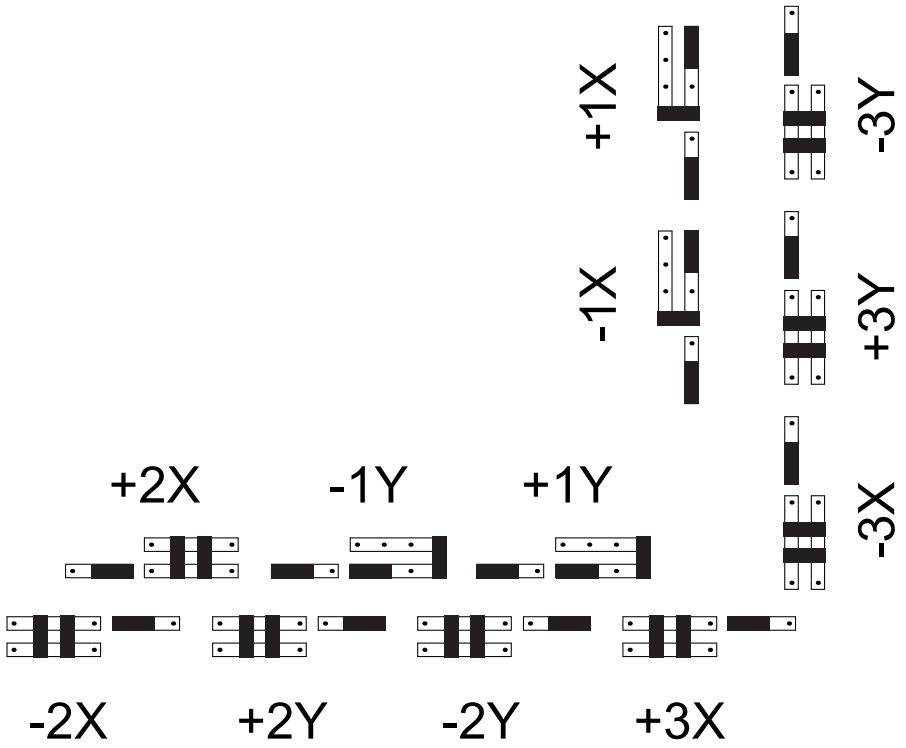


**Figure 60: Jumper configuration for rotational motion of a head with 0° and 90° electrode orientation using signal attenuators. The arrangement of the jumpers corresponds to the arrangement on the main circuit board.**

## 45° electrode orientation with attenuation

The following table outlines the signals used during coarse motion for 45° electrode orientation (see the *Head compatibility and head geometry conventions* section for details), when the optional signal attenuators are installed. The signals are for positive direction, in the case of negative direction the sign has to be inverted. The figure below shows the corresponding jumper configuration.

| Electrode | +X motion | +Y motion | +Z motion |
|---|---|---|---|
| +1X | +C | GND | +0.73C |
| -1X | -C | GND | -0.73C |
| +1Y | GND | +C | -0.73C |
| -1Y | GND | -C | +0.73C |
| +2X | +C | GND | +0.27C |
| -2X | -C | GND | -0.27C |
| +2Y | GND | +C | +C |
| -2Y | GND | -C | -C |
| +3X | +C | GND | -C |
| -3X | -C | GND | +C |
| +3Y | GND | +C | -0.27C |
| -3Y | GND | -C | +0.27C |

**Table 15: Coarse motion signals applied on the outer piezo electrodes during coarse motion for 45° electrode orientation with installed signal attenuators.**

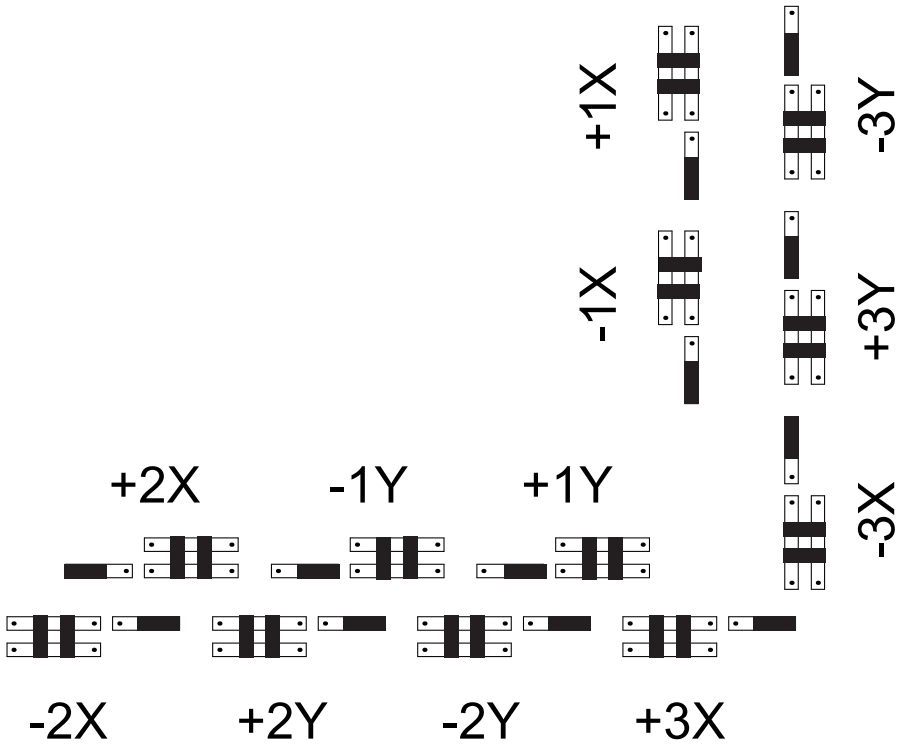


**Figure 61: Jumper configuration for rotational motion of a head with 45° electrode orientation using signal attenuators. The arrangement of the jumpers corresponds to the arrangement on the main circuit board.**

# Troubleshooting

## Instrument doesn’t power up correctly, LEDs do not light up

SYMPTOM: The instrument doesn’t react. The *Power LED* (2) and the *Connector/Active LED* (1) are off.

REASON: Fuses blown.

SOLUTION: Disconnect the AKBE from the mains. Remove and check the *fuses* (4). If the fuses are blown, replace them with fuses of the same rating (T1A), and try powering up the AKBE. Should the fuses blow again, please contact SPECS.

REASON: AKBE damaged.

SOLUTION: Disconnect the AKBE from the mains. Remove and check the fuses. If the fuses are intact, but the unit is still not working, please contact SPECS.

SYMPTOM: The instrument doesn’t react. The *Power LED* (2) is on, but the *Connector/Active LED* (1) is off.

REASON: Missing or improperly wired output plug.

SOLUTION: Make sure that the AKBE is connected to the experiment, i.e. the *HV OUTPUT* connector (7) is not left open. If a cable is connected to the *HV OUTPUT* connector (7), but the *Connector/Active LED* (1) is not on, please make sure that pins 1 and 20 are shorted, according to the HV output pin layout section. Make sure that the PMD4b HV input is connected to the *AKBE HV THROUGH OUTPUT* (8) as explained in the *HV through output* section, and that the PMD4b is switched on.

Note: For certain microscopes the connection between *AKBE HV THROUGH OUTPUT* (8) and PMD4b HV INPUT is not required. The the *Connector/Active LED* (1) will light orange as soon as a correctly wired plug is connected to the *HV OUTPUT* connector (7).

SYMPTOM: The instrument reacts, but signals from *HV INPUT 1* (11) and *HV INPUT 2* (10) are not routed to the microscope head. The *Power LED* (2) is on and the *Connector/Active LED* (1) is orange.

REASON: PMD4b is switched off or not connected to the *HV THROUGH OUTPUT* (8).

SOLUTION: Make sure that the PMD4b HV input is connected to the *AKBE HV THROUGH OUTPUT* (8) as explained in the *HV through output* section, and that the PMD4b is switched on.

## Instrument doesn’t react to software or PMD4b handset inputs

SYMPTOM: The instrument and the PMD4b do not react to software inputs, and a “PMD didn’t respond” software error message appears. The *Power LED* (2) and the *Connector/Active LED* (1) of the AKBE are on.

REASON: Digital communication between PMD4 and controller software is not working correctly.

SOLUTION: Please refer to the PMD4 manual for details.

SYMPTOM: The instrument and the PMD4b do not react to software inputs, but no software error message appears. The *Power LED* (2) and the *Connector/Active LED* (1) of the AKBE are on.

REASON: The HV Output enable switch of the PMD4b is in the disable position.

SOLUTION: Make sure that the HV Output enable switch of the PMD4b is in the enable position.

REASON: The *DIGITAL PORT* (6) of the AKBE is not connected to the extension port of the PMD4b using the digital port cable delivered with the AKBE.

SOLUTION: Make sure that the *DIGITAL PORT* (6) of the AKBE is connected to the extension port of the PMD4b, and that the digital port cable delivered with the AKBE is used for this purpose. A normal computer screen VGA cable might not work.

SYMPTOM: The instrument and the PMD4b do not react to handset inputs. The *Power LED* (2) and the *Connector/Active LED* (1) of the AKBE are on.

REASON: The HV Output enable switch of the PMD4b is in the disable position.

SOLUTION: Make sure that the HV Output enable switch of the PMD4b is in the enable position.

REASON: The *DIGITAL PORT* (6) of the AKBE is not connected to the extension port of the PMD4b using the digital port cable delivered with the AKBE.

SOLUTION: Make sure that the *DIGITAL PORT* (6) of the AKBE is connected to the extension port of the PMD4b, and that the digital port cable delivered with the AKBE is used for this purpose. A normal computer screen VGA cable might not work.

# Specifications

## General

| | |
|---|---|
| Casing | Wavetronics, stackable |
| Power | Internal power supply |
| HV inputs (signals from HVA4) | 2 |
| HV inputs (signals from PMD4b) | 1 |
| HV outputs (signals to PMD4b) | 1 |
| HV outputs (signals to microscope head) | 1 |
| Operating temperature | +5 ˚C to +35 ˚C |
| Dimensions | 33.0 × 26.8 × 5.4 cm (W×D×H) |
| Weight | Approx. 3.2 kg |

## AC line input

| | |
|---|---|
| Voltage | 90 – 253 V, 50-60 Hz |
| Power consumption | 10 W (typical) 30 W (maximum) |
| Maximum inrush current | 40 A (< 2 ms) |
| Maximum line voltage surge amplitude | According to EN 61000-4-5 |

## HVA4 inputs specifications

| | |
|---|---|
| Channels | 6 |
| Connector | Souriau TRIM TRIO UTG01619P |
| Voltage range | Up to ±400 V |
| Absolute maximum voltage range to GND | ±450 V |
| Absolute maximum peak current (relays inactive) | 22 A |
| EMC protection | According to EN61326-1, Table-1 |

# PMD4b through input specifications

| | |
|---|---|
| Channels | 4 |
| Connector | D-sub 25-pin male |
| Voltage range | Up to ±400 V |
| Absolute maximum voltage range to GND | ±450 V |
| Absolute maximum peak current (relays inactive) | 22 A |
| EMC protection | According to EN61326-1, Table-1 |

# PMD4b through output specifications

| | |
|---|---|
| Channels | 4 |
| Connector | D-sub 25-pin female |
| Voltage range | Up to ±400 V |
| Absolute maximum voltage range to GND | ±450 V |
| Asolute maximum peak current (relays inactive) | 22 A |
| EMC protection | According to EN61326-1, Table-1 |

# Piezo motor HV output specifications

| | |
|---|---|
| Channels | 20 |
| Connector | D-sub 37-pin female |
| Voltage range | Up to ±400 V |
| Absolute maximum voltage range to GND | ±450 V |
| Asolute maximum current (relays inactive) | 22 A |
| EMC protection | According to EN61326-1, Table-1 |

# Digital port specifications

| | |
|---|---|
| Input lines (ClkEP, Din, LoadEP) | |
| Input impedance | > 10 kΩ |
| Low input threshold | 1.2 V |
| High input threshold | 3.0 V |
| Maximum input voltage | 5.0 V |
| Output lines (Dout) | |
| Output impedance | < 1 kΩ |
| High output voltage | > 4.5 V (@ 0.5 mA load) |
| Low output voltage | < 0.5 V (@ 0.5 mA load) |
| Clock | |
| Maximum clock frequency | 250 kHz |
| Signal risetime restrictions | <20% of clock period |
| Isolation | |
| Isolation between GND and DGND | 16V @ 10 mA, limited by TVS suppressors |
| EMC-Protection | According to EN61326-1 |

# Operating Conditions

| | |
|---|---|
| Environment | The AKBE is designed for indoors dry laboratory use only |
| Ambient temperature | 5 ˚C to 35 ˚C<br>in accordance with IEC-60068-2-1 and IEC-60068-2-2 |
| Humidity | 10-50% relative humidity, non-condensing<br>in accordance with IEC-60068-2-56 |
| Maximum altitude | 2000 m |
| Pollution degree | 2 (indoor use only) |

# Storage and Transportation Conditions

| | |
|---|---|
| Ambient temperature | -20 ˚C to 70 ˚C<br>in accordance with IEC-60068-2-1 and IEC-60068-2-2 |
| Humidity | 5-95% relative humidity, non condensing<br>in accordance with IEC-60068-2-56 |
| Pollution degree | 2 (indoor use only) |

# Legal Information

## Warranty

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## Copyright



## Trademarks

# Declaration of Conformity

CE

According to ISO/IEC Guide 22 and EN 45014

| | |
|---|---|
| **Manufacturer's name:** | SPECS Zurich GmbH |
| **Manufacturer's addres:** | Technoparkstrasse 1<br>CH-8005 Zurich<br>Switzerland |

The manufacturer hereby declares that the product

| | |
|---|---|
| **Product name:** | Nanonis Besocke interface |
| **Model number:** | AKBE |
| **Product category:** | Electrical equipment for measurement, control and laboratory use |

Conforms by design to the following directives, standards or other normative documents:

**Council directive 2004/108/EC, Electromagnetic Compatibility, EN 61326-1: 2006**

| | | |
|---|---|---|
| **Emission:** | EN 55011 | Radiated and Conducted emission |
| **Immunity**: | EN 61000 | Electromagnetic compatibility (EMC), Part 4-2, 4-3, 4-4, 4-5, 4-6, 4-11, 3-2 |

**Supplementary information**

EMC requires the use of well-shielded coaxial cables not longer than 3 meters

Berlin, 25.7.2012

Oliver Schaff

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