MS207E

H-820 Hexapod Microrobot

User Manual

Version: 2.5.0 Date: 08/16/2024

This document describes the following product:

- **H-820.D2**
  Hexapod microrobot, basic model, 20 kg load capacity, 20 mm/s velocity, D-sub connector

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Subject to change. This manual is superseded by any new release. The latest respective release is available for download (p. 2) on our website.

Contents

1 About this Document

1.1 Objective and Target Group of this User Manual

This user manual contains the information necessary for using the H-820 as intended.

We assume that the user has basic knowledge of closed-loop systems, motion control concepts, and applicable safety measures.

1.2 Symbols and Typographic Conventions

The following symbols and typographic conventions are used in this user manual:

CAUTION

Dangerous situation
Failure to comply could result in minor injuries.

➢ Precautions to avoid the risk.

NOTICE

Dangerous situation
Failure to comply could result in damage to the equipment.

➢ Precautions to avoid the risk.

INFORMATION

Information for easier handling, tricks, tips, etc.

Symbol/Label	Meaning
RS-232	Labeling of an operating element on the product (example: socket of the RS-232 interface)
	Warning sign on the product which refers to detailed information in this manual.

PI

1.3 Figures

For better understandability, the colors, proportions, and degree of detail in illustrations can deviate from the actual circumstances. Photographic illustrations may also differ and must not be seen as guaranteed properties.

1.4 Other Applicable Documents

The devices and software tools from PI mentioned in this documentation are described in separate manuals.

Device / program	Document number	Document content
C-887.5xx controller	MS247EK	Short instructions for hexapod systems
	MS244E	User manual
	C887T0011	EtherCAT interface of the C-887.53 controller series
	C887T0007	Coordinate systems for hexapod microrobots
	C887T0021	Hexapod motion. Position and orientation in space, center of rotation.
PIVirtualMove	SM163E	Determining the valid poses of the hexapod by simulation
PC software included in the controller's scope of delivery	Various	Refer to the user manual for the C-887.5xx controller for details.

1.5 Downloading Manuals

INFORMATION

If a manual is missing or problems occur with downloading:

➢ Contact our customer service department (p. 33).

Downloading manuals

1. Open the website **www.pi.ws**.
2. Search the website for the product number (e.g., H-820).
3. In the search results, select the product to open the product detail page.
4. Select ***Downloads***.

   The manuals are shown under ***Documentation***. Software manuals are shown under ***General Software Documentation***.

5. For the desired manual, select ***ADD TO LIST*** and then ***REQUEST***.
6. Fill out the request form and select ***SEND REQUEST***.

   The download link will be sent to the email address entered in the form.

2 Safety

2.1 Intended Use

The hexapod microrobot (short "hexapod") is a laboratory device as defined by DIN EN 61010-1. It is built for indoor use and use in an environment which is free of dirt, oil, and lubricants.

In accordance with its design, the hexapod is intended for positioning, adjusting, and shifting of loads on six axes at various velocities.

The hexapod can only be used as intended in conjunction with a suitable controller available from PI (p. 13), which coordinates all motion of the hexapod.

2.2 General Safety Instructions

The H-820 is built according to state-of-the-art technology and recognized safety standards. Improper use of the H-820 may result in personal injury and/or damage to the H-820.

- Use the H-820 for its intended purpose only, and only when it is in perfect condition.
- Read the user manual.
- Immediately eliminate any faults and malfunctions that are likely to affect safety.

The operator is responsible for installing and operating the H-820 correctly.

2.3 Organizational Measures

User manual

- Always keep this user manual together with the H-820. The latest versions of the user manuals are available for download on our website (p. 2).
- Add all information from the manufacturer such as supplements or technical notes to the user manual.
- If you give the H-820 to other users, include this user manual as well as all other relevant information provided by the manufacturer.
- Do the work only if the user manual is complete. Missing information due to an incomplete user manual can result in minor injury and damage to equipment.
- Install and operate the H-820 only after you have read and understood this user manual.

Personnel qualification

The H-820 may only be installed, started, operated, maintained, and cleaned by authorized and appropriately qualified personnel.

3 Product Description

3.1 Product View

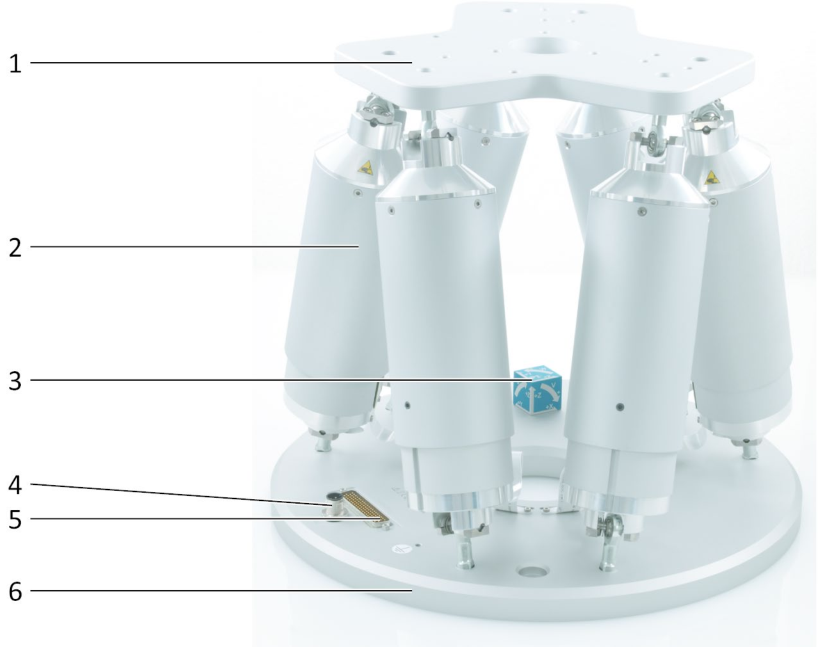


Figure 1: Elements of the H-820

1 Motion Platform
2 Strut
3 Coordinate cube
4 Panel plug for power supply cable
5 Panel plug for data transmission cable
6 Base plate

3.2 Technical Features

3.2.1 Struts

The hexapod has six adjustable-length struts. Each strut carries out linear motion. Each set of settings of the six struts defines a position of the motion platform in six degrees of freedom (three translational axes and three rotational axes).

Each strut is equipped with the following components:

- Actuator
- Reference and limit switches
- Joints for connecting to the base plate and motion platform

The actuator contains a brushless DC motor with an incremental rotary encoder and a drive screw.

3.2.2 Reference Switch and Limit Switches

The reference switch of a strut functions independently of the angular positions of the strut ends and the lengths of the other struts.

When a limit switch is activated, the power source of the motor is switched off to protect the hexapod against damage from malfunctions.

3.2.3 Controller

The hexapod is intended for operation with a suitable controller from PI (p. 13). With the controller, it is possible to command motion of individual axes, combinations of axes or all six axes at the same time in a single motion command.

The controller calculates the configuration of the individual struts from the target positions specified for the translational and rotational axes. The velocities and accelerations of the struts are calculated so that all struts start and stop at the same time.

Every time the controller of a hexapod equipped with incremental encoders is switched on or rebooted, the hexapod must complete a referencing move, in which each strut moves to its reference switch. After the referencing move, the motion platform is in the reference position and can be commanded to move to absolute target positions.

A referencing move is not required for a hexapod with absolute measuring sensors.

You will find further information in the user manual for the controller.

3.2.4 Motion

The platform moves along the translational axes and around the rotational axes.

The translation axes are labeled X, Y, and Z.

The axes of rotation can have the following designations:

Application	**Rotation around X**	**Rotation around Y**	**Rotation around Z**
Controller, PIHexapodEmulator, PIVirtualMove, manuals If available: Coordinate cube	U	V	W
Data table of the hexapod	θX	θY	θZ

Application	Rotation around X	Rotation around Y	Rotation around Z
Measurement report of the hexapod, figures of the coordinate systems	A A (rot X)	B B (rot Y)	C C (rot Z)

Using the controller, custom coordinate systems can be defined and used instead of the default coordinate system.

Default and user-defined coordinate systems are always right-handed systems. It is **not** possible to convert a right-handed system to a left-handed system.

The following is a description of how the hexapod behaves with the default coordinate system. Work with user-defined coordinate systems is described in the C887T0007 User Manual.

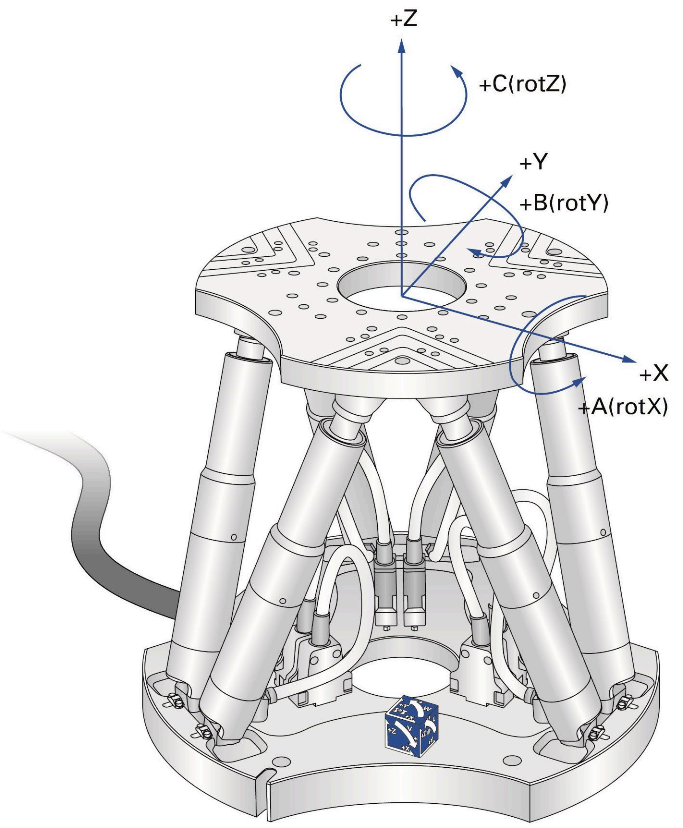


Figure 2: Coordinate system of a hexapod. For better clarity, the coordinate system is depicted above the platform.

Translation

Translations are described in the spatially-fixed coordinate system. The translational axes X, Y, and Z meet at the origin of the coordinate system (0,0,0). For further information, refer to the glossary (p. 45).

Rotation

Rotations take place around the rotational axes U, V, and W. The rotational axes meet at the center of rotation (also referred to as "pivot point"). The rotational axes and therefore also the center of rotation always move together with the platform of the hexapod (see also the example below for consecutive rotations).

A specified rotation in space is calculated from the individual rotations in the order U -> V- > W.

For further information on the center of rotation, refer to the glossary (p. 45).

INFORMATION

The dimensional drawing (p. 40) contains the following:

- Orientation of the default coordinate system
- Position of the default center of rotation

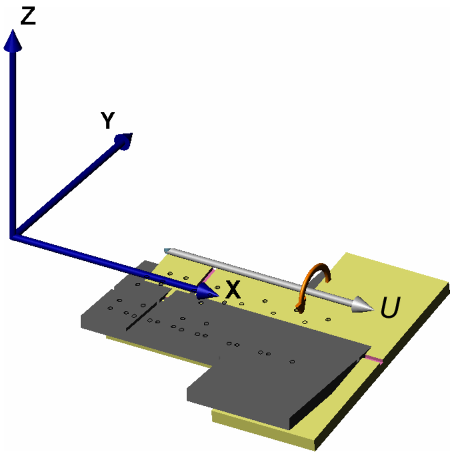
Example: Consecutive rotations

For a clearer view, the figures have been adapted as follows:

- Round platform replaced by T-shaped platform
- Coordinate system shown shifted
- Center of rotation in the top left corner of the platform

1. The U axis is commanded to move to position 10.

   The rotation around the U axis tilts the rotational axes V and W.

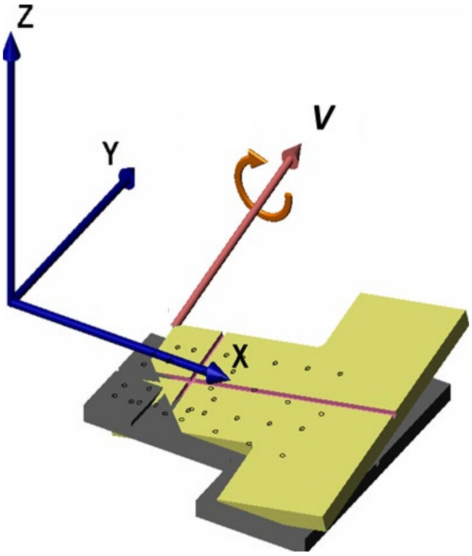


Platform in reference position

Platform position: U = 10 (U parallel to spatially fixed Xaxis)

2. The V axis is commanded to move to position –10.

   The rotation takes place around rotational axis V, which was tilted during the previous rotation.
   Die Rotation um die V-Achse verkippt die Rotationsachsen U und W.



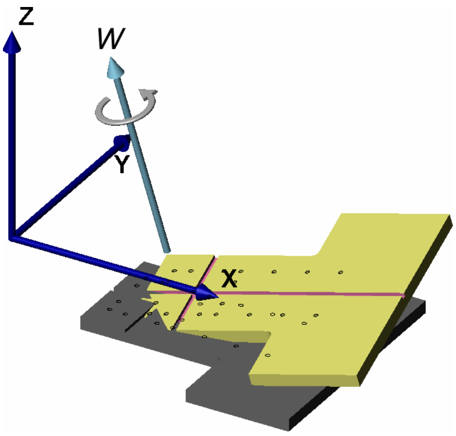
Platform in reference position

Platform position: U = 10, V = –10 (U and V parallel to the platform level)

3. The Waxis is commanded to move to position 10.

   The rotation takes place around the rotational axis W, which was tilted during the previous rotations. The Waxis is always vertical to the platform level.

   The rotation around the Waxis tilts the rotational axes U and V.



Platform in reference position

Platform position: U = 10, V = –10, W = 10 (U and V parallel to the platform level, W vertical to the platform level)

For further data on the travel ranges, refer to the "Specifications" (p. 35) section.

3.2.5 ID Chip

The hexapod has an ID chip that contains data on the type of hexapod, its serial number, and the date of manufacture. The data is loaded from the ID chip when the controller is switched on or rebooted. Depending on the data loaded, the controller keeps the current configuration or installs a new configuration.

For simple replacement, the configuration data for all standard hexapods is stored at the factory in every standard controller (e.g., geometry data and control parameters). The configuration data for customized hexapods is only stored on the controller if the hexapod and controller are delivered together, or if PI was correspondingly informed before delivery of the controller.

For further information and application notes, see the documentation of the controller used.

3.3 Scope of Delivery

Order number	Components
H-820	Hexapod according to your order
Packaging, consisting of:	
Inner and outer box Foam and corrugated cardboard cushions Pallet	
Documentation, consisting of:	
H820T0001	Instructions for unpacking the hexapod
MS247EK	Short instructions for hexapod systems
Screw sets:	
000034605	Mounting kit: ▪ 6 socket head screws, M6x30 ISO 4762 ▪ 1 hex key 5.0 DIN 911
000077312	▪ Double open-end wrench, 10 x 13 mm DIN 895
000036450	Accessories for connecting to the grounding system: ▪ 1 flat-head screw with cross recess, M4x8 ISO 7045 ▪ 2 flat washers, form A-4.3 DIN 7090 ▪ 2 safety washers, Schnorr Ø 4 mm N0110

Note that the cables required for connecting the H-820 to the electronics must be ordered separately.

3.4 Optional Accessories

Order number	Data transmission cable, available lengths
C-815.82D02	Data transmission cable for hexapods, drag chain compatible, HD D-sub 78 m/f, 2 m
C-815.82D03	Data transmission cable for hexapods, drag chain compatible, HD D-sub 78 m/f, 3 m
C-815.82D05	Data transmission cable for hexapods, drag chain compatible, HD D-sub 78 m/f, 5 m
C-815.82D07	Data transmission cable for hexapods, drag chain compatible, HD D-sub 78 m/f, 7.5 m
C-815.82D10	Data transmission cable for hexapods, drag chain compatible, HD D-sub 78 m/f, 10 m
C-815.82D20	Data transmission cable for hexapods, drag chain compatible, HD D-sub 78 m/f, 20 m

Order Number	Power Supply Cables, Available Lengths
C-815.82P02A	Power supply cable for hexapods, drag-chain compatible, M12 m/f angled, 2 m
C-815.82P03A	Power supply cable for hexapods, drag-chain compatible, M12 m/f angled, 3 m
C-815.82P05A	Power supply cable for hexapods, drag-chain compatible, M12 m/f angled, 5 m
C-815.82P07A	Power supply cable for hexapods, drag-chain compatible, M12 m/f angled, 7.5 m
C-815.82P10A	Power supply cable for hexapods, drag-chain compatible, M12 m/f angled, 10 m
C-815.82P20A	Power supply cable for hexapods, drag-chain compatible, M12 m/f angled, 20 m

To order, contact our customer service department (p. 33).

3.5 Suitable Controllers

Model	Description
C-887.52	6-axis controller for hexapods, TCP/IP, RS-232, benchtop device, incl. control of two additional axes
C-887.521	6-axis controller for hexapods, TCP/IP, RS-232, benchtop device, incl. control of two additional axes, analog inputs
C-887.522	6-axis controller for hexapods, TCP/IP, RS-232, benchtop device, incl. control of two additional axes, motion stop
C-887.523	6-axis controller for hexapods, TCP/IP, RS-232, benchtop device, incl. control of two additional axes, motion stop, analog inputs
C-887.53	6-axis controller for hexapods, TCP/IP, RS-232, benchtop device, incl. control of two additional axes, EtherCAT interface
C-887.531	6-axis controller for hexapods, TCP/IP, RS-232, benchtop device, incl. control of two additional axes, EtherCAT interface, analog inputs
C-887.532	6-axis controller for hexapods, TCP/IP, RS-232, benchtop device, incl. control of two additional axes, EtherCAT interface, motion stop
C-887.533	6-axis controller for hexapods, TCP/IP, RS-232, benchtop device, incl. control of two additional axes, EtherCAT interface, motion stop, analog inputs

To order, contact our customer service department (p. 33).

4 Unpacking

The hexapod is delivered in a special packaging with adapted foam inserts.

NOTICE

Impermissible mechanical load!
Impermissible mechanical load can damage the hexapod.

➢ Only ship the hexapod in the original packaging.
➢ Only hold the hexapod by the base plate.

Unpacking the hexapod

➢ Proceed as described in H820T0001 (in the scope of delivery (p. 12)).

Keeping the packaging

➢ Keep **all** packaging material in case the product needs to be transported later.

5 Installing

5.1 General Notes on Installation

The hexapod can be mounted in any orientation.

NOTICE

Impermissible mechanical load and collisions!

Impermissible mechanical load and collisions between the hexapod, the load to be moved, and the surroundings can damage the hexapod.

- Only hold the hexapod by the base plate.
- Use the PIVirtualMove simulation program to determine the valid poses before installing the hexapod and load. See "Determining Valid Poses" (p. 17) for the definition of a valid pose.
- Repeat the determination of valid poses if you change the hexapod type and before any change to the installation position, load to be moved, external forces and torques, or the coordinate system used.
- If you define your own coordinate system and use it instead of the factory-set coordinate system: Note that the PIVirtualMove simulation program calculates narrower travel range limits than the controller when using user-defined coordinate systems. If you want to avoid commanding poses that lie outside the travel range limits calculated by PIVirtualMove:
  - Use the controller to determine if poses can be commanded that lie outside the travel range limits calculated by PIVirtualMove by querying with the `TRA?` command.
  - If necessary, use the commands `NLM` and `PLM` to set soft limits in the controller according to the travel range limits calculated by PIVirtualMove.
- While installing the hexapod and the load, make sure that the actual system setup corresponds to the system setup for which you determined the valid poses in the PIVirtualMove simulation program.
- Avoid high forces and torques on the motion platform during installation.
- To avoid unintentional deactivation of the hexapod system and resulting position changes of the hexapod system, make sure that the power supply is not interrupted.
- Make sure that no collisions between the hexapod, the load to be moved, and the surroundings are possible in the workspace of the hexapod.

5.2 Determining Valid Poses

To avoid damaging the hexapod, only valid poses may be commanded. The PIVirtualMove simulation program is intended for determining the valid poses according to the following definition:

A pose is valid if it can be reached by all six axes X, Y, Z, U, V, W with the coordinate system used and the system setup used (installation position of the hexapod, load to be moved, external forces and torques) **and** the permissible load of the struts is **not** exceeded.

Tools and accessories

- PC with a Windows operating system on which the PIVirtualMove simulation program is installed.

Determining valid poses of the hexapod

➢ Follow the instructions in the PIVirtualMove user manual (SM163E).

INFORMATION

The PIVirtualMove simulation program calculates the valid poses based on the maximum payload of the hexapod (= limit value when servo mode is switched on). With the servo mode switched off, the maximum holding force is based on the self-locking of the actuators in the hexapod struts and is lower than the maximum payload.

INFORMATION

The load of the hexapod struts varies depending on the following factors:

- Activation state of the servo mode in the controller
- Installation position of the hexapod
- Load to be moved: mass and position of the center of mass on the motion platform
- Forces and torques acting on the motion platform
- Poses to be approached by the motion platform during operation (coordinates for translation and rotation)

5.3 Grounding the Hexapod

The hexapod is not grounded via the power supply cable. If a functional grounding is required for potential equalization:

1. Connect the base plate to the grounding system:
   - For connection, use the supplied accessories (p. 12) and the M4 hole marked with the ground connection symbol (p. 40).
2. Connect the motion platform to the grounding system:
   - Use one of the mounting holes in the motion platform (p. 40) for connection.
     or
   - If the motion platform and the load are connected conductively to each other, connect the load to the grounding system.

5.4 Mounting the Hexapod on a Surface

NOTICE

Impermissible mechanical load!

An impermissible mechanical load can damage the hexapod.

➢ Only hold the hexapod by the base plate.

NOTICE

Warping the base plate!

Incorrect mounting can warp the base plate. A warped base plate reduces the accuracy.

➢ Mount the hexapod onto a flat surface. The recommended flatness of the surface is 300 µm.

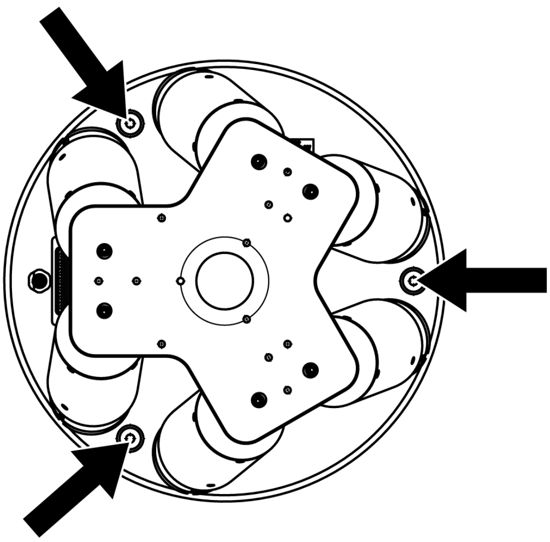


Figure 3: Mounting holes in the base plate

Requirements

✓ You have read and understood the General Notes on Installation (p. 17).

Tools and accessories

- Hex key 5.0 and three of the supplied screws (p. 12).

Mounting the hexapod

1. Provide three M6 threaded holes in the support for mounting with M6x30 screws.

   The arrangement of the mounting holes in the base plate of the hexapod can be found in the dimensional drawing (p. 40) as well as in the corresponding figure.

2. Mount the hexapod on the three mounting holes in the base plate using the M6x30 screws supplied.

5.5 Fixing the Load to the Hexapod

NOTICE

Impermissible mechanical load and collisions!

Impermissible mechanical load and collisions between the hexapod, the load to be moved, and the surroundings can damage the hexapod.

- ➢ While installing the hexapod and the load, make sure that the actual system setup corresponds to the system setup for which you determined the valid poses in the PIVirtualMove simulation program.
- ➢ Avoid high forces and torques on the motion platform during installation.
- ➢ Make sure that no collisions between the hexapod, the load to be moved, and the surroundings are possible in the workspace of the hexapod.

NOTICE

Excessively long screws!

The hexapod can be damaged by screws that are inserted too deeply.

- ➢ When selecting the screw length, observe the thickness of the motion platform or the depth of the mounting holes (p. 40) together with the load to be mounted.
- ➢ Only use screws that do not project under the motion platform after being screwed in.
- ➢ Only mount the hexapod and the load on the mounting fixtures (holes) intended for this purpose.

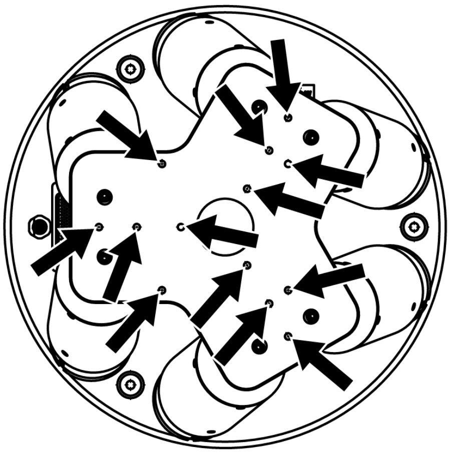


Figure 4: M6 mounting holes in the motion platform

Requirements

✓ You have read and understood the General Notes on Installation (p. 17).

✓ You have determined the permissible load and the workspace of the hexapod (p. 17).

✓ You have designed the load and the surroundings of the hexapod so that the permissible load of the hexapod is adhered to and no collisions can occur.

Tools and accessories

- At least three M6 screws of suitable length
- Suitable tool for tightening the screws

Fixing the load

1. Align the load so that at least three mounting holes in the motion platform can be used to fix the load.

   The arrangement of the mounting holes in the motion platform of the hexapod can be found in the dimensional drawing (p. 40) as well as in the corresponding figure.
2. Use the screws to fix the load to the selected mounting holes in the motion platform.

5.6 Optional: Removing the Coordinate Cube

You can remove the coordinate cube from the base plate of the hexapod.

Tools and accessories

- Hex key AF 2.0

Removing the coordinate cube

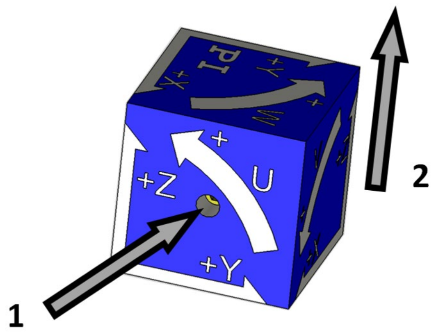


Figure 5: Removing the Coordinate Cube

1. Loosen the threaded pin M4x8.
2. Pull the coordinate cube upwards away from the base plate.

5.7 Connecting the Hexapod to the Controller

Requirements

✓ The controller is **switched off**, i.e., the on/off switch is in the position O.

Tools and accessories

- Data transmission cable and power supply cable, available as accessories (p. 13)

Connecting the hexapod to the controller

➢ Connect the hexapod and the controller to each other:
  - Pay attention to the assignment specified on the labeling of the sockets, plug connectors, and cables.
  - Pay attention to the mechanical coding of connectors and sockets.
  - Do not use force.
  - Use the integrated screws to secure the connections against accidental disconnection.

Standard Cabling

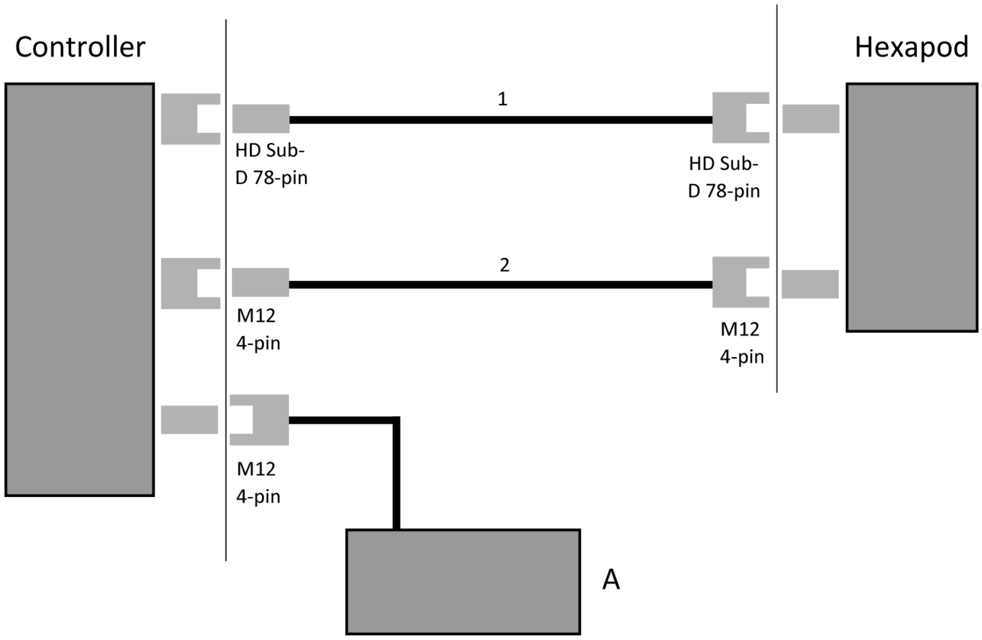


Figure 6: Connection diagram

	Panel plug / connector, male
	Socket / connector, female
Controller	Refer to "Suitable Controllers (p. 13)"
Hexapod	H-820.D2
A	Power adapter, from the scope of delivery of the controller, 24 V DC output
1	Data transmission cable
2	Power supply cable

6 Startup

6.1 General Notes on Startup

CAUTION

Risk of crushing by moving parts!

Risk of minor injuries from crushing between the moving parts of the hexapod and a stationary part or obstacle.

➢ Keep your fingers away from areas where they could be caught by moving parts.

NOTICE

Incorrect configuration of the controller!

The configuration data used by the controller (e.g., geometry data and servo control parameters) must be adapted to the hexapod. If incorrect configuration data is used, the hexapod can be damaged by uncontrolled motion or collisions.

When the controller is switched on or rebooted, the configuration data is adapted using the data that is loaded from the ID chip.

➢ Once you have established communication via TCP/IP or RS-232, send the `CST?` command. The response shows the hexapod, to which the controller is adapted.

➢ Only operate the hexapod with a controller whose configuration data is adapted to the hexapod.

NOTICE

Damage due to collisions!

Collisions can damage the hexapod, the load to be moved, and the surroundings.

➢ Make sure that no collisions are possible between the hexapod, the load to be moved, and the surroundings in the workspace of the hexapod.

➢ Do not place any objects in areas where they can be caught by moving parts.

➢ Only command valid poses. See "Determining Valid Poses" (p. 17) for the definition of a valid pose.

➢ Stop the motion immediately if a controller malfunction occurs.

6.2 Starting Up the Hexapod System

Requirements

- ✓ You have read and understood the General Notes on Startup (p. 25).
- ✓ You have correctly installed the hexapod, i.e., you have mounted the hexapod onto a surface, fixed the load to the hexapod and connected the hexapod to the controller according to the instructions in "Installation" (p. 17).
- ✓ You have read and understood the user manual of the controller.

Accessories

- PC with suitable software (refer to the user manual of the controller)

Starting up the hexapod system

1. Start up the controller (refer to the user manual of the controller).
2. Run a few motion cycles for test purposes (refer to the user manual of the controller).

7 Maintenance

PI offers a range of wraparound services for all their products, many of which are designed to increase the system's lifetime and uptime:

- Remote system setup: An expert ensures that your system is optimized and runs perfectly.
- Return-to-base preventative maintenance programs: Proactive verification of your system's condition and performance.
- Customer training: Ensures that the system continues to perform optimally throughout its lifetime.

Contact your PI representative to learn more about PI's wraparound service benefits.

NOTICE

Damage due to improper maintenance!

The hexapod can become misaligned as a result of improper maintenance. The specifications can change as a result (p. 35).

➢ Only loosen screws according to the instructions in this manual.

Depending on the operating conditions and the period of use of the hexapod, the following maintenance measures are required.

7.1 Performing a Maintenance Run

Frequent motion over a limited travel range can cause the lubricant to be distributed unevenly on the drive screw.

➢ Perform a maintenance run over the entire travel range at regular intervals (see user manual of the controller). The more often motion is performed over a limited travel range, the shorter the time has to be between the maintenance runs.

7.2 Cleaning the Hexapod

Requirements

✓ You have removed the cables for data transmission and the power supply from the hexapod.

Cleaning the hexapod

- If necessary, clean the surfaces of the hexapod with a cloth that is lightly dampened with a mild cleanser or disinfectant.

7.3 Packing the Hexapod for Transport

NOTICE

Impermissible mechanical load!
Impermissible mechanical load can damage the hexapod.

- Only ship the hexapod in the original packaging.
- Only hold the hexapod by the base plate.

NOTICE

Damage from applying high forces!
Hexapod struts with direct drive can be carefully moved by hand in the case of an error. Blocked struts can be damaged by the use of force.

- If one or more struts of the hexapod are blocked, do **not** move the hexapod by hand.
- If you move the hexapod by hand, do not use high forces.

Accessory

- Original packaging (p. 12)

Uninstalling the hexapod

1. Command hexapod motion to the transport position:

   X = Y = Z = U = V = W = 0

2. Uninstall the hexapod system:

   a) Remove the load from the motion platform of the hexapod.

   b) Switch the controller off.

   c) Remove the data transmission cable and the power supply cable from the controller.

   d) Loosen all connections between the cables attached permanently to the hexapod and the cable set used, and remove the cables from all attachments (e.g., connector holder).

   e) Remove the hexapod from the surface.

Packing the hexapod

- Proceed as described in H820T0001 (in the scope of delivery (p. 12)).

8 Troubleshooting

Fault: Unexpected hexapod behavior	
Possible causes	**Remedial measures**
▪ Defective cable ▪ Bent pin ▪ Connector or soldered joints loosened	➢ Check the data transmission and power supply cables. ➢ Replace the cables by cables of the same type and test the function of the hexapod. ➢ Contact our customer service department (p. 33).

Fault: Hexapod does not achieve the specified repeatability	
Possible causes	**Remedial measures**
▪ Motion platform is warped ▪ Warped base plate	➢ Mount the hexapod on an even surface (p. 19). ➢ Only mount loads with a flat footprint surface. The recommended flatness of the surface is 300 µm.
▪ Poor lubrication because of small motions over a long period of time	➢ Do a maintenance run over the entire travel range (p. 27).
▪ External disturbances	➢ Make sure that no vibrations are transmitted to the system. ➢ Make sure that forces, e.g., also through dragged cables, do not affect the movement of the cover plate. ➢ Make sure that the system is in a thermal equilibrium.

Fault: Travel accuracy is poor	
Possible causes	**Remedial measures**
▪ Unsuitable control parameters for the application ▪ The system behavior has changed due to an increasing ease of operation.	➢ Carry out a tuning of the parameters. ➢ Contact our customer service department (p. 33).

Fault: Hexapod does not move	
Possible causes	**Remedial measures**
▪ Foreign body has entered the drive spindle ▪ Faulty motor ▪ Sensor defective ▪ Blocked or broken joint ▪ Load too big	➢ Test a strut (refer to the user manual for the controller). Führen Sie den Beintest in der Referenzposition durch, sofern die Störung nicht in maximaler oder minimaler Auslenkung der Plattform in Z auftritt. ➢ Contact our customer service department (p. 33).
▪ The mechanics is not supplied with voltage.	➢ Check the power supply cable. ➢ If applicable, check the power adapter of the mechanics. ➢ Check the Power Good signal of the hexapod. Options: – In PIMikroMove, open the ***Diagnostic Information*** window by selecting the ***C-887 > Show diagnostic information...*** menu item. – Send the `DIA?` command. Meaning of the displayed information: ▪ 1 (Hexapod powered): – = 1 - power supply for the drives of the hexapod exists – = 0 - power supply for the drives of the hexapod has been interrupted ▪ 2 (Controller E-Stop activated): – = 1 - 24-V output of the C-887.5xx controller is active – = 0 - 24-V output of the C-887.5xx controllers is inactive ▪ 3 (Temperature): – = <Temparaturwert> ▪ 4 (Faulty point in waveform): – = 1 - Faulty point in waveform For further information, refer to the user manual for the C-887.5xx controller.
▪ The servo mode was switched off due to a malfunction.	1. Send the `SVO?` command to check the activation state of the servo mode. 2. If SVO 0 is answered, ensure that the malfunction has been corrected. 3. Activate the servo using `SVO X`.
Controller with **E-Stop** socket: ▪ Nothing connected to **E-Stop** ▪ "Break contact" is active	Controllers with the **E-Stop** socket support the "Motion Stop" functionality, with which the hexapod motion can be stopped with external devices (pushbuttons, switches). ➢ Check the state of the E-Stop function: `dia?`

Fault: Hexapod does not move	
Possible causes	**Remedial measures**
on **E-Stop** In both cases, the **24 V Out 7 A** output of the controller is disabled.	1= 1 {Hexapod powered} 2= 1 {E-stop activated} 3= +33.0 {Temperature} 4= -1 {Faulty point in waveform} or using the ***Diagnostic Information*** in PIMikroMove. If you do **not** use the "Motion Stop" functionality: ➢ Make sure that the C887B0038 shorting plug from the scope of delivery of the controller is inserted in the **E-Stop** socket. If you use the "Motion Stop" functionality: 1. Check your system and make sure that the hexapod can be moved safely. 2. Activate the **24 V Out 7 A** output with "Make contact" (for details, refer to the user manual for the controller). If you use the C-887.MSB motion-stop-box from PI: Press the mushroom button first to unlock it, then press the green pushbutton. 3. Switch the servo mode on for the hexapod axes. Use the SVO command or the corresponding operating elements in the PC software. Note: A new referencing move is not necessary.
▪ Incorrect or missing configuration data	➢ Send the `CST?` command. The response shows the hexapod, to which the controller is adapted. ➢ Set the correct hexapod using `DBG?` choosehexapod {type of hexapod} ➢ Send the `ERR?` command. Error code "233" in the answer indicates that the configuration data for the hexapod is missing on the controller. Contact our customer service department (p. 33) in order to receive valid configuration data.
▪ The motion platform is located at a position outside the travel range limits. Commanding a permitted target position generates error code 7 ("Position out of limits"). ▪ A reference move is not possible for hexapods	➢ Create a KSD coordinate system that does not take the Cartesian limits into consideration, and increase the struts' travel ranges to get back into a permissible range of motion: Query the current limits: SPA? 1 0x30 (neg) SPA? 1 0x15 (pos) Multiply the answer by 1.5, and later set this value as described below (for example, here 30 / -30)

Fault: Hexapod does not move	
Possible causes	**Remedial measures**
with absolute-measuring sensors.	ksd limit z 0 ken limit spa 1 0x30 -30 2 0x30 -30 3 0x30 -30 4 0x30 -30 5 0x30 -30 6 0x30 -30 spa 1 0x15 30 2 0x15 30 3 0x15 30 4 0x15 30 5 0x15 30 6 0x15 30 svo x 1 mov z -5 oder mov z 5 depending on the final position of the hexapod (above or below). KEN 0 When the hexapod has moved towards the middle again, restart the system (`rbt`).

Fault: Hexapod does not start a referencing move	
Possible causes	**Remedial measures**
▪ The hexapod is equipped with absolute measuring encoders.	➢ The `FRF` command does not start a referencing move for axes with absolute measuring sensors but sets the target positions to the current position values.
▪ Motion is generally not possible	➢ Check if one of the causes mentioned in the "Hexapod does not move" section applies to your problem.

If the problem with your hexapod is not listed in the table or cannot be solved as described, contact our customer service department (p. 33).

9 Customer Service Department

For inquiries and orders, contact your PI representative or send us an email (mailto:service@pi.de).

➢ If you have questions concerning your system, provide the following information:
  - Product and serial numbers of all products in the system
  - Firmware version of the controller (if applicable)
  - Version of the driver or the software (if applicable)
  - PC operating system (if applicable)

If possible: Take photographs or make videos of your system that can be sent to our customer service department if requested.

The latest versions of the user manuals are available for download on our website (p. 2).

10 Technical Data

Subject to change. You can find the latest product specifications on the product web page at www.pi.ws (https://www.physikinstrumente.com/en/).

10.1 Specifications

10.1.1 Data Table

Motion	H-820.D2	Tolerance
Active axes	X | Y | Z | θX | θY | θZ	
Travel range in X	± 50 mm	
Travel range in Y	± 50 mm	
Travel range in Z	± 25 mm	
Rotation range in θX	± 15°	
Rotation range in θY	± 15°	
Rotation range in θZ	± 30°	
Maximum velocity in X	20 mm/s	
Maximum velocity in Y	20 mm/s	
Maximum velocity in Z	20 mm/s	
Maximum angular velocity in θX	200 mrad/s	
Maximum angular velocity in θY	200 mrad/s	
Maximum angular velocity in θZ	200 mrad/s	
Typical velocity in X	2 mm/s	
Typical velocity in Y	2 mm/s	
Typical velocity in Z	2 mm/s	
Typical angular velocity in θX	20 mrad/s	
Typical angular velocity in θY	20 mrad/s	
Typical angular velocity in θZ	20 mrad/s	

Positioning	H-820.D2	Tolerance
Minimum incremental motion in X	5 µm	typ.
Minimum incremental motion in Y	5 µm	typ.
Minimum incremental motion in Z	5 µm	typ.
Minimum incremental motion in θX	12.5 µrad	typ.

Positioning	H-820.D2	Tolerance
Minimum incremental motion in θY	12.5 µrad	typ.
Minimum incremental motion in θZ	12.5 µrad	typ.
Unidirectional repeatability in X	± 1.5 µm	typ.
Unidirectional repeatability in Y	± 1.5 µm	typ.
Unidirectional repeatability in Z	± 0.5 µm	typ.
Unidirectional repeatability in θX	± 8 µrad	typ.
Unidirectional repeatability in θY	± 8 µrad	typ.
Unidirectional repeatability in θZ	± 25 µrad	typ.
Backlash in X	30 µm	typ.
Backlash in Y	30 µm	typ.
Backlash in Z	3 µm	typ.
Backlash in θX	30 µrad	typ.
Backlash in θY	30 µrad	typ.
Backlash in θZ	300 µrad	typ.
Integrated sensor	Incremental rotary encoder	

Drive properties	H-820.D2	Tolerance
Drive type	Brushless DC motor	
Nominal voltage	24 V	

Mechanical properties	H-820.D2	Tolerance
Maximum load capacity, base plate in any orientation	10 kg	
Maximum load capacity, base plate horizontal	20 kg	
Maximum holding force, base plate in any orientation	5 N	
Maximum holding force, base plate horizontal	200 N	
Overall mass	15 kg	
Material	Aluminum	

Miscellaneous	H-820.D2	Tolerance
Operating temperature range	0 to 50 °C	
Connector for data transmission	HD D-sub 78 (m)	
Connector for supply voltage	M12 4-pole (m)	

Miscellaneous	H-820.D2	Tolerance
Recommended controllers / drivers	C-887.5x	

Connecting cables are not in the scope of delivery and must be ordered separately.

Ask about custom versions.

When measuring position specifications, typical velocity is used. The data is included in the delivery of the product in the form of a measurement report and is stored at PI.
The maximum travel ranges of the individual coordinates (X, Y, Z, θX, θY, θZ) are interdependent. The data for each axis shows its maximum travel range when all other axes are in the zero position of the nominal travel range and the default coordinate system is in use, or rather when the pivot point is set to 0,0,0.

At PI, technical data is specified at 22 ±3 °C. Unless otherwise stated, the values are for unloaded conditions. Some properties are interdependent. The designation "typ." indicates a statistical average for a property; it does not indicate a guaranteed value for every product supplied. During the final inspection of a product, only selected properties are analyzed, not all. Please note that some product characteristics may deteriorate with increasing operating time.

10.1.2 Specifications for Data Transmission and Power Supply Cables

The following table lists the technical data of all optionally available cable sets, irrespective of whether they are suitable for the H-820 hexapods. Refer to "Optional Accessories" (p. 13)for a selection of suitable cable sets.

Data Transmission and Power Supply Cables

Data transmission cable	Power supply cable, single-side angled connector	Power supply cable, straight connectors
All hexapod types	H-820, H-824, H-825, H-840, H-850	H-810, H-811, H-206
C-815.82D02	C-815.82P02A	C-815.82P02E
C-815.82D03	C-815.82P03A	C-815.82P03E
C-815.82D05	C-815.82P05A	C-815.82P05E
C-815.82D07	C-815.82P07A	C-815.82P07E
C-815.82D10	C-815.82P10A	C-815.82P10E
C-815.82D20	C-815.82P20A	C-815.82P20E

The models differ with respect to the following features:

1. Cable type
2. Length
3. Connector type (power cables only)

These features are coded in the product number by the characters after the C-815.82 as follows:

Character following the C-815.82	Meaning	Possible values
First character	Cable type	D – Data transmission cable P – Power supply cable
Second character	Length	02 – 2 m 03 – 3 m 05 – 5 m 07 – 7.5 m 10 – 10 m 20 – 20 m
Third character	Connector type (power supply cable only)	A – Angled connector E – Straight connector

General		Unit
Cable length L	2 / 3 / 5 / 7.5 / 10 / 20	m
Maximum velocity	3	m/s
Maximum acceleration	5	m/s^2
Maximum number of bending cycles	1 million	
Operating temperature range	-10 to +70	°C

Power supply cable, straight connectors		Unit
Minimum bending radius in a drag chain	49	mm
Minimum bending radius with the fixed installation	24.5	mm
Outer diameter	4.9	mm
Connector	M12 m/f	

Power supply cable, angled connector			Unit
Cable length L	3	2 / 5 / 7.5 / 10 / 20	m
Minimum bending radius in a drag chain	72	94	mm
Minimum bending radius with the fixed installation	36	57	mm
Outer diameter	7.2	7.5	mm
Connector	M12 m/f		

Data transmission cable		Unit
Minimum bending radius in a drag chain	107	mm
Minimum bending radius with the fixed installation	81	mm
Outer diameter	10.7	mm
Connector	HD D-sub 78 m/f	

Cables longer that 20 m require additional power drivers.

10.2 Maximum Ratings

The hexapod is designed for the following operating data:

Maximum operating voltage	⚠	Maximum operating frequency (unloaded)	⚠	Maximum current consumptio n	⚠
24 V DC		⎓		5 A	

10.3 Ambient Conditions and Classifications

Degree of pollution	2
Air pressure	1100 hPa to 780 hPa
Transport temperature	–25 °C to +85 °C
Storage temperature	0 °C to 70 °C
Humidity	Highest relative humidity of 80% at temperatures of up to 31°C, decreasing linearly to a relative humidity of 50% at 40°C
Degree of protection according to IEC 60529	IP20
Area of application	For indoor use only
Maximum altitude	2000 m

10.4 Dimensions

Dimensions in mm. Note that the decimal points are separated by a comma in the drawings.

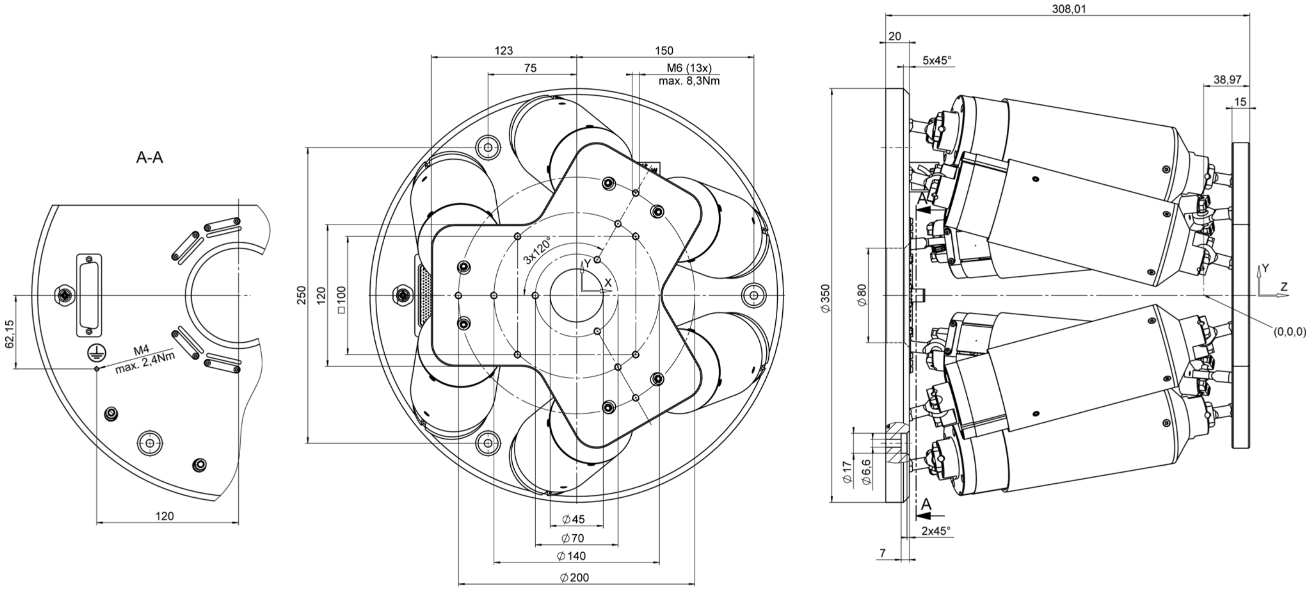


Figure 7: H-820.D2 Hexapod, at zero position of nominal travel range

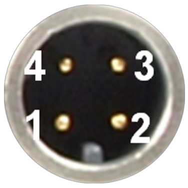
If the controller's factory settings are used for the coordinate system and the center of rotation, the hexapod in the figure corresponds to the position X=Y=Z=U=V=W=0.

The (0,0,0) coordinates indicate the origin of the coordinate system. When the default settings for the coordinate system and center of rotation are used, and the hexapod is at position X=Y=Z=U=V=W=0, the center of rotation is at the origin of the coordinate system.

10.5 Pin Assignment

10.5.1 Power Supply Connector

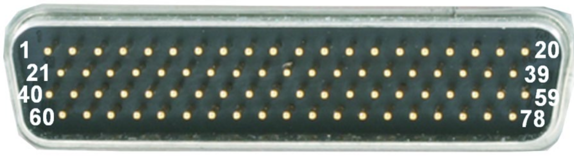
Power supply via 4-pin M12 panel plug

Pin	Function	
1	GND	
2	GND	
3	24 V DC	
4	24 V DC	

10.5.2 Data Transmission Connector

Data transmission between hexapod and controller

HD D-sub 78 panel plug

Function	
All signals: TTL	

Pin Assignment

Pin	Pin	Signal
1		CH1 Sign IN
	21	CH1 Ref OUT
2		nc
	22	CH1 A+ OUT
3		CH1 A- OUT
	23	GND
4		CH2 Sign IN
	24	CH2 Ref OUT
5		nc
	25	CH2 A+ OUT

Pin	Pin	Signal
40		CH1 MAGN IN
	60	CH1 LimP OUT
41		CH1 LimN OUT
	61	CH1 B+ OUT
42		CH1 B- OUT
	62	GND
43		CH2 MAGN IN
	63	CH2 LimP OUT
44		CH2 LimN OUT
	64	CH2 B+ OUT

Pin	Pin	Signal
6		CH2 A- OUT
	26	GND
7		CH3 Sign IN
	27	CH3 Ref OUT
8		nc
	28	CH3 A+ OUT
9		CH3 A- OUT
	29	GND
10		CH4 Sign IN
	30	CH4 Ref OUT
11		nc
	31	CH4 A+ OUT
12		CH4 A- OUT
	32	GND
13		CH5 Sign IN
	33	CH5 Ref OUT
14		nc
	34	CH5 A+ OUT
15		CH5 A- OUT
	35	GND
16		CH6 Sign IN
	36	CH6 Ref OUT
17		nc
	37	CH6 A+ OUT
18		CH6 A- OUT
	38	GND
19		ID Chip
	39	GND
20		24 V input

Pin	Pin	Signal
45		CH2 B- OUT
	65	GND
46		CH3 MAGN IN
	66	CH3 LimP OUT
47		CH3 LimN OUT
	67	CH3 B+ OUT
48		CH3 B- OUT
	68	GND
49		CH4 MAGN IN
	69	CH4 LimP OUT
50		CH4 LimN OUT
	70	CH4 B+ OUT
51		CH4 B- OUT
	71	GND
52		CH5 MAGN IN
	72	CH5 LimP OUT
53		CH5 LimN OUT
	73	CH5 B+ OUT
54		CH5 B- OUT
	74	GND
55		CH6 MAGN IN
	75	CH6 LimP OUT
56		CH6 LimN OUT
	76	CH6 B+ OUT
57		CH6 B- OUT
	77	GND
58		Brake/Enable drive
	78	GND
59		Power Good 24 V output

11 Old Equipment Disposal

In accordance with EU law, electrical and electronic equipment may not be disposed of in EU member states via the municipal residual waste.

Dispose of your old device according to international, national, and local rules and regulations.

To fulfill the responsibility as the product manufacturer, Physik Instrumente (PI) GmbH & Co. KG undertakes environmentally correct disposal of all old PI equipment made available on the market after 13 August 2005 without charge.

If you have an old device from PI, you can send it to the following address free of charge:

Physik Instrumente (PI) GmbH & Co. KG

Auf der Roemerstrasse 1

76228 Karlsruhe, Germany

12 Glossary

User-defined coordinate system

Using the controller, custom coordinate systems can be defined and used instead of the factory-set coordinate systems.

Work with user-defined coordinate systems and the work-and-tool concept is described in the C887T0007 technical note.

Workspace

The entirety of all poses that the hexapod can approach from its current position is referred to as workspace.

The workspace can be limited by the following external factors:

- Installation space
- Dimensions and position of the load

To avoid subjecting the hexapod to an impermissible mechanical load, the forces acting on the hexapod struts at the poses must be taken into consideration in addition to the workspace. Valid poses can be calculated with the PIVirtualMove simulation program.

Center of rotation

The center of rotation describes the intersection of the rotational axes U, V, and W. When the default settings for the coordinate system and the center of rotation are used, the center of rotation after a referencing move is located at the origin of the coordinate system (0,0,0), see the dimensional drawing of the hexapod (p. 40).

The center of rotation always moves together with the platform.

Depending on the active --> operating coordinate system, the center of rotation can be moved from the origin of the coordinate system in the X and/or Y and/or Z direction with the SPI command. The center of rotation that can be moved using the SPI command is also referred to as "pivot point".

Hexapod system

The combination of hexapod, controller, cables, and power adapter(s) is referred to as "hexapod system" in this manual.

Pose

The spatial position of the hexapod, i.e., the combination of its position and orientation in three-dimensional space is referred to as "pose". The pose of a hexapod is defined by six coordinates in relation to a right-handed Cartesian coordinate system:

- Translation axes (also referred to as "linear axes"): X, Y, Z
- Rotational axes: U, V, W

A pose is valid if it can be reached by all six axes X, Y, Z, U, V, W with the coordinate system used and the system setup used (installation position of the hexapod, load to be moved, external forces and torques) **and** the permissible load of the struts is **not** exceeded.

Valid poses can be calculated with the PIVirtualMove simulation program.

For other possible designations of the U, V, and W axes, see "Motion" (p. 8).

Default coordinate system

The X, Y, and Z axes of the Cartesian coordinate system are always spatially fixed, i.e., the coordinate system does not move when the platform of the hexapod moves. The X, Y and Z axes are also referred to as translational axes.

The intersection of the axes X, Y, and Z of the spatially fixed Cartesian coordinate system (0,0,0) is referred to as the origin.

The Z axis is perpendicular to the base plate of the hexapod.

The following example figures of the H-810 hexapod show that the coordinate system does not move along with motion of the platform.

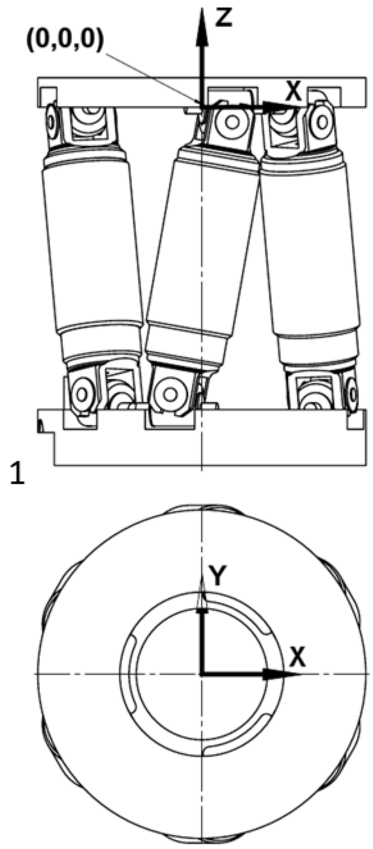


Figure 8: H-810 hexapod in the reference position.

1 Cable exit

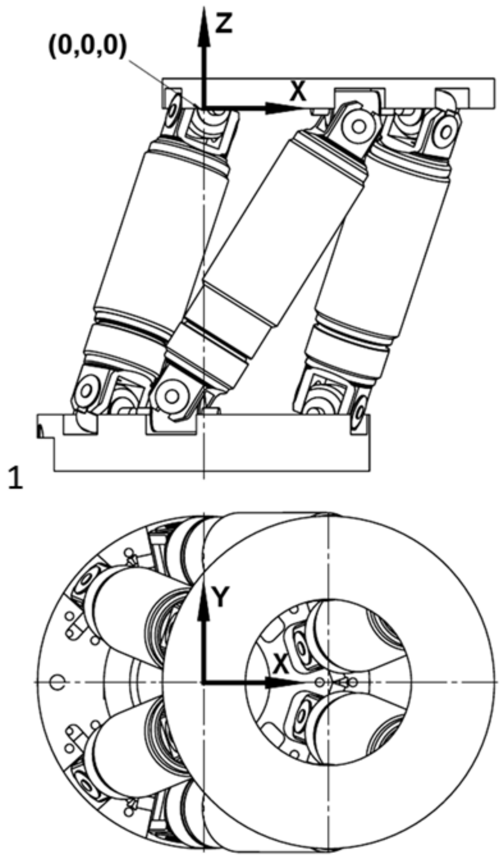


Figure 9: H-810 hexapod, the platform of which has been moved in X.

1 Cable exit

13 Appendix

13.1 Explanations of the Performance Test Sheet

The hexapod is tested for the positioning accuracy of the translation axes before delivery. The performance test sheet is included in the scope of delivery.

The following figure shows the test setup used.

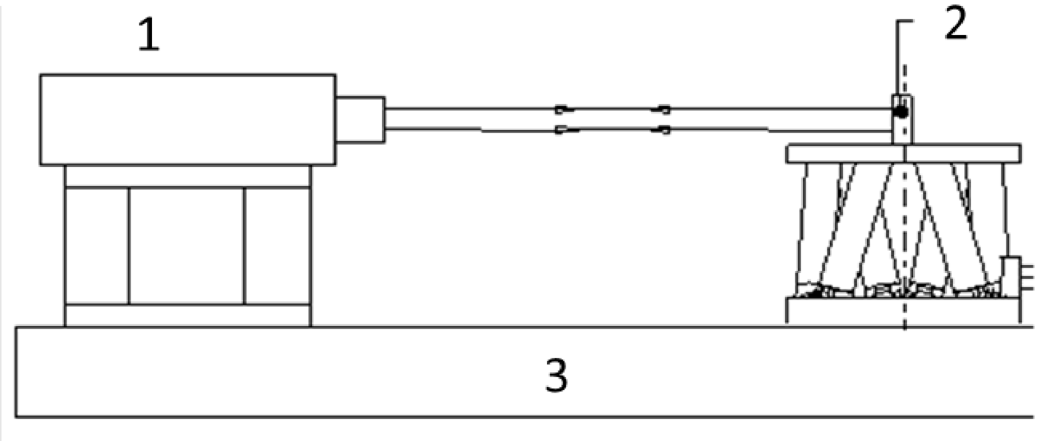


Figure 10: Test setup for measuring the X or Y axis.

1 Laser interferometer
2 Mirror
3 Bench

The following test cycles are performed:

- Motion over the entire travel range with at least 20 measuring points, in at least five cycles.
- Motion over partial sections, e.g., ±1 mm in increments of for example, 100 µm

13.2 European Declarations of Conformity

For the H-820, declarations of conformity were issued according to the following European statutory requirements:

EMC Directive

RoHS Directive

The standards applied for certifying conformity are listed below.

EMC: EN 61326-1

Safety: EN 61010-1

RoHS: EN IEC 63000