MS198E

H-810 Hexapod Microrobot

User Manual

Version: 2.0.0 Date: 22.06.2018

This document describes the following product:

- **H-810.D2**
  Miniature-Hexapod microrobot, direct drive,
  Sub-D connection, 5 kg load capacity,
  2.5 mm/s, 2 m cable set

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Subject to change. This manual is superseded by any new release. The latest respective release is available for download (p. 3) on our website.

Contents

1 About this Document

In this Chapter

1.1 Objective and Target Audience of this User Manual

This manual contains information on the intended use of the H-810.

It assumes that the reader has a fundamental understanding of basic servo systems as well as motion control concepts and applicable safety procedures.

The latest versions of the user manuals are available for download (p. 3) on our website.

1.2 Symbols and Typographic Conventions

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

CAUTION

Dangerous situation
If not avoided, the dangerous situation will result in minor injury.

➢ Actions to take to avoid the situation.

NOTICE

Dangerous situation
If not avoided, the dangerous situation will result in damage to the equipment.

➢ Actions to take to avoid the situation.

INFORMATION

Information for easier handling, tricks, tips, etc.

Symbol/Label	**Meaning**
1. 2.	Action consisting of several steps whose sequential order must be observed
➢	Action consisting of one or several steps whose sequential order is irrelevant
▪	List item
p. 5	Cross-reference to page 5
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.

1.3 Other Applicable Documents

The devices and software tools that are mentioned in this documentation are described in their own manuals.

Device/program	Document no.	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	Motion of the Hexapod. Position and Orientation in Space, Center of Rotation
PI Hexapod Simulation Tool	A000T0068	Determining the workspace and the permissible load of the hexapod
PC software included in the controller's scope of delivery	Various	For details, see the user manual for the C-887.5xx controller.

1.4 Downloading Manuals

INFORMATION

If a manual is missing or problems occur with downloading:

➢ Contact our customer service department (p. 41).

INFORMATION

For products that are supplied with software (CD in the scope of delivery), access to the manuals is protected by a password. Protected content is only displayed on the website after entering the access data.
You need the product CD to get the access data.

For products with CD: Get access data

1. Insert the product CD into the PC drive.
2. Switch to the Manuals directory on the CD.
3. In the Manuals directory, open the Release News (file including ***releasenews*** in the file name).
4. Get the access data for downloading protected content in the "User login for software download" section of the Release News. Possible methods for getting:
   – Link to a page for registering and requesting the access data
   – Direct input of user name and password
5. If the access data needs to be requested via a registration page:
   a) Follow the link in the Release News.
   b) Enter the required information in the browser window.
   c) Click ***Show login data*** in the browser window.
   d) Note the user name and password shown in the browser window.

Downloading manuals

If you have requested access data for protected contents via a registration page (see above):

➢ Click the links in the browser window to change to the content for your product and log in using the access data that you received.

General procedure:

1. Open the website **www.pi.ws**.
2. If access to the manuals is protected by a password:
   a) Click ***Login***.
   b) Log in with the user name and password.
3. Click ***Search***.
4. Enter the product number up to the period (e.g., P-882) or the product family (e.g., PICMA® Bender) into the search field.
5. Click ***Start search*** or press the Enter key.
6. Open the corresponding product detail page in the list of search results:
   a) If necessary: Scroll down the list.
   b) If necessary: Click ***Load more results*** at the bottom of the list.
   c) Click the corresponding product in the list.
7. Click the ***Downloads*** tab.

   The manuals are shown under ***Documentation***.
8. Click the desired manual and save it to the hard disk of your PC or to a data storage medium.

2 Safety

In this Chapter

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 intended use of the hexapod is only possible in conjunction with a suitable controller available from PI (p. 8), which coordinates all motion of the hexapod.

2.2 General Safety Instructions

The H-810 is built according to state-of-the-art technology and recognized safety standards. Improper use can result in personal injury and/or damage to the H-810.

- Only use the H-810 for its intended purpose, and only use it if it is in a good working order.
- Read the user manual.
- Immediately eliminate any faults and malfunctions that are likely to affect safety.

The operator is responsible for the correct installation and operation of the H-810.

2.3 Organizational Measures

User manual

- Always keep this user manual available with the H-810.
  The latest versions of the user manuals are available for download (p. 3) on our website.

- Add all information from the manufacturer to the user manual, for example supplements or technical notes.
- If you give the H-810 to other users, also include this user manual as well as other relevant information provided by the manufacturer.
- Only use the device on the basis of the complete user manual. Missing information due to an incomplete user manual can result in minor injury and damage to equipment.
- Only install and operate the H-810 after you have read and understood this user manual.

Personnel qualification

The H-810 may only be installed, started up, operated, maintained, and cleaned by authorized and appropriately qualified personnel.

3 Product Description

In this Chapter

3.1 Features and Applications

The H-810 hexapod achieves a velocity of up to 2.5 mm/s. It can be loaded with a maximum of 5 kg in a vertical orientation and with a maximum of 2.5 kg in any other orientation.

The parallel-kinematic design offers the following advantages:

- Positioning operations in six independent axes (three translational axes, three rotational axes) with short settling times
- The center of rotation moves together with the motion platform
- High accuracy and step resolution in all axes
- No accumulation of errors of individual axes
- No friction and torques from moving cables

The hexapod is controlled with a controller that can be ordered separately from PI (p. 8). The position commands to the controller are entered as Cartesian coordinates.

3.2 Model Overview

Model	Designation
H-810.D2	Miniature-Hexapod microrobot, direct drive, Sub-D connection, 5 kg load capacity, 2.5 mm/s, 2 m cable set

3.3 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. 41).

3.4 Product View

Figure 1: Product view

1 Motion platform
2 Strut
3 Power supply cable
4 Data transmission cable
5 Base plate

3.5 Scope of Delivery

Order number	Components
H-810	Hexapod according to your order (p. 7) Cables with a length of 2 m are installed permanently.
000015165	Steward snap-on ferrite
Packaging, consisting of:	
	▪ Outer box ▪ Inner box ▪ Top and bottom ring-shaped pad for securing the inner box ▪ Foam cover for the inner box ▪ Foam insert for the inner box ▪ Transport safeguard, consisting of three corrugated plastic sheets ▪ Pallet
Documentation, consisting of:	
H810T0001	Technical note on unpacking the hexapod
MS247EK	Short instructions for hexapod systems
Screw set:	
000020110	Mounting kit: ▪ 6 socket head screws, M4x25 ISO 4762 ▪ 1 hex key 3.0 DIN 911

3.6 Technical Features

3.6.1 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:

- One 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.

3.6.2 Reference Point Switch and Limit Switches

The reference point 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.

3.6.3 Control

Der hexapod is intended for operation with a suitable controller from PI (p. 8). The controller makes it 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 settings for the individual struts from the target positions given 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 reference move, in which each strut moves to its reference point switch. After the reference move, the motion platform is in the reference position and can be commanded to move to absolute target positions.

For further information, see the user manual for the controller.

3.6.4 Motion

The platform moves along the translational axes X, Y, and Z and around the rotational axes U, V, and W.

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 technical note.

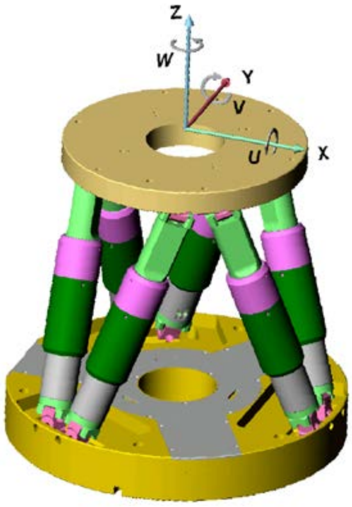


Figure 2: Coordinate system and rotations to the rotational coordinates U, V, and W. The coordinate system is depicted above the platform for better clarity.

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, see the glossary (p. 51).

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

For further information on the center of rotation, see the glossary (p. 51).

INFORMATION

The dimensional drawing (p. 46) contains the following:

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

Example: Consecutive rotations

INFORMATION

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.

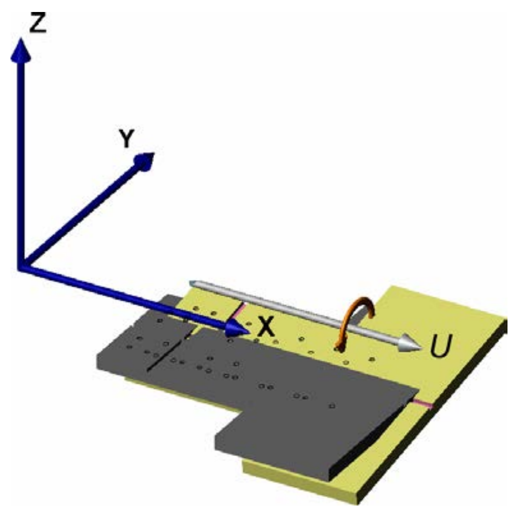


Figure 3: Rotation around the U axis

Platform in reference position

Platform position: U = 10 (U parallel to spatially-fixed X axis)

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.

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

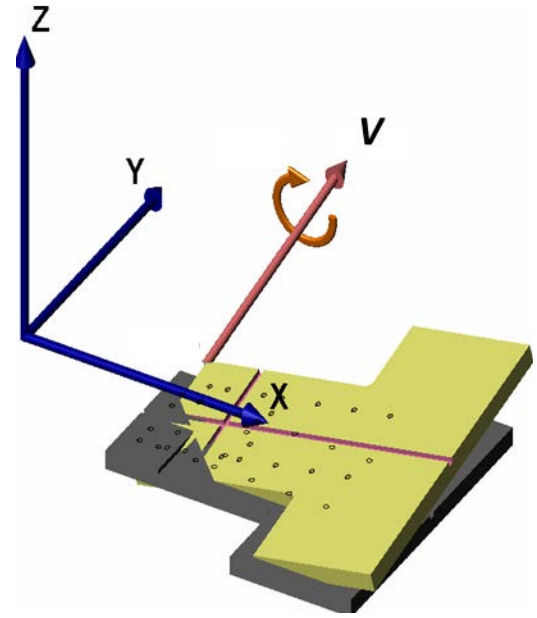


Figure 4: Rotation around the V axis

 Platform in reference position

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

3. The W axis is commanded to move to position 10.

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

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

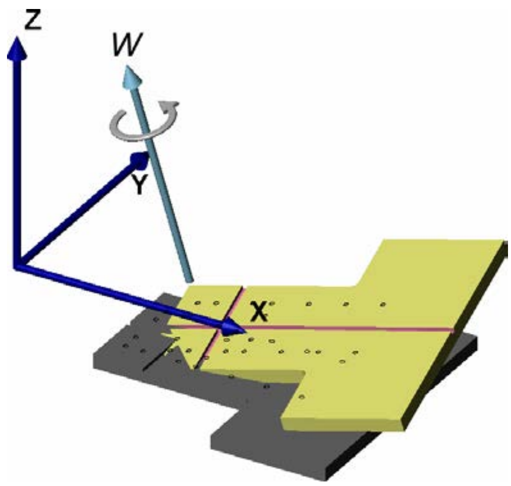


Figure 5: Rotation around the W axis

■ 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, see the "Specifications" section (p. 43).

3.6.5 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.

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

1. Open the outer box.

2. Remove the top ring-shaped pad from the inner box.
3. Lift the inner box out of the outer box.

4. Open the inner box.

5. Remove the foam cover.

6. Hold the hexapod by the base plate and take it out of the foam insert together with the connection cables.
7. Remove the plastic foil from the hexapod.
8. Compare the contents with the items listed in the contract and the packing list. If parts are incorrectly supplied or missing, contact PI immediately.
9. Inspect the hexapod for signs of damage. If you notice signs of damage, contact PI immediately.

10. Remove the transport safeguard:
    – Pull the three corrugated plastic sheets that are clamped between the base plate and the motion platform of the hexapod.

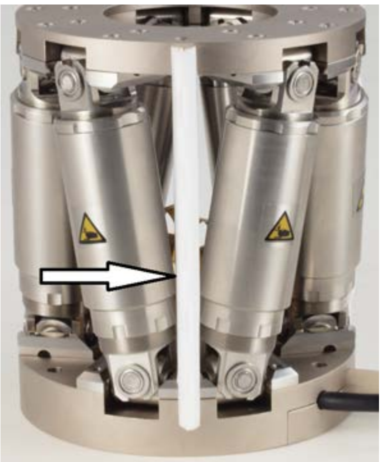


Figure 6: Hexapod with transport safeguard, one of three corrugated plastic sheets visible and marked with an arrow

11. Keep all packaging materials in case the product needs to be transported again later.

5 Installation

In this Chapter

5.1 General Notes on Installation

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.
- Before installing the load, determine the limit value for the load of the hexapod with a simulation program (p. 22).
  The limit values determined with the simulation program are only valid when the controller has the servo mode switched on for the axes of the motion platform of the connected hexapod.
- Before installing the load, determine the workspace of the hexapod with a simulation program (p. 22).
  The limits of the workspace vary according to the current position of the hexapod (translational and rotational coordinates) as well as the active coordinate system and the current coordinates of the center of rotation.
- If you do **not** mount the hexapod with a horizontally oriented base plate but in any other orientation:
  - Support the motion platform or the load appropriately when the servo mode or the controller is switched off.
- 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.

NOTICE

Cable break due to excessively bent or crushed cable!

A cable break leads to failure of the hexapod.

- Ensure that your application fulfills the following requirements for the cables permanently installed at your hexapod:
  - The cables are **not** subject to tensile stress.
  - The cables are **not** being moved.
- Secure the cables in a suitable manner.
- H-811.I2: Affix the permanently installed data transmission cable with the supplied connector holder (p. 10) to the surface.

INFORMATION

The optionally available PIVeriMove Hexapod software for collision checking makes it possible to check mathematically for possible collisions between the hexapod, load, and surroundings. The use of the software is recommended when the hexapod is located in a limited installation space and/or operated with a spatially limiting load. For details on activation and configuration of PIVeriMove, see the C887T0002 technical note (in the scope of delivery of the software).

5.2 Determining the Permissible Load and Workspace

Tools and Accessories

- PC with Windows operating system with the PI Hexapod Simulation Tool installed. For further information, see the A000T0068 technical note.

Determining the workspace and the permissible load of the hexapod

- Follow the instructions in the A000T0068 technical note to determine the workspace and the limit value for the load of the hexapod with the simulation program.

The limit values in the following table are for orientation. They only apply when the center of mass is at the origin of the default coordinate system (0,0,0).

	Servo mode switched on for hexapod – max. load capacity		**Servo mode switched off for hexapod – max. holding force**	
Mounting position of the base plate	Mounted horizontally	Mounted as desired	Mounted horizontally	Mounted as desired*
H-810.D2	5 kg	2.5 kg	15 N	–

* The struts of the hexapod have a very low self-locking threshold when the servo mode or the controller is switched off.

If you need help in determining the limit value for the load or determining the workspace:

- Contact our customer service department (p. 41).

5.3 Attaching the Snap-on Ferrite

Figure 7: Power supply cable of the hexapod with snap-on ferrite

1 Power supply cable of the hexapod
2 000015165 snap-on ferrite
3 M12 connector (m) (for connection to the controller)

INFORMATION

The snap-on ferrite ensures the electromagnetic compatibility of the hexapod system.

000015165 snap-on ferrite: The 000015165 snap-on ferrite is included in the scope of delivery of the hexapod. The snap-on ferrite is intended for permanent attachment to the power supply cable of the hexapod.

000012097 snap-on ferrite: When a cable set with line driver boxes is used, the 000012097 snap-on ferrite is included in the scope of delivery of the cable set. The snap-on ferrite is intended for permanent attachment to the hexapod-side cable of the power supply.

➢ When attaching the snap-on ferrite, make sure that it is correctly positioned on the cable. The snap-on ferrite can only be removed with special tools (not included in the scope of delivery).
➢ 000015165 snap-on ferrite: Attach the snap-on ferrite to the power supply cable of the hexapod before you connect the hexapod to the controller for the first time.
➢ 000012097 snap-on ferrite: Attach the snap-on ferrite to the hexapod-side cable of the power supply before connecting the hexapod to the power supply for the first time.

Tools and accessories

- 000015165 snap-on ferrite, included in the scope of delivery of the hexapod (p. 10)
- 000012097 snap-on ferrite, included in the scope of delivery of a cable set with the line driver boxes

Permanently attaching the snap-on ferrite

1. 000015165 snap-on ferrite:
   Put the power supply cable of the hexapod into the open snap-on ferrite close to and behind the M12 connector (m) that is intended for connection to the controller (see figure).
   000012097 snap-on ferrite:
   Put the hexapod-side cable of the power supply into the open snap-on ferrite approx. 10 to 15 cm behind the power supply (without figure).
2. Close the snap-on ferrite:
   a) Align the cable so that it is not squeezed when the snap-on ferrite is closed.
   b) Carefully press the two halves of the snap-on ferrite around the cable until the lock engages.

5.4 Grounding the Hexapod

If a functional grounding is required for potential equalization:

1. Connect the base plate to the grounding system:
   – Use one of the mounting holes with Ø 4.5 mm (p. 24) for connection.
2. Connect the motion platform to the grounding system:
   – Use one of the mounting holes in the motion platform (p. 46) for connection.
   or
   – If the motion platform and the load are connected conductively to each other, connect the load to the grounding system.

5.5 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 of the base plate!

Incorrect mounting can warp the base plate. Warping of the base plate reduces the accuracy.

➢ Mount the hexapod on an even surface. The recommended flatness of the surface is 100 µm.

Requirements

✓ You have read and understood the general notes on installation (p. 21).

Tools and accessories

- Hex key 3.0 and three of the supplied M4x25 screws (p. 10)

Mounting the hexapod

1. Drill three M4 threaded holes into the surface for mounting with M4x25 screws.

   The arrangement of the three mounting holes in the hexapod's base plate can be found in the dimensional drawing (p. 46).

2. Mount the hexapod on the three mounting holes in the base plate with the included screws.

5.6 Affixing 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.

➢ Make sure that the installed load observes the limit value resulting from the load test (p. 22).

➢ 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. 46) 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.

Requirements

- ✓ You have read and understood the general notes on installation (p. 21).
- ✓ You have determined the permissible load and the workspace of the hexapod (p. 22).
- ✓ You have designed the load and the surroundings of the hexapod so that the permissible load of the hexapod is observed and no collisions can occur.

Tools and accessories

- 3 M4 screws of suitable length
- Suitable tool for tightening the screws

Affixing the load

1. If you have **not** mounted the hexapod with a horizontally oriented base plate but in any other orientation, compensate for the low self-locking of the hexapod struts:

   a) Connect the hexapod to the controller (p. 27).

   b) Switch on the servo mode for the axes of the motion platform by switching on the controller (see manual for the controller).

   or

   – Support the motion platform or the load appropriately.

   The arrangement of the mounting holes in the motion platform of the hexapod can be found in the dimensional drawing (p. 46).
2. Use the screws to affix the load to the selected mounting holes in the motion platform.

5.7 Connecting the Hexapod to the Controller

Cables with a length of 2 m are installed permanently on the hexapod. Additional cable sets are available on request (p. 41). Cable sets with a length >20 m include line driver boxes (e.g., C-887.5A50 cable set with a length of 50 m).

NOTICE

Incorrect wiring!

When a cable set with line driver boxes is used:

Interchanging the cables between the channels of the line drive boxes causes the hexapod not to move or move uncontrollably. Uncontrolled motion of the hexapod can cause collision that can damage the hexapod, the load to be moved or the surroundings.

➢ When connecting the line driver boxes, observe the channel assignment that is specified on the labeling of the sockets and connectors.

INFORMATION

When a cable set with line driver boxes is used:

The **24 V Out 7 A** connection on the controller is not available for the hexapod because this connection is required for the power supply of the hexapod-side line driver box. A C-887.5PS power supply for the hexapod and a snap-on ferrite (000012097) are therefore included in the scope of delivery of the cable set.

➢ Attach the snap-on ferrite to the hexapod-side cable of the power supply (p. 23) before connecting the hexapod to the power supply for the first time.

Requirements

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

Tools and Accessories

- Optional: Additional cable set, available on request (p. 41)

Connecting the hexapod to the controller

➢ Connect the hexapod and the controller to each other:

– Observe the connection diagram that matches your cable set (see below).

– Observe the assignment that is given by the labeling on the sockets, connectors and cables.

– Observe the mechanical coding of connectors and sockets.

– Do not use force.

– Use the integrated screws to secure the connections against accidental disconnection.

Standard cabling (without line driver boxes)

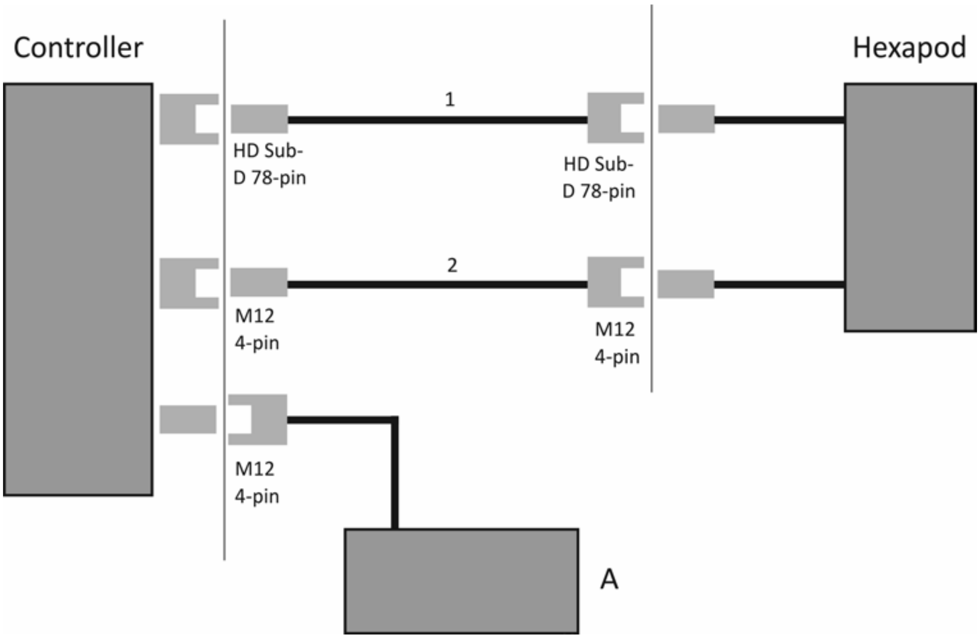


Figure 8: Connection diagram of cable set without line driver boxes

	Panel plug / connector, male
	Socket / connector, female
Controller	See "Suitable Controllers" (p. 8)
Hexapod	H-810.D2
A	C-887.5PS power adapter, from the scope of delivery of the controller, output 24 V DC
1	If the hexapod **cannot** directly be connected to the controller: additional data transmission cable, available on request (p. 41).
2	If the hexapod **cannot** directly be connected to the controller: additional power supply cable, available on request (p. 41).

Cabling with line driver boxes

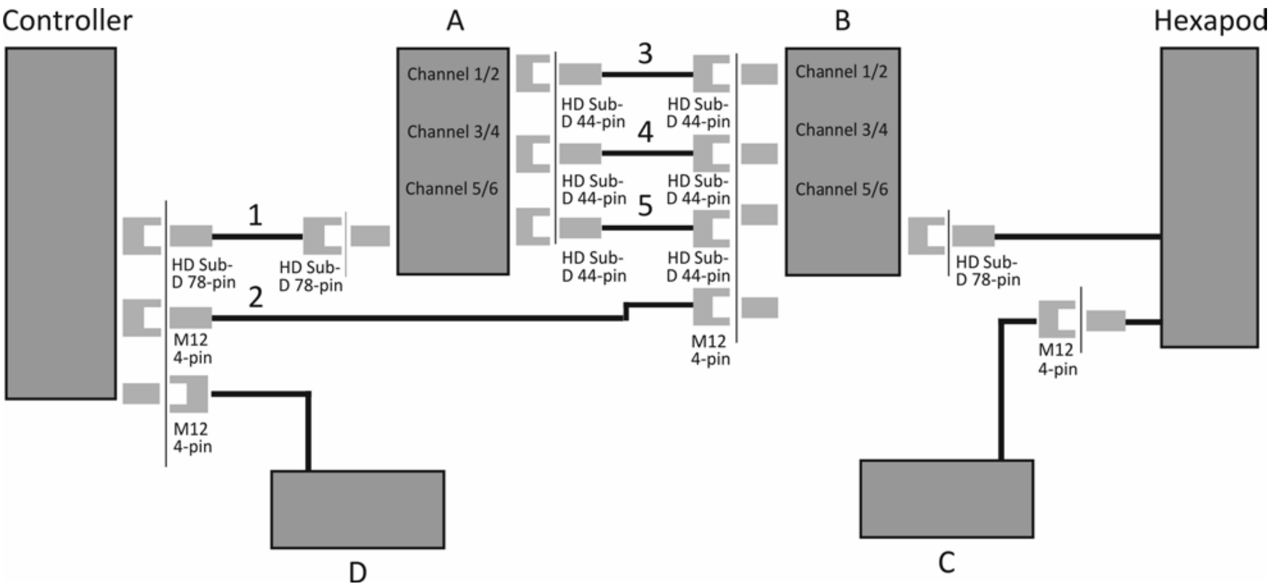


Figure 9: Connection diagram of cable set with line driver boxes

	Panel plug / connector, male
	Socket / connector, female
Controller	See "Suitable Controllers" (p. 8)
Hexapod	H-810.D2
A	C887B0057 controller-side line driver box, from the scope of delivery of the cable set*
B	C887B0058 hexapod-side line driver box, from the scope of delivery of the cable set*
C	C-887.5PS power adapter, from the scope of delivery of the cable set*, output 24 V DC
D	C-887.5PS power adapter, from the scope of delivery of the controller, output 24 V DC
1	Data transmission cable 3 m K040B0241, from the scope of delivery of the cable set*
2	Power supply cable for the hexapod-side line driver box, 47 m K060B0228, from the scope of delivery of the cable set*
3, 4, 5	Data transmission cable 44 m K040B0277, from the scope of delivery of the cable set* **Observe channel assignment!**

* Cable set used: C-887.5A50.

6 Startup

In this Chapter

6.1 General Notes on Startup

CAUTION

Risk of crushing by moving parts!

There is a 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 can get caught by moving parts.

NOTICE

Incorrect configuration of the controller!

The configuration data used by the controller (e.g., geometrical 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.

➢ Stop the motion immediately if a controller malfunction occurs.

NOTICE

Damage from unintentional position changes!

The self-locking of the hexapod struts is very low. Although the installed load complies with the limit value resulting from the load test (p. 22), it can trigger an unintentional change in the position of the hexapod if the servo mode or the controller is switched off and in addition, one of the following conditions is met:

- The hexapod is **not** mounted with a horizontally oriented base plate but in any other orientation.
- The hexapod is mounted with a horizontally oriented base plate and is **not** in the reference position.

As a result of unintentional position changes, the actuators in the hexapod struts can be damaged, and collisions between the hexapod, the load to be moved and the surroundings are possible. Collisions can damage the hexapod, the load to be moved or the surroundings.

➢ Support the motion platform or the load appropriately when the servo mode or the controller is switched off.

6.2 Starting Up the Hexapod System

Requirements

✓ You have read and understood the general notes on startup (p. 31).

✓ You have correctly installed the hexapod, i.e., you have mounted the hexapod onto a surface, affixed the load to the hexapod and connected the hexapod to the controller according to the instructions in "Installation" (p. 21).

✓ You have read and understood the user manual of the controller.

Accessories

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

Starting up the hexapod system

1. Start up the controller (see user manual of the controller).
2. Perform a few motion cycles for testing purposes (see user manual of the controller).

7 Maintenance

In this Chapter

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. 43).

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

Depending on the operational 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 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.

NOTICE

Cable break due to excessively bent or crushed cable!
A cable break leads to failure of the hexapod.

- ➢ Pack the hexapod so that the cables are not bent or crushed too much.

Accessories

- Original packaging (p. 10)
- Transport safeguard (p. 10)
- 4 cable ties

Packing the hexapod

1. Command a motion of the hexapod 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 the three M4x25 screws with which the hexapod is mounted on the surface.

   e) Remove the three M4x25 screws.

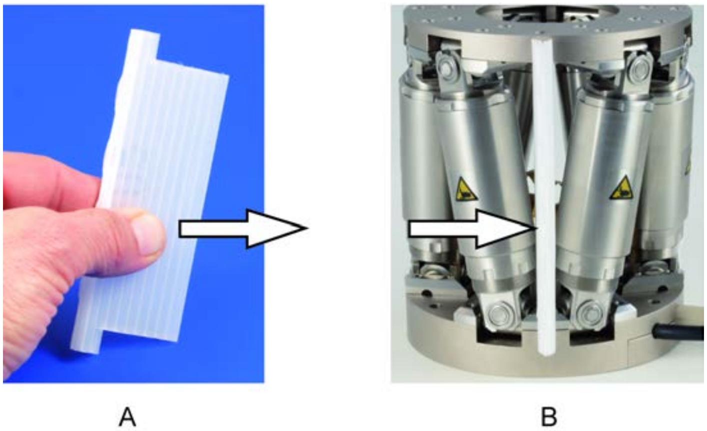


Figure 10: Inserting the corrugated plastic sheet of the transport safeguard into the hexapod

A Transport safeguard: one of three corrugated plastic sheets
B Hexapod with transport safeguard

3. Place the transport safeguard between the base plate and the motion platform:
   - Insert the three corrugated plastic sheets between the strut pairs that are arranged in a V-shape (see figure above).
4. Prepare the cables on the hexapod for packing. Do **not** bend the cables:
   - Wind the power supply cable with a diameter of approx. 15 cm and secure it with two cable ties.
   - Wind the data transmission cable with a diameter of approx. 15 cm and secure it with two cable ties.
5. Wrap the hexapod in a plastic foil to protect it against dirt.
6. Open the outer box.
7. Remove the top ring-shaped pad from the inner box.
8. Lift the inner box out of the outer box.
9. Open the inner box.
10. Remove the foam cover.

11. Hold the hexapod by the base plate and place the hexapod and the cables into the corresponding recesses in the foam insert of the inner box.

12. Place the foam cover in the inner box so that the hexapod fits in the corresponding recess of the cover and the cables are not squeezed.
13. Close the inner box.
14. Make sure that the bottom ring-shaped pad is in the outer box. The feet of the ring-shaped pad must be facing downwards.
15. Put the inner box into the ring-shaped pad in the outer box.

16. Place the top ring-shaped pad on the inner box.
17. Close the outer box.
18. Secure the box on the pallet.

7.3 Cleaning the Hexapod

Requirements

- ✓ You have disconnected the hexapod from the controller.

Cleaning the hexapod

- ➢ When necessary, clean the surface of the hexapod with a cloth dampened lightly with a mild cleanser or disinfectant.

8 Troubleshooting

Problem	Possible causes	Solution
Unexpected hexapod behavior.	▪ Cable defective ▪ 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. 41).
The hexapod does not achieve the specified accuracy.	▪ Warped base plate	➢ Mount the hexapod onto an even surface (p. 24). The recommended flatness of the surface is 100 µm.
	▪ Increased wear due to small motion over a long period of time	➢ Perform a maintenance run over the entire travel range (p. 33).
The hexapod does not move.	▪ Worn drive screw ▪ Foreign body has entered the drive screw ▪ Faulty motor ▪ Blocked or broken joint ▪ Dirty encoder	➢ Carry out a strut test (see user manual for the controller). The strut test should be carried out in the reference position, unless the malfunction occurs with maximum or minimum displacement of the platform in Z. ➢ Contact our customer service department (p. 41).
The hexapod does not move.	Controller with **E-Stop** socket: ▪ Nothing connected to **E-Stop** ▪ "Break contact" is active on **E-Stop** In both cases, the **24 V Out 7 A** output of the controller is disabled.	Controllers with the **E-Stop** socket support the "Motion Stop" functionality, with which the motion of the hexapod can be stopped with external devices (pushbuttons, switches). 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

Problem	Possible causes	Solution
		with "Make contact" (for details, see 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 reference move is not necessary
The hexapod does not move.	▪ Incorrect or missing configuration data	➢ Send the CST? command. The response shows the hexapod, to which the controller is adapted. ➢ 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. 41) in order to receive valid configuration data.

If the problem with your hexapod is not listed in the table or cannot be solved as described, contact our customer service department (p. 41).

9 Customer Service

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

- If you have questions concerning your system, have the following information ready:
  - Product and serial numbers of all products in the system
  - Firmware version of the controller (if available)
  - Version of the driver or the software (if available)
  - Operating system on the PC (if available)
- 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 (p. 3) on our website.

10 Technical Data

In this Chapter

10.1 Specifications

10.1.1 Data Table

Motion and positioning	H-810.D2	Unit	Tolerance
Active axes	X, Y, Z, θ_X, θ_Y, θ_Z		
Travel range* X, Y	±20	mm	
Travel range* Z	±6.5	mm	
Travel range* θ_X, θ_Y	±10	°	
Travel range* θ_Z	±30	°	
Actuator design resolution	40	nm	
Min. incremental motion X, Y	1	µm	typ.
Min. incremental motion Z	0.5	µm	typ.
Minimum incremental motion θ_X, θ_Y	15	µrad	typ.
Minimum incremental motion θ_Z	30	µrad	typ.
Backlash X, Y	1	µm	typ.
Backlash Z	0.5	µm	typ.
Backlash θ_X, θ_Y	15	µrad	typ.
Backlash θ_Z	30	µrad	typ.
Repeatability X, Y	±0.5	µm	typ.
Repeatability Z	±0.1	µm	typ.
Repeatability θ_X, θ_Y	±3	µrad	typ.
Repeatability θ_Z	±15	µrad	typ.

Motion and positioning	H-810.D2	Unit	Tolerance
Max. velocity X, Y, Z	2.5	mm/s	
Max. velocity $θ_X$, $θ_Y$, $θ_Z$	60	mrad/s	
Typ. Velocity X, Y, Z	2	mm/s	
Typ. Velocity $θ_X$, $θ_Y$, $θ_Z$	50	mrad/s	

Mechanical properties	H-810.D2	Unit	Tolerance
Load capacity (horizontal base plate / any orientation)	5 / 2.5	kg	max.
Holding force (horizontal base plate)	15	N	max.
Motor type	Brushless DC motor		

Miscellaneous	H-810.D2	Unit	Tolerance
Operating temperature range	0 to 50	°C	
Material	Stainless steel, aluminum		
Mass	1.7	kg	±5 %
Cable length	2	m	±10 mm
Recommended controller	C-887.5x		

Technical data specified at 20±3 °C.

* The travel ranges of the individual coordinates (X, Y, Z, θX, θY, θZ) are interdependent. The data for each axis in this table shows its maximum travel range, where all other axes and the pivot point are at the reference position.

10.1.2 Maximum Ratings

The hexapod is designed for the following operating data:

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

10.2 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

10.3 Dimensions

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

The figure shows the hexapod in the reference position.

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 the reference position, the center of rotation is located at the origin of the coordinate system.

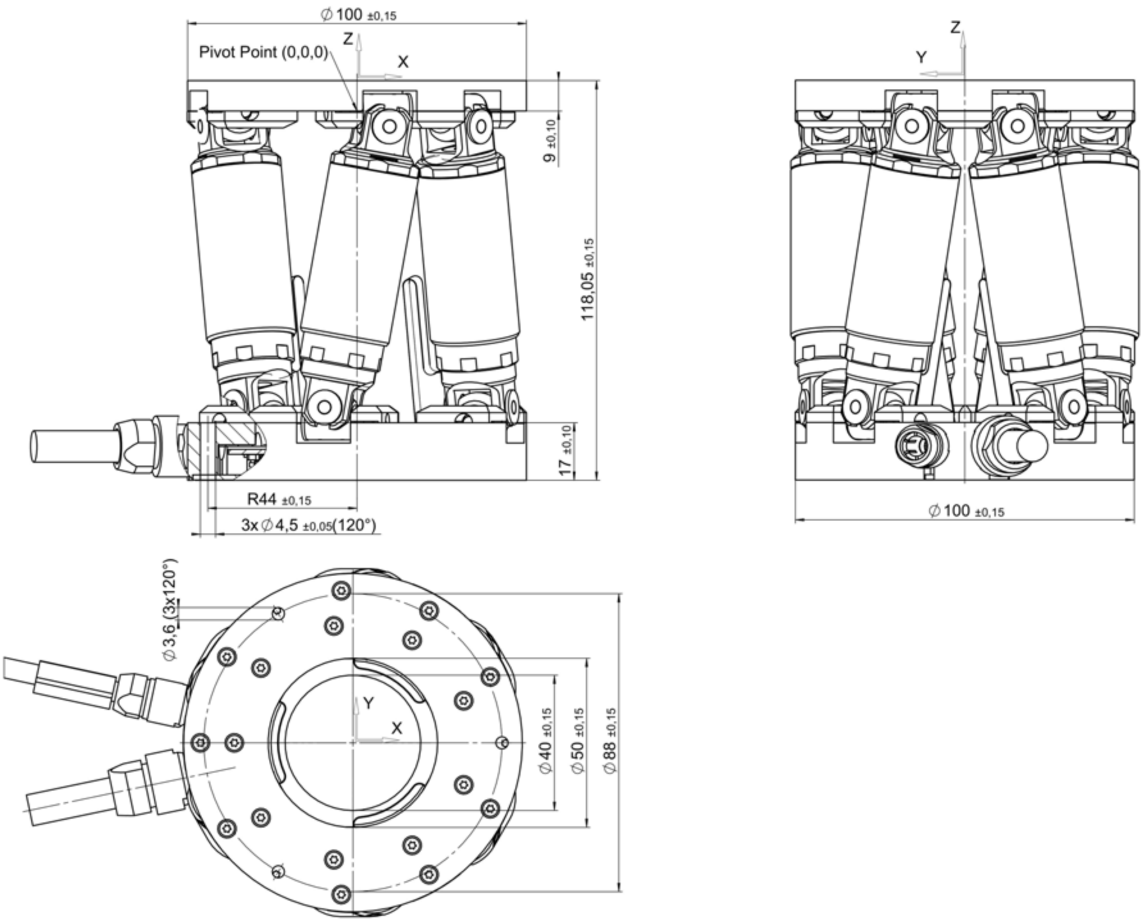
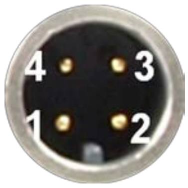


Figure 11: H-810.D2 hexapod (dimensions in mm)

10.4 Pin Assignment

10.4.1 Power Supply Connection

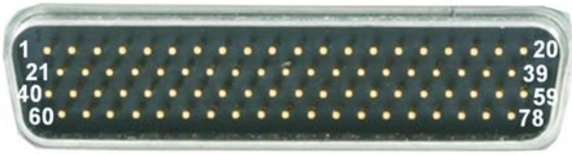
Power supply via 4-pin M12 Connector

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

10.4.2 Data Transmission Connection

Data transmission between hexapod and controller

Connector HD Sub-D 78 m

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 equipment according to international, national, and local rules and regulations.

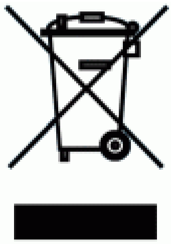
In order to fulfil its responsibility as the product manufacturer, Physik Instrumente (PI) GmbH & Co. KG undertakes environmentally correct disposal of all old PI equipment made available on the market after 13 August 2005 without charge.

Any old PI equipment can be sent free of charge to the following address:

Physik Instrumente (PI) GmbH & Co. KG

Auf der Roemerstr. 1

D-76228 Karlsruhe, Germany



12 Glossary

User-defined coordinate system

Using the controller, custom coordinate systems can be defined and used instead of the default 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 combinations of translations and rotations that the hexapod can approach from the current position is referred to as the workspace.

The workspace can be limited by the following external factors:

- Installation space
- Dimensions and position of the load

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 reference move is located at the origin of the coordinate system (0,0,0), see the dimensional drawing of the hexapod (p. 46).

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, cable set, and power supply is referred to as "hexapod system" in this manual.

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.

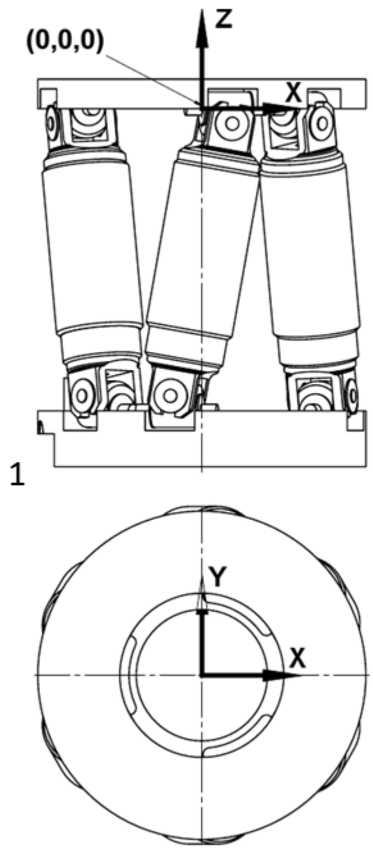


Figure 12: H-810 hexapod in the reference position.

1 Cable exit

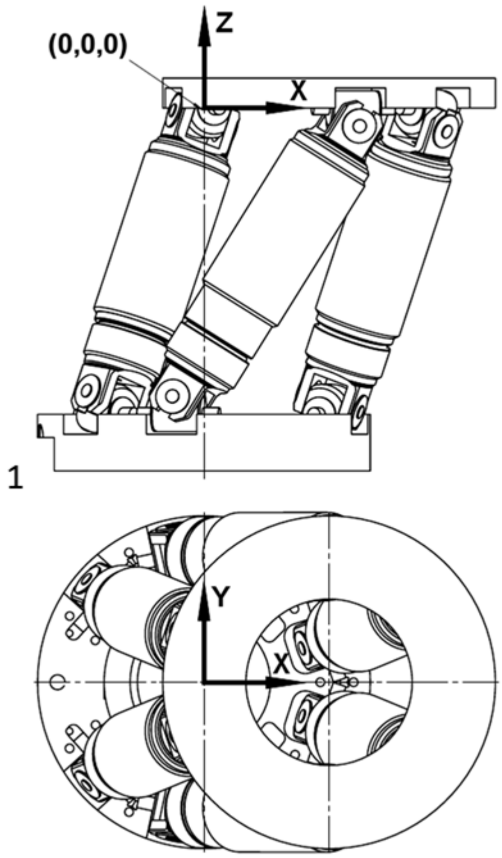


Figure 13: H-810 hexapod, the platform of which has been moved in X.

1 Cable exit

13 Appendix

In this Chapter

13.1 Explanations of the Performance Test Sheet

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

The following figure shows the test setup used.

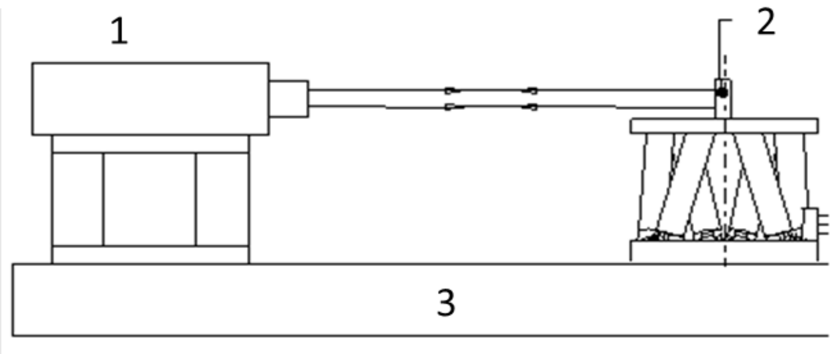


Figure 14: Test setup for measuring the X or Y axis.

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, 10 µm

13.2 EU Declaration of Conformity

For the H-810, an EU Declaration of Conformity has been issued in accordance with the following European directives:

EMC Directive

RoHS Directive

The applied standards certifying the conformity are listed below.

EMC: EN 61326-1

Safety: EN 61010-1

RoHS: EN 50581