



# Precision Parallel Positioners

6-AXIS HEXAPODS & SPACEFABS WITH NANOMETER RESOLUTION

## Product Overview

parallel-kinematic systems, Hexapods, controllers, software



**H-850**  
**6-Axis Hexapod**  
For Loads of up to 250 kg

- Travel ranges to 100 mm / 60°
- Vacuum-compatible version to 10<sup>-6</sup> hPa
- For high loads



**H-840**  
**6-Axis Hexapod**  
High Velocity, Medium Load, Affordable

- Travel ranges to 100 mm / 60°
- Cost-effective



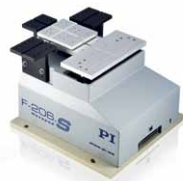
**H-824**  
**6-Axis Hexapod**  
Low-Profile, Precision Parallel-Kinematic System

- Travel ranges to 45 mm / 25°
- Vacuum-compatible version to 10<sup>-6</sup> hPa
- Cost-effective



**H-811**  
**6-Axis Miniature Hexapod**  
Fast, Compact and Highly Precise

- Travel ranges to 34 mm / 42°
- Especially compact
- Vacuum-compatible version to 10<sup>-6</sup> hPa



**H-206**  
**6-Axis Precision Alignment System**  
Ideal for Fiber Alignment

- Bidirectional repeatability 0.3 µm
- Min. incremental motion 0.1 µm / 2 µrad



**SF-3000 BS**  
**PI miCos SpaceFAB**  
6-Axis Positioning System

- Travel ranges to 100 mm / 10°
- Vacuum-compatible version to 10<sup>-9</sup> hPa



**H-810**  
**6-Axis Miniature Hexapod**  
High Precision in a Small Package

- Travel ranges to 40 mm / 60°
- Especially compact

## Product Overview

PARALLEL-KINEMATIC SYSTEMS, HEXAPODS, CONTROLLERS, SOFTWARE



**P-911KNMV**  
**UHV-Compatible Miniature**  
**Piezo Hexapod**

High-Precision Positioning even in  
Strong Magnetic Fields

- Travel ranges to  
1.5 mm / 2°
- Non-magnetic
- Vacuum-compatible  
version to 10<sup>-6</sup> hPa
- Especially compact



**M-850KHLH**  
**Vacuum-Compatible High-Load**  
**Hexapod**

Precise Positioning of Loads of  
up to 1 Ton

- Vacuum-compatible  
version to 10<sup>-6</sup> hPa
- For high loads
- Repeatability to 2 µm



**M-850KHTH**  
**1000 kg High-Load Hexapod**

6 Axes, Large Travel Range, Accuracy  
in the Micrometer Range

- Travel ranges to  
400 mm / 40°
- For high loads



**M-850KPAH**  
**6-Axis Positioner**

Low-profile Precision Positioning System  
for Large Surface Loads to 200 KG

- Travel ranges to  
100 mm / 6°
- For high loads



**M-850KWAH**  
**Weather-Resistant Hexapod**  
**for Astronomy**

Precision 6-Axis Positioner for  
Outdoor Applications

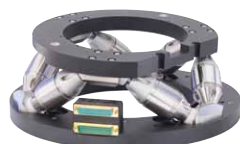
- Clear aperture  
Ø 420 mm
- Long lifetime:  
2 million cycles



**N-510KHFS**  
**High-Stiffness Nanopositioning**  
**Z Stage with NEXLINE® Piezomotors**

High-Precision Vertical Positioning,  
with Capacitive Feedback

- Travel range 400 µm  
coarse, 40 µm fine
- Closed-loop resolution  
to 2 nm



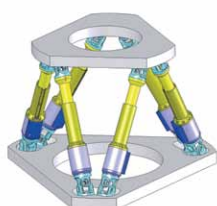
**N-515KNPH**  
**Non-Magnetic Piezo Hexapod**

6-Axis Precision Positioning System  
with NEXLINE® Piezo Stepping Drives

- Travel ranges  
10 mm, 6°
- Non-magnetic
- Nanometer-resolution

## Product Overview

PARALLEL-KINEMATIC SYSTEMS, HEXAPODS, CONTROLLERS, SOFTWARE



### H-845

#### Modular, Scalable Hexapod Concept

Faster Custom Designs for Extreme Loads

- Scalable travel ranges
- For high loads



### C-887

#### Controller for Hexapod Positioning Systems

6-D Vector Motion Control, Comprehensive Functionality

- Optional control of additional motion axes
- Extensive software support



### Software from PI

Effective and Comfortable Solutions

- Rapid start-up
- Universal command set
- Dedicated Hexapod software



### C-843KALM

#### Hexapod Controller for Use at High Altitudes

Signal Transmission over Long Distances

- Works under extreme environmental conditions



### E-712KNHC

#### High-End Digital Motion Controller

For Multiaxis Systems With Piezo Stepping Drives and Complex Control Loops

- Digital motion controller for Hexapods with piezo stepping drives
- Optional control of additional motion axes



### Application Examples

- Control designs
- Handling systems, tool inspection, Medical technology, space telescopes, ...



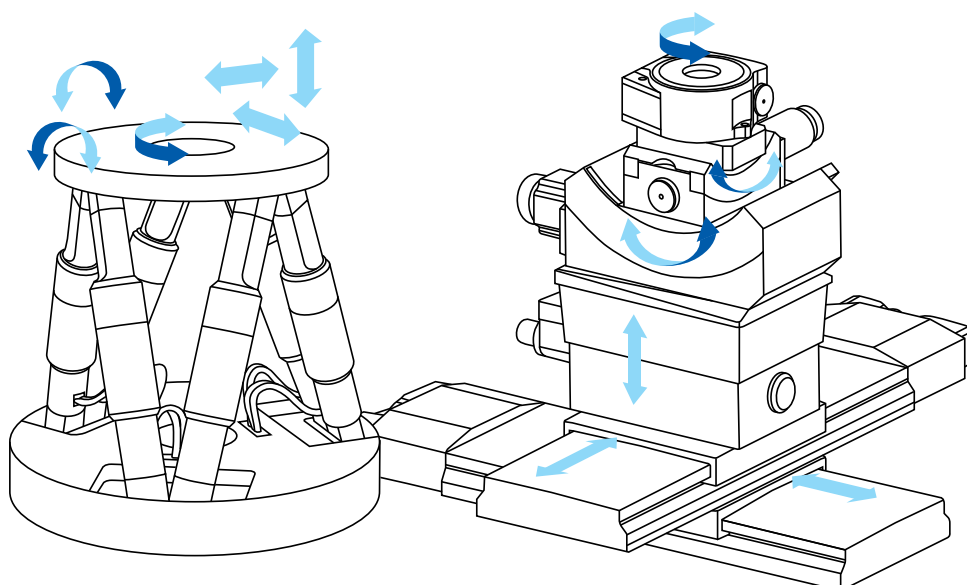
### Accessories

for Hexapod systems

- Manual control unit
- Fiber nanopositioning system
- Extension cable set

# Hexapods – Parallel-Kinematics Positioning Systems

HIGH-PRECISION MOTION CONTROL IN UP TO SIX AXES



## Compact positioning system with 6 degrees of freedom

Hexapod platforms are used for precision positioning and alignment of loads in all six degrees of freedom, three linear axes, and three rotational axes.

Hexapods have a parallel-kinematics structure, i.e., the work piece is actuated simultaneously by multiple actuators, rather than taking a stacked approach. The parallel arrangement of the actuators optimizes the overall system stiffness and allows for a large central aperture.

## Precise positioning of loads from 2 kg to 2000 kg

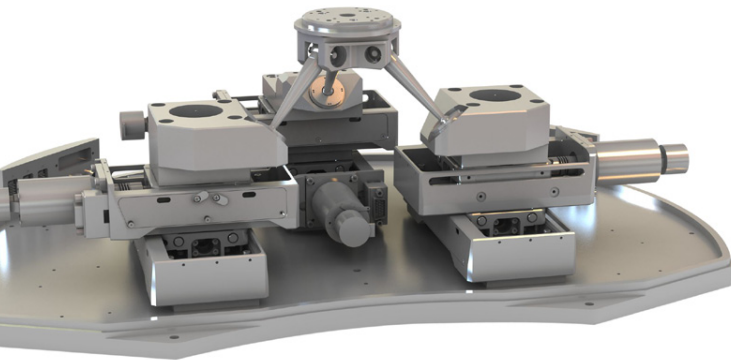
Depending on their design, Hexapods can position loads from several kg up to several tons in any spatial orientation, in other words independently of the mounting orientation and with submicrometer precision.

## Advantages over serial kinematics design

Hexapods can be designed considerably more compact than serially stacked multi-axis positioning systems and there are no moving cables to increase the footprint. Since only a single lightweight platform is actuated the moving mass is significantly smaller, too. This results in improved dynamics with considerably faster response and reduced step-and-settle times. Furthermore, there are no cable management issues as with serial-kinematics multi-axis positioners. Here friction and torque caused by the cables reduce the positioning accuracy and repeatability.

This principle where the lowest axis not only moves the mass of the payload but also the mass all other positioning mechanics above reduces the stiffness and dynamic performance and results in the accumulation of individual off-axis errors.

- Large central aperture
- Three linear axes, three rotational axes
- Low moving mass, low inertia
- Excellent dynamic behavior, fast step-and-settle
- Small installation space
- High stiffness
- Freely definable pivot point
- Minimized axis crosstalk motion
- Very good repeatability



If the stiffness requirements of the total system are lower, a 3-strut design can also be used in which additional degrees of freedom are produced because a passive strut can be moved in two or more axes. Example: In the SpaceFAB the individual struts are driven by one XY translation stage each (figure: PI miCos GmbH)

## Selection of the mechanical components

A Hexapod is more than the sum of its individual parts. All components have to be carefully selected and designed with the idea of multi-axis motion in mind. This starts with the use of backlash-free mechanical parts and thermally matched materials. The joints also play a very important part because there are 12 of them and all are involved in every move the Hexapod makes. The precision of every strut (actuator) itself is important, too, however it is not enough to equip these actuators with high-resolution sensors and hope the Hexapod system accuracy will be identical to the sensor resolution. On the contrary, there are other more important factors.

## Motors and drives

PI Hexapods are based on electromechanical or piezoelectric drives and differ significantly from the hydraulic Hexapods known from flight or driving simulators. Depending on the application, direct-drive designs or gear motors are used, rollerscrews or ballscrews, brushless motors and even linear motors are employed. PI also makes non-magnetic and EUV compatible Hexapods.

## Joints

A number of different joint designs is also available to optimize the Hexapods. If high load capacity and overall stiffness are important universal joints with two orthogonally arranged axes, i.e. two degrees of freedom, are the premium choice.

Ball and socket joints offer more degrees of freedom in a relatively simple design. However, the overall stiffness and precision in case of external loads and torque can suffer. A compensating preload is recommended

but requires drives with high output forces such as the NEXLINE® piezo walk motors shown in the figure here.

If the highest precision is required, flexure joints are recommended. They exhibit neither friction nor backlash and do not require lubricants. However, they only work over relatively small travel ranges.

## The work space

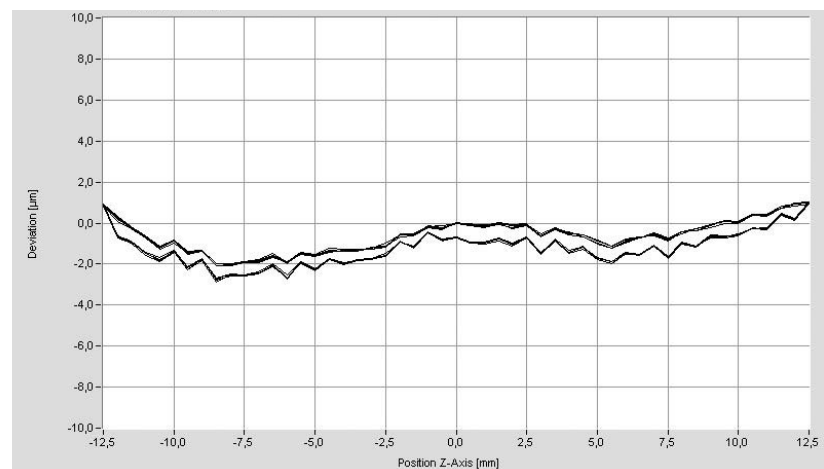
In addition to linear motion, the Hexapod platform can carry out any combination of tilting and rotation around a freely selectable pivot point. Due to the parallel kinematics design, the work space is also not limited by cables movement and cable management systems.



Universal joints of the H-840 Hexapod model



Ball and socket joints

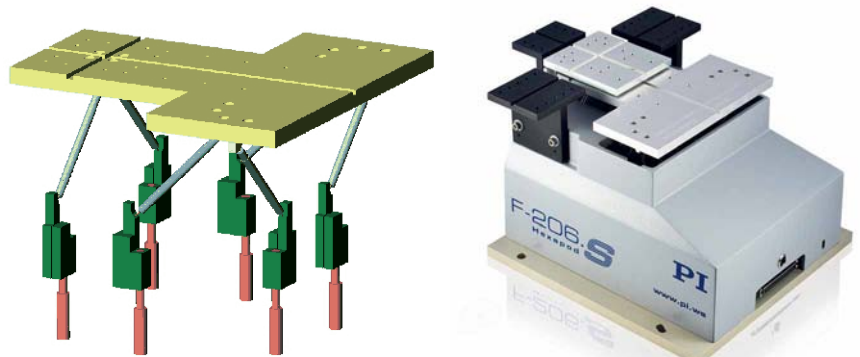


The Z-axis positioning accuracy of an H-824 Hexapod over 25 mm full travel is in the range of a few micrometers only, with the repeatability well below  $\pm 0.1 \mu\text{m}$



## Hexapods with passive struts

Instead of variable, active struts, Hexapods can be designed with passive struts that show constant strut length. In this case the coupling points or joints are usually moved along a linear path. This design is advantageous when the drive unit is to be separated from the platform, e.g., outside of vacuum chambers.



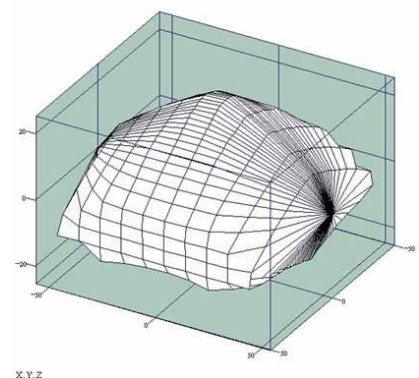
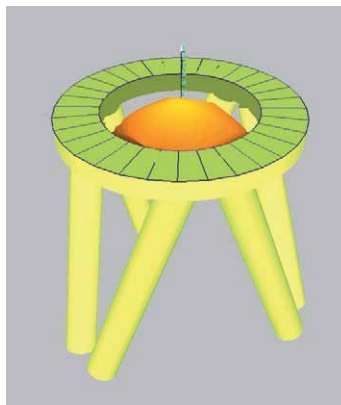
Constant strut-length Hexapod design. The drive units move the joint position up and down affecting the linear and rotary position of the platform

## Advanced motion control

The individual drives of a Hexapod do not necessarily point in the direction of motion, which is why a powerful controller that can handle the required coordinate transformations in real time is needed.

PI uses advanced digital controllers along with user-friendly software. All motion commands are specified in Cartesian coordinates, and all transformations to the individual actuators take place inside the controller.

An important Hexapod property is the freely definable pivot point. The possibility to rotate around any point in space opens up new applications from fiber alignment to astronomy.



The entirety of all combinations of translations and rotations that a Hexapod can approach from any given position is called the work space; it is given in reference to the origin of the coordinate system used. The work space can be limited by external factors such as obstacles or the position and size of the load

## Application examples

FOR HANDLING SYSTEMS, TOOL INSPECTION, MEDICAL TECHNOLOGY, SPACE TELESCOPES, ...

### Patient positioning in radiotherapy

In modern medical technology, a Hexapod can help in radiation treatment, for example: the Hexapod makes sure the patient is brought into exactly the right position and orientation. This makes it possible to precisely direct the radiation and mitigate the effect on surrounding tissue (figure: courtesy of CIVCO Medical Solutions).



### Positioning of telescope reflectors

In the ALMA project (Atacama desert, Chile), up to 64 antennas are combined to form a virtual single giant radio telescope. PI M-850k Hexapods are integrated to position the secondary reflectors in the antennas. The M-850K mechanics and controllers, specially designed for operation in hostile conditions, can position loads of up to 75 kg with sub-micron resolution (figure: © ALMA: ESO/NAOJ/NRAO).



### Magnetic levitation platform

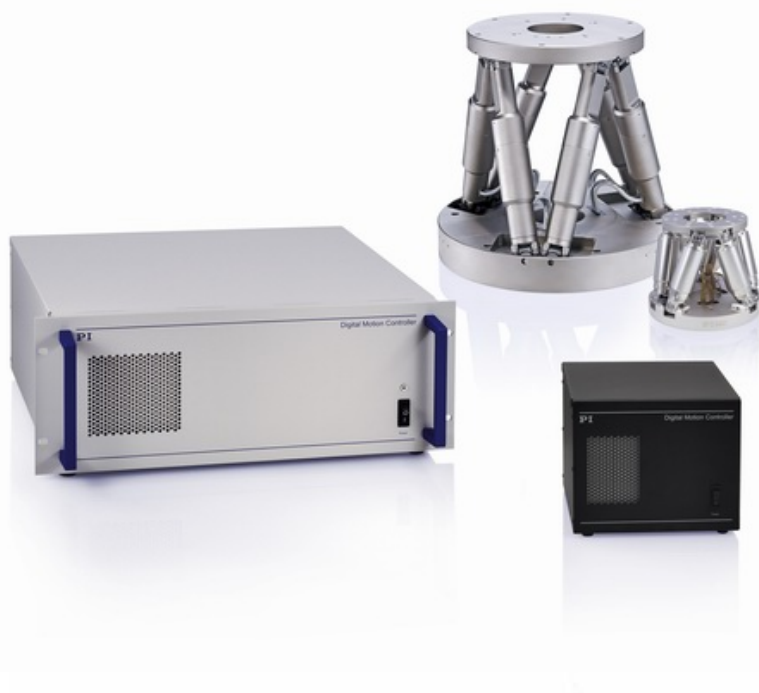
An unusual example of a Hexapod positioning system: instead of struts, magnetic fields ensure that the platform assumes and maintains the desired position. The relatively large XY motions are accompanied by small angles and Z displacements with accuracy in the nanometer range. The control and operation is performed by a digital controller. In addition to high accelerations and velocities the system is frictionless, vacuum compatible and does not generate any particles.





## Controller for Hexapod Positioning Systems

6-D VECTOR MOTION CONTROL, COMPREHENSIVE FUNCTIONALITY



### C-887

- Sophisticated controller using vector algorithms
- Freely programmable, virtual pivot point
- Data recorder
- Macro program functionality
- Stand-alone operation possible and control through TCP/IP and RS-232 interfaces
- Extensive software support

#### Digital controller for 6-axis-parallel kinematics

Included in the delivery of all PI standard Hexapod systems

- C-887.11, 19" controller, comprises the control for two additional single axes with servo motors, the functionality can be enhanced with many additional options
- C-887.21 compact bench-top controller for a lower system price

Extensive software support

#### Functions

Real-time system. Position control using Cartesian coordinates, vectorized motion. Stable, virtual pivot point can be defined freely in the working space. Data recorder for recording operating parameters such as motor control, velocity, position or position error. Macro command language. Stand-alone operation possible with Autostart macro or connection of keyboard and monitor. Optional: Manual control unit

#### Custom designs

Custom designs are available for use at high altitudes, e.g. for astronomical telescope applications. Processing of absolute sensors. Control of motor brakes. Processing of additional (redundant) position sensors for increased safety requirements, e.g. in medical technology

#### Software

PIMikroMove user software. Common command set for all PI positioning systems. Shared libraries for Windows and Linux. Complete set of LabVIEW VI's. Graphical user interfaces, configuration software and graphically displayed scan routine.

Optional: PIVeriMove software for checking a restricted operating space

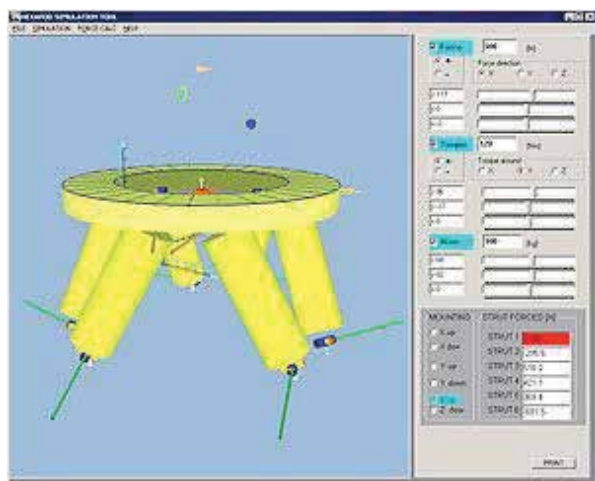
#### Interfaces

TCP/IP Ethernet can also be used for remote control and service, RS-232. Monitor, mouse and keyboard interface. On request: RS-422 for up to 1.4 km cable length

#### Possible enhancements for C-887.11

- Analog interfaces/photometer cards for visible light (F-206.VVU) or the infrared light range (F-206.iiU)
- F-206.NCU fast piezo nano-alignment system for alignment with nanometer precision

	C-887.11	C-887.21
Function	6-D controller for Hexapods, 19", incl. control of two additional single axes, can be enhanced with many options	6-D controller for Hexapods, compact bench-top for a lower system price
Drive type	Servo motors (Hexapod and additional axes) Optional: Piezo drives	Servo motors
<b>Motion and control</b>		
Servo characteristics	32-bit PID filter	
Trajectory profile modes	Trapezoid, linear interpolation	
Processor	CPU: 1.8 GHz, motion control chip with 2.5 kHz servo update rate	
Encoder input	AB (quadrature) differential TTL signal, 5 MHz	
Stall detection	Servo off, triggered by position error	
Reference point switch	TTL signal	
<b>Electrical properties</b>		
Max. output power per channel	10-bit output for PWM drivers, 24 kHz	
Max. output voltage per channel	TTL in PWM operation for SIGN and MAGN	
<b>Interface and operation</b>		
Communication interfaces	TCP/IP, RS-232 VGA (monitor), USB (keyboard, mouse, manual control unit)	
Hexapod connection	MDR, 68-pin for data transmission M12 4-pin. for power supply	
Connection for additional single axes	15-pin sub-D	–
I/O ports	Optional: Analog inputs (photometer cards)	–
Command set	PI General Command Set (GCS)	
User software	PIMikroMove	
Software drivers	LabVIEW driver, shared libraries for Windows and Linux	
Manual control	Optional: C-887.MC control unit for Hexapods	
<b>Miscellaneous</b>		
Operating voltage	100 to 240 VAC, 50 / 60 Hz	
Operating temperature range	5 to 40°C	
Mass	11 kg	5 kg
Dimensions	395 x 483 x 185 mm	255 x 226 x 185 mm



All PI Hexapod systems are delivered with an extensive software package. Included are simulation programs that calculate the working space of the Hexapod and the individual loads on each actuator depending on the Hexapod orientation in space



Highly advanced digital controllers are also available for Hexapods with piezo stepping drives which are suitable for operation in strong magnetic fields or UHV environments

## Hexapod Controller for Use at High Altitudes

SIGNAL TRANSMISSION OVER LONG DISTANCES

### C-843K



- Differential transmission of the control signals over long distances
- Control via TCP/IP
- Cooling system and special case
- Sophisticated controller using vector algorithms
- Freely programmable, virtual pivot point
- Data recorder
- Macro program functionality
- Extensive software support

In the ALMA project (Atacama desert, Chile), up to 64 antennas are combined to form a virtual single giant radio telescope. Not only the Hexapod systems from PI, which position the secondary reflectors in the antennas, must be adapted to the extreme ambient conditions but also the controllers that send their commands sometimes over distances of several hundreds of meters. This robust Hexapod controller is dedicated for use under such conditions and it can, therefore, easily dissipate heat even in thin mountain air and does not require a fan

## High-End Digital Motion Controller

FOR MULTIAxis SYSTEMS WITH PIEZO STEPPING DRIVES AND COMPLEX CONTROL LOOPS

### E-712KNHC

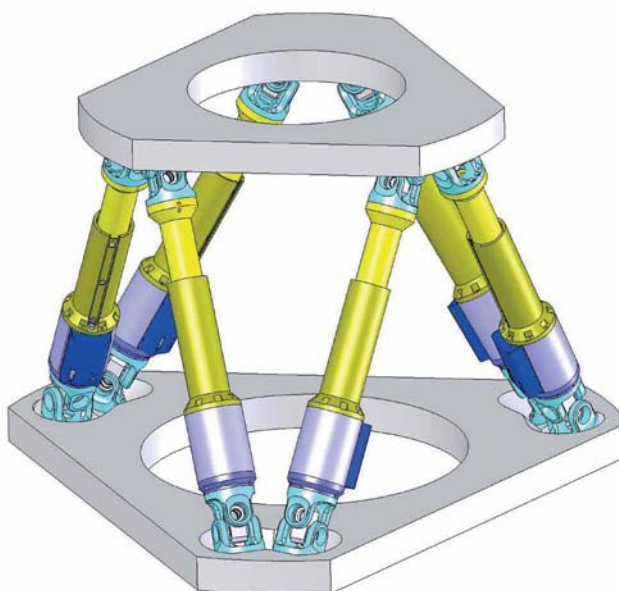


- Digital motion controller of the newest generation: up to 50 kHz servo update rate; highly stable 20-bit D/A converter
- Multiaxis coordinate transformation for parallel-kinematic systems (Hexapods)
- Combined control of different positioning technologies feasible
- Flexible interfaces: Ethernet, USB, RS-232
- Extensive software support
- Optional high-bandwidth analog inputs and outputs
- Modular design for greatest flexibility in meeting custom requirements

The E-712 digital controller system can be configured to drive complex piezo positioning systems, for example parallel-kinematic designs with piezo stepping drives. Multiaxis coordinate transformation and coordination of the individual drive sequences required by the piezo-walk motors can be handled by the sophisticated firmware. Its modular design allows the controller to be adapted quickly to any requirement such as a variety of feedback sensors and the integration of additional control loops e.g. for active vibration damping

## Modular, Scalable Hexapod Concept

FASTER CUSTOM DESIGNS FOR EXTREME LOADS



- Scalable travel ranges and angles
- Loads scalable to 400 kg in any orientation, horizontally to 1000 kg
- High precision, bidirectional repeatability of around 5  $\mu\text{m}$
- Velocity to 20 mm/s
- Brushless DC motors with brakes
- Sophisticated controller using vector algorithms, virtual pivot point
- Extensive software support

Precision positioning of heavy loads in six degrees of freedom can be achieved with a high degree of flexibility by parallel-kinematic structures. The workpiece is actuated simultaneously by multiple actuators, rather than taking a stacked approach. The parallel arrangement of the actuators optimizes the total stiffness, dynamics and allows for a large central aperture.

Custom high-load positioning systems often need to be completely integrated, i.e., the payload acts as the platform to which the 6 actuators need to be attached.

Starting with six identical single struts, PI has developed a concept for an adapted kinematic system that meets a wide variety of requirements. A set of different modules for motors, drives, and joints supports the design process and saves time as well as investment costs. The modular design allows

special requirements to be implemented and integrated in the customer's application much faster.

The aim is to react to customer requests as quickly as possible and to adapt the positioning system according to the individual task at hand.

### **Powerful digital controller, open software architecture**

User-defined, stable pivot point, software-selectable. Positions commanded in Cartesian coordinates. Macro programming. Open source LabVIEW driver set. Work space simulation software. Optional: Control of two additional motorized axes.

## Hexapod-Specific Software

Due to their parallel kinematic structure, Hexapods necessitate a particularly complex control system. The position coordinates, for example, are given in virtual Cartesian axes which are then converted into positioning commands for the individual actuators by the controller. PI supplies special software that allow the 6-axes positioners to be more convenient in operation and easier to integrate.

### Determining the work space

The limits of the work space vary depending on the current position of the Hexapod (translation and rotation coordinates) and the current coordinates of the pivot point. A special software tool included with each PI Hexapod calculates these limits and displays them graphically.

### Checking the permissible load

As with any multiaxis positioning system, the load limit of the Hexapod varies as a function of a number of factors such as orientation of the Hexapod, size and position of the payload, current position

(translation and rotation coordinates) of the Hexapod platform, and forces and moments acting on the platform.

The Hexapod software package includes a PI simulation tool that calculates all forces and moments and compares them individually against the specified load limits of the corresponding Hexapod mechanics.

### Preventing collisions with PIVeriMove

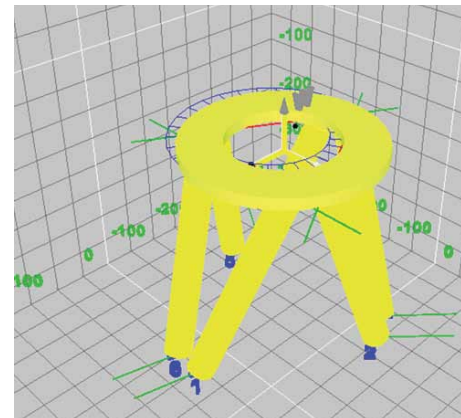
Another proprietary PI simulation software tool enables offline graphical configuration and simulation of the Hexapod motion in the application environment. CAD data of objects can be imported or approximated with simple shapes such as cylinders and cuboids. PIVeriMove then checks restrictions in the work space. Implemented in the controller firmware or the application software, this prevents the Hexapod from approaching positions where the platform, struts, or the mounted load would collide with the surroundings.

### Emulation: The Hexapod system as a virtual machine

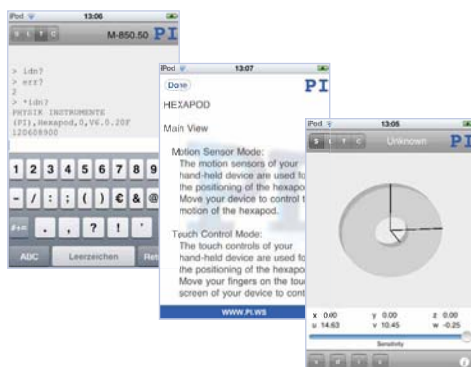
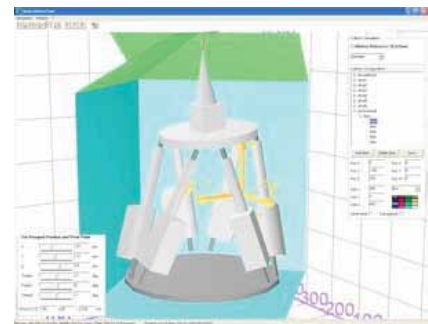
A virtual machine that can be installed on the customer's host PC is available to emulate a complete Hexapod systems (mechanics, controller and even peripherals). Application programs can then be developed and pre-tested, different load scenarios can be simulated and the work space can be determined before the system arrives, saving significant cost and development time.

### HexaApp: PI Hexapod control via iPhone, iPad or iPod

The Hexapod system can also be controlled wirelessly from mobile Apple iOS devices. A corresponding app enables command control of touchscreen, motion sensors or via a command input window.



The simulation software graphically displays the position and the available work space of the Hexapod model





## 6-Axis Miniature Hexapod

FAST, COMPACT AND HIGHLY PRECISE



### H-811

- Smallest Hexapod with vacuum option
- Travel ranges to 34 mm / 42°
- Load capacity to 5 kg
- Actuator resolution 40 nm
- Min. incremental motion to 0.2  $\mu\text{m}$
- Repeatability to  $\pm 0.1 \mu\text{m}$
- Includes integrated scan algorithms for fiber optic alignment

#### Reference-class 6-axis positioning system

Parallel-kinematic design for six degrees of freedom making it significantly more compact and stiff than serial-kinematic systems, higher dynamic range, no moved cables: Higher reliability, reduced friction. Vacuum-compatible version to  $10^{-6}$  hPa available

#### Direct drive with brushless DC motors (BLDC) and long-life ball screws

High precision, velocity and lifetime

#### Powerful digital controller, open software architecture

User-defined, stable pivot point, software-selectable. Positions commanded in Cartesian coordinates. Macro programming. Open source LabVIEW driver set. Work space simulation software. Virtual Hexapod machine software. Optional: Collision avoidance software (external obstacles).

H-811.xx1 includes C-887.11, 6D vector motion controller plus 2 additional servo axes. Options:

- Analog interfaces/photometer cards for visible light (F-206.VVU) or the infrared light range (F-206.iiU)
- F-206.NCU fast piezo nano-alignment system for alignment with nanometer precision

H-811.xx2 includes C-887.21 compact 6D vector motion controller

#### Fields of application

Research and industry, standard and vacuum environments. For micromanipulation, laser and optics alignment, biotechnology, tool control

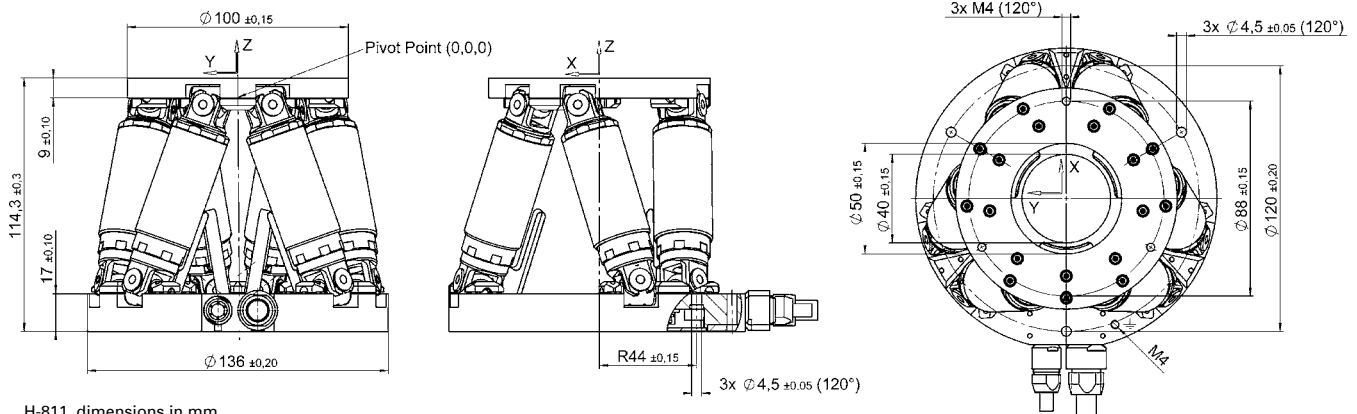
	H-811.D1x	Unit	Tolerance
Active axes	X, Y, Z, $\theta_x$ , $\theta_y$ , $\theta_z$		
<b>Motion and positioning</b>			
Travel range* X, Y, Z	$\pm 17$ , $\pm 16$ , $\pm 6.5$	mm	
Travel range* $\theta_x$ , $\theta_y$ , $\theta_z$	$\pm 10$ , $\pm 10$ , $\pm 21$	°	
Single-actuator design resolution	40	nm	
Min. incremental motion X, Y	0.5	$\mu\text{m}$	typ.
Min. incremental motion Z	0.2	$\mu\text{m}$	typ.
Min. incremental motion $\theta_x$ , $\theta_y$ , $\theta_z$	3.5	$\mu\text{rad}$	typ.
Backlash X, Y	1	$\mu\text{m}$	typ.
Backlash Z	0.2	$\mu\text{m}$	typ.
Backlash $\theta_x$ , $\theta_y$	10	$\mu\text{rad}$	typ.
Backlash $\theta_z$	15	$\mu\text{rad}$	typ.
Repeatability X, Y	$\pm 0.3$	$\mu\text{m}$	typ.
Repeatability Z	$\pm 0.1$	$\mu\text{m}$	typ.
Repeatability $\theta_x$ , $\theta_y$	$\pm 4$	$\mu\text{rad}$	typ.
Repeatability $\theta_z$	$\pm 8$	$\mu\text{rad}$	typ.
Max. velocity X, Y, Z	10	mm/s	
Max. velocity $\theta_x$ , $\theta_y$ , $\theta_z$	250	mmrad/s	
Typ. velocity X, Y, Z	5	mm/s	
Typ. velocity $\theta_x$ , $\theta_y$ , $\theta_z$	120	mmrad/s	
<b>Mechanical properties</b>			
Stiffness X, Y	0.2	N/ $\mu\text{m}$	
Stiffness Z	3.6	N/ $\mu\text{m}$	
Load (base plate horizontal / any orientation)	5 / 2.5	kg	max.
Holding force, de-energized (base plate horizontal / any orientation)	15 / 2.5	N	max.
Motor type	Brushless DC motor		
<b>Miscellaneous</b>			
Operating temperature range	0 to 50	°C	
Material	Stainless steel, aluminum		
Mass	2.2	kg	$\pm 5\%$
Cable length	2	m	$\pm 10$ mm

Vacuum versions to  $10^{-6}$  hPa are available under the following ordering number: H-811.DVx. Specifications for vacuum versions can differ.

Technical data specified at  $20 \pm 3^\circ\text{C}$ .

Ask about custom designs!

\* The travel ranges of the individual coordinates (X, Y, Z,  $\theta_x$ ,  $\theta_y$ ,  $\theta_z$ ) are interdependent. The data for each axis in this table shows its maximum travel, where all other axes are at their zero positions. If the other linear or rotational coordinates are not zero, the available travel may be less.



## 6-Axis Precision Alignment System

IDEAL FOR FIBER ALIGNMENT



### H-206

- Flexure based for highest precision
- Includes integrated scan algorithms for fiber optic alignment
- Actuator resolution 33 nm
- Bidirectional repeatability 0.3  $\mu\text{m}$  / 6  $\mu\text{rad}$
- Min. incremental motion 0.1  $\mu\text{m}$  / 2  $\mu\text{rad}$
- Velocity from 10  $\mu\text{m/s}$  to 10 mm/s

### Reference-class 6-axis positioning system

Parallel-kinematic design for six degrees of freedom making it significantly more compact and stiff than serial-kinematic systems, guidance errors of individual axes do not add up. Higher dynamics, higher reliability. Driven by DC motors

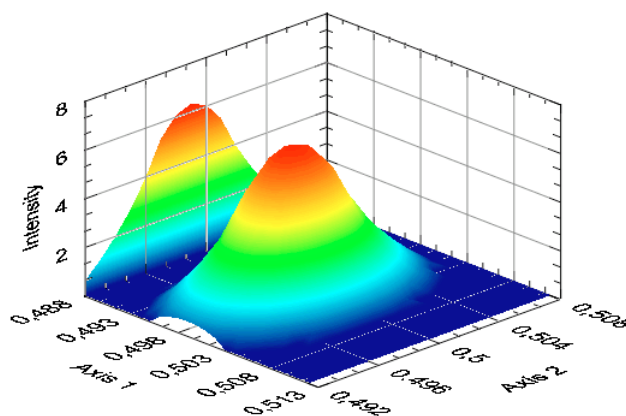
### Powerful digital controller, open software architecture

User-defined, stable pivot point, software-selectable. Positions commanded in Cartesian coordinates. Macro programming. Open source LabVIEW driver set. Work space simulation software. Virtual Hexapod machine software. Optional: Collision avoidance software (external obstacles).

H-206.F11 includes C-887.11, 6D vector motion controller plus 2 additional servo axes. Options:

- Analog interfaces/photometer cards for visible light (F-206.VVU) or the infrared light range (F-206.iiU)
- F-206.NCU fast piezo nano-alignment system for alignment with nanometer precision

H-206.F12 includes C-887.21 compact 6D vector motion controller



The H-206 includes rapid automatic scan routines for fast multi-axis alignment. The graphic shows 2D optical signal intensity of a fiber optic component. Complete device scan ensures detection of the global peak and prevents locking on to a local maximum

### Fields of application

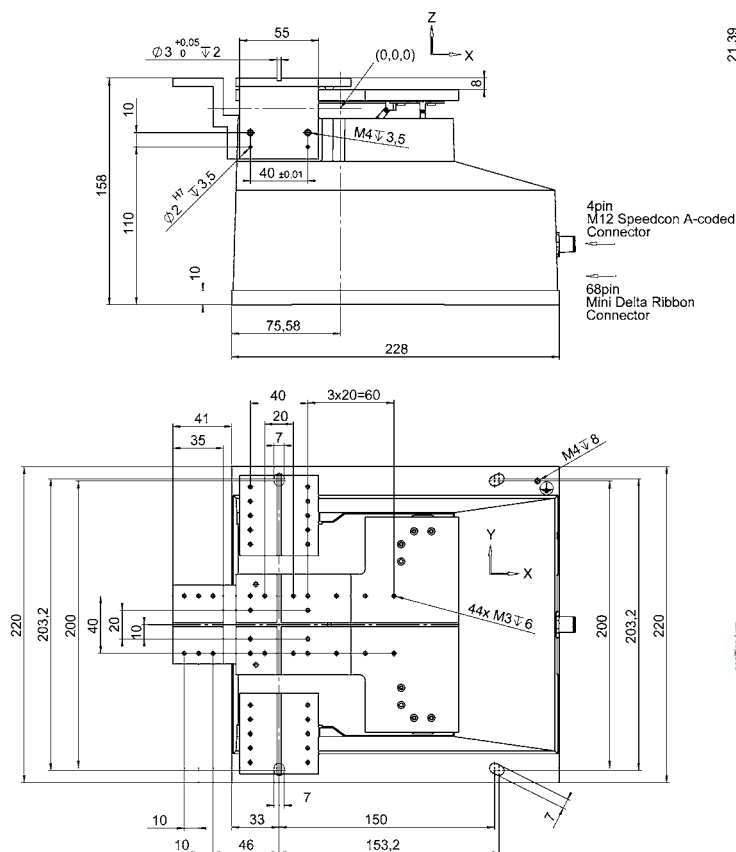
Research and industry. For fiber alignment, micromanipulation systems, optical testing set-ups

	H-206.F1x	Unit	Tolerance
Active axes	X, Y, Z, $\theta_x$ , $\theta_y$ , $\theta_z$		
Motion and positioning			
Travel range* X	-8 to 5.7	mm	
Travel range* Y	±5.7	mm	
Travel range* Z	±6.7	mm	
Travel range* $\theta_x$	±5.7	°	
Travel range* $\theta_y$	±6.6	°	
Travel range* $\theta_z$	±5.5	°	
Single-actuator design resolution	33	nm	
Min. incremental motion X, Y, Z	0.1	µm	typ.
Min. incremental motion $\theta_x$ , $\theta_y$ , $\theta_z$	2 µrad (0.4°)		typ.
Bidirectional repeatability X, Y, Z	0.3	µm	typ.
Bidirectional repeatability $\theta_x$ , $\theta_y$ , $\theta_z$	6	µrad	typ.
Max. velocity X, Y, Z	10	mm/s	
Load (baseplate horizontal)	1.5	kg	max.
Miscellaneous			
Operating temperature range	5 to 35	°C	
Material	Aluminum		
Mass	5.8	kg	±5%
Cable length	3	m	±10 mm

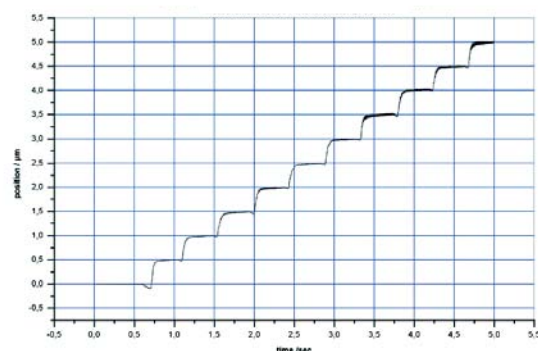
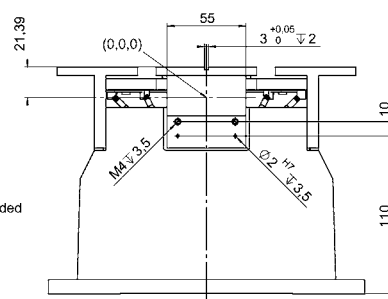
Technical data specified at 20±3°C.

Ask about custom designs!

\* The travel ranges of the individual coordinates ( $X, Y, Z, \theta_x, \theta_y, \theta_z$ ) are interdependent. The data for each axis in this table shows its maximum travel, where all other axes are at their zero positions. If the other linear or rotational coordinates are not zero, the available travel may be less.



H-206.S, dimensions in mm



The H-206 Hexapod shows extremely good repeatability of minute steps, in the above graph: 0.5  $\mu\text{m}$  steps with a load of 1 kg in X direction

## PI miCos SpaceFAB

### 6-AXIS POSITIONING SYSTEM

- Low-profile, compact system
- Linear travel ranges to 50 x 12.7 x 100 mm, rotations to 10°
- Load capacity to 3 kg
- Vacuum versions available
- Virtual pivot point
- User-friendly software, controller, and amplifier included
- Ask about custom designs and complete solutions!



#### PI miCos reference-class 6-axis positioning system

Parallel-kinematic design for six degrees of freedom making it significantly more compact and stiffer than serial-kinematic systems, higher dynamics. Vacuum-compatible versions to 10<sup>-6</sup> hPa are available on request

#### Special controller and customer-friendly software

Positions commands in Cartesian coordinates. Simulation software calculates the work space. Macro functionality

#### Fields of application

Industry and research, vacuum environments. For automated alignment of optical components, automation, biomedicine and biogenetics

\* The travel ranges of the individual coordinates ( X, Y, Z,  $\theta_x$ ,  $\theta_y$ ,  $\theta_z$ ) are interdependent. The data for each axis in this table shows its maximum travel, where all other axes are at their zero positions. If the other linear or rotational coordinates are not zero, the available travel may be less. Further data, see [www.pimicos.com](http://www.pimicos.com)

	SpaceFAB SF-3000 BS
Active axes	X, Y, Z, $\theta_x$ , $\theta_y$ , $\theta_z$
<b>Motion and positioning</b>	
Travel range* X	50 mm
Travel range* Y	12.7 mm
Travel range* Z	100 mm
Travel range* $\theta_x$ , $\theta_y$ , $\theta_z$	10°
Min. incremental motion X, Y, Z, unloaded	0.2 µm
Min. incremental motion $\theta_x$ , $\theta_y$ , $\theta_z$ unloaded	0.0005°
Bidirectional repeatability X, Y, Z	± 0.5 µm
Bidirectional repeatability $\theta_x$ , $\theta_y$ , $\theta_z$	20 µrad
Max. velocity X, Y, Z	30 mm/s
Typ. velocity X, Y, Z	10 µm/s to 10 mm/s
Max. velocity $\theta_x$ , $\theta_y$ , $\theta_z$	10°/s
<b>Mechanical properties</b>	
Max. load (baseplate horizontal)	3 kg
<b>Miscellaneous</b>	
Material	Stainless steel, aluminum black anodized
Mass	24 kg



## Customer-Specific Manufacturing

SpaceFAB 6-axis positioning systems can be easily adapted to individual customer requirements. Vacuum-compatible versions as well as a scaling of the load capacity or dimensions are possible.

What they all have in common is the control with a highly developed digital controller. The commands are comfortably given in Cartesian coordinates, the pivot point for rotary motions can be placed arbitrarily by the customer. In „Contouring Mode“ trajectories can be predefined, and the SpaceFAB can move along them.

A simulation program, the SpaceFAB Simulator, shows possible travel ranges in a specific application-related environment.

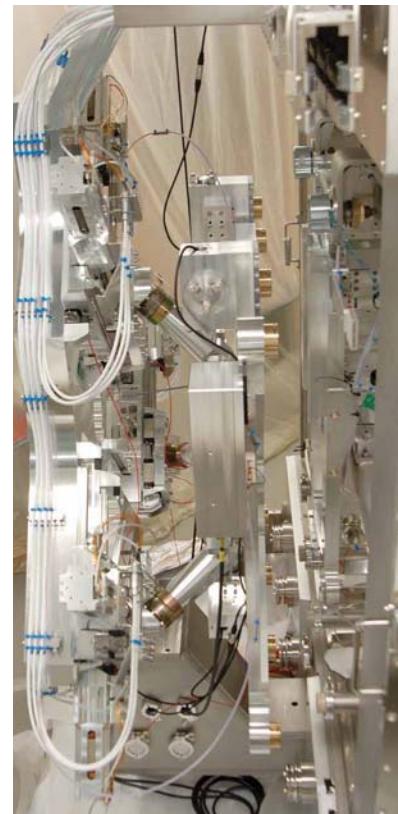
## Complete Solution from One Hand: Automated Sandwich Assembly in Six Degrees of Freedom

A special challenge for the use of a SpaceFAB was an assembly line production under vacuum conditions with  $10^{-6}$  mbar. The goal was a fully automated sandwich assembly of a carrier with a precision foil and a

rear-side counter holder integrated in the production process.

The 1 m<sup>2</sup> foil has to be positioned in relation to the carrier with an accuracy of  $\pm 20$   $\mu$ m. Since the position of the carrier varies, the assembly process, which could not take longer than 10 seconds, could only be done with a positioning system with six degrees of freedom. For the desired travels of 50 mm in the direction of assembly and 20 mm perpendicular to this, a SpaceFAB was recommended due to its low height.

The system developed for this application can move loads of 100 kg with low vibration, fast, and very precisely. The key to this is an ingenious combination of a mechanical system, spindle pitch and high encoder resolution. PI miCos also assumed responsibility for the software for controlling the sandwich assembly and the integration of the sensor and camera measurements as well as for the monitoring of the gripper magnets.



Impressive demonstration: Vacuum version of the SpaceFAB in a transparent chamber

## 6-Axis Hexapod

FOR LOADS OF UP TO 250 KG



### H-850

- Load capacity to 250 kg
- Repeatability to  $\pm 0.2 \mu\text{m}$
- Travel ranges to 100 mm /  $60^\circ$
- Actuator resolution to 5 nm
- MTBF 20,000 h

#### Reference-class 6-axis positioning system

Parallel-kinematic design for six degrees of freedom making it significantly more compact and stiff than serial-kinematic systems, higher dynamic range, no moved cables: Higher reliability, reduced friction. Vacuum-compatible versions to  $10^{-6}$  hPa are available

#### Drive variants

H-850.H1x with DC gear motors for heavy loads

H-850.G1x with powerful DC motors for higher velocity. Heavy-duty, ultra-high-resolution bearings for 24/7 applications

#### Powerful digital controller, open software architecture

User-defined, stable pivot point, software-selectable. Positions commanded in Cartesian coordinates. Macro programming. Open source LabVIEW driver set. Work space simulation software. Virtual Hexapod machine software. Optional: Collision avoidance software (external obstacles).

H-850.xx1 includes C-887.11, 6D vector motion controller plus 2 additional servo axes. Options:

- Analog interfaces/photometer cards for visible light (F-206.VVU) or the infrared light range (F-206.iiU)
- F-206.NCU fast piezo nano-alignment system for alignment with nanometer precision

H-850.xx2 includes C-887.21 compact 6D vector motion controller

#### Fields of application

Research and industry, standard and vacuum environments. For astronomy, optics positioning, aviation and aerospace

	H-850.H1x	H-850.G1x	Unit	Tolerance
	for higher loads and holding forces	for higher velocity and precision		
Active axes	X, Y, Z, $\theta_x$ , $\theta_y$ , $\theta_z$	X, Y, Z, $\theta_x$ , $\theta_y$ , $\theta_z$		
<b>Motion and positioning</b>				
Travel range* X, Y	±50	±50	mm	
Travel range* Z	±25	±25	mm	
Travel range* $\theta_x$ , $\theta_y$	±15	±15	°	
Travel range* $\theta_z$	±30	±30	°	
Single-actuator design resolution	0.005	0.05	µm	
Min. incremental motion X, Y	1	1	µm	typ.
Min. incremental motion Z	0.5	0.5	µm	typ.
Min. incremental motion $\theta_x$ , $\theta_y$ , $\theta_z$	5	5	µrad	typ.
Backlash X, Y	4	5	µm	typ.
Backlash Z	1	1.5	µm	typ.
Backlash $\theta_x$ , $\theta_y$	15	25	µrad	typ.
Backlash $\theta_z$	30	45	µrad	typ.
Repeatability X, Y	±1	±0.5	µm	typ.
Repeatability Z	±0.3	±0.2	µm	typ.
Repeatability $\theta_x$ , $\theta_y$	±5	±3	µrad	typ.
Repeatability $\theta_z$	±9	±6	µrad	typ.
Max. velocity X, Y, Z	0.5	8	mm/s	
Max. velocity $\theta_x$ , $\theta_y$ , $\theta_z$	6	100	mrad/s	
Typ. velocity X, Y, Z	0.3	5	mm/s	
Typ. velocity $\theta_x$ , $\theta_y$ , $\theta_z$	3	50	mrad/s	
<b>Mechanical properties</b>				
Stiffness X, Y	7	7	N/µm	
Stiffness Z	100	100	N/µm	
Load (base plate horizontal / any orientation)	250 / 50	50 / 20	kg	max.
Holding force, de-energized (base plate horizontal / any orientation)	2000 / 500	250 / 85	N	max.
Motor type	DC motor, gearhead	DC motor, gearhead		
<b>Miscellaneous</b>				
Operating temperature range	-10 to 50	-10 to 50	°C	
Material	Aluminum	Aluminum		
Mass	17	17	kg	±5%
Cable length	3	3	m	±10 mm

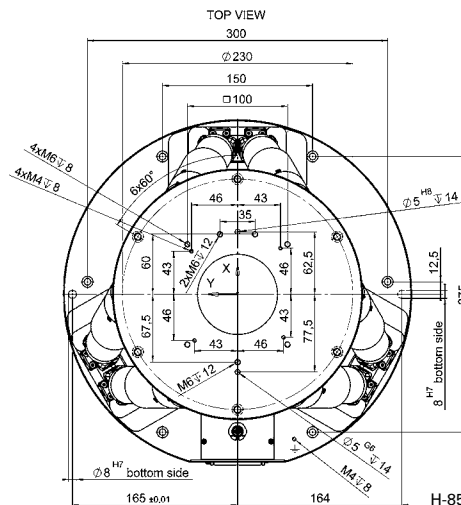
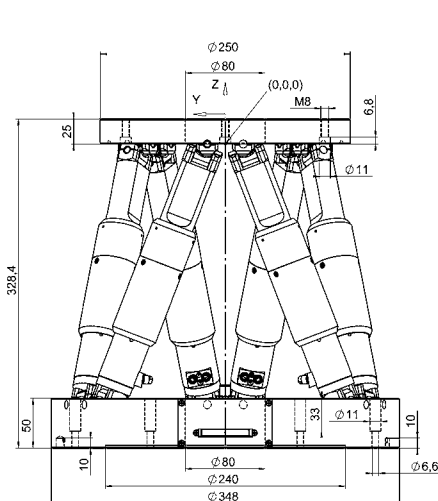
Vacuum versions to  $10^{-6}$  hPa are available under the following ordering number: H-850.xV. Specifications for vacuum versions can differ.

Technical data specified at  $20 \pm 3^\circ\text{C}$ . Ask about custom designs!

\* The travel ranges of the individual coordinates (X, Y, Z,  $\theta_x$ ,  $\theta_y$ ,  $\theta_z$ ) are

interdependent. The data for each axis in this table shows its maximum travel, where all other axes are at their zero positions. If the other linear or

rotational coordinates are not zero, the available travel may be less.



H-850, dimensions in mm

## 6-Axis Hexapod

HIGH VELOCITY, MEDIUM LOAD, AFFORDABLE



### H-840

- Load capacity to 30 kg
- Travel ranges to 100 mm / 60°
- Actuator resolution to 16 nm
- Repeatability to  $\pm 0.4 \mu\text{m}$
- MTBF 20,000 h
- Velocity to 50 mm/s

#### Precision-class 6-axis system

Parallel-kinematic design for six degrees of freedom making it significantly more compact and stiff than serial-kinematic systems, higher dynamic range, no moved cables: Higher reliability, reduced friction

#### Drive variants

H-840.G1x with DC gear motors

H-840.D1x with powerful DC motors for higher velocity

#### Powerful digital controller, open software architecture

User-defined, stable pivot point, software-selectable. Positions commanded in Cartesian coordinates. Macro programming. Open source LabVIEW driver set. Work space simulation software. Virtual Hexapod machine software. Optional: Collision avoidance software (external obstacles).

H-840.xx1 includes C-887.11, 6D vector motion controller plus 2 additional servo axes. Options:

- Analog interfaces/photometer cards for visible light (F-206.VVU) or the infrared light range (F-206.iiU)
- F-206.NCU fast piezo nano-alignment system for alignment with nanometer precision

H-840.xx2 includes C-887.21 compact 6D vector motion controller

#### Fields of application

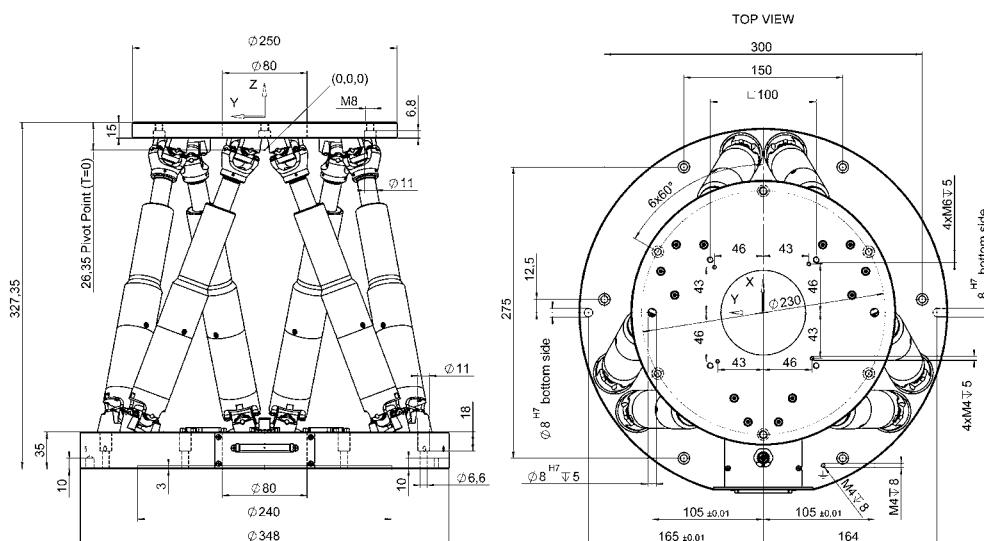
Research and industry. For micromanipulation, laser and optics alignment, biotechnology, tool control

	H-840.G1x	H-840.D1x	Unit	Tolerance
	for higher resolution and load	for higher velocity		
Active axes	X, Y, Z, $\theta_x$ , $\theta_y$ , $\theta_z$	X, Y, Z, $\theta_x$ , $\theta_y$ , $\theta_z$		
Motion and positioning				
Travel range* X, Y	±50	±50	mm	
Travel range* Z	±25	±25	mm	
Travel range* $\theta_x$ , $\theta_y$	±15	±15	°	
Travel range* $\theta_z$	±30	±30	°	
Single-actuator design resolution	0.017	0.5	µm	
Min. incremental motion X, Y	1	3	µm	typ.
Min. incremental motion Z	0.5	1	µm	typ.
Min. incremental motion $\theta_x$ , $\theta_y$ , $\theta_z$	5	5	µrad	typ.
Backlash X, Y	7	7	µm	typ.
Backlash Z	2	2	µm	typ.
Backlash $\theta_x$ , $\theta_y$	30	30	µrad	typ.
Backlash $\theta_z$	60	60	µrad	typ.
Repeatability X, Y	±0.5	±0.5	µm	typ.
Repeatability Z	±0.4	±0.4	µm	typ.
Repeatability $\theta_x$ , $\theta_y$	±7	±7	µrad	typ.
Repeatability $\theta_z$	±12	±12	µrad	typ.
Max. velocity X, Y, Z	2.5	50	mm/s	
Max. velocity $\theta_x$ , $\theta_y$ , $\theta_z$	30	600	mrad/s	
Typ. velocity X, Y, Z	2	30	mm/s	
Typ. velocity $\theta_x$ , $\theta_y$ , $\theta_z$	20	300	mrad/s	
Mechanical properties				
Load (base plate horizontal / any orientation)	30 / 10	10 / 3	kg	max.
Holding force, de-energized (base plate horizontal / any orientation)	100 / 25	15 / 5	N	max.
Motor type	DC motor, gearhead	DC motor		
Miscellaneous				
Operating temperature range	-10 to 50	-10 to 50	°C	
Material	Aluminum	Aluminum		
Mass	12	12	kg	±5%
Cable length	3	3	m	±10 mm

Technical data specified at 20±3°C.

Ask about custom designs!

\* The travel ranges of the individual coordinates (X, Y, Z,  $\theta_x$ ,  $\theta_y$ ,  $\theta_z$ ) are interdependent. The data for each axis in this table shows its maximum travel, where all other axes are at their zero positions. If the other linear or rotational coordinates are not zero, the available travel may be less.



H-840, dimensions in mm



## 6-Axis Hexapod

LOW-PROFILE, PRECISION PARALLEL-KINEMATIC SYSTEM



### H-824

- Load capacity to 10 kg, self-locking version
- Travel ranges to 45 mm / 25°
- Actuator resolution to 7 nm
- Min. incremental motion to 0.3  $\mu\text{m}$
- Repeatability to  $\pm 0.1 \mu\text{m}$  /  $\pm 2.5 \mu\text{rad}$
- Velocity up to 25 mm/s

#### Precision-class 6-axis positioning system

Parallel-kinematic design for six degrees of freedom making it significantly more compact and stiff than serial-kinematic systems, higher dynamic range, no moved cables: Higher reliability, reduced friction. Vacuum-compatible versions to  $10^{-6}$  hPa are available

#### Low-profile due to folded drive design

H-824.G1x with DC gear motors  
H-824.D1x with powerful DC motors for higher velocity

#### Powerful digital controller, open software architecture

User-defined, stable pivot point, software-selectable. Positions commanded in Cartesian coordinates. Macro programming. Open source LabVIEW driver set. Work space simulation software. Virtual Hexapod machine software. Optional: Collision avoidance software (external obstacles).

H-824.xx1 includes C-887.11, 6D vector motion controller plus 2 additional servo axes. Options:

- Analog interfaces/photometer cards for visible light (F-206.VVU) or the infrared light range (F-206.iiU)
- F-206.NCU fast piezo nano-alignment system for alignment with nanometer precision

H-824.xx2 includes C-887.21 compact 6D vector motion controller

#### Fields of application

Research and industry, standard and vacuum environments. For micromanipulation, laser and optics alignment, biotechnology, tool control

	H-824.G1x	H-824.D1x	Unit	Tolerance
	for higher resolution and load	for higher velocity		
Active axes	X, Y, Z, $\theta_x$ , $\theta_y$ , $\theta_z$	X, Y, Z, $\theta_x$ , $\theta_y$ , $\theta_z$		
<b>Motion and positioning</b>				
Travel range* X, Y	±22.5	±22.5	mm	
Travel range* Z	±12.5	±12.5	mm	
Travel range* $\theta_x$ , $\theta_y$	±7.5	±7.5	°	
Travel range* $\theta_z$	±12.5	±12.5	°	
Single-actuator design resolution	0.007	0.5	μm	
Min. incremental motion X, Y, Z	0.3	1	μm	typ.
Min. incremental motion $\theta_x$ , $\theta_y$ , $\theta_z$	3.5	12	μrad	typ.
Backlash X, Y	3	3	μm	typ.
Backlash Z	1	1	μm	typ.
Backlash $\theta_x$ , $\theta_y$	20	20	μrad	typ.
Backlash $\theta_z$	25	25	μrad	typ.
Repeatability X, Y	±0.5	±0.5	μm	typ.
Repeatability Z	±0.1	±0.1	μm	typ.
Repeatability $\theta_x$ , $\theta_y$	±2	±2	μrad	typ.
Repeatability $\theta_z$	±2.5	±2.5	μrad	typ.
Max. velocity X, Y, Z	1	25	mm/s	
Max. velocity $\theta_x$ , $\theta_y$ , $\theta_z$	11	270	mrads	
Typ. velocity X, Y, Z	0.5	10	mm/s	
Typ. velocity $\theta_x$ , $\theta_y$ , $\theta_z$	5.5	55	mrads	
<b>Mechanical properties</b>				
Stiffness X, Y	1.7	1.7	N/μm	
Stiffness Z	7	7	N/μm	
Load (base plate horizontal / any orientation)	10 / 5	5 / 2.5	kg	max.
Holding force, de-energized (base plate horizontal / any orientation)	100 / 50	15 / 5	N	max.
Motor type	DC motor, gearhead	DC motor		
<b>Miscellaneous</b>				
Operating temperature range	-10 to 50	-10 to 50	°C	
Material	Aluminum	Aluminum		
Mass	8	8	kg	±5%
Cable length	3	3	m	±10 mm

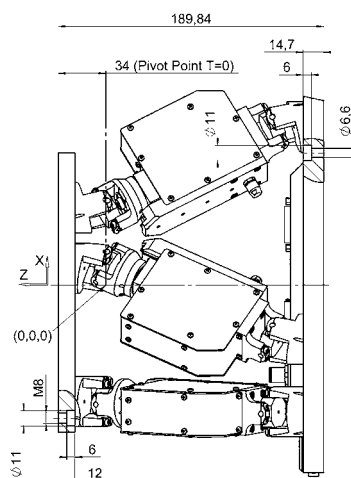
Vacuum versions to  $10^{-6}$  hPa are available under the following ordering number: H-824.xVx. Specifications for vacuum versions can differ.

Technical data specified at  $20 \pm 3^\circ\text{C}$ . Ask about custom designs!

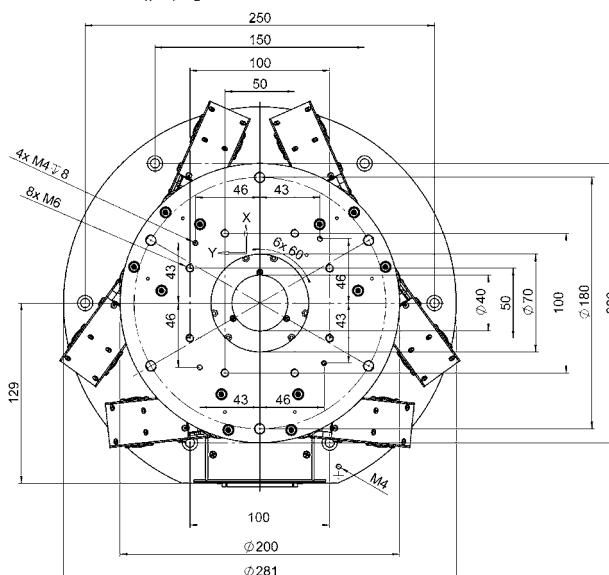
\* The travel ranges of the individual coordinates (X, Y, Z,  $\theta_x$ ,  $\theta_y$ ,  $\theta_z$ ) are

interdependent. The data for each axis in this table shows its maximum travel, where all other axes are at their zero positions. If the other linear or

rotational coordinates are not zero, the available travel may be less.



H-824, dimensions in mm



## Vacuum-Compatible High-Load Hexapod

PRECISE POSITIONING OF LOADS OF UP TO 1 TON



### M-850K

- Vacuum compatible to  $10^{-6}$  hPa
- Load capacity to 1000 kg
- Six Degrees of Freedom
- Repeatability to 2  $\mu\text{m}$
- Drive: brushless motors with brake

Experiments on accelerator rings are often carried out under vacuum conditions. This vacuum-compatible Hexapod is well-suited for high precision positioning of loads of up to 1 ton (H-840 standard Hexapod (30 kg load) for size comparison)

	Travel ranges	Rotation ranges	Max. velocity	Dimensions
M-850KHLH Vacuum-Compatible High Load Hexapod	X, Y, Z: $\pm 12$ mm	$\theta_x, \theta_y: \pm 3^\circ$ $\theta_z: \pm 4^\circ$	X, Y, Z: 0.5 mm/s	Ø external: 1 m Height: 0.5 m

## 1000 kg High-Load Hexapod

6 AXES, LARGE TRAVEL RANGE, ACCURACY IN THE MICROMETER RANGE



### M-850K

- Six Degrees of Freedom
- Load capacity to 1000 kg in any orientation
- Travel ranges to 400 mm /  $40^\circ$
- Resolution to 0.8  $\mu\text{m}$  / 0.5  $\mu\text{rad}$
- Sophisticated controller using vector algorithms

Brushless DC servo motors with brakes in this custom parallel-kinematic Hexapod positioning system allow loads of up to one ton to be positioned in any orientation with micrometer accuracy over ranges up to 400 mm

	Stellwege	Max. Belastbarkeit	Max. Geschwindigkeit	Unidir. Wiederholgenauigkeit	Abmessungen
M-850KTH High-Load Hexapod	X, Y: $\pm 200$ mm Z: $\pm 100$ mm $\theta_x, \theta_y: \pm 20^\circ$ $\theta_z: \pm 5^\circ$	1000 kg	1 mm/s	X, Y, Z: $\pm 1$ $\mu\text{m}$ $\theta_x, \theta_y, \theta_z: \pm 3$ $\mu\text{rad}$	Base platform: Ø 900 mm Upper platform: Ø 800 mm Height: 714 mm Aperture: Ø 500 mm

## 6-Axis Positioner

LOW-PROFILE PRECISION POSITIONING SYSTEM FOR LARGE SURFACE LOADS TO 200 KG

### M-850K



- Six Degrees of Freedom
- Low-profile design due to parallel kinematics
- Encoder resolution 0.1  $\mu$ m
- Repeatability 0.3 mm in 6-D space
- Integrated brakes and additional safety switches
- No moving cables for improved reliability, reduced friction
- High velocity to 16 mm/s
- Cartesian coordinate control with virtualized pivot point

Hexapod design for precise orientation of large surface loads, e. g. of inspection and assembly systems in LCD production or the positioning of patients in medical engineering

	Travel ranges	Min. incremental motion	Max. load	Mass	Dimensions
M-850KPAH positioning-system	X, Y: $\pm 50$ mm Z: $\pm 25$ mm $\theta_x, \theta_y, \theta_z: \pm 3^\circ$	X, Y, Z: 0.1 mm $\theta_x, \theta_y, \theta_z: 0.8$ mrad	Static: 800 kg Dynamic: 200 kg	70 kg	1200 x 530 x 184 mm

## Weather-Resistant Hexapod for Astronomy

PRECISION 6-AXIS POSITIONER FOR OUTDOOR APPLICATIONS

### M-850K



- Unidirectional repeatability 5  $\mu$ m
- Load capacity to 75 kg
- Clear aperture  $\varnothing$  420 mm
- Long lifetime: 2 million cycles
- Drive: brushless motors
- Corresponds to protection class IP 64
- Corrosion protection

The M-850KWAH custom Hexapod for astronomy applications is protected by rubber boots and suitable materials. The special mechanical design as well as a non-standard controller make it particularly well-suited for telescope applications in the highlands of Chile, where it is operated outdoors at elevations up to 5,000 m above sea level

	Travel ranges	Max. load	Mass	Dimensions
M-850KWAH Weather-Resistant for Astronomy	X: $\pm 10$ mm Y: $\pm 11$ mm Z: $\pm 16$ mm	75 kg	46 kg	$\varnothing$ external: 580 mm Height: 357 mm

## High-Stiffness Nanopositioning Z Stage with NEXLINE® Piezomotors

HIGH-PRECISION VERTICAL POSITIONING, WITH CAPACITIVE FEEDBACK

### N-510K



- Closed-loop resolution to 2 nm
- Self-locking, no heat generation at rest
- Hybrid piezo drive combines high stiffness, long travel and very fast response
- Travel range 400  $\mu\text{m}$  coarse, 40  $\mu\text{m}$  fine
- Direct metrology: One single control loop with capacitive sensors
- Piezo stepping drive w/o wear and tear and outstanding lifetime due to PICMA® piezo actuators

The N-510KHFS Z-stage combines NEXLINE® piezo stepping drives with PICMA® piezo actuators, and meets the strict requirements of inspection tasks in the semiconductor industry. Both drive technologies are controlled by a single control loop based on capacitive position feedback sensors providing accuracy in the nanometer range

	Travel ranges	Max. velocity	Bidir. Repeatability	Max. load	Dimensions
N-510KHFS hybrid focusing system	Coarse: 400 $\mu\text{m}$ Fine: 40 $\mu\text{m}$	1 mm/s	50 nm (full travel)	2.5 kg	Ø external: 300 mm Height 68.5 mm

## Non-Magnetic Piezo Hexapod

6-AXIS PRECISION POSITIONING SYSTEM WITH NEXLINE® PIEZO STEPPING DRIVES

### N-515K



- For high-energy physics and medical applications
- Travel ranges 10 mm, 6°
- Nonmagnetic
- Load capacity to 50 kg
- Nanometer resolution
- Low Profile: only 140 mm height
- Self-locking, no heat generation at rest

This 6-axis parallel kinematics positioning system with NEXLINE® high-load actuators was designed for use in strong magnetic fields such as are encountered in the vicinity of beam control systems on accelerator rings or in MRI scanners

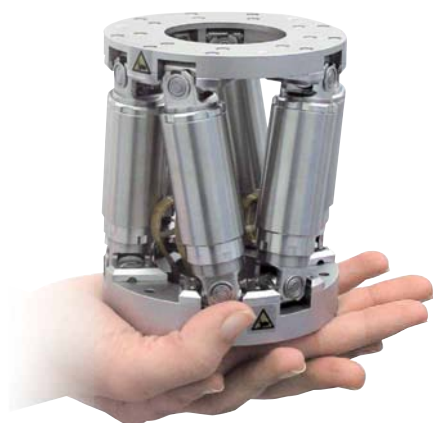
	Travel ranges	Max. load	Dimensions
N-515KNPH Non-Magnetic Piezo Hexapod	X, Y, Z: 10 mm $\theta_x, \theta_y, \theta_z$ : 6°	50 kg	Ø Base plate, external: 380 mm Ø moving platform, top: 300 mm Height: 140 mm Clear aperture: Ø 202 mm



## 6-Axis Miniature Hexapod

HIGH PRECISION IN A SMALL PACKAGE

### H-810



- Most compact standard Hexapod in the PI portfolio
- Travel ranges to 40 mm / 60°
- Load capacity to 5 kg
- Actuator resolution 40 nm
- Min. incremental motion to 0.5  $\mu\text{m}$
- Repeatability to  $\pm 0.1 \mu\text{m}$

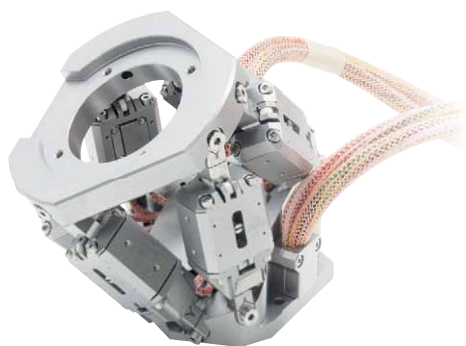
Despite its compact dimensions, the H-810 offers a large a travel range of up to 40 mm. Brushless DC motors and ball screws provide for high precision and long lifetime

	Max. load	Travel ranges	Rotation ranges	Max. velocity	Dimensions
H-810 miniature Hexapod	5 kg	X, Y: $\pm 20 \text{ mm}$ Z: $\pm 6.5 \text{ mm}$	$\theta_x, \theta_y: \pm 10^\circ$ $\theta_z: \pm 30^\circ$	2.5 mm/s	$\varnothing$ external: 100 mm Height: 118 mm

## UHV-Compatible Miniature Piezo Hexapod

HIGH-PRECISION POSITIONING EVEN IN STRONG MAGNETIC FIELDS

### P-911K



- Ultra-compact
- UHV-compatible to  $10^{-9} \text{ hPa}$
- Nonmagnetic
- Ultra-high precision flexure joints
- Load capacity to 1.5 kg
- Travel ranges to 1.5 mm, to  $2^\circ$
- With NEXLINE® piezo stepping drives

The space-saving parallel-kinematic design allows for the low overall height of less than 90 mm and a diameter of only 100 mm. NEXLINE® piezo stepping motor drives and integrated incremental sensors ensure a position resolution down to 0.1  $\mu\text{m}$  in the linear axes

	Travel ranges	Max. load	Sensor resolution	Dimensions
P-911KNMV miniature Hexapod	X, Y, Z: 1.5 mm $\theta_x, \theta_y, \theta_z: 2^\circ$	1.5 kg	0.1 $\mu\text{m}$	$\varnothing$ external: 100 mm Height 90 mm

# Notes on Specifications for Hexapods

## MOTION AND POSITIONING

### Travel range

The distance between two limit switches defines the travel range of the individual struts. The maximum travel ranges of the motion axes are interdependent. The stated values indicate the maximum travel of each axis, where all other axes are at their zero positions. If the other linear or rotational coordinates are not zero, the available travel may be less.

### Design resolution

The theoretical minimum motion that can be made, based on the selection of the mechanical drive components (spindle pitch, gear ratio, angular motor resolution etc.). Design resolution is usually better than the practical position resolution (minimum incremental motion). For linear encoders, the design describes the resolution of the position feedback sensor system.

### Min. incremental motion

The minimum motion that can be repeatedly executed for a given input is called minimum incremental motion. The values stated are typical measured values.

### Backlash

Position error that occurs upon reversing direction due to error in the drivetrain. The values stated are typical measured values. Data for vacuum versions can differ.

### Repeatability

Values stated are typical measured values (RMS, 1 sigma) for unidirectional repeatability.

### Max. velocity

This is the short-term peak value for horizontal mounting, with no load, and not intended for continuous operation. Data for vacuum versions can differ.

### Typ. velocity

Recommended value for continuous operation; also referred to as average or continuous velocity. This value depends on the application.

### Mechanical properties

#### Stiffness

Typical tolerance:  $\pm 20\%$

#### Max. load

Load limit, load at center of stage, positioning system in closed-loop operation. Higher loads will reduce the possible travel ranges and may also reduce the lifetime. Data for vacuum versions can differ.

#### Max. holding force

The maximum force of the Hexapod when powered down, depending on the orientation of the base plate.

### Miscellaneous

#### Operating temperature range

Safe operation, no damage to the drives. All technical data specified in the data sheet refer to room temperature ( $22^{\circ}\text{C} \pm 3^{\circ}\text{C}$ ).

### Material

Hexapods are made of anodized aluminum or stainless steel. Small amounts of other materials may be used (for bearings, pre-load, coupling, mounting, etc.). For special applications other materials such as invar are possible.

### Mass

Typical tolerance:  $\pm 5\%$

### Cable length

Typical tolerance:  $\pm 10 \text{ mm}$

## Software from PI

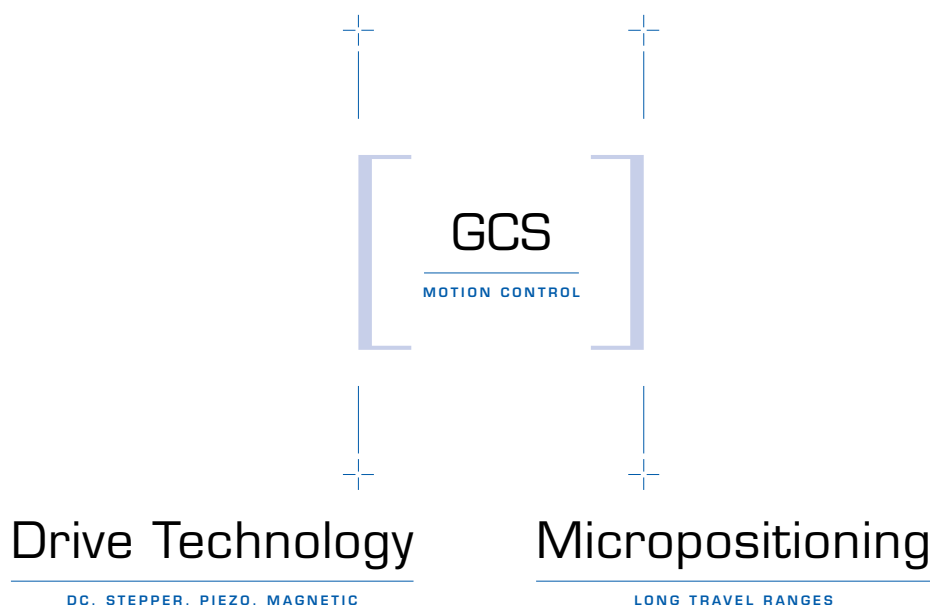
EFFECTIVE AND COMFORTABLE SOLUTIONS

### Parallel Kinematics

UP TO 6 DEGREES OF FREEDOM

### Nanopositioning

SUB-NANOMETER RESOLUTION



### Drive Technology

DC, STEPPER, PIEZO, MAGNETIC

### Micropositioning

LONG TRAVEL RANGES

#### Supported operating systems

- Windows XP (SP3)
- Windows VISTA
- Windows 7 32/64 bit
- Linux 32/64 bit

All digital controllers made by PI are accompanied by a comprehensive software package. PI supports users as well as programmers with detailed online help and manuals which ease initiation of the inexperienced but still answer the detailed questions of the professional. Updated software and drivers are always available to PI customers free of charge via the Internet.

PI software covers all aspects of the application\* from the easy start-up to convenient system operation via a graphical interface and quick and comprehensive integration in customer written application programs.

#### Universal command set simplifies commissioning and programming

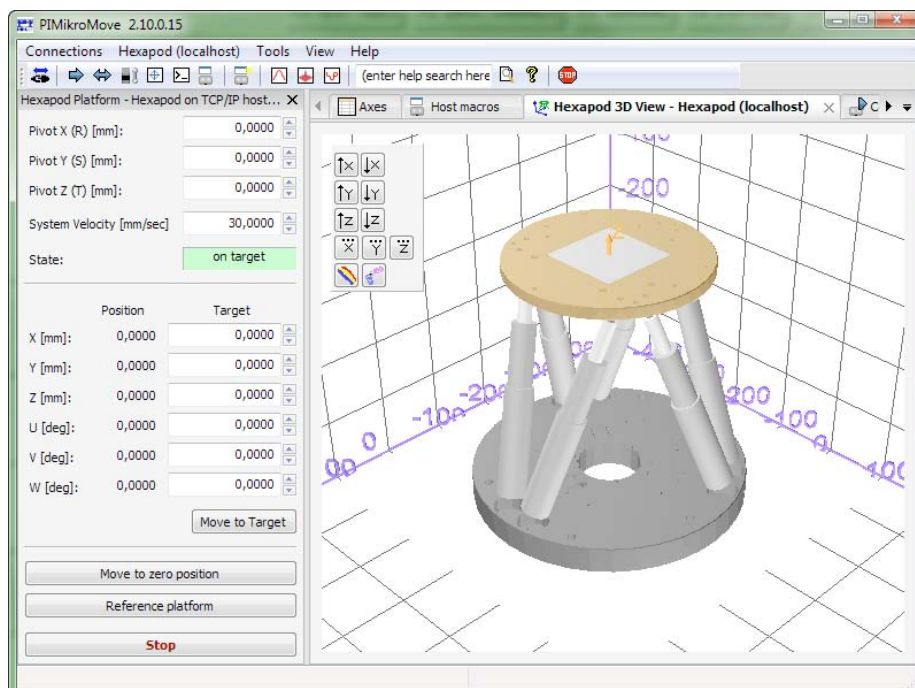
PI's General Command Set (GCS) structure is consistent for all controllers regardless of

their complexity and purpose. GCS with its many preprogrammed functions accelerates the orientation phase and the application development process significantly while reducing the chance of errors, because the commands for all supported devices are identical in syntax and function. Further advantages are that different PI controllers can be added and integrated more easily and system upgrades can be introduced with a minimum of programming effort.

\* Not every function is available for all controllers. For details, please refer to the corresponding product data sheets.

## Software from PI

EFFECTIVE AND COMFORTABLE SOLUTIONS



### Optimizing system behavior

When the mechanical properties of a positioning system are changed, e.g., by applying a different load, motion control parameters often need to be adapted. PI software provides tools for optimization of the system response and stability. Different parameter sets can be saved for later recall, also accessible from custom application programs.

### PIMikroMove software ensures rapid start-up

PIMikroMove is PI's convenient graphical user interface for any type of digital controller and positioning system, regardless of whether piezoelectric, linear motors, or classical electrical motor drives are used and independent of the configuration and number of axes.

All connected controllers and axes are displayed and controlled consistently with the same graphical interface. Two or more independent axes can be controlled by the position pad using a mouse or joystick; Hexapod six-axis positioning systems are also displayed graphically.

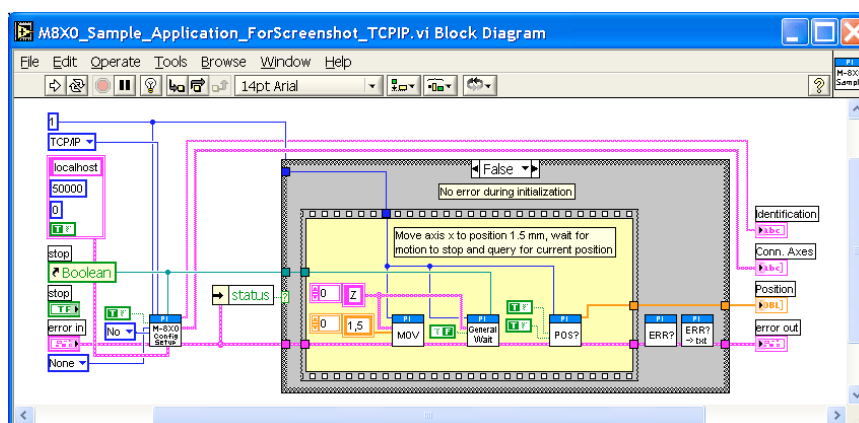
Macro programs simplify repetitive tasks for example in automated processes. The macros are created as GCS command sets that can be executed directly on the controller, e.g., as a start-up macro that allows stand-alone operation; they can also be processed by the host PC.

Scan and align algorithms can record analog values, e.g., the output of a power meter as a function of position for later evaluation with external software. They can also automatically find the global maximum of, for example, the coupling efficiency of optical devices.

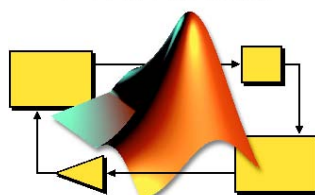
Depending on the specific controller, PIMikroMove supports a number of additional functions. A data recorder can record system parameters and other variables during motion for later analysis.

## Programming

RAPID INTEGRATION OF PI POSITIONING SYSTEMS AND CONTROLLERS



# MATLAB® Enabled



MathWorks Partner



In measuring and control technology and automation engineering, many applications are produced in LabVIEW. PI provides complete LabVIEW drivers sets to facilitate programming. A controller-specific Configuration\_Setup VI is integrated at the start of the LabVIEW application and includes all system information and initiation steps required for start-up. The application itself is implemented with controller-independent VIs. In case of a controller change or upgrade, it is usually only necessary to exchange the Configuration\_Setup VI, whereas the application-specific code remains identical due to the consistent GCS command set structure. The driver set includes many specific exemplary programs, e.g., comprehensive scan and align applica-

tions that can be used as template for own programs. Moreover, the open source code of many VIs allows for rapid adaptation to the user needs.

### Flexible integration in text-based programming languages

The integration of PI positioning systems in text-based programming languages under Microsoft Windows or Linux is simplified by program libraries and exemplary codes.

These libraries support all common programming languages and all PI positioning systems, allowing the PI GCS command set functions to be integrated seamlessly in external programs.

### Third-party software packages

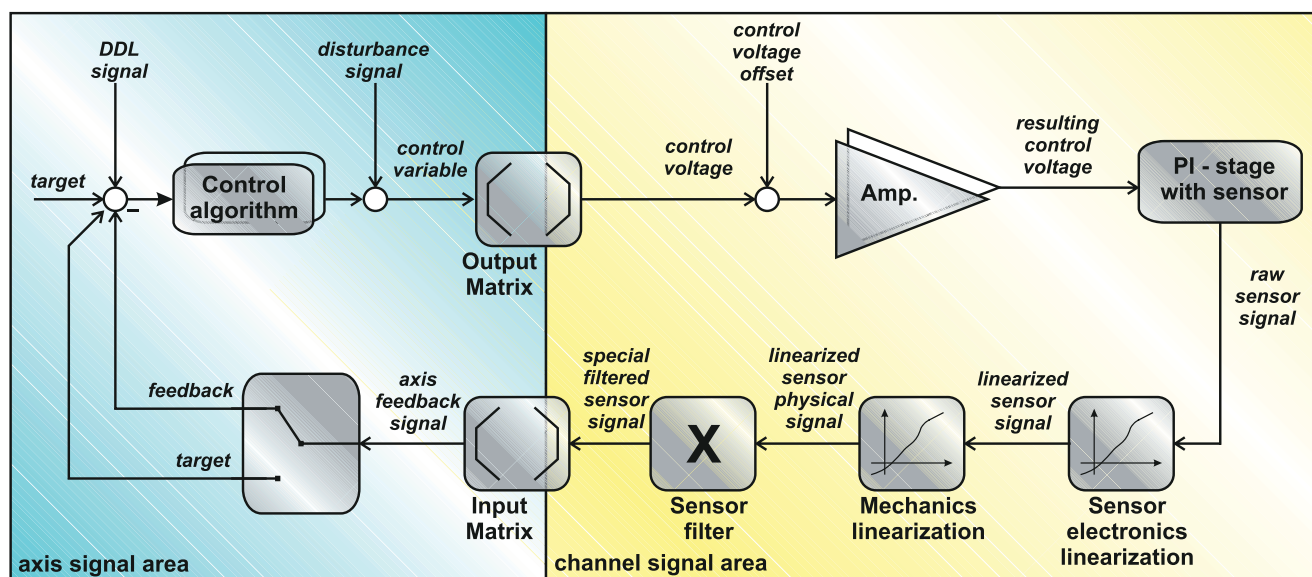
Drivers for the PI GCS commands have now been integrated in many third-party software packages. This allows for the seamless integration of PI positioning systems in software suites such as MetaMorph, µManager, MATLAB, and ScanImage. Moreover, EPICS and TANGO drivers are available for integration into experiments of large-scale research facilities. The drivers for µManager, MATLAB and a large part of the EPICS drivers are being developed and serviced in-house by PI.

### Supported languages and software environments

- C, C++, Python, Visual C++, Visual Basic, Delphi
- LabVIEW, MATLAB, µManager, EPICS, TANGO, MetaMorph
- and all programming environments that support the loading of DLLs

## Control-Loop Integrates Active Vibration Damping

FOR UHV-COMPATIBLE HEXAPOD 6D-POSITIONER



Control design of an E-712 digital controller for active vibration damping

Positioning systems for UHV environments require special mechanical design features.

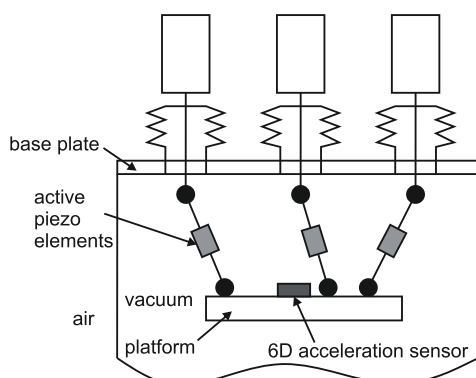
One particularly elegant solution is the implementation of a parallel-kinematic 6-axis Hexapod with constant leg length, in which only passive parts of the drive system are accommodated inside the vacuum chamber. Electrical and electronic parts, such as motors, sensors, wiring or parts in need of

lubrication are situated outside the vacuum chamber. As a result, the space needs within the chamber are very low and the passive hexapod structure inside the chamber is very stiff. Moreover, the vacuum is contaminated as little as possible and no additional cooling of the drives is needed.

### Integrated active vibration damping

A crucial factor for the precision is the decoupling of low frequency ambient vibrations that excite resonances in the mechanical system and thus would interfere with the stability and precision of the platform.

For this purpose, the passive struts are equipped with piezo ceramic actuators. A newly developed 6D acceleration sensor feeds vibration back to a closed-loop piezo controller. Digital linearization algorithms for the mechanical and electronic systems and filter functions for the sensor signals further enhance the performance resulting in damping factors in excess of 20 for multi-directional vibrations up to 50 Hz. Linearization algorithms for the mechanical and electronic systems and filter functions for the sensor values then allow undesired vibrations to be dampened completely.



The Hexapod design is based on passive, constant-length struts, where the position of the joint is being shifted by external linear actuators. The active and the passive structures are separated by the base plate of the vacuum chamber



## Accessories

FOR HEXAPOD SYSTEMS



**C-887.MC**  
**Hexapod control unit, USB connector,**  
**3 m cable**

- Manual control
- Freely definable step size
- Display for position values



**F-206.NCU**  
**Rapid 3-axis piezo nanopositioning**  
**system**  
For use in combination with Hexapod  
systems

- Consists of P-611.3SF NanoCube® XYZ nanopositioning system, 100 x 100 x 100 µm, strain gauge sensors with integrated fiber adapter interface and E-760.3S0 NanoCube® piezo controller board, ISA bus



**F-206.VVU**  
**Photometer card, visible range,**  
**2 channels**

- Optical inputs in the 480 to 1040 nm range
- Analog inputs 0–10 V

**F-206.iiU**  
**Photometer card, IR range, 2 channels**

- Optical inputs in the 850 to 1680 nm range
- Analog inputs 0–10 V



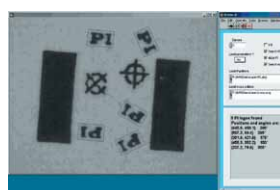
**C-887.A20**  
**Hexapod cable set, 20 m**

- For differential signal transmission



**F-206.TMU**  
**Additional mounting platform**  
fits H-206 Hexapods

- For quick interchange of complete pre-mounted setups
- magnetic kinematically clamped



**F-311.LV**  
**PIMotion&Vision LabVIEW driver set**  
supports intelligent automated  
procedure

- Integrates vision systems with PI micro- and nanopositioners
- Includes standard procedures e.g. for gap measurement, autofocus, aligning edges as well as complex alignment routines in six degrees of freedom with an unlimited number of axes of motion



**F-603**  
**Fiber, objective and waveguide**  
**holders**  
fits H-206 and P-611 NanoCube®

- Mount on a Variety of PI Alignment Systems
- Precision Machined from High-Strength Aluminum/Brass

## Drives that Set the World in Motion

FOR INDUSTRY AND RESEARCH



### Future Technology Solutions

Today PI delivers micro- and nanopositioning solutions for all important high-tech markets:

- Semiconductor technology
- Optical metrology, microscopy
- Biotechnology and medical devices
- Precision automation and handling
- Precision machining
- Data storage technology
- Photonics, telecommunications
- Nanotechnology
- Micropositioning
- Aviation and aerospace
- Astronomy

**PI (Physik Instrumente) is the leading supplier of piezo-based positioning systems with accuracies in the range of a few nanometers.**

The extensive product portfolio is based on a wide range of technologies with electromotive or piezoelectric drives for up to six motion axes. Hexapods, nanometer sensors, control electronics as well as software and are supplemented by customized solutions.

All key technologies are developed in-house. This means that every phase from the design right down to the shipment can be controlled: The precision mechanics and the electronics as well as the position sensors and the piezo ceramics or actuators. The latter are produced by the subsidiary company PI Ceramic.

PI is, therefore, the only manufacturer of nanopositioning technology which employs the piezoelectric drives it produces. This ensures

a high degree of flexibility for developing customized piezoceramic components.

More than 100 patents and patents applied for stand for more than 40 years of experience and pioneering work. PI products are employed wherever technology in industry and research is pushed forward – worldwide.

With four German factories and ten subsidiaries and sales offices abroad, the PI group is represented internationally.

PI stands for quality in products, processes and service. The ISO-9001 certification, which focuses not only on product quality but also on customer expectations and satisfaction, was achieved back in 1994.

PI is also certified according to the ISO 14001 (environmental management) and OHSAS 18001 (occupational safety) standards, which taken together form an Integrated Management System (IMS).

## Milestones

A SUCCESS STORY

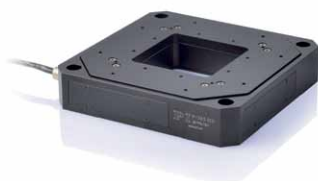


- |   |  |
|---|--|
| <b>1970</b> PI founding year  | <b>2001</b> New company building in Karlsruhe, Germany                     |
| <b>1977</b> PI headquarters move to Waldbronn, Germany  | <b>2002</b> PI Ceramic company building extended                           |
| <b>1987</b> Foundation of a subsidiary in the USA   | <b>2002</b> Foundation of a subsidiary in China                            |
| <b>1991</b> Foundation of a subsidiary in Japan   | <b>2002</b> Market launch of PICMA® multilayer Piezo stack actuators       |
| <b>1991</b> Market launch of 6-axis parallel-kinematics positioning systems (Hexapods)                              | <b>2004</b> Market launch of NEXLINE® high-performance piezo linear drives |
| <b>1992</b> Foundation of PI Ceramic, Thuringia, Germany; crucial step towards market leadership in nanopositioning | <b>2007</b> Market launch of NEXACT® piezo linear drives                   |
| <b>1993</b> Foundation of subsidiaries in the UK and in France  | <b>2010</b> Acquisition of the expansion site next to the PI headquarters  |
| <b>1994</b> Market launch of capacitive position sensors  | <b>2011</b> Foundation of a subsidiary in Korea                            |
| <b>1995</b> Foundation of a subsidiary in Italy   | <b>2011</b> Foundation of a subsidiary in Singapore                        |
| <b>1998</b> Market launch of digital control electronics  | <b>2011</b> Acquisition of the majority shares of miCos GmbH               |
| <b>2001</b> Market launch of PILine® Ultrasonic Piezomotors   | <b>2012</b> Extension of the buildings in Karlsruhe and Lederhose          |



## Product Portfolio

### NANOPOSITIONING SYSTEMS, MICROPOSITIONING TECHNOLOGY & NANOMETROLOGY



#### Nanopositioning

##### Resolution Down to Picometers

Nanopositioning systems achieve motion resolutions and positioning accuracy in the nanometer range and below. The target position is achieved within a few milliseconds and stably maintained. Piezo actuators or piezo stepping drives are used as drives. Digital motion controllers optimize the performance of the system. These systems are required in optical metrology, microscopy, or in microchip production. To achieve the necessary position resolution and stability, PI manufactures and develops the sensor systems and offers these as an independent product line.

- From linear axes to motion in 6 degrees of freedom
- Parallel-kinematic principle for multi-axis systems
- Versions with direct position measurement
  - capacitive sensors: Subnanometer resolution
  - Incremental sensors: Nanometer resolution, wide measurement ranges
- Available in a variety of designs, travel ranges, and precision classes



#### PiezoWalk® Stepping Drives

##### Precise Positioning over Several Millimeters

Piezo stepping drives transfer the advantages of conventional piezo actuators to applications with larger travel ranges. The interplay of the motion of individual actuators brings about a walk motion with high resolution and dynamics within a single step and thus, in principle, allows unlimited travel ranges. The actuators are prestressed against the moving slider. The drive is therefore self-locking when switched off without holding currents or additional mechanical components. There is therefore no heat dissipation or control dither, the position is maintained with a high degree of stability.

- Two principles:
  - NEXLINE®: Generated force up to 600 N
  - NEXACT®: Fast motion and generated force up to 10 N
- Integration levels from an economical OEM drive to a multi-axis positioning system
- Compact design, variable travel due to variable rod length
- Nanometer resolution
- Vacuum compatible and non-magnetic



#### PILine® Ultrasonic Piezomotors

##### Small and Fast over Long Distances

Ultrasonic piezomotors are an alternative to the conventional motor spindle combinations or to magnetic drives and allow outstandingly flat positioning systems. They offer excellent start/stop dynamics, high velocity and self-locking in a small package. PI supplies miniaturized versions, OEM motors and drives, and also complete positioning systems with controller. Piezomotors from PI are vacuum-compatible in principle and suitable for operation under strong magnetic fields.

- Integration levels from an economical OEM drive to a multi-axis positioning system
- Flexible travel ranges
- Easy mechanical integration
- Self-locking at rest
- Holding force to 15 N
- Velocity to 500 mm/s





## PICMA® Piezo Ceramic Multilayer Actuators

### Higher Reliability and Performance

PI uses its own PICMA® piezo ceramic actuators in its high-precision positioning systems for nanopositioning. Their all-ceramic insulation makes for highest humidity resistance which results in superior reliability and lifetime. With the piezo ceramics development being part of the PI group a fast and flexible adaptation to customers' requirements is possible.

- Long lifetime, unaffected by humidity
- Flexible cross sections and displacements
- Resolution to below one nanometer
- Response time to below one millisecond



## Digital Control Technology

### Achieve the Optimum in Performance

The performance characteristics of a precision positioning system depend equally on the stage mechanics and the control. Digital controllers use specially adapted algorithms to process process values such as sensor signal or position target value. Motions on trajectories, settling times, or trajectory deviations can thus be optimized during fast scanning operations.

- For all drive systems
- High resolution D/A and A/D converters, state of the art processor technology
- Digital real-time interfaces
- Extensive software and drivers
- Information on coordinates for parallel kinematics/Hexapods



## Micropositioning

### Precision Positioning over Long Travel

Micropositioning systems provide motion resolution and positioning accuracies in the range between a few tens of micrometers and 0.1  $\mu\text{m}$ . Brushless DC or stepper motors are available as drives, as well as linear drives such as PILine® ultrasonic piezomotors or NEXACT® piezo stepping drives. The precision of the system depends on the integrated drive, position sensor, and guides. In conventional motors, the quality of the gear, the spindle, or the worm drive play also an essential role. Digital controls with suitable control and linearization methods make it possible to improve the system characteristics.

- Linear positioners
  - Travel ranges between 5 and 1000 mm
  - Velocity to 150 mm/s
  - Low-cost designs, variants as modular system
- DC and stepper micrometer drives
  - Travel ranges to 50 mm and velocity to 30 mm/s
  - Resolution to <100 nm
- Rotary stage with unlimited slewing range
  - to 720 °/s
  - Resolution to 1  $\mu\text{rad}$
  - Incremental encoders for direct position measurement as an optional extra

## PI General Catalog

## Request it now!

The 530 page hardbound catalogue from PI is the most comprehensive reference book on the fundamentals of nanopositioning, piezo systems and micro-positioning technology yet. The catalog contains 200 product families, with more than 1000 drawings, graphs, images and technical diagrams.



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