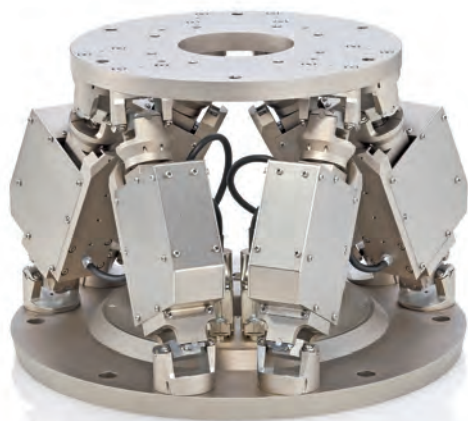


6-Axis Hexapod

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 μm
- Repeatability to $\pm 0.1 \mu\text{m}$ / $\pm 2.5 \mu\text{rad}$
- Velocity up to 25 mm/s

EtherCAT[®]  **Option**

EtherCAT[®] is a registered trademark and patented technology, licensed by Beckhoff Automation GmbH, Germany.

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

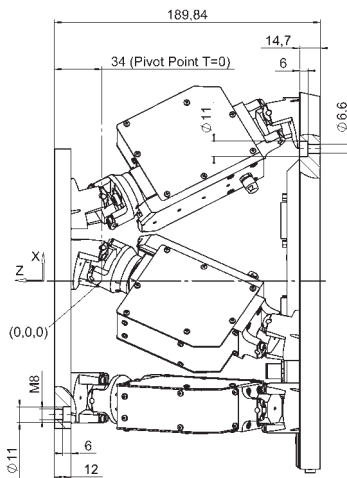
	H-824.G1x	H-824.D1x	Unit	Tolerance
	for higher resolution and load	for higher velocity		
Active axes	X, Y, Z, θ_x , θ_y , θ_z	X, Y, Z, θ_x , θ_y , θ_z		
Motion and positioning				
Travel range* X, Y	±22.5	±22.5	mm	
Travel range* Z	±12.5	±12.5	mm	
Travel range* θ_x , θ_y	±7.5	±7.5	°	
Travel range* θ_z	±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 θ_x , θ_y , θ_z	3.5	12	µrad	typ.
Backlash X, Y	3	1	µm	typ.
Backlash Z	1	1	µm	typ.
Backlash θ_x , θ_y	20	15	µrad	typ.
Backlash θ_z	25	25	µrad	typ.
Repeatability X, Y	±0.5	±0.5	µm	typ.
Repeatability Z	±0.1	±0.1	µm	typ.
Repeatability θ_x , θ_y	±2	±2	µrad	typ.
Repeatability θ_z	±2.5	±2.5	µrad	typ.
Max. velocity X, Y, Z	1	25	mm/s	
Max. velocity θ_x , θ_y , θ_z	11	270	mrads	
Typ. velocity X, Y, Z	0.5	10	mm/s	
Typ. velocity θ_x , θ_y , θ_z	5.5	55	mrads	
Mechanical properties				
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		
Miscellaneous				
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.

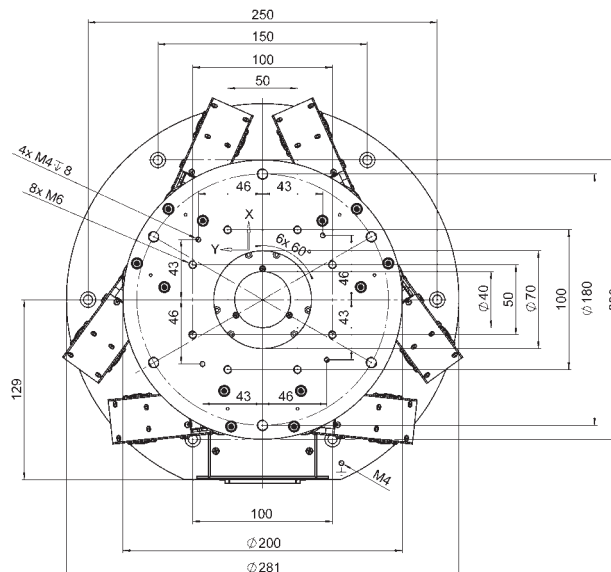
Technical data specified at $20 \pm 3^\circ\text{C}$. Ask about custom designs!
* The travel ranges of the individual coordinates (X, Y, Z, θ_x , θ_y , θ_z) are

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



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
Motion and control		
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	
Electrical properties		
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	
Interface and operation		
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	
Miscellaneous		
Operating voltage	100 to 240 VAC, 50 / 60 Hz	
Operating temperature range	5 to 40°C	
Mass	11 kg	5 kg
Dimensions	395 × 483 × 185 mm	255 × 226 × 185 mm

Linear Actuators & Motors

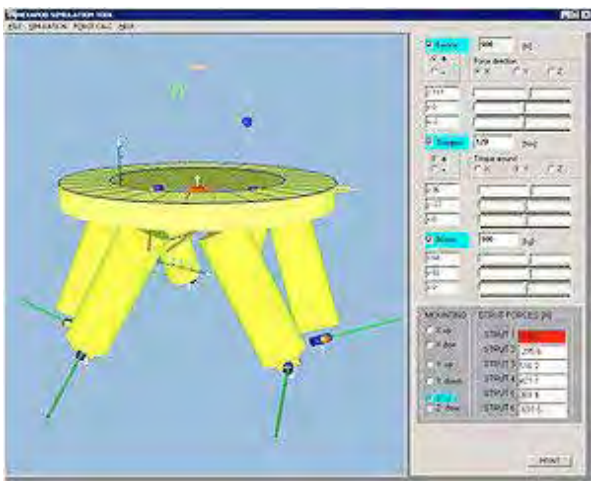
Nanopositioning & Piezoelectrics

Nanometrology

Hexapods Parallel Kinematics

Micropositioning

Appendix



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-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

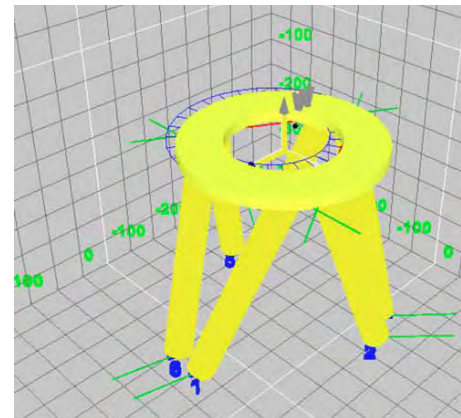
Another proprietary PI simulation software tool enables offline graphical configuration and simulation of the Hexapod motion in the application environment. CAD data of objects can be imported or approximated with simple shapes such as cylinders and cuboids. PIVeriMove then checks restrictions in the 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

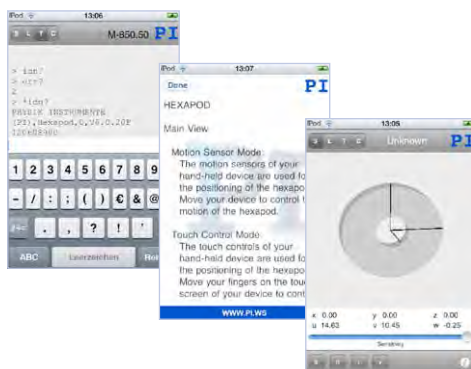
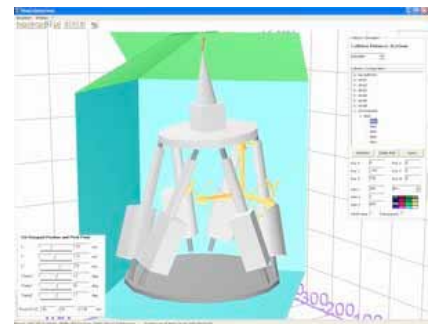
A virtual machine that can be installed on the customer's host PC is available to emulate a complete Hexapod systems (mechanics, controller and even peripherals). Application programs can then be developed and pre-tested, different load scenarios can be simulated and the work space can be determined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

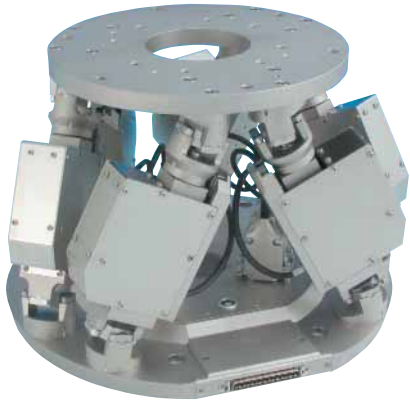


The M-824 was replaced by the H-824, see above



M-824 Compact 6-Axis-Positioning System

Precision Parallel-Kinematics Micropositioner with Controller, Vacuum Versions



M-824.3DG compact
6-axis Hexapod

- **Extremely Compact**
- **Travel Ranges to 45 mm (linear), 25° (rotation)**
- **Load Capacity to 10 kg, Self Locking Version**
- **Resolution to 7 nm**
- **Min. Incremental Motion to 300 nm**
- **Repeatability $\pm 0.5 \mu\text{m}$**
- **Velocity to 25 mm/sec**
- **Vacuum-Compatible Versions Available**

The M-824 is the ideal micro-positioning system for all complex positioning tasks which depend on high speed and accuracy in six independent axes. In addition to positioning all axes, it allows the user to define a center of rotation (pivot point) anywhere inside or outside the system envelope by one simple software command.

Extremely Compact, Two Motor Versions

The M-824 uses a very compact drive with motor and spindle mounted side-by-side and, with a height of 188 mm, has a considerably lower profile than either the M-850, page 4-6, or M-840, page 4-8 Hexapods. Two versions featuring different drives are offered: the self-locking M-824.3DG with DC motor and gearhead can position loads of up to 5 kg in any orientation (10 kg with baseplate horizontal) with sub-micron precision. The M-824.3PD with integrated ActiveDrive™ system provides a significantly higher velocity of up to 25 mm/sec with loads up to 5 kg.

Hexapod vs. Serial Kinematics Systems

The Hexapod is driven by six high-resolution actuators all

connected directly to the same moving platform. This design provides a high system stiffness and a large clear aperture.

Because of the low mass of the moving platform, positioning operations can be performed with far lower settling times than with conventional, stacked multi-axis systems. In such systems, runout, guiding errors, and the friction and inertia of moving cables all accumulate to limit accuracy and repeatability—problems which do not affect parallel kinematic systems like the Hexapod.

Fixed Virtual Pivot Point

For optics and other alignment tasks, it is important to be able to define a fixed pivot point. The sophisticated Hexapod controller allows choosing any point in space as the pivot point for the rotation axes by

Ordering Information

M-824.3PD
Compact Hexapod Microrobot with Controller, Direct Drive

M-824.3DG
Compact Hexapod Microrobot with Controller, DC Motor Gearhead

M-824.3VP
Compact Hexapod Microrobot with Controller, Direct Drive, Vacuum Compatible to 10^{-6} hPa

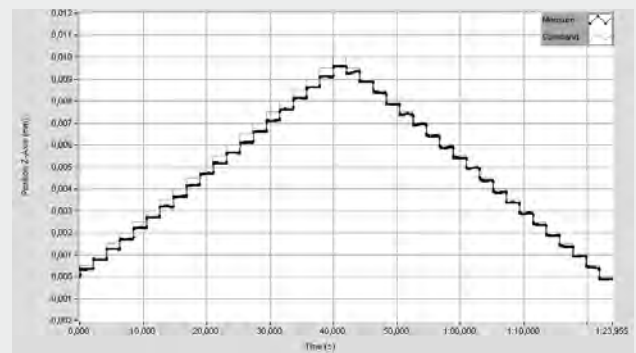
M-824.3VG
Compact Hexapod Microrobot with Controller, DC Motor Gearhead, Vacuum Compatible to 10^{-6} hPa

software command. The pivot point remains fixed relative to the platform.

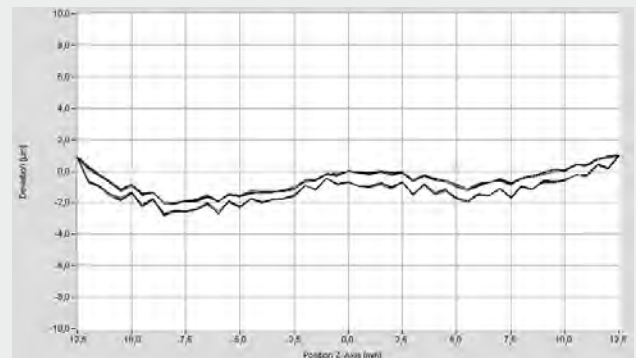
Target positions in 6-space are entered in user-friendly coordinates and reached by smooth vectorized motion.

Open Architecture

Control of the hexapod is facilitated by the controller's open



Interferometer tests show the high repeatability, here with 500 nm steps



The interferometer test shows the Z axis accuracy over the entire travel range of 25 mm and the extremely high repeatability of $\pm 0.046 \mu\text{m}$

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Application Examples

- **Biotechnology**
- **Semiconductor technology**
- **Micromachining**
- **Micromanipulation**
- **X-ray diffraction measurements**
- **Tool control**

Hexapod Options & Accessories



Photometer card



The F-206.MC6 manual control pad facilitates system setup and testing procedures. It permits independent motion in all degrees of freedom with programmable step size

Optical Metrology Boards

The controllers for the F-206, M-840 and M-850 Hexapod systems can be equipped/retrofitted with the following photometer cards: F-206.VVU (2-channel, visual) and F-206.iiU (2-channel, IR).

F-206.MC6 6D Interactive Control Pad Upgrade

The F-206.MC6 manual control pad facilitates system setup

and testing procedures. It consists of a board that plugs into the Hexapod controller and a control pad with six digital "potentiometer" knobs (one for each degree of freedom).

The manual pad works seamlessly with the Hexapod software, and allows programmable step sizes of 1 μm to 500 μm (linear) and 0.001 to 0.5deg (angular) per step.

External positioning commands (via the computer interface) can be intermixed with manual positioning input without loss of the true position, because both inputs operate on the same position registers of the Hexapod controller. The control pad comes with a 3 m cable. A 3 m extension cable is available as part number C-815.MC6.

More Options see F-311 PIMotion&Vision™ System, F-361 Optical Power Meter and F-603 Fiber, Objective and Waveguide Holders. (www.pi.ws)

Technical Data

Model	F-206.iiU, F-206.VVU Optical Metrology Boards
Optical power range	5 nW – 10 mW
Analog input voltage range	0 – 10 V
A/D resolution	16-bit
Sample rate	10 kHz
Bandwidth	300 Hz (optical input), 10 kHz (electrical input)
Max. sensitivity at:	880 nm (visible, F-206.VVU); 1550 nm (IR range, F-206.iiU)
40% sensitivity at:	480 / 1040 nm (visible, F-206.VVU); 850 / 1680 nm (IR range, F-206.iiU)

F-206.NCU Rapid NanoAlign Upgrade

For applications where alignment with nanometer-range resolution is required, or where rapid mapping of the entire cross-section of a component in as short a time as possible is desired, the F-206.NCU Rapid NanoAlign upgrade is recommended. It consists of

the P-611.3SF XYZ piezo-drive NanoCube® (see p. 2-52) and the E-760 controller board (see p. 2-138), which is installed in the F-206 controller.



F-206.NCU Rapid NanoAlign Upgrade consists of the P-611 NanoCube® piezo nanopositioner and the E-760 controller card