Micropositioning

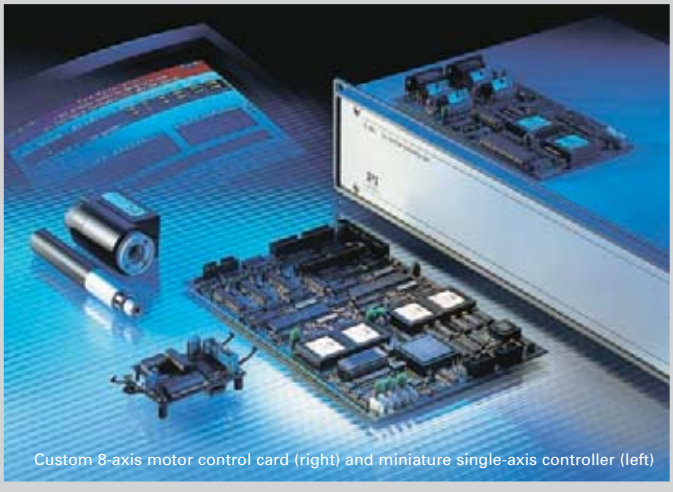
Precision Linear / Rotary / Multi-Axis Positioning Systems

Micropositioning Solutions from PI—Translation Stages, Rotation Stages, 6D Positioning Systems, Analog & Digital Motion Controllers

- **Hexapod, parallel-kinematic positioning systems with 6 degrees of freedom**
- **Motorized translation stages with 5 to 306 mm travel**
- **Integrated linear encoders for highest accuracy and repeatability (direct metrology)**
- **Optional piezo drives with 1 nm resolution**
- **Choice of piezomotors, DC servo-motors, stepper motors and hybrid systems with controllers and software**
- **ActiveDrive™: integrated servo-amplifier**
- **High-resolution rotation and tip/tilt stages, resolution <0.001°, speeds to 90°/s**
- **Optional piezo drives with sub-microradian resolution**
- **Fast voice-coil drives (scanners)**
- **Large selection of motor controllers for up to 30 axes**
- **Non-magnetic piezo ceramic linear servo-motors with speeds up to 500 mm/s**
- **Custom designs**

Typical Applications

- Photonics packaging and alignment
- Micromechanics and micromanufacturing
- Medical technology
- Semiconductor technology
- Data storage Device Testing
- Lasers & electro-optics
- Cell manipulation
- Biotechnology
- Micro-Assembly



Custom 8-axis motor control card (right) and miniature single-axis controller (left)

Hexapod 6-Axis Systems / Parallel Kinematics

Selection Guide: Hexapods, Parallel Kinematics

Parallel Kinematics (PKM) 3-Axis & 6-Axis Stages for Micro / Nanopositioning

PI parallel kinematics (PKM) precision positioning systems have many advantages over serial kinematics stages, such as lower inertia, improved dynamics, smaller package size and higher stiffness.

With two decades of Hexapod design and manufacturing experience, PI electro-mechanical Piezo Hexapods are the most advanced multiaxis precision positioning systems in the world, providing significantly higher precision than hydraulically driven systems. They are available in many sizes, and configurations for loads from 2 kg to more than 1000 kg, and most are self locking.

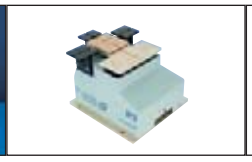
Models	Description	Travel [mm]	Load Capacity [kg]	Page
M-810	Ultra-compact electro mechanical 6-axis Hexapod. Small, yet high forces	to 40 mm / 60°	5	4-14
M-824	Vacuum compatible compact 6-axis Hexapod	to 45 mm / 25°	10	4-10
M-840	HexaLight™ 6-axis Hexapod, fast, medium load capacity optional photometer, to 50 mm/s	to 100 mm / 60°	10	4-8
M-850	High-load 6-axis Hexapod, optional photometer	to 100 mm / 60°	200	4-6
F-206	HexAlign™ 6-axis micro alignment system. Very accurate, optional photometer	to 12 mm / 6°	2	4-12
M-850KWAH	Custom secondary mirror 6-axis Hexapod alignment system for astronomy, water resistant	to 16 mm	100	4-15
M-850KHLH	Ultra-high load 6-axis Hexapod	to 24 / 8°	1000	4-15
N-515KNPH	Piezo Hexapod with nonmagnetic PiezoWalk® high-force linear motors	to 10 mm / 6°	50	1-17
M-880.PD	Tripod 3-axis high-load $XY\theta_Z$ stage for LCD and semiconductor inspection	20 x 20 mm / 8°	150	4-16
M-833	Tripod: 3-axis stage: X, Z, and goniometer (θ_Y)	±25 mm (X, Z), ±30° (θ_Y)	4	4-16
M-850KLAH	High-load Hexapod w/ large free aperture, for inspection systems	to 50 mm / 10°	200	4-15
N-510	Tripod Z-Tip/Tilt nanopositioning platform	1.3 / 10 mrad	20	1-17

M-810 Miniature Hexapod

M-824 Vacuum compatible compact Hexapod

M-840 HexaLight™ Hexapod, fast, medium load capacity

M-850 High-load Hexapod, optional photometer



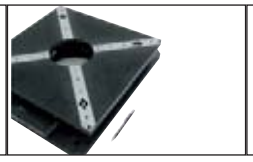
F-206 Photonics alignment system

M-850KWAH For astronomy

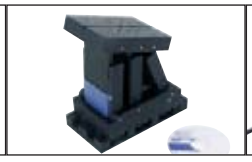
M-850KHLH Ultra-high load Hexapod

M-850KLAH Custom, for inspection systems

N-515KNPH Non-magnetic piezo hexapod



M-880 Tripod high-load $XY\theta_Z$ Stage



M-833 Tripod: X, Z, goniometer (θ_Y)

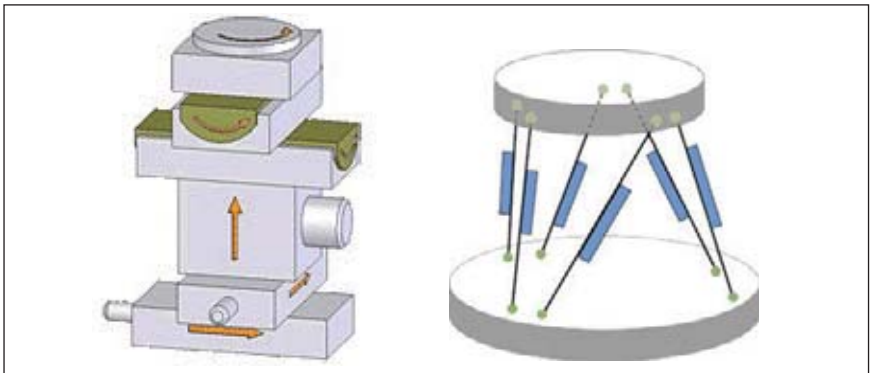
N-510 Tripod Z-tip/tilt nanopositioning platform

Notes on specifications see p. 4-17 *ff*

Parallel Kinematics Positioning Systems

Controlling Motion in up to 6 Axes with Sub-Micron Precision

The ALMA project in the Atacama desert in Chile is to include up to 64 antennas interconnected to form an enormous radio telescope. PI Hexapod systems are used to position the secondary reflectors in the antennas. The M-850K systems, specially designed for outdoor operation in hostile conditions, can position loads of up to 75 kg (photo: Vertex Antennentechnik GmbH)



Stacked serial kinematics 6D system vs. Hexapod parallel kinematics system designs. Advantages such as compactness and minimized inertia (one platform for all six actuators) are easily seen. The reduced inertial mass makes for significantly faster response than with serial kinematics. Because there are no moving cables to cause friction, repeatability is improved also

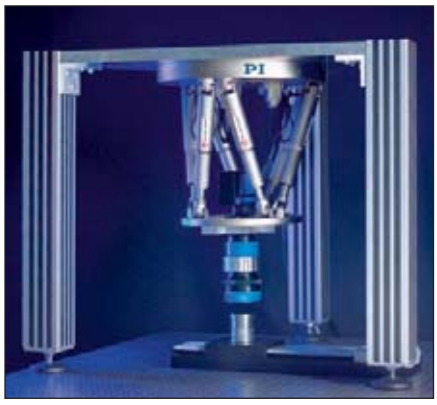
PI is the leading manufacturer of Hexapod high-performance micro- and nanopositioning systems. These parallel-kinematics devices, in a number of different forms, are suitable for diverse applications, ranging from handling systems in electronics fabrication and tool control in precision machining, through medical technology, to optical systems like those found in space telescopes and satellite receiving antennas. Various models of the powerful parallel kinematic machines (PKM) can move masses of 50, 200 or even 1000 kilograms with micron accuracy as required in their respective applications.

These Hexapod systems are all built with six, high-resolution electro-mechanical or piezoelectric actuators all acting on a common platform. It is the familiar flight simulator design, but considerably more precise: in place of hydraulic cylinders, the Hexapods are driven by highly accurate, precision-controlled rotary or linear motors. Different drive principles are employed, depending on the application: Hexapods with NEXLINE® drives make for a positioning system which is not only vacuum compatible but also completely non-magnetic p. 1-3 *ff.*

All PI Hexapod systems include a sophisticated, yet easy to use controller. The Hexapod controller allows the user to set a pivot point anywhere inside or outside the Hexapod working space, by a simple software command. This freely definable pivot point stays with the platform, no matter how it moves—an invaluable feature for example in optics applications. Moves are specified in Cartesian coordinates and the PC-based controller transforms them into the required motion-vectors for the individual actuator drives. The latest controller generation features flexible interfaces: high-speed RS-232, or TCP/IP interface for remote / network / Internet addressing.

Advantages of PKM:

- Low moved mass, lower inertia
- Better dynamic behaviour, shorter settling times
- Smaller package size
- Higher stiffness
- No accumulation of position errors, increased accuracy
- Freely definable pivot point
- Reduced runout errors
- No moving cables: better repeatability



This automated interferometric inspection system allows optical mold inserts to be checked directly while still on the production line. The hexapod is mounted "upside down" on a 20-millimeter-thick aluminum plate with the interferometer positioned in the central core of the hexapod, where it does not interfere with the motion. Control is integrated into a MatLab program, which also handles the metrological image processing (photo: Physik Instrumente (PI) / Fraunhofer Institute for Production Technology IPT

M-850 Hexapod 6-Axis Positioning System

High-Load Parallel-Kinematics Micropositioner with Controller, to 2000 N


M-850 Hexapod Microrobot

- **Six Degrees of Freedom**
- **Works in Any Orientation**
- **No Moving Cables for Improved Reliability and Precision**
- **200 kg Load Capacity (Vertical)**
- **Heavy-Duty, Ultra-High-Resolution Bearings for 24/7 Applications**
- **Repeatability to ±1 µm**
- **Encoder Resolution to 0.005 µm**
- **Significantly Smaller and Stiffer than Serial-Kinematics Systems, Better Dynamics**
- **Vacuum-Compatible Versions Available**
- **Linear and Rotary Multi-Axis Scans**
- **Virtual Pivot Point**
- **Sophisticated Controller Using Vector Algorithms**
- **MTBF 20,000 h**

Application Examples

- Alignment of secondary mirrors
- Semiconductor technology
- Optics alignment
- Medical technology
- Micromachining
- Micromanipulation
- X-ray diffraction measurements
- Satellite testing equipment
- Tool control

The M-850 is the ideal micropositioning system for all complex positioning tasks which depend upon high load capacity and accuracy in six independent axes. The use of extremely stiff and accurate components for the M-850 Hexapod results in an unusually high natural frequency of 500 Hz with a 10 kg load. It can withstand loads of 200 kg vertically, and at least 50 kg in any direction. In addition to positioning all axes with resolutions in the submicron and arcsecond ranges, it allows the user to define the center of rotation (pivot point) anywhere inside or outside the system envelope by one simple software command.

Two models are available: The M-850.50 featuring higher speed and direct-drive actuators, and the M-850.11 with a gear ratio that makes it self-locking even with large loads.

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 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 interface architecture, which provides a variety of high-level commands and includes a macro language for programming and storing command sequences.

Automatic Optical Alignment

With the internal or external photometer option and the integrated scanning routines, just a few commands are needed to perform an automated alignment of optical components. For more information on photometers / optical power meters, see www.pi.ws.

A smaller, even-more-precise hexapod, specially developed for alignment of collimators, fiber bundles and I/O chips, is available as the F-206 (see p. 4-12).

Ordering Information

M-850.11
Hexapod Microrobot with Controller, DC-Motor w/ Gearhead

M-850.V11
Hexapod Microrobot with Controller, DC-Motor w/ Gearhead, Vacuum Compatible to 10^{-6} hPa

M-850.50
Hexapod Microrobot with Controller, Direct Drive

M-850.V50
Hexapod Microrobot with Controller, Direct Drive, Vacuum Compatible to 10^{-6} hPa

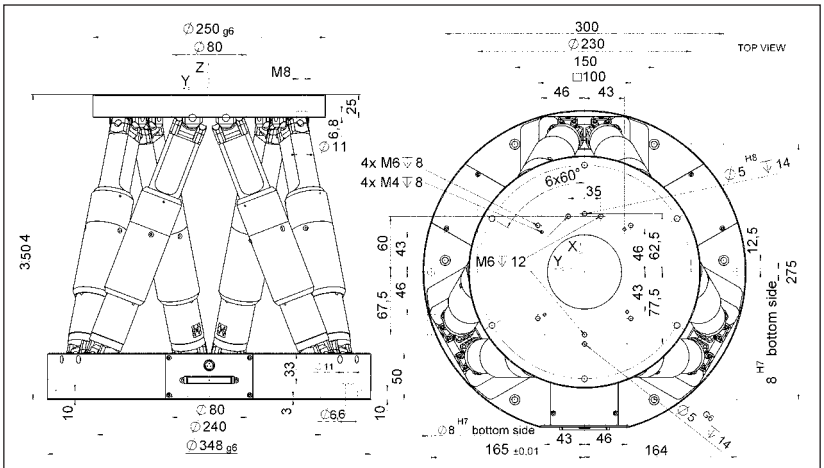
Optional Photometers

F-206.iiU
Photometer Card, IR Range, 2 Channels

F-206.VVU
Photometer Card, Visual Range, 2 Channels


Custom Hexapod designed for neurosurgery Photo: IPA

Custom "6+3" Hexapod with additional struts providing independent position feedback



M-850 Hexapod. Dimensions in mm

Linear Actuators & Motors
Nanopositioning / Piezoelectrics
Nanometrology
Micropositioning
Hexapod 6-Axis Systems / Parallel Kinematics
Linear Stages
Translation (X)
Vertical (Y)
Multi-Axis
Rotary & Tilt Stages
Accessories
Servo & Stepper Motor Controllers
Single-Channel
Hybrid
Multi-Channel
Micropositioning Fundamentals
Index

Technical Data

Model	M-850.11	M-850.50	Units
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	±50	±50	mm
*Travel range Z	±25	±25	mm
*Travel range θ_X, θ_Y	±15	±15	°
*Travel range θ_Z	±30	±30	°
Actuator drive	DC-motor	DC-motor	
Actuator stroke	±25	±25	mm
Integrated sensor	Rotary encoder	Rotary encoder	
Sensor resolution	2048	2048	
Actuator design resolution	0.005	0.05	µm
**Min. incremental motion X, Y, Z	1 (XY), 0.5 (Z)	1 (XY), 0.5 (Z)	µm (6-axis move!)
**Min. incremental motion θ_X, θ_Y, θ_Z	5	5	µrad (6-axis move!)
Repeatability X, Y	±2	±2	µm
Repeatability Z	±1	±1	µm
Repeatability θ_X, θ_Y, θ_Z	±10	±10	µrad
Max. velocity X, Y, Z	0.5	8	mm/s
Max. velocity θ_X, θ_Y, θ_Z	6	100	mrad/s
Typ. velocity X, Y, Z	0.3	5	mm/s
Typ. velocity θ_X, θ_Y, θ_Z	3	50	mrad/s
Mechanical properties			
Stiffness (k_x, k_y)	3	3	N/µm
Stiffness (k_z)	100	100	N/µm
Max. load (baseplate horizontal/any orientation)	200 / 50	200 / 50	kg
Max. holding force (baseplate horizontal/any orientation)	2000 / 500	250 / 85	N
Resonant frequency*** F_X,F_Y	90	90	Hz
Resonant frequency*** F_Z	500	500	Hz
Miscellaneous			
Operating temperature range	-10 to +50	-10 to +50	°C
Material	Aluminum	Aluminum	
Mass	17	17	kg
Controller			
Controller included	M-850.502	M-850.502	
Operating voltage	100–240 VAC, 50/60 Hz	100–240 VAC, 50/60 Hz	

Technical data are specified at 20 ±3 °C. Data for vacuum versions may differ.

Custom water-resistant Hexapod

HexControl™ software showing scan of a fiber optics component

*The max. travel of the several 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.

**Six-axis move. No moving cables (unlike serial-kinematic stacked systems) to introduce bending forces, torque and friction which degrade positioning accuracy.
Example: The following position is in the workspace:
X: +20 mm θ_X : +10°
Y: +20 mm θ_Y : +10°
Z: +5 mm θ_Z : -2°

***Baseplate mounted horizontally with 10 kg load

M-840 HexaLight™ 6-Axis Positioning System

High-Speed Parallel-Kinematics Micropositioner with Controller, to 50 mm/s

M-840 HexaLight™ 6D-Micropositioning System

- **Six Degrees of Freedom, Travel Ranges to 100 mm/ 60° Rapid Response**
- **No Moving Cables for Improved Reliability and Precision**
- **Load Capacity 10 kg, Self-Locking Version M-840.DG**
- **Velocity up to 50 mm/s**
- **Repeatability up to ±2 µm**
- **Encoder Resolution to 0.016 µm**
- **Significantly Smaller and Stiffer than Serial-Kinematics Systems, Better Dynamics**
- **Vacuum-Compatible Versions Available**
- **Virtual Pivot Point**
- **Sophisticated Controller Using Vector Algorithms**
- **MTBF 20,000 h**

The M-840 is the ideal Micropositioning System for all complex positioning tasks which depend upon high speed and accuracy in six independent axes.

Application Examples

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

Faster Positioning in All Six Axes

In comparison with the M-850 Hexapod (see p. 4-6 *ff*) the M-840 is designed for higher speeds and lighter loads. Loads of up to 10 kg can be positioned at up to 50 mm/s and 600 mrad/s with micron accuracy. In addition to positioning all axes, it allows the user to define the center of rotation (pivot point) anywhere inside or outside the system envelope by one simple software command.

Two models are available: The M-840.5PD featuring higher speed and direct-drive actuators, and the M-840.5DG with a gear ratio that makes it self-locking.

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 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

Ordering Information

M-840.5PD
Hexapod 6-Axis Parallel Kinematics Microrobot with Controller, Direct Drive

M-840.5DG
Hexapod 6-Axis Parallel Kinematics Microrobot with Controller, Gearhead Drive

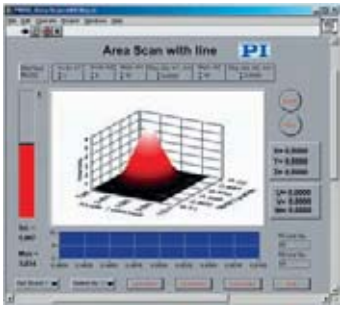
Optional Photometer

F-206.iiU
Photometer Card, IR Range, 2 Channels

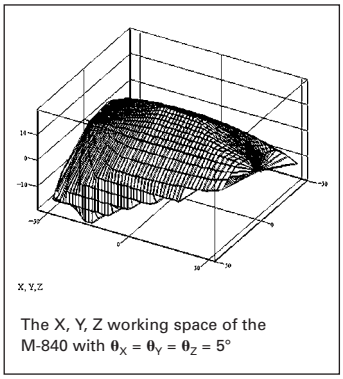
F-206.VVU
Photometer Card, Visible Range, 2 Channels

F-361.10
NIST Traceable Optical Power Meter, 1000 to 1600 nm

Ask about custom designs!



HexControl™ software showing scan of a fiber optics component



The X, Y, Z working space of the M-840 with $\theta_X = \theta_Y = \theta_Z = 5°$

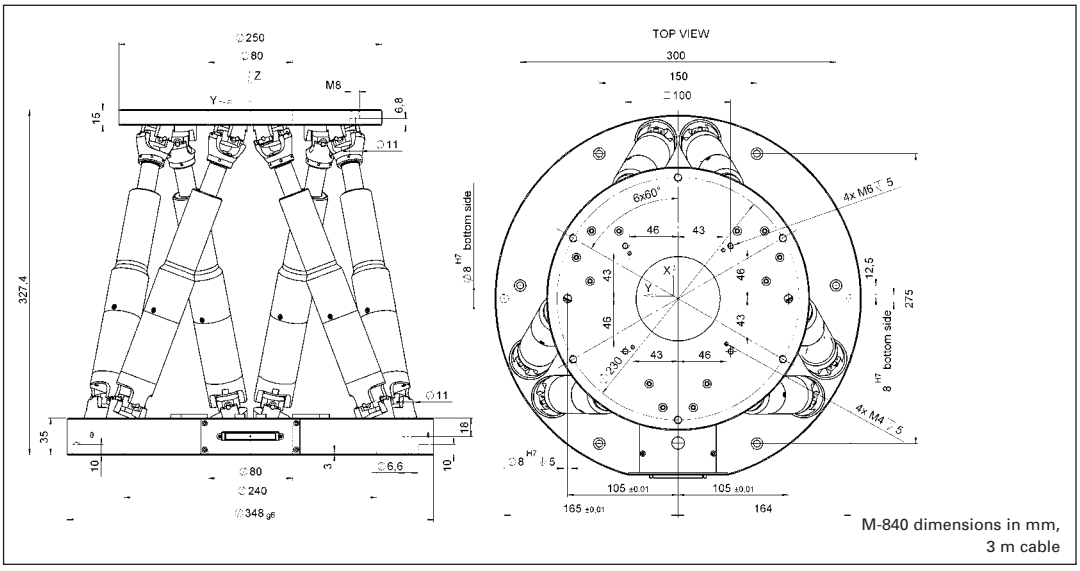
interface architecture, which provides a variety of high-level commands and includes a macro language for programming and storing command sequences.

Automatic Optical Alignment

With the internal or external photometer option and the integrated scanning routines, just a few commands are needed to perform an automated alignment of optical components. For more information on photometers / optical power meters, see www.pi.ws.

A smaller, even-more-precise hexapod, specially developed for alignment of collimators, fiber bundles and I/O chips, is available as the F-206 see p. 4-12 *ff.*

For a compact, vacuum-compatible Hexapod see M-824 see p. 4-10 *ff.*



M-840 dimensions in mm, 3 m cable

Hexapodcontroller with optional display and keyboard

High-Speed Photometer F-361

Technical Data

Model	M-840.5PD	M-840.5DG	Units
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,	±50	±50	mm
*Travel range Z	±25	±25	mm
*Travel range θ_X, θ_Y,	±15	±15	°
*Travel range θ_Z	±30	±30	°
Actuator drive	DC-motor	DC-motor	
Actuator stroke	±25	±25	mm
Integrated sensor	Rotary encoder	Rotary encoder	
Sensor resolution	2048	2048	
Actuator design resolution	0.5	0.017	µm
**Min. incremental motion X, Y	3	1	µm
**Min. incremental motion Z	1	0.5	µm
**Min. incremental motion θ_X, θ_Y, θ_Z	5	5	µrad
Repeatability X, Y	±2	±2	µm
Repeatability Z	±1	±1	µm
Repeatability θ_X, θ_Y, θ_Z	±20	±20	µrad
Max. velocity X, Y, Z	50	2.5	mm/s
Max. velocity θ_X, θ_Y, θ_Z	600	30	mrad/s
Typ. velocity X, Y, Z	30	2	mm/s
Typ. velocity θ_X, θ_Y, θ_Z	300	20	mrad/s
Mechanical properties			
Max. load (baseplate horizontal/any orientation)	10 / 3	10 / 3	kg
Max. holding force (baseplate horizontal/any orientation)	15 / 5	100 / 25	N
Resonant frequency*** F_X, F_Y	100	100	Hz
Resonant frequency*** F_Z	300	300	Hz
Miscellaneous			
Operating temperature range	-10 to +50	-10 to +50	°C
Material	Aluminum	Aluminum	
Mass	12	12	kg
Controller			
Delivered controller	M-850.502	M-850.502	
Operating voltage	100–240 VAC, 50/60 Hz	100–240 VAC, 50/60 Hz	

Technical data are specified at 20 ±3 °C. Data for vacuum versions may differ.

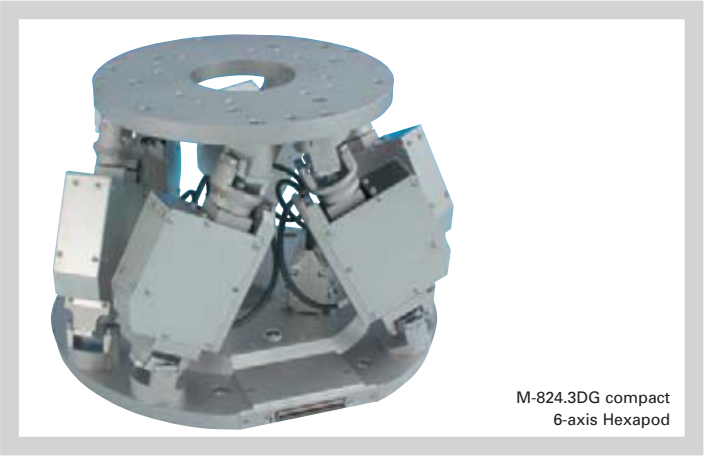
*The max. travel of the several coordinates (X, Y, Z, θ_X, θ_Y, θ_Z) are interdependent. The data for each axis in this table shows its maximum travel, where all other axes are at their zero positions. If the other linear or rotational coordinates are not zero, the available travel may be less.

**Six-axis move. No moving cables (unlike serial-kinematic stacked systems) to introduce bending forces, torque and friction which degrade positioning accuracy.

***Baseplate mounted horizontally without load

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 ±0.5 µm**
- **Velocity to 25 mm/sec**
- **Vacuum-Compatible Versions Available**

The M-824 is the ideal micropositioning 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.

Application Examples

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

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 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

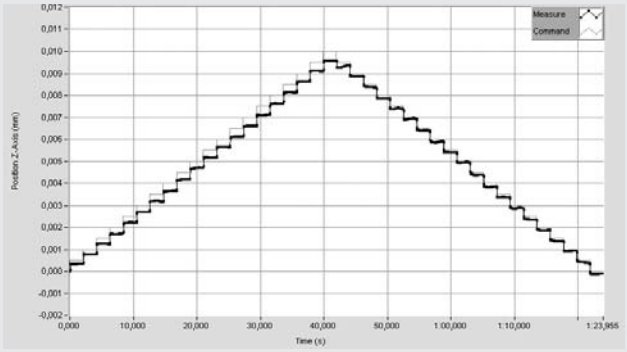
Ordering Information

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

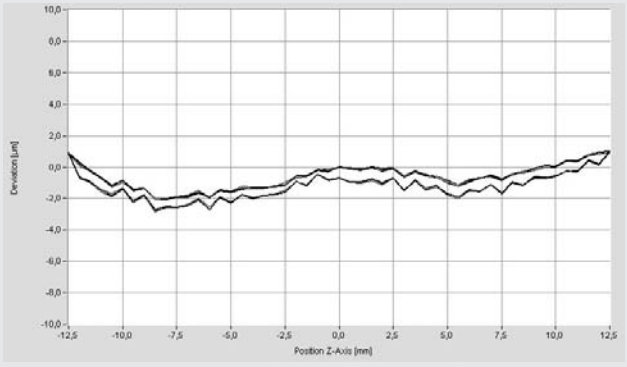
M-824.3DG
Compact Hexapod Microrobot with Controller, DC Motor Gearhead

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



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



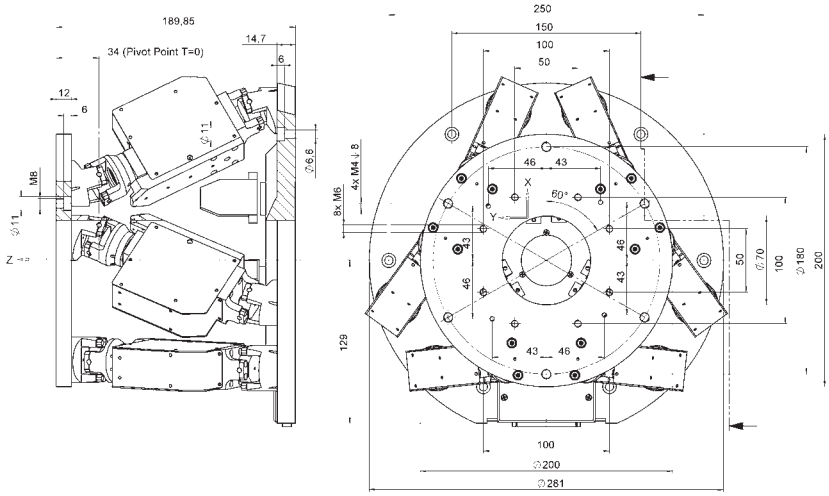
The interferometer test shows the Z axis accuracy over the entire travel range of 25 mm and the extremely high repeatability of ±0.046 µm

interface architecture, which provides a variety of high-level commands and includes a macro language for programming and storing command sequences.

Vacuum Versions

Both models are available as vacuum versions that enable use in applications such as X-ray diffraction microscopy with ambient pressures down to 10^{-6} hPa.

The M-824 comes with a powerful 6D controller and sophisticated, user-friendly positioning and alignment sofware. Keypad and display are optional



M-824 dimensions in mm, 3 m cable included

Technical Data

Model	M-824.3DG	M-824.3PD	Units
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 drive	DC-motor, gearhead	ActiveDrive™ DC Motor	
Actuator stroke	±12.5	±12.5	mm
Single-actuator design resolution	0.007	0.5	µm
Integrated sensor	Rotary encoder	Rotary encoder	
Sensor resolution	2048	2048	cts./rev.
**Min. incremental motion X, Y, Z	0.3	1	µm
**Min. incremental motion θ_X, θ_Y, θ_Z	3.5	12	µrad
Repeatability X, Y, Z	±0.5	±0.5	µm
Repeatability θ_X, θ_Y, θ_Z	±6	±6	µrad
Max. velocity X, Y, Z	1	25	mm/s
Max. velocity θ_X, θ_Y, θ_Z	11	270	mrad/s
Typ. velocity X, Y, Z	0.5	10	mm/s
Typ. velocity θ_X, θ_Y, θ_Z	5.5	55	mrad/s
Mechanical properties			
*Stiffness X, Y	1.7	1.7	N/µm
Stiffness Z	7	7	N/µm
Load capacity (baseplate horizontal/any orientation)	10/5***	5/2.5	kg
Miscellaneous			
Operating temperature range	-10 to +50	-10 to +50	°C
Material	Aluminum	Aluminum	
Mass	8	8	kg
Controller			
Controller included	M-850.502	M-850.502	
Operating voltage	100–240 VAC, 50/60 Hz	100–240 VAC, 50/60 Hz	

*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
**Simultaneous motion of all 6 actuators! No moving cables (as in serial-kinematics stacked systems) to introduce bending sources, torque and friction, which degrade positioning accuracy
***Self Locking
Technical data are specified at 20 ±3 °C.
Data for vacuum versions may differ.

F-206.S HexAlign™ 6 Axis-Hexapod

Parallel-Kinematics Precision Alignment System / Manipulator, with Controller

The F-206.S Hexapod comes with a digital 6D controller and comprehensive software

- **Parallel Kinematics with 6 Degrees of Freedom**
- **0.033 µm Actuator Resolution**
- **Repeatability 0.3 µm in Space**
- **No Moving Cables for Improved Reliability, Reduced Friction**
- **Better Dynamics, More Compact than Serial Kinematics Systems**
- **For Scanning and Alignment**
- **Cartesian Coordinate Control with Virtualized Pivot Point**
- **Powerful Digital Controller with Open Source LabView™ Drivers, DLL Libraries...**
- **Integrated Fiber Alignment Routines**

The F-206.S HexAlign™ Hexapod is a highly accurate micropositioning system for complex multi-axis alignment tasks. It is based on PI's long experience with ultra-high-resolution, parallel kinematics stages. Unlike hexapods with variable-length struts ("legs") the F-206 features constant-length struts and friction-free flexure guides. This gives the F-206 even higher precision than other hexapod designs.

Application Examples

- Micromachining
- Photonics packaging
- Fiber alignment
- Semiconductor handling / test systems
- Micromanipulation (life science)
- Optical device testing
- Collimator and fiber bundle alignment
- MEMS positioning/alignment

Compact, Plug & Play

The F-206.S Hexapod is considerably smaller and more accurate than comparable serial kinematics six-axis systems (stacks of single-axis units).

The parallel kinematics of the F-206 is immune to the cumulative bending and guiding errors of the various axes which, together with the inertia and friction of the moving cables, can limit accuracy in stacked systems. In addition, rotations are not set in hardware, but about a pivot point freely definable in software. A high-performance controller does all necessary coordinate transformation for coordinating the six drives. Because all the actuators are attached directly to the same moving platform, there are none of the servo-tuning problems associated with the loading and inertia differences of the different axes, as are inherent in stacked systems.

Virtualized Pivot Point

It is important to have a fixed pivot point for alignment tasks, especially in photonics packaging. Because the parallel kinematics motion of the F-206 is calculated with complex algorithms in the digital controller, it was easy to allow programming any point in space as center of rotation. Furthermore, the cartesian coordinates of any position and any orientation can be entered directly and the specified target will be reached after travel along a smooth path.

Six Degrees of Freedom, No Moving Cables

In the F-206 parallel kinematics design, all cable terminations are on the stationary base, eliminating unpredictable friction and inertia, improving resolution and repeatability. Further advantages of the system are:

- No cable guides required
- Reduced Size and Inertia
- Improved Dynamic and Settling Behavior
- Identical Modular Actuators for Simplified Servicing

Open Command Set, Simplified Programming

Integration of the F-206 in complex applications is facilitated by the system's open command set and comprehensive tool libraries. The controller can be operated either through a host PC, or directly through a keyboard and monitor. It can also run programs stored in a user-friendly, fully documented macro language.

Automatic Optical Alignment

Optional internal and external photometers are available.

Ordering Information

F-206.S0
Hexapod 6-Axis Precision Alignment System / Manipulator with 6 DOF Hexapod Controller

F-206.SD
Hexapod 6-Axis Precision Alignment System / Manipulator with 6 DOF Hexapod Controller, Built-in Display and Keypad

Options and Accessories

F-206.AC8
Upgrade for 2 Additional Servo-Motor Control Channels on F-206 Controller

F-206.MHU
Force-Limiting Mounting Platform, (included with F-206.SD)

F-206.NCU
Upgrades: Rapid Nanopositioning Upgrade for F-206.S. Consists of P-611.3SF NanoCube and E-760 Controller Card

F-206.MC6
6D Interactive Manual Control Pad

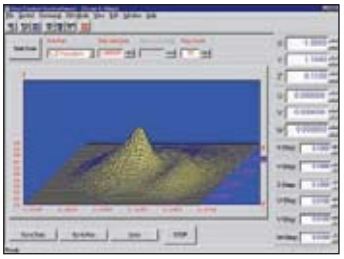
F-206.VVU
2-Channel Photometer Card, (Visual Range)

F-206.iiU
2-Channel Photometer Card (IR Range)

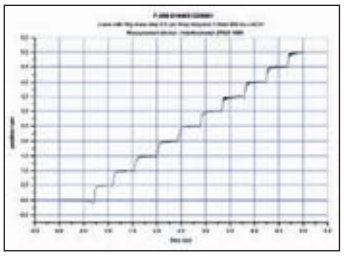
F-361.10
Absolute-Measuring Optical Power Meter, 1000-1600 nm Wavelength

Additional Accessories, see www.pi.ws.

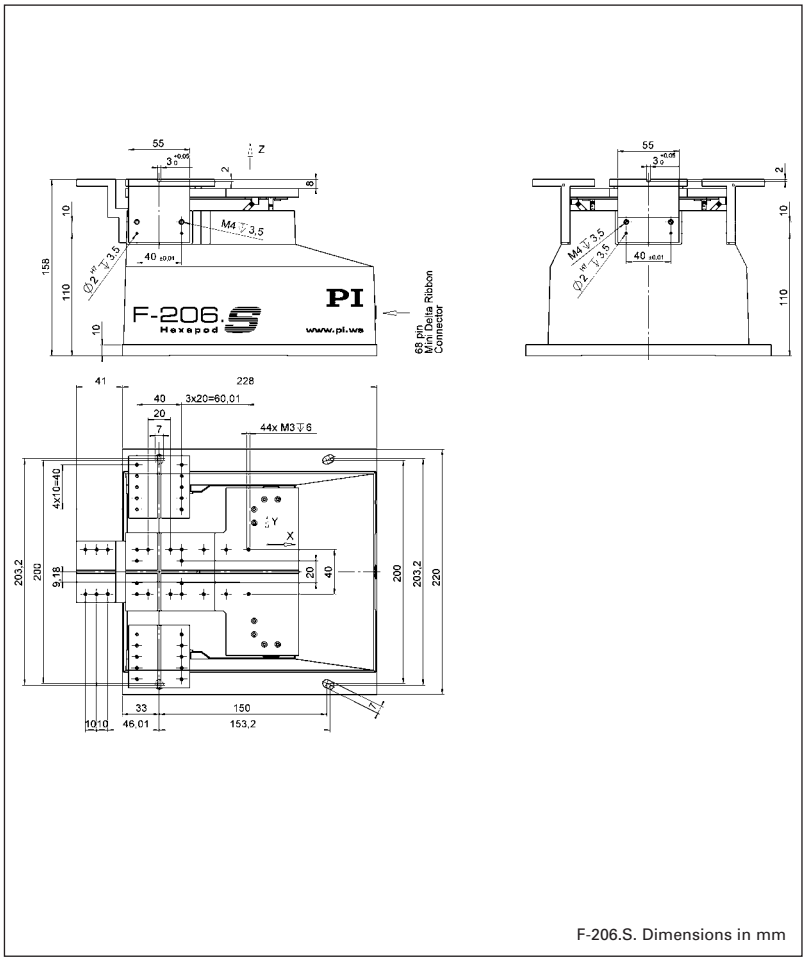
Both types are fully integrated with the controller hardware and with routines designed for automatic alignment of collimators, optical fibers and arrays. For more information on the photometers see www.pi.ws.



HexControl™ Software displaying scan of photonics component



Interferometer test of an F-206.S system shows the excellent repeatability of small steps, here 0.5 µm spaced at 100 ms



F-206.S. Dimensions in mm

Technical Data

Model	F-206.S0 / F-206.SD
Travel range X*	-8 to +5.7 mm
Travel range Y*	±5.7 mm
Travel range Z*	±6.7 mm
Travel range θ_X *	±5.7°
Travel range θ_Y *	±6.6°
Travel range θ_Z *	±5.5°
Actuator resolution	33 nm
Minimum incremental motion X, Y, Z**	0.1 µm (6-axis move!)
Minimum incremental motion θ_X, θ_Y, θ_Z**	2 µrad (0.400115°) (6-axis move!)
Bidirectional repeatability X, Y, Z	0.3 µm
Bidirectional repeatability θ_X, θ_Y, θ_Z	3.6 µrad
Speed X, Y, Z	0.01 to 10 mm/s
Maximum load in Z	2 kg (centered on platform)
Mass	5.8 kg
Controller	Digital Hexapod controller with optional photometer card and integrated scan and align routines
Operating voltage	100–240 VAC, 50/60 Hz
Software	LabView™ drivers, software for alignment of arrays, DLL libraries, HexControl™, scan and align software, terminal software

*Travel ranges in the coordinate directions (X, Y, Z θ_X, θ_Y, θ_Z) are interdependent. The data given shows maximum travel range of the axis in question (i.e. its travel when all other axes are at their zero positions). If this is not the case, the available travel may be less.

**Six-axis move. No moving cables (unlike serial-kinematic stacked systems) to introduce bending forces, torque and friction which degrade positioning accuracy.

M-850K Vacuum Hexapod 6-Axis Positioner

Parallel-Kinematics System for Wide Temperature Ranges

This custom hexapod was designed to work in a thermo-vacuum chamber

- 6 Degrees of Freedom, Works in Any Orientation
- Vacuum Compatible up to 10^{-6} hPa
- 200 kg Load Capacity (Vertical)
- Repeatability to ±1 µm
- Encoder Resolution to 5 nm

Model	Operating temperature range	Storage temperature	Travel ranges	Dimensions
M-850KTVH Vacuum Hexapod	-10 bis +25 °C	-20 bis +40 °C	±50 mm (X,Y), ±25 mm (Z) ±15° (θ_X, θ_Y), ±30° (θ_Z)	Ø 350 mm 330 mm height

M-850K Weatherproof Hexapod

Ultra-High-Precision Hexapod for Outdoor Operation

This customer-specific M-850KWAH Hexapod can operate outdoors at altitudes up to 5000 m

- Load Capacity to 750 N
- Unidirectional Repeatability to 5 µm
- Clear Aperture Ø 420 mm
- Long Lifetime: 2 Million Cycles
- Drive: Brushless Motors
- Correspond to protection class IP 64
- Corrosion Protection

Model	Travel Range X / Y / Z	Max. load capacity	Mass	Dimensions
M-850KWAH Weatherproof Hexapod	±10 / ±11 / ±16 mm	750 N	46 kg	Outer Ø 580 mm height 357 mm

M-810 Miniature Hexapod

High Precision in a Small Package

The miniature M-810 Hexapod provides long travel ranges despite its compact design

- Most-Compact Hexapod in the PI Portfolio
- Travel Range 40 x 40 x 13 mm
- Resolution of a Single Strut <100 nm
- Integrated Driver Electronics

Model	Load capacity	Travel range X / Y / Z	Travel range θ_x / θ_y / θ_z	Max. velocity	Dimensions
M-810.00	5 kg	±20 mm ±20 mm ±6,5 mm	±11° ±11° ±30°	10 mm/s	Outer Ø 100 mm height 118 mm

M-850K Ultra-High-Load Hexapod

Precise Hexapod for Ultra-High Loads up to 1 Ton

The vaccum compatible Hexapod M-850KHLH provides six degrees of freedom for loads up to 1 t, here with a standard M-840 hexapod for size comparison

- Six Degrees of Freedom
- Max. Load Capacity to 1000 kg
- Repeatability to 2 µm
- Drive: Brushless Motors with Brake
- Vacuum Compatible up to 10^{-6} hPa

Model	Travel range X / Y / Z	Rotation range θ_X, θ_Y, θ_Z	Max. velocity X/Y/Z	Dimensions
M-850KHLH	±12 mm	±3° / ±3° / ±4°	0.5 mm/s	Ø outside 1 m height 0.5 m

M-850K Large-Aperture High-Load Hexapod

6-Axis Precision Positioning & Alignment System for Inspection Systems

Dimensions of 100 x 84 x 40 cm and a load capacity of up to 200 kg makes this custom Hexapod system suitable for all kinds of fine-positioning tasks, as in TV-screen inspection

- 200 kg Load Capacity (Vertical)
- Very Large Aperture (640 x 820 mm)
- Six Degrees of Freedom
- No Moving Cables for Improved Reliability and Precision
- Parallel-Kinematics Design—Significantly Smaller and Stiffer than Serial-Kinematics Systems, Better Dynamics
- Virtual Pivot Point
- Sophisticated Controller Using Vector Algorithms Included

Model	Max. load base-plate horizontal optional)	Travel range X / Z / Z	Travel range θ_X, θ_Y, θ_Z	Typ. velocity	Dimensions
M-850KLAH Large Hexapod	200 / 50 kg	±25 mm	±5°	2 mm/s lin. 25 mrad/s rot.	100 x 84 x 40 cm

M-850K Ultra-High Load Hexapod

6-Axes, Long Travel, Micron Precision, 1 Ton in Any Orientation

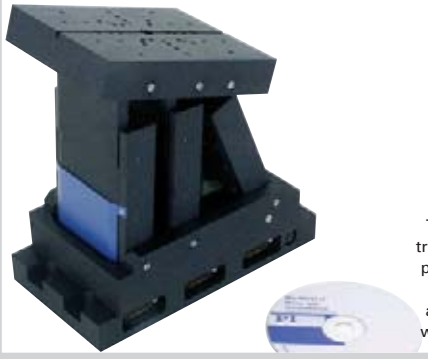
This custom parallel-kinematics system positions loads up to one ton in any orientation with micron accuracy

- Load Capacity to 1000 kg in Any Orientation
- Six Degrees of Freedom
- Travel Ranges to ±200 mm, to ±20°
- Resolution to 0.8 µm, to 0.5 µrad
- Drive: Brushless Motors with Brake
- Sophisticated Controller Using Vector Algorithms

Model	Travel ranges	Push/ pull force	Max. velocity	Unidirectional Repeatability	Dimensions
M-850KHTH High-Load Hexapod with Long Travel Range	±200 mm (X, Y), ±100 mm (Z) ±20° (θ_X, θ_Y), ±5° (θ_Z)	10,000 N	1 mm/s	±1 µm; ±3 µrad	Baseplate: 900 mm Ø Upper platform: 800 mm Ø height 714 mm aperture: Ø 500 mm

M-833 Parallel Kinematic Tripod / Goniometer

Precision Positioning in X, Z, θ_Y



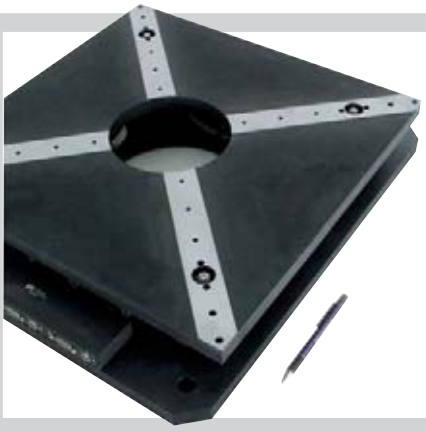
The M-833 parallel-kinematics tripod is designed for precision positioning, offering elevation, translation and tilt motion around the (horizontal) y-axis, with a user-defined pivot point

- **Goniometer Z Stage with Freely Selectable Pivot Point**
- **Travel Ranges ±25 mm / ±25 mm / ±30°**
- **Load Capacity to 4 kg**
- **Min. Incremental Motion to 0.1 µm**
- **ActiveDrive™ Servo Motors**
- **Compact Design with Parallel Kinematics**

Model	Travel ranges	Max. velocity	Stiffness	Dimensions
M-833.00 Tripod Goniometer-Stage	±25 mm (X, Z), ±30° (θ_Y)	10 mm/s (linear)	50 N/µm	223,2 x 110 x 192 mm

M-880 3-Axis Planar Precision Positioning System

XY-Rot-Z Parallel Kinematics System with Very High Holding Force



M-880.PD for planar load positioning up to 20 kg with sub-micron accuracy

- **Travel Ranges 20 x 20 mm / 8°**
- **Static Load Capacity to 150 kg**
- **ActiveDrive™ Servo Motors**
- **Low Profile through Parallel Kinematics**
- **Min. Incremental Motion to 0.75 µm**
- **Large Clear Aperture**
- **Sophisticated Controller Included**

Model	Active Axes	Travel range	Max. velocity	Stiffness (linear axes)	Dynamic load capacity	Static load capacity
M-880.PD	X, Y, θ_Z	±10 mm, ±4°	20 mm/s	5 N/µm	200 N	1500 N

Notes on Specifications for Micropositioning Stages

Active axes

Specifications given in the data sheet are measured in relation to the defined motion axis. A different motor orientation may result in modified data.

Motion and positioning

Travel range

The maximum allowed travel is limited by the length of the drive screw in a spindle/motor combination. Given in the data sheet is the distance between the two limit switches, if present.

Integrated sensor

Rotary or linear encoder

Encoder resolution

Rotary encoder: counts per drive-screw revolution
Linear encoder: interpolated minimum increment that can be distinguished

Design resolution

The theoretical minimum movement that can be made, based on the selection of the mechanical drive components (drive screw 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 of the position feedback sensor system.

Minimum incremental motion

The minimum motion that can be repeatably executed for a given input, which is sometimes referred to as practical or operational resolution. Design resolution and practical resolution have to be distinguished. Design resolutions of 1 nm or better can be achieved with many motor, gearbox and leadscrew combinations. In practical applications, however, stiction/friction, windup, and elastic deformation limit operating resolution. Several PI motorized micropositioners are available with additional piezo fine positioners for applications where repeatable nanometer scale resolution and / or fast response are required.
The data table states typical measured values.
For repeatable nanometer or sub-nanometer resolution see the "Piezo Flexure Stages / High-Speed Scanning Systems" (p. 2-3 *ff*) and "Piezo Actuators & Cmponents" (p. 1-61 *ff*) sections.

Backlash

Position error that appears upon reversing direction due to error in the drivetrain. See page 4-128 *ff* for details. The data table states typical measured values.

Rotation / linear input, tangent-arm length

Angular displacement of tangent-arm rotation stages is determined by the arm length and the linear motion input pushing the arm (see p. 4-82) for information on how to calculate angular displacement from linear input).

Unidirectional / bidirectional repeatability

Values are typical results (RMS, 1 sigma), see also Glossary

Pitch / yaw

The maximum angular deviation around Y- (pitch) and Z-axis (yaw) over the whole travel range, with X being the direction of motion. Pitch and yaw are usually given as ± values. The data table states typical measured values. See "Definition of Axes and Angles" (see p-128 *ff*).

Max. velocity

This is the short-term peak value for horizontal mounting, with no load, and not intended for continuous operation. The average velocity and continuous velocity are lower than the peak value and depend on the load conditions and other environmental parameters.

Origin repeatability

Repeatability of the reference switch (if present)

Mechanical properties

Motor resolution

Resolution with micro-stepping specified for PI's stepper motor controllers.

Stiffness in motion direction

Typical tolerance: ±20 %

Max. normal load capacity

Centered, vertical load (horizontal installation).

Max. push / pull force

Active and passive force limit in operating direction, at center of stage. Some stages may be able to generate higher forces at the cost of reduced lifetime.

Drive properties

Drive type / Operating voltage

ActiveDrive™: The operating voltage (usually 24 VDC) for the ActiveDrive™ motors is provided by an external power supply (included in the delivery).

DC motors: DC servo motors require a supply voltage of up to 12 VDC. The operating voltage is usually given as differential value where the magnitude determines the velocity, and the sign determines the motion direction.

Stepper motors: PI stepper motors are usually driven in chopper mode.

Electrical power

Motor manufacturer's information.

Torque

Motor manufacturer's information.

Miscellaneous

Operating temperature range

Safe operation, no damage to the mechanics. All technical data specified in the data sheet refer to room temperature (22 °C ±3 °C).

Material

Micropositioning stages are typically made of anodized aluminum or stainless steel. Small amounts of other materials may be used (for bearings, preload, coupling, mounting, etc.). For special applications other materials are possible like Invar.

Al: Aluminum
N-S: Nonmagnetic stainless steel
St: Steel
I: Invar

Mass

Typical tolerance: ±5 %

Cable length

Typical tolerance: ±10 mm

Recommended motor controller

Compatible motor controllers are described in the "Servo & Stepper Motor Controllers" (p. 4-109 *ff*) section

For further information read "Micropositioning Fundamentals" section (p. 4-127 *ff*).

Linear Stages

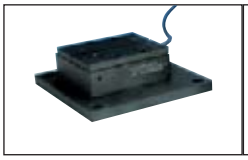
Selection Guide: Linear Translation Stages

Many Motor Options, Travel 5 to 300 mm. Sub-µm to 2 Nanometer Precision

PI motorized translation stages are available with a number of different drive options, from stepper motors to ceramic ultrasonic linear motors. All models provide sub-micron resolution, the hybrid models achieve true 2 nanometer resolution. Speeds reach up to 400 mm/sec.

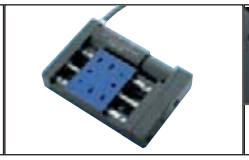
Models	Description	Precision*	Max. Speed [mm/s]	Load Capacity [kg]	Travel [mm]	Page
V-106	Voice-coil scanner, very fast, to 25 Hz scanning frequency	●●●○○	to 270	0.1	6, 20	4-48
M-110/11/12	Mini translation stage, choice of DC,stepper, ballscrew, leadscrew	●●○○○	to 2	3	5, 15, 25	4-22
M-122.2DD	Fast mini translation stage w/ linear encoder, DC direct drive, ballscrew	●●●○○	20	5	25	4-24
N-661	NEXACT® Miniature Linear Slide, subnanometer resolution	●●●●○	10		20	4-25
P-653	PILine® miniature linear motor / slide: 8 mm length, PCB-mounted		200	0.015	2	1-32
M-661, M-662	Piezo motor driven stage speed to 400 mm/s, 0.1 µm resolution	●○○○○	400	0.5	19	4-26
M-663	Smallest stage with linear motor and linear encoder, speed to 400 mm/s, 0.1 µm linear encoder. XY-combinations possible	●●●○○	400	0.5	19	4-28
M-664	Low-profile, high speed stage, piezo linear motor, 0.1 µm linear encoder	●●●○○	400	0.5	25	4-30
M-682	Low-profile, high speed stage, piezo linear motor, 0.1 µm linear encoder	●●●○○	400	5	50	4-32
M-664KCEP	High-speed stackable PILine® actuator	●●○○○	400	0.5	50	4-57
M-126	Compact, crossed roller bearings, very high resolution, choice of motors	●●●○○	1 to 50	20	25	4-38
M-405 / 10 / 15	Crossed roller bearings, very high resolution, choice of motors	●●●○○	1 to 6	50	50, 100, 150	4-40
M-605	Compact, integrated linear encoder, very high accuracy, protective bellow	●●●●○	50	20	25, 50	4-42
M-511, M-521, M-531	Ballscrew drive, high load capacity and lifetime, optional linear encoder, choice of motors	●●●○○/●●●●○	6 to 125	100	102, 204, 306	4-44
M-511.HD, M-714	Hybrid drive. DC motor & piezo. Extremely accurate. 2 nm linear encoder	●●●●●	125, 0.2	100, 20	102, 7	4-46 4-62
M-403KSTS	With integrated stepper motor controller, 0.5 µm resolution	●●○○○	10	50	200	4-56
M-403, M-404	Low-cost translation stages. Choice of leadscrew and ballscrew drive	●○○○○/●●○○○	1.5 to 50	20	25 -200	4-34
M-413, M-414	Low-cost translation stages. Choice of leadscrew and ballscrew drive	●○○○○/●●○○○	1.5 to 50	50	100-300	4-36
M-011, M-014	Magnetic bearings. Low profile, excellent guidance, 10 nm resolution with piezo option	●●●●○	–	1 to 5	15, 25	4-52 4-54
M-105, M-106	Manual stages with motor and piezo options, crossed roller bearings	–	–	10	6, 18	4-50

*Relative to similar products in this class. Combination of guiding precision, drive principle and encoder type.



V-106 Voice Coil Scanner. 20 mm, up to 25 Hz

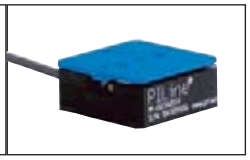
M-110 – M-112 Very small, high resolution



M-122.2DD Fast mini stage w/ linear encoder

P-653 PCB-mounted sub-miniature stage

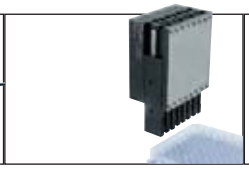
M-661, M-662 Very small & fast, piezo linear motor



M-663 Small, fast; linear motor & linear encoder

M-664 Linear motor & linear encode, fast.

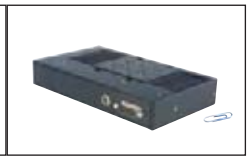
M-682 Low-profile, high speed piezo linear motor



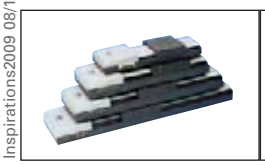
M-664KCEP Stackable, cost-effective PILine® actuator

M-126 Compact, very high resolution

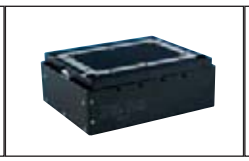
M-405, M-410, M-415 very high precision



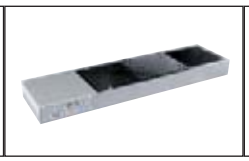
M-605 Compact, bellows, linear encoder



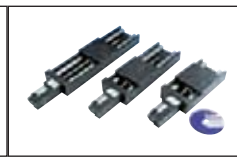
M-511 / 521 / 531 high-load, high precision



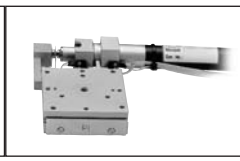
M-511.HD, M-714 Hybrid, stage, extremely accurate



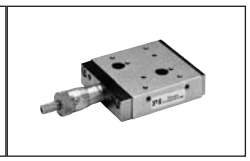
M-403KSTS Stage with integrated motor controller



M-403, M-404, M-413, M-414 Low-cost



M-011, M-014 Side-drive, magnetic-bearings



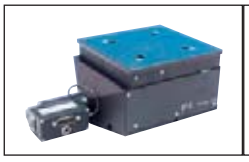
M-105, M-106 Manual translation stages

Selection Guide: Z & Multi-Axis Stages

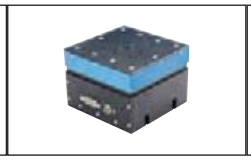
Modular and Integrated Systems

All models provide sub-micron resolution. Some Z stages can be combined with translation stages to form multiaxis positioning systems. Piezo options are available for some models to provide for nanometer level precision.

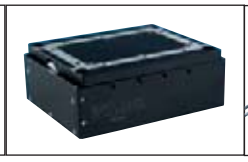
Models	Description	Min. Inc. Motion	Load Capacity [kg]	Travel [mm]	Page
M-451	Vertical stage, wedge drive, high stiffness, choice of servo and stepper motors	0.1 µm	12	12.5	4-58
M-501	Vertical stage, ballscrew drive, high resolution, fast, choice of closed-loop servo motors	<0.1 µm	10	12.5	4-60
M-714	Hybrid stage for Z applications. DC-servo + piezo drive. Extremely accurate and smooth, 2 nm linear encoder, self locking	2 nm	10	7	4-62
M-686	Linear motor-driven low profile XY stage, linear encoder, 0.1 µm resolution very fast	0.1 µm	5	25 x 25	4-64
M-900KOPS	Planar XY scanner, linear encoder, high load	0.1 µm	66	50 x 50	4-66
F-130, F-131	Compact coarse / fine XYZ hybrid fiber alignment system with motor drives and piezo actuators	1 nm / 50 nm	1	to 15 x 15 x 15	4-66
M-833	Tripod: 3-axis stage: X, Z, and goniometer (θ_Y)	0.1 µm	4	50 mm (X, Z), 60° (θ_Y)	4-16
N-510	Tripod Z-Tip/Tilt nanopositioning platform	5 nm	20	1.3 / 10 mrad	1-17
M-880.PD	Tripod 3-axis high-load XYθ_Z stage for LCD and semiconductor inspection	0.1 µm	20 dynamic / 150 static	20 x 20 / 8°	4-16



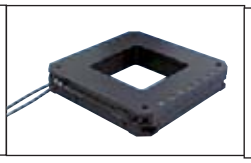
M-451 Vertical stage, wedge drive, high stiffness



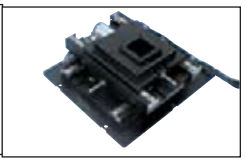
M-501 Vertical stage, ballscrew drive, high resolution, fast



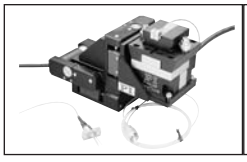
M-714 Hybrid Z-stage. DC-servo + piezo drive



M-686 Linear motor-driven XY stage



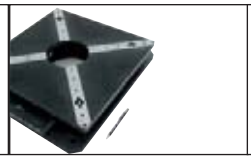
M-900KOPS Planar XY scanner, linear encoder, high load



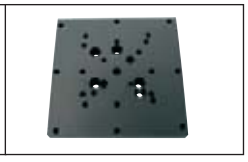
F-130, F-131 Compact XYZ fiber alignment system

M-833 Tripod X, Z, goniometer (θ_Y)

N-510 Tripod Z-Tip/Tilt nanopositioning platform



M-880 Tripod high-load XYθ_Z stage



Accessories

For suitable motor controllers see „Servo & Stepper Motor Controllers“ p. 4-109 *ff*

For adapter plates and brackets see “Accessories” p. 4-89 *ff*

Notes on specifications see p. 4-67 *ff*

M-110 · M-111 · M-112 Compact Micro-Translation Stage

Choice of Drives & Travel Ranges, XY(Z) Combinations Possible

M-112.2DG, M-111.2DG, M-110.2DG (from front to back) providing 25 mm, 15 mm and 5 mm travel range

- **Travel Ranges 5, 15 and 25 mm**
- **Very Cost Effective**
- **Min. Incremental Motion to 50 nm**
- **Max. Velocity 2 mm/s**
- **Closed-Loop DC Motors and Stepper Motors**
- **Non-Contact Limit and Reference Switches**
- **Optional Recirculating Ball Screw Drives Provide High Speeds & Long Lifetimes**
- **Vacuum-Compatible Versions Available to 10^{-6} hPa**

Ordering Information

Translation stage

M-11 . □ □

- **0** Travel Range 5 mm
- **1** Travel Range 15 mm
- **2** Travel Range 25 mm

- **DG** DC Motor Gearhead
- **2S** Stepper Motor with Gearhead

- **1** Leadscrew
- **2** Ball screw

Ask about custom designs!

M-110, M-111 and M-112 are ultra-high resolution motorized translation stages providing linear motion of 5 to 25 mm in an extremely compact package. They feature a precision leadscrew with sub-micron resolution and precision linear ball bearings guaranteeing <0.5 µm straightness of travel.

Application Examples

- Fiber optics testing
- Fiber positioning
- Metrology
- Micromachining
- Photonics packaging
- Quality assurance testing
- Testing equipment

Compact Dimensions, High Performance

To meet industrial demands, the M-11x.2 linear translation stages are equipped with a recirculating ball screw for precise motion with reduced friction. This allows 24/7 duty cycles. M-110, M-111 and M-112 can be combined to XY and XYZ systems for multiaxis alignment applications.

Stepper and Servo Motors

A miniature DC or stepper motor actuates motion via a backlash-compensated screw / nut system and gearhead. Both drive options provide a cost-effective solution for industrial and OEM environments. To meet the most critical positioning demands, the DC motor is equipped with a high resolution encoder featuring resolution down to 0.007 µm per count.

Limit and Reference Switches

For the protection of your equipment, non-contact Hall-effect limit and reference switches are installed. The direction-sensing reference switch supports advanced automation applications with high precision.

All stages include an integral 0.5 m cable with 15-pin sub-D connector and come with a 3 m extension cable. On the DC servo versions, the connector features integrated line drivers for cable lengths up to 10 meters between stage and controller (DC-motors only).

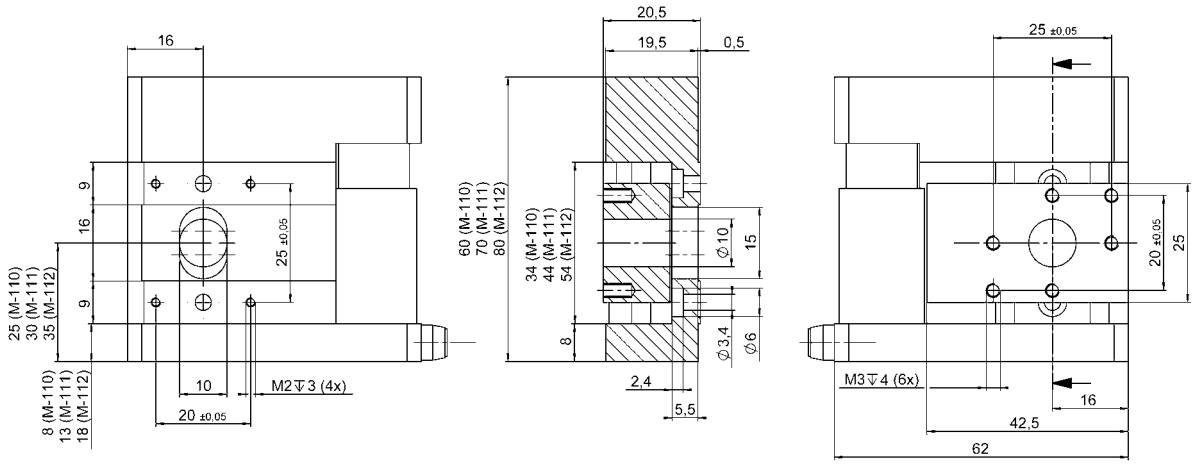
Low Cost of Ownership

The combination of these positioners with the networkable, single-channel C-863 Mercury™ (DC-Motor, see p. 4-114) or C-663 Mercury™ Step (see p. 4-112) controller offers high performance for a very competitive price in both single- and multiaxis configurations. For 3 or 4 axes, the C-843 PC plug-in board for DC motors (see p. 4-120) can also be recommended.

F-130 fiber alignment system consisting of an M-110 XYZ positioning system and a P-611 XYZ Piezo-Nano Positioning system.This combination can be operated by the C-880 controller or NI controllers (request our technote!)

Note

See “Accessories“ (see p. 4-89 *ff*) for adapters, brackets, etc.



M-110, M-111 and M-112. Cable length: 500 mm, 15-pin sub-D connector with integrated encoder line drivers. C-815.38 motor cable included: 3 m, sub-D, 15/15 pin (m/f)

Technical Data

Model	M-110.1DG / M-111.1DG / M-112.1DG	M-110.12S / M-111.12S / M-112.12S	M-110.2DG / M-111.2DG / M-112.2DG	M-110.22S / M-111.22S / M-112.22S	Units
Motion and positioning					
Travel range	5 / 15 / 25	5 / 15 / 25	5 / 15 / 25	5 / 15 / 25	mm
Integrated sensor	Rotary encoder	–	Rotary encoder	–	
Sensor resolution	2048		2048		Cts./rev.
Design resolution	0.0069	0.038*	0.0086	0.046*	µm
Min. incremental motion	0.05	0.05	0.2	0.2	µm
Backlash	2	2	4	4	µm
Unidirectional repeatability	0.1	0.1	0.5	0.5	µm
Pitch / Yaw	±50 / ±150 / ±150	±50 / ±150 / ±150	±50 / ±150 / ±150	±50 / ±150 / ±150	µrad
Max. velocity	1 / 1.5 / 1.5	1 / 1 / 1	1.5 / 2 / 2	1 / 1 / 1	mm/s
Mechanical properties					
Drive screw	Leadscrew	Leadscrew	Recirculating ballscrew	Recirculating ballscrew	
Thread pitch	0.4	0.4	0.5	0.5	mm
Gear ratio	28.44444:1	28.44444:1	28.44444:1	28.44444:1	
Motor resolution*	–	384*	–	384*	
Max. load	30 / 30 / 20	30 / 30 / 20	30 / 30 / 20	30 / 30 / 20	N
Max. push / pull force	10	10	10	10	N
Max. holding force	10	10	10	10	N
Max. lateral force	15 / 10 / 10	15 / 10 / 10	15 / 10 / 10	15 / 10 / 10	N
Drive properties					
Motor type	DC-motor, gearhead	2-phase stepper motor	DC-motor, gearhead	2-phase stepper motor	
Operating voltage	0 to ±12	24	0 to ±12	24	V
Electrical power	0.52 / 1.75 / 1.75	1.5	0.52 / 1.75 / 1.75 1.5		W
Current consumption	160 / 320 / 320**		160 / 320 / 320**		mA
Limit and reference switches	Hall-effect	Hall-effect	Hall-effect	Hall-effect	
Miscellaneous					
Operating temperature range	-20 to +65	-20 to +65	-20 to +65	-20 to +65	°C
Material	Al (black anodized)	Al (black anodized)	Al (black anodized)	Al (black anodized)	
Mass	0.3 / 0.4 / 0.5	0.3 / 0.4 / 0.5	0.3 / 0.4 / 0.5	0.3 / 0.4 / 0.5	kg
Recommended controller/driver	C-863 single-axis C-843 PCI board, for up to 4 axes	C-863 single-axis	C-863 single-axis C-843 PCI board, for up to 4 axes	C-863 single-axis	

*2-phase stepper motor, 24 V chopper voltage, max. 0.25 A/phase, 24 full steps/rev., motor resolution with C-663 stepper motor controller
**thermally limited

M-122 Precision Micro-Translation Stage

Fast & Compact with Direct Position Measurement

The M-122.2DD miniature translation stage features an optical linear encoder with 0.1 µm position resolution and a highly efficient ballscrew

- **Travel Range 25 mm**
- **0.1 µm Optical Linear Encoder for Highest Accuracy & Repeatability**
- **Min. Incremental Motion to 0.2 µm**
- **Max. Velocity 20 mm/s**
- **Cross-Roll Bearings**
- **Recirculating Ball Screw Drives Provide High Speeds & Long Lifetimes**

The M-122 palm-top-sized translation stage combines small dimensions, high speeds and very high accuracy at a competitive price. It features a space-saving, folded drive train with the servo motor and drive screw side-by-side. Equipped with a non-contacting optical linear encoder and a preloaded, precision-ground, ball-screw, these stages can provide much higher accuracy and better repeatability than conventional stepper motor stages or rotary encoder-equipped servo motor stages.

Low Friction, High Speed, Maintenance-Free

Due to its low-friction, the backlash-free ball screw yields significantly higher mechanical efficiency than leadscrews, and allows maintenance-free, high duty-cycle operation at high velocities up to 20 mm/sec.

XY and XYZ Combinations

M-122 stages can be combined to very compact XY and XYZ systems. The M-122.AP1 mounting bracket is available to mount the Z-axis.

Limit and Reference Switches

For the protection of your equipment, non-contact Hall-effect limit and reference switches are installed. The direction-sensing reference switch supports advanced automation applications with high precision.

Low Cost of Ownership

The combination of these positioners with the networkable, single-channel C-863 Mercury™ servo motor controller (s. p. 4-114) offers high performance for a very competitive price in both single- and multiaxis configurations. For multiaxis applications, the C-843 PC plug-in controller board with on-board servo amplifiers (s. p. 4-120) is another cost-effective alternative.

Application Examples

- Photonics packaging
- Fiber positioning
- Metrology
- Quality assurance testing
- Testing equipment
- Micromachining

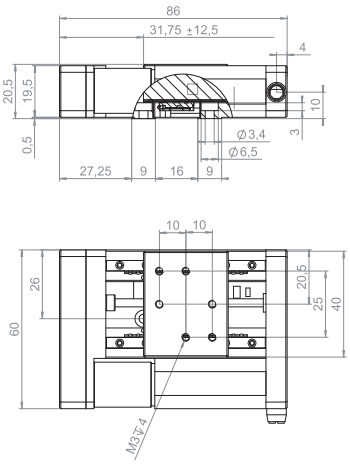
Ordering Information

M-122.2DD
High-Precision Translation Stage, 25 mm, Direct-Drive DC Motor, Ballscrew

Accessories

M-122.AP1
Angle bracket for vertical mounting of M-122 stages

Ask about custom designs



M-122.2DD dimensions in mm, 3 m cable, Sub-D connector 15-pin

Technical Data

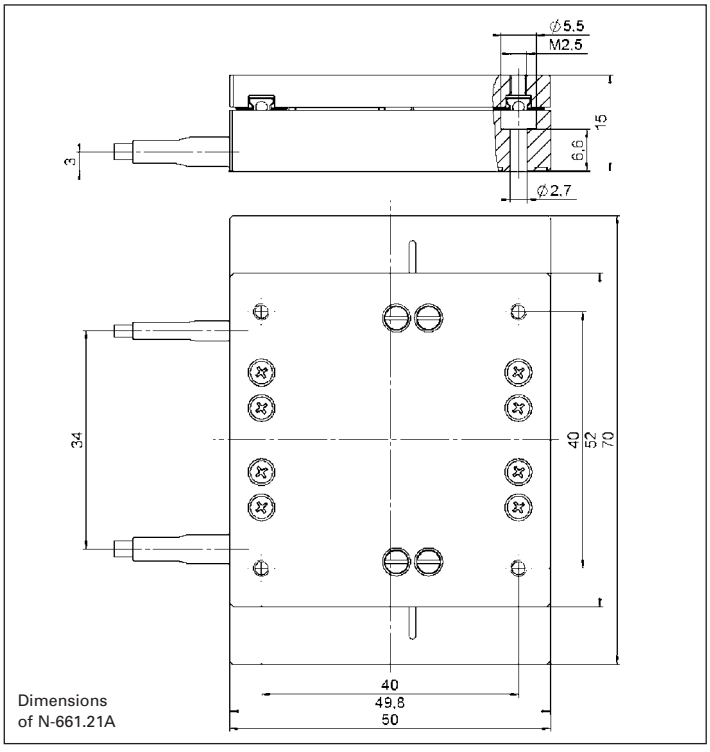
Model	M-122.2DD
Active axes	X
Motion and positioning	
Travel range	25 mm
Integrated sensor	Linear encoder
Sensor resolution	0.1 µm
Design resolution	0.1 µm
Min. incremental motion	0.2 µm
Backlash	0.2 µm
Unidirectional repeatability	0.15 µm
Pitch	±150 µrad
Yaw	±150 µrad
Max. velocity	20 mm/s
Origin repeatability	1 µm
Mechanical properties	
Drive screw	Recirculating ballscrew
Thread pitch	0.5 mm
Stiffness in motion direction	0.25 N/µm
Max. load	50 N
Max. push/pull force	20 N
Max. lateral force	25 N
Drive properties	
Motor type	DC motor
Operating voltage	0 to ±12 V
Electrical power	2.25 W
Limit and reference switches	Hall-effect
Miscellaneous	
Operating temperature range	-20 to +65
Material	Aluminum, steel
Dimensions	86 x 60 x 20.5 mm
Mass	0.22 kg
Recommended controller/driver	C-863 (single-axis) C-843 PCI board (up to 4 axes)

N-661 Miniature Linear Slide with NEXACT® Drive

PiezoWalk® Drive Provides Nanometer Precision, Smooth Motion and Rapid Response

The N-661 miniature linear stage integrates a PiezoWalk® NEXACT® linear motor combined with a high-resolution linear encoder. It provides 20 mm travel and resolution down to the nanometer range.

- **Travel Range 20 mm**
- **Self Locking at Rest, no Heat Generation, no Servo Dither**
- **Compact Design: 70 x 50 x 20 mm**
- **Zero-Wear Piezo Stepping Drive, Ideal for Micro- and Nano-Manipulation**
- **Integrated Linear Encoder Option for Highest Accuracy with 20 nm Resolution**
- **Two Operating Modes: Continuous Stepping Mode and Continuously Variable, High-Dynamics Analog Mode for 30 pm Resolution**
- **Up to 10 N Force Generation**



Dimensions of N-661.21A

The compact N-661 nanopositioning stage is based on the NEXACT® PiezoWalk® drive. This dual-mode, high-performance piezo stepping linear motor can provide sub-nanometer resolution and high force, along with very rapid response. When run in its analog mode, fast oscillations with amplitudes up to 7 microns and resolutions down to 30 pm can be achieved. This mode is of great value in high-throughput applications as well as in dynamic laser tuning, cell penetration applications, or even for active vibration damping. The stage is equipped with a precision guiding system and an optical linear encoder to enable highly repeatable positioning.

Ordering Information

N-661.21A
Miniature NEXACT® Translation Stage, 20 mm, Linear Encoder, 20 nm Resolution

Ask about custom designs

Application Examples

- Life science
- Photonics
- Laser tuning
- Motion in strong magnetic fields

The products described in this document are in part protected by the following patents: German Patent No. P4408618.0

Technical Data

Model	N-661.21A
Active axes	X
Motion and positioning	
Travel range	20 mm
Step size in stepping mode (open-loop)	To 5 µm
Integrated sensor	Linear encoder
Sensor resolution	20 nm *
Travel range in analog mode	7 µm
Open-loop resolution	0.03 nm
Closed-loop resolution	20 nm*
Bidirectional repeatability	40 nm
Pitch	50 µrad
Yaw	50 µrad
Step frequency	1.5 kHz
Max. velocity	10 mm/s*
Mechanical properties	
Stiffness in motion direction	2.4 N/µm
Max. push / pull force (active)	10 N
Max. holding force (passive)	15 N
Lateral Force	50 N
Drive properties	
Drive type	NEXACT® linear drive
Operating Voltage	-10 V to +45 V
Miscellaneous	
Operating temperature range	0 to 50 °C
Material	Aluminum
Mass	150 g
Cable length	1.5 m
Connector	15-pin sub-HDD connector, one channel
Recommended controller/driver	E-861.1A1 Controller for NEXACT® (see p. 1-20)

*With E-861. Depending on drive electronics.

M-661 · M-662 PILine® Miniature Linear Motor Stage

With Ultrasonic Piezo Linear Drives

PILine® M-662 (left side) and M-661 stages are the smallest piezo-motor-driven translation stages available on the market that achieve speeds of up to 500 mm/s

- **Smallest Translation Stages with Linear Motor Drive**
- **Travel Ranges to 20 mm**
- **Max. Velocity 500 mm/s**
- **Acceleration to 5 g**
- **Incremental Motion to 50 nm**
- **Self Locking at Rest**
- **XY-Combination Possible**
- **MTBF 20.000 h**
- **Vacuum Versions to 10^{-7} hPa**

M-661 and M-662 PILine® translation stages offer accelerations to 5 g with millisecond response and velocities to 500 mm/sec in an extremely compact package. Providing travel ranges to 20 mm, they are among the smallest motorized translation stages currently on the market. Both models are designed for open-loop operation (a similar closed-loop stage with linear encoder is available as model M-663. The M-662, with its square footprint, is also suitable for use in XY configurations. For applications where the smallest dimensions are essential, the P-652 micro stage is offered.

Application Examples

- Biotechnology
- Micromanipulation
- Microscopy
- Quality assurance testing
- Semiconductor testing
- Metrology
- Mass storage device testing
- R&D
- Photonics packaging

Working Principle

PILine® piezo motors use a new, patented, ultrasonic drive developed by PI. A the heart of the system is a piezo ceramic plate, which is excited with high-frequency eigenmode oscillations. A friction tip attached to the plate moves along an inclined linear path at the eigenmode frequency. Through its contact with the friction bar, the moving part of the mechanics drives forward or backwards. With each oscillatory cycle, the mechanics execute a step of a few nanometers; the macroscopic result is smooth motion with a virtually unlimited travel range.

Advantages of PILine® Micropositioning Systems

The ultrasonic piezoceramic drives used in PILine® micropositioners have a number of advantages over classical drives:

- Higher Accelerations, up to 5 g
- Speeds up to 500 mm/s
- Small Form Factor
- Self-Locking When Powered Down
- No Shafts, Gears or Other Rotating Parts
- Non-Magnetic and Vacuum-Compatible Drive Principle

Choice of Drive Electronics

Special driver electronics are required to create the ultrasonic oscillations for PILine® piezo-motors. The driver controls the motor speed as a function of an analog ±10 V signal. The driver is not included, as it is available in different versions, from the low-priced C-184.161 OEM-board to the C-185.161 bench-top unit. The stage and the driver electronics, however, must be ordered together, so that they can be tuned to one-another for optimum performance.

Ordering Information

M-661.370
PILine® Translation Stage, 18 mm, Open-Loop

M-662.470
PILine® Translation Stage, 20 mm, Open-Loop, XY Mountable

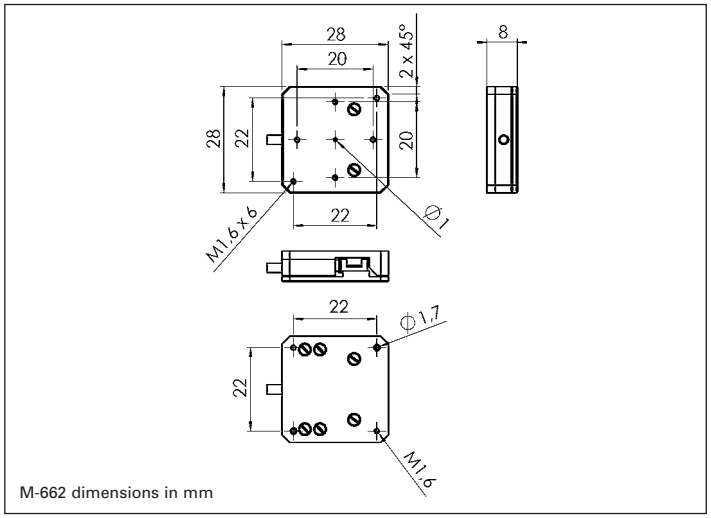
Accessories:

C-184.161
Analog OEM Driver Board for PILine® P-661 Motors

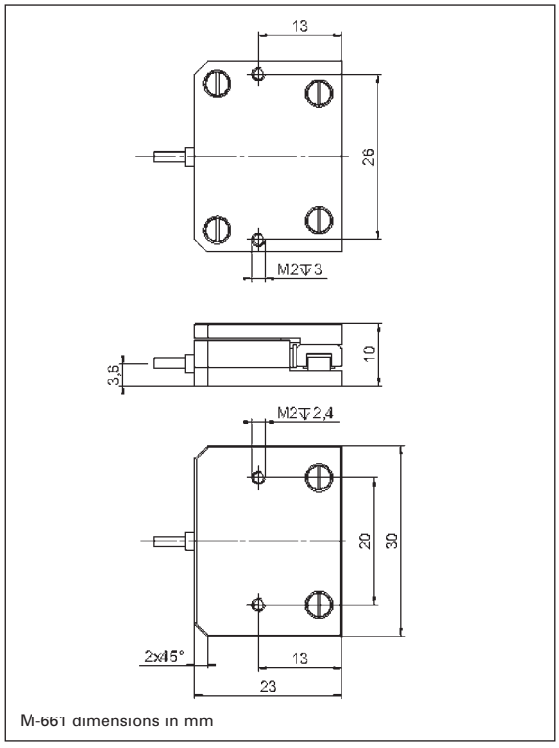
C-185.161
Analog Stand-Alone Drive Electronics with Power Supply for PILine® P-661 Motors

Notes

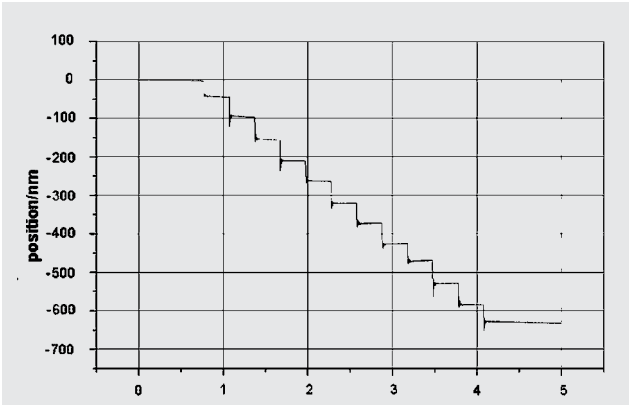
The products described in this document are in part protected by the following patents:
US Pat. No. 6,765,335
German Patent No. 10154526



M-662 dimensions in mm



M-661 dimensions in mm



50 nm steps created with a system incorporating an M-662.470 open-loop piezo linear motor stage

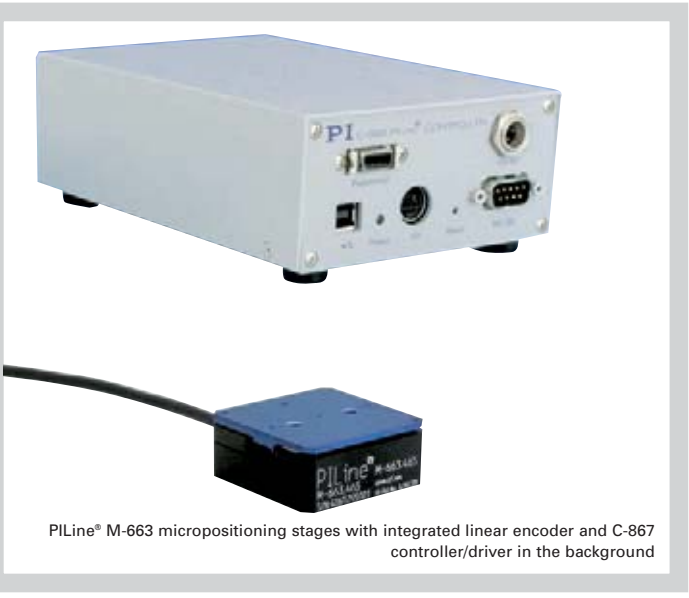
Technical Data

Model	M-661.370	M-662.470	Units	Tolerance
Motion and positioning				
Travel range	18	20	mm	
Min. incremental motion	0.05*	0.05*	µm	typ.
Max. velocity	500	500	mm/s	
Mechanical properties				
Max. load	5	5	N	
Max. push/pull force	1	1	N	
Max. holding force	2	2	N	
Drive properties				
Motor type	P-661 PILine® ultrasonic piezomotor drive	P-661 PILine® ultrasonic piezomotor drive		
Operating voltage	120 (Peak-Peak)** 42 (RMS)**	120 (Peak-Peak)** 42 (RMS)**	V	
Electrical power	5***	5***	W	nominal
Current	400***	400***	mA	
Miscellaneous				
Operating temperature range	-20 to +50	-20 to +50	°C	
Material	Al (black anodized)	Al (black anodized)		
Dimensions	30 x 23 x 10	28 x 28 x 8		
Mass	0.03	0.03	kg	±5%
Cable length	1.5	1.5	m	±10 mm
Connector	LEMO connector	LEMO connector		
Recommended controller/driver	C-184.161 OEM board C-185.161 Bench-top	C-184.161 OEM board C-185.161 Bench-top (p. 1-36)		

*The minimum incremental motion is a typical value that can be achieved in the open-loop mode of a piezomotor stage. To obtain it, it is important to follow the mounting guidelines in the motor documentation.
**The stage supply power is drawn from the drive electronics, which runs on 12 VDC.
***For drive electronics.

M-663 PILine® Linear Motor Stage

Compact, Fast, with Ultrasonic Piezo Linear Drives, Direct Position Measurement



PILine® M-663 micropositioning stages with integrated linear encoder and C-867 controller/driver in the background

- **Smallest Translation Stage with Closed-Loop Linear Motor and Encoder**
- **Travel Range 19 mm**
- **Max. Velocity 400 mm/s**
- **Acceleration up to 10 g**
- **Direct Metrology Linear Encoder**
- **0.1 µm Resolution**
- **XY Combination Possible**
- **Vacuum-Compatible Versions Available**

PILine® M-663 micropositioning systems offer high velocities of up to 400 mm/s and travel ranges of 19 mm in a compact package. The M-663 is the smallest closed-loop translation stage with piezomotor drives currently on the market. Its square footprint makes it suitable for use in compact XY configurations.

Application Examples

- Biotechnology
- Micromanipulation
- Microscopy
- Quality assurance testing
- Metrology
- Mass storage device testing
- R&D
- Photonics packaging

Working Principle

PILine® motors have a new, patented, ultrasonic drive developed by PI. The core piece of the system is a piezoceramic plate, which is excited to produce high-frequency eigenmode oscillations. A friction tip attached to the plate moves along an inclined linear path at the eigenmode frequency. Through its contact with the friction bar, the moving part of the mechanics drives forward or backwards. With each oscillatory cycle, the mechanics executes a step of a few nanometers; the macroscopic result is smooth motion with a virtually unlimited travel range.

Advantages of PILine® Micropositioning Systems

The ultrasonic piezoceramic drives used in PILine® micropositioners have a number of advantages over classical drives:

- Higher Accelerations, up to 5 g
- Speeds up to 500 mm/s
- Small Form Factor
- Self-Locking When Powered Down
- No Shafts, Gears or Other Rotating Parts
- Non-Magnetic and Vacuum-Compatible Drive Principle

Optimized Controller and Drive Electronics

PILine® motors require a special drive electronics to generate the ultrasonic oscillations for piezoceramic element. For optimum performance the highly specialized C-867 (see p. 4-116) motion controller is recommended. This sophisticated controller also inte-grates the drive electronics. Furthermore, the controller has a number of special features, including dynamic parameter switching for an optimized high-speed motion and settling behavior to take into account the motion characteristics typical of piezomotors. The broad-band encoder input (50 MHz) supports the outstanding high accelerations and velocities of PILine® drives at high resolutions.
Optionally, for use with third party servo controllers, the C-185 analog drive electronics (stand-alone unit) is available. It controls the motor speed by an analog ±10 V signal. For optimum performance the driver must be tuned together with the mechanics and should be ordered at the same time as the motor/stage.

Ordering Information

M-663.465
PILine® Translation Stage, 19 mm, Linear Encoder, 0.1 µm Resolution

M-663.Y65
PILine® Translation Stage, 19 mm, Linear Encoder, 0.1 µm Resolution, turned cable outlet, XY mountable

M-663.46V
PILine® Translation Stage, 19 mm, Linear Encoder, 0.1 µm Resolution, Vacuum Compatible to 10-6 hPa

Accessories:

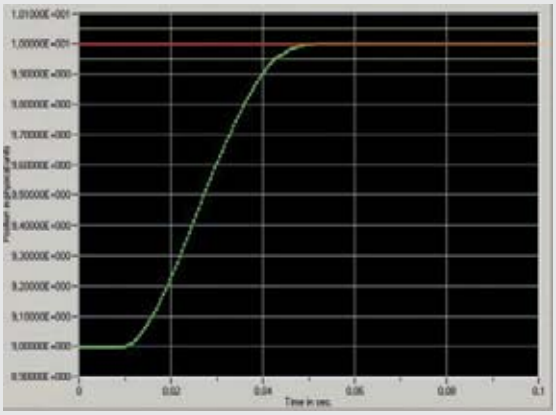
C-867.161
Piezomotor Controller with Drive Electronics, 1 Channel, for PILine® Systems with P-661 Motors

Driver for use with separate controller:

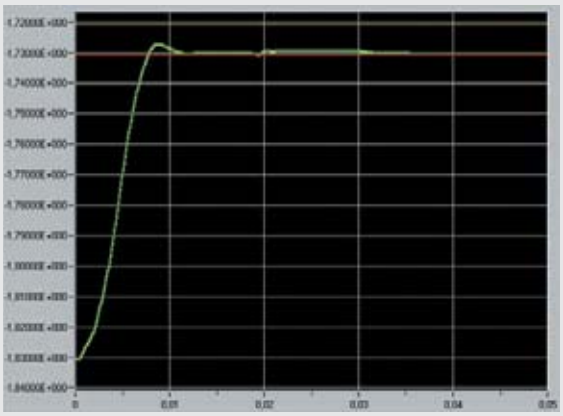
C-185.161
Analog Stand-Alone Drive Electronics with Power Supply for PILine® P-661 Motors

Note

The products described in this document are in part protected by the following patents:
US Pat. No. 6,765,335
German Patent No. 10154526



A 1 mm step performed by an M-663 stage with 300 g load controlled by a C-867 controller/driver reaches the end position in less than 40 ms

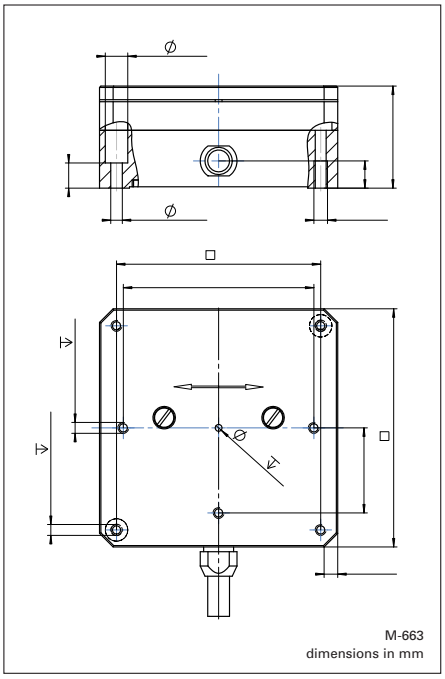


An M-663 with 100 g load settles to 0.1 µm accuracy in 10 ms after a 100 µm step, measured with C-867 controller/driver

Technical Data

Model	M-663.465	Units	Tolerance
Active axes	X		
Motion and positioning			
Travel range	19	mm	
Integrated sensor	Linear encoder		
Sensor resolution	0.1	µm	
Min. incremental motion	0.1	µm	typ.
Bidirectional repatability	±0.3	µm	typ.
Unidirectional repeatability	0.2	µm	typ.
Pitch	300	µrad	typ.
Yaw	300	µrad	typ.
Max. velocity	400	mm/s	
Reference switch repeatability	1	µm	typ.
Mechanical properties			
Max. load	5	N	
Max. push/pull force	2	N	
Max. holding force	2	N	
Drive properties			
Motor type	P-661 PILine® ultrasonic piezomotor		
Motor voltage range	120 (peak-peak)* 42 (RMS)*	V	
Electrical power	5**	W	nominal
Current	400**	mA	
Reference switch	Hall-effect		
Miscellaneous			
Operating temperature range	-20 to +50	°C	
Material	Al (black anodized)		
Dimensions	35 x 35 x 15	mm	
Mass	40	g	±5%
Cable length	1.5	m	±10 mm
Connector	MDR, 14-pin		
Recommended controller/driver	C-867.161 Single-axis controller/driver (p. 4-116) C-185.161 Drive electronics (p. 1-36)		

*Power is supplied by the drive electronics which runs on 12 V DC
**For drive electronics



M-663
dimensions in mm

XY combination of two M-663s; CD for size comparison

M-664 PILine® Linear Motor Stage

Low-Profile High-Speed with Ultrasonic Piezo Linear Drives & Direct Position Measurement

Fast and compact M-664 piezo translation stage with linear encoder

- **Travel Range 25 mm**
- **Max. Velocity 400 mm/s**
- **Ultra-Low Profile, 15 mm**
- **Direct Metrology Linear Encoder with 0.1 µm Resolution**
- **High Guiding Accuracy with Crossed Roller Bearings**
- **Compact XY Combinations**
- **Piezo Linear Motor with 4 N Drive Force**
- **Self Locking at Rest**

M-664 micropositioning systems are low-profile, high-accuracy translation stages with linear encoders. The M-664 stage is next-larger in the series of piezomotor-driven stages of which the M-663 (see p. 4-28) is the smallest. For improved guiding accuracy, the M-664 uses two crossed roller bearings mounted on ground aluminum profiles. The integrated P-664 PILine® linear motor can generate forces up to 4 N and maximum closed-loop velocities to 400 mm/s over a 25 mm travel range.

Application Examples

- Biotechnology
- Micromanipulation
- Microscopy
- Quality assurance testing
- Metrology
- Mass storage device testing
- R&D
- Photonics packaging

Advantages of PILine® Micropositioning Systems

The ultrasonic piezoceramic drives used in PILine® micropositioners have a number of advantages over classical drives:

- Higher Accelerations, up to 5 g
- Speeds up to 500 mm/s
- Small Form Factor
- Self-Locking When Powered Down
- No Shafts, Gears or Other Rotating Parts
- Non-Magnetic and Vacuum-Compatible Drive Principle

Optimized Controller and Drive Electronics

PILine® motors require a special drive electronics to generate the ultrasonic oscillations for the piezoceramic element. For optimum performance the highly specialized C-867 motion controller (see p. 4-116) is recommended. This sophisticated controller also integrates the drive electronics. Furthermore, the controller has a number of special features, including dynamic parameter switching for an optimized high-speed motion and settling behavior to take into account the motion characteristics typical of piezomotors. The broadband encoder input (50 MHz) supports the outstanding high accelerations and velocities of PILine® drives at high resolutions.

Ordering Information

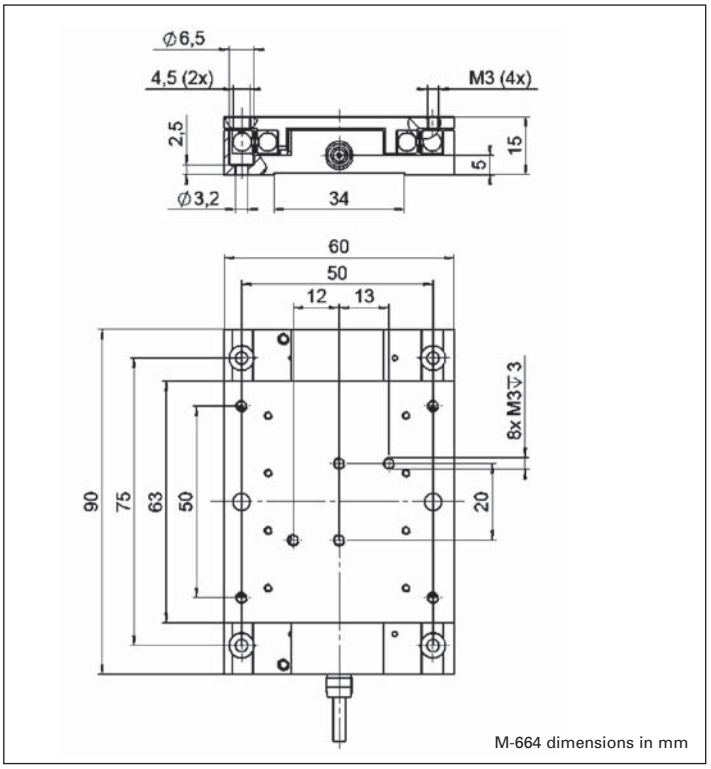
M-664.164
PILine® Micro Positioning Stage with P-664 Piezo Linear Motor, 25 mm, 4 N

Ask about custom designs!

Optionally, for use with third party servo controllers, the C-185 analog drive electronics (stand-alone unit, see p. 1-36) is available. It controls the motor speed by an analog ±10 V signal. For optimum performance this driver must be tuned together with the stage and should be ordered at the same time as the motor/stage.

Notes

The products described in this document are in part protected by the following patents:
US Pat. No. 6,765,335
German Patent No. 10154526



M-664 dimensions in mm

PILine® Micropositioning stages: M-682, M-664 and M-663 (from left)

Technical Data

Model	M-664.164	Tolerance
Active axes	X	
Motion and positioning		
Travel range	25 mm	
Integrated sensor	Linear encoder	
Sensor resolution	0.1 µm	
Min. incremental motion	0.3 µm	typ.
Bidirectional repeatability	0.2 µm	typ.
Unidirectional repeatability	0.2 µm	typ.
Pitch	±50 µrad	typ.
Yaw	±50 µrad	typ.
Max. velocity	400 mm/s	
Reference switch repeatability	1 µm	typ.
Mechanical properties		
Max. load	25 N	
Max. push/pull force	4 N	
Max. holding force	3 N	
Drive properties		
Motor type	P-664 PILine® ultrasonic piezo drive	
Operating voltage	168 V (peak-to-peak) * 60 V (RMS) *	
Electrical power	10 W **	nominal
Current	800 mA **	
Limit and reference switches	Hall-effect	
Miscellaneous		
Operating temperature range	-20 to +50 °C	
Material	Al (black anodized)	
Dimensions	90 x 60 x 15 mm	
Mass	0.190 kg	±5 %
Cable length	1.5 m	±10 mm
Connector	MDR, 14-pin	
Recommended controller/driver	C-867.164 single-axis controller/driver C-185.164 drive electronics	

*The stage supply power is drawn from the drive electronics, which runs on 12 V.
**For drive electronics

M-682 PILine® Linear Motor Stage

Compact, Fast, with High-Force Piezomotor, Direct Position Measurement


M-682 Translation stage

- **Integration of the Powerful PILine® RodDrive**
- **Low Profile, Compact Dimensions**
- **Max. Velocity 350 mm/s**
- **Up to 7 N Pushing Force**
- **Direct Metrology Linear Encoder, 0.1 µm Resolution**
- **Non-Magnetic and Vacuum-Compatible Versions Available**

M-682 translation stages are low-profile, high-accuracy positioning systems based on the M-674 RodDrive ultrasonic linear motor actuator.

The M-682 positioner combines the advantages of its high-performance, high-speed drive with a high-precision guiding system and the superior accuracy of a direct-metrology linear encoder providing 0.1 µm resolution.

In addition to the standard, 50 mm model, custom M-682 versions with different travel ranges as well as vacuum-compatible and non-magnetic designs are feasible and available on request.

Application Examples

- Microscopy
- Metrology
- Quality assurance testing
- Semiconductor testing
- R&D
- Mass storage device testing

RodDrive Replaces Classical Motor/Leadscrew Systems

The M-682 is an example of how an M-674 RodDrive linear motor actuator can be employed to design a very compact positioning system. The RodDrive represents a higher level of integration than OEM piezo motors motors such as the P-664 (see p. 1-28) and significantly simplifies the stage design because preloading and alignment of motor and friction bar are taken care of inside the actuator.

Advantages of PILine® Micropositioning Systems

The ultrasonic piezoceramic drives used in PILine® micropositioners have a number of advantages over classical drives:

- Higher Accelerations, up to 5 g
- Speeds up to 500 mm/s
- Small Form Factor
- Self-Locking When Powered Down
- No Shafts, Gears or Other Rotating Parts
- Non-Magnetic and Vacuum-Compatible Drive Principle

Optimized Controller and Drive Electronics

PILine® motors require a special drive electronics to generate the ultrasonic oscillations for piezoceramic element. For optimum performance the highly specialized C-867 motion controller (see p. 4-116) is recommended. This sophisticated controller also integrates the drive electronics. Furthermore, the controller has a number of special features, including dynamic parameter switching for an optimized high-speed motion and settling behavior to take into account the motion characteristics typical of piezomotors. The broadband encoder input (50 MHz) supports the outstanding high accelerations and velocities of PILine® drives at high resolutions.

Optionally, for use with third party servo controllers, the C-185 analog drive electronic (see p. 1-36, stand-alone unit) is available. It controls the motor speed by an analog ±10 V signal. For optimum performance this driver must be tuned together with the stage and should be ordered at the same time as the motor/stage.

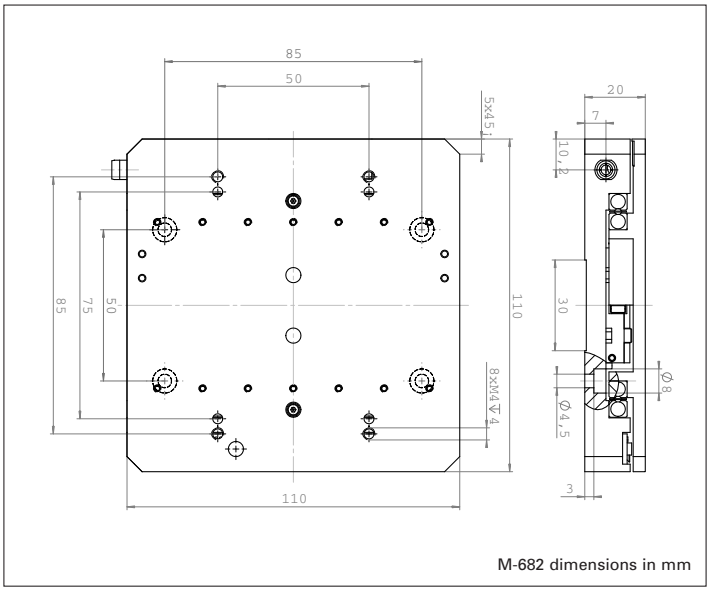
Ordering Information

M-682.174
PILine® High-Speed Linear Stage with RodDrive

Ask about custom designs

Notes

The products described in this document are in part protected by the following patents:
US Pat. No. 6,765,335
German Patent No. 10154526



M-682 dimensions in mm

M-674 PILine® RodDrive with 7 N generated force and travel ranges of 50, 100 and 150 mm

Custom non-magnetic M-682 version with custom dimensions containing non-magnetic RodDrive

Technical Data

Model	M-682.174	Units
Active axes	X	
Motion and positioning		
Travel range	50 mm	
Integrated sensor	Linear encoder	
Sensor resolution	0.1 µm	
Design resolution	0.1 µm	typ.
Min. incremental motion	0.1 µm	typ.
Bidirectional repeatability	±0.2 µm	typ.
Unidirectional repeatability	0.2 µm	typ.
Pitch	±50 µrad	typ.
Yaw	±50 µrad	typ.
Max. speed	350 mm/s	
Reference switch repeatability	1 µm	typ.
Mechanical properties		
Max. load	50 N	
Max. push/pull force	7 N	
Max. Holding force	7 N	
Drive properties		
Motor type	M-674 RodDrive PILine® ultrasonic piezomotor	
Operating voltage	200 V (Peak-Peak) * 70 V (RMS)*	
Electrical power	15 W**	nominal
Current	1.5 A**	
Limit and reference switches	Hall-effect	
Miscellaneous		
Operating temperature range	-20 to +50 °C	
Material	Al (black anodized)	
Dimensions	110 x 110 x 20 mm	
Mass	0.57 kg	±5%
Cable length	1.5 m	±10 mm
Connector	MDR, 14-pin	
Recommended controller/driver	C-867.D64 Single-axis Controller / Driver C-185.D64 driver	

*Motor power is supplied by the drive electronics, which runs on 12 VDC
**For drive electronics

M-403 · M-404 Precision Translation Stage

Cost-Effective, Large Choice of Drives & Travel Ranges

M-403 linear stage versions (from left) M-403.1PD, M-403.2PD, M-403.4PD, M-403.6PD und M-403.8PD provide travel ranges from 25 to 200 mm

Ordering Information

- **3** Linear Translation Stage with lead screw, 80 mm wide
- **4** Precision-Linear Stage with ball screw, 80 mm wide

M-40 [ ] . [ ] [ ]

- [ ] (1st box): **1** Travel Range 25 mm; **2** Travel Range 50 mm; **4** Travel Range 100 mm; **6** Travel Range 150 mm; **8** Travel Range 200 mm
- [ ] (2nd box): **PD** ActiveDrive™ DC Motor (includes 24 V power supply); **DG** DC Motor Gearhead; **2S** 2-Phase Stepper Motor; **VP** ActiveDrive™ DC-Motor (includes 24 V power supply), Vacuum Compatible to 10^{-6} hPa; **VG** DC Motor Gearhead, Vacuum Compatible to 10^{-6} hPa

Ask about custom designs!

- **For Cost-Sensitive Precision Positioning Applications**
- **Travel Ranges 25 to 200 mm**
- **Resolution to 0.012 µm**
- **Min. Incremental Motion to 0.1 µm**
- **Preloaded Precision Leadscrew or Recirculating Ball Screw Drives Provide High Speeds & Long Lifetimes**
- **Stress-Relieved Aluminum Base for Highest Stability**
- **Vacuum-Compatible Versions Available**
- **M-413 and M-414 Versions for Higher Load Requirements**

The M-403 and M-404 linear translation stage series provide cost-effective solutions for precision positioning of loads up to 20 kg over travel ranges to 200 mm. They are designed with high-value components and feature a precision-machined, high-density, stress-relieved aluminum base for exceptional stability with minimum weight.

The highly precise M-403 drive includes a preloaded lead screw, providing a minimum incremental motion of 0.2 µm. For higher velocities and long lifetime, the M-404 versions feature a low-friction ball screw offering a minimum incremental motion down to 0.1 µm. Three motor drive options allow easy adaptation to different automation applications.

Five travel ranges from 25 to 200 mm are offered. The stages can carry up to 20 kg and push/pull up to 50 N. Special versions for vacuum applications are also available (see ordering information).

Application Examples

- Automation
- R&D
- Semiconductor technology
- Metrology
- Quality assurance testing

Maintenance-Free, High Guiding Precision

All models are equipped with high-precision linear guiding rails and recirculating ball bearings. The recirculating ball bearings are maintenance free and immune to cage migration. The choice of components and careful mounting guarantees high load capacity, longer lifetime and high guiding accuracy. Additionally, in the M-404 series the bearings are polished to achieve the optimum guiding accuracy.

Low Cost of System Ownership

The combination of these stages with the networkable single-axis C-863 Mercury™ (see p. 4-114) and C-663 Mercury™ Step (see p. 4-112) controllers offers high performance for a very competitive price in both single and multiaxis configurations. Alternatively, the C-843 motion controller PCI card with on-board servo amplifiers is available.

Three Motor Drive Options

The top-of-the-line M-40x.xPD high-speed versions come equipped with the high-performance ActiveDrive™ system. The ActiveDrive™ design, developed by PI, features a high-efficiency PWM (pulse width modulation) servo-amplifier mounted side-by-side with the DC motor and offers several advantages:

- Increased efficiency, by eliminating power losses between the amplifier and motor
- Reduced cost of ownership and improved reliability, because no external driver is required
- Elimination of PWM amplifier noise radiation, by mounting the amplifier and motor together in a single, electrically shielded case

M-40x.xDG models are equipped with a DC motor and a shaft-mounted optical encoder, providing a minimum incremental motion of down to 0.1 µm.

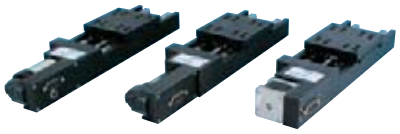
M-40x.x2S models feature a cost-effective direct-drive, 2-phase stepper motor, providing very smooth operation and a resolution of 0.16 µm.

Limit and Reference Switches

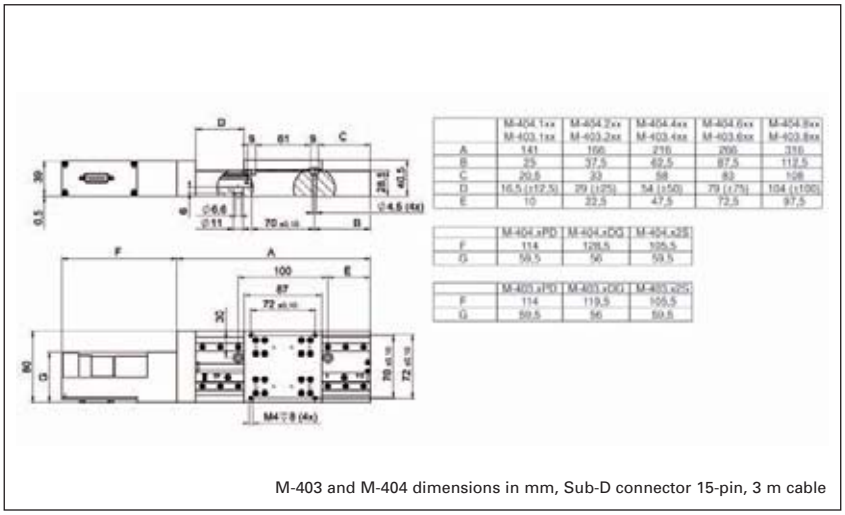
For the protection of your equipment, non-contact Hall-effect limit and reference switches are installed. The direction-sensing reference switch supports advanced automation applications with high precision.

Other Family Members

The M-403/M-413 and M-404/M-414 series of linear stages form a modular system. The M-403 is the basic family, providing travel ranges from 25 to 200 mm. M-413 is designed for higher loads with travel ranges from 100 to 300 mm. The M-404 and M-414 stages have the same travel ranges and load capacities, but offer higher precision and more speed.



Different motor versions of the M-403 linear stage family with 100 mm travel range (from left) M-403.4PD (DC-motor/ActiveDrive™), M-403.4DG (DC-motor/gearhead) and M-403.42S (stepper motor)



M-403 and M-404 dimensions in mm, Sub-D connector 15-pin, 3 m cable

Technical Data

Model	M-404.xPD	M-404.xDG	M-404.x2S	M-403.xPD	M-403.xDG	M-403.x2S	Units
Motion and positioning							
Travel range	for all models: 25 / 50 / 100 / 150 / 200 mm (see Order Information)						
Integrated sensor	Rotary encoder	Rotary encoder	–	Rotary encoder	Rotary encoder	—	
Sensor resolution	4000	2000	–	4000	2000	—	Cts./rev.
Design resolution	0.25	0.012	0.16**	0.25	0.018	0.16**	µm
Min. incremental motion	0.25	0.1	0.2	0.25	0.2	0.2	µm
Backlash	0.5	2	2	6	10	6	µm
Unidirectional repeatability	0.5	1	1	1	1	1	µm
Pitch	75	75	75	200	200	200	µrad
Yaw	75	75	75	200	200	200	µrad
Max. velocity	50	1.5	3	10*	2.5	3	mm/s
Origin repeatability	1	1	1	1	1	1	µm
Mechanical properties							
Spindle	Recirculating ballscrew	Recirculating ballscrew	Recirculating ballscrew	Leadscrew	Leadscrew	Leadscrew	
Spindle pitch	1	1	1	1	1	1	mm
Gear ratio	–	42.92063:1	–	–	28.44444:1	–	
Motor resolution**	–	–	6400**	–	–	6400**	steps/rev.
Stiffness in motion direction	3500	3500	3500	3500	3500	3500	N/µm
Max. load	200	200	200	200	200	200	N
Max. push/pull force	50	50	50	50	50	50	N
Max. lateral force	100	100	100	100	100	100	N
Drive properties							
Motor type	ActiveDrive™ DC Motor	DC-motor, gearhead	2-phase stepper motor**	ActiveDrive™ DC Motor	DC-motor, gearhead	2-phase stepper motor**	
Operating voltage	24	0–12	24	24	0–12	24	V
Electrical power	26	2.5	4.8	26	2.5	4.8	W
Torque	50	3	200	50	3	200	Ncm
Limit and reference switches	Hall-effect	Hall-effect	Hall-effect	Hall-effect	Hall-effect	Hall-effect	
Miscellaneous							
Operating temperature range	-20 to +65	-20 to +65	-20 to +65	-20 to +65	-20 to +65	-20 to +65	°C
Material	for all models: Aluminum (black anodized)						
Mass (depends on dimensions/travel range)	1.7 / 1.8 / 2.1 / 2.2 / 2.5 kg						
Recommended controller/driver	C-863 (single-axis) C-843 PCI board (up to 4 axes)	C-863 (single-axis) C-843 PCI board (up to 4 axes)	C-663 (single-axis)	C-863 (single-axis) C-843 PCI board (up to 4 axes)	C-863 (single-axis) C-843 PCI board (up to 4 axes)	C-663 (single-axis)	

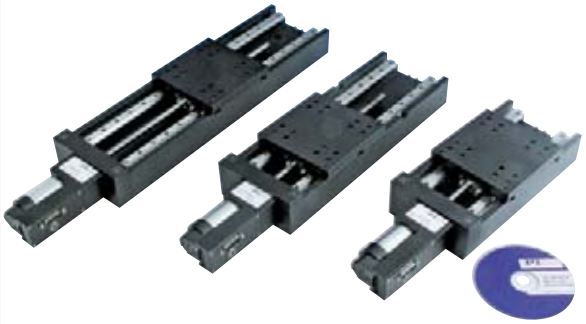
*Max. recommended velocity

**2-phase stepper motor, 24 V chopper voltage, max. 0.8 A/phase, 400 full steps/rev., motor resolution with C-663 stepper motor controller

Data for vacuum versions may differ.

M-413 · M-414 High-Load Precision Stage

Cost-Effective, Large Choice of Drives & Travel Ranges, Loads to 50 kg



M-413 linear stage versions (from right: the M-413.1PD, M-413.2PD and M-413.3PD provide travel ranges from 100 to 300 mm (CD for size comparison)

Ordering Information

M-41 .

- 3 Linear Translation Stage with leadscrew, 120 mm wide
- 4 Precision-Linear Stage with ball screw, 120 mm wide

Travel Range:
- 1 Travel Range 100 mm
- 2 Travel Range 200 mm
- 3 Travel Range 300 mm

Drive:
- PD ActiveDrive™ DC Motor (includes 24 V power supply)
- DG DC Motor Gearhead
- 2S 2-Phase Stepper Motor
- VP ActiveDrive™ DC Motor (includes 24 V power supply), Vacuum Compatible to 10^{-6} hPa
- VG DC Motor Gearhead, Vacuum Compatible to 10^{-6} hPa

- **For Cost-Sensitive Precision Positioning Applications**
- **Travel Ranges 100 to 300 mm**
- **Resolution to 0.018 µm**
- **Min. Incremental Motion to 0.1 µm**
- **Preloaded Precision Leadscrew or Recirculating Ball Screw Drives Provide High Speeds & Long Lifetimes**
- **Stress-Relieved Aluminum Base for Highest Stability**
- **Vacuum-Compatible Versions Available**
- **M-413 and M-414 Versions for Reduced Load Requirements**

The M-413 and M-414 linear translation stage series provide cost effective solutions for precision positioning of higher loads up to 50 kg over travel ranges up to 300 mm.
They are designed with a precision-machined, high-density, stress-relieved aluminum base for exceptional stability and robustness. The highly precise M-413 drive includes a preloaded leadscrew, providing a minimum incremental motion of 0.2 µm.

High Resolution Ball Screws & Lead Screws

For higher velocities and a long lifetime the M-414 versions feature a low-friction ball screw offering a minimum incremental motion down to 0.1 µm.
Three motor drive options allow the optimum adaptation to the requirements of different automation applications.
M-413s and M-414s are available in 3 lengths providing travel ranges from 100 to 300 mm. The stages can carry up to 50 kg and push/pull up to 50 N. Special versions for vacuum applications are available (see ordering information).

Application Examples

- Automation
- R&D
- Semiconductor technology
- Metrology
- Quality assurance testing

Maintenance-Free, High Guiding Precision

All models are equipped with high-precision linear guiding rails and recirculating ball bearings. The recirculating ball bearings are maintenance free and immune to cage migration. The choice of components and careful mounting guarantees high load capacity, longer lifetime and high guiding accuracy. Additionally the bearings are polished to guide the carriage with optimum straightness and flatness.

Low Cost of System Ownership

The combination of these stages with the networkable single-axis C-863 Mercury™ (see p. 4-114) and C-663 Mercury™ Step (see p. 4-112) controllers offers high performance for a very competitive price in both single and multiaxis configurations. Alternatively, the C-843 motion controller PCI card with on-board servo amplifiers (!) is available.

Three Motor Drive Options

M-41x.xPD high-speed versions come equipped with the high-performance ActiveDrive™ system. The ActiveDrive™ design, developed by PI, features a high-efficiency PWM (pulse width modulation) servo-amplifier mounted side-by-side with the DC motor and offers several advantages:

- Increased efficiency, by eliminating power losses between the amplifier and motor
- Reduced cost of ownership and improved reliability, because no external driver is required
- Elimination of PWM amplifier noise radiation, by mounting the amplifier and motor together in a single, electrically shielded case

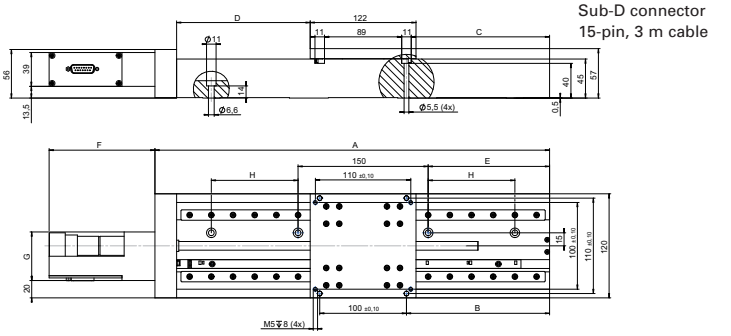
M41x.xDG models are equipped with a DC motor with a low-backlash gearhead and a shaft-mounted optical encoder to give a minimum incremental motion of 0.1 µm.
M-41x.x2S models feature a cost-effective direct-drive, 2-phase stepper motor, providing very smooth operation and a resolution of 0.2 µm.

Limit and Reference Switches

For the protection of your equipment, non-contact Hall-effect limit and reference switches are installed. The direction-sensing reference switch supports advanced automation applications with high precision.

Other Family Members

The M-403/M-413 and M-404/M-414 series of linear stages form a modular system. The M-403 is the basic family, providing travel ranges from 25 to 200 mm. M-413 is designed for higher loads with travel ranges from 100 to 300 mm. The M-404 and M-414 stages have the same travel ranges and load capacities, but offer higher precision and more speed.

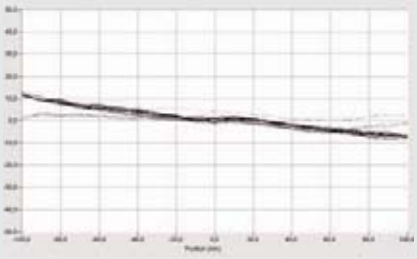


M-413 and M-414 dimensions in mm, Sub-D connector 15-pin, 3 m cable

	M-414.1xx M-413.1xx	M-414.2xx M-413.2xx	M-414.4xx M-413.4xx
A	255	355	455
B	65	115	165
C	59.5	109.5	159.5
D	54 (±50)	104 (±100)	154 (±150)
E	40	90	140

	M-414.xPD	M-414.xDG	M-414.x2S
F	120	133	105.5
G	59.5	56	59.5

	M-413.xPD	M-413.xDG	M-414.x2S
F	120	122	105.5
G	59.5	56	59.5



‚Polished bearings provide excellent guiding accuracy: better than 15 arcseconds (75 µrad) over 200 mm of travel, as shown above for the M-414 stage

Technical Data

Model	M-414.xPD	M-414.xDG	M-414.x2S	M-413.xPD	M-413.xDG	M-413.x2S	Units
Motion and positioning							
Travel range	for all models: 100 / 200 / 300 mm (see Ordering Information)						
Integrated sensor	Rotary encoder	Rotary encoder	–	Rotary encoder	Rotary encoder	–	
Sensor resolution	4000	2000	–	4000	2000	–	cts/rev.
Design resolution	0.5	0.023	0.31	0.25	0.018	0.16	µm
Min. incremental motion	0.5	0.1	0.4	0.25	0.2	0.2	µm
Backlash	0.5	4	2	6	10	6	µm
Unidirectional repeatability	0.5	1	1	1	1	1	µm
Pitch	100	100	100	300	300	300	µrad
Yaw	100	100	100	300	300	300	µrad
Max. velocity	100	3	6	10#	2.5	3	mm/s
Origin repeatability	1	1	1	1	1	1	µm
Mechanical properties							
Spindle	Recirculating ballscrew	Recirculating ballscrew	Recirculating ballscrew	Leadscrew	Leadscrew	Leadscrew	
Spindle pitch	2	2	2	1	1	1	mm
Gear ratio	–	42.92063:1	–	–	28.44444:1	–	
Motor resolution	–	–	6400*	–	–	6400*	steps/rev.
Stiffness in motion direction	6000	6000	6000	6000	6000	6000	N/µm
Max. load	500	500	500	500	500	500	N
Max. push/pull force	50	50	50	50	50	50	N
Max. lateral force	200	200	200	200	200	200	N
Drive properties							
Motor type	ActiveDrive™ DC motor	DC motor, gearhead	2-phase stepper motor*	ActiveDrive™ DC motor	DC motor, gearhead	2-phase stepper motor*	
Operating voltage	24	0–12	24	24	0–12	24	V
Electrical power	70	3.6	4.8	70	3.6	4.8	W
Torque	80	3	200	80	3	200	Ncm
Limit and reference switches	Hall-effect	Hall-effect	Hall-effect	Hall-effect	Hall-effect	Hall-effect	
Miscellaneous							
Operating temperature range	-20 to +65	-20 to +65	-20 to +65	-20 to +65	-20 to +65	-20 to +65	°C
Material	for all models: Aluminum (black anodized)						
Mass (depends on dimensions/travel range)	4.4 / 5.4 / 6.6	4.2 / 5.2 / 6.4	4.4 / 5.4 / 6.6	4.4 / 5.4 / 6.6	4.2 / 5.2 / 6.4	4.4 / 5.4 / 6.6	kg
Recommended controller/driver	C-863 (single-axis) C-843 PCI board (up to 4 axes)	C-863 (single-axis) C-843 PCI board (up to 4 axes)	C-663 (single-axis)	C-863 (single-axis) C-843 PCI board (up to 4 axes)	C-863 (single-axis) C-843 PCI board (up to 4 axes)	C-663 (single-axis)	

Data for vacuum versions may differ.
*2-phase stepper motor, 24 V chopper voltage, max. 0.8 A/phase, 400 full steps/rev., motor resolution with C-663 stepper motor controller
Max. recommended velocity

M-126 High-Resolution Translation Stage

Compact Linear Stage with Crossed Roller Bearings

M-126.CG1 translation stage with compact DC motor/gearhead

- **Min. Incremental Motion to 0.1 µm (3.5 nm Resolution)**
- **Repeatability to 0.1 µm**
- **Velocity to 50 mm/s**
- **Travel Ranges 20 and 25 mm**
- **Manual, DC-Servo and Stepper-Motor Drives**
- **ActiveDrive™ Option**
- **Crossed Roller Bearings**
- **Ballscrew and Leadscrew Versions**
- **XY and XYZ Combinations**
- **Direction-Sensing Reference Switch**
- **Variety of Cost-Effective Motion Controllers**

M-126 micropositioning systems are compact, high-precision translation stages with preloaded leadscrew and ballscrew drives for excellent resolution and repeatability. All models are equipped with precision crossed roller bearings providing straightness of travel of better than 2 µm.

Five motorized versions are available: M-126.CG1 utilizes a compact closed-loop DC motor with shaft-mounted high-resolution position encoder and a precision gearhead providing 0.1 µm minimum incremental motion, M-126.DG1 is equipped with a larger motor than M-126.CG1 and provides higher velocity. The M-126.2S1 stepper motor version has a 2-phase stepper motor that provides a minimum incremental motion of 0.1 µm (controller depending).

Higher Speed with ActiveDrive™ and Ballscrews

The top-of-the-line M-126.PD2 is equipped with a low friction ballscrew and and provides velocities to 50 mm/sec. Model M-126.PD1 features a leadscrew and is recommended for lower speeds to 15 mm/sec and/or duty cycle applications. Both versions boast the high-perfomance ActiveDrive™. PI's ActiveDrive™ design, features a high-efficiency PWM (pulse width modulation) servo-amplifier mounted side-by-side with the DC motor and offers several advantages:

- Increased efficiency by eliminating power losses between the amplifier and motor
- Reduced cost of ownership and improved reliability because no external driver is required
- Elimination of PWM amplifier noise radiation by mounting the amplifier and motor together in a single electrically shielded case

Limit and Reference Switches

For the protection of your equipment, non-contact Hall-effect limit and reference switches are installed. The direction-sensing reference switch supports advanced automation applications with high precision.

XY and XYZ Combinations

All stages can be cross-stacked and combined with the M-125.90 Z-axis mounting bracket to provide multi-axis motion.

Notes

For adapters, bracket, etc. see p. 4-90 *ff.*

Ordering Information

M-126.CG1
Translation Stage, 25 mm, Compact DC Motor Gearhead

M-126.DG1
Translation Stage, 25 mm, DC Motor Gearhead

M-126.PD1
Translation Stage, 25 mm, ActiveDrive™ DC Motor (includes 24 V power supply)

M-126.PD2
Translation Stage, 20 mm, ActiveDrive™ DC Motor, Ballscrew (includes 24 V power supply)

M-126.2S1
Translation Stage, 25 mm, 2-Phase Stepper Motor

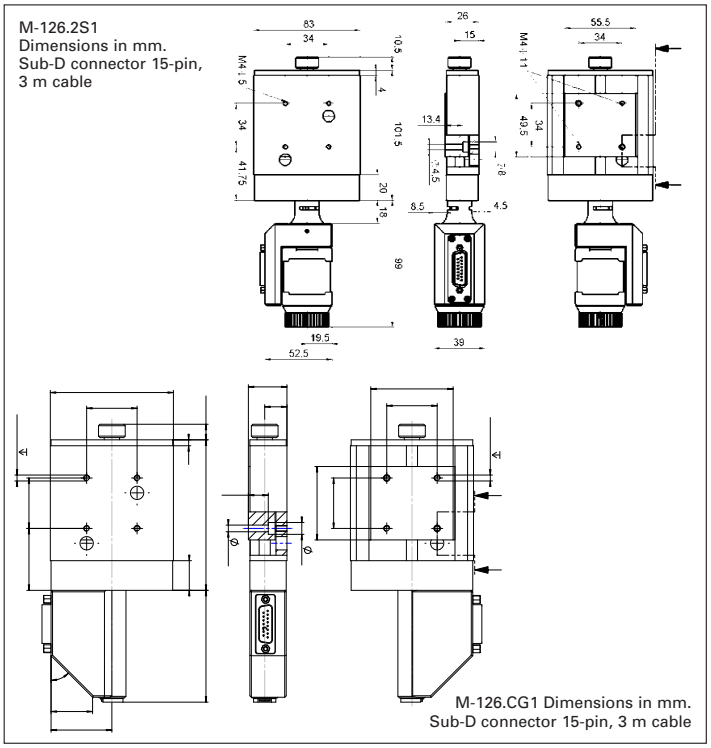
M-126.M0
Translation Stage, 25 mm, Manual Drive, Leadscrew

M-125.90
Z-axis Mounting Bracket for Vertical Mount of M-126 Stages

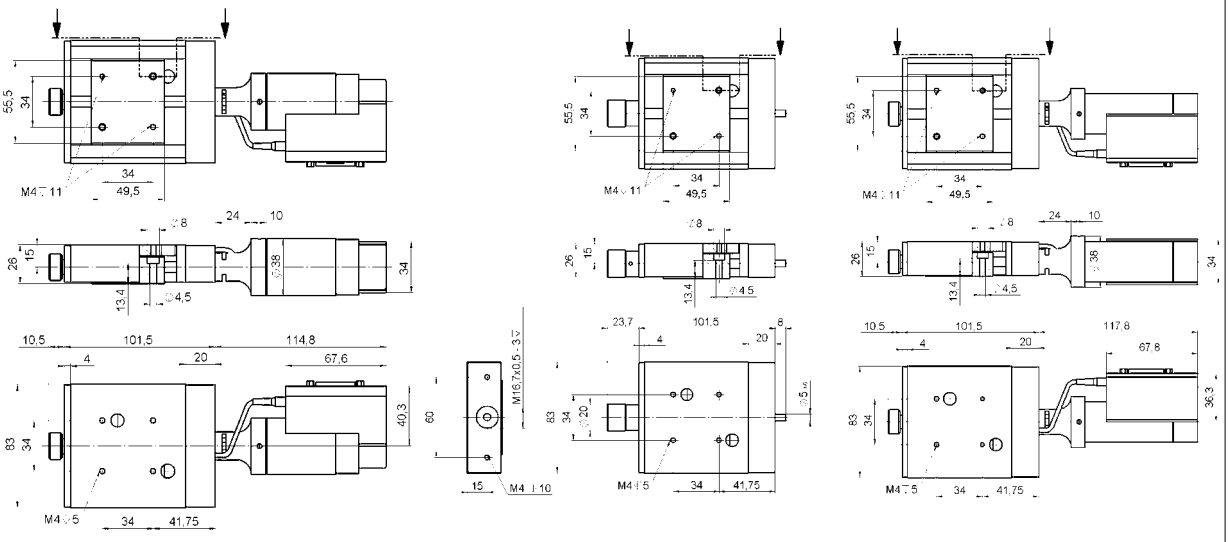
M-126.80
Adapter Plate for Honeycomb Tables

Ask about custom designs!

M-126.2S1
Dimensions in mm.
Sub-D connector 15-pin, 3 m cable



M-126.CG1 Dimensions in mm.
Sub-D connector 15-pin, 3 m cable



M-126.PD1 / .PD2 Dimensions in mm.
Sub-D connector 15-pin, 3 m cable

M-126.M0 Dimensions in mm.
Sub-D connector 15-pin, 3 m cable

M-126.DG1 Dimensions in mm.
Sub-D connector 15-pin, 3 m cable

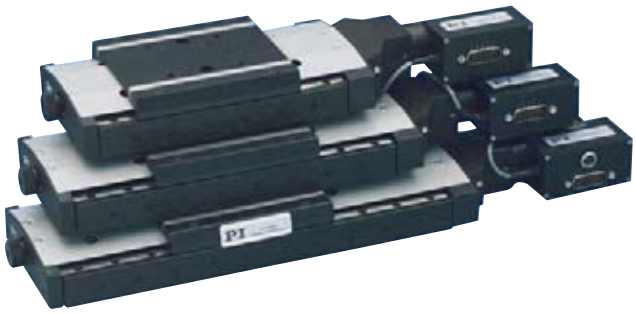
Technical Data

Model	M-126.M0	M-126.CG1	M-126.DG1	M-126.PD1	M-126.PD2	M-126.2S1	Units
Active Axes	X	X	X	X	X	X	
Motion and positioning							
Travel range	25	25	25	25	20	25	mm
Integrated sensor	–	Rotary encoder	Rotary encoder	Rotary encoder	Rotary encoder	–	
Sensor resolution	–	2048	2000	4000	4000	–	Cts./rev
Design resolution	–	0.0035	0.0085	0.125	0.25	0.08**	µm
Min. incremental motion	1	0.1	0.1	0.25	0.5	0.1**	µm
Unidirectional repeatability	–	0.2	0.1	0.1	± 0.3	0.1**	µm
Bidirectional repeatability	–	2	1	1	1	1**	µm
Accuracy	–	2.5	2.5	2.5	2.5	2.5	µm
Pitch / Yaw	±50	±50	±50	±50	±50	±50	µrad
Straightness / Flatness	2	2	2	2	2	2	µm
Max. velocity	–	0.7	1.5	15*	50	6**	mm/s
Origin repeatability	–	1	1	1	1	1	µm
Mechanical properties							
Drive Screw	Leadscrew	Leadscrew	Leadscrew	Leadscrew	Recirculating ballscrew	Leadscrew	
Thread pitch	0.5	0.5	0.5	0.5	1	0.5	mm
Gear ratio	–	69.12:1	(28/12)*:01 ~ 29.6:1	–	–	–	
Motor resolution	–	–	–	–	–	6400**	steps/rev.
Max. load	200	200	200	200	200	200	N
Max. push / pull force	50 / 50	40 / 40	50 / 50	50 / 50	40 / 40	50 / 50	N
Max. lateral force	100	100	100	100	100	100	N
Drive properties							
Motor type	–	DC Motor, gearhead	DC Motor, gearhead	ActiveDrive™ DC Motor	ActiveDrive™ DC Motor	2-phase stepper motor	
Operating voltage	–	0 to ±12	0 to ±12	24 (PWM)	24 (PWM)	24	V
Electrical power	–	2	3	30	30		W
Limit and reference switches	–	Hall-effect	Hall-effect	Hall-effect	Hall-effect	Hall-effect	
Miscellaneous							
Operating temperature range	-20 to +65	-20 to +65	-20 to +65	-20 to +65	-20 to +65	-20 to +65	°C
Material	Aluminum, steel	Aluminum, steel	Aluminum, steel	Aluminum, steel	Aluminum, steel	Aluminum, steel	
Mass	0.6	0.8	0.9	0.9	0.9	1	kg
Recommended controller/driver	–	C-863 single-axis C-843 PCI board, for up to 4 axes	C-863 single-axis C-843 PCI board, for up to 4 axes	C-863 single-axis C-843 PCI board, for up to 4 axes	C-863 single-axis (p. 4-114) C-843 PCI board (p. 4-120), for up to 4 axes	C-663 single-axis (p. 4-112)	

*Max. recommended velocity
**2-phase stepper motor, 24 V chopper voltage, max. 0.8 A/phase, 400 full steps/rev., motor resolution with C-663 stepper motor controller

M-405 · M-410 · M-415 Precision Translation Stage

High-Load Linear Stage with Crossed Roller Bearings



M-405.DG, M-410.DG and
M-415.PD high-precision translation stages

Ordering Information

Translation Stage

M-4 .

- **05** Travel Range 50 mm
- **10** Travel Range 100 mm
- **15** Travel Range 150 mm

- **CG** DC Motor Gearhead
- **DG** DC Motor Gearhead
- **PD** ActiveDrive™ DC Motor, Includes 24 V Power Supply
- **2S** 2-Phase Stepper Motor
- **M0** Manual Drive

Ask about custom designs!

- **Travel Ranges up to 150 mm**
- **Stress-Relieved Aluminum Base for Highest Stability**
- **Crossed Roller Bearings**
- **Manual, DC-Servo and Stepper-Motor Drives**
- **Knob for Convenient Manual Position Adjustment**
- **Direction-Sensing Reference Switch**

M-400 series translation stages are compact, leadscrew-driven stages with a travel range of 50, 100 and 150 mm. All models are equipped with low-friction leadscrews for excellent resolution and repeatability. Precision crossed roller bearings guarantee 2 µm/100 mm straightness of travel. The stage base is precision machined from high-density, stress-relieved aluminum for exceptional stability and minimum weight.

Five Versions

One manual and four motorized versions are available: Models M-4xx.2S are equipped with direct-drive, 2-phase stepper motors providing 0.1 µm minimum incremental motion. Models M-4xx.CG and M-4xx.DG utilize closed-loop DC motors with shaft-mounted position encoders and precision gearheads providing 0.1 µm minimum incremental motion (encoder resolution 3 nm). The top-of-the-line M-4xx.PD versions feature the high-performance ActiveDrive™ system.

ActiveDrive™

The ActiveDrive™ design, developed by PI, features a high-efficiency PWM (pulse width modulation) servo-amplifier mounted side-by-side with the DC motor and offers several advantages:

- Increased efficiency, by eliminating power losses between the amplifier and motor
- Reduced cost of ownership and improved reliability, because no external driver is required
- Elimination of PWM amplifier noise radiation, by mounting the amplifier and motor together in a single, electrically shielded case

Limit and Reference Switches

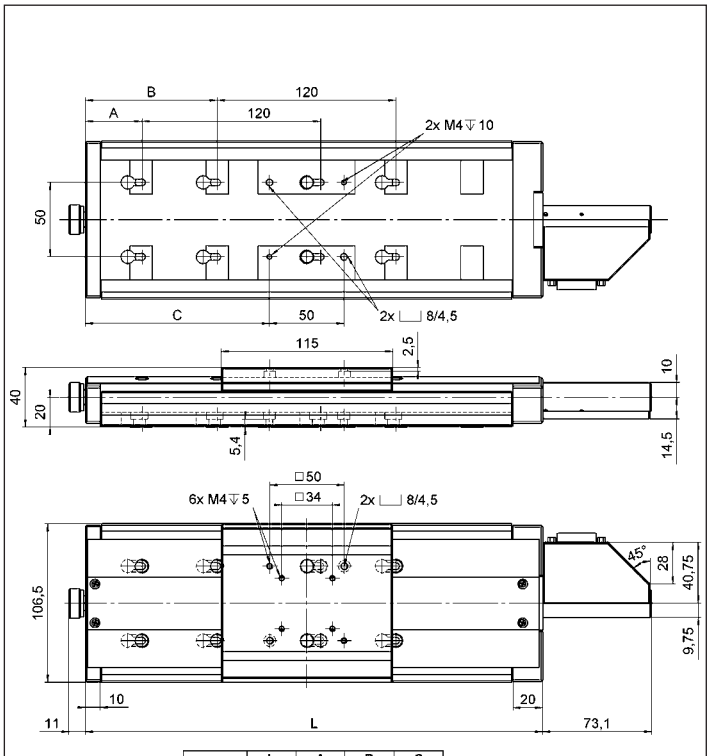
For the protection of your equipment, non-contact Hall-effect limit and reference switches are installed. The direction-sensing reference switch supports advanced automation applications with high precision (motorised versions only). All stages of this series can be cross stacked and combined with the M-592.00 Z-axis mounting bracket to provide multi-axis motion.

Notes

See “Accessories” for adapters, bracket, etc. (p. 4-90 *ff*).

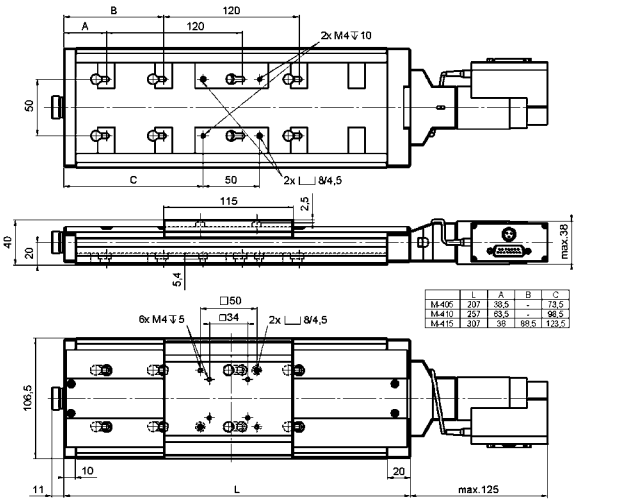
Application Examples

- Automation
- R&D
- Semiconductor technology
- Metrology
- Quality assurance testing



	L	A	B	C
M-405	207	38,5	-	73,5
M-410	257	63,5	-	98,5
M-415	307	38	88,5	123,5

M-410.CG, M-415.CG
dimensions in mm, cable length 3 m, Sub-D connector 15-pin



M-405.DG, M-410.DG, M-415.DG, M-405.PD, M-410.PD and M-415.PD
dimensions in mm, cable length 3 m, Sub-D connector 15-pin

M-405.CG translation stage

Technical Data

Model	M-405.CG / M-410.CG / M-415.CG	M-405.DG / M-410.DG / M-415.DG	M-405.PD / M-410.PD / M-415.PD	M-405.2S / M-410.2S / M-415.2S	Units
Motion and positioning					
Travel range	50 / 100 / 150	50 / 100 / 150	50 / 100 / 150	50 / 100 / 150	mm
Integrated sensor	Rotary encoder	Rotary encoder	Rotary encoder	–	
Sensor resolution	2048	2000	4000		cts./rev.
Encoder bandwidth					
Design resolution	0.0035	0.0085	0.125	0.0781	µm
Min. incremental motion	0.1	0.1	0.25	0.1	µm
Unidirectional repeatability	0.2	0.2	0.2	0.2	µm
Bidirectional repeatability	2	2	2	2	µm
Pitch, yaw	±25 / ±50 / ±75	±25 / ±50 / ±75	±25 / ±50 / ±75	±25 / ±50 / ±75	µrad
Max. velocity	0.7	1.5	15	3.5	mm/s
Mechanical properties					
Spindle pitch	0.5	0.5	0.5	0.5	mm
Gear ratio	69.12:1	$(28/12)^4$:1 ≈ 29.6:1			
Motor resolution	–	–	–	6400*	steps/rev.
Max. load	200	200	200	200	N
Max. push / pull force	40 / 40	50 / 50	50 / 50	50 / 50	N
Max. lateral force	150	150	150	150	N
Drive properties					
Motor type	DC-motor, gearhead	DC-motor, gearhead	ActiveDrive™ DC Motor	2-phase stepper motor*	
Operating voltage	0 to ±12	0 to ±12	0 to ±24	24	V
Electrical power	2	3	30	–	W
Limit and reference switches	Hall-effect	Hall-effect	Hall-effect	Hall-effect	
Miscellaneous					
Operating temperature range	-20 to +65	-20 to +65	-20 to +65	-20 to +65	°C
Material	Aluminum, steel	Aluminum, steel	Aluminum, steel	Aluminum, steel	
Mass	2	2.1	2.1	2.1	kg
Recommended controller/driver	C-863 (single-axis) C-843 PCI board (up to 4 axes)	C-863 (single-axis) C-843 PCI board (up to 4 axes)	C-863 (single-axis, p. 4-114) C-843 PCI board (p. 4-120) (up to 4 axes)	C-663 (single-axis) (p. 4-112)	

*2-phase stepper motor, 24 V chopper voltage, max. 0.8 A/phase, 400 full steps/rev., motor resolution with C-663 stepper motor controller

M-605 High-Accuracy Translation Stage

Ultra-Compact, with Direct Position Measurement

M-605.2DD high precision translation stage

- **Integrated 0.1 µm Linear Encoder for Highest Accuracy**
- **Travel Ranges 25 mm (1“) and 50 mm (2“)**
- **Max. Velocity 50 mm/s with ActiveDrive™ Motor**
- **High Load Capacity up to 30 kg**
- **Zero-Backlash Recirculating Ballscrews**
- **Non-contact Limit and Reference Switches**
- **Stress-Relieved Aluminum Base for Highest Stability**
- **Flexible Bellows Protects the Mechanics from Dust and Spray**
- **XY & XYZ Combinations Possible**
- **MTBF >20,000 h**

M-605 series translation stages are designed to meet the most demanding positioning requirements in applications where space is limited.
They feature a space-saving design with the ballscrew side-by-side to the motor and an extremely flat, precision-machined base of high-density, stress-relieved aluminum providing exceptional stability and minimum weight.

Application Examples

- R&D
- Semiconductor testing
- Mass storage device testing
- Metrology
- Photonics packaging
- Quality assurance testing
- Precision Linear Motion Control

Integrated Linear Scale Encoder

For highest accuracy and repeatability, M-605 stages are equipped with integrated linear-scale encoders (direct metrology) providing 0.1 µm minimum incremental motion and 1 µm full-travel accuracy.

Heavy Duty and Maintenance Free

All models are equipped with high-precision linear guiding rails and recirculating ball bearings. The choice of components and careful mounting guarantees high load capacity, longer lifetime and high guiding accuracy.

Ballscrews for High Speed, Precision and Lifetime

The precision-ground ballscrew is maintenance-free and preloaded to eliminate mechanical play. Its significantly reduced friction, compared to conventional leadscrews, allows for higher velocity, lower power consumption and longer lifetime.
A flexible bellows protects the mechanics from dust and spray.

ActiveDrive™

For maximum dynamic performance, the M-605 series stages are equipped with the highly efficient ActiveDrive™ direct-drive system, which can achieve speeds of up to 50 mm/s. The ActiveDrive™ design, developed by PI, features a high-efficiency PWM (pulse width modulation) servo-amplifier mounted side-by-side with the DC motor and offers several advantages:

- Increased efficiency, by eliminating power losses between the amplifier and motor
- Reduced cost of ownership and improved reliability, because no external driver is required
- Elimination of PWM amplifier noise radiation, by mounting the amplifier and motor together in a single, electrically shielded case

Limit and Reference Switches

For the protection of your equipment, non-contact Hall-effect limit and reference switches are installed. The direction-sensing reference switch supports advanced automation applications with high precision.

Precision Assembly

Each M-605 stage is precision assembled and optimized using laser interferometers for performance testing.

Ordering Information

M-605.1DD
Compact Precision Linear Stage, 25 mm, 0.1 µm Linear Encoder, ActiveDrive™ DC Motor

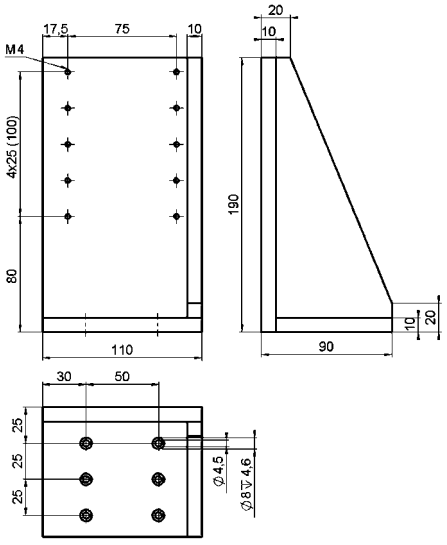
M-605.2DD
Compact Precision Linear Stage, 50 mm, 0.1 µm Linear Encoder, ActiveDrive™ DC Motor

Accessories:
M-605.AV0
Angle Bracket for Vertical Mount of M-605 on M-605

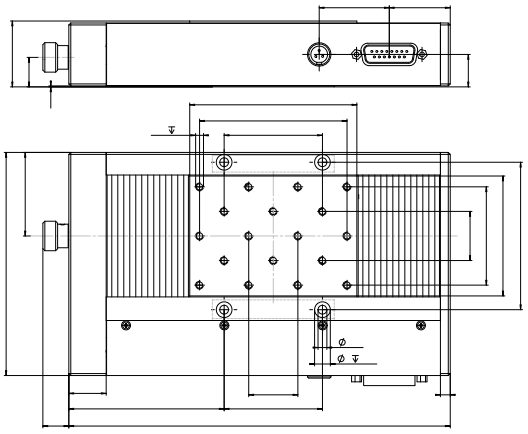
M-110.01
Adapter Plate for Horizontal Mount of M-605 on Honeycomb Tables, M-400- and M-500 Series Translation Stages and Several Rotation Stages

Ask about custom designs!

M-605.2DD XYZ-combination



M-605.AV0 angle bracket for vertical mount of M-605 on M-605



M-605.2DD dimensions (in mm). C-815.38 motor cable included: 3 m, sub-D, 15/15 pin (m/f)

Technical Data

Model	M-605.1DD	M-605.2DD	Units
Active Axes	X	X	
Motion and positioning			
Travel range	25	50	mm
Integrated sensor	Linear encoder	Linear encoder	
Sensor resolution	0.1	0.1	µm
Design resolution	0.1	0.1	µm
Min. incremental motion	0.3	0.3	µm
Unidirectional repeatability	0.1	0.1	µm
Bidirectional repeatability	0.2	0.2	µm
Accuracy	1	1	µm
Pitch	50	50	µrad
Yaw	50	50	µrad
Max. velocity	50	50	mm/s
Origin repeatability	1	1	µm
Mechanical properties			
Thread pitch	1	1	mm
Max. load	300	300	N
Max. push / pull force	20 / 20	20 / 20	N
Max. lateral force	100	100	N
Drive properties			
Motor type	ActiveDrive™ DC Motor	ActiveDrive™ DC Motor	
Operating voltage	24 (PWM)	24 (PWM)	V
Electrical power	6	6	W
Limit and reference switches	Hall-effect	Hall-effect	
Miscellaneous			
Operating temperature range	-20 to +65	-20 to +65	°C
Material	Al (black anodized)	Al (black anodized)	
Mass	1.5	1.8	kg
Recommended controller/driver	C-863 single-axis C-843 PCI board (up to 4 axes)	C-863 single-axis (p. 4-114) C-843 PCI board (p. 4-120) (up to 4 axes)	

M-511 · M-521 · M-531 Heavy-Duty Micropositioning Stage

High-Precision Linear Guiding, Long Travel, Direct Position Measurement

M-531.DD, M-521.DD, M-511.DD and
M-505.2DG heavy duty translation stages
with recirculating ballscrew drive (bottom to top)

Ordering Information

1 = Travel Range 102 mm / 4''
2 = Travel Range 204 mm / 8''
3 = Travel Range 306 mm / 12''

M-5 [ ] **1.** [ ] Precision Translation Stage

DG = DC Motor Gearhead
DD = ActiveDrive™ DC Motor, 0.1 µm Linear Encoder
DDB = ActiveDrive™ DC Motor, 0.1 µm Linear Encoder, Motor Brake
PD = ActiveDrive™ DC Motor Rotary Encoder
2S = 2-Phase Stepper Motor
VG = DC Motor Gearhead, Vacuum Compatible to 10^{-6} hPa
VP = ActiveDrive™ DC Motor, Vacuum Compatible to 10^{-6} hPa
VD = ActiveDrive™ DC Motor, 0.1 µm Linear Encoder, Vacuum Compatible to 10^{-6} hPa

- **Travel Ranges 102, 204 and 306 mm (4", 8", 12")**
- **Max. Velocity 125 mm/s with ActiveDrive™ Motors**
- **Optional 0.1 µm Linear Encoder for Highest Accuracy**
- **Load Capacity of 100 kg**
- **Stress-Relieved Aluminum Base for Highest Stability**
- **Zero-Backlash Recirculating Ballscrews**
- **Non-contact Limit and Reference Switches**
- **XY & XYZ Combinations (Special Z-Stages Available)**
- **MTBF >20,000 h**

M-5x1-series translation stages are designed to meet the most demanding positioning requirements and are available in a number of different models. They boast an extremely low profile design to allow multiaxis combinations (see also page 4-58 and page 4-60) and feature a precision-machined base of high-density, stress-relieved aluminum for exceptional stability and minimum weight.

Application Examples

- R&D
- Semiconductor testing
- Mass storage device testing
- Metrology
- Photonics packaging
- Quality assurance testing
- Precision Linear Motion Control

Heavy Duty and Maintenance Free

The stages are equipped with high-precision linear guiding rails with recirculating ball bearings to guarantee 1 µm/100 mm straightness and flatness. Precision-ground recirculating ball screws with preloaded nuts provide low-friction, maintenance-free and backlash-free positioning. This equipment provides high load capacity and guiding accuracy with long lifetime.

Four Drive Options

Maximum dynamic performance is possible with versions featuring the highly efficient ActiveDrive™ direct-drive system, which can achieve speeds of up to 125 mm/s.

The ActiveDrive™ design, developed by PI, features a high-efficiency PWM (pulse width modulation) servo-amplifier mounted side-by-side with the DC motor and offers several advantages:

- Increased efficiency, by eliminating power losses between the amplifier and motor
- Reduced cost of ownership and improved reliability, because no external driver is required
- Elimination of PWM amplifier noise radiation, by mounting the amplifier and motor together in a single, electrically shielded case

The M-5x1.PD version provides velocities up to 125 mm/sec. It is equipped with an ActiveDrive™ DC motor and rotary encoder.

The M-5x1.DD models provide superior repeatability of only 0.2 µm by means of integrated optical linear encoders. A motor brake which assures maintenance of the stage position after power-down is also available. The M-5x1.DG versions feature closed-loop DC motors with shaft-mounted position encoders and precision gearheads providing minimum incremental motion to 0.1 µm with velocities up to 6 mm/s.

The M-5x1.2S versions models feature a cost-effective direct-drive, 2-phase stepper motor, providing very smooth operation and a resolution of 0.1 µm.

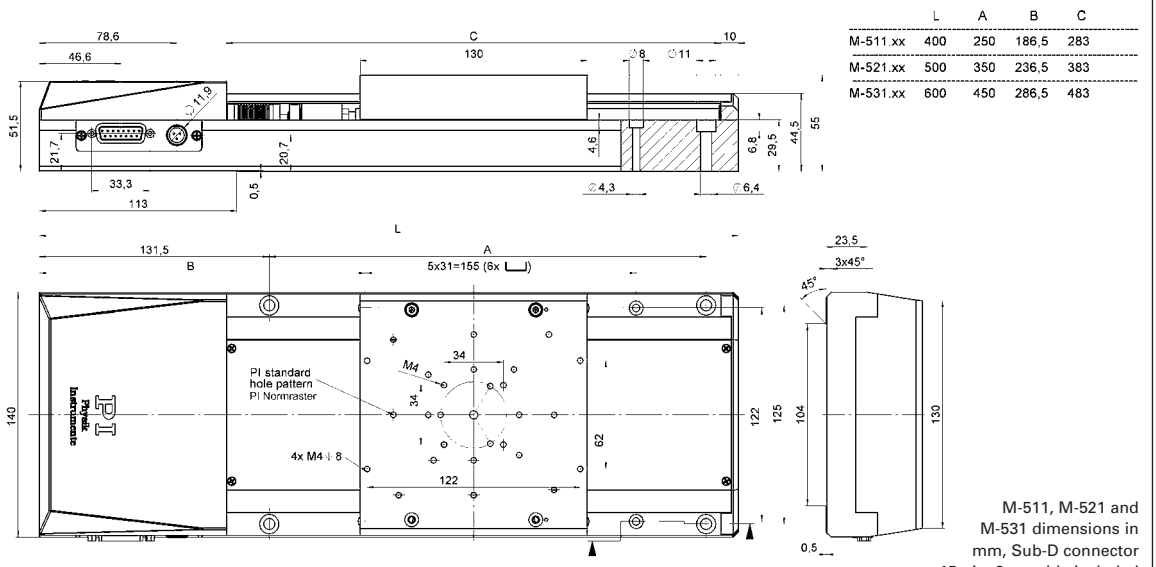
Precision Assembly

The stages are individually tested and optimized using a laser interferometer.

Notes

For adapters, bracket, etc. (see page 4-90 *ff*).

XYZ combination with two
M-511.DD linear stages and an
M-501.1PD precision vertical stage



	L	A	B	C
M-511.xx	400	250	186,5	283
M-521.xx	500	350	236,5	383
M-531.xx	600	450	286,5	483

M-511, M-521 and M-531 dimensions in mm, Sub-D connector 15-pin, 3 m cable included

Technical Data

Model	M-511.DD / M-521.DD / M-531.DD	M-511.PD / M-521.PD / M-531.PD	M-511.DG / M-521.DG / M-531.DG	M-511.2S / M-521.2S / M-531.2S	Unit
Motion and positioning					
Travel range	102 / 204 / 306	102 / 204 / 306	102 / 204 / 306	102 / 204 / 306	mm
Integrated sensor	Linear encoder	Rotary encoder	Rotary encoder	–	
Sensor resolution	0.1 µm	4000	2048	–	cts./rev.
Design resolution	0.1	0.5	0.033	0.31	µm
Min. incremental motion	0.1	0.5	0.1	0.1	µm
Unidirectional repeatability	±0.1	±0.5	±0.2	±0.2	µm
Bidirectional repeatability	±0.2	–	–	–	µm
Backlash	–	1	1	1	µm
Accuracy per 50 mm	0.2	2	2	2	µm
Pitch/Yaw	±25 / ±35 / ±50	±25 / ±35 / ±50	±25 / ±35 / ±50	±25 / ±35 / ±50	µrad
Straightness/Flatness per 100 mm	1	1	1	1	µm
Max. velocity	50	125	6	20	mm/s
Mechanical properties					
Thread pitch	2	2	2	2	mm
Gear ratio	–	–	$(28/12)^4$:1 ≈ 29.6:1	–	
Motor resolution*	–	–	–	6400*	steps/rev.
Max. load	1000	1000	1000	1000	N
Max. push/pull force	80 / 80	80 / 80	80 / 80	80 / 80	N
Max. lateral force	200	200	200	200	N
Drive properties					
Motor type	ActiveDrive™ DC Motor	ActiveDrive™ DC Motor	DC-motor, gearhead	2-phase stepper motor*	
Operating voltage	24 (PWM)	24 (PWM)	0 to ±12	24	V
Electrical power	30	30	3		W
Limit and reference switches	Hall-effect	Hall-effect	Hall-effect	Hall-effect	
Miscellaneous					
Operating temperature range	-20 to +65	-20 to +65	-20 to +65	-20 to +65	°C
Material	Al (black anodized)	Al (black anodized)	Al (black anodized)	Al (black anodized)	
Mass	5 / 6.1 / 7.2	5 / 6.1 / 7.2	4.9 / 6 / 7.1	4.9 / 6 / 7.1	kg
Recommended controller/driver	C-863 (single-axis) C-843 PCI board (up to 4 axes)	C-863 (single-axis) C-843 PCI board (up to 4 axes)	C-863 (single-axis, p. 4-1149) C-843 PCI board (p. 4-120) (up to 4 axes)	C-663 (single-axis) (p. 4-112)	

* 2-phase stepper motor, 24 V chopper voltage, max. 0.8 A/phase, 400 full steps/rev., motor resolution with C-663 stepper motor controller

M-511.HD Nano-Precision Heavy-Duty Stage

Hybrid DC/Piezo Precision Stage, High Speed, 2 nm Resolution

M-511.HD hybrid nanopostioner

- **Simultaneous Control of Piezo-Flexure Drives & DC-Servo/Ballscrew Drives**
- **100 mm Travel Range, 125 mm/sec Max. Velocity**
- **Reliable Execution of Nanometer Level Increments**
- **2 nm Linear Encoder Resolution**
- **Millisecond Settling Time to Nanometer Precision**
- **Frictionless Piezo Drive and Flexure-Decoupled Ballscrew**
- **Active Compensation of Backlash and Stick/Slip Effects**
- **Excellent Velocity Control**

The M-511.HD is an advancement on PI's proven M-5x1 precision micropositioning stage series. The new hybrid system overcomes the limitations of conventional precision positioning systems by combining the well-known advantages of piezo-flexure-drives (unlimited resolution and very rapid response) with the long travel ranges and high holding forces of a servo-motor/ballscrew arrangement. The M-511.HD allows velocities to 125 mm/s with an encoder resolution of 2 nm and load capacity of 50 kg for horizontal operation.

Application Examples

- Surface Inspection
- Microscopy
- Laser technology
- Interferometry
- Metrology

Long Travel Ranges with Nanometer Precision

The challenge of implementing hybrid technology is not only the positioning stage design, but also the use of high-resolution sensors over large travel ranges, the processing of the resulting high-frequency signals and the design of special control algorithms to take full advantage of the hybrid concept.

On the mechanical side, this is accomplished by decoupling the moving platform from the positioner's motor-ballscrew-drive by frictionless flexures and stiff, highly responsive piezo actuators.

Due to its high stiffness and instantaneous, sub-millisecond range response, the integrated piezo flexure drive provides active stick/slip compensation during startup and settling and is the key to achieving consistent and repeatable nanometer level positioning increments. It also cancels out motion irregularities caused by the ball screw and significantly improves velocity control.

Servo-control of the system employs a single high-resolution position feedback sensor (direct metrology) which means that the inherent piezo precision is available over the entire travel range of 100 mm, and longer travel ranges are basically feasible. The resolution and the positioning accuracy mainly depend on the choice of the feedback sensor.

Hybrid Controller Technology is Key to Success

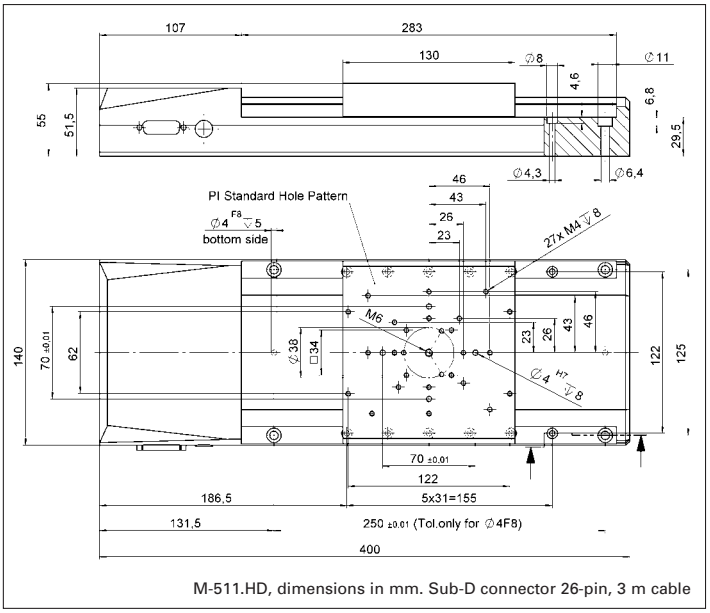
PI's highly specialized C-702 hybrid nanopositioning controller (see p. 4-118) compares the actual platform position (by reading the integrated linear encoder) with a calculated, smooth trajectory in real time. Its complex control algorithms continuously actuate both the piezoelectric and servo motor drives in a way to provide the best possible overall performance.

This makes hybrid systems ideal for applications where extremely smooth motion is required, where the position of an incident needs to be read and refound precisely, or where an externally specified target position needs to be hit within few a nanometers, such as in surface inspection or metrology.

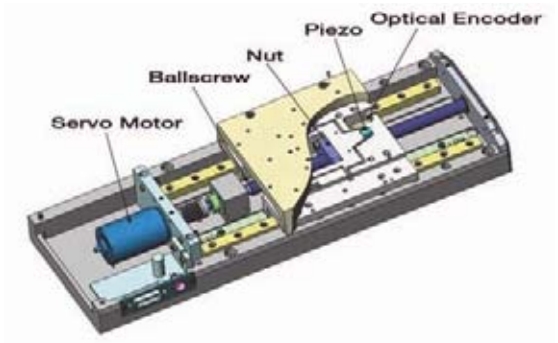
Ordering Information

M-511.HD
Ultra-High-Precision Hybrid Translation Stage, 100 mm Travel, 2 nm Linear Encoder Resolution

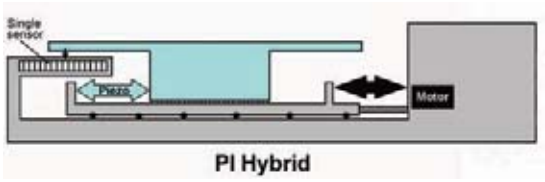
Ask about custom designs!



M-511.HD, dimensions in mm. Sub-D connector 26-pin, 3 m cable



Working principle of the M-511.HD. The platform is decoupled from the motor drive train by the piezo actuator and the flexure guides. This also reduces the inertia of the piezo-driven platform and allows for rapid response



PI Hybrid drive combines motorized and piezo positioning system with integrated, internal, high-resolution sensor in one control loop

Technical Data

Model	M-511.HD
Active axes	X
Motion and positioning	
Travel range	100 mm
Integrated sensor	Linear encoder
Sensor resolution	0.002 µm
Design resolution	0.002 µm
Min. incremental motion	0.004 µm
Hysteresis at the platform	0.01 µm
Unidirectional repeatability	0.01 µm
Accuracy	<0.05 µm
Pitch	±25 µrad
Yaw	±25 µrad
Straightness	1 µm
Flatness	1 µm
Max. velocity	50 mm/s
Origin repeatability	1 µm
Mechanical properties	
Drive screw	Recirculating ballscrews
Guiding	Precision linear guiding rails, recirculating ball bearings
Screw pitch	2 mm/rev.
Max. load	500 N
Max. push/pull force	80/80 N
Max. lateral force	200 N
Drive properties	
Drive type	Hybrid drive: DC motor with low-inertia, flexure-decoupled and piezo actuated stage platform
Motor type	DC motor
Operating voltage (motor)	24 V
Electrical power	30 W
Piezo drive type	PICMA® Multilayer piezo with flexure
Piezo voltage	±36 V
Limit and reference switches	Hall-effect
Miscellaneous	
Operating temperature range	-20 to +65 °C
Material	Al (black anodized)
Mass	5.1 kg
Recommended controller/driver	C-702 hybrid motor controller (p. 4-118)

V-106 QuickScan™ High-Dynamics Scanner

Voice-Coil Drive with Direct Position Measurement

V-106.11S and V-106.14S high-dynamics scanning stages with voice coil drives

- **Fast Scanning and Positioning**
- **Travel Ranges of 20 mm and 6 mm**
- **Linear Encoder Provides 0.1 µm Resolution, 0.2 µm Repeatability**
- **Scanning Frequency to Tens of Hz**
- **Velocity up to 270 mm/s**
- **PCI-Card Controller with On-Board Amplifiers Available**

QuickScan™ micropositioning stages of the V-106 series were designed for high-dynamics precision scanning and positioning applications, like those in biotechnology and fiber optics. They are based on zero-friction voice coil drives (linear motors), which, combined with high-precision linear encoders, offer a position resolution of 0.1 µm and minimal step size of 0.2 µm.

V-106 micropositioning stages achieve significantly higher dynamics than leadscrew-based units. The specially designed voice coil drive sys-tem makes possible scanning frequencies of some tens of hertz. With an applied load of 90 grams, the scan frequency of the V-106.11S is still 20 Hz over a travel range of 1 mm. The excellent dynamic characteristics are advantageous not only for scanning applications: positioning tasks see them as short settling times like 75 ms for 5 mm with a 90 gram load.

Application Examples

- Bioanalytics
- Scanning microscopy
- Semiconductor testing
- Micromanufacturing
- Microdispensing
- Optical device testing
- Photonics alignment & packaging

Direct Drive and Direct Metrology—Precise Motion

The design of the V-106 is based on three key precision components:

- A frictionless voice-coil (linear motor) drive
- A non-contacting direct-motion metrology linear encoder for sub-micron repeatability
- Precision cross-roller bearings for ultra-straight and smooth motion

Unlike leadscrew-driven translation stages, the voice-coil linear-motor in the V-106 is frictionless, quiet and not subject to wear and tear. In addition, it provides higher dynamics, speed, acceleration and responsiveness (step-and-settle)—ideal features for high-throughput applications. The embedded drive also reduces the length considerably compared to conventional motor/screw-driven stages.

For highly repeatable motion, a non-contacting optical linear encoder with 0.1 µm resolution is mounted inside the stage and feeds position information back to the motion controller.

The integrated, non-contact reference switch increases versatility in automation applications.

Versatile PCI Board Controller

V-106 voice coil stages can be controlled by the C-843 digital contoller in PCI plug-in-board format. C-843 controllers are equipped with on-board linear servo-amplifiers for precise control of up to four axes. This lowers system costs and simplifies setup by eliminating additional external amplifiers and cables.

Ordering Information

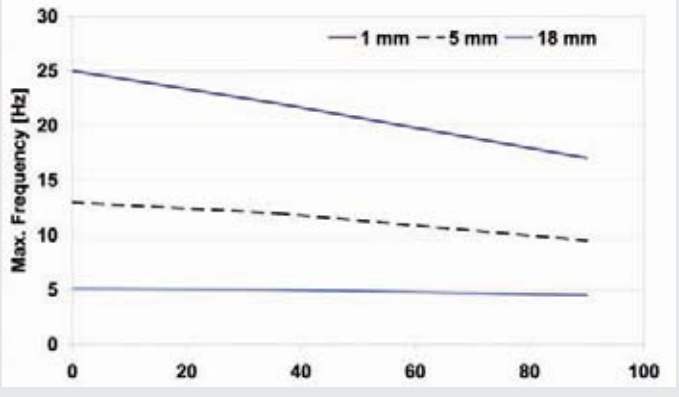
V-106.11S
QuickScan Voice Coil Scanning Stage, 6 mm

V-106.14S
QuickScan Voice Coil Scanning Stage, 20 mm

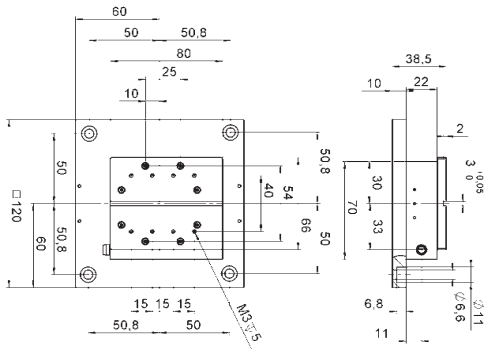
Frictionless Voice Coil Linear Drives

High-accuracy voice coil linear drives work on the same principle as electromagnetic loudspeakers. However, for precision positioning applications, they must provide much higher forces and high stability to hold a position without jitter. They must also be designed for closed-loop operation to allow for precise positioning.

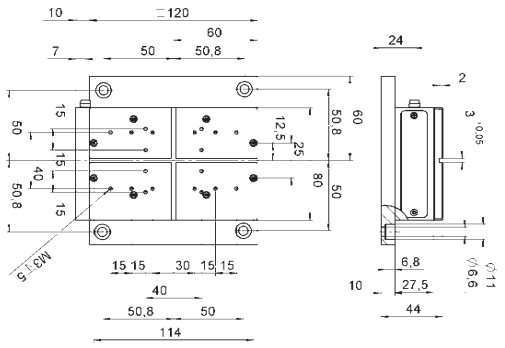
These zero-friction magnetic linear drives, characterized by their excellent dynamics, are ideally suited for scanning applications requiring travel ranges in the millimeter to centimeter range. PI offers voice coil drives in V-106 standard systems; custom systems are available on request.



V-106.14S maximum scanning frequency for different loads and scan amplitudes for example 18 mm scans with up to 90 g load at >4 Hz frequency are feasible. The velocity is up to 270 mm/s



V-106.11S dimensions in mm



V-106.14S dimensions in mm

Technical Data

Model	V-106.11S	V-106.14S	Units	Tolerances
Active axes	X	X		
Motion and positioning				
Travel range	6	20	mm	
Integrated sensor	Linear encoder	Linear encoder		
Sensor resolution	0.1	0.1	µm	
Design resolution	0.1	0.1	µm	
Minimum incremental motion	0.2	0.2	µm	typ.
Backlash	0.2	0.2	µm	typ.
Unidirectional repeatability	0.2	0.2	µm	typ.
Pitch	50	50	µrad	typ.
Yaw	50	50	µrad	typ.
Max. velocity*	240	270	mm/s	
Reference repeatability	1	1	µm	typ.
Mechanical properties				
Mass moved	102	172	g	typ.
Load	36	81	N	max.
Push-/pull force**	5	3.3	N	max.
Push-/pull force with C-843**	2.3	1.5	N	max.
Lateral force	18	40	N	max.
Drive properties				
Drive type	Voice coil	Voice coil		
Continuous average current	0.42	0.42	A	nominal
Peak current	1.8	1.8	A	max. (3s)
Average force	1.2	0.8	N	nominal
Coil resistance	10	10	Ω	typ.
Coil inductance	100	100	µH	typ.
Force constant	2.88	1.92	N/A	
Voltage generation constant	36.1	24	Vs/m	
Miscellaneous				
Operating temperature range	0–55	0–55	°C	
Body material	Al	Al		
Mass (without cable)	800	1000	g	±5%
Cable length	0.3	0.3	m	±10 mm
Connectors	Sub-D 15 (m)	Sub-D 15 (m)		
Recommended controller / driver	C-843	C-843 (p. 4-120)		

*With C-843 controller
**The C-843 controller provides 8 V and 0.8 A max. and therefore limits the push/pull force
See Notes (Technical Data) for further information page 4-67 *ff*

M-105 · M-106 Linear Slide

Precision Crossed Roller Guides, PiezoMike Option, XY(Z) Combinations

M-106.10 translation stage with differential micrometer drive

- **Travel Range to 18 mm**
- **All-Stainless-Steel Construction**
- **XY and XYZ Combinations**
- **Resolution up to 0.1 µm**
- **Optional PiezoMike with 10 nm Resolution**
- **Optional Motor Drives**

M-105 and M-106 are micrometer-driven translation stages with travel ranges of 18 mm and 5 mm, respectively. The carriage is spring preloaded against the micrometer tip for excellent repeatability and elimination of backlash. M-105 and M-106 stages are available in one-, two- or three-axis configurations. Precision crossed roller bearings guarantee straightness of travel of better than 2 µm. The M-106 is equipped with a differential micrometer drive providing resolution of 0.1 µm.

PiezoMike Option

Versions with PiezoMike drive provide additional 30 µm fine range for remotely controlled ultra-high-resolution (e.g. scanning or tracking, (see p. 1-54) for further details and recommended controllers).

The vertical stage in the XYZ assembly supports the load through the micrometer spindle (not the preload springs) providing excellent stability.

Motor Drive Upgrades

Two motor drives are available, the M-231.17 and the M 232.17 actuators (see p. 1-48 and p. 1-49). Both provide resolution a resolution of 0.1 µm.

Ordering Information

M-105.10
Translation Stage, 18 mm

M-105.11
Translation Stage, 18 mm, with Lockable Micrometer Drive

M-105.20
XY-Translation Stage, 18 mm

M-105.30
XYZ-Translation Stage, 18 mm, (Includes M-009.10, Side Mount Z-Bracket)

M-105.1P
Translation Stage, 18 mm, PiezoMike Drive

M-105.2P
XY-Translation Stage, 18 mm, PiezoMike Drive

M-105.3P
XYZ-Translation Stage, 18 mm, PiezoMike- Drive (Includes M-009.10, Side Mount Z-Bracket)

M-106.10
Translation Stage, 5 mm, Differential Micrometer Drive

M-106.20
XY-Translation Stage, 5 mm, Differential Micrometer Drive

M-106.30
XYZ-Translation Stage, 5 mm, Differential Micrometer Drive (Includes M-009.10, Side Mount Z-Bracket)

M-105.1B
Translation Stage, Basic Unit, Order Drives Separately

M-105.2B
XY-Translation Stage, Basic Unit, Order Drives Separately

M-105.3BA
XYZ-Translation Stage, Basic Unit (Includes M-105.VB1, Top Mount Z-Bracket), Order Drives Separately

M-105.3BB
XYZ-Translation Stage, Basic Unit (Includes M-009.10, Side Mount Z-Bracket), Order Drives Separately

Accessories

M-232.17
DC-Mike, Linear Actuator

M-009.10
Z-axis Mounting Bracket for Vertical Mount of M-105/6 (Attaches to Side of M-105)

M-105.VB1
Z-axis Mounting Bracket for Vertical Mount of M-105/6 (Attaches to Top of M-105)

M-009.20
Mounting Bracket for Mounting P-280 PZT NanoPositioning Systems or F-010 Fiber Holders

M-009.30
Z-axis Mounting Bracket for Vertical Mount of M-105/6 Stages on PI Standard Hole Pattern

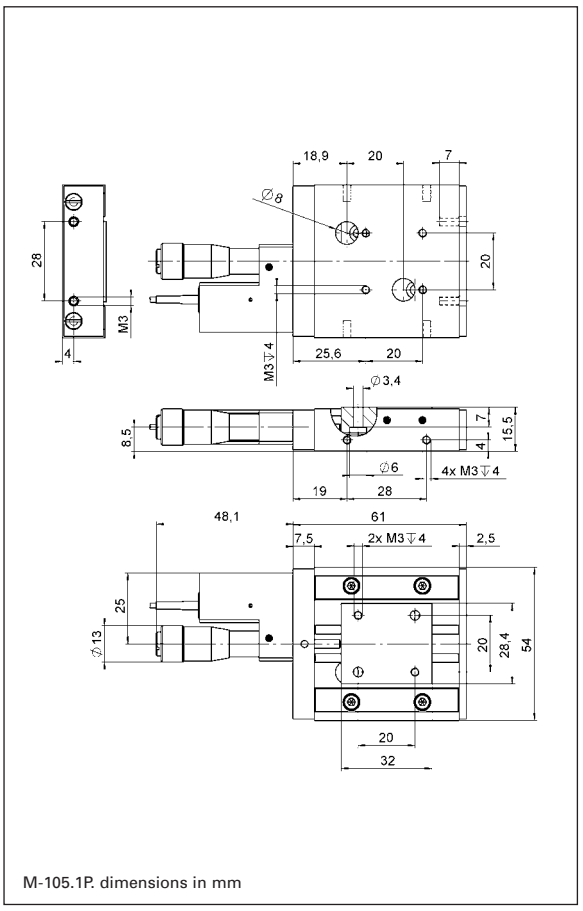
Technical Data

Model	M-105.10*	M-105.1P*	M-106.10*	Unit
Travel range	18	18	5	mm
Piezo fine travel range	–	30	–	µm
Min. incremental motion (piezo drive)	–	0.01	–	µm
Min. incremental motion (micrometer drive)**	1	1	0.1	µm
Backlash	2	2	2	µm
Straightness	2	2	2	µm
Flatness	2	2	2	µm
Max. normal load capacity	100	100	100	kg
Max. push/pull force	20 / 4	20 / 4	20 / 4	N
Max. lateral force	4	4	4	N
Drive	M-626.00	P-854.00	M-653.00	
Micrometer pitch	0.5 / –	0.5 / –	0.4 / 0.02	mm/rev.
Mass	0.32	0.38	0.33	kg
Body material	St	St	St	
Recommended piezo driver	–	E-660 (p. 2-119), E-610 (p. 2-110) E-500 System (p. 2-142)	–	

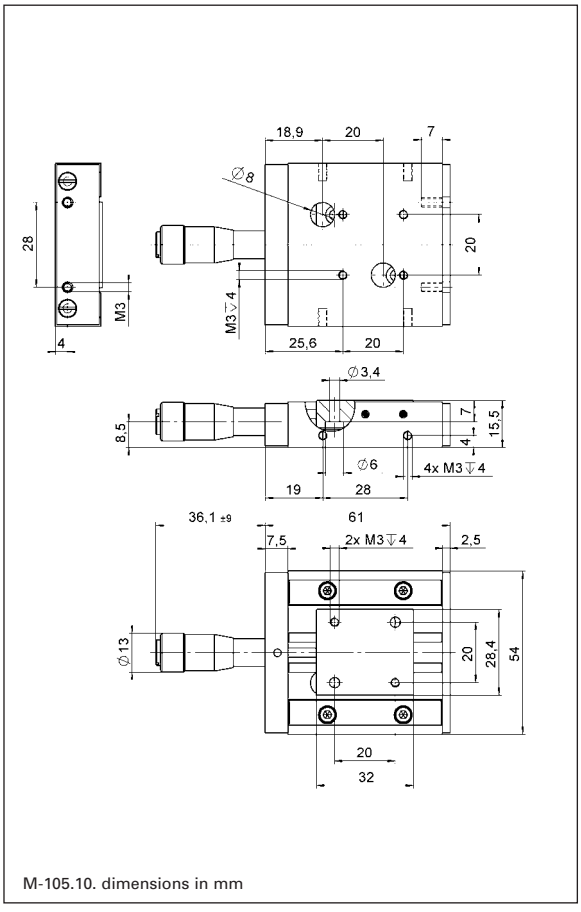
*Versions M-105.2x, M-106.2x and M-105.3x M-106.x0 are combinations of basic .1x. versions
**Motorized versions achieve up to 100 nm.

Notes

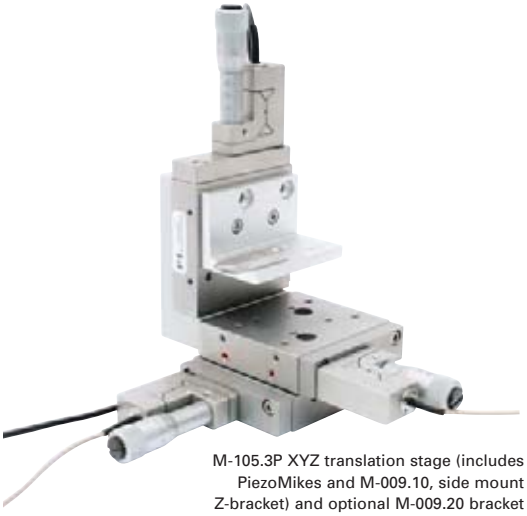
See “Accessories” for adapters, bracket, etc. see p. 4-89 ff.



M-105.1P. dimensions in mm



M-105.10. dimensions in mm

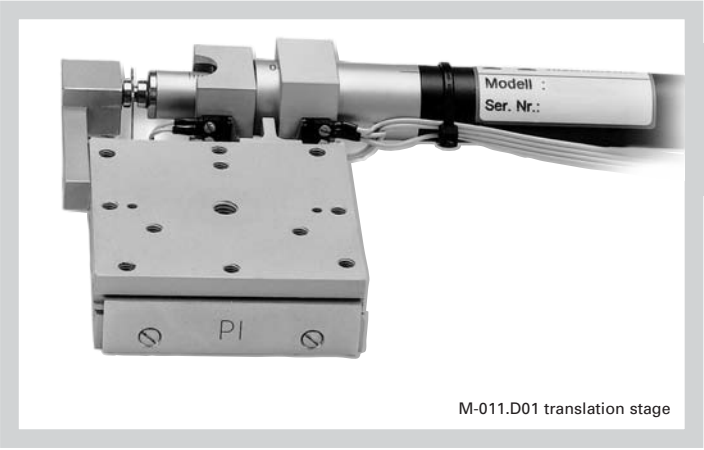


M-105.3P XYZ translation stage (includes PiezoMikes and M-009.10, side mount Z-bracket) and optional M-009.20 bracket with F-010.00 V-groove fiber holder

Combination of M-105.1B basic unit and M-232.17 high-resolution DC-Mike actuator

M-011 Linear Slide with DC/Piezo Drive

Compact, Nanometer-Precise Piezo Drive, High-Accuracy Guiding



M-011.D01 translation stage

- **Travel Range to 15 mm**
- **Compact Side Drive**
- **Straightness/Flatness ≤0.2 µm**
- **PZT Drive for Scanning and Tracking Applications**
- **0.1 µm Resolution with Closed-Loop DC Motor**
- **5 nm Resolution with Closed-Loop PZT Drive**

M-011 ultra-high-precision magnetically-coupled stages use the force of integrated magnets to preload the bearing. This magnetic preload results in extremely uniform and smooth motion with minimum friction. Unlike conventional stages, where two bearings with limited parallelism guide the carriage (inducing runout and rotational errors) in M-011 stages, only one of the two linear bearings has a guiding function (V-groove) while the second bearing is for support only (U-groove).

Ultra-Straight Motion

The coupling between the stage and the space-saving side-drive units (DC-motor drives, PZTs, micrometer drives) is not rigid but via magnets. This design allows only on-axis forces (drive direction) to be transmitted to the stage; torque-induced positioning errors resulting from non-parallelism between the drive axis and the guiding axis are eliminated.

Six Different Versions

The basic version, the M-011.00, is equipped with a precision manual micrometer providing a sensitivity of 1 µm. M-011.D01 is equipped with a closed-loop DC-motor drive providing 0.1 µm minimum incremental motion.

High-Resolution Piezo Option

For both the manual and motorized version, closed-loop and open-loop piezo drives are available. They provide 5 nm minimum incremental motion over a travel range of 30 µm and allow for dynamic operation such as scanning and tracking. The closed-loop piezo drive provides repeatability of 60 nm (see the "Piezo Actuators" section for further details on piezo actuators and recommended controllers). All stages can be cross stacked and combined with the M-052 Z-axis mounting bracket to provide multi-axis motion (vertical use of the M-011 only permitted with loads less than 0.1 kg, no extended Z-axis bracket for motorized Z-stage available).

Upgrades

M-011 stages without piezo drives or DC-motor drives can be upgraded at a later date (see ordering information).

Notes

See "Accessories" (p. 4-90 *ff*) for adapters, brackets, etc.

Application Examples

- Microscopy
- Quality control
- Metrology

Ordering Information

M-011.00
Translation Stage, 15 mm

M-011.P0
Translation Stage, 15 mm, Manual + PZT Drive

M-011.PS
Translation Stage, 15 mm, Manual + Closed-Loop PZT Drive

M-011.D01
Translation Stage, 10 mm, DC-Motor Drive

M-011.DP1
Translation Stage, 10 mm, DC-Motor + PZT Drive

M-011.DS1
Translation Stage, 10 mm, DC-Motor + Closed-Loop PZT Drive

Upgrades

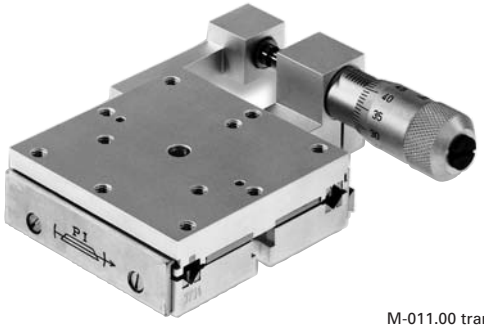
M-011.U0 Upgrade Kit with Open-Loop PZT Drive

M-011.US Upgrade Kit with Closed-Loop PZT Drive

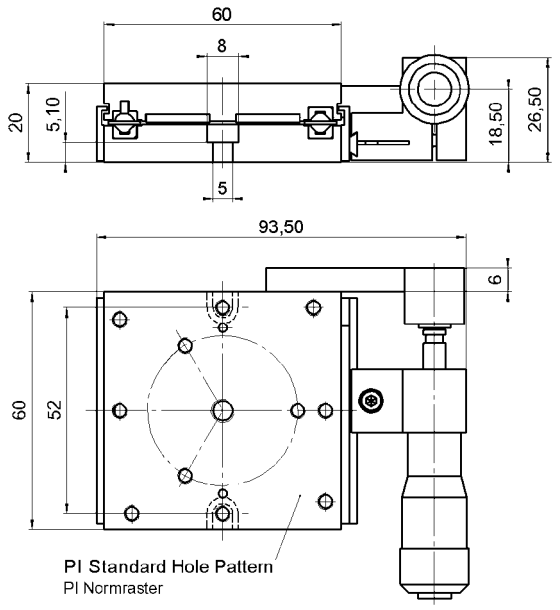
M-011.UD Upgrade Kit with DC-Motor Drive and Limit Switches (Factory Installed)

Ask about custom designs!

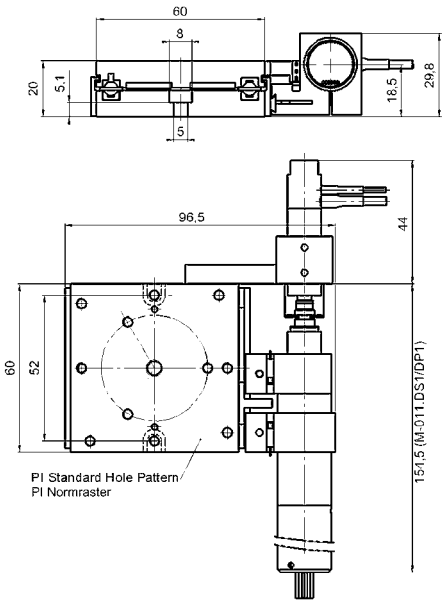
XY combination of two M-011.00 stages



M-011.00 translation stage



M-011.00 dimensions (in mm),
see p. 4-91 for PI Standard Hole Pattern



M-011.DS1 dimensions (in mm),
see p. 4-91 for PI Standard Hole Pattern

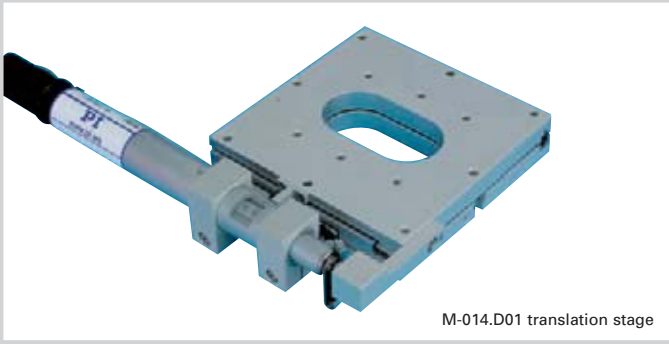
Technical Data

Model	M-011.00	M-011.P0	M-011.PS	M-011.D01	M-011.DP1	M-011.DS1	Units
Travel range	15	15	15	10	10	10	mm
Piezo fine travel range	–	30	30	–	30	30	µm
Min. incremental motion (piezo drive)	–	0.005	0.005	–	0.005	0.005	µm
Repeatability (piezo drive)	–	–	0.06	–	–	0.06	µm
Design resolution (DC Motor)	–	–	–	0.0035	0.0035	0.0035	µm
Min. incremental motion	1	1	1	0.1	0.1	0.1	µm
Unidirectional repeatability	–	–	–	0.1	0.1	0.1	µm
Bidirectional repeatability	–	–	–	2	2	2	µm
Backlash	–	–	–	2*	2*	2*	µm
Straightness / flatness per 5 mm	0.1	0.1	0.1	0.1	0.1	0.1	µm
Straightness / flatness full travel	0.2	0.2	0.2	0.2	0.2	0.2	µm
Max. velocity (motor)	–	–	–	0.7	0.7	0.7	mm/sec
Max. normal load capacity	1	1	1	1	1	1	kg
Max. push/pull force	7 / 5	7 / 5	7 / 5	7 / 5	7 / 5	7 / 5	N
Max. lateral force	5	5	5	5	5	5	N
Drive	M-623	M-623	M-623	M-227.10	M-227.10	M-227.10	
Piezo drive	–	P-840.20	P-841.20	–	P-840.20	P-841.20	
Encoder resolution	–	–	–	2048	2048	2048	counts/rev.
Drivescrew pitch	0.5	0.5	0.5	0.5	0.5	0.5	mm/rev.
Gear ratio	–	–	–	69.12:1	69.12:1	69.12:1	
Nominal motor power	–	–	–	2	2	2	W
Motor voltage	–	–	–	12	12	12	V
Mass	0.35	0.4	0.42	0.55	0.6	0.62	kg
Body material	Al, St	Al, St	Al, St	Al, St	Al, St	Al, St	
Recommended piezo controller	–	E-660, E-610 E-500 System	E-610 E-500 System	–	E-660, E-610 E-500 System	E-610 E-500 System	
Recommended motor controller	–	–	–	C-843 C-848, C-863	C-843, C-848, C-863	C-843, C-848, C-863	

* gearhead

M-014 Linear Slide with Aperture

Nanometer-Precise Piezo Drive, High-Accuracy Guides



M-014.D01 translation stage

- **Travel Range 25 mm**
- **Compact Side Drive**
- **Straightness/Flatness ≤0.3 µm**
- **PZT Drive for Scanning and Tracking Applications**
- **0.1 µm Resolution w/ Closed-Loop DC Motor**
- **5 nm Resolution with Closed-Loop PZT Drive**
- **30 mm Ø Clear Aperture**

M-014 ultra-high-precision magnetically coupled stages use the force of integrated magnets to preload the bearing. This magnetic preload results in extremely uniform and smooth motion with minimum friction. Unlike conventional stages, where two bearings with limited parallelism guide the carriage (inducing runout and rotational errors) in M-014 stages, only one of the two linear bearings has a guiding function (V-groove) while the second bearing is for support only (U-groove).

Ultra-Straight Motion

The coupling between the stage and the space-saving side drive units (DC-motor drives, PZTs, micrometer drives) is not rigid but via magnets. This design allows only on-axis forces (drive direction) to be transmitted to the stage; torque-induced positioning errors induced by non-parallelism between the drive axis and the guiding axis are eliminated.

Six Different Versions

The basic version, the M-014.00, is equipped with a precision manual micrometer providing a sensitivity of 1 µm. M-014.D01 is equipped with a closed-loop DC-motor drive providing 0.1 µm minimum incremental motion.

High-Resolution Piezo Option

For both the manual and motorized version, closed-loop and open-loop piezo drives are available. They provide 5 nm minimum incremental motion over a travel range of 45 µm and allow for dynamic operation such as scanning and tracking. The closed-loop piezo drive provides repeatability of 90 nm (see the "Piezo Actuators" section for further details on piezo actuators and recommended controllers).

All stages can be cross stacked and combined with the M-053.10 (manual versions) and M-053.20 (motorized versions) Z-axis mounting bracket to provide multi-axis motion. Vertical use of the M-014 is only permitted with loads less than 0.5 kg. For vertical positioning with loads in excess of 0.5 kg we recommend M-126 stages (see page 4-38) and the 125.90 Z-axis mounting bracket.

Upgrades

M-014 stages without PZT or DC-motor drives can be upgraded at a later date (see ordering information).

Notes

See "Accessories" (p. 4-90 *ff*) for adapters, brackets, etc.

Application Examples

- Microscopy
- Quality control
- Metrology

Ordering Information

M-014.00
Translation Stage, 25 mm

M-014.P0
Translation Stage, 25 mm, Manual + PZT Drive

M-014.PS
Translation Stage, 25 mm, Manual + Closed-Loop PZT Drive

M-014.D01
Translation Stage, 25 mm, DC-Motor Drive

M-014.DP1
Translation Stage, 25 mm, DC-Motor + PZT Drive

M-014.DS1
Translation Stage, 25 mm, DC-Motor + Closed-Loop PZT Drive

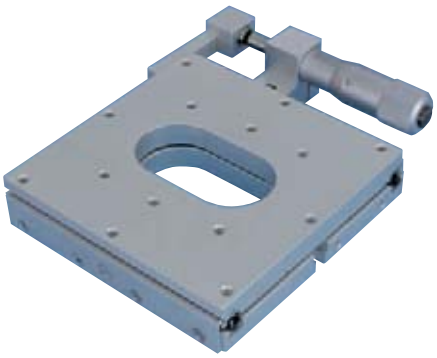
Upgrades

M-014.U0
Upgrade Kit with Open-Loop PZT Drive

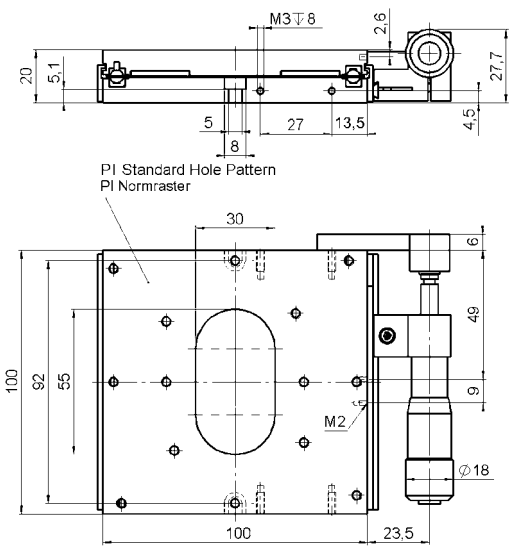
M-014.US
Upgrade Kit with Closed-Loop PZT Drive

M-014.UD
Upgrade Kit with DC-Motor Drive and Limit Switches (Factory Installed)

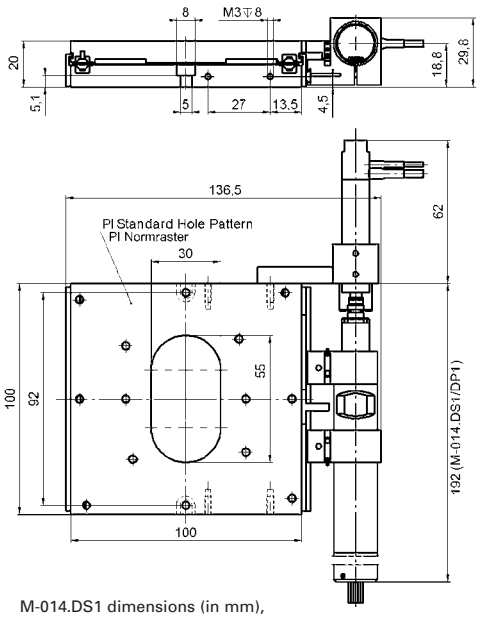
Ask about custom designs!



M-014.00 translation stage



M-014.00 dimensions (in mm),
see p. 4-91 for PI Standard Hole Pattern



M-014.DS1 dimensions (in mm),
see p. 4-91 for PI Standard Hole Pattern

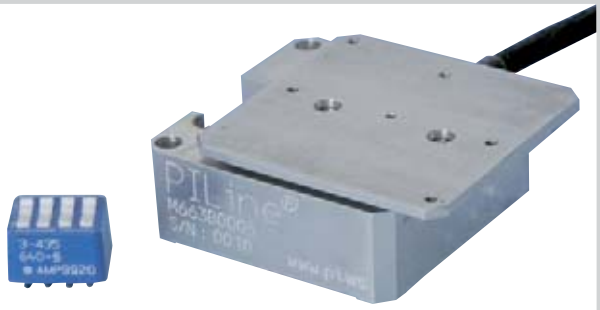
Technical Data

Model	M-014.00	M-014.P0	M-014.PS	M-014.D01	M-014.DP1	M-014.DS1	Units
Travel range	25	25	25	25	25	25	mm
Piezo fine travel range		45	45		45	45	µm
Min. incremental motion (piezo drive)	–	0.005	0.005	–	0.005	0.005	µm
Repeatability (piezo drive)	–	–	0.09	–	–	0.09	µm
Design resolution (DC Motor)	–	–	–	0.0035	0.0035	0.0035	µm
Min. incremental motion	1	1	1	0.1	0.1	0.1	µm
Unidirectional repeatability	–	–	–	0.1	0.1	0.1	µm
Bidirectional repeatability	–	–	–	2	2	2	µm
Backlash	–	–	–	2*	2*	2*	µm
Straightness / flatness per 5 mm	0.1	0.1	0.1	0.1	0.1	0.1	µm
Straightness / flatness full travel	0.3	0.3	0.3	0.3	0.3	0.3	µm
Max. normal load capacity	5	5	5	5	5	5	kg
Max. velocity (motor)	–	–	–	1	1	1	mm/sec
Max. push/pull force	15/5	15/5	15/5	15/5	15/5	15/5	N
Max. lateral force	10	10	10	10	10	10	N
Drive	M-624	M-624	M-624	M-227.25	M-227.25	M-227.25	
Piezo drive	–	P-840.30	P-841.30	–	P-840.30	P-841.30	
Encoder resolution	–	–	–	2048	2048	2048	counts/rev.
Drive screw pitch	0.5	0.5	0.5	0.5	0.5	0.5	mm/rev.
Gear ratio	–	–	–	69.12:1	69.12:1	69.12:1	
Nominal motor power	–	–	–	2	2	2	W
Motor voltage	–	–	–	12	12	12	V
Mass	0.72	0.78	0.8	0.98	1.04	1.06	kg
Body material	Al, St	Al, St	Al, St	Al, St	Al, St	Al, St	
Recommended piezo controller	–	E-660, E-610 E-500 System	E-610 E-500 System	–	E-660, E-610 E-500 System	E-610 E-500 System	
Recommended motor controller	–	–	–	C-843, C-848, C-863	C-843, C-848, C-863	C-843, C-848, C-863	

* gearhead

M-663K Vacuum-Compatible Miniature Translation Stage

Fast, Compact, with Ceramic Piezo Linear Motor



The M-663KVLS Linear Slide is vacuum compatible down to 10^{-6} hPa

- Smallest Translation Stage with Closed-Loop Linear Motor and Encoder
- Travel Range 19 mm
- Vacuum Compatible up to 10^{-6} hPa
- Direct Metrology Linear Encoder
- Resolution 0.1 µm
- XY Combination Possible

Model	Travel	Max. velocity	Load capacity	Push/pull force	Dimensions
M-663KVLS Vacuum Linear Stage	19 mm	400 mm/s	5 N	2 N	35 x 35 x 15 mm

M-403K Smart Translation Stage

Integrated Stepper Motor Controller

The M-403KSTS combines the versatility of the C-663 Mercury™ Step stepper motor controller with its stand-alone and non-volatile macro program capabilities, with the performance of an M-403 precision translation stage

- Precision Translation Stage and Motor Controller in a Single Package
- Plug & Play Operation Through USB and RS-232 Interface
- Internal Memory for Stand Along Operation w/o PC
- Travel Range 200 mm, Resolution 1 µm
- Stress-Relieved Aluminum Base for Highest Stability
- Preloaded Frictionless Ball Screw
- Joystick for Manual Operation
- XY Combination Possible
- Networkable with other Mercury™ Controllers and PI Positioners
- Non-Contact Limit and Reference Switches

Model	Travel	Load capacity	Max. velocity	Integrated controllers	Dimensions
M-403KSTS Smart Translation Stage	200 mm	500 N	10 mm/s	C-663 Mercury™ Step Steppermotor controller, USB, RS-232 interfaces	581 x 152 x 50 mm

M-110K Compact Precision Linear Actuator

With Guidance, Optional Piezo Tip for Sub-Nanometer Resolution

M-110KGLA compact linear actuator with nanometer resolution due to optional piezo drive

- Compact Design
- Travel Range 5 mm, optional 15 µm piezo tip
- Stepper motor drive
- Linear bearings
- Push force to 10 N
- Non-Contact Limit Switches

Model	Travel	Max. velocity	Max. push force	Dimensions
M-110KGLA Guided Actuator	5 mm	3 mm/s	10 N	25 x 19.5 x 83 mm

M-674K High-Precision Z Actuator for Bio-Automation

Ceramic PILine® Motor and Linear Encoder for High Speed & Precision

Equipped with two ultrasonic piezo-motors, the slim M-674KCPP offers up to 7 N push and pull force. The 9 mm width is matched to standard multiwell plate sizes, ideally suited to automation tasks in biotechnology

- **High Speed to 100 mm/sec**
- **High Push/Pull Force to 7 N**
- **Extremely Slim Design, Matched with Standard Multiwell Plates**
- **Stackable**
- **Integrated Linear Encoder for Highest Accuracy**
- **Self Locking at Rest**
- **Non-Magnetic and Vacuum-Compatible Working Principle**

Model	Travel	Push/pull force	Velocity	Resolution	Dimensions
M-674KCPP Compact PILine® Positioner	50 mm	7 N	100 mm/s	0.1 µm	120 x 40 x 9 mm

M-664K Vertical Drive for Bio-Automation

High-Speed, Compact, Cost-Effective, Stackable PILine® Actuator

Stack of 8 M-664KCEP linear actuators, shown with well plate. The integrated ceramic piezomotor provides high speeds to 100 mm/sec. The low-profile design with only 9 mm width allows stacking for multi-channel dispensing in bio-automation tasks

- **High Speed to 100 mm/sec**
- **Slim Design, Matched with Standard Multiwell Plates**
- **Travel range 50 mm**
- **Cost-Effective Design**
- **Stackable**
- **Non-Magnetic and Vacuum-Compatible Working Principle**
- **Self Locking at Rest**

Model	Travel	Push/pull force	Max. closed-loop velocity	Resolution	Dimensions
M-664KCEP Compact PILine® Positioner	50 mm	5 N	100 mm/s	0.5 µm	120 x 40 x 9 mm

M-682K Non-Magnetic Translation Stage

Low-Profile, High-Speed with Piezo Ceramic Motor

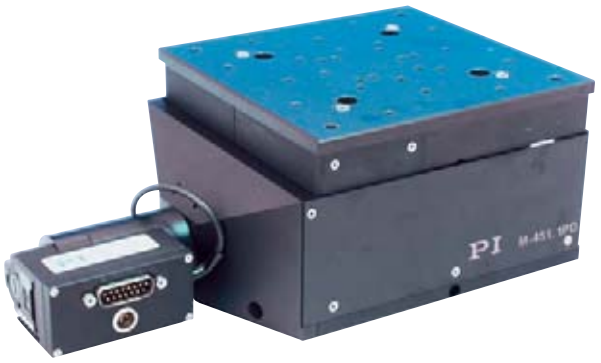
Custom non-magnetic M-682KNMS linear stage with integrated RodDrive linear motor

- **Integrated Non-Magnetic PILine® RodDrive**
- **Travel Range 50 mm**
- **Integrated Linear Encoders with 0.1 µm Resolution**
- **Up to 6 N Force Generation**
- **Closed-Loop Velocity up to 100 mm/s**
- **Low Profile, Small Footprint**

Model	Travel	Load capacity	Max. push/ pull force	Dimensions
M-682KNMS PILine® Positioner	50 mm	50 N	6 N	110 x 110 x 20 mm

M-451 High-Load Precision Z-Stage

Combinations with Piezo-Nanopositioning Stages Possible



M-451.1PD precision elevation stage

- **Encoder Resolution 3 Nanometer**
- **Min. Incremental Motion to 100 nm**
- **Travel Range 12.5 mm (1/2")**
- **Load Capacity up to 12 kg, High Stiffness**
- **ActiveDrive™ Motor**
- **Non-contact Limit and Reference Switches**
- **Mounting Platform for P-500 and PIMars™ Piezo-Nanopositioning Systems**
- **Self-Locking**

The M-451 Z-stage series is ideal for high-precision, high-load vertical positioning tasks. These stages feature a precision-machined base of high-density, stress-relieved aluminum for exceptional stability and minimum weight. Precision-cross-roller guided wedges and low-friction leadscrews provide maintenance-free positioning. The stages are self locking to 12 kg.

Application Examples

- R&D
- Semiconductor technology
- Mass storage device testing
- Metrology

ActiveDrive™ for High Dynamics

Model M-451.1PD with Active Drive™ provides incremental motion down to 0.2 µm. The ActiveDrive™ design, developed by PI, features a high-efficiency PWM (pulse width modulation) servo-amplifier mounted side-by-side with the DC-motor and offers several advantages:

- Increased efficiency, by eliminating power losses between the amplifier and motor
- Reduced cost of ownership and improved reliability, because no external driver is required
- Elimination of PWM amplifier noise radiation, by mounting the amplifier and motor together in a single, electrically shielded case

High Accuracy with Gearhead/ Encoder Combination

Models M-451.1DG are equipped with closed-loop DC-motors with shaft-mounted position encoders and precision gearheads providing 0.1 µm minimum incremental motion and 3 nanometer encoder resolution.

Stepper Motor Version for Open-Loop Operation

Models M-451.12S models feature a cost-effective direct-drive, 2-phase stepper motor, providing very smooth operation and a resolution of 6400 steps/rev. (with the C-663 controller). Minimum incremental motion to 0.2 µm is possible.

Limit and Reference Switches

For the protection of your equipment, non-contact Hall-effect limit and reference switches are installed. The direction-sensing reference switch supports advanced automation applications with high precision.

Ordering Information

M-451.1PD
Vertical Stage, 12.5 mm,
ActiveDrive™ DC Motor
(includes 24 V power supply)

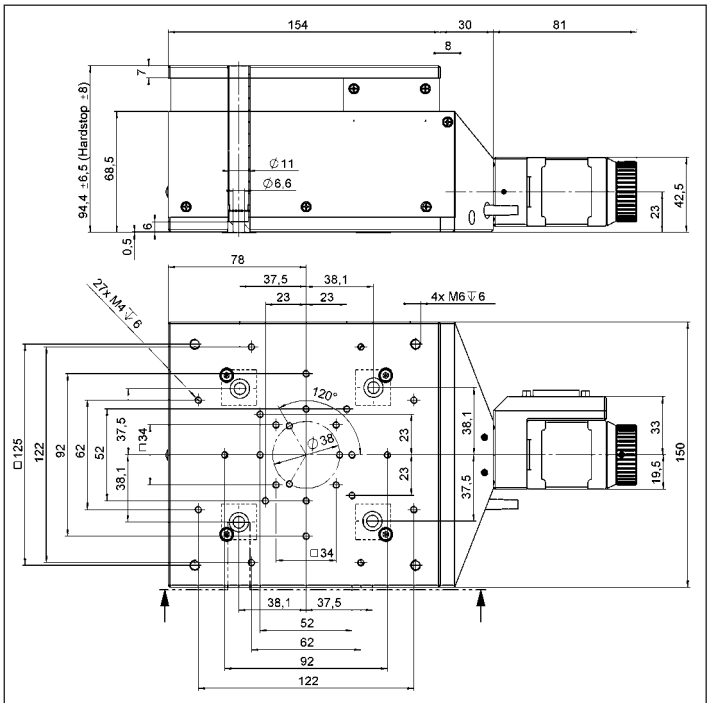
M-451.1DG
Vertical Stage, 12.5 mm,
DC Motor Gearhead

M-451.12S
Vertical Stage, 12.5 mm,
2-Phase Stepper Motor

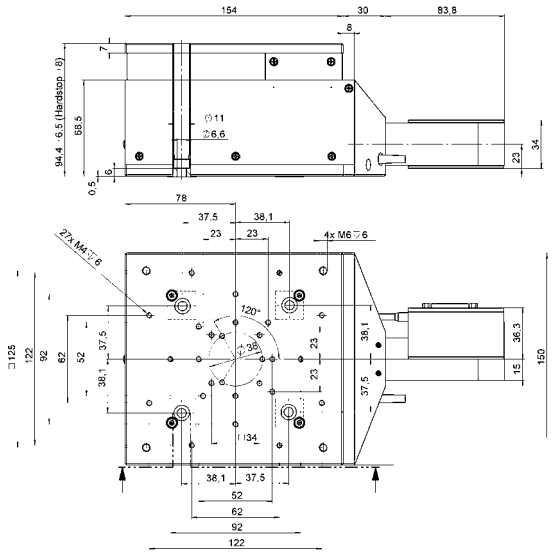
Ask about custom designs!

Compatible with Nanopositioning/Scanning Stages

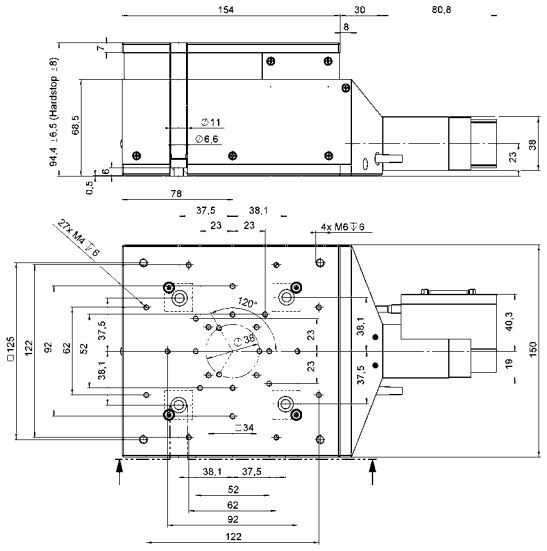
M-451 is designed to work with a variety of PI piezo nanopositioning stages such as the P-527 series and P-561 PIMars™ series. These piezo-driven positioning and scanning stages provide sub-nanometer resolution and accuracy and very high scanning speed.



M-451.12S precision elevation Z-stage dimensions in mm.
Sub-D connector 15-pin, 3 m cable



M-451.1PD precision elevation Z-stage dimensions in mm.
Sub-D connector 15-pin, 3 m cable



M-451.1DG precision elevation Z-stage dimensions in mm.
Sub-D connector 15-pin, 3 m cable

Technical Data

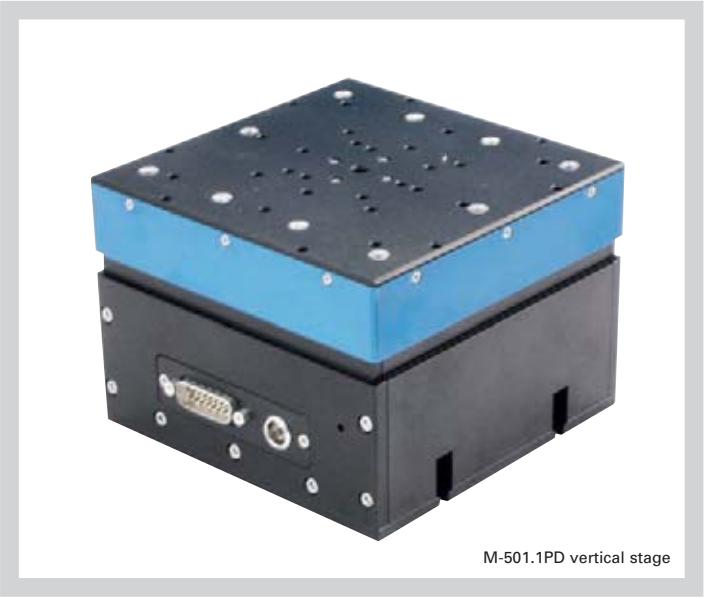
Model	M-451.1PD	M-451.1DG	M-451.12S	Unit
Active axes	Z	Z	Z	
Motion and positioning				
Travel range	12.5	12.5	12.5	mm
Integrated sensor	Rotary encoder	Rotary encoder	–	
Sensor resolution	4000	2000	–	cts./rev.
Design resolution	0.042	0.0028	0.026	µm
Min. incremental motion	0.2	0.1	0.2	µm
Backlash	1	1	1	µm
Unidirectional repeatability	0.3	0.3	0.3	µm
Pitch/Yaw	±75	±75	±75	µrad
Straightness	1	1	1	µm
Flatness	1	1	1	µm
Max. velocity	3	0.5	0.8	mm/s
Origin repeatability	1	1	1	µm
Mechanical properties				
Drive screw	Leadscrew	Leadscrew	Leadscrew	
Thread pitch	0.5	0.5	0.5	mm
Gear ratio	–	29.6:1	–	
Motor resolution*	–	–	6,400*	steps/rev.
Max. load (self-locking)	120	120	120	N
Drive properties				
Motor type	ActiveDrive™ DC Motor	DC Motor, gearhead	2-phase stepper motor*	
Operating voltage	24	0 to ±12	24	V
Electrical power	25	4	4.8	W
Limit and reference switches	Hall-effect	Hall-effect	Hall-effect	
Miscellaneous				
Operating temperature range	-20 to +50	-20 to +50	-20 to +50	°C
Material	Al (black anodized)	Al (black anodized)	Al (black anodized)	
Mass	5	5	5	kg
Recommended controller/driver	C-863 (single-axis) C-843 PCI board (up to 4 axes)	C-863 (single-axis, p. 4-114) C-843 PCI board (up to 4 axes, p. 4-120)	C-663 (single-axis, p. 4-112)	

*2-phase stepper motor, 24 V chopper voltage, max. 0.8 A/phase, 400 full steps/rev., motor resolution with C-663 stepper motor controller

P-562.3CD PIMars™ XYZ piezo-nanopositioning & scanning system (200 µm x 200 µm x 200 µm) mounted on an M-451.1PD elevation stage

M-501 Precision Vertical Stage

Compact XYZ Combinations with M-511 Translation Stage Series



M-501.1PD vertical stage

- **Travel Range 12.5 mm (1/2")**
- **Ultra-High-Resolution Encoder**
- **ActiveDrive™ Motor**
- **Zero-Backlash Recirculating Ballscrews**
- **Non-Contact Limit and Reference Switches**
- **Stress-Relieved Aluminum Base for Highest Stability**
- **MTBF >20,000 h**
- **Self Locking to 10 kg**

The M-501 Z-stage is the latest family member of the M-500 series of translation stages. It is ideal for forming compact XYZ combinations together with the low-profile M-511, M-521 and M-531 translation stages. M-501 vertical stages feature a precision-machined base of high-density, stress-relieved aluminum for exceptional stability and minimum weight. Precision-ground recirculating ball screws with preloaded nuts provide low-friction, maintenance-free and backlash-free positioning.

Application Examples

- R&D
- Semiconductor testing
- Mass storage device testing
- Metrology
- Photonics packaging
- Quality assurance testing

Two DC-motor drives are currently available:

M-501.1PD with ActiveDrive™ for High Velocity
This model features an ultra-high-resolution ballscrew-mounted encoder (40 960 counts/rev!) and provides a minimum incremental motion of better than 100 nanometers (design resolution 24 nm).

For superior dynamic performance the ActiveDrive™ motor is integrated. The ActiveDrive™ design, developed by PI, features a high-efficiency PWM (pulse width modulation) servo-amplifier mounted side-by-side with the DC motor and offers several advantages:

- Increased efficiency, by eliminating power losses between the amplifier and motor
- Reduced cost of ownership and improved reliability because no external driver is required
- Elimination of PWM amplifier noise radiation, by mounting the amplifier and motor together in a single, electrically shielded case

M-501.1DG with Gearhead
These versions feature closed-loop DC motors with shaft-mounted position encoders and precision gearheads providing a minimum incremental motion to 0.1 µm and 5 nanometer encoder resolution.

The gearhead version can hold loads to 10 kg in power-off mode.

Ordering Information

M-501.1PD
Vertical Stage, 12.5 mm, ActiveDrive™ DC Motor (includes 24 V power supply)

M-501.1DG
Vertical Stage, 12.5 mm, DC Motor Gearhead

Ask about custom designs!

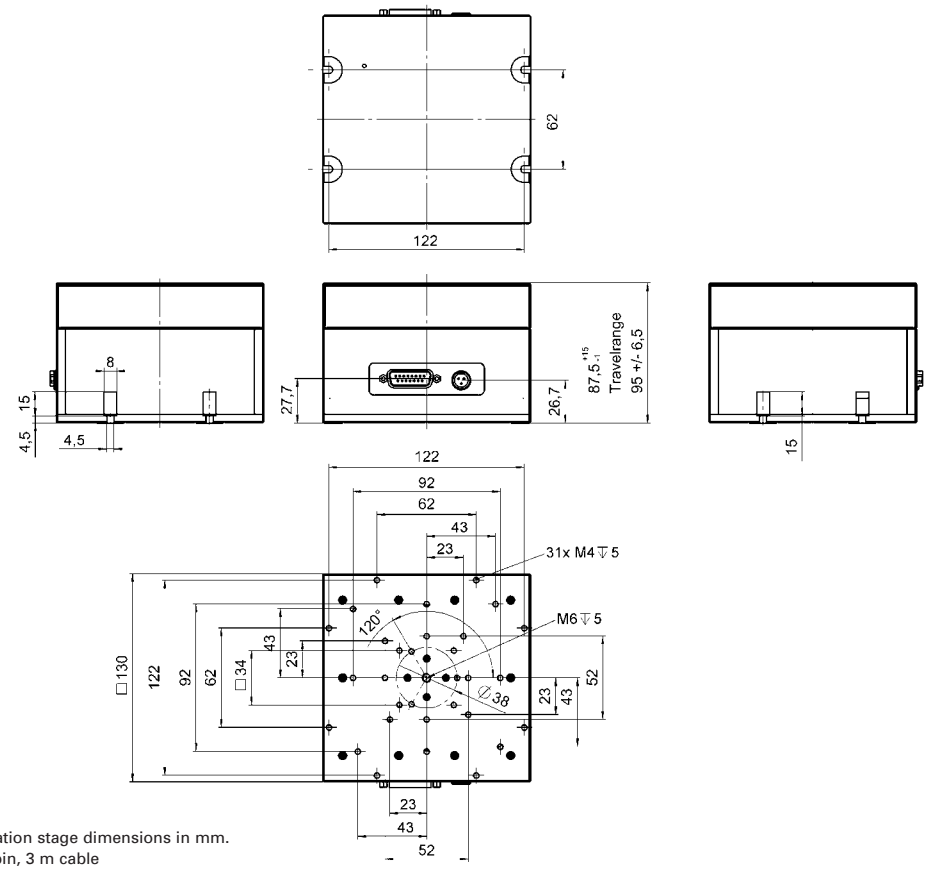
Limit and Reference Switches

For the protection of your equipment, non-contact Hall-effect limit and reference switches are installed. The direction-sensing reference switch supports advanced automation applications with high precision.

Notes

For adapters, bracket, etc. (see p. 4-90).

XYZ combination of M-521.DD (204 mm), M-511.DD (102 mm) and M-501.1PD vertical stage



M-501 precision elevation stage dimensions in mm.
Sub-D connector 15-pin, 3 m cable

Technical Data

Model	M-501.1PD	M-501.1DG	Units
Active axes	Z	Z	
Motion and positioning			
Travel range	12.5	12.5	mm
Integrated sensor	Rotary encoder	Rotary encoder	
Sensor resolution	40,960	2048	Cts./rev.
Design resolution	0.024	0.005	µm
Min. incremental motion	<0.1	<0.1	µm
Unidirectional repeatability	0.1	0.1	µm
Pitch/Yaw	±15	±15	µrad
Max. velocity	3	1	mm/s
Origin repeatability	1	1	µm
Mechanical properties			
Spindle pitch	1	1	mm
Gear ratio	80/26 (belt drive)	80/26 (belt drive); (28/12)⁴:1 ~ 29,6:1 gearhead	
Max. Load	50	100	N
Max. Holding force	20	100	N
Drive properties			
Motor type	ActiveDrive™ DC Motor	DC Motor, gearhead	
Operating voltage	24 (PWM)	0 to ±12	V
Electrical power	17	4	W
Limit and reference switches	Hall-effect	Hall-effect	
Miscellaneous			
Operating temperature range	-20 to +50	-20 to +50	°C
Material	Al (black anodized)	Al (black anodized)	
Recommended controller/driver	C-863 (single-axis), C-843 PCI board (up to 4 axes)	C-863 (single-axis, p. 4-114), C-843 PCI board (up to 4 axes, p. 4-120)	

M-714 Nanometer-Precision Linear Stage

Heavy-Duty Precision Hybrid DC/Piezo Drive with High Guiding-Accuracy

Hybrid Z-positioner M-714.HD

- **Simultaneous Control of Piezo-Flexure Drives & DC-Servo/Ballscrew Drives**
- **7 mm Vertical Travel Range, 10 kg Load Capacity**
- **High Holding Forces with Minimum Power Consumption**
- **Integrated Precision Linear Encoder Provides 2 nm Resolution**
- **Active Backlash Compensation and Stick/Slip Compensation**
- **Frictionless Piezo Drive and Flexure-Decoupled Ballscrew**
- **Millisecond Settling Time to Nanometer Precision**

The M-714 was designed from the ground up to use the hybrid drive technology. The hybrid design overcomes the limitations of conventional precision positioning systems by combining the well-known advantages of piezo-flexure-drives (unlimited resolution and very rapid response) with the long travel ranges and high holding forces of a servo-motor/ballscrew arrangement. The M-714 can position loads up to 10 kg with nanometer precision over 7 mm in vertical or horizontal direction. Compared to high-resolution magnetic linear drives, the hybrid principle allows high holding forces with minimum power consumption, without counterbalancing the load. The angular deviation is less than ±10 µrad over the entire travel range of 7 mm.

Application Examples

- Surface Inspection
- Microscopy
- Laser technology
- Interferometry
- Metrology

Long Travel Ranges with Nanometer Precision

The challenge of implementing hybrid technology is not only the positioning stage design, but also the use of high-resolution sensors over large travel ranges, the processing of the resulting high-frequency signals and the design of special control algorithms to take full advantage of the hybrid concept.

On the mechanical side, this is accomplished by decoupling the moving platform from the positioner's motor-ballscrew-drive by frictionless flexures and stiff, highly responsive piezo actuators.

Due to its high stiffness and instantaneous, sub-millisecond range response, the integrated piezo flexure drive provides active stick/slip compensation during startup and settling and is the key to achieving consistent and repeatable nanometer level positioning increments. It also cancels out motion irregularities caused by the ball screw and significantly improves velocity control.

Servo-control of the system employs a single high-resolution position feedback sensor (direct metrology) which means that the inherent piezo precision is available over the entire travel range of 7 mm, and longer travel ranges are basically feasible. The resolution and the positioning accuracy mainly depend on the choice of the feedback sensor.

Hybrid Controller Technology is Key to Success

PI's highly specialized C-702 hybrid nanopositioning controller (see p. 4-118) compares the actual platform position (by reading the integrated linear encoder) with a calculated, smooth trajectory in real time. Its complex control algorithms continuously actuate both the piezoelectric and servo motor drives in a way to provide the best possible overall performance.

This makes hybrid systems ideal for applications where extremely smooth motion is required, where the position of an incident needs to be read and refound precisely, or where an externally specified target position needs to be hit within a few nanometers, such as in surface inspection or metrology.

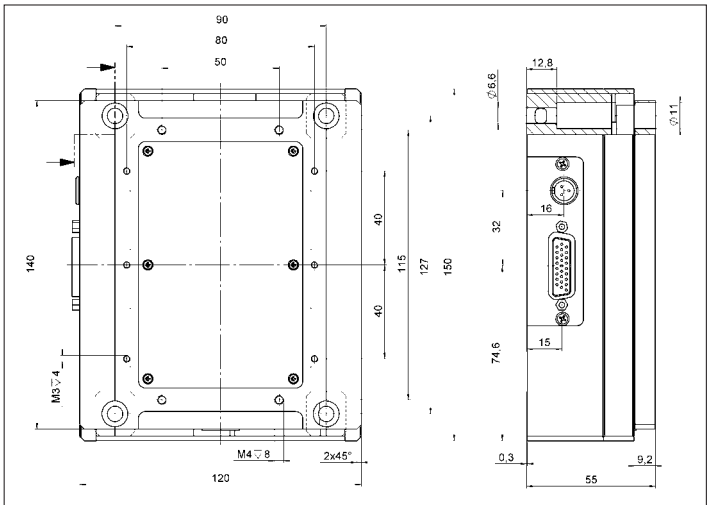
Ordering Information

M-714.2HD
Ultra-High Precision Hybrid Nanopositioning Stage, 7 mm Travel, 2 nm Linear Encoder Resolution

Ask about custom designs!

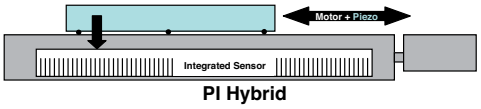
Notes

The M-714.2HD positioning system is optimized for vertical operation. If horizontal operation is intended, please note with your order.



M-714, dimensions in mm. Sub-D connector 26-pin, 3 m cable

10 nm steps of an M-714 stage, as commanded by a C-702 digital controller and measured by an interferometer



PI Hybrid

PI Hybrid drive combines motorized and piezo positioning system with integrated, internal, high-resolution sensor in one control loop

Technical Data

	M-714.2HD
Motion and positioning	
Travel range	7 mm
Integrated sensor	Linear encoder
Sensor resolution	0.002 µm
Design resolution	0.002 µm
Min. incremental motion	0.004 µm
Hysteresis at the platform	0.01 µm
Unidirectional repeatability	0.01 µm
Accuracy	<0.05 µm
Pitch	±10 µrad
Yaw	±10 µrad
Max. velocity	0.2 mm/s
Origin repeatability	1 µm
Mechanical properties	
Drive screw	Leadscrew
Guiding	Crossed-roller bearings
Screw pitch	1 mm/rev.
Gear ratio	80:1
Belt drive transmission ratio	3:1
Max. push/pull force	100/100 N
Self inhibition	100 N
Max. lateral force	200 N
Drive properties	
Drive type	Hybrid drive: DC-motor with low-inertia, flexure-decoupled and piezo actuated stage platform
Motor type	DC-motor, gearhead
Operating voltage (motor)	24 V
Electrical power	13 W
Piezo drive type	PICMA® Multilayer piezo with flexure
Piezo voltage	±36 V
Limit and reference switches	Hall-effect
Miscellaneous	
Operating temperature range	-20 °C to +65 °C
Material	Al (black anodized)
Mass	2.1 kg
Recommended controller/driver	C-702 hybrid motor controller (p. 4-118)

M-686 PILine® XY Piezo Linear-Motor Stage

Fast, Low Profile and Large Aperture with Direct Position Measurement

The M-686.D64 open-frame stage with closed-loop piezo motors provides 25 x 25 mm travel range

- **Integrated Closed-Loop Piezomotor Drives Provide High Speed to 100 mm/s**
- **Travel Ranges 25 x 25 mm**
- **Integrated Linear Encoders with 0.1 µm Resolution**
- **Compact Design: 32 mm Profile Height, 170 x 170 mm Footprint**
- **Clear Aperture 78 x 78 mm, 66 x 66 mm in Extreme Position**
- **Self-Locking at Rest**
- **Compatible with PI Piezo Nanopositioning / Scanning Stages**

M-686 open-frame piezomotor stages are mainly designed for automated positioning applications in microscopy. The optimized form factor with a low profile height of only 32 mm and the standardized mounting pattern allows the combination with many PI standard nanopositioning systems.

Application Examples

- Biotechnology
- Microscopy
- Scanning microscopy
- Confocal microscopy
- Semiconductor testing
- Handling

Space Saving Piezomotors

Compared to conventional motorized translation stages, the M-686 provides a lower profile and smaller footprint. The compact PILine® piezoelectric linear motors and high-resolution linear encoders make both, the lead screw duct and the flanged, bulky stepper motor employed in traditional stages obsolete. In addition, the piezomotors are self-locking at rest and hold the stage in a stable position without heating up.

Compatibility to PI Nanopositioning and Scanning Stages

A number of standard PI piezo flexure stages (150 x 150 mm footprint) can be mounted directly on the M-686 open-frame stage. Depending on the application, these highly specialized, ultra-precise nanopositioning systems are available as fast XY scanners (for fluorescence microscopy), as vertical Z positioners (3D imaging), or with up to 6 degrees of freedom.

Limit and Reference Switches

For the protection of your equipment, non-contact Hall-effect limit and reference switches are installed. The direction-sensing reference switch supports advanced automation applications with high precision.

Advantages of PILine® Micropositioning Systems

The ultrasonic piezoceramic drives used in PIline® micropositioners have a number of advantages over classical drives:

- Higher Accelerations, up to 5 g
- Speeds up to 500 mm/s
- Small Form Factor
- Self-Locking When Powered Down
- No Shafts, Gears or Other Rotating Parts
- Non-Magnetic and Vacuum-Compatible Drive Principle

Ordering Information

M-686.D64
XY Open-Frame Stage with Closed-Loop PILine® Piezomotor Drives, 25 x 25 mm, 7 N, 0.1 µm Linear Encoder

Ask about custom designs!

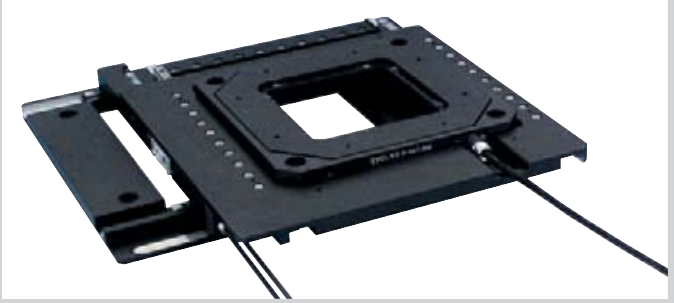
Notes

Nanopositioning stages that fit directly on the M-686:

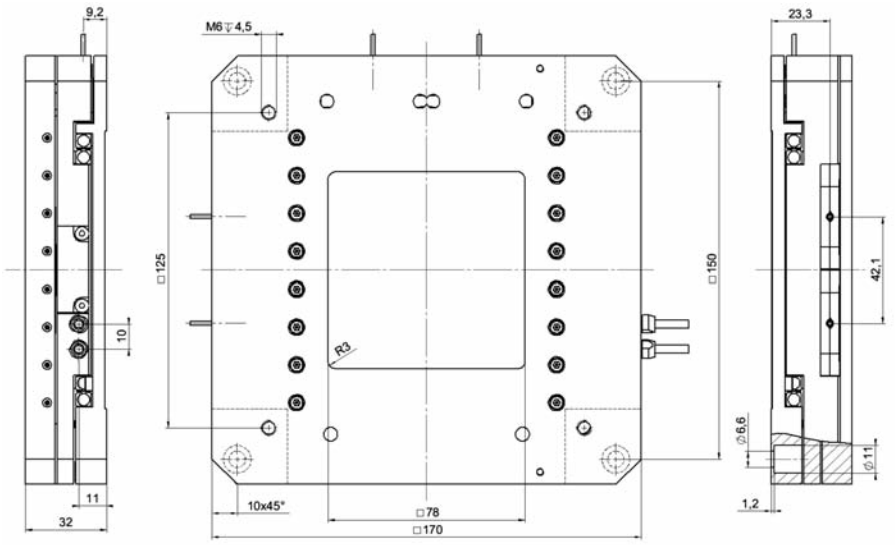
P-561 to P-563
PIMars™ XYZ Nanopositioning systems with up to 300 µm travel

P-541.2 to P-542.2
Low-profile microscopy XY scanners

P-541.Z
Low-profile Z/tip/tilt piezo nanopositioning stages for microscopy



Customized M-686 stage with a bigger footprint, to sink the piezo Z scanner. The system height together with the P-541 piezo scanner is reduced to only 33 mm



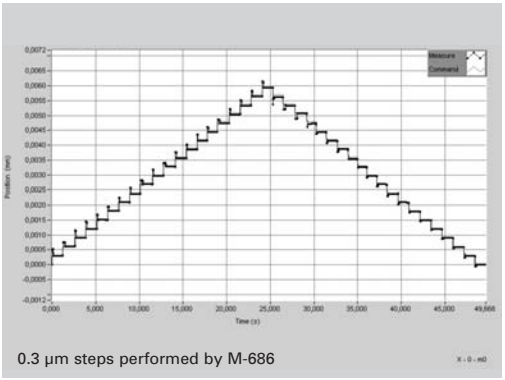
M-686.D64, dimensions in mm. The minimum aperture is 66 x 66 mm with both axes at the maximum position

Technical Data

Model	M-686.D64
Active axes	XY
Motion and positioning	
Travel range	25 x 25 mm
Integrated sensor	Linear encoder
Sensor resolution	0.1 µm
Design resolution	0.1 µm
Min. incremental motion	0.3 µm
Bidirectional repeatability	0.3 µm
Pitch / yaw	±50 µrad
Max. velocity	100 mm/s
Mechanical properties	
Load Capacity*	50 N
Max. push/pull force	7 N
Max. lateral force	4 N
Drive properties	
Motor type	2 x PILine® P-664 per axis
Operating voltage	190 V (Peak-Peak)** 67 V (RMS)**
Electrical power	10 W / axis***
Miscellaneous	
Operating temperature range	-20 to +50 °C
Material	Aluminium (black anodized)
Mass	1.2 kg
Cable length	1.5 m
Connector	2 x MDR connector, 14-pin
Recommended controller/driver	2 x C-867.D64 single-axis controller / driver 2 x C-185.D64 single-axis drive electronics for external servo-controllers (p. 4-116, p. 1-36)

*10 N for max. velocity
**The operating voltage or the piezomotor is supplied by the drive electronics which requires 12 VDC
***For drive electronics

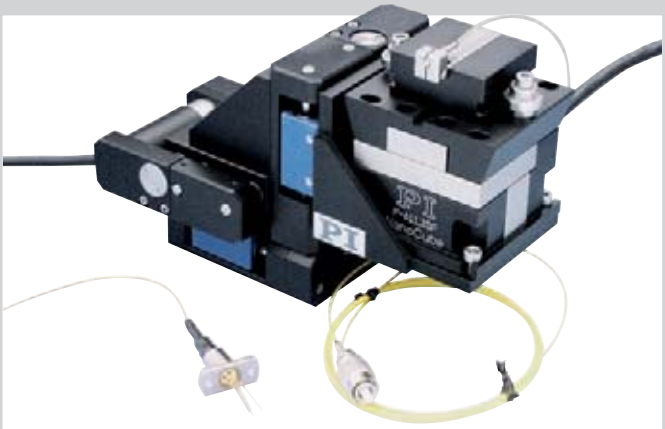
M-686 open-frame stage with P-541.2DD piezo scanner on top, providing a resolution of 0.1 nm and a scanning range of 30 x 30 µm. The system height of the combination with the P-541 XY (or Z) piezo scanner is only 48 mm



0.3 µm steps performed by M-686

F-130 · F-131 Compact XYZ Fiber Aligner

Nanometer Precision with Motor and Piezo Drive Combination



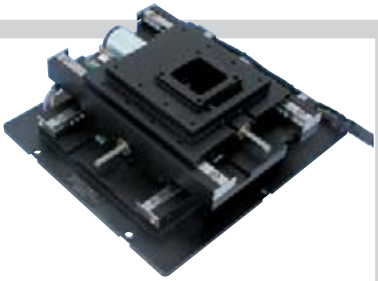
F-130.3SD XYZ Alignment System, 1 nm resolution, with optional F-603.22 ferrule holder

- **Compact, Highly Responsive Coarse / Fine Positioning System, Ideal for Automated Photonics Alignment**
- **5 or 15 mm Motorized Coarse Travel range, 50 nm Min. Incremental Motion**
- **Fast Piezo Drive with Resolution to 1 nm, 100 µm Fine Travel Range, Optional Position Feedback Sensors**
- **Choice of Motors: Stepper or Closed-Loop DC-Motor**
- **Recommended: C-880 Automation Controller**
- **Extensive Accessories, Software Support**

Model	F-130.3SD & F-131.3SD	F-130.3SS & F-131.3SS	F-130.3OD & F-131-3OD	F-130.3OS & F-131.3OS
Drive	Closed-Loop DC motors, closed-loop PZT drives	Stepper motors, closed-loop PZT drives	Closed-Loop DC motors, open-loop PZT drives	Stepper motors, open-loop PZT drives
Motorized travel range (XYZ)	5 & 15 mm	5 & 15 mm	5 & 15 mm	5 & 15 mm
Closed-loop/open-loop resolution (PZT)	2/1	2/1	–/1	–/1

M-900K OEM Planar Scanner

High-Precision XY Positioning System



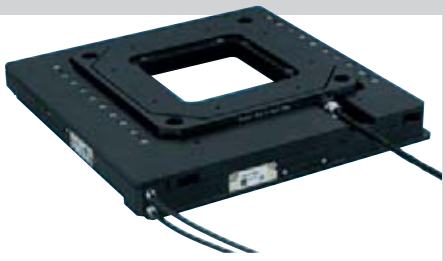
Fast and with high guiding accuracy: the M-900KOPS planar scanner was developed for OEM applications e.g. inside whitelight interferometers

- **Max. Velocity 10 mm/s**
- **Linear encoder with 0.1 µm Resolution**
- **Self-Locking**
- **Load Capacity to 660 N**
- **Low-Backlash, Direct Drive**
- **DC-Servo or Stepper Motor Drives**

Model	Travel range	Min. incremental motion	Bidirectional repeatal
M-900 KOPS planar scanner	50 x 50 mm	0.3 µm	±0.1 µm

M-686K PILine® Microscopy Stage

Low Profile, Large Aperture, High Speed



The customized M-686KPMS stage offers a larger footprint, to sink the optional P-541 piezo scanner by 10 mm. The system height together with the P-541 piezo scanner is reduced to only 34 mm

- **Integrated Closed-Loop Piezomotor Drives Provide High Speed to 100 mm/s**
- **Travel Ranges 25 x 25 mm**
- **Integrated Linear Encoders with 0.1 µm Resolution**
- **Low-Profile Combinations with PI Piezo Nanopositioning / Scanning Stages**
- **Clear Aperture 78 x 78 mm, 66 x 66 mm in Extreme Position**
- **Self-Locking at Rest**

Model	Active Axes	Travel	Max. velocity	Load capacity	Dimensions
M-686KPMS PILine® Micro-scopy Stage	X, Y	50 x 50 mm	100 mm/s	50 N (10 N for max. velocity)	210 x 210 x 28 mm

Notes on Specifications for Micropositioning Stages

Active axes

Specifications given in the data sheet are measured in relation to the defined motion axis. A different motor orientation may result in modified data.

Motion and positioning

Travel range

The maximum allowed travel is limited by the length of the drive screw in a spindle/motor combination. Given in the data sheet is the distance between the two limit switches, if present.

Integrated sensor

Rotary or linear encoder

Encoder resolution

Rotary encoder: counts per drive-screw revolution
Linear encoder: interpolated minimum increment that can be distinguished

Design resolution

The theoretical minimum movement that can be made, based on the selection of the mechanical drive components (drive screw 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 of the position feedback sensor system.

Minimum incremental motion

The minimum motion that can be repeatably executed for a given input, which is sometimes referred to as practical or operational resolution. Design resolution and practical resolution have to be distinguished. Design resolutions of 1 nm or better can be achieved with many motor, gearbox and leadscrew combinations. In practical applications, however, stiction/friction, windup, and elastic deformation limit operating resolution. Several PI motorized micropositioners are available with additional piezo fine positioners for applications where repeatable nanometer scale resolution and / or fast response are required.
The data table states typical measured values.
For repeatable nanometer or sub-nanometer resolution see the "Piezo Flexure Stages / High-Speed Scanning Systems" (see p. 2-3 *ff*) and "Piezo Actuators & Components (see p. 1-61 *ff*) sections.

Backlash

Position error that appears upon reversing direction due to error in the drivetrain. See page 4-127 *ff* for details. The data table states typical measured values. Data for vacuum versions may differ.

Rotation / linear input, tangent-arm length

Angular displacement of tangent-arm rotation stages is determined by the arm length and the linear motion input pushing the arm (see p. 4-82) for information on how to calculate angular displacement from linear input).

Unidirectional / bidirectional repeatability

Values are typical results (RMS, 1 sigma), see also Glossary

Pitch / yaw

The maximum angular deviation around Y- (pitch) and Z-axis (yaw) over the whole travel range, with X being the direction of motion. Pitch and yaw are usually given as ± values. The data table states typical measured values. See "Definition of Axes and Angles" (see p. 4-127 *ff*).

Max. velocity

This is the short-term peak value for horizontal mounting, with no load, and not intended for continuous operation. The average velocity and continuous velocity are lower than the peak value and depend on the load conditions and other environmental parameters. Data for vacuum versions may differ.

Origin repeatability

Repeatability of the reference switch (if present)

Mechanical properties

Motor resolution

Resolution with micro-stepping specified for PI's stepper motor controllers.

Stiffness in motion direction

Typical tolerance: ±20 %

Max. normal load capacity

Centered, vertical load (horizontal installation).

Max. push / pull force

Active and passive force limit in operating direction, at center of stage. Some stages may be able to generate higher forces at the cost of reduced lifetime. Data for vacuum versions may differ.

Holding force when powered down

A main feature of piezomotor linear dirves is the self-locking capability at rest, without current consumption and heat generation. Piezomotor characteristics cause a decline of the holding-force in long-term off-time. The data refer to long-term minimum holding force.

Drive properties

Drive type / Operating voltage

ActiveDrive™: The operating voltage (usually 24 VDC) for the ActiveDrive™ motors is provided by an external power supply (included in the delivery).

DC motors: DC servo motors require a supply voltage of up to 12 VDC. The operating voltage is usually given as differential value where the magnitude determines the velocity, and the sign determines the motion direction.

Stepper motors: PI stepper motors are usually driven in chopper mode.

Electrical power

Motor manufacturer's information.

Torque

Motor manufacturer's information.

Miscellaneous

Operating temperature range

Safe operation, no damage to the mechanics. All technical data specified in the data sheet refer to room temperature (22 °C ±3 °C).

Material

Micropositioning stages are typically made of anodized aluminum or stainless steel. Small amounts of other materials may be used (for bearings, preload, coupling, mounting, etc.). For special applications other materials are possible like Invar.

Al: Aluminum
N-S: Nonmagnetic stainless steel
St: Steel
I: Invar

Mass

Typical tolerance: ±5 %

Cable length

Typical tolerance: ±10 mm

Recommended motor controller

Compatible motor controllers are described in the "Servo & Stepper Motor Controllers" (see p. 4-109 *ff*) section

For further information read "Micropositioning Fundamentals" section (see p. 4-127 *ff*).

Rotary & Tilt Stages

Selection Guide: Rotary Stages

High Resolution Rotary Stages: Stepper, Servo and Piezo Driven

All models provide resolutions better than 1/1000 degree. Closed-loop DC-servo motors and stepper motors, direct-drives and gear-box versions are available. Some models offer additional piezo drives for sub-microradian precision.

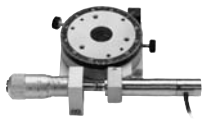
Models	Description	Travel [µm]	Load Capacity [kg]	Page
M-116	Miniature rotation stage, compact, clear aperture, high resolution, compatible with M-110, M-111, M-112 and M-122 stages	>360	1.5	4-74
M-060, M-061, M-062	Continuous travel range, compact, clear aperture, high resolution, 60 to 120 mm diameter	>360	50–65	4-76
M-037	Continuous travel range, compact, clear aperture, high resolution, 60 mm diameter	>360	30	4-78
M-038	Continuous travel range, compact, clear aperture, high resolution, 100 mm diameter	>360	40	4-80
M-035	Tangent-arm drive, manual, with motor and piezo options, very high resolution, 60 mm diameter	19	30	4-82
M-036	Tangent-arm drive, manual, with motor and piezo options, very high resolution, 100 mm diameter	21	40	4-84

M-116 Mini rotation stage, high resolution, fits M-110 linear stage series

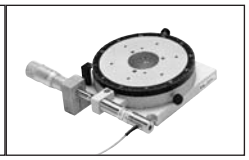
M-060, M-061, M-062 Continuous travel range, compact, high resolution

M-037 Continuous travel range, compact, high resolution

M-038 Continuous travel range, compact, high resolution



M-035 Tangent-arm drive, manual, motor/piezo options

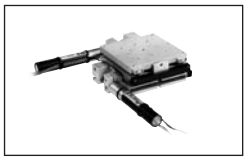


M-036 Tangent-arm drive, manual, motor/piezo options

Notes on specifications see p. 4-86 *ff*

High-Resolution Tip/Tilt Stages with Optional Piezo Drive

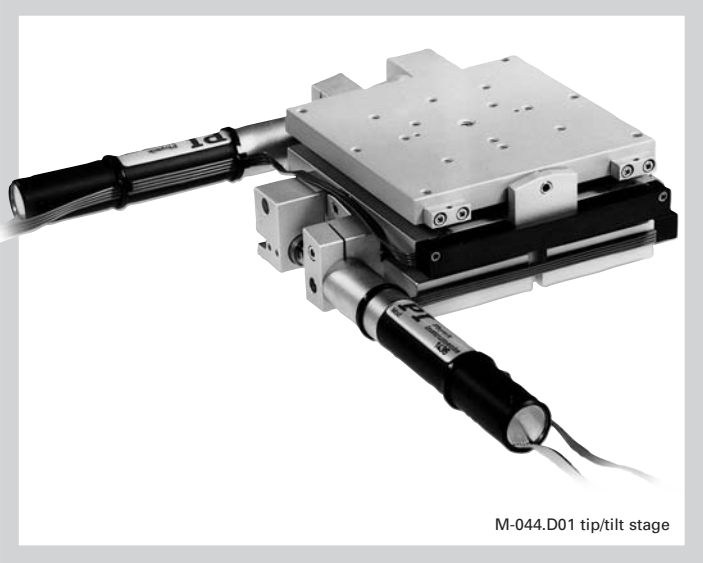
Models	Description	Min. Inc. Motion	Travel [µm]	Load Capacity [kg]	Page
M-041 – M-044	Tip & tip/tilt stages, high resolution, piezo option	to 0.5 µrad	±9	4.5	4-71



M-041 – M-044 Tip & tip/tilt stages, high resolution, piezo option

M-041 – M-044 Tip/Tilt Stage

Piezo Drive Option for Nanometer Precision



M-044.D01 tip/tilt stage

- **One- & Two-Axis Tilt Stages**
- **Zero Backlash**
- **Sub-µrad Resolution**
- **Manual and DC-Motor Drives**
- **Compatible with Leading Industrial Motion Controllers**
- **Optional Piezo Drives for Tracking and Scanning**

M-041 through M-044 are one- and two-axis (θ_X, θ_Y) tip/tilt stages for small loads. They are spring preloaded for elimination of backlash and feature resolution and repeatability superior to that of goniometric cradles. Versions with piezo translators allow ultra-high-resolution dynamic scanning and tracking. See the "Fast Steering Mirrors / Active Optics" section for fast, ultra-high-resolution, tip/tilt platforms (p. 2-79 *ff*).

The two basic versions (with part number extension .00) are equipped with manual micrometer drives providing 65 and 80 µrad minimum incremental motion, respectively. The versions with extension .D01 are equipped with closed-loop, DC-servo-motor drives (model M-227.10 (see p. 1-42) for further details and recommended motor controllers) providing 15 and 12 µrad minimum incremental motion, respectively. Sets of limit switches eliminate the possibility of overtravel.

High-Resolution Piezo Option

For sub-µrad resolution and dynamic tracking or scanning, optional open-loop/closed-loop piezo drive upgrade kits are available. See the P-840 and P-841 (see p. 1-74) in the "Piezo Actuators & Components" section for further details and recommended controllers. The piezo drives can also be ordered subsequently to upgrade manual or motorized systems.

Notes

See "Accessories", page 4-90 *ff.* for adapters, brackets, etc.

Ordering Information

M-041.00
Small Tilt Stage, Manual Micrometer Drive

M-041.D01
Small Tilt Stage, DC-Motor Drive

M-042.00
Small Tip/Tilt Stage, Manual Micrometer Drive

M-042.D01
Small Tip/Tilt Stage, DC-Motor Drive

M-043.00
Tilt Stage, Manual Micrometer Drive

M-043.D01
Tilt Stage, DC-Motor Drive

M-044.00
Tip/Tilt Stage, Manual Micrometer Drive

M-044.D01
Tip/Tilt Stage, DC-Motor Drive

Upgrades

M-041.U0
Open-Loop Piezo Drive Upgrade Kit for M-041 Tilt Stages

M-041.US
Closed-Loop Piezo Drive Upgrade Kit for M-041 Tilt Stages

M-042.U0
Open-Loop Piezo Drive Upgrade Kit for M-042 Tip/Tilt Stages

M-042.US
Closed-Loop Piezo Drive Upgrade Kit for M-042 Tip/Tilt Stages

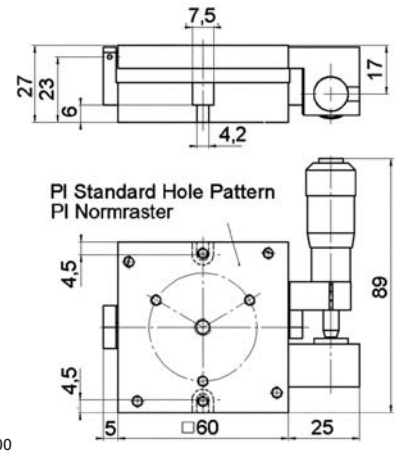
M-043.U0
Open-Loop Piezo Drive Upgrade Kit for M-043 Tilt Stages

M-043.US
Closed-Loop Piezo Drive Upgrade Kit for M-043 Tilt Stages

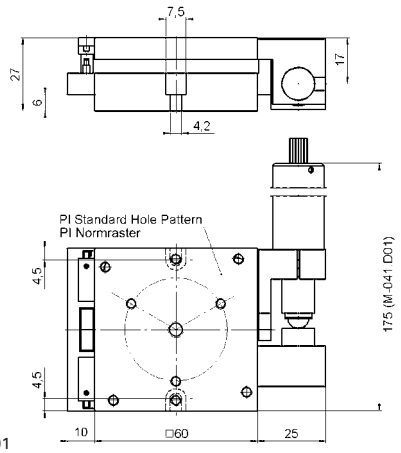
M-044.U0
Open-Loop Piezo Drive Upgrade Kit for M-044 Tip/Tilt Stages

M-044.US
Closed-Loop Piezo Drive Upgrade Kit for M-044 Tip/Tilt Stages

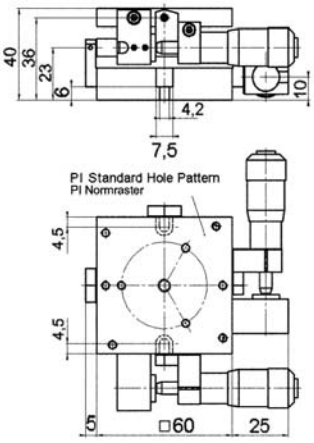
Ask about custom designs!



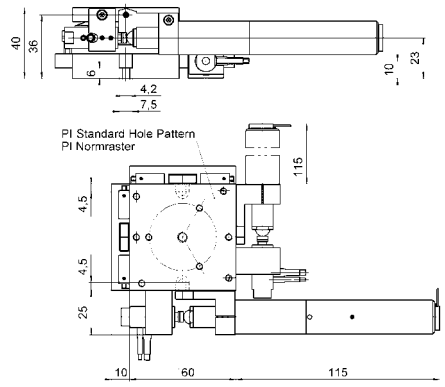
M-041.00
dimensions (in mm), see p. 4-91 for PI Standard Hole Pattern



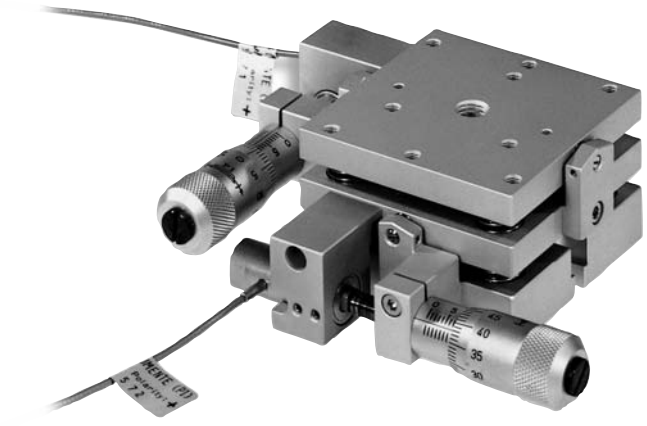
M-041.D01
dimensions (in mm), see p. 4-91 for PI Standard Hole Pattern



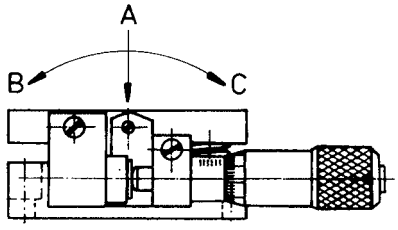
M-042.00
dimensions (in mm), see p. 4-91 for PI Standard Hole Pattern



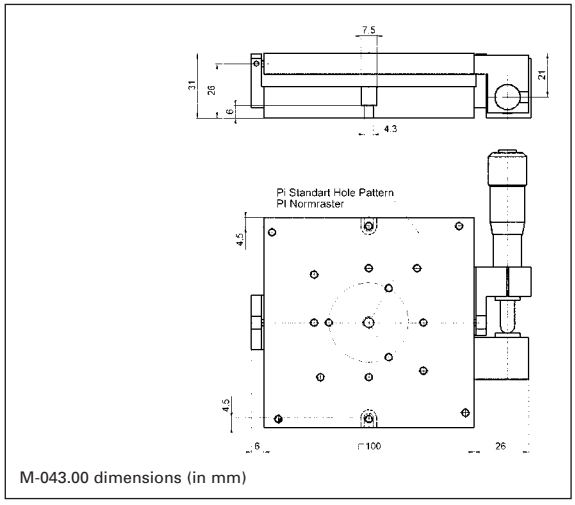
M-042.D01 with optional PZT drives
(dimensions in mm), see p. 4-91 for PI Standard Hole Pattern



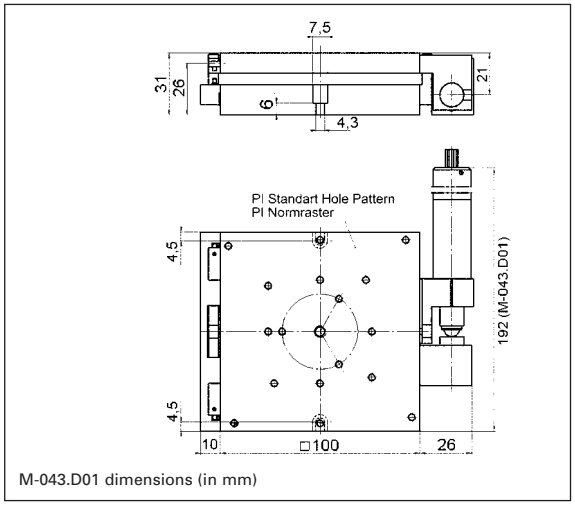
M-042.00 tip/tilt stage with optional PZT drives



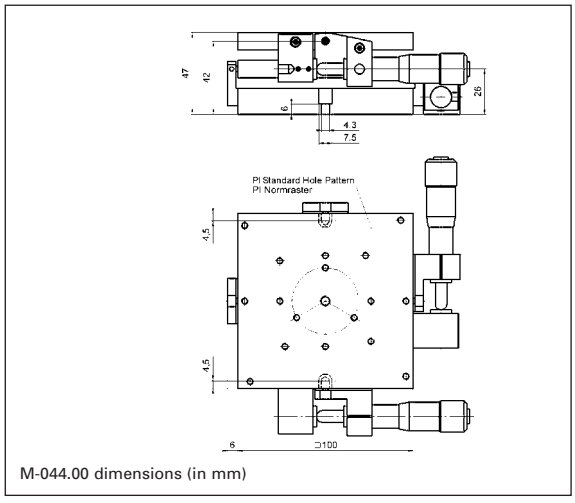
Load and torque definition of M-041,
M-042, M-043 and M-044 tip/tilt stages



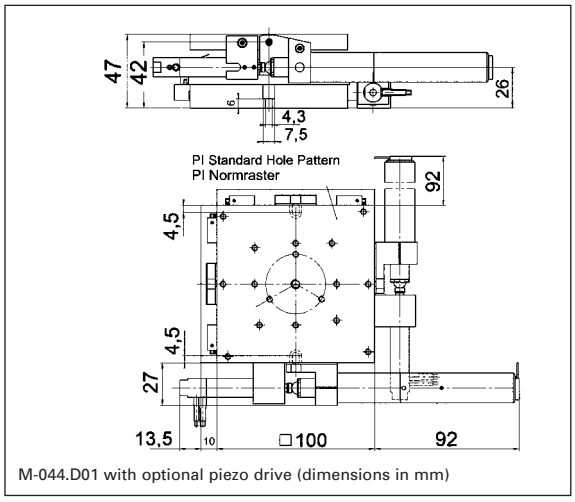
M-043.00 dimensions (in mm)



M-043.D01 dimensions (in mm)



M-044.00 dimensions (in mm)



M-044.D01 with optional piezo drive (dimensions in mm)

Technical Data

Model	M-041.00	M-042.00	M-043.00	M-044.00	M-041.D01	M-042.D01	M-043.D01	M-044.D01	Units
Tilt axes	θ_x	$\theta_x\theta_y$	θ_x	$\theta_x\theta_y$	θ_x	$\theta_x\theta_y$	θ_x	$\theta_x\theta_y$	
Tilt range	±9	±9	±7	±7	±9	±9	±7	±7	° (axis)
Fine range (piezo option)	±1.2	±0.6	±1.4	±1.4	±1.2	±0.6	±1.4	±1.4	mrad (axis)
Design resolution	–	–	–	–	0.28	0.28	0.23	0.23	µrad
Min. incremental motion	80	80	65	65	5	5	5	5	µrad
Min. incremental motion (piezo option)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	µrad
Rotation / linear input	80	80	65	65	80	80	65	65	µrad/µm
Unidirectional repeatability	–	–	–	–	20	20	15	15	µrad
Backlash	–	–	–	–	200	200	175	175	µrad
Max. velocity (motor)	–	–	–	–	4.5	4.5	3.6	3.6	°/s
Max. load (A)	4	4	5	5	4	4	5	5	kg
Max torque (B, C)	450, 150	450, 150	750, 250	750, 250	450, 150	450, 150	750, 250	750, 250	mNm
Drive	M-622 Micrometer	M-622 Micrometer	M-624 Micrometer	M-624 Micrometer	M-227.10 DC-Mike	M-227.10 DC-Mike	M-227.10 DC-Mike	M-227.10 DC-Mike	
Piezo drive (optional) M-04x.U0 / M-04x.US	P-840.20 / P-841.20	P-840.10 / P-841.10	P-840.30 / P-841.30	P-840.30 / P-841.30	P-840.20 / P-841.20	P-840.10 / P-841.10	P-840.30 / P-841.30	P-840.30 / P-841.30	
Mass	0.4	0.6	0.8	1.2	0.5	0.7	0.9	1.5	kg
Body material	Al	Al	Al	Al	Al	Al	Al	Al	

M-116 Precision Rotation Stage

Compact, Multi-Axis Combinations with M-110 Translation Stage Series

M-116.DG micro rotary stage

- **Compact Design**
- **Continuous Rotation Range**
- **Encoder Resolution 2.5 µrad**
- **Clear Aperture**
- **Max. Velocity 20 degrees/second**
- **Preloaded Worm Drive for Zero Backlash**
- **Fits Directly on M-110 Micro Translation Stages**
- **Non-Contact Reference Switch**
- **Repeatability to ±10 µrad**

M-116 rotation stages are equipped with low-friction, spring-preloaded worm gear drives allowing unlimited rotation in either direction in an extremely compact package.

Stepper and Servo Motors

Both drive options provide a cost-effective solution for industrial and OEM environments. A miniature DC or stepper motor actuates motion via a spring-preloaded worm gear drive and zero-backlash (with M-116.xxH versions) gearhead.

To meet the most critical positioning demands, the DC motor is equipped with a high-resolution encoder featuring resolution of 2 048 counts per revolution. The combination of the extremely low-stiction/low-friction construction and high-resolution encoder allows for minimum incremental motion of 25 µrad at speeds up to 20 degrees/second.

Multi-Axis Combinations

M-116 rotary stages can be combined with the M-110, M-111 and M-112 micro linear stages without an additional adapter plate to keep the total height at a minimum.

Clear Aperture, Lens Adapter

The M-116 is designed with a clear aperture for extended versatility in optics applications. The M-116.AL1 lens adapter is available to accommodate 0.5" optics such as polarizers.

Non-Contact Limit and Reference Switches

Motorized models are equipped with an integrated Hall-effect origin switch. To protect your equipment and increase versatility in automation applications, the rotary stage can optionally be equipped with Hall-effect limit switches. Travel can be limited to a range between 0° and 330° ±2°.

For ease of operation and setup, all models come with a scale ring on the outer edge of the turntable.

Ordering Information

M-116.DG
Rotation Stage, 360°, Closed-Loop DC Motor Gearhead

M-116.DGH
Rotation Stage, 360°, Closed-Loop Backlash-Free DC Motor Gearhead

M-116.2SH
Rotation Stage, 360°, 2-Phase Stepper Motor with Backlash-Free Gearhead

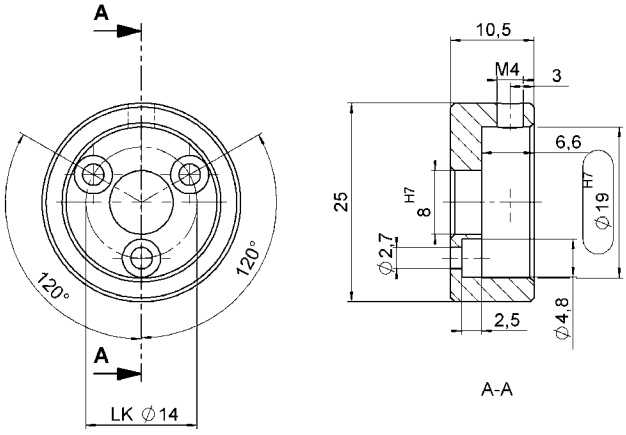
M-116.AL1
Lens Adapter for 0.5" Optics

Ask about custom designs!

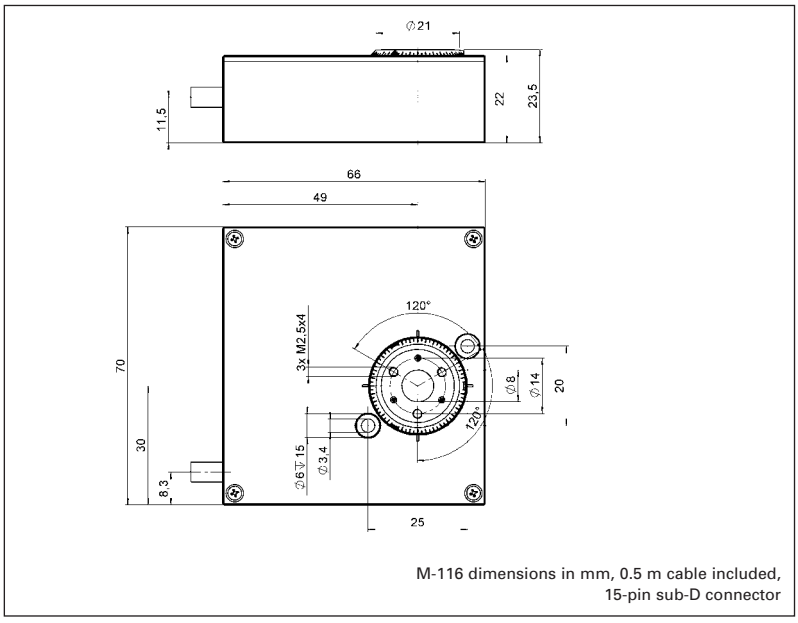
XY θ_z micropositioning combination consisting of (from top to bottom) M-116 micro rotary stage and two M-111 translation stages (M-110.01 adapter for mounting the M-111 on a honeycomb breadboard with M6 on 25 mm centers)

Application Examples

- R&D
- Laser technology
- Metrology
- Adjustment of optics
- Photonics packaging
- Quality assurance testing



Dimensions of the M-116.AL1 lens adapter for 0.5" optic devices such as polarizers



M-116 dimensions in mm, 0.5 m cable included, 15-pin sub-D connector

Technical Data

Model	M-116.DG	M-116.DGH	M-116.2SH	Units
Active axes	Rotation	Rotation	Rotation	
Motion and positioning				
Rotation range	>360	>360	>360	°
Integrated sensor	Rotary encoder	Rotary encoder	–	
Sensor resolution	2048	2048	–	Cts./rev.
Design resolution	2.45 (0.00013)	3.16 (0.00018)	16.9* (0.00097)	µrad (°)
Min. incremental motion	50	25	30	µrad
Backlash	1000	500	500	µrad
Unidirectional repeatability	12	10	10	µrad
Max. velocity	20	20	20	°/s
Mechanical properties				
Worm gear ratio	44:1	44:1	44:1	
Gear ratio	28.444:1	22.0335:1	22.0335:1	
Motor resolution	–	–	384*	steps/rev.
Axial force	±15	±15	15	N
Max. Torque (θ_X, θ_Y)	±1.5	±1.5	±1.5	Nm
Max. Torque clockwise (θ_Z)	0.4	0.4	0.4	Nm
Max. torque counterclockwise (θ_Z)	0.8	0.8	0.8	Nm
Drive properties				
Motor type	DC-motor, gearhead	DC-motor, gearhead	2-phase stepper motor*	
Operating voltage	0 to ±12	0 to ±12	24	V
Electrical power	1.75	1.75		W
Reference switch	optical	optical	optical	
Miscellaneous				
Operating temperature range	-20 to +65	-20 to +65	-20 to +65	°C
Material	Aluminum	Aluminum	Aluminum	
Mass	0.4	0.4	0.4	kg
Recommended controller/driver	C-863 single-axis C-843 PCI board, for up to 4 axes	C-863 single-axis (p. 4-114) C-843 PCI board (p. 4-120), for up to 4 axes	C-663 single-axis (p. 4-112)	

*2-phase stepper motor, 24 V chopper voltage, max. 0.25 A/phase, 24 full steps/rev., motor resolution with C-663 stepper motor controller

M-060 · M-061 · M-062 Precision Rotation Stage

Unlimited Travel Range

M-060.PD, M-061.PD and M-062.PD from front to rear

- **Continuous Rotation Range**
- **Ultra-High Resolution**
- **Max. Velocity 90 deg/sec**
- **Preloaded Worm Drive for Zero Backlash**
- **ActiveDrive™ DC-Servo, Stepper-Motor and Manual Drives**
- **Direction-Sensing Reference Switch**

M-06x series rotation stages are equipped with ultra-precise, ultra-low-friction, spring-preloaded worm gear drives allowing unlimited rotation in either direction. Models M-060 feature a 60 mm diameter turntable, models M-061, a 100 mm table and models M-062, a 120 mm table.

DC-Motor and Stepper-Motor Drive

One manual drive and three motor drives (four with M-062 models) are available:

Application Examples

- R&D
- Semiconductor testing
- Mass storage device testing
- Metrology
- Photonics packaging
- Quality assurance testing

M-06x.PD with ActiveDrive™

This version features a direct-coupled motor/encoder. For superior dynamic performance, we integrated our unsurpassed ActiveDrive™ system. The ActiveDrive™ design, developed by PI, features a high-efficiency PWM (pulse width modulation) servo-amplifier mounted side-by-side with the DC-Motor and offers several advantages:

- Increased efficiency, by eliminating power losses between the amplifier and motor
- Reduced cost of ownership and improved reliability, because no external driver is required
- Elimination of PWM amplifier noise radiation, by mounting the amplifier and motor together in a single, electrically shielded case

M-06x.DG with Zero-Backlash DC-Motor/Gearhead Drive

The M-06x.DG are equipped with 3-watt DC motors with zero-backlash gearhead and shaft-mounted encoders (2048 counts/rev.). The gear ratio of 29.6:1, provides higher resolution than the direct drive motors.

M-60x.2S Stepper-Motor Drive

The M-060x.2S models feature a cost-effective direct-drive, 2-phase stepper-motor, providing very smooth operation and a resolution of 6400 steps/rev.

Non-Contact Limit and Reference Switches

Motorized models are equipped with an integrated Hall-effect origin switch. To protect your equipment and increase versatility in automation applications, the rotary stage can optionally be equipped with Hall-effect limit switches. Travel can be limited to a range between 0° and 268° ±2°.

Coarse position can be read from an adjustable scale ring on the outer edge of the turntable graduated in 2 degree increments. The manual versions also feature a drive-shaft-mounted indicator with 0.1-degree graduations.

Ordering Information

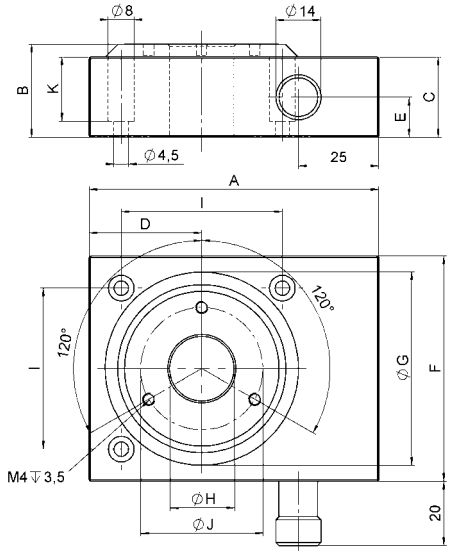
Precision Rotation Stage, 360°

M-06 .

- **0 =** Ø 60 mm
- **1 =** Ø 100 mm
- **2 =** Ø 120 mm

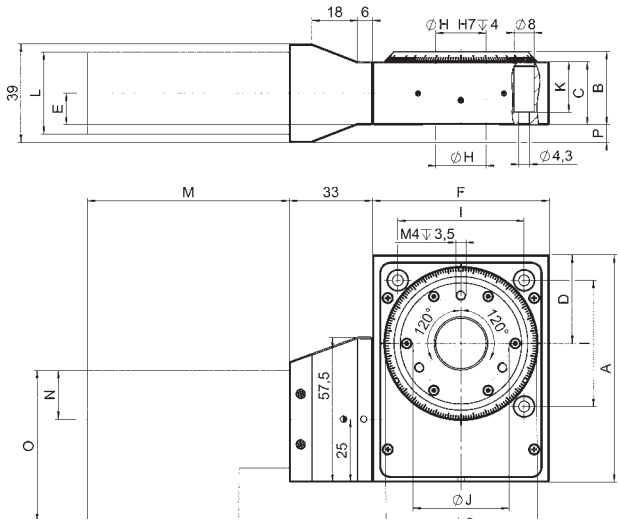
- **PD =** ActiveDrive™ DC Motor
- **DG =** Closed-Loop DC Motor Gearhead
- **2S =** 2-Phase Stepper Motor
- **M0 =** Manual Drive

Ask about custom designs!



[mm]	M-060.M0	M-061.M0	M-062.M0
A	90	130	150
B	29	34	42
C	25	30	38
D	35	55	65
E	12,5	15	21,5
F	70	110	130
G	60	100	120
H	20	35	45
I	50	90	110
J	38	50	60
K	20	20	28

M-060.MO, M-061.MO, M-062.MO rotation stages, with manual drive, dimensions in mm



DIMENSIONS	M-060.PD	M-060.DG	M-060.2S	M-061.PD	M-061.DG	M-061.2S	M-062.PD	M-062.DG	M-062.2S
A	90	90	90	130	130	130	150	150	150
B	29	29	29	34	34	34	42	42	42
C	25	25	25	30	30	30	38	38	38
D	35	35	35	55	55	55	65	65	65
E	12.5	12.5	12.5	15	15	15	21.5	21.5	21.5
F	70	70	70	110	110	110	130	130	130
G	50	50	60	100	100	100	120	120	120
H	20	20	20	35	35	35	45	45	45
I	50	50	50	90	90	90	110	110	110
J	38	38	35	50	50	50	60	60	60
K	20	20	20	20	20	20	28	25	25
L	39	34	39	39	34	39	39	34	39
M	80.8	83.8	81	80.8	83.8	81	80.8	83.8	81
N	19	15	18.5	19	15	18.5	19	15	18.5
O	59.3	51	52.5	59.3	51	52.5	59.3	51	52.5
P	7	7	7	4.5	4.5	4.5	-	-	-

Motorized M-060, M-061, M-062 rotation stages, dimensions in mm

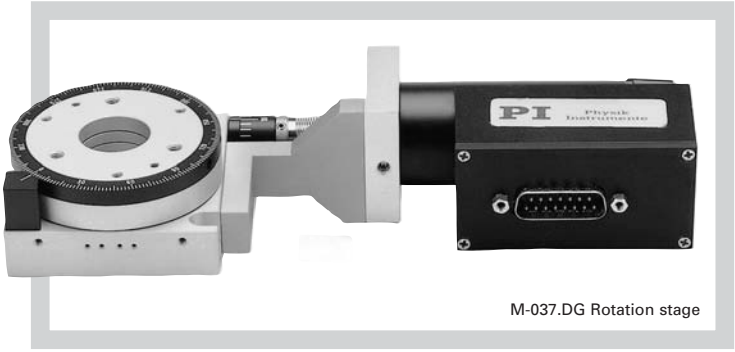
Technical Data

Model	M-060.M0 / M-061.M0 / M-062.M0	M-060.PD / M-061.PD / M-062.PD	M-060.DG / M-061.DG / M-062.DG	M-060.2S / M-061.2S / M-062.2S	Units
Active axes	Rotation	Rotation	Rotation	Rotation	
Motion and positioning					
Rotation range	>360	>360	>360	>360	°
Integrated sensor	–	Rotary encoder	Rotary encoder		
Sensor resolution	–	4000	2000		Cts./rev.
Design resolution	–	32 (0.0018) / 17.5 (0.001) / 15 (0.0008)	2.1 (0.00012) / 1.2 (6.9 x 10^{-5}) / 0.96 (5.5x10^{-5})	19.7 (0.0011) / 10.9 (0.00063) / 8.9 (0.00051)*	µrad (°)
Min. incremental motion	–	32 / 17.5 / 15	6.3 / 6 / 5	40 / 20 / 18*	µrad
Backlash	–	200 / 200 / 240	200 / 200 / 240	200 / 200 / 240	µrad
Unidirectional repeatability	–	50 / 50 / 60	50 / 50 / 60	50 / 50 / 60	µrad
Max. velocity	–	90	16 / 9 / 7.3	36 / 20 / 16	°/s
Mechanical properties					
Worm gear ratio	50:1 / 90:1 / 110:1	50:1 / 90:1 / 110:1	50:1 / 90:1 / 110:1	50:1 / 90:1 / 110:1	
Gear ratio	–	–	$(28/12)^4$:1 ≈ 29.6:1	–	
Motor resolution	–	–	–	6400*	steps/rev.
Axial force	±500 / ±550 / ±650	±500 / ±550 / ±650	±500 / ±550 / ±650	±500 / ±550 / ±650	N
Max. torque θ_X, θ_Y	±6 / ±6 / ±7	±6 / ±6 / ±7	±6 / ±6 / ±7	±6 / ±6 / ±7	Nm
Max. torque θ_Z	±4 / ±6 / ±8	±4 / ±6 / ±8	±4 / ±6 / ±8	±4 / ±6 / ±8	Nm
Drive properties					
Motor type	–	ActiveDrive™ DC-Motor	DC-Motor, gearhead	2-phase Stepper-Motor**	
Operating voltage	–	24 (PWM)	12 differential	24	V
Electrical power	–	30	3	–	
Reference switch	Hall-effect	Hall-effect	Hall-effect	Hall-effect	
Miscellaneous					
Operating temperature range	-20 to +65	-20 to +65	-20 to +65	-20 to +65	°C
Material	Aluminum	Aluminum	Aluminum	Aluminum	
Mass	0.42 / 1.36 / 2.24	0.94 / 1.88 / 2.76	0.94 / 1.88 / 2.76	0.96 / 1.9 / 2.78	kg
Recommended controller/driver		C-863 single-axis C-843 PCI board, for up to 4 axes	C-863 single-axis (p. 4-114) C-843 PCI board (p. 4-120), for up to 4 axes	C-663 single-axis (p. 4-112)	

*with C-663 stepper-motor controller
**2-phase stepper-motor, 24 V chopper voltage, max. 0.8 A/phase, 400 full steps/rev

M-037 Compact Precision Rotation Stage

Unlimited Travel Range, Vacuum-Compatible Versions



M-037.DG Rotation stage

- **Ultra-High Resolution**
- **Compact Design**
- **Continuous Rotation Range**
- **Preloaded Worm Drive for Zero Backlash**
- **ActiveDrive™ Manual, DC-Servo and Stepper-Motor Drives**
- **Clear Aperture Ø 20 mm**
- **Vacuum-Compatible Versions Available to 10^{-6} hPa**

M-037 rotation stages are equipped with ultra-precise worm gear drives allowing unlimited rotation in either direction. An integrated spring preload eliminates backlash. Double-row ball bearings allow zero backlash, high load capacity and extremely low wobble.

The worm gear ratio is 180:1, which allows an extraordinary position resolution of the turntable.

DC-Motor and Stepper Motor Drives

A variety of servo and stepper motors are available, besides the manual version.

Model M-037.DG is closed-loop DC motors with shaft-mounted position encoders and precision gearheads providing 3.5 µrad at a design resolution of 0.6 µrad.

Model M-037.2S models feature a cost-effective direct-drive, 2-phase stepper motor, providing very smooth operation and a resolution of 5.45 µrad at a minimum incremental motion of 21 µm.

ActiveDrive™

Model M-037.PD is equipped with the high efficient Active Drive™ direct drive and provides velocities up to 45°/s. The ActiveDrive™ design, developed by PI, features a high-efficiency PWM (pulse width modulation) servo-amplifier mounted side-by-side with the DC motor and offers several advantages:

- Increased efficiency, by eliminating power losses between the amplifier and motor
- Reduced cost of ownership and improved reliability, because no external driver is required
- Elimination of PWM amplifier noise radiation, by mounting the amplifier and motor together in a single, electrically shielded case

Coarse position can be read from an adjustable scale ring on the outer edge of the turntable graduated in 2 degree increments.

Each M-037 stage is individually broken in before delivery to achieve the exceptional mechanical precision.

Notes

For adapters, bracket, etc. see page 4-90 *ff.*

Ordering Information

M-037.00
Rotation Stage, Ø 60 mm, 360°, Manual Drive

M-037.DG
Rotation Stage, Ø 60 mm, 360°, Closed-Loop DC Motor Gearhead

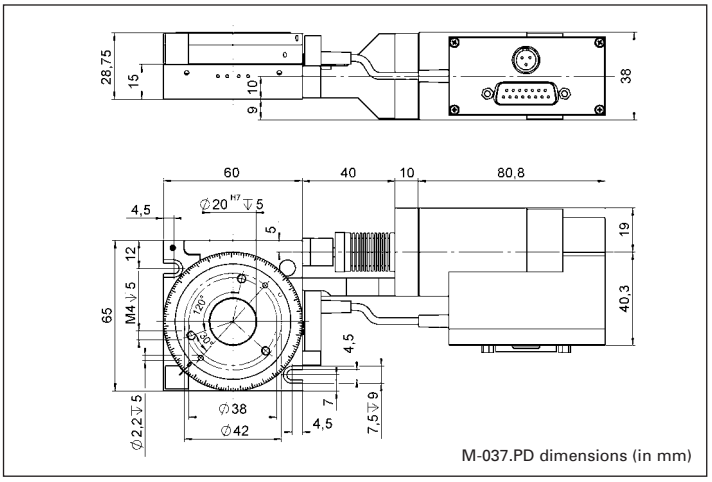
M-037.VG
Vacuum Compatible to 10^{-6} hPa of M-037.DG

M-037.PD
Rotation Stage, Ø 60 mm, 360°, ActiveDrive™ DC Motor (includes 24 V power supply)

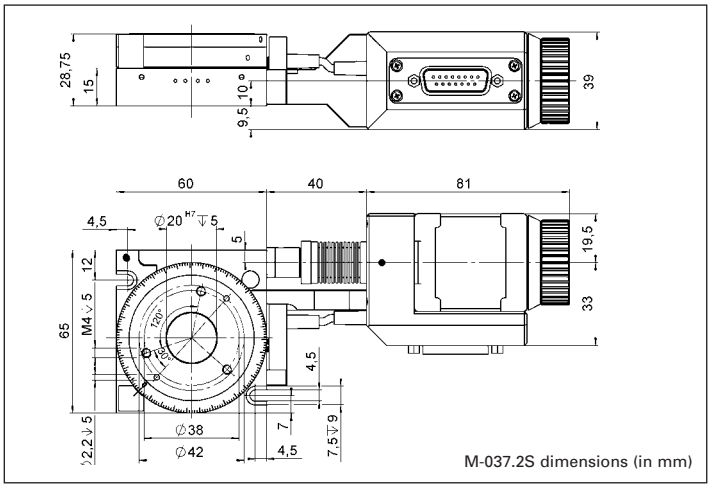
M-037.VP
Vacuum Compatible to 10^{-6} hPa of M-037.PD

M-037.2S
Rotation Stage, Ø 60 mm, 360°, 2-Phase Stepper Motor

Ask about custom designs!

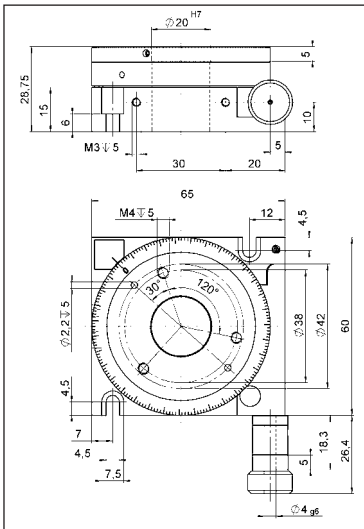


M-037.PD dimensions (in mm)

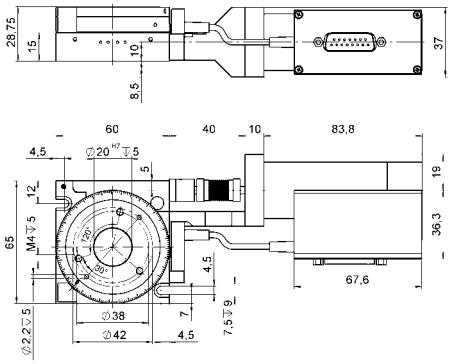


M-037.2S dimensions (in mm)

M-037.00 Rotation stage



M-037.00 dimensions (in mm)



M-037.DG dimensions (in mm)

Linear Actuators & Motors
Nanopositioning / Piezoelectrics
Nanometrology
Micropositioning
Hexapod 6-Axis Systems / Parallel Kinematics
Linear Stages
Translation (X)
Vertical (Y)
Multi-Axis
Rotary & Tilt Stages
Accessories
Servo & Stepper Motor Controllers
Single-Channel
Hybrid
Multi-Channel
Micropositioning Fundamentals
Index

Technical Data

Model	M-037.00	M-037.DG	M-037.PD	M-037.2S	
Active axes	Rotation	Rotation	Rotation	Rotation	
Motion and positioning					
Rotation range	>360	>360	>360	>360	°
Integrated sensor	–	Rotary encoder	Rotary encoder	–	
Sensor resolution	–	2000	4000	–	cts./rev.
Design resolution	–	0.59 (34 x 10^{-6})	8.75 (0.0005)	5.45* (0.00031)	µrad (°)
Min. incremental motion	–	3.5	27	21	µrad
Backlash	–	200	200	200	µrad
Unidirectional repeatability	–	30	30	30	µrad
Wobble	<150	<150	<150	<150	µrad
Max. velocity	–	6	45	10	°/s
Mechanical properties					
Worm gear ratio	180:1	180:1	180:1	180:1	
Gear ratio	–	$(28/12)^4 \approx 29.6:1$	–	–	
Motor resolution	–	–	–	6400*	steps/rev.
Load capacity/axial force, self-locking	±300	±300	±300	±300	N
Max. torque (θ_X, θ_Y)	±3	±3	±3	±3	Nm
Max. torque clockwise (θ_Z)	1	1	1	1	Nm
Max. torque counter clockwise (θ_Z)	0.5	0.5	0.5	0.5	Nm
Drive properties					
Motor type	–	DC motor, gearhead	ActiveDrive™ DC Motor	2-phase stepper motor*	
Operating voltage	–	0 to ±12	24 (PWM)	24	V
Electrical power	–	3	30		W
Reference switch	–	Hall-effect	Hall-effect	Hall-effect	
Miscellaneous					
Operating temperature range	-20 to +65	-20 to +65	-20 to +65	-20 to +65	°C
Material	Aluminum	Aluminum	Aluminum	Aluminum	
Mass	0.3	0.65	0.62	0.64	kg
Recommended controller/driver	–	C-863 (single-axis) C-843 PCI-Karte (for up to 4 axes)	C-863 (single-axis, p. 4-114) C-843 PCI-Karte (p. 4-120) (for up to 4 axes)	C-663 (single-axis, p. 4-112)	

incl. motor cable, 3 m, sub-D connector 15-pin
*2-phase stepper motor, 24 V chopper voltage, max. 0.8 A/phase, 400 full steps/rev., motor resolution with C-663 stepper motor controller

M-038 Precision Rotation Stage

Unlimited Travel Range, Vacuum-Compatible Versions

M-038.PD1 Rotation Stage

- **Ultra-High Resolution**
- **Max. Velocity 90°/s**
- **Continuous Rotation Range**
- **Preloaded Worm Drive for Zero Backlash**
- **ActiveDrive™ Manual, DC-Servo and Stepper-Motor Drives**
- **Clear Aperture Ø 40.2 mm**
- **Vacuum-Compatible Versions Available to 10^{-6} hPa**

M-038 rotation stages are equipped with an ultra-precise worm gear drive allowing continuous rotation in either direction. Double-row ball bearings allow high load capacity, zero backlash and extremely low wobble. The new and improved M-038.xx1 versions now feature a larger central aperture and a higher-performance worm wheel drive.

The worm gear ratio of 176:1 allows an extraordinary high position resolution of the turntable.

Custom M-038 stages at the coordinate measuring machine

DC-Motor and Stepper Motor Drives

A variety of servo motor and stepper motors are available, besides the manual version.

Model M-038.DG1 equipped with a closed-loop DC motor with shaft-mounted position encoder and precision gearhead providing minimum incremental motion of 3.5 µrad at a design resolution of 0.6 µrad.

Model M-038.2S1 models feature a cost-effective direct-drive, 2-phase stepper motor, providing very smooth operation and a resolution of 5.45 µrad at a minimum incremental motion of 21 µm.

ActiveDrive™

Model M-038.PD is equipped with the highly efficient Active Drive™ direct drive and reaches velocities up to 45°/s. The ActiveDrive™ design, developed by PI, features a high-efficiency PWM (pulse width modulation) servo-amplifier mounted side-by-side with the DC motor and offers several advantages:

- Increased efficiency, by eliminating power losses between the amplifier and motor
- Reduced cost of ownership and improved reliability, because no external driver is required
- Elimination of PWM amplifier noise radiation, by mounting the amplifier and motor together in a single, electrically shielded case

Coarse position can be read from an adjustable scale ring on the outer edge of the turntable graduated in 2 degree increments. Each M-038 stage is individually broken-in before delivery to achieve the exceptional mechanical precision.

Ordering Information

M-038.001
Rotation Stage, Ø 100 mm, 360°, Manual Drive

M-038.DG1
Rotation Stage, Ø 100 mm, 360°, Closed-Loop DC Motor Gearhead

M-038.VG1
Rotation Stage, Ø 100 mm, 360°, Closed-Loop DC Motor Gearhead, Vacuum Compatible to 10^{-6} hPa

M-038.PD1
Rotation Stage, Ø 100 mm, 360°, ActiveDrive™ DC Motor (Includes 24 V Power Supply)

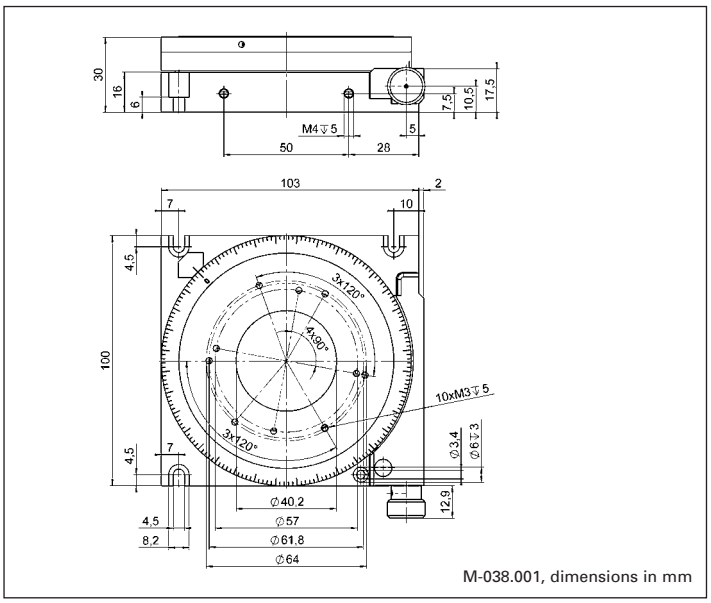
M-038.VP1
Rotation Stage, Ø 100 mm, 360°, ActiveDrive™ DC Motor (Includes 24 V Power Supply), Vacuum Compatible to 10^{-6} hPa

M-038.2S1
Rotation Stage, Ø 100 mm, 360°, 2-Phase Stepper Motor

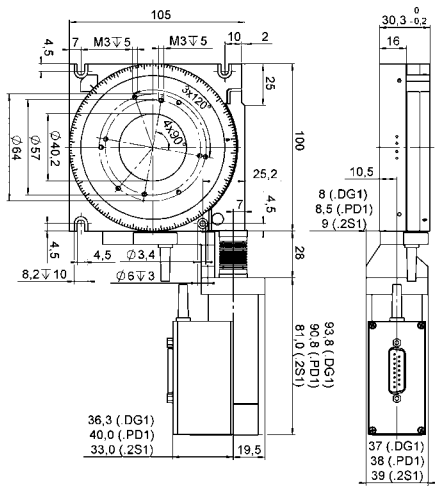
Ask about custom designs!

Notes

See "Accessories" for adapters, bracket, etc. see page 4-90 *ff.*



M-038.001, dimensions in mm



M-038 Motorized versions, dimensions in mm. Sub-D connector 15-pin, 3 m cable

Custom M-038 with folded drive

Linear Actuators & Motors
Nanopositioning / Piezoelectrics
Nanometrology
Micropositioning
Hexapod 6-Axis Systems / Parallel Kinematics
Linear Stages
Translation (X)
Vertical (Y)
Multi-Axis
Rotary & Tilt Stages
Accessories
Servo & Stepper Motor Controllers
Single-Channel
Hybrid
Multi-Channel
Micropositioning Fundamentals
Index

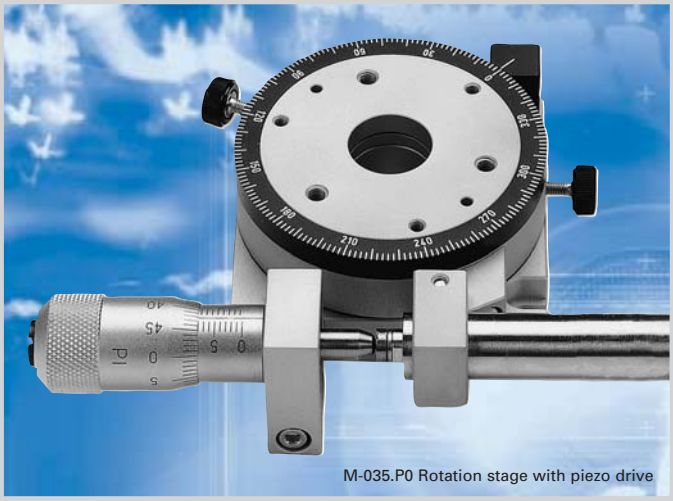
Technical Data

Model	M-038.001	M-038.DG1	M-038.PD1	M-038.2S1	Units
Active axes	Rotation	Rotation	Rotation	Rotation	
Motion and positioning					
Rotation range	>360°	>360°	>360°	>360°	
Integrated sensor	–	Rotary encoder	Rotary encoder	–	
Sensor resolution	–	2000	4000	–	steps/rev.
Design resolution	–	0.60 (35 x 10^{-6})	8.95 (0.0005)	5.58* (0.00032)	µrad (°)
Min. incremental motion	–	3.5	27	21	µrad
Backlash	–	200	200	200	µrad
Unidirectional repeatability	–	20	20	20	µrad
Wobble	<75	<75	<75	<75	µrad
Max. velocity	–	6	90	10	°/s
Mechanical properties					
Worm gear ratio	176:1	176:1	176:1	176:1	
Gear ratio	–	2401:81 ≈ 29.6:1	–	–	
Motor resolution	–	–	–	6400*	steps/rev.
Max. load/axial force	±400	±400	±400	±400	N
Maximum torque (θ_X, θ_Y)	±6	±6	±6	±6	
Maximum torque CW**	2	2	2	2	Nm
Maximum torque CCW**	0.8	0.8	0.8	0.8	Nm
Drive properties					
Motor type	–	DC Motor, gearhead	ActiveDrive™ DC Motor	2-phase stepper motor*	
Electrical power	–	3	30		W
Reference switch	–	Hall-effect	Hall-effect	Hall-effect	
Miscellaneous					
Operating voltage	–	12 V differential	24 (PWM)	24	V
Operating temperature range	-20 to +65	-20 to +65	-20 to +65	-20 to +65	°C
Material	Aluminum	Aluminum	Aluminum	Aluminum	
Mass	0.9	1.25	1.35	1.25	kg
Recommended controller/driver		C-863 (single-axis) C-843 PCI board (for up to 4 axes)	C-863 (single-axis, p. 4-114) C-843 PCI board (p. 4-120) (for up to 4 axes)	C-663 (single-axis, p. 4-112)	

*2-phase stepper motor, 24 V chopper voltage, max. 0.8 A/phase, 400 full steps/rev., motor resolution with C-663 stepper motor controller
**CW: clockwise; CCW: counter-clockwise

M-035 Compact Precision Rotation Stage

Piezo Drive Option for Nanometer Precision


M-035.P0 Rotation stage with piezo drive

- **Sub-Microradian Resolution**
- **360° Coarse Range, up to 19° Fine Range with Resolution <1 µrad**
- **Precision Micrometer or DC Motor Drives**
- **Piezo Option for High-Resolution Scanning and Tracking**
- **Clear Aperture Ø 20 mm**

M-035 series precision rotation stages with tangent-arm drive feature high resolution, excellent repeatability and minimum wobble. The stages are equipped with double-row ball bearings for zero backlash and high load capacity. Both the rotation platform and the scale ring (graduated in 2-degree increments) can be independently coarse positioned over 360° degrees and then locked with screws.

Drive Options

A total of six different drive types are offered. They include various combinations of piezoelectric fine-positioner (closed-loop or open-loop), manual and motorized micrometer drives.

Manual Drive

The basic version, the M-035.50, is equipped with a micrometer drive and a zero-backlash magnetic coupling. The micrometer motion, when converted into rotation, provides a positioning range of 19° degrees. The resolution is approximately 23 µrad.

DC Motor Drive

The motorized version, the M-035.D01 features a high-resolution DC motor drive unit (M-227.10, see p. 1-42 *ff*) and has a range of about 12.6° with resolution of 2 µrad. A set of limit switches on the rotation stage protects against overtravel damage.

High-Resolution Piezo Option

For applications requiring extremely high angular resolution, models M-035.PS and M-035.P0 (with manual micrometer drive) and M-035.DS1 and M-035.DP1 (motorized) are available. They have an additional piezoelectric fine adjustment, which can also be used for dynamic operation. The piezo drive has a linear travel range of 45 µm with sub-nanometer-resolution, which converts to a rotation range of approx. 1 mrad and sub-µrad resolution.

The piezo drives in the M-035.PS and M-035.DS1 versions is also equipped with a position sensor, making closed-loop operation possible with higher stability, reproducibility and accuracy. For more details on the piezo drives, see the "Piezo Actuators" section.

Flexibility

M-035 stages without PZT or DC-motor drives can be upgraded at a later date.

Notes

For adapters, bracket, etc. see p. 4-90 *ff*

Ordering Information

M-035.50
Rotation Stage, Ø 60 mm, Micrometer Drive

M-035.P0
Rotation Stage, Ø 60 mm, Micrometer Drive + Piezo Drive

M-035.PS
Rotation Stage, Ø 60 mm, Micrometer Drive + Closed-Loop Piezo Drive

M-035.D01
Rotation Stage, Ø 60 mm, DC Motor Drive

M-035.DP1
Rotation Stage, Ø 60 mm, DC Motor + Piezo Drive

M-035.DS1
Rotation Stage, Ø 60 mm, DC Motor + Closed-Loop Piezo Drive

Upgrade Kits

M-035.U0
Upgrade Kits with Open-Loop Piezo Drive

M-035.US
Upgrade Kits with Closed-Loop Piezo Drive

M-035.UD
Upgrade Kits with DC Motor Drive (Factory installed)

Ask about custom designs!

Rotation Range Conversion

M-035 and M-036 rotation stages use a tangent-arm which extends beyond the platform. The angular equivalent of the linear actuator displacement can be calculated by the following equation:

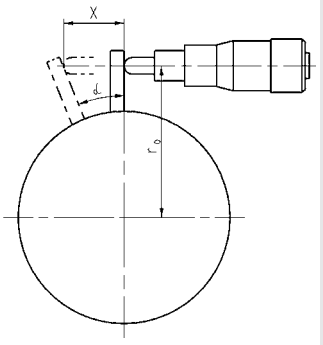
$\alpha \approx \arctan (x/r_0)$

where:
x = displacement of linear actuator [mm]
α = rotation angle [°]
r_o = distance of linear actuator contact point to center of rotation @ 0 degrees [mm]
r_o is 44 mm for the M-035 rotation stages and 66 mm for the M-036 rotation stages.

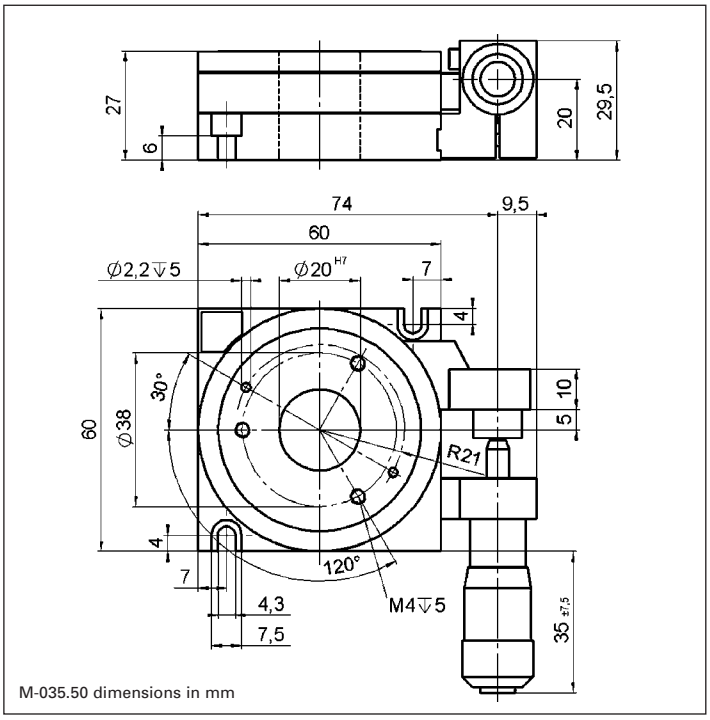
Example:

The rotation angle of an M-035 for a linear displacement x = 5 mm:

$\alpha \approx \arctan (5/44) \approx 6.48°$.

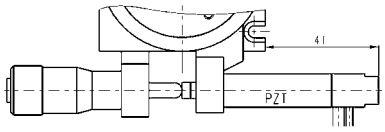


Relation between linear displacement and rotation



M-035.50 dimensions in mm

M-035.50 Rotation stage



M-035.PS, M-035.P0 dimensions in mm

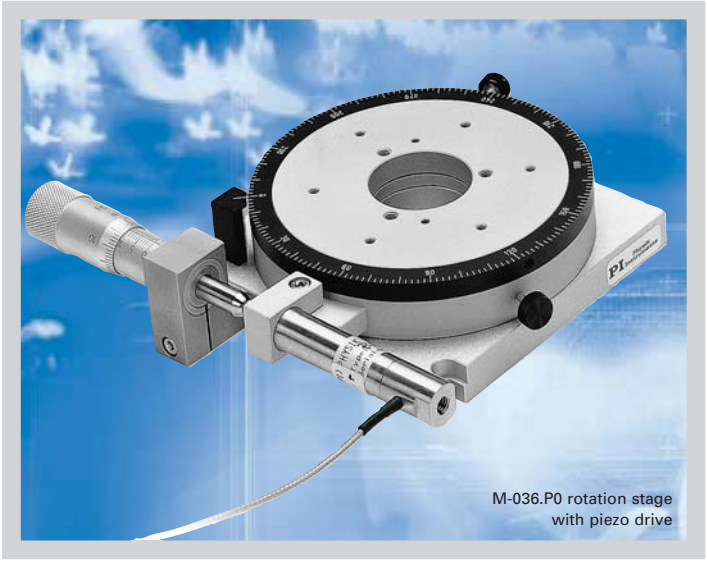
Technical Data

Model	M-035.50	M-035.P0	M-035.PS	M-035.D01	M-035.DP1	M-035.DS1	Units
Coarse rotation range	360	360	360	360	360	360	°
Rotation range (micrometer drive)	19	19	19	12.6	12.6	12.6	°
Rotation range (piezo drive)	–	1,040	1,040	–	1,040	1,040	µrad
Min. incremental motion (piezo drive)	–	<1	<1	–	<1	<1	µrad
Repeatability (piezo drive)	–	–	2	–	–	2	µrad
Unidirectional repeatability (motor drive)	–	–	–	10	10	10	µrad
Backlash (motor drive)	–	–	–	50	50	50	µrad
Design resolution (motor drive)	–	–	–	0.08	0.08	0.08	µrad
Min. incremental motion (motor)	–	–	–	2	2	2	µrad
Minimum incremental motion (micrometer drive)	23	23	23	–	–	–	µrad
Rotation / linear input	22.7	22.7	22.7	22.7	22.7	22.7	µrad/µm
Tangent-arm length	44	44	44	44	44	44	mm
Wobble	<150	< 150	<150	<150	<150	<150	µrad
Max. velocity	–	–	–	1.2	1.2	1.2	°/s
Max. axial force	±300	±300	±300	±300	±300	±300	N
Max. torque (θ_X, θ_Y)	±3	±3	±3	±3	±3	±3	Nm
Max. torque CW*	3	3	3	3	3	3	Nm
Max. torque CCW*	0.05	0.05	0.05	0.05	0.05	0.05	Nm
Drive (manual or motor)	M-622	M-622	M-622	M-227.10	M-227.10	M-227.10	
Piezo drive	–	P-840.30	P-841.30	–	P-840.30	P-841.30	
Mass	0.4	0.5	0.52	0.6	0.65	0.67	kg
Body material	Al, St	Al, St	Al, St	Al, St	Al, St	Al, St	
Recommended controller	–	–	–	C-863, single axis, C-843 PCI board for up to 4 axes	C-863, single axis, C-843 PCI board for up to 4 axes	C-863, single axis , (p. 4-114) C-843 PCI board (p. 4-120) for up to 4 axes	
Recommended piezo controller	–	E-660, E-610 E-500 System	E-610 E-500 System	–	E-660, E-610 E-500 System	E-610 (p. 2-110) E-500 System (p. 2-142)	

*CW: clockwise; CCW: counter-clockwise

M-036 Precision Rotation Stage

Piezo Drive Option for Nanometer Precision


M-036.P0 rotation stage with piezo drive

- **Sub-Microradian Resolution**
- **360° Coarse Range, up to 21° Fine Range**
- **Precision Micrometer or DC Motor Drives**
- **Piezo Option for High-Resolution Scanning and Tracking**
- **Ø 30 mm Clear Aperture**

M-036 series precision rotation stages with tangent-arm drive feature high resolution, excellent repeatability and minimum wobble. The stages are equipped with double-row ball bearings for zero backlash and high load capacity. Both the rotation platform and the scale ring (graduated in 2-degree increments) can be independently coarse positioned over 360° degrees and then locked with screws.

Drive Options

A total of six different drive types are offered. They include various combinations of piezoelectric fine-positioners (closed-loop or open-loop), manual and motorized micrometer drives.

Manual Drive

The basic version, the M-036.00, is equipped with a micrometer drive and a zero-backlash magnetic coupling. The micrometer motion, when converted into rotation, provides a positioning range of 21° degrees (see p. 4-82 for information on how to convert linear input into rotation). The resolution is approximately 15 µrad.

DC Motor Drives

The motorized version, the M-036.D01 features a high-resolution DC motor drive unit (M-227.25, p. 1-42) and has a resolution of 2 µrad. (see p. 7-60 for information on how to convert linear input into rotation). A set of limit switches on the rotation stage protects against overtravel damage.

High-Resolution Piezo Option

For applications requiring extremely high angular resolution, models M-036.PS and M-036.P0 (with manual micrometer drive) and M-036.DS1 and M-036.DP1 (motorized) are available. They have an additional piezoelectric fine adjustment, which can also be used for dynamic operation. The piezo drive has a linear travel range of 45 µm with sub-nanometer resolution, which converts to a rotation range of approx. 0.7 mrad and sub-µrad resolution.

The piezo drives in the M-036.PS and M-036.DS1 versions are also equipped with a position sensor, making closed-loop operation possible, with higher stability, reproducibility and accuracy. For more details on the piezo drives, see the "Piezo Actuators & Components" section (p. 1-61 *ff*).

Upgrades

M-036 stages without piezo or DC-motor drives can be upgraded at a later date.

Notes

See "Accessories", page 4-89 *ff.* for adapters, brackets, etc.

Ordering Information

M-036.00
Precision Rotation Stage, Ø 100 mm, Micrometer Drive

M-036.P0
Precision Rotation Stage, Ø 100 mm Micrometer + Piezo Drive

M-036.PS
Precision Rotation Stage, Ø 100 mm, Micrometer + Closed-Loop Piezo Drive

M-036.D01
Precision Rotation Stage, Ø 100 mm, DC Motor Drive

M-036.DP1
Precision Rotation Stage, Ø 100 mm, DC Motor + Piezo Drive

M-036.DS1
Precision Rotation Stage, Ø 100 mm, DC Motor + Closed-Loop Piezo Drive

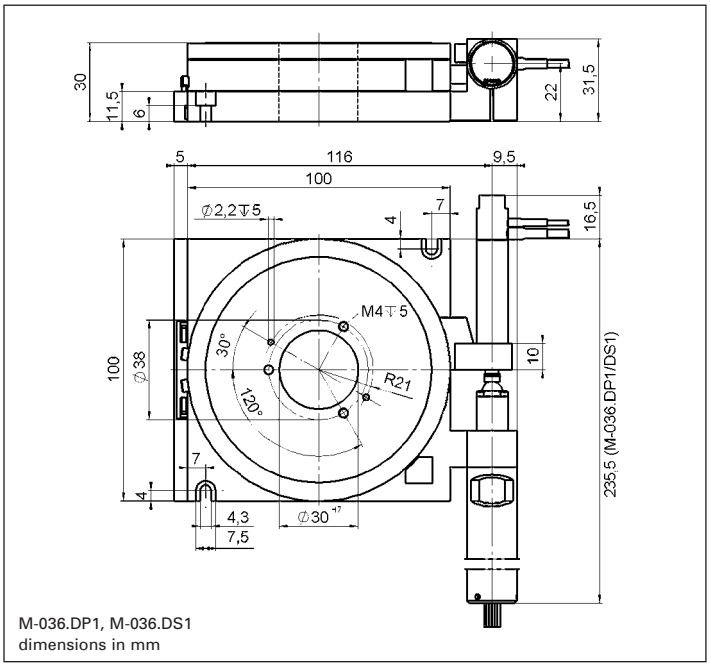
Upgrade Kits

M-036.U0
Upgrade Kit with Open-loop Piezo Drive

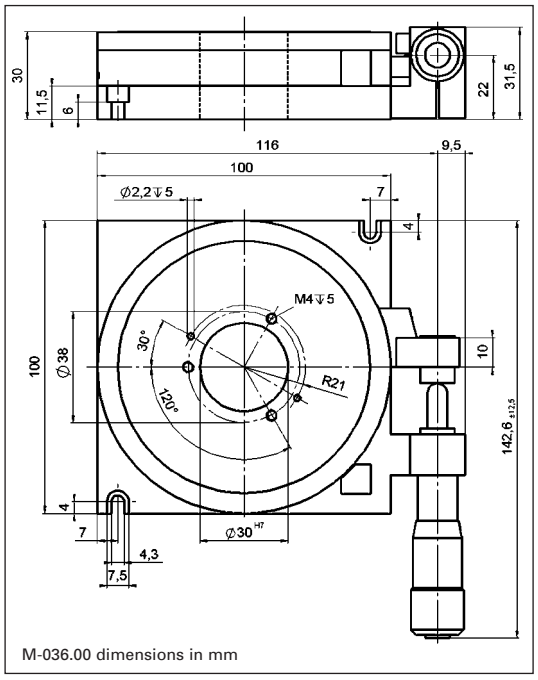
M-036.US
Upgrade Kit with Closed-Loop Piezo Drive

M-036.UD
Upgrade Kit with DC Motor Drive (for factory installation)

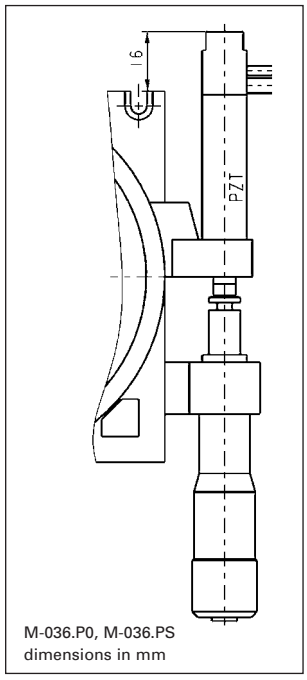
Ask about custom designs!



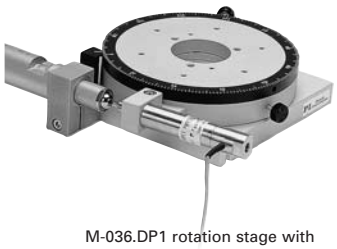
M-036.DP1, M-036.DS1 dimensions in mm



M-036.00 dimensions in mm



M-036.P0, M-036.PS
dimensions in mm


M-036.DP1 rotation stage with
DC-mike and piezo drive

Linear Actuators & Motors
Nanopositioning / Piezoelectrics
Nanometrology
Micropositioning
Hexapod 6-Axis Systems / Parallel Kinematics
Linear Stages
Translation (X)
Vertical (Y)
Multi-Axis
Rotary & Tilt Stages
Accessories
Servo & Stepper Motor Controllers
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Multi-Channel
Micropositioning Fundamentals
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Technical Data

Model	M-036.00	M-036.P0	M-036.PS	M-036.D01	M-036.DP1	M-036.DS1	Units
Coarse rotation range	360	360	360	360	360	360	°
Rotation range (micrometer drive)	21	21	21	10 **	10 **	10 **	°
Rotation range (piezo drive)	–	700	700	–	700	700	µrad
Minimum incremental motion (piezo drive)	–	<1	<1	–	<1	<1	µrad
Repeatability (piezo drive)	–	–	2	–	–	2	µrad
Unidirectional repeatability (motor drive)	–	–	–	10	10	10	µrad
Backlash (motor drive)	–	–	–	40	40	40	µrad
Design resolution (motor drive)	–	–	–	0.08	0.08	0.08	µrad
Minimum incremental motion (motor drive)	–	–	–	2	2	2	µrad
Minimum incremental motion (micrometer drive)	23	23	23	–	–	–	µrad
Rotation / linear input	15	15	15	15	15	15	µrad/µm
Tangent-arm length	66	66	66	66	66	66	mm
Wobble	<75	<75	<75	<75	<75	<75	µrad
Max. velocity	–	–	–	0.8	0.8	0.8	°/s
Max. axial force	±400	±400	±400	±400	±400	±400	N
Max. torque (θ_x, θ_y)	±6	±6	±6	±6	±6	±6	Nm
Max. torque CW*	4.5	4.5	4.5	4.5	4.5	4.5	Nm
Max. torque CCW*	0.075	0.075	0.075	0.075	0.075	0.075	Nm
Drive (manual or motor)	M-624	M-624	M-624	M-227.25	M-227.25	M-227.25	
Piezo drive	-	P-840.30	P-841.30	-	P-840.30	P-841.30	
Mass	0.85	0.95	0.97	1.05	1.15	1.17	kg
Body material	Al, St	Al, St	Al, St	Al, St	Al, St	Al, St	
Recommended controllers	–	–	–	C-843, C-848, C-863	C-843, C-848, C-863	C-843, C-848, C-863 (p. 4-120, p. 4-122, p. 4-114)	
Recommended piezo controllers	–	E-660, E-610 E-500 System	E-610 E-500 System	–	E-660, E-610 E-500 System	E-610 (p. 2-110) E-500 System (p. 2-142)	

*CW: clockwise CCW: counter-clockwise
**Limited by limit switch position.

Notes on Specifications for Micropositioning Stages

Active axes

Specifications given in the data sheet are measured in relation to the defined motion axis. A different motor orientation may result in modified data.

Motion and positioning

Travel range

The maximum allowed travel is limited by the length of the drive screw in a spindle/motor combination. Given in the data sheet is the distance between the two limit switches, if present.

Integrated sensor

Rotary or linear encoder

Encoder resolution

Rotary encoder: counts per drive-screw revolution
Linear encoder: interpolated minimum increment that can be distinguished

Design resolution

The theoretical minimum movement that can be made, based on the selection of the mechanical drive components (drive screw 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 of the position feedback sensor system.

Minimum incremental motion

The minimum motion that can be repeatably executed for a given input, which is sometimes referred to as practical or operational resolution. Design resolution and practical resolution have to be distinguished. Design resolutions of 1 nm or better can be achieved with many motor, gearbox and leadscrew combinations. In practical applications, however, stiction/friction, windup, and elastic deformation limit operating resolution. Several PI motorized micropositioners are available with additional piezo fine positioners for applications where repeatable nanometer scale resolution and / or fast response are required.

The data table states typical measured values.

For repeatable nanometer or sub-nanometer resolution see the "Piezo Flexure Stages / High-Speed Scanning Systems" (p. 2-3 *ff*) and "Piezo Actuators & Components" (p. 1-61 *ff*) sections.

Backlash

Position error that appears upon reversing direction due to error in the drivetrain. See page 4-128 *ff* for details. The data table states typical measured values. Data for vacuum versions may differ.

Rotation / linear input, tangent-arm length

Angular displacement of tangent-arm rotation stages is determined by the arm length and the linear motion input pushing the arm (see p. 4-82) for information on how to calculate angular displacement from linear input).

Unidirectional / bidirectional repeatability

Values are typical results (RMS, 1 sigma), see also Glossary

Pitch / yaw

The maximum angular deviation around Y- (pitch) and Z-axis (yaw) over the whole travel range, with X being the direction of motion. Pitch and yaw are usually given as ± values. The data table states typical measured values. See "Definition of Axes and Angles" (see page 4-128 *ff*).

Max. velocity

This is the short-term peak value for horizontal mounting, with no load, and not intended for continuous operation. The average velocity and continuous velocity are lower than the peak value and depend on the load conditions and other environmental parameters. Data for vacuum versions may differ.

Origin repeatability

Repeatability of the reference switch (if present)

Mechanical properties

Motor resolution

Resolution with micro-stepping specified for PI's stepper motor controllers.

Stiffness in motion direction

Typical tolerance: ±20 %

Max. normal load capacity

Centered, vertical load (horizontal installation).

Max. push / pull force

Active and passive force limit in operating direction, at center of stage. Some stages may be able to generate higher forces at the cost of reduced lifetime. Data for vacuum versions may differ.

Drive properties

Drive type / Operating voltage

ActiveDrive™: The operating voltage (usually 24 VDC) for the ActiveDrive™ motors is provided by an external power supply (included in the delivery).

DC motors: DC servo motors require a supply voltage of up to 12 VDC. The operating voltage is usually given as differential value where the magnitude determines the velocity, and the sign determines the motion direction.

Stepper motors: PI stepper motors are usually driven in chopper mode.

Electrical power

Motor manufacturer's information.

Torque

Motor manufacturer's information.

Miscellaneous

Operating temperature range

Safe operation, no damage to the mechanics. All technical data specified in the data sheet refer to room temperature (22 °C ±3 °C).

Material

Micropositioning stages are typically made of anodized aluminum or stainless steel. Small amounts of other materials may be used (for bearings, preload, coupling, mounting, etc.). For special applications other materials are possible like Invar.

Al: Aluminum
N-S: Nonmagnetic stainless steel
St: Steel
I: Invar

Mass

Typical tolerance: ±5 %

Cable length

Typical tolerance: ±10 mm

Recommended motor controller

Compatible motor controllers are described in the Servo & Stepper Motor Controllers (see p. 4-109 *ff*) section

For further information read "Micropositioning Fundamentals" section (see p. 4-127 *ff*).

Accessories

Accessories

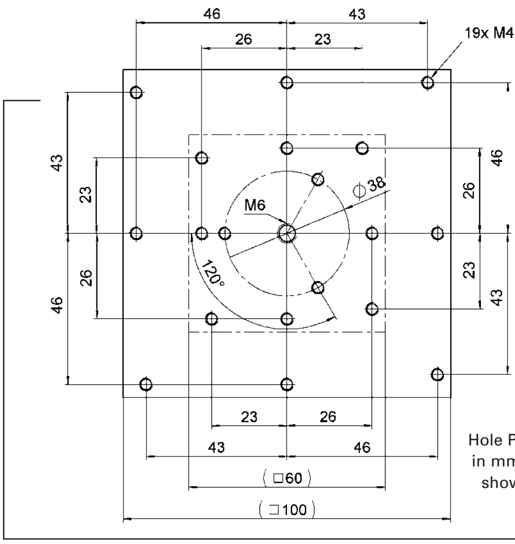
Mounting Adapters for Micropositioning

The following table gives an overview of all possible combinations of PI linear, rotary and tilt stages. Select the positioner to be mounted on top from the left column (e.g. M-035, M-037) and the supporting positioner from the top row.

Example:

To mount an M-035 vertically on an M-511, the M-053.10 adapter is required. No adapter is required for horizontal mounting.

	Bottom	M-035, M-037	M-036	M-038	M-060*	M-105, M-106	M-110	M-111	M-112	M-122	M-126
Top	***Orientation***										
M-035, M-037	horizontal	x	x	x	x	M-105.AP	x	x	x	x	M-105.AP
M-035, M-037	vertical	M-052.40	M-052.40	x	M-052.40	M-052.00 + M-105.AP	x	x	x	x	M-052.00
M-036, M-038	horizontal	x	x	x	x	M-400.AP	x	x	x	x	M-400.AP
M-036, M-038	vertical	M-053.40	M-053.40	M-053.40	M-053.40	M-053.10** + M-400.AP	x	x	x	x	M-053.10** + M-400.AP
M-06x	horizontal	x	x	x	x	x	x	x	x	x	x
M-06x	vertical	x	x	x	x	x	x	x	x	x	x
M-105, M-106	horizontal	M-105.AP	M-105.AP	x	M-105.AP	n/r	x	x	x	x	M-105.AP
M-105, M-106	vertical	M-009.30 + M-009.10	M-009.30 + M-009.10	M-009.30 + M-009.10	M-009.30 + M-009.10	M-009.10 M-105.VB1	x	x	x	x	M-009.30 + M-009.10
M-110	horizontal	M-110.01	M-110.01	M-110.01	M-110.01	x	n/r	n/r	n/r	n/r	M-110.01
M-110	vertical	x	x	x	x	x	M-110.02	M-110.02	M-110.02	M-110.02	x
M-111	horizontal	M-110.01	M-110.01	M-110.01	M-110.01	x	n/r	n/r	n/r	n/r	M-110.01
M-111	vertical	x	x	x	x	x	M-110.03	M-110.03	M-110.03	M-110.03	x
M-112	horizontal	M-110.01	M-110.01	M-110.01	M-110.01	x	n/r	n/r	n/r	n/r	M-110.01
M-112	vertical	x	x	x	x	x	M-110.04	M-110.04	M-110.04	M-110.04	x
M-116	horizontal	x	x	x	x	x	n/r	n/r	n/r	n/r	M-110.01
M-116	vertical	x	x	x	x	x	x	x	x	x	x
M-122	horizontal	M-110.01	M-110.01	M-110.01	M-110.01	x	n/r	n/r	n/r	n/r	M-110.01
M-122	vertical	x	x	x	x	x	M-122.AP1	M-122.AP1	M-122.AP1	M-122.AP1	x
M-126	horizontal	M-105.AP	M-105.AP	x	M-105.AP	M-105.AP	x	x	x	x	n/r
M-126	vertical	x	x	x	M-125.90 + M-105.AP	M-125.90 + M-105.AP	x	x	x	x	M-125.90
M-400	horizontal	x	x	x	x	x	x	x	x	x	x
M-400	vertical	x	x	x	x	x	x	x	x	x	x
M-403, M-404	horizontal	x	x	x	x	x	x	x	x	x	x
M-403, M-404	vertical	x	x	x	x	x	x	x	x	x	x
M-413, M-414	horizontal	x	x	x	x	x	x	x	x	x	x
M-413, M-414	vertical	x	x	x	x	x	x	x	x	x	x
M-511, M-521, M-531	horizontal	x	x	x	x	x	x	x	x	x	x
M-511, M-521, M-531	vertical	x	x	x	x	x	x	x	x	x	x
M-605	horizontal	x	x	x	x	x	x	x	x	x	x
M-605	vertical	x	x	x	x	x	x	x	x	x	x



PI Standard Hole Pattern, dimensions in mm. The dashed lines show the pattern of the 60 x 60 mm stages

M-405, M-410, M-415	M-403, M-404	M-413, M-414	M-451	M-511, M-521, M-531	M-605	M6 / 25 mm	1/4-20/1"
M-105.AP	M-403.AP1	M-413.AP1	n/r	n/r	M-605.11	B-094.00	x
M-052.00	M-403.AP1 + M-052.40	M-413.AP1 + M-052.40	M-053.10	M-053.10	x	x	x
M-400.AP	M-403.AP1	M-413.AP1	n/r	n/r	M-605.11	B-094.00	x
M-053.10** + M-400.AP	M-403.AP1 + M-052.40	M-413.AP1 + M-052.40	M-053.10	M-053.10**	x	x	x
x	M-403.AP1 + M-06x.HP	M-413.AP1 + M-06x.HP	M-06x.HP	M-06x.HP	x	M-06x.HP	M-06x.HP
x	x	x	x	x	x	x	x
M-105.AP	M-403.AP1 + M-105.AP	M-413.AP1 + M-105.AP	M-105.AP	M-105.AP	M-605.11	M-105.HP/ M-105.HP1	M-105.HP/ M-105.HP1
M-009.30 + M-009.10	x	x	x	x	x	x	x
M-110.01	M-403.AP1 M-110.01	M-413.AP1 M-110.01	M-110.01	M-110.01	M-110.01	M-110.01	M-110.01
x	x	x	x	x	x	x	x
M-110.01	M-403.AP1 M-110.01	M-413.AP1 M-110.01	M-110.01	M-110.01	M-110.01	M-110.01	M-110.01
x	x	x	x	x	x	x	x
M-110.01	M-403.AP1 M-110.01	M-413.AP1 M-110.01	M-110.01	M-110.01	M-110.01	M-110.01	M-110.01
x	x	x	x	x	x	x	x
M-110.01	M-403.AP1 M-110.01	M-413.AP1 M-110.01	M-110.01	M-110.01	M-110.01	M-110.01	M-110.01
x	x	x	x	x	x	x	x
M-110.01	M-403.AP1 M-110.01	M-413.AP1 M-110.01	M-110.01	M-110.01	M-110.01	M-110.01	M-110.01
x	x	x	x	x	x	x	x
x	M-403.AP1	M-413.AP1	n/r	M-105.AP	M-605.11	M-126.80	M-126.80
x	M-403.AP1 M-125.90	M-413.AP1 M-125.90	M-125.90	M-125.90	x	x	x
M-592.00	x	x	x	M-400.AP	x	x	x
n/r	x	x	x	M-592.00	x	M-490.MS	M-490.MS
x	n/r	x	M-403.AP3	M-403.AP3	x	M-403.AP1	M-403.AP1
x	M-403.AP2	x	x	x	x	x	x
x	x	n/r	M-403.AP3	M-403.AP3	x	M-413.AP1	M-413.AP1
x	x	M-413.AP2	x	x	x	x	x
x	x	x	x	n/r	x	M-590.00	M-590.00
x	x	x	x	M-592.10	x	x	x
M-110.01	x	x	x	M-110.01	n/r	M-110.01	M-110.01
x	x	x	x	x	M-605.AV1	x	x

n/r.: no adapter required;
x: combination not possible;
*For M-061/M-062 no combinations possible
**Versions with DC-Mike Drive require angle bracket M-053.20

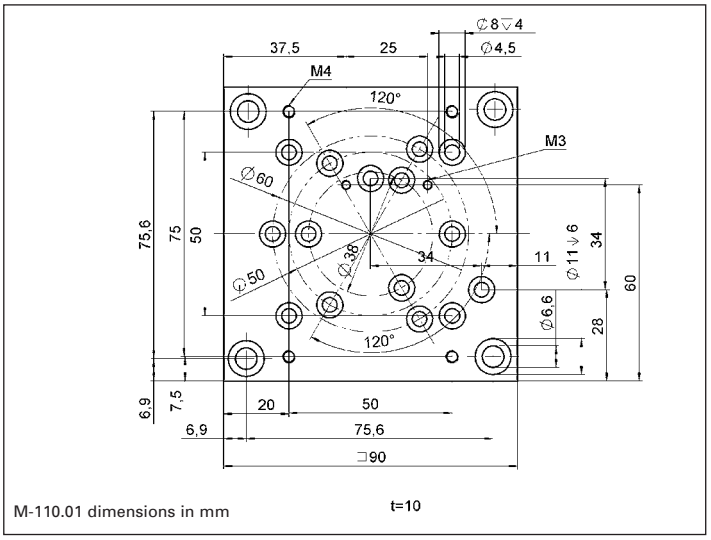
Accessories

Mounting Adapters for M-110, M-111, M-112 Stages

M-110.01

Adapter plate for mounting of M-110 and M-111 (F-130) and M-605 series stages on honeycomb tables (metric & imperial).

Material: Al

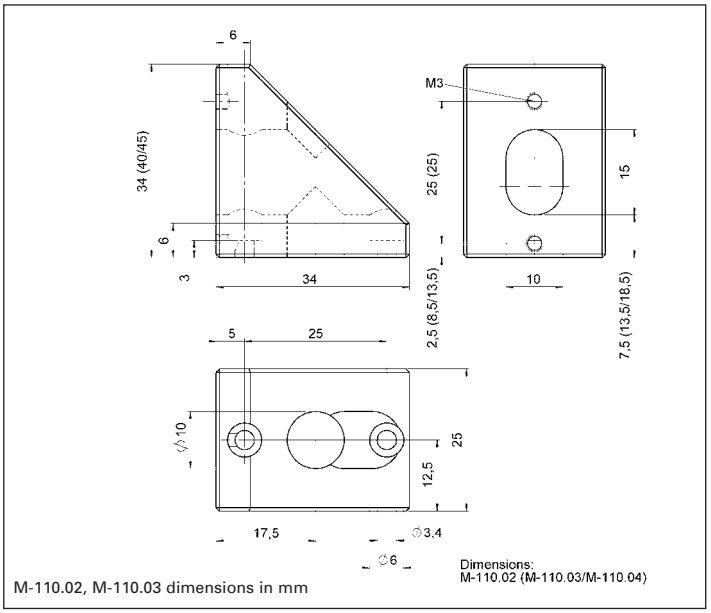


M-110.01 dimensions in mm

M-110.02, M-110.03, M-110.04

Z-axis mounting bracket for vertical mount of M-110 (M-110.02), M-111 (M-110.03) and M-112 (M-110.04) series stages on M-110, M-111 and M-112 series stages.

Material: Al



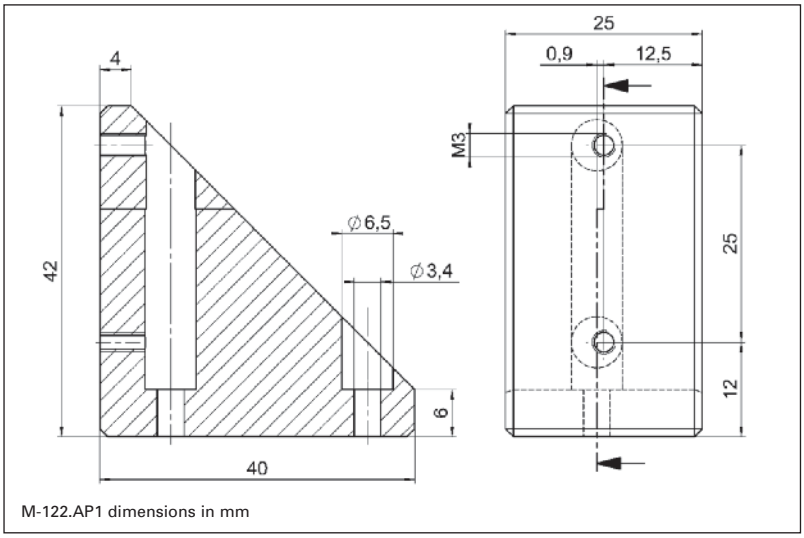
M-110.02, M-110.03 dimensions in mm

Mounting Adapters for M-122 Stages

M-122.AP1

Mounting bracket for vertical mount of M-122 on M-110, M-111, M-112 and M-122 stages.

Material: Al

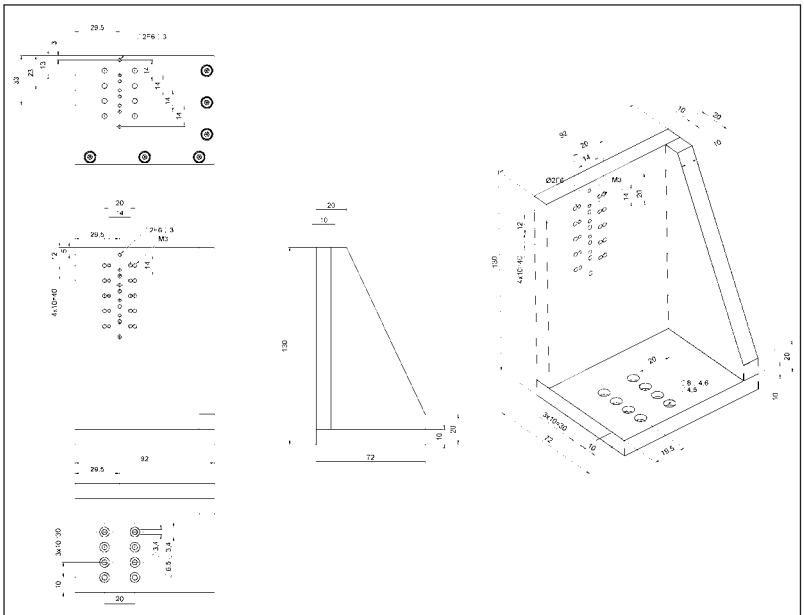


M-122.AP1 dimensions in mm

M-122.AV1

Z-axis mounting bracket for vertical mount of M-122 stages.

Material: Al



M-122.AV1 dimensions in mm

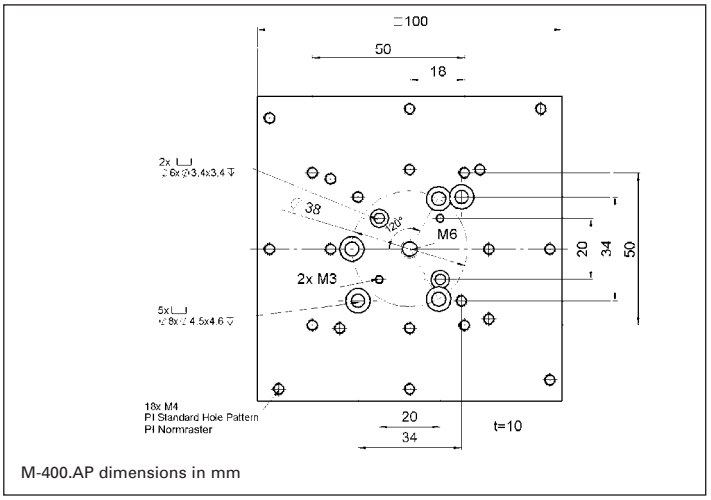
Accessories

Mounting Adapters for Honeycomb Tables and M-405, M-410 and M-415 Stages

M-400.AP

Adapter plate for mounting stages w/o PI standard hole pattern (e.g. M-405, M-410 and M-415) on stages with PI standard hole pattern and vice versa.

Material: Al; Mass: 0.25 kg

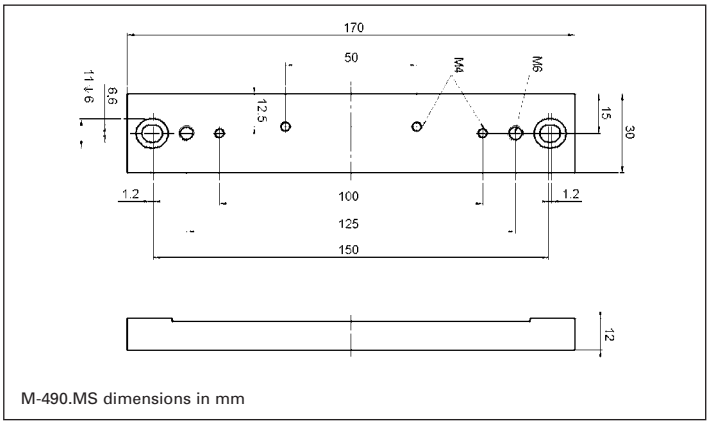


M-400.AP dimensions in mm

M-490.MS

Set of two for mounting M-405, M-410 and M-415 stages on honeycomb table tops etc. (metric and imperial).

Material: Al; Mass: 0.4 kg

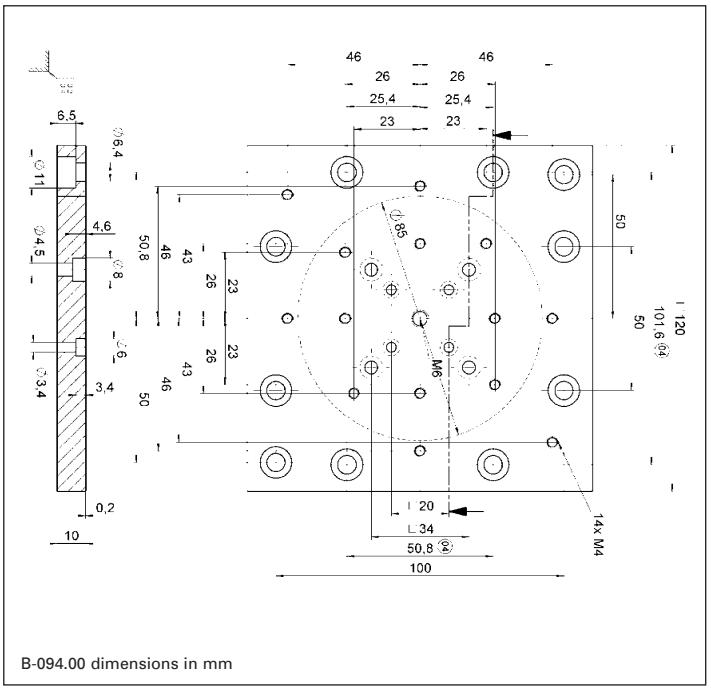


M-490.MS dimensions in mm

B-094.00

Adapter plate for mounting several translation stages and rotary stages on honeycomb tables (M 6 on 25 mm spacing).

Material: Al



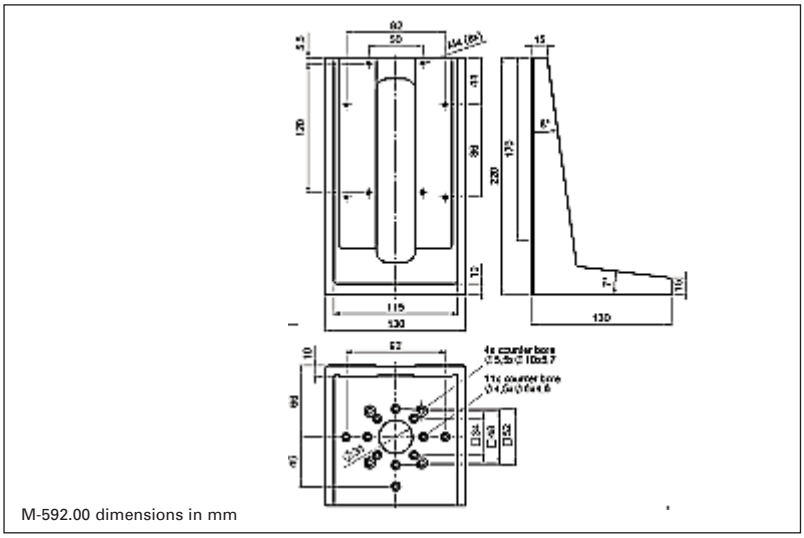
B-094.00 dimensions in mm

Mounting Adapters for M-405, M-410, M-415, M-511, M-521 and M-531 Stages

M-592.00

Z-axis mounting bracket for vertical mount of M-405, M-410 and M-415 stages.

Material: Al; Mass: 1.1 kg

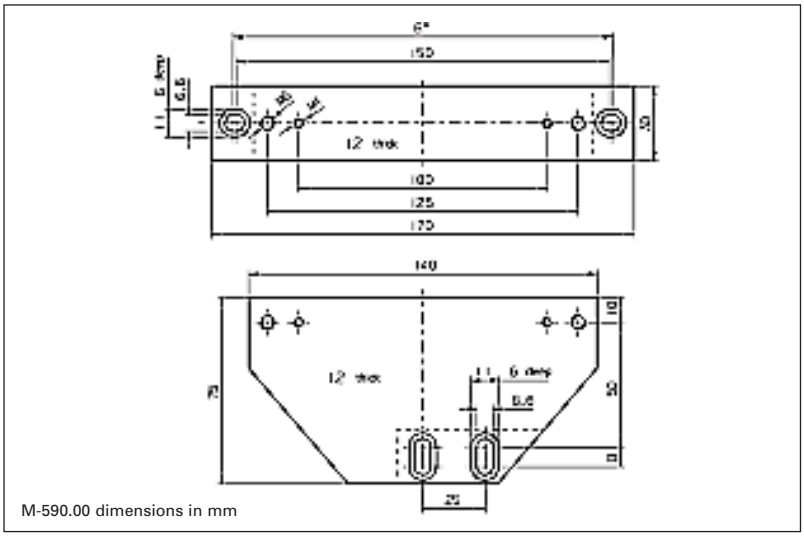


M-592.00 dimensions in mm

M-590.00

Three-point support set for mounting M-511, M-521 and M-531 stages on honeycomb table tops etc. (metric and imperial).

Material: Al; Mass: 0.4 kg

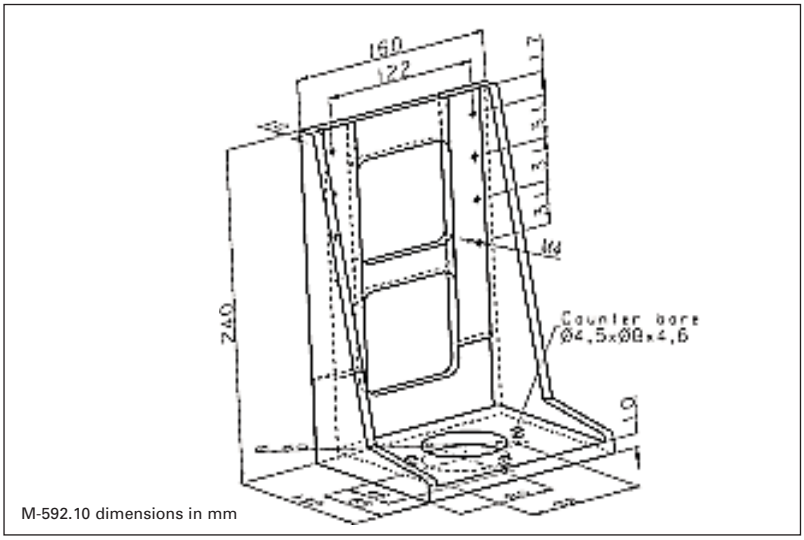


M-590.00 dimensions in mm

M-592.10

Z-axis mounting bracket for vertical mount of M-511, M-521 and M-531 stages.

Material: Al; Mass: 1.5 kg



M-592.10 dimensions in mm

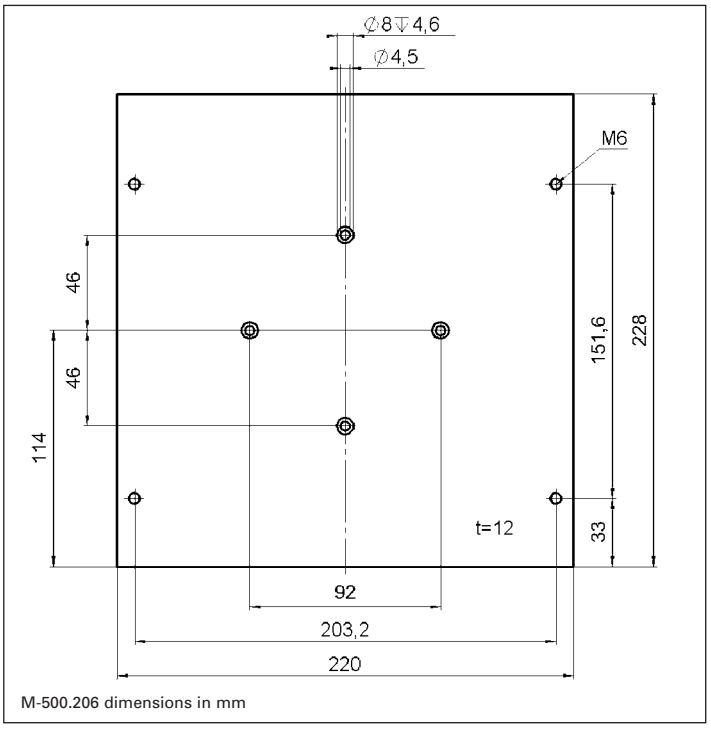
Accessories

Mounting Adapters for M-511, M-521 and M-531 Stages

M-500.206

Adapter plate for mounting F-206 MicroMotion Robots on M-511, M-521 and M-531 translation stages.

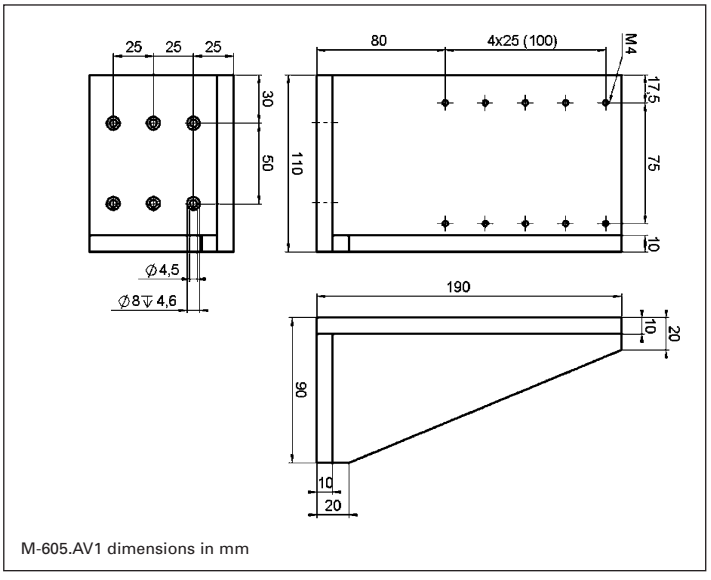
Material: Al



M-500.206 dimensions in mm

M-605.AV1

Adapter bracket for vertical mounting of M-605 on M-605 stages.



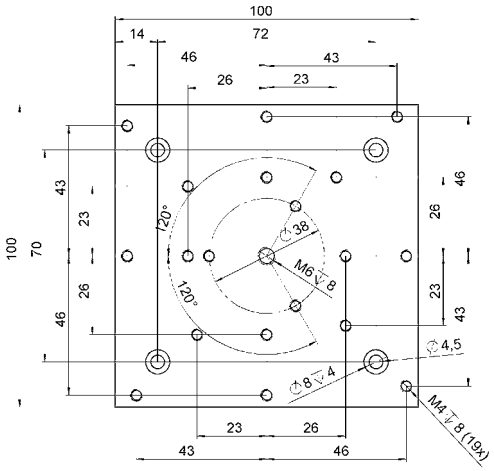
M-605.AV1 dimensions in mm

Mounting Adapters for M-403 / M-404 Stages

M-403.AP1

Adapter plate for horizontal mount of stages with PI standard hole pattern and vertical mount of rotation stages on M-403/M-404 stages.

Material: Al

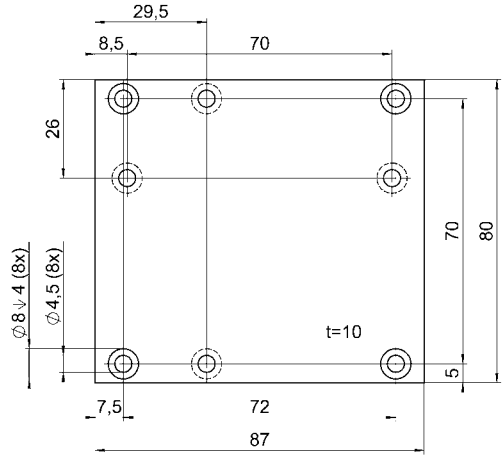


M-403.AP1 dimensions in mm

M-403.AP2

Adapter bracket for vertical mount of M-403/M-404 on M-403/M-404 stages.

Material: Al

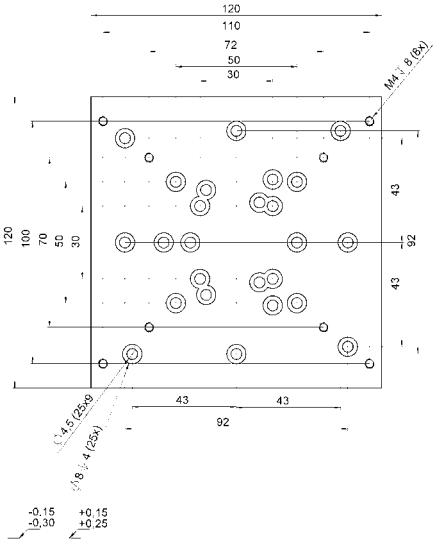


M-403.AP2 dimensions in mm

M-403.AP3

Adapter plate for mount on PI standard hole pattern and horizontal mount of M-403/404 on M-413/M-414, M-451, M-505 and M-511/521/531 stages.

Material: Al



M-403.AP3 dimensions in mm

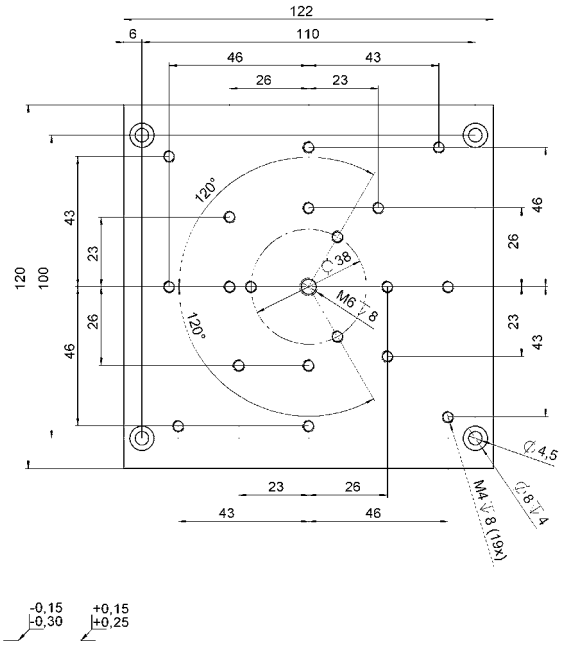
Accessories

Mounting Adapters for M-413 / M-414 Stages

M-413.AP1

Adapter plate for horizontal mount of stages with PI standard hole pattern and vertical mount of rotation stages on M-413/M-414 stages.

Material: Al

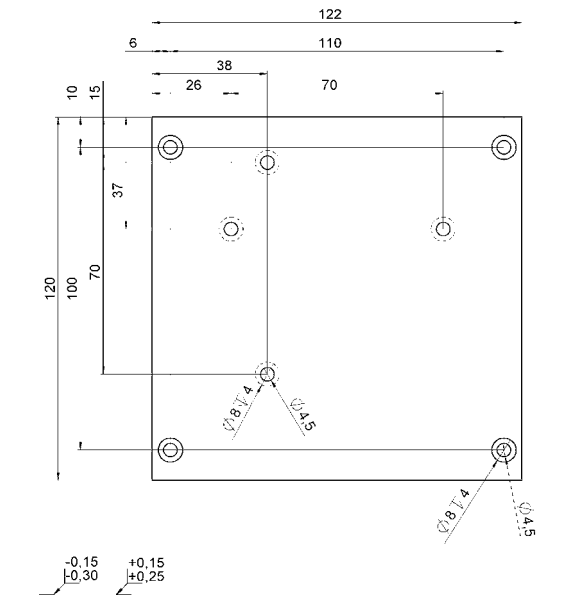


M-413.AP1 dimensions in mm

M-413.AP2

Adapter bracket for vertical mount of M-413/M-414 on M-413/M-414 stages.

Material: Al



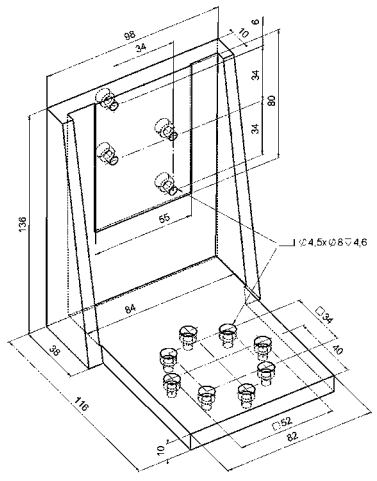
M-413.AP2 dimensions in mm

Mounting Adapters for M-126 and M-105 Stages

M-125.90

Z-axis mounting bracket for vertical mount of M-126 stages.

Material: Al; Weight: 0.68 kg

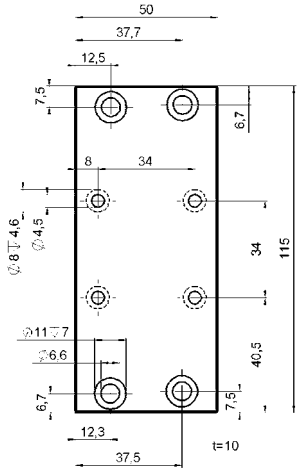


M-125.90 dimensions in mm

M-126.80

Adapter plate for mounting M-126 stages on honeycomb tables (metric & imperial).

Material: Al

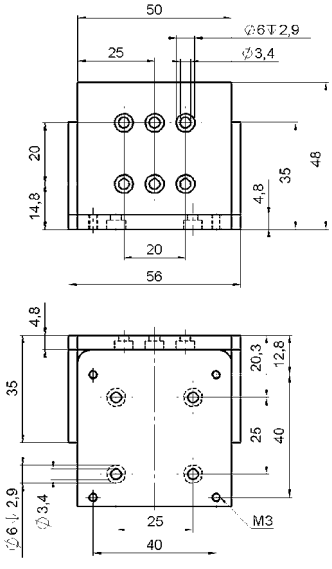


B-126.80 dimensions in mm

M-105.NC

Mounting bracket for mounting P-611 NanoCube® NanoPositioning stages on M-105, M-110 and M-111 stages. Can be combined with B-082.10 adapter plate for adaptation to other PI translation stages.

Material: Al



M-105.NC dimensions in mm

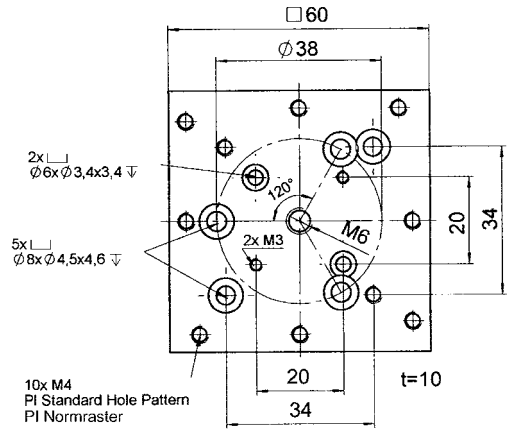
Accessories

Mounting Adapters for M-105 / M-106 and M-126 Stages

M-105.AP

Adapter plate for mounting stages w/o PI standard hole pattern (M-105/M-106, M-126 etc.) on stages with PI standard hole pattern and vice versa.

Material: Al, Weight: 0.09 kg

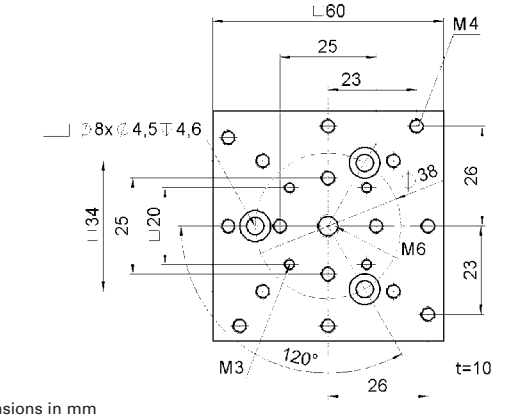


M-105.AP dimensions in mm

B-082.10

Adapter plate for horizontal mount of M-105/M-106 stages on stages with PI standard hole pattern (e.g. M-011, M-014).

Material: Al, Weight: 0.14 kg

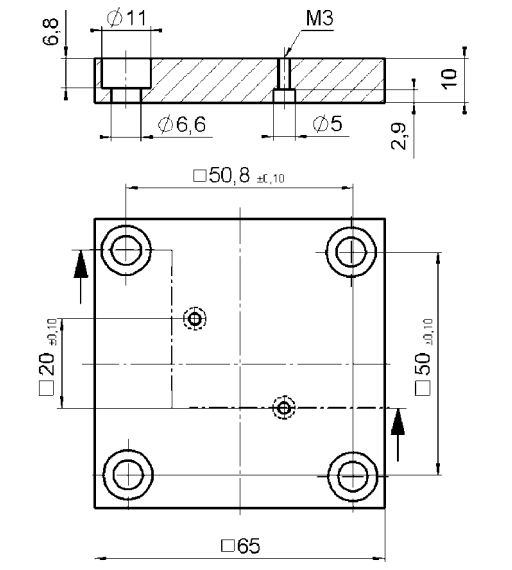


B-082.10 dimensions in mm

M-105.HP

Adapter plate. For mounting M-105 stages (and F-110) on honeycomb tables (metric & imperial).

Material: Al



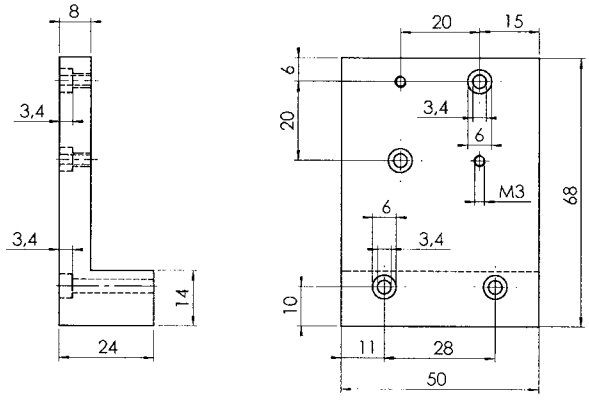
M-105.HP dimensions in mm

Mounting Adapters for M-105 / M-106 Stages

M-009.10

Z-axis mounting bracket for vertical mount of M-105/106 stages on M-105/106 stages (attaches to side of M-105).

Material: Al; Weight: 0.1 kg

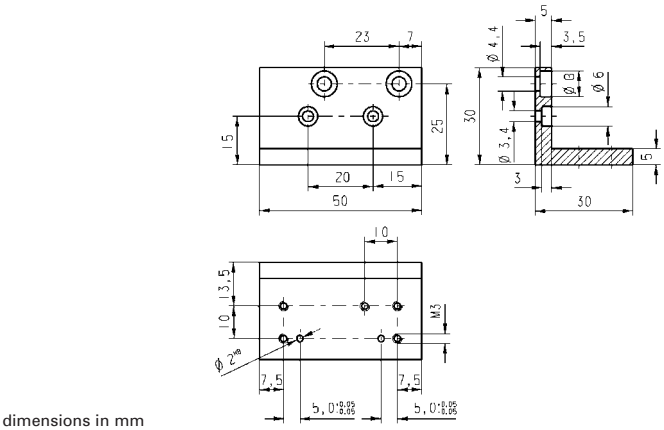


M-009.10 dimensions in mm

M-009.20

Mounting bracket for mounting P-280 PZT block actuators or F-010 fiber holders on vertically mounted M-105 / M-106 stages.

Material: Al; Weight: 0.04 kg

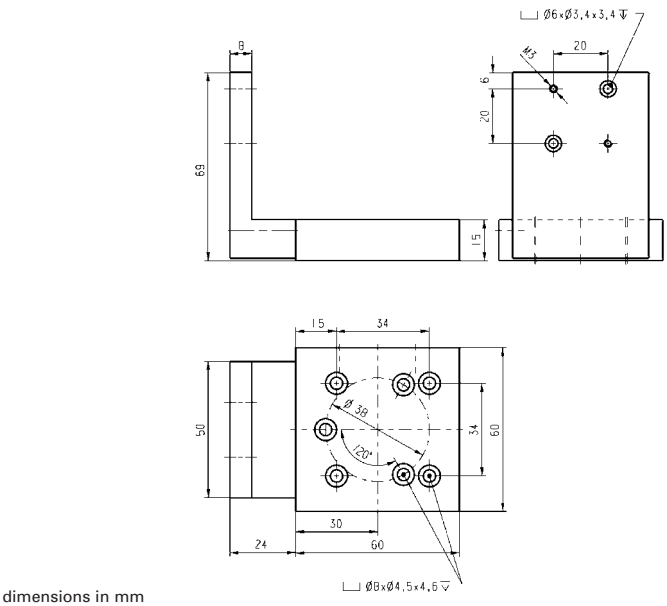


M-009.20 dimensions in mm

M-009.30

Z-axis adapter plate for vertical mount of M-105/6 stages on stages with PI Standard Hole Pattern (requires M-009.10)

Material: Al; Weight: 0.14 kg



M-009.30 dimensions in mm

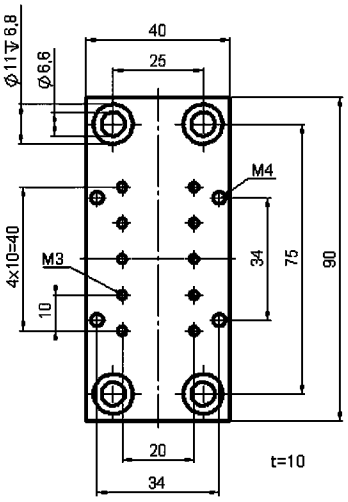
Accessories

Mounting Adapters for M-105 Stages

M-105.HP1

Adapter plate. For mounting M-105 stages (and F-110) on honeycomb tables (metric & imperial).

Material: Al

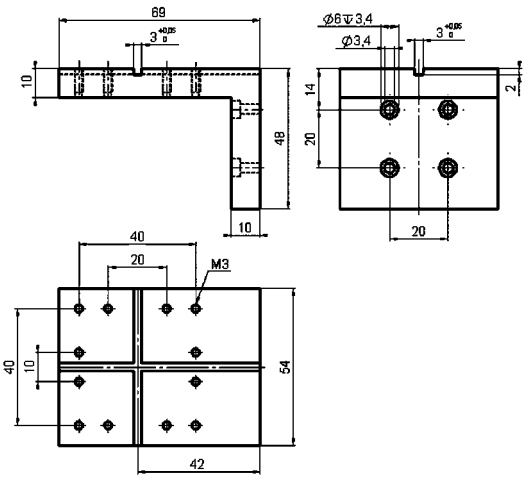


M-105.HP1 dimensions in mm

M-105.MB

Mounting bracket for mounting accessories (e.g. F-603 objective holders) on M-105 stages.

Material: AL; Mass: 1.46 kg

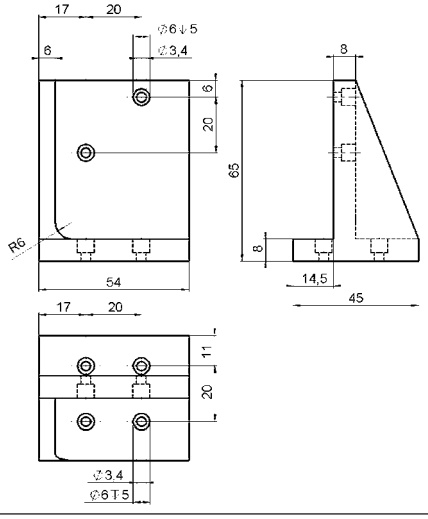


M-105.MB dimensions in mm

M-105.VB1

Z-axis mounting bracket for vertical mount of M-105/M-106 stages on M-105/M-106 stages (attaches to top of M-105).

Material: Al; Mass: 0.39 kg



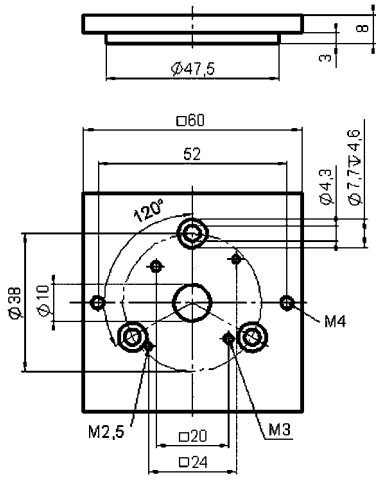
M-105.VB1 dimensions in mm

Mounting Adapters for M-037, M-038 Rotation Stages

M-087.10

Adapter plate for horizontal mounting of translation stages (e. g. M-105) on M-035 and M-037 rotation stages.

Material: Al; Mass: 0.07 kg

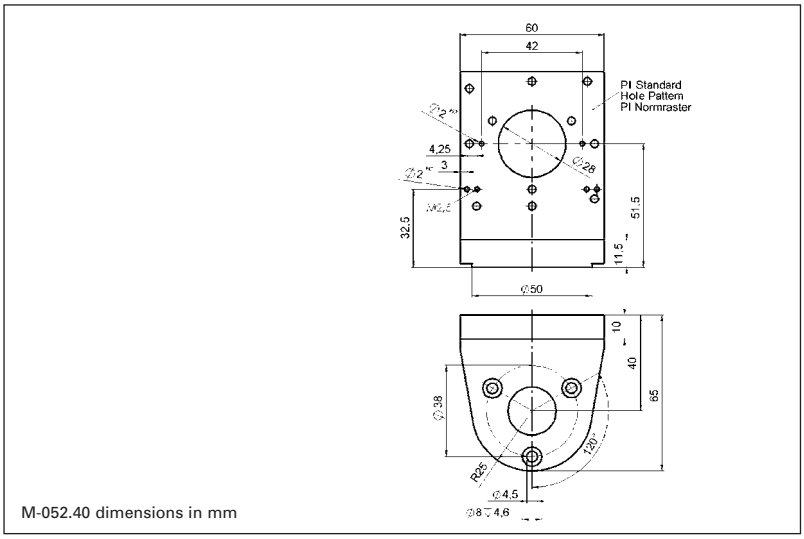


M-087.10 dimensions in mm

M-052.40

Z-axis mounting bracket for vertical mount of M-011, M-035, M-037 and M-041/42 on M-035 and M-037 rotation stages.

Material: Al; Mass: 0.19 kg

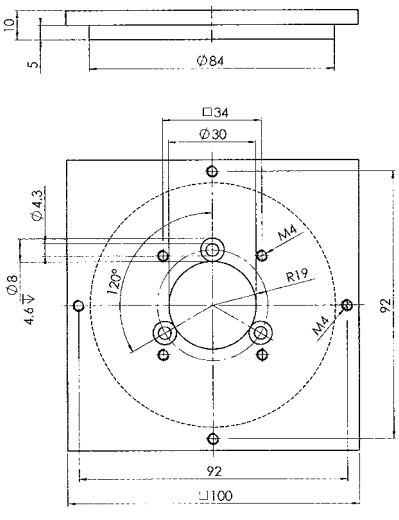


M-052.40 dimensions in mm

M-088.10

Adapter plate for horizontal mounting of translation stages on M-036 rotation stage.

Material: Al; Mass: 0.2 kg



M-088.10 dimensions in mm

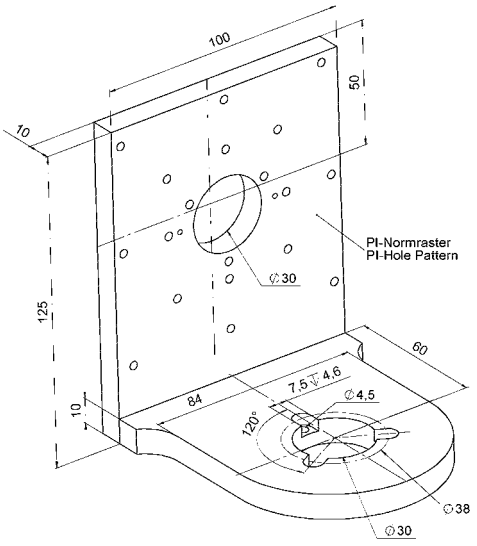
Accessories

Mounting Adapters for M-037, M-038 Rotation Stages

M-053.40

Z-axis mounting bracket for vertical mount of M-014 (manual versions), M-036, M-038 and M-043/M-044 on M-036 and M-038 rotation stages.

Material: Al; Mass: 0.5 kg



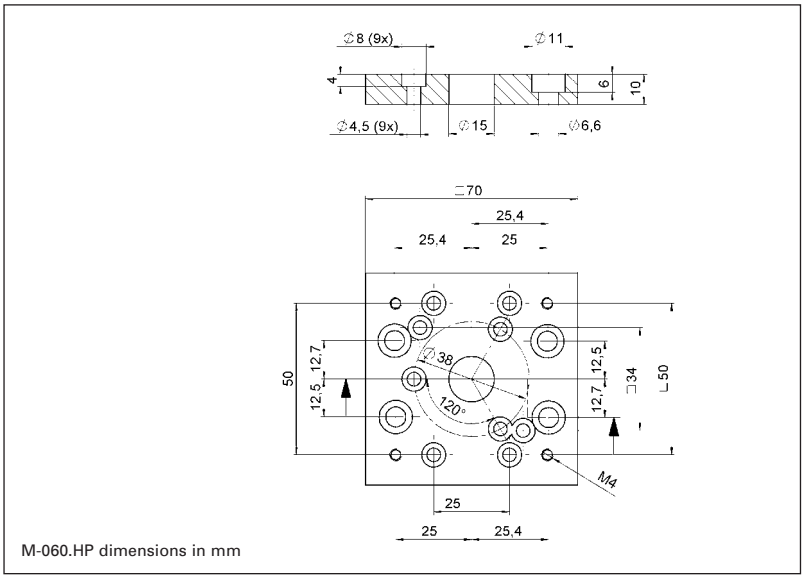
M-053.40 dimensions in mm

Mounting Adapters for M-060, M-061 and M-062 Stages

M-060.HP

Adapter plate for horizontal mount of M-06x stages on M-035, M-036, M-060, M-451, M-505 and M-5x1 stages.

Material: Al

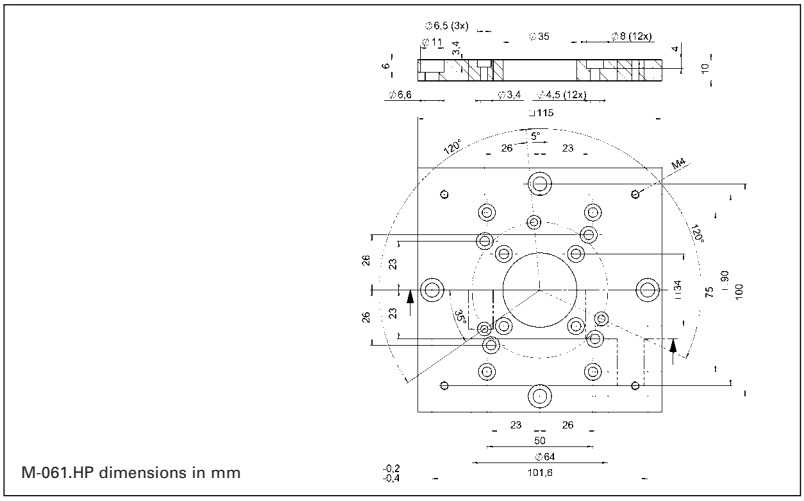


M-060.HP dimensions in mm

M-061.HP

Adapter plate for horizontal mount of M-06x stages on M-035, M-036, M-038, M-060, M-451, M-505 and M-5x1 stages.

Material: Al

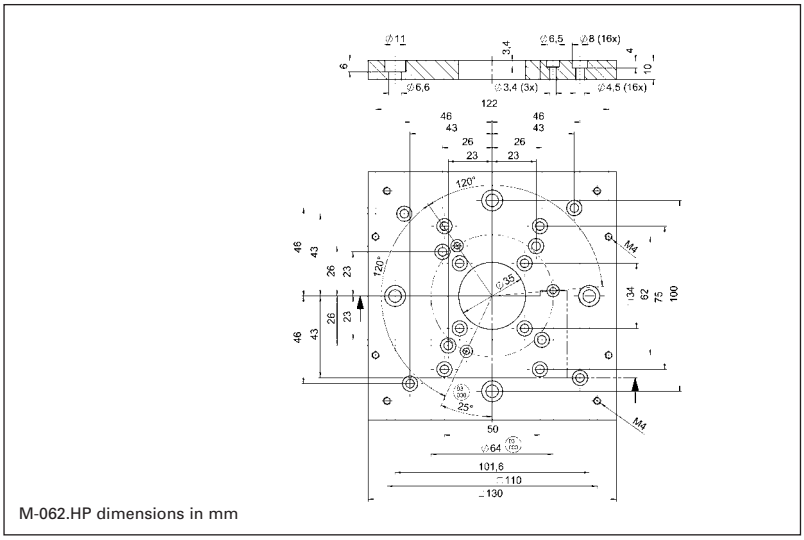


M-061.HP dimensions in mm

M-062.HP

Adapter plate for horizontal mount of M-06x stages on M-035, M-036, M-038, M-060, M-451, M-505 and M-5x1 stages.

Material: Al



M-062.HP dimensions in mm

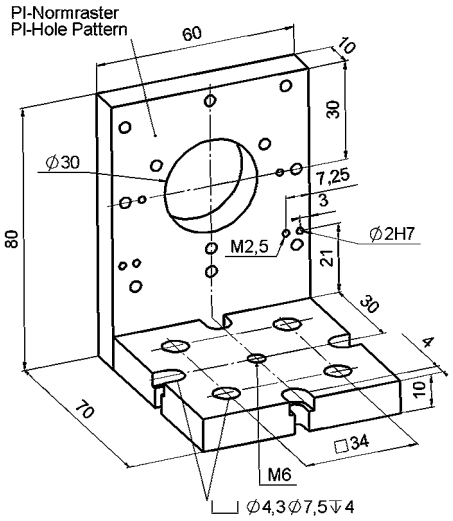
Accessories

Mounting Brackets for M-011, M-035, M-037, M-041, M-042 Stages

M-052.00

Z-axis mounting bracket for vertical mount of M-011, M-035, M-037 and M-041/42 on stages with PI standard hole pattern.

Material: Al; Mass: 0.22 kg

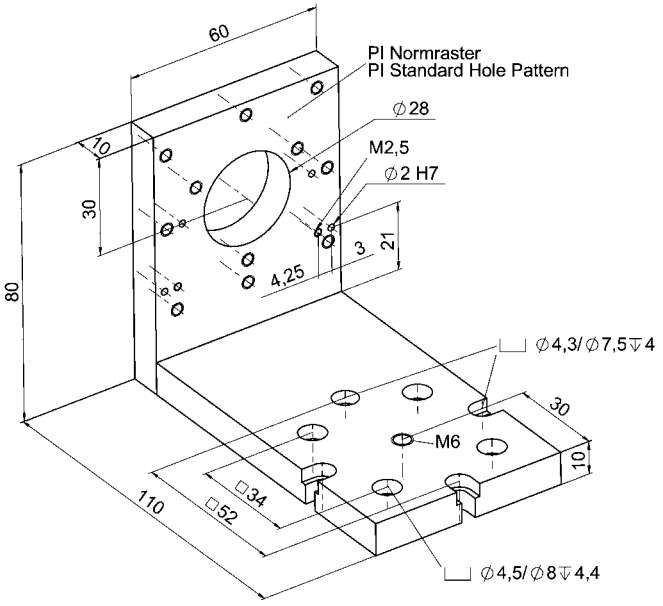


M-052.00 dimensions in mm

M-052.30

Z-axis mounting bracket (laterally extended M-052.00) for vertical mount of M-011, M-035, M-037 and M-041/42 on stages with PI standard hole pattern.

Material: Al; Mass: 0.4 kg



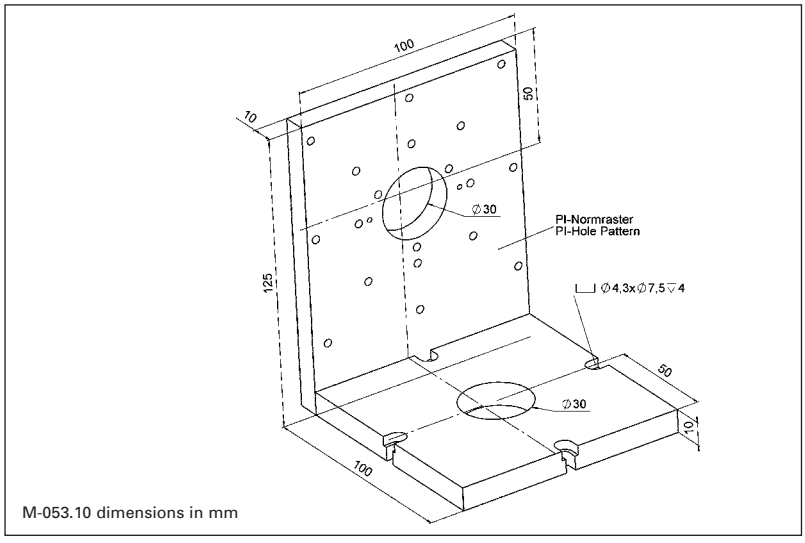
M-052.30 dimensions in mm

Mounting Brackets for M-014, M-036, M-043, M-044 Stages

M-053.10

Z-axis mounting bracket for vertical mount of M-014 (non-motorized), M-036 and M-043/44 on stages with PI standard hole pattern.

Material: Al; Mass: 0.6 kg

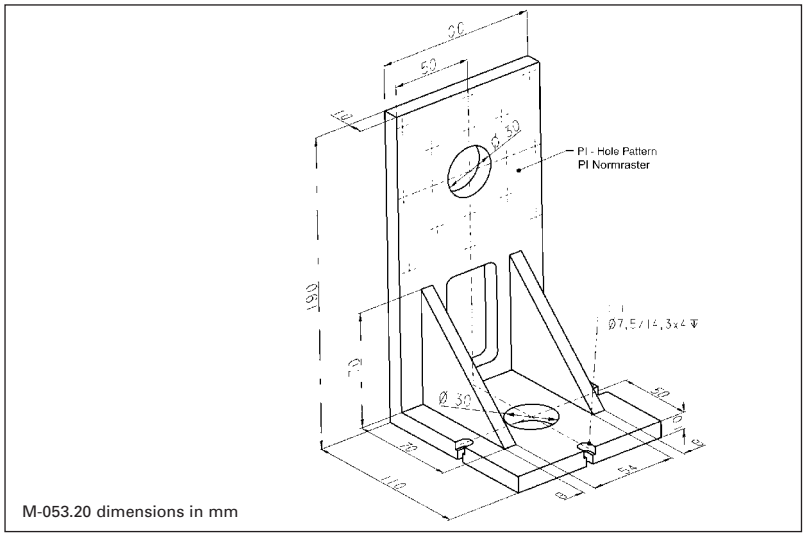


M-053.10 dimensions in mm

M-053.20

Z-axis mounting bracket (vertically extended M-053.10) for vertical mount of M-014 (motorized), M-036 and M-043/44 on stages with PI standard hole pattern.

Material: Al; Mass: 0.7 kg

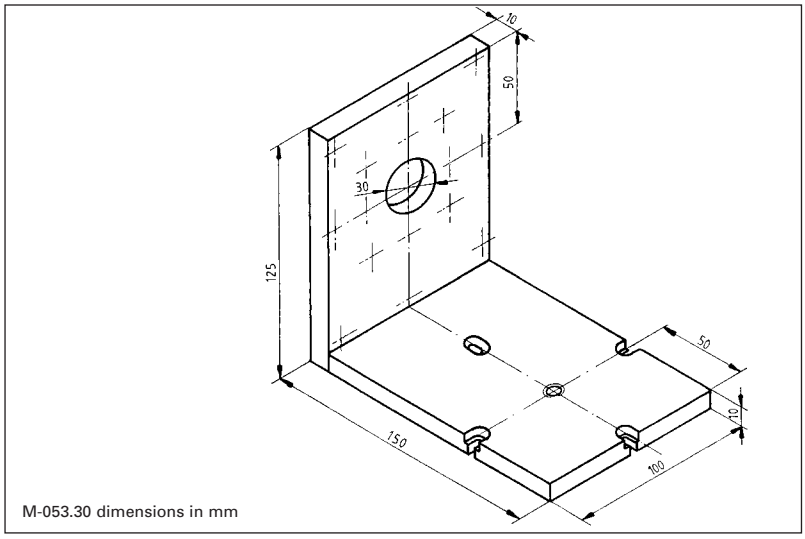


M-053.20 dimensions in mm

M-053.30

Z-axis mounting bracket (laterally extended M-053.10) for vertical mount of M-014 (non-motorized), M-036 and M-043/44 on stages with PI standard hole pattern.

Material: Al; Mass: 0.7 kg



M-053.30 dimensions in mm

Accessories

Flexible Couplings and Mounting Adapters for Micrometers

M-149 flexible couplings

M-149

The M-149 flexible bellows couplings allow zero-backlash connection between motor shaft and drive shaft automatically compensating for parallel and angular misalignment.

Dimensions in mm

(outside diameter x length; bore shaft diameters left/right)

M-149.01:
17 x 30.2 mm; 4 mm / 4 mm

M-149.02:
17 x 30.2 mm; 5 mm / 5 mm

M-149.03:
17 x 30.2 mm; 6 mm / 6 mm

M-149.11:
12 x 23.6 mm; 4 mm / 4 mm

M-149.12:
12 x 23.6 mm; 5 mm / 5 mm

M-149.14:
12 x 23.6 mm; 2 mm / 5 mm

M-149 flexible couplings

M-151

Holders for manual micrometers and DC-Mikes on M-011 and M-014.

Dimensions in mm

(inner diameter x length)

M-151.10:

12 x 17 mm (holds M-623/4 micrometer)

M-151.30:

16 x 10 mm (holds 10 mm M-227)

M-151.40:

16 x 14 mm (holds 25 & 50 mm M-227)

M-151.50:

19 x 14 mm (holds 25 & 50 mm M-227)

Servo & Stepper Motor Controllers

Selection Guide: Motor Controllers

For Servo Motors and Stepper Motors, Piezo Motors and Hybrid Systems

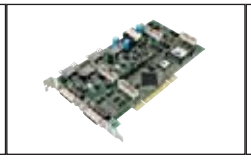
PI offers a large variety of innovative motion control solutions for precision micropositioning devices from classical stepper motors, ceramic linear motors to fast voice-coil-driven scanners and complex Hexapod 6-degree-of-freedom robots. Standard automation controllers handle up to 18 axes. Custom systems have been built capable of coordinating up to 273 axes.

Models	Description	Axes	Output for Motor Types	PC Interfaces	Page
C-184 C-185	Drivers for PILine® ultrasonic piezo linear motors	1	PILine® ultrasonic piezomotor	–	1-36
C-663	Mercury™ stepper motor controller compact, networkable, economical	1, to 16**	2-phase-stepper	RS-232, USB	4-112
C-863	Mercury™ DC-Servo motor controller compact, networkable, economical	1, to 16**	DC-servo	USB, RS-232	4-114
C-843	PCI bus controller card, integrated linear amplifier and PWM outputs, also drives the V-106 voice coil scanners	2, 4	DC-servo, voice coil	PCI Bus	4-120
C-848	Servo-motor controller, 19"-package, integrated linear amplifier and PWM outputs	2, 4	DC-servo	RS-232, TCP/IP	4-122
C-880	Automation platform, very flexible, optional photometer and photonics alignment routines	4 - 18	DC-servo, piezo, voice coil	RS-232, TCP/IP	4-124
C-702	Motion Controller & Driver for Simultaneous Operation of Closed-Loop DC Servo Motors and Piezo Actuators	2	DC-servo (PWM) / piezo	TCP/IP, RS-232, VGA, Keyboard	4-118
C-867	High-speed, closed-loop controller/driver for closed-loop PILine® piezomotors, networkable	1 to 16**	PILine® ultrasonic piezomotor	USB, RS-232	4-116
E-861	Networkable Controller for NEXACT® Linear Motors and Positioners	1 to 16**	NEXACT® piezo stepping motors	USB, RS-232	1-20

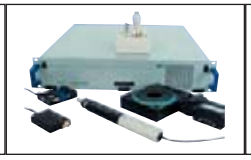
** networkable, on single interface

C-184, C-185 PILine® driver electronics

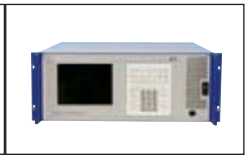
C-663 Stepper motor controller, C-863 Servo motor controller



C-843 PCI bus DC motor controller card



C-848 Servo motor controller

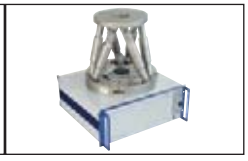


C-880 Automation platform for plug-in cards

C-702 Hybrid motion controller & driver

C-867 High-speed, ultrasonic piezo motor controller

E-861 NEXACT® piezo stepping motor controller

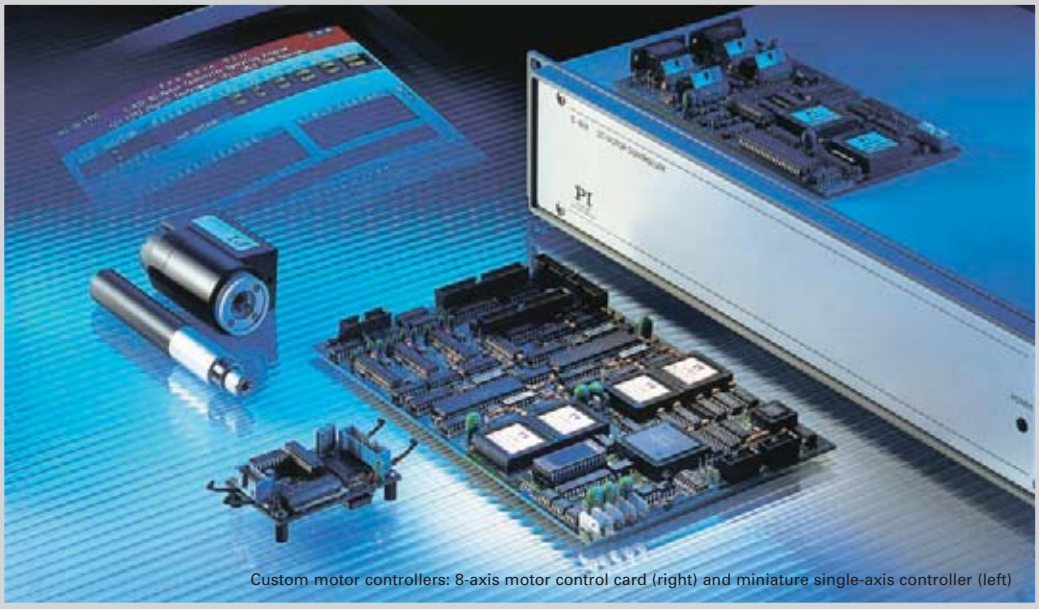


Hexapod controller for 6-axis parallel kinematics systems; RS-232, TCP/IP; optional display & keyboard; description see Hexapods, p. 4-3 *ff*

Piezo Drivers / Servo Controllers: See Page 2-99 *ff*

Accessories, p. 4-126

Motion Controllers for Micropositioning Systems: Features, Applications, Systems Experience



Custom motor controllers: 8-axis motor control card (right) and miniature single-axis controller (left)

PI offers a large variety of innovative motion control solutions for precision positioners. Included products range from compact, single-axis controllers for DC servomotors, stepper motors and piezomotors, to complex multi-axis control systems for parallel-kinematics, 6-DOF Hexapods. PI's novel dual-loop hybrid controller combines the advantages of electromagnetic motors and piezo technology. Custom motion control systems have been built capable of coordinating up to 273 axes.

Positioning and Sequencing: Automation System Solutions from PI

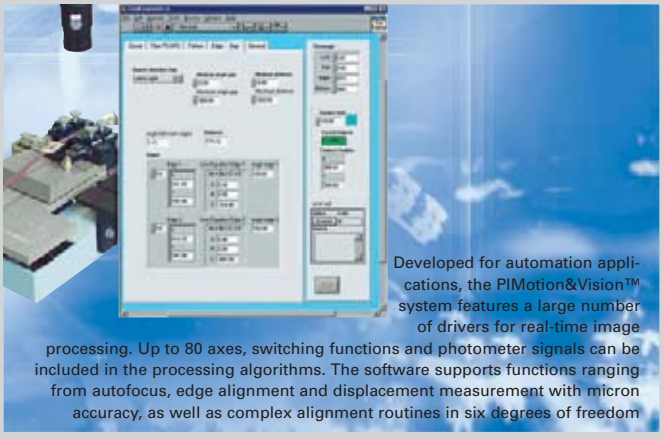
The motion controllers shown here are specially designed for PI micropositioning systems. With PI mechanics, the comprehensive palette of software, and all necessary cables included, plug-and-play operation is the rule. With some controllers, it is possible to network up to 16 axes or more for simple system scalability. In addition to standard systems, custom systems have been assembled with control for several hundred axes.

Integrated Drivers

All PI motor controllers are equipped with integrated servo-amplifiers and/or drivers in order to simplify system design and reduce costs. In addition, the DC-motor controllers offer PWM outputs for use with external amplifiers or with the integrated amplifiers in PI's direct-drive, ActiveDrive™ stages, such as the M-511.PD.

Range of Motion Controllers

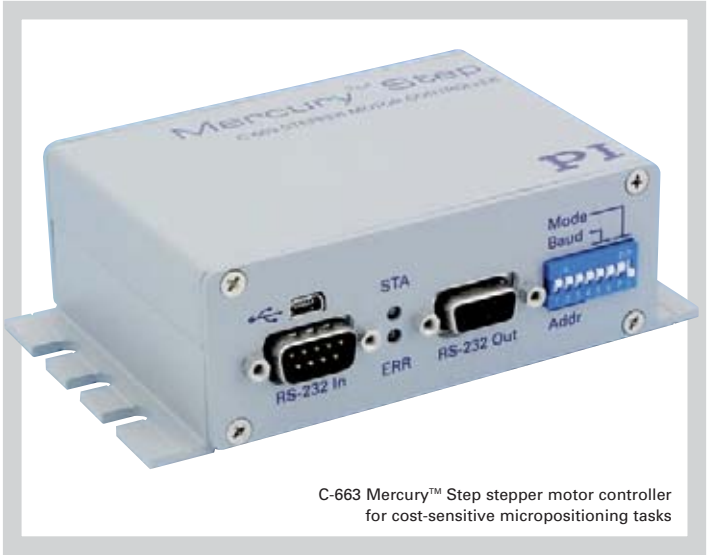
- Choice of Different Control Strategies
- Stepper Motor Controllers
- DC-Motor Controllers
- Dual Servo-Loop Hybrid Controllers
- Drivers / Controllers for Ceramic Ultrasonic Servo-Drives
- Controllers for PiezoWalk® Stepping Motors (see p. 1-3 *ff*)
- Six Degree-of-Freedom Hexapod Controllers
- Automation Platform
- Custom Controllers with up to 273 Channels



Developed for automation applications, the PIMotion&Vision™ system features a large number of drivers for real-time image processing. Up to 80 axes, switching functions and photometer signals can be included in the processing algorithms. The software supports functions ranging from autofocus, edge alignment and displacement measurement with micron accuracy, as well as complex alignment routines in six degrees of freedom

C-663 Mercury™ Step Controller

1-Axis Networkable Stepper-Motor Controller



C-663 Mercury™ Step stepper motor controller for cost-sensitive micropositioning tasks

- **High Performance at Low Cost**
- **Stand-Alone Functionality**
- **Network Capability for Multi-Axis Applications**
- **Compatible and Networkable with C-863 Mercury™ DC-Motor Controllers**
- **Joystick Port for Manual Control**
- **Non-Volatile Macro Memory**
- **Parameters Changeable On-the-Fly**

The Mercury™ Step stepper motor controller is the perfect solution for cost-effective and flexible motion control applications where a precision positioner is to be controlled by a PC or PLC (programmable logic controller). The C-663 supplements the successful C-863 Mercury™ servo motor controller.

Microstepping of 1/16 full step (up to 6400 steps/rev. with PI stepper motors) provides for ultra-smooth, high-resolution motion.

Multi-Axis Control, Combination of DC & Stepper Motors

The networking feature allows the user to start out with one Mercury™ controller and add more units later for multiaxis setups.

The Mercury™ Step stepper motor controller shares its programming language with the well-established Mercury™ DC-motor controller. Up to 16 Mercury™ controllers (DC and stepper) can be daisy chained and operated from one computer.

Flexible Automation

The C-663 offers a number of features to achieve automation and handling tasks in research and industry in a very cost-effective way. Programming is facilitated by the high-level mnemonic command language with macro and compound-command functionality. Macros can be stored in the non-volatile memory for later recall.

For easy synchronization of motion with internal or external trigger signals four input and four output lines are provided. A joystick can also be connected for manual control.

Stand-alone capability is provided by a user-programmable autostart macro to run automation tasks at power up (no run-time computer communication required!).

User-Friendly: Comprehensive Software Package and Two Interface Options

Easy data interchange with laptop or PC is possible via the USB interface. To facilitate industrial applications, an RS-232 interface is also standard.

The included software supports networking of multiple controller devices. LabVIEW™ drivers and Windows DLLs allow for easy programming and integration into your system. Mercury™ Step controllers can also be operated using the PI General Command Set (GCS) via a DLL. PI-GCS allows networking of different PI-controllers such as piezo drivers and multi-axis servo controllers with minimal programming effort.

Contents of Delivery

Each Mercury™ Step comes with a wide-range power supply, RS-232 communications cables, a USB cable and a comprehensive software package.

Application Examples

- Flexible automation
- Handling
- Quality control
- Testing equipment
- Photonics applications
- Fiber positioning

Ordering Information

C-663.10
Mercury™ Step Stepper Motor Controller with Wide-Range Power Supply, 24 V

C-819.20
2-Axis Analog Joystick for Mercury™ Controller

C-819.20Y
Y-Cable for Connecting 2 Controllers to C-819.20

C-170.IO
I/O cable, 2 m, open end

C-170.PB
Push Button Box, 4 Buttons and 4 LEDs

Mercury™ Step controller with M-403.62S precision translation stage

Technical Data

Model	C-663.10
Function	Stepper motor controller, stand-alone capability
Drive type	2-phase stepper motor
Channels	1
Motion and control	
Trajectory profile modes	Trapezoidal, point-to-point
Microstep resolution	1/16 full step
Limit switches	2 x TTL, programmable
Reference switches	1 x TTL, programmable
Motor brake	1 x TTL, programmable
Electrical properties	
Operating voltage	15 to 30 V
Current limitation per motor phase	1000 mA
Interface and operation	
Interface/Communication	USB, RS-232 (bus architecture)
Motor connector	Sub-D 15 (f)
Controller network	Up to 16 units* on single interface
I/O ports	4 analog/digital in, 4 digital out
Command set	Mercury™ native command set, GCS
User software	MMCRun, PIMikroMove®
Software drivers	GCS (PI General Command Set)-DLL, LabVIEW drivers, native Mercury™ DLL
Supported functionality	Start-up macro
Manual control	Joystick, Y-cable for 2D motion, pushbutton box
Miscellaneous	
Operating temperature range	0 to 50 °C
Mass	0.3 kg
Dimensions	130 x 76 x 40 mm³

*16 with USB; 6 with RS-232 (depending on RS-232 output driver of PC)

C-863 Mercury™ Servo Controller

1-Axis DC-Servo-Motor Controller with Network Feature

The C-863 Mercury™ DC servo controller features USB and RS-232 interfaces and incremental encoder signal processing at 20 MHz bandwidth

- **High Performance at Low Cost**
- **DC Servo-Motor Controller Supplies up to 30 W**
- **20 MHz Encoder Input for High Speed & Resolution**
- **Macro Programmable Stand-Alone Functionality**
- **Network Capability for Multi-Axis Applications**
- **Non-Volatile EEPROM for Macros and Parameters**
- **Digital I/O Lines (TTL)**
- **Motor-Brake Control**
- **USB and RS-232 Interface**
- **Optional Joystick for Manual Control**
- **Works with All PI Micropositioners**

The latest generation Mercury™ C-863 servo motor controller is even more powerful and versatile than its predecessors. Easy data interchange with laptop or PC is possible via the USB interface. The RS-232 interface provides for easy integration in industrial applications. The compact design with its integrated amplifier makes it ideal for building high-performance, cost-effective micropositioning systems.

Application Examples

- Fiber positioning
- Automation
- Photonics / integrated optics
- Quality assurance testing
- Testing equipment

Flexible Automation

The Mercury™ offers a number of features to achieve automation and handling tasks in research and industry in a very cost-effective way. Programming is facilitated by the high-level mnemonic command language with macro and compound-command functionality. Macros can be stored in the non-volatile memory for later recall.

Stand-alone capability is provided by a user-programmable autostart macro to run automation tasks at power up (no run-time computer communication required!).

For easy synchronization of motion with internal or external trigger signals four input and four output lines are provided.

Multi-Axis Control, Combination of DC & Stepper Motors

Up to 16 C-863 Mercury™ DC servo controllers and C-663 stepper motor controllers can be daisy-chained and addressed via the same interface.

The networking feature allows the user to start out with one controller and add more units later for multiaxis setups.

Easy Programming

All servo and stepper motor controllers of the Mercury™ family can be operated using the PI general command set (GCS). PI-GCS allows networking of different controller units, both for piezo-based and motorized positioning units, with minimal programming effort. In addition, the C-863 can be programmed using the native command set of previous Mercury™ controllers.

Cost-Saving Due to Integrated Amplifier and PWM Outputs

The unique Mercury™ concept combines a high-performance motion controller and an integrated power amplifier in a small package. Additional PWM control outputs allow the direct operation of any DC-motor-driven PI micro-positioning system—even high-speed stages such as the M-500 ActiveDrive™ Translation Stages—reducing costs, increasing reliability and simplifying the setup.

Contents of Delivery

Each controller is delivered with a wide-range power supply, RS-232 communication cable, a daisy-chain network cable and a comprehensive software package.

Ordering Information

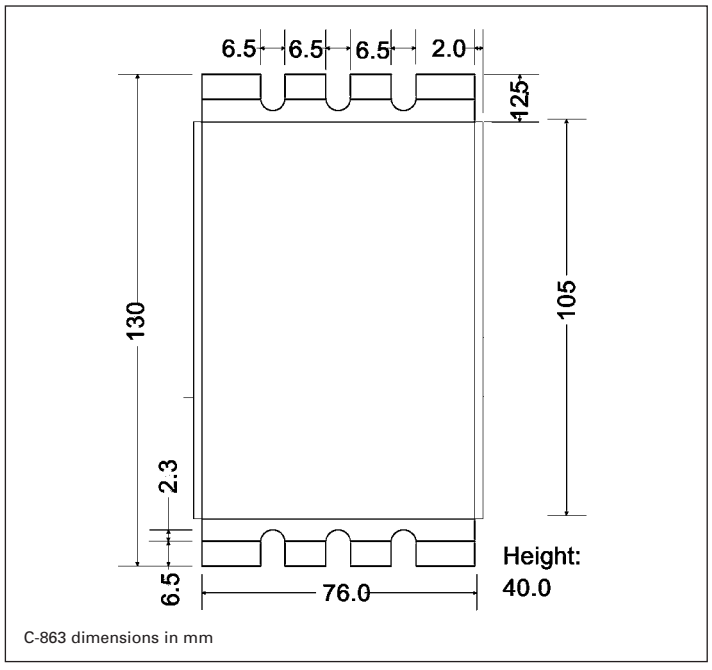
C-863.10
Mercury™ DC-Motor Controller, 1 Channel, with Wide-Range Power Supply

C-819.20
2-Axis Analog Joystick for Mercury™ Controller

C-819.20Y
Y-Cable for Connecting 2 Controllers to C-819.20

C-170.IO
I/O Cable, 2 m, Open End

C-170.PB
Push Button Box, 4 Buttons and 4 LEDs



C-863 dimensions in mm

Technical Data

Model	**C-863.10**
Function	DC-servo-motor controller, 1 channel
Motion and control	
Servo characteristics	P-I-D servo control, parameter change on-the-fly
Trajectory profile modes	Trapezoidal, point-to-point
Encoder input	AB (quadrature) single-ended or differential TTL signal, 20 MHz
Stall detection	Servo off, triggered by programmable position error
Input limit switch	2 x TTL (pull-up/pull-down, programmable)
Input reference switch	1 x TTL
Motor brake	1 x TTL, software controlled
Electrical properties	
Output power	max. 30 W (PWM)
Output voltage	0 to 15 V
Current	80 mA + motor current (3 A max.)
Interfaces and operation	
Communication interfaces	USB, RS-232 (9-pin [m] sub-D)
Motor connector	15-pin (f) sub-D
Controller network	Up to 16 units on single interface
I/O ports	4 analog/digital in, 4 digital out (TTL)
Command set	Mercury Command Set, GCS (via DLL)
User software	PIMikroMove®, MMCRun
Software drivers	GCS (PI General Command Set)-DLL, LabVIEW drivers, native Mercury™ DLL
Supported functionality	Start-up macro; internal safety circuitry: watchdog timer
Manual control (optional)	2-axis joystick, Y-cable for 2D motion, pushbutton box
Miscellaneous	
Operating voltage	15 to 30 V included: external power supply, 15 V / 2 A
Operating temperature range	+5 to +50 °C
Mass	0.3 kg
Dimensions	130 x 76 x 40 mm

C-867 Controller for PILine® Piezo Linear Drives

Servo-Controller with Integrated Driver for High-Speed Ultrasonic Piezo Motors

The C-867 piezo motor controller and the M-664 low-profile positioner with integrated PILine® ceramic linear drive

- **Optimized for PILine® Ultrasonic Piezo Linear Motors**
- **High-Bandwidth Encoder Inputs Allow High Speed and Resolution**
- **PID Servo-Control with Dynamic Parameter Switching**
- **Integrated Piezo Motor Power Driver**
- **USB, RS-232 and Analog Interfaces (e. g. for Joystick)**
- **4 + 4 Programmable TTL-I/Os for Flexible Automation**
- **Data Recorder**
- **Daisy-Chain Networking for up to 16 Axes**
- **Powerful Macro Programming Language, e. g. for Stand-Alone Operation**
- **Extensive Software Support, LabVIEW, DLL, ...**

The C-867 controller was especially designed for closed-loop positioning systems equipped with PILine® piezo linear motor drives. In addition to the digital servo-controller, the compact case also contains the driver electronics for the piezo ceramic motors.

Application Examples

- Biotechnology
- Fiber positioning
- Automation
- Photonics / integrated optics
- Quality assurance testing
- Testing equipment

The controller can be operated by a host PC either via a USB port or an RS-232 interface. Alternatively, stand-alone operation is possible by uploading macro command sequences to the internal non-volatile memory, or through a joystick or a push-button box.

Highly Specialized PID Servo-Controller

The C-867 is based on a highly specialized DSP (Digital Signal Processor) to handle the PID servo-control algorithm as well as other system functions. Because of the motion properties typical for ultrasonic piezomotors, the controller has a number of advanced features, including dynamic control parameter adaption. By automatically switching between gainsets for dynamic and static operation optimized settling behavior of a couple of 10 milliseconds is achieved. The broadband encoder input (50 MHz) allows the use of high resolution encoders with the outstanding high accelerations and velocities PILine® drives deliver.

Integrated Piezomotor Drivers

To reduce the number of components in PILine® positioning systems, the piezomotor drive electronics has been integrated in the controller. Various controller versions are available, each optimized for the piezomotor type used. The C-867.161 version, for example, contains the drive electronics for the M-663 see p. 4-28 linear stages.

The integrated drivers are finetuned to the connected drives before delivery in order to provide optimal system performance.

Software / Programming

In addition to the user software for setup, system optimization and operation, comprehensive LabVIEW and DLL libraries are provided.

The PIMikroMove™ user software provides the PITuningTool for system performance optimization. Graphic displays show the system's behaviour and facilitate parameter setting.

Advantages of PILine® Micro Positioning Systems

PILine® ultrasonic ceramic drives provide several advantages over classical motors and drivers:

- Smaller dimensions
- Self-locking when powered down; no holding current
- High acceleration up to 5 g
- High velocity up to 500 mm/s
- No leadscrews, gears or other mechanical components, no wear or maintenance
- No lubricants
- Non-magnetic and vacuum compatible operating principle

Ordering Information

C-867.161
Piezomotor Controller with Drive Electronics, Networkable, for PILine® Systems with P-661 Motors

C-867.164
Piezomotor Controller with Drive Electronics, Networkable, for PILine® Systems with P-664 Motors

C-867.D64
Piezomotor Controller with Drive Electronics, Networkable, for PILine® Systems with M-674 RodDrive

Accessories:

C-819.20
2-Axis Analog Joystick

C-819.20Y
Y-Cable for Connecting 2 Controllers to C-819.20

C-170.PB
Push Button Box, 4 Buttons and 4 LEDs

Ask about custom designs!

Technical Data

Model	C-867.161	C-867.164	C-867.D64
Function	Controller and drive electronics for PILine® piezomotors / systems	Controller and drive electronics for PILine® piezomotors / systems	Controller and drive electronics for PILine® piezomotors / systems
Drive type	PILine® P-661 motors	PILine® P-664 motors	PILine® RodDrive M-674, 2 x P-664
Channels	1	1	1
Motion and control			
Servo characteristics	Programmable PID V-ff filter, parameter changes on the fly	Programmable PID V-ff filter, parameter changes on the fly	Programmable PID V-ff filter, parameter changes on the fly
Trajectory profile modes	Trapezoidal	Trapezoidal	Trapezoidal
Encoder input	A/B differential signals, 50 x 10^6 impulse/s	A/B differential signals, 50 x 10^6 impulse/s	A/B differential signals, 50 x 10^6 impulse/s
Stall detection	Servo off, triggered by programmable position error	Servo off, triggered by programmable position error	Servo off, triggered by programmable position error
Limit switch	2 TTL (programmable)	2 TTL (programmable)	2 TTL (programmable)
Reference switch	1 TTL (active high/low, programmable)	1 TTL (active high/low, programmable)	1 TTL (active high/low, programmable)
Electrical properties			
Output power	5 W	10 W	15 W
Output voltage	120 V_{pp}, 42 V_{rms}	168 V_{pp}, 60 V_{rms}	190 V_{pp}, 67 V_{rms}
Interfaces and operation			
Communication interfaces	USB, RS-232	USB, RS-232	USB, RS-232
Motor connector	MDR14	MDR14	MDR14
Controller network	Up to 16 units on single interface	Up to 16 units on single interface	Up to 16 units on single interface
I/O ports	4 analog/digital in, 4 digital out on mini DIN 9-pin digital: TTL analog: 0 to 5 V	4 analog/digital in, 4 digital out on mini DIN 9-pin digital: TTL analog: 0 to 5 V	4 analog/digital in, 4 digital out on mini DIN 9-pin digital: TTL analog: 0 to 5 V
Command set	PI General Command Set (GCS)	PI General Command Set (GCS)	PI General Command Set (GCS)
User software	PIMikroMove™	PIMikroMove™	PIMikroMove™
Software drivers	GCS-DLL, LabVIEW drivers	GCS-DLL, LabVIEW drivers	GCS-DLL, LabVIEW drivers
Supported functionality	Start-up macro; macro; data recorder for recording parameters as motor input voltage, velocity, position or position error	Start-up macro; macro; data recorder for recording parameters as motor input voltage, velocity, position or position error	Start-up macro; macro; data recorder for recording parameters as motor input voltage, velocity, position or position error
Manual control	Pushbutton box, joystick (for 2 axes), Y-cable for 2D motion	Pushbutton box, joystick (for 2 axes), Y-cable for 2D motion	Pushbutton box, joystick (for 2 axes), Y-cable for 2D motion
Miscellaneous			
Operating Voltage	12 VDC from external power supply (included)	12 VDC from external power supply (included)	12 VDC from external power supply (included)
Current consumption	300 mA without motor	300 mA without motor	300 mA without motor
Operating temperature range	+5 to +40 °C	+5 to +40 °C	+5 to +40 °C
Mass	950 g	950 g	950 g
Dimensions	174 x 104 x 63 mm (without ground connection, rubber feet) 182 x 104 x 74 mm	174 x 104 x 63 mm (without ground connection, rubber feet) 182 x 104 x 74 mm	174 x 104 x 63 mm (without ground connection, rubber feet) 182 x 104 x 74 mm

C-702 Hybrid System Controller

High Velocity-Constancy for Nanometer-Precision Hybrid DC/Piezo Nanopositioning Systems

C-702 Hybrid Controller

- **Motion Controller & Driver for Simultaneous Operation of Closed-Loop DC Servo Motors and Piezo Actuators**
- **2 Channels**
- **Sample Rate 10 kHz**
- **Piezo Resolution 24-bit**
- **Fast Serial Bus for Incremental High-Resolution Sensor**
- **Realtime Operating System**
- **Interfaces: TCP/IP Ethernet, RS-232, VGA, Keyboard**

The C-702 digital hybrid motion controller has been designed for precision control of the M-511.HD (see p. 4-46) and M-714 (see p. 4-62) nanopositioning stages. Both are based upon the PI hybrid drive technology integrating piezoelectric and motorized drive components to form one motion and servo-control system. The result is a nanopositioning system for high loads that can follow a motion profile with nanometer position accuracy and high constancy of velocity over several millimeters of travel.

Application Examples

- Surface Inspection
- Microscopy
- Laser technology
- Interferometry
- Metrology

Highly Effective Servo-Control for a Complex Drive Technology

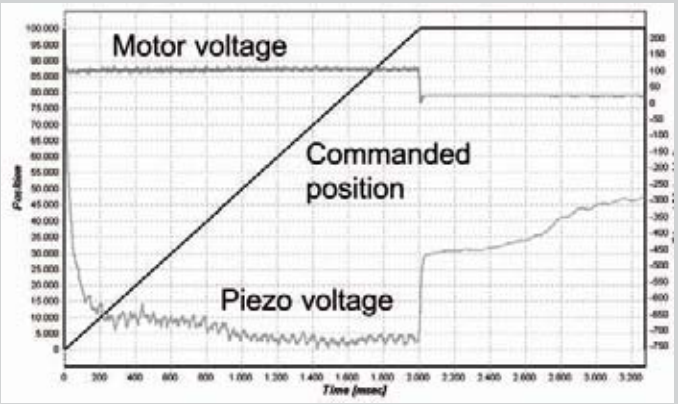
The optimized interaction between the piezoelectric and motorized drive components to make them a single motion unit requires a high-speed sensor as well as powerful control algorithms. The digital, 2-channel, C-702 controller, based on modern CPU technology with a real time operating system, has been designed for this task. It is able to read the position signals with virtually no delay and process the data immediately. The integrated piezo amplifiers use a high-resolution 24-bit DAC to fully support the high position resolution of the piezo actuators. The new ultra-fast broadband SSI interface for the optical linear encoder supports stage velocities of 300 mm/s at a resolution of 2 nm. With special cabling, external sensor signals, like those from an interferometer, can be used for servo-control via an SSI interface.

One Controller for One Motion System

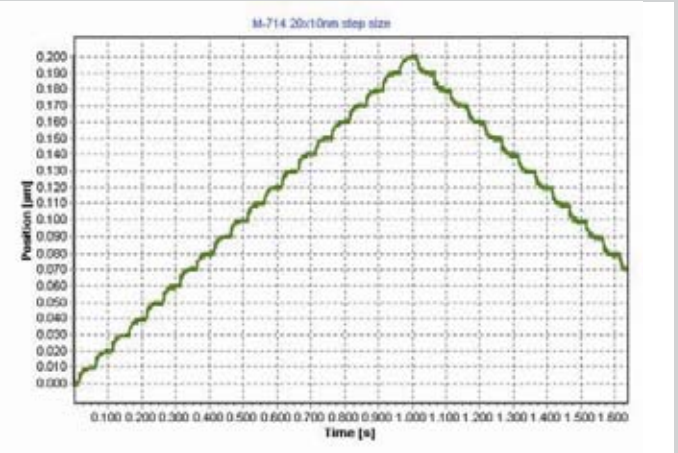
In PI hybrid systems, the motor-leadscrew and piezo actuator are fully integrated to form one motion system. The motor and piezo act together at all times. The result is far more than a coarse-adjust/fine-adjust system: effects like startup stick/slip and backlash can be completely compensated and a motion profile with high constancy of velocity can be followed. Because of the high-piezo stiffness, setting to a few nanometers only takes a few milliseconds, significantly faster than with conventional, higher-inertia, linear-motor-driven stages. Furthermore minimal increments in the range of the sensor resolution can be reliably executed. To allow high velocities beyond 100 mm/sec and nanometer-range incremental resolution, position information must be transmitted and processed very rapidly and a complex control algorithm is required.

Ordering Information

C-702.00
Ultra-High-Precision
Hybrid Controller, 2 Channels

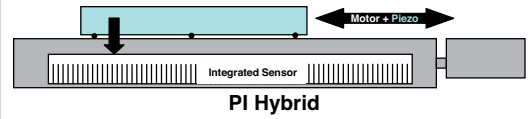


PI hybrid servo-controller output during a positioning command. The controller reads the system position off a high-resolution encoder and actuates both the motor and piezoelectric actuator at the same time giving a system with the advantages of both drives



10 nm steps of an M-714 stage, as measured by an interferometer

M-511.HD hybrid stage (left),
M-714.00 (right front) and the C-702 controller (rear)



PI Hybrid

6PI Hybrid drive combines DC motor and piezo actuator with integrated, internal, high-resolution sensor in one servo loop

Technical Data

Model	C-702.00
Function	Motion Controller for Hybrid Nanopositioning Systems
Drive type	DC motor (PWM)/piezo
Channels	2
Motion and control	
Servo characteristics	PID V-ff filter, notch filter, hysteresis setting (motor); proportional-integral (P-I) algorithm with notch filter (piezo)
Sampling rate	10 kHz
Trajectory profile modes	Trapezoidal, S-curve
Processor	32-bit Intel Celeron
Position range	32 bit
Limit switches	2 lines per axis
Reference switch	1 line per axis
Motor brake	Software programmable
Electrical properties	
Operating voltage	24 VDC (via M-500.PS wide range power supply*)
Output power/channel	PWM: 19.5 kHz, 10-bit resolution
Piezo voltage	±36 V (24-bit resolution)
Power consumption	< 25 W
Interfaces and operation	
Communication interfaces	TCP/IP, RS-232, VGA, Keyboard
Motor connector	Sub-D connector, 26-pin**
Encoder input	Serial SSI interface for incremental encoder
Controller network	via TCP/IP
I/O ports	8 TTL inputs, 8 TTL outputs
Command set	ASCII, PI General Command Set (GCS)
User software	PIMikroMove®
Software drivers	GCS (PI General Command Set)-DLL, LabVIEW™ drivers
Supported functionality	Autostart macro, user-programmable macro
Miscellaneous	
Operating temperature range	+10 to +50 °C
Mass	1.35 kg
Dimensions	130 x 205 x 76 mm

*M-500.PS: wide range power supply, 100 to 250 VAC, 50 to 60 Hz
**Sub-D 26 contains connection for motor, piezo, reference and limit switches and sensor, Internal heat sink with very silent fan

C-843 DC-Servo-Motor Controller

Servo Motion Controller/Driver PCI Board for 2 or 4 Axes

C-843.41 DC-motor controller board with M-110.DG linear stage, M-235.5DG heavy duty linear actuator, M-511.DD direct drive translation stage and M-501.1DG vertical stage. No external amplifier is required to drive any of these or other PI stages. Small motors are driven through the C-843's onboard linear amplifiers, direct-drive PI stages (e.g. M-511.DD) employ ActiveDrive™ controlled off the C-843's PWM outputs.

- **Two and Four Axis Version**
- **Very Cost-Effective: Servo Amplifiers On-Board**
- **Additional PWM Outputs for High-Power Motors**
- **Trapezoidal Curve, S-Curve and Velocity Profile**
- **32 kSamples RAM for High-Speed Buffer Operations**
- **16 I/O Lines for Flexible Automation**
- **Fast PCI Communication, 120 µs for Position Read**
- **Motor-Brake Control Output**
- **Extensive Software Support**
- **General Command Set (GCS) Compatible**

The C-843 PCI motion controller card drives up to 4 axes of micropositioning equipment. Because there is no need for external servo-amplifiers, this new card is a very cost-effective, easy-to-set-up solution.

On-Board Servo-Amplifiers

Unlike other PCI controller cards, the new C-843 comes with on-board, low-noise linear amplifiers for the small DC motors used in most compact micropositioning stages and actuators.

In addition, PWM outputs are available to drive more powerful equipment (all direct-drive translation and rotation stages from PI feature the integrated ActiveDrive™ PWM amplifiers, and also connect to the C-843 with no external power amplifiers).

The PWM mode and linear amplifier mode can be programmed individually for each of the 4 (or 2) channels.

High-Performance PID Control

The C-843 employs a fast DSP (digital signal processor) providing high-performance PID motion control with many options for trajectory generation and filter settings for superior positioning and tracking accuracy. Position, velocity, acceleration and several other motion parameters can be programmed individually for each axis on-the-fly. High-bandwidth counters (5 MHz) support differential encoder feedback (incremental rotary encoders or linear scales) for fast and accurate positioning.

I/O for Flexible Automation

In addition to 3 TTL inputs per channel for limit and reference signals, 16 more I/O lines are available for flexible automation tasks (trigger functions, etc.). The C-843 also features motor-brake output lines (e.g. for M-531.DDB stages).

High-Speed Buffering

The integrated 32 k-sample trace memory allows online buffering (read and write) at integer multiples of the servo-loop time of up to four independent system variables (positions, velocities, internal register contents, etc.) This allows the observation of the motion system and also performing customized trajectory profiles.

PI General Command Set (GCS)

The comprehensive command structure is based on the PI General Command Set (GCS). With GCS the development of custom application programs is simplified, because the commads for all supported devices are identical in syntax and function. PI controllers for nanopositioning systems, for piezomotors and servo or stepper motors can be commanded with GCS.

Software / Programming

In addition to the user software for setup, system optimization and operation, comprehensive LabVIEW and DLL libraries are provided. The user friendly PI MikroMove™ provides a convenient interface for stage operation including tuning tool, joystick operation, terminal and macro editor.

Communications to/from the board consist of packet-based messages passed via memory access. An interrupt line is provided so that the chipset can signal the PC when special conditions arise, such as reception of an encoder index pulse. For system programmers the C-843 offers direct access to the DSP.

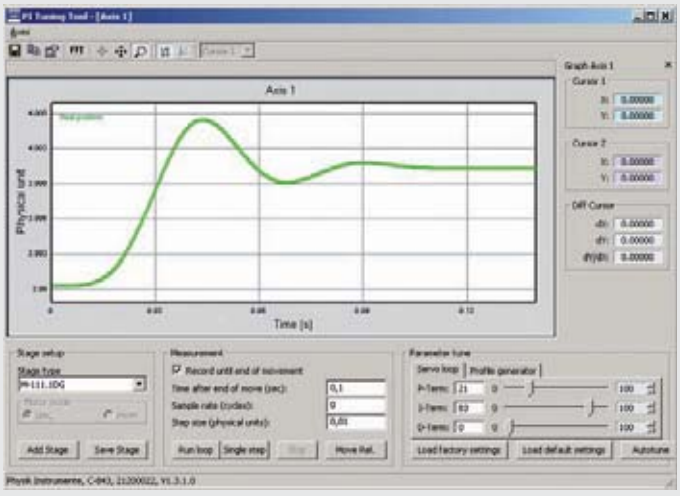
Ordering Information

C-843.21
DC-Motor Controller PCI PC Board, 2-Axis

C-843.41
DC-Motor Controller PCI PC Board, 4-Axis

C-843.JS
Joystick and PCI Interface Board for C-843 Motor Controller

PIMikroMove® tabular presentation of four connected axes with display of absolute and relative positioning input, current position, halt axis button, state and velocity setting.



The Tuning Tool which is integrated in PIMikroMove® demonstrates acquiring and displaying step and settle data of micropositioning systems. Controls allow adjustment of the PID parameters for best performance.

Technical Data

Model	C-843
Function	PC plug-in DC-servo-motor controller board, 32-bit plug-and-play PCI-bus interface, supported by main boards with 3.3 V and 5 V PCI bus connectors (universal card)
Axes	2 (C-843.21); 4 (C-843.41)
Servo characteristics	Programmable PID V-ff filter, parameter changes on-the-fly
Profile modes	Trapezoidal, S-curve, velocity profile
Output power / resolution	Analog 6 watts/channel (drawn directly from PC power supply), 12-bit D/A converters, PWM 10-bit, 24.5 kHz
Current limitation	500 mA per channel (short-circuit-proof)
Encoder input	AB (quadrature) differential TTL signals, 5 x 10^6 counts/s
Stall detection	Servo off, triggered by programmable position error
Limit switches	2 TTL / axis (active high/low, programmable)
Reference switches	1 TTL / axis (active high/low, programmable)
I/O ports	8 TTL inputs, 8 TTL outputs
Motor connectors	15-pin (f) sub-D per channel (2 on board + 2 on bracket for C-843.41)
Interface/communication	PC PCI bus
Command set	PI General Command Set (see p. A-8)

C-848 DC-Servo-Motor Controller

DC Motor Controller for 2 or 4 Axes

C-848.43 Precision Motion Controller with various PI-stages: M-112.2DG micro-translation stage, M-232.17 DC-Mike, M-062.DG rotary stage and M-235.5DG heavy-duty DC-Mike

- **Simultaneous Operation of up to 4 DC Servo-Motors/ -Positioning Stages or Voice-Coil Scanners**
- **Powerful Macro Command Language**
- **16 I/O Lines for Flexible Automation**
- **Electronic Gearing**
- **Extensive Software Support**
- **RS-232 and Optional IEEE 488 Interface**

The C-848 is a flexible, multi-purpose, rackmount positioning and motion controller for DC servo-motors. It is designed for general positioning and automation tasks in research and industry.

Flexible Multi-Processor Architecture

Based on a dual-processor structure, the C-848 offers the flexibility expected in today´s demanding prototyping and high-precision production environment.

In parallel with the general processor handling communication and macro execution, a fast DSP motion-control chipset is dedicated to trajectory generation and servo-control. In addition to three inputs per channel for limit switches and home position, eight TTL inputs and eight TTL outputs are available for flexible automation.

The C-848 also offers advanced motion control features such as:

- Linear interpolation
- Trajectory generation for trapezoidal and s-curve profiles
- Electronic gearing
- Real-time reference and limit position capture

Integrated Servo-Amplifiers/-PWM Output

Integrated, low-noise, linear power amplifiers allow operation of any PI micropositioning system without additional external amplifiers, reducing costs and simplifying the setup. In addition to the linear amplifiers, PWM (pulse width modulation) output signals are available to drive PI micropositioning stages equipped with ActiveDrive™ motors.

PI General Command Set (GCS)

The comprehensive command structure is based on the PI General Command Set (GCS). With GCS the development of custom application programs is simplified, because the commands for all supported devices are identical in syntax and function. PI controllers for nanopositioning systems, for piezomotors and servo or stepper motors can be commanded with GCS.

Software / Programming

In addition to the user software for setup, system optimization and operation, comprehensive LabView™ and DLL libraries are provided.

Control of the C-848 is provided either through the RS-232 or an optional TCP/IP interface. For manual control, the unit can be operated with a C-819.10 joystick.

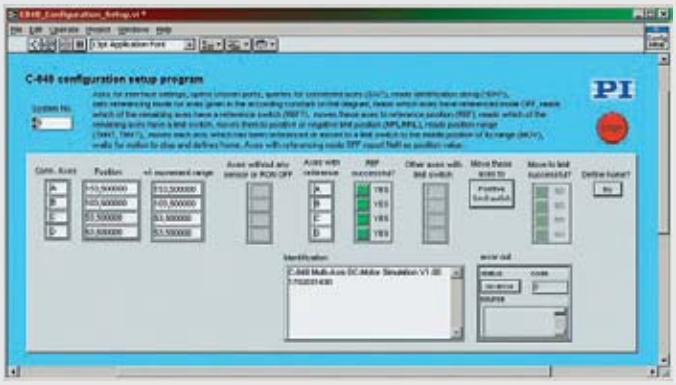
The C-848 can also run in stand-alone mode, and a standard computer keyboard and monitor can be connected for direct programming.

Ordering Information

C-848.23
DC Servo Motion Controller, 2 Channels, 19“ Rack Mount, RS-232

C-848.43
DC Servo Motion Controller, 4 Channels, 19“ Rack Mount, RS-232

Accessories
C-819.10
Analog Joystick



Software for easy setup of the C-848 system

C-848 Control software, terminal window

Technical Data

Model	C-848.43	C-848.23
Function	DC-servo-motor controller	DC-servo-motor controller
Drive type	DC servo-motors Voice-Coil Linear Drives	DC servo-motors Voice-Coil Linear Drives
Channels	4	2
Motion and control		
Servo characteristics	Programmable PID V-ff filter, 100 µs per active axis, parameter changes on the fly	
Trajectory profile	Linear interpolation, trapezoidal, s-curve, electronic gearing	
Processor	Dual Processor: CPU 133 MHz and Motion chip, 2.5 kHz servo update rate	
Encoder input	AB (quadrature) differential TTL signal, 5 MHz	
Stall detection	Servo off, triggered by programmable position error	
Limit switches	2 TTL lines per axis, programmable	
Reference switch	1 TTL line real-time position capture per axis	
Motor brake	TTL, software programmable	
Electrical properties		
Operating voltage	Wide-range power supply, 100 to 240 VAC, 50 to 60 Hz	
Output power/channel	Analog H-bridge ±12 V, 5 W/channel, 12-bit D/A converters, 10-bit output for PWM drivers, 24.5 kHz	
Output voltage/channel	Analog: ±10.5 V PWM: TTL for SIGN and MAGN	
Current limitation	1 A per channel (short-circuit proof)	
Interfaces and operation		
Communication interfaces	RS-232 standard (cable included),	RS-232 standard (cable included),
Motor connector	Sub-D connector, 15-pin	
Controller network	Via TCP/IP option	
I/O ports	8 TTL inputs, 8 TTL outputs	
Command set	PI General Command Set (GCS)	
User software	C-848 Control user software, PIMikromove®	
Software drivers	LabView™ driver, DLL & COM for C, BASIC for Windows	
Supported functionality	Autostart macro, user-programmable macro Monitor and keyboard connectors Motor-Brake Control	
Manual control	Joystick via controller or host PC	
Miscellaneous		
Temperature range	+10 to +50 °C	+10 to +50 °C
Mass	8.2 kg	8.4 kg
Dimensions	447 x 450 x 90 mm (19-inch rackmount)	447 x 450 x 90 mm (19-inch rackmount)

C-880 Automation Platform

Flexible, Modular Controller for up to 18 Axes

Fiber alignment configuration example. Top: C-880.00D equipped with F-206.IRU IR-photometer card, 2 x C-842.43 servo-motor control cards and an E-760.3Si piezo controller card. Bottom left: M-511.DD precision translation stage with 0.1 µm linear encoder for rapid loading/unloading; F-131.3SD fiber alignment system with 15 mm travel range in XYZ and 1 nm resolution. Bottom right: M-501.1PD precision vertical stage with 0.008 µm encoder resolution; M-061.PD rotation stage and the F-210 fiber rotator

- **Up to 18 Axes with (Servo-Motors, Voice Coil Drives and Piezo Actuators)**
- **Plug-and-Play Setup**
- **Large Variety of Accessories: I/O Cards, Photometers, Manual Control Pad**
- **RS-232 and Optional IEEE 488 Interface**
- **Extensive Software Support**

The C-880 Automation Platform is a modular and highly versatile system for complex multi-axis positioning and automation tasks. It was conceived for applications ranging from photonics alignment and packaging to biotechnology.

Based on a rugged industrial PC, it offers the flexibility expected in today´s demanding prototyping and high-precision production environment.

Application Examples

- Biotechnology
- Fiber positioning
- Flexible automation
- Semiconductor testing
- Micro-assembly
- Photonics / integrated optics
- Quality assurance testing

A variety of models and options are available, making it possible to control nanopositioning systems with up to 18 axes. Servo-motors, voice coil-drives and piezo actuators/ stages can be combined in almost any combination. Available options include photometer cards for fully automated fiber alignment, a relay board for flexible automation, an integrated screen and keyboard for stand-alone operation, and a manual control pad.

PI General Command Set (GCS)

The comprehensive command structure is based on the PI General Command Set (GCS). With GCS the development of custom application programs is simplified, because the commands for all supported devices are identical in syntax and function. PI controllers for nanopositioning systems, for piezomotors and servo or stepper motors can be commanded with GCS.

Software / Programming

In addition to the user software for setup, system optimization and operation, comprehensive LabView and DLL libraries are provided.

Accessories for Flexible Automation

To live up to its name of "Automation Controller", a variety of options and high-level drivers are available for the C-880:

■ C-880.TCP
TCP/IP interface card, allowing operation of more than one C-880 from a single PC interface.

■ C-880.R8
Relay Board which can switch power on up to 8 channels. The high-power capacity (24 V, 1 A) can be used to directly drive loads like pneumatic valves, magnets, relays, etc.

■ F-206.MC6
Interactive manual control pad. This option allows easy manual control of any 6 motorized axes in the system using control knobs with programmable step-sizes.

Ordering Information

C-880.00
Automation Platform, Chassis with Power Supply, RS-232 Interface

C-880.00D
Automation Platform, Chassis with Power Supply, RS-232 Interface with Front-Panel Keypad and LCD Monitor

Options:

C-842.23
DC-Servo Motion Controller, 2 Channels, ISA-Bus

C-842.43
DC-Servo Motion Controller, 4 Channels, ISA-Bus

E-760.3Si
NanoCube® Piezo Controller, ISA-Bus PC Plug-In Board, Photometer IR Range

E-760.3SV
NanoCube® Piezo Controller, ISA-Bus PC Plug-In Board, Photometer Visible Range

Accessories:

C-880.TCP
TCP/IP Interface Card

F-206.iiU
Photometer Card, IR Range, 2 Channels

F-206.VVU
Photometer Card, Visible Range, 2 Channels

F-206.MC6
Manual Control Pad for 6 Channels

C-880.R8
Relay Board for 8 Relays

■ F-206.iiU / F-206.VVU
Photometer and A/D Cards. These cards are equipped with fiber-optic connectors, infrared- or visible-light photodiodes and amplifiers. Both have integrated 12-bit A/D converters with inputs accessible via a BNC socket on the card bracket.

C-880 Configuration Software makes for quick and easy on-site upgrades

Technical Data

Model	C-880.00	C-880.00D
Function	Multi-Axis Automation Platform	Multi-Axis Automation Platform with Front-Panel Keyboard and LCD Monitor
Drive type	with C-842.23/C-842.43: Servo-Motors, Voice Coil Drives with E-760.3S0: Piezo Drives	
Channels	Up to 18 Axes with (servo-motors, voice coil drives), and Piezo Actuators (max. 6 piezo axes)	
Motion and control		
Servo characteristics	C-842.23 & C-842.43: Programmable 32-bit PID V-ff filter, 100 µs per active axis, parameter changes on the fly E-760: Analog proportional-integral (P-I) algorithm with notch filter	
Trajectory profile modes	Linear interpolation, trapezoidal, s-curve, electronic gearing	
Processor	CPU 133 MHz C-842.23 & C-842.43: motion chip, 2.5 kHz servo update rate E-760: DSP	
Electrical properties		
Operating voltage	100 to 250 VAC, 50/60 Hz	
Output power per channel	C-842.23 & C-842.43: analog H-bridge with ±12 V output, 5 W/channel, 12-bit D/A converters, 10-bit output for PWM drivers, 24.5 kHz E-760: 9 W peak , 3 W continuous	
Output voltage / channel	C-842.23 & C-842.43: analog: ±10.5 V PWM mode: TTL level for SIGN and MAGN E-760: -20 to 120 V	
Current limitation	C-842.23 & C-842.43: 1 A/channel (short-circuit proof) E-760: 90 mA peak, 30 mA continuous	
Interfaces and operation		
Communication interfaces	RS-232 standard, including cable	
Motor connector	Sub-D 15-pin; Piezo: Sub-D, 25-pin	
Controller network	Via TCP/IP option	
I/O ports	C-842.23 & C-842.43: 8 TTL inputs, 8 TTL outputs C-880.R8: 8 channels, 60 W max., 24 V/channel, 1 A/channel	
Command set	PI General Command Set (GCS), ASCII Communications	
User software	PIMikroMove®	
Software drivers	GCS-DLL, LabVIEW™ drivers	
Supported functionality	Autostart macro, user-programmable macros, Monitor and keyboard connectors, Motor-brake control, Switching of high-power relays, Read-out of analog interface boards (photometer cards)	
Manual control	Manual control pad (F-206.MC6 option)	
Miscellaneous		
Operating temperature range	+10 to +50 °C	
Dimensions	19-inch case, 450 mm x 460 mm x 180 mm	

Accessories

C-819.10 Joystick

Analog Joystick for C-848 Motor Controller

The C-819.10 joystick can be used to operate the C-848 DC-motor-controllers via the PC game port.

C-819.20 2-axis joystick

C-819.20

2-Axis Analog Joystick for Mercury™ Controller

C-819.20Y

Y-Cable for Connecting 2 Controllers to C-819.20

C-819.30

3-Axis Analog Joystick for Mercury™ Controller

C-170.PB

Push Button Box, 4 Buttons and 4 LEDs

C-815.34

RS-232 Cable, 3 m, Null Modem, 9/9-pin with 25/9-pin Adapter

Motor Cables

All PI micropositioners come with the appropriate motor cables. The cables shown here are available as replacements or can be used as extension cables.

C-815.38

Motor Cable, 3 m, sub-D 15-pin (f) / 15-pin (male)

C-815.38 Motor Cable

C-815.83

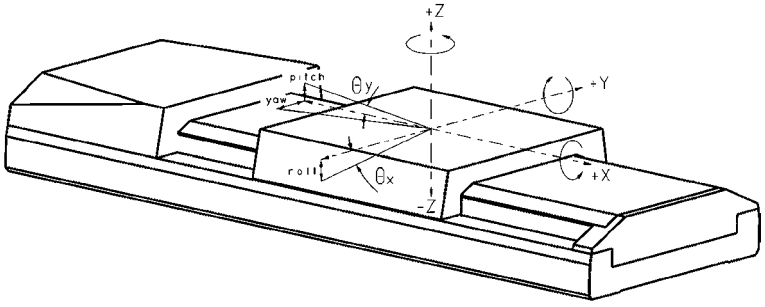
Motor Cable, 10 m, sub-D 15-pin (f) / 15-pin (male)

C-815.34 RS-232 Cable

C-815.62

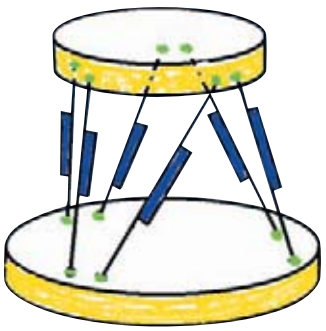
Motor Cable, 3 m, 10-pin (Flat Ribbon)/15-pin (male)

Micropositioning Fundamentals



Micropositioning Fundamentals

Glossary of Micropositioning Terms



Hexapod parallel kinematics system designs advantages such as compactness and minimized inertia (one platform for all six actuators) are easily seen. The reduced inertial mass makes for significantly faster response than with serial kinematics. Because there are no moving cables to cause friction, repeatability is increased also.
See also p. 4-5

Absolute Accuracy

For any given input this is the maximum difference between the commanded (ideal) position and the actual position. For real systems, resolution is usually a great deal higher than absolute accuracy, which is limited by backlash, hysteresis, drift, drive or sensor nonlinearity and cosine error. The best absolute accuracy is achieved with direct metrology sensor systems. In such systems, the position of the platform itself is measured, with, for example, an interferometer or linear glass scale. Indirect metrology systems (e. g. rotary encoders), or open-loop stepper-motor-driven stages, have significantly lower absolute accuracies. Independent of this fact, they can still offer high resolutions and repeatabilities.

Backlash

Position error that appears upon reversing direction. Backlash is caused by play in the drive train components coming after the encoder, such as gearheads or bearings, and by friction in the guiding system. Unlike hysteresis, it can lead to instability in closed-loop setups because it causes a deadband in the servo-loop. Some manufacturers promote controllers with automatic backlash compensation that add the estimated amount of lost motion upon each reversal. This solution is very limited in practice, as backlash is not constant but varies with temperature, deceleration, acceleration, load, leadscrew position, direction, wear, etc.

Bidirectional Repeatability

The accuracy of returning to a position from any position, regardless of direction. Effects such as hysteresis and backlash affect bidirectional repeatability. See also "Unidirectional Repeatability".

Coarse / Fine Drives

See Hybrid Drives on page 4-132.

Cosine Error

An on-axis cumulative error that occurs when a drive system is misaligned in regard to the driven part. The error is the difference between the distance moved and the distance moved times the cosine of the angle between the ideal drive axis and the actual drive axis.

DC-Mike / Stepper-Mike Drives

DC- and Stepper-Mikes are linear actuators, consisting of a micrometer spindle and a motor drive. PI offers compact versions with DC-motor gearhead combinations, as well as high-power, direct drive, ballscrew versions (for example M-235) capable of generating high forces. Most models are equipped with non-rotating tips and limit switches. All provide resolutions in the submicrometer range.

Definition of Axes and Angles

X: Linear motion in (first) positioning direction

Y: Linear motion perpendicular to X in basic plane (usually horizontal)

Z: Linear motion perpendicular to X and Y (usually vertical)

θ_X: Angular motion around X (roll)

θ_Y: Angular motion around Y (pitch)

θ_Z: Angular motion around Z (yaw)

Degree of Freedom (DOF)

A degree of freedom corresponds to an active axis of a motion system. An XY stage has two degrees of freedom.

Flexure

See description under "Guiding Techniques", see page 4-131.

Guiding Accuracy

See Runout.

Hysteresis

Hysteresis is a position error that occurs when reversing direction. Unlike backlash, hysteresis position error results from friction-based relaxation of elastic forces in the drivetrain components. Hysteresis varies greatly with load, acceleration and velocity.

Maximum Push/Pull Force

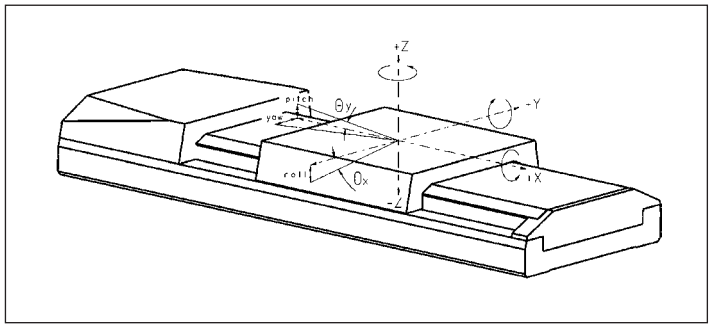
Active and passive force limit in operating direction, at center of stage. Some stages may be able to generate higher forces at the cost of reduced lifetime.

Micropositioning

Micropositioning systems are motor-driven stages with travel ranges of a few millimeters up to a few hundred millimeters, where positioning accuracy down to the sub-micron level can be achieved. Because the guiding systems in such stages—usually crossed roller bearings—generate frictional forces, their resolution and repeatability are typically limited to 0.1 µm. The guiding system working principle also adds errors that are typically in the micrometer range. Submicron incremental motion with travel ranges of a few to a few hundred millimeters, typically motor-driven.

Minimum Incremental Motion

The minimum motion that can be repeatedly executed for a given input, which is sometimes referred to as practical or operational resolution. Design resolution and practical resolution must be distinguished. Design resolutions of 1 nm or better can be achieved with many motor, gearbox and lead-



screw combinations. In practical applications, however, stiction/friction, windup, and elastic deformation limit resolution to fractions of a micron. Minimum incremental motion must be determined by actual measurements. Repeatable nanometer or sub-nanometer resolution can be provided by solid-state actuators (piezo actuators) and PZT flexure stages (see the "Piezo Flexure Stages / High-Speed Scanning Systems" (p. 2-3 *ff*) and "Piezo Actuators & Components" (p. 1-61 *ff*) sections of the PI Catalog for details).

Nanopositioning

Nanometer to sub-nanometer incremental motion with travel ranges in the micron to millimeter ranges, typically with piezoelectric drives with no stiction, friction or backlash and excellent dynamic characteristics. Good nanopositioning systems can settle to within a few nanometer of a target within a few milliseconds.
For longer travel ranges with nanometer precision, see the piezo stepping drives PiezoWalk® Linear Drives and PI's M-511.HD (see p. 4-46) and M-714 (see p. 4-62) hybrid-drive translation stages.

Orthogonality Error

The deviation from the ideal 90° angle between the X, Y and Z motion axes.

Parallel Kinematics

Multi-axis system design in which all actuators act directly upon the same moving platform. Advantages are lower inertia, no moving cables, lower center of gravity, no cumulative guiding error, more-compact construction. See also "Serial Kinematics".

Precision

An undefined term used differently by different manufacturers to refer to absolute accuracy, repeatability, or resolution.

Pulse Width Modulation (PWM)

The PWM mode is a highly effective method of transmitting electrical energy at a variable rate by varying the width of pulses in a train rather than the amplitude of an analog signal. See "ActiveDrive™".

Design Resolution

The theoretical minimum movement that can be made. This is a calculated value based on the drive components (drive screw pitch, gear ratio, motor angular resolution etc.) and does not account for nonlinearities like friction, backlash, etc. Design resolution must not be confused with minimum incremental motion. In systems with high gear ratios or microstepping motors, the design resolution can be in the subnanometer range. In practice, incremental motion of less than 0.1 µm is prevented by guiding system friction (except with air bearings and flexures).

Resolution

See "Design Resolution" and "Minimum Incremental Motion".

Runout

Deviation from the planned trajectory. For linear stages, runout describes unwanted motion in all 5 degrees of freedom (off-axis motion) other than the intended motion in the commanded direction. For a translation in X, linear runout occurs in Y and Z, tip and tilt occur in θX (roll), θY (pitch) and θZ (yaw). Runout is caused by the guiding system itself, by the way the stage is mounted (tension!) and the load conditions. See also "Wobble".

Serial Kinematics

Multi-axis system design in which each actuator drives its own separate platform. Advantages are simpler assembly and control algorithm. Disadvantages are poorer dynamic performance, no integrated parallel metrology possible, cumulative guiding errors, poor accuracy. See also "Parallel Kinematics".

Stick-Slip Effect

Limits minimum incremental motion. The stick-slip effect is observed as jump in position at the transition from static friction to dynamic friction as the drive force increases. Frictionless devices such as piezo actuators are not effected by the stick-slip effect, allowing them to provide resolution in the subnanometer realm.

Unidirectional Repeatability

The accuracy of returning to a given position from the same direction. Because unidirectional repeatability is almost unaffected by backlash and hysteresis, it is often considerably better than bidirectional repeatability.

Wobble

For rotary stages, unwanted off-axis rotary motion.

Motors & Drives

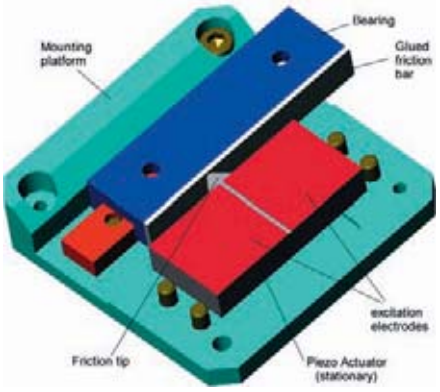
Linear Drives

Piezo Drives

It is important to distinguish between different types of piezo drives: classical piezo actuators (direct acting), flexure amplified actuators, and piezo linear motors. Direct-drive piezo actuators offering resolutions of under one nanometer can be combined with classical motorized actuators and stages to form coarse/fine systems or the more advanced hybrid systems (p. 4-132). Piezo linear motors provide basically unlimited travel ranges. PI offers two types: Ultrasonic (high-speed) motors and PiezoWalk® (high-force, high resolution) motors. Piezo actuators can achieve extremely high accelerations of many thousands of g's, are frictionless and backlash-free. For details, see the "Piezo Flexure Stages / High-Speed Scanning Systems" (p. 2-3 *ff*) section, the "PiezoWalk® Motors / Actuators" (p. 1-3 *ff*) section and the tutorial "Piezoelectrics in Positioning" (p. 2-171 *ff*) section.

Ultrasonic Piezomotors

Ultrasonic piezomotors are direct-drive systems; they do not use leadscrews or gearheads and are backlash-free. In addition, they neither create, nor are influenced by, magnetic fields. The drive consists of a stator, containing a piezoceramic oscillator and a slider (friction bar), which is attached to the moving part of the stage. With PI ultrasonic piezomotors speeds of up to 500 mm/s and resolutions of 0.1 µm in closed-loop are possible. They are also extremely compact, self-locking and have lifetimes of over 20,000 hours. PI piezomotors are used in miniature translation stages like the M-661, M-662, M-663 and M-664 series, and in XY stages like the M-686.



Working principle of an ultrasonic linear piezomotor drive

Voice-Coil Linear Drives

These friction-free electromagnetic linear drives are characterized by their good dynamics, albeit with relatively low holding force. They are used primarily in scanning applications with travel ranges in the millimeter to low centimeter range. PI offers voice coil drives in the V-106 stages, as well as in custom-designed systems.

Classic Drive Systems

ActiveDrive™ DC Motor

Some of the advantages of DC-motor drives are good dynamic performance, fast response, high torque at low rpm, low heat dissipation and low vibration. The cost of a high-performance amplifier, however, is generally higher than that for a stepper motor.

The ActiveDrive™ system reduces this cost considerably, by integrating a PWM (pulse width modulation) driver and amplifier in the motor case. This design provides several advantages:

- Increased efficiency, by eliminating power losses between the amplifier and motor Reduced cost, more-compact system, and improved reliability, because no external driver and cabling are required
- Elimination of PWM amplifier noise radiation by mounting the amplifier and motor together in a single electrically shielded case
- Positioning accuracy is assured with either rotary or optical linear encoders.

DC Servo-Motor

A direct current motor that is operated in a closed-loop system (servo-loop). Characteristics of DC servo-motors are lack of vibration, smooth running, wide speed range and very good low-speed torque. For optimum performance, a good motor controller with PID (proportional, integral, derivative) algorithm and filter settings is mandatory. Some of the advantages of DC motor drives are good dynamic performance, fast response, high torque at low rpm, low heat dissipation and low vibration.

DC-Motor / Gearhead Drive

A few advantages of DC-motor/gearhead drives are very high angular resolution, small form factor and low power consumption with high torque. They can be operated by PC controller boards such as the C-843 without an external amplifier. PI uses various types with maximum power in the 2 to 3 watt range and optical rotary encoders with up to 4000 counts per revolution. Most models use preloaded gearheads to eliminate backlash.

Stepper Motor

An electric motor providing motion in discrete angular steps, without the need of position sensor or servo-loop. Stepper motors have very long lifetimes and are especially suited for applications where predictable positioning is required as opposed to fast response and extreme acceleration. Another advantage lies in the simple control electronics. Compared to closed-loop DC motors of the same size, stepper motors provide poorer dynamic performance and dissipate more heat, especially in steady state operation. PI offers microstepped 2-phase motors, which are very cost-effective.

Drive Screws

Leadscrews

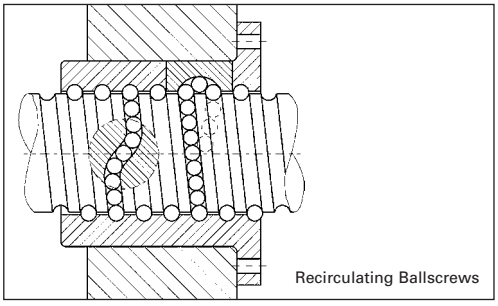
Leadscrews can provide very high resolutions and very smooth motion. A leadscrew drive consists of a motor-driven screw with a nut coupled to the sled of the stage. The nut can be spring preloaded to reduce backlash. Leadscrews are self-locking but exhibit higher friction than recirculating ballscrews, with the predictable effect on velocity, required motor power, and lifetime. Typical leadscrews have a pitch between 0.4 and 0.5 mm/revolution, or up to 1 mm/ revolution for longer travel ranges.

Recirculating Ballscrews

Recirculating ballscrews have significantly less friction than leadscrews, because they replace sliding friction with rolling friction.

A recirculating ballscrew drive consists of a motor-driven screw with a nut (ball housing) coupled to the sled of the stage, and a number of balls riding between the screw and the nut in a closed-circuit passage. Backlash can be eliminated by selecting the proper ball-to-thread-diameter ratio. Ballscrews are not self-locking, but are maintenance free, very efficient and offer high speeds and long lifetime in continuous operation. Standard PI ballscrews have pitches of 0.5, 1 or 2 mm/revolution.

The screw type is noted in the data sheet of each product.

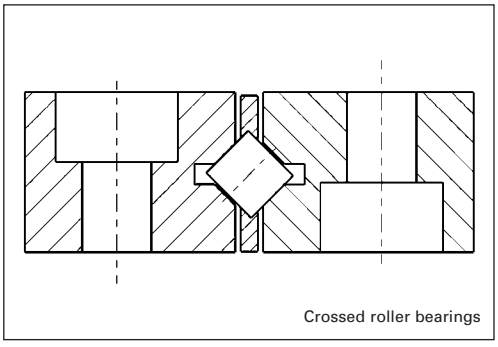


Recirculating Ballscrews

Guiding Systems

Crossed Roller Bearings

In crossed roller bearings the point contact of the balls is replaced by the line contact of the rollers. They are therefore stiffer and can be operated with reduced preload, resulting in reduced friction. Smoother travel and higher load capacity can also be achieved. Crossed roller bearings are employed in most PI compact translation stages such as the M-105/M-106, M-126 und M-405/M-410/M-415 series.

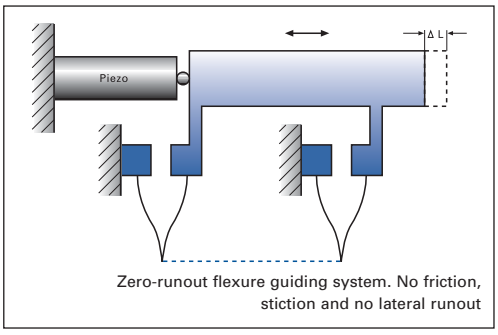


Crossed roller bearings

Flexures

A flexure is a frictionless, stictionless device that relies upon the elastic deformation (flexing) of a solid material. The flexure design is ideal for actuators where the required displacement is relatively small compared to the actuator's outer dimensions. Sliding and rolling are entirely eliminated from the design. In addition to absence of internal friction, flexure devices exhibit zero runout, high stiffness and load capacity, and resistance to shock and vibration.

Flexures can be manufactured from non-magnetic materials and require no lubricants or other operating materials (like air bearings). Thus, operation in vacuum is equally possible. PI provides piezo-driven flexure stages with sub-nanometer resolution, sub-nanometer flatness and straightness and sub-µrad pitch, yaw and roll (see the "Piezo Flexure Stages / High-Speed Scanning Systems" (p. 2-3 *ff*) section).



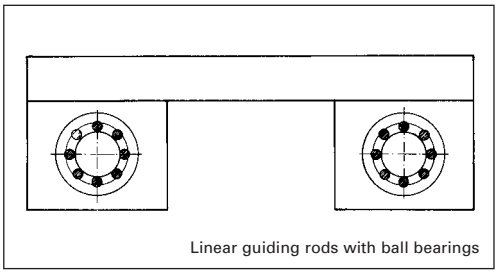
Zero-runout flexure guiding system. No friction, stiction and no lateral runout

Linear Guiding Rods with Ball Bearings

Precision-ground rods of hardened steel and linear ball bearings are used for the M-110, M-111 and M-112 translation stage series. A brass tube serves as ball cage. To reduce backlash and guarantee low friction, the rods and ball bearings have to be matched to very tight tolerances.

Linear Rails with Double-Row Recirculating Ball Bearings

The M-511, 521, 531, and M-605 series of motorized



Linear guiding rods with ball bearings

translation stages are equipped with precision double linear rails. The moving carriage is supported by a total of four preloaded linear bearings with two rows of recirculating balls each. The rails are bolted to the precision-machined stage base by several screws. Precision assembly allows these bearings to yield excellent results in terms of straightness, smoothness and load capacity. They are also immune to the cage migration problems of crossed roller bearings (can be an issue where small ranges are scanned repeatedly) and are maintenance free.

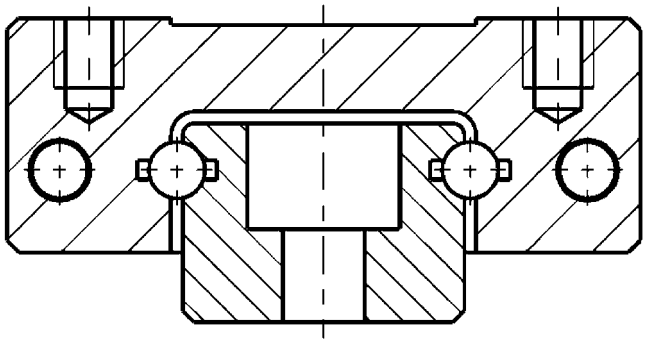
Magnetic-Kinematic Ball Bearings

Straightness of travel, symmetrical movement and absence of backlash are especially important for precision mechanical positioning.

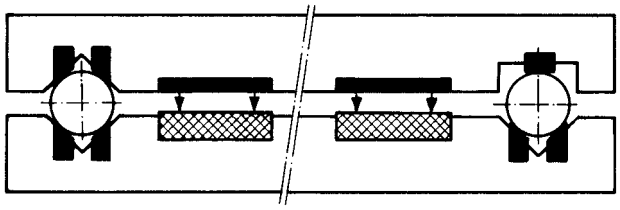
M-011 and M-014 magnetically coupled stages use the force of integrated magnets to preload the bearing.

This magnetic preload results in extremely smooth and uniform motion with minimum friction. To guarantee optimum straightness of travel, only one of the two linear bearings guides the stage (V-groove) while the second bearing is for support only (U-groove). Straightness and flatness is better than 0.2 µm over 25 mm. Minimum incremental motion with the optional piezo drive is as low as 5 nm.

Due to the limited magnetic force, only small loads can be handled in vertical applications. The same consideration limits permissible lateral forces.



Linear Rails with double row recirculating ball bearings



Magnetic-kinematic ball bearings

Hybrid Drives (Coarse / Fine)

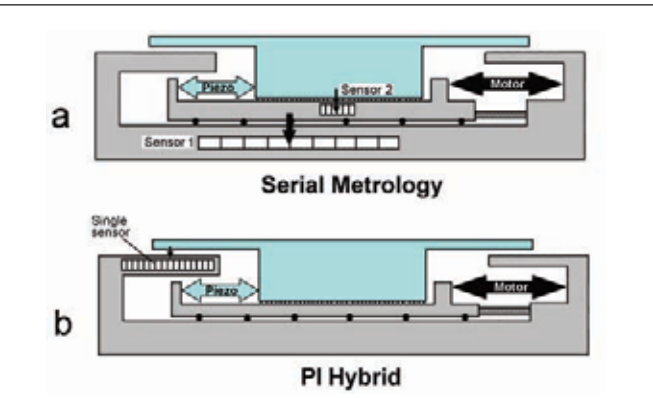
Classic Combinations

Combinations of different drive concepts are called hybrid drives. PI's micropositioning systems realize stacked systems of piezo and manual or motorized stages, where a motor/screw drive combination provides a long travel range and a piezo drive adds fine positioning accuracy and exceptional responsiveness over small ranges. For example, PI offers a fiber-scanning and coupling system comprising a 6-DoF micropositioner (F-206) mounted beside a multi-axis piezo system (P-611 Nanocube®) with high position resolution.

The servo-control algorithms with stacked systems like these generally operate independently, with the piezo system only becoming activated after the motorized positioner has come to a complete stop. Because separate position sensors are used. the absolute accuracy (not the resolution) is limited by the precision of the motorized long-range positioner.

Novel Hybrid Concept

A novel concept is implemented in the M-511.HD and M-714 Hybrid Translation Stages and C-702 Hybrid Controllers, that evaluate a nanometer-precision, long-range, sensor and provide nanometer accuracy over the whole travel range. The motor-leadscrew and the piezo actuator are fully integrated to form one motion system, and act simultaneously at all times. Thus every move benefits from the specific advantages of both the motorized actuator and the piezo actuator from startup to settling.The result is immediate starting, smoothness of motion, and a highly constant velocity. This makes hybrid systems ideal for applications where the position of an incident needs to be read and repositioned precisely, or where an externally specified target position needs to be hit

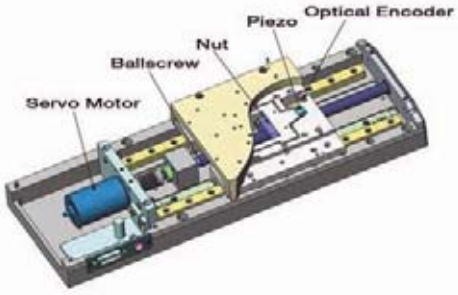


Different types of combined motorized and piezo positioning systems:
a) Serially stacked drives with individual integrated position sensors
b) PI Hybrid drive with integrated, internal, high-resolution sensor, for use with highly specialized controller

within few a nanometers, such as in surface inspection or metrology.

On the mechanical side, this is accomplished by decoupling the motion platform of the hybrid positioning stage from the micropositioner's motor-spindle-drive by frictionless flexures and stiff, fast response piezo actuators. The piezo actuators actively smooth out the irregularities in the motion of the platform caused by the motorized drive train to provide full move capability down to the sensor range.

The control algorithms treat the motor and piezo combination as one single drive unit and continuously compare the actual platform position (by reading the integrated linear encoder) with a calculated, smooth trajectory.



Working principle of the M-511.HD. The platform is decoupled from the motor drive train by the piezo actuator and the flexure guides. This also reduces the inertia of the piezo-driven platform and allows for rapid response

Metrology

Position Sensing—Rotary Encoder

A shaft-mounted position encoder provides highly accurate signals whenever the position changes by a known, small amount. By monitoring the encoder pulses, called counts, the controller can keep track of the relative motion of the stage. To discover the absolute position, it is necessary to drive the stage to a limit or reference switch. Most controllers have commands to automate this procedure, which is called referencing.

Position Sensing—Linear Encoder

Non-contact optical linear encoders measure the actual position directly, thus eliminating drive train errors such as non-linearity, backlash or elastic deformations (Direct Metrology).

Serial Metrology

Position-sensor-system design for multi-axis systems in which some of the sensors measure motion components between two moving platforms. Advantages are easy integration in serial kinematics systems and simple control algorithms. Disadvantages are failure to detect off-axis motion (runout) of the intermediate platforms, making Active Trajectory Control impossible.

Parallel Metrology

Position-sensor-system design for multi-axis systems in which all of the sensors measure motion components between the base and the same moving platform. Primary advantage is that all contributions to the motion in a given direction are detected and are thus inside the servo-loop. This means that the off-axis motion of all actuators can be compensated (Active Trajectory Control). Parallel Metrology is also easily integrated in parallel kinematics systems. A complex control algorithm is required.

Direct Metrology

Position-sensor-system design where the motion of the moving platform is sensed directly. Primary advantage is that drivetrain errors such as backlash and play are eliminated. Direct metrology requires sometimes a more complex stage design.

Indirect Metrology

Position-sensor-system design where the motion of the moving platform is inferred by sensing motion somewhere else, typically in the drive train. Advantage is that the design can place the sensor at the most convenient point. The results are affected by drive train errors such as backlash and play.

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