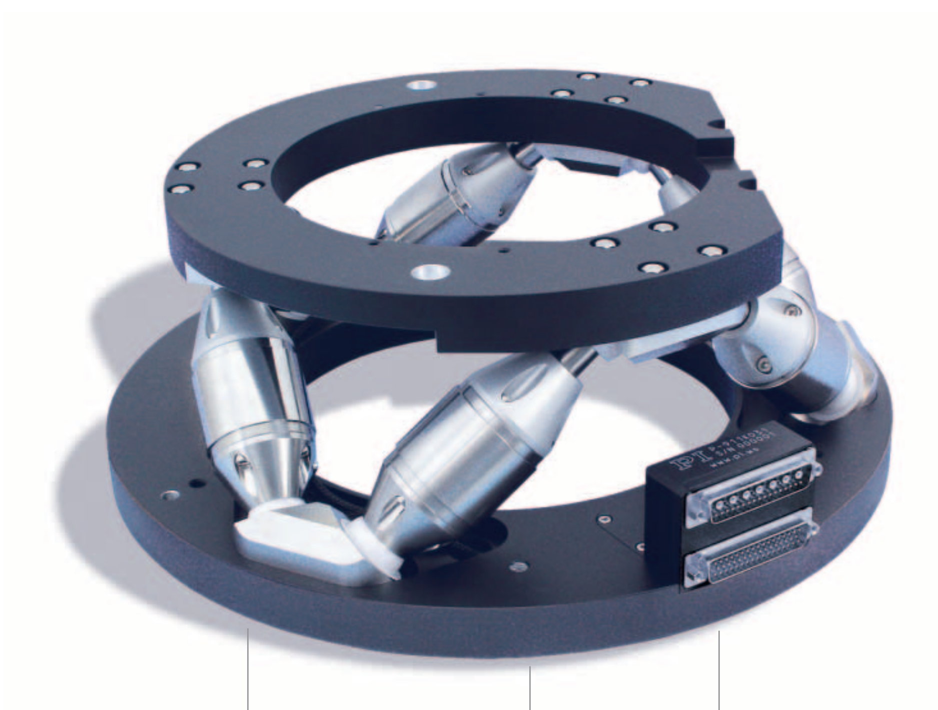
Piezo Nano Positioning

updated 2011



Nanopositioning

Micropositioning

Nanometrology

Thank You!

Dear Customers,

Annual growth rates in double figures, a further expansion of our production capacity and the development of new, globally unique drive technologies: This sums up the last few years at PI.

We owe the success of our business to you.

Your loyalty, your trust, your suggestions and the application problems you have asked us to solve have confirmed PI's role as the leading supplier of piezo-based drives and positioning systems operating with nanometer accuracy.

Our current catalog illustrates some of our products and capabilities. We want to fill you with enthusiasm for our technology. At PI, we not only strive to supply products but also to be your partner in the often difficult quest for technological leadership and commercial success.

Long-term business relationships, reliability, and open and friendly communication with customers and suppliers form an important mainstay for PI–more important than short-term gain.

We are aware of our responsibility towards our customers and take this responsibility very seriously. This is why we continuously invest in the highest quality equipment and qualified personnel. We will continue to extend our leading-edge position as a supplier of high-quality products at the highest technological level.

Find your inspiration–our staff will be delighted to be of service to you.

Kind regards

Dr. Karl Spanner
President

About this Catalog

- 200 product families, 30 % of them new
- More than 1,000 products on over 500 pages
- Comprehensive, consistent data-, for a better comparison between products
- More than 1,000 drawings, images, measurement graphs and technical diagrams
- Comprehensive, detailed selection guides and application overviews
- The well-established PI piezo tutorial with background information far exceeding standard product descriptions: a reference work on the basics of piezo technology and precision positioning.

Our "Inspirations 2009" catalog offers all this (and more), and it impressively mirrors the growth that PI has experienced in the recent years.
In detail, the product groups were reorganized into 4 major sections "Linear Drives, Nanopositioning Systems, Nanometrology Sensors and Micropositioning Systems" to reflect the need of our customers.
Additional sub-sections and the use of a colored index system simplify the product search. The product selection guides in each sub-section contain referencing data, scaled down product illustrations, and cross-references to other related sections.

If you cannot find what you are looking for or have any questions, just call or email your local PI representative, or use our extensive online search utility. We will work with you to find the optimum solution – based on catalog product or a custom design optimized for your application.

For up-to-date information on the latest products software updates, user manuals, contact information and a growing list of our world wide subsidiaries and representatives, visit our website at www.pi.ws.

Birgit Schulze,
Stefan Vorndran,
Steffen Arnold
Marketing

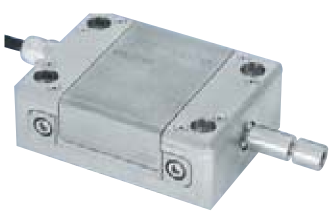
Linear Actuators & Motors

PiezoWalk® Motors / Actuators

PiezoWalk® Precision Drives

Millimeter Travel, Nanometer Resolution, High Forces

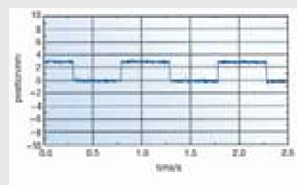
PiezoWalk® drives break away from the limitations of conventional Nanopositioning actuators. They offer a basically unlimited travel range and still provide the characteristic features of a piezoelectric actuator: an open-loop resolution down to 30 picometers and a very high stiffness for dynamic operation and force generation. PI offers two product lines based on different versions of the PiezoWalk® principle: NEXLINE® and NEXACT®. Both provide specific advantages depending on the application.


Custom PiezoWalk® linear actuator

PiezoWalk® piezo stepping drives usually consist of several individual piezo actuators and generate motion through succession of coordinated clamp / unclamp and shear-motion cycles (steps). Each cycle provides only a few microns of motion, but running at hundreds of hertz, the drive achieves continuous motion in the mm/second range.

The PiezoWalk® working principle provides high force capabilities, resolution and repeatability. These properties are typically better for piezo stepping actuators compared to inertia drives or ultrasonic motors.

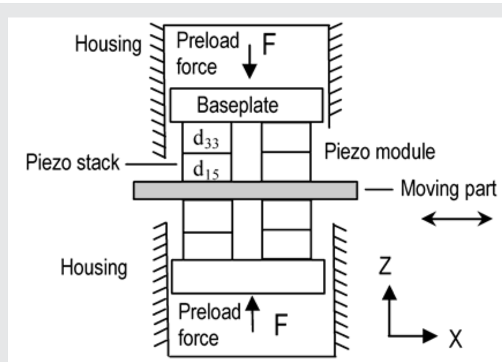
The operation is possible in two different modes: a high-resolution, high dynamics analog mode within a single step, and a step mode with virtually unlimited travel range.


50 picometer steps with a NEXLINE® drive, measured with external ultra-high-resolution capacitive sensor. This performance provides a big safety margin for next generation nanotechnology applications

Features and Advantages of PiezoWalk® Drives

- Very high resolution, limited typically only by the sensor. In fine-adjustment, analog mode, resolution of 30 picometers has been demonstrated.
- High force generation and stiffness. NEXLINE® drives can hold and generate forces to 600 N, NEXACT® to 15 N.
- PiezoWalk® drives hold a stable position to nanometer level in power-off mode. Due to the actuator design, the maximum clamping force is applied at rest.
- Because a position can be held with zero operating voltage, leakage currents cannot affect the integrity of the piezo drive.
- PiezoWalk® drives are available for non-magnetic applications such as super-conductivity experiments. They do not create magnetic fields nor are they influenced by them.
- The active parts in PiezoWalk® drives are made of vacuum-compatible ceramics. The drives also work in UV-light environments.
- NEXLINE® drives can survive shock loads of several g during transportation.
- PiezoWalk® drives are available in three levels of integration to provide flexibility for OEMs: OEM drives, packaged actuators and integrated into complex positioning systems such as multi-axis translation stages or 6-DOF Hexapods.

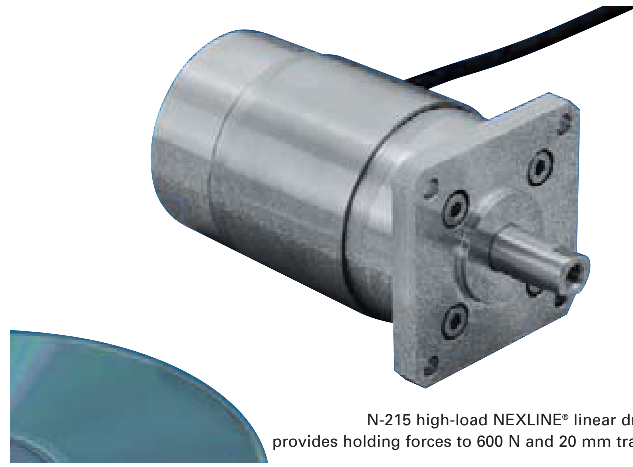

6-axis parallel-kinematic nanopositioning system (Hexapod) with N-215 based NEXLINE® high-load actuators for use in strong magnetic fields



NEXLINE® linear actuator principle

NEXLINE® High-Force Drives for Nanopositioning

NEXLINE® systems are based on very rugged, high-efficiency shear and clamping actuators and incorporate a preloading mechanism to provide pushing and holding forces up to 600 N with high lifetime. The rigid design with resonant frequencies of hundreds of hertz allows the construction of very stiff structures and helps to suppress vibration. The analog operating mode can be used for dithering and active vibration cancellation.



N-215 high-load NEXLINE® linear drive provides holding forces to 600 N and 20 mm travel

Compact NEXACT® Drives for Moderate Forces

NEXACT® drives use bending actuators which combine the feed forward and the clamping cycles. They provide push/pull forces to 15 N with maximum velocities of more than 10 mm/s at low operating voltages of 40 V. The compact and cost-effective NEXACT® drives are available with various drive electronics, ranging from cost-effective OEM drives for open-loop operation in stepping mode to the sophisticated E-861 servo-controller for high-resolution, closed-loop linear translation stages.

N-310 actuartor with E-861 servo-controller (integrated drive electronics)

N-111 NEXLINE® OEM Linear Actuator

Nanopositioning Over Long Travel, PiezoWalk® Principle

N-111 compact OEM nanopositioning actuator. In principle the movement by piezo steps allows an infinite travel range

- **Travel Range 10 mm**
- **Resolutionto 0.025 nm Open-Loop, 5 nm Closed-Loop**
- **Up To 50 N Force Generation and 70 N Holding Force**
- **Self Locking at Rest, No Heat Generation**
- **Non-Magnetic and Vacuum-Compatible Working Principle**
- **Cleanroom Compatible**

The innovative N-111 NEXLINE® OEM linear actuators are compact actuators for nanopositioning with travel ranges to 10 mm, high resolution, and generated forces to 50 N. The operating principle is based on coordinated motion of a number of highly preloaded linear and shear piezo elements acting on a runner. NEXLINE® drives thus combine long travel ranges with piezo-class precision. For closed-loop operation without an additional position sensor the N-111.2A is equipped with a linear encoder that provides 5 nm resolution over the full travel range. In open-loop operation position resolution down to 25 picometers can be achieved by use of a high-dynamics analog mode.

Application Examples

- Semiconductor technology
- Semiconductor testing
- Wafer inspection
- Nano lithography
- Nano-imprinting
- Nanometrology
- Active vibration damping
- Motion in strong magnetic fields

NEXLINE® Working Principle for Application Flexibility

NEXLINE® PiezoWalk® drives can be used wherever high loads must be positioned very precisely over long distances and then perhaps subjected to small-amplitude dynamic adjustment, as for active vibration control. By varying the combination of longitudinal and shear piezo elements, the step size, dynamic operating range (analog travel), clamping force, speed and stiffness can all be optimized for a particular application.

One Working Principle – Different Operating Modes

NEXLINE® PiezoWalk® drives overcome the limitations of conventional nanopositioning systems in their combination of long travel ranges and high resolution and stiffness. The piezoceramic clamping and shear elements act directly on a moving runner that is coupled to the moved object. While in full step mode the runner can be moved over larger distances with maximum velocity, nanostepping mode allows uniform motion with highly constant speed. In open-loop operation any position resolution may be achieved which only depends on the stability of the control signal. Analog operation over a distance of less than one step enables high-dynamics positioning with resolutions far below one nanometer.

Choice of Controllers for Optimization

NEXLINE®operation is supported by two motion controller models providing different features. The E-755 controller offers full functionality for nanometer precise positioning. The E-712 supplies more sophisticated linearization algorithms resulting in very smooth motion with highly constant velocity. It can also provide higher speed with maximum force.

Z / tip / tilt platform with NEXLINE® drives and position sensors; 300 mm (12'') diameter, 200 N load capacity, 1.3 mm travel range, 10 mrad tilt range

Ordering Information

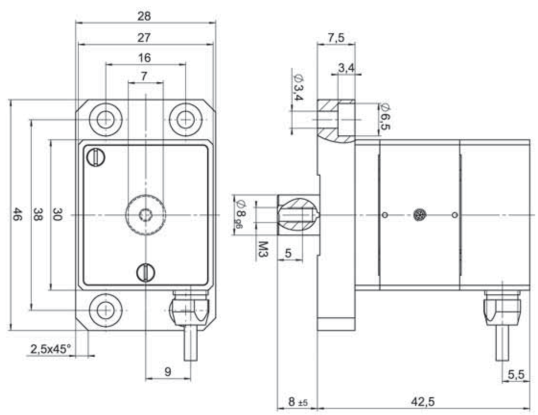
N-111.20
NEXLINE® OEM Piezo Stepping Actuator, 10 mm, 50 N

N-111.2A
NEXLINE® OEM Piezo Stepping Actuator, 10 mm, 50 N, Linear Encoder, 5 nm Resolution

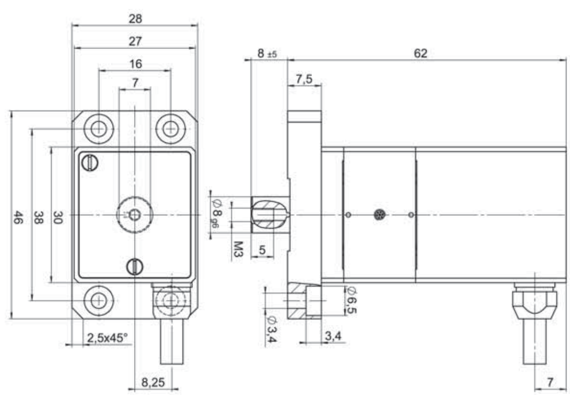
Ask about custom designs!

Patented Technology

The products described in this document are in part protected by the following patents:
German Patent No. 10148267
US Patent No. 6,800,984



N-111.20 dimensions in mm



N-111.2A dimensions in mm

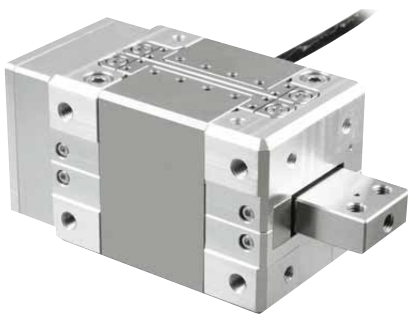
Technical Data

Model	N-111.20	N-111.2A	Tolerance
Active axes	X	X	
Motion and positioning			
Travel range	10 mm	10 mm	
Step size (in step mode)	10 nm to 7 µm	10 nm to 7 µm	
Travel range in analog mode	±2 µm	±2 µm	
Integrated sensor	–	Linear encoder	
Open-loop resolution	0.025 nm	0.025 nm	typ.
Closed-loop resolution	–	5 nm	
Max. velocity (10 % duty cycle, full step mode)*	1.0 mm/s	1.0 mm/s	
Max. velocity (100 % duty cycle, full step mode)*	0.6 mm/s	0.6 mm/s	
Max. velocity (100 % duty cycle, nanostepping mode)**	0.4 mm/s	0.4 mm/s	
Mechanical properties			
Stiffness in motion direction	16 N/µm	16 N/µm	±20%
Drive force (active)***	50 N	50 N	max.
Holding force (passive)	70 N	70 N	min.
Drive properties			
Motor type	NEXLINE®	NEXLINE®	
Operating voltage	±250 V	±250 V	
Miscellaneous			
Operating temperature range	-40 to 80 °C	-40 to 80 °C	
Material	Aluminium stainless steel, titanium	Aluminium stainless steel, titanium	
Mass	245 g	325 g	
Cable length	1.5 m	1.5 m	±10 mm
Connector	Sub-D connector NEXLINE® single-channel	Sub-D connector NEXLINE® single-channel plus sensor connector	
Recommended controller	E-755,101, E-712	E-755.1A1, E-712	

* Depending on drive electronics. Data refer to operation together with E-712 controller.
** Depending on drive electronics. Data refer to operation together with E-712 controller. Together with the E-755 controller a velocity of up to 0.1 mm/s (closed-loop) and 0.2 mm/s (open-loop) can be achieved. The maximum speed in nanostepping mode is set so as to ensure the highest possible velocity constancy, with no speed fluctuations while steps are being performed.
*** Data refer to full step mode operation.

N-216 NEXLINE® Linear Actuator

High-Force PiezoWalk® Drive for Long-Range Nanopositioning



N-216 NEXLINE® High-Load Actuator. Feed motion is realized by piezo stepping motion which allows basically unlimited travel ranges with nanometer accuracy

- **Travel Range 20 mm**
- **Resolutionto 0.03 nm Open-Loop, 5 nm Closed-Loop**
- **Up to 800 N Holding Force**
- **Self Locking at Rest**
- **Non-Magnetic and Vacuum-Compatible Working Principle**
- **Cleanroom Compatible**

N-216 NEXLINE® high-load linear actuators are ultra-precision nanopositioning actuators with travel ranges to 20 mm and push / pull forces to 600 N. The operating principle is based on coordinated motion of a number of highly preloaded linear and shear piezo elements acting on a runner. NEXLINE® drives combine long travel ranges with piezo-class precision.

N-216 comes in two versions for open- or closed-loop operation, as well as in two different load configurations. Closed-loop versions are equipped with a linear encoder for direct position measurement of the moving runner. The encoder features 5 nm resolution over the full travel range. In open-loop operation a positioning resolution to 30 picometers can be realized by use of the high-dynamics analog operation mode.

Application Example

- Semiconductor technology
- Semiconductor testing
- Wafer inspection
- Nano lithography
- Nano-imprinting
- Nanometrology
- Active vibration damping
- Motion in strong magnetic fields

Unlimited Lifetime

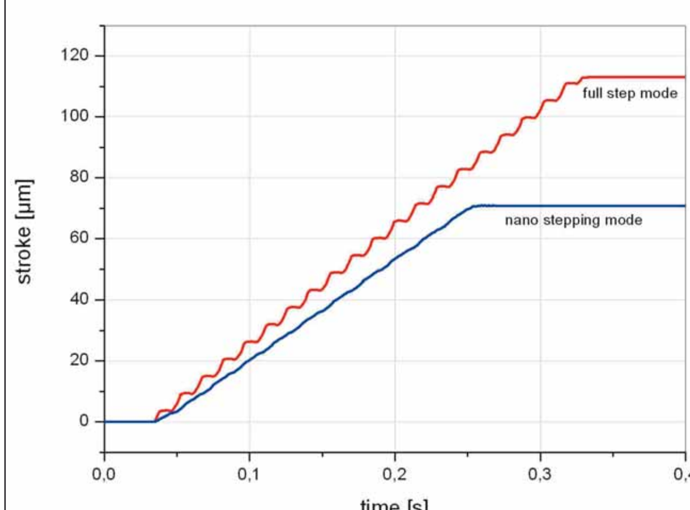
The application area of NEXLINE® drives often lies in the difficult-to-access internals of machines, where nanometer-realm adjustment and vibration cancellation are required. Long lifetime is therefore a basic requirement for NEXLINE® actuators. To promote long lifetime, the controller can reduce the operating voltage on all the piezo elements to zero at any position and still maintain the full holding force.

One Working Principle – Different Operating Modes

NEXLINE® PiezoWalk® drives overcome the limitations of conventional nanopositioning systems in their combination of long travel ranges and high resolution and stiffness. The piezoceramic clamping and shear elements act directly on a moving runner that is coupled to the moved object. While in full step mode the runner can be moved over larger distances with maximum velocity, nanostepping mode allows uniform motion with highly constant speed. In open-loop operation any position resolution may be achieved which only depends on the stability of the control signal. Analog operation over a distance of less than one step enables high-dynamics positioning with resolutions far below one nanometer.

Choice of Controllers for Optimization

NEXLINE®operation is supported by two motion controller models providing different features. The E-755 controller offers full functionality for nanometer precise positioning. The E-712 supplies more sophisticated linearization algorithms resulting in very smooth motion with highly constant velocity. It can also provide higher speed with maximum force.



Motion mode comparison of a NEXLINE® actuator: The nanostepping mode provides a very smooth motion. Full step mode allows higher speed

Ordering Information

N-216.10
NEXLINE® Piezo Stepping High-Load Actuator, 20 mm, 300 N, Open-Loop

N-216.1A
NEXLINE® Piezo Stepping High-Load Actuator, 20 mm, 300 N, Linear Encoder, 5 nm Resolution

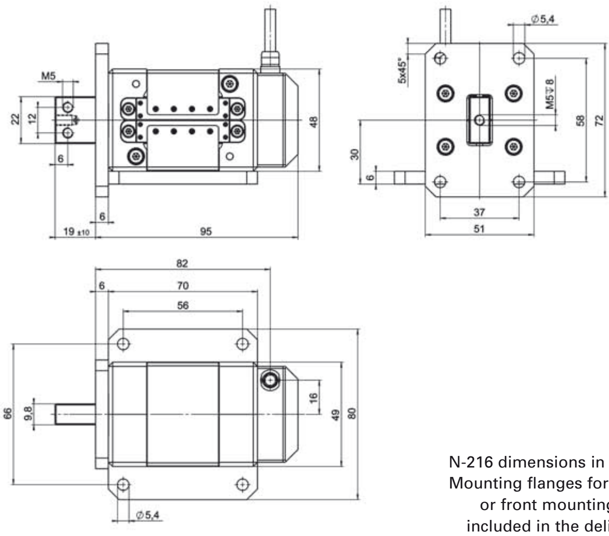
N-216.20
NEXLINE® Piezo Stepping High-Load Actuator, 20 mm, 600 N, Open-Loop

N-216.2A
NEXLINE® Piezo Stepping High-Load Actuator, 20 mm, 600 N, Linear Encoder, 5 nm Resolution

Ask about custom designs!

Patented Technology

The products described in this document are in part protected by the following patents:
German Patent No. 10148267
US Patent No. 6,800,984



N-216 dimensions in mm. Mounting flanges for side or front mounting are included in the delivery

6-axis parallel kinematics (Hexapod) with integrated NEXLINE® high-load actuators, suitable for applications in strong magnetic fields

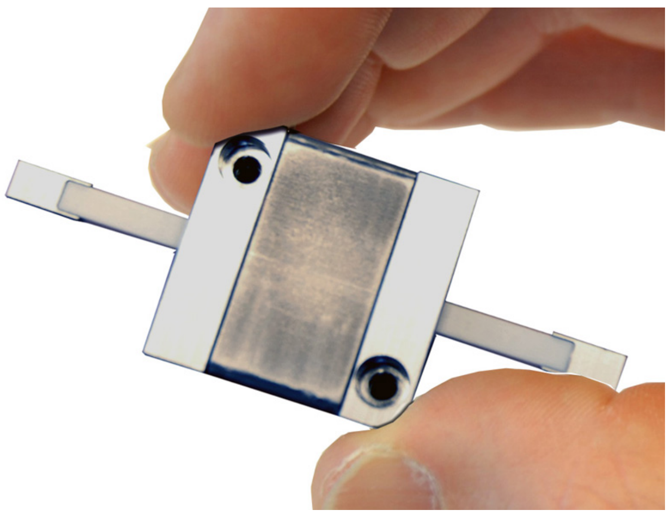
Technical Data

Model	N-216.10 / N-216.1A	N-216.20 / N-216.2A	Tolerance
Active axes	X	X	
Motion and positioning			
Displacement	20 mm	20 mm	
Step size (in step mode)	10 nm to 10 µm	10 nm to 10 µm	
Travel range in analog mode	±3 µm	±3 µm	
Integrated sensor	N-216.10: none N-216.1A: linear encoder	N-216.20: none N-216.2A: linear encoder	
Open-loop resolution	0.03 nm	0.03 nm	typ.
Closed-loop resolution	– / 5 nm (N-216.1A)	– / 5 nm (N-216.2A)	
Max. velocity (10 % duty cycle, full step mode)*	1.0 mm/s	1.0 mm/s	
Max. velocity (100 % duty cycle, full step mode)*	0.6 mm/s	0.6 mm/s	
Max. velocity (100 % duty cycle, nanostepping mode)**	0.4 mm/s	0.4 mm/s	
Mechanical properties			
Drive force (active)***	300 N	600 N	max.
Holding force (passive)	400 N	800 N	min.
Drive properties			
Motor type	NEXLINE®	NEXLINE®	
Operating voltage	±250 V	±250 V	
Miscellaneous			
Operating temperature range	-40 to 80 °C	-40 to 80 °C	
Material	Aluminum, stainless steel	Aluminum, stainless steel	
Mass	1150 g	1250 g	
Cable length	2.0 m	2.0 m	
Connector	Sub-D connector NEXLINE® single-channel N-216.1A: plus sensor connector	Sub-D connector NEXLINE® single-channel N-216.2A: plus sensor connector	
Recommended controller	E-755, E-712	E-755, E-712	

* Depending on drive electronics. Data refer to operation together with E-712 controller.
** Depending on drive electronics. Data refer to operation together with E-712 controller. Together with the E-755 controller a velocity of up to 0.1 mm/s (closed-loop) and 0.2 mm/s (open-loop) can be achieved. The maximum speed in nanostepping mode is set so as to ensure the highest possible velocity constancy, with no speed fluctuations while steps are being performed.
*** Data refer to full step mode operation.

N-310 NEXACT® OEM Miniature Linear Motor/Actuator

Compact, High-Speed PiezoWalk® Drive



- **20 mm Standard Travel Range, Flexible Choice of the Runner Length**
- **Compact and Cost-Effective Design**
- **0.03 nm Resolution****
- **To 10 N Push/Pull Force**
- **Low Operating Voltage**
- **Self Locking at Rest, No Head Dissipation, Nanometer Stability**
- **Non-Magnetic and Vacuum-Compatible Working Principle**

N-310 NEXACT® PiezoWalk® linear drives feature travel ranges of 20 mm and push/pull force capacities to 10 N in a compact package of only 25 x 25 x 12 mm. With their high resolution, NEXACT® drives, are ideal for high-precision positioning over long travel ranges.

Application Examples

- Semiconductor technology
- Wafer inspection
- Nano lithography
- Surface Measurement Technique
- Profilometry
- Microscopy
- Motion in strong magnetic fields

The N-310 can be operated in open-loop and closed-loop mode (with the addition of an external position sensor). A variety of NEXACT® controllers facilitates the integration into micro- or nanopositioning applications.

Advantages of PiezoWalk® Piezo Stepping Drives

NEXLINE® and NEXACT® drives offer several advantages over traditional drive technologies:

- Resolution in the picometer range
- Compact dimensions
- High drive forces from ten newtons (NEXACT®) up to several hundred newtons (NEXLINE®)
- High-dynamics performance with sub-microsecond response
- Self-locking when powered down; no holding current
- Zero backlash, no wear or maintenance, no mechanical components like gears or leadscrews.
- Non-Magnetic and Vacuum Compatible Operating Principle

Working Principle for Application Flexibility

NEXACT® PiezoWalk® technology overcomes the limitations of conventional nanopositioning drives and combines virtually unlimited travel ranges with high stiffness in a very small package. Furthermore, NEXACT® actuators provide piezo-class resolution (far below one nanometer) and millisecond responsiveness. The special drive design reduces the operating voltage to 45 V and below.

In operation, piezoceramic bending elements act on the runner, which is connected to the moving part of the application. The length of the runner determines the travel range. Force capacity, resolution and velocity are determined by the piezo geometry and drive electronics and are scalable. To move the runner over longer distances the stepping mode is used, whereas for distances smaller than one step, the linear (analog) mode enables high-dynamics positioning with resolutions far below one nanometer.

Wear- and Maintenance-Free

In contrast to ordinary DC or stepper motor drives, the PiezoWalk® drives effect linear motion directly, without the need to transform rotation with mechanical elements such as gears, leadscrews and nuts. Therefore, mechanical limitations such as backlash and wear are eliminated and the drive is maintenance-free.

Ordering Information

N-310.01
NEXACT® OEM linear drive, 20 mm, 10 N

Ask about custom designs

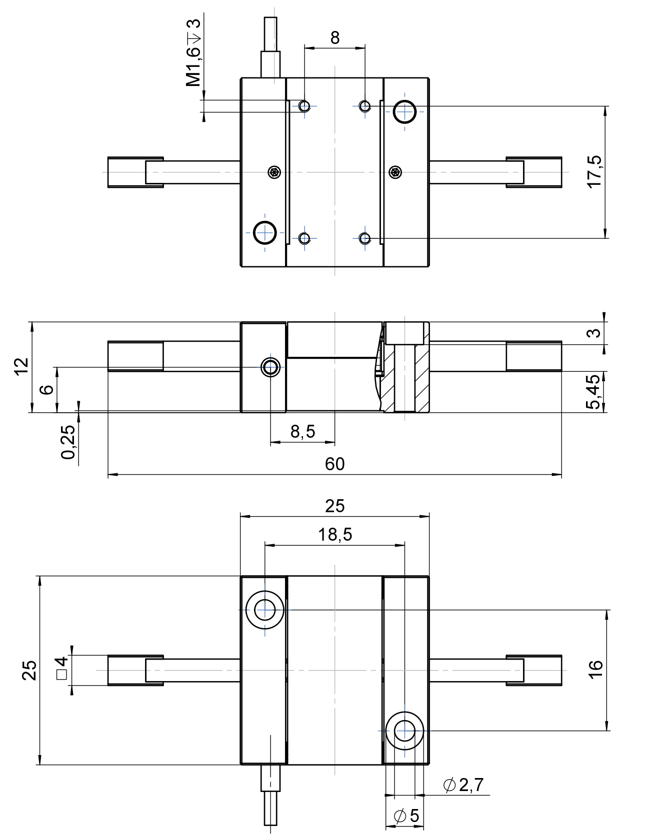
Self-Locking PiezoWalk® Piezo Stepping Drive

NEXLINE® and NEXACT® exhibit high stiffness and are self-locking even when powered down due to the clamping action of the piezo actuators in the mechanics. This entails nanometer position stability at rest, with no heat dissipation or servo-dither.

Controller and Drive Electronics Optimized for the Application

NEXACT® actuators require special drive electronics to control the complex stepping sequences. The E-860 series NEXACT® controllers are available in different open-and closed-loop versions. For example, the E-861 includes a complete NEXACT® servo-controller with low-noise, 24-bit drivers and a powerful DSP. It also comes with ample software for easy integration and highly effective computer control. For applications which do not require the highest resolution lower-priced drive electronics, ranging all the way to OEM boards, can be ordered.

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



N-310.01 Actuator, dimensions in mm


Translation stage with N-310 NEXACT® drive. The positioner offers 20 mm travel range with an encoder resolution of 25 nm

Technical Data

Model	N-310.01	Tolerance
Active axes	X	
Motion and positioning		
Travel range	20 mm	
Step size (in step mode)	5 nm to 5 µm	
Travel range in analog operation	7 µm	max.
Open-loop resolution	0.03 nm**	typ.
Step frequency	1.5 kHz*	max.
Max. speed	10 mm/s*	max.
Mechanical properties		
Push/Pull force (active)	10 N	max.
Drive properties		
Drive type	NEXACT® linear drive	
Operating voltage	-10 V to +45 V	
Miscellaneous		
Operating temperature range	0 to 50 °C	
Body material	Stainless steel, non-magnetic	
Mass	50 g	±5 %
Cable length	1.5 m	±10 mm
Connector	HD Sub-D connector 15 pin, single channel	
Recommended controller/driver	E-860-series (see p. 1-20)	

*Depending on the control electronics.
**Depending on the drive electronics. 5 nm with E-861.

Piezo • Nano • Positioning

N-381 NEXACT® Linear Actuator, Manipulator, Piezo Stepper

High-Resolution PiezoWalk® Linear Actuator with Optional Position Sensor

N-381 piezo stepper linear actuator for sample positioning and manipulation provides long travel, high speed and very high resolution; shown with E-861 NEXACT® Controller

- **Travel Range 30 mm**
- **Zero-Wear Piezo Stepping Drive, Ideal for Micro- and Nano-Manipulation**
- **Integrated Linear Encoder Option for Highest Accuracy with 20 nm Resolution**
- **Very High Acceleration, e.g. for Cell Penetration**
- **Two Operating Modes: Continuous Stepping Mode and Continuously Variable, High-Dynamics Analog Mode for 30 pm Resolution****
- **Up to 10 N Force Generation**
- **Self Locking at Rest, no Heat Generation**
- **Smooth Motion, no Closed-Loop Jitter**
- **Vacuum-Compatible and Non-Magnetic Versions**

The compact N-381 linear actuators are ideal drives and micro manipulators e.g. for biotechnology and nanotechnology applications. Rapid accelerations, velocities of 10 mm/s and forces up to 10 N enable high-dynamics and throughput for automation tasks. The PiezoWalk® drive principle allows long travel ranges and fast oscillations of 7 µm amplitude with frequencies up to several 100 Hz. This "analog mode" can be used to provide rapid acceleration, e.g. in cell penetration applications, or smooth motion for dynamic laser tuning or even for active damping of oscillations. Two models are available: The N-381.3A model is equipped with a high-resolution position sensor, allowing sub-micrometer repeatability in closed-loop operation. The N-381.30 open-loop version is intended for high precision applications where the absolute position is not important or is controlled by an external loop (video, laser, quadcell, etc.).

Application Examples

- Drive unit for scanning stage
- Cell manipulation, biohandling
- Micromanipulation
- Life science
- Photonics
- Laser tuning
- Motion in strong magnetic fields

Piezo Stepping Drive—the Multi-Functional Piezo Linear Motor

A great advantage characteristic of the NEXACT® piezo stepping drive is its dual-mode operating principle combining the best features of other piezo motor designs, such as high resolution, high force and high speed into one compact unit. At the target position the drive requires no current and generates no heat while providing long-term, nanometer stability. This autolocking feature also completely eliminates servo-jitter as it occurs with other closed-loop motors. Since motion is not based on dynamic friction as with piezo inertial drives (stick-slip-motors) but solely caused by the nanometer precise motion of clamped piezo actuators, there is no wear to limit the lifetime. When operated in closed-loop, excellent velocity control is achieved.

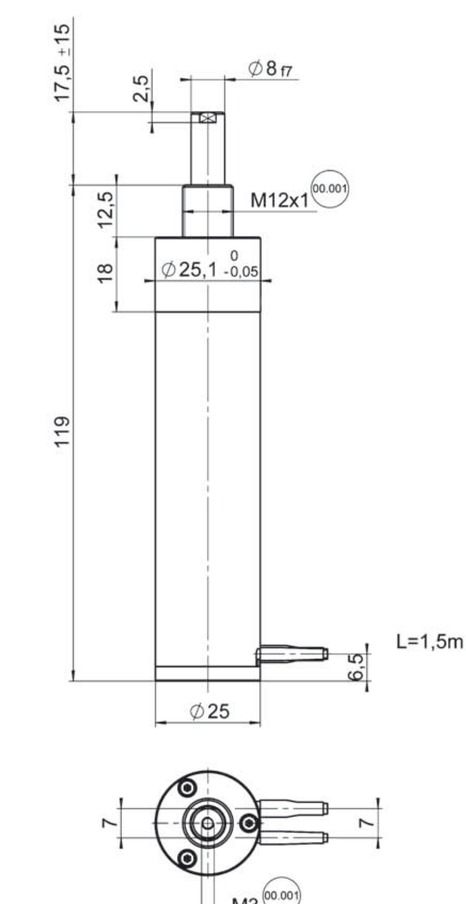
Ordering Information

N-381.3A
NEXACTUATOR® Linear Actuator, 30 mm, 20nm Encoder Resolution

N-381.00
NEXACTUATOR® Linear Actuator, 30 mm, Open-Loop

Available on request

Ask about custom designs!



N-381 dimensions in mm

Working Principle for Application Flexibility

NEXACT® PiezoWalk® technology overcomes the limitations of conventional nanopositioning drives and combines virtually unlimited travel ranges with high stiffness in a very small package. Furthermore, NEXACT® actuators provide piezo-class resolution (far below one nanometer) and millisecond responsiveness. The special drive design reduces the operating voltage to 45 V and below.

In operation, piezoceramic bending elements act on the runner, which is connected to the moving part of the application. The length of the runner determines the travel range and can be chosen as required. To move the runner over longer distances the stepping mode is used, whereas for distances smaller than one step, the analog mode enables high-dynamics positioning with resolutions far below one nanometer.

Controllers and Drivers Optimized for the Application

NEXACT® actuators require special drive electronics to control the complex stepping sequences. The E-861 (see p.1-20) includes a complete NEXACT® servo-controller with low-noise drivers and a powerful DSP. It also comes with ample software for easy integration and highly effective computer control. For applications which do not require the highest resolution, the E-862 (see p. 3-10) lower-priced drive electronics, can be ordered.

The products described in this document are in part protected by the following patents:

German Patent No. P4408618.0

Technical Data (Preliminary)

Model	N-380 Open-Loop	N-381 Closed-Loop
Active axes	X	X
Motion and positioning		
Travel range	30 mm	30 mm
Step size (in step mode)	0.1 to 15 µm	–
Integrated sensor	–	Incremental linear encoder
Sensor resolution	–	20 nm*
Travel range in analog mode	7 µm	7 µm
Open-loop resolution	0.03 nm**	0.03 nm**
Closed-loop resolution	–	20 nm*
Step frequency	0 to 800 Hz	–
Max. velocity	10 mm/s*	10 mm/s*
Mechanical properties		
Stiffness in motion direction	2.4 N/µm	2.4 N/µm
Max. push / pull force (active)	10 N	10 N
Max. holding force (passive)	15 N	15 N
Lateral force	10 N	10 N
Drive properties		
Drive type	NEXACT® linear drive	NEXACT® linear drive
Operating voltage	-10 V to +45 V	-10 V to +45 V
Miscellaneous		
Operating temperature range	0 to 50 °C	0 to 50 °C
Material	Stainless steel / CFRP	Stainless steel / CFRP
Mass	250 g	255 g
Cable length	1.5 m	1.5 m
Connector	15-pin HD-Sub-D connector, one channel	15-pin HD-Sub-D connector, one channel
Recommended controller/driver	E-860 series (see p. 1-20)	E-861.1A1 (see p. 1-20)

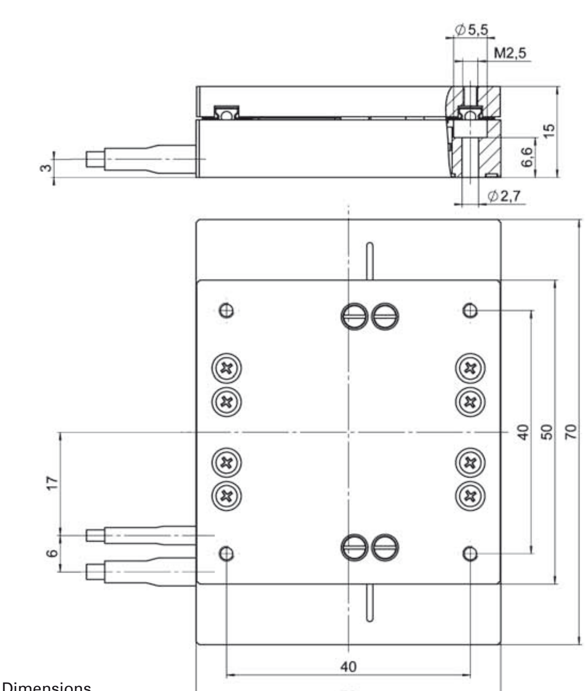
*With E-861. Depending on drive electronics.
**Depending on the drive electronics. 1 nm with E-861.

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 tun-ing, 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

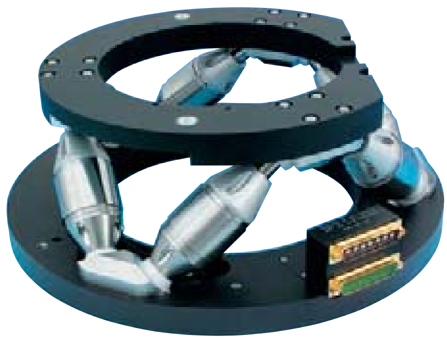
Technical Data

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	200 nm
Pitch	500 µrad
Yaw	150 µrad
Max. Step frequency (open-loop)	0.8 kHz
Max. velocity	10 mm/s*
Mechanical properties	
Stiffness in motion direction	2.4 N/µm
Max. load capacity	20 N
Max. push / pull force (active)	10 N
Max. holding force (passive)	15 N
Lateral Force	20 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.

N-515K Non-Magnetic Piezo Hexapod

6-Axis Precision Positioning System with NEXLINE® Linear Drives



6-axis parallel kinematics (Hexapod) with integrated N-215 NEXLINE® high-load actuators, suitable for applications in strong magnetic fields

- **Travel Ranges 10 mm Linear, 6° Rotation**
- **Large Clear Aperture Ø 202 mm**
- **Non-Magnetic**
- **Nanometer Resolution**
- **Low-Profile: 140 mm Height Only**
- **Parallel Kinematics for Enhanced Dynamics and Better Multi-Axis Accuracy**
- **Up to 500 N Force Generation**
- **Self Locking at Rest, No Heat Generation**

Model	Travel Range	Load capacity	Dimensions
N-515KNPH NEXLINE® Piezo Hexapod	X, Y, Z: 10 mm θ_X, θ_Y, θ_Z: 6°	50 kg	Outer Ø baseplate, 380 mm Ø moved platform (top) 300 mm 140 mm height

N-510 High-Force NEXLINE® Z/Tip/Tilt Platform

Nanometer Precision for Semiconductor Industry, Wafer Alignment

Z, tip, tilt nanopositioning platform with 3 integrated drives (tripod design)

- **Self Locking at Rest, No Heat Generation**
- **Vacuum Compatible and Non-Magnetic Designs Feasible**
- **Parallel Kinematics for Enhanced Dynamics and Better Multi-Axis Accuracy**
- **NEXLINE® Piezo Walking Drive Free from Wear and Tear**
- **Load Capacity 200 N**
- **High Precision with Integrated 5 nm Incremental Sensors + Picometer Resolution Dithering Mode**

Model	Travel	Load capacity	Linear velocity	Dimensions
N-510 NEXLINE® Z, tip, tilt platform	1,3 mm vertical range 10 mrad tilt angle	200 N	0.2 mm/s	Ø 300 mm (12´´) clear aperture Ø 250 mm

N-510K High-Stiffness NEXLINE® Z Stage

High-Precision Positioning, with Capacitive Sensors

The N-510KHFS hybrid-drive nanopositioner offers maximum accuracy for semiconductor inspection applications

- **Self Locking at Rest, No Heat Generation**
- **Hybrid Drive: PiezoWalk® plus PICMA®**
- **Travel Range: 400 µm Coarse + 40 µm Fine**
- **2 nm Closed-Loop Resolution**
- **Direct Metrology: One Single Control Loop with Capacitive Sensors**
- **High Push and Holding Force to 25 N**
- **Piezo Walking Drive w/o Wear and Tear & Outstanding Lifetime due to PICMA® Piezo Actuators**

Model	Vertical travel	Velocity	Bidirectional repeatability	Load capacity	Dimensions
N-510KHFS Hybrid-Focus System	400 µm coarse 40 µm fine	1 mm/sec	50 nm (full travel)	25 N	Ø 300 mm 68.5 mm height

E-755 Digital NEXLINE® Controller

Controller for Picometer-Precision PiezoWalk® Linear Actuators / Positioners

E-755 digital NEXLINE® controller with N-214 nanopositioner, 20 mm travel range.

- **Special Control Algorithms for NEXLINE® Nanopositioning Linear-Motor Actuators**
- **32-Bit Digital Filters**
- **24-Bit DAC Resolution**
- **Fully Programmable Low-Pass and Notch Filters**
- **Non-Volatile User Settings and Last-Position Data**
- **Daisy-Chain Networking for up to 16 Axes**
- **PI GCS (General Command Set) Compatible**

E-755 digital single-axis nanopositioning controllers are designed to drive the patented NEXLINE® nanopositioning linear drives. Combining advanced control technology and sensor signal processing with special drive algorithms, the E-755 can provide precision motion control over hundreds of millimeters with picometer-range resolution. Coordinated action of shearing and clamping piezo elements is what allows NEXLINE® to break through the barriers of conventional nanopositioning actuators.

Application Examples

- Semiconductor technology
- Quality assurance testing in semiconductor industry
- Astronomical telescopes
- Truss structures
- Active vibration control
- Alignment in high magnetic fields, as in particle physics, atomic fusion and superconductivity research

The E-755 offers two different control modes for the NEXLINE® walking drives: a high-resolution, high dynamics direct piezo mode, with basically unlimited resolution (analog mode), and a long-range stepping mode with theoretically unlimited travel range.

High-Resolution Servo-Control

E-755 controllers are based on powerful 32-bit DSPs and come in open- and closed-loop versions. Both versions feature four high-resolution (24-bit) linear amplifiers with the output range of ±250 V required to control a single-axis NEXLINE® drive. For the closed-loop models, high-resolution incremental position sensors are supported by special excitation and read-out electronics.

The sensors supported may provide better than nanometer resolution. A power-down routine in the E-755 firmware saves the current position, allowing a closed-loop system to be ready for operation without referencing next time it is powered up.

NEXLINE® Working Principle for Application Flexibility

NEXLINE® PiezoWalk® drives are ideal wherever high loads must be positioned very precisely over long distances and then perhaps subjected to small-amplitude dynamic adjustment, as for active vibration control. By varying the characteristics of the longitudinal and shear piezo elements, the step size, dynamic operating range (analog travel), clamping force, speed and stiffness can all be optimized for a particular application.

NEXLINE® PiezoWalk® piezoceramic clamping and shearing elements act directly on a moving runner that is coupled to the moved part in the application. While the runner can bemoved large distances in step mode, high-dynamics positioning over distances of less than one step is possible with resolutions far below one nanometer in analog mode. The patented PiezoWalk® thus overcomes the limitations of conventional nanopositioning actuators and combines long travel ranges with high resolution and stiffness.

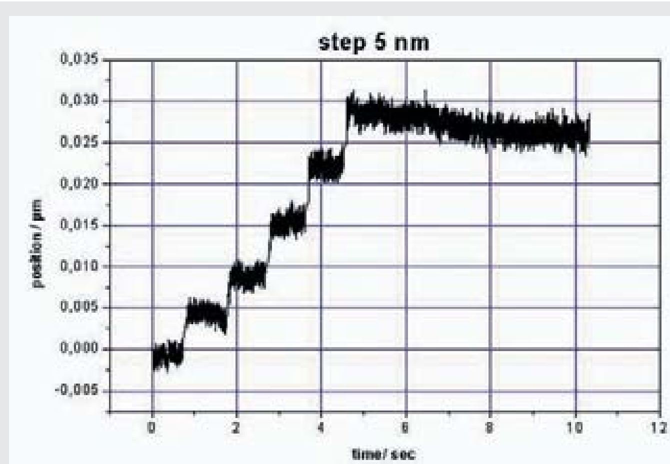
Extreme Actuator Lifetime

To eliminate long-term offset voltages, which limit the lifetime of conventional piezo drives, the E-755 controller uses a special procedure to bring the actuator to a full-holding-force, zero-voltage condition, no matter where it may be along its travel range. Due to the resulting long lifetime, NEXLINE® nanoposition-

Ordering Information

E-755.1A1
Digital Controller for NEXLINE® Nanopositioning Linear Drives, Incremental Sensors

E-755.101
Digital Controller for NEXLINE® Nanopositioning Linear Drives



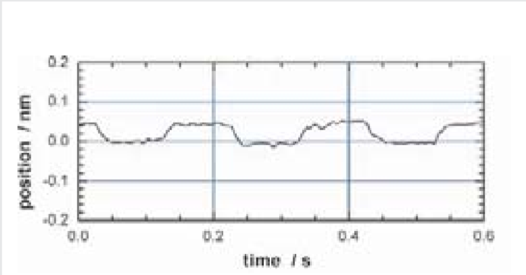
Steps of 5 nm performed by a system consisting of an N-214 NEXLINE® nanopositioner and an E-755.1A1 controller, measured by a high-resolution interferometer. Note the excellent system response to consecutive 5 nm step commands. In this case the closed-loop resolution is limited by the linear encoder in the N-214 (5 nm / increment); the E-755 can work with linear encoders with sub-nanometer resolution ing actuators are ideal for installation in inaccessible locations deep inside complex equipment, where nanometer-precise alignment and vibration cancellation are required.

Linearization

E-755-controlled nanopositioning systems provide outstanding linearity, achieved by digital polynomial linearization. The linearization can improve linearity to 0.001 % over the full travel range.

The products described in this datasheet are in part protected by the following patents:
German Patent No. 10148267
US Patent No. 6,800,984

Six-axis nonmagnetic Hexapod with N-215-based NEXLINE® high-load actuators for use in high magnetic fields. The system is driven by six E-755 controllers and additional hardware/firmware to automatically perform the necessary parallel-kinematics coordinate transformation



Steps of 50 picometers with a NEXLINE® drive in open-loop mode measured with external, ultra-high-resolution, capacitive sensor

Technical Data

Model	E-755.1A1	E-755.101
Funktion	Digital controller for NEXLINE® nanopositioning linear drives with incremental encoder	Digital controller for NEXLINE® nanopositioning linear drives
Axes	1	1
Processor	DSP 32-bit floating point, 50 MHz	DSP 32-bit floating point, 50 MHz
Sensor		
Sensor channels	1	–
Servo update time	0.2 ms	–
Sensor sampling time	0.1 ms	–
Dynamic cycle time	0.2 ms	0.1 ms
Servo characteristics	P-I, notch filter	–
Sensor type	Incremental sensor	–
Amplifier		
Amplifier channels	4	4
Output voltage	-250 to +250 V	-250 to +250 V
Peak output power per channel	5.5 W	5.5 W
Average output power per channel	3 W, limited by temperature sensor	3 W, limited by temperature sensor
Peak current	44 mA	44 mA
Average current per channel	25 mA, limited by temperature sensor	25 mA, limited by temperature sensor
Current limitation	Short-circuit-proof	Short-circuit-proof
Resolution DAC	24 bit	24 bit
Interfaces and operation		
Communication interfaces	RS-232	RS-232
Piezo connector	Sub-D Special	Sub-D Special
Sensor connector	15-pin sub-D connector	–
Controller network	Daisy-chain, up to 16 units	Daisy-chain, up to 16 units
Command set	GCS	GCS
User software	PIMikroMove™, NanoCapture™ , PITerminal	PIMikroMove™, NanoCapture™ , PITerminal
Software drivers	LabVIEW drivers, DLLs	LabVIEW drivers, DLLs
Supported functionality	NEXLINE® Control algorithms (closed-loop), data recorder, position storage	NEXLINE® Control algorithms (open-loop), data recorder
Display	Status LEDs	Status LEDs
Linearization	4th order polynomial	4th order polynomial
Miscellaneous		
Operating temperature range	5 to 50 °C	5 to 50 °C
Overtemp protection	Deactivation at 70 °C	Deactivation at 70 °C
Dimensions	264 x 260 x 47 mm	264 x 260 x 47 mm
Mass	2.3 kg	2.3 kg
Operating voltage	24 V (power supply included)	24 V (power supply included)
Power consumption	48 W, 2 A max.	48 W, 2 A max.

E-861 PiezoWalk® NEXACT® Controller/Driver

Networkable Controller for NEXACT® Linear Drives and Positioners

PiezoWalk® System: E-861.1A1 NEXACT® Controller with open-loop N-310.01 NEXACT® linear drive; suitable for installation in stage with linear encoder

- **For NEXACT® Drives and Positioning Systems**
- **Complete System with Controller, Integrated Power Amplifiers and Software**
- **Open-Loop Operation, or Closed-Loop with Linear Encoder**
- **High Performance at Low Cost**
- **Daisy-Chain Networking for Multi-Axis Operation**
- **Non-Volatile Macro Storage for Stand-Alone Functionality with Autostart Macro**
- **I/O for Automation, Joystick for Manual Operation**
- **Parameter Changes On-the-Fly**

The new, compact E-861 controller is designed to operate NEXACT® linear drives and closed-loop positioning systems using them, simply and precisely. In perfect harmony with the mechanics, the E-861 supports both motion modes of the PiezoWalk® stepping drive: for longer moves, the stepping mode, and for moves shorter than typically 7 µm, the analog mode, which provides high-dynamics positioning with resolutions of less than 1 nm. The NEXACT® drive design minimizes piezo operating voltages to 45 V and below.

Flexible Automation

E-861 controllers offer a number of features to support automation and handling. For example, macros can be stored in non-volatile memory.

A programmable autostart macro allows stand-alone operation without external communication. Upon power-up, the macro with its internal command sequence is executed automatically.

For easy synchronization of motion with internal or external trigger signals, four input and four output lines are provided.

Multi-Axis Operation

Up to 16 E-861 controllers can be networked and controlled over a single PC interface.

Such daisy chain networks are flexible, can be extended at any time and are compatible with other PI controllers (e.g. DC servo-motor and stepper motor controllers).

Ordering Information

E-861.1A1
NEXACT® Controller, 1 Channel, Linear Encoder

Easy System Setup, Comprehensive Software

All parameters can be set and checked by software. System setup and configuration is done with the included PIMikroMove™ user-interface software. Interfacing to custom software is facilitated with included LabView drivers and DLLs. With the PI General Command Set (GCS), system programming is the same with all PI controllers, so controlling a system with a variety of different controllers is possible without difficulty.

Technical Data

Model	E-861.1A1
Function	Controller for NEXACT® drives / systems
Drive type	N-310.01 NEXACT® linear drive
Channels	1
Motion and control	
Servo characteristics	P-I-D servo control, parameter change on-the-fly
Trajectory profile modes	Trapezoidal
Encoder input	Analog encoder input sine-cosine, interpolation circuit preset for differential transmission, 2 V_{pp} amplitude and 2.27 V offset of the encoder signal
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
Electrical properties	
Output power	max. 40 W
Output voltage	-10 to +45 V
Current consumption	max. 2 A
Interfaces and operation	
Communication interfaces	USB 1.0, RS-232 (9-pin (m) D-Sub)
Motor connector	D-Sub 15-pin (f) High Density
Sensor connector	D-Sub 15-pin (m) High Density
Controller network	Up to 16 units on single interface
I/O ports	4 analog/digital in, 4 digital out (TTL)
Command set	PI General Command Set (GCS)
User software	PIMikroMove™, PI Terminal
Software drivers	GCS-DLL, LabVIEW drivers
Supported functionality	Start-up macro; data recorder for categories like current position or velocity; internal safety circuitry: watchdog timer
Manual control (optional)	Joystick, Y-cable for 2D motion, pushbutton box
Miscellaneous	
Operating voltage	24 V included: external power supply, 24 V, 2.5 A
Operating temperature range	0 to +50 °C
Mass	1.1 kg
Dimensions	206 x 130 x 66 mm (with mounting rails)

PILine® Ultrasonic Motors

High-Speed Precision Actuators

PILine® Ultrasonic Piezomotors – Working Principle

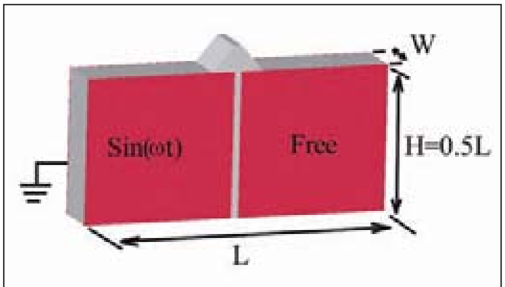
PILine® linear piezomotors are based on a novel, patented ultrasonic drive developed by PI. Ultrasonic oscillations of a piezoceramic actuator are transferred to linear motion along a friction bar, which is attached to the moving part of a mechanical setup.

At the heart of the system is a monolithic piezoceramic plate, segmented by two electrodes. Depending on the desired direction of motion, the left or right electrode of the piezoceramic plate is excited to produce high-frequency eigenmode oscillations at tens to hundreds of kilohertz. An alumina friction tip (pusher) attached to the plate moves along an inclined linear path at the eigenmode frequency.

The pusher is preloaded against the friction bar which is attached to the slider, turntable, etc. Through its oscillations, it provides micro-impulses that drive the moving part 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. State-of-the-art ultrasonic motors can produce accelerations to 5 g and velocities to 500 mm/s.

Ultrasonic motors cannot provide the unlimited resolution of linear piezo actuators and flexure-guided piezo positioning stages. These motors transfer motion through friction, which is why their repeatability is limited to about 50 nm. Much higher resolution and holding forces can be achieved with PiezoWalk® piezomotors / drives (see p. 1-3 *ff)*.



State-of-the-art PILine® ultrasonic motors are based on a simple construction allowing for the design of low-cost drive units and extremely compact, high-speed micro-positioning stages smaller than a matchbox

PILine® Levels of Integration

PILine® ultrasonic drive products are offered in three different levels of integration. The drive electronics and controller can be chosen accordingly.

- P-661 and P-664 OEM motors require the greatest amount of care at the customer's site. Motor and friction bar – the length depends on the desired travel range – have to be integrated into a mechanical setup. Operation requires preload of the motor against the friction bar, guiding and, if necessary, the servo-loop.
- M-674 RodDrives can replace classical drive elements like rotary motor / leadscrew assemblies, or magnetic linear drives integrated into a micropositioner or handling device. Integration requires guiding and – if necessary – the servo-loop.
- Linear positioning stages represent the highest level of manufacturer integration. The piezomotor is integrated completely in a high-quality mechanical setup including the servo-loop with direct-metrology linear encoders.

PILine® levels of integration: OEM motor, RodDrive, linear positioning stage

Features and Advantages of PILine® Ultrasonic Piezomotors

- Compact Size: the direct-drive principle allows the design of ultra-compact translation stages. The M-662, for example, provides 20 mm travel in a 28 x 28 x 8 mm package.

- Low Inertia, High Acceleration, Speed and Resolution: PILine® drives achieve velocities to 500 mm/s and accelerations to 5 g. They are also very stiff, a prerequisite for their fast step-and-settle times – on the order of a few milliseconds – and provide resolution to 10 nm. The lack of a leadscrew means no lubricant flow or material relaxation to cause submicron creep. There is also no rotational inertia to limit acceleration and deceleration.

- Excellent Power-to-Weight Ratio: PILine® drives are optimized for high performance in a minimum package. No comparable drive can offer the same combination of acceleration, speed and precision.

- Safe: The minimum inertia of the moving platform together with the "slip clutch" effect of the drive provide better protection of precision fixtures / devices than leadscrew-driven stages. Despite the high speeds and accelerations, there is a much lower risk of pinching fingers or other injuries than with conventional drives. This means users may not need interlocks, light curtains or other measures to keep them safe.

- Self-Locking Feature: PILine® drives create a braking force when not energized without the position shift common with conventional mechanical brakes. Other benefits of the self-locking are the elimination of servo dither and steady-state heat dissipation.

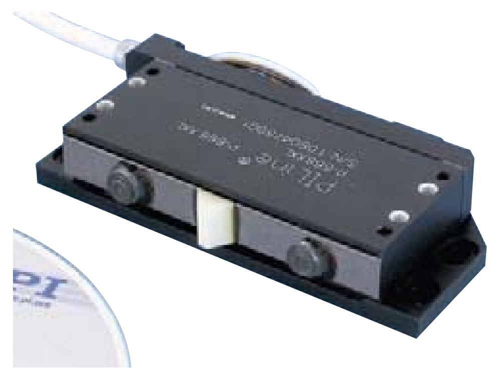
- Vacuum Compatibility: Vacuum compatible versions of PILine® drives are available.

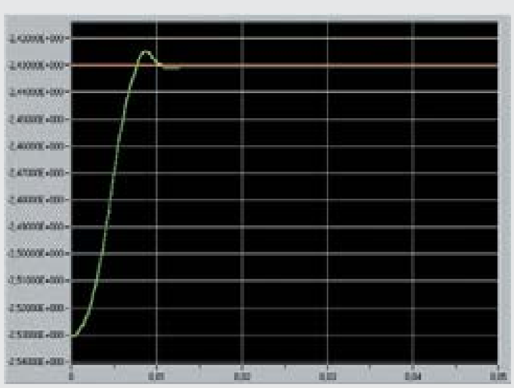
- Negligible EMI: PILine® drives do not create magnetic fields nor are they influenced by them, a decisive advantage in many applications.

- Custom Solutions / Flexibility for OEMs: PILine® drives are available in open-loop and closed-loop translation stages and as OEM components. PI develops and manufactures all piezo ceramic components in-house. This gives us the flexibility to provide custom motors (size, force, environmental conditions) for OEM and research applications.

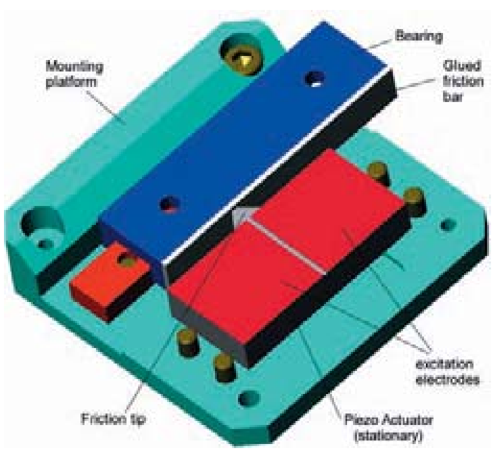
- Quality, Lifetime, Experience: Based on PI's 4 decades of experience with piezo nanopositioning technology, PILine® drives offer exceptional precision and reliability with an MTBF of >20,000 hours. Rotating components such as gears, shafts and moving cables that are prone to failure in conventional motion systems, are not part of the PILine® design.

Custom high-force ultrasonic piezo motors can provide forces to 50 N





Settling behavior of a PILine® M-663 linear stage, 100 µm step. A stable position to within 0.1 µm can be reached in only 10 ms



Principle design of a PILine® ultrasonic piezomotor-driven translation stage

Piezo • Nano • Positioning

P-661 PILine® Piezo Linear Drive

Fast, Compact OEM Ultrasonic Linear Motor

PILine® P-661 OEM piezo linear motor

- **Patented Principle Features with High Forces in Small Space**
- **Max. Velocity 500 mm/s**
- **Acceleration to 5 g**
- **Min. Incremental Motion to 0.05 µm**
- **Self-Locking to 1.5 N**
- **No Electro-Magnetic Fields**
- **MTBF 20,000 h**
- **Integrated Actuators & Positioning Systems Also Available**

PILine® Linear Motors – Small, Fast, Highly Effective

Despite their small size, PILine® linear motors generate high driving and holding forces.

Application Examples

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

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.

High Speed and Acceleration

PILine® piezomotor drives can provide accelerations of up to 5 g and speeds of up to 500 mm/s, together with high resolution and high holding force. Because the ceramic stator is pressed against the slider, holding forces are generated when the motor ist powered down. The result is very high position stability without the heat dissipation common in conventional linear motors.

Accessories for Easy Integration

PILine® piezomotors require a special drive electronics to generate the ultrasonic oscillations for the piezoceramic element. The drive electronics is available as OEM board, standalone device or integrated controller and therefore not inclued in the delivery. PI offers friction bars with different lengths.

Long Lifetime

PI has over 30 years experience with piezo technology and nanopositioning. PILine® drives offer high precision and reliability, with over 20,000 hours MTBF. This is because PILine® piezo linear motor drives have no mechanical components such as shafts and gears which can cause failures in conventional motors.

Ordering Information

P-661.P01
PILine® Miniature Linear Piezomotor, 2 N

Accessories:

P-661.B01
Friction Bar for P-661 PILine® Miniature Linear Piezomotor, 15 mm

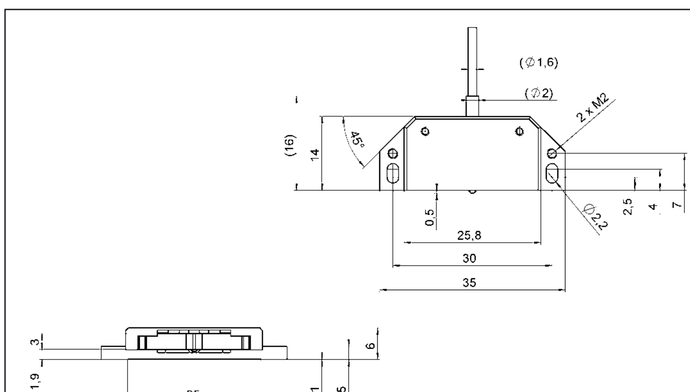
P-661.B02
Friction Bar for P-661 PILine® Miniature Linear Piezomotor, 25 mm

P-661.B05
Friction Bar for P-661 PILine® Miniature Linear Piezomotor, 55 mm

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

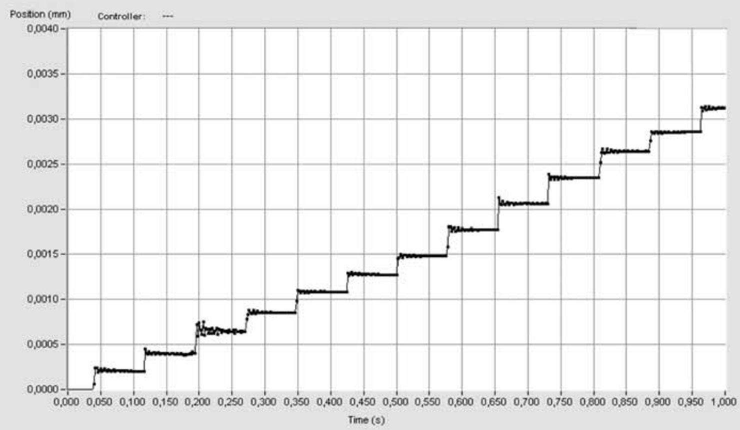
Controller for closed-loop operation are available as C-867 s. p. 4-116.



Dimensions of the P-661 in mm

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



0.3 µm steps performed by P-661 piezomotor integrated in an M-662 translation stage

Technical Data

Model	P-661.P01	Units	Tolerance
Motion and positioning			
Travel range	No limit*	mm	
Minimum incremental motion, open-loop	0.05**	µm	typ.
Max. velocity	500	mm/s²	
Mechanical properties			
Stiffness when powered down	0.7	N/µm	±10 %
Holding force when powered down	1.5	N	max.
Push / pull force	2	N	max.
Preload on friction bar	9	N	±10 %
Drive properties			
Resonant frequency	210	kHz	typ.
Motor voltage range	120 (peak-peak) 42 (RMS)	V	
Operating voltage drive electronics	12	V	
Electrical power drive electronics	5	W	
Miscellaneous			
Operating temperature range	-20 to +50	°C	
Body material	Al (black anodized)		
Mass	0.01	kg	±5 %
Cable length	1.6	m	±10 mm
Connector	Open leads		
Recommended controller/driver	C-184.161 OEM board C-185.161 in box		
Dimensions	14 x 35 x 6	mm	
MTBF	>20,000	h	

* The travel range of piezo linear motors is virtually unlimited and depends on the length of the friction bar, which is available separately.
** The minimum incremental motion is a typical value that can be achieved in the open-loop mode of a piezomotor stage. To reach the specs it is important to follow the mounting guidelines of the OEM-motors.

U-164 PILine® Piezo Linear Drive

Fast, Compact OEM Ultrasonic Linear Motor

OEM ultrasonic piezo linear motor U-164.01

- **Patented Principle Features with High Forces in Small Space**
- **Easy Mounting**
- **Max. Velocity 500 mm/s**
- **Acceleration up to 5 g**
- **Min. Incremental Motion to 0,05 µm**
- **Self Locking, Push-/Pull Forces to 4 N**
- **No Electro-Magnetic Fields**
- **Integrated Actuators & Positioning Systems Also Available**

PILine® Linear Motors—Small, Fast, Highly Effective

Despite their small size, PILine® linear motors generate high driving and holding forces. PILine® piezo motors have a new, patented, ultrasonic drive developed by PI. The core piece of the system is a piezoceramic 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 executes a step of a few nanometers; the macroscopic result is smooth motion with a virtually unlimited travel range.

Application Examples

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

High Speed and Acceleration

PILine® piezomotor drives can provide accelerations of up to 5 g and speeds of up to 500 mm/s, together with high resolution and high holding force. Because the ceramic stator is pressed against the slider, holding forces are generated when the motor ist powered down. The result is very high position stability without the heat dissipation common in conventional linear motors.

Accessories for Easy Integration

The PILine® motors require a special drive electronics to generate the ultrasonic oscillations for the piezoceramic element. The drive electronics is available as OEM board, stand-alone device or integrated inside a controller and therefore not included in the delivery. PI offers friction bars with different lengths.

Long Lifetime

PI has over 30 years experience with piezo technology and nanopositioning. PILine® drives offer high precision and reliability. This is because PILine® piezo linear motor drives have no mechanical components such as shafts and gears which can cause failures in conventional motors.

Ordering Information

U-164.01
PILine® Piezo Linear Motor, 4 N

Accessories:

P-664.B01
Friction Bar for PILine® Miniature Linear Piezomotor, 15 mm

P-664.B02
Friction Bar for PILine® Miniature Linear Piezomotor, 25 mm

P-664.B05
Friction Bar for PILine® Miniature Linear Piezomotor, 55 mm

C-184.164
Analog OEM Driver Board for PILine® Motors

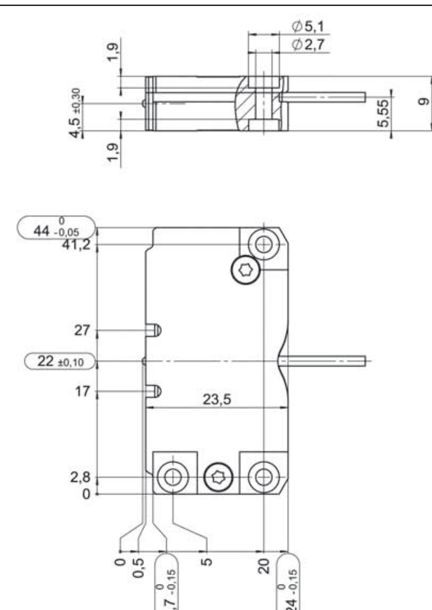
C-185.164
Analog Stand-Alone Drive Electronics with Power Supply for PILine® Motors

Controllers for closed-loop operation are available as C-867 (see p. 4-116).

Ask about custom designs!

Patent Information

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



U-164.01, dimensions in mm

Technical Data (preliminary)

Model	U-164.01	Unit	Tolerance
Motion and positioning			
Displacement	unlimited*	mm	
Minimum incremental motion, open-loop	0.05**	µm	typ.
Max. velocity	500	mm/s	
Mechanical properties			
Stiffness when powered down	3	N/µm	±10 %
Holding force when powered down	3	N	Max.
Push / pull force	4	N	Max.
Preload on friction bar	18	N	±10 %
Drive properties			
Resonant frequency	155	kHz	typ.
Motor voltage	60 (RMS)	V	
Operating voltage driver electronics	12	V	
Max. el. power consumption driver	10	W	
Miscellaneous			
Operating temperature range	-20 to +50	°C	
Body material	Al (black anodized)		
Mass	0.02	kg	±5 %
Cable length	1.0	m	±10 mm
Connector	Open leads		
Recommended controller/driver	C-184.164 OEM board C-185.164 in box		

*The travel range of piezo linear motors is virtually unlimited and depends on the length of the friction bar, which is available separately.

**The minimum incremental motion is a typical value that can be achieved in the open-loop mode of a piezomotor stage. To reach the specifications it is important to follow the mounting guidelines of the OEM-motors.

M-272 Linear Drive for Automation

Fast and Self-Locking with PILine® Piezomotors

The M-272 linear drive for automation offers a travel range of 50 mm

- **Force Generation up to 8 N**
- **Self Locking at Rest**
- **Velocity up to 200 mm/s**
- **5 µm Encoder Resolution**
- **Linear Guiding**

PILine® piezoceramic ultrasonic drives offer an affordable alternative to motor-leadsrew combinations and electromagnetic linear motors when small dimensions and/or high speed are important. With velocities of up to 200 mm/s, these drives are fast, compact, and are readily integrated. In addition, PILine® motors are self-locking when at rest with zero heat generation, and doing away with the need for an additional motor brake.

The novel M-272 closed-loop linear drive combines motor, actuator, linear encoder, guiding system and brake functionality in a very compact package. Due to the integrated guiding system a payload can be easily attached to the drive rod of the M-272 drive. The drive can also function as a drop-in-replacement for motor-leadscrew drives facilitating assembly and reducing the number of components significantly. Due to the integrated linear encoder, positioning can be done precisely and repeatably.

Application Examples

- Automation
- Handling
- Micromanipulation
- Metrology

Self-locking Instead of Quiescent Current

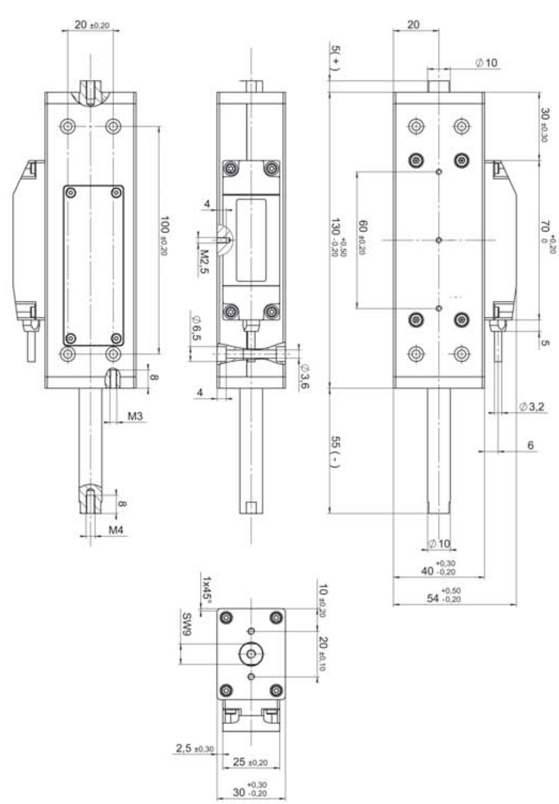
PILine® piezo motors are based on a new, patented, ultrasonic drive principle developed by PI. The core piece of the system is a piezoceramic plate, which is excited with high-frequency eigenmode oscillations. A friction tip attached to the plate moves along an inclined linear path at the eigenmode frequency.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

The ceramic plate is preloaded against the runner and thus generates the holding force when the drive is at rest.

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

Ordering Information

M-272
PILine® Linear Actuator with Ultrasonic Motor and Linear Encoder, 50 mm, 8 N



M-272 Dimensions in mm

Cost-effective combination:
M-272 closed-loop linear pusher and C-867.OE controller card

Technical Data (Preliminary Data)

Model	M-272	Tolerance
Active axes	X	
Motion and positioning		
Travel range	50 mm	
Integrated sensor	Linearencoder	
Sensor resolution	5 µm	
Design resolution	5 µm	typ.
Min. incremental motion	10 µm	typ.
Backlash	5 µm	typ.
Unidirectional repeatability	10 µm	typ.
Velocity	200 mm/s	max.
Mechanical properties		
Guiding	Ball bearings	
Push/pull force	8 N	max.
Holding force	8 N	max.
Lateral force	5 N	max.
Drive properties		
Motor type	U-164 PILine® ultrasonic piezomotor	
Current	800 mA	
Reference switch	Hall-effect	
Miscellaneous		
Operating temperature range	-20 to +50 °C	
Material	Aluminum	
Dimensions		
Mass	0.5 kg	± 5%
Cable length	0.5 m	± 10 mm
Connector	MDR, 14-pin	

Recommended controller/driver: C-867.OE
 * Power for the motor is supplied by the drive electronics, which requires 12 VDC.
** For drive electronics

PI Piezo • Nano • Positioning

M-674 PILine® RodDrive Piezo Linear Drive

Integrated Fast Ultrasonic Piezo Drives

The M-674 PILine® RodDrive, shown with C-184 OEM and C-185 bench-top driver electronics, provides 7 N pushing force and travel ranges of 50, 100 and 150 mm

- **Drive-Component for Integration into Micropositioning Systems**
- **Travel Ranges to 150 mm**
- **Push/Pull Forces to 7 N**
- **Min. Incremental Motion to 0.05 µm**
- **Velocity to 450 mm/s**
- **Self-Locking at Rest**

M-674 PILine® RodDrives represent a level of integration between PILine® OEM piezo linear motors such as P-664 (see p. 1-28) and guided micropositioning systems such as the M-682 (see p. 4-32) series stages.
RodDrives may replace classical drive elements like rotary motor/leadscrew assemblies, or magnetic linear drives integrated into a micropositioner.

Application Examples

- System integration for micropositioning products
- Automation
- Handling
- Micromanipulation
- Biotechnology
- Metrology

They consist of a rod which is preloaded by piezo linear motors from two sides. Depending on the way of integration, either the rod or the motor block is coupled to the moving platform.

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

Working Principle

RodDrives employ a patented ultrasonic drive developed by PI. The highly compact, integrated P-664 piezomotors can provide velocities of 450 mm/s, together with high resolution and holding force. The maximum travel is determined by the length of the rod and is basically unlimited. Customized adaptations in terms of operating and holding force are feasible by varying type and number of motors used.
Because the integrated ceramic motors are preloaded against the rod, RodDrives resist motion with an intrinsic holding force when at rest. The result is very high position stability without the heat dissipation common with conventional linear motors. Furthermore, there are no gears, leadscrews or other mechanical components to contribute play or backlash.

Variety of Drivers / Controllers

PILine® piezomotors require a drive electronics for exciting the ultrasonic oscillations. The drive electronics is available as OEM board, stand-alone device or integrated inside a closed-loop motion controller and therefore not included in the delivery.

Ordering Information

M-674.164
PILine® RodDrive, 50 mm, 7 N

M-674.264
PILine® RodDrive, 100 mm, 7 N

M-674.364
PILine® RodDrive, 150 mm, 7 N

Accessories:

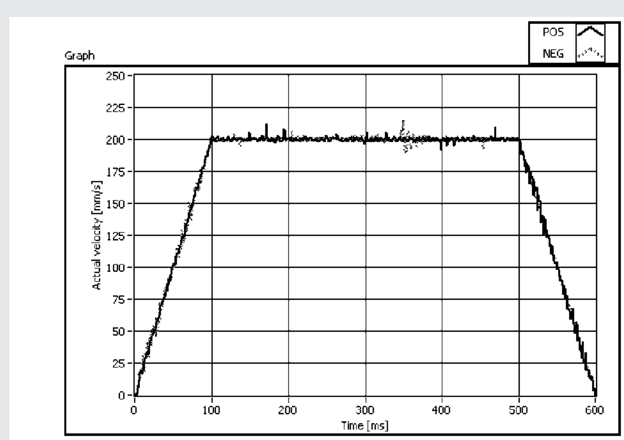
C-184.D64
Analog OEM Driver Board for PILine® RodDrive M-674

C-185.164
Analog Stand-Alone Drive Electronics with Power Supply for PILine® P-664 Motors

C-867.D64
Piezomotor Controller with Drive Electronics, 1 Channel, for PILine® Systems with M-674 RodDrive

Closed-Loop Operation: Optimized for High Velocity and Rapid Step/Settling

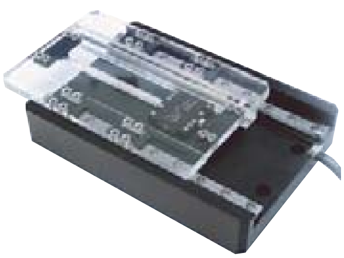
Together with a position sensor, RodDrives can be operated in closed-loop with the C-867.D64 (see p. 4-116) piezo motor controller. This specialized servo-controller also integrates the motor drive electronics and enables highly constant speeds up to 350 mm/s with very short settling times (tens of milliseconds). RodDrives can also be operated with conventional servo-controllers. In this case, the C-185 (see p. 1-36)



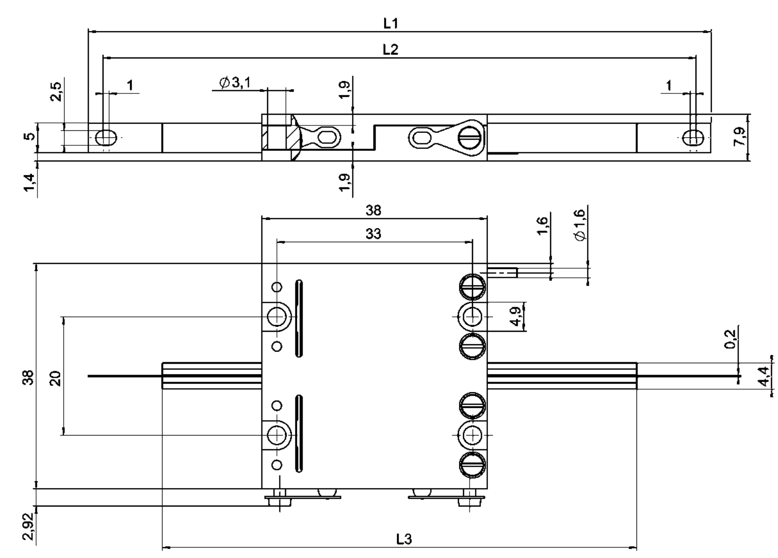
Constancy of closed-loop velocity at 200 mm/s of an integrated M-674 RodDrive (to be ordered separately) external drive electronics is required which accepts a ±10 V analog signal from the controller.

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



The M-674 integrated into a Micropositioning Stage



	M-674.164	M-674.264	M-674.364
L1	105	155	205
L2	100	150	200
L3	80	130	180

Dimensions of the M-674 RodDrive in mm

Technical Data

Model	M-674.164	M-674.264	M-674.364	Units	Tolerance
Motion and positioning					
Travel range	50	100	150	mm	x
Minimum incremental motion, open-loop	0.05*	0.05*	0.05*	µm	typ.
Max. velocity	450	450	450	mm/s	
Max. acceleration	10	10	10	m/s²	
Mechanical properties					
Stiffness when powered down	5**	5**	5**	N/µm	±10 %
Holding force when powered down	7	7	7	N	max.
Push / pull force	7	7	7	N	max.
Drive properties					
Resonant frequency	155	155	155	kHz, typ.	
Integrated piezo motor	2 x PILine® P-664 (Dual Motor)	2 x PILine® P-664 (Dual Motor)	2 x PILine® P-664 (Dual Motor)		
Motor voltage range	190 (peak-peak)*** 67 (RMS)***	190 (peak-peak)*** 67 (RMS)***	190 (peak-peak)*** 67 (RMS)***	V	
Operating voltage drive electronics	12	12	12	V	
Max. elec. power consumption drive electronics	15	15	15	W	
Miscellaneous					
Operating temperature range	-20 to +50	-20 to +50	-20 to +50	°C	
Body material	PEEK-PTFE	PEEK-PTFE	PEEK-PTFE		
Mass	0.1	0.12	0.14	kg	±5 %
Cable length	1.5	1.5	1.5	m	±10 mm
Connector	LEMO connector	LEMO connector	LEMO connector	LEMO connector	
Recommended controller/driver	C-184.D64 OEM drive electronics board C-185.D64 driver ****C-867.D64 Controller for closed-loop operation	C-184.D64 OEM drive electronics board C-185.D64 driver ****C-867.D64 Controller for closed-loop operation	C-184.D64 OEM drive electronics board C-185.D64 driver ****C-867.D64 Controller for closed-loop operation		

*The minimum incremental motion is a typical value that can be achieved in the open-loop mode of a piezomotor stage. To reach the specs it is important to follow the mounting guidelines of the OEM-drives.
**Stiffness at 25 °C.
***The operating voltage is supplied by the drive electronics.
****MDR 14-connector for closed-loop systems separate required

P-653 PILine® Miniature Linear Motor / Slide

OEM Drive for High Volume Applications

The P-653 miniature drive including the drive electronics measures only 11 mm featuring 2 mm travel range. Side view of slider (bottom)

- **True Linear Motor Slide / No Rotary Conversion Losses**
- **Cost-Effective OEM Drive for High Quantity-Applications**
- **Preassembled and Mounted on a PCB Board**
- **Very Compact: Piezomotor Drive is Only 8 mm Long**
- **Fast Response: Full Stroke in <50 ms**
- **Force Generation to 0.15 N**
- **Self Locking at Rest**
- **Travel Range 2 mm, Velocity up to 200 mm/s**

P-653 PILine® OEM piezomotor drives are ideal for OEM applications where space is limited and moved masses are small. These tiny linear positioners can be used to replace classical drive elements like miniaturized motor/spindle systems or other linear motors, which P-653 outclasses with its speed of up to 200 mm/s. PILine® piezo linear motors offer a number of advantages over classical drives:

- High velocities
- Compact design
- High push/pull and holding forces relative to the drive size

Integration of the P-653 in an application is simple because the moving slider and the piezo actuator are delivered assembled as a unit and already mounted on a PCB board. Drive electronics is included on the same board and requires a supply voltage of only 5 VDC.

Mechanical mounting is thus facilitated as well: All that remains is to affix the payload to the slider.

The motors are designed for moving small objects such as optical fibers, optics, micro- or electro-mechanical elements fast and precisely.

Application Examples

- Consumer electronics
- Miniature mechatronics
- Micromanipulation
- Micropositioning
- Toys

Working Principle

P-653 drives employ a new, patented, ultrasonic piezomotor drive developed by PI. The highly compact, integrated piezomotor can attain velocities of up to 200 mm/s together with high position resolution and—considering its length of only 8 mm—a high holding force. Because the ceramic stator is pressed against the slider, piezomotor drives resist motion with an intrinsic holding force when the unit is at rest. The result is very high position stability, without the heat dissipation common with conventional linear motors. During operation, the oscillating piezoceramic propels the slider over the length of the motor. There are no gears, leadscrews or other mechanical components to contribute play or backlash.

Simple Control

The high-frequency, nanometer level oscillations (~500 kHz) needed by the PILine® motors are created by driver electronics, which self-adjusts to the resonant frequency of the motor ceramic, meaning that no individual tuning is necessary. The driver electronics can in turn be controlled by short voltage pulses.

Order Information

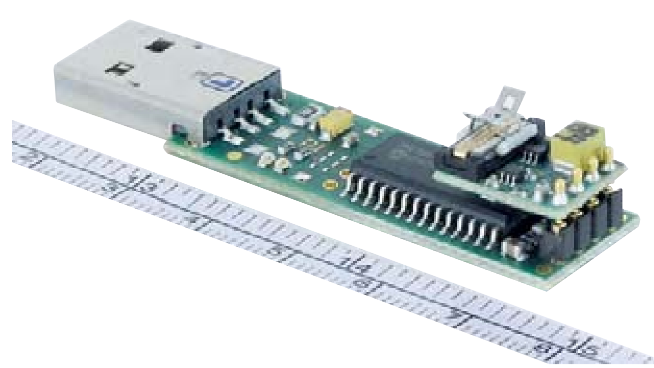
P-653.01
Miniatur PILine® OEM Drive, 2 mm Travel Range, 0.15 N, mounted on PCB board

P-653.01D
Miniature PILine® OEM Drive, 2 mm Travel Range, 0.15 N, Demo Sample Kit with USB Interface

Ask about custom designs

Note

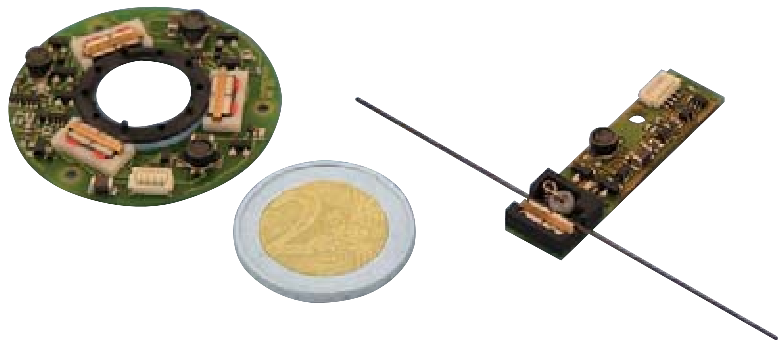
The products described in this document are in part protected by the following patents:
German Patent No. 102004059429
International Patent No. WO2006/027031A1



Included in the P-653.01D demo sample there is the P-653.01 OEM drive together with additional electronics featuring an USB interface

P-653K PILine® Miniature Rotary and Linear Piezo Motor Actuators

Compact PCB Mounted Motion Control Solutions for OEMs

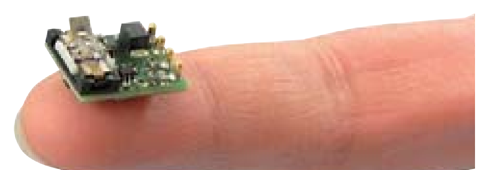


Two custom piezo motors based on the P-653 ultrasonic miniature motor show the versatility and adaptability of the basic concept: P-653KMRD on the right is based on the RodDrive principle and provides a virtually unlimited linear travel range. With the P-653KROT three miniature motors move a ring, for example for fast positioning of optical elements

Application Examples

- Consumer electronics
- Miniature mechatronics
- Micromanipulation
- Micropositioning
- Medical technology
- Optomechanics: Rotating Filters, etc.

- **Cost-Effective OEM Drive for High Quantity-Applications**
- **Preassembled and Mounted on a PCB Board**
- **Miniature Piezo Motor Drive: 8 mm Length Only!**
- **Fast Response: Full Stroke in <50 ms for Single Actuators**
- **Force Generation to 0.15 N; Torque to 2 mNm**
- **Self Locking at Rest**
- **Travel Range 50 mm (Runner), Velocity up to 200 mm/s and 230 rev/min, respectively**



The P-653 miniature drive including the drive electronics measures only 11 mm

Technical Data

Model	P-653KMRD	P-653KROT
Active axes	X	θ_Z
Motion and positioning		
Travel range	50 mm	>360 deg
Step size at 0.25 ms ON time	5 to 15 µm	0.2 to 0.5 arcsec
Step size at 1.0 ms ON time	20 to 120 µm	0.6 to 3.5 arcsec
Max. velocity, without load	100 to 200 mm/s*	200 to 230 rev/min
Typ. velocity, without load	50 to 90 mm/s	120 to 150 rev/min
Mechanical properties		
Holding force when powered down	0.3 N	–
Max. push / pull force	0.15 N	–
Max. torque active / passive	–	2 / 4 mNm
Drive properties		
Resonant frequency (typ.)	515 kHz	515 kHz
Integrated piezo motor	P-653 PILine®	3 x P-653 PILine®
Operating voltage driver electronics	5 VDC	5 VDC
Current consumption incl. drive electronics	0.1 A	0.3 A
Control voltage	5 V TTL	5 V TTL
Miscellaneous		
Operating temperature range	-40 to +80 °C	-40 to +80 °C
Mass	2 g ±5%	4.5 g ±5%
Connectors	Miniature 4 pin connector	Miniature 4 pin connector
Recommended driver	Piezomotor drive electronics included	Piezomotor drive electronics included
Dimensions	40 x 10 x 4 mm incl. drive electronics	Ø 40 mm, 5 mm high incl. drive electronics, clear aperture Ø 14 mm
Typ. min. endurance	25 km	1.000.000 cycles

All data refer to 100% duty cycle.
*no load. Differing data at 5g: 80 to 140 mm/s, at 10g: 50 to 100 mm/s

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

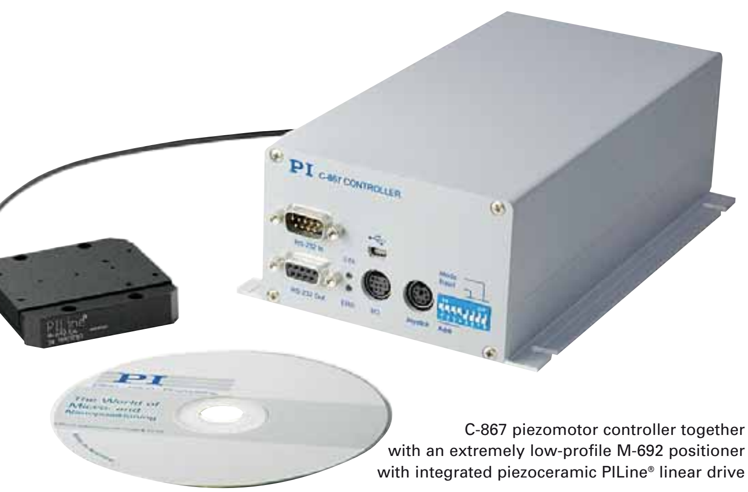
- Integrated Non-Magnetic PILine® RodDrive
- Travel Range 50 mm
- Integrated Linear Encoders with 0.1 µm Resolution
- Up to 6 N Force Generation
- Closed-Loop Velocity up to 100 mm/s
- Low Profile, Small Footprint

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

PI Piezo • Nano • Positioning

C-867 Controller for PILine® Piezo Linear Drives

Servo-Controller with Integrated Driver for High-Speed Ultrasonic Piezo Motors



C-867 piezomotor controller together with an extremely low-profile M-692 positioner with integrated piezoceramic PILine® 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 is especially designed for closed-loop positioning systems equipped with PILine® piezo linear motor drives. A compact case contains both drive electronics for the piezo ceramic motors and components for controlling and communication.

Application Examples

- Biotechnology
- Microscopy
- Fiber positioning
- Automation
- Photonics / integrated optics
- Quality assurance testing
- Testing equipment

The controller can be operated from a host PC either via a USB port or an RS-232 interface. Alternatively, a stand-alone operation is possible. Here, stored macro commands can be executed, or manual control by joystick or pushbutton box is possible.

Two models are available: C-867.160 is used to operate single-axis positioning systems, the two-channel C-867.260 is used with XY scanning stages.

Highly Specialized PID Servo-Controller

The C-867 is based on a highly specialized DSP (Digital Signal Processor) that handles 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 an optimized settling behavior within a couple of 10 milliseconds is achieved. The broadband encoder input (50 MHz) allows high resolution encoders to be used with the outstandingly high accelerations and velocities that PILine® drives deliver.

Highest Stability by Frequency Control

The integrated piezomotor drive electronics support all PILine® ultrasonic piezomotors used for the M-66x to M-69x positioning stage series.

Drift in the mechanical frequency of the motor caused by temperature or load changes is automatically compensated by a frequency-control loop which adjusts the operating frequency of the driving voltage. This leads to the highest stability in pushing force, velocity and closed-loop control.

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 optimizing system performance. Graphic displays show the system's behaviour and facilitate parameter setting.

Advantages of PILine® Micropositioning Systems

Positioning systems equipped with ceramic ultrasonic drives of the PILine® series provide several advantages over positioners that apply classic drive technology:

- Smaller dimensions
- Higher holding force when powered down; no holding current
- Increased acceleration of up to 5 g
- Increased velocity of up to 500 mm/s or 720°/s
- No leadscrews, gears or other mechanical components, no wear or maintenance
- No lubricants
- Non-magnetic and vacuum-compatible operating principle

Ordering Information

C-867.160
Piezomotor Controller with Drive Electronics, Networkable, for PILine® Systems

C-867.260
Piezomotor Controller with Drive Electronics, 2 Channels, for PILine® Systems

Accessories:

C-819.20
Analog Joystick for 2 axes

C-819.20Y
Y-Cable for Connecting 2 Controllers to C-819.20

C-170.PB
Pushbutton Box, 4 Buttons and 4 LEDs

Ask about custom designs!

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

The two-channel C-867.260 controller operates XY scanning stages, here: a customized M-686 stage for microscopy

Technical Data

Model	C-867.160	C-867.260
Function	Controller and drive electronics for PILine® piezomotors / systems	
Drive type	PILine® motors, single and dual drives with P-661, P-664, U-161 or U-164	
Channels	1	2
Motion and control		
Servo characteristics	Programmable PID V-ff filter, parameter changes on the fly	
Trajectory profile modes	Trapezoidal	
Encoder input	A/B differential signals, 50 x 10^6 impulses/s	
Stall detection	Servo off, triggered by programmable position error	
Limit switch	2 x TTL per channel (programmable)	
Reference switch	1 x TTL per channel (active high / low, programmable)	
Electrical properties		
Max. output power / channel	15 W	
Max. output voltage / channel	200 V_{pp}	
Interfaces and operation		
Communication interfaces	USB, RS-232	
Motor connector	MDR14	2 x MDR14
Controller network	Up to 16 units on single interface	
I/O ports	4 analog/digital in, 4 digital out (Mini-DIN, 9-pin) digital: TTL analog: 0 to 5 V	
Command set	PI General Command Set (GCS)	
User software	PIMikroMove	
Software 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	
Manual control	Pushbutton box, joystick, Y-cable for control of 2 axes with joystick	Pushbutton box, joystick
Miscellaneous		
Operating voltage	24 VDC from external power supply (included)	
Current consumption	300 mA + motor current (2 A max.)	600 mA + motor current (4 A max.)
Operating temperature range	+5 °C to +40 °C	
Mass	1.0 kg	2.4 kg
Dimensions	206 x 130 x 66 mm (including mounting rails)	320 x 150 x 80.5 mm (including mounting rails)

C-184 · C-185 PILine® Drive Electronics

OEM Boards and Stand-Alone Units fot Ultrasonic Piezomotors

C-185.D64 single-channel bench-top driver electronics with PILine® M-674 RodDrive featuring travel ranges up to 150 mm and 7 N drive force at 450 mm/s

- **For PILine® Ultrasonic OEM Motors and Positioners**
- **Accepts Analog Drive Signal from Standard Controller**
- **Available as Cost-Effective OEM board and Plug-and-Play Desktop Unit**

The C-184 OEM-board and the C-185 stand-alone unit are single-channel drive electronics for PILine® ultrasonic piezomotors and PILine® stages. Piezomotor drive electronics convert analog input signals into the high-frequency drive signals necessary to excite the required oscillations in the piezomotor stator which cause the motion. Both the C-184 and C-185 are available in three versions, for use with different motors and translation stages.

OEM and Integrated Electronics

The philosophy behind the design of PILine® ultrasonic drives dictates that they be easily adaptable to customer requirements. This includes making the drive electronics both independent of control signal type and available either as an OEM board or as a stand-alone unit in its own case. While the OEM boards are the most economic solution for large quantities, the stand-alone units make it possible to plug a system with PILine® stages together and put it into operation quickly and easily, for example for system evaluation purposes.

Analog Control

Both drivers control the motor speed based on an analog signal from 0 to 10 V. With an external position sensor and a servo controller, it is possible to set up a very fast, closed-loop system.

For optimum closed-loop system performance, the C-867 (see p. 4-116) piezo servo-controller is recommended.

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

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

Ordering Information

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

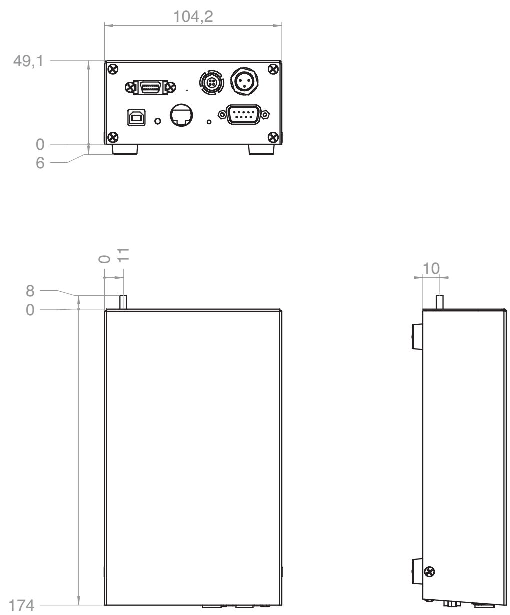
C-184.164
Analog OEM Driver Board for PILine® P-664 Motors

C-185.164
Analog Stand-Alone Drive Electronics with Power Supply for PILine® P-664 Motors

C-184.D64
Analog OEM Driver Board for PILine® RodDrive M-674

C-185.D64
Analog Stand-Alone Drive Electronics with Power Supply for PILine® RodDrive M-674

C-184.164 OEM driver board with PILine® P-664 OEM motor



Dimensions of single-channel bench-top C-185 in mm

Technical Data

Model	C-184	C-185
Function	Analog drive electronics (OEM board) for PILine® C-184.161: P-661 Motors & Positioners C-184.164: P-664 Motors & Positioners C-184.D64: M-674 RodDrive	Analog single-channel driver box for PILine® C-185.161: P-661 Motors & Positioners C-185.164: P-664 Motors & Positioners C-185.D64: M-674 RodDrive
Channels	1	1
Electrical properties		
Control in	Differential, -10 V up to +10 V, polarity controls direction	Differential, -10 V up to +10 V, polarity controls direction
Operating voltage	12 V, ±10 %	12 VDC external power supply (included)
Output power / channel	Model dependent: C-184.161: 5 W C-184.164: 10 W C-184.D64: 15 W	Model dependent: C-185.161: 5 W C-185.164: 10 W C-185.D64: 15 W
Output voltage / channel	Model dependent: C-184.161: 120 V_{PP} / 42 V_{RMS}, 210 kHz C-184.164: 168 V_{PP} / 60 V_{RMS}, 155 kHz C-184.D64: 190 V_{PP} / 67 V_{RMS}, 155 kHz	Model dependent: C-185.161: 120 V_{PP} / 42 V_{RMS}, 210 kHz C-185.164: 168 V_{PP} / 60 V_{RMS}, 155 kHz C-185.D64: 190 V_{PP} / 67 V_{RMS}, 155 kHz
Interfaces and operation		
Motor connector	Solder pads	LEMO connector or MDR connector, 14-pin
I/O ports	Solder pads	Sub-D connector, 15-pin
Miscellaneous		
Operating temperature range	+5 to +40 °C	+5 to +40 °C
Mass	C-184.161, C-184.164: 15 g C-184.D64: 24 g	690 g
Dimensions	65 x 38 mm	174 x 104 x 49 mm (without ground connection, pads and fitting panel) 182 x 104 x 49 mm (with ground connection)

Details on Specifications for PILine® Drives

Motion and positioning

Travel range

The maximum allowed travel is limited by the length of the friction bar in a PILine® drive. The distance between the two limit switches gives the travel range.

Minimum incremental motion

The typical minimum motion that can be executed for a given input in open-loop operation, which is sometimes referred to as practical or operational resolution. The data table states typical measured values. For repeatable minimum incremental motion, a position feedback sensor and servo loop is required.

For repeatable nanometer or subnanometer resolution see the Piezo Flexure Stages / High-Speed scanning Systems (p. 2-3 *ff*), PiezoWalk® Motors / Actuators (p. 1-3 *ff*) and Piezo Actuators & Components (p. 1-61 *ff*) Sections.

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.

Mechanical properties

Stiffness when powered down

Stiffness in motion direction. Typical tolerance: ±10%

Push / pull force

Active force limit in operating direction. The maximum force depends on the velocity.

Holding force when powered down

A main feature of piezomotor linear drives 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 the long-term minimum holding force.

Drive properties

Resonant frequency

Ultrasonic excitation frequency of the piezo ceramic actuator

Motor voltage range

Required excitation voltage range.

Operating voltage drive electronics

Supply voltage for the drive electronics. It is recommended to operate PILine® drives with suitable PI drive electronics only, referred to in the individual data table.

Miscellaneous

Operating temperature range

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

Mass

Typical tolerance: ±5%

Cable length

Typical tolerance: ±10 mm

Recommended controller/driver

To reach the specifications and to avid damage to the drive, it is strongly recommended to use PI driver and control electronics only. Compatible controllers already include the ultrasonic drive electronics

DC-Servo & Stepper Actuators

M-227 DC-Mike High-Resolution Linear Actuator

Non-Rotating Tip, Long Stroke to 50 mm

M-227.10 (w/ piezo tip), M-227.25, M-227.50 (w/ ball tip), high-resolution DC-Mike actuators and several tip options

Ordering Information

M-227.10
High-Resolution DC-Mike Linear Actuator, 10 mm

M-227.25
High-Resolution DC-Mike Linear Actuator, 25 mm

M-227.50
High-Resolution DC-Mike Linear Actuator, 50 mm

M-219.10
Ball Tip

P-855.20
Piezo Actuator for Micrometer Drive

- **Travel Ranges 10, 25 and 50 mm**
- **Min. Incremental Motion to 0.05 µm**
- **Non-Rotating Tip**
- **Closed-Loop DC-Motors**
- **Sub-nm Resolution with Optional PZT Drive**
- **MTBF >5,000 h**

M-227 are ultra-high-resolution linear actuators providing linear motion up to 50 mm with sub-micron resolution in a compact package. They consist of a micrometer with non-rotating tip, driven by a closed-loop DC-motor/gearhead combination with motor-shaft-mounted high-resolution encoder. The combination of an extremely low stiction/friction construction and high-resolution encoder allows for a minimum incremental motion of 50 nanometers at speeds up to 1 mm/sec.

Non-Rotating Tip

Compared to conventional rotating-tip micrometer drives, the non-rotating-tip design offers several advantages:

- Elimination of torque-induced positioning errors
- Elimination of sinusoidal motion errors
- Elimination of wear at the contact point
- Elimination of tip-angle-dependent wobble

Compact, High-Precision, Cost-Effective

M-227 actuators provide a cost-effective solution for industrial and OEM environments.

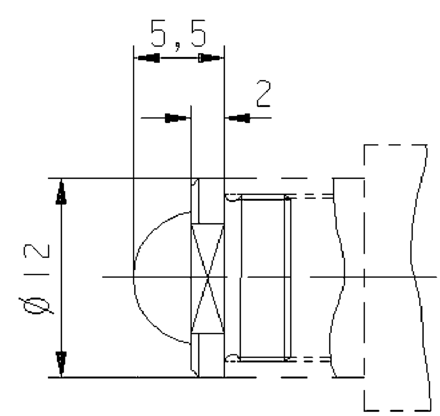
Integrated Line Drivers

All actuators 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 actuator and controller.

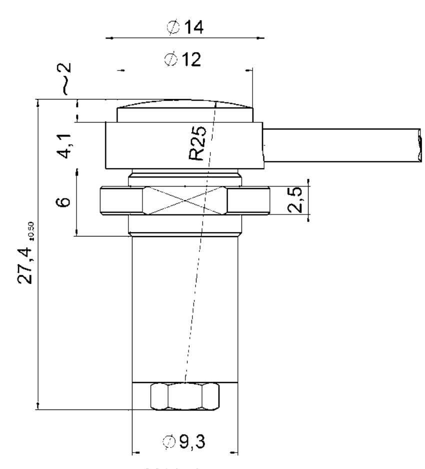
High-Resolution Piezo Option

All models come with standard flat tips. A variety of other tips are also available, such as a piezoelectric tip featuring 20 µm travel with sub-nanometer resolution for dynamic scanning and tracking see p. 1-73 and 1-58.

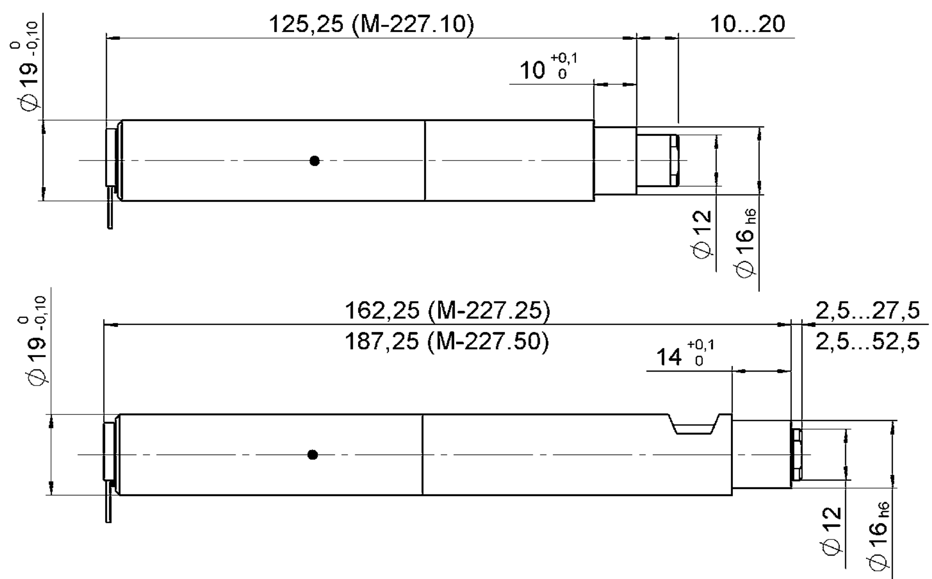
For higher loads and integrated limit switches refer to the M-230 (see p. 1-46 *ff*), M-235 (see p. 1-50 *ff*) and M-238.



M-219.10 ball tip option



P-855.20 piezo tip option



M-227 DC-Mike, dimensions (in mm). C-815.38 motor cable included: 3 m, sub-D, 15/15 pin (m/f)

Technical Data

Model	M-227.10	M-227.25	M-227.50	Units
Active axes	X	X	X	
Motion and positioning				
Travel range	10	25	50	mm
Integrated sensor	Rotary encoder	Rotary encoder	Rotary encoder	
Sensor resolution	2048	2048	2048	Cts./rev.
Design resolution	0.0035	0.0035	0.0035	µm
Min. incremental motion	0.05	0.05	0.05	µm
Backlash	2	2	2	µm
Unidirectional repeatability	0.1	0.1	0.1	µm
Max. velocity	0.75	0.75	0.75	mm/s
Mechanical properties				
Drive screw	Leadscrew	Leadscrew	Leadscrew	
Thread pitch	0.5	0.5	0.5	mm
Gear ratio	69.12:1	69.12:1	69.12:1	
Max. push/pull force	40	40	40	N
Max. lateral force	0.1	0.1	0.1	N
Drive properties				
Motor type	DC-motor, gearhead	DC-motor, gearhead	DC-motor, gearhead	
Operating voltage	0 to ±12	0 to ±12	0 to ±12	V
Electrical power	1.25	1.25	1.25	W
Miscellaneous				
Operating temperature range	-20 to +65	-20 to +65	-20 to +65	°C
Material	Al (anodized), steel	Al (anodized), steel	Al (anodized), steel	
Mass	0.16	0.22	0.26	kg
Cable length	0.1	0.1	0.1	m
Connector	15-pin sub-D connector	15-pin sub-D connector	15-pin sub-D connector	
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 (see p. 4-114) C-843 PCI-board, for up to 4 axes (see p. 4-120)	

*Higher forces on request

Piezo • Nano • Positioning

M-228 · M-229 Stepper Linear Actuator Series

High-Load, Compact and Highly Cost-Efficient, with Limit Switches

M-228 and M-229 series linear actuators are driven by powerful direct-drive stepper motors, or are equipped with more compact, gearhead stepper motors: M-229.26S, M-228.11S, M-229.25S, M-228.10S (from left)

- **Highly Cost-Efficient, Compact Design**
- **10 and 25 mm Travel Range**
- **High Load Capacity to 80 N**
- **Gearhead Version: 46 nm Resolution (with C-663 Controller)**
- **Direct Drive: Max. Velocity 5 mm/s**
- **Non-Rotating Tip**
- **Non-Contact Limit and Reference Switches**

M-228 and M-229 series linear actuators provide a travel range of 10, resp. 25 mm, and are equipped with high-resolution stepper motors. The stepper mikes can push or pull loads up to 80 N, and provide speeds up to 5 mm/s. Models featuring gearhead/stepper motor combinations offer the same stroke in a more compact package.

Application Examples

- Quality assurance testing
- Testing equipment
- Alignment of secondary mirrors
- Automation
- Metrology
- Precision machining

Cost-Effective Design, Valuable Features

The cost-effective design offers many useful features such as a non-rotating tip, limit and reference switches and a mechanical position display.

A spherical tip and a 3 m extension cable are included in the delivery. The more compact gearhead versions include an additional flat tip.

Non-Rotating Tip

Compared to conventional rotating-tip micrometer drives, the non-rotating tip design offers several advantages:

- Elimination of torque-induced positioning errors
- Elimination of sinusoidal motion errors
- Elimination of wear at the contact point
- Elimination of tip-angle-dependent wobble

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 actuators with the networkable C-663 Mercury Step controller (s. p. 4-112) offers high performance for a very competitive price in both single and multi-axis configurations.

Ordering Information

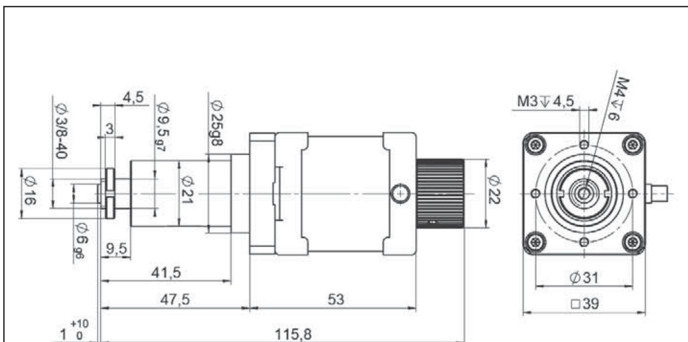
M-228.10S
Stepper-Mike Linear Actuator, 10 mm, Stepper Motor, Gearhead, Limit Switches

M-228.11S
Stepper-Mike Linear Actuator, 10 mm, Stepper Motor, Direct Drive, Limit Switches

M-229.25S
Stepper-Mike Linear Actuator, 25 mm, Stepper Motor, Gearhead, Limit Switches

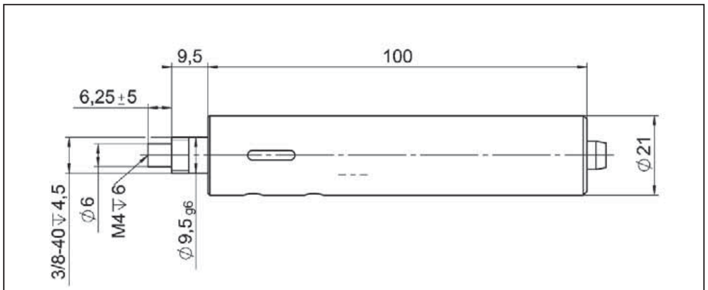
M-229.26S
Stepper-Mike Linear Actuator, 25 mm, Stepper Motor, Direct Drive, Limit Switches

Ask about custom designs!

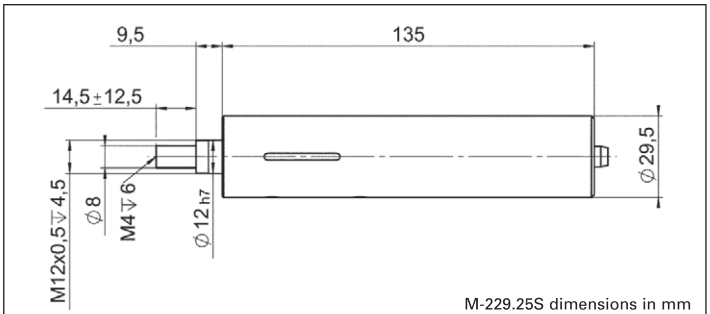


M-228.11S dimensions in mm

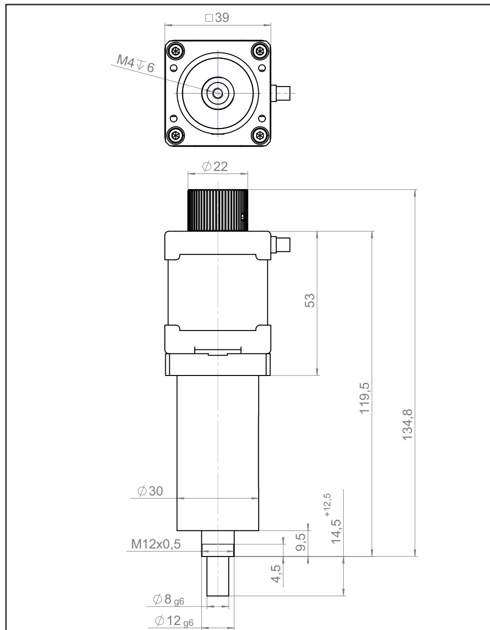
M-229 high-load stepper mike with gearhead, C-663 Mercury stepper motor controller (rear)



M-228.10S dimensions in mm



M-229.25S dimensions in mm



M-229.26S dimensions in mm

Technical Data

Model	M-228.10S	M-228.11S	M-229.25S	M-229.26S	Units
Active axes	X	X	X	X	
Motion and positioning					
Displacement	10	10	25	25	mm
Design resolution*	0.046	0.078	0.046	0.078	µm
Min. incremental motion*	1	1	1	1	µm
Backlash**	5	10	10	10	µm
Unidirectional repeatability	±2	±2	±2	±2	µm
Max. velocity*	1.5	5	1.5	5	mm / s
Reference switch repeatability	1	1	1	1	µm
Mechanical properties					
Drive screw	Leadscrew	Leadscrew	Leadscrew	Leadscrew	
Thread pitch	0.5	0.5	0.5	0.5	mm / rev.
Gear ratio	28.44444:1	–	28.44444:1	–	
Motor resolution*	384	6400	384	6400	steps / rev.
Max. push/pull force	20	50	50	80	N
Drive properties					
Motor type	2-phase stepper motor	2-phase stepper motor	2-phase stepper motor	2-phase stepper motor	
Operating voltage	24***	24#	24##	24#	V
Reference and limit 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·(anodized), steel, brass	Al·(anodized), steel, brass	Al·(anodized), steel, brass	Al·(anodized), steel, brass	
Mass	0.23	0.36	0.4	0.61	kg
Cable length	0.5	0.6	0.5	0.6	m
Connector	15-pin sub-D connector	15-pin sub-D connector	15-pin sub-D connector	15-pin sub-D connector	
Recommended controller	C-663 single-axis	C-663 single-axis	C-663 single-axis	C-663 single-axis	

Please avoid lateral forces at the tip.

* with C-663 stepper motor controller

** with preload

*** max. 0,25 A / phase; 24 full steps / rev.

\# max. 0,85 A / phase; 400 full steps / rev.

\#\# max. 1 A / phase; 24 full steps / rev.

M-230 Precision Linear Actuator

Non-Rotating Tip, Limit Switches, Stroke to 25 mm

M-230.10, M-230.25, high-resolution DC-Mike actuators, 10 and 25 mm travel range

Ordering Information

M-230.10
High-Resolution DC-Mike Linear Actuator, 10 mm, Limit Switches

M-230.10S
High-Resolution Stepper-Mike Linear Actuator, 10 mm, Limit Switches

M-230.25
High-Resolution DC-Mike Linear Actuator, 25 mm, Limit Switches

M-230.25S
High-Resolution Stepper-Mike Linear Actuator, 25 mm, Limit Switches

- **Travel Range 10 & 25 mm**
- **Min. Incremental Motion to 0,05 µm**
- **Non-Rotating Tip**
- **Max. Velocity 2 mm/s**
- **Closed-Loop DC Motors and Stepper Motors**
- **Non-Contact Limit and Reference Switches**
- **Front Mount or Clamp Mount**
- **MTBF>20.000 h**

M-230 are ultra-high-resolution linear actuators providing linear motion up to 25 mm with sub-micron resolution in a compact package. They consist of a micrometer with non-rotating tip driven by a 2-phase stepper motor or a closed-loop DC motor / gearhead combination with motor-shaft-mounted, high-resolution encoder.

Non-Rotating Tip

Compared to conventional rotating-tip micrometer drives, the non-rotating-tip design offers several advantages:

- Elimination of torque-induced positioning errors
- Elimination of sinusoidal motion errors
- Elimination of wear at the contact point
- Elimination of tip-angle-dependent wobble

Application Examples

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

High Accuracy & Long Life

M-230 actuators provide a cost-effective solution for heavier-duty industrial and OEM environments. They feature extremely low-stiction, low-friction construction, allowing for minimum incremental motion as low as 50 nanometers and speeds up to 2 mm/sec.

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.

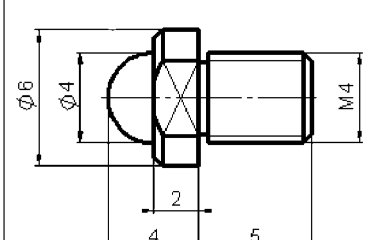
Integrated Line Drivers

All actuators 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 actuator and controller.

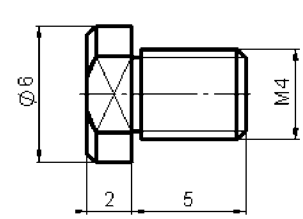
High-Load Versions

For higher loads and travel ranges refer to the M-235 (see p. 1-50) and M-238 (see p. 1-52).

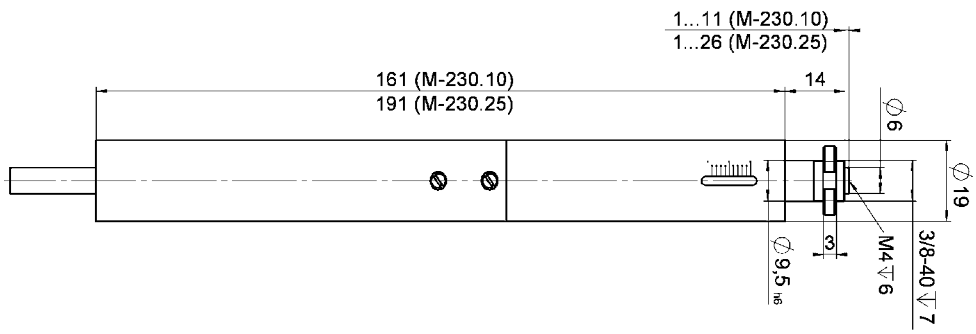
A screw-in ball tip and a flat tip are included.



Ball tip (included)



Flat tip (included)



M-230. Cable length: 500 mm, 15-pin sub-D connector with integrated line drivers (DC motor models). Dimensions in mm

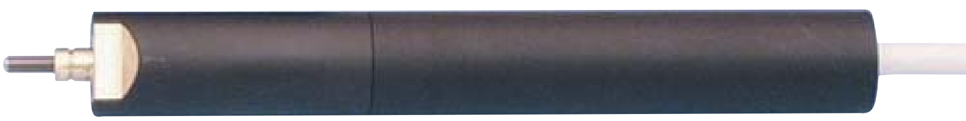
Technical Data

Model	M-230.10	M-230.25	M-230.10S	M-230.25S	Units
Active axes	X	X	X	X	
Motion and positioning					
Travel range	10	25	10	25	mm
Integrated sensor	Rotary encoder	Rotary encoder			
Sensor resolution	2,048	2,048			Cts./rev.
Design resolution	0.0046	0.0046	0.037	0.037	µm
Min. incremental motion	0.05	0.05	0.05	0.05	µm
Backlash	2	2	2	2	µm
Unidirectional repeatability	0.1	0.1	0.1	0.1	µm
Max. velocity	1.2	1.2	2	2	mm/s
Reference switch repeatability	1	1	1	1	µm
Mechanical properties					
Spindle	Leadscrew	Leadscrew	Leadscrew	Leadscrew	
Spindle pitch	0.4	0.4	0.4	0.4	mm
Gear ratio	42.92063:1	42.92063:1	28.44444:1	28.44444:1	
Motor resolution**			384**	384**	steps/rev.
Max. push/pull force	70	70	45*	45*	N
Max. lateral force	30	20	30	20	N
Drive properties					
Motor type	DC-motor, gearhead	DC-motor, gearhead	2-phase stepper motor**	2-phase stepper motor**	
Operating voltage	0 to ±12	0 to ±12	24	24	V
Electrical power	2	2			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 (anodized), steel	Al (anodized), steel	Al (anodized), steel	Al (anodized), steel	
Mass	0.3	0.35	0.3	0.35	kg
Cable length	0.5	0.5	0.5	0.5	m
Connector	15-pin sub-D connector	15-pin sub-D connector	15-pin sub-D connector	15-pin sub-D connector	
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, for up to 4 axes (p. 4-120)	C-663 single-axis	C-663 single-axis (p. 4-112)	

*at velocities of up to 1 mm/s
**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-231 DC-Mike Precision Linear Actuator

With Limit Switches, Suitable for Fiber Alignment



M-231.17 high-resolution DC-Mike actuator, 17 mm travel range

Ordering Information

M-231.17
High-Resolution DC-Mike Linear Actuator, 17 mm, Limit Switches

- **Travel Range 17 mm**
- **Min. Incremental Motion to 0.1 µm**
- **Max. Velocity 2.5 mm/s**
- **Closed-Loop DC-Motors**
- **Non-Contact Limit and Reference Switches**
- **Fits M-105 Fiber Aligners**
- **MTBF >5.000 h**

The M-231 is an ultra-high-resolution linear actuator providing linear motion up to 17 mm with sub-micron resolution in a compact package. It consists of a leadscrew which is driven by a closed-loop DC-motor/gearhead combination with motor-shaft-mounted, high-resolution encoder (2048 counts/rev.).

Upgrade for Manual Aligners

The M-231 was especially designed to fit existing manual translation stages (e.g. M-105, see p. 4-50 *ff*) as a direct replacement for a manual micrometer.

Limit and Reference Switches

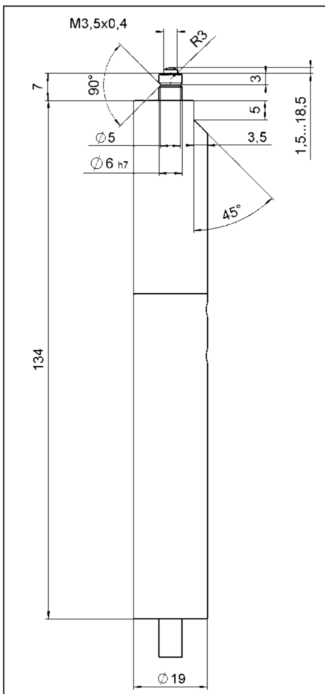
For the protection of your equipment, non-contact Hall-effect limit and reference switches are installed. The reference switch supports advanced automation applications with high precision.

Application Examples

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

Integrated Line Drivers

All actuators 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 actuator and controller.



M-231, dimensions (in mm). Cable length: 500 mm, 15-pin, sub-D connector with integrated line drivers

For higher loads and travel ranges, refer to the M-230 (see p. 1-46), M-235 (see p. 1-50) and M-238 (see p. 1-52).

M-231 mounted on M-105 XYZ positioning systems

Technical Data

Model	M-231.17	Units
Active axes	X	
Motion and positioning		
Travel range	17	mm
Integrated sensor	Rotary encoder	
Sensor resolution	2,048	Cts./rev.
Design resolution	0.007	µm
Min. incremental motion	0.1	µm
Backlash	2	µm
Unidirectional repeatability	0.2	µm
Max. velocity	1.5	mm/s
Reference switch repeatability	1	µm
Mechanical properties		
Spindle	Leadscrew	
Spindle pitch	0.4	mm
Gear ratio	28.44444:1	
Max. push/pull force	40	N
Drive properties		
Motor type	DC-motor, gearhead	
Operating voltage	0 to ±12	V
Electrical power	2	W
Limit and reference switches	Hall-effect	
Miscellaneous		
Operating temperature range	-20 to +65	°C
Material	Al (anodized), steel	
Mass	0.17	kg
Recommended controller/driver	C-863 single-axis (p. 4-114) C-843 PCI board, for up to 4 axes (p. 4-120)	

M-232 DC-Mike Precision Linear Actuator

Compact Package, Suitable for Fiber Alignment

M-232.17 high-resolution DC-Mike actuator mounted on M-105 translation stage

- **Travel Range 17 mm**
- **Min. Incremental Motion to 0,1 µm**
- **Max. Velocity 2,5 mm/s**
- **Closed-Loop DC-Motors**
- **Non-Contact Limit and Reference Switches**
- **Fits M-105 Fiber Aligners**
- **MTBF >5.000 h**

The M-232 is an ultra-high-resolution linear actuator providing linear motion up to 17 mm with sub-micron resolution in a compact package. It features a space-saving design with a leadscrew side-by-side to a closed-loop DC-motor/gearhead combination and a high-resolution encoder (2048 counts/rev.). They feature a low-stiction, low-friction construction allowing for minimum incremental motion of 100 nanometers at speeds of up to 2.5 mm/sec.

Upgrade for Manual Aligners

The M-232 was especially designed to fit existing manual translation stages (e.g. M-105 see p. 4-50 *ff*) as a direct replacement for a manual micrometer.

Application Examples

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

Limit and Reference Switches

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

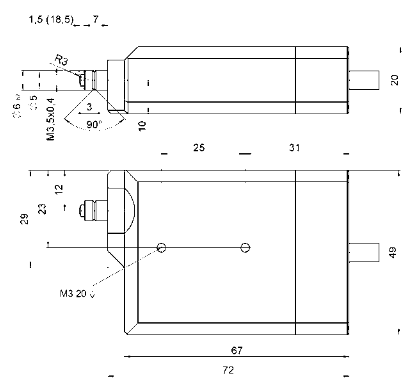
Integrated Line Drivers

All actuators 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 actuator and controller.

For higher loads and travel ranges, refer to the M-230 (see p. 1-46), M-235 (see p. 1-50) and M-238 (see p. 1-52).

Ordering Information

M-232.17
Compact High-Resolution DC-Mike Linear Actuator, 17 mm, Limit Switches



M-232, dimensions (in mm). Cable length: 500 mm, 15-pin sub-D connector with integrated line drivers

Technical Data

Model	M-232.17	Units
Active axes	X	
Motion and positioning		
Travel range	17	mm
Integrated sensor	Rotary encoder	
Sensor resolution	2,048	Cts./rev.
Design resolution	0.007	µm
Min. incremental motion	0.1	µm
Backlash	2	µm
Unidirectional repeatability	0.2	µm
Max. velocity	1.5	mm/s
Reference switch repeatability	1	µm
Mechanical properties		
Spindle	Leadscrew	
Spindle pitch	0.4	mm
Gear ratio	28.44444:1	
Max. push/pull force	40	N
Drive properties		
Motor type	DC-motor, gearhead	
Operating voltage	0 to ±12	V
Electrical power	2	W
Limit and reference switches	Hall-effect	
Miscellaneous		
Operating temperature range	-20 to +65	°C
Material	Al (anodized), steel	
Mass	0.17	kg
Recommended controller/driver	C-863 single-axis (p. 4-114) C-843 PCI board, for up to 4 axes (p. 4-112)	

M-235 Heavy-Duty Precision Linear Actuator

High-Dynamics, Stroke to 50 mm, Forces to 120 N

M-235.2DG (top) and
M-235.5DG (bottom) high-resolution
DC-Mike, ballscrew

- **Travel Range 20 & 50 mm**
- **Min. Incremental Motion to 0.1 µm**
- **High-Speed Direct Drive Option**
- **Push/Pull Load 120 N**
- **Lateral Force 100 N**
- **Recirculating Ballscrew Drives Provide High Speeds & Long Lifetimes**
- **Closed-Loop DC Motors and Stepper Motors**
- **Non-Contact Limit and Reference Switches**
- **MTBF >20.000 h**
- **Vacuum-Compatible Versions Available to 10^{-6} hPa**

The M-235 is an ultra-high-resolution linear actuator providing linear motion of up to 50 mm with sub-micron resolution in a compact package. It consists of a preloaded ultra-low-friction, heavy-duty ballscrew which is driven by a 2-phase stepper motor or a closed-loop DC motor with motor-shaft-mounted, high-resolution encoder (2048 counts/rev.).

Three Different Drives

The M-235 is available with three different motor drives:

Application Examples

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

The M-235.5DD version is equipped with a direct drive motor for high-speed positioning applications. The DC-motor models provide a minimum incremental motion of 100 nm only and are equipped with high-resolution rotary encoders for position control. The M-235.x2S versions have a high-power, low-vibration 2-phase stepper motor.

Non-Rotating Tip

Compared to conventional rotating-tip micrometer drives, the non-rotating-tip design offers several advantages:

- Elimination of torque-induced positioning errors
- Elimination of sinusoidal motion errors
- Elimination of wear at the contact point
- Elimination of tip-angle-dependent wobble

Ballscrews for High Speed and Long Lifetime

The recirculating ballscrew is maintenance-free and preloaded to eliminate mechanical play. Its significantly reduced friction, compared to conventional lead screws, allows for higher velocity, lower power consumption and longer service life. Thus, a bidirectional repeatability of 1 µm is made 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.

Integrated Line Drivers

All actuators 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 actuator and controller (DC-motors only).

A screw-in ball tip and a flat tip are included.

Ordering Information

M-235.2DD
High-Power Linear Actuator, 20 mm, Ballscrew, Direct-Drive DC Motor

M-235.2VD
Vacuum Version of M-235.2DD

M-235.2DG
High-Power Linear Actuator, 20 mm, Ballscrew, DC Motor Gearhead

M-235.2VG
Vacuum Version of M-235.2DG

M-235.22S
High-Power Linear Actuator, 20 mm, Ballscrew, Stepper Motor

M-235.5DD
High-Power Linear Actuator, 50 mm, Ballscrew, Direct-Drive DC Motor

M-235.5VD
Vacuum Version of M-235.5DD

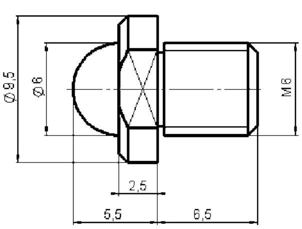
M-235.5DG
High-Power Linear Actuator, 50 mm, Ballscrew, DC Motor Gearhead

M-235.5VG
Vacuum Version of M-235.5DG

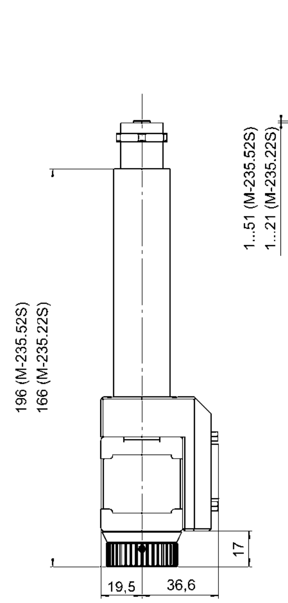
M-235.52S
High-Power Linear Actuator, 50 mm, Ballscrew, Stepper Motor

Ask about custom designs!

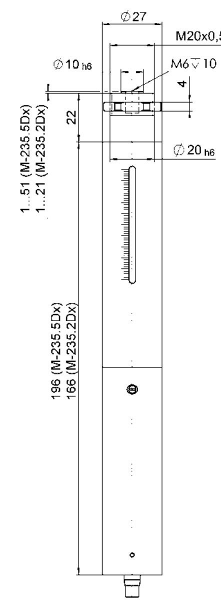
M-235.22S high-resolution Stepper-Mike,
20 mm travel range, ballscrew



Ball tip (included)



M-235.22S and M-235.52S dimensions in mm, cable length 500 mm, 15-pin Sub-D connector



M-235.2DD, M-235.2DG, M-235.5DD and M-235.5DG dimensions in mm. Cable length 500 mm, 15-pin Sub-D connector with integrated line drivers

Technical Data

Model	M-235.2DG	M-235.2DD	M-235.22S	M-235.5DG	M-235.5DD	M-235.52S	Units
Active axes	X	X	X	X	X	X	
Motion and positioning							
Travel range	20	20	20	50	50	50	mm
Integrated sensor	Rotary encoder	Rotary encoder		Rotary encoder	Rotary encoder		
Sensor resolution	2.048	2.048		2.048	2.048		Cts./rev.
Design resolution	0.016	0.5	0.156	0.016	0.5	0.156	µm
Min. incremental motion	0.1	0.5	0.1	0.1	0.5	0.1	µm
Unidirectional repeatability	0.1	0.5	0.2	0.1	0.5	0.2	µm
Bidirectional repeatability	1	1	1	1	1	1	µm
Max. velocity	2.6	>30	20	2.6	>30	20	mm/s
Mechanical properties							
Gear ratio	29.6:1			29.6:1			
Motor resolution*			6,400*			6,400*	steps/rev.
Max. push/pull force	120	>50	100**	120	>50	100**	N
Max. lateral force	100	100	100	100	100	100	N
Drive properties							
Motor type	DC-motor, gearhead	DC-motor	2-phase stepper motor*	DC-motor, gearhead	DC-motor	2-phase stepper motor*	
Operating voltage	0 to ±12	0 to ±12	24	0 to ±12	0 to ±12	24	V
Electrical power	4	17	4.75	4	17	4.75	W
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	Al (anodized), steel	Al (anodized), steel	Al (anodized), steel	Al (anodized), steel	Al (anodized), steel	Al (anodized), steel	
Mass	0.55	0.5	0.65	0.7	0.65	0.8	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-663 single-axis	C-863 single-axis C-843 PCI board, for up to 4 axes	C-863 single-axis (p. 4-114) C-843 PCI board, for 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
**at up to 10 mm/sec
Data for vacuum versions may differ.

PI Piezo • Nano • Positioning

M-238 High-Load, High-Resolution Linear Actuator

Forces to 400 N, Optional Direct Position Measurement

M-238.5PL Heavy-Duty Mike actuator (with CD for size comparison)

- **High Load Capacity to 400 N**
- **Travel Range 50 mm**
- **Resolution to 0.1 µm**
- **Max. Velocity 30 mm/s**
- **Preloaded Frictionless Ball Screw**
- **Optional 0.1 µm Direct-Metrology Linear Encoder for Exceptional Precision**
- **MTBF >20,000 h**
- **Vacuum-Compatible Versions Available for 10^{-6} hPa**

The M-238 is a high-load, high-precision actuator providing linear motion up to 50 mm, a load capacity to 400 N and high velocity to 30 mm/s. It consists of a low-friction, heavy-duty ballscrew, driven by a closed-loop, ActiveDrive™ DC-Motor with gearbox. The M-238 is therefore well suited for high duty-cycle operation in industrial environments. An optional linear encoder provides exceptional accuracy and repeatability.

Application Examples

- Quality assurance testing
- Testing equipment
- Precision machining
- Astronomy
- Flexible automation
- Metrology

Direct Metrology Linear Encoder to Compensate Mechanical Play

The M-238.5PL model is equipped with a non-contact, optical, linear encoder (direct metrology) with an output resolution of 0.1 µm. Because the encoder measures the actual position of the non-rotating actuator tip, drive-train errors like backlash and elastic deformations are eliminated. A lower-cost version with a rotary encoder is available as model number M-238.5PG.

ActiveDrive™ DC-Motor

DC motor drives offer several advantages, such as high dynamics, high torque at low rotational speed, low heat and low vibration.

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

Non-Rotating Tip

Compared to conventional rotating-tip micrometer drives, the non-rotating-tip design offers several advantages:

- Elimination of torque-induced positioning errors
- Elimination of sinusoidal motion errors
- Elimination of wear at the contact point
- Elimination of tip-angle dependent wobble

The lateral guiding of the tip withstands lateral forces of up to 100 N.

Ordering Information

M-238.5PG
Heavy-Duty DC-Mike Actuator, 400 N, 50 mm, ActiveDrive™

M-238.5PL*
Heavy-Duty DC-Mike Actuator, 400 N, 50 mm, ActiveDrive™, Direct-Metrology Encoder

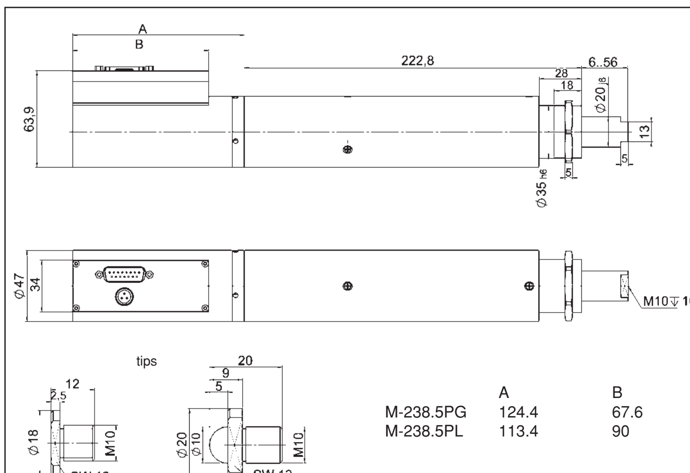
*Ask for availability in your region

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.

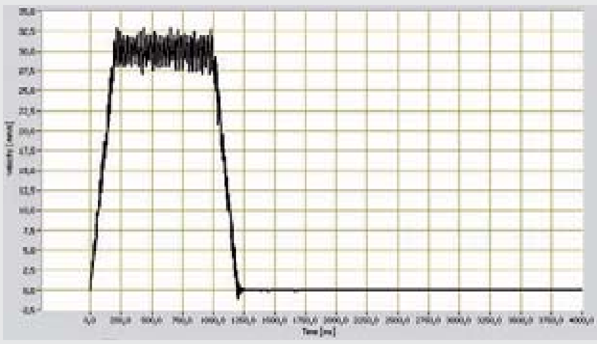
Limit and Reference Switches

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.

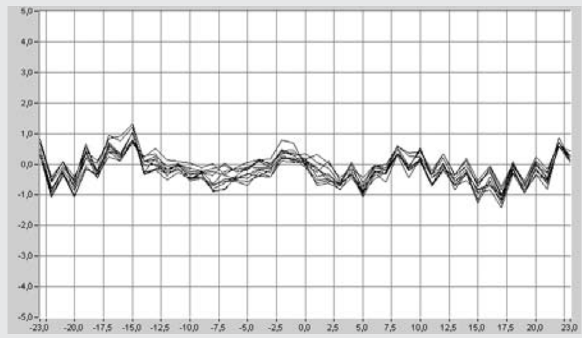


	A	B
M-238.5PG	124.4	67.6
M-238.5PL	113.4	90

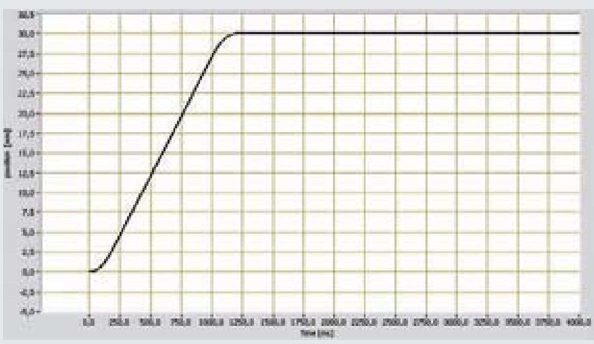
M-238 dimensions in mm



M-238.5PL velocity at 30 mm/s is highly constant.



M-238.5PL repeatability is better than 0.3 µm.



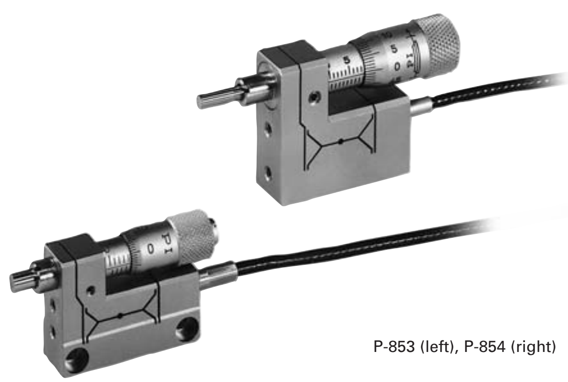
The settling time for a 30 mm step is less than 1.5 seconds.

Technical Data

Model	M-238.5PG	M-238.5PL	Units	Tolerance
Active axes	X	X		
Motion and positioning				
Travel range	50	50	mm	
Integrated sensor	Rotary encoder	Linear encoder		
Sensor resolution	4000 cts/rev.	0.1 µm		
Design resolution	0.13	0.1	µm	typ.
Min. incremental motion	0.5	0.3	µm	typ.
Backlash	3	1	µm	typ.
Unidirectional repeatability	1	0.3	µm	typ.
Max. velocity	30	30	mm/s	
Origin repeatability	1	1	µm	±20 %
Mechanical properties				
Spindle pitch	2	2	mm/rev.	
Gear ratio	3.71:1	3.71:1		
Push/pull force	400	400	N	Max.
Lateral force	100	100	N	Max.
Drive properties				
Motor type	DC-motor, ActiveDrive™	DC-motor, ActiveDrive™		
Operating voltage	24 (PWM)	24 (PWM)	V	
Electrical power	80	80	W	nominal
Miscellaneous				
Operating temperature range	-10 to 50	-10 to 50	°C	
Material	Al (anodized), steel	Al (anodized), steel		
Mass	2.4	2.4	kg	±5 %
Cable length	3	3	m	±10 mm
Connector	D-Sub 15 (m)	D-Sub 15 (m)		
Recommended controller/driver	C-863, C-843	C-863 (p. 4-114), C-843 (p. 4-120)		

P-853 · P-854 Piezoelectric Micrometer Drive

Hybrid PiezoMike Provides Sub-Nanometer Resolution



P-853 (left), P-854 (right)

- **Alternative for Standard Micrometer Drives**
- **Manual Travel to 18 mm**
- **Piezoelectric High-Resolution Travel to 25 µm**
- **Sub-Nanometer Resolution**
- **Dynamic Operation to 10 Hz**

P-853/P-854 PiezoMikes are micrometer drives with integrated high-resolution piezo linear drives. They can be operated manually, like standard micrometer drives. Sensitivity of the micrometer is 1 µm. By controlling the piezo voltage, the micrometer tip is automatically moved in and out (up to 25 µm) relative to the manually set position. Resolution of the piezoelectric motion is in the sub-nanometer range. The PiezoMike can therefore be used as a remotely controlled fine positioning element.

Working Principle

A sophisticated wire EDM (electric discharge machining) flexure motion amplifier doubles the displacement of a piezo linear actuator. It also serves as a linear guide to the micrometer drive, which is moved back and forth when the piezo drive voltage is changed. This design is compact and mechanically stable.

Ordering Information

P-853.00
PiezoMike, Piezoelectric Micrometer Drive, 6 mm, 25 µm

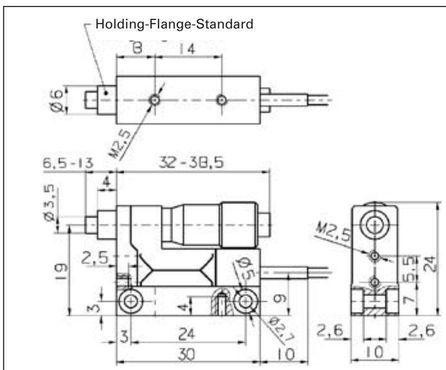
P-854.00
PiezoMike, Piezoelectric Micrometer Drive, 18 mm, 25 µm

Ask about custom designs!

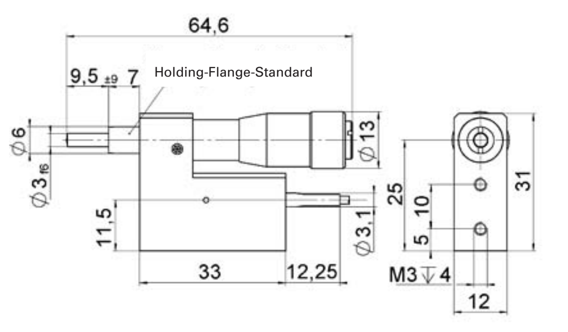
PiezoMike Applications

The PiezoMike can be mounted like a micrometer drive by clamping around the sleeve.

The P-853.00 is equipped with a 6 mm holding flange and can be directly attached to M-311 miniature translation stages (see www.pi.ws). The P-854 can be attached to the M-105 linear positioners (see p. 4-50).



P-853 dimensions (in mm)



P-854 dimensions (in mm)

M-313.80 XYZ miniature stage with P-853 PiezoMikes and optional fiber holder

Technical Data

Model	P-853.00	P-854.00	Units
Travel range (micrometer drive)	6	18	mm
Piezo fine travel range (@ 0 to 100 V)	25	25	µm ±20%
Min. incremental motion (piezo drive)	<1	<1	nm
Micrometer sensitivity	1	1	µm
Max. axial push/pull force	10 / 5	20 / 5	N
Micrometer drive	M-619.10	M-626.10	
Micrometer pitch	0.5	0.5	mm/rev.
Stiffness	1	1.5	N/µm
Electrical capacitance (piezo)	0.45	1.5	µF
Electrical connection	LEMO Cable: coaxial FFA.00.250, male. RG 178, Teflon coated, 1 m	LEMO Cable: coaxial, FFA.00.250, male. RG 178, Teflon coated, 1 m	
Mass	0.05	0.1	kg
Body material	N -S	N -S	
Recommended piezo driver	E-660, E-610, E-500 System	E-660 (p. 2-116), E-610 (p. 2-110), E-500 (p. 2-142) System	

M-168 Stepper-Mike Precision Linear Actuator

Non-Rotating Tip, Strokes to 50 mm

Linear Actuators & Motors
PiezoWalk® Motors / Actuators
PILine® Ultrasonic Motors
DC-Servo & Stepper Actuators
Piezo Actuators & Components
Guided / Preloaded Actuators
Unpackaged Stack Actuators
Patches/Benders/Tubes/Shear..
Nanopositioning / Piezoelectrics
Nanometrology
Micropositioning
Index

M-168 Stepper-Mikes providing 10, 25 and 50 mm travel range (from front to back)

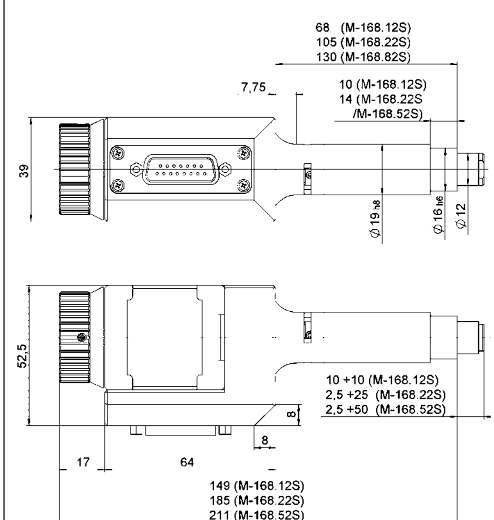
Ordering Information

M-168.12S
High-Resolution Stepper-Mike Linear Actuator, 10 mm

M-168.22S
High-Resolution Stepper-Mike Linear Actuator, 25 mm

M-168.52S
High-Resolution Stepper-Mike Linear Actuator, 50 mm

Ask about custom designs!



M-168.12S, M-168.22S and M-168.52S dimensions in mm.
Sub-D connector 15-pin, 3 m cable included (C-815.38)

- **10, 25 and 50 mm Travel Range**
- **Resolution <0.1 µm**
- **2-Phase Stepper Motor**
- **Manual Positioning Knob**
- **Sub-nm-Resolution with Optional PZT Actuator**
- **>5,000 h MTBF**

M-168 are compact, high-resolution linear actuators providing linear motion up to 50 mm with sub-micron resolution. They consist of a micrometer drive with non-rotating tip driven by a 6400 microstep/rev and 2-phase stepper motor.

Non-Rotating Tip

Compared to conventional rotating-tip micrometer drives, the non-rotating-tip design offers several advantages:

- Elimination of torque-induced positioning errors
- Elimination of sinusoidal motion errors
- Elimination of wear at the contact point
- Elimination of tip-angle-dependent wobble

M-168 Stepper-Mikes feature an extremely low-stiction, low-friction construction allowing for high resolution and repeatability. A manual positioning knob provides coarse resolution of 5 µm. All models come with standard flat tips (see p. 1-58 for spherical tips and other options).

High-Resolution Piezo Option

The optional piezo tip provides 20 µm travel with sub-nanometer resolution for dynamic scanning and tracking (see p. 1-73).

Technical Data

Model	M-168.12S	M-168.22S	M-168.52S	Unit
Travel range	10	25	50	mm
Design resolution	0.025	0.025	0.025	µm
Min. incremental motion	0.05	0.05	0.05	µm
Unidirectional repeatability	0.1	0.1	0.1	µm
Backlash	2	2	2	µm
Max. velocity	5	5	5	mm/s
Max. push/pull force	50	50	50	N
Max. lateral force	0.02	0.02	0.02	N (at tip)
Motor resolution*	6400*	6400*	6400*	steps/rev.
Drive screw pitch	0.5	0.5	0.5	mm/rev.
Weight	0.4	0.45	0.5	kg
Recommended motor controllers	C-663 single-axis	C-663 single-axis	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-653 · M-655 Differential Micrometer Drive

Stroke to 20 mm, Manual

M-653.00 differential micrometer drive

- 0.1 µm Sensitivity
- 1 µm Graduations
- Travel Range up to 20 mm

Model	Travel range coarse/fine	Spindle pitch coarse/fine	Shaft ø	Tip ø	Total length at 0 mm
M-653.00	5/0.2 mm	0.4/0.02 mm	6 mm	3 mm	56 mm
M-655.00	20/1.0 mm	0.5/0.05 mm	12 mm	6,8 mm	112 mm

M-631 · M-632 · M-633 Micrometer Drive

Non-Rotating Tip, Optional Piezo Drive, Manual

M-633, M-632, M-631 Micrometers (from top)

- 10, 25 and 50 mm Travel Range
- Pitch 0.5 mm/rev.
- Low-Friction Construction
- 1 µm Manual Sensitivity
- Sub-nm Resolution with Optional PZT Actuator

Model	Travel range	Max. push/ pull force	Tip ø	Shaft ø	Total length at 0 mm
M-631.00	10 mm	50 N	12 mm	16 mm	76 mm
M-632.00	25 mm	50 N	12 mm	16 mm	110.5 mm
M-633.00	50 mm	50 N	12 mm	16 mm	170.5 mm

M-619 – M-626 Precision Micrometer Drive

Stroke to 25 mm, Manual

Micrometer drives with up to 25 mm travel

- 1 µm Sensitivity
- 10 µm Graduations
- Model M-626.05 with Lockable Spindle

Model	Travel range	Shaft ø	Tip ø	Total length at 0 mm
M-619.00 M-619.10	6.5 mm 6.5 mm	6 mm 6 mm	3.5 mm 3.5 mm	37 mm 44.5 mm
M-620.00 M-621.00	10 mm 10 mm	6 mm 8 mm	3 mm 5 mm	44 mm 45 mm
M-622.00 M-623.00	15 mm 15 mm	10 mm 12 mm	5.5 mm 5.5 mm	63 mm 69 mm
M-626.00 & M-626.05 M-626.10	18 mm 18 mm	6 mm 6 mm	3 mm 3 mm	53 mm 64.5 mm
M-624.00	25 mm	12 mm	6.8 mm	87 mm

M-227K Vacuum Compatible Linear Actuator

High-Resolution DC-Mike Linear Actuator

The M-227KVLA Vacuum Compatible linear actuator is equipped with rotary encoder and DC-motor with gearhead

- Compact Design
- Vacuum Compatible up to 10^{-6} hPa
- Non-Rotating Tip
- Closed-Loop DC-Motors

Model	Travel range	Push/pull force	Design resolution	Max. velocity	Dimensions
M-227KVLA	10 mm	40 N	0.059 µm	0.3 mm/s	Ø 19 mm Length 146.5 ±5 mm

M-230K Compact Stepper Motor Linear Actuator

High-Resolution Linear Actuator with Folded Drive

For fine positioning tasks (e.g. in astronomy applications) the extremely compact M-230KCLA features resolution better than 5 nanometers

- Push/Pull Force to 400 N
- Highly Compact with Folded Drive
- High-Resolution Stepper Motor
- Min. Incremental Motion to 15 nm
- Hall-Effect Limit Switches
- Custom Tip for Load Mounting

Model	Travel range	Design resolution	Max. velocity	Thread pitch	Dimensions
M-230KCLA	4 mm	4.45 nm	9 µm/s	0.1 mm	107 x 60 x 30 mm + flange length 24.5 ±2 mm

M-238K Ultra-High-Load Precision Linear Actuator

High-Performance Linear Actuator Pushes Up To 1400 N

M-238KHLA High-Load measures and keeps the absolute position without current

- High-Resolution Incremental Rotary Encoder + Absolute Position Measurement with Linear Potentiometer
- Push/Pull Force to 1400 N
- Fast: Velocity to 30 mm/s
- Auto Locking at Rest with No Power Consumption & Heat Generation
- Brushless DC-Servomotor

Model	Travel range	Min. incremental Motion	Design resolution	Motor power	Dimensions
M-238KHLA	75 mm	2 µm	0.5 µm	250 W	Ø 64 mm Total length 185 +75 mm

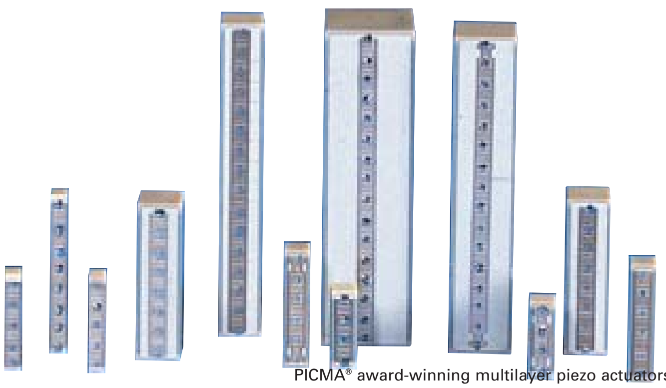
Piezo Actuators & Components

PICMA® Piezo Actuators—Extreme Lifetime, for Industrial Reliability Requirements

Full-Ceramic Encapsulation & Patented Design

PI has 4 decades of experience with piezo ceramic actuators in motion control applications in industry and research. Currently PI employs more than 100 people fully dedicated to piezo ceramic research, development and production. Extensive know-how and the most modern equipment make for the unique flexibility and worldwide leadership in piezo matters.
PI piezo actuators not only show an optimal combination of travel and stiffness, but are also designed for maximum lifetime under actual operating conditions in industrial environments.

Maximum lifetime means highest possible reliability. PI's award-winning, patented PICMA® actuators are based upon the newest technology which reduces the failure rate by a factor 10 compared to conventionally designed multilayer actuators.

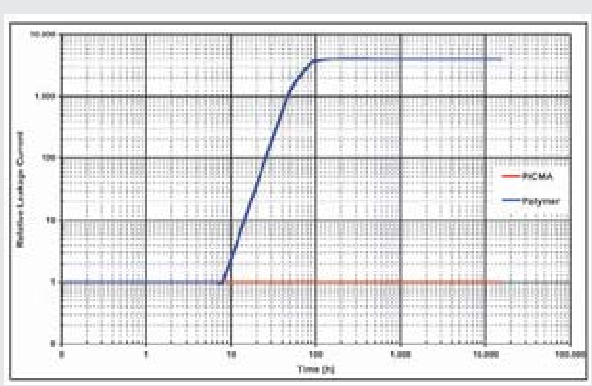


PICMA® award-winning multilayer piezo actuators feature full-ceramic insulation

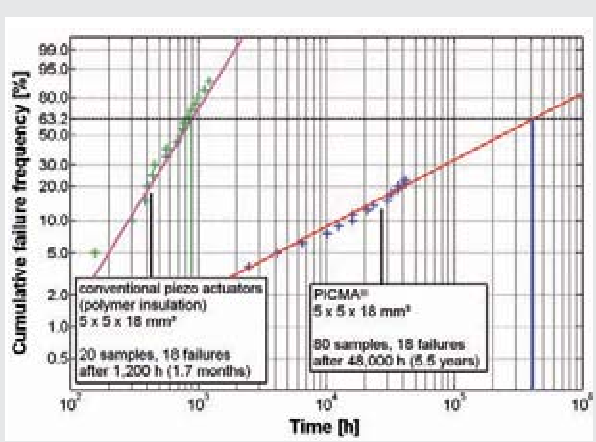
Long Term Tests Prove DC Reliability

PI's monolithic ceramic-encapsulated design provides better humidity protection than conventional polymer-film insulation. Diffusion of water molecules into the insulation layer is greatly reduced by the use of co-fired, outer ceramic encapsulation (fig. 2). Humidity is the main influence on the long-term reliability in low-dynamics or quasi-static operation modes, where the piezo actuator is supplied with a DC voltage to maintain a position for a long time.

Comparative tests with both PICMA® and conventional multilayer piezo actuators have proven the positive effects of the ceramic encapsulation. While polymer-coated piezos typically only survive 30 days of continuous operation - PICMA® actuators are still working after more than 4 years!



PICMA® piezo actuators (lower curve) compared with polymer-insulated multilayer piezo actuators. PICMA® actuators are insensitive to high humidity in this test. In conventional actuators, the leakage current begins to rise after only a few hours—an indication of degradation of the insulation and reduced lifetime.



Results of an accelerated DC-lifetime-test of PICMA® actuators compared to conventional actuators (100 V DC, room temperature, 90 % R.H.). The expected MTTF (Mean Time To Failure) for PICMA® is 80 years (700 000 hrs of continuous operation). All of the polymer-insulated samples have failed after 1,600 hrs (MTTF 805 hrs = 1 month)

PICMA® Piezo Actuators

Continuous Dynamic Operation

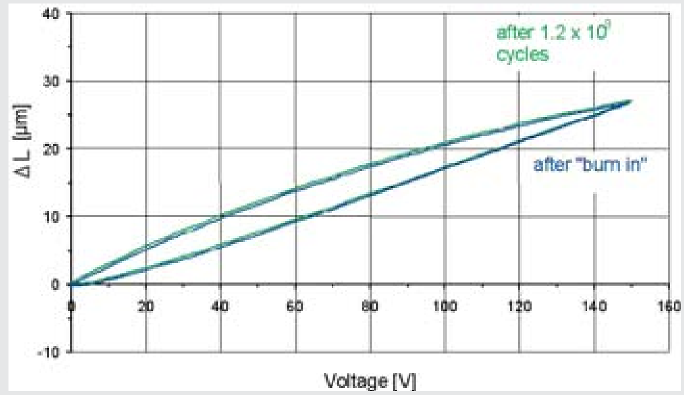
Here, the well-known lifetime-limiting factors of conventional designs are humidity, crack formation inside the ceramic leading to rising leakage currents and delamination of electrodes under extreme dynamic conditions.

PI reduces the cracking probability by a special patented design where segmented slots take care of excessive tensional stresses. Furthermore, the special electrode design ensures excellent, stable, electric contact even after billions of cycles.

PICMA® multilayer piezo actuators show no significant decrease in displacement even after many billions of cycles.

Long-Term Test under Cryogenic Conditions

To suit an application requiring 10 years minimum lifetime under cryogenic conditions, accelerated lifetime tests with PICMA® piezo actuators have been successfully performed. Inserted in a cryogenic bath of liquid nitrogen (75 K), the piezo is placed in a vacuum chamber ($2 \cdot 10^{-3}$ mbar) and subjected to dynamic operation at 90 % of the maximum voltage range (>105 V) with an operating frequency up to 1000 Hz. After one month of continuous operation there were no degradations in piezo performance to be measured, neither mechanic concerning the displacement, nor electrical concerning electrical capacitance or resonant frequency. (Dr. Bosotti et al., University of Milano, Italy, 2005)



AC tests were performed for 4.0 x 10^9 cycles at 8 samples PICMA® 5x5x18 using a 116 Hz-sine wave excitation (1.0 x 10^7 cycles per day) at a unipolar operating voltage of 100 V, 15 MPa preload. Control measurements were taken every 10^9 cycles. There was no significant decrease in displacement.

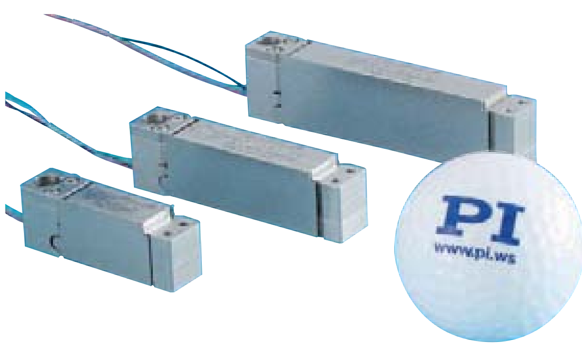
Large Operating Temperature Range , Optimum UHV Compatibility - Minimum Outgassing

Another advantage of fully ceramic-encapsulation PICMA® actuators is the extended operating temperature range, up to 150 °C, a huge improvement over the 80 °C limit common for other, polymer-insulated, monolithic actuators. The heat generation in dynamic operation is proportional to the operating frequency. Thus, a higher operating temperature allows for higher operating frequencies and duty cycles. Additionally, the lack of polymer insulation and the high Curie temperature make for optimal ultra-high-vacuum compatibility (no outgassing / high bakeout temperatures, up to 150 °C).

Piezo • Nano • Positioning

P-601 PiezoMove™ Z-Actuator

Flexure-Guided OEM Piezo Actuator with Long Stroke to 400 µm



PiezoMove™ Lever-amplified piezo actuators of the P-601 series

- **Flexure Guidance for Frictionless, Ultra-Straight Motion**
- **Travel Ranges to 400 µm**
- **Resolution to 0.2 nm**
- **High Dynamics and Stiffness**
- **Custom Designs with Longer Travel or Faster Response and Non-Magnetic Versions Feasible**
- **Outstanding Lifetime Due to PICMA® Piezo Actuators**
- **Choice of Closed-Loop and Open-Loop Models**
- **Ideal OEM Actuator for Precision Motion Control in Optics, Medical, Biotech and Microfluidics Applications**

The flexure-guided, lever-amplified PiezoMove™ P-601 actuators provide large vertical travel ranges up to 400 µm, fast response and high positioning accuracy in a very small package. With settling times of only a few milliseconds and a resolution in the sub-nanometer range they are well suited for both static and dynamic applications.

P-601 PiezoMove™ lever-amplified actuators cover the range between direct-driven preloaded piezo translators, such as the P-840 series (see p. 1-74) and single-axis nanopositioning stages, like the P-611 series (see p. 2-20). Compared to direct-driven piezo translators, lever-amplified actuators offer larger travel ranges and much higher lateral stiffness and guiding precision. Compared to single-axis nanopositioning stages, they offer significantly smaller sizes. PiezoMove™ lever-amplified actuators feature a resolution to 0.2 nm and a repeatability to 8 nm.

Application Example

- Nanopositioning
- Imaging
- High-speed switching
- Patch clamp
- Micro-dispensing
- Semiconductor testing
- Adaptronics / Automation
- Photonics / integrated optics
- Biotechnology

OEM Actuator with Integrated Guidance

With their highly precise, frictionless flexure guidance, a very high stiffness and excellent straightness of motion are achieved. Together with their small dimensions and the cost-effective design, the P-601 lever amplified actuators are especially suited for OEM applications. Versions with strain-gauge sensors (SGS) are equipped with a full bridge circuit that is insensitive to thermal drift. Versions without sensors are also available for open-loop applications such as in high-speed switches and pumps. In addition to the standard steel models, special invar and non-magnetic versions are available on request.

Ceramic Insulated Piezo Actuators Provide Long Lifetime

Highest possible reliability is assured by the use of award-winning PICMA® multilayer piezo actuators. PICMA® actuators are the only actuators on the market with ceramic-only insulation, which makes them resistant to ambient humidity and leakage-current failures. They are thus far superior to conventional actuators in reliability and lifetime.

Ordering Information

P-601.1S
PiezoMove™ OEM Flexure-Guided, Lever-Amplified Actuator, 100 µm, SGS-Sensor

P-601.3S
PiezoMove™ OEM Flexure-Guided, Lever-Amplified Actuator, 250 µm, SGS-Sensor

P-601.4S
PiezoMove™ OEM Flexure-Guided, Lever-Amplified Actuator, 400 µm, SGS-Sensor

P-601.1SL
PiezoMove™ OEM Flexure-Guided, Lever-Amplified Actuator, 100 µm, SGS-Sensor, LEMO Connector

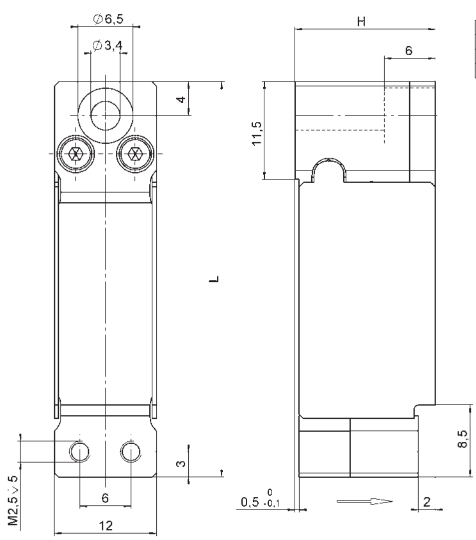
P-601.3SL
PiezoMove™ OEM Flexure-Guided, Lever-Amplified Actuator, 250 µm, SGS-Sensor, LEMO Connector

P-601.4SL
PiezoMove™ OEM Flexure-Guided, Lever-Amplified Actuator, 400 µm, SGS-Sensor, LEMO Connector

P-601.10
PiezoMove™ OEM Flexure-Guided, Lever-Amplified Actuator, 100 µm, Open-Loop

P-601.30
PiezoMove™ OEM Flexure-Guided, Lever-Amplified Actuator, 250 µm, Open-Loop

P-601.40
PiezoMove™ OEM Flexure-Guided, Lever-Amplified Actuator, 400 µm, Open-Loop



	H	L
P-601.1S	16,5	46,5
P-601.3S	18,0	64,5
P-601.4S	20,5	82,5

P-601 dimensions in mm

Technical Data

Model	P-601.1S P-601.1SL	P-601.3S P-601.3SL	P-601.4S P-601.4SL	P-601.x0 Open-loop versions	Units	Tolerance
Active axes	Z	Z	Z	Z		
Motion and positioning						
Integrated sensor	SGS	SGS	SGS	–		
Open-loop travel, -20 to +120 V	100	250	400	as P-601.xS	µm	min. (+20 %/-0 %)
Closed-loop travel	100	250	400	–	µm	calibrated
Open-loop resolution	0.2	0.3	0.4	as P-601.xS	nm	typ.
Closed-loop resolution	2	6	12	–	nm	typ.
Linearity, closed-loop	0.1	0.3	0.3	–	%	typ.
Repeatability	8	10	30	–	nm	typ.
Runout θ_X, θ_Y	20 / 10	20 / 10	20 / 10	as P-601.xS	µrad	typ.
Mechanical properties						
Stiffness in motion direction	0.8	0.38	0.28	as P-601.xS	N/µm	±20 %
Unloaded resonant frequency	750	440	350	as P-601.xS	Hz	±20 %
Resonant frequency @ 30 g	620	350	290	as P-601.xS	Hz	±20 %
Push/pull force capacity in motion direction	30/10	20/10	15/10	as P-601.xS	N	Max.
Lateral force	30	30	30	as P-601.xS	N	Max.
Drive properties						
Ceramic type	PICMA® P-885	PICMA® P-885	PICMA® P-885	as P-601.xS		
Electrical capacitance	1.5	3.1	4.6	as P-601.xS	µF	±20 %
Dynamic operating current coefficient	1.9	1.6	1.4	as P-601.xS	µA/(Hz•µm)	±20 %
Miscellaneous						
Operating temperature range	-20 to 80	-20 to 80	-20 to 80	-20 to 80	°C	
Material	Stainless steel	Stainless steel	Stainless steel	Stainless steel		
Mass without cables	0.05	0.08	0.11	as P-601.xS	kg	±5 %
Cable length	S-version: 0.3 SL-version: 1.5	S-version: 0.3 SL-version: 1.5	S-version: 0.3 SL-version: 1.5	0.3	m	±10 mm
Sensor / voltage connection	S-version: open leads SL-version: LEMO	S-version: open leads SL-version: LEMO	S-version: open leads SL-version: LEMO	Open leads (no sensor)		

Recommended controller / amplifier
E-610 controller / amplifier (p. 2-110), E-625 bench-top controller (p. 2-114)

P-602 PiezoMove Flexure Actuator with High Stiffness

Integrated Guiding System, High Force and Large Travel Ranges

P-602 linear actuator family featuring travel ranges of 100, 500, and 1000 µm (from left to right)

Ordering Information

PiezoMove® OEM Linear Actuator with High Stiffness

P-602.[ ][ ]

- 1 Travel Range 100 µm
- 3 Travel Range 300 µm
- 5 Travel Range 500 µm
- 8 Travel Range 1000 µm

- **00** Open-loop
- **S0** SGS Sensor
- **SL** SGS Sensor, LEMO Connector

PiezoMove® OEM Linear Actuators with High Force

P-602.[ ][ ]

- 1 Travel Range 100 µm
- 3 Travel Range 300 µm
- 5 Travel Range 500 µm

- **08** Open-loop
- **S8** SGS Sensor
- **L8** SGS Sensor, LEMO Connector

Ask about custom designs!

- **Frictionless Flexure Guiding System for Straight Motion**
- **Integrated Motion Amplifier for Travel Ranges to 1 mm**
- **High Dynamics and Stiffness, Forces to 400 N, Backlash-Free Construction**
- **Outstanding Lifetime Due to PICMA® Piezo Actuators**
- **Available with Integrated Position Sensor**
- **Custom Designs with Larger Travel or Faster Response and Non-Magnetic Versions Feasible**
- **Ideal for OEM-Applications in Adaptronics, Biotechnology or Microfluidics**

P-602 PiezoMove flexure-guided piezo actuators integrate a frictionless high-efficiency motion amplifier to combine large travel ranges up to 1 millimeter with high stiffness and very fast response. They do not contain any components that require maintenance or are subject to wear or tear. The flexure guides eliminate tip motion permitting only for a very slight tilt at the drive head. This design feature saves the cost for additional guiding systems when integrating these actuators in applications for the active control of tools, vibrations or deformations for accuracies down to a few 10s of nanometers.

Application Examples

- Nanopositioning
- Adaptronics
- Active vibration control
- Nano-imprinting
- Active Tool control
- Laser technology
- Semiconductor technology
- Active and adaptive optics

Options and Custom Versions

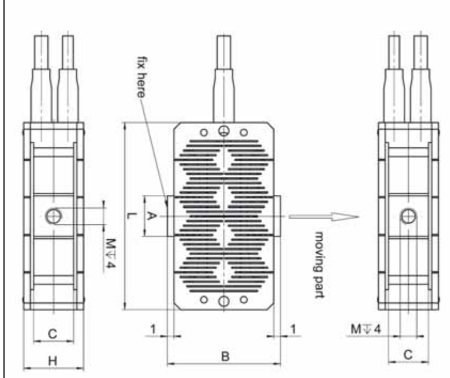
For OEM applications, PiezoMove actuators can be modified in various ways to suit the customer's requirements. The stiffness and force generation can be influenced via the lever design and the dimensions of the piezo ceramics used in the actuator. If only a small force and low guiding accuracy are required, large strokes of several 100 µm and high frequencies can be achieved with small actuators, e.g. for micropump drives. For high-accuracy applications, an integrated position feedback sensor is available. The actuators were designed to allow for considerable cost savings in large production runs.

OEM Control Electronics

PI also supplies a variety of controllers to match the actuators. These range from simple amplifier modules (see p. 2-164) and analog closed-loop OEM controllers (see p. 2-110) to high-performance digital controllers (see p. 2-100*ff*). The great choice of actuators and controllers allows customers to select the optimum combination of performance and cost for their application.

Ceramic-Insulated Piezo Actuators Provide Superior Lifetime

The highest possible reliability is assured by employing the award-winning PICMA® multilayer piezo actuators. PICMA® actuators are the only actuators on the market with a ceramic-only insulation which makes them resistant to ambient humidity and leakage-current failures. They are thus far superior to conventional actuators in reliability and lifetime.



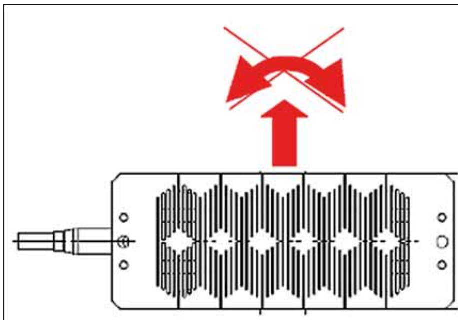
	L	B	H
P-602.1xx	28	17	9
P-602.3xx	46	19	9
P-602.5xx	85	26	9
P-602.8xx	126	34	14
P-602.1x8	28	22	14
P-602.3x8	46	24	14
P-602.5x8	85	31	14

	M	A	C
P-602.1xx	M2,5	6	6
P-602.3xx	M2,5	6	6
P-602.5xx	M2,5	6	6
P-602.8xx	M4	10	11
P-602.1x8	M2,5	6	11
P-602.3x8	M2,5	6	11
P-602.5x8	M2,5	6	11

P-602 dimensions in mm

Linear Actuators & Motors
PiezoWalk® Motors / Actuators
PILine® Ultrasonic Motors
DC-Servo & Stepper Actuators
Piezo Actuators & Components
Guided / Preloaded Actuators
Unpackaged Stack Actuators
Patches / Benders / Tubes / Shear..
Nanopositioning / Piezoelectrics
Nanometrology
Micropositioning
Index

PI offers a large variety of standard and custom lever-amplified piezo actuators for almost any application



P-602: Flexure guides provide straight motion with no tip and minimum tilt

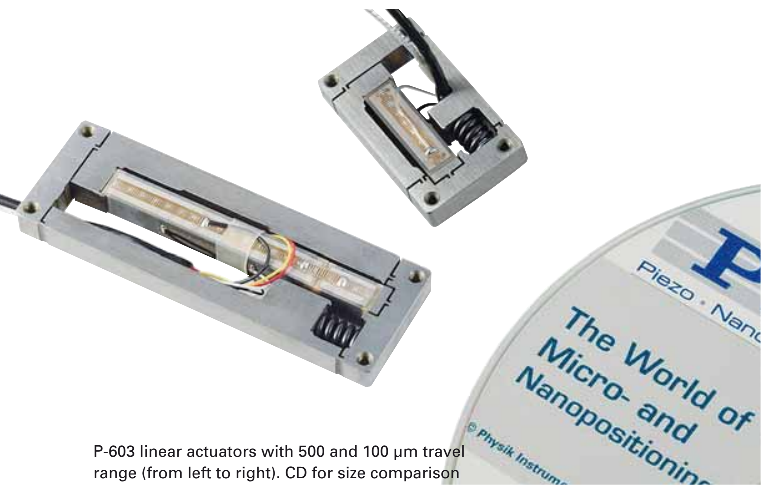
Technical Data (preliminary)

Model	P-602.100 P-602.1S0 P-602.1SL	P-602.300 P-602.3S0 P-602.3SL	P-602.500 P-602.5S0 P-602.5SL	P-602.108 P-602.1S8 P-602.1L8	P-602.308 P-602.3S8 P-602.3L8	P-602.508 P-602.5S8 P-602.5L8	P-602.800 P-602.8S0 P-602.8SL	Units	Tolerance
Active axes	X	X	X	X	X	X	X		
Motion and positioning									
Integrated sensor	- / SGS / SGS	- / SGS / SGS	- / SGS / SGS	- / SGS / SGS	- / SGS / SGS	- / SGS / SGS	- / SGS / SGS		
Open-loop travel, -20 to +120 V	120	300	600	100	300	500	1000	µm	min. (+20%/-0)
Closed-loop travel	- / 100 / 100	- / 300 / 300	- / 500 / 500	- / 100 / 100	- / 300 / 300	- / 500 / 500	- / 1000 / 1000	µm	
Open-loop resolution	0.2	0.3	0.4	0.2	0.3	0.4	0.5	nm	typ.
Closed-loop resolution	- / 2 / 2	- / 3 / 3	- / 3 / 3	- / 2 / 2	- / 3 / 3	- / 3 / 3	- / 7 / 7	nm	typ.
Linearity, closed-loop	- / 0.5 / 0.5	- / 0.5 / 0.5	- / 0.5 / 0.5	- / 0.5 / 0.5	- / 0.5 / 0.5	- / 0.5 / 0.5	- / 1.5 / 1.5	%	typ.
Repeatability	- / 10 / 10	- / 20 / 20	- / 35 / 35	- / 10 / 10	- / 20 / 20	- / 35 / 35	- / 60 / 60	nm	typ.
Mechanical properties									
Stiffness in motion direction	0.8	0.35	0.3	2.3	0.75	0.65	0.4	N/µm	± 20%
Unloaded resonant frequency	1000	450	230	1000	450	230	150	Hz	± 20%
Blocking force	80	105	150	230	225	325	400	N	max.
Drive properties									
Ceramic type	PICMA® P-885	PICMA® P-885	PICMA® P-885	PICMA® P-888	PICMA® P-888	PICMA® P-888	PICMA® P-888		
Electrical Capacitance	1.5	3.1	6.2	6	13	26	39	µF	± 20%
Dynamic operating current coefficient	1.9	1.3	1.6	7.5	5	6	4	µA/(Hz•µm)	± 20%
Miscellaneous									
Operating temperature range	-20 to 80	-20 to 80	-20 to 80	-20 to 80	-20 to 80	-20 to 80	-20 to 80	°C	
Material	Stainless steel	Stainless steel	Stainless steel	Stainless steel	Stainless steel	Stainless steel	Stainless steel		
kg	28 x 17 x 9	46 x 19 x 9	85 x 26 x 9	28 x 22 x 14	46 x 24 x 14	85 x 31 x 14	126 x 34 x 14	mm	
Mass	0.022	0.04	0.105	0.05	0.088	0.215	0.355	kg	± 5%
Cable length	0.5 / 0.5 / 2	0.5 / 0.5 / 2	0.5 / 0.5 / 2	0.5 / 0.5 / 2	0.5 / 0.5 / 2	0.5 / 0.5 / 2	0.5 / 0.5 / 2	m	± 10 mm
Sensor / voltage connection	0- and S-version: open leads SL-version: LEMO connector	0- and S-version: open leads SL-version: LEMO connector	0- and S-version: open leads SL-version: LEMO connector	0- and S-version: open leads L-version: LEMO connector	0- and S-version: open leads L-version: LEMO connector	0- and S-version: open leads L-version: LEMO connector	0- and S-version: open leads SL-version: LEMO connector		

Recommended controller / amplifier
E-610 controller / amplifier see p. 2-110, E-625 bench-top controller see p. 2-114

P-603 PiezoMove Linear Actuator

Low-cost and with Large Travel Ranges



P-603 linear actuators with 500 and 100 µm travel range (from left to right). CD for size comparison

- **Frictionless, High-Precision Flexure Guiding System**
- **Travel Ranges to 500 µm**
- **Cost-Effective Design**
- **Outstanding Lifetime Due to PICMA® Piezo Actuators**
- **Available with Integrated Position Sensor**
- **Ideal OEM Actuators for Precision Motion Control in Optics, Medical, Biotech and Microfluidics Applications**
- **Custom Designs with Larger Travel or Faster Response and Non-Magnetic Versions Feasible**

P-603 PiezoMove flexure-guided piezo actuators integrate a frictionless high-efficiency motion amplifier to combine large travel ranges up to 500 µm with high stiffness and very fast response. The flexure guides reduce tip at the drive head to a minimum saving the cost for additional guiding systems when integrating these actuators in micro-dispensing devices, pumps or servo valves. The overall precision of 10s of nanometers also makes these devices ideal for nanomanipulation applications.

Application Example

- Nanopositioning
- CCD / CMOS camera technology / Micro scanning
- Cell manipulation, biohandling
- Medical technology
- Micropumps
- Micro-dispensing
- Slit width adjustment
- Cavity Tuning
- Beam stabilization
- Photonics / integrated optics
- Switches

Options and Custom Versions

For OEM applications, PiezoMove actuators can be modified in various ways to suit the customer's requirements. The stiffness and force generation can be influenced via the lever design and the dimensions of the piezo ceramics used in the actuator. If only a small force and low guiding accuracy are required, large strokes of several 100 µm and high frequencies can be achieved with small actuators, e.g. for micropump drives. For high-accuracy applications, an integrated position feedback sensor is available. The actuators were designed to allow for considerable cost savings in large production runs.

OEM Control Electronics

PI also supplies a variety of controllers to match the actuators. These range from simple amplifier modules (see p. 2-164) and analog closed-loop OEM controllers (see p. 2-110) to high-performance digital controllers (see p. 2-100*ff*). The great choice of actuators and controllers allows customers to select the optimum combination of performance and cost for their application.

Increased Lifetime Through Humidity Resistance

The monolithic ceramic-encapsulated design provides better humidity protection than polymer-film insulation. Diffusion of water molecules into the insulation layer is greatly reduced by the use of cofired, outer ceramic encapsulation. Due to their high resonant frequency the actuators are suitable for highly dynamic applications with small loads; depending on the load an external preload for dynamic applications is recommended. The high Curie temperature of 320° gives PICMA® actuators a usable temperature range extending up to 150 °C, far beyond 80°C as is common for conventional multilayer actuators. With conventional multilayer actuators, heat generation – which is proportional to operating frequency – either limits the operating frequency or duty cycle in dynamic operation, or makes ungainly cooling provisions necessary. At the low end, operation down to a few Kelvin is possible (with reduced travel range).

Ordering Information

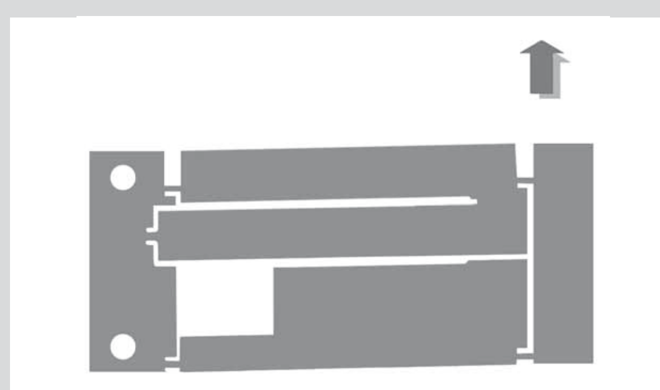
PiezoMove® OEM Linear Actuator with High Stiffness

P-603.☐☐☐

- **1** Travel Range 100 µm
- **3** Travel Range 300 µm
- **5** Travel Range 500 µm

- **00** Open loop
- **S0** SGS Sensor
- **SL** SGS Sensor, LEMO Connector

Ask about custom designs!

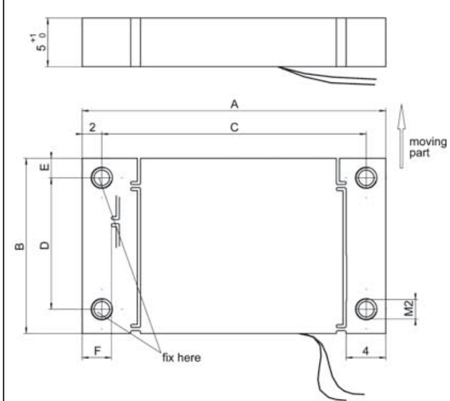


The flexure guiding system prevents tip and tilt at the drive head!

Levels of Integration: From Stack Actuator to 6-Axis Stage

	Stack actuators	Lever-amplified actuators	Positioning systems
Travel ranges	up to approx. 150 µm	up to 1 mm	up to 2 mm
Axes moved	one	one	up to three linear axes and three tip/ tilt axes
Sensors	SGS optional	SGS optional	SGS or direct measuring capacitive sensors
Linearity	up to 99.8 %	up to 99.8 %	over 99.9 %
Guidance	none	flexures for rotations <10"	flexures for rotations <2"
Space required	low	low	depends on features
Price	low	low	depends on features
Integration effort	high	low	low

Flexure guided, lever-amplified actuators form a reasonably priced and easily integrated class of products between conventional piezo stack actuators and the complex piezo nanopositioning systems



	A	B	C	D	E	F
P-603.1xx	31	18	27	13,5	2	3
P-603.3xx	51	20	47	13,5	3,25	3,5
P-603.5xx	60	20	56	16	2	3

P-603 dimensions in mm

Technical Data (preliminary)

Model	P-603.1S0 P-603.1SL	P-603.3S0 P-603.3SL	P-603.5S0 P-603.5SL	P-603.x00 open-loop versions	Units	Tolerance
Active axes	X	X	X	X		
Motion and positioning						
Integrated sensor	SGS	SGS	SGS	–		
Open-loop travel, -20 to +120 V	100	300	550	as P-603.xS0	µm	min. (+20%/-0)
Closed-loop travel	100	300	500	–	µm	calibrated
Open-loop resolution	0.2	0.3	0.4	as P-603.xS0	nm	typ.
Closed-loop resolution	2	4	7.5	–	nm	typ.
Linearity, closed-loop	0.3	0.3	0.3	–	%	typ.
Repeatability	8	10	30	–	nm	typ.
Mechanical properties						
Stiffness in motion direction	0.25	0.14	0.06	as P-603.xS0	N/µm	±20%
Unloaded resonant frequency	900	450	300	as P-603.xS0	Hz	±20%
Blocking force	20	35	25	as P-603.xS0	N	max.
Drive properties						
Ceramic type	PICMA® P-885	PICMA® P-885	PICMA® P-885	PICMA® P-885		
Electrical Capacitance	1.5	3.1	3.7	as P-603.xS0	µF	±20%
Dynamic operating current coefficient	1.9	1.3	1.6	as P-603.xS0	µA/(Hz•µm)	±20%
Miscellaneous						
Operating temperature range	-20 to 80	-20 to 80	-20 to 80	-20 to 80	°C	
Material	Stainless steel	Stainless steel	Stainless steel	Stainless steel		
Dimensions	31x18x5	50x20x5	51x20x5	as P-603.xS0	mm	
Mass	0.02 / 0.031	0.032 / 0.043	0.038 / 0.049	as P-603.xS0	kg	±5%
Cable length	0.5	0.5	0.5	0.5	m	±10 mm
Sensor / voltage connection	S-version: open leads SL-version: LEMO connector (SGS Sensor)	S-version: open leads SL-version: LEMO connector (SGS Sensor)	S-version: open leads SL-version: LEMO connector (SGS Sensor)	Open leads		

Recommended controller / amplifier
E-610 controller / amplifier see p. 2-110, E-625 bench-top controller see p. 2-114

P-810 · P-830 Piezo Actuators

For Light and Medium Loads

P-810 & P- 830 piezo actuators

- **Outstanding Lifetime Due to PICMA® Piezo Ceramics**
- **Travel Range to 60 µm**
- **Pushing Forces to 1000 N**
- **Pulling Forces to 5 N**
- **Sub-Millisecond Response**
- **Sub-Nanometer Resolution**

The P-810 and P-830 series translators are high-resolution linear actuators for static and dynamic applications. They provide sub-millisecond response and sub-nanometer resolution.

Application Examples

- Static and dynamic precision positioning
- Fiber positioning
- Laser tuning
- Patch-Clamp
- Nanotechnology

Design

These actuators consist of a highly reliable monolithic multilayer piezoceramic stack protected by a stainless steel case. PI offers a variety of preloaded translators for applications involving higher tensile loads (see the "Selection Guide" on p. 1-62).

Ceramic Insulated Piezo Actuators Provide Long Lifetime

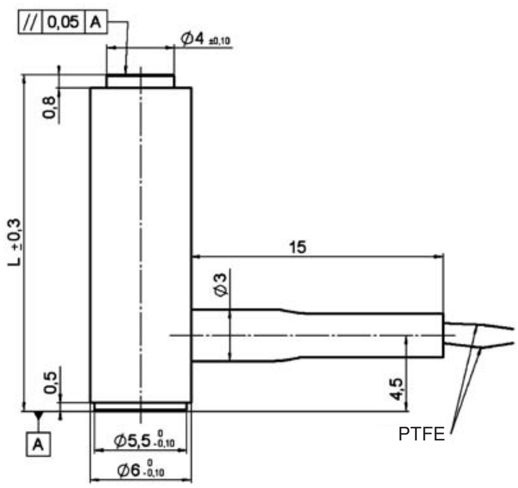
Highest possible reliability is assured by the use of award-winning PICMA® multilayer piezo actuators. PICMA® actuators are the only actuators on the market with ceramic-only insulation, which makes them resistant to ambient humidity and leakage-current failures. They are thus far superior to conventional actuators in reliability and lifetime.

Mounting

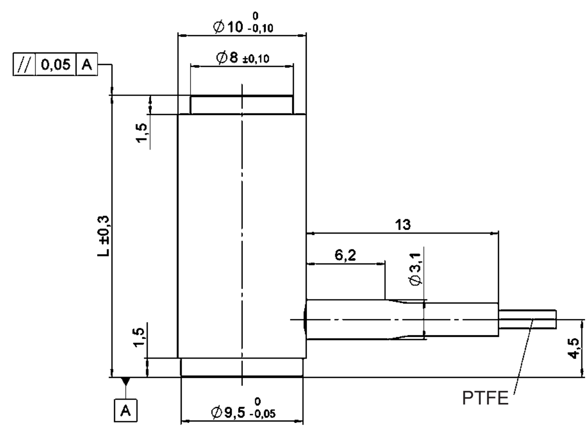
Attachment is realized via the ferromagnetic end surfaces, with epoxy or magnets.
Read details in Mounting and Handling Guidelines (p. 1-67).
For extensions, adapter cables and connectors, see "Accessories" (p. 1-104 *ff*).

Piezo Drivers, Controllers & Amplifiers

High-resolution amplifiers and servo-control electronics, both digital and analog, are described in the "Piezo Drivers / Servo Controllers" section (see p. 2-99 *ff*).



P-810 dimensions in mm. Two 0.1 m long teflon insulated pigtails. Length L: see table. Max. torque at top piece: 0.08 Nm.



P-830 dimensions in mm. Two 0.1 m long teflon insulated pigtails. Length L: see table. Max. torque at top piece: 0.2 Nm.

Technical Data and Product Order Numbers

Order number	Travel range for 0 to 100 V [µm] ±20 %	*Resolution [nm]	**Static large-signal stiffness [N/µm] ±20 %	Push- / pull force capacity [N]	Electrical capacitance [µF] ±20 %	Dynamic operating current coefficient [µA / (Hz • µm)]	Resonant frequency (unloaded) [kHz] ±20 %	Mass [g] ±5 %	Length L [mm] ±0.3
P-810.10	15	0.15	14	50 / 1	0.3	3.0	22	4	20
P-810.20	30	0.3	7	50 / 1	0.7	3.0	15	6	38
P-810.30	45	0.45	4	50 / 1	1.0	3.0	12	8	56
P-830.10	15	0.15	57	1000 / 5	1.5	12.5	23	10	22
P-830.20	30	0.3	27	1000 / 5	3.0	12.5	14	16	40
P-830.30	45	0.45	19	1000 / 5	4.5	12.5	10	21	58
P-830.40	60	0.6	15	1000 / 5	6.0	12.5	8.5	27	76

*The resolution of piezo actuators is not limited by stiction or friction. Value given is noise equivalent motion with E-503 amplifier p. 2-144

**Dynamic small-signal stiffness is ~ 30 % higher. Operating temperature range: -20 to 120° C. Case: non-magnetic steel; end pieces: stainless steel. Recommended preload for dynamic operation: 10–20 MPa.

Recommended amplifiers / controllers

One channel: E-831 amplifier (p. 2-164), E-610 amplifier / controller (p. 2-110)

Multi-channel: E-663 amplifier (p. 2-136)

P-820 Preloaded Piezo Actuators

For Light and Medium Loads

P-820.10 and P-820.30 piezo actuators

- **Outstanding Lifetime Due to PICMA® Piezo Actuators**
- **Travel Range to 45 µm**
- **Pushing Forces to 50 N**
- **Pulling Forces to 10 N**
- **Sub-Millisecond Response**
- **Sub-Nanometer Resolution**
- **Optional Ball Tip**

The P-820 series piezo translators are high resolution linear actuators for static and dynamic applications. They provide sub-millisecond response and sub-nanometer resolution.

Design

These actuators consist of a friction-free, preloaded monolithic piezo ceramic stack integrated in a stainless steel housing.

Ceramic Insulated Piezo Actuators Provide Long Lifetime

Highest possible reliability is assured by the use of award-winning PICMA® multilayer piezo actuators. PICMA® actuators are the only actuators on the market with ceramic-only insulation, which makes them resistant to ambient humidity and leakage-current failures. They are thus far superior to conventional actuators in reliability and lifetime.

Mounting

Mounting is at the foot, with push/pull forces of less than 3 N, the actuator can be held by clamping the case. The optional ball tip (P-820.95) is intended to decouple torque and off-center forces from the piezo ceramic. The magnetic adapter P-176.30 is to be glued onto the top piece in order to provide magnetic coupling.
Read details in Mounting and Handling Guidelines (p. 1-67).

Factory Installed Options

P-820.95 Ball Tip

Accessories

P-176
Magnetic Adapter (see p. 1-103)
For extensions, adapter cables and connectors, see "Accessories" in the piezo electronics chapter (see p. 1-168 *ff*).

Piezo Drivers, Controllers & Amplifiers

High-resolution amplifiers and servo-control electronics, both digital and analog, are described in the "Piezo Drivers / Servo Controllers" (see p. 2-99 *ff*) section.

Application Examples

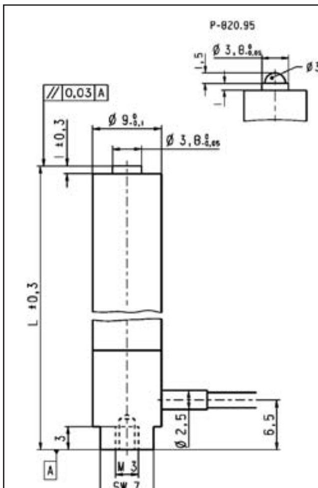
- Static and dynamic precision positioning
- Fiber positioning
- Laser tuning
- Nanotechnology

Ordering Information

P-820.10
Preloaded Piezo Actuator, 15 µm Travel range

P-820.20
Preloaded Piezo Actuator, 30 µm Travel range

P-820.30
Preloaded Piezo Actuator, 45 µm Travel range



P-820 dimensions in mm.
Length L: see table

Technical Data

Model	P-820.10	P-820.20	P-820.30	Units
Displacement at 0 to 100 V	15	30	45	µm ±20 %
*Resolution	0.15	0.3	0.45	nm
**Static large-signal stiffness	13	7	4	N/µm ±20 %
Push/pull force capacity	50 / 10	50 / 10	50 / 10	N
Max. torque limit (on tip)	0.08	0.08	0.08	Nm
Electrical capacitance	0.3	0.7	1.0	µF ±20 %
Dynamic operating current coefficient (DOCC)	3.0	3.0	3.0	µA / (Hz • µm)
Unloaded resonant frequency fo	22	15	12	kHz ±20 %
Operating temperature	-20 to +80	-20 to +80	-20 to +80	°C
Voltage connection	VL	VL	VL	
Mass	8	11	14	g ±5 %
Material: case, end pieces	N-S	N-S	N-S	
Length L	26	44	62	mm ±0.3

*The resolution of piezo actuators is not limited by stiction or friction. Value given is noise equivalent motion with E-503 amplifier (p. 2-146)
**Dynamic small-signal stiffness is ~ 30 % higher
Recommended amplifiers / controllers
One channel: E-610 controller / amplifier (p. 2-110)
Modular system E-500 (p. 2-142) with amplifier module E-503 (multi-channel) (p. 2-146)
Multi-channel: E-663 amplifier (p. 2-136)

P-855 Miniature Piezo Actuator

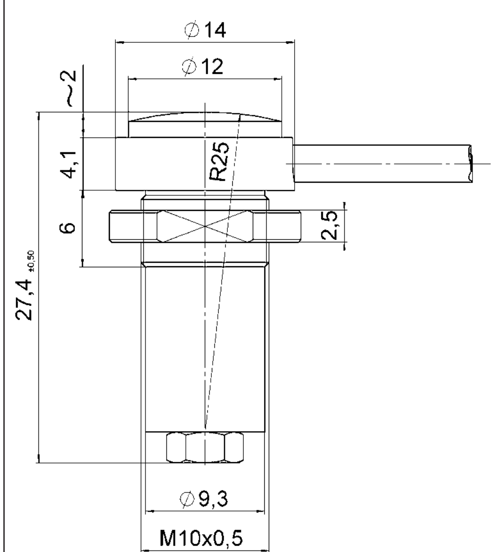
Micrometer-Mountable Open-Loop Piezo Translator

Linear Actuators & Motors
PiezoWalk® Motors / Actuators
PILine® Ultrasonic Motors
DC-Servo & Stepper Actuators
Piezo Actuators & Components
Guided / Preloaded Actuators
Unpackaged Stack Actuators
Patches / Benders / Tubes / Shear..
Nanopositioning / Piezoelectrics
Nanometrology
Micropositioning
Index

P-855.20 piezo translator

Ordering Information

P-855.20
Piezo Actuator for Micrometer Drive



P-855 dimensions in mm, cable length 1 m

- **Displacement 20 µm**
- **Mounts Inside Micrometer Tip**
- **Sub-msec Response**
- **Sub-nm Resolution**

P-855 piezo translators are high-resolution linear actuators specially designed for integration in micrometer tips. They fit the M-227 DC-Mike motorized actuators (see p. 1-42), the M-168 Stepper Mike (see p. 1-55) motorized actuators and the M-631 to M-633 manual micrometers (see p. 1-56).

The piezo translators consist of a monolithic PICMA® piezo ceramic integrated in a stainless steel housing.

P-855 actuators provide sub-millisecond response and sub-nanometer resolution.

Application Examples

- Laser tuning
- Static and dynamic positioning of small parts
- Fiber positioning

Superior Lifetime with Ceramic-Encapsulated Piezos

Highest possible reliability is assured by the use of award-winning PICMA® multilayer piezo actuators. PICMA® actuators are the only ceramic-encapsulated PZT actuators on the market, which makes them resistant to ambient humidity and leakage-current failures. They are thus far superior to conventional actuators in reliability and lifetime.

Accessories

Extension cables, adapters & connectors: see in "Accessories" in the "Piezo Drivers / Servo Controllers" (see p. 2-168 *ff*) section.

Notes

See the "Piezo Drivers / Servo Controllers" (see p. 2-99 *ff*) section for our comprehensive line of low-noise modular and OEM control electronics for computer and manual control.

Read details in Mounting and Handling Guidelines (p. 1-67).

Technical Data

Model	P-855.20	Tolerance
Open-loop travel @ -20 to 120 V	20 µm	±20 %
*Open-loop resolution	0.2 nm	
**Static large-signal stiffness	48 N/µm	±20 %
Push / pull force capacity	100 / 5 N	
Operating voltage range	-20 to 120 V	
Piezo ceramic type	PICMA®	
Electrical capacitance	1.5 µF	±20 %
Dynamic operating current coefficient (DOCC)	12.5 µA/(Hz • µm)	
Unloaded resonant frequency	18 kHz	±20 %
Operating temperature range	-40 bis +80 °C	
Voltage connection	VL	
Mass	28 g	±5 %
Recommended amplifier	E-610 (p. 2-110) E-500 System (p. 2-142)	

*Resolution of piezo actuators is not limited by friction or stiction. Noise equivalent motion with E-505 amplifier
**Dynamic small-signal stiffness ~50 % higher

P-840 · P-841 Preloaded Piezo Actuators

Optional with Integrated Position Sensor

P-840, P-841 piezo translators (DIP switch for size comparison)

- **Outstanding Lifetime Due to PICMA® Piezo Ceramic Stacks**
- **Travel Range to 90 µm**
- **Compact Case**
- **Pushing Forces to 1000 N**
- **Pulling Forces to 50 N**
- **Sub-Millisecond Response**
- **Sub-Nanometer Resolution**
- **Option: Ball Tip, Vacuum Version**

The P-840 and P-841 series translators are high-resolution linear actuators for static and dynamic applications. They provide sub-millisecond response and sub-nanometer resolution.

Application Examples

- Static and dynamic Precision positioning
- Disc-drive-testing
- Adaptronics
- Smart structures
- Active vibration control
- Switches
- Laser tuning
- Patch-Clamp
- Nanotechnology

Design

These translators are equipped with highly reliable multilayer piezo ceramic stacks protected by a non-magnetic stainless steel case with internal spring preload. The preload makes them ideal for dynamic applications and for tensile loads as well.

Ceramic Insulated Piezo Actuators Provide Long Lifetime

Highest possible reliability is assured by the use of award-winning PICMA® multilayer piezo actuators. PICMA® actuators are the only actuators on the market with ceramic-only insulation, which makes them resistant to ambient humidity and leakage-current failures. They are thus far superior to conventional actuators in reliability and lifetime.

Optimum UHV Compatibility - Minimum Outgassing

The lack of polymer insulation and the high Curie temperature make for optimal ultra-high-vacuum compatibility (no outgassing / high bakeout temperatures, up to 150 °C).

Mounting

Mounting is at the foot, with push/pull forces of less than 5 N, the actuator can be held by clamping the case. The optional ball tip (P-840.95) is intended to decouple torque and off-center forces from the piezo ceramic. The magnetic adapter P-176.20 is to be glued onto the top piece in order to provide magnetic coupling.

Read details in Mounting and Handling Guidelines (p. 1-67).

High Accuracy in Closed-Loop Operation

The standard model P-840 is designed for open-loop positioning. Version P-841 with integrated high-resolution strain gauge position sensors provides high precision for closed-loop operation (further details see p. 2-199).

Piezo Drivers, Controllers & Amplifiers

High-resolution amplifiers and servo-control electronics, both digital and analog, are described in the "Piezo Drivers / Servo Controllers" (see p. 2-99) section.

Ordering Information

P-840.10
Preloaded Piezo Actuator, 15 µm Travel range

P-840.20
Preloaded Piezo Actuator, 30 µm Travel range

P-840.30
Preloaded Piezo Actuator, 45 µm Travel range

P-840.40
Preloaded Piezo Actuator, 60 µm Travel range

P-840.60
Preloaded Piezo Actuator, 90 µm Travel range

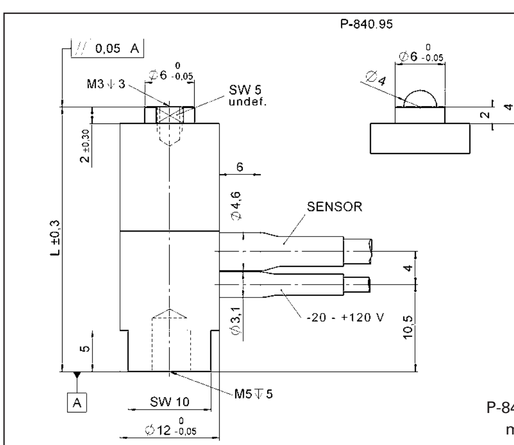
P-841.10
Preloaded Piezo Actuator with SGS-Sensor, 15 µm Travel range

P-841.20
Preloaded Piezo Actuator with SGS-Sensor, 30 µm Travel range

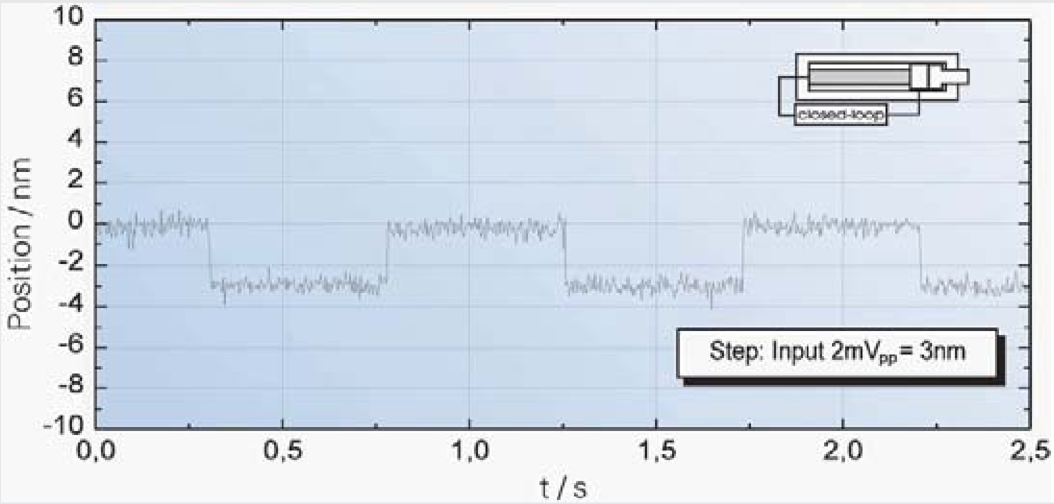
P-841.30
Preloaded Piezo Actuator with SGS-Sensor, 45 µm Travel range

P-841.40
Preloaded Piezo Actuator with SGS-Sensor, 60 µm Travel range

P-841.60
Preloaded Piezo Actuator with SGS-Sensor, 90 µm Travel range



P-840, P-841 dimensions in mm. Length L: See table



Response of a P-841.10 to a 3 nm peak-to-peak square wave control input signal, measured with servo-control bandwidth set to 240 Hz and 2 msec setting time.

Technical Data

Model	P-841.10 P-840.10	P-841.20 P-840.20	P-841.30 P-840.30	P-841.40 P-840.40	P-841.60 P-840.60	Units
Open-loop travel @ 0 to 100 V	15	30	45	60	90	µm ±20 %
Closed-loop travel	15 / –	30 / –	45 / –	60 / –	90 / –	µm
Integrated feedback sensor*	SGS / –	SGS / –	SGS / –	SGS / –	SGS / –	
Closed-loop / open-loop resolution**	0.3 / 0.15	0.6 / 0.3	0.9 / 0.45	1.2 / 0.6	1.8 / 0.9	nm
Static large-signal stiffness***	57	27	19	15	10	N/µm ±20 %
Pushing forces to 1000 N	1000	1000	1000	1000	1000	N
Pulling forces to 50 N	50	50	50	50	50	N
Max. torque limit (on tip)	0.35	0.35	0.35	0.35	0.35	Nm
Electrical capacitance	1.5	3.0	4.5	6.0	9.0	µF ±20 %
Dynamic operating current coefficient (DOCC)	12.5	12.5	12.5	12.5	12.5	µA / (Hz • µm)
Unloaded resonant frequency fo	18	14	10	8.5	6	kHz ±20 %
Operating temperature	-20 to +80	-20 to +80	-20 to +80	-20 to +80	-20 to +80	°C
Voltage connection	LEMO	LEMO	LEMO	LEMO	LEMO	
Sensor connection	LEMO	LEMO	LEMO	LEMO	LEMO	
Mass without cables	20	28	46	54	62	g ±5 %
Material: case, end pieces	N-S	N-S	N-S	N-S	N-S	
Length L	32	50	68	86	122	mm ±0.3

*Closed-loop models can attain linearity up to 0.15 % and are shipped with performance reports.
**Resolution of piezo actuators is not limited by stiction or friction. Value given is noise equivalent motion with E-503 amplifier. (p. 2-146)
***Dynamic small-signal stiffness is ~ 30 % higher.
Recommended amplifiers / controllers
Single-channel: E-610 servo-controller / amplifier (p. 2-110), E-625 servo-controller, bench-top (p. 2-114), E-621 controller module (p. 2-160)
Single channel: modular piezo controller system E-500 (p. 2-142) with amplifier module E-505 (high-power) (p. 2-147) and E-509 controller (p. 2-152) (optional)
Multi-channel: modular piezo controller system E-500 (p. 2-142) with amplifier module E-503 (three channels) (p. 2-146) or E-505 (1 per axis, high-power) (p. 2-147) and E-509 controller (p. 2-152) (optional)

P-842 – P-845 Preloaded Piezo Actuators

For High Loads and Force Generation, Optional with Integrated Position Sensors

P-844 piezo actuators
(battery for size comparison)

- **Outstanding Lifetime Due to PICMA® Piezo Ceramic Stacks**
- **Travel Range to 90 µm**
- **Pushing Forces to 3000 N**
- **Pulling Forces to 700 N**
- **Sub-Millisecond Response**
- **Sub-Nanometer Resolution**
- **Options: Vacuum Version, Water-Resistant Case**

The P-842 / P-843 and P-844 / P-845 series piezo translators are high-resolution linear actuators for static and dynamic applications. They provide sub-millisecond response and sub-nanometer resolution.

Design

These translators are equipped with PICMA® multilayer piezo ceramic stacks protected by a non-magnetic stainless steel case with internal spring preload. The preload makes them ideal for dynamic applications (such as precision machining, active damping etc.) and for tensile loads as well.

High Accuracy in Closed-Loop Operation

P-842 and P-844 are designed for open-loop positioning or use with external feedback. Versions P-843 and P-845 are equipped with integrated high-resolution SGS-position sensors for high precision in closed-loop operation (for further notes see the nanopositioning tutorial, see p. 2-199).

Ceramic Insulated Piezo Actuators Provide Long Lifetime

Highest possible reliability is assured by the use of award-winning PICMA® multilayer piezo actuators. PICMA® actuators are the only actuators on

Application Examples

- Static and dynamic precision positioning
- Disc-drive-testing
- Optics
- Metrology / interferometry
- Smart structures / adaptronics
- Precision mechanics / machining
- Active vibration control
- Switches
- Laser tuning

Technical Data and Product Order Numbers

Model	Open-loop travel for 0 to 100 V [µm] ±20 %	Closed-loop travel [µm]*	Integrated feedback sensor**	Closed-loop / Open-loop reslolution [nm]***	Static large-signal stiffness [N/µm] ±20 %	Push/pull force capacity [N]	Electrical capacitance [µF] ±20 %
P-842.10	15	–	–	- / 0.15	57	800 / 300	1.5
P-842.20	30	–	–	- / 0.3	27	800 / 300	3.0
P-842.30	45	–	–	- / 0.45	19	800 / 300	4.5
P-842.40	60	–	–	- / 0.6	15	800 / 300	6.0
P-842.60	90	–	–	- / 0.9	10	800 / 300	9.0
P-843.10	15	15	SGS	0.3 / 0.15	57	800 / 300	1.5
P-843.20	30	30	SGS	0.6 / 0.3	27	800 / 300	3.0
P-843.30	45	45	SGS	0.9 / 0.45	19	800 / 300	4.5
P-843.40	60	60	SGS	1.2 / 0.6	15	800 / 300	6.0
P-843.60	90	90	SGS	1.8 / 0.9	10	800 / 300	9.0
P-844.10	15	–	–	- / 0.15	225	3000 / 700	6.0
P-844.20	30	–	–	- / 0.3	107	3000 / 700	12.0
P-844.30	45	–	–	- / 0.45	75	3000 / 700	18.0
P-844.40	60	–	–	- / 0.6	57	3000 / 700	24.0
P-844.60	90	–	–	- / 0.9	38	3000 / 700	36.0
P-845.10	15	15	SGS	0.3 / 0.15	225	3000 / 700	6.0
P-845.20	30	30	SGS	0.6 / 0.3	107	3000 / 700	12.0
P-845.30	45	45	SGS	0.9 / 0.45	75	3000 / 700	18.0
P-845.40	60	60	SGS	1.2 / 0.6	57	3000 / 700	24.0
P-845.60	90	90	SGS	1.8 / 0.9	38	3000 / 700	36.0

the market with ceramic-only insulation, which makes them resistant to ambient humidity and leakage-current failures. They are thus far superior to conventional actuators in reliability and lifetime.

Optimum UHV Compatibility - Minimum Outgassing

The lack of polymer insulation and the high Curie temperature make for optimal ultra-high-vacuum compatibility (no outgassing / high bakeout temperatures, up to 150 °C).

Mounting

Mounting is at the foot, with push/pull forces of less than 100 N, the actuator can be held by clamping the case. The flexible tips P-176.50 / P-176.60 can be applied for protection of the ceramics from shearing forces (see p. 1-103 *ff*) Read details in Mounting and Handling Guidelines (p. 1-67).

Options

P-703.20
High vacuum options (see p. 1-102 *ff*)

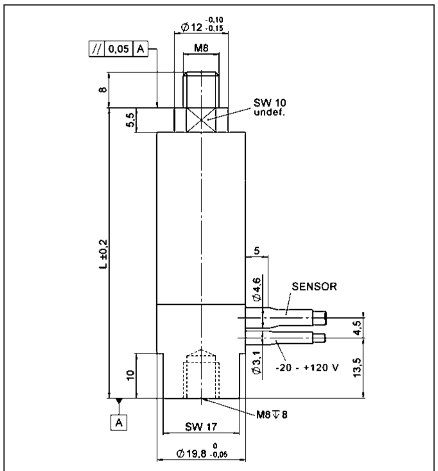
Accessories

P-176.50
Flexible tip for P-842 / P-843 (see p. 1-103 *ff*)
P-176.60
Flexible tip for P-844 / P-845 (see p. 1-103 *ff*)
For extensions, adapter cables and connectors, see "Accessories" in the Piezo Actuators & Components section (p. 1-104 *ff*).

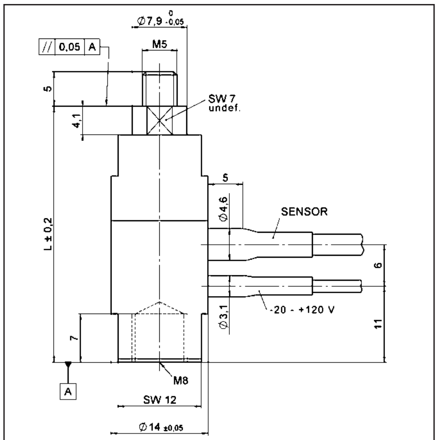
Piezo Drivers, Controllers & Amplifiers

High-resolution amplifiers and servo-control electronics, both digital and analog, are described in the "Piezo Drivers / Servo Controllers" section.

Dynamic operating current coefficient [µA / (Hz • µm)]	Resonant frequency (unloaded) [kHz] ±20 %	Mass without cable [g] ±5 %	Length L [mm]
12.5	18	31	37
12.5	14	42	55
12.5	10	53	73
12.5	8.5	64	91
12.5	6	86	127
12.5	18	31	37
12.5	14	42	55
12.5	10	53	73
12.5	8.5	64	91
12.5	6	86	127
50	16	84	47
50	12	108	65
50	9	132	83
500	7.5	156	0101
50	5.5	204	137
50	16	84	47
50	12	108	65
50	9	132	83
50	7.5	156	101
50	5.5	204	137



P-844, P-845 dimensions in mm. Length L: see table. Max. torque at top piece: 1 Nm



P-842, P-843 dimensions in mm. Length L: see table. Max. torque at top piece: 0.35 Nm

Voltage connection:
LEMO FFA.00.250. coaxial cable, RG 178, PTFE.

Sensor connector: LEMO FFA.0S.304 connector; 1 m coaxial cable with PUR-insulation.

Temperature range: -40 to 80 °C; Case / end pieces: non-magnetic steel.

*Closed-loop models can attain linearity up to 0.15 % and are shipped with performance reports.
**Resolution of piezo actuators is not limited by stiction or friction. Noise equivalent motion with E-503 amplifier (see p. 2-146).
***Dynamic small-signal stiffness is ~ 30 % higher.
Recommended amplifiers / controllers
Single-channel: E-610 servo-controller / amplifier (p. 2-110), E-625 servo-controller, bench-top(p. 2-114), E-621 controller module (p. 2-160)
Single channel: modular piezo controller system E-500 (p. 2-142) with amplifier module E-505 (high-power) (p. 2-147) and E-509 controller (p. 2-152) (optional)
Multi-channel: modular piezo controller system E-500 (p. 2-142) with amplifier module E-503 (three channels) (p. 2-146) or E-505 (1 per axis, high-power, see p. 2-147) and E-509 controller (p. 2-152) (optional)

P-212, P-216 PICA™ Power Piezo Stack Actuators

Preloaded Piezo Actuators (HVPZT) w/ Sensor Option

From left:
P-212.1S and .8S, P-216.9S,
.4S and .1S piezo actuators
(CD for size comparison)

Ordering Information

P-21 [ ] . [ ] [ ] [ ]

- **2** Preloaded Piezo Actuator, 1000 V, 2000 N
- **6** Preloaded Piezo Actuator, 1000 V, 4500 N
- **0** w/o Sensor
- **S** w/SGS Position Sensor
- **T** modified for Low Temperature
- **V** modified for High Temperature/Vacuum
- **1** Travel Range 15 µm
- **2** Travel Range 30 µm
- **4** Travel Range 60 µm
- **8** Travel Range 120 µm
- **9** Travel Range 180 µm (P-216 only)

Please read "Options and Accessories" (page 1-102 *ff*) for further information.
Extensions cables, adapters & connectors: see in "Accessories" in the "Piezo Drivers / Servo Controllers" (see p. 2-168 *ff*) section.

Option:

P-177.50
Dynamic applications (with E-481): temperature sensor and protective air for PICA™ HVPZT

- **Travel Range to 180 µm**
- **Pushing Forces to 4500 N**
- **Pulling Forces to 500 N**
- **Sub-millisecond Response**
- **Sub-nanometer Resolution**
- **Options: Vacuum, High- and Low-Temperature**

The P-212 and P-216 series are high-resolution linear piezo actuators (translators) for static and dynamic applications. They provide sub-millisecond response and sub-nanometer resolution.

Application Examples

- Optics
- Metrology / interferometry
- Adaptronics
- Precision engineering / micromechanics
- Adaptive mechanics
- Active vibration damping
- Switches
- Laser tuning
- Force generation / materials testing
- Nanotechnology

These actuators have the friction-free, preloaded PICA™ Power actuators inside. The preload makes them ideal for dynamic applications like precision machining or active damping.

High Displacement with Ultra-High Reliability

PICA™ Power actuators are optimized for high-temperature working conditions and high-duty-cycle dynamic applications.

All PICA™ piezo ceramics are specifically designed for high-duty-cycle applications. With PI's extensive applications knowledge, gained over several decades, performance does not come at the price of reliability. All materials used are specifically matched for robustness and lifetime. Endurance tests on PICA™ actuators prove consistent performance, even after billions (1,000,000,000) of cycles.

Open- and Closed-Loop Models for Optimum Dynamics and Linearity

The standard models are ideal for open loop positioning applications. In this mode the actuator displacement is roughly proportional to the applied voltage.

Open-loop operation is ideal for applications where fast response and very high resolution with maximum bandwidth are essential. Here, commanding and reading the target position in absolute values is either not important or carried out by external position sensors (see p. 2-104).

For highest positioning accuracy and repeatability, select the factory installed closed-loop option with integrated ultra-high-resolution strain gauge position sensors and operate with PI servo-control electronics. For more information, read the tutorial "Piezoelectrics in Positioning" (see p. 2-169 *ff*).

Mechanical Mounting

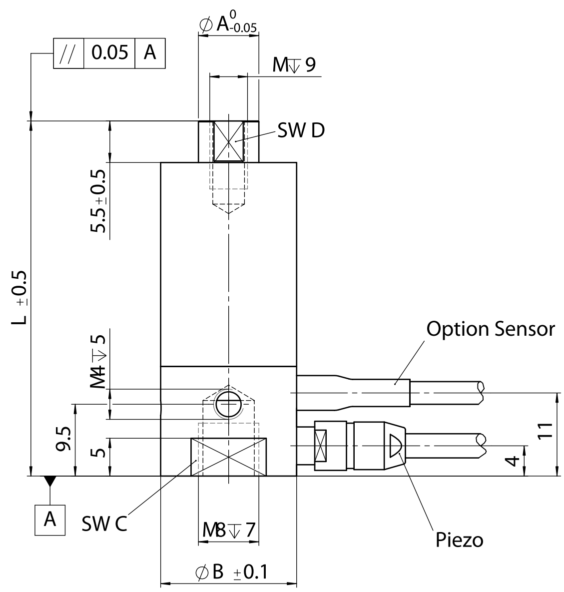
Mounting is at the foot, with push/pull forces of less than 5 N, the actuator can be held by clamping the case. The optional ball tip is intended to decouple torque and off-center forces from the translator. Read details in Mounting and Handling Guidelines (p. 1-67).

High Flexibility with PI Amplifiers, Drivers & Controllers

PI offers a wide range of control electronics for piezo actuators from low-power drivers to the high-performance amplifier / controller E-481.

For closed-loop operation PI offers a wide variety of analog and digital controllers. The E-500 modular system can be easily upgraded from an amplifier to a servo controller, including different interface / display modules.

High-resolution amplifiers and servo-control electronics, both digital and analog, see selection guide in the „Piezo Drivers / Servo Controllers" section (see p. 2-97 *ff*).



	L [mm]	ØA [mm]	ØB [mm]	C	D	M
P-212.1x	47	8	18	15	7	5
P-212.2x	60	8	18	15	7	5
P-212.4x	86	8	18	15	7	5
P-212.8x	139	8	18	15	7	5
P-216.1x	47	10	25	22	8	6
P-216.2x	60	10	25	22	8	6
P-216.4x	86	10	25	22	8	6
P-216.8x	139	10	25	22	8	6
P-216.9x	191	10	25	22	8	6

P-212 and P-216, dimensions in mm.
End pieces and case of stainless steel. Sensor connection: LEMO FFA.0S.304; 1 m coaxial cable with PUR insulation.
Input voltage connection: LEMO FGG.0B.701.CJA.1173, PUR cable, 2-conductor, shielded

Technical Data

	P-212.10	P-212.20	P-212.40	P-212.80	P-216.10	P-216.20	P-216.40	P-216.80	P-216.90	Unit	Tolerance
Operating voltage	0 to1000	0 to1000	0 to 1000	0 to 1000	0 to 1000	0 to 1000	0 to 1000	0 to 1000	0 to 1000	V	
Motion and positioning											
Closed-loop travel*	15	30	60	120	15	30	60	120	180	µm	
Closed-loop resolution*/**	0.3	0.6	1.2	2.4	0.3	0.6	1.2	2.4	3.6	nm	typ.
Open-open resolution**	0.15	0.3	0.6	1.2	0.15	0.3	0.6	1.2	1.8	nm	typ.
Linearity*	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	%	typ.
Mechanical properties											
Static large-signal stiffness***	90	60	34	18	210	140	80	50	32	N/µm	±20%
Unloaded resonant frequency	17	12	7	4.5	17	12	7	4.5	3	kHz	±20%
Push/pull force capacity	2000/300	2000/300	2000/300	2000/300	4500/500	4500/500	4500/500	4500/500	4500/500	N	Max.
Shear force limit	15	10	10	10	60	36	23	23	23	N	
Torque limit (on tip)	0.5	0.5	0.5	0.5	1	1	1	1	1	Nm	
Drive properties											
Electrical capacitance	47	90	180	370	130	250	500	1000	1500	nF	±20%
Dynamic operating current coefficient	5	5	5	5	13	13	13	13	13	µA/(Hz • µm)	±20%
Miscellaneous											
Mass (with cable)	110	120	150	210	170	200	250	370	480	g	±5%

* Requires SGS sensor. SGS versions are shipped with performance reports
** Measured with an Interferometer. The resolution of piezo actuators is not limited by stiction or friction
*** Dynamic small-signal stiffness is ~50% higher
Piezo ceramic type: PICA™ Power
Operating temperature range: -40 to +80 °C
Recommended controller/driver see p. 2-100 *ff*
For maximum lifetime, voltages in excess of 750 V should be applied only for short durations
See Notes (Technical Data) for further information (p. 1-106 *ff*)

P-225, P-235 PICA™ Power Piezo Stack Actuators

Preloaded High-Load Piezo Actuators (HVPZT) w/ Sensor Option

High-load piezo actuators P-235.1S, .4S and .9S, P-225.8S and .1S (from left) with CD for size comparison

Ordering Information

P-2□5.□□□

- **2** Preloaded High-Load Piezo Actuator, 1000 V, 12500 N
- **3** Preloaded High-Load Piezo Actuator, 1000 V, 30000 N
- **0** w/o Sensor
- **S** w/SGS Position Sensor
- **T** modified for Low Temperature
- **V** modified for High Temperature/Vacuum
- **1** Travel Range 15 µm
- **2** Travel Range 30 µm
- **4** Travel Range 60 µm
- **8** Travel Range 120 µm
- **9** Travel Range 180 µm (P-235 only)

Please read "Options and Accessories" (page 1-102 *ff*) for further information.
Extensions cables, adapters & connectors: "Accessories" in the "Piezo Drivers / Servo Controllers" (see p. 2-168 *ff*) section.

Option:

P-177.50
Dynamic applications (with E-481): temperature sensor and protective air for PICA™ HVPZT

P-706.00
Water-resistant case

- **Extremely High Stiffness**
- **Pushing Forces to 30,000 N**
- **Pulling Forces to 3500 N**
- **Travel Ranges to 180 µm**
- **Options: Versions for Vacuum, High- and Low-Temperatures and with Water-Resistant Case**

P-225 and P-235 are preloaded, high-load piezo actuators (translators) for static and dynamic applications. They provide sub-millisecond re-sponse and sub-nanometer resolution.

These ultra-high-force linear actuators consist of PICA™ Power piezoelectric ceramic-stacks encapsulated in a stainless steel case with stainless steel end pieces and a frictionless internal spring preload. The high load capacity and preload makes them ideal for machining applications and active vibration cancellation.

Aplication Examples

- Precision engineering / micromechanics
- Adaptive mechanics
- Active vibration damping
- Adaptronics
- Static and dynamic precision positioning
- Force generation / materials testing

High Displacement with Ultra-High Reliability

PICA™ Power actuators are optimized for high-temperature working conditions and high-duty-cycle dynamic applications.

All PICA™ piezo ceramics are specifically designed for high-dutycycle applications. With PI's extensive applications knowledge, gained over several decades, performance does not come at the price of reliability. All materials used are specifically matched for robustness and lifetime. Endurance tests on PICA™ actuators prove consistent performance, even after billions (1,000,000,000) of cycles.

Open- and Closed-Loop Models for Optimum Dynamics and Linearity

The standard models are ideal for open loop positioning applications. In this mode the actuator displacement is roughly proportional to the applied voltage.

Open-loop operation is ideal for applications where the fastest response and the highest bandwidth are essential. Here, commanding and reading the target position in absolute values is either not important or carried out by an external feedback loop.

For highest positioning accuracy and repeatability, select the factory installed closed-loop option with integrated ultra-high- resolution strain gauge position sensors and operate with PI servo-control electronics. For more information, read the tutorial "Piezoelectrics in Positioning" (see p. 2-169 *ff*).

High Flexibility with PI Amplifiers, Drivers & Controllers

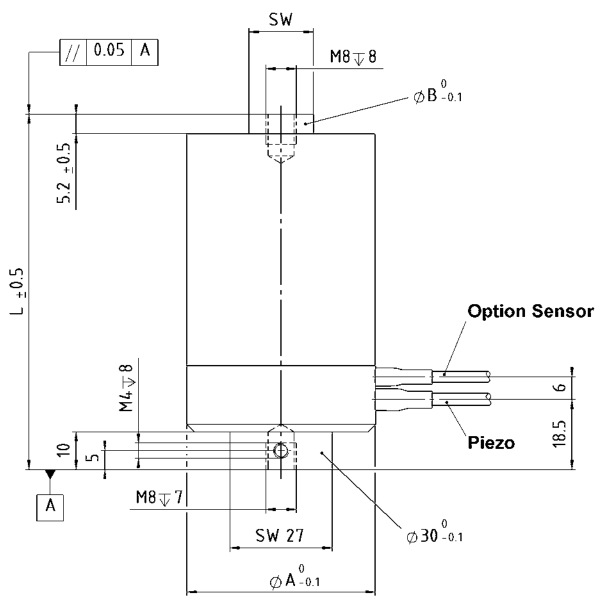
PI offers a wide range of control electronics for piezo actuators from economical, low-power piezo drivers to the E-481 high-performance amplifier / controller providing 2000 W of dynamic power.

For closed-loop operation a wide variety of analog and digital controllers is available. The E-500 modular system can be easily upgraded from an amplifier to a servo controller, including different interface / display modules.

Read details in Mounting and Handling Guidelines (p. 1-67).

High-resolution amplifiers and servo-control electronics, both digital and analog, see selection guide in the "Piezo Drivers / Servo Controllers" section (see p. 2-99 *ff*).

Linear Actuators & Motors
PiezoWalk® Motors / Actuators
PILine® Ultrasonic Motors
DC-Servo & Stepper Actuators
Piezo Actuators & Components
Guided / Preloaded Actuators
Unpackaged Stack Actuators
Patches/Benders/Tubes/Shear..
Nanopositioning / Piezoelectrics
Nanometrology
Micropositioning
Index



	L [mm]	ØA [mm]	ØB [mm]	SW
P-225.1x	55	39.8	16	13
P-225.2x	68	39.8	16	13
P-225.4x	94	39.8	16	13
P-225.8x	147	39.8	16	13
P-235.1x	55	49.8	20	17
P-235.2x	68	49.8	20	17
P-235.4x	94	49.8	20	17
P-235.8x	147	49.8	20	17
P-235.9x	199	49.8	20	17

P-225 and P-235, dimensions in mm. End pieces and case of stainless steel. Sensor connection: LEMO FFA.0S.304; 1 m coaxial cable with PUR insulation. Voltage connection: LEMO FGG.0B.701.CJA.1173, 1 m cable with PUR insultaion, 2-conductor, shielded

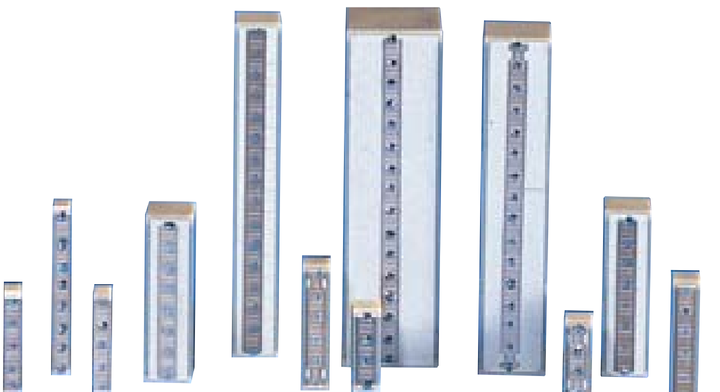
Technical Data

Model	P-225.10	P-225.20	P-225.40	P-225.80	P-235.10	P-235.20	P-235.40	P-235.80	P-235.90	Unit	Tolerance
Operating voltage	0 to 1000	0 to 1000	0 to 1000	0 to 1000	0 to 1000	0 to 1000	0 to 1000	0 to 1000	0 to 1000	V	
Motion and positioning											
Closed-loop travel*	15	30	60	120	15	30	60	120	180	µm	
Closed-loop resolution*/**	0.3	0.6	1.2	2.4	0.3	0.6	1.2	2.4	3.6	nm	typ.
Open-loop resolution**	0.15	0.3	0.6	1.2	0.15	0.3	0.6	1.2	1.8	nm	typ.
Linearity*	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	%	typ.
Mechanical properies											
Static large-signal stiffness***	480	330	200	110	860	600	380	210	150	N/µm	±20
Unloaded resonant frequency	14	10	7	4	14	10	7	3,9	2,8	kHz	±20 %
Push/pull force capacity	12500 / 2000	12500 / 2000	12500 / 2000	12500 / 2000	30000 / 3500	30000 / 3500	30000 / 3500	30000 / 3500	30000 / 3500	N	Max.
Shear force limit	255	152	84	73	707	420	232	147	147	N	
Torque limit (on tip)	1,5	1,5	1,5	1,5	2	2	2	2	2	Nm	
Drive properties											
El. capacitance	320	630	1300	2600	550	1100	2400	5100	7800	nF	±20 %
Dynamic operating current coefficient	33	33	33	33	65	65	65	65	65	µA/(Hz • µm)	±20 %
Miscellaneous											
Mass (with cable)	410	470	610	900	580	690	940	1400	1900	g	±5 %

*Requires SGS sensor. SGS versions are shipped with performance reports
**Measured with an interferometer. The resolution of piezo actuators is not limited by stiction or friction
***Dynamic small-signal stiffness is ~50 % higher
Piezo ceramic type: PICA™ Power
Operating temperature range: -40 to +80 °C
Recommended controller/driver see p. 2-100 *ff*
For maximum lifetime, voltages in excess of 750 V should be applied only for short durations
See Notes (Technical Data) for further information (see p. 1-106 *ff*)

P-882 · P-888 PICMA® Multilayer Piezo Stack Actuators

Ceramic-Insulated High-Power Actuators



PICMA® piezo actuators are available with cross-sections of 2 x 3, 3 x 3, 5 x 5, 7 x 7 and 10 x 10 mm²

- **Superior Lifetime Even Under Extreme Conditions**
- **Very Large Operating Temperature Range**
- **High Humidity Resistance**
- **Excellent Temperature Stability**
- **High Stiffness**
- **Peak Current up to 20 A**
- **UHV Compatible to 10^{-9} hPa**
- **Sub-Millisecond Response / Sub-Nanometer Resolution**
- **Ideal for Dynamic Operation**

PICMA® (PI Ceramic Monolithic Multilayer Actuator) piezo stack actuators are characterized by their high performance and reliability, even in extremely harsh environments. They are superior to conventional multilayer actuators in industrial applications and high-endurance situations, where they show substantially longer lifetimes both in static and dynamic operation.

Application Examples

- Precision mechanics / -machining
- High-speed switching
- Active and adaptive Optics
- Active vibration damping
- Pneumatic & hydraulic valves
- Metrology / Interferometry
- Life science, Biotechnology
- Nanotechnology

New Production Process, Optimized Piezo Ceramics

PICMA® piezo actuators are made from a ceramic material in which the piezoceramic properties such as stiffness, capacitance, displacement, temperature stability and lifetime are optimally combined. Thus the actuators accomplish sub-nanometer resolution in positioning and sub-millisecond response!

Increased Lifetime Through Humidity Resistance

The monolithic ceramic-encapsulated design provides better humidity protection than polymer-film insulation. Diffusion of water molecules into the insulation layer is greatly reduced by the use of cofired, outer ceramic encapsulation. Due to their high resonant frequency the actuators are suitable for highly dynamic applications with small loads; depending on the load an external preload for dynamic applications is recommended. The high Curie temperature of 320 °C gives PICMA® actuators a usable temperature range extending up to 150 °C, far beyond 80 °C as is common for conventional multilayer actuators. With conventional multilayer actuators, heat generation - which is proportional to operating frequency - either limits the operating frequency or duty cycle in dynamic operation, or makes ungainly cooling provisions necessary. At the low end, operation down to a few Kelvin is possible (with reduction in performance specifications).

Optimum UHV Compatibility - Minimum Outgassing

The lack of polymer insulation and the high Curie temperature make for optimal ultra-high-vacuum compatibility (high bakeout temperatures, up to 150 °C).

PICMA® actuator with optional 0.1 m PTFE insulated wire leads and optional rounded top piece for decoupling lateral forces

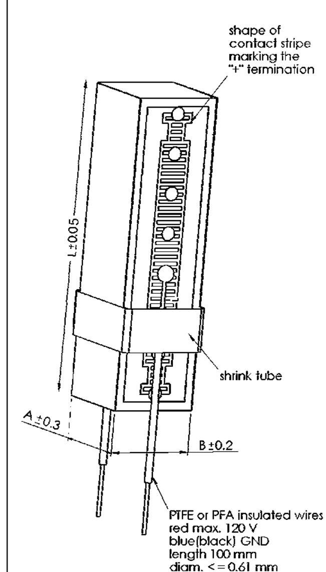
Ideal for Closed-Loop Operation

The ceramic surface of the actuators is extremely well suited for use with resistive or optical fiber strain gauge sensors. Such sensors can be easily applied to the actuator surface and exhibit significantly higher stability and linearity than with conventional polymer-insulated actuators.

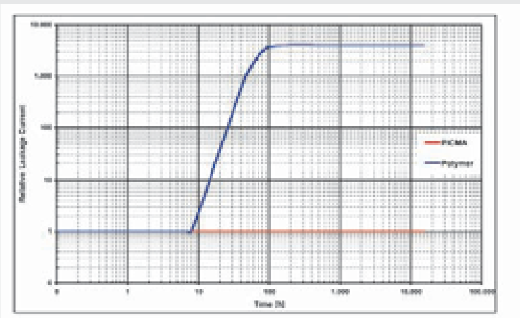
Piezo Drivers, Controllers & High-Voltage Amplifiers

High-resolution amplifiers and servo-control electronics, both digital and analog, are described in the "Piezo Drivers / Servo Controllers" section.

Read more on PICMA® reliability on page 2-12 *ff.*

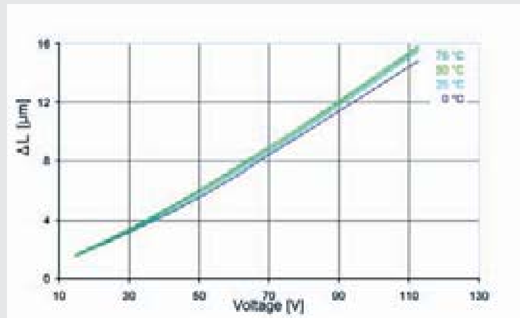


PICMA® actuators, dimensions in mm



PICMA® piezo actuators (bottom curve) compared with conventional multilayer actuators with polymer insulation (top curve). PICMA® actuators are not affected by the high-humidity test conditions. Conventional piezo actuators exhibit increased leakage current after only a few hours. Leakage current is an indicator quality and expected lifetime.

Test conditions: U = 100 VDC, T = 25 °C, Relative Humidity = 70 %



The displacement of PICMA® actuators exhibits very low temperature dependence. This, in combination with their low heat generation, makes PICMA® actuators optimal for dynamic operation

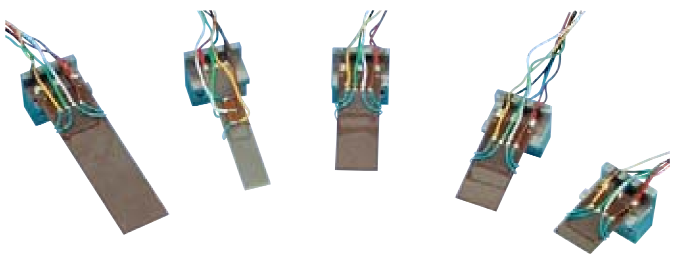
Technical Data / Product Order Numbers

Order number*	Dimensions A x B x L [mm]	Nominal displacement [µm @ 100 V]	Max. displacement [µm @ 120 V]	Blocking force [N @ 120 V]	Stiffness [N/µm]	Electrical capacitance [µF] ±20 %	Resonant frequency [kHz] ±20 %
P-882.10	2 x 3 x 9	6.5 ±20 %	8 ±20 %	190	24	0.15	135
P-882.30	2 x 3 x 13.5	11 ±20 %	13 ±20 %	210	16	0.22	90
P-882.50	2 x 3 x 18	15 ±10 %	18 ±10 %	210	12	0.31	70
P-883.10	3 x 3 x 9	6.5 ±20 %	8 ±20 %	290	36	0.21	135
P-883.30	3 x 3 x 13.5	11 ±20 %	13 ±20 %	310	24	0.35	90
P-883.50	3 x 3 x 18	15 ±10 %	18 ±10 %	310	18	0.48	70
P-885.10	5 x 5 x 9	6.5 ±20 %	8 ±20 %	800	100	0.6	135
P-885.30	5 x 5 x 13.5	11 ±20 %	13 ±20 %	870	67	1.1	90
P-885.50	5 x 5 x 18	15 ±10 %	18 ±10 %	900	50	1.5	70
P-885.90	5 x 5 x 36	32 ±10 %	38 ±10 %	950	25	3.1	40
P-887.30	7 x 7 x 13.5	11 ±20 %	13 ±20 %	1700	130	2.2	90
P-887.50	7 x 7 x 18	15 ±10 %	18 ±10 %	1750	100	3.1	70
P-887.90	7 x 7 x 36	32 ±10 %	38 ±10 %	1850	50	6.4	40
P-888.30	10 x 10 x 13.5	11 ±20 %	13 ±20 %	3500	267	4.3	90
P-888.50	10 x 10 x 18	15 ±10 %	18 ±10 %	3600	200	6.0	70
P-888.90	10 x 10 x 36	32 ±10 %	38 ±10 %	3800	100	13.0	40

Standard piezo ceramic type: 252
*For optional PTFE insulated wires, pigtail length 100 mm, change order number extension to .x1 (e. g. P-882.11).
Recommended preload for dynamic operation: 15 MPa
Maximum preload for constant force: 30 MPa
Resonant frequency at 1 V_{pp}, unloaded, free at both sides. The value is halved for unilateral clamping
Capacitance at 1 V_{pp}, 1 kHz
Operating voltage: -20 to +120 V
Operating temperature range: -40 to +150 °C
Standard Mechanical Interfaces: Ceramics
Standard Electrical Interfaces: Solderable pads
Available Options: strain gauge sensors, special mechanical interfaces, etc.
Other specifications on request.

P-871 PICMA® Piezo Bender Actuators

Low-Voltage Multilayer Piezo Bender Actuators with Position Sensor



P-871.140, P-871.128, P-871.122 and P-871.112 closed-loop bender actuators (from left to right)

- **Closed-Loop Operation for Superior Accuracy**
- **Nanometer-Resolution**
- **Displacement to 1.6 mm**
- **Ceramic Encapsulation for Extended Lifetime**
- **Ideal for Scanning Applications**
- **Vacuum-Compatible Versions**
- **Low Operating Voltage**
- **Mounting Hardware Included**
- **Special OEM- and Bench-Top Amplifiers Available**

P-871 transducers are unique closed-loop piezo benders based on the open-loop PL 122 to PL 140 PICMA® -series multilayer actuators p. 1-94. Equipped with high-resolution position feedback sensors they provide better linearity, accuracy and repeatability than other piezo benders on the market. P-871 bender actuators achieve longer positioning ranges than typical piezo stack actuators, up to 1.6 mm, while still providing fast response times in the millisecond range.

Application Examples

- Wire bonders
- Pneumatic valves
- Fiber optic positioning & switches
- (Laser)- Beam steering
- Micropositioning
- Acceleration sensors
- Nanotechnology

Design

These multilayer piezoelectric components are manufactured from ceramic layers of only about 50 µm thickness. They feature internal silver-palladium electrodes and ceramic insulation applied in a cofiring process. Due to the thin layers the operating voltage is significantly lower than for classical parallel bimorph bender elements. For ease of installation, the units come complete with the mounting hardware, cables and connectors.

Closed-Loop Position Control for Higher Accuracy

P-871s are ideal devices for scanning, positioning and beam deflection applications and provide much better accuracy, stability and repeatability than conventional open-loop actuators. The special bender design allows the direct application of a strain gauge sensor to the surface without the need for a polymer insulation layer in between. The advantages are faster response, reduced phase lag and precise position control with non-linearity of <0.5 %. The settling time for a small-signal step (up to 1 % nominal travel) to an accuracy of better than 1 % is between 10 ms (P-871.112) and 30 ms (P-871.140).

Ceramic Insulated Piezo Actuators Provide Long Lifetime

Highest possible reliability is assured by the use of award-winning PICMA® multilayer piezo actuators. PICMA® actuators are the only actuators on the market with ceramic-only insulation, which makes them resistant to ambient humidity and leakage-current failures. They are thus far superior to conventional actuators in reliability and lifetime.

Optimum UHV Compatibility - Minimum Outgassing

The lack of polymer insulation and the high Curie temperature make for optimal ultra-high-vacuum compatibility (no outgassing / high bakeout temperatures, up to 150 °C).

Amplifiers, Drivers & Controllers

PI offers a wide range of standard amplifiers and controllers for piezo actuators. The E-651.1S and E-651.2S desktop controllers and the OEM board E-614.2BS (see p. 2-121) are specifically designed to operate P-871 bender actuators.

Ordering Information

P-871.112
PICMA® Multilayer Piezo Bender Actuator, 160 µm, 9.6 mm Width, SGS-Sensor

P-871.122
PICMA® Multilayer Piezo Bender Actuator, 400 µm, 9.6 mm Width, SGS-Sensor

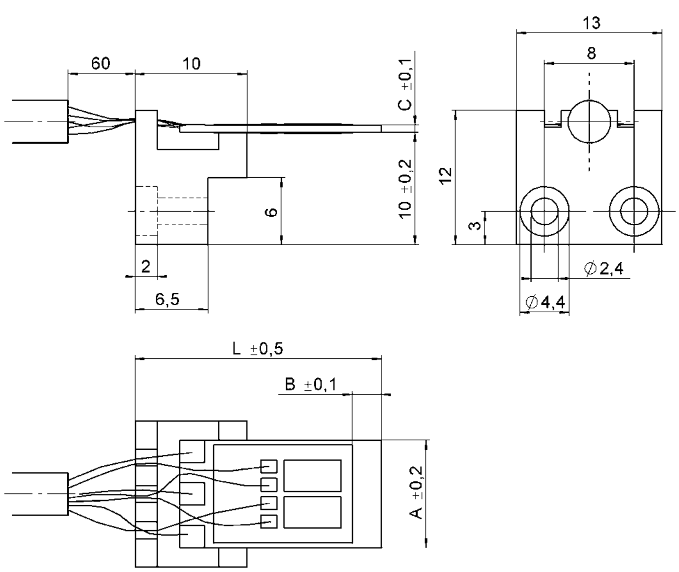
P-871.127
PICMA® Multilayer Piezo Bender Actuator, 720 µm, 9.6 mm Width, SGS-Sensor

P-871.128
PICMA® Multilayer Piezo Bender Actuator, 720 µm, 6.3 mm Width, SGS-Sensor

P-871.140
PICMA® Multilayer Piezo Bender Actuator, 1600 µm, 11 mm Width, SGS-Sensor

Ask about custom designs

E-651 2-channel and 1-channel controllers with P-871 bender actuators



	L	A	B	C
P-871.112	22	9,6	2,6	0,65
P-871.122	29	9,6	9,6	0,65
P-871.127	35	9,6	15,6	0,65
P-871.128	40	6,25	17	0,75
P-871.140	49	11	29,1	0,60

P-871 dimensions in mm, cable length >1 m

Technical Data

Model	P-871.112*	P-871.122	P-871.127	P-871.128*	P-871.140	Units
Closed-loop travel	±80	±200	±360	±360	±800	µm
Integrated feedback sensor	SGS	SGS	SGS	SGS	SGS	
Closed-loop linearity	0.5	0.5	0.5	0.5	0.5	%
Static large-signal stiffness	0.02	0.01	0.003	0.002	0.0007	N/µm
Blocking force	±2.0	±1.1	±1.0	±0.5	±0.5	N ±20 %
Electrical capacitance	2 x 1.1	2 x 2.4	2 x 3.4	2 x 1.2	2 x 4.0	µF ±20 %
Unloaded resonant frequency	2540	1010	560	340	195	Hz ±20 %
Resonant frequency @ 6.5 g load	480	220	145	100	60	Hz ±20 %

Operating voltage: 0 to 60 V (±30 V)
Recommended driver / controller: E-651 bench top / E-614 PCI card (p. 2-123)
Connector: 1 LEMO connector for both sensor and voltage supply
Operating temperature range: -20 to +85 °C; ** to +150 °C
Resonant frequency at 1 Vpp, capacitance at 1 Vpp, 1 kHz
All specifications depend on the real clamping conditions and on the applied mechanical load.
Other specifications on request.

P-007 – P-056 PICA™ Stack Actuator

Piezo actuator for highly dynamic applications

Variety of standard and custom PICA™ Stack piezo actuators

- **High Load Capacity to 100 kN**
- **High Force Generation to 80 kN**
- **Large Cross Sections to 56 mm Diameter**
- **A selection of Variety of Shapes**
- **Extreme Reliability >10⁹ Cycles**
- **Sub-Millisecond Response, Sub-Nanometer Resolution**
- **Vacuum-Compatible Versions**

PICA™ Stack piezo ceramic actuators are offered in a large variety of standard shapes and sizes with additional custom designs to suit any application.

Ultra-High Reliability, High Displacement, Low Power Requirements

PICA™ piezo actuators are specifically designed for high-duty-cycle applications. With our extensive applications knowledge, gained over several decades, we know how to build performance that does not come at the price of reliability. All materials used are specifically matched for robustness and lifetime. Endurance tests on PICA™ actuators prove consistent performance, even after billions (1,000,000,000) of cycles. The combination of high displacement and low electrical capacitance provides for excellent dynamic behavior with reduced driving power requirements.

Application Examples

- Nanopositioning
- High-load positioning
- Precision mechanics / -machining
- Semiconductor technology / test systems
- Laser tuning
- Switches
- Smart structures (Adaptronics)

Standard actuators are covered with heat-shrink tube, shown here is the model P-025.40

Flexibility / Short Leadtimes

All manufacturing processes at PI Ceramic are set up for flexibility. Should our standard actuators not fit your application, let us provide you with a custom design. Our engineers will work with you to find the optimum solution at a very attractive price, even for small quantities. Some of our custom capabilities are listed below:

- Custom Materials
- Custom Voltage Ranges
- Custom Geometries (Circular, Rectangular, Triangular, Layer Thickness ...)
- Custom Load / Force Ranges
- Custom Flat or Spherical Endplates (Alumina, Glass, Sapphire, ...)
- Extra-Tight Length Tolerances
- Integrated Piezoelectric Sensor Discs
- Special High / Low Temperature Versions
- Vacuum Compatible Versions

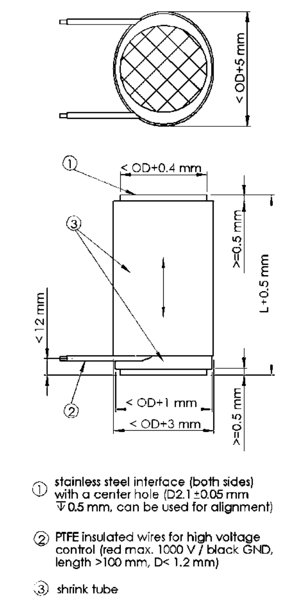
Because all piezoelectric materials used in PICA™ actuators are manufactured at PI Ceramic, leadtimes are short and quality is outstanding. All standard and custom actuators are delivered with performance test sheets.

Piezo Drivers, Controllers & High-Voltage Amplifiers

High-resolution amplifiers and servo-control electronics, both digital and analog, are described in the “Piezo Drivers / Servo Controllers” (see p. 2-99 *ff*) section.

PICA™ Stack piezo actuators are delivered with metal end-caps for improved robustness and reliability.
For preloaded versions with steel casings (see p. 1-78, p. 1-80).

Custom PICA™-Stack actuator with 350 µm displacement

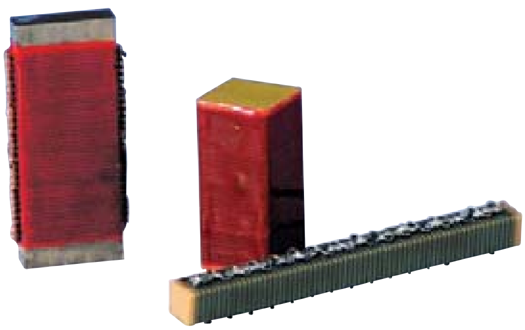


① stainless steel interface (both sides) with a center hole (D2.1 ±0.05 mm ⊽ 0.5 mm, can be used for alignment)

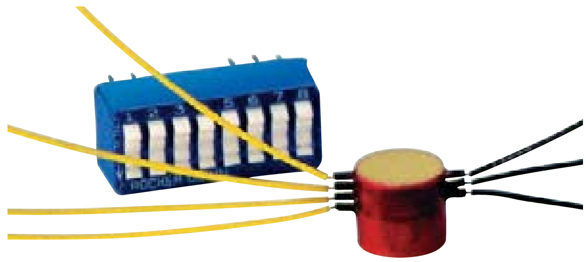
② PTFE insulated wires for high voltage control (red max. 1000 V / black GND, length >100 mm, D< 1.2 mm)

③ shrink tube

PICA™-Stack dimensions, see technical data table for further information



Custom PICA™-Stack actuators with rectangular cross-sections.



Custom PICA™-Stack actuator, each layer wired individually.

Technical Data / Product Order Numbers

Order number	Displacement [µm] -10/+20%	Diameter D [mm]	Length L [mm] ±0.5	Blocking force [N]	Stiffness [N/µm]	Capacitance [nF] ±20%	Resonant frequency [kHz]
P-007.00	5	7	8	650	130	11	126
P-007.10	15	7	17	850	59	33	59
P-007.20	30	7	29	1000	35	64	36
P-007.40	60	7	54	1150	19	130	20
P-010.00	5	10	8	1400	270	21	126
P-010.10	15	10	17	1800	120	64	59
P-010.20	30	10	30	2100	71	130	35
P-010.40	60	10	56	2200	38	260	20
P-010.80	120	10	107	2400	20	510	10
P-016.10	15	16	17	4600	320	180	59
P-016.20	30	16	29	5500	190	340	36
P-016.40	60	16	54	6000	100	680	20
P-016.80	120	16	101	6500	54	1300	11
P-016.90	180	16	150	6500	36	2000	7
P-025.10	15	25	18	11000	740	400	56
P-025.20	30	25	30	13000	440	820	35
P-025.40	60	25	53	15000	250	1700	21
P-025.80	120	25	101	16000	130	3400	11
P-025.90	180	25	149	16000	89	5100	7
P-025.150	250	25	204	16000	65	7100	5
P-025.200	300	25	244	16000	54	8500	5
P-035.10	15	35	20	20000	1300	700	51
P-035.20	30	35	32	24000	810	1600	33
P-035.40	60	35	57	28000	460	3300	19
P-035.80	120	35	104	30000	250	6700	11
P-035.90	180	35	153	31000	170	10000	7
P-045.20	30	45	33	39000	1300	2800	32
P-045.40	60	45	58	44000	740	5700	19
P-045.80	120	45	105	49000	410	11000	10
P-045.90	180	45	154	50000	280	17000	7
P-050.20	30	50	33	48000	1600	3400	32
P-050.40	60	50	58	55000	910	7000	19
P-050.80	120	50	105	60000	500	14000	10
P-050.90	180	50	154	61000	340	22000	7
P-056.20	30	56	33	60000	2000	4300	32
P-056.40	60	56	58	66000	1100	8900	19
P-056.80	120	56	105	76000	630	18000	10
P-056.90	180	56	154	78000	430	27000	7

Standard piezo ceramic type: PIC 151
Recommended preload for dynamic operation: 15 MPa
Maximum preload for constant force: 30 MPa
Resonant frequency at 1 V_{pp}, unloaded, free at both sides. The value is halved for unilateral clamping
Capacitance at 1 V_{pp}, 1 kHz
blocking force at 1000 V
Operating voltage: 0 to 1000 V
Operating temperature range: -20 to +85 °C
Standard mechanical interfaces: steel plates, 0.5 to 2 mm thick (depends on model)
Standard electrical interfaces: two PTFE-insulated wires, pigtail length 100 mm
Available options: integrated piezo force sensor or strain gauge sensors, non magnetic, vacuum compatible, etc.
Other specifications on request.

P-010.xxP – P-056.xxP PICA™ Power Actuator

Piezo Stack Actuators for High-Level Dynamic Applications

Variety of PICA™ Power piezo stack actuators from 5 µm to 180 µm travel range

- **Operating Temperature to 150 °C**
- **High Load Capacity to 80 kN**
- **High Force Generation to 70 kN**
- **Large Cross Sections to 56 mm Diameter**
- **Extreme Reliability >10^9 Cycles**
- **Sub-Millisecond Response, Sub-Nanometer Resolution**
- **UHV Versions to 10^{-9} hPa**
- **Non-Magnetic Versions**
- **Temperature Sensor PT1000 Applied**

PICA™ Power piezoceramic stack actuators are offered in a large variety of standard shapes and sizes, with additional custom designs to suit any application. Based on the PIC 255 material, PICA™ Stack Power actuators are optimized for high-temperature working conditions and high-duty-cycle dynamic applications.

Application Examples

- Nanopositioning
- Active vibration damping
- High-load positioning
- Precision mechanics / -machining
- Semiconductor technology / test systems
- Laser tuning
- Switches
- Smart structures (Adaptronics)
- Nanotechnology

High Displacement with Ultra-High Reliability

PICA™ Power actuators are optimized for high-temperature working conditions and high-duty-cycle dynamic applications.

All PICA™ piezo ceramics are specifically designed for high-duty-cycle applications. With PI's extensive applications knowledge, gained over several decades, performance does not come at the price of reliability. All materials used are specifically matched for robustness and lifetime. Endurance tests on PICA™ actuators prove consistent performance, even after billions (1,000,000,000) of cycles.

Flexibility / Short Leadtimes

All manufacturing processes at PI Ceramic are set up for flexibility. Should our standard actuators not fit your application, let us provide you with a custom design. Our engineers will work with you to find the optimum solution at a very attractive price, even for small quantities. Some of our custom capabilities are listed below:

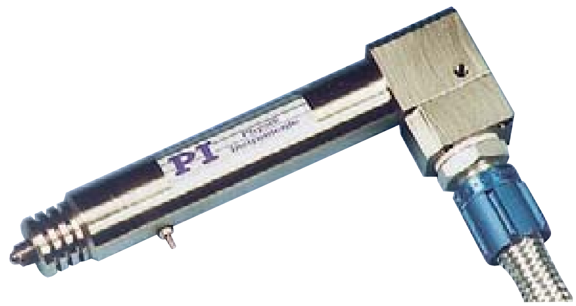
- Custom Materials
- Custom Voltage Ranges
- Custom Geometries (Circular, Rectangular, Triangular, Layer Thickness ...)
- Custom Load / Force Ranges
- Custom Flat or Spherical Endplates (Alumina, Glass, Sapphire, ...)
- Extra-Tight Length Tolerances
- Integrated Piezoelectric Sensor Discs
- Special High / Low Temperature Versions
- Vacuum Compatible Versions

Because all piezoelectric materials used in PICA™ actuators are manufactured at PI Ceramic, leadtimes are short and quality is outstanding. All standard and custom actuators are delivered with performance test sheets.

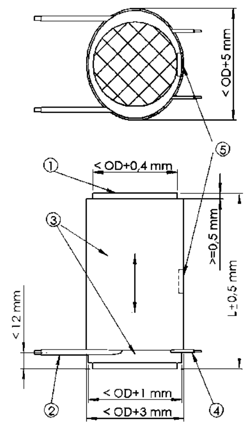
Piezo Drivers, Controllers & High-Voltage Amplifiers

PI offers a wide range of piezo control electronics, from low-power drivers to the ultra-high-performance E-481 power amplifier delivering 2000 W of dynamic power. For closed-loop positioning applications, a variety of analog and digital controllers is also available. The modular E-500 system can be upgraded from an amplifier to a servo-controller and offers a variety of computer interfaces. Of course, PI also designs custom amplifiers and controllers (see p. 2-98 *ff*).

OEM-PICA™ Power piezo actuators are available with cross sections to 56 mm



Custom preloaded PICA™ Power piezo actuator with forced-air cooling



1. Edelstahlscheiben, oben u. unten m. Zentralbohrung (D = 2,1 ±0,05 mm, T = 0,5 mm) z.B. f. Zentrierung
2. Teflonlitzen (rot max. 1000 V / schwarz GND) L >100 mm, D <1,2 mm
3. Schrumpfschlauch
4. Litzen f. Temperatursensor (PTFE isoliert, gelb/gelb, L >100 mm, D <0,7 mm)
5. Temperatur Sensor PT1000, mittig

PICA™ Power dimensions in mm, see technical data table for further information

Technical Data / Product Order Numbers

Order number	Displacement [µm] -10/+20%	Diameter D [mm]	Length L [mm] ±0.5	Blocking force [N]	Stiffness [N/µm]	Capacitance [nF] ±20%	Resonant frequency [kHz]
P-010.00P	5	10	9	1200	240	17	129
P-010.10P	15	10	18	1800	120	46	64
P-010.20P	30	10	31	2100	68	90	37
P-010.40P	60	10	58	2200	37	180	20
P-010.80P	120	10	111	2300	19	370	10
P-016.10P	15	16	18	4500	300	130	64
P-016.20P	30	16	31	5400	180	250	37
P-016.40P	60	16	58	5600	94	510	20
P-016.80P	120	16	111	5900	49	1000	10
P-016.90P	180	16	163	6000	33	1600	7
P-025.10P	15	25	20	9900	660	320	58
P-025.20P	30	25	33	12000	400	630	35
P-025.40P	60	25	60	13000	220	1300	19
P-025.80P	120	25	113	14000	120	2600	10
P-025.90P	180	25	165	14000	80	4000	7
P-035.10P	15	35	21	18000	1200	530	55
P-035.20P	30	35	34	23000	760	1200	34
P-035.40P	60	35	61	26000	430	2500	19
P-035.80P	120	35	114	28000	230	5200	10
P-035.90P	180	35	166	29000	160	7800	7
P-045.20P	30	45	36	36000	1200	2100	32
P-045.40P	60	45	63	41000	680	4300	18
P-045.80P	120	45	116	44000	370	8800	10
P-045.90P	180	45	169	45000	250	13000	7
P-056.20P	30	56	36	54000	1800	3300	32
P-056.40P	60	56	63	66000	1100	6700	18
P-056.80P	120	56	116	68000	570	14000	10
P-056.90P	180	56	169	70000	390	21000	7

Standard piezo ceramic type: PIC 255
Recommended preload for dynamic operation: 15 MPa
Maximum preload for constant force: 30 MPa
Resonant frequency at 1 V_{pp}, unloaded. The value is halved for unilateral clamping
Capacitance at 1 V_{pp}, 1 kHz
blocking force at 1000 V
Operating voltage: 0 to 1000 V
Operating temperature range: -20 to +150 °C
Standard mechanical interfaces: steel plates, 0.5 to 2 mm thick (depends on model)
Standard electrical interfaces: two PTFE-insulated wires, pigtail length 100 mm
Available options: integrated piezo sensor or strain gauge sensors, non magnetic, vacuum compatible, etc.
Other specifications on request.

P-010.xxH – P-025.xxH PICA™ Thru Actuator

High-Load Piezo Stack Actuators with Aperture


PICA™ Thru piezo stack actuators with clear aperture

- **Clear Aperture for Transmitted-Light Applications for Mechanical Preloading**
- **Extreme Reliability >10⁹ Cycles**
- **Large Cross Sections to 56 mm Diameter**
- **Variety of Shapes**
- **Sub-Millisecond Response, Sub-Nanometer Resolution**
- **Vacuum-Compatible Versions**

PICA™ Thru actuators are hollow piezo stack actuators, offered in a large variety of standard shapes and sizes with additional custom designs to meet all customer requirements. They combine the advantage of a clear aperture with the strength and force generation of stack actuators. These tubular devices are high-resolution linear actuators for static and dynamic applications. The clear aperture facilitates transmitted-light applications. Furthermore the electrical consumption is reduced due to the decreased electrical capacitance.

Application Examples

- Optics
- Image stabilization
- Laser tuning
- Laser treatment
- Precision mechanics / -machining
- Confocal microscopy
- Nanopositioning

Ultra-High Reliability, High Displacement, Low Power Requirements

PICA™ piezo actuators are specifically designed for high-duty-cycle applications. With our extensive applications knowledge, gained over several decades, we know how to build performance that does not come at the price of reliability. All materials used are specifically matched for robustness and lifetime. Endurance tests on PICA™ actuators prove consistent performance, even after billions (1,000,000,000) of cycles. The combination of high displacement and low electrical capacitance provides for excellent dynamic behavior with reduced driving power requirements.

Flexibility / Short Leadtimes

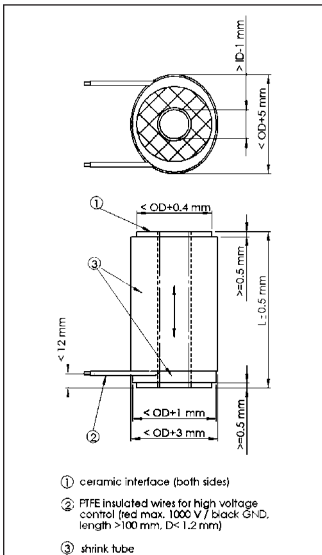
All manufacturing processes at PI Ceramic are set up for flexibility. Should our standard actuators not fit your application, let us provide you with a custom design. Our engineers will work with you to find the optimum solution at a very attractive price, even for small quantities. Some of our custom capabilities are listed below:

- Custom Materials
- Custom Voltage Ranges
- Custom Geometries (Circular, Rectangular, Triangular, Layer Thickness ...)
- Custom Load / Force Ranges
- Custom Flat or Spherical Endplates (Alumina, Glass, Sapphire, ...)
- Extra-Tight Length Tolerances
- Integrated Piezoelectric Sensor Discs
- Special High / Low Temperature Versions
- Vacuum Compatible Versions

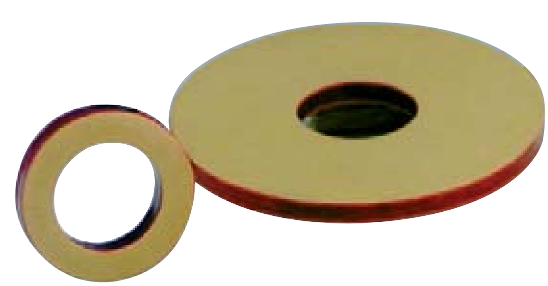
Because all piezoelectric materials used in PICA™ actuators are manufactured at PI Ceramic, leadtimes are short and quality is outstanding. All standard and custom actuators are delivered with performance test sheets.

Piezo Drivers, Controllers & High-Voltage Amplifiers

High-resolution amplifiers and servo-control electronics, both digital and analog, are described in the "Piezo Drivers / Servo Controllers" section.



PICA™ Thru dimensions in mm, see technical data table for further information


Customized PICA™ Thru actuator discs

Standard actuators are delivered with black heat shrink tube (shown here is the model P-010.20H)

Custom PICA™ Thru piezo actuator with 56 mm outside diameter, 8 mm inner diameter, 250 µm displacement. Pen for size comparison

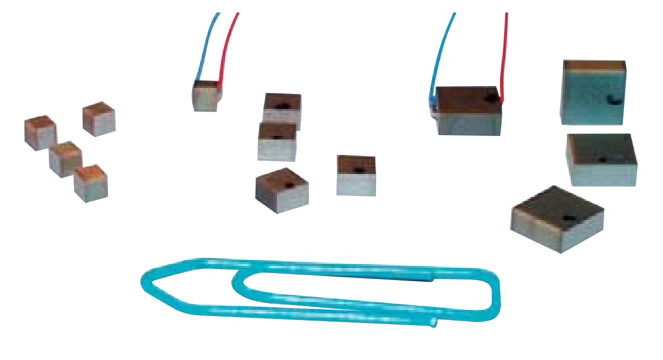
Technical Data / Product Order Numbers

Order numbers	Displacement [µm] -10/+20 %	Diameter OD [mm]	Diameter ID [mm]	Length L [mm] ±0.5	Blocking force [N]	Stiffness [N/µm]	Capacitance [nF] ±20 %	Resonant frequency [kHz]
P-010.00H	5	10	5	7	1200	230	15	144
P-010.05H	10	10	5	12	1300	130	29	84
P-010.10H	15	10	5	15	1700	110	40	67
P-010.15H	20	10	5	21	1500	76	59	48
P-010.20H	30	10	5	27	1800	59	82	39
P-010.30H	40	10	5	40	1600	40	120	28
P-010.40H	60	10	5	54	1800	29	180	21
P-016.00H	5	16	8	7	2900	580	42	144
P-016.05H	10	16	8	12	3400	340	83	84
P-016.10H	15	16	8	15	4100	270	120	67
P-016.15H	20	16	8	21	3800	190	170	48
P-016.20H	30	16	8	27	4500	150	230	39
P-016.30H	40	16	8	40	4000	100	340	28
P-016.40H	60	16	8	52	4700	78	490	21
P-025.10H	15	25	16	16	7400	490	220	63
P-025.20H	30	25	16	27	8700	290	430	39
P-025.40H	60	25	16	51	9000	150	920	22
P-025.50H	80	25	16	66	9600	120	1200	17

Piezo ceramic type PIC 151
Recommended preload for dynamic operation: 15 MPa
Maximum preload for constant force: 30 MPa
Resonant frequency at 1 V_{pp}, unloaded, free at both sides. The value is halved for unilateral clamping
Capacitance at 1 V_{pp}, 1 kHz
Blocking force at 1000 V
Operating voltage range: 0 to 1000 V
Operating temperature range: -20 to +85 °C
Standard mechanical interface (top & bottom): ceramic, 0.5–2 mm thick (depends on model)
Standard electrical interface: two PTFE-insulated wires, pigtail length 100 mm
Available options: integrated force piezo sensor or strain gauge sensors, non-magnetic, vacuum compatible, etc.
Ask about custom designs and further specifications.

PL022 · PL033 · PL055 PICMA® Chip Actuators

Miniature Multilayer Piezo Stack Actuators



PICMA® chip miniature piezo actuators are the smallest ceramic encapsulated multilayer piezo actuators available, paper clip for size comparison

- **Superior Lifetime Even Under Extreme Conditions**
- **Ultra-Compact: from 2 x 2 x 2 mm**
- **Ideal for Dynamic Operation**
- **Sub-Millisecond Response**
- **Sub-Nanometer Resolution**
- **Vacuum Compatible to 10^9 hPa**
- **High Humidity Resistance**

Smallest Dimensions – High Performance

PICMA® Chip actuators sized from 2 x 2 x 2 mm are the smallest monolithic multilayer piezo stack actuators available. Providing sub-nanometer resolution and sub-millisecond response, they are ideally suited to high-level dynamic applications.

New Production Process, Optimized Piezo Ceramics

PICMA® actuators are made from a ceramic material in which the piezoceramic properties such as stiffness, capacitance, displacement, temperature stability and lifetime are optimally combined. Thus the actuators accomplish sub-nanometer resolution in positioning and sub-millisecond response!

Application Examples

- Static and dynamic precision positioning
- Laser tuning
- Micro-dispensing
- Metrology / Interferometry
- Life science, Biotechnology
- Photonics

Increased Lifetime Through Humidity Resistance

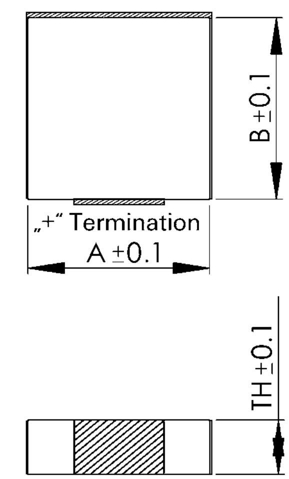
The monolithic ceramic-encapsulated design provides better humidity protection than polymer-film insulation. Diffusion of water molecules into the insulation layer is greatly reduced by the use of cofired, outer ceramic encapsulation. Due to their high resonant frequency the actuators are suitable for highly dynamic applications with small loads; depending on the load an external preload for dynamic applications is recommended. The high Curie temperature of 320 °C gives PICMA® actuators a usable temperature range extending up to 150 °C, far beyond 80 °C as is common for conventional multilayer actuators. With conventional multilayer actuators, heat generation – which is proportional to operating frequency – either limits the operating frequency or duty cycle in dynamic operation, or makes ungainly cooling provisions necessary. At the low end, operation down to a few Kelvin is possible (with reduction in performance specifications).

Optimum UHV Compatibility – Minimum Outgassing

The lack of polymer insulation and the high Curie temperature make for optimal ultra-high-vacuum compatibility (high bakeout temperatures, up to 150 °C).

Piezo Drivers, Controllers & High-Voltage Amplifiers

High-resolution amplifiers and servo-control electronics, both digital and analog, are described in the "Piezo Drivers / Servo Controllers" section.



PICMA® chip miniature piezo actuator, dimensions in mm. See technical data table for A, B, TH. Lateral tolerances for PL055 0.15 mm

Technical Data / Product Order Numbers

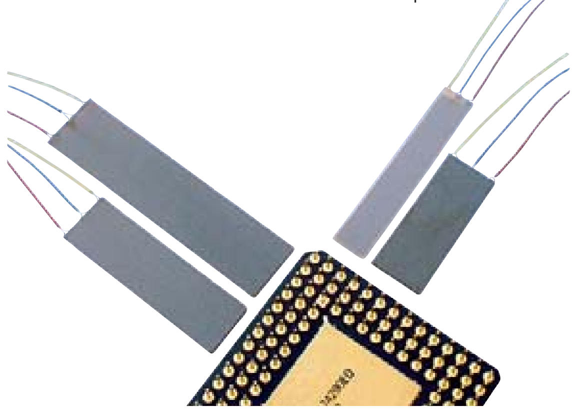
Order number*	Dimensions A x B x TH in mm	Nominal displacement [µm @ 100 V] ±20 %	Blocking force [N]	Electrical capacitance [nF] ±20 %	Resonant frequency [kHz]
PL022.30	2 x 2 x 2	2.2	>120	25	>300
PL033.30	3 x 3 x 2	2.2	>300	50	>300
PL055.30	5 x 5 x 2	2.2	>500	250	>300

* For optional PTFE insulated wire leads change order number extension to .x1 (e. g. PL022.31)
Resonant frequency at 1 V_{pp}, unloaded, free at both sides. The value is halved for unilateral clamping
Capacitance at 1 V_{pp}, 1 kHz
Operating voltage: -20 to +100 V
Operating temperature range: 150 °C
Standard electrical interfaces: Solderable pads
Other specifications on request.
Recommended preload for dynamic operation: 15 MPa
Maximum preload for constant force: 30 MPa

PL112 · PL140 PICMA® Bender Actuators

Multilayer Piezo Bender Actuators with High Travel and Low Operating Voltage

Bender actuators with optional wire leads (order number extension .x1); micro processor for size comparison



- **Ceramic Encapsulation for Better Protection and Longer Lifetime**
- **Positioning Range up to 2 mm**
- **Fast Response (10 msec)**
- **Nanometer-Range Resolution**
- **Low Operating Voltage**
- **Vacuum-Compatible Versions to 10^{-9} hPa**
- **Available with Integrated Position Sensor**
- **Special OEM- and Bench-Top Amplifiers Available**

PICMA® multilayer bender piezo actuators provide a deflection of up to 2 mm, forces up to 2 N and response times in the millisecond range. These multilayer piezoelectric components are manufactured from ceramic layers of only about 50 µm thickness. They feature internal silver-palladium electrodes and ceramic insulation applied in a cofiring process. The benders have two outer active areas and one central electrode network dividing the actuator in two segments of equal capacitance, similar to a classical parallel bimorph.

Application Examples

- Wire bonding
- Pneumatic valves
- Fiber optic switches
- (Laser)-Beam steering
- Micropositioning
- Acceleration sensors

Advantages

PICMA® Bender piezo actuators offer several advantages over classic bimorph components manufactured by gluing together two ceramic plates (0.1 to 1 mm thick): faster response time and higher stiffness. The main advantage, however, is the drastically reduced (by a factor of 3 to 10) operating voltage of only 60 V. The reduced voltage allows smaller drive electronics and new applications, such as in medical equipment. Additionally, these devices offer improved humidity resistance due to the ceramic encapsulation.

Increased Lifetime Through Humidity Resistance

The monolithic ceramic-encapsulated design provides better humidity protection than polymer-film insulation. Diffusion of water molecules into the insulation layer is greatly reduced by the use of cofired, outer ceramic encapsulation. Due to their high resonant frequency the actuators are suitable for highly dynamic applications with small loads; depending on the load an external preload for dynamic applications is recommended. The high Curie temperature of 320 °C gives PICMA® actuators a usable temperature range extending up to 150 °C, far beyond 80 °C as is common for conventional multilayer actuators. With conventional multilayer actuators, heat generation – which is proportional to operating frequency – either limits the operating frequency or duty cycle in dynamic operation, or makes ungainly cooling provisions necessary. At the low end, operation down to a few Kelvin is possible (with reduction in performance specifications).

Optimum UHV Compatibility – Minimum Outgassing

The lack of polymer insulation and the high Curie temperature make for optimal ultra-high-vacuum compatibility (high bakeout temperatures, up to 150 °C).

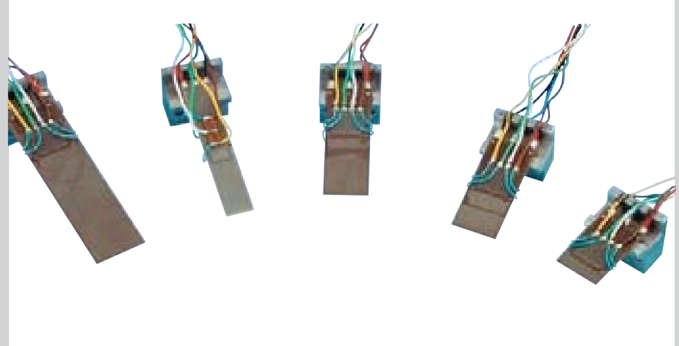
Closed-Loop Version

For closed-loop positioning the versions P-871 with integrated strain gauge sensors are available (see p. 1-84).

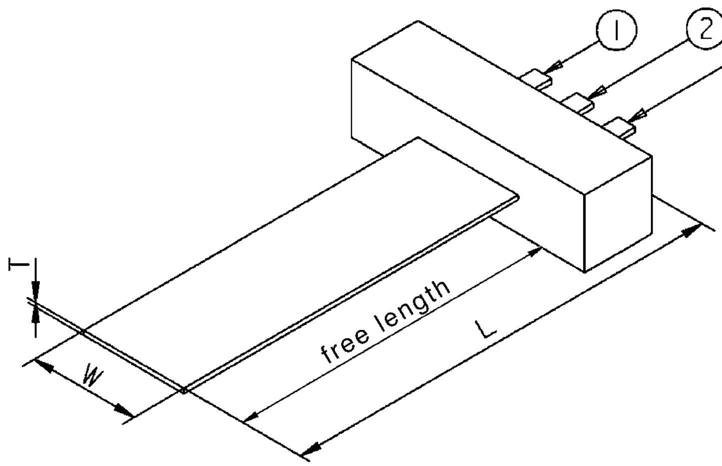
Drivers and Controllers

PI offers a wide selection of low noise amplifiers and controllers for piezo actuators (see section „Piezo Electronics“). Customized piezo electronics are developed on request.

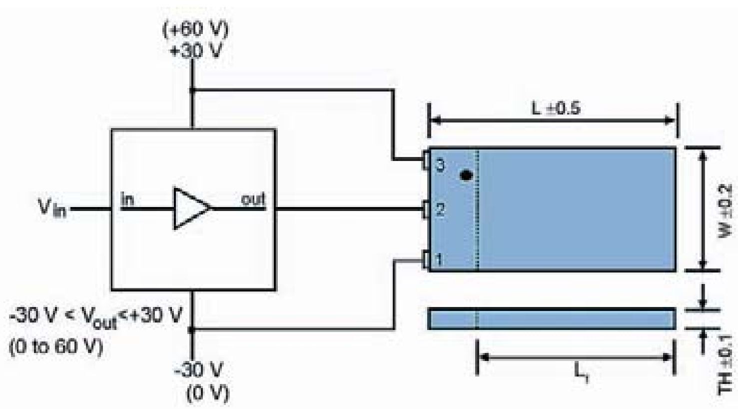
The E-650.00 and E-650.0E piezo amplifiers (see p. 2-122) are especially designed for operating the PICMA® bender actuators.



Bender actuators with strain gauge positioning sensors are available with product number P-871



Recommended clamping: non-conducting material with rounded clamping end face for protection of ceramics (not included). See table for dimensions



Differential control of PICMA® bender actuators
Pin Assignments:
1: -30 V [or GND]
2: -30 V to +30 V [or 0 to 60 V]
3: +30 V [or +60 V]
Dimensions in mm

Technical Data / Product Order Numbers

Order number*	Operating voltage [V]	Nominal displacement [µm] ±20 %	Free length [mm]	Dimensions L x W x T [mm]	Blocking force [N]	Electrical capacitance [µF] ±20 %	Resonant frequency [Hz] ±20 %
PL112.10**	0 - 60 (±30)	±80	12	17.8 x 9.6 x 0.65	±2.0	2 x 1.1	>1000
PL122.10	0 - 60 (±30)	±250	22	25.0 x 9.6 x 0.65	±1.1	2 x 2.4	660
PL127.10	0 - 60 (±30)	±450	27	31.0 x 9.6 x 0.65	±1.0	2 x 3.4	380
PL128.10**	0 - 60 (±30)	±450	28	35.5 x 6.3 x 0.75	±0.5	2 x 1.2	360
PL140.10	0 - 60 (±30)	±1000	40	45.0 x 11.0 x 0.60	±0.5	2 x 4.0	160

*For optional PTFE insulated wire leads change order number extension to .x 1 (e. g. PL112.11)
Operating temperature range: -20 to +85 °C;
**to +150 °C Resonant frequency at 1 V_{pp}, capacitance at 1 V_{pp}, 1 kHz

All parameters depend on actual clamping conditions and applied load.
Ask about custom designs and further specifications.

P-876 DuraAct™

Piezoelectric Patch Transducers

P-876.A12 and .A15 actuators. Golf ball for size comparison

- **Actuator, Sensor or Energy Source**
- **Highly Formable Ceramics**
- **Can be Applied to Curved Surfaces**
- **Customized Solutions on Request**
- **Cost-Effective**

P-876 DuraAct™ patch transducers offer the functionality of piezoceramic materials as sensors and actuators as well as for electrical charge generation and storage. Used as bender actuators, they allow high deflections of up to 0.8 mm with high force and high precision. Other possible operation modes of DuraAct™ transducers are as high-dynamics sensors (e.g. for structural health monitoring) or for energy harvesting.

Application Examples

- High-dynamics actuators
- Adaptive systems
- Vibration and noise cancellation
- Deformation control and stabilization
- Damage monitoring
- Energy harvesting

Integration into Adaptive Systems

With their compact design, DuraAct™ transducers can be applied to structure areas where deformations are to be generated or detected. For this purpose the transducers can be affixed to the surfaces of structures or integrated as structural elements themselves. Whole areas can be monitored effectively by applying an array of several modules to a surface.

DuraAct™ patch transducers are ideally suited for active and adaptive systems. Embedded in a servo-control loop, they can reduce vibrations and control structures in the nanometer range.

Robust and Cost-Effective Design for Industrial Applications

The laminated design with piezoceramic plate and polymers provide a mechanically preloaded and electrically insulated device for easy handling. P-876 patch transducers feature a rugged design with the mechanical stability of a structural material.

Energy Harvesting: Self-Sustaining Systems in a Small Package

One possible application of DuraAct™ patch transducers is in the field of energy harvesting. Transformation of mechanical vibrations of up to some kilohertz into the corresponding potential difference can yield electrical power in the milliwatt range. This power can supply miniature electronic devices like diodes, sensors or even radio transmitters for remote data control.

DuraAct™ transducers can be offered in highly customized versions:

Ordering Information

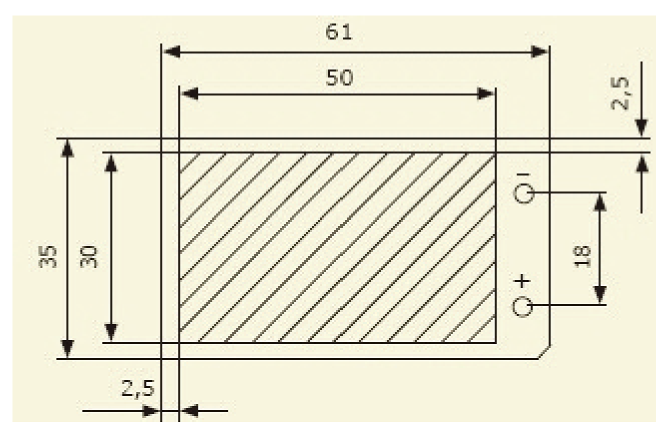
P-876.A11
DuraAct™ Patch Transducer, 61 x 35 x 0.4 mm

P-876.A12
DuraAct™ Patch Transducer, 61 x 35 x 0.5 mm

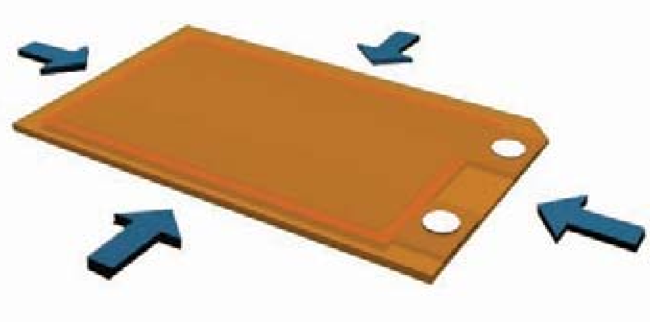
P-876.A15
DuraAct™ Patch Transducer, 61 x 35 x 0.8 mm

Ask for custom designs!

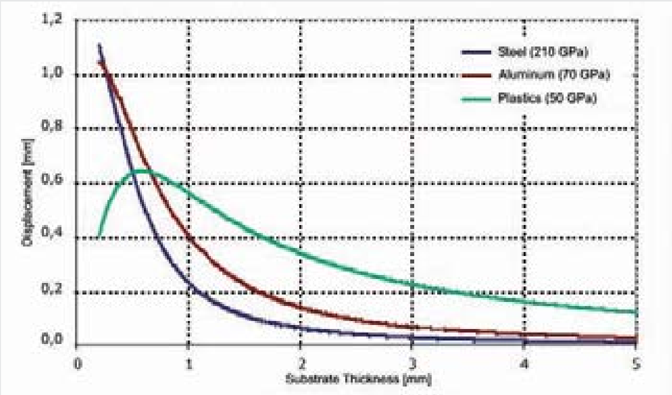
- Flexible choice of dimensions
- Flexible choice of thickness and bending properties
- Flexible choice of piezoceramic materials and operating temperature
- Various electrical connection designs
- Combining sensor and actuator functions (multiple ceramic layers)



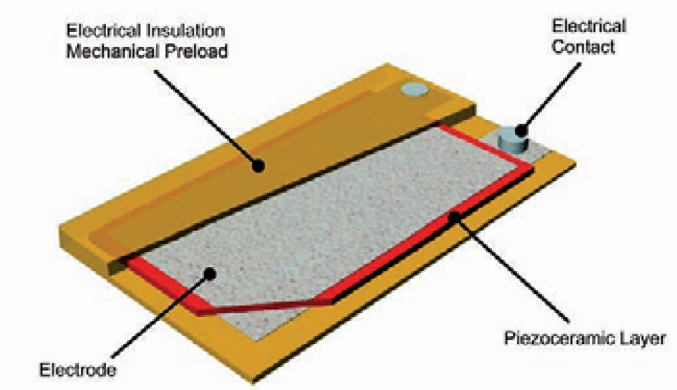
Dimensions of the P-876 in mm



Lateral contraction of a DuraAct™ patch transducer when voltage is applied



Deflection of a bending transducer as a function of the substrate thickness for different materials. A bending transducer consists of a substrate with a P-876 actuator (here: P-876.A15) glued to one side. A contraction of the actuator effects a deflection W



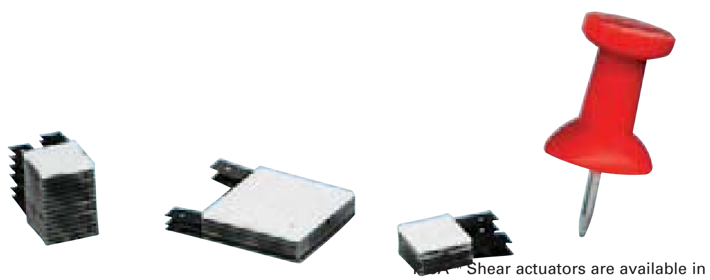
Design principle of the transducer

Technical Data

Model	P-876.A11	P-876.A12	P-876.A15	Tolerances
Operating voltage	-50 to +200 V	-100 to +400 V	-250 to +1000 V	
Motion and positioning				
Lateral contraction, open-loop	400 µm/m 1.6 µm/m/V	650 µm/m 1.3 µm/m/V	800 µm/m 0.64 µm/m/V	min.
Mechanical properties				
Blocking force	90 N	265 N	775 N	
Length	61 mm	61 mm	61 mm	±0.5 mm
Width	35 mm	35 mm	35 mm	±0.5 mm
Thickness	0.4 mm	0.5 mm	0.8 mm	±0.05 mm
Bending radius	12 mm	20 mm	70 mm	max.
Drive properties				
Piezo ceramic type	PIC 252 Layer thickness: 100 µm	PIC 255 Layer thickness: 200 µm	PIC 255 Layer thickness: 500 µm	
Electrical capacitance	150 nF	90 nF	45 nF	±20 %
Miscellaneous				
Operating temperature range	-20 to +150 (180) °C	-20 to +150 (180) °C	-20 to +150 (180) °C	
Mass	2.1 g	3.5 g	7.2 g	±5 %
Voltage connection	Solder pads	Solder pads	Solder pads	
Recommended controller/driver	E-413.D2 E-835	E-413.D2 (p. 2-120) E-835	E-508 (p. 2-150) E-835 (p. 2-166)	

P-111 · P-151 PICA™ Shear Actuators

Compact Multi-Axis Actuators Based on the Piezo Shear Effect



PICA™ Shear actuators are available in cross-sections from 3 x 3 mm to 16 x 16 mm

- **Compact Single- and Multi-Axis Actuators**
- **X-, XY-, XZ- and XYZ-Versions**
- **High Resonant Frequencies**
- **Extreme Reliability >10⁹ Cycles**
- **Picometer-Resolution / Sub-Millisecond Response**
- **UHV Versions to 10⁻⁹ hPa**
- **Non-Magnetic and Clear Aperture Versions**

The unique PICA™ Shear piezo actuator series are exclusively available from PI. These devices are extremely compact and feature sub-nanometer resolution and ultra-fast response. They come in a variety of geometries providing displacements to 10 µm. Possible applications for these devices are e.g. scanning microscopy, or in motor drives.

Application Examples

- Nanopositioning
- Precision mechanics / -machining
- Active vibration damping
- Semiconductor technology / test systems
- Laser tuning
- Atomic force microscopy
- Switches
- Scanning applications
- Linear motors
- Nanotechnology

High Stiffness and High Displacement

PICA™ Shear actuators exhibit high stiffness, both parallel and perpendicular to the motion direction. Based on the piezoelectric shear effect, the PICA™ Shear X and XY actuators show almost twice the displacement amplitudes of conventional piezo actuators at the same electric field. Consequently they can be made smaller and have higher resonant frequencies. This results in reduced power requirements for a given induced displacement in dynamic X- and Y-axis operation.

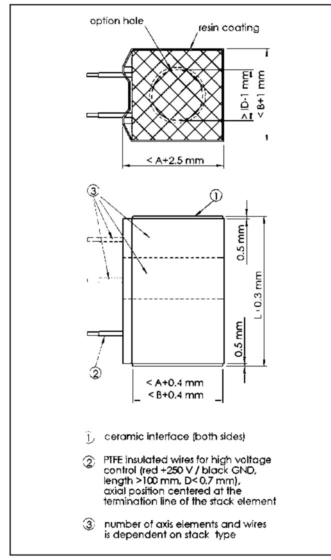
High Reliability under High Duty Cycles, Low Power Requirements

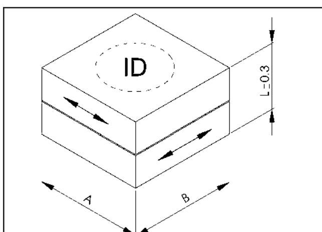
PICA™ Shear actuators are specifically designed for high-duty-cycle applications. All materials used are specifically matched for robustness and lifetime. Endurance tests proved consistent performance, even after billions (1,000,000,000) of cycles. The combination of high displacement and low electrical capacitance provides for excellent dynamic behavior with reduced driving power requirements.

Short Leadtime for Standard & Custom Designs

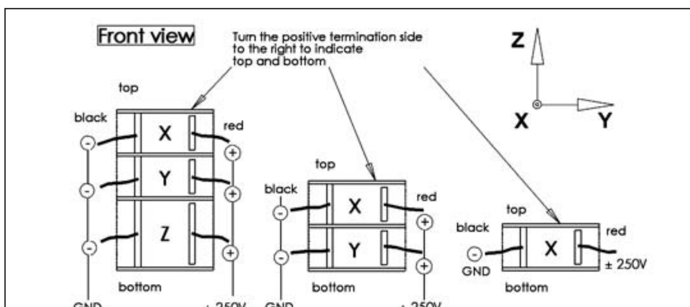
All manufacturing processes at PI Ceramic are set up for maximum flexibility. Should our standard actuators not fit your application, let us provide you with a custom design. Our engineers will work with you to find the optimum solution at a very attractive price, even for small quantities. Some of our custom capabilities are listed below:

- Custom Materials
- Custom Voltage Range / Custom Displacement
- Clear Aperture
- Custom Load / Force Ranges
- Custom Flat or Spherical Endplates (Metal, Ceramics, Glass, Sapphire, ...) / Optical Surface Quality

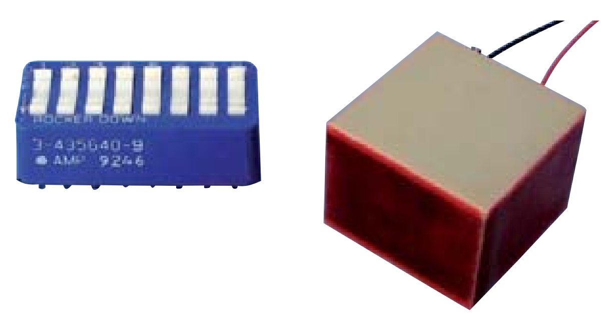




PICA™ Shear dimensions, see technical data table for A, B, L



Axis and lead assignment for PICA™ Shear actuators



The standard actuator P-151.10 is delivered with a 10 cm lead

- Extra-Tight Length Tolerances
- Combination with Piezoelectric Shear Sensors (no Pyroelectric Effect)
- Low-Temperature Designs, Down to Liquid-He
- Vacuum Compatible and Non-Magnetic Versions

Because all piezoelectric materials used in these actuators are manufactured at PI Ceramic, leadtimes are short and quality is outstanding. All standard and custom actuators are delivered with performance test sheets.

Amplifiers and Controllers

The E-413.OE bipolar piezo driver is recommended for operating these actuators. Other high-resolution amplifiers and servo-control electronics, both digital and analog, are described in the “Piezo Drivers / Servo Controllers” section.

Technical Data / Product Order Numbers

Order number	Active axes	Displacement [µm] -10/+20% for -250 to 250 V	Cross section A x B / ID [mm]	Length L [mm] ±0.3	Max. shear load [N]	Axial Stiffness [N/µm]	Capacitance [nF] ±20%	Resonant frequency [kHz]
P-111.01	X	1*	3 x 3	3.5	20	70	0.5	330
P-111.03	X	3*	3 x 3	5.5	20	45	1.5	210
P-111.05	X	5	3 x 3	7.5	20	30	2.5	155
P-121.01	X	1*	5 x 5	3.5	50	190	1.4	330
P-121.03	X	3*	5 x 5	5.5	50	120	4.2	210
P-121.05	X	5	5 x 5	7.5	40	90	7	155
P-141.03	X	3*	10 x 10	5.5	200	490	17	210
P-141.05	X	5	10 x 10	7.5	200	360	28	155
P-141.10	X	10	10 x 10	12	200	230	50	100
P-151.03	X	3*	16 x 16	5.5	300	1300	43	210
P-151.05	X	5	16 x 16	7.5	300	920	71	155
P-151.10	X	10	16 x 16	12	300	580	130	100
P-112.01	XY	1 x 1*	3 x 3	5	20	50	0.5 / 0.5	230
P-112.03	XY	3 x 3*	3 x 3	9.5	10	25	1.5 / 1.5	120
P-122.01	XY	1 x 1*	5 x 5	5	50	140	1.4 / 1.4	230
P-122.03	XY	3 x 3*	5 x 5	9.5	40	70	4.2 / 4.2	120
P-122.05	XY	5 x 5	5 x 5	14	30	50	7 / 7	85
P-142.03	XY	3 x 3*	10 x 10	9.5	200	280	17 / 17	120
P-142.05	XY	5 x 5	10 x 10	14	100	190	28 / 28	85
P-142.10	XY	10 x 10	10 x 10	23	50	120	50 / 50	50
P-152.03	XY	3 x 3*	16 x 16	9.5	300	730	43 / 43	120
P-152.05	XY	5 x 5	16 x 16	14	300	490	71 / 71	85
P-152.10	XY	10 x 10	16 x 16	23	100	300	130 / 130	50
P-123.01	XYZ	1 x 1 x 1*	5 x 5	7.5	40	90	1.4 / 1.4 / 2.9	155
P-123.03	XYZ	3 x 3 x 3*	5 x 5	15.5	10	45	4.2 / 4.2 / 7.3	75
P-143.01	XYZ	1 x 1 x 1*	10 x 10	7.5	200	360	5.6 / 5.6 / 11	155
P-143.03	XYZ	3 x 3 x 3*	10 x 10	15.5	100	170	17 / 17 / 29	75
P-143.05	XYZ	5 x 5 x 5	10 x 10	23	50	120	28 / 28 / 47	50
P-153.03	XYZ	3 x 3 x 3*	16 x 16	15.5	300	450	43 / 43 / 73	75
P-153.05	XYZ	5 x 5 x 5	16 x 16	23	100	300	71 / 71 / 120	50
P-153.10	XYZ	10 x 10 x 10	16 x 16	40	60	170	130 / 130 / 230	30
P-153.10H	XYZ	10 x 10 x 10	16 x 16 / 10	40	20	120	89 / 89 / 160	30
P-151.03H	X	3*	16 x 16 / 10	5.5	200	870	30	210
P-151.05H	X	5	16 x 16 / 10	7.5	200	640	49	155
P-151.10H	X	10	16 x 16 / 10	12	200	460	89	100

Standard piezo ceramic type: 255
* Tolerances ±30 %
Unloaded (longitudinal) resonant frequency measured at 1 V_{pp}, capacitance at 1 V_{pp}, 1 kHz, unloaded, free at both sides
Capacitance at 1 V_{pp}, 1 kHz
Operating voltage: -250 V to +250 V
Operating temperature range: -20 to +85 °C
Standard mechanical interfaces: Ceramics
PTFE-insulated wires, pigtail length 100 mm
Available options: integrated piezo force sensors, non magnetic, vacuum compatible, free aperture etc.
Other specifications on request.

PT120 · PT140 PT Piezo Tube Actuators

Piezoceramic Tube Actuators with Small Tolerances and Various Options

A selection of PT piezoceramic tubes

- **Standard & Custom Sizes**
- **Optional Quartered Electrodes for XYZ-Positioning & Scanning**
- **Sub-Nanometer Resolution**
- **Ideal for OEM-Applications**

PT-series piezoceramic tubes are used in a wide range of applications from microdispensing to scanning microscopy. These monolithic components contract laterally (radially) and longitudinally when a voltage is applied between their inner and outer electrodes. Multi-electrode tubes are available to provide XYZ motion for use in manipulation and scanning microscopy applications. PI also provides ultra-high linearity, closed-loop scanning stages for SPM and nanomanipulation.

Application Examples

- Micropositioning
- Scanning microscopy (AFM, STM, etc.)
- Fiber stretching / modulation
- Micropumps
- Micromanipulation
- Ultrasonic and sonar applications

Precision and Flexibility

PT piezo tubes are manufactured to the tightest tolerances. We can provide tubes with diameters as small as 0.8 mm and tolerances as tight as 0.05 mm. All manufacturing processes at PI Ceramic are set up for maximum flexibility. Should our standard actuators not fit your application, let us provide you with a custom design. Our engineers will work with you to find the optimum solution at a very attractive price, even for small quantities. Some of our custom capabilities are listed below:

- Custom Materials
- Custom Voltage Ranges / Displacement
- Custom Geometries
- Extra-Tight Tolerances
- Applied Sensors
- Special High / Low Temperature Versions

Short Leadtime

Because all piezoelectric materials used in PT tube actuators are manufactured at PI Ceramic, leadtimes are short and quality is outstanding.

Dimensions

max. L: 50 mm
max. OD: 80 mm
min. d: 0.30 mm

Electrodes

Fired silver-plated inside and outside as standard; thin film electrodes (e. g. copper-nickel or gold) as outer electrodes optional.

Options

Single or double wrapped, circumferential bands or quartered outer electrodes.

Polarization

Inner electrode positive potential

Tube actuators are not designed to withstand large forces (see PICA™ Thru actuators p. 1-90), but their high resonant frequencies make them especially suitable for dynamic operation with light loads.

Application examples are micro pumps, scanning microscopy, ink-jet printing, ultrasonic and sonar applications.

Piezo Drivers, Controllers & High-Voltage Amplifiers

High-resolution amplifiers and servo-control electronics, both digital and analog, are described in the "Piezo Drivers / Servo Controllers" section.

Equations

The axial contraction and radial displacement of piezo tubes can be calculated as follows:

(Equation 1)

$$\Delta L \approx d_{31} \cdot L \cdot \frac{U}{d}$$

where:
- d_{31} = *strain coefficient (displacement normal to polarization direction) [m/V]*
- L = *length of ceramic tube [m]*
- U = *operating voltage [V]*
- d = *wall thickness [m]*

(Equation 2)

$$\Delta d \approx d_{33} \cdot U$$

where:
- d = *change in wall thickness [m]*
- d_{33} = *strain coefficient (field and displacement in polarization direction) [m/V]*
- U = *operating voltage [V]*

Typical values for d_{31} and d_{33} are -200 pm/V and 500 pm/V, respectively.

XY scanning tubes with quartered outer electrodes; see table for specifications

Linear Actuators & Motors
PiezoWalk® Motors / Actuators
PILine® Ultrasonic Motors
DC-Servo & Stepper Actuators
Piezo Actuators & Components
Guided / Preloaded Actuators
Unpackaged stack Actuators
Patches/Benders/Tubes/Shear..
Nanopositioning / Piezoelectrics
Nanometrology
Micropositioning
Index

The radial contraction is the superposition of the increase in wall thickness and the tangential contraction; it can be estimated by the following equation:

(Equation 3)

$$\frac{\Delta r}{r} \approx d_{31} \frac{U}{d}$$

where:

r = *radius of piezo tube*
d_{31} = *strain coefficient (displacement normal to polarization direction) [m/V]*
U = *operating voltage [V]*
d = *wall thickness [m]*

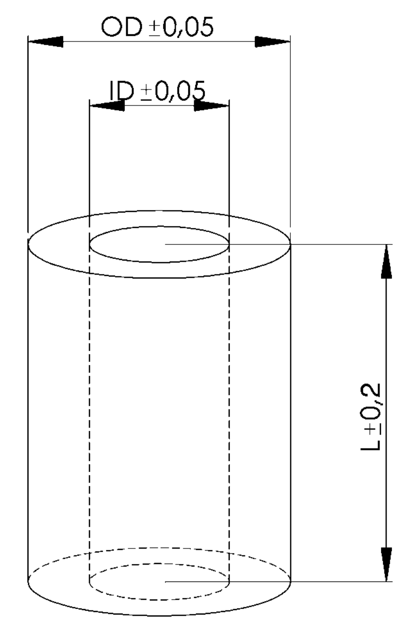
For a given division of the outer electrode of a piezo tube into four 90° sections the differential control (±U) of opposing electrodes results in bending of one of the ends, due to superposition of radial and axial contraction. Such tubes are applied as XY scanner in scanning-probe microscopes such as atomic force microscopes. The scanning range can be evaluated as follows:

(Equation 4)

$$\Delta x \approx \frac{2\sqrt{2} \cdot d_{31} \cdot L^2 \cdot U}{\pi \cdot ID \cdot d}$$

where:

Δx = *scanning range in X and Y (for symmetrical electrodes) [m]*
d_{31} = *strain coefficient (displacement normal to polarization direction) [m/V]*
U = *operating voltage [V]*
L = *length [m]*
ID = *inner diameter [m]*
d = *wall thickness [m]*



PT Tube dimensions, in mm
(see table for further information)

Technical Data / Product Order Numbers

Order number	Dimensions [mm] L x OD x ID**	Max. operating voltage [V]	Electrical capacitance [nF] ±20%	Axial contraction [µm] @ max. V	Radial contraction [µm] @ max. voltage	XY deflection [µm] @ ±200 V
PT120.00	20 x 2.2 x 1.0	500	3	5	0.7	-
PT130.00	30 x 3.2 x 2.2	500	10	9	0.9	-
PT130.90	30 x 3.2 x 2.2	500	12	9	0.9	-
PT130.94*	30 x 3.2 x 2.2	±200	4 x 2.4	9	0.9	±35
PT130.10	30 x 6.35 x 5.35	500	18	9	1.8	-
PT130.14*	30 x 6.35 x 5.35	±200	4 x 3.8	9	1.8	±16
PT130.20	30 x 10.0 x 9.0	500	36	9	3	-
PT130.24*	30 x 10.0 x 9.0	±200	4 x 8.5	9	3	±10
PT130.30	30 x 10.0 x 8.0	1000	18	9	3	-
PT130.40	30 x 20.0 x 18.0	1000	35	9	6	-
PT140.70	40 x 40.0 x 38.0	1000	70	15	12	-

*Quartered electrodes for XY deflection
**OD (outer diameter), ID (inner diameter) ±0.05 mm. PT120 / PT130.00: ID ±0.1 mm

Other specifications on request.

Piezo • Nano • Positioning

Nanopositioning / Piezoelectrics

Nanopositioning Solutions from PI

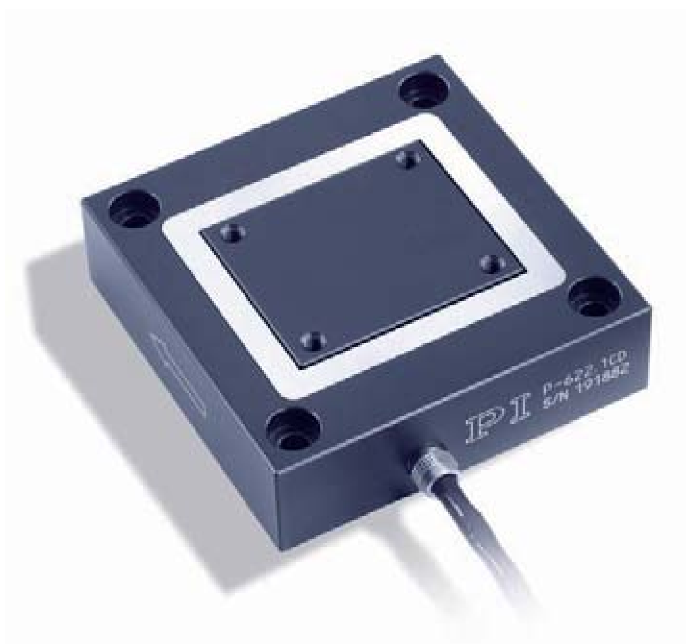
- 1- to 6-axis standard, OEM and custom designs
- Parallel kinematics and parallel metrology for better multi-axis accuracy
- Closed-loop operation with SGS and capacitive position sensors for higher linearity and repeatability
- Integrated capacitive position sensors for sub-nanometer-resolution and stability
- Finite Element Analysis (FEA) computer-designed flexures for nanometer and microradian trajectory control
- Invar, titanium, steel and aluminum versions for optimized thermal match
- High-performance controllers and amplifiers (digital, analog, modular, OEM) with 60 to 1500 V output ranges; Ultra-high-output power amplifiers featuring energy recovery and 2000 W peak power
- Single- and multi-channel digital controllers with dynamic digital linearization (DDL) to eliminate tracking error
- Patented feedforward technology and digital signal processing for faster settling and higher bandwidth
- Modular NanoAutomation® piezo controllers with high-speed parallel interfaces
- Optional opto-isolated inputs for maximum EMI immunity
- Optimized mechanical design, control algorithms and software for highest throughput

Piezoelectric nanopositioning systems large (e.g. for precision machining), medium (e.g. for interferometry), small (e.g. for data storage medium testing)

Typical Applications

- CD, DVD mastering, testing
- Image stabilization, resolution enhancement
- Photonics alignment & packaging
- Fiber optic switches
- Scanning interferometry
- Vibration cancellation
- Laser beam steering
- Adaptive optics
- Scanning microscopy
- Auto-focus systems
- Nanometrology
- Wafer and mask positioning / alignment
- Microlithography
- Fast tool servos
- Smart structures / structural deformation
- Nanopositioning
- Semiconductor test equipment
- Precision machining (non-circular turning, boring, grinding, polishing)
- Biotechnology

Piezo Flexure Stages / High-Speed Scanning Systems



Piezo Systems

Precision Flexure-Guided Nanopositioners and Scanners

Drive, sensors, mechanics and control electronics with software – components of PI's positioning systems

From Piezo Actuators to Piezo Nanopositioning and Scanning Systems

Piezo ceramic actuators are at the heart of most PI nanopositioning systems. These actuators provide sub-nanometer resolution and sub-millisecond response time by frictionless motion based on molecular effects. To form a high performance nanopositioning system, the intrinsic advantages of the piezo drive have to be complemented by a frictionless, stiff guidance system and highly linear, responsive nanometrology sensors for position feedback. Sophisticated digital servo systems, low noise drivers and control algorithms are necessary to support the mechanical part of the nanopositioning system.

Flexures – the Main Mechanical Component

Flexure motion is based on the elastic deformation (flexing) of a solid material. Friction and stiction are entirely eliminated, and flexures exhibit high stiffness, load capacity and resistance to shock and vibration. Flexures are maintenance free and not subject to wear. They are vacuum compatible, operate over a wide temperature range and require neither lubricants nor compressed air for operation. PI flexures are optimized for highest possible stiffness and straightness / flatness in the nanometer realm combined in many cases with integrated motion amplifiers. This allows for extended travel up to the millimeter range.

Excellent Guiding Accuracy

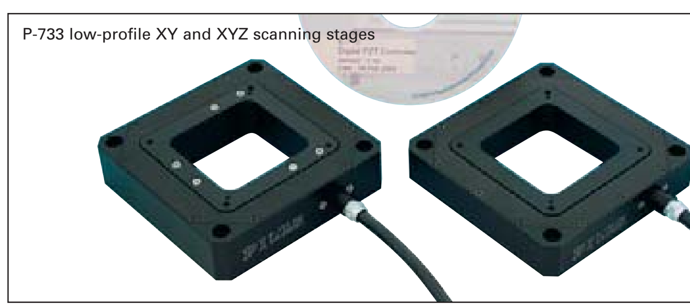
The multilink flexure guiding systems employed in most PI piezo nanopositioners eliminate cosine errors and provide bidirectional flatness and straightness in the nanometer or microradian range. This high precision means that even the most demanding positioning tasks can be run bidirectionally for higher throughput.

Lifetime / PICMA® Piezo Actuators

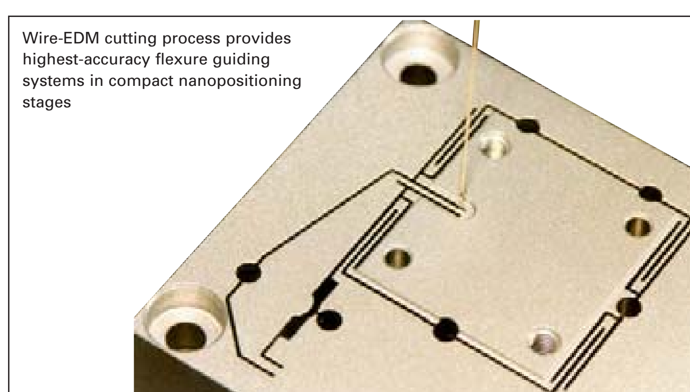
PI nanopositioning systems employ the award-winning PICMA® piezo actuators, the only actuators with co-fired ceramic encapsulation. The PICMA® piezo technology was specifically developed by PI's piezo ceramic division to provide higher performance and lifetime in nanopositioning applications.

Multilayer piezo actuators are similar to ceramic capacitors and are not affected by wear and tear. Read p. 2-12 *ff* for details.

Linear Actuators & Motors
Nanopositioning / Piezoelectrics
Piezo Flexure Stages / High-Speed Scanning Systems
Linear
Vertical & Tip/Tilt
2- and 3-Axis
6-Axis
Fast Steering Mirrors / Active Optics
Piezo Drivers / Servo Controllers
Single-Channel
Multi-Channel
Modular
Accessories
Piezoelectrics in Positioning
Nanometrology
Micropositioning
Index



P-733 low-profile XY and XYZ scanning stages



Wire-EDM cutting process provides highest-accuracy flexure guiding systems in compact nanopositioning stages

CE & RoHS Compliance

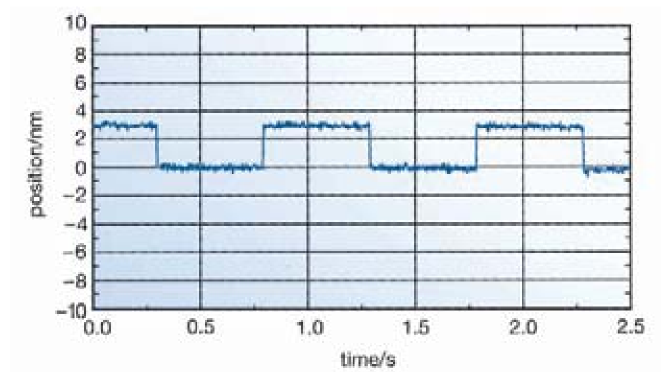
All standard PI nanopositioning systems are fully CE and RoHS compliant.

Measuring Nanometers: Stage Metrology Selection

Achieving nanometer and subnanometer precision requires a stage internal metrology system, capable of measuring motion on the nanometer scale. The five primary characteristics to consider when selecting a stage metrology system are linearity, sensitivity (resolution), stability, bandwidth, and cost. Other factors include the ability to measure the moving platform directly and contact vs. noncontact measurement. Three types of sensors are typically used in piezo nanopositioning applications—capacitive, strain, and LVDT. Table 1 summarizes the characteristics of each sensor type. For long travel ranges of 1mm and above, classical piezo multilayer or stack drives are replaced by PiezoWalk® motors. These unique drives are complemented by special optical linear sensors to achieve nanometer precision and linearities of 0.001%.

PI capacitive sensors measure the gap between two plates or one plate and a planar, conducting surface based on electrical capacitance. These sensors can be designed to become an integral part of a nanopositioning system, with virtually no effect on size and mass (inertia). Capacitive sensors offer the highest resolution, stability, and bandwidth. They enable direct measurement of the moving platform and are noncontact. Capacitive sensors also offer the highest linearity (accuracy). PI's capacitive sensors / control electronics use a high-frequency AC excitation signal for enhanced bandwidth and drift-free measurement stability (subnanometer stability over several hours, see p. 3-17 *ff*). PI's exclusive ILS linearization system further improves system linearity. If used with PI's digital controllers, digital polynomial linearization of mechanics and electronics makes possible an overall system linearity of better than 0.01%. Capacitive sensors are the metrology system of choice for the most demanding applications.

A strain gauge sensor is a resistive metal or semiconductor film bonded to a piezo stack or—for enhanced precision—to the guiding system of a flexure stage. It offers high resolution and bandwidth and is typically chosen for cost-sensitive applications. As a contact type sensor, it measures indirectly, in that the position of the moving platform is inferred from a measurement at the lever, flexure or stack. PI employs full-bridge implementations with multiple strain gauges per axis for enhanced thermal stability. PI's PICMA® drive technology also enables higher performance of actuator-applied strain gauge sensors.



Response of a PI Nanopositioning stage to a square wave control signal clearly shows the true sub-nm positional stability, incremental motion and bidirectional repeatability. Measured with external capacitive gauge, 20 pm resolution.

LVDT sensors measure magnetic energy in a coil. A magnetic core attached to the moving platform moves within a coil attached to the frame producing a change in the inductance equivalent to the position change. LVDT sensors provide noncontact, direct measurements of position. They are cost-effective and offer high stability and repeatability.

Table 1

Sensor Type	Sensitivity* (Resolution)	Linearity*	Sability* / Repeatability	Bandwidth*	Metrology Type	Excitation Signal
Capacitive	Best	Best	Best	Best	Direct / Noncontact	AC
Strain	Better	Good	Good	Better	Inferred** (Indirect) / Contact	DC
LVDT	Good	Good	Better	Good	Direct / Noncontact	AC
Linear Encoder	Best***	Best***	Best***	Better	Direct / Noncontact	DC

*The ratings describe the influence of the sensor on the performance of the whole nanopositioning system. Resolution, linearity, repeatability, etc. specifications in the PI product data sheets indicate the performance of the complete system and include the controller, mechanics and sensor. They are verified using external nanometrology equipment (Zygo Interferometers). It is important not to confuse these figures with the theoretical performance of the sensor alone.

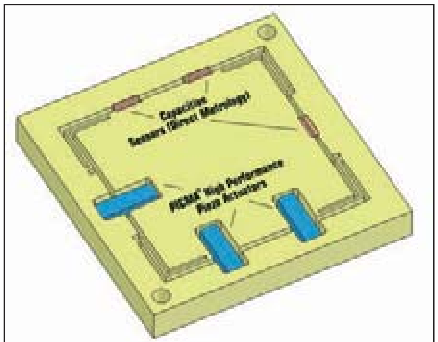
**Strain type sensors (metal foil, semiconductor, or piezoresistive) infer position information from strain.

***for travel ranges >1mm

Parallel and Serial Designs

There are two ways to achieve multi-axis motion: parallel and serial kinematics. Serial kinematics (nested or stacked systems) are simpler and less costly to implement, but they have some limitations compared to parallel kinematics systems.

In a multi-axis serial kinematics system, each actuator (and usually each sensor) is assigned to exactly one degree of freedom. In a parallel kinematics multi-axis system, all actuators act directly on the same moving platform (relative to ground), enabling reduced size and inertia, and the elimination of microfriction caused by moving cables. This way, the same resonant frequency and dynamic behavior can be obtained for both the X and Y axes. The advantages are higher dynamics and scanning rates, better trajectory guidance as well as better reproducibility and stability.

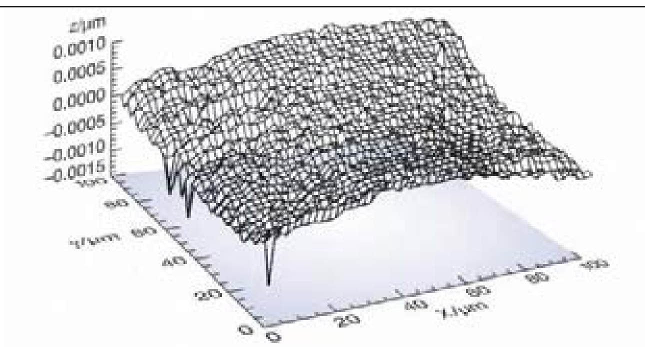


Principle of a PI XY-Theta-Z, minimum-inertial-mass, monolithic, parallel kinematics nanopositioning system. Accuracy, responsiveness and straightness/flatness are much better than in stacked multi-axis (serial kinematics) systems.

Direct Parallel Metrology: Multi-Axis Measurements Relative to a Fixed Reference

Parallel kinematics facilitates implementation of Direct Parallel Metrology—measurement of all controlled degrees of freedom relative to ground. This is a more difficult design to build but it leads to clear performance advantages.

A parallel metrology sensor sees all motion in its measurement direction, not just that of one actuator. This means that all motion is inside the servo-loop, no matter which actuator may have caused it, resulting in superior multi-axis precision, repeatability and flatness, as shown in the figure below. Direct parallel metrology also allows stiffer servo settings for faster response. Off-axis disturbances—external or internal, such as induced vibration caused by a fast step of one axis—can be damped by the servo.



Flatness of an active-trajectory-controlled nanopositioning stage over 100 x 100 µm scanning range is about 1 nm

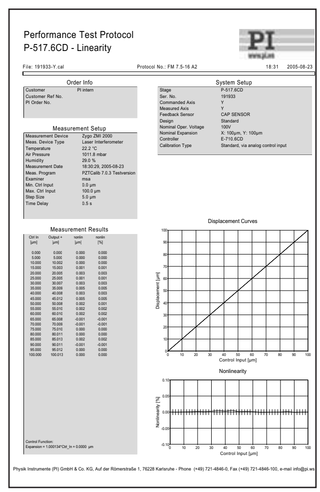
Linear Actuators & Motors
Nanopositioning / Piezoelectrics
Piezo Flexure Stages / High-Speed Scanning Systems
Linear
Vertical & Tip/Tilt
2- and 3-Axis
6-Axis
Fast Steering Mirrors / Active Optics
Piezo Drivers / Servo Controllers
Single-Channel
Multi-Channel
Modular
Accessories
Piezoelectrics in Positioning
Nanometrology
Micropositioning
Index

Test & Metrology Protocol for Piezo Systems
Getting What You Bargained For

Piezo nanopositioning systems are significant investments and PI believes in optimizing the performance of every customer's system. PI individually tests every stage and optimizes the static and dynamic performance for the customer's application. The metrology test protocol is part of the system's delivery package. It shows the customer what the performance of the system was at the time of delivery and which system components belong together. For PI every metrology procedure and its recording is a quality assurance instrument, and only nanopositioning systems which meet their specifications will leave the premises.

Furthermore, PI makes significant continuing investments in improved-quality, higher-performance nanometrology equipment so that we can deliver better value to our customers.

Because a nanomechanism can only be as accurate as the equipment it was tuned and tested with, PI closed-loop stages are measured exclusively with prestigious Zygo interferometers. PI's nanometrology metrology laboratories are seismically, electromagnetically and thermally isolated, with temperatures controlled to better than 0.25 °C / 24 hrs. We are confident that our metrology capabilities and procedures are the benchmark for the industry.



Performance Test Protocol
P-517.6CD - Linearity

File: 191933-Y.cal | Protocol No.: FM 7.5-16 A2 | 18:31 2005-08-23

Order Info

Customer	PI intern
Customer Ref No.	
PI Order No.	

System Setup

Stage	P-517.6CD
Ser. No.	191933
Commanded Axis	Y
Measured Axis	Y
Feedback Sensor	CAP SENSOR
Design	Standard
Nominal Oper. Voltage	100V
Nominal Expansion	X: 100µm, Y: 100µm
Controller	E-710.6CD
Calibration Type	Standard, via analog control input

Measurement Setup

Measurement Device	Zygo ZMI 2000
Meas. Device Type	Laser Interferometer
Temperature	22.2 °C
Air Pressure	1011.8 mbar
Humidity	29.0 %
Measurement Date	18:30:29, 2005-08-23
Meas. Program	PZTCalib 7.0.3 Testversion
Examiner	msa
Min. Ctrl Input	0.0 µm
Max. Ctrl Input	100.0 µm
Step Size	5.0 µm
Time Delay	0.5 s

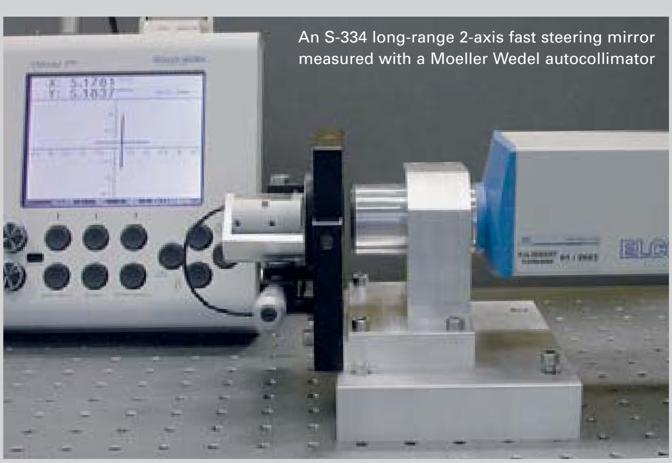
Measurement Results

Ctrl In [µm]	Output + [µm]	nonlin [µm]	nonlin [%]
0.000	0.000	0.000	0.000
5.000	5.000	0.000	0.000
10.000	10.002	0.000	0.000
15.000	15.003	0.001	0.001
20.000	20.005	0.003	0.003
25.000	25.005	0.001	0.001
30.000	30.007	0.003	0.003
35.000	35.009	0.005	0.005
40.000	40.008	0.003	0.003
45.000	45.012	0.005	0.005
50.000	50.008	0.002	0.001
55.000	55.010	0.002	0.002
60.000	60.010	0.002	0.002
65.000	65.008	-0.001	-0.001
70.000	70.009	-0.001	-0.001
75.000	75.010	0.000	0.000
80.000	80.011	0.000	0.000
85.000	85.013	0.002	0.002
90.000	90.011	-0.001	-0.001
95.000	95.012	0.000	0.000
100.000	100.013	0.000	0.000

Control Function:
Expansion = 1.000134*Ctrl_In + 0.0000 µm

Physik Instrumente (PI) GmbH & Co. KG, Auf der Römerstraße 1, 76228 Karlsruhe - Phone (+49) 721-4846-0, Fax (+49) 721-4846-100, e-mail info@pi.ws

All PI nanopositioning systems come with extensive system performance documentation

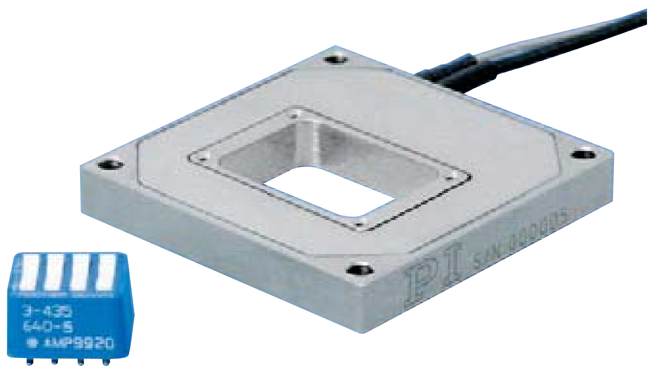


An S-334 long-range 2-axis fast steering mirror measured with a Moeller Wedel autocollimator

An S-340 2-axis fast steering mirror platform measured with a Zygo interferometer

P-712 Low-Profile Piezo Scanner

Compact OEM System



P-712 piezo scanner with up to 40 µm travel range

- **High Dynamic, to 5 ms Settling Time**
- **Travel Range up to 40 µm**
- **Resolution to 0.2 nm**
- **Compact Design with Low Profile, 40 x 40 x 6 mm**
- **Clear Aperture 25 x 15 mm**
- **PICMA® High-Power Actuators**

P -712 piezo scanners are ideal for applications where limited space requires small-sized equipment. The high resonant frequency allows for fast linear scanning with 30 µm travel in one axis and provides settling times of about 5 ms. The P-712 linear scanner is offered in two versions, one with SGS position sensors for closed-loop operation, and one without sensors for open-loop.

Application Examples

- Optical path tuning
- Biotechnology
- Medical technology
- Image processing / stablilization
- CCD / CMOS camera technology

A similar XY version is available with product number P-713 / P-714 (see p. 2-56).

Excellent Guiding Accuracy

Flexures optimized with Finite Element Analysis (FEA) are used to guide the stage. FEA techniques are used to give the design the highest possible stiffness in, and perpendicular to, the direction of motion, and to minimize linear and angular runout. Flexures allow extremely high-precision motion, no matter how minute, as they are completely free of play and friction.

Electric discharge machining (EDM) with fine cutting wires is used to obtain the required precision for the flexures which make up the guidance system and determine the stiffness.

Optional Position Control

High-resolution, broadband, strain gauge sensors (SGS) are applied to appropriate locations on the drive train and measure the displacement of the moving part of the stage relative to the base indirectly. The SGS sensors assure optimum position stability in the nanometer range and fast response.

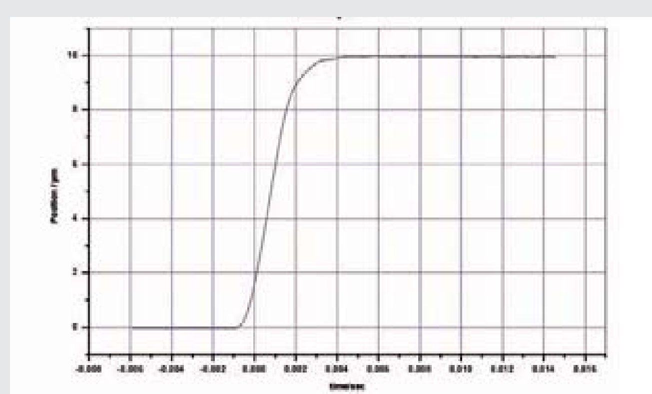
Ceramic Insulated Piezo Actuators Provide Long Lifetime

Highest possible reliability is assured by the use of award-winning PICMA® multilayer piezo actuators. PICMA® actuators are the only actuators on the market with ceramic-only insulation, which makes them resistant to ambient humidity and leakage-current failures. They are thus far superior to conventional actuators in reliability and lifetime.

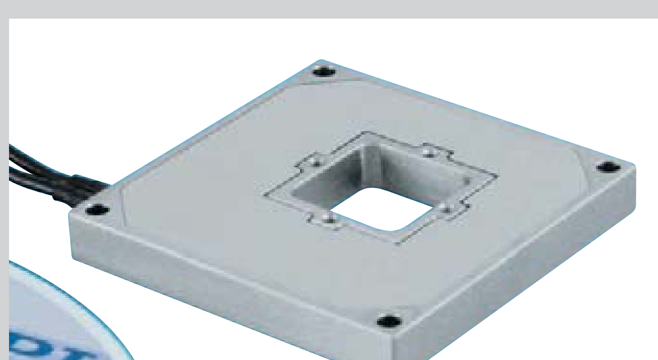
Ordering Information

P-712.10L
Low-Profile OEM Nanoscanner, 40 µm, Open-Loop

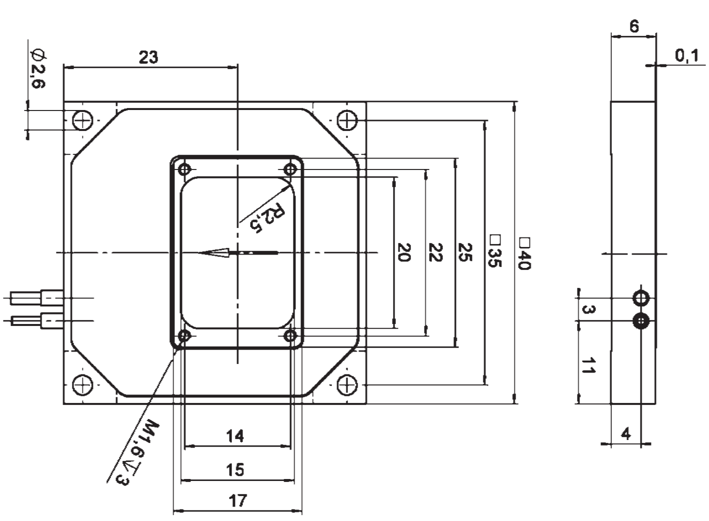
P-712.1SL
Low-Profile OEM Nanoscanner, 30 µm, SGS-Sensor



Settling time for the P -712 at 30 µm is in the 5 ms range



The P -713 XY-scanner is based on the same principle as the P -712 offering a travel range of 15 x 15 µm and a very high resonant frequency of over 2 kHz



P-712 dimensions in mm

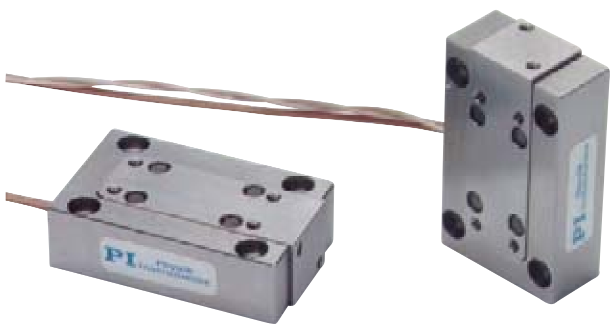
Technical Data

Model	P-712.1SL	P-712.10L	Units	Tolerance
Active axes	X	X		
Motion and positioning				
Integrated sensor	SGS	–		
Open-loop travel, -20 to +120 V	40	40	µm	min. (+20 %/0 %)
Closed-loop travel	30	–	µm	calibrated
Closed-loop resolution	2	–	nm	typ.
Open-loop resolution	0.2	0.2	nm	typ.
Linearity, closed-loop	0.3	–	%	typ.
Repeatability	±5	–	nm	typ.
Pitch	±5	±5	µrad	typ.
Yaw	±20	±20	µrad	typ.
Mechanical properties				
Stiffness in motion direction	0.6	0.6	N/µm	±20 %
Unloaded resonant frequency	1550	1550	Hz	±20 %
Resonant frequency under load	1090 (20 g)	1090 (20 g)	Hz	±20 %
Push/pull force capacity in motion direction	6	6	N	Max.
Load capacity	5	5	N	Max.
Lateral Force	6	6	N	Max.
Drive properties				
Ceramic type	PICMA® P-882	PICMA® P-882		
Electrical capacitance	0.3	0.3	µF	±20 %
Dynamic operating current coefficient	1.3	1.3	µA/(Hz • µm)	±20 %
Miscellaneous				
Operating temperature range	-20 to 80	-20 to 80		
Material	Stainless steel	Stainless steel		
Dimensions	40 x 40 x 6	40 x 40 x 6	mm	
Mass	0.095	0.095	kg	±5 %
Cable length	1.5	1.5	m	±10 mm
Voltage connection	LEMO	LEMO		
Sensor connector	LEMO	–		

Recommended controller / amplifier
Single-channel (1 per axis): E-610 servo controller / amplifier (p. 2-110), E-625 servo controller, bench-top (p. 2-114)

P-753 LISA Linear Actuator & Stage

High-Dynamics, Very Stable Piezo Nanopositioner



P-753.11C LISA nano-precision actuators / positioning stages

- **Versatile Design: Flexure Stage or Actuator**
- **Resolution 0.05 nm, Rapid Response**
- **Capacitive Sensors for Highest Linearity**
- **Frictionless Precision Flexure Guidance for Frictionless, Ultra-Straight Motion**
- **Outstanding Lifetime Due to PICMA® Piezo Actuators**
- **Vacuum-Compatible and Nonmagnetic Versions Available**

The P-753 LISA (Linear Stage Actuators) high-speed nanopositioners can be used both as linear actuators or as translation stages. They are equipped with capacitive feedback sensors, frictionless, flexure guiding systems and high-performance piezo drives providing a positioning and scanning range of up to 38 µm with very fast settling time and extremely low tip/tilt error.

Application Examples

- Disc-drive-testing
- Metrology
- Nanopositioning
- Scanning microscopy
- Photonics / integrated optics
- Interferometry
- Biotechnology
- Micromanipulation

Direct-Drive Design for Fastest Response

The direct-drive design, together with careful attention to mass minimization, results in significant reduction in inertial recoil forces applied to the supporting structures, enhancing overall system response, throughput and stability with settling times in the millisecond range.

PI's proprietary capacitive sensors measure position directly and without physical contact. They are free of friction and hysteresis, a fact which, in combination with the positioning resolution of well under 1 nm, makes it possible to achieve very high levels of linearity. A further advantage of direct metrology with capacitive sensors is the high phase fidelity and the high bandwidth of up to 10 kHz.

Automatic Configuration

The „.CD“ versions are equipped with an ID-chip that stores all individual stage data and servo-control parameters. This data is read out automatically by the AutoCalibration Function of PI's digital piezo controllers. Thus, digital controllers and nanopositioning stages with ID-chip can be operated in any combination.

High Reliability and Long Lifetime

The compact P-753 LISA systems are equipped with preloaded PICMA® high-performance piezo actuators which are integrated into a sophisticated, FEA-modeled, flexure guiding system. The PICMA® actuators feature cofired ceramic encapsulation and thus offer better performance and reliability than conventional piezo actuators. Actuators, guidance and sensors are maintenance-free and not subject to wear, and thus offer an extraordinary reliability.

Ordering Information

P-753.11C
LISA High-Dynamics Nanopositioning System, 12 µm, Direct Metrology, Capacitive Sensor, LEMO Connector

P-753.21C
LISA High-Dynamics Nanopositioning System, 25 µm, Direct Metrology, Capacitive Sensor, LEMO Connector

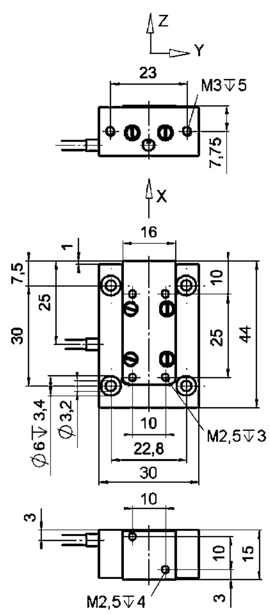
P-753.31C
LISA High-Dynamics Nanopositioning System, 38 µm, Direct Metrology, Capacitive Sensor, LEMO Connector

P-753.1CD*
LISA High-Dynamics Nanopositioning System, 12 µm, Direct Metrology, Capacitive Sensor, Sub-D Connector

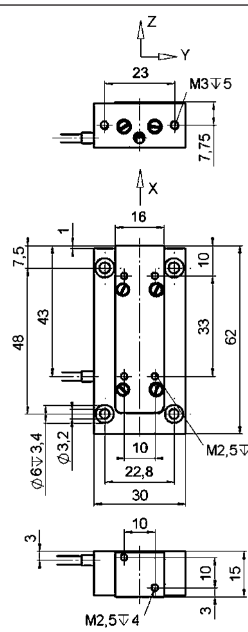
P-753.2CD*
LISA High-Dynamics Nanopositioning System, 25 µm, Direct Metrology, Capacitive Sensor, Sub-D Connector

P-753.3CD*
LISA High-Dynamics Nanopositioning System, 38 µm, Direct Metrology, Capacitive Sensor, Sub-D Connector

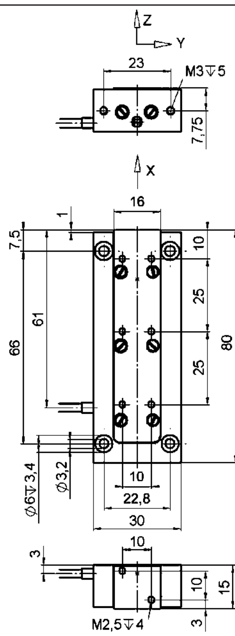
*Vacuum versions to 10^{-9} hPa are available as P-753.xUD, non-magnetic vacuum versions can be ordered as P-753.xND.



P-753.1 dimensions in mm, max. torque at M2.5 threads: 30 Ncm



Picture sub text 03
P-753.2 dimensions in mm, max. torque at M2.5 threads: 30 Ncm



P-753.3 dimensions in mm, max. torque at M2.5 threads: 30 Ncm

Technical Data

Model	P-753.11C	P-753.21C	P-753.31C	P-753.1CD	P-753.2CD	P-753.3CD	Units	Tolerance
Active axes	X	X	X	X	X	X		
Motion and positioning								
Integrated sensor	Capacitive	Capacitive	Capacitive	Capacitive	Capacitive	Capacitive		
Closed-loop travel	12	25	38	12	25	38	µm	calibrated
Closed-loop / open-loop resolution	0.05	0.1	0.2	0.05	0.1	0.2	nm	typ., full travel
Linearity, closed-loop	0.03	0.03	0.03	0.03	0.03	0.03	%	typ.
Repeatability	±1	±2	±3	±1	±2	±3	nm	typ.
Pitch / yaw	±5	±7	±10	±5	±7	±10	µrad	typ.
Mechanical properties								
Stiffness in motion direction	45	24	16	45	24	16	N/µm	±20 %
Unloaded resonant frequency	5.6	3.7	2.9	5.6	3.7	2.9	kHz	±20 %
Resonant frequency @ 200 g	2.5	1.7	1.4	2.5	1.7	1.4	kHz	±20 %
Push/pull force capacity in motion direction	100 / 20	100 / 20	100 / 20	100 / 20	100 / 20	100 / 20	N	Max.
Load capacity (vertical/horizontal mounting)	10 / 2	10 / 2	10 / 2	10 / 2	10 / 2	10 / 2	kg	Max.
Drive properties								
Ceramic type	PICMA® P-885	PICMA® P-885	PICMA® P-885	PICMA® P-885	PICMA® P-885	PICMA® P-885		
Electrical capacitance	1.5	3.1	4.6	1.5	3.1	4.6	µF	±20 %
Dynamic operating current coefficient	12	15	15	12	15	15	µA/(Hz • µm)	±20 %
Miscellaneous								
Operating temperature range	-20 to 80	-20 to 80	-20 to 80	-20 to 80	-20 to 80	-20 to 80	°C	
Material	Stainless steel	Stainless steel	Stainless steel	Stainless steel	Stainless steel	Stainless steel		
Dimensions	44 x 30 x 15	44 x 30 x 62	44 x 30 x 80	44 x 30 x 15	44 x 30 x 62	44 x 30 x 80	mm	
Mass	0.15	0.205	0.25	0.16	0.215	0.26	kg	±5 %
Cable length	1.5	1.5	1.5	1.5	1.5	1.5	m	±10 mm
Sensor / voltage connection	LEMO	LEMO	LEMO	Sub-D Special	Sub-D Special	Sub-D Special		

Resolution of PI Piezo Nanopositioners is not limited by friction or stiction. Value given is noise equivalent motion with E-503 (p. 2-146) amplifier.
Recommended controller / amplifier
LEMO connector: E-500 (p. 2-142) piezo controller system with E-505 high-power amplifier (p. 2-147) and E-509 servo module (p. 2-152)
Sub-D special connector: E-610 servo controller / amplifier card (p. 2-110), E-625 servo controller, bench-top (p. 2-114), E-665 high-power display controller, bench-top (p. 2-116), E-753 digital controller (p. 2-108)

Piezo • Nano • Positioning

P-752 High Precision Nanopositioning Stage

High-Dynamics, Very Stable Piezo Scanner with Extreme Guiding Accuracy

P-752.11C piezo nanopositioning system

- **0.1 nm Resolution, Fast Response**
- **Travel to 35 µm**
- **Capacitive Sensors for Highest Linearity**
- **Flexure Guidance for Frictionless, Ultra-Straight Motion**
- **Outstanding Lifetime Due to PICMA® Piezo Actuators**

P-752 series high-speed nanopositioning stages are extremely precise devices, providing a positioning and scanning range up to 30 µm with very rapid settling and extremely low tip/tilt errors. These stages were specially designed for high-speed dithering and disk drive testing applications.

Application Examples

- Disc-drive-testing
- Metrology
- Nanopositioning
- Scanning microscopy
- Photonics / integrated optics
- Interferometry
- Biotechnology
- Micromanipulation

Direct-Drive Design for Fastest Response

The direct-drive design, together with careful attention to mass minimization, results in significant reduction in inertial recoil forces applied to the supporting structures, enhancing overall system response, throughput and stability. In combination with the E-500 controller system the P-752.11C stage with 300 g load settles to better than 1 % with less 10 msec.

P-752 stages are equipped with capacitive sensors providing sub-nanometer resolution and stability. PI's proprietary capacitive sensors measure position directly and without physical contact. They are free of friction and hysteresis, a fact which, in combination with the positioning resolution of well under 1 nm, makes it possible to achieve very high levels of linearity. Further advantages of direct metrology with capacitive sensors are the high phase fidelity and the high bandwidth of up to 10 kHz.

Automatic Configuration

The ".CD" versions are equipped with an ID-chip that stores all individual stage data and servo-control parameters. This data is read out automatically by the AutoCalibration function of PI's digital piezo controllers. Thus, digital controllers and nanopositioning stages with ID-chip can be operated in any combination.

Higher Precision in Periodic Motion

The highest dynamic accuracy in scanning applications is made possible by the DDL algorithm, which is available in most of PI's modern digital controllers. DDL eliminates tracking errors, improving dynamic linearity and usable bandwidth by up to three orders of magnitude!

High Reliability and Long Lifetime

The compact P-752 systems are equipped with preloaded PICMA® high-performance piezo actuators which are integrated into a sophisticated, FEA-modeled, flexure guiding system. The PICMA® actuators feature cofired ceramic encapsulation and thus offer better performance and reliability than conventional piezo actuators. Actuators, guidance and sensors are maintenance-free and not subject to wear, and thus offer an extraordinary reliability.

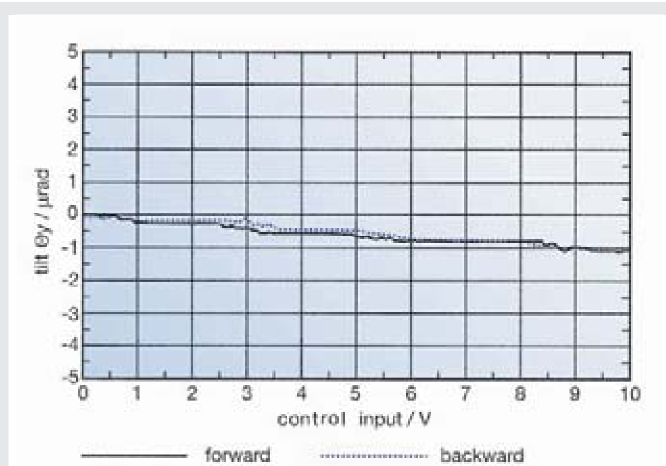
Ordering Information

P-752.11C
High-Dynamics Piezo Nanopositioning System, 15 µm, Direct Metrology, Capacitive Sensor, LEMO Connector

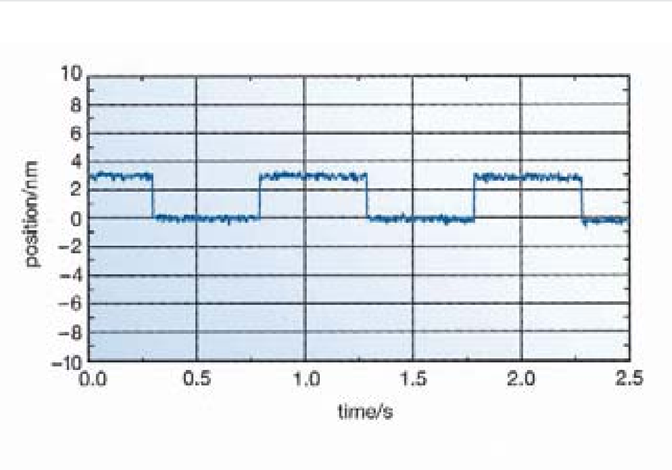
P-752.21C
High-Dynamics Piezo Nanopositioning System, 30 µm, Direct Metrology, Capacitive Sensor, LEMO Connector

P-752.1CD
High-Dynamics Piezo Nanopositioning System, 15 µm, Direct Metrology, Capacitive Sensor, Sub-D Connector

P-752.2CD
High-Dynamics Piezo Nanopositioning System, 30 µm, Direct Metrology, Capacitive Sensor, Sub-D Connector



Typical 0.5 µrad bidirectional trajectory repeatability (P-752.11C stage) means processes may be performed bidirectionally for twice the productivity



Response of a P-752.11C to a square wave control signal with 3 nm amplitude shows true sub-nm positional stability, incremental motion and bidirectional repeatability (measured with E-501 & E-503.00 & E-509.C1 controller, bandwidth set to 240 Hz)

Technical Data

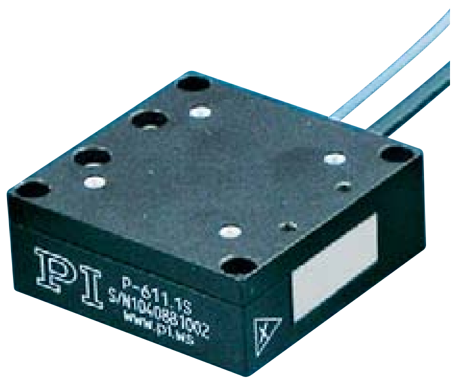
Model	P-752.11C	P-752.1CD	P-752.21C	P-752.2CD	Units	Tolerance
Active axes	X	X	X	X		
Motion and positioning						
Integrated sensor	Capacitive	Capacitive	Capacitive	Capacitive		
Open-loop travel, -20 to +120 V	20	20	35	35	µm	min. (+20 %/-0 %)
Closed-loop travel	15	15	30	30	µm	calibrated
Closed-loop / open-loop resolution	0.1	0.1	0.2	0.2	nm	typ.
Linearity, closed-loop	0.03	0.03	0.03	0.03	%	typ.
Repeatability	±1	±1	±2	±2	nm	typ., full travel
Pitch / yaw	±1	±1	±1	±1	µrad	typ.
Mechanical properties						
Stiffness in motion direction	30	30	20	20	N/µm	±20 %
Unloaded resonant frequency	3200	3200	2100	2100	Hz	±20 %
Resonant frequency @ 300 g	980	980	600	600	Hz	±20 %
Push/pull force capacity in motion direction	100 / 10	100 / 10	100 / 10	100 / 10	N	Max.
Load capacity	30	30	30	30	N	Max.
Drive properties						
Ceramic type	PICMA® P-885	PICMA® P-885	PICMA® P-885	PICMA® P-885		
Electrical capacitance	2.1	2.1	3.7	3.7	µF	±20 %
Dynamic operating current coefficient	17	17	15	15	µA/(Hz • µm)	±20 %
Miscellaneous						
Operating temperature range	-20 to 80	-20 to 80	-20 to 80	-20 to 80	°C	
Material	Stainless steel	Stainless steel	Stainless steel	Stainless steel		
Dimensions	66 x 40 x 13.5	66 x 40 x 13.5	84 x 40 x 13.5	84 x 40 x 13.5	mm	
Mass	0.25	0.25	0.35	0.35	kg	±5 %
Cable length	1.5	1.5	1.5	1.5	m	±10 mm
Sensor / voltage connection	LEMO	Sub-D Special	LEMO	Sub-D Special		

Resolution of PI Piezo Nanopositioners is not limited by friction or stiction. Value given is noise equivalent motion with E-503 (p. 2-146) amplifier.

Recommended controller / amplifier
LEMO connector: E-500 piezo controller system (p. 2-142) with E-505 high-power amplifier (p. 2-147) and E-509 servo module (p. 2-152)
Sub-D special connector: E-610 servo controller / amplifier (p. 2-110), E-625 servo controller, bench-top (p. 2-114), E-665 high-power display controller, bench-top (p. 2-116), E-753 digital controller (p. 2-108)

P-611.1 Piezo Nanopositioner

Cost-Effective, Compact Linear Positioning System



P-611.1 linear nanopositioning system, 100 µm travel, resolution of 0.2 nm

- **Compact Design: Footprint 44 x 44 mm**
- **Travel Range to 120 µm**
- **Resolution to 0.2 nm**
- **Cost-Effective Mechanics/Electronics System Configurations**
- **Outstanding Lifetime Due to PICMA® Piezo Actuators**
- **Z Stage, XY, XZ and XYZ Versions Available**

P-611.1 piezo stages are flexure-guided nanopositioning systems featuring a compact footprint of only 44 x 44 mm. The linear stages described here are part of the P-611 family of positioners available in 1 to 3 axis configurations. Despite their small dimensions, the systems provide up to 120 µm travel with sub-nanometer resolution. They are ideally suited for positioning tasks such as optical-path length correction in interferometry, sample positioning in microscopy or scanning applications. Equipped with ceramic-encapsulated piezo drives and a stiff zero-stiction, zero-friction flexure guiding system, all P-611 piezo stages combine millisecond responsiveness with nanometric precision and extreme reliability.

Application Examples

- Micromachining
- Microscopy
- Micromanipulation
- Semiconductor testing

Closed-Loop and Open-Loop Versions

High-resolution, fast-responding, strain gauge sensors (SGS) are applied to appropriate locations on the drive train and provide a high-bandwidth, nanometer-precision position feedback signal to the controller. The sensors are connected in a full-bridge configuration to eliminate thermal drift, and assure optimal position stability in the nanometer range.

The open-loop models are ideal for applications where fast response and very high resolution are essential, but absolute positioning is not important. They can also be used when the position is controlled by an external feedback system such as an interferometer, a PSD (position sensitive diode), CCD chip / image processing system, or the eyes and hands of an operator.

Versatility & Combination with Motorized Stages

The P-611 family of piezo stages comprises a variety of single- and multi-axis versions (X, XY, Z, XZ and XYZ) that can be easily combined with a number of very compact manual or motorized micropositioning systems to form coarse/fine positioners with longer travel ranges (see p. 2-36, 2-50 *ff*).

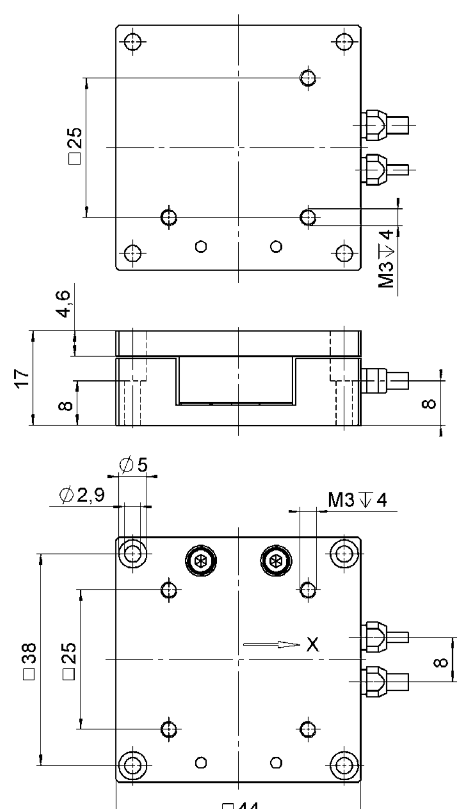
High Reliability and Long Lifetime

The compact P-611 systems are equipped with preloaded PICMA® high-performance piezo actuators which are integrated into a sophisticated, FEA-modeled, flexure guiding system. The PICMA® actuators feature cofired ceramic encapsulation and thus offer better performance and reliability than conventional piezo actuators. Actuators, guidance and sensors are maintenance-free and not subject to wear, and thus offer an extraordinary reliability.

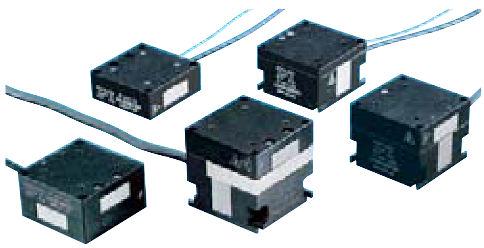
Ordering Information

P-611.10
Linear Nanopositioning System, 120 µm, No Sensor

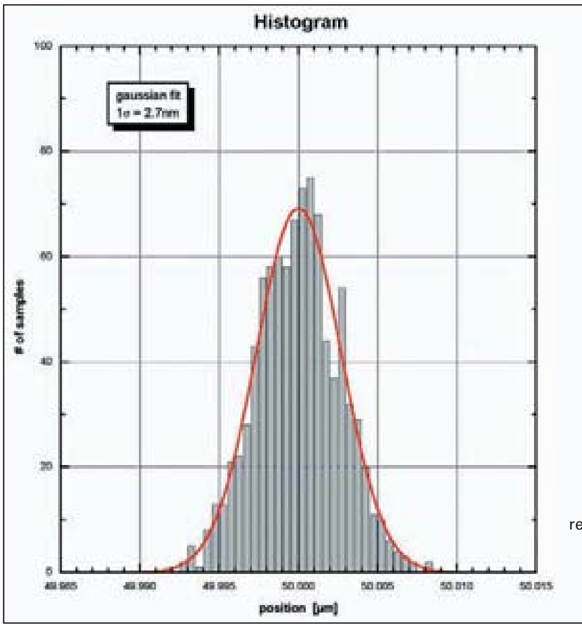
P-611.1S
Linear Nanopositioning System, 100 µm, SGS-Sensor



P-611.1S dimensions in mm



The whole P-611 family: X, Z, XY, XZ and XYZ stages



P-611.1S repeatability equals 2.7 nm

System properties	
System configuration	P-611.1S and E-665.SR controller, 30 g load
Closed-loop amplifier bandwidth, small signal	45 Hz
Settling time (10 % step width)	18 ms

Technical Data

Model	P-611.1S	P-611.10	Unit	Tolerance
Active axes	X	X		
Motion and positioning				
Integrated sensor	SGS	–		
Open-loop travel, -20 to 120 V	120	120	µm	min. (+20 %/0 %)
Closed-loop travel	100	–	µm	calibrated
Open-loop resolution	0.2	0.2	nm	typ.
Closed-loop resolution	2	–	nm	typ.
Linearity, closed-loop	0.1	–	%	typ.
Repeatability	<10	–	nm	typ.
Pitch	±5	±5	µrad	typ.
Yaw	±20	±20	µrad	typ.
Flatness	10	10	nm	typ.
Mechanical properties				
Stiffness in motion direction	0.2	0.2	N/µm	±20 %
Unloaded resonant frequency	400	400	Hz	±20 %
Resonant frequency @ 30 g	300	300	Hz	±20 %
Resonant frequency @ 100 g	195	195	Hz	±20 %
Push/pull force capacity in motion direction	15 / 10	15 / 10	N	Max.
Load capacity	15	15	N	Max.
Drive properties				
Ceramic type	PICMA® P-885	PICMA® P-885		
Electrical capacitance	1.5	1.5	µF	±20 %
Dynamic operating current coefficient	1.9	1.9	µA/(Hz • µm)	±20 %
Miscellaneous				
Operating temperature range	-20 to 80	-20 to 80	°C	
Material	Aluminum, steel	Aluminum, steel		
Dimensions	44 x 44 x 17	44 x 44 x 17	mm	
Mass	0.135	0.135	kg	±5 %
Cable length	1.5	1.5	m	±10 mm
Voltage connection	LEMO	LEMO		
Sensor connector	LEMO	–		

Resolution of PI Piezo Nanopositioners is not limited by friction or stiction. Noise equivalent motion with E-503 amplifier (p. 2-146).
Dynamic Operating Current Coefficient in µA per Hz and µm. Example: Sinusoidal scan of 50 µm at 10 Hz requires approximately 0.9 mA drive current.

Recommended controller / amplifier
E-610 servo controller / amplifier (p. 2-110), E-625 servo controller, bench-top (p. 2-114), E-665 powerful servo controller, bench-top (p. 2-116), for open-loop systems:
E-660 bench-top (p. 2-119) for multiple independent axes:
E-621 controller module (p. 2-160)

P-620.1 – P-629.1 PIHera® Piezo Linear Stage

Compact Nanopositioning System Family with Long Travel Ranges

PIHera® piezo nanopositioning systems feature travel ranges from 50 to 1800 µm

- **Travel Ranges 50 to 1800 µm**
- **High-Precision, Cost-Efficient**
- **Resolution to 0.1 nm**
- **Direct Metrology with Capacitive Sensors**
- **0.02 % Positioning Accuracy**
- **Frictionless, High-Precision Flexure Guiding System**
- **Outstanding Lifetime Due to PICMA® Piezo Actuators**
- **X-, XY-, Z-, XYZ Versions**
- **Vacuum-Compatible Versions Available**

Single-axis PIHera® systems are piezo-nanopositioning stages featuring travel ranges from 50 to 1800 µm. Despite the increased travel ranges, the units are extremely compact and provide rapid response and high guiding precision. This and the long travel range is achieved with a friction-free and extremely stiff flexure system.

Application Examples

- Interferometry
- Microscopy
- Nanopositioning
- Biotechnology
- Quality assurance testing
- Semiconductor technology

The PIHera® piezo nanopositioning series also includes Z- and XY-stages (see p. 2-40, p. 2-54).

Nanometer Precision in Milliseconds

One of the advantages of PIHera® stages over motor-driven positioning stages is the rapid response to input changes and the fast and precise settling behavior. The P-622.1CD, for example, can settle to an accuracy of 10 nm in only 30 msec (other PI stages provide even faster response)!

Superior Accuracy With Direct-Metrology Capacitive Sensors

A choice of tasks such as optical path adjustment in interferometry, sample positioning in microscopy, precision alignment or optical tracking require the relatively long scanning ranges and nanometer precision offered by PIHera® nanopositioning stages.

PI's proprietary capacitive sensors measure position directly and without physical contact. They are free of friction and hysteresis, a fact which, in combination with the positioning resolution of well under 1 nm, makes it possible to achieve very high levels of linearity. A further advantage of direct metrology with capacitive sensors is the high phase fidelity and the high bandwidth of up to 10 kHz.

Designed for Precision

High stiffness is achieved with the FEA-optimized design of the frictionless flexure elements, which assure excellent guiding accuracy and dynamics. A straightness and flatness in the nanometer range is achieved.

Ordering Information

P-620.1CD* / P-620.1CL*
PIHera® Precision Piezo Linear Nanopositioning System, 50 µm, Direct Metrology, Capacitive Sensor

P-621.1CD* / P-621.1CL*
PIHera® Precision Piezo Linear Nanopositioning System, 100 µm, Direct Metrology, Capacitive Sensor

P-622.1CD* / P-622.1CL*
PIHera® Precision Piezo Linear Nanopositioning System, 250 µm, Direct Metrology, Capacitive Sensor

P-625.1CD* / P-625.1CL*
PIHera® Precision Piezo Linear Nanopositioning System, 500 µm, Direct Metrology, Capacitive Sensor

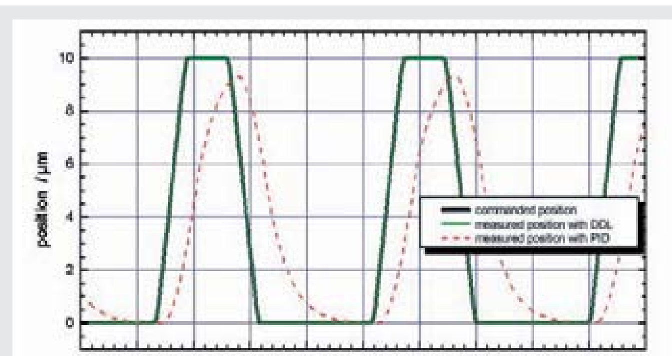
P-628.1CD* / P-628.1CL*
PIHera® Precision Piezo Linear Nanopositioning System, 800 µm, Direct Metrology, Capacitive Sensor

P-629.1CD* / P-629.1CL*
PIHera® Precision Piezo Linear Nanopositioning System, 1500 µm, Direct Metrology, Capacitive Sensor

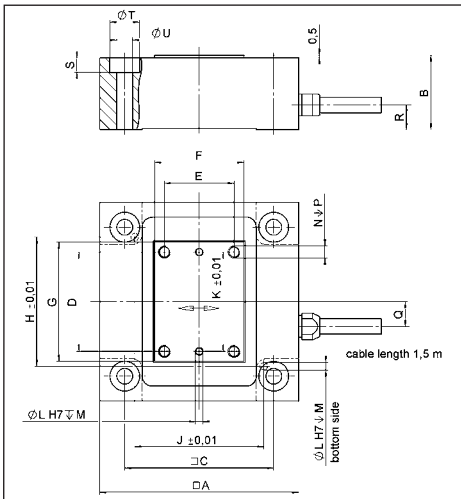
*.1CD with Sub-D Connector
*.1CL with LEMO Connector

Open-loop versions are available as P-62x.10L.
Vacuum versions to 10^{-9} hPa are available as P-62x.1UD.

System properties	
System configuration	P-625.1CD and E-500 modular piezo controller system with E-505.00F amplifier and E-509.C1A servo controller; 250 g load
Closed-loop amplifier bandwidth, large signal	30 Hz
Settling time (full travel)	31 ms



Rapid scanning motion of a P-621.1CD (commanded rise time 5 ms) with the E-710 controller ##600300 and Digital Dynamic Linearization (DDL) option. DDL virtually eliminates the tracking error (<20 nm) during the scan. The improvement over a classical PI controller is up to 3 orders of magnitude, and increases with the scanning frequency



	A	B	C	D	E	F	G	H	J	K	∅L	M	N	P	Q	R	S	∅T	∅U
P-620.1CD / 10L	30	12	24	15	12	15	18	19	24	15	1,01	1,5	M2	4	4,5	6	2	4,4	2,2
P-621.1CD / 10L	40	15	30	20	14	18	24	26	26	20	1,51	2,5	M2,5	5	5	5	3	6	3,2
P-622.1CD / 10L	50	15	40	24	20	25	30	35	35	24	1,51	2,5	M2,5	5	5,5	5	3	6	3,2
P-625.1CD / 10L	60	15	50	40	27	32	44,5	46	46	40	1,51	2,5	M2,5	5	5,5	5	3	6	3,2
P-628.1CD / 10L	80	17	70	58	41	45	63	66	66	58	1,51	2,5	M2,5	5	5,5	5	3	6	3,2

P-62x.1CD/.1CL/.10L dimensions in mm

PIHera® XYZ combination, P-62x.2 XY piezo stage (see p. 2-54), P-62x.Z vertical stage (see p. 2-40)

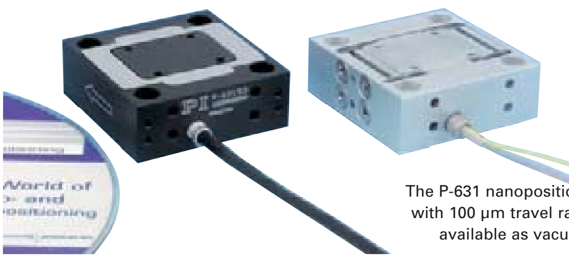
Technical Data

Model	P-620.1CD/ P-620.1CL	P-621.1CD/ P-621.1CL	P-622.1CD/ P-622.1CL	P-625.1CD/ P-625.1CL	P-628.1CD/ P-628.1CL	P-629.1CD/ P-629.1CL/	P-62x.10L open-loop version	Units	Tolerance
Active axes	X	X	X	X	X	X	X		
Motion and positioning									
Integrated sensor	Capacitive	Capacitive	Capacitive	Capacitive	Capacitive	Capacitive	–		
Open-loop travel, -20 to +120 V	60	120	300	600	950	1800	as P-62x.1CD	µm	min. (+20 %/-0 %)
Closed-loop travel	50	100	250	500	800	1500	–	µm	calibrated
Closed-loop / open-loop resolution	0.1 / 0.2	0.2 / 0.4	0.4 / 0.7	0.5 / 1.4	0.5 / 1.8	2 / 3	as P-62x.1CD	nm	typ.
Linearity, closed-loop	0.02	0.02	0.02	0.02	0.03*	0.03**	–	%	typ.
Repeatability	±1	±1	±1	±5	±10	±14	–	nm	typ.
Pitch / yaw	±3	±3	±3	±6	±6	±10	as P-62x.1CD	µrad	typ.
Mechanical properties									
Stiffness in motion direction	0.42	0.35	0.2	0.1	0.12	0.13	as P-62x.1CD	N/µm	±20 %
Unloaded resonant frequency	1100	800	400	215	125	125	as P-62x.1CD	Hz	±20 %
Resonant frequency @ 20 g	550	520	340	180	115	120	as P-62x.1CD	Hz	±20 %
Resonant frequency @ 120 g	260	240	185	110	90	110	as P-62x.1CD	Hz	±20 %
Push/pull force capacity in motion direction	10	10	10	10	10	10	as P-62x.1CD	N	Max.
Load capacity	10	10	10	10	10	10	as P-62x.1CD	N	Max.
Lateral Force	10	10	10	10	10	8	as P-62x.1CD	N	Max.
Drive properties									
Ceramic type	PICMA® P-883	PICMA® P-885	PICMA® P-885	PICMA® P-885	PICMA® P-887	PICMA® P-888	as P-62x.1CD		
Electrical capacitance	0.35	1.5	3.1	6.2	19	52	as P-62x.1CD	µF	±20 %
Dynamic operating current coefficient	0.9	1.9	1.9	1.6	3	4.3	as P-62x.1CD	µA/(Hz • µm)	±20 %
Miscellaneous									
Operating temperature range	-20 to 80	-20 to 80	-20 to 80	-20 to 80	-20 to 80	-20 to 80	-20 to 150	°C	
Material	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum		
Dimensions	30 x 30 x 12	40 x 40 x 15	50 x 50 x 15	60 x 60 x 15	80 x 80 x 17	100 x 100 x 22.5	as P-62x.1CD	mm	
Mass	0.11	0.16	0.2	0.24	0.38	0.72	as P-62x.1CD	kg	±5 %
Cable length	1.5	1.5	1.5	1.5	1.5	1.5	1.5 m	±10 mm	
Sensor / voltage connection	CD version: Sub-D special CL version: LEMO	CD version: Sub-D special CL version: LEMO	CD version: Sub-D special CL version: LEMO	CD version: Sub-D special CL version: LEMO	CD version: Sub-D special CL version: LEMO	CD version: Sub-D special CL version: LEMO	LEMO (no sensor)		

Resolution of PI Piezo Nanopositioners is not limited by friction or stiction. The value given is noise equivalent motion with E-710 controller (p. 2-128).
*With digital controller. For analog controller 0.05 %.
**With digital controller. For analog controller 0.07 %.
Recommended controller / amplifier
CD version: E-610 servo controller / amplifier (p. 2-110), E-625 servo controller, bench-top (p. 2-114), E-665 powerful servo controller, bench-top (p. 2-116)
Single-channel digital controller: E-753 (bench-top) (p. 2-108)
CL version: E-500 modular piezo controller system (p. 2-142) with E-505 amplifier module (high power) p. 2-147 and E-509 controller (p. 2-152)
Open-loop version: E-500 modular piezo controller system (p. 2-142) with E-505 amplifier module (high power) (p. 2-147)

P-631 Compact Piezo Nanopositioning System

Cost-Effective, Scalable Design for High-Volume Applications



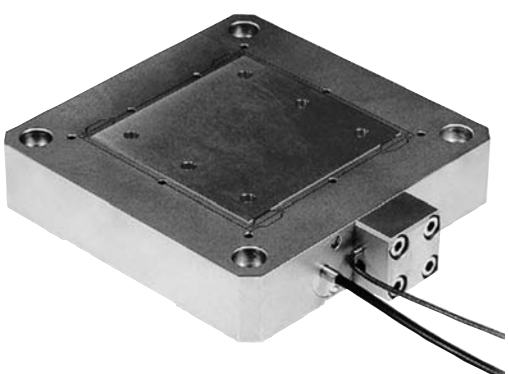
The P-631 nanopositioning stage with 100 µm travel range is also available as vacuum version

- Cost-Effective, Compact Design for High-Volume Applications
- Travel Range 100 µm, Longer Ranges on Request
- Direct Metrology with Capacitive Sensors
- Resolution to 0,2 nm
- Outstanding Lifetime Due to PICMA® Piezo Actuators
- Mechanically Compatible to P-621 PIHera® Nanopositioning Stages

Model	Closed-loop / open-loop travel @ -20 to +120 V	Closed-loop / openloop resolution	Linearity	Pitch / yaw	Load capacity
P-631.1CD	120 / 100 µm	0.2 / 0.4 nm	0.02 %	25 µrad	10 N

P-750 Piezo Nanopositioning System

Dynamic High-Load Nanopositioning Stages with Direct Metrology



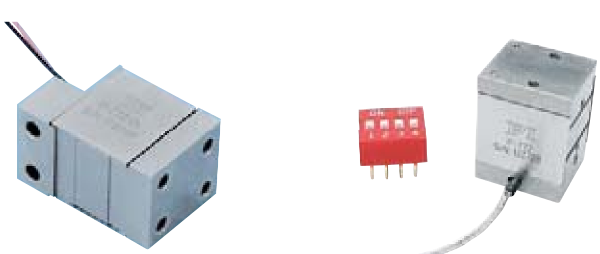
The P-750.10 piezo stage is equipped with high-precision capacitive position sensors

- 1 nm Lateral Guiding Accuracy
- Frictionless, High-Precision Flexure Guiding System
- Load Capacity 10 kg
- Resolution <1 nm
- Superior Accuracy With Direct-Metrology Capacitive Sensors
- Direct Drive for Faster Response
- 75 µm Travel Range
- Outstanding Lifetime Due to PICMA® Piezo Actuators

Model	Closed-loop / open-loop travel	Closed-loop / open-loop resolution	Load capacity	Rotation around θ_X, θ_Y	Unloaded resonant frequency
P-750.00	– /75 µm	– / 0.4 nm	100 N	±10 µrad	600 Hz
P-750.20 with capacitive sensor	75 / 75 µm	1 / 0.4 nm	100 N	±10 µrad	600 Hz

P-772 Miniature Nanopositioning System

High Dynamics and Direct Position Measurement



The P-772 piezo nanopositioning system is available with capacitive sensors for closed-loop operation (left) or as open-loop version (right). DIP switch for size comparison.

- Smallest Stage with Direct Metrology
- Frictionless, High-Precision Flexure Guiding System
- Resolution <0.1 nm
- Travel Range to 12 µm
- Closed-Loop and Open-Loop Versions
- Rapid Response and Settling
- Outstanding Lifetime Due to PICMA® Piezo Actuators

Modell	Closed-loop / open-loop travel @ 0 to +100 V	Closed-loop / open-loop resolution	Linearity	Unloaded resonant frequency	Load capacity
P-772.1CD / P-772.1CL	10 / 12 µm	0.05 / 0.05 nm	0.03 %	1.7 kHz	5 N
P-772.0L	– />10 µm	– / 0.05 nm	–	1.7 kHz	5 N

P-720 PIFOC® Piezo Nanofocusing Systems

Compact High-Dynamics Scanner for Small Objectives

The P-720 objective nanofocusing / scanning drive (objective not included) was designed for small objectives. Similar PIFOC® systems are available for large objectives and with position sensors

- Travel Range 100 µm
- Rapid Response & Settling Behavior
- Scans and Positions Objectives with Sub-nm Resolution
- Frictionless, High-Precision Flexure Guiding System
- Outstanding Lifetime Due to PICMA® Piezo Actuators

Model	Max. objective diameter	Travel	Open-loop, resolution	Stiffness	Push/pull force capacity	Rotation around θ_X, θ_Y
P-720.00	25 mm	100 µm	0.5 nm	0.2 N/µm	100 / 20 N	13 µrad

P-721K PIFOC® Nosepiece Nanopositioner

Compact Design, Sub-Nanometer Resolution

P-721KTPZ Compact Nosepiece Nanopositioner

- Positioning and Scanning of Microscope Turrets
- Direct-Metrology Capacitive Sensors for Highest Linearity, Stability and Control Dynamics
- Frictionless, High-Precision Flexure Guiding System for Better Focus Stability
- Outstanding Lifetime Due to PICMA® Piezo Actuators

Model	Travel	Closed-loop/ open-loop resolution	Resonant frequency (fully loaded)	Dimensions
P-721KTPZ Turret-PIFOC®	80 µm	10 / 0.5 nm	215 Hz	44.5 x 42 x 53 mm (W x L x H)

P-721K Power-PIFOC® Nosepiece Nanopositioner

For High-Resolution Microscopy. High-Load Capacity, Capacitive Feedback

The P-721KPTZ high-load PIFOC® allows precision positioning of a complete microscope turret

- Scans and Positions Objectives with Sub-nm Resolution
- Travel Ranges to 150 µm, Millisecond Settling Time
- Parallel Flexure Guiding for Minimized Objective Offset
- Direct Metrology with Capacitive Sensors for Highest Linearity
- Outstanding Lifetime Due to PICMA® Piezo Actuators

Model	Load capacity	Closed-loop travel	Resonant frequency	Mass
P-721KPTZ	20 N	to 150 µm	410 Hz (no load)	1.5 kg

P-721 PIFOC® Piezo Flexure Objective Scanner

Fast Nanopositioner and Scanner for Microscope Objectives

P-721.CLQ piezo objective nanopositioning system with P-721.12Q QuickLock option and objective (adapter and objective not included)

- **Scans and Positions Objectives with Sub-nm Resolution**
- **Travel Ranges to 140 µm, Millisecond Settling Time**
- **Significantly Faster Response and Higher Lifetime than Motorized Z-Stages**
- **Parallel Precision Flexure Guiding for Better Focus Stability**
- **Choice of Position Sensors: Capacitive Direct Metrology (Higher Performance) or Strain Gauge (Lower Cost)**
- **Compatible with Metamorph™ Imaging Software**
- **Outstanding Lifetime Due to PICMA® Piezo Actuators**
- **QuickLock Adapter for Easy Attachment**

P-721 PIFOCs® are high-speed, piezo-driven microscope objective nanofocusing/scanning devices, providing a positioning and scanning range of 100 µm with sub-nanometer resolution and very high motion of linearity up to 0.03 %.

Application Examples

- 3D-Imaging
- Z Stack Acquisition
- Screening
- Interferometry
- Metrology
- Disc-drive-testing
- Autofocus systems
- Confocal microscopy
- Biotechnology
- Semiconductor testing

PIFOCs® are also available with up to 460 µm travel (P-725 p. 2-28), and for exceptional dynamic and step performance (models P-726 p. 2-32 and P-725.SDD p. 2-30).

Superior Accuracy With Direct-Metrology Capacitive Sensors

Capacitive position feedback is used in the top-of-the-line models. PI's proprietary capacitive sensors measure position directly and without physical contact. They are free of friction and hysteresis, a fact which, in combination with the positioning resolution of well under 1 nm, makes it possible to achieve very high levels of linearity. A further advantage of direct metrology with capacitive sensors is the high phase fidelity and the high bandwidth of up to 10 kHz.

Alternatively, strain gauge sensor (SGS) models are available. The sensors are connected in a bridge configuration to eliminate thermal drift, and assure optimal position stability in the nanometer range.

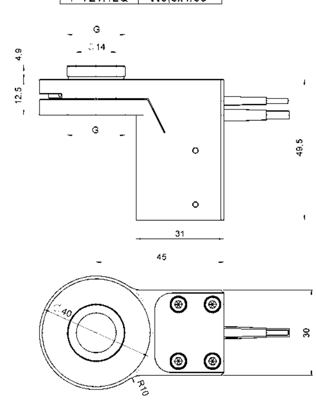
Open-loop models are available for applications where fast response and very high resolution are essential. Here, specifying or reporting absolute position values is either not required or is handled by external sensors, such as interferometers, a vision system or photodiode PSD (position sensitive detector). These models retain the inherent piezo advantages such as high resolution and speed.

Simple Installation with QuickLock Thread Options

The PIFOC® is mounted between the turret and the objective with the QuickLock thread adapter. After threading the adapter into the turret, the Quick Lock is affixed in the desired position. Because the PIFOC® body need not to be rotated, cable wind-up is not an issue.

QuickLock Adapter

	G
P-721.02Q	M26x0,75
P-721.03Q	M27x0,75
P-721.04Q	M28x0,75
P-721.05Q	M32x0,75
P-721.06Q	M26x1/36"
P-721.08Q	M19x0,75
P-721.11Q	M25x0,75
P-721.12Q	W0,8x1/36"



P-721.CLQ, .CDQ, .SL2 dimensions in mm (adapter to be ordered separately)

Ordering Information

P-721.CDQ
Fast PIFOC® Piezo Nanofocusing Z-Drive, 100 µm, Direct Metrology, Capacitive Sensor, Sub-D Connector, for Quick Lock Thread Adapters

P-721.CLQ
Fast PIFOC® Piezo Nanofocusing Z-Drive, 100 µm, Direct Metrology, Capacitive Sensor, LEMO Connector, for Quick Lock Thread Adapters

P-721.SL2
Fast PIFOC® Piezo Nanofocusing Z-Drive, 100 µm, SGS-Sensor, LEMO Connector, for Quick Lock Thread Adapters

P-721.0LQ
Fast PIFOC® Piezo Nanofocusing Z-Drive, 100 µm, No Sensor, LEMO Connector, for Quick Lock Thread Adapters

Extension Tubes for Objectives

P-721.90Q
Extens. Tube, 12.5 mm, Thread W0.8 x 1/36"

P-721.91Q
Extens. Tube, 12.5 mm, Thread M25 x 0.75

P-721.92Q
Extens. Tube, 12.5 mm, Thread M26 x 0.75

P-721.93Q
Extens. Tube, 12.5 mm, Thread M27 x 0.75

P-721.94Q
Extens. Tube, 12.5 mm, Thread M28 x 0.75

P-721.95Q
Extens. Tube, 12.5 mm, Thread M32 x 0.75

P-721.96Q
Extens. Tube, 12.5 mm, Thread M26 x 1/36"

P-721.98Q
Extens. Tube, 12.5 mm, Thread M19 x 0.75

QuickLock Thread Adapters see figure

Piezo • Nano • Positioning

PIFOC® Long Range Objective Scanning System

High-Dynamics Sub-Nanometer Piezo Drive; Controller & Software

PIFOC® long range objective scanning system with QuickLock thread adapter and controller (objective not included)

- **Complete System with Controller: Fast Digital Controller, Software-Configurable Servo Parameters**
- **Travel Range 100 µm**
- **Scans and Positions Objectives with Sub-nm Resolution**
- **Frictionless, High-Precision Flexure Guiding System for Better Focus Stability**
- **Higher Linearity and Stability Through Digital Control and Direct Metrology with Capacitive Sensors**
- **Clear Aperture up to 29 mm Ø, QuickLock Adapter for Easy Attachment**
- **Interfaces: USB, RS-232 and analog**
- **Comprehensive Software Package, Compatible with MetaMorph Imaging Software**

The PIFOC® piezo objective scanner systems include a high precision piezo mechanism and a custom-tuned compact digital controller. This combination provides higher performance at reduced costs. The integrated, frictionless and stiff piezo flexure drive ensures high stiffness and fast settling times, as well as an exceptional guiding accuracy and response.
The settling time of less than 10 ms increases the throughput and allows rapid Z-stack acquisition.

Application Examples

- Microscopy
- Confocal microscopy
- 3D Imaging
- Screening
- Autofocus systems
- Surface analysis
- Wafer inspection

Position Measurement with Highly Accurate Capacitive Sensors or Lower-Priced Strain Gauge Sensors

Capacitive sensors measure the position directly and without contact, they offer therefore a position resolution of far below one nanometer and excellent values in linearity.
As an alternative, compact and lower-priced strain gauge sensors (SGS) with nanometer-level resolution can be used which are applied to appropriate places on the drive train and thus measure the displacement of the moving part of the stage. The linearity is improved considerably with the digital controller provided.

Simple Installation with QuickLock Thread Options

The PIFOC® is mounted between the turret and the objective with the QuickLock thread adapter. After threading the adapter into the turret, the QuickLock is affixed in the desired position. Because the PIFOC® body need not to be rotated, cable wind-up is not an issue. For applications which require a particularly large optical aperture a version with a 29 mm diameter threaded inserts is available.

Digital Controller for Automated Scans

Included in the delivery is a digital controller which opens up the possibilities of digital control for piezo-driven nanopositioning systems for the same price as analog controllers. The advantage: higher linearity, simple operation and access to advanced features.

Ordering Information

PD72Z1CAA
Fast PIFOC® Piezo Nanofocusing Z-Drive, 100 µm, Capacitive Sensor, M32 Large Aperture QuickLock Thread Adapters, Digital Controller with USB, RS-232

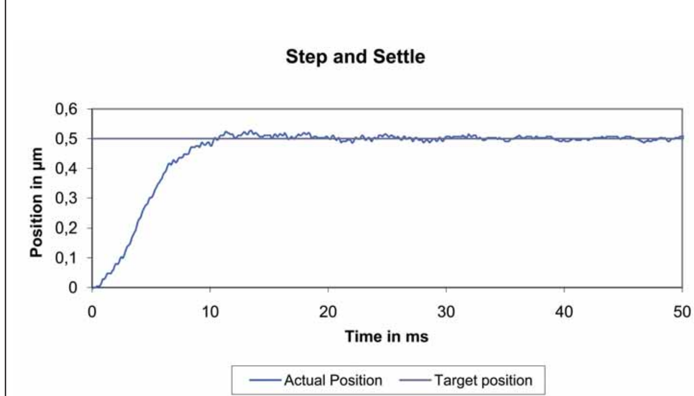
PD72Z1CAQ
Fast PIFOC® Piezo Nanofocusing Z-Drive, 100 µm, Capacitive Sensor, M25 QuickLock Thread Adapters, Digital Controller with USB, RS-232

PD72Z1SAA
Fast PIFOC® Piezo Nanofocusing Z-Drive, 100 µm, SGS Sensor, M32 Large Aperture QuickLock Thread Adapters, Digital Controller with USB, RS-232

PD72Z1SAQ
Fast PIFOC® Piezo Nanofocusing Z-Drive, 100 µm, SGS Sensor, M25 QuickLock Thread Adapters, Digital Controller with USB, RS-232

Flexibility: Software Configurable Servo Parameters

All servo controllers require tuning and adjustment of servo parameters for optimum performance (e.g. as a result of changes to the load or the motion profile). With a digital controller, all adjustments are carried out by simple software commands and the resulting motion or transient characteristics can be viewed, analyzed and further optimized immedi-

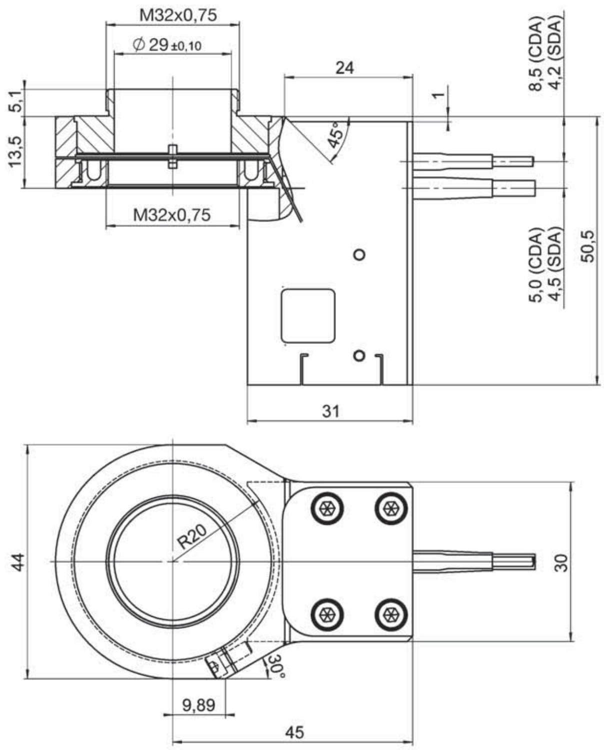


Settling time of the system PD72Z1CAQ with 150 g objective

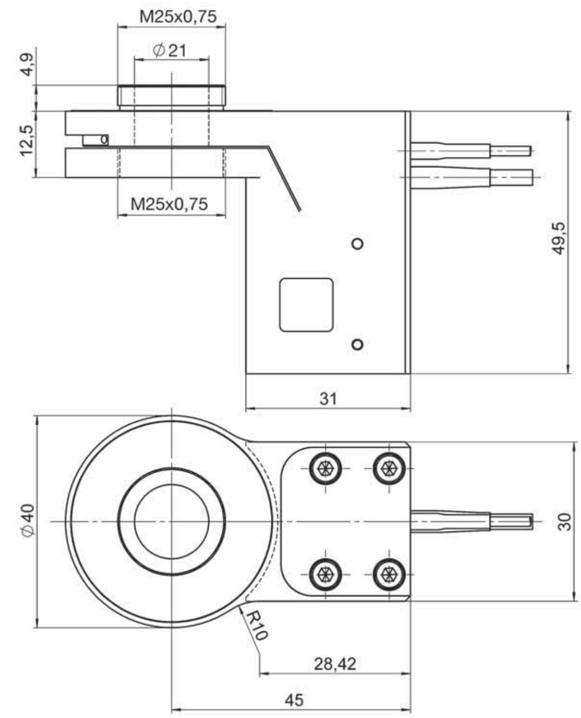
ately with the provided software. It is also possible to switch between previously found sets of parameters when the controller is in operation. Since jumpers and potentiometers no longer have to be set manually, system integration becomes much more straightforward.
System setup with the included user-interface software is fast and easy, interfacing to the customers' software is facilitated with the included LabVIEW drivers and DLLs.
Drivers for MetaMorph and µManager are available.

Technical Data

Model	PD72Z1SAA PD72Z1SAQ	PD72Z1CAA PD72Z1CAQ	Units	Tolerance
Active axes	Z	Z		
Motion and positioning				
Integrated sensor	SGS	Capacitive		
Closed-loop travel	100	100	µm	
Closed-loop resolution	5	1	nm	typ.
Closed-loop linearity	0.2	0.06	%	typ.
Repeatability	±10	±5	nm	typ.
Runout θX, θY	13	13	µrad	typ.
CrossTalk in X, Y	100	100	nm	typ.
Settling time (0.5 µm step with 5 % accuracy, 150 g)	10	10	ms	typ.
Mechanical properties				
Stiffness in motion direction	0.3	0.3	N/µm	±20%
Unloaded resonant frequency	580	580	Hz	±20%
Resonant frequency @ 120 g	235	235	Hz	±20%
Resonant frequency @ 200 g	180	180	Hz	±20%
Push/pull force capacity in motion direction	100 / 20	100 / 20	N	Max.
Drive properties				
Ceramic type	PICMA® P-885	PICMA® P-885		
Controller				
Function	Digital controller for single-axis piezo nanopositioning systems			
Processor	DSP 32-bit floating point, 150 MHz			
Communication interfaces	USB, RS-232			
Linearization	5th order polynomials			
Amplifier power	10 W (<5 ms); 5 W (>5 ms)			
I/O Connector	HD-Sub-D 26-pin, 1 Analog input 0 to 10 V, 1 Sensor monitor 0 to 10 V, 1 digital input (LVTTL, programmable), 5 digital outputs (LVTTL, 3 predefined, 2 programmable)			
User software	PIMikroMove, NanoCapture			
Software drivers	LabVIEW drivers, DLLs			
Supported functionality	Digital setting of the control parameters, wave generator, data recorder, auto zero, trigger I/O; compatible to MetaMorph, µManager			
Display	Status LED, overflow LED			
Miscellaneous				
Operating temperature range	10 to 50	10 to 50	°C	
Material scanner	Aluminum	Aluminum		
Weight	0.22 (scanner), 0.5 (controller)	0.24 (scanner), 0.5 (controller)	kg	±5%
Cable length to controller	1	1	m	
Dimensions controller	160 x 96 x 33	160 x 96 x 33	mm	



PD72Z1xAA with M32 QuickLock thread adapter (large aperture version, 29 mm), dimensions in mm



PD72Z1xAQ with M25 QuickLock thread adapter, dimensions in mm

Piezo • Nano • Positioning

PIFOC® Long Range Objective Scanning System

High-Dynamics Sub-Nanometer Piezo Drive; Controller & Software

PIFOC® long range objective scanning system with QuickLock thread adapter and controller (objective not included)

- **Complete System with Controller: High Performance Digital Servo Software Configurable Parameters**
- **Travel Ranges to 400 µm**
- **Scans and Positions Objectives with Sub-nm Resolution**
- **Frictionless, High-Precision Flexure Guiding System for Better Focus Stability**
- **Higher Linearity and Stability Through Digital Control and Direct Metrology with Capacitive Sensors**
- **Clear Aperture up to 29 mm Ø, QuickLock Adapter for Easy Attachment**
- **Interfaces: USB, RS-232 and Analog**
- **Extensive Software Support, Compatible with MetaMorph Imaging Software**

The PIFOC® piezo objective scanner systems include a high precision piezo mechanism and a custom-tuned compact digital controller. This combination provides higher performance at reduced costs. The piezo mechanisms combine large travel ranges of up to 400 µm with extreme position stability. The integrated, frictionless and stiff piezo flexure guiding system and the sophisticated digital servo, ensure high stiffness, fast response and minimal settling times. Highly parallel motion with minimum tilt improve image quality. Nevertheless, the focusing systems are extremely compact.

The settling time of less than 20 ms increases the throughput and allows rapid Z-stack acquisition.

For applications which need a particularly large clear aperture a version with a 29 mm diameter threaded insert is available.

Digital Controller for Automated Scans

Included in the delivery is a digital controller which opens up the possibilities of digital control for piezo-driven nanopositioning systems for the same price as analog controllers. The advantage: higher precision and simpler operation. The controller can also be used for applications which provide analog control signals: as a standard, a broadband analog input is provided as well as the two digital interfaces.

Flexibility: Software Configurable Servo Parameters

All servo controllers require tuning and adjustment of servo parameters for optimum performance (e.g. as a result of changes to the load or the motion profile). With a digital controller, all adjustments are carried out by simple software commands and the resulting motion or transient characteristics can be viewed, analyzed and further optimized immediately with the provided software. It is also possible to switch between previously

Ordering Information

PD72Z2CAA
Fast PIFOC® Piezo Nanofocusing Z-Drive, 250 µm, Capacitive Sensor, M32 Large Aperture QuickLock Thread Adapters, Digital Controller with USB, RS-232

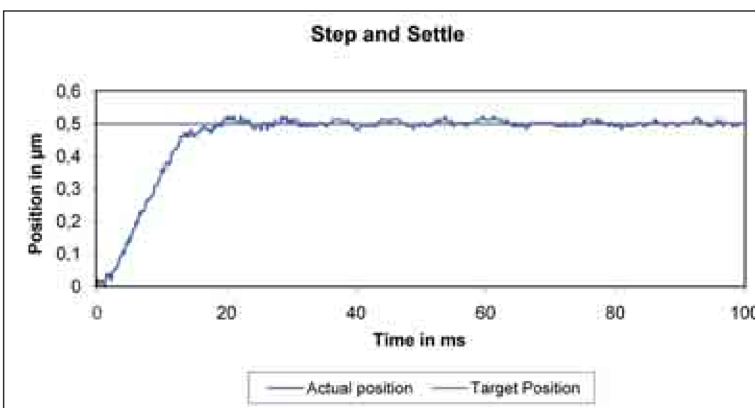
PD72Z2CAQ
Fast PIFOC® Piezo Nanofocusing Z-Drive, 250 µm, Capacitive Sensor, M25 QuickLock Thread Adapters, Digital Controller with USB, RS-232

PD72Z4CAA
Fast PIFOC® Piezo Nanofocusing Z-Drive, 400 µm, Capacitive Sensor, M32 Large Aperture QuickLock Thread Adapters, Digital Controller with USB, RS-232

PD72Z4CAQ
Fast PIFOC® Piezo Nanofocusing Z-Drive, 400 µm, Capacitive Sensor, M25 QuickLock Thread Adapters, Digital Controller with USB, RS-232

Application Examples

- Microscopy
- Confocal microscopy
- 3D Imaging
- Screening
- Autofocus systems
- Surface analysis
- Wafer inspection
- Multi-Photon Spectroscopy



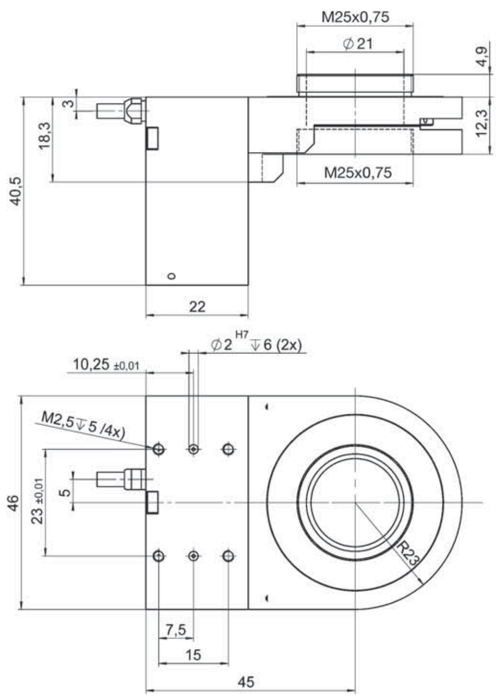
Settling time of the system PD72Z4CAQ with 150 g objective found sets of parameters when the controller is in operation. Since jumpers and potentiometers no longer have to be set manually, system integration becomes much more straightforward.

Easy System Setup, Comprehensive Software

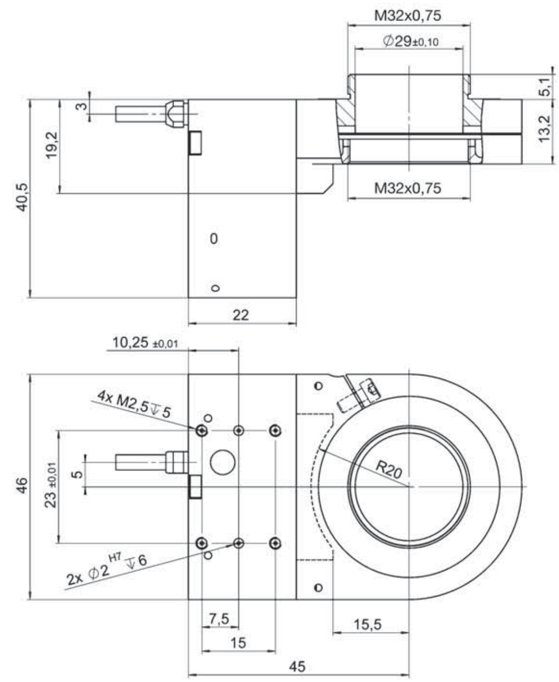
All parameters can be set and checked by software. System setup and configuration is done with the included user-interface software. Interfacing to custom software is facilitated with included LabVIEW drivers and DLLs. Drivers for MetaMorph and µManager are available.

Technical Data

Model	PD72Z2CAA PD72Z2CAQ	PD72Z4CAA PD72Z4CAQ	Units	Tolerance
Active axes	Z	Z		
Motion and positioning				
Integrated sensor	Capacitive	Capacitive		
Closed-loop travel	250	400	µm	
Closed-loop resolution	1.5	2.5	nm	typ.
Linearity, closed-loop	0.06	0.06	%	typ.
Repeatability	±5	±5	nm	typ.
Runout θX	6	10	µrad	typ.
Runout θY	45	45	µrad	typ.
Crosstalk in X	20	60	nm	typ.
Crosstalk in Y	40	60	nm	typ.
Settling time (0.5 µm step to 5 % accuracy, 150 g)	15	20	ms	typ.
Mechanical properties				
Stiffness in motion direction	0.17	0.12	N/µm	±20%
Unloaded resonant frequency	330	230	Hz	±20%
Resonant frequency @ 150 g	140	120	Hz	±20%
Push/pull force capacity in motion direction	100 / 20	100 / 20	N	Max.
Drive properties				
Ceramic type	PICMA® P-885	PICMA® P-885		
Controller				
	Digital controller for single-axis piezo nanopositioning systems			
Processor	DSP 32-bit floating point, 150 MHz			
Communication interfaces	USB, RS-232			
Linearization	5th order polynomials			
Amplifier power	10 W (<5 ms); 5 W (>5 ms)			
I/O Connector	HD-Sub-D 26-pin, 1 Analog input 0 to 10 V, 1 Sensor monitor 0 to 10 V, 1 digital input (LVTTL, programmable), 5 digital outputs (LVTTL, 3 predefined, 2 programmable)			
User software	PIMikroMove, NanoCapture			
Software drivers	LabVIEW drivers, DLLs			
Supported functionality	Digital setting of the control parameters, wave generator, data recorder, auto zero, trigger I/O; Compatible to MetaMorph, µManager			
Display	Status LED, overflow LED			
Miscellaneous				
Operating temperature range	10 to 50 °C			
Material scanner	Aluminum			
Weight	0.23 kg (scanner), 0.5 kg (controller)			±5%
Cable length to controller	1.5 m			
Dimensions controller	160 x 96 x 33 mm			



PD72ZxCAQ with M25 QuickLock thread adapters, dimensions in mm



PD72ZxCAA with M32 large aperture QuickLock thread adapters, dimensions in mm

High Reliability and Long Lifetime

The compact PIFOC® systems are equipped with preloaded PICMA® high-performance piezo actuators which are integrated into a sophisticated, FEA-modeled, flexure guiding system. The PICMA® actuators feature cofired ceramic encapsulation and thus offer better performance and reliability than conventional piezo actuators. Actuators, guidance and sensors are maintenance-free and not subject to wear, and thus offer an extraordinary reliability.

Choice of Controllers

A large choice of analog and digital piezo controllers as OEM, bench-top and 19-inch-rackmount versions is available.

QuickLock P-721.12Q thread adapter exploded view with microscope objective and PIFOC® P-721.CLQ (mounting tools are included, QuickLock adapter and objective not included)

Technical Data

Model	P-721.CLQ	P-721.CDQ	P-721.SL2	P-721.0LQ	Units	Tolerance
Active axes	Z	Z	Z	Z		
Motion and positioning						
Integrated sensor	Capacitive	Capacitive	SGS	–		
Open-loop travel, -20 to +120 V	140	140	140	140	µm	min. (+20 %/-0%)
Closed-loop travel	100	100	100	–	µm	calibrated
Open-loop resolution	0.5	0.5	0.5	0.5	nm	typ.
Closed-loop resolution	0.7	0.7	5	–	nm	typ.
Linearity, closed-loop	0.03	0.03	0.2	–	%	typ.
Repeatability	±5	±5	±10	–	nm	typ.
Runout θX, θY	13	13	13	13	µrad	typ.
Crosstalk X, Y	100	100	100	100	nm	typ.
Mechanical properties						
Stiffness in motion direction	0.3	0.3	0.3	0.3	N/µm	±20 %
Unloaded resonant frequency	580	580	580	550	Hz	±20 %
Resonant frequency @ 120 g	235	235	235	235	Hz	±20 %
Resonant frequency @ 200 g	180	180	180	180	Hz	±20 %
Push/pull force capacity in motion direction	100 / 20	100 / 20	100 / 20	100 / 20	N	Max.
Drive properties						
Ceramic type	PICMA® P-885	PICMA® P-885	PICMA® P-885	PICMA® P-885		
Electrical capacitance	3.1	3.1	3.1	3.1	µF	±20 %
Dynamic operating current coefficient	3.9	3.9	3.9	3.9	µA/(Hz•µm)	±20 %
Miscellaneous						
Operating temperature range	-20 to 80	-20 to 80	-20 to 80	-20 to 80	°C	
Material	Aluminum	Aluminum	Aluminum	Aluminum		
Mass	0.24	0.24	0.22	0.22	kg	±5 %
Max. objective diameter	39	39	39	39	mm	
Cable length	1.5	1.5	1.5	1.5	m	±10 mm
Sensor / voltage connection	LEMO	Sub-D Special	LEMO	LEMO (no sensor)		
Recommended controller / amplifier	E-610 servo controller/amplifier (p. 2-110), modular piezo controller system E-500 (p. 2-142) with amplifier module E-505 (high performance) (p. 2-147) and E-509 servo controller (p. 2-152)	E-625 servo controller, bench top (p. 2-114), E-665 powerful servo controller, bench-top (p. 2-116), Single-channel digital controller: E-753 (bench-top) (p. 2-108)	E-610 servo controller/amplifier, E-625 servo controller, bench-top, E-665 powerful servo controller, bench-top	E-610 servo controller/amplifier		

Resolution of PI Piezo Nanopositioners is not limited by friction or stiction. Value given is noise equivalent motion with E-503 amplifier (p. 2-144)

Piezo • Nano • Positioning

N-725 PIFOC® High-Load Objective Scanner

1 mm Travel, Fast Response and Nanometer Precision

N-725 PIFOC® is the first piezo-objective drive with integrated NEXACT® Piezo Linear Motor, combining smooth motion, long travel ranges and fast response with extreme position stability

- **High Force & High-Dynamics for Positioning and Scanning of Large Objectives up to 29 mm Ø**
- **1 mm Travel for Applications with Large Penetration Depth**
- **Ideal for e. g. Two-Photon Microscopy**
- **Very Fast Response: 20 ms Step and Settle Time**
- **Self Locking at Rest, no Heat Generation, no Servojitter**
- **Drive Resolution < 1 nm, 20 nm Encoder Resolution**
- **Two Motion Modes: Continuous Nanostepping and High-Dynamics Analog Mode**
- **Compact Design: Ø 48 mm, 40.5 mm Height**
- **Frictionless, High-Precision Flexure Guiding System for Better Focus Stability**
- **QuickLock Thread Adapter for Simple Installation**

The N-725 PIFOC® is the first piezo objective nanopositioner equipped with a PiezoWalk® linear motor. This drive combines smooth motion, long travel ranges and fast step and settle with extreme position stability. Its exceptional stroke of 1 mm renders stepper motor positioners -often used as range extenders for piezo drives- unnecessary. The focussing plane can be selected in an extended range without any change of the mechanics. Together with a step and settle time of less than 20 ms this allows for higher throughput.

The large travel range is a big advantage for applications that have large optical penetration depth like two-photon microscopy where it allows to make use of the full working range of the objective and quickly scan through z stacks of up to 1 mm.

Application Examples

- 3-D Imaging
- Screening
- Autofocus systems
- Microscopy
- Confocal microscopy
- Surface structure analysis
- Wafer inspection

Simple Installation with QuickLock Thread Options

The PIFOC® is mounted between the turret and the objective with the QuickLock thread adapter. After threading the adapter into the turret, the QuickLock is affixed in the desired position. Because the PIFOC® body need not to be rotated, cable wind-up is not an issue.

PiezoWalk® – the Multi-Functional Piezo Linear Motor

A great advantage characteristic of the NEXACT® drive principle is its dual-mode operating principle combining the best features of piezo motor designs, such as high resolution, high force and high speed into one compact unit. At the target position the drive requires no current and generates no heat while providing long-term, nanometer stability. This autolocking feature also completely eliminates servo jitter as it occurs with other closed-loop motors. Since motion is solely caused by the nanometer precise motion of clamped piezo actuators, there is no wear to limit the lifetime. When operated in closed-loop, excellent velocity control is achieved.
See p. 1-12 for further information on NEXACT® PiezoWalk® technology.

Controller and Drive Electronics Optimized for the Application

NEXACT® actuators require special drive electronics to control the complex stepping sequences. The E-861 includes complete NEXACT® servo controller with low-noise drivers and a powerful DSP. It also comes with ample software for easy integration and highly effective computer control. For applications which do not require the highest resolution, the E-862 lower-priced drive electronics can be ordered.

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

Ordering Information

N-725.1A
PIFOC® Piezo Nanofocusing Z-Drive with NEXACT® Linear Motor, 1 mm, Linear Encoder, 20 nm Resolution, for QuickLock Thread Adapters

Accessories

QuickLock Thread Adapters: see figure

P-721.90Q
Extens. Tube, 12.5 mm, Thread W0.8 x 1/36''

P-721.91Q
Extens. Tube, 12.5 mm, Thread M25 x 0.75

P-721.92Q
Extens. Tube, 12.5 mm, Thread M26 x 0.75

P-721.93Q
Extens. Tube, 12.5 mm, Thread M27 x 0.75

P-721.94Q
Extens. Tube, 12.5 mm, Thread M28 x 0.75

P-721.95Q
Extens. Tube, 12.5 mm, Thread M32 x 0.75

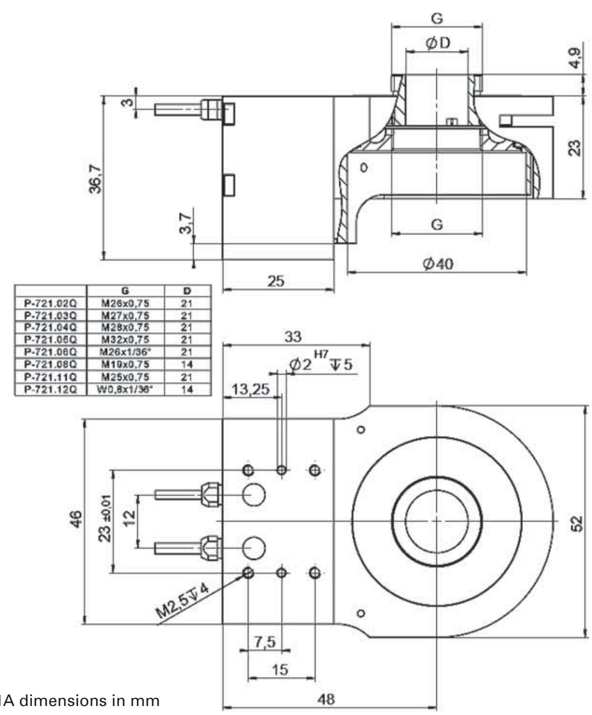
P-721.96Q
Extens. Tube, 12.5 mm, Thread M26 x 1/36''

P-721.98Q
Extens. Tube, 12.5 mm, Thread M19 x 0.75

Ask about custom designs!

Scanner for Higher Resolution and Higher Loads

PI offers a range of related PIFOC® objective scanners with different specifications. The P-725 models e. g. (s. p. 2-28) offer resolutions of less than one nanometer. For larger loads and dynamic scanning applications the models P-726 (s. p. 2-32) and P-725.DD (s. p. 2-30) are also available with travel ranges of up to 100 µm.



	G	D
P-721.02Q	M26x0,75	21
P-721.03Q	M27x0,75	21
P-721.04Q	M28x0,75	21
P-721.05Q	M32x0,75	21
P-721.06Q	M26x1/36°	21
P-721.08Q	M19x0,75	14
P-721.11Q	M25x0,75	21
P-721.12Q	W0,8x1/36°	14

N-725.1A dimensions in mm

Technical Data

Model	N-725.1A
Active axes	Z
Motion and positioning	
Travel range	1 mm
Integrated sensor	Linear encoder
Sensor resolution	20 nm *
Travel range in analog mode	7 µm
Closed-loop resolution	20 nm *
Linearity, closed-loop	0.1%
Bidirectional repeatability	50 nm
Rotation (X, Y) typ.	15 µrad / 100 µm
Step and Settle (200 nm), typ.	20 ms
Max. velocity	10 mm/s*
Mechanical properties	
Stiffness in motion direction	0.5 N/µm
Max. push / pull force (active)	10 N
Drive properties	
Drive type	NEXACT® linear drive
Operating voltage	-10 V to +45 V
Miscellaneous	
Operating temperature range	0 to 50°C
Material	Aluminium
Mass	440 g
Cable length	1.5 m
Connector	HD sub-D connector, 15-pin
Recommended controller	E-861.1A1 Controller for NEXACT® Linear Drives and Positioners

* With E-861. Depending on drive electronics.

P-725 PIFOC® Long-Travel Objective Scanner

High-Precision Positioner / Scanner for Microscope Objectives

P-725.2CL with QuickLock option P-721.12Q for W0.8 x 1/36” threads and objective (QuickLock adapter and objective not included)

Ordering Information

P-725 PIFOC® Piezo Nanofocusing Z-Drive for Long Scanning Ranges

P-725. ☐ ☐

- **1** Travel Range 100 µm (closed-loop)
- **2** Travel Range 250 µm (closed-loop)
- **4** Travel Range 400 µm (closed-loop)

- **CA** Capacitive Sensor, Sub-D Connectors, for Large Aperture QuickLock Thread Adapters
- **CD** Capacitive Sensor, Sub-D Connectors, for QuickLock Thread Adapters
- **CL** Capacitive Sensor, LEMO Connector, for QuickLock Thread Adapters
- **0L** No Sensor, LEMO Connectors, for QuickLock Thread Adapters, Travel Range see Data Table

Accessories
QuickLock Thread Adapters s. fig.,
Extension Tubes for Objectives s. www.pi.ws

- **Travel Ranges to 460 µm**
- **Significantly Faster Response and Higher Lifetime than Motorized Z-Stages**
- **Scans and Positions Objectives with Sub-nm Resolution**
- **Direct Metrology with Capacitive Sensors for Highest Linearity**
- **Parallel Precision Flexure Guiding for Better Focus Stability**
- **Compatible with MetaMorph Imaging Software**
- **Outstanding Lifetime Due to PICMA® Piezo Actuators**
- **QuickLock Adapter for Easy Attachment**
- **Clear Aperture up to 29 mm Ø**

P-725 PIFOC® nanofocus systems are long-travel (up to 460 µm), high-speed, piezo-driven microscope objective nanofocusing/scanning devices. The innovative, frictionless, flexure guiding system provides enhanced precision for superior focus stability with fast response for rapid settling and scanning. Despite the larger travel range, they are 20 % shorter than P-721 units (p. 2-25) while providing sub-nanometer resolution. For applications which require a particularly high resolution, such as the two photon spectroscopy, there are versions which allow a free aperture of up to 29 mm in diameter.

Application Examples

- 3D-Imaging
- Screening
- Interferometry
- Metrology
- Disc-drive-testing
- Autofocus systems
- Confocal microscopy
- Biotechnology
- Semiconductor testing

Superior Accuracy With Direct-Metrology Capacitive Sensors

PI's proprietary capacitive sensors measure position directly and without physical contact. They are free of friction and hysteresis, a fact which, in combination with the positioning resolution of well under 1 nm, makes it possible to achieve very high levels of linearity. Further advantages of direct metrology with capacitive sensors is the high phase fidelity and the high bandwidth of up to 10 kHz.
Open-loop models are available for applications where fast response and very high resolution are essential. Here, specifying or reporting absolute position values is either not required or is handled by external sensors, such as interferometers, a vision system or photodiode PSD (position sensitive detector). These models retain the inherent piezo advantages such as high resolution and speed.

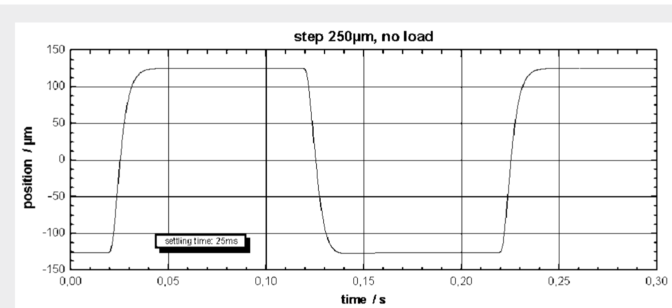
Open-loop models are available for applications where fast response and very high resolution are essential. Here, specifying or reporting absolute position values is either not required or is handled by external sensors, such as interferometers, vision system or photodiode PSD (position sensitive detector). These models retain the inherent piezo advantages as high resolution and speed.

Simple Installation with QuickLock Thread Options

The PIFOC® is mounted between the turret and the objective with the QuickLock thread adapter. After threading the adapter into the turret, the QuickLock is affixed in the desired position. Because the PIFOC® body need not to be rotated, cable wind-up is not an issue.

High Reliability and Long Lifetime

The compact PIFOC® systems are equipped with preloaded PICMA® high-performance piezo actuators which are integrated into a sophisticated, FEA-modeled, flexure guiding system. The PICMA® actuators feature

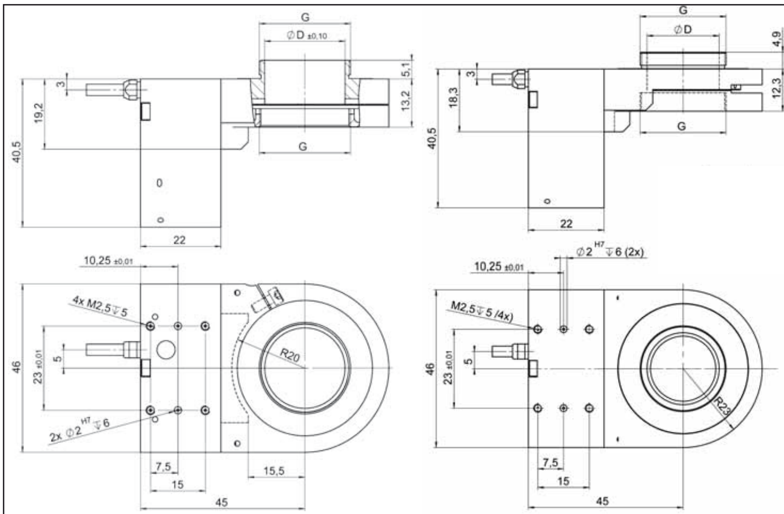


Fastest step and settle: The P-725.2CL can perform a 250 µm step to 1 % accuracy in only 25 ms (no load; 50 ms with a load of 150 g. With E-665.CR controller) cofired ceramic encapsulation and thus offer better performance and reliability than conventional piezo actuators. Actuators, guidance and sensors are maintenance-free and not subject to wear, and thus offer an extraordinary reliability.

Scanner for Higher Dynamics and Higher Loads

PI offers a series of related PIFOC® objective scanners with different specifications. For higher loads and dynamic scanning applications the models P-726 (s. p. 2-32) and P-725.DD (s. p. 2-30) featuring a stroke of up to 100 µm are available.

Alternatively, the sample can be moved into focus: The P-737 piezo Z-nanopositioner features a large aperture to hold a variety of sample holders.



Large Aperture QuickLock Thread Adapter

	G	D
P-721.02A	M26x0,75	23
P-721.03A	M27x0,75	24
P-721.04A	M28x0,75	25
P-721.05A	M32x0,75	29
P-721.06A	M26x1/36"	23
P-721.11A	M25x0,75	22

QuickLock Thread Adapter

	G	D
P-721.02Q	M26x0,75	21
P-721.03Q	M27x0,75	21
P-721.04Q	M28x0,75	21
P-721.05Q	M32x0,75	21
P-721.06Q	M26x1/36"	21
P-721.08Q	M19x0,75	14
P-721.11Q	M25x0,75	21
P-721.12Q	W0,8x1/36"	14

P-725.xCA dimensions in mm
(thread adapter ordered separately)

P-725.xCD, .xCL dimensions in mm
(thread adapter ordered separately)

Technical Data

Model	P-725.1CL P-725.1CD P-725.1CA	P-725.2CL P-725.2CD P-725.2CA	P-725.4CL P-725.4CD P-725.4CA	P-725.x0L open-loop version	Units	Tolerance
Active axes	Z	Z	Z	Z		
Motion and positioning						
Integrated sensor	Capacitive	Capacitive	Capacitive	-		
Open-loop travel, -20 to +120 V	150	330	460	as P-725.xCL	µm	min. (+20 %/-0 %)
Closed-loop travel	100	250	400	-	µm	calibrated
Open-loop resolution	0.3	0.4	0.5	as P-725.xCL	nm	typ.
Closed-loop resolution	0.65	0.75	1.25	-	nm	typ.
Linearity, closed-loop	0.03	0.03	0.03	-	%	typ.
Repeatability	±5	±5	±5	-	nm	typ.
Runout Θ_X	1	6	10	as P-725.xCL	µrad	typ.
Runout Θ_Y	20	45	45	as P-725.xCL	µrad	typ.
Crosstalk in X	20	20	60	as P-725.xCL	nm	typ.
Crosstalk in Y	20	40	60	as P-725.xCL	nm	typ.
Mechanical properties						
Stiffness in motion direction	0.23	0.17	0.12	as P-725.xCL	N/µm	±20 %
Unloaded resonant frequency	470	330	230	as P-725.xCL	Hz	±20 %
Resonant frequency @ 150 g	185	140	120	as P-725.xCL	Hz	±20 %
Push/pull force capacity in motion direction	100 / 20	100 / 20	100 / 20	as P-725.xCL	N	Max.
Drive properties						
Ceramic type	PICMA® P-885	PICMA® P-885	PICMA® P-885	as P-725.xCL		
Electrical capacitance	4.2	6.2	6.2	as P-725.xCL	µF	±20 %
Dynamic operating current coefficient	5.2	3.1	1.9	as P-725.xCL	µA/(Hz • µm)	±20 %
Miscellaneous						
Operating temperature range	-20 to 80	-20 to 80	-20 to 80	-20 to 80	°C	
Material	Aluminum	Aluminum	Aluminum	Aluminium		
Max. objective diameter	39	39	39	39	mm	
Mass	0.215	0.23	0.23	as P-725.xCL	kg	±5 %
Sensor / voltage connection	CL-version: LEMO others: Sub-D special	CL-version: LEMO others: Sub-D special	CL-version: LEMO others: Sub-D special	LEMO (no sensor)		

Recommended controller / amplifier
CL-versions:
E-610 servo controller / amplifier (p. 2-110); E-500 modular piezo controller system (p. 2-142) with E-505 high-performance amplifier module (p. 2-147) and E-509 controller (p. 2-152)
CD/CA-versions:
E-621 controller module (p. 2-160), E-625 servo controller, bench-top (p. 2-114), E-665 display servo controller, with digital interface, bench-top (p. 2-116)
Single-channel digital controller: E-753 (bench-top) (p. 2-108), E-709

P-725.xDD PIFOC® High-Dynamics Piezo Scanner

Nanopositioning and Scanning System for Microscope Objectives

P-725.CDD direct-drive version for high-dynamics focusing

- Fastest Settling Time under 5 ms with Microscope Objective
- 20 µm Travel Range
- Scans and Positions Objectives with Sub-nm Resolution
- Parallel Flexure Guiding for Minimized Objective Offset
- Choice of Position Sensors: Capacitive Direct Metrology (Higher Performance) or Strain Gauges (Lower Cost)
- Compatible with Metamorph™ Imaging Software
- Outstanding Lifetime Due to PICMA® Piezo Actuators
- QuickLock Adapter for Easy Attachment

Direct Drive for Ultra-Fast Scanning and Positioning

The P-725.xDD objective positioners were designed for extremely fast motion over relatively short travel ranges up to 20 µm. Their ultra-stiff direct piezo drive (1.2 kHz resonant frequency) enables the highest scanning rates and response times of only 5 msecs – essential for time-critical tasks.

Application Exampels

- 3D-Imaging
- Screening
- Interferometry
- Metrology
- Disc-drive-testing
- Autofocus systems
- Confocal microscopy
- Biotechnology
- Semiconductor testing

Superior Accuracy With Direct-Metrology Capacitive Sensors

Capacitive position feedback is used in the top-of-the-line model. PI's proprietary capacitive sensors measure position directly and without physical contact. They are free of friction and hysteresis, a fact which, in combination with the positioning resolution of well under 1 nm, makes it possible to achieve very high levels of linearity. A further advantage of direct metrology with capacitive sensors is the high phase fidelity and the high bandwidth of up to 10 kHz.

Alternatively compact, more cost-efficient strain gauge sensors (SGS) featuring nanometer resolution are implemented. Absolute-measuring SGS-sensors are applied to appropriate places on the drive train and thus measure the displacement of the moving part of the stage relative to the base.

Simple Installation with QuickLock Thread Options

The PIFOC® is mounted between the turret and the objective with the QuickLock thread adapter. After threading the adapter into the turret, the QuickLock is affixed in the desired position. Because the PIFOC® body need not to be rotated, cable wind-up is not an issue.

High Reliability and Long Lifetime

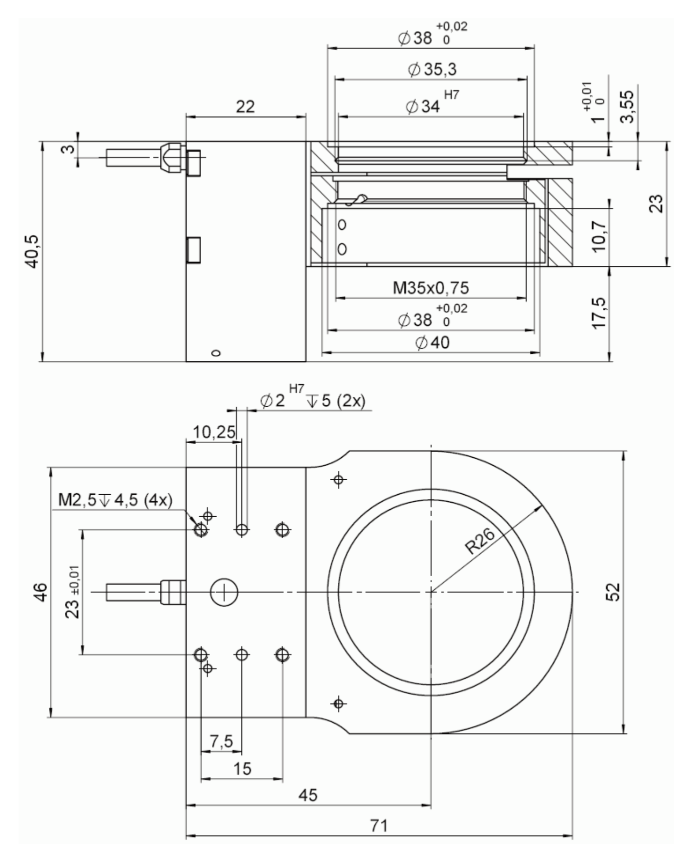
The compact PIFOC® systems are equipped with preloaded PICMA® high-performance piezo actuators which are integrated into a sophisticated, FEA-modeled, flexure guiding system. The PICMA® actuators feature cofired ceramic encapsulation and thus offer better performance and reliability than conventional piezo actuators. Actuators, guidance and sensors are maintenance-free and not subject to wear, and thus offer an extraordinary reliability.

Ordering Information

P-725.CDD
Fast PIFOC® Piezo Nanofocusing Z-Drive, 20 µm, Capacitive Sensor, Sub-D Connector, for QuickLock Thread Adapters

P-725.SDD
Fast PIFOC® Piezo Nanofocusing Z-Drive, 20 µm, SGS-Sensor, LEMO Connector, for QuickLock Thread Adapters

Ask about custom designs!



P-725.xDD dimensions in mm

Model	P-725.CDD	P-725.SDD	Units	Tolerance
Active axes	Z	Z		
Motion and positioning				
Integrated sensor	Capacitive	SGS		
Open-loop travel, -20 to +120 V	20	20	µm	min. (+20 %/-0 %)
Closed-loop travel	20	20	µm	calibrated
Open-loop resolution	0.2	0.2	nm	typ.
Closed-loop resolution	0.2	0.2	nm	typ.
Linearity, closed-loop	0.04	0.5	%	typ.
Repeatability	±1.5	±5	nm	typ.
Runout θ_X, θ_Y	2	2	µrad	typ.
Crosstalk in X, Y	150	150	nm	typ.
Mechanical properties				
Stiffness in motion direction	1.5	1.5	N/µm	±20 %
Unloaded resonant frequency	1180	1180	Hz	±20 %
Resonant frequency @ 200 g	450	450	Hz	±20 %
Push/pull force capacity in motion direction	100 / 20	100 / 20	N	Max.
Drive properties				
Ceramic type	PICMA® P-887	PICMA® P-887		
Electrical capacitance	3.1	3.1	µF	±20 %
Dynamic operating current coefficient	19.4	19.4	µA/(Hz • µm)	±20 %
Miscellaneous				
Operating temperature range	-20 to 80	-20 to 80	°C	
Material	Aluminum	Aluminum		
Mass	0.21	0.2	kg	±5 %
Cable length	1.5	1.5	m	±10 mm
Sensor / voltage connection	Sub-D Special	LEMO		

Recommended controller
E-610 servo controller / amplifier (p. 2-110), E-625 servo controller, bench-top (p. 2-114), E-665 high-power servo controller, bench-top (p. 2-116)
Single-channel digital controller: E-753 (bench-top) (p. 2-108)

P-726 PIFOC® High-Load Objective Scanner

High-Dynamic Piezo Z Scanner for Heavy Objectives

High-dynamics P-726 PIFOC® for large microscope objectives over 60 mm in length

- **High-Dynamics Positioning and Scanning for Large Objectives**
- **1120 Hz Resonant Frequency, 560 Hz with 210 g Load**
- **Typical Settling Time about 6 ms**
- **Travel Range 100 µm**
- **Direct-Metrology Capacitive Sensors for Best Linearity, Stability and Control Dynamics**
- **Resolution to 0.3 nm**
- **Frictionless, High-Precision Flexure Guiding System for Better Focus Stability**

The P-726 PIFOC® Nanofocusing system was developed to achieve the fastest possible stepping time with the heavy, high-numerical-aperture objectives used in many of today's high-resolution microscopy applications. Its extremely stiff design offers excellent settling time and scanning frequency values even when objectives of several hundred grams are moved. High stiffness is achieved with the rotationally symmetric arrangement of multiple piezo drives and the optimized design of the flexure and lever elements, which assure the excellent guiding accuracy and dynamics.

Furthermore, like other members of the PIFOC® family, the P-726 is equipped with direct metrology capacitive position sensors that allow resolutions far below one nanometer.

Application Examples

- 3-D Imaging
- Screening
- Autofocus systems
- Microscopy
- Confocal microscopy
- Surface analysis
- Wafer inspection

Direct Metrology with Capacitive Sensors for Highest Stability and Accuracy

PI's proprietary capacitive position sensors measure the actual motion of the moving part relative to the stationary base (direct metrology). Errors in the drive train, actuator, lever arm or in guiding system do not influence the measurements. The result is exceptional motion linearity, higher long-term stability and a stiffer, more-responsive servo loop, because external influences are immediately recognized by the sensor. Due to this sensor principle, the P-726 features a resolution of under 0.4 nm in closed-loop and a linearity of 0.02 %.

Simple Installation with QuickLock Thread Options

The PIFOC® is mounted between the turret and the objective with the QuickLock thread adapter. After threading the adapter into the turret, the QuickLock is affixed in the desired position. Because the PIFOC® body need not to be rotated, cable wind-up is not an issue.

Ordering Information

P-726.1CD
High-Dynamics PIFOC® Piezo Nanofocusing Z-Drive, 100 µm, Capacitive Sensor

QuickLock Thread Adapter as Accessories:

P-726.04
P-726 PIFOC® Thread Adapter M28 x 0.75

P-726.05
P-726 PIFOC® Thread Adapter M32 x 0.75

P-726.06
P-726 PIFOC® Thread Adapter M26 x 1/36"

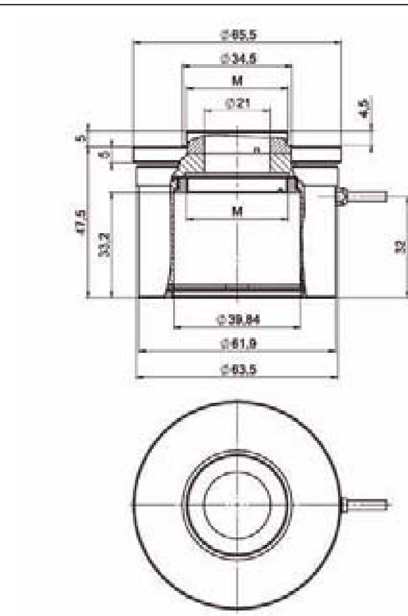
P-726.11
P-726 PIFOC® Thread Adapter M25 x 0.75

P-726.12
P-726 PIFOC® Thread Adapter W0.8 x 1/36"

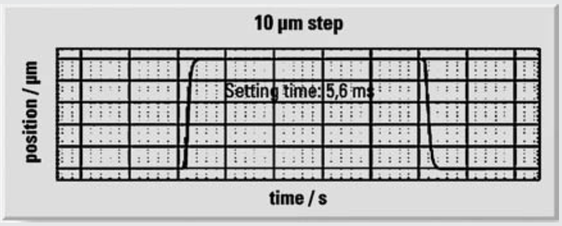
Ask about custom designs!

Ceramic Insulated Piezo Actuators Provide Long Lifetime

Highest possible reliability is assured by the use of award-winning PICMA® multilayer piezo actuators. PICMA® actuators are the only actuators on the market with ceramic-only insulation, which makes them resistant to ambient humidity and leakage-current failures. They are thus far superior to conventional actuators in reliability and lifetime.



P-726 dimensions in mm with P-726.05 M32 QuickLock adapter



P-726 settling time under load

Technical Data

	P-726.1CD	Tolerance
Active axes	Z	
Motion and positioning		
Integrated sensor	Capacitive, direct metrology	
Closed-loop travel	100 µm	calibrated
Closed-loop resolution	0.4 nm	typ.
Open-loop resolution	0.3 nm	typ.
Linearity, closed-loop	0.02 %	typ.
Repeatability	±3 nm	typ.
Runout Θ_X, Θ_Y	±5 µrad	typ.
Crosstalk X, Y	50 nm	typ.
Mechanical properties		
Stiffness in motion direction	3.4 N/µm	±20 %
Unloaded resonant frequency	1120 Hz	±20 %
Resonant frequency under load	560 Hz @ 210 g	±20 %
Resonant frequency under load	480 Hz @ 310 g	±20 %
Push/pull force capacity in motion direction	100 / 50 N	Max.
Drive properties		
Piezo ceramic type	PICMA® P-885	
Electrical capacitance	6 µF	±20 %
Dynamic operating current coefficient	7.5 µA/(Hz • µm)	±20 %
Miscellaneous		
Operating temperature range	-20 to 80 °C	
Material	Aluminum, steel	
Dimensions	Diameter: 65 mm, Height: 50.7 mm	
Max. objective diameter	M32	
Mass	575 g	±5 %
Cable length	1.5 m	±10 mm
Sensor / voltage connection	Sub-D Special	
Recommended controller / amplifier	Single-channel digital controller: E-753 (bench-top) (p. 2-108) E-625 bench-top controller (p. 2-114), E-665 high-power bench-top controller (p. 2-116) E-500 modular piezo controller system (p. 2-142) with E-505 high-power amplifier module (p. 2-147) and E-509 servo-controller (p. 2-152)	
System properties		
System configuration	E-500 modular piezo controller system with E-505 high-power amplifier module and E-509 servo-controller 310 g load (objective mass)	
Closed-loop amplifier bandwidth, small signal, 10 µm	130 Hz	
Closed-loop amplifier bandwidth, large signal	70 Hz	

P-726 QuickLock thread adapter exploded view with P-726 PIFOC® (mounting tools included)

Piezo • Nano • Positioning

P-611.Z Piezo Z-Stage

Compact Nanopositioner

P-611 Z-axis nanopositioning stage, 100 µm closed-loop travel, resolution to 0.2 nm

- **Compact: Footprint Only 44 x 44 mm**
- **Travel Range to 120 µm**
- **Resolution to 0.2 nm**
- **Cost-Effective Mechanics/Electronics System Configurations**
- **Frictionless, High-Precision Flexure Guiding System**
- **Outstanding Lifetime Due to PICMA® Piezo Actuators**
- **X, XY, XZ and XYZ Versions also Available**

P-611 Z stages are piezo-based nanopositioning systems with 100 µm closed-loop travel range featuring a compact footprint of only 44 x 44 mm. The stages described here are part of the P-611 family of positioners available in 1- to 3-axis configurations. Equipped with ceramic-encapsulated piezo drives and a stiff, zero-stiction, zero-friction flexure guiding system, all P-611 piezo stages combine millisecond responsiveness with nanometric precision and extreme reliability.

The P-611.Z versions described here are ideally suited for use in applications such as microscopy, auto-focusing and photonics packaging.

Application Examples

- Photonics / integrated optics
- Micromachining
- Micromanipulation
- Semiconductor testing

Closed-Loop and Open-Loop Versions

High-resolution, fast-responding, strain gauge sensors (SGS) are applied to appropriate locations on the drive train and provide a high-bandwidth, nanometer-precision position feedback signal to the controller. The sensors are connected in a full-bridge configuration to eliminate thermal drift, and assure optimal position stability in the nanometer range.

The open-loop models are ideal for applications where fast response and very high resolution are essential, but absolute positioning is not important. They can also be used when the position is controlled by an external feedback system such as an interferometer, a PSD (position sensitive diode), CCD chip / image processing system, or the eyes and hands of an operator.

Versatility & Combination with Motorized Stages

The P-611 family of piezo stages comprises a variety of single- and multi-axis versions (X, XY, Z, XZ and XYZ) that can be easily combined with a number of very compact manual or motorized micropositioning systems to form coarse/fine positioners with longer travel ranges (see p. 2-20, p. 2-50 *ff*).

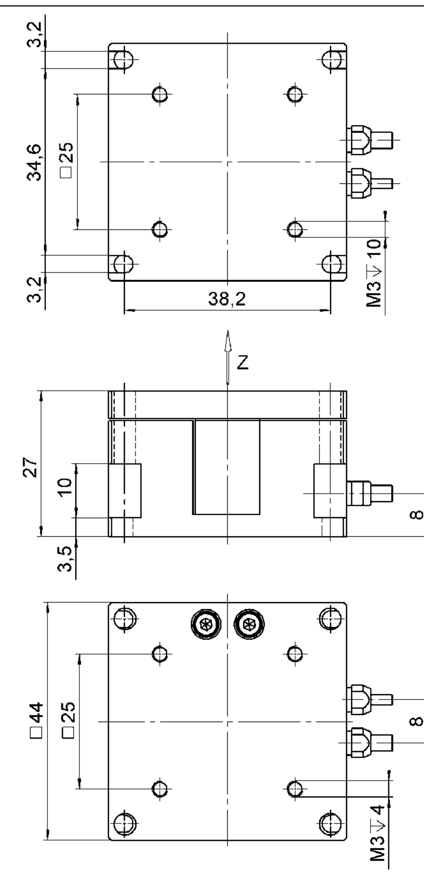
High Reliability and Long Lifetime

The compact P-611 systems are equipped with preloaded PICMA® high-performance piezo actuators which are integrated into a sophisticated, FEA-modeled, flexure guiding system. The PICMA® actuators feature cofired ceramic encapsulation and thus offer better performance and reliability than conventional piezo actuators. Actuators, guidance and sensors are maintenance-free and not subject to wear, and thus offer an extraordinary reliability.

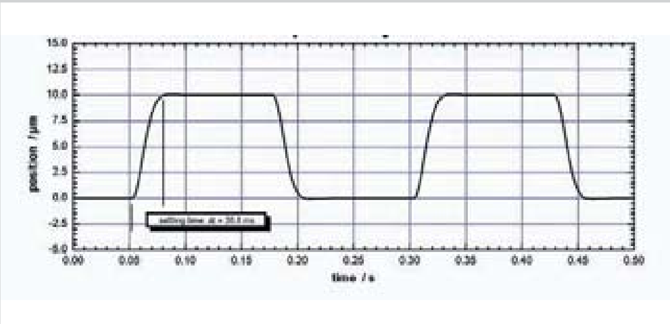
Ordering Information

P-611.Z0
Vertical Nanopositioning Stage, 120 µm, No Sensor

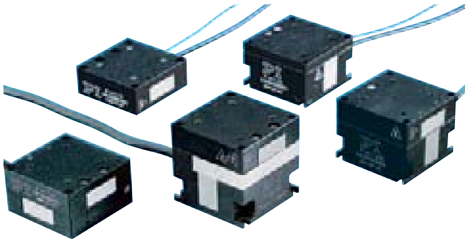
P-611.ZS
Vertical Nanopositioning Stage, 100 µm, SGS-Sensor



P-611.ZS dimensions in mm



The settling time of a P-611.Z with a load of 30 g is 26 ms for a 10 µm step. Measured with interferometer



The whole P-611 family: X, Z, XY, XZ and XYZ stages

Technical Data

Model	P-611.ZS	P-611. Z0	Unit	Tolerance
Active axes	Z	Z		
Motion and positioning				
Integrated sensor	SGS	-		
Open-loop travel, -20 to +120 V	120	120	µm	min. (+20 %/0 %)
Closed-loop travel	100	-	µm	
Open-loop resolution	0.2	0.2	nm	typ.
Closed-loop resolution	2	-	nm	typ.
Linearity	0.1	-	%	typ.
Repeatability	<10	-	nm	typ.
Runout θZ (Z motion)	±5	±5	µrad	typ.
Runout θX (Z motion)	±20	±20	µrad	typ.
Runout θY (Z motion)	±5	±5	µrad	typ.
Mechanical properties				
Stiffness	0.45	0.45	N/µm	±20 %
Unloaded resonant frequency	460	460	Hz	±20 %
Resonant frequency @ 30 g	375	375	Hz	±20 %
Resonant frequency @ 100 g	265	265	Hz	±20 %
Push/pull force capacity	15 / 10	15 / 10	N	Max.
Drive properties				
Ceramic type	PICMA® P-885	PICMA® P-885		
Electrical capacitance	1.5	1.5	µF	±20 %
Dynamic operating current coefficient	1.9	1.9	µA/(Hz • µm)	±20 %
Miscellaneous				
Operating temperature range	-20 to 80	-20 to 80	°C	
Material	Aluminum, steel	Aluminum, steel		
Dimensions	44 x 44 x 27	44 x 44 x 27	mm	
Mass	176	176	g	±5 %
Cable length	1.5	1.5	m	±10 mm
Sensor connector	LEMO	LEMO		
Voltage connection	LEMO	LEMO		

Resolution of PI Piezo Nanopositioners is not limited by friction or stiction. Value given is noise equivalent motion with E -503 amplifier (p. 2-146)
Recommended controller / amplifier
E-610 servo controller / amplifier (p. 2-110), E-625 servo controller, bench-top (p. 2-114), E-665 powerful servo controller, bench-top (p. 2-116), E-660 bench-top for open-loop systems (p. 2-119)

System properties	
System Configuration	P-611.1S and E-665.SR controller, 30 g load
Amplifier bandwidth, small signal	40 Hz
Settling time (10 % step width)	25 ms

P-612.Z Piezo Z Stage

Compact Nanopositioning Stage with Aperture

P-612.ZSL
compact nano-elevation stage with a
20 mm x 20 mm clear aperture

- **Travel Range 100 µm**
- **Resolution to 0.2 nm**
- **Linearity 0.2 %**
- **Compact: Footprint 60 x 60 mm**
- **Very Cost-Effective Controller/Piezomechanics Systems**
- **Frictionless, High-Precision Flexure Guiding System**
- **Outstanding Lifetime Due to PICMA® Piezo Actuators**

These elevation stages are cost-effective, compact, piezo-based positioning systems with travel ranges of 100 µm. The space-saving design features a footprint of only 60 x 60 mm. The 20 x 20 mm clear aperture makes them ideally suited for sample positioning in microscopy. Equipped with PICMA® piezo drives and zero-stiction, zero-friction flexure guiding system, the series provides nanometer-range resolution and millisecond response time.

Application Examples

- Interferometry
- Scanning microscopy
- Nanopositioning
- Biotechnology
- Quality assurance testing
- Semiconductor fabrication

Position Servo-Control with Nanometer Resolution

High-resolution, broadband, strain gauge sensors (SGS) are applied to appropriate locations on the drive train and measure the displacement of the moving part of the stage relative to the base. The SGS sensors assure optimum position stability in the nanometer range and fast response.

The open-loop models are ideal for applications where fast response and very high resolution are essential, but absolute positioning is not important. They can also be used when the position is controlled by an external sensor such as an interferometer, a PSD (position sensitive detector), CCD chip / image processing system, or the eyes and hands of an operator.

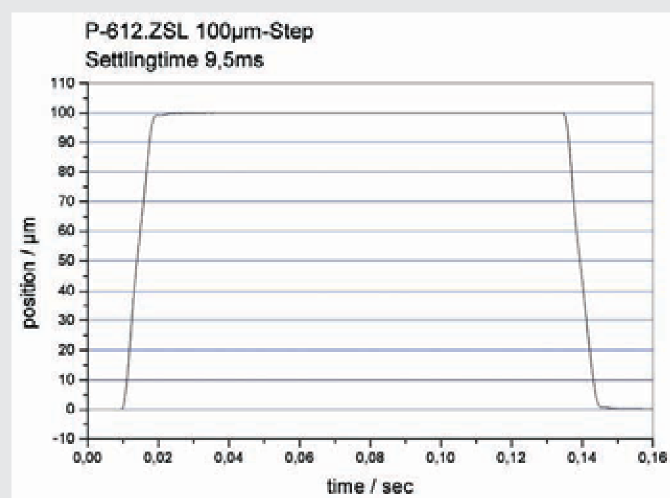
High Reliability and Long Lifetime

The compact P-612 systems are equipped with preloaded PICMA® high-performance piezo actuators which are integrated into a sophisticated, FEA-modeled, flexure guiding system. The PICMA® actuators feature cofired ceramic encapsulation and thus provide better performance and reliability than conventional piezo actuators. Actuators, guiding system and sensors are maintenance-free, not subject to wear and offer an extraordinary reliability.

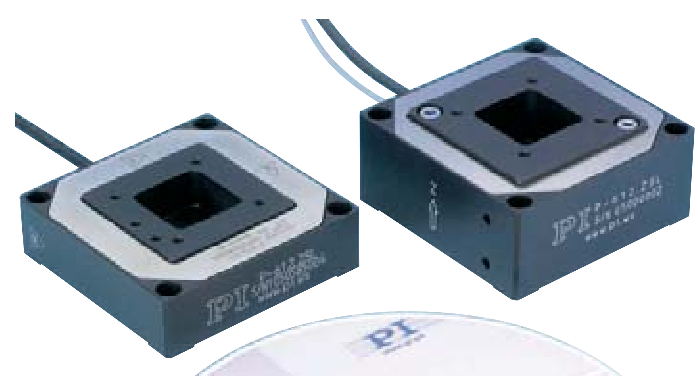
Ordering Information

P-612.ZSL
Vertical Nanopositioning Stage, 100 µm, 20 x 20 mm Aperture, SGS-Sensor

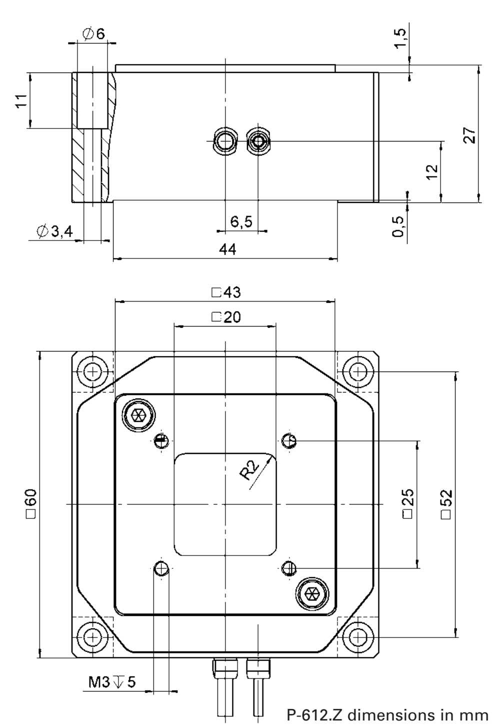
P-612.Z0L
Vertical Nanopositioning Stage, 100 µm, 20 x 20 mm Aperture, No Sensor



Settling takes less than 10 ms over the entire travel range in closed-loop operation



P-612s are available as XY-scanners (P-612.2SL, on the left) and vertical stages (P-612.ZSL, on the right) providing a travel range of 100 µm per axis



P-612.Z dimensions in mm

System properties	
System configuration	P-612.ZSL and E-625.SR controller, 30 g load
Closed-loop amplifier small signal bandwidth	110 Hz
Closed-loop amplifier large signal bandwidth	80 Hz
Settling time (10 % step width)	8 ms

Technical Data

Model	P-612.ZSL	P-612.Z0L	Units	Tolerance
Active axes	Z	Z		
Motion and positioning				
Integrated sensor	SGS	–		
Open-loop travel, -20 to +120 V	110	110	µm	min. (+20 %/-0 %)
Closed-loop travel	100	–	µm	calibrated
Open-loop resolution	0.2	0.2	nm	typ.
Closed-loop resolution	1.5	–	nm	typ.
Linearity, closed-loop	0.2	–	%	typ.
Repeatability	±4	–	nm	typ.
Runout θ_X, θ_Y	±10	±10	µrad	typ.
Crosstalk X, Y	±20	±20	µm	typ.
Mechanical properties				
Stiffness in motion direction	0.63	0.63	N/µm	±20 %
Unloaded resonant frequency	490	490	Hz	±20 %
Resonant frequency under load	420 (30 g)	420 (30 g)	Hz	±20 %
Load capacity	15 / 10	15 / 10	N	Max.
Drive properties				
Ceramic type	PICMA® P-885	PICMA® P-885		
Electrical capacitance	3	3	µF	±20 %
Dynamic operating current coefficient	3.8	3.8	µA/(Hz • µm)	±20 %
Miscellaneous				
Operating temperature range	-20 to 80	-20 to 80	°C	
Material	Aluminum	Aluminum		
Mass	0.28	0.275	kg	±5 %
Cable length	1.5	1.5	m	±10 mm
Sensor / voltage connection	LEMO	LEMO (no sensor)		

Resolution of PI Piezo Nanopositioners is not limited by friction or stiction. Value given is noise equivalent motion with E-503 amplifier. (p. 2-146)
Recommended controller / amplifier
E-610 servo controller / amplifier card (p. 2-110), E-625 servo-controller, bench-top (p. 2-114), E-665 high-power servo-controller with display, bench-top (p. 2-116), E-660 bench-top for open-loop systems (p. 2-119)

P-620.Z – P-622.Z PIHera® Precision Z-Stage

Nanopositioning System Family with Direct Metrology and Long Travel Ranges

P-620.ZCL, P-621.ZCL and P-622.ZCL (from left) PIHera® piezo nano-elevation stages, 50 to 400 µm (CD for size comparison)

- **Vertical Travel Range 50 to 400 µm**
- **High-Precision, Cost-Efficient**
- **Resolution to 0.1 nm**
- **Direct Metrology with Capacitive Sensors**
- **0,02 % Positioning Accuracy**
- **Frictionless, High-Precision Flexure Guiding System**
- **Outstanding Lifetime Due to PICMA® Piezo Actuators**
- **X-, XY-, Z- XYZ-Versionen**
- **Vacuum-Compatible Versions Available**

Z-axis PIHera® systems are cost-efficient piezo nanopositioning stages featuring travel ranges up to 400 µm and provide sub-nanometer resolution. Despite the increased travel ranges, the units are extremely compact and provide sub-nanometer resolution. The long travel range is achieved with a friction-free and extremely stiff flexure system, which also offers rapid response and excellent guiding accuracy.

Application Examples

- Interferometry
- Microscopy
- Nanopositioning
- Biotechnology
- Quality assurance testing
- Semiconductor technology

PIHera® piezo nanopositioning stages are also available as X- and XY-stages (see p. 2-22 and p. 2-54).

Nanometer Precision in Milliseconds

One of the advantages of PIHera® stages over motor-driven positioning stages is the rapid response to input changes and the fast and precise settling behavior. The P-622.1CD, for example, can settle to an accuracy of 10 nm in only 30 msec (other PI stages provide even faster response)!

Superior Accuracy With Direct-Metrology Capacitive Sensors

A choice of tasks such as optical path adjustment in interferometry, sample positioning in microscopy, precision alignment or optical tracking require the relatively long scanning ranges and nanometer precision offered by PIHera® nanopositioning stages.

PI's proprietary capacitive sensors measure position directly and without physical contact. They are free of friction and hysteresis, a fact which, in combination with the positioning resolution of well under 1 nm, makes it possible to achieve very high levels of linearity. A further advantage of direct metrology with capacitive sensors is the high phase fidelity and the high bandwidth of up to 10 kHz.

Designed for Precision

High stiffness is achieved with the FEA-optimized design of the frictionless flexure elements, which assure excellent guiding accuracy and dynamics. A straightness and flatness in the nanometer range is achieved.

Ordering Information

P-620.ZCD
PIHera® Precision Vertical Nanopositioning Stage, 50 µm, Capacitive Sensor, Sub-D Connector

P-620.ZCL
PIHera® Precision Vertical Nanopositioning Stage, 50 µm, Capacitive Sensor, LEMO Connector

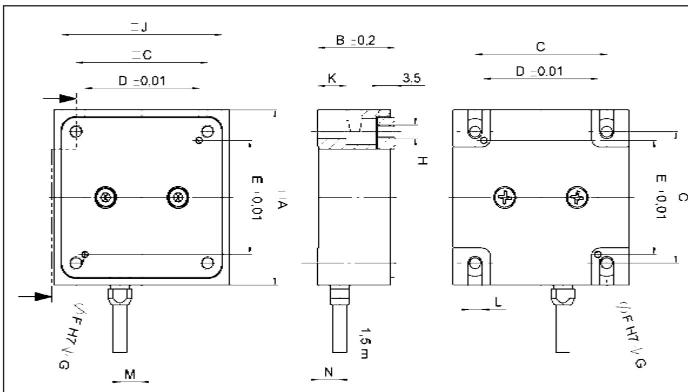
P-621.ZCD
PIHera® Precision Vertical Nanopositioning Stage, 100 µm, Capacitive Sensor, Sub-D Connector

P-621.ZCL
PIHera® Precision Vertical Nanopositioning Stage, 100 µm, Capacitive Sensor, LEMO Connector

P-622.ZCD
PIHera® Precision Vertical Nanopositioning Stage, 250 µm, Capacitive Sensor, Sub-D Connector

P-622.ZCL
PIHera® Precision Vertical Nanopositioning Stage, 250 µm, Capacitive Sensor, LEMO Connector

Open-loop versions are available as P-62x.Z0L



	A	B	C	D	E	∅ F
P-620.ZCD / Z0L	30	15	24	19	24	1,01
P-621.ZCD / Z0L	40	17,5	30	26	26	1,51
P-622.ZCD / Z0L	50	17,5	40	35	35	1,51

	G	H	J	K	L	M	N
P-620.ZCD / Z0L	2	M2	28	5	2,2	4,5	6
P-621.ZCD / Z0L	2,5	M3	36,5	6,5	3,2	5	5
P-622.ZCD / Z0L	2,5	M3	46,5	6,5	3,2	5	5

P-62x.ZCD / .ZCL / .Z0L dimensions in mm

System properties	
System configuration	P-621.ZCD with E-753 digital controller and 30 g load
Amplifier bandwidth, small signal	25 Hz
Amplifier bandwidth, large signal	25 Hz
Settling time (full travel)	15 ms


PIHera® XYZ combination

Technical Data

Model	P-620.ZCD P-620.ZCL	P-621.ZCD P-621.ZCL	P-622.ZCD P-622.ZCL	P-62x.Z0L Open-loop versions	Units	Tolerance
Active axes	Z	Z	Z	Z		
Motion and positioning						
Integrated sensor	Capacitive	Capacitive	Capacitive	–		
Open-loop travel, -20 to +120 V	65	140	400	as P-62x.ZCD	µm	min. (+20 %/-0 %)
Closed-loop travel	50	100	250	–	µm	
Open-loop resolution	0.1	0.2	0.5	as P-62x.ZCD	nm	typ.
Closed-loop resolution	0.2	0.3	1	–	nm	typ.
Linearity	0.02	0.02	0.02	–	%	typ.
Repeatability	±1	±1	±1	–	nm	typ.
Runout θ_X, θ_Y)	<20	<20	<80	as P-62x.ZCD	µrad	typ.
Mechanical properties						
Stiffness	0.5	0.6	0.24	as P-62x.ZCD	N/µm	±20 %
Unloaded resonant frequency	1000	790	360	as P-62x.ZCD	Hz	±20 %
Resonant frequency @ 30 g	690	500	270	as P-62x.ZCD	Hz	±20 %
Push/pull force capacity	10 / 5	10 / 8	10 / 8	as P-62x.ZCD	N	Max.
Load capacity	10	10	10	as P-62x.ZCD	N	Max.
Lateral Force	10	10	10	as P-62x.ZCD	N	Max.
Drive properties						
Ceramic type	PICMA® P-883	PICMA® P-885	PICMA® P-885	as P-62x.ZCD		
Electrical capacitance	0.7	3	6.2	as P-62x.ZCD	µF	±20 %
Dynamic operating current coefficient	1.8	3.8	3.1	as P-62x.ZCD	µA/(Hz • µm)	±20 %
Miscellaneous						
Operating temperature range	-20 to 80	-20 to 80	-20 to 80	-20 to 150	°C	
Material	Aluminum	Aluminum	Aluminum	Aluminum		
Mass	0.12	0.17	0.24	as P-62x.ZCD	g	±5 %
Cable length	1.5	1.5	1.5	as P-62x.ZCD	m	±10 mm
Sensor / voltage connection	Sub-D special (CD-version) CL-version: LEMO	Sub-D special (CD-version) CL-version: LEMO	Sub-D special (CD-version) CL-version: LEMO	LEMO (no sensor)		

Recommended controller
CD-Versions:
E-610 servo controller / amplifier (p. 2-110), E-625 servo controller, bench-top (p. 2-114), E-665 powerful servo controller, bench-top (p. 2-116)
Single-channel digital controller: E-753 (bench-top) (p. 2-108)
CL-Versions:
Modular piezo controller system E-500 (p. 2-142) with amplifier module E-505 (high performance) (p. 2-147) and E-509 controller (p. 2-152)
Open-loop versions: modular piezo controller system E-500 (p. 2-142) with amplifier module E-505 (high performance) (p. 2-147)

PInano™ Z, Scanner for SR-Microscopy

Low-Profile, Low-Cost, Nanopositioning System for Super Resolution Microscopy

PInano™ Z nanopositioning stages (shown with optional slide and Petri dish holder) feature a very low profile of 20 mm (0.8”), a large aperture and deliver highly accurate motion with sub-nanometer resolution

- **Extremely Fast Step & Settle, From 5 msec**
- **Low Profile for Easy Integration: 20 mm (0.8")**
- **100 and 200 µm Travel Ranges**
- **Proprietary Technology: Outstanding Lifetime Due to PICMA® Piezo Ceramic Stacks**
- **Cost-Effective Design due to Piezoresistive Sensors**
- **Compatible w/ Leading Image Acquisition Software Package**
- **Closed-Loop Control for High Repeatability and Accuracy**
- **USB Controller & Software Included**

High-Speed, Low Profile, Optimized for Microscopy

The new PInano™ Z low-profile piezo Z stages are optimized for very fast step and settle and easy integration into high-resolution microscope applications. They feature a very low profile of 0.8" (20 mm), a large aperture, and travel ranges of up to 200 µm with sub-nanometer closed-loop resolution–ideal for leading-edge microscopy and imaging applications.

Application Examples

- 3D Imaging
- Scanning microscopy
- Laser technology
- Interferometry
- Metrology
- Biotechnology
- Micromanipulation

Longest lifetime is guaranteed by the integrated ceramic-encapsulated PICMA® piezo actuators. Due to the significantly higher humidity resistance, the patented PICMA® design provides up to 10 times longer life than conventional piezo actuators (see latest test results at www.pi.ws/picma).

Cost Effective Design, High Performance

PInano™ series piezo positioning stages are designed to provide high performance at minimum cost. For highly-stable, closed loop operation, piezoresistive sensors are applied directly to the moving structure and precisely measure the displacement of the stage platform. The very high sensitivity of these sensors provides optimum position stability and responsiveness as well as nanometer resolution. A proprietary servo controller significantly improves the motion linearity compared to conventional piezoresistive sensor controllers.

Excellent Guiding Accuracy

Flexures optimized with Finite Element Analysis (FEA) are used to guide the stage. FEA techniques are used to give the design the highest possible stiffness in, and perpendicular to, the direction of motion, and to minimize linear and angular runout. Flexures allow extremely high-precision motion, no matter how minute, as they are completely free of play and friction.

Controller & Software Included

The PInano™ Z stage comes complete with a powerful digital closed-loop controller. The controller features two digital interfaces (USB & RS-232) as well as a high-speed analog interface and is compatible with leading image acquisition software packages such as MetaMorph etc.
The controllers are delivered including software for Windows operating systems. DLLs and LabVIEW drivers are available for automated control.
The extensive command set is based on the hardware-independent General Command Set (GCS), which is common to all current PI controllers for both nano- and micropositioning systems. GCS reduces the programming effort in the face of complex multi-axis positioning tasks or when upgrading a system with a different PI controller.

Ordering Information

P-736.ZR1S
PInano™ Z Piezo Slide Scanner System, 100 µm, Slide-Size Aperture, Piezoresistive Sensors, with USB Fully Digital Controller

P-736.ZR2S
PInano™ Z Piezo Slide Scanner System, 200 µm, Slide-Size Aperture, Piezoresistive Sensors, with USB Fully Digital Controller

Accessories

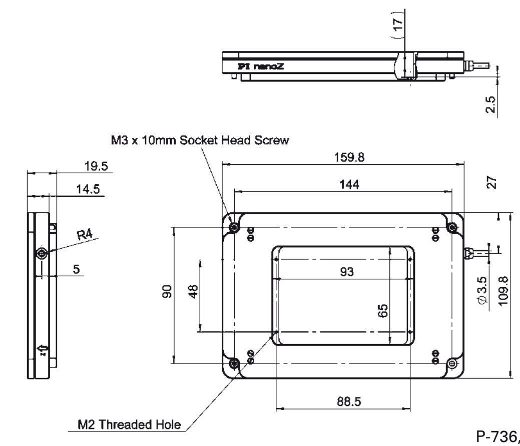
P-545.PD3
35mm Petri Dish Holder for P-545 PInano™ Piezo Stages

P-545.SH3
Microscope Slide Holder for PInano™ Piezo Stages

P-736.AP1
Adapter Plate P-736 PInano™ Piezo Z to M-545 XY Microscope Stages

The PInano™ Z stage can be combined with the M-545 high-stability, long-travel manual/motorized microscope stage (25 x 25 mm)

A compact piezo controller with a digital servo, USB, RS-232 and a high–speed analog interface is included



P-736, dimensions in mm

Technical Data

Model	P-736.ZR1S	P-736.ZR2S	Units	Tolerance
Active axes	Z	Z		
Motion and positioning				
Integrated sensor	piezoresistive	piezoresistive		
Closed-loop travel	100	200	µm	
Open-loop resolution	0.2	0.4	nm	typ.
Closed-loop resolution	0.4	0.7	nm	typ.
Linearity	±0.1	±0.1	%	typ.
Repeatability	<4	<5	nm	typ.
Mechanical properties				
Settling time (10% step width)	5	7	ms	
Load	500	500	g	max.
Drive properties				
Ceramic type	PICMA® P-885	PICMA® P-885		
Miscellaneous				
Operating temperature range	15 to 40	15 to 40	°C	
Material	Aluminum	Aluminum		
Mass	550	550	g	±5%
Cable length	1.5	1.5	m	±10 mm

P-737 PIFOC® Specimen-Focusing Z Stage

Low-Profile, Long-Range Piezo Z Nanopositioner for Microscopy Samples

P-737 piezo Z-stage for high-resolution microscopy

- **High-Speed Piezo Z Motion with Travel Ranges to 250 µm (Up to 500 µm on Request)**
- **Nanometer Resolution**
- **Large Clear Aperture to Accommodate Specimen Holders**
- **Perfect Mechanical Fit with XY OEM Manual or Motorized Stages**
- **Response Times in the Millisecond Range**

PIFOC® P-737 high-speed vertical positioning systems are designed for use with XY microscopy stages–OEM manual stages as well as aftermarket motorized stages.

While the XY stage positions the sample, the piezo-actuator-based P-737 moves the sample along the optical axis to quickly and precisely adjust the focus. Vertical stepping with an accuracy in the nanometer range takes only a few milliseconds.

The large aperture is designed to accommodate a variety of specimen holders including slides or multiwell plates.

Application Examples

- Fluorescence microscopy
- Confocal microscopy
- Biotechnology
- Autofocus systems
- 3D Imaging
- Medical technology

High-Speed Z Steps for Fast Focus Control and Z Stack Acquisition

The immediate response of the solid-state piezo drives enables rapid Z-steps with typically 10 to 20 times faster step & settle times than classical stepper motor drives. This leads to higher image acquisition speed and throughput.

Closed-Loop Position Control for High-Precision and Stability

For high stability and repeatability, P-737 stages are equipped with position feedback. High-resolution, fast-responding, strain gauge sensors (SGS) are applied to appropriate locations on the drive train and provide a high-bandwidth, nanometer-precision position feedback signal to the controller. The sensors are connected in a full-bridge configuration to eliminate thermal drift, and assure optimal position stability in the nanometer range.

Excellent Guiding Accuracy

Flexures optimized with Finite Element Analysis (FEA) are used to guide the stage. FEA techniques are used to give the design the highest possible stiffness in, and perpendicular to, the direction of motion, and to minimize linear and angular runout. Flexures allow extremely high-precision motion, no matter how minute, as they are completely free of play and friction.

Ordering Information

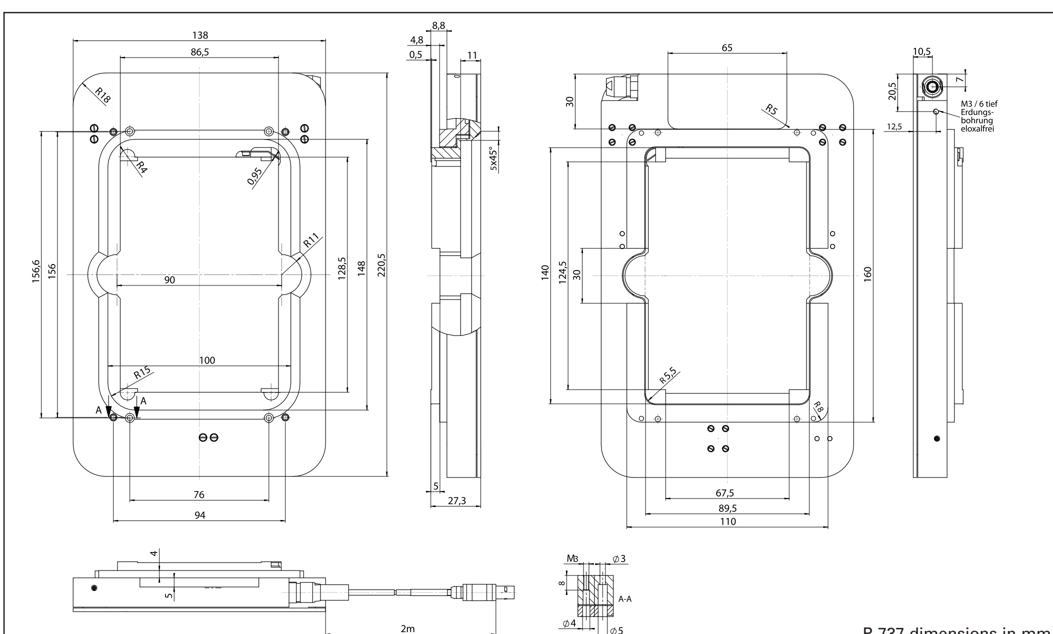
P-737.1SL
PIFOC® Nanofocusing Z-Stage for Microscope Sample Holder, 100 µm, SGS, LEMO Connector, for Märzhäuser Microscope Stages

P-737.2SL
PIFOC® Nanofocusing Z-Stage for Microscope Sample Holder, 250 µm, SGS, LEMO Connector, for Märzhäuser Microscope Stages

Versions with up to 500 µm travel or with direct-measuring, high-resolution capacitive sensors on request.

Ceramic Insulated Piezo Actuators Provide Long Lifetime

Highest possible reliability is assured by the use of award-winning PICMA® multilayer piezo actuators. PICMA® actuators are the only actuators on the market with ceramic-only insulation, which makes them resistant to ambient humidity and leakage-current failures. They are thus far superior to conventional actuators in reliability and lifetime.



P-737 dimensions in mm

The P-737 piezo Z-stage (shown with multiwell plate) is compatible with motorized microscope XY stages like the one shown from Märzhäuser

Instead of moving the sample, it is also possible to move the objective. The P-725 PIFOC® Objective Scanner offers travel ranges over 400 µm with nanometer resolution and response times in the millisecond range

Technical Data

Model	P-737.1SL	P-737.2SL	Units	Tolerance
Active axes	Z	Z		
Motion and positioning				
Integrated sensor	SGS	SGS		
Open-loop travel, -20 to +120 V	150	280	µm	min. (+20 %/-0 %)
Closed-loop travel	100	250	µm	
Open-loop resolution	0.8	1	nm	typ.
Closed-loop resolution	2.5	4	nm	typ.
Linearity, closed-loop	0.2	0.2	%	typ.
Repeatability	6	12	nm	typ.
Runout X	±36	±36	µrad	typ.
Runout Y	±36	±140	µrad	typ.
Mechanical properties				
Unloaded resonant frequency	270	210	Hz	±20 %
Resonant frequency @ 100 g	230	180	Hz	±20 %
Resonant frequency @ 200 g	210	155	Hz	±20 %
Push/pull force capacity in motion direction	50 / 20	50 / 20	N	Max.
Drive properties				
Ceramic type	PICMA® P-885	PICMA® P-885		
Electrical Capacitance	6.3	9.3	µF	±20 %
Dynamic operating current coefficient	7.9	4.6	µA/(Hz • µm)	±20 %
Miscellaneous				
Operating temperature range	-20 to 80	-20 to 80	°C	
Material	Aluminum	Aluminum		
Dimensions	220.5 x 138 x 27.3	220.5 x 138 x 27.3	mm	
Mass	0.7	0.7	kg	±5 %
Cable length	2	2	m	±10 mm
Sensor / voltage connection	LEMO	LEMO		
System properties				
System configuration	E-500 System with E-503 amplifier (6 W) E-509 servo module	E-500 System with E-503 amplifier (6 W) E-509 servo module		
Closed-loop amplifier bandwidth, small signal	60	30	Hz	typ.
Settling time (10 % step width)	24	30	ms	typ.

Recommended controller / amplifier
Single-channel: E-610 servo controller / amplifier (p. 2-110), E-625 servo controller, bench-top (p. 2-114), E-665 powerful servo controller, bench-top (p. 2-116)

P-733.Z High-Dynamics Z-Nanopositioner / Scanner

Direct Position Metrology and Clear Aperture

P-733.ZCD Piezo Z-Stage

- **Travel Range 100 µm**
- **Direct Metrology with Capacitive Sensors**
- **Resolution to 0.3 nm, Closed-Loop**
- **Clear Aperture 50 x 50 mm**
- **Versions with Additional Degrees of Freedom Available**
- **XY and XYZ Versions Also Available**
- **Vacuum-Compatible Versions Available**

P-733.Z piezo vertical stages offer a positioning and scanning range of 100 µm with sub-nanometer resolution. The 50 x 50 mm clear aperture is ideal for applications such as scanning or confocal microscopy. Their fast settling time of less than 10 ms allows high throughput rates.

Application Examples

- Scanning microscopy
- Confocal microscopy
- Mask / wafer positioning
- Surface measurement technique
- Nano-imprinting
- Micromanipulation
- Image processing / stablilization
- Nanopositioning with high flatness & straightness

Capacitive Sensors for Highest Accuracy

PI's proprietary capacitive sensors measure position directly and without physical contact. They are free of friction and hysteresis, a fact which, in combination with the positioning resolution of well under 1 nm, makes it possible to achieve very high levels of linearity. A further advantage of direct metrology with capacitive sensors is the high phase fidelity and the high bandwidth of up to 10 kHz. The resolution of the P-733.Z is better than 0.3 nm.

Because of the direct measurement of the actual distance between the fixed frame and the moving part of the stage, errors in the drive train, actuator, lever arm or in guiding system do not influence the measuring accuracy. The result is exceptional motion linearity, higher long-term stability and a stiffer, more-responsive control loop, because external influences are immediately recognized by the sensor. The capacitive sensor non-linearity is typically less than 0.03 %, the repeatability of the P-733.Z is better than 2 nm.

Ceramic Insulated Piezo Actuators Provide Long Lifetime

Highest possible reliability is assured by the use of award-winning PICMA® multilayer piezo actuators. PICMA® actuators are the only actuators on the market with ceramic-only insulation, which makes them resistant to ambient humidity and leakage-current failures. They are thus far superior to conventional actuators in reliability and lifetime.

Large Variety of Models for a Broad Range of Applications

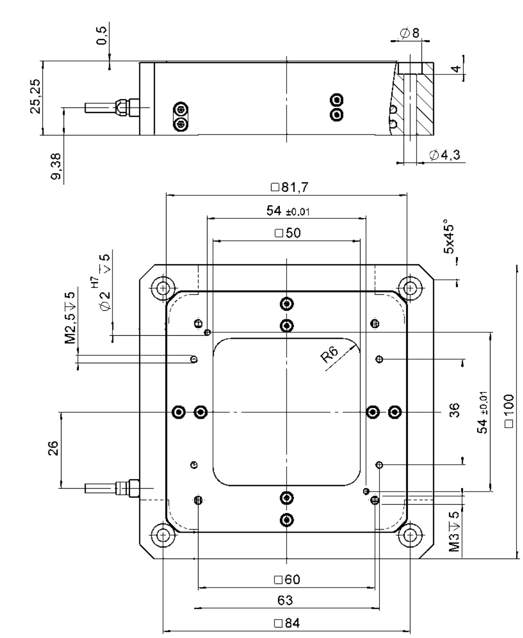
For scanning and positioning tasks in XY, the P-733.2CD and .3CD versions are available with a travel range of 100 x 100 µm. For high-dynamics applications, the P-733.2DD and P-733.3DD models can be offered with direct drive and reduced travel range (see p. 2-62).

For ultra-high-vacuum applications down to 10^{-9} hPa, nanopositioning systems as well as comprehensive accessories, such as suitable feedthroughs, are available.

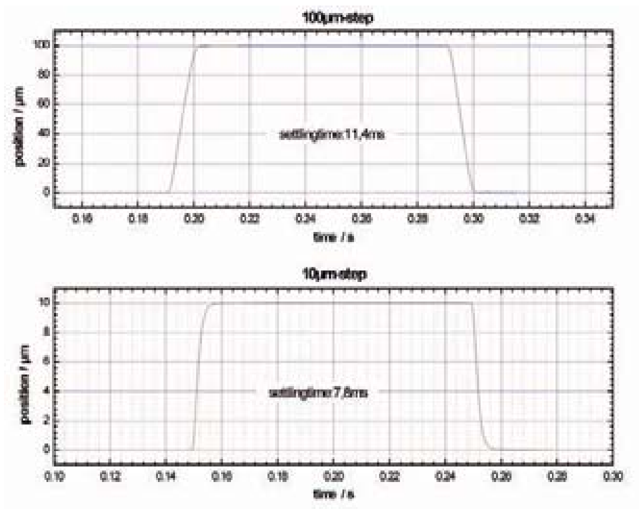
Ordering Information

P-733.ZCD
Compact Precision Nanopositioning Vertical Stage, 100 µm, Capacitive Sensor, Sub-D Connector

P-733.ZCL
Compact Precision Nanopositioning Vertical Stage, 100 µm, Capacitive Sensor, LEMO Connector



P-733.Z dimensions in mm



Step response of the P-733.ZCD. Settling time is in the 10 ms range

System properties	
System configuration	E-500 modular system with E-503 amplifier and E-509 sensor module; 20 g load
Amplifier bandwidth, small signal	96 Hz
Settling time (10 % step width)	8 ms

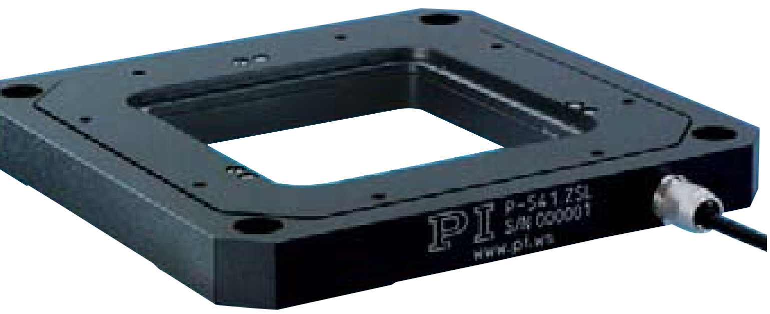
Technical Data

Model	P-733.ZCD P-733.ZCL	Tolerance
Active axes	Z	
Motion and positioning		
Integrated sensor	Capacitive	
Open-loop travel, -20 to +120 V	115 µm	min. (+20 %/-0 %)
Closed-loop travel	100 µm	
Open-loop resolution	0.2 nm	typ.
Closed-loop resolution	0.3 nm	typ.
Linearity	0.03 %	typ.
Repeatability	<2 nm	typ.
Rotation around Z	<10 µrad	typ.
Rotation around X	<5 µrad	typ.
Rotation around Y	<5 µrad	typ.
Mechanical properties		
Stiffness	2.5 N/µm	±20 %
Unloaded resonant frequency	700 Hz	±20 %
Resonant frequency @ 120 g	530 Hz	±20 %
Resonant frequency @ 200 g	415 Hz	±20 %
Push/pull force capacity	50 / 20 N	Max.
Drive properties		
Ceramic type	PICMA® P-885	
Electrical capacitance	6 µF	±20 %
Dynamic operating current coefficient	7.5 µA/(Hz • µm)	±20 %
Miscellaneous		
Operating temperature range	20 to 80 °C	
Material	Aluminum	
Dimensions	100 x 100 x 25 mm	
Mass	580 g	±5 %
Cable length	1,5 m	±10 mm
Sensor connection	Sub-D special (CD-version); 2x LEMO (CL-version)	
Voltage connection	Sub-D special (CD-version); 1 x LEMO (CL-version)	

Dynamic Operating Current Coefficient in µA per Hz and mrad. Example: Sinusoidal scan of 10 µm at 10 Hz requires approximately 3 mA drive current.
Recommended controller
One channel: E-610 controller / amplifier (p. 2-110), E-625 bench-top controller (p. 2-114), E-621 modular controller (p. 2-160)
Multi-channel: modular piezo controller system E-500 (p. 2-142) with amplifier module E-503 (three channels) (p. 2-146) or E-505 (1 per axis, high-power) (p. 2-147) and E-509 controller (p. 2-152)
Single-channel digital controller: E-753 (bench-top) (p. 2-108)

P-541.Z Piezo Z and Z/Tip/Tilt Stages

Low Profile, Large Aperture



P-541 series nanopositioning Z-stages and Z-tip/tilt stages offer travel ranges of 100 µm with sub-nanometer resolution. They feature a very low profile of 16.5 mm and a large 80 x 80 mm aperture. Versions with strain gauge and capacitive position feedback sensors are available

- **Low Profile for Easy Integration: 16.5 mm; 80 x 80 mm Clear Aperture**
- **Vertical and Z/Tip/Tilt Stages**
- **100 µm Travel Range, 1 mrad Tilt**
- **Parallel-Kinematics / Metrology for Enhanced Responsiveness / Multi-Axis Precision**
- **Choice of Sensors: Strain Gauge (Lower Cost) or Capacitive Sensors (Higher Performance)**
- **Outstanding Lifetime Due to PICMA® Piezo Actuators**
- **Combination with Long-Travel M-686 Microscopy Stages**

Low Profile, Optimized for Microscopy Applications

The P-541 Z stages and Z/tip/tilt stages are for ideal alignment, nano-focusing or metrology tasks in the nanometer range. They feature a very low profile of 16.5 mm, a large 80 x 80 mm aperture, and offer highly accurate motion with sub-nanometer resolution.

Application Examples

- Scanning microscopy
- Mask / wafer positioning
- Interferometry
- Metrology
- Biotechnology
- Micromanipulation

A variety of P-541 XY scanning stages with the same footprint are also available (see p. 2-60). Due to the low-profile design, the stages can easily be integrated in high-resolution microscopes.

Choice of Position Sensors

PI's proprietary capacitive sensors measure position directly and without physical contact. They are free of friction and hysteresis, a fact which, in combination with the positioning resolution of well under 1 nm, makes it possible to achieve very high levels of linearity. A further advantage of direct metrology with capacitive sensors is the high phase fidelity and the high bandwidth of up to 10 kHz.

Alternatively, economical strain gauge sensors are available. PI uses a bridge configuration to eliminate thermal drift, and assure optimal position stability in the nanometer range.

Active and Passive Guidance for Nanometer Flatness and Straightness

Flexures optimized with Finite Element Analysis (FEA) are completely free of play and friction to allow extremely high-precision motion. The FEA techniques also optimize straightness and flatness and provide for the highest possible stiffness in, and perpendicular to, the direction of motion.

Due to the parallel-kinematics design there is only one common moving platform for all axes, minimizing mass, enabling identical dynamic behaviour and eliminiating cumulative errors. Parallel kinematics also allows for a more compact construction and faster response compared to stacked or nested designs.

Ordering Information

P-541.ZCD
Vertical Nanopositioning Stage with Large Aperture, 100 µm, Direct Metrology, Capacitive Sensors

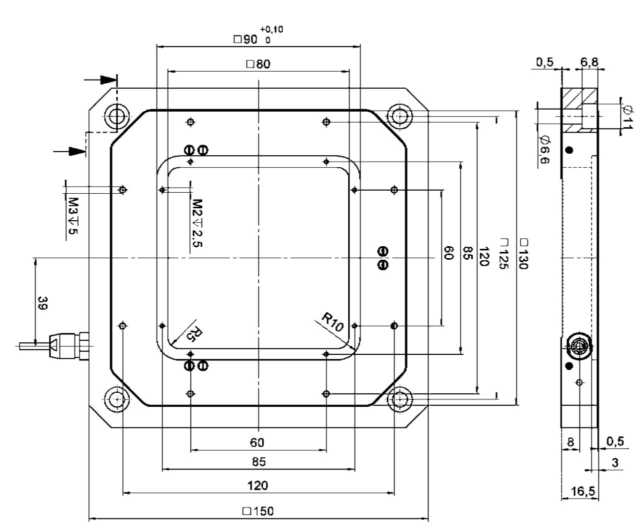
P-541.TCD
Vertical Tip / Tilt Nanopositioning Stage with Large Aperture, 100 µm / 1 mrad, Parallel Metrology, Capacitive Sensors

P-541.ZSL
Vertical Nanopositioning Stage with Large Aperture, 100 µm, Strain Gauge Sensors

P-541.TSL
Vertical Tip / Tilt Nanopositioning Stage with large Aperture, 100 µm, Strain Gauge Sensors

Ceramic Insulated Piezo Actuators Provide Long Lifetime

Highest possible reliability is assured by the use of award-winning PICMA® multilayer piezo actuators. PICMA® actuators are the only actuators on the market with ceramic-only insulation, which makes them resistant to ambient humidity and leakage-current failures. They are thus far superior to conventional actuators in reliability and lifetime.



P-541.Z dimensions in mm

M-686 open-frame stage with P-541 piezo scanner on top makes an ideal combination for microscopy tasks. The system height is only 48 mm

System properties	
System configuration	P-541.ZCD and E-500 modular system with E-503 amplifier and E-509 sensor module, 20 g load
Amplifier bandwidth, small signal	60 Hz
Settling time (10 % step width)	9 ms

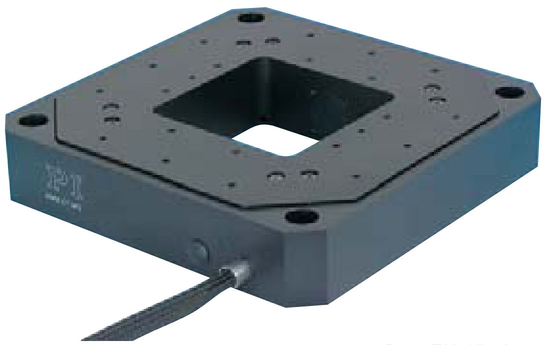
Technical Data

Models	P-541.ZCD	P-541.TCD*	P-541.ZSL	P-541.TSL	P-541.T0L*	P-541.Z0L	Units	Tolerane
Active axes	Z	Z, θ_X, θ_Y	Z	Z, θ_X, θ_Y	Z	Z, θ_X, θ_Y		
Motion and positioning								
Integrated sensor	Capacitive	Capacitive	SGS	SGS	Open-loop	Open-loop		
Open-loop Z-travel, -20 to +120 V	150	150	150	150	150	150	µm	min. (+20 %/0 %)
Open-loop tip/tilt angle, -20 to +120 V	–	±0.6	–	±0.6	–	±0.6	mrad	min. (+20 %/0 %)
Closed-loop Z-travel	100	100	100	100	–	–	µm	
Closed-loop tip/tilt angle	–	±0.4	–	±0.4	–	–	mrad	
Open-loop Z-resolution	0.2	0.2	0.2	0.2	0.2	0.2	nm	typ.
Open-loop tip/tilt angle resolution	–	0.020	–	0.020	0.020		µrad	typ.
Closed-loop Z-resolution	0.5	0.5	2.5	2.5	–	–	nm	typ.
Closed-loop tip/tilt resolution	–	0.080	–	0.250			µrad	typ.
Linearity Z, θ_X, θ_Y	0.03	0.03	0.2	0.2	–	–	%	typ.
Repeatability Z	<2	<2	<10	<10	–	–	nm	typ.
Repeatability θ_X, θ_Y	–	0.01	–	0.05	–	–	µrad	typ.
Runout θ_X, θ_Y	<±5	<±5	<±5	<±5	<±5	<±5	µrad	typ.
Mechanical properties								
Stiffness Z	0.8	0.8	0.8	0.8	0.8	0.8	N/µm	±20 %
Unloaded resonant frequency (Z)	410	410	410	410	410	410	Hz	±20 %
Unloaded resonant frequency (θ_X, θ_Y)	–	330	–	330	–	330	Hz	±20 %
Resonant frequency @ 200 g (Z)	250	250	250	250	250	250	Hz	±20 %
Resonant frequency @ 200 g (θ_X, θ_Y)	–	270	–	270	–	270	Hz	±20 %
Push/pull force capacity	50 / 20	50 / 20	50 / 20	50 / 20	50 / 20	50 / 20	N	Max.
Drive properties								
Ceramic type	PICMA® P-885	PICMA® P-885	PICMA® P-885	PICMA® P-885	PICMA® P-885	PICMA® P-885		
Electrical capacitance	6.3	6.3	6.3	6.3	6.3	6.3	µF	±20 %
Dynamic operating current coefficient	7.9	7.9	7.9	7.9	7.9	7.9	µA / (Hz • µm)	±20 %
Miscellaneous								
Operating temperature range	20 to 80	20 to 80	20 to 80	20 to 80	20 to 80	20 to 80	°C	
Material	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum		
Mass	750	750	730	730	700	700	g	±5 %
Cable length	1.5	1.5	1.5	1.5	1.5	1.5	m	±10 mm
Sensoranschluss	Sub-D Special	Sub-D Special	LEMO	3 x LEMO	–	–		
Voltage connection	Sub-D Special	Sub-D Special	LEMO	3 x LEMO	LEMO	3 x LEMO		

*Parallel kinematics design; the maximum displacement for translation and tilt motion cannot be achieved at the same time
Resolution of PI Piezo Nanopositioners is not limited by friction or stiction. Value given is noise equivalent motion with E-503 (p. 2-146) or E-710 controller (p. 2-128).
Recommended controller / amplifier
Single-channel (1 per axis): E-610 servo controller / amplifier (p. 2-110), E-625 servo controller, bench-top (p. 2-114), E-621 controller module (p. 2-160)
Multi-channel: modular piezo controller system E-500 (p. 2-142) with amplifier module E-503 (three channels) (p. 2-146) or E-505 (1 per axis, high-power) (p. 2-147) and E-509 controller (p. 2-152)
Single-channel digital controller: E-753 (bench-top) (p. 2-108)
Multi-channel digital controllers: E-710 bench-top (p. 2-128), E-712 modular (p. 2-140), E-725 high-power (p. 2-126), E-761 PCI board (p. 2-130)

P-518, P-528, P-558 Piezo Z/Tip/Tilt Stage

High-Dynamics with Large Clear Aperture



P-528 Z/tip/tilt piezo nanopositioning system

- **1- and 3-Axis Versions**
- **Closed-Loop Vertical / Tilt Range to 200 µm / 2 mrad (Open-Loop to 240 / 2.4)**
- **Parallel Kinematics / Metrology for Enhanced Responsiveness & Multi-Axis Precision**
- **Frictionless, High-Precision Flexure Guiding System**
- **Outstanding Lifetime Due to PICMA® Piezo Actuators**
- **Clear Aperture 66 x 66 mm**
- **Capacitive Sensors for Highest Linearity**

P-5x8 series, Z/tip/tilt nanopositioners / scanners are open-frame, high-resolution, piezo-driven stages providing motion to 240 µm and 2.4 mrad with resolutions of up to 0.5 nm and 50 nrad. The 66 x 66 mm clear aperture is ideal for transmitted-light applications.

XY and XYZ multi-axis versions in the same form factor are also offered as P-517, P-527 (see p. 2-70) models with six degrees of freedom are available upon request.

Capacitive Position Sensors for Higher Accuracy

PI's proprietary capacitive sensors measure position directly and without physical contact. They are free of friction and hysteresis, a fact which, in combination with the positioning resolution of well under 1 nm, makes it possible to achieve very high levels of linearity. A further advantage of direct metrology with capacitive sensors is the high phase fidelity and the high bandwidth of up to 10 kHz.

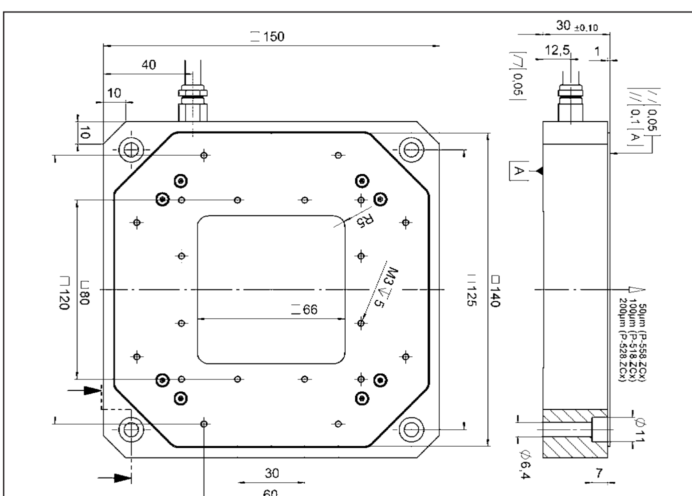
Excellent Guiding Accuracy

Flexures optimized with Finite Element Analysis (FEA) are used to guide the stage. FEA techniques are used to give the design the highest possible stiffness in, and perpendicular to, the direction of motion, and to minimize linear and angular runout. Flexures allow extremely high-precision motion, no matter how minute, as they are completely free of play and friction.

Flatness and Straightness is further enhanced by active trajectory control: Multi-axis nanopositioning systems equipped with both parallel kinematics and parallel direct metrology are able to measure platform position in all degrees of freedom against one common fixed reference. In such systems, undesirable motion from one actuator in the direction of another (cross-talk) is detected immediately and actively compensated by the servo-loops. This Active Trajectory Control Concept can keep deviation from a trajectory to under a few nanometers, even in dynamic operation.

Higher Precision in Periodic Motion

The highest dynamic accuracy in scanning applications is



P-558, P-518, P-528 dimensions in mm

Application Examples

- Metrology
- Interferometry
- Optics
- Lithography
- Scanning microscopy
- Mass storage device testing
- Laser technology
- Micromachining

Ordering Information

P-558.ZCD
Precision Nanopositioning Z-Stage, 50 µm, Direct Metrology, Capacitive Sensors, Sub-D Connector

P-558.ZCL
Precision Nanopositioning Z-Stage, 50 µm, Direct Metrology, Capacitive Sensors, LEMO Connector

P-518.ZCD
Precision Nanopositioning Z-Stage, 100 µm, Direct Metrology, Capacitive Sensors, Sub-D Connector

P-518.ZCL
Precision Nanopositioning Z-Stage, 100 µm, Direct Metrology, Capacitive Sensors, LEMO Connector

P-528.ZCD
Precision Nanopositioning Z-Stage, 200 µm, Direct Metrology, Capacitive Sensors, Sub-D Connector

P-528.ZCL
Precision Nanopositioning Z-Stage, 200 µm, Direct Metrology, Capacitive Sensors, LEMO Connector

P-558.TCD
Precision Nanopositioning Z/Tip/Tilt Stage, 50 µm, 0.6 mrad, Parallel Metrology, Capacitive Sensors, Sub-D Connector

P-518.TCD
Precision Nanopositioning Z/Tip/Tilt Stage, 100 µm, 1.4 mrad, Parallel Metrology, Capacitive Sensors, Sub-D Connector

P-528.TCD
Precision Nanopositioning Z/Tip/Tilt Stage, 200 µm, 2.4 mrad, Parallel Metrology, Capacitive Sensors, Sub-D Connector

made possible by the DDL algorithm, which is available in PI's modern digital controllers. DDL eliminates tracking errors, improving dynamic linearity and usable bandwidth by up to three orders of magnitude!

Ceramic Insulated Piezo Actuators Provide Long Lifetime

Highest possible reliability is assured by the use of award-winning PICMA® multilayer piezo actuators. PICMA® actuators are the only actuators on the market with ceramic-only insulation, which makes them resistant to ambient humidity and leakage-current failures. They are thus far superior to conventional actuators in reliability and lifetime.

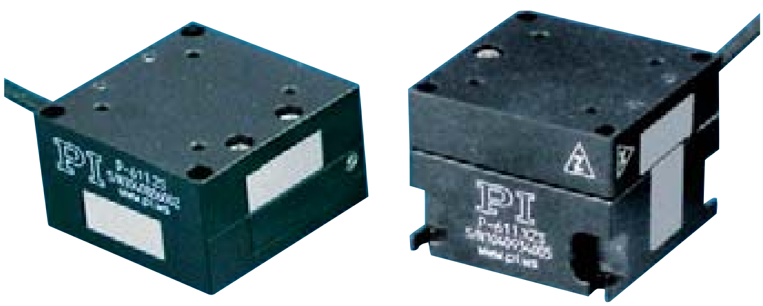
Technical Data

Model	P-558.ZCD/ P-558.ZCL	P-558.TCD	P-518.ZCD/ P-518.ZCL	P-518.TCD	P-528.ZCD/ P-528.ZCL	P-528.TCD	Units	Tolerance
Active axes	Z	Z, θ_x, θ_y	Z	Z, θ_x, θ_y	Z	Z, θ_x, θ_y		
Motion and positioning								
Integrated sensor	Capacitive	Capacitive	Capacitive	Capacitive	Capacitive	Capacitive		
Open-loop travel, -20 to +120 V	60	60	140	140	240	240	µm	min. (+20 %/-0 %)
Open-loop tip/tilt angle, -20 to +120 V	–	±0.3 mrad	–	±0.7 mrad	–	±1.2 mrad	mrad	min. (+20 %/-0 %)
Closed-loop travel	50	50	100	100	200	200	µm	
Closed-loop tip/tilt angle	–	±0.25 mrad	-	±0.5 mrad	–	±1 mrad	mrad	
Open-loop resolution	0.2	0.2	0.2	0.4	0.6	0.6	nm	typ.
Open-loop tip/tilt angle resolution	–	0.02	–	0.04	–	0.06	µrad	typ.
Closed-loop resolution	0.5	0.5	0.8	0.8	1	1	nm	typ.
Closed-loop tip/tilt resolution	–	0.05	–	0.05	–	0.1	µrad	typ.
Linearity θ_x, θ_y	–	0.03	–	0.03	–	0.03	%	typ.
Repeatability	±5	±5	±5	±5	±10	±10	nm	typ.
Repeatability θ_x, θ_y	–	±0.03	–	±0.05	–	±0.1	µrad	typ.
Runout θ_z (Z motion)	<10	<10	<10	<10	<20	<20	µrad	typ.
Runout θ_x, θ_y (Z motion)	<50	<50	<50	<50	<100	<100	µrad	typ.
Mechanical properties								
Stiffness	4	4	2.7	2.7	1.5	1.5	N/µm	±20 %
Unloaded resonant frequency (Z)	570	570	500	500	350	350	Hz	±20 %
Unloaded resonant frequency (θ_x, θ_y)	-	610	-	530	-	390	Hz	±20 %
Resonant frequency @ 30 g in Z	410	410	350	350	210	210	Hz	±20 %
Resonant frequency @ 500 g in X, Y	-	430	-	370	-	250	Hz	±20 %
Resonant frequency @2500 g in Z	245	245	200	200	130	130	Hz	±20 %
Resonant frequency @ 2500 g θ_x, θ_y	-	240	-	190	-	115	Hz	±20 %
Push/pull force capacity	100 / 50	100 / 50	100 / 50	100 / 50	100 / 50	100 / 50	N	Max.
Drive properties								
Ceramic type	PICMA® P-885	PICMA® P-885	PICMA® P-885	PICMA® P-885	PICMA® P-885	PICMA® P-885		
Electrical capacitance	6	6	8.4	8.4	14.8	14.8	µF	±20 %
Dynamic operating current coefficient	15	15	10.5	10.5	9.2	9.2	µA/(Hz•µm)	±20%
Miscellaneous								
Operating temperature range	-20 to 80	-20 to 80	-20 to 80	-20 to 80	-20 to 80	-20 to 80	°C	
Material	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum		
Dimensions	150 x 150 x 30	150 x 150 x 30	150 x 150 x 30	150 x 150 x 30	150 x 150 x 30	150 x 150 x 30	mm	
Mass	1380	1380	1400	1400	1420	1420	g	±5 %
Cable length	1.5	1.5	1.5	1.5	1.5	1.5	m	±10 mm
Sensor / voltage connection	CD-version: Sub-D special CL-version: LEMO	Sub-D Special	CD-version: Sub-D special CL-version: LEMO	Sub-D Special	CD-version: Sub-D special CL-version: LEMO	Sub-D Special		

Resolution of PI Piezo Nanopositioners is not limited by friction or stiction. Value given is noise equivalent motion with E-503 (p. 2-146) or E-710 controller (p. 2-128)
Recommended controller
CD-Versions:
Single-channel (1 per axis): E-610 servo controller / amplifier (p. 2-110), E-625 servo controller, bench-top (p. 2-114)
Single-channel digital controller: E-753 (bench-top) (p. 2-108)
CL-Versions:
Single-channel: E-500 modular piezo controller system (p. 2-142) with E-505 (p. 2-147) high-power amplifier module and E-509 servo-controller (p. 2-152)
Multi-channel versions:
Multi-channel digital controllers: E-710 bench-top (p. 2-128), E-712 modular (p. 2-140), E-725 high-power (p. 2-126), E-761 PCI board (p. 2-130)

P-611.XZ · P-611.2 XZ & XY Nanopositioner

Compact 2-Axis Piezo System for Nanopositioning Tasks



P-611 XY- and XZ-nanopositioning systems (from left), 100 µm travel, resolution to 0.2 nm

- **Compact: Footprint 44 x 44 mm**
- **Travel Range to 120 x 120 µm**
- **Resolution to 0.2 nm**
- **Cost-Effective Mechanics/Electronics System Configurations**
- **Frictionless, High-Precision Flexure Guiding System**
- **Outstanding Lifetime Due to PICMA® Piezo Actuators**
- **X, Z and XYZ Versions also Available**

P-611 piezo stages are flexure-guided nanopositioning systems featuring a compact footprint of only 44 x 44 mm. The XY- and XZ-versions described here are part of a family of positioners available in 1 to 3 axis configurations. Despite their small dimensions the systems provide up to 120 µm travel with sub-nanometer resolution. They are ideally suited for planar positioning tasks such as optical-path length correction in interferometry, sample positioning in microscopy or scanning applications, for autofocus and photonics applications. Both versions are available with 100 µm travel per axis. Equipped with ceramic-encapsulated piezo drives and a stiff, zero-stiction, zero-friction flexure guiding system, all P-611 piezo stages combine millisecond responsiveness with nanometric precision and extreme reliability.

Application Examples

- Fiber positioning
- Semiconductor testing
- Micromachining
- Micromanipulation
- MEMS fabrication/testing
- Photonics / integrated optics

Closed-Loop and Open-Loop Versions

High-resolution, fast-responding, strain gauge sensors (SGS) are applied to appropriate locations on the drive train and provide a high-bandwidth, nanometer-precision position feedback signal to the controller. The sensors are connected in a full-bridge configuration to eliminate thermal drift, and assure optimal position stability in the nanometer range.

The open-loop models are ideal for applications where fast response and very high resolution are essential, but absolute positioning is not important. They can also be used when the position is controlled by an external linear position sensor such as an interferometer, a PSD (position sensitive diode), CCD chip / image processing system, or the eyes and hands of an operator.

Versatility & Combination with Motorized Stages

The P-611 family of piezo stages comprises a variety of single- and multi-axis versions (X, XY, Z, XZ and XYZ) that can be easily combined with a number of very compact manual or motorized micropositioning systems to form coarse/fine positioners with longer travel ranges (see p. 2-20, p. 2-36 and p. 2-50).

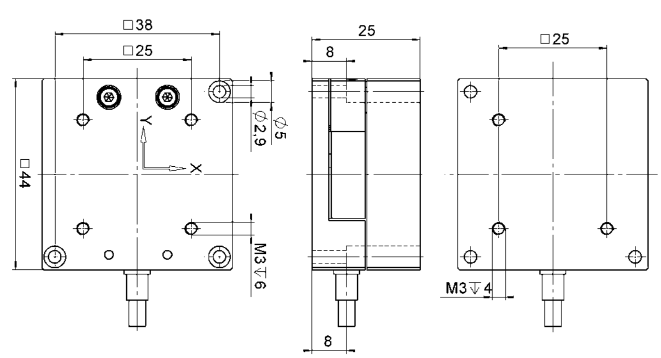
Ordering Information

P-611.2S
XY Nanopositioning System, 100 x 100 µm, SGS-Sensor

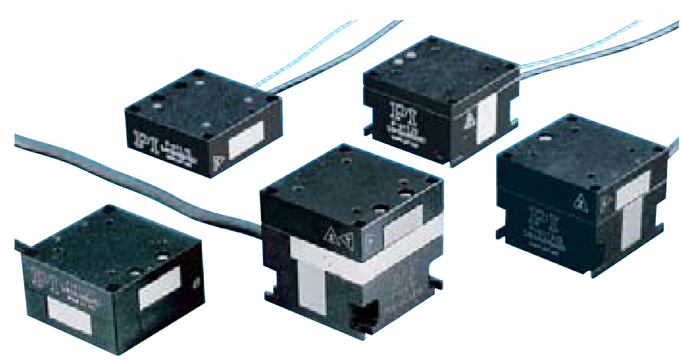
P-611.20
XY Nanopositioning System, 100 x 100 µm, No Sensor

P-611.XZS
XZ Nanopositioning System, 100 x 100 µm, SGS-Sensor

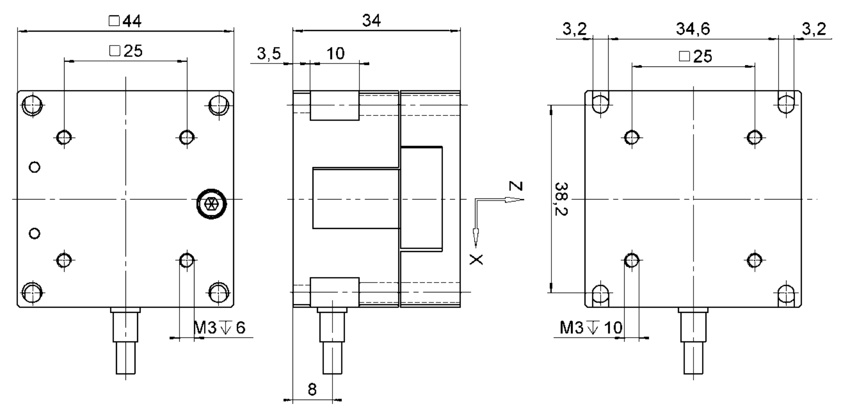
P-611.XZ0
XZ Nanopositioning System, 100 x 100 µm, No Sensor



P-611.2S dimensions in mm



The whole P-611 family: X, Z, XY, XZ and XYZ stages



P-611.XZS dimensions in mm

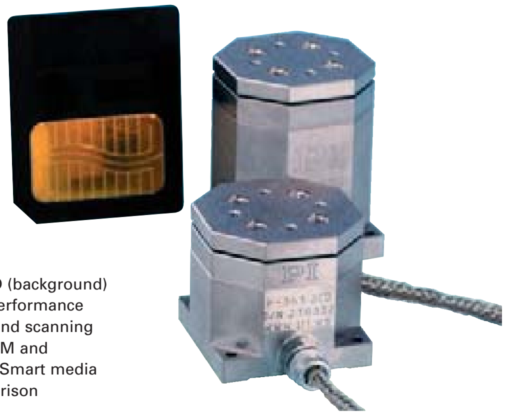
Technical Data

Models	P-611.2S	P-611.20	P-611.XZS	P-611.XZ0	Units	Tolerance
Active axes	X, Y	X, Y	X, Z	X, Z		
Motion and positioning						
Integrated sensor	SGS	–	SGS	–		
Open-loop travel, -20 to +120 V	120	20	120	120	µm	min. (+20 %/0 %)
Closed-loop travel	100	–	100	–	µm	
Open-loop resolution	0.2	0.2	0.2	0.2	nm	typ.
Closed-loop resolution	2	–	2	–	nm	typ.
Linearity	0.1	–	0.1	–	%	typ.
Repeatability	<10	–	<10	–	nm	typ.
Pitch in X,Y	±5	±5	±5	±5	µrad	typ.
Runout θ_X (Z motion)	–	–	±10	±10	µrad	typ.
Yaw in X	±20	±20	±20	±20	µrad	typ.
Yaw in Y	±10	±10	–	–	µrad	typ.
Runout θ_Y (Z motion)	–	–	±10	+/-10	µrad	typ.
Mechanical properties						
Stiffness	0.2	0.2	0.2 Z: 0.35	0.2 Z: 0.35	N/µm	±20 %
Unloaded resonant frequency	X: 345; Y: 270	X: 345; Y: 270	X: 365; Z: 340	X: 365; Z: 340	Hz	±20 %
Resonant frequency @ 30 g	X: 270; Y: 225	X: 270; Y: 225	X: 280; Z: 295	X: 280; Z: 295	Hz	±20 %
Resonant frequency @ 100 g	X: 180; Y: 165	X: 180; Y: 165	X: 185; Z: 230	X: 185; Z: 230	Hz	±20 %
Push/pull force capacity in motion direction	15 / 10	15 / 10	15 / 10	15 / 10	N	Max.
Load capacity	15	15	15	15	N	Max.
Drive properties						
Ceramic type	PICMA® P-885	PICMA® P-885	PICMA® P-885	PICMA® P-885		
Electrical capacitance	1.5	1.5	1.5	1.5	µF	±20 %
Dynamic operating current coefficient	1.9	1.9	1.9	1.9	µA/(Hz • µm)	±20 %
Miscellaneous						
Operating temperature range	-20 to 80	-20 to 80	-20 to 80	-20 to 80	°C	
Material	Aluminum, steel	Aluminum, steel	Aluminum, steel	Aluminum, steel		
Dimensions	44 x 44 x 25	44 x 44 x 25	44 x 44 x 34	44 x 44 x 34	mm	
Mass	0.235	0.235	0.27	0.27	kg	±5 %
Cable length	1.5	1.5	1.5	1.5	m	±10 mm
Sensor connection	LEMO	–	LEMO	–		
Voltage connection	LEMO	LEMO	LEMO	LEMO		

Resolution of PI Piezo Nanopositioners is not limited by friction or stiction. Value given is noise equivalent motion with E-503 amplifier (p. 2-146)
Dynamic Operating Current Coefficient in µA per Hz and µm. Example: Sinusoidal scan of 50 µm at 10 Hz requires approximately 0.9 mA drive current.
Recommended controller / amplifier
Single-channel (1 per axis): E-610 servo controller / amplifier (p. 2-110), E -625 servo controller, bench-top (p. 2-114), E-621 controller module (p. 2-160)
Multi-channel: modular piezo controller system E-500 (p. 2-142) with amplifier module E-503 (three channels) (p. 2-146) or E-505 (1 per axis, high-power) (p. 2-147) and E-509 controller (p. 2-152)

P-363 PicoCube™ XY(Z) Piezo Scanner

High-Dynamics Nanoscanner for Scanning Probe Microscopy



P-363.2CD and .3CD (background) PicoCube™, high-performance piezo positioning- and scanning systems or AFM/STM and nanomanipulation. Smart media card for size comparison

- **Ultra-High-Performance Closed-Loop Scanner for AFM/SPM**
- **Compact Manipulation Tool for Bio/Nanotechnology**
- **Resonant Frequency 9.8 kHz**
- **Capacitive Sensors for Highest Accuracy**
- **Parallel-Motion Metrology for Automated Compensation of Guiding Errors**
- **50 Picometer Resolution**
- **5 x 5 x 5 µm Travel Range**
- **Vacuum-Compatible Versions**

The P-363 PicoCube™ XY/XYZ is an ultra-high-performance closed-loop piezo scanning system. Designed for AFM, SPM and nanomanipulation applications, it combines an ultra-low inertia, high-speed XY/XYZ piezo scanner with non-contact, direct-measuring, parallel-metrology capacitive feedback capable of 50 picometers resolution. On top of being extremely precise, the PicoCube™ system is also very small and rugged. Measuring only 30 x 30 x 40 mm (with removable top plate, 30 x 30 x 28 mm for XY version), it is easy to integrate in any scanning apparatus.

Application Examples

- Scanning microscopy (SPM)
- Biotechnology
- Micromanipulation
- Nanopositioning
- Nano-imprinting
- Nanometrology
- Nanolithography

SPM, AFM, STM, Nanolithography, Nanoimprinting, Nanometrology

The PicoCube™ was specifically developed to overcome the limitations of the open-loop scanners currently available for SPM, AFM and STM. In addition to these applications, the PicoCube™ is also the ideal scanning and manipulation tool for nanoimprinting, nanolithography, ultra-high-resolution, near-field, scanning optical microscopy and nano-surface-metrology applications.

Higher Precision Through Parallel-Motion Metrology w/ Capacitive Sensors

The PicoCube™ is based on a proprietary, ultra-fast, piezo-driven scanner design equipped with direct-measuring, capacitive position sensors (parallel metrology). Unlike conventional sensors, they measure the actual distance between the fixed frame and the moving part of the stage. This results in higher-motion linearity, long-term stability, phase fidelity, and—because external disturbances are seen by the sensor immediately—a stiffer, faster-responding servo-loop.

Multi-axis nanopositioning systems equipped with parallel direct metrology are able to measure the platform position in all degrees of freedom against one fixed reference. In such systems, undesirable motion from one actuator in the direction of another (cross-talk) is detected immediately and actively compensated by the servo-loops. This Active Trajectory Control Concept can keep deviation from a trajectory to under a few nanometers, even in dynamic operation.

Ordering Information

P-363.3CD
PicoCube™ High-Precision XYZ Nanopositioning System, 5 x 5 x 5 µm, Parallel Metrology, Capacitive Sensors, Sub-D Connector

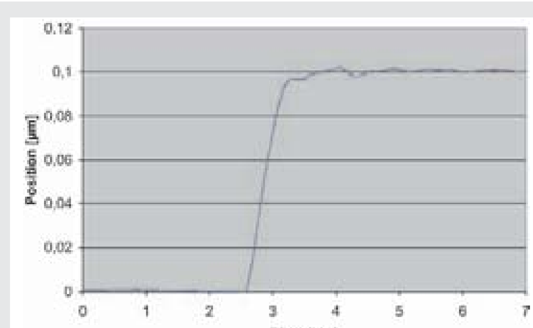
P-363.3UD
PicoCube™ High-Precision XYZ Nanopositioning System, 5 x 5 x 5 µm, Parallel Metrology, Capacitive Sensors, Sub-D Connector, Vacuum Compatible to 10^{-9} hPa

P-363.2CD
PicoCube™ High-Precision XY Nanopositioning System, 5 x 5 µm, Parallel Metrology, Capacitive Sensors, Sub-D Connector

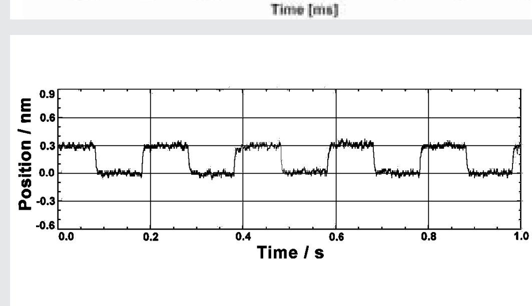
P-363.2UD
PicoCube™ High-Precision XY Nanopositioning System, 5 x 5 µm, Parallel Metrology, Capacitive Sensors, Sub-D Connector, Vacuum Compatible to 10^{-9} hPa

P-363.3CL
PicoCube™ High-Precision XYZ Nanopositioning System, 5 x 5 x 5 µm, Parallel Metrology, Capacitive Sensors, LEMO Connector

P-363.2CL
PicoCube™ High-Precision XY Nanopositioning System, 5 x 5 µm, Parallel Metrology, Capacitive Sensors, LEMO Connector



The P-363 settles to within 1 nm in 1 ms (100 nm step, X and Y motion; faster response in Z)



300 picometer steps (0.3 nm) performed with the P-363, measured with an external high-resolution, capacitive measurement system

Nanometer Accuracy in 1 Millisecond with 30-Picometer Resolution

PicoCube™ systems provide resolution of 30 picometers and below. The ultra-fast XY/XYZ piezo drives offer resonant frequencies of 9.8 kHz in Z and >3 kHz in X and Y! The high resonant frequency and high-bandwidth capacitive feedback allow step and settle to 1% accuracy in as little as one millisecond.

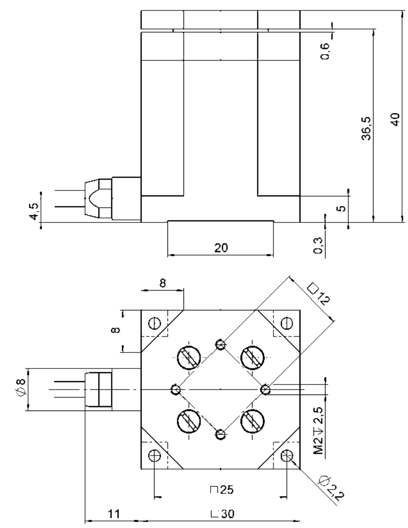
Rugged Design

In spite of its ability to move and position on an atomic scale, the PicoCube™ boasts a rugged design for real-world applications. For extra-high stability and reduced mass, the body is precision machined from heat-treated and stress-relieved titanium. The sophisticated frictionless design also ensures that the (moving) top plate protects the internal actuator/sensor unit from contamination.

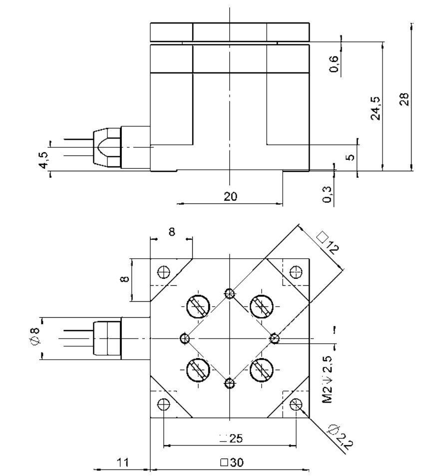
Controller

For dynamic scanning operation the E-725.3CM high-power digital controller offers advanced linearization algorithms for sub-nanometer precision (see p. 2-126).

Alternatively the analog E-536 PicoCube™ controller (see p. 2-134) comes in different versions optimized for resolution or power. An optional E-517 24-bit interface module is also available (see p. 2-156).



P-363.3Cx dimensions in mm. Removable top plate



P-363.2Cx dimensions in mm. Removable top plate

Technical Data

Model	P-363.3CD	P-363.2CD	Units
Active axes	X, Y, Z	X, Y	
Motion and positioning			
Integrated sensor	Capacitive	Capacitive	
Open-loop travel X, Y, -250 to +250 V	±3	±3	µm
Open-loop travel, -250 to +250 V	±2.7	–	µm
Closed-loop travel X, Y	±2.5	±2.5	µm
Closed-loop travel	±2.5	–	µm
Open-loop resolution	0.03*	0.03*	nm
Closed-loop resolution	0.1	0.1nm	
Linearity	0.05	0.05	%
Repeatability	1**	1**	nm
Pitch / yaw in X, Y	0.5	0.5	µrad
Runout X, Y (Z motion)	0.2	–	µrad
Straightness in X, Y	3	3	nm
Flatness in X, Y	<10	<10	nm
Crosstalk X, Y (Z motion)	5	–	nm
Mechanical properties			
Unloaded resonant frequency in X, Y	3.1	4.2	kHz
Unloaded resonant frequency (Z)	9.8	–	kHz
Resonant frequency in X, Y	1.5 (20 g)	2.1 (20 g)	kHz
Load capacity	10	10	N
Ceramic type	PICA™, PICA™ Shear	PICA™ Shear	
Miscellaneous			
Operating temperature range	-20 to 80	-20 to 80	°C
Material	Titanium	Titanium	
Dimensions	30 x 30 x 40	30 x 30 x 28	mm
Mass	225	190	g
Cable length	1.5	1.5	m
Sensor / voltage connection***	Sub-D connector PicoCube™	Sub-D connector PicoCube™	
Recommended controller	E-536 PicoCube™ Controller	E-536 PicoCube™ Controller	

Resolution of PI Piezo Nanopositioners is not limited by friction or stiction. Value given is noise equivalent motion with E-536 controller (p. 2-134)

*With E-536.3xH Controller

**for 10% travel in Z; 50 nm for 100% travel in Z

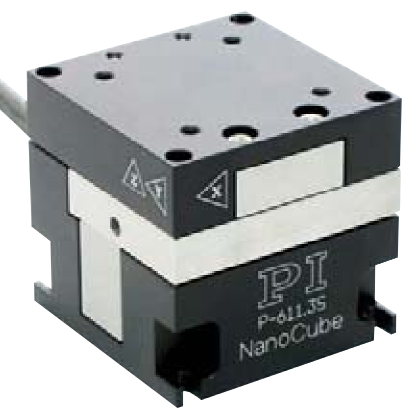
***P-363.xCL versions with LEMO connectors

System properties

System configuration	P-363.3CD (Z-axis) with 20 g load and E-536 servo controller
Settling time	(10% step width) 1 ms

P-611.3 NanoCube® XYZ Piezo Stage

Compact Multi-Axis Piezo System for Nanopositioning and Fiber Alignment



NanoCube® XYZ-nanopositioning system,
100 x 100 x 100 µm closed-loop travel range, resolution 1 nm

- **Up to 120 x 120 x 120 µm Travel Range**
- **Very Compact: 44 x 44 x 44 mm**
- **Resolution to 0.2 nm, Rapid Response**
- **Frictionless, High-Precision Flexure Guiding System**
- **Outstanding Lifetime Due to PICMA® Piezo Actuators**
- **Fast Multi-Axis Scanning**
- **Version with Integrated Fiber Adapter Interface**
- **Cost-Effective Mechanics/Electronics System Configurations**

The P-611 NanoCube® piezo stage is a versatile, multi-axis piezo-nanopositioning system. Its 100 x 100 x 100 µm positioning and scanning range comes in an extremely compact package of only 44 x 44 x 44 mm. Equipped with a stiff, zero-stiction, zero-friction guiding system, this NanoCube® provides motion with ultra-high resolution and settling times of only a few milliseconds. The minimal moved masses and the stiff piezo drive make it ideal for high-throughput applications such as fiber alignment where it enables significantliy faster device characterization than achievable with conventional motorized drives.

Application Examples

- Photonics / integrated optics
- Micromanipulation
- Biotechnology
- Semiconductor testing
- Fiber positioning

Closed-Loop and Open-Loop Versions

High-resolution, fast-responding, strain gauge sensors (SGS) are applied to appropriate locations on the drive train and provide a high-bandwidth, nanometer-precision position feedback signal to the controller. The sensors are connected in a full-bridge configuration to eliminate thermal drift, and assure optimal position stability in the nanometer range.
The open-loop models are ideal for applications where fast response and very high resolution are essential, but absolute positioning is not important, e.g. in tracking or fiber positioning. They can also be used when the position is controlled by an external linear position sensor such as an interferometer, a PSD (position sensitive diode), CCD chip / image processing system, or the eyes and hands of an operator.

Versatility & Combination with Motorized Stages

The P-611 family of piezo stages comprises a variety of single- and multi-axis versions (X, XY, Z, XZ and XYZ) that can be easily combined with a number of very compact manual or motorized micropositioning systems to form coarse/fine positioners with longer travel ranges (see p. 2-20, p. 2-36 and p. 2-50). For fiber positioning tasks, several fiber, waveguide and optics adapters are available for mounting on the NanoCube® P-611.3SF (e.g. for combination with the F-206.S nanoalignment system see p. 4-12).

High Reliability and Long Lifetime

The compact P-611 systems are equipped with preloaded PICMA® high-performance piezo actuators which are integrated into a sophisticated, FEA-modeled, flexure guiding system. The PICMA® actuators feature cofired ceramic encapsulation and thus offer better performance and reliability than conventional piezo actuators. Actuators, guidance and sensors are maintenance-free and not subject to wear, and thus offer an extraordinary reliability.

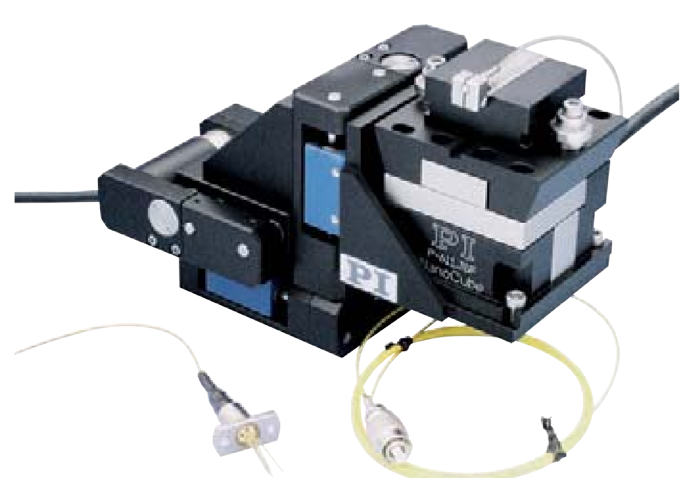
Ordering Information

P-611.3S
NanoCube® XYZ Nanopositioning System, 100 x 100 x 100 µm, Strain Gauge Sensors

P-611.3O
NanoCube® XYZ Nanopositioning System, 100 x 100 x 100 µm, Open-Loop

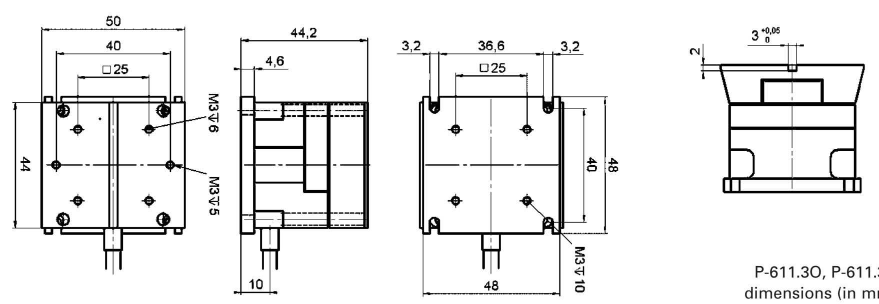
P-611.3SF
NanoCube® XYZ Nanopositioning System, 100 x 100 x 100 µm, Strain Gauge Sensors, Fiber Adapter Interface

P-611.3OF
NanoCube® XYZ Nanopositioning System, 100 x 100 x 100 µm, Open-Loop, Fiber Adapter Interface



Combination of P-611.3SF NanoCube® XYZ Nanopositioning System,
100 x 100 x 100 µm and M-111 XYZ MicroPositioner 15 x 15 x 15 mm

Linear Actuators & Motors
Nanopositioning / Piezoelectrics
Piezo Flexure Stages / High-Speed Scanning Systems
Linear
Vertical & Tip/Tilt
2- and 3-Axis
6-Axis
Fast Steering Mirrors / Active Optics
Piezo Drivers / Servo Controllers
Single-Channel
Multi-Channel
Modular
Accessories
Piezoelectrics in Positioning
Nanometrology
Micropositioning
Index



P-611.3O, P-611.3S dimensions (in mm)

Technical Data

Model	P-611.3S P-611.3SF	P-611.3O P-611.3OF	Units	Tolerance
Active axes	X, Y, Z	X, Y, Z		
Motion and positioning				
Integrated sensor	SGS			
Open-loop travel, -20 to +120 V	120 / axis	120 / axis	µm	min. (+20 %/0 %)
Closed-loop travel	100 / axis	–	µm	
Open-loop resolution	0.2	0.2	nm	typ.
Closed-loop resolution	1	–	nm	typ.
Linearity	0.1	–	%	typ.
Repeatability	<10	–	nm	typ.
Pitch in X,Y	±5	±5	µrad	typ.
Runout θ_X (Z motion)	±10	±10	µrad	typ.
Yaw in X	±20	±20	µrad	typ.
Yaw in Y	±10	±10	µrad	typ.
Runout θ_Y (Z motion)	±10	±10	µrad	typ.
Mechanical properties				
Stiffness	0.3	0.3	N/µm	±20 %
Unloaded resonant frequency X / Y / Z	350 / 220 / 250	350 / 220 / 250	Hz	±20 %
Resonant frequency @ 30 g X / Y / Z	270 / 185 / 230	270 / 185 / 230	Hz	±20 %
Resonant frequency @ 100 g X / Y / Z	180 / 135 / 200	180 / 135 / 200	Hz	±20 %
Push/pull force capacity in motion direction	+15 / -10	+15 / -10	N	Max.
Load capacity	15	15	N	Max.
Drive properties				
ceramic type	PICMA® P-885	PICMA® P-885		
Electrical capacitance	1.5	1.5	µF	±20 %
Dynamic operating current coefficient	1.9	1.9	µA/(Hz • µm)	±20 %
Miscellaneous				
Operating temperature range	-20 to 80	-20 to 80	°C	
Material	Aluminum, steel	Aluminum, steel		
Dimensions	44 x 44 x 43.2 SF-version: 44 x 50 x 44.2	44 x 44 x 43.2 OF-version: 44 x 50 x 44.2	mm	
Mass	0.32	0.32	kg	±5 %
Cable length	1.5	1.5	m	±10 mm
Sensor connector	Sub-D	–		
Voltage connection	Sub-D	Sub-D		
Recommended controller / amplifier	E-664 Nanocube® Controller (p. 2-137)	3 x E-610.00F OEM amplifier modules (p. 2-110); E-663 3-channel amplifier, bench-top (p. 2-136)		

Resolution of PI Piezo Nanopositioners is not limited by friction or stiction. Value given is noise equivalent motion with E-503 amplifier (p. 2-146)
Dynamic Operating Current Coefficient in µA per Hz and µm. Example: Sinusoidal scan of 50 µm at 10 Hz requires approximately 0.8 mA drive current.
Adapter cable with LEMO connectors for sensor and operating voltage available.

PI Piezo • Nano • Positioning

P-615 NanoCube® XYZ Piezo System

Long-Travel Multi-Axis Piezo Stage for Precision Alignment Applications

P-615NanoCube® XYZ Nanopositioning System provides up to 420 x 420 x 300 µm travel range

- **Up to 420 x 420 x 300 µm Travel Range**
- **Resolution 1 nm**
- **Parallel-Kinematics / Metrology for Enhanced Responsiveness / Multi-Axis Precision**
- **Clear Aperture of 10 mm Ø, Ideal for Alignment and Photonics Packaging Applications**
- **Outstanding Lifetime Due to PICMA® Piezo Actuators**
- **Open- & Closed-Loop Versions**
- **Vacuum-Compatible Versions to 10^{-9} hPa**
- **Frictionless, High-Precision Flexure Guiding System**

The P-615 NanoCube® is a multi-axis piezo nanopositioning and alignment system. Its 420 x 420 x 300 µm, XYZ positioning and scanning range comes in a compact package. Equipped with a zero-stiction, zero-friction guidance system, this NanoCube® provides motion with ultra-high resolution and settling times of only a few milliseconds.

Fiber Positioning

The P-615 NanoCube® is equipped with a fiber adapter interface similar to the P-611.3SF and accommodates all F-603-series fiber holders and accessories. Fiber optics handling is facilitated by the clear aperture.

Application Examples

- Micromanipulation
- Biotechnology
- Semiconductor testing
- Photonics / integrated optics

Double Stiffness for Fast Response

The P-615's unique flexure design has double the stiffness in the vertical axis than in X and Y, providing faster response and higher operating frequencies under load. For example, the settling time to reach a commanded position with 1 % accuracy is only 15 ms in the Z-axis with 100 g load (as opposed to 10 ms without load).

Open-Loop and Closed-Loop Operation

The open-loop basic model P-615.30L is ideal for applications where fast response and very high resolution are essential but specifying or reporting absolute position values is either not required or is handled by external sensors, e. g. in tracking or fiber positioning tasks. In open-loop mode, the piezo displacement is roughly proportional to the applied voltage (see p. 2-184).

Capacitive Sensors for Highest Accuracy

The P-615.3C models are equipped with high-accuracy, capacitive position sensors. PI's proprietary capacitive sensors measure position directly and without physical contact. They are free of friction and hysteresis, a fact which, in combination with the positioning resolution of well under 1 nm, makes it possible to achieve very high levels of linearity. A further advantage of direct metrology with capacitive sensors is the high phase fidelity and the high bandwidth of up to 10 kHz.

Active and Passive Guidance for Nanometer Flatness and Straightness

Wire-cut flexures optimized with Finite Element Analysis (FEA) are used to guide the stage. The FEA techniques give the design the highest possible stiffness and minimize linear and angular runout. Further enhancement is achieved by active trajectory control: multi-axis nanopositioning systems equipped with parallel metrology are able to measure platform position in all degrees of freedom against a common, fixed reference. In such systems, undesirable motion from one actuator in the direction of another (cross-talk) is detected immediately and actively compensated by the servo-loops. This can keep deviation from a trajectory to under a few nanometers, even in dynamic operation.

Ordering Information

P-615.3CD
NanoCube® XYZ Nanopositioning System with Long Travel Range, 350 x 350 x 250 µm, Parallel Metrology, Capacitive Sensors, Sub-D Connector

P-615.3CL
NanoCube® XYZ Nanopositioning System with Long Travel Range, 350 x 350 x 250 µm, Parallel Metrology, Capacitive Sensors, LEMO Connector

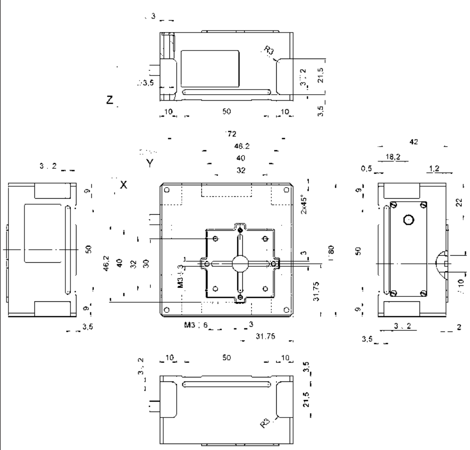
P-615.30L
NanoCube® XYZ Nanopositioning System with Long Travel Range, 420 x 420 x 300 µm, Parallel Metrology, Open-Loop, LEMO Connector

P-615.3UD
NanoCube® XYZ Nanopositioning System with Long Travel Range, 350 x 350 x 250 µm, Parallel Metrology, Capacitive Sensors, Sub-D Connector, Vacuum Compatible to 10^{-9} hPa

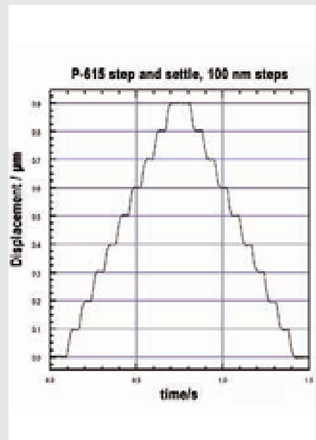
Ceramic Insulated Piezo Actuators Provide Long Lifetime

Highest possible reliability is assured by the use of award-winning PICMA® multilayer piezo actuators. PICMA® actuators are the only actuators on the market with ceramic-only insulation, which makes them resistant to ambient humidity and leakage-current failures. They are thus far superior to conventional actuators in reliability and lifetime.

Linear Actuators & Motors
Nanopositioning / Piezoelectrics
Piezo Flexure Stages / High-Speed Scanning Systems
Linear
Vertical & Tip/Tilt
2- and 3-Axis
6-Axis
Fast Steering Mirrors / Active Optics
Piezo Drivers / Servo Controllers
Single-Channel
Multi-Channel
Modular
Accessories
Piezoelectrics in Positioning
Nanometrology
Micropositioning
Index



P-615 dimensions in mm.
The clear aperture has a diameter of 10 mm.



P-615, X-axis with 100 g load performing 100 nm steps in rapid sequence without overshoot. Settling time for the Z-axis to reach a commanded position with 1 % accuracy is only 15 ms.

P-615 with optional fiber holder F-603.22

Technical Data

Model	P-615.3CD / P-615.3CL	P-615.30L	Units	Tolerance
Active axes	X, Y, Z	X, Y, Z		
Motion and positioning				
Integrated sensor	Capacitive	–		
Open-loop travel in X/Y/Z, -20 to +120 V	420 / 420 / 300	420 / 420 / 300	µm	min. (+20 %/-0 %)
Closed-loop travel X/Y/Z	350 / 350 / 250	–	µm	
Open-loop resolution X/Y/Z	0.5	0.5	nm	typ.
Closed-loop resolution X/Y/Z	1	–	nm	typ.
Linearity X/Y/Z	0.02	–	%	typ.
Repeatability in X, Y, Z	±7.5 / ±7.5 / ±5	–	nm	typ.
Pitch in X,Y	100	100	µrad	typ.
Yaw in X, Y	50	50	µrad	typ.
Runout θ_X, θ_Y (Z motion)	10	10	µrad	typ.
Mechanical properties				
Stiffness X / Y / Z	0.13 / 0.13 / 0.35	0.13 / 0.13 / 0.35	N/µm	±20 %
Unloaded resonant frequency in X / Y / Z	210 / 210 / 250	210 / 210 / 250	Hz	±20 %
Resonant frequency @ 100 g in X / Y / Z	125 / 125 / 200	125 / 125 / 200	Hz	±20 %
Push/pull force capacity in motion direction	20 / 10	20 / 10	N	Max.
Load capacity	20	20	N	Max.
Drive properties				
Ceramic type	PICMA® P-885	PICMA® P-885		
Electrical capacitance in X / Y / Z	3.7 / 3.7 / 6.2	3.7 / 3.7 / 6.2	µF	±20 %
Dynamic operating current coefficient (DOCC) in X / Y / Z	1.3 / 1.3 / 3.1	1.3 / 1.3 / 3.1	µA/(Hz·µm)	±20 %
Miscellaneous				
Operating temperature range	-20 to 80	-20 to 80	°C	
Material	Aluminum	Aluminum		
Mass	0.58	0.57	kg	±5 %
Cable length	1.5	1.5	m	±10 mm
Sensor / voltage connection	Sub-D special (CD-version); LEMO (CL-version)	LEMO (no sensor)		

Resolution of PI Piezo Nanopositioners is not limited by friction or stiction. Value given is noise equivalent motion with E-503 amplifier (p. 2-146).

Recommended controller
Multi-channel digital controllers: E-710 bench-top (p. 2-128), E-712 modular (p. 2-140), E-725 high-power (p. 2-126), E-761 PCI board (p. 2-130)
Multi-channel:
E-500 modular piezo controller system (p. 2-142) with E-509 servo-controller (p. 2-152) (optional) and as amplifier either E-503 (three channels) (p. 2-146) or E-505 (1 per axis, high-power, p. 2-147) modules P-615.30L (p. 2-68): E-610 controller / amplifier (p. 2-110) (1 per axis)

P-620.2 - P-629.2 PIHera® XY Piezo Stage

High-Precision Nanopositioner Family–Compact and Long Travel Ranges

PIHera® XY-Nanopositioniersysteme mit Stellwegen von 50 x 50 µm bis 1800 x 1800 µm

- **Travel Ranges 50 to 1800 µm**
- **High-Precision, Cost-Efficient**
- **Resolution to 0.1 nm**
- **Frictionless, High-Precision Flexure Guiding System**
- **0,02 % Positioning Accuracy**
- **Outstanding Lifetime Due to PICMA® Piezo Actuators**
- **X-, XY-, Z- and XYZ-Versions**
- **Vacuum-Compatible Versions Available**

Two-axis (XY) PIHera® systems are piezo-nanopositioning stages featuring travel ranges from 50 to 1800 µm. Despite the increased travel ranges, the units are extremely compact and provide rapid response and high guiding precision. This, and the long travel range is achieved with a friction-free and extremely stiff flexure system sub-nanometer resolution. The

Application Examples

- Interferometry
- Microscopy
- Nanopositioning
- Biotechnology
- Quality assurance testing
- Semiconductor technology

PIHera® piezo nanopositioning series also includes Z and X stages (see p. 2-22 and p. 2-40).

Nanometer Precision in Milliseconds

One of the advantages of PIHera® stages over motor-driven positioning stages is the rapid response to input changes and the fast and precise settling behavior. The P-622.1CD, for example, can settle to an accuracy of 10 nm in only 30 msec (other PI stages provide even faster response)!

Superior Accuracy With Direct-Metrology Capacitive Sensors

A choice of tasks such as optical path adjustment in interferometry, sample positioning in microscopy, precision alignment or optical tracking require the relatively long scanning ranges and nanometer precision offered by PIHera® nanopositioning stages.

PI's proprietary capacitive sensors measure position directly and without physical contact. They are free of friction and hysteresis, a fact which, in combination with the positioning resolution of well under 1 nm, makes it possible to achieve very high levels of linearity. A further advantage of direct metrology with capacitive sensors is the high phase fidelity and the high bandwidth of up to 10 kHz.

Designed for Precision

High stiffness is achieved with the FEA-optimized design of the frictionless flexure elements, which assure excellent guiding accuracy and dynamics. A straightness and flatness in the nanometer range is achieved.

Ordering Information

P-620.2CD* / P-620.2CL*
PIHera® Precision XY Nanopositioning System, 50 x 50 µm, Direct Metrology, Capacitive Sensors

P-621.2CD* / P-621.2CL*
PIHera® Precision XY Nanopositioning System, 100 x 100 µm, Direct Metrology, Capacitive Sensors

P-622.2CD* / P-622.2CL*
PIHera® Precision XY Nanopositioning System, 250 x 250 µm, Direct Metrology, Capacitive Sensors

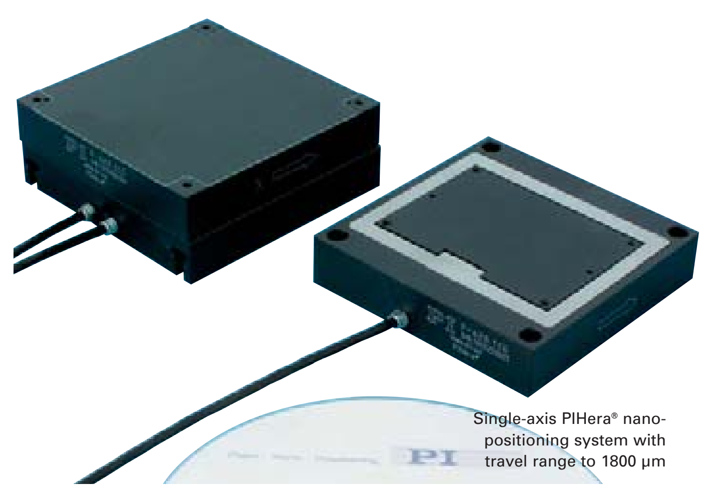
P-625.2CD* / P-625.2CL*
PIHera® Precision XY Nanopositioning System, 500 x 500 µm, Direct Metrology, Capacitive Sensors

P-628.2CD* / P-628.2CL*
PIHera® Precision XY Nanopositioning System, 800 x 800 µm, Direct Metrology, Capacitive Sensors

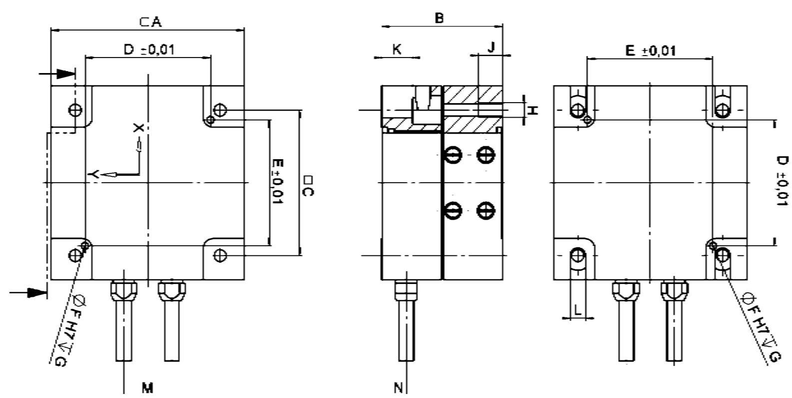
P-629.2CD* / P-629.2CL*
PIHera® Precision XY Nanopositioning System, 1500 x 1500 µm, Direct Metrology, Capacitive Sensors

*.2CD with Sub-D Connector
*.2CL with LEMO Connector

Open-loop versions are available as P-62x.20L.
Vacuum versions to 10^{-9} hPa are available as P-62x.2UD.



Single-axis PIHera® nano-positioning system with travel range to 1800 µm



	A	B	C	D	E	ØF	G
P-620.2CD / .20L	30	21,5	24	24	19	1,01	1,5
P-621.2CD / .20L	40	25	30	26	26	1,51	2,5
P-622.2CD / .20L	50	25	40	35	35	1,51	2,5
P-625.2CD / .20L	60	25	50	46	46	1,51	2,5
P-628.2CD / .20L	80	30	70	66	66	1,51	2,5

	H	J	K	L	M	N
P-620.2CD / .20L	M2	3,5	5,1	2,2	9	6
P-621.2CD / .20L	M3	5	6,25	3,2	10	5
P-622.2CD / .20L	M3	5	6,25	3,2	11	5
P-625.2CD / .20L	M3	6	6,25	3,2	11	5
P-628.2CD / .20L	M3	6	6,75	3,2	11	5

P-62x.2CD/.2CL/.20L Abmessungen in mm

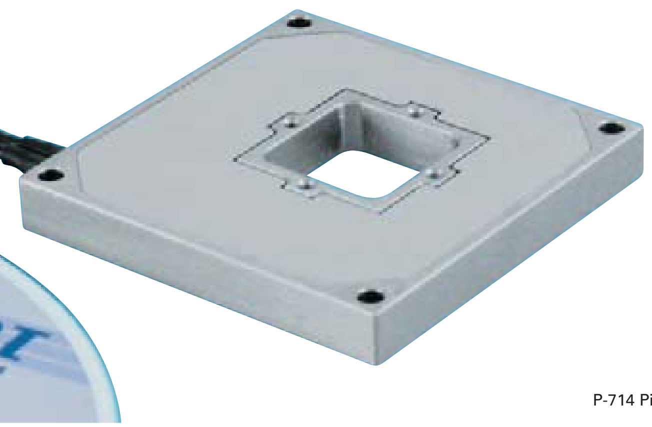
Technical Data

Model	P-620.2CD/ P-620.2CL	P-621.2CD/ P-621.2CL	P-622.2CD/ P-622.2CL	P-625.2CD/ P-625.2CL	P-628.2CD/ P-628.2CL	P-629.2CD P-629.2CL	P-62x.20L open-loop versions	Units	Tolerance
Active axes	X, Y	X, Y	X, Y	X, Y	X, Y	X, Y	X, Y		
Motion and positioning									
Integrated sensor	Capacitive	Capacitive	Capacitive	Capacitive	Capacitive	Capacitive	–		
Open-loop travel X, Y, -20 to +120 V	60	120	300	600	950	1800	as P-62x.2CD	µm	min. (+20 %/-0 %)
Closed-loop travel	50	100	250	500	800	1500	–	µm	
Open-loop resolution	0.1	0.2	0.4	0.5	0.5	2	as P-62x.2CD	nm	typ.
Closed-loop resolution	0.2	0.4	0.7	1.4	3.5	3.5	–	nm	typ.
Linearity	0.02	0.02	0.02	0.03	0.03	0.03	–	%	typ.
Repeatability	±2	±2	±2	±5	±10	±14	as P-62x.2CD	nm	typ.
Pitch / yaw	±3	±3	±3	±3	±20	±30	as P-62x.2CD	µrad	typ.
Mechanical properties									
Stiffness	0.22	0.25	0.2	0.1	0.05	0.1	as P-62x.2CD	N/µm	±20 %
Unloaded resonant frequency in X,	575	420	225	135	75	60	as P-62x.2CD	Hz	±20 %
Unloaded resonant frequency in Y	800	535	300	195	105	100	as P-62x.2CD	Hz	±20 %
Resonant frequency in X @ 50 g	270	285	180	120	60	55	as P-62x.2CD	Hz	±20 %
Resonant frequency in Y @ 50 g	395	365	215	150	85	85	as P-62x.2CD	Hz	±20 %
Resonant frequency in X @ 100 g	285	220	160	105	55	50	as P-62x.2CD	Hz	±20 %
Resonant frequency in Y @ 100 g	300	285	175	125	75	80	as P-62x.2CD	Hz	±20 %
Push/pull force capacity in motion direction	10 / 5	10 / 8	10 / 8	10 / 8	10 / 8	10 / 8	as P-62x.2CD	N	Max.
Load capacity	10	10	10	10	10	10	as P-62x.2CD	N	Max.
Lateral Force	10	10	10	10	10	10	as P-62x.2CD	N	Max.
Drive properties									
Ceramic type	PICMA® P-883	PICMA® P-885	PICMA® P-885	PICMA® P-885	PICMA® P-887	PICMA® P-888	as P-62x.2CD		
Electrical Capacitance	0.35	1.5	3.1	6.2	19	52	as P-62x.2CD	µF	±20 %
Dynamic operating current coefficient	0.9	1.9	1.9	1.6	3	4.3	as P-62x.2CD	µA/(Hz•µm)	±20 %
Miscellaneous									
Operating temperature range	-20 to 80	-20 to 80	-20 to 80	-20 to 80	-20 to 80	-20 to 80	-20 to 150	°C	
Material	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum		
Mass	0.195	0.295	0.348	0.43	0.7	1.37	as P-62x.2CD	kg	±5 %
Cable length	1.5	1.5	1.5	1.5	1.5	1.5	1.5	m	±10 mm
Sensor / voltage connection	CD version: 2x Sub-D special CL version: LEMO	CD version: 2x Sub-D special CL version: LEMO	CD version: 2x Sub-D special CL version: LEMO	CD version: 2x Sub-D special CL version: LEMO	CD version: 2x Sub-D special CL version: LEMO	CD version: 2x Sub-D special CL version: LEMO	2x LEMO (no sensor)		

Lower axis: X; upper axis: Y.
Resolution of PI Piezo Nanopositioners is not limited by friction or stiction. The value given is noise equivalent motion with E-710 controller (p. 2-128)
Recommended controller
CD version: E-610 servo controller / amplifier (p. 2-110), E-625 servo controller, bench-top (p. 2-114), E-665 powerful servo controller, bench-top (p. 2-116)
Multi-channel digital controllers: E-710 bench-top (p. 2-128), E-712 modular (p. 2-140), E-725 high-power (p. 2-126), E-761 PCI board (p. 2-140)
CL version: E-500 modular piezo controller system (p. 2-142) with E-505 amplifier module (1 per axis, high power) (p. 2-147) and E-509 controller (p. 2-152)
Open-loop versions: E-500 modular piezo controller system (p. 2-142) with E-505 amplifier module (1 per axis, high power) (p. 2-147)

P-713 · P-714 XY Piezo Scanner

Cost-Effective OEM System with Low Profile



P-714 Piezo Scanner

- **Ideal for Pixel Sub-Stepping in Image Enhancement**
- **Small Footprint and Low Profile: 45 x 45 x 6 mm with Clear Aperture**
- **Very Cost-Effective Design**
- **Travel Ranges to 20 x 20 µm**
- **Parallel Kinematics for Better Multi-Axis Accuracy and Dynamics**

P-713 / P-714 family piezo scanners and positioners with travel ranges of 15 x 15 µm feature especially compact designs. Ideal applications for the P-713 and P-714 are high-dynamics scanning or tracking tasks such as sub-stepping methods for enhancing image resolution. Such tasks involve moving to specific positions in a small area (e. g. marked cells or CCD photosites) and from there following or performing motion with an amplitude of a few microns. The resonant frequency of up to over 2 kHz makes for settling times of a few milliseconds, even after a full-range move, all with closed-loop repeatability of under 5 nm.

A single-axis version with similar footprint is available as P-712 (see p. 2-14) and XY versions with longer travel ranges are available on request.

Application Examples

- Pixel dithering / sub-stepping image resolution enhancement
- Quality assurance testing
- Optical Metrology
- Microscopy
- Imaging
- CCD / CMOS camera technology

Flexibility

P-713 and P-714 nanopositioners are offered in different versions for different applications. The lowest-cost, basic version of the P-713 offers guiding accuracy in the motion plane of 50 µrad, a value generally good enough for dithering and interlacing tasks in scanning patterns of a few microns. For more demanding applications, the P-714 offers greater accuracy, typically 5 µrad or <10 nm absolute.

Nanometer Position Servo-Control

If servo-control is required and no external position sensor is available, the P-714.2SL version, equipped with high-resolution strain gauge sensors (SGS) can provide nanometer-range resolution.

High-resolution, broadband, strain gauge sensors (SGS) are applied to appropriate locations on the drive train and measure the displacement of the moving part of the stage relative to the base indirectly. The SGS sensors assure optimum position stability in the nanometer range and fast response.

Ceramic Insulated Piezo Actuators Provide Long Lifetime

Highest possible reliability is assured by the use of award-winning PICMA® multilayer piezo actuators. PICMA® actuators are the only actuators on the market with ceramic-only insulation, which makes them resistant to ambient humidity and leakage-current failures. They are thus far superior to conventional actuators in reliability and lifetime.

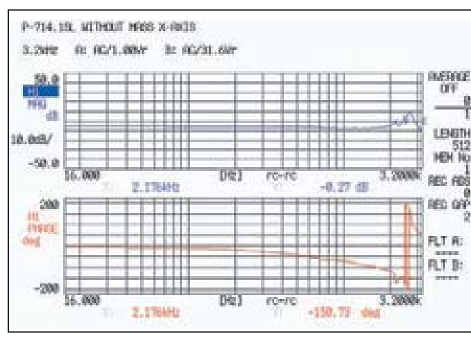
Ordering Information

P-713.20L
Low-Profile OEM XY Nanoscanner, 15 x 15 µm, No Sensor, LEMO Connector

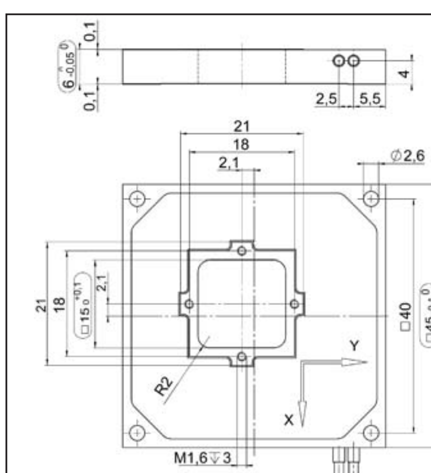
P-714.20L
Low-Profile OEM XY Nanoscanner, 15 x 15 µm, Improved Guiding Accuracy, No Sensor, LEMO Connector

P-713.2SL
Low-Profile OEM XY Nanoscanner, 15 x 15 µm, SGS-Sensor, LEMO Connector

P-714.2SL
Low-Profile OEM XY Nanoscanner, 15 x 15 µm, Improved Guiding Accuracy, SGS-Sensor, LEMO Connector



The resonant frequency of an unloaded P-713 / P-714 scanner is over 2 kHz

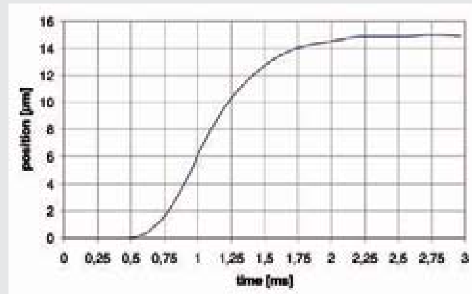


P-713/P-714 dimensions in mm

Linear Actuators & Motors
Nanopositioning / Piezoelectrics
Piezo Flexure Stages / High-Speed Scanning Systems
Linear
Vertical & Tip/Tilt
2- and 3-Axis
6-Axis
Fast Steering Mirrors / Active Optics
Piezo Drivers / Servo Controllers
Single-Channel
Multi-Channel
Modular
Accessories
Piezoelectrics in Positioning
Nanometrology
Micropositioning
Index

See the "Selection Guide" for comparison with other nanopositioning systems (see p. 2-4 *ff*).

System properties	
System controller	P-714.2SL with modular system E-500 (E-503 amplifier and E-509 sensor module); 20 g load
Bandwidth, small signal	300 Hz
Bandwidth, large signal	220 Hz
Settling time (10 % step width)	3.1 ms
Settling time (full travel)	4.5 ms



Settling time for the P-713/P-714 at 15 µm is in the 2 ms range

Technical Data

Model	P-713.20L	P-713.2SL	P-714.20L	P-714.2SL	Units	Tolerance
Active axes	X, Y	X, Y	X, Y	X, Y		
Motion and positioning						
Integrated sensor	-	SGS	-	SGS		
Open-loop travel, -20 to +120 V	20	20	20	20	µm	min. (+20 %/0 %)
Closed-loop travel	-	15	-	15	µm	
Open-loop resolution	0.1	0.1	0.1	0.1	nm	typ.
Closed-loop resolution	-	1	-	1	nm	typ.
Linearity	-	0.3	-	0.3	%	typ.
Repeatability	-	<4	-	<4	nm	typ.
Pitch	typ. ±1 max. ±5	typ. ±1 max. ±5	typ. ±1 max. ±5	typ. ±1 max. ±5	µrad	typ.
Yaw	typ. ±40 max. ±50	typ. ±40 max. ±50	typ. ±40 max. ±50	typ. ±40 max. ±50	µrad	µrad
Mechanical properties						
Stiffness	0.8	0.8	0.8	0.8	N/µm	±20 %
Unloaded resonant frequency	2250	2250	2250	2250	Hz	±20 %
Resonant frequency under load	1310 (20 g) 1020 (50 g) 460 (100 g)	1310 (20 g) 1020 (50 g) 460 (100 g)	1310 (20 g) 1020 (50 g) 460 (100 g)	1310 (20 g) 1020 (50 g) 460 (100 g)	Hz	±20 %
Push/pull force capacity in motion direction	5 / 5	5 / 5	5 / 5	5 / 5	N	Max.
Load capacity	2	2	2	2	N	Max.
Drive properties						
Ceramic type	PICMA® P-882	PICMA® P-882	PICMA® P-882	PICMA® P-882		
Electrical capacitance in X , Y	0.31	0.31	0.31	0.31	µF	±20 %
Dynamic operating current coefficient (DOCC) in X, Y	2.5	2.5	2.5	2.5	µA/(Hz • µm)	±20 %
Miscellaneous						
Operating temperature range	-20 to 80	-20 to 80	-20 to 80	-20 to 80	°C	
Material	Stainless steel, ferromagnetic	Stainless steel, ferromagnetic	Stainless steel, ferromagnetic	Stainless steel, ferromagnetic		
Dimensions	45 x 45 x 6	45 x 45 x 6	45 x 45 x 6	45 x 45 x 6		
Mass	0.1	0.1	0.1	0.1	kg	±5 %
Cable length	1.5	1.5	1.5	1.5	m	±10 mm
Sensor connection	-	LEMO	-	LEMO		
Voltage connection	LEMO	LEMO	LEMO	LEMO		

Resolution of PI piezo nanopositioners is not limited by friction or stiction. Value given is noise equivalent motion with E-503 amplifier (p. 2-146)

Dynamic Operating Current Coefficient in µA per Hz and µm. Example: Sinusoidal scan of 10 µm at 100 Hz requires approximately 2.5 mA drive current.

Recommended controller / amplifier

Single-channel (1 per axis): E-610 servo controller / amplifier (p. 2-110), E-625 servo controller, bench-top (p. 2-114), E-621 controller module (p. 2-160)

Multi-channel: modular piezo controller system E-500 (p. 2-142) with amplifier module E-503 (three channels) (p. 2-146) or E-505 (1 per axis, high-power) (p. 2-147) and E-509 controller (p. 2-152)

P-612 XY Piezo Nanopositioning System

Compact, Clear Aperture

P-612.2SL XY piezo stage (CD for size comparison)

- Compact: Footprint 60 x 60 mm
- 100 x 100 µm Closed-Loop Travel Range (130 x 130 Open-Loop)
- For Cost-Sensitive Applications
- Clear Aperture 20 x 20 mm
- Parallel-Kinematics for Enhanced Responsiveness / Multi-Axis Precision
- Outstanding Lifetime Due to PICMA® Piezo Actuators
- Z-Stage Also Available

The P-612.2SL is a piezo-based nanopositioning system featuring a compact footprint of only 60 x 60 mm and a height of 18 mm. Due to the 20 x 20 mm open aperture, the system is excellently suited for sample positioning in microscopy or scanning applications. Equipped with piezo drives and zero-stiction, zero-friction flexure guiding system, the series provides nanometer-range resolution and millisecond response time. A Z stage with the same form factor is available for vertical positioning applications (see P-612.ZSL p. 2-36).

Cost-Effective Design

Flexures optimized with Finite Element Analysis (FEA) are used to guide the compact, low-cost stage. Flexures allow extremely high-precision motion, no matter how minute, as they are completely free of play and friction. They also optimize stiffness in and perpendicular to the direction of motion.

Position Servo-Control with Nanometer Resolution

High-resolution, broadband, strain gauge sensors (SGS) are applied to appropriate locations on the drive train and measure the displacement of the moving part of the stage relative to the base directly. The SGS sensors assure optimum position stability in the nanometer range and fast response.

The open-loop models are ideal for applications where fast response and very high resolution are essential, but absolute positioning is not important. They can also be used in applications where the position is controlled by an external linear position sensor such as an interferometer, a PSD (position sensitive diode), CCD chip / image processing system, or the eyes and hands of an operator.

Ordering Information

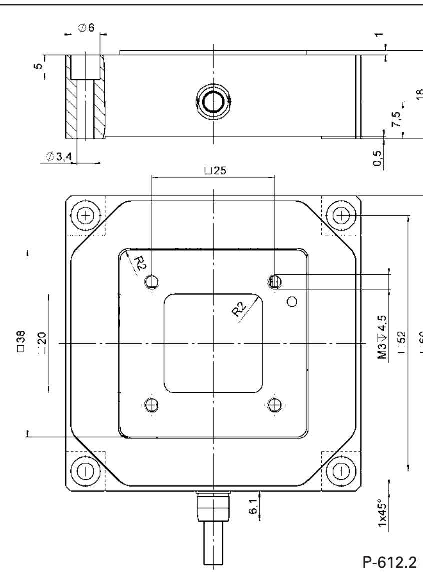
P-612.2SL
XY Nanopositioning System with 20 x 20 mm Aperture, 100 x 100 µm, Strain Gauge Sensors

P-612.20L
XY Nanopositioning System with Aperture 20 x 20 mm, 100 x 100 µm, Open-Loop

Ceramic Insulated Piezo Actuators Provide Long Lifetime

Highest possible reliability is assured by the use of award-winning PICMA® multilayer piezo actuators. PICMA® actuators are the only actuators on the market with ceramic-only insulation, which makes them resistant to ambient humidity and leakage-current failures. They are thus far superior to conventional actuators in reliability and lifetime.

System properties	
System configuration	P-612.2 SL and E-500 modular system with E-503 amplifier and E-509 sensor module, 100 load
Amplifier bandwidth, small signal	45 Hz
Settling time (10 % step width)	15 ms



P-612.2 dimensions in mm

P-612 are available as XY-scanners (P-612.2SL, on the left) and vertical stages (P-612.ZSL, on the right) providing a travel range of 100 µm per axis

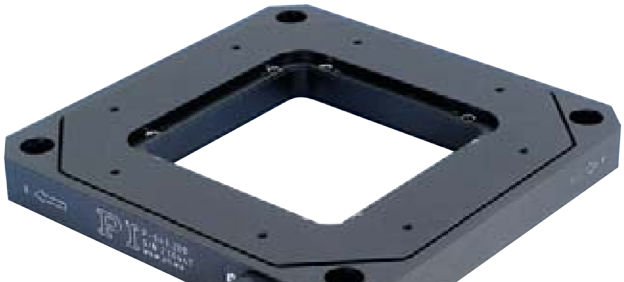
Technical Data

Model	P-612.2SL	P-612.20L	Units	Tolerance
Active axes	X, Y	X, Y		
Motion and positioning				
Integrated sensor	SGS	–		
Open-loop travel, -20 to +120 V	130	130	µm	min. (+20 %/-0 %)
Closed-loop travel	100	–		µm
Open-loop resolution	0.8	0.8	nm	typ.
Closed-loop resolution	5	–	nm	typ.
Linearity	0.4	–	%	typ.
Repeatability	<10	–	nm	typ.
Pitch	±10	±10	µrad	typ.
Yaw in X/ Y	±10 / ±50	±10 / ±50	µrad	typ.
Mechanical properties				
Stiffness	0.15	0.15	N/µm	±20 %
Unloaded resonant frequency	400	400	Hz	±20 %
Resonant frequency @ 100 g	200	200	Hz	±20 %
Push/pull force capacity in motion direction	15 / 5	15 / 5	N	Max.
Load capacity	15	15	N	Max.
Drive properties				
Ceramic type	PICMA® P-885	PICMA® P-885		
Electrical capacitance	1.5	1.5	µF	±20 %
Dynamic operating current coefficient	1.9	1.9	µA/(Hz • µm)	±20 %
Miscellaneous				
Operating temperature range	-20 to 80	-20 to 80	°C	
Material	Aluminum, steel	Aluminum, steel		
Mass	105	105	g	±5 %
Cable length	1.5	1.5	m	±10 mm
Sensor connector	LEMO connector	–		
Voltage connection	LEMO connector	LEMO connector		

Resolution of PI Piezo Nanopositioners is not limited by friction or stiction. Noise equivalent motion with E-503 amplifier (p. 2-146)
Recommended controller
Single-channel (1 per axis): E-610 servo-controller / amplifier (p. 2-110) , E-625 servo-controller, bench-top (p. 2-114), E-621 controller module (p. 2-160)
Multi-channel: modular piezo controller system E-500 (p. 2-142) with amplifier module E-503 (three channels) (p. 2-146) or E-505 (1 per axis, high-power) (p. 2-147) and E-509 controller (p. 2-152)

P-541.2 – P-542.2 Piezo XY-Stage

Low-Profile XY Nanopositioning System with Large Aperture



The P-541/P-542-series nanopositioning stages feature a very low profile of 16.5 mm, a large 80 x 80 mm aperture and deliver highly accurate motion with sub-nanometer resolution. Dimensions and hole pattern are the same for all P-541/P-542 stages

- **Low Profile for Easy Integration: 16.5 mm; 80 x 80 mm Clear Aperture**
- **Up to 200 x 200 µm Travel Range**
- **Parallel-Kinematics / Metrology for Enhanced Responsiveness & Multi-Axis Precision**
- **High-Dynamics Direct-Drive Version**
- **Choice of Sensors: Strain Gauge (Lower Cost) or Capacitive Sensors (Higher Performance)**
- **Outstanding Lifetime Due to PICMA® Piezo Actuators**
- **Combination with Long Travel Microscopy Stages or Longer Stroke**

Low Profile, Optimized for Microscopy Applications

P-541/P-542 nanopositioning and scanning stages are designed for easy integration into high-resolution microscopes. They feature a very low profile of 16.5 mm, a large 80 x 80 mm aperture, and offer highly accurate motion with sub-nanometer resolution.

A variety of Z stages and Z-tip/tilt stages with the same footprint are also offered to suit a wide range of applications (p. 2-44). They are ideal for alignment, nano-focusing or metrology tasks.

Application Examples

- Laser technology
- Scanning microscopy
- Mask / wafer positioning
- Interferometry
- Metrology
- Biotechnology
- Micromanipulation

Choice of Drives: Long Range or High-Speed Direct Drive

Lever-amplified XY systems with 100 and 200 µm travel and direct-driven XY scanners with 45 µm travel are available. Their high resonant frequencies of 1.5 kHz in both axes allow for faster step response and higher scanning rates, needed for example in single-molecule microscopy, or in other time-critical applications.

Parallel Kinematics for Fast Response

In a parallel kinematics multi-axis system, all actuators act directly on one moving platform. This means that all axes move the same minimized mass and can be designed with identical dynamic properties. Systems with parallel kinematics and metrology have additional advantages over serially stacked or nested systems, including more-compact construction and no cumulative error from the different axes.

Parallel kinematics systems can be operated with up to six degrees of freedom with low inertia and excellent dynamic performance. Multi-axis nanopositioning systems equipped with both parallel kinematics and parallel, direct metrology are able to measure platform position in all degrees of freedom against one common fixed reference. In such systems, undesirable motion from one actuator in the direction of another (cross talk) is detected immediately and actively compensated by the servo-loops.

Tailored Position Measurement

Integrated high-resolution position sensors provide fast response and positional stability in the nanometer range. Top-of-the-line models use capacitive sensors. They measure displacement directly and without physical contact (direct metrology) enabling superior linearity. Alternatively, versions with cost-effective strain gauge sensors (SGS) are also available.

Ordering Information

P-541.2DD
XY Nanopositioning System with large Aperture, High-Speed Direct Drive, 45 x 45 µm, Parallel Kinematics, Capacitive Sensors

P-541.2CD
XY Nanopositioning System with large Aperture, 100 x 100 µm, Parallel Kinematics, Capacitive Sensors

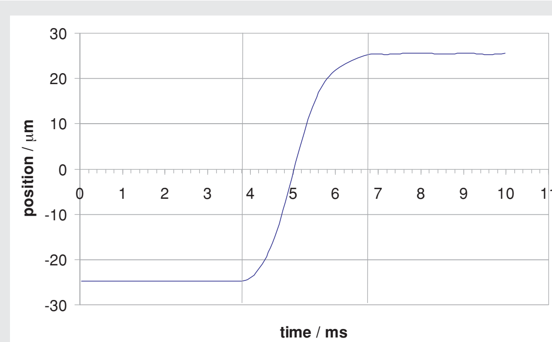
P-542.2CD
XY Nanopositioning System with large Aperture, 200 x 200 µm, Parallel Kinematics, Capacitive Sensors

P-541.2SL
XY Nanopositioning System with large Aperture, 100 x 100 µm, Strain Gauge Sensors

P-542.2SL
XY Nanopositioning System with large Aperture, 200 x 200 µm, Strain Gauge Sensors

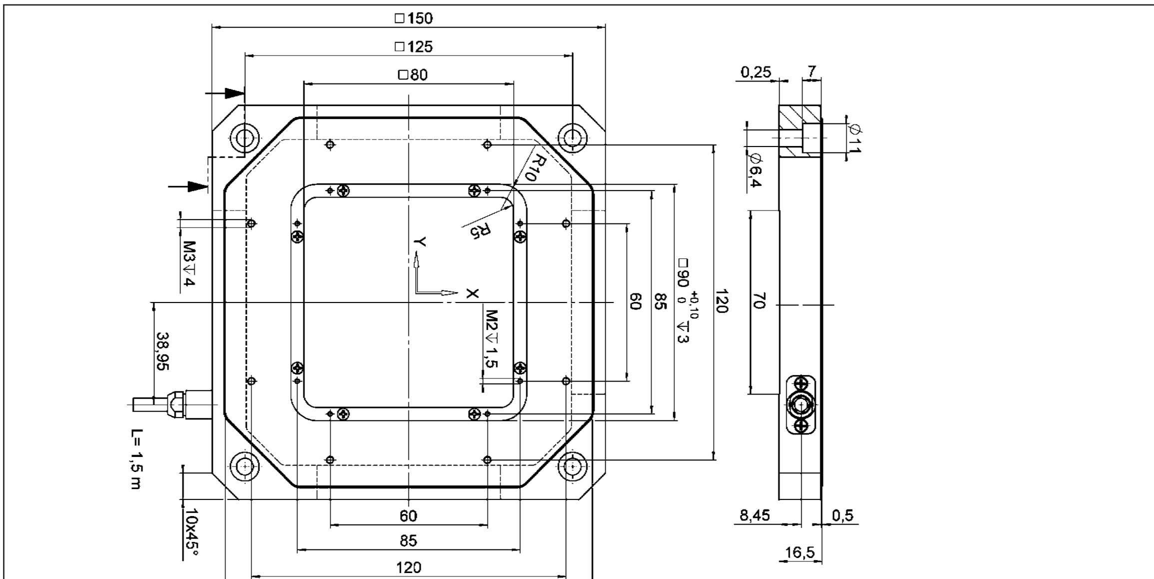
P-541.20L
XY Nanopositioning System with large Aperture, 100 x 100 µm, Open Loop

P-542.20L
XY Nanopositioning System with large Aperture, 200 x 200 µm, Open Loop



The settling time of a P-541.2DD stage is only 3 ms for a 50 µm step

System properties	
System configuration	P-541.2CD and E-500 modular system with E-503 amplifier and E-509 sensor module, 200 g load
Amplifier bandwidth, large signal	35 Hz
Settling time (full travel)	28 ms



P-541.2 and P-542.2, dimensions in mm

Technical Data

Model	P-541.2CD	P-542.2CD	P-541.2DD	P-541.2SL	P-542.2SL	P-541.20L	P-542.20L	Units	Tolerance
Active axes	X, Y	X, Y	X, Y	X, Y	X, Y	X, Y	X, Y		
Motion and positioning									
Integrated sensor	Capacitive	Capacitive	Capacitive	SGS	SGS	–	–		
Open-loop travel, -20 to +120 V	175 x 175	290 x 290	60 x 60	175 x 175	290 x 290	175 x 175	290 x 290	µm	min. (+20 %/0 %)
Closed-loop travel	100 x 100	200 x 200	45 x 45	100 x 100	200 x 200	–	–	µm	
Closed-loop / open-loop resolution	0.3 / 0.2	0.7 / 0.4	0.3 / 0.1	2.5 / 0.2	4/0.4	– / 0.2	– / 0.4	nm	typ.
Linearity	0.03	0.03	0.03*	0.2	0.2	–	–	%	typ.
Repeatability	<5	<5	<5	<10	<10	–	–	nm	typ.
Pitch	<±5	<±5	<±3	<±5	<±5	<±5	<±5	µrad	typ.
Yaw	<±10	<±10	<±3	<±10	<±10	<±10	<±10	µrad	typ.
Mechanical properties									
Stiffness in motion direction	0.47	0.4	10	0.47	0.4	0.47	0.4	N/µm	±20 %
Unloaded resonant frequency	255	230	1550	255	230	255	230	Hz	±20 %
Resonant frequency @ 100 g	200	190	–	200	190	200	190	Hz	±20 %
Resonant frequency @ 200 g	180	–	1230	180	–	180	–	Hz	±20 %
Resonant frequency @ 300 g	150	145	–	150	145	150	145	Hz	±20 %
Push/pull force capacity in motion direction	100 / 30	100 / 30	100 / 30	100 / 30	100 / 30	100 / 30	100 / 30	N	Max.
Load capacity	20	20	20	20	20	20	20	N	Max.
Drive properties									
Ceramic type	PICMA® P-885	PICMA® P-885	PICMA® P-885	PICMA® P-885	PICMA® P-885	PICMA® P-885	PICMA® P-885		
Electrical capacitance per axis	4.2	7.5	9	4.2	7.5	4.2	7.5	µF	±20 %
Dynamic operating current coefficient per axis	5.2	4.8	25	5.2	4.8	5.2	4.8	µA/(Hz • µm)	±20 %
Miscellaneous									
Operating temperature range	20 to 80	20 to 80	20 to 80	-20 to 80	-20 to 80	-20 to 80	-20 to 80	°C	
Material	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum		
Mass	1100	1150	1210	1050	1100	1050	1100	g	±5 %
Cable length	1.5	1.5	1.5	1.5	1.5	1.5	1.5	m	±10 mm
Sensor connection	Sub-D Special	Sub-D Special	Sub-D Special	LEMO	LEMO	–	–		
Voltage connection	Sub-D Special	Sub-D Special	Sub-D Special	LEMO	LEMO	LEMO	LEMO		

Resolution of PI Piezo Nanopositioners is not limited by friction or stiction. Value given is noise equivalent motion with E-503 (p. 2-146) or E-710 controller (p. 2-128).
Dynamic Operating Current Coefficient in µA per Hz and µm. Example: Sinusoidal scan of 10 µm at 10 Hz requires approximately 0.48 mA drive current for the P-542.2CD.
*With digital controller. Non-linearity of direct drive stages measured with analog controllers is up to 0.1 % typ.
Recommended controller / amplifier
Single-channel (1 per axis): E-610 servo controller / amplifier (p. 2-110), E-625 servo controller, bench-top (p. 2-114), E-621 controller module (p. 2-160)
Multi-channel: modular piezo controller system E-500 (p. 2-142) with amplifier module E-503 (three channels) (p. 2-146) or E-505 (1 per axis, high-power) (p. 2-147) and E-509 controller (p. 2-152) (for systems with sensors)
Multi-channel digital controllers: E-710 bench-top (p. 2-128), E-712 modular (p. 2-140), E-725 high-power (p. 2-126), E-761 PCI board (p. 2-130)

PI Piezo • Nano • Positioning

P-545 PI nano™ XYZ / PI nano™ XY Piezo Stage Systems

Low-Profile, Low-Cost Nanopositioning Systems for Super-Resolution Microscopy

PI nano™series nanopositioning stages feature a very low profile of 20 mm (0.8), a large aperture for 3 x 1'' slides and deliver highly accurate motion with sub-nanometer resolution in up to 3 axes. Slide / petri dish holders optional

- **Low Profile for Easy Integration: 20 mm (0.8")**
- **Up to 200 x 200 x 200 µm Travel Ranges**
- **Large Clear Aperture for 3 x 1" Slides**
- **Recessed Sample Holders for Maximized Utility Available**
- **Outstanding Lifetime Due to PICMA®Piezo Actuators**
- **Cost-Effective Design due to Piezoresistive Sensors**
- **Compatible w/ Leading Image Acquisition Software Package**
- **Closed-Loop Control for High Repeatability and Accuracy**
- **Millisecond Step Time, Ideal for Super-Resolution Microscopy**
- **24-Bit Controller w/ USB, Ethernet, RS-232 Interface and Analog Control**
- **Available Manual Long-Travel Stage with Motor Upgrade Option**

Long Travel, Low Profile, Optimized for Microscopy

PI nano™ XY and XYZ low-profile piezo scanning stages are optimized for easy integration into high-resolution microscopes. They feature a very low profile of 20 mm (0.8") and a large aperture designed to hold Petri dishes and standard slide holders. The long travel ranges of up to 200 x 200 x 200 µm with nanometer closed-loop resolution are ideal for leading-edge microscopy and imaging applications.

Application Examples

- Super-resolution microscopy
- 3D Imaging
- Laser technology
- Interferometry
- Metrology
- Biotechnology
- Screening
- Micromanipulation

Cost Effective Design, High Performance

PI nano™ series piezo positioning stages are designed to provide high performance at minimum cost. For highly-stable, closed loop operation, piezoresistive sensors are applied directly to the moving structure and precisely measure the displacement of the stage platform. The very high sensitivity of these sensors provides optimum position stability and responsiveness as well as nanometer resolution. A proprietary servo controller significantly improves the motion linearity compared to conventional piezoresistive sensor controllers.

High Reliability and Long Lifetime

The compact P-545 systems are equipped with preloaded PICMA® high-performance piezo actuators which are integrated into a sophisticated, FEA-modeled, flexure guiding system. The PICMA® actuators feature cofired ceramic encapsulation and provide better performance and reliability than conventional piezo actuators. Actuators, guidance and sensors are maintenance-free, not subject to wear and offer extraordinary reliability.

Ordering Information

P-545.2R7
PInano™ XY Piezo Stage, Slide-Size Aperture, 200 x 200 µm, Piezoresistive Sensors, with USB Controller

P-545.3R7
PInano™ XYZ Piezo Stage, Slide-Size Aperture, 200 x 200 x 200 µm, Piezoresistive Sensors, with USB Controller

Controller included

E-545.3RD
PInano™ Multi-Channel Piezo Controller with High-Speed Digital Interface, 3 Channels, Piezoresistive Sensors, Sub-D Connectors

Accessories

M-545.2MO
XY Microscope Stage, 25 x 25 mm, Micrometer-Driven, High Stability, Compatible with PI® Piezo Stages, for Olympus Microscopes

M-545.2MN
XY Microscope Stage, 25 x 25 mm, Micrometer-Driven, High Stability, Compatible with PI® Piezo Stages, for Nikon Microscopes

M-545.2ML
XY Microscope Stage, 25 x 25 mm, Micrometer-Driven, High Stability, Compatible with PI® Piezo Stages, for Leica Microscopes

M-545.2MZ
XY Microscope Stage, 25 x 25 mm, Micrometer-Driven, High Stability, Compatible with PI® Piezo Stages, for Zeiss Microscope

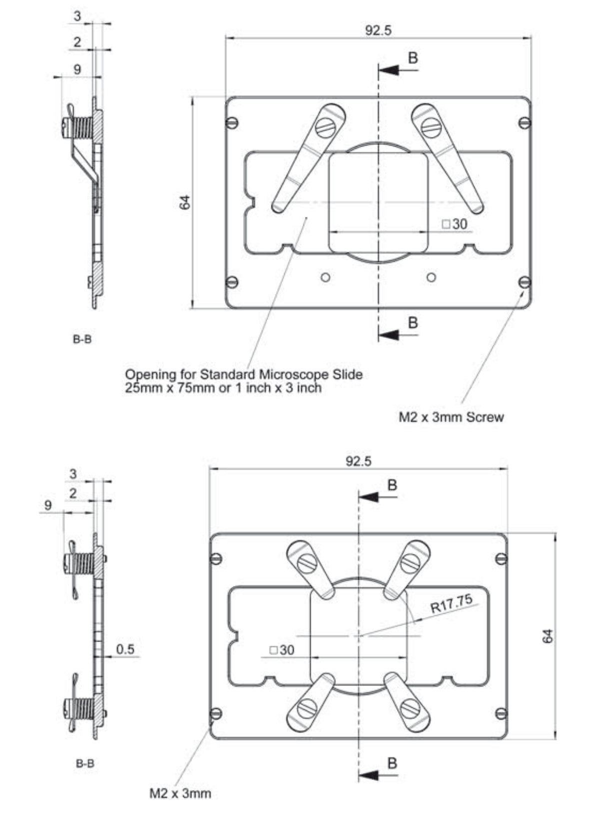
P-545.PD3
35mm Petri Dish Holder for P-545 PInano™ Piezo Stages

P-545.SH3
Microscope Slide Holder for PInano™ Piezo Stages

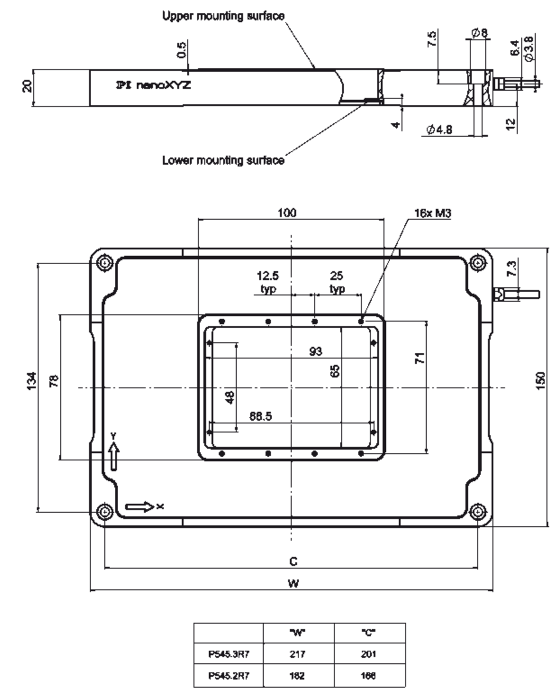
P-545.PP3
Plain Plate for Accessories for PInano™ Piezo Stages

Additional accessories on request.

Background: the piezo controller is included and comes with a 24-bit resolution USB port as well as ethernet, RS-232 and analog interface. Foreground: The optional M-545 manual XY stage provides a stable platform for the PI nano™ piezo stages. Custom stage version shown



Accessories: Slide holder (above) and Petri dish holder (below), dimensions in mm



P-545 dimensions in mm

Technical Data

Model	P-545.2R7	P-545.3R7	Unit	Tolerance
Active axes	X, Y	X, Y, Z		
Motion and positioning				
Integrated sensor	piezoresistive	piezoresistive		
Closed-loop travel	200 x 200	200 x 200 x 200	µm	
Closed-loop resolution*	1	1	nm	typ.
Linearity	±0.1	±0.1	%	typ.
Repeatability	< 5	< 5	nm	typ.
Mechanical properties				
Push/pull force capacity	100 / 30	100 / 30	N	max.
Load	50	50	N	max.
Drive properties				
Ceramic type	PICMA® P-885	PICMA® P-885		
Electrical capacitance	6	6 (X, Y), 12 (Z)	µF	±20%
Miscellaneous				
Operating temperature range	-20 to 80	-20 to 80	°C	
Material	Aluminum	Aluminum		
Mass	1	1.2	kg	±5%
Cable length	1.5	1.5	m	±10 mm
Sensor / voltage connection	Sub-D, 25 pin	Sub-D, 25 pin		
Piezo controller (included in delivery)	E-545	E-545		

* Resolution of PI Piezo Nanopositioners is not limited by friction or stiction. Value given is noise equivalent motion measured with interferometer.

PI Piezo • Nano • Positioning

P-733.2 · P-733.3 XY(Z) Piezo-Nanopositioning Stage

High-Precision XY(Z) Scanner Family with Aperture

P -733.3 DD (left) and P -733.2 DD, high-speed, direct drive XY(Z) scanning stages are the fastest scanning stages with large aperture currently available (2.2 kHz resonant frequency!). Both units feature a footprint of only 100 x 100 mm. CD for size comparison.

- **Travel Ranges to 100 x 100 µm in X,Y & to 10 µm in Z**
- **Resolution to 0.1 nm with Capacitive Sensors**
- **High-Speed Versions with Direct Drive**
- **Vacuum and Non-Magnetic Versions**
- **Parallel Kinematics for Better Multi-Axis Accuracy and Dynamics**
- **Parallel Metrology for Active Trajectory Control**
- **Frictionless, High-Precision Flexure Guiding System**
- **Clear Aperture 50 x 50 mm for Transmitted-Light Applications**

P-733 XY and XYZ piezo driven stages are fast and highly accurate nanopositioning and scanning systems. They provide a positioning and scanning range of 100 x 100 (x10) µm together with sub-nanometer resolution and are equipped with parallel-metrology capacitive position feedback for superior multi-axis linearity and repeatability. The guiding accuracy minimizes runout to under 10 nm over the whole travel range. In addition, the high-speed Z-axis of the P-733.3CD can actively compensate any out-of-plane Z-axis deviation during XY motion.

Application Examples

- Image processing / stablilization
- Scanning microscopy
- Surface inspection
- Metrology / interferometry
- Biotechnology
- Semiconductor testing
- Mask / wafer positioning
- Micromanipulation
- Nanopositioning with high flatness & straightness

Fastest Multi-Axis Systems / Direct Drive, Low Profile and Large Apertures

P-733.2DD / .3DD multi-axis piezo nanopositioning systems are the fastest ultra-high-precision, open-frame stages for scanning microscopy. They provide a positioning and scanning range of 30 x 30 (x10) µm. P-733 nanopositioning and scanning stages feature very low profiles, as low as 20 mm (0.8 inch). The novel, high-stiffness direct drive gives the systems resonant frequencies as high as 2.2 kHz (4 x that of other comparable systems), enabling millisecond scanning rates with sub-nanometer resolution.

Parallel-Kinematics / Metrology for Enhanced Responsiveness

In a parallel kinematics multi-axis system, all actuators act directly on one moving platform. This means that all axes move the same minimized mass and can be designed with identical dynamic properties. Multi-axis nanopositioning systems equipped with both parallel kinematics and parallel, direct metrology are able to measure platform position in all degrees of freedom against one common fixed reference. In such systems, undesirable motion from one actuator in the direction of another (cross talk) is detected immediately and actively compensated by the servo-loops.

Capacitive Sensors for Subnanometer Resolution

PI's proprietary capacitive sensors measure position directly and without physical contact. They are free of friction and hysteresis, a fact which, in combination with the positioning resolution of well under 1 nm, makes it possible to achieve very high levels of linearity. A further advantage of direct metrology with capacitive sensors is the high phase fidelity and the high bandwidth of up to 10 kHz. The closed-loop resolution is 0.3 nm for the X and Y axes and 0.2 nm for the optional Z-axis. The direct drive versions are rated to 0.1 nm resolution for every axis.

Large Variety of Models for a Broad Range of Applications

For Z-axis scanning applications, the P-733.ZCD (see p. 2-42) version is available with a travel range of 100 µm. For ultra-high-vacuum applications down to 10^{-9} hPa, nanopositioning systems as well as comprehensive accessories, such as suitable feedthroughs, are available.

Ordering Information

P-733.2DD
High-Dynamics High-Precision XY Nanopositioning System, 30 x 30 µm, Direct Drive, Capacitive Sensors, Parallel Metrology, Sub-D Connector

P-733.3DD
High-Dynamics Precision XYZ Nanopositioning System, 30 x 30 x 10 µm, Direct Drive, Capacitive Sensors, Parallel Metrology, Sub-D Connector

P-733.2CD* / P-733.2CL*
High-Precision XY Nanopositioning System, 100 x 100 µm, Capacitive Sensors, Parallel Metrology

P-733.3CD* / P-733.3CL*
Precision XYZ Nanopositioning System, 100 x 100 x 10 µm, Capacitive Sensors, Parallel Metrology

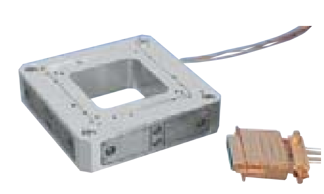
P-733.2VL* / P-733.2VD*
High-Precision XY Nanopositioning System, 100 x 100 µm, Capacitive Sensors, Parallel Metrology, Vacuum Compatible to 10-6 hPa

P-733.2UD
High-Precision XY Nanopositioning System, 100 x 100 µm, Capacitive Sensors, parallel metrology, Sub-D Connector, Vacuum Compatible to 10-9 hPa

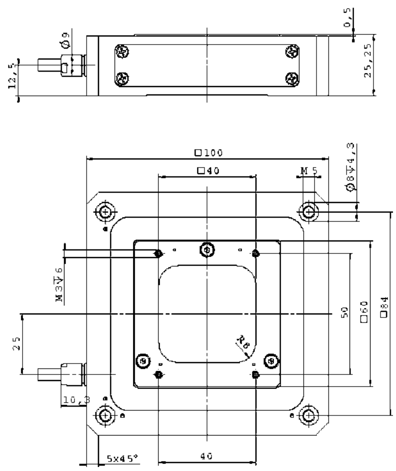
*.xxD with Sub-D Connector

*.xxL with LEMO Connector

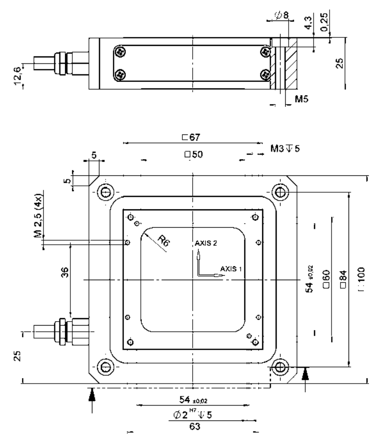
Ask about custom designs



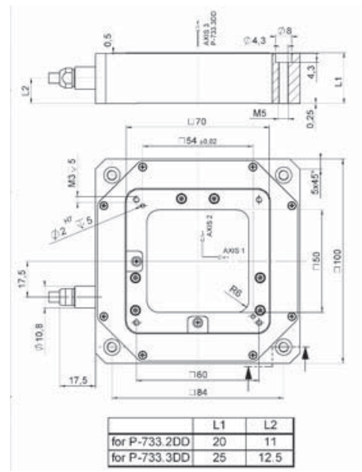
P-733.2UD non-magnetic XY scanning stage for UHV to 10^{-9} hPa



P-733.3 dimensions in mm



P-733.2 dimensions in mm



P-733.xDD dimensions in mm

Technical Data

Model	P-733.2CD P-733.2CL	P-733.3CD P-733.3CL	P-733.2DD	P-733.3DD	Units	Tolerance
Active axes	X, Y	X, Y, Z	X, Y	X, Y, Z		
Motion and positioning						
Integrated sensor	Capacitive	Capacitive	Capacitive	Capacitive		
Open-loop travel, -20 to +120 V	115 x 115	115 x 115 x 12	33 x 33	33 x 33 x 14	µm	min. (+20 %/-0 %)
Closed-loop travel	100 x 100	100 x 100 x 10	30 x 30	30 x 30 x 10	µm	
Open-loop resolution	0.2	0.2 (0.1 in Z)	0.1	0.1	nm	typ.
Closed-loop resolution	0.3	0.3 (0.2 in Z)	0.1	0.1	nm	typ.
Linearity (X, Y)	0.03	0.03	0.03*	0.03*	%	typ.
Linearity (Z)	–	0.03	–	0.03*	%	typ.
Repeatability (X, Y)	<2	<2	<2	<2	nm	typ.
Repeatability (Z)	–	<1	–	<1	nm	typ.
Pitch (X,Y)	<±3	<±3	<±5	<±5	µrad	typ.
Yaw (X, Y)	<±10	<±10	<±10	<±10	µrad	typ.
Runout θZ (motion in Z)		<±5		<±5	µrad	typ.
Mechanical properties						
Stiffness	1.5	1.4 (9 in Z)	20	4 (10 in Z)	N/µm	±20 %
Unloaded resonant frequency	500	460 (1400 in Z)	2230	1200 (1100 in Z)	Hz	±20 %
Resonant frequency @ 120 g	370	340 (1060 in Z)	-	-	Hz	±20 %
Resonant frequency @ 200 g	340	295 (650 in Z)	1550	530 (635 in Z)	Hz	±20 %
Push/pull force capacity in motion direction	50/20	50/20	50/20	50/20	N	Max.
Drive properties						
Ceramic type	PICMA® P-885	PICMA® P-885	PICMA® P-885	PICMA® P-885		
Electrical capacitance	6	6 (2.4 in Z)	6.2	6.2 (3.3 in Z)	µF	±20 %
Dynamic operating current coefficient	7.5	7.5 (30 in Z)	25	25 (41 in Z)	µA	(Hz • µm) ±20 %
Miscellaneous						
Operating temperature range	-20 to 80	-20 to 80	-20 to 80	-20 to 80	°C	
Material	Aluminum	Aluminum	Aluminum	Aluminum		
Mass	0.58	0.675	0.58	0.675	kg	±5 %
Cable length	1.5	1.5	1.5	1.5	m	±10 mm
Sensor/ voltage connection	Sub-D special (CD-version) LEMO (CL-version)	Sub-D special (CD-version) LEMO (CL-version)	Sub-D special	Sub-D special		

*With digital controller. Non-linearity of direct drive stages measured with analog controllers is up to 0.1 % typ.

Recommended controller:
Single-channel (1 per axis): E-610 servo controller / amplifier (p. 2-110), E -625 servo controller, bench-top (p. 2-114), E-621 controller module (p. 2-160)
Multi-channel: modular piezo controller system E-500 (p. 2-142) with amplifier module E-503 (three channels) (p. 2-146) or E-505 (1 per axis, high-power) (p. 2-147) and E-509 controller (p. 2-152)
Multi-channel digital controllers: E-710 bench-top (p. 2-128), E-712 modular (p. 2-140), E-725 high-power (p. 2-126), E-761 PCI board (p. 2-130)

P-517 · P-527 Multi-Axis Piezo Scanner

High-Dynamics Nanopositioner / Scanner with Direct Position Metrology

P-527.2CL parallel-kinematic nanopositioning system

- **Travel Ranges to 200 µm**
- **Sub-Nanometer Resolution**
- **Frictionless, High-Precision Flexure Guiding System**
- **Capacitive Sensors for Highest Linearity**
- **Parallel-Kinematics / Metrology for Enhanced Responsiveness / Multi-Axis Precision**
- **Clear Aperture 66 x 66 mm**
- **Outstanding Lifetime Due to PICMA® Piezo Actuators**

P-517 and P-527 high-dynamics, multi-axis piezo-nanopositioning stages are available in XY ΘZ, XY and XYZ configurations featuring linear travel ranges to 200 x 200 x 20 µm and rotation ranges to 4 mrad. The 66 x 66 mm clear aperture is ideal for transmitted-light applications.
Z/tip/tilt versions in the same form factor are also offered as models P-518, P-528, P-558 (see p. 2-46) and as custom versions with up to six degrees of freedom.

Capacitive Sensors for Highest Accuracy

PI's proprietary capacitive sensors measure position directly and without physical contact. They are free of friction and hysteresis, a fact which, in combination with the positioning resolution of well under 1 nm, makes it possible to achieve very high levels of linearity. A further advantage of direct metrology with capacitive sensors is the high phase fidelity and the high bandwidth of up to 10 kHz.

Application Examples

- Metrology
- Interferometry
- Optics
- Lithography
- Nanopositioning
- Scanning microscopy
- Mass storage device testing
- Laser technology
- Micromachining

Technical Data

Models	P-517.2CL	P-527.2CL	P-517.3CL/ P-517.3CD	P-527.3CL/ P-527.3CD	P-517.RCD	P-527.RCD
Active axes	X, Y	X, Y	X, Y, Z	X, Y, Z	X, Θ_Y, Θ_Z	Θ_Y, Θ_Z
Motion and positioning						
Integrated sensor	Capacitive	Capacitive	Capacitive	Capacitive	Capacitive	Capacitive
Open-loop travel, -20 to +120 V	130	250	130; Z: 25	250; Z: 25	130; Θ_Z: ±1.3 mrad	250; Θ_Z: ±2.5 mrad
Closed-loop travel	100	200	100; Z: 20	200; Z: 20	100; Θ_Z: ± 1 mrad	200; Θ_Z: ± 2 mrad
Open-loop resolution	0.3	0.5	0.3; Z: 0.1	0.5; Z: 0.1	0.3; Θ_Z: 0.1 µrad	0.5; Θ_ZZ: 0.1 µrad
Closed-loop resolution	1	2	1; Z: 0.1	2; Z: 0.1	1; Θ_Z: 0.3 µrad	2; Θ_Z: 0.3 µrad
Linearity	0.03	0.03	0.03	0.03	0.03	0.03
Repeatability	±5	±10	±5; Z: ±1	±10; Z: ±1	±5; Z: ±0.5 µrad	±10
Mechanical properties						
Stiffness	2	1	2; Z: 15	1; Z: 15	2	1
Unloaded resonant frequency	450	350	450; Z: 1100	350; Z: 1100	450; Z: 400	350; Z: 300
Resonant frequency @ 500 g X, Y	250	190	250	190	250	190
Resonant frequency @ 2500 g X, Y	140	110	140	110	140	110
Push/pull force capacity in motion direction	50 / 30	50 / 30	50 / 30	50 / 30	50 / 30	50 / 30
Drive properties						
Ceramic type	PICMA® P-885	PICMA® P-885	PICMA® P-885	PICMA® P-885	PICMA® P-885	PICMA® P-885
Electrical capacitance	9.2	9.2	9; Z: 6	9; Z: 6	9	9
Dynamic operating current coefficient (DOCC)	11.5	5.8	11.5; Z: 37	5.5; Z: 37	11.5	5.5
Miscellaneous						
Operating temperature range	-20 to 80	-20 to 80	-20 to 80	-20 to 80	-20 to 80	-20 to 80
Material	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum
Mass	0.14	0.14	0.145	0.145	0.14	0.14
Sensor / voltage connection	LEMO	LEMO	Sub-D special (CD-version) LEMO (CL-version)	; Sub-D special (CD-version) LEMO (CL-version)	Sub-D Special	Sub-D Special

Resolution of PI Piezo Nanopositioners is not limited by friction or stiction. Value given is noise equivalent motion with E -503 or E-710 controller (p. 2-146 or p. 2-128)
Linear Dynamic Operating Current Coefficient in µA per Hz and µm. Example for P-527.2xx: Sinusoidal scan of 30 µm at 10 Hz requires approximately 1.8 mA drive current (p. 2-70). Electrical capacitance and DOCC of the rotatic stated.
Recommended controller
Versions with LEMO connectors: Single-channel (1 per axis): E-610 servo-controller / amplifier (p. 2-110), E-625 servo-controller, bench-top (p. 2-114), E-621 controller module (p. 2-160) Multi-channel: modular piezo controller sy (three channels) (p. 2-146) or E-505 (1 per axis, high-power) (p. 2-147) and E-509 controller (p. 2-152)
Versions with Sub-D connectors: Multi-channel digital controllers: E-710 bench-top (p. 2-128), E-712 modular (p. 2-140), E-725 high-power (p. 2-126), E-761 PCI board (p. 2-130)

Active and Passive Guidance for Nanometer Flatness and Straightness

Flexures optimized with Finite Element Analysis (FEA) are used to guide the stage. The FEA techniques provide for the highest possible stiffness in, and perpendicular to, the direction of motion, and minimize linear and angular runout. Flexures allow extremely high-precision motion, no matter how minute, as they are completely free of play and friction. Due to the parallel kinematics design there is only one common moving platform for all axes, minimizing mass, enabling identical dynamic behavior and eliminating cumulative errors. Parallel kinematics also allows for a more compact construction and faster response compared to stacked or nested designs. The high precision due to flexure guidance is further enhanced by Active Trajectory Control: Multi-axis nanopositioning systems equipped with both parallel kinematics and parallel direct metrology are able to measure platform position in all degrees of freedom against one common fixed reference. In such systems, undesirable motion from one actuator in the direction of another (cross-talk) is detected immediately and actively compensated by the servo-loops. This Active Trajectory Control Concept can keep deviation from a trajectory to under a few nanometers, even in dynamic operation.

Ceramic Insulated Piezo Actuators Provide Long Lifetime

Highest possible reliability is assured by the use of award-winning PICMA® multilayer piezo actuators. PICMA® actuators are the only actuators on the market with ceramic-only insulation, which makes them resistant to ambient humidity and leakage-current failures. They are thus far superior to conventional actuators in reliability and lifetime.

Ordering Information

P-517.2CL
Precision XY Nanopositioning System, 100 x 100 µm, Capacitive Sensors, Parallel Metrology, LEMO Connector

P-527.2CL
Precision XY Nanopositioning System, 200 x 200 µm, Capacitive Sensors, Parallel Metrology, LEMO Connector

P-517.3CL
Precision XYZ Nanopositioning System, 100 x 100 x 20 µm, Capacitive Sensors, Parallel Metrology, LEMO Connector

P-517.3CD
Precision XYZ Nanopositioning System, 100 x 100 x 20 µm, Capacitive Sensors, Parallel Metrology, Sub-D Connector

P-527.2CL
Precision XY Nanopositioning System, 200 x 200 µm, Capacitive Sensors, Parallel Metrology, LEMO Connector

P-527.3CD
Precision XYZ Nanopositioning System, 200 x 200 x 20 µm, Capacitive Sensors, Parallel Metrology, Sub-D Connector

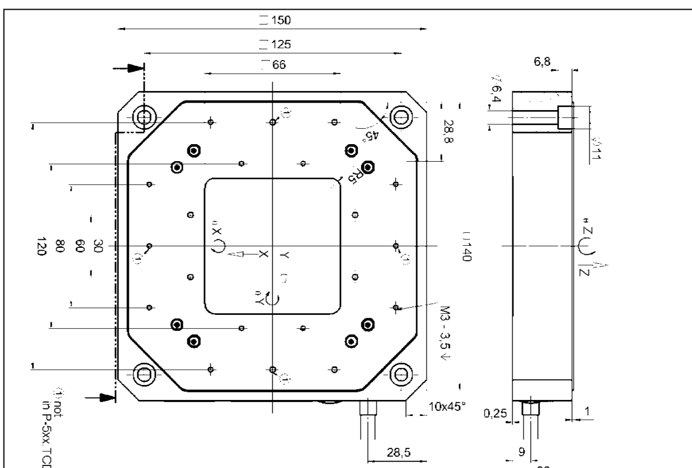
P-517.RCD
Precision XY / rotation nanopositioning system, 100 x 100 µm, 2 mrad, Capacitive Sensors, Parallel Metrology, Sub-D Connector

P-527.RCD
Precision XY / rotation nanopositioning system, 200 x 200 µm, 4 mrad, Capacitive Sensors, Parallel Metrology, Sub-D Connector

Units	Tolerance
µm	min.(+20%/0%)
µm	
nm	typ.
nm	typ.
%	typ.
nm	typ.
N/µm	±20%
Hz	±20%
Hz	±20%
Hz	±20%
N	Max.
µF	±20%
µA/(Hz • µm)	±20%
°C	
kg	±5%

on axes base upon differential motion in X, Y; therefore not

stem E-500 (p. 2-142) with amplifier module E-503



P-517, P-527 dimensions in mm, cable length 1.5 m

P-561 · P-562 · P-563 PIMars™ XYZ Piezo System

High-Precision Nanopositioning Stage, 3 to 6 Axes

P-562 PIMars™ multi-axis, parallel-kinematics nanopositioning stages are available with up to 340 µm travel per axis. Custom versions to 6 DOF are available

- **Parallel-Kinematics / Metrology for Enhanced Responsiveness / Multi-Axis Precision**
- **Travel Ranges to 340 x 340 x 340 µm**
- **Capacitive Sensors for Highest Linearity**
- **Frictionless, High-Precision Flexure Guiding System**
- **Excellent Scanning Flatness**
- **High-Dynamics XYZ Version Available; Custom Versions to 6-DOF**
- **Clear Aperture 66 x 66 mm**
- **Outstanding Lifetime Due to PICMA® Piezo Actuators**
- **UHV Versions to 10^{-9} hPa**

PIMars™ open-frame piezo stages are fast and highly accurate multi-axis scanning and nanopositioning systems with flatness and straightness in the nanometer range.

The 66 x 66 mm clear aperture is ideal for transmitted-light applications such as near-field scanning or confocal micro-scopy and mask positioning.

Large Variety of Models

PIMars™ multi-axis nanopositioners are offered in a large variety of configurations. Standard models include long-travel systems (to 300 x 300 x 300 µm), high-speed and vacuum versions. Custom six-axis designs with rotation to 6 mrad are available on request.

Application Examples

- Scanning microscopy
- Mask/wafer positioning
- Interferometry
- Metrology
- Biotechnology
- Micromanipulation

PI offers versions specially designed for applications in ultra-high vacuum with vacuum-qualified components only. The integrated ceramic-encapsulated PICMA® actuators allow high bakeout temperatures and assure minimal outgassing rates. A non-magnetizable version is available on request.

Direct Drive for Ultra-Fast Scanning and Positioning

The P-561.3DD versions have resonant frequencies to 1.0 kHz, enabling millisecond scanning rates with sub-nanometer resolution.

Capacitive Sensors for Highest Accuracy and Position Stability

PI's proprietary capacitive sensors measure position directly and without physical contact. They are free of friction and hysteresis, a fact which, in combination with the positioning resolution of well under 1 nm, makes it possible to achieve very high levels of linearity. A further advantage of direct metrology with capacitive sensors is the high phase fidelity and the high bandwidth of up to 10 kHz.

Active and Passive Guidance for Nanometer Flatness and Straightness

Wire-cut flexures optimized with Finite Element Analysis (FEA) are used to guide the stage. The FEA techniques give the design the highest possible stiffness and minimize linear and angular runout. Further enhancement is achieved by active trajectory control: multi

Ordering Information

P-561.3CD
PIMars™ XYZ Piezo-Nano-positioning System, 100 x 100 x 100 µm, Parallel Metrology

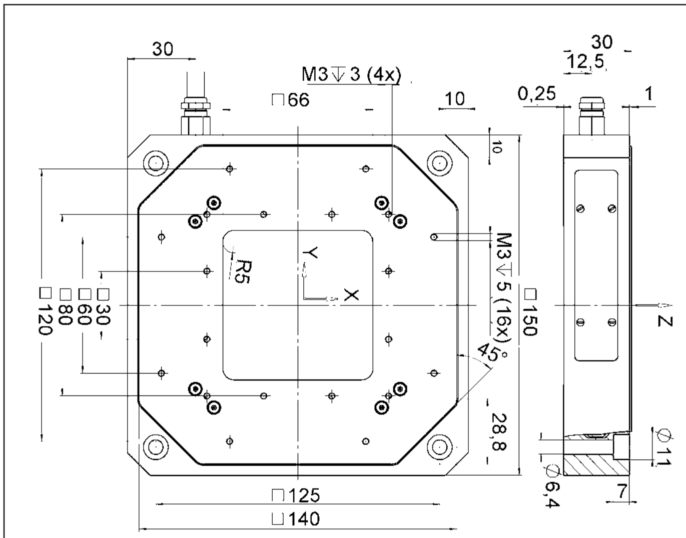
P-562.3CD
PIMars™ XYZ Piezo-Nano-positioning System, 200 x 200 x 200 µm, Parallel Metrology

P-563.3CD
PIMars™ XYZ Piezo-Nanopositioning System, 300 x 300 x 300 µm, Parallel Metrology

P-561.3DD
PIMars™ High-Dynamics XYZ Nanopositioning System, 45 x 45 x 15 µm, Parallel Metrology, Direct Drive

Vacuum-compatible versions to 10^{-6} hPa for the P-561.3CD, P-562.3CD and P-563.3CD models are available as P-561.3VD, P-562.3VD and P-563.3VD; versions to 10^{-9} hPa as P-561.3UD, P-562.3UD and P-563.3UD.

Super-invar & titanium versions are available, 6-DOF versions on request.

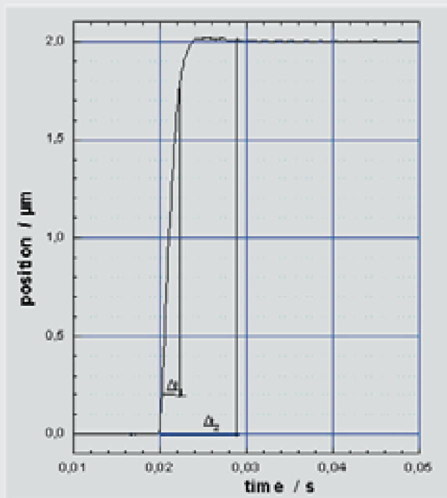


P-561, P-562, P-562 dimensions in mm

System properties

System Configuration	P-561.3CD with E-710 digital controller, 330 g load
Amplifier bandwidth, small signal	25 Hz in X, Y; 35 Hz in Z
Settling time (10 % step)	20 ms

axis nanopositioning systems equipped with parallel metrology are able to measure platform position in all degrees of freedom against a common, fixed reference. In such systems, undesirable motion from one actuator in the direction of another (cross-talk) is detected immediately and actively compensated by the servo-loops. This can keep deviation from a trajectory to under a few nanometers, even in dynamic operation.



P-562.3CD (unloaded) step and settle is faster than 10 ms in X, Y and Z

Technical Data

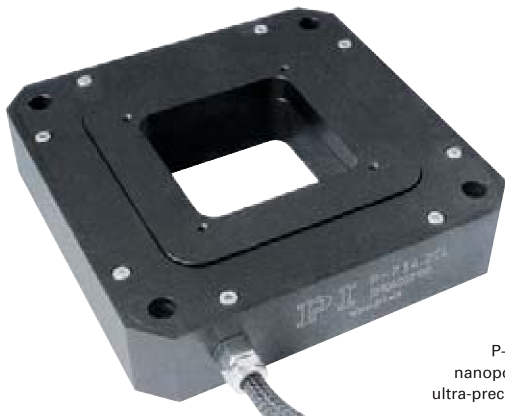
Model	P-561.3CD	P-562.3CD	P-563.3CD	P-561.3DD	Units	Tolerance
Active axes	X, Y, Z	X, Y, Z	X, Y, Z	X, Y, Z		
Motion and positioning						
Integrated sensor	Capacitive	Capacitive	Capacitive	Capacitive		
Open-loop travel, -20 to +120 V	150 x 150 x 150	300 x 300 x 300	340 x 340 x 340	58 x 58 x 18	µm	min. (+20 %/0 %)
Closed-loop travel	100 x 100 x 100	200 x 200 x 200	300 x 300 x 300	45 x 45 x 15	µm	
Open-loop resolution	0.2	0.4	0.5	0.1	nm	typ.
Closed-loop resolution	0.8	1	2	0.2	nm	typ.
Linearity	0.03	0.03	0.03	0.01*	%	typ.
Repeatability in X, Y, Z	2 / 2 / 2	2 / 2 / 4	2 / 2 / 4	2 / 2 / 2	nm	typ.
Pitch in X,Y	±1	±2	±2	±3	µrad	typ.
Runout θ_x, θ_y (Z motion)	±15	±20	±25	±3	µrad	typ.
Yaw in X, Y	±6	±10	±10	±3	µrad	typ.
Flatness in X, Y	±15	±20	±25	±10	nm	typ.
Crosstalk X, Y (Z motion)	±30	±50	±50	±20	nm	typ.
Mechanical properties						
Unloaded resonant frequency in X / Y / Z	190 / 190 / 380	160 / 160 / 315	140 / 140 / 250	920 / 920 / 1050**	Hz	±20 %
Resonant frequency @ 100 g in X / Y / Z	-	145 / 145 / 275	120 / 120 / 215	860 / 860 / 950	Hz	±20 %
Resonant frequency @330 g in X / Y / Z	140 / 140 / 300	130 / 130 / 195	110 / 110 / 170	500 / 500 / 470	Hz	±20 %
Push force capacity in motion direction in X / Y / Z	200 / 200 / 50	120 / 120 / 50	100 / 100 / 50	200 / 200 / 50	N	Max.
Pull force capacity in motion direction in X / Y / Z	30 / 30 / 30	30 / 30 / 30	30 / 30 / 30	30 / 30 / 30		
Load capacity	50	50	50	50	N	Max.
Drive properties						
Ceramic type	PICMA® P-885	PICMA® P-885	PICMA® P-885	PICMA® P-885 in Z, P-888 in XY		
Electrical capacitance in X / Y / Z	5.2 / 5.2 / 10.4	7.4 / 7.4 / 14.8	7.4 / 7.4 / 14.8	38 / 38 / 6	µF	±20 %
Dynamic operating current coefficient (DOCC) in X / Y / Z	6.5 / 6.5 / 13	4.6 / 4.6 / 9.25	3.1 / 3.1 / 6.1	106 / 106 / 50	µA/ (Hz • µm)	±20 %
Miscellaneous						
Operating temperature range	-20 to 80	-20 to 80	-20 to 80	-20 to 80	°C	
Material	Aluminum	Aluminum	Aluminum	Aluminum		
Mass	1.45	1.45	1.45	1.55	kg	±5 %
Cable length	1.5	1.5	1.5	1.5	m	±10 mm
Sensor / voltage connection	Sub-D Special	Sub-D Special	Sub-D Special	Sub-D Special		

Resolution of PI Piezo Nanopositioners is not limited by friction or stiction. Value given is noise equivalent motion with E-710 (p. 2-128) controller.
*With digital controller. Non-linearity of direct drive stages measured with analog controllers is typically up to 0.1 %.

Recommended controller
Multi-channel digital controllers: E-710 bench-top (p. 2-128), E-712 modular (p. 2-140), E-725 high-power (p. 2-126), E-761 PCI board (p. 2-130)

P-734 XY Piezo Scanner

High-Dynamics System with Minimum Runout & Clear Aperture



P-734 low-bow flexure nanopositioning stage with ultra-precise trajectory control

- **Ultra-Precision Trajectory Control, Ideal for Surface Analysis and Scanning Microscopy**
- **Parallel-Kinematics / Metrology for Enhanced Responsiveness / Multi-Axis Precision**
- **Travel Range 100 x 100 µm, Clear Aperture 56 x 56 mm**
- **Capacitive Sensors for Resolution <0,4 nm**
- **Outstanding Lifetime Due to PICMA® Piezo Actuators**

P-734 high-dynamics, XY piezo nanopositioning stages feature linear travel ranges to 100 x 100 µm with sub-nanometer resolution and maximum flatness of motion.

Flatness in the Low Nanometer Range

P-734 open-frame XY nanopositioning and scanning stages are ideal for nanometrology tasks that require extreme flatness of scanning. These stages feature an ultra-precise, flexure guiding system which confines motion to the XY plane and reduces runout in Z to a few nanometers or less. This unsurpassed trajectory precision is fundamental for highest-precision surface metrology applications. These stages provide a positioning and scanning range of 100 x 100 µm with accuracy and resolution in the nanometer and sub-nanometer range.

Application Examples

- Scanning microscopy
- Metrology / interferometry
- Semiconductor testing
- Mask/wafer positioning
- Image processing / stablilization
- Biotechnology
- Micromanipulation
- Nanopositioning

Excellent Guiding Accuracy

Flexures optimized with Finite Element Analysis (FEA) are used to guide the stage. FEA techniques are used to give the design the highest possible stiffness in, and perpendicular to, the direction of motion, and to minimize linear and angular runout. Flexures allow extremely high-precision motion, no matter how minute, as they are completely free of play and friction.

Higher Precision in Periodic Motion

The highest dynamic accuracy in scanning applications is made possible by the DDL algorithm, which is available in PI's modern digital controllers. DDL eliminates tracking errors, improving dynamic linearity and usable bandwidth by up to three orders of magnitude!

Direct Position Measurement with Sub-Nanometer Accuracy

PI's proprietary capacitive sensors measure position directly and without physical contact. They are free of friction and hysteresis, a fact which, in combination with the positioning resolution of well under 1 nm, makes it possible to achieve very high levels of linearity. A further advantage of direct metrology with capacitive sensors is the high phase fidelity and the high bandwidth of up to 10 kHz.

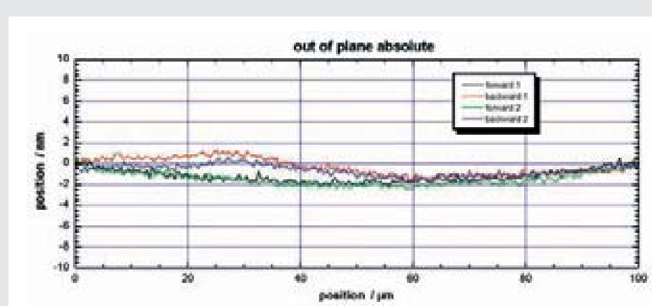
Parallel Kinematics and Metrology with Capacitive Sensors for High Trajectory Fidelity

In a parallel kinematics multi-axis system, all actuators act directly on one moving platform. This means that all axes move the same minimized mass and can be designed with identical dynamic properties. Systems with parallel kinematics and metrology have additional advantages over serially stacked or nested systems, including more-compact construction and no cumulative error from the different axes. Parallel kinematics systems can be operated with up to six degrees of freedom with low inertia and excellent dynamic performance. Multi-axis nanopositioning systems equipped with both parallel kinematics and parallel, direct metrology are able to measure platform position in all degrees of freedom against one common fixed reference. In such systems, undesirable motion from one actuator in the direction of another (cross talk) is detected immediately and actively compensated by the servo-loops. This Active Trajectory Control Concept can keep deviation from a trajectory to under a few nanometers, even in dynamic operation.

Ordering Information

P-734.2CD
High-Precision XY Nanopositioning System with Minimum Runout, 100 x 100 µm, Capacitive Sensors, Parallel Metrology, Sub-D Connector

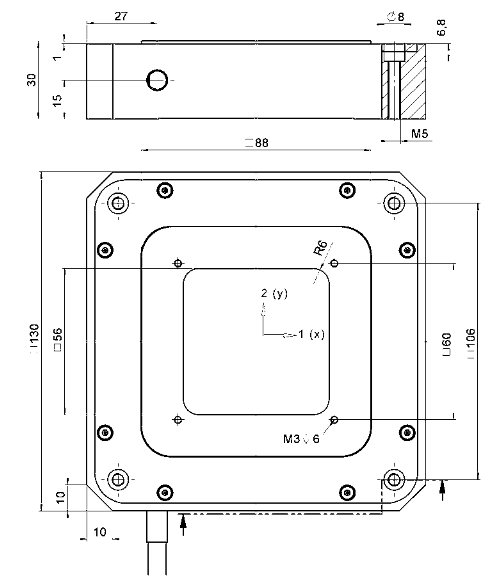
P-734.2CL
High-Precision XY Nanopositioning System with Minimum Runout, 100 x 100 µm, Capacitive Sensors, Parallel Metrology, LEMO Connector



Typical flatness of P-734 motion is in the low nanometer range

Ceramic Insulated Piezo Actuators Provide Long Lifetime

Highest possible reliability is assured by the use of award-winning PICMA® multilayer piezo actuators. PICMA® actuators are the only actuators on the market with ceramic-only insulation, which makes them resistant to ambient humidity and leakage-current failures. They are thus far superior to conventional actuators in reliability and lifetime.



P-734 dimensions in mm

Technical Data

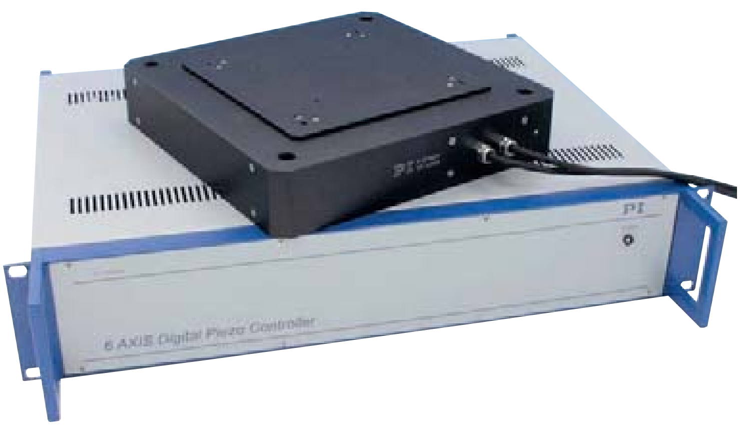
Models	P-734.2CL	P-734.2CD	Units	Tolerance
Active axes	X, Y	X, Y		
Motion and positioning				
Integrated sensor	Capacitive	Capacitive		
Open-loop travel, -20 to +120 V	110 x 110	110 x 110	µm	min. (+20 %/-0 %)
Closed-loop travel	100 x 100	100 x 100	µm	
Open-loop resolution	0.2	0.2	nm	typ.
Closed-loop resolution	0.3	0.3	nm	typ.
Linearity	0.03	0.03	%	typ.
Repeatability	<2.5	<2.5	nm	typ.
Pitch	<3	<3	µrad	typ.
Yaw	<10	<10	µrad	typ.
Flatness	typ. <5, max. <10	typ. <5, max. <10	nm	typ.
Mechanical properties				
Stiffness	3	3	N/µm	±20 %
Unloaded resonant frequency	500	500	Hz	±20 %
Resonant frequency @ 200 g	350	350	Hz	±20 %
Resonant frequency @ 500 g	250	250	Hz	±20 %
Push/pull force capacity in motion direction	300 / 100	300 / 100	N	Max.
Load capacity	20	20	N	Max.
Drive properties				
Ceramic type	PICMA® P-885	PICMA® P-885		
Electrical Capacitance	6.2	6.2	µF	±20%
Dynamic operating current coefficient	7.8	7.8	µA/(Hz • µm)	±20%
Miscellaneous				
Operating temperature range	-20 to 80	-20 to 80	°C	
Material	Aluminum	Aluminum		
Mass (with cables)	1.04	1.04	kg	±5 %
Cable length	1.5	1.5	m	±10 mm
Sensor connection	2x LEMO	Sub-D Special		
Voltage connection	4x LEMO	Sub-D Special		

Dynamic Operating Current Coefficient in µA per Hz and µm. Example: Sinusoidal scan of 10 µm at 10 Hz requires approximately 7.8 mA drive current.

Recommended controller / amplifier
P-734.2CL (p. 2-64): E-500 modular piezo controller system (p. 2-142) with amplifier module E-503 (three channels) (p. 2-146) or E-505 (1 per axis, high performance) (p. 2-147) and E-509 controller (p. 2-152)
P-734.2CD (p. 2-64): Multi-channel digital controllers: E-710/E-725 bench-top (p. 2-128, p. 2-126), E-712 modular (p. 2-140), E-761 PCI board (p. 2-130)

P-587 6-Axis Precision Piezo Stage

Long Scanning Range, Direct Position Measurement



P-587 piezo-driven parallel-kinematics nanopositioning / scanning stage with E-710.6CD 6-axis digital controller

- **For Surface Metrology, Scanning and Positioning in all Six Degrees of Freedom**
- **800 x 800 x 200 µm Linear Range**
- **Up to 1 mrad Rotational Range**
- **Parallel-Kinematics / Metrology for Enhanced Responsiveness / Multi-Axis Precision**
- **Direct Metrology with Capacitive Sensors for Highest Linearity**
- **Outstanding Lifetime Due to PICMA® Piezo Actuators**
- **Frictionless, High-Precision Flexure Guiding System**
- **Active Trajectory Control in All 6 Degrees of Freedom**

The P-587.6CD is a unique, highly accurate, 6-axis scanning and positioning system based on piezo flexure drives. It provides a linear travel range of 800 x 800 x 200 µm and rotation ranges up to 1 mrad.

Application Examples

- Interferometry
- Metrology
- Nano-imprinting
- Semiconductor testing
- Semiconductor fabrication

Direct Position Measurement with Sub-Nanometer Accuracy

PI's proprietary capacitive sensors measure position directly and without physical contact. They are free of friction and hysteresis, a fact which, in combination with the positioning resolution of well under 1 nm, makes it possible to achieve very high levels of linearity. A further advantage of direct metrology with capacitive sensors is the high phase fidelity and the high bandwidth of up to 10 kHz.

Excellent Guiding Accuracy

Flexures optimized with Finite Element Analysis (FEA) are used to guide the stage. FEA techniques are used to give the design the highest possible stiffness in, and perpendicular to, the direction of motion, and to minimize linear and angular runout. Flexures allow extremely high-precision motion, no matter how minute, as they are completely free of play and friction. A flatness and straightness in the low nanometer range is achieved, important for surface metrology applications.

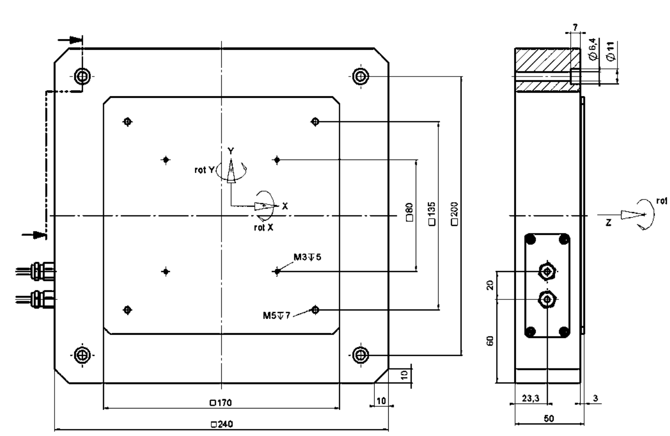
Parallel Kinematics and Metrology with Capacitive Sensors for High Trajectory Fidelity

In a parallel kinematics multi-axis system, all actuators act directly on one moving platform. This means that all axes move the same minimized mass and can be designed with identical dynamic properties. Parallel kinematics systems have additional advantages over serially stacked systems, including more-compact construction and no cumulative errors from the individual axes. Multiaxis nanopositioning systems equipped with direct metrology are able to measure platform position in all degrees of freedom against one common reference. In such systems, undesirable motion from one actuator in the direction of another (cross-talk) is detected immediately and actively compensated by the servo-loops. This Active Trajectory Control Concept can keep deviation from a trajectory to under a few nanometers, even in dynamic operation.

Automatic Configuration

PI digital piezo controllers and nanopositioning stages with ID-Chip can be operated in any combination, supported by the AutoCalibration function of the controller. Individual stage data and optimized servo-control parameters are stored in the ID-Chip and are read out automatically by the digital controllers.

Ordering Information
P-587.6CD 6-Axis Nanopositioning System with Long Travel Range, 800 x 800 x 200 µm, ±0.5 mrad, Parallel Metrology, Capacitive Sensors



P-587 dimensions in mm

Technical Data

Model	P-587.6CD	Tolerance
Active axes	X, Y, Z, θ_X, θ_Y, θ_Z	
Motion and positioning		
Integrated sensor	Capacitive	
Closed-loop travel X, Y	800 µm	
Closed-loop travel	200 µm	
Closed-loop tip/tilt angle	±0.5 mrad	
Closed-loop θZ angle	±0.5 mrad	
Closed-loop / open-loop resolution X, Y	2.2 / 0.9 nm	typ.
Closed-loop / open-loop resolution Z	0.7 / 0.4 nm	typ.
Closed-loop / open-loop resolution θ_X, θ_Y	0.1/ 0.05 µrad	typ.
Closed-loop / open-loop resolution θ_Z	0.3 / 0.1 µrad	typ.
Linearity X, Y, Z	0.01 %	typ.
Linearity θ_X, θ_Y, θ_Z	0.1 %	typ.
Repeatability X, Y	±3 nm	typ.
Repeatability	±2 nm	typ.
Repeatability θ_X, θ_Y	±0.1 µrad	typ.
Repeatability θ_Z	±0.15 µrad	typ.
Flatness	<15 nm	typ.
Mechanical properties		
Stiffness X / Y / Z	0.55 / 0.55 / 1.35 N/µm	
Unloaded resonant frequency in X / Y / Z	103 / 103 / 235 Hz	±20 %
Resonant frequency @ 500 g in X / Y / Z	88 / 88 / 175 Hz	±20 %
Resonant frequency @ 2000 g in X / Y / Z	65 / 65 / 118 Hz	±20 %
Push/pull force capacity in motion direction	50 / 10 N	Max.
Drive properties		
Ceramic type	PICMA®	
Electrical capacitance in X / Y / Z	81 / 81 / 18.4 µF	±20 %
Dynamic operating current coefficient (DOCC) in X, Y, θ_Z	12.6 µA/(Hz • µm)	±20 %
Dynamic operating current coefficient (DOCC) Z, θ_X, θ_Y	11.5 µA/(Hz • µm)	±20 %
Miscellaneous		
Operating temperature range	-20 to 80 °C	
Material	Aluminum	
Dimensions	240 x 240 x 50 mm	
Mass	7.2 kg	±5 %
Cable length	1.5 m	±10 mm
Sensor / voltage connection	2 x Sub-D Special	
Recommended controller / amplifier	E-710.6CD (p. 2-128) or E-712.6CD (p. 2-140) digital controller	

The maximum rotational angle in θ_Z is 8 mrad, the tilt angles around X and Y rate 3 mrad.
Due to parallel kinematics linear motion is not possible when the stage is in extreme position.

PI Piezo • Nano • Positioning

P-562.6CD PIMars 6-Axis Piezo Stage System

High-Precision Nanopositioning System with 6 Degrees of Freedom

P-562.6CD PIMars six-axis parallel-kinematics nanopositioning stage

Ordering Information

P-562.6CD
PIMars 6-Axis Nanopositioning System, 200 µm, 1 mrad, Parallel Metrology

Other travel ranges on request!

- **6 Motion Axes: 3 x Linear, 3 x Rotation**
- **Travel Ranges to 200 µm Linear and 1 mrad Tilt Angle**
- **Enhanced Responsiveness & Multi-Axis Precision: Parallel Kinematics / Metrology**
- **Highest Linearity and Stability with Capacitive Sensors**
- **Frictionless, High-Precision Flexure Guiding System**
- **Excellent Scan-Flatness**
- **Clear Aperture 66 x 66 mm**
- **Outstanding Lifetime Due to PICMA® Piezo Actuators**
- **UHV Versions to 10^{-9} hPa**

PIMars open-frame piezo stages are fast and highly accurate multi-axis scanning and nanopositioning systems with flatness and straightness in the nanometer range. Thanks to the parallel-kinematic design, where all piezo drives act on the same moving platform, and sophisticated digital control algorithms it is possible to achieve highly precise motion in all degrees of freedom: three linear axes and three rotary axes. The travel ranges amount to 200 µm in X, Y and Z, and the tilt angles are ±0.5 mrad about the respective axis. Systems with larger travel ranges or faster response are available on request. A six-axis system with 800 µm travel range in the X and Y axis is available as the P-587.6CD s. p. 2-76.

Application Examples

- Scanning microscopy (SPM)
- Mask/wafer positioning
- Interferometry
- Metrology
- Biotechnology
- Micromanipulation

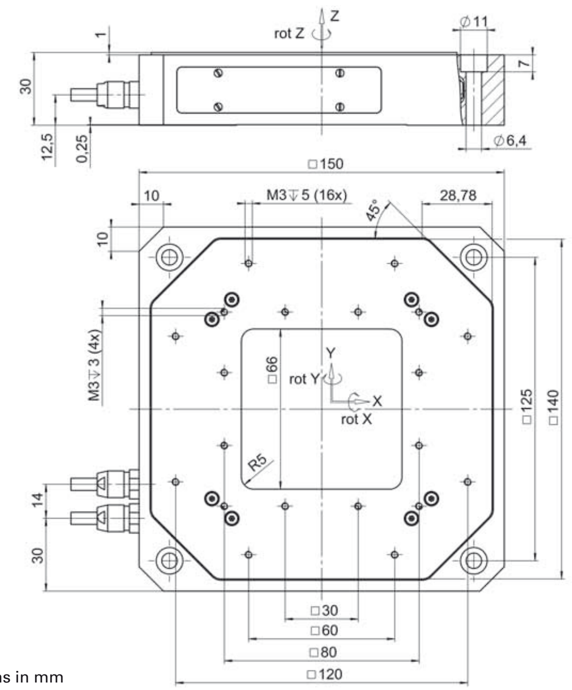
PIMars systems feature a large 66 x 66 mm clear aperture for transmitted-light applications such as near-field scanning or confocal microscopy and mask positioning. PIMars stages for ultra-high vacuum applications are also available. These versions contain vacuum-qualified components only. The integrated ceramic-encapsulated PICMA® actuators allow high bakeout temperatures and assure minimal outgassing rates. A non-magnetizable version is available on request.

Capacitive Sensors for Highest Accuracy and Stability

PI's proprietary capacitive sensors measure position directly and without physical contact. They are free of friction and hysteresis, a fact which, in combination with the positioning resolution of well under 1 nm, makes it possible to achieve very high levels of linearity. Further advantages of direct metrology with capacitive sensors are the excellent long-term stability, high phase fidelity and the high bandwidth of up to 10 kHz.

Active and Passive Guidance for Nanometer Flatness and Straightness

Wire-cut flexures optimized with Finite Element Analysis (FEA) are used to guide the stage. The FEA techniques give the design the highest possible stiffness and minimize linear and angular runout. Further enhancement is achieved by active trajectory control: multiaxis nanopositioning systems equipped with parallel metrology are able to measure platform position in all degrees of freedom against a common, fixed reference. In such systems, undesirable motion from one actuator in the direction of another (cross-talk) is detected immediately and actively compensated by the servo-loops. This can keep deviation from a trajectory to under a few nanometers, even in dynamic operation.



P-562 dimensions in mm

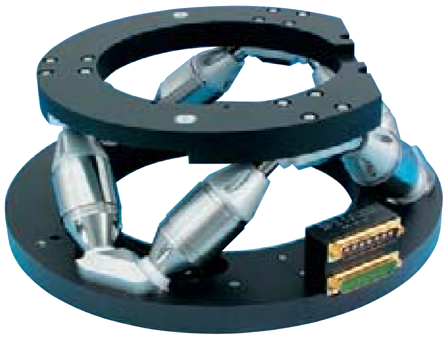
Technical Data

Model	P-562.6CD	Tolerance
Active axes	X, Y, Z, θX, θY, θZ	
Motion and Positioning		
Integrated sensor	Capacitive	
Closed-loop travel X, Y, Z	200 µm	
Closed-loop tip/tilt angle	±0.5 mrad	
Closed-loop resolution X, Y, Z	1 nm	typ.
Closed-loop tip/tilt resolution	0.1 µrad	typ.
Linearity X, Y, Z	0.01 %	typ.
Linearity θX, θY, θZ	0.1 %	typ.
Repeatability in X, Y, Z	±2 / ±2 / ±3 nm	typ.
Repeatability θX / θY / θZ	±0.1 / ±0.1 / ±0.15 µrad	typ.
Flatness	< 15 nm	typ.
Unloaded resonant frequency in X / Y / Z	110 / 110 / 190 Hz	±20%
Load capacity	50 N	max.
Push/pull force capacity in motion direction	120 / 30 N	max.
Drive properties		
Ceramic type	PICMA®	
Electrical capacitance in X / Y / Z	7.4 / 7.4 / 14.8 µF	±20%
Dynamic operating current coefficient in X, Y, Z	4.6 / 4.6 / 9.2 µA/(Hz • µm)	±20%
Miscellaneous		
Operating temperature range	-20 to 80 °C	
Material	Aluminium	
Mass	1.45 kg	±5%
Cable length	1.5 m	±10 mm
Sensor / voltage connection	2 x Sub-D Special	

Recommended controller / amplifier
E-710.6CD s. p. 2-128 or E-712.6CD digital controller s. p. 2-140

N-515K Non-Magnetic Piezo Hexapod

6-Axis Precision Positioning System with NEXLINE® Linear Drives



6-axis parallel kinematics (Hexapod) with integrated N-215 NEXLINE® high-load actuators, suitable for applications in strong magnetic fields

- **Travel Ranges 10 mm Linear, 6° Rotation**
- **Large Clear Aperture Ø 202 mm**
- **Non-Magnetic**
- **Nanometer Resolution**
- **Low-Profile: 140 mm Height Only**
- **Parallel Kinematics for Enhanced Dynamics and Better Multi-Axis Accuracy**
- **Up to 500 N Force Generation**
- **Self Locking at Rest, No Heat Generation**

Model	Travel range	Load capacity	Dimensions
N-515KNPH NEXLINE® Piezo Hexapod	X, Y, Z: 10 mm θ_X, θ_Y, θ_Z: 6°	50 kg	Outer Ø baseplate, 380 mm Ø moved platform (top) 300 mm 140 mm height

N-510 High-Force NEXLINE® Z/Tip/Tilt Platform

Nanometer Precision for Semiconductor Industry, Wafer Alignment

Z, tip, tilt nanopositioning platform with 3 integrated drives (tripod design)

- **Self Locking at Rest, No Heat Generation**
- **Vacuum Compatible and Non-Magnetic Designs Feasible**
- **Parallel Kinematics for Enhanced Dynamics and Better Multi-Axis Accuracy**
- **NEXLINE® Piezo Walking Drive Free from Wear and Tear**
- **Load Capacity 200 N**
- **High Precision with Integrated 5 nm Incremental Sensors + Picometer Resolution Dithering Mode**

Model	Travel	Load capacity	Linear velocity	Dimensions
N-510 NEXLINE® Z, tip, tilt platform	1,3 mm vertical range 10 mrad tilt angle	200 N	0.2 mm/s	Ø 300 mm (12´´) Clear aperture 250 mm

N-510K High-Stiffness NEXLINE® Z Stage

High-Precision Positioning, with Capacitive Sensors

The N-510KHFS hybrid-drive nanopositioner offers maximum accuracy for semiconductor inspection applications

- **Self Locking at Rest, No Heat Generation**
- **Hybrid Drive: PiezoWalk® plus PICMA®**
- **Travel Range: 400 µm Coarse + 40 µm Fine**
- **2 µm Closed-Loop Resolution**
- **Direct Metrology: One Single Control Loop with Capacitive Sensors**
- **High Push and Holding Force to 25 N**
- **Piezo Walking Drive w/o Wear and Tear & Outstanding Lifetime due to PICMA® Piezo Actuators**

Model	Vertical travel	Velocity	Bidirectional repeatability	Load capacity	Dimensions
N-510KHFS Hybrid-Focus System	400 µm coarse 40 µm fine	1 mm/sec	50 nm (full travel)	25 N	Ø 300 mm 68.5 mm height

P-915K Fast XY Piezo Scanner

Cost-Effective OEM Slide for Imaging

The fast P-915KXXYS open-loop XY scanner is ideally suited for image enhancement e.g. for CCD chips

- **For Pixel Sub-Stepping to Enhance Image Resolution**
- **Compact Design: 40 x 60 x 7 mm**
- **Highly Cost-Efficient Open-Loop Design**
- **Travel Ranges to 4 x 4 µm**
- **Parallel Kinematics for Enhanced Dynamics and Better Multi-Axis Accuracy**

Model	Travel	Resolution	Load capacity	Dimensions
P-915KXXYS XY Scanner	4 x 4 µm	0.4 nm	50 g	40 x 60 x 7 mm

P-915K High-Dynamics XY Piezo Scanner

Cost-Effective OEM Slide with Large Aperture for Imaging Applications

The P-915KHDS XY scanning stage is driven by 4 PICMA® piezo actuators to provide high stiffness, high dynamics and superior lifetime

- **Direct Drive for High Dynamics**
- **Scanning Stage for Pixel Sub-Stepping: Enhances Image Resolution**
- **Cost-Efficient Design**
- **15 x 15 µm Travel Range**
- **Load Capacity to 5 N**
- **Clear Aperture 30 x 45 mm**

Model	Travel range	Resolution	Resonant frequency	Dimensions
P-915KHDS High-Dynamics XY Scanner	15 x 15 µm	0.1 nm	1850 Hz	Baseplate 85 x 54 mm Moved platform 69 x 69 mm Clear aperture 30 x 45 mm

P-915K Vacuum Compatible XYZ Piezo Scanner

Large Clear Aperture, High-Dynamics, High-Load Nanopositioner

The P-915KLVS high-dynamics scanner offers a very large clear aperture of 200 x 200 mm

- **Vacuum Compatible to 10^{-6} hPa**
- **Direct Metrology with Capacitive Sensors**
- **Excellent Straightness: <0.1 µrad Runout**
- **Frictionless, High-Precision Flexure Guiding System**
- **Direct Metrology with Capacitive Sensors**

Model	Travel	Re-solution	Resonant frequency	Load capacity	Dimensions
P-915KLVS Large XYZ Scanner	100 x 100 x 100 µm	1 nm	110 Hz (X,Y) 230 Hz (Z)	50 kg	340 x 340 x 60 mm Clear aperture 200 x 200 mm

P-732 Piezo Z-Stage with Aperture

High-Dynamics Nanopositioner / Scanner

P-732.ZC vertical nanopositioning stage with aperture

- **15 µm Vertical Travel Range**
- **High Stiffness for Dynamic Operation**
- **<1 nm Resolution**
- **Straightness of Travel <10 µrad**
- **Clear Aperture with 25 mm Diameter**

Model	Travel	Resolution	Linearity	Laod capacity	Rotation around θ_X, θ_Y
P-732.ZC	15 µm	0.1 nm	0.03 %	20 N	<10 µrad

P-915K Vacuum-Compatible Piezo-Z Stage

High-Load, High Dynamics and Large Clear Aperture

The direct-drive P-915KVPZ stage provides high stiffness for fast operation

- **Travel Range 45 µm**
- **Large Clear Aperture 273 x 273 mm**
- **Direct Metrology with Capacitive Sensors**
- **Direct Drive for High Dynamics and Stiffness**
- **Vacuum Compatible up to 10^{-6} hPa**
- **Outstanding Lifetime Due to PICMA® Piezo Actuators**

Model	Travel	Resolution	Push/ Pull force capacity	Material	Dimensions
P-915KVPZ Z Stage	45 µm	0.3 nm	20 N	Stainless stell	Moving platform: 375 x 375 mm Clear aperture: 273 x 273 mm

P-915K Low-Profile Piezo Objective Scanner

For High Scanning Frequencies

The P-915KLPZ objective scanner allows high scanning frequencies

- **Very Low Profile of 15 mm**
- **Travel Range 75 µm**
- **Clear Aperture for Objectives with W0.8 x 1/36” Thread**
- **Frictionless, High-Precision Flexure Guiding System for Better Focus Stability and Minimized Runout**
- **Very Low Profile**
- **Outstanding Lifetime Due to PICMA® Piezo Actuators**

Model	Active axes	Travel range	Resonant frequency @ 150 g	Dimensions
P-915KLPZ Objective Scanner	Z	75 µm	200 Hz	60 x 60 x 15 mm

P-915K XY-Theta-Z Piezo Stage

3 Degrees of Freedom in the XY Plane

The P-915KPPS is equipped with FEA-modeled flexures for higher stiffness in all three directions of motion

- **Travel Ranges 250 x 250 µm, 16 mrad**
- **Frictionless, High-Precision Flexure Guiding System**
- **High Stiffness >1 N/µm**
- **Outstanding Lifetime Due to PICMA® Piezo Actuators**

Model	Travel	Resolution	Load capacity	Settling (system combination with E-621	Dimensions
P-915KPPS XY-Rot-Z-Piezo Stage	250 x 250 µm ±8 mrad	3 nm 15 µrad	2 kg	45 ms (250 µm) 28 ms (16 mrad)	60 x 60 x 100 mm

P-313 PicoCube™ XY(Z) Piezo Scanner

Picometer Precision, High Bandwidth, No Servo Lag, for Scanning Probe Microscopy

A new drive concept allows high-linearity positioning in open-loop operation

- **Ultra-High-Performance Scanner for AFM/SPM**
- **20 Picometers Resolution, <1 nm Hysteresis**
- **Very High Bandwidth with no Servo Lag Due to New Drive Concept**
- **Compact Manipulation Tool for Bio-/Nanotechnology**
- **Resonant Frequency 4.0 kHz (X, Y), 11 kHz (Z)**
- **1 x 1 x 0.8 µm Travel Range**

Model	Travel range (±250 V)	Resolution	Dimensions
P-313.30 PicoCube™ XYZ Scanner	1 x 1 µm (X,Y) 0.8 µm (Z)	0.02 nm (X, Y) 0.14 nm (Z)	30 x 30 x 29.4 mm Moved platform 20 x 20 mm

P-628K Long-Travel XY Piezo Stage with Nanometer Flatness

Novel Active Z-Axis Design Provides Real Time Runout Compensation

The P-628KHFS with an active Z-axis provides an improved straightness of travel with only 9.5 mm added height compared to an P-628.2 nanopositioning stage

- **Closed-Loop Travel Range 800 x 800 µm (up to 1500 µm Possible)**
- **Improved Straightness of Travel <1nm**
- **High-Precision, Cost-Efficient**
- **Resolution to 0.1 nm, 0.02 % Positioning Accuracy**
- **Frictionless, High-Precision Flexure Guiding System**
- **Outstanding Lifetime Due to PICMA® Piezo Actuators**

Model	Travel ranges	Unload resonant frequency	Load capacity	Dimensions
P-628KHFS High Flatness XY Stage	800 x 800 µm (X, Y)	75 Hz (X), 105 Hz (Y)	10 N	80 x 80 x (9.5 + 30) mm

Fast Steering Mirrors / Active Optics

Piezo Tip/Tilt Mirrors Fundamentals

Single Axis Designs

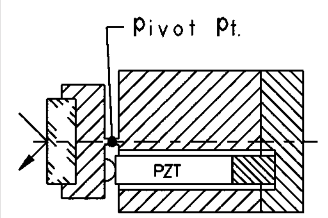


Fig. 1. Single-flexure, single-piezo actuator tilt platform design

Single-Axis Systems / Scanners

Two designs of single-axis (θ_X) tilt platforms are available:

I. Single-Flexure, Single-Actuator Tilt Platform

Examples: S-224 and S-226.

The platform is supported by one flexure and pushed by one linear piezo actuator (see Fig. 1). The flexure determines the pivot point and doubles as a preload for the piezo actuator. The advantages of the single-flexure, single-actuator design are the straightforward construction, low cost and small size. If angular stability over a wide temperature range is a critical issue, the differential piezo drive is recommended.

II. Differential-Piezo-Drive Tilt Platform

This design features two piezo actuators operating in push/pull mode supporting the platform (see Fig. 2). The actuators are wired in a bridge which is supplied with a constant and a variable drive voltage. The case features integrated zero-friction, zero-stiction flexures which assure excellent guiding accuracy.

The differential design exhibits excellent angular stability over a wide temperature range. With this arrangement, temperature changes only affect the vertical position of the platform (piston motion) and have no influence on the angular position. In the closed-loop models, availability of two sensor signals permits better linearity and resolution.

A variety of single- and multi-axis implementations is possible.

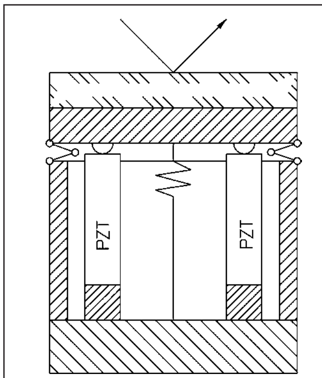


Fig. 2. Design of a differential-piezo-drive tilt platform

Multi-Axis Tip/Tilt Systems / Scanners

PI offers two standard designs, both using parallel kinematics. Parallel kinematics systems have the following advantages over serial systems: only one moving platform, fixed pivot point, better dynamics, smaller form-factor. In addition, the design offers better linearity than attainable with two single-axis systems (e.g. two galvoscanners) in a stacked configuration.

I. Piezo Tripod Z/Tip/Tilt Platform

Examples: S-315 and S-316, S-325.

The platform is supported by three piezo actuators spaced at 120° intervals. Because expansion of an individual actuator affects both θ_X and θ_Y, more complex control algorithms are required.

With coordinate transformation, platform position commands can be resolved into targets for individual actuators (see the equations and Fig. 3 for details). The piezo tripod has one advantage over the differential drive: in addition to tilt motion, it allows active vertical control (piston motion) of the platform—an important feature for applications involving optical path-length adjustment (phase-shifting).

Also, the design allows for a central clear aperture, ideal for transmitted-light applications. As with the differential drives, temperature changes have no effect on the angular stability.

II. Differential-Piezo-Drive Tip/Tilt Platform

Examples:
S-334, S-330, S-340.

The platform is driven by two pairs of piezo actuators arranged at 90° angles. Each pair is controlled as a unit in push-pull mode. The four actuators are connected in a bridge circuit and supplied with one fixed and two variable voltages. Because each actuator pair is parallel to one of the orthogonal tip/tilt axes θ_X and θ_Y, no coordinate transformation is required.

Like the piezo tripod design, the differential drive exhibits excellent angular stability over a wide temperature range. In the closed-loop models, availability of two sensor signals permits better linearity and resolution.

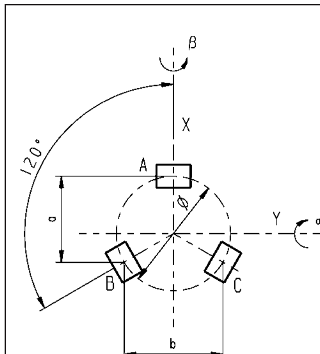


Fig. 3. Piezo tripod drive: A, B, C are the linear displacements of the respective actuators

$\alpha = \frac{2A - (B+C)}{2a}$

$\beta = (B-C) / b$

$z = (A+B+C) / 3$

Example:
S-315 tip/tilt platform (see page 3-16).
Ø = 13.9 mm
a = 10.4 mm
b = 12.0 mm
A, B, C 0 to 12 µm

Dynamic Behavior of Piezo Steering Mirrors

The maximum operating frequency of a tilt platform is heavily dependent on its mechanical resonant frequency. The performance characteristics of the amplifier, servo-controller and sensors are also very important. To estimate the effective resonant frequency of the tilt mirror system (platform + mirror), the moment of inertia of the mirror substrate must first be calculated.

Moment of inertia of a rotationally symmetric mirror:

$$I_M = m \left[\frac{3R^2 + H^2}{12} + \left(\frac{H}{2} + T \right)^2 \right]$$

Moment of inertia of a rectangular mirror:

$$I_M = m \left[\frac{L^2 + H^2}{12} + \left(\frac{H}{2} + T \right)^2 \right]$$

where:

m = mirror mass [g]

I_M = moment of inertia of the mirror [g · mm²]

L = mirror length perpendicular to the tilt axis [mm]

H = mirror thickness [mm]

T = distance, pivot point to platform surface (see technical data table for individual model) [mm]

R = mirror radius [mm]

Using the resonant frequency of the unloaded platform (see individual technical data table) and the moment of inertia of the mirror substrate, the system resonant frequency is calculated according to the following equation:
Resonant frequency of a tilt platform/mirror system

$$f' = \frac{f_0}{\sqrt{1 + I_M / I_0}}$$

where:

f' = resonant frequency of platform with mirror [Hz]

f_0 = resonant frequency of unloaded platform [Hz]

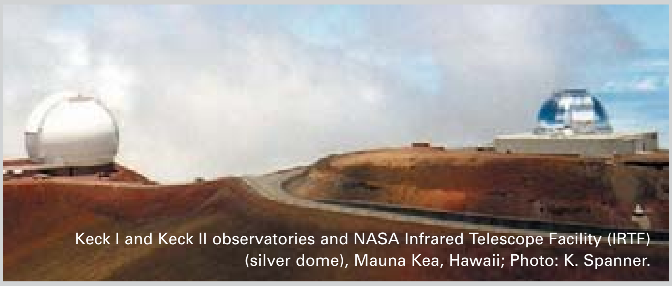
I_0 = moment of inertia of the platform (see technical data table for the individual model) [g · mm²]

I_M = moment of inertia of the mirror [g · mm²]

For more information on static and dynamic behavior of piezo actuators, see pp. 2-196 *ff.*

Custom Systems for Telescopes

PI Steering Mirrors and Alignment Systems in Astronomy



Keck I and Keck II observatories and NASA Infrared Telescope Facility (IRTF) (silver dome), Mauna Kea, Hawaii; Photo: K. Spanner.

The Horsehead Nebula; Photo: Brian Lula.

Resolution in large earthbound telescopes is limited by atmospheric turbulence and vibrations. During the last 15 years PI has designed several large-aperture tip/tilt systems for image stabilization. Piezoelectrically driven active secondary mirrors can improve the effective resolution up to 1000 % by correcting for these image shifts in real time, especially during long integrations with weak light sources.

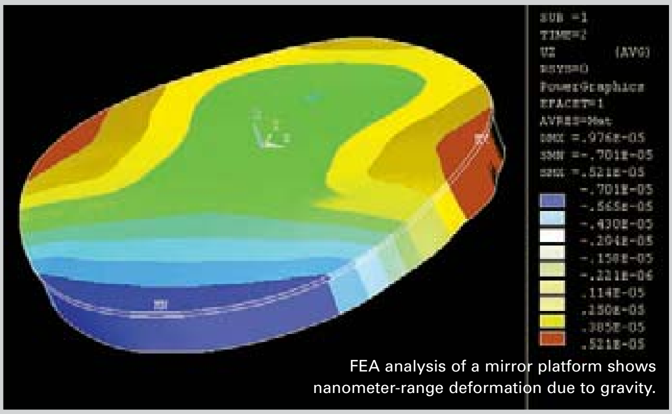
Momentum Compensation
Due to the inertia of the large mirrors and the high accelerations required to correct for image fluctuations, significant forces can be induced in the telescope structure, causing unwanted vibrations. PI has developed momentum compensation systems integrated into the tip/tilt platforms which cancel undesirable vibrations and thus offer significantly better stabilization than uncompensated systems.

Active tip/tilt mirror system for the Keck Outrigger telescope in Hawaii. The units are controlled by a high-performance digital controller with a fiber optic interface (not shown).
Mirror diameter: 250 mm
Tip/tilt range: ±150 µrad
Resolution: nanoradian range
Position measurement: capacitive

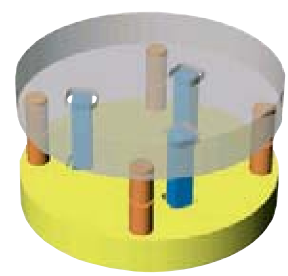
Example of a combined high-speed piezo tip/tilt plaftform with a long range, low-speed 6-axis hexapod alignment system

High-Resolution Linear Actuators
273 PI actuators are used for tip/tilt/piston movement of segmented mirror panels in the SALT Telescope.
Features: 16 nm design resolution; 0.15 µm minimum incremental motion; non-rotating tip, compact design.

Active Optics / Steering Mirrors



FEA analysis of a mirror platform shows nanometer-range deformation due to gravity.



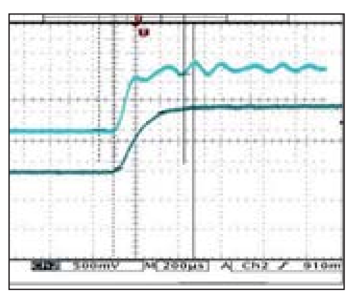
Basic design of a piezo tip/tilt platform featuring three actuators and four sensors. Large platforms handle optics to Ø500 mm

Fast Steering Mirrors: Why Piezo?

- Faster and more precise than conventional actuators
- Better stability through differential drive designs
- Stiff mechanical interface, 1 DOF only
- Tip/tilt & piston movements
- Up to Ø50 cm apertures

Applications of Fast Steering Mirrors

- Fast beam steering, alignment, switching
- Image resolution enhancement (pixel multiplication, dithering)
- Optical path length stabilization
- Vibration cancellation (laser systems, imaging)
- Interferometry, Fabry-Perot filters
- Image stabilization, high speed background subtraction
- Laser beam stabilization (resonators, optical setups)
- Laser beam scanning (lithography, optical setups)
- Laser beam steering and tracking (telecommunication satellites, etc.)
- Bore-sight systems
- Dynamic error correction (e.g. in polygon scanning mirrors)
- Mass storage device testing and manufacture



Fast: 200 µs step response. Standard (top), optimized amplifier (bottom), 0.2 µrad steps

S-330 Piezo Tip/Tilt-Platform

High-Dynamics, Large-Angle Piezo Tip/Tilt Platforms for Fast Steering Mirrors

S-330 tip/tilt platforms with optical beam deflection angles of 4, 10 and 20 mrad

- **Resolution to 20 nrad, Excellent Position Stability**
- **Optical Beam Deflection to 20 mrad (>1°)**
- **Higher Dynamics, Stability & Linearity Through Parallel-Kinematics Design**
- **Sub-Millisecond Response**
- **For Mirrors up to 50 mm Diameter**
- **Closed-Loop Versions for Better Linearity**
- **Excellent Temperature Stability**

S-330 piezo tip/tilt platforms are fast and compact tip/tilt units, providing precise angular motion of the top platform around two orthogonal axes.

Application Examples

- Image processing / stabilization
- Interlacing, dithering
- Laser scanning / beam steering
- Optics
- Optical filters / switches
- Beam stabilization

These flexure-guided, piezoelectric platforms can provide higher accelerations than other implementations, enabling step response times in the sub-millisecond range. Closed-loop and open-loop versions with 3 different tilt ranges up to 10 mrad (20 mrad optical deflection) are available.

Parallel-kinematics design for improved stability, linearity and dynamics

PI piezo tip/tilt mirror systems are based on a parallel-kinematics design with coplanar axes and a single moving platform. Two pairs of differentially-driven piezo actuators are employed to provide the highest possible angular stability over a wide temperature range. Compared to stacked, (two-stage) piezo or galvo scanners, the single-platform design provides several advantages: smaller package size, identical dynamic performance in both axes, faster response and better linearity. It also prevents polarization rotation.

Fast Piezo Ceramic Drives

Frictionless, flexure-guided piezo ceramic drives provide higher accelerations than other actuators, such as voice-coils, and enable response in the millisecond range and below. Piezo actuators do not require energy to hold a position. The resulting low heat signature is a great advantage in infrared imaging systems like those used in astronomy.

Closed Loop Operation

For high stability and repeatability, absolute-measuring strain gauge sensors (SGS) are applied to appropriate locations on the drive train. They provide a high-bandwidth, position feedback signal to the controller. The sensors are connected in a bridge configuration to eliminate thermal drift, and assure optimal position stability. Open-loop systems are also available.

Ordering Information

S-330.2SL
High-Dynamics Piezo Tip/Tilt Platform, 2 mrad, SGS, LEMO Connector

S-330.2SD
High-Dynamics Piezo Tip/Tilt Platform, 2 mrad, SGS, Sub-D Connector

S-330.20L
High-Dynamics Piezo Tip/Tilt Platform, 2 mrad, Open-Loop, LEMO Connector

S-330.4SL
High-Dynamics Piezo Tip/Tilt Platform, 5 mrad, SGS, LEMO Connector

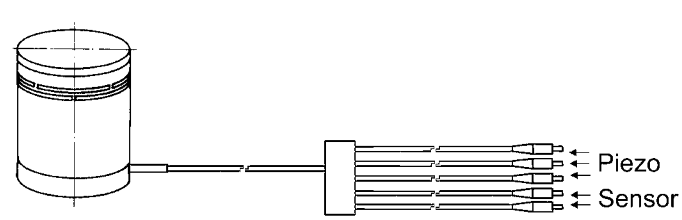
S-330.4SD
High-Dynamics Piezo Tip/Tilt Platform, 5 mrad, SGS, Sub-D Connector

S-330.40L
High-Dynamics Piezo Tip/Tilt Platform, 5 mrad, Open-Loop, LEMO Connector

S-330.8SL
High-Dynamics Piezo Tip/Tilt Platform, 10 mrad, SGS, LEMO Connector

S-330.8SD
High-Dynamics Piezo Tip/Tilt Platform, 10 mrad, SGS, Sub-D Connector

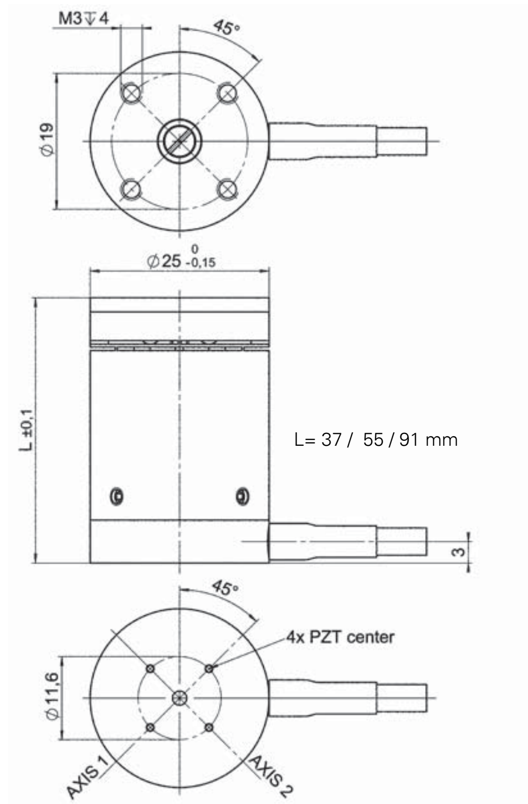
S-330.80L
High-Dynamics Piezo Tip/Tilt Platform, 10 mrad, Open-Loop, LEMO Connector



Circuit diagram and cable configuration of the S-330.xSL closed-loop versions. The S-330.xSD models feature a single Sub-D connector and can be operated by the E-616 controller.

Ceramic Insulated Piezo Actuators Provide Long Lifetime

Highest possible reliability is assured by the use of award-winning PICMA® multilayer piezo actuators. PICMA® actuators are the only actuators on the market with ceramic-only insulation, which makes them resistant to ambient humidity and leakage-current failures. They are thus far superior to conventional actuators in reliability and lifetime.



S-330 dimensions in mm

Technical Data

Model	S-330.2SL	S-330.4SL	S-330.8SL	S-330.2SD S-330.4SD S-330.8SD	S-330.20L S-330.40L S-330.80L	Units	Tolerance
Active axes	Θ_X, Θ_Y	Θ_X, Θ_Y	Θ_X, Θ_Y	Θ_X, Θ_Y	Θ_X, Θ_Y		
Motion and positioning							
Integrated sensor	SGS	SGS	SGS	SGS	–		
Open-loop tip/tilt angle, -20 to +120 V	3.5	7	15	as SL version	as SL version	mrad	min.
Closed-loop tip/tilt angle	2	5	10	as SL version	–	mrad	
Open-loop tip/tilt angle resolution	0.02	0.1	0.2	as SL version	as SL version	µrad	typ.
Closed-loop tip/tilt resolution	0.05	0.25	0.5	as SL version	–	µrad	typ.
Linearity in Θ_X, Θ_Y	0.1	0.2	0.25	as SL version	–	%	typ.
Repeatability Θ_X, Θ_Y	0.15	0.5	1	as SL version	–	µrad	typ.
Mechanical properties							
Unloaded resonant frequency (Θ_X, Θ_Y)	3.7	3.3	3.1	as SL version	as SL version	kHz	±20%
Resonant frequency loaded in Θ_X, Θ_Y (with 25 x 8 mm glass mirror)	2.6	1.6	1.0	as SL version	as SL version	kHz	±20%
Distance of pivot point to platform surface	6	6	6	6	6	mm	±1 mm
Platform moment of inertia	1530	1530	1530	1530	1530	g x mm²	±20%
Drive properties							
Ceramic type	PICMA®	PICMA®	PICMA®	PICMA®	PICMA®		
Electrical capacitance	3/axis	6/axis	12.5/axis	as SL	as SL	µF	±20%
Dynamic operating current coefficient	0.22/axis	0.4/axis	0.8/axis	as SL	as SL	µA/(Hz • mrad)	±20%
Miscellaneous							
Operating temperature range	-20 to 80	-20 to 80	-20 to 80	-20 to 80	-20 to 80	°C	
Material case	Stainless steel	Stainless steel	Stainless steel	Stainless steel	Stainless steel		
Material platform	Invar	Invar	Invar	Invar	Invar		
Mass	0.2	0.38	0.7	as SL version	as SL version	kg	±5%
Cable length	1.5	1.5	1.5	1.5	1.5	m	±10 mm
Sensor / voltage connection	LEMO	LEMO	LEMO	Sub-D connector	LEMO		

Recommended controller / amplifier

Versions with LEMO connector: modular piezo controller system E-500 (p. 2-142) with amplifier module E-503.00S (three channels) (p. 2-146) or 1 x E-505.00S and 2 x E-505 (high speed applications) (p. 2-147) and E-509 controller (p. 2-152) (optional)

Open-loop: E-663 three channel amplifier (p. 2-136)

Versions with Sub-D connectors: E-616 servo controller for tip/tilt mirror systems (p. 2-132)

S-334 Miniature Piezo Tip/Tilt-Mirror

Fast Steering Mirror with up to 120 mrad Deflection

S-334 Tip/Tilt Mirror System / Scanner Provides Optical Deflection Angle up to 120 mrad

- **Miniature Design**
- **Optical Beam Deflection to 120 mrad (~ 6.8°)**
- **Coplanar Axes & Fixed Pivot Point Eliminate Polarization Rotation**
- **Factory Installed Mirror**
- **Millisecond Response, Resolution to 0.5 µrad**
- **Closed-loop Position Servo-Control for High Accuracy**
- **For Mirrors up to 12.5 mm (0.5") Diameter**
- **Frictionless, High-Precision Flexure Guiding System**
- **Parallel Kinematics for Enhanced Dynamics and Better Multi-Axis Accuracy**

S-334 piezo tip/tilt mirrors / scanners provide extremely large deflection angles in a miniaturized package. These fast steering mirror systems are based on a sophisticated parallel-kinematics design with two coplanar, orthogonal axes and a fixed pivot point.

Large Tip/Tilt Ranges with Excellent Motion Characteristics

The novel flexure/lever design with minimized inertia allows for the exceptionally large tip/tilt range of 60 mrad (50 mrad in closed-loop operation, which is equivalent to 100 mrad optical beam deflection) and very fast response in the millisecond range. These parameters make the system unique in the market of piezo driven tip/tilt mirror systems.

Sub-Microradian Resolution

In addition to the large angles and the high dynamics the S-334 provides sub-micro-radian resolution. The integrated high-resolution, full-bridge strain gauge sensors (SGS) provide absolute position control, excellent repeatability and high linearity, typically better than 0.25 % over the entire travel range.

Differential Drive for Improved Stability and Dynamics

The S-334 is based on a parallel-kinematics design with coplanar axes and a single moving platform. Two pairs of differentially-driven piezo actuators are employed to provide the highest dynamics and position stability over a wide temperature range.

Compared to stacked, (two-stage), piezo or galvo scanners, the single-platform design provides several advantages: smaller package size, identical dynamic performance in both axes, faster response and better linearity. It also prevents polarization rotation.

High Reliability and Long Lifetime

The compact S-334 systems are equipped with preloaded PICMA® high-performance piezo actuators which are integrated into a sophisticated, FEA-modeled, flexure guiding system. The PICMA® actuators feature cofired ceramic encapsulation and provide better performance and reliability than conventional piezo actuators. Actuators, guidance and sensors are maintenance-free, not subject to wear and offer extraordinary reliability.

Factory Installed Mirror

The S-334 is equipped with a factory-installed mirror 10 mm in diameter and 2 mm thick (flatness λ/5, reflectivity >98 % from 500 nm to 2 µm).

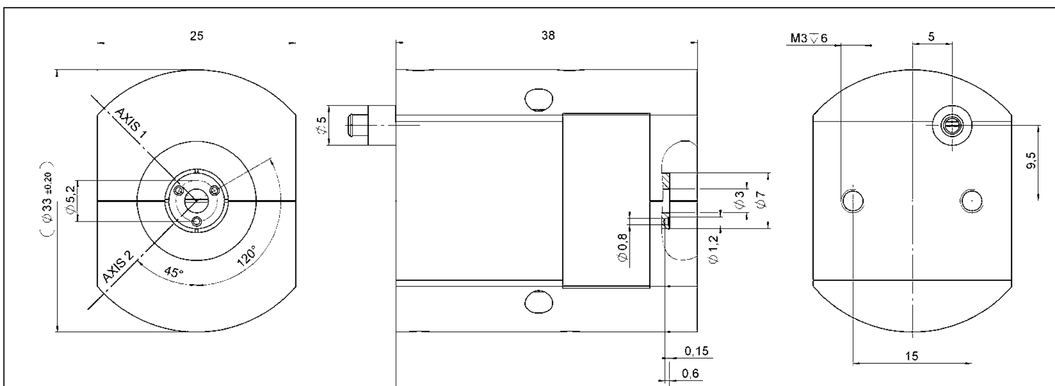
Ordering Information

S-334.2SD
High-Dynamics Piezo Tip/Tilt Platform, 50 mrad, SGS, Sub-D Connector, incl. Mirror

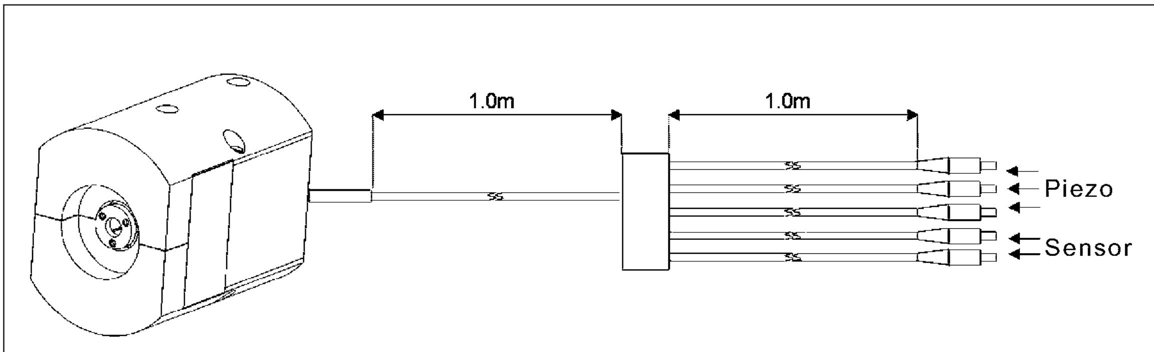
S-334.2SL
High-Dynamics Piezo Tip/Tilt Platform, 50 mrad, SGS, LEMO Connector, incl. Mirror

Application Examples

- Image processing / stablilization
- Interlacing, dithering
- Laser scanning / beam steering
- Optics
- Optical filters / switches
- Scanning microscopy
- Beam stabilization



S-334 dimensions in mm



S-334.2SL cable configuration

Technical Data

Model	S-334.2SL	S-334.2SD	Units	Tolerance
Active Axes	θ_X, θ_Y	θ_X, θ_Y		
Motion and positioning				
Integrated sensor	SGS	SGS		
*Open-loop tilt angle at -20 to +120 V	60	60	mrad	min. (+20 %/-0 %)
*Closed-loop tilt angle	50	50	mrad	
Open-loop resolution	0.5	0.5	µrad	typ.
Closed-loop resolution	5	5	µrad	typ.
Linearity	0.05	0.05	%	typ.
Repeatability	5	5	µrad	typ.
Mechanical properties				
Resonant frequency under load (with standard mirrors)	1.0	1.0	kHz	±20 %
Resonant frequency with 12.5 mm diam. x 2 mm glass mirror	0.8	0.8	kHz	±20 %
Load capacity	0.2	0.2	N	Max.
Distance of pivot point to platform surface	6	6	mm	±1 mm
Platform moment of inertia	1530	1530	g x mm²	±20 %
Standard mirror (mounted)	diameter: 10 mm, thickness: 2 mm, BK7, λ/5, R > 98 % (λ = 500 nm to 2 µm)	diameter: 10 mm, thickness: 2 mm, BK7, λ/5, R > 98 % (λ = 500 nm to 2 µm)		
Drive properties				
Ceramic type	PICMA® P-885	PICMA® P-885		
Electrical capacitance	6	6	µF	±20 %
Miscellaneous				
Operating temperature range	-20 to 80	-20 to 80	°C	
Material casing	Titanium	Titanium		
Mass	0.065	0.065	kg	±5 %
Cable length	2	2	m	±10 mm
Sensor / voltage connection	LEMO connector	25-pin sub-D connector		
Recommended controller / amplifier	Modular piezo controller system E-500 (p. 2-144) with amplifier module E-503.00S (three channels) (p. 2-146) or 1 x E-505.00S and 2 x E-505 (high speed applications) (p. 2-147) and E-509 servo controller (p. 2-152) Open-loop: E-663 three channel amplifier (p. 2-136)	E-616 controller for tip/tilt mirror systems (p. 2-132)		

Resolution of PI piezo tip/tilt platforms is not limited by friction or stiction. Noise equivalent motion with E-503 amplifier. (p. 2-146)
*Mechanical tilt, optical beam deflection is 120 mrad (open loop) and 100 mrad (closed-loop), respectively.

S-325 Piezo Z / Tip/Tilt Platform

High-Speed Tripod System for Mirrors and Optics

S-325.30L piezoelectric fast steering mirror platform / scanner

- **Optical Beam Deflection to 10 mrad, Resolution to 50 nrad**
- **Piston Movement up to 30 µm (for Path Length Adjustment)**
- **Compact Tripod Design with Coplanar Axes Eliminates Polarization Rotation**
- **Sub-Millisecond Responsiveness**
- **Closed-Loop Versions for Higher Precision**
- **For Mirrors up to 25 mm (1") Diameter**
- **Frictionless, High-Precision Flexure Guiding System**
- **Parallel Kinematics for Enhanced Dynamics and Better Multi-Axis Accuracy**

The S-325 Z/tip/tilt platforms and actuators provide high speed and precise movement of the platform in two tilt axes as well as sub-nanometer linear resolution with sub-millisecond response. The design is based on a parallel-kinematics direct-drive piezo tripod (see p. 2-83), and they are especially optimized for industrial applications where 1.000.000.000 motion cycles have to be performed without failure or performance degradation. The systems are designed for mirrors and optics up to 25 mm in diameter and can be mounted in any orientation.

The tripod drive offers optimum angular stability over a wide temperature range. Compared to stacked, (two-stage), piezo or galvo scanners, the single platform design provides several advantages: smaller package size, identical size, identical dynamic performance in all axes, faster response and better linearity. It also prevents polarization rotation.

All three piezo linear actuators can be driven individually (for tip/tilt movement) or in parallel (for vertical movement) by a three-channel amplifier.

High Resolution, Stability and Dynamics

The S-325 offers piston movement of up to 30 µm (ideal for path length adjustment) and mechanical tilt up to 5 mrad (equivalent to 10 mrad optical beam deflection). The zero-friction piezo drives and flexure guidance allow sub-nanometer linear resolution and sub-microradian angular resolution.

Ordering Information

S-325.3SD
High-Dynamics Piezo Z/Tip/Tilt Platform, 5 mrad, 30 µm, SGS, Sub-D Connector

S-325.3SL
High-Dynamics Piezo Z/Tip/Tilt Platform, 5 mrad, 30 µm, SGS, LEMO Connector

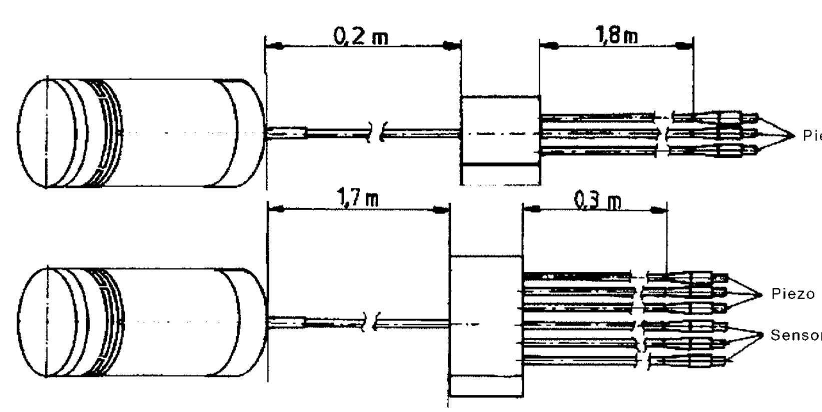
S-325.30L
High-Dynamics Piezo Z/Tip/Tilt Platform, 5 mrad, 30 µm, Open-Loop, LEMO Connector

Open-Loop and Closed-Loop Operation

In open-loop mode, the platform linear motion is roughly proportional to the applied voltage. The S-325.30L open-loop model is ideal for high-bandwidth, high-resolution applications where the absolute angular position is of secondary importance (e. g. for tracking) or where feedback is provided by an external sensor (e. g. CCD, PSD). The S-325.3SL model is equipped with high-resolution strain gauge sensors and provides absolute position control, high linearity and high repeatability. The new E-616 controller/driver module (see p. 2-132) is ideally suited for tip/tilt OEM applications.

Application Examples

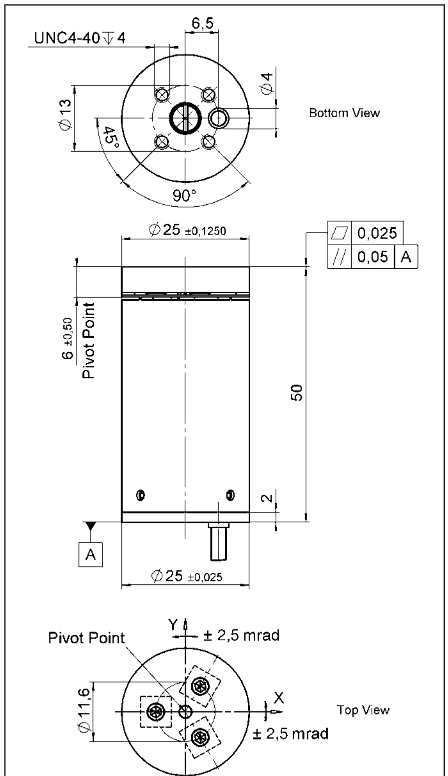
- Image processing / stablilization
- Optical trapping
- Laser scanning / beam steering
- Laser tuning
- Optical filters / switches
- Optics
- Beam stabilization



S-325 cable configuration (top: S-325.30L, bottom: S-325.3SL)

High Reliability and Long Lifetime

The compact S-325 systems are equipped with preloaded PICMA® high-performance piezo actuators which are integrated into a sophisticated, FEA-modeled, flexure guiding system. The PICMA® actuators feature cofired ceramic encapsulation and provide better performance and reliability than conventional piezo actuators. Actuators, guidance and sensors are maintenance-free, not subject to wear and offer extraordinary reliability.



S-325 dimensions in mm

Technical Data

Model	S-325.30L	S-325.3SL	S-325.3SD	Units	Tolerance
Active axes	Z, Θ_X, Θ_Y	Z, Θ_X, Θ_Y	Z, Θ_X, Θ_Y		
Motion and positioning					
Integrated sensor	–	SGS	SGS		
Open-loop travel, 0 to +100 V	30	30	30	µm	min. (+20 %/-0 %)
Open-loop tip/tilt angle, 0 to +100 V	5	5	5	mrad	min. (+20 %/-0 %)
Closed-loop travel	–	30	30	µm	
Closed-loop tip/tilt angle	–	4	4	mrad	
Open-loop resolution	0.5	0.5	0.5	nm	typ.
Open-loop tip/tilt angle resolution	0.05	0.05	0.05	µrad	typ.
Closed-loop linear resolution	–	0,6	0,6	nm	typ.
Closed-loop tip/tilt resolution	–	0.1	0.1	µrad	typ.
Mechanical properties					
Unloaded resonant frequency	2	2	2	kHz	±20 %
Resonant frequency (with 25 x 8 mm glass mirror)	1	1	1	kHz	±20 %
Distance of pivot point to platform surface	6	6	6	mm	±0.5 mm
Platform moment of inertia	515	515	515	g • mm²	±20 %
Drive properties					
Ceramic type	PICMA® P-885	PICMA® P-885	PICMA® P-885		
Electrical capacitance	9.3	9.3	9.3	µF	±20 %
Dynamic operating current coefficient	39	39	39	µA / (Hz • mrad)	±20 %
Miscellaneous					
Operating temperature range	-20 to 80	-20 to 80	-20 to 80	°C	
Material casing	Aluminum	Aluminum	Aluminum		
Mass	0.065	0.065	0.065	kg	±5 %
Cable length	2	2	1.5	m	±10 mm
Sensor / voltage connection	LEMO	LEMO	Sub-D		

For maximum tilt range, all three piezo actuators must be biased at 50 V. Due to the parallel-kinematics design linear travel and tilt angle are interdependent. The values quoted here refer to pure linear / pure angular motion. See equations (p. 2-84).
Recommended controller / amplifier
Versions with LEMO connector: modular piezo controller system E-500 (p. 2-142) with amplifier module E-503.00S (three channels) (p. 2-146) or 1 x E-505.00S and 2 x E-505 (high speed applications) (p. 2-147) and E-509 controller (p. 2-152) (optional)
Single-channel (1 per axis): E-610 OEM servo controller / amplifier (p. 2-110), E-625 servo controller bench-top (p. 2-114)
Versions with Sub-D connectors: E-616 servo controller for tip/tilt mirror systems (p. 2-132)

S-310 – S-316 Piezo Z/Tip/Tilt Scanner

High-Speed System with Clear Aperture

S-310.10, S-316.10 piezo systems for scanning, optics alignment and mirror shifter alignment

- **10 mm Clear Aperture**
- **Piezo Tripod Design**
- **Optical Beam Deflection to 2,4 mrad**
- **Piston Movement up to 12 µm (phase shifter)**
- **Sub-Millisecond Response, Sub-Microradian Resolution**
- **Closed-Loop Versions for Higher Precision**
- **For Optics, Mirrors or Other Components**
- **Frictionless, High-Precision Flexure Guiding System**
- **Parallel Kinematics for Enhanced Dynamics and Better Multi-Axis Accuracy**

S-310 to S-316 multi-axis tip/tilt platforms and Z-positioners are fast, compact units based on a piezo tripod design. They offer piston movement up to 12 µm and tilt movement up to 1.2 mrad (2.4 mrad optical beam deflection) with sub-millisecond response and settling.

Application Examples

- Image processing / stablilization
- Interferometry
- Laser scanning / beam steering
- Laser tuning
- Optical filters / switches
- Beam stabilization

The tripod design features optimum angular stability over a wide temperature range.

The systems are designed for mirrors and optics up to 25 mm in diameter and can be mounted in any orientation; the clear aperture is ideal for transmitted-light applications (e. g. for optical filters).

Open-Loop and Closed-Loop Operation

In open-loop mode, the tip/tilt angle is roughly proportional to the applied voltage. The S-310 to S-315 open-loop models are ideal for high-speed, high resolution applications where the absolute angular position is of secondary importance (e. g. for tracking) or where feedback is provided by an external sensor (e. g. CCD, PSD). The S-316.10 model is equipped with high-resolution strain gauge sensors and provides absolute position control, high linearity and high repeatability.

Available Versions

S-310.10, S-314.10

Open-loop Z-platforms; all three piezo linear actuators are electrically connected in parallel, providing vertical positioning (piston movement) of the top ring. Only one drive channel is required.

S-311.10, S-315.10

Open-loop Z/tip/tilt positioners; all three piezo linear actuators can be driven individually (or in parallel) by a three-channel amplifier. Vertical (piston movement) positioning and tip/tilt positioning are possible.

S-316.10

Closed-loop Z/tip/tilt positioner. All three piezo linear actuators are equipped with strain gauge position feedback sensors and can be driven individually (or in parallel) by a three-channel amplifier with a position servo-controller. Vertical positioning (piston movement) and tip/tilt positioning are possible. The integrated position feedback sensors provide sub-microradian resolution and high repeatability.

Ordering Information

S-310.10
Piezo Actuator, Clear Aperture, 6 µm, LEMO Connector

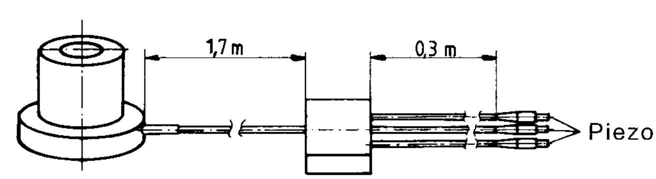
S-311.10
Piezo Z/Tip/Tilt Platform, Clear Aperture, 600 µrad, 6 µm, LEMO Connector

S-314.10
Piezo Actuator, Clear Aperture, 12 µm, LEMO Connector

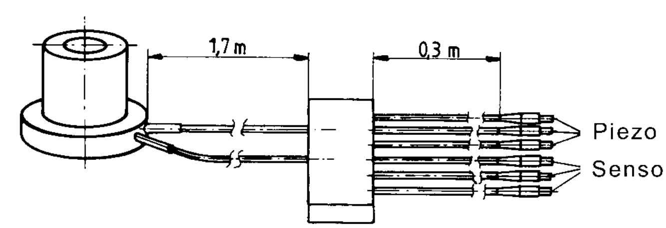
S-315.10
Piezo Z/Tip/Tilt Platform, Clear Aperture, 1.2 mrad, 12 µm, LEMO Connector

S-316.10
Piezo Z/Tip/Tilt Platform, Clear Aperture, 1.2 mrad, 12 µm, SGS, LEMO Connector

S-316.10
Piezo Z/Tip/Tilt Platform, Clear Aperture, 1.2 mrad, 12 µm, SGS, Sub-D Connector



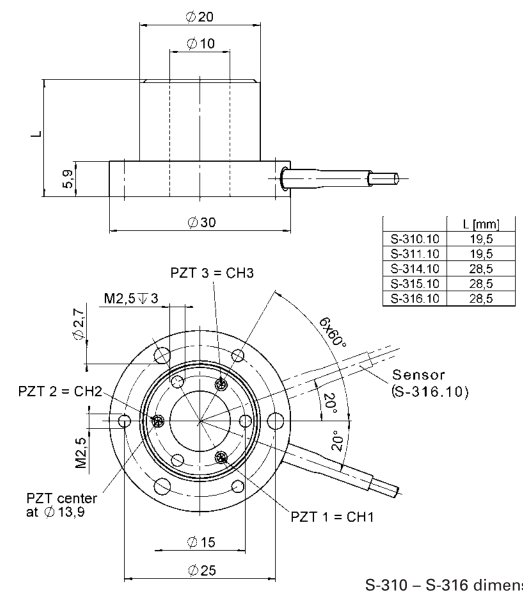
S-315 cable configuration



S-316 cable configuration

High Reliability and Long Lifetime

The compact S-310 - S-316 systems are equipped with preloaded PICMA® high-performance piezo actuators which are integrated into a sophisticated, FEA-modeled, flexure guiding system. The PICMA® actuators feature cofired ceramic encapsulation and provide better performance and reliability than conventional piezo actuators. Actuators, guidance and sensors are maintenance-free, not subject to wear and offer extraordinary reliability.



S-310 – S-316 dimensions (in mm)

Technical Data

Model	S-310.10	S-314.10	S-311.10	S-315.10	S-316.10	Units	Tolerance
Active axes	Z	Z	Z, Θ_X, Θ_Y	Z, Θ_X, Θ_Y	Z, Θ_X, Θ_Y		
Motion and positioning							
Integrated sensor	–	–	–	–	SGS		
Open-loop travel, 0 to +100 V	6 / –	12 / –	6 / –	12 / –	12 / 12	µm	min. (+20 %/-0 %)
*Open-loop tilt angle @ 0 to 100 V	–	–	600	1200	1200	µrad	min. (+20 %/-0 %)
Closed-loop travel	–	–	–	–	12	µm	
*Closed-loop tilt angle	–	–	–	–	1200	mrad	
Open-loop resolution	0.1	0.2	0.1	0.2	0.2	nm	typ.
Open-loop tip/tilt angle resolution			0.02	0.05	0.05	µrad	typ.
Closed-loop resolution	–	–	–	–	0.4	nm	typ.
Closed-loop tip/tilt resolution	–	–	–	–	0.1	µrad	typ.
Linearity	–	–	–	–	0.2	%	typ.
Mechanical properties							
Stiffness	20	10	20	10	10	N/µm	±20 %
Unloaded resonant frequency (Z)	9.5	5.5	9.5	5.5	5.5	kHz	±20 %
Resonant frequency (with 15 x 4 mm glass mirror)	6.5	4.4	6.5	4.1	4.1	kHz	±20 %
Resonant frequency (with 20 x 4 mm glass mirror)	6.1	4.2	6.1	3.4	3.4	kHz	±20 %
Distance of pivot point to platform surface	–	–	5	5	5	mm	±1 mm
Platform moment of inertia	–	–	150	150	150	g • mm²	±20 %
Drive properties							
Ceramic type	PICMA® P-882	PICMA® P-882	PICMA® P-882	PICMA® P-882	PICMA® P-882		
Electrical capacitance	0.39	0.93	0.39	0.93	0.93	µF	±20 %
Dynamic operating current coefficient	8	10	8	10	10	µA / (Hz • mrad)	±20 %
Miscellaneous							
Operating temperature range	-20 to 80	-20 to 80	-20 to 80	-20 to 80	-20 to 80	°C	
Material	Stainless steel	Stainless steel	Stainless steel	Stainless steel	Stainless steel		
Mass	0.45	0.55	0.45	0.55	0.55	kg	±5%
Cable length	2	2	2	2	2	m	±10 mm
Sensor connection	–	–	–	–	LEMO		
Voltage connection	LEMO	LEMO	LEMO	LEMO	LEMO		

Resolution of PI piezo tip/tilt platforms is not limited by friction or stiction. Noise equivalent motion with E-503 amplifier (p. 2-146).

*Mechanical tilt, optical beam deflection is twice as large. For maximum tilt range, all three piezo actuators must be biased at 50 V. Due to the parallel-kinematics design linear travel and tilt angle are interdependent. The values quoted here refer to pure linear / pure angular motion (equations p. 2-84).

Recommended controller / amplifier
Single-channel (1 per axis): E-610 servo-controller / amplifier (p. 2-110), E-625 servo-controller, bench-top (p. 2-114)

Multi-channel: modular piezo controller system E-500 (p. 2-142) with amplifier module E-503 (three channels) (p. 2-146) or E-505 (1 per axis, high-power) (p. 2-147) and E-509 controller (p. 2-152) (optional), E-517 interface module (p. 2-156) (optional)

S-323 Piezo Z/Tip/Tilt Platform

High Dynamics & Stability Nanopositioning System with Direct Metrology

The S-323 Z/tip/tilt platform integrates capacitive sensors for highest resolution and stability

- Optical Beam Deflection to 6 mrad
- Sub-µrad Resolution for High Positioning Stability
- Position Servo-Control with Capacitive Sensors
- Frictionless, High-Precision Flexure Guiding System
- System Combination with Digital Controllers for Highest Linearity

Model	Active axes	Travel range	Resolution	Unloaded resonant frequency
S-323.3CD	Z, θ_X, θ_Y	30 µm, ±1.5 mrad	0.1 nm, ±0.05 µrad	1.7 kHz

S-303 Piezo Phase Shifter

Highest Dynamics and Stability with Capacitive Feedback Sensor

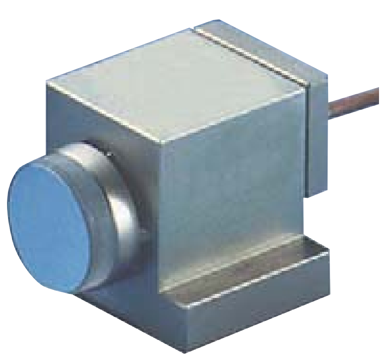

S-303 closed-loop model (left) and open-loop model (right). DIP switch for size comparison

- 25 kHz Resonant Frequency for Sub-Millisecond Dynamics
- Capacitive Sensor Option for Highest Linearity and Stability
- 3 µm Travel Range
- Compact Size: 30 mm Diameter x 10 mm
- Aperture with Open-Loop Versions
- Invar Option for Highest Thermal Stability

Model	Active axes	Closed-loop/ open-loop travel @ -20 to +120V	Closed-loop/ open-loop resolution	Unloaded resonant frequency
S-303.CD (closed-loop)/ S-302.0L (open-loop)	Z	2 / 3 µm	0.03 nm	25 kHz

S-224 -S-226 Piezo Tilt-Mirror

Fast Steering Mirror Combines Highest Dynamics and Compact Design


S-224 Piezo tip/tilt mirror for high-speed beam steering tasks and image stabilization applications

- Optical Beam Deflection to 4.4 mrad
- Sub-µrad Resolution, Sub-Millisecond Response
- Frictionless, High-Precision Flexure Guiding System
- Includes BK7 Mirror
- Optional Position Feedback Sensor
- Outstanding Lifetime Due to PICMA® Piezo Actuators

Model	Active axes	Open-loop tilt angle @ 0 to +100V	Closed-loop/ open-loop resolution	Unloaded resonant frequency
S-224.00 (open-loop)/ S-226.00 (closed-loop)	θ_X	2.0 / 2.2 mrad	0.05 / 0.1 µrad	9 kHz

Piezo Drivers / Servo Controllers

PI Piezo • Nano • Positioning

E-709 Compact and Cost-Optimized Digital Piezo Controller

Increased Performance for Piezo Systems with Strain Sensors

Compact, low-cost E-709 digital controller (preliminary case design) with P-712 piezo-scanner

- **Fast Digital Controller, Software Configurable Servo Parameters**
- **Linearity of SGS and Piezoresistive Sensors Improved by up to 0.02 %**
- **2 Digital Interfaces: USB, RS-232**
- **Comprehensive I/O Functions**
- **Additional High-Bandwidth Analog Control Input / Sensor Input**
- **Low-Cost OEM Versions Available**
- **Comprehensive Software Package**

The E-709 opens up the possibilities of digital control for piezo-driven nanopositioning systems for the same price as analog controllers. It was designed for piezo actuators and nanopositioning stages which are equipped with cost effective measuring systems such as strain gauges or piezoresistive sensors. The advantage: higher precision, more control options and very simple operation. In addition, PI provides the full functionality of its comprehensive software packages free of charge! The E-709 can also be used for applications providing analog control signals. In addition to 2 digital interfaces, a standard broadband analog input is installed as well.

Digital Linearization for Strain Sensors: 10 x More Precise!

For the first time, the E-709 nanopositioning controller opens up the advantages of digital control to compact systems with strain sensors. These sensors are based on the strain of metal foils or semiconductor films (piezoresistive sensors) and are used when space limitations prevent the use of the more advanced capacitive sensors, or where the requirements in terms of resolution or temperature stability are not as critical.
The limited linearity of these strain sensors can be improved by digital controllers, which use additional linearization algorithms to minimize the deviation between target and actual position. This improves the accuracy by up to one order of magnitude and achieves linearity values of up to 0.02 %.

Flexibility: Software Configurable Servo Parameters

All servo controllers require tuning and adjustment of servo parameters for optimum performance (e.g. as a result of changes to the load or the motion profile). With a digital controller, all adjustments are carried out by simple software commands and the resulting motion or transient characteristics can be viewed, analyzed and further optimized immediately with the provided software. It is also possible to switch between previously found sets of parameters when the controller is in operation. Since jumpers and potentiometers no longer have to be set manually, system integration becomes much more straight forward.

OEM Versions at an Even Lower Price

E-709 controllers are also offered without case. A lower cost version sold as the E-609 is available for purely analog control signals, maintaining the advantages of digital signal processing and parameter setting. The target position is controlled via an analog signal, allowing system components with analog output (e.g. autofocus) to be integrated easily.
An E-709 version for capacitive position sensors is also available to control the large variety of ultra-high precison single-axis nanopositioning systems PI offers.

Ordering Information

E-709.PRG
Digital Piezo Controller, 1 Channel, -30 to 130 V, Piezoresistive Sensors, Bench-Top

E-709.SRG
Digital Piezo Controller, 1 Channel, -30 to 130 V, SGS-Sensor, Bench-Top

E-709.PR
Digital Piezo Controller, 1 Channel, OEM Module, -30 to 130 V, Piezoresistive Sensors

E-709.SR
Digital Piezo Controller, 1 Channel, OEM Module, -30 to 130 V, SGS-Sensor

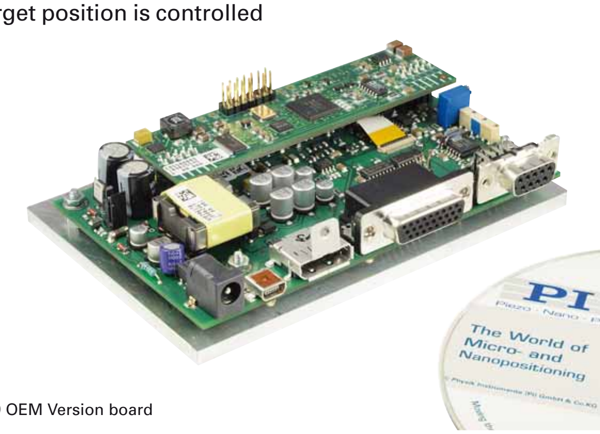
Accessories

E-709.01
Adapter HD-Sub-D 26-pin to Sub-D 9-pin with I/O Lines, 0.5 m

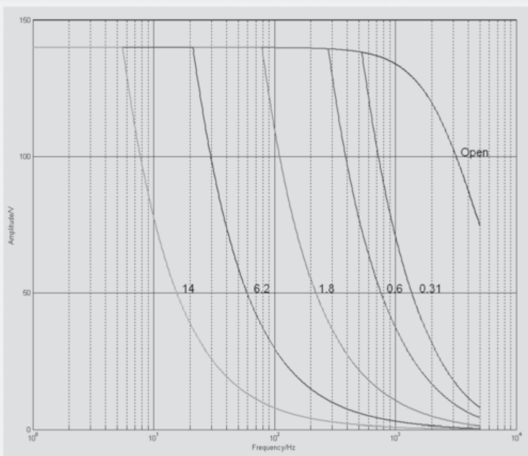
E-709.02
Adapter Cable HD-Sub-D 26-pin to Open Leads, 1 m

E-709.03
Adapter LEMO to Sub-D 9-pin

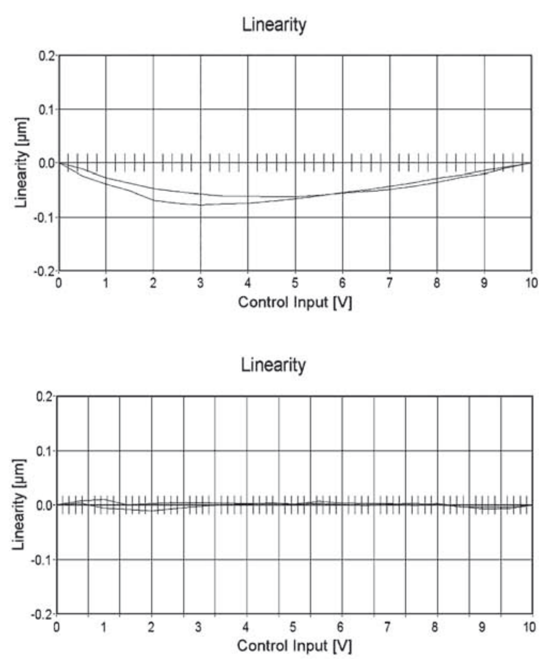
The E-709 is also available as a compact, low-cost controller for capacitive sensor-equipped positioning systems.



E-709 OEM Version board



E-709: operating limits with various PZT loads (open-loop), capacitance is measured in µF



Comparison of the linearity of a strain gauge sensor with analog controller (top) and the E-709 digital controller (bottom), which improves the linearity by up to one order of magnitude

Technical Data

Modell	E-709.SR E-709.SRG E-709.PR E-709.PRG
Function	Digital controller for single-axis piezo nanopositioning systems (.SR, .PR: OEM board)
Channels	1
Processor	DSP 32-bit floating point, 150 MHz
Servo characteristics	P-I, two notch filters
Sampling rate, servo control	10 kHz
Sampling rate, sensor	10 kHz
Sensor	
Sensor type	Metal foil strain gauge sensors (.SR, .SRG), Piezoresistive sensors (.PR, .PRG)
Linearization	5th order polynomials
Sensor bandwidth	5 kHz
Sensor resolution	16 bit
Ext. synchronization	No
Amplifier	
Output voltage	-30 V to +130 V
Peak output power	10 W (<5 ms)
Average output power	5 W (>5 ms)
Peak current	100 mA (<5 ms)
Average current	50 mA (>5 ms)
Current limitation	Short-circuit-proof
Resolution DAC	16 bit
Interfaces and operation	
Communication interfaces	USB, RS-232
Piezo / sensor connector	Sub-D 9-pin
I/O connector	HD-Sub-D 26-pin, 1x analog control input 0 to 10 V, 1x sensor monitor 0 to 10 V, 1x digital input (LVTTL, programmable), 5x digital output (LVTTL, 3x predefined, 2x programmable)
Command set	PI General Command Set (GCS)
User software	PIMikroMove , NanoCapture
Software drivers	LabVIEW drivers, DLLs
Supported functionality	Wave generator, data recorder, auto zero, trigger I/O
Display	Status LED, overflow LED
Miscellaneous	
Operating temperature range	8 to 50 °C (over 40 °C, max. power av. power derated)
Dimensions	160 x 96 x 33 mm
Mass	0.5 kg
Operating voltage	24 VDC
Power consumption	24 W max.

Piezo • Nano • Positioning

E-709 Compact and Cost-Optimized Digital Piezo Controller

For Piezo Systems with Capacitive Sensors

Compact single-channel digital controller E-709 with PIFOC® objective scanners

- **Flexibility of Digital Signal Processing for the Cost of Analog**
- **Digital Control Algorithms with 10 kHz Sampling Rate**
- **For Capacitive Sensors**
- **Linearity to 0.02 %**
- **USB and RS-232 Interfaces**
- **Fast 25 Mbit/s Serial Interface**
- **Additional High-Bandwidth Analog Control Input / Sensor Input**
- **Analog Output, e.g. for External Amplifiers**
- **Low-Cost OEM-Versions Available**
- **Fast Digital Controller, Software-Configurable Servo Parameters**
- **Parameter Input Using Software**

The E-709 piezo controller provides the flexibility and ease of use of a digital signal processing unit for the cost of an analog one. All motion and servo-control parameters can be set by software and adjusted on-the-fly during operation. In addition, digital 5th order polynomial linearization algorithms can improve the motion linearity of the attached piezo positioning system significantly over an analog servo system. In addition to a variety of digital interfaces, an analog input and output are also included. A software command allows the analog input to be interpreted as position control signal or as a sensor value. The analog output can be configured for the control of external amplifiers or for the output of position values.

Flexibility: Software Configurable Servo Parameters

All servo controllers require tuning and adjustment of servo parameters for optimum performance (e.g. as a result of changes to the load or the motion profile). With a digital controller, all adjustments are carried out by simple software commands and the resulting motion or transient characteristics can be viewed, analyzed and further optimized immediately with the provided software. It is also possible to switch between previously found sets of parameters when the controller is in operation. Since jumpers and potentiometers no longer have to be set manually, system integration becomes much more straightforward.

Digital or Analog?

Digital controllers provide advantages when high positioning linearity is important or when servo parameters need to be modified frequently. This could be the case when load changes occur or to optimize motion profiles for both step operation and continuous operation achieving the fastest settling time and the highest tracking accuracy. With analog controllers a compromise has to be found during system setup and changes require physical access to the unit. With digital controllers the best parameters for either condition can be set on-the-fly by a software command.

OEM Versions for Cost Sensitive Applications

An unpackaged version of the E-709 is offered for OEMs. An even lower-cost version sold as the E-609 comes with an analog-only control input, maintain-ing the advantages of digital signal processing and parameter setting. This is designed for applications where analog control signals are readily available, (e. g. Autofocus).

E-709 OEM version board (picture shows version for strain gauge sensors)

Ordering Information

E-709.CR
Digital Piezo Controller, 1 Channel, OEM Module, -30 to 130 V, Capacitive Sensor

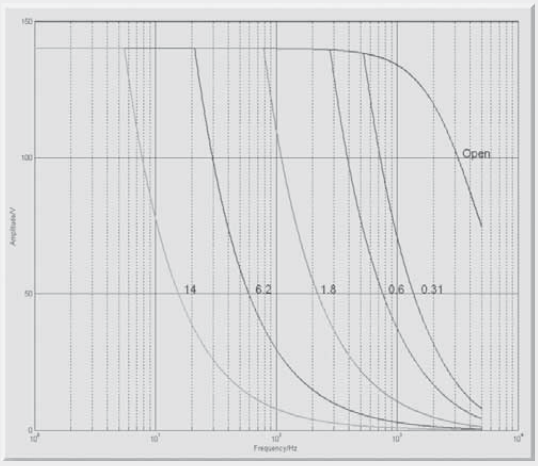
E-709.CRG
Digital Piezo Controller, 1 Channel, -30 to 130 V, Capacitive Sensor, Bench-Top

Accessories:

E-709.01
Adapter HD-Sub-D 26-pin to Sub-D 9-pin with I/O Lines, 0.5 m

E-709.02
Adapter Cable HD-Sub-D 26-pin to Open Leads, 1 m

The E-709 is also available for piezo systems with strain gauge and piezoresistive sensors.



E-709: operating limits with various PZT loads (open-loop), capacitance is measured in µF

Technical Data

Modell	**E-709.CR / E-709.CRG**
Function	Digital controller for single-axis piezo nanopositioning systems (.CR: OEM board)
Channels	1
Processor	DSP 32-bit floating point, 150 MHz
Sampling rate, servo-control	10 kHz
Sampling rate, sensor	10 kHz
Sensor	
Servo characteristics	P-I, 2 notch filter, sensor linearization
Sensor type	Capacitive sensors
Sensor bandwidth	5 kHz
Sensor resolution	16 bit
Ext. synchronization	No
Amplifier	
Output voltage	-30 V to +130 V
Peak output power	10 W (< 5 ms)
Average output power	5 W (> 5 ms)
Peak current	100 mA (< 5 ms)
Average current	50 mA (> 5 ms)
Current limitation	Short-circuit-proof
Resolution DAC	17 bit
Interfaces and operation	
Communication interfaces	USB, RS-232, SPI
Piezo / sensor connector	Sub-D-Special connector
I/O Connector	HD-Sub-D 26-pin, 1 analog input 0 to 10 V, 1 sensor monitor 0 to 10 V, 1 digital input (LVTTL, programmable), 1 analog output, 5 digital outputs (LVTTL, 3 predefined, 2 programmable)
Command set	PI General Command Set (GCS)
User software	PIMikroMove, NanoCapture
Software drivers	LabVIEW drivers, DLLs
Supported functionality	Wave generator, data recorder, auto zero, trigger I/O
Display	Status LED, overflow LED
Linearization	5th order polynomials
Target ground connector	- / yes
Miscellaneous	
Operating temperature range	12 to 50 °C (over 40 °C, max. av. power derated)
Dimensions	160 x 96 x 33 mm
Mass	260 g / 470 g
Motor voltage range	24 VDC
Max. power consumptions	24 W

Linear Actuators & Motors
Nanostelltechnik / Piezoelektronik
Piezo Flexure Stages / High-Speed Scanning Systems
Linear
Vertical & Tip/Tilt
2- and 3-Axis
6-Axis
Fast Steering Mirrors / Active Optics
Piezo Drivers / Servo Controllers
Single-Channel
Multi-Channel
Modular
Accessories
Piezoelectrics in Positioning
Nanometrology
Micropositioning
Index

E-753 Digital Piezo Controller

High-Speed, Single-Axis Controller

E-753 Single-channel digital controller together with the PIHera® P-629.1CD nanopositioning stage with 1500 µm travel

- **Next Generation Digital Controller Provides Higher Flexibility, Accuracy and Speed**
- **100 kHz Sensor Sampling; 32-bit Floating Point DSP; 24-bit Low-Noise D/A Converters**
- **Ethernet (TCP/IP) Interface for Remote Control Capability, RS-232**
- **Auto-Loading of Calibration Data from Stage ID-Chip for Interchangeability of Controller and Mechanics**
- **Additional High-Bandwidth Analog Control Input / Sensor Input**
- **Digital I/O Lines for Task Triggering**
- **Extensive Software Support**
- **For Nanopositioning Systems with Capacitive Sensors**

The E-753 next-generation digital piezo controller is the result of PI's 30+ years of experience with piezo motion control systems. It is ideal when it comes to meeting the most demanding accuracy and dynamic-performance requirements of nanopositioning systems of the highest precision class. The E-753 replaces the E-750 controller.

Digital Linearization and Control Algorithms for Highest Accuracy

Linearization algorithms based on higher-order polynomials improve the positioning accuracy to 0.001 % of the travel range. During fast periodic motion, as typical for scanning applications, the tracking accuracy can be further improved with Dynamic Digital Linearization (DDL, E-710.SCN). This optionally available control algorithm reduces the tracking error by a factor of up to 1000 and enables the spatial and temporal tracking during a dynamic scan.

Higher Velocity and Bandwidth for Dynamic Applications

The controller is perfectly suited for high-dynamics operation thanks to its high-resolution DA-converter and high-performance voltage amplifier. The high-speed processor with a sensor sampling rate of 100 kHz assures settling times in the millisecond range and below.

Flexibility for a Variety of Applications

PI nanopositioning systems which are equipped with an ID-chip and calibrated with a digital controller have the mechanics-related calibration and servo-control parameters stored in the chip. The controller automatically adapts to the connected mechanics by the appropriate use of this data, so that recalibration is not necessary when system components are replaced.

The integrated wave generator can save and output periodic motion profiles. In addition to sine and triangle waves, arbitrary, user-defined profiles can be created.

Simple System Integration

All parameters can be checked and reset via software. System setup and configuration is done with the included NanoCapture™ and PIMikroMove™ user-interface software. Interfacing to custom software is facilitated with included LabVIEW drivers and DLLs. System programming is the same with all PI controllers, so controlling a system with a variety of different controllers is possible without difficulty.

Ordering Information

E-753.1CD
High-Speed Single-Channel Digital Piezo Controller for Capacitive Sensors

E-710.SCN
DDL (Dynamic Digital Linearization) Firmware Upgrade

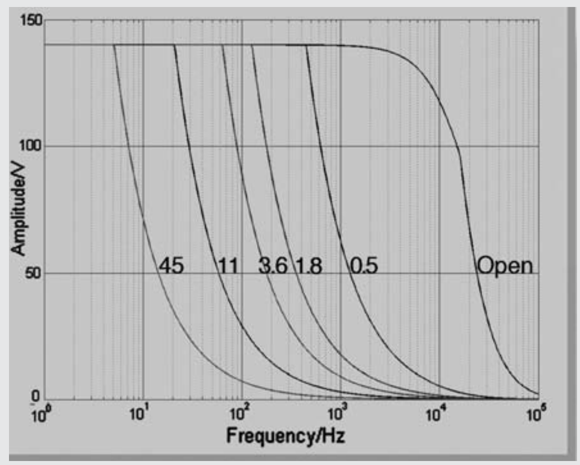
E-753.IO
Cable for Digital I/O Lines, 1.5 m, Solderable End

Ask about custom designs

P-725 PIFOC® objective Z-positioner and E-753 controller constitute an optimal system for high-speed, high-resolution positioning and scanning.

Technical Data

Model	E-753.1CD
Function	Digital controller for single-axis piezo nanopositioning systems with capacitive sensors
Axes	1
Processor	DSP 32-bit floating point, 60 MHz
Sampling rate, servo-control	25 kHz
Sampling rate, sensor	100 kHz
Sensor	
Servo characteristics	P-I, two notch filters
Sensor type	Capacitive
Sensor channels	1
Sensor bandwidth	5.6 kHz
Sensor resolution	17-bit
Ext. synchronization	Yes
Amplifier	
Output voltage	-30 V to 135 V
Amplifier channels	1
Peak output power <5 ms	15 W
Average output power >5 ms	5 W
Peak current <5 ms	110 mA
Average current >5 ms	40 mA
Current limitation	Short-circuit-proof
Resolution DAC	24-bit
Interfaces and operation	
Communication interfaces	Ethernet, RS-232
Piezo connector	Sub-D special connector
Sensor connection	Sub-D special connector
Analog input	LEMO, ±10 V, 18 bit
Digital input	2 x LEMO, TTL
Digital output	2 x LEMO, TTL
Command set	GCS
User software	NanoCapture™, PIMikroMove™
Software drivers	LabVIEW drivers, DLLs
Supported functionality	Wave generator, trigger I/O, data recorder
Display	Status LEDs
Linearization	4th order polynomials, DDL (optional)
Separate protective ground connector	Yes
Miscellaneous	
Operating temperature range	5 to 50 °C
Overtemp protection	Deactivation of the piezo voltage output at 85 °C
Mass	0.9 kg (controller)
Dimensions	Controller: 264 x 125 x 48 mm (with rubber feet) Power supply: 174 x 95 x 58 mm (with rubber feet)
Power consumption	10 W max.
Operating Voltage	24 VDC from external power supply (included)



E-753 open-loop operating limits with various PZT loads. Graphs reflect the large signal-current limitation of the amplifier circuit, not the actual bandwidth.

Piezo • Nano • Positioning

E-610 Piezo Amplifier / Controller

1-Channel OEM Piezo Driver Module with Optional Position Servo-Control

E-610.C0 for piezo positioning systems with capacitive sensors

- **Cost-Effective 1-Channel OEM Solution**
- **Closed-Loop and Open-Loop Versions**
- **Notch Filter for Higher Bandwidth**
- **Position Control with Strain Gauge or Capacitive Sensor**
- **18 W Peak Power**

The E-610 is an OEM amplifier & position servo-control board for low-voltage piezo actuators and positioning systems. It integrates a low-noise piezo amplifier which can output and sink peak currents of 180 mA in a voltage range of -20 to +120 V. Three versions are available: E-610.00 (only amplifier) and closed-loop versions E-610.S0 and E-610.C0 with additional components for position measurement and servo control.

Closed-Loop and Open-Loop Piezo Positioning

The units are designed to provide high-resolution operation of piezo actuators and positioning systems in voltage-controlled mode (open-loop) and in position-controlled mode (closed-loop).

In closed-loop position control mode, displacement of the piezo is highly linear and proportional to the analog signal. The servo modifies the amplifier output voltage based on the position sensor signal. Thus, positioning accuracy and repeatability down to the sub-nanometer range is possible, depending on the piezo mechanics and on the sensor type.

PI employs proprietary position sensors for fast response and optimum positioning resolution and stability in the nanometer range and below. For high-end applications, capacitance sensors provide direct and non-contact position feedback (direct metrology). Strain gauge sensors (SGS) are available for cost-effective applications. The integrated notch filters (adjustable for each axis) improve the stability and allow high-bandwidth operation closer to the resonant frequency of the mechanics.

In open-loop (voltage-controlled) operation the output voltage is determined by an external analog signal. Open-loop operation is ideal for applications where fast response and very high resolution with maximum bandwidth are essential. Here, commanding and reading the target position in absolute values is either not important or carried out by external position sensors (see p. 2-104).

Remote Control via Computer Interface

For digital-interface computer control, consider the E-621 (see p. 2-160) and E-625 (see p. 2-114) instead.

Alternatively control via PC using a D/A board is possible. PI offers a LabVIEW driver set which can be used with certain D/A boards from National Instruments.

Operation / Contents of Delivery

A single stabilized voltage in the range of 12 to 30 V is sufficient to operate the E-610. An integrated DC/DC converter generates the piezo operating voltage and all other voltages used internally. All inputs and outputs (except capacitive sensor lines) are available on the male 32-pin rear connector. A matching female 32-pin connector is included in the contents of delivery to interface with your circuitry.

Ordering Information

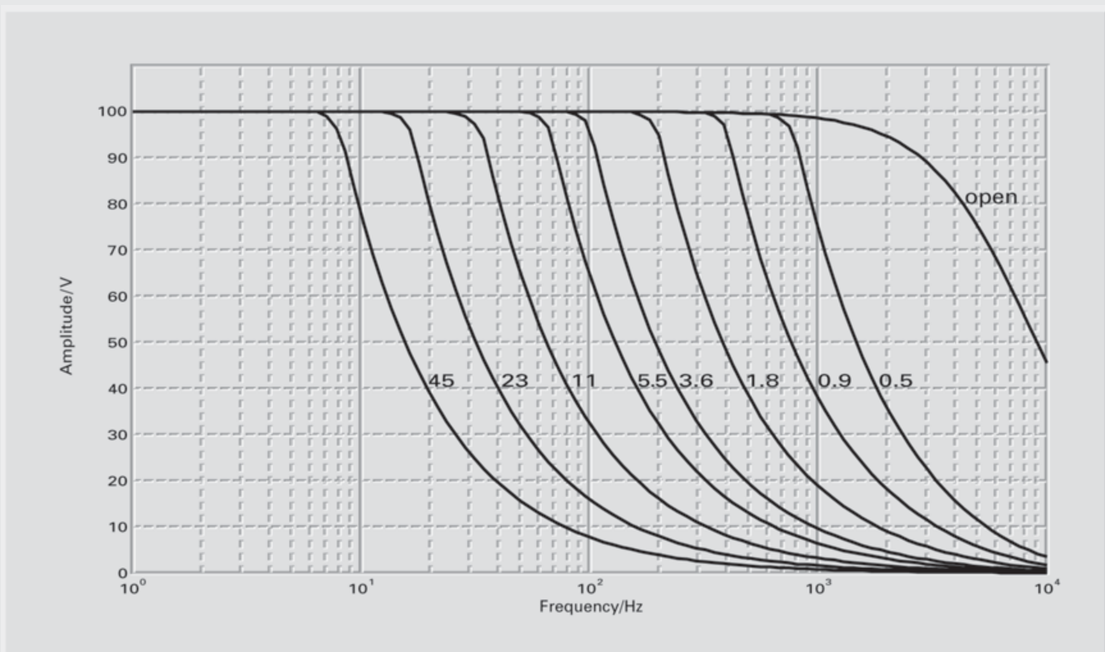
E-610.00
Piezo Amplifier, 1 Channel, OEM Module, -20 to 120 V

E-610.C0
Piezo Amplifier / Servo-Controller, 1 Channel, OEM Module, -20 to V, Capacitive Sensor

E-610.S0
Piezo Amplifier / Servo-Controller, 1 Channel, OEM Module, -20 to 120 V, SGS-Sensor

E-500.ACD
LabVIEW Driver Set for Analog Controllers

E-500.HCD
HyperBit™ Functionality for Enhanced System Resolution (Supports Certain D/A Boards)



E-610: operating limits with various PZT loads (open-loop), capacitance is measured in µF

Technical Data

Model	E-610.00	E-610.C0 / E-610.S0
Function	Piezo Amplifier, 1 Channel, OEM Module	Piezo Amplifier / Servo-Controller, OEM Module
Sensor		
Servo characteristics	–	P-I (analog), notch filter
Sensor type	–	Capacitive (.C0) / SGS (.S0)
Amplifier		
Control input voltage range	-2 to +12 V	-2 to +12 V
Output voltage	-20 to 120 V	-20 to 120 V
Peak output power	18 W (<15 ms)	18 W (.C0: <50 ms, .S0: <15 ms)
Average output power	10 W	10 W
Peak current	180 mA (<15 ms)	180 mA (.C0: <50 ms, .S0: <15 ms)
Average current	100 mA	100 mA
Current limitation	Short-circuit-proof	Short-circuit-proof
Noise, 0 to 100 kHz	1.6 mV_{rms}	0.5 mV_{rms} (.C0) / 1.6 mV_{rms} (.S0)
Voltage gain	10 ±0.1	10 ±0.1
Input impedance	100 kΩ	100 kΩ
Interfaces and operation		
Input / Output	32-pin (male) on rear panel (DIN 41612/D)	32-pin (male) on rear panel (DIN 41612/D)
Piezo connector	LEMO	LEMO
Sensor connection	–	LEMO
DC Offset	External potentiometer (not included), adds 0 to + 10 V to Control In	External potentiometer (not included), adds 0 to + 10 V to Control In
Miscellaneous		
Operating temperature range	+5 to +50 °C	+5 to +50 °C
Dimensions	7HP/3U	7HP/3U
Mass	0.3 kg	0.35 kg
Operating Voltage	12 to 30 V DC, stabilized	12 to 30 V DC, stabilized
Current consumption, max.	2 A	2 A

E-617 High-Power Piezo Amplifier

Top-Hat & OEM Modules with Energy Recovery for High-Dynamics 24/7 Operation

The E-617.001 high-power piezo amplifier is intended for top-hat-rail mounting in switching cabinets

- **Peak Power to 280 W**
- **High Currents to 2000 mA**
- **Energy Recovery for Low Power Consumption**
- **OEM Module and Top-Hat-Rail Versions**

The E-617 is an exceptionally efficient, high-power, piezo amplifier for low-voltage piezo actuators. Providing peak power of up to 280 W and average power of 100 W, it can output and sink a peak current of 2000 mA. This allows driving high-capacitance piezo actuators at frequencies in the kilohertz range.

Energy Recovery Operating Principle

The working principle of the E-617 series is ideally suited for high-dynamics scanning and switching applications.

The innovative, efficient circuitry reduces power consumption and heat dissipation, especially in dynamic applications. Charge is transferred to the piezo actuator using low-loss PWM techniques. When the actuator is discharged, the energy not consumed is fed through the energy recovery circuitry for reuse in the next charging cycle.

Two models are available: The E-617.001 version is equipped for top-hat rail mounting which makes it ideal for automation and industry applications. The E-617.00F version is a compact module for chassis mounting.

High Performance with High Capacitive Loads

The E-617 amplifiers provide precision control of piezo actuators and positioning systems in open-loop operation with an analog control voltage amplified by the factor 12. Such analog operation is ideal for applications where fast response and very high resolution with maximum bandwidth are essential, but where commanding and reading the target position absolutely is either not important or carried out by external position sensors.

Power Supply / Contents of Delivery

Only one unipolar stabilized voltage in the range of 23 to 26 V is required to operate the E-617.

All connections of the E-617.001 top-hat rail module are conveniently provided on the front of the device. All inputs and outputs of the E-617.00F OEM module are via a 32-pin rear connector. Mating connectors are included.

Remote Control via Computer Interface

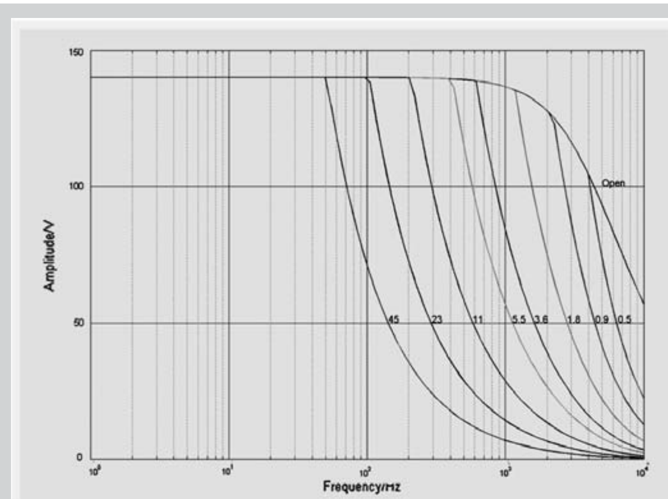
Optionally, digital control via an external D/A converter is possible. For several D/A boards from National Instruments, PI offers a corresponding LabVIEW driver set which is compatible with the PI General Command Set (GCS), the command set used by all PI controllers. A further option includes the patented Hyperbit™ technology providing enhanced system resolution.

Ordering Information

E-617.001
High-Power-Piezo Amplifier with Energy Recovery, 1 Channel, -30 to 135 V, 100 W, Top-Hat Rail

E-617.00F
High-Power-Piezo Amplifier with Energy Recovery, OEM-Module, 1 Channel, -30 to 135 V, 100 W

The same functionality and specifications are available in the E-504 amplifier module. see p. 2-148.



E-617: operating limits with various PZT loads (open-loop), capacitance is measured in µF

E-617.00F high-power piezo amplifier OEM module

Technical Data

Model	E-617.001	E-617.00F
Function	High-Power-Piezo Amplifier with Energy Recovery, 1 Channel, -30 to 135 V, for Top-Hat Rail mounting	High-Power-Piezo Amplifier with Energy Recovery, OEM-Module, 1 Channel, -30 to 135 V
Amplifier		
Input voltage	-3 to +12 V	-3 to +12 V
Output voltage	-30 to +135 V	-30 to +135 V
Peak output power <5 ms	280 VA	280 VA
Average output power >5 ms	Equivalent to 100 W reactive power	Equivalent to 100 W reactive power
Peak current, <5 ms	2000 mA	2000 mA
Average current, >5 ms	1000 mA	1000 mA
Current limitation	Short-circuit-proof	Short-circuit-proof
Voltage gain	12 ±0.1	12 ±0.1
Amplifier bandwidth, small signal	3.5 kHz	3.5 kHz
Ripple, noise, 0 to 100 kHz	<30 mV_{rms} <100 mV_{pp}	<30 mV_{rms} <100 mV_{pp}
Capacitive base load (internal)	2.5 µF	2.5 µF
Suggested capacitive load	>3 µF	>3 µF
Output impedance	0.5 Ω	0.5 Ω
Amplifier resolution	1 mV	1 mV
Amplifier classification	class D (switching amp), 100 kHz	class D (switching amp), 100 kHz
Input impedance	100 kΩ	100 kΩ
Interfaces and operation		
Piezo connector	Phoenix-plug connector MINI-COMBICON 3-pin IMC1.5/3-ST-3.81	LEMO ERA.00.250.CTL (front); DIN 41612 32-pin (rear)
Analog input	Phoenix-plug connector MINI-COMBICON 6-pin IMC1.5/6-ST-3.81	SMB
DC-Offset	External potentiometer (not included), adds 0 to + 10 V to Control In	External potentiometer (not included), adds 0 to + 10 V to Control In
Miscellaneous		
Operating temperature range	+5 to +50 °C (10% derated over 40 °C)	+5 to +50 °C (10% derated over 40 °C)
Dimensions	205 x 105 x 60 mm	7HP/3U
Mass	1 kg	0.35 kg
Operating voltage	23 to 26 VDC, stabilized, on Phoenix plug MINI-COMBICON 3-pin IMC1.5/3-ST-3.81	23 to 26 VDC, stabilized, on 32-pin rear connector
Max. power consumption	<30 W	<30 W

E-625 Piezo Servo-Controller & Driver

Compact Bench-Top Device with High-Speed Interface

E-625.SR (left) and E-625.CR compact piezo servo-controllers

- **Optionally Integrated 20-Bit High-Speed RS-232 Interface**
- **Network Capability with up to 12 Channels**
- **12 W Peak Power**
- **Position Control with Strain Gauge or Capacitive Sensor**
- **Notch Filter for Higher Bandwidth**
- **Table for User-Defined Curves**
- **Additional Analog Interface**

The single-channel E-625 piezo controller is equipped with a high-speed RS-232 interface and precision 20-bit D/A and A/D converters for exceptional positional stability and resolution. It integrates a low-noise integrated piezo amplifier which can output and sink peak currents of 120 mA for low-voltage piezoelectric actuators (-20 to 120 V). Servo-controller versions for position sensing with capacitive or SGS sensors are available.
PI employs proprietary position sensors for fast response and optimum positioning resolution and stability in the nanometer range and below. For high-end applications, capacitance sensors provide direct and non-contact position feedback (direct metrology). Strain gauge sensors (SGS) are available for cost-effective applications. The integrated notch filters (adjustable for each axis) improve the stability and allow high-bandwidth operation closer to the resonant frequency of the mechanics.

Multi-Axis Network for up to 12 Channels

Up to twelve E-625 for capacitive or SGS sensors can be networked and controlled over a single RS -232 interface. The different units are connected in parallel (not daisy-chained) over the link providing higher data rates than possible with serial links. Between the individual E-625s, parallel networking with optional E-625.CN cables is used.

High-Resolution Digital Interface

The RS-232 digital interface includes high-precision 20-bit D/A and A/D converters for optimum position stability and resolution and supports fast communication with the host computer, with up to 300 bidirectional read/write operations per second.

Waveform Memory

The built-in wave generator can store user-defined data points internally. These values can then be output automatically (or under the control of an external signal) and programmed for point-by-point or full-scan triggering. Thus, trajectory profiles can be repeated reliably and commanded easily.

Extensive Software Support

The controllers are delivered with Windows operating software. Comprehensive DLLs and LabVIEW drivers are available for automated control.
The extensive command set is based on the hardware-independent General Command Set (GCS), which is common to all current PI controllers for both nano- and micropositioning systems. GCS reduces the programming effort in the face of complex multi-axis positioning tasks or when upgrading a system with a different PI controller.

Ordering Information

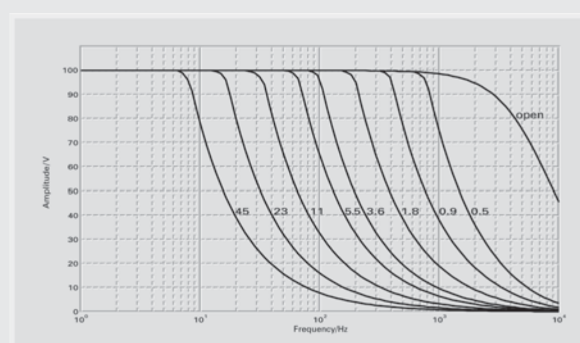
E-625.CR
Piezo Amplifier / Servo-Controller, 1 Channel, -20 to 120 V, Capacitive Sensor, RS-232

E-625.SR
Piezo Amplifier / Servo-Controller, 1 Channel, -20 to 120 V, SGS-Sensor, RS-232

E-625.CN
Network Cable for Networking of Two E-625

E-625.C0
PIFOC® Piezo Amplifier / Servo-Controller, 1 Channel, -20 to 120 V, Capacitive Sensor

E-625.S0
PIFOC® Piezo Amplifier / Servo-Controller, 1 Channel, -20 to 120 V, SGS-Sensor



E-625: operating limits with various PZT loads (open-loop), capacitance is measured in µF

Ideal system configuration: E-625.CR with P-725 PIFOC® microscope objective positioner

Two single-channel piezo controllers: E-625 and the more powerful E-665 (background)

Technical Data

Model	E-625.SR / E-625.CR
Function	Piezo Amplifier / Servo-Controller
Axes	1
Sensor	
Servo characteristics	P-I (analog), notch filter
Sensor type	SGS (.SR) / capacitive (.CR)
Sensor resolution	20-bit
Amplifier	
Control input voltage range	-2 to 12 V
Min. output voltage	-20 to 120 V
Peak output power, < 5 ms	12 W
Average output power	6 W
Peak current, < 5 ms	120 mA
Average current	60 mA
Current limitation	Short-circuit-proof
Noise, 0 to 100 kHz	0.8 mVrms
Voltage gain	10 ±0.1
Input impedance	100 kΩ
Interfaces and operation	
Interface / communication	RS-232 (9-pin Sub-D connector), 20 bit ADC/DAC, 9.6–115.2 kBaud E-625.S0 and E-625.C0 without interface
Piezo connector	LEMO ERA.00.250.CTL (.SR) / Sub-D Special (.CR)
Sensor connection	LEMO EPL.0S.304.HLN (.SR) / Sub-D Special (.CR)
Control input sockets	SMB
Sensor monitor socket	SMB
Controller network	up to 12 channels. parallel
Supported functionality	Wave table, 64 data points, 100 Hz, external trigger
Miscellaneous	
Operating temperature range	+5 to +50 °C
Overheat protection	Deactivation at 75°C
Dimensions	205 x 105 x 60 mm
Mass	1.05 kg
Operating voltage	12 to 30 V DC, stabilized
Current consumption	2 A

Piezo • Nano • Positioning

E-665 Piezo Amplifier / Servo Controller

Display, Analog & Digital Interface

Control of the E-665.SR piezo servo-controller is realized either via the digital high-speed interface or directly via the analog input

- **Integrated 20-Bit High-Speed RS-232 Interface**
- **Network Capability with up to 12 Channels**
- **36 W Peak Power**
- **Notch Filter for Higher Bandwidth**
- **Position Control with Strain Gauge or Capacitive Sensor**
- **Table for User-Defined Curves**
- **Additional Analog Interface**

The E-665 is a bench-top piezo linear amplifier and position servo-controller with integrated high-speed 20-bit computer interface and a high-bandwidth analog interface. It integrates a low-noise piezo amplifier which can output and sink peak currents of 360 mA for low-voltage piezoelectric actuators (-20 to 120 V). Servo-controller versions for position sensing with capacitive or SGS sensors are available.

Closed-Loop Piezo Positioning

PI employs proprietary position sensors for fast response and optimum positioning resolution and stability in the nanometer range and below. For high-end applications, capacitance sensors provide direct and non-contact position feedback (direct metrology). Strain gauge sensors (SGS) are available for cost-effective applications.

The piezo controllers comprise additional circuitry for position sensing and servo-control. In closed-loop position control mode, displacement of the piezo is highly linear and proportional to the analog signal. The servo modifies the amplifier output voltage based on the position sensor signal. Thus, positioning accuracy and repeatability down to the subnanometer range is possible, depending on the piezo mechanics and on the sensor type.

High-Resolution Digital Interface

The RS-232 digital interface includes high-precision 20-bit D/A and A/D converters for optimum position stability and resolution and supports fast communication with the host computer, with up to 300 bidirectional read/write operations per second.

Waveform Memory

The built-in wave generator can store user-defined data points internally. These values can then be output automatically (or under the control of an external signal) and programmed for point-by-point or full-scan triggering. Thus, trajectory profiles can be repeated reliably and commanded easily.

Multi-Axis Network for up to 12 Channels

Up to twelve E-665s for capacitive or SGS sensors can be networked and controlled over a single RS-232 interface. The different modules are connected in parallel (not daisy-chained) over the link providing higher data rates than possible with serial links.

Extensive Software Support

The controllers are delivered with Windows operating software. Comprehensive DLLs and LabVIEW drivers are available for automated control.

The extensive command set is based on the hardware-independent General Command Set (GCS), which is common to all current PI controllers for both nano- and micropositioning systems. GCS reduces the programming effort in the face of complex multi-axis positioning tasks or when upgrading a system with a different PI controller.

The GCS commands are available at the controller terminal, in macros and in the form of a universal driver set for LabVIEW (VIs), Windows dynamic link libraries (DLL) and COM objects

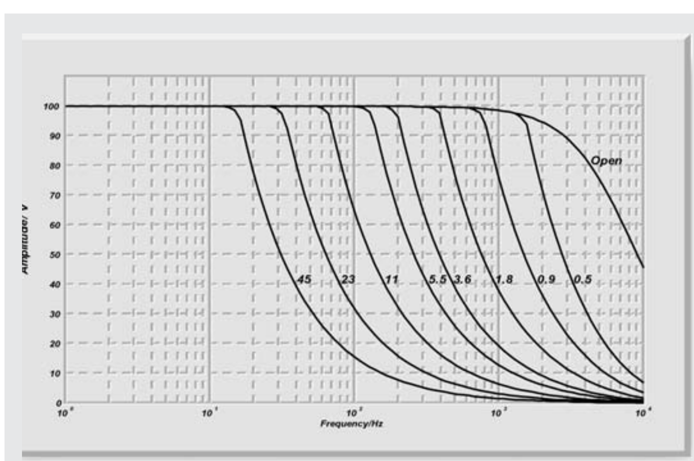
Ordering Information

E-665.CR
Piezo Amplifier / Servo-Controller, 1 Channel, RS-232, -20 to 120 V, Capacitive Sensor

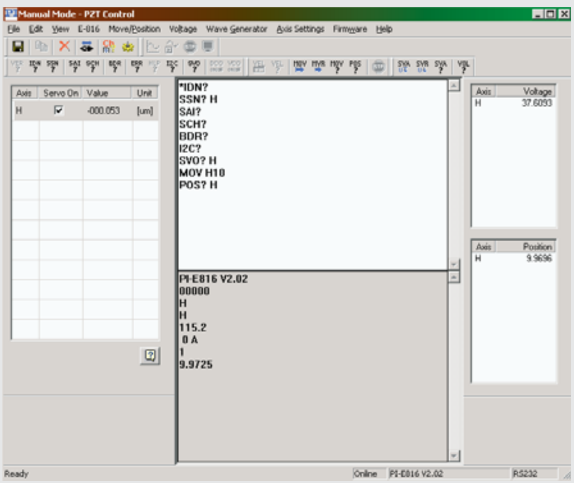
E-665.SR
Piezo Amplifier / Servo-Controller, 1 Channel, RS-232, -20 to 120 V, SGS-Sensor

E-665.C0
PIFOC® Piezo Amplifier / Servo-Controller, 1 Channel, Capacitive Sensor

E-665.S0
PIFOC® Piezo Amplifier / Servo-Controller, 1 Channel, SGS Sensor



E-665: operating limits with various PZT loads (open-loop), capacitance is measured in µF



Screenshot of the included PZT-Control software for E-665. The commands in the editor are compatible to the PI General Command Set

Technical Data

Model	E-665.SR, E-665.CR
Function	Piezo amplifier & position servo-controller with digital interface
Axes	1
Sensor	
Servo characteristics	P-I (analog), notch filter
Sensor type	SGS (.SR) / capacitive (CR)
Amplifier	
Control input voltage range	-2 to +12 V
Min. output voltage	-20 to 120 V
Peak output power, < 20 ms	36 W
Average output power	12 W
Peak current, < 20 ms	360 mA
Average current	120 mA
Current limitation	Short-circuit-proof
Noise, 0 to 100 kHz	0.5 (.SR) / 4.0 (.CR) mV_{rms}
Voltage gain	10 ±0.1
Input impedance	100 kΩ
Interfaces and operation	
Interface / communication	RS-232 (9-pin Sub-D connector), 20 bit ADC/DAC, 9.6 - 115.2 kBaud
Piezo connector	LEMO ERA.00.250.CTL (.SR) / Sub-D special (.CR)
Sensor connection	LEMO EPL.0S.304.HLN (.SR) / Sub-D special (.CR)
Analog input	BNC
Sensor monitor socket	BNC
Controller network	up to 12 channels, parallel
Supported functionality	Wave table, 64 data points, 100 Hz, external trigger
Display	2 x 4½-digits, LED
DC Offset	10-turn pot., adds 0 to 10 V to Control In
Miscellaneous	
Operating temperature range	5 to 50 °C
Overheat protection	Deactivation at 85 °C
Dimensions	236 x 88 x 273 mm + handles
Mass	2.5 kg
Operating voltage	90-120 / 220-240 VAC, 50-60 Hz (linear power supply)
Max. power consumption	50 W

E-661 Piezo Controller with Parallel Interface

For Maximum Command-Throughput Capacity

E-661.CP high-speed bench-top controller with parallel interface

- **10 µs High-Speed Parallel Command Port**
- **Additional Analog Interface**
- **For Piezo Stages with Capacitive Sensors**
- **Notch Filter for Higher Bandwidth**
- **Integrated Piezo Power Amplifier**
- **OEM Modules and Multi-Channel System Available**

The compact, high-speed E-661 piezo controller is designed for nanopositioning systems with integrated capacitive position feedback sensors. It possesses a low-noise integrated piezo amplifier providing -20 to 120 V with 80 mA sink and source capability. The E-661 comes with a metal case for EMI protection and an external power supply.

High-Speed Interface

The controller features a high-speed parallel command port with optical coupled inputs and extra low-noise, linear, 16-bit D/A converters. Real-time position feedback is realized via a special trigger option. Additionally a broadband analog interface is installed (0 to 10 V).

Nanometer Resolution in Milli-Seconds

This high-performance controller is designed for nanopositioning tasks with highest precision and maximum turnover. Positioning with nanometer precisions and settling times of a few milliseconds are achieved in combination with the P-726 (see p. 2-32) objective positioners or P-753 (see p. 2-16) LISA™ actuators. More and more high-tech branches require “nanometer accuracy within milliseconds”. This is the case in microscopy/pharmaceutical research or quality testing for read/write heads, where every millisecond saved raises the throughput and helps reduce costs.

Single and Multi-Channel Systems

The same performance is available in modular form as the E-612.C0 (see p. 2-162). Up to four E-612.C0 piezo amplifier modules can be installed in one E-501.10 chassis for a multi-channel system. An internal address bus allows control of all modules over a single parallel command port.

Ordering Information

E-661.CP
Piezo Controller with High-Speed Parallel Interface, -20 to 120 V, Capacitive Sensor

Model	E-661.CP
Function	High-Speed Piezo Controller
Channels	1
Capacitive sensor circuit	
Clock frequency	1.6 MHz
Bandwidth	1.5 kHz
Amplifier	
Output voltage	-20 to +120 V
Average output power	8 W
Average current	80 mA
Current limitation	Short-circuit proof (5 minutes to shutdown)
Bandwidth (no load)	>500 Hz
Digital circuit	
Data	16-bit
Input level	TTL
Timing	THmin 10 µs; TLmin 10 µs
Input current	10 mA
On-target indication	On: target position ±0.025 % to 0.2 %, jumper-selectable
Analog input / output	
Control input voltage	-2 to 12 V
Input impedance	27 kΩ, 1 nF
Sensor monitor output	
Voltage range	-12 to +12 V (jumper-selectable)
Output impedance	10 Ω (10 nF)
Bandwidth	1.5 kHz
Connectors	
Digital interface	25-pin sub-D
Piezo	LEMO ERA.00.250
Sensor	LEMO EPL.00.250
Sensor monitor output	SMB
Analog input	SMB
Power consumption	15 V, 2 A (external power supply included)
Dimensions	125 x 50 x 262 mm

E-831 Piezo Driver

OEM Module, Power Supply for up to 3 Axes

E-831.03 amplifier module.

- **Cost Effective Piezo Driver**
- **Small Size**
- **Low Noise, High Stability**
- **Easy-to-Use**
- **Full Overcurrent, Short-Circuit and Temperature Protection**
- **Power-up/down Without Voltage Spikes**

The E-831.03 OEM piezo driver module is a very compact, cost-effective, single-channel, 4-quadrant power amplifier for low-voltage piezoelectric actuators.

It provides a peak output power of 12 W and average power of 2 W (expandable to 5 W with external heat sink). The E-831.03 is a high-precision amplifier with a fixed gain of 10.0 and outputs voltages in the range of -20 to 120 V for control input signals ranging from of -2 to 12 V. The output is fully compensated for the capacitive loads of up to 10 µF typical of PI's low-voltage PZTs such as PICMA® piezo actuators. For monitoring purposes, the output voltage is internally divided by 100 and provided at a special monitor pin.

Because piezo actuators require virtually no power in steadystate operation and the power consumption depends on the operating frequency, high-powered amplifiers are not required for many applications. With a peak output current of 100 mA (sink/source) the E-831 is well-suited for switching applications and fast transitions where the capacitive load (the piezo actuator) needs to be charged as quickly as possible. The small-signal bandwidth is about 3 kHz.

E-841.05 power supply module

Power Supplies for E-831.03

The E-841.05 (input voltage range 10 to 30V) and E-842.05 (input voltage range 30 V to 72 V) switched power supply modules provide all the operating voltages (±15 V, -26 V and +127 V DC) required by the E-831.03 amplifier module. Both models supply enough power for up to three E-831.03 amplifiers with a total output power of 5 W.

A sync. input on the power supply allows synchronization of the internal switching frequency with an external clock (185 to 220 kHz) for elimination of interference in AC-driven position sensors or DACs.

Easy Implementation

E-831 and E-841/E-842 modules are enclosed in metal cases with solderable pins for PCB mounting. They are designed to work together without additional components.

Triple Safety

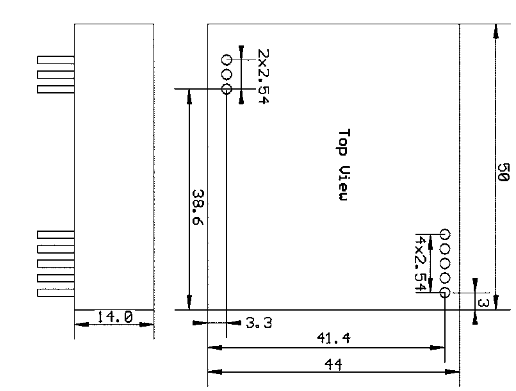
The E-831 amplifier is short-circuit proof with both a low-speed current limiter of 50 mA and a high-speed (8 msec) current limiter of 100 mA. When the case temperature rises above 70 °C (can be reached after a few minutes with maximum current) an internal temperature sensor shuts down the output stage until the temperature drops below 60 °C. This operation mode is indicated by the active-high TEMP-OFL TTL status line.

Ordering Information

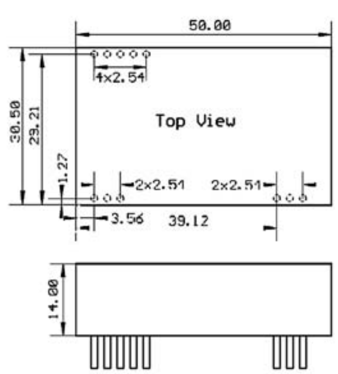
E-831.03
Single-Channel Piezo Driver Module for LVPZTs

E-841.05
Power Supply Module for E-831, Input 10 to 30 V

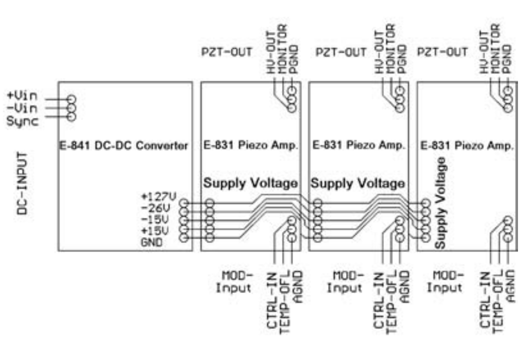
E-842.05
Power Supply Module for E-831, Input 30 to 72 V



Tiny: E-841.05/E-842.05 dimensions in mm.



Tiny: E-831.03 dimensions in mm, decimal places separated by commas in drawings.



Scheme for a three-channel amplifier consisting of an E-841 power supply and three E-831 amplifiers.

Technical Data E-831.03

Models	E-831.03
Function:	Single-channel piezo amplifier module
Output voltage range:	from [U+ - 6 V] (121 V for U+ = 127 V) to [U- + 8 V] (-20 V for U- = 28 V)
Gain	10 ±0.1
Max. output current:	100 mA for 8 ms (sink/source)
Max. average current:	50 mA for 2 min without heatsink
Output protection:	short-circuit protected, the module is overload protected to 70 °C case temperature
Max. output power:	2 W without ext. heatsink 5 W with ext. heatsink or forced airflow
Control input range:	-2 to +12 V
Input impedance:	100 kΩ
Dynamic current requirements:	depend on load, amplitude and slew rate
Cut off frequency:	3.5 kHz, no load
Operating temperature range:	+5° to +50° Celsius
Operating voltages: (all currents without dynamic load)	+15 V / 20 mA (14 to16 V) -15 V / 7 mA (-14 th -16 V) +127 V / 1.8 mA +125 to 135 V) -26 V / 1.8 mA (-24 to -30 V)
Case	Metal shielded case, size: 50 x 30 x 14 mm
Soldering pins	1 mm diameter, 4 mm length

Technical Data E-84x.05

Models	E-841.05, E-842.05
Function:	Power Supply Module for E-831
Output voltages:	+127 V, 30 mA; -26 V, 30 mA; +15 V, 60 mA; -15 V, 20 mA
Max. output Power:	8 W
Max. average Power	8 W with forced air flow (5 W without)
Output protection:	short-circuit protected (1 min.)
Input voltage:	10 - 30 V (E-841.05); 30 - 72 V (E-842.05)
Quiescent current:	100 mA @15 V; 60 mA @30 V; 25 mA @72 V
Max. input current:	1000 mA (E-841.05 @ 10V); 200 mA (E-842.05 @ 72V)
Power-on, peak current:	1500 mA
Switching frequency	100 kHz typical
External clock frequency:	200 kHz (185 - 220 kHz possible)
Synchronization signal:	preferred TTL-level with duty cycle 50 %; operating from 1.8 V_{pp} and offsets within ±7 V
Output ripple:	<100 mV_{pp}
Operating temperature range:	5° to +50° Celsius (with power derating above 40 °C)
Case	Metal shielded case, size: 50 x 44 x 14 mm
Soldering pins	1 mm diameter, 4 mm length

E-660 Piezo Driver

OEM Module / Bench-Top

E-660.OE OEM Version

E-660.00 Bench-top piezo driver

Ordering Information

E-660.00
Piezo Amplifier, 5 to 110 V, Bench-Top

E-660.OE
Amplifier Module, 5 to 110 V, OEM Version

- **Compact Single-Channel Piezo Driver**
- **Output Voltage Range 5 to 110 V**
- **12 V Battery or External PS Operation**

The E-660.00 piezo driver is a low-cost amplifier for low-voltage piezo actuators and positioning stages. It can output and sink a peak current of 20 mA and an average current of 10 mA. The E-660 is designed for static and low-level dynamics applications. The low operating current of only 150 mA @ 12 V makes the unit suitable for battery operation.

Voltage-Controlled Piezo Operation

This precision piezo driver is designed for voltage-controlled piezo operation in both dynamic and static mode. Its output voltage is determined by the analog control signal at the BNC Control Input socket, optionally combined with the DC-offset potentiometer. Voltage-controlled operation (in contrast to position-controlled operation) is used in applications where the fastest possible response and very high resolution with maximum bandwidth are essential, and/or when commanding and reading the target position in absolute values is either not important or accomplished with external position feedback.

The precision 10-turn potentiometer can also be used alone to set the output voltage manually.

Compact OEM Version

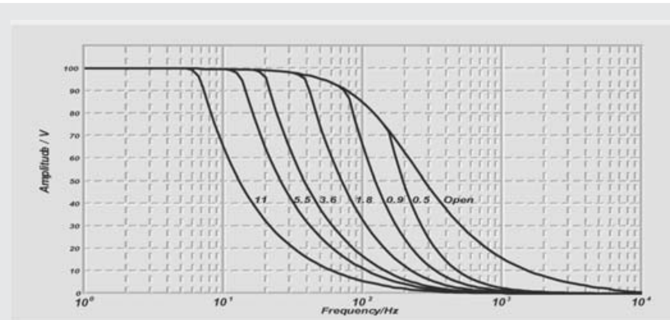
The E-462.OE version is fully enclosed in a metal case and designed for mounting on circuit boards. All inputs and outputs are via 8 header pins located on the bottom of the module. This OEM module does not provide manual controls.

Remote Control via Computer Interface

Optionally, digital control via an external D/A converter is possible. For several D/A boards from National Instruments, PI offers a corresponding LabVIEW driver set which is compatible with the PI General Command Set (GCS), the command set used by all PI controllers. A further option includes the patented HyperBit™ technology providing enhanced system resolution.

Technical Data

Model	E-660.00	E-660.OE	Unit
Function	Power amplifier	Power amplifier	
Channels	1	1	
Amplifier			
Input voltage	0 to +11	0 to +11	V
Output voltage	5 to 110	5 to 110	V
Peak output power	2	2	W
Average output power	1	1	W
Peak current, < 5 ms	20	20	mA
Average current, >5 ms	10	10	mA
Current limitation	Short-circuit-proof	Short-circuit-proof	
Voltage gain	10 ±0.1	10 ±0.1	
Ripple, noise, 0 to 10 kHz	5	5	mVrms
Input impedance	100	10	kΩ
Interfaces and operation			
Piezo connector	LEMO ERA.00.250.CTL	Header pins	
Control Input sockets	BNC	Header pins	
DC-Offset	1-turn pot., adds 10 to 0 V to Control In	–	
Miscellaneous			
Operating temperature range	5 to +50	5 to +50	°C
Dimensions	160 x 90 x 60	67 x 41 x 20	mm
Mass	0.5	0.25	kg
Operating voltage	10 to 15 VDC, stabilized	10 to 15 VDC, stabilized	V
Max. power consumption	3	3	W



E-660: operating limits with various PZT loads (open-loop), capacitance is measured in µF

E-462 PICA™ Piezo Driver

Compact, Bench-Top or OEM Module

E-462.00 Bench-top piezo amplifier

- Single-Channel Piezo Driver
- Output Voltage Range 10 to 1000 V
- 12 V Battery or External PS Operation
- For Static or Quasi-Static Operation
- DC-Offset Potentiometer for Input-Signal Bias & Manual Control

The E-462.00 piezo driver is a low-cost amplifier / driver for PICA™ high-voltage PZTs. It can output a peak current of 0.5 mA and is specially designed for static and quasi-static applications. Because the unit requires an operating current of only 80 mA @ 12 V, battery operation is possible.

Analog Control

E-462 amplifiers are designed to provide precise control of open-loop piezo positioning systems. The amplifier output voltage is determined by the analog signal at the Control Input combined with the DC-offset potentiometer setting.

PCB-Mount Version for OEMs

The E-462.OE version is fully enclosed in a metal case and designed for mounting on circuit boards. All input connections are via 6 header pins located on the bottom. The HV output is via a coaxial cable with LEMO connector. This OEM module does not provide manual controls. If dynamic (>1 Hz) PZT operation is required, please consider the E-464 (see p. 2-139) (3-channel bench-top amplifier), E-470 (see p. 2-158) or E-508 (see p. 2-150) amplifiers (modular systems with sensor / servo option).

Computer Control

Optionally digital control via a D/A converter is possible. For several D/A boards from National Instruments PI offers a corresponding LabVIEW™ driver set which is compatible with the PI General Command Set (GCS), the command set used by all PI controllers. A further option includes the patented Hyperbit™ technology providing enhanced system resolution.

Ordering Information

E-462.00
HVPZT Piezo Amplifier, 1000 V

E-462.OE
HVPZT Piezo Amplifier Module, 1000 V, OEM Version

E-500.ACD
LabVIEW™ Driver Set for Analog Controllers (Supports Certain D/A Boards)

E-500.HCD
HyperBit™ Functionality for Enhanced System Resolution

Extension cables, adapters & connectors: see in "Accessories" in the "Piezo Drivers / Servo Controllers" section (page 2-168 *ff*).

Ask about custom designs!

Technical Data

Model	E-462.00	E-462.OE
Function	Power amplifier for PICA™ high-voltage PZTs	Power amplifier for PICA™ high-voltage PZTs
Amplifier		
Channels	1	1
Output voltage	10 to 1000 V	10 to 1000 V
Average output power	0.3 W	0.3 W
Peak output power < 5ms	0.5 W	0.5 W
Max. average output current	0.3 mA	0.3 mA
Peak output current < 5 ms	0.5 mA	0.5 mA
Current limitation	Short-circuit-proof	Short-circuit-proof
Ripple, noise 0 to 100 kHz	50 mV_{RMS} 50 (100 nF) mV_{P-P}	
Voltage gain	100 ±1	200 ±1
Control input voltage	0 to +10 V	0 to +5 V
Input impedance	10 kΩ	10 kΩ
Frequency response	Static and quasi-static applications only	Static and quasi-static applications only
Interface and operation		
PZT voltage output socket	LEMO EGG.0B.701.CJL1173	LEMO PHG.0B.701.CJL1173 D42
Control input socket	BNC	Header pins
DC-Offset	1-turn pot., adds 0 to +10 V to Control input	–
Miscellaneous		
Dimensions	160 x 90 x 60 mm	67 x 41 x 20 mm
Mass	0.5 kg	0.25 kg
Operating voltage	10 to 15, stabilized VDC	10 to 15, stabilized VDC
Max. operating current	80 mA	80 mA
Operating temperature range	+5 to +50 °C (over 40 °C, max. av. power derated 10 %)	+5 to +50 °C (over 40 °C, max. av. power derated 10 %)
Power supply	Wall-plug unit	–

E-835 DuraAct™ Piezo Driver Module

Bipolar Operation for Piezoelectric Patch Transducers

The E-835.00 piezo amplifier module for P-876 DuraAct™ patch transducers provides 30 W of power in a very compact package

- **OEM Module for DuraAct™ Piezoelectric Patch Transducers**
- **Peak Power to 30 W**
- **Output Voltage Range -100 to +250 V**
- **High Bandwidth >4 kHz**
- **Compact: 87 x 50 x 21 mm**
- **Can be Used to Drive PicaShear™ Piezo Shear Actuators**

Ordering Information

E-835.00
OEM Piezo Amplifier for DuraAct™ Patch Transducer

Ask about custom designs!

The powerful, cost-effective E-835 OEM piezo amplifier module is designed for driving the P-876 DuraAct™ piezo patch transducers. It provides a peak output power of 30 W with a peak current of 120 mA in the semi-bipolar voltage range (-100 V/+250 V). The continuous output power is rated at 3 W.

This compact piezo amplifier module supplies adequate power for a broad range of DuraAct™ patch transducer applications, e. g. active vibration damping, structure monitoring and stabilization.

Voltage-Controlled Piezo Operation

The E-835 piezo driver module provides precision control for DuraAct™ Patch Transducers both in static and dynamic operation. Its output voltage is determined by an external analog signal in the -4 to +10 V-range applied to the respective input.

Operation / Contents of Delivery

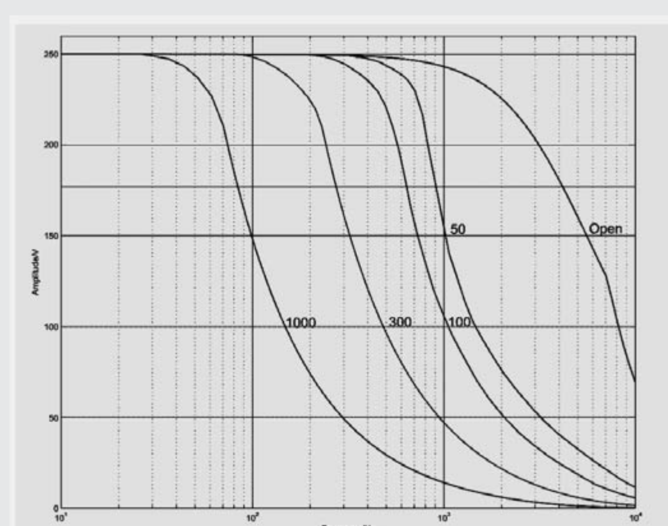
The required electrical power can be supplied by a commercial 12 V-power supply (not included). An integrated DC/DC converter provides the piezo voltage and other voltages required internally. All inputs and outputs are on solder pads.

The E-835 piezo amplifier module is also suitable for operating PICA™ Shear piezo actuators at about 60 % of the nominal maximum displacement.

Read the general considerations on piezo amplifiers.

Adaptive Structures with Piezo Patch Transducers

P-876 DuraAct™ patch trans ducers combine the actuatorand sensor functionality of piezoceramic materials. Used as a bender or contraction actuators, they provide high deflection with high force and precision. Other possible DuraAct™ operation modes are as high-dynamics sensor (e. g. for structural health monitoring) or as energy harvesters.



E-835.00: frequency response with various PZT loads (250 V, open-loop), capacitance is measured in nF

Technical Data

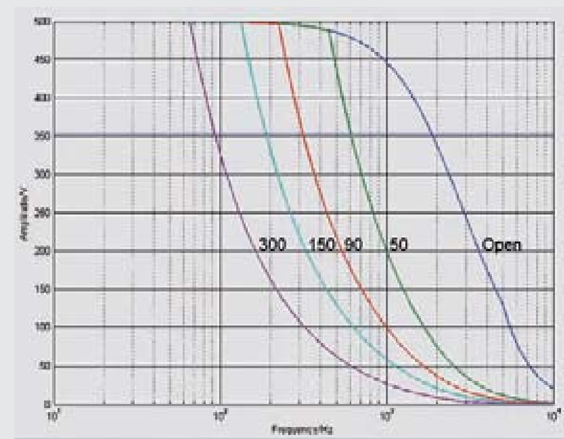
Model	E-835.00
Function	Power amplifier for DuraAct™ piezo patch transducers
Channels	1
Amplifier	
Input voltage	-4 to 10 V
Output voltage	-100 to 250 V
Peak output power	30 W (<15 ms)
Average output power	3 W
Peak current	120 mA (<15 ms)
Average current	40 mA
Current limitation	Short-circuit-proof
Voltage gain	25
Amplifier bandwidth, small signal	4.2 kHz (60 nF)
Amplifier bandwidth, large signal	4.2 kHz (unloaded); 500 Hz (60 nF)
Ripple, noise, 20 MHz	2 mV_{pp}
Output impedance	33 Ω
Amplifier resolution	<10 mV
Input impedance	100 kΩ
Interfaces and operation	
Piezo voltage	Soldering pads
Control input	Soldering pads
Piezo voltage monitor	Soldering pad, 1:100
Miscellaneous	
Operating temperature range	+5 °C to +50 °C (10 % derated over 40 °C)
Overheat protection	Deactivation at 100 °C
Dimensions	87 x 50 x 21 mm
Mass	67 g
Operating voltage	12 V / 1.7 A; 5.5 mm – barrel connector
Max. power consumption	20 W

PI Piezo • Nano • Positioning

E-413 DuraAct™ & PICAShear™ Piezo Driver

Bipolar Operation for Patch Transducers and Shear Actuators

The E-413.D2 OEM amplifier module for piezoceramic DuraAct™ patch transducers (left). The piezo amplifier for piezo shear actuators is available as a bench-top version (E-413.00, front, right) or as an OEM module (E-413.OE, rear, right)



E-413: operating limits with various PZT loads (open-loop), capacitance is measured in nF

- **Peak Power to 50 W**
- **OEM Module / Bench-Top for PICAShear™ Actuators**
- **OEM Module for DuraAct™ Piezoelectric Patch Transducers**

Technical Data

Model	E-413.00	E-413.OE	E-413.D2
Function	Power amplifier for PICAShear™ piezo actuators, bench-top	Power amplifier for PICAShear™ piezo actuators, OEM module	Power amplifier for DuraAct™ piezoelectric patch transducers, OEM module
Amplifier			
Input voltage range	-5 to +5 V	-5 to +5 V	-2 to 8 V
Output voltage range	-250 to 250 V	-250 to 250 V	-100 to 400 V
Amplifier channels	1	1	1
Peak output power	50 W (<3 ms)	50 W (<3 ms)	50 W (<5 ms)
Average output power	<12 W (>3 ms)	<12 W (>3 ms)	<6 W (>5 ms)
Peak current	100 mA (<3 ms)	100 mA (<3 ms)	100 mA (<5 ms)
Average current	24 mA (>3 ms)	24 mA (>3 ms)	12 mA (>5 ms)
Current limitation	Short-circuit proof	Short-circuit proof	Short-circuit proof
Voltage gain	50 ±0.1	50 ±0.1	50 ±0.1
Ripple, noise, <10 kHz	100 mV_{P-P} @100 nF	100 mV_{P-P} @100 nF	100 mV_{P-P} @100 nF
Amplifier resolution	<10 mV	<10 mV	<10 mV
Input impedance	100 kΩ	100 kΩ	100 kΩ
Interface and operation			
Piezo connector	Conec sub-D 5W1 with HV (rear)	DIN 41612, 32-pin. (rear)	DIN 41612, 32-pin. (rear)
Control input voltage	SMB connector (rear)	DIN 41612, 32-pin. (rear)	DIN 41612, 32-pin. (rear)
Miscellaneous			
Operating temperature range	+5 to +50 °C (10% derated over 40 °C)	+5 to +50 °C (10% derated over 40 °C)	+5 to +50 °C (10% derated over 40 °C)
Dimensions	220 x 105 x 54 mm	14HP / 3U	7HP / 3U
Mass	1.14 kg	0.8 kg	0.4 kg
Operating voltage	24 V / 2 A	24 V / 2 A	24 V / 1 A
Power consumption	48 W	48 W	24 W

Ordering Information

E-413.D2
Piezo Amplifier for DuraAct™ Patch Transducers, -100 to +400 V

E-413.00
Piezo Amplifier for PICAShear™ Actuators, -250 to +250 V, Bench Top

E-413.OE
Piezo Amplifier for PICAShear™ Actuators, -250 to +250 V, OEM Module

Accessories:
E-500.ACD
LabVIEW Driver Set for Analog Controllers (Supports Certain D/A Boards)

E-500.HCD
HyperBit™ Functionality for Enhanced System Resolution

E-650 Piezo Driver for Multilayer Bender Actuators

OEM Module / Bench-Top

E-650.OE amplifier for multilayer-piezo bender actuators, OEM version

E-650.00 amplifier for multilayer-piezo bender actuators

- Specifically Designed to Drive Multilayer Bimorph Actuators Without Position Sensor
- Bench-Top and OEM Versions
- Up to 18 W Peak Power
- Voltage Display

E-650.00 is a bench-top piezo driver, especially designed for low-voltage, multilayer piezo bender actuators (bimorphs) such as the PL112 to PL140 (see p. 1-94). It is equipped with a special circuit that can provide one fixed voltage and a variable voltage in the range of 0 to 60 V for differential piezo operation. The driver can output and sink a peak current of 300 mA. A 3½-digit display shows the piezo voltage.

Voltage-Controlled Piezo Operation

This precision piezo driver is designed for voltage-controlled piezo operation in both dynamic and static mode. Its output voltage is determined by the analog control signal at the BNC Control Input socket, optionally combined with the DC-offset potentiometer. Voltage-controlled operation (in contrast to position-controlled operation) is used in applications where the fastest possible response and very high resolution with maximum bandwidth are essential, and/or when commanding and reading the target position in absolute values is either not important or accomplished with external position feedback.
The precision 10-turn potentiometer can also be used alone to set the output voltage manually.

Compact OEM Version

The E-650.OE is the OEM version of the E-650.00. It provides peak output power of 8 W. The electronics are fully enclosed in a metal case. All inputs and outputs are via 8 header pins located on the bottom of the module. The E-650.OE is not intended for manual operation.

Ordering Information

E-650.00
Piezo Driver for Bender Actuators, 0 to 60 V, Bench-Top

E-650.OE
Piezo Driver Module for Bender Actuators, 0 to 60 V, OEM Version

Remote Control via Computer Interface

Optionally, digital control via an external D/A converter is possible. For several D/A boards from National Instruments, PI offers a corresponding LabVIEW driver set which is compatible with the PI General Command Set (GCS), the command set used by all PI controllers. A further option includes the patented HyperBit™ technology providing enhanced system resolution.

Technical Data

Model	E-650.00	E-650.OE
Function	Power amplifier	Power amplifier
Amplifier		
Input voltage	0 to +10 V	0 to +10 V
Output voltage	0 to 60 V, plus fixed reference voltage of 60 V	0 to 60 V, plus fixed reference voltage of 60 V
Peak output power	18 W	8 W
Average output power	6 W	4 W
Peak current, < 5ms	300 mA	140 mA
Average current, >5 ms	100 mA	60 mA
Current limitation	Short-circuit-proof	Short-circuit-proof
Voltage gain	6 ±0.1	6 ±0.1
Amplifier bandwidth, large signal	600 Hz @ 1000 nF load, 6 kHz @ no load	200 Hz @ 1000 nF load, 3 kHz no load
Input impedance	100 kΩ	100 kΩ
Interfaces and operation		
Piezo connector	9-pin sub-D connector	Header pins
Control input sockets	BNC	Header pins
Display	3½-digit LCD	–
Miscellaneous		
Operating temperature range	5 to 50 °C	5 to 50 °C
Dimensions	160 x 125 x 50 mm	70 x 42 x 30 mm
Mass	0.7 kg	0.15 kg
Operating voltage	90–240 VAC, 50–60 Hz, (external switching P/S, included)	±15 V, 315 mA max., stabilized

E-651 – E-614 Piezo Amplifier / Servo Controller

Piezo Controller for Closed-Loop Multilayer Bender Actuators

E-651 dual- and single-channel controllers for closed-loop piezo benders

- Controller for Closed-Loop Multilayer Bimorph Actuators
- Bench-Top & OEM-Board Versions
- 1- and 2-Channel Versions

E-651 is a bench-top piezo controller, especially designed for low-voltage, multilayer piezo bender actuators equipped with strain gauge sensors such as the P-871 (see p. 1-84). One and two channel versions are available.

The E-614.2BS OEM board provides the same functionality as the E-651.2S two-channel controller in a smaller package.

Closed-Loop and Open-Loop Piezo Positioning

In closed-loop position control mode, displacement of the piezo bender is proportional to the analog signal applied to the BNC control input socket. The controller is calibrated in such a way that ±5 V input corresponds to maximum nominal deflection.

The E-651 can also be operated as piezo driver (open-loop, or voltage-controlled mode). The output voltage is then determined directly by the analog input signal in the -5 to +5 V range. Multiplying by the gain factor of 6, an output voltage range of 0 to 60 V results.

Ordering Information

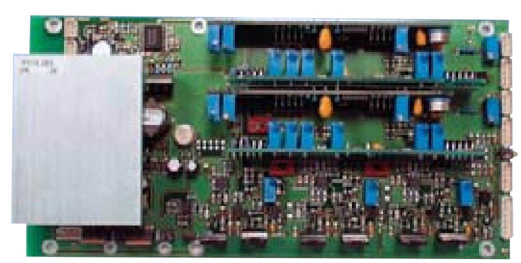
E-651.1S
Piezo Amplifier / Servo Controller for Bender Actuators, 1 Channel, 0 to 60 V, DMS-Sensor, Bench-Top

E-651.2S
Piezo Amplifier / Servo Controller for Bender Actuators, 2 Channels, 0 to 60 V, DMS-Sensor, Bench-Top

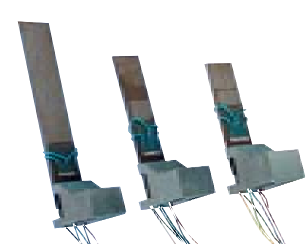
E-614.2BS
Piezo Amplifier / Servo Controller for Bender Actuators, 2 Channels, 0 to 60 V, DMS-Sensor, OEM Board

Technical Data

Models	E-651.1S	E-651.2S
Function	Piezo amplifier & servo controller for multilayer bender actuators, bench-top	Piezo amplifier & servo controller for multilayer bender actuators, bench-top
Channels	1	2
Sensor		
Servo characteristics	P-I (analog)	P-I (analog)
Sensor type	SGS	SGS
Sensor bandwidth	Low-pass filter cut-off frequency: 100 Hz / 5 kHz selectable	Low-pass filter cut-off frequency: 100 Hz / 5 kHz selectable
Amplifier		
Input voltage	-5 to +5 V	-5 to +5 V
Output voltage	0 to 60 V, plus fixed reference voltage of 60 V	0 to 60 V, plus fixed reference voltage of 60 V
Peak output power per channel, < 5 ms	1 W	1 W
Average output power per channel, >5 ms	0.5 W	0.5 W
Peak current per channel	6 mA	6 mA
Average current per channel	18 mA	18 mA
Current limitation	Short-circuit-proof	Short-circuit-proof
Voltage gain	**6**	**6**
Input impedance	100 kΩ	100 kΩ
Interfaces and operation		
Piezo / sensor connector	LEMO EPG.0B.307.HLN	LEMO EPG.0B.307.HLN
Analog input	BNC	BNC
Sensor monitor output	0 to +10 V for nominal displacement	0 to +10 V for nominal displacement
Sensor monitor socket	BNC	BNC
Miscellaneous		
Operating temperature range	5 to 50 °C	5 to 50 °C
Overtemp protection	Deactivation at 75 °C	Deactivation at 75 °C
Dimensions	125 x 90 x 265 mm	125 x 90 x 265 mm
Mass	1.36 kg	1.45 kg
Operating voltage	14 to 16 V DC (C-890.PS wide-range power supply included)	14 to 16 V DC (power supply C-890.PS included)
Power consumption	15 W	15 W



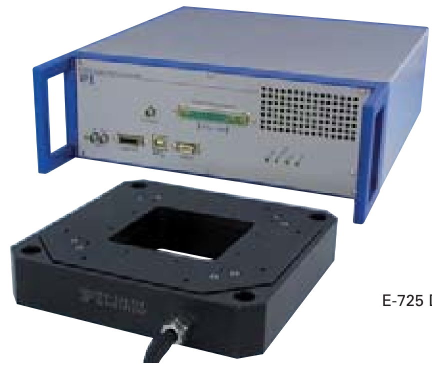
E-614.2BS two-channel OEM controller board



PICMA® P-871 closed-loop piezo bender actuators, providing displacement up to 1.6 mm with high linearity

E-725 Digital Piezo Controller

For 3-Axis High-Speed Precision Positioning Systems



E-725 Digital 3-channel controller with P-528 Z/tip/tilt nanopositioning system

Ordering Information

E-725.3CD
Digital Multi-Channel Piezo Controller, 3-Channel, Sub-D Connector for Capacitive Sensors

E-725.3CM
Digital Multi-Channel Piezo Controller, for PicoCube™ and Capacitive Sensors

Ask about custom designs

- **For Nanopositioning Systems with Capacitive Sensors**
- **3-Channel Version**
- **Powerful Digital Controller: DSP 32-bit Floating Point, 225 MHz; 20 kHz Sampling Rate; 24-bit DAC**
- **Communication via Ethernet, USB, RS-232**
- **4th Order Polynomial Linearization for Mechanics & Electronics**
- **Dynamic Digital Linearization (DDL) Option for Improved Path Accuracy**
- **Auto-Loading of Calibration Data from Stage ID-Chip for Interchangeability of Controller and Mechanics**
- **Additional High-Bandwidth Analog Control Input / Sensor Input**
- **Optional High-Speed Parallel I/O Interface**
- **Flexible Wave Generators**
- **Digital I/O Lines for Task Triggering**
- **Extensive Software Support**

The E-725 digital piezo controller is a compact, high-performance drive electronics for nanopositioning systems with up to three axes. High-power amplifiers permit dynamic scans even for piezo systems with large range or direct drive. State-of-the-art processor technology optimizes the operating parameters for improved linearity and tracking accuracy. High-resolution D/A converters provide for nanopositioning that deserves this name.

With the E-725.3CM, PI for the first time offers a digital controller for the P-363 PicoCube™ (see p. 2-66), a fast precision scanner for atomic force microscopy.

Optional interfaces and analog in- and outputs make it possible to process external sensor or control values.

Digital Linearization and Control Algorithms for Highest Accuracy

Linearization algorithms based on higher-order polynomials improve the positioning accuracy to better than 0.01 % for capacitive sensors, typically 10 times better than achievable with conventional controllers.

More than just a Controller – Trajectory Control and Data Recording

During fast periodic motion, as typical for scanning applications, the tracking accuracy can be further improved with Dynamic Digital Linearization (DDL, E-710.SCN). This optionally available control algorithm reduces the tracking error by a factor of up to 1000.

This control algorithm enables the spatial and temporal tracking during a dynamic scan. The integrated wave generator can output periodic motion profiles. In addition to sine and triangle waves, arbitrary, user-defined motion profiles can be created and stored. The flexibly configurable data recorder enables simultaneous recording and read-out of the corresponding data.

Extensive Software Support

The controllers are delivered with Windows operating software. Comprehensive DLLs and LabVIEW drivers are available for automated control.

Automatic Configuration

PI digital piezo controllers and nanopositioning stages with ID-Chip can be operated in any combination, supported by the AutoCalibration function of the controller. Individual stage data and optimized servo-control parameters are stored in the ID-Chip and are read out automatically by the digital controllers.

Technical Data

Model	E-725.3CD	E-725.3CM	Tolerance
Function	Digital Controller for Multi-Axis Piezo Nanopositioning Systems with Capacitive Sensors	Digital Controller for Multi-Axis Piezo Nanopositioning Systems with Capacitive Sensors	
Axes	3	3	
Processor	DSP 32-bit floating point, 225 MHz	DSP 32-bit floating point, 225 MHz	
Sampling rate, servo-control	20 kHz	20 kHz	
Sampling rate, sensor	20 kHz	20 kHz	
Sensor			
Servo characteristics	P-I, two notch filters	P-I, two notch filters	
Sensor type	Capacitive	Capacitive	
Sensor channels	3	3	
Sensor bandwidth (-3 dB)	5.6 kHz	5.6 kHz	max.
Sensor resolution	18 bit	18 bit	
Ext. synchronization	Yes	Yes	
Amplifier			
Output voltage	-30 to 135 V	-250 to 250 V	±3 V
Amplifier channels	4	4	
Peak output power per channel	25 W	47 W	max.
Average output power per channel*	10 W	10 W	max.
Peak output current per channel	190 mA	190 mA	max.
Average output current per channel*	120 mA	60 mA	max.
Current limitation	Short-circuit proof	Short-circuit proof	
Resolution DAC	24 bit	24 bit	
Interfaces and operation			
Communication interfaces	Ethernet, USB, RS-232	Ethernet, USB, RS-232	
Piezo / sensor connector	Sub-D special connector	Sub-D special connector	
Analog input	1 x Lemo, ±10 V, 18 bit	1 x Lemo, ±10 V, 18 bit	
Digital input / output	MDR20; 2 x IN, 8 x OUT	MDR20; 2 x IN, 8 x OUT	
Command set	PI General Command Set (GCS)	PI General Command Set (GCS)	
User software	NanoCapture™, PIMikroMove™	NanoCapture™, PIMikroMove™	
Software drivers	LabVIEW driver, DLLs	LabVIEW driver, DLLs	
Supported functionality	Wave-Gen, Trigger I/O	Wave-Gen, Trigger I/O	
Display	LEDs for Power, On Target, Error, Cmd	LEDs for Power, On Target, Error, Cmd	
Linearization	4th order polynomial, DDL (Dynamic Digital Linearization)	4th order polynomial, DDL (Dynamic Digital Linearization)	
Separate protective ground connector	Yes	Yes	
Miscellaneous			
Operating temperature range	5 to 50 °C	5 to 50 °C	
Overheat protection	Max. 71 °C, deactivation of the piezo voltage output	Max. 71 °C, deactivation of the piezo voltage output	
Mass	3.5 kg	3.6 kg	
Dimensions	263 x 89 x 302 mm (with handles)	263 x 89 x 302 mm (with handles)	
Power consumption	70 W	70 W	max.
Operating voltage	24 VDC from external power supply (included)	24 VDC from external power supply (included)	

* The total output power of all 4 amplifier channels should not exceed 34.5 W to avoid overcurrent (E-725 is equipped with a 3.15 AM fuse).

E-710 Digital Piezo Controller

3 to 6 axes, for highest precision

E-710.6CD 6-axis Digital Piezo Controller top model of the E-710 family, shown with custom Super-Invar 6-DOF piezo flexure nanopositioning stage

- **For Nanopositioning Systems with Capacitive Feedback Sensors**
- **All Control Parameters Software-Settable**
- **3-, 4- & 6-Channel Versions**
- **Firmware Linearization: Dynamic Digital Linearization (DDL) Option Improves Scanning Linearity**
- **Coordinate Transformation for Parallel-Kinematics / Parallel-Metrology Systems**
- **Auto-Loading of Calibration Data from Stage ID-Chip for Interchangeability of Controller and Mechanics**
- **Interface Options: High-Speed Parallel I/O Interface and Analog Inputs**
- **Notchfilter for Higher Bandwidth**
- **Extensive Software Support**
- **Option: Digital Sensor-Signal Transmission over 15 m and More**

E-710 digital piezo controllers offer sophisticated functionality in a variety of configurations. Based on powerful 32-bit DSPs (digital signal processor) they include integrated, low-noise power amplifiers for piezo actuators and excitation/read-out electronics for extremely high-resolution capacitive position sensors. E-710s provide up to 8 piezo driver channels, 7 sensor channels and the processing power for coordinated control of up to 6 logical axes, e.g. for parallel kinematics systems.

Digital Linearization and Control Algorithms for Highest Accuracy

Linearization algorithms based on higher-order polynomials improve the positioning accuracy to 0.001 % of the travel range. The high-speed processor with a sensor sampling rate of 25 kHz, assures settling times in the millisecond range and below. The controller is perfectly suited for high-dynamics operation, thanks to its high-resolution DA-converters and high-performance voltage amplifiers.

More than just a Controller—Trajectory Control and Data Recording

During fast periodic motion, as typical for scanning applications, the tracking accuracy can be further improved with Dynamic Digital Linearization (DDL, E-710.SCN). This optionally available control algorithm reduces the tracking error by a factor of up to 1000.
This control algorithm enables the spatial and temporal tracking during a dynamic scan. The integrated wave generator can save and output periodic motion profiles. In addition to sine and triangle waves, arbitrary, user-defined profiles can be created. The flexibly configurable data recorder enables simultaneous recording and read-out of the corresponding data.

Sensor-Signal Transmission up to 15 m

A remote sensor interface box is available for applications where the distance between the mechanics and electronics is greater than 10 m. This DST option (digital sensor-signal transmission), includes a compatible E-710 controller. It is designed to reduce the interference that begins to degrade performance when the analog sensor excitation and readout signal paths exceed 10 m. The connection between the sensor box and the controller can be up to 15 m (longer distances on request), as the digital signals it carries are far more robust.

Simple System Integration

All parameters can be checked and reset via software. System setup and configuration is done with the included NanoCapture™ and PIMikroMove™ user-interface software. Interfacing to custom software is facilitated with included LabVIEW drivers and DLLs. System programming is the same with all PI controllers, so controlling a system with a variety of different controllers is possible without difficulty.

Ordering Information

See Ordering Numbers / Interface Options on next page

Options and Accessories

E-710.SCN
DDL (Dynamic Digital Linearization) Firmware Upgrade

E-710.3X3
Extension Cable for E-710.3CD, 3 Sub-D Connectors, 3 m

E-710.3X5
Extension Cable for E-710.3CD, 3 Sub-D Connectors, 5 m

E-710.1X3
Extension Cable for E-710, 1 Sub-D Connectors, 3 m

E-710.DST4
DST Cable (Digital Signal Transmission) for E-710.6SD, 8 m

Linear Actuators & Motors

Nanopositioning / Piezoelectrics

Piezo Flexure Stages / High-Speed Scanning Systems

Linear

Vertical & Tip/Tilt

2- and 3-Axis

6-Axis

Fast Steering Mirrors / Active Optics

Piezo Drivers / Servo Controllers

Single-Channel

Multi-Channel

Modular

Accessories

Piezoelectrics in Positioning

Nanometrology

Micropositioning

Index

Ordering Information / Interface Options

Channels	Connector (piezomechanics)	Base Model	Parallel I/O Interface	Analog Input*	Analog Input* + Parallel I/O Interface	DST** + Analog Input*
3	1 x Special Sub-D, 3 ch.	E-710.3CD	E-710.P3D	E-710.A3D	E-710.APD	incl. Parallel I/O Interface E-710.APS
4	4 x LEMO	E-710.4CL	E-710.P4L	–	–	–
	4 x Special Sub-D, 1 ch.	E-710.4CD	E-710.P4D	–	–	–
	1 x Special Sub-D, 3 ch. + 1 x Special Sub-D, 1 ch.	E-710.C4D	E-710.4PD	–	–	–
6	2 x Special Sub-D, 3 ch.	E-710.6CD	–	Standard	–	Analog input on DST box E-710.6SD

*LEMO connector
**Digital Signal Transmission

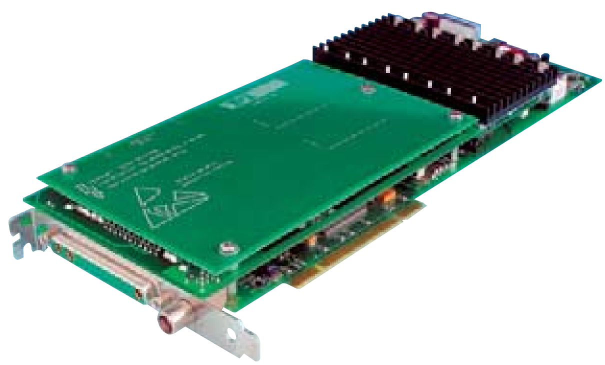
The digital sensor-signal transmission (DST) allows a distance up to 15 m between positioning unit and controller

Technical Data

Model	E-710.3CD / E-710.P3D / E-710.A3D E-710.APD / E-710.APS	E-710.4CD / E-710.4CL / E-710.C4D E-710.4PD / E-710.P4D / E-710.P4L	E-710.6CD / E-710.6SD
Function	Digital piezo controller for multi-axis nanopositioning systems with capacitive sensors	Digital piezo controller for multi-axis nanopositioning systems with capacitive sensors	Digital piezo controller for multi-axis nanopositioning systems with capacitive sensors
Axes	3	4	6
Processor	32-bit, floating-point DSP	32-bit, floating-point DSP	2 x 32-bit, floating-point DSP
Sampling rate, servo-control	200 µs / 5 kHz	200 µs / 5 kHz	200 µs / 5 kHz
Sampling rate, sensor	50 µs / 20 kHz	50 µs / 20 kHz	40 µs / 25 kHz
Sensor			
Servo characteristics	P-I, two notch filters	P-I, two notch filters	P-I, two notch filters
Sensor type	Capacitive	Capacitive	Capacitive
Sensor channels	3	4	6
Sensor resolution	16 bit	16 bit	16 bit
Ext. synchronization	Yes	Yes	Yes
Amplifier			
Output voltage	-20 to 110 V	-20 to 110 V	-20 to 110 V
Amplifier channels	4	4	8
Peak output power per channel,	25 W	25 W	25 W
Average output power per channel	6 W	6 W	6 W
Peak current per channel, <20 ms	200 mA	200 mA	200 mA
Average current per channel, >20 ms	60 mA	60 mA	60 mA
Current limitation	Short-circuit-proof	Short-circuit-proof	Short-circuit-proof
Resolution DAC	20 bit	20 bit	20 bit
Interfaces and operation see separate table			
Communication interfaces	RS-232; IEEE 488 Parallel I/O (E-710.Pxx / .xPx only)	RS-232; IEEE 488; Parallel I/O (E-710.Pxx / .xPx only)	RS-232; IEEE 488
Command set	GCS	GCS	GCS
User software	PIMikroMove™, PZTControl™, NanoCapture™	PIMikroMove™, PZTControl™, NanoCapture™	PIMikroMove™, PZTControl™, NanoCapture™
Software drivers	LabVIEW drivers, DLLs	LabVIEW drivers, DLLs	LabVIEW drivers, DLLs
Supported functionality	Wave generator, data recorder	Wave generator, data recorder	Wave generator, data recorder
Display	Power LED	Power LED	Power LED
Linearization	4th order polynomials, DDL (optional)	4th order polynomials, DDL (optional)	4th order polynomials, DDL
Miscellaneous			
Operating temperature range	5 to 50 °C	5 to 50 °C	5 to 50 °C
Dimensions	450 x 88 x 343 mm + handles	450 x 88 x 343 mm + handles	450 x 88 x 343 mm + handles
Mass	7 kg	7 kg	7 kg
Operating voltage	90–120 or 220–264 VAC, 50–60 Hz	90–120 or 220–264 VAC, 50–60 Hz	90–120 or 220–264 VAC, 50–60 Hz
Max. power consumption	60 W	60 W	120 W

E-761 Digital Piezo Controller

Cost-Efficient PCI Board for Piezo Stages with up to 3 Axes



E-761 Digital Piezo Controller in PCI-Board Format

- **For Piezo Stages with Capacitive Sensors**
- **High-Speed PCI Interface**
- **3 Logical Axes, 4 Piezo Amplifiers**
- **Additional High-Bandwidth Analog Interface**
- **32-Bit Digital Filters**
- **Notch Filter for Higher Bandwidth**
- **24-Bit Ultra-Low-Noise DAC Converters**
- **Auto-Loading of Calibration Data from Stage ID-Chip for Interchangeability of Controller and Mechanics**
- **Coordinate Transformation for Parallel-Kinematics / Parallel-Metrology Systems**
- **Extensive Software Support**

E-761 digital piezo controllers offer advanced control technology in a cost-effective PCI-board format. They were designed to run piezo stages with up to three logical axes. The E-761 incorporates four instrumentation-class, 24-bit digital-analog converters (DAC) behind ultra-low-noise power amplifiers, and is based on a specialized 32-bit digital signal processor (DSP) with proprietary firmware.

Having PCI-board format, the E-761 digital controller can be easily installed in any commercial or industrial PC, allowing for easy integration with other devices such as frame grabbers. The PCI interface with its high bandwidth makes possible a very fast communication between software and controller. This is a definite plus in time-critical applications or when controlling several axes.

Additionally, the E-761.3CT version offers three digital output lines for a variety of triggering tasks.

Improved Trajectory Accuracy Through Parallel Metrology

Digital controllers have a number of advantages over conventional analog piezo controllers. Sensor and actuator axes need not be parallel to each other, or to the orthogonal logical axes used to command the system. The flexible coordinate transformation algorithm permits operation of complex, multi-axis, parallel metrology stages (e. g. 3-axis Z-tip-tilt-stages). With parallel motion metrology, the controller compensates the undesired off-axis motion of each actuator automatically using the others (active trajectory control). High-end nanopositioning systems with active trajectory control can attain motion accuracies in the sub-nanometer range.

Digital Linearization and Control Algorithms for Highest Accuracy

Linearization algorithms based on higher-order polynomials improve the positioning accuracy to 0.001 % of the travel range.

During fast periodic motion, as typical for scanning applications, the tracking accuracy can be further improved with Dynamic Digital Linearization (DDL, E-710.SCN). This optionally available control algorithm reduces the tracking error by a factor of up to 1000.

The integrated wave generator can save and output periodic motion profiles. In addition to sine and triangle waves, arbitrary, user-defined profiles can be created.

Automatic Configuration

PI digital piezo controllers and nanopositioning stages with ID-chips can be operated in any combination, supported by the controller's AutoCalibration function. Individual stage data and optimized servo-control parameters are stored in the ID-Chips and are read out automatically by the digital controller.

Simple System Integration

All parameters can be set and checked by software. System setup and configuration is done with the included NanoCapture™ and PZTControl™ user-interface software. Interfacing to custom software is facilitated with included LabVIEW drivers and DLLs. All PI controllers use the same command set, a significant advantage during application software development, system upgrade or when operating a variety of different controllers from one application.

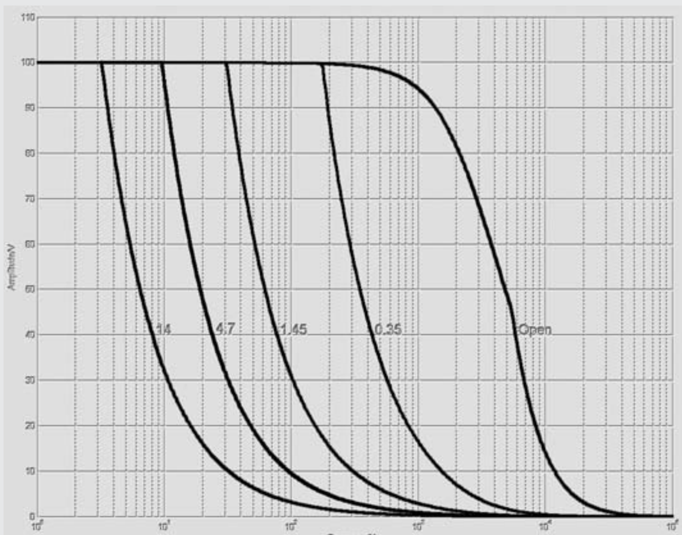
Ordering Information

E-761.3CD
Digital Piezo Nanopositioning Controller, 3 Axes, Sub-D-Special, PCI Board

E-761.00T
Trigger Output Bracket for E-761.3CD

E-761.3CT
Digital Piezo Nanopositioning Controller, 3 Axes, Sub-D-Special, PCI Board, Trigger Output

Ask about custom designs!



E-761: operating limits with various PZT loads (open-loop), capacitance is measured in µF

Technical Data

Model	E-761.3CD	E-761.3CT
Function	Digital piezo controller and power amplifier, PCI board	Digital piezo controller and power amplifier, PCI board, trigger output
Axes	3	3
Processor	32-bit, floating-point DSP	32-bit, floating-point DSP
Sampling rate, servo-control	40 µs / 25 kHz (sensor-oversampling factor 4)	40 µs / 25 kHz (sensor-oversampling factor 4)
Sensor		
Servo characteristics	P-I, two notch filters	P-I, two notch filters
Sensor type	Capacitive	Capacitive
Sensor channels	3	3
Sensor resolution	16-bit	16-bit
Ext. synchronization	Yes	Yes
Amplifier		
Output voltage	-20 to 120 V	-20 to 120 V
Amplifier channels	4	4
Peak output power per channel,	5.3 W	5.3 W
Average output power per channel	1.7 W	1.7 W
Peak current per channel, <20 ms	50 mA	50 mA
Average current per channel, >20 ms	10 mA	10 mA
Current limitation	Short-circuit-proof	Short-circuit-proof
Resolution DAC	24-bit	24-bit
Interfaces and operation		
Interface / communication	PCI connector	PCI connector
Piezo / sensor connector	Sub-D special	Sub-D special
Control Input sockets	LEMO	LEMO
Digital output	-	3 x TTL
Command set	GCS	GCS
User software	NanoCapture™, PZTControl™	NanoCapture™, PZTControl™
Software drivers	LabVIEW drivers, Windows and Linux Libraries (DLL)	LabVIEW drivers, Windows and Linux Libraries (DLL)
Supported functionality	Wave generator	Wave generator, trigger output
Display	Status LED for piezo voltage	Status LED for piezo voltage
Linearization	4th order polynomial	4th order polynomial
Miscellaneous		
Operating temperature range	+5 to +50 °C (derated 10 % over 40 °C)	+5 to +50 °C (derated 10 % over 40 °C)
Overtemp protection	Deactivation at 60 °C	Deactivation at 60 °C
Dimensions	287 x 108 x 25 mm (2 slots)	287 x 108 x 25 mm + 122 x 45x 26 mm (3 slots)
Mass	0.56 kg	0.56 (PCI-board only)
Operating voltage	5 V	5 V
Power consumption	20 W, 4 A max.	20 W, 4 A max.

PI Piezo • Nano • Positioning

E-616 Controller for Multi-Axis Piezo Tip/Tilt Mirrors and Platforms

Flexible Multi Channel OEM Electronics with Coordinate Transformation

The E-616 OEM controller and the S-334 fast steering mirror system providing a tip/tilt range of up to 60 mrad

Ordering Information

E-616.SS0
Multi Channel Servo-Controller / Driver for Piezo Tip/Tilt Mirror Platforms with SGS and Differential Drive

E-616.S0
Multi Channel Servo-Controller / Driver for Piezo Tip/Tilt Mirror Platforms with SGS and Tripod Drive

- **Three Integrated Amplifiers Provide up to 10 W Peak Power**
- **Closed-Loop and Open-Loop Versions**
- **Internal Coordinate Transformation Simplifies Control of Parallel Kinematics Designs (Tripod & Differential Drive)**
- **Compact and Cost-Effective Design for OEMs**

The E-616 is a special controller for piezo based tip/tilt mirrors and tip/tilt platforms. It contains two servo controllers, sensor channels and power amplifiers in a compact unit. The controller works with high-resolution SGS position sensors used in PI piezo mechanics and provides optimum position stability and fast response in the nanometer and µrad-range respectively. A high output power of 10 W per channel allows dynamic operation of the tip/tilt mirrors for applications such as (laser) beam steering and stabilization.

Tripod or Differential Piezo Drive? One for All!

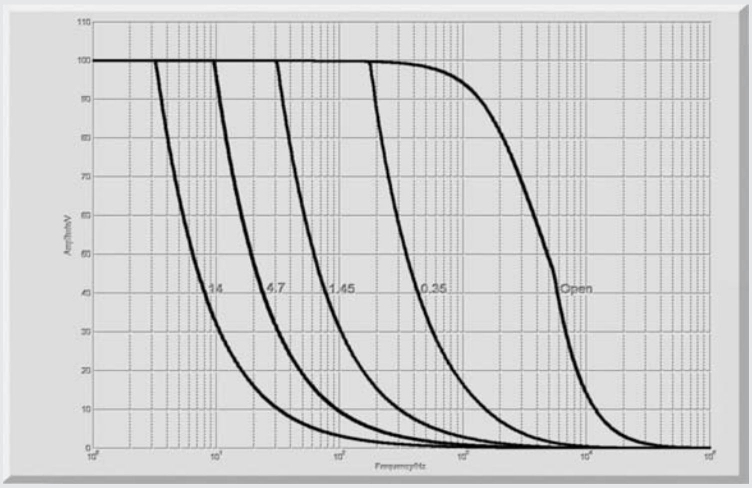
PI offers two basic piezo tip/tilt mirror designs. Both are parallel-kinematics designs where the individual piezo actuators affect the same moving platform. With the tripod design (e.g. S-325, see p. 2-92) the platform is driven by three piezo actuators placed with 120° spacing. The differential drive design (S-330, see p. 2-88 or S-334, see p. 2-90) with two orthogonal axes and a fixed pivot point is based on two pairs of actuators operating in push / pull-mode. The differential evaluation of two sensors per axis provides an improved linearity and resolution.

Internal Coordinate Transformation Simplifies Control

Parallel-kinematics require the transformation of the commanded tilt angles into the corresponding linear motion of the individual actuators. In the E-616.S0, this is taken care of by an integrated circuit, eliminating the need of additional external hardware or software. Additionally with the E-616.S0 all actuators can be commanded by an offset-voltage simultaneously. As a result a vertical movement, for example for optical path tuning, is obtained.

Simple Setup and Operation

To facilitate integration, setup and operation the E-616 features both front and rear panel connections: The 25 pin sub-D piezo & sensor connector is located on the front, along with offset trim pots and LEDs for Power and Overflow. A 32 pin rear connector allows commanding and reading the sensor and amplifier monitor outputs.



E-616: operating limits with various PZT loads (open-loop), capacitance is measured in µF

Technical Data

Model	E-616.S0	E-616.SS0
Function	Controller for parallel-kinematics piezo tip/tilt mirror systems with strain gauge sensors, tripod design	Controller for parallel-kinematics piezo tip/tilt mirror systems with strain gauge sensors, differential design
Tilt axes	2	2
Sensor		
Servo characteristics	P-I (analog), notch filter	P-I (analog), notch filter
Sensor type	SGS	SGS
Sensor channels	3	2
External synchronization	200 kHz TTL	200 kHz TTL
Amplifier		
Control input voltage range	-2 V to +12 V	-2 V to +12 V
Output voltage	-20 V to +120 V	-20 V to +120 V
Amplifier channels	3	3
Peak output power per channel	10 W	10 W
Average output power per channel	5 W	5 W
Peak current	100 mA	100 mA
Average current per channel	50 mA	50 mA
Current limitation	Short-circuit-proof	Short-circuit-proof
Voltage gain	10	10
Amplifier bandwidth, small signal	3 kHz	3 kHz
Amplifier bandwidth, large signal	See frequency diagram	See frequency diagram
Ripple, noise, 0 to 100 kHz	<20 mVpp	<20 mVpp
Amplifier resolution	<1 mV	<1 mV
Interfaces and operation		
Piezo / sensor connector	25-pin sub-D connector	25-pin sub-D connector
Analog input	32-pin connector	32-pin connector
Sensor monitor output	0 to +10 V for nominal displacement	0 to +10 V for nominal displacement
Sensor monitor socket	32-pin connector	32-pin connector
Display	Power-LED and sensor OFL display	Power-LED and sensor OFL display
Miscellaneous		
Operating temperature range	5 °C to 50 °C	5 °C to 50 °C
Overheat protection	Max. 75 °C, deactivation of the piezo voltage output	Max. 75 °C, deactivation of the piezo voltage output
Dimensions	160 mm x 100 mm x 10 TE	160 mm x 100 mm x 10 TE
Mass	700 g	700 g
Operating voltage	12 to 30 V DC	12 to 30 V DC
Power consumption	30 W	30 W

E-663 Three-Channel Piezo Driver

For Open-Loop Piezo Systems and Actuators Without Position Sensors

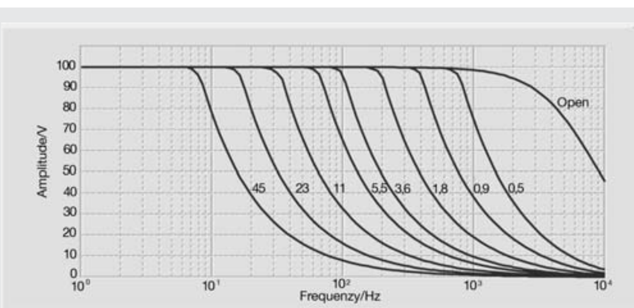
E-663.00 bench-top device

- 3 Independent Channels
- 3 x 14 W Peak Power
- Output Voltage Range -20 to 120 V
- High-Bandwidth Analog Control Interface
- Precision 10-Turn Potentiometers for Manual Control
- 3 LED Voltage Displays

The E-663.00 is a piezo driver module for low-voltage piezo actuators and positioners. It contains three independent amplifiers that can output and sink a peak current of 140 mA in the -20 to +120 V voltage range. Three 3½-digit LED displays show the output voltage of each individual channel.

Voltage-Controlled Piezo Operation

This precision piezo driver is designed for voltage-controlled piezo operation in both dynamic and static modes. In open-loop (voltage-controlled) piezo operation the amplifier output voltage is determined by an analog signal at the Control Input optionally combined with the DC-offset potentiometer. Voltage controlled operation (in contrast to position-controlled operation) is used in applications where the fastest possible response and very high resolution with maximum bandwidth are essential, and/or when commanding and reading the target position in absolute values is either not important or accomplished with an external feedback loop. (see p. 2-104) The precision 10-turn potentiometer can also be used alone to set the output voltage manually.



E-663: operating limits with various PZT loads (open-loop), capacitance is measured in µF

Remote Control via Computer Interface

Optionally, digital control via an external D/A converter is possible. For several D/A boards from National Instruments, PI offers a corresponding LabVIEW driver set which is compatible with the PI General Command Set (GCS), the command set used by all PI controllers. A further option includes the patented HyperBit™ technology providing enhanced system resolution.

Ordering Information

E-663.00
Piezo Amplifier, 3 Channels, -20 to 120 V, Bench-Top

Technical Data

Model	E-663.00	Tolerance
Function	Power amplifier	
Channels	3	Max.
Amplifier		
Input voltage	-2 to +12 V	
Min. output voltage	-20 to 120 V	
Peak output power per channel	14 W	Max.
Average output power per channel	6 W	Max.
Peak current per channel	140 mA	<5 ms
Average current per channel	60 mA	>5 ms
Current limitation	Short-circuit-proof	
Noise, 0 to 100 kHz	<1 mVrms	
Voltage gain	10 ±0.1	
Input impedance	100 kΩ	
Interfaces and operation		
Piezo connector	3 x LEMO ERA.00.250.CTL	
Control Input socket	3 x BNC	
Display	3 x 3 1/2 -digit, LED	
DC-Offset	3 x 10-turn pots, adds 0 to 10 V to Control In	
Miscellaneous		
Operating temperature range	5 to +50°C	
Dimensions	236 x 88 x 273 mm + handles	
Mass	4.6 kg	
Operating voltage	90–120 / 220–240 VAC, 50–60 Hz (linear power supply)	
Power consumption	60 W	Max.

E-664 NanoCube® Piezo Controller

For XYZ-Nanopositioning System P-611.3S

E-664 Controller for NanoCube® XYZ nanopositioning systems

- **Integrated Amplifier with 3 x 14 W Peak Power**
- **Position Servo-Control with Notch Filter for Higher Bandwidth and Stability**
- **3 Displays for Voltage / Position**
- **Cost-Effective Controller for P-611.3S NanoCube® Nanopositioning Systems**
- **Manual and External Control**

The E-664 is a bench-top amplifier & position servo-controller that is especially designed for the P-611.3S NanoCube® XYZ nanopositioning system (see p. 2-52). Three integrated low-noise amplifiers and control circuitry for strain gauge position sensors allow closed-loop position resolution down to 2 nm and dynamic operation.

The combination of the E-664 servo-controller and P-611.3S NanoCube® piezo stage makes for a very cost-effective precision 3D nanopositioning system.

Closed-Loop and Open-Loop Piezo Positioning

The E-664 servo controller can be operated both in closed-loop (position-control) and in open-loop (voltage-control) mode. In closed-loop mode, piezo displacement is proportional to the analog signal applied to the BNC control-input socket. The integrated notch filters (adjustable for each axis) improve the stability and allow high-bandwidth operation closer to the piezomechanics resonant frequency. In open-loop operation the output voltage is determined by the analog control signal at the BNC Control Input socket, optionally combined with the DC-offset potentiometer. Voltage controlled operation (in contrast to position-controlled operation) is used in applications where the fastest possible response and very high resolution with maximum bandwidth are essential, and/or when commanding and reading the target position in absolute values is either not important or accomplished with an external feedback loop (see p. 2-104). The precision 10-turn potentiometers can also be used alone to set the output voltages manually.

Versatile I/O Supports Automation

On-target and overflow status information is displayed separately for every channel. This information is also present on a 14-pin I/O connector on the rear panel that also carries the analog control input and sensor monitor lines.

Remote Control via Computer Interface

Optionally, digital control via an external D/A converter is possible. For several D/A boards from National Instruments, PI offers a corresponding LabVIEW driver set which is compatible with the PI General Command Set (GCS), the command set used by all PI controllers. A further option includes the patented HyperBit™ technology providing enhanced system resolution.

Ordering Information

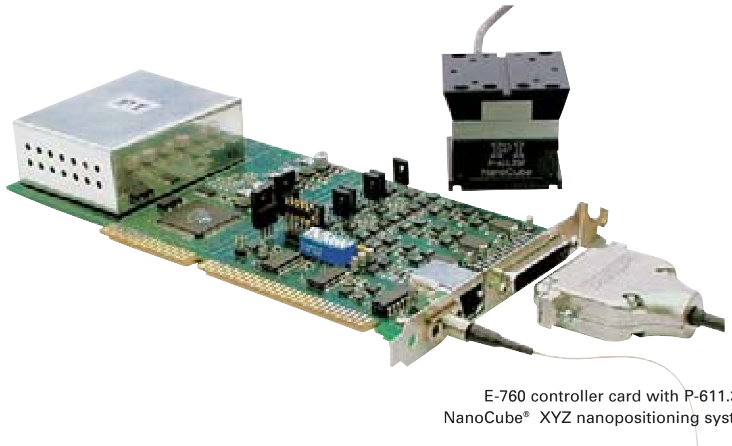
E-664.S3
NanoCube® Piezo Controller,
3 Channels, SGS-Sensors,
-20 to 120 V

Technical Data

Model	E-664.S3
Function	Power amplifier & position servo controller for P-611.3S NanoCube® nanopositioning system
Axes	3
Sensor	
Servo characteristics	P-I (analog), notch filter
Sensor type	SGS
Amplifier	
Input voltage	-2 to +12 V
Output voltage	-20 to 120 V
Peak output power per channel <5 ms	14 W
Average output power per channel >5 ms	6 W
Peak current per channel <5 ms	140 mA
Average current per channel >5 ms	60 mA
Current limitation	Short-circuit-proof
Voltage gain	10 ±0.1
Ripple, noise, 0 to 100 kHz	<1 mVrms
Interfaces and operation	
Piezo connector	25-pin sub-D connector
Sensor connector	25-pin sub-D connector
Control Input sockets	3 x BNC (rear), I/O connector
I/O ports	14-pin connector for on-target and overflow status, Control In and sensor monitor outputs
Display	3 x 3½-digits, LED
Miscellaneous	
Operating temperature range	5 to 50°C
Overtemp protection	Deactivation at 75°C
Dimensions	236 x 88 x 273 mm + handles
Mass	3 kg
Operating voltage	90–120 / 220–240 VAC, 50–60 Hz (linear power supply)
Max. power consumption	60 W

E-760 NanoCube® Piezo Controller Card

For C-880 Automation Controller and F-206 Hexapod Precision Alignment System



E-760 controller card with P-611.3SF NanoCube® XYZ nanopositioning system

Ordering Information

E-760.3SV
NanoCube® Piezo Controller, Board for C-880 and F-206 Controller Systems, Photodetector (Visual Range)

E-760.3Si
NanoCube® Piezo Controller, Board for C-880 and F-206 Controller Systems, Photodetector (Infrared Range)

- **3 x 9 W Peak Power**
- **Position Servo-Control**
- **For P-611 NanoCube® and F-206 HexAlign™ 6-DOF Alignment Systems**
- **Built-in Optical Metrology for Automated Alignment**

The E-760 is a piezo amplifier and position servo-controller card that was especially designed for the P-611 NanoCube® (see p. 2-50) XYZ nanopositioning system operated together with the F-206, M-824, M-840 or M-850 (see p. 4-6 *ff*). In addition to three low-noise amplifiers and position servo-controller circuits, it is equipped with optical metrology and I/O for automatic alignment of photonics components. All functions are accessible via the computer-bus interface. In addition, there is an analog input for position control and an FC connector for the optical metrology. Thus, positioning accuracy and repeatability down to the sub-nanometer range is possible.

Technical Data

Models	E-760.3SV	E-760.3Si	Units
Function	Piezo controller card for P-611 NanoCube® systems	Piezo controller card for P-611 NanoCube® systems	
Axes	3	3	
Sensor			
Servo characteristics	P-I (analog), notch filter	P-I (analog), notch filter	
Sensor type	SGS	SGS	
Sensor channels	3	3	
Amplifier			
Input voltage	-2 to +12 V	-2 to +12 V	
Output voltage	-20 to 120 V	-20 to 120 V	
Amplifier channels	3	3	
Peak output power per channel	9	9	W
Average output power per channel	1	1	W
Peak current per channel, <5 ms	90	90	mA
Average current per channel, >5 ms	8	8	mA
Current limitation	Short-circuit-proof	Short-circuit-proof	
Voltage gain	10 ±0.1	10 ±0.1	
Interfaces and operation			
Communication interfaces	Standard computer bus (ISA); FC-connector	Standard computer bus (ISA); FC-connector	
Piezo / sensor connector	25-pin sub-D connector	25-pin sub-D connector	
Analog input	8-pin connector (piezo); FC connector (optical metrology)	8-pin connector (piezo); FC connector (optical metrology)	
Supported functionality	Visible-range detector	Infrared-range detector	

E-536 PicoCube™ Piezo Controller

High Dynamics, High Resolution, for up to 3 Axes

E-536.3C 3-channel PicoCube™ Controller

- **For P-363 PicoCube™ Systems**
- **Peak Power 3 x 100 W**
- **Ultra-Low Noise**
- **Output Voltage ±250 V**

The E-536 is a controller for the P-363 PicoCube™ pico-positioning system providing three ultra-low-noise amplifier channels for piezo shear actuators. The controller design meets the special requirements of the high-speed, ultra-high-performance PicoCube™ XY(Z) piezo stages (see p. 2-74) of ±250 V for both static and dynamic applications.

The high-performance E-536.3x can output and sink peak currents up to 200 mA featuring a small-signal bandwidth of 10 kHz. The E-536.3xH ultra-high-resolution models provide a position resolution below 0.03 nm at a peak power of 50 W. Both models are available with or without a servo module for closed-loop or open-loop operation.

Superior Resolution and High Dynamics

Open-loop operation is ideal for applications where fast response and very high resolution with maximum bandwidth are essential. Here, commanding and reading the traget position in absolute values is either not important or carried out by external position sensors. Together with the P-363 PicoCube™ a resolution of 0.05 nm or better is achieved.

Excellent Position Accuracy with Capacitive Sensors

The E-536.3C versions have integrated sensor electronics and servo-controllers for closed-loop position control. Position feedback is provided by capacitive sensors, like those in the PicoCube™, with resolutions down to 0.1 nm.

Computer Control

Control via PC is possible by installing the E-517, 24-bit interface/display module.

Optionally digital control via a D/A converter is possible. For several D/A boards from National Instruments PI offers a corresponding LabVIEW™ driver set which is compatible with the PI General Command Set (GCS), the command set used by all PI controllers. A further option includes the patented Hyperbit™ technology providing enhanced system resolution.

Ordering Information

E-536.3C
PicoCube™ Piezo Controller, 3 Channels, Capacitive Sensors

E-536.30
PicoCube™ Piezo Controller, 3 Channels, Open-Loop

E-536.3CH
PicoCube™ Piezo Controller, 3 Channels, High-Resolution, Capacitive Sensors

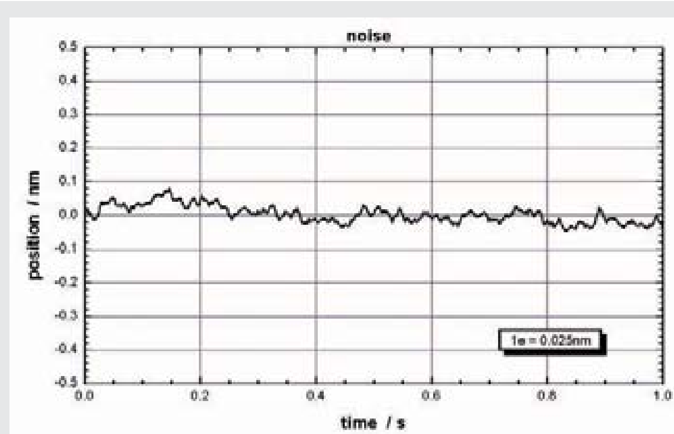
E-536.30H
PicoCube™ Piezo Controller, 3 Channels, High-Resolution, Open-Loop

E-517.i3
Interface- / Display Module, 24 Bit D/A, TCP/IP, USB, RS-232, 3 Channels

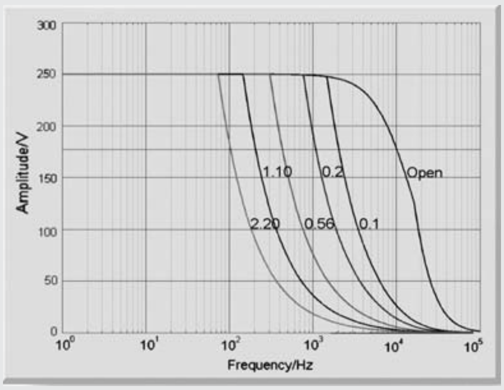
E-500.HCD
Hyperbit™ Functionality for Enhanced System Resolution

(Supports certain D/A boards.)

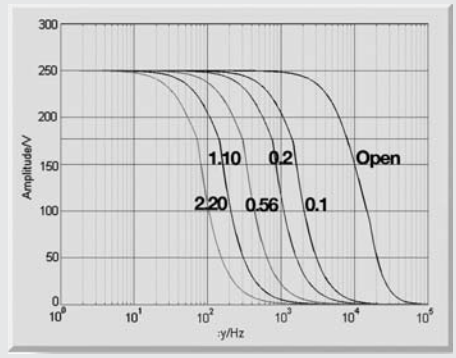
E-536 controller with P-363 PicoCube™ pico-positioning system



Positional noise measurement of E-536 amplifier driving a P-363 pico-positioning system in open loop shows 1-sigma resolution of 25 picometers (0.025 nm). Measured with ultra-high-resolution capacitive sensor



E-536.3x: operating limits with various PZT loads, capacitance is measured in µF



E-536.3xH: operating limits with various PZT loads, capacitance is measured in µF

Technical Data

Model	E-536.3C / E-536.30	E-536.3CH / E-536.30H
Function	Power amplifier & servo-controller for P-363 PicoCube™	Power amplifier & servo-controller for P-363 PicoCube™
Amplifier		
Output voltage	-250 to +250 V	-250 to +250 V
Amplifier channels	3	3
Average output power per channel	10 W, limited by temperature sensor	6 W, limited by temperature sensor
Peak output power per channel, <3 ms	100 W	50 W
Average current	30 mA	15 mA
Peak current per channel, <3 ms	200 mA	100 mA
Amplifier bandwidth, small signal	10 kHz	2 kHz
Amplifier bandwidth, large signal, @ 100 nF	0.2 kHz	0.125 kHz
Ripple, noise, 0 to 100 kHz	0.8 mV_{RMS}, <5 mV_{P-P} (100 nF)	0.5 mV_{RMS}, <3 mV_{P-P} (100 nF)
Current limitation	Short-circuit proof	Short-circuit proof
Voltage gain	+50	+50
Input impedance	100 kΩ	100 kΩ
Sensor*		
Servo characteristics	Analog proportional-integral (P-I) algorithm with notch filter	Analog proportional-integral (P-I) algorithm with notch filter
Sensor type	capacitive sensors	capacitive sensors
Sensor channels	3 / -	3 / -
Sensor bandwidth	1.5 kHz	1.5 kHz
Sensor Monitor output	0 to +10 V	0 to +10 V
Interfaces and operation		
PZT output sockets	LEMO EGG.0B.701.CJL.1173	LEMO EGG.0B.701.CJL.1173
Sensor target and probe sockets	LEMO EPL.00.250.NTD	LEMO EPL.00.250.NTD
Control Input sockets	SMB	SMB
Sensor Monitor socket	LEMO FGG.0B.306.CLAD56	LEMO FGG.0B.306.CLAD56
Control Input voltage	Servo off: -5 to +5 V, Servo on: 0 to +10 V	Servo off: -5 to +5 V, Servo on: 0 to +10 V
DC Offset	10-turn pot., adds 0 to +10 V to Control IN	10-turn pot., adds 0 to +10 V to Control IN
Miscellaneous		
Operating voltage	115 VAC / 50-60 Hz or 230 VAC / 50-60 Hz	115 VAC / 50-60 Hz or 230 VAC / 50-60 Hz
Mass	8.1 kg / 7.8 kg (with E-516 module)	8.1 kg / 7.8 kg (with E-516 module)
Dimensions	450 x 132 x 296 mm + handles	450 x 132 x 296 mm + handles

*only E-536.3Cx with capacitive sensors
Interfaces / communication: RS-232, TCP/IP, USB (with optional E-517 computer interface and display module only)
Operating temperature range: +5 °C to +50 °C (over 40 °C, max. av. power derated 10 %), high-voltage output is automatically deactivated if temperature is too high by internal temperature sensor (75 °C max.)

E-464 PICA™ Piezo Driver / Amplifier

For Piezo Systems and Actuators, for up to 3 Axes

E-464.00 3-channel HVPZT amplifier

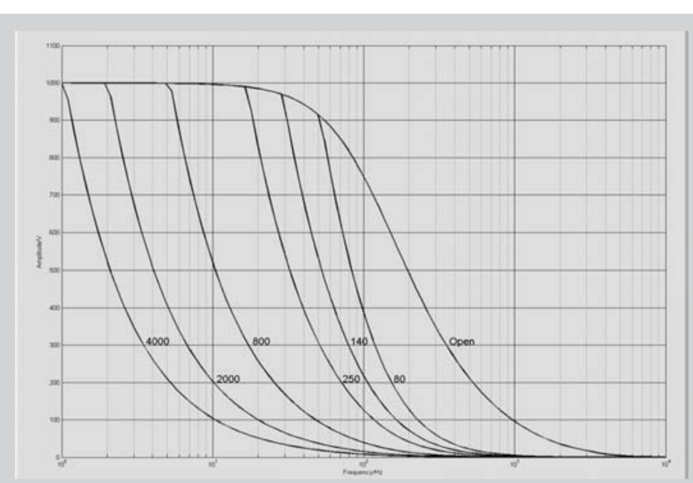
- **3 Powerful Channels**
- **Peak Power 3 x 25 W**
- **Output Voltage Range 0 to 1100 V**
- **3 LED Voltage Displays**
- **Precision DC-Offset Potentiometers for Input-Signal Bias & Manual Control**

The E-464 is a bench-top piezo driver/amplifier for PICA™ high-voltage PZTs. Its three low-noise, 4-quadrant amplifiers provide a gain of 100 and can output and sink a peak current of 25 mA and an average current of >3 mA each. If only 1 channel is operated, an average output power of 12 W can be achieved.

Three $3^1/_2$-digit LED displays show the output voltage of each individual channel.

Analog Control

E-464 amplifiers are designed to provide precise control of open-loop piezo positioning systems. The amplifier output voltage is determined by the analog signal at the Control Input combined with the DC-offset potentiometer setting.



E-464: operating limits with various PZT loads, capacitance is measured in nanofarads

Computer Control

Optionally digital control via a D/A converter is possible. For several D/A boards from National Instruments PI offers a corresponding LabVIEW™ driver set which is compatible with the PI General Command Set (GCS), the command set used by all PI controllers. A further option includes the patented HyperBit™ technology providing enhanced system resolution.

Ordering Information

E-464.00
HVPZT Piezo Amplifier, 3 Channels, 1100 V, Bench-Top

E-500.ACD
CD with Driver Set for Analog Controllers

E-500.HCD
HyperBit™ Functionality for Enhanced System Resolution Supports certain D/A boards

Extension cables, adapters & connectors: see in "Accessories" (p. 2-168 *ff*)

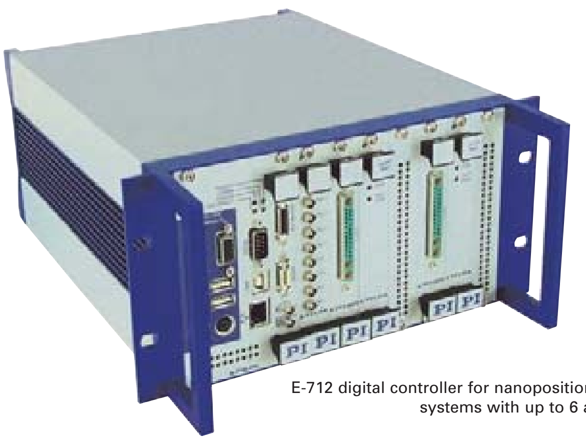
Ask about custom designs!

Technical Data

Model	E-464.00
Function	Power amplifier for PICA™ high-voltage PZTs
Amplifier	
Output voltage	0 to +1100 V
Amplifier channels	3
Average output power per channel	>3.5 W (up to 12 W if 1 channel is operated)
Peak output power per channel, <5 ms	25 W
Average current per channel	>3.5 mA (up to 12 mA if 1 channel is operated)
Peak current per channel, <5 ms	25 mA
Amplifier bandwidth, small signal	1 kHz
Amplifier bandwidth, large signal	3.5 Hz (660 nF); 35 Hz (70 nF)
Ripple, noise 0 to 100 kHz	5 mV_{RMS} 50 mV_{P-P} (100 nF)
Current limitation	Short-circuit-proof
Voltage gain	+100 ±1
Control input voltage	0 to 11 V
Input impedance	100 kΩ
Interface and operation	
PZT voltage output socket	3 x LEMO EGG.0B.701.CJL1173
Control input socket	3 x BNC
DC Offset	3 x 10-turn pot, adds 0 to +10 V to Control IN
Display	3 x $3^1/_2$-digit LED display for output voltages
Miscellaneous	
Operating voltage	100 to 120 or 220 to 240 VAC, selectable (fuse change required)
Operating temperature range	+5 to +50 °C (over 40 °C, max. av. power derated 10 %)
Mass	4.3 kg
Dimensions	236 x 88 x 273 mm + handles

E-712 Digital Piezo Controller

Modular System for up to 6 Axes with Highest Precision



E-712 digital controller for nanopositioning systems with up to 6 axes

- **Digital Controller of the Newest Generation: 600 MHz Tact Rate; up to 50 kHz Servo Update Rate; Highly Stable 20-bit D/A Converter**
- **Real-Time Operating System for Excellent Trajectory Control**
- **Modular Design for Greatest Flexibility in Meeting Custom Requirements**
- **Auto-Loading of Calibration Data from Stage ID-Chip for Interchangeability of Controller and Mechanics**
- **Versatile Interfaces: Ethernet, USB, RS-232**
- **Optional High-Bandwidth Analog Inputs and Outputs**
- **Extensive Software Support**

The E-712 digital piezo controller is ideal when it comes to meeting the most demanding accuracy and dynamic-performance requirements of multi-axis nanopositioning systems. The high-performance, real-time operating system makes possible coordinated servo-control of multiple axes (also in parallel-kinematics systems) and thus ensures excellent trajectory control even during complex motion. The modular design allows flexible confection of systems supporting the number of axes and channels required for the application. Flexibility in meeting customers' needs is also behind the interface design: The optional analog inputs and outputs support processing external sensor or control signals as well as driving external amplifiers.

Digital Linearization and Control Algorithms for Highest Accuracy

Linearization algorithms based on higher-order polynomials improve the positioning accuracy to 0.01% of the travel range. The high-speed processor with a sensor sampling rate of 50 kHz, assures settling times in the millisecond range and below. The controller is perfectly suited for high-dynamic operation, thanks to its high-resolution DA-converters and high-performance voltage amplifiers.

More than just a Controller—Trajectory Control and Data Recording

During fast periodic motion, as typical for scanning applications, the tracking accuracy can be further improved with Dynamic Digital Linearization (DDL, E-710.SCN). This optionally available control algorithm reduces the tracking error by a factor of up to 1000.

This control algorithm enables the spatial and temporal tracking during a dynamic scan. The integrated wave generator can save and output periodic motion profiles. In addition to sine and triangle waves, arbitrary, user-defined profiles can be created. The flexibly configurable data recorder enables simultaneous recording and read-out of the corresponding data.

Flexible Analog Inputs

Four analog inputs allow different configurations. As Control In, the applied voltage is correlated to one of the motion axis e.g. to give a target value. Configured as the input line for an external sensor signal the inputs may be used for autofocusing instead of an integrated sensor.

Simple System Integration

All parameters can be checked and reset via software. System setup and configuration is done with the included NanoCapture™ and PIMikroMove™ user-interface software. Interfacing to custom software is facilitated with included LabVIEW drivers and DLLs.

Ordering Information

E-712.3CD
Modular Digital Multi-Channel Piezo Controller, 3 Channels, Capacitive Sensors

E-712.3CDA
Modular Digital Multi-Channel Piezo Controller, 3 Channels, Capacitive Sensors, Analog INs and OUTs

E-712.6CD
Modular Digital Multi-Channel Piezo Controller, 6 Channels, Capacitive Sensors

E-712.6CDA
Modular Digital Multi-Channel Piezo Controller, 6 Channels, Capacitive Sensors, Analog INs and OUTs

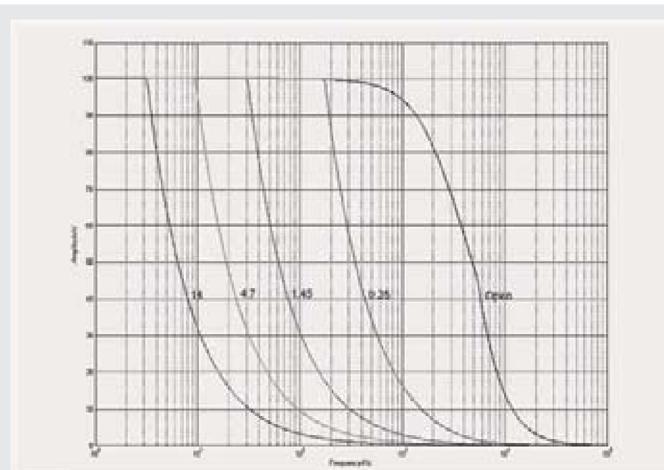
Ask about custom designs!

Options and Accessories

E-710.SCN
DDL (Dynamic Digital Linearization) Firmware Upgrade

E-711.i1B
Analog Cable for Analog I/O, BNC Connector, 1.5 m

E-711.i10
Analog Cable for Analog I/O, Solderable End, 1.5 m



E-712 operating limits with various PZT loads, capacitance is measured in µF

System programming is the same with all PI controllers, so controlling a system with a variety of different controllers is possible without difficulty.

Technical Data

Model	E 712.3CD/E 712.3CDA	E 712.6CD/E 712.6CDA
Function	Modular digital controller for multi-axis piezo nanopositioning systems with capacitive sensors	Modular digital controller for multi-axis piezo nanopositioning systems with capacitive sensors
Axes	3	6
Processor	PC-based, 600 MHz, real-time operating system	PC-based, 600 MHz, real-time operating system
Sampling rate, servo-control	50 kHz	20 kHz
Sampling rate, sensor	50 kHz	20 kHz
Sensor		
Servo characteristics	P-I, two notch filters	P-I, two notch filters
Sensor type	Capacitive	Capacitive
Sensor channels	3	6
Sensor bandwidth (-3 dB)	5.6 kHz	5.6 kHz
Sensor resolution	16-bit	16-bit
Ext. synchronization	Yes	Yes
Amplifier		
Output voltage	-30 to +135 V	-30 to +135 V
Amplifier channels	4	8
Peak output power per channel	6 W	6 W
Average output power per channel	3.5 W	3.5 W
Peak current	140 mA	140 mA
Average current per channel	60 mA	60 mA
Current limitation	Short-circuit-proof	Short-circuit-proof
Resolution DAC	20-bit	20-bit
Interfaces and operation		
Communication interfaces	Ethernet, USB, RS-232	Ethernet, USB, RS-232
Piezo / sensor connector	Sub-D special	Sub-D special
Analog in/out	E-712.3CD: none E-712.3CDA: 4 x in, 4 x out (LEMO), ±10 V	E-712.6CD: none E-712.6CDA: 4 x in, 4 x out (LEMO), ±10 V
Digital in/out	MDR20; 2 x IN, 8 x OUT; TTL	MDR20; 2 x IN, 8 x OUT; TTL
Command set	PI General Command Set (GCS)	PI General Command Set (GCS)
User software	NanoCapture™, PIMikroMove®	NanoCapture™, PIMikroMove®
Software drivers	LabVIEW drivers, DLLs	LabVIEW drivers, DLLs
Supported functionality	Wave gen, trigger I/O	Wave gen, trigger I/O
Display	LEDs for OnTarget, Err, Power	LEDs for OnTarget, Err, Power
Linearization	4^{th} order polynomials, DDL option (Dynamic Digital Linearization)	4^{th} order polynomials, DDL option (Dynamic Digital Linearization)
Miscellaneous		
Operating temperature range	5 to 50 °C	5 to 50 °C
Overtemp protection	Max. 75 °C, deactivation of the piezo voltage output	Max. 75 °C, deactivation of the piezo voltage output
Mass	5.35 kg/5.53 kg	5.78 kg/5.96 kg
Dimensions	9,5" chassis, 236 x 132 x 296 mm + handles (47 mm length)	9,5" chassis, 236 x 132 x 296 mm + handles (47 mm length)
Power consumption	100 W max.	100 W max.
Operating voltage	90 to 240 VAC, 50-60 Hz	90 to 240 VAC, 50-60 Hz

E-500 · E-501 Modular Piezo Controller

Flexible System for Piezo Actuators and Nanopositioners

Configuration example: E-500 Chassis with optional modules: E-505 piezo amplifier (3 x), E-509.S servo-controller for SGS sensors, E-517.i3 24-bit interface / display module

Configuration example: E-501 chassis with optional modules: E-503 piezo amplifier, E-509.C2A servo-controller for capacitive position sensors, E-517.i3 24-bit interface / display module

- **Up to 3 Axes, Custom Systems up to 12 Axes and More**
- **Choice of Amplifier Modules for Low-Voltage and High-Voltage, 14 to 400 W Peak Power**
- **Choice of Position Servo Control Modules for SGS & Capacitive Sensors, 1 to 3 Channels**
- **Choice of PC Interface / Display Modules**
- **19- & 9½-Inch Chassis**

The E-500 modular piezo controller system offers a broad choice of control modules for nanopositoning systems and actuators. This includes piezo amplifier and position servo controller modules for up to three channels with different features as well as display and interface modules. Flexible configuration makes the system adaptable to a wide range of applications.

30-channel controller consisting of 3 E-500.621 chassis, each of which can accomodate up to 12 E-621 modules

E-500 systems are assembled to order, tested, and, if a servo-controller is present, calibrated with the associated piezo mechanics.

Remote Control via Computer Interface

Installing the E-517, computer interface/display module (see p. 2-156) with 24-bit resolution makes possible control from a host PC.

Optionally, digital control via an external D/A converter is possible. For several D/A boards from National Instruments, PI offers a corresponding LabVIEW driver set which is compatible with the PI General Command Set (GCS), the command set used by all PI controllers. A further option includes the patented HyperBit™ technology providing enhanced system resolution.

Two chassis are available:

The E-500.00 19'' rackmount chassis provides operating voltages for all compatible modules including amplifiers, servo-controllers, display and interface modules (see system configuration see p. 2-144).

Ordering Information

E-500.00
19"-Chassis for Modular Piezo Controller System, 1 to 3 Channels

E-501.00
9½"-Chassis for Modular Piezo Controller System, 1 to 3 Channels

E-500.ACD
LabVIEW Driver Set for Analog Controllers

E-500.HCD
HyperBit™ Functionality for Enhanced System Resolution (Supports Certain D/A Boards)

Ask about custom designs!

Technical Data

Model	E-500.00	E-501.00
Function	19"-Chassis for Piezo Controller System: Amplifier Modules, Sensor- / Servo-Control Modules, Interface / Display Modules	9.5"-Chassis for Piezo Controller System: Amplifier Modules, Sensor- / Servo-Control Modules, Interface / Display Modules
Channels	1, 2, 3 (up to 3 amplifier modules)	1, 3 (1 amplifier module)
Dimensions	450 x 132 x 296 mm + handles	236 x 132 x 296 mm + handles
Operating voltage	90–264 VAC, 50–60 Hz	90–120 / 220–264 VAC, 50–60 Hz
Max. power consumption	180 W	80 W

E-500 · E-501 Modular Piezo Controller

Module Survey & Ordering Information

A more compact 9½-inch version of the system is available as the E-501.00. It can hold one amplifier module (1- or 3-channel units available), one servo-control module (1- or 3-channel) and one display / interface module (1- or 3-channel).

A modified E-500 chassis for more channels is available on request. For systems with up to 12 channels, the E-500.621 chassis with E-621 amplifier / controller modules can be used (see p. 2-160).

The following modules can be installed in an E-500 / E-501 chassis:

Amplifier modules

E-503.00

Piezo Amplifier Module, -20 to 120 V, 3 Channels

E-504.00F

High-Power-Piezo Amplifier Module, 1 Channel, 280 W Peak Power, 100 W Average Power, -30 to 135 V

E-505.00

Piezo Amplifier Module, 200 W, -20 to 120 V, 1 Channel

E-508.00

HVPZT-Piezo Amplifier Module, +3 to +1100 V, 1 Channel

Sensor and Servo-Control Modules

E-509.C1A

Sensor / Piezo Servo-Control Module, Capacitive Sensor, 1 Channel

E-509.C2A

Sensor / Piezo Servo-Control Module, Capacitive Sensors, 2 Channels

E-509.C3A

Sensor / Piezo Servo-Control Module, Capacitive Sensors, 3 Channels

E-509.S1

Sensor / Piezo Servo-Control Module, SGS Sensor, 1 Channel

E-509.S3

Sensor / Piezo Servo-Control Module, SGS-Sensors, 3 Channels

E-509.E3 (see p. 2-152)

PISeca™ Sensor / Piezo Servo-Control Module for Single-Electrode Capacitive Sensor Probes, 3 Channels

E-509.E03 (see p. 2-152)

PISeca™ Modular Signal Conditioner Electronics for Single Electrode Capacitive Sensors, 3 Channels

Module for Servo-Control for External Piezo Amplifier

E-515.E3

In- / Output Module for Servo Control with External Piezo Amplifier, 3 Channels
Note: this module can only be used together with an E-509 servo controller module and is installed in the amplifier slot

Interface / Display Modules

E-517.i1

Interface / Display Module, 24-Bit D/A, TCP / IP, USB, RS-232, 1 Channel

E-517.i3

Interface / Display Module, 24-Bit D/A, TCP / IP, USB, RS-232, 3 Channels

E-515.01

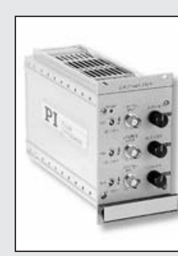
Display Module for Piezo Voltage and Displacement, 1 Channel

E-515.03

Display Module for Piezo Voltage and Displacement, 3 Channels

E-508, p. 2-150

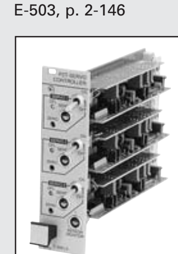
E-505, p. 2-147



E-503, p. 2-146

E-515, p. 2-154

E-517, p. 2-156



E-509, p. 2-152

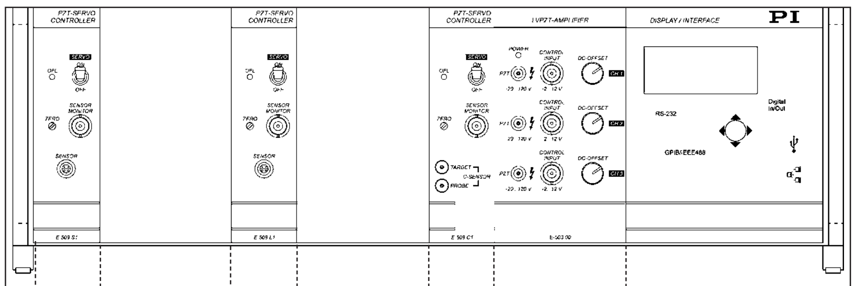
Linear Actuators & Motors
Nanopositioning / Piezoelectrics
Piezo Flexure Stages / High-Speed Scanning Systems
Linear
Vertical & Tip/Tilt
2- and 3-Axis
6-Axis
Fast Steering Mirrors / Active Optics
Piezo Drivers / Servo Controllers
Single-Channel
Multi-Channel
Modular
Accessories
Piezoelectrics in Positioning
Nanometrology
Micropositioning
Index

E-500 · E-501 Modular Piezo Controller

System Configuration

E-500, 19″ Chassis Models

E-501, 9.5″ Chassis



E-500 chassis with the following optional modules: E-503 LVPZT amplifier, three E-509 piezo servo-controllers (E-509.S1: strain gauge; E-509.C1A: capacitive sensor) and DAC interface/display.

	Contr. Slot 3	Amplifier Slot 3	Contr. Slot 2	Amplifier Slot 2	Contr. Slot 1	Amplifier Slot 1	Display/ Interface Slot
Installable Amplifier Modules							
E-503.00 (-20 to 120 V, 3 ch) / E-503.00S*							
E-504.00 (-30 to 135 V, 1 ch) / E-504.00S*							
E-505.00 (-20 to 120 V, 1 ch) / E-505.00S*							
E-508.XX (+3 to 1100 V, 1 ch)							
Installable Sensor & Position Servo-Control Modules							
E-509.C1A (Capacitive, 1 ch)							
E-509.S1 (SGS, 1 ch)							
E-509.C2A (Capacitive, 2 ch)							
E-509.C3A (Capacitive, 3 ch)							
E-509.S3 (SGS, 3 ch)							
Installable Display/Interface Modules							
E-515 (1 / 3 ch)							
E-517 (1 / 3 ch)							
Minimal Configuration, Piezo Amplifier Function only							
Extended Configuration, Piezo Amplifier with additional Position Servo-Controller							
Extended Configuration, Piezo Amplifier with additional Display/Interface, no Servo-Controller							
Extended Configuration, Piezo Amplifier with additional Servo-Controller and Display/Interface							

Can be installed in E-500   Can be installed in E-501 or E-500

* For differential tip/tilt systems with one fixed voltage of +100 V.

Configuration Examples

- **Low-Voltage Piezo Amplifiers, 3 Channels (14 W), Medium Dynamics, No Display:**

  1 x E-501.00
  9½"-Chassis for Modular Piezo Controller System, 1 to 3 Channels

  1 x E-503.00
  Piezo Amplifier Module, -20 to 120 V, 3 Channels

- **High-Voltage Piezo Amplifier for PICA™, 3 Channels, with PC Interface and Display:**

  1 x E-500.00
  19"-Chassis for Modular Piezo Controller System, 1 to 3 Channels

  3 x E-508.00
  HVPZT-Piezo Amplifier Module, +3 to +1100 V, 1 Channel

  1 x E-517.i3
  Interface / Display Module, 24 Bit D/A, TCP/IP, USB, RS-232, 3 Channels

- **High-Voltage Piezo Amplifier / Servo-Controller (Strain Gauge Sensors), 3 Channels, with PC Interface and Display:**

  1 x E-500.00
  19"-Chassis for Modular Piezo Controller System, 1 to 3 Channels

  3 x E-508.00
  HVPZT-Piezo Amplifier Module, +3 to +1100 V, 1 Channel

  1 x E-509.S3
  Sensor / Piezo Servo-Control Module, SGS-Sensors, 3 Channels

  1 x E-517.i3
  Interface / Display Module, 24 Bit D/A, TCP/IP, USB, RS-232, 3 Channels

- **Position Feedback Control of a P-734.2CL XY Nanopositioning Stage (Capacitive Position Sensors), Minimum Response Time, Analog Control:**

  1 x E-500.00
  19"-Chassis for Modular Piezo Controller System, 1 to 3 Channels

  2 x E-505.00
  Piezo Amplifier Module, 200 W, -20 to 120 V, 1 Channel

  1 x E-509.C2A
  Sensor / Piezo Servo-Control Module, Capacitive Sensors, 2 Channels

- **Position Feedback Control of a P-733.2CL XY Nanopositioning Stage (Capacitive Position Sensors) and P-721.CLQ PIFOC® Objective Positioner (Capacitive Position Sensor), Medium Dynamics, PC Control, Compact Design:**

  1 x E-501.00
  9½"-Chassis for Modular Piezo Controller System, 1 to 3 Channels

  1 x E-503.00
  Piezo Amplifier Module, -20 to 120 V, 3 Channels

  1 x E-509.C3A
  Sensor / Piezo Servo-Control Module, Capacitive Sensors, 3 Channels

  1 x E-517.i3
  Interface / Display Module, 24 Bit D/A, TCP/IP, USB, RS-232, 3 Channels

- **Position Feedback Control of a S-325 Tip/Tilt Platform (Strain Gauge Sensors), Minimum Response Time, Analog Control:**

  1 x E-500.00
  19"-Chassis for Modular Piezo Controller System, 1 to 3 Channels

  2 x E-505.00
  Piezo Amplifier Module, 200 W, -20 to 120 V, 1 Channel

  1 x E-505.00S
  Offset Voltage Supply for Tip/Tilt Systems, One Fixed Voltage of +100 V

  1 x E-509.S3
  Sensor / Piezo Servo-Control Module, SGS-Sensors, 3 Channels

- **Position Feedback Control of a P-733.2CL XY Nanopositioning Stage (Capacitive Position Sensors) and a P-721.SL2 PIFOC® Objective Positioner (Strain Gauge Position Sensor), Minimum Response Time, Analog Control:**

  1 x E-500.00
  19"-Chassis for Modular Piezo Controller System, 1 to 3 Channels

  3 x E-505.00
  Piezo Amplifier Module, 200 W, -20 to 120 V, 1 Channel

  1 x E-509.C2A
  Sensor / Piezo Servo-Control Module, Capacitive Sensors, 2 Channels

  1 x E-509 .S1
  Sensor / Piezo Servo-Control Module, SGS Sensor, 1 Channel

- **Position Feedback Control of 3 P-841.10 Piezo Translators (Strain Gauge Position Sensors), Medium Dynamics, Analog Control, with Future Upgrade Option for High-Power, High-Dynamics Amplifiers E-505 (Large Chassis):**

  1 x E-500.00
  19"-Chassis for Modular Piezo Controller System, 1 to 3 Channels

  1 x E-503.00
  Piezo Amplifier Module, -20 to 120 V, 3 Channels

  1 x E-509.S3
  Sensor / Piezo Servo-Control Module, SGS-Sensors, 3 Channels

  Option:

  1 x E-515.03
  Display Module for Piezo Voltage and Displacement, 3 Channels

E-503 Piezo Amplifier Module

3 Channels, for E-500 Piezo Controller System

E-503.00 Piezo amplifier module

- **Module for E-500 Piezo Controller Rack**
- **3 x 14 W Peak Power**
- **Output Voltage Range -20 to 120 V**
- **Prepared for Position Servo-Control Upgrade (optional)**
- **Prepared for Interfaces / Display Modules (optional)**

The E-503 is a piezo driver module for low-voltage piezo actuators and positioners. It contains three independent amplifiers that can output and sink a peak current of 140 mA in the -20 to 120 V voltage range. For frequency response with selected capacitive loads, see graph below. The piezo amplifier module is designed to work in the E-500 Controller system (see p. 2-142).

The units are designed to provide high-resolution operation of piezo actuators and positioning systems in voltage-controlled mode (open-loop) and optionally in position-controlled mode (closed-loop).

Modular Design for Flexibility: Optional Servo Controller Upgrade

The E-503 amplifier module can be installed in the E-500 / E-501 controller chassis. The modular design makes the E-500 piezo controller system very flexible. An optional E-509 piezo servocontroller module can be installed along with the E-503 amplifier module, for closed-loop piezo position control. In this configuration, the E-503 output voltage is set by the servo-control loop.

Voltage Controlled Piezo Positioning

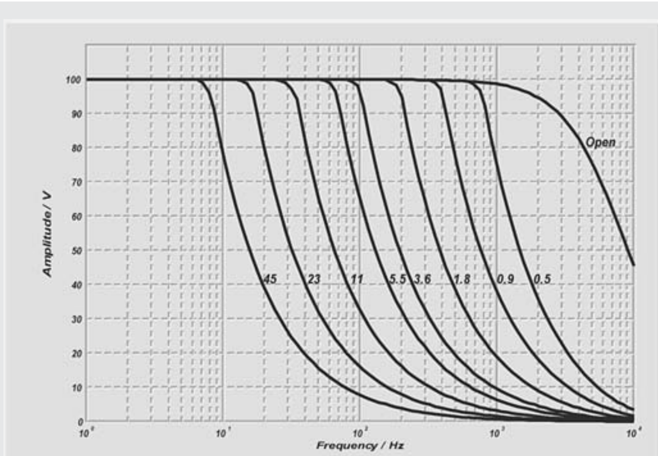
In open-loop (voltage-controlled) piezo operation the amplifier output voltage is determined by an analog signal at the Control Input optionally combined with the DC-offset potentiometer. Open-loop operation is ideal for applications where fast response and very high resolution with maximum bandwidth are essential. Here, commanding and reading the target position in absolute values is either not important or carried out by external position sensors. The precision 10-turn potentiometer can also be used alone to set the output voltage manually.

Bestellinformation

E-503.00
Piezo Amplifier Module,
-20 to 120 V, 3 Channels

E-503.00S
Piezo Amplifier Module,
-20 to 120 V, 3 Channels,
Modified E-503.00 for S-330, S-334, S-340 Tip/Tilt Systems, with
One Fixed Voltage of +100 V,
Two Variable Voltages

Ask about custom designs



E-503: operating limits with various PZT loads (open-loop), capacitance is measured in µF

Technical Data

Model	E-503.00	E-503.00S
Function	Power amplifier	Power amplifier
Channels	3	2
Amplifier		
Control input voltage range	-2 to +12 V	-2 to +12 V
Output voltage	-20 bis 120 V	-20 bis 120 V; one additional fixed voltage of +100 V
Peak output power per channel	14 W	14 W
Average output power per channel	6 W	6 W
Peak current per channel, <5 ms	140 mA	140 mA
Average current per channel, >5 ms	60 mA	60 mA
Current limitation	Short-circuit-proof	Short-circuit-proof
Voltage gain	10 ±0.1	10 ±0.1
Input impedance	100 kΩ / 1 nF	100 kΩ / 1 nF
Interfaces and operation		
Piezo connector	LEMO ERA.00.250.CTL	LEMO ERA.00.250.CTL
Analog input	BNC	BNC
DC Offset	10-turn pot., adds 0 to 10 V to Control In	10-turn pot., adds 0 to 10 V to Control In
Miscellaneous		
Operating temperature range	5 to 50 °C	5 to 50 °C
Overheat protection	Deactivation at 85 °C	Deactivation at 85 °C
Dimensions	14HP/3U	14HP/3U
Mass	0.9 kg	0.9 kg
Operating Voltage	E-500 System	E-500 System
Max. power consumption	30 W	30 W

E-505 Piezo Amplifier Module

High Power, E-500 Piezo Controller System

E-505.00 is a high-performance amplifier module for the piezo servo-controller system E-500

- **200 W Peak Power**
- **Output Voltage Range -20 to 120 V**
- **Module for E-500 Piezo Controller Rack**
- **Prepared for Position Servo-Control Upgrade (optional)**
- **Prepared for Interfaces / Display Modules (optional)**

The E-505 piezo amplifier module is designed to work in the E-500 Controller system (see p. 2-142). It features a low-noise, high-power amplifier for low-voltage piezo actuators and positioners, that can output and sink a peak current of up to 2000 mA in the -20 to 120 V voltage range. The E-505 units are designed to provide high-resolution operation of piezo actuators and positioning systems in voltage-controlled mode (open-loop) and optionally in position-controlled mode (closed-loop). For switching applications the E-505.10 version provides a peak output current of up to 10 A.

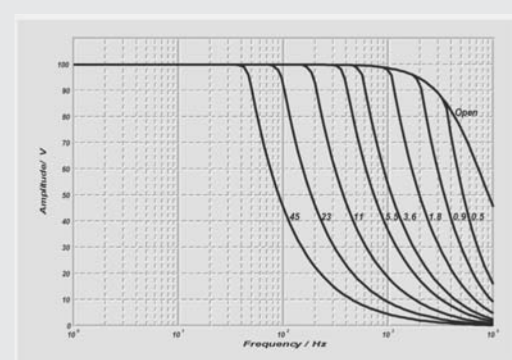
For frequency response with selected capacitive loads, see graph below.

Ordering Information

E-505.00
Piezo Amplifier Module, 200 W, -20 to 120 V, 1 Channel

E-505.10
Piezo Amplifier Module for Switching Applications, 1000 W, -20 to 120 V, 1 Channel

E-505.00S
Offset Voltage Supply for Tip/Tilt Systems, One Fixed Voltage of +100 V



E-505: operating limits with various PZT loads (open-loop), capacitance is measured in µF

Technical Data

Model	E-505.00	E-505.10	E-505.00S
Function	Power amplifier	Power Amplifier for Switching Applications*	Offset Voltage Supply for Tip/Tilt Systems
Channels	1	1	1
Amplifier			
Control input voltage range	-2 to +12 V	-2 to +12 V	–
Output voltage	-20 to +120 V	-20 to +120 V	100 V
Peak output power	200 W (<5 ms)	1000 W (<200 µs)	200 W (<5 ms)
Average output power	30 W	30 W	30 W
Peak current	2 A (<5 ms)	10 A (<200 µs)	2 A (<5 ms)
Average current	300 mA	300 mA	300 mA
Current limitation	Short-circuit-proof	Short-circuit-proof	Short-circuit-proof
Noise, 0 to 100 kHz	<0.7 mVrms	1.0 mVrms	<0.7 mVrms
Voltage gain	12 ±0.1	12 ±0.1	–
Input impedance	1 MΩ / 1 nF	1 MΩ / 1 nF	–
Interfaces and operation			
Piezo connector	LEMO ERA.00.250.CTL	LEMO ERA.00.250.CTL	LEMO ERA.00.250.CTL
Analog input	BNC	BNC	–
DC-Offset	10-turn pot., adds 0 to 10 V to Control In	10-turn pot., adds 0 to 10 V to Control In	–
Miscellaneous			
Operating temperature range	+5 to +50 °C	+5 to +50 °C	+5 to +50 °C
Overheat protection	Deactivation at +85 °C	Deactivation at +85 °C	Deactivation at +85 °C
Dimensions	14HP/3U	14HP/3U	14HP/3U
Mass	0.9 kg	0.9 kg	0.9 kg
Operating Voltage	E-500 System	E-500 System	E-500 System
Max. power consumption	45 W	45 W	45 W

* For piezo actuators with special high-current layout

Modular Design for Flexibility: Optional Servo Controller Upgrade

Up to three E-505 amplifier modules can be installed in one E-500 chassis. The flexible, modular design of the E-500 piezo servo-controller system allows easy installation of an optional E.509 sensor- / servo-controller module for closed-loop operation. The output voltage is then set by the servo-control loop. Closed-loop piezo mechanics from PI can provide positioning accuracy and repeatability down to the nanometer range and below.

E-504 Piezo Amplifier Module

High Power through Energy Recovery, E-500 Piezo Controller System

E-504.00F High-power amplifier module with energy recovery

- Peak Power 280 W
- High Average Output Power 100 W
- Very Energy Efficient Through Energy Recovery
- Output Voltage Range -30 to 135 V
- Module for E-500 Piezo Controller Rack
- Prepared for Position Servo-Control Upgrade (optional)
- Prepared for Interface / Display Modules (optional)

The E-504 power amplifier extends the E-500 modular piezo controller system with a high-output amplifier for low-voltage actuators and positioners.

The innovative, efficient energy recovery circuitry reduces power consumption and heat dissipation, especially in dynamic applications. This makes possible peak output currents up to 2000 mA and a peak power of 280 W, with an average output power of up to 100 W.

Working Principle

Charge is transferred to the piezo actuator using low-loss PWM techniques. When the actuator is discharged, the energy not consumed is fed through the energy recovery circuitry for reuse in the next charging cycle.

The working principle of the E-504 series is perfectly qualified for high-dynamics scanning and switching applications. For applications where static position stability in the sub-nanometer range is essential, the E-505 (see p. 2-147) amplifier module is recommended.

Modular Design for Flexibility: Optional Servo-Controller Upgrade

Up to three E-504 amplifier modules can be installed in one E-500 controller chassis. The flexible, modular design of the E-500 piezo controller system allows easy installation of an optional E-509 sensor- / servo-controller module for closed-loop operation. The output voltage of the E-504 is then set by the servo-control loop. Closed-loop piezo mechanics from PI can provide positioning accuracy and repeatability down to the nanometer range and below.

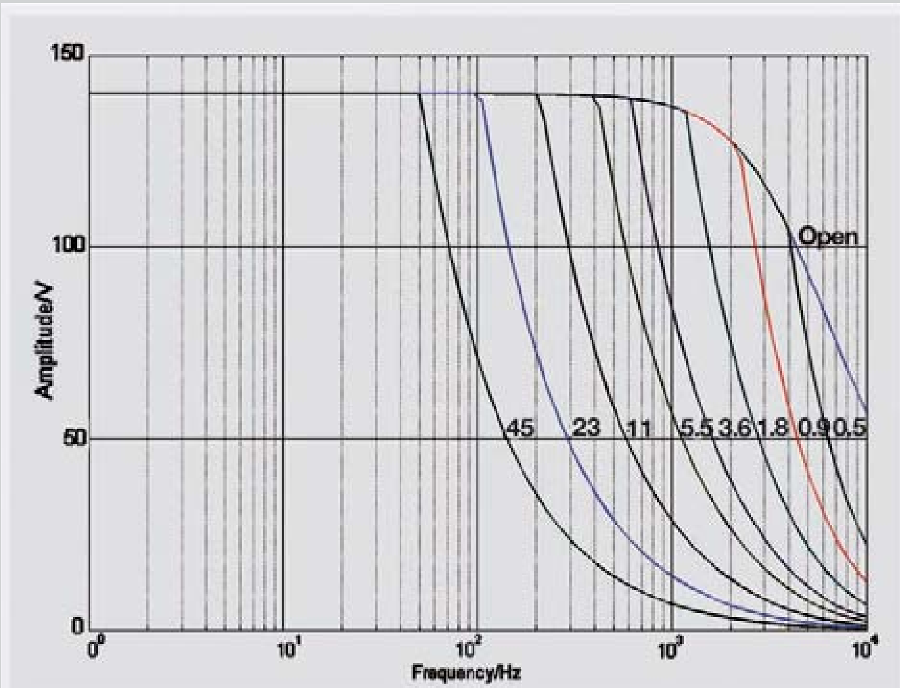
Open-Loop Operation

In open-loop (voltage-controlled) piezo operation the amplifier output voltage is determined by an analog signal at the Control Input, optionally combined with the DC-offset potentiometer. Open-loop operation is ideal for applications where fast response and very high resolution with maximum bandwidth are essential. Here, commanding and reading the target position in absolute values is either not important or carried out by external position sensors. The precision 10-turn potentiometer can also be used alone to set the output voltage manually.

The same functionality and specifications are available in the E-617 amplifier module. (see p. 2-112).

Ordering Information

E-504.00F
High-Power-Piezo Amplifier Module, 1 Channel, 280 W Peak Power, 100 W Average Power, -30 to 135 V



E-504: operating limits with various PZT loads (open-loop), capacitance is measured in µF

Technical Data

Model	E-504.00F
Function	Power amplifier with energy recovery, 1 channel
Amplifier	
Control input voltage range	-2.5 to +12 V
Output voltage	-30 V to 135 V
Peak output power <5 ms	280 W
Average output power	Equivalent to 100 W reactive power
Peak output current <5 ms	2000 mA
Average current	1000 mA
Current limitation	Short-circuit-proof
Voltage gain	12 ±0.1
Ripple, noise, 0 to 10 kHz	5 mV_{RMS} 20 mV_{P-P}
Output impedance	0,5 Ω / 2,5 µF
Interfaces and operation	
Piezo connector	LEMO ERA.00.250.CTL
Analog input	SMB
DC-Offset	10-turn pot., adds 0 to +10 V to Control In
Miscellaneous	
Operating temperature range	+5 to +50°C
Dimensions	One 14T slot wide, 3H high
Mass	0.9 kg
Operating voltage	E-500 System
Max. power consumption	<30 W

Piezo • Nano • Positioning

E-506 Linearized Piezo Amplifier

Charge Control for High Dynamics

E-506.10 charge-controlled Piezo driver module

Ordering Information

E-506.10
High Linearity Piezo Amplifier Module, 30 W Average Output Power, -30 to 130 V, 1 Channel

Ask about custom designs!

- **Highly Linear Amplifier Module**
- **280 W Peak Power**
- **Output Voltage Range -30 to 130 V**
- **Module for E-500 Piezo Controller Rack**
- **Prepared for Position Servo-Control Upgrade (optional)**
- **Prepared for Interfaces / Display Modules (optional)**

The E-506.10 piezo amplifier module uses a charge control principle. Here, the input signal controls the amount of electrical charge which is transferred to the piezo actuator. The result is a highly precise, linear displacement of the piezo actuator in high-dynamics operation.

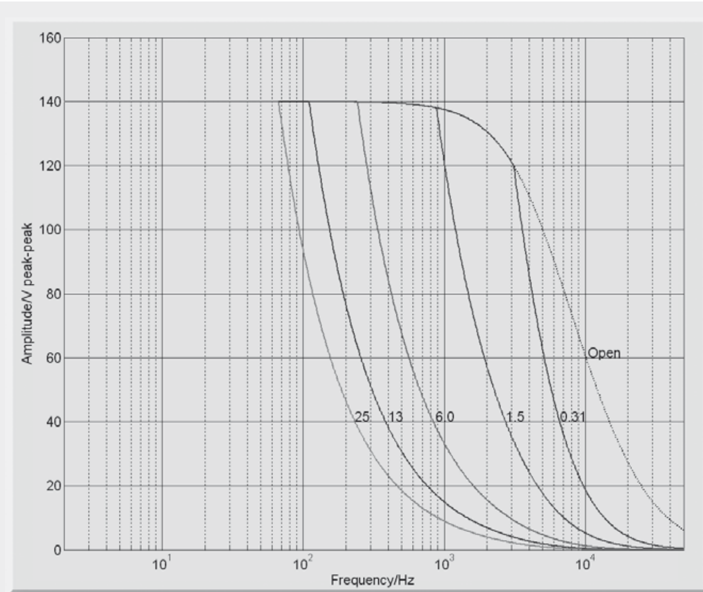
The typical hysteresis which piezo actuators show when operated with a voltage-controlled piezo amplifier can such be reduced to 2 % only. An additional position feedback is not required.

The E-506.10 piezo amplifier module is designed to work in the E-500 Controller system (s. p. 2-142). It features a low-noise high-power amplifier for low-voltage piezo actuators and positioners, that can output and sink a peak current of up to 2A in the -30 to 130 V voltage range.

Piezo Over Temperature Protection

The E-506 can evaluate a temperature sensor on the piezo actuator in order to protect the actuators, especially when used in dynamic applications. Automatic switch-off then reliably prevents the pre-set temperature threshold from being exceeded.

For frequency response with selected capacitive loads, see graph below.



E-506.10: operating limits with various PZT loads (open-loop), capacitance is measured in µF.
The minimum capacitive load is 0.3 µF

Technical Data

Model	**E-506.10**	
Function	Linearised amplifier module, charge-controlled	
Channels	1	
Amplifier		
Input voltage	-2 to +12 V	
Output voltage*	-30 to 130 V	
Peak output power, < 2.5 ms	280 W	max.
Average output power	30 W	max.
Peak current, < 2.5 ms	2 A	
Average current	215 mA	
Current limitation	Short-circuit-proof	
Ripple, noise	<0.6 mV_{rms}	
Reference capacitance (adjustable)	1 to 280 µF	
Input impedance	1 MΩ / 1 nF	
Interfaces and operation		
Piezo connector (voltage output)	LEMO 2-pin EGG.0B.302.CLL	
Analog input	BNC	
DC Offset	10-turn pot., adds 0 to 10 V to Control In	
Piezo temperature sensor (input)	PT 1000; LEMO socket; deactivation of the piezo voltage output at 150°C	
Miscellaneous		
Operating temperature range	+5 to +50 °C	
Dimensions	14HP / 3U	
Mass	0.9 kg	
Operating voltage	E-500 System	
Power consumption	55 W	max.

* Max. 85 °C, deactivation of the piezo voltage output (internal overtemp protection)

Minimum frequencies* for charge-controlled operation

Capacitance (piezo actuator)	**ftrans**
0.33 µF	250 mHz
1.06 µF	80 mHz
6.2 µF	9 mHz
14 µF	4 mHz

* Voltage-controlled operation for lower frequencies

E-508 PICA™ Piezo Amplifier Module

High-Power Module with 1100 V Output Voltage, E-500 Piezo Controller System

E-508.00 Piezo amplifier plug-in module

- Peak Power up to 400 W
- Output Voltage Range 3 to ±1100 V or bipolar
- Plug-In Module for E-500 System
- E-508.OE for Switching Applications
- Prepared for Position Servo-Control Upgrade (optional)
- Prepared for Interfaces / Display Modules (optional)

The E-508 plug-in module is a piezo driver / amplifier for the E-500 / E-501 piezo controller systems suitable for PICA™ piezo actuators (HVPZT). Its low-noise, 4-quadrant amplifiers can output and sink peak currents of 50 mA (E-508.OE: up to 400 mA) over an 1100 V range. The units are designed to provide high-resolution operation of piezo actuators and positioning systems in voltage-controlled mode (open-loop) and optionally in position-controlled mode (closed-loop).

Modular Design for Flexibility: Optional Servo Controller Upgrade

Up to three E-500 piezo amplifier modules can be installed in one E-500 chassis. The flexible, modular design of the E-500 piezo controller system allows easy installation of an optional E.509 sensor- / servo-controller module for closed-loop operation. The output voltage is then set by the servo-control loop. Closed-loop piezo mechanics from PI can provide positioning accuracy and repeatability down to the nanometer range and below.

Voltage Controlled Piezo Positioning

In open-loop (voltage-controlled) piezo operation the amplifier output voltage is determined by an analog signal at the Control Input optionally combined with the DC-offset potentiometer. Open-loop operation is ideal for applications where fast response and very high resolution with maximum bandwidth are essential. Here, commanding and reading the target position in absolute values is either not important or carried out by external position sensors (see p. 2-104). The precision 10-turn potentiometer can also be used alone to set the output voltage manually.

OEM Version for Fast Switching Applications

The E-508.OE is the high-current OEM version, especially designed for switching applications. It can output a peak current of 400 mA for 5 ms. The E-508.OE is directly controlled by an analog signal.

For extensions, adapter cables and connectors, see "Accessories" in the piezo electronics chapter (see p. 2-168 *ff*).

Ordering Information

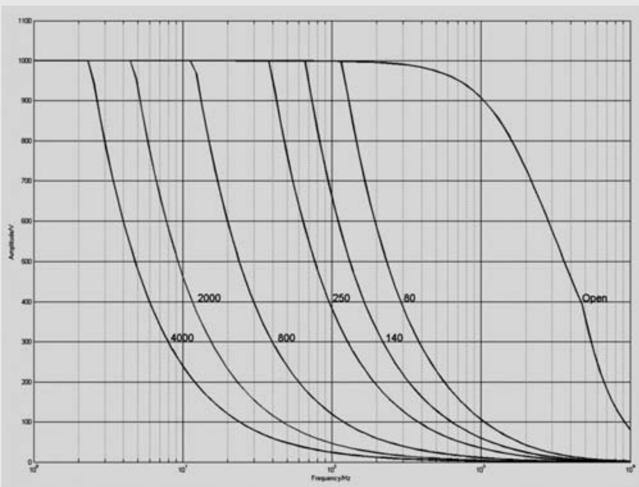
E-508.00
HVPZT Piezo Amplifier Module, +3 to +1100 V, 1 Channel

E-508.OE
HVPZT Piezo Amplifier Module, OEM Version, 400 mA Peak Current

Ask about custom designs!

The E-508.00 plug-in module (right) and the E-508.OE, OEM module optimized for switching applications

Linear Actuators & Motors
Nanopositioning / Piezoelectrics
Piezo Flexure Stages / High-Speed Scanning Systems
Linear
Vertical & Tip/Tilt
2- and 3-Axis
6-Axis
Fast Steering Mirrors / Active Optics
Piezo Drivers / Servo Controllers
Single-Channel
Multi-Channel
Modular
Accessories
Piezoelectrics in Positioning
Nanometrology
Micropositioning
Index



E-508: operating limits with various PZT loads (open-loop), capacitance is measured in nF

Technical Data

Model	E-508.00	E-508.OE	Unit
Function	Power amplifier for PICA™ high-voltage piezos	Power amplifier for PICA™ high-voltage piezos	
Amplifier			
Output voltage	3 to +1100 (Standard) (-260 to +780 -550 to +550 +260 to -780 -3 to -1100) (jumper selectable)	3 to +1100 (Standard) (-260 to +780 -550 to +550 +260 to -780 -3 to-1100) (factory-settable)	V
Amplifier channels	1	1	
Average output power	13	13	W
Peak output power, <5 ms	50	400	W
Average current	12	12	mA
Peak current, <5 ms	50	400	mA
Amplifier bandwidth, small signal	6	10	kHz
Amplifier bandwidth, large signal	50 (200 nF)	50 (200 nF)	Hz
Ripple, noise 0 to 100 kHz	5 50 (100 nF)	20 200 (100 nF)	mV_{RMS} mV_{P-P}
Current limitation	Short-circuit-proof	Short-circuit-proof	
Voltage gain	+100 ±1, -100 ±1 (selectable)	+100 ±1, -100 ±1 (selectable)	
Control input voltage	Servo off: ±1/100 of selected output range Servo on: 0 to 10 V	Servo off: ±1/100 of selected output range Servo on: 0 to 10 V	
Input impedance	100	100	kΩ
Interfaces and operation			
Piezo voltage output	LEMO EGG.0B.701.CJL.1173	LEMO EGG.0B.701.CJL.1173	
Input	BNC	SMB	
DC-Offset	10-turn pot., adds 0 to 10 V to Control In	–	
Miscellaneous			
Operating voltage	E-500 System	E-500 System	
Operating temperature range	+5 to +50 °C (10 % derated over 40 °C)	+5 to +50 °C (10 % derated over 40 °C)	°C
Mass	0.75	0.75	kg
Dimensions	14 HP/3 U	14 HP/3 U	

E-509 Signal Conditioner / Piezo Servo Module

3-Channel Servo-Controller Module for E-500 Piezo Controller System

E-509 3-channel servo-controller module for nanopositioning systems with strain gauge sensors

Ordering Information

E-509.C1A
Sensor / Piezo Servo-Control Module, Capacitive Sensor, 1 Channel

E-509.C2A
Sensor / Piezo Servo-Control Module, Capacitive Sensors, 2 Channels

E-509.C3A
Sensor / Piezo Servo-Control Module, Capacitive Sensors, 3 Channels

E-509.S1
Sensor / Piezo Servo-Control Module, SGS Sensor, 1 Channel

E-509.S3
Sensor / Piezo Servo-Control Module, SGS-Sensors, 3 Channels

Ask about custom designs!

- **Position Servo-Control for Piezo Mechanics with SGS or Capacitive Sensors**
- **1-, 2- and 3-Channel Versions**
- **Improves Linearity**
- **Eliminates Drift and Hysteresis**
- **Notch Filter for Higher Bandwidth**
- **Increases Piezo Stiffness**
- **ILS Circuitry Maximizes Capacitive Sensor Linearity**
- **Plug-In Module for E-500 System**
- **Prepared for Interfaces / Display Modules (optional)**

The E-509 module is both a signal conditioner for high-resolution capacitive and SGS displacement sensors and a servo-controller for closed-loop piezo nanopositioning mechanics. It compensates for the drift and hysteresis inherent in PZT materials and quickly adjusts the operating voltage on the PZT as soon as a change in force or load occurs. Single- and multi-channel versions for strain gauge and capacitive sensors are available.

Nanometer-Precise Piezo Positioning

The proportional-integral (P-I) algorithm used by the E-509 servo-controller is optimized for piezo operation. Both P and I parameters as well as the control bandwidth can be set internally. The integrated notch filters (adjustable for each axis) improve the stability and allow high-bandwidth operation closer to the piezomechanics' resonant frequency. Closed-loop piezo mechanics from PI can provide positioning accuracy and repeatability down to the nanometer range and below.

Two Types of Sensors

PI employs proprietary position sensors for fast response and optimum positioning resolution and stability in the nanometer range and below. For high-end applications, capacitance sensors provide direct and non-contact position feedback (direct metrology). Strain gauge sensors (SGS) are available for cost-effective applications.

For PISeca™ single-plate high-resolution capacitive sensors (see p. 3-8), the E-509.E3 or E-509.E03 versions are available (see p. 2-152).

The E-509 controller module installed in an E-501 9½-inch chassis together with E-516 digital interface and E-503 three-channel amplifier modules

Technical Data

Model	E-509.C1A/E-509.C2A/E-509.C3A	E-509.S1/E-509.S3
Function	Signal conditioner & servo-controller for piezo mechanics	Signal conditioner & servo-controller for piezo mechanics
Channels	1/2/3	1/3
Sensor		
Servo characteristics	P-I (analog), notch filter	P-I (analog), notch filter
Sensor type	Capacitive	SGS
Sensor channels	1 / 2 /3	1 / 3
Sensor bandwidth	0.3 to 3 kHz (selectable with jumper); up to 10 kHz on request	0.3; 1; 3 kHz
Noise factor	0.115 ppm/Hz½	
Thermal drift	<0.3 mV / C°	<3 mV / C°
Linearity	<0.05%	<0.2%
Interfaces and operation		
Sensor connection	LEMO EPL.00.250.NTD	LEMO ERA.0S.304.CLL
Sensor monitor output	0–10 V	0–10 V
Sensor monitor socket	LEMO 6-pin FGG.0B.306.CLAD56	BNC (1-ch.) / 3-pin. LEMO (3-ch.)
Supported functionality	ILS (Integrated Linearization System)	ILS (Integrated Linearization System)
Display	Overflow LED	Overflow LED
Miscellaneous		
Operating temperature range	+5 to +50 °C	+5 to +50 °C
Dimensions	7HP/3U	7HP/3U
Mass	0.35 kg	0.35 kg
Operating Voltage	E-500 System	E-500 System
Max. power consumption	4 to 8 W	4 to 8 W

E-515 Display Module for Piezo Controllers

Voltage and Displacement Display for E-500 Piezo Controller System

The E-515.03 displays piezo voltage or displacement for up to three channels

Ordering Information

E-515.01
Display Module for Piezo Voltage and Displacement, 1 Channel

E-515.03
Display Module for Piezo Voltage and Displacement, 3 Channels

- **3½-digit Display for Voltage and Position**
- **1- & 3-Channel Versions**
- **Plug-In Module for E-500 System**

The E-515.01 and E-515.03 are one and three channel display modules for piezo voltage and displacement data. Toggle switches for each channel select voltage or displacement mode. The voltage/displacement range for each channel is internally set by jumpers and trimmers.

The display module is designed to work in the E-500 piezo controller system (see p. 2-142).

Technical Data

Model	E-515.01	E-515.03
Function	Display Module for Piezo Voltage and Position	Display Module for Piezo Voltage and Position
Channels	1	3
Display linearity	0.1%	0.1%
Display	1 x 3½ digits	3 x 3½ digits
Dimensions	21HP/3U	21HP/3U
Mass	0.3 kg	0.3 kg
Operating voltage	E-500 System	E-500 System

E-515.E3 Servo In-/Output Module

Servo Control with External Piezo Amplifier, E-500 Piezocontroller System

The E-515.E3 plug-in module makes analog in- and output lines available on the front panel

Ordering Information

E-515.E3
In- / Output Module for Servo Control with External Piezo Amplifier, 3 Channels

- **Servo Control Connection for up to 3 External Piezo Amplifiers**
- **For Use with E-509 Servo-Controller in E-500 or E-501 Rack**
- **Easy-To-Use BNC Connectors**
- **High-Resolution, 10-Turn, DC-Offset Potentiometers**

The E-515.E3 servo in/out module allows easy connection of up to 3 external piezo amplifiers to an E-509 position servo-controller module, when installed in the modular E-500 or E-501 piezo controller rack.

BNC connections for control input and servo output (to the amplifier) are available on the front panel.

The analog control input signals can be shifted manually by 0 to 10 V with a high-resolution 10-turn, DC-offset potentiometers.

Together with the E-509 sensor & servo controller module positioning accuracy and repeatability down to the sub-nanometer range is possible, depending on the piezo mechanics and amplifier used.

Interface for Computer Control

Installing the E-517, computer interface/display module with 24-bit resolution makes possible control from a host PC.

Optionally, digital control via a D/A converter is possible. For several D/A boards from National Instruments, PI offers a corresponding LabVIEW™ driver set which is compatible with the PI General Command Set (GCS), the command set used by all PI controllers. A further option includes the patented Hyperbit™ technology providing enhanced system resolution.

Technical Data

Models	E-515.E3
Function	In- / Output Module for Servo Control with External Piezo Amplifier, 3 Channels
Control input voltage range	0 to 10 V in closed-loop operation with E-509
Servo Output Voltage Range	-2 to 12 V
Bandwidth	10 kHz
Current limitation	Short-circuit-proof
Input impedance	10 kΩ/1 nF
Interfaces and operation	
Control input sockets	3 x BNC
Servo-control output socket	3 x BNC
DC offset	3 x 10-turn pot., adds 0 to +10 V to Control In
Miscellaneous	
Operating voltage	E-500 system
Operating temperature range	+5 to +50 °C
Mass	280 g
Dimensions	One 7T slot wide, 3H high

E-517 Digital Piezo Controller Operation Module

Wave Generator, Data Recorder, Display, Multiple Interfaces, for E-500 System

The E-517 piezo display and D/A converter module, provides USB and TCP/IP connectivity

- Low-Noise 24-bit D/A Converter
- Sample Rate 25 kHz
- TCP/IP, USB, IEEE 488 and RS-232 Interfaces
- 6-Digit Display for Voltage and Position
- 1- & 3-Channel Versions
- Wave Generator with Programmable Trigger-I/O
- Module for E-500 Piezo Controller Rack

Ordering Information

E-517.i1
Interface / Display Module,
24 Bit D/A, TCP/IP, USB, RS-232,
Single Channel

E-517.i3
Interface / Display Module,
24 Bit D/A, TCP/IP, USB, RS-232,
3 Channels

Ask about custom designs!

The E-517 is a microprocessor controlled interface and display module for the E-500 piezo controller system (see p. 2-142). It is equipped with low-noise, 24-bit D/A converters and can be controlled through four digital interfaces: TCP/IP, USB, RS-232 and IEEE 488 (GPIB).

Alternatively, stand-alone operation is possible by uploading macro command sequences to the internal non-volatile memory. For manual control a trackball interface is provided. An LCD display indicates position or operating voltages of the individual channels / axes.

Wave Generator

The integrated wave generator can output periodic motion profiles. In addition to sine and triangle waves, arbitrary, user-defined motion profiles can be created and stored.

Extensive Software Support

The controllers are delivered with Windows operating software. Comprehensive DLLs and LabVIEW drivers are available for automated control.

Technical Data

Model	E-517.i1	E-517.i3
Function	Digital operation module	Digital operation module
Channels	1	3
Processor	DSP 60 MHz	DSP 60 MHz
Sampling rate, sensor	25 kHz, 8-times oversampling	25 kHz, 8-times oversampling
Thermal drift	Stability: 0.2 mV	Stability: 0.2 mV
Linearity @ nominal range	0.01 %	0.01 %
Resolution	DAC: 24 bit, ±12 V ADC: 18 bit, sampling	DAC: 24 bit, ±12 V ADC: 18 bit, sampling
Interfaces and operation		
Interfaces/communication	Ethernet (TCP/IP), USB, RS-232, IEEE 488	Ethernet (TCP/IP), USB, RS-232, IEEE 488
I/O ports	1 trigger input 1 trigger output 5 V MDR14 connector	3 trigger inputs 3 trigger outputs 5 V MDR14 connector
Command set	PI General Command Set (GCS)	PI General Command Set (GCS)
User software	PIMikroMove™	PIMikroMove™
Software drivers	Lab VIEW drivers, Windows and Linux Libraries (DLL)	Lab VIEW drivers, Windows and Linux Libraries (DLL)
Supported functionality	Wave generator, data recorder, macro programming	Wave generator, data recorder, macro programming
Display	LCD display for monitor signals (position and voltage), states and trackball menus	LCD display for monitor signals (position and voltage), states and trackball menus
Manual control	Operation via trackball	Operation via trackball
Miscellaneous		
Operating temperature range	+5 to +50° C	+5 to +50° C
Dimensions	21HP / 3U	21HP / 3U
Mass	0.37 kg	0.37 kg
Operating voltage	E-500 system	E-500 system

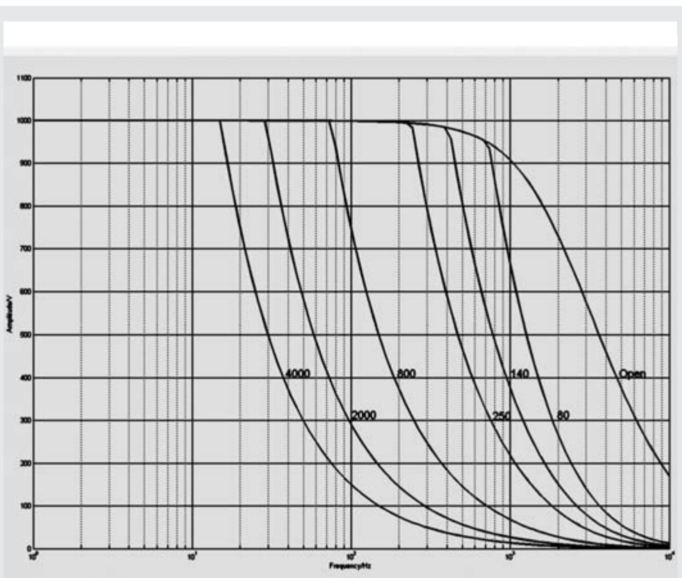
E-470 – E-472 / E-421 PICA™ Piezo Controller

Modular High-Power Amplifier/Controller

E-471 Configuration example: E-471.20 HVPZT amplifier, with optional E-509 PZT servo-controller and E-516 20-bit DAC interface/display

- **Peak Power 550 W**
- **Output Voltage 3 to 1100 V or Bipolar**
- **Optional Position Servo-Control Modules**
- **Optional 20-Bit Computer Interface Module & Display**
- **Precision DC-Offset Potentiometer for Input-Signal Bias & Manual Control**

The E-470 series high-power piezo amplifiers/controllers are specifically designed to drive high-capacitance PICA™ PZT actuators. They are based on the E-421 four-quadrant amplifier module, which can output and sink a peak current of 500 mA and an average current of 100 mA in a voltage range of 3 to 1100 V (jumper selectable bipolar range also provided). 3 standard configurations are available:



E-421, E-470, E-471, E-472: operating limits with various PZT loads, capacitance is measured in nanofarads

- E-470.20 is a bench-top amplifier in a 9.5″ chassis for open-loop operation (1 channel)
- E-471.20 is the amplifier module in a 19″ rackmount chassis that can hold additional servo-control, interface and display modules
- E-472.20 is a 2-channel version in a 19″ rackmount chassis for dynamic open-loop operation

These amplifiers can be used to drive open and closed-loop piezo positioning systems.

Open Loop Piezo Operation

For open-loop piezo operation the amplifier output voltage is determined by the analog signal at the Control Input combined with the DC-offset potentiometer setting. Open-loop operation is ideal for applications where the fastest response and the highest bandwidth are essential. Here, commanding and reading the target position in absolute values is either not important or carried out by an external feedback loop.

Optional Servo Controller Upgrade

The E-471.20 version allows easy installation of an optional E-509 sensor- / servo-controller module for closed-loop piezo position control. In this mode the amplifier is slaved to the E-509 servo controller. Depending on the attached piezo mechanics and feedback sensor, positioning accuracy and repeatability in the nanometer range and below are feasible.

Computer Control

The E-517 computer interface/display module can also be installed in the E-471 / E-472.

Ordering Information

E-470.20
HVPZT Piezo Amplifier, 550 W, 1100 V, Bench-Top

E-471.20
HVPZT Piezo Amplifier, Controller & Interface / Display Upgrade possible, 550 W, 1100 V, Bench-Top, 19″

E-472.20
HVPZT Piezo Amplifier, 2 Channels, 550 W, 1100 V, Bench-Top, 19″

E-421.00
HVPZT Piezo Amplifier Module, 550 W, 1100 V, Integrated P / S

Upgrades for E-471.20

Sensor / Position Servo-Control Modules

E-509.C1A
Sensor / Servo-Controller Module, Capacitive Sensor

E-509.S1
Sensor / Servo-Controller Module, SGS - Sensor

Computer Interface & Display Modules

E-517.i1
Interface- / Display Module, 24 Bit D/A, TCP/IP, USB, RS-232, 1 Channel

E-515.01
Display Module for PZT Voltage and Position

E-500.ACD
CD with Driver Set for Analog Controllers

E-500.HCD
Hyperbit™ Functionality for Enhanced System Resolution

Supports certain D/A boards.

Extension cables, adapters & connectors: see in "Accessories" in the "Piezo Drivers / Servo Controllers" (page 2-168 *ff*).

Ask about custom designs!

Optionally digital control via a D/A converter is possible. For several D/A boards from National Instruments PI offers a corresponding LabVIEW™ driver set which is compatible with the PI General Command Set (GCS), the command set used by all PI controllers. A further option includes the patented HyperBit™ technology providing enhanced system resolution.

Please read details on Calibration Information (see p. 2-103).


E-421.00 HVPZT piezo amplifier module

Technical Data

Model	**E-470.20, E-471.20, E-472.20, E-421.00**
Function	Power amplifier for PICA™ high-voltage PZTs (servo-controller option for E-471)
Amplifier	
Output voltage	3 to +1100 V (default) (Selectable -260 to +780 V -550 to +550 V +260 to -780 V -3 to -1100 V)
Amplifier channels	1 (E-472: 2)
Average output power	110 W
Peak output power, <5 ms	550 W
Average current	100 mA
Peak current, <5 ms	500 mA
Amplifier bandwidth, small signal	DC to 3 kHz, related to load capacitance, see operating limits graph
Amplifier bandwidth, large signal	DC to 3 kHz, related to load capacitance, see operating limits graph
Ripple, noise 0 to 100 kHz	<25 mV_{RMS} 100 mV_{P-P} (200 nF)
Current limitation	Short-circuit-proof
Voltage gain	+100 ±1, -100 ±1 (selectable)
Control input voltage	Servo off: ±1/100 of selected output range Servo on: 0 to 10 V
Input impedance	100 kΩ
Interfaces and operation	
PZT voltage output	LEMO EGG.0B.701.CJL1173
Control input	BNC
DC Offset	10-turn pot., adds 0 to +10 V to Control IN
Miscellaneous	
Operating voltage	100-120 or 220-240 VAC, selectable (fuse change required)
Operating temperature range	+5 to +50 °C (over 40 °C, max. av.) power derated 10 %
Mass	5.2 kg (E-470); 7.6 kg (E-471); 10.1 kg (E-472); 2.5 kg (E-420)
Dimensions	236 x 132 x 296 mm + handles (E-470) 450 x 132 x 296 mm + handles (E-471, E-472) 215 x 123 x 185 mm (E-420)

E-481 PICA™ Piezo High-Power Amplifier/Controller

2000 W and Energy Recovery for High Efficiency

E-481.00 high-power amplifier, optionally available with E-509 servo-controller and E-517 interface and display module

- **Peak Power 2000 W**
- **Energy Recovery**
- **Output Voltage 0 to ±1000 V or Bipolar**
- **Overheat Protection for Piezo Actuators with Temperature Sensor**
- **Optional Position Servo-Control Modules**
- **Computer Interface & Display Modules**

The E-481 high-power piezo amplifier/controller is specifically designed for dynamic operation of high-capacitance PICA™ PZT actuators.

The E-481 is based on a novel design combining pulse width modulation and energy recovery. Instead of dissipating the reactive power in heat sinks, this energy is temporarily stored in inductive elements. Only the active power used by the piezo actuator has to be delivered. The energy not used by the actuator is returned to the amplifier and reused as supply voltage via a step-up transforming process. A peak sink and source current of up to 2000 mA is possible.

Selectable Output Range

The output range can be set to positive, negative or bipolar, and provides a voltage swing of 1100 V in open-loop operation.

Open-Loop and Closed-Loop Operation

E-481 amplifiers can be used to drive open- and closed-loop piezo positioning systems.

For open-loop piezo operation the amplifier output voltage is determined by the analog signal at the Control Input combined with the DC-offset potentiometer setting. Open-loop operation is ideal for applications where the fastest response and the highest bandwidth are essential. Here, commanding and reading the target position in absolute values is either not important or carried out by an external feedback loop. The Control In signal can be adjusted by various settings.

Optional Servo Controller Upgrade

The E-481.00 allows easy installation of an optional E-509 (see p. 2-152) sensor- / servo-controller module for closed-loop piezo position control. In this mode the amplifier is slaved to the E-509 servo controller. Depending on the attached piezo mechanics and feedback sensor, positioning accuracy and repeatability in the nanometer range and below are feasible.

Computer Control

The E-517 computer interface/display module can also be installed in the E-481.

Optionally digital control via a D/A converter is possible. For several D/A boards from National Instruments PI offers a corresponding LabVIEW™ driver set which is compatible with the PI General Command Set (GCS), the command set used by all PI controllers. A further option includes the patented Hyperbit™ technology providing enhanced system resolution.

Thermal Piezo Protection Circuit

The E-481 features a temperature sensor input and control circuit to shut down the amplifier if the connected piezo ceramic exceeds a maximum temperature threshold.

Ordering Information

E-481.00
HVPZT Piezo Amplifier / Controller, Energy Recovery, 1100 V, 2000 W, 19''

Note
Requires Piezo Actuators with Option P-177.50, Temperature Sensor and Protective Air

Upgrades
Sensor / Servo-Control Modules

E-509.C1A
Sensor / Servo-Controller Module, Capacitive Sensor

E-509.S1
Sensor / Servo-Controller Module, SGS-Sensor

Interface / Display Modules

E-517.i1
Interface-/Display Module, 24 Bit D/A Ethernet, USB, RS-232, 1 Channel

E-515.01
Display Module for PZT Voltage and Position

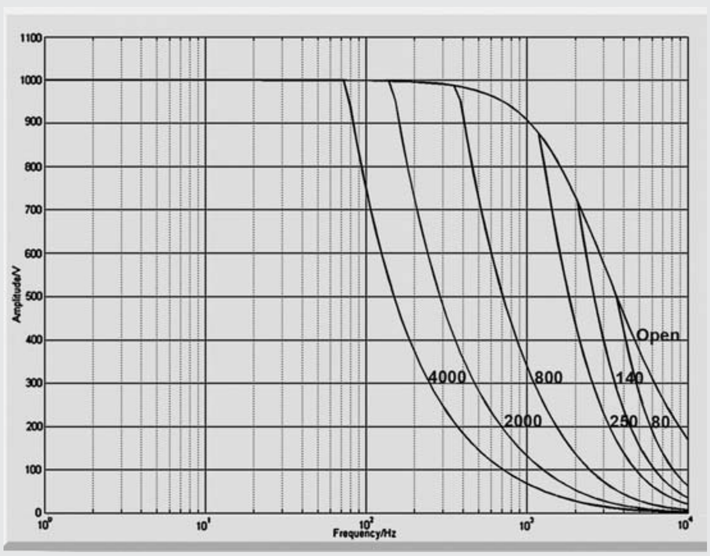
E-500.ACD
LabVIEW with Driver Set for Analog Controllers

E-500.HCD
Hyperbit™ Functionality for Enhanced System Resolution

Supports Certain D/A Boards.

Extension cables, adapters & connectors: see in "Accessories" in the "Piezo Drivers / Servo Controllers" section, (p. 2-168 *ff*).

Ask about custom designs!



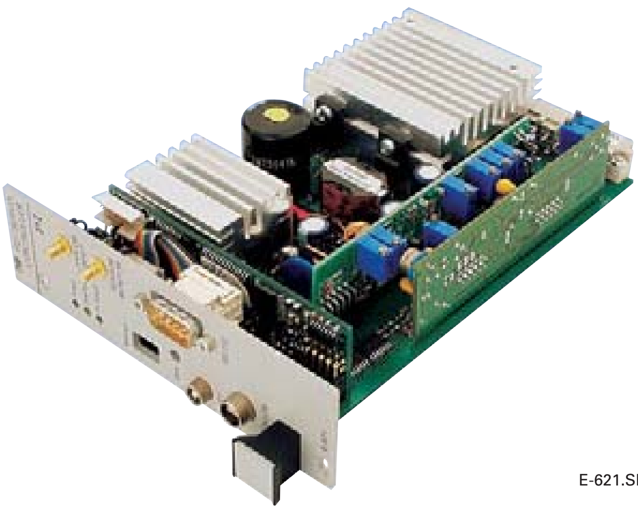
E-481: operating limits with various PZT loads, capacitance is measured in nF

Technical Data

Model	E-481.00
Function	Power amplifier for PICA™ high-voltage PZTs
Amplifier	
Output voltage	0 to 1100 V (default) (Selectable -260 to +780 V -550 to +550 V +260 to -780 V 0 to -1100 V)
Amplifier channels	1
Average output power	equivalent to 630 VA reactive power
Peak output power <5 ms	2000 VA
Average current	>600 mA
Peak current <5 ms	2000 mA
Amplifier bandwidth, small signal	5 kHz (660 nF), 1 Hz (3.4 µF)
Amplifier bandwidth, large signal	1.4 kHz (660 nF), 350 Hz (3.4 µF)
Ripple, noise 0 to 100 kHz	150 mV_{RMS} 2000 mV_{P-P} (100 nF)
Current limitation	Short-circuit-proof
Voltage gain	+100
Control input voltage	Servo off: ±1/100 of selected output range Servo on: 0 to 10 V
Input impedance	100 kΩ
Interface and operation	
PZT voltage output socket	LEMO EGG.0B.701.CJL1173
Control input socket	BNC
PZT temperature sensor	Max 85 °C, high voltage output is automatically deactivated if PZT temperature out of range
DC Offset	10-turn pot., adds 0 to +10 V to Control IN
Miscellaneous	
Operating voltage	100–120 or 220–240 VAC, 50–60 Hz (fuse change required)
Operating temperature range	+5 to +50 °C (over 40 °C, max. av. power derated 10 %)
Weight	8.6 kg
Dimensions	288 x 450 x 158 mm

E-621 Piezo Servo-Controller & Driver

Modules with Fast 20-Bit Interface



E-621.SR module

- Integrated 20-Bit High-Speed RS-232 Interface
- Network Capability with up to 12 Channels
- Up to 12 W Peak Power
- Position Control with Strain Gauge or Capacitive Sensor
- Notch Filter for Higher Bandwidth
- Additional Analog Interface
- Table for User-Defined Curves

Ordering Information

E-621.CR
Piezo Amplifier / Servo-Controller Module, 1 Channel, -20 to 120 V, Capacitive Sensor, RS-232

E-621.SR
Piezo Amplifier / Servo-Controller Module, 1 Channel, -20 to 120 V, SGS-Sensor, RS-232

E-500.621
19"-Chassis for up to twelve E-621 Modules, Power Supply

E-501.621
9,5"-Chassis for up to four E-621 Modules, Power Supply

The E-621 is equipped with an RS-232 interface and precision 20-bit D/A and A/D converters for exceptional positional stability and resolution. It integrates a low-noise piezo amplifier which can output and sink peak currents of 120 mA for low-voltage piezoelectric actuators. Servo-controller versions for position sensing with capacitive or SGS sensors are available.

Closed-Loop and Open-Loop Piezo Positioning

The E-621 controller module provides precision control of piezo actuators and positioning systems both in closed-loop and open-loop operation. The piezo controllers comprise additional circuitry for position sensing and servo-control. Displacement of the piezo is controlled by an analog signal. Positioning accuracy and repeatability down to the sub-nanometer range is possible, depending on the piezo mechanics and sensor type. High-resolution position sensors provide optimum positional stability and fast response in the nanometer range. Capacitive sensors measure position directly and without physical contact (direct metrology). Alternatively compact cost-effective strain gauge sensors (SGS) are available. The integrated notch filters (adjustable for each axis) improve stability and allow high-bandwidth operation closer to the resonant frequency of the mechanics.

In open-loop operation the output voltage is determined by an external analog signal. Open-loop operation is ideal for applications where fast response and very high resolution with maximum bandwidth are essential. Here, commanding and reading the target position in absolute values is either not important or carried out by external position sensors.

High-Resolution Digital Interface

The RS-232 digital interface includes high-precision 20-bit D/A and A/D converters for optimum position stability and resolution and supports fast communication with the host computer, with up to 300 bidirectional read/write operations per second.

Multi-Axis Network for up to 12 Channels

Up to twelve E-621s for capacitive or SGS sensors can be networked and controlled over a single RS-232 interface. The different modules are connected in parallel (not daisy-chained) over the link. Only an additional 10 ms internal bus communications time is required to reach any of the units behind the one actually connected to the host PC.

Waveform Memory

The built-in wave generator can store user-defined data points internally. These values can then be output automatically (or under the control of an external signal) and programmed for point-by-point or full-scan triggering. Thus, trajectory profiles can be repeated reliably and commanded easily.

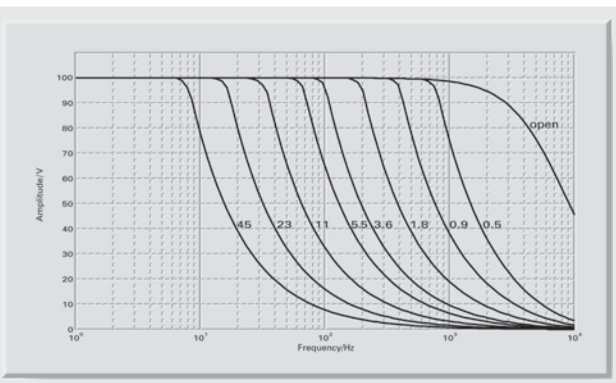
Software / GCS Command Set

The E-621 controller comes with Windows™ installation software, DLLs and Lab View™ drivers. The extensive command set is based on the hardware-independent General Command Set (GCS), which is common to all current PI controllers for both nano- and micropositioning systems. GCS reduces the programming effort in the face of complex multi-axis positioning tasks or when upgrading a system with a different PI controller.

4 x E-621 in an E-501.621 chassis

Technical Data

Model	E-621.SR / E-621.CR
Function	Power amplifier & piezo controller
Sensor	
Servo characteristics	P-I (analog), notch filter
Sensor type	SGS (.SR) / capacitive (.CR)
Amplifier	
Control input voltage range	-2 to 12 V
Output voltage	-20 to 120 V
Peak output power, <5 ms	12 W
Average output power	6 W
Peak current, <5 ms	120 mA
Average current	60 mA
Current limitation	Short-circuit-proof
Noise, 0 to 100 kHz	0.8 mVrms
Voltage gain	10 ±0.1
Input impedance	100 kΩ
Interfaces and operation	
Interface / communication	RS-232 (9-pin Sub-D connector), 9.6 - 115.2 kBaud, 20-bit
Piezo connector	LEMO ERA.00.250.CTL (.SR) / Sub-D special (.CR)
Sensor connection	LEMO EPL.0S.304.HLN (.SR) / Sub-D special (.CR)
Analog input	SMB
Sensor monitor output	SMB
Controller network	up to 12 channels. parallel
Command set	PI General Command Set (GCS)
User software	PZTControl™, NanoCapture™
Software drivers	LabVIEW drivers, DLLs
Supported functionality	Wave table, 64 data points, 100 Hz, external trigger
DC Offset	External potentiometer (not included), adds 0 to + 10 V to Control In
Miscellaneous	
Operating temperature range	+5°C to +50°C (10 % derated over 40°C)
Overheat protection	Deactivation at 75°C
Dimensions	7HP/3U
Mass	0.6 kg
Operating Voltage	12 to 30 V DC, stabilized
Current consumption, max.	2 A



E-621: operating limits with various PZT loads (open-loop), capacitance is measured in µF

E-621.CR module for capacitive sensors

E-612 Piezo Controller Module / System

1- to 4-Channel System with High-Speed Parallel Port

E-612 module, E-661 desktop device and E-501.10 chassis (power supply included) for up to four E-612 modules

Ordering Information

E-612.C0
Piezo Controller with High-Speed Parallel Interface, OEM Module, -20 to 120 V, Capacitive Sensor

E-501.10
9,5"-Chassis for up to 4 E-612.C0 Modules, incl Power Supply

- **10 µs High-Speed Parallel Command Port**
- **Additional Analog Interface**
- **For Piezo Stages with Capacitive Sensors**
- **Notch Filter for Higher Bandwidth**
- **Integrated Piezo Power Amplifier**
- **Versatile Design: Module for Multi-Channel Chassis or Single-Channel Bench-Top Device (E-661)**

The fast E-612 piezo controller module is designed for nanopositioning systems with integrated capacitive position feedback sensors. It possesses a low-noise integrated piezo amplifier providing -20 to 120 V with 80 mA sink and source capability.

High-Speed Interface

The controller features a high-speed parallel command port with optical coupled inputs and extra low-noise, linear, 16-bit D/A converters. Real-time position feedback is realized via a special trigger option. Additionally a broadband analog interface is installed (0 to 10 V).

Nanometer Resolution in Milli-Seconds

This high-performance controller is designed for nanopositioning tasks with highest precision and maximum turnover. Positioning with nanometer precisions and settling times of a few milliseconds are achieved in combination with the P-726 objective positioners (see p. 2-32) or P-753 LISA™ actuators (see p. 2-16). More and more high-tech branches require "nanometer accuracy within milliseconds". This is the case in microscopy/pharmaceutical research or quality testing for read/write heads, where every millisecond saved raises the throughput and helps reduce costs.

Single and Multi-Channel Systems

Up to four E-612.C0 piezo controller modules can be installed in one E-501.10 chassis. An internal address bus allows control of all modules over a single parallel command port. The E-612 is also available in a compact, single-channel bench-top version (model E-661.CP). It comes with a metal case for EMI protection and an external power supply (see p. 2-116).

Linear Actuators & Motors
Nanopositioning / Piezoelectrics
Piezo Flexure Stages / High-Speed Scanning Systems
Linear
Vertical & Tip/Tilt
2- and 3-Axis
6-Axis
Fast Steering Mirrors / Active Optics
Piezo Drivers / Servo Controllers
Single-Channel
Multi-Channel
Modular
Accessories
Piezoelectrics in Positioning
Nanometrology
Micropositioning
Index

Technical Data (Controller)

Model	E-612.C0
Function	High-Speed Piezo Controller Module
Channels	1
Capacitive sensor circuit	
Clock frequency	1.6 MHz
Bandwidth	1.5 kHz
Amplifier	
Output voltage	-20 to +120 V
Average output power	8 W
Average current	80 mA
Current limitation	short-circuit proof (5 minutes to shutdown)
Bandwidth (no load)	>500 Hz
Digital circuit	
Data	16-bit
Input level	TTL
Timing	THmin 10 µs; TLmin 10 µs
Input current	10 mA
On-target indication	On: target position ±0.025 % to 0.2 %, jumper-selectable
Analog input / output	
Control input voltage	-2 to 12 V
Input impedance	27 kΩ, 1 nF
Sensor monitor output	
Voltage range	-12 to +12 V (jumper-selectable)
Output impedance	10 Ω (10 nF)
Bandwidth	1.5 kHz
Connectors	
Digital interface	25-pin sub-D
Piezo	LEMO ERA.00.250
Sensor	LEMO EPL.00.250
Sensor monitor output	SMB
Analog input	SMB
Power consumption	+5 V, 0.12 A, ± 15 V, 0.16 A, +130 V, 80 mA max.; -27 V, 80 mA max
Dimensions	Euroboard (64-pin rear connector. Mating extender card: Mod. P-896.00)

Technical Data (Chassis & Power Supply)

Model	E-501.10
Function	Chassis for 1–4 E-612.C0 piezo controller modules
Operating voltage	90–120 VAC, 50–60 Hz; 220–264 VAC, 50–60 Hz
Power Supply	linear regulated power supply, integrated
P/S Output voltages	+130 V, 0.2 A; -27 V, 0.2 A; +24 V, 1 A; ±15 V, 0.5 A; +5 V, 1 A
Max. power consumption	50 W
Primary fuse	0,63 A slow
Dimensions	236 x 132 x 296 mm + handles

Accessories

Cables, Connectors & Adapters for LVPZT Piezo Translators and Nanopositioning Systems

Notes

Unless stated otherwise, PI LVPZT translators and Nanopositioners are equipped with LEMO connectors and 1 m cables. The voltage connector is an FFS.00.250.CTCE24 as shown on the P-890 cable (Fig. 2). The sensor connector is an FFA.0S.304.CLAC32 as shown on the P-892 cable (p. 2-170, Fig. 9). Standard insulation materials are Teflon for the voltage cable and PUR for the sensor cable.

Fig. 1. P-891.xx LVPZT extension cable

P-891.xx LVPZT Extension Cable (Fig. 1)

Plug (left): LEMO FFS.00.250.CTCE31
Socket (right):

LEMO PCS.00.250.CTL.CTME31
Cable: RG 174 (PVC)
P-891.01 1 m
P-891.02 2 m
P-891.03 3 m
P-891.05 5 m
P-891.10 10 m

Fig. 2. P-890 LVPZT cable LEMO/ solderable end

P-890 LVPZT Cable LEMO/ Solderable End (Fig. 2)

Plug: FFS.00.250.CTCE24
(fits LVPZT amplifiers, e.g. E-505.00)
Cable: RG 178 (Teflon)
This cable can be soldered to PZTs with pigtails
P-890.10 1 m
P-890.20 5 m

Fig. 3. P-893.10 BNC adapter cable

P-893.10 LVPZT/BNC Adapter Cable (Fig. 3)

LEMO Plug / BNC female, adapter cable
Cable: RG 174 (PVC), 1 m
Plug: LEMO FFS.00.250.CTCE31 (male) and BNC.ST.250.NTAE31.
Allows LVPZT amplifier output voltage (e.g. E-505, etc.) to be connected to an oscilloscope, etc.

Fig. 4. P-210.20 BNC-cable

P-210.20 BNC Cable (Fig. 4)

BNC plug / solderable end.
Cable: RG 174 (PVC), 1 m. This cable can be soldered to PZTs with pigtails

Fig. 5. P-894.10 LVPZT adapter

P-894.10 LVPZT Adapter (Fig. 5)

LEMO plug / 2 x LEMO socket, adapter
Type: FTL.00.250.CTF with 1 x plug (right), 2 x socket (left, center). Allows two cables with LEMO FFS.00.250 male plugs to be connected to a device with LEMO 00.250 socket (e.g. E-505.00 amplifier module) or P-891 extension cable.

Fig. 6. P-894.30 BNC adapter

P-894.30 BNC/LVPZT Adapter (Fig. 6)

LEMO socket / BNC female, adapter
Type: ABA.00.250.NTL
Allows a cable with LEMO FFS.00.250 male plug to be attached to a device with BNC socket (e.g. direct operation of an LVPZT from a signal generator).

Accessories

Cables, Connectors & Adapters for PICA™ HVPZT Piezo Translators and Nanopositioning Systems

Notes

Unless stated otherwise, PI's preloaded PICA™ HVPZT piezo translators and nanopositioners are equipped with LEMO connectors and 1 m PVC cables. The voltage connector is an FGG.0B.701.CJL.1173. With integrated P-177.10 strain gauge, an additional sensor cable is installed. The length of the sensor cable is 1 m, the material PUR and the connector a LEMO FFA.0S.304.CLAC32 as shown on the P-892 cable (see page 2-170, Fig. 9).

Fig. 7. P-202 PICA™ HVPZT cable

P-202.xx PICA™ HVPZT Cable LEMO plug / solderable end

Plug: FGG.0B.701.CJL.1173 (fits PICA™ HVPZT amplifiers, e.g. E-508.00)

Cable with PUR insulation, 2-conductor, shielded

This cable can be soldered to PZTs with pigtails

P-202.06	0.6 m
P-202.10	1 m
P-202.12	2 m
P-202.13	3 m
P-202.15	5 m

Fig. 8. P-203 extension cable for PICA™ HVPZTs

P-203.xx PICA™ HVPZT Extension Cable

Plug: FGG.0B.701.CJL.1173
Socket: PHG.0B.701.CJL.1173
Cable: PUR-insulation, 2-conductor, shielded

P-203.01	1 m
P-203.02	2 m
P-203.03	3 m
P-203.05	5 m
P-203.10	10 m
P-203.15	15 m

Accessories
Sensor Extension Cables

Fig. 09. P-892.xx Sensor extension cables for LVDTs and strain gauges

P-892.xx Sensor Extension Cable (Fig. 9)

For strain gauge sensors or LVDTs.
Plug (right):
FFA.0S.304.CLAC32
Socket (left):
PCA.0S.304.CLLC32
Cable: 4 wires; ≈ Ø 0.20 mm;
#32 AWG (American)
≈ #35 SWG (British)
PVC-Isolation

P-892.01	1 m
P-892.02	2 m
P-892.03	3 m
P-892.05	5 m
P-892.10	10 m

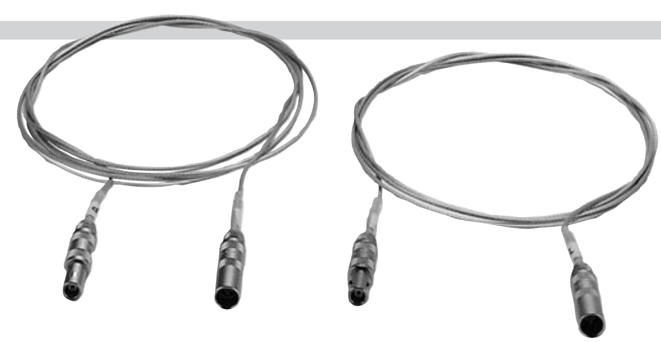


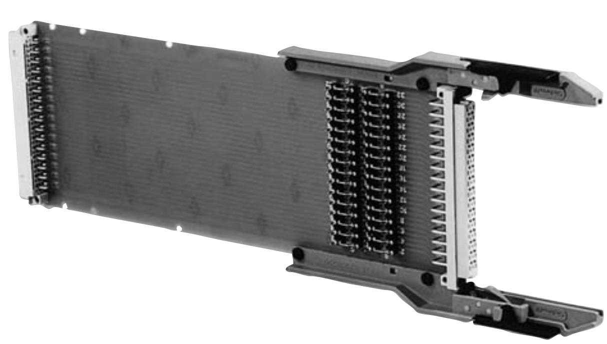
Fig. 10. D-892.xx capacitve sensor extension cables

D-892 Sensor Extension Cable Set (Fig. 10)

For capacitive sensors.
Set of two.
Plug (e.g., far left)
FFA.00.250.CTLC20

Socket (e.g., far right)
PCA.00.250.CTAC22
Cable: LSM 75 (Teflon)

D-892.01	1 m
D-892.02	2 m
D-892.03	3 m



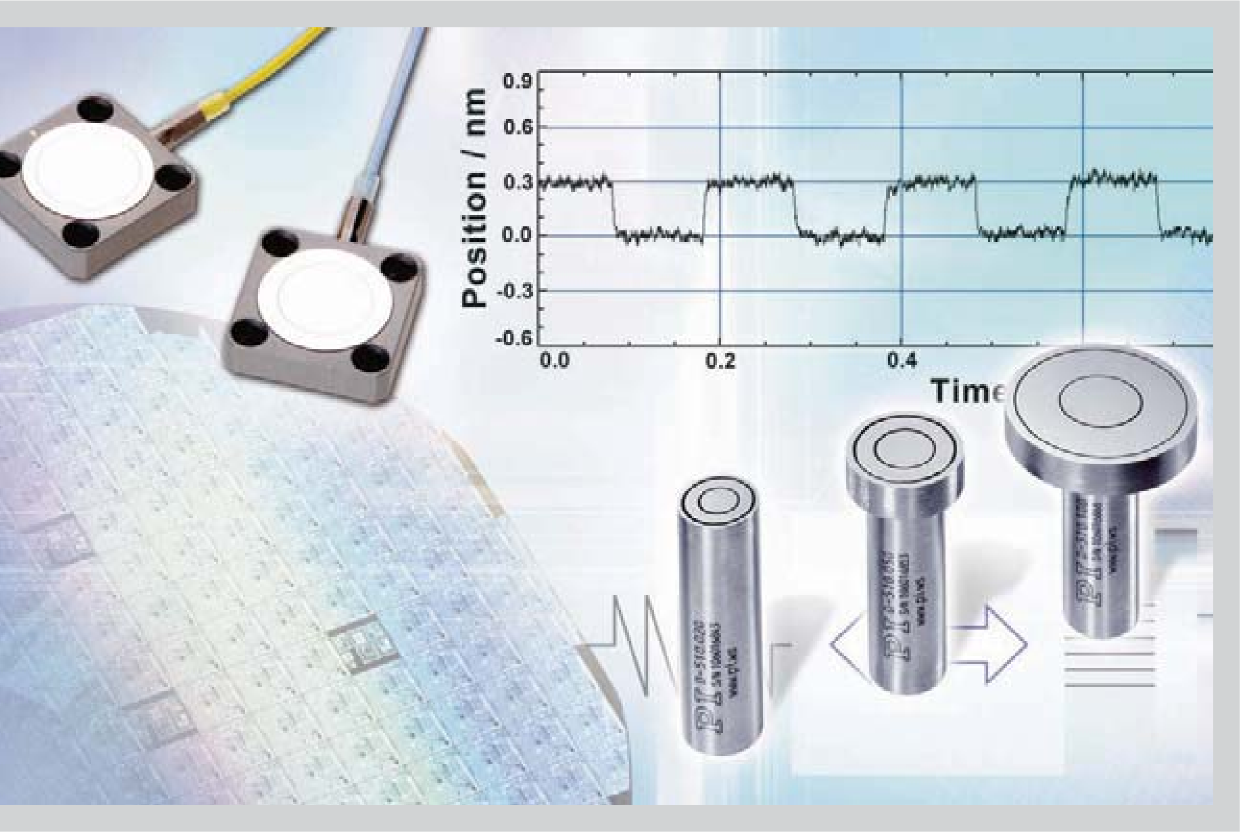
P-895.00 extension board for servicing

P-895.00 Extension Board

The board is used for the extension of the 32-pin connector of all PI E-500 and E-501 electronics (except E-515 and E-516). It is required for calibration and maintenance work. To allow the measurements of electrical current, all traces on the board are jumpered.

Piezo • Nano • Positioning

Nanometrology



Capacitive Position Metrology

Overview

E-852 signal conditioner electronics with PISeca™ D-510.020 1-plate capacitive sensor

Properties of PI Sensors

- **Measurement Ranges from 10 up to 500 µm and More**
- **Sub-Nanometer Position Resolution**
- **Non-Contact Absolute Measurement of Displacement / Motion / Vibration**
- **Immune to Wear and Tear**
- **Ideal for Multi-Axis Applications**
- **Improved Linearity with ILS Signal Electronics**
- **High Bandwidth up to 10 kHz**
- **Measures Position of the Moved Interface (Direct Metrology)**
- **High Temperature and Long-Term Stability (<0.1 nm/3 h)**
- **Vacuum Compatible**
- **Compact 1- and 2-Electrode Sensors, Custom Designs**
- **Guard-Ring Electrode Eliminates Boundary Effects**
- **Invar Versions for Highest Temperature Stability (5 x 10^{-6}/K)**

Standard D-015, D-050, D-100 2-plate sensors (front from left) and a selection of custom sensors

One- and Two-plate Sensors

Capacitive sensors perform non-contact measurements of geometric quantities representing distance, displacement, separation, position, length or other linear dimensions with sub-nanometer accuracy. PI offers capacitive sensors for the integration in user applications in two-plate-capacitor versions for highest performance and as PISeca™ single-electrode sensors, for more flexibility and easier integration.

Measurement Principle

The measurement principle in both cases is the same: two conductive surfaces set up a homogenous electric field; the change in displacement of the two plates is proportional to the signal conditioner output. Dual-plate sensors measure the distance between two well-defined sensor plates with carefully aligned surfaces which generate the most accurate electric field and hence provide optimal results. Single-plate capacitive sensors measure the capacitance against electrically conductive references, such as metallic plates, and are very convenient to install and connect.

Nanopositioning and Nanometrology

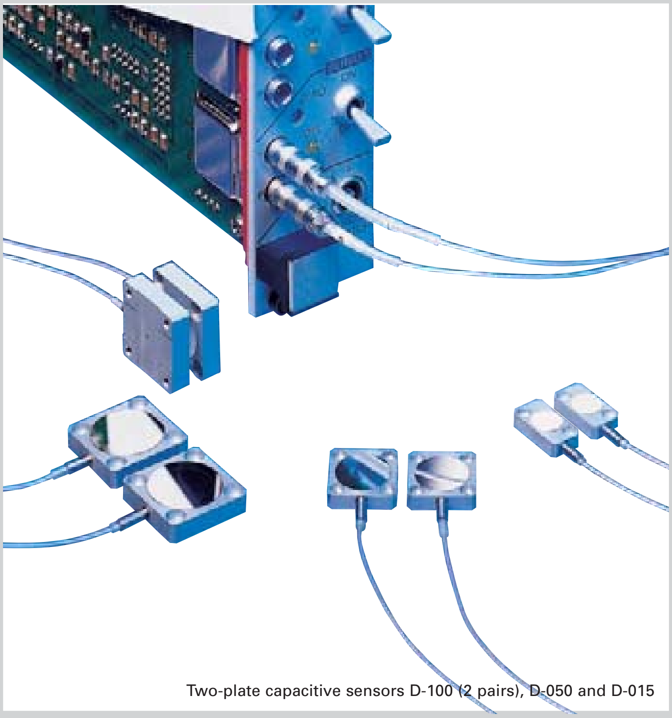
PI offers the widest range of high-dynamics and high-resolution nanopositioning systems worldwide. The precision and repeatability achieved would not be possible without highest-resolution measuring devices. Capacitive sensors are the metrology system of choice for the most demanding nanopositioning applications. The sensors and the equally important excitation and read-out electronics are developed and manufactured at PI by expert teams with longstanding experience.

Test and Calibration

PI's nanometrology calibration laboratories are seismically, electromagnetically and thermally isolated, and conform to modern international standards.

PI calibrates every capacitive measurement system individually, optimizing the performance for the customer's application. Such precision is the basis of all PI products, standard and customized, and assures optimum results in the most varied of applications.

Function, Properties, Advantages



Two-plate capacitive sensors D-100 (2 pairs), D-050 and D-015

D-510.050 with LEMO connector for easy handling

Accuracy

Accuracy, linearity, resolution, stability and bandwidth are far better than with conventional nanometrology sensors like LVDT or strain gauge sensors.

Non-contact operation means no parasitic forces influencing the application and results in measurement free of friction and hysteresis.

Guard-Ring Design for Improved Linearity

Sensor design has a strong influence on linearity. The superior PI design uses a guard-ring electrode that eliminates sensor electrode boundary effects. This ensures a homogenous field in the measurement zone and results in higher measuring linearity.

Single- and Multi-Channel Electronics

PI's signal conditioner electronics are specially designed for high bandwidth, linearity and ultra-low noise and are perfectly matched to the various PI sensor probes. PI offers signal conditioner electronics and controllers for one to three channels. The E-509 multi-channel modules plug into the modular E-500 / E-501 controller chassis. Bandwidth and measurement range can be factory-set to meet the specific needs of each application. The E-852 one-channel signal conditioner electronics for PISeca™ single-plate sensors are designed as stand-alone systems with user-selectable bandwidth and range setting and can be synchronized to operate in multi-channel applications.

Higher Linearity through ILS Electronics

All of PI's signal conditioning electronics are equipped with the PI proprietary ILS linearization circuit that minimizes non-parallelism errors.

Easy Handling and Integration

PISeca™ single-electrode sensors are particularly easy to install in a measurement system. On the single-channel electronics, an LED-bar indicates the optimum probe-to-target gap for the different measurement range settings. The multi-channel electronics come optionally with displays and/or a PC interface on a module in the same housing.

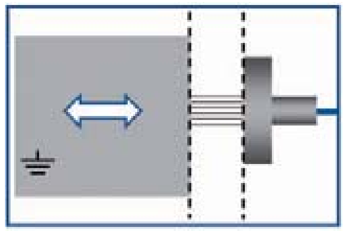
Ideal for Closed-Loop Piezo Nanopositioning

Closed-loop nanopositioning systems may be controlled by sensor / servo-controller modules of PI's E-500 series. Such modules are available for connecting up to three position sensors, either stand-alone or integrated into the motion system. Closed-loop operation eliminates the drift and hysteresis that otherwise affect piezo actuators.

For nanopositioning tasks with the most stringent accuracy requirements PI offers high-end digital controllers.

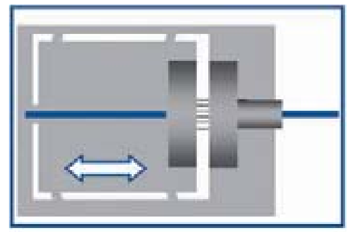
The P-752.11C piezo nanopositioning system with integrated capacitive sensors provides position resolution down to 0.1 nm

Applications for Capacitive Position Sensors



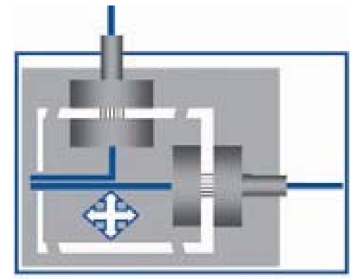
Measuring Displacement with Nanometer Precision

Capacitive displacement sensors measure the shortest of distances with highest reliability. The quantity measured is the change of capacitance between sensor plate and the target surface using a homogeneous electric field. Accuracies in the sub-nanometer range are regularly achieved. Absolute measurement is possible with a well-adjusted, calibrated system.



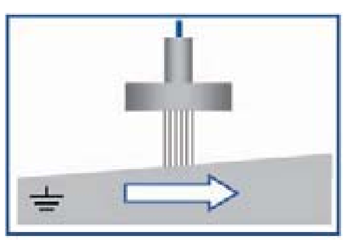
Nanopositioning / Closed-Loop Systems

One application of high-resolution displacement measurement is for nanopositioning. Two-plate capacitive sensors can measure distance, and hence position, of a moving object with excellent precision. The high sensor bandwidth allows closed-loop control in high-dynamics applications.



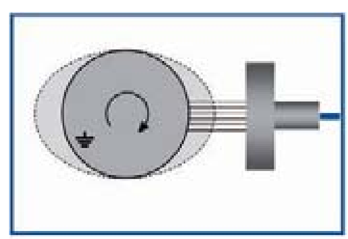
Parallel Metrology / High-Precision Multi-Axis Measurements

Closed-loop, multi-axis nanopositioning tasks are realized with high-performance positioners that make use of direct metrology and parallel kinematics. This allows measuring all degrees of freedom at the same time, which compensates guiding errors (Active Trajectory Control concept). Here, capacitance gauges are the most precise measuring systems available, and give the best position resolution results.



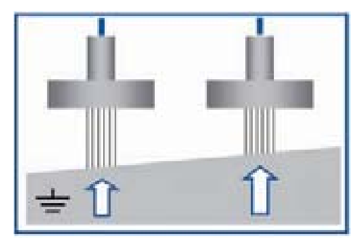
Measuring Straightness and Flatness / Active Cross-Talk Compensation

Excellent resolution in straightness and flatness measurements over long travel ranges is achieved with capacitive single electrode sensors. One application is measuring cross-talk in nanopositioning. Crosstalk, off-axis motion from one actuator in the motion direction of another, is detected immediately and actively compensated out by the servo-loops. The high sensor bandwidth provides excellent dynamic performance.



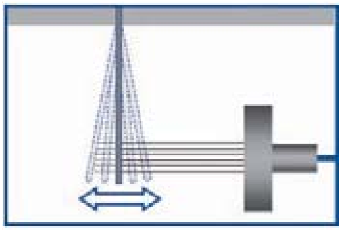
Out-of-Plane Measurement / Constant-Height Scans / Out-of-Round Measurement

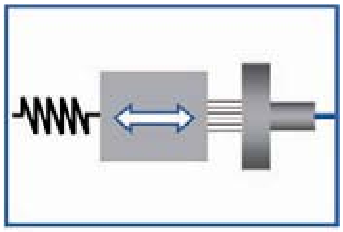
Compensation of undulating and oscillating motion, e.g. in constant height scans or in white-light interferometry, are applications for which capacitive sensors are especially well suited.

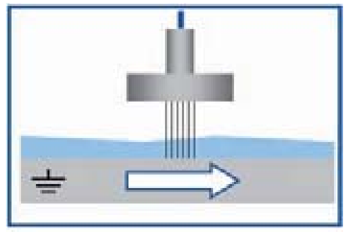


Tip / Tilt Measurement and Compensation

Integrating capacitive sensors in a system is a good way to measure tip/tilt motion precisely. The moved object's tip angle is measured differentially, and, if required, compensated out.







Vibration, Flatness, Thickness

The high dynamics of the PISeca™ capacitive gauge system even allows measurements of vibrations and oscillations with excellent resolution. Flatness of a rotating workpiece or differences in thickness in the nanometer range can be detected. One field of application is in the production of disk drives or in active compensation of vibration.

Force Sensors with Micronewton Sensitivity

Single-electrode capacitive sensors, which measure subnanometer displacement from a distance with no contact, are frequently used as high-resolution force sensors. In a system having suitably well-defined stiffness, the measured displacements translate to forces with resolutions in the micronewton range, all without influencing the process being measured.

Layer Thickness with Sub-Micron Accuracy

Measuring the thickness of a film or layer of non-conducting material on a moving, conductive, surface (e.g. a rotating drum) is an ideal job for capacitive sensors due to their noncontact operation and their high dynamic performance.

D-510 PISeca™ Capacitive Sensors

Single-Plate Sensors with Excellent Position Resolution

PISeca™ high-precision capacitive sensor probes with E-852 signal conditioner electronics. Sensor probes (from left): D-510.100 with 100 µm, D-510.050 with 50 µm, D-510.020 with 20 µm nominal measurement range

- **Non-Contact Measurement for Distance / Motion / Vibration**
- **Absolute Position Sensing**
- **Sub-Nanometer Resolution**
- **Measurement Ranges to 500 µm**
- **Easy Integration**
- **High Bandwidth**

The new PISeca™ single-electrode capacitive sensors from PI perform non-contact measurements of distance, position or motion against any kind of electrically conductive target. They feature the highest resolution and linearity available.

The PISeca™ single-electrode capacitive gauges are fundamentally very temperature stable, have excellent dynamics and are easy to work with.

Application Examples

- Semiconductor technology / test & measurement
- Data storage
- Automotive industry
- Metrology
- Precision machining

Capacitive Position Sensors for Highest Accuracy and Lifetime

Single-electrode capacitive (capacitance) sensors are direct metrology devices. They use an electric field to measure change of capacitance between the probe and a conductive target surface, without physical contact. This makes them free of friction and hysteresis and provides high phase fidelity and bandwidth.

In combination with suitable sensor electronics (E-852.10) resolutions down to the sub-nanometer range and bandwidths to 10 kHz can be achieved. For high-dynamics measurements, a bandwidth up to 10 kHz is possible, with a resolution still down to the 1-nm range. With sufficient mounting accuracy, excellent linearity can be attained (up to 0.1%).

Guard-Ring Capacitor Provides Higher Linearity

Sensor design has a strong influence on linearity because the operating principle is based on that of an ideal parallel-plate capacitor. The superior PI design uses a guard-ring electrode that shields the sensor electrode from boundary effects. This ensures a homogeneous electric field in the measurement zone and results in higher measuring linearity.

Easy Handling and Integration

All PISeca™ sensor probes feature an integrated LEMO connector for easy mounting and replacement in the field. The standardized shaft diameter allows compatibility and flexibility.

Factory Calibration for Improved Linearity

Highest possible linearity and accuracy are achieved with factory calibration of the sensor probe together with the signal conditioner electronics. Two measurement ranges can be calibrated at the same time for one particular sensor probe. Factory calibration also optimizes parameters like ILS (linearization), gain and offset and eliminates cable capacitance influences. The E-852.10 provides two calibrated, optionally extended measurement ranges are available.

High-Precision Machining

The measuring surfaces of the PISeca™ sensors are machined with diamond tools using sophisticated process control techniques. The result is the smooth, ultra-flat, mirrored surface required to obtain highest resolution. The standard material is stainless steel.

Ordering Information

D-510.020
PISeca™ Single-Electrode Capacitive Sensor Probe, 8 mm Diameter, 20 µm Nominal Range

D-510.050
PISeca™ Single-Electrode Capacitive Sensor Probe, 12 mm Diameter, 50 µm Nominal Range

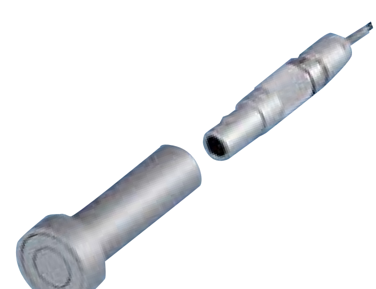
D-510.100
PISeca™ Single-Electrode Capacitive Sensor Probe, 20 mm Diameter, 100 µm Nominal Range

Ask about custom designs!

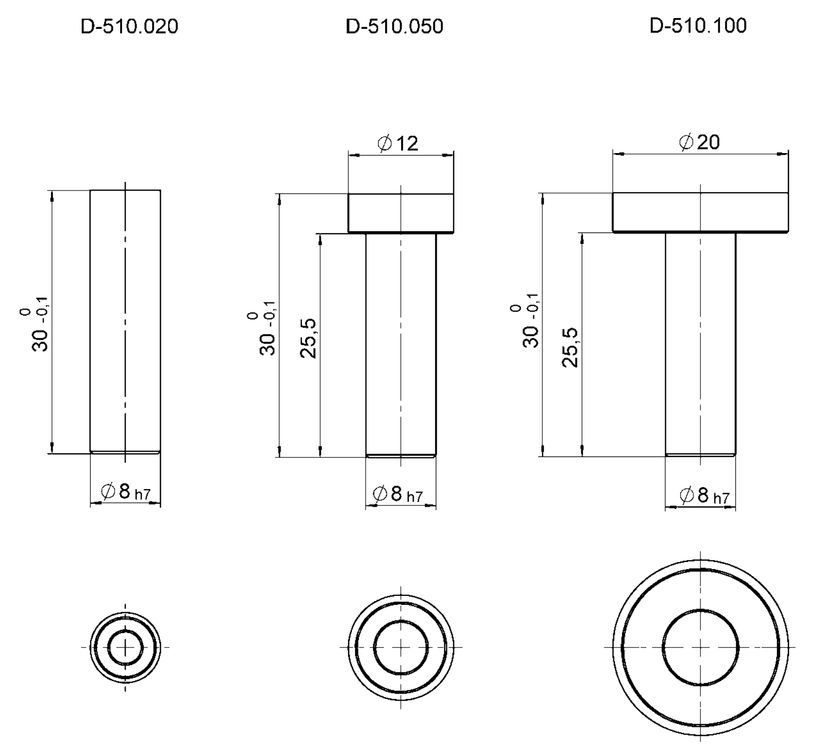
Custom Sensors / Two-Plate Sensors

In addition to the standard sensors listed here, PI can offer a variety of custom versions for different measuring ranges, geometries, materials match, etc. Systems with custom electronics are also available.

If ultimate performance is required, the D-100 series two-plate capacitive sensors are recommended (see p. 3-14 *ff*).



D-510.050 with LEMO-connector for easy handling



D-510.020, D-510.050 and D-510.100 capacitive sensor probes, dimensions in mm.
Sensor connection LEMO FFC00.650.CLA.543, triaxial, cable length 1 m

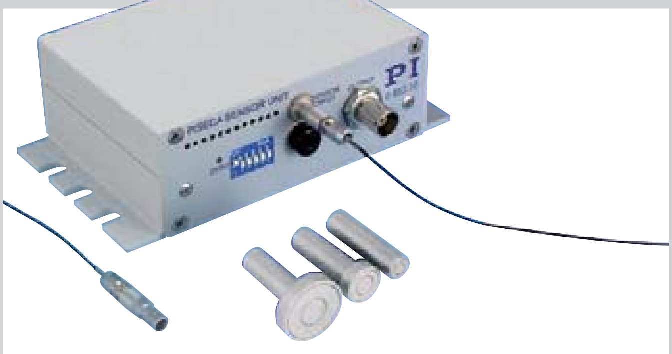
Technical Data

Model	D-510.020	D-510.050	D-510.100	Units	Tolerance
Sensor type	Single-electrode, capacitive	Single-electrode, capacitive	Single-electrode, capacitive		
Measurement accuracy					
Nominal measurement range*	20	50	100	µm	
Min. gap	10	25	50	µm	
Max. gap	150	375	750	µm	
Static resolution**	<0.001	<0.001	<0.001	% of measurement range	typical
Dynamic resolution**	<0.002	<0.002	<0.002	% of measurement range	typical
Linearity***	<0.2	<0.1	<0.1	%	
Mechanical properties					
Sensor active diameter	3.8	6	8.4	mm	
Sensor active area	11.2	27.9	56.1	mm^2	
Sensor diameter	8	12	20	mm	
Sensor area	50.3	113.1	314.0	mm^2	
Mounting shaft diameter	8	8	8	mm	
Miscellaneous					
Operating temperature range	-20 to +100	-20 to +100	-20 to +100	°C	
Material	Stainless steel	Stainless steel	Stainless steel		
Mass	8	10	16	g	±5 %
Recommended signal conditioner electronics	E-852.10 E-509.E	E-852.10 E-509.E	E-852.10 (p. 3-10) E-509.E (p. 3-12)		

*Extended measurement ranges available for calibration with E-852 signal conditioner electronics
**Static resolution: bandwidth 10 Hz, dynamic: bandwidth 10 kHz, with E-852.10 signal conditioner electronics
***Linearity over nominal measurement range

E-852 PISeca™ Signal Conditioner

For Capacitive Single-Plate Sensors



E-852 signal conditioner electronics with PISeca™ capacitive sensor probes D-510.100, D-510.050, D-510.020 (from left)

- **Cost-Effective System Solution for PISeca™ Capacitive Position Sensor Probes**
- **Special Linearization System (ILS) for Maximum Linearity**
- **Bandwidth Adjustable from 10 Hz to 10 kHz**
- **Multiple Measurement Ranges per Probe**
- **LED-Bar Measuring-Range Display for Easy Setup & Sensor Installation**
- **External Synchronization for Multi-Channel Applications**

The economical E-852.10 signal conditioner electronics is specially designed for the PISeca™ D-510 series of single-electrode capacitive position sensor probes. It provides analog output with very high linearity, exceptional long-term-stability, sub-nanometer position resolution and bandwidths up to 6.6 kHz.

Measurement Principle of Capacitive Sensors

Single-electrode capacitive (capacitance) sensors are direct metrology devices. They use an electric field to measure change of capacitance between the probe and a conductive target surface, without physical contact. This makes them free of friction and hysteresis and provides high phase fidelity and bandwidth.

Application Examples

- Semiconductor technology / test & measurement
- Data storage
- Automotive industry
- Metrology
- Precision machining

Selectable Bandwidth and Measurement Range

The selectable bandwidth setting allows the user to adapt the system to different applications. For the highest accuracy and sub-nanometer resolution, the bandwidth can be limited to 10 Hz.

For high-dynamics measurements, a bandwidth up to 10 kHz is possible, with a resolution still down to the 1-nm range.

The user can choose a measurement range from 20 to 500 µm, depending on the nominal measurement range of the selected sensor. The E-852.10 provides different extended measuring ranges for each selected sensor.

Easy Sensor Installation

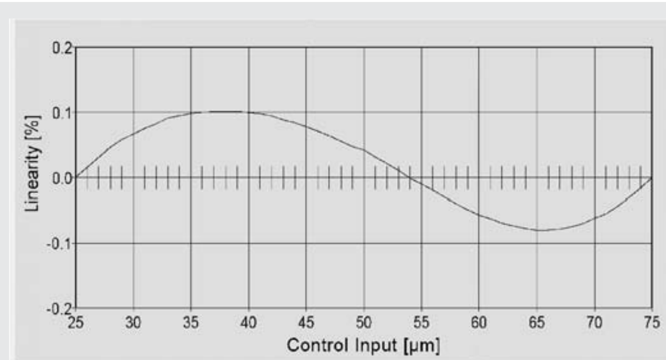
The simple installation of the single-electrode PISeca™ probes is facilitated by the E-852´s LED-bar indicating the optimum gap between probe and target.

Factory Calibration for Improved Linearity

Highest possible linearity and accuracy are achieved with factory calibration of the sensor probe together with the signal conditioner electronics. Two measurement ranges can be calibrated at the same time for one particular sensor probe. Factory calibration also optimizes parameters like ILS (linearization), gain and offset and eliminates cable capacitance influences.

Integrated Linearization System (ILS) for Highest Accuracy

A proprietary linearization circuit compensates the influences of parallelism errors between sensor and target and guarantees an excellent measuring linearity (to 0.1%).



Output linearity error of E-852 signal conditioner / D-510.050 sensor combination (nominal measurement range)

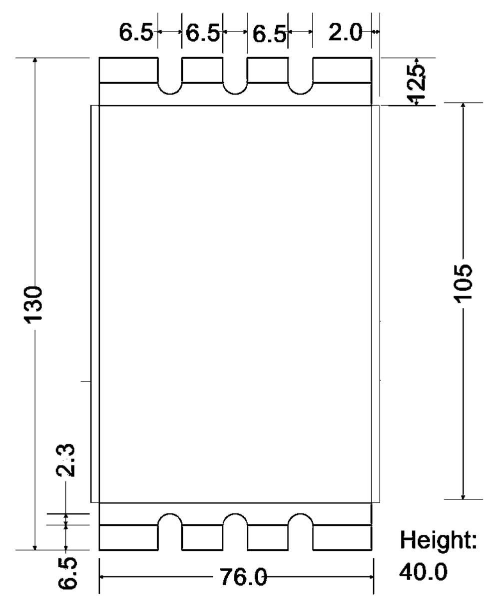
Ordering Information

E-852.10
PISeca™ Signal Conditioner Electronics for Single Electrode Capacitive Sensors, 1 Channel (with Power Supply)

Ask about custom designs!

Multi-Channel Measurements

PISeca™ sensor electronics are equipped with I/O lines for the synchronization of multiple sensor systems.



E-852.10, dimensions in mm

Technical Data

Model	E-852
Function	Signal conditioner for PISeca™ capacitive sensor probes
Channels	1
Sensor	
Sensor type	Single-electrode, capacitive
Sensor bandwidth	10 / 3 / 0.3 kHz 1.1 / 0.1 / 0.01 kHz (option)
Measurement range extension factors*	1 & 2.5 (calibrated), 2 & 5 (option)
Ext. synchronization	Auto master-slave
Temperature stability	0.71 ±0.25 mV / °C
Electrical properties	
Output voltage	-10 to +10 V / -5 to +5 V / 0 to +10 V
Output signal	1 kΩ / 1 nF
Supply voltage	±15 V (125 mA), +5 V (20 mA)
Static resolution**	<0.001 % of measurement range (RMS)
Dynamic resolution**	<0.002 % of measurement range (RMS)
Linearity @ nominal range	<0.1 % (<0.2 % for D-510.020)
Interface and operation	
Sensor connection	LEMO ECP.00.650.NLL.543 socket, triaxial
Analog output	BNC
Supported functionality	LED bar (gap indicator)
Linearization	ILS
Miscellaneous	
Operating temperature range	+5 to +40 °C
Mass	0.355 kg, E-852.PS1 power supply: 1.2 kg
Dimensions	80 x 130 x 40 mm, E-852.PS1 power supply: 100 x 170 x 62 mm
Target ground connector	Banana jack

*Extension factors to multiply by the nominal measurement range
**Static: bandwidth 10 Hz, dynamic: bandwidth 10 kHz, cable length 1 m

E-509 PISeca™ Signal Conditioner / Piezo Servo Module

3-Channel Sensor Module with/without Servo-Controller, for E-500 System

The E-509.E3 module offers sensor signal read-out and servo control for three channels

- **E-509.E03: 3-Channel Signal Conditioner Module**
- **E-509.E3: 3-Channel Sensor Module with Additional Servo Controllers for Piezo Positioning Systems**
- **Integrated Linearization System (ILS) for Maximum Linearity**
- **Optional: Measurement Range**
- **Variable Bandwidth**
- **Plug-In Modules for E-500 / E-501 Chassis**

The analog E-509.Ex sensor electronics is specially designed for the PISeca™ D-510 series of single-electrode, capacitive position sensor probes. Based on the E-500 modular controller system, it provides three channels of analog output featuring very high linearity, exceptional long-term stability, sub-nanometer position resolution and bandwidths up to 10 kHz.

Application Examples

- Semiconductor technology / test & measurement
- Data storage
- Automotive industry
- Metrology
- Precision machining

Two models are available: E-509.E03 is a signal conditioner module. In addition, the E-509.E3 version includes a full servo-controller. With it, the position values from external single-plate capacitive sensors can thus be used for servo-control of piezo nanopositioning systems.

The combination of sensor and electronics provides a system for capacitive displacement measurement with flexible high-end solutions for best linearity and highest resolution.

Selectable Bandwidth and Measurement Range

The selectable bandwidth setting allows the user to adapt the system to different applications. For the highest accuracy and sub-nanometer resolution, the bandwidth can be limited to 300 Hz.

For high-dynamics applications, a bandwidth up to 10 kHz is possible, with a resolution still better than 4 nm.

Factory-set measurement ranges from 20 to 500 µm are possible, depending on the nominal measurement range of the selected sensor head.

Factory Calibration for Improved Linearity

Highest possible linearity and accuracy are achieved with factory calibration of the sensor electronics for the particular measurement range. Factory calibration also optimizes parameters like ILS (linearization), gain and offset and eliminates cable capacitance influences.

Position Servo Control with PISeca™

The position servo-control portion of the E-509 is identical for all versions, consisting of an analog P-I (proportional, integral) controller. Proportional and integral gain can be set internally. Control bandwidth can also be set. A notch filter allows operation of the piezo positioning system closer to its mechanical resonant frequency.

Multi-Channel Measurements

The three channels of the PISeca™ E-509.Ex sensor electronics are automatically synchronized for the use in connected sensor systems.

Ordering Information

E-509.E3
PISeca™ Sensor / Piezo Servo-Control Module for Single-Electrode Capacitive Sensor Probes, 3 Channels

E-509.E03
PISeca™ Modular Signal Conditioner Electronics for Single Electrode Capacitive Sensors, 3 Channels

Accessories:

E-500.00
19"-Chassis for Modular Piezo Controller System, 1 to 3 Channels

E-501.00
9.5" Chassis for Modular Piezo Controller System, 1 to 3 Channels

E-515.03
Display Module for Piezo Voltage and Displacement, 3 Channels

E-517.i3
Interface / Display Module, 24 Bit D/A, TCP/IP, USB, RS-232, 3 Channels

E-503.00
Piezo Amplifier Module, -20 to +120 V, 3 Channels

E-515.E3
Analog Output for Controller Signal, Plug-In Module, 3 Channels

Ask about custom designs

The E-509.E3 servo-controller module in an E-501 9.5" chassis with E-503 piezo amplifier module and E-516 PC-interface/display module provides servo-control of piezo nanopositioning systems with external PISeca™ D-510 capacitive 1-plate sensors

Technical Data

Model	E-509.E03	E-509.E3
Function	Signal conditioner electronics for PISeca™	Sensor / Servo-Controller Module for PISeca™
Channels	3	3
Sensor		
Servo characteristics	–	Analog proportional-integral (P-I) algorithm with notch filter
Sensor type	PISeca™ single-electrode, capacitive	PISeca™ single-electrode, capacitive
Sensor bandwidth	3 kHz 0.3 / 10 kHz (selectable)	3 kHz 0.3 / 10 kHz (selectable)
Measurement range extension factors*	2 / 2.5 / 5 (option)	2 / 2.5 / 5 (option)
Synchronization	3 synchronized channels	3 synchronized channels
Electrical properties		
Output voltage	0 to 10 V	0 to 10 V
	-5 to +5 V, -10 to 0 V (selectable)	
Thermal drift	<1 mV / °C	<1 mV / °C
Resolution @ 300 Hz (RMS)	<0.001 % of measurement range	<0.001 % of measurement range
Resolution @ 3 kHz (RMS)	<0.0025 % of measurement range	<0.0025 % of measurement range
Linearity @ nominal range	<0.1 % (<0.2 % for D-510.020)	<0.1 % (<0.2 % for D-510.020)
Interfaces and operation		
Sensor connection	3 x LEMO ECP.00.650.NLL.543 socket, triaxial	3 x LEMO ECP.00.650.NLL.543 socket, triaxial
Signal output	LEMO 6-pin FGG.0B.306.CLAD56	LEMO 6-pin FGG.0B.306.CLAD56
Display	–	3 x Overflow LED
Supported functionality	ILS	ILS
Miscellaneous		
Operating temperature range	+5 to +40 °C	+5 to +40 °C
Dimensions	7T/3H	7T/3H
Target ground connector	3 x banana jack	3 x banana jack
Operating voltage	E-500 system	E-500 system

*Extension factors to multiply by the nominal measurement range of the selected sensor head D-510, to be specified with order

D-015 · D-050 · D-100 Capacitive Sensors

Sub-Nanometer-Resolution Position Sensors

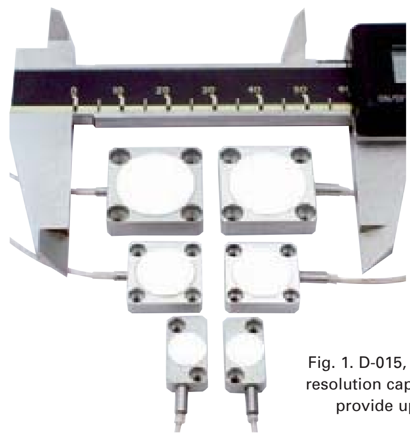


Fig. 1. D-015, D-050, D-100 ultra-high-resolution capacitive position sensors provide up to 10,000 times higher resolution than calipers

- **For Applications Requiring Highest Precision**
- **Measuring Range to 1000 microns**
- **Resolution to 0.01 nm**
- **Linearization to 0.01 % with Digital Controller**
- **Bandwidth up to 10 kHz**
- **Servo Controller E-509.CxA, Compatible with E-500 Controller System**
- **Custom Designs**

Measurement Method

Capacitive position sensors are analog non-contact devices. A two-electrode capacitive position sensor consists of two RF-driven plates that are part of a capacitive bridge. The high-frequency AC excitation provides better long term stability than DC excited sensors (see p. 3-19, Fig. 5). One plate (probe) is fixed, the other plate (target) is connected to the object to be positioned. Since the plate size and the dielectric medium (air) remains unchanged, capacitance is directly related to the distance between the plates. Ultra-precise electronics convert the capacitance information into a signal proportional to distance.

Direct Metrology, Parallel Metrology

The sensors offered by PI are the most accurate measuring systems for nanopositioning applications currently on the market. In contrast to high-resolution sensors measuring deformation in the drive train (see p. 2-8 *ff*), like strain gauge or piezoresistive sensors, capacitive sensors are non-contact, direct-metrology devices–a fact which gives them many advantages:

- Better Phase Fidelity
- Higher Bandwidth
- No Periodic Error
- Non-Contacting
- Ideal for Parallel Metrology
- Higher Linearity
- Better Reproducibility
- Higher Long-Term Stability

Capacitive sensors are especially well-suited for parallel metrology configurations. In multi-axis nanopositioning systems, parallel metrology means that the controller monitors all controlled degrees of freedom relative to "ground" (the fixed frame) and uses each actuator to compensate the undesired off-axis motion of the others automatically (active trajectory control). As a result, it is possible to keep deviations in the sub-nanometer and sub-microradian range (see p. 2-212 *ff* in the "Tutorial" section).

Resolution

Resolution on the order of picometers is achievable with short-range, two-electrode capacitive position sensors (single-electrode capacitive position sensors provide less resolution, linearity and accuracy than two-electrode sensors). Theoretical measurement resolution is limited only by quantum noise. In practical applications, stray radiation, electronics-induced noise and geometric effects are the limiting factors. For example, with the 100 µm range, a D-100.00 sensor and E-509.C1A electronics, the effective noise factor is $0.02\ \mathrm{nm}/\sqrt{\mathrm{Hz}}$. This translates to 0.2 nm at 100 Hz bandwidth. The maximum standard bandwidth (jumper selectable) is 3 kHz.

Figure 2 shows a D-015, 15 µm capacitive position sensor and an interferometer, both measuring nanometer-range actuator cycles. The graphs clearly show the superior resolution of the capacitive position sensing technique.

Ordering Information

D-015.00
Capacitive Position Sensor, 15 µm, Aluminum

D-050.00
Capacitive Position Sensor, 50 µm, Aluminum

D-100.00
Capacitive Position Sensor, 100 µm, Aluminum

Ask about custom designs!

Notes

In addition to the standard sensors listed here, PI offers a variety of custom versions along with custom electronics for different measuring ranges, material match etc. If you don't find what you are looking for, please call your local PI Sales Engineer.

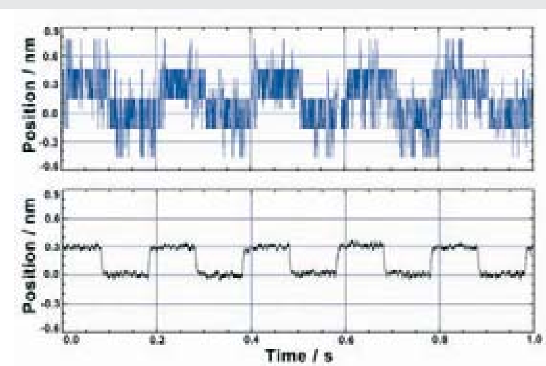
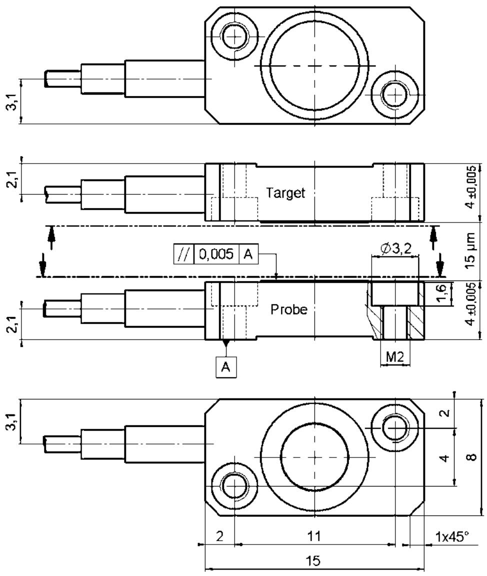
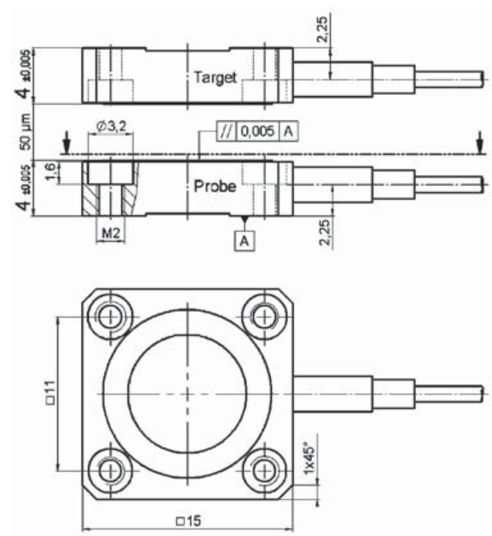


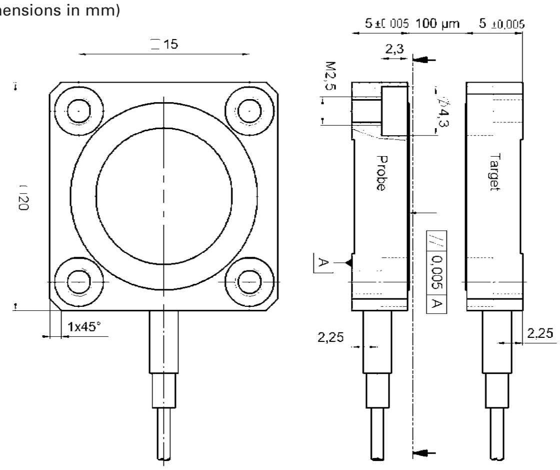
Fig. 2. Piezo nanopositioning system making 0.3 nm steps, measured with PI capacitive sensor (lower curve) and with a highly precise laser interferometer. The capacitive sensor provides significantly higher resolution than the interferometer.



D-015.00 (dimensions in mm)



D-050.00 (dimensions in mm)



D-100.00 (dimensions in mm)

Technical Data

Model	D-015.00	D-050.00	D-100.00	Units
Sensor				
Sensor typ	Capacitive	Capacitive	Capacitive	
Nominal measurement range	15	50	100	µm
Extended measurement range	45	150	300	µm
Resolution*	0.0005	0.0005	0.0005	% of measurement range
Linearity**	0.01	0.01	0.01	%
Sensor active area	16.6	67.7	113.1	mm²
Thermal drift***	50	50	50	ppm/K
Miscellaneous				
Operating temperature range	-20 bis 80	-20 bis 80	-20 bis 80	°C
Material	Aluminum	Aluminum	Aluminum	
Recommended sensor electronics	E-509.CxA	E-509.CxA	E-509.CxA (p. 3-16)	

Ask for custom materials
*3 kHz, with E-509.C3A servo controller
**With digital controller. Up to 0,05 % typ. with E-509 analog controller
***Change of active surface size in ppm (parts per million), refers to measurement range

E-509 Signal Conditioner / Piezo Servo Module

3-Channel Servo-Controller Module for E-500 Piezo Controller System

E-509 3-channel servo-controller module for nanopositioning systems with strain gauge sensors

Ordering Information

E-509.C1A
Sensor / Piezo Servo-Control Module, Capacitive Sensor, 1 Channel

E-509.C2A
Sensor / Piezo Servo-Control Module, Capacitive Sensors, 2 Channels

E-509.C3A
Sensor / Piezo Servo-Control Module, Capacitive Sensors, 3 Channels

Ask about custom designs!

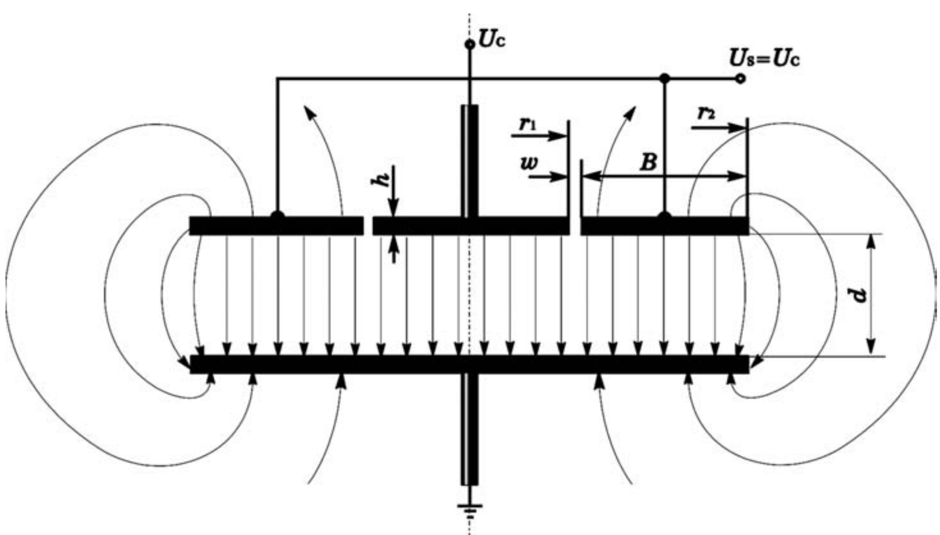
- **1-, 2- and 3-Channel Versions**
- **Improves Linearity**
- **Eliminates Drift and Hysteresis**
- **Notch Filter for Higher Bandwidth**
- **Increases Piezo Stiffness**
- **ILS Circuitry Maximizes Capacitive Sensor Linearity**
- **Plug-In Module for E-500 System**
- **Prepared for Interfaces / Display Modules (optional)**

The E-509 module is both a signal conditioner for high-resolution capacitive and SGS displacement sensors and a servo-controller for closed-loop piezo nanopositioning mechanics. For more information (see page 2-152).

Technical Data

Model	E-509.C1A/E-509.C2A/E-509.C3A	E-509.S1/E-509.S3
Function	Signal conditioner & servo-controller for piezo mechanics	Signal conditioner & servo-controller for piezo mechanics
Channels	1/2/3	1/3
Sensor		
Servo characteristics	P-I (analog), notch filter	P-I (analog), notch filter
Sensor type	Capacitive	SGS
Sensor channels	1 / 2 /3	1 / 3
Sensor bandwidth	0.3 to 3 kHz (selectable with jumper); up to 10 kHz on request	0.3; 1; 3 kHz
Noise factor	0.115 ppm/Hz½	
Thermal drift	<0.3 mV / °C	<3 mV / °C
Linearity	<0.05%	<0.2%
Interfaces and operation		
Sensor connection	LEMO EPL.00.250.NTD	LEMO ERA.0S.304.CLL
Sensor monitor output	0–10 V	0–10 V
Sensor monitor socket	LEMO 6-pin FGG.0B.306.CLAD56	BNC (1-ch.) / 3-pin. LEMO (3-ch.)
Supported functionality	ILS (Integrated Linearization System)	ILS (Integrated Linearization System)
Display	Overflow LED	Overflow LED
Miscellaneous		
Operating temperature range	+5 to +50 °C	+5 to +50 °C
Dimensions	7HP/3U	7HP/3U
Mass	0.35 kg	0.35 kg
Operating Voltage	E-500 System	E-500 System
Max. power consumption	4 to 8 W	4 to 8 W

Nanometrology Fundamentals



Resolution / Bandwidth

Resolution in nanopositioning relates to the smallest change in displacement that can still be detected by the measuring devices.

For capacitive sensors, resolution is in principle unlimited, and is in practice limited by electronic noise. PI signal conditioner electronics are optimized for high linearity, bandwidth and minimum noise, enabling sensor resolution down to the picometer range.

Electronic noise and sensor signal bandwidth are interdependent. Limiting the bandwidth reduces noise and thereby improves resolution. The working distance also influences the resolution: the smaller the working distance of the system, the lower the absolute value of the electronic noise.

Figure 1 shows measurements of nanometer-range actuator cycles taken with a D-015, 15 µm capacitive position sensor and a laser interferometer. The graphs clearly show the superior performance of the capacitive position sensing technique.

Figure 2 illustrates the influence of bandwidth upon resolution: the PISeca™ single-electrode sensors show excellent resolution down to the sub-nanometer range, even at high bandwidths.

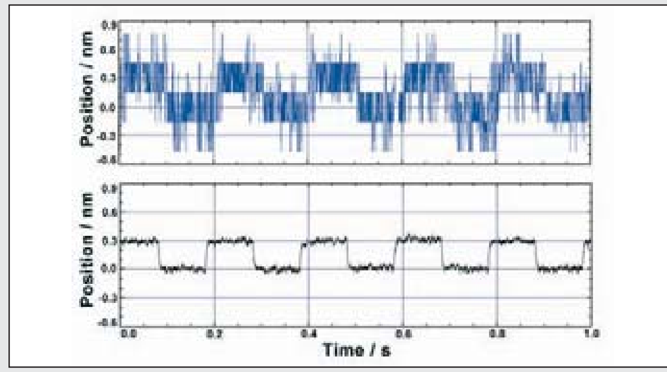


Fig. 1: Piezo nanopositioning system making 0.3 nm steps, measured with PI capacitive sensor (lower curve) and with a highly precise laser interferometer. The capacitive sensor provides significantly higher resolution than the interferometer

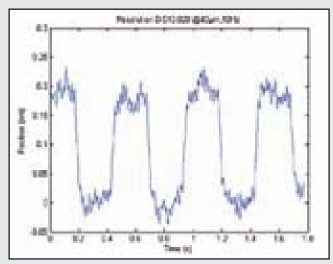


Fig. 2: Resolution significantly below 1 nm is achieved with a 20 µm PISeca™ single-electrode sensor (D-510.020) and the E-852 signal conditioner electronics. Left: 0.2 nm-steps under quasi-static conditions (bandwidth 10 Hz), right: 1 nm-steps with maximum bandwidth (6.6 kHz)

Linearity and Stability of PI sensors

The linearity of a measurement denotes the degree of constancy in the proportional relation between change in probe-target distance and the output signal. Usually linearity is given as linearity error in percent of the full measurement range. A linearity error of 0.1 % with range of 100 µm gives a maximum error of 0.1 µm. Linearity error has no influence whatsoever upon resolution and repeatability of a measurement.

Linearity is influenced to a high degree by homogeneity of the electric field and thus by any non-parallelism of the probe and target in the application. PI capacitive position sensor electronics incorporate a proprietary design providing superior linearity, low sensitivity to cable capacitance, low background noise and low drift. The Integrated Linearization System (ILS) compensates for non-parallelism influences.

A comparison between a conventional capacitive position sensor system and a PI ILS system is shown in Figure 3. When used with PI digital controllers (which add polynomial linearization) a positioning linearity of up to 0.003 % is achievable.

Figure 4 shows the linearity of a P-752.11C piezo flexure nanopositioning stage with integrated capacitive position sensor operated in closed-loop

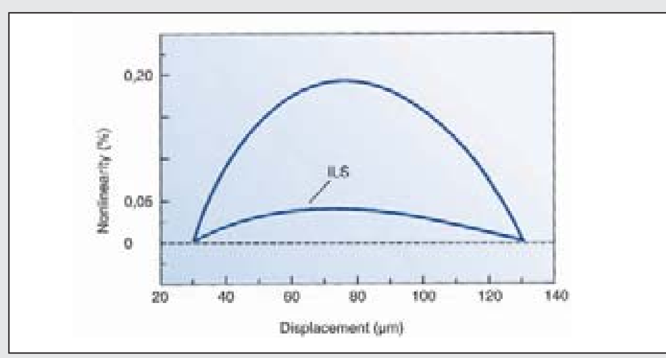


Fig. 3: Linearity of conventional capacitive position sensor system vs. PI ILS (integrated linearization system), shown before digital linearization

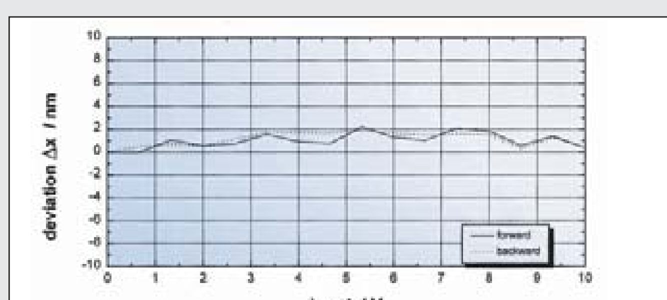


Fig. 4: Linearity of a P-752.11C, 15 µm piezo nanopositioning stage operated with E-500/E-509.C1A control electronics. The travel range is 15 µm, the gain 1.5 µm/V. Linearity is better than 0.02 %; even higher linearity is achievable with PI digital controllers

mode with an analog controller. All errors contributed by the mechanics, PZT drive, sensors and electronics are included in the resulting linearity of better than 0.02 %. Even higher linearity is achievable with PI digital controllers like the E-710.

Stability of the measurement is limited mainly by thermal and electronic drift. For accuracy and repeatability reasons, it is thus necessary to maintain constant environmental conditions. The exceptional long-term stability of the PI capacitive position sensor and electronics design is shown in Figure 5.

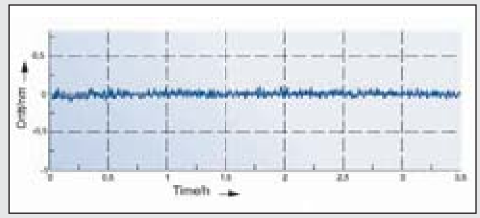


Fig. 5: Measurement stability of an E-509.C1A capacitive position sensor control module with 10 pF reference capacitor over 3.5 hours (after controller warm-up)

Principle of the Measurement

Signal/Displacement Proportionality

When a voltage is applied to the two plates of an ideal capacitor, it creates a homogenous electric field. Apart from constant factors, the electrical capacitance of the setup is determined by sensor area and plate distance. Thus, a change in displacement leads directly to a change in capacitance. This value is matched to a reference capacitance in a bridge circuit.

The Design of the signal conditioner electronics is such that the output signal is proportional to the gap change. The planes of the sensor surface ("probe") and the target form the two capacitor plates. The target should not be below a certain size because of boundary effects. This is important for applications with, say, a rotating drum as target. For metallic materials, the thickness of the target has no influence on the measurement.

Guard Ring Geometry/Design

The proportionality referred to is based on the homogeneity of the electric field. To eliminate boundary effects, the superior PI design uses a guard-ring electrode that surrounds the active sensor area and is actively kept at the same potential (see Fig. 7). This design shields the active sensor area and provides for excellent containment of the measurement zone. Thus optimum measuring linearity over the full range is achieved within the specified accuracy.

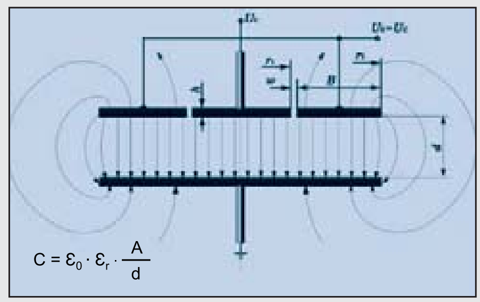


Fig. 6: Capacitive sensor working principle. The capacitance C is proportional to the active sensor area A, ϵ_0 is constant, ϵ_r is the dielectric constant of the material between the plates, generally air

Fig. 7: Capacitive sensors with guard ring design provide superior linearity

Calibration for Best Accuracy

PI's nanometrology calibration laboratories offer optimum conditions for factory calibration. As references, ultra-high-accuracy incremental sensors like laser interferometers are used.

PISeca™ systems are calibrated at PI with a NEXLINE® positioning system having a closed-loop resolution better than 0.01 nm in a test stand with friction-free flexure guidance and an incremental reference sensor featuring a resolution better than 0.1 nm (Fig. 8 and 9).

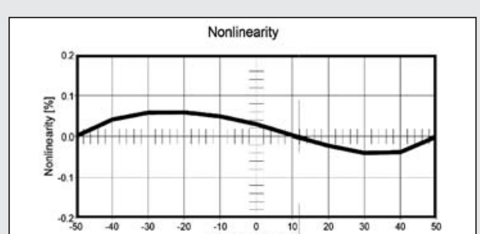


Fig. 8: Output linearity error of a PISeca™ single-electrode system is typically less than 0.1% over the full measurement range

Direct Metrology, Parallel Metrology

Direct Metrology / Parallel Metrology with Two-Plate Capacitive Sensors

Capacitive sensors are the ideal choice for nanometrology applications in positioning, scanning and metrology requiring the highest possible accuracy. Two-plate capacitive sensors achieve the highest linearity and long-term stability. The measurement probe can be attached directly to the moved surface (direct metrology) and provide absolute, non-contact displacement values against a reference surface, with no influence whatsoever on the motion performed. These sensors are particularly well-suited for parallel-kinematics nanopositioning systems. There, in a multi-axis system, motion in all degrees of freedom is measured against a common reference, and the runout of the various actuators can be compensated out in real time (active trajectory control). In this way, motion accuracies in the subnanometer and submicroradian ranges can be achieved.

Special Design Eliminates Cable Influences

When measuring distance by detection of capacitance changes, fluctuations in the cable capacitance can have an adverse effect on accuracy. This is why most capacitive measurement systems only provide satisfactory results with short, well-defined cable lengths.
PI systems use a special design which eliminates cable influences, permitting use of cable lengths of up to 3 m without difficulty. For optimum results, we recommend calibration of the sensor-actuator system in the PI metrology lab.
Longer distances between sensor and electronics can be spanned with special, loss-free, digital transmission protocols.

Electrode Geometry, Sensor Surface Flatness and Finish

During sensor production, great care is taken to maintain critical mechanical tolerances. Measuring surfaces are diamond machined using sophisticated process control techniques. The result is the smooth, ultra-flat, mirrored surfaces required to obtain the highest resolution commercially available.

Parallelism of Measuring Surfaces

For optimum results, target and probe plates must remain parallel to each other during measurement. For small measurement distances and small active areas, any divergence has a strong influence on the measurement results. Tilt adversely affects linearity and gain, although not resolution or repeatability (see fig. 12).
Positioning systems with multi-link flexure guidance reduce tip and tilt to negligable levels (see Fig. 13) and achieve outstanding accuracy.

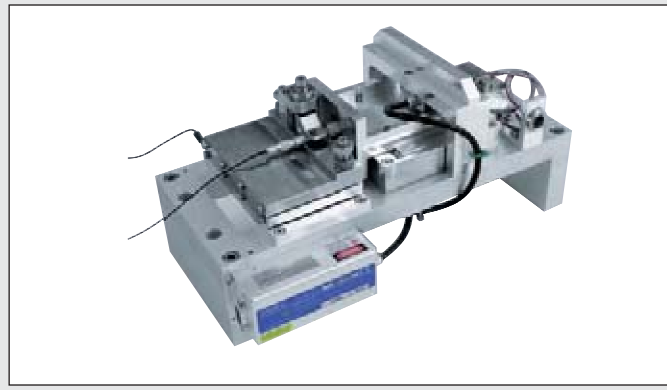


Fig. 9: Ultra-high-precision NEXLINE® positioning system with incremental sensor in a calibration and test stand for PISeca™ sensors. The resolution is significantly better than that of a laser interferometer

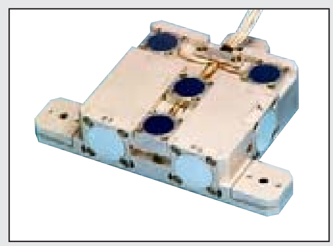


Fig. 10: Capacitive position sensors in an ultra-high-accuracy, six-axis nanopositioning system designed by PI for the German National Metrology Institute (PTB). Application: scanning microscopy

Fig. 11: Digital sensor-signal transmission (DST) allows a distance up to 15 m between positioning unit and controller, here an E-710 multi-axis digital piezo controller

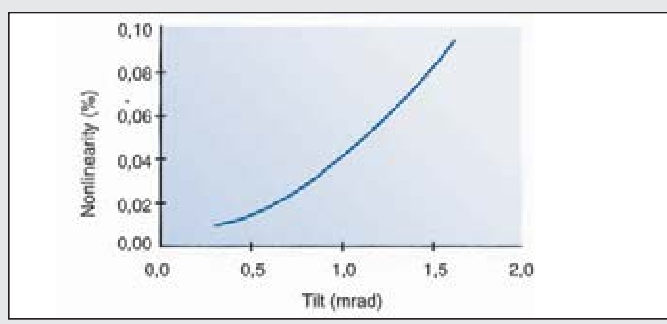


Fig. 12: Nonlinearity vs. tilt. Resolution and repeatability are not affected by tilt

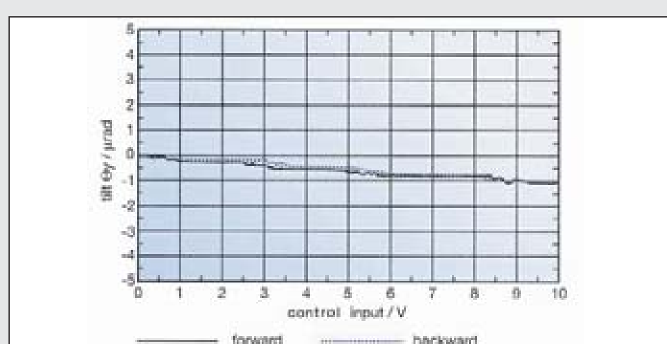


Fig. 13. Flexure-guided nanopositioning systems like the P-752 offer submicroradian guiding accuracy and are optimally suited for capacitive sensors

Glossary

Measurement Range

The measurement range depends on the size of the active sensor area as well as on the electronics used.
Due to PI's proprietary signal conditioner electronics design, the mid-range distance is always identical to the selected measurement range. The probe-to-target gap may vary from 50 % to 150 % of the measurement range (see Fig. 14).
The sensor capacitance is the same as that of the reference capacitance in the electronics. Different reference capacitances can be used to extend the nominal (standard) measurement range (see Fig. 15).

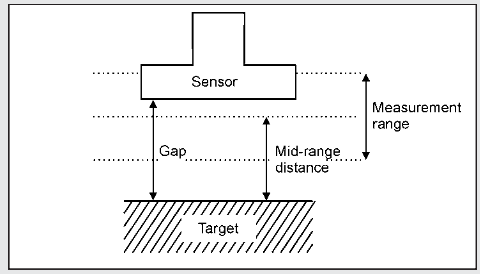


Fig. 14: Definitions: measurement range and mid-range distance have identical values

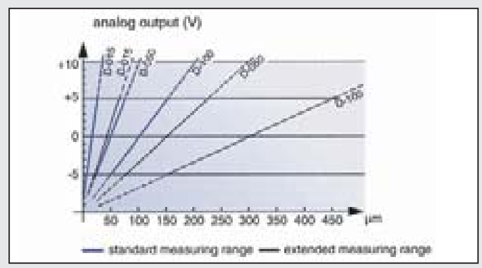


Fig. 15: Measuring ranges of different PI capacitive position sensors (standard ranges in blue, extended ranges in black)

Target

Two-electrode capacitive sensors consist of two electrodes, named probe and target.
Single-electrode sensors measure against a surface that is called the target. The target surface is, in principle, a conductive material electrically connected to ground. Measurement against semi-conductors is possible as well.

While two-plate capacitive sensors consist of two well-defined high-quality planes, with single-plate sensors, target surface characteristics can influence the results. A curved or rough surface will deteriorate the resolution because the results refer to an average gap (see Fig. 16 and 17). Surface shape also influences the homogeneity of the electric field and thereby the measurement linearity. For factory calibration, a target plane that is considerably larger than the sensor area is used.

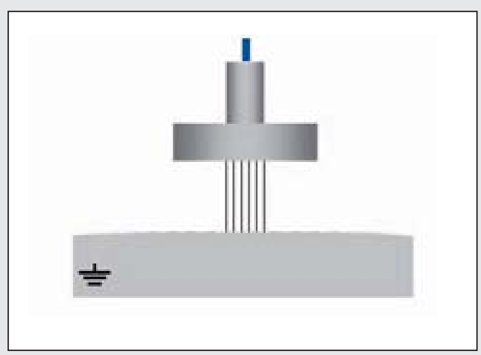


Fig. 16: Roughness of the target surface downgrades resolution and linearity

Environment

Precision measurement with nanometer accuracy requires minimizing environmental influences. Constancy of temperature and humidity during the measurement are as essential as cleanliness.
Electronics from PI are basically very temperature stable. Temperature drift is under 0.2% of full measurement range with a change of temperature of 10 C°. Temperature changes also cause all material in the system to expand or contract, thus changing the actual measured gap.
The influence of a change in relative humidity of 30 percentage points is less than 0.5% of the measurement range. Condensation must always be avoided. Dusty or damaged sensor surfaces will also worsen the measurement quality.
Environmental conditions at the time of calibration are noted on the calibration sheet PI provides with each individual system.

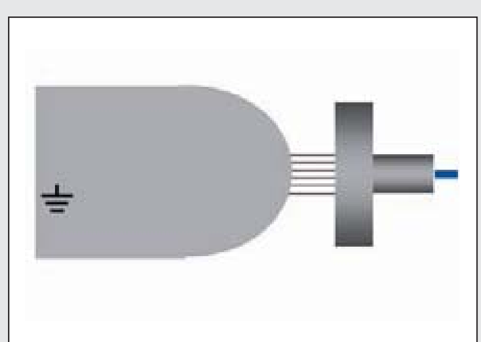


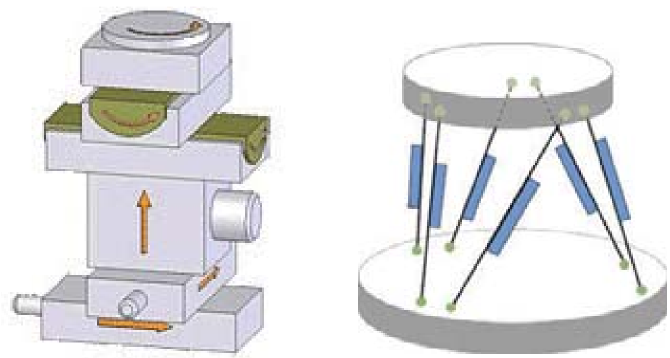
Fig. 17: Curved surfaces lead to an averaged distance measurement

Hexapod 6-Axis Systems / Parallel Kinematics

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

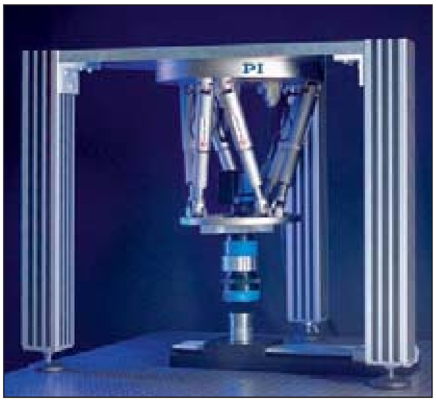
PI is the leading manufacturer of Hexapod high-performance micro- and nanopositioning systems. These parallel-kinematics devices, in a number of different forms, are suitable for diverse applications, ranging from handling systems in electronics fabrication and tool control in precision machining, through 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.

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

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.



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

PI Piezo • Nano • Positioning

M-810 Miniature Hexapod

6 Degrees of Freedom & High Precision in a Small Package

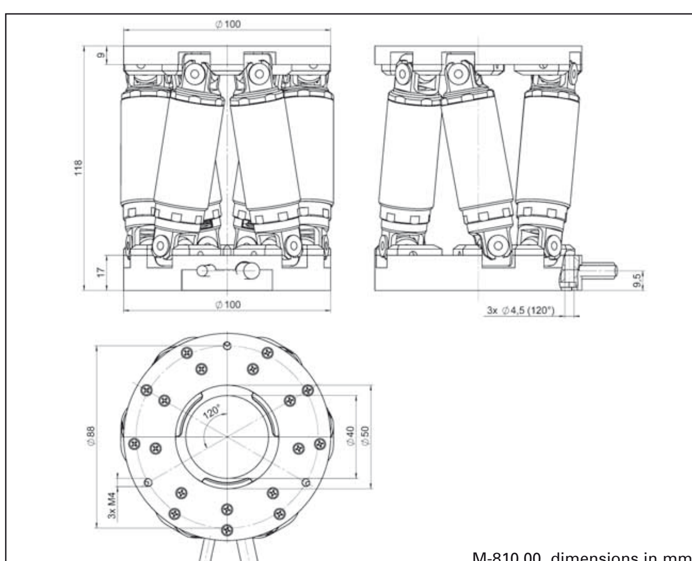
The miniature Hexapod M-810 provides long travel ranges despite its compact design

- **Most-Compact Hexapod in the PI Portfolio**
- **Travel Ranges 40 x 40 x 13 mm, Rotation to 60 Degrees**
- **Load Capacity to 5 kg**
- **Resolution of a Single Strut 40 nm**
- **Min. Incremental Motion to 200 nm**
- **Repeatability up to ±0.5 µm**
- **Velocity to 10 mm/s**

With a platform diameter of only 10 cm the M-810 Hexapod is the most compact parallel-kinematics micropositioning system to date. In addition to positioning all six axes with high speed and accuracy, it allows the user to define the center of rotation (pivot point) anywhere inside or outside the system envelope by one simple software command. This makes it ideal for all complex positioning tasks with restricted space.

Application Examples

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



M-810.00, dimensions in mm

Ordering Information

M-810.00
Miniature-Hexapod Microrobot with Controller, Direct Drive

Ask about custom designs

Extremely Compact, Great Freedom of Motion

The M-810.00 with its direct-drive torque motors and ActiveDrive™ system with integrated servo ampifiers provides an increased velocity of up to 10 mm/s for loads up to 5 kg. Small and compact, the Hexapod allows a large stroke of up to 40 mm (linear) and 60° (angular).

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.

User-Defined 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 with a simple 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.

Technical Data

	M-810.00	Unit
Active axes	X, Y, Z, ΘX, ΘY, ΘZ	
Motion and positioning		
*Travel range X, Y	±20	mm
*Travel range Z	±6.5	mm
*Travel range ΘX, ΘY	±11	°
*Travel range ΘZ	±30	°
Actor drive	Brushless DC Motor, ActiveDrive™	
Actuator stroke	±7.5	mm
Single-actuator design resolution	0.04	µm
Integrated sensor	Rotary encoder	
Sensor resolution	12800	Cts./rev.
**Min. incremental motion X, Y	1	µm
**Min. incremental motion Z	0.2	µm
**Min. incremental motion ΘX, ΘY, ΘZ	3.5	µrad
Repeatability X, Y	±2	µm
Repeatability Z	±0.5	µm
Repeatability ΘX, ΘY, ΘZ	±5	µrad
Backlash X, Y	2	µm
Backlash Z	0.5	µm
Max. velocity X, Y, Z	10	mm/s
Max. velocity ΘX, ΘY, ΘZ	250	mrad/s
Typ. velocity X, Y, Z	5	mm/s
Typ. velocity ΘX, ΘY, ΘZ	120	mrad/s
Mechanical properties		
Stiffness X, Y	0.1	N/µm
Stiffness Z	4	N/µm
Max. load (baseplate horizontal / any orientation)	5 / 2.5	kg
Miscellaneous		
Operating temperature range	0 to +50	°C
Material	Stainless steel, aluminum	
Mass	1.7	kg
Controller		
Operating Voltage	100–240 VAC, 50/60 Hz	

* The travel ranges of the individual coordinates (X, Y, Z, ΘX, ΘY, ΘZ) are interdependent. The data for each axis in this table shows its maximum travel, 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). Eliminates bending, inertia and friction, improving accuracy.

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

The M-810 miniature Hexapod is now available with a modified cable exit. This makes for even more compact integration

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 micro-positioning 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 arc-second 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.

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

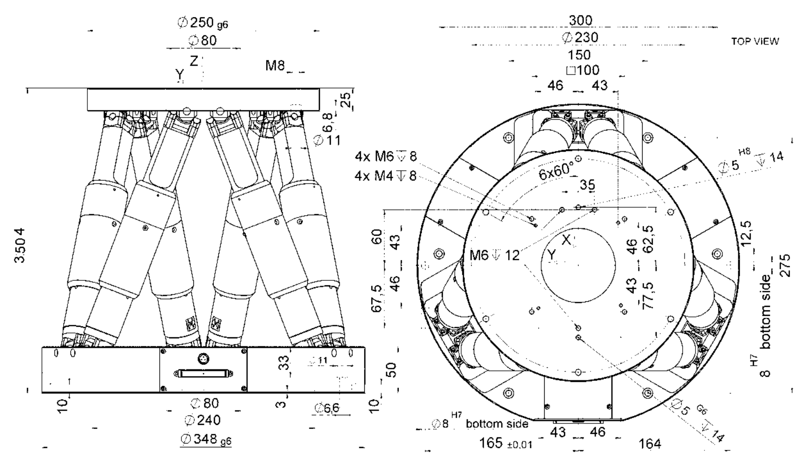
Custom Hexapod designed for neurosurgery Photo: IPA

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).

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



M-850 Hexapod. Dimensions in mm

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

Piezo • Nano • Positioning

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

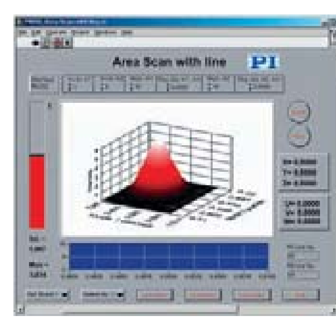
Optional Photometer

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

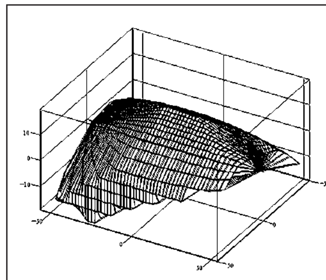
F-206.VVU
Photometer Card, Visible Range, 2 Channels

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 $\theta_X = \theta_Y = \theta_Z = 5°$

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

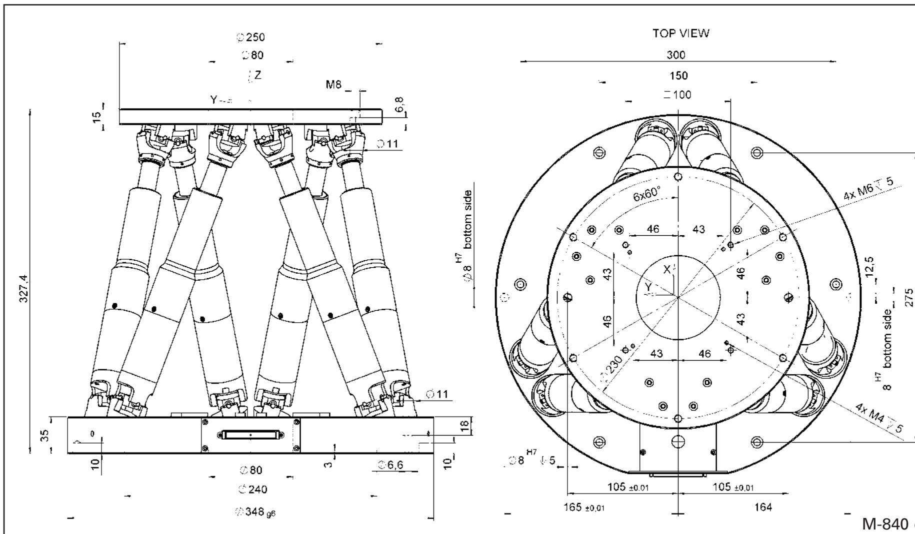
interface architecture, which provides a variety of high-level commands and includes a macro language for programming and storing command sequences.

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

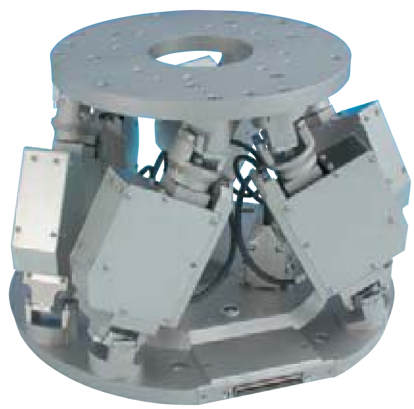
Model	M-840.5PD	M-840.5DG	Units
Active axes	X, Y, Z, θ_X, θ_Y, θ_Z	X, Y, Z, θ_X, θ_Y, θ_Z	
Motion and positioning			
*Travel range X, Y,	±50	±50	mm
*Travel range Z	±25	±25	mm
*Travel range θ_X, θ_Y,	±15	±15	°
*Travel range θ_Z	±30	±30	°
Actuator drive	DC-motor	DC-motor	
Actuator stroke	±25	±25	mm
Integrated 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

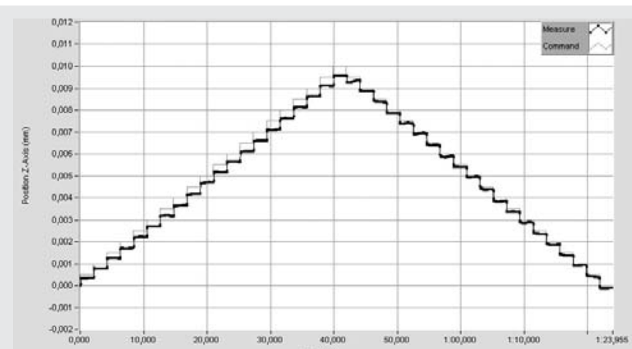
Ordering Information

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

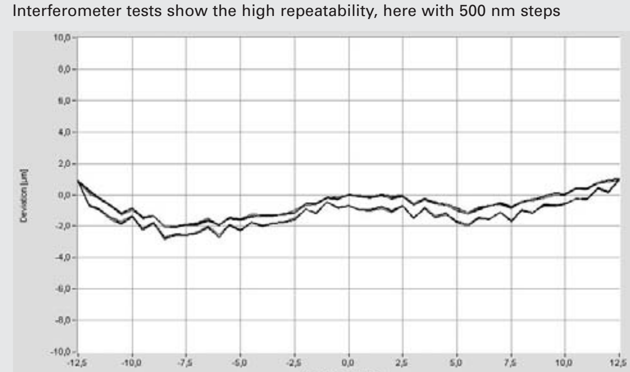
M-824.3DG
Compact Hexapod Microrobot with Controller, DC Motor Gearhead

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

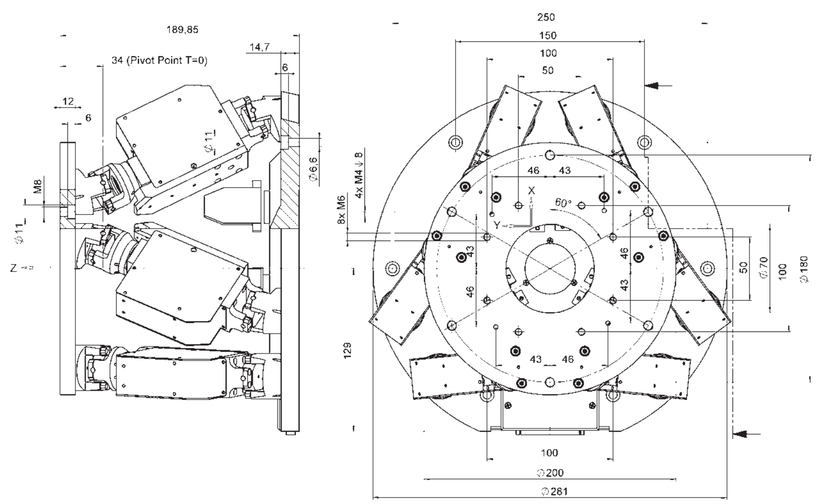


The interferometer test shows the Z axis accuracy over the entire travel range of 25 mm and the extremely high repeatability of ±0.046 µm interface architecture, which provides a variety of high-level commands and includes a macro language for programming and storing command sequences.

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)

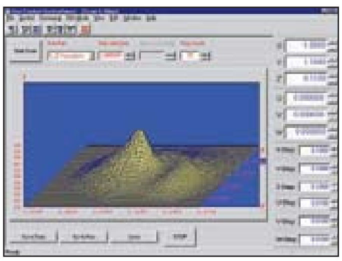
F-206.iiU
2-Channel Photometer Card (IR Range)

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

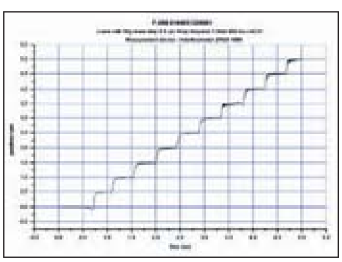
Additional Accessories, see www.pi.ws.

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

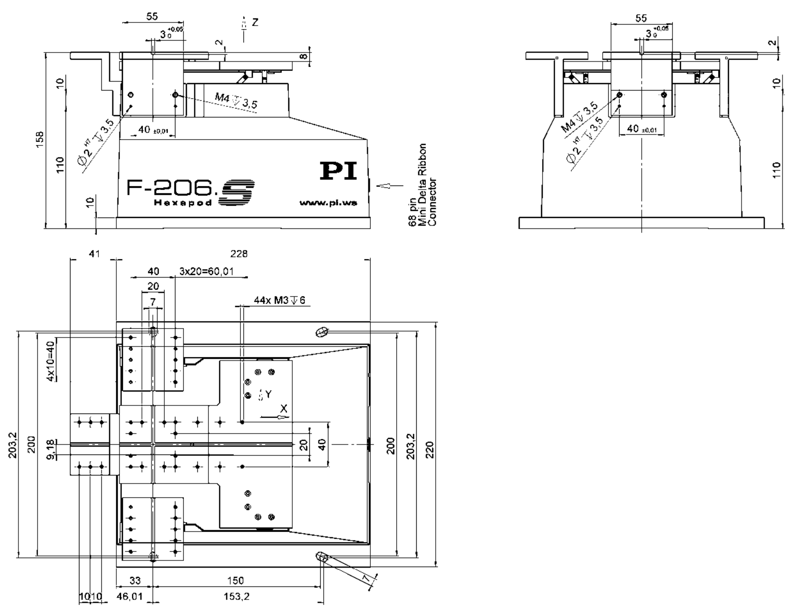
Both types are fully integrated with the controller hardware and with routines designed for automatic alignment of collimators, optical fibers and arrays. For more information on the photometers see www.pi.ws.



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

- 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

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

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 baseplate 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

Linear Stages

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

- 1 Leadscrew
- 2 Ball screw

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

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).

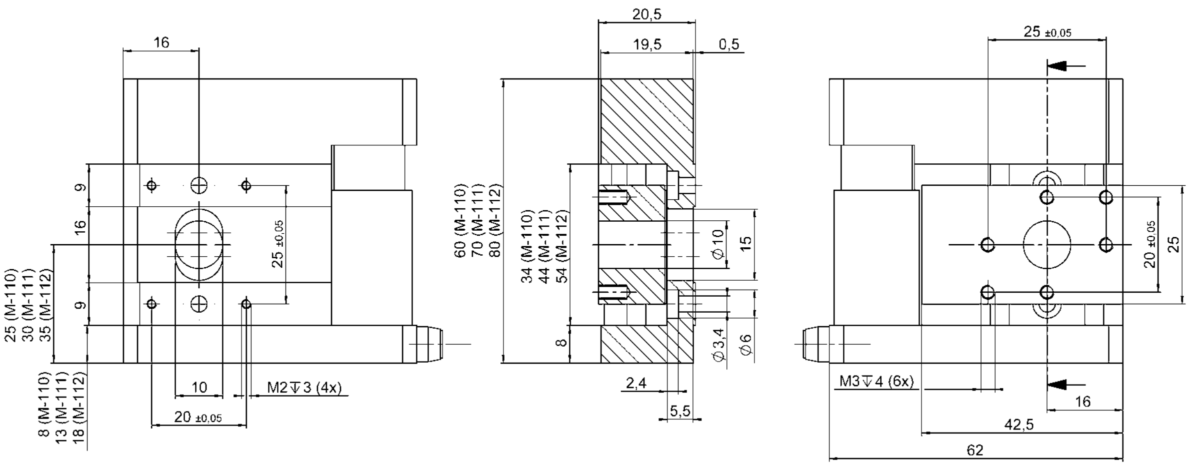
Low Cost of Ownership

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)

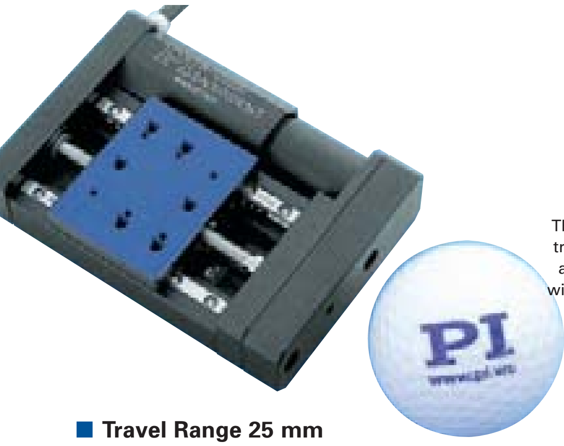
Technical Data

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.

Application Examples

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

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.

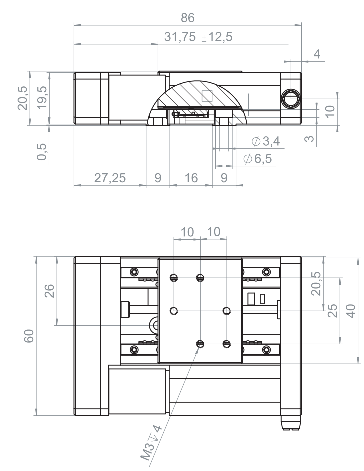
Ordering Information

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

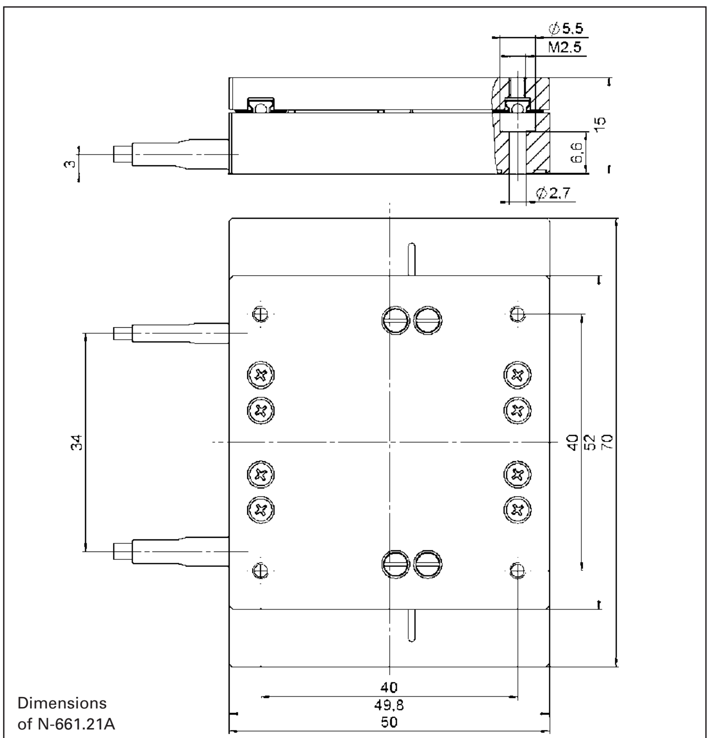
Model	M-122.2DD
Active axes	X
Motion and positioning	
Travel range	25 mm
Integrated sensor	Linear encoder
Sensor resolution	0.1 µm
Design resolution	0.1 µm
Min. incremental motion	0.2 µm
Backlash	0.2 µm
Unidirectional repeatability	0.15 µm
Pitch	±150 µrad
Yaw	±150 µrad
Max. velocity	20 mm/s
Origin repeatability	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® piezomotors. 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

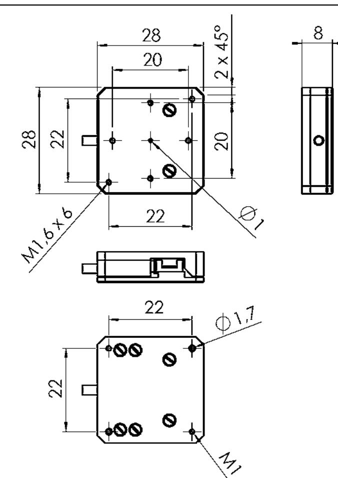
Accessories:

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

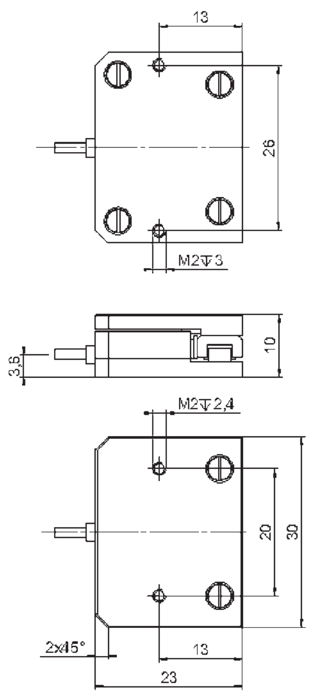
C-185.161
Analog Stand-Alone Drive Electronics with Power Supply for PILine® P-661 Motors

Notes

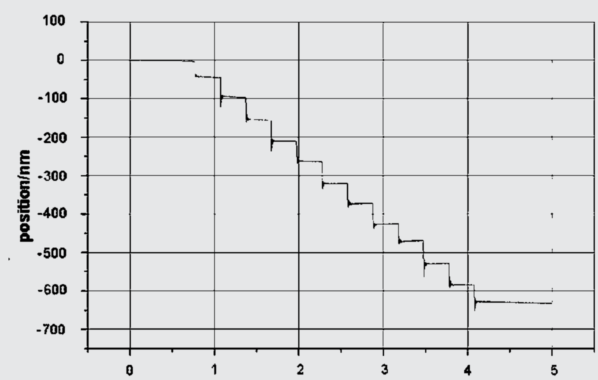
The products described in this document are in part protected by the following patents:
US Pat. No. 6,765,335
German Patent No. 10154526



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.

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

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

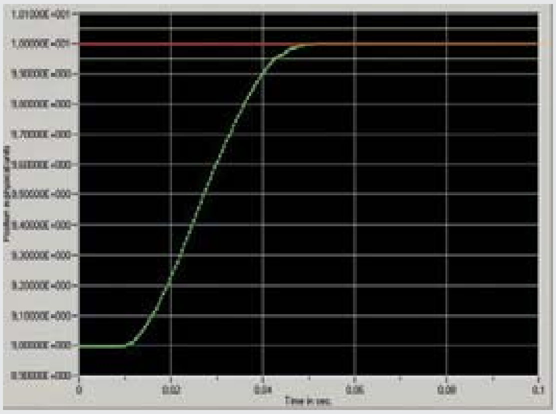
M-663.46V
PILine® Translation Stage, 19 mm, Linear Encoder, 0.1 µm Resolution, Vacuum Compatible to 10-6 hPa

Accessories:

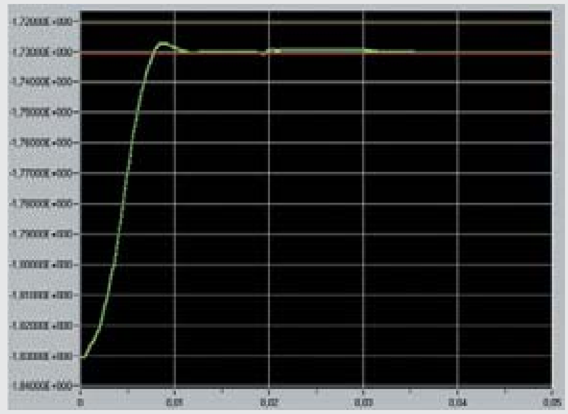
C-867.161
Piezomotor Controller with Drive Electronics, 1 Channel, for PILine® Systems with P-661 Motors

Driver for use with separate controller:

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



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

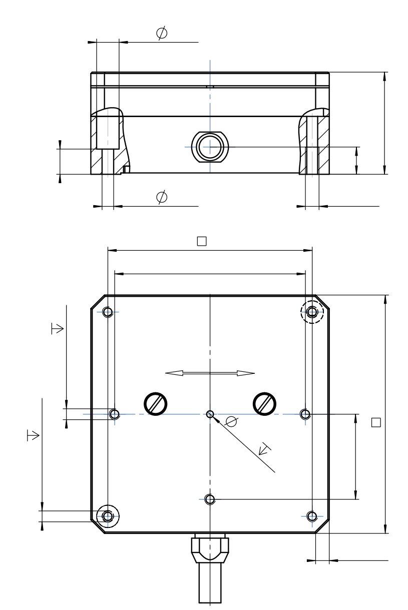


An M-663 with 100 g load settles to 0.1 µm accuracy in 10 ms after a 100 µm step, measured with C-867 controller/driver

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**
- Non-Magnetic and Vacuum-Compatible Drive Principle

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® micropositioning systems 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

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

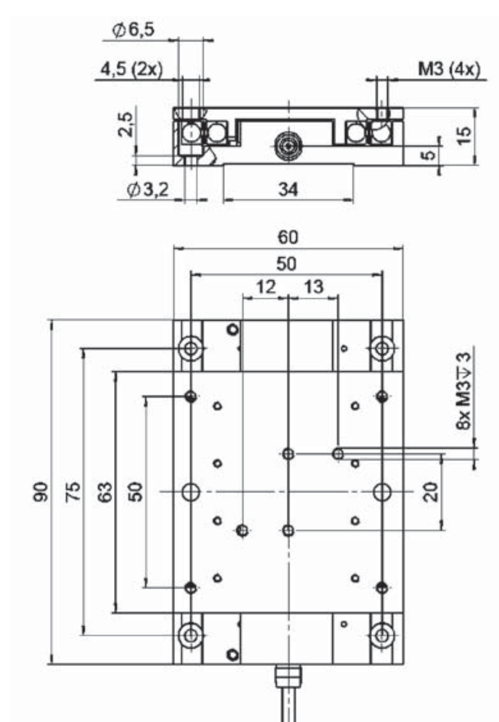
M-664.164
PILine® Micro Positioning Stage with P-664 Piezo Linear Motor, 25 mm, 4 N

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-683 PILine® Precision Micro Translation Stage

Low-Profile & High-Speed with Ultrasonic Piezomotors, Direct Position Metrology

M-683.2U4 (50 mm) low-profile translation stage with integrated high-speed ceramic linear motors

- **Max. Velocity 350 mm/s**
- **Low Profile: Only 21 mm Height**
- **Compact XY Combination Possible**
- **Up to 6 N Force Generation**
- **Direct Metrology Linear Encoder, 0.1 µm Resolution**
- **Travel Range 50 mm**
- **Excellent Guiding Accuracy Through Crossed Roller Bearings**
- **PILine®: Non-Magnetic and Vacuum-Compatible Working Principle**
- **Self Locking at Rest**

M-683 precision micropositioning stages make use of PILine® ultrasonic piezo linear motors enabling a compact design and low profile. An integrated linear encoder enables closed-loop control with 0.1 µm resolution. The M-683 translation stages use paired crossed-roller bearings mounted on ground-aluminum profiles for better guiding accuracy. Integrated U-164 PILine® linear motors provide push forces to 6 N and a maximum velocity of up to 350 mm/s. The stages can be arranged to form compact XY systems. If an additional Z-axis is required, the M-110 microstage series (see page 4-22) is recommended due to its higher holding force. The M-683 design is scalable and can be extended to provide longer travel ranges to 300 mm. Vacuum-compatible versions are also available on request.

Application Examples

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

Limit and Reference Switches

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

Advantages of PILine® Micro Positioning Systems

PILine® ultrasonic ceramic drives provide several advantages over classical motors and drivers:

- Higher Acclerations, 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
- No Lubricants
- Non-Magnetic and Vacuum Compatible Operating Principle

Optimized Controller and Drive Electronics

For optimum performance the highly specialized C-867 motion controller (see page 4-116) is recommended. This dedicated piezo motor controller also integrates the drive electronics which PILine® motors require to generate the ultrasonic oscillations for the piezoceramic element.

Furthermore, the controller has a number of special characteristics, including continuous automatic drive frequency adjustment, dynamic parameter switching for optimized high-speed motion and settling behavior and some other features to address the requirements of ultrasonic motors. 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) (see page 1-36) is available. It accepts an analog ±10 V signal to control the motor velocity. 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

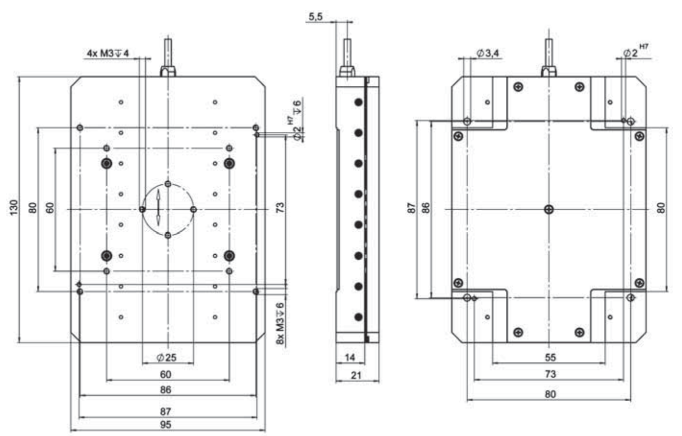
M-683.2U4
PILine® High-Speed Linear Stage, 50 mm, 6 N

Accessories:

M-110.05
Adapter bracket for vertical mount of M-110 stages on M-683 stages

Patent Protection

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-683.2U4 dimensions in mm

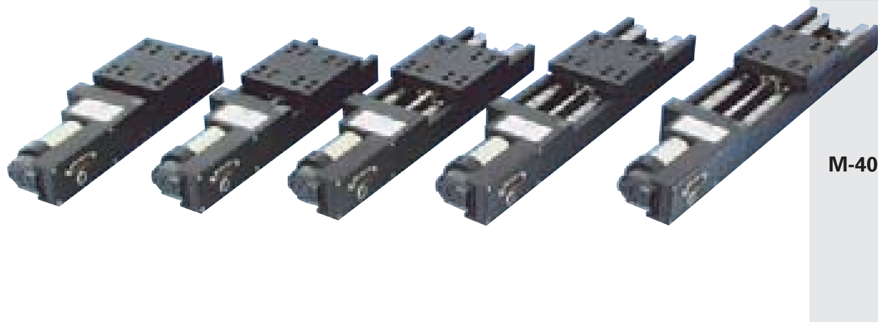
Technical Data

Model	M-683.2U4	Tolerance
Active axes	X	
Motion and positioning		
Travel range	50 mm	
Integrated sensor	Linear encoder	
Sensor resolution	0.1 µm	
Min. incremental motion	0.3 µm	typ.
Bidirectional repeatability	±1 µm	typ.
Unidirectional repeatability	0.2 µm	typ.
Pitch	±150 µrad	typ.
Yaw	±50 µrad	typ.
Max. velocity	350 mm/s	
Reference switch repeatability	1 µm	typ.
Mechanical properties		
Max. load capacity	50 N	
Max. push / pull force	6 N	
Max. holding force	6 N	
Drive properties		
Motor type	2 x U-164 PILine® ultrasonic piezo drive	
Operating Voltage	60 V_{rms}*	
Electrical power	15 W**	nominal
Power consumption	1.5 A**	
Reference Switch	optical	
Limit Switches	Hall-effect	
Miscellaneous		
Operating temperature range	0 to +50 °C	
Material	Al (black anodized)	
Dimensions	130 x 95 x 21 mm	
Mass	0.65 kg	±5 %
Cable length	1.5 m	±10 mm
Connector	MDR, 14-pin	
Recommended controller / driver	C-867.160 single-axis controller / driver C-185.D64 drive electronics	

*Power to the motor is supplied by the drive electronics, which runs on 12 V DC, or by the controller (24 V).
**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

M-40[ ].[ ][ ]

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

- **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

- **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

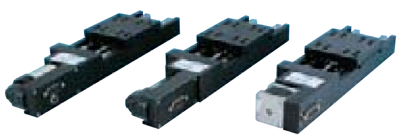
M-40x.xDG models are equipped with a DC motor and a shaft-mounted optical encoder, providing a minimum incremental motion of down to 0.1 µm. M-40x.x2S models feature a cost-effective direct-drive, 2-phase stepper motor, providing very smooth operation and a resolution of 0.16 µm.

Limit and Reference Switches

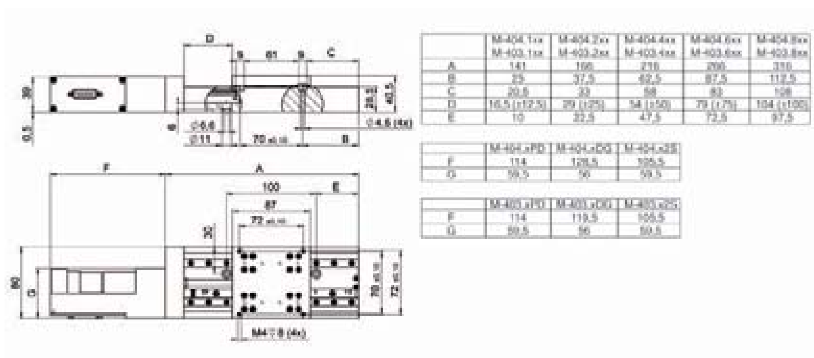
For the protection of your equipment, non-contact Hall-effect limit and reference switches are installed. The direction-sensing reference switch supports advanced automation applications with high precision.

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

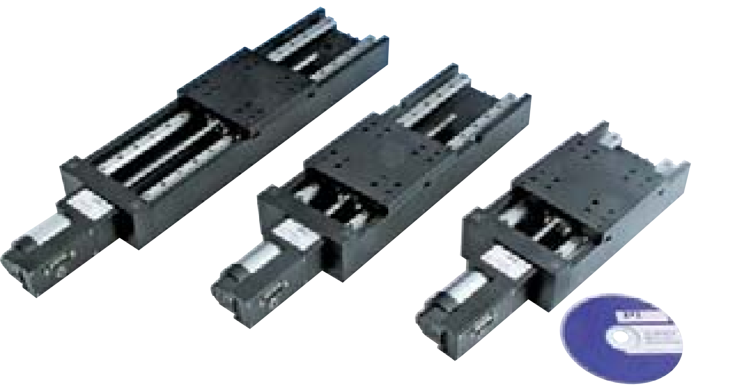
Technical Data

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 / 100 mm	75	75	75	200	200	200	µrad
Yaw / 100 mm	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

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

- **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

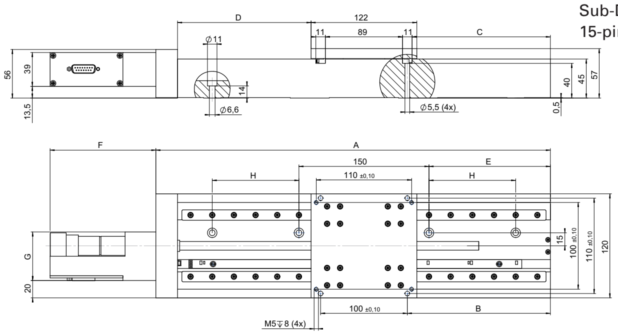
M41x.xDG models are equipped with a DC motor with a low-backlash gearhead and a shaft-mounted optical encoder to give a minimum incremental motion of 0.1 µm.
M-41x.x2S models feature a cost-effective direct-drive, 2-phase stepper motor, providing very smooth operation and a resolution of 0.2 µm.

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.

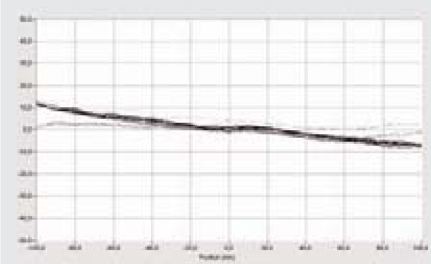


M-413 and M-414 dimensions in mm, Sub-D connector 15-pin, 3 m cable

	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 mm	100	100	100	300	300	300	µrad
Yaw /100 mm	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

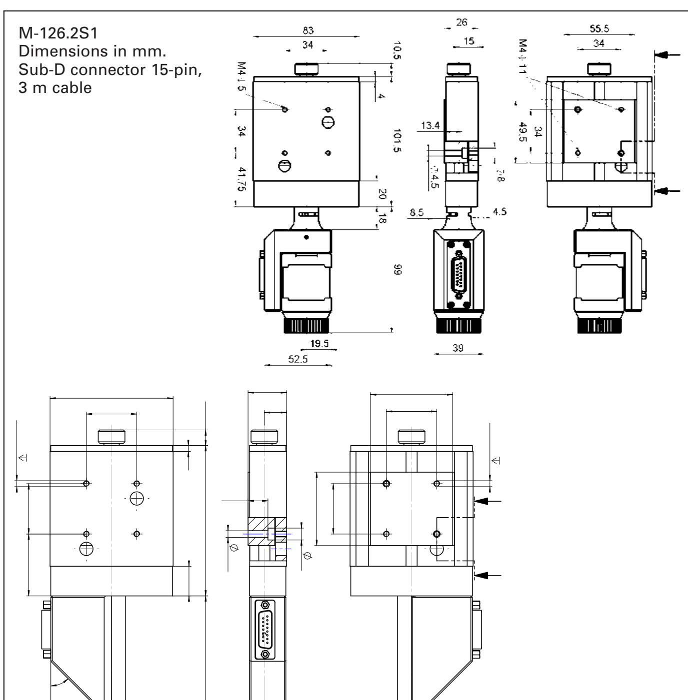
M-126.M0
Translation Stage, 25 mm, Manual Drive, Leadscrew

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

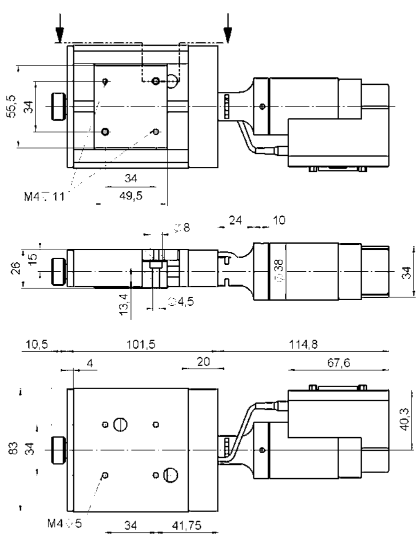
M-126.80
Adapter Plate for Honeycomb Tables

Ask about custom designs!

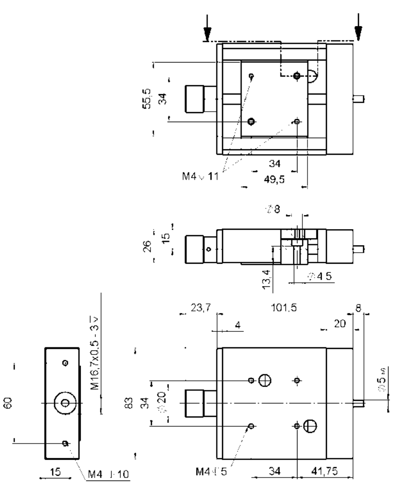
M-126.2S1
Dimensions in mm.
Sub-D connector 15-pin, 3 m cable



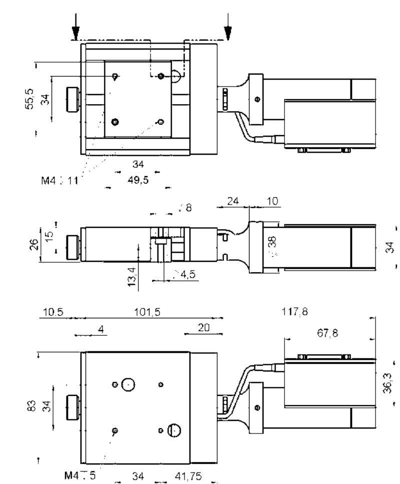
M-126.CG1 Dimensions in mm.
Sub-D connector 15-pin, 3 m cable



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)^4:01 ~ 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

Piezo • Nano • Positioning

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

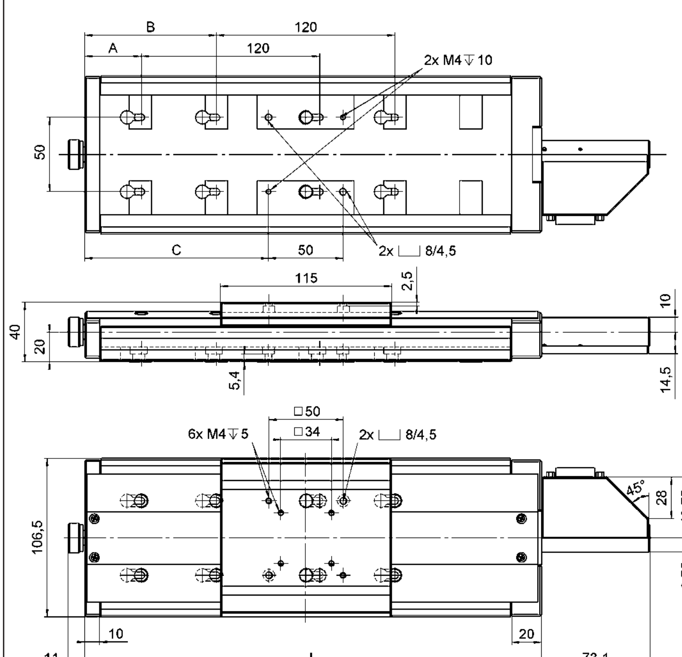
For the protection of your equipment, non-contact Hall-effect limit and reference switches are installed. The direction-sensing reference switch supports advanced automation applications with high precision (motorised versions only). All stages of this series can be cross stacked and combined with the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

Notes

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

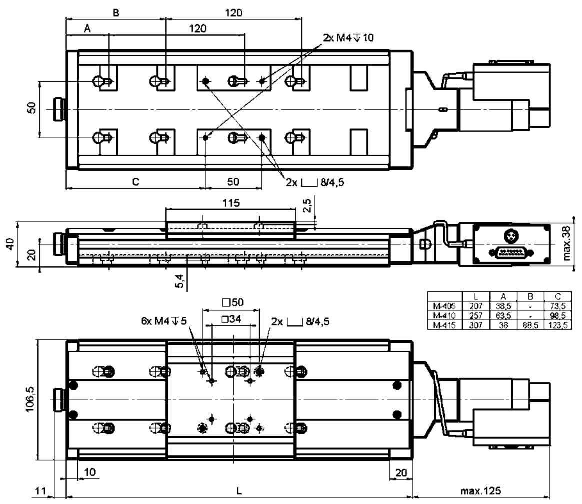
Application Examples

- 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

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!

Limit and Reference Switches

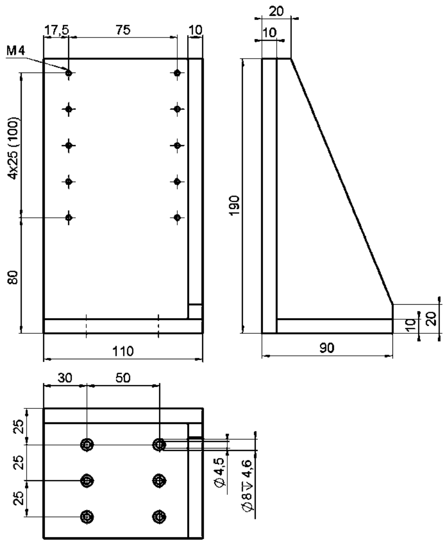
For the protection of your equipment, non-contact Hall-effect limit and reference switches are installed. The direction-sensing reference switch supports advanced automation applications with high precision.

Precision Assembly

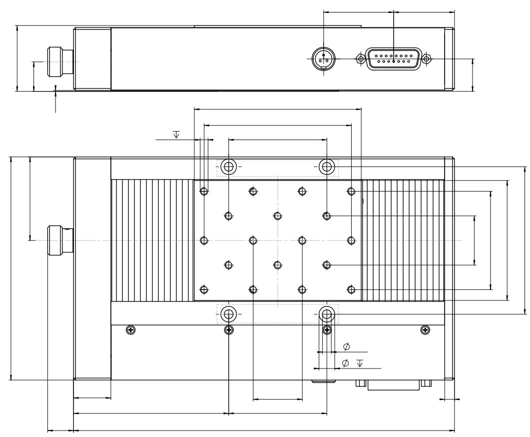
Each M-605 stage is precision assembled and optimized using laser interferometers for performance testing.

M-605.2DD XYZ-combination

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



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.

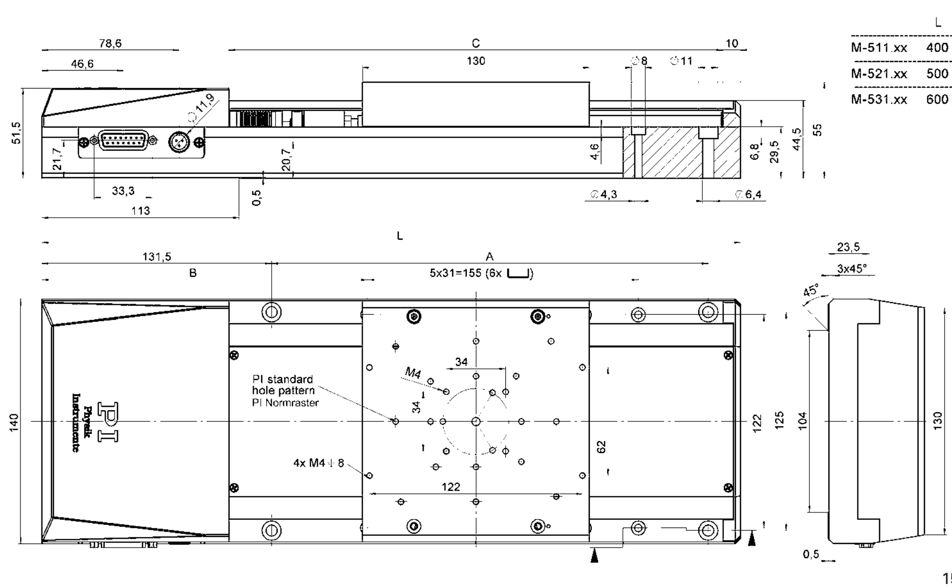
Precision Assembly

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
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	–	–	$(28/12)^4:1 \approx 29.6:1$	–	
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

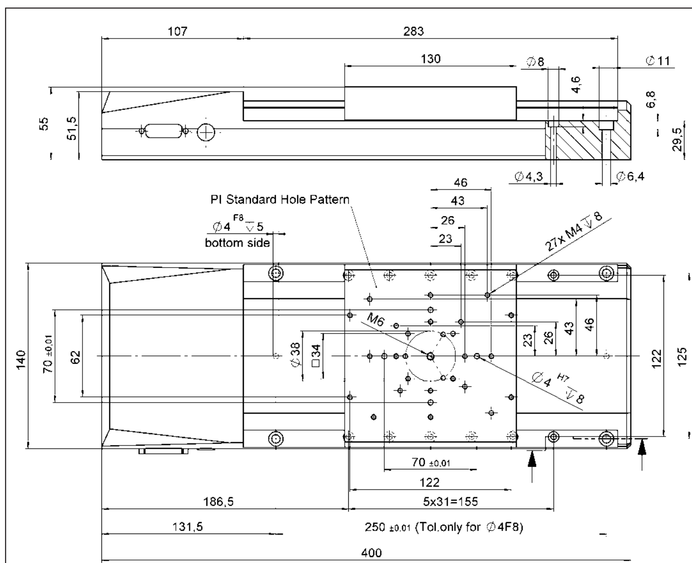
PI's highly specialized C-702 hybrid nanopositioning controller (see p. 4-118) compares the actual platform position (by reading the integrated linear encoder) with a calculated, smooth trajectory in real time. Its complex control algorithms continuously actuate both the piezoelectric and servo motor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

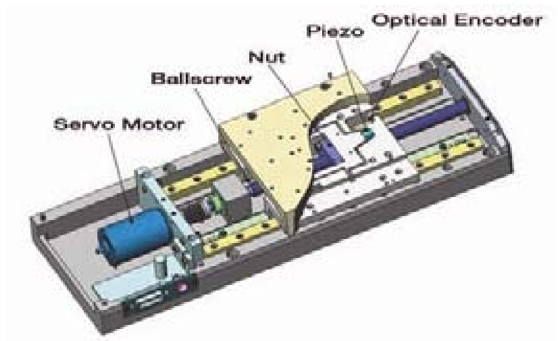
Ordering Information

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

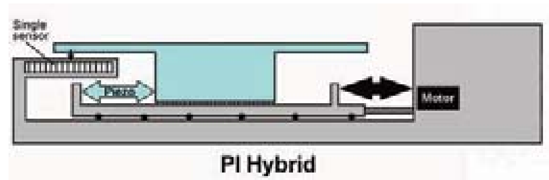
Ask about custom designs!



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 system 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

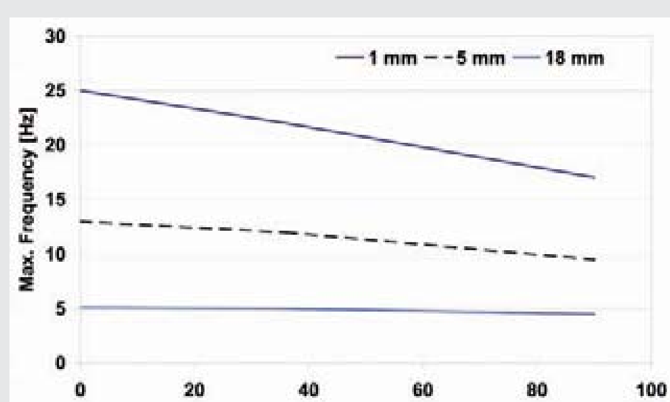
V-106.11S
QuickScan Voice Coil Scanning Stage, 6 mm

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

Frictionless Voice Coil Linear Drives

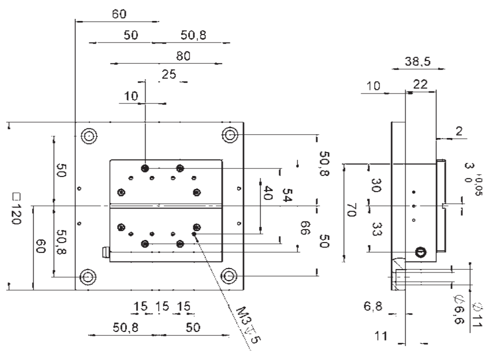
High-accuracy voice coil linear drives work on the same principle as electromagnetic loudspeakers. However, for precision positioning applications, they must provide much higher forces and high stability to hold a position without jitter. They must also be designed for closed-loop operation to allow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

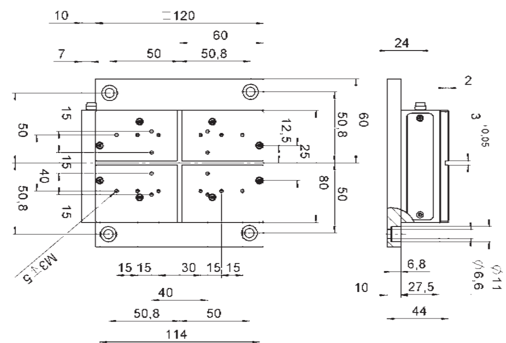


V-106.14S maximum scanning frequency for different loads and scan amplitudes for example 18 mm scans with up to 90 g load at >4 Hz frequency are feasible. The velocity is up to 270 mm/s

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



V-106.11S dimensions in mm



V-106.14S dimensions in mm

Technical Data

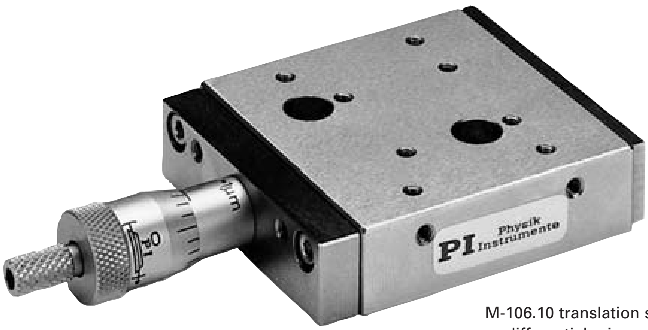
Model	V-106.11S	V-106.14S	Units	Tolerances
Active axes	X	X		
Motion and positioning				
Travel range	6	20	mm	
Integrated sensor	Linear encoder	Linear encoder		
Sensor resolution	0.1	0.1	µm	
Design resolution	0.1	0.1	µm	
Minimum incremental motion	0.2	0.2	µm	typ.
Backlash	0.2	0.2	µm	typ.
Unidirectional 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*

PI Piezo • Nano • Positioning

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

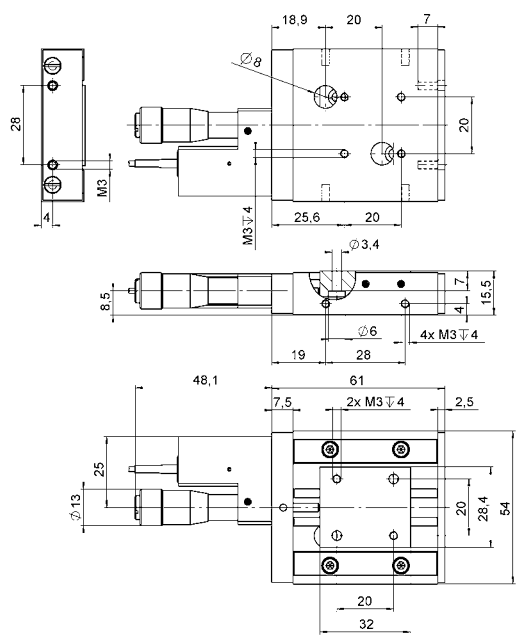
Technical Data

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)	–	

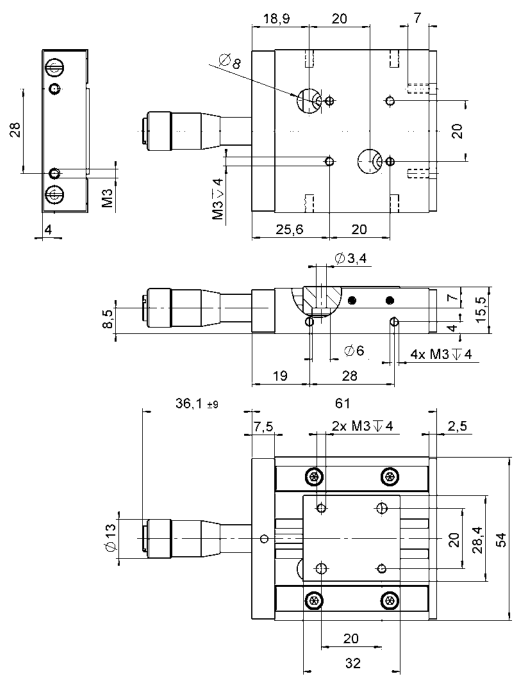
*Versions M-105.2x, M-106.2x and M-105.3x M-106.x0 are combinations of basic .1x. versions
**Motorized versions achieve up to 100 nm.

Notes

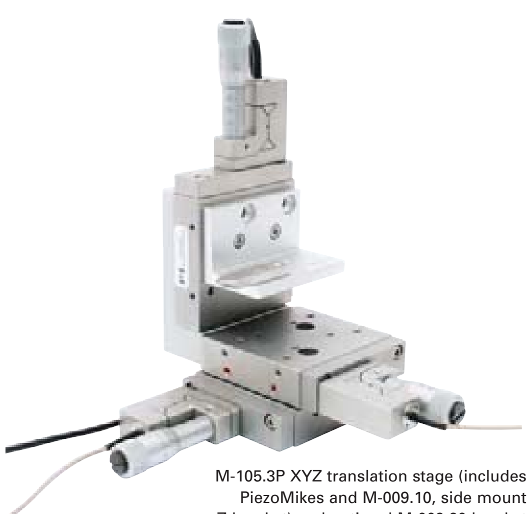
See "Accessories" for adapters, bracket, etc. see p. 4-89 ff.



M-105.1P. dimensions in mm



M-105.10. dimensions in mm

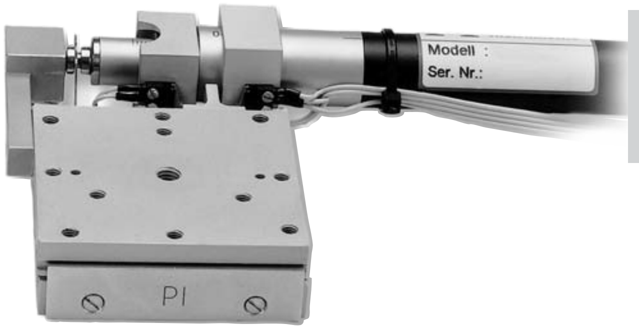


M-105.3P XYZ translation stage (includes PiezoMikes and M-009.10, side mount Z-bracket) and optional M-009.20 bracket with F-010.00 V-groove fiber holder

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.

Application Examples

- Microscopy
- Quality control
- Metrology

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.

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

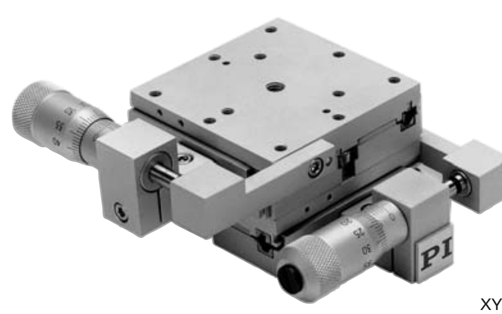
Upgrades

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

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

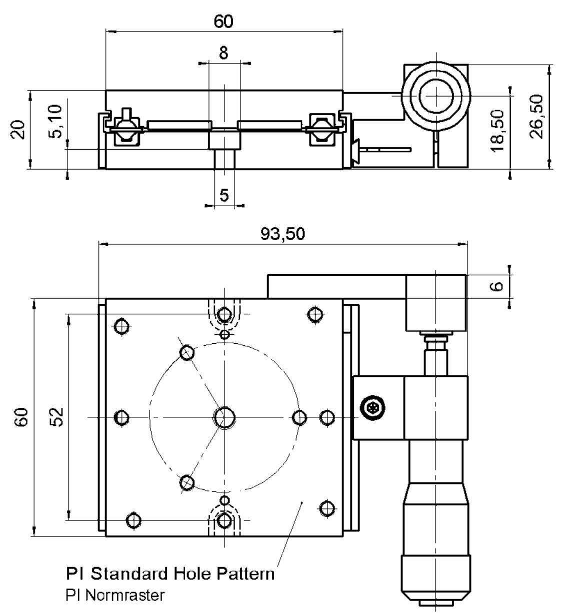
M-011.UD Upgrade Kit with DC-Motor Drive and Limit Switches (Factory Installed)

Ask about custom designs!

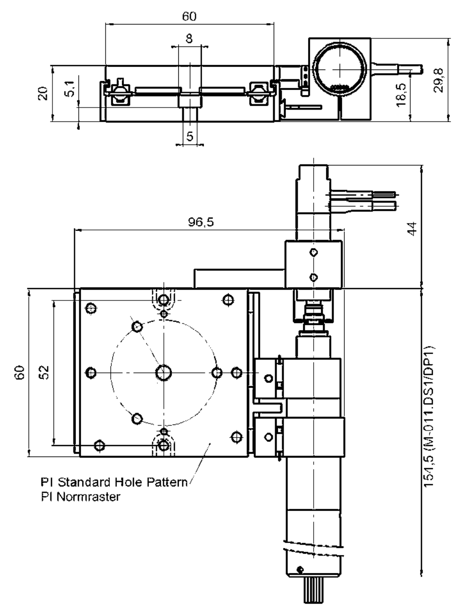


XY combination of two M-011.00 stages

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

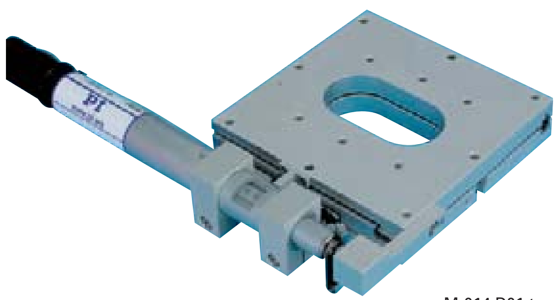
Technical Data

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.

Application Examples

- Microscopy
- Quality control
- Metrology

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.

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

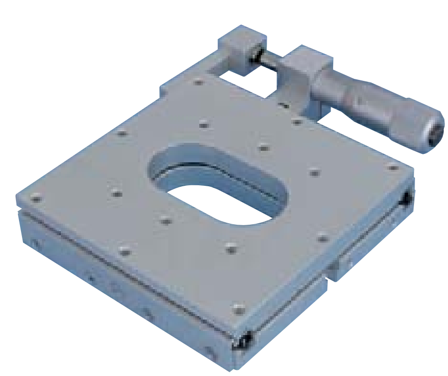
Upgrades

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

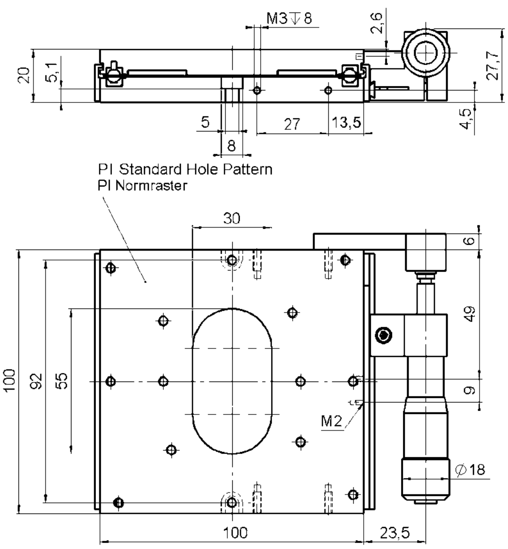
M-014.US
Upgrade Kit with Closed-Loop PZT Drive

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

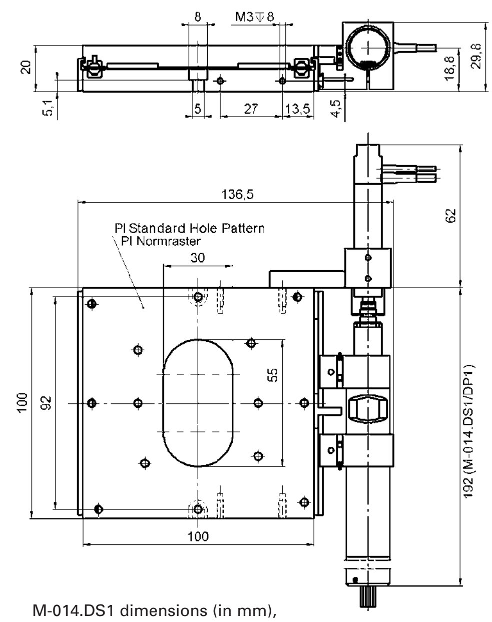
Ask about custom designs!


M-014.00 translation stage

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



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

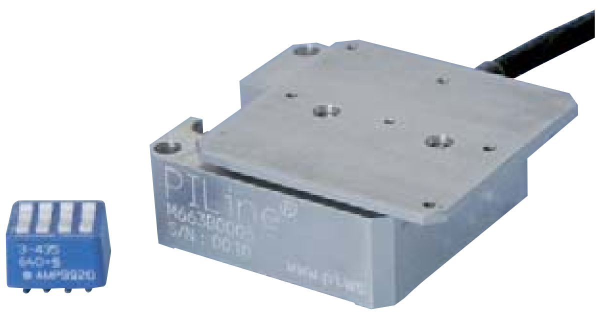
Technical Data

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

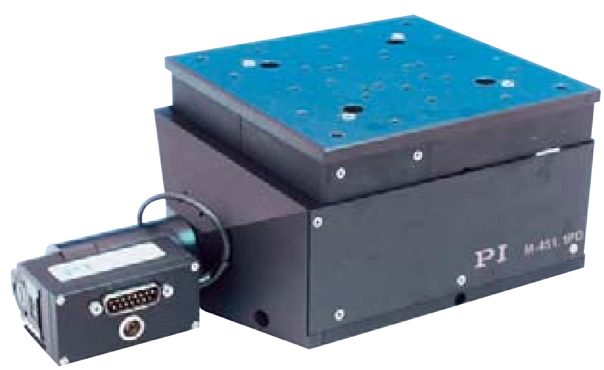
Custom non-magnetic M-682KNMS linear stage with integrated RodDrive linear motor

- **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 lead-screws 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.

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.

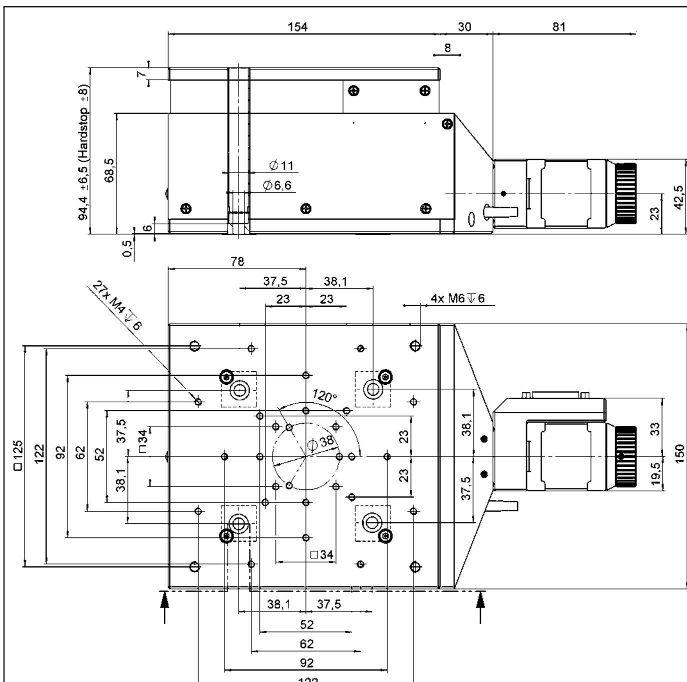
Ordering Information

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

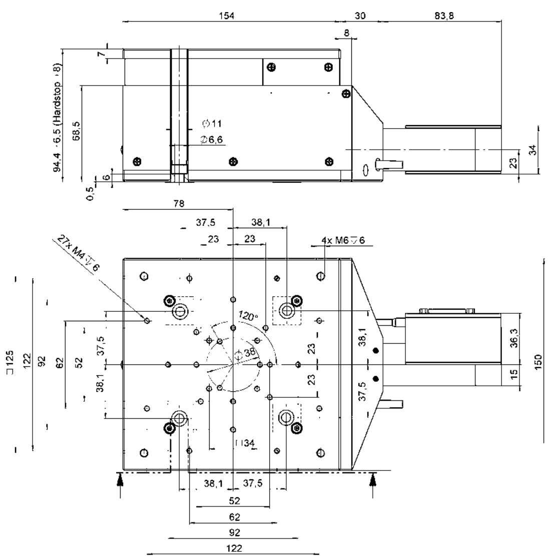
M-451.1DG
Vertical Stage, 12.5 mm, DC Motor Gearhead

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

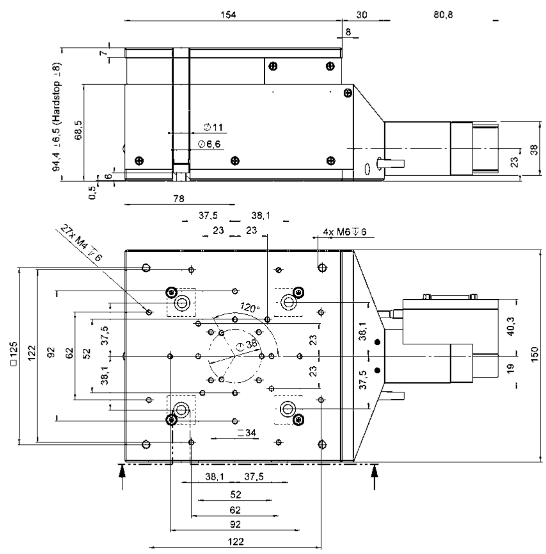
Ask about custom designs!



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

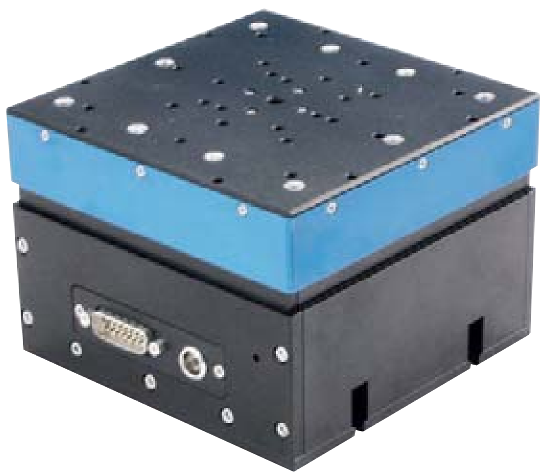
Model	M-451.1PD	M-451.1DG	M-451.12S	Unit
Active axes	Z	Z	Z	
Motion and positioning				
Travel range	12.5	12.5	12.5	mm
Integrated sensor	Rotary encoder	Rotary encoder	–	
Sensor resolution	4000	2000	–	cts./rev.
Design resolution	0.042	0.0028	0.026	µm
Min. incremental motion	0.2	0.1	0.2	µm
Backlash	1	1	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.

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.

Application Examples

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

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!

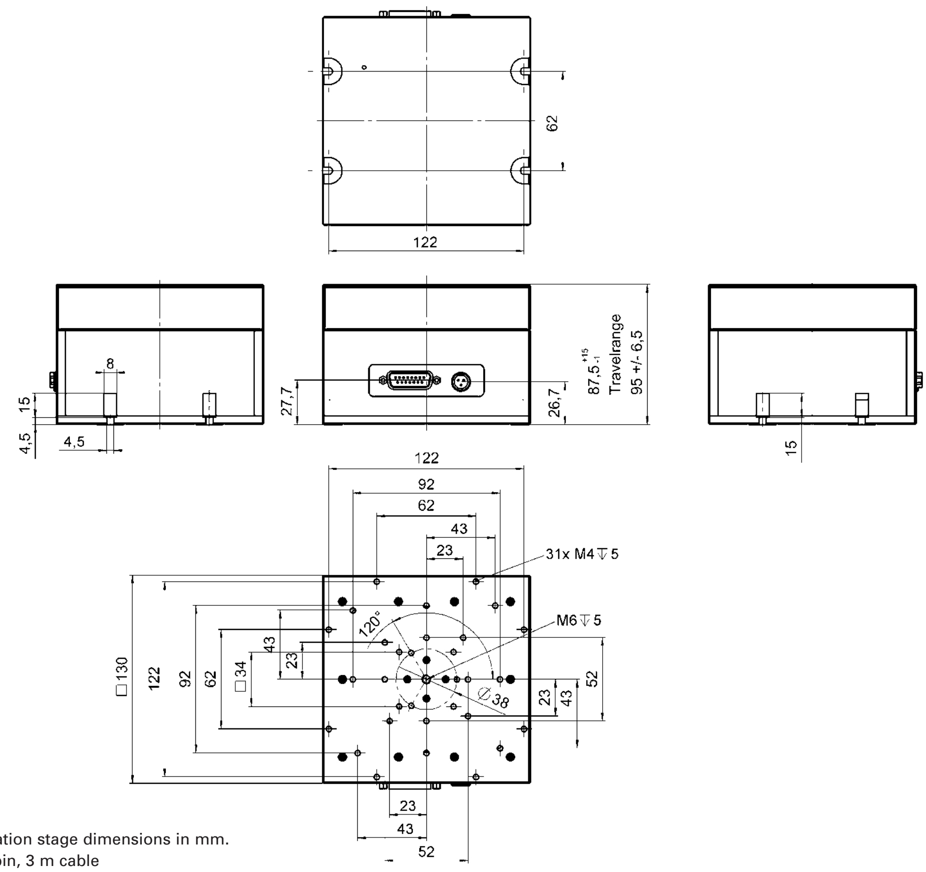
Limit and Reference Switches

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.

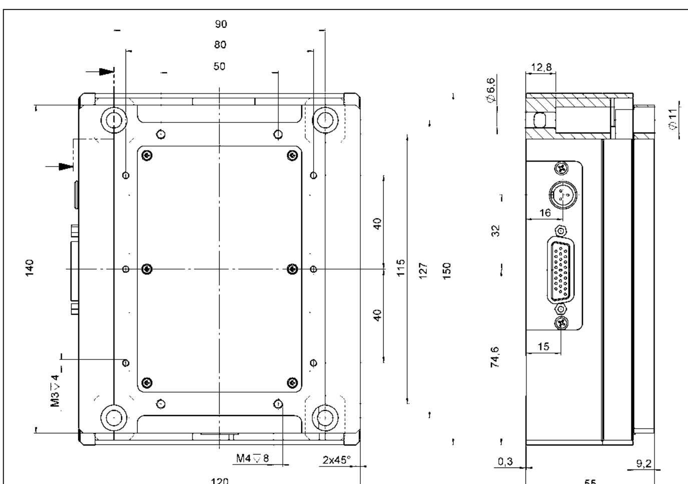
Ordering Information

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

Ask about custom designs!

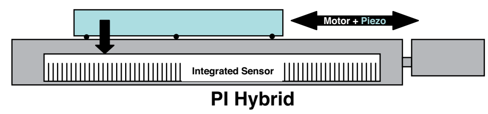
Notes

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 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!

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

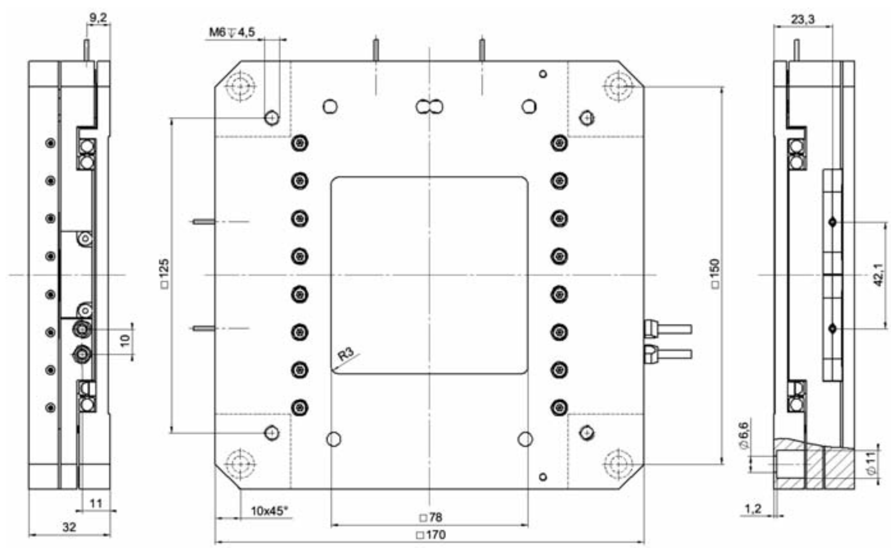
Notes

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



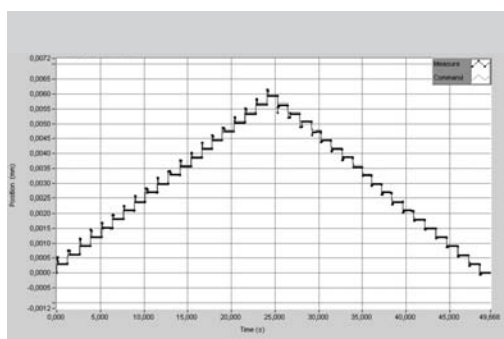
M-686.D64, dimensions in mm. The minimum aperture is 66 x 66 mm with both axes at the maximum position

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

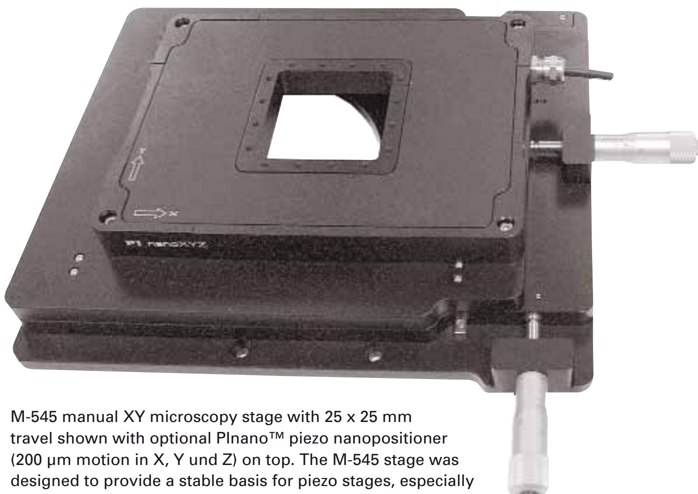


0.3 µm steps performed by M-686

PI Piezo • Nano • Positioning

M-545 Open-Frame Microscope Stage

Long-Range Motion for Sample Positioning



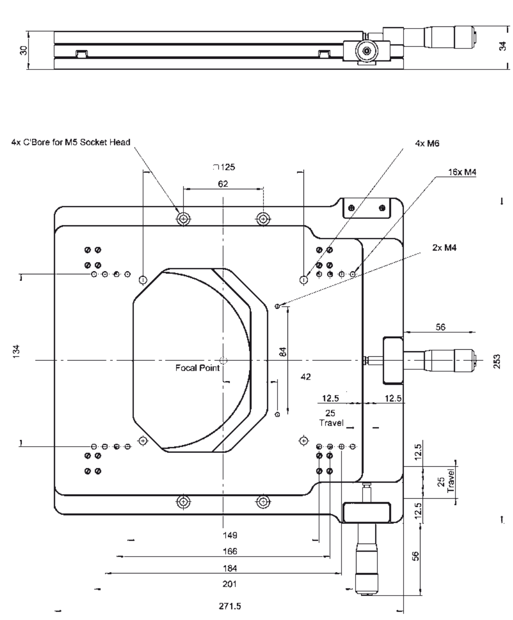
M-545 manual XY microscopy stage with 25 x 25 mm travel shown with optional PInano™ piezo nanopositioner (200 µm motion in X, Y und Z) on top. The M-545 stage was designed to provide a stable basis for piezo stages, especially when the highest step-and-settle performance is required

- **Stable Platform for P-545 PInano™ Piezo Nanopositioning Systems**
- **Low Profile for Easy Integration: 30 mm**
- **25 mm x 25 mm Travel Range**
- **Micrometer Screws, Motor Upgrade Available**
- **For Nikon, Zeiss, Leica and Olympus Mikroscopes**

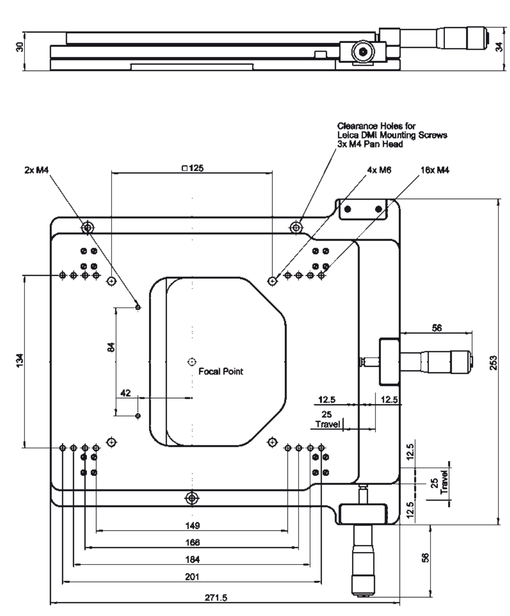
The M-545, 25 x 25 mm microscope stage, is designed to provide a stable platform for piezo scanning stages of the P-545 PInano™ series. These high-speed, high-resolution XY / XYZ piezo stages allow nanometer-precision adjustment of the specimen holder in up to three dimensions over 200 µm. The M-545 is also compatible with the following capacitive-feedback type piezo stages: P-733, P-5x7, P-5x8, P-54x and P-56x (s. p. 2-72).
The basic M-545 model is equipped with manual micrometers.

Motorizing for Automated Tasks

The M-545 XY-stage can be supplemented with motorized actuators M-229 (s. p. 1-44). The product number M-545.USC comprises the complete package of two stepper linear actuators with controller and joystick. M-545.USG includes two stepper linear actuators with mounting



M-545.2MO, M-545.2MN dimensions in mm.
Mounting adapters for Olympus and Nikon microscopes respectively included in delivery



M-545.2ML dimensions in mm

Ordering Information

M-545.2MO
XY Microscope Stage, 25 x 25 mm, Micrometer Drive, High Stability, Compatible with PI Piezo Stages, for Olympus Microscopes

M-545.2MN
XY Microscope Stage, 25 x 25 mm, Micrometer Drive, High Stability, Compatible with PI Piezo Stages, for Nikon Microscopes

M-545.2ML
XY Microscope Stage, 25 x 25 mm, Micrometer Drive, High Stability, Compatible with PI Piezo Stages, for Leica Microscopes

M-545.2MZ
XY Microscope Stage, 25 x 25 mm, Micrometer Drive, High Stability, Compatible with PI Piezo Stages, for Zeiss Microscope

Versions for other microscopes on request.

Accessories

M-545.USC
Factory Installed Stepper-Mike Upgrade for M-545 XY Microscope Stages: Includes Stepper-Mikes, Joystick and Controller

M-545.USG
Factory Installed Stepper-Mike Upgrade for M-545 XY Microscope Stages: Includes Stepper-Mikes, Joystick

M-545.SHP
Adapter Plate for Sample Holders for M-545 XY Microscope Stages

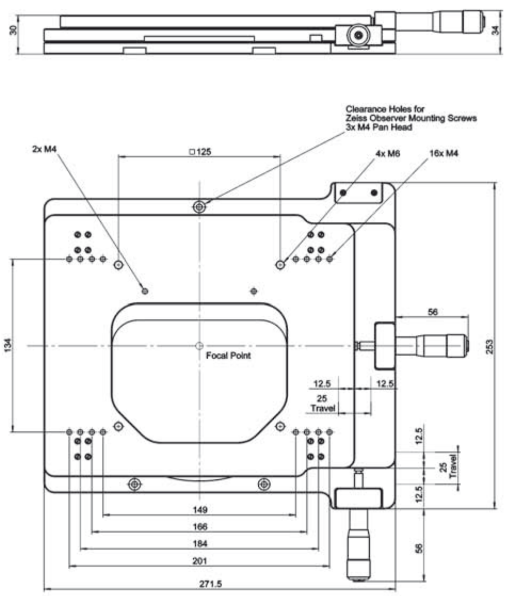
Accommodates the following PI nanopositioning stage series:
P-517/518/527/528, P-541/542, P-560 PIMars and P-545 PInano™

Adapter available for P-733 nanopositioners:

P-733.AP1
Adapter Plate for Mounting of P-733 Piezo Stages on M-545 XY Microscope Stage

Additional accessories on request.

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



M-545.2MZ dimensions in mm

Technical Data

Model	M-545.2M	Unit	Tolerance
Active axes	XY		
Motion and positioning			
Displacement	25 x 25	mm	
Min. incremental motion	1	µm	typ.
Min. incremental motion with M-229 stepper linear actuators	1	µm	typ.
Velocity with M-229 stepper linear actuators	1.5	mm/s	max.
Mechanical properties			
Max. load	50	N	
Preload	10	N	
Miscellaneous			
Material	Aluminum, stainless steel		
Mass	4	kg	±5%

Find further specifications on M-229 stepper linear actuators in the datasheet (s. p. 1-44)

M-545 XY Microscope Stage with Ultrasonic Linear Drives

High Stability, Low Profile, High Speed, Direct Position Measurement

The M-545.2U microscope stage with closed-loop ultrasonic piezo motors provides 25 x 25 mm travel range and very high stability

- **Integrated Closed-Loop Linear Piezomotor Drives Provide Smooth Motion and High Speed to 50 mm/s**
- **Travel Ranges 25 x 25 mm**
- **Integrated Linear Encoders with 0.5 µm Resolution**
- **Compact Design: 30 mm Profile Height,**
- **Mounts Directly to Microscopes**
- **Self-Locking at Rest, with no Servo Dither**
- **Compatible with PI Piezo Nanopositioning / Scanning Stages**

M-545.2U piezomotor stages are mainly designed for automated positioning applications in microscopy. The form factor of the M-545 is optimized for a low profile height of 30 mm only; the mounting pattern is compatible with many PI piezo nanopositioning stages.

Space Saving Piezomotors

Compared to conventional motorized translation stages, the M-545 provides a lower profile and smaller footprint. The compact PILine® piezoelectric linear motors and linear encoders make both, the lead screw duct and the flanged, bulky stepper motors employed in traditional stages obsolete. In addition, the piezomotors are **self-locking at rest** and hold the stage in a stable position without generating heat.

Compatibility to PI Nanopositioning and Scanning Stages

A number of standard PI piezo flexure stages (PInano™ family, P-736, etc) can be mounted directly on the M-545 stage. Depending on the application, these highly specialized, ultra-precise nanopositioning systems are available as fast XYZ 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 Acceleration, Speed
- Smooth Motion, no Vibrations
- Small Form Factor
- Self-Locking when Powered Down, no Dither, no Energy Consumption
- No Shafts, Gears or Other Rotating Parts
- Non-Magnetic , Vacuum Compatible Drive Principle

Ordering Information

XY Microscope Stage System with Closed-Loop PILine® Piezomotor Drives, 25 x 25 mm, 0.5 µm Linear Encoder, Includes C-867.260 2 Axis Controller and Joystick.

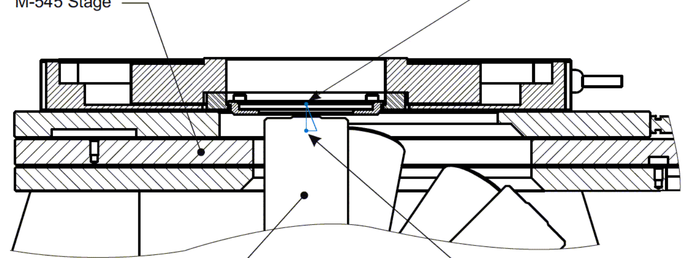
MD5422LOU
for Olympus Microscopes
MD5422LNU
for Nikon Microscopes
MD5422LLU
for Leica Microscopes
MD5422LZU
for Zeiss Microscopes

Ask about custom designs

Application Examples

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

Preliminary Specs



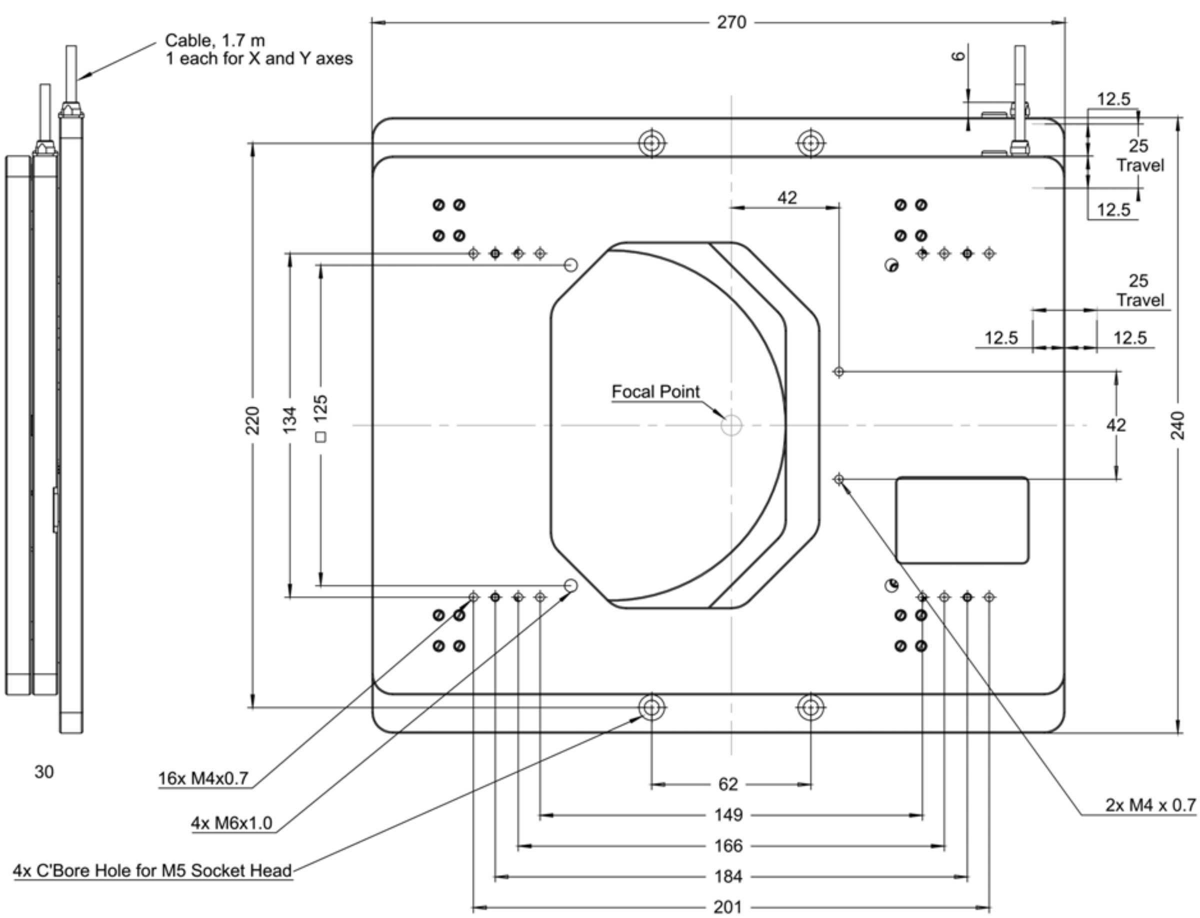
PInano™ XYZ piezo scanner mounted on a M-545.2U Microscope stage. The XYZ piezo nanopositioning stage provides <1 nm resolution and 200x200x200µm scanning range. The high stability and autolocking feature of M-545 provides significant advantages over other microscope stage designs when using fast piezo scanning stages.

The two-channel C-867.260 controller

Preliminary Specs

Model	M-545.2U
Active axes	XY
Travel range	25 x 25 mm
Integrated sensor	Linear encoder
Sensor resolution	0.5 µm (no dither at rest)
Min. incremental motion	1 µm
Unidirectional repeatability	1 µm
Bidirectional repeatability	2 µm
Max. velocity	50 mm/s
Load Capacity	50*N
Max. push/pull force	5 N
Max. lateral force	4 N
Motor type	PILine® U-164
Operating voltage	67 V (RMS)***
Electrical power	10 W / Axis**
Operating temperature range	10 to +30 °C
Material	Aluminum (black anodized)
Mass	3.2 kg
Cable length	1.7 m
Connector	2 x MDR connector, 14-pin
Controller/driver	C-867.260 2-axis Controller/Driver or 2x C-867.160 1-axis Controller/Driver

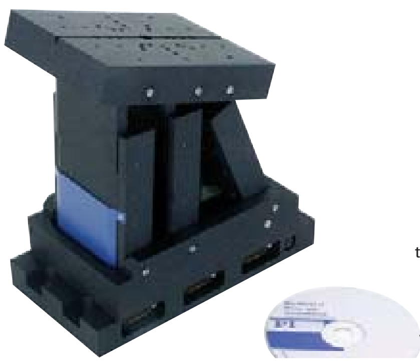
* 10 N for max. velocity. ** For drive electronics
*** Piezomotor drive voltage; controller requires 12 VDC



M-545 dimensions in 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

PI Piezo • Nano • Positioning

F-130 · F-131 Compact XYZ Fiber Aligner

Nanometer Precision with Motor and Piezo Drive Combination

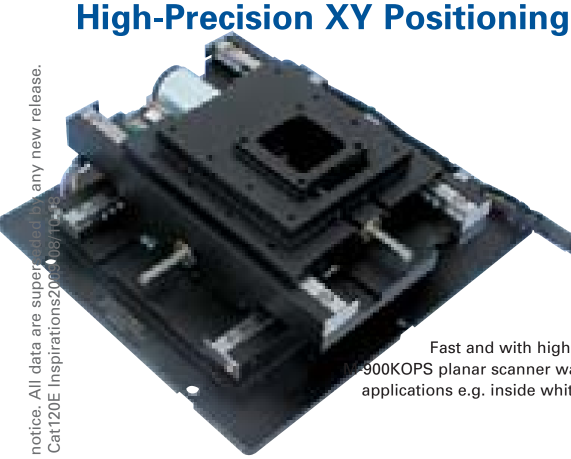
F-130.3SD XYZ Alignment System, 1 nm resolution, with optional F-603.22 ferrule holder

- 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

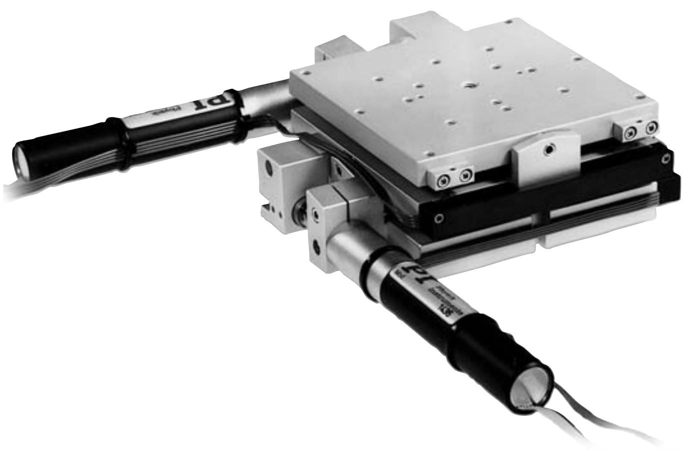
- Integrated Closed-Loop Piezomotor Drives Provide High Speed to 100 mm/s
- Travel Ranges 25 x 25 mm
- Integrated Linear Encoders with 0.1 µm Resolution
- Low-Profile Combinations with PI Piezo Nanopositioning / Scanning Stages
- Clear Aperture 78 x 78 mm, 66 x 66 mm in Extreme Position
- Self-Locking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

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

Rotary & Tilt Stages

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

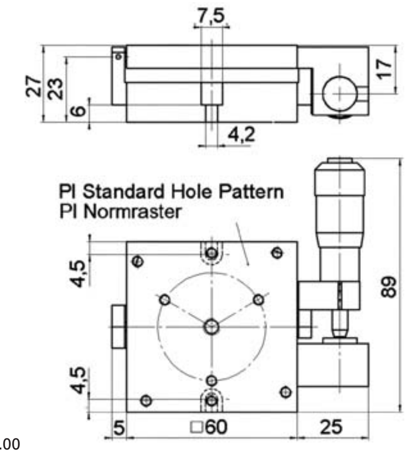
M-043.U0
Open-Loop Piezo Drive Upgrade Kit for M-043 Tilt Stages

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

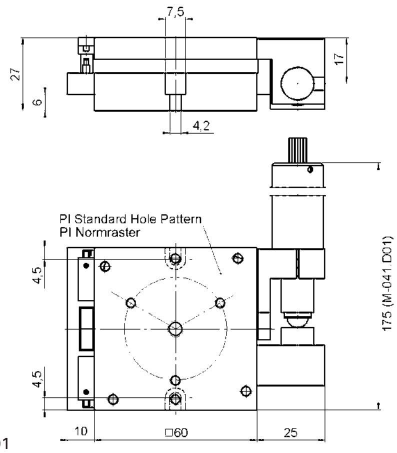
M-044.U0
Open-Loop Piezo Drive Upgrade Kit for M-044 Tip/Tilt Stages

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

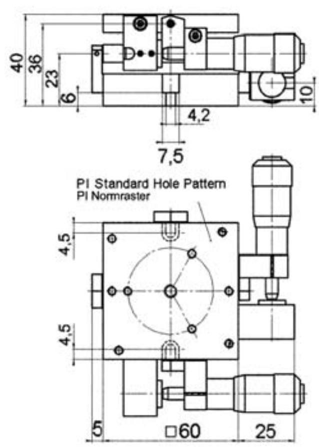
Ask about custom designs!



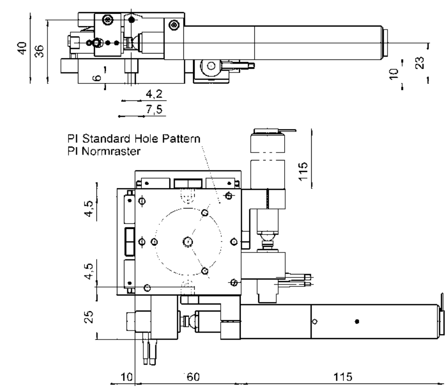
M-041.00
dimensions (in mm), see p. 4-91 for PI Standard Hole Pattern



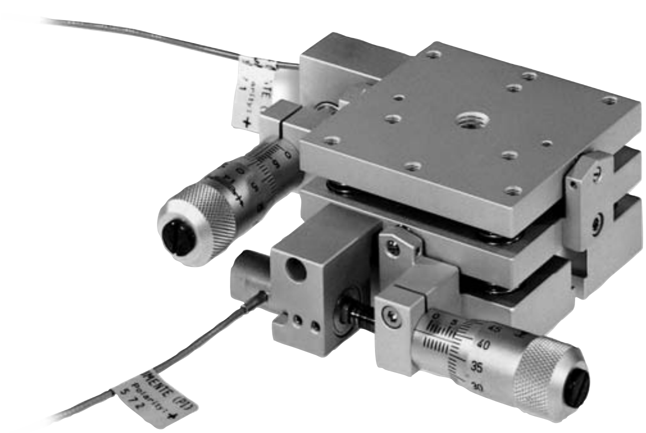
M-041.D01
dimensions (in mm), see p. 4-91 for PI Standard Hole Pattern



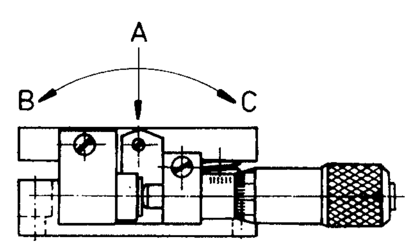
M-042.00
dimensions (in mm), see p. 4-91 for PI Standard Hole Pattern



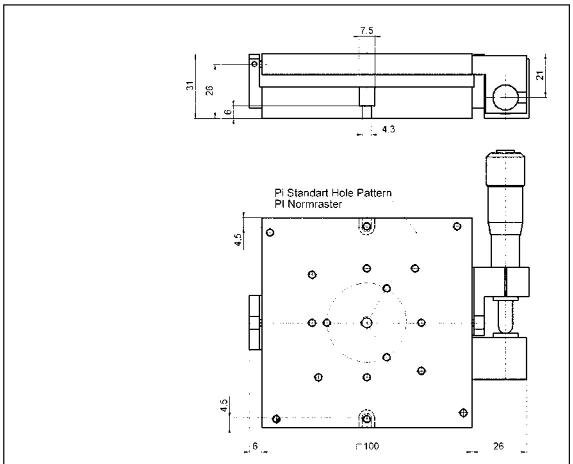
M-042.D01 with optional PZT drives
(dimensions in mm), see p. 4-91 for PI Standard Hole Pattern



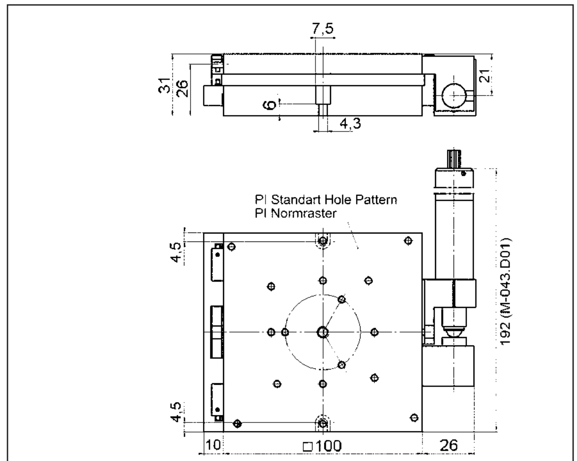
M-042.00 tip/tilt stage with optional PZT drives



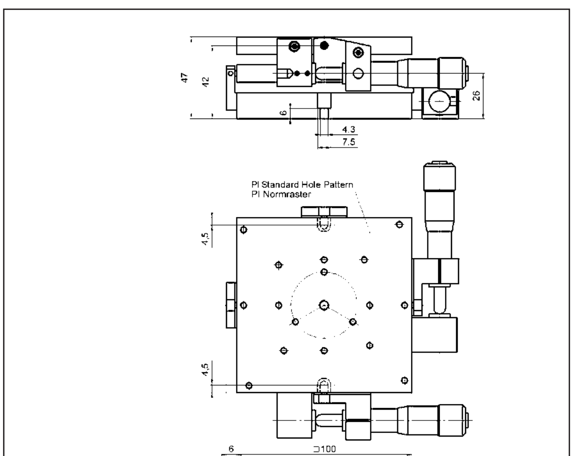
Load and torque definition of M-041, M-042, M-043 and M-044 tip/tilt stages



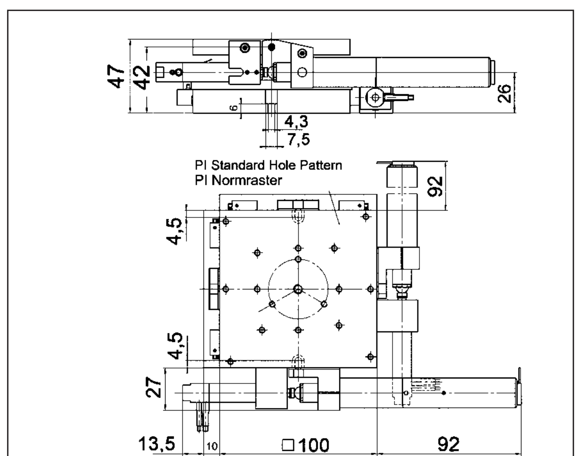
M-043.00 dimensions (in mm)



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	

Piezo • Nano • Positioning

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.

Application Examples

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

Ordering Information

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

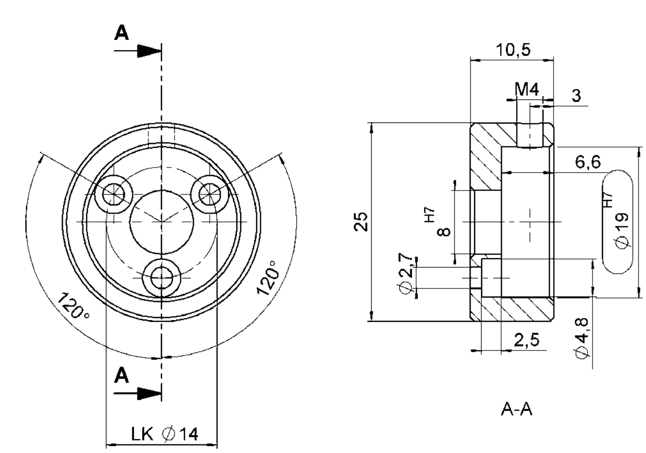
M-116.DGH
Rotation Stage, 360°, Closed-Loop Backlash-Free DC Motor Gearhead

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

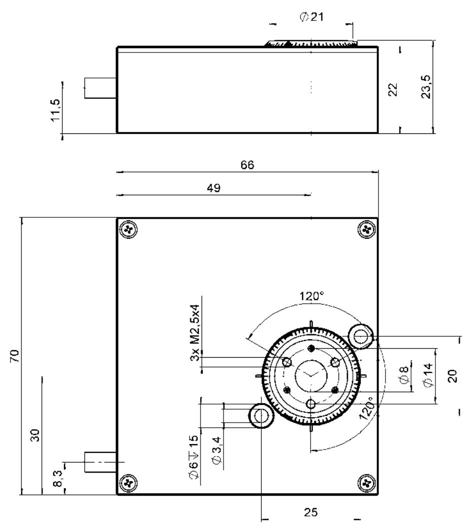
M-116.AL1
Lens Adapter for 0.5″ Optics

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)



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

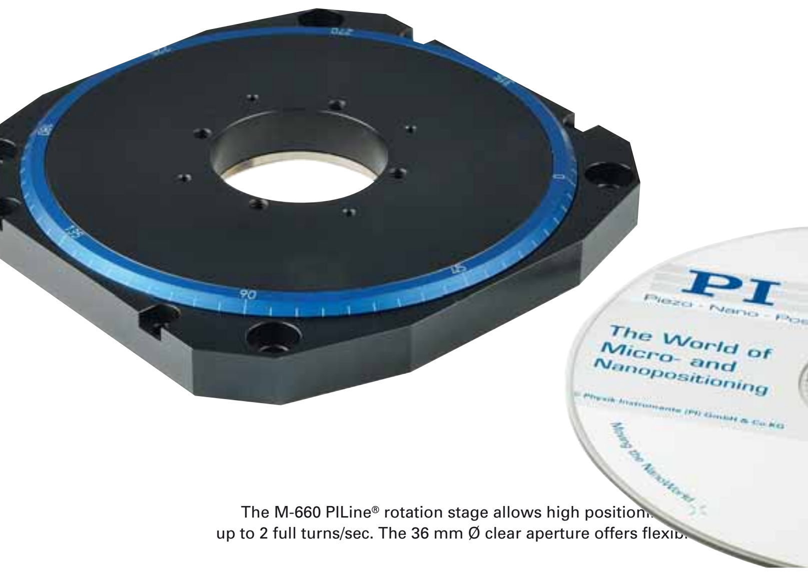
Technical Data

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-660 PILine® Rotation Stage

Fast Positioning, Ultra-Low Profile



The M-660 PILine® rotation stage allows high position
up to 2 full turns/sec. The 36 mm Ø clear aperture offers flexib

- **Unlimited Travel Range**
- **Max. Velocity 720 °/s**
- **Low Profile: Only 14 mm in Height**
- **Self-Locking Ceramic Direct Drive: Energy Saving & High Position Stability**
- **Direct Metrology Linear Encoder, 34 µrad Resolution**
- **PILine® Direct Drive: Non-Magnetic and Vacuum-Compatible Working Principle**
- **Compact Combinations with Linear Stages**

M-660 precision rotation stages use PILine® ultrasonic piezo motors that act on a ceramic friction ring to drive the platform. This direct drive principle allows for the compact design and low profile of the stage. An integrated incremental encoder offers precision position control with up to 34 µrad resolution. The integrated U-164 PILine® linear motors provide a maximum torque of 0.3 Nm, independent from the direction of motion, and a maximum velocity of up to 720 °/sec. The maximum load is 2 kg.

Applicatotion Examples

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

M-660s can be built in different sizes or with other specifications, and they are available upon request as vacuum-compatible versions.

Advantages of PILine® Micropositioning Systems

Positioning systems equipped with ceramic ultrasonic drives of the PILine® series provide several advantages over positioners that apply classic drive technology:

- Smaller dimensions
- Higher holding force when powered down; no holding current
- Increased acceleration of up to 5 g
- Increased velocity of up to 500 mm/s or 720 °/s, resp.
- No leadscrews, gears or other mechanical components, no wear or maintenance
- No lubricants
- Non-magnetic and vacuum-compatible operating principle

Optimized Controller and Drive Electronics

For optimum performance, the highly specialized C-867 motion controller (s. p. 4-116) is recommended. This dedicated piezo motor controller also integrates the drive electronics which PILine® motors require to generate the ultrasonic oscillations on the piezoceramic element.

Furthermore, the controller has a number of special characteristics to address the requirements of ultrasonic motors, such as continuous automatic drive frequency adjustment, dynamic parameter switching for optimized high-speed motion and settling behavior. The broad-band encoder input (50 MHz) supports the outstanding high accelerations and velocities of PILine® drives at high resolutions.

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

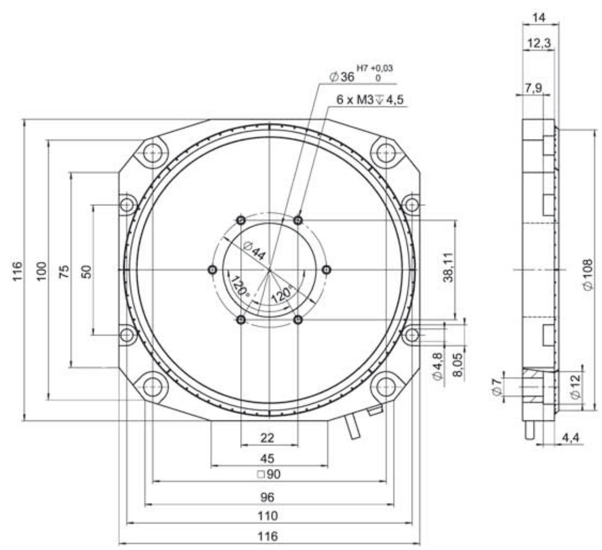
Ordering Information

M-660.55
PILine® Rotation Stage, Ø 108 mm, 360°, 34 µrad Resolution

Ask about custom designs!

Patented Technology

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-660.55, dimensions in mm

Technical Data

Model	M-660.55	Units	Tolerance
Active axes	Theta Z		
Motion and positioning			
Rotation range	No limit	°	
Integrated sensor	Incremental encoder		
Design resolution	34	µrad	typ.
Min. incremental motion	34	µrad	typ.
Bidirectional repeatability	34	µrad	
Max. velocity	720	°/s	
Mechanical properties			
Load capacity / axial force	20	N	max.
Holding force	0.3	Nm	max.
Max. torque cw/ccw (θ Z)	0.3	Nm	max.
Drive properties			
Motor type	2 x U-164 PILine® ultrasonic piezo drive		
Operating voltage	60 (RMS)*	V	
Electrical power	0.2	W	nominal
Current consumption**	0.3 (2 max.)	A	
Reference switch	optical		
Miscellaneous			
Operating temperature range	-20 to +50	°C	
Material	Al (black anodized)		
Mass	0.4	kg	±5%
Cable length	1.3	m	±10 mm
Connector	MDR, 14-pin		
Recommended controller / driver	C-867 single-axis controller / driver		

* The operating voltage is supplied by the drive electronics
** For drive electronics

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.

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!

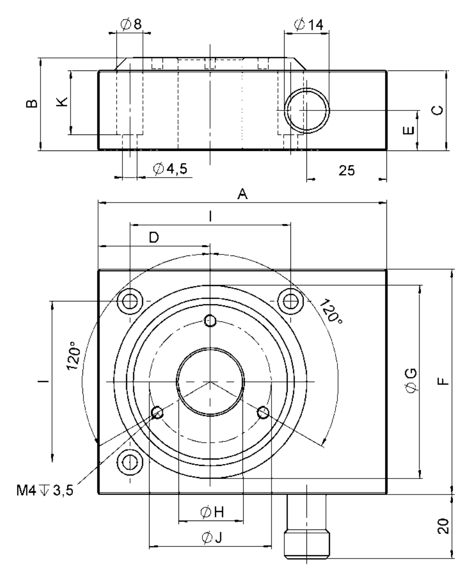
M-60x.2S Stepper-Motor Drive

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

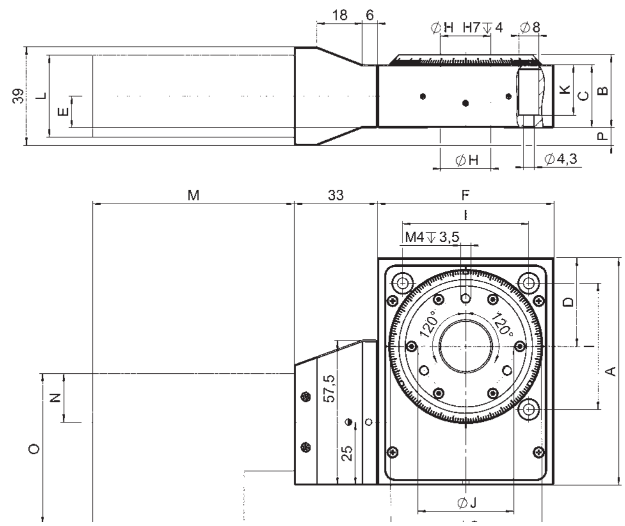
Motorized models are equipped with an integrated Hall-effect origin switch. To protect your equipment and increase versatility in automation applications, the rotary stage can optionally be equipped with Hall-effect limit switches. Travel can be limited to a range between 0° and 268° ±2°.

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.



[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	60	60	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	38	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

Accessories

Accessories

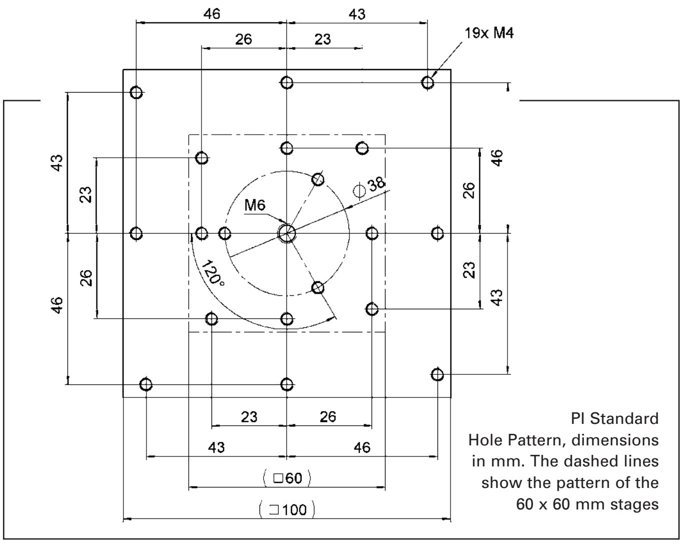
Mounting Adapters for Micropositioning

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

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

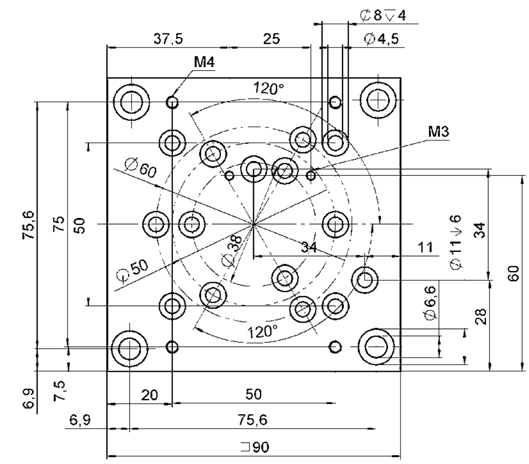
Accessories

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

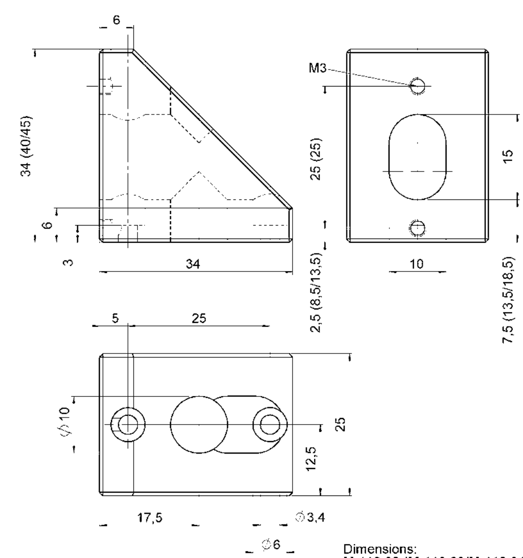


M-110.01 dimensions in mm

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



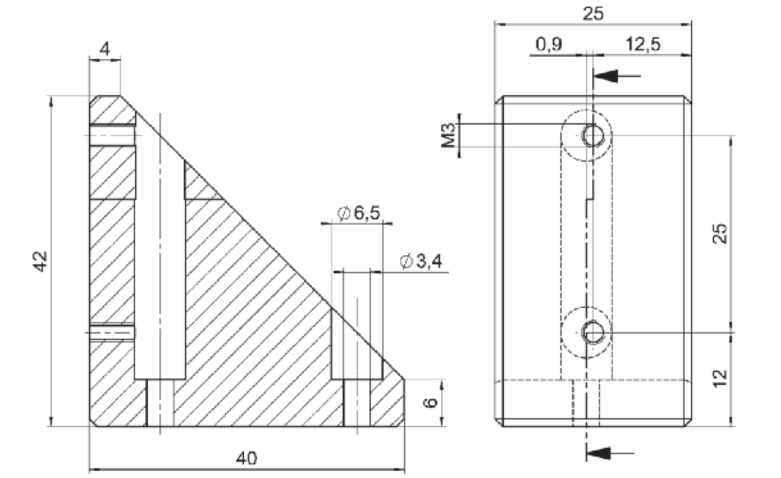
M-110.02, M-110.03 dimensions in mm

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

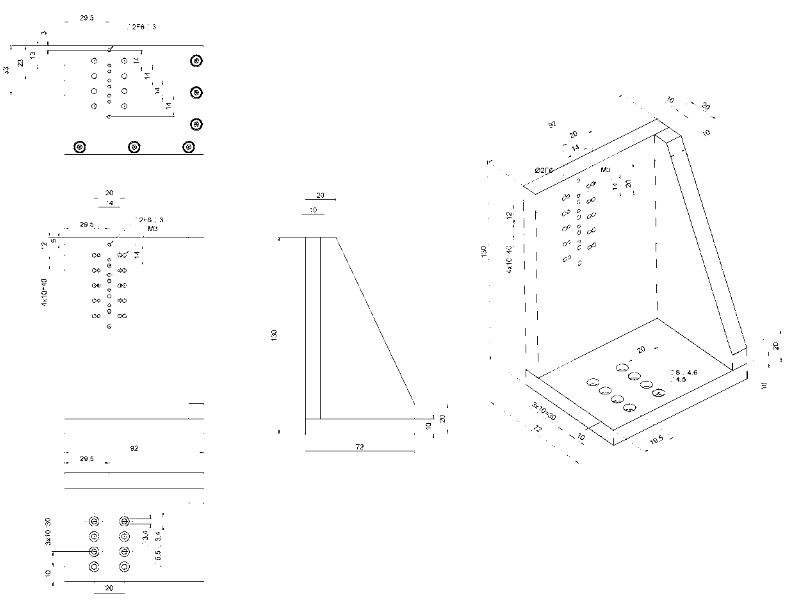


M-122.AP1 dimensions in mm

M-122.AV1

Z-axis mounting bracket for vertical mount of M-122 stages.

Material: Al



M-122.AV1 dimensions in mm

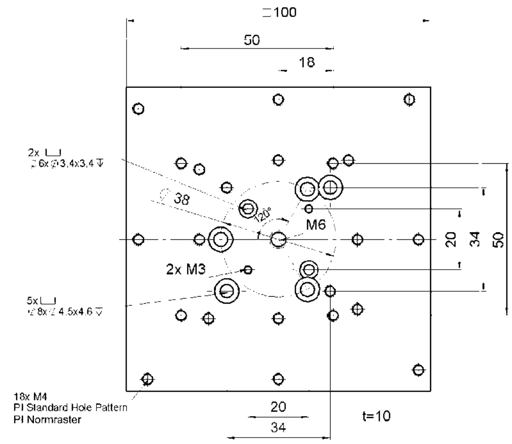
Accessories

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

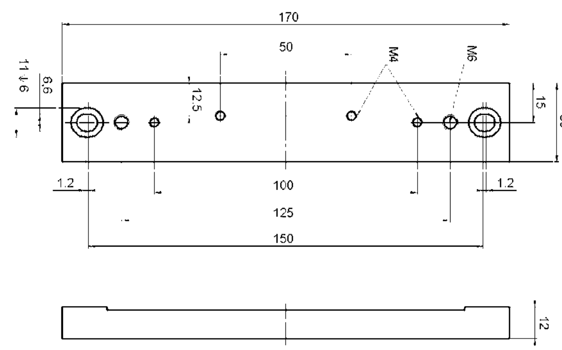


M-400.AP dimensions in mm

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

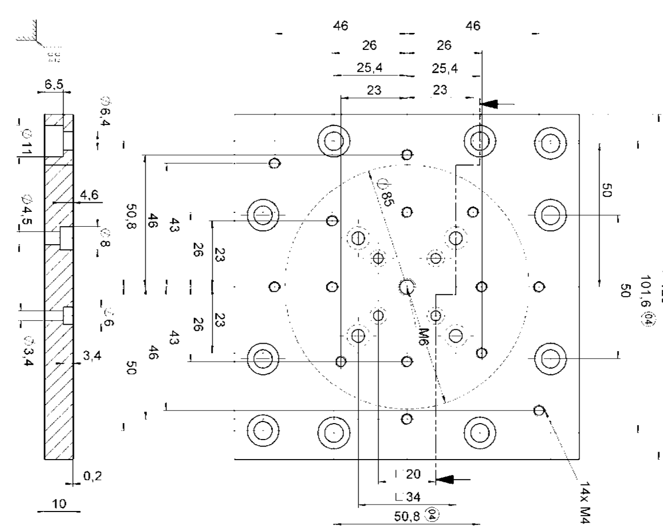


M-490.MS dimensions in mm

B-094.00

Adapter plate for mounting several translation stages and rotary stages on honeycomb tables (M 6 on 25 mm spacing).

Material: Al



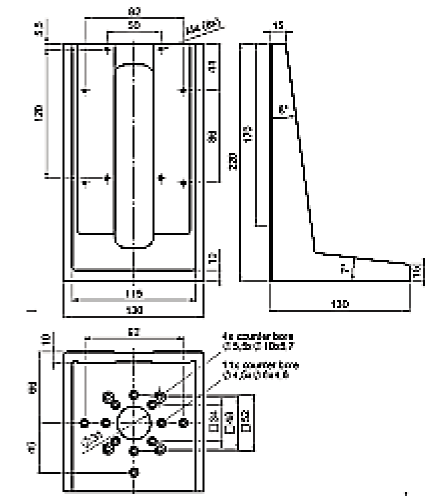
B-094.00 dimensions in mm

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

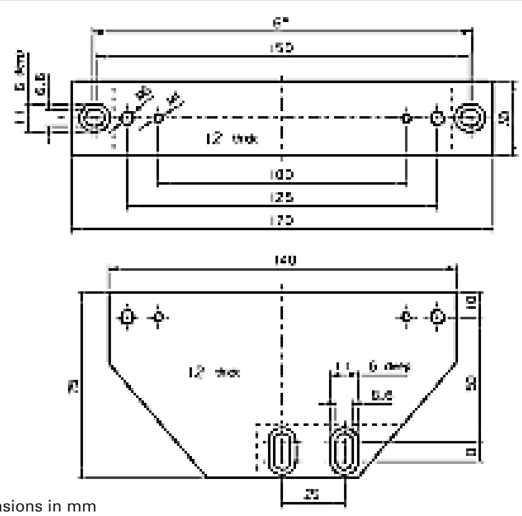


M-592.00 dimensions in mm

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

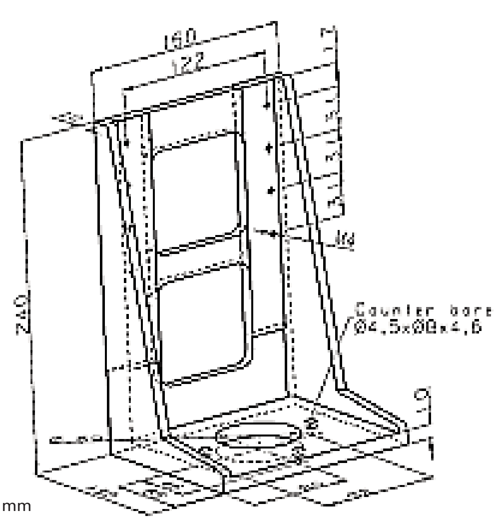


M-590.00 dimensions in mm

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

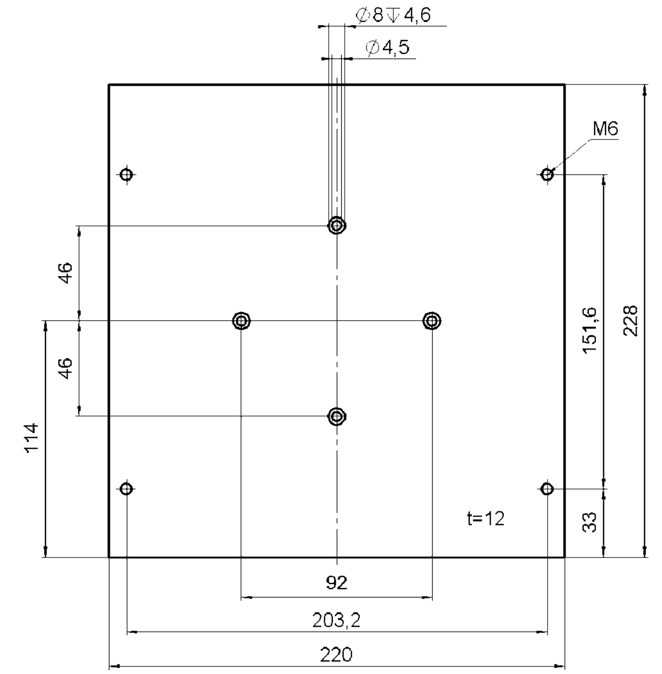
Accessories

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.

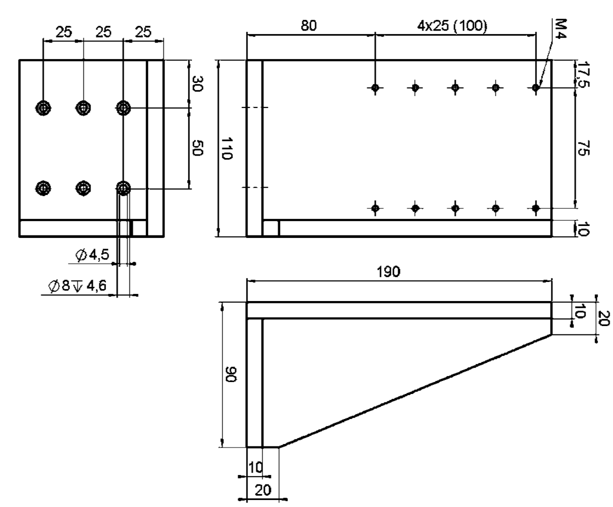
Material: Al



M-500.206 dimensions in mm

M-605.AV1

Adapter bracket for vertical mounting of M-605 on M-605 stages.



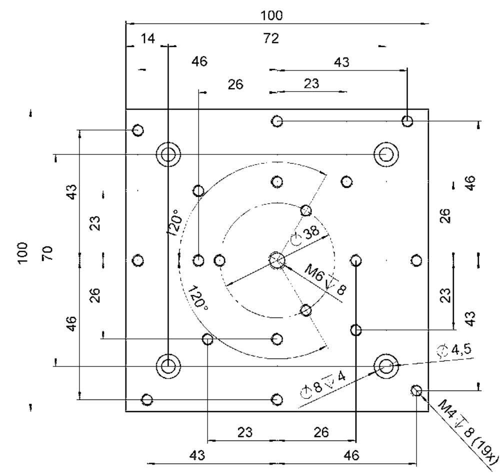
M-605.AV1 dimensions in mm

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

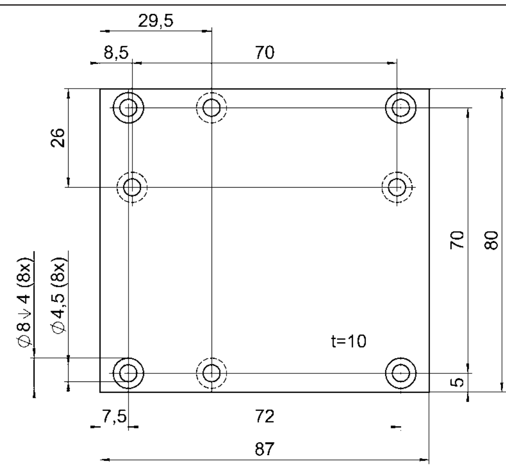


M-403.AP1 dimensions in mm

M-403.AP2

Adapter bracket for vertical mount of M-403/M-404 on M-403/M-404 stages.

Material: Al

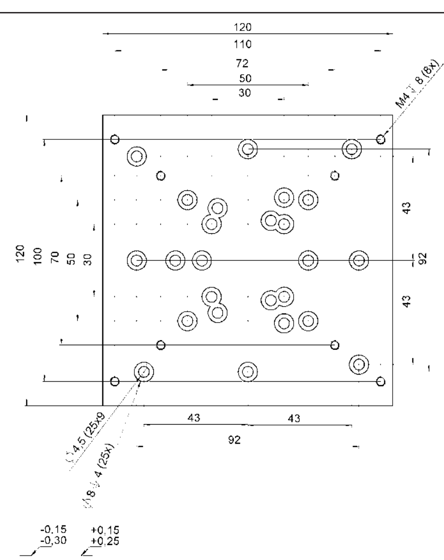


M-403.AP2 dimensions in mm

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

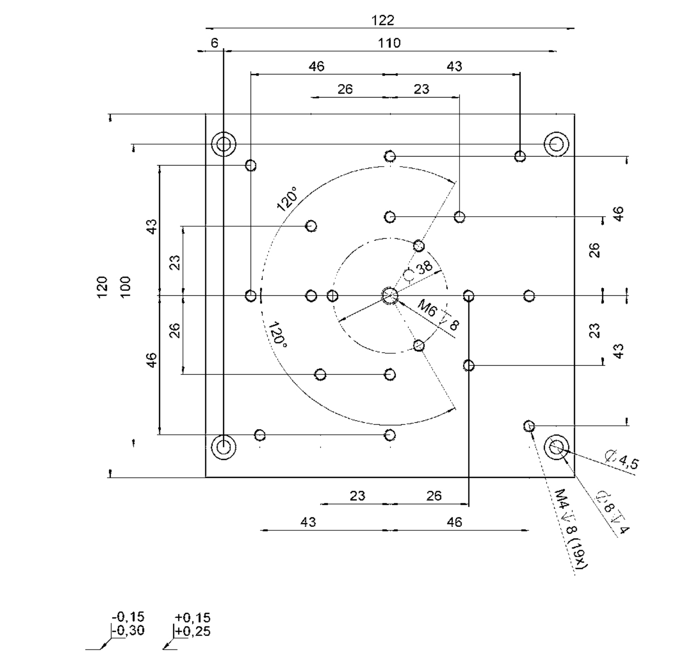
Accessories

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

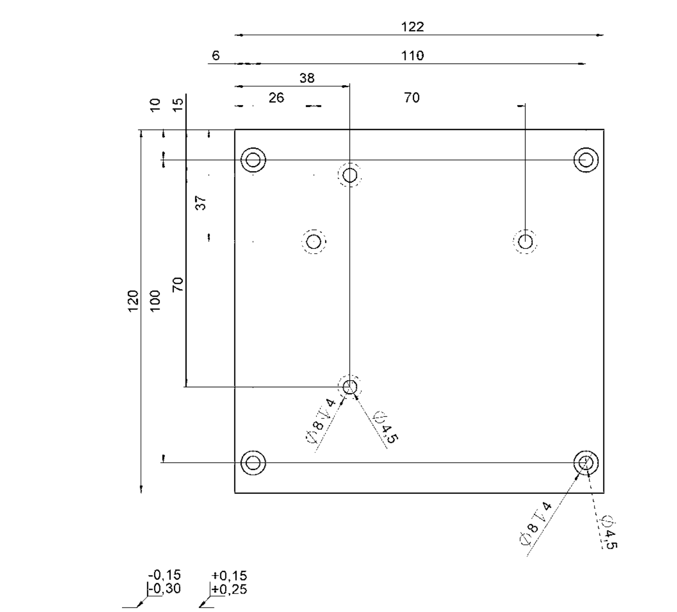


M-413.AP1 dimensions in mm

M-413.AP2

Adapter bracket for vertical mount of M-413/M-414 on M-413/M-414 stages.

Material: Al



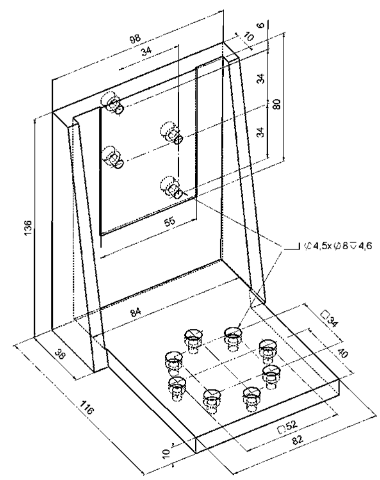
M-413.AP2 dimensions in mm

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

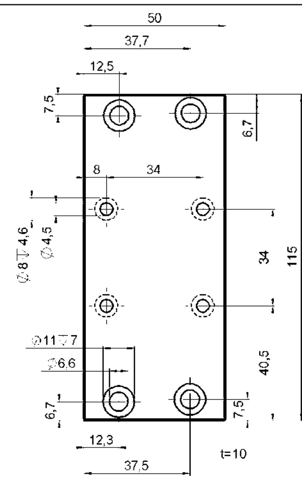


M-125.90 dimensions in mm

M-126.80

Adapter plate for mounting M-126 stages on honeycomb tables (metric & imperial).

Material: Al

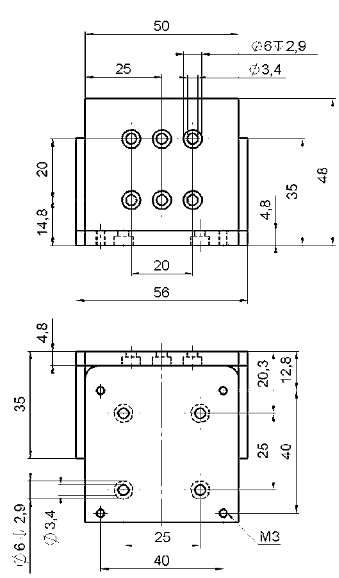


B-126.80 dimensions in mm

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

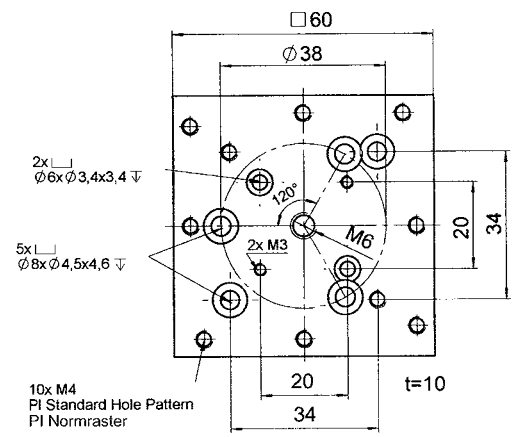
Accessories

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

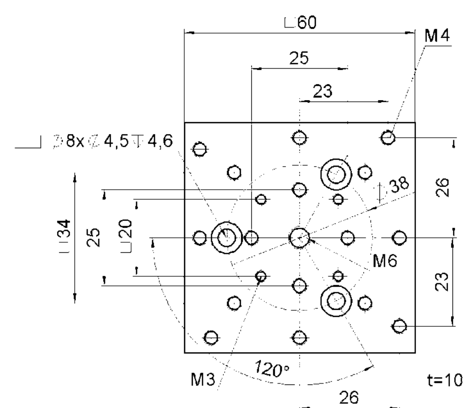


M-105.AP dimensions in mm

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

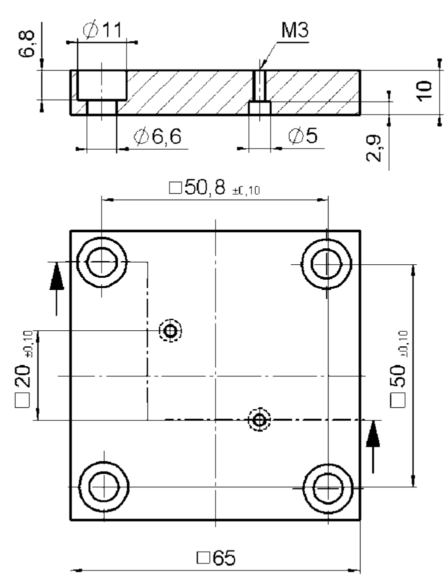


B-082.10 dimensions in mm

M-105.HP

Adapter plate. For mounting M-105 stages (and F-110) on honeycomb tables (metric & imperial).

Material: Al



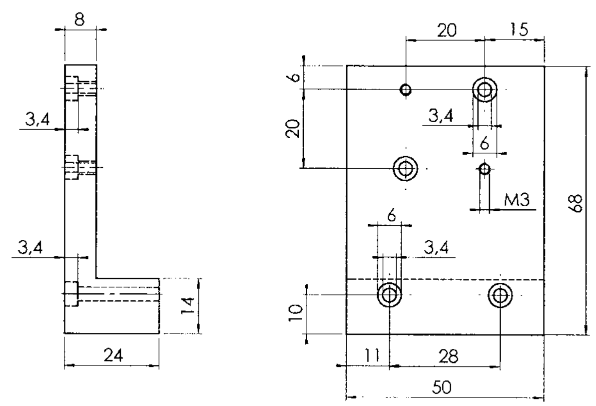
M-105.HP dimensions in mm

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

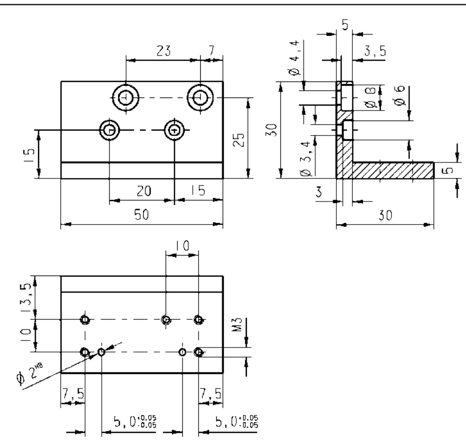


M-009.10 dimensions in mm

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

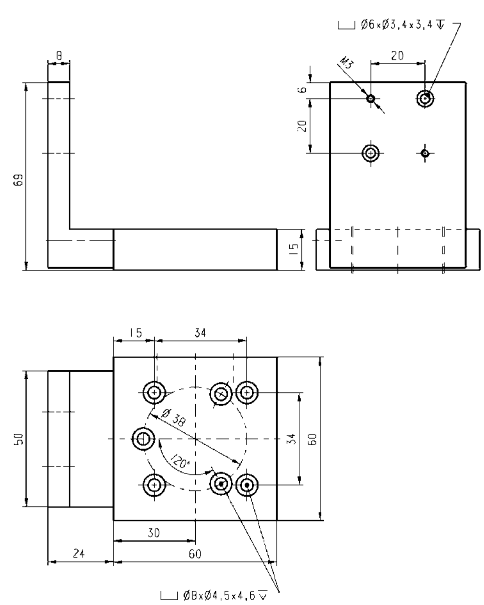


M-009.20 dimensions in mm

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

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

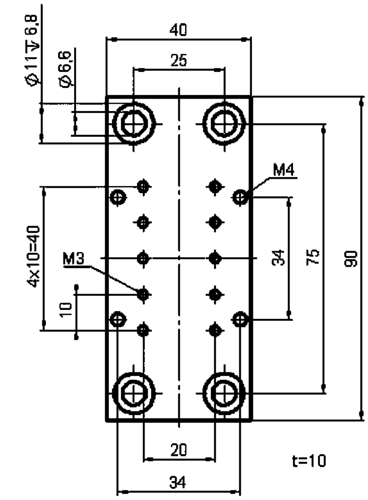
Accessories

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

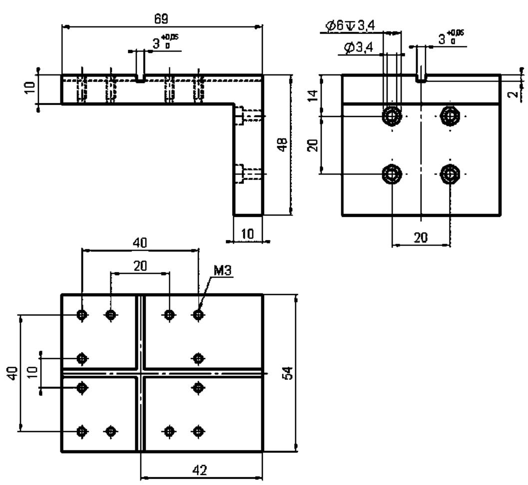


M-105.HP1 dimensions in mm

M-105.MB

Mounting bracket for mounting accessories (e.g. F-603 objective holders) on M-105 stages.

Material: AL; Mass: 1.46 kg

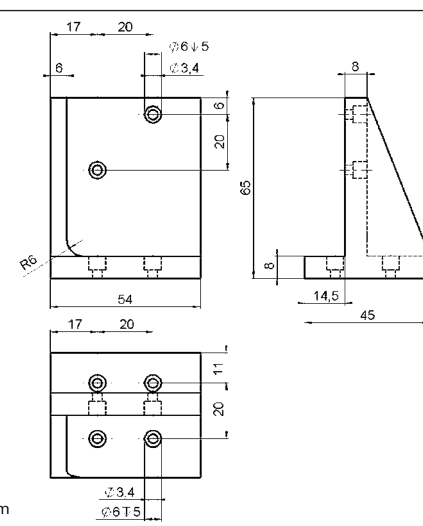


M-105.MB dimensions in mm

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



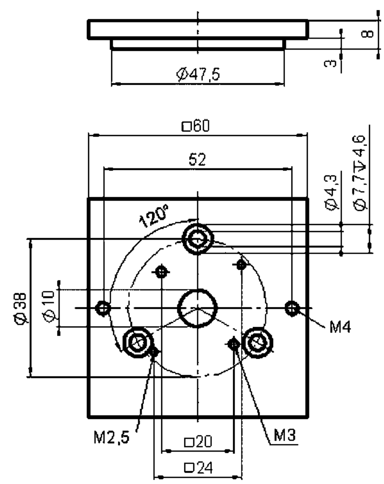
M-105.VB1 dimensions in mm

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

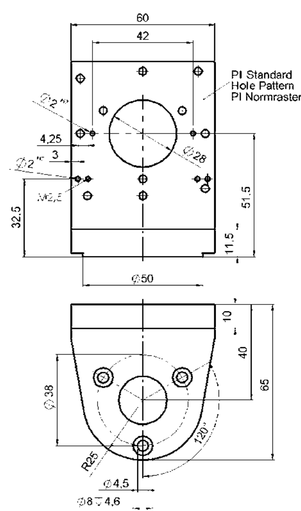


M-087.10 dimensions in mm

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

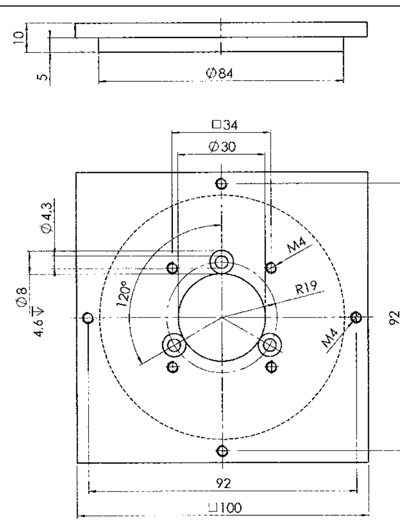


M-052.40 dimensions in mm

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

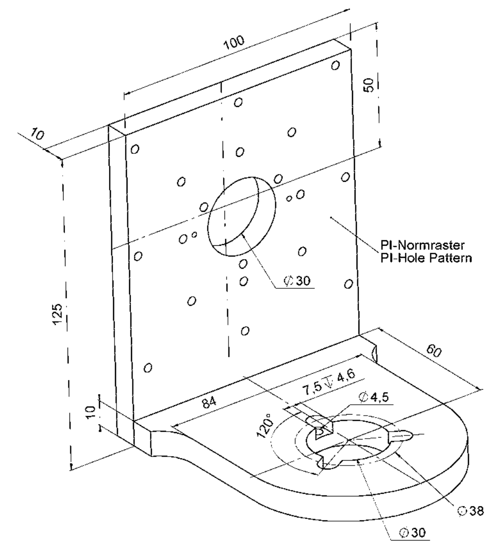
Accessories

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



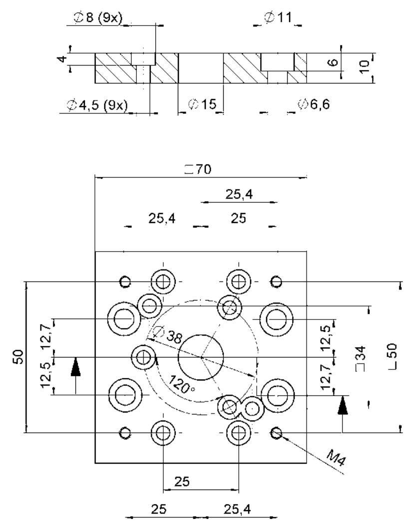
M-053.40 dimensions in mm

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

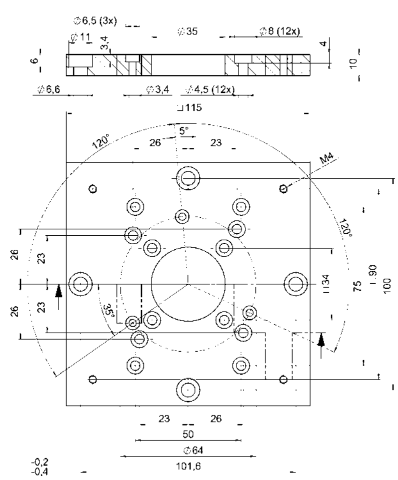


M-060.HP dimensions in mm

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

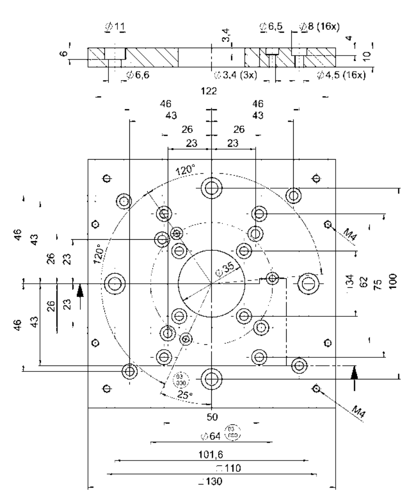


M-061.HP dimensions in mm

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

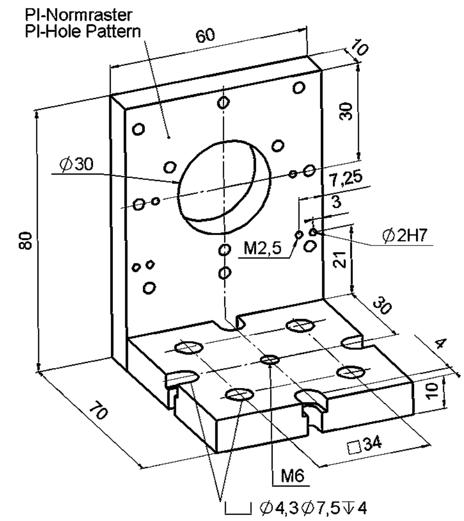
Accessories

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

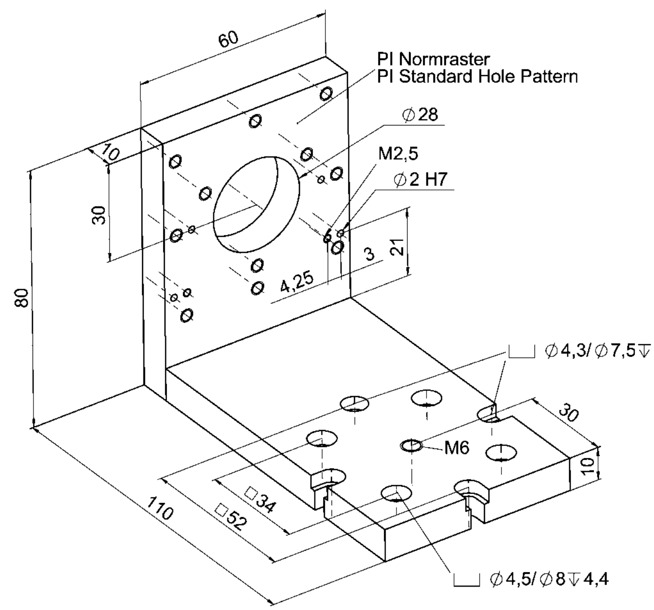


M-052.00 dimensions in mm

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



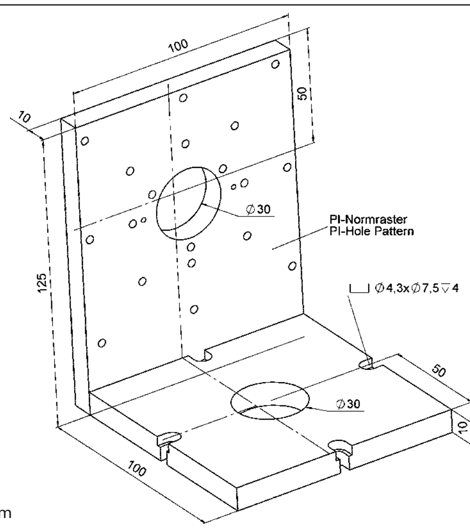
M-052.30 dimensions in mm

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

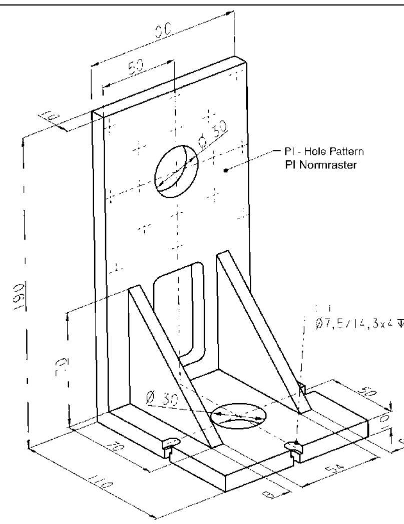


M-053.10 dimensions in mm

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

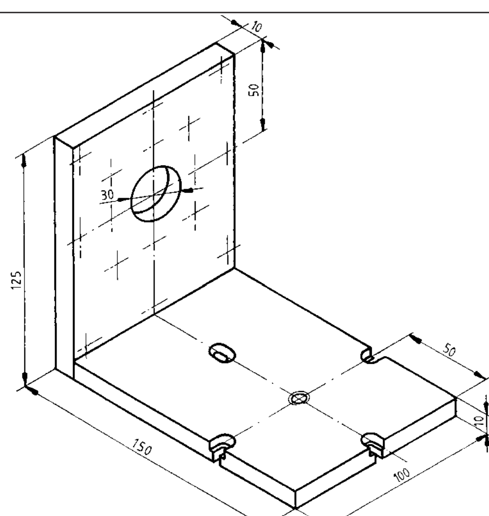


M-053.20 dimensions in mm

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

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

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

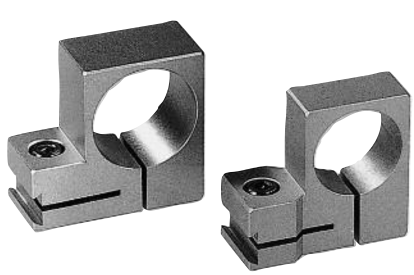
M-149.02:
17 x 30.2 mm; 5 mm / 5 mm

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-151 Holders

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

PI Piezo • Nano • Positioning

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 Mercury DC-Motor Controllers**
- **Joystick Port for Manual Control**
- **Non-Volatile Macro Memory**
- **Data Recorder**
- **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.

Application Examples

- Flexible automation
- Handling
- Quality control
- Testing equipment
- Photonics applications
- Fiber positioning

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

Up to 16 Mercury class controllers can be networked and controlled over a single PC interface.

Such daisy chain networks are flexible, can be extended at any time and are compatible with over PI controllers for DC servo-motors or stepper motors, PILine® ultrasonic piezomotor drives or piezostepping drives.

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 be operated using the PI General Command Set (GCS). PI-GCS allows networking of different PI-controllers such as piezo drivers and multi-axis servo controllers with minimal programming effort.

Ordering Information

C-663.11
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

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.

Mercury Step controller with M-403.62S precision translation stage

Technical Data

Model	C-663.11
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	PI General Command Set (GCS)
User software	PIMikroMove®
Software drivers	LabVIEW drivers
Supported functionality	Start-up macro, data recorder for recording parameters as motor input voltage, velocity, position or position error
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)

Piezo • Nano • Positioning

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**
- **Data Recorder**
- **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**

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

Up to 16 Mercury class controllers can be networked and controlled over a single PC interface.

Such daisy chain networks are flexible, can be extended at any time and are compatible with other PI controllers for DC servo-motors or stepper motors, PILine® ultrasonic piezomotor drives or piezo stepping drives.

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.

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, in-creasing reliability and simplifying the setup.

Ordering Information

C-863.11
Mercury DC-Motor Controller, 1 Channel, with Wide-Range Power Supply

C-819.20
2-Axis Analog Joystick for Mercury Controller

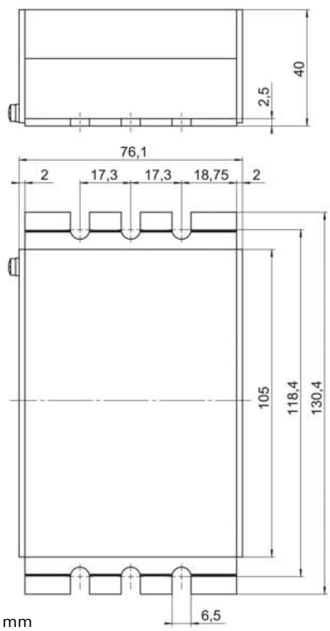
C-819.20Y
Y-Cable for Connecting 2 Controllers to C-819.20

C-170.IO
I/O Cable, 2 m, Open End

C-170.PB
Push Button Box, 4 Buttons and 4 LEDs

Contents of Delivery

Each controller is delivered with a wide-range power supply, USB and RS-232 communication cable, a daisy-chain network cable and a comprehensive software package.



C-863 dimensions in mm

Technical Data

Model	**C-863.11**
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	PI General Command Set (GCS)
User software	PIMikroMove®
Software drivers	LabVIEW drivers
Supported functionality	Start-up macro, data recorder for recording parameters as motor input voltage, velocity, position or position error; 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

C-867 piezomotor controller together with an extremely low-profile M-692 positioner with integrated piezoceramic PILine® 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 is especially designed for closed-loop positioning systems equipped with PILine® piezo linear motor drives. A compact case contains both drive electronics for the piezo ceramic motors and components for controlling and communication.

Application Examples

- Biotechnology
- Microscopy
- Fiber positioning
- Automation
- Photonics / integrated optics
- Quality assurance testing
- Testing equipment

The controller can be operated from a host PC either via a USB port or an RS-232 interface. Alternatively, a stand-alone operation is possible. Here, stored macro commands can be executed, or manual control by joystick or pushbutton box is possible.

Two models are available: C-867.160 is used to operate single-axis positioning systems, the two-channel C-867.260 is used with XY scanning stages.

Highly Specialized PID Servo-Controller

The C-867 is based on a highly specialized DSP (Digital Signal Processor) that handles 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 an optimized settling behavior within a couple of 10 milliseconds is achieved. The broadband encoder input (50 MHz) allows high resolution encoders to be used with the outstandingly high accelerations and velocities that PILine® drives deliver.

Highest Stability by Frequency Control

The integrated piezomotor drive electronics support all PILine® ultrasonic piezomotors used for the M-66x to M-69x positioning stage series.

Drift in the mechanical frequency of the motor caused by temperature or load changes is automatically compensated by a frequency-control loop which adjusts the operating frequency of the driving voltage. This leads to the highest stability in pushing force, velocity and closed-loop control.

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 optimizing system performance. Graphic displays show the system's behaviour and facilitate parameter setting.

Advantages of PILine® Micropositioning Systems

Positioning systems equipped with ceramic ultrasonic drives of the PILine® series provide several advantages over positioners that apply classic drive technology:

- Smaller dimensions
- Higher holding force when powered down; no holding current
- Increased acceleration of up to 5 g
- Increased velocity of up to 500 mm/s or 720°/s
- No leadscrews, gears or other mechanical components, no wear or maintenance
- No lubricants
- Non-magnetic and vacuum-compatible operating principle

Ordering Information

C-867.160
Piezomotor Controller with Drive Electronics, Networkable, for PILine® Systems

C-867.260
Piezomotor Controller with Drive Electronics, 2 Channels, for PILine® Systems

Accessories:
C-819.20
Analog Joystick for 2 axes

C-819.20Y
Y-Cable for Connecting 2 Controllers to C-819.20

C-170.PB
Pushbutton Box, 4 Buttons and 4 LEDs

Ask about custom designs!

The two-channel C-867.260 controller operates XY scanning stages, here:
a customized M-686 stage for microscopy

Technical Data

Model	C-867.160	C-867.260
Function	Controller and drive electronics for PILine® piezomotors / systems	
Drive type	PILine® motors, single and dual drives with P-661, P-664, U-161 or U-164	
Channels	1	2
Motion and control		
Servo characteristics	Programmable PID V-ff filter, parameter changes on the fly	
Trajectory profile modes	Trapezoidal	
Encoder input	A/B differential signals, 50 x 10^6 impulses/s	
Stall detection	Servo off, triggered by programmable position error	
Limit switch	2 x TTL per channel (programmable)	
Reference switch	1 x TTL per channel (active high / low, programmable)	
Electrical properties		
Max. output power / channel	15 W	
Max. output voltage / channel	200 V_{pp}	
Interfaces and operation		
Communication interfaces	USB, RS-232	
Motor connector	MDR14	2 x MDR14
Controller network	Up to 16 units on single interface	
I/O ports	4 analog/digital in, 4 digital out (Mini-DIN, 9-pin) digital: TTL analog: 0 to 5 V	
Command set	PI General Command Set (GCS)	
User software	PIMikroMove	
Software 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	
Manual control	Pushbutton box, joystick, Y-cable for control of 2 axes with joystick	Pushbutton box, joystick
Miscellaneous		
Operating voltage	24 VDC from external power supply (included)	
Current consumption	300 mA + motor current (2 A max.)	600 mA + motor current (4 A max.)
Operating temperature range	+5 °C to +40 °C	
Mass	1.0 kg	2.4 kg
Dimensions	206 x 130 x 66 mm (including mounting rails)	320 x 150 x 80.5 mm (including mounting rails)

C-867.OE OEM Controller Board for PILine® Piezo Drives

Affordable OEM Piezo Motor Controller with CAN Interface

Controller C-867.OE for piezo linear drives

Ordering Information

C-867.OE
OEM Driver / Controller Card for PILine® Ultrasonic Motors, 1 Channel

Ask about custom designs!

- **Optimized for all PILine® Ultrasonic Piezo Linear Motors with Single or Double Drive**
- **PID Servo-Control with Dynamic Parameter Switching**
- **Integrated Piezo Motor Power Driver with Frequency Control**
- **CAN, RS-232, and Analog Interfaces (e.g. for Joystick)**
- **Data Recorder**
- **Powerful Macro Command Language, e.g. for Standalone Operation**
- **Extensive Software Support, LabVIEW, DLL, ...**

The C-867 OEM card is a cost-effective motion controller for closed-loop positioning systems equipped with PILine® ultrasonic piezo motors. The controller card integrates both the servo controller / communication hardware and the driver electronics for the ultrasonic piezo motors.

For seamless integration in industrial automation environments, the controller can be operated via RS-232 and CAN interfaces. In addition, an analog (joystick) interface and non-volatile macro command memory make stand-alone operation possible.

Application Examples

- Biotechnology
- Microscopy
- Fiber positioning
- Automation
- Photonics / integrated optics
- Quality assurance testing
- Testing equipment

Highly Specialized PID Servo-Controller

The C-867 is based on a highly specialized DSP (Digital Signal Processor) that handles 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 an optimized settling behavior within a couple of 10 milliseconds is achieved. The broadband encoder input (50 MHz) allows high-resolution encoders to be used with the outstandingly high accelerations and velocities that PILine® drives deliver.

Highest Stability and Reliability with Automatic Frequency Control

The integrated piezomotor drive electronics supports all types of PILine® ultrasonic piezomotors currently available.
Variations in the resonant frequency of the motor caused by temperature or load changes are automatically compensated for by a frequency-control loop which adjusts the operating frequency of the driving voltage. This leads to higher stability of the motor output force and velocity and to higher position accuracy.

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 PI Tuning Tool for optimizing system performance. Graphic displays show the system's behaviour and facilitate parameter setting.

Cost-effective combination:
M-272 closed-loop linear pusher and C-867.OE controller card

Technical Data

Model	C-867.OE
Function	Controller and drive electronics for PILine® piezomotors / systems
Drive type	PILine® motors, single and dual drives with P-661, P-664, U-161, U-164 and U-264
Channels	1
Motion and control	
Servo characteristics	Programmable PID V-ff filter, parameter changes on-the-fly
Trajectory profile modes	Trapezoidal
Encoder input	A / B differential signals, 50 MHz
Stall detection	Servo off, triggered by programmable position error
Limit switches	2 TTL (programmable)
Reference switches	1 TTL (active high / low, programmable)
Electrical properties	
Max. output power	15 W
Max. output voltage	200 V_{pp}
Interfaces and operation	
Communication interfaces	RS-232, CAN, input / output 32-pin (male) on rear panel (DIN 41612 / D)
Motor connector	MDR14
Command set	PI General Command Set (GCS)
User software	PIMikroMove
Software 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
Miscellaneous	
Operating voltage	24 VDC from external power supply (not included)
Current	150 mA + motor current (2 A max.)
Operating temperature range	+5 °C to +40 °C
Mass	420 g
Dimensions	175 x 100 x 38 mm (connectors included)

PI Piezo • Nano • Positioning

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

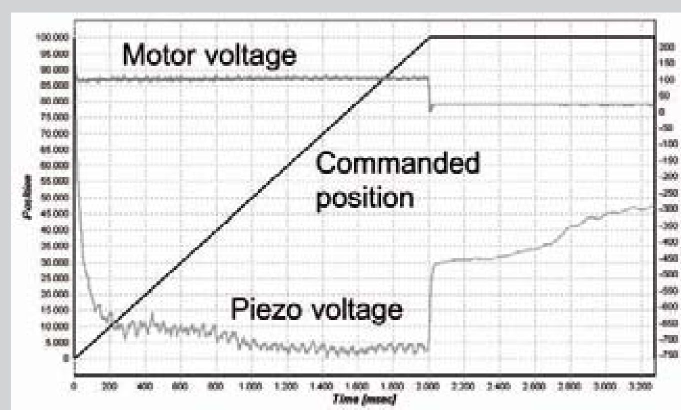
The optimized interaction between the piezoelectric and motorized drive components to make them a single motion unit requires a high-speed sensor as well as powerful control algorithms. The digital, 2-channel, C-702 controller, based on modern CPU technology with a real time operating system, has been 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

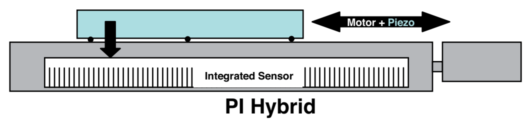
C-702.00
Ultra-High-Precision
Hybrid Controller, 2 Channels



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)



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

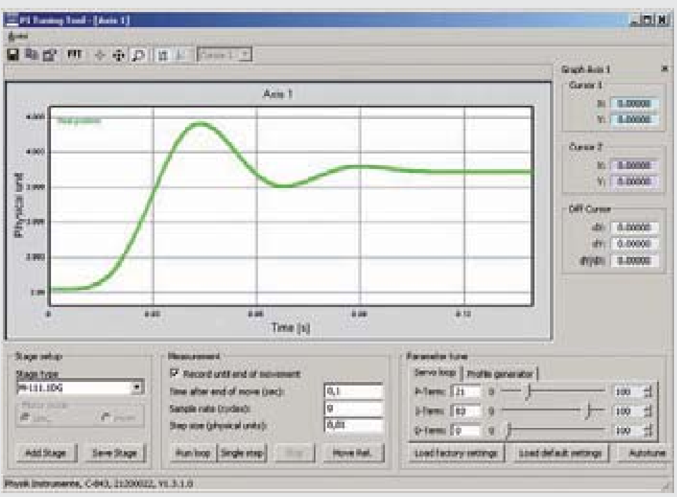
C-843.21
DC-Motor Controller PCI PC Board, 2-Axis

C-843.41
DC-Motor Controller PCI PC Board, 4-Axis

C-843.JS
Joystick and PCI Interface Board for C-843 Motor Controller

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

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.

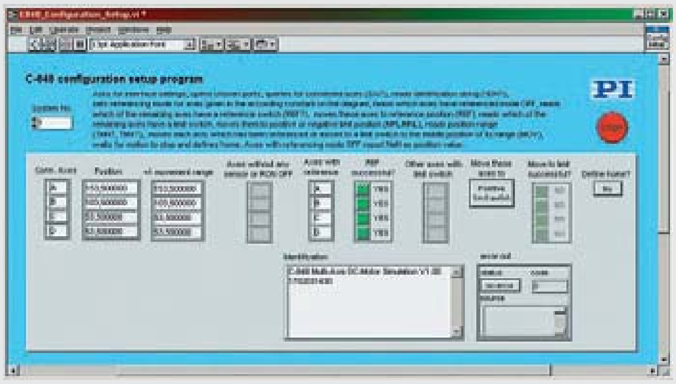
The C-848 can also run in stand-alone mode, and a standard computer keyboard and monitor can be connected for direct programming.

Ordering Information

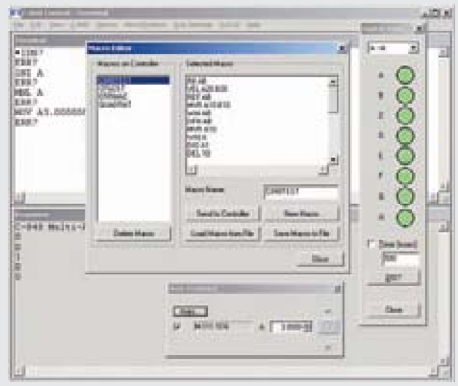
C-848.23
DC Servo Motion Controller, 2 Channels, 19“ Rack Mount, RS-232

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 TCP/IP 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

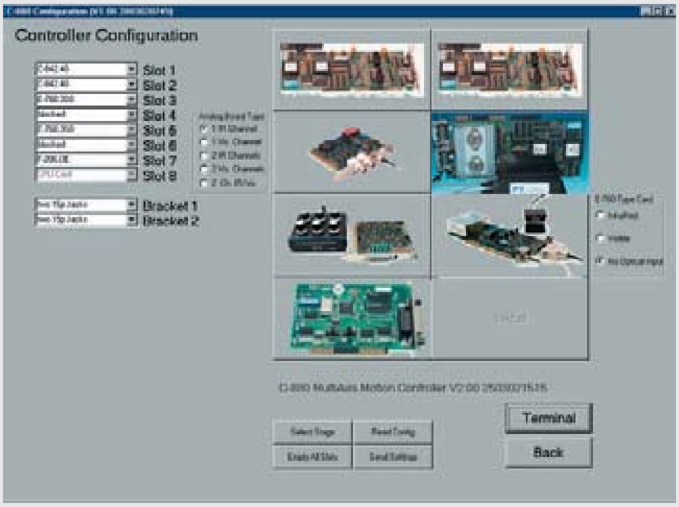
F-206.VVU
Photometer Card, Visible Range, 2 Channels

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.

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



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)

Index

Product Index

Product Index

S

V

Headquarters

GERMANY

Physik Instrumente (PI) GmbH & Co. KG
Auf der Römerstr. 1
76228 Karlsruhe/Palmbach
Tel: +49 (721) 4846-0
Fax: +49 (721) 4846-100
info@pi.ws · www.pi.ws

PI Ceramic GmbH
Lindenstr.
07589 Lederhose
Tel: +49 (36604) 882-0
Fax: +49 (36604) 882-25
info@piceramic.de
www.piceramic.de

Subsidiaries

USA (East) & CANADA

PI (Physik Instrumente) L.P.
16 Albert St.
Auburn, MA 01501
Tel: +1 (508) 832 3456
Fax: +1 (508) 832 0506
info@pi-usa.us
www.pi-usa.us

USA (West) & MEXICO

PI (Physik Instrumente) L.P.
5420 Trabuco Rd., Suite 100
Irvine, CA 92620
Tel: +1 (949) 679 9191
Fax: +1 (949) 679 9292
info@pi-usa.us
www.pi-usa.us

JAPAN

PI Japan Co., Ltd.
Akebono-cho 2-38-5
Tachikawa-shi
Tokyo 190
Tel: +81 (42) 526 7300
Fax: +81 (42) 526 7301
info@pi-japan.jp
www.pi-japan.jp

PI Japan Co., Ltd.
Hanahara Dai-ni-Building, #703
4-11-27 Nishinakajima,
Yodogawa-ku, Osaka-shi
Osaka 532
Tel: +81 (6) 6304 5605
Fax: +81 (6) 6304 5606
info@pi-japan.jp
www.pi-japan.jp

CHINA

Physik Instrumente (PI Shanghai) Co., Ltd.
Building No. 7-301
Longdong Avenue 3000
201203 Shanghai, China
Tel: +86 (21) 687 900 08
Fax: +86 (21) 687 900 98
info@pi-china.cn
www.pi-china.cn

UK & IRELAND

PI (Physik Instrumente) Ltd.
Lambda House
Batford Mill
Harpenden, Hertfordshire
AL5 5BZ
Tel: +44 (1582) 711 650
Fax: +44 (1582) 712 084
uk@pi.ws
www.physikinstrumente.co.uk

FRANCE

PI France S.A.S.
32 rue Delizy
93694 Pantin Cedex
Tel: +33 (1) 57 14 07 10
Fax: +33 (1) 41 71 18 98
info@pifrance.fr
www.pifrance.fr

ITALY

Physik Instrumente (PI) S.r.l.
Via G. Marconi, 28
20091 Bresso (MI)
Tel: +39 (02) 665 011 01
Fax: +39 (02) 665 014 56
info@pionline.it
www.pionline.it