Nanopositioning / Piezoelectrics

Piezo Stages, Systems, Fast Piezo Steering Mirrors

2010/2011

More Info:
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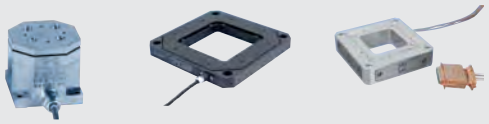
Overview: Single and Multi-Axis Systems

PI Products for Nanopositioning

Microscopy & Imaging Stages

XY Stages



Actuators & Linear Motors

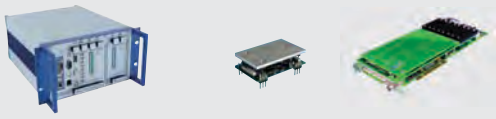
XYZ Stages

Linear Stages (X-Stages)

6-Axis Stages

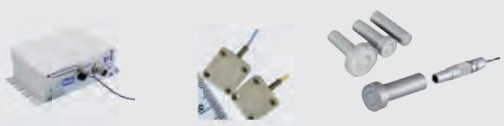
Z- and Z/Tip/Tilt Stages

Piezo Controllers and Drivers



Tip/Tilt Mirror Platforms

Nanometrology Sensors



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

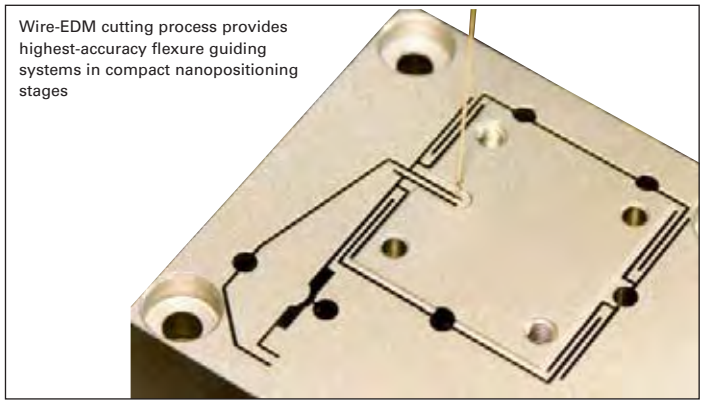
The multilink flexure guiding systems employed in most PI piezo nanopositioners eliminate cosine errors and provide bidirectional flatness and straightness in the nanometer or microradian range. This high precision means that even the most demanding positioning tasks can be run bidirectionally for higher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

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

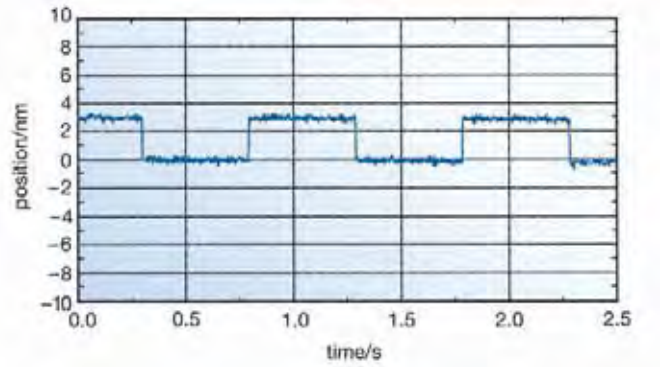
All standard PI nanopositioning systems are fully CE and RoHS compliant.

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.

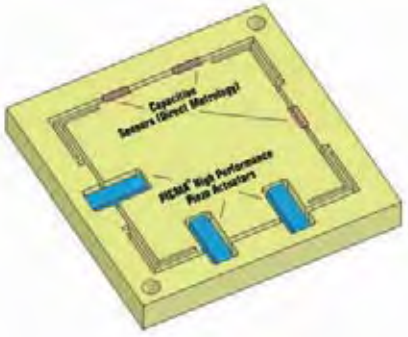
**Strain type sensors (metal foil, semiconductor, or piezoresistive) infer position information from strain.

***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.

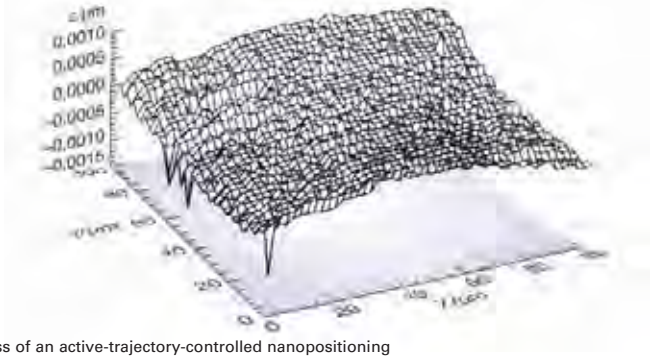


Principle of a PI XY-Theta-Z, minimum-inertial-mass, monolithic, parallel kinematics nanopositioning system. Accuracy, responsiveness and straightness/flatness are much better than in stacked multi-axis (serial kinematics) systems.

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

Analog and Digital Controllers

PI offers the largest selection of digital and analog piezo drivers / linear amplifiers and piezo motion controllers worldwide.

The electronics play a key role for maximum performance of piezoelectric nanopositioning stages, tip/tilt mirrors and actuators. Ultra-low-noise, high-stability servo-controllers and linear amplifiers are essential, because piezoelectric actuators respond to even microvolt changes of the control voltage with motion.

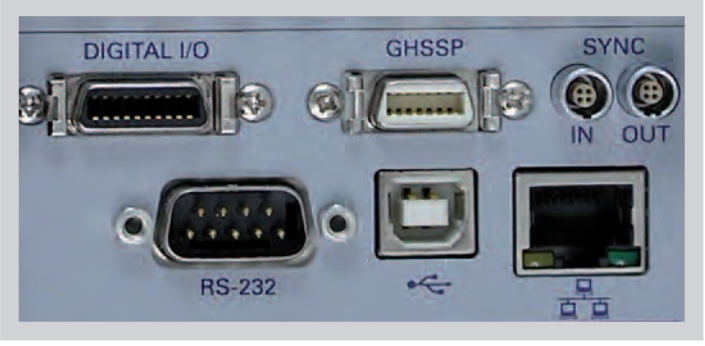
For industrial applications, where maximum throughput is crucial, PI offers digital control algorithms for dynamic linearization and reduced settling times. For dynamic high-power applications, PI's unique energy-recovery power amplifiers provide up to 2000 W of peak power!

State-of-the-art PI digital control systems offer several advantages over analog control systems: coordinate transformation, real-time linearity compensation and elimination of some types of drift. Digital controllers also allow virtually instant changes of servo parameters for different load conditions, etc. However, not all digital controllers are created equal. Poor implementations can add noise and lack certain capabilities of a well-designed analog implementation, such as fast settling time, compatibility with advanced feed-forward techniques, stability and robust operation.

PI digital controllers can download device-specific parameters from ID-chip-equipped nanopositioning stages, facilitating interchangeability of nanomechanisms and controllers.

All PI nanopositioning controllers (analog and digital) are equipped with one or more user-tunable notch filters. A controller with notch filter can be tuned to provide higher bandwidth because side-effects of system resonances can be suppressed before they affect system stability. For the most demanding step-and-settle applications, PI's exclusive Mach™ InputShaping® implementation is available as an option.

See page 2-100 *ff* Section for a complete overview on PI's piezo drivers and controllers.



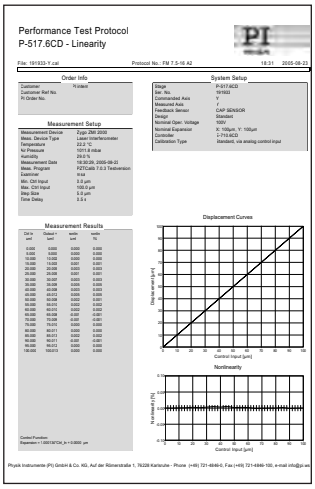
More...

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.

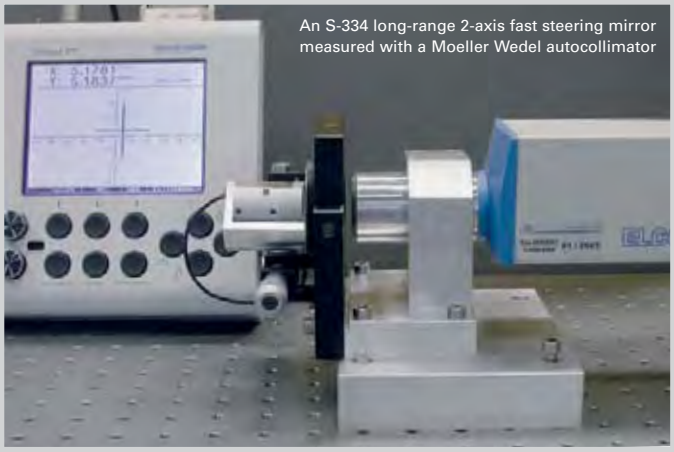
Furthermore, PI makes significant continuing investments in improved-quality, higher-performance nanometrology equipment so that we can deliver better value to our customers.

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

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

Moving the Nanoworld

NanoAutomation®: Precision Positioning for Science and Industry

PI headquarters in Karlsruhe

Future Technology Solutions

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

- Semiconductor Technology
- Optical Metrology, Microscopy
- Biotechnology and Medical Devices
- Precision Automation and Handling
- Precision Machining
- Data Storage
- Photonics, Fiber Optics, Telecom
- Nano Technology
- Microsystems Technology
- Aerospace Engineering
- Astronomy


PI reception desk: Our employees look forward to your visit

PI is market and technological leader for precision positioning systems with accuracies well under one nanometer. Nanometer-range motion control is the key to worlds where millions of transistors fit on one square millimeter, where molecules are manipulated, where thousands of "virtual slices" are made in the observation of living cells, or where optical fiber bundles no larger than a human hair are aligned in six degrees of freedom.

Worlds We Call NanoWorlds

Continuous innovation and reinvestment of profits over the decades has allowed PI to attain its present market status. This status is also based on long-term customer relationships and on the freedom to transform ideas into reality.

Over 30 Years Experience

When PI introduced piezoelectric nanopositioning technology more than 30 years ago, typical customers were research labs and universities working on laser cavity tuning, Fabry-Perot interferometers and filters. Few foresaw that whole industrial sectors like semiconductor manufacturing or biotechnology would become dependent on progress in nanopositioning. Today, not even the precision machining industry can do without nanometer-level positioning systems.

Key Technologies In-House

PI follows a vertical integration strategy designed to develop and maintain all key technologies in-house. We supervise each and every step from design to delivery in the following areas: software, precision mechanics, digital and analog control electronics, sub-nanometer capacitive position sensors, piezo ceramics and piezo actuators. This assures the highest quality and reduces cost.

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

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

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

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-510.101 with 100 µm, D-510.051 with 50 µm, D-510.021 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.

D-510.021 with LEMO connector for easy handling

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.

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*).

Ordering Information

D-510.021
PISeca, Single-Electrode Capacitive Sensor Probe, 8 mm Diameter, 20 µm Nominal Range

D-510.051
PISeca, Single-Electrode Capacitive Sensor Probe, 12 mm Diameter, 50 µm Nominal Range

D-510.101
PISeca, Single-Electrode Capacitive Sensor Probe, 20 mm Diameter, 100 µm Nominal Range

Accessories

D-891.01E
Sensor Cable PISeca, 1 m

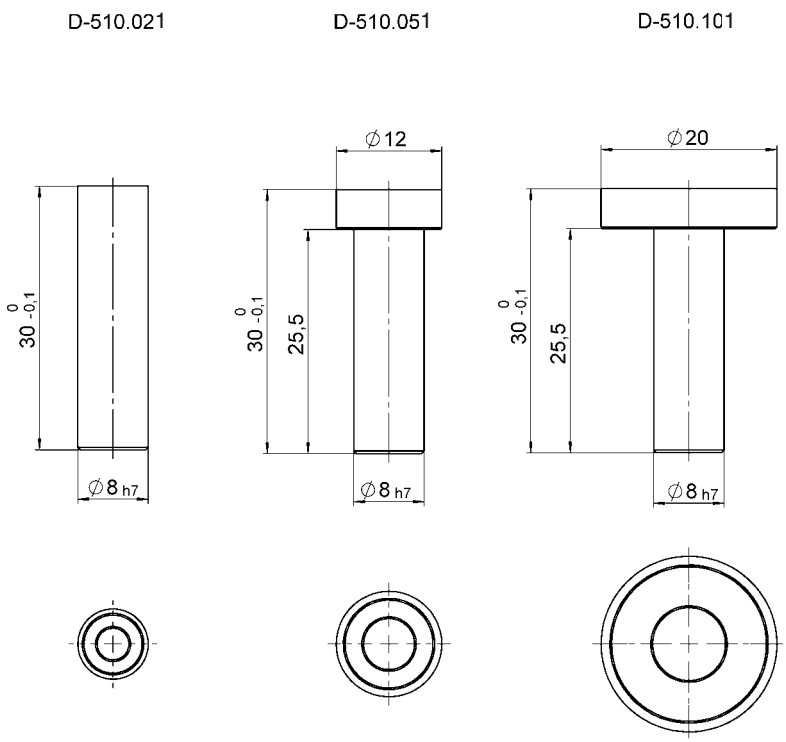
D-891.02E
Sensor Cable PISeca, 2 m

D-891.01A
Sensor Cable PISeca, Right-Angle Connector, 1 m

D-891.02A
Sensor Cable PISeca, Right-Angle Connector, 2 m

Other cable lengths available on request.

Ask about custom designs!



D-510.021, D-510.051 and D-510.101 capacitive sensor probes, dimensions in mm. Sensor connection LEMO FFC00.650.CLA.543, triaxial

Technical Data

Model	D-510.021	D-510.051	D-510.101	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 measure-ment range	typical
Dynamic resolution**	<0.002	<0.002	<0.002	% of measure-ment 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	mm²	
Sensor diameter	8	12	20	mm	
Sensor area	50.3	113.1	314.0	mm²	
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

D-015 · D-050 · D-100 Capacitive Sensors

Sub-Nanometer-Resolution Position Sensors

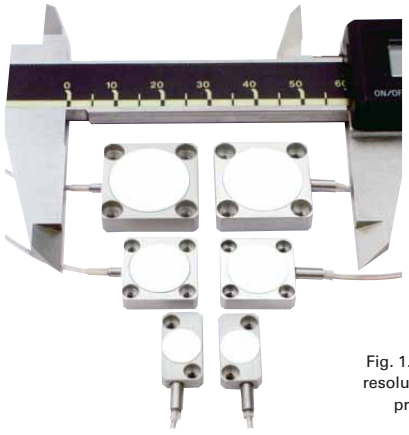


Fig. 1. D-015, D-050, D-100 ultra-high-resolution capacitive position sensors provide up to 10,000 times higher resolution than calipers

- **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 nm/$\sqrt{\text{Hz}}$. 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.

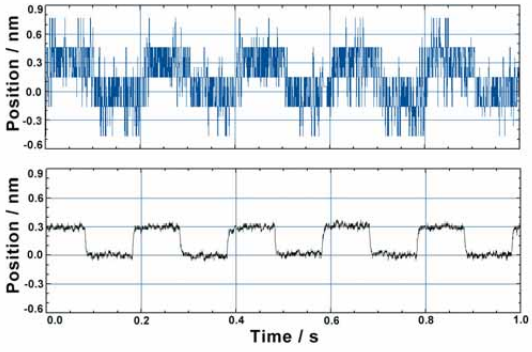
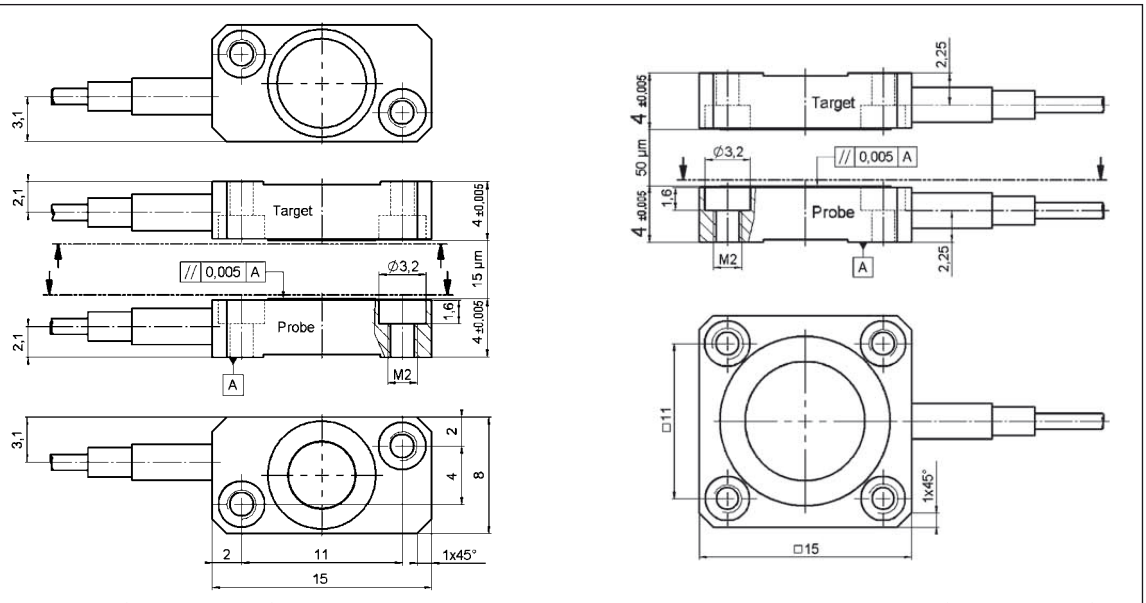
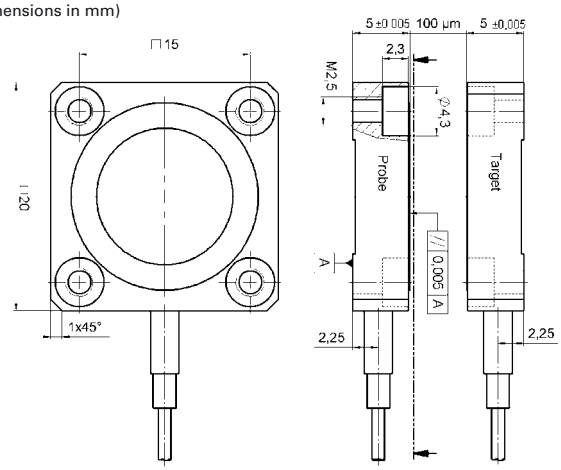


Fig. 2. Piezo nanopositioning system making 0.3 nm steps, measured with PI capacitive sensor (lower curve) and with a highly precise laser interferometer. The capacitive sensor provides significantly higher resolution than the interferometer.



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	56.5	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

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

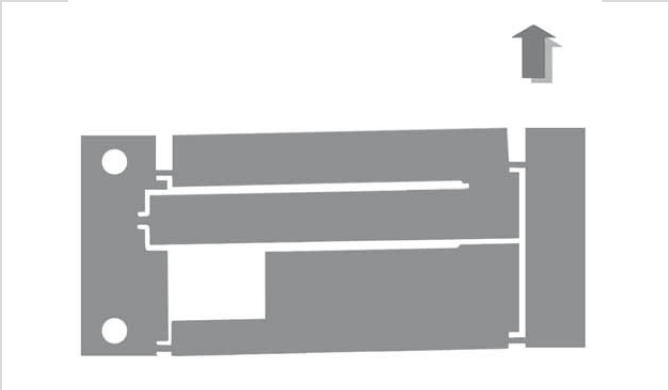
PiezoMove® OEM Linear Actuator with High Stiffness

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!

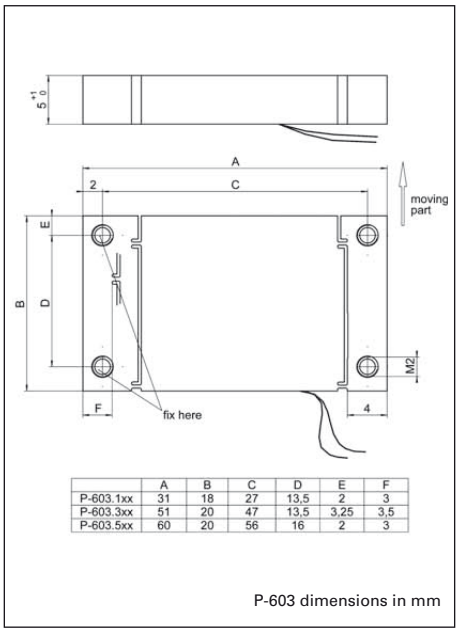


The flexure guiding system prevents tip and tilt at the drive head!

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

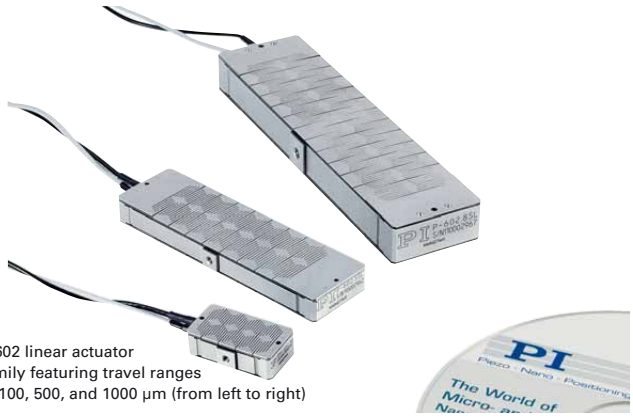
Technical Data (preliminary)

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-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

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

P-602. ☐

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

PiezoMove® OEM Linear Actuators with High Force

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

P-602. ☐

- **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

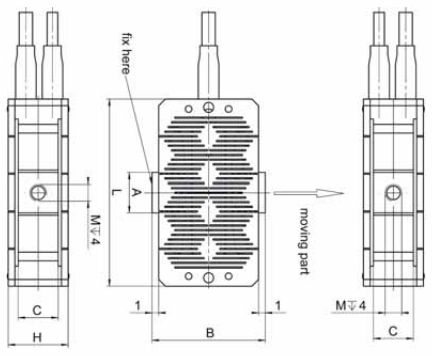
For OEM applications, PiezoMove actuators can be modified in various ways to suit the customer's requirements. The stiffness and force generation can be influenced via the lever design and the dimensions of the piezo ceramics used in the actuator. If only a small force and low guiding accuracy are required, 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.

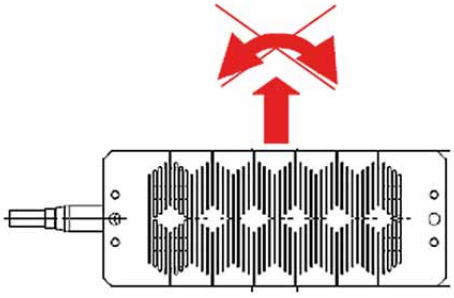


	L	B	H
P-602.1xx	28	17	9
P-602.3xx	46	19	9
P-602.5xx	85	26	9
P-602.8xx	126	34	14
P-602.1x8	28	22	14
P-602.3x8	46	24	14
P-602.5x8	85	31	14

	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

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

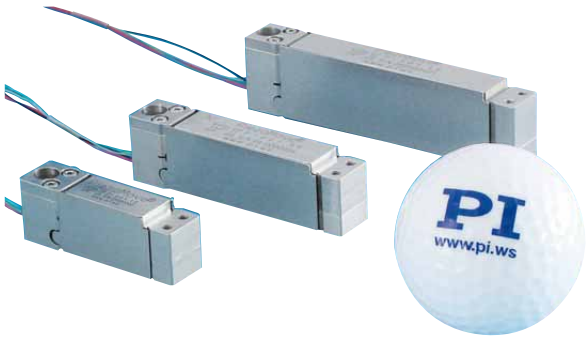
Technical Data (preliminary)

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-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

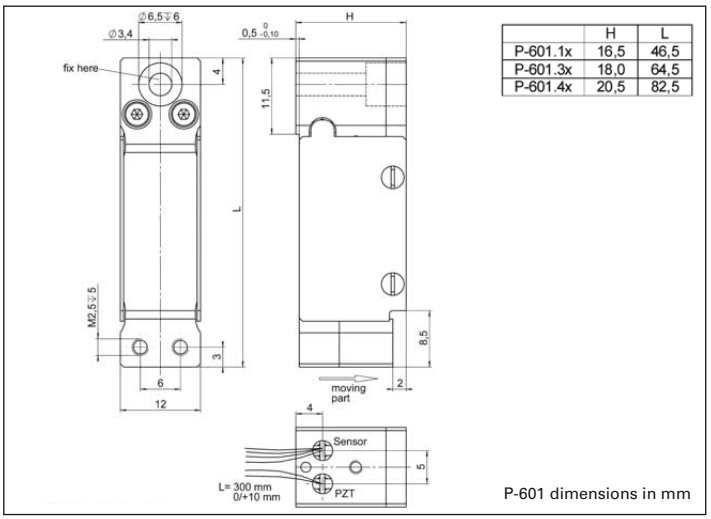
P-601.3SL
PiezoMove™ OEM Flexure-Guided, Lever-Amplified Actuator, 250 µm, SGS-Sensor, LEMO Connector

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

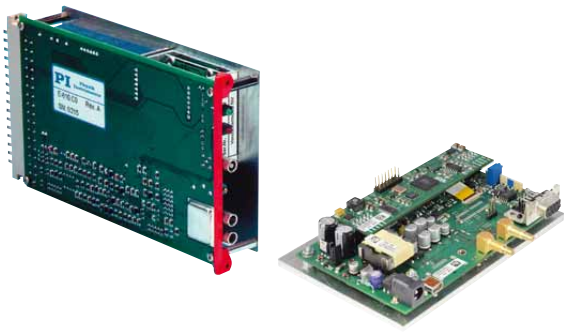
P-601.30
PiezoMove™ OEM Flexure-Guided, Lever-Amplified Actuator, 250 µm, Open-Loop

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

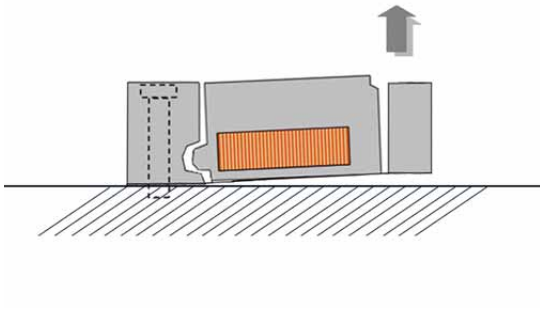


	H	L
P-601.1x	16,5	46,5
P-601.3x	18,0	64,5
P-601.4x	20,5	82,5

P-601 dimensions in mm



The E-610 analog controller OEM module left or the E-609 digital OEM controller are available for closed-loop versions with position sensor



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

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)

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.

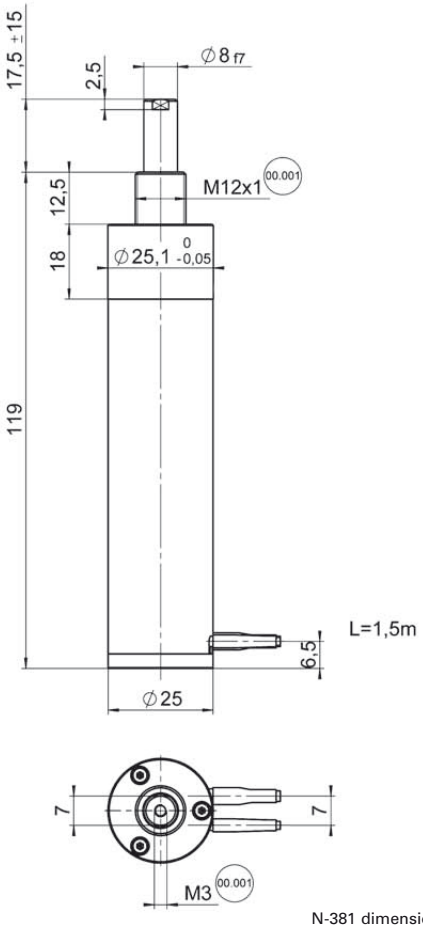
Ordering Information

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

N-381.30
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

Index

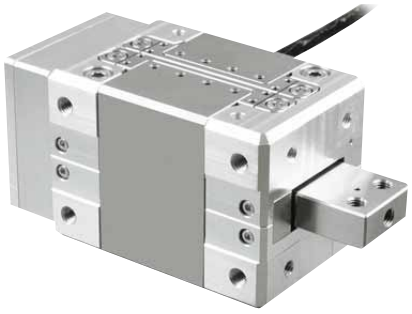
Technical Data (Preliminary)

Model	N-381.30	N-381.3A
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-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.

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

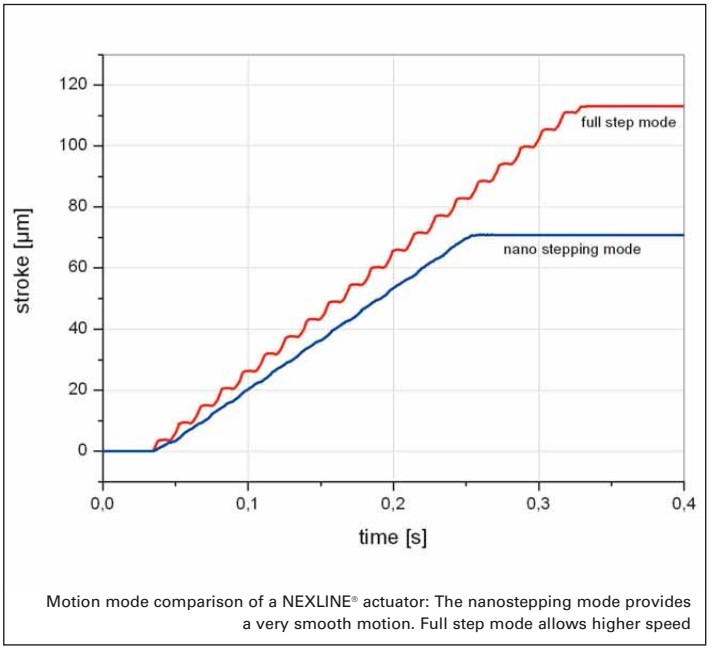
N-216.20
NEXLINE® Piezo Stepping High-Load Actuator, 20 mm, 600 N, Open-Loop

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

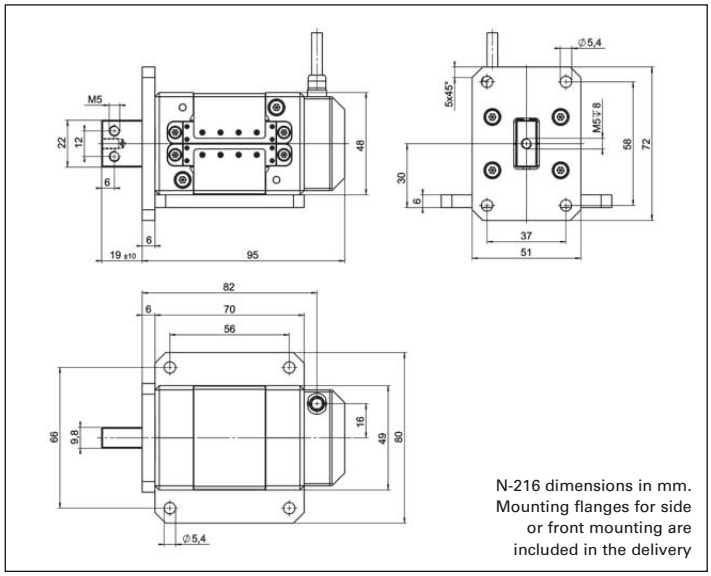
Ask about custom designs!

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



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



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-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.

Ordering Information

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

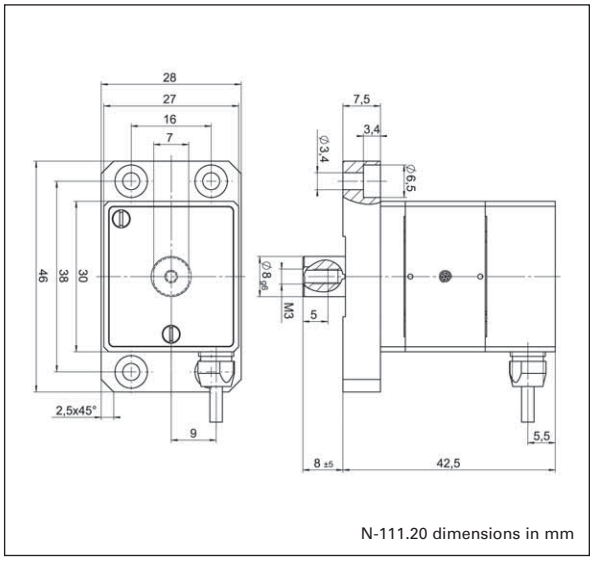
N-111.2A
NEXLINE® OEM Piezo Stepping Actuator, 10 mm, 50 N, Linear Encoder, 5 nm Resolution

Ask about custom designs!

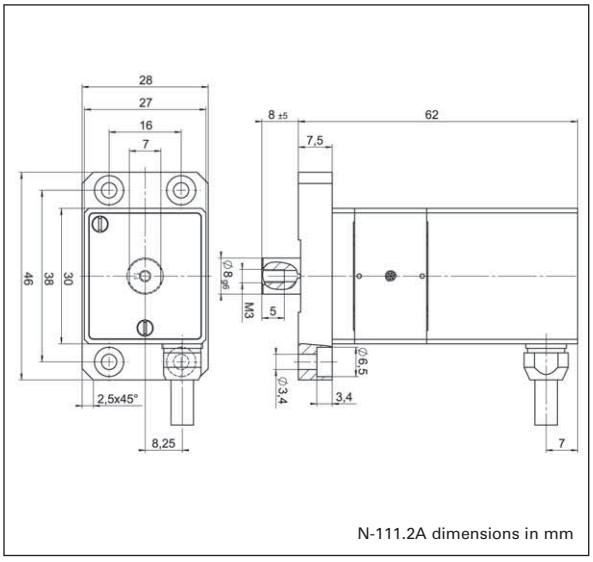
Patented Technology

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

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



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.

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

Full-Ceramic Encapsulation & Patented Design

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

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.

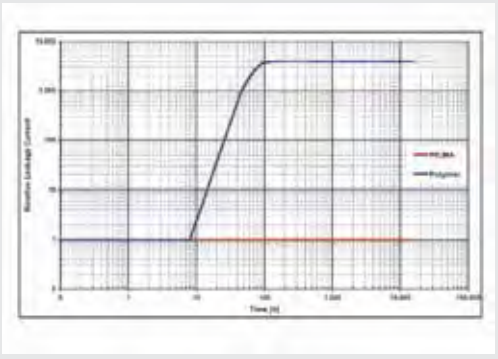
PI piezo actuators not only show an optimal combination of travel and stiffness, but are also designed for maximum lifetime under actual operating conditions in industrial environments.

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.

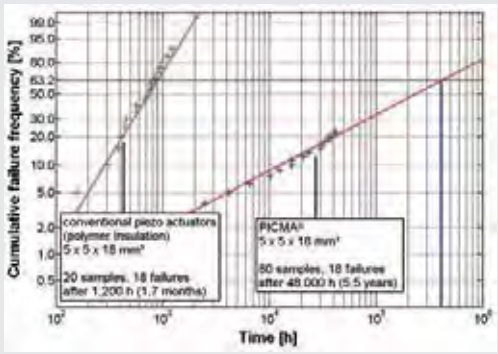
Long Term Tests Prove DC Reliability

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. 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)

Continuous Dynamic Operation

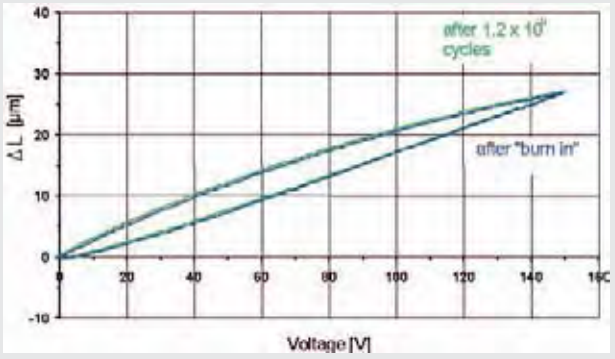
Here, the well-known lifetime-limiting factors of conventional designs are humidity, crack formation inside the ceramic leading to rising leakage currents and delamination of electrodes under extreme dynamic conditions.

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 109 cycles at 8 samples PICMA® 5x5x18 using a 116 Hz-sine wave excitation (1.0 x 107 cycles per day) at a unipolar operating voltage of 100 V, 15 MPa preload. Control measurements were taken every 109 cycles. There was no significant decrease in displacement.

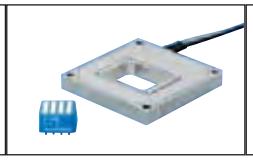
Large Operating Temperature Range , Optimum UHV Compatibility—Minimum Outgassing

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 bake-out temperatures, up to 150 °C).

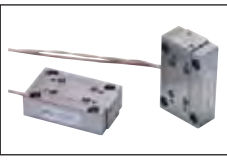
Selection Guide: Single-Axis Piezo Stages

Nanometer Precision, Travel Ranges 15 µm to 1,800 µm

P-772 Smallest stage with direct metrology. 12 µm

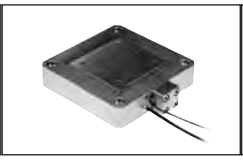


P-712 Low profile, low cost, 30 µm

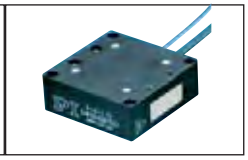


P-753 LISA Stage / actuator, to 38 µm

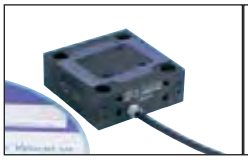
P-752 Fast & extremely precise to 30 µm



P-750 High-load stage, 75 µm



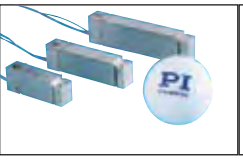
P-611 100 µm, compact, low cost



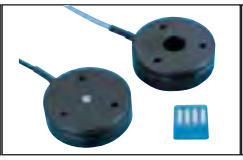
P-631 OEM high-volume stage

P-62x.1 Family: 50 to 1800 µm, compact

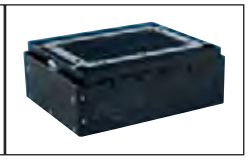
P-721, P-725: PIFOC® lens positioners, 100 to 500 µm,



P-601 Flexure-guided actuator, 100 to 400 µm



S-303 Phase shifter, very fast



M-511.HD, M-714 Hybrid stage, travel to 100 mm

Models	Description	Travel [µm]	Sensor	Dynamics*	Precision**	Page
P-772	Ultra-compact flexure guided system	10	Capacitive	●●●●●	●●●●●	2-24
P-712	Compact scanner, fast, low profile, aperture, ideal for imaging	15	SGS	●●●●●	●●○○○	2-14
P-753	Nanopositioning stage and actuator in one, very compact, fast and accurate	12, 25, 38	Capacitive	●●●●●	●●●●●	2-16
P-752	Nanopositioning stage, very fast and accurate, outstanding guiding accuracy	15, 30	Capacitive	●●●●●	●●●●○	2-18
P-750	High load stage, outstanding guiding accuracy	75	Capacitive	●●●●○	●●●●●	2-24
P-611	Compact, low-cost. X, Z, XY and XYZ combinations	100	SGS	●●●○○	●●●○○	2-20
P-631	Compact precision OEM stage for high-volume applications	100, more on request	Capacitive	●●●○○	●●●●○	2-24
P-62x.1	PIHera® piezo nanopositioners, compact, very accurate, long travel ranges, excellent value. X, XY and XYZ combinations	50 to 1800	Capacitive	●●●●○ to ●○○○○	●●●●○ to ●●●○○	2-22
P-721, P-725	PIFOC® objective nanofocusing system, very fast and accurate, with QuickLock mounting system, direct metrology	100, 250, 500	Capacitive / SGS	●●●○○	●●●●○ / ●●○○○	2-26 2-28
P-2601	Closed-loop, with flexure guidance	110, 300, 400	SGS	●●●●○	●●○○○	1-68
S-303	Phase shifter, extremely precise, 25 kHz resonant frequency, optional sensors	3	Capacitive	●●●●●	●●●●●	2-96
M-511.HD, M-714	Hybrid drive: piezo & servo motor, extremely accurate, 2 nm linear encoder, long travel to 100 mm	Up to 100 mm	Linear Encoder	●●●●○	●●●●○	4-46

*Dynamics: Combination of system settling time / bandwidth / load capacity relative to the typical application of the product
**Precision: Combination of guiding precision, sensor precision, resolution, relative to comparable products in class

Multi-Axis Piezo Stages: see p. 2-6

Piezo Motor Driven Long Travel Stages: see p. 4-19 *ff*

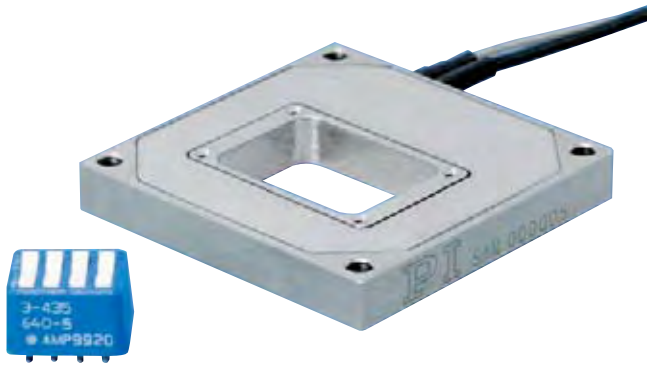
Notes on Specifications see p. 2-78 *ff*

All models are precision flexure guided, and equipped with the patented PICMA® long-life piezo actuators. Capacitive position feedback sensors are available for the highest performance applications, alternatively, strain gauge sensors are available as well as open loop models.

Microscope Stages...

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.

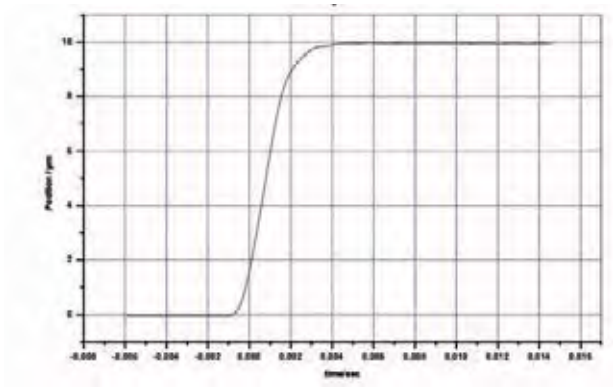
Ceramic Insulated Piezo Actuators Provide Long Lifetime

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.

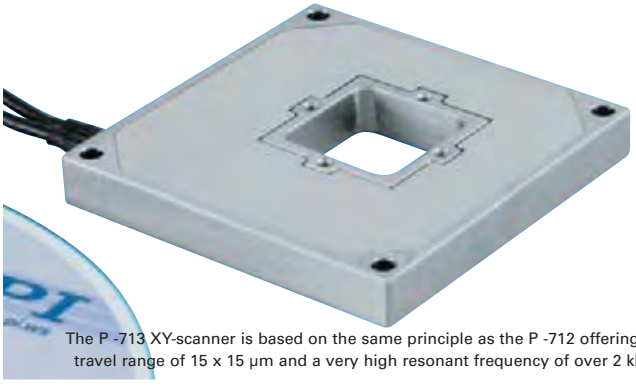
Ordering Information

P-712.10L
Low-Profile OEM Nanoscanner, 40 µm, Open-Loop

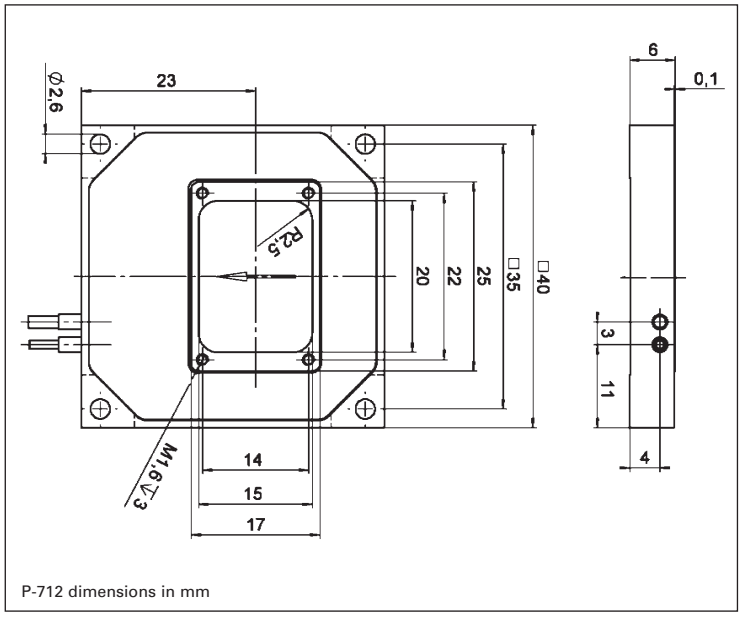
P-712.1SL
Low-Profile OEM Nanoscanner, 30 µm, SGS-Sensor



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

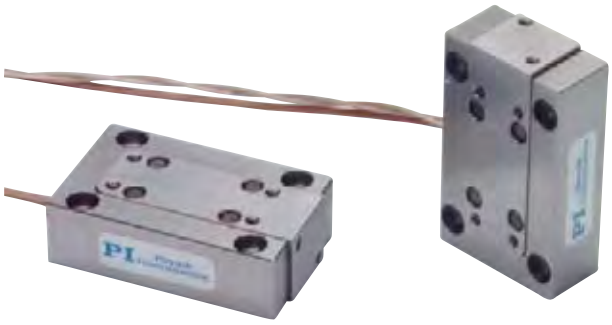
Technical Data

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

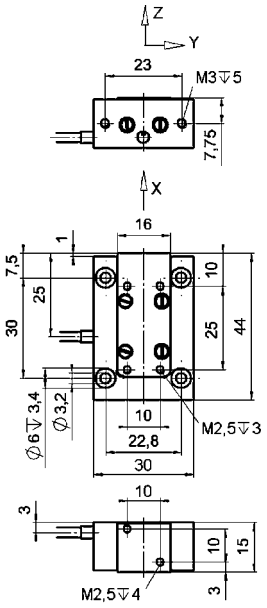
P-753.31C
LISA High-Dynamics Nanopositioning System, 38 µm, Direct Metrology, Capacitive Sensor, LEMO Connector

P-753.1CD*
LISA High-Dynamics Nanopositioning System, 12 µm, Direct Metrology, Capacitive Sensor, Sub-D Connector

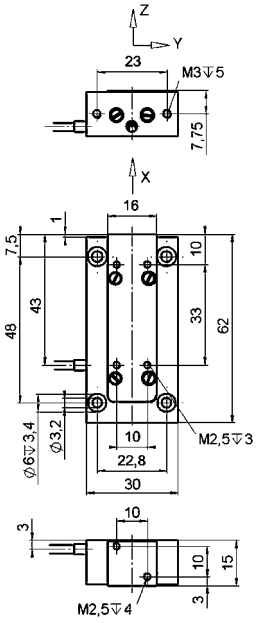
P-753.2CD*
LISA High-Dynamics Nanopositioning System, 25 µm, Direct Metrology, Capacitive Sensor, Sub-D Connector

P-753.3CD*
LISA High-Dynamics Nanopositioning System, 38 µm, Direct Metrology, Capacitive Sensor, Sub-D Connector

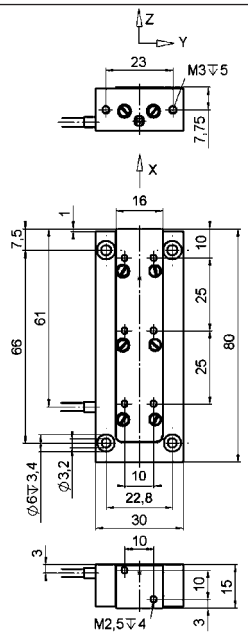
*Vacuum versions to 10^{-9} hPa are available as P-753.xUD, non-magnetic vacuum versions can be ordered as P-753.xND.



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	Hz	±20 %
Resonant frequency @ 200 g	2.5	1.7	1.4	2.5	1.7	1.4	Hz	±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)

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.

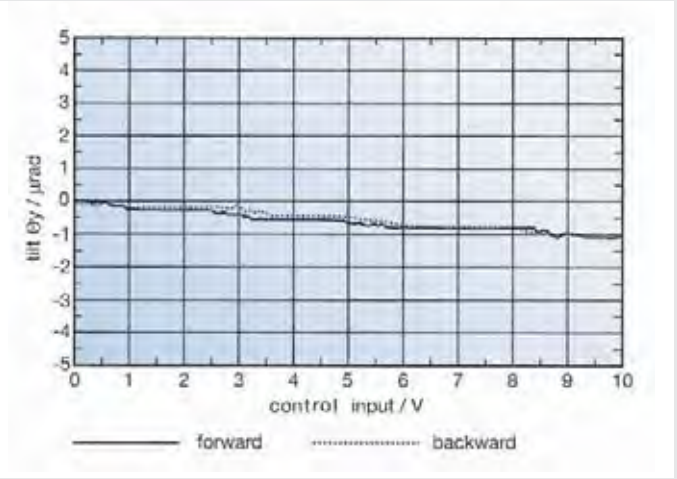
Ordering Information

P-752.11C
High-Dynamics Piezo Nanopositioning System, 15 µm, Direct Metrology, Capacitive Sensor, LEMO Connector

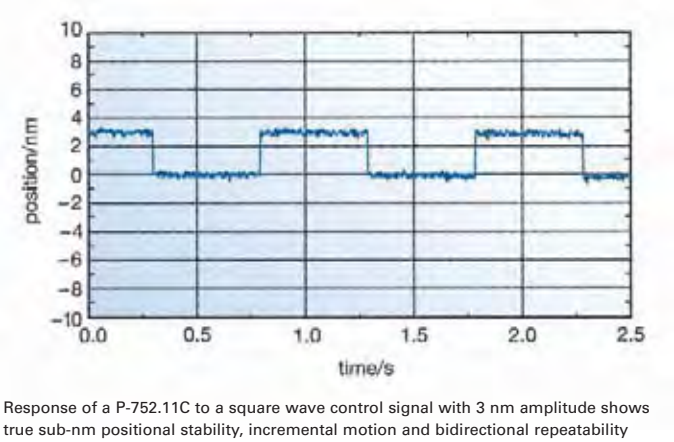
P-752.21C
High-Dynamics Piezo Nanopositioning System, 30 µm, Direct Metrology, Capacitive Sensor, LEMO Connector

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

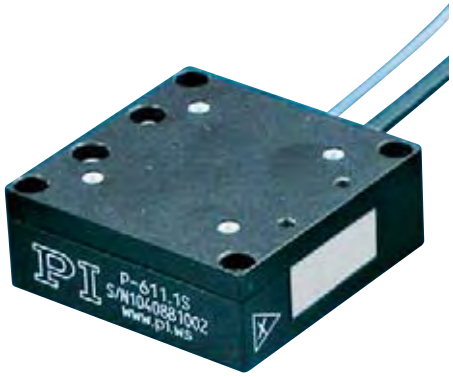
Model	P-752.11C	P-752.1CD	P-752.21C	P-752.2CD	Units	Tolerance
Active axes	X	X	X	X		
Motion and positioning						
Integrated sensor	Capacitive	Capacitive	Capacitive	Capacitive		
Open-loop travel, -20 to +120 V	20	20	35	35	µm	min. (+20 %/-0 %)
Closed-loop travel	15	15	30	30	µm	calibrated
Closed-loop / 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*).

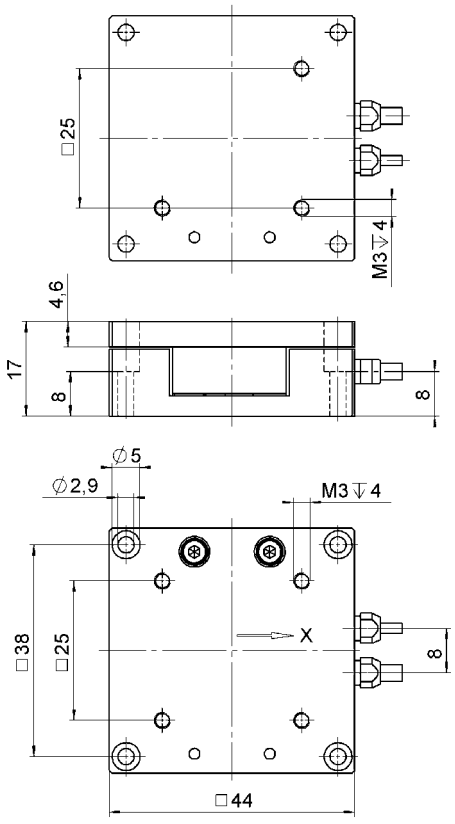
High Reliability and Long Lifetime

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.

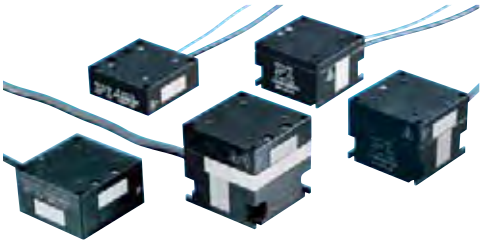
Ordering Information

P-611.10
Linear Nanopositioning System, 120 µm, No Sensor

P-611.1S
Linear Nanopositioning System, 100 µm, SGS-Sensor

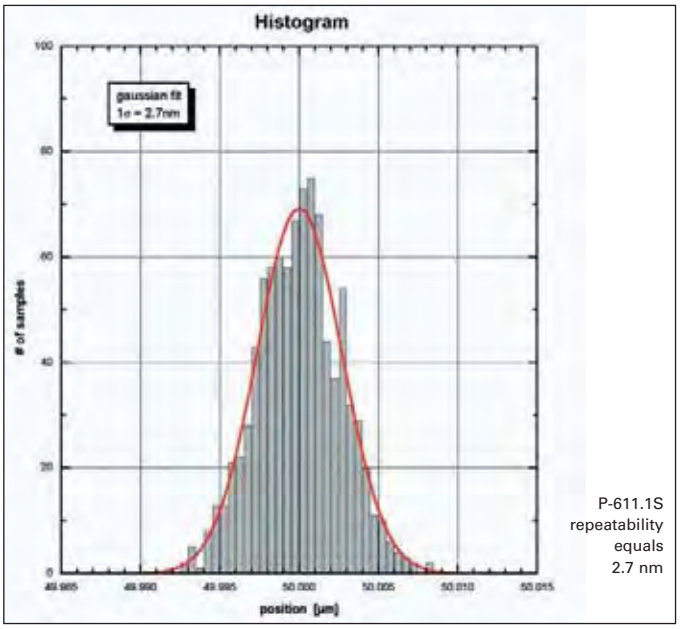


P-611.1S dimensions in mm



The whole P-611 family: X, Z, XY, XZ and XYZ stages

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



P-611.1S repeatability equals 2.7 nm

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

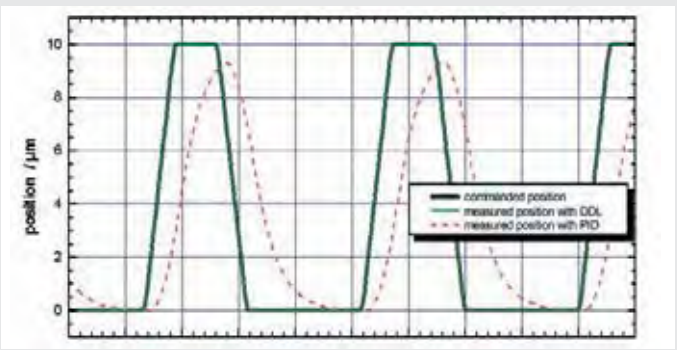
P-628.1CD* / P-628.1CL*
PIHera® Precision Piezo Linear Nanopositioning System, 800 µm, Direct Metrology, Capacitive Sensor

P-629.1CD* / P-629.1CL*
PIHera® Precision Piezo Linear Nanopositioning System, 1500 µm, Direct Metrology, Capacitive Sensor

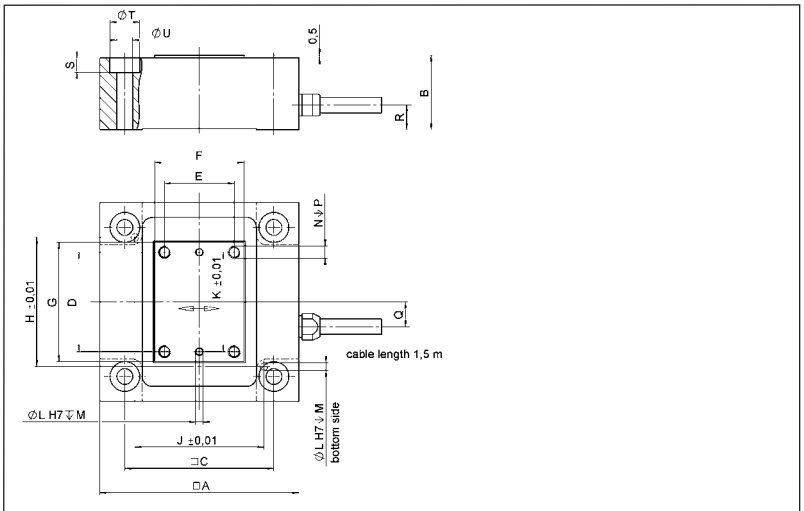
*.1CD with Sub-D Connector
*.1CL with LEMO Connector

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	ØL	M	N	P	Q	R	S	ØT	ØU
P-620.1CD / 10L	30	12	24	15	12	16	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)

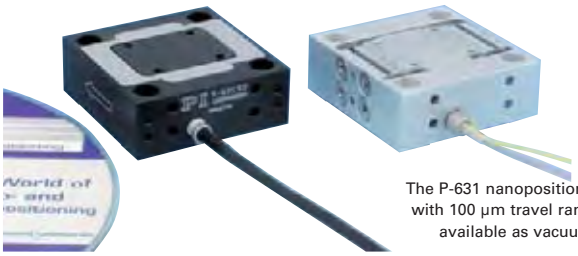
Technical Data

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



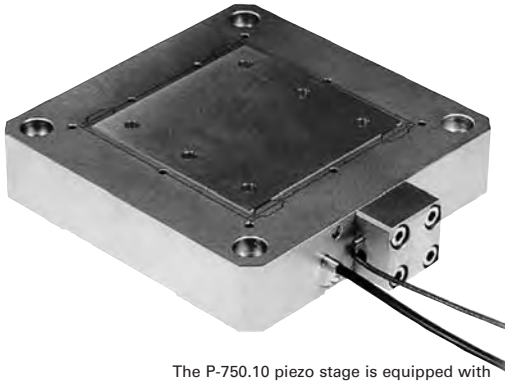
The P-631 nanopositioning stage with 100 µm travel range is also available as vacuum version

- 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



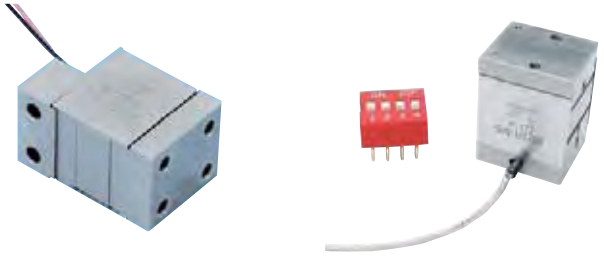
The P-750.10 piezo stage is equipped with high-precision capacitive position sensors

- 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

Overview

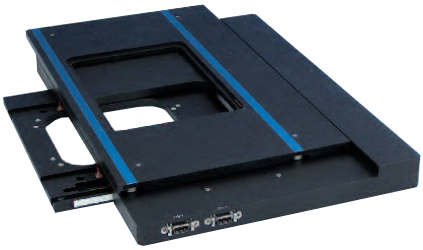
Piezo Stages, Objective Scanners for Microscopy

PInano™ Cost Effective Piezo Stages for SR Microscopy

- Z, XY, XYZ, Low Profile, Travel to 200x200x200µm
- Fast Response, High Speed Version for Particle Tracking
- Cost-Effective and Very Reliable with PICMA® Technology
- Compatible w/ Leading Image Acquisition Software Package

PIFOC® Drives: Fastest Z-Steps, for high NA Objectives

- Fastest Z-Scanners. Fres to 1100 Hz, Step & Settle <5 msec
- Long Travel Versions to 1000 µm
- Capacitive Non-Contact Sensors; Superior Linearity & Stability
- Quick Lock Adapter for Easy Attachment



PILine® Long Travel XY Piezo Linear-Motor Stages

- Closed-Loop; Linear Motors & Encoders: High Speed to 100 mm/s
- Self-Locking Piezomotor Principle:
  Extreme Stability at Rest, No Heat Generation
- Low Profile Design, Motors Completely Integrated
- Compatible with PI Piezo Scanning Stages

Piezo Stage for Well Plate Scanning

- High-Speed Piezo Motion with Travel Ranges to 500 µm
- Nanometer Resolution + much Faster than Motorized Stages
- Large Clear Aperture to Accommodate Specimen Holders
- Perfect Mechanical Fit to OEM Manual or Motorized Stages

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.

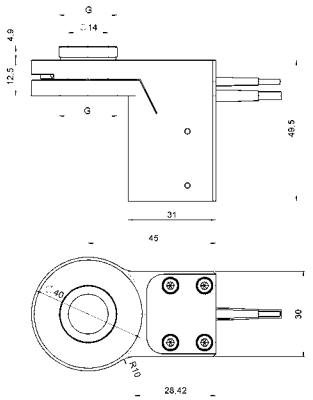
Open-loop models are available for applications where fast response and very high resolution are essential. Here, specifying or reporting absolute position values is either not required or is handled by external sensors, such as interferometers, a vision system or photodiode PSD (position sensitive detector). 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

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)

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)

- **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**

Ordering Information

P-725 PIFOC® Piezo Nanofocusing Z-Drive for Long Scanning Ranges

- **1** Travel Range 100 µm (closed-loop)
- **2** Travel Range 250 µm (closed-loop)
- **4** Travel Range 400 µm (closed-loop)

P-725. ☐ ☐

- **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

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.

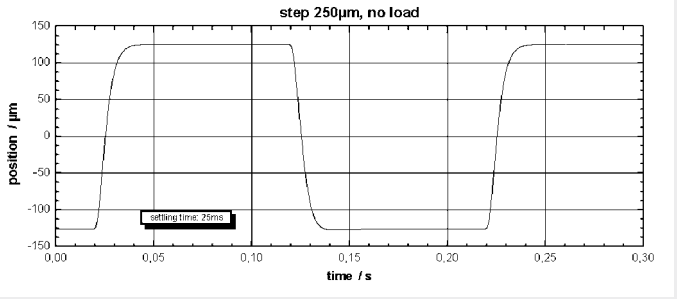
Open-loop models are available for applications where fast response and very high resolution are essential. Here, specifying or reporting absolute position values is either not required or is handled by external sensors, such as interferometers, vision system or photodiode PSD (position sensitive detector). 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



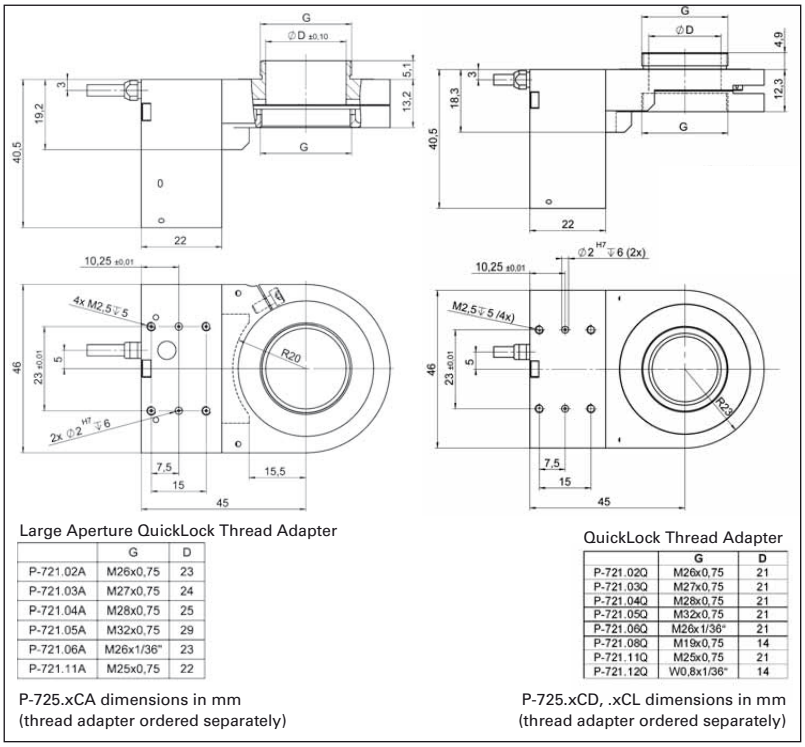
Fastest step and settle: The P-725.2CL can perform a 250 µm step to 1 % accuracy in only 25 ms (no load; 50 ms with a load of 150 g. With E-665.CR controller)

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

P-725.xCA dimensions in mm
(thread adapter ordered separately)

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.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

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

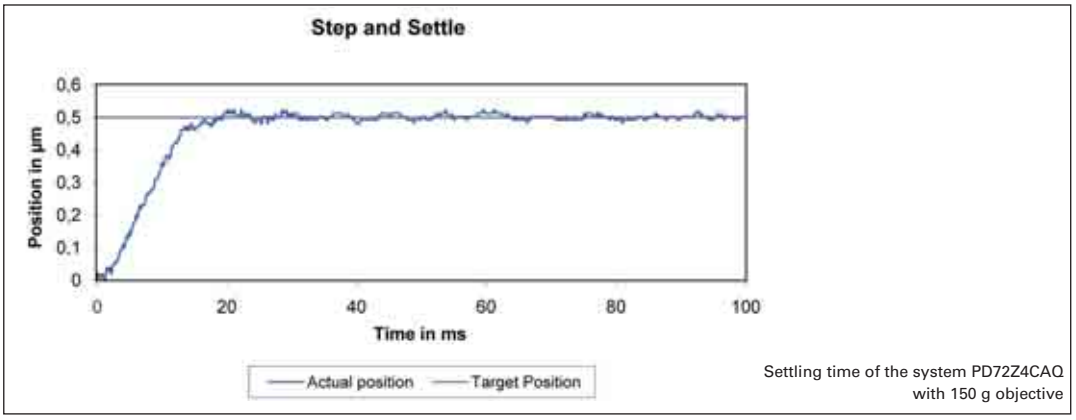
PD72Z2CAQ
Fast PIFOC® Piezo Nanofocusing Z-Drive, 250 µm, Capacitive Sensor, M25 QuickLock Thread Adapters, Digital Controller with USB, RS-232

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

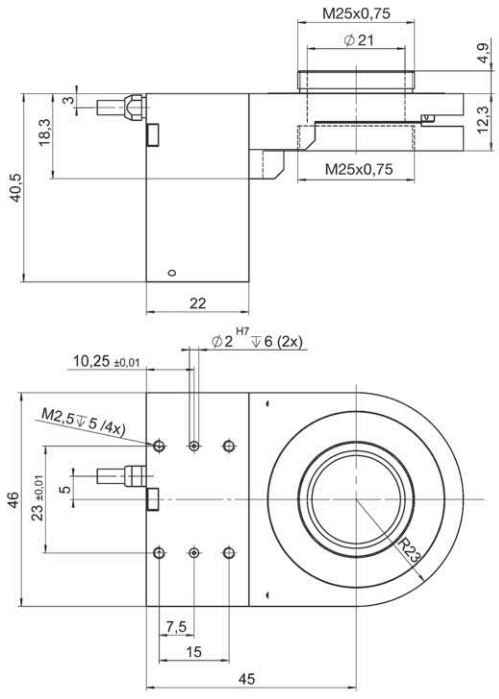
found sets of parameters when the controller is in operation. Since jumpers and potentiometers no longer have to be set manually, system integration becomes much more straightforward.

Easy System Setup, Comprehensive Software

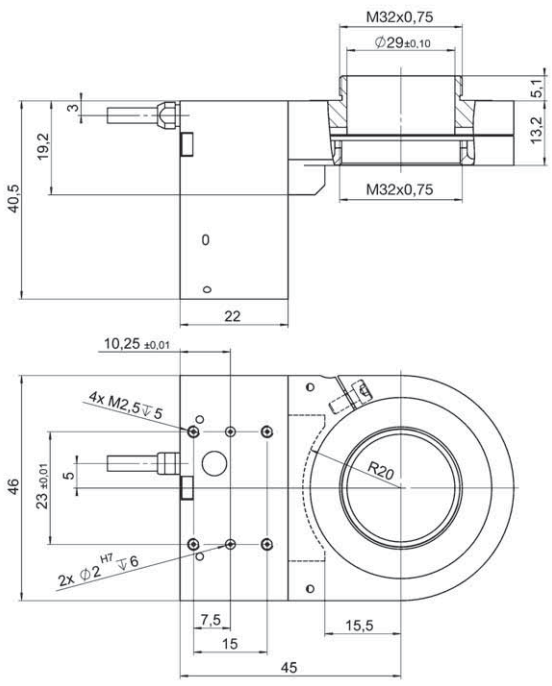
All parameters can be set and checked by software. System setup and configuration is done with the included user-interface software. Interfacing to custom software is facilitated with included LabVIEW drivers and DLLs. Drivers for MetaMorph and µManager are available.

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

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.

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.

Application Exampels

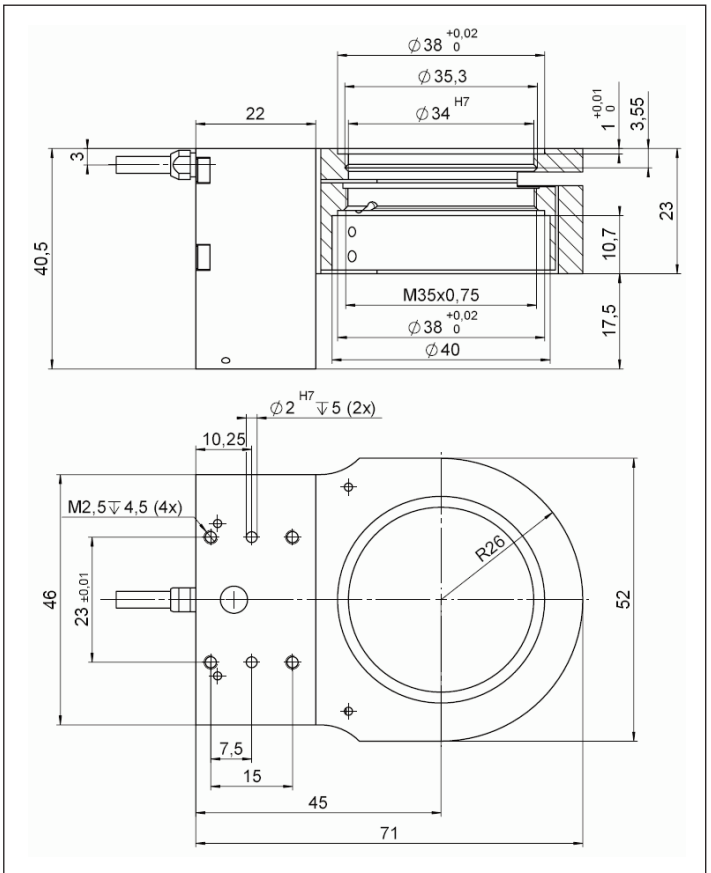
- 3D-Imaging
- Screening
- Interferometry
- Metrology
- Disc-drive-testing
- Autofocus systems
- Confocal microscopy
- Biotechnology
- Semiconductor testing

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

NEXACT® Long-Range Focusing System for Microscopy

NEXACT® technology enables 1 mm travel and maximum dynamics

Special PIFOC® design with PiezoWalk Linear Motor drive: 5 nm resolution over 1 mm µm travel

The new PIFOC® drives with NEXACT® piezo stepping motors are unique objective nanopositioners. They combine travel ranges of one millimeter or more with 5-nanometer resolution and high dynamics. For fast step-and-settle, the drives have a resonant frequency of 560 Hz carrying an objective weighing 200 g.

P-721K PIFOC® Nosepiece / Turret Nanopositioners

For High-Resolution Microscopy. High-Load Capacity, Capacitive Feedback

- 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

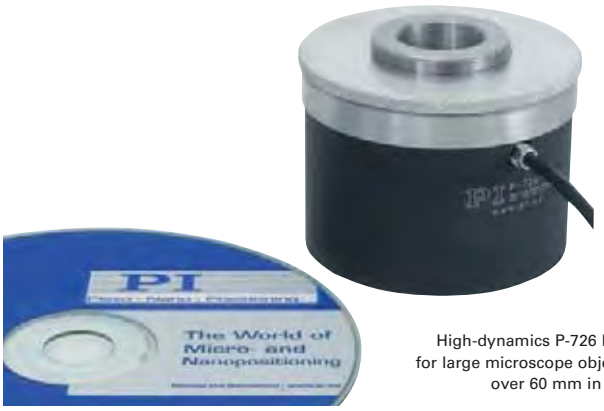
P-720 PIFOC® Piezo Scanner for Small Objectives

Compact High-Dynamics Scanner

- 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

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"

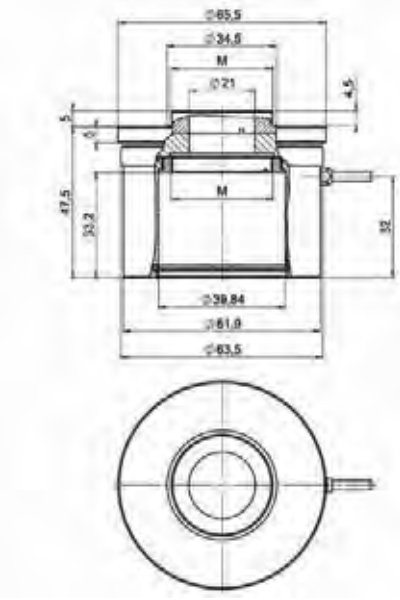
P-726.11
P-726 PIFOC® Thread Adapter M25 x 0.75

P-726.12
P-726 PIFOC® Thread Adapter W0.8 x 1/36"

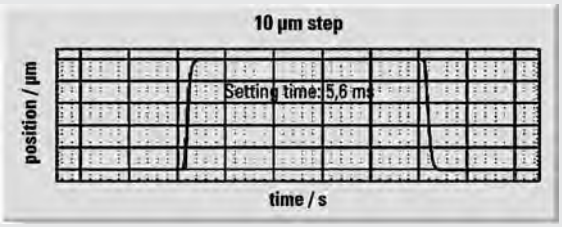
Ask about custom designs!

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

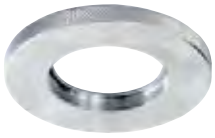


P-726 settling time under load

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	

Microscope Turret


Knurled Ring


Turret Ring


PIFOC®


Objective Ring


Objective

P-726 QuickLock thread adapter exploded view with P-726 PIFOC® (mounting tools included)

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

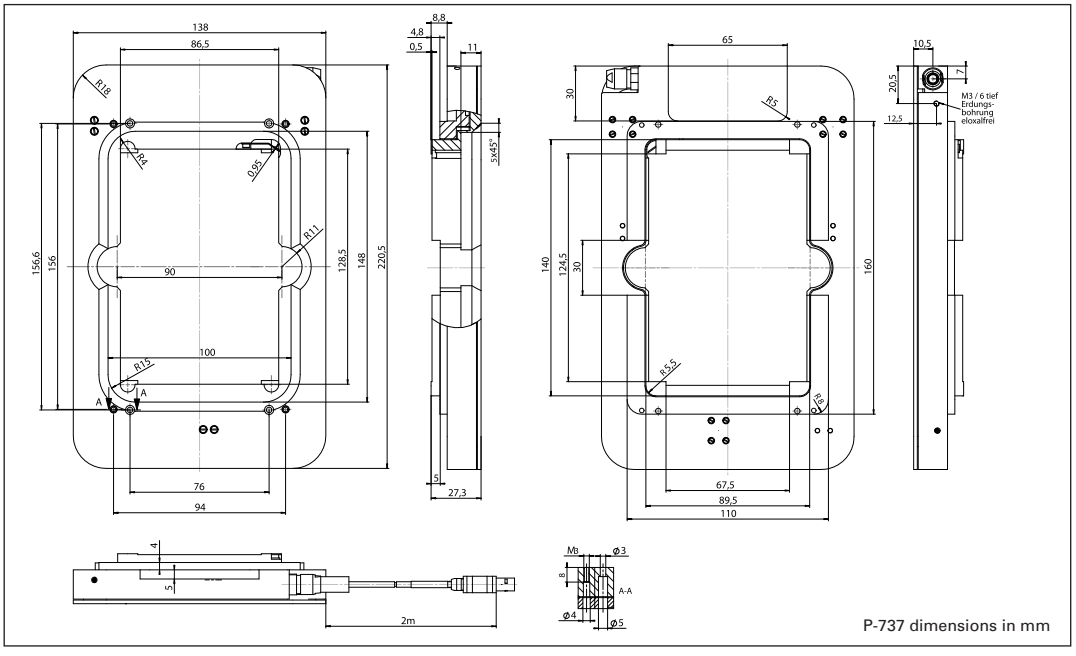
P-737.1SL
PIFOC® Nanofocusing Z-Stage for Microscope Sample Holder, 100 µm, SGS, LEMO Connector, for Märzhäuser Microscope Stages

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

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 ser vo controller, bench-top (p. 2-116)

M-545 Microscope Stage

Long-Range Motion for Sample Positioning

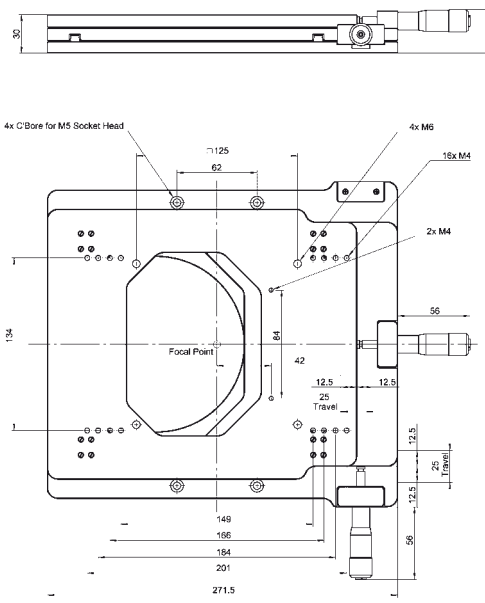
M-545 manual XY microscopy stage with 25 x 25 mm travel shown with optional PI nano™ piezo nanopositioner (200 µm motion in X, Y und Z) on top. The M-545 stage was designed to provide a stable basis for piezo stages, especially when the highest step-and-settle performance is required

- **Stable Platform for P-545 PI nano™ Piezo-Nanopositioniersysteme**
- **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**

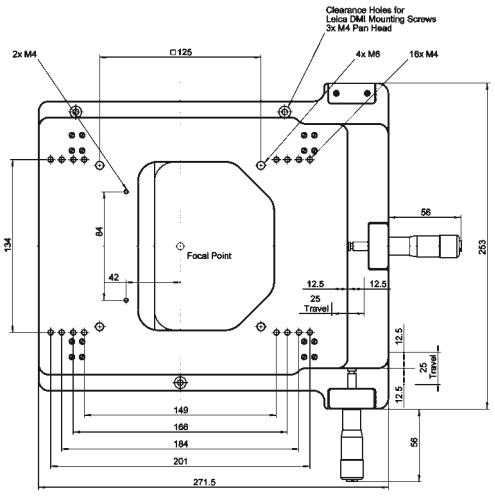
The M-545, 25 x 25 mm microscope stage, is designed to provide a stable platform for piezo scanning stages of the P-545 PI nano™ series. These high-speed, high-resolution XY / XYZ piezo stages allow nanometer-precision adjustment of the specimen holder in up to three dimensions over 200 µm. The M-545 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 hardware.



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
PI nano™ Manual XY Open-Frame Stage, 25 x 25 mm, for Olympus Microscopes

M-545.2MN
PI nano™ Manual XY Open-Frame Stage, 25 x 25 mm, for Nikon Microscopes

M-545.2ML
PI nano™ Manual XY Open-Frame Stage, 25 x 25 mm, for Leica Microscopes

M-545.2MZ
PI nano™ Manual XY Open-Frame Stage, 25 x 25 mm, for Zeiss Microscopes

Versions for other microscopes on request.

Accessories

M-545.USC
Upgrade Kit with Stepper-Mikes, Controller and Joystick for M-545 PI nano™ Manual XY Open-Frame Stage

M-545.USG
Upgrade Kit with Stepper-Mikes, for M-545 PI nano™ Manual XY Open-Frame Stage

M-545.SHP
Adapter Plate for Sample Holders for M-545 PI nano™ Manual XY Open-Frame Stage

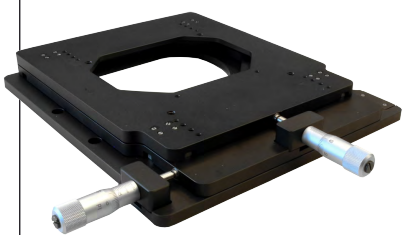
Accommodates the following PI nanopositioning stage series:
P-517/518/527/528, P-541/542, P-560 PIMars™ and P-545 PI nano™

Adapter available for P-733 nanopositioners:

P-733.AP1
Adapter Plate for Mounting of P-733 Stages on M-545 PI nano™ Manual XY Open-Frame Stage

Additional accessories on request.

Ask about custom designs!

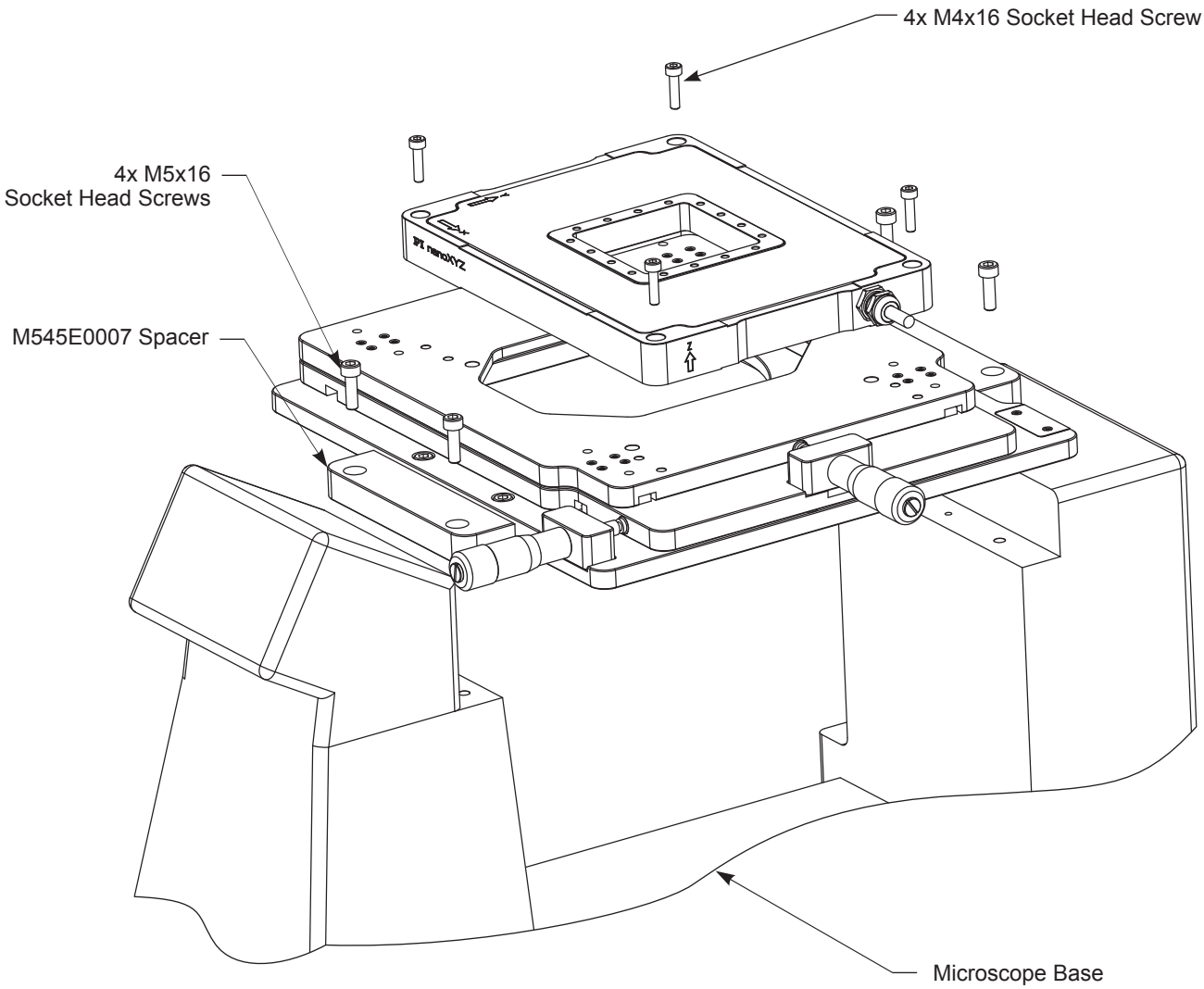


M-545 manual XY microscopy stage

M-545.2MN Mounting (for Nikon Microscopes)

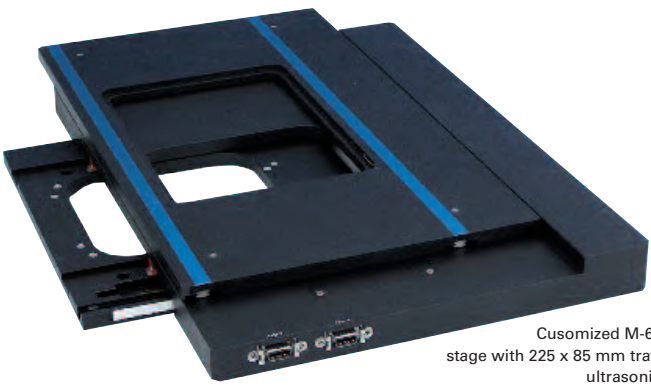
Spacer plates are used to adapt the M-545 stage to the Nikon microscope base.

The proper hardware sizes are shown below.



M-686K Custom Piezo Motor Microscope Stage

Low Profile and High Velocity with PILine® Ultrasonic Piezo Motors



Cusomized M-686 microscopy stage with 225 x 85 mm travel and PILine® ultrasonic piezo motors

- **Low 27-mm-profile**
- **Velocity 100 mm/s**
- **Large Clear Aperture to Accomodate Specimen Holders or P-737 PIFOC® Specimen-Focusing Z-Stage**
- **Travel Range 25 x 25 mm, 130 x 85 mm or 225 x 85 mm**
- **Up to 7 N Force Generation**
- **Direct Metrology Linear Encoder with 0.2 µm Resolution**
- **PILine® Ceramic Motors: Non-Magnetic and Vacuum-Compatible Working Principle**
- **Self Locking at Rest**

P-545 PI nano™ XY / XYZ Piezo Microscope Stages

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

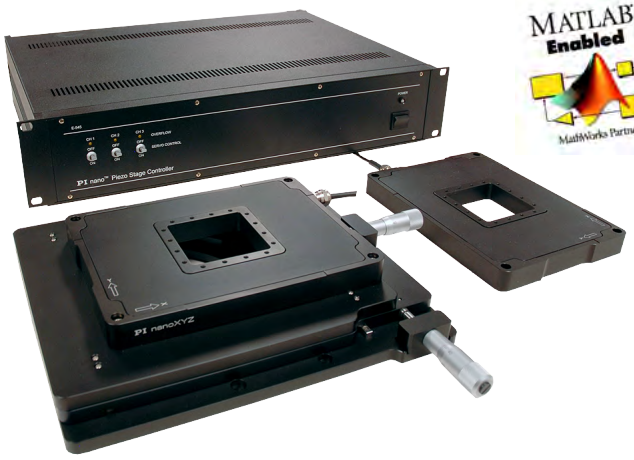
- Super-resolution microscopy
- 3D Imaging
- Laser technology
- Interferometry
- Metrology
- Biotechnology
- Screening
- Micromanipulation

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.



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

Ordering Information

P-545.2R7
PI nano™ XY Nanopositioning System, Aperture for 3 x 1" Microscope Slides, 200 x 200 µm, Piezoresistive Sensors, with USB Controller

P-545.3R7
PI nano™ XYZ Nanopositioning System, Aperture for 3x1" Microscope Slides, 200 x 200 x 200 µm, Piezoresistive Sensors, with USB Controller

Accessories

M-545.2MO
PI nano™ Manual XY Open-Frame Stage, 25 x 25 mm, for Olympus Microscopes

M-545.2MN
PI nano™ Manual XY Open-Frame Stage, 25 x 25 mm, for Nikon Microscopes

M-545.2ML
PI nano™ Manual XY Open-Frame Stage, 25 x 25 mm, for Leica Microscopes

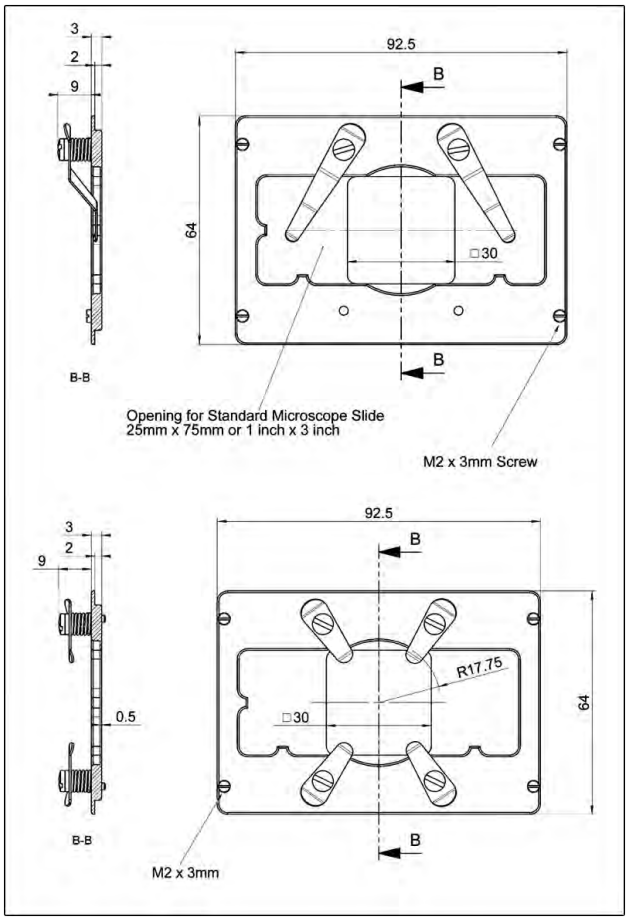
M-545.2MZ
PI nano™ Manual XY Open-Frame Stage, 25 x 25 mm, for Zeiss Microscopes

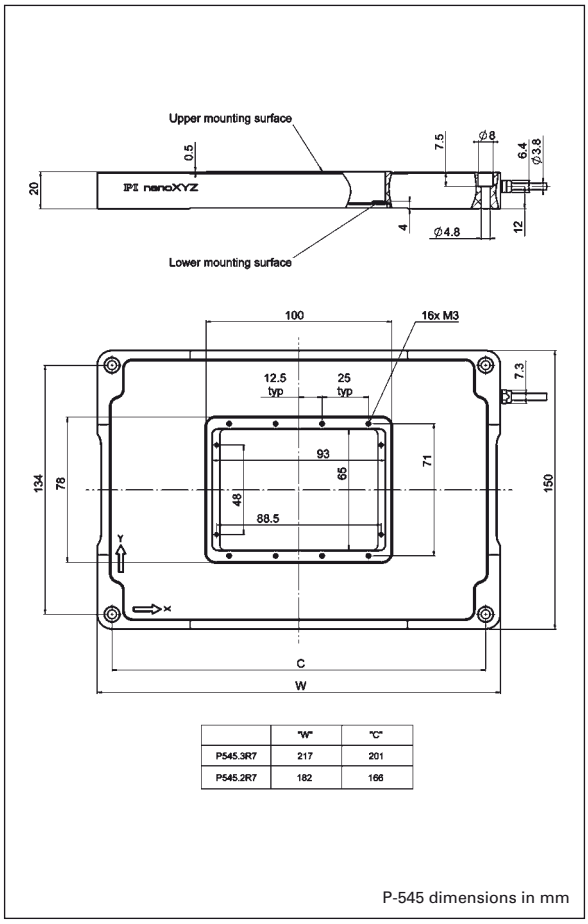
P-545.PD3
35mm Petri Dish Holder for P-545 PI nano™ XY Nanopositioning Systems

P-545.SH3
25 x 75mm Slide Holder for P-545 PI nano™ XY Nanopositioning Systeme

P-545.PP3
Plain Plate for Accessories for P-545 PI nano™ XY Nanopositioning Systems

High Speed Version for Particle Tracking Available





	"W"	"C"
P545.3R7	217	201
P545.2R7	182	166

P-545 dimensions in mm

Accessories: Slide holder (above) and Petri dish holder (below), 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.

PInano™ Z, High-Speed Piezo-Z Slide Scanner

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

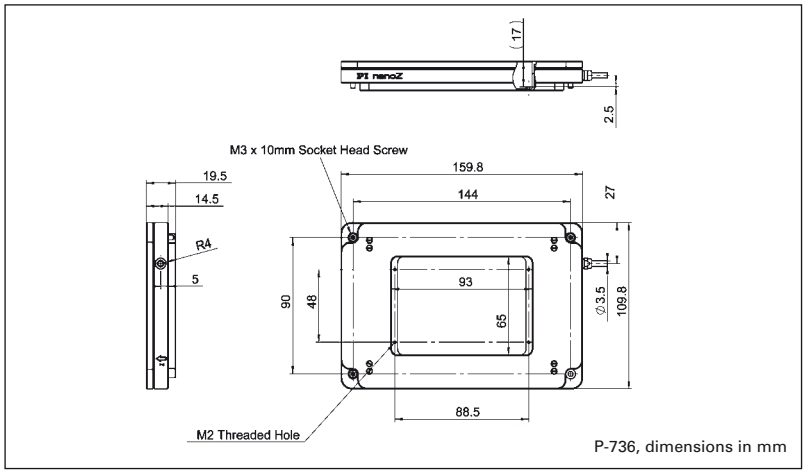
P-545.PD3
35mm Petri Dish Holder for P-545 PInano™ Piezo Stages

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

Selection Guide: Z & Z/Tip/Tilt Piezo Stages

Highly Responsive, Flexure Guided Piezo Nanopositioning Systems

P-721, P-720 Compact nanofocusing systems

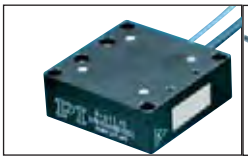
P-725 PIFOC® long travel nanofocusing system

P-725.xDD PIFOC® high-dynamics piezo scanner

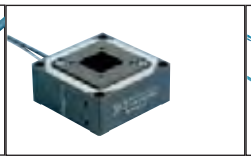
P-726 Fast nanofocusing system for heavy objectives

P-721K PIFOC® nosepiece positioners

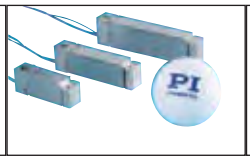
P-737 microscopy Z-stage for sample positioning



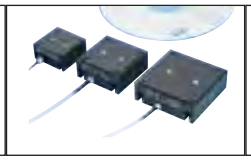
P-611.Z Compact, low-cost, nanopositioning stage



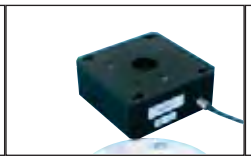
P-612.Z compact nanopositioner w/ aperture



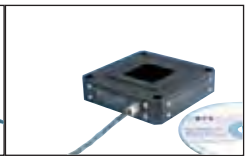
P-601 Flexure guided OEM Z-actuator / stage, 100 to 400 µm



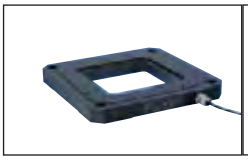
P-620.Z, P-622.Z Compact, long-travel stages, to 400 µm



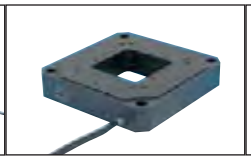
P-732 High-Dynamics scanning stage w/aperture



P-733.Z 100 µm Z-stage with aperture



P-541.Z Low- profile Z-/tip/tilt stage



P-518, P-528, P-558 Z/tip/tilt stages

N-515KNPH Non-magnetic NEXLINE Hexapod

Notes on Specifications see p. 2-78 *ff*

*Dynamics: Combination of system settling time / bandwidth / load capacity relative to the typical application of the product

**Precision: Combination of guiding precision, sensor precision, resolution, relative to comparable products in class

Models	Description	Travel [µm / mrad]	Sensor	Dynamics*	Precision**	Page
P-720	PIFOC® objective nanofocusing system, very compact, for small objectives, open loop	100	–	●●○○○	●●○○○	2-25
P-721	PIFOC® objective nanofocusing system, very fast and accurate, with QuickLock mounting system, direct metrology	100	Capacitive / SGS	●●●○○	●●●●○ / ●●○○○	2-26
P-725	PIFOC® objective nanofocusing system, compact, light-weight, long travel ranges, QuickLock mounting system, direct metrology	100, 250, 400	Capacitive	●●○○○	●●●○○	2-28
P-725.xDD	PIFOC® objective nanofocusing system, high-dynamics, direct-metrology	20	Capacitive /SGS	●●●●●	●●●●●	2-30
P-726	PIFOC® high-power nanofocusing system for large objectives	100	Capacitive	●●●●●	●●●●●	2-32
P-721KTPZ	PIFOC® nosepiece nanopositioning system, high stiffness, direct metrology	80	Capacitive	●●●○○	●●●●○	2-25
P-721KPTZ	High-load PIFOC® nosepiece nanopositioner, direct metrology	150	Capacitive	●●●●○	●●●●○	2-25
P-737	PIFOC® Z-axis microscopy piezo stage for high-resolution sample positioning and scanning	to 250	SGS	●●○○○	●●●○○	2-34
P-611.Z	Compact, low-cost Z nanopositioning piezo stage	100	SGS	●●○○○	●●○○○	2-36
P-612.Z	Compact nanopositioning Z-stage, clear aperture	100	SGS	●●○○○	●●○○○	2-38
P-601	Closed-loop, with flexure guidance	110, 300, 400	SGS	●●●●○	●●○○○	1-68
P-620.Z – P-622.Z	PIHera® Z-axis nanopositioners, compact, very accurate, long travel range	50, 100, 250	Capacitive	●●●○○	●●●○○	2-40
P-732	High-dynamics vertical nanopositioning/scanning stage	15	Capacitive	●●●●○	●●●○○	2-48
P-733.Z	Z scanning piezo stage 50 x 50 mm aperture, vacuum versions available	100	Capacitive	●●●○○	●●●○○	2-42
P-541.Z	Low-profile Z-stage, 80 x 80 mm aperture	100 / 1 mrad	Capacitive / SGS	●●○○○	●●●○○	2-44
P-518, P-528, P-558	Z-axis and tip/tilt piezo stage platforms 66 x 66 mm clear aperture	to 200 / 4 mrad	Capacitive	●●●○○	●●●●○	2-46
N-510	Tripod Z-tip/tilt nanopositioning platform with NEXLINE® piezo motors	1.3 mm / 10 mrad	Linear encoder	●●●○○		2-49
P-915KVPZ	Vacuum-compatible piezo Z stage	45	Capacitive	●●●●○	●●●●○	2-48
P-915KLPZ	Low-profile piezo objective scanner, open-loop	75	–	●●●●○	●●●○○	2-48
N-515KNPH	Nonmagnetic 6-axis piezo Hexapod precision positioning system with NEXLINE® piezo motor actuators	to 10 mm / 6°	Linear encoder	●●○○○	●●●○○	2-49
N-510KHFS	Tripod Z-Tip/Tilt nanopositioning platform with additional fine positioning	400 plus	Capacitive 40 µm	●●○○○	●●●●○	2-49

All models are precision flexure guided, and equipped with the patented PICMA® long-life piezo actuators. Capacitive position feedback sensors are available for the highest performance applications. Alternatively, strain gauge sensors are available as well as open loop models. Multi-axis systems are based on parallel-kinematics with one moving platform.

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*).

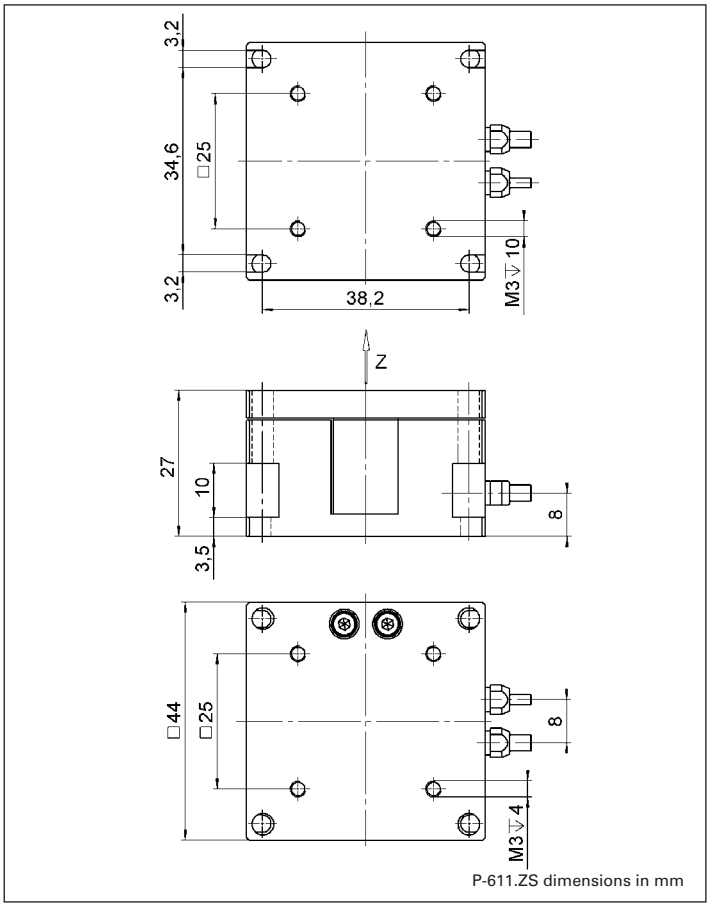
High Reliability and Long Lifetime

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.

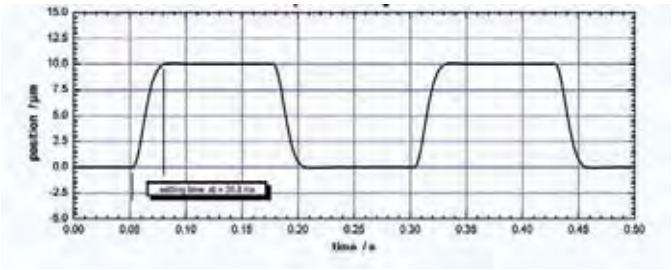
Ordering Information

P-611.Z0
Vertical Nanopositioning Stage,
120 µm, No Sensor

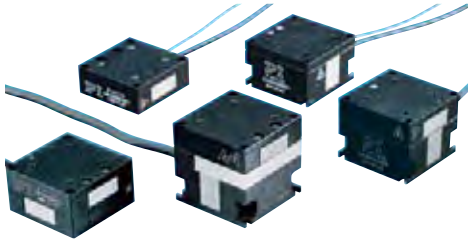
P-611.ZS
Vertical Nanopositioning Stage,
100 µm, SGS-Sensor



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

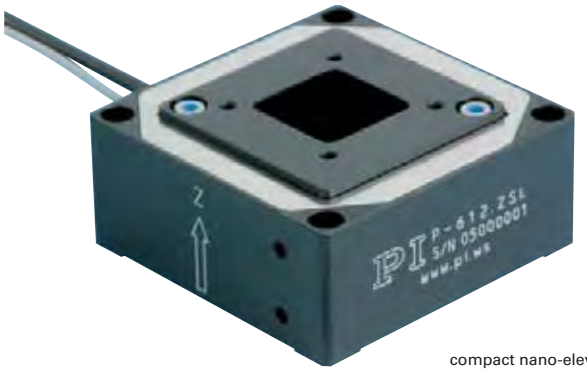
Model	P-611.ZS	P-611. Z0	Unit	Tolerance
Active axes	Z	Z		
Motion and positioning				
Integrated sensor	SGS	-		
Open-loop travel, -20 to +120 V	120	120	µm	min. (+20 %/0 %)
Closed-loop travel	100	-	µm	
Open-loop resolution	0.2	0.2	nm	typ.
Closed-loop resolution	2	-	nm	typ.
Linearity 0.1		-	%	typ.
Repeatability	<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 Nano positioners is not limited by friction or stiction. V alue 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.

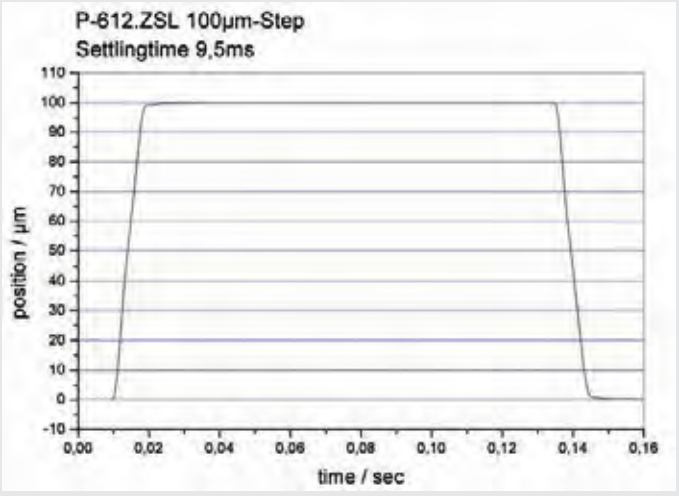
High Reliability and Long Lifetime

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.

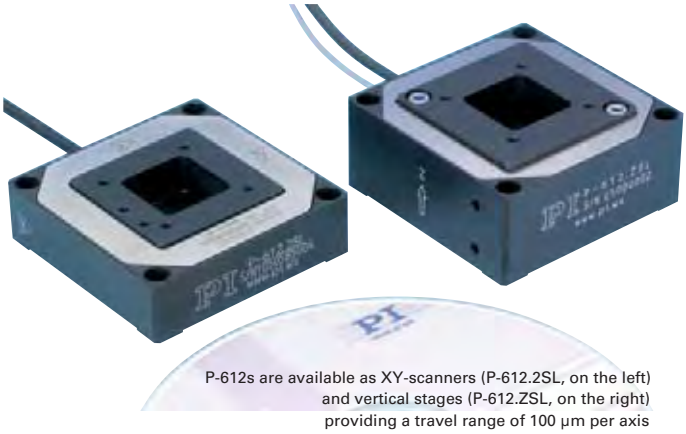
Ordering Information

P-612.ZSL
Vertical Nanopositioning Stage, 100 µm, 20 x 20 mm Aperture, SGS-Sensor

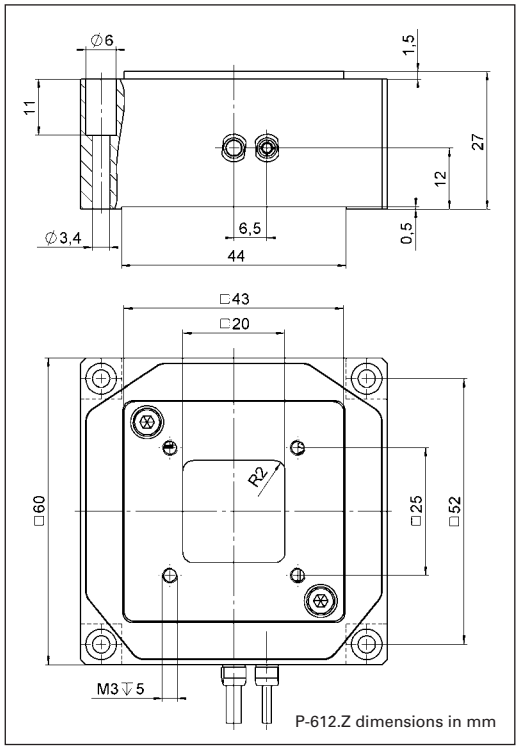
P-612.Z0L
Vertical Nanopositioning Stage, 100 µm, 20 x 20 mm Aperture, No Sensor



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 reso - lution. Despite the increased travel ranges, the units are extremely compact and pro - vide sub-nanometer reso - lution. The long travel range is achieved with a friction-free and extremely stiff flexure system, which also offers rapid response and excellent guiding accuracy.

PIHera® piezo nanopositioning stages are also available as X- and XY-stages (see p. 2-22 and p. 2-54).

Application Examples

- Interferometry
- Microscopy
- Nanopositioning
- Biotechnology
- Quality assurance testing
- Semiconductor technology

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

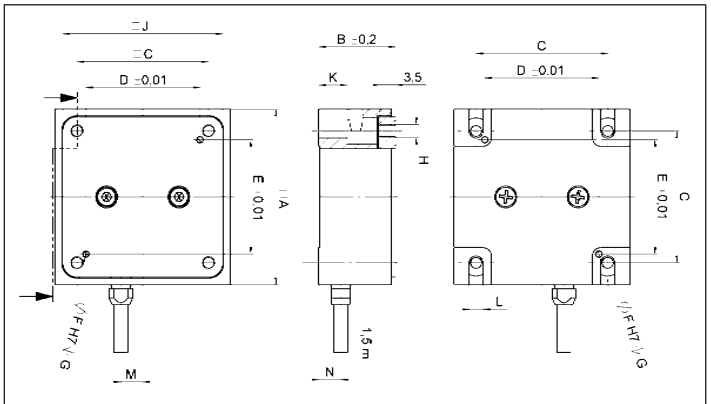
P-621.ZCD
PIHera® Precision Vertical Nanopositioning Stage, 100 µm, Capacitive Sensor, Sub-D Connector

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

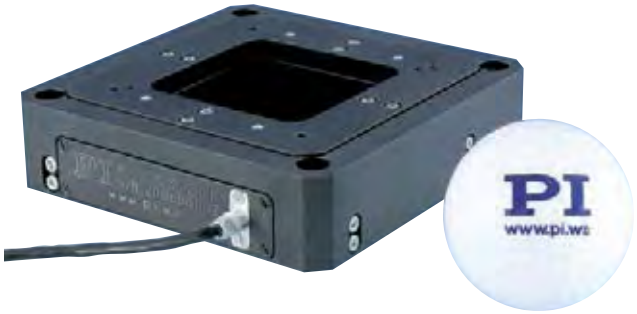
Technical Data

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	0 / 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)

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

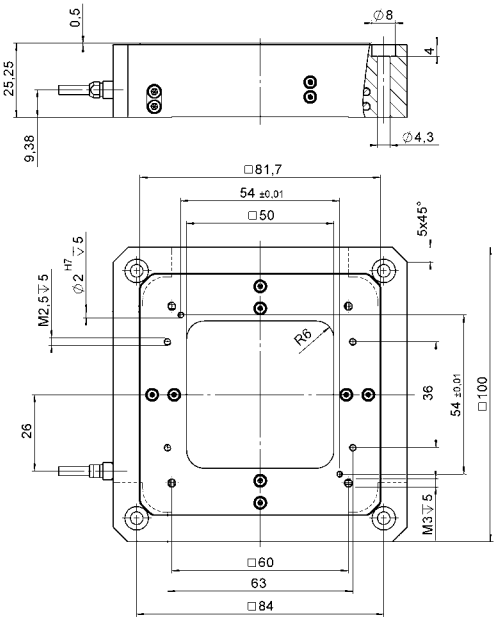
For scanning and positioning tasks in XY, the P-733.2CD and .3CD versions are available with a travel range of 100 x 100 µm. For high-dynamics applications, the P-733.2DD and P-733.3DD models can be offered with direct drive and reduced travel range (see p. 2-62).

For ultra-high-vacuum applications down to 10^{-9} hPa, nanopositioning systems as well as comprehensive accessories, such as suitable feedthroughs, are available.

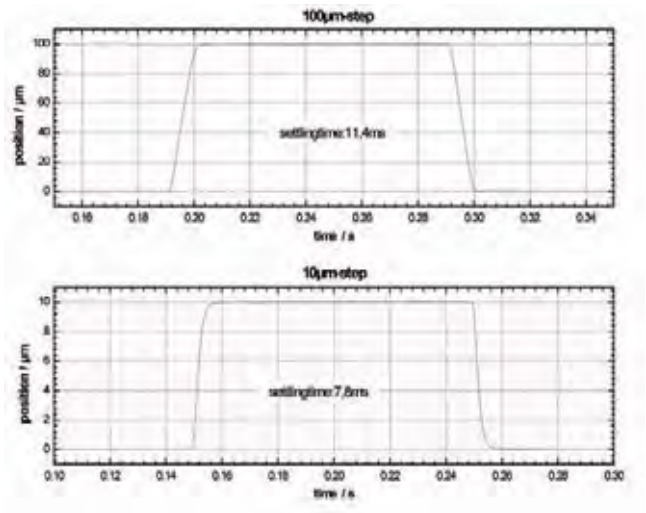
Ordering Information

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

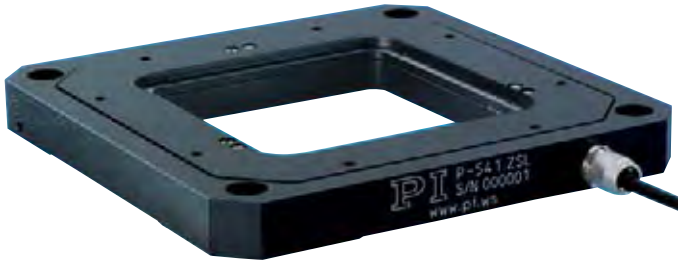
Technical Data

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. V ersions 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 perpendi - cular to, the direction of motion.

Due to the parallel-kinematics design there is only one common moving platform for all axes, minimizing mass, en - abling identical dynamic be - haviour 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

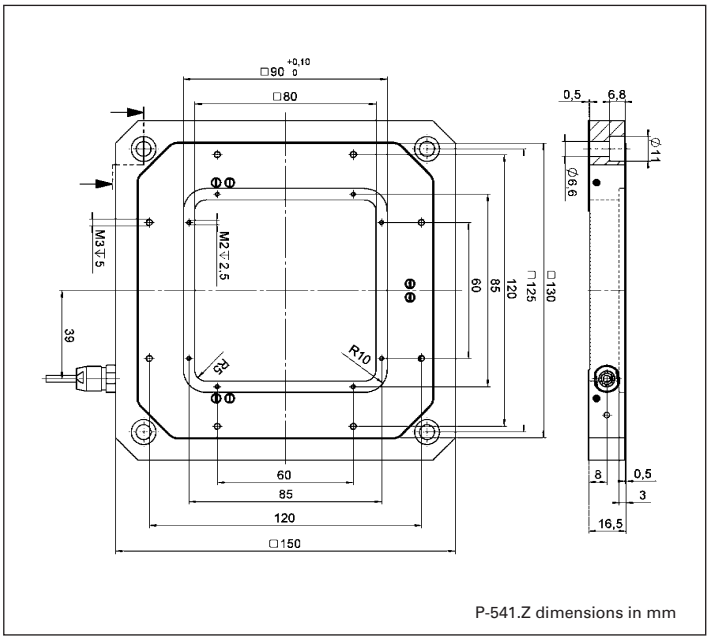
P-541.TCD
Vertical Tip / Tilt Nanopositioning Stage with Large Aperture, 100 µm / 1 mrad, Parallel Metrology, Capacitive Sensors

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

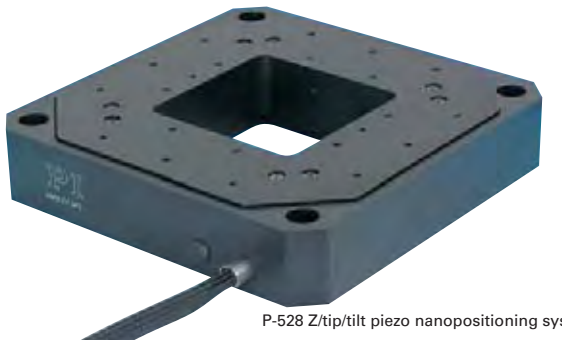
Technical Data

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	–	0.001	–	0.001	–	0.001	µrad	typ.
Closed-loop Z-resolution	0.5	0.5	2.5	2.5	–	–	nm	typ.
Closed-loop tip/tilt resolution	–	0.002	–	0.002	–	–	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. V alue given is noise equivalent motion with E-50 3 (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.

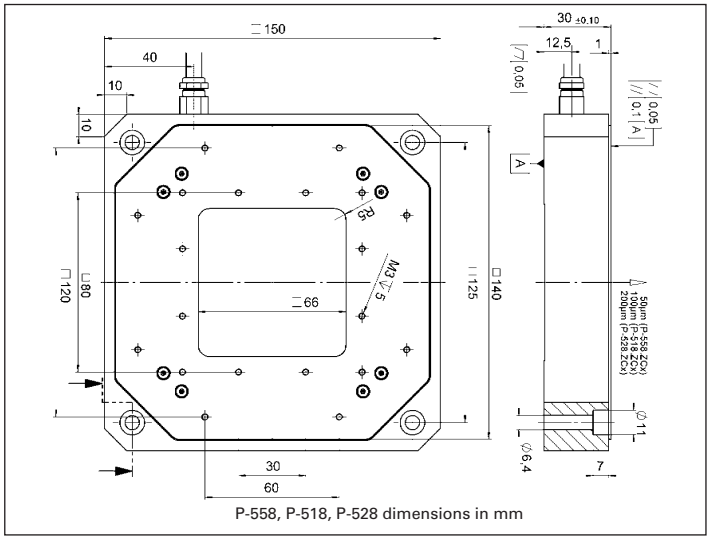
Excellent Guiding Accuracy

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.

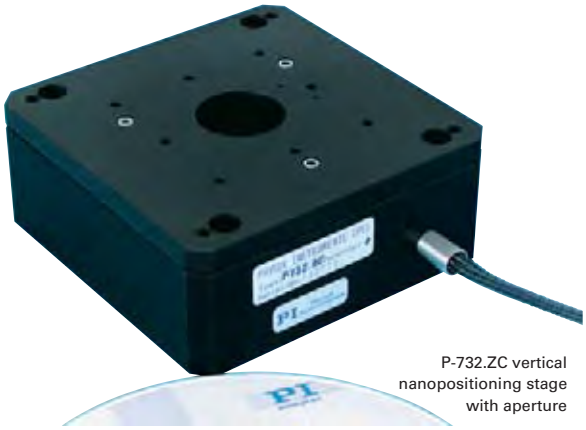
Technical Data

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	150x150x30	150x150x30	150x150x30	150x150x30	150x150x30	150x150x30	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 CL-version:	CD-version: Sub-D special 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. V alue given is noise equivalent motion with E-50 3 (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-732 Piezo Z-Stage with Aperture

High-Dynamics Nanopositioner / Scanner



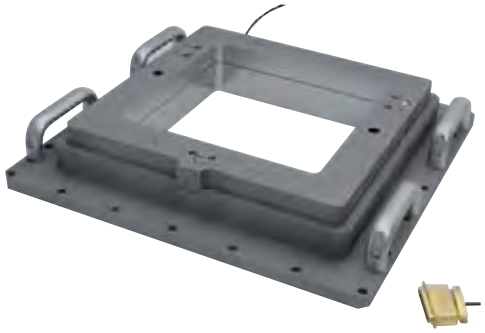
P-732.ZC vertical nanopositioning stage with aperture

- 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 Aper ture



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

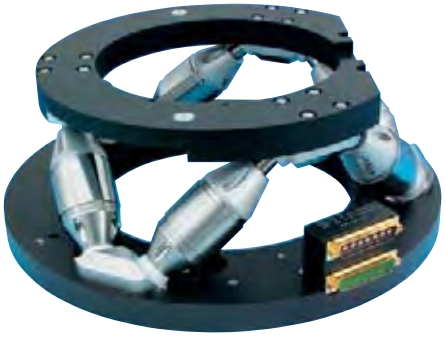
The P-915KLPZ objective scanner allows high scanning frequencies

- 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

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

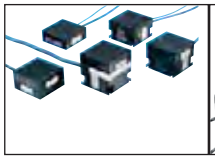
The N-510KHFS hybrid-drive nanopositioner offers maximum accuracy for semiconductor inspection applications

- **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**

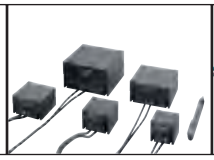
Model	Vertical V travel	elocity	Bidirectional repeatability	Load capacity	Dimensions
N-510KHFS Hybrid-Focus System	400 µm coarse 40 µm fine	1 mm/sec	50 nm (full travel)	25 N	Ø 300 mm 68.5 mm height

Selection Guide: Multi-Axis Piezo Stages

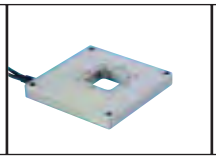
Nanometer Precision, Travel from 15 µm to 1,800 µm, Serial & Parallel Designs



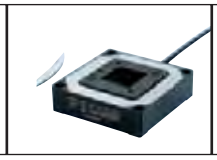
P-611 NanoCube® family. Compact, low-cost, 100 µm



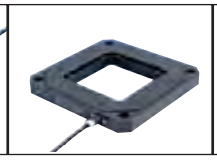
P-620.2 – P-629.2 XY stages. Compact, accurate, long travel



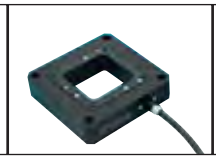
P-713, P-714 Compact XY-scanner, low cost, fast



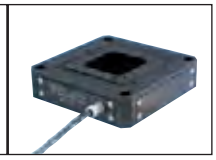
P-612 Compact, economical XY stage, 100 µm



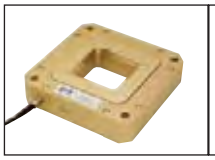
P-541.2 Low profile, 100 and to 200 µm in XY



P-733.2DD, /.3DD High speed, ultra-high resolution stages



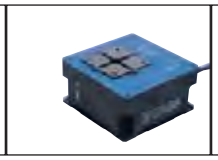
P-733 Scanning stage. Vacuum version available



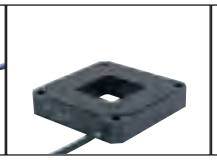
P-734 Ultra low bow scanning stage

P-363, P-313 PicoCube® for AFM, SPM

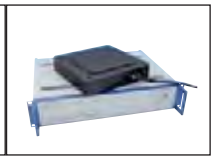
P-561, P-562, P-563 Multi-axis piezo stage compact



P-615 NanoCube® XYZ alignment system



P-517, P-527 Multi-axis piezo stage



P-587 6-axis nanopositioning stage

Single Axis Piezo Stages and Z/Tip/Tilt stages: See page 2-14 *ff* and 2-25 *ff*

Piezo Motor Driven Stages: See page 4-25 *ff*. Notes on Specifications see p. see p. 2-78 *ff*

Models	Description	Travel [µm]	Sensor	Dynamics*	Precision**	Page
P-611	Compact, low-cost X, Z, XY and XYZ nanopositioning stages	100 / Axis	SGS	●●○○○	●●○○○	2-50 *ff*
P-620.2– P-629.2	PIHera® XY piezo nanopositioners. Very compact & accurate (direct metrology), long travel range.	50, 100, 250, 500, 1000, 1800	Capacitive	●●●○○	●●●○○	2-54
P-713, P-714	Compact XY-scanner, low cost, fast.	15 x 15	–/SGS	●●●●●	●●○○○	2-56
P-612	Compact, low-cost, XY stage. 100 x 100 µm travel, clear aperture.	100 x 100	SGS	●●○○○	●●○○○	2-58
P-541.2	Low profile XY scanning piezo stage 80 x 80 mm aperture, parallel kinematics.	to 200 x 200	SGS/ Capacitive	●●○○○	●●●○○	2-60
P-733.2DD, P-733.3DD	High-speed scanning piezo stage, XY and XYZ versions, ideal for scanning microscopy, parallel kinematics	30 x 30 (x10)	Capacitive	●●●●●	●●●●●	2-62
P-733.2, P-733.3	XY(Z) piezo scanning piezo stage 50 x 50 mm aperture, vacuum versions available, parallel kinematics	100 x 100 (x10)	Capacitive	●●●○○	●●●●○	2-62
P-734	XY nano-scanning piezo stage, extremely flat and straight motion (1–2 nm); 56 x 56 mm clear aperture, parallel kinematics.	100 x 100	Capacitive	●●●○○	●●●●●	2-64
P-363	PicoCube® XY and XYZ high-precision system for AFM, SPM, nanomanipulation; 50 picometer resolution, parallel metrology	5 x 5 and 5 x 5 x 5	Capacitive	●●●●●	●●●●●	2-66
P-313	PicoCube® XYZ high-precision scanner for bio- / nanomanipulation	1 x 1 x 1	–	●●●○○	●●●○○	2-74
P-615	NanoCube® XYZ piezo alignment system, clear aperture, ideal for fiber alignment, parallel kinematics.	to 350 / Axis	Capacitive	●●●○○	●●●○○	2-68
P-517, P-527	Multi-axis piezo stage 66 x 66 mm clear aperture, parallel kinematics, custom 6-axis model available	to 200 in XY, 20 in Z, to 2 mrad	Capacitive	●●●○○	●●●●○	2-70
P-561 – P-563	PIMars™ XYZ piezo stage; 66 x 66 mm clear aperture, parallel kinematics, custom 6-axis model available	to 300 x 300 x 300	Capacitive	●●●○○	●●●●○	2-72
P-587	6-axis-nanopositioning stage, XYZ, $\theta_x \theta_y \theta_z$.	to 800 µm / 8 mrad	Capacitive	●●●○○	●●●●●	2-76
P-915KPPS	XY-Theta-Z piezo stage, high stiffness	250 x 250; ±8 mrad	SGS	●●●●○	●●●○○	2-74
P-628KHFS	Long-travel XY piezo stage, nanometer flatness	800 x 800	Capacitive	●●○○○	●●●●○	2-74
P-915KXYS	Fast XY OEM scanner, cost-effective	4 x 4	–	●●●●○	●●●○○	2-75
P-915KHDS	XY OEM slide, large aperture, direct drive	15 x 15	–	●●●●○	●●●○○	2-75
P-915KLVS	Vacuum compatible XYZ stage, w/ large aperture	100 x 100 x 100	Capacitive	●●●○○	●●●●○	2-75

*Dynamics: Combination of system settling time / bandwidth / load capacity relative to the typical application of the product.
**Precision: Combination of guiding precision, sensor precision, resolution, relative to comparable products in class.

All models are precision flexure guided, and equipped with the patented PICMA® long-life piezo actuators. Capacitive position feedback sensors are available for highest performance applications, alternatively, strain gauge sensors are available as well as open loop models. For the highest precision and dynamics requirements, parallel-kinematics / parallel metrology stages are recommended.

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).

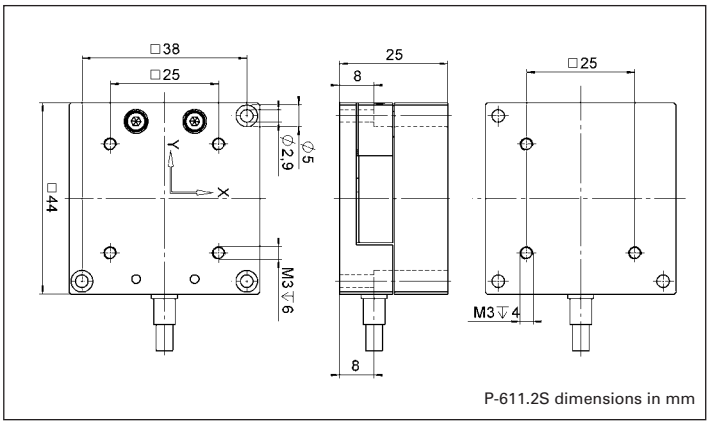
Ordering Information

P-611.2S
XY Nanopositioning System, 100 x 100 µm, SGS-Sensor

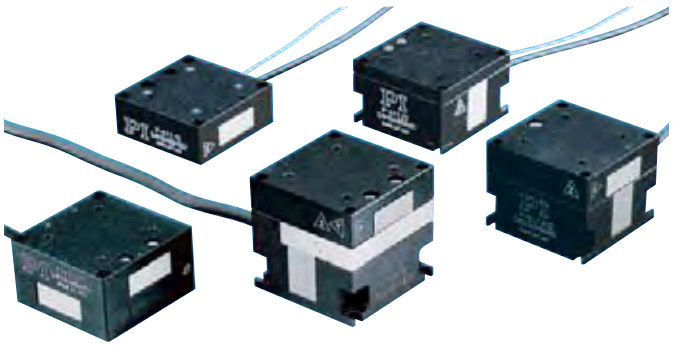
P-611.20
XY Nanopositioning System, 100 x 100 µm, No Sensor

P-611.XZS
XZ Nanopositioning System, 100 x 100 µm, SGS-Sensor

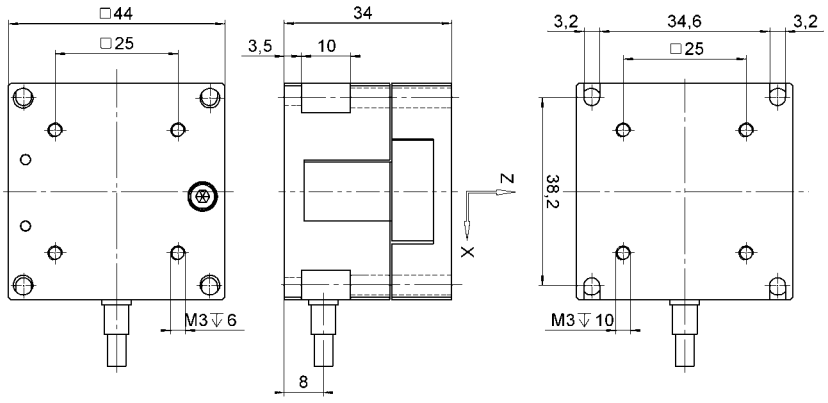
P-611.XZ0
XZ Nanopositioning System, 100 x 100 µm, No Sensor



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. V alue given is noise equivalent motion with E-50 3 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-62 1 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-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.

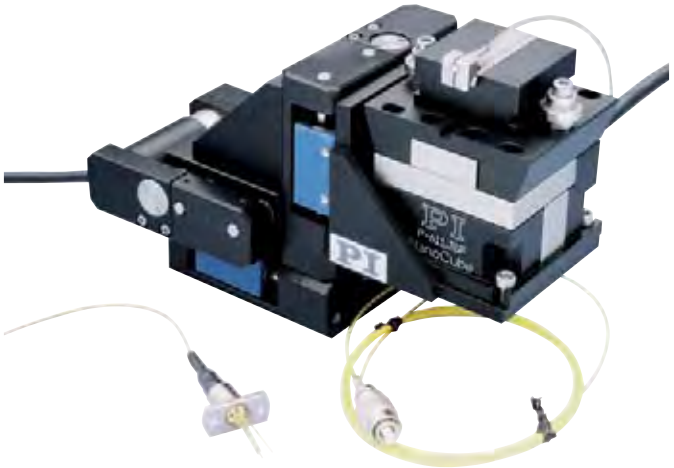
Ordering Information

P-611.3S
NanoCube® XYZ Nanopositioning System, 100 x 100 x 100 µm, Strain Gauge Sensors

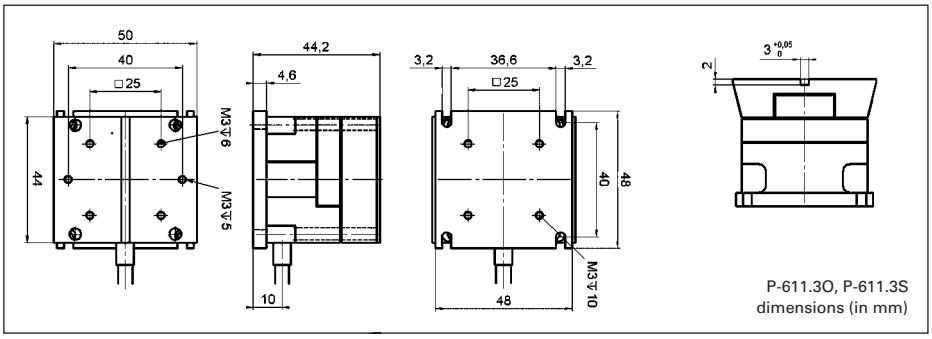
P-611.30
NanoCube® XYZ Nanopositioning System, 100 x 100 x 100 µm, Open-Loop

P-611.3SF
NanoCube® XYZ Nanopositioning System, 100 x 100 x 100 µm, Strain Gauge Sensors, Fiber Adapter Interface

P-611.30F
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



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. V alue given is noise equivalent motion with E-50 3 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.

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 PIHera® piezo nanopositioning series also includes Z and X stages (see p. 2-22 and p. 2-40).

Application Examples

- Interferometry
- Microscopy
- Nanopositioning
- Biotechnology
- Quality assurance testing
- Semiconductor technology

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

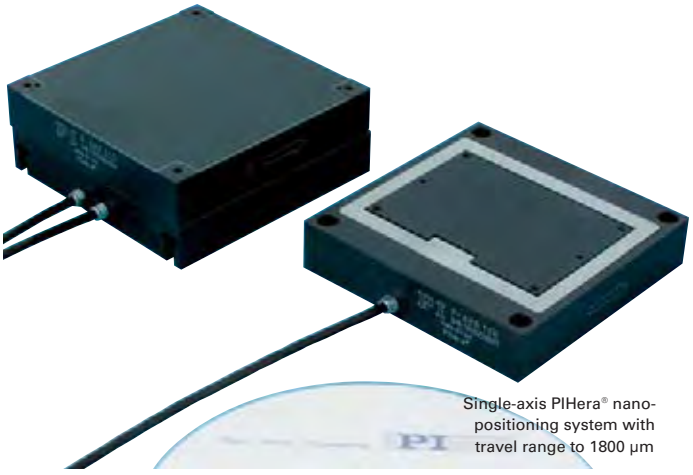
P-625.2CD* / P-625.2CL*
PIHera® Precision XY Nanopositioning System, 500 x 500 µm, Direct Metrology, Capacitive Sensors

P-628.2CD* / P-628.2CL*
PIHera® Precision XY Nanopositioning System, 800 x 800 µm, Direct Metrology, Capacitive Sensors

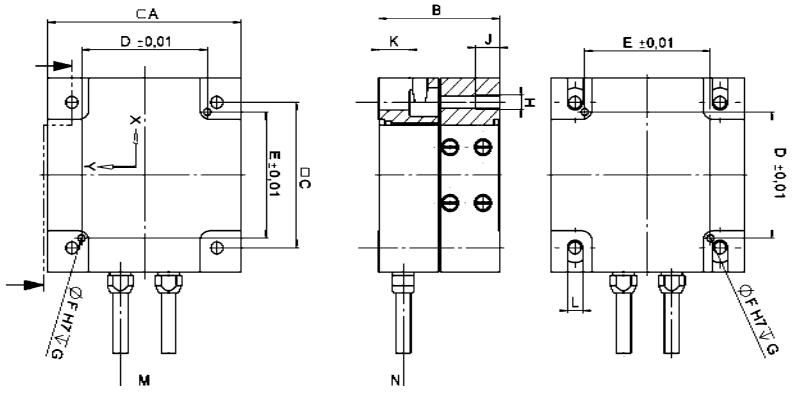
P-629.2CD* / P-629.2CL*
PIHera® Precision XY Nanopositioning System, 1500 x 1500 µm, Direct Metrology, Capacitive Sensors

*.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® nanopositioning 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

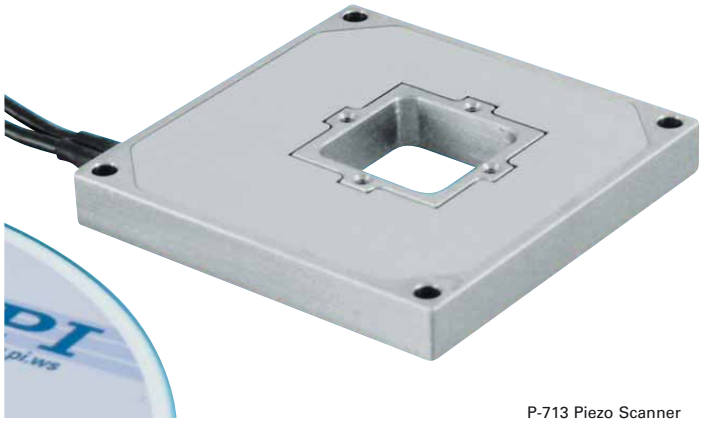
Technical Data

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 T	olerance
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 c ontroller, 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 XY Piezo Scanner

Cost-Effective OEM System with Low Profile



P-713 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 family piezo scanners and positioners with travel ranges of 15 x 15 µm feature especially compact designs. Ideal applications for the P-713 are high-dynamic 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

The basic version of the P-713 nanopositioner offers a guiding accuracy in the motion plane of 50 µrad. This value is generally sufficient for dithering and interlacing tasks in scanning patterns of a few microns. For more demanding applications, the P-714 offers higher accuracy of typically < 25 µrad.

Nanometer Position Servo-Control

If servo-control is required and no external position sensor is available, the P-713.2SL 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

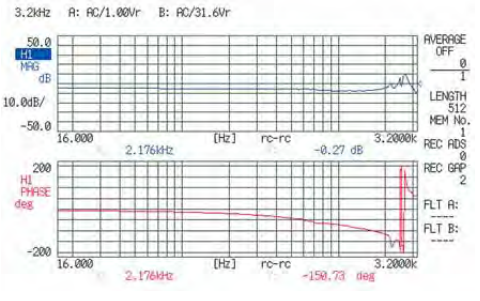
Highest possible reliability is assured by the use of award-winning PICMA® multilayer piezo actuators. PICMA® actuators are the only actuators on the market with ceramic-only insulation, which makes them resistant to ambient humidity and leakage-current failures. They are thus far superior to conventional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

See the “Selection Guide” for comparison with other nanopositioning systems (see p. 2-4 *ff*).

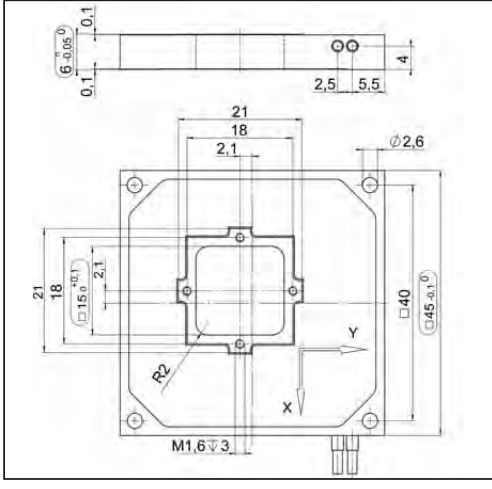
Ordering Information

P-713.20L
Low-Profile OEM XY Nanoscanner, 20 x 20 µm, No Sensor, LEMO Connector

P-713.2SL
Low-Profile OEM XY Nanoscanner, 15 x 15 µm, SGS-Sensor, LEMO Connector

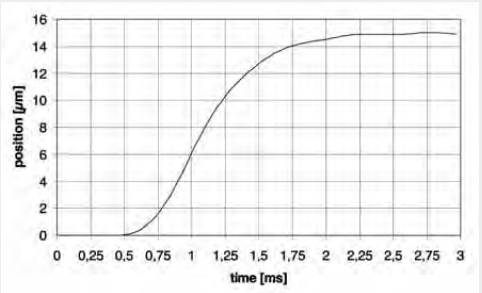


The resonant frequency of an unloaded P-713 scanner is over 2 kHz



P-713 dimensions in mm

System properties	
System controller	P-713.2SL 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 at 15 µm is in the 2 ms range

Technical Data

Model	P-713.20L	P-713.2SL	Units	Tolerance
Active axes	X, Y	X, Y		
Motion and positioning				
Integrated sensor	-	SGS		
Open-loop travel, -20 to +120 V	20	20	µm	min. (+20 %/0 %)
Closed-loop travel	-	15	µm	
Open-loop resolution	0.1	0.1	nm	typ.
Closed-loop resolution	-	1	nm	typ.
Linearity	-	0.3	%	typ.
Repeatability	-	<4	nm	typ.
Pitch	typ. ±1 max. ±5	typ. ±1 max. ±5	µrad	typ.
Yaw	typ. ±40 max. ±50	typ. ±40 max. ±50	µrad	µrad
Mechanical properties				
Stiffness	0.8	0.8	N/µm	±20 %
Unloaded resonant frequency	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)	Hz	±20 %
Push/pull force capacity in motion direction	5 / 5	5 / 5	N	Max.
Load capacity	2	2	N	Max.
Drive properties				
Ceramic type	PICMA® P-882	PICMA® P-882		
Electrical capacitance in X , Y	0.31	0.31	µF	±20 %
Dynamic operating current coefficient (DOCC) in X, Y	2.5	2.5	µA/(Hz • µm)	±20 %
Miscellaneous				
Operating temperature range	-20 to 80	-20 to 80	°C	
Material	Stainless steel, ferromagnetic	Stainless steel, ferromagnetic		
Dimensions	45 x 45 x 6	45 x 45 x 6		
Mass	0.1	0.1	kg	±5 %
Cable length	1.5	1.5	m	±10 mm
Sensor connection	-	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)

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.

Ceramic Insulated Piezo Actuators Provide Long Lifetime

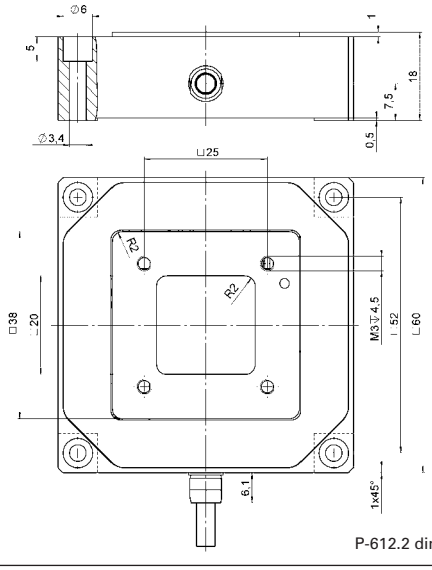
Highest possible reliability is assured by the use of award-winning PICMA® multilayer piezo actuators. PICMA® actuators are the only actuators on the market with ceramic-only insulation, which makes them resistant to ambient humidity and leakage-current failures. They are thus far superior to conventional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

Ordering Information

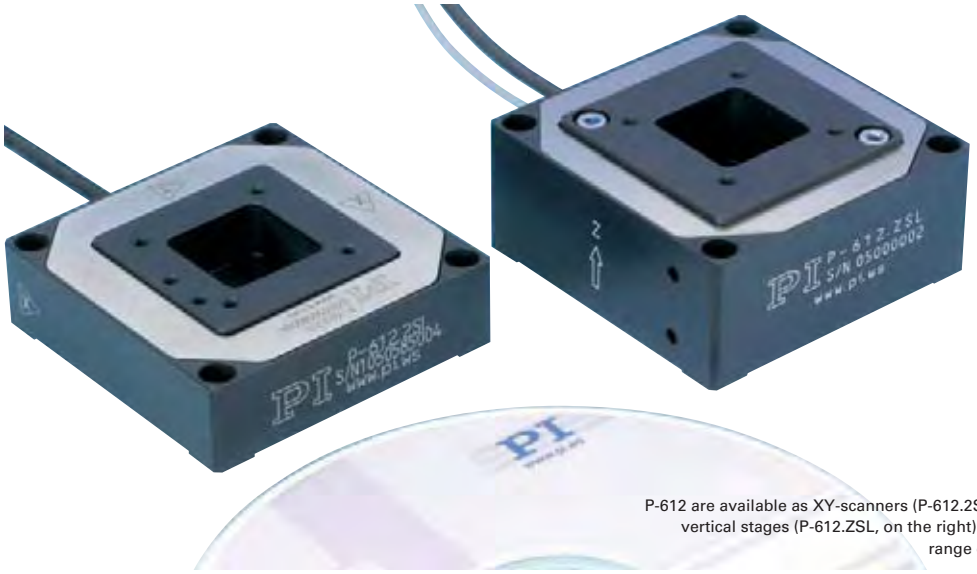
P-612.2SL
XY Nanopositioning System with 20 x 20 mm Aperture, 100 x 100 µm, Strain Gauge Sensors

P-612.20L
XY Nanopositioning System with Aperture 20 x 20 mm, 100 x 100 µm, Open-Loop

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.

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.

Application Examples

- Laser technology
- Scanning microscopy
- Mask / wafer positioning
- Interferometry
- Metrology
- Biotechnology
- Micromanipulation

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

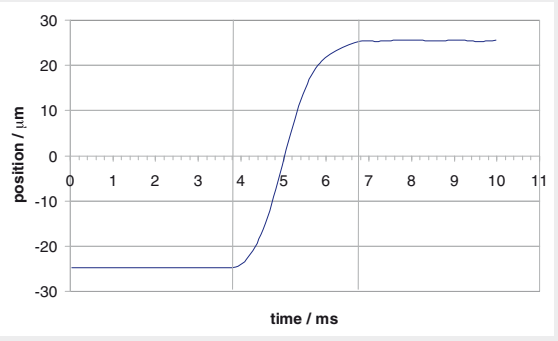
P-542.2CD / P-542.2CL
XY Nanopositioning System with Large Aperture, 200 x 200 µm, Parallel Kinematics, Capacitive Sensors

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

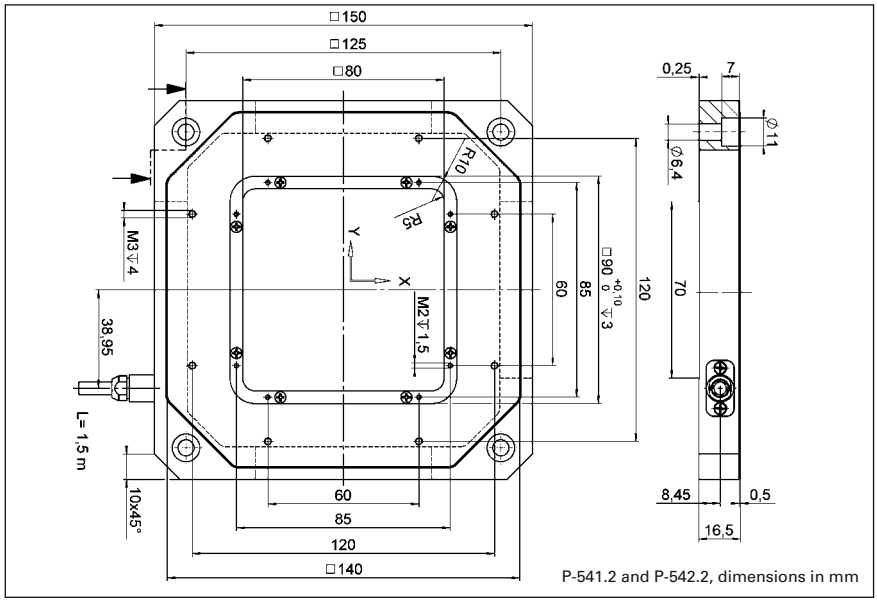
P-541.20L
XY Nanopositioning System with Large Aperture, 100 x 100 µm, Open Loop

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

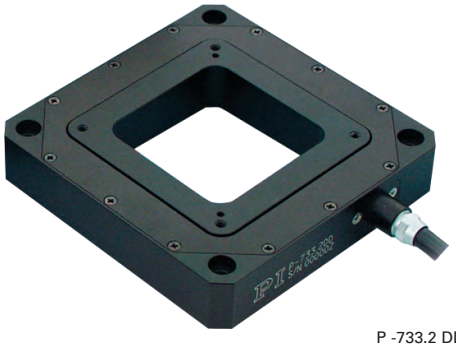
Technical Data

Model	P-541.2CD	P-542.2CD P-542.2CL	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	
Open-loop / closed-loop resolution	0.2 / 0.3	0.4 / 0.7	0.1 / 0.3	0.2 / 2.5	0.4 / 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 / LEMO	Sub-D Special	LEMO	LEMO	–	–		
Voltage connection	Sub-D Special	Sub-D Special / LEMO	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)

P-733.2 · P-733.3 XY(Z) Piezo-Nanopositioning Stage

High-Precision XY(Z) Scanner Family with Aperture



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

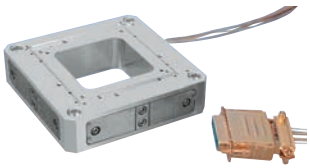
P-733.2VL* / P-733.2VD*
High-Precision XY Nanopositioning System, 100 x 100 µm, Capacitive Sensors, Parallel Metrology, Vacuum Compatible to 10-6 hPa

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

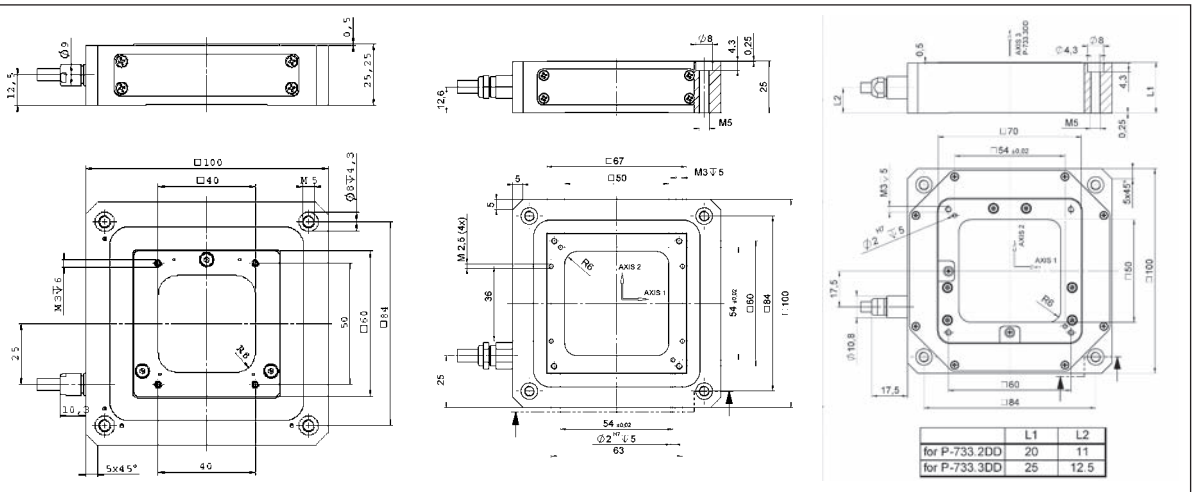
*.xxD with Sub-D Connector

*.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-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.

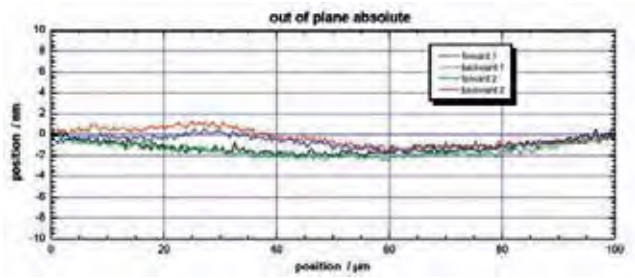
Parallel Kinematics and Metrology with Capacitive Sensors for High Trajectory Fidelity

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

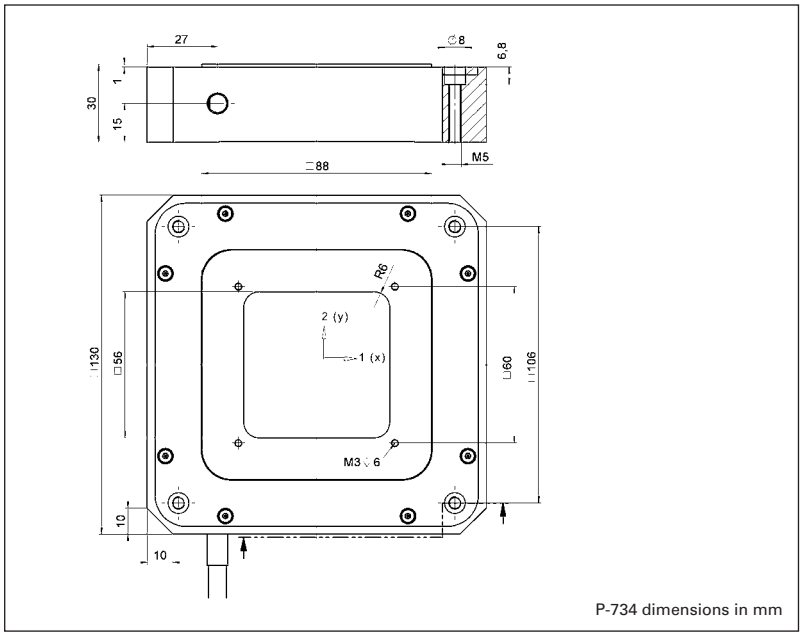
P-734.2CL
High-Precision XY Nanopositioning System with Minimum Runout, 100 x 100 µm, Capacitive Sensors, Parallel Metrology, LEMO Connector



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-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 nanosurface-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 act ively 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

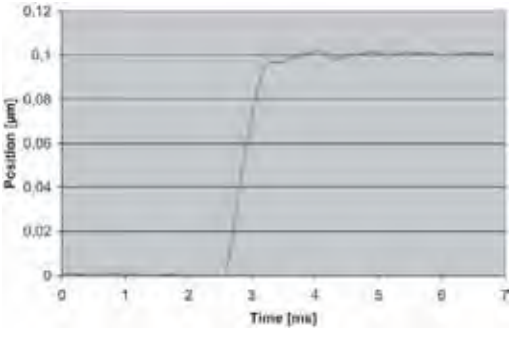
P-363.3UD
PicoCube™ High-Precision XYZ Nanopositioning System, 5 x 5 x 5 µm, Parallel Metrology, Capacitive Sensors, Sub-D Connector, Vacuum Compatible to 10^{-9} hPa

P-363.2CD
PicoCube™ High-Precision XY Nanopositioning System, 5 x 5 µm, Parallel Metrology, Capacitive Sensors, Sub-D Connector

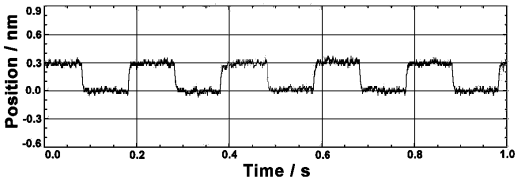
P-363.2UD
PicoCube™ High-Precision XY Nanopositioning System, 5 x 5 µm, Parallel Metrology, Capacitive Sensors, Sub-D Connector, Vacuum Compatible to 10^{-9} hPa

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 feed back allow step and settle to 1% accuracy in as little as one millisecond.

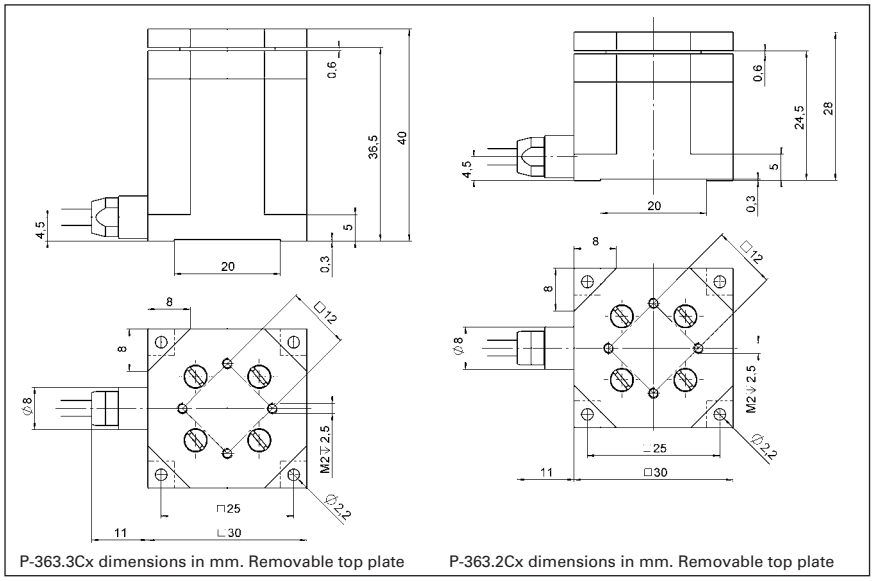
Rugged Design

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 opera - tion 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. V alue 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-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

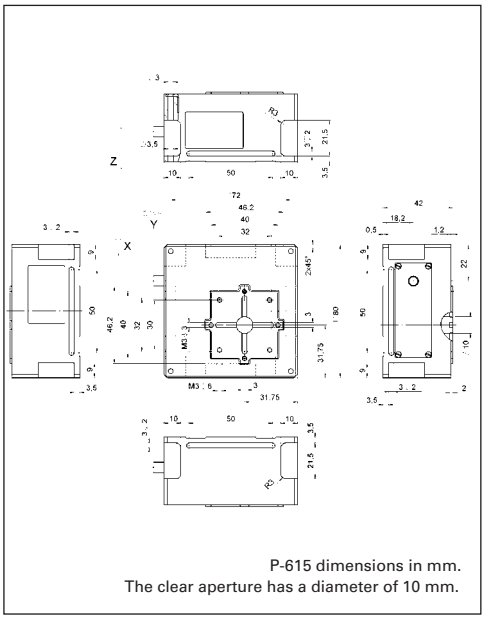
P-615.3CL
NanoCube® XYZ Nanopositioning System with Long Travel Range, 350 x 350 x 250 µm, Parallel Metrology, Capacitive Sensors, LEMO Connector

P-615.30L
NanoCube® XYZ Nanopositioning System with Long Travel Range, 420 x 420 x 300 µm, Parallel Metrology, Open-Loop, LEMO Connector

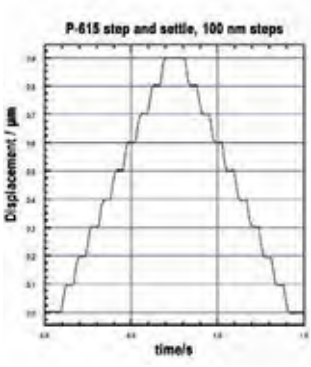
P-615.3UD
NanoCube® XYZ Nanopositioning System with Long Travel Range, 350 x 350 x 250 µm, Parallel Metrology, Capacitive Sensors, Sub-D Connector, Vacuum Compatible to 10^{-9} hPa

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.



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); (no LEMO (CL-version)	LEMO 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-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-527.3CL/ P-517.3CD 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 rotati
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-72 5 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 T rajectory 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 T rajectory 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

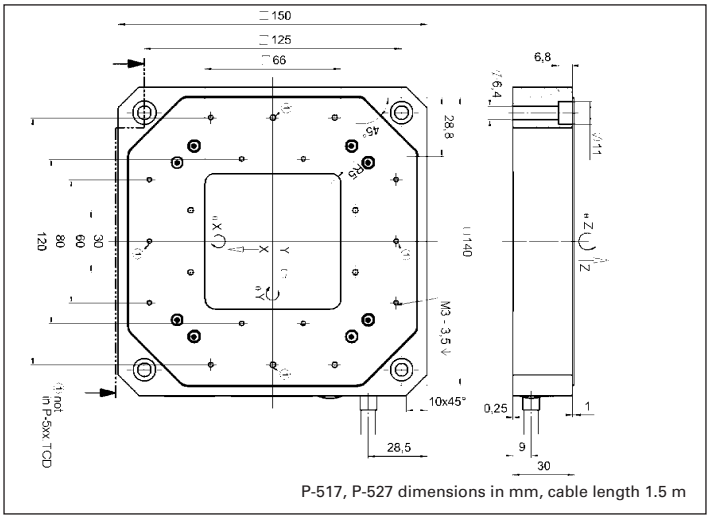
P-517.RCD
Precision XY / rotation nanopositioning system, 100 x 100 µm, 2 mrad, Capacitive Sensors, Parallel Metrology, Sub-D Connector

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

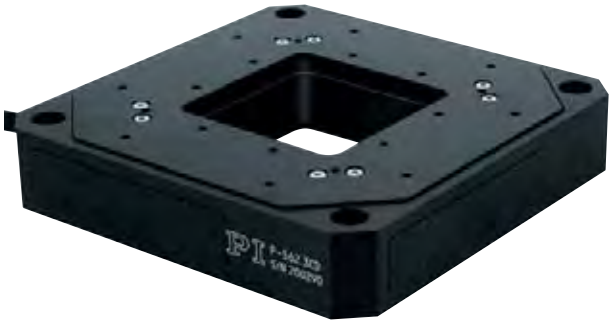
stem E-500 (p. 2-142) with amplifier module E-503



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.

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 tempera - tures and assure minimal outgassing rates. A non-magnetizable version is available on request.

Application Examples

- Scanning microscopy
- Mask/wafer positioning
- Interferometry
- Metrology
- Biotechnology
- Micromanipulation

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-Nanopositioning System, 100 x 100 x 100 µm, Parallel Metrology

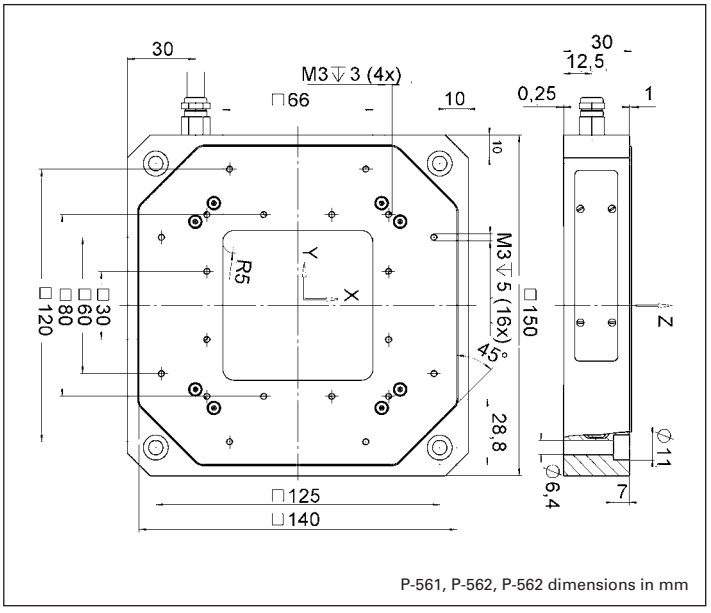
P-562.3CD
PIMars™ XYZ Piezo-Nanopositioning System, 200 x 200 x 200 µm, Parallel Metrology

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.

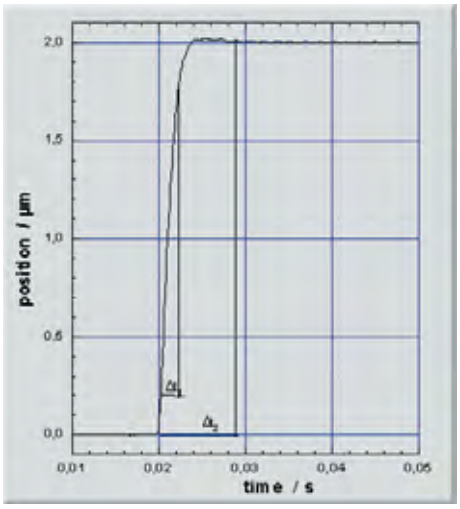


P-561, P-562, P-562 dimensions in mm

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 nano - meters, 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 @ 30 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. V alue given is noise equivalent motion with E-71 0 (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-915K XY-Theta-Z Piezo Stage

3 Degrees of Freedom in the XY Plane

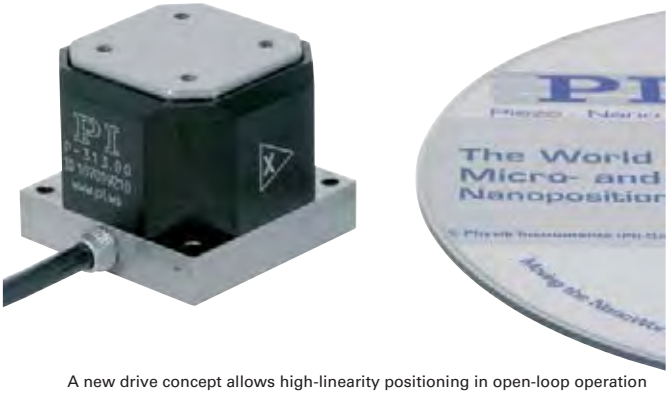
The P-915KPPS is equipped with FEA-modeled flexures for higher stiffness in all three directions of motion

- 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

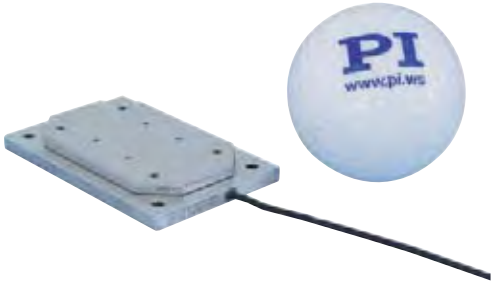
The P-628KHFS with an active Z-axis provides an improved straightness of travel with only 9.5 mm added height compared to an P-628.2 nanopositioning stage

- 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

P-915K Fast XY Piezo Scanner

Cost-Effective OEM Slide for Imaging



The fast P-915KXYS 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-915KXYS 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 Resolution		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

N-515K Non-Magnetic Piezo Hexapod

6-Axis Precision Positioning System with NEXLINE® Linear Drives

- 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

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

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.

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.

Application Examples

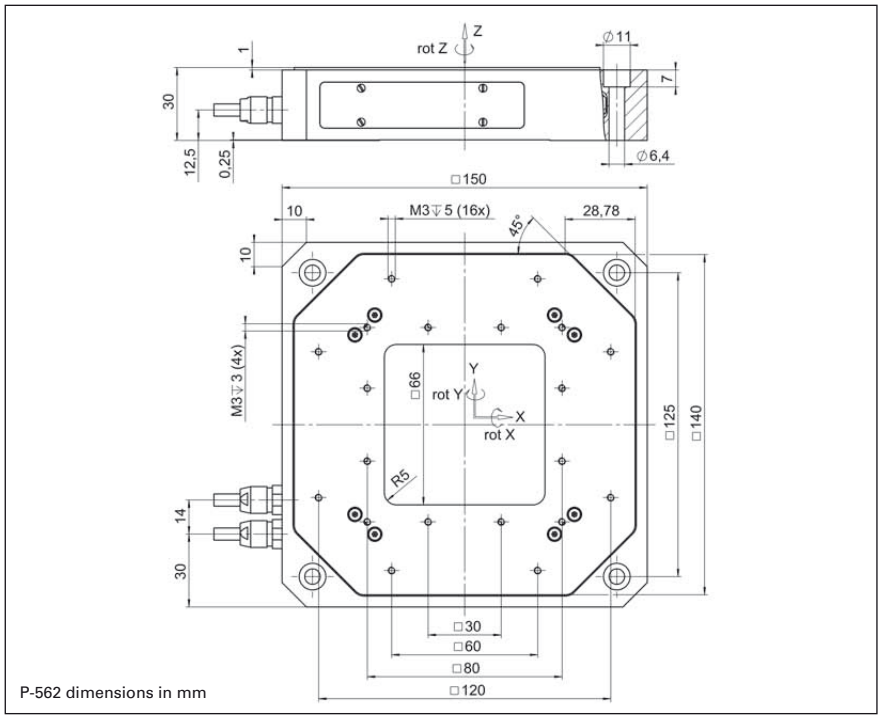
- Scanning microscopy (SPM)
- Mask/wafer positioning
- Interferometry
- Metrology
- Biotechnology
- Micromanipulation

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 (crosstalk) 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

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 extre - mely 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 appli cations.

Parallel Kinematics and Metrology with Capacitive Sensors for High Trajectory Fidelity

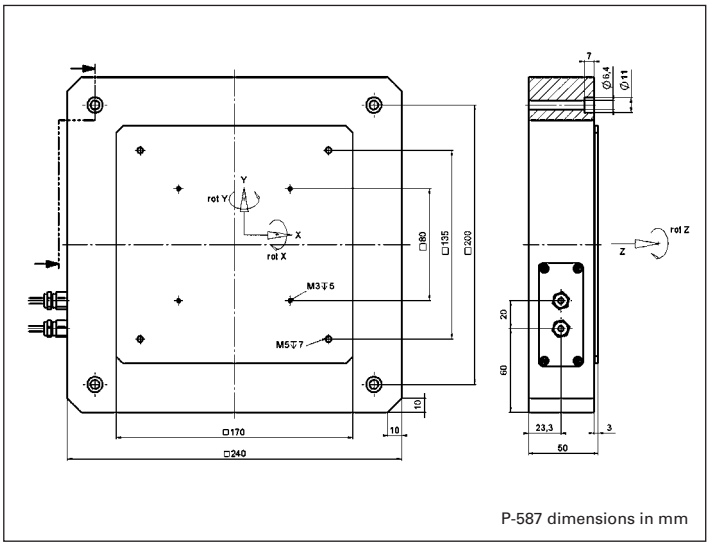
In a parallel kinematics multi-axis system, all actuators act directly on one moving platform. This means that all axes move the same minimized mass and can be designed with identical dynamic properties. Parallel kinematics systems have additional advantages over serially stacked systems, including more-compact 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 T rajectory 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	0.9 / 2.2 nm	typ.
Closed-loop / open-loop resolution Z	0.4 / 0.7 nm	typ.
Closed-loop / open-loop resolution θ_X, θ_Y	0.05 / 0.1 µrad	typ.
Closed-loop / open-loop resolution θ_Z	0.1 / 0.3 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.

Notes on Specifications for Piezo Stages, Systems and Actuators

Motion and positioning

Performance specifications are valid for room temperature (22 ±3 °C) and closed-loop systems are calibrated at this temperature (specifications for different operating temperatures on request). Recalibration is recommended for operation at a significantly higher or lower temperature. Custom designs for ultra-low or ultra-high temperatures on request.

Integrated feedback sensor

Absolute measuring capacitive and SGS sensors are used to provide position information to the controller. For details see the tutorial "Piezoelectrics in Positioning" section (see p. 2-188 *ff*).

Open-loop travel for PICMA® Ceramic Equipped Piezo Stages and Actuators

Typical open-loop travel at 0 to 100 V operating voltage. Max. recommended operating voltage range is -20 to +120 V (extremes for short durations only).

Open-loop travel for PICA™ Ceramic Equipped Piezo Actuators

Typical open-loop travel of high-voltage piezo actuators at 0 to +1000 V operating voltage. Voltages in excess of +750 V should not be applied for long durations. Operation in the range of -200 to +750 V is recommended for maximum lifetime and displacement.

Closed-loop travel for PICMA® Ceramic Equipped Piezo Stages and Actuators

Travel provided in closed-loop operation. PI piezo amplifiers have an output voltage range of -20 to +120 V or -30 to +135 V to provide enough margin for the servo-controller to compensate for load changes, etc.

Open-loop / closed-loop resolution

Resolution of piezo flexure stages is basically infinitesimal because it is not limited by stiction or friction. Instead of resolution, the noise-equivalent motion is specified. V alues are typical results (RMS, 1 σ), measured with E-503/E-508) amplifier module in E-500/501 chassis.

Full-range repeatability (typ.)

Typical values in closed-loop mode (RMS, 1 σ). Repeatability is a percentage of the total distance or angle traveled. For small ranges, repeatability is significantly better.

Pitch / Yaw / Roll / Rotational Runout

Typical rotational off-axis error; sometimes associated with a particular motion axis, as in "Rotational runout (Z motion)".

Straightness / Flatness / Crosstalk

Typical linear off-axis error; sometimes associated with a particular motion axis, as in "Crosstalk (Z motion)".

Mechanical properties

Stiffness

Static large-signal stiffness of the stage in operating direction at room temperature. Small-signal stiffness and dynamic stiffness may differ because of effects caused by the active nature of piezoelectric material, compound effects, etc. For details see the tutorial "Piezoelectrics in Positioning" section (see p. 2-171 *ff*).

Unloaded resonant frequency

Lowest resonant frequency in operating direction (does not specify the maximum operating frequency). For details see the tutorial "Piezoelectrics in Positioning" section (see p. 2-171 *ff*).

Resonant frequency with load

Resonant frequency of the loaded system.

Push/pull force capacity (in operating direction)

Specifies the maximum forces that can be applied to the system along the active axis. Limited by the piezoceramic material and the flexure design. If larger forces are applied, damage to the piezoceramic, the flexures or the sensor can occur. The force limit must also be considered in dynamic applications.

Example: the dynamic forces generated by sinusoidal operation at 500 Hz, 20 µm peak-to-peak, 1 kg moved mass, are approximately ±100 N. For details see the tutorial "Piezoelectrics in Positioning" section (see p. 2-171 *ff*).

Load capacity

Maximum vertical load, when the stage is mounted horizontally . Limited by the flexures or the load capacity of the piezo actuators.

Lateral force limit

Maximum lateral force orthogonal to the operating direction. Limited by the piezoceramics and the flexures. For XY stages the push/pull force capacity of the other module (in its operating direction) limits the lateral force that can be tolerated.

Torque limit (θ_X, θ_Y, θ_Z)

Maximum torque that can be applied to the system before damage occurs. Limited by the piezo ceramics and the flexures

Drive properties

Electrical capacitance

The piezo capacitance values indicated in the technical data tables are small-signal values (measured at 1 V , 1000 Hz, 20 °C, no load). Large-signal values at room temperature are 30 to 50 % higher . The capacitance of piezoceramics changes with amplitude, temperature, and load, up to 200 % of the unloaded, small-signal capacitance at room tempera - ture. For detailed information on power requirements, refer to the amplifier frequency-response graphs in the "Piezo Drivers / Servo Controllers" (see p. 2-99 *ff*) section of this catalog.

Dynamic Operating Current Coefficient (DOCC)

Average electrical current (supplied by the amplifier) required to drive a piezo actuator per unit frequency and unit displacement (sine-wave opera - tion). For example to find out if a selected amplifier can drive a given piezo stage at 50 Hz with 30 µm amplitude, multiply DOC coefficient by 50 x 30 and check if the result is smaller or equal to the output current of the selected amplifier . For details see the tutorial "Piezoelectrics in Positioning" section (see p. 2-169 *ff*).

Miscellaneous

Operating temperature range

Typically -20 to +80 °C, the temperature range indicates where the piezo stage may be operated without damage. Nevertheless, recalibration or zero-point-adjustment may be required if the system is operat ed at different temperatures. Performance specifications are valid for room temperature range.

Material

Flexure stages are usually made of anodized aluminum or stainless steel. Small amounts of other materials may be used internally (for spring preload, piezo coupling, mounting, thermal compensation, etc.).

Al: Aluminum
N-S: Non-magnetic stainless steel
S: Ferromagnetic stainless steel
I: Invar
T: Titanium

Voltage connection

Standard operating voltage connectors are LEMO and sub-D type connectors.

Low-voltage piezos :
LEMO FF A.00.250, male.
Cable: coaxial, RG 178, T eflon coated, 1 m

Sub-D special connectors include lines for stage ID infor - mation used by digital controllers with AutoCalibration function

Sensor connection

Standard sensor connectors are LEMO and sub-D type connectors.
Sub-D special connectors contain both piezo voltage and sensor connections.

For extension cables and adapters, see "Accessories" p. 2-89 *ff*, in the "Piezo Drivers / Servo Controllers" section.

Fast Steering Mirrors / Active Optics

Selection Guide: Piezo Steering Mirrors

Fast Steering Mirrors (FSM), Tip/Tilt Platform & Active Optics

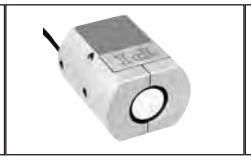
Piezo-driven tip/tilt platforms and scanners (steering mirrors, beam deflectors, phase shifters) provide higher accelerations and bandwidth than other actuators such as voice-coils or galvos. All are flexure-guided for zero friction and stiction and excellent guiding accuracy. Multiaxis models are parallel-kinematic designs with coplanar axes. Open- and closed-loop models with strain gauge and capacitive sensors (highest precision) are available.

PI FSM's provide resolution down to nanoradians and excellent position stability. They can perform optical beam steering over ranges of up to 120 mrad, and have extremely low response times (milliseconds to microseconds). They are ideal for dynamic operation (e. g. tracking, scanning, drift and vibration cancellation) as well as static positioning of optics and samples.

Models	Description	Axes	Tilt Angle / opt Deflection [mrad]	Linear Travel [µm]	Sensor	Page
S-310, S-316	Clear aperture, 5 models, open- and closed-loop, Z-actuators and Z/tip/tilt versions, for optics to 1" diameter	1 & 3	0.6 / 1.2 or 1.2 / 2.4	6 / 12	SGS	2-94
S-325	3-axis (tripod) Z/tip/tilt platform for optics to 1" diameter	3	5 / 10	30	SGS	2-92
S-334	Ultra-compact 2-axis FSM with largest optical deflection to 120 mrad. With 10 mm mirror	2	60 / 120		SGS	2-90
S-330	High-dynamics tip/tilt FSM with two orthogonal axes, for optics to 2" diameter. 3 models	2	2 / 4, 5 / 10, 10/ 20	–	SGS	2-88
S-224, S-226	With mirror, compact, very fast, available with sensor or without	1	to 2.2 / 4.4	–	SGS	2-96
S-303	Phase Shifters. Extremely precise, 25 kHz resonant frequency, optional sensors	1	–	3	Capacitive	2-96
S-323	Z/tip/tilt platform, high dynamics	2	3 / 6	30	Capacitive	2-96
P-541.Z	Low-profile Z & Z/tip/tilt platform, 80 x 80 mm aperture	3	1	100	Capacitive / SGS	2-44
P-528	Z-axis and tip/tilt piezo stage platforms 66 x 66 mm clear aperture	3	4	200	Capacitive	2-46
N-510	Tripod Z-tip/tilt Nanopositioning Platform	3	10 / 20	1300	Linear encoder	1-17

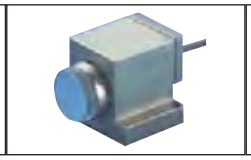
S-310, S-316 Z/tip/tilt platforms with aperture

S-325 Z/Tip/tilt platform

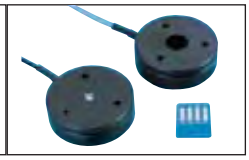


S-334 2-Axis FSM, very large optical deflection

S-330 Tip/tilt steering mirror platforms, high dynamics, 1" diameter

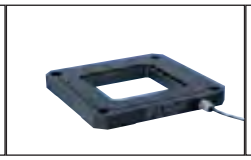


S-224, S-226 With mirror, compact, fast

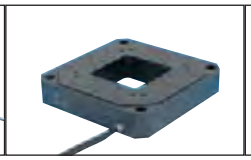


S-303 Phase shifters, 3 µm, picometer resolution

S-323: Z/tip/tilt platform with capacitive sensors



P-541.Z Low-profile large aperture Z/tip/tilt piezo stage



P-528 Large aperture Z/tip/tilt piezo stage

N-510 Tripod Z/tip/tilt nanopositioning platform

Astronomy: High bandwidth 8" secondary steering mirror and long range 6-axis alignment system

More tip/tilt piezo stages see p. 2-25 *ff*

Notes on specifications see p. 2-97 *ff*

Piezo Tip/Tilt Mirrors Fundamentals

Single Axis Designs

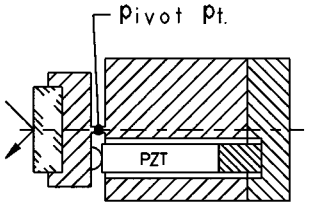


Fig. 1. Single-flexure, single-piezo actuator tilt platform design

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.

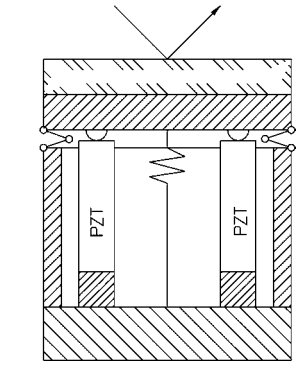


Fig. 2. Design of a differential-piezo-drive tilt platform

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.

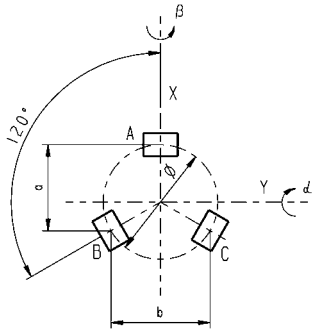


Fig. 3. Piezo tripod drive: A, B, C are the linear displacements of the respective actuators

$\alpha = \frac{2A - (B+C)}{2a}$
$\beta = (B-C) / b$
$z = (A+B+C) / 3$

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]

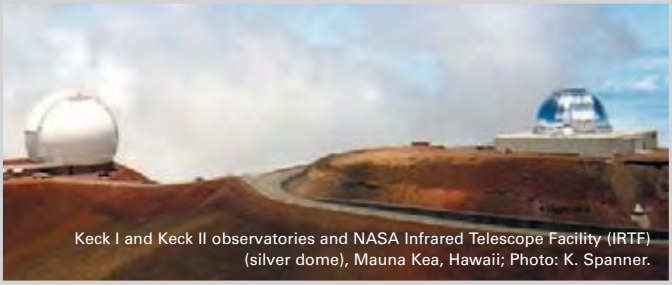
I_0 = moment of inertia of the platform (see technical data table for the individual model) [g · mm²]

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

25cm secondary mirror

Piezo driven steering platform, µm/mrad range; nm/nrad precision

Momentum compensation

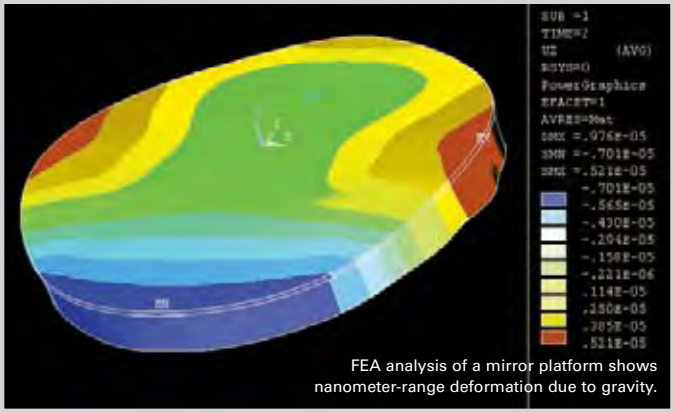
Hexapod actuators range: mm/degrees resolution: µm/µrad

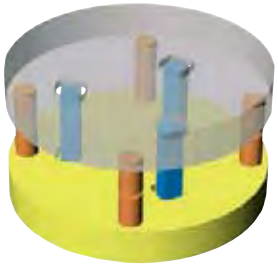
Base plate

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.

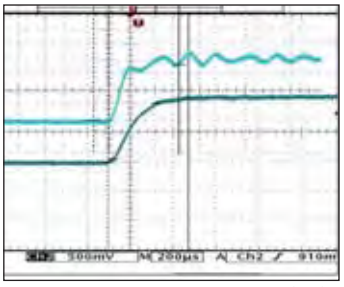

Basic design of a piezo tip/tilt platform featuring three actuators and four sensors. Large platforms handle optics to Ø500 mm

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

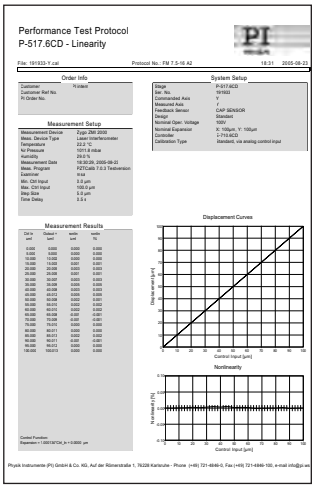

Fast: 200 µs step response. Standard (top), optimized amplifier (bottom), 0.2 µrad steps

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

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

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

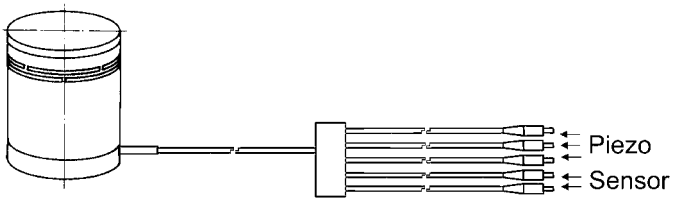
S-330.4SD
High-Dynamics Piezo Tip/Tilt Platform, 5 mrad, SGS, Sub-D Connector

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

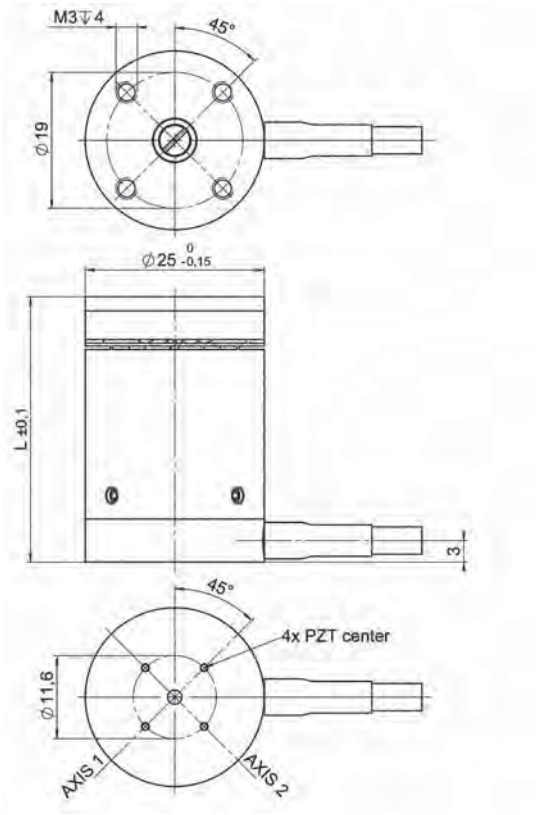
S-330.80L
High-Dynamics Piezo Tip/Tilt Platform, 10 mrad, Open-Loop, LEMO Connector



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).

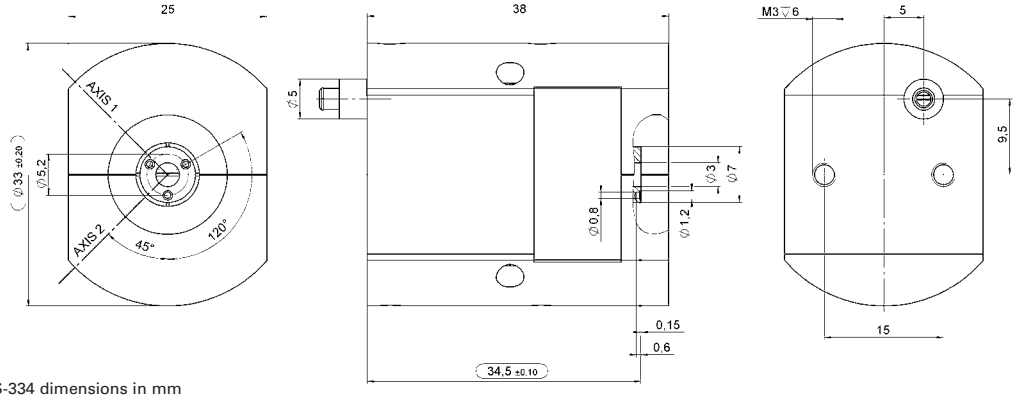
Ordering Information

S-334.2SD
High-Dynamics Piezo Tip/Tilt Platform, 50 mrad, SGS, Sub-D Connector, incl. Mirror

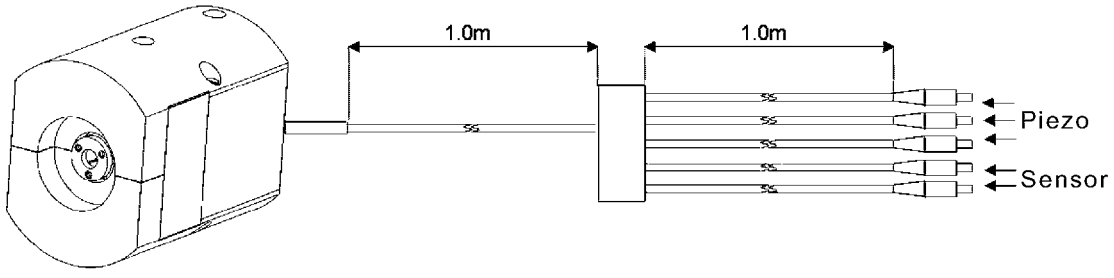
S-334.2SL
High-Dynamics Piezo Tip/Tilt Platform, 50 mrad, SGS, LEMO Connector, incl. Mirror

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

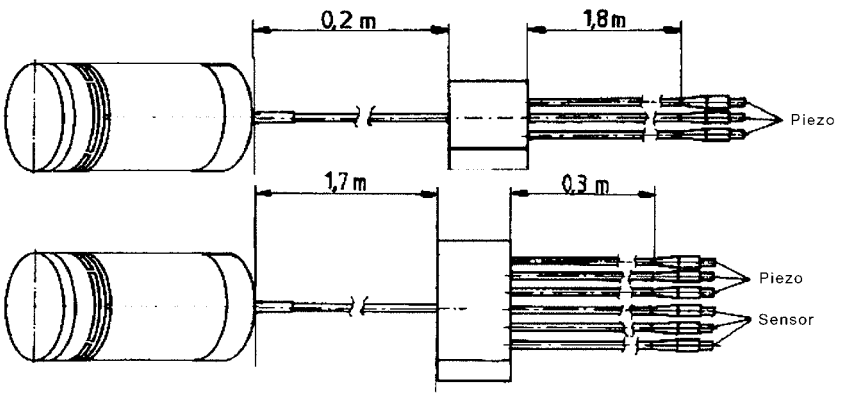
S-325.30L
High-Dynamics Piezo Z/Tip/Tilt Platform, 5 mrad, 30 µm, Open-Loop, LEMO Connector

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

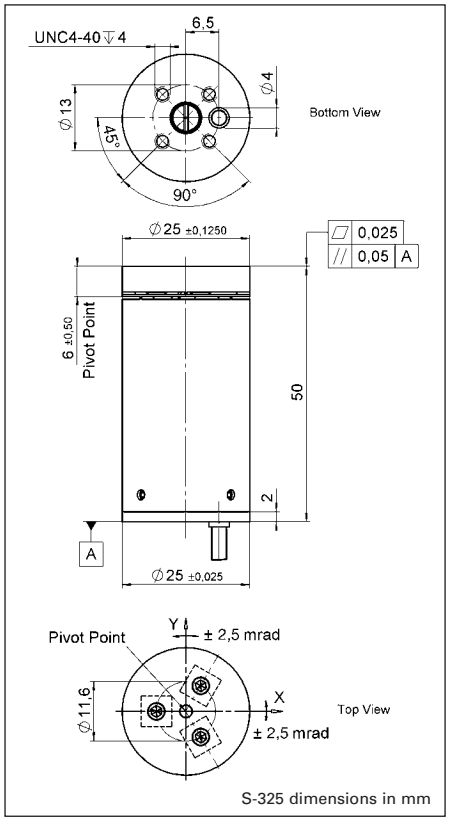
- Image processing / stablilization
- Optical trapping
- Laser scanning / beam steering
- Laser tuning
- Optical filters / switches
- Optics
- Beam stabilization



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

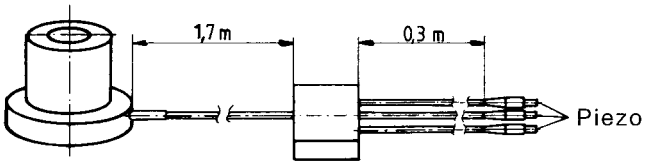
S-311.10
Piezo Z/Tip/Tilt Platform, Clear Aperture, 600 µrad, 6 µm, LEMO Connector

S-314.10
Piezo Actuator, Clear Aperture, 12 µm, LEMO Connector

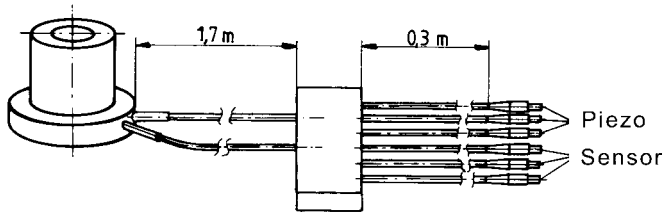
S-315.10
Piezo Z/Tip/Tilt Platform, Clear Aperture, 1.2 mrad, 12 µm, LEMO Connector

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



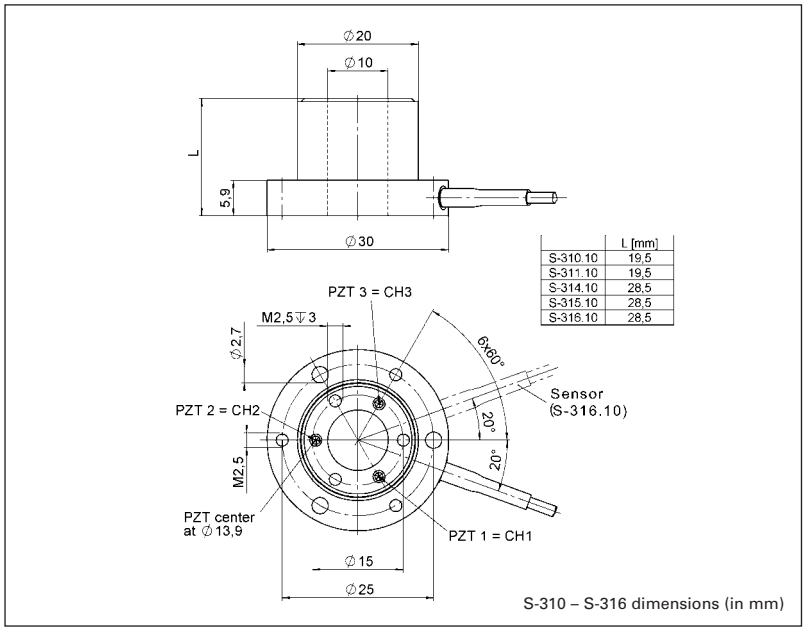
S-315 cable configuration



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.



	L [mm]
S-310.10	19,5
S-311.10	19,5
S-314.10	28,5
S-315.10	28,5
S-316.10	28,5

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

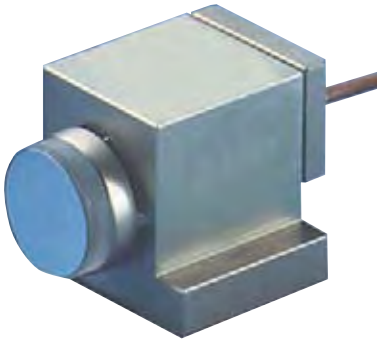
S-303 closed-loop model (left) and open-loop model (right). DIP switch for size comparison

- 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

Details on Specifications for Active Optics / Steering Mirrors

Motion and Positioning

Performance specifications are valid for room temperature (22° ±3 °C) and closed-loop systems are calibrated at this temperature (specifications for other operating temperatures on request). Recalibration is recommended for operation at a significantly higher or lower temperature. Custom designs for ultra-low or ultra-high temperatures on request.

Integrated feedback sensor

Absolute measuring capacitive and strain gauge (SGS) sensors are used to provide position information to the controller. For details see the tutorial "Piezoelectrics in Positioning" section (see p. 2-187).

Open-loop linear travel @ 0 to 100 V

Typical open-loop travel at 0 to 100 V operating voltage. Max. recommended operating voltage range is -20 to +120 V (extremes for short durations only).

Closed-loop linear travel

Travel provided in closed-loop operation. PI piezo amplifiers have an output voltage range of -20 to +120 V or -30 to +135 V to provide enough margin for the servo-controller to compensate for load changes, etc.

Open-Loop Tilt Angle @ 0 to 100 V

Typical open-loop tilt angle at 0 to 100 V operating voltage. For differential-drive tilt platforms, 0° is reached at 50 V drive voltage, the maximum negative angle at 0 V and the maximum positive angle at 100 V. Max. operating voltage range is -20 to +120 V (outside 0 to 100 V for short durations only).

Closed-Loop Travel

Tilt provided in closed-loop operation at room temperature. PI piezo amplifiers have an output voltage range of -20 to +120 V or -30 to 135 V to provide enough margin for the controller to compensate for load changes etc.

Open-loop / closed-loop resolution

Resolution of piezo flexure stages is basically infinitesimal because it is not limited by stiction or friction. Instead of resolution, the noise-equivalent motion is specified. Values are typical results (RMS, 1 σ), measured with E-503 amplifier module in E-500/501 chassis.

Full-range repeatability (typ.)

Typical values in closed-loop mode (RMS, 1 σ). Repeatability is a percentage of the total distance or angle traveled. For small ranges, repeatability is significantly better.

Pitch / Yaw / Roll / Rotational Runout

Typical rotational off-axis error; sometimes associated with a particular motion axis, as in "Rotational runout (Z motion)".

Straightness / Flatness / Crosstalk

Typical linear off-axis error; sometimes associated with a particular motion axis, as in "Crosstalk (Z motion)".

Mechanical Properties

Stiffness

Static large-signal stiffness of the piezo mechanics in operating direction at room temperature. Small-signal stiffness and dynamic stiffness may differ because of effects caused by the active nature of piezoelectric material, compound effects, etc. For details see the tutorial "Piezoelectrics in Positioning" section (see p. 2-189 *ff*).

Unloaded resonant frequency

Lowest tilt resonant frequency around active axis without mirror attached to platform (does not specify the maximum operating frequency). For details see the tutorial "Piezoelectrics in Positioning" Section (see p. 2-192 *ff*).

Resonant frequency with mirror

Example of how a load (mirror) attached to the platform affects the resonant frequency (calculated data). See "Dynamic Behavior" (p. 2-84) for further details.

Drive Properties

Electrical capacitance

The piezo capacitance values indicated in the technical data tables are small-signal values (measured at 1 V, 1000 Hz, 20 °C, no load). Large-signal values at room temperature are 30 to 50 % higher. The capacitance of piezo ceramics changes with amplitude, temperature, and load, up to 200 % of the unloaded, small-signal capacitance at room temperature. For detailed information on power requirements, refer to the amplifier frequency-response graphs in the "Piezo Drivers / Servo Controllers" (see p. 2-99 *ff*) section of this catalog.

Dynamic Operating Current Coefficient (DOCC)

Average electrical current (supplied by the amplifier) required to drive a piezo actuator per unit frequency and unit displacement (sine-wave operation). For example, to find out if a selected amplifier can drive a given piezo tilt platform at 50 Hz with 300 µrad amplitude, multiply the DOC coefficient by 50 and 300 and check if the result is less than or equal to the output current of the selected amplifier. For details see the tutorial "Piezoelectrics in Positioning" (see p. 2-195 *ff*) section.

Miscellaneous

Operating temperature range

Typically -20 to +80 °C, the temperature range indicates where the piezo stage may be operated without damage. Performance specifications are valid for room temperature (22 °C) and closed-loop systems are calibrated for optimum performance at this temperature (specifications for other operating temperatures on request). Recalibration is recommended for operation at a significantly higher or lower temperature. Custom designs for ultra-low or ultra-high temperatures on request.

Material

Flexure stages are usually made of anodized aluminum or stainless steel. Small amounts of other materials may be used internally (for spring preload, piezo coupling, mounting, thermal compensation, etc.).

- Al: Aluminum
- N-S: Non-magnetic stainless steel
- S: Ferromagnetic stainless steel
- I: Invar
- T: Titanium

Voltage connection

Standard operating voltage connectors are LEMO and sub-D type connectors.

LEMO connector: LEMO FFA. 00.250, male. Cable: coaxial, RG 178, Teflon coated, 1 m

Sensor connection

Standard sensor connectors are LEMO and sub-D type connectors.

Sub-D special connectors contain both piezo voltage and sensor connections.

For extension cables and adapters, see "Accessories" (p. 2-168 *ff*), in the "Piezo Drivers / Servo Controllers" Section.

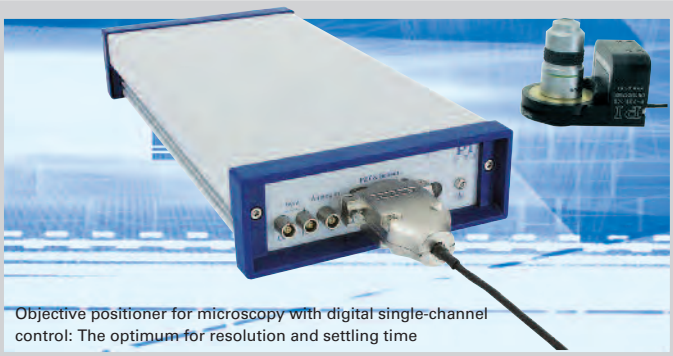
Digital Control

Best Performance for Positioning Systems

Contents

Digital Control

Digital Processes Improve Performance



Objective positioner for microscopy with digital single-channel control: The optimum for resolution and settling time

Digital technology opens up new opportunities for improving performance in control engineering which did not exist with conventional analog technology.

A significant advantage of PI's digital controllers is that all motion parameters can be specifically influenced by calculating algorithms.

These advantages lie mainly in the improved precision and dynamic properties, and also the ease of operation of PI's positioning systems and drive solutions.

High-Resolution Signal Conversion

The most important requirement here is that the signal conversion from analog input signals to digital data for the subsequent processing is done quickly and with high resolution. Information which is lost at conversion is lost forever. The same applies to the generation of the analog control signal: The best algorithms are useless if the analog control signal cannot be generated in high resolution. PI therefore uses the latest generation of A/D and D/A converters with a minimum 20-bit resolution. Analog signals are thus resolved into more than one million data points.

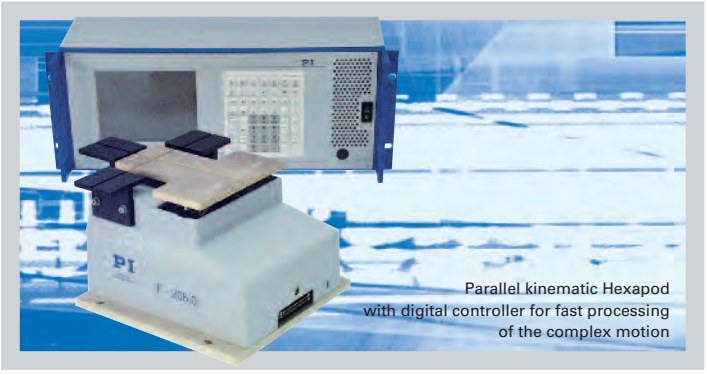
Fast Data Processing

The incoming volume of data needs to be processed rapidly in order to compete with the conventional analog controllers in terms of "real time". This requires fast processors. PI relies on modern DSPs and powerful PC solutions, depending on the task the controller has to fulfill.

A control cycle is thus completed, for example, in 0.02 milliseconds – this corresponds to a servo rate of 50 kHz. Updated sensor data and control signals have therefore also to be provided.

Digital Processes Improve Performance

The performance of a positioning system is no longer decided by its mechanical properties alone. In the case of dynamic applications, for example, it is naturally also important that the system is as stiff as possible and the moving mass very small, the sensor bandwidth broad and the amplifier flank steep. There will nevertheless be phase shifts between the control signal – the target motion – and the actual motion. Linearization algorithms minimize the difference between the target and the actual value and allow faster settling and also the adjustment of the control signal.



Parallel kinematic Hexapod with digital controller for fast processing of the complex motion

Digital Data Processing

Classical nanopositioning technology employs the following algorithms in digital controllers to improve the system performance:

Linearization of the Electronics:

All digital PI controllers for nanopositioning behave in a similar way. This allows any piezo devices which are tuned to digital control to also be operated by different controllers without any loss of performance. The tuning data required are stored on an ID-Chip in the stage and retrieved by the controller at power up.

Linearization of the Mechanics:

The linearity of regulated systems as a whole is a measure of its positional accuracy. Piezo actuators as such have a high degree of nonlinearity – up to 15% of the travel – and this must be compensated by the control in order for the system to reach the position as accurately as possible. With digital controllers, the nonlinearity of the motion is reduced using calculations with higher order polynomials to values below 0.001% – which corresponds to an accuracy of better than one nanometer for a travel range of 100 µm.

Controller and Controlling Methods:

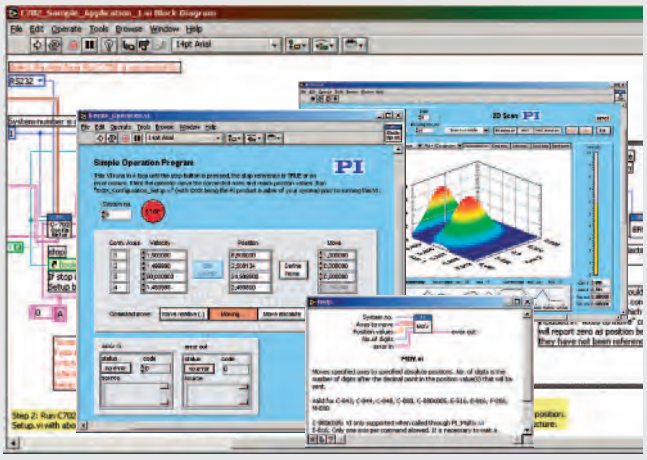
The task of the controller is to compensate differences between target and actual position. This is conventionally done with PID controllers. Depending on the application, other control concepts in combination with linearizing algorithms can bring about better results, however. PI thus offers model-based state controllers (Advanced Piezo Control) as an optional extra.

Dynamic Linearization:

Digital Dynamic Linearization (DDL) reduces the deviation of periodic trajectories during the motion even further. This is relevant for scanning applications, where the task is to identify a certain position and take it up again with precision, or for applications where the trajectory must be maintained for processing steps.

Digital Control

Simplified Operation and Advanced Functionality



Quick access to the full functionality

Operation via Software

The complete digitalization of all operational steps makes the process parameters easily accessible via software. PI software additionally provides diagnostic tools and tuning support, such as the graphic display of step responses for parameter optimization.

Operation via Digital Interfaces

Fast USB or TCP/IP interfaces, as well as RS-232, are the standard interfaces supported by modern digital controllers. Furthermore, PI also provides real-time capable interfaces such as a 32-bit parallel input / output interface (PIO). Customized serial interfaces are also possible to provide a link to the application environment.

Simplified Control of Multi-Axis Systems

PI uses parallel kinematics for precise positioning in three or more axes. The actuators and drives here act simultaneously on the platform to be moved – in the case of hexapods, for example. The motion of the platform in the six directions requires that the individual axes be coordinated. This coordinate transformation enables the user to place commands in Cartesian coordinates, while the controller controls the individual drives required for this.

Additional Functions of the Digital Controllers*

Computing power and memory size which go hand in hand with digital controllers allow useful additional functions to be implemented.

Coordinate transformation for parallel kinematics for simple control in Cartesian coordinates.

Coordination of the walk motion for PiezoWalk® Drives; linearization of the actuator travel for Walk Drives.

Software access to all motion parameters and the graphic display of the effects.

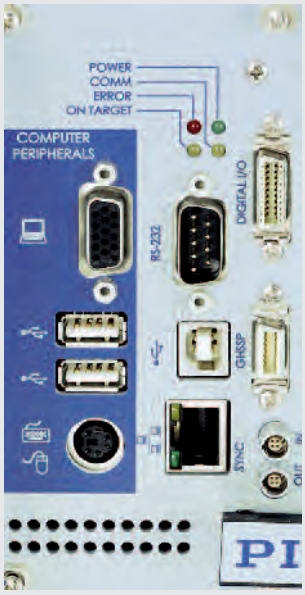
Macro memory to store and retrieve motions which can be triggered externally.

Function generator and trajectory memory for the retrieval of predefined trajectories and the generation of customized wave forms.

Data recorders record sensor and control data for subsequent processing.

The **ID Chip** permits the flexible exchange of controllers and nanopositioners without the need to retune the operational parameters.

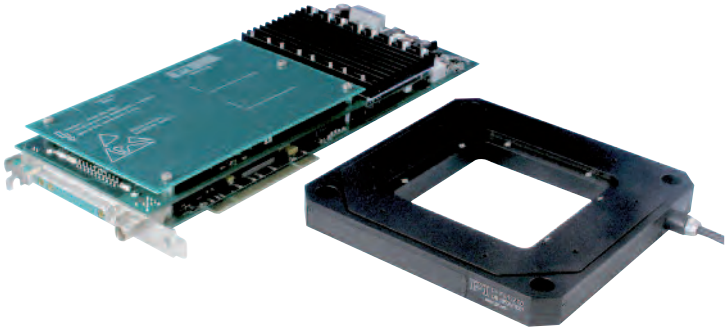
* Not all controllers have all the functions.
The individual ranges of functions are listed in the relevant datasheets.



The E-712 provides RS-232, USB and RS-232 as standard interfaces. Additionally, digital I/O lines and optional analog interfaces or a real-time PIO are available.

Digital Control

Exceeding the Pure Function…



The digital E-761 nanopositioning controller as PC Plug-in card (here with XY nanopositioning system) presents a low-cost alternative to the tabletop or rack-mounting version with casings.

Piezo, Nano, Positioning

PI offers the world's largest selection of positioning and drive systems for precise positioning in the accuracy range from one micrometer down to below one nanometer. Piezo actuators, piezo walk or ultrasonic drives as well as conventional motors and combinations of all these enable PI to provide custom-engineered positioning systems. The requirements of biotechnology, semiconductor production, optical metrology and astronomy have one thing in common here: The high degree of precision required and PI as the supplier of the solution.

Continuous Progress

As far as PI is concerned, the certification of a quality management system is a commitment to continuously improve products and processes. Suppliers are integrated into the development process in order to transfer PI's high standards to them. PI's absolute commitment to quality leads it to train its own staff in Development and Production, provide laboratories for EMC and environmental tests, and use the latest CAD and simulation tools. A commitment which those working in the field of nanotechnology cannot do without.

As Flexible as the Drive: The Control

Fast settling or slow speed with high constancy, high positional stability, positional resolution and dynamics – different applications require a high degree of control flexibility. PI therefore offers a broad spectrum of electronics from very versatile controllers to highly specialized ones: As an OEM board for integration, a plug-and-play desktop unit or with a modular construction.

Piezo Amplifier in cost-efficient and compact OEM Design

Service

The **scope of supply** of a PI system consisting of controller and stage includes everything required for its operation.

- Any necessary external power supplies
- All power, communication and system cables
- The comprehensive operating manual in printed form
- Software CD with comprehensive setup function

Firmware and software updates are available free of charge via the Internet, as are the operating manuals. You will receive access to the PI download portal when you purchase the controller. Firmware updates can easily be carried out via the standard controller interfaces.

PI offers comprehensive **software support**. PI software is included in the scope of supply and serves to start up the system, and also to analyze and optimize the system's behavior. DLLs, LabView drivers or the support of MatLab facilitate the programming.

It goes without saying that the PI software is compatible with the latest Microsoft operating systems and can also be operated under LINUX.

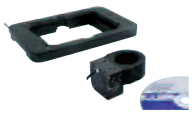
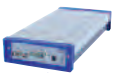
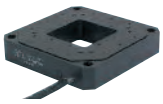
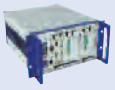
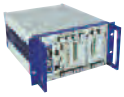
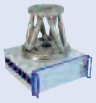
When developing the instruments, top priority is given to the use of state of the art components. This ensures a **long availability and replaceability** of the systems even beyond the product lifecycle.

Customized product development and adaptations are an important part of our technical progress. We offer you:

- The complete range of our product spectrum from electronic components and complete devices as an OEM circuit board to the modular system in a case.
- Small batch production and mass production.
- Product development according to special product standards (country or market-specific standards such as the Medical Devices Act) and the corresponding certification.
- Adaptation of the systems to special environmental conditions (vacuum, space, clean room)
- Copy-exactly agreements

Digital Control

Product Overview: As flexible as PI drives

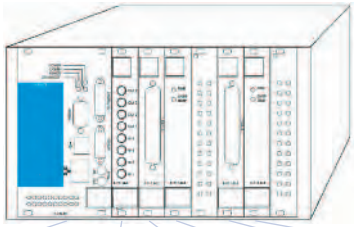
	Drives	Hardware platform	Axis	Power/channel	Interfaces	Software platform
	Nanopositioning systems with Single-Axis	 E-753	1	5 W	Ethernet, RS-232, Analog	PI General Command Set
	Nanopositioning systems with up to 3 axes, low-power requirement	 E-761	3	1,7 W	PCI Plug-In Board	PI General Command Set
	Nanopositioning systems with up to 3 axes	 E-725	3	10 W	Ethernet, USB, RS-232; optional Analog, PIO	PI General Command Set
	Nanopositioning systemes with up to 6 axes	 E-712	3 / 6	8 W	Ethernet, USB, RS-232; optional Analog, PIO	PI General Command Set
	PICOCUBE® high-speed scanner	 E-712	3	up to 15 W	Ethernet, USB, RS-232; optional Analog, PIO	PI General Command Set
	NEXLINE® heavy-duty nanopositioning drive	 E-755 E-712	1	up to 10 W	RS-232 Ethernet, USB, optional Analog, PIO (only E-712)	PI General Command Set
	NEXLINE® parallel-kinematic with up to 3 axes	 E-712	3	15 W	Ethernet, USB, RS-232; optional Analog, PIO	PI General Command Set
	Positioning systems with NEXACT® Nanopositioning Drive (with Encoder Analysis)	 E-861	1	40 W	USB, RS-232	PI General Command Set
	Positioning systems with DC-servomotors and encoder analysis / PILine® ultrasonic piezo drives with encoder analysis / stepper motors	 C-863 C-867 C-663	1		USB, RS-232, networkable	PI General Command Set
	Hexapoden/ parallel kinematics with any drives	 Included	up to 6		RS-232; depending on design, Ethernet or USB	PI General Command Set

E-712 Digital Nanopositioning Controller

Modular Platform for Precision Piezo Systems and NEXLINE® Drives

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**



	Preconfigured system	Digital controller unit	Case unit	Interface modul	Sensor modul	Amplifier modul	Sensor modul	Amplifier modul
Nanopositioning systems with voltage requirement of up to +120 V with 3 axes and capacitive sensors	E-712.3CD	E-712.M1*	E-712.R1*	–	E-711.SC3H*	E-711.AL4P*	–	-
Nanopositioning systems with voltage requirement of up to +120 V with up to 6 axes and capacitive sensors	E-712.6CD	E-712.M1*	E-712.R1*	–	E-711.SC3H*	E-711.AL4P*	E-711.SC3H*	E-711.AL4P*
Nanopositioning systems with voltage requirement of up to +120 V with three (six) axes and capacitive sensors; 4 analog inputs and outputs for direct issuing of commands and sensor/position evaluation	E-712.3CD (E-712.6CD)	E-712.M1*	E-712.R1*	E-711.IA4	E-711.SC3H*	E-711.AL4P*	(E-711.SC3H)*	(E-711.AL4P)*
Nanopositioning systems with voltage requirement of up to +120 V with 3 (six) axes and capacitive sensors; Parallel I/O interface for fast, digital commands PIO	E-712.3CD (E-712.6CD)	E-712.M1*	E-712.R1*	E-711.IP	E-711.SC3H*	E-711.AL4P*	(E-711.SC3H)*	(E-711.AL4P)*
Nanopositioning systems with voltage requirement of up to +120 V with 3 (six) axes and capacitive sensors and long distance between positioner and controller.		E-712.M1	E-712.R1	E-711.IA4 or E-711.IP optional	E-711.0CT	E-711.AL4P	(E-711.0CT)	(E-711.AL4P)
Nanopositioning systems with voltage requiremen ±250 V (PICOCUBE®) with up to 3 axes and capacitive sensors	E-712.3CM	E-712.M1*	E-712.R4*	E-711.IA4 or E-711.IP optional	E-711.SC3H*	E-711.AM4*	–	–
Nanopositioning systems with voltage requirement of up to +120 V with three (six) and incremental sensors		E-712.M1	E-712.R1	E-711.IA4 or E-711.IP optional	E-711.SA3 (E-711.SA6)	E-711.AL4P	–	(E-711.AL4P)
NEXLINE® positioning system with single-axis, incremental sensors and analog interfaces or PIO (optional)		E-712.N1**	E-712.R4	E-711.IA4 or E-711.IP optional	E-711.SA3	E-711.AM4	–	–
NEXLINE® positioning system with 3 axes (combined stepping drive), inkremental sensors and analog interfaces or PIO (optional)		E-712.N1**	E-712.R4	E-711.IA4 or E-711.IP optional	E-711.SA3	E-711.AM4	–	–
NEXLINE® positioning system with 3 axes (combined stepping drive), capacitive sensors and analog interfaces or PIO (optional)		E-712.N1**	E-712.R4	E-711.IA4 or E-711.IP optional	E-711.SC3	E-711.AM4	–	–

* The modul is already included.
** The single- or 3-channel NEXLINE® operation is adjustable via software commands.

E-712 Digital Nanopositioning Controller

Modular System for up to 6 Axes with Highest Precision

Example for the modular use of an E-712 for the vertical and tilt system with three mixed, hybrid drives. They consist of NEXLINE® linear actuators with additional PICMA® actuators for an increased fine adjustment range.

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 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 and 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.

Flexible Analog Inputs and Real-time PIO

Each of the four optionally available analog inputs can be configured in two ways. When used as a control input, the applied voltage is linked to one of the axes, for target value settings, for example. When configured as an external sensor input, additional sensor signals e.g. for auto-focusing, can be read in. Alternatively, the system can be equipped with a fast 32-bit PIO (Parallel I/O) for placing commands. The PIO supports a restricted command set required for the motion with 100,000 read and write commands per second.

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-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

These models have RS-232, USB and TCP/IP Interfaces.

Further Interfaces are available:

E-711.IA4
Analog Interface Module, 4 I/O for E-712 modular, digital, Controller System

E-711.IP
PIO Interface Module for E-712 modular, digital, Controller System

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

Examples of the modular use of one E-712 for a mixed operation of low voltage and medium voltage actuators (120 V or ±250 V). The positioning system has two separate axis systems for the adjusting and actual measurement process in an inspection system.

Technical Data

Model	E 712.3CD	E 712.6CD	E-712.3CM
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	Modular digital controller for PicoCube® nanopositioning systems with capacitive sensors
Axes	3	6	3
Processor	PC-based, 600 MHz, real-time operating system	PC-based, 600 MHz, real-time operating system	PC-based, 600 MHz, real-time operating system
Sampling rate, servo-control	50 kHz	20 kHz	50 kHz
Sampling rate, sensor	50 kHz	20 kHz	50 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	6	3
Sensor bandwidth (-3 dB)	10 kHz	10 kHz	10 kHz
Sensor resolution	18 Bit	18 Bit	18 Bit
Ext. synchronization	Yes	Yes	Yes
Amplifier			
Output voltage	-30 V to +135 V	-30 V to +135 V	-250 V to +250 V
Amplifier channels	4	8	4
Peak output power per channel	25 W	25 W	45 W
Average output power per channel	8 W	8 W	15 W
Peak current	250 mA	250 mA	180 mA
Average current per channel	100 mA	100 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			
Communication interfaces	Ethernet, USB, RS-232	Ethernet, USB, RS-232	Ethernet, USB, RS-232
Piezo / sensor connector	Sub-D special connector	Sub-D special connector	Sub-D special connector
Analog in/out	optional je 4 x LEMO, ±10 V (E-711.IA4)	optional je 4 x LEMO, ±10 V (E-711.IA4)	optional je 4 x LEMO, ±10 V (E-711.IA4)
Digital in/out	MDR20; 2 x IN, 8 x OUT; TTL	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)	PI General Command Set (GCS)
User software	NanoCapture™, PIMikroMove®	NanoCapture™, PIMikroMove®	NanoCapture™, PIMikroMove®
Software drivers	LabVIEW Drivers, DLLs	LabVIEW Drivers, DLLs	LabVIEW Drivers, DLLs
Supported functionality	Wave gen, trigger I/O	Wave gen, trigger I/O	Wave gen, trigger I/O
Display	LEDs for OnTarget, Err, Power	LEDs for OnTarget, Err, Power	LEDs for OnTarget, Err, Power
Linearization	4th order polynomials, DDL-Option (Dynamic Digital Linearization)	4th order polynomials, DDL-Option (Dynamic Digital Linearization)	4th order polynomials, DDL-Option (Dynamic Digital Linearization)
Miscellaneous			
Operating temperature range	5 to 50 °C	5 to 50 °C	5 to 50 °C
Overtemp protection	Max. 75°C, of the piezo voltage output	Max. 75°C, deactivation of the piezo voltage output	Max. 75°C, deactivation of the piezo voltage output
Mass	5.35 kg	5.78 kg	5.43 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)	9,5" chassis, 236 x 132 x 296 mm + handles (47 mm length)
Power consumption	100 W max.	100 W max.	100 W max.
Operating voltage	90 to 240 VAC, 50–60 Hz	90 to 240 VAC, 50–60 Hz	90 to 240 VAC, 50–60 Hz

E-712 Basic Modules

Powerful Processor, Fast Digital Interfaces and Cases

E-712 module with fast standard interfaces USB, Ethernet and RS-232

- **Digital Controller of the Newest Generation: 600 MHz Processor; up to 50 kHz Servo Update Rate**
- **Versions for Conventional Nanopositioning and NEXLINE® Piezo Linear Drives**
- **Real-Time Operating System for Excellent Trajectory Control**
- **Flexible Interfaces: Ethernet, USB, RS-232**

The modular E-712 digital controller is the platform for the most demanding nanopositioning applications. The basic elements of the modular concept are the casing (E-712.R1 or E-712.R4) and the CPU (E-712.M1 or E-712.N1). Further components are available such as different amplifiers, signal conditioners and additional interfaces from the E-711 range.

How many axes would you like?

For special applications, up to 13 channels can be operated in a 19" chassis (482 mm). Conventional applications with up to 6 axes can be fitted into compact 9.5" (241 mm) casings. The casings are equipped with power supplies to suit the type of drive: The E-712.R1 is designed for conventional nanopositioning with low-voltage actuators with up to 6 axes. The E-712.R4 is designed for up to 3 NEXLINE® drives or PicoCube® AFM scanners.

Adjusting the stepping motion of a drive allows operating modes from fast stepping or a constant speed mode to the purely analog shear operation. As an alternative to operating one individual drive, the same E-712 controller can also operate nanopositioning systems with three NEXLINE® drives in coordination.

The Hard Core

The E-712 is PC based. Its computing power is designed for processing times by having a servo update rate of up to 50 kHz, for example. In addition, algorithms for linearization, control, to transform coordinates or store trajectory information are carried out in real time. Even for dynamic applications, the position can thus be achieved with an accuracy of a few nanometers, for example. The varying requirements placed on the motions mean

Ordering Information

For conventional nanopositioning systems with PICMA® low voltage piezo actuating or for PicoCube™

E-712.M1
Digital Computer and Interface Module E-712 with Ethernet Interface, USB, RS-232

E-712.R1
Digital Modular Piezo Controller System, 3 to 6 Channels, 9,5" Chassis with P/S

E-710.SCN
DDL (Dynamic Digital Linearization) Firmware Upgrade

E-712.U1
Advanced Piezo Control Option

E-712.U2
Firmware Upgrade PicoPlane™: Option for Nanometer Precision (convenient hardware required)

E-712.U3
Real-Time System Upgrade for Host PC

For NEXLINE® linear drives:

E-712.N1
Digital NEXLINE® Processor and Interface Module E-712 with Ethernet Interface, USB, RS-232

E-712.R4
Digital Modular Piezo Controller System, 3 to 6 Channels, 9.5" Chassis with Power Supply for ±250 V Piezo Voltage

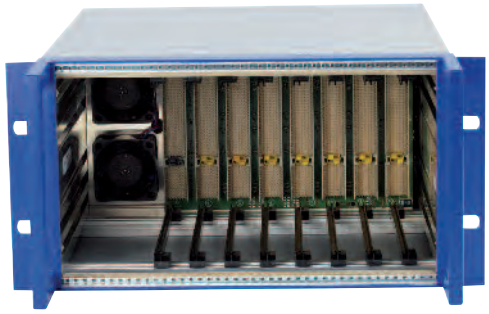
Ask about custom designs!

Custom design of an E-712 system in a 19" chassis for multi-combined piezo actuators and drives

there is a different computer module for nanopositioning applications with conventional ceramic actuators and NEXLINE® Walk Drives.

Modern Interfaces

The computer module offers USB, RS-232 and a fast Ethernet interface as standard. The system can further be supplemented with an analog interface module or a very fast 32-bit PIO.



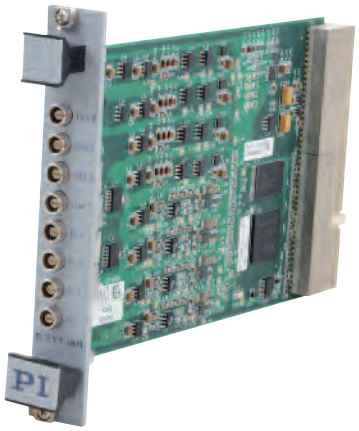
The basic configuration of an E-712 system always includes a chassis (picture) and a rack- or rather an interface module

Technical Data

Model	E-712.M1	E-712.N1
Function	Digital NanoAutomation processor- and interface module with Ethernet Interface, USB Interface, RS-232	Digital NEXLINE® processor- and interface module with Ethernet Interface, USB Interface, RS-232
Processor	PC based, 600 MHz, real-time operating system	PC based, 600 MHz, real-time operating system
Sample rate control (max.)	50 kHz	50 kHz
Sample rate sensor (max.)	50 kHz	50 kHz
Sensor characteristics	P-I, two notch filters or advanced piezo control, optional	P-I, two notch filters
Temperature sensor	Yes	Yes
Interfaces and operation		
Communication interfaces	RS-232, USB, Ethernet (FTP, UDP, HTTP, TCP/IP)	RS-232, USB, Ethernet (FTP, UDP, HTTP, TCP/IP)
Digital Input	MDR 20, 2 x IN, TTL	MDR 20, 2 x IN, TTL
Digital Output	MDR 20, 8 x OUT, TTL	MDR 20,8 x OUT, TTL
Command set	PI General Command Set (GCS)	PI General Command Set (GCS)
User software	PI MikroMove™ , NanoCapture™	PI MikroMove™ , NanoCapture™
Software drivers	LabVIEW Driver, DLLs	LabVIEW Driver, DLLs
Supported functionality	Wave generator, data recorder, trigger I/O	data recorder, trigger I/O
Display	LEDs for OnTarget, Error, Power	LEDs for OnTarget, Error, Power
Linearization	4th order polynomials, DDL Option (Dynamic Digital Linearization)	4th order polynomials; linearization stepping drive
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
Dimensions	12 TE 3 HE	12 TE 3HE
Mass	0.52 kg	0.52 kg
Operating voltage	90 to 240 VAC; 50–60 Hz	90 to 240 VAC; 50–60 Hz

E-712 Analog Interface Module

Command and Readout in Real-Time



E-711.IA4 analog interface module

Ordering Information

E-711.IA4
Analog Interface Module, 4 I/O

Accessories:

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

Ask about custom designs!

- **4 Analog Inputs**
- **4 Analog Outputs**
- **20-bit DA-Converter**
- **18-bit AD-Converter**
- **Powerful FPGA**
- **Smallest Possible Latency**
- **Integrated Self-Testing**

The analog interface module for the E-712 digital controller system offers an additional option for the placing of commands and read-out of 4 channels.

Setting the Target Value in Real-Time

Depending on the application, the target value can be set in the form of an analog voltage, from an autofocus routine or an automation environment, for example. These signals can be read-in directly via the analog E-711.IA4 interface module and used to command an axis. It is therefore not necessary to convert them into a digital signal at the host; this process, which depends on the host operating system, does not therefore cause a delay.

The high resolution of up to 18 bit and the operating system of the E-712 controller allow the input signal to be processed in real time.

Analog Data Output

The data output is also done via the analog interface in 16-bit resolution. The analog output can be configured so that it can directly output the sensor values or the controlled position settings. The latter is useful if the signal is to be used as the input of external power amplifiers, for example.

Digital Real-Time Interface

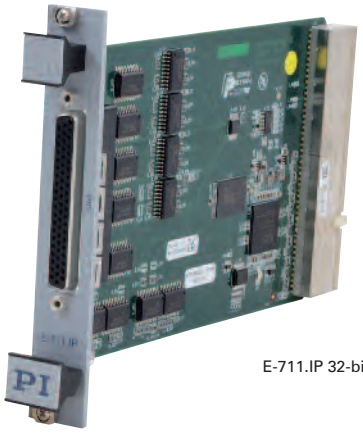
A further option for fast signal transmission is the use of the fast parallel 32 bit interface (PIO). This is available as the option E-711.IP.

Technical Data

Model	E-711.IA4
Function	Analog Interface Module
Channels	4 In-, 4 Outputs
Resolution Input	18-bit
Resolution Output	16-bit, 20-bit effective
Analog Input	4 LEMO, ±10V
Analog Output	4 LEMO, ±10V
Dimensions	4 TE 3 HE
Mass	0.16 kg

E-712 Parallel-I/O Interface Modules

Fast, Digital Command in Real-Time



E-711.IP 32-bit PIO interface

- **32-bit Resolution**
- **Configured for up to 6 Axis**
- **Fast Communication with 500 ns Read and 1200 ns Write**
- **Optional Real-Time System**

Ordering Information

E-711.IP
PIO Interface Module for E-712 modular, digital, Controller System

E-712.U3
Real-Time System Upgrade for Digital Piezo Controller

Ask about custom designs!

Fast parallel interfaces (PIO) are used where the speed of transmission via the digital standard interface is not sufficient. The PIO supports a restricted command set required for the motion with up to 2 million read or write commands per second.

Real-Time Operating System as an Optional Extra

The limiting factor when networking several devices in one application is not necessarily the speed of the interface, but often the operating system as well. For such cases, PI offers a software upgrade to use a real-time operating system on the host computer. The system can be booted on the host PC or as a live version directly from a data carrier. The fully functional real-time system is based on real-time Linux and allows the PI Controller to be controlled via the PIO interface. A PI GCS (General Command Set) library is used for the communication. It supports all user software supplied by PI for Linux and also the integration of additional data acquisition cards and the programming of your own control algorithms, e.g. in C++ or MATLAB/SIMULINK.

Technical Data

Model	E-711.IP
Function	PIO Interface module
Resolution	32-bit
Communication interfaces	HD-Sub-D 62 connector
Speed of command	500 ns read / 1200 ns write
Supported functionality / software drivers	Optional Linux-based real-time system (E-712.U3)
Dimensions	4 TE 3 HE
Mass	0.15 kg

E-712 Sensor Modules

High-Resolution and Solid for Capacitive and Incremental Sensors

E-711.SC3H sensor module for capacitive dual-plate sensors with nanometer resolution

- **Flexible Choice of Sensor Analysis, depend on Positioning Mechanic**
- **For capacitive Dual- or Single-Plate Sensors or incremental Sensors**
- **Resolution of a few Nanometers up to the Sub-Nano Region**
- **Up to 6 Channels**

Ordering Information

E-711.SC3H
Module for Capacitive Sensors, 3 Channels, for E-712 modular, digital, Controller System

E-711.0CT
Digital Sensor Signal Transmission, 3 Channels, Capacitive Sensors, for E-712 Digital Controller

E-711.SE3
Module for PISeca™ Capacitive Single-Electrode Sensors, 3 Channels, for E-712 modular, digital, Controller System

E-711.SA3
Module for incremental Sensors, 3 Channels, for E-712 modular, digital, Controller System

E-711.SA6
Module for incremental Sensors, 6 Channels, for E-712 modular, digital, Controller System

Ask about custom designs!

The choice of sensor module depends on the type of sensor used in the positioning system. For high stability and resolutions in the region of a few nanometers and lower, PI prefers to use 2 types of position sensor: capacitive or incremental ones.

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.

Capacitive sensors can have two configurations: One and two-electrode sensors. PI usually uses two-electrode sensors in its nanopositioning systems. PISeca™ one-electrode sensors are available as external sensors. Capacitive sensors measure absolute position.

Large Distances between Controller and Stage

An application where the positioning system with capacitive sensors and the controller are more than 3 meters apart requires digital, interference-free transmission of the sensor signal. The sensor evaluation is done in a separate instrument positioned close to the positioning system where the sensor signal is digitized with 18-bit resolution and transmitted to the controller. This type of transmission works over distances of up to 30 meters, a 10-meter cable is included with the option E-711.0CT.

Offset sensor analysis with 10 m cable for capacitive sensors: E-711.0CT

Incremental Encoders

Where the travel range is typically greater than 1 mm, PI uses incremental sensors (linear or ring encoders). They achieve resolutions of about one nanometer with a linearity of up to 1 % of the grating period. Incremental encoders measure changes relative to a reference position (relative rather than absolute).

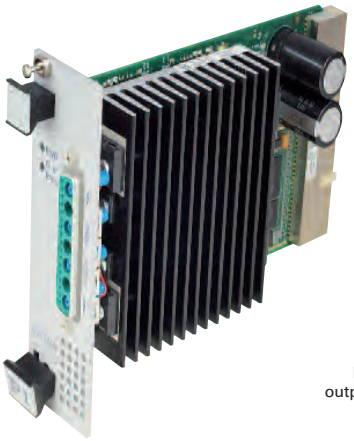
PISeca™ capacitive single-electrode sensors. Easy assembly and High-Precision qualified these sensors for measurements of distances and motions

Technical Data

Model	E-711.SC3H	E-711.0CT	E-711.SE3	E-711.SA3
Function	Modul for capacitive sensors	Module for capacitive sensors with sensor analysis (DST)	Module for capacitive PISeca™ single-electrode sensors	Module for incremental sensors
Channels	3	3	3	3
Sensor type	capacitive	capacitive	Single-electrode, capacitive	incremental
Sensor bandwidth	10 kHz	10 kHz		
Sensor resolution	18-bit	18-bit	18-bit	16-bit
Sensor communication	Sub-D Special (multi-axis, capacitiv)	Sub-D Special (multi-axis, capacitiv), 10 m cable length between sensor analysis and controller	Sub-D Special (multi-axis, capacitiv)	Sub-D Special
Dimensions	4 TE 3 HE	4 TE 3 HE; Sensor analysis 198.5 x 102.9 x 38.3 mm	4 TE 3 HE	4 TE 3 HE
Mass	0.18 kg	Sensor analysis: 0.65 kg Interfacekarte: 0.15 kg	0.18 kg	0.15 kg

E-712 Amplifier Modules

High-Power and Low-Noise for Dynamic and Precision



E-711.AM4 amplifier module with ±250 V output voltage forPicoCube™ and NEXLINE®

- **Flexible Opions for Nanopositioning, PicoCube™ and NEXLINE® Drives**
- **4 Channels**
- **High-Voltage, 8 W per Channel**
- **Highest Stability, Low Noise**
- **20-bit Effective**
- **Powerful FPGA**

The amplifier modules are designed to operate all piezoceramic drive systems used by PI for nanopositioning on the basis of the E-712 digital controller system.

PICMA® Based Nanopositioning Technology

Conventional positioning systems use the direct displacement of the piezoceramics for the movement. PI uses the reliable PICMA® high performance actuators for this in a typical voltage range of between -20 and +120 V.

PicoCube™ AFM-Scanner

Based on PICAShear™ actuators, the PicoCube™ scanners offer maximum resolution and dynamics up to the kilohertz region. The shear actuators used are operated in a voltage range between -250 and +250 V.

NEXLINE® with Long Travel Range

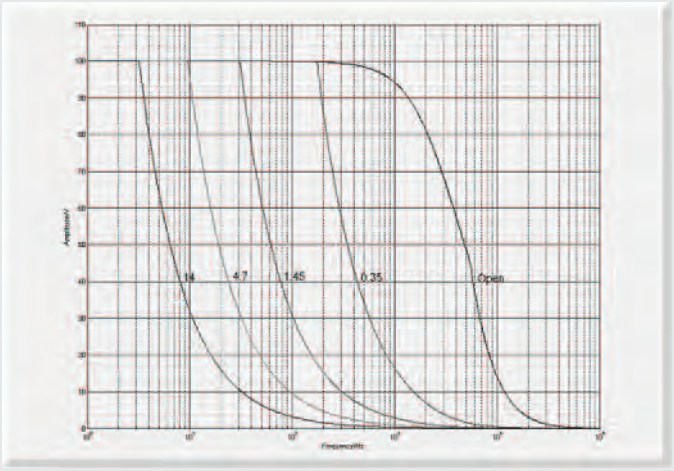
NEXLINE® linear drives offer maximum precision and stiffness over long travel ranges. The PiezoWalk® walking drive principle is based on shear actuators with a voltage range of between -250 and +250 V.

Ordering Information

E-711.AL4P
High-Power Amplifier Module, 3 Channels, 8 W, for E-712 modular, digital, Controller System

E-711.AM4
Amplifier module forPicoCube™, 3 Channels, for E-712 modular, digital, Controller System, -250 V bis +250 V

Ask about custom designs!



E-712 operating limits with various capacitive loads, capacitance is measured in µF

Technical Data

Model	E-711.AL4P	E-711.AM4	Units
Function	High-Power amplifier module, 8 W, -30 bis +135 V	Amplifier module, ±250 V	
Channels	4	4	
Output Voltage min.	-30	-250	V
Input Voltage max.	135	250	V
Peak output power per channel	25	45	W
Average output power per channel	8	15	W
Peak current per Channel	250	180	mA
Average current per channel	100	60	mA
Current limitation	Short-circuit-proof	Short-circuit-proof	
Resolution DAC	20	20	bit
Dimensions	8 TE 3 HE	8 TE 3 HE	
Mass	0.48	0.48	kg

Interfaces

Digital Interfaces

Digital or Analog Interfacing?

Analog interfacing provides high bandwidth and remains the most common way of commanding piezoelectric motion systems. It is usually the choice when the control signal in the application is provided in analog form. A key advantage of analog interfacing is its intrinsic deterministic (real-time) behavior, contrasted to the difficulty of accurately timing high-bandwidth communications on present-day multitasking PCs.

However, when analog control signals are not available, or when a significant distance between the control signal source and the nanopositioning controller would affect signal quality, digital interfacing, which must not be confused with digital control, is the preferred choice.

Digital signals can be transferred through copper wires, or for complete EMI immunity, through optical fibers.

Supported Digital Interfaces

PI's controllers are equipped with fast TCP/IP, USB and RS-232 interfaces (for details and exceptions see data sheets). Positioning commands can be formulated directly in SI units (e.g. microns and microradians), a feature which facilitates programming the system. In addition, parameters for the servo-loop, low-pass and notch filters are easily optimized and can be stored in non-volatile memory.

An optional parallel interface (PIO) bypasses the command parser and allows reading and writing up to 20,000 positions per second. Fast PCI interfaces offer transfer rates up to 1 MHz.

Interface Bandwidth vs. Timing

Piezo-driven stages can respond to a motion command on a millisecond or microsecond time scale.

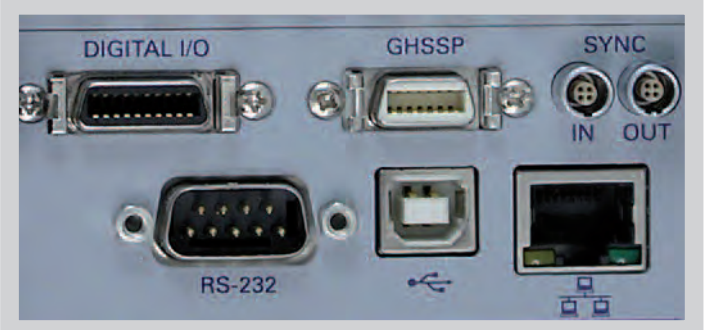
That is why synchronization of motion commands and data acquisition have a high impact on the quality of many applications, like imaging or micromachining. The USB, for example, was designed to transfer huge blocks of data at high speeds, but exact timing was a much lesser concern. While insignificant in less responsive positioning systems, this kind of non-deterministic behavior may not be tolerable in high-speed tracking or scanning applications. Each motion command—comprising just a few bytes—must be transferred instantaneously and without latency. A lower-bandwidth bus with higher timing accuracy may perform better in many applications.

There are several factors that affect the response of a digital interface: the timing accuracy of the operating system on the controlling computer; the bus timing protocol; the bandwidth of the bus; and, the time it takes the digital interface (in the piezo controller) to process each command. Parallel-port interfaces do not require command parsing and offer the best combination of throughput and timing accuracy.

In addition to the interface properties, the bandwidth of the nanopositioning system (mechanics and servo) matters. A slow system (e.g. 100 Hz resonant frequency) will not benefit from a responsive interface as much as a high-speed mechanism.

Speed Comparison

E-712 Nanopositioning controller	
MOV Commando	
RS-232	1.73 ms
TCP/IPt	0.07 ms
USB	0.13 ms
POS Query	
RS-232	2.57 ms
TCP/IPt	0.40 ms
USB	0.63 ms



PI controllers are available with a number of different interfaces for highest flexibility. In addition to the modern Ethernet (TCP/IP) and USB, many industrial customers still appreciate the robust RS-232 protocol.

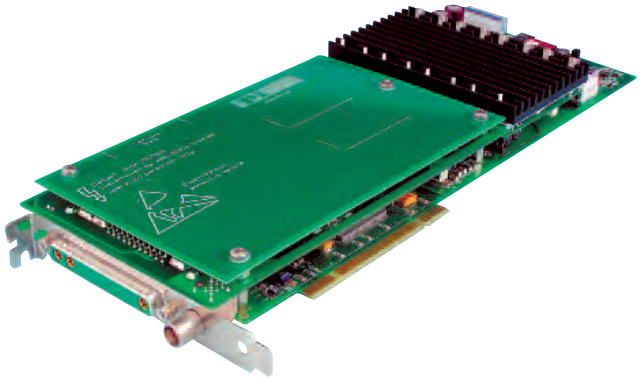
E-712.U3 Real-Time Upgrade: Real-time operating system for system integration

The use of real-time operating systems on the host PC avoids time delays when communicating with other system components, e.g. a vision system. PI offers a real-time Linux-based operating system as an upgrade for the host PC and also the linking of the GCS (PI General Command Set) software drivers to this operating system.

- A library which is 100 % compatible with all other PI GCS libraries is used for the communication with the real-time system. All PI GCS host software available for Linux can be run on this system.
- The real-time system running in the real-time CPU links PI interfaces and additional data acquisition cards for control. Open functions to enable you to implement your own control algorithms are made available. Furthermore, there is the possibility to record data, such as positions and voltages, from the PI interfaces and the additional data acquisition cards in real time, and also to output predefined tables with positions, for example, in real time to the PI interfaces and the additional data acquisition cards.
- The programming of your own real-time functions can be carried out in C/C++, MATLAB/SIMULINK and SCILAB.
- The system includes a PI GCS server, which allows the system to be operated as a blackbox using TCP/IP, via a Windows computer, for example.
- The system can be booted when installed on a PC or as a live version directly from the data carrier.
- A free demo version with restricted functionality is available.

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.

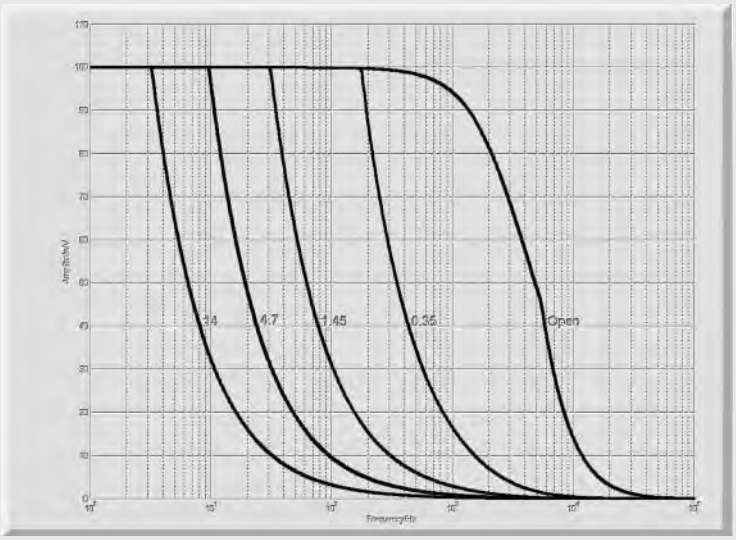
Ordering Information

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.

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

- **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**

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!

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-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

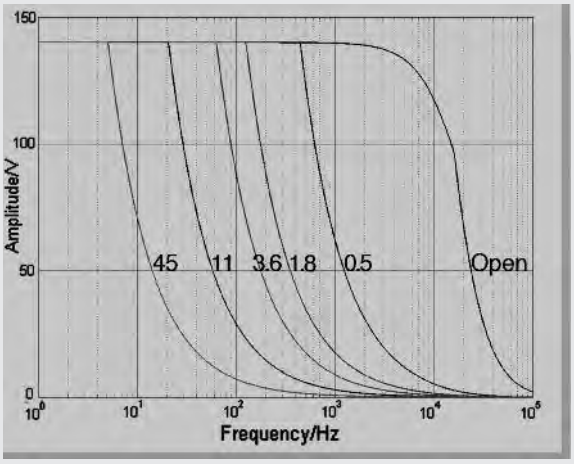
E-753.IO
Cable for Digital I/O Lines, 1.5 m, Solderable End

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.

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.

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-

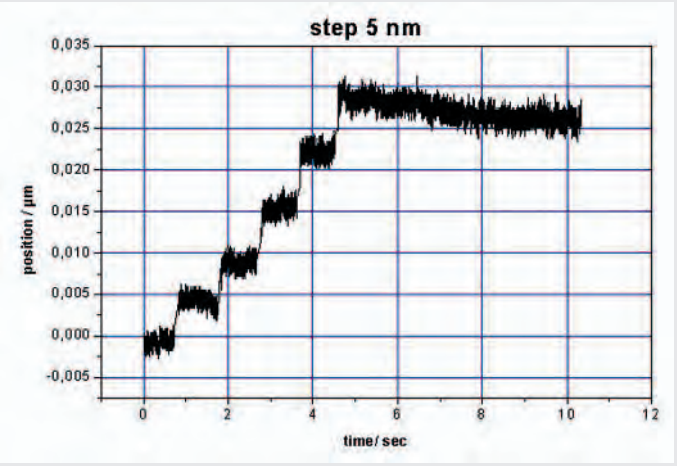
Ordering Information

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

E-755.101
Digital Controller for NEXLINE® Nanopositioning Linear Drives

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

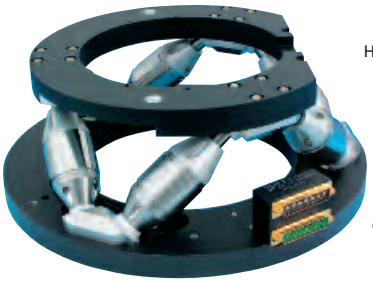


Steps of 5 nm performed by a system consisting of an N-214 NEXLINE® nanopositioner and an E-755.1A1 controller, measured by a high-resolution interferometer. Note the excellent system response to consecutive 5 nm step commands. In this case the closed-loop resolution is limited by the linear encoder in the N-214 (5 nm / increment); the E-755 can work with linear encoders with sub-nanometer resolution

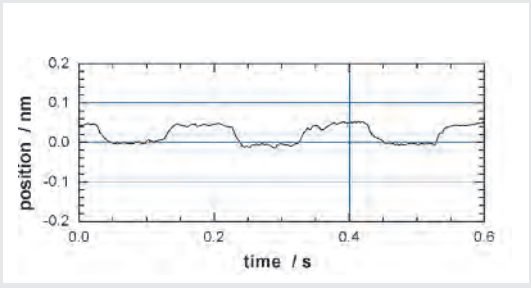
ing actuators are ideal for installation in inaccessible locations deep inside complex equipment, where nanometer-precise alignment and vibration cancellation are required.

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.



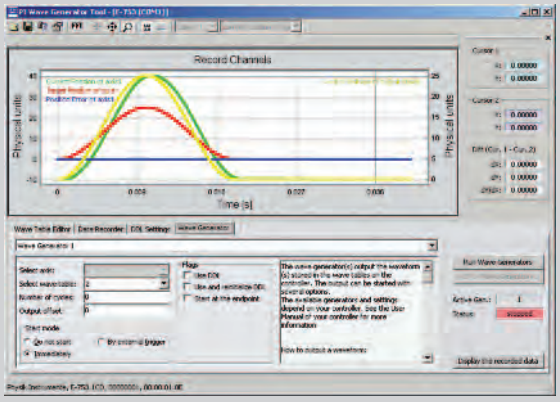
Steps of 50 picometers with a NEXLINE® drive in open-loop mode measured with external, ultra-high-resolution, capacitive sensor

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.

Advanced Functionality – Requirements from the Applications

Trajectory Storage, Data Recorder, Macros, System Recognition, Autofocus…



Data recorder and wave generator are part of the MikroMove® software for all digital controllers.

Data Recorder: Data Acquisition and Output

The flexibly configurable data recorder enables simultaneous recording and read-out of input and output signals, such as for sensor positions or control voltages depending on time stamps or using trigger signals.

Wave and Profile Generator: Pre-Defined and Programmable Trajectory Profiles

Trajectory profiles of arbitrary, user-defined mathematical functions enable complex 2-axis motion. Depending on the controller used, either time and position data value pairs can be saved (Wave Generator) or complete trajectory profiles with velocity, acceleration and jerk (rate of change of acceleration) can be specified (Profile Generator). The functionality includes:

- Programming of complex functions
- Quick access to common functions (e. g. sine, ramps, triangle and square waves ...)
- Coordination of two axes, e. g. for applications requiring circular motion
- Saving of defined functions in the controller

All controller specific functionalities are available as DLL function calls and LabVIEW VIs, which enables their simple integration in external programs. Additional graphical user interfaces allow convenient selection and customization.

Autofocus

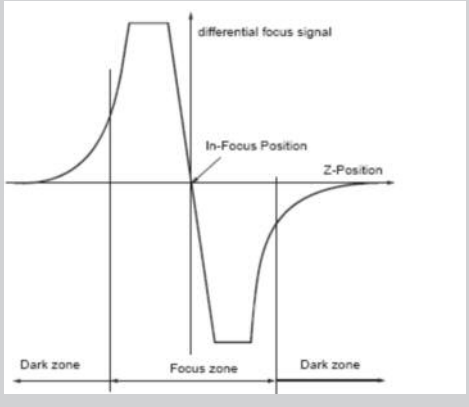
Autofocus routines stored in the firmware allow a function to be implemented which regulates according to an external sensor signal – on the signal output of a vision system, for example. The underlying zero transition method regulates towards a voltage of 0 V at the analog input of the digital controller. This must be able to perform the autofocus routine and have an analog control input.

The autofocus algorithms are possible as standard functions for the E-753 (1 channel), E-725 (3 channels) and E-712 (up to 6 channels) nanopositioning controllers.

ID-Chip Recognition for Automatic Adaptation of the Controllers to the Piezomechanics

The best results for the positional accuracy (linearity) of the piezo system are achieved by adapting various operating parameters. These depend on the individual stage. If digital electronics are tuned once, these parameters are stored in the ID-Chip of the stage. They are therefore automatically available again for the operation at a different digital controller, without the need for an adaptation. This exchangeability between stage and controller is a significant step forward for the flexible use of the systems.

ID-Chip recognition is performed in all E-753, E-725 and E-712 nanopositioning controllers.



Autofocus with the zero transition method: If the control signal is zero, the position is stably maintained. Possible drifts, which lead to a change of the input signal, can be compensated in this way.

DDL: Dynamic Digital Linearization

Nanometer Trajectory during Dynamc Scans

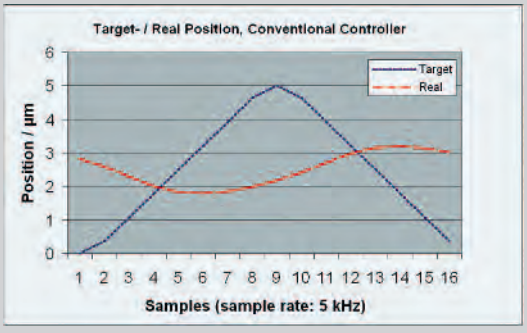
Improved Piezo Control: Dynamic Digital Linearization (DDL)

Conventional piezo controllers cannot completely avoid phase-shift and tracking errors in applications with rapid, periodic motion. This is due in part to the non-linear nature of the piezoelectric material, the finite control bandwidth and the inherent limitations of P-I (proportional-integral) servo-control, which only reacts when a position error is detected. The DDL option (ordering number E-710.SCN), available with recent digital piezo controllers such as E-753 (single-channel, see p. 2-108) or E-712 (multi-channel, see p. 2-140), solves this problem. This technology, developed by PI, reduces the error between the current and desired position to imperceptible values. The dynamic linearity and effectively usable bandwidth are thus improved by up to three orders of magnitude. DDL is of benefit to single- and multi-axis applications where motion follows a given trajectory repeatedly (see measurement curves).

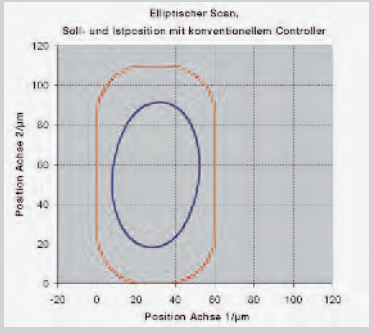
Ordering Information

E-710.SCN
Firmware Upgrade DDL
(Dynamic Digital Linearization)

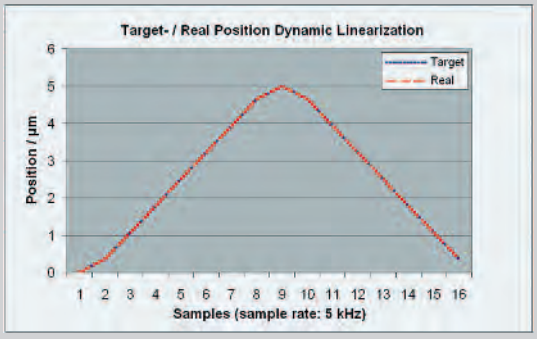
Available for controller E-712, E-725 and E-753.



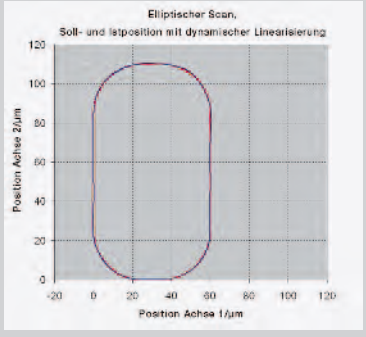
Nanopositioning systems with conventional PID controller: Single axis movement with a 312 Hz triangular signal. The difference between target and actual position can be up to 2.6 µm.



Elliptical scan with a XY piezo scanner and conventional P-I-servo controller. The outer curve shows the desired position, the inner curve shows the actual motion.



Nanopositioning system with DDL option: The same single axis movement as above, with 312 Hz triangular signal. The difference between target and actual position is practically unobservable and is about 7 nanometers.



The same scan as before but with a DDL controller. The tracking error is reduced to a few nanometers, desired and actual position cannot be distinguished in the graph.

DDL: Dynamic Digital Linearization

Application Examples

Moving samples into the spotlight:

Nanopositioning systems in fluorescence microscopy

Single molecule analysis provides detailed information on chemical characteristics or biological functions, but the detection of individual molecules is by no means easy. The extremely sensitive method of laser-based fluorescence analysis is thus used to increase the signal-to-noise ratio.

Confocal microscope with single molecule sensitivity

PicoQuant of Berlin, Germany supplies the MicroTime 200 confocal, time-resolved fluorescence microscope for this task. "This system uses the time-correlated single photon count for its data acquisition and can produce both 2D and 3D images" explains Dr. Felix Koberling, Head of System Development at PicoQuant. This makes it possible to realize a variety of the methods currently used in fluorescence microscopy such as FCS (Fluorescence Correlation Spectroscopy) and FRET (Fluorescence Resonance Energy Transfer) as well as so-called fluorescence lifetime imaging. Here not only the measured intensity but also the respective fluorescence lifetime is used for the visualization and quantification in order to analyze intracellular processes even in living cells. Its modular design means the fluorescence microscope is also very flexible in adjusting to different applications. (www.picoquant.de)

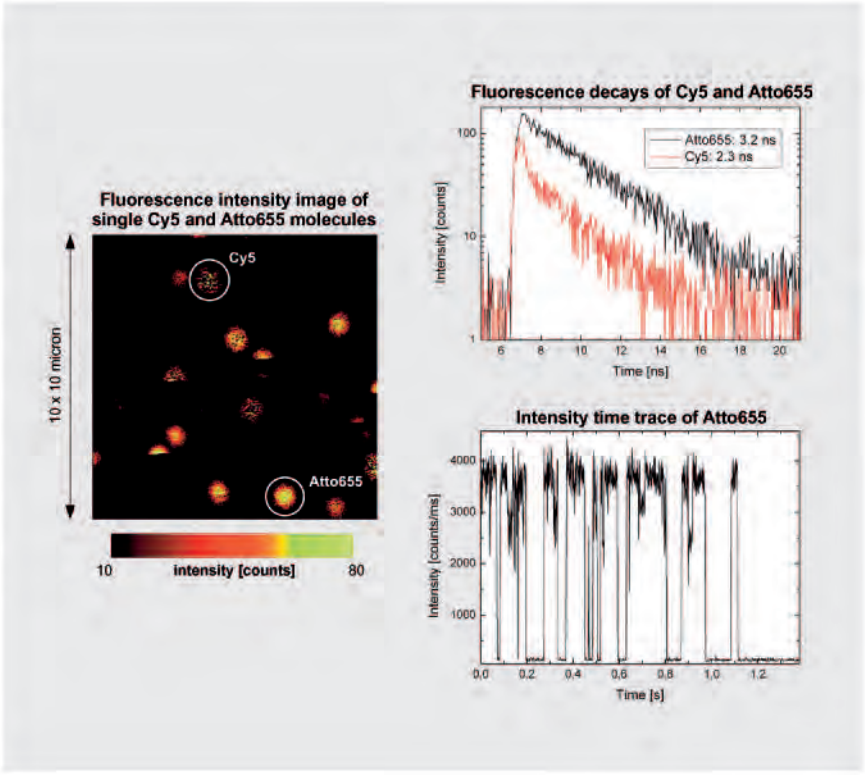
Maximum repeatability thanks to dynamic digital linearization

The P-733.2CD piezo stage was the scanner system of choice for the microscope. With a travel range of 100 x 100 µm and sub-nanometer resolution, this high-accuracy nanopositioning system matches the requirements of fluorescence microscopy perfectly.

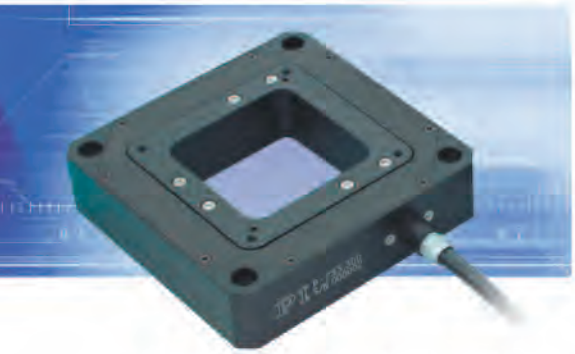
If the sample cannot be moved because it is enclosed in an environmental chamber, for example, the same positioning system can be used to the microscope objective instead. In all cases, however, the integrated direct-measuring capacitive sensors allow the scanner to produce an accurate determination of the actual position value. The first step is typically to record the image of a sample by scanning an area quickly before in a second step individual points of interest are analyzed in detail. In order to return to the exact location of these points within a few nanometers, an advanced digital control algorithm (DDL) was devised. The Dynamic Digital Linearization algorithm improves scanning linearity, i.e. repeatability by up to three orders of magnitude compared to conventional PID (proportional, integral, derivative control).

The third dimension: Additional focus adjustment

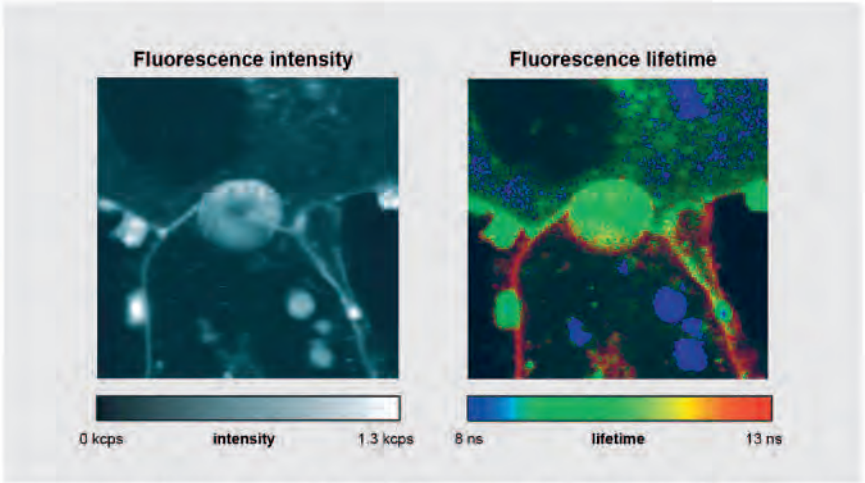
The P-721.CLQ PIFOC® Z-drives are used for three-dimensional images. They provide millisecond response times and their flexure guiding and capacitive sensors enable very accurate positioning, even when the travel ranges are relatively large. "PI's piezo-based nanopositioning systems make a decisive contribution to the fact that we can achieve very high-quality results with our MicroTime 200", says Koberling in conclusion.



Single molecule image of a mixture of immobilized Atto665- and Cy5-molecules. The single molecules can be distinguished by the fluorescence lifetime. (Photo: PicoQuant)



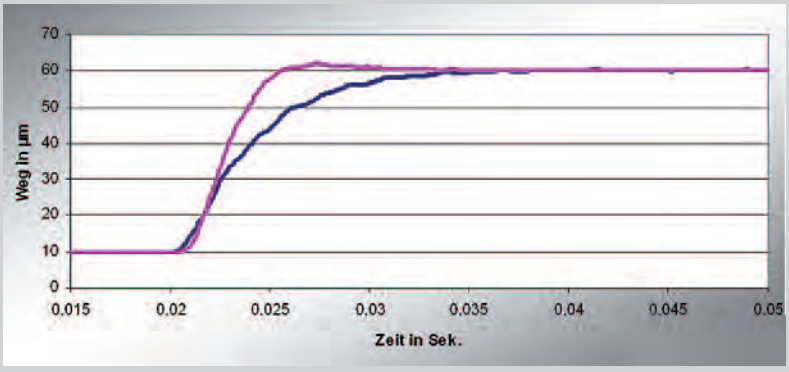
The P-733 piezo-based nanopositioning system provides a travel range of 100 x 100 µm. The optional Dynamic Digital Linearisation (DDL) features for digital motion controllers improves the scanning linearity by a factor of to 1000. Tracking error and phase lag are reduced to almost non noticeable values. (Photo: Physik Instrumente (PI))



Fluorescence intensity image (left) and fluorescence lifetime image of a liver cancer cell, stained with the NBD dye to analyze the organization of lipids. In the image on the right, the lifetime can be used to clearly identify different lipid structures. (Photo: PicoQuant)

Advanced Piezo Control

Alternative Regulation Concept for Faster Settling



Transient response of an system with optimated PID parameters (blue) and Advanced Piezo Control (pink).

An alternative control concept is provided for the modular E-712 controller for nanopositioning systems: Advanced Piezo Control. It is based on a state controller which, in turn, is based on a model of the positioning system.

Advanced Piezo Control actively damps the resonance frequency, in contrast to conventional PID controllers with notch filter where the mechanical resonance is cut out of the excitation spectrum.

Advanced Piezo Control for Faster and More Stable Control

The consequences are faster settling times and lower sensitivity with respect to interferences from the outside.

The phase trueness is significantly improved compared to the damping with one or even two notch filters. This has immediate effects on the trajectory trueness and the settling response.

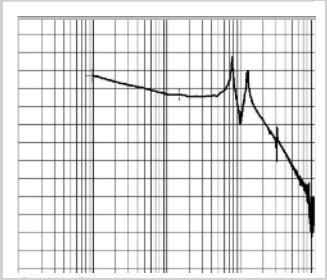
Limitations of the Advanced Piezo Control

If the mechanical system has too many resonances close together, or if the resonance frequency to be damped is about 1 kHz or more, the state controller in this form no longer has any advantage over conventional PID controllers. Please discuss your application with us.

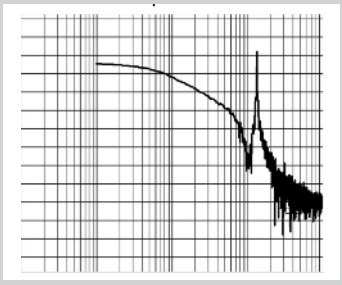
Ordering Information

E-712.U1
Firmware Upgrade Advanced Piezo Control Regleroption

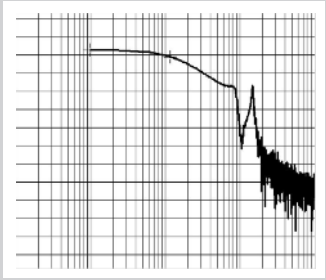
Advanced Piezo Control is also available for the Controller E-753 (1 Channel) and for the E-725 (3 Channels). Ask your PI Sales Department.



Bode diagram of an unloaded, unregulated system with two resonance frequencies.



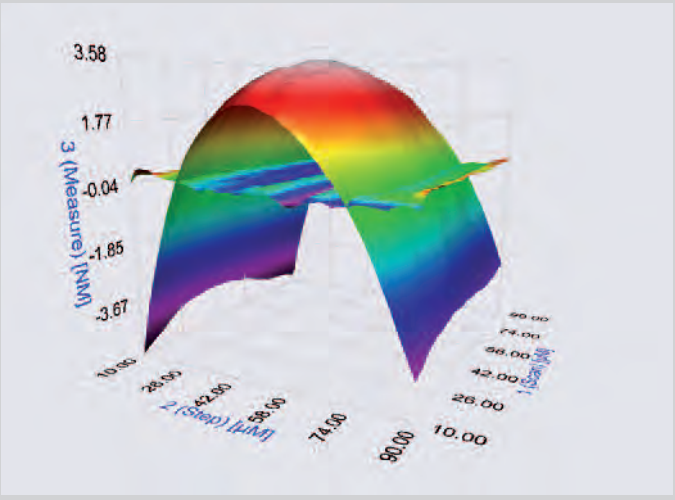
Bode diagram of a regulated system with one notch filter at the first resonance.



Bode diagram of a system regulated with Advanced Piezo Control. The resonances are better suppressed, the phase deviation is lower compared to the suppression with a notch filter.

PICOPlane™ for Piezo Systems

Implement Motions with Nanometer Flatness



The PicoPlane™ algorithm reduces the undesirable crosstalk on the Z-axis to values below one nanometer

PI nanopositioning systems intrinsically have a high tracking accuracy, which is typically in the region of about 10 nanometers.

This is achieved by using flexures which are very stiff in the direction perpendicular to the direction of motion.

AFM — One Nanometer is Just About Good Enough

There are applications, however, which require a planar motion of one nanometer or so. This is the case with scanning atomic force microscopes, where the structure of the sample is on the atomic scale and where inaccuracies in the sample positioning cannot be tolerated.

PICOPlane™ for Nanometer Evenness

PICOPlane™ is a one or two-dimensional method which counteracts the crosstalk into the axis perpendicular to the scan plane or the line of motion and reduces it to a minimum.

The requirement here is a dynamic and finely controllable axis with small stroke. This axis operates in the direction of the crosstalk, which has previously been measured and stored in the controller. The mapping process here has the advantage over the active control that the correction movement can occur virtually in real time. This ensures that, during the scanning motions, no phase shift between the actual and controlled crosstalk occurs as distortion.

Hardware Requirements

This additional axis can either be added to the existing piezo system, or is already integrated. PI offers both solutions, depending on the nanopositioning system. The digital controller belonging to the system must provide an additional unregulated channel and support the PICOPlane™ algorithm.

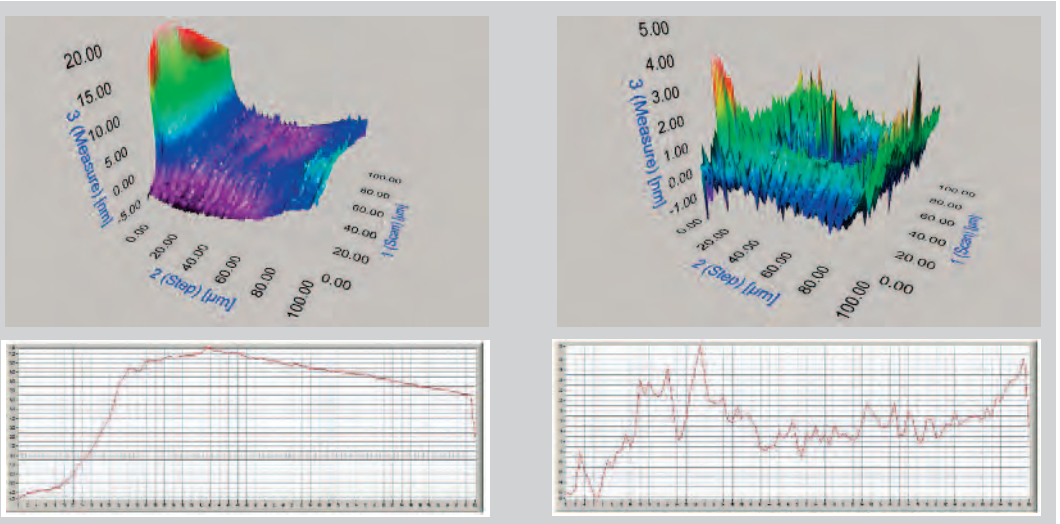
Ordering Information

E-712.U2
Firmware Upgrade PicoPlane™: Option for Nanometer Guiding Accuracy (compatible hardware required)

PICOPlane™ requires additional Amplifier Channel and a PICOPlane™ Axis.

PICOPlane™ is also available for Compact gerät E-725 (3 Channels).

PIHera™ XY-scanner with travel range of 800x800 µm and PICOPlane™ Upgrade



Area scan and cross section of the measurement of the crosstalk from the XY plane without (left) and with (right) PICOPlane™ activated. The effect is a significantly reduced deviation in the Z-axis.

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

Ordering Information

E-861.1A1
NEXACT® Controller, 1 Channel, 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**

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)

C-663/863/867 Mercury™ Motion Controller

Networkable single-axis controller for step, DC and piezo motors

The C-867 piezomotor controller and the M-692 low-profile positioner with integrated PILine® ceramic linear drive

- **Flexible and reasonably priced**
- **Stepper motor control or servo controller for DC and piezo ultrasonic motors**
- **High-speed encoder input up to 50 MHz**
- **USB, RS-232 and analog interfaces**
- **4 + 4 programmable TTL inputs/outputs for flexible automation**
- **Macro programmable for stand-alone operation**
- **Daisy-chain network capability for up to 16 axes**
- **Nonvolatile EEPROM for macros and parameters**
- **Optional joystick for manual operation**

Technical Data

Model	C-863.10	C-663.10	C-867.160
Function	DC-servo-motor controller	Stepper motor controller	Controller / driver for PILine® piezo motors / systems
Drive configuration	DC motor analog and PWM (ActiveDrive™)	2-Phase-Stepper motor	PILine® motors, single or dual U-161 to U-164
Motion and control			
Servo characteristics	P-I-D-servo control, parameter change on-the-fly	–	P-I-D-servo control, parameter change on-the-fly
Trajectory profile modes	Trapezoidal, point-to-point	Trapezoidal, point-to-point	Trapezoidal, point-to-point
Encoder input	A/B quadrature TTL signal; 20 MHz	–	A/B quadrature TTL signal; 50 MHz
Micro-step resolution	–	1/16 full step	–
Stall detection	Servo off, triggered by programmable position error	1/16 full step	Servo off, triggered by programmable position error
Input limit switch	2 x TTL, programmable	2 x TTL, programmable	2 x TTL, programmable
Input reference switch	1 x TTL, programmable	1 x TTL, programmable	1 x TTL, programmable
Motor brake	1 x TTL, software controlled	1 x TTL, programmable	–
Electrical properties			
Output power	max. 30 W (PWM)	15 to 30 V	max. 15 W
Output voltage	0 to 15 V	–	max. 200 Vpp
Current limiting / motor phase	–	1000 mA	–
Interfaces and operating			
Communication interfaces	USB, RS-232	USB, RS-232	USB, RS-232
Motor connector	Sub-D connector, 15-pin (f)	Sub-D connector, 15-pin (f)	MDR14
Controller network	Up to 16 units on single interface	Up to 16 units on single interface	Up to 16 units on single interface
I/O ports	4 analog/digital Inputs, 4 digital Outputs (TTL)	4 analog/digital Inputs, 4 digital Outputs (TTL)	4 analog/digital Inputs, 4 digital Outputs (TTL)
Command set	Mercury™ Command Set, GCS (via DLL)	Mercury™ Command Set, GCS (via DLL)	PI General Command Set (GCS)
User software	PIMikroMove®, MMCRun	PIMikroMove®, MMCRun	PIMikroMove®
Software drivers	GCS (PI General Command Set)-DLL, LabVIEW drivers, native Mercury™ DLL	GCS (PI General Command Set)-DLL, LabVIEW-drivers, native Mercury™ DLL	GCS (PI General Command Set)-DLL, LabVIEW drivers
Supported functionality	Start-up macro; internal safety circuitry: Watchdog Timer	Start-Up Macro	Start-Up Macro, Macro, data recorder for recording parameters as motor input voltage, velocity position or position error
Manual control (optional)	Pushbutton box, joystick (for 2 axis), Y-cable for 2D motion	Pushbutton box, joystick (for 2 axis), Y-cable for 2D motion	Pushbutton box, joystick (for 2 axis), Y-cable for 2D motion
Miscellaneous			
Operating voltage	15 to 30 V included: external power suplly 15 V / 2 A	24 VDC from external power supply (included)	24 VDC from external power supply (included)
Operating temperature range	0 to +50 °C	0 to 50 °C	+5 to +40 °C
Mass	0.3 kg	0.3 kg	1.01 kg
Dimensions	130 x 76 x 40 mm	130 x 76 x 40 mm³	206 x 130 x 66 mm (without mounting rails)

Ordering Information

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

C-663.10
Mercury™ Step Stepper Motor Controller, 1 Channel, 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

Hexapod Controller

Easily Operate Powerful Multi-Axis Positioning

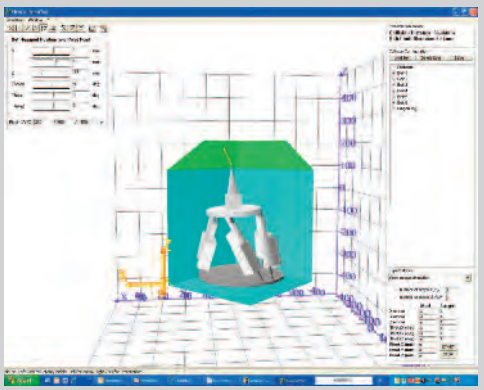
High-Power Hexapod Controller

- **For hexapods plus two further motorized axes, six further piezo axes as optional extra**
- **Real-time operating system**
- **TCP/IP and RS-232 interface**
- **Simple placing of commands in Cartesian coordinates, integrated coordinate transformation**
- **PivotAnywhere™: Freely programmable pivoting point of the motion**
- **Comprehensive software package**

Technical Data

Function	Multi-Axis Automation platfrom; Hexapod controller
Drive type	Servo motors and piezo drives (optional)
Channels	Up to 8 axes, (servo motors), max. 6 piezo axes (optional)
Motion and control	
Servo characteristics	Programmable 32-bit-PID V-ff filter, 100 µs/active axis
Processor	CPU 133 MHz C-842.23/C-842.43: Motion chip, 2.5 kHz Servo Update Rate
Electrical properties	
Operating Voltage	100 to 250 VAC, 50 / 60 Hz
Output power per 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 per channel	±10.5 V analog PWM: TTL for SIGN and MAGN
Current limitation	1 A max. (short-circuit-proof)
Interfaces and operation	
Communication interfaces	RS-232, TCP/IP
Motor connector	System connector
Controller network	Via TCP/IP
Command set	PI General Command Set (GCS), ASCII Communication
User software	PIMikroMove®
Software driver	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	with front keyboard and LCD-display (optional) Manual control F-206.MC6 (optional)
Miscellaneous	
Operating temperature range	+10 °C to +50 °C
Dimensions	19-inch case, 450 mm x 460 mm x 180 mm

M-850 Precise Hexapod for Loads up to 200 kg with Standard Controller



Simulation of the motion of the hexapods in a freely programmable environment to prevent collisions. The program can run on the host PC during the motion of the hexapod and prevent undesirable position during the operation.

Thinking in Systems

All in One Hand – All from One Hand

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

To assure that the subassemblies used satisfy PI's quality requirements, PI fabricates all components itself, develops the ultra-high-resolution sensors and controllers, and programs both control algorithms and operating software. In Lederhose (Thuringia) at PI Ceramic, piezoelectric drives are developed, optimized and manufactured. With PIC, PI is the only positioning system manufacturer worldwide which develops its own piezoelectric actuators to meet market requirements. The resulting flexibility is an important reason for the technological leadership enjoyed by PI and its customers.

Capacitive Sensors for Nanometrology

Special sensors can fulfill the requirements of many applications for dynamics, linearity and stability better than that provided by standard strain gauges. Non-contact capacitive sensors measure position without drift and provide linearity to 0,01% of the measurement range. The high resolution of up to 0.0005 % allows detection and compensation of the smallest position errors. PI uses capacitive sensors developed in-house, making it possible to adapt the sensor geometries to the space available. Placing the sensors as close as possible to the moving platform, PI provides direct metrology systems—systems in which motion is detected where it is used. PI capacitive sensors are also offered as stand-alone products for nano - metrology applications.

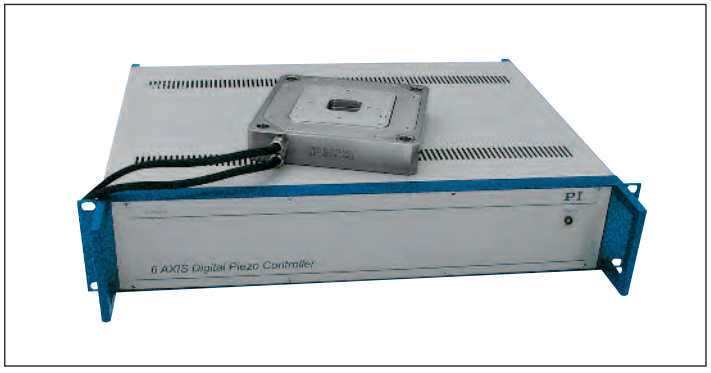
Control of Positioning Systems

The characteristics of drives and sensors are made usable by the drive and control electronics. PI has designed all electronics to match the mechanics optimally. Electronic amplifiers for piezoelectric actuators must provide low noise and drift. Fast rise times make possible sub-millisecond response times and optimized control algorithms minimize settling times.

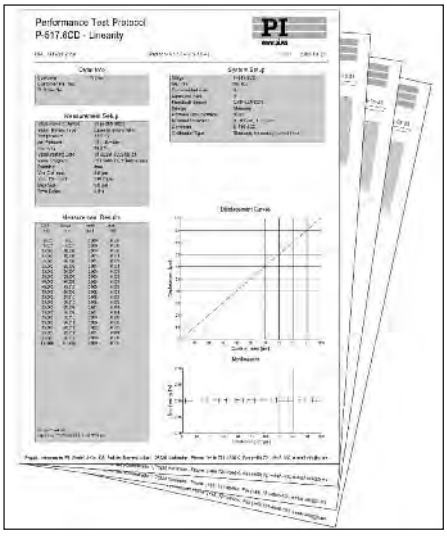
Digital controllers include advanced algorithms to improve the system performance: coordinate transformation matrices matched to the mechanical geometries allow for commanding complex systems in Cartesian coordinates; filters support servo-control by suppressing resonant vibrations; pre-shaping of control signals minimizes trajectory deviation during dynamic scans. All functions are easily accessible through fast and modern interfaces and comprehensive user software and software drivers.

Flexibility Through Competent Partners

High quality requires qualified partners. Over the years PI has thus qualified a number of highly specialized suppliers with whom we now work as partners—partners whose conception of quality is every bit as high as our own.



E-710 6-axis Digital Piezo Controller with 6-DOF piezo nanopositioning stage



All PI nanopositioning systems come with extensive system performance documentation

PI Software

Operating Positioning Systems Effectively & Conveniently

Communication between PI components is based upon a universal command set (GCS – General Command Set). It decouples hardware and software, and is used for all drive principles.

The high quality of positioning systems is made apparent in daily operation by PI software. Starting with simple commissioning, through convenient operation with a graphical interface, to quick and simple integration in customized programs with high performance, PI software covers all aspects important to an application.

Universal Command Set Simplifies Commissioning and Programming

For uniform operation of nano and micropositioning systems, the universal PI General Command Set (GCS) is used. GCS operation is independent of the controller or drive principle used, so that several positioning systems can be controlled together, or new systems can be introduced with a minimum of programming effort. With GCS the development of custom application programs is simplified and less prone to errors, because the commands for all supported devices are identical in syntax and function. Through the use of the GCS command set with its convenient functions, the orientation phase and application development process is significantly accelerated.

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 Linux libraries for 32- and 64-bit platforms. This facilitates the development of custom macros, as well as integration with programming languages like LabVIEW, C++ or MATLAB.

All about software in the internet—a server offers download of manuals and software CD mirrors

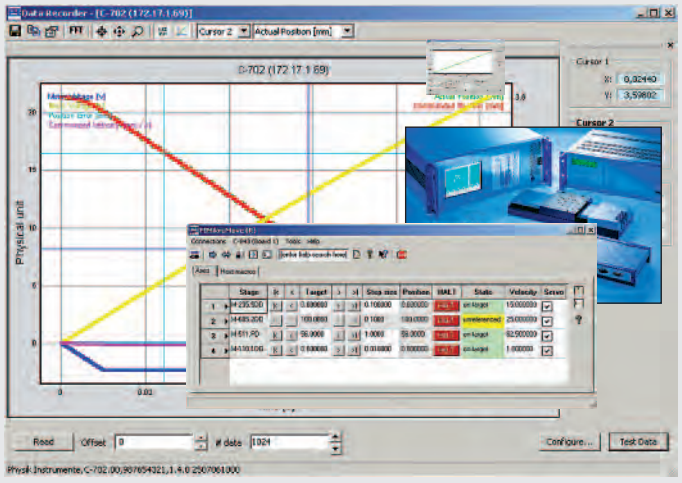
Software Updates Online

PI supports users with free updates, detailed online help and well structured manuals which ease initiation of the inexperienced but still answer the detailed questions of the professional.

Supported Operating Systems
Microsoft Windows Vista
Microsoft Windows XP
Microsoft Windows 2000
Linux

PIMikroMove™ Software

Simple Operation of Positioning Systems



A uniform interface for all axes

- **Operation of PI Motor, Piezo, Piezomotor, Hexapod & Hybrid Controllers**
- **1D/2D Scan and AutoFind**
- **Macros for Recurring Tasks and Automation**
- **Optimizing all Servo Parameters**

PI positioning systems can be controlled with PIMikroMove™ in a clear and simple manner; all connected controllers and axes are accessed via the same graphical interface.

PIMikroMove™ supports quick commissioning of controllers and positioners, comprehensive system optimization as well as the programming of macros.

All Axes in One View

With PIMikroMove™ all axes connected can be controlled from one program instance. This, independent of which PI controller is connected to which axis and which interface (TCP/IP, USB, RS-232, GPIB, PCI). For example, it is possible to have two axes in an XY application connected to two different controllers, but still command them with PIMikroMove™ from the same window.

Optimal System Behavior

PIMikroMove™ also allows the user to optimize the system behavior through convenient servo tuning. This possibility is especially helpful if the mechanical properties of a system are changed, for example by applying a different load. The system response and stability can then be optimized with the convenient parameter tuning tool. For recurring tasks, different sets of optimized parameters can be saved as stage profiles and then activated as needed in custom-programmed applications.

Macros Ease Recurring Tasks

PIMikroMove™ considerably simplifies the creation of macros for recurring tasks. Execution of a macro, consisting of a previously stored list of GCS commands, can be commanded over the interface or, if supported by the controller, run automatically on power-up, with or without a host PC connected.

Controllers without their own macro facility, like the C-843, can be commanded by host macros which PIMikroMove™ edits and stores in the host PC. Host macro execution can be triggered with digital I/O lines or software commands and support multiple axes connected to different controllers.

With the position pad, two or more independent axes can be moved by a mouse or joystick as an XY stage, also in vector moves.

1D/2DScan and AutoFind

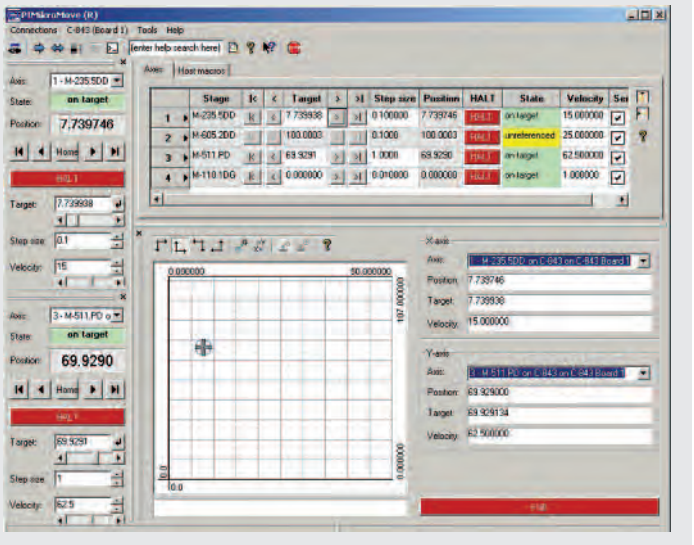
Scan 1D/2D can measure an input source while moving up to two axes. Moved axes and input source need not be assigned to the same controller. The input source to be measured can be an analog input, an axis position or a raw position sensor value. The measured data is visualized and can be saved to a file on the host PC. AutoFind tries to find the maximum of an intensity signal by modifying the position of two axes.

FFT, Profile Generator, Data Recorder

PIMikroMove™ also supports controller-specific features.

Data recorder: record various motion and system parameters, run FFT (Fast Fourier Transformation) on the data as well as export it to programs like Microsoft Excel (CSV format).

Profile Generator: synchronize motion of several axes along multi-order, mathematically defined curves or customized arbitrary functions.



All axes and the position pad can be displayed in one window

Symbols and Units

A	Surface area [m^2] (meter^2)
α	Coefficient of Thermal Expansion (CTE) [K^{-1}] (1 / kelvin)
C	Capacitance (F) [A·s/V]
d_{ij}	Piezo modulus (tensor components) [m/V] (meter/volt)
d_s	Distance, thickness [m] (meter)
ϵ	Dielectric constant [A·s/V·m] (ampere · second / volt · meter)
E	Electric field strength [V/m] (volt/meter)
f	Operating frequency [Hz] (hertz = 1/second)
F	Force [N] (newton)
f_0	Unloaded resonant frequency [Hz] (hertz = 1/second)
g	Acceleration due to gravity: 9.81 m/s^2 (meter/second^2)
i	Current [A] (ampere)
k_S	Stiffness of restraint (load) [N/m] (newton/meter)
k_T	Stiffness of piezo actuators [N/m] (newton/meter)
L_0	Length of non-energized actuator [m] (meter)
ΔL	Change in length (displacement) [m] (meter)
ΔL_0	Nominal displacement with zero applied force, [m] (meter)
$\Delta L_{t=0.1}$	Displacement at time t = 0.1 sec after voltage change, [m] (meter)
m	Mass [kg] (kilogram)
P	Power [W] (watt)
Q	Charge [C] (coulomb = ampere x second)
S	Strain [$\Delta L/L$] (dimensionless)
t	Time [s] (second)
T_C	Curie temperature [°C]
U	Voltage [V] (volt)
U_{p-p}	Peak-to-peak voltage [V] (volt)

PI Piezo • Nano • Positioning

Program Overview

- Piezo Ceramic Actuators & Motors
- Piezo Nanopositioning Systems and Scanners
- Active Optics / Tip-Tilt Platforms
- Capacitive Nanometrology Sensors
- Piezo Electronics: Amplifiers and Controllers
- Hexapod 6-Axis Positioners / Robots
- Micropositioning Stages & Actuators
- Photonics Alignment Systems, Solutions for Telecommunications
- Motor Controllers
- Ultrasonic Linear Motors

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