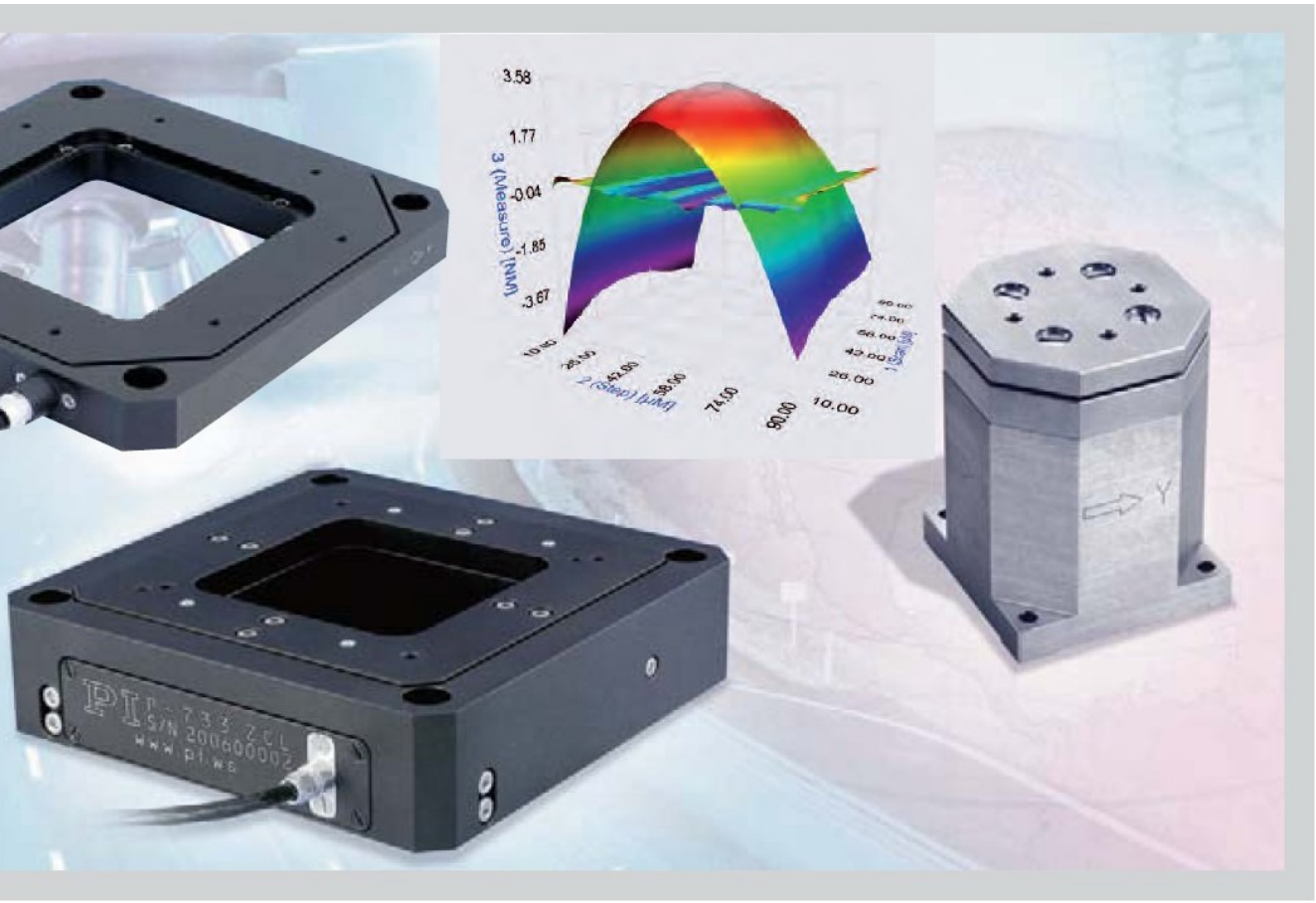
Planar AFM Piezo Scanner Stages & Controllers

Piezo Systems, Parallel Kinematics, Low Bow, Single Module



PICOPlane™ for AFM Scanner Piezo Systems

Implement Motions with Nanometer Flatness

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

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

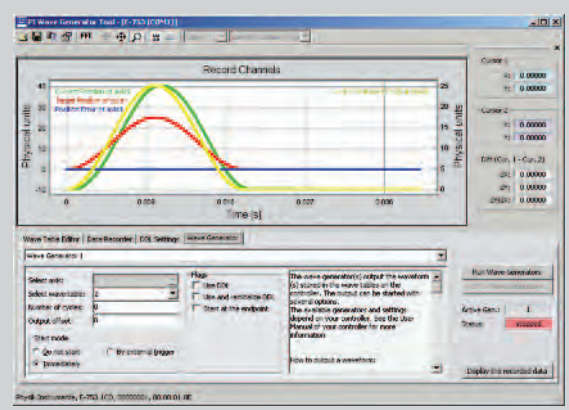
E-712.U2
Firmware Upgrade PicoPlane™: Option for Nanometer Guiding Accuracy (compatible hardware required)

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

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

Advanced Digital Piezo Control

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

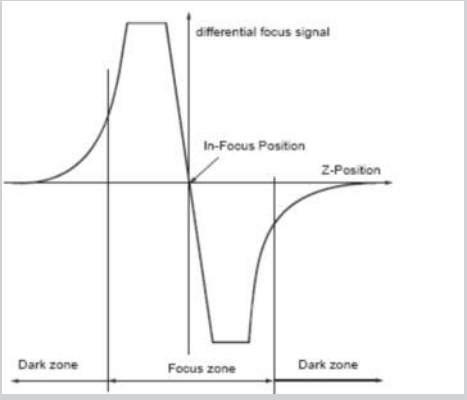
Autofocus routines stored in the firmware allow a function to be implemented which regulates according to an external sensor signal – on the signal output of a vision system, for example. The underlying zero transition method regulates towards a voltage of 0 V at the analog input of the digital controller.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



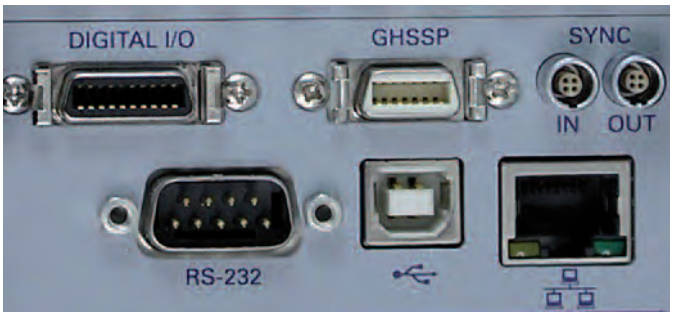
Autofocus with the zero transition method: If the control signal is zero, the position is stably maintained. Possible drifts, which lead to a change of the input signal, can be compensated in this way.

DDL: Dynamic Digital Linearization

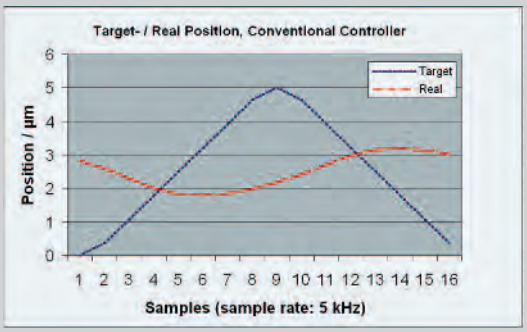
Nanometer Trajectory during Dynamc Scans

Improved Piezo Control: Dynamic Digital Linearization (DDL)

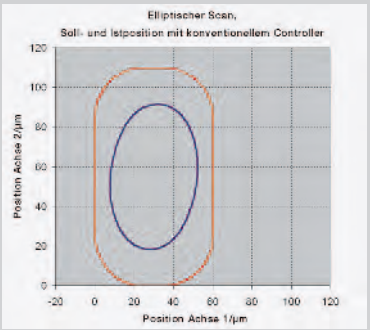
Conventional piezo controllers cannot completely avoid phase-shift and tracking errors in applications with rapid, periodic motion. This is due in part to the non-linear nature of the piezoelectric material, the finite control bandwidth and the inherent limitations of P-I (proportional-integral) servo-control, 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).



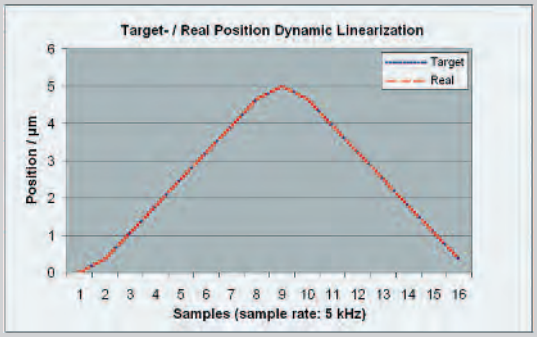
PI controllers are available with a number of different interfaces for highest flexibility. In addition to the modern Ethernet (TCP/IP) and USB, many industrial customers still appreciate the robust RS-232 protocol.



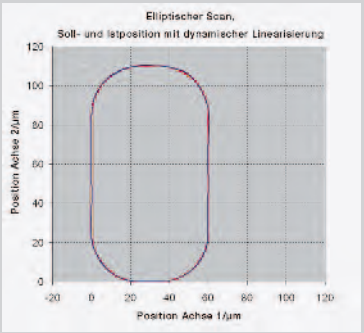
Nanopositioning systems with conventional PID controller: Single axis movement with a 312 Hz triangular signal. The difference between target and actual position can be up to 2.6 µm.



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.

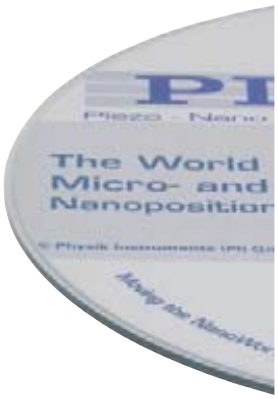


The same scan as before but with a DDL controller. The tracking error is reduced to a few nanometers, desired and actual position cannot be distinguished in the graph.

P-313 PicoCube™ 20 Picometer Planar XY(Z) Piezo Scanner

Picometer Precision, High Bandwidth, No Servo Lag, for Scanning Probe Microscopy

XY Stage



- 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

P-628K Long-Travel XY Piezo Stage with Nanometer Flatness

Novel Active Z-Axis Design Provides Real Time Runout Compensation

- 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

P-915K XY-Theta-Z Piezo Stage

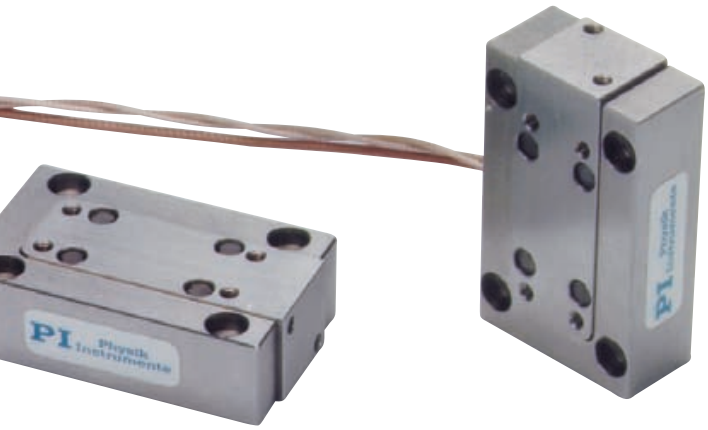
3 Degrees of Freedom in the XY Plane

- 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-753 High Stiffness Z-Stage

High-Dynamics, Very Stable Piezo Nanopositioner



P-753 High Stiffness, fast ano-precision 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

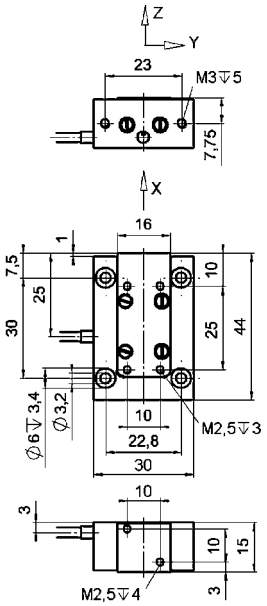
P-753.31C
LISA High-Dynamics Nanopositioning System, 38 µm, Direct Metrology, Capacitive Sensor, LEMO Connector

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

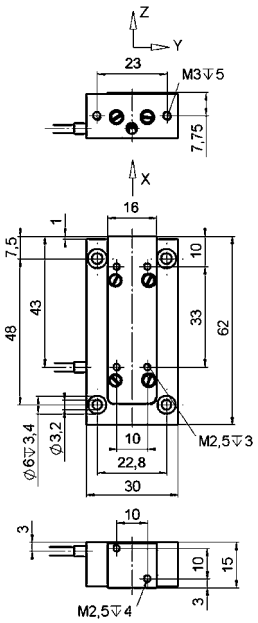
P-753.2CD*
LISA High-Dynamics Nanopositioning System, 25 µm, Direct Metrology, Capacitive Sensor, Sub-D Connector

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

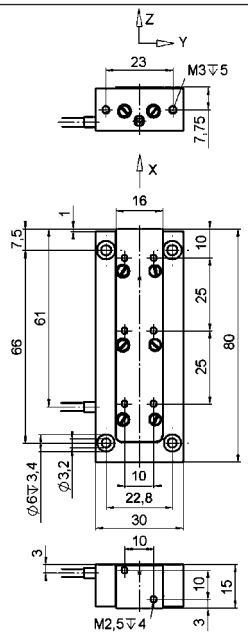
*Vacuum versions to 10^{-9} hPa are available as P-753.xUD, non-magnetic vacuum versions can be ordered as P-753.xND.



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

Index

Model	P-753.11C	P-753.21C	P-753.31C	P-753.1CD	P-753.2CD	P-753.3CD	Units	Tolerance
Active axes	X	X	X	X	X	X		
Motion and positioning								
Integrated sensor	Capacitive	Capacitive	Capacitive	Capacitive	Capacitive	Capacitive		
Closed-loop travel	12	25	38	12	25	38	µm	calibrated
Closed-loop / open-loop resolution	0.05	0.1	0.2	0.05	0.1	0.2	nm	typ., full travel
Linearity, closed-loop	0.03	0.03	0.03	0.03	0.03	0.03	%	typ.
Repeatability	±1	±2	±3	±1	±2	±3	nm	typ.
Pitch / yaw	±5	±7	±10	±5	±7	±10	µrad	typ.
Mechanical properties								
Stiffness in motion direction	45	24	16	45	24	16	N/µm	±20 %
Unloaded resonant frequency	5.6	3.7	2.9	5.6	3.7	2.9	kHz	±20 %
Resonant frequency @ 200 g	2.5	1.7	1.4	2.5	1.7	1.4	kHz	±20 %
Push/pull force capacity in motion direction	100 / 20	100 / 20	100 / 20	100 / 20	100 / 20	100 / 20	N	Max.
Load capacity (vertical/horizontal mounting)	10 / 2	10 / 2	10 / 2	10 / 2	10 / 2	10 / 2	kg	Max.
Drive properties								
Ceramic type	PICMA® P-885	PICMA® P-885	PICMA® P-885	PICMA® P-885	PICMA® P-885	PICMA® P-885		
Electrical capacitance	1.5	3.1	4.6	1.5	3.1	4.6	µF	±20 %
Dynamic operating current coefficient	12	15	15	12	15	15	µA/(Hz • µm)	±20 %
Miscellaneous								
Operating temperature range	-20 to 80	-20 to 80	-20 to 80	-20 to 80	-20 to 80	-20 to 80	°C	
Material	Stainless steel	Stainless steel	Stainless steel	Stainless steel	Stainless steel	Stainless steel		
Dimensions	44 x 30 x 15	44 x 30 x 62	44 x 30 x 80	44 x 30 x 15	44 x 30 x 62	44 x 30 x 80	mm	
Mass	0.15	0.205	0.25	0.16	0.215	0.26	kg	±5 %
Cable length	1.5	1.5	1.5	1.5	1.5	1.5	m	±10 mm
Sensor / voltage connection	LEMO	LEMO	LEMO	Sub-D Special	Sub-D Special	Sub-D Special		

Resolution of PI Piezo Nanopositioners is not limited by friction or stiction. Value given is noise equivalent motion with E-503 (p. 2-146) amplifier.
Recommended controller / amplifier
LEMO connector: E-500 (p. 2-142) piezo controller system with E-505 high-power amplifier (p. 2-147) and E-509 servo module (p. 2-152)
Sub-D special connector: E-610 servo controller / amplifier card (p. 2-110), E-625 servo controller, bench-top (p. 2-114), E-665 high-power display controller, bench-top (p. 2-116), E-753 digital controller (p. 2-108)

P-752 High Stiffness 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.

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.

Application Examples

- Disc-drive-testing
- Metrology
- Nanopositioning
- Scanning microscopy
- Photonics / integrated optics
- Interferometry
- Biotechnology
- Micromanipulation

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!

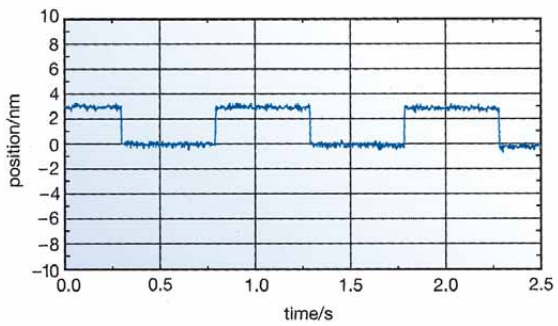
Ordering Information

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

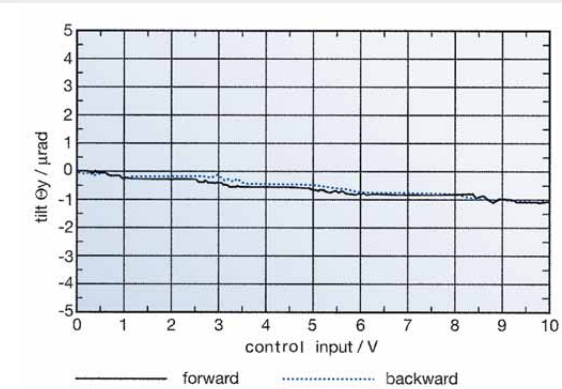
P-752.21C
High-Dynamics Piezo Nanopositioning System, 30 µm, Direct Metrology, Capacitive Sensor, LEMO Connector

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



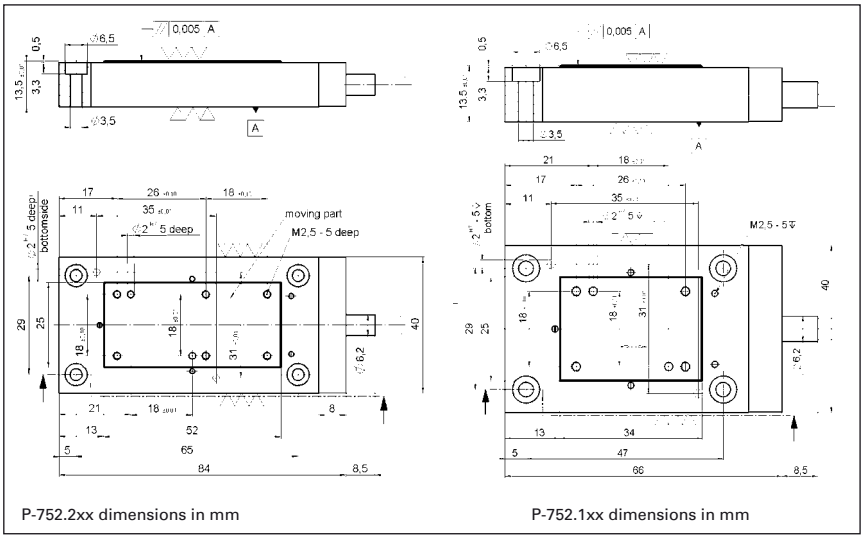
Response of a P-752.11C to a square wave control signal with 3 nm amplitude shows true sub-nm positional stability, incremental motion and bidirectional repeatability (measured with E-501 & E-503.00 & E-509.C1 controller, bandwidth set to 240 Hz)



Typical 0.5 µrad bidirectional trajectory repeatability (P-752.11C stage) means processes may be performed bidirectionally for twice the productivity

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.



P-752.2xx dimensions in mm

P-752.1xx dimensions in mm

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		

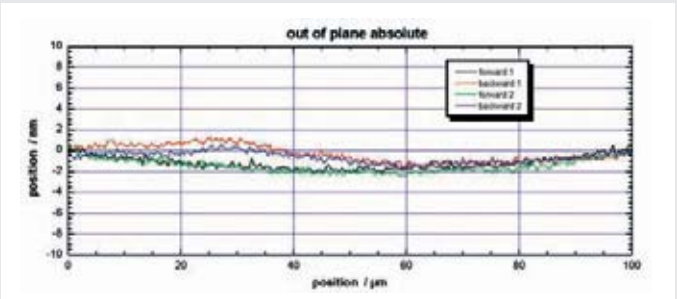
Resolution of PI Piezo Nanopositioners is not limited by friction or stiction. Value given is noise equivalent motion with E-503 (p. 2-146) amplifier.

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-734 Planar Low Bow XY Piezo Scanner

High-Dynamics System with Minimum Runout & Clear Aperture

P-734 low-bow flexure nanopositioning stage with ultra-precise trajectory control



Typical flatness of P-734 motion is in the low nanometer range

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

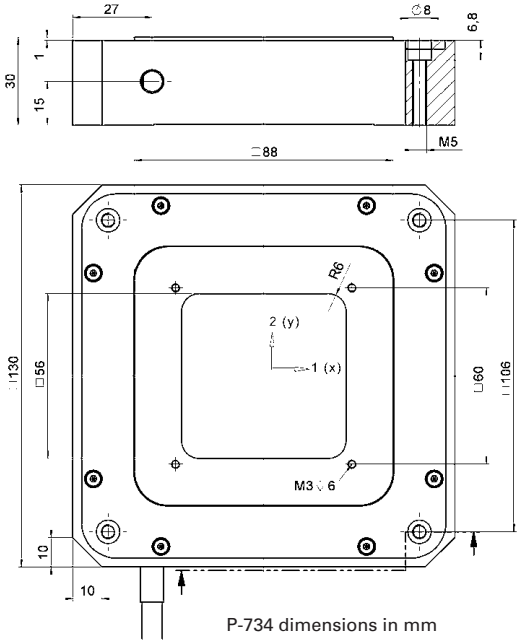
P-734.2CL
High-Precision XY Nanopositioning System with Minimum Runout, 100 x 100 µm, Capacitive Sensors, Parallel Metrology, LEMO Connector

- **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**

Controllers: Click Here

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

E-725 Digital 3-channel controller with nanopositioning system

Technical Data

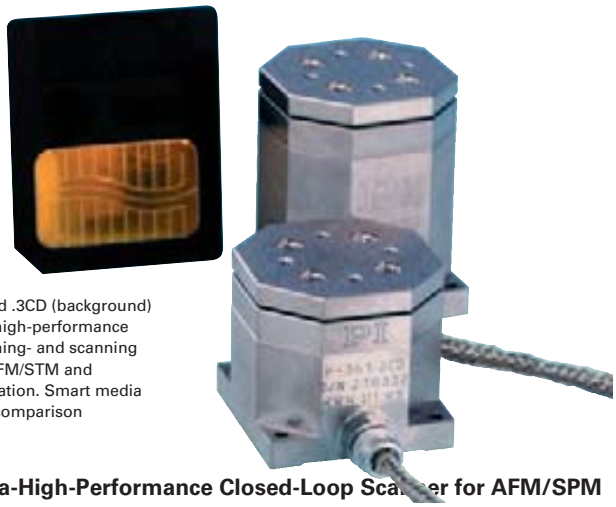
Models	P-734.2CL	P-734.2CD	Units	Tolerance
Active axes	X, Y	X, Y		
Motion and positioning				
Integrated sensor	Capacitive	Capacitive		
Open-loop travel, -20 to +120 V	110 x 110	110 x 110	µm	min. (+20 %/-0 %)
Closed-loop travel	100 x 100	100 x 100	µm	
Open-loop resolution	0.2	0.2	nm	typ.
Closed-loop 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

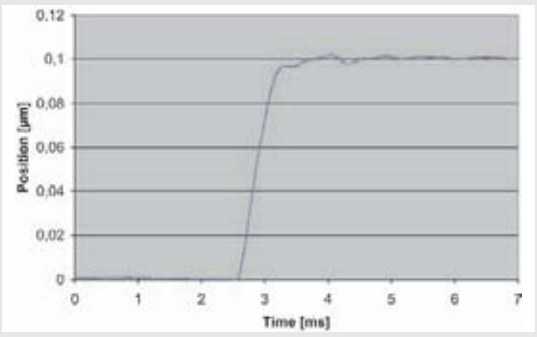
P-363.3UD
PicoCube™ High-Precision XYZ Nanopositioning System, 5 x 5 x 5 µm, Parallel Metrology, Capacitive Sensors, Sub-D Connector, Vacuum Compatible to 10^{-9} hPa

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

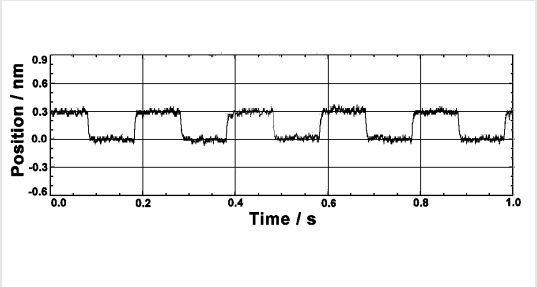
P-363.2UD
PicoCube™ High-Precision XY Nanopositioning System, 5 x 5 µm, Parallel Metrology, Capacitive Sensors, Sub-D Connector, Vacuum Compatible to 10^{-9} hPa

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

Paper on Molecular Stretching Application

Controllers: Click Here

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

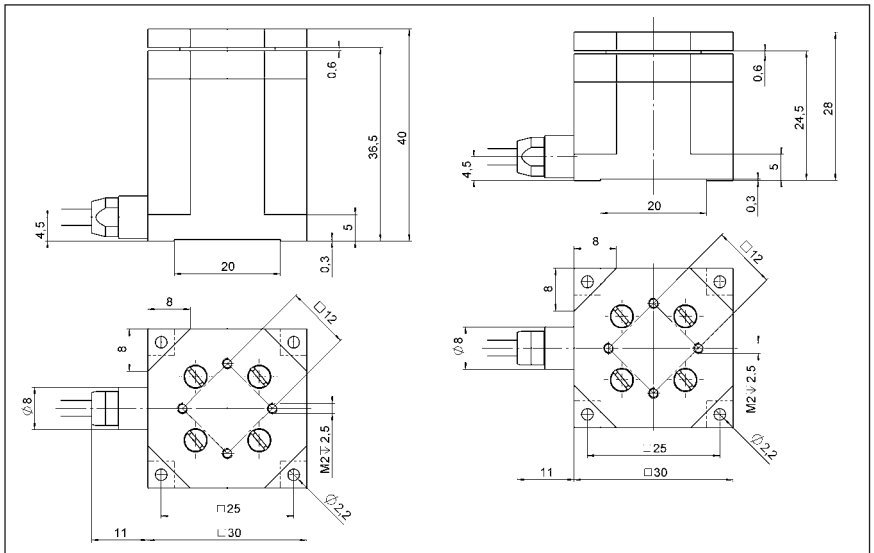
In spite of its ability to move and position on an atomic scale, the PicoCube™ boasts a rugged design for real-world applications. For extra-high stability and reduced mass, the body is precision machined from heat-treated and stress-relieved titanium. The sophisticated frictionless design also ensures 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).

E-536 controller with P-363 PicoCube® pico-positioning system



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-733 Planar XY(Z) Piezo-Nanopositioning Stage

High-Precision XY(Z) Scanner Family with Aperture

P -733.3 DD (left) and P -733.2 DD, high-speed, direct drive XY(Z) scanning stages are the fastest scanning stages with large aperture currently available (2.2 kHz resonant frequency!). Both units feature a footprint of only 100 x 100 mm. CD for size comparison.

- **Travel Ranges to 100 x 100 µm in X,Y & to 10 µm in Z**
- **Resolution to 0.1 nm with Capacitive Sensors**
- **High-Speed Versions with Direct Drive**
- **Vacuum and Non-Magnetic Versions**
- **Parallel Kinematics for Better Multi-Axis Accuracy and Dynamics**
- **Parallel Metrology for Active Trajectory Control**
- **Frictionless, High-Precision Flexure Guiding System**
- **Clear Aperture 50 x 50 mm for Transmitted-Light Applications**

P-733 XY and XYZ piezo driven stages are fast and highly accurate nanopositioning and scanning systems. They provide a positioning and scanning range of 100 x 100 (x10) µm together with sub-nanometer resolution and are equipped with parallel-metrology capacitive position feedback for superior multi-axis linearity and repeatability. The guiding accuracy minimizes runout to under 10 nm over the whole travel range. In addition, the high-speed Z-axis of the P-733.3CD can actively compensate any out-of-plane Z-axis deviation during XY motion.

Application Examples

- Image processing / stablilization
- Scanning microscopy
- Surface inspection
- Metrology / interferometry
- Biotechnology
- Semiconductor testing
- Mask / wafer positioning
- Micromanipulation
- Nanopositioning with high flatness & straightness

Fastest Multi-Axis Systems / Direct Drive, Low Profile and Large Apertures

P-733.2DD / .3DD multi-axis piezo nanopositioning systems are the fastest ultra-high-precision, open-frame stages for scanning microscopy. They provide a positioning and scanning range of 30 x 30 (x10) µm. P-733 nanopositioning and scanning stages feature very low profiles, as low as 20 mm (0.8 inch). The novel, high-stiffness direct drive gives the systems resonant frequencies as high as 2.2 kHz (4 x that of other comparable systems), enabling millisecond scanning rates with sub-nanometer resolution.

Parallel-Kinematics / Metrology for Enhanced Responsiveness

In a parallel kinematics multi-axis system, all actuators act directly on one moving platform. This means that all axes move the same minimized mass and can be designed with identical dynamic properties. Multi-axis nano positioning systems equipped with both parallel kinematics and paral - lel, 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 appli cations, the P-733.ZCD (see p. 2-42) version is available with a travel range of 100 µm. For ultra-high-vacuum appli cations 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

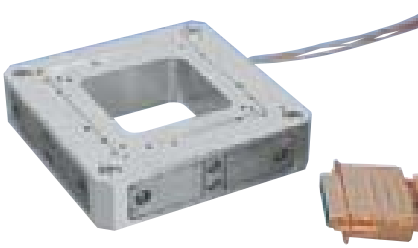
P-733.2VL* / P-733.2VD*
High-Precision XY Nanopositioning System, 100 x 100 µm, Capacitive Sensors, Parallel Metrology, Vacuum Compatible to 10-6 hPa

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

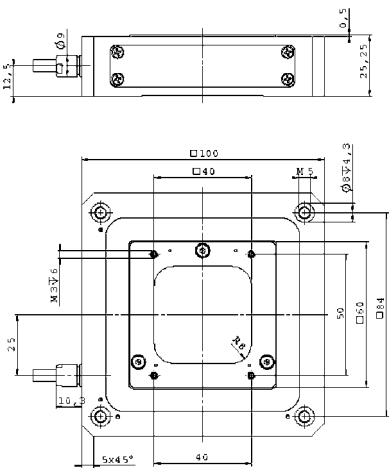
*.xxD with Sub-D Connector

*.xxL with LEMO Connector

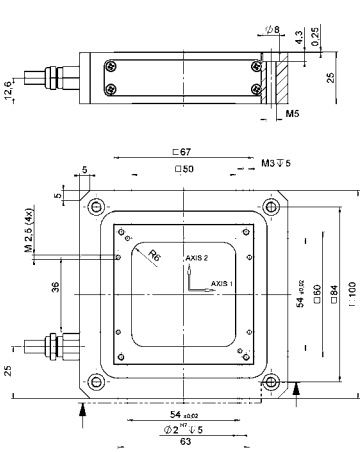
Ask about custom designs



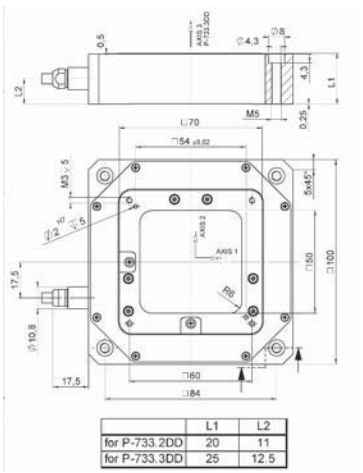
P-733.2UD non-magnetic XY scanning stage for UHV to 10^{-9} hPa



P-733.2 dimensions in mm



P-733.3 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 LEMO (CL-version)	Sub-D special (CD-version) (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-561 · P-562 · P-563 PIMars™ Planar 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

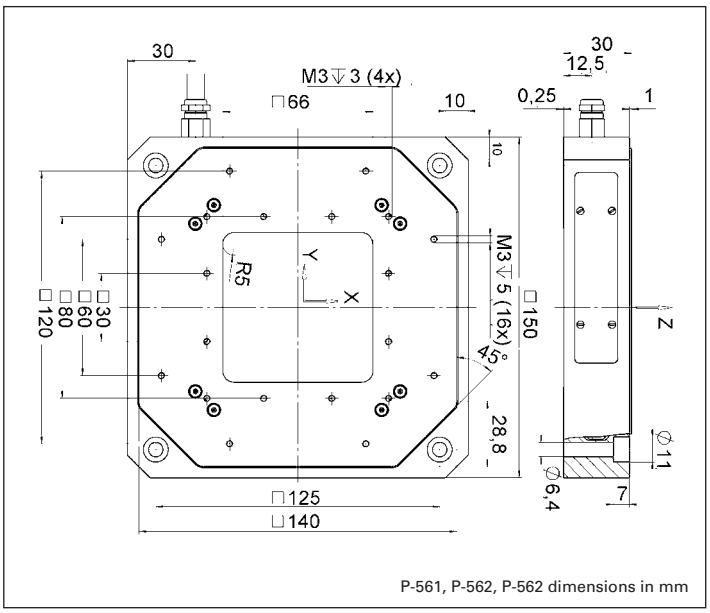
P-562.3CD
PIMars™ XYZ Piezo-Nanopositioning System, 200 x 200 x 200 µm, Parallel Metrology

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.



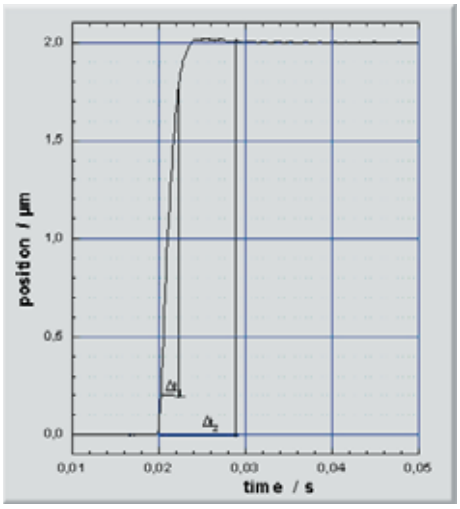
P-561, P-562, P-562 dimensions in mm

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



E-725 Digital 3-channel controller with nanopositioning system

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)

Ultra-Long Travel PIHera® Planar 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

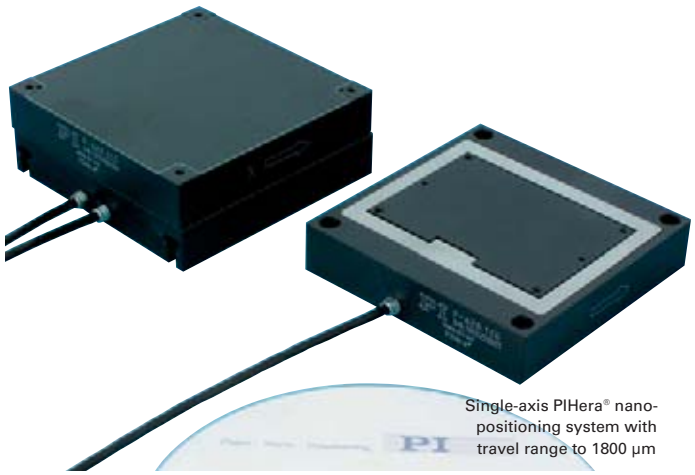
P-625.2CD* / P-625.2CL*
PIHera® Precision XY Nanopositioning System, 500 x 500 µm, Direct Metrology, Capacitive Sensors

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

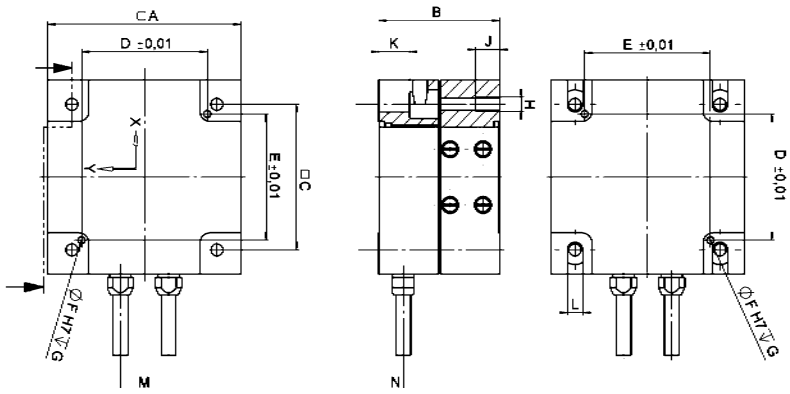
P-629.2CD* / P-629.2CL*
PIHera® Precision XY Nanopositioning System, 1500 x 1500 µm, Direct Metrology, Capacitive Sensors

*.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

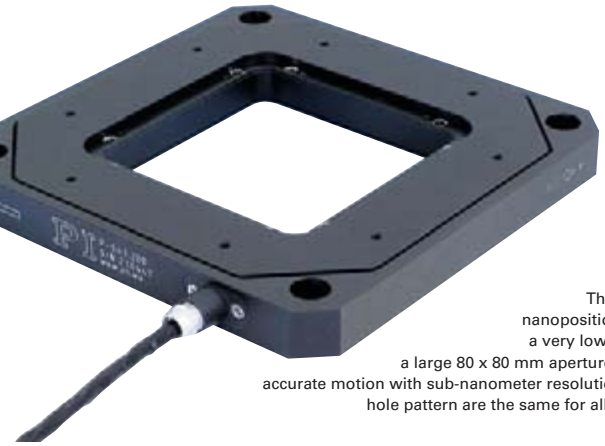
Technical Data

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-541.2 – P-542.2 Planar 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

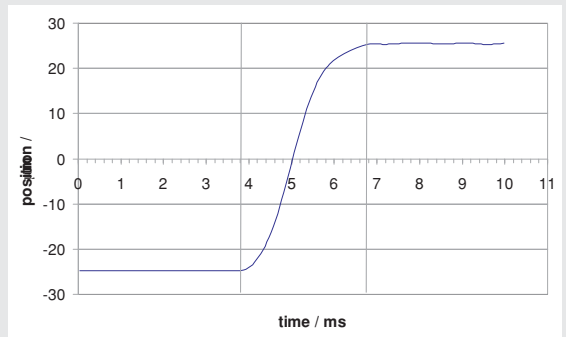
P-542.2CD
XY Nanopositioning System with large Aperture, 200 x 200 µm, Parallel Kinematics, Capacitive Sensors

P-541.2SL
XY Nanopositioning System with large Aperture, 100 x 100 µm, Strain Gauge Sensors

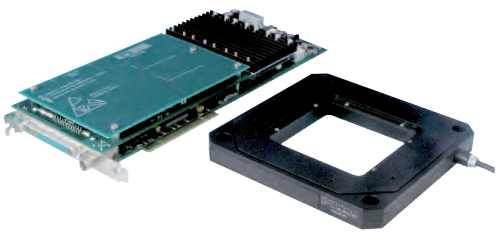
P-542.2SL
XY Nanopositioning System with large Aperture, 200 x 200 µm, Strain Gauge Sensors

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

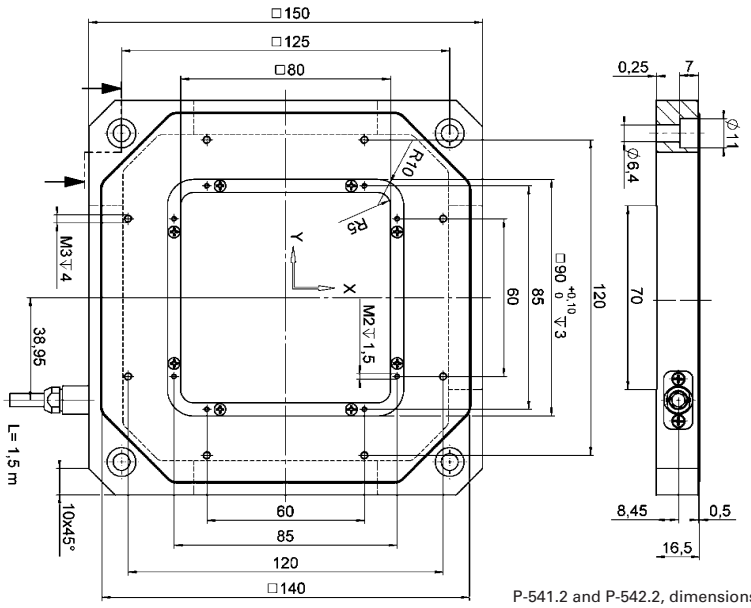
P-542.20L
XY Nanopositioning System with large Aperture, 200 x 200 µm, Open Loop



The settling time of a P-541.2DD stage is only 3 ms for a 50 µm step



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



P-541.2 and P-542.2, dimensions

E-725 Digital 3-channel controller with nanopositioning system

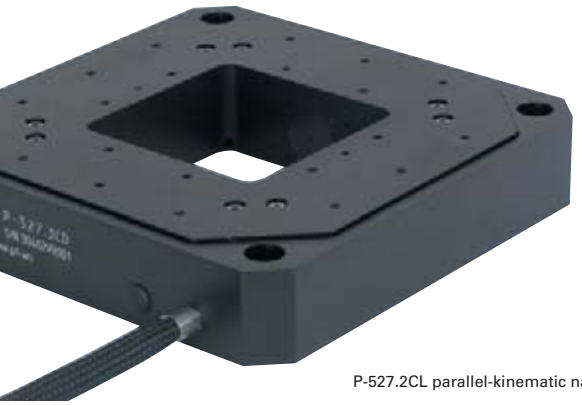
Technical Data

Model	P-541.2CD	P-542.2CD	P-541.2DD	P-541.2SL	P-542.2SL	P-541.20L	P-542.20L	Units	Tolerance
Active axes	X, Y	X, Y	X, Y	X, Y	X, Y	X, Y	X, Y		
Motion and positioning									
Integrated sensor	Capacitive	Capacitive	Capacitive	SGS	SGS	–	–		
Open-loop travel, -20 to +120 V	175 x 175	290 x 290	60 x 60	175 x 175	290 x 290	175 x 175	290 x 290	µm	min. (+20 %/0 %)
Closed-loop travel	100 x 100	200 x 200	45 x 45	100 x 100	200 x 200	–	–	µm	
Closed-loop / open-loop resolution	0.2 / 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	kg	±5 %
Cable length	1.5	1.5	1.5	1.5	1.5	1.5	1.5	m	±10 mm
Sensor connection	Sub-D Special	Sub-D Special	Sub-D Special	LEMO	LEMO	–	–		
Voltage connection	Sub-D Special	Sub-D Special	Sub-D Special	LEMO	LEMO	LEMO	LEMO		

Resolution of PI Piezo Nanopositioners is not limited by friction or stiction. V alue given is noise equivalent motion with E-50 3 (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-517 · P-527 Planar 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.

	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

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

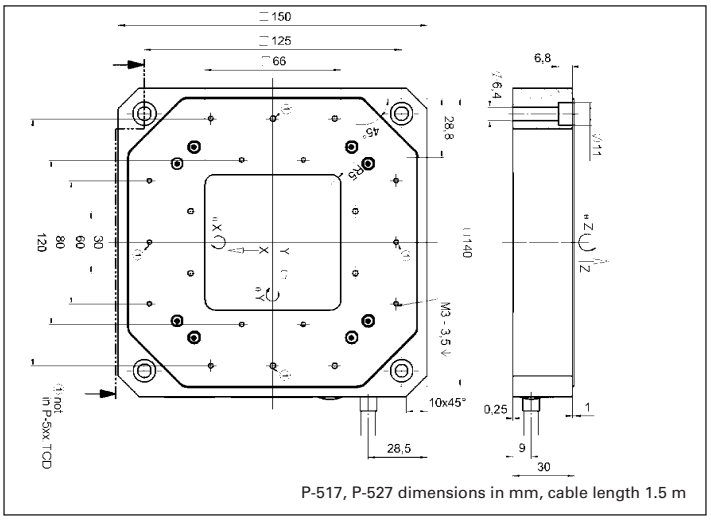
P-527.2CL
Precision XY Nanopositioning System, 200 x 200 µm, Capacitive Sensors, Parallel Metrology, LEMO Connector

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

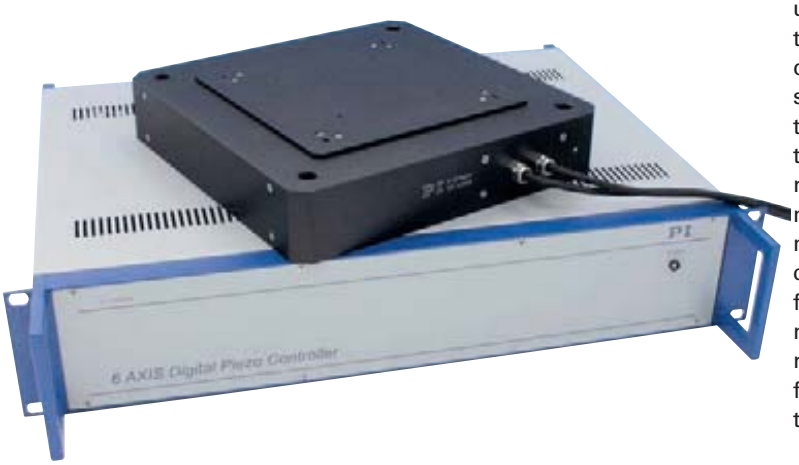
E-725 Digital 3-channel controller with nanopositioning system



P-517, P-527 dimensions in mm, cable length 1.5 m

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

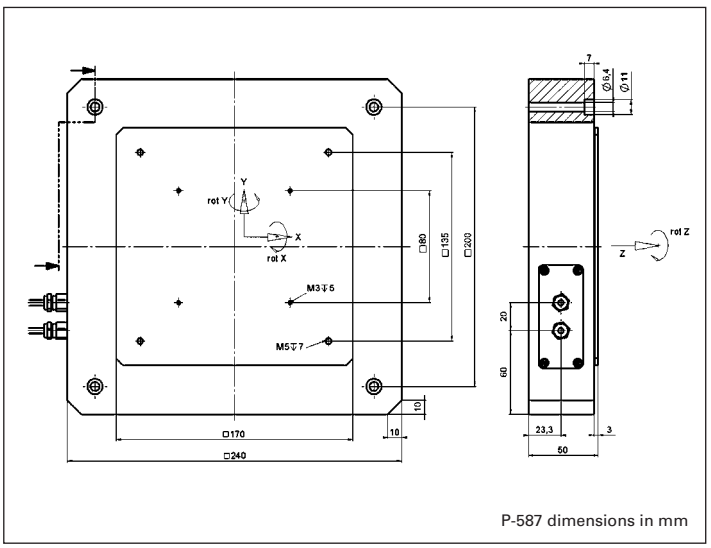
In a parallel kinematics multi-axis system, all actuators act directly on one moving platform. This means that all axes move the same minimized mass and can be designed with identical dynamic properties. Parallel kinematics systems have additional advantages over serially stacked systems, including more-compact 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.

PIMars 6-Axis Planar Piezo Stage

High-Precision Nanopositioning System with 6 Degrees of Freedom

P-562.6CD PIMars six-axis parallel-kinematics nanopositioning stage

- **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

Ordering Information

P-562.6CD
PIMars 6-Axis Nanopositioning System, 200 µm, 1 mrad, Parallel Metrology

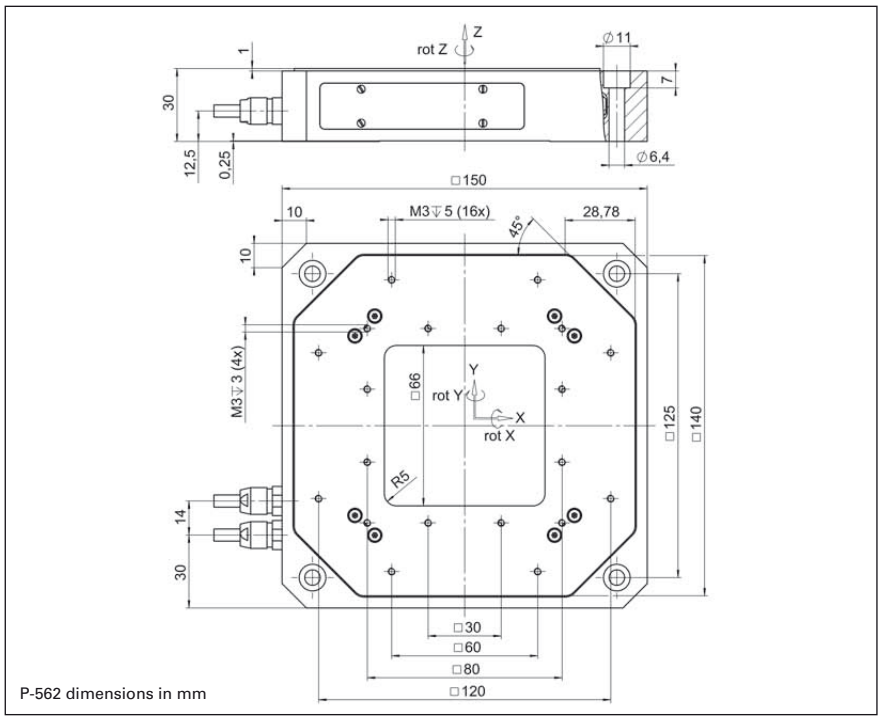
Other travel ranges on request!

Capacitive Sensors for Highest Accuracy and Stability

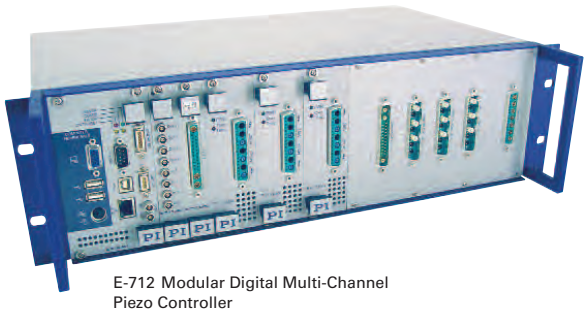
PI's proprietary capacitive sensors measure position directly and without physical contact. They are free of friction and hysteresis, a fact which, in combination with the positioning resolution of well under 1 nm, makes it possible to achieve very high levels of linearity. Further advantages of direct metrology with capacitive sensors are the excellent long-term stability, high phase fidelity and the high bandwidth of up to 10 kHz.

Active and Passive Guidance for Nanometer Flatness and Straightness

Wire-cut flexures optimized with Finite Element Analysis (FEA) are used to guide the stage. The FEA techniques give the design the highest possible stiffness and minimize linear and angular runout. Further enhancement is achieved by active trajectory control: multiaxis nanopositioning systems equipped with parallel metrology are able to measure platform position in all degrees of freedom against a common, fixed reference. In such systems, undesirable motion from one actuator in the direction of another (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


E-712 Modular Digital Multi-Channel Piezo Controller

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

Microscope Stage Family with Ultrasonic Linear Drives

Extreme Stability, Low Profile, Fast Response, Direct Position Measurement

Ultrasonic motor XY microscope stage with inserted optional Piezo-Z scanning stage. Stages come with controller, joystick & software

- **Integrated Closed-Loop Linear Piezomotor Drives Provide Smooth Motion and High Speed to 150 mm/sec**
- **Significantly Higher Stability than Conventional Lead-screw-Driven Stages: Self-Locking at Rest, no Servo Dither**
- **Travel Ranges to 225x85mm**
- **Integrated Linear Encoders, Sensor Resolution to 0.1 µm**
- **Compact Design, Low Profile, Mounts Directly to Microscope**
- **Compatible with Piezo-Z and Piezo XYZ Scanning Stages**

Customized long travel PILine® microscope stages

Compact Design
All PI microscope stages are designed for excellent stability. The PILine® piezomotor stages excel in precision positioning and automation applications. Their form factors are optimized for a low profile height; the mounting pattern is compatible with a variety of flexure actuated PI piezo nanopositioning / scanning stages.

10X Higher Stability
The PILine® stages are based on a completely different drive principle. than conventional motorized translation stages. The compact integrated piezoelectric linear motors and linear encoders make both the lead screw duct and the bulky flanged, stepper motors employed in traditional stages obsolete. An ultrasonic ceramic piezo linear motor directly drives the moving platform. At rest the motor directly clamps the stage, without holding current, allowing the exceptional long term stability

Compatibility to PI Nanopositioning and Scanning Stages
A number of standard PI piezo flexure stages can be mounted directly on the motorized stage. Depending on the application, these highly specialized, ultra-precise nanopositioning systems provide fast XYZ scanning (for fluorescence microscopy) or Z-motion (3D imaging, Z-stacks).

Inverted and Upright Microscopes
PILine® stages can be designed for inverted or upright microscopes. Talk to us about your application!

Advantages of PI Ultrasonic Motors over Classical Drives

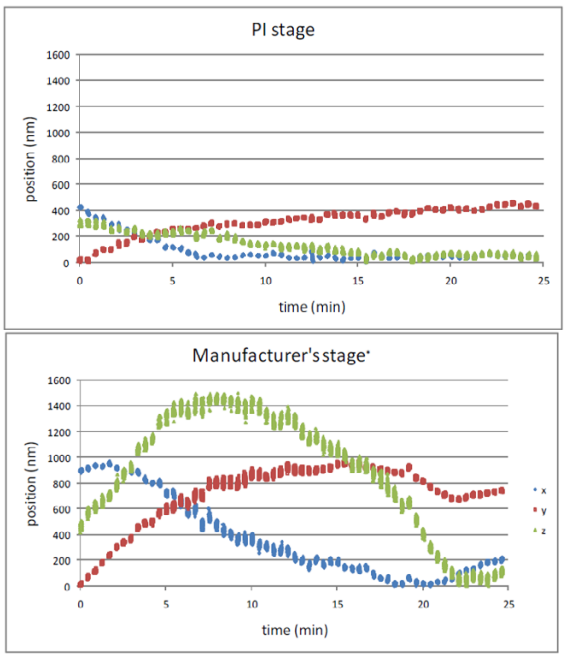
- Self-Locking at rest, no servo dither, no heat
- Smaller Form Factor
- No vibration, smooth motion
- Higher acceleration, speed
- No rotating shafts, gears, …
- Non-magnetic, vacuum compatible drive princip

M-545 piezomotor microscope stage, 25x25mm travel range The controller and a joystick is included with all systems.

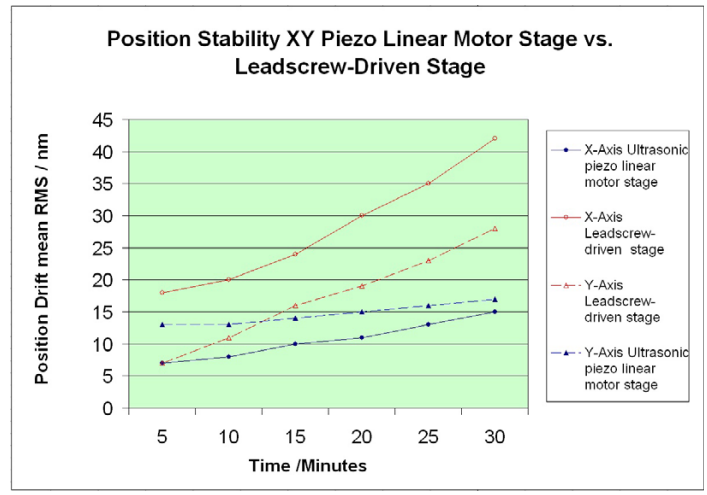
PILine® Microscope Stage Family, General Specs	
Description	XY Microscope stage with controller, software and joystick
Travel range	100x75 to 225x85mm
Controller	C-867.262
Joystick	Included (USB)
Compatible piezo-Z / XYZ stages	P-736K003, P-737, PI Mars, PInano™
Max Speed	Up to. 150mm/sec
Resolution	0.1µm
Repeatability	0.4µm
Max load	5 kg
Mass	4kg

*PILine® Microscope Stages have several advantages over classical stepper and electromagnetic motor stages: Stability: Self clamping, low heat generation at low speed, no heat at rest. Convenience: Lower noise than stepper motors. Precision and stiffness: direct drive and direct metrology encoders. Large dynamic range: Fast response and crisp settling, smooth and high velocity constancy even at low velocities of 20µm/sec.

Custom Piezo-Z flexure stage, 200µm Travel, sub-nanometer resolution, millisecond response.



Stability comparison if a PI M-545 manual microscope stage (top) with a manufacturer's stage (bottom). Green: Z; Red:Y, Blue: X



Position stability of PI M-686 piezomotor stage vs leadscrew driven stage. Excerpt from: Design Considerations for Micro- and Nanopositioning, Leveraging the Latest for Biophysical Applications, Current Pharmaceutical Biotechnology, 2009, 10, 515-521 by S.C. Jordan, and P.C. Anthony. http://www.bentham.org/cpb/sample/cpb10-5/0008G%5B1%5D.pdf

M-545 manual microscope stage

PInano™ low profile XYZ piezo flexure scanning stage

M-686 PILine® High Stability 25x25 mm XY Piezo Motor Stage

Ideal Base for Piezo Scanner Stages

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

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

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

Application Examples

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

Space Saving Piezomotors

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

Compatibility to PI Nanopositioning and Scanning Stages

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

Limit and Reference Switches

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

Advantages of PILine® Micropositioning Systems

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

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

Ordering Information

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

Ask about custom designs!

Notes

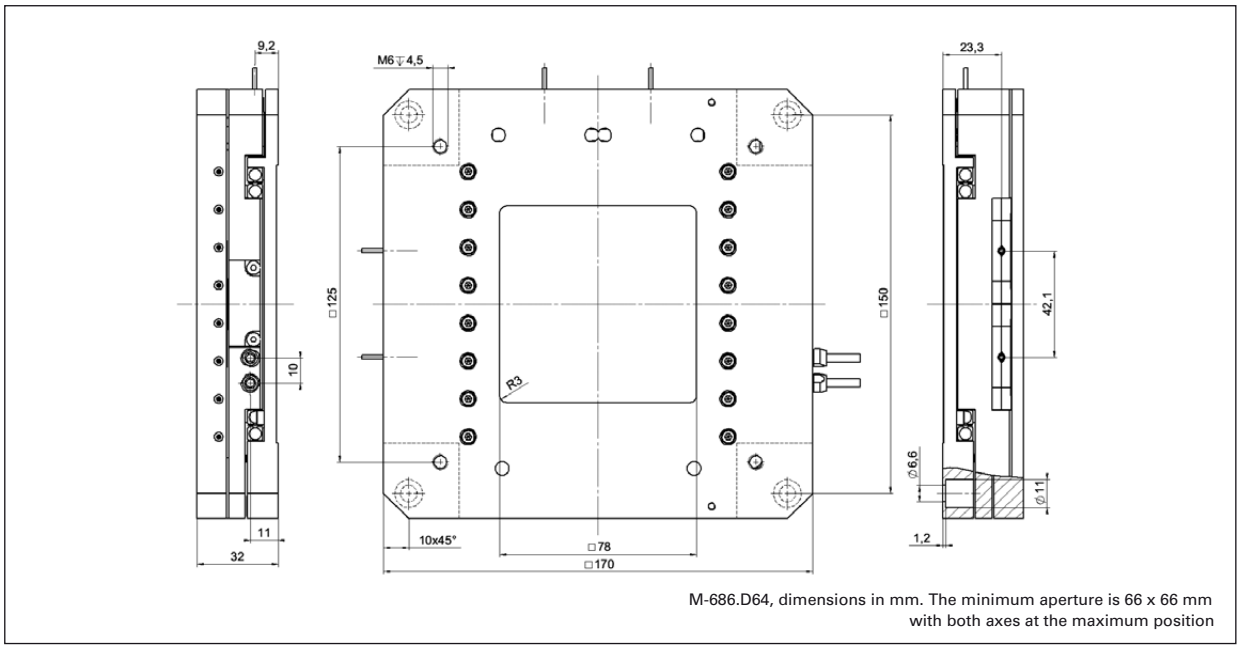
Nanopositioning stages that fit directly on the M-686:

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

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

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

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



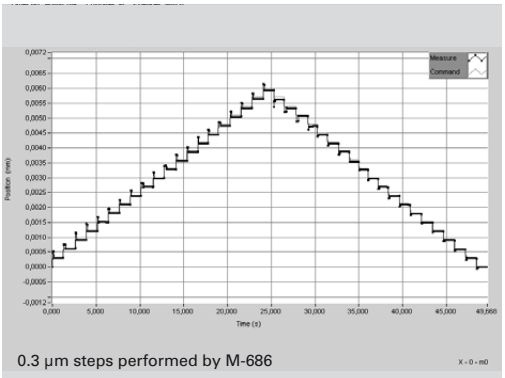
M-686.D64, dimensions in mm. The minimum aperture is 66 x 66 mm with both axes at the maximum position

Technical Data

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

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

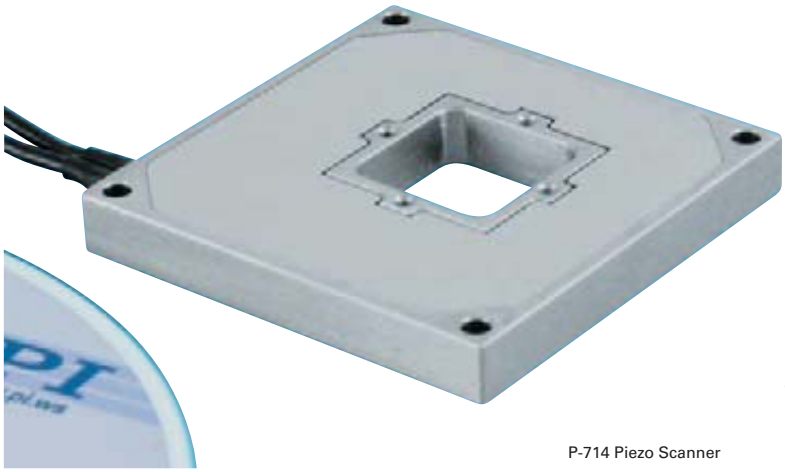
M-686 open-frame stage with P-541.2DD piezo scanner on top, providing a resolution of 0.1 nm and a scanning range of 30 x 30 µm. The system height of the combination with the P-541 XY (or Z) piezo scanner is only 48 mm



0.3 µm steps performed by M-686

P-713 · P-714 XY Planar Piezo Scanner

Cost-Effective OEM System with Low Profile



P-714 Piezo Scanner

- **Ideal for Pixel Sub-Stepping in Image Enhancement**
- **Small Footprint and Low Profile: 45 x 45 x 6 mm with Clear Aperture**
- **Very Cost-Effective Design**
- **Travel Ranges to 20 x 20 µm**
- **Parallel Kinematics for Better Multi-Axis Accuracy and Dynamics**

P-713 / P-714 family piezo scanners and positioners with travel ranges of 15 x 15 µm feature especially compact designs. Ideal applications for the P-713 and P-714 are high-dynamics scanning or tracking tasks such as sub-stepping methods for enhancing image resolution. Such tasks involve moving to specific positions in a small area (e. g. marked cells or CCD photosites) and from there following or performing motion with an amplitude of a few microns. The resonant frequency of up to over 2 kHz makes for settling times of a few milliseconds, even after a full-range move, all with closed-loop repeatability of under 5 nm.
A single-axis version with similar footprint is available as P-712 (see p. 2-14) and XY versions with longer travel ranges are available on request.

Application Examples

- Pixel dithering / sub-stepping image resolution enhancement
- Quality assurance testing
- Optical Metrology
- Microscopy
- Imaging
- CCD / CMOS camera technology

Flexibility

P-713 and P-714 nanopositioners are offered in different versions for different applications. The lowest-cost, basic version of the P-713 offers guiding accuracy in the motion plane of 50 µrad, a value generally good enough for dithering and interlacing tasks in scanning patterns of a few microns. For more demanding applications, the P-714 offers greater accuracy, typically 5 µrad or <10 nm absolute.

Nanometer Position Servo-Control

If servo-control is required and no external position sensor is available, the P-714.2SL version, equipped with high-resolution strain gauge sensors (SGS) can provide nanometer-range resolution.
High-resolution, broadband, strain gauge sensors (SGS) are applied to appropriate locations on the drive train and measure the displacement of the moving part of the stage relative to the base indirectly . The SGS sensors assure optimum position stability in the nanometer range and fast response.

Ceramic Insulated Piezo Actuators Provide Long Lifetime

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

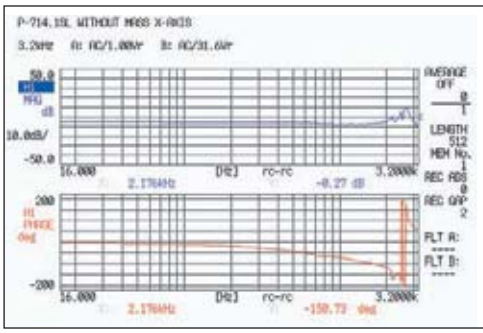
Ordering Information

P-713.20L
Low-Profile OEM XY Nanoscanner, 15 x 15 µm, No Sensor, LEMO Connector

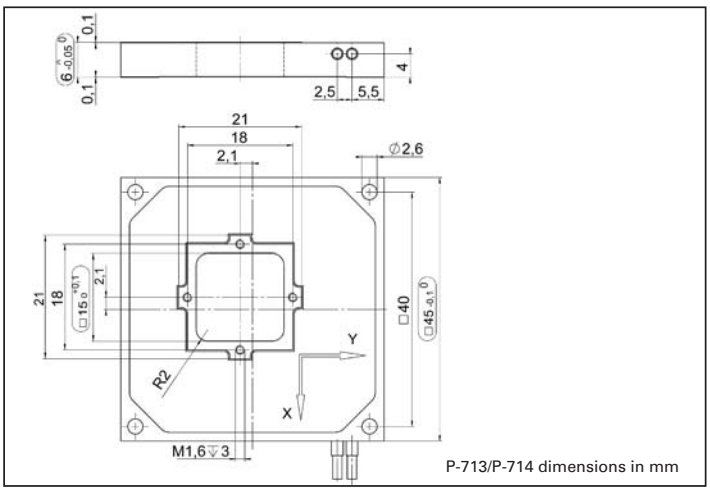
P-714.20L
Low-Profile OEM XY Nanoscanner, 15 x 15 µm, Improved Guiding Accuracy, No Sensor, LEMO Connector

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

P-714.2SL
Low-Profile OEM XY Nanoscanner, 15 x 15 µm, Improved Guiding Accuracy, SGS-Sensor, LEMO Connector



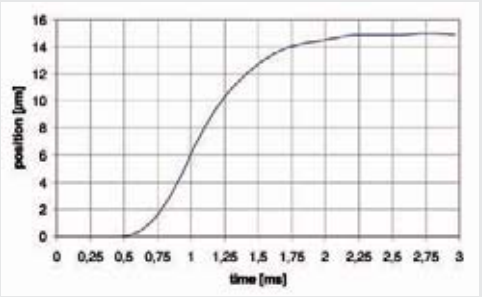
The resonant frequency of an unloaded P-713 / P-714 scanner is over 2 kHz



P-713/P-714 dimensions in mm

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

System properties	
System controller	P-714.2SL with modular system E-500 (E-503 amplifier and E-509 sensor module); 20 g load
Bandwidth, small signal	300 Hz
Bandwidth, large signal	220 Hz
Settling time (10 % step width)	3.1 ms
Settling time (full travel)	4.5 ms



Settling time for the P-713/P-714 at 15 µm is in the 2 ms range

Technical Data

Model	P-713.20L	P-713.2SL	P-714.20L	P-714.2SL	Units	Tolerance
Active axes	X, Y	X, Y	X, Y	X, Y		
Motion and positioning						
Integrated sensor	-	SGS	-	SGS		
Open-loop travel, -20 to +120 V	20	20	20	20	µm	min. (+20 %/0 %)
Closed-loop travel	-	15	-	15	µm	
Open-loop resolution	0.1	0.1	0.1	0.1	nm	typ.
Closed-loop resolution	-	1	-	1	nm	typ.
Linearity	-	0.3	-	0.3	%	typ.
Repeatability	-	<4	-	<4	nm	typ.
Pitch	typ. ±1 max. ±5	typ. ±1 max. ±5	typ. ±1 max. ±5	typ. ±1 max. ±5	µrad	typ.
Yaw	typ. ±40 max. ±50	typ. ±40 max. ±50	typ. ±40 max. ±50	typ. ±40 max. ±50	µrad	µrad
Mechanical properties						
Stiffness	0.8	0.8	0.8	0.8	N/µm	±20 %
Unloaded resonant frequency	2250	2250	2250	2250	Hz	±20 %
Resonant frequency under load	1310 (20 g) 1020 (50 g) 460 (100 g)	1310 (20 g) 1020 (50 g) 460 (100 g)	1310 (20 g) 1020 (50 g) 460 (100 g)	1310 (20 g) 1020 (50 g) 460 (100 g)	Hz	±20 %
Push/pull force capacity in motion direction	5 / 5	5 / 5	5 / 5	5 / 5	N	Max.
Load capacity	2	2	2	2	N	Max.
Drive properties						
Ceramic type	PICMA® P-882	PICMA® P-882	PICMA® P-882	PICMA® P-882		
Electrical capacitance in X , Y	0.31	0.31	0.31	0.31	µF	±20 %
Dynamic operating current coefficient (DOCC) in X, Y	2.5	2.5	2.5	2.5	µA/(Hz • µm)	±20 %
Miscellaneous						
Operating temperature range	-20 to 80	-20 to 80	-20 to 80	-20 to 80	°C	
Material	Stainless steel, ferromagnetic	Stainless steel, ferromagnetic	Stainless steel, ferromagnetic	Stainless steel, ferromagnetic		
Dimensions	45 x 45 x 6	45 x 45 x 6	45 x 45 x 6	45 x 45 x 6		
Mass	0.1	0.1	0.1	0.1	kg	±5 %
Cable length	1.5	1.5	1.5	1.5	m	±10 mm
Sensor connection	-	LEMO	-	LEMO		
Voltage connection	LEMO	LEMO	LEMO	LEMO		

Resolution of PI piezo nanopositioners is not limited by friction or stiction. 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 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 Planar 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

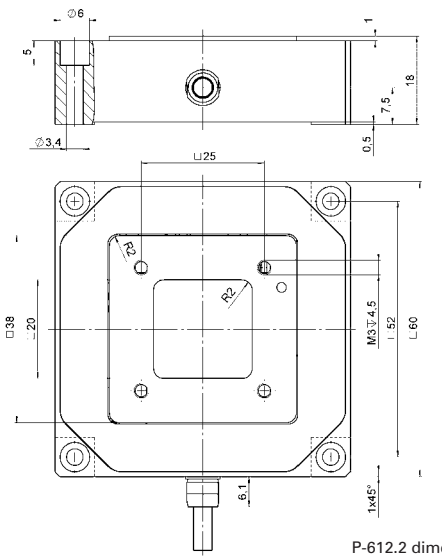
Highest possible reliability is assured by the use of award-winning PICMA® multilayer piezo actuators. PICMA® actuators are the only actuators on the market with ceramic-only insulation, which makes them resistant to ambient humidity and leakage-current failures. They are thus far superior to conventional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

Ordering Information

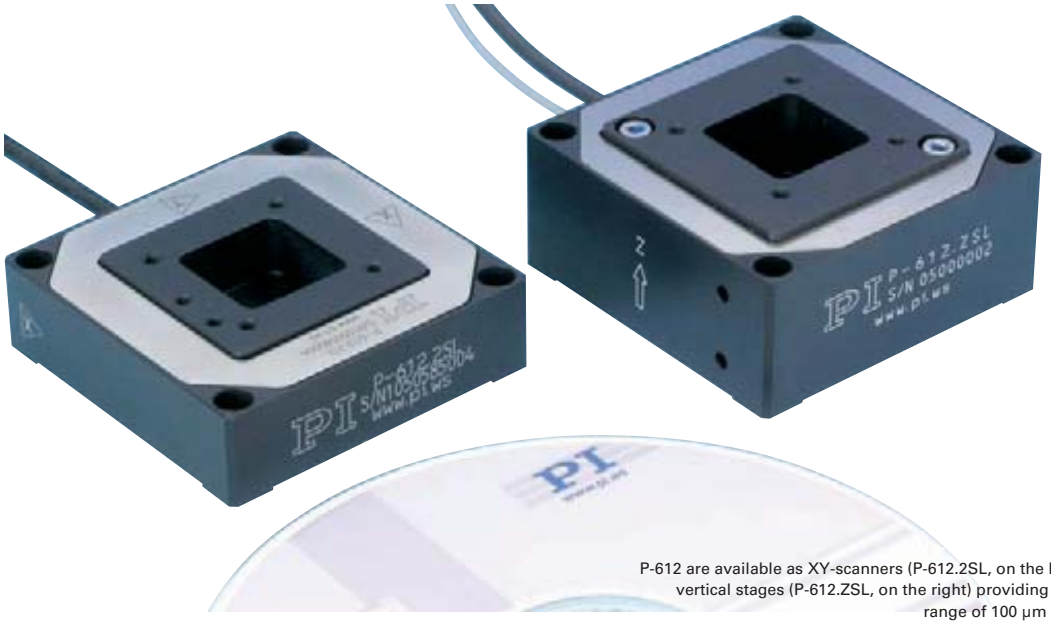
P-612.2SL
XY Nanopositioning System with 20 x 20 mm Aperture, 100 x 100 µm, Strain Gauge Sensors

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-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

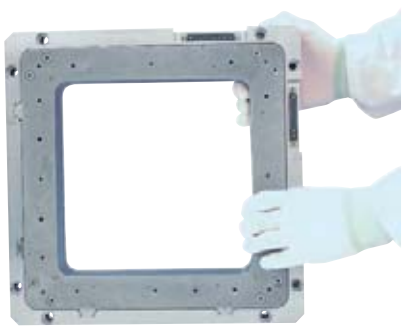
The P-915KHDS XY scanning stage is driven by 4 PICMA® piezo actuators to provide high stiffness, high dynamics and superior lifetime

- 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

PICA™ Shear Scanner Actuators

Compact Multi-Axis Actuators Based on the Piezo Shear Effect

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

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

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

Application Examples

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

High Stiffness and High Displacement

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

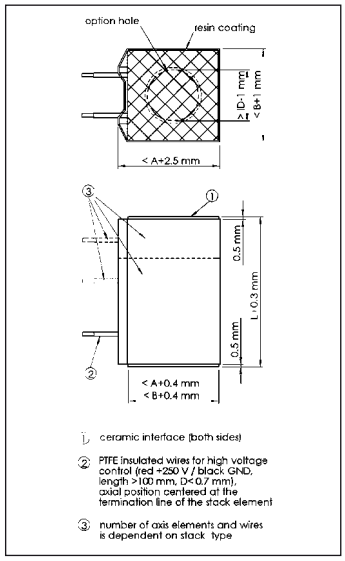
High Reliability under High Duty Cycles, Low Power Requirements

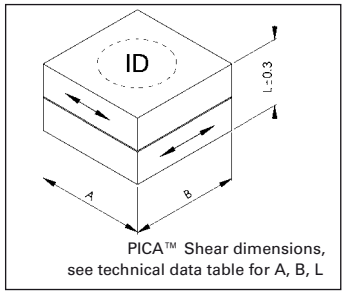
PICA™ Shear actuators are specifically designed for high-duty-cycle applications. All materials used are specifically matched for robustness and lifetime. Endurance tests proved consistent performance, even after billions (1,000,000,000) of cycles. The combination of high displacement and low electrical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

Short Leadtime for Standard & Custom Designs

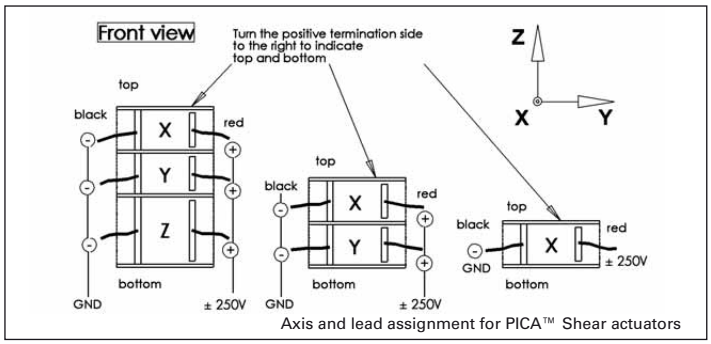
All manufacturing processes at PI Ceramic are set up for maximum flexibility . Should our standard actuators not fit your application, let us provide you with a custom design. Our engineers will work with you to find the optimum solution at a very attractive price, even for small quantities. Some of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

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

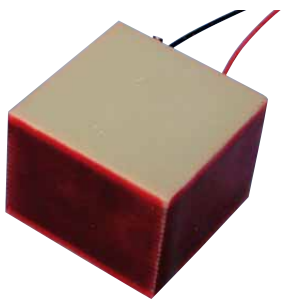




PICA™ Shear dimensions, see technical data table for A, B, L



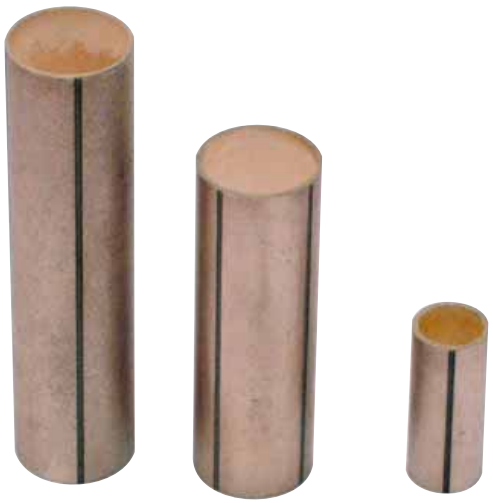
Axis and lead assignment for PICA™ Shear actuators



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

Piezo Scanner Tubes

Piezoceramic Tube Actuators with Small Tolerances and Various Options



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

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

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

Application Examples

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

Precision and Flexibility

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

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

Short Leadtime

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

Dimensions

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

Electrodes

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

Options

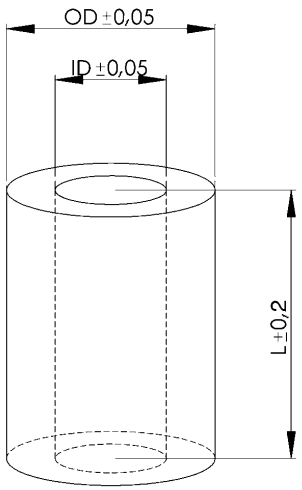
Single or double wrapped, circumferential bands or quartered outer electrodes.

Polarization

Inner electrode positive potential

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

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



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

Piezo Drivers, Controllers & High-Voltage Amplifiers

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

Equations

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

(Equation 1)

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

where:

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

(Equation 2)

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

where:

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

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

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

(Equation 3)

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

where:

r = radius of piezo tube

d_{31} = strain coefficient (displacement normal to polarization direction) [m/V]

U = operating voltage [V]

d = wall thickness [m]

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

(Equation 4)

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

where:

Δx = scanning range in X and Y (for symmetrical electrodes) [m]

d_{31} = strain coefficient (displacement normal to polarization direction) [m/V]

U = operating voltage [V]

L = length [m]

ID = inner diameter [m]

d = wall thickness [m]

Technical Data / Product Order Numbers

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

*Quartered electrodes for XY deflection

**OD (outer diameter), ID (inner diameter) ±0.05 mm. PT120 / PT130.00: ID ±0.1 mm

Other specifications on request.

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.

E-709 Compact and Cost-Optimized Digital Piezo Controller

Increased Performance for Piezo Systems with Strain Sensors

Compact, low-cost E-709 digital controller (preliminary case design) with P-712 piezo-scanner

- **Fast Digital Controller, Software Configurable Servo Parameters**
- **Linearity of SGS and Piezoresistive Sensors Improved by up to 0.02 %**
- **2 Digital Interfaces: USB, RS-232**
- **Comprehensive I/O Functions**
- **Additional High-Bandwidth Analog Control Input / Sensor Input**
- **Low-Cost OEM Versions Available**
- **Comprehensive Software Package**

The E-709 opens up the possibilities of digital control for piezo-driven nanopositioning systems for the same price as analog controllers. It was designed for piezo actuators and nanopositioning stages which are equipped with cost effective measuring systems such as strain gauges or piezoresistive sensors. The advantage: higher precision, more control options and very simple operation. In addition, PI provides the full functionality of its comprehensive software packages free of charge! The E-709 can also be used for applications providing analog control signals. In addition to 2 digital interfaces, a standard broadband analog input is installed as well.

Digital Linearization for Strain Sensors: 10 x More Precise!

For the first time, the E-709 nanopositioning controller opens up the advantages of digital control to compact systems with strain sensors. These sensors are based on the strain of metal foils or semiconductor films (piezoresistive sensors) and are used when space limitations prevent the use of the more advanced capacitive sensors, or where the requirements in terms of resolution or temperature stability are not as critical.

The limited linearity of these strain sensors can be improved by digital controllers, which use additional linearization algorithms to minimize the deviation between target and actual position. This improves the accuracy by up to one order of magnitude and achieves linearity values of up to 0.02 %.

Flexibility: Software Configurable Servo Parameters

All servo controllers require tuning and adjustment of servo parameters for optimum performance (e.g. as a result of changes to the load or the motion profile). With a digital controller, all adjustments are carried out by simple software commands and the resulting motion or transient characteristics can be viewed, analyzed and further optimized immediately with the provided software. It is also possible to switch between previously found sets of parameters when the controller is in operation. Since jumpers and potentiometers no longer have to be set manually, system integration becomes much more straight forward.

OEM Versions at an Even Lower Price

E-709 controllers are also offered without case. A lower cost version sold as the E-609 is available for purely analog control signals, maintaining the advantages of digital signal processing and parameter setting. The target position is controlled via an analog signal, allowing system components with analog output (e.g. autofocus) to be integrated easily.

An E-709 version for capacitive position sensors is also available to control the large variety of ultra-high precison single-axis nanopositioning systems PI offers.

Ordering Information

E-709.PRG
Digital Piezo Controller, 1 Channel, -30 to 130 V, Piezoresistive Sensors, Bench-Top

E-709.SRG
Digital Piezo Controller, 1 Channel, -30 to 130 V, SGS-Sensor, Bench-Top

E-709.PR
Digital Piezo Controller, 1 Channel, OEM Module, -30 to 130 V, Piezoresistive Sensors

E-709.SR
Digital Piezo Controller, 1 Channel, OEM Module, -30 to 130 V, SGS-Sensor

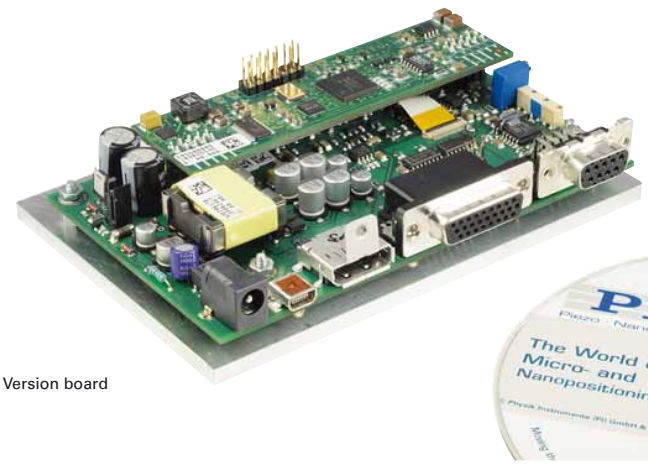
Accessories

E-709.01
Adapter HD-Sub-D 26-pin to Sub-D 9-pin with I/O Lines, 0.5 m

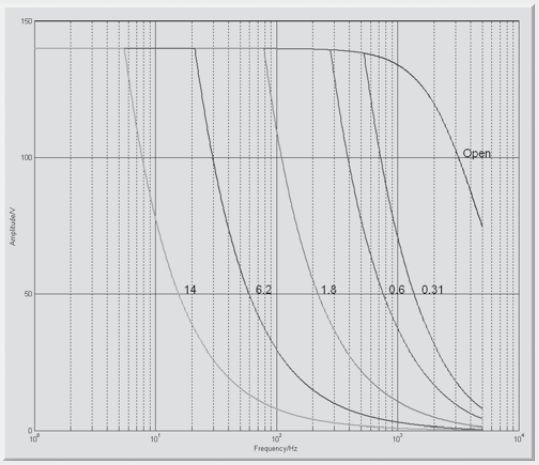
E-709.02
Adapter Cable HD-Sub-D 26-pin to Open Leads, 1 m

E-709.03
Adapter LEMO to Sub-D 9-pin

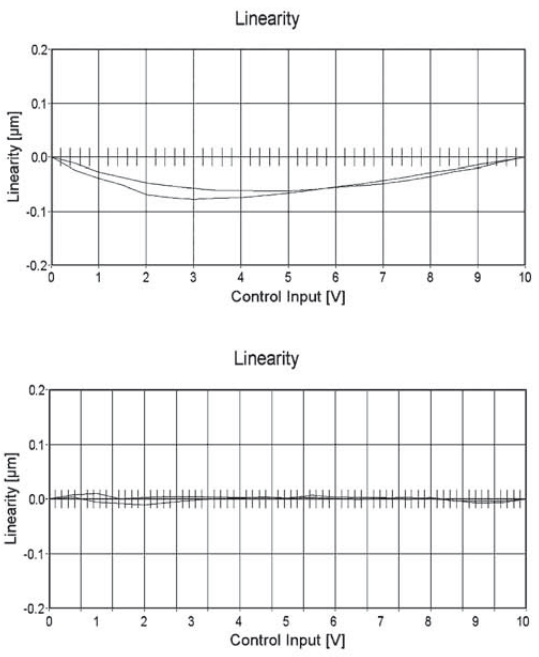
The E-709 is also available as a compact, low-cost controller for capacitive sensor-equipped positioning systems.



E-709 OEM Version board



E-709: operating limits with various PZT loads (open-loop), capacitance is measured in µF



Comparison of the linearity of a strain gauge sensor with analog controller (top) and the E-709 digital controller (bottom), which improves the linearity by up to one order of magnitude

Technical Data

Modell	**E-709.SR** **E-709.SRG** **E-709.PR** **E-709.PRG**
Function	Digital controller for single-axis piezo nanopositioning systems (.SR, .PR: OEM board)
Channels	1
Processor	DSP 32-bit floating point, 150 MHz
Servo characteristics	P-I, two notch filters
Sampling rate, servo control	10 kHz
Sampling rate, sensor	10 kHz
Sensor	
Sensor type	Metal foil strain gauge sensors (.SR, .SRG), Piezoresistive sensors (.PR, .PRG)
Linearization	5th order polynomials
Sensor bandwidth	5 kHz
Sensor resolution	16 bit
Ext. synchronization	No
Amplifier	
Output voltage	-30 V to +130 V
Peak output power	10 W (<5 ms)
Average output power	5 W (>5 ms)
Peak current	100 mA (<5 ms)
Average current	50 mA (>5 ms)
Current limitation	Short-circuit-proof
Resolution DAC	16 bit
Interfaces and operation	
Communication interfaces	USB, RS-232
Piezo / sensor connector	Sub-D 9-pin
I/O connector	HD-Sub-D 26-pin, 1x analog control input 0 to 10 V, 1x sensor monitor 0 to 10 V, 1x digital input (LVTTL, programmable), 5x digital output (LVTTL, 3x predefined, 2x programmable)
Command set	PI General Command Set (GCS)
User software	PIMikroMove , NanoCapture
Software drivers	LabVIEW drivers, DLLs
Supported functionality	Wave generator, data recorder, auto zero, trigger I/O
Display	Status LED, overflow LED
Miscellaneous	
Operating temperature range	8 to 50 °C (over 40 °C, max. power av. power derated)
Dimensions	160 x 96 x 33 mm
Mass	0.5 kg
Operating voltage	24 VDC
Power consumption	24 W max.

E-709 Compact and Cost-Optimized Digital Piezo Controller

For Piezo Systems with Capacitive Sensors

Compact single-channel digital controller E-709 with PIFOC® objective scanners

- **Flexibility of Digital Signal Processing for the Cost of Analog**
- **Digital Control Algorithms with 10 kHz Sampling Rate**
- **For Capacitive Sensors**
- **Linearity to 0.02 %**
- **USB and RS-232 Interfaces**
- **Fast 25 Mbit/s Serial Interface**
- **Additional High-Bandwidth Analog Control Input / Sensor Input**
- **Analog Output, e.g. for External Amplifiers**
- **Low-Cost OEM-Versions Available**
- **Fast Digital Controller, Software-Configurable Servo Parameters**
- **Parameter Input Using Software**

The E-709 piezo controller provides the flexibility and ease of use of a digital signal processing unit for the cost of an analog one. All motion and servo-control parameters can be set by software and adjusted on-the-fly during operation. In addition, digital 5th order polynomial linearization algorithms can improve the motion linearity of the attached piezo positioning system significantly over an analog servo system. In addition to a variety of digital interfaces, an analog input and output are also included. A software command allows the analog input to be interpreted as position control signal or as a sensor value. The analog output can be configured for the control of external amplifiers or for the output of position values.

Flexibility: Software Configurable Servo Parameters

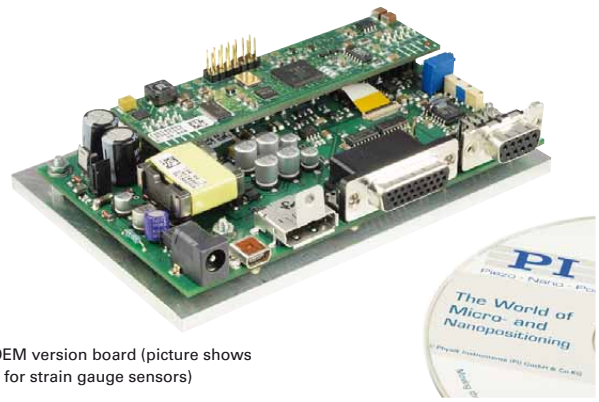
All servo controllers require tuning and adjustment of servo parameters for optimum performance (e.g. as a result of changes to the load or the motion profile). With a digital controller, all adjustments are carried out by simple software commands and the resulting motion or transient characteristics can be viewed, analyzed and further optimized immediately with the provided software. It is also possible to switch between previously found sets of parameters when the controller is in operation. Since jumpers and potentiometers no longer have to be set manually, system integration becomes much more straightforward.

Digital or Analog?

Digital controllers provide advantages when high positioning linearity is important or when servo parameters need to be modified frequently. This could be the case when load changes occur or to optimize motion profiles for both step operation and continuous operation achieving the fastest settling time and the highest tracking accuracy. With analog controllers a compromise has to be found during system setup and changes require physical access to the unit. With digital controllers the best parameters for either condition can be set on-the-fly by a software command.

OEM Versions for Cost Sensitive Applications

An unpackaged version of the E-709 is offered for OEMs. An even lower-cost version sold as the E-609 comes with an analog-only control input, maintain-ing the advantages of digital signal processing and parameter setting. This is designed for applications where analog control signals are readily available, (e. g. Autofocus).



E-709 OEM version board (picture shows version for strain gauge sensors)

Ordering Information

E-709.CR
Digital Piezo Controller, 1 Channel, OEM Module, -30 to 130 V, Capacitive Sensor

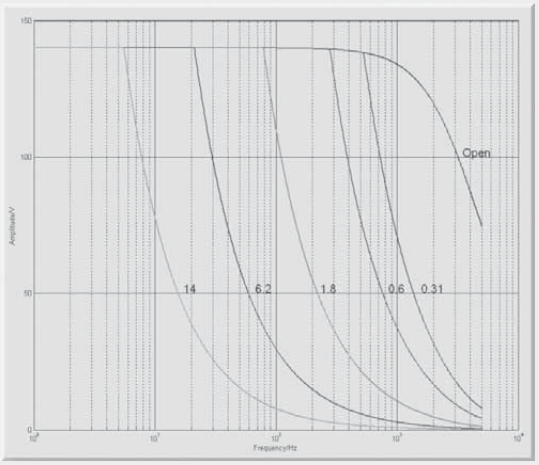
E-709.CRG
Digital Piezo Controller, 1 Channel, -30 to 130 V, Capacitive Sensor, Bench-Top

Accessories:

E-709.01
Adapter HD-Sub-D 26-pin to Sub-D 9-pin with I/O Lines, 0.5 m

E-709.02
Adapter Cable HD-Sub-D 26-pin to Open Leads, 1 m

The E-709 is also available for piezo systems with strain gauge and piezoresistive sensors.



E-709: operating limits with various PZT loads (open-loop), capacitance is measured in µF

Technical Data

Modell	E-709.CR / E-709.CRG
Function	Digital controller for single-axis piezo nanopositioning systems (.CR: OEM board)
Channels	1
Processor	DSP 32-bit floating point, 150 MHz
Sampling rate, servo-control	10 kHz
Sampling rate, sensor	10 kHz
Sensor	
Servo characteristics	P-I, 2 notch filter, sensor linearization
Sensor type	Capacitive sensors
Sensor bandwidth	5 kHz
Sensor resolution	16 bit
Ext. synchronization	No
Amplifier	
Output voltage	-30 V to +130 V
Peak output power	10 W (< 5 ms)
Average output power	5 W (> 5 ms)
Peak current	100 mA (< 5 ms)
Average current	50 mA (> 5 ms)
Current limitation	Short-circuit-proof
Resolution DAC	17 bit
Interfaces and operation	
Communication interfaces	USB, RS-232, SPI
Piezo / sensor connector	Sub-D-Special connector
I/O Connector	HD-Sub-D 26-pin, 1 analog input 0 to 10 V, 1 sensor monitor 0 to 10 V, 1 digital input (LVTTL, programmable), 1 analog output, 5 digital outputs (LVTTL, 3 predefined, 2 programmable)
Command set	PI General Command Set (GCS)
User software	PIMikroMove, NanoCapture
Software drivers	LabVIEW drivers, DLLs
Supported functionality	Wave generator, data recorder, auto zero, trigger I/O
Display	Status LED, overflow LED
Linearization	5th order polynomials
Target ground connector	- / yes
Miscellaneous	
Operating temperature range	12 to 50 °C (over 40 °C, max. av. power derated)
Dimensions	160 x 96 x 33 mm
Mass	260 g / 470 g
Motor voltage range	24 VDC
Max. power consumptions	24 W

E-753 Ultra-High Performance Single Axis 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 Nano Capture™ 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

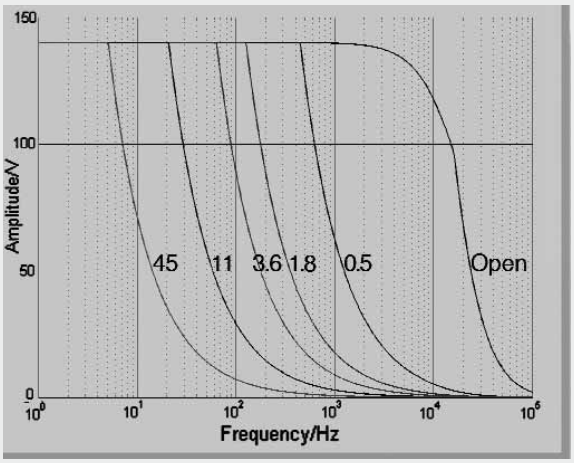
E-753.IO
Cable for Digital I/O Lines, 1.5 m, Solderable End

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

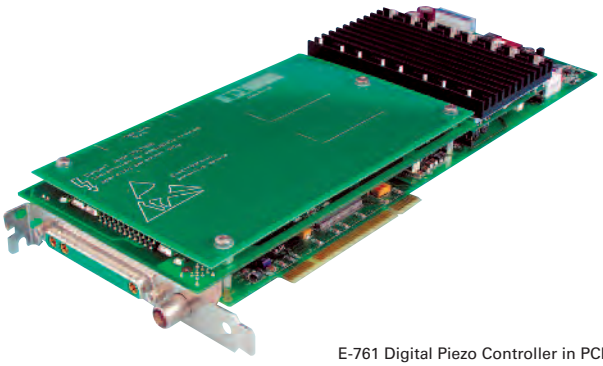
Model	E-753.1CD
Function	Digital controller for single-axis piezo nanopositioning systems with capacitive sensors
Axes	1
Processor	DSP 32-bit floating point, 60 MHz
Sampling rate, servo-control	25 kHz
Sampling rate, sensor	100 kHz
Sensor	
Servo characteristics	P-I, two notch filters
Sensor type	Capacitive
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-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.

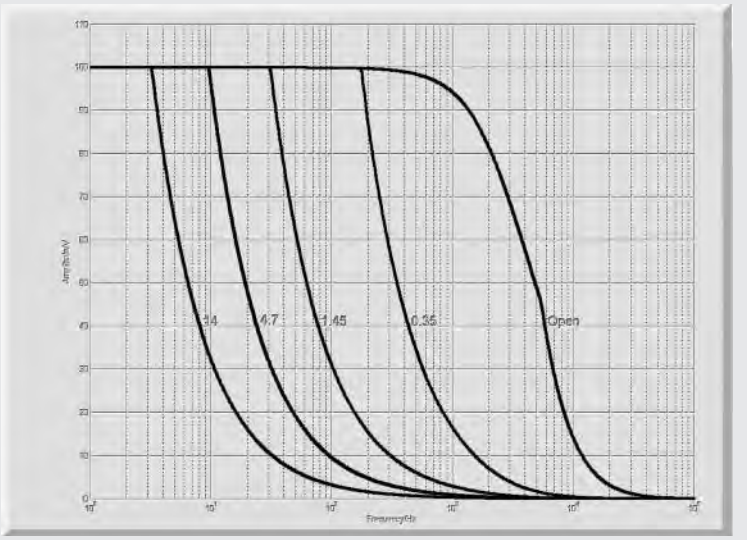
Ordering Information

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 nanopositioning system

Ordering Information

E-725.3CD
Digital Multi-Channel Piezo Controller, 3-Channel, Sub-D Connector for Capacitive Sensors

E-725.3CM
Digital Multi-Channel Piezo Controller, for PicoCube™ and Capacitive Sensors

Ask about custom designs!

- **For Nanopositioning Systems with Capacitive Sensors**
- **3-Channel Version**
- **Powerful Digital Controller: DSP 32-bit Floating Point, 225 MHz; 20 kHz Sampling Rate; 24-bit DAC**
- **Communication via Ethernet, USB, RS-232**
- **4th Order Polynomial Linearization for Mechanics & Electronics**
- **Dynamic Digital Linearization (DDL) Option for Improved Path Accuracy**
- **Auto-Loading of Calibration Data from Stage ID-Chip for Interchangeability of Controller and Mechanics**
- **Additional High-Bandwidth Analog Control Input / Sensor Input**
- **Optional High-Speed Parallel I/O Interface**
- **Flexible Wave Generators**
- **Digital I/O Lines for Task Triggering**
- **Extensive Software Support**

The E-725 digital piezo controller is a compact, high-performance drive electronics for nanopositioning systems with up to three axes. High-power amplifiers permit dynamic scans even for piezo systems with large range or direct drive. State-of-the-art processor technology optimizes the operating parameters for improved linearity and tracking accuracy. High-resolution D/A converters provide for nanopositioning that deserves this name.

With the E-725.3CM, PI for the first time offers a digital controller for the P-363 PicoCube™ (see p. 2-66), a fast precision scanner for atomic force microscopy.

Optional interfaces and analog in- and outputs make it possible to process external sensor or control values.

Digital Linearization and Control Algorithms for Highest Accuracy

Linearization algorithms based on higher-order polynomials improve the positioning accuracy to better than 0.01 % for capacitive sensors, typically 10 times better than achievable with conventional controllers.

More than just a Controller – Trajectory Control and Data Recording

During fast periodic motion, as typical for scanning applications, the tracking accuracy can be further improved with Dynamic Digital Linearization (DDL, E-710.SCN). This optionally available control algorithm reduces the tracking error by a factor of up to 1000.

This control algorithm enables the spatial and temporal tracking during a dynamic scan. The integrated wave generator can output periodic motion profiles. In addition to sine and triangle waves, arbitrary, user-defined motion profiles can be created and stored. The flexibly configurable data recorder enables simultaneous recording and read-out of the corresponding data.

Extensive Software Support

The controllers are delivered with Windows operating software. Comprehensive DLLs and LabVIEW drivers are available for automated control.

Automatic Configuration

PI digital piezo controllers and nanopositioning stages with ID-Chip can be operated in any combination, supported by the AutoCalibration function of the controller. Individual stage data and optimized servo-control parameters are stored in the ID-Chip and are read out automatically by the digital controllers.

Technical Data

Model	E-725.3CD	E-725.3CM	Tolerance
Function	Digital Controller for Multi-Axis Piezo Nanopositioning Systems with Capacitive Sensors	Digital Controller for Multi-Axis Piezo Nanopositioning Systems with Capacitive Sensors	
Axes	3	3	
Processor	DSP 32-bit floating point, 225 MHz	DSP 32-bit floating point, 225 MHz	
Sampling rate, servo-control	20 kHz	20 kHz	
Sampling rate, sensor	20 kHz	20 kHz	
Sensor			
Servo characteristics	P-I, two notch filters	P-I, two notch filters	
Sensor type	Capacitive	Capacitive	
Sensor channels	3	3	
Sensor bandwidth (-3 dB)	5.6 kHz	5.6 kHz	max.
Sensor resolution	18 bit	18 bit	
Ext. synchronization	Yes	Yes	
Amplifier			
Output voltage	-30 to 135 V	-250 to 250 V	±3 V
Amplifier channels	4	4	
Peak output power per channel	25 W	47 W	max.
Average output power per channel*	10 W	10 W	max.
Peak output current per channel	190 mA	190 mA	max.
Average output current per channel*	120 mA	60 mA	max.
Current limitation	Short-circuit proof	Short-circuit proof	
Resolution DAC	24 bit	24 bit	
Interfaces and operation			
Communication interfaces	Ethernet, USB, RS-232	Ethernet, USB, RS-232	
Piezo / sensor connector	Sub-D special connector	Sub-D special connector	
Analog input	1 x Lemo, ±10 V, 18 bit	1 x Lemo, ±10 V, 18 bit	
Digital input / output	MDR20; 2 x IN, 8 x OUT	MDR20; 2 x IN, 8 x OUT	
Command set	PI General Command Set (GCS)	PI General Command Set (GCS)	
User software	NanoCapture™, PIMikroMove™	NanoCapture™, PIMikroMove™	
Software drivers	LabVIEW driver, DLLs	LabVIEW driver, DLLs	
Supported functionality	Wave-Gen, Trigger I/O	Wave-Gen, Trigger I/O	
Display	LEDs for Power, On Target, Error, Cmd	LEDs for Power, On Target, Error, Cmd	
Linearization	4th order polynomial, DDL (Dynamic Digital Linearization)	4th order polynomial, DDL (Dynamic Digital Linearization)	
Separate protective ground connector	Yes	Yes	
Miscellaneous			
Operating temperature range	5 to 50 °C	5 to 50 °C	
Overheat protection	Max. 71 °C, deactivation of the piezo voltage output	Max. 71 °C, deactivation of the piezo voltage output	
Mass	3.5 kg	3.6 kg	
Dimensions	263 x 89 x 302 mm (with handles)	263 x 89 x 302 mm (with handles)	
Power consumption	70 W	70 W	max.
Operating voltage	24 VDC from external power supply (included)	24 VDC from external power supply (included)	

* The total output power of all 4 amplifier channels should not exceed 34.5 W to avoid overcurrent (E-725 is equipped with a 3.15 AM fuse).

E-712 Advanced 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-536 PicoCube® Ultra-Low Noise Piezo Controller

High Dynamics, High Resolution, for up to 3 Axes

E-536.3C 3-channel PicoCube® Controller

- **For P-363 PicoCube® Systems**
- **Peak Power 3 x 100 W**
- **Ultra-Low Noise**
- **Output Voltage ±250 V**

The E-536 is a controller for the P-363 PicoCube® pico-positioning system providing three ultra-low-noise amplifier channels for piezo shear actuators. The controller design meets the special requirements of the high-speed, ultra-high-perform - ance PicoCube ® XY(Z) piezo stages (see p. 2-66) of ±250 V for both static and dynamic applications.

The high-performance E-536.3x can output and sink peak currents up to 200 mA featuring a small-signal bandwidth of 10 kHz. The E-536.3xH ultra-high-resolution models provide a position resolution below 0.03 nm at a peak power of 50 W . Both models are available with or without a servo module for closed-loop or open-loop operation.

Superior Resolution and High Dynamics

Open-loop operation is ideal for applications where fast response and very high resolution with maximum bandwith are essential. Here, commanding and reading the traget position in absolute values is either not important or carried out by external position sensors. Together with the P-363 PicoCube® a resolution of 0.05 nm or better is achieved.

Excellent Position Accuracy with Capacitive Sensors

The E-536.3C versions have integrated sensor electronics and servo-controllers for closed-loop position control. Position feedback is provided by capacitive sensors, like those in the PicoCube ®, with resolutions down to 0.1 nm.

Computer Control

Control via PC is possible by installing the E-517, 24-bit interface/display module.

Optionally digital control via a D/A converter is possible. For several D/A boards from National Instruments PI offers a corresponding LabVIEW™ driver set which is compatible with the PI General Command Set (GCS), the command set used by all PI controllers. A further option includes the patented Hyperbit™ technology providing enhanced system resolution.

Ordering Information

E-536.3C
PicoCube® Piezo Controller, 3 Channels, Capacitive Sensors

E-536.30
PicoCube® Piezo Controller, 3 Channels, Open-Loop

E-536.3CH
PicoCube® Piezo Controller, 3 Channels, High-Resolution, Capacitive Sensors

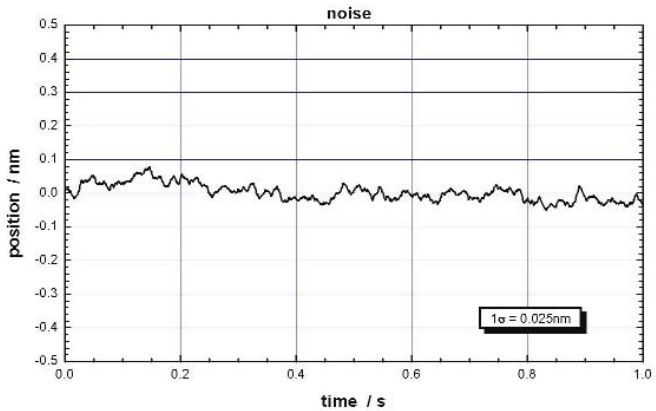
E-536.30H
PicoCube® Piezo Controller, 3 Channels, High-Resolution, Open-Loop

E-517.i3
Interface- / Display Module, 24 Bit D/A, TCP/IP, USB, RS-232, 3 Channels

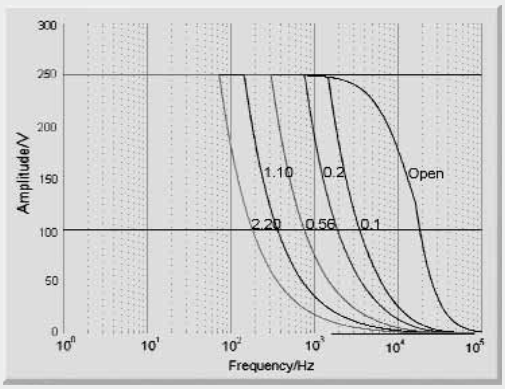
E-500.HCD
Hyperbit™ Functionality for Enhanced System Resolution

(Supports certain D/A boards.)

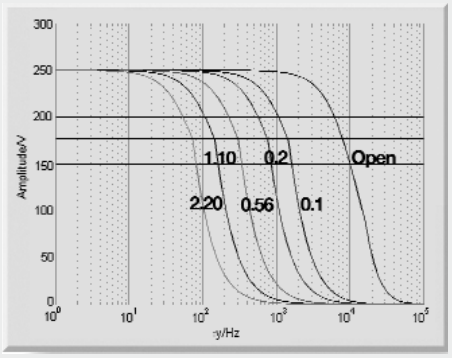
E-536 controller with P-363 PicoCube® pico-positioning system



Positional noise measurement of E-536 amplifier driving a P-363 pico-positioning system in open loop shows 1-sigma resolution of 25 picometers (0.025 nm). Measured with ultra-high-resolution capacitive sensor



E-536.3x: operating limits with various PZT loads, capacitance is measured in µF



E-536.3xH: operating limits with various PZT loads, capacitance is measured in µF

Technical Data

Model	E-536.3C / E-536.30	E-536.3CH / E-536.30H
Function	Power amplifier & servo-controller for P-363 PicoCube®	Power amplifier & servo-controller for P-363 PicoCube®
Amplifier		
Output voltage	-250 to +250 V	-250 to +250 V
Amplifier channels	3	3
Average output power per channel	10 W, limited by temperature sensor	6 W, limited by temperature sensor
Peak output power per channel, <3 ms	100 W	50 W
Average current	30 mA	15 mA
Peak current per channel, <3 ms	200 mA	100 mA
Amplifier bandwidth, small signal	10 kHz	2 kHz
Amplifier bandwidth, large signal, @ 100 nF	0.2 kHz	0.125 kHz
Ripple, noise, 0 to 100 kHz	0.8 mV_{RMS}, <5 mV_{P-P} (100 nF)	0.5 mV_{RMS}, <3 mV_{P-P} (100 nF)
Current limitation	Short-circuit proof	Short-circuit proof
Voltage gain	+50	+50
Input impedance	100 kΩ	100 kΩ
Sensor*		
Servo characteristics	Analog proportional-integral (P-I) algorithm with notch filter	Analog proportional-integral (P-I) algorithm with notch filter
Sensor type	capacitive sensors	capacitive sensors
Sensor channels	3 / -	3 / -
Sensor bandwidth	1.5 kHz	1.5 kHz
Sensor Monitor output	0 to +10 V	0 to +10 V
Interfaces and operation		
PZT output sockets	LEMO EGG.0B.701.CJL.1173	LEMO EGG.0B.701.CJL.1173
Sensor target and probe sockets	LEMO EPL.00.250.NTD	LEMO EPL.00.250.NTD
Control Input sockets	SMB	SMB
Sensor Monitor socket	LEMO FGG.0B.306.CLAD56	LEMO FGG.0B.306.CLAD56
Control Input voltage	Servo off: -5 to +5 V, Servo on: 0 to +10 V	Servo off: -5 to +5 V, Servo on: 0 to +10 V
DC Offset	10-turn pot., adds 0 to +10 V to Control IN	10-turn pot., adds 0 to +10 V to Control IN
Miscellaneous		
Operating voltage	115 VAC / 50-60 Hz or 230 VAC / 50-60 Hz	115 VAC / 50-60 Hz or 230 VAC / 50-60 Hz
Mass	8.1 kg / 7.8 kg (with E-516 module)	8.1 kg / 7.8 kg (with E-516 module)
Dimensions	450 x 132 x 296 mm + handles	450 x 132 x 296 mm + handles

*only E-536.3Cx with capacitive sensors
Interfaces / communication: RS-232, TCP/IP, USB (with optional E-517 computer interface and display module only)
Operating temperature range: +5 °C to +50 °C (over 40 °C, max. av . power derated 10 %), high-voltage output is automatically deactivated if temperature is too high by internal temperature sensor (75 °C max.)

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

Request or download the complete PI Nanopositioning & Piezo Actuator Catalog

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