Piezo · Nano · Positioning

Tools for Microscopy & Imaging

Piezo Stages, Lens Positioners & Scanners, Steering Mirrors, Actuators

PDF Catalog, Updated July 2008

More Info:
Click Images

Overview: Tools for Microscopy & Imaging

Piezo Stages & Piezo Objective Scanners

P-721.CLQ PIFOC® High-Speed Nanofocusing/Scanning Z-Drives

- Scans and Positions Objectives with Sub-nm Resolution
- High Linearity and Stability with Direct-Measuring Sensors
- Travel to 100 µm, Fast Settling Time
- Very Straight Motion for Enhanced Focus Stability
- Ask about DIC Prism Holder Option
- Compatible with Metamorph™ Imaging Software
- Quick Lock Adapter for Easy Attachment

See p. 6 or Online Datasheet Available at www.pi.ws

P-725 PIFOC® Long-Range, High-Speed Nanofocusing Z-Drives

- Scans and Positions Objectives with Sub-nm Resolution
- High Linearity and Stability with Direct-Measuring Sensors
- Travel to 460 µm, Fast Settling Time
- Frictionless Precision Flexure Guiding System
- Enhanced Guiding Precision for Better Focus Stability
- Ask about DIC Prism Holder Option
- Controller Compatible with Metamorph™ Imaging Software
- Quick Lock Adapter for Easy Attachment

See p. 10 or Online Datasheet Available at www.pi.ws

P-726 High-Power PIFOC® Nanofocusing Z-Drives

- Resonant Frequency: 430 Hz (with 300g), 1100 Hz Without Objective
- Closed-Loop Position Noise: <0.4 nm
- Position Stability Over 100s: 4nm
- Maximum Operating Frequency (amplitude <10 µm): 150 Hz
- Settling Time (10 µm steps): 6 ms

See p. 12 or Online Datasheet Available at www.pi.ws

P-737 PIFOC® Z-Axis Microscopy Piezo Stage for High-Resolution Sample Positioning and Scanning

- High-Speed Piezo Motion with Travel Ranges to 500 µm
- Nanometer Resolution
- Large Clear Aperture to Accommodate Specimen Holders
- Perfect Mechanical Fit to OEM Manual or Motorized Stages
- Sub-Millisecond Response Times

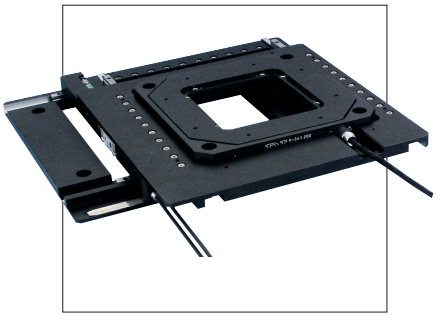
See p. 13 or Online Datasheet Available at www.pi.ws

More Info:
Click Images

Overview: Tools for Microscopy... (cont.)

Piezo Scanning Stages & Piezo Motor Stages

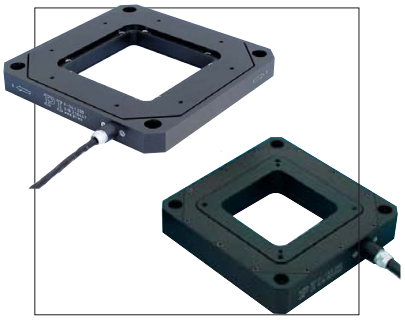
M-686 PILine® XY Piezo Linear-Motor Stage



- 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

See p. 15 or Online Datasheet Available at www.pi.ws

P-541.2CD and P-733.2DD Low-Profile, XY Piezo Scanning Microscopy Stages



- Low Profile for Easy Integration
- Higher Speed Through Direct Drive
- Travel to 200 x 200 µm or 30 x 30 High-Speed Version
- Frictionless Precision Flexure Guiding System
- Parallel-Kinematics/Metrology for Enhanced Responsiveness/Multi-Axis Precision
- 80 x 80 mm or 50 x 50 mm Clear Aperture
- PICMA® High-Performance Piezo Actuators for Superior Lifetime

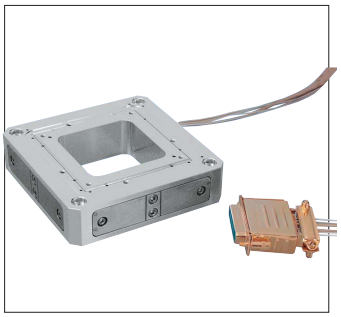
See pp. 17-26, or Online Datasheet Available at www.pi.ws

P-714 Low-Profile OEM XY Piezo-Scanners for Imaging Applications

- Ideal for Interlacing, CCD Resolution Enhancement
- Compact Size of only 45 x 45 x 6 mm
- Clear Aperture
- Highly Cost-Efficient Design
- 15 x 15 µm Travel Range
- Parallel-Kinematics Design for Higher Dynamics

See p. 27 or Online Datasheet Available at www.pi.ws

P-733.2UD Non-Magnetic XY Scanning Stage for UHV to 10^{-9} hPa



- Travel Ranges of 100 x 100 µm
- Resolution to 0.1 nm
- Direct Metrology with Capacitive Sensors
- Parallel Kinematics for Better Multi-Axis Accuracy and Dynamics
- Parallel-Motion Metrology for Highest Linearity and Stability
- 50 x 50 mm Clear Aperture for Transmitted-Light Applications

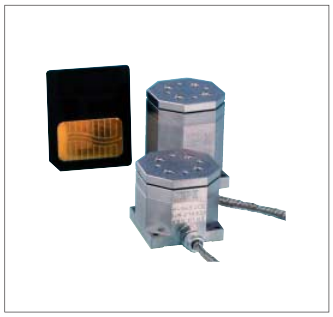
See p. 23 or Online Datasheet Available at www.pi.ws

More Info:
Click Images

Overview: Tools for Microscopy... (cont.)

Piezo Stages & Piezo Tubes, Piezo Controllers

P-363 PicoCube® High-Speed, XY(Z) Piezo Stages for Nanotechnology, SPM, AFM



- Ultra-High-Performance Closed-Loop Scanner for AFM/SPM
- Compact Manipulation Tool for Nanotechnology
- Resonant Frequency 9.8 kHz
- Ultra-High-Precision Capacitive Feedback
- 50 Picometers Resolution, 5 x 5 x 5 µm Travel Range
- Very Small Package, Rugged Design

See p. 29 or Online Datasheet Available at www.pi.ws

PT120 - PT140 Piezoceramic Tubes (HVPZT) and P-151 PICA™-Shear Piezo Actuators

- Standard Custom Sizes
- For OEM Applications
- XYZ-Positioning
- Sub-Nanometer Resolution
- For Scanning Microscopy (STM, AFM, etc.)

See Online Datasheet Available at www.pi.ws

M-824 Vacuum Compatible 6-Axis Stage for X-Ray Microscopy

- Resolution to 7 nm
- Velocity to 25 mm/sec
- Load Capacity to 10 kg, Self Locking Version!!
- Min. Incremental Motion to 300 nm
- Travel Ranges to 45 mm (linear), 25° (rotation)!!

See Online Datasheet Available at www.pi.ws

Digital and Analog Piezo Controllers

- For Piezo Stages with Capacitive Sensors and SGS
- High-Speed Digital and Analog Interfaces
- 1 to 6 Axes
- OEM- , PCI and Rack-Mount Controllers
- 32-Bit Digital Filters
- 24-Bit Ultra-Low-Noise DAC Converters
- Extensive Software Support, Compatible with Image Acquisition Systems

See p. 44 or Online Datasheet Available at www.pi.ws

More Info:
Click Images

Overview: Tools for Microscopy ... (cont.)

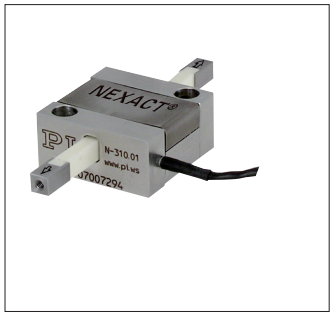
Precision Actuators and Linear Motors

M-674 PILine® RodDrive Integrated Piezo Linear Motor Drive

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

See p. 31 or Online Datasheet Available at www.pi.ws

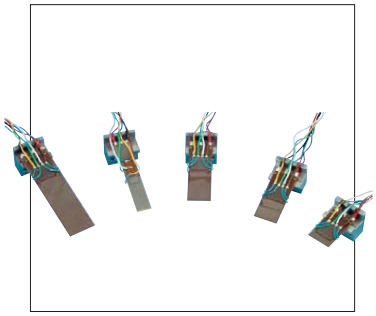
N-310 Compact NEXACT® Nanopositioning Motor with Step & Scan Mode



- 20 mm Standard Travel Range
- Compact and Cost-Effective Design
- 0.03 nm Resolution, Very Fast Response
- To 10 N Push/Pull Force
- Low Operating Voltage
- Self Locking, with no Heat Dissipation, Nanometer Stability
- Non-Magnetic and Vacuum-Compatible Working Principle

See p. 33 or Online Datasheet Available at www.pi.ws

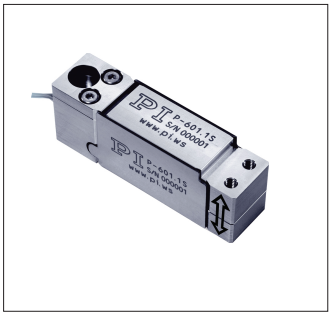
P-871 High-Deflection PICMA® Multilayer Piezo Bender Actuators



- Closed-Loop Operation for Superior Accuracy
- Nanometer-Range Resolution
- Deflection up to 2 mm
- Ceramic Insulation for Extended Lifetime
- Vacuum-Compatible Versions
- Low Operating Voltage
- Mounting Hardware Included
- Special Controllers / Drivers Available

See p. 35 or Online Datasheet Available at www.pi.ws

P-601 PiezoMove® High-Precision Flexure-Guided Z-Actuator for OEMs



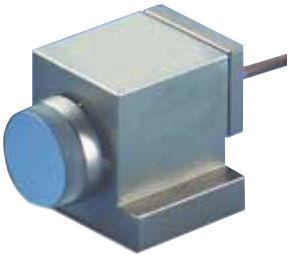
- Flexure Guidance for Frictionless, Ultra-Straight Motion
- To Sub-Millisecond Response , Travel Ranges to 480 µm
- Resolution to 0.2 nm
- High Dynamics and Stiffness
- PICMA® High-Performance Piezo Actuators
- Open and Closed-Loop Versions
- Ideal for OEM Applications

See p. 37 or Online Datasheet Availble at www.pi.ws

More Info:
Click Images

Overview: Fast Beam Steering Mirrors

Piezo-Driven, Flexure Guided, for Optical Trapping, Confocal Microscopy



See www.pi.ws

S-224 / S-226 High-Speed Mini Piezo Tilt Mirror; Nano-rad Resolution; to 100 µ-second Response; Up to 4.4 mrad Optical Beam Deflection.

See www.pi.ws

S-334 Ultra-Long-Range Piezo Tip/Tilt Mirror. Optical Deflection to 100 mrad (~6°). 1.0 kHz Resonant Frequency with Mirror.

See www.pi.ws

S-310 – S-316, Fast Multi-Axis Tip/Tilt Platforms and Z Positioners; Piezo Tripod Design Allows Z Motion/Tilt.

See www.pi.ws

S-325 High-Speed Piezo Tip/Tilt/Piston Platform. Piezo Tripod Design, 10 mrad Optical Beam Deflection, Piston Movement up to 30 µm.

See www.pi.ws

S-340 High-Speed Piezo Tip/Tilt Platform. Fixed Orthogonal Axes; 4 mrad Optical , Beam Deflection, Mirrors to Ø100mm.

See www.pi.ws

S-330. Ideal for Optical Trapping. Nanorad Resolution, Beam Deflection to 20 mrad (>1°), Sub-Millisecond Response.

See www.pi.ws

S-303 High-Speed Piezo Phase Shifters with Direct Metrology Option <0.1 Nanometer Resolution, Open- or Closed Loop Option.

See www.pi.ws

Example of a Combined High-Speed Piezo Tip/Tilt Plaftform with a Long Range, Low-Speed 6-Axis Hexapod Alignment System.

P-721 Piezo-Z Lens Focusing Device

PIFOC® High-Speed Nanofocusing/Scanning Z-Drives with Direct Metrology

P-721.CLQ with Quick Lock option P-721.12Q and objective (not included).

- **Scans and Positions Objectives with Sub-nm Resolution**
- **High Linearity and Stability with Direct-Measuring Sensors**
- **Travel to 100 µm, fast Settling Time**
- **Very Straight Motion for Enhanced Focus Stability**
- **Ask about DIC Prism Holder Option**
- **Compatible with Metamorph™ Imaging Software**
- **Quick Lock Adapter for Easy Attachment**

P-721 PIFOCs® are high-speed, piezo-driven microscope objective nanofocusing/scanning devices, providing a positioning and scanning range of 100 µm with sub-nanometer resolution and very high linearity. They were designed for tasks such as surface metrology or deconvolution microscopy (Z-stack acquisition). The frictionless, flexure guiding system provides enhanced precision for superior focus stability with fast response for rapid settling and scanning.

Application Examples

- Scanning interferometry
- Surface structure analysis
- Disk drive testing
- Autofocus systems
- Confocal microscopy
- Biotechnology
- Semiconductor test equipment

Superior Accuracy Through Direct-Motion Metrology with Capacitive Sensors

P-721.CLQ and .CDQ are equipped with direct-measuring capacitve position sensors. Unlike conventional sensors, capacitive sensors measure the actual distance between the fixed frame and the moving part of the stage. They detect errors contributed by all components in the drive train—from the actuator through the flexures to the platform. 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.

P-721.LLQ is a lower cost version, equipped with a direct-measuring LVDT sensor providing 10 nm resolution. A variety of analog and digital controllers is available to drive these units. The P-721.CDQ can be operated with the E-665 servo-controller (see page 6-30) through an analog or digital interface. The E-750 high-speed, digital NanoAutomation® controller, (p. 6-12) can also be used.

Easy Installation

Attach the objective to the PIFOC®. The new Quick Lock thread adapters allow easy attachment to any of a variety of objective thread types.

Then screw a thread adapter onto the microscope and attach the PIFOC® with the Quick Lock system. Mounting does not require rotation of the PIFOC® unit, and the optical path is extended by only 12.5 mm (infinity corrected microscope required; extension tubes are available to adjust path lengths of other objectives on a turret). Thread adapters are ordered separately.

Working Principle / Reliability

PIFOCs® are equipped with the award winning PICMA® piezodrives, integrated into a sophisticated flexure guiding system. The wire-EDM-cut flexures are FEA modeled for zero stiction, zero friction and exceptional guiding precision. The ceramic-encapsulated PICMA® drives are more robust than conventional piezo actuators, featuring superior lifetime and performance in both dynamic and static applications.

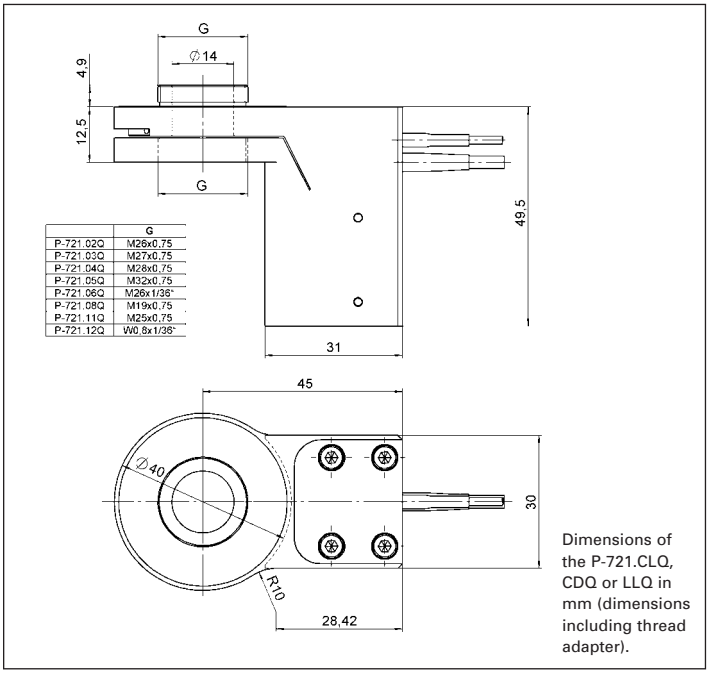
Because guidance, actuators and sensors are all frictionless and maintenance-free, these nanopositioning systems achieve outstanding levels of reliability.

Other PIFOCs®

PIFOCs® are also available with up to 460 µm travel (P-725, see page 2-22) and for open-loop operation only (P-720, see page 2-20). Custom units for moving a whole turret are available on request.

Notes

See the "Selection Guide" on p. 2-14 *ff.* for comparison with other nanopositioning systems.



	G
P-721.02Q	M26x0.75
P-721.03Q	M27x0.75
P-721.04Q	M28x0.75
P-721.05Q	M32x0.75
P-721.06Q	M26x1/36"
P-721.08Q	M19x0.75
P-721.11Q	M25x0.75
P-721.12Q	W0.8x1/36"

Dimensions of the P-721.CLQ, CDQ or LLQ in mm (dimensions including thread adapter).

Page references refer to PI's hardcover catalog

Ordering Information

P-721.CLQ
PIFOC® Objective Positioner & Scanner, 100 µm, Capacitive Sensor, LEMO Connectors, for Quick Lock Thread Adapters

P-721.CDQ
PIFOC® Objective Positioner & Scanner, 100 µm, Capacitive Sensor, Sub-D connector, for Quick Lock Thread Adapters

P-721.LLQ
PIFOC® Objective Positioner & Scanner, 100 µm, LVDT Sensor, LEMO Connectors, for Quick Lock Thread Adapters

P-721.0LQ
PIFOC® Objective Positioner & Scanner, 100 µm, Open-Loop, LEMO Connectors, for Quick Lock Thread Adapters

Accessories: Quick Lock Adapters

P-721.11Q
Quick Lock Adapter, M25 x 0.75

P-721.12Q
Quick Lock Adapter, W0.8 x 1/36"

P-721.02Q
Quick Lock Adapter, M26 x 0.75

P-721.03Q
Quick Lock Adapter, M27 x 0.75

P-721.04Q
Quick Lock Adapter, M28 x 0.75

P-721.05Q
Quick Lock Adapter, M32 x 0.75

P-721.06Q
Quick Lock Adapter, M26 x 1/36"

P-721.08Q
Quick Lock Adapter, M19 x 0.75

Extension Tubes for Objectives

P-721.90Q
12.5 mm Extens. Tube, W0.8 x 1/36"

P-721.91Q
12.5 mm Extens. Tube, M25 x 0.75

P-721.92Q
12.5 mm Extens. Tube, M26 x 0.75

P-721.93Q
12.5 mm Extens. Tube, M27 x 0.75

P-721.94Q
12.5 mm Extens. Tube, M28 x 0.75

P-721.95Q
12.5 mm Extens. Tube, M32 x 0.75

P-721.96Q
12.5 mm Extens. Tube, M26 x 1/36"

P-721.98Q
12.5 mm Extens. Tube, M19 x 0.75

Ask about custom designs!

Quick lock thread adapter P-721.12Q exploded view with microscope objective and PIFOC® P-721.CLQ. Mounting tools are included.

Custom PIFOC® nosepiece nanopositioner for microscope turret.

Technical Data

Models	P-721.CLQ P-721.CDQ	P-721.LLQ	P-721.0LQ	Units	Notes see p. 2-84
Max. objective diameter	39	39	39	mm	
Open-loop travel @ 0 to 100 V	90	90	90	µm ±20%	A2
Closed-loop travel	100	100	-	µm	A5
Integrated feedback sensor	Capacitive	LVDT	-		B
* Closed- / open loop resolution	0.7 / 0.5	10 / 0.5	- / 0.5	nm	C1
Closed-loop linearity (typ.)	0.03	0.1	-	%	
Full-range repeatability (typ.)	±5	±20	-	nm	C3
Stiffness	0.3	0.3	0.3	N/µm ±20%	D1
Push/pull force capacity (in operating direction)	100 / 20	100 / 20	100 / 20	N	D3
Tilt (θ_X) (typ.)	0.5	0.5	0.5	µrad	E1
Tilt (θ_Y) (typ.)	13	13	13	µrad	E1
Lateral runout (Y) (typ.)	100	100	100	nm	E2
Electrical capacitance	3.0	3.0	3.0	µF ±20%	F1
** Dynamic operating current coefficient (DOCC)	4.2	4.2	4.2	µA/(Hz x µm)	F2
Unloaded resonant frequency	580	580	580	Hz ±20%	G2
Resonant frequency @ 120 g load	250	250	250	Hz ±20%	G3
Resonant frequency @ 200 g load	190	190	190	Hz ±20%	G3
Operating temperature range	-20 to 80	-20 to 80	-20 to 80	°C	H2
Voltage connection	VL	VL	VL		J1
Sensor connection	2 x C	L	-		J2
Weight (with cables)	240	230	220	g ±5%	
Body material	Al	Al	Al		L
Recommended driver/ controller (codes explained p. 2-17)	H, M, F	H, E	G, C		

* For calibration information see p. 2-8. Resolution of PI piezo nanopositioners is not limited by friction or stiction. The value given is noise equivalent motion with E-503 amplifier.

** Dynamic Operating Current Coefficient in µA per Hz and µm. Example: Sinusoidal scan of 30 µm at 10 Hz requires approximately 1.2 mA drive current.

P-720 Piezo-Z Lens Focusing Device

PIFOC® for Small Microscope Objectives

P-720 objective nanofocusing / scanning drive (objective not included)

- **Scans and Positions Objectives with Sub-nm Resolution**
- **Low Inertia for Fast Settling**
- **Frictionless Precision Flexure Guiding System**
- **Travel to 100 µm**
- **Straightness of Travel ≤13 µrad**
- **PICMA® High-Performance Piezo Drives**

P-720 PIFOCs® are high-speed, piezo-driven microscope objective nanofocusing/scanning devices which can be mounted on most microscopes. The frictionless, flexure guiding system combines high guiding precision for superior focus stability with fast response for rapid settling and scanning. The units are screwed between the turret and the objective, providing a positioning and scanning range of up to 100 µm with sub-nanometer resolution, while extending the optical path by only 13 mm (infinity-corrected microscope required; extension tubes are available to adjust path lengths of other objectives on the turret). The standard thread is W0.8 x 1/36", for alternate threads see the P-721.CLQ. For larger positioning ranges, to 460 µm, see the P-725, page 2-22.

Application Examples

- Scanning interferometry
- Surface structure analysis
- Disk drive testing
- Autofocus systems
- Confocal microscopy
- Biotechnology
- Semiconductor test equipment

Operation

The P-720 open-loop PIFOC® is designed for fast, high-resolution positioning and scanning tasks where the absolute position is not important or where an external sensor is used. The vertical position of the objective is roughly proportional to the drive voltage (see p. 4-15 *ff.* in the "Tutorial: Piezoelectrics in Positioning" section for behavior of open-loop piezos).
If absolute position control, high linearity, or repeatability in the nanometer range is required, refer to the P-721 and P-725 closed-loop devices (see pages 2-20 and 2-22).

Working Principle / Reliability

PIFOCs® are equipped with the award winning PICMA® piezo drives, integrated into a sophisticated flexure guiding system. The wire-EDM-cut flexures are FEA modeled for zero stiction, zero friction and exceptional guiding precision. The ceramic-encapsulated PICMA® drives are more robust than conventional piezo actuators, featuring superior lifetime and performance in both dynamic and static applications.

Notes

See the "Selection Guide" on p. 2-14 *ff.* for comparison with other nanopositioning systems.

Ordering Information

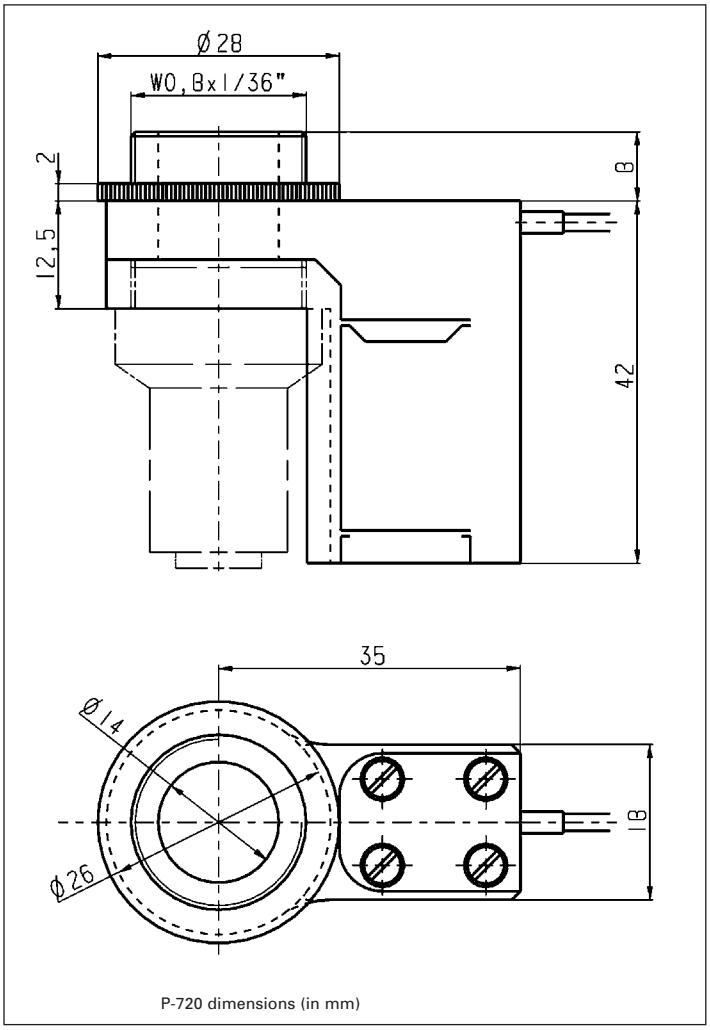
P-720.00
PIFOC® Objective Positioner & Scanner, 100 µm, W0.8 x 1/36"

For PIFOC® Objective Positioners & Scanners with direct metrology and travel ranges to 400 µm see P-721 and P-725, p. 2-20 and p. 2-22

P-720.01
Objective extension tube, 13 mm

Ask about custom designs!

P-721 on a microscope turret



P-720 dimensions (in mm)

Custom PIFOC® nosepiece nanopositioner for microscope turret.

Technical Data

Models	P-720.00	Units	Notes see p. 2-84
Max. objective diameter	25	mm	
Open-loop travel @ 0 to 100 V	100	µm ±20%	A2
* Open-loop resolution	1	nm	C1
Stiffness	0.2	N/µm ±20%	D1
Push/pull force capacity (in operating direction)	100 / 20	N	D3
Tilt (θ_X, θ_Y) (typ.)	13	µrad	E1
Lateral runout (Y) (typ.)	100	nm	E2
Electrical capacitance	3.0	µF ±20%	F1
** Dynamic operating current coefficient (DOCC)	3.8	µA/(Hz 3 µm)	F2
Unloaded resonant frequency	400	Hz ±20%	G2
Resonant frequency @ 120 g load	180	Hz ±20%	G3
Resonant frequency @ 200 g load	150	Hz ±20%	G3
Operating temperature range	-20 to 80	°C	H2
Voltage connection	VL		J1
Weight (with cables)	100	g ±5%	
Body material	Al		L
Recommended driver/controller (codes explained p. 2-17)	G, C, (A)		

* For calibration information see p. 2-8. Resolution of PI piezo nanopositioners is not limited by friction or stiction. The value given is noise equivalent motion with E-503 amplifier.

** Dynamic Operating Current Coefficient in µA per Hz and µm. Example: Sinusoidal scan of 30 µm at 10 Hz requires approximately 1.2 mA drive current.

P-725 Piezo-Z Lens Focusing Device

PIFOC® Long-Range, High-Speed Nanofocusing Z-Drives with Direct Metrology

P-725.2CL with Quick Lock option
P-721.12Q for W0.8 x 1/36" threads and objective.

- **Scans and Positions Objectives with Sub-nm Resolution**
- **High Linearity and Stability with Direct-Measuring Capacitive Sensors**
- **Travel to 460 µm, Fast Response & Settling Time**
- **Frictionless Precision Flexure Guiding System**
- **Enhanced Guiding Precision for Better Focus Stability**
- **Ask about DIC Prism Holder Option**
- **Controller Compatible with Metamorph™ Imaging Software**
- **Quick Lock Adapter for Easy Attachment**

P-725 PIFOCs® are long-travel, high-speed, piezo-driven microscope objective nanofocusing/scanning devices.
Despite the increased travel ranges (up to 460 µm), they are 20% shorter than P-721 units (see page 2-20), while providing sub-nanometer resolution. Equipped with ultra-precise, direct-measuring capacitive sensors, these devices are ideal for tasks such as surface metrology or deconvolution microscopy (Z-stack acquisition). The newly designed, frictionless, flexure guiding system provides enhanced precision for superior focus stability with fast response for rapid settling and scanning.

P-725 PIFOCs® are mounted between the turret and the objective, extending the optical path by only 12.5 mm (infinity corrected microscope required; extension tubes are available to adjust path lengths of other objectives on the turret). Custom designs for positioning the complete turret are available on request.

Superior Accuracy Through Direct-Motion Metrology with Capacitive Sensors

P-725s are equipped with absolute-measuring, direct-metrology capacitive sensors. These sensors make possible motion linearity to 0.03% with effective resolution in the sub-nanometer range. They boast high bandwidth and exhibit no periodic errors.
Unlike conventional sensors, capacitive sensors measure the actual distance between the fixed frame and the moving part of the stage. They detect errors contributed by all components in the drive train —from the actuator through the flexures to the platform. 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. See p. 2-4 *ff.* and p. 5-2 *ff.* for more information.

Fastest Step-and-Settle: 25 Milliseconds for 250 Microns

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

Controllers

A variety of analog and digital controllers is available to drive these units. The P-725.xCD models can be operated with the E-665 servo-controller through an analog or digital interface (see page 6-30). The E-750 high-speed digital NanoAutomation® controller can also be used (see page 6-12).

Working Principle / Reliability

PIFOCs® are equipped with the award winning PICMA® piezo drives, integrated into a sophisticated flexure guiding system. The wire-EDM-cut flexures are FEA modeled for zero stiction, zero friction and exceptional guiding precision. The ceramic-encapsulated PICMA® drives are more robust than conventional piezo actuators, featuring superior lifetime and performance in both dynamic and static applications.
Because guidance, actuators and sensors are all frictionless and maintenance-free, these

Ordering Information

P-725.1CL*
PIFOC® Objective Positioner & Scanner, 100 µm, Capacitive Sensor, LEMO Connectors, for Quick Lock Thread Adapters

P-725.1CD
PIFOC® Objective Positioner & Scanner, 100 µm, Capacitive Sensor, Sub-D Connector, for Quick Lock Thread Adapters

P-725.2CL*
PIFOC® Objective Positioner & Scanner, 250 µm, Capacitive Sensor, LEMO Connectors, for Quick Lock Thread Adapters

P-725.2CD
PIFOC® Objective Positioner & Scanner, 250 µm, Capacitive Sensor, Sub-D Connector, for Quick Lock Thread Adapters

P-725.4CL*
PIFOC® Objective Positioner & Scanner, 400 µm, Capacitive Sensor, LEMO Connectors, for Quick Lock Thread Adapters

P-725.4CD
PIFOC® Objective Positioner & Scanner, 400 µm, Capacitive Sensor, Sub-D Connector, for Quick Lock Thread Adapters

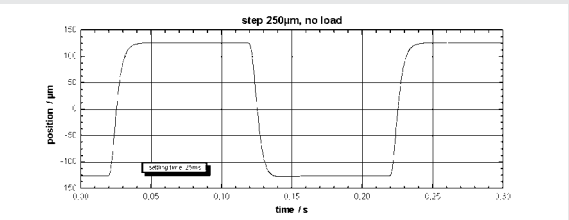
*Also available w/o sensor (open-loop): P-725.10L, P-725.20L and P-725.40L.

Accessories
Quick Lock adapters and objective distance tubes see p. 2-21

Ask about custom designs!

Application Examples

- Scanning interferometry
- Surface structure analysis
- Disk drive testing
- Autofocus systems
- Confocal microscopy
- Biotechnology
- Semiconductor test equipment



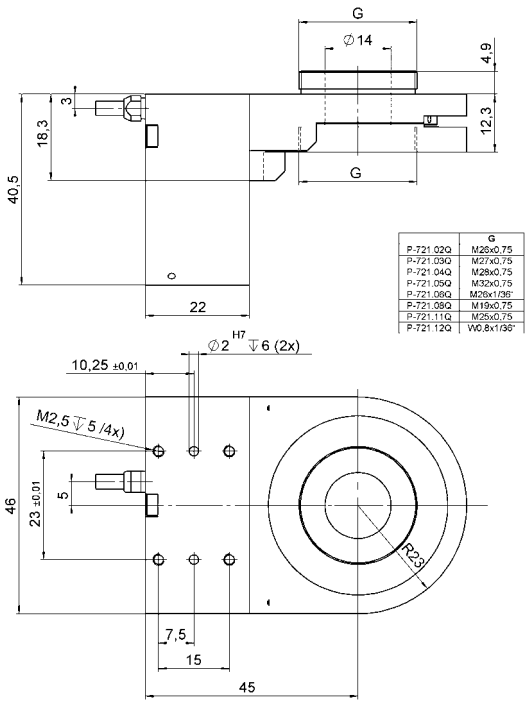
25 ms for a 250 µm step top dynamic performance of the P-725.2CL

nanopositioning systems achieve outstanding levels of reliability.

Notes

For low-profile, large aperture Z stages, see the P-541.ZSL on p. 2-48 and the P-541.ZCD on p. 2-50.
See the "Selection Guide" on p. 2-14 *ff.* for comparison with other nanopositioning systems.

P-721.12Q Quick Lock thread adapter, exploded view with microscope objective and PIFOC®. Mounting tools are included.



	G
P-721.02Q	M26x0.75
P-721.03Q	M27x0.75
P-721.04Q	M28x0.75
P-721.05Q	M32x0.75
P-721.06Q	M26x1/36"
P-721.08Q	M19x0.75
P-721.11Q	M25x0.75
P-721.12Q	W0.8x1/36"

Dimensions of the P-725 in mm (dimensions in mm, thread adapter ordered separately, decimal places separated by commas in drawings).

Technical Data

Models	P-725.1CL, P-725.1CD	P-725.2CL, P-725.2CD	P-725.4CL, P-725.4CD	Units	Notes see p. 2-84
Max. objective diameter	39	39	39	mm	
Min. open-loop travel @ -20 to 120 V	150	330	460	µm ±20%	A2
Closed-loop travel	100	250	400	µm	A5
Integrated feedback sensor	Capacitive	Capacitive	Capacitive		B
* Closed-loop resolution	0.65	0.75	1.25	nm	C1
Closed-loop linearity (typ.)	0.03	0.03	0.03	%	
Full-range repeatability (typ.)	±2	±3	±5	nm	C3
Stiffness	0.25	0.2	0.15	N/µm ±20%	D1
Push/pull force capacity (in operating direction)	100 / 20	100 / 20	100 / 20	N	D3
Tilt (θ_X) (typ.)	1	6	18	µrad	E1
Tilt (θ_Y) (typ.)	20	45	25	µrad	E1
Lateral runout (Y) (typ.)	40	40	40	nm	E2
Electrical capacitance	4.2	6.0	6.0	µF ±20%	F1
** Dynamic operating current coefficient (DOCC)	4.0	2.5	1.9	µA/(Hz x µm)	F2
Unloaded resonant frequency	530	330	200	Hz ±20%	G2
Resonant frequency @ 120 g load	205	180	115	Hz ±20%	G3
Resonant frequency @ 200 g load	160	140		Hz ±20%	G3
Operating temperature range	-20 to 80	-20 to 80	-20 to 80	°C	H2
Voltage connection	VL ***	VL ***	VL ***		J1
Sensor connection	2 x C ***	2 x C ***	2 x C ***		J2
Weight (with cables)	215 (230)	230 (245)	230 (245)	g ±5%	
Body material	Al	Al	Al		L
Recommended driver/controller (codes explained p. 2-17)	H, M, F	H, M, F	H, M, F		

* For calibration information see p. 2-8. Resolution of PI piezo nanopositioners is not limited by friction or stiction. The value given is noise equivalent motion with E-503 amplifier.
** Dynamic Operating Current Coefficient in µA per Hz and µm. Example (P-725.2C): Sinusoidal scan of 30 µm at 10 Hz requires approximately 0.75 mA drive current.
*** P-725.xCD with Sub-D connector for voltage and sensor.

News & Applications

The fastest microscope objective Z-piezo stage

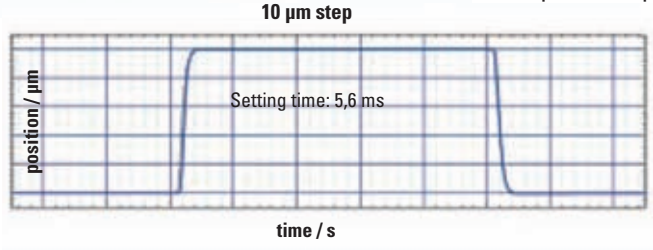
P-726 High-Performance PIFOC®

PI has extended its successful PIFOC® line of objective nanopositioners with a new, high-power unit. The P-726 PIFOC® can move heavy, high-NA objectives (>200 g, 7 oz) faster than any other system currently available, with accuracies of 1 nm over a travel range of 100 µm.

Here, the convincing performance specifications – achieved with a load of 300 g (11 oz): The E-726 can be operated with a variety of controllers ranging from the economical E-621 card, the E-625 controller to a number of digital controllers for the highest possible performance.

- Resonant frequency: 430 Hz (with 300 g), 1100 Hz without objective
- Closed-loop position noise: <0.4 nm
- Position stability over 100 s: 4 nm
- Maximum operating frequency (amplitude <10 µm): 150 Hz*
- Maximum operating frequency with full travel (100 µm): 60 Hz*
- Settling time (10 µm steps): 6 ms**
- Settling time (full travel): 15 ms**

* Amplifier power limited. Higher performance with E-505, 200 W power module
** Faster settling with smaller load



Settling behavior of the P-726 for a 10 µm step.

P-737 Specimen Z-Stage

PIFOC® Z-Axis Microscopy Piezo Stage for High-Resolution Sample Positioning and Scanning

P-737 piezo Z-stage for high-resolution microscopy, shown with multiwell plate

- **High-Speed Piezo Z-Motion with Travel Ranges to 250 µm**
- **Nanometer Resolution**
- **Large Clear Aperture to Accommodate Specimen Holders**
- **Perfect Mechanical Fit to XY OEM Manual or Motorized Stages**
- **Sub-Millisecond Response Times**

PIFOC® P-737 high-speed vertical positioning systems are designed for use with XY microscopy stages – OEM manual stages as well as aftermarket motorized stages.

While the XY stage positions the sample, the piezo-actuator-based P-737 moves the sample along the optical axis to quickly and precisely adjust the focus. Vertical stepping with an accuracy in the nanometer range takes only a few milliseconds.

Application Examples

- Fluorescence microscopy
- Confocal microscopy
- Biotechnology
- 3D Imaging
- Autofocus systems
- Medical technology

The large aperture is designed to accommodate a variety of specimen holders including slides or multiwell plates.

High-Speed Z-Steps for Fast Focus Control and Z-Stack Acquisition

The immediate response of the solid-state piezo drives enables rapid Z-steps with typically 10 to 20 times faster step-and-settle times than classical stepper motor drives. This leads to more image acquisition speed and throughput.

Closed-Loop Position Control for High-Precision and Stability

For high stability and repeatability, P-737 stages are equipped with position sensors. High-resolution, absolute measuring strain gauge sensors (SGS) are applied to appropriate places on the drive train and feed the platform position information back to a piezoelectric controller. The sensors are connected in a full-bridge configuration to eliminate thermal drift, and assure optimal position stability and rapid response with nanometer resolution.

Excellent Guiding Accuracy

Flexures optimized with Finite Element Analysis (FEA) are

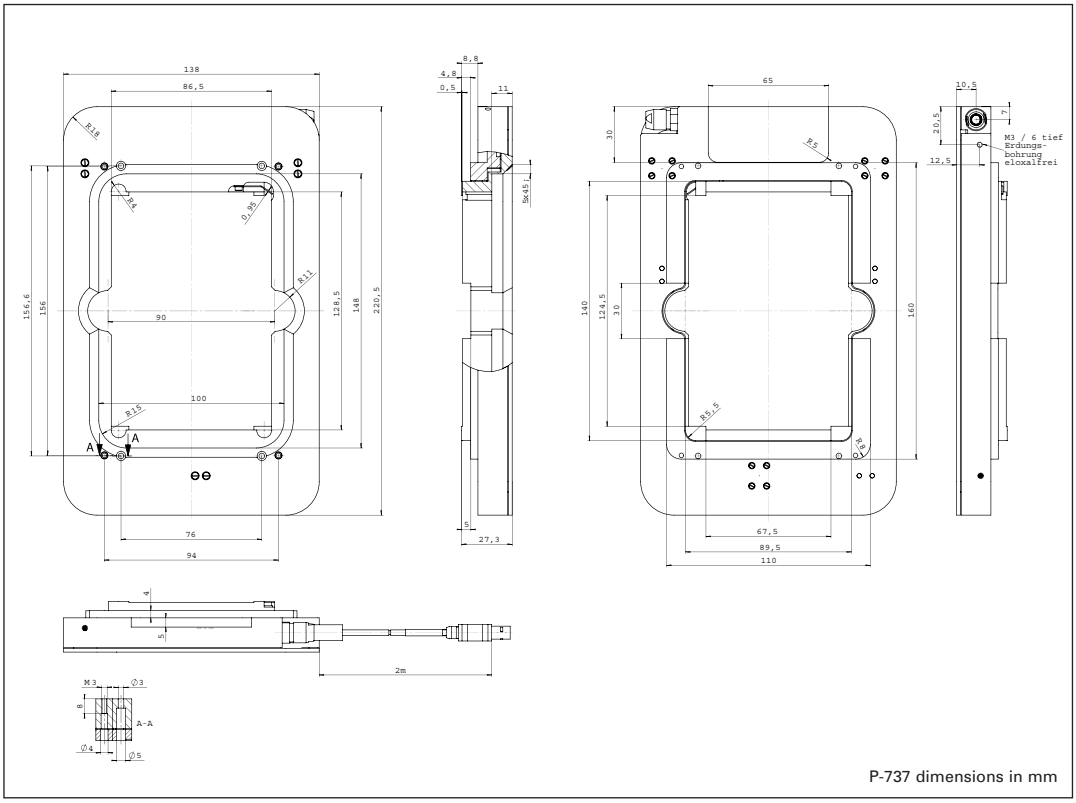
Ordering Information

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

P-737.2SL
PIFOC® Nanofocusing Z-Stage for Microscope Sample Holder, 200 µm, SGS, LEMO Connector, for Märzhäuser Microscope Stages

Versions with up to 500 µm travel or with direct-measuring, high-resolution capacitive sensors on request.

Ask about custom designs!

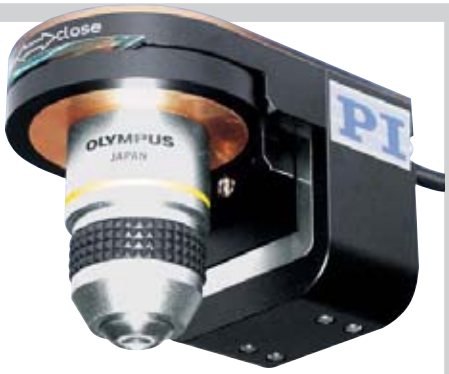


P-737 dimensions in mm

used to guide the stage. The FEA techniques give the design 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.

Superior Lifetime with Ceramic-Encapsulated Piezos

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



Instead of moving the sample, it is also possible to move the objective. The P-725 PIFOC® Objective Scanner offers travel ranges over 400 µm with nanometer resolution and response times in the millisecond range

Technical Data

Models	P-737.1SL	P-737.2SL	Units	Tolerance
Active axes	Z	Z		
Motion and positioning				
Integrated sensor	SGS	SGS		
Closed-loop travel	100	250	µm	calibrated
Closed-loop resolution	2.5	4	nm	typ.
Open-loop resolution	0.3	0.5	nm	typ.
Closed-loop linearity	0.2	0.2	%	typ.
Repeatability	6	12	nm	typ.
Mechanical properties				
Unloaded resonant frequency	400	250	Hz	±20 %
Resonant frequency under load	350 (100 g)	210 (100 g)	Hz	±20 %
Push/pull force capacity in motion direction	100 / 20	100 / 20	N	max.
Load	20	20	N	max.
Drive properties				
Piezo ceramic type	PICMA®	PICMA®		
Electrical capacitance	4.5	9.3	µF	±20 %
Dynamic operating current coefficient	6.2	5.8	µA/(Hz x µm)	±20 %
Miscellaneous				
Operating temperature range	-20 to 80	-20 to 80	°C	
Material	Aluminum	Aluminum		
Dimensions	220.5 x 138 x 27.3	220.5 x 138 x 27.3	mm	
Mass	0.7	0.7	kg	±5 %
Cable length	2.0	2.0	m	±10 mm
Voltage connection	LEMO connector (low voltage)	LEMO connector (low voltage)		
Sensor connection	LEMO connector (SGS sensor)	LEMO connector (SGS sensor)		
Recommended controller/amplifier	E-625.SR, 14 W, single-channel desktop unit E-665.SR, 36 W, single-channel desktop unit E-610.SR, 14 W, OEM electronics E-500 modular system with output to 100 W			
System properties				
System configuration	E-500 system with E-503.00 14 W amplifier and E-509.S1 servo-control module for SGS			
Small-signal bandwidth	60	45	Hz	typ.
Settling time (to within 10 % of step size)	10	15	ms	typ.

M-686 PILine® XY Piezo Linear-Motor Stage

Fast, Low Profile and Large Aperture with Direct Position Measurement

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

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

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

Application Examples

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

Space Saving Piezomotors

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

Compatibility to PI Nanopositioning and Scanning Stages

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

Limit and Reference Switches

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

Advantages of PILine® Micropositioning Systems

The ultrasonic piezoceramic drives used in 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

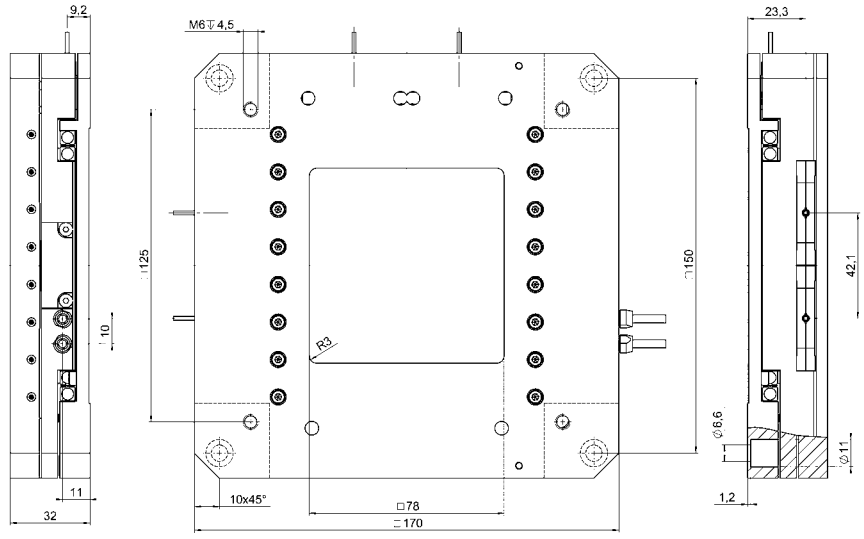
Nanopositioning stages that fit directly on the M-686:

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 scanner by 10 mm. The system height together with the P-541 piezo scanner is reduced to only 33 mm



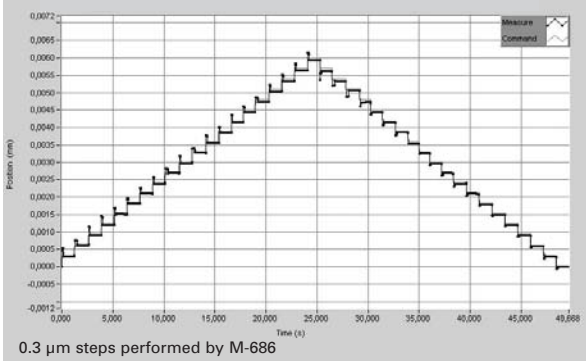
M-686.D64, dimensions in mm. The minimum aperture is 66 x 66 mm with both axes at the maximum position

Technical Data

	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-866.D64 single-axis controller / driver 2 x C-185.D64 single-axis drive electronics

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

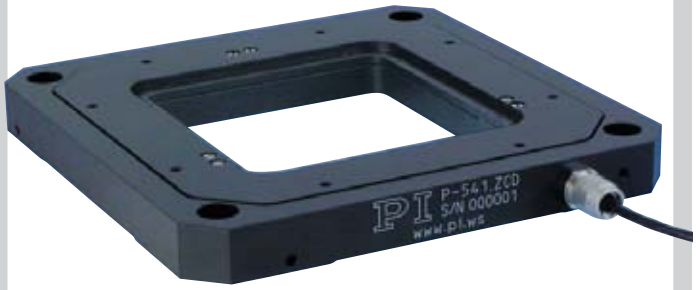
M-686 open-frame stage with P-541.2DD piezo scanner on top, providing a resolution of 0.1 nm and a scanning range of 30 x 30 µm. The system height of the combination with the P-541 XY (or Z) piezo scanner is only 48 mm



0.3 µm steps performed by M-686

P-541.ZCD Low-Profile Piezo Stage

Low-Profile Z/Tip/Tilt Piezo Nanopositioning System for Microscopy with Parallel Metrology



P-541 nanopositioning Z- and Z-tip/tilt 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. Strain gauge and capacitive sensors are available for feedback.

- **Lower Profile for Easy Integration: 16.5 mm**
- **Z and Tip/Tilt Versions**
- **Choice of Strain Gauge (Lower Cost) or Capacitive Sensors (Higher Performance)**
- **100 µm Linear Travel Range, 1 mrad Tilt**
- **80 x 80 mm Clear Aperture**
- **PICMA® High-Performance Piezo Actuators for Superior Lifetime**
- **Ideal for fast Z-Stack Acquisition and 3D Deconvolution Imaging**

Low Profile, Optimized for Microscopy Applications

P-541 series nanopositioning Z-stages and Z-tip/tilt stages are designed for alignment, nano-focusing or metrology tasks, etc. 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. XY scanning stages with the same footprint are also available (see p. 2-62).

Due to the single-module, low-profile design, the stages can easily be integrated in high-resolution microscopes.

Application Examples

- Scanning microscopy
- Mask & wafer alignment
- Scanning interferometry
- Surface metrology
- Biotechnology
- Micromanipulation

Superior Accuracy Through Direct-Motion Metrology with Capacitive Feedback Sensors

Integrated capacitive sensors measure the actual distance between the fixed frame and the moving part of the stage directly and include any flex or other errors in the drive train—from the actuator through the lever and flexures to the platform—in the measurement. 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. See p. 2-4 *ff.* and p. 5-2 for more information.

Dynamic Digital Control for Best Scanning Linearity

Use our new digital control electronics with DDL (Dynamic Digital Linearization) to increase linearity and effective bandwidth in scanning applications by up to 1000-fold (see p. 6-16). By virtually eliminating tracking errors, DDL also increases the usable travel range.

Working Principle and Reliability

P-540-series stages are equipped with the award-winning PICMA® piezo drives, integrated into a sophisticated, single-module, parallel-kinematics, flexure guiding system. The wire-EDM-cut flexures are FEA modeled for zero stiction, zero friction and exceptional guiding precision. The ceramic-encapsulated PICMA® drives are more robust than conventional piezo actuators, featuring superior lifetime and performance in both dynamic and static applications.

Because guidance, actuators and sensors are all frictionless and maintenance-free, these nanopositioning systems achieve outstanding levels of reliability.

Notes

See the "Selection Guide" on p. 2-14 *ff.* for comparison with other nanopositioning systems.

Ordering Information

P-541.ZCD
Microscopy Z-Nanopositioning Stage, 100 µm, Direct Metrology, Capacitive Sensors

P-541.TCD
Microscopy Z, Tip/Tilt Nanopositioning Stage, 100 µm / 1 mrad, Parallel Metrology, Capacitive Sensors

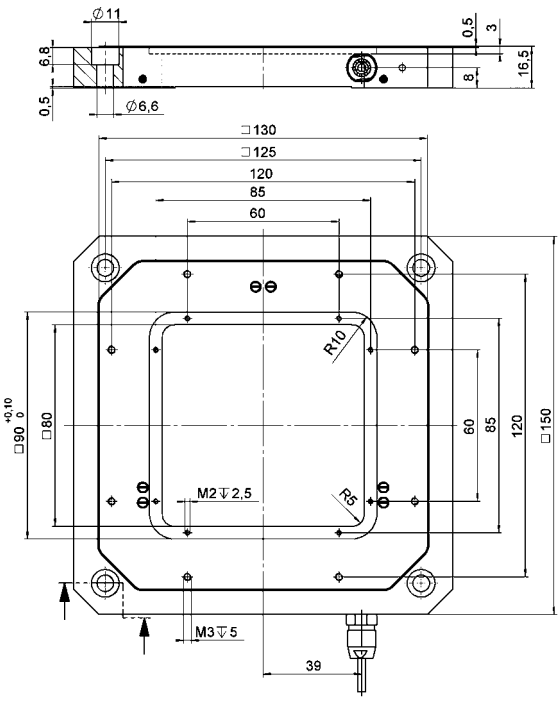
Version with Strain Gauge Sensors see p. 2-48

P-541.ZSL
Microscopy Z Nanopositioning Stage, 100 µm, Strain Gauge Sensors

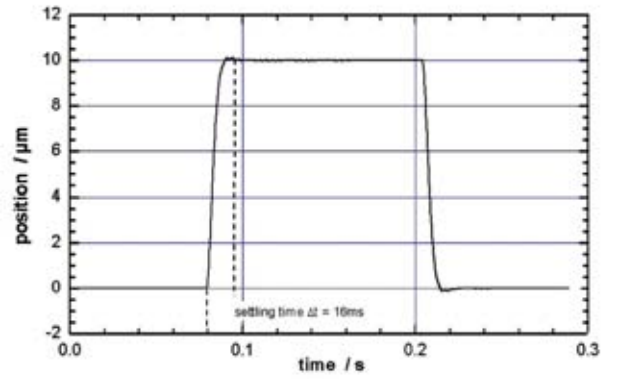
P-541.TSL
Microscopy Z Tip / Tilt Nanopositioning Stage, 100 µm / 1 mrad, Strain Gauge Sensors

Vacuum Versions Available.

P-540-Series XY Stages see p. 2-62



P-541.Z and P-541.T dimensions in mm.



The settling time of a P-541.ZCD stage is approx. 16 ms for a 10 µm step within a positioning accuracy of 1%.

For high-resolution Z-positioning systems with up to 460 µm travel see the P-721 and P-725 PIFOC® nanofocusing drives (see p. 2-20 and p. 2-22).

Technical Data

Models	P-541.ZCD	P-541.TCD	Units	Notes see p. 2-84
Active axes	Z	Z, θ_X, θ_Y		
Min. open-loop travel -20 to 120 V	150	150 (1.5 mrad)	µm	A2
Closed-loop travel	100	100 (1 mrad)	µm	A5
Integrated feedback sensor	capacitive	capacitive		B
* Closed-loop / open-loop resolution	0.8 / 0.2	0.8 / 0.2 (80 nrad / 20 nrad)	nm	C1
Closed-loop linearity (typ.)	0.03	0.03	%	
Repeatability		<5		nm
Push force capacity	100	100	N	D3
Pull force capacity	20	20	N	D3
Max. load	20	20	N	D4
Electrical capacitance	6.75	6.75	µF ±20%	F1
** Dynamic Operating Current Coefficient	8.5	8.5 (Z)	µA/(Hz x µm)	F2
Resonant frequency unloaded	410	410 (Z)	Hz ±20%	G2
Resonant frequency @ 185 g load	300	300 (Z)	Hz ±20%	G3
Operating temperature	-20 to 80	-20 to 80	°C	H2
Voltage & sensor connection	D	D		J1/J2
Body material	Al	Al		L
Recommended amplifier/controller (codes explained p. 2-17)	H, F, L	K		

* For calibration information see p. 2-8. Resolution of PI piezo nanopositioning systems is not limited by friction or stiction. Noise equivalent motion with E-710, E-750, E-503 controllers / amplifiers.

** Dynamic Operating Current Coefficient of linear axes is in µA per Hz and µm. Example: Sinusoidal scan of 10 µm at 10 Hz requires approximately 0.85 mA drive current.

P-541.2 · P-542.2 Low Profile XY Stage

Low-Profile, XY Piezo Scanning Microscopy Stages with Parallel Metrology

P-540-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.

- **Low Profile for Easy Integration: 16.5 mm**
- **Parallel Kinematics and Optional Parallel Metrology for Fast Response and Superior Multi-Axis Precision**
- **Choice of Strain Gauge (Lower Cost) or Capacitive Sensors (Higher Performance)**
- **To 200 x 200 µm Travel Range**
- **Direct Drive Version for High-Speed Positioning & Scanning**
- **80 x 80 mm Clear Aperture**
- **PICMA® High-Performance Piezo Actuators for Superior Lifetime**

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.

Application Examples

- Optical trapping
- Scanning microscopy
- Mask & wafer alignment
- Scanning interferometry
- Surface metrology
- Biotechnology
- Micromanipulation

Choice of Drives: Long Range or High-Speed Direct Drive

A variety of models are offered to suit a large range of applications: lever-amplified XY systems with 100 and 200 µm travel and direct-driven XY scanners with 45 µm travel. 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.
Z stages and Z-tip/tilt stages are also available (see p. 2-50).

Higher Precision Through Parallel Kinematics/-Metrology with Capacitive Feedback Sensors

P-540-series XY piezo positioning stages feature a single-module, parallel-kinematics design with all actuators operating on one central platform and no moving cables to cause microfriction. Advantages over serial kinematics setups are a lower profile, reduced inertia and better, axis-independent dynamics.

Capacitive sensors measure the actual distance between the fixed frame and the moving part of the stage directly and include any flex or other errors in the drive train—from the actuator through the lever and flexures to the platform—in the measurement. 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. See p. 2-4 *ff.* and p. 5-2 *ff.* for more information.

With parallel direct metrology, all capacitive sensors measure the position of the same moving platform against the same stationary reference (the fixed frame). This means that all motion is inside the servo-loop, no matter which actuator may have caused it, resulting in superior multi-axis precision. Advantages include: higher resolution in non-diffraction-limited imaging techniques (NSOM, etc.) and reduced blurring of edges in high-speed microscopy applications.

Dynamic Digital Control for Best Scanning Linearity

Use our new digital control electronics with DDL (Dynamic Digital Linearization) to increase linearity and effective bandwidth in scanning applications by up to 1000-fold (see catalog E-710). By virtually eliminating tracking errors, DDL also increases the usable travel range.

Working Principle / Reliability

P-540-series stages are equipped with the award-winning PICMA® piezo drives, integrated into a sophisticated, single-module, parallel-kinematics, flexure guiding system. The wire-EDM-cut flexures are FEA modeled for zero stiction, zero friction and exceptional guiding precision. The ceramic-encapsulated PICMA® drives are more robust than conventional piezo actuators, featuring superior lifetime and performance in both dynamic and static applications. Because guidance, actuators and sensors are all frictionless and maintenance-free, these nanopositioning systems achieve outstanding levels of reliability.

Ordering Information

P-541.2DD
Microscopy XY Nanopositioning & Scanning Stage, High-Speed Direct Drive, 45 x 45 µm, Parallel Metrology, Capacitive Sensors

P-541.2CD
Microscopy XY Nanopositioning & Scanning Stage, 100 x 100 µm, Parallel Metrology, Capacitive Sensors

P-542.2CD
Microscopy XY Nanopositioning & Scanning Stage, 200 x 200 µm, Parallel Metrology, Capacitive Sensors

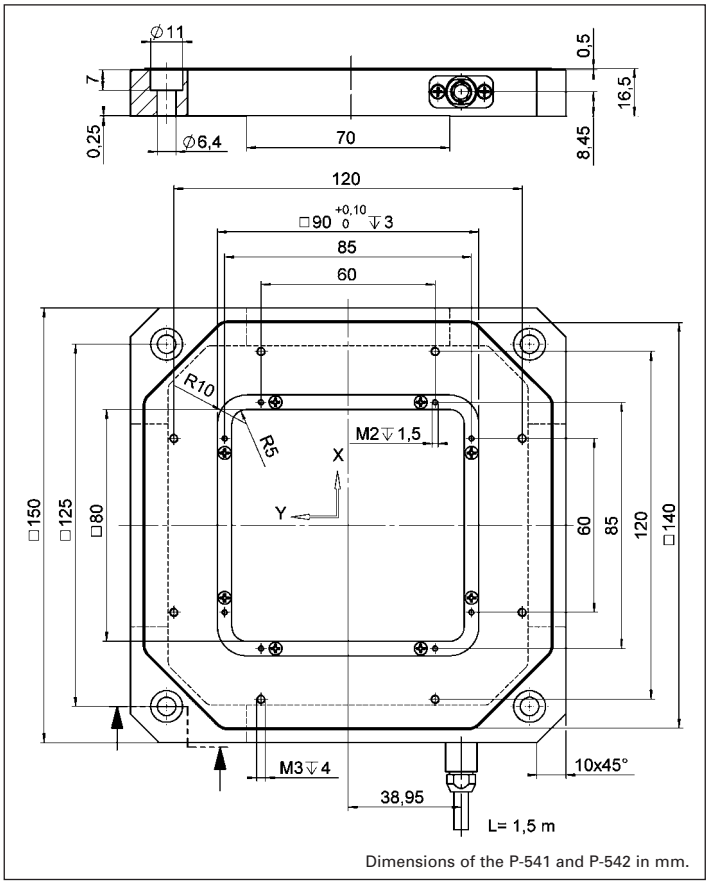
Versions with Strain Gauge Sensors see p. 2-60

P-541.2SL
Microscopy XY Nanopositioning & Scanning Stage, 100 x 100 µm, Strain Gauge Sensors

P-542.2SL
Microscopy XY Nanopositioning & Scanning Stage, 200 x 200 µm, Strain Gauge Sensors

Vacuum Versions Available.

P-540-Series Z-Tip/Tilt Stages see p. 2-50



Dimensions of the P-541 and P-542 in mm.

For fully independent XYZ motion, the P-541/P-542 XY stages can be combined with the P-725 PIFOC® nanofocusing Z-drives.

Technical Data

Models	P-541.2CD	P-542.2CD	P-541.2DD	Units	Notes see p. 2-84
Active axes	XY	XY	XY		
Min. open-loop travel -20 to 120 V	150 x 150	250 x 250	60 x 60	µm	A2
Closed-loop travel	100 x 100	200 x 200	45 x 45	µm	A5
Integrated feedback sensor	capacitive	capacitive	capacitive		B
* Closed-loop / open-loop resolution	0.8 / 0.2	1.5 / 0.4	0.3 / 0.1	nm	C1
Closed-loop linearity (typ.)	0.03	0.03	0.03	%	
Repeatability	<5		<5	nm	
Push force capacity	100, 100	100, 100	200, 200	N	D3
Pull force capacity	20, 20	20, 20	20, 20	N	D3
Max. load	20	20	20	N	D4
Electrical capacitance (per axis)	6.75	7.5	28	µF ±20%	F1
** Dynamic Operating Current Coefficient (per axis)	8.5	4.8		µA/(Hz x µm)	F2
Resonant frequency unloaded	500, 500	370, 370	1500, 1500	Hz ±20%	G2
Resonant frequency @ 185 g load		250	1200, 1200	Hz ±20%	G3
Operating temperature	-20 to 80	-20 to 80	-20 to 80	°C	H2
Voltage & sensor connection	D	D	D		J1/J2
Body material	Al	Al	Al		L
Recommended amplifier/controller (codes explained p. 2-17)	H, F, L, K	H, F, L, K	H, F, L, K		

* For calibration information see p. 2-8. Resolution of PI piezo nanopositioning systems is not limited by friction or stiction. Noise equivalent motion with E-710, E-750, E-503 controllers / amplifiers.

** Dynamic Operating Current Coefficient in µA per Hz and µm. Example: Sinusoidal scan of 10 µm at 10 Hz with the P-542.2CD requires approximately 0.48 mA drive current.

P-733.2DD · P-733.3DD Direct Drive Stage

Ultra-High-Speed, XY / XYZ Scanning Microscopy Stages with Parallel Metrology

P-733.3DD (left side) and P-733.2DD, 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. Compact disc for size comparison.

- **Higher Speed Through Direct Drive**
- **Up to 2.2 kHz Resonant Frequency in X and Y**
- **30 x 30 or 30 x 30 x 10 µm Travel Range**
- **100 Picometers Resolution**
- **Capacitive Sensors for Highest Linearity**
- **Parallel-Kinematics/Metrology for Enhanced Responsiveness / Multi-Axis Precision**
- **Active Runout Compensation**
- **50 x 50 mm Clear Aperture**
- **Frictionless Precision Flexure Guiding System**
- **PICMA® High-Performance Piezo Drives**

Fastest Multi-Axis Systems w/Large Apertures

P-733.2DD / .3DD multi-axis piezo nanopositioning systems are the fastest ultra-high-precision, open-frame stages for microscopy. They provide a positioning and scanning range of 30 x 30 (x10) µm and are equipped with parallel-metrology capacitive position feedback for superior multi-axis linearity and repeatability.

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.

Application Examples

- Optical trapping
- Imaging (resolution enhancement)
- Scanning microscopy
- Surface structure analysis
- Biotechnology
- Atomic force microscopy
- Semiconductor test equipment
- Precision mask and wafer alignment
- Scanning interferometry
- Nanomanipulation
- Biophysics

Low-Profile and Clear Aperture—Ideal for Microscopy

P-733 nanopositioning and scanning stages are designed for easy integration into high-resolution microscopes. They feature very low profiles, as low as 20 mm (0.8 inch), a 50 x 50 mm aperture, and offer highly accurate motion with sub-nanometer resolution.

Higher Precision Through Parallel Kinematics/Metrology

P-733 piezo scanning stages feature a parallel-kinematics design with direct-measuring, non-contact capacitive position sensors (parallel, direct metrology).
These sensors make possible motion linearity to 0.03% with effective resolution in the sub-nanometer range. PI capacitive sensors are absolute-measuring, direct-metrology devices that boast very high bandwidth and exhibit no periodic errors.

Unlike conventional sensors, capacitive sensors measure the actual distance between the fixed frame and the moving part of the stage. They detect errors contributed by all components in the drive train—from the actuator through the flexures to the platform. 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. See p. 2-4 *ff.* and p. 5-2 *ff.* for more information.

Parallel kinematics means that all actuators act directly on the same moving platform leading to reduced size, inertia and the elimination of microfriction caused by moving cables. The advantages are enhanced dynamics, higher scanning rates, and better reproducibility.

Ordering Information

P-733.2DD
XY High-Speed Direct Drive Piezo Scanning Stage, 30 x 30 µm, Parallel Metrology, Sub-D Connector

P-733.3DD
XYZ High-Speed Direct Drive Piezo Scanning Stage, 30 x 30 x 10 µm, Parallel Metrology, Sub-D Connector

Vacuum Versions Available

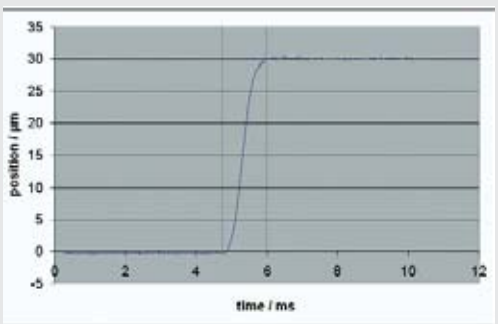
With parallel metrology, all sensors measure the position of the same moving platform against the same stationary reference (the fixed frame). This means that—in contrast to serial metrology—all motion is inside the servo-loop, no matter which actuator may have caused it, resulting in superior multi-axis precision (Active Trajectory Control).

Dynamic Digital Control for Best Scanning Linearity

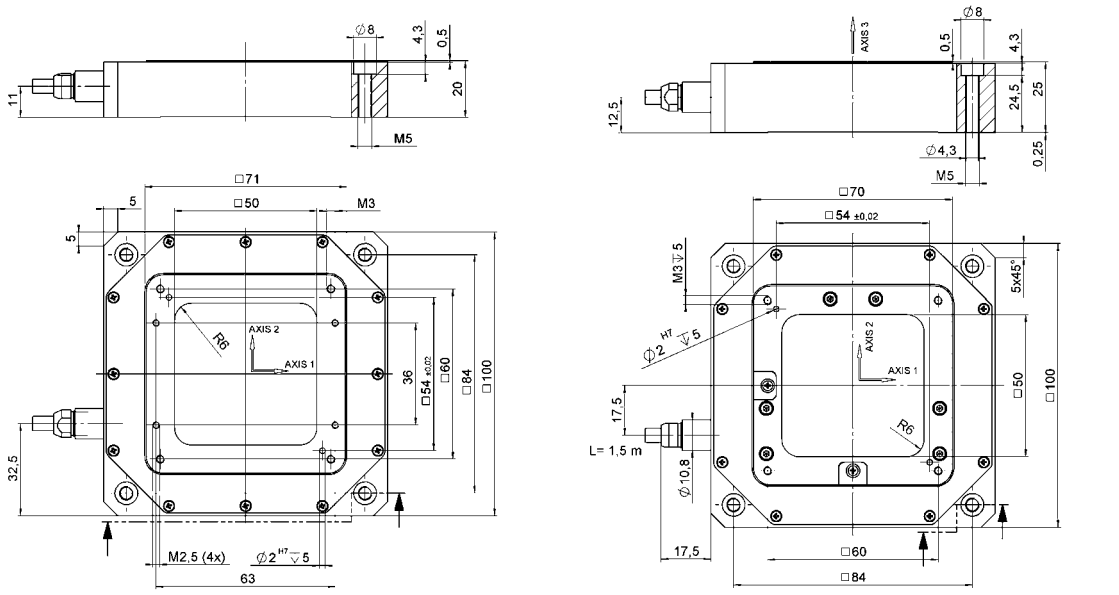
Use our new digital control electronics with DDL (Dynamic Digital Linearization) to increase linearity and effective bandwidth in scanning applications by up to 1000-fold (see p. 6-16). By virtually eliminating tracking errors, DDL also increases the usable travel range.

Working Principle / Reliability

P-733 nanopositioning stages are equipped with the award winning PICMA® piezo drives,



0 to 100 % travel in 1.36 msec, without overshoot. The P-733.2DD is the fastest, highest precision closed-loop XY scanning stage with large aperture currently available.



Dimensions of P-733.2DD in mm.

Dimensions of P-733.3DD in mm.

integrated into a sophisticated, single-module, parallel-kinematics, flexure guiding system. The wire-EDM-cut flexures are FEA modeled for zero stiction, zero friction and exceptional guiding precision. The ceramic-encapsulated PICMA® drives are more robust than conventional piezo actuators, featuring superior lifetime and performance in both dynamic and static applications.

Because guidance, actuators and sensors are all frictionless and maintenance-free, these nanopositioning systems achieve outstanding levels of reliability.

Vacuum Applications

PI offers versions specially designed for applications in ultra-high vacuum (see p. 2-66). A non-magnetizable version is available on request.

Notes

See the "Selection Guide" on p. 2-14 *ff.* for comparison with other nanopositioning systems.

Technical Data

Models	P-733.2DD	P-733.3DD	Units	Notes see p. 2-84
Active axes	X,Y	X,Y,Z		
Min. open-loop travel @ -20 to 120 V	33 x 33	33 x 33 x 14	µm ±20%	A2
Closed-loop travel	30 x 30	30 x 30 x 10	µm	A5
Integrated feedback sensor	capacitive	capacitive		B
* Closed-loop / open-loop resolution	0.1 / 0.1	0.1 / 0.1	nm	C1
Closed-loop linearity (typ.)	0.03	0.03	%	
Full-range repeatability (typ.)	±1.0	±1.0	nm	C3
Stiffness (X,Y,Z)	20, 20, -	4, 4, 10	N/µm ±20%	D1
Push / pull force capacity (in operating direction)	300 / 100	300 / 100	N	D3
Max. (±) normal load	20	20	N	D4
Tilt θ_x, θ_z (typ.)	3	3	µrad	E1
Electrical capacitance (X, Y, Z)	6.0, 6.0, -	6.0, 6.0, 4.4	µF ±20%	F1
** Dynamic operating current (X, Y, Z) coefficient (DOCC)	25, 25,-	25, 25, 50	µA/(Hz x µm)	F2
Unloaded resonant frequency (X, Y, Z)	2230, 2230, -	1200, 1200, 1200	Hz ±20%	G2
Resonant frequency @ 50 g load (X, Y, Z)	1800, 1800, -		Hz ±20%	G3
Resonant frequency @ 200 g load (X, Y, Z)		530, 530, 635	Hz ±20%	G3
Operating temperature range	-20 to 80	-20 to 80	°C	H2
Voltage connection	sub-D, special	sub-D, special		J1
Sensor connection	sub-D, special	sub-D, special		J2
Weight (with cables)	525	635	g ±5%	
Body material	Al	Al		L
Recommended amplifier/controller (codes explained p. 2-17)	H, F, L	H, F, L		

* For calibration information see p. 2-8. Resolution of PI piezo nanopositioners is not limited by friction or stiction. The value given is noise equivalent motion with E-503 amplifier.

** Dynamic Operating Current Coefficient in µA per Hz and µm. Example: Sinusoidal scan of 10 µm at 100 Hz requires approximately 25 mA drive current.

P-733 Piezo Stage

High-Dynamics XY and XYZ Nanopositioning / Scanning Stages with Parallel Metrology

P-733.3CD XY scanning stage with active Z-axis
P-733 stages are ideal for single-molecule microscopy

- **Travel Ranges of 100 x 100 µm in X, Y and 10 µm in Z**
- **Direct Metrology with Capacitive Sensors**
- **Resolution to 0.1 nm**
- **Parallel Kinematics for Better Multi-Axis Accuracy and Dynamics**
- **Parallel Metrology for Active Trajectory Control**
- **50 x 50 mm Clear Aperture for Transmitted-Light Applications**

P-733 XY piezo driven stages are fast and highly accurate nanopositioning and scanning systems. They provide a positioning and scanning range of 100 x 100 (x 10) µm together with sub-nanometer resolution. The 50 x 50 mm clear aperture is ideal for transmitted-light applications such as near-field scanning microscopy. 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 / stabilization
- Scanning microscopy
- Metrology / Interferometry
- Biotechnology
- Semiconductor testing
- Mask / wafer positioning
- Micromanipulation
- Nanopositioning

Capacitive Sensors for Higher Linearity

Capacitive sensors measure position directly and without physical contact. This makes them 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.

Parallel Kinematics and Metrology for High Trajectory Fidelity

In a parallel kinematics multi-axis system, all actuators act directly on the same moving platform. This means that all axes see the same moved mass and can be designed with identical dynamic properties. Parallel kinematics systems have additional advantages over serially stacked systems, including more-compact construction, no cumulative error from the different axes and no moving cables to cause friction that degrades resolution and linearity. Parallel kinematics systems can be operated with up to six degrees of freedom with low inertia and excellent dynamic performance.

Multiaxis nanopositioning systems equipped with both parallel kinematics and Direct Metrology are able to measure platform position in all degrees of freedom against a common, fixed reference: i.e. parallel metrology. 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. Known as Active Trajectory Control Concept, the parallel kinematics/parallel metrology combination can keep deviation from a trajectory to under a few nanometers, even in dynamic operation.

Superior 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.

Wide Variety for Flexibility in Many Applications

For the highest dynamics applications, the P-733.2DD and P-733.3DD models with direct drive are available.

For Z-axis scanning applications, the P-733.ZCD version is available with a travel range of 100 µm.

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

Ordering Information

P-733.2CD
XY Piezo Nanopositioning / Scanning Stage, 100 x 100 µm, Capacitive Sensors, Parallel Metrology, Sub-D Connector

P-733.2CL
XY Piezo Nanopositioning / Scanning Stage, 100 x 100 µm, Capacitive Sensors, Parallel Metrology, LEMO Connector

P-733.3CD
XYZ Piezo Nanopositioning / Scanning Stage, 100 x 100 x 10 µm, Capacitive Sensors, Parallel Metrology, Sub-D Connector

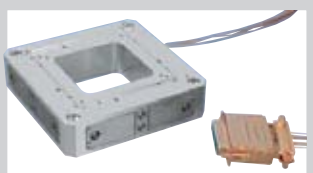
P-733.3CL
XYZ Piezo Nanopositioning / Scanning Stage, 100 x 100 x 10 µm, Capacitive Sensors, Parallel Metrology, LEMO Connector

P-733.2VL
XY Piezo Nanopositioning / Scanning Stage, 100 x 100 µm, Capacitive Sensors, Parallel Metrology, LEMO Connector, Vacuum Compatible down to 10^{-6} hPa

P-733.2VD
XY Piezo Nanopositioning / Scanning Stage, 100 x 100 µm, Capacitive Sensors, Parallel Metrology, Sub-D Connector, Vacuum Compatible down to 10^{-6} hPa

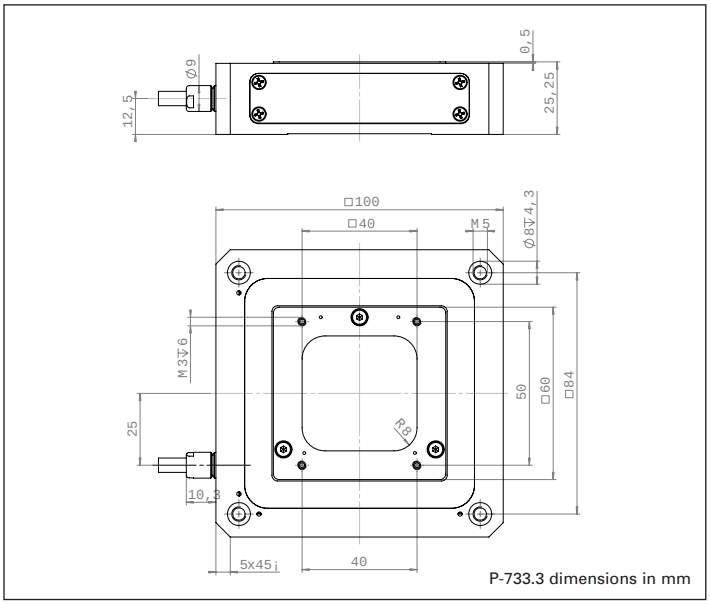
P-733.2UD
XY Piezo Nanopositioning / Scanning Stage, 100 x 100 µm, Capacitive Sensors, Parallel Metrology, Sub-D Connector, Vacuum Compatible down to 10^{-9} hPa

Ask about custom designs.

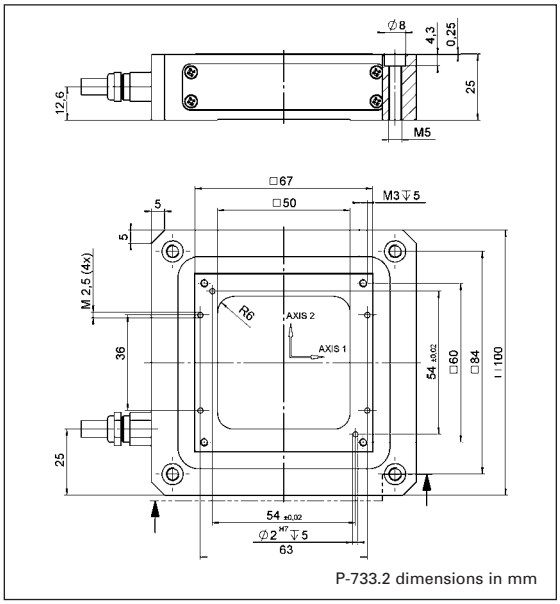


P-733.2UD non-magnetic XY scanning stage for UHV to 10^{-9} hPa

Page references refer to PI's hardcover catalog



P-733.3 dimensions in mm



P-733.2 dimensions in mm

Technical Data

	P-733.2CD	P-733.3CD	Units	Tolerance
Active axes	X, Y	X, Y, Z		
Motion and positioning				
Integrated sensor	Capacitive	Capacitive		
Open-loop travel, -20 to +120 V	115 x 115	115 x 115 x 12	µm	min.
Closed-loop travel	100 x 100	100 x 100 x 10	µm	
Open-loop resolution	0.2	0.2 in X, Y, 0.1 in Z	nm	typical
Closed-loop resolution	0.3	0.3 in X, Y, 0.2 in Z	nm	typical
Linearization	0.01	0.01 in X, Y, 0.03 in Z	%	typical
Repeatability	<2	<2 in X, Y, 1 in Z	nm	typical
Pitch	2	1	µrad	typical
Yaw	10	10	µrad	typical
Mechanical properties				
Stiffness in motion direction	1.4	1.4 in X, Y, 9.0 in Z	N/µm	±20 %
Unloaded resonant frequency	460	460 in X, Y, 1400 in Z	Hz	±20 %
Resonant frequency @ 120 g	340	340 in X, Y, 1060 in Z	Hz	±20 %
Resonant frequency @ 200 g	295	295 in X, Y, 610 in Z	Hz	
Push/pull force capacity in motion direction	300 / 100	300 / 100	N	Max.
Load	20	20	N	Max.
Drive properties				
Ceramic type	PICMA®	PICMA®		
Electrical capacitance	6.0 per axis	6.0 in X, Y, 3.3 in Z	µF	±20 %
Dynamic operating current coefficient	7.5 per axis	7.5 in X, Y, 40 in Z	µA/(Hz x µm)	±20 %
Miscellaneous				
Operating temperature range	-20 to +80	-20 to +80	°C	
Material	Al	Al		
Mass	580	675	g	±5 %
Cable length	1.5	1.5	m	±10 mm
Sensor connection	Sub-D Mix (CD-version) 4x LEMO (CL-version)	Sub-D Mix (CD-version) 6x LEMO (CL-version)		
Voltage connection	Sub-D Mix (CD-version) 2x LEMO (CL-version)	Sub-D Mix (CD-version) 3x LEMO (CL-version)		
Recommended controller/amplifier	H, F, L	H, F, L		

P-733.Z Piezo Z-Stage

High-Speed Piezo Z-Nanopositioning Stage with Direct Metrology

P-733.ZCD vertical piezo stage

- **Travel Range 100 µm**
- **Fast: <8 ms Settling Time, 700 Hz Resonant Frequency**
- **Direct Metrology with Capacitive Sensors**
- **Closed-loop Resolution to 0.3 nm**
- **50 x 50 mm Clear Aperture**
- **XY and XYZ Versions also Available**
- **Vacuum-Compatible Versions Available**

P-733.Z piezo Z-stages offer a positioning and scanning range of 100 µm with sub-nanometer resolution. The fast response and large clear aperture are ideal for applications such as fast focusing, scanning or 3D microscopy. The settling time of the P-733.Z is in the 10 ms range.

Capacitive Sensors for Highest Accuracy

Capacitive sensors measure position directly and without physical contact. This makes them free of friction and hysteresis, a fact which, in combination with the positioning resolution of well under 1 nm, makes it possible to achieve very high levels of linearity. A further advantage of direct metrology with capacitive sensors is the high phase fidelity and the high bandwidth of up to 10 kHz. The resolution of the P-733.Z is better than 0.3 nm.

Capacitive position sensors measure the actual motion of the moving part relative to the stationary base (Direct Metrology). Errors in the drive train, actuator, lever arm or in guiding system do not influence the measurements. The result is exceptional motion linearity, higher long-term stability and a stiffer, more-responsive control loop, because external influences are immediately recognized by the sensor. The capacitive sensor non-linearity is typically less than 0.03 %, the repeatability of the P-733.Z better than 2 nm.

Application Examples

- Scanning microscopy
- Confocal microscopy
- Mask/wafer positioning
- Surface inspection
- Nano-imprint
- Micromanipulation

Superior Lifetime

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

Large Variety of Models for a Broad Range of Applications

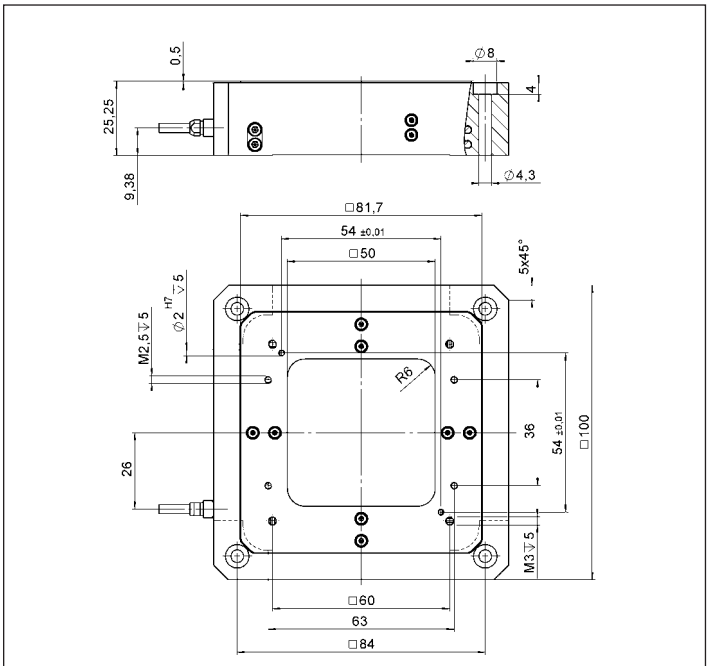
For scanning and positioning tasks in XY, the P-733.2CD and .3CD versions are available with a travel range of 100 x 100 µm. For high-dynamics applications, the P-733.2DD and .3DD models can be offered with direct drive and reduced travel range.

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

Ordering Information

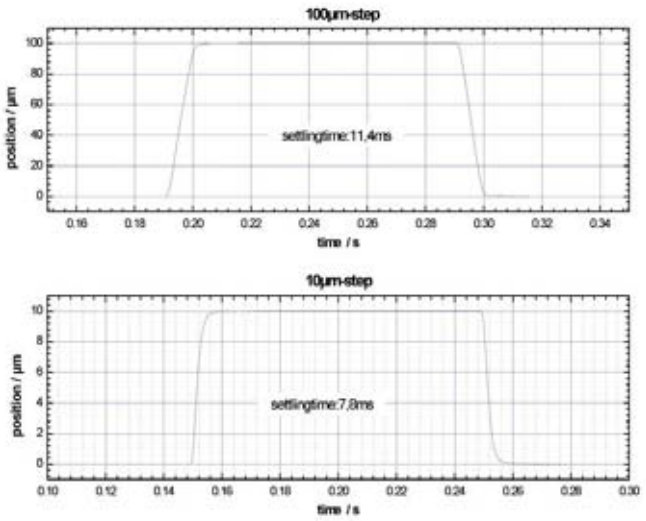
P-733.ZCD
Z-Piezo Nanopositioning / Scanning Stage, 100 µm, Capacitive Sensor, Sub-D Connector

P-733.ZCL
Z-Piezo Nanopositioning / Scanning Stage, 100 µm, Capacitive Sensor, LEMO Connector



P-733.Z dimensions in mm

Page references refer to PI's hardcover catalog



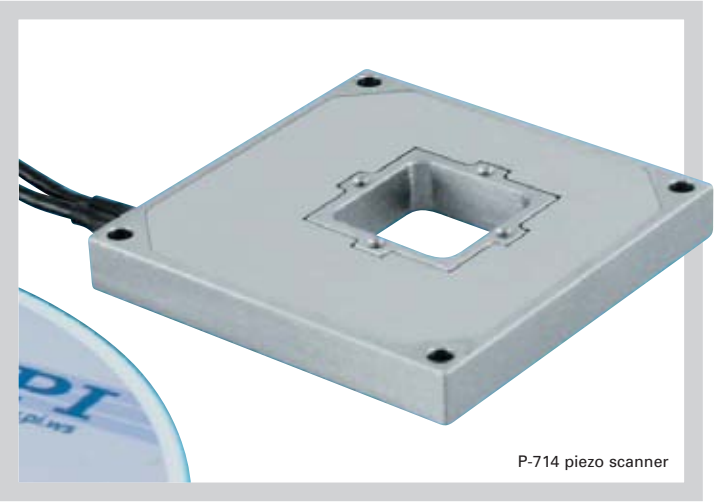
Step response of the P-733.ZCD. Settling time <8 msec for a 10 µm step

Technical Data

	P-733.ZCD P-733.ZCL	Units	Tolerance
Active axes	Z		
Motion and positioning			
Integrated sensor	Capacitive		
Open-loop travel, -20 to +120 V	120	µm	min.
Closed-loop travel	100	µm	
Open-loop resolution	0.2	nm	typical
Closed-loop resolution	0.3	nm	typical
Linearity	0.03	%	typical
Repeatability	<2	nm	typical
Pitch	<5	µrad	typical
Yaw	<5	µrad	typical
Mechanical properties			
Stiffness in motion direction	2.5	N/µm	±20 %
Unloaded resonant frequency	700	Hz	±20 %
Resonant frequency @ 120 g	530	Hz	±20 %
Resonant frequency @ 200 g	415	Hz	±20 %
Load	20	N	Max.
Drive properties			
Ceramic type	PICMA®		
Electrical capacitance	6	µF	±20 %
Dynamic operating current coefficient	7.5	µA/(Hz x µm)	±20 %
Miscellaneous			
Operating temperature range	-20 bis 80	°C	
Material	Al		
Mass	580	g	±5 %
Cable length	1.5	m	±10 mm
Sensor connection	Sub-D mix (CD-version) 2x LEMO (CL-version)		
Voltage connection	Sub-D mix (CD-version) 1x LEMO (CL-version)		
Recommended controller/amplifier	H, F, L		

P-713 · P-714 Miniature XY Stages

Low-Profile OEM XY Piezo-Scanners for Imaging Applications


P-714 piezo scanner

- **Ideal for Interlacing, CCD Resolution Enhancement**
- **Compact Size of only 45 x 45 x 6 mm**
- **Clear Aperture**
- **Highly Cost-Efficient Design**
- **15 x 15 µm Travel Range**
- **Parallel-Kinematics Design for Higher 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 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, with closed-loop repeatability of under 5 nm.

Application Examples

- Interlacing, image resolution enhancement
- Quality assurance
- Optical metrology
- Microscopy
- Imaging
- CCD 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 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. If servo-control is required and no external position sensor is available, the P-714.2SL version is equipped with high-resolution strain gauge sensors (SGS) which offer nanometer-range resolution.

Superior Lifetime

Reliability is assured by the use of award-winning PICMA® multilayer actuators, which are integrated into a sophisticated, single-module, flexure guiding system. The PICMA® actuators feature cofired ceramic encapsulation and thus offer better performance and reliability than conventional piezo actuators. The wire-EDM-cut flexures are FEA modeled to make them extremely precise. In addition they are maintenance-free and not subject to wear.

Notes

See the "Piezo Drivers & Nanopositioning Controllers" section, p. 6-8 *ff.* for our comprehensive line of low-noise modular and OEM control electronics for computer and manual control.

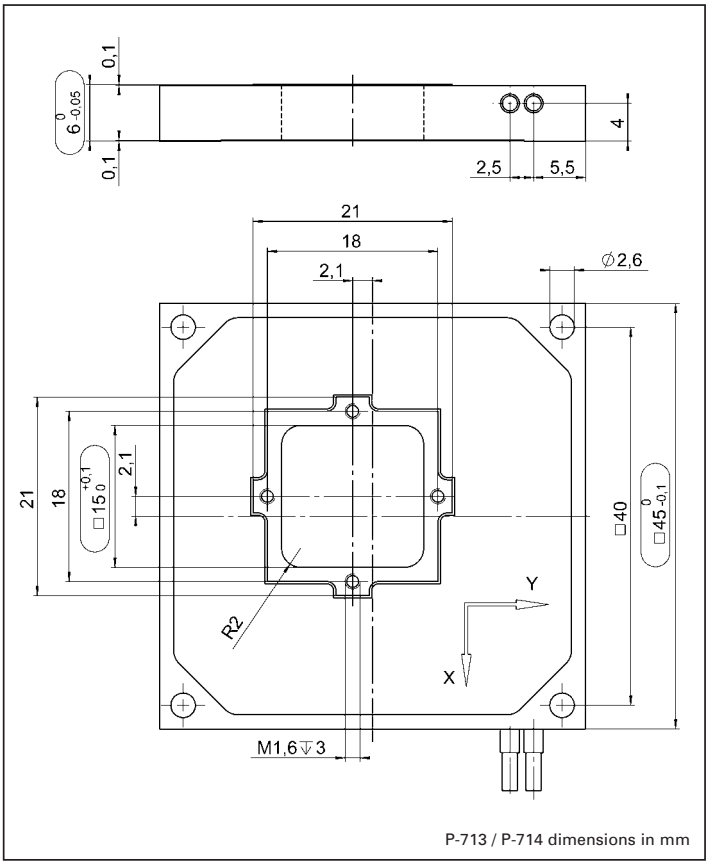
See the "Selection Guide" on p. 2-14 *ff.* for comparison with other nanopositioning systems.

Ordering Information

P-713.20L
XY Piezo Scanner, 15 x 15 µm, SGS Sensor

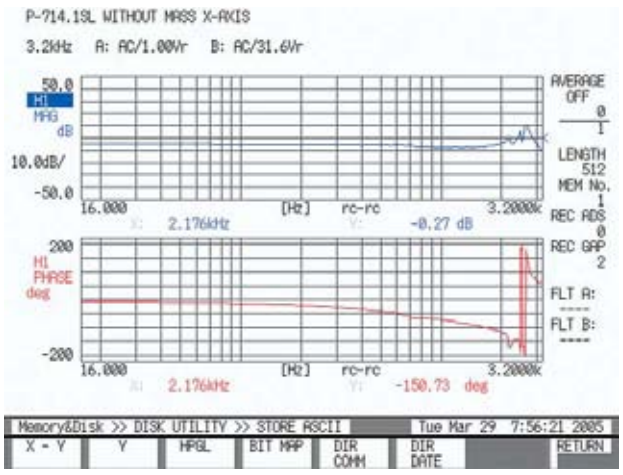
P-714.20L
XY Piezo Scanner, 15 x 15 µm, Improved Guiding Accuracy, Open-Loop

P-714.2SL
XY Piezo Scanner, 15 x 15 µm, Improved Guiding Accuracy, SGS Sensors

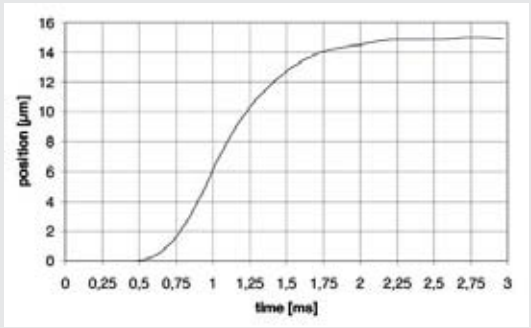


P-713 / P-714 dimensions in mm

Page references refer to PI's hardcover catalog



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



The settling time for a 15 µm step is 2 ms

Technical Data

Models	P-713.20L	P-714.20L	P-714.2SL	Units	Notes see p. 2-84
Active axes	X, Y	X, Y	X, Y		
Open-loop travel @ -20 to 120 V (X/Y)	20 / 20	20 / 20	25 / 20	µm ±20%	A2
Closed-loop travel	-	-	15 / axis	µm	A5
Integrated feedback sensor	-	-	SGS		B
* Open- / closed-loop resolution	0.1 / -	0.1 / -	1 / 0.1	nm	C1
Closed-loop linearity (typ.)	-	-	0.3	%	
Repeatability	-	-	<5	nm	
θ_X, θ_Y	Typ. <1 µrad <5 µrad	Typ. <1 µrad <5 µrad	Typ. <1 µrad <5 µrad		
θ_Z	Typ. <30 µrad <50 µrad	Typ. <5 µrad <15 µrad	Typ. <5 µrad <15 µrad		
Stiffness	0.8	0.8	0.8	N/µm ±20%	D1
Max. normal load				kg	D4
Electrical capacitance	1.5 / axis	1.5 / axis	1.5 / axis	µF ±20%	F1
** Dynamic operating current coefficient (DOCC)	1.7 / axis	1.7 / axis	1.7 / axis	µA/(Hz x µm)	F2
Unloaded resonant frequency (X/Z)	2250	2250	2250	Hz ±20%	G2
Resonant frequency @ 20 g load	1310	1310	1310	Hz ±20%	G2
Resonant frequency @ 50 g load	1020	1020	1020		
Resonant frequency @ 100 g load	460	460	460	Hz ±20%	G2
Operating temperature range	-20 to 80	-20 to 80	-20 to 80	°C	H2
Voltage connection	VL	VL	VL		J1
Sensor connection	-	-	L		J2
Weight (with cable)	105	105	105	g ±5%	
Body material	S	S	S		L
Recommended amplifier/controller (codes explained p. 2-17)	A, G	A, G	D, H		

* For calibration information see p. 2-8. Resolution of piezo nanopositioners is not limited by friction or stiction. Noise equivalent motion with E-503 amplifier.
** Dynamic Operating Current Coefficient in µA per Hz and µm.

P-363 Piezo Stage with Direct Metrology

PicoCube® High-Speed, XY(Z) Piezo Stages for Nanotechnology, SPM, AFM

P-363.2CD and .3CD (background) PicoCube®, high-performance piezo positioning- and scanning systems. Smart media card for size comparsion.

- **Ultra-High-Performance Closed-Loop Scanner for AFM/SPM**
- **Compact Manipulation Tool for Nanotechnology**
- **Resonant Frequency 9.8 kHz**
- **Ultra-High-Precision Capacitive Feedback**
- **Parallel-Motion Metrology for Highest Linearity and Stability**
- **50 Picometers Resolution**
- **5 x 5 x 5 µm Travel Range**
- **Very Small Package**
- **Rugged Design**

Ultra-High-Performance Scanner/Manipulator for Nanotechnology

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 (30 x 30 x 26 mm for XY version), it is easy to integrate in any scanning apparatus.

Application Examples

- Atomic Force Microscopy
- Micromanipulation
- Biotechnology
- Nanomanipulation
- Nanoimprinting
- Nanometrology
- Nanolithography

AFM, STM, SPM, Nanolithography, Nanoimprinting, Nanometrology

The PicoCube® was specifically developed to overcome the limitations of the open-loop scanners currently available for STM, AFM and SPM. In addition to these applications, the PicoCube® is also the ideal scanning and manipulation tool for nanoimprinting, nanolithography, ultra-high-resolution, near-field, scanning optical microscopy and nano-surface-metrology applications.

Higher Precision Through Parallel-Motion Metrology

The PicoCube® is based on a proprietary, ultra-fast, piezo-driven scanner design equipped with direct-measuring, capacitve 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. See p. 2-4 *ff.* and p. 5-2 *ff.* for more information.

PI capacitive sensor electronics use the proprietary ILS (Integrated Linearization System) for enhanced linearity and are less sensitive to EMI than other high-resolution sensor systems.

With parallel metrology, all sensors measure the position of the same moving platform against the same stationary reference. This means that all motion is inside the servo-loop, resulting in superior multi-axis precision (Active Trajectory Control).

Nanometer Accuracy in 1 Millisecond with 50-Picometer Resolution

PicoCube® systems provide resolution of 50 picometers and below. The ultra-fast XY/XYZ piezo drives offer resonant frequencies of 9.8 kHz in Z and >3 kHz in X and Y! The high resonant frequency and high-bandwidth capacitive feedback allow step and settle to 1% accuracy in as little as one millisecond.

Rugged Design

In spite of its ability to move and position on an atomic scale, the PicoCube® boasts a rugged design for real-world applications. For extra-high stability and reduced mass, the body is precision machined from heat-treated and stress-relieved titanium. The sophisticated frictionless design also ensures that the (moving) top plate protects the internal actuator/sensor unit from contamination.

Control

The PicoCube® controller is based on the E-500, 19" rack-mount chassis with one E-509.CA3 servo-controller and three E-507.36 power amplifier modules. This controller is equipped with high-speed analog interfaces (0 to 10 V). An optional E-516 20-bit interface module (see page 6-26) is also available.

Ordering Information

P-363.3CD
PicoCube® XYZ Positioning- and Scanning System, 5 x 5 x 5 µm, Parallel-Motion Metrology, Capacitive Sensors, Sub-D Connectors

P-363.3UD
Vacuum Version of P-363.3CD to 10^{-9} hPa

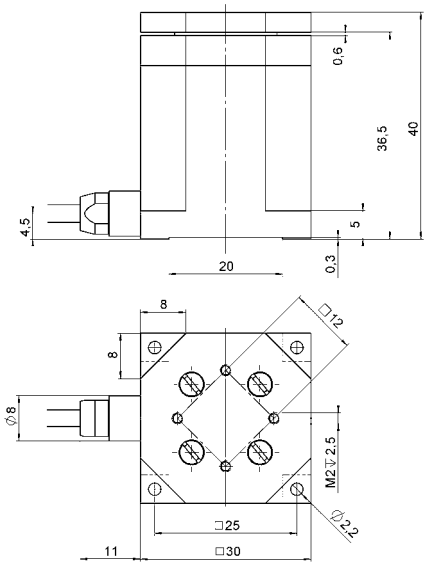
P-363.2CD
PicoCube® XY Positioning- and Scanning System, 5 x 5 µm, Parallel-Motion Metrology, Capacitive Sensors, Sub-D Connectors

P-363.2UD
Vacuum Version of P-363.2CD to 10^{-9} hPa

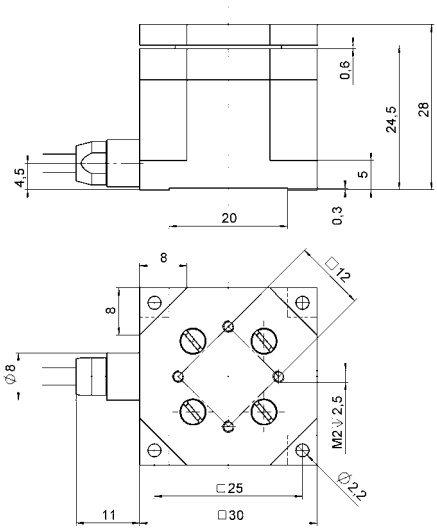
P-363.3CL
PicoCube® XYZ Positioning- and Scanning System, 5 x 5 x 5 µm, Parallel-Motion Metrology, Capacitive Sensors, Lemo Connectors

P-363.2CL
PicoCube® XY Positioning- and Scanning System, 5 x 5 µm, Parallel-Motion Metrology, Capacitive Sensors, Lemo Connectors

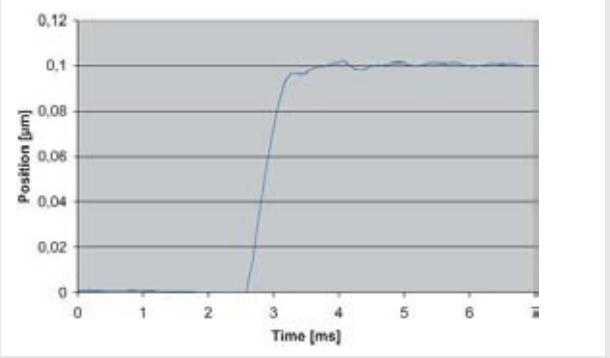
Different travel ranges or dimensions on request.



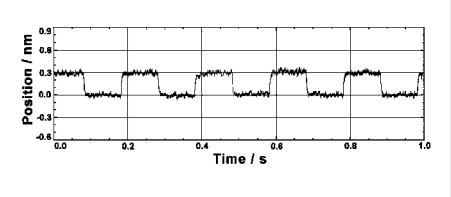
Dimensions of the P-363.3CD in mm. Removable top plate.



Dimensions of the P-363.2CD in mm. Removable top plate.



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.

Technical Data

Models	P-363.3CD	P-363.2CD	Units	Notes see p. 2-84
Active axes	X, Y, Z	X, Y		
Open-loop travel @ -250 to +250V	6, 6, 5.5	6, 6	µm	A5
Closed-loop travel	5, 5, 5	5, 5	µm	A2
Integrated feedback sensor	capacitive	capacitive		B
* Closed- / Open-loop resolution	0.1 / 0.05	0.1 / 0.05	nm	C1
Closed-loop linearity (X, Y, typ.)	1	1	nm	
Max. load	10	10	N	D4
Tilt, off-axis (typ.)	0.5	0.5	µrad	
Electrical capacitance	60 (X, Y); 110 (Z)	60	nF ±20%	F1
Unloaded resonant frequency (X, Y)	3.1	4.2	kHz ±20%	G2
Unloaded resonant frequency (Z)	9.8	–	kHz ±20%	G2
Resonant frequency @ 20 g load (X, Y)	1.5	2.1	kHz ±20%	G3
Operating temperature range	-40 to 120	-40 to 120	°C	H2
** Voltage and sensor connection	Sub-D special	Sub-D special		J1
Weight (with cables)	225	190	g ±5%	
Body material	Titanium	Titanium		L
Recommended amplifier/controller	E-500 rack, E-509, E-507.36 amplifier	E-500 rack, E-509, E-507.36 amplifier		

* For calibration information see p. 2-8.
Resolution of PI piezo nanopositioners is not limited by friction or stiction. The value given is noise equivalent motion with E-509.C3A controller and E-507.36 amplifier.

** P-363.xCL versions with Lemo connectors

M-674 Fast OEM Linear Motor / Actuator

PILine® RodDrive Integrated Piezo Linear Motor Drive

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

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

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

Application Examples

- System Integration for Micropositioning Products
- Automation
- Handling
- Micromanipulation
- Biotechnology
- Metrology

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

Advantages of PILine® Micropositioning Systems

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

- Higher Accelerations, up to 10 g
- Speeds up to 500 mm/s
- Small Form Factor
- Self-Locking When Powered Down
- No Shafts, Gears or Other Rotating Parts
- Non-Magnetic and Vacuum Compatible Drive Principle

Working Principle

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

Variety of Drivers / Controllers

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

Ordering Information

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

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

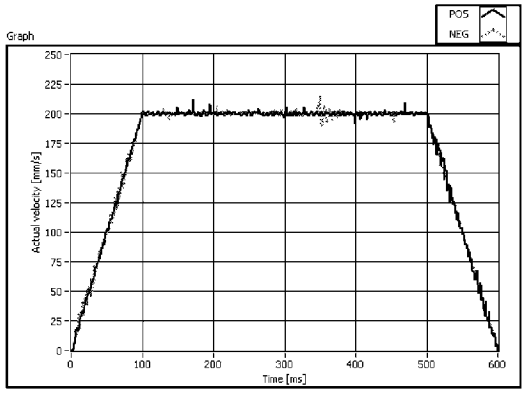
M-674.364
PILine® RodDrive, 150 mm, 7 N

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

Together with a position sensor, RodDrives can be operated in closed-loop with the C-866.D64 piezo motor controller. This specialized servo-controller also integrated the motor drive electronics and enables highly constant speeds up to 350 mm/s with very short settling times (10´s of msecs). RodDrives can also be operated with conventional servo-controllers. In this case, the C-185 (to be ordered separately) external drive electronics is required which accepts a ±10 V analog signal from the controller.

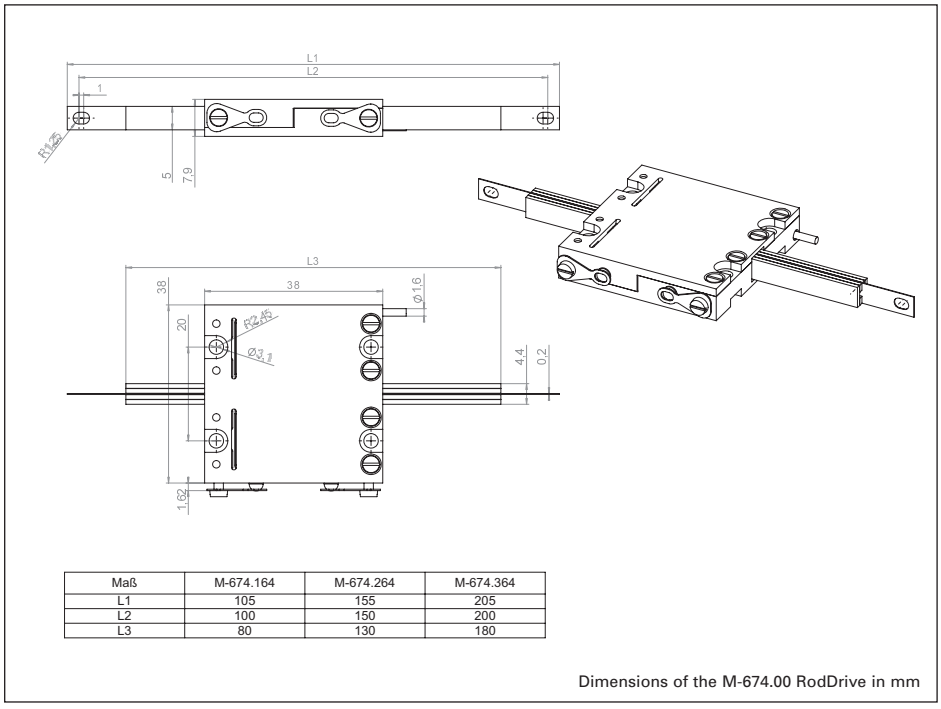
Note

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



Constancy of closed-loop velocity at 200 mm/s of an integrated M-674 RodDrive

The M-674 integrated into a Micropositioning Stage



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

Dimensions of the M-674.00 RodDrive in mm

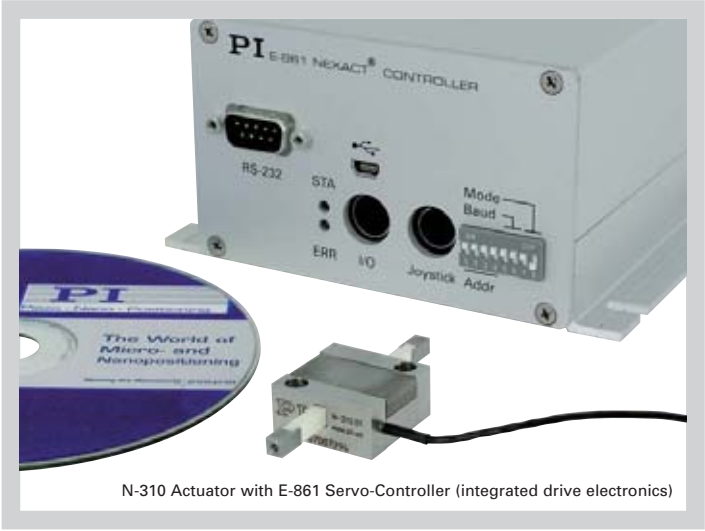
Technical Data

Models	M-674 M-674.164	M-674 M-674.264	M-674 M-674.364	Units	Tolerance
Motion and positioning					
Travel range	50	100	150	mm	x
Minimum incremental motion, open-loop	0.05*	0.05*	0.05*	µm	typ.
Max. velocity	450	450	450	mm/s	
Max. acceleration	20	20	20	m/s	
Mechanical properties					
Stiffness when powered down	5**	5**	5**	N/µm	±10 %
Holding force when powered down	7	7	7	N	max.
Push / pull force	7	7	7	N	max.
Drive properties					
Resonant frequency	155	155	155	kHz, typ.	
Integrated piezo motor	2 x PILine® P-664 (Dual Motor)	2 x PILine® P-664 (Dual Motor)	2 x PILine® P-664 (Dual Motor)		
Motor voltage range	200 (peak-peak)*** 70 (RMS)***	200 (peak-peak)*** 70 (RMS)***	200 (peak-peak)*** 70 (RMS)***	V	
Operating voltage drive electronics	12	12	12	V	
Max. elec. power consumption drive electronics	15	15	15	W	
Miscellaneous					
Operating temperature range	-20 to +50	-20 to +50	-20 to +50	°C	
Body material	PEEK-PTFE	PEEK-PTFE	PEEK-PTFE		
Mass	0.1	0.12	0.14	kg	±5 %
Cable length	1.5	1.5	1.5	mm	±10 mm
Connector	LEMO connector	LEMO connector	LEMO connector	LEMO connector	
Recommended controller/driver	C-184.D64 OEM drive electronics board C-185.D64 driver C-866.D64 Controller for closed-loop operation	C-184.D64 OEM drive electronics board C-185.D64 driver C-866.D64 Controller for closed-loop operation	C-184.D64 OEM drive electronics board C-185.D64 driver C-866.D64 Controller closed-loop operation		

* The minimum incremental motion is a typical value that can be achieved in the open-loop mode of a piezomotor stage. To reach the specs it is important to follow the mounting guidelines of the OEM-motors.
** Stiffness at 25 °C.
*** The operationg voltage is supplied by the drive electronics.

N-310 Ultra-Precision Linear Motor / Actuator

Compact NEXACT® OEM Piezo Stepping Drives with Long Travel Ranges



N-310 Actuator with E-861 Servo-Controller (integrated drive electronics)

- **20 mm Standard Travel Range**
- **Compact and Cost-Effective Design**
- **0.03 nm Resolution**
- **To 10 N Push/Pull Force**
- **Low Operating Voltage**
- **Self Locking, with no Heat Dissipation, Nanometer Stability**
- **Non-Magnetic and Vacuum-Compatible Working Principle**

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

Application Examples

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

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

Advantages of PiezoWalk® piezo stepping drives

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

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

Working Principle for Application Flexibility

NEXACT® PiezoWalk® technology overcomes the limitations of conventional nanopositioning drives and combines virtually unlimited travel ranges with high stiffness in a very small package. Furthermore, NEXACT® actuators provide piezo-class resolution (far below one nanometer) and millisecond responsiveness. The special drive design reduces the operating voltage to 40 V and below.

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

Wear and Maintenance-Free

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

Self-Locking PiezoWalk® Piezo Stepping Drive

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

Controller and Drive Electronics appropriated for the Application

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

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

Ordering Information

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

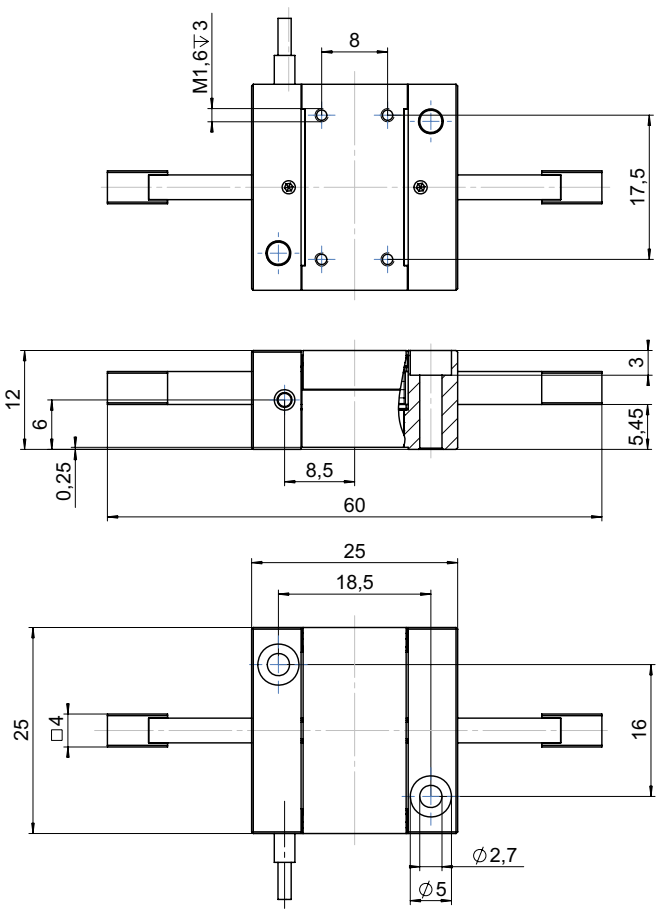
Ask about custom designs

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

Technical Data

Models	N-310.01	Tolerance
Active axes	X	
Motion and positioning		
Travel range	±20 mm	
Step size (in step mode)	5 nm to 5 µm	
Travel range in analog operation	7 µm	max.
Open-loop resolution	0.025 nm	typ.
Step frequency	1.5 kHz*	max.
Max. speed	10 mm/s*	max.
Mechanical properties		
Push/Pull force (active)	10 N	max.
Drive properties		
Drive type	NEXACT® linear drive	
Operating voltage	-10 V to +40 V	
Miscellaneous		
Operating temperature range	0 to 50 °C	
Body material	Stainless steel	
Mass	50 g	±5 %
Cable length	1.5 m	±10 mm
Connector	NEXACT® linear drive (D-Sub 15, 3 row)	
Recommended controller/driver	E-860-series	

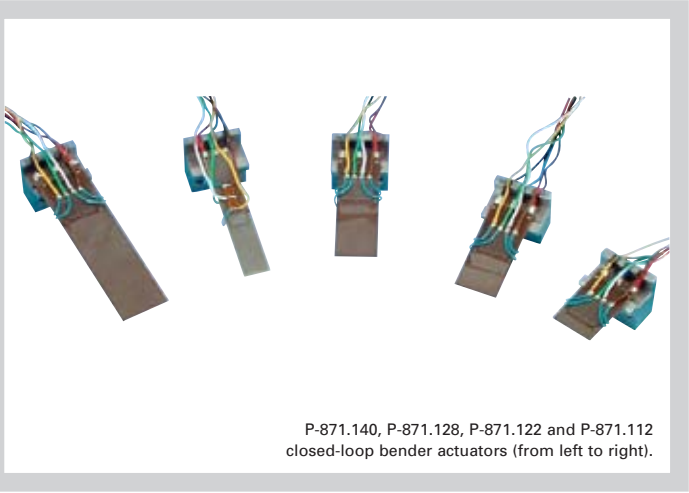
* Depending on the control electronics.



N-310.01 Actuator, dimensions in mm

P-871 Compact Piezo Benders (Bimorph)

Closed-Loop, High-Deflection PICMA® Multilayer Piezo Bender Actuators (LVPZT)



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

- **Closed-Loop Operation for Superior Accuracy**
- **Nanometer-Range Resolution**
- **Deflection up to 1.6 mm**
- **Ceramic Insulation for Extended Lifetime**
- **Ideal for Scanning Applications**
- **Vacuum-Compatible Versions**
- **Low Operating Voltage**
- **Mounting Hardware Included**
- **Special Controllers / Drivers Available**

closed-loop piezo benders based on the open-loop PL122 to PL140 PICMA®-series multilayer actuators. Equipped with high-resolution position feedback sensors they provide better linearity, accuracy and repeatability than other piezo benders on the market. P-871 bender actuators achieve typical piezo actuators, up to 1.6 mm, and response times in the millisecond range. For ease of installation, the units come complete with the mounting hardware, cables and connectors.

Application Examples

- Wire bonding
- Fiber optic switches
- Beam deflection and stabilization
- Scanning of optical components
- Alignment of optical components

Long Lifetime and High Performance—Ideal for Dynamic Operation

PICMA® Bender actuators are superior to conventional actuators in high-endurance situations. They show substantially longer lifetimes both in static and dynamic operation, even in harsh environments. The monolithic, ceramic-encapsulated design provides better humidity protection than polymer-film insulation. Diffusion of water molecules into the insulation layer is greatly reduced by the use of cofired, outer ceramic encapsulation.

Closed-Loop Position Control for Higher Accuracy

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

Amplifiers, Drivers & Controllers

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

Ordering Information

P-871.112
Closed-loop Piezo Bender Actuator, 160 µm, 9.6 mm Width, SGS

P-871.122
Closed-loop Piezo Bender Actuator, 400 µm, 9.6 mm Width, SGS

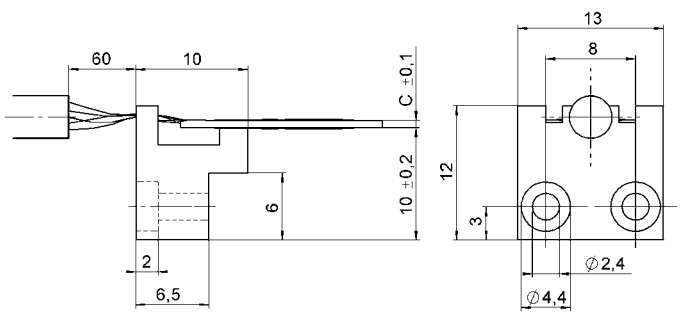
P-871.127
Closed-loop Piezo Bender Actuator, 720 µm, 9.6 mm Width, SGS

P-871.128
Closed-loop Piezo Bender Actuator, 720 µm, 6.3 mm Width, SGS

P-871.140
Closed-loop Piezo Bender Actuator, 1600 µm, 11.0 mm Width, SGS

Of course, PI also designs custom actuators, amplifiers and controllers.

Page references refer to PI's hardcover catalog



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

Dimensions of P-871 in mm.

Technical Data

Models	P-871.112 *	P-871.122	P-871.127	P-871.128 *	P-871.140	Units
Closed-Loop Deflection	160	400	720	720	1600	µm
Integrated Feedback Sensor	SGS	SGS	SGS	SGS	SGS	
Closed-loop linearity	0.5	0.5	0.5	0.5	0.5	%
Stiffness	0.02	0.01	0.003	0.002	0.0007	N/µm ± 20%
Blocking force	2.0	1.1	1.0	0.5	0.5	N ± 20%
Electrical capacitance	2 x 1.1	2 x 1.6	2 x 2.3	2 x 1.2	2 x 2.7	µF ± 20%
Unloaded resonant frequency	2540	1010	560	340	195	Hz ± 20%
Resonant frequency @ 6.5 g load	480	220	145	100	60	Hz ± 20%
Mass (incl. cables)	33.5	34.5	34.5	34.0	35.5	g
Recommended driver / controller	E-651 / E-614	E-651 / E-614	E-651 / E-614	E-651 / E-614	E-651 / E-614	

Operating voltage: 0 to 60 V
Cable length: >1000 mm
Connector: 1 LEMO connector for both sensor and voltage supply
Parameters depend on applied load
Operating temperature: -20 °C to +85 °C
* -20 °C to +150 °C

P-601 Precision Flexure Actuator

PiezoMove® Flexure-Guided Actuator for Optics Positioning and Nano-Pumps

P-601 PiezoMove® Lever Amplified Z-Actuators.

Ordering Information

P-601.1S
PiezoMove® Lever Amplified Actuator, 100 µm, SGS

P-601.3S
PiezoMove® Lever Amplified Actuator, 250 µm, SGS

P-601.4S
PiezoMove® Lever Amplified Actuator, 400 µm, SGS

P-601.10
PiezoMove® Lever Amplified Actuator, 110 µm, Open-Loop

P-603.30
PiezoMove® Lever Amplified Actuator, 300 µm, Open-Loop

P-601.40
PiezoMove® Lever Amplified Actuator, 480 µm, Open-Loop

- **Zero-Wear Flexure Guidance, Frictionless, Ultra-Straight**
- **Travel Ranges to 480 µm**
- **Resolution to 0.2 nm**
- **High Dynamics and Stiffness**
- **PICMA® High-Performance Piezo Actuators**
- **Open and Closed-Loop Versions**
- **Ideal for OEM Applications**

Lever amplified PiezoMove® P-601 actuators combine large vertical travel ranges up to 480 µm and a high positioning accuracy in a very compact design. With settling times of only a view milliseconds and a resolution in the sub-nanometer range they are well suited for static and dynamical applications.

PiezoMove® P-601 lever amplified actuators cover the range between direct-driven preloaded piezo translators, such as the P-840 series, and single-axis nanopositioning stages, like the P-611 series. Compared to direct-driven piezo translators, lever amplified actuators offer larger travel ranges, a much higher lateral stiffness and guiding precision. Compared to single-axis nanopositioning stages, they offer clearly smaller dimensions. PiezoMove® lever amplified actuators feature a resolution to 0.2 nm and a repeatability to 8 nm.

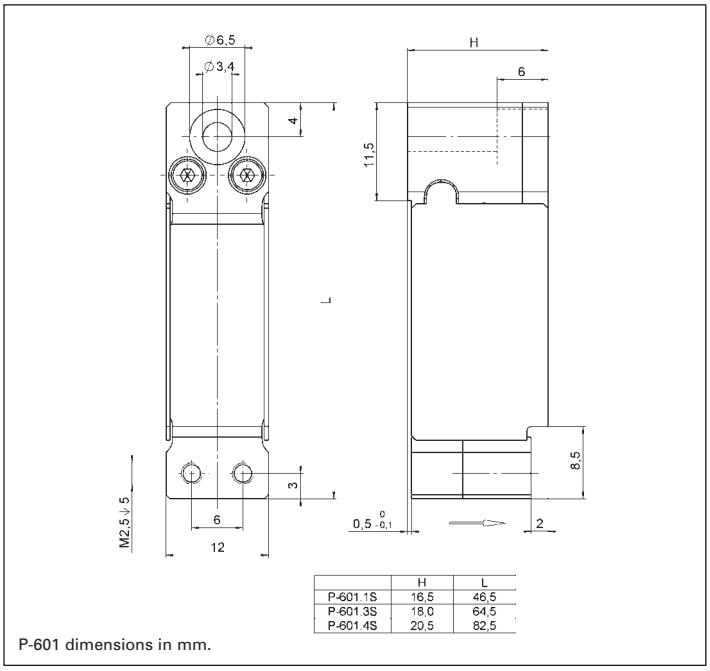
With their highly precise, frictionless flexure guidance, a very high stiffness and excellent straightness of motion are reached. Together with their small dimensions and the cost-effective design, the P-601 lever amplified actuators are especially suited for OEM applications. Versions with strain-gauge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

Application Example

- Nanopositioning
- Semiconductor Testing
- Adaptronics
- Photonics / Integrated Optics
- Biotechnology

Superior Lifetime

Reliability is assured by the use of award-winning PICMA® multilayer actuators, which are integrated into a sophisticated, single-module, flexure guiding system. The PICMA® actuators feature cofired ceramic encapsulation and thus offer better performance and reliability than conventional piezo actuators. The wire-EDM-cut flexures are FEA modeled to make them extremely precise. In addition they are maintenance-free and not subject to wear.



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

P-601 dimensions in mm.

Technical Data

Models	P-601.10	P-601.1S	P-601.30	P-601.3S	P-601.40	P-601.4S	Units	Tolerances
Active Axis	Z	Z	Z	Z	Z	Z		
Motion and Positioning								
Integrated sensor	–	SGS	–	SGS	–	SGS		
Travel range -20 to +120 V, open-loop	110	110	300	300	480	480	µm	min.
Travel range closed-loop	–	100	–	250	–	400	µm	
Resolution open-loop	0.2	0.2	0.3	0.3	0.4	0.4	nm	typ.
Resolution closed-loop	2	2	6	6	12	12	nm	typ.
Linearity	–	0.1	–	0.3	–	0.3	%	typ.
Unidirectional repeatability	–	8	–	10	–	30	nm	typ.
Pitch	20	20	20	20	20	20	µrad	typ.
Yaw	10	10	10	10	10	10	µrad	typ.
Mechanical Properties								
Stiffness in motion direction	0.8	0.8	0.38	0.38	0.28	0.28	N/µm	±20 %
Resonant frequency unloaded	750	750	440	440	350	350	Hz	±20 %
Resonant frequency loaded (30 g)	620	620	350	350	290	290	Hz	±20 %
Push-/pull force in motion direction	30/10	30/10	20/10	20/10	15/10	15/10	N	Max.
Lateral force	30	30	30	30	30	30	N	Max.
Drive Properties								
Drive type	PICMA®	PICMA®	PICMA®	PICMA®	PICMA®	PICMA®		
Electrical capacitance	1.5	1.5	3.1	3.1	4.6	4.6	µF	±20 %
DOOC	1.9	1.9	1.6	1.6	1.4	1.4	µA/(Hz x 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		
Mass	50	50	75	75	110	110	g	±5 %
Cable length	250	250	250	250	250	250	mm	±10 mm
Sensor connection	Open leads	Open leads	Open leads	Open leads	Open leads	Open leads		
Voltage connection	Open leads	Open leads	Open leads	Open leads	Open leads	Open leads		
Recommenden driver/controller	A, G	D, H	A, G	D, H	A, G	D, H		

News & Applications

Technology that gets under your skin

Ultrasonic piezo linear drives—new application in non-invasive medical technology

In medical engineering, modern PILine® ultrasonic piezo linear drives are opening up applications which were impossible using classic electric motor leadscrew systems. Due to the piezoelectric effect and the direct creation of linear motion, PILine® drives are not only faster, lighter and more compact than conventional motorized drives, but they can also be made non-magnetic. They achieve resolutions of 20 nm (0.02 µm) and velocities of up to 1 m/s. Their travel range is basically unlimited, and they are available in a number of different integration levels to match the desired (OEM) application. Medical engineering provides an up-to-date example.

The SkinDex scanner is based on the technology of optical coherence tomography (OCT) and examines the tissue on and under the skin surface non-invasively. The results obtained are extraordinary. The information contained in the 2-D and 3-D sectional images is comparable to that of a histological examination.

OCT uses the basic transparency of skin together with the interference fringes obtainable with white light. The optical paths are made up of optical fibers.

Exact positioning for precise results

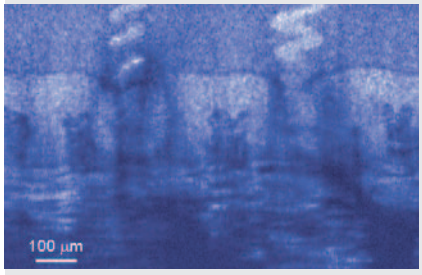
To enable creation of 2- and 3-dimensional images from interference patterns, the optical fibers must be moved both axially and laterally during the scan. This task requires positioners capable of the highest precision. Ultimately, it is the performance of the drives which determine the system resolution and hence the quality of the images.

A PILine® P-661 OEM motor is used to position the reference-arm mirror (depth parameter). This motor was chosen primarily because of its compact design and, considering its size, its high force capacity of 2 newtons (0.5 lbf). Total travel is 2 mm, the position resolution in this application 30 nm (0.03 µm, 1.18 micro-inch).

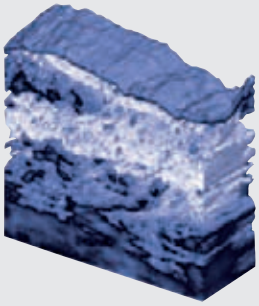
As the images are recorded sequentially, the high speed and excellent dynamic response of the drive is a great advantage. As a result, the SkinDex needs only a few seconds to generate its highly informative images. The lateral motions of the optical fibers in the sensing arm executing the surface scan are also performed by a PI drive.

In this case it is a PIHera® P-622.2CD, a flexure-guided, 2-axis, piezo nanopositioning system, which provides a resolution of 1 nm (0.001 µm, 0.04 µ-inch) and covers an area of 250 x 250 µm. Piezo-based drives have thus again contributed to an innovation from which many people will benefit in the future.

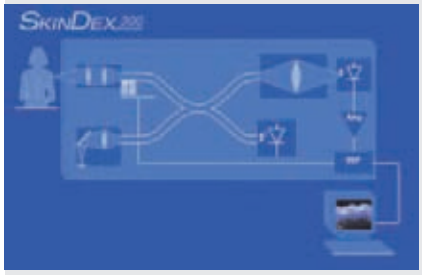
The SkinDex scanner based on OCT technology for non-invasive but reliable examination of the tissue on and under the skin surface (photo ISIS Optronics).



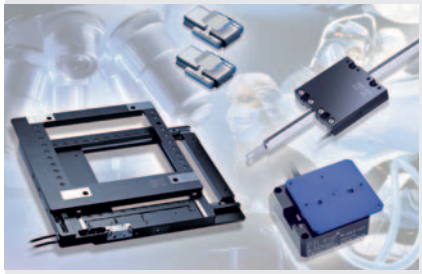
A look under the skin of the ball of the thumb. Even the untrained eye can recognize the spiral-shaped sweat-gland ducts.



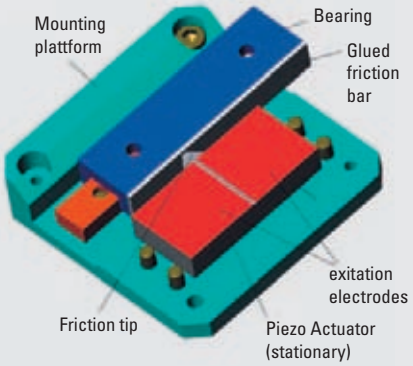
3-D OCT image: Individual laminar and cylindrical structures such as larger blood vessels are visible under the rough skin surface.



White-light interferometry is the basis of OCT. Using optical fibers, light is divided into a sensing and a reference beam. After being reflected by the target (i.e., a cutaneous structure) and the reference mirror respectively, the beams are recombined and enter the detector. An interference signal pattern results (photo: ISIS Optronics).



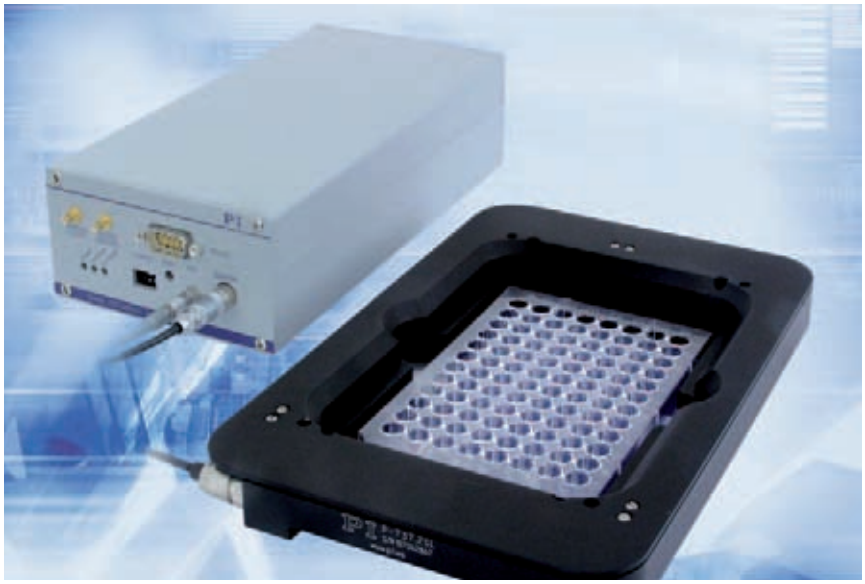
Integration levels in PILine® ultrasonic motor technology: from 8-millimeter drives, through the successful Rod-Drive linear drive, to integrated multi-axis systems.



Working principle of an ultrasonic piezo drive.

News & Applications

PIFOC® Revisited: P-737 Piezo-Z Microscopy Specimen Scanning Stage



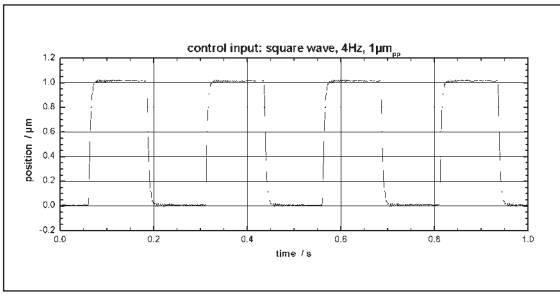
PI is the inventor of high-speed Piezo-Z objective steppers. Today the term PIFOC® is practically synonymous with all high-resolution vertical drives for microscope objectives. Depending on the application, it can be advantageous to adjust the sample instead of the objective. While no sample stage can beat the speed of the fastest PIFOC® objective positioners (due to the stiffer and more compact design), the P-737 stage allows for convenient Z-stack imaging with multiple objectives and very high throughput. Im both cases the effect remains the same: the focal plane moves through the sample. This is why the P-737 is also marketed under the PIFOC® trademark.

PIFOC® P-737 high-speed vertical positioning systems are designed for integration into motorized XY microscopy stages of leading manufacturers such as Märzhäuser. While the XY stage positions the sample, the piezo flexure-based P-737 moves the sample along the optical axis to adjust the focus quickly and precisely. Vertical stepping with nanometer precision takes only a few milliseconds. The large aperture is designed to accommodate a variety of specimen holders including slides or multiwell plates.

High-speed Z-steps for fast focus control and imaging

The immediate response of the solid-state piezo drives enables rapid Z-steps with typically 10-to-20-times-faster step-and-settle than classical stepper motor drives. This leads to significantly higher image acquisition speed and throughput. The P-737 is available with travel ranges of 100 or 250 µm and offers a choice of feedback sensors between strain gauge or non-contact, capacitive position sensors, depending on the accuracy requirements.

Settling time is in the 10 ms range – here, 1 µm steps



Analog or Digital Systems

The P-737 together with the E-625 piezo-controller, offers a cost-effective system for high-speed, high-resolution positioning of microscopy specimens. The controller features a choice of a 20-bit digital interface or a broadband analog interface for the target position.

The capacitive-sensor-equipped version can also be operated with the sophisticated E-753 digital servo-controller. The main advantage of this controller is its adaptability to changing load conditions on the piezo stage. No matter what load is applied, the system can always provide an optimum combination of speed, settling time and resolution.

PIFOC® objective positioners and scanners are available with travel ranges of up to 400 µm. QuickLock thread adapters enable fast mounting of the PIFOC® on the microscope and flexible replacement of objective

More Info:
Click Images

Overview: Piezo Controllers and Drivers

For Closed-Loop & Open-Loop Piezo Stages / Actators, Digital & Analog Control

E-710 Multi-Channel Digital Piezo Controllers with Dynamic Linearization

- For Piezo Nanopositioners with Capacitive Feedback Sensors
- 3-, 4- & 6-Channel Versions, 32-Bit Digital Filters
- Hardware and Firmware Linearization
- Coordinate Transformation for Parallel Kinematics /Parallel Metrology Systems
- Optional Dynamic Digital Linearization (Firmware Option) Improves Scanning Linearity
- ID Chip Support for Automatic Calibration
- Optional High-Speed Parallel I/O or DSP Interface
- Optional Analog Input
- GCS (General Command Set) Compatible

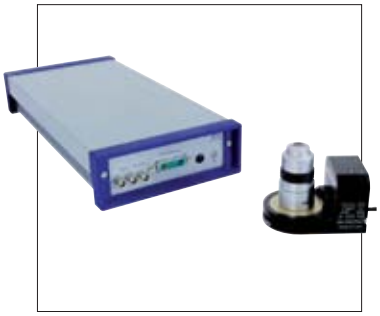
See Online Datasheet Available at www.pi.ws

E-712 Modular Digital Piezo Controller System, up to 6 Axes

- Digital Controller of the Newest Generation: 600 MHz Processor; up to 50 kHz Sensor Update Rate; Highly Stable 20-bit D/A Converters
- Real-Time Operating System for Excellent Trajectory Control
- Modular Design for Greatest Flexibility in Meeting Custom Requirements
- Auto-Calibrating from Stage ID-Chip for Interchangeability of Controller and Mechanics w/o Recalibration
- Flexible Interfacing: USB, RS-232 & Ethernet
- Optional High-Bandwidth Analog Inputs and Outputs

See p. 45 or Online Datasheet Available at www.pi.ws

E-753 Digital High-Speed Piezo Controller for Single-Channel Nanopositioning Systems



- 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
- Automatic Calibration Data Coaching from Stage ID-Chip
- Additional High-Bandwidth Analog Control Input / Sensor Input
- Digital I/O Lines for Triggering Tasks
- Extensive Software Support
- For Nanopositioning Systems with Capacitive Sensors

See Online Datasheet Available at www.pi.ws

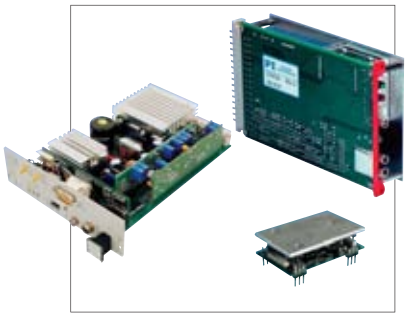
E-500 – E-501 Modular Piezo Control Systems (HVPZT & LVPZT)

- For High- and Low-Voltage Piezo Systems
- 19- and 9.5-Inch Chassis
- Optional Position Servo-Control Modules
- Optional Display and Digital Interface Module

See Online Datasheet Available at www.pi.ws

Overview: Piezo Controllers... (cont.)

E-610, E-625, E-831 Piezo Amplifiers / Controller Modules with Optional Computer Interface



- Analog & Optional 20-Bit High Speed Digital Interface
- Single Channel, Network Capability with up to 12 Channels
- For Capacitive, LVDT and Strain Gauge Position Sensors
- Open-Loop and Closed-Loop Versions
- Stand Alone or Rack-Mount Operation

See Online Datasheet Available at www.pi.ws

E-755 Digital Controller for NEXLINE® Nanopositioning Linear Drives

- Special Control Algorithms for NEXLINE® Nanopositioning Linear Drives
- 32-Bit Digital Filters
- 24-Bit DAC Resolution
- Fully Programmable Low-Pass and Notch Filters
- Non-Volatile User Settings and Last-Position Data
- PI General Command Set Compatible

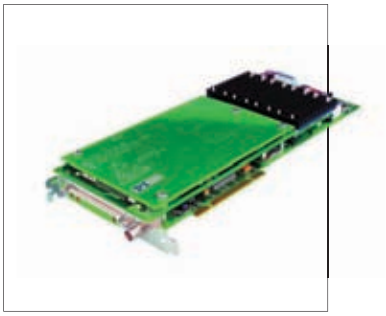
See Online Datasheet Available at www.pi.ws

E-625 and E-665 Piezo Amplifiers & Servo-Controllers

- Analog & 20-Bit High-Speed Digital Interface
- SGS, LVDT and Capacitive Sensor Servo-Control
- Wave Table for User-Defined Curves
- Network Capability with up to 4 or up to 12 Channels
- GCS (General Command Set) Compatible

See Online Datasheet Available at www.pi.ws

E-761 Digital Piezo Controller PCI Board for Piezo Stages••



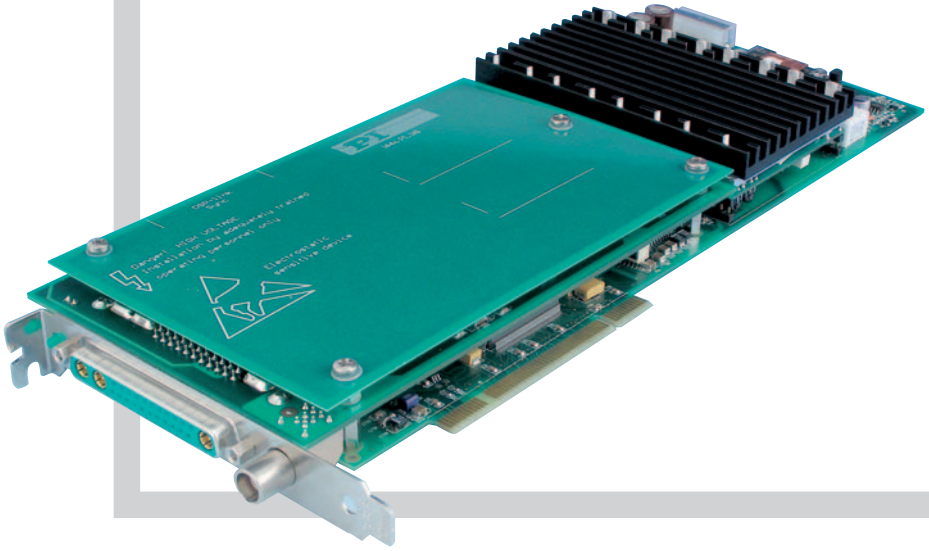
- For Piezo Stages with Capacitive Sensors
- High-Speed PCI Interface
- 3 Logical Axes, 4 Piezo Amplifiers
- Additional High-Bandwidth Analog Interface
- 32-Bit Digital Filters
- 24-Bit Ultra-Low-Noise DAC Converters
- Coordinate Transformation for Parallel-Kinematics / Parallel-Metrology Systems

See p. 44 or Online Datasheet Available at www.pi.ws

News & Applications

World's First Digital Piezo Nanopositioning Controller on PCI Board

New E-761 digital piezo controller in the PCI-board format



E-761 3-channel digital nanopositioning controller: very advanced control technology in cost-effective PCI format to control up to three logical axes

The E-761 digital nanopositioning controller offers very advanced control technology in the cost-effective PCI-board format. It is able to control nanopositioning systems with up to three logical axes and four piezo actuators.

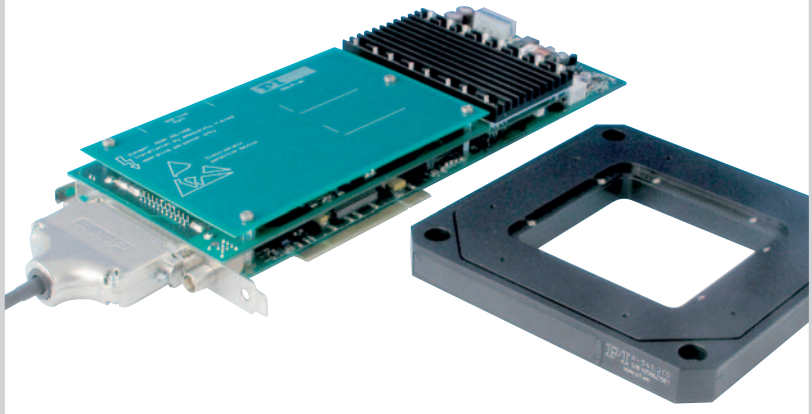
Many of today's high-tech applications, such as imaging, metrology, scanning microscopy and surface analysis require a combination of high-speed motion control and high-resolution vision. They also require extremely fast data acquisition and precise synchronization between the imaging and motion control devices. Peripheral components with PCI bus interface are ideal for these tasks, because the PCI bus was designed to give high-bandwidth access to the microprocessor in the PC. With the E-761, PI introduces the world's first fully digital piezoelectric nanopositioning controller on a PCI board.

The PCI bus allows for very rapid communication and easy integration with devices such as frame grabbers – a feature which is very advantageous in real-time data acquisition applications or when operating multiple axes or controllers simultaneously.

The internal coordinate transformation means it is no problem to operate complex, multi-axis stages, such as three-axis X-Y-Θ_Z stages or Z-tip-tilt platforms. In systems with parallel metrology, the E-761 can also automatically compensate undesired off-axis motion (active trajectory control), making it possible to attain motion accuracies in the sub-nanometer range.

Of course, this digital controller has the technical refinements you have come to expect from PI, such as 32-bit digital filters, 24-bit DAC resolution, multi-stage sensor and electronics linearization, plug & play ID-chip support and an extensive software support package.

P-541.2CD low-profile XY piezo stage with capacitive sensors: a perfect fit for the E-761



News & Applications

New Multi-Axis Piezo Controller Provides Higher Precision, Flexibility

Digitally Controlling the Nano-World – in up to 6 Axes

The new, E-712 multi-axis piezo-controller picks up where the successful E-710 left off. It features a faster processor, a real-time operating system and significantly higher servo update and sensor sampling rates to provide extremely precise coordinated motion in up to 6 degrees of freedom with nanometer precision.

The E-712 controller is available in 3- and 6-channel configurations.

Additional advantages:

- Versatile interfaces: TCP/IP for remote control through the internet; additional USB 2.0 and the classic RS-232. Available high-resolution analog inputs for direct control with high-bandwidth analog signals.
- 20-bit D/A converters make possible sub-nanometer position resolution, even over long travel ranges of >1000 µm, like those of the new P-629 PIHera® piezo nanopositioning stages.
- Available high-power amplifier modules, to supplement the integrated amplifiers for high-frequency scanning / tracking applications.
- Software – tunable, proportional-integral, digital servo-control with 2 notch filters allows operation of the piezomechanics closer to its resonant frequency.
- 600 MHz processor and sensor and servo update rates of up to 50 kHz assure faster updating of the position and control data – especially important for high-dynamics periodic motion. In addition, optional Digital Dynamic Linearization, ensures that tracking errors are reduced to the nanometer level even in high-dynamics scanning applications.
- Internal coordinate transformation for parallel-kinematics systems with user-friendly position commands in Cartesian coordinates.

Mature operating software with intuitive interfaces make operating the system almost child's play. No programming knowledge is needed, whether commissioning, optimizing system parameters, creating new user-defined motion profiles for the integrated wave generator, or recording data generated during the motion. The comprehensive package of supporting software, including LabVIEW drivers and DLLs, ensures easy integration in a variety of system environments.

News & Applications

Ultra-Low-Noise PicoCube® Controller

Reference-Class System for Nanotechnology

New E-536 controllers enable even higher resolution and bandwidth with the minute P-363 PicoCube® piezo stages.

The minute P-363 PicoCube®, together with its reference-class, ultra-low-noise E-536 driver/controller, are ideally suited for nanotechnology applications. They provide significantly higher dynamics, resolution and positional stability than previous multi-axis scanning stages. Nano-imprint lithography, scanning microscopy and biotechnology benefit from the extremely high resolution of up to 25 picometers over travel ranges of 5 µm per axis.

Controllers: Optimized for Highest Resolution / Bandwidth

Two controller versions are available. For high-speed scanning applications the E-536.3C high-power models featuring 100 watts per channel are recommended. The E-536.3CH ultra-low noise versions are optimized for highest positioning accuracy and resolution in the picometer range.

Compact 2-Axis and 3-Axis Stages

The compact PicoCube® is available as XY and XYZ system. It is based on exceptionally robust, high-stiffness shear piezo drives and employs non-contact, direct-measuring, parallel-metrology capacitive sensors for position feedback.

The low-inertia drives allow for a resonant frequency of 10 kHz, important for high speed scanning applications. Measuring only 30 x 30 x 26 mm (XY version), it is easy to integrate in any scanning apparatus.

For more information, see p. 29

Nanometrology, Nanopositioning, NanoAutomation®

Ultra-Precision Motion Control Solutions for High-Tech Markets

PI headquarters

Motion Control Technology - 30 Years Ahead of its Time

PI has been a world market leader in nanopositioning technology and ultra-high-precision motion-control systems for many years. The first nanopositioning systems served research centers working in interferometry and laser technology. Today, entire branches of industry – such as the semiconductor industry, biotechnology and, increasingly, the machine-tool industry – are dependent on progress in nanopositioning.

Key Technologies Under One Roof: A Plus for Our Customers

PI has a strategy of vertical integration with all key technologies developed and maintained in one company. This permits direct control over every step from conception to shipment, optimizing quality and cost. As a customer, you, too, can profit from our over 30 years experience in micro- and nanopositioning.
PI can react quickly to development and production needs of OEM customers – even for highly complex custom products and assemblies.

Applications

Today PI delivers Nanopositioning & measuring solutions for all high-tech markets:

- Microscopy & Optics
- Bio & Nanotechnology
- Photonics, Fiber Optics, Telecom
- Life Sciences
- Lasers, Metrology
- Aerospace Engineering
- Medical Technology
- Astronomy


PI Ceramic, piezo ceramics factory

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 downlowd the complete PI Nanopositioning & Piezo Actuator Catalog

Call or go to: http://www.pi.ws

Headquarters

GERMANY

Physik Instrumente (PI) GmbH & Co. KG
Auf der Römerstr. 1
D-76228 Karlsruhe/Palmbach
Tel: +49 (721) 4846-0
Fax: +49 (721) 4846-100
info@pi.ws · www.pi.ws

PI Ceramic GmbH
Lindenstr.
D-07589 Lederhose
Tel: +49 (36604) 882-0
Fax: +49 (36604) 882-25
info@piceramic.de
www.piceramic.de

Subsidiaries

USA (East) & CANADA

PI (Physik Instrumente) L.P.
16 Albert St.
Auburn, MA 01501
Tel: +1 (508) 832 3456
Fax: +1 (508) 832 0506
info@pi-usa.us
www.pi-usa.us

USA (West) & MEXICO

PI (Physik Instrumente) L.P.
5420 Trabuco Rd., Suite 100
Irvine, CA 92620
Tel: +1 (949) 679 9191
Fax: +1 (949) 679 9292
info@pi-usa.us
www.pi-usa.us

JAPAN

PI Japan Co., Ltd.
Akebono-cho 2-38-5
Tachikawa-shi
J-Tokyo 190
Tel: +81 (42) 526 7300
Fax: +81 (42) 526 7301
info@pi-japan.jp
www.pi-japan.jp

PI Japan Co., Ltd.
Hanahara Dai-ni Building, #703
4-11-27 Nishinakajima,
Yodogawa-ku, Osaka-shi
J-Osaka 532
Tel: +81 (6) 6304 5605
Fax: +81 (6) 6304 5606
info@pi-japan.jp
www.pi-japan.jp

CHINA

Physik Instrumente (PI Shanghai) Co., Ltd.
Building No. 7-301
Longdong Avenue 3000
201203 Shanghai, China
Tel: +86 (21) 687 900 08
Fax: +86 (21) 687 900 98
info@pi-china.cn
www.pi-china.cn

GREAT BRITAIN

PI (Physik Instrumente) Ltd.
Lambda House
Batford Mill
GB-Harpenden, Hertfordshire
AL5 5BZ
Tel: +44 (1582) 764 334
Fax: +44 (1582) 712 084
info@physikinstrumente.co.uk
www.physikinstrumente.co.uk

FRANCE

PI France S.A.S.
32 rue Delizy
F-93694 Pantin Cedex
Tel: +33 (1) 481 039 38
Fax: +33 (1) 481 009 66
info@pi-france.fr
www.pi-france.fr

ITALY

Physik Instrumente (PI) S.r.l.
Via G. Marconi, 28
I-20091 Bresso (MI)
Tel: +39 (02) 665 011 01
Fax: +39 (02) 665 014 56
info@pionline.it
www.pionline.it