Piezo · Nano · Positioning

The World of Nano- and Micropositioning

Supplement, June 2005

Micropositioning, Nanopositioning, NanoAutomation®

Cutting-Edge Solutions for Industry and Research

PI headquarters

Positioning 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 Micro- & NanoPositioning solutions for all important high-tech markets:

- Semiconductors
- Data Storage
- Photonics, Fiber Optics, Telecom
- Life Sciences
- Lasers, Optics, Microscopy
- Aerospace Engineering
- Precision Machining
- Astronomy


PI Ceramic, piezo ceramics factory

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P-541.2SL · P-542.2SL

Low-Profile, Parallel-Kinematics XY Piezo Scanning Stages for Microscopy

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. Dimensions and patterns are the same for all P-541/P-542 stages.

- **Low Profile for Easy Integration: 16.5 mm**
- **Parallel Kinematics for Fast Response**
- **To 200 x 200 µm Travel Range**
- **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.

Choice of Travel Ranges

Two versions are offered, the 100 µm version featuring a higher resonant frequency for faster positioning and a 200 µm version applications requiring a longer travel range. Models with a shorter positioning range for faster scanning and Z, tip/tilt stages for tasks like nano-focusing are also available (see p. 6).

Application Examples

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

Parallel Kinematics for Faster Response

All 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.

Open- and Closed-Loop Models

Open- and closed-loop versions are offered to suit your application. The open-loop models are ideal for applications where fast response and very high resolution are essential, but absolute positioning is not important. They can also be used when the position is controlled by an external linear position sensor such as an intereferometer; a PSD quad cell; a CCD chip / image processing system; or the eyes and hands of an operator.

The closed-loop versions are equipped with high-resolution strain gauge sensors mounted on the flexure guiding system for optimum position stability and responsiveness. The sensors are operated in a full bridge circuit and provide position information with nanometer resolution to the servo controller.

Models with capacitive position sensors for critical applications, requiring the highest positioning linearity are also available.

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-541.2SL
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

P-541.20L
Microscopy XY Nanopositioning & Scanning Stage, 100 x 100 µm, Open-Loop

P-542.20L
Microscopy XY Nanopositioning & Scanning Stage, 200 x 200 µm, Open-Loop

Version with Capacitive Sensors (direct metrology)
see p. 4

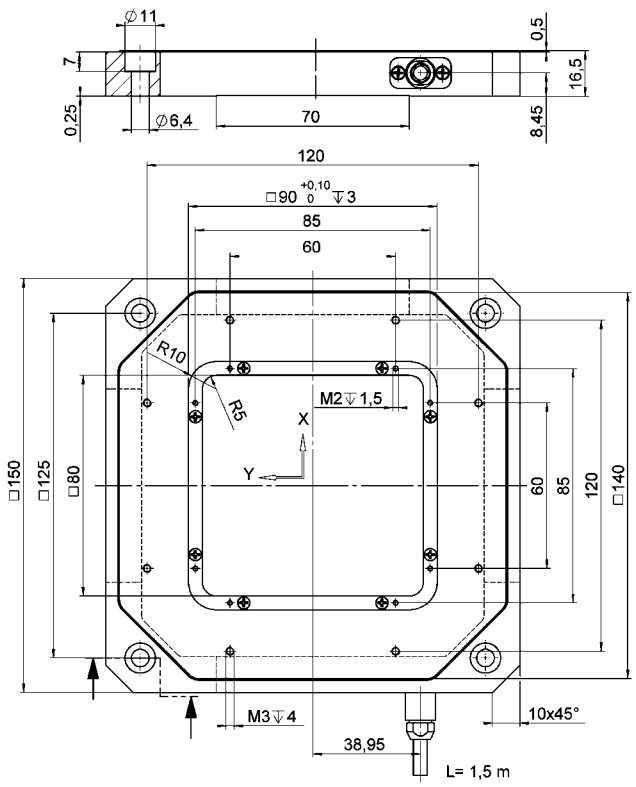
P-541.2DD
Microscopy XY Nanopositioning & Scanning Stage, High-Speed Direct Drive, 45 x 45 µm, Parallel Metrology, Capacitive Sensors

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

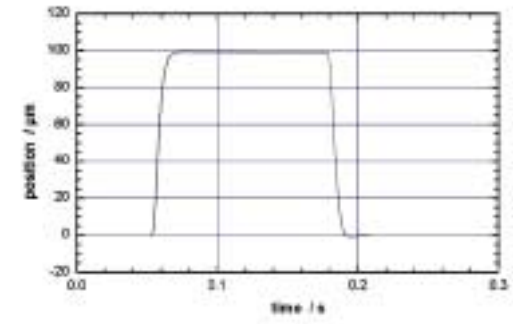
P-542.2CD
Microscopy XY Nanopositioning & Scanning Stage, 200 x 200 µm, Parallel Metrology, Capacitive Sensors

Vacuum Versions Available.

P-540-Series Z-Tip/Tilt Stages
see p. 6



Dimensions of the P-541.2 and P-542.2 in mm.



Settling behavior of the P-541.ZSL stage.

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Capacitive Position Sensors
Piezo Drivers & Nano-positioning Controllers
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Technical Data

Model	P-541.2SL	P-541.20L	P-542.2SL	P-542.20L	Units	Notes (see p. 18)
Active axes	XY	XY	XY	XY		
Min. open-loop travel -20 to 120 V	150 x 150	150 x 150	250 x 250	250 x 250	µm	A2
Closed-loop travel	100 x 100	100 x 100	200 x 200	200 x 200	µm	A5
Integrated feedback sensor	SGS	-	SGS	-		B
*Closed-loop / open-loop resolution	2.5 / 0.2	- / 0.2	4 / 0.4	- / 0.4	nm	C1
Closed-loop linearity (typ.)	0.5	-	0.5	-	%	
Repeatability	<10				nm	
Push force capacity	100, 100	100, 100	100, 100	100, 100	N	D3
Pull force capacity	30, 30	30, 30	30, 30	30, 30	N	D3
Maximal load	20	20	20	20	N	D4
Electrical capacitance (per axis)	6.75	6.75	7.5	7.5	µF ±20%	F1
** Dynamic Operating Current Coefficient (per axis)	8.5	8.5	4.8	4.8	µA/(Hz x µm)	F2
Resonant frequency unloaded	500, 500	500, 500	370, 370	370, 370	Hz ±20%	G2
Resonant frequency with 185 g load			250	250	Hz ±20%	G3
Operating temperature	-20 to 80	-20 to 80	-20 to 80	-20 to 80	°C	H2
Voltage & sensor connection	VL, L	VL	VL, L	VL		J1/J2
Body material	Al	Al	Al	Al		L
Recommended controller (codes explained p. 17)	D, H	A, G	D, H	A, G		

* Resolution of PI Piezo Nanopositioning systems is not limited by friction or stiction. Noise equivalent motion with E-503 amplifier
** Dynamic Operating Current Coefficient in µA per hertz and µm. Example: Sinusoidal scan of 10 µm at 10 Hz with the P-542.2 requires approximately 0.48 mA drive current.

P-541.2CD · P-542.2CD

Low-Profile, XY Piezo Scanning Microscopy Stages with Direct, 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) and 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

- 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, for example in single-molecule microscopy, or in other time-critical applications.
Z stages and Z-tip/tilt stages are also available (see p. 8).

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 drivetrain—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.

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.

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 (indirect metrology)
see p. 2

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. 8

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.

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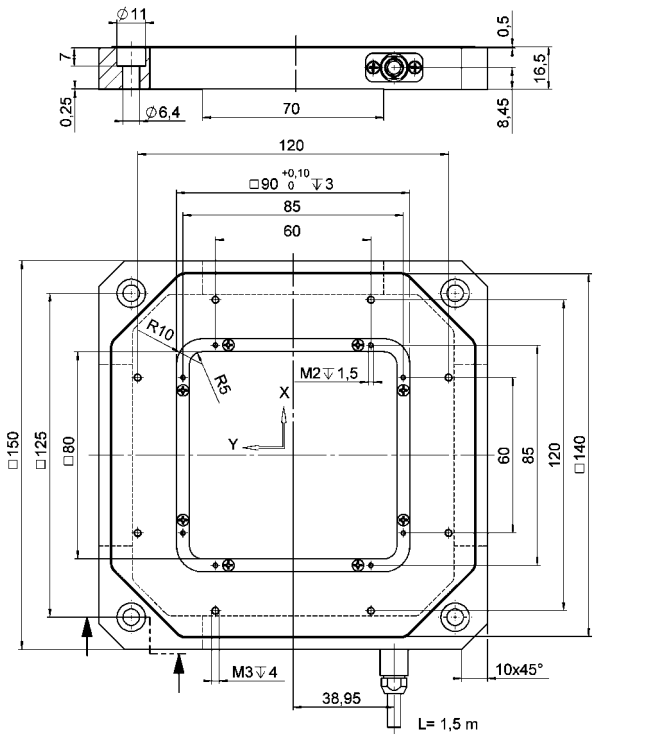


Dimensions of the P-541 and P-542 in mm.

Technical Data

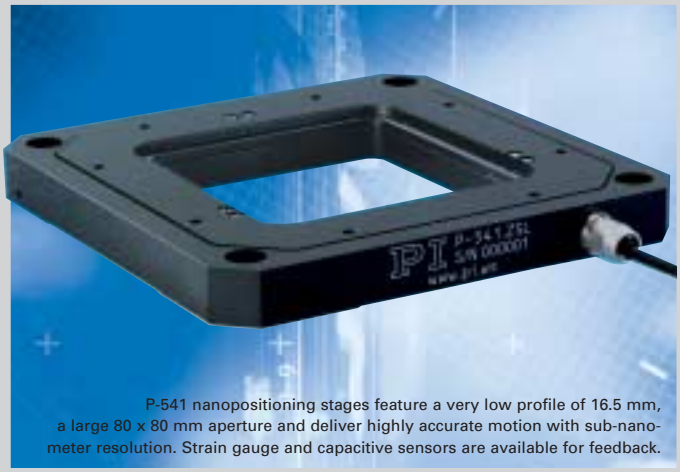
Model	P-541.2CD	P-542.2CD	P-541.2DD	Units	Notes (see p. 18)
Active axes	XY	XY	XY		
Min. open-loop travel -20 to 120 V	150 x 150	250 x 250	60 x 60	µm	A2
Closed-loop travel	100 x 100	200 x 200	45 x 45	µm	A5
Integrated feedback sensor	capacitive	capacitive	capacitive		B
* Closed-loop / open-loop resolution*	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
Maximal 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 with 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 controller (codes explained p. 17)	H, F, L, K	H, F, L, K	H, F, L, K		

* 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 hertz and µm. Example: Sinusoidal scan of 10 µm at 10 Hz with the P-542.2CD requires approximately 0.48 mA drive current.

P-541.ZSL

Low-Profile Z, Tip/Tilt Piezo Nanopositioning Stages for Microscopy



P-541 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. Strain gauge and capacitive sensors are available for feedback.

- **Lower Profile for Easy Integration: 16.5 mm**
- **Z and Tip/Tilt Versions**
- **Fast Response**
- **100 µm Linear Travel Range**
- **80 x 80 mm Clear Aperture**
- **PICMA® High-Performance Piezo Actuators for Superior Lifetime**
- **Combination with Long Travel Microscopy Stages**

Low Profile, Optimized for Microscopy and Interferometry Applications

P-541 series nanopositoning Z-stages and Z-tip/tilt are designed for alignment, nanofocusing 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). Due to the 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

Open- and Closed-Loop Models

Open- and closed-loop versions are offered to suit your application. The open-loop model is ideal for applications where fast response and very high resolution are essential, but absolute positioning is not important. It can also be used when the position is controlled by an external linear position sensor such as an interefero-meter PSD quad cell; a CCD chip or an image processing system; or the eyes and hands of an operator.

The closed-loop version is equipped with high-resolution strain gauge sensors mounted on the flexure guiding system for optimum position stability and responsiveness. The sensors are operated in a full bridge circuit and provide position information with nanometer resolution to the servo controller.

Models with capacitive position sensors for critical applications, requiring the highest positioning linearity are also available.

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.

Ordering Information

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

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

P-541.Z0L
Microscopy Z Nanopositioning Stage, 100 µm, Open-Loop

P-541.T0L
Microscopy Z, Tip/Tilt Nano-positioning Stage, 100 µm / 1 mrad, Open-Loop

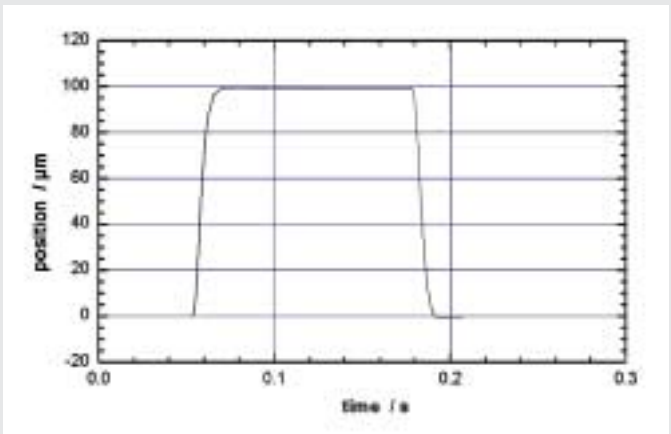
Version with Capacitive Sensors (direct metrolgy) see p. 8

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, Direct Metrology, Capacitive Sensors

Vacuum Versions Available.

P-540-Series XY Stages see p. 2



Settling behavior of the P-541.ZSL stage.

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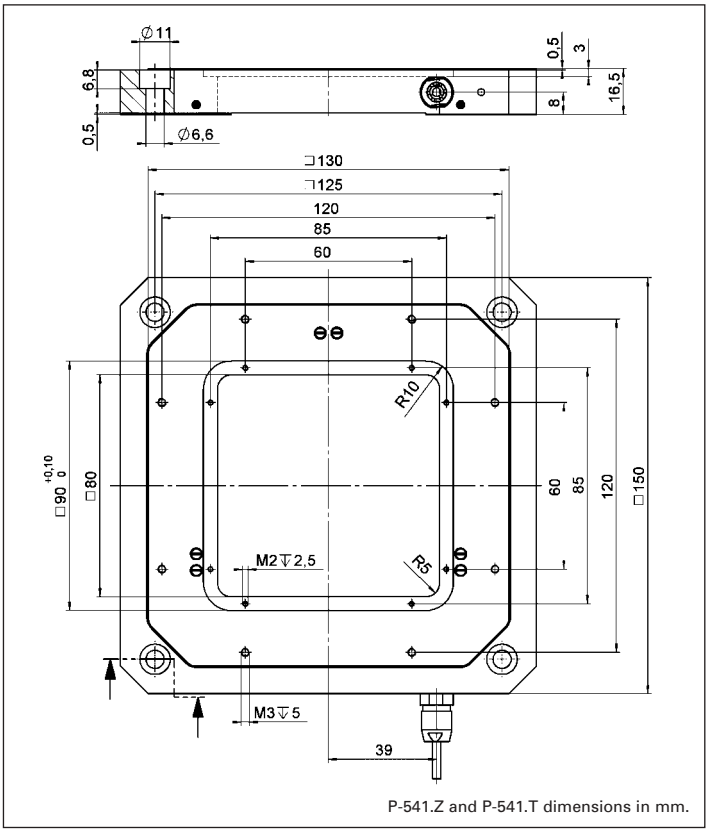


P-541.Z and P-541.T dimensions in mm.

Technical Data

Model	P-541.ZSL	P-541.Z0L	P-541.TSL	P-541.T0L	Units	Notes (see p. 18)
Active axes	Z	Z	Z, θ_X, θ_Y	Z, θ_X, θ_Y		
Min. open-loop travel -20 to 120 V	150	150	150 (1.5 mrad)	150 (1.5 mrad)	µm	A2
Closed-loop travel	100	-	100 (1 mrad)	-	µm	A5
Integrated feedback sensor	SGS	-	SGS	-		B
Closed-loop / open-loop resolution*	2.5 / 0.2	-0.2	2.5 / 0.2 (250 nrad / 20 nrad)	- / 0.2 (- / 20 nrad)	nm	C1
Closed-loop linearity (typ.)	0.5	-	0.5	-	%	
Repeatability	<10				nm	
Push force capacity	50	50	50	50	N	D3
Pull force capacity	20	20	20	20	N	D3
Maximal load	20	20	20	20	N	D4
Electrical capacitance	6.75	6.75	6.75	6.75	µF ±20%	F1
Dynamic Operating Current Coefficient	8.5	8.5	8.5 (Z)	8.5 (Z)	µA/(Hz x µm)	F2
Resonant frequency unloaded	410	410	410 (Z)	410 (Z)	Hz ±20%	G2
Resonant frequency with 185 g load	300	300	300 (Z)	300 (Z)	Hz ±20%	G3
Operating temperature	-20 to 80	-20 to 80	-20 to 80	-20 to 80	°C	H2
Voltage & sensor connection	VL, L	VL	VL, L	VL		J1/J2
Body material	Al	Al	Al	Al		L
Recommended driver / controller (codes explained p. 17)	D, H	C, G, A	D, H	C, G, A		

* Resolution of PI Piezo Nanopositioning systems is not limited by friction or stiction. Noise equivalent motion with E-503 amplifier.
** Dynamic Operating Current Coefficient of linear axes is in µA per hertz and µm. Example: Sinusoidal scan of 10 µm at 10 Hz requires approximately 0.85 mA drive current.

P-541.ZCD

Low-Profile Z, Tip/Tilt Piezo Nanopositioning Stages for Microscopy with Direct 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 Acquisation an 3D Deconvolution Imaging**

Low Profile, Optimized for Microscopy Applications

P-541 series nanopositoning 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. 4).

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 drivetrain—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.

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 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.

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

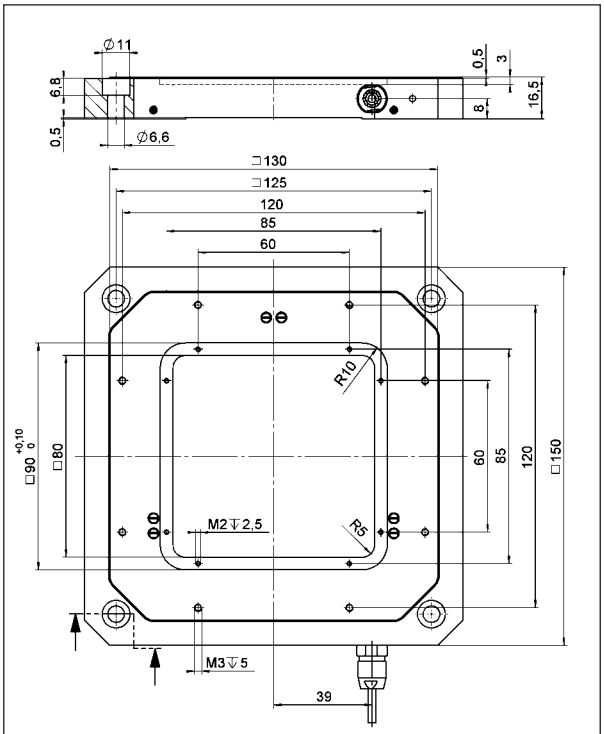
Version with Strain Gauge Sensors (indirect metrology)
see p. 6

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

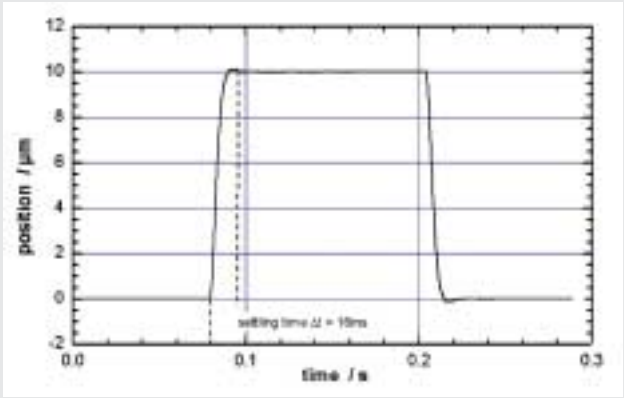
P-541.TSL
Microscopy Z Tip / Tilt Nanopositioning Stage, 100 µm / 1 mrad, Strain Gauge Sensors

Vacuum Versions Available.

P-540-Series XY Stages see p. 4



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%.

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Piezo Drivers & Nano-positioning Controllers
Hexapods / Micropositioning
Photonics Alignment Solutions
Motion Controllers
Ceramic Linear Motors & Stages
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Technical Data

Model	P-541.ZCD	P-541.TCD	Units	Notes (see p. 18)
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
Maximal 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 with 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 driver / controller (codes explained p. 17)	H, F, L	K		

* 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 hertz and µm. Example: Sinusoidal scan of 10 µm at 10 Hz requires approximately 0.85 mA drive current.

P-713 · P-714

Low-Profile OEM XY Piezo-Scanners


P-714 piezo scanner

- **Compact Size of Only 45 x 45 x 6 mm with Clear Aperture**
- **Highly Cost-Efficient Design**
- **15 x 15 µm Travel Range**
- **High Dynamics**

tilayer actuators, which are integrated into a sophisticated, single-module, flexure guiding system. The PICMA® actuators have ceramic-only insulation 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.

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 family piezo scanners and positioners with travel ranges of 15 x 15 µm feature especially compact sizes. Ideal applications for the P-713 and P-714 are high-dynamics scanning or tracking tasks. Such tasks of 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 ms, even after a full-range move, with closed-loop repeatability of under 5 nm.

Application Examples

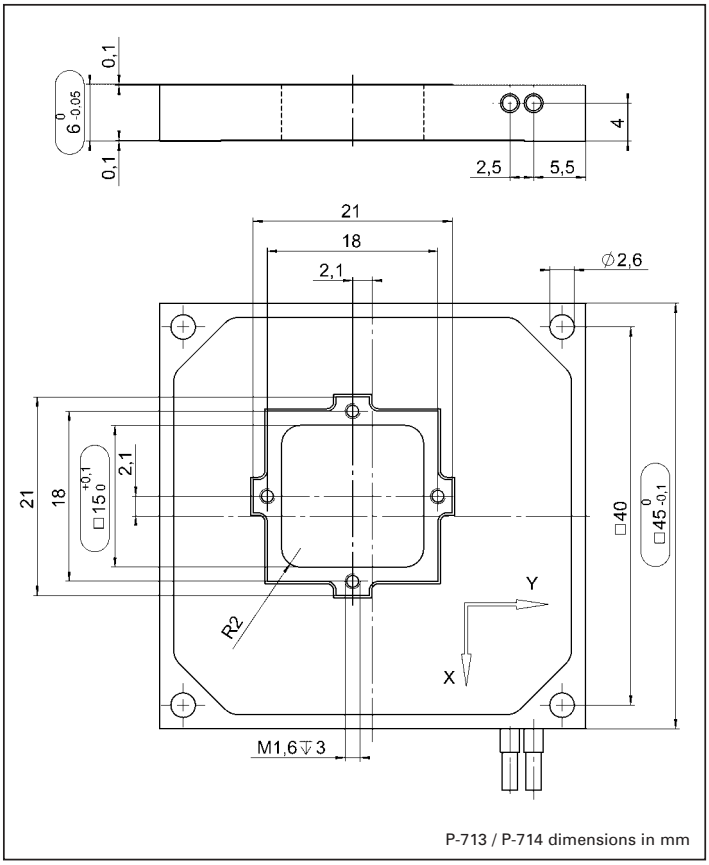
- Interlacing, image resolution enhancement
- Quality assurance
- Optical metrology
- Microscopy
- Imaging
- CCD camera technology

Flexibility

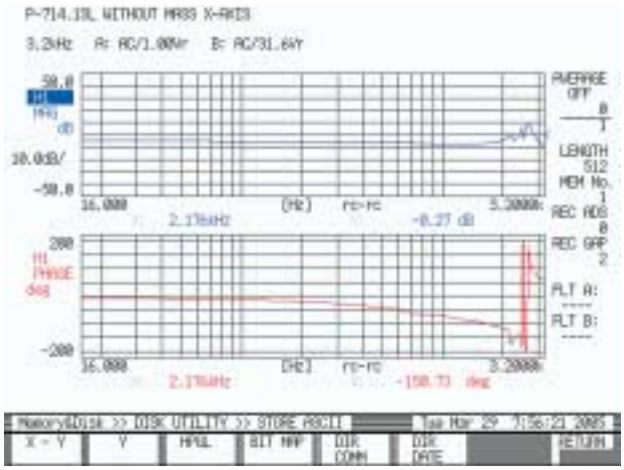
P-713 and P-714 nanopositioners are offered in different versions for different applications. The lowest-cost, basic version of the P-713 offers guiding accuracy in the motion plane of 50 µrad, a value generally good enough for interlacing tasks in scanning patterns of a few microns. For more demanding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

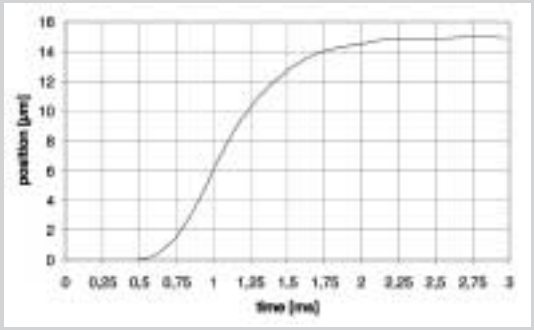
Reliability is assured by the use of award-winning PICMA® mul-



P-713 / P-714 dimensions in mm



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

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Technical Data

Model	P-713.20L	P-714.20L	P-714.2SL	Units	Notes (see p. 18)
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 capacity	1.5 / axis	1.5 / axis	1.5 / axis	µF ±20%	F1
Dynamical 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 with 20 g load	1310	1310	1310	Hz ±20%	G2
Resonant frequency with 50 g load	1020	1020	1020		
Resonant frequency with 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. 17)	A, G	A, G	D, H		

* Dynamic Operating Current Coefficient in µA per hertz and µm.
** Resolution of piezo nanopositioners is not limited by friction or stiction. Noise equivalent motion with E-503 amplifier.

P-611.1 · P-611.2

Compact X and XY Piezo-NanoPositioners


X and XY nanopositioning systems, 100 µm travel range, 1 nm resolution

- **100 µm Travel Range**
- **Small Footprint: 44 x 44 mm**
- **Resolution 1 nm**
- **PICMA® High-Performance Piezo Actuators**
- **Low Cost**

P-611s are piezo-based nanopositioning systems featuring a compact footprint of only 44 x 44 mm. The X- and XY-versions described here are ideally suited for planar positioning tasks such as optical-path length correction in interferometry, sample positioning in microscopy or scanning applications. Both versions are available with 100 µm travel range. Equipped with piezo drives and zero-stiction, zero-friction flexure guiding system, the series provides nanometer-range resolution and millisecond response time.

Application Examples

- Micromaching
- Sample positioning (microscopy)
- Micromanipulation (life sciences)
- Semiconductor test systems

Flexibility

The P-611 family is very flexible because of the variety of single- and multi-axis versions (X, XY, Z, XZ and XYZ) and because all versions can be easily combined with a variety of micropositioning systems to form hybrid systems with longer travel ranges (see catalog P-611.3S).

Open- and Closed-Loop Models

Open- and closed-loop versions are available to suit your application. The open-loop models are ideal for applications where fast response and very high resolution are essential, but absolute positioning is not important. They can also be used when the position is controlled by an external linear position sensor such as an interferometer; a PSD, quad cell; CCD chip / image processing system, or the eyes and hands of an operator.

The closed-loop versions are equipped with high-resolution strain gauge sensors mounted on the flexure guiding system for optimum position stability and responsiveness. The sensors are operated in a full bridge circuit and provide position information with nanometer resolution to the servo-controller.

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 have ceramic-only insulation 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.

Ordering Information

P-611.10
Nanopositioning System 100 µm, SGS Sensor

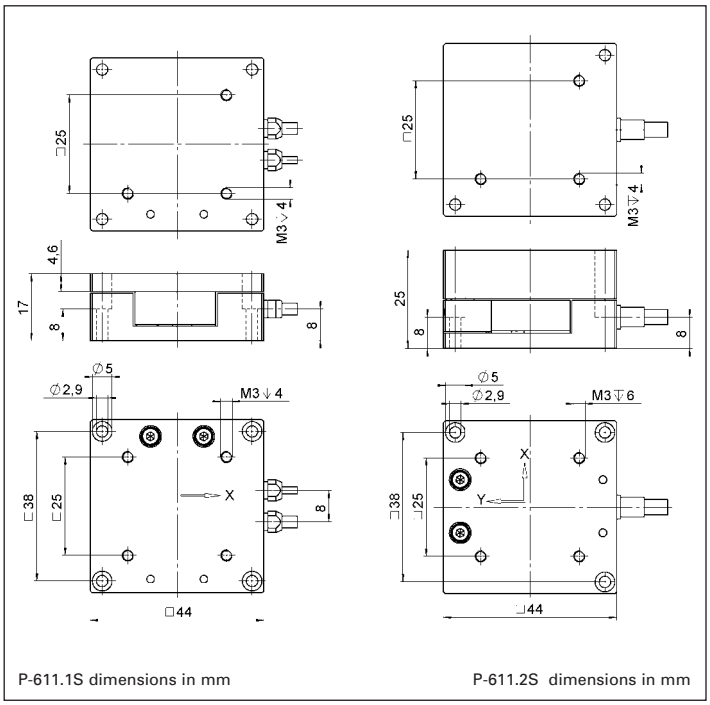
P-611.1S
Nanopositioning System 100 µm, Open-Loop

P-611.20 XY
Nanopositioning System 100 x 100 µm, SGS Sensor

P-611.2S XY
Nanopositioning System 100 x 100 µm, Open-Loop

Z and XZ Versions see p. 14
NanoCube® XYZ Version see Catalog P-611.3S

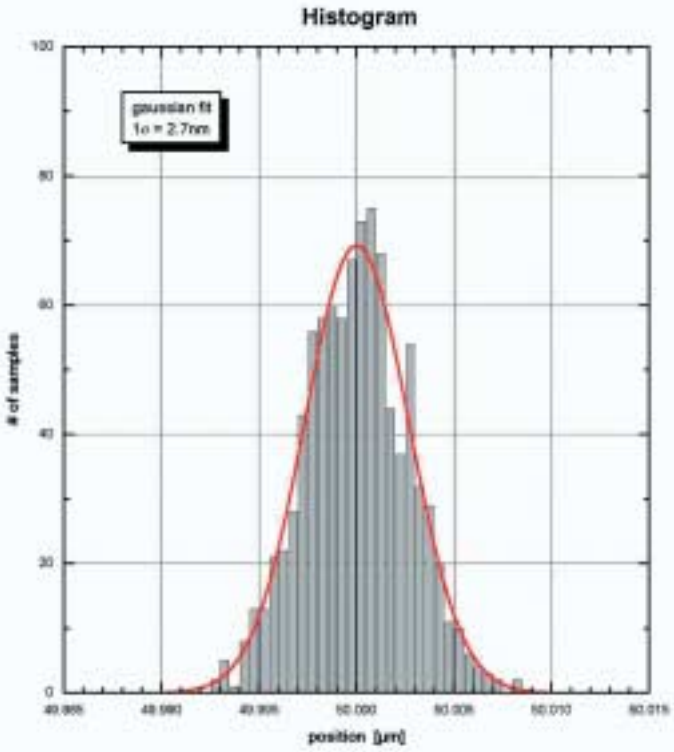
Ask about custom designs.



P-611.1S dimensions in mm

P-611.2S dimensions in mm


The P-611 family



The P-611.1S shows a repeatability of 2.6 nm.

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Technical Data

Model	P-611.1S	P-611.10	P-611.2S	P-611.20	Unit	Notes (see p. 18)
Active axis	X	X	X, Y	X, Y		
Open-loop travel @ -20 to 120 V	120	120	120 / axis	120 / axis	µm ±20%	A2
Closed-loop travel	100	-	100 / axis	-	µm	A5
Integrated feedback sensor	SGS	-	SGS	-		B
Closed-/open-loop resolution**	2 / 0.2	- / 0.2	2 / 0.2	- / 0.2	nm	C1
Closed-loop linearity (typ.)	0.1	0.1	0.1	0.1	%	
Repeatability	<10		<10		nm	
Stiffness	0.3	0.3	0.3	0.3	N/µm ±20%	D1
Max. normal load	+1.5 / -0.5	+1.5 / -0.5	+1.5 / -0.5	+1.5 / -0.5	kg	D4
Electrical capacity	1.5	1.5	1.5 / axis	1.5 / axis	µF ±20%	F1
Dynamical operating current coefficient (DOCC)*	1.7	1.7	1.7 / axis	1.7 / axis	µA/(Hz x µm)	F2
Unloaded resonant frequency (X/Z)	400	400	345 / 270	345 / 270	Hz ±20%	G2
Resonant frequency with 30 g load	300	300	270 / 225	270 / 225	Hz ±20%	
Resonant frequency with 100 g load	195	195	180 / 165	180 / 165	Hz ±20%	
Operating temperature range	-20 to 80	-20 to 80	-20 to 80	-20 to 80	°C	H2
Voltage connection	VL	VL	VL	VL		J1
Sensor connection	L	-	L	-		J2
Weight (with cable)	135	135	235	235	g ±5%	
Body material	S/Al	S/Al	S/Al	S/Al		L
Recommended amplifier / controller (codes explained p. 17)	D, H	A, G	D, H	A, G		

* Dynamic Operating Current Coefficient in µA per hertz and µm. Example: Sinusoidal scan of 50 µm at 10 Hz requires approximately 0.8 mA drive current.
** Resolution of PZT Nanopositioners is not limited by friction or stiction. Noise equivalent motion with E-503 amplifier.

P-611.ZS · P-611.XZS

Compact Z and XZ Piezo-NanoPositioners

Z and XZ nanopositioning system, 100 µm travel range, 1 nm resolution

- **100 µm Travel Range**
- **Small Footprint: 44 x 44 mm**
- **Resolution 1 nm**
- **PICMA® High-Performance Piezo Actuators**
- **Low Cost**

P-611s are piezo-based nanopositioning systems featuring a compact footprint of only 44 x 44 mm. The Z- and XZ-versions described here are ideally suited for use in applications like microscopy, auto-focusing and photonics packaging. Both versions are available with 100 µm travel range. Equipped with piezo drives and zero-stiction, zero-friction flexure guiding system, the series provides nanometer-range resolution and millisecond response time.

Flexibility

The P-611 family is very flexible because of the variety of single- and multi-axis versions (X, XY, Z, XZ and XYZ) and because all versions can be easily combined with a variety of micropositioning systems to form hybrid systems with longer travel ranges (see catalog P-611.3S).

Application Examples

- Photonics packaging & fiber optics (see also P-611.3SF, p. 800500)
- Micromachining
- Micromanipulation (life sciences)
- Semiconductor test systems

Open- and Closed-Loop Models

Open- and closed-loop versions are available to suit your application. The open-loop models are ideal for applications where fast response and very high resolution are essential, but absolute positioning is not important. They can also be used when the position is controlled by an external linear position sensor such as an interferometer; a PSD, quad cell; CCD chip / image processing system, or the eyes and hands of an operator.

The closed-loop versions are equipped with high-resolution strain gauge sensors mounted on the flexure guiding system for optimum position stability and responsiveness. The sensors are operated in a full bridge circuit and provide position information with nanometer resolution to the servo-controller.

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 have ceramic-only insulation 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.

Ordering Information

P-611.ZS
Z Nanopositioning System
100 x 100 µm, SGS Sensor

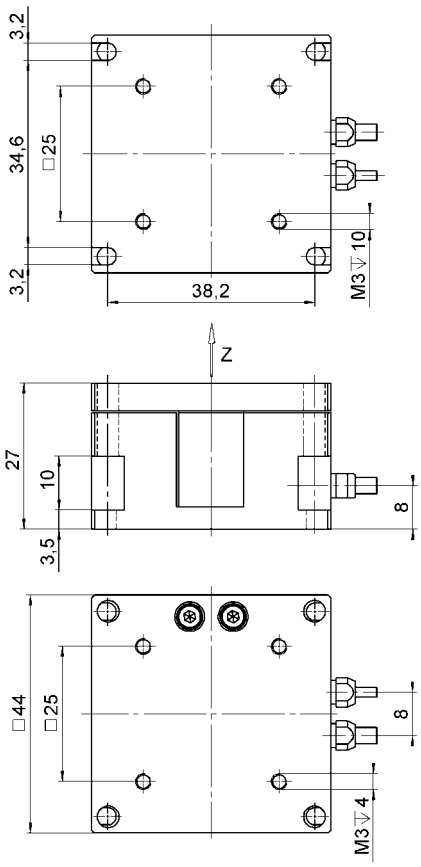
P-611.Z0
Z Nanopositioning System
100 x 100 µm, Open-Loop

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

P-611.XZ0
XZ Nanopositioning System
100 x 100 µm, Open-Loop

X and XY Versions see p. 12
NanoCube® XYZ Version see Catalog P-611.3S

Ask about custom designs



P-611.ZS dimensions in mm

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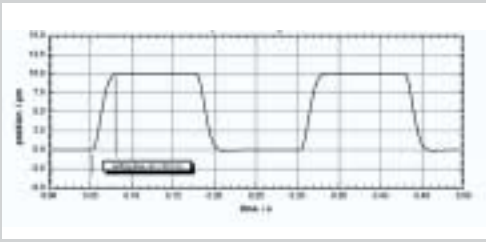
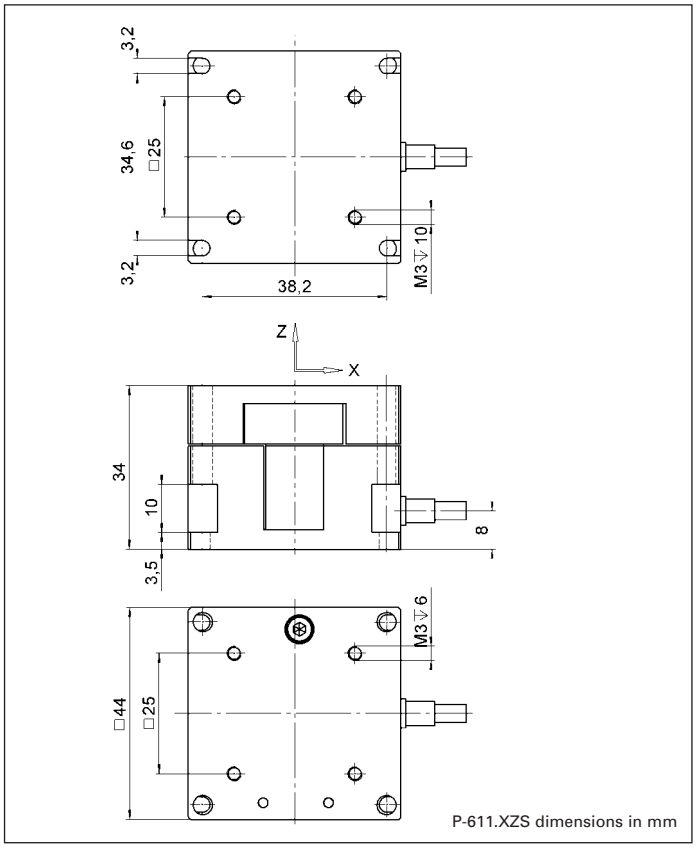
The P-611 family



The settling time of a P-611.Z with a load of 30 g is 26 ms.



P-611.XZS dimensions in mm

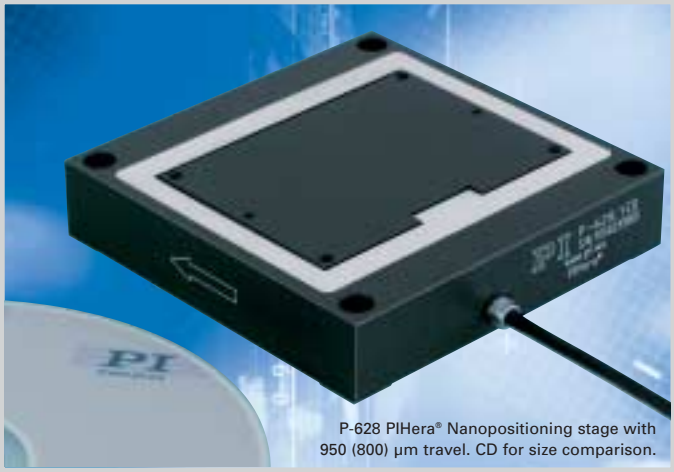
Technical Data

Model	P-611.ZS	P-611. Z0	P-611.XZS	P-611.XZ0	Unit	Notes (see p. 18)
Active axis	Z	Z	X, Z	X, Z		
Open-loop travel @ -20 to 120 V	120	120	120 / axis	120 / axis	µm ±20%	A2
Closed-loop travel	100	-	100 / axis	-	µm	A5
Integrated feedback sensor	SGS	-	SGS	-		B
Closed-/open-loop resolution**	2 / 0.2	- / 0.2	2 / 0.2	- / 0.2	nm	C1
Repeatability	<10	-	<10	-	nm	
Closed-Loop linearity (typ.)	0.1	-	0.1	-	%	
Stiffness	0.45	0.45	0.21 / 0.35	0.21 / 0.35	N/µm ±20%	D1
Max. normal load	+1.5 / -0.5	+1.5 / -0.5	+1.5 / -0.5	+1.5 / -0.5	kg	D4
Electrical capacity	1.5	1.5	1.5 / axis	1,5 / axis	µF ±20%	F1
Dynamical operating current coefficient (DOCC)*	1.7	1.7	1.7 / axis	1.7 / axis	µA/(Hz x µm)	F2
Unloaded resonant frequency (X/Z)	460	460	365 / 340	365 / 340	Hz ±20%	G2
Resonant frequency with 30 g load	370	370	280 / 295	280 / 295	Hz ±20%	
Resonant frequency with 100 g load	265	265	185 / 230	185 / 230	Hz ±20%	
Operating temperature range	-20 to 80	-20 to 80	-20 to 80	-20 to 80	°C	H2
Voltage connection	VL	VL	VL	VL		J1
Sensor connection	L	-	L	-		J2
Weight (with cable)	176	176	270	270	g ±5%	
Body material	S / Al	S / Al	S / Al	S / Al		L
Recommended amplifier / controller (codes explained p. 17)	D, H	A, G	D, H	A, G		

* Dynamic Operating Current Coefficient in µA per hertz and µm. Example: Sinusoidal scan of 50 µm at 10 Hz requires approximately 0.8 mA drive current.
** Resolution of PZT NanoPositioners is not limited by friction and stiction. Noise equivalent motion with E-503 amplifier.

P-628.1

PIHera® Compact 950 µm Piezo Nano-Translation Stage with Direct Metrology



P-628 PIHera® Nanopositioning stage with 950 (800) µm travel. CD for size comparison.

- **Travel 950 µm (Open-Loop), 800 µm (Closed-Loop)**
- **Compact Design**
- **Resolution < 1 nm**
- **PICMA® Longlife Piezo Drive**
- **Direct Metrology with Capacitive Sensors for Highest Precision**
- **0.03 % Position Accuracy**

P-628.1 PIHera® systems are piezo nano-translation stages featuring exceptionally long travel ranges to 950 µm. Despite the increased travel ranges the units are extremely compact, while providing sub-nanometer resolution. The long travel range is achieved with a newly designed, friction-free and extremely stiff flexure system which also offers excellent guiding accuracy and rapid settling.

Superior Accuracy Through Direct-Motion-Metrology Capacitive Feedback Sensors

Applications such as optical path control in interferometry, or sample positioning in microscopy require long travel ranges with nanometer positioning accuracy. PIHera® offers travel ranges to 950 µm. The closed-loop versions are equipped with non contact, zero friction, direct-measuring two-plate capacitve position sensors. Unlike conventional indirect sensors (such as strain gauge / piezo resistive sensors), they measure the position directly rather than the strain in the actuator / guiding system.

Capacitive sensors are absolute-measuring high-bandwidth devices and show none of the periodic errors found in incremental encoders. This permits motion linearity of better than 0.03 % and effective resolution in the sub-nanometer range. This technique, combined with the inherent precision of the PI two-plate capacitive sensor and the temperature-compensated design, results in higher linearity scans, and provides superior responsiveness, resolution, repeatability and stability.

Dynamic Digital Control for Best Scanning Linearity

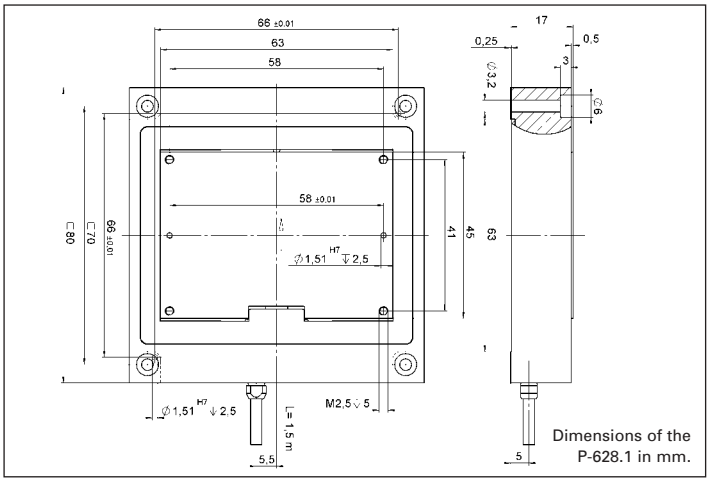
Use our new digital control electronics with the dynamic digital control option for the highest linearity in scanning applications (see catalog E-710). These systems virtually eliminate tracking errors and permit use of the entire travel range with high dynamic accuracy in the nanometer range.

Ordering Information

P-628.1CD
PIHera® Piezo-Nanopositioning System, 800 µm, Capacitive Sensors, Sub-D Connector

P-628.1CL
PIHera® Piezo-Nanopositioning System, 800 µm, Capacitive Sensors, LEMO Connectors

P-628.10L
PIHera® Piezo-Nanopositioning System, 950 µm, Open-Loop, LEMO Connector



Dimensions of the P-628.1 in mm.

Technical Data

Model	P-628.1CD/P-628.1CL	Units
Active axes	X	
Closed-loop travel	800	µm
Min. open-loop travel -20 to 120 V	950	mm
Integrated feedback sensor	capacitive	
Open-loop resolution*	0.5	nm
Closed-loop resolution*	1.8	nm
Closed-loop linearity (typ.)	0.03	%
Push/pull force capacity (in X)	10 / 8	N
Max. Load	10	N
Lateral force limit	10	N
Tilt θ_X, θ_Y (typ.)	6	µrad
Electrical capacitance	18.6	µF ±20%
Unloaded resonant frequency	125	Hz ±20%
Resonant frequency @ 20 g load	115	Hz ±20%
Resonant frequency @ 120 g load	90	Hz ±20%
Operating temperature range	-40 to 120	°C
Voltage and sensor connection	D**	
Weight (with cables)	375	g ±5%
Body material	Al	
Recommended controller (codes explained p. 17)	F, M, L, H	

* Resolution of PI Piezo NanoPositioners is not limited by friction or stiction. Noise equivalent motion with E-710 controller.
** P-628.1CL version with LEMO connectors.

Recommended Amplifier/Controller Reference List

The list below is referred to by technical data tables of the these sections of this catalog: "Piezo Actuators", "Nanopositioning & Scanning Systems", "Active Optics / Steering Mirrors" and "Hexapods / Micropositioning".
For most PI PZT Actuators and PZT Nano-Positioning systems more than one amplifier/controller combination is available. The best choice depends on the application and personal preference. A low-level dynamic application does not require a high-power amplifier. In OEM applications, there may not be enough space for rackmount amplifiers/controllers. The information below is a general guide; please refer to the technical data for each amplifier/controller for details, and call your local PI representative if you need further assistance.

A: Quasi-Static Applications:

* E-660.00 (bench-top) or
* E-660.OE (OEM module)

B: Low-Power Applications:

E-463 (3-channel bench-top amplifier)

B: Quasi-Static Applications:

* E-461.00 (bench-top) or E-461.OE* (OEM module)

C: E-610.00* OEM amplifie module

D: E-610.S0* OEM amplifier/controller module or E-662.SR* bench-top amplifier/controller

E: E-610.L0* OEM amplifier/controller module or E-662.LR* bench-top amplifier/controller

F: E-610.C0* OEM amplifier/controller module

G: Low- & Medium-Power Applications:

E-500 (E-501) chassis + E-503 (three-channel amp.) + optional. E-515/E-516 display/interface. Alternatively, E-663 (3-channel bench-top amplifier)

G: High-Power Applications:

E-500 chassis + E-505* (1-channel amp.) + optional E-515/E-516 display/interface

H: Low- & Medium-Power Applications:

E-500 (E-501) chassis + E-503 (3-channel amp.) + E-509.ab controller (a: sensor type; b: # axis (see E-509 description) + optional E-515/E-516 display/interface

H: High-Power Applications:

E-500 chassis + E-505 (1-channel amp.) + E-509.ab controller (a: sensor type; b: # axes, see E-509 description) + optional E-515/E-516 display/interface

I: Low- & Medium-Power Applications:

E-500 chassis + * E-507 (1 channel amp.) + optional E-515/E-516 display/interface.

I: High-Power Applications:

E-420 (OEM amplifier module) or E-470 (bench-top amplifier) or E-472 (2-channel, 19" rack).

J: Low- & Medium-Level Dynamic Applications:

E-500 chassis + * E-507 (1-channel amp.) + E-509.ab (a: sensor type; b: # axis (see E-509 description) + optional E-515/E-516 display/interface

J: High-Level Dynamic Applications:

E-471 + E-509.a1 (a: sensor type, see E-509 description) + optional E-515/E-516 display/interface

K:

E-710.3CD digital controller. Sub-D special connector for operation voltage and sensors.

L:

E-710.4CL digital controller. LEMO connectors for operating voltage and sensors. (See E-710 description for details).

L:

E-501.10/E-612.C0 or E-661.CP high-speed parallel port NanoAutomation® controller. (See E-612.C0 description for details).

M:

E-750.CP digital controller. special sub-D connector for operating voltage and sensor signal. (See E-750 description for details).

N:

E-760 NanoCube™ controller card. (See E-760 description for details).

N:

E-764.00 NanoCube™ controller. (See E-664.00 descruption for details).

* Depending on the number of axes (channels) to be driven, more than one module may be required.

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Notes (Technical Data)

A2 Open-loop travel @ 0 to 100 V

Typical open-loop travel at 0 to 100 V operating voltage. Max. operating voltage range is -20 to +120 V (extremes for short durations only). For details see p. 4-40 in the "Tutorial: Piezoelectrics in Positioning" section.

A4 Open-loop travel @ 0 to -1000 V

Typical open-loop travel at 0 to -1000 V operating voltage. Voltages in excess of -750 V should not be applied for long durations. Operation in the range of +200 to -750 V is recommended for maximum lifetime and displacement. For details see p. 4-40 in the "Tutorial: Piezoelectrics in Positioning" section.

A5 Closed-loop travel

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

B Integrated feedback sensor

Absolute measuring capacitive and LVDT (inductive) sensors are used to provide position information to the controller. For details see page 4-21 in the "Tutorial: Piezoelectrics in Positioning" section.

C0 Open-loop resolution

Resolution of piezo flexure stages is basically infinitesimal because it is not limited by stiction and friction. Instead of resolution, the noise equivalent motion is specified. Values are typical results (RMS, 1s), measured with E-507 amplifier module in E-500/501 chassis.

C1 Closed-loop /open-loop resolution

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

C3 Full-range repeatability (typ.)

Typical values in closed-loop mode. Repeatability is a percentage of the total angle traveled. For small ranges, repeatability is significantly better.

D1 Stiffness

Static large-signal stiffness of the stage in operating direction at room temperature. Small-signal stiffness and dynamic stiffness may differ because of effects caused by the active nature of piezo material, compound effects, etc. Further details see "Tutorial: Piezoelectrics in Positioning" section, page 4-23.

D3 Push/pull force capacity (in operating direction)

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

Example:
the dynamic forces generated by sinusoidal operation at 500 Hz, 20 µm peak-to-peak, 1 kg moved mass, are approximately ±100 N. Further details see page 4-27 in the "Tutorial: Piezoelectrics in Positioning" section.

D4 Max. (+/-) normal load

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

D5 Lateral force limit

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

D6 Torque limit ($\theta_X/\theta_Y/\theta_Z$)

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

E1 Tip/Tilt (typ.)

Typical rotational off-axis error.

E2 Lateral runout (X/Y/Z)

Linear off-axis error.

F1 Electrical capacitance

The PZT capacitance values indicated in the technical data tables are small-signal values (measured at 1 V, 1000 Hz, 20°C, no load) large-signal values at room temperature are 30 to 50% higher. The capacitance of PZT ceramics changes with amplitude, temperature, and load, up to 200% of the unloaded, small-signal capacitance at room temperature. For detailed information on power requirements, refer to the amplifier frequency-response graphs in the "PZT Control Electronics" section of this catalog.

F2 Dynamic Operating Current Coefficient (DOCC)

Average electrical current (supplied by the amplifier)

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required to drive a piezo actuator per unit frequency and unit displacement (sine-wave operation). E.g. to find out if a selected amplifier can drive a given piezo stage at 50 Hz with 30 µm amplitude, multiply DOC coefficient by 50 3 30 and check if the result is smaller or equal to the output current of the selected amplifier. For details see p. 4-31ff. in the "Tutorial: Piezoelectrics in Positioning" section.

G2 Unloaded resonant frequency

Lowest resonant frequency in operating direction (does not specify the maximum operating frequency). For details see p. 4-28 in the "Tutorial: Piezoelectrics in Positioning" section.

G3 Resonant frequency with xx g load

Resonant frequency of the loaded system.

H2 Operating temperature range

Standard range, other temperature ranges on request. Closed-Loop Systems are calibrated for optimum performance at room temperature. Recalibration is recommended if operation is at a significantly higher or lower temperature.

J1 Voltage connection

Standard operating voltage connectors are LEMO-type connectors.

VL (Voltage Low): LEMO FFA.00.250, male. Cable: coaxial, RG 178, Teflon coated, 1m
VH (Voltage High): LEMO FFA.0A.250, male. Cable: coaxial, RG 174, PVC coa ed, 1m.
D: Sub-D special connector
ID: Sub-D special connector for digital controllers with AutoCalibration function

For extension cables and adapters, see "Accessories" on p. 6-43 *ff.,* in the "PZT Control Electronics" section.

J2 Sensor connection

Standard sensor connectors are LEMO-type connectors.

C: LEMO FFA.00.250, female. Cable: coaxial, Teflon coated, 1m.
L: LEMO FFA.0S.304, Cable: PUR coated, 1m.
D: Sub-D special connector
ID: Sub-D special connector for digital controllers with AutoCalibration function

For extension cables and adapters, see "Accessories" on p. 6-43 *ff.,* in the "PZT Control Electronics" section.

L Body material

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

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

M-824

Compact 6-Axis Parallel Kinematic Robot

M-824 Six DOF micropositioning system, vacuum version

- **Six Degrees of Freedom**
- **Vacuum Compatible Versions**
- **Load Capacity 10 kg**
- **Travel Ranges to 45 mm (linear), 25° (rotation)**
- **7 nm Resolution**
- **300 nm Min. Incremental Motion**
- **Repeatability ±0.5 µm**
- **Very Compact Design**
- **Self Locking to 10 kg**

The new M-824 is based on PI´s experience of more than a decade with parallel kinematics Hexapods like the M-850 / M-840 and F-206 (see catalog). The M-824 is the ideal micropositioning system for all complex positioning tasks which depend upon high accuracy and resolution in six independent axes. In addition to positioning all axes it allows the user to define the center of rotation (pivot point) anywhere inside or outside the system envelope by one simple software command.The vacuum version, the M-824.3VG, enables use in applications such as X-ray diffraction microscopy with ambient pressures down to 10^{-6} hPa.

Application Examples

- Micromachining
- Micromanipulation
- Life sciences
- X-ray diffraction measurements
- Semiconductor handling systems
- Tool control for precision machining & manufacturing

Extremely Compact

The M-824 uses a very compact drive and, with a height of 188 mm, has a considerably lower profile than either the M-850 or M-840 Hexapods. The unit can be mounted in any orientation, and can position loads of up to 10 kg.

Hexapod vs Serial Kinematics Systems

The M-824 is based on 6 actuators with a high resolution of 0.007 µm, all connected directly to the same moving platform. The principle is similar to that seen in flight simulators, but considerably more precise. In place of the hydraulic actuators used there, the M-824 uses highly accurate micrometer screws and servo-motors.

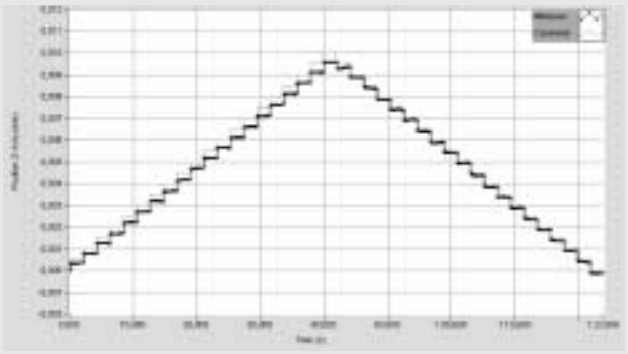
The low mass of the moving platform permits positioning with significantly shorter settling times compared to those obtainable in conventional, stacked, multi-axis systems (serial kinematics).

Ordering Information

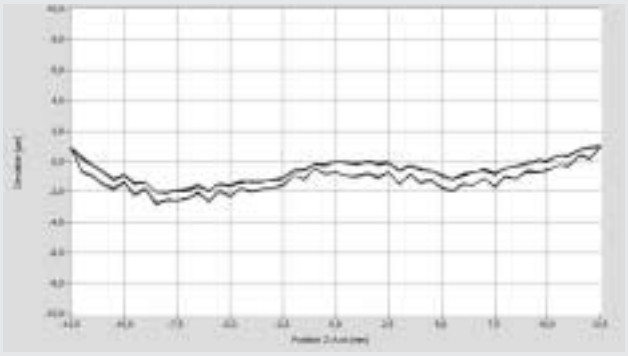
M-824.3DG
Hexapod 6-Axis Parallel Kinematics Robot with Controller.

M-824.3VG
Hexapod 6-Axis Parallel Kinematics Robot with Controller, Vacuum Version down to 10^{-6} hPa.

In serial kinematics systems wobble and guiding errors in the bearings of each axis accumulate. Friction and torque caused by moving cables further limit accuracy and repeatability. The parallel kinematics Hexapods are not affected by these ills because all actuators operate directly on the same platform. A further advantage is that the rotation axes do not have their centers of rotation determined by the hardware.



The interferometer test shows the highly repeatable minimum incremental motion of 500 nm.



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

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Plug-and-Play

The M-824 is a true plug-and-play system and comes with a powerful 6D controller. Its sophisticated, user-friendly positioning and alignment software can save hundreds of hours of the programming time required to achieve similar functionality with a conventional, stacked, 6-axis system.

Freely Definable Pivot Point

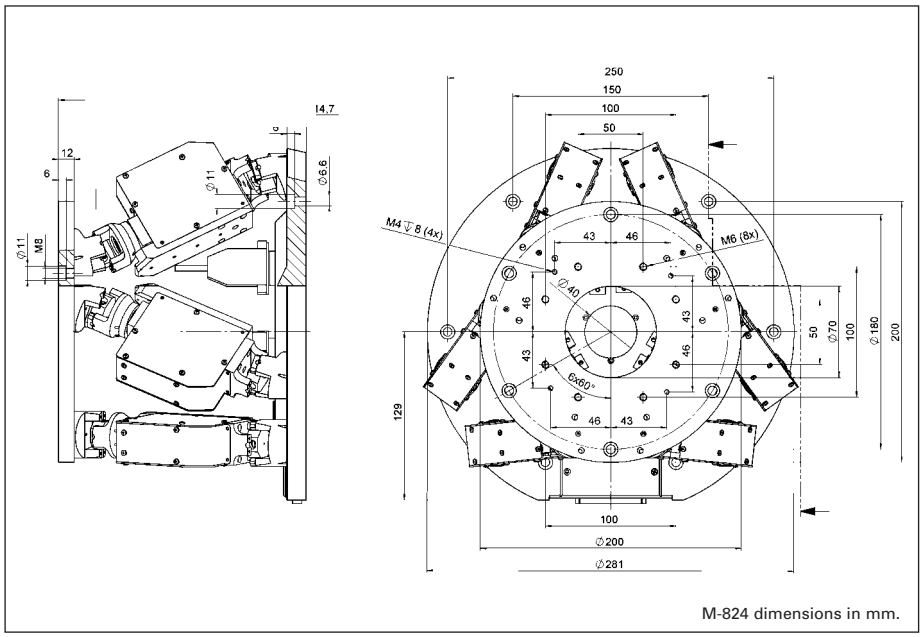
For optics and other alignment tasks, it is important to be able to define a fixed pivot point. The sophisticated Hexapod controller allows choosing any point in space as the pivot point for the rotation axes.
Target positions in 6-space are entered in user-friendly coordinates and reached by smooth vectorized motion.

Open Interface Architecture

Control of the M-824 is facilitated by the controller's open interface architecture, which provides a variety of high-level commands and includes a macro language for programming and storing command sequences.

Vacuum Version

The M-824.3VG is available in a vacuum-compatible model suitable for operation down to to 10^{-6} hPa.



M-824 dimensions in mm.

Technical Data

Model	M-824.3DG	Unit
Travel X, Y**	±22.5	mm
Travel Z**	±12.5	mm
Travel θ_X, θ_Y**	±7.5	°
Travel θ_Z**	±12.5	°
Actuator stroke	±12.5	mm
Actuator design resolution	0.007	µm
* Min. incremental motion X, Y	0.3	µm
* Min. incremental motion Z	0.3	µm
* Min. incremental motion θ_X, θ_Y, θ_Z	3.5	µrad*
Repeatability X, Y	±0.5	µm*
Repeatability Z	±0.5	µm
Repeatability θ_X, θ_Y, θ_Z	±6	µrad
Typ. velocity X, Y, Z	0.5	mm / s
Typ. velocity θ_X, θ_Y, θ_Z	0.35	°/s
Max. velocity X, Y, Z	1	mm / s
Max. velocity θ_X, θ_Y, θ_Z	0.7	°/s
Stiffness (k_X, k_Y)	1.7	N / µm
Stiffness (k_Z)	7	N / µm
Load capacity (vertical mounting)	10***	kg
Weight	7.8	kg

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

* Simultaneous motion of all 6 actuators! No moving cables (as in serial-kinematics stacked systems) to introduce bending sources, torque and friction, which degrade positioning accuracy.
** The travel ranges of the individual coordinates (X, Y, Z, θ_X, θ_Y, θ_Z) are interdependent. The data for each axis in this table shows its maximum travel, where all other axes are at their zero positions. If the other linear or rotational coordinates are not zero, the available travel may be less.
*** Self locking

M-403

High-Resolution Translation Stages with Stepper and DC Motor Drives


M-403.4PD translation stage

- **Resolution <0.02 µm**
- **Min. Incremental Motion 0.2 µm**
- **Travel Range to 100 mm**
- **Stress-Relieved Aluminum Base for Highest Stability**
- **Zero-Backlash Recirculating Ballscrews**
- **Low-Cost System**

The optimum choice of high-value, low-cost components makes the M-403 linear stage very attractive and economical. The stage is lead-screw-driven and provides a minimum incremental motion of 0.2 µm. It is designed with a precision-machined, high-density, stress-relieved aluminum base for exceptional stability and minimum weight.

High Load and Maintenance Free

All models of the M-403 are equipped with high-precision linear guiding rails and recirculating ball bearings. Their high load capacity allows them to carry up to 20 kg. The recirculating ball bearings are maintenance free and immune to the cage migration which can plague crossed roller bearings.

Three Motor Drives

The top-of-the-line M-403.4PD features the high-performance ActiveDrive™ system. This design, developed by PI, has a high-efficiency PWM servo-amplifier mounted side by side with the DC motor and offers several advantages:

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

The M-403.4DG is equipped with a DC motor with zero-backlash gearhead and a shaft-mounted optical encoder, providing a minimum incremental motion of 0.5 µm.

The M-403.42S features a direct-drive, 2-phase stepper motor with zero vibration, providing a resolution of 0.2 µm steps.

Application Examples

- Qualitiy control
- Semiconductor test equipment
- Metrology
- Data storage test
- Research & development

Ordering Information

M-403.4PD
Linear Translation Stage, 80 mm wide, 100 mm Travel range, ActiveDrive™

M-403.4DG
Linear Translation Stage, 80 mm wide, 100 mm Travel range, DC motor

M-403.42S
Linear Translation Stage, 80 mm wide, 100 mm Travel range, stepper motor


M-403 family of translation stages: (from left) M-403.4PD, M-403.4DG and M-403.42S

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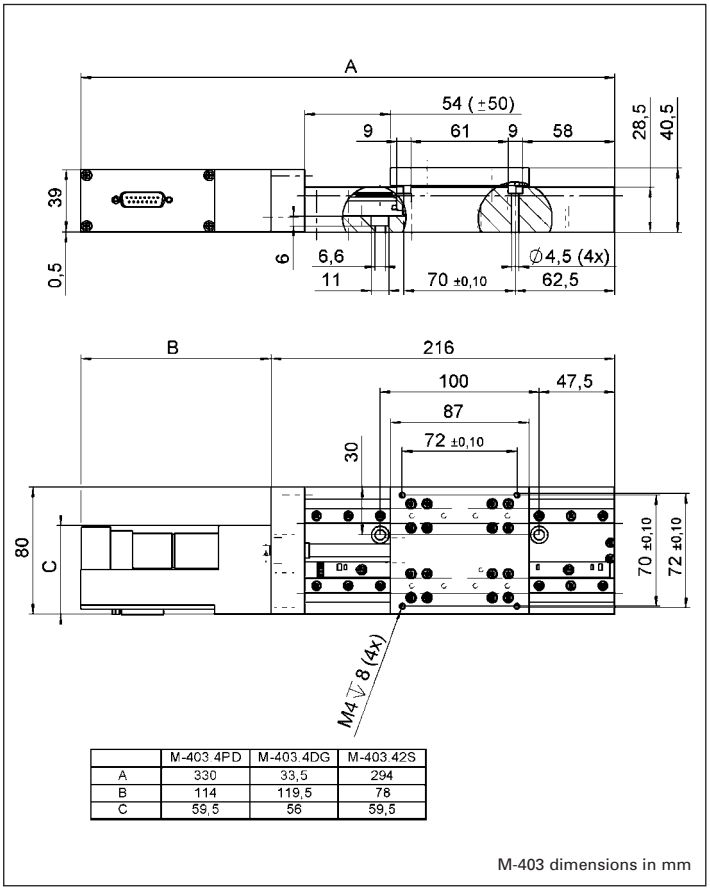


	M-403.4PD	M-403.4DG	M-403.42S
A	330	33,5	294
B	114	119,5	78
C	59,5	56	59,5

M-403 dimensions in mm

Technical Data

Model	M-403.4PD	M-403.4DG	M-403.42S	Units	Notes (see p. 24)
Travel range	100	100	100	mm	
Design resolution	0.25	0.0175	0.1	µm	A3
Min. incremental motion	0.75	0.5	0.2	µm	A4
Backlash	1	6	2	µm	
Unidir. repeatability	1	1	1	µm	
Pitch (θ_Y)	200	200	200	µrad	
Yaw (θ_Z)	200	200	200	µrad	
Axial stiffness	3500	3500	3500	N/mm	
Max. velocity	10*	2.5	3	mm/sec.	
Max. normal load capacity	200	200	200	N	B1
Max. push/pull force	50	50	50	N	B2
Max. lateral force	200	200	200	N	
Encoder resolution	4000	2000	-	counts/rev.	
Motor resolution	-	-	10,000**	steps/rev.	
Lead screw pitch	1	1	1	mm/rev.	
Gear ratio	-	28.444	-		
Operating temperatur	-20 bis +65	-20 bis +65	-20 bis +65	°C	
Nominal motor power	26	2.5	-	W	
Motor voltage range	24***	0-12	24**	V	
Weight	2	2	2	kg	
Body material	Al	Al	Al		
Recommended motor controller (codes explained p. 18)	C-862	C-862	C-630		

* Max. recommanded velocity
** 2-phase stepper, 24 V chopper voltage, max. 0.8 A / phase, 10,000 microsteps with C-600 / C-630 controller.
*** ActiveDrive™ (integrated PWM servo-amplifier), required external 24 V power supply included.

Notes (Technical Data)

A3 Design Resolution

The theoretical minimum movement that can be made, based on the selection of the mechanical drive components (drive screw pitch, gear ratio, angular motor resolution etc.). Design resolution is usually better than the practical position resolution (minimum incremental motion). The resolution of piezo actuators and PZT flexure NanoPositioners is not limited by stiction and friction (it depends on amplifier, sensor and servo noise. The practical resolution of most PI PZT NanoPositioning systems is in the sub-nanometer range.

A4 Minimum Incremental Motion

The minimum motion that can be repeatably executed for a given input, which is sometimes referred to as practical or operational resolution. Design resolution and practical resolution have to be distinguished. Design resolutions of 1 nm or better can be achieved with many motor, gearbox and leadscrew combinations. In practical applications, however, stiction/friction, windup, and elastic deformation limit operating resolution.

Repeatable nanometer or subnanometer resolution can be provided by solid-state actuators (PZTs) and PZT flexure stages (see the "PZT Flexure NanoPositioners" and "PZT Actuators" sections for details). Several PI MicroPositioners are available with additional PZT fine positioners for applications where repeatable nanometer scale resolution is required. The resolution of PZT actuators is not limited by stiction and friction.

A5 Rotation / Linear Input, Tangent-Arm Length

Angular displacement of Tangent-Arm Rotation Stages is determined by the arm length and the linear motion input pushing the arm (see page 7-49 for information on how to calculate angular displacement from linear input).

B1 Max. Normal Load Capacity

Centered, vertical load (horizontal installation).

B2 Max. Push/Pull Force

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

D1 PZT Drive

See the "PZT Actuators" section for details.

D2 Recommended Motor Controller

See "Motor Controllers" section.

L Body Material

Stages are usually made of anodized aluminum or stainless steel. Small amounts of other materials can be used internally (for bearings, preload, coupling, mounting, etc.).

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

Advantages of PILine® Linear Piezo Motor Drives

P-661 OEM drive with electronics and different-friction bars (compact disc for size comparison).

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

The driving force is taken from the energy in the longitudinal oscillation component. The transverse component serves to increase/decrease the pressure of the friction tip against the friction bar. The transverse oscillation energy determines the maximum frictional force and hence the holding and driving force of the motor.

PILine® drives have no gears, spindles or other mechanical parts which could cause backlash or hysteresis.

- Compact Size: The direct-drive principle allows the design of ultra-compact translation stages, with travel/ size ratios close to 1. The M-661.4P0, for example, provides 20 mm travel in a 25 x 25 x 8 mm^3 package.

- Low Inertia: High Acceleration, Speed and Resolution: PILine® drives achieve Velocities to 800 mm/s and accelerations to 20 g. They are also very stiff, a prerequisite for their fast step-and-settle times—on the order of a few milliseconds—and provide resolution to 0.05 µm. The lack of a leadscrew means no lubricant flow and material relaxation to cause submicron creep. There is also no rotational inertia to limit acceleration and deceleration.

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

- Safe: PILine® drives do not require limit switches. Even if driven into the hard stop, the motor and stage will not be damaged. The minimum inertia of the moving platform together with the "slip clutch" effect of the friction drive, give excellent protection against damage.

- Precision fixtures and devices are much safer than with leadscrew-driven stages. PILine® drives are also "finger-safe": Despite the high speeds and accelerations, there is no risk of pinching or worse. This means users do not need interlocks, light curtains or other measures to keep them safe.

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

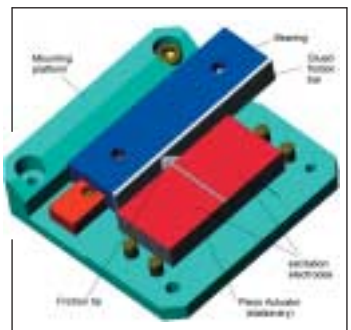
- Vacuum Compatible: PILine® drives are 100% ceramic and can be used in a vacuum without performance loss.

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

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

- Quality, Lifetime, Experience: Based on PI's 30+ years of experience with piezo nanopositioning technology, PILine® drives offer exceptional precision and reliability with an MTBF of >20,000 hours. Components such as gears, shafts and moving cables that are prone to failure in conventional motion systems, are simply not part on the PiLine® design.

Ultrasonic Piezo Drives—How do they work?



Principle design of a PI piezo linear motor driven translation stage.

PI linear ultrasonic drives consist of a piezoelectric oscillator made from a rectangular piezoelectric plate upon which are mounted one, two or more frictional elements. Due to electrical excitation of the actuator, each friction tip installed on it moves along an elliptical trajectory, transmitting pushing forces to a friction bar on the moving portion of the translation stage.

The pushing force exerted by the actuator comes basically from the energy of the longitudinal wave, i.e. in the actuator shown, the longitudinal wave is the pushing wave. The transversal oscillation energy in the actuator is used basically for switching the longitudinal motion at regular intervals by pressing the frictional elements against the frictional trunk. The transversal oscillation force regulates the maximal available frictional force between friction tip or tips and the frictional trunk on the moved element, i.e. the transversal oscillation has an engage/disengage function.

P-661

PILine® High-Speed, Small OEM Piezo Linear Motors

P-661 OEM piezo linear motor incl. C-180 drive electronics.

- **Smallest High Speed Linear Motor**
- **Patented Principle with High Holding Forces**
- **Velocity to 800 mm/s**
- **Acceleration to 20g**
- **Self-Locking**
- **20,000 h MTBF**

PILine® Linear Motors-Smaller, Faster, More Effective

Despite their small size, PILine® P-661 linear motor drives generate higher driving and holding forces than conventional piezomotors.

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

Application Examples

- Biotechnology
- Micromanipulation
- Microscopy
- Quality Control
- Semiconductor Test Equipment
- Metrology
- Mass Storage Testing
- R&D
- Photonics Packaging

High Speed and Acceleration, Self-Locking

PILine® piezomotor drives can provide accelerations of up to 20 g and speeds of up to 800 mm/s, together with high resolution and high holding force. Because the ceramic stator is pressed against the slider, holding forces are generated when the motor is at rest The result is very high position stability without the heat dissipation common in conventional linear motors.

Integration

These drives can be operated in any orientation. For best performance, both the drive housing and the friction bar must the mounted on flat surfaces. The environment must be kept clean, dry and free of dust.

Accessories

PILine® motors require a drive electronics for exciting the ultrasonic oscillations. The way of how to control this drive electronics either by analog or pulsed signals strongly depends on the electronics. Therefore the drive electronics is not include in the delivery and can be ordered separately.

Pulsed-Mode Operation: C-180, C-181, C-170

Pulsed operation is especially suited for applications requiring small steps or rapid end-to-end motion, as in microscopy, automation or similar applications. The motor can be controlled with 5 V TTL pulses connected to the signal input on the drive electronics. The width of the pulses will determine the approximate length of the steps the motor makes. The smallest possible step is about 50 nm, requiring a pulse of about 10 µs in duration. The pulse rate and width can beu sed to influence the step size and rate, thus determining the velocity. A flexible, programmable pulse generator with integrated C-181 driver is available as the C-170.161.

Analog Driver: C-184, C-185

The C-184 (OEM board) or C-185 (stand-alone) analog driver controls the motor speed as a function of a ±10 V analog input. With an external position sensor and a controller, it is thus possible to set up a very fast, closed-loop system. The M-663 stage with integrated linear encoder (see p. 10-8) can also be run with this driver.

Long Lifetime

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

Ordering Information

P-661.P00
PILine® Miniature Linear Piezo Motor, 2N

Accessories

P-661.B01
Friction Bar for P-661 PILine® Piezo Linear Motor, 15 mm

P-661.B02
Friction Bar for P-661 PILine® Piezo Linear Motor, 25 mm

P-661.B05
Friction Bar for P-661 PILine® Piezo Linear Motor, 55 mm

C-180.161
Pulse-Mode OEM Drive Electronics for PILine® P-661 Piezo Linear Motors

C-181.161
Pulse-Mode Drive Electronics for PILine® P-661 Piezo Linear Motors or Translation Stages with P-661 Motors; with Power Supply

C-184.161
Analog OEM Drive Electronics for PILine® P-661 Piezo Linear Motors

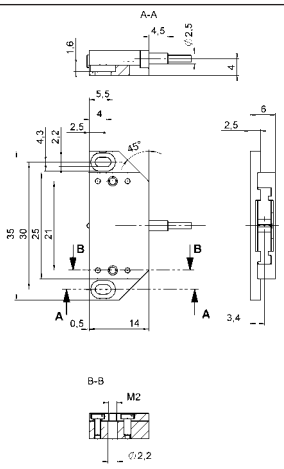
C-185.161
Analog Drive Electronics for PILine® P-661 Piezo Linear Motors or Translation Stages with P-661 Motors; with Power Supply

C-170.161
RedStone Open-Loop Piezomotor Controller/Driver, 1 Channel, for PILine® Systems with P-661 Motors

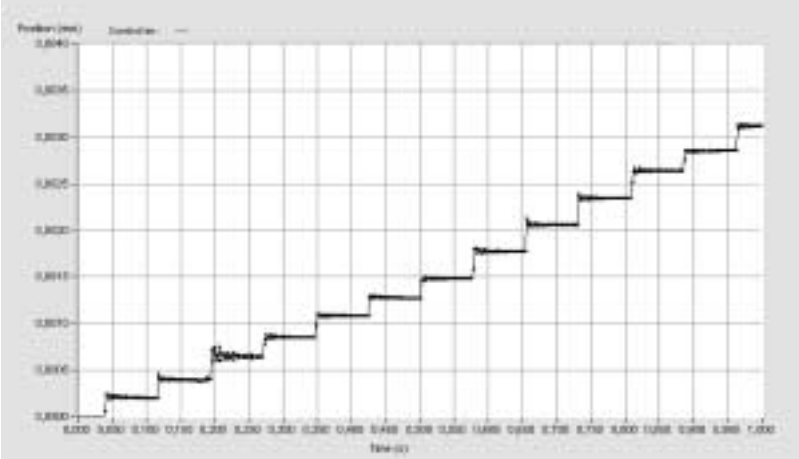
C-170.261
RedStone Open-Loop Piezomotor Controller/Driver, 2 Channels, for PILine® Systems with P-661 Motors

Note

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

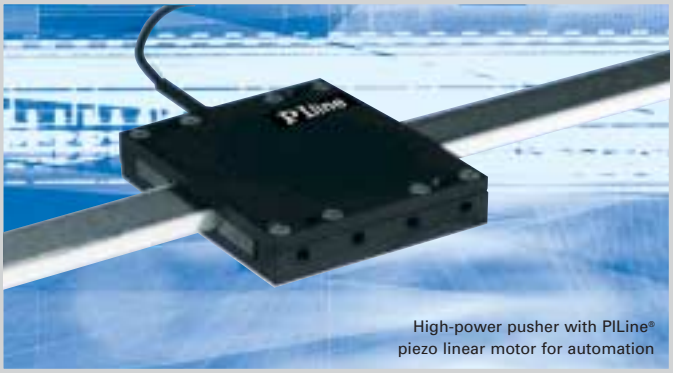


P-661 dimensions in mm



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

The P-661 OEM piezo linear motor is used for the M-661 linear stage (front right). The C-180 OEM-board drive electronics (left) is also available as C-181 version in a box (background)



High-power pusher with PILine® piezo linear motor for automation

Technical Data

Model	P-661	Units	Notes s. p. 10-16
Travel range *	unlimited		
Min. incremental motion**	0.1	µm	
Max. speed	800	mm/s	
Max. push/pull force	1	N	B2
Max. holding force	2	N	
Weight	10	g	
Operating voltage (drive elec.)	12	V	
Operating current	0.5	A	

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

** The minimum incremental motion is a typical value that can 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.

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M-661 · M-662

PILine® Miniature Translation Stages with Ultrasonic Piezo Linear Motors

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

- **Smallest Translation Stage with High-Speed Linear Motor Drive**
- **Velocity to 500 mm/s**
- **Acceleration to 20 g**
- **Resolution to 50 nm**
- **20 mm Travel Range**
- **Self-Locking**
- **XY-Combinations Available**
- **20,000 h MTBF**
- **Vacuum Versions to 10^{-7} hPa**

PILine® – Ultimate Motion in the Smallest Package

PILine® M-661- and M-662-series micropositioning systems are the smallest high-speed piezo-motor-driven translation stages currently available on the market.

Application Examples

- Biotechnology
- Micromanipulation
- Microscopy
- Quality Control
- Semiconductor Test Equipment
- Shutters
- High-Speed-Scanning
- R&D
- Photonics Packaging

Working Principle

M-661 and M-662 stages have a new, patented, ultrasonic drive developed by PI. The highly compact, integrated P-661 piezomotor drive can provide accelerations of up to 20 g and velocities of 500 mm/s and more, together with high resolution and holding force. Because the ceramic stator is pressed against a slider of the stage, piezomotors resist motion with an intrinsic holding force when the stage is 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.

M-661 / M-662 Fast and Compact

Both models are operated without position feedback, where they can achieve speeds of up to 500 mm/s. The square footprint of the M-662.470 makes it suitable for XY-configurations, while the M-661.370, which is even smaller, is designed for single-axis systems.

Drive Electronics for Open-Loop Operation

Two different driver electronics solutions are available for PILine® open-loop stages and OEM motors. They can either be operated by a simple pulsed-mode driver (C-181), or by a more sophisticated version which allows controlling the speed with an analog signal in the ±10 V range (C-185).

C-181, C-170 – Pulsed Mode Operation

Pulsed operation is especially suited for applications requiring small steps or rapid end-to-end motion, as in microscopy, automation or similar applications.

The motor can be controlled with 5 V TTL pulses connected to the signal input on the driver electronics. The width of the pulses will determine the approximate length of the steps the motor makes. The smallest possible step is about 50 nm, requiring a pulse of about 10 µs in duration. The pulse rate and width can be used to influence the step size and rate, thus determining the velocity.

Ordering Information

M-661.370
PILine® Ultra-Compact Translation Stage with P-661 Piezo Linear Motor Drive, 18 mm Travel

M-662.470
PILine® Ultra-Compact Translation Stage with P-661 Piezo Linear Motor Drive, 20 mm Travel

M-662.4V0
Vacuum-compatible version of the M-662.470

C-181.161
Pulse-Mode Drive Electronics for PILine® P-661 Piezo Linear Motors or Translation Stages with P-661 Motors; with Power Supply

C-185.161
Analog Drive Electronics for PILine® P-661 Piezo Linear Motors or Translation Stages with P-661 Motors; with Power Supply

C-170.161
RedStone Open-Loop Piezomotor Controller/Driver, 1 Channel, for PILine® Systems with P-661 Motors

C-170.261
RedStone Open-Loop Piezomotor Controller/Driver, 1 Channel, for PILine® Systems with P-664 Motors

A flexible, programmable pulse generator with integrated C-181 driver is available as C-170.161.

C-185 Analog Driver

The C-185 analog driver controls the motor speed as a function of a ±10 V analog input. With an external position sensor and a controller, it is thus possible to set up a very fast, closed-loop system. The M-663 stage with integrated linear encoder (see p. 10-8) can also be run with this driver.

Accessories

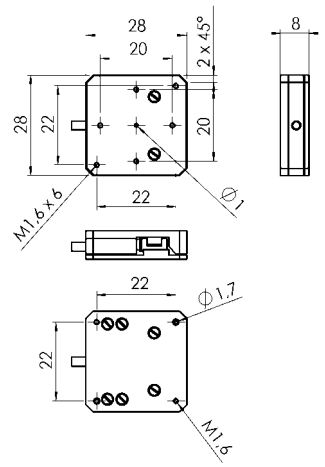
For the operation of PILine® stages and piezo linear motors, a drive electronics is required. The driver is necessary to create the ultrasonic oscillations of the piezoceramic actuator of the motor. The choice of the drive electronics depends on

the application and the motion controller used and is therefore not part of delivery of a PILine® stage or motor. The unit with the drive electronics, however, must be ordered at the same time as the stage, so that they can be tuned for optimum performance with each other.

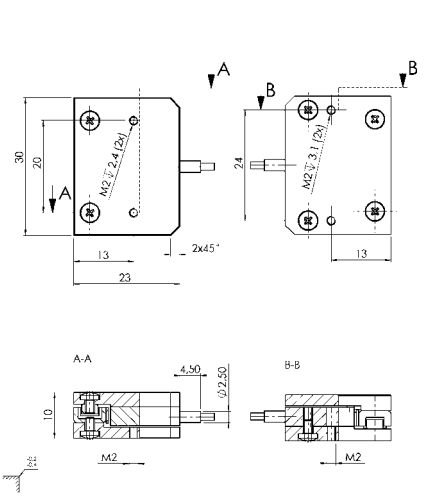
Notes

For more information on the advantages of PILine® systems, see page 10-3.

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

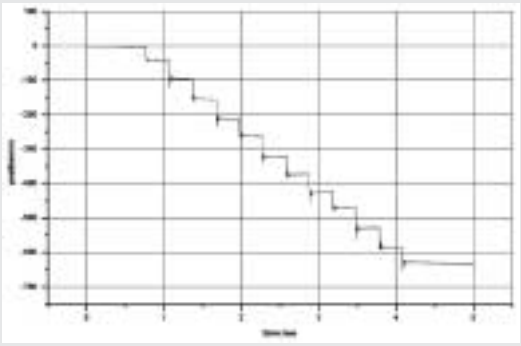


M-662.470 dimensions in mm; decimal places separated by commas.



M-661.370 dimensions in mm

In place of the bench-top electronics, the C-181.161 OEM board (left rear) can be used with M-661 /P-661 ultra-compact piezo linear motors.



50 nm steps created with a system consisting of C-170.161 RedStone and PILine® M-662.470 open-loop piezo linear motor stage.

Technical Data

Model	M-661.370	M-662.470	Units	Notes
Travel range	18	20	mm	
Design resolution	-	-	µm	A3
Min. incremental motion	0.05	0.05	µm	A4
Bidirectional repeatability	-	-	µm	
Max. velocity	500	500	mm/s	
Max. normal load capacity	5	5	N	B1
Max. push/pull force	1	1	N	B2
Max. holding force	2	2	N	
Operating voltage (drivers)	12	12	V	
Operating voltage (piezo	60	60	V	
Integrated piezomotor	P-661	P-661		
Operating current	<500	<500	mA	
Weight	0.03	0.03	kg	
Dimensions (L x W x H)	30 x 23 x 10	28 x 28 x 8	mm	
Body material	Aluminum	Aluminum		L
MTBF	>20,000	>20,000		
Recommended driver	C-181.161 (TTL); C-170.161 (TTL); C-185.161 (analog)	C-181.161 (TTL); C-170.161 (TTL); C-185.161 (analog)		

M-663

PILine® Miniature Translation Stages with Closed-Loop Ultrasonic Piezo Linear Motors

M-663 with C-865 controller/driver.

- **Smallest Translation Stage with Linear Motor Drive and Linear Encoder**
- **Velocity up to 500 mm/s**
- **Accelerations up to 20 g**
- **Resolution to 0.1 µm**
- **Integrated Direct-Metrology Linear Encoder**
- **20 mm Travel Range**
- **AutoLock Feature**
- **XY Combinations Available**
- **20,000 h MTBF**
- **Vacuum Versions Available**

PILine® – Ultimate Motion in the Smallest Package

PILine® M-663 micropositioning systems are the smallest piezo-motor-driven translation stages with linear encoders currently available on the market.

Application Examples

- Biotechnology
- Micromanipulation
- Microscopy
- Quality Control
- Semiconductor Test Equipment
- Metrology
- Mass Storage Testing
- R&D
- Photonics Packaging

Working Principle

M-663 stages have a new, patented, ultrasonic drive developed by PI. The highly compact, integrated P-661 piezomotor drive can provide accelerations of up to 20 g and velocities of up to 500 mm/s, together with high resolution and holding force. Because the ceramic stator is pressed against a slider in the stage, piezomotors resist motion with an intrinsic holding force when the stage is 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.

Direct-Motion Metrology with 0.1 µm Resolution

M-663 stages are equipped with high-resolution, direct-measuring optical linear encoders. Two different models are available: The M-663.465 for operation with PI's C-865 controller (see page 10-14) and the M-663.485 for operation with conventional servo-controllers.

M-663.465 with C-865.161: Optimized for High Velocity and Fast Settling

The M-663.465 is designed for operation with the C-865.161 piezomotor controller. That specialized controller achieves speeds of up to 500 mm/s with very short settling times, and has integrated drive electronics for the M-663.465.

M-663.485 with C-185.161: For Operation with Conventional Servocontroller

The M-663.485 is designed for operation with conventional servo-controllers from different manufacturers such as GALIL, NI or DeltaTau, which also provide special options for piezo linear motors. This requires the C-185.161 external drive electronics which accepts a ±10 V analog signal from the controller. Please request more information from the corresponding supplier. With non-PI controllers, however, the maximum closed-loop velocity is limited to 400 mm/s because the encoder bandwidth of the M-663.485 is limited at 12 MHz.

Accessories

For the operation of PILine® stages and piezo linear motors, a special drive electronics is – either integrated in the C-865 controller or separate – required. The driver is necessary to create the ultrasonic oscillations of the piezoceramic actuator of the motor. The choice of the drive electronics depends on the application and the motion controller used and is therefore not part of delivery of a PILine® stage or motor. The unit with the drive electronics, however, must be ordered at the same time as the stage, so that they can be tuned for optimum performance with each other.

Ordering Information

M-663.465
PILine® Micropositioning Stage with P-661 Piezo Linear Motor, 20 mm Travel, 0.1 µm Linear Encoder, for C-865.161 Controller/Driver

M-663.485
PILine® Micropositioning Stage with P-661 Piezo Linear Motor, 20 mm Travel, 0.1 µm Linear Encoder, for C-185.161 Drive Electronics

Accessories

C-865.161
Piezomotor Controller with Drive Electronics, 1 Axis, for PILine® Systems with P-661 Motors

C-185.161
Analog Drive Electronics for PILine® P-661 Piezo Linear Motors or Translation Stages with P-661 Motors; with Power Supply

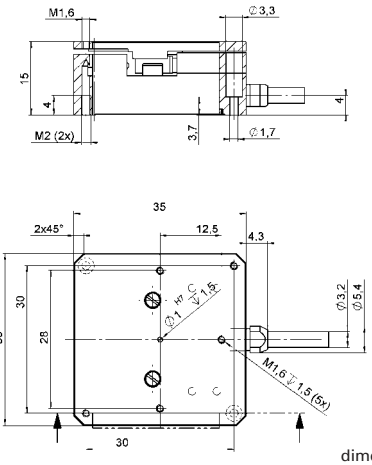
Ask about custom designs!

Notes

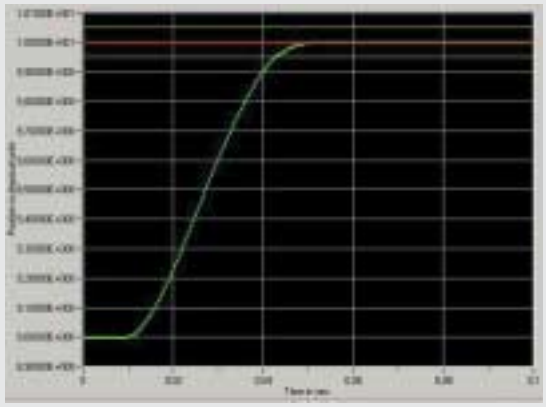
For more information on the advantages of PILine® systems, see page 10-3.

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

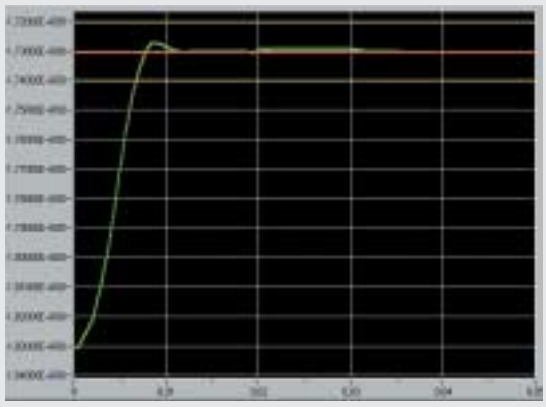
XY combination of two M-663s (one is a special version with side cable entry). CD for size comparison.



M-663
dimensions in mm;
decimal places separated by commas.



A 1 mm step performed by an M-663.465 stage with 300 g load controlled by a C-865 Controller/Driver reaches the end position in less than 40 ms.



An M-663.465 with 100 g load settles to 0.1 µm accuracy in 10 ms after a 100 µm step, measured with C-865 Controller/Driver.

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Technical Data

Model	M-663.465	M-663.485	Units	Notes, see page 10-16
Travel range	20	20	mm	
Design resolution	0.1	0.1	µm	A3
Min. incremental motion	0.1	0.1	µm	A4
Bidirectional repeatability	±0.3	±0.3	µm	
Max. speed	500	400*	mm/s	
Max. load	5	5	N	B1
Max. push/pull force	1	1	N	B2
Max. holding force	2	2	N	
Operating voltage (drive electronics)	12	12	V	
Operating voltage (piezo)	60	60	V	
Integrated piezomotor	P-661	P-661		
Operating current	<500	<500	mA	
Weight	0.05	0.05	kg	
Dimensions (L x W x H)	35 x 35 x 15	35 x 35 x 15	mm	
Body material	Al	Al		L
MTBF	>20,000	>20,000	mm	
Recommended controller/driver	C-865	C-185 drive electronics + separate controller**		

* Depends on controller.
** If using an NI controller, we recommend the C-809 Motion Interface (see page 9-22). For GALIL controllers, the C-809.G40 Cable Adapter can be used.

M-665

PILine® Low-Profile Translation Stages with Ultrasonic Piezo Linear Motors

Low-Profile PILine® M-665 piezo linear motor stage with integrated linear encoder.

- **Piezo-Motor-Driven Translation Stage**
- **Low-Profile, only 26.5 mm**
- **Velocity to 400 mm/s**
- **Acceleration to 20 g**
- **0.1 µm Linear Encoder (Direct-Motion Metrology)**
- **50 mm Travel**
- **AutoLock Feature**
- **XY CombinationsAvailable**
- **20,000 h MTBF**
- **Vacuum Versions to 10^{-8} hPa Available**

PILine® – Ultimate Motion in the Smallest Package

PILine® M-665 micropositioning systems are low-profile, high-accuracy piezo-motor-driven translation stages with linear encoders and high-precision guidings.

Application Examples

- Biotechnology
- Micromanipulation
- Microscopy
- Quality Control
- Semiconductor Test Equipment
- Metrology
- Mass Storage Testing
- R&D
- Photonics Packaging

Working Principle

M-665 stages have a new, patented, ultrasonic drive developed by PI. The highly compact, integrated P-665 piezomotor drive can provide accelerations of up to 20 g and velocities of up to 400 mm/s, together with high resolution and holding force. Because the ceramic stator is pressed against a slider in the stage, piezomotors resist motion with an intrinsic holding force when the stage is 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.

Direct-Motion Metrology with 0.1 µm Resolution

M-665 stages are equipped with high-resolution direct-measuring optical linear encoders. Two different models are available: The M-665.265 for operation with PI's C-865 controller (see page 10-14) and the M-665.285 for operation with conventional servo-controllers.

M-665.265 with C-865.165: Optimized for High Velocity and Fast Settling

The M-665.265 is designed for operation with the C-865.161 Piezomotor Controller. That specialized controller achieves speeds of up to 400 mm/s with very short settling times, and has integrated drive electronics for the M-665.265.

M-665.285 with C-185.165: For Operation with Conventional Servo-Controllers

The M-665.285 is designed for operation with conventional servo-controllers. This requires the C-185.165 external drive electronics, which accepts a ±10 V analog signal from the controller for example controllers from different manufacturers such as GALIL, NI or DeltaTau, which also provide special options for piezo linear motors. Please request more information from the corresponding supplier. With non-PI controllers, the maximum closed-loop velocity depends on the design.

Accessories

For the operation of PILine® stages and piezo linear motors, a drive electronics is required. The driver is necessary to create the ultrasonic oscillations of the piezoceramic actuator of the motor. The choice of the drive electronics depends on the application and the motion controller used and is therefore not part of delivery of a PILine® stage or motor. The unit with the drive electronics, however, must be ordered at the same time as the stage, so that they can be tuned for optimum performance with each other.

Ordering Information

M-665.265
PILine® Low-Profile Translation Stage with P-665 Piezo Linear Motor, 50 mm Travel, 0.1 µm Linear Encoder, for C-865.165 Controller/Driver

M-665.26V
Vacuum-Compatible Version of the M-665.265 to 10^{-8} hPa

M-665.285
PILine® Low-Profile Translation Stage with P-665 Piezo Linear Motor, 50 mm Travel, 0.1 µm Linear Encoder, for C-185.165 Drive Electronics

Accessories

C-865.165
Piezomotor Controller with Drive Electronics, 1 Axis, for PILine® Systems with P-665 Motors

C-185.165
Analog Drive Electronics for PILine® P-665 Piezo Linear Motors or Translation Stages with P-665 Motors; with Power Supply

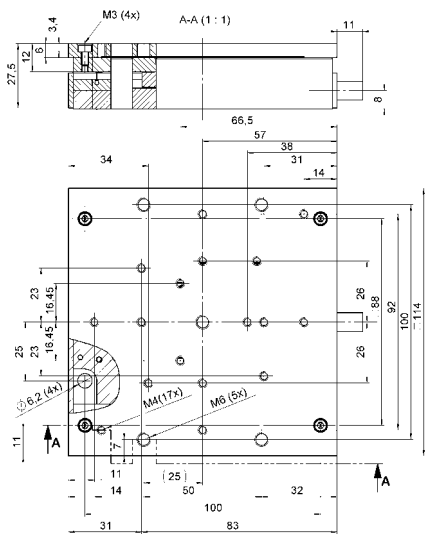
Notes

For more information on the advantages of PILine® systems, see page 10-3.

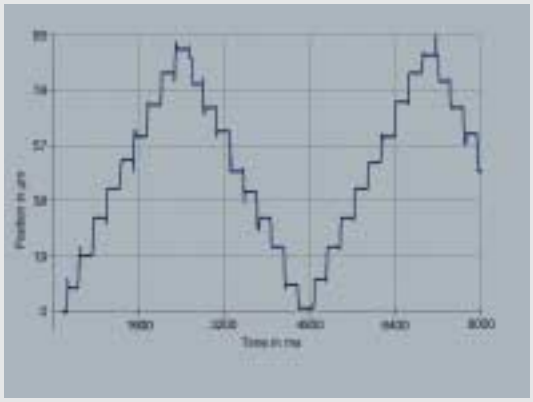
The products described in this datasheet are in part protected by the following patents:
German Patent No. 19945042


M-665 vacuum version, to 10^{-8} hPa.


M-665 with C-865 controller/driver.



M-665 dimensions in mm; decimal places separated by commas.


PILine® Piezo linear motor stage performing 1 µm steps. Piezomotors are self-locking. After a stable position is reached, there is no servo dither as common with other linear motors.

Technical Data

Model	M-665.265	M-665.285	Units	Notes
Travel range	50	50	mm	
Design resolution	0.1	0.1	µm	A3
Min. incremental motion	0.2	0.2	µm	A4
Unidirectional repeatability	±0.3	±0.3	µm	
Pitch θ_X	70	70	µrad	
Yaw θ_Y	70	70	µrad	
Encoder bandwidth	32	12	MHz	
Max. speed	400	400*	mm/s	
Max. load	50	50	N	B1
Max. push/pull force	4	4	N	B2
Max. holding force	5	5	N	
Integrated piezomotor	P-665	P-665		
Operating current	<800	<800	mA	
Weight	0,8	0,8	kg	
Body material	Al	Al		L
Recommended controller/driver + separate servo-controller	C-865.165	C-185.165 drive electronics + separate controller**	D2	

* Depends on controller.
** If using an NI controller, we recommend the C-809 Motion Interface (see p. 9-22). With GALIL controllers, the C-809.G40 cable adapter can be used.

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C-170

RedStone Open-Loop Controller/Driver for PILine® Piezo Linear Motors

C-170 RedStone controller with two M-662.470 micro positioning stages.

- **Drives 2 PILine® Open-Loop Piezo Linear Motor Stages**
- **Integrated Progammable Motion Sequencer and Ultrasonic Driver for 2 Axes (No External Driver Required)**
- **Single 12 VDC Operation**
- **Stand-Alone Functionality**
- **Analog Joystick Option**
- **Network Option for Multi-Axis Applications**
- **Flash Memory for Motion Sequences and Parameters**
- **8 Programmable TTL Input/Output Lines**
- **4 Analog Inputs**
- **Serial Communication**

C-170 RedStone controllers are compact and cost-effective units for the operation of open-loop PILine® piezo linear motors and stages.
They incorporate programmable microsecond timers and ultrasonic drivers to operate one or two motors and/or micropositioning stages under computer control or in an autonomous stand-alone mode.

Application Examples

- Test equipment
- Micro-machining
- Scanning applications
- Life sciences
- Metrology
- Quality control
- Switches, shutters, sorters
- R&D
- Photonics packaging automation
- Fiber optic instrumentation

Integrated Drive Electronics, Optimized for PILine® Stages and Motors

To assure the best possible system performance, the integrated drive electronics is fine-tuned to the connected stage at the factory. Micropositioning systems such as the M-661/M-662 miniature-stages can then achieve speeds of 500 mm/s and more with minimum incremental motion of 50 nm.
The integrated piezomotor driver electronics is also available as a separate product for use with external pulse generators (ordering number C-181).

Driving PILine® Motors in Open-Loop

The distance and velocity traveled corresponds to the width, frequency and number of motor-on pulses. By varying the pulse width, the step length and thus the motor velocity can be controlled. As the mechanical environment also influences the motion, the size of single steps is not highly repeatable. For precise position control, a system with a position feedback device is recommended (closed-loop operation).

In addition to the single step and step sequence operating modes, RedStone controllers provide a high-speed CW mode with acceleration to 20 g and velocities to 500 mm/s and more. The CW mode is practical for applications where fast end-to-end motion is required, such as shutter or switching applications.

Complete Software Package and Macro Command Language

RedStone controllers come with a complete software package, consisting of DLL and LabView™ drivers and turnkey operating software for all Windows™ systems.

The RedStone high-level command language was derived from the successful C-862 Mercury DC-Motor controller. Motion sequences can be stored in non-volatile memory for execution on demand by software commands or external TTL-trigger signals. An autostart macro can be defined to call macro commands at power-up without the need for computer communications.

Ordering Information

C-170.161
RedStone Open-Loop Piezomotor Controller/Driver, 1 Channel, for PILine® Systems with P-661 Motors

C-170.261
RedStone Open-Loop Piezomotor Controller/Driver, 2 Channels, for PILine® Systems with P-661 Motors

C-890.PS
Wide-Range Power Supply

C-862.CN
Network Connecting Cable

C-862.PB3
Software-Accessable Push Button Box

C-819.20
Analog Joystick

Advantages of PILine® Micropositioning Systems

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

- Higher accelerations, up to 20 g
- Velocities up to 500 mm/s and more
- Small form factor
- Self-locking when at rest
- No shafts, gears or other rotating parts

Notes

To reduce the number of components in the system, the piezomotor drive electronics has been integrated in the C-170 controller. The model C-170.161 is optimized for positioners with piezomotors P-661.

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

Piezo Actuators
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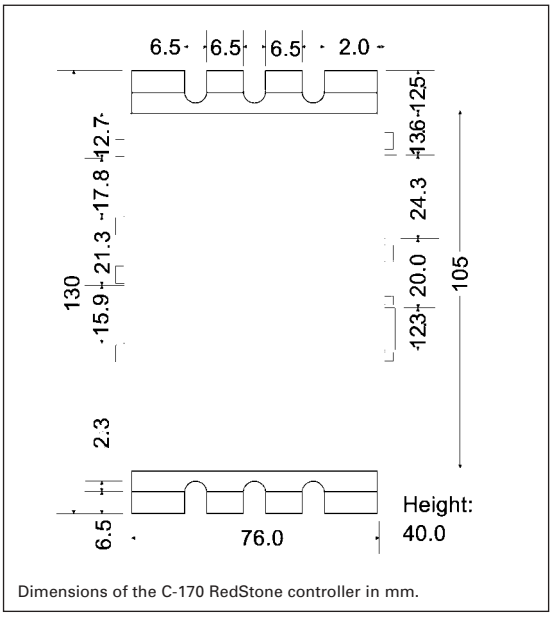
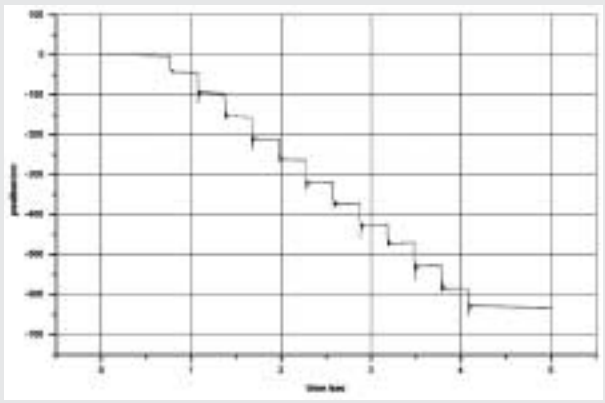


Dimensions of the C-170 RedStone controller in mm.

RedStone operating software allows easy setting of the open-loop motion parameters step size, frequency and number of steps within a move (burst).



50 nm steps created with a system consisting of C-170.161 RedStone and PILine® M-662.470 open-loop piezo linear motor stage.

Technical Data

Model	C-170.1xx; C-170.2xx RedStone
Function	Controller/driver for open-loop PILine® piezo linear motors / stages
Axes	1 (C-170.1xx); 2 (C-170.2xx)
Supply voltage	12 V DC from external power supply (included in delivery)
Power	0.6 W idle, 6 W per channel max.
Interface/communication	RS-232, 9600 baud
Network	Daisy-chain up to 8 units, address setting via dip switch
Analog & digital I/O connector	9-pin socket
Command set	40 high-level ASCII commands; 32 macro commands; 1 autostart macro
Weight	310 g
Size	130 x 76 x 40 mm
Firmware	EEPROM resident
Firmware update	via serial port

C-865

High-Speed Controller/Driver for PILine® Piezo Linear Motors

C-865 with a PILine® M-663 miniature translation stage.

- **Optimized for PILine® Piezo Linear Motors**
- **High-Speed Encoder Input: 35 MHz**
- **PID Servo Algorithm with Dynamic Parameter Switching**
- **Integrated Piezomotor Drive Electronics**
- **S-Curve Profile Generator**
- **Limit Switch Control**
- **3 TTL Inputs, 3 TTL Outputs**
- **Analog Input**
- **Comprehensive High-Level Language Command Set**
- **Extensive Software Support**
- **1 Mbit RAM for Real-Time Tracing**

The C-865 controller was specially designed for the newest generation of PILine® piezo linear motors and stages. This compact unit contains not only servo-control and communications circuitry, but also the drive electronics for the piezoceramic motors.

Application Examples

- Flexible Automation
- Quality Control
- Test Equipment
- Biotechnology
- Photonics
- Fiber Alignment

Specialized PID Servo-Controller

The C-865 uses a highly specialized DSP (Digital Signal Processor) to handle the PID servo-control algorithm, which has a wide range of options for controlling and programming acceleration, velocity or settling as well as other system functions.

Because of the static friction which is typical for piezomotors, the controller has a number of special features, including dynamic parameter switching for an optimized high-speed motion and settling behavior. The high-bandwidth encoder input with a limit frequency of 35 MHz has ample reserves for the high speeds characteristic of piezo linear motors.

Integrated Drive Electronics, Optimized for PILine® Stages and Motors

To assure the best possible system performance, the integrated drive electronics is fine-tuned to the connected stage at the factory. M-663 miniature-stages can then, for example, achieve speeds of to 500 mm/s and more with a resolution of 0.1 µm and settling times of less than 10 ms.

Communication and Programming

Programming the C-865 is simplified by comprehensive software support, including LabView™ drivers and DLLs. All units are equipped with both USB and RS-232 Interfaces for communication with the host PC. Programmers can access the DSP registers directly with low-level commands if they need the highest possible read/write speeds.

Advantages of PILine® Micropositioning Systems

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

- Higher Accelerations, up to 20 g
- Speeds to 500 mm/s and more
- Small Form Factor
- Self-Locking When at Rest
- No Shafts, Gears or Other Rotating Parts

Notes

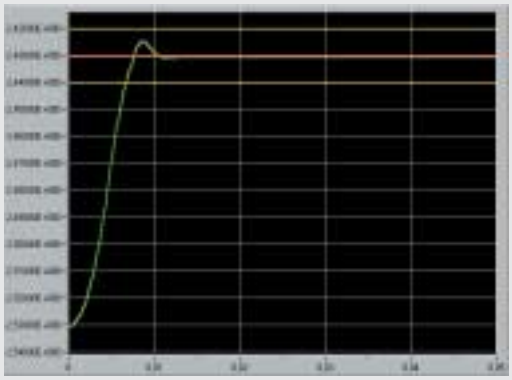
To reduce the number of components in the system, the piezomotor drive electronics has been integrated in the C-865 controller. Models C-865.161 and C-865.165 are optimized for positioners with motors P-661 and the M-665 stage, respectively.

Ordering Information

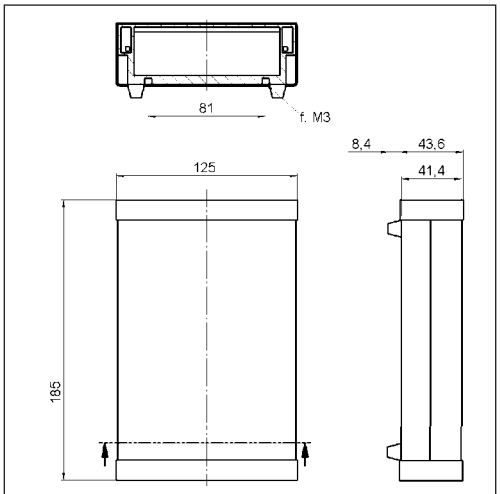
C-865.161
Piezomotor Controller with Drive Electronics, 1 Channel, for PILine® Systems with P-661 Motors

C-865.165
Piezomotor Controller with Drive Electronics, 1 Channel, for PILine® M-665 Translation Stages

The C-865 operating software facilitates optimization and convenient operation of PILine® positioning systems. The results of the parameter setting can immediately be seen in the display as shown in the next graphics.



Settling behavior of a PILine® M-663 linear stage with 100 g load after a 0.1 mm step. With dynamic parameter switching and the high servo rate, the C-865 can reach a stable position to within 0.1 µm (1 encoder count) in only 10 ms. Vertical axis displays motion in mm, horizontal axis time in seconds.



C-865.1 single-axes controller, dimensions in mm (decimal places delimited by commas in drawings).

Technical Data

Model	C-865.1xx
Function	Controller / Driver for PILine® Piezomotor Systems
Axes	1
Controller characteristics	Programmable PID, V-ff filter, on-the-fly parameter change
Trajectory profile	S-Curve
Resolution / Output voltage	16-bit DAC, 0 to 60 Vrms (C-865.x61) or 0 to 170 Vrms (C-865.x65), at piezomotor MDR14 connector
Encoder input	A/B differential signal, 35 x 10^6 Impulse/s, 4 x interpolated
Stall recognition	Stop motor, deactivate servo, when position error exceeds programmable threshhold.
Limit Switch Control	2 programmable TTL lines (active high/low)
Reference switch	1 programmable TTL lines (active high/low)
Operating voltage	12 V DC, external power supply (included)
Operating current	190 mA (w/o piezomotor), current limit 1 A
Interfaces / Communication	USB 1.1; RS-232, max. 115,200 Baud
Analog and digital I/O Connections	DB9 Connector
Command Set	PI General Command Set
Weight	565 g
Dimensions	185 x 125 x 44 mm

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