P-541.2 – P-542.2 Piezo XY-Stage

Low-Profile XY Nanopositioning System with Large Aperture

The P-541/P-542-series nanopositioning stages feature a very low profile of 16.5 mm, a large 80 x 80 mm aperture and deliver highly accurate motion with sub-nanometer resolution. Dimensions and hole pattern are the same for all P-541/P-542 stages

- **Low Profile for Easy Integration: 16.5 mm; 80 x 80 mm Clear Aperture**
- **Up to 200 x 200 µm Travel Range**
- **Parallel-Kinematics / Metrology for Enhanced Responsiveness & Multi-Axis Precision**
- **High-Dynamics Direct-Drive Version**
- **Choice of Sensors: Strain Gauge (Lower Cost) or Capacitive Sensors (Higher Performance)**
- **Outstanding Lifetime Due to PICMA® Piezo Actuators**
- **Combination with Long Travel Microscopy Stages or Longer Stroke**

Low Profile, Optimized for Microscopy Applications

P-541/P-542 nanopositioning and scanning stages are designed for easy integration into high-resolution microscopes. They feature a very low profile of 16.5 mm, a large 80 x 80 mm aperture, and offer highly accurate motion with sub-nanometer resolution.
A variety of Z stages and Z-tip/tilt stages with the same footprint are also offered to suit a wide range of applications (p. 2-44). They are ideal for alignment, nano-focusing or metrology tasks.

Application Examples

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

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

Lever-amplified XY systems with 100 and 200 µm travel and direct-driven XY scanners with 45 µm travel are available. Their high resonant frequencies of 1.5 kHz in both axes allow for faster step response and higher scanning rates, needed for example in single-molecule microscopy, or in other time-critical applications.

Parallel Kinematics for Fast Response

In a parallel kinematics multi-axis system, all actuators act directly on one moving platform. This means that all axes move the same minimized mass and can be designed with identical dynamic properties. Systems with parallel kinematics and metrology have additional advantages over serially stacked or nested systems, including more-compact construction and no cumulative error from the different axes. Parallel kinematics systems can be operated with up to six degrees of freedom with low inertia and excellent dynamic performance. Multi-axis nanopositioning systems equipped with both parallel kinematics and parallel, direct metrology are able to measure platform position in all degrees of freedom against one common fixed reference. In such systems, undesirable motion from one actuator in the direction of another (cross talk) is detected immediately and actively compensated by the servo-loops.

Tailored Position Measurement

Integrated high-resolution position sensors provide fast response and positional stability in the nanometer range. Top-of-the-line models use capacitive sensors. They measure displacement directly and without physical contact (direct metrology) enabling superior linearity. Alternatively, versions with cost-effective strain gauge sensors (SGS) are also available.

Ordering Information

P-541.2DD
XY Nanopositioning System with Large Aperture, High-Speed Direct Drive, 45 x 45 µm, Parallel Kinematics, Capacitive Sensors

P-541.2CD
XY Nanopositioning System with Large Aperture, 100 x 100 µm, Parallel Kinematics, Capacitive Sensors

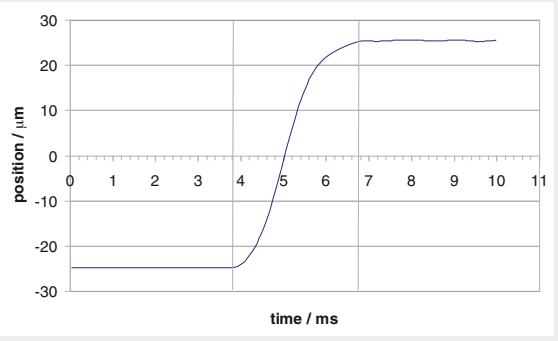
P-542.2CD / P-542.2CL
XY Nanopositioning System with Large Aperture, 200 x 200 µm, Parallel Kinematics, Capacitive Sensors

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

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

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

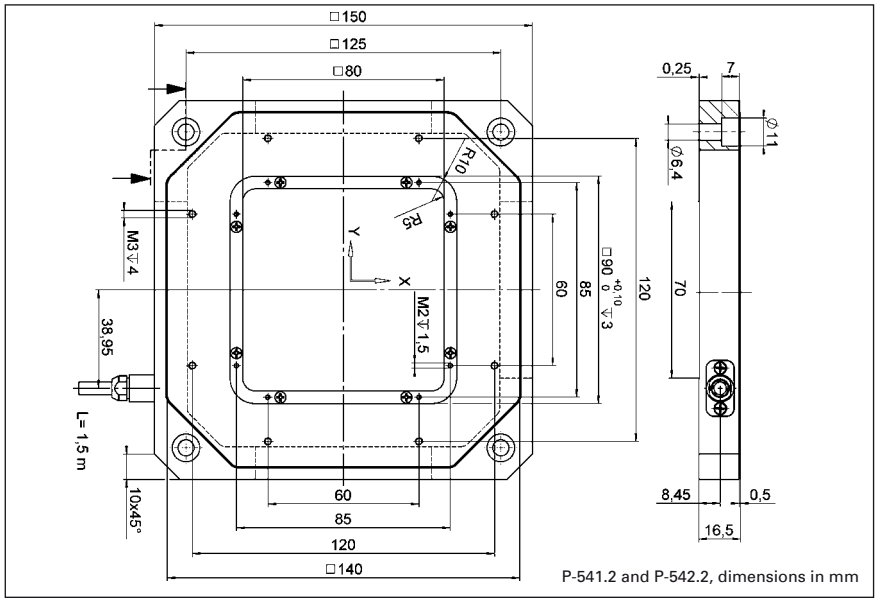
P-542.20L
XY Nanopositioning System with Large Aperture, 200 x 200 µm, Open Loop



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

System properties	
System configuration	P-541.2CD and E-500 modular system with E-503 amplifier and E-509 sensor module, 200 g load
Amplifier bandwidth, large signal	35 Hz
Settling time (full travel)	28 ms

XY Nanopositioning Stage



P-541.2 and P-542.2, dimensions in mm

Latest information on nanopositioning stages: www.pi.ws

Technical Data

Model	P-541.2CD	P-542.2CD P-542.2CL	P-541.2DD	P-541.2SL	P-542.2SL	P-541.20L	P-542.20L	Units	Tolerance
Active axes	X, Y	X, Y	X, Y	X, Y	X, Y	X, Y	X, Y		
Motion and positioning									
Integrated sensor	Capacitive	Capacitive	Capacitive	SGS	SGS	–	–		
Open-loop travel, -20 to +120 V	175 x 175	290 x 290	60 x 60	175 x 175	290 x 290	175 x 175	290 x 290	µm	min. (+20 %/0 %)
Closed-loop travel	100 x 100	200 x 200	45 x 45	100 x 100	200 x 200	–	–	µm	
Open-loop / closed-loop resolution	0.2 / 0.3	0.4 / 0.7	0.1 / 0.3	0.2 / 2.5	0.4 / 4	0.2 / –	0.4 / –	nm	typ.
Linearity	0.03	0.03	0.03*	0.2	0.2	–	–	%	typ.
Repeatability	<5	<5	<5	<10	<10	–	–	nm	typ.
Pitch	<±5	<±5	<±3	<±5	<±5	<±5	<±5	µrad	typ.
Yaw	<±10	<±10	<±3	<±10	<±10	<±10	<±10	µrad	typ.
Mechanical properties									
Stiffness in motion direction	0.47	0.4	10	0.47	0.4	0.47	0.4	N/µm	±20 %
Unloaded resonant frequency	255	230	1550	255	230	255	230	Hz	±20 %
Resonant frequency @ 100 g	200	190	–	200	190	200	190	Hz	±20 %
Resonant frequency @ 200 g	180	–	1230	180	–	180	–	Hz	±20 %
Resonant frequency @ 300 g	150	145	–	150	145	150	145	Hz	±20 %
Push/pull force capacity in motion direction	100 / 30	100 / 30	100 / 30	100 / 30	100 / 30	100 / 30	100 / 30	N	Max.
Load capacity	20	20	20	20	20	20	20	N	Max.
Drive properties									
Ceramic type	PICMA® P-885	PICMA® P-885	PICMA® P-885	PICMA® P-885	PICMA® P-885	PICMA® P-885	PICMA® P-885		
Electrical capacitance per axis	4.2	7.5	9	4.2	7.5	4.2	7.5	µF	±20 %
Dynamic operating current coefficient per axis	5.2	4.8	25	5.2	4.8	5.2	4.8	µA/(Hz•µm)	±20 %
Miscellaneous									
Operating temperature range	20 to 80	20 to 80	20 to 80	-20 to 80	-20 to 80	-20 to 80	-20 to 80	°C	
Material	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum		
Mass	1100	1150	1210	1050	1100	1050	1100	g	±5 %
Cable length	1.5	1.5	1.5	1.5	1.5	1.5	1.5	m	±10 mm
Sensor connection	Sub-D Special	Sub-D Special / LEMO	Sub-D Special	LEMO	LEMO	–	–		
Voltage connection	Sub-D Special	Sub-D Special / LEMO	Sub-D Special	LEMO	LEMO	LEMO	LEMO		

Resolution of PI Piezo Nanopositioners is not limited by friction or stiction. Value given is noise equivalent motion with E-503 (p. 2-146) or E-710 controller (p. 2-128).
Dynamic Operating Current Coefficient in µA per Hz and µm. Example: Sinusoidal scan of 10 µm at 10 Hz requires approximately 0.48 mA drive current for the P-542.2CD.
*With digital controller. Non-linearity of direct drive stages measured with analog controllers is up to 0.1 % typ.
Recommended controller / amplifier
Single-channel (1 per axis): E-610 servo controller / amplifier (p. 2-110), E-625 servo controller, bench-top (p. 2-114), E-621 controller module (p. 2-160)
Multi-channel: modular piezo controller system E-500 (p. 2-142) with amplifier module E-503 (three channels) (p. 2-146) or E-505 (1 per axis, high-power) (p. 2-147) and E-509 controller (p. 2-152) (for systems with sensors)
Multi-channel digital controllers: E-710 bench-top (p. 2-128), E-712 modular (p. 2-140), E-725 high-power (p. 2-126), E-761 PCI board (p. 2-130)

P-517 · P-527 Multi-Axis Piezo Scanner

High-Dynamics Nanoscanner for Scanning Probe Microscopy

P-527.2CL parallel-kinematic nanopositioning system

- **Travel Ranges to 200 µm**
- **Sub-Nanometer Resolution**
- **Frictionless, High-Precision Flexure Guiding System**
- **Capacitive Sensors for Highest Linearity**
- **Parallel-Kinematics / Metrology for Enhanced Responsiveness / Multi-Axis Precision**
- **Clear Aperture 66 x 66 mm**
- **Outstanding Lifetime Due to PICMA® Piezo Actuators**

P-517 and P-527 high-dynamics, multi-axis piezo-nanopositioning stages are available in XY ΘZ, XY and XYZ configurations featuring linear travel ranges to 200 x 200 x 20 µm and rotation ranges to 4 mrad. The 66 x 66 mm clear aperture is ideal for transmitted-light applications.
Z/tip/tilt versions in the same form factor are also offered as models P-518, P-528, P-558 (see p. 2-46) and as custom versions with up to six degrees of freedom.

Capacitive Sensors for Highest Accuracy

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

Application Examples

- Metrology
- Interferometry
- Optics
- Lithography
- Nanopositioning
- Scanning microscopy
- Mass storage device testing
- Laser technology
- Micromachining

Technical Data

Model	P-517.2CL	P-527.2CL	P-517.3CL/ P-517.3CD	P-527.3CL/ P-527.3CD	P-517.RCD	P-527.RCD
Active axes	X, Y	X, Y	X, Y, Z	X, Y, Z	X, Y, θ_z	X, Y, θ_z
Motion and positioning						
Integrated sensor	Capacitive	Capacitive	Capacitive	Capacitive	Capacitive	Capacitive
Open-loop travel, -20 to +120 V	130	250	130; Z: 25	250; Z: 25	130; θ_z: ±1.3 mrad	250; θ_z: ±2.5 mrad
Closed-loop travel	100	200	100; Z: 20	200; Z: 20	100; θ_z: ± 1 mrad	200; θ_z: ± 2 mrad
Open-loop resolution	0.3	0.5	0.3; Z: 0.1	0.5; Z: 0.1	0.3; θ_z: ±0.1 µrad	0.5; θ_z: ±0.1 µrad
Closed-loop resolution	1	2	1; Z: 0.1	2; Z: 0.1	1; θ_z: ±0.3 µrad	2; θ_z: ±0.3 µrad
Linearity	0.03	0.03	0.03	0.03	0.03	0.03
Repeatability	±5	±10	±5; Z: ±1	±10; Z: ±1	±5; θ_z: ±0.5 µrad	±10; θ_z : ±1 µrad
Mechanical properties						
Stiffness	2	1	2; Z: 15	1; Z: 15	2	1
Unloaded resonant frequency	450	350	450; Z: 1100	350; Z: 1100	450; θ_z: 400	350; θ_z: 300
Resonant frequency @ 500 g X, Y	250	190	250	190	250	190
Resonant frequency @ 2500 g X, Y	140	110	140	110	140	110
Push/pull force capacity in motion direction	50 / 30	50 / 30	50 / 30	50 / 30	50 / 30	50 / 30
Drive properties						
Ceramic type	PICMA® P-885	PICMA® P-885	PICMA® P-885	PICMA® P-885	PICMA® P-885	PICMA® P-885
Electrical capacitance	9.2	9.2	9; Z: 6	9; Z: 6	9	9
Dynamic operating current coefficient (DOCC)	11.5	5.8	11.5; Z: 37	5.5; Z: 37	11.5	5.5
Miscellaneous						
Operating temperature range	-20 to 80	-20 to 80	-20 to 80	-20 to 80	-20 to 80	-20 to 80
Material	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum
Mass	1.4	1.4	1.45	1.45	1.4	1.4
Sensor / voltage connection	LEMO	LEMO	Sub-D special (CD-version) LEMO (CL-version)	Sub-D special (CD-version) LEMO (CL-version)	Sub-D Special	Sub-D Special

Resolution of PI Piezo Nanopositioners is not limited by friction or stiction. Value given is noise equivalent motion with E -503 or E-710 controller (p. 2-146 or p. 2-128)
Linear Dynamic Operating Current Coefficient in µA per Hz and µm. Example for P-527.2xx: Sinusoidal scan of 30 µm at 10 Hz requires approximately 1.8 mA drive current (p. 2-70). Electrical capacitance and DOCC of the rotation axes base upon differential motion in X, Y; therefore not stated.
Recommended controller
Versions with LEMO connectors: Single-channel (1 per axis): E-610 servo-controller / amplifier (p. 2-110), E-625 servo-controller, bench-top (p. 2-114), E-621 controller module (p. 2-160) Multi-channel: modular piezo controller system E-500 (p. 2-142) with amplifier module E-503 (three channels) (p. 2-146) or E-505 (1 per axis, high-power) (p. 2-147) and E-509 controller (p. 2-152)
Versions with Sub-D connectors: Multi-channel digital controllers: E-710 bench-top (p. 2-128), E-712 modular (p. 2-140), E-725 high-power (p. 2-126), E-761 PCI board (p. 2-130)

Active and Passive Guidance for Nanometer Flatness and Straightness

Flexures optimized with Finite Element Analysis (FEA) are used to guide the stage. The FEA techniques provide for the highest possible stiffness in, and perpendicular to, the direction of motion, and minimize linear and angular runout. Flexures allow extremely high-precision motion, no matter how minute, as they are completely free of play and friction. Due to the parallel kinematics design there is only one common moving platform for all axes, minimizing mass, enabling identical dynamic behavior and eliminating cumulative errors. Parallel kinematics also allows for a more compact construction and faster response compared to stacked or nested designs. The high precision due to flexure guidance is further enhanced by Active Trajectory Control: Multi-axis nanopositioning systems equipped with both parallel kinematics and parallel direct metrology are able to measure platform position in all degrees of freedom against one common fixed reference. In such systems, undesirable motion from one actuator in the direction of another (cross-talk) is detected immediately and actively compensated by the servo-loops. This Active Trajectory Control Concept can keep deviation from a trajectory to under a few nanometers, even in dynamic operation.

Ceramic Insulated Piezo Actuators Provide Long Lifetime

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

Units	Tolerance
µm	min.(+20%/0%)
µm	
nm	typ.
nm	typ.
%	typ.
nm	typ.
N/µm	±20%
Hz	±20%
Hz	±20%
Hz	±20%
N	Max.
µF	±20%
µA/(Hz • µm)	±20%
°C	
kg	±5%

Ordering Information

P-517.2CL
Precision XY Nanopositioning System, 100 x 100 µm, Capacitive Sensors, Parallel Metrology, LEMO Connector

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

P-517.3CL
Precision XYZ Nanopositioning System, 100 x 100 x 20 µm, Capacitive Sensors, Parallel Metrology, LEMO Connector

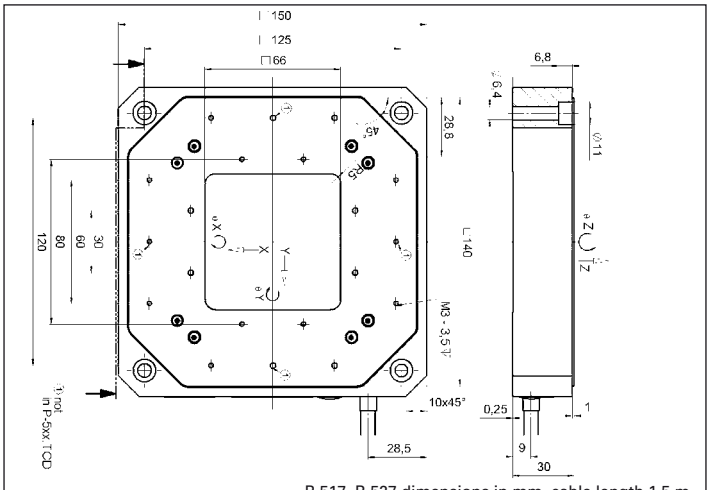
P-517.3CD
Precision XYZ Nanopositioning System, 100 x 100 x 20 µm, Capacitive Sensors, Parallel Metrology, Sub-D Connector

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

P-527.3CD
Precision XYZ Nanopositioning System, 200 x 200 x 20 µm, Capacitive Sensors, Parallel Metrology, Sub-D Connector

P-517.RCD
Precision XY / Rotation Nanopositioning System, 100 x 100 µm, 2 mrad, Capacitive Sensors, Parallel Metrology, Sub-D Connector

P-527.RCD
Precision XY / Rotation Nanopositioning System, 200 x 200 µm, 4 mrad, Capacitive Sensors, Parallel Metrology, Sub-D Connector



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