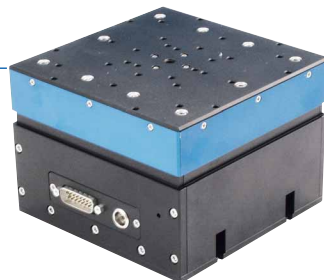


## Vertical Micropositioning Stages

HIGH LOAD



COMPACT



INDIVIDUAL

# M-451 High-Load Precision Z-Micropositioning Stage

## Combinations with Piezo-Nanopositioning Stages Possible



M-451.1PD precision elevation stage

- Encoder Resolution 3 Nanometer
- Min. Incremental Motion to 100 nm
- Travel Range 12.5 mm (1/2")
- Load Capacity up to 12 kg, High Stiffness
- ActiveDrive™ Motor
- Non-contact Limit and Reference Switches
- Mounting Platform for P-500 and PIMars™ Piezo-Nanopositioning Systems
- Self-Locking

The M-451 Z-stage series is ideal for high-precision, high-load vertical positioning tasks. These stages feature a precision-machined base of high-density, stress-relieved aluminum for exceptional stability and minimum weight. Precision-cross-roller guided wedges and low-friction lead-screws provide maintenance-free positioning. The stages are self locking to 12 kg.

### ActiveDrive™ for High Dynamics

Model M-451.1PD with Active Drive™ provides incremental motion down to 0.2 μm. The ActiveDrive™ design, developed by PI, features a high-efficiency PWM (pulse width modulation) 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

### High Accuracy with Gearhead/Encoder Combination

Models M-451.1DG are equipped with closed-loop DC-motors with shaft-mounted position encoders and precision gearheads providing 0.1 μm minimum incremental motion and 3 nanometer encoder resolution.

### Stepper Motor Version for Open-Loop Operation

Models M-451.12S models feature a cost-effective direct-drive, 2-phase stepper motor, providing very smooth operation and a resolution of 6400 steps/rev. (with the C-663 controller). Minimum incremental motion to 0.2 μm is possible.

### Limit and Reference Switches

For the protection of your equipment, non-contact Hall-effect limit and reference switches are installed. The direction-sensing reference

### Ordering Information

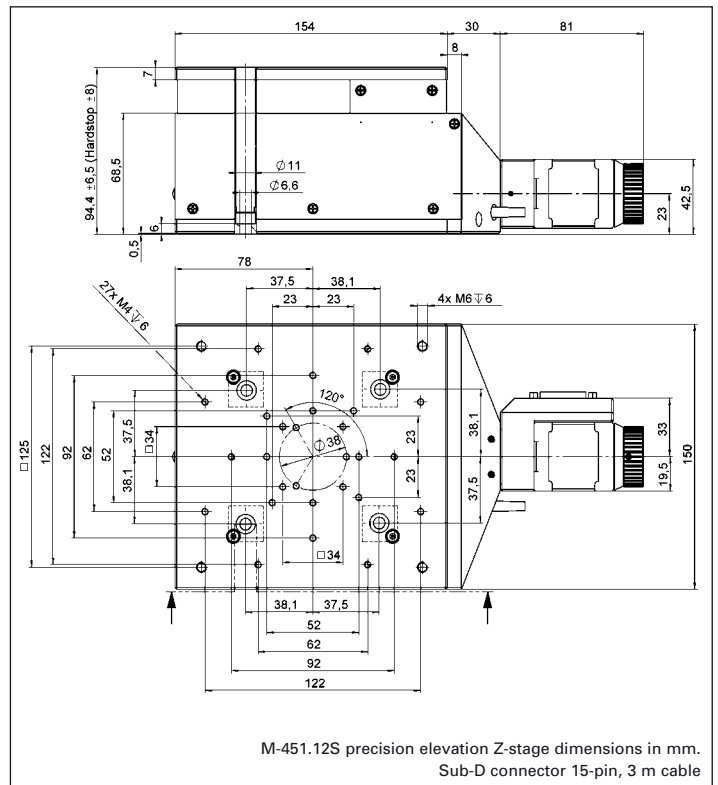
- M-451.1PD**  
Vertical Stage, 12.5 mm, ActiveDrive™ DC Motor (includes 24 V power supply)
- M-451.1DG**  
Vertical Stage, 12.5 mm, DC Motor Gearhead
- M-451.12S**  
Vertical Stage, 12.5 mm, 2-Phase Stepper Motor

Ask about custom designs!

switch supports advanced automation applications with high precision.

### Compatible with Nanopositioning/Scanning Stages

M-451 is designed to work with a variety of PI piezo nanopositioning stages such as the P-527 series and P-561 PIMars™ series. These piezo-driven positioning and scanning stages provide sub-nanometer resolution and accuracy and very high scanning speed.



M-451.12S precision elevation Z-stage dimensions in mm. Sub-D connector 15-pin, 3 m cable

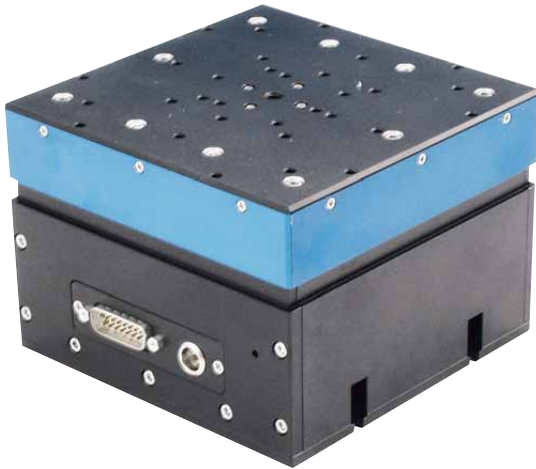
### Application Examples

- R&D
- Semiconductor technology
- Mass storage device testing
- Metrology



# M-501 Precision Z-Micropositioning Stage

## Compact XYZ Combinations with M-511 Translation Stage Series



M-501.1PD vertical stage

- Travel Range 12.5 mm (1/2")
- Ultra-High-Resolution Encoder
- ActiveDrive™ Motor
- Zero-Backlash Recirculating Ballscrews
- Non-Contact Limit and Reference Switches
- Stress-Relieved Aluminum Base for Highest Stability
- MTBF >20,000 h
- Self Locking to 10 kg

The M-501 Z-stage is the latest family member of the M-500 series of translation stages. It is ideal for forming compact XYZ combinations together with the low-profile M-511, M-521 and M-531 translation stages. M-501 vertical stages feature a precision-machined base of high-density, stress-relieved aluminum for exceptional

stability and minimum weight. Precision-ground recirculating ball screws with preloaded nuts provide low-friction, maintenance-free and backlash-free positioning.

Two DC-motor drives are currently available:

### M-501.1PD with ActiveDrive™ for High Velocity

This model features an ultra-high-resolution ballscrew-mounted encoder (40 960 counts/rev!) and provides a minimum incremental motion of better than 100 nanometers (design resolution 24 nm).

For superior dynamic performance the ActiveDrive™ motor is integrated. The ActiveDrive™ design, developed by PI, fea-

tures a high-efficiency PWM (pulse width modulation) 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

### M-501.1DG with Gearhead

These versions feature closed-loop DC motors with shaft-mounted position encoders and precision gearheads providing a minimum incremental motion to 0.1 μm and 5 nanometer encoder resolution.

The gearhead version can hold loads to 10 kg in power-off mode.

### Ordering Information

**M-501.1PD**  
Vertical Stage, 12.5 mm, ActiveDrive™ DC Motor (includes 24 V power supply)

**M-501.1DG**  
Vertical Stage, 12.5 mm, DC Motor Gearhead

**Ask about custom designs!**

### Limit and Reference Switches

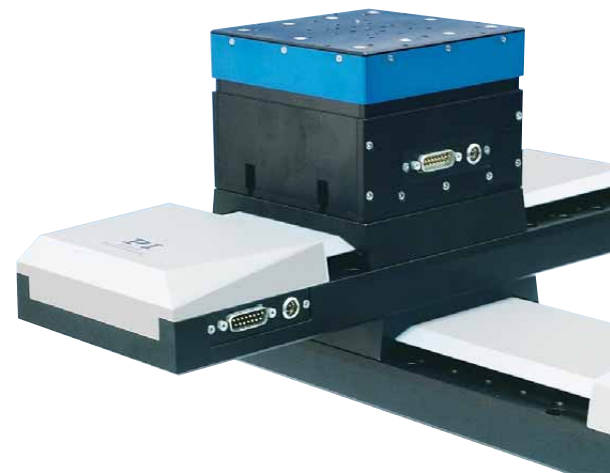
For the protection of your equipment, non-contact Hall-effect limit and reference switches are installed. The direction-sensing reference switch supports advanced automation applications with high precision.

### Notes

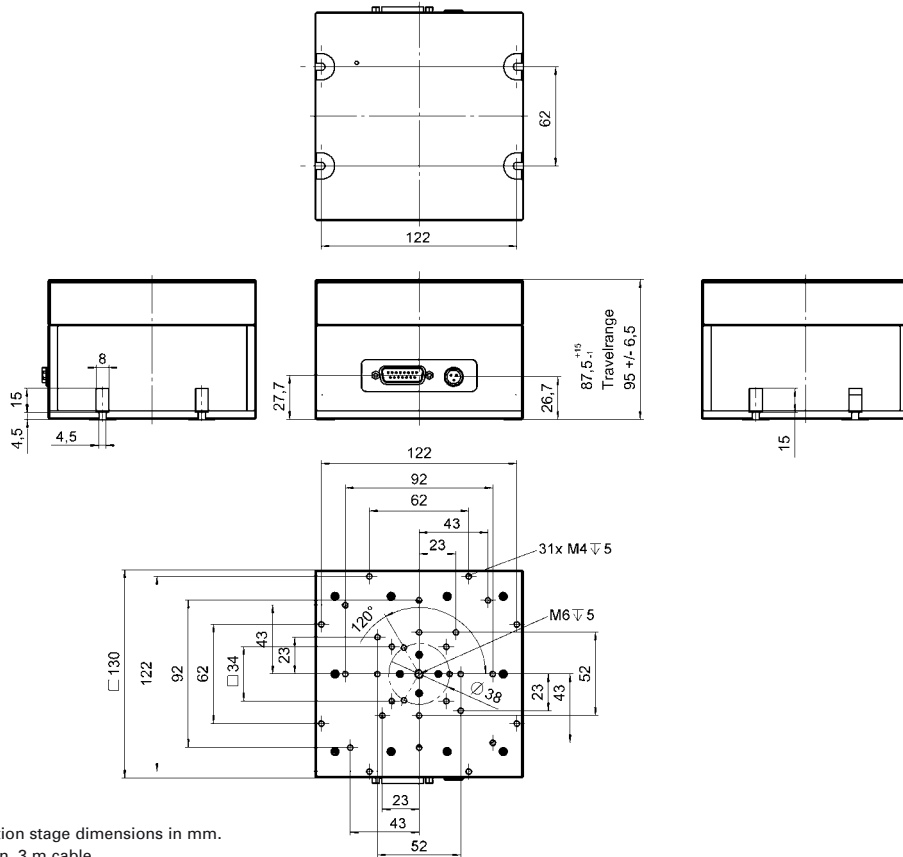
For adapters, bracket, etc. (see p. 4-90).

### Application Examples

- R&D
- Semiconductor testing
- Mass storage device testing
- Metrology
- Photonics packaging
- Quality assurance testing



XYZ combination of M-521.DD (204 mm), M-511.DD (102 mm) and M-501.1PD vertical stage



M-501 precision elevation stage dimensions in mm.  
Sub-D connector 15-pin, 3 m cable

### Technical Data

Model	M-501.1PD	M-501.1DG	Units
Active axes	Z	Z	
<b>Motion and positioning</b>			
Travel range	12.5	12.5	mm
Integrated sensor	Rotary encoder	Rotary encoder	
Sensor resolution	40,960	2048	Cts./rev.
Design resolution	0.024	0.005	µm
Min. incremental motion	<0.1	<0.1	µm
Unidirectional repeatability	0.1	0.1	µm
Pitch/Yaw	±15	±15	µrad
Max. velocity	3	1	mm/s
Origin repeatability	1	1	µm
<b>Mechanical properties</b>			
Spindle pitch	1	1	mm
Gear ratio	80/26 (belt drive)	80/26 (belt drive); (28/12):1 ~ 29,6:1 gearhead	
Max. Load	50	100	N
Max. Holding force	20	100	N
<b>Drive properties</b>			
Motor type	ActiveDrive™ DC Motor	DC Motor, gearhead	
Operating voltage	24 (PWM)	0 to ±12	V
Electrical power	17	4	W
Limit and reference switches	Hall-effect	Hall-effect	
<b>Miscellaneous</b>			
Operating temperature range	-20 to +50	-20 to +50	°C
Material	Al (black anodized)	Al (black anodized)	
Recommended controller/driver	C-863 (single-axis), C-843 PCI board (up to 4 axes)	C-863 (single-axis, p. 4-114), C-843 PCI board (up to 4 axes, p. 4-120)	

# M-714 Nanometer-Precision Linear Stage

## Heavy-Duty Precision Hybrid DC/Piezo Drive with High Guiding-Accuracy



Hybrid Z-positioner M-714.HD

- **Simultaneous Control of Piezo-Flexure Drives & DC-Servo/Ballscrew Drives**
- **7 mm Vertical Travel Range, 10 kg Load Capacity**
- **High Holding Forces with Minimum Power Consumption**
- **Integrated Precision Linear Encoder Provides 2 nm Resolution**
- **Active Backlash Compensation and Stick/Slip Compensation**
- **Frictionless Piezo Drive and Flexure-Decoupled Ballscrew**
- **Millisecond Settling Time to Nanometer Precision**

The M-714 was designed from the ground up to use the hybrid drive technology. The hybrid design overcomes the limitations of conventional precision positioning systems by combining the well-known advantages of piezo-flexure-drives (unlimited resolution and very rapid response) with the long travel ranges and high holding forces of a servo-motor/ballscrew arrangement. The M-714 can position loads up to 10 kg with nanometer precision over 7 mm in vertical or horizontal direction. Com-

pared to high-resolution magnetic linear drives, the hybrid principle allows high holding forces with minimum power consumption, without counterbalancing the load. The angular deviation is less than  $\pm 10 \mu\text{rad}$  over the entire travel range of 7 mm.

### Long Travel Ranges with Nanometer Precision

The challenge of implementing hybrid technology is not only the positioning stage design, but also the use of high-resolution sensors over large travel ranges, the processing of the resulting high-frequency signals and the design of special control algorithms to take full advantage of the hybrid concept.

On the mechanical side, this is accomplished by decoupling the moving platform from the positioner's motor-ballscrew-

drive by frictionless flexures and stiff, highly responsive piezo actuators.

Due to its high stiffness and instantaneous, sub-millisecond range response, the integrated piezo flexure drive provides active stick/slip compensation during startup and settling and is the key to achieving consistent and repeatable nanometer level positioning increments. It also cancels out motion irregularities caused by the ball screw and significantly improves velocity control.

Servo-control of the system employs a single high-resolution position feedback sensor (direct metrology) which means that the inherent piezo precision is available over the entire travel range of 7 mm, and longer travel ranges are basically feasible. The resolution and the positioning accuracy mainly depend on the choice of the feedback sensor.

### Hybrid Controller Technology is Key to Success

PI's highly specialized C-702 hybrid nanopositioning controller (see p. 4-118) compares the actual platform position (by

### Ordering Information

**M-714.2HD**  
Ultra-High Precision Hybrid Nanopositioning Stage,  
7 mm Travel, 2 nm Linear Encoder Resolution

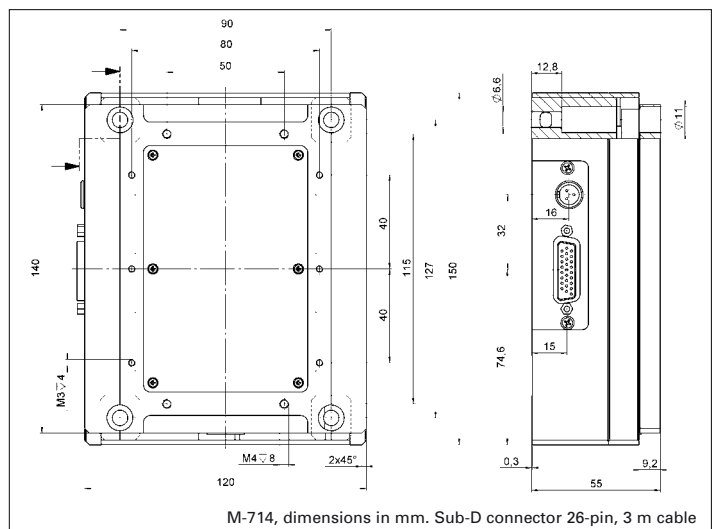
**Ask about custom designs!**

reading the integrated linear encoder) with a calculated, smooth trajectory in real time. Its complex control algorithms continuously actuate both the piezoelectric and servo motor drives in a way to provide the best possible overall performance.

This makes hybrid systems ideal for applications where extremely smooth motion is required, where the position of an incident needs to be read and reformed precisely, or where an externally specified target position needs to be hit within a few nanometers, such as in surface inspection or metrology.

### Notes

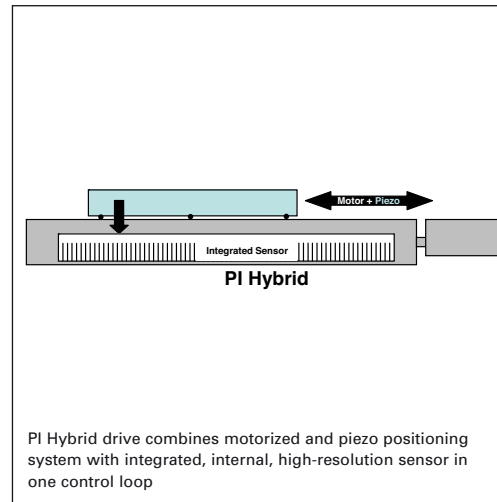
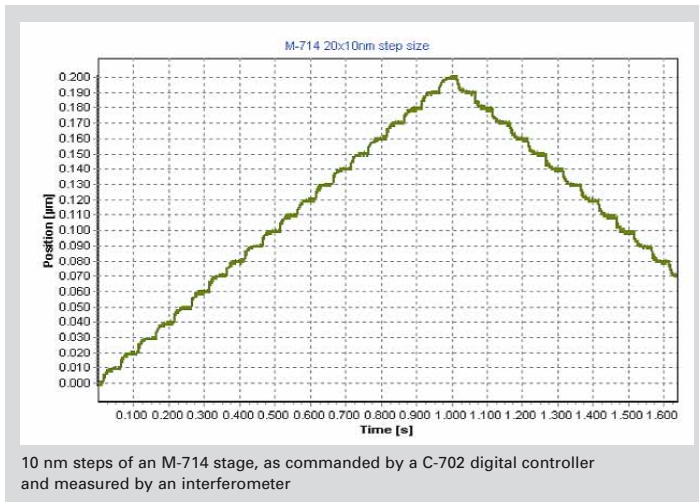
The M-714.2HD positioning system is optimized for vertical operation. If horizontal operation is intended, please note with your order.



### Application Examples

- Surface Inspection
- Microscopy
- Laser technology
- Interferometry
- Metrology





## Technical Data

M-714.2HD	
<b>Motion and positioning</b>	
Travel range	7 mm
Integrated sensor	Linear encoder
Sensor resolution	0.002 µm
Design resolution	0.002 µm
Min. incremental motion	0.004 µm
Hysteresis at the platform	0.01 µm
Unidirectional repeatability	0.01 µm
Accuracy	<0.05 µm
Pitch	±10 µrad
Yaw	±10 µrad
Max. velocity	0.2 mm/s
Origin repeatability	1 µm
<b>Mechanical properties</b>	
Drive screw	Leadscrew
Guiding	Crossed-roller bearings
Screw pitch	1 mm/rev.
Gear ratio	80:1
Belt drive transmission ratio	3:1
Max. push/pull force	100/100 N
Self inhibition	100 N
Max. lateral force	200 N
<b>Drive properties</b>	
Drive type	Hybrid drive: DC-motor with low-inertia, flexure-decoupled and piezo actuated stage platform
Motor type	DC-motor, gearhead
Operating voltage (motor)	24 V
Electrical power	13 W
Piezo drive type	PICMA® Multilayer piezo with flexure
Piezo voltage	±36 V
Limit and reference switches	Hall-effect
<b>Miscellaneous</b>	
Operating temperature range	-20 °C to +65 °C
Material	Al (black anodized)
Mass	2.1 kg
Recommended controller/driver	C-702 hybrid motor controller (p. 4-118)

# P-620.Z – P-622.Z PIHera® Precision Z-Stage

## Nanopositioning System Family with Direct Metrology and Long Travel Ranges



P-620.ZCL, P-621.ZCL and P-622.ZCL (from left) PIHera® piezo nano-elevation stages, 50 to 400 µm (CD for size comparison)

- Vertical Travel Range 50 to 400 µm
- High-Precision, Cost-Efficient
- Resolution to 0.1 nm
- Direct Metrology with Capacitive Sensors
- 0,02 % Positioning Accuracy
- Frictionless, High-Precision Flexure Guiding System
- Outstanding Lifetime Due to PICMA® Piezo Actuators
- X-, XY-, Z- XYZ-Versionen
- Vacuum-Compatible Versions Available

Z-axis PIHera® systems are cost-efficient piezo nanopositioning stages featuring travel ranges up to 400 µm and provide sub-nanometer resolution. Despite the increased travel ranges, the units are extremely compact and provide sub-nanometer resolution. The long

travel range is achieved with a friction-free and extremely stiff flexure system, which also offers rapid response and excellent guiding accuracy.

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

### Application Examples

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

### Nanometer Precision in Milliseconds

One of the advantages of PIHera® stages over motor-driven positioning stages is the rapid response to input changes and the fast and precise settling behavior. The P-622.1CD, for example, can settle to an accuracy of 10 nm in only 30 msec (other

PI stages provide even faster response)!

### Superior Accuracy With Direct-Metrology Capacitive Sensors

A choice of tasks such as optical path adjustment in interferometry, sample positioning in microscopy, precision alignment or optical tracking require the relatively long scanning ranges and nanometer precision offered by PIHera® nanopositioning stages.

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

### Designed for Precision

High stiffness is achieved with the FEA-optimized design of the frictionless flexure elements, which assure excellent guiding

### Ordering Information

#### P-620.ZCD

PIHera® Precision Vertical Nanopositioning Stage, 50 µm, Capacitive Sensor, Sub-D Connector

#### P-620.ZCL

PIHera® Precision Vertical Nanopositioning Stage, 50 µm, Capacitive Sensor, LEMO Connector

#### P-621.ZCD

PIHera® Precision Vertical Nanopositioning Stage, 100 µm, Capacitive Sensor, Sub-D Connector

#### P-621.ZCL

PIHera® Precision Vertical Nanopositioning Stage, 100 µm, Capacitive Sensor, LEMO Connector

#### P-622.ZCD

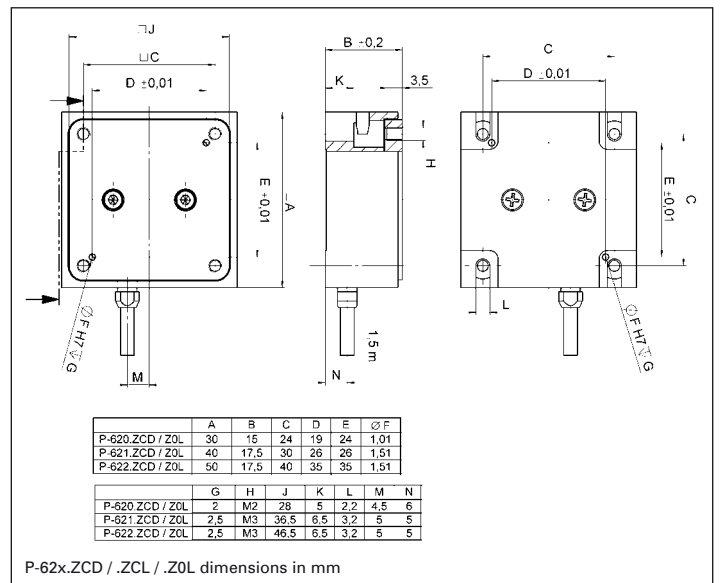
PIHera® Precision Vertical Nanopositioning Stage, 250 µm, Capacitive Sensor, Sub-D Connector

#### P-622.ZCL

PIHera® Precision Vertical Nanopositioning Stage, 250 µm, Capacitive Sensor, LEMO Connector

Open-loop versions are available as P-62x.Z0L

accuracy and dynamics. A straightness and flatness in the nanometer range is achieved.





## System properties

System configuration	P-621.ZCD with E-753 digital controller and 30 g load
Amplifier bandwidth, small signal	25 Hz
Amplifier bandwidth, large signal	25 Hz
Settling time (full travel)	15 ms



PIHera® XYZ combination

## Technical Data

Model	P-620.ZCD P-620.ZCL	P-621.ZCD P-621.ZCL	P-622.ZCD P-622.ZCL	P-62x.Z0L Open-loop versions	Units	Tolerance
Active axes	Z	Z	Z	Z		
<b>Motion and positioning</b>						
Integrated sensor	Capacitive	Capacitive	Capacitive	–		
Open-loop travel, -20 to +120 V	65	140	400	as P-62x.ZCD	µm	min. (+20 %/-0 %)
Closed-loop travel	50	100	250	–	µm	
Open-loop resolution	0.1	0.2	0.5	as P-62x.ZCD	nm	typ.
Closed-loop resolution	0.2	0.3	1	–	nm	typ.
Linearity	0.02	0.02	0.02	–	%	typ.
Repeatability	±1	±1	±1	–	nm	typ.
Runout $\theta_x, \theta_y$ )	<20	<20	<80	as P-62x.ZCD	µrad	typ.
<b>Mechanical properties</b>						
Stiffness	0.5	0.6	0.24	as P-62x.ZCD	N/µm	±20 %
Unloaded resonant frequency	1000	790	360	as P-62x.ZCD	Hz	±20 %
Resonant frequency @ 30 g	690	500	270	as P-62x.ZCD	Hz	±20 %
Push/pull force capacity	10 / 5	10 / 8	10 / 8	as P-62x.ZCD	N	Max.
Load capacity	10	10	10	as P-62x.ZCD	N	Max.
Lateral Force	10	10	10	as P-62x.ZCD	N	Max.
<b>Drive properties</b>						
Ceramic type	PICMA® P-883	PICMA® P-885	PICMA® P-885	as P-62x.ZCD		
Electrical capacitance	0.7	3	6.2	as P-62x.ZCD	µF	±20 %
Dynamic operating current coefficient	1.8	3.8	3.1	as P-62x.ZCD	µA/(Hz • µm)	±20 %
<b>Miscellaneous</b>						
Operating temperature range	-20 to 80	-20 to 80	-20 to 80	-20 to 150	°C	
Material	Aluminum	Aluminum	Aluminum	Aluminum		
Mass	0.12	0.17	0.24	as P-62x.ZCD	kg	±5 %
Cable length	1.5	1.5	1.5	as P-62x.ZCD	m	±10 mm
Sensor / voltage connection	Sub-D special (CD-version) CL-version: LEMO	Sub-D special (CD-version) CL-version: LEMO	Sub-D special (CD-version) CL-version: LEMO	LEMO (no sensor)		

### Recommended controller

#### CD-Versions:

E-610 servo controller / amplifier (p. 2-110), E-625 servo controller, bench-top (p. 2-114), E-665 powerful servo controller, bench-top (p. 2-116)

Single-channel digital controller: E-753 (bench-top) (p. 2-108)

#### CL-Versions:

Modular piezo controller system E-500 (p. 2-142) with amplifier module E-505 (high performance) (p. 2-147) and E-509 controller (p. 2-152)

Open-loop versions: modular piezo controller system E-500 (p. 2-142) with amplifier module E-505 (high performance) (p. 2-147)

## Program Overview

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

## Request or download the complete PI Nanopositioning & Piezo Actuator Catalog



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