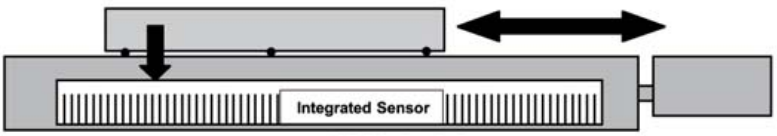
Long Travel Nanopositioning Linear Stages

Flexure Drives, Hybrid Drives, PiezoWalk Drives

NOVEL



PI Hybrid

COMPACT

HIGH LOAD

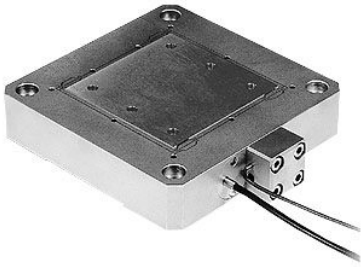
More Info:
Click Images

Piezo Stages w/ Long Travel and / or High Load

The N-661 miniature piezo motor stage integrates a PiezoWalk® linear motor and a high-resolution linear encoder. 20mm travel & nanometer resolution.

PIHera® flextensional piezo nanopositioning systems feature travel ranges from 50 to1800µm

Hybrid piezo stages provide long travel and high force. Left: M-511.HD, 100 mm, Front: M-714, 7 mm for vertical use and C-702 controller (rear).



The P-750.10 piezo stage is equipped with high-precision capacitive position sensors and can handle loads to 10 kg

P-602 flextensional nanopositioning actuator family provides travel ranges from 100µm to 1mm

N-664 High Resolution Linear Translation Stage with PiezoWalk® Linear Motor. 0.5 Nanometer Linear Encoder Resolution, 2nm minimum incremental motion

High-Resolution Translation Stage

NANOMETER STEP SIZES

N-664

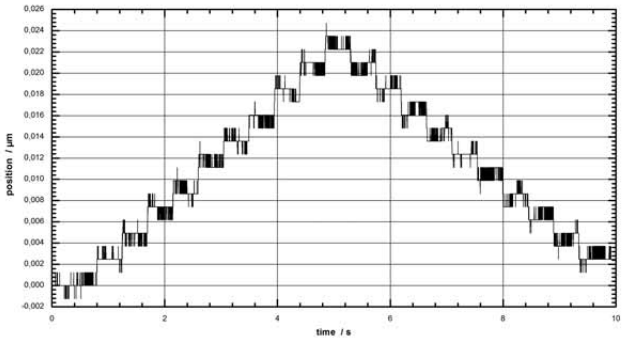
- Travel range 30 mm
- Encoder resolution 0.5 nm
- Minimal incremental motion 2 nm
- Excellent guiding accuracy
- Max. velocity 10 mm/s

Reference-class translation stage with linear motor

Piezo motor-based direct drive
NEXACT® piezo stepping motor with subnanometer resolution. High load capacity and precision due to crossed roller bearings. Reference switch. Low operating voltage. Self-locking at rest, no heat generation

Direct measuring principle
High-precision linear encoder PIOne with subnanometer resolution

Application fields
Research and industry. Option: vacuum version

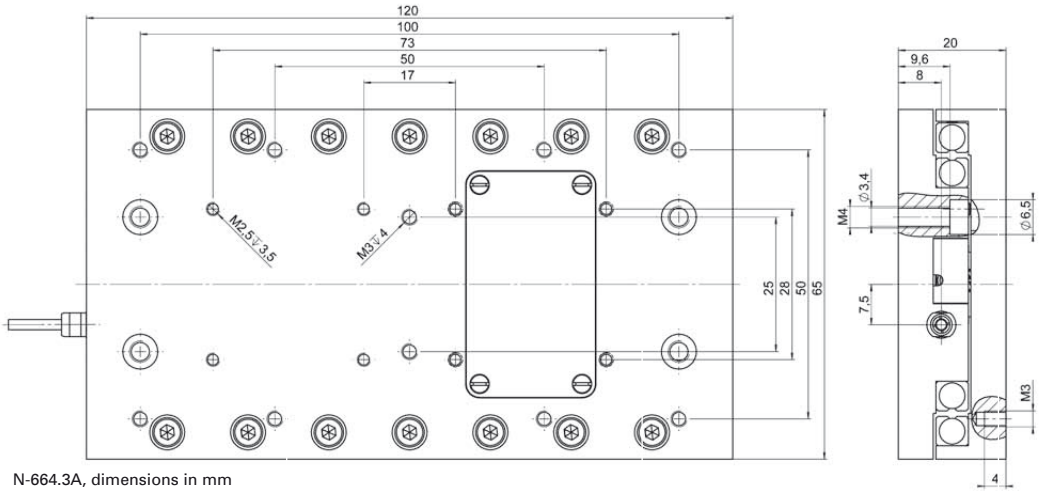


2 nm steps of a N-664.3A with an E-861 Controller

Related Products
M-511.HD Nano-Precision Heavy-Duty Stage
N-661 Miniature Linear Stage with NEXACT® Drive

	N-664.3A	Units	Tolerance
Active axes	X		
Motion and positioning			
Travel range	30	mm	
Min. incremental motion	2	nm	
Integrated sensor	PIOne linear nanometrology encoder		
Open-loop resolution	0.03	nm	typ.
Closed-loop resolution	0.5*	nm	
Max. step frequency, open-loop	0.8	kHz	max.
Max. velocity	10*	mm/s	max.
Linearity	< 0.002% (0,5 µm) along the entire travel range; 0.03% (5 nm) along 20 µm		
Bidirectional repeatability	< 10	nm	
Pitch	40	µrad	typ.
Yaw	40	µrad	typ.
Mechanical properties			
Stiffness in motion direction	2.5	N/µm	±20%
Max. load	20	N	
Max. push / pull force (active)	10	N	max.
Max. holding force (passive)	15	N	min.
Lateral force	50	N	max.
Drive properties			
Drive type	NEXACT® linear drive		
Operating voltage	-10 to +45	V	
Miscellaneous			
Operating temperature range	0 to 50	°C	
Material	Aluminum, nickel-plated		
Mass	530	g	±5%
Cable length	1.5	m	±10 mm
Connector	HD sub-D connector, 15-pin (motor) Sub-D 15 (f) 15-pin (sensor)		
Recommended controller	E-861 controller for NEXACT® linear drives and positioners		

* With E-861. Depending on drive electronics



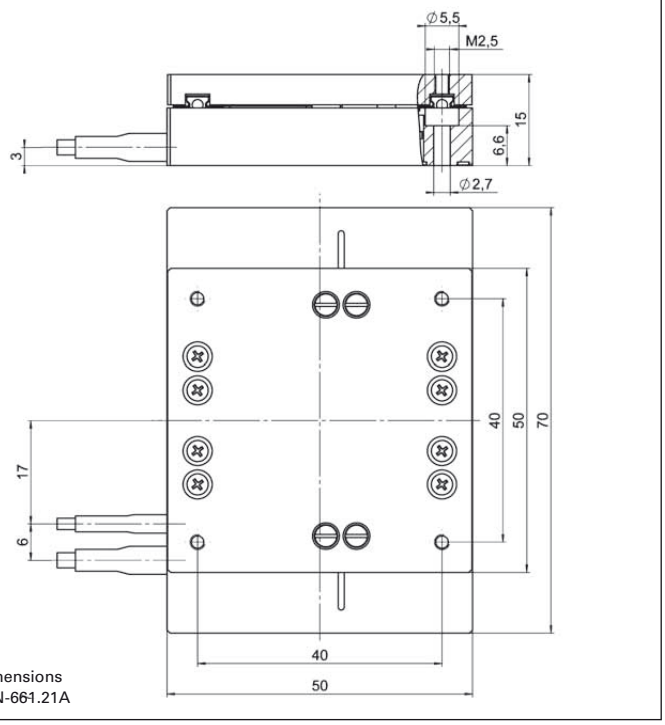
N-664.3A, dimensions in mm

20 mm Nanopositioning Stage with PiezoWalk Motor Drive

PiezoWalk® Drive Provides Nanometer Precision, Smooth Motion and Rapid Response

The N-661 miniature linear stage integrates a PiezoWalk® NEXACT® linear motor combined with a high-resolution linear encoder. It provides 20 mm travel and resolution down to the nanometer range.

- **Travel Range 20 mm**
- **Self Locking at Rest, no Heat Generation, no Servo Dither**
- **Compact Design: 70 x 50 x 20 mm**
- **Zero-Wear Piezo Stepping Drive, Ideal for Micro- and Nano-Manipulation**
- **Integrated Linear Encoder Option for Highest Accuracy with 20 nm Resolution**
- **Two Operating Modes: Continuous Stepping Mode and Continuously Variable, High-Dynamics Analog Mode for 30 pm Resolution**
- **Up to 10 N Force Generation**



Dimensions of N-661.21A

The compact N-661 nanopositioning stage is based on the NEXACT® PiezoWalk® drive. This dual-mode, high-performance piezo stepping linear motor can provide sub-nanometer resolution and high force, along with very rapid response. When run in its analog mode, fast oscillations with amplitudes up to 7 microns and resolutions down to 30 pm can be achieved. This mode is of great value in high-throughput applications as well as in dynamic laser tun-ing, cell penetration applications, or even for active vibration damping. The stage is equipped with a precision guiding system and an optical linear encoder to enable highly repeatable positioning.

Ordering Information

N-661.21A
Miniature NEXACT® Translation Stage, 20 mm, Linear Encoder, 20 nm Resolution

Ask about custom designs

Application Examples

- Life science
- Photonics
- Laser tuning
- Motion in strong magnetic fields

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

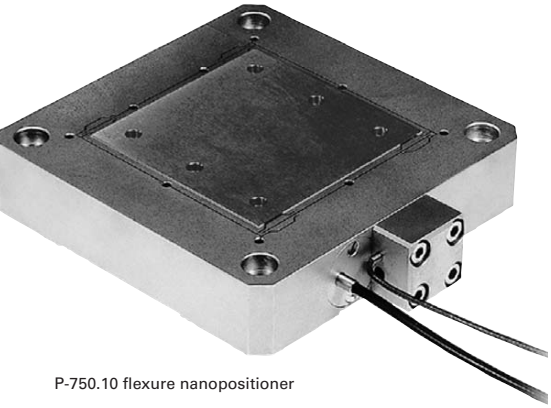
Technical Data

Model	N-661.21A
Active axes	X
Motion and positioning	
Travel range	20 mm
Step size in stepping mode (open-loop)	To 5 µm
Integrated sensor	Linear encoder
Sensor resolution	20 nm *
Travel range in analog mode	7 µm
Open-loop resolution	0.03 nm
Closed-loop resolution	20 nm*
Bidirectional repeatability	200 nm
Pitch	500 µrad
Yaw	150 µrad
Max. Step frequency (open-loop)	0.8 kHz
Max. velocity	10 mm/s*
Mechanical properties	
Stiffness in motion direction	2.4 N/µm
Max. load capacity	20 N
Max. push / pull force (active)	10 N
Max. holding force (passive)	15 N
Lateral Force	20 N
Drive properties	
Drive type	NEXACT® linear drive
Operating Voltage	-10 V to +45 V
Miscellaneous	
Operating temperature range	0 to 50 °C
Material	Aluminum
Mass	150 g
Cable length	1.5 m
Connector	15-pin sub-HDD connector, one channel
Recommended controller/driver	E-861.1A1 Controller for NEXACT® (see p. 1-20)

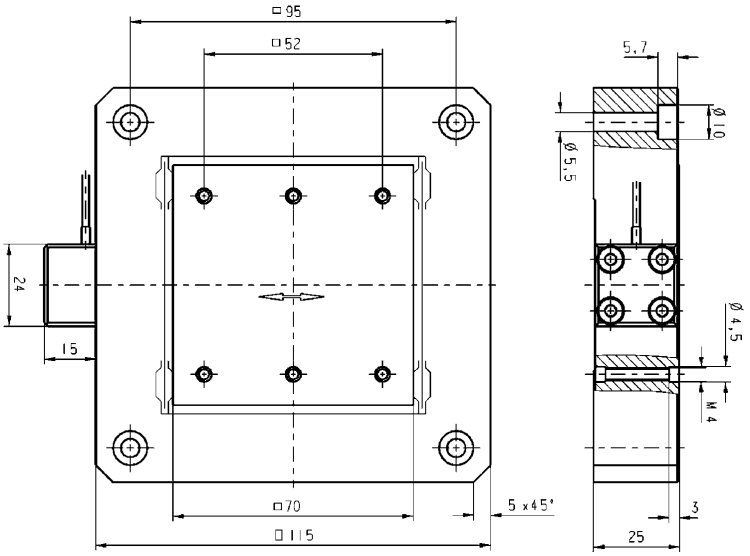
*With E-861. Depending on drive electronics.

P-750 High Load 75 µm Flexure Stage

High-Load Piezo-Driven Nanopositioning Stages with Direct Metrology



P-750.10 flexure nanopositioner



- **10 kg Load Capacity**
- **1 nm Lateral Guiding Precision**
- **Resolution <1 nm**
- **PICMA® High-Performance Piezo Drives**
- **Fast Response**
- **75 µm Travel Range**
- **Direct Metrology with Capacitive Sensors for Highest Precision**
- **Frictionless Precision Flexure Guiding System**

P-750 high-load, piezo-driven flexure-guided, nanopositioning stages are designed to provide motion in one axis with extremely low off-axis error . They feature a positioning and scanning range up to 75 µm with fast settling, on the order of a few milliseconds. Closed-loop versions with integrated capacitive and L VDT (linear variable differential transformer) feedback sensors are offered for enhanced accuracy and repeatability.

Superior Accuracy Through Direct-Motion Metrology

The capacitive-sensor equipped versions (P-750.10) permit motion linearity to 0.03% with effective resolution in the sub-nanometer range. PI capacitive sensors are absolute-measuring, direct-metrology devices that boast very high bandwidth and exhibit no periodic errors.

Unlike conventional indirect sensors, capacitive sensors measure the actual distance between the fixed frame and the moving part of the stage. They detect errors contributed by all components in the drive train—from the actuator through the flexures to the platform. This results in higher motion linearity, long-term stability, phase fidelity , and—because external disturbances are seen by the sensor immediately—a stiffer , faster -responding servo-loop. See p. 2-4 *ff.* and p. 5-2 *ff.* for more information.

P-750.10 models are equipped with lower -cost, direct-metrology L VDT sensors providing 10 nm resolution.

Dynamic Digital Control for Best Scanning Linearity

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

Models	P-750.10	P-750.20	Units
Active axes	X	X	
Open-loop travel @ 0 to 100 V	75	75	µm ±20%
Closed-loop travel	75	75	µm
Integrated feedback sensor	LVDT	capacitive	
* Closed-loop / open-loop resolution	10 / 1	1 / 1	nm
Closed-loop linearity (typ.)	0.1	0.03	%
Full-range repeatability (typ.)	±20	±3	nm
Stiffness	12	12	N/µm ±20%
Push/pull force capacity (in operating direction)	800 / 100	800 / 100	N
Max. (±) normal load	100	100	N
Lateral force limit	50	50	N
Tilt (θ_y, θ_z) (typ.)	10	10	µrad
Lateral runout (Y) (typ.)	1	1	nm
Electrical capacitance	7.5	7.5	µF ±20%
** Dynamic operating current coefficient (DOCC)	12.5	12.5	µA/(Hz ± µm)
Unloaded resonant frequency	600	600	Hz ±20%
Resonant frequency @ 1900 g load	250	250	Hz ±20%
Operating temperature range	-20 to 80	-20 to 80	°C
Voltage connection	VL	VL	
Sensor connection	L	2 x C	
Weight (with cables)	2550	2550	g ±5%
Body material	N-S	N-S	

Ordering Information

P-750.00
Piezo Flexure Stage, 75 µm

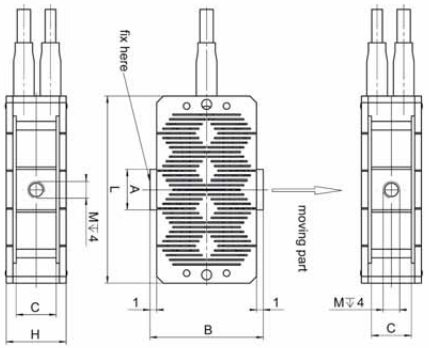
P-750.10
Piezo Flexure Stage, 75 µm, LVDT Sensor

P-750.20
Piezo Flexure Stage, 75 µm, Capacitive Sensor

P-602 High Stiffness Flexure Actuators, to 1000 µm

Integrated Guiding System, High Force and Large Travel Ranges

P-602 linear actuator
family featuring travel ranges
of 100, 500, and 1000 µm (from left to right)



	L	B	H
P-602.1xx	28	17	9
P-602.3xx	46	19	9
P-602.5xx	85	26	9
P-602.8xx	126	34	14
P-602.1x8	28	22	14
P-602.3x8	46	24	14
P-602.5x8	85	31	14

	M	A	C
P-602.1xx	M2,5	6	6
P-602.3xx	M2,5	6	6
P-602.5xx	M2,5	6	6
P-602.8xx	M4	10	11
P-602.1x8	M2,5	6	11
P-602.3x8	M2,5	6	11
P-602.5x8	M2,5	6	11

- **Frictionless Flexure Guiding System for Straight Motion**
- **Integrated Motion Amplifier for Travel Ranges to 1 mm**
- **High Dynamics and Stiffness, Forces to 400 N, Backlash-Free Construction**
- **Outstanding Lifetime Due to PICMA® Piezo Actuators**
- **Available with Integrated Position Sensor**
- **Custom Designs with Larger Travel or Faster Response and Non-Magnetic Versions Feasible**

Model	P-602.100 P-602.1S0 P-602.1SL	P-602.300 P-602.3S0 P-602.3SL	P-602.500 P-602.5S0 P-602.5SL	P-602.108 P-602.1S8 P-602.1L8	P-602.308 P-602.3S8 P-602.3L8	P-602.508 P-602.5S8 P-602.5L8	P-602.800 P-602.8S0 P-602.8SL	Units	Tolerance
Active axes	X	X	X	X	X	X	X		
Motion and positioning									
Integrated sensor	- / SGS / SGS	- / SGS / SGS	- / SGS / SGS	- / SGS / SGS	- / SGS / SGS	- / SGS / SGS	- / SGS / SGS		
Open-loop travel, -20 to +120 V	120	300	600	100	300	500	1000	µm	min. (+20%/-0)
Closed-loop travel	- / 100 / 100	- / 300 / 300	- / 500 / 500	- / 100 / 100	- / 300 / 300	- / 500 / 500	- / 1000 / 1000	µm	
Open-loop resolution	0.2	0.3	0.4	0.2	0.3	0.4	0.5	nm	typ.
Closed-loop resolution	- / 2 / 2	- / 3 / 3	- / 3 / 3	- / 2 / 2	- / 3 / 3	- / 3 / 3	- / 7 / 7	nm	typ.
Linearity, closed-loop	- / 0.5 / 0.5	- / 0.5 / 0.5	- / 0.5 / 0.5	- / 0.5 / 0.5	- / 0.5 / 0.5	- / 0.5 / 0.5	- / 1.5 / 1.5	%	typ.
Repeatability	- / 10 / 10	- / 20 / 20	- / 35 / 35	- / 10 / 10	- / 20 / 20	- / 35 / 35	- / 60 / 60	nm	typ.
Mechanical properties									
Stiffness in motion direction	0.8	0.35	0.3	2.3	0.75	0.65	0.4	N/µm	± 20%
Unloaded resonant frequency	1000	450	230	1000	450	230	150	Hz	± 20%
Blocking force	80	105	150	230	225	325	400	N	max.
Drive properties									
Ceramic type	PICMA® P-885	PICMA® P-885	PICMA® P-885	PICMA® P-888	PICMA® P-888	PICMA® P-888	PICMA® P-888		
Electrical Capacitance	1.5	3.1	6.2	6	13	26	39	µF	± 20%
Dynamic operating current coefficient	1.9	1.3	1.6	7.5	5	6	4	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	Stainless steel	Stainless steel	Stainless steel	Stainless steel	Stainless steel	Stainless steel	Stainless steel		

PIHera® Piezo Linear Stage Family, to 1.8 mm, High Precision

PIHera® piezo nanopositioning systems feature travel ranges from 50 to 1800 µm

- **Travel Ranges 50 to 1800 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 Versions**
- **Vacuum-Compatible Versions Available**

Ordering Information

P-620.1CD* / P-620.1CL*
PIHera® Precision Piezo Linear Nanopositioning System, 50 µm, Direct Metrology, Capacitive Sensor

P-621.1CD* / P-621.1CL*
PIHera® Precision Piezo Linear Nanopositioning System, 100 µm, Direct Metrology, Capacitive Sensor

P-622.1CD* / P-622.1CL*
PIHera® Precision Piezo Linear Nanopositioning System, 250 µm, Direct Metrology, Capacitive Sensor

P-625.1CD* / P-625.1CL*
PIHera® Precision Piezo Linear Nanopositioning System, 500 µm, Direct Metrology, Capacitive Sensor

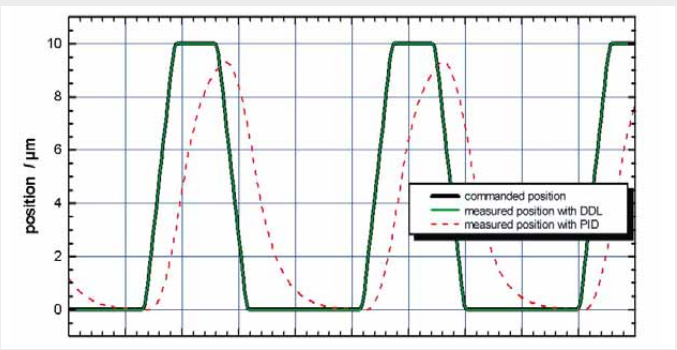
P-628.1CD* / P-628.1CL*
PIHera® Precision Piezo Linear Nanopositioning System, 800 µm, Direct Metrology, Capacitive Sensor

P-629.1CD* / P-629.1CL*
PIHera® Precision Piezo Linear Nanopositioning System, 1500 µm, Direct Metrology, Capacitive Sensor

*.1CD with Sub-D Connector
*.1CL with LEMO Connector

Open-loop versions are available as P-62x.10L.
Vacuum versions to 10^{-9} hPa are available as P-62x.1UD.

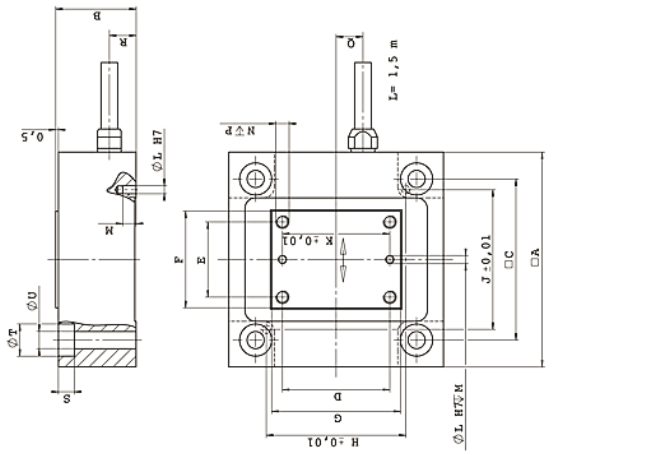
System properties	
System configuration	P-625.1CD and E-500 modular piezo controller system with E-505.00F amplifier and E-509.C1A servo controller; 250 g load
Closed-loop amplifier bandwidth, large signal	30 Hz
Settling time (full travel)	31 ms



Rapid scanning motion of a P-621.1CD (commanded rise time 5 ms) with the E-710 controller ##600300 and Digital Dynamic Linearization (DDL) option. DDL virtually eliminates the tracking error (<20 nm) during the scan. The improvement over a classical PI controller is up to 3 orders of magnitude, and increases with the scanning frequency

Application Examples

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



	A	B	C	D	E	F	G	H	J	K	◇L	M	N	P	Q	R	S	◇T	◇U
P-620.1CD / 10L	30	12	24	15	12	15	18	19	24	15	1.01	1.5	M2	4	4.5	6	2	4.4	2.2
P-621.1CD / 10L	40	15	30	20	14	18	24	26	26	20	1.51	2.5	M2.5	5	5	5	3	6	3.2
P-622.1CD / 10L	50	15	40	24	20	25	30	35	35	24	1.51	2.5	M2.5	5	5.5	5	3	6	3.2
P-625.1CD / 10L	60	15	50	40	27	32	44.5	46	46	40	1.51	2.5	M2.5	5	5.5	5	3	6	3.2
P-628.1CD / 10L	80	17	70	58	41	45	63	66	66	58	1.51	2.5	M2.5	5	5.5	5	3	6	3.2
P-629.1CD / 10L	100	22.5	90	60	40	60	84	82	82	60	2.01	3.5	M2.5	5	10	7.5	4	8	4.3

P-62x.1CD/.1CL/.10L dimensions in mm

PIHera® XYZ combination, P-62x.2 XY piezo stage (see p. 2-54), P-62x.Z vertical stage (see p. 2-40)

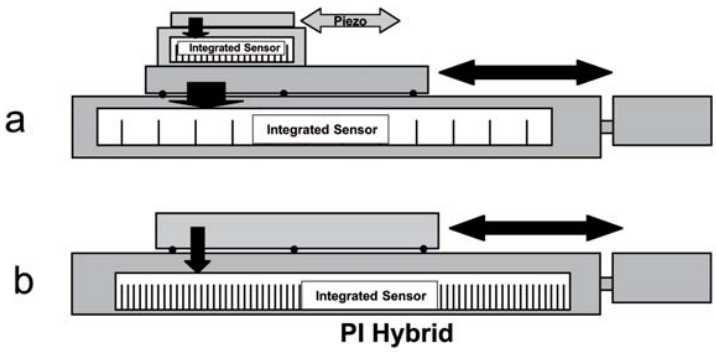
Technical Data

Model	P-620.1CD/ P-620.1CL	P-621.1CD/ P-621.1CL	P-622.1CD/ P-622.1CL	P-625.1CD/ P-625.1CL	P-628.1CD/ P-628.1CL	P-629.1CD/ P-629.1CL/	P-62x.10L open-loop version	Units	Tolerance
Active axes	X	X	X	X	X	X	X		
Motion and positioning									
Integrated sensor	Capacitive	Capacitive	Capacitive	Capacitive	Capacitive	Capacitive	–		
Open-loop travel, -20 to +120 V	60	120	300	600	950	1800	as P-62x.1CD	µm	min. (+20 %/-0 %)
Closed-loop travel	50	100	250	500	800	1500	–	µm	calibrated
Closed-loop / open-loop resolution	0.2 / 0.1	0.4 / 0.2	0.7 / 0.4	1.4 / 0.5	1.8 / 0.5	3 / 2	as P-62x.1CD	nm	typ.
Linearity, closed-loop	0.02	0.02	0.02	0.02	0.03*	0.03**	–	%	typ.
Repeatability	±1	±1	±1	±5	±10	±14	–	nm	typ.
Pitch / yaw	±3	±3	±3	±6	±6	±10	as P-62x.1CD	µrad	typ.
Mechanical properties									
Stiffness in motion direction	0.42	0.35	0.2	0.1	0.12	0.13	as P-62x.1CD	N/µm	±20 %
Unloaded resonant frequency	1100	800	400	215	125	125	as P-62x.1CD	Hz	±20 %
Resonant frequency @ 20 g	550	520	340	180	115	120	as P-62x.1CD	Hz	±20 %
Resonant frequency @ 120 g	260	240	185	110	90	110	as P-62x.1CD	Hz	±20 %
Push/pull force capacity in motion direction	10	10	10	10	10	10	as P-62x.1CD	N	Max.
Load capacity	10	10	10	10	10	10	as P-62x.1CD	N	Max.
Lateral Force	10	10	10	10	10	8	as P-62x.1CD	N	Max.
Drive properties									
Ceramic type	PICMA® P-883	PICMA® P-885	PICMA® P-885	PICMA® P-885	PICMA® P-887	PICMA® P-888	as P-62x.1CD		
Electrical capacitance	0.35	1.5	3.1	6.2	19	52	as P-62x.1CD	µF	±20 %
Dynamic operating current coefficient	0.9	1.9	1.9	1.6	3	4.3	as P-62x.1CD	µA/(Hz • µm)	±20 %
Miscellaneous									
Operating temperature range	-20 to 80	-20 to 80	-20 to 80	-20 to 80	-20 to 80	-20 to 80	-20 to 150	°C	
Material	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum		
Dimensions	30 x 30 x 12	40 x 40 x 15	50 x 50 x 15	60 x 60 x 15	80 x 80 x 17	100 x 100 x 22.5	as P-62x.1CD	mm	
Mass	0.11	0.16	0.2	0.24	0.38	0.72	as P-62x.1CD	kg	±5 %
Cable length	1.5	1.5	1.5	1.5	1.5	1.5	1.5 m	±10 mm	
Sensor / voltage connection	CD version: Sub-D special CL version: LEMO	CD version: Sub-D special CL version: LEMO	CD version: Sub-D special CL version: LEMO	CD version: Sub-D special CL version: LEMO	CD version: Sub-D special CL version: LEMO	CD version: Sub-D special CL version: LEMO	LEMO (no sensor)		

Resolution of PI Piezo Nanopositioners is not limited by friction or stiction. The value given is noise equivalent motion with E-710 controller (p. 2-128).
*With digital controller. For analog controller 0.05 %.
**With digital controller. For analog controller 0.07 %.
Recommended controller / amplifier
CD version: 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 version: E-500 modular piezo controller system (p. 2-142) with E-505 amplifier module (high power) p. 2-147 and E-509 controller (p. 2-152)
Open-loop version: E-500 modular piezo controller system (p. 2-142) with E-505 amplifier module (high power) (p. 2-147)

Hybrid Nanopositioning Product Overview

Nanopositioning Systems with Hybrid Drive, Hybrid Controller



Different types of combined motorized and piezo positioning systems:
a) Serially stacked drives with individual integrated position sensors
b) PI Hybrid drive with integrated, internal, high-resolution sensor, for use with highly specialized controller.

- **Long Travel Ranges with Nanometer Resolution**
- **Travel Range: to 100 mm Translation/7 mm Elevation**
- **Resolution to 2 nm**
- **Velocity to 125 mm/s**
- **Linear Encoder for Highest Precision**
- **Backlash-Free Precision Ballscrew under Frictionless Piezo Drive**

C-702 Controller—Key to Hybrid Technology

The optimized interaction between the piezoelectric and motorized drive components to make them a single motion unit requires a high-speed sensor as well as powerful control algorithms. The digital, 2-channel, C-702 controller, based on modern CPU technology with a real time operating system, has been designed for this task. It is able to read the position signals with virtually no delay and process the data immediately. The integrated piezo amplifiers use a high-resolution 24-bit DAC to fully support the high position resolution of the piezo actuators. The new ultra-fast broadband SSI interface for the optical linear encoder supports stage velocities of 600 mm/s at a resolution of 1 nm. With custom firmware, one of the sensor interfaces can be reprogrammed for use as a high-speed command interface capable of processing commands at the servo rate.

Application Examples

- Surface inspection
- Microscopy
- Laser technology
- Interferometry
- Metrology

M-714 Heavy-Duty Nanopositioning System

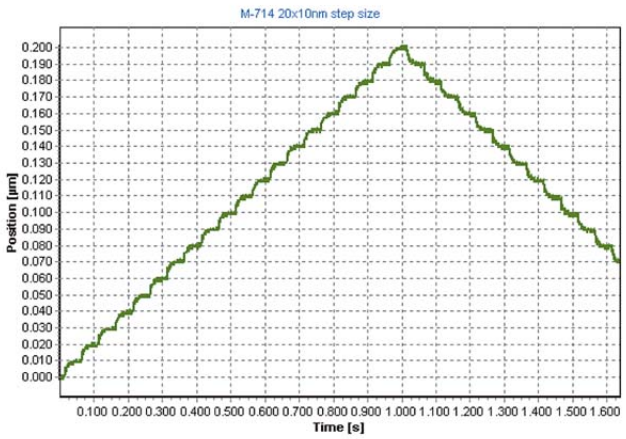
The M-714 was designed from the ground up to use the hybrid drive technology. A high gear reduction ratio enables the M-714 to position loads up to 10 kg with nanometer precision, even in the vertical direction. Compared to high-resolution magnetic linear drives, the hybrid principle allows high holding forces with minimum power consumption, without counterbalancing the load. The angular deviation is less than ±10 µrad over the entire travel range of 7 mm. The high-performance drive components, including ballscrew, bearings, motor and gearhead are chosen for minimum mechanical play and friction.

M-511.HD Long-Travel, High-Speed Nanopositioning Systems

The M-511.HD is based on the proven design of the M-5x1 precision micropositioning stage series, with an integrated, flexure-guided, piezo actuator added. The M-511.HD allows velocities to 125 mm/s with an encoder resolution of 2 nm and load capacity of 50 kg for horizontal operation.

C-702 Highlights!

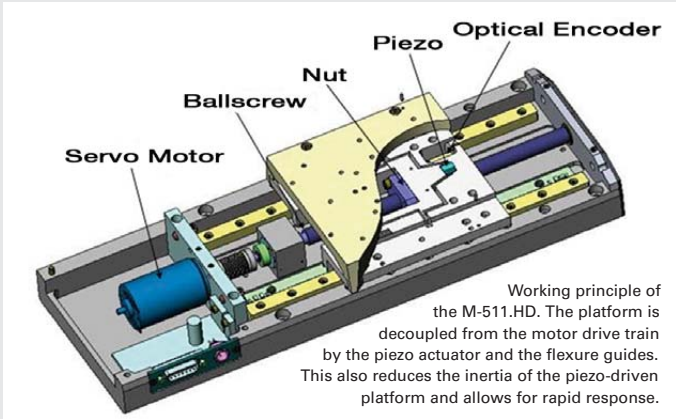
- Two channels
- 10 kHz Sampling Rate
- 24-Bit Piezo Motion Resolution (<1 picometer)
- High-Resolution Incremental Sensor with Serial Interface
- Real-Time Operating System
- Interfaces: VGA, Keyboard, Mouse, RS-232, TCP/IP Ethernet



10 nm steps of an M-714 stage, as measured by an interferometer.

Hybrid Nanopositioning Technology by PI

Long Travel Linear Slides with Nanometer Precision



Working principle of the M-511.HD. The platform is decoupled from the motor drive train by the piezo actuator and the flexure guides. This also reduces the inertia of the piezo-driven platform and allows for rapid response.

- **Active Compensation of Stick/Slip During Startup and Settling**
- **Active Backlash Compensation**
- **Excellent Velocity Control**
- **Millisecond Settling to Nanometer Accuracy**
- **Reliable Execution of Minimal Increments**
- **High Drive and Holding Forces with Minimal Power**

The direct integration of piezo actuators in micropositioning stages allows combining travel ranges of hundreds of millimeters with resolutions in the nanometer range. Servo-control of the system employs a single high-resolution position feedback sensor (parallel metrology) which means that the high resolution can be used over the entire travel range. This makes hybrid systems ideal for applications where the position of an incident needs to be read and refound precisely , or where an externally specified target position needs to be hit within few a nanometers, such as in surface inspection or metrology. The challenge of implementing hybrid technology is not only the mechanical design of the positioning stage, 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 design.

Integrated Servo-Control Spans Both Drives

The basic idea of combining classical motorized micropositioners with high-resolution piezo actuators is not new . For example, PI offers a fiber -scanning and coupling system comprising a 6-DoF micropositioner (F-206) mounted beside a multi-axis piezo system (P-611 Nanocube®) with high position resolution.

The servo-control algorithms with stacked systems like these generally operate independently, with the piezo system only becoming activated after the motorized positioner has come to a complete stop. Because separate position sensors are used the absolute accuracy (not the resolution) is limited by the precision of the motorized long-range positioner.

The new PI hybrid systems use a single high-resolution encoder and a controller that can actuate both drives at the same time. Thus every move benefits from the specific advantages of both the motorized actuator and the piezo actuator from startup to settling.

On the mechanical side, this is accomplished by decoupling the motion platform of the hybrid positioning stage from the micropositioner' s motor - ballscrew-drive by frictionless flexures and stiff, fast response piezo actuators.

The controller continuously compares the actual platform position (by reading the integrated linear encoder) with a calculated, smooth trajectory . The piezo actuators actively compensate out the irregularities in the motion of the platform caused by the motorized drive train.

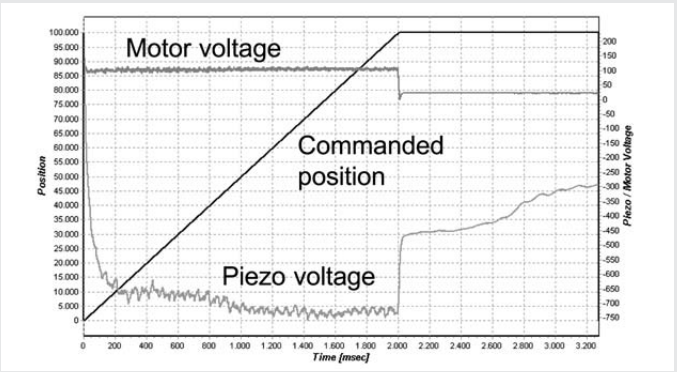
Absolute Accuracy

The servo-control loops for both the motorized and the piezo drive use the same position sensor . The result is a motion system with hundreds of millimeters travel but with the precision of a piezo-based nanopositioner. The resolution and the positioning accuracy depend on the choice of the feedback sensor. PI hybrid systems currently use optical linear encoders with a resolution of 2 nm. Depending on the stage, a minimum incremental motion or a repeatability of 2 nm can be achieved over the entire travel range.

One Controller for One Motion System

In PI hybrid systems, the motor-leadscrew and piezo actuator are fully integrated to form one motion system. The motor and piezo act together at all times. The result is far more than a coarse-adjust/fine-adjust system: effects like startup stick/slip and backlash can be completely compensated and a motion profile with high constancy of velocity can be followed. Because of the high piezo stiffness, setting to a few nanometers only takes a few milliseconds, significantly faster than with conventional, higher-inertia, linear -motor-driven stages. Furthermore minimal increments in the range of the sensor resolution can be reliably executed.

To allow high velocities beyond 100 mm/sec and nanometer -range incremental resolution, position information must be transmitted and processed very rapidly and a complex control algorithm is required. PI's C-702 is a controller providing PWM signal generators, piezo amplifiers and control algorithms specially tailored for hybrid systems.



PI hybrid servo-controller output during a positioning command. The controller reads the system position off a high-resolution encoder and actuates both the motor and piezoelectric actuator at the same time giving a system with the advantages of both drives.

M-511.HD Hybrid Nanopositioning Linear Stage

Hybrid Long-Travel, High-Load Translation Stage with Nanometer Precision

M-511.HD hybrid nanopostioner

- **Simultaneous Control of Piezo-Flexure Drives & DC-Servo/Ballscrew Drives**
- **100 mm Travel Range, 125 mm/sec Max. Velocity**
- **Reliable Execution of Nanometer Level Increments**
- **2 nm Linear Encoder Resolution**
- **Millisecond Settling Time to Nanometer Precision**
- **Frictionless Piezo Drive and Flexure-Decoupled Ballscrew**
- **Active Compensation of Backlash and Stick/Slip Effects**
- **Excellent Velocity Control**

The M-511.HD is an advancement on PI's proven M-5x1 precision micropositioning stage series. The new hybrid system 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-511.HD allows velocities to 125 mm/s with an encoder resolution of 2 nm and load capacity of 50 kg for horizontal operation.

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 100 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 compares the actual platform position (by 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 refound precisely , or where an externally specified target position needs to be hit within few a nanometers, such as in surface inspection or metrology.

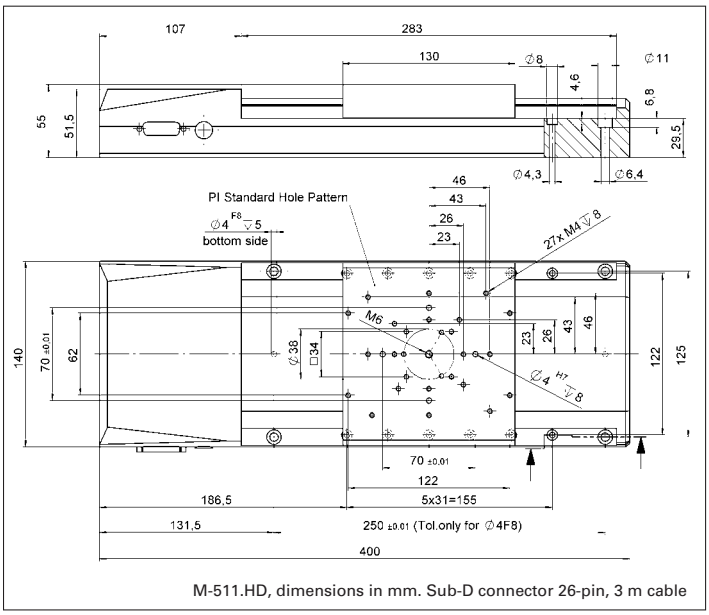
Ordering Information

M-511.HD
Ultra-High-Precision Hybrid Translation Stage, 100 mm Travel, 2 nm Linear Encoder Resolution

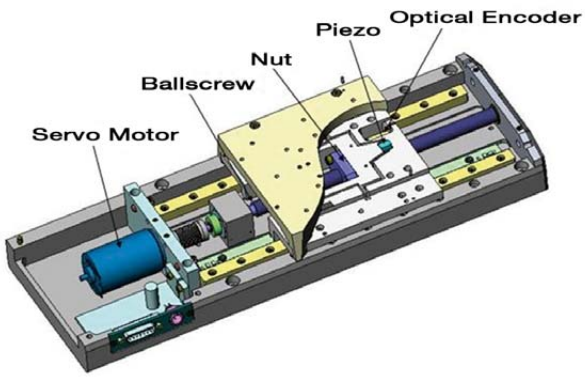
Ask about custom designs!

Application Examples

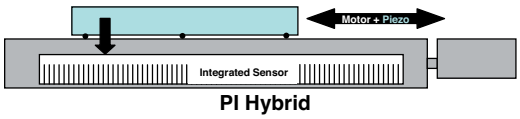
- Surface Inspection
- Microscopy
- Laser technology
- Interferometry
- Metrology



M-511.HD, dimensions in mm. Sub-D connector 26-pin, 3 m cable



Working principle of the M-511.HD. The platform is decoupled from the motor drive train by the piezo actuator and the flexure guides. This also reduces the inertia of the piezo-driven platform and allows for rapid response



PI Hybrid

PI Hybrid drive combines motorized and piezo positioning system with integrated, internal, high-resolution sensor in one control loop

Technical Data

	M-511.HD
Active axes	X
Motion and positioning	
Travel range	100 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	±25 µrad
Yaw	±25 µrad
Straightness	1 µm
Flatness	1 µm
Max. velocity	125 mm/s
Origin repeatability	1 µm
Mechanical properties	
Drive screw	Recirculating ballscrews
Guiding	Precision linear guiding rails, recirculating ball bearings
Screw pitch	2 mm/rev.
Max. load	500 N
Max. push/pull force	80/80 N
Max. lateral force	200 N
Drive properties	
Drive type	Hybrid drive: DC motor with low-inertia, flexure-decoupled and piezo actuated stage platform
Motor type	DC motor
Operating voltage (motor)	24 V
Electrical power	30 W
Piezo drive type	PICMA® Multilayer piezo with flexure
Piezo voltage	±36 V
Limit and reference switches	Hall-effect
Miscellaneous	
Operating temperature range	-20 °C to +65 °C
Material	Al (black anodized)
Mass	5.1 kg
Recommended controller/driver	C-702 hybrid motor controller

M-714 Hybrid Stage for Vertical Applications

Heavy-Duty Nanopositioning System with Hybrid Drive

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. Compared 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 ±10 µrad over the entire travel range of 7 mm.

Application Examples

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

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 compares the actual platform position (by 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 refound precisely , or where an externally specified target position needs to be hit within few a nanometers, such as in surface inspection or metrology.

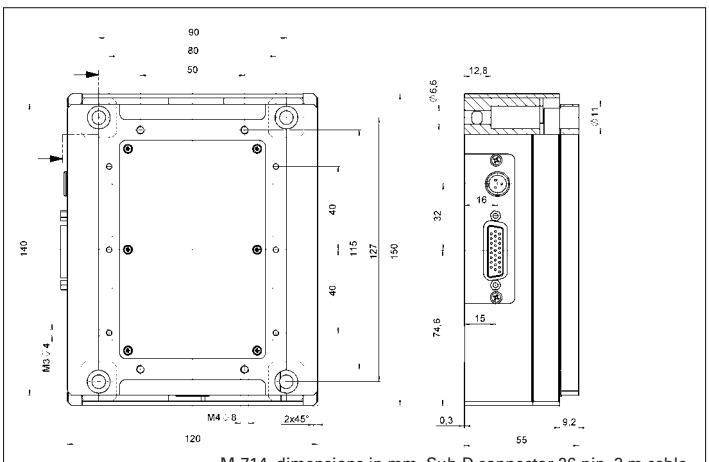
Ordering Information

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

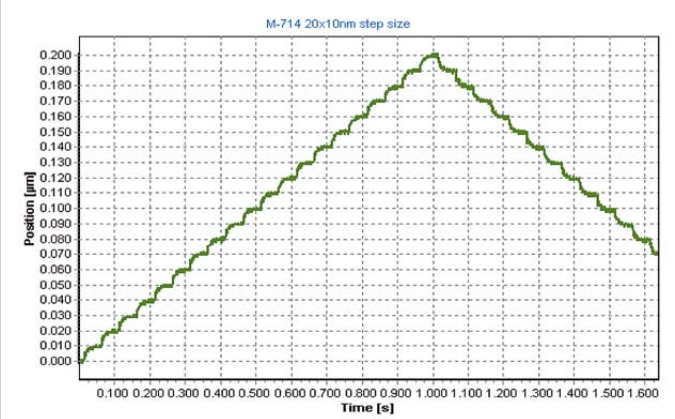
Ask about custom designs!

Notes

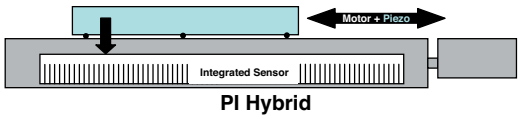
The M-714.2HD positioning system is optimized for vertical operation. If horizontal operation is intended, please note with your order.



M-714, dimensions in mm. Sub-D connector 26-pin, 3 m cable



10 nm steps of an M-714 stage,
as measured by an interferometer



PI Hybrid

PI Hybrid drive combines motorized and piezo positioning system with integrated, internal, high-resolution sensor in one control loop

Technical Data

	M-714.2HD
Motion and positioning	
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
Mechanical properties	
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
Drive properties	
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	4.5 W
Piezo drive type	PICMA® Multilayer piezo with flexure
Piezo voltage	±36 V
Limit and reference switches	Hall-effect
Miscellaneous	
Operating temperature range	-20 °C to +65 °C
Material	Al (black anodized)
Mass	2.1 kg
Recommended controller/driver	C-702 hybrid motor controller

C-702 Hybrid Nanopositioning Controller

Controller for Hybrid Piezo Stages – Key to Hybrid Technology

C-702 Hybrid Controller

- **Motion Controller & Driver for Simultaneous Operation of Closed-Loop DC Servo Motors and Piezo Actuators**
- **2 Channels**
- **Sample Rate 10 kHz**
- **Piezo Resolution 24-bit**
- **Fast Serial Bus for Incremental High-Resolution Sensor**
- **Realtime Operating System**
- **Interfaces: TCP/IP Ethernet, RS-232, VGA, Keyboard**

The C-702 digital hybrid motion controller has been designed for precision control of the M-511.HD and M-714 nanopositioning stages. Both are based upon the PI hybrid drive technology integrating piezoelectric and motorized drive components to form one motion and servo-control system. The result is a nanopositioning system for high loads that can follow a motion profile with nanometer position accuracy and high constancy of velocity over several millimeters of travel.

Highly Effective Servo-Control for a Complex Drive Technology

The optimized interaction between the piezoelectric and motorized drive components to make them a single motion unit requires a high-speed sensor as well as powerful control algorithms. The digital, 2-channel, C-702 controller, based on modern CPU technology with a real time operating system, has been designed for this task. It is able to read the position signals with virtually no delay and process the data immediately. The integrated piezo amplifiers use a high-resolution 24-bit DAC to fully support the high position resolution of the piezo actuators. The new ultra-fast broadband SSI interface for the optical linear encoder supports stage velocities of 300 mm/s at a resolution of 2 nm. With special cabling, external sensor signals, like those from an interferometer, can be used for servo-control via an SSI interface.

One Controller for One Motion System

In PI hybrid systems, the motor-leadscrew and piezo actuator are fully integrated to form one motion system. The motor and piezo act together at all times. The result is far more than a coarse-adjust/fine-adjust system: effects like startup stick/slip and backlash can be completely compensated and a motion profile with high constancy of velocity can be followed. Because of the high-piezo stiffness, setting to a few nanometers only takes a few milliseconds, significantly faster than with conventional, higher-inertia, linear -motor-driven stages.

Function	Motion Controller for Hybrid Nanopositioning Systems
Drive type	DC motor (PWM)/piezo
Channels	2
Motion and control	
Servo characteristics	PID V-ff filter, notch filter, hysteresis setting (motor); proportional-integral (P-I) algorithm with notch filter (piezo)
Sampling rate	10 kHz
Trajectory profile modes	Trapezoidal, S-curve
Processor	32-bit Intel Celeron
Position range	32 bit
Limit switches	2 lines per axis
Reference switch	1 line per axis
Motor brake	Software programmable
Electrical properties	
Operating voltage	24 VDC (via M-500.PS wide range power supply*)
Output power/channel	PWM: 19.5 kHz, 10-bit resolution
Piezo voltage	±36 V (24-bit resolution)
Power consumption	< 25 W
Interfaces and operation	
Communication interfaces	TCP/IP, RS-232, VGA, Keyboard
Motor connector	Sub-D connector, 26-pin**
Encoder input	Serial SSI interface for incremental encoder
Controller network	via TCP/IP
I/O ports	8 TTL inputs, 8 TTL outputs
Command set	ASCII, PI General Command Set (GCS)
User software	PIMikroMove®
Software drivers	GCS (PI General Command Set)-DLL, LabVIEW™ drivers
Supported functionality	Autostart macro, user-programmable macro
Miscellaneous	
Operating temperature range	+10 to +50 °C
Mass	1.35 kg
Dimensions	130 x 205 x 76 mm

* M-500.PS: wide range power supply, 100 to 250 VAC, 50 to 60 Hz
** Sub-D 26 contains connection for motor, piezo, reference and limit switches, sensor Internal heat sink with very silent fan

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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