

# M-511.HD1 Nano-Precision Heavy-Duty Stage

## Hybrid DC/Piezo Precision Stage, High Speed, 0.5nm Resolution



M-511.HD1 hybrid nanopositioner

- **Simultaneous Control of Piezo-Flexure Drives & DC-Servo/Ballscrew Drives**
- **100 mm Travel Range, 50 mm/sec Max. Velocity**
- **Reliable Execution of Nanometer Level Increments**
- **0.5nm 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.HD1 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.HD1

allows velocities to 50 mm/s with an encoder resolution of 0.5nm and load capacity to 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 (see p. 4-118) compares the actual platform position (by reading the integrated linear

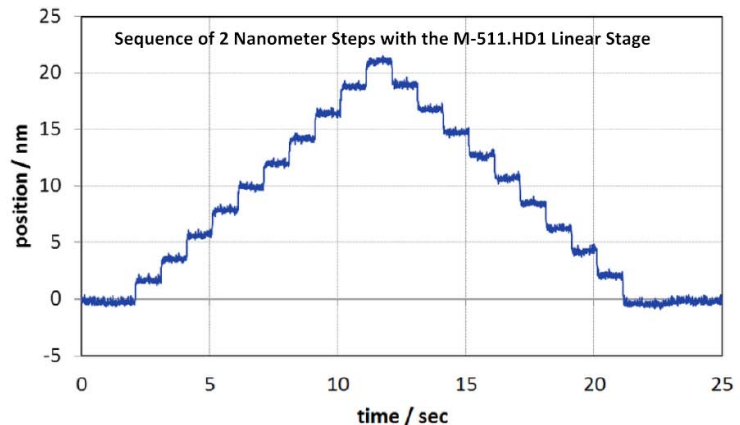
### Ordering Information

**M-511.HD1**  
Ultra-High-Precision Hybrid Translation Stage, 100 mm Travel  
0.5nm Linear Encoder Resolution

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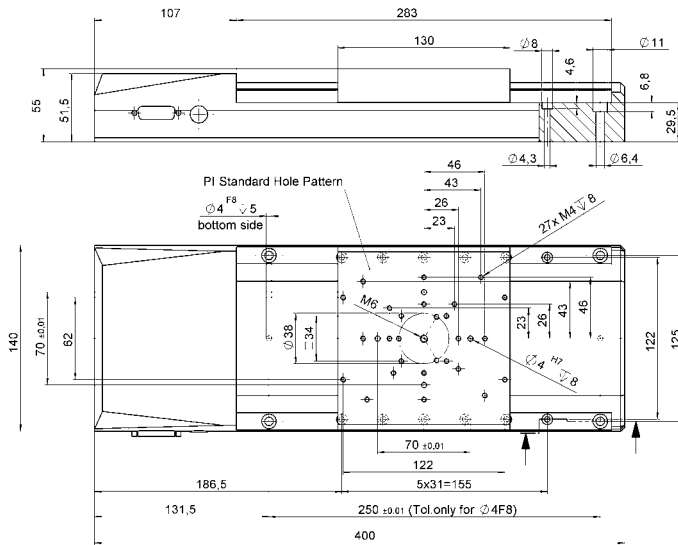
encoder) with a calculated, smooth trajectory in real time. Its complex control algorithms continuously actuate both the piezoelectric and servo motor drives in a way to provide the best possible overall performance.

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.

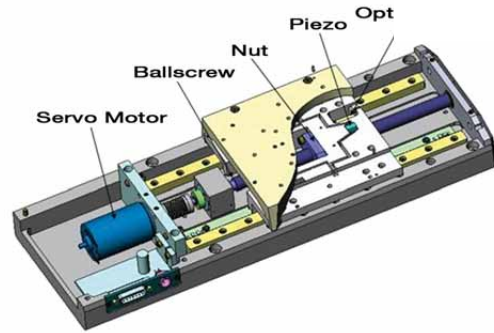


### Application Examples

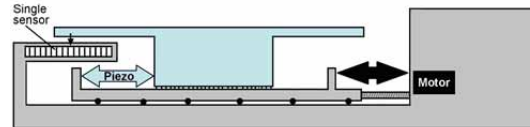
- Surface Inspection
- Microscopy
- Laser technology
- Interferometry
- Metrology



M-511.HD1, dimensions in mm. Sub-D connector 26-pin, 3 m cable



Working principle of the M-511.HD1. 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

<b>Model</b>	<b>M-511.HD1</b>
Active axes	X
<b>Motion and positioning</b>	
Travel range	100 mm
Integrated sensor	Linear encoder
Sensor resolution	0.5 nm
Design resolution	0.5 nm
Min. incremental motion	2 nm
Hysteresis at the platform	0.01 $\mu\text{m}$
Unidirectional repeatability	0.01 $\mu\text{m}$
Accuracy	<0.05 $\mu\text{m}$
Pitch	$\pm 25 \mu\text{rad}$
Yaw	$\pm 25 \mu\text{rad}$
Straightness	1 $\mu\text{m}$
Flatness	1 $\mu\text{m}$
Max. velocity	50 mm/s
Origin repeatability	1 $\mu\text{m}$
<b>Mechanical properties</b>	
Drive screw	Recirculating ballscrews
Guiding	Precision linear guiding rails, recirculating ball bearings
Screw pitch	2 mm/rev.
Max. load	200 N
Max. push/pull force	80/80 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
Operating voltage (motor)	24 V
Electrical power	30 W
Piezo drive type	PICMA® Multilayer piezo with flexure
Piezo voltage	$\pm 36 \text{ V}$
Limit and reference switches	Hall-effect
<b>Miscellaneous</b>	
Operating temperature range	-20 to +65 °C
Material	Al (black anodized)
Mass	5.1 kg
Recommended controller/driver	C-702 hybrid motor controller (p. 4-118)

# 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

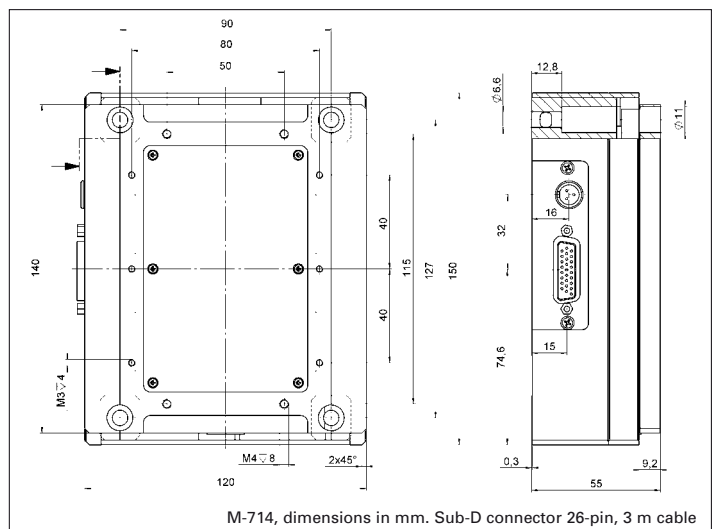
**Ask about custom designs!**

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

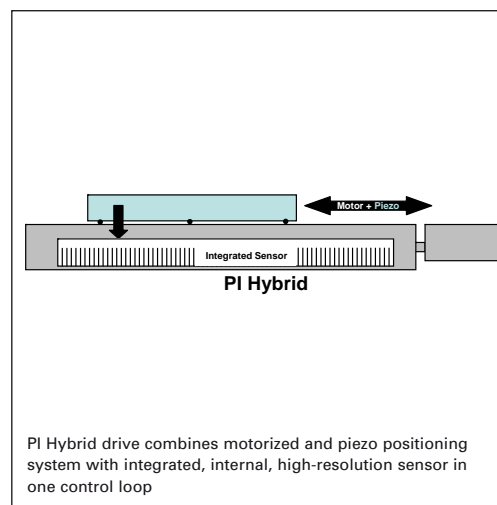
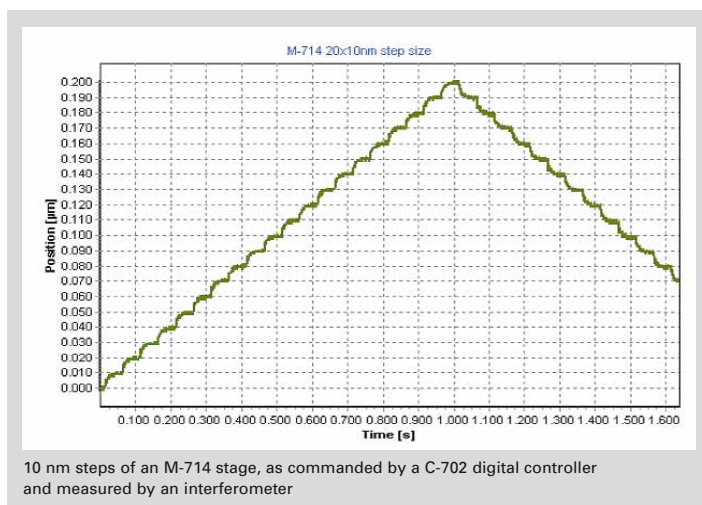
The M-714.2HD positioning system is optimized for vertical operation. If horizontal operation is intended, please note with your order.



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

### 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)

# 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

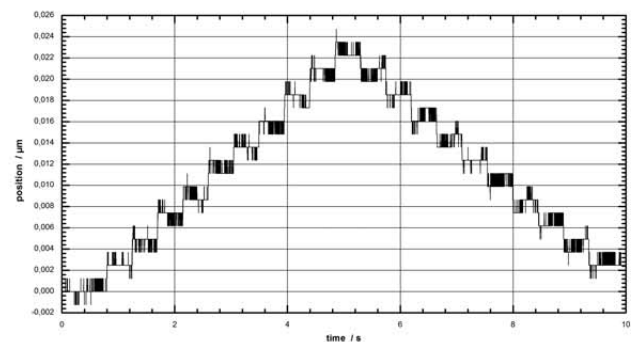
High-precision linear encoder PIONe with subnanometer resolution

#### Application fields

Research and industry. Option: vacuum version

#### Related Products

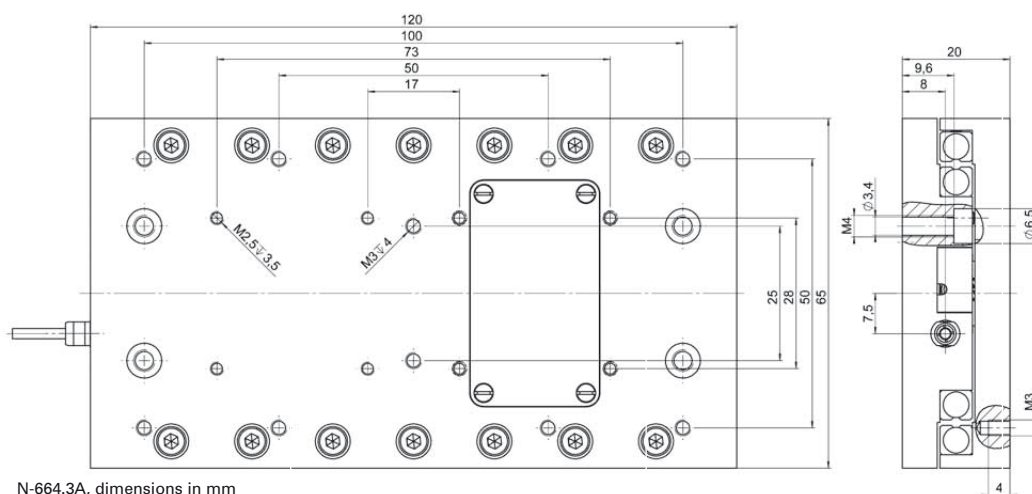
- M-511.HD Nano-Precision Heavy-Duty Stage
- N-661 Miniature Linear Stage with NEXACT® Drive



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

	N-664.3A	Units	Tolerance
Active axes	X		
<b>Motion and positioning</b>			
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 $\mu\text{m}$ ) along the entire travel range; 0.03% (5 nm) along 20 $\mu\text{m}$		
Bidirectional repeatability	< 10	nm	
Pitch	40	$\mu\text{rad}$	typ.
Yaw	40	$\mu\text{rad}$	typ.
<b>Mechanical properties</b>			
Stiffness in motion direction	2.5	N/ $\mu\text{m}$	$\pm 20\%$
Max. load	20	N	
Max. push / pull force (active)	10	N	max.
Max. holding force (passive)	15	N	min.
Lateral force	50	N	max.
<b>Drive properties</b>			
Drive type	NEXACT® linear drive		
Operating voltage	-10 to +45	V	
<b>Miscellaneous</b>			
Operating temperature range	0 to 50	$^{\circ}\text{C}$	
Material	Aluminum, nickel-plated		
Mass	530	g	$\pm 5\%$
Cable length	1.5	m	$\pm 10$ 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



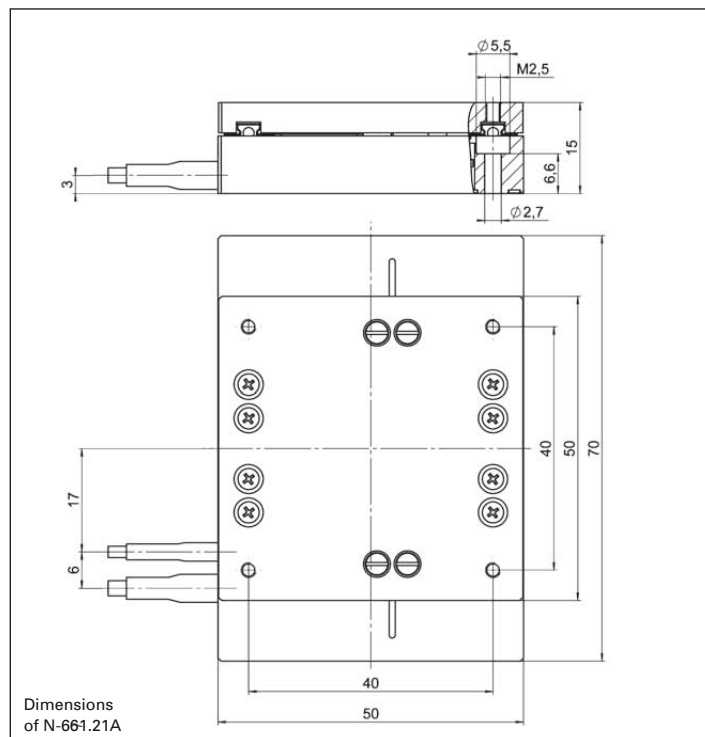
# N-661 Miniature Linear Slide with NEXACT® Drive

## 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**



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 tuning, 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
<b>Motion and positioning</b>	
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*
<b>Mechanical properties</b>	
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
<b>Drive properties</b>	
Drive type	NEXACT® linear drive
Operating Voltage	-10 V to +45 V
<b>Miscellaneous</b>	
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.