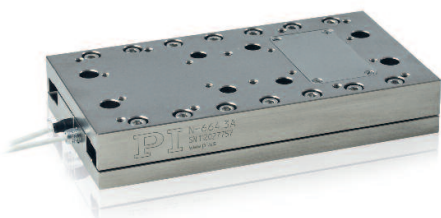
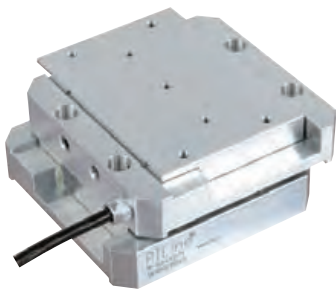
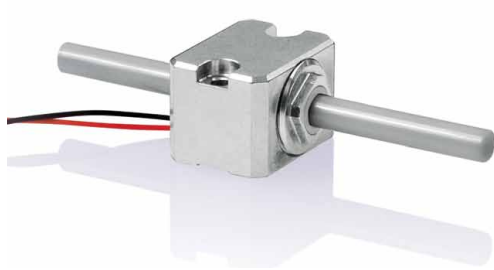


## Piezoceramic Motors/ Positioners

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# PIShift Piezoelectric Inertia Drives

LOW-COST LINEAR STICK-SLIP MOTORS

- Compact, multi-purpose linear drive
- Flexible travel ranges
- Easy mechanical integration
- Self-locking at rest
- Holding force to 10 N
- Velocity over 5 mm/s
- Simple, low-cost control



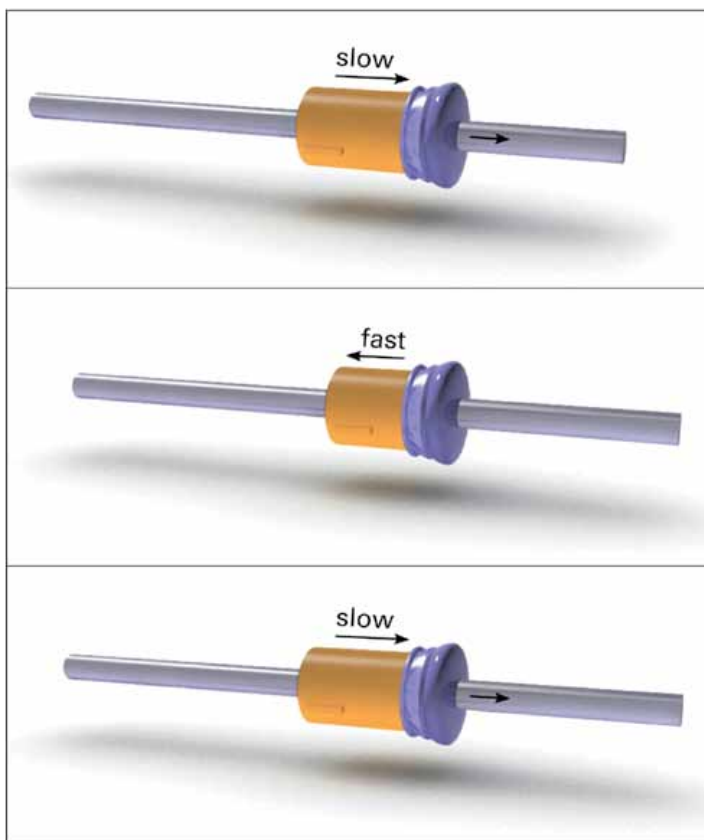
PIShift are space-saving and low-cost piezo-based inertia drives with relatively high holding forces of up to 10 N and a travel range that is only limited by the length of the moving rod. They make use of the stick-slip effect – a cyclical alternation of static and sliding friction between a moving runner and the drive element. The driving force behind this principle is a small piezo actuator operating at a frequency of more than 20 kHz and achieving velocities of more than 5 mm/s.

### Silent and energy-saving

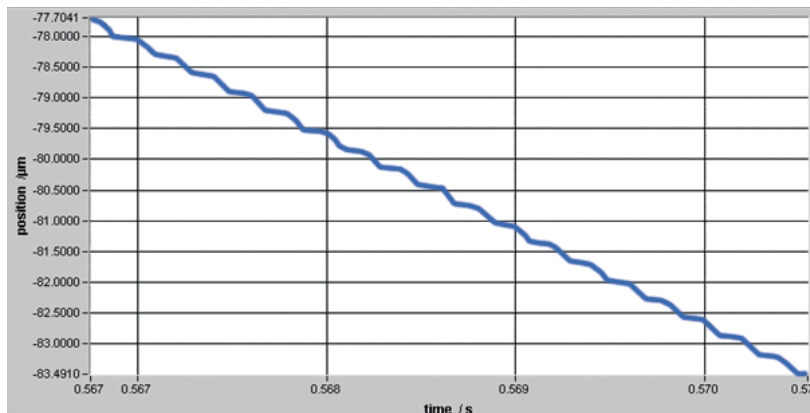
The drive works silently at this frequency. At a standstill, the drive produces its maximum clamping force, with zero holding current and no heat generation.

### Easy integration

For easy integration, the static housing can either be bolted to a level surface or mounted via a threaded flange. The load is coupled to the moving runner. Compact drive electronics are available in single or multi-channel versions and can be controlled via analog or digital interfaces. The piezo drive element in the actuator requires less than 50 V operating voltage.



The PIShift drive principle is based on a single piezo actuator that is controlled with a modified sawtooth voltage provided by a special drive electronics. The actuator expands slowly taking along the runner. When the piezo element contracts quickly, the runner cannot follow due to its inertia and remains at its position.

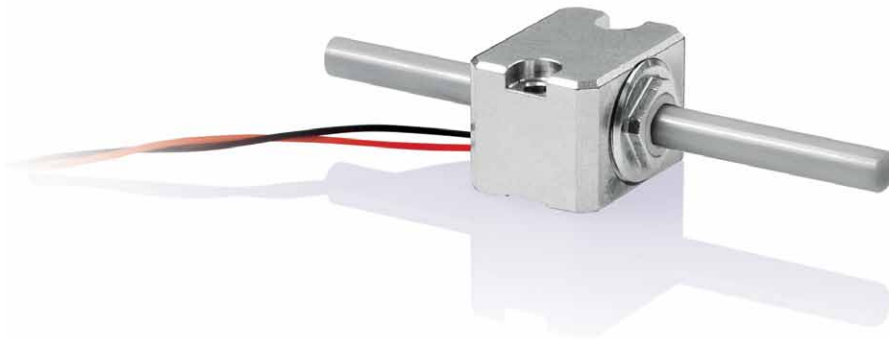


A full cycle produces a feed of typically 300 nanometers. The mechanical components are designed so that there is minimum backstep during the fast contraction.

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# Linear Actuator with PIShift Stick Slip Motor

COST-EFFECTIVE AND EASY TO INTEGRATE



## N-412 • N-422

- Simple integration: Two mounting versions
- Quiet: Drive frequency >20 kHz
- Velocity over 5 mm/s
- Sub-micron resolution
- Holding force to 10 N

### Piezomotor-based direct drive

OEM actuator without position sensor. Continuous motion with step frequencies in the ultrasound range. Easy integration, the housing can either be bolted to a level surface (N-412) or mounted via a threaded flange (N-422)

### PIShift inertia drive

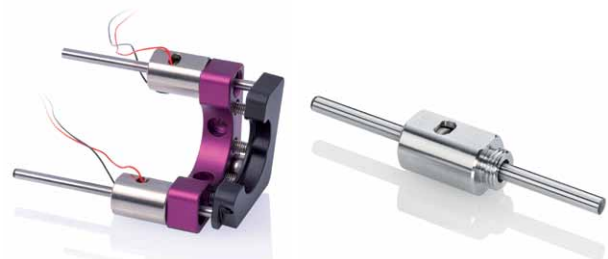
Self-locking, no heat generation at rest. Noiseless drive with operating frequencies beyond 20 kHz. Resolution in step mode approx. 300 nm, open-loop

### Fields of application

Research and industry. Alignment of optical elements, micromanipulation, biotechnology, cell manipulation, medical technology

### Recommended controller / amplifier

E-870 PIShift drive electronics



PIShift drives mounted in a cardanic N-412.50 for mounting via the threaded flange mirror for aligning the tilting angles

### Related products

- N-310 NEXACT® OEM miniature linear motor/actuator
- N-381 NEXACT® linear actuator, manipulator, piezo stepper
- U-264 RodDrive piezomotor direct drive
- M-272 ceramic linear drive for automation

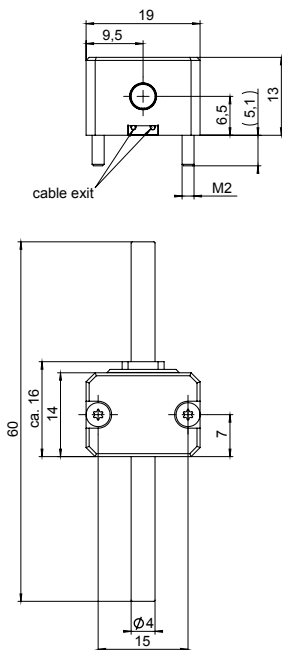
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Perliminary Data	N-412.50	N-422.50	Unit	Tolerance
Active axes	X	X		
<b>Motion and positioning</b>				
Travel range	30	40	mm	
Step frequency*	>20	>20	kHz	max.
Max. velocity*	5	5	mm/s	min.
<b>Mechanical properties</b>				
Stiffness in motion direction	>4	>4	N/ $\mu$ m	$\pm 20\%$
Push / pull force (active)	5	7	N	max.
Max. holding force (passive)	10	10	N	min.
<b>Drive properties</b>				
Drive type	PIShift inertia drive	PIShift inertia drive		
Operating voltage	48	48	V <sub>pp</sub>	max.
Power consumption	15 W (actuator) 30 W (drive input)	15 W (actuator) 30 W (drive input)	W	nominal
<b>Miscellaneous</b>				
Operating temperature range	0 to 50	0 to 50	$^{\circ}$ C	
Material**	Stainless steel	Stainless steel		
Dimensions	$\varnothing$ 18 mm, length 26 mm + rod	21,5 mm x 18 mm x 13 mm + rod		
Mass	25	25	g	$\pm 5\%$
Cable length	1,5	1,5	m	$\pm 10$ mm
Connector	DIN 4-pin	DIN 4-pin		
Recommended controller / driver	E-870 PIShift drive electronics	E-870 PIShift drive electronics		

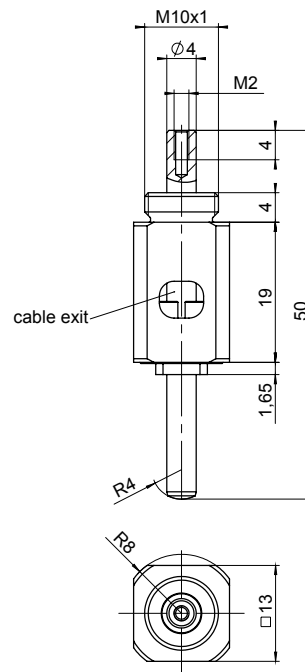
Ask about custom designs!

\* Depending on drive electronics.

\*\* Ceramic rod.



N-422.50, dimensions in mm. Version for mounting on an even surface vertical to the direction of motion



N-412.50, dimensions in mm. Version for mounting on the front via the M10 threaded flange

**KEY FEATURES**

- Piezo stick slip motor with subnanometer resolution
- Travel range up to 26 mm (1")
- Uni-directional repeatability down to 0.018  $\mu\text{m}$
- Maximum speed 10 mm/sec
- Load capacity up to 1 kg
- Encoder resolution 1 nm
- Optional integrated linear scale

The LPS-45 is a low profile linear stage utilizing piezo stick slip motor for increased precision and load capacity. The big platform and the cross roller bearing are guaranteeing a smooth and high accurate movement in the range of sub nanometer. LPS-45 stages can be controlled with our E-871 closed loop piezo controller. The optional linear encoder provides nanometer repeatability. Vacuum compatible and non magnetic versions are available.

**LINEAR PIEZO STAGE LPS-45**



**Six axes micro robot system**



With one SpaceFAB 450 PS all six degrees of freedom can be moved without additional positioning elements.

**TECHNICAL DATA**

Travel range (mm)	13	26
Straightness / Flatness ( $\mu\text{m}$ )	$\pm 1$	$\pm 2$
Pitch ( $\mu\text{rad}$ )	$\pm 50$	$\pm 80$
Yaw ( $\mu\text{m}$ )	$\pm 50$	$\pm 80$
Weight (kg)	0.13	0.145
Motor	PM-013	
Linear scale		LS-013
Speed max. (mm/sec)	10	
Resolution calculated ( $\mu\text{m}$ )		0.001
Resolution typical ( $\mu\text{m}$ )	0.5	0.006
Bi-directional Repeatability ( $\mu\text{m}$ )		$\pm 0.018$
Uni-directional Repeatability ( $\mu\text{m}$ )		0.018
Nominal Current (A)		
Accuracy		on request
Velocity range (mm/sec)		0.005 ... 10
Material		Aluminum, black anodized

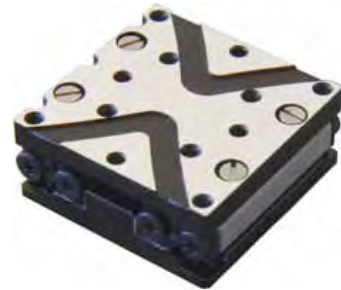
Note: FS = full step, RE = rotary encoder  
 More info: Detailed information concerning motors and encoders, see appendix.

**KEY FEATURES**

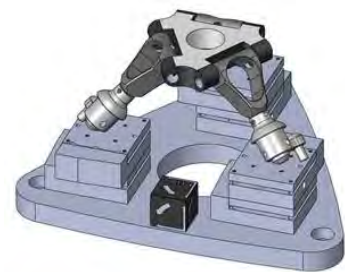
- Piezo stick slip motor with subnanometer resolution
- Travel range up to 26 mm (1")
- Uni-directional repeatability down to 0.020 μm
- Maximum speed 10 mm/sec
- Load capacity up to 0.2 kg
- Encoder resolution 1 nm
- Optional integrated linear scale

The LPS-23 is a low profile linear stage utilizing piezo stick slip motor for increased precision and load capacity. The big platform and the cross roller bearing are guaranteeing a smooth and high accurate movement in the range of sub nanometer. LPS-23 stages can be controlled with E-871 closed loop piezo controller. The optional linear encoder provides nanometer repeatability. Vacuum compatible and non magnetic versions are available.

**LINEAR PIEZO STAGE LPS-23**



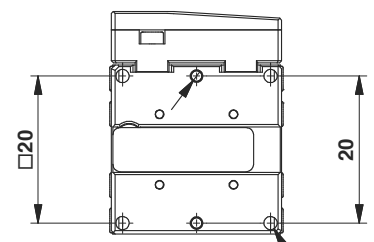
Six axes micro robot system



With one SpaceFAB 230 PS all six degrees of freedom can be moved without additional positioning elements.

**TECHNICAL DATA**

Travel range (mm)	13	26
Straightness / Flatness (μm)	± 2	± 4
Pitch (μrad)	± 80	± 110
Yaw (μm)	± 80	± 80
Motor	PM-014	
Linear scale		LS-013
Speed max. (mm/sec)	10	
Resolution calculated (μm)		0.001
Resolution typical (μm)	0.5	0.01
Bi-directional Repeatability (μm)		± 0.02
Uni-directional Repeatability (μm)		0.02
Nominal Current (A)		
Accuracy	on request	
Velocity range (mm/sec)	0.5 ... 10	
Material	Aluminum, black anodized	



Note: FS = full step, RE = rotary encoder  
 More info: Detailed information concerning motors and encoders, see appendix.

# Stick / Slip Drive Electronics

VERSATILE AND COST-EFFECTIVE



## E-870

- For PIShift and PiezoMike piezo inertia drives
- Ideal for OEM applications
- One to four actuators, serial control (through demultiplexing)
- With digital USB interface

### Drive electronics for one to four axes

OEM module with solder pins or on carrier board with connectors and terminal strips for the operation of open-loop PIShift piezo inertia drives

### Operating modes

Full-step mode, max. piezo voltage 0 to 100 V (configurable). Various command modes. Configuration of the operating parameters can be programmed via USB or via hardware settings. Serial control of up to 4 actuators by one unit

### Interfaces

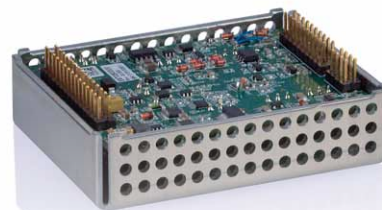
USB for control, configuration and for firmware updates. Interfaces for TTL and analog control. Optional SPI interface

### Fields of application

Lab automation, medical technology, handling

### Related products

N-412 • N-422 PIShift linear actuator



E-870.10: Single-channel driver for piezo inertia drives (to be plugged in or soldered)



The E-870.41 allows the serial control of up to four PIShift or PiezoMike actuators through demultiplexing

Perliminary Data	E-870.10	E-870.11	E-870.41
Function	Drive electronics for PIShift linear drives, OEM circuit board with solder pins	Drive electronics for PIShift linear drives, OEM circuit board with connectors	Drive electronics for PIShift linear drives, OEM circuit board with connectors
Channels	1	1	4 (serial control through demultiplexing)
<b>Amplifier</b>			
Channels	1	1	1 (4-fold demultiplexing)
Output voltage	0 to 100 V	0 to 100 V	0 to 100 V
Peak output power	30 W	30 W	30 W
Output current/channel (<5 ms)	±650 mA	±650 mA	±650 mA
<b>Interface and operation</b>			
Communication interfaces	USB 2.0, analog Interface, ±10 V, 10 bit ADC, TTL inputs	USB 2.0, analog Interface, ±10 V, 10 bit ADC, TTL inputs	USB 2.0, analog Interface, ±10 V, 10 bit ADC, TTL inputs
Actuator connection	Solder pins	DIN 4-pin	DIN 4-pin
Analog and digital inputs	Solder pins	Terminal strip	Terminal strip
Digital output	Overtemperature protection indicated at 75°C, operating status and error output		
Command set	PI GCS 2	PI GCS 2	PI GCS 2
User software	Configuration and operation tool	Configuration and operation tool	Configuration and operation tool
Software drivers	LabVIEW driver, shared libraries for Windows	LabVIEW driver, shared libraries for Windows	LabVIEW driver, shared libraries for Windows
Supported functionality	Alternative command modes: pulse-controlled, pulse slope-controlled, quadrature decoder control, analog velocity control		
Display	–	LED display for operation, error status and overtemperature protection	LED display for operation, error status and overtemperature protection
Manual control	–	Integrated pushbutton control forwards/backwards, joystick via USB	Integrated pushbutton control forwards/backwards, joystick via USB
<b>Miscellaneous</b>			
Operating temperature range	0 to 50°C	0 to 50°C	0 to 50°C
Overtemp protection	Deactivation at 85°C	Deactivation at 85°C	Deactivation at 85°C
Dimensions	76 mm × 61 mm × 20 mm	92.5 mm × 104 mm × 36 mm	92.5 mm × 105 mm × 36 mm
Mass	100 g	172 g	185 g
Operating voltage	12 to 24 V (power supply not included in the scope of delivery)	12 to 24 V (power supply not included in the scope of delivery)	12 to 24 V (power supply not included in the scope of delivery)
Max. power consumption	35 W	35 W	35 W



## Networkable Servo Controller for Stick-Slip Piezo Motors

1 AXIS, FOR POSITIONERS WITH PISHIFT INERTIA DRIVES



### E-871

- Broadband encoder input
- Macro programmable for stand-alone functionality
- Data recorder
- Non-volatile EEPROM for macros and parameters

#### Digital servo controller for PIShift piezomotors

1 channel. Integrated power amplifier and voltage generator for PIShift piezo inertia drives. Point-to-point motion, actuator mode for nanometer-precise positioning to target position

#### Extensive functionality

Powerful macro command language. Non-volatile macro storage, e. g. for stand-alone functionality with autostart macro. Data recorder. ID chip for quick start-up, parameter changes on-the-fly. Extensive software support, e. g. for LabVIEW, shared libraries for Windows and Linux

#### Mercury class motion controller

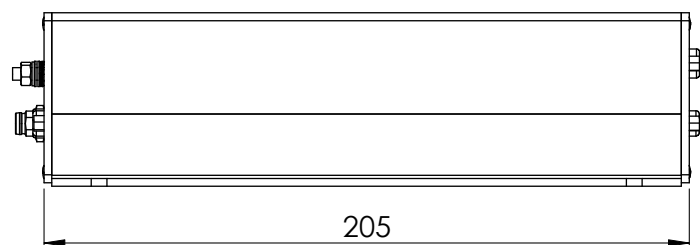
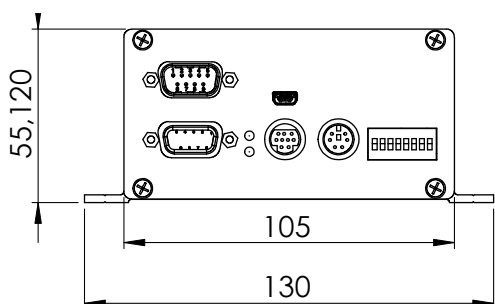
Daisy-chain networking for up to 16 axes operated via a common computer interface.

Interfaces: USB and RS-232 for commands. A/B (quadrature) encoder input. TTL inputs for limit and reference point switches. I/O ports (analog/digital) for automation. Interface for analog joystick.

Delivery scope including wide-range power supply, USB and RS-232 cable, daisy-chain network cable

E-871.1A1	
Function	Piezomotor controller for PIShift drives and positioning systems
Channels	1
<b>Motion and control</b>	
Servo characteristics	PID controller, parameter changes on-the-fly
Encoder input	Analog encoder input sine-cosine, interpolation selectable up to 20000; Interpolation circuit for differential transmission 1 V <sub>pp</sub> and 2.5 V offset of the encoder signal
Stall detection	Servo off
Input limit switch	2 × TTL (pull-up/pull-down, programmable)
Input reference switch	1 × TTL and Zero+ & Zero- for integrated reference in the encoder
<b>Electrical properties</b>	
Max. output power	30 W
Output voltage	0 to 100 V, drive-dependent selection
Max. operating current	1.5 A
<b>Interface and operation</b>	
Communication interfaces	USB, RS-232 (9-pin (m) Sub-D)
Motor connector	HD Sub-D 15-pin (f)
Sensor connection	HD Sub-D 15-pin (m)
Controller network	Up to 16 units on single interface*
I/O ports	4 analog/digital in, 4 digital out
Command set	PI General Command Set (GCS)
User software	PIMikroMove, PITerminal
Software drivers	LabVIEW driver, shared libraries for Windows and Linux
Supported functionality	Point-to-point motion, start-up macro, data recorder for recording parameters as motor input voltage, position or position error; internal safety circuitry: watchdog; ID chip
Manual control (optional)	Pushbutton box, joystick (for 2 axes), Y-cable for 2-D motion
<b>Miscellaneous</b>	
Operating voltage	24 V; included: external power supply, 24V; 2.0 A
Operating temperature range	0 to 50°C
Mass	1.1 kg
Overtemp protection	75°C
Dimensions	205 mm × 130 mm × 55 mm (incl. mounting rails)

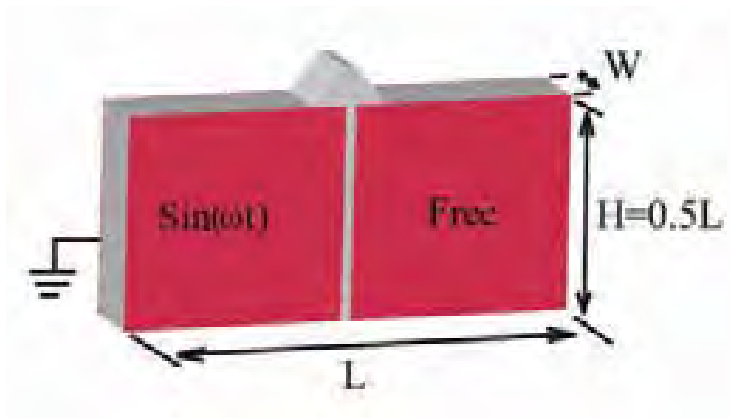
\* 16 units via USB; 6 units via RS-232.



E-871, dimensions in mm

## PILine® Ultrasonic Piezomotors

COMPACT DRIVES, FAST AND SELF-LOCKING



Latest PI Catalogs:  
[www.pi.ws](http://www.pi.ws)

# Ultrasonic Piezo Motor Basics

## PILine® Ultrasonic Piezomotors – Working Principle

PILine® linear piezomotors are based on a novel, patented ultrasonic drive developed by PI. At the heart of the system is a rectangular monolithic piezoceramic plate (the stator), segmented on one side by two electrodes. Depending on the desired direction of motion, the left or right electrode of the piezoceramic plate is excited to produce high-frequency eigenmode oscillations at tens to hundreds of kilohertz. An alumina friction tip (pusher) attached to the plate moves along an inclined linear path at the eigenmode frequency. Through its contact with the friction bar, it provides micro-impulses that drive the moving part of the mechanics (slider, turntable, etc.) forward or backwards. With each oscillatory cycle, the mechanics executes a step of a few nanometers; the macroscopic result is smooth motion with a virtually unlimited travel range. The driving force is taken from the energy in the longitudinal oscillation component. The transverse component serves to increase / decrease the pressure of the friction tip against the friction bar. The transverse oscillation energy determines the maximum frictional force and hence the holding and driving force of the motor. State-of-the-art ultrasonic motors can produce

accelerations to 10 g and velocities to 500 mm/s. Ultrasonic motors cannot provide the unlimited resolution of linear piezo actuators and flexure-guided piezo positioning stages. These motors transfer motion through friction, which is why their repeatability is limited to about 50 nm. Much higher resolution and holding forces can be achieved with PiezoWalk® piezomotors / drives.

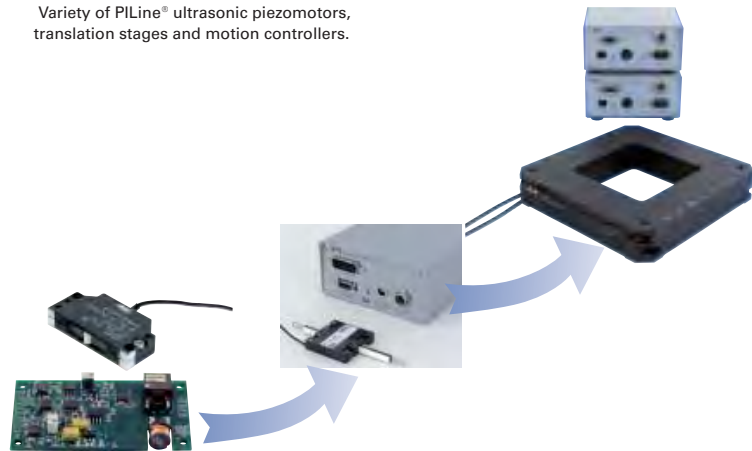
### PILine® Levels of Integration

PILine® ultrasonic drive products are offered in three different levels of integration. The drive electronics and controller can be chosen accordingly.

- P-661 and P-664 OEM motors require the greatest amount of care at the customer's site. Motor and friction bar – the length depends on the travel range – have to be integrated into a mechanical setup. Operation requires preload of the motor against the friction bar, guiding and, if necessary, the servo-loop.
- M-674 RodDrives can replace classical drive elements like rotary motor / leadscrew assemblies, or magnetic linear drives integrated into a micropositioner or handling device. Integration requires guiding and – if necessary – the servo-loop.



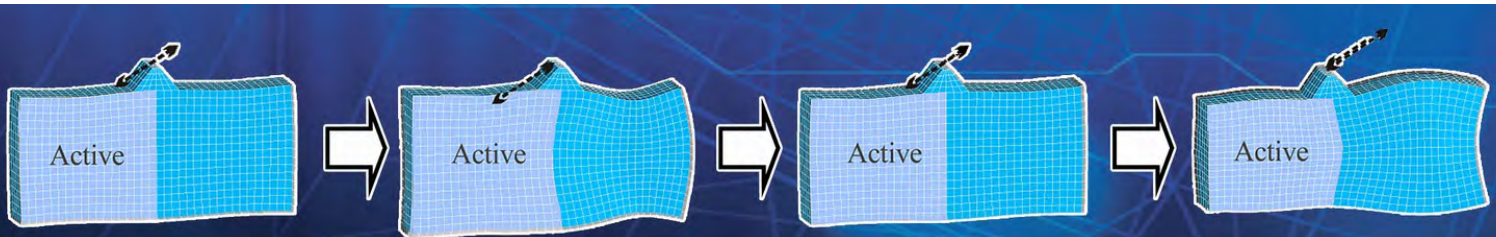
Variety of PILine® ultrasonic piezomotors, translation stages and motion controllers.



PILine® levels of integration: OEM motor, RodDrive, linear positioning stage.

- Linear positioning stages represent the highest level of manufacturer integration. The piezomotor is integrated completely in a high-quality mechanical setup including if necessary the servo-loop with direct-metrology linear encoders.

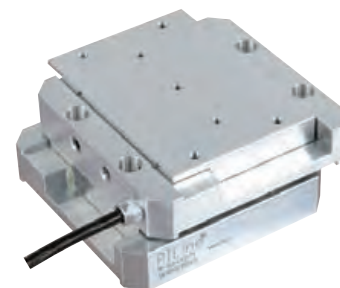
PILine® ultrasonic motors are based on a simple construction allowing for the design of low-cost drive units and extremely compact, high-speed micro-positioning stages smaller than a matchbox.



# Ultrasonic Piezo Motor Basics

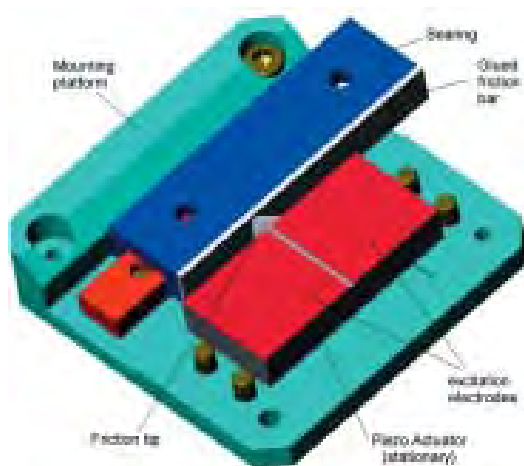
## Features and Advantages of PLine® Ultrasonic Piezomotors

- **Compact Size:** the direct-drive principle allows the design of ultra-compact translation stages. The M-662, for example, provides 20 mm travel in a 28 x 28 x 8 mm package.
- **Low inertia, high acceleration, speed and resolution:** PLine® drives achieve velocities to 500 mm/s and accelerations to 10 g. They are also very stiff, a prerequisite for their fast step-and-settle times – on the order of a few milliseconds – and provide resolution to 0.05 µm. The lack of a leadscrew means no lubricant flow or material relaxation to cause sub-micron creep. There is also no rotational inertia to limit acceleration and deceleration.
- **Excellent Power -to-Weight Ratio:** PLine® drives are optimized for high performance in a minimum package. No comparable drive can offer the same combination of acceleration, speed and precision.
- **Safe:** The minimum inertia of the moving platform together with the “slip clutch” effect of the friction drive provide better protection of precision fixtures / devices than leadscrew-driven stages. Despite the high speeds and accelerations, there is a much lower risk of pinching fingers or other injuries than with conventional drives. This means users may not need interlocks, light curtains or other measures to keep them safe.
- **Self-Locking Feature:** PLine® drives create a braking force when not energized without the position shift common with conventional mechanical brakes. Other benefits of the self-locking are the elimination of servo dither and

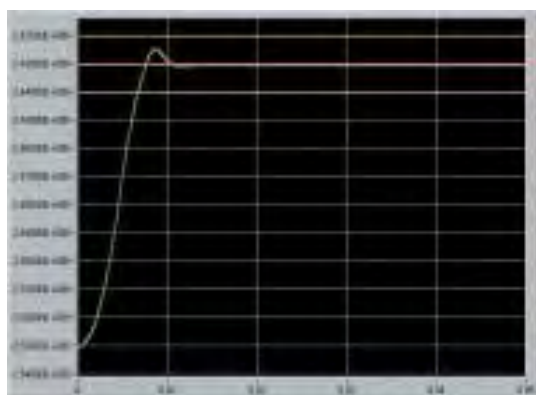


steady-state heat dissipation.

- **Vacuum Compatibility:** Vacuum compatible versions of PLine® drives are available.
- **Negligible EMI:** PLine® drives do not create magnetic fields nor are they influenced by them, a decisive advantage in many applications.
- **Custom Solutions / Flexibility for OEMs:** PLine® drives are available in open-loop and closed-loop translation stages and as OEM components. PI develops and manufactures all piezo ceramic components in-house. This gives us the flexibility to provide custom motors (size, force, environmental conditions) for OEM and research applications.
- **Quality, Lifetime, Experience:** Based on PI's 30+ years of experience with piezo nano-positioning technology, PLine® drives offer exceptional precision and reliability with an MTBF of >20,000 hours. Rotating components such as gears, shafts and moving cables that are prone to failure in conventional motion systems, are not part of the PLine® design.



Principle design of a PLine® ultrasonic piezomotor-driven translation stage.



Settling behavior of a PLine® M-663 linear stage, 100 µm step. A stable position to within 0.1 µm can be reached in only 10 ms.

Custom high-force ultrasonic piezo motors can provide forces to 50N.







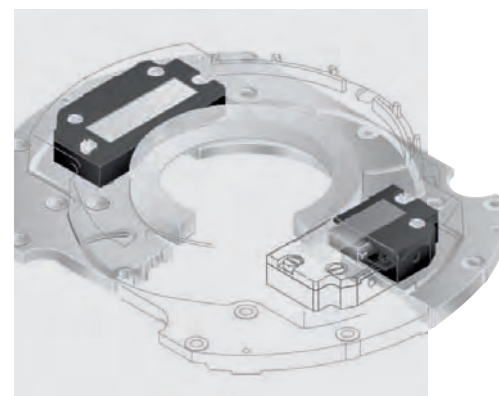
### Technical Progress with Ultrasonic Piezomotors



they generate high holding forces even when no electrical power is applied, they run extremely quiet and operate at ambient temperatures between  $-20\text{ }^{\circ}\text{C}$  and  $+50\text{ }^{\circ}\text{C}$ .



OEM ultrasonic piezo linear motor U-164.01

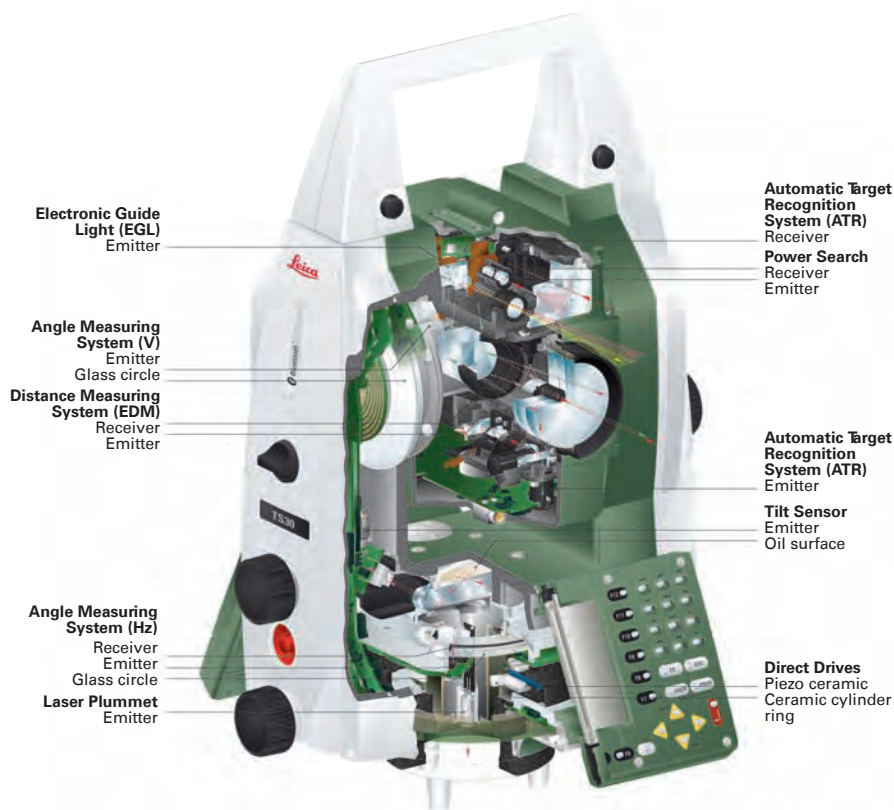


The rotations are produced by two U-164 ultrasonic motors that are preloaded against a friction ring. (Photo: Leica Geosystems AG/ Physik Instrumente (PI))

Leica Geosystems AG benefits from PLine® ultrasonic motors employed in their new generation of surveying instruments for geodesy. The requirements for the drive of the new “Leica TS30” total station were, amongst others, higher speeds, shorter positioning times and a very high positioning accuracy when moving the measuring optics.

These requirements were exceeded by far through the employment of PLine® ultrasonic motors. PI’s U-164 piezomotor was chosen for the vertical as well as the horizontal movement of the measuring optics. Rotations are produced by two such motors which are preloaded against a pivot mounted friction ring doubling as a brake when at rest. In operation, the ceramic piezomotors

oscillate with ultrasonic frequencies. Generating a feed motion of the friction ring. This principle of operation provides unrivalled speeds of  $>180\text{ }^{\circ}/\text{sec}$  and high accelerations of up to  $360\text{ }^{\circ}/\text{s}^2$  and an angular measuring accuracy of  $0.5\text{ }''$ . The drive also improves starting and stopping behavior and reduces power consumption. The maintenance-free motors are self locking, i.e.



The cross-section of the total station shows the limited installation space available for the drives  
(Photo: Leica Geosystems AG, Switzerland)

As the above example illustrates, ultrasonic piezomotors continuously expand into new fields of application. Given their great flexibility,

it is hard to predict which application will benefit next from these novel drive systems.

## Fast, Compact & Energy Efficient

### OEM Ultrasonic Piezo Motors

U-164 ultrasonic piezo motors are particularly compact, reliable and maintenance-free drives which are self-locking when at rest and intrinsically non-magnetic and vacuum-compatible. In the application, they provide as yet unrivalled speeds and accelerations while offering a high positioning resolution and low power consumption.

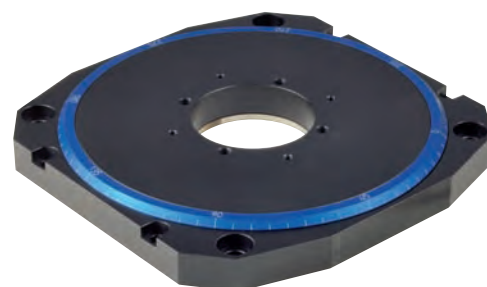
With its PLine® series PI offers a broad range of positioning systems with piezo ultrasonic motors: From simple motors to fully integrated custom solutions.

## Rotation Stage with 720 °/s is only 15 mm High: PLine® Technology Makes it Possible

The M-660 PLine® ultra-low-profile rotation stage opens up new possibilities in fast positioning, from microscopy or biotechnology to test systems of mass storage. The stage achieves a speed of up to 120 RPM. The integrated U-164 PLine® linear motors provide a torque of 0.3 Nm and the stage is designed for a maximum load of 1 kg. These ultrasonic piezo motors transfer force to a ceramic friction ring mounted on the moving platform and they are self-locking when at rest. An integrated optical encoder provides position feedback with 40 µm resolution.

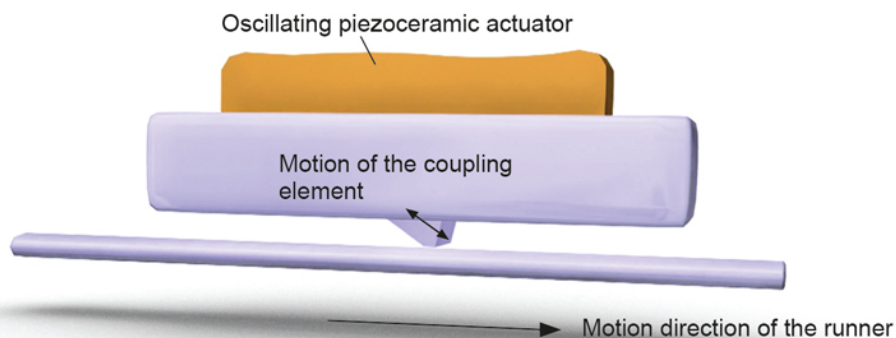
### M-660 in figures:

- Ultra-low profile, 15 mm high, 35 mm Ø aperture
- Maximum speed 720 °/s, direct Encoder, 40 µrad resolution
- Self-locking: Ceramic direct drive provides significantly higher positional stability than classic motors
- Compact combinations with translation stages possible



# PILine® Ultrasonic Piezomotors

COMPACT DRIVES, FAST AND SELF-LOCKING



- Integration levels from economical OEM motors to multi-axis positioning systems
- Excellent dynamic properties, fast step & settle
- Basically unlimited travel ranges
- Easy mechanical integration
- Self-locking at rest
- Holding force up to 15 N
- Velocity up to 500 mm/s
- Resolution to 0.05 µm (50 nm)

### Direct-driven PILine® linear motors

These linear drives dispense with the mechanical complexity of classical rotary motor/gear/leadscrew combinations. These components can be very susceptible to wear, especially in miniaturized systems.

The simplicity of the ultrasonic linear motor promotes its precision, reliability and cost efficiency. An integral part of the ultrasonic piezomotor is a piezo ceramic that is preloaded against a moving runner with a coupling

element. The piezo element is electrically excited to produce high-frequency oscillations that cause the runner to move.

### Piezomotors are self-locking

The preload of the piezoceramic actuator against the runner ensures that the drive self-locks at rest and when powered down. As a result, it does not consume any power, it does not heat up and keeps the position stable mechanically. Applications with a short duty cycle, that are battery-operated or heat-sensitive benefit from these characteristics.

### Lifetime and reliability

The motion of the piezoceramic actuator is based on crystalline effects and is not subject to any wear. The coupling to the runner, on the other hand, is subject to friction effects. Depending on the operating mode, running distances over 2000 km or a MTBF of 20000 hours are achieved.

### Dynamics in use

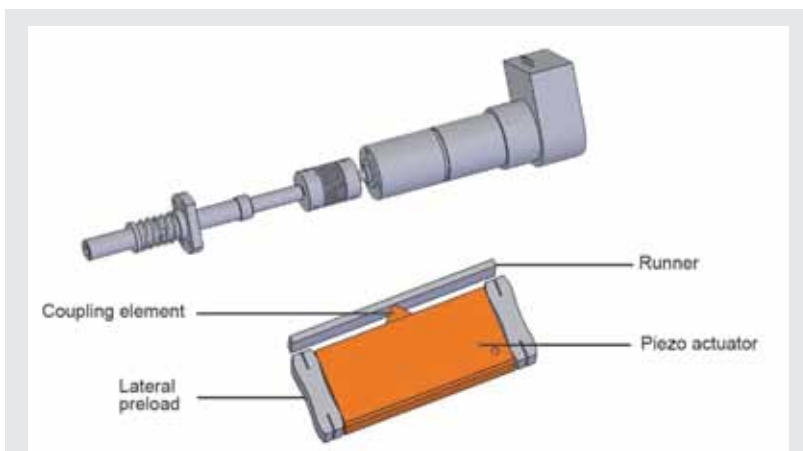
The stiff design, direct coupling and fast response of the piezo ceramics to electric inputs allows for very fast start / stop behavior and velocities to hundreds of mm/sec.

### Patented technology

The products described in this document are in part protected by the following patents:

US Pat. No. 6,765,335B2

European Patent No. 1267425B1



Motor-lead screw combinations (above) transform the rotational motion of the motor into linear motion. Due to play in the mechanical components responsiveness is limited. Linear motors such as PILine® generate linear motion directly and provide much faster response and better stability



**Piezomotors for all applications – e. g. in vacuum environments and strong magnetic fields**

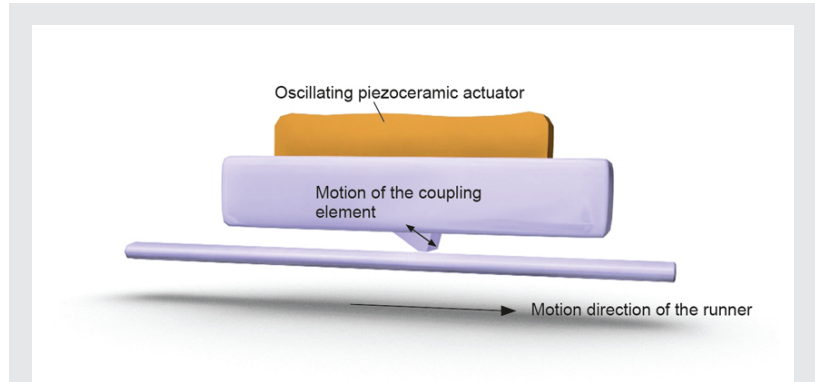
Piezomotors from PI are intrinsically vacuum-compatible and suitable for operation in strong magnetic fields. Special versions are offered for this purpose. Nanometer resolution or forces up to several 100 N can be achieved with PiezoWalk® linear motors.



The benefit of the low profile PLine® drives becomes apparent with positioning systems such as the M-660 rotation stage (left, 14 mm high) or the M-687 microscopy XY stage (right, 25 mm high): a consistently flat design without lead screw ducts or flanged motors



Implementation of rotary motion: PLine® motors act on a ring-shaped runner



The piezoceramic actuator is excited with a high frequency electric signal (100 to 200 kHz). The deformation of the actuator leads to a periodic diagonal motion of the coupling element to the runner. The created feed is roughly 10 nm per cycle; the high frequencies lead to the high velocities



PLine® integration levels (left to right): OEM motor, U-264 RodDrive low-profile actuator (unguided) and M-272 closed-loop, guided linear actuator

# Rotation Stage with Direct Drive

LOW PROFILE, FAST



## M-660

- Low profile: Only 14 mm height
- Direct position measurement with up to 4  $\mu$ rad resolution
- Max. velocity 720 °/s
- Compact combinations with translation stages are possible
- Vacuum versions to  $10^{-6}$  hPa

### Precision-class rotation stage

With fast direct drive; unlimited slewing range. A vacuum-compatible version down to  $10^{-6}$  hPa is available

### PILine® piezo ultrasonic drive

Self-locking, no heat generation at rest. Excellent start/stop dynamics. Non-contact reference point switch

### Direct measuring principle

Non-contact measuring, optical linear encoder. Variants with different resolutions. High repeatability

### Valid patents

US Patent No. 6,765,335B2

European Patent No. 1267425B1

### Application fields

Research and industry. For micromanipulation, automation, optical metrology

### Related products

M-060 • M-061 • M-062 Precision Rotation Stage

M-116 Micro Rotation Stage

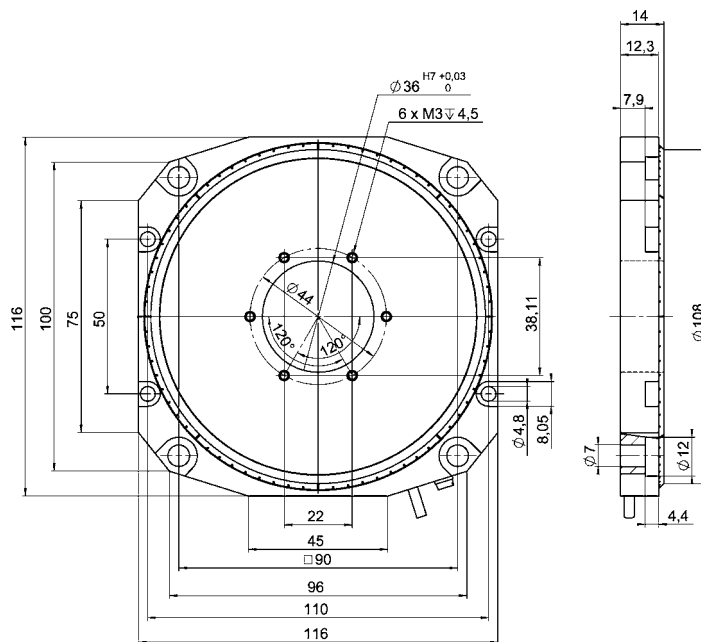
C-867 PILine® Motion Controller

	M-660.45	M-660.55	Unit	Tolerance
Active axes	$\theta_2$	$\theta_2$		
<b>Motion and positioning</b>				
Rotation range	No limit	No limit	°	
Integrated sensor	Incremental encoder	Incremental encoder		
Design resolution	4 (0.00023)	34 (0.00195)	$\mu\text{rad}$ (°)	typ.
Min. incremental motion	12	34	$\mu\text{rad}$ typ.	
Bidirectional repeatability	$\pm 24$	$\pm 68$	$\mu\text{rad}$	
Velocity	720	720	° / s	max.
<b>Mechanical properties</b>				
Load capacity/axial force	20	20	N	max.
Holding force	0.3	0.3	Nm max.	
Torque cw/ccw ( $\theta_2$ )	0.3	0.3	Nm max.	
<b>Drive properties</b>				
Motor type	U-164 PILine® ultrasonic piezomotor	U-164 PILine® ultrasonic piezomotor		
Reference point switch	Optical	Optical		
<b>Miscellaneous</b>				
Operating temperature range	-20 bis 50	-20 bis 50	°C	
Material	Al (black anodized)	Al (black anodized)		
Mass	470	470	g	$\pm 5 \%$
Cable length	1.3	1.3	m	$\pm 10 \text{ mm}$
Connector	MDR, 14-pin	MDR, 14-pin		
Recommended controller/driver	C-867 PILine® Motion Controller	C-867 PILine® Motion Controller		

Vacuum versions to  $10^{-6}$  hPa are available under the following order number: M-660.x5V.  
Ask about custom designs!



C-867 motion controller



M-660.55, dimensions in mm

# XY Stage with Piezoceramic Linear Motors

HIGH STABILITY AND SPEED, LOW-PROFILE, DIRECT POSITION MEASUREMENT



## M-686

- Higher stability with self-clamping linear motors
- Max. velocity 100 mm/s
- Very low profile of only 32 mm, no protruding parts
- Travel range 25 × 25 mm
- 100 nm, optical linear encoders provide excellent repeatability and accuracy

### Precision-class XY stage

With fast direct drive. Clear aperture 78 × 78 mm, 65 × 65 mm at full displacement

### PILine® piezo ultrasonic drive

Self-locking, no heat generation at rest. Excellent start/stop dynamics. Flat supporting surface, no lead screw ducts or flange-mounted motors. Crossed roller guide for higher running accuracy and load capacity. Non-contact limit and reference point switches

### Direct measuring principle

Non-contact, direct-measuring, optical linear encoder per axis. High repeatability

### Valid patents

US Patent No. 6,765,335B2  
European Patent No. 1267425B1

### Application fields

Research and industry. For microscopy, biotechnology, laboratory automation. Special versions for standard light microscopes available on request



Customized M-686 stage with a bigger footprint makes it possible to sink the piezo Z scanner. The system height together with the P-541 piezo scanner is reduced to only 33 mm.

### The following stages fit directly

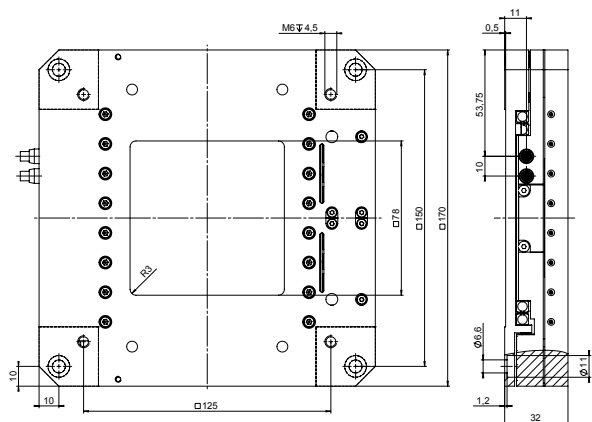
P-561 • P-562 • P-563 PIMars Nanopositioning Stage  
P-541.2 • P-542.2 Piezo XY Stage  
P-541.Z Vertical Nanopositioning Stage

### Related products

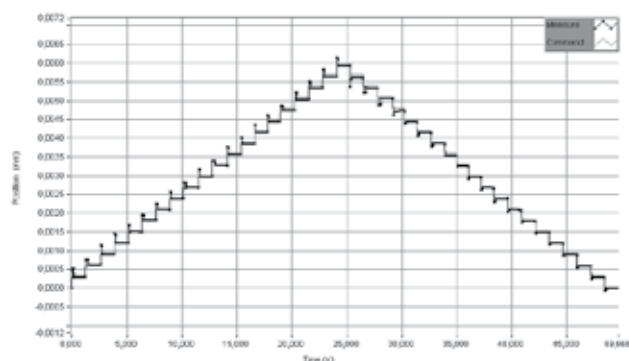
M-683 Dynamic Micropositioning Stage  
M-545 Microscopy Stage

	M-686.D64	Unit	Tolerance
Active axes	XY		
<b>Motion and positioning</b>			
Travel range	25 x 25	mm	
Integrated sensor	Linear encoder		
Sensor resolution	0,1	µm	
Design resolution	0,1	µm	typ.
Min. incremental motion	0,3	µm	typ.
Bidirectional repeatability	±0,3	µm	
Pitch / yaw	±50	µrad	typ.
Velocity	100	mm/s m	ax.
<b>Mechanical properties</b>			
Load capacity*	50	N	max.
Push / pull force	7	N	max.
Holding force	6	N	max.
<b>Mechanical properties</b>			
Motor type	PILine® U-164 (Dual Motor)		
Reference point switch	Optical		
Limit switches	Hall-effect		
<b>Miscellaneous</b>			
Operating temperature range	-20 to 50	°C	
Material	Al (black anodized)		
Dimensions	170 x 170 x 32	mm	
Mass	1,8	kg	±5 %
Cable length	1,5	m	±10 mm
Connector	2x MDR, 14-pin		
Recommended controller/driver	C-867 PILine® Motion Controller		

Ask about custom designs!  
 \* 10 N for maximum velocity.



M-686.D64, dimensions in mm. At an extreme displacement, the aperture still is 65 x 65 mm



Series of 0.3 µm steps performed by M-686 shows excellent equidistance and repeatability; measured with laser interferometer



M-686 open-frame long-travel stage combined with P-541.2DD high-speed piezo scanner (0.1 nanometer resolution). The system height of the combination with the P-541 XY (or Z) piezo scanner is only 48 mm



The two-channel C-867.260 controller serves to control XY scanning stages, as in this case a customized M-686 stage for microscopy

# Dynamic Micropositioning Stage

LOW PROFILE, LINEAR ENCODER



## M-683

- Piezoceramic linear drive with excellent dynamics
- Max. velocity 350 mm/s
- Low profile: only 21 mm
- Travel range 50 mm
- Encoder resolution 0.1  $\mu\text{m}$

### Precision-class micropositioning stage

Integrated piezoceramic direct drive. A vacuum-compatible version down to  $10^{-6}$  hPa is available

### PILine® piezo ultrasonic drive

Self-locking, no heat generation at rest. Excellent start/stop dynamics. Crossed roller guides. Non-contact limit and reference point switches

### Direct-metrology linear encoder

Excellent linearity and repeatability

### Application fields

Research and industry. For biotechnology, micromanipulation, test equipment

### Related products

M-605 High-Accuracy Translation Stage

N-661 Miniature Linear Stage with NEXACT® Drive

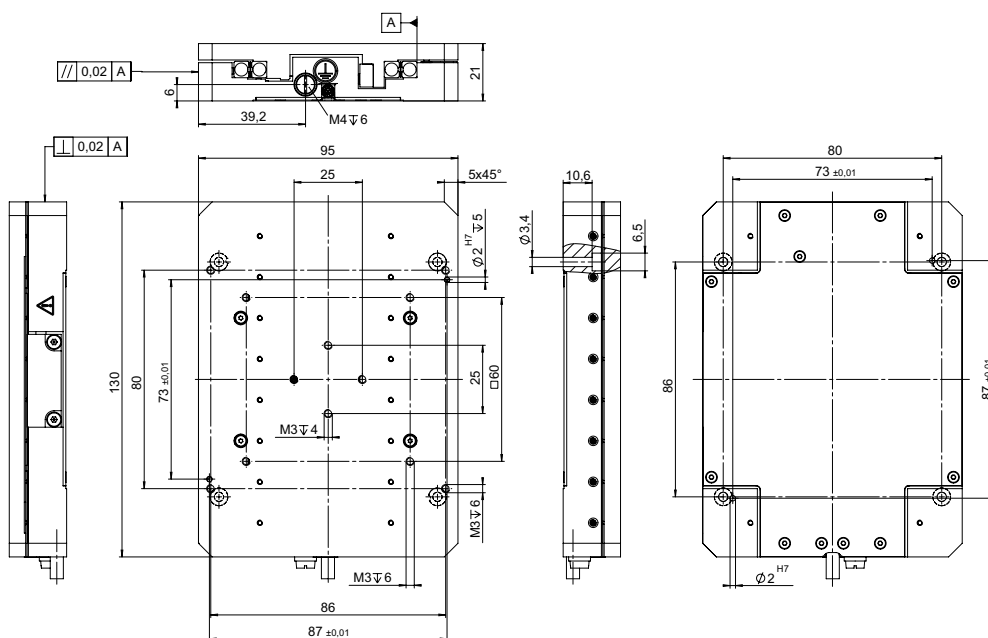
### Valid patents

US Patent Nr. 6,765,335B2

European Patent Nr. 1267425B1

	M-683.2U4	Unit	Tolerance
Active axes	X		
<b>Motion and positioning</b>			
Travel range	50	mm	
Integrated sensor	Linear encoder		
Sensor resolution	0.1	µm	
Min. incremental motion	0.3	µm	typ.
Bidirectional repeatability	±1	µm	typ.
Unidirectional repeatability	0.2	µm	typ.
Pitch	±150	µrad	typ.
Yaw	±50	µrad	typ.
Velocity	350	mm/s	max.
Reference point switch repeatability	±1	µm	typ.
<b>Mechanical properties</b>			
Guiding	Crossed-roller bearings		
Load capacity	50	N	max.
Push / pull force	6	N	max.
Holding force	6	N	max.
<b>Drive properties</b>			
Motor type	PILine® U-164 (dual motor)		
Reference point switch	Optical		
Limit switches	Hall-effect		
<b>Miscellaneous</b>			
Operating temperature range	0 to +50	°C	
Material	Al (black anodized)		
Dimensions	130 × 95 × 21	mm	
Mass	0.65	kg	±5 %
Cable length	1.5	m	±10 mm
Connector	MDR, 14-pin		
Recommended controller	C-867 PILine® controller incl. driver		

M-683.2V4: Delivery includes 1 m cable (vacuum), feedthrough and 1.5 m cable (air). Specifications for vacuum versions can differ. Ask about custom designs!



M-683.2U4, dimensions in mm

# Compact Linear Positioning Stage

FAST LINEAR MOTOR, LINEARENCODER



## M-663

- Max. velocity 400 mm/s
- Travel range 19 mm
- 0.1 µm linear encoder
- XY combinations without adapter plate possible

### Precision-class micropositioning stage

Integrated piezoceramic direct drive. A vacuum-compatible version down to 10<sup>-6</sup> hPa is available

### PI Line® piezo ultrasonic drive

Self-locking, no heat generation at rest. Excellent start/stop dynamics. Centered ball bearings. Non-contact reference point switch

### Direct measuring principle

Non-contact, optical linear encoder. High linearity and repeatability

### Valid patents

US Patent No. 6,765,335B2

European Patent No. 1267425B1

### Application fields

Research and industry. For optical metrology, laser technology, micromanipulation, biotechnology, photonics packaging



XY combination of two M-663

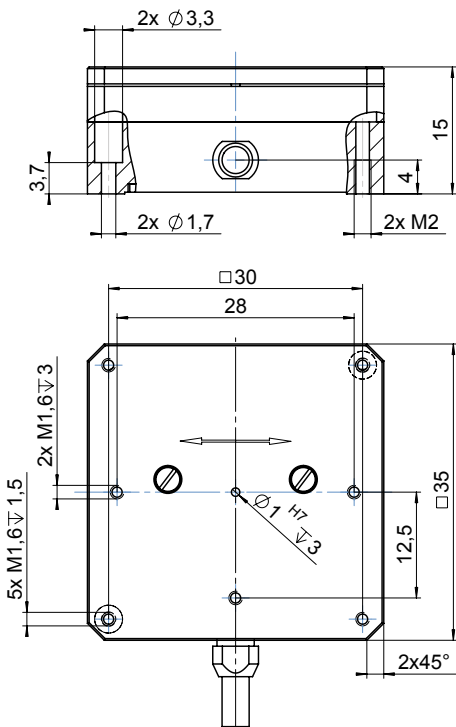
### Related products

M-110 • M-111 • M-112 Compact, Cost-Ef.cient Linear Stage  
 M-122 Compact, Fast Linear Stage  
 M-683 Fast Micropositioning Stage  
 C-867 PI Line® Motion Controller

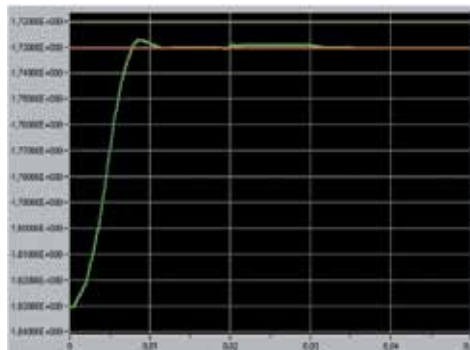


	M-663.465	Unit	Tolerance
Active axes	X		
<b>Motion and positioning</b>			
Travel range	19	mm	
Integrated sensor	Linear encoder		
Sensor resolution	0.1	µm	
Min. incremental motion	0.3	µm	typ.
Unidirectional repeatability	0.2	µm	typ.
Bidirectional repeatability	±0.3	µm	
Pitch / yaw	±300	µrad	typ.
Velocity	400	mm/s max.	
Reference point switch repeatability	1	µm	typ.
<b>Mechanical properties</b>			
Load capacity	5	N	max.
Push / pull force	2	N	max.
Holding force	2	N	max.
<b>Drive properties</b>			
Motor type	P-661 PILine® ultrasonic piezomotor		
Reference point switch	Optical		
<b>Miscellaneous</b>			
Operating temperature range	-20 to 50	°C	
Material	Al (black anodized)		
Dimensions	35 x 35 x 15	mm	
Mass	40	g	±5 %
Cable length	1.5	m	±10 mm
Connector	MDR, 14-pin		
Recommended controller/driver	C-867 PILine® Motion Controller		

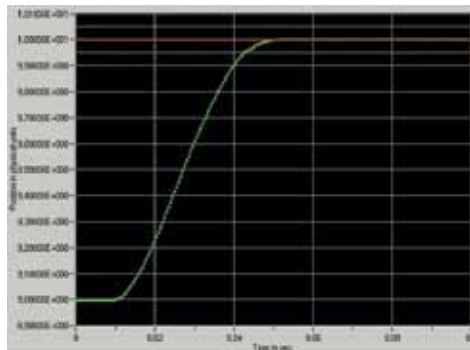
Vacuum versions to 10<sup>-6</sup> hPa are available under the following ordering number: M-663.46V.  
 A version with 90 deg. shifted cable exit for XY mounting is available as the M-663.Y65



M-663.465, dimensions in mm



Step and settle example:  
 An M-663 positioner loaded with 100 g can execute a 100 µm step and settle to within 0.1 µm in only 10 ms. Performed with a C-867 PILine® motion controller



1-mm step performed by an M-663 stage and a C-867 controller. The stage is loaded with 300 g and reaches the target position in less than 40 ms

# Linear Drive for Automation

FAST AND SELF-LOCKING WITH PILINE® PIEZOMOTOR



## M-272

- Velocity up to 150 mm/s
- Self-locking at rest
- Integrated linear encoder
- Integrated linear guiding system

### Compact standard-class linear drive

Fast, maintenance-free and easy to integrate. Integrated ball bearing guidance

### PILine® ultrasonic drive

Cost effective alternative to the conventional combination of electric motor and spindle. Ceramic direct drive, self-locking at rest, no heat generation

### Integrated linear scale encoder

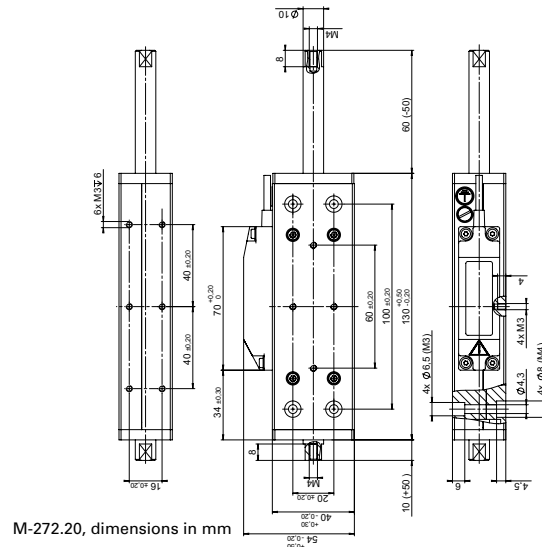
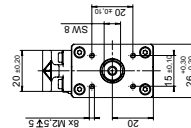
Reliable position control, repeatable accuracy. Optical reference point switch

### Application fields

Automation, handling, micromanipulation, metrology

### Related Products

- N-310 NEXACT® OEM Miniature Linear Motor / Actuator
- M-664 Precision Stage with Linear Drive
- M-228 • M-229 Linear Actuator Series with Stepper Motor
- C-867 Controller for PILine®
- C-867.OE Controller Board for PILine®



M-272.20, dimensions in mm

	M-272.20	Tolerance
Active axes	X	
<b>Motion and positioning</b>		
Travel range	50 mm	
Integrated sensor	Linear encoder	
Sensor resolution	0.6 µm	
Min. incremental motion	1.8 µm	typ.
Unidirectional repeatability	2 µm	typ.
Bidirectional repeatability	3 µm	typ.
Velocity	150 mm/s	max.
<b>Mechanical properties</b>		
Guiding	Ball bearings	
Push/pull force	8 N	max.
Holding force	8 N	max.
Lateral force	10 N	max.
<b>Drive properties</b>		
Motor type	U-164 PILine® ultrasonic piezo drive	
Current consumption	800 mA*	
Reference point switch	Optical	
<b>Miscellaneous</b>		
Operating temperature range	-20 to +50 °C	
Material	Aluminum	
Mass	0.47 kg	± 5%
Cable length	1.5 m	± 10 mm
Connector	MDR, 14-pin	

Recommended controller/driver: C-867.OE

Power for the motor is supplied by the drive electronics, which requires 24 V DC.

\* For drive electronics



Cost-effective combination: M-272 Closed-loop Linear Pusher and C-867.OE Controller Card

# PILine® Motion Controller

FOR ULTRASONIC PIEZOMOTORS, 1 AND 2 AXES



## C-867

- For PILine® ultrasonic piezo linear motors
- 50-MHz encoder inputs for high velocity and position resolution
- USB, RS-232 and analog interfaces (e.g. for a joystick)

### Servocontroller and power amplifier

One and two channels, bench top, proprietary PID control for ultrasonic motors, network-compatible with up to 16 units per interface

### For PILine® ultrasonic linear motors

Power amplifier for PILine® drives and stages with up to two piezomotors per channel. Automated frequency tracking for improved servo performance

### Incremental encoders

Differential signal transmission (A/B). Evaluation of TTL signals for limit and reference point switches

### Digital communication

USB, RS-232 and analog interfaces (e. g. for a joystick). Data recorder. Powerful macro programming language, e. g. for standalone operation. Extensive software support, e. g. LabVIEW, shared libraries for Windows and Linux

	C-867.160	C-867.260
Function	Controller for single-axis positioning or scanning stages	Controller for XY positioning or scanning stages
Drive type	PILine® motors, single and dual drives with P-661, P-664, U-161 and U-164	
Channels 1		2
<b>Motion and control</b>		
Servo characteristics	Programmable PID filter, parameter changes on the fly	
Trajectory profile modes	Trapezoid	
Encoder input	A/B (quadrature) differential, 50 MHz	
Stall detection	Servo off, triggered by programmable position error	
Limit switches	2 TTL (programmable) per channel	
Reference point switch	1 TTL per channel (active high/low, programmable)	
<b>Electrical properties</b>		
Max. output power per channel	15 W	
Max. output voltage per channel	200 V <sub>pp</sub>	
<b>Interface and operation</b>		
Communication interfaces	USB, RS-232	
Motor connector	MDR14	2 × MDR14
Controller network	Up to 16 units on single interface	
I/O ports	4 analog/digital in 4 digital out (Mini-DIN, 9-pin) Digital: TTL Analog: 0 to 5 V	
Command set	PI General Command Set (GCS)	
User software	PIMikroMove	
Software drivers	GCS-DLL, LabVIEW driver	
Supported functionality	Start-up macro, macro, data recorder for recording parameters as motor input voltage, velocity, position or position error	
Manual control	Pushbutton box, joystick (for two axes), Y cable for 2-D motion	Pushbutton box, joystick (for two axes)
<b>Miscellaneous</b>		
Operating voltage	24 VDC from external power supply (included)	
Max. operating current	300 mA plus motor current (max. 2 A)	600 mA plus motor current (max. 4 A)
Operating temperature range	5 to 40°C	
Mass	1 kg	2.4 kg
Dimensions	206 × 130 × 66 mm (incl. mounting rails)	320 × 150 × 80.5 mm (incl. mounting rails)

Ask about custom designs!



The two-channel C-867.260 controller serves to control XY scanning stages, as in this case a customized M-686 stage for microscopy

# OEM Piezomotors

## TECHNICAL DATA

### Different integration levels offer flexibility

PILine® allow the design of positioning systems with higher dynamics and smaller dimensions. PI offers various integration levels of PILine® drives for easier integration into customer designs:

- Complete positioning stages with integrated PILine® motors are available in custom designs for OEMs,
- Linear actuators move the load via a guided rod. Position feedback is available as an option,

- RodDrives are unguided and open-loop linear drives that replace motor-leadscrew combinations. They can easily be coupled to a guided positioning platform,

- The integration of OEM motors requires more experience and technical knowledge because the optimal preload between runner and actuator has to be set-up by the customer.

### Drive electronics

To produce the ultrasonic oscillations in the piezo actuator, special drive electronics are required that are also provided by PI. These range from OEM boards to integrated servo controllers for closed-loop systems.



OEM motor

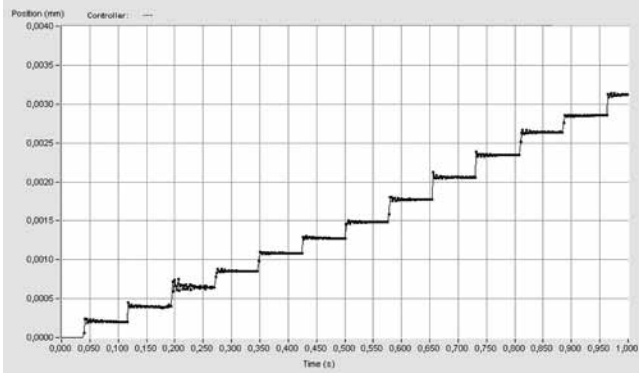


Drive electronics create the ultrasonic oscillations in the piezo-ceramic actuator of the PILine® drive. PI offers universal drives for all actuator sizes – as well as specialized, compact boards

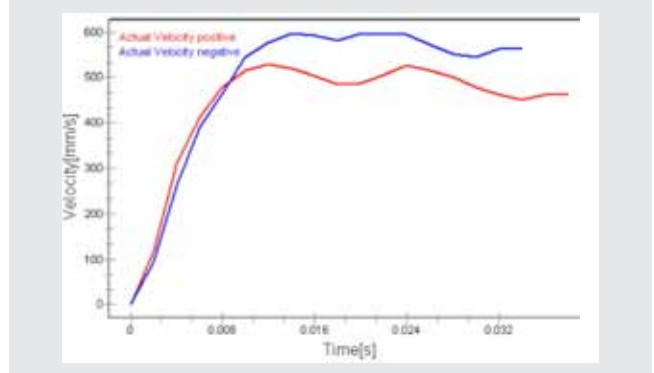
PILine® Piezo Linear Drive	P-661	U-164	Unit	Tolerance
<b>Motion and positioning</b>				
Travel range*	No limit	No limit	mm	
Min. incremental motion, open-loop**	0.05	0.05	µm	typ.
Open-loop velocity	500	500	mm/s	max.
<b>Mechanical properties</b>				
Stiffness, de-energized	0.7	3	N/µm	±10 %
Holding force, de-energized	1.5	3	N	max.
Push / pull force	2	4	N	max.
Optimum preload on runner	9	18	N	±10 %
<b>Drive properties</b>				
Resonant frequency	210	155	kHz	±2 kHz
Motor voltage	42 V <sub>rms</sub> (120 V <sub>pp</sub> )	60 V <sub>rms</sub> (170 V <sub>pp</sub> )		
<b>Miscellaneous</b>				
Operating temperature range	-20 to +50	-20 to +50	°C	
Casing material	Al (black anodized)	Al (black anodized)		
Mass	10	20	g	±5 %

\* The travel range of piezo linear motors is practically unlimited and it only depends on the length of the runner

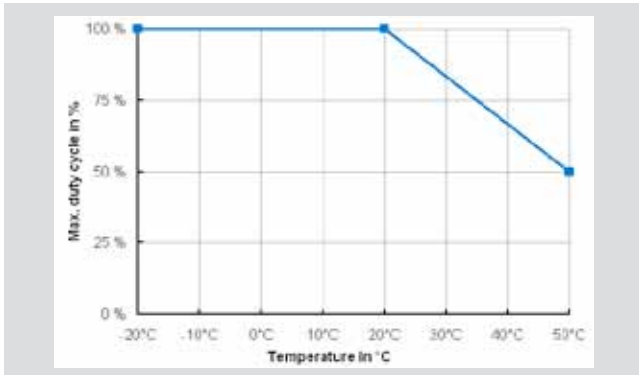
\*\* The minimum incremental motion is a typical value which can be reached in open-loop operation. However, it is important to follow the installation guidelines for the motors



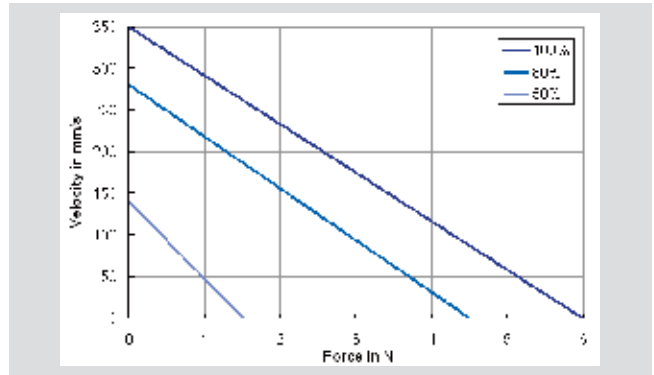
Open-loop step sequence of a PLine® based translation stage. Steps of approx. 300 nm shown. For repeatable increments closed-loop operation is recommended, because the step size depends on the force applied from outside



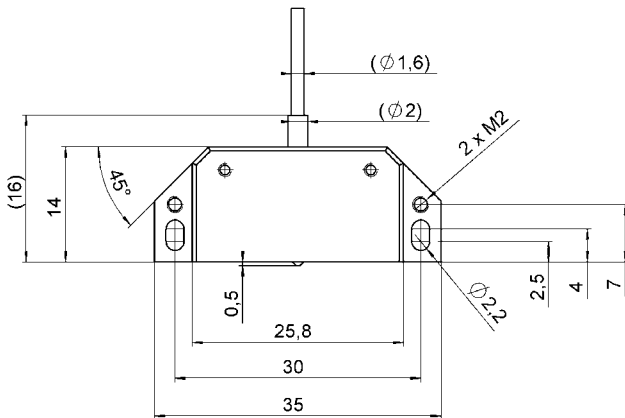
PLine® ultrasonic linear motors provide excellent dynamic properties. They provide acceleration to several g and can achieve step and settle of a few 10 ms for small distances



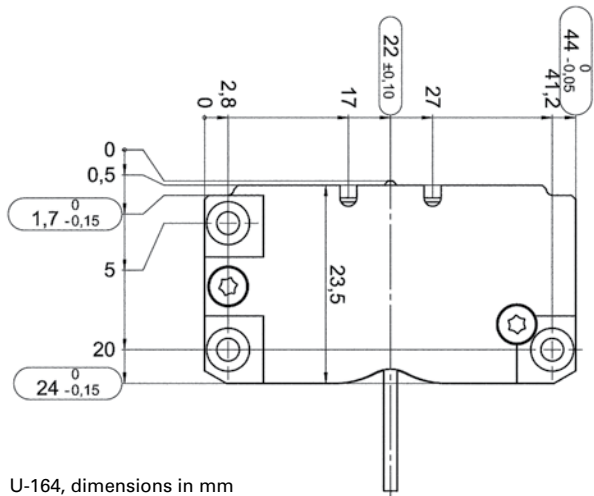
Maximum duty cycle depending on the ambient temperature with a control signal level of 100 %



Force / velocity motor characteristic of a U-164 PLine® motor. The percentages refer to the control signal level, which denotes the coupling of the electric power of the actuator



P-661, dimensions in mm



U-164, dimensions in mm

## Vertical Drive for Bio-Automation



- Actuator with PILINE® piezomotor
- Compact and cost-effective design
- Stackable
- Non-magnetic and vacuum-compatible operating principle
- Self-locking at rest

	Travel range	Max. push/pull force	Max. closed-loop velocity	Resolution	Dimensions
M-664KCEP compact PILINE® positioner	50 mm	5 N	100 mm/s	0.5 µm	120 × 40 × 9 mm

## Z Actuator for Bio-Automation



- Extremely slim design, matched with standard multiwell plates
- Stackable
- Integrated linear encoder for highest accuracy
- Self-locking at rest
- Non-magnetic and vacuum-compatible operating principle

	Travel range	Max. push/pull force	Max. closed-loop velocity	Resolution	Dimensions
M-674KCPP compact PILINE® positioner	50 mm	7 N	100 mm/s	0.1 µm	120 × 40 × 9 mm

## Micro Linear Stage



- Smallest micropositioning stages with linear motor drive
- Acceleration 5 g
- Push / pull force 1 N
- Self-locking at rest
- XY combination possible
- MTBF 20,000 h
- Vacuum-compatible versions to 10<sup>-7</sup> hPa

	Travel range	Max. load	Max. velocity	Min. incremental motion	Dimensions
M-661.370	18 mm	5 N	500 mm/s	50 nm	30 × 23 × 10 mm
M-662.470	20 mm	5 N	500 mm/s	50 nm	28 × 28 × 8 mm



# RodDrive Piezomotor Direct Drive

LOW PROFILE, HIGH SPEED, EASY INTEGRATION



## U-264

- Velocity up to 250 mm/s
- Travel ranges up to 150 mm
- Linear drive for integration
- Generated force up to 15 N

### Fast OEM linear drive

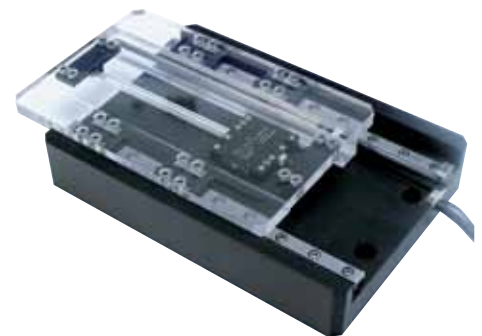
For integration into guided systems

### RodDrive direct drive with integrated and preloaded PiLine ultrasonic piezo drives

Self-locking, no heat generation at rest. Excellent start/stop dynamics. Easy integration by coupling the rod to a guided payload (e.g. a linear slide)

### Application fields

OEM drives for automation. For handling and high-precision positioning systems



RodDrive integrated in a micro stage

### Related Products

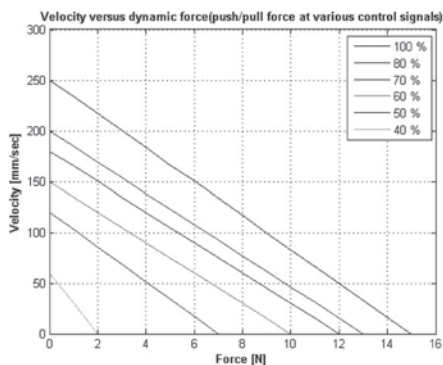
M-272 Linear Drive for Automation

N-310 NEXACT OEM Miniature Linear Motor / Actuator

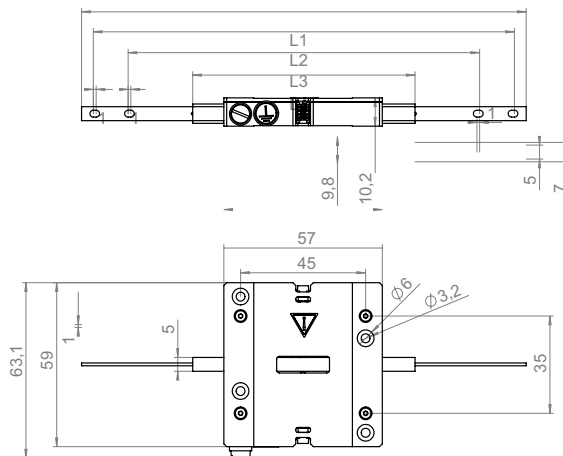
C-872 Driver for PiLine® Ultrasonic Piezomotors

	U-264.10/20/30	U-264.11/21/31	Units	Tolerance
<b>Motion and positioning</b>				
Travel range	50 / 100 / 150	50 / 100 / 150	mm	
Open-loop step size	0.1*	2*	µm	typ.
Open-loop velocity	250	200	mm/s	max.
<b>Mechanical properties</b>				
Stiffness when powered down	1.5	1.5	N/µm	±10 %
Holding force when powered down	8	15	N	max.
Push/pull force	7 (at 50 mm/s) 2 (at 250 mm/s)	12 (at 50 mm/s) 3 (at 200 mm/s)	N	max.
<b>Drive properties</b>				
Resonant frequency	158	159	kHz	±2 kHz
Motor voltage	200 V <sub>pp</sub> 65 V <sub>rms</sub>	200 V <sub>pp</sub> 65 V <sub>rms</sub>		
Input impedance	40 to 80**	50 to 100**	Ω	
<b>Miscellaneous</b>				
Operating temperature range	0 to 40	0 to 40	°C	
Material case	Al (black anodized)	Al (black anodized)		
Mass	0.08 / 0.09 / 0.1	0.08 / 0.09 / 0.1	kg	±5 %
Connector	D-Sub 15 (m)	D-Sub 15 (m)		
Recommended controller/driver	C-872.160 driver, C-867 motion controller/driver	C-872.160 driver, C-867 motion controller/driver		
Dimensions	57 x 63 x 10.2 plus rod	57 x 63 x 10.2 plus rod	mm	

\* pulsed operation, 1 msec ON time, 50 % duty cycle  
 \*\* at resonant frequency



U-264.11/21/31, velocity (open-loop) vs. dynamic force (push/pull force) at various drive signal amplitudes



	U-264.10/11	U-264.20/21	U-264.30/31
L1	160.0	210.0	260.0
L2	151.5	201.5	251.5
L3	126.5	176.5	226.5
L4	80.0	130.0	180.0

U-264, dimensions in mm



PI Line RodDrive with variable travel ranges

# OEM Driver for PLine® Piezomotors

HIGHLY EFFICIENT PIEZOMOTOR AMPLIFIER



## C-872

- For all PLine® motors
- Analog control input
- Automatic frequency control
- Minimum heat generation

**All-purpose driver for all PLine® single and dual drives**  
 OEM board with analog control input. Suitable for PLine® ultrasonic piezomotors P-661, U-161, U-164 and PLine® RodDrive U-264

**PLine® ultrasonic piezomotors and drives**  
 High velocity. Self-locking, no heat generation at rest. Excellent start/stop dynamics

**Resonance tracking**  
 Automatically adjusts the driving frequency for maximum motor performance and efficiency (can be switched off)



RodDrive Piezomotor Direct Drive

- Related products**
- U-264 RodDrive Piezomotor Direct Drive
  - M-272 Ceramic Linear Drive for Automation
  - C-867.OE Controller Board PLine®

Preliminary Data	C-872.160	Unit	Tolerance
Function	Driver for PLine® ultrasonic piezomotors / single and dual drives with P-661, U-161, U-164 and U-264		
Channels	1		
Control In	±10 V defines the velocity, polarity defines the direction of motion, 12-bit A/D converter		
<b>Electrical properties</b>			
Output power	50	W	max.
Output voltage	240 (AC voltage, amplitude and frequency depending on motor selection)	V <sub>pp</sub>	max.
Current limitation	2.5 (short-circuit-proof)	A	max.
<b>Interface and operation</b>			
DIP switches	Motor selection, frequency control activated / deactivated		
Motor connector	MDR14 and sub-D 15 (f)		
I/O ports	Sub-D 15 (m) 1x frequency control activated/deactivated Looped through: 3x signals for limit and reference point switches (TTL), 4x encoder signal (A/B, differential)		
<b>Miscellaneous</b>			
Operating voltage	24 VDC, 50 W, from external power supply (not included)		
Current consumption	2.5	A	max.
Operating temperature range	5 to 40	°C	
Mass	0.125	kg	
Dimensions	172 x 100 x 20 (incl. connector)	mm	

# PILine® Motion Controller

OEM BOARD, COST-EFFECTIVE, WITH CAN INTERFACE



## C-867.OE

- For PILINE® ultrasonic piezomotors
- 50-MHz encoder inputs for high velocity and position resolution
- CAN, RS-232 and analog interfaces (e.g. for a joystick)

### Servocontroller and power amplifier

One channel, proprietary PID control for ultrasonic motors, standard Eurocard size

### For PILINE® ultrasonic linear motors

Power amplifier for PILINE® drives and stages. Automated frequency tracking for improved servo performance

### Incremental encoders

Differential signal transmission (A/B). TTL inputs for limit and reference point switches

### Digital communication

CAN, RS-232 and analog interfaces (e.g. for a joystick). Data recorder. Powerful macro programming language, e.g. for standalone operation Extensive software support, e.g. for LabVIEW, shared libraries for Windows and Linux



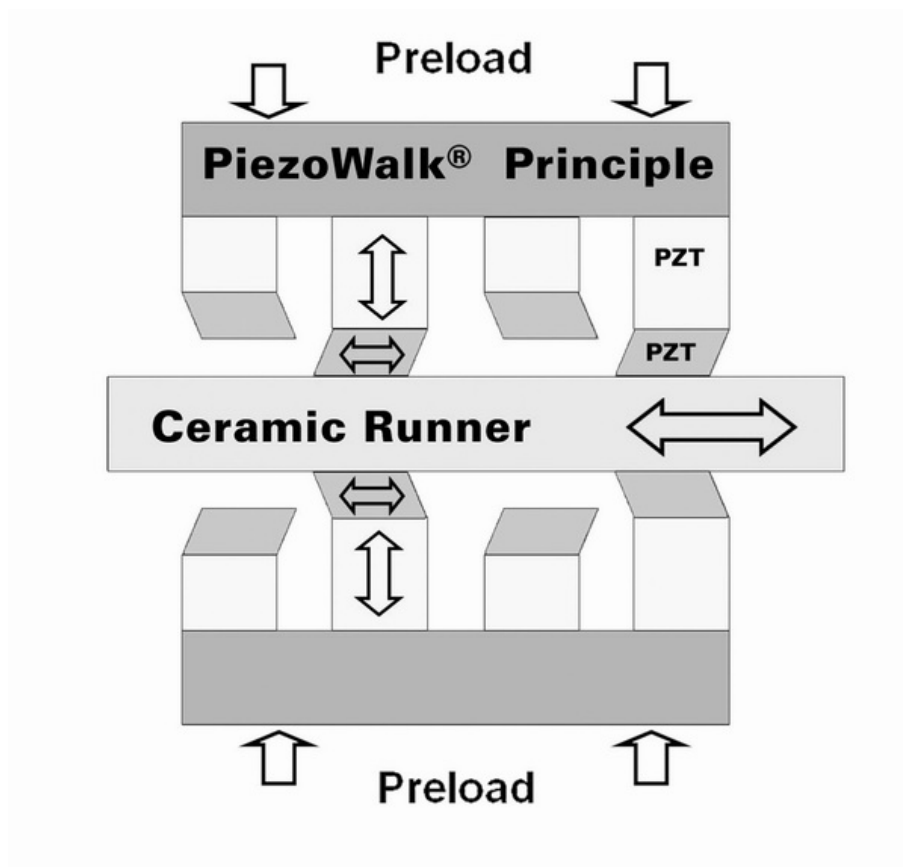
Cost-effective combination: M-272 closed-loop linear pusher and C-867.OE motion controller

### Related Products

C-867 PILINE® Motion Controller

	C-867.OE
Function	Controller and drive electronics for PLine® piezomotors/systems
Drive type	PLine® motors, single and dual drives with P-661, P-664, U-161, U-164 and U-264
Channels	1
<b>Motion and control</b>	
Servo characteristics	Programmable PID filter, parameter changes on the fly
Trajectory profile modes	Trapezoid
Encoder input	A/B (quadrature) differential, 50 MHz
Stall detection	Servo off, triggered by programmable position error
Limit switches	2 TTL (programmable)
Reference point switch	1 TTL (active high/low, programmable)
<b>Electrical properties</b>	
Max. output power	15 W
Max. output voltage	200 V <sub>pp</sub>
<b>Interface and operation</b>	
Communication interfaces	RS-232, CAN, Input / output 32-pin (male) on rear panel (DIN 41612 / D)
Motor connector	MDR14
Command set	PI General Command Set (GCS)
User software	PIMikroMove
Software drivers	GCS-DLL, LabVIEW driver
Supported functionality	Start-up macro, macro, data recorder for recording parameters as motor input voltage, velocity, position or position error
<b>Miscellaneous</b>	
Operating voltage	24 VDC from external power supply (not included)
Max. operating current	150 mA plus motor current (max. 2 A)
Operating temperature range	5 to 40°C
Mass	420 g
Dimensions	175 × 100 × 38 mm (incl. connector)

# PiezoWalk® Motors / Actuators



Latest PI Catalogs:  
[www.pi.ws](http://www.pi.ws)

# Piezo Stepping Motor Basics

## PiezoWalk® Precision Drives – Millimeter Travel, Nanometer Resolution, High Forces

PiezoWalk® drives break away from the limitations of conventional Nanopositioning actuators. They offer a basically

unlimited travel range and still provide the characteristic features of a piezoelectric actuator: an open-loop resolution down to 30 picometers and a very high stiffness for dynamic operation and force generation. PI offers two product lines

based on different versions of the PiezoWalk® principle: NEXLINE® and NEXACT®. Both provide specific advantages depending on the application.

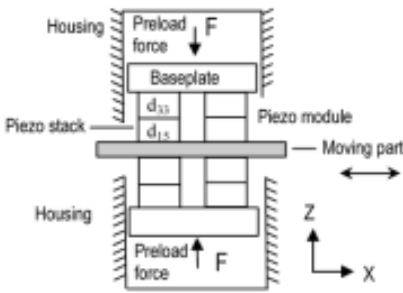
ity. These properties are typically better for piezo stepping actuators compared to inertia drives or ultrasonic motors. The operation is possible in two different modes: a high-resolution, high dynamics analog mode within a single step, and a step mode with virtually unlimited travel range.

PiezoWalk® piezo stepping drives usually consist of several individual piezo actuators and generate motion through succession of coordinated clamp / unclamp and shear motion cycles (steps). Each cycle provides only a few microns of movement, but running at hundreds of hertz, the drive achieves continuous motion in the mm/second range.

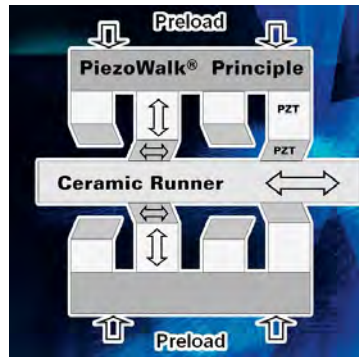


Custom PiezoWalk® linear actuator

The PiezoWalk® working principle provides high force capabilities, resolution and repeatabil-



NEXLINE® linear actuator principle



## Features and Advantages of PiezoWalk® Drives

- Very high resolution, limited typically only by the sensor. In fine-adjustment, analog mode, resolution of 30 picometers has been demonstrated.
- High force generation and stiffness. NEXLINE® drives can hold and generate forces to 600 N, NEXACT® to 15 N.
- PiezoWalk® drives hold a stable position to nanometer level in power-off mode. Due to the actuator design, the maximum clamping force is applied at rest.
- Because a position can be held with zero operating voltage, leakage currents cannot affect the integrity of the piezo drive.

- PiezoWalk® drives are available for non-magnetic applications such as super-conductivity experiments. They do not create magnetic fields nor are they influenced by them.
- The active parts in PiezoWalk® drives are made of vacuum-compatible ceramics. The drives also work in UV-light environments.
- NEXLINE® drives can survive shock loads of several g during transportation.
- PiezoWalk® drives are available in three levels of integration to provide flexibility for OEMs: OEM drives, packaged actuators and integrated into complex positioning systems such as multi-axis translation stages or 6-DOF Hexapods.



50 picometer steps with a NEXLINE® drive, measured with external ultra-high-resolution capacitive sensor. This performance provides a big safety margin for next generation nanotechnology applications



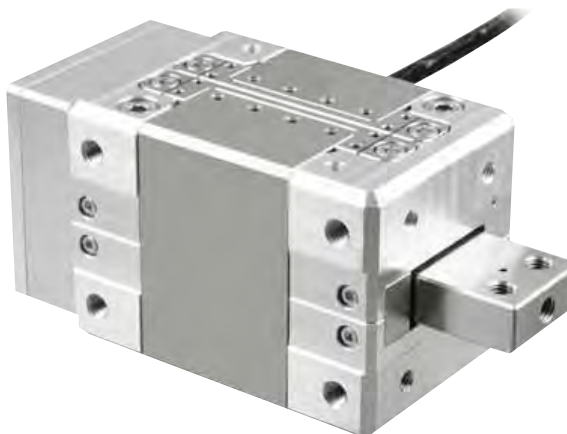
6-axis parallel-kinematic nanopositioning system (Hexapod) with N-215 based NEXLINE® high-load actuators for use in strong magnetic fields



# Piezo Stepping Motor Basics

## NEXLINE® High-Force Drives for Nanopositioning

NEXLINE® systems are based on very rugged, high-efficiency shear and clamping actuators and incorporate a preloading mechanism to provide pushing and holding forces up to 600 N with high lifetime. The rigid design with resonant frequencies of hundreds of hertz allows the construction of very stiff structures and helps to suppress vibration. The analog operating mode can be used for dithering and active vibration cancellation.



N-215 high-load NEXLINE® linear drive provides holding forces to 600 N and 20 mm travel



NEXLINE® linear actuator principle

## Compact NEXACT® Drives for Moderate Forces

NEXACT® drives use bending actuators which combine the feed forward and the clamping cycles. They provide push/pull forces to 15 N with maximum velocities of more than 10 mm/s at low operating voltages of 40 V. The compact and cost-effective NEXACT® drives are available with various drive electronics, ranging from cost-effective OEM drives for open-loop operation in stepping mode to the sophisticated E-861 servo-controller for high-resolution, closed-loop linear translation stages.



# N-310 NEXACT® OEM Miniature Linear Motor/Actuator

## Compact, High-Speed PiezoWalk® Drive



N-310 Actuator with E-861 Servo-Controller (integrated drive electronics)

- 10 to 125 mm Standard Travel Range, Flexible Choice of the Runner Length
- Compact and Cost-Effective Design
- 0.03 nm Resolution\*\*
- To 10 N Push/Pull Force
- Low Operating Voltage
- Self Locking at Rest, No Heat Generation, Nanometer Stability
- Non-Magnetic and Vacuum-Compatible Working Principle

N-310 NEXACT® PiezoWalk® linear drives feature travel ranges of up to 125 mm and push/pull force capacities to 10 N in a compact package of only 25 x 25 x 12 mm. With their high resolution, NEXACT® drives, are ideal for high-precision positioning over long travel ranges.

The N-310 can be operated in open-loop and closed-loop mode (with the addition of an external

position sensor). A variety of NEXACT® controllers facilitates the integration into micro- or nanopositioning applications.

### Working Principle for Application Flexibility

NEXACT® PiezoWalk® technology overcomes the limitations of conventional nanopositioning drives and combines virtually unlimited travel ranges with high stiffness in a very small package. Furthermore, NEXACT® actuators provide piezo-class resolution (far below one nanometer) and millisecond responsiveness. The special drive design reduces the operating voltage to 45 V and below.

In operation, piezoceramic bending elements act on the runner, which is connected to the moving part of the application. The length of the runner determines the travel range.

Force capacity, resolution and velocity are determined by the piezo geometry and drive electronics and are scalable. To move the runner over longer distances the stepping mode is used, whereas for distances smaller than one step, the linear (analog) mode enables high-dynamics positioning with resolutions far below one nanometer.

### Wear- and Maintenance-Free

In contrast to ordinary DC or stepper motor drives, the PiezoWalk® drives effect linear motion directly, without the need to transform rotation with mechanical elements such as gears, leadscrews and nuts. Therefore, mechanical limitations such as backlash and wear are eliminated and the drive is maintenance-free.

### Self-Locking PiezoWalk® Piezo Stepping Drive

NEXLINE® and NEXACT® exhibit high stiffness and are self-locking even when powered down due to the clamping action of the piezo actuators in the mechanics. This entails nanometer position stability at rest, with no heat generation or servo-dither.

### Controller and Drive Electronics Optimized for the Application

NEXACT® actuators require special drive electronics to control the complex stepping sequences. The E-860 series NEXACT® controllers are available in different open- and closed-loop versions. For example, the E-861 includes a complete NEXACT® servo-controller with low-noise, 24-bit drivers and a powerful DSP. It also comes with ample software for easy integration and highly effective computer control. For applications which do

### Ordering Information

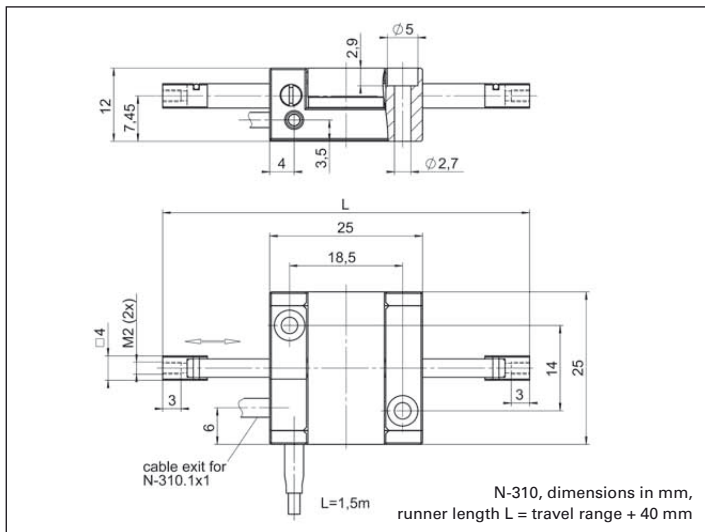
- N-310.10**  
NEXACT® OEM Linear Drive, 10 mm, 10 N
  - N-310.101**  
NEXACT® OEM Linear Drive, 10 mm, 10 N, Shifted Cable Exit
  - N-310.11**  
NEXACT® PiezoWalk® OEM Linear Drive, 20 mm, 10 N
  - N-310.111**  
NEXACT® PiezoWalk® OEM Linear Drive, 20 mm, 10 N, Shifted Cable Exit
  - N-310.12**  
NEXACT® OEM Linear Drive, 30 mm, 10 N
  - N-310.121**  
NEXACT® OEM Linear Drive, 30 mm, 10 N, Shifted Cable Exit
  - N-310.13**  
NEXACT® OEM Linear Drive, 50 mm, 10 N
  - N-310.131**  
NEXACT® OEM Linear Drive, 50 mm, 10 N, Shifted Cable Exit
  - N-310.14**  
NEXACT® OEM Linear Drive, 75 mm, 10 N
  - N-310.141**  
NEXACT® OEM Linear Drive, 75 mm, 10 N, Shifted Cable Exit
  - N-310.15**  
NEXACT® OEM Linear Drive, 100 mm, 10 N
  - N-310.151**  
NEXACT® OEM Linear Drive, 100 mm, 10 N, Shifted Cable Exit
  - N-310.16**  
NEXACT® OEM Linear Drive, 125 mm, 10 N
  - N-310.161**  
NEXACT® OEM Linear Drive, 125 mm, 10 N, Shifted Cable Exit
- Ask about custom designs!**

not require the highest resolution, the E-862 lower-priced drive electronics can be ordered.

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

### Application Examples

- Semiconductor technology
- Wafer inspection
- Nano lithography
- Surface Measurement Technique
- Profilometry
- Microscopy
- Motion in strong magnetic fields



Translation stage with N-310 NEXACT® drive. The positioner offers 20 mm travel range with an encoder resolution of 25 nm

**Technical Data**

Model	N-310	Tolerance
Active axes	X	
<b>Motion and positioning</b>		
Travel range	N-310-10: 10 mm N-310-11: 20 mm N-310-12: 30 mm N-310-13: 50 mm N-310-14: 75 mm N-310-15: 100 mm N-310-16: 125 mm	
Step size (in step mode)	5 nm to 5 µm	
Travel range in analog operation	7 µm	max.
Open-loop resolution	0.03 nm**	typ.
Step frequency	1.5 kHz*	max.
Max. speed	10 mm/s*	max.
<b>Mechanical properties</b>		
Push/Pull force (active)	10 N	max.
<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	
Body material	Stainless steel, non-magnetic	
Mass	50 g (20 mm travel range)	±5%
Cable length	1.5 m	±10 mm
Connector	HD Sub-D connector 15 pin, single channel	
Recommended controller/driver	E-862, E-861 (see p. 1-20)	

\*Depending on the control electronics.

\*\*Depending on the drive electronics. 1 nm with E-861.

# N-381 NEXACT® Linear Actuator, Manipulator, Piezo Stepper

## High-Resolution PiezoWalk® Linear Actuator with Optional Position Sensor

N-381 piezo stepper linear actuator for sample positioning and manipulation provides long travel, high speed and very high resolution; shown with E-861 NEXACT® Controller



- **Travel Range 30 mm**
- **Zero-Wear Piezo Stepping Drive, Ideal for Micro- and Nano-Manipulation**
- **Integrated Linear Encoder Option for Highest Accuracy with 20 nm Resolution**
- **Very High Acceleration, e.g. for Cell Penetration**
- **Two Operating Modes: Continuous Stepping Mode and Continuously Variable, High-Dynamics Analog Mode for 30 µm Resolution\*\***
- **Up to 10 N Force Generation**
- **Self Locking at Rest, no Heat Generation**
- **Smooth Motion, no Closed-Loop Jitter**
- **Vacuum-Compatible and Non-Magnetic Versions**

The compact N-381 linear actuators are ideal drives and micro manipulators e.g. for biotechnology and nanotechnology applications. Rapid accelerations, velocities of 10 mm/s

and forces up to 10 N enable high-dynamics and throughput for automation tasks. The PiezoWalk® drive principle allows long travel ranges and fast oscillations of 7 µm amplitude with frequencies up to several 100 Hz. This “analog mode” can be used to provide rapid acceleration, e.g. in cell penetration applications, or smooth motion for dynamic laser tuning or even for active damping of oscillations. Two models are available: The N-381.3A model is equipped with a high-resolution position sensor, allowing sub-micrometer repeatability in closed-loop operation. The N-381.30 open-loop version is intended for high precision applications where the absolute position is

not important or is controlled by an external loop (video, laser, quadcell, etc.).

### Piezo Stepping Drive — the Multi-Functional Piezo Linear Motor

A great advantage characteristic of the NEXACT® piezo stepping drive is its dual-mode operating principle combining the best features of other piezo motor designs, such as high resolution, high force and high speed into one compact unit. At the target position the drive requires no current and generates no heat while providing long-term, nanometer stability. This autolocking feature also completely eliminates servo-jitter as it occurs with other

### Ordering Information

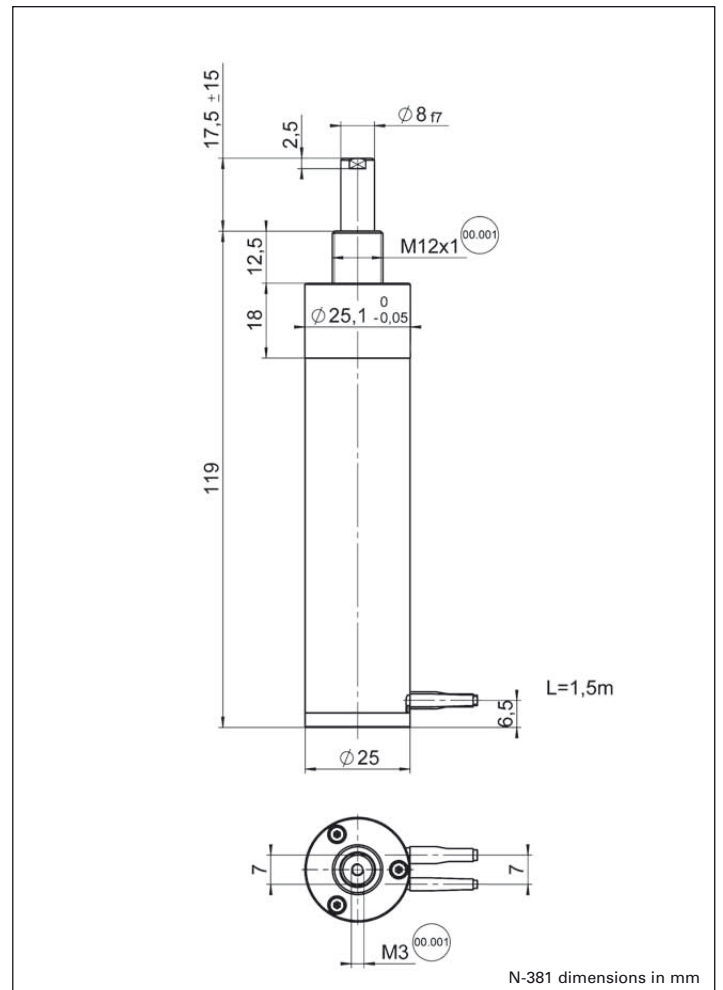
**N-381.3A**  
NEXACTUATOR® Linear Actuator, 30 mm, 20 nm Encoder Resolution

**N-381.30**  
NEXACTUATOR® Linear Actuator, 30 mm, Open-Loop

Available on request

Ask about custom designs!

closed-loop motors. Since motion is not based on dynamic friction as with piezo inertial drives (stick-slip-motors) but solely caused by the nanometer precise motion of clamped piezo actuators, there is no wear to limit the lifetime. When operated in closed-loop, excellent velocity control is achieved.



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### Application Examples

- Drive unit for scanning stage
- Cell manipulation, biohandling
- Micromanipulation
- Life science
- Photonics
- Laser tuning
- Motion in strong magnetic fields

### Working Principle for Application Flexibility

NEXACT® PiezoWalk® technology overcomes the limitations of conventional nanopositioning drives and combines virtually unlimited travel ranges with high stiffness in a very small package. Furthermore, NEXACT® actuators provide piezo-class resolution (far below one nanometer) and millisecond responsiveness. The special drive design reduces the operating voltage to 45 V and below.

In operation, piezoceramic bending elements act on the runner, which is connected to the moving part of the application. The length of the runner determines the travel range

and can be chosen as required. To move the runner over longer distances the stepping mode is used, whereas for distances smaller than one step, the analog mode enables high-dynamics positioning with resolutions far below one nanometer.

### Controllers and Drivers Optimized for the Application

NEXACT® actuators require special drive electronics to control the complex stepping sequences. The E-861 (see p.1-20) includes a complete NEXACT® servo-controller with low-noise drivers and a powerful DSP. It also comes with ample software for easy integration and highly effective computer control. For applications which do not require the highest reso-

lution, the E-862 (see p. 3-10) lower-priced drive electronics, can be ordered.

The products described in this document are in part protected by the following patents:

German Patent No. P4408618.0

Model	N-381.30	N-381.3A
Active axes	X	X
<b>Motion and positioning</b>		
Travel range	30 mm	30 mm
Step size (in step mode)	0.1 to 15 µm	–
Integrated sensor	–	Incremental linear encoder
Sensor resolution	–	20 nm*
Travel range in analog mode	7 µm	7 µm
Open-loop resolution	0.03 nm**	0.03 nm**
Closed-loop resolution	–	20 nm*
Step frequency	0 to 800 Hz	–
Max. velocity	10 mm/s*	10 mm/s*
<b>Mechanical properties</b>		
Stiffness in motion direction	2.4 N/µm	2.4 N/µm
Max. push / pull force (active)	10 N	10 N
Max. holding force (passive)	15 N	15 N
Lateral force	10 N	10 N
<b>Drive properties</b>		
Drive type	NEXACT® linear drive	NEXACT® linear drive
Operating voltage	-10 V to +45 V	-10 V to +45 V
<b>Miscellaneous</b>		
Operating temperature range	0 to 50 °C	0 to 50 °C
Material	Stainless steel / CFRP	Stainless steel / CFRP
Mass	250 g	255 g
Cable length	1.5 m	1.5 m
Connector	15-pin HD-Sub-D connector, one channel	15-pin HD-Sub-D connector, one channel
Recommended controller/driver	E-860 series (see p. 1-20)	E-861.1A1 (see p. 1-20)

\*With E-861. Depending on drive electronics.

\*\*Depending on the drive electronics. 1 nm with E-861.

# Miniature Linear Slide

WITH NANOMETER RESOLUTION



## LPS-24

- Only 24 mm width
- With integrated linear encoder with 150 or 2 nm resolution
- Holding force 5 N
- NEXACT® piezomotors

### Reference-class linear positioning system

Direct metrology with linear encoder

### NEXACT® piezo stepping drive

High-resolution piezoelectric linear drive. Compact design, holding force up to 5 N. Nanostepping mode with <1 nm resolution. Constant velocity motion. Long lifetime, drive principle based exclusively on mechanical stiction

### PIOne linear encoder

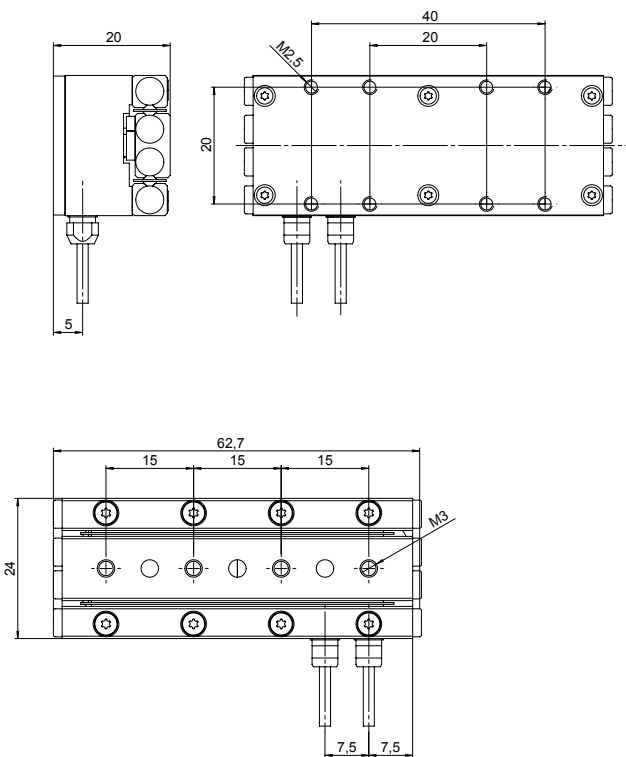
Optional. Based on interferometric measurement prin-

ciple. 2 or 0.5 nm designs. Direction-sensing homing track. Compact design for easy integration in positioning systems. Patented Technology

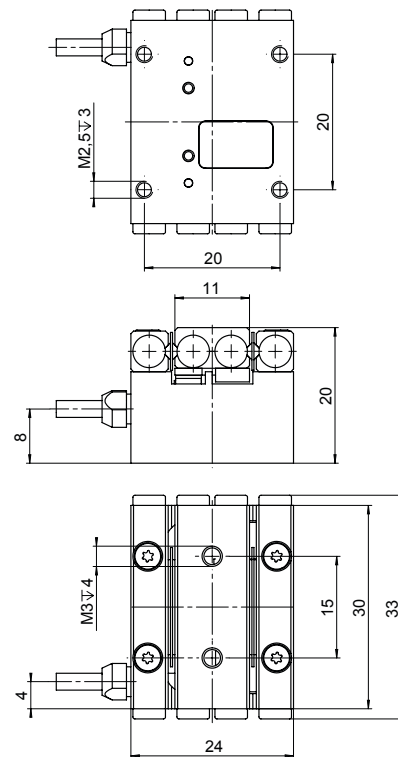
### Fields of application

Sample handling, positioning of samples and optical or mechanical components for installations limited in space. For use in research and industry. Vacuum versions available on request

Preliminary data	LPS-24 5862-9-1110	LPS-24 5862-9-1230	Unit	Tolerance
Active axes	X	X		
<b>Motion and positioning</b>				
Travel range	15	15	mm	
Integrated sensor	optical linear encoder	optical linear encoder PIONe		
Sensor resolution	150	2	nm	
Open-loop resolution	0.03	0.03	nm	typ.
Min. incremental motion	300	4	nm	
Velocity, closed-loop	10	10	mm/s	max.
Unidirectional repeatability	± 250	± 50	nm	typ.
Crosstalk, angular error	±100	±100	μrad	typ.
<b>Mechanical properties</b>				
Stiffness in motion direction	1	1	N/μm	±20 %
Load capacity	10	10	N	max.
Feed force (active)	5	5	N	max.
Holding force (passive)	5	5	N	max.
<b>Drive properties</b>				
Motor type	NEXACT® linear drive	NEXACT® linear drive		
Operating voltage	-10 to +45	-10 to +45	V	
<b>Miscellaneous</b>				
Operating temperature range	0 to 50	0 to 50	°C	
Material	Steel	Steel		
Dimensions	24 mm × 33 mm × 20 mm	24 mm × 63 mm × 20 mm		
Cable length	1.5	1.5	m	±10 mm
Connector	HD Sub-D (m) 15-pin (motor) HD Sub-D 15 (f) 15-pin (sensor)	HD Sub-D (m) 15-pin (motor) HD Sub-D 15 (f) 15-pin (sensor)		
Recommended controller/driver	E-861.1A1	E-861.1A1		



LPS-24 with 2 nm resolution, dimensions in mm



LPS-24 with 150 nm resolution, dimensions in mm

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# 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

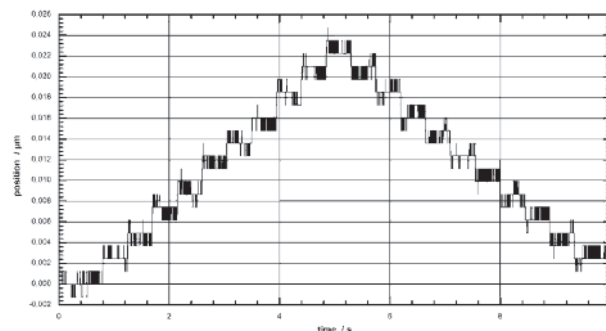
High-precision linear encoder PIONE with subnanometer resolution

#### Fields of application

Research and industry. Option: vacuum version

#### Related products

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

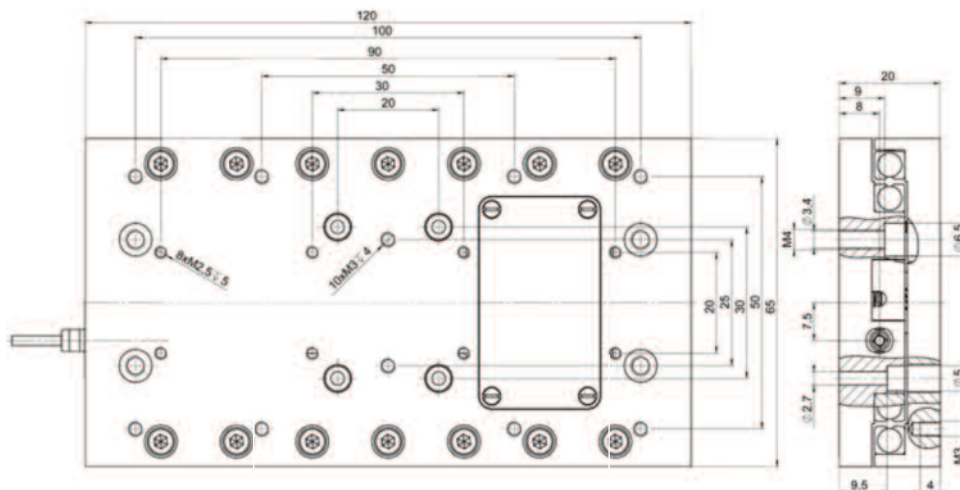


2 nm steps of a N-664.3A with an E-861 Controller



	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	
Step frequency, open-loop	0.8	kHz	max.
Velocity*	10	mm/s	max.
Linearity error	<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.
<b>Mechanical properties</b>			
Stiffness in motion direction	2.5	N/µm	±20%
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	°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

**KEY FEATURES**

- Piezo driven stepping motor with subnanometer resolution
- Travel range up to 52 mm (2")
- Uni-directional repeatability down to 0.005 μm
- Maximum speed 10 mm/sec
- Load capacity up to 2 kg
- Encoder resolution 0.5 nm
- Integrated linear scale

**LINEAR PIEZO STAGE LPS-65**



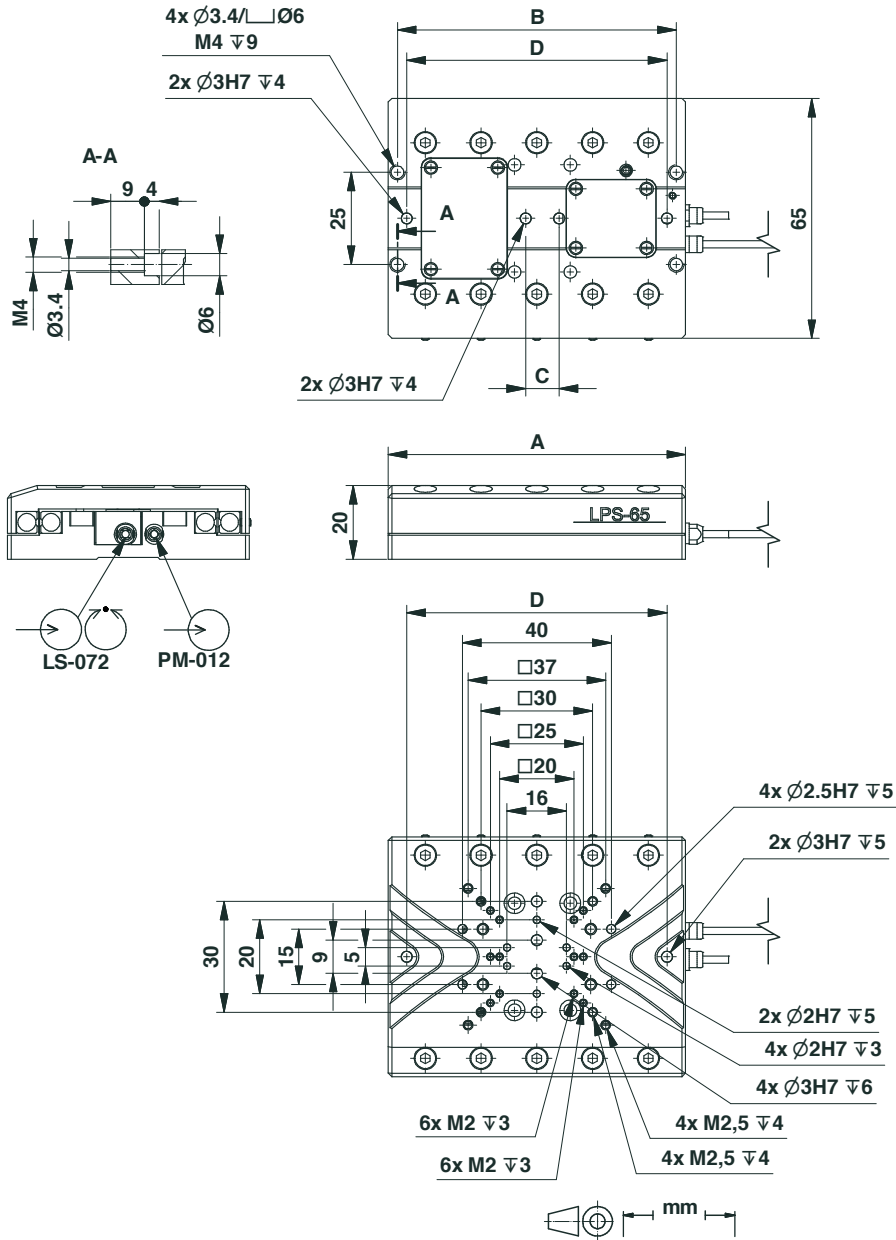
The LPS-65 is a low profile linear stage utilizing synchronized piezo stepping motor for increased precision and load capacity. The big platform and the cross roller bearing are guaranteeing a smooth and high accurate movement in the range of sub nanometer. LPS-65 stages can be controlled with our E-861 piezo controller and the linear encoder provides nanometer repeatability. Vacuum compatible versions are available.

**TECHNICAL DATA**

Travel range (mm)	13	26	52
Straightness / Flatness (μm)	± 1	± 1.5	± 2
Pitch (μrad)	± 40	± 50	± 60
Yaw (μm)	± 40	± 50	± 60
Weight (kg)	0.3	0.4	0.6
Motor	PM-012		
Linear scale			LS-072
Speed max. (mm/sec)	10		
Resolution calculated (μm)			0.0005
Resolution typical (μm)			0.001
Bi-directional Repeatability (μm)			± 0.001
Uni-directional Repeatability (μm)			0.001
Nominal Current (A)			
Accuracy	on request		
Velocity range (mm/sec)	0.001 ... 10		
Material	Aluminum, black anodized		

Note: FS = full step, RE = rotary encoder  
 More info: Detailed information concerning motors and encoders, see appendix.

**LINEAR PIEZO STAGE LPS-65**



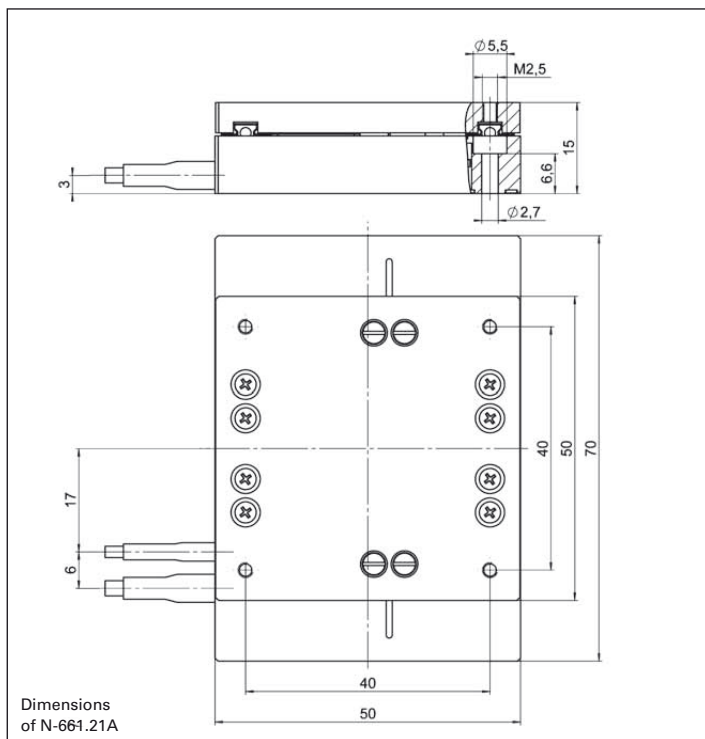
# N-661 Miniature Linear Slide with NEXACT® Drive

## 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.

# N-111 NEXLINE® OEM Linear Actuator

## Nanopositioning Over Long Travel, PiezoWalk® Principle



N-111 compact OEM nanopositioning actuator. In principle the movement by piezo steps allows an infinite travel range

- Travel Range 10 mm
- Resolution to 0.025 nm Open-Loop, 5 nm Closed-Loop
- Up To 50 N Force Generation and 70 N Holding Force
- Self Locking at Rest, No Heat Generation
- Non-Magnetic and Vacuum-Compatible Working Principle
- Cleanroom Compatible

The innovative N-111 NEXLINE® OEM linear actuators are compact actuators for nanopositioning with travel ranges to 10 mm, high resolution, and generated forces to 50 N. The operating principle is based on coordinated motion of a number of highly preloaded linear and shear piezo elements acting on a runner. NEXLINE® drives thus combine long travel ranges with piezo-class pre-

cision. For closed-loop operation without an additional position sensor the N-111.2A is equipped with a linear encoder that provides 5 nm resolution over the full travel range. In open-loop operation position resolution down to 25 picometers can be achieved by use of a high-dynamics analog mode.

### NEXLINE® Working Principle for Application Flexibility

NEXLINE® PiezoWalk® drives can be used wherever high loads must be positioned very precisely over long distances and then perhaps subjected to small-amplitude dynamic adjustment, as for active vibration control. By varying the combination of longitudinal and shear piezo elements, the step size, dynamic operating range (analog travel), clamping force, speed and stiffness can all be optimized for a particular application.

### One Working Principle – Different Operating Modes

NEXLINE® PiezoWalk® drives overcome the limitations of conventional nanopositioning systems in their combination of long travel ranges and high resolution and stiffness. The piezoceramic clamping and shear elements act directly on a moving runner that is coupled to the moved object. While in full step mode the runner can be moved over larger distances with maximum velocity, nanostepping mode allows uniform motion with highly constant speed. In open-loop operation any position resolution may be achieved which only depends on the stability of the control signal. Analog operation over a distance of less than one step enables high-dynamics positioning with resolutions far below one nanometer.

### Choice of Controllers for Optimization

NEXLINE® operation is supported by two motion controller models providing different features. The E-755 controller offers full functionality for nanometer precise positioning. The E-712 supplies more sophisticated linearization

### Ordering Information

- N-111.20**  
NEXLINE® OEM Piezo Stepping Actuator, 10 mm, 50 N
  - N-111.2A**  
NEXLINE® OEM Piezo Stepping Actuator, 10 mm, 50 N, Linear Encoder, 5 nm Resolution
- Ask about custom designs!**

algorithms resulting in very smooth motion with highly constant velocity. It can also provide higher speed with maximum force.

### Patented Technology

The products described in this document are in part protected by the following patents:  
German Patent No. 10148267  
US Patent No. 6,800,984

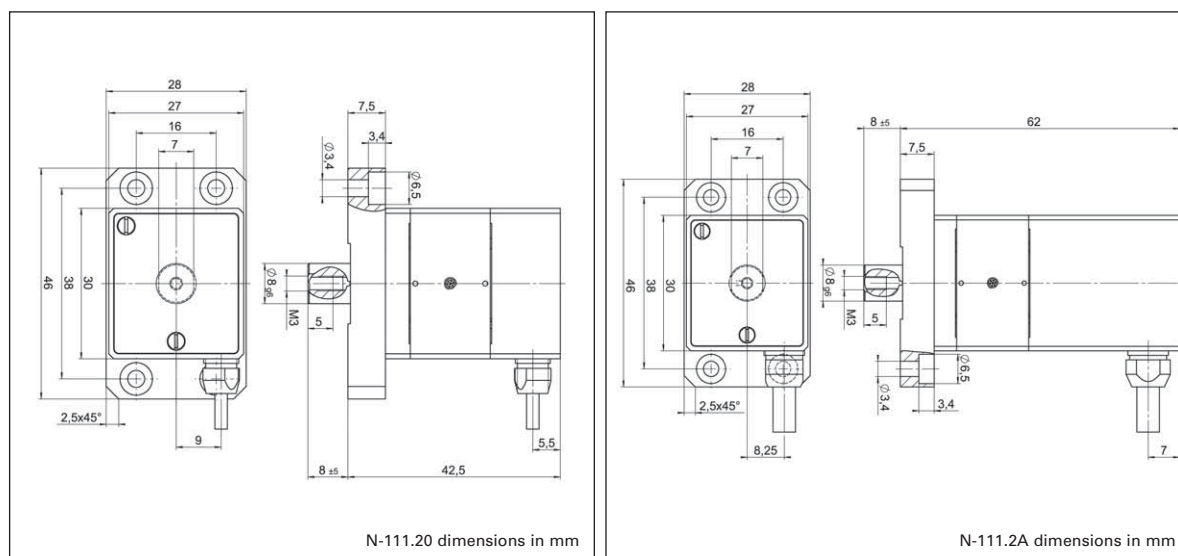
### Application Examples

- Semiconductor technology
- Semiconductor testing
- Wafer inspection
- Nano lithography
- Nano-imprinting
- Nanometrology
- Active vibration damping
- Motion in strong magnetic fields



Z / tip / tilt platform with NEXLINE® drives and position sensors; 300 mm (12") diameter, 200 N load capacity, 1.3 mm travel range, 10 mrad tilt range

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### Technical Data

Model	N-111.20	N-111.2A	Tolerance
Active axes	X	X	
<b>Motion and positioning</b>			
Travel range	10 mm	10 mm	
Step size (in step mode)	10 nm to 7 $\mu$ m	10 nm to 7 $\mu$ m	
Travel range in analog mode	$\pm 2$ $\mu$ m	$\pm 2$ $\mu$ m	
Integrated sensor	–	Linear encoder	
Open-loop resolution	0.025 nm	0.025 nm	typ.
Closed-loop resolution	–	5 nm	
Max. velocity (10 % duty cycle, full step mode)*	1.0 mm/s	1.0 mm/s	
Max. velocity (100 % duty cycle, full step mode)*	0.6 mm/s	0.6 mm/s	
Max. velocity (100 % duty cycle, nanostepping mode)**	0.4 mm/s	0.4 mm/s	
<b>Mechanical properties</b>			
Stiffness in motion direction	16 N/ $\mu$ m	16 N/ $\mu$ m	$\pm 20\%$
Drive force (active)***	50 N	50 N	max.
Holding force (passive)	70 N	70 N	min.
<b>Drive properties</b>			
Motor type	NEXLINE®	NEXLINE®	
Operating voltage	$\pm 250$ V	$\pm 250$ V	
<b>Miscellaneous</b>			
Operating temperature range	-40 to 80 °C	-40 to 80 °C	
Material	Aluminium stainless steel, titanium	Aluminium stainless steel, titanium	
Mass	245 g	325 g	
Cable length	1.5 m	1.5 m	$\pm 10$ mm
Connector	Sub-D connector NEXLINE® single-channel	Sub-D connector NEXLINE® single-channel plus sensor connector	
Recommended controller	E-755,101, E-712	E-755.1A1, E-712	

\* Depending on drive electronics. Data refer to operation together with E-712 controller.

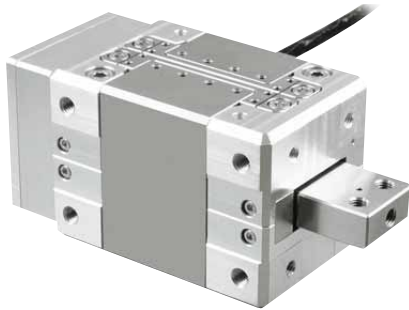
\*\* Depending on drive electronics. Data refer to operation together with E-712 controller. Together with the E-755 controller a velocity of up to 0.1 mm/s (closed-loop) and 0.2 mm/s (open-loop) can be achieved. The maximum speed in nanostepping mode is set so as to ensure the highest possible velocity constancy, with no speed fluctuations while steps are being performed.

\*\*\* Data refer to full step mode operation.



# N-216 NEXLINE® Linear Actuator

## High-Force PiezoWalk® Drive for Long-Range Nanopositioning



N-216 NEXLINE® High-Load Actuator. Feed motion is realized by piezo stepping motion which allows basically unlimited travel ranges with nanometer accuracy

- Travel Range 20 mm
- Resolution to 0.03 nm Open-Loop, 5 nm Closed-Loop
- Up to 800 N Holding Force
- Self Locking at Rest
- Non-Magnetic and Vacuum-Compatible Working Principle
- Cleanroom Compatible

N-216 NEXLINE® high-load linear actuators are ultra-precision nanopositioning actuators with travel ranges to 20 mm and push / pull forces to 600 N. The operating principle is based on coordinated motion of a number of highly preloaded linear and shear piezo elements acting on a runner. NEXLINE® drives combine long travel ranges with piezo-class precision.

N-216 comes in two versions for open- or closed-loop operation, as well as in two different load configurations. Closed-loop versions are equipped with a linear encoder for direct

position measurement of the moving runner. The encoder features 5 nm resolution over the full travel range. In open-loop operation a positioning resolution to 30 picometers can be realized by use of the high-dynamics analog operation mode.

### Unlimited Lifetime

The application area of NEXLINE® drives often lies in the difficult-to-access internals of machines, where nanometer-realm adjustment and vibration cancellation are required. Long lifetime is therefore a basic requirement for NEXLINE® actuators. To promote long lifetime, the controller can reduce the operating voltage on all the piezo elements to zero at any position and still maintain the full holding force.

### One Working Principle – Different Operating Modes

NEXLINE® PiezoWalk® drives overcome the limitations of conventional nanopositioning systems in their combination of long travel ranges and high resolution and stiffness. The piezo-ceramic clamping and shear

elements act directly on a moving runner that is coupled to the moved object. While in full step mode the runner can be moved over larger distances with maximum velocity, nanostepping mode allows uniform motion with highly constant speed. In open-loop operation any position resolution may be achieved which only depends on the stability of the control signal. Analog operation over a distance of less than one step enables high-dynamics positioning with resolutions far below one nanometer.

### Choice of Controllers for Optimization

NEXLINE® operation is supported by two motion controller models providing different features. The E-755 controller offers full functionality for nanometer precise positioning. The E-712 supplies more sophisticated linearization algorithms resulting in very smooth motion with highly constant velocity. It can also provide higher speed with maximum force.

### Ordering Information

**N-216.10**  
NEXLINE® Piezo Stepping High-Load Actuator, 20 mm, 300 N, Open-Loop

**N-216.1A**  
NEXLINE® Piezo Stepping High-Load Actuator, 20 mm, 300 N, Linear Encoder, 5 nm Resolution

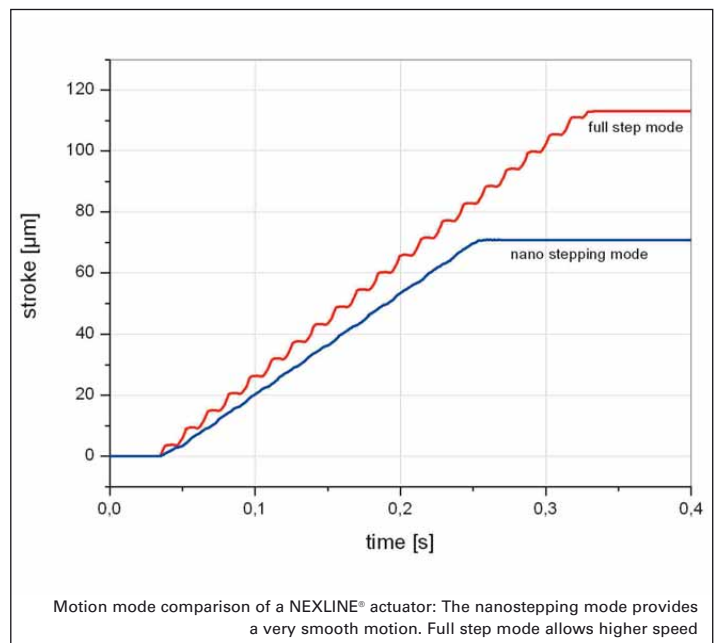
**N-216.20**  
NEXLINE® Piezo Stepping High-Load Actuator, 20 mm, 600 N, Open-Loop

**N-216.2A**  
NEXLINE® Piezo Stepping High-Load Actuator, 20 mm, 600 N, Linear Encoder, 5 nm Resolution

Ask about custom designs!

### Patented Technology

The products described in this document are in part protected by the following patents:  
German Patent No. 10148267  
US Patent No. 6,800,984

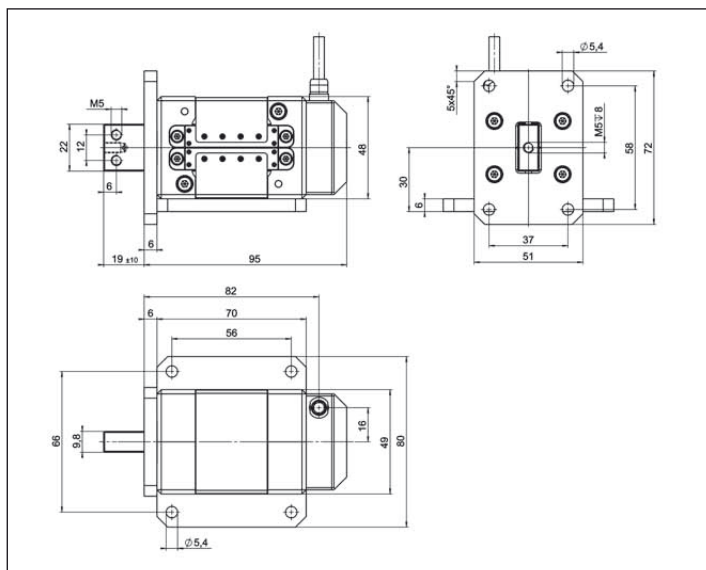


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### Application Example

- Semiconductor technology
- Semiconductor testing
- Wafer inspection
- Nano lithography
- Nano-imprinting
- Nanometrology
- Active vibration damping
- Motion in strong magnetic fields





6-axis parallel kinematics (Hexapod) with integrated NEXLINE® high-load actuators, suitable for applications in strong magnetic fields

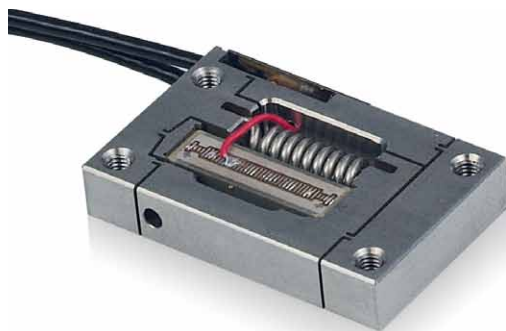
**Technical Data**

Index

Model	N-216.10 / N-216.1A	N-216.20 / N-216.2A	Tolerance
Active axes	X	X	
<b>Motion and positioning</b>			
Displacement	20 mm	20 mm	
Step size (in step mode)	10 nm to 10 μm	10 nm to 10 μm	
Travel range in analog mode	±3 μm	±3 μm	
Integrated sensor	N-216.10: none N-216.1A: linear encoder	N-216.20: none N-216.2A: linear encoder	
Open-loop resolution	0.03 nm	0.03 nm	typ.
Closed-loop resolution	- / 5 nm (N-216.1A)	- / 5 nm (N-216.2A)	
Max. velocity (10% duty cycle, full step mode)*	1.0 mm/s	1.0 mm/s	
Max. velocity (100% duty cycle, full step mode)*	0.6 mm/s	0.6 mm/s	
Max. velocity (100% duty cycle, nanostepping mode)**	0.4 mm/s	0.4 mm/s	
<b>Mechanical properties</b>			
Drive force (active)***	300 N	600 N	max.
Holding force (passive)	400 N	800 N	min.
<b>Drive properties</b>			
Motor type	NEXLINE®	NEXLINE®	
Operating voltage	±250 V	±250 V	
<b>Miscellaneous</b>			
Operating temperature range	-40 to 80 °C	-40 to 80 °C	
Material	Aluminum, stainless steel	Aluminum, stainless steel	
Mass	1150 g	1250 g	
Cable length	2.0 m	2.0 m	
Connector	Sub-D connector NEXLINE® single-channel N-216.1A: plus sensor connector	Sub-D connector NEXLINE® single-channel N-216.2A: plus sensor connector	
Recommended controller	E-755, E-712	E-755, E-712	

\* Depending on drive electronics. Data refer to operation together with E-712 controller.  
 \*\* Depending on drive electronics. Data refer to operation together with E-712 controller. Together with the E-755 controller a velocity of up to 0.1 mm/s (closed-loop) and 0.2 mm/s (open-loop) can be achieved. The maximum speed in nanostepping mode is set so as to ensure the highest possible velocity constancy, with no speed fluctuations while steps are being performed.  
 \*\*\* Data refer to full step mode operation.

# Piezo Actuators & Components



Latest PI Catalogs:  
[www.pi.ws](http://www.pi.ws)

# Piezoelectric Actuators and Components

## Advantages of PI Piezoelectric

- Sub-Nanometer resolution
- Large force generation (up to 50,000 N and more)
- Microsecond-range response
- No backlash, stiction or friction
- Immune to magnetic fields
- Extremely low steady-state power consumption
- No wear and tear
- Vacuum and clean-room compatibility
- Operation at cryogenic temperatures possible

Piezoelectric translators are solid-state ceramic actuators which convert electrical energy directly into linear motion (mechanical energy) with virtually unlimited resolution.



## Quality and Selection

PI offers a comprehensive assortment of high-resolution piezoelectric actuators and drives for industrial and scientific applications. In addition to the hundreds of models pre-

## High-Force Piezo Systems

The long-established and successful high-force / high-voltage piezo system product line has been improved and completely reworked. All high-voltage piezo actuators now make exclusive use of the modern PICA™ Power piezo ceramics. For high dynamics applications, the integrated preload and low electric power requirements of the packaged PICA™ Power actuators is a special advantage.

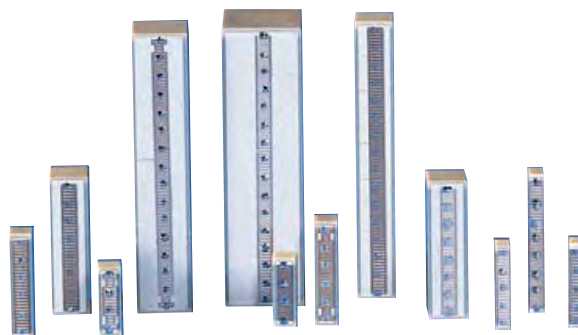
## Piezo-Electric All-Rounder—DuraAct™ Patch Transducers

The laminated patch transducers are suitable both for actuator and sensor tasks in various fields such as adaptronics. Even in high-dynamics applications, the rugged design ensures reliability, high resistance to damage and a lifetime well over 10<sup>9</sup> cycles.

- High-dynamics actuators
- Adaptive systems
- Vibration and noise cancellation
- Deformation control and stabilization
- Structural health monitoring
- Energy harvesting

sented in this catalog, PI can also deliver custom designs. All manufacturing steps from the PZT powder to the finished product are controlled by PI. PI's proprietary PICMA® technology with ceramic encapsu-

lation stands for high reliability and longer lifetime. Closed-loop piezo actuators and the corresponding control electronics are offered for higher linearity.



PICMA® piezoelectric actuators



Applied directly to a substrate, or used as part of the structure itself, DuraAct™ patch transducers can detect and produce vibrations or contour deformations at the source, inside the structure



Variety of piezoceramic stacks

# PICMA® Piezo Actuators—Extreme Lifetime, for Industrial Reliability Requirements

## Full-Ceramic Encapsulation & Patented Design

PI has 4 decades of experience with piezo ceramic actuators in motion control applications in industry and research. Currently PI employs more than 100 peo-

ple fully dedicated to piezo ceramic research, development and production. Extensive know-how and the most modern equipment make for the unique

flexibility and worldwide leadership in piezo matters.

PI piezo actuators not only show an optimal combination of travel and stiffness, but are also designed for maximum lifetime under actual operating conditions in industrial environments.

Maximum lifetime means highest possible reliability. PI's award-winning, patented PICMA® actuators are based upon the newest technology which reduces the failure rate by a factor 10 compared to conventionally designed multilayer actuators.

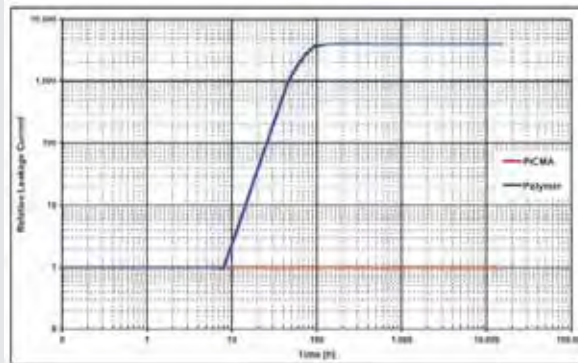


PICMA® award-winning multilayer piezo actuators feature full-ceramic insulation

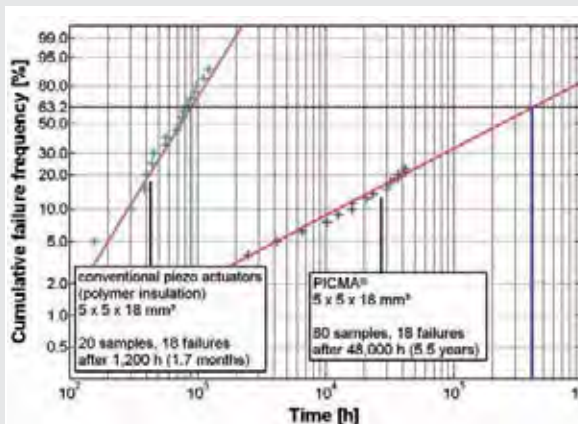
### Long Term Tests Prove DC Reliability

PI's monolithic ceramic-encapsulated design provides better humidity protection than conventional polymer-film insulation. Diffusion of water molecules into the insulation layer is greatly reduced by the use of co-fired, outer ceramic encapsulation (fig. 2). Humidity is the main influence on the long-term reliability in low-dynamics or quasi-static operation modes, where the piezo actuator is supplied with a DC voltage to maintain a position for a long time.

Comparative tests with both PICMA® and conventional multilayer piezo actuators have proven the positive effects of the ceramic encapsulation. While polymer-coated piezos typically only survive 30 days of continuous operation - PICMA® actuators are still working after more than 4 years!



PICMA® piezo actuators (lower curve) compared with polymer-insulated multilayer piezo actuators. PICMA® actuators are insensitive to high humidity in this test. In conventional actuators, the leakage current begins to rise after only a few hours—an indication of degradation of the insulation and reduced lifetime.



Results of an accelerated DC-lifetime-test of PICMA® actuators compared to conventional actuators (100 V DC, room temperature, 90 % R.H.). The expected MTTF (Mean Time To Failure) for PICMA® is 80 years (700 000 hrs of continuous operation). All of the polymer-insulated samples have failed after 1,600 hrs (MTTF 805 hrs = 1 month)

## PICMA<sup>®</sup> Piezo Actuators

### Continuous Dynamic Operation

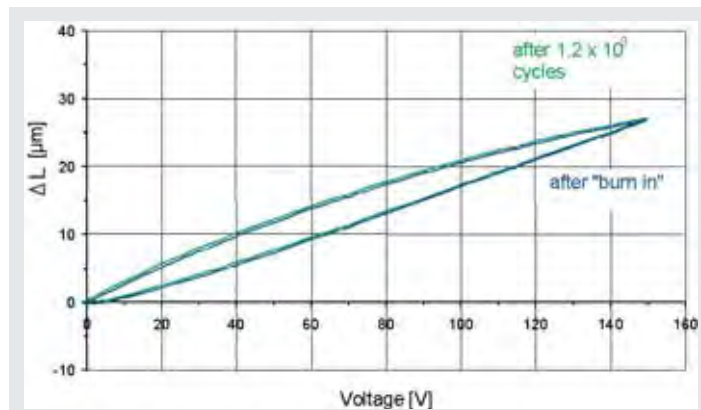
Here, the well-known lifetime-limiting factors of conventional designs are humidity, crack formation inside the ceramic leading to rising leakage currents and delamination of electrodes under extreme dynamic conditions.

PI reduces the cracking probability by a special patented design where segmented slots take care of excessive tensional stresses. Furthermore, the special electrode design ensures excellent, stable, electric contact even after billions of cycles.

PICMA<sup>®</sup> multilayer piezo actuators show no significant decrease in displacement even after many billions of cycles.

### Long-Term Test under Cryogenic Conditions

To suit an application requiring 10 years minimum lifetime under cryogenic conditions, accelerated lifetime tests with PICMA<sup>®</sup> piezo actuators have been successfully performed. Inserted in a cryogenic bath of liquid nitrogen (75 K), the piezo is placed in a vacuum chamber ( $2 \cdot 10^{-3}$  mbar) and subjected to dynamic operation at 90% of



AC tests were performed for  $4.0 \times 10^9$  cycles at 8 samples PICMA<sup>®</sup> 5x5x18 using a 116 Hz-sine wave excitation ( $1.0 \times 10^7$  cycles per day) at a unipolar operating voltage of 100 V, 15 MPa preload. Control measurements were taken every  $10^9$  cycles. There was no significant decrease in displacement.

the maximum voltage range (>105 V) with an operating frequency up to 1000 Hz. After one month of continuous operation there were no degradations in piezo performance to be measured, neither mechanic concerning the displacement, nor electrical concerning electrical capacitance or resonant frequency. (Dr. Bosotti et al., University of Milano, Italy, 2005)

### Large Operating Temperature Range , Optimum UHV Compatibility - Minimum Outgassing

Another advantage of fully ceramic-encapsulation PICMA<sup>®</sup>

actuators is the extended operating temperature range, up to 150 °C, a huge improvement over the 80 °C limit common for other, polymer-insulated, monolithic actuators. The heat generation in dynamic operation is proportional to the operating frequency. Thus, a higher operating temperature allows for higher operating frequencies and duty cycles. Additionally, the lack of polymer insulation and the high Curie temperature make for optimal ultra-high-vacuum compatibility (no outgassing / high bake-out temperatures, up to 150 °C).



# Cost-Efficient PiezoMove Linear Flexure Actuator

FRICTIONLESS GUIDINGS AND TRAVEL RANGES TO 0.5 MM



## P-603

- Flexure guides for linear motion with minimum tip and tilt
- Travel ranges to 500  $\mu\text{m}$
- Optimized design for manufacturing in large quantities
- Available with integrated position sensor

### Precision-class piezo linear actuator

Frictionless flexure-guided design minimizes unwanted tip and tilt motion. Integrated motion amplifier. Medium stiffness

### PICMA® high-performance piezo drive

Piezoceramic actuators with all-ceramic insulation. Longer lifetime, humidity resistance and operating temperatures to 80°C

### Position sensor option for closed-loop operation

Strain gauge sensor made of metal foil: Compact and with a linearity error to 0.2% for high position stability and repeatability. Indirect position measurement

### Fields of application

Research and industry. Ideal OEM actuators for precision motion control in optics, medical, biotech and microfluidics applications, e.g. for micropumps, valve control, dosing systems

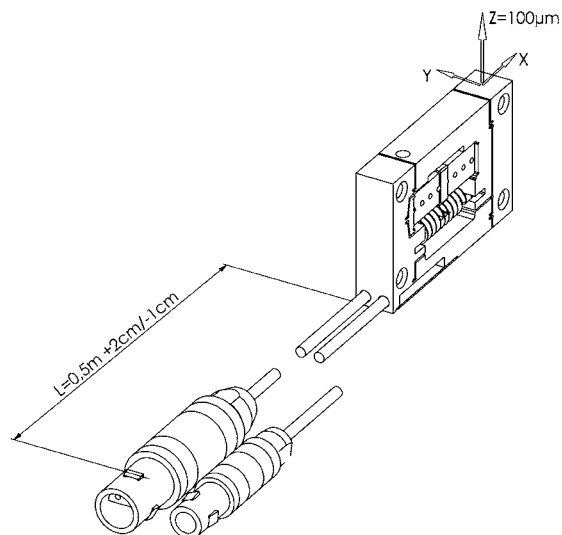
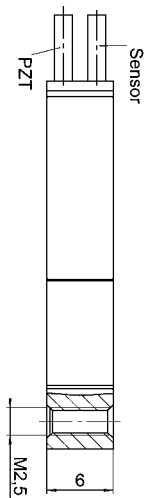
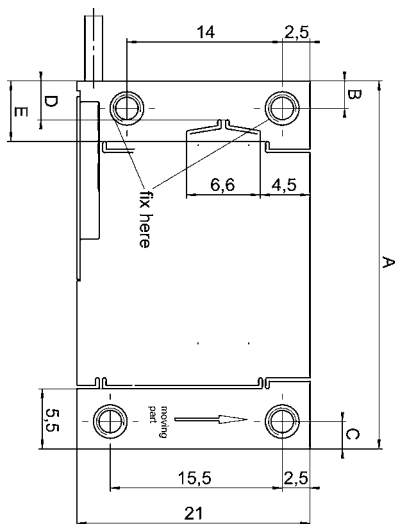


PiezoMove actuators of the P-603 series are available with travel ranges of 100  $\mu\text{m}$ , 300  $\mu\text{m}$  and 500  $\mu\text{m}$

### Related products

- P-601 PiezoMove flexure-guided linear actuator
- P-602 PiezoMove linear actuator with high stiffness
- P-713 XY piezo scanner

	P-603.1S1 P-603.1S2	P-603.3S1 P-603.3S2	P-603.5S1 P-603.5S2	P-603.x01 open-loop versions	Unit
Active axes	Z	Z	Z	Z	
<b>Motion and positioning</b>					
Integrated sensor	SGS	SGS	SGS	–	
Open-loop travel, -20 to 120 V	120	380	550	as P-603.xS1	µm
Closed-loop travel	100	300	500	–	µm
Open-loop resolution, 180g	2	3	5	as P-603.xS1	nm
Closed-loop resolution, 180g	6	8	10	–	nm
Closed-loop non-linearity	0.2	0.2	0.2	–	%
Unidir. Repeatability, 10%, 1 Sigma	7	10	20	–	nm
<b>Mechanical properties</b>					
Stiffness in motion direction	0.3	0.14	0.06	as P-603.xS1	N/µm
Unloaded resonant frequency	900	410	300	as P-603.xS1	Hz
Resonant frequency @ 180 g	160	110	80	as P-603.xS1	Hz
Push / pull force capacity in motion direction	40 / 20	35 / 13	30 / 10	as P-603.xS1	N
<b>Drive properties</b>					
Piezoceramics	PICMA® P-885	PICMA® P-885	PICMA® P-885	as P-603.xS1	
Electrical capacitance	1.5	3.1	3.7	as P-603.xS1	µF
Dynamic operating current coefficient	1.9	1.3	1.6	as P-603.xS1	µA / (Hz × µm)
<b>Miscellaneous</b>					
Operating temperature range	-20 to 80	-20 to 80	-20 to 80	as P-603.xS1	°C
Material	Stainless steel	Stainless steel	Stainless steel	as P-603.xS1	
Dimensions	33.5 mm × 21 mm × 6 mm	52 mm × 21 mm × 6 mm	62 mm × 21 mm × 6 mm	as P-603.xS1	
Mass	S1 version: 0.03 S2 version: 0.04	S1 version: 0.04 S2 version: 0.05	S1 version: 0.05 S2 version: 0.06	as P-603.xS1	kg
Cable length	0.5	0.5	0.5	as P-603.xS1	m
Sensor connection	S1 versions: Wire leads S2 versions: LEMO (strain gauge sensor)			–	
Voltage connection	S1 versions: Wire leads S2 versions: LEMO (low voltage)			as P-603.xS1	
Recommended controller / amplifier	E-610.S0 controller E-625.SR controller, bench-top device E-709.SRG controller, bench-top device with digital linearization			E-610.00 amplifier E-831 OEM amplifier module	



	A	B	C	D	E
P-603.1xx	33,5	2,5	2,5	3,5	5,5
P-603.3xx	52	2,75	2,5	3,5	5,6
P-603.5xx	62	2,5	2,5	4,5	6,2

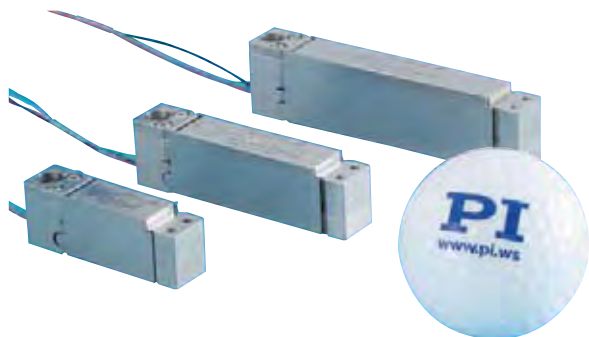
P-603, dimensions in mm

Direction of motion of the P-603.  
The flexure guiding system prevents tip and tilt at the drive head



# P-601 PiezoMove™ Z-Motor Actuator

## Flexure-Guided OEM Piezo Actuator with Long Stroke to 400 µm



PiezoMove™ Lever-amplified piezo actuators of the P-601 series

- Flexure Guidance for Frictionless, Ultra-Straight Motion
- Travel Ranges to 400 µm
- Resolution to 0.2 nm
- High Dynamics and Stiffness
- Custom Designs with Longer Travel or Faster Response and Non-Magnetic Versions Feasible
- Outstanding Lifetime Due to PICMA® Piezo Actuators
- Choice of Closed-Loop and Open-Loop Models
- Ideal OEM Actuator for Precision Motion Control in Optics, Medical, Biotech and Microfluidics Applications

The flexure-guided, lever-amplified PiezoMove™ P-601 actuators provide large vertical travel ranges up to 400 µm, fast response and high positioning accuracy in a very small package. With settling times of only

a few milliseconds and a resolution in the sub-nanometer range they are well suited for both static and dynamic applications.

P-601 PiezoMove™ lever-amplified actuators cover the range between direct-driven preloaded piezo translators, such as the P-840 series (see p. 1-74) and single-axis nanopositioning stages, like the P-611 series (see p. 2-20). Compared to direct-driven piezo translators, lever-amplified actuators offer larger travel ranges and much higher lateral stiffness and guiding precision. Compared to single-axis nanopositioning stages, they offer significantly smaller sizes. PiezoMove™ lever-amplified actuators feature a resolution to 0.2 nm and a repeatability to 8 nm.

### OEM Actuator with Integrated Guidance

With their highly precise, frictionless flexure guidance, a very high stiffness and excellent straightness of motion are achieved. Together with their small dimensions and the cost-effective design, the P-601 lever amplified actuators are especially suited for OEM applications. Versions with strain-gauge sensors (SGS) are equipped with a full bridge circuit that is insensitive to thermal drift. Versions without sensors are also available for open-loop applications such as in high-speed switches and pumps. In addition to the standard steel models, special invar and non-magnetic versions are available on request.

### Ceramic Insulated Piezo Actuators Provide Long Lifetime

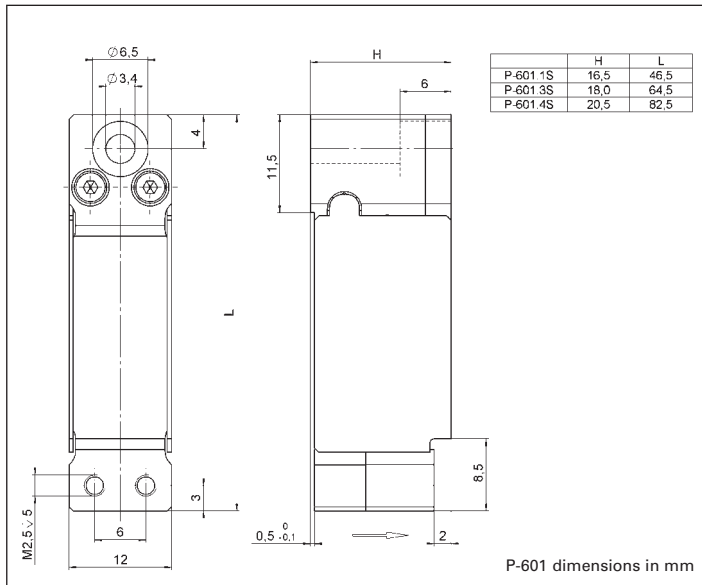
Highest possible reliability is assured by the use of award-winning PICMA® multilayer piezo actuators. PICMA® actuators are the only actuators on the market with ceramic-only insulation, which makes them resistant to ambient humidity and leakage-current failures. They are thus far superior to conventional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

### Ordering Information

- P-601.1S**  
PiezoMove™ OEM Flexure-Guided, Lever-Amplified Actuator, 100 µm, SGS-Sensor
- P-601.3S**  
PiezoMove™ OEM Flexure-Guided, Lever-Amplified Actuator, 250 µm, SGS-Sensor
- P-601.4S**  
PiezoMove™ OEM Flexure-Guided, Lever-Amplified Actuator, 400 µm, SGS-Sensor
- P-601.1SL**  
PiezoMove™ OEM Flexure-Guided, Lever-Amplified Actuator, 100 µm, SGS-Sensor, LEMO Connector
- P-601.3SL**  
PiezoMove™ OEM Flexure-Guided, Lever-Amplified Actuator, 250 µm, SGS-Sensor, LEMO Connector
- P-601.4SL**  
PiezoMove™ OEM Flexure-Guided, Lever-Amplified Actuator, 400 µm, SGS-Sensor, LEMO Connector
- P-601.10**  
PiezoMove™ OEM Flexure-Guided, Lever-Amplified Actuator, 100 µm, Open-Loop
- P-601.30**  
PiezoMove™ OEM Flexure-Guided, Lever-Amplified Actuator, 250 µm, Open-Loop
- P-601.40**  
PiezoMove™ OEM Flexure-Guided, Lever-Amplified Actuator, 400 µm, Open-Loop

### Application Example

- Nanopositioning
- Imaging
- High-speed switching
- Patch clamp
- Micro-dispensing
- Semiconductor testing
- Adaptronics / Automation
- Photonics / integrated optics
- Biotechnology



Index

**Technical Data**

Model	P-601.1S P-601.1SL	P-601.3S P-601.3SL	P-601.4S P-601.4SL	P-601.x0 Open-loop versions	Units	Tolerance
Active axes	Z	Z	Z	Z		
<b>Motion and positioning</b>						
Integrated sensor	SGS	SGS	SGS	–		
Open-loop travel, -20 to +120 V	100	250	400	as P-601.xS	µm	min. (+20 %/-0 %)
Closed-loop travel	100	250	400	–	µm	calibrated
Open-loop resolution	0.2	0.3	0.4	as P-601.xS	nm	typ.
Closed-loop resolution	2	6	12	–	nm	typ.
Linearity, closed-loop	0.1	0.3	0.3	–	%	typ.
Repeatability	8	10	30	–	nm	typ.
Runout $\theta_x, \theta_y$	20 / 10	20 / 10	20 / 10	as P-601.xS	µrad	typ.
<b>Mechanical properties</b>						
Stiffness in motion direction	0.8	0.38	0.28	as P-601.xS	N/µm	±20 %
Unloaded resonant frequency	750	440	350	as P-601.xS	Hz	±20 %
Resonant frequency @ 30 g	620	350	290	as P-601.xS	Hz	±20 %
Push/pull force capacity in motion direction	30/10	20/10	15/10	as P-601.xS	N	Max.
Lateral force	30	30	30	as P-601.xS	N	Max.
<b>Drive properties</b>						
Ceramic type	PICMA® P-885	PICMA® P-885	PICMA® P-885	as P-601.xS		
Electrical capacitance	1.5	3.1	4.6	as P-601.xS	µF	±20 %
Dynamic operating current coefficient	1.9	1.6	1.4	as P-601.xS	µA/(Hz•µm)	±20 %
<b>Miscellaneous</b>						
Operating temperature range	-20 to 80	-20 to 80	-20 to 80	-20 to 80	°C	
Material	Stainless steel	Stainless steel	Stainless steel	Stainless steel		
Mass without cables	0.05	0.08	0.11	as P-601.xS	kg	±5 %
Cable length	S-version: 0.3 SL-version: 1.5	S-version: 0.3 SL-version: 1.5	S-version: 0.3 SL-version: 1.5	0.3	m	±10 mm
Sensor / voltage connection	S-version: open leads SL-version: LEMO	S-version: open leads SL-version: LEMO	S-version: open leads SL-version: LEMO	Open leads (no sensor)		

Recommended controller / amplifier  
E-610 controller / amplifier (p. 2-110), E-625 bench-top controller (p. 2-114)

# P-602 PiezoMove Flexure Motor Actuator, High Stiffness

## 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)

- 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
- Ideal for OEM-Applications in Adaptronics, Biotechnology or Microfluidics

P-602 PiezoMove flexure-guided piezo actuators integrate a frictionless high-efficiency motion amplifier to combine large travel ranges up to 1 millimeter

### Application Examples

- Nanopositioning
- Adaptronics
- Active vibration control
- Nano-imprinting
- Active Tool control
- Laser technology
- Semiconductor technology
- Active and adaptive optics

with high stiffness and very fast response. They do not contain any components that require maintenance or are subject to wear or tear. The flexure guides eliminate tip motion permitting only for a very slight tilt at the drive head. This design feature saves the cost for additional guiding systems when integrating these actuators in applications for the active control of tools, vibrations or deformations for accuracies down to a few 10s of nanometers.

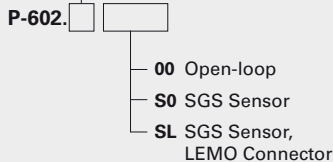
### Options and Custom Versions

For OEM applications, PiezoMove actuators can be modified in various ways to suit the customer's requirements. The

### Ordering Information

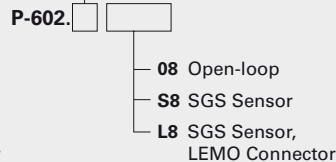
#### PiezoMove® OEM Linear Actuator with High Stiffness

- 1 Travel Range 100 μm
- 3 Travel Range 300 μm
- 5 Travel Range 500 μm
- 8 Travel Range 1000 μm



#### PiezoMove® OEM Linear Actuators with High Force

- 1 Travel Range 100 μm
- 3 Travel Range 300 μm
- 5 Travel Range 500 μm



Ask about custom designs!

stiffness and force generation can be influenced via the lever design and the dimensions of the piezo ceramics used in the actuator. If only a small force and low guiding accuracy are required, large strokes of several 100 μm and high frequencies can be achieved with small actuators, e.g. for micropump drives. For high-accuracy applications, an integrated position feedback sensor is available. The actuators were designed to allow for considerable cost savings in large production runs.

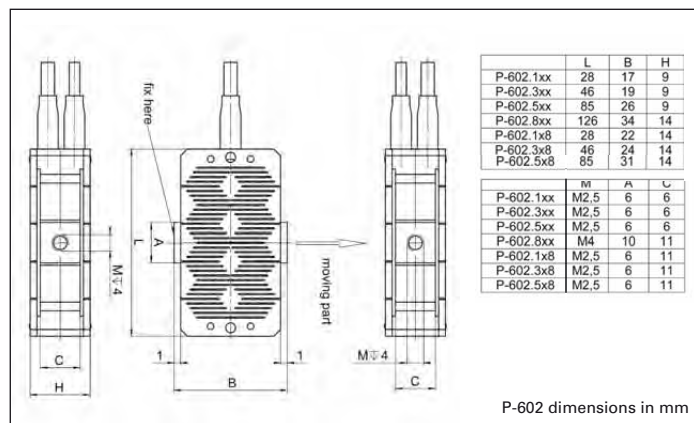
### OEM Control Electronics

PI also supplies a variety of controllers to match the actuators. These range from simple amplifier modules (see p. 2-164) and analog closed-loop OEM controllers (see p. 2-110)

to high-performance digital controllers (see p. 2-100ff). The great choice of actuators and controllers allows customers to select the optimum combination of performance and cost for their application.

### Ceramic-Insulated Piezo Actuators Provide Superior Lifetime

The highest possible reliability is assured by employing the award-winning PICMA® multi-layer piezo actuators. PICMA® actuators are the only actuators on the market with a 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.

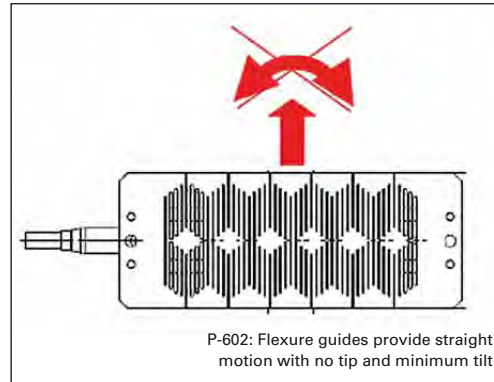


P-602 dimensions in mm

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PI offers a large variety of standard and custom lever-amplified piezo actuators for almost any application



Technical Data (preliminary)

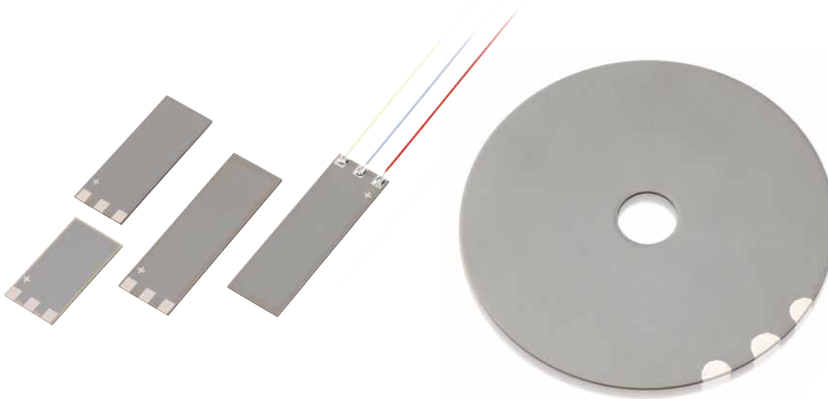
Model	P-602.100 P-602.1S0 P-602.1SL	P-602.300 P-602.3S0 P-602.3SL	P-602.500 P-602.5S0 P-602.5SL	P-602.108 P-602.1S8 P-602.1L8	P-602.308 P-602.3S8 P-602.3L8	P-602.508 P-602.5S8 P-602.5L8	P-602.800 P-602.8S0 P-602.8SL	Units	Tolerance
Active axes	X	X	X	X	X	X	X		
<b>Motion and positioning</b>									
Integrated 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.
<b>Mechanical properties</b>									
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.
<b>Drive properties</b>									
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%
<b>Miscellaneous</b>									
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		
kg	28 x 17 x 9	46 x 19 x 9	85 x 26 x 9	28 x 22 x 14	46 x 24 x 14	85 x 31 x 14	126 x 34 x 14	mm	
Mass	0.022	0.04	0.105	0.05	0.088	0.215	0.355	kg	± 5%
Cable length	0.5 / 0.5 / 2	0.5 / 0.5 / 2	0.5 / 0.5 / 2	0.5 / 0.5 / 2	0.5 / 0.5 / 2	0.5 / 0.5 / 2	0.5 / 0.5 / 2	m	± 10 mm
Sensor / voltage connection	0- and S-version: open leads SL-version: LEMO connector	0- and S-version: open leads SL-version: LEMO connector	0- and S-version: open leads SL-version: LEMO connector	0- and S-version: open leads L-version: LEMO connector	0- and S-version: open leads L-version: LEMO connector	0- and S-version: open leads L-version: LEMO connector	0- and S-version: open leads SL-version: LEMO connector		

Index

Recommended controller / amplifier  
E-610 controller / amplifier see p. 2-110, E-625 bench-top controller see p. 2-114

# PICMA® Bender Piezo Actuator

ALL-CERAMIC BENDER ACTUATORS WITH HIGH DISPLACEMENT



## PL112 – PL140 • PD410

- Displacement to 2 mm
- Fast response in the ms range
- Nanometer resolution
- Low operating voltage

### PICMA® multilayer bender elements with high reliability

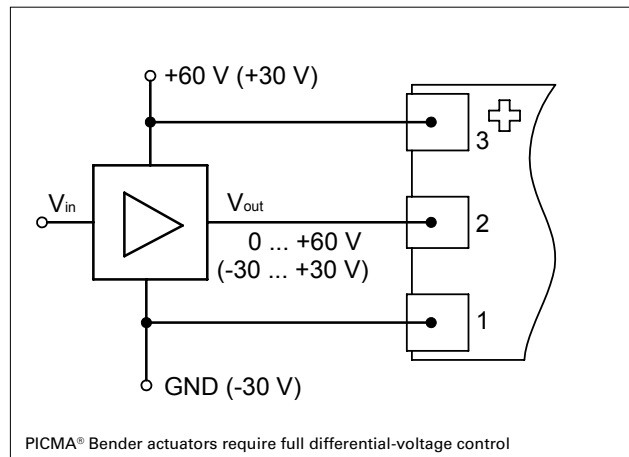
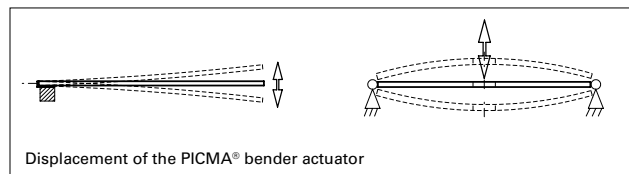
Operating voltage 0 to 60 V. Bidirectional displacement. Ceramic insulation, polymer-free. UHV-compatible to  $10^{-9}$  hPa, no outgassing, high bakeout temperature. Reliable even under extreme conditions

### Fields of application

Research and industry, vacuum. For medical technology, laser technology, sensor systems, automation tasks, pneumatic valves

### Suitable drivers

E-650 Piezo Amplifier for Multilayer Bender Actuators



**Rectangular bender actuators**

Order number	Operating voltage [V]	Displacement [ $\mu\text{m}$ ] $\pm 20\%$	Free length $L_f$ [mm]	Dimensions $L \times W \times TH$ [mm]	Blocking force [N] $\pm 20\%$	Electrical capacitance [ $\mu\text{F}$ ] $\pm 20\%$	Resonant frequency [Hz] $\pm 20\%$
PL112.10*	0 - 60 ( $\pm 30$ )	$\pm 80$	12	17.8 $\times$ 9.6 $\times$ 0.65	$\pm 2.0$	2 * 1.1	2000
PL122.10	0 - 60 ( $\pm 30$ )	$\pm 250$	22	25.0 $\times$ 9.6 $\times$ 0.65	$\pm 1.1$	2 * 2.4	660
PL127.10	0 - 60 ( $\pm 30$ )	$\pm 450$	27	31.0 $\times$ 9.6 $\times$ 0.65	$\pm 1.0$	2 * 3.4	380
PL128.10*	0 - 60 ( $\pm 30$ )	$\pm 450$	28	35.5 $\times$ 6.3 $\times$ 0.75	$\pm 0.5$	2 * 1.2	360
PL140.10	0 - 60 ( $\pm 30$ )	$\pm 1000$	40	45.0 $\times$ 11.0 $\times$ 0.6	$\pm 0.5$	2 * 4.0	160

**Round bender actuators**

Order number	Operating voltage [V]	Displacement [ $\mu\text{m}$ ] $\pm 20\%$	Free length $L_f$ [mm]	Dimensions $OD \times ID \times TH$ [mm]	Blocking force [N] $\pm 20\%$	Electrical capacitance [ $\mu\text{F}$ ] $\pm 20\%$	Resonant frequency [Hz] $\pm 20\%$
PD410.10*	0 - 60 ( $\pm 30$ )	$\pm 270$	-	44 $\times$ 7 $\times$ 0.65	$\pm 20$	2 * 10.5	1000

For optional 100 mm PTFE-insulated wire leads, AWG 32 ( $\varnothing$  0.49 mm), change order number extension to 1 (e. g. PL112.11).

Piezo ceramic type: PIC 251, \*PIC252.

Standard connections: Solderable contacts.

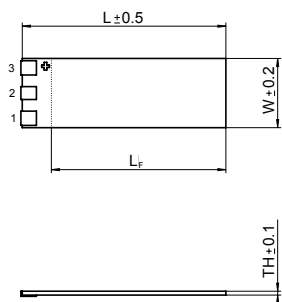
Resonant frequency at  $1 V_{pp}$ , clamped on one side with free length  $L_f$ , without mass load. For PD410.10: Restraint with rotatable mounting on the outer circumference.

Capacitance at  $1 V_{pp}$ , 1 kHz, RT.

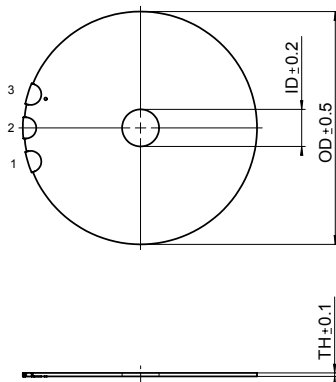
Operating temperature range: -20 to 85°C; \* -20 to 150°C.

Recommended mounting: Epoxy resin adhesive. All specifications depend on the real clamping conditions and on the applied mechanical load.

Custom designs or different specifications on request.



PL112 – PL140.10, dimensions in mm.  
L,  $L_f$ , W, TH see data table



PD410 round PICMA® Bender Piezo Actuator, dimensions in mm. ID, OD, TH see data table



# P-882 · P-888 PICMA<sup>®</sup> Multilayer Piezo Stack Actuators

## Ceramic-Insulated High-Power Actuators



PICMA<sup>®</sup> piezo actuators are available with cross-sections of 2 x 3, 3 x 3, 5 x 5, 7 x 7 and 10 x 10 mm<sup>2</sup>

- Superior Lifetime Even Under Extreme Conditions
- Very Large Operating Temperature Range
- High Humidity Resistance
- Excellent Temperature Stability
- High Stiffness
- Peak Current up to 20 A
- UHV Compatible to 10<sup>-9</sup> hPa
- Sub-Millisecond Response / Sub-Nanometer Resolution
- Ideal for Dynamic Operation

PICMA<sup>®</sup> (PI Ceramic Monolithic Multilayer Actuator) piezo stack actuators are characterized by their high performance and reliability, even in extremely harsh environments. They are superior to conventional multilayer actuators in

industrial applications and high-endurance situations, where they show substantially longer lifetimes both in static and dynamic operation.

### New Production Process, Optimized Piezo Ceramics

PICMA<sup>®</sup> piezo actuators are made from a ceramic material in which the piezoceramic properties such as stiffness, capacitance, displacement, temperature stability and lifetime are optimally combined. Thus the actuators accomplish sub-nanometer resolution in positioning and sub-millisecond response!

### Increased Lifetime Through Humidity Resistance

The monolithic ceramic-encapsulated design provides better humidity protection than poly-

mer-film insulation. Diffusion of water molecules into the insulation layer is greatly reduced by the use of cofired, outer ceramic encapsulation. Due to their high resonant frequency the actuators are suitable for highly dynamic applications with small loads; depending on the load an external preload for dynamic applications is recommended. The high Curie temperature of 320 °C gives PICMA<sup>®</sup> actuators a usable temperature range extending up to 150 °C, far beyond 80 °C as is common for conventional multilayer actuators. With conventional multilayer actuators, heat generation - which is proportional to operating frequency - either limits the operating frequency or duty cycle in dynamic operation, or makes ungainly cooling provisions necessary. At the low end, operation down to a few Kelvin is possible (with reduction in performance specifications).

### Optimum UHV Compatibility - Minimum Outgassing

The lack of polymer insulation and the high Curie temperature make for optimal ultra-high-vacuum compatibility (high bakeout temperatures, up to 150 °C).



### Ideal for Closed-Loop Operation

The ceramic surface of the actuators is extremely well suited for use with resistive or optical fiber strain gauge sensors. Such sensors can be easily applied to the actuator surface and exhibit significantly higher stability and linearity than with conventional polymer-insulated actuators.

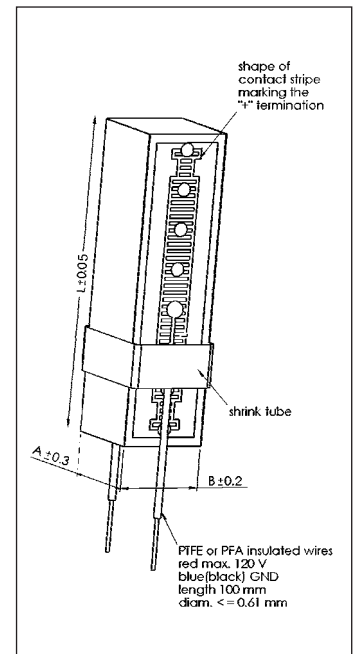
### Piezo Drivers, Controllers & High-Voltage Amplifiers

High-resolution amplifiers and servo-control electronics, both digital and analog, are described in the "Piezo Drivers / Servo Controllers" section.

Read more on PICMA<sup>®</sup> reliability on page 2-12 ff.

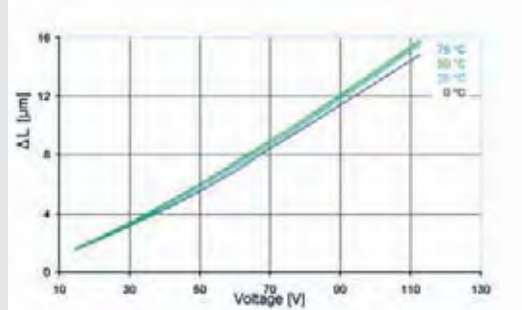
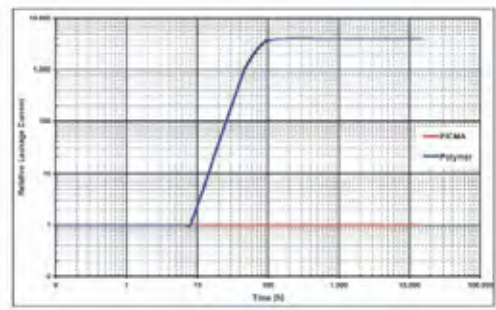
### Application Examples

- Precision mechanics / -machining
- High-speed switching
- Active and adaptive Optics
- Active vibration damping
- Pneumatic & hydraulic valves
- Metrology / Interferometry
- Life science, Biotechnology
- Nanotechnology



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PICMA<sup>®</sup> piezo actuators (bottom curve) compared with conventional multilayer actuators with polymer insulation (top curve). PICMA<sup>®</sup> actuators are not affected by the high-humidity test conditions. Conventional piezo actuators exhibit increased leakage current after only a few hours. Leakage current is an indicator quality and expected lifetime.

The displacement of PICMA<sup>®</sup> actuators exhibits very low temperature dependence. This, in combination with their low heat generation, makes PICMA<sup>®</sup> actuators optimal for dynamic operation

Test conditions: U = 100 VDC, T = 25 °C, Relative Humidity = 70 %

Technical Data / Product Order Numbers

Order number*	Dimensions A x B x L [mm]	Nominal displacement [μm @ 100 V]	Max. displacement [μm @ 120 V]	Blocking force [N @ 120 V]	Stiffness [N/μm]	Electrical capacitance [μF] ±20 %	Resonant frequency [kHz] ±20 %
P-882.10	2 x 3 x 9	6.5 ±20 %	8 ±20 %	190	24	0.15	135
P-882.30	2 x 3 x 13.5	11 ±20 %	13 ±20 %	210	16	0.22	90
P-882.50	2 x 3 x 18	15 ±10 %	18 ±10 %	210	12	0.31	70
P-883.10	3 x 3 x 9	6.5 ±20 %	8 ±20 %	290	36	0.21	135
P-883.30	3 x 3 x 13.5	11 ±20 %	13 ±20 %	310	24	0.35	90
P-883.50	3 x 3 x 18	15 ±10 %	18 ±10 %	310	18	0.48	70
P-885.10	5 x 5 x 9	6.5 ±20 %	8 ±20 %	800	100	0.6	135
P-885.30	5 x 5 x 13.5	11 ±20 %	13 ±20 %	870	67	1.1	90
P-885.50	5 x 5 x 18	15 ±10 %	18 ±10 %	900	50	1.5	70
P-885.90	5 x 5 x 36	32 ±10 %	38 ±10 %	950	25	3.1	40
P-887.30	7 x 7 x 13.5	11 ±20 %	13 ±20 %	1700	130	2.2	90
P-887.50	7 x 7 x 18	15 ±10 %	18 ±10 %	1750	100	3.1	70
P-887.90	7 x 7 x 36	32 ±10 %	38 ±10 %	1850	50	6.4	40
P-888.30	10 x 10 x 13.5	11 ±20 %	13 ±20 %	3500	267	4.3	90
P-888.50	10 x 10 x 18	15 ±10 %	18 ±10 %	3600	200	6.0	70
P-888.90	10 x 10 x 36	32 ±10 %	38 ±10 %	3800	100	13.0	40

Standard piezo ceramic type: 252

\*For optional PTFE insulated wires, pigtail length 100 mm, change order number extension to .x1 (e. g. P-882.11).

Recommended preload for dynamic operation: 15 MPa

Maximum preload for constant force: 30 MPa

Resonant frequency at 1 V<sub>pp</sub>, unloaded, free at both sides. The value is halved for unilateral clamping

Capacitance at 1 V<sub>pp</sub>, 1 kHz

Operating voltage: -20 to +120 V

Operating temperature range: -40 to +150 °C

Standard Mechanical Interfaces: Ceramics

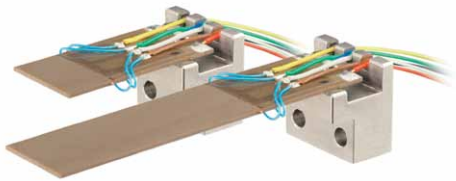
Standard Electrical Interfaces: Solderable pads

Available Options: strain gauge sensors, special mechanical interfaces, etc.

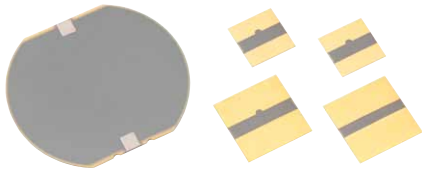
Other specifications on request.

# Custom Designs

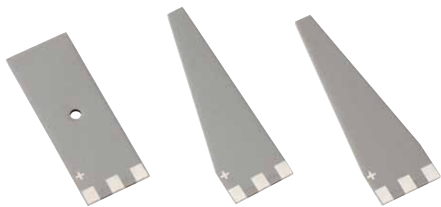
PICMA® BENDER PIEZO ACTUATORS



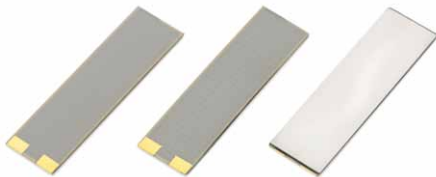
P-871 bender actuators with attached SGS position sensors offer closed-loop, position-controlled displacements of up to 1.6 mm with response times in the millisecond range. The integrated sensors allow a considerably better linearity and repeatability in closed-loop operation. For easy installation, the actuators are supplied with cables, connectors and a mounting adapter.



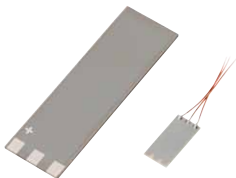
Multilayer contracting plates can be manufactured in a variety of shapes, e. g. rectangular or disk-shaped, and are available on request. These plates can be applied e. g. to metal or silicon substrates, in order to realize bender or pump elements with low control voltages.



Multilayer bender actuators can be manufactured in almost any shape. The manufacturing process allows, among other things, inner holes with an all-ceramic insulation. The height of the active layers can be varied from a minimum height of 15  $\mu\text{m}$  so that control voltages of only 10 V can be used.



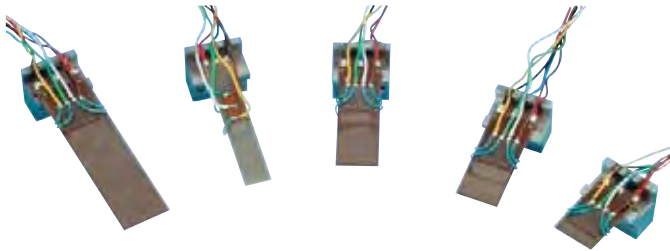
Benders with unidirectional displacement consist of a single active piezoceramic layer that is glued together with a substrate of  $\text{Al}_2\text{O}_3$  ceramics or stainless steel. In comparison with the bimorph structure, these actuators achieve a higher stiffness and a greater displacement, which only takes place in one direction, however.



PICMA® Bender Piezo Actuators can be manufactured in the smallest dimensions of only a few millimeters. Here, a version with connection wire leads and a side length of 4 x 10 mm is shown compared to a PL127.10.

# P-871 PICMA® Piezo Bender Motor Actuators

## Low-Voltage Multilayer Piezo Bender Actuators with Position Sensor



P-871.140, P-871.128, P-871.122 and P-871.112 closed-loop bender actuators (from left to right)

- Closed-Loop Operation for Superior Accuracy
- Nanometer-Resolution
- Displacement to 1.6 mm
- Ceramic Encapsulation for Extended Lifetime
- Ideal for Scanning Applications
- Vacuum-Compatible Versions
- Low Operating Voltage
- Mounting Hardware Included
- Special OEM- and Bench-Top Amplifiers Available

P-871 transducers are unique closed-loop piezo benders based on the open-loop PL 122 to PL 140 PICMA® -series multilayer actuators p. 1-94. Equipped with high-resolution position feedback sensors they provide better linearity, accuracy and repeatability than other piezo benders on the market. P-871 bender actuators achieve longer positioning ranges than typical piezo stack actuators,

up to 1.6 mm, while still providing fast response times in the millisecond range.

### Design

These multilayer piezoelectric components are manufactured from ceramic layers of only about 50 µm thickness. They feature internal silver-palladium electrodes and ceramic insulation applied in a cofiring process. Due to the thin layers the operating voltage is significantly lower than for classical parallel bimorph bender elements. For ease of installation, the units come complete with the mounting hardware, cables and connectors.

### Closed-Loop Position Control for Higher Accuracy

P-871s are ideal devices for scanning, positioning and beam deflection applications and provide much better accu-

racy, stability and repeatability than conventional open-loop actuators. The special bender design allows the direct application of a strain gauge sensor to the surface without the need for a polymer insulation layer in between. The advantages are faster response, reduced phase lag and precise position control with non-linearity of <0.5%. The settling time for a small-signal step (up to 1 % nominal travel) to an accuracy of better than 1 % is between 10 ms (P-871.112) and 30 ms (P-871.140).

### 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.

### Optimum UHV Compatibility - Minimum Outgassing

The lack of polymer insulation and the high Curie temperature make for optimal ultra-high-

### Ordering Information

- P-871.112**  
PICMA® Multilayer Piezo Bender Actuator, 160 µm, 9.6 mm Width, SGS-Sensor
- P-871.122**  
PICMA® Multilayer Piezo Bender Actuator, 400 µm, 9.6 mm Width, SGS-Sensor
- P-871.127**  
PICMA® Multilayer Piezo Bender Actuator, 720 µm, 9.6 mm Width, SGS-Sensor
- P-871.128**  
PICMA® Multilayer Piezo Bender Actuator, 720 µm, 6.3 mm Width, SGS-Sensor
- P-871.140**  
PICMA® Multilayer Piezo Bender Actuator, 1600 µm, 11 mm Width, SGS-Sensor

Ask about custom designs

vacuum compatibility (no outgassing / high bakeout temperatures, up to 150 °C).

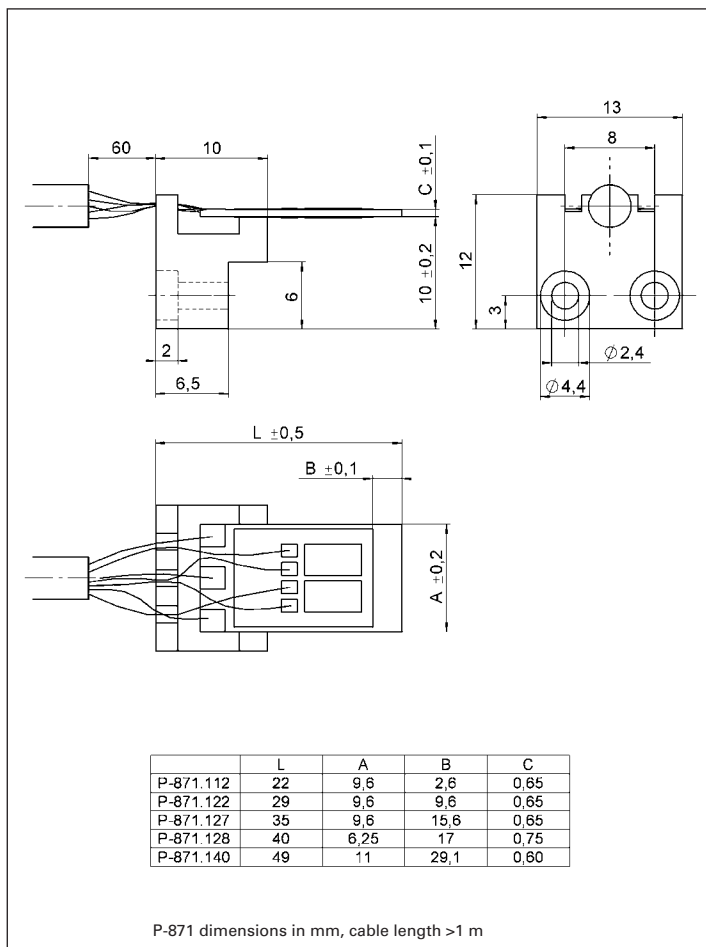
### Amplifiers, Drivers & Controllers

PI offers a wide range of standard amplifiers and controllers for piezo actuators. The E-651.1S and E-651.2S desktop controllers and the OEM board E-614.2BS (see p. 2-121) are specifically designed to operate P-871 bender actuators.

### Application Examples

- Wire bonders
- Pneumatic valves
- Fiber optic positioning & switches
- (Laser)- Beam steering
- Micropositioning
- Acceleration sensors
- Nanotechnology

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**Technical Data**

Model	P-871.112*	P-871.122	P-871.127	P-871.128*	P-871.140	Units
Closed-loop travel	±80	±200	±360	±360	±800	µm
Integrated feedback sensor	SGS	SGS	SGS	SGS	SGS	
Closed-loop linearity	0.5	0.5	0.5	0.5	0.5	%
Static large-signal stiffness	0.02	0.01	0.003	0.002	0.0007	N/µm
Blocking force	±2.0	±1.1	±1.0	±0.5	±0.5	N ±20 %
Electrical capacitance	2 x 1.1	2 x 2.4	2 x 3.4	2 x 1.2	2 x 4.0	µF ±20 %
Unloaded resonant frequency	2540	1010	560	340	195	Hz ±20 %
Resonant frequency @ 6.5 g load	480	220	145	100	60	Hz ±20 %

Operating voltage: 0 to 60 V (±30 V)  
 Recommended driver / controller: E-651 bench top / E-614 PCI card (p. 2-123)  
 Connector: 1 LEMO connector for both sensor and voltage supply  
 Operating temperature range: -20 to +85 °C; \*\* to +150 °C  
 Resonant frequency at 1 Vpp, capacitance at 1 Vpp, 1 kHz  
 All specifications depend on the real clamping conditions and on the applied mechanical load.  
 Other specifications on request.

# P-842 – P-845 Preloaded Piezo Linear Actuators

For High Loads and Force Generation, Optional with Integrated Position Sensors



P-844 piezo actuators (battery for size comparison)

- Outstanding Lifetime Due to PICMA® Piezo Ceramic Stacks
- Travel Range to 90 µm
- Pushing Forces to 3000 N
- Pulling Forces to 700 N
- Sub-Millisecond Response
- Sub-Nanometer Resolution
- Options: Vacuum Version, Water-Resistant Case

The P-842 / P-843 and P-844 / P-845 series piezo translators are high-resolution linear actuators for static and dynamic applications. They provide sub-millisecond response and sub-nanometer resolution.

### Design

These translators are equipped with PICMA® multilayer piezo ceramic stacks protected by a non-magnetic stainless steel case with internal spring preload. The preload makes them ideal for dynamic applications (such as precision machining, active damping etc.) and for tensile loads as well.

### High Accuracy in Closed-Loop Operation

P-842 and P-844 are designed for open-loop positioning or use with external feedback. Versions P-843 and P-845 are equipped with integrated high-resolution SGS-position sensors for high precision in closed-loop operation (for fur-

### Application Examples

- Static and dynamic precision positioning
- Disc-drive-testing
- Optics
- Metrology / interferometry
- Smart structures / adaptronics
- Precision mechanics / machining
- Active vibration control
- Switches
- Laser tuning

ther notes see the nanopositioning tutorial, see p. 2-199).

### 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

### Technical Data and Product Order Numbers

Model	Open-loop travel for 0 to 100 V [µm] ±20 %	Closed-loop travel [µm]*	Integrated feedback sensor**	Closed-loop / Open-loop resolution [nm]***	Static large-signal stiffness [N/µm] ±20 %	Push/pull force capacity [N]	Electrical capacitance [µF] ±20 %
P-842.10	15	–	–	- / 0.15	57	800 / 300	1.5
P-842.20	30	–	–	- / 0.3	27	800 / 300	3.0
P-842.30	45	–	–	- / 0.45	19	800 / 300	4.5
P-842.40	60	–	–	- / 0.6	15	800 / 300	6.0
P-842.60	90	–	–	- / 0.9	10	800 / 300	9.0
P-843.10	15	15	SGS	0.3 / 0.15	57	800 / 300	1.5
P-843.20	30	30	SGS	0.6 / 0.3	27	800 / 300	3.0
P-843.30	45	45	SGS	0.9 / 0.45	19	800 / 300	4.5
P-843.40	60	60	SGS	1.2 / 0.6	15	800 / 300	6.0
P-843.60	90	90	SGS	1.8 / 0.9	10	800 / 300	9.0
P-844.10	15	–	–	- / 0.15	225	3000 / 700	6.0
P-844.20	30	–	–	- / 0.3	107	3000 / 700	12.0
P-844.30	45	–	–	- / 0.45	75	3000 / 700	18.0
P-844.40	60	–	–	- / 0.6	57	3000 / 700	24.0
P-844.60	90	–	–	- / 0.9	38	3000 / 700	36.0
P-845.10	15	15	SGS	0.3 / 0.15	225	3000 / 700	6.0
P-845.20	30	30	SGS	0.6 / 0.3	107	3000 / 700	12.0
P-845.30	45	45	SGS	0.9 / 0.45	75	3000 / 700	18.0
P-845.40	60	60	SGS	1.2 / 0.6	57	3000 / 700	24.0
P-845.60	90	90	SGS	1.8 / 0.9	38	3000 / 700	36.0

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Latest Product Specs: [www.pi.ws](http://www.pi.ws)

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.

**Optimum UHV Compatibility - Minimum Outgassing**

The lack of polymer insulation and the high Curie temperature make for optimal ultra-high-vacuum compatibility (no outgassing / high bakeout temperatures, up to 150 °C).

**Mounting**

Mounting is at the foot, with push/pull forces of less than 100 N, the actuator can be held by clamping the case. The flexible tips P-176.50 / P-176.60 can be applied for protection of the ceramics from shearing forces (see p. 1-103 ff) Read details in Mounting and Handling Guidelines (p. 1-67).

**Options**

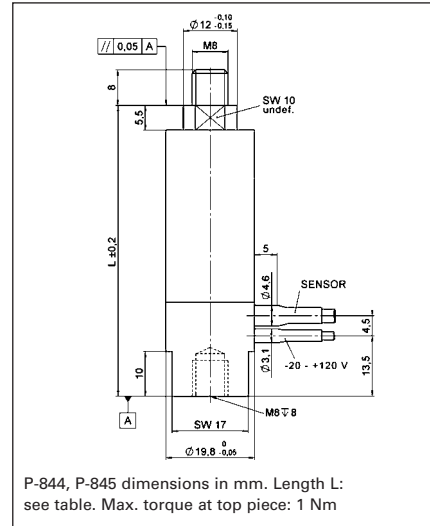
P-703.20  
High vacuum options (see p. 1-102 ff)

**Accessories**

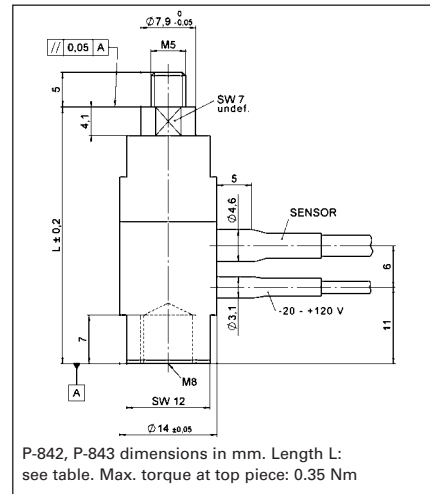
P-176.50  
Flexible tip for P-842 / P-843 (see p. 1-103 ff)  
P-176.60  
Flexible tip for P-844 / P-845 (see p. 1-103 ff)  
For extensions, adapter cables and connectors, see "Accessories" in the Piezo Actuators & Components section (p. 1-104 ff).

**Piezo Drivers, Controllers & Amplifiers**

High-resolution amplifiers and servo-control electronics, both digital and analog, are described in the "Piezo Drivers / Servo Controllers" section.



P-844, P-845 dimensions in mm. Length L: see table. Max. torque at top piece: 1 Nm



P-842, P-843 dimensions in mm. Length L: see table. Max. torque at top piece: 0.35 Nm

Dynamic operating current coefficient [µA / (Hz • µm)]	Resonant frequency (unloaded) [kHz] ±20%	Mass without cable [g] ±5%	Length L [mm]
12.5	18	31	37
12.5	14	42	55
12.5	10	53	73
12.5	8.5	64	91
12.5	6	86	127
12.5	18	31	37
12.5	14	42	55
12.5	10	53	73
12.5	8.5	64	91
12.5	6	86	127
50	16	84	47
50	12	108	65
50	9	132	83
500	7.5	156	0101
50	5.5	204	137
50	16	84	47
50	12	108	65
50	9	132	83
50	7.5	156	101
50	5.5	204	137

Voltage connection:  
LEMO FFA.00.250. coaxial cable, RG 178, PTFE.

Sensor connector: LEMO FFA.0S.304 connector; 1 m coaxial cable with PUR-insulation.

Temperature range: -40 to 80 °C; Case / end pieces: non-magnetic steel.

\*Closed-loop models can attain linearity up to 0.15% and are shipped with performance reports.

\*\*Resolution of piezo actuators is not limited by stiction or friction. Noise equivalent motion with E-503 amplifier (see p. 2-146).

\*\*\*Dynamic small-signal stiffness is ~ 30% higher.

Recommended amplifiers / controllers

Single-channel: E-610 servo-controller / amplifier (p. 2-110), E-625 servo-controller, bench-top (p. 2-114), E-621 controller module (p. 2-160)

Single channel: modular piezo controller system E-500 (p. 2-142) with amplifier module E-505 (high-power) (p. 2-147) and E-509 controller (p. 2-152) (optional)

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, see p. 2-147) and E-509 controller (p. 2-152) (optional)



# PI: Drives that Set the World in Motion

PRECISION POSITIONING FOR SCIENCE AND INDUSTRY



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Today PI delivers micro- and nanopositioning solutions for all important high-tech markets:

- Semiconductor technology
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- Nanotechnology
- Micropositioning
- Aerospace engineering
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**PI (Physik Instrumente) is the leading supplier of piezo-based positioning systems with accuracies in the range of a few nanometers.**

The extensive product portfolio is based on a wide range of technologies with electromotive or piezoelectric drives for up to six motion axes. Hexapods, nanometer sensors, control electronics as well as software and are supplemented by customized solutions.

All key technologies are developed in-house. This means that every phase from the design right down to the shipment can be controlled: The precision mechanics and the electronics as well as the position sensors and the piezo ceramics or actuators. The latter are produced by the subsidiary company PI Ceramic.

PI is, therefore, the only manufacturer of nanopositioning technology which employs the piezoelectric drives it produces. This ensures a high degree of flexibility for developing customized piezoceramic components.

More than 100 patents and patents applied for stand for more than 40 years of experience and pioneering work. PI products are employed wherever technology in industry and research is pushed forward – worldwide.

With four German factories and ten subsidiaries and sales offices abroad, the PI group is represented internationally.

PI stands for quality in products, processes and service. The ISO-9001 certification which focuses not only on product quality but also on customer expectations and satisfaction was achieved back in 1994.

PI is also certified according to the ISO 14001 (environmental management) and OHSAS 18001 (occupational safety) standards, which taken together form an Integrated Management System (IMS).



## Milestones

THE SUCCESS STORY



- 1970** PI founding year
- 1977** PI moved its headquarters to Waldbronn, Germany
- 1987** Foundation of a subsidiary in the USA
- 1991** Foundation of a subsidiary in Japan
- 1991** Market launch of 6-axis parallel-kinematics positioning systems (Hexapods)
- 1992** Foundation of PI Ceramic, Thuringia, Germany; crucial step towards market leadership in nanopositioning
- 1993** Foundation of subsidiaries in the UK and in France
- 1994** Market launch of capacitive position sensors
- 1995** Foundation of a subsidiary in Italy
- 1998** Market launch of digital control electronics
- 2001** Market launch of PLine® ultrasonic piezomotors
- 2001** New company building in Karlsruhe, Germany
- 2002** PI Ceramic company building extended
- 2002** Foundation of a subsidiary in China
- 2002** Market launch of PICMA® multilayer piezo stack actuators
- 2004** Market launch of NEXLINE® high-performance piezo linear drives
- 2007** Market launch of NEXACT® piezo linear drives
- 2010** Acquisition of the expansion site next to the PI headquarters
- 2011** Foundation of a subsidiary in Korea
- 2011** Foundation of a subsidiary in Singapore
- 2011** Acquisition of the majority shares of miCos GmbH
- 2012** Extension of the PI headquarters company building in Karlsruhe



## PI General Catalog

## Request it now!

The 530 page hardbound catalogue from PI is the most comprehensive reference book on the fundamentals of nanopositioning, piezo systems and micro-positioning technology yet. The catalog contains 200 product families, with more than 1000 drawings, graphs, images and technical diagrams.



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