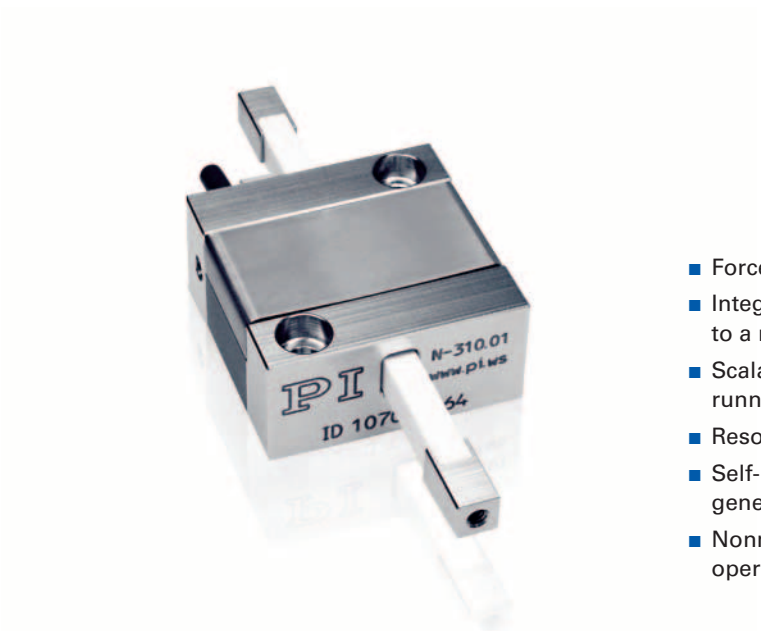
PiezoWalk® Piezo Stepping Drives

Nanometer Precision with a High Feed Force



- Forces from 10 to 800 N
- Integration levels from an OEM motor to a multi-axis positioning system
- Scalable travel range due to scalable runner length
- Resolution to 0.03 nm
- Self-locking when at rest, no heat generation
- Nonmagnetic and vacuum-compatible operating principle

Why PiezoWalk®?

PiezoWalk® drives were developed more than 10 years ago for the semiconductor industry, which is very demanding when it comes to reliability, position resolution and long-term stability. PI received the SEMI Technology Innovation Showcase Award for the PiezoWalk® technology in 2005. The drives are continuously developed further, and a large number of variants are now available for different areas of application.

Directly Driven PiezoWalk® Linear Motors

As essential components, these piezo stepping drives have several piezo actuators that are preloaded against a guided runner. These piezo actuators perform a stepping motion during operation that causes a forward feed of the runner. The piezo actuators can be operated to perform very small stepping and feed motions so that a high motion resolution of far below one nanometer is achieved.

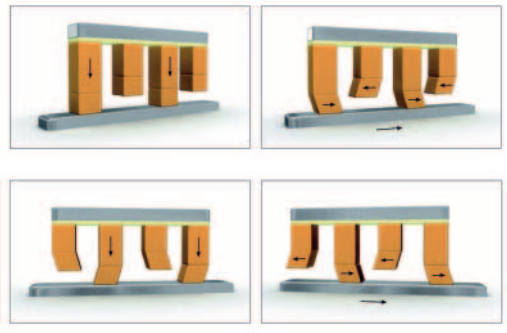
Piezo stepping drives do not require any mechanical components such as coupling or gearhead, which cause friction and backlash and would considerably limit the precision and reliability of high-resolution motor-spindle-based drive systems.

Stepping Motion Sequence

With PiezoWalk® stepping drives, piezo actuators work in pairs as clamping and feed elements on a moving runner. Cyclical control induces a stepping motion of the actuators on the runner, and the runner is moved forwards and backwards.

With NEXLINE® drives, the stepping motion is realized via separately controlled, powerful longitudinal and shear actuators, achieving a high stiffness with feed forces of several 100 N. The more compact NEXACT® drives perform the stepping motion with bending elements.

A suitable selection of the piezo elements optimizes step size, clamping force, velocity and stiffness for the respective requirements.



Motion sequence of a NEXLINE® actuator

Piezomotors are Self-Locking

Preloading the piezoceramic actuators against the runner ensures self-locking of the drive when at rest and switched off. As a result, it does not consume any power, does not heat up, and keeps the position mechanically stable. Applications with a low duty cycle that require a high time and temperature stability profit from these characteristics.

Lifetime and Reliability

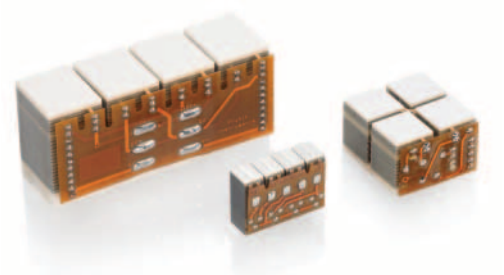
The motion of the piezoceramic actuator is based on crystalline effects and is not subject to any wear. Unlike other piezomotor principles, the coupling of the piezo actuators to the runner is not subject to sliding friction effects; the feed is achieved by the physical clamping and lifting of the actuators.

Piezomotors for Applications – e.g. in a Vacuum and in Strong Magnetic Fields

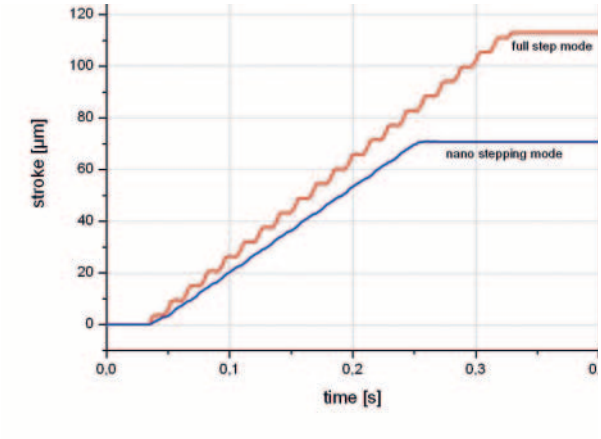
Piezomotors from PI are vacuum-compatible in principle and suitable for operation under strong magnetic fields. For these purposes, special versions of the drives are offered. Piezo stepping drives can also be used in clean rooms or in environments with a hard ultraviolet radiation.

Two Technologies for More Flexibility

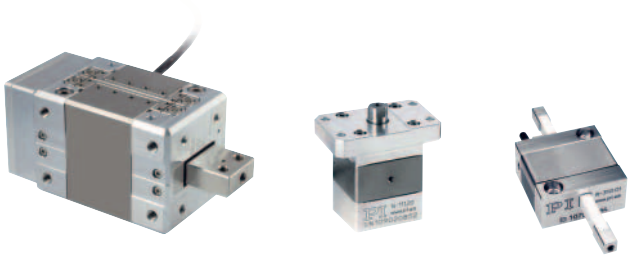
For the piezo stepping drives, PI uses two different technologies that can be adapted to the respective requirements. NEXLINE® stepping drives are designed for high push and holding forces up to 800 N and work with low velocities. The more compact NEXACT® drives achieve higher velocities and develop forces from 10 to 20 N.



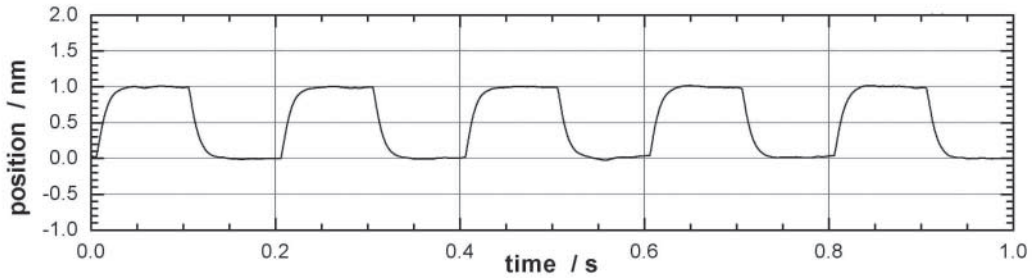
Various designs and sizes of NEXLINE® modules (left and right) as well as NEXACT® (center)



Constant velocity and smooth driving of a NEXLINE® drive are best achieved in nanostepping mode, but the maximum attainable velocity is higher in full-step mode



OEM piezomotors (from left): N-216 and N-111 with NEXLINE®, N-310 with NEXACT® drives

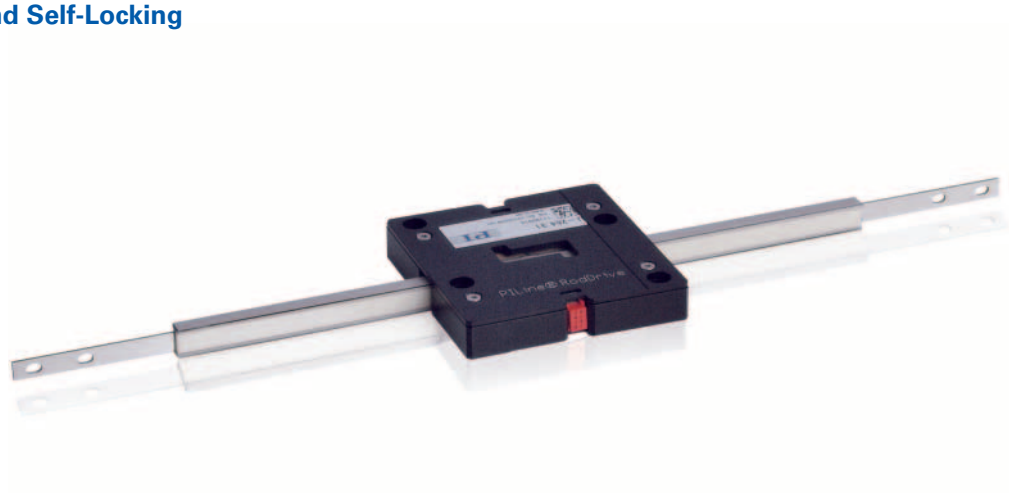


Sequence of open-loop 1 nm motions of a NEXLINE® drive

PILine® Ultrasonic Piezomotors

Compact Drives, Fast and Self-Locking

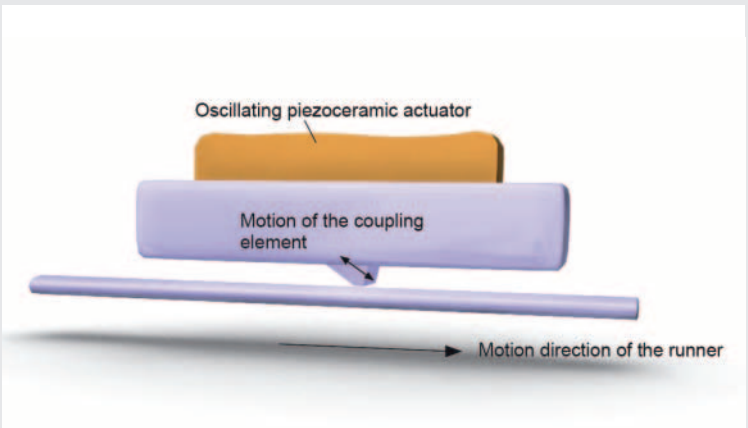
- Integration levels from an economical OEM motor to a multi-axis positioning system
- Excellent dynamic properties, fast step-and-settle
- Basically unlimited travel ranges
- Easy mechanical integration
- Self-locking at rest
- Holding force up to 15 N
- Velocity up to 500 mm/s
- Resolution to 0.05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



Direct-Driven PILine® Linear Motors

These linear drives dispense with the mechanical complexity of classical rotary motor/gear/leadscrew combinations in favor of costs and reliability.

These components can be very susceptible to wear, especially in miniaturized systems. An integral part of the ultrasound piezomotor is piezo ceramics that is pretensioned against a movably guided runner via a coupling element. The piezo element is excited to high-frequency oscillations that cause the runner to move.



The piezoceramic actuator is excited to ultrasonic vibrations with a high-frequency AC voltage between 100 and 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

Piezomotors are Self-Locking

Preloading the piezoceramic actuators against the runner ensures self-locking of the drive when at rest and powered down. As a result, it does not consume any power, does not heat up, and keeps the position mechanically stable. Applications with a low 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 2 000 km or a MTBF of 20 000 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/s.

Patented Technology

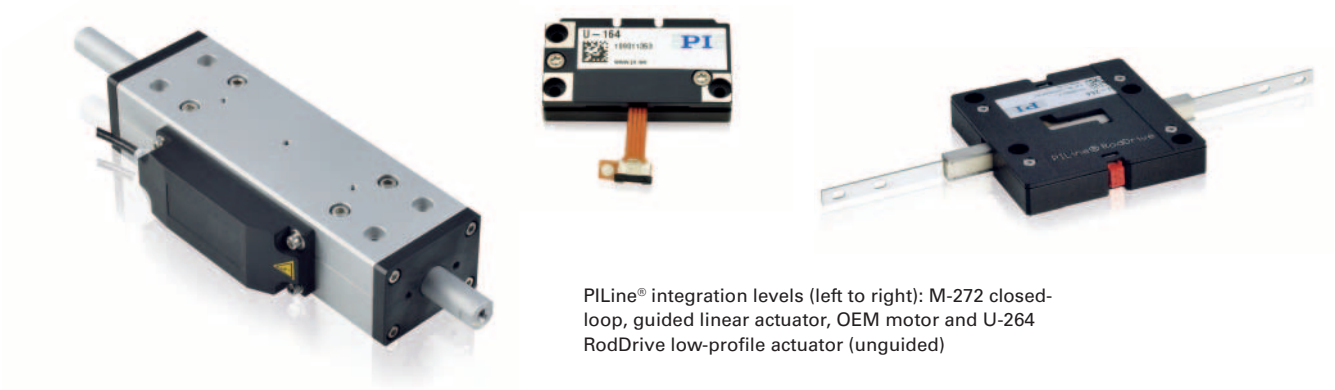
The products described in this document are in part protected by the following patents:

US patent no. 6,765,335B2

European patent no. 1267425B1

PILine® Ultrasonic Piezomotors

OEM Motors, Technical Data



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

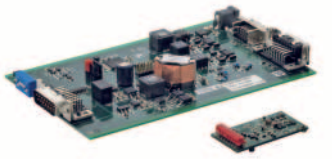
Different Integration Levels Offer Flexibility

PILine® drives 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:

- Positioning stages with integrated PILine® drives, available in customized designs for OEM
- Linear actuators move the load via a guided rod. Position feedback is available as an option
- RodDrives are unguided, 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 ultrasound 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.

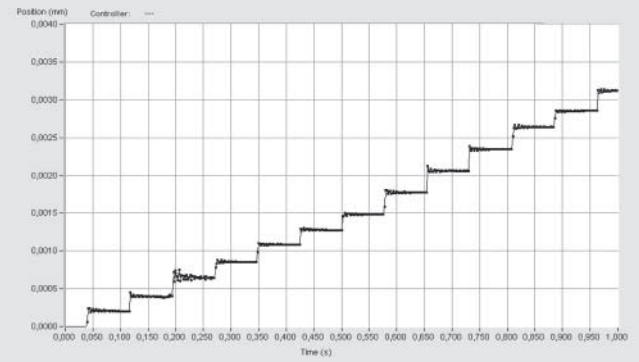


Drive electronics create the ultrasonic vibrations for the piezoceramic actuator of the PILine® drive. PI offers universal drivers for all actuator sizes – as well as specialized, compact boards

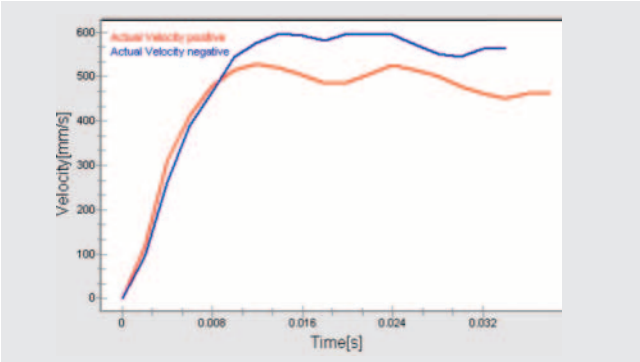
Motion and positioning	P-661	U-164	Unit	Tolerance
Travel range*	No limit	No limit	mm	to 1 mm
Min. incremental motion, open-loop**	0.05	0.05	µm	typ.
Velocity (open-loop)	500	500	mm/s	max.
Mechanical properties				
Stiffness, de-energized	0.7	3	N/µm	±10 %
Holding force, de-energized	1.5	3	N	max.
Push / pull force	2	4	N	max.
Preloading on friction bar	9	18	N	±10 %
Integration effort	average	low		low
Drive properties				
Resonant frequency	210	155	kHz	±2 kHz
Motor voltage	42 V_{rms} (120 V_{pp})	60 V_{rms} (170 V_{pp})		
Miscellaneous				
Operating temperature range	-20 to +50	-20 to +50	°C	
Casing material	Aluminum, anodized	Aluminum, anodized		
Weight	10	20	g	±5 %

* The travel range of piezo linear motors is practically unlimited. It only depends on the length of the runner

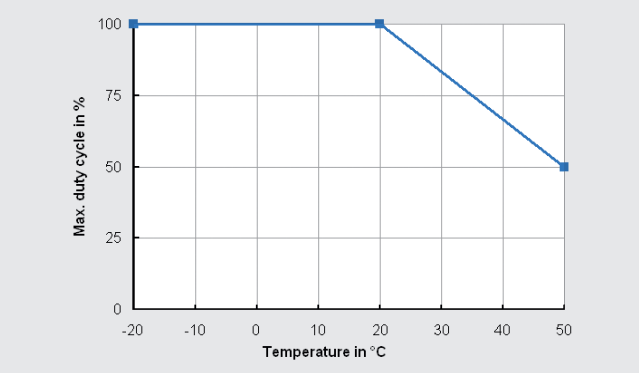
** The minimum incremental motion is a typical value which can be reached in open-loop operation. However, it is important to follow the installation guidelines for the motors



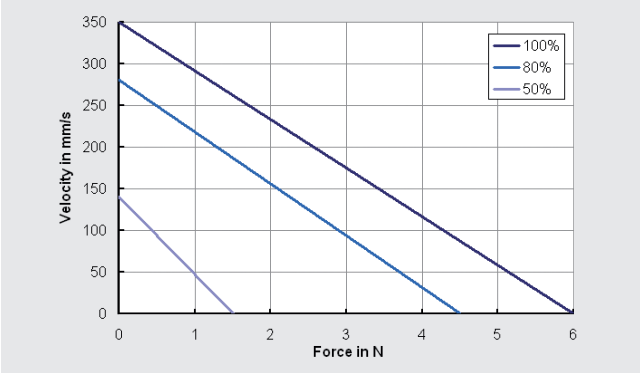
Open-loop step sequence of a PILine® based translation stage. Steps of approx. 300 nm shown. For repeatable increments closed-loop operation is recommended, because the step size depends on the force applied from outside



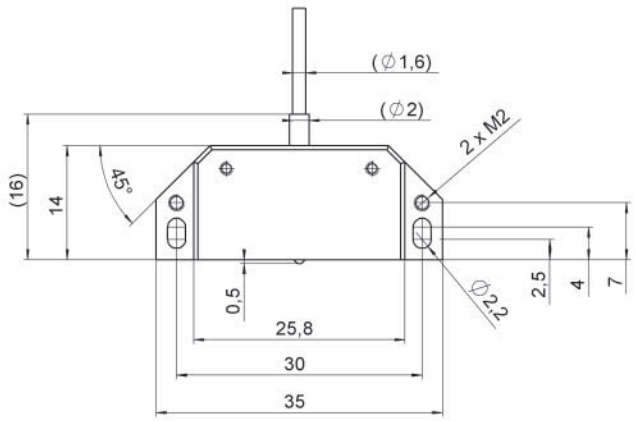
PILine® ultrasonic linear motors provide excellent dynamic properties. They provide acceleration to several g and can achieve step-and-settle of a few 10 microseconds for small distances



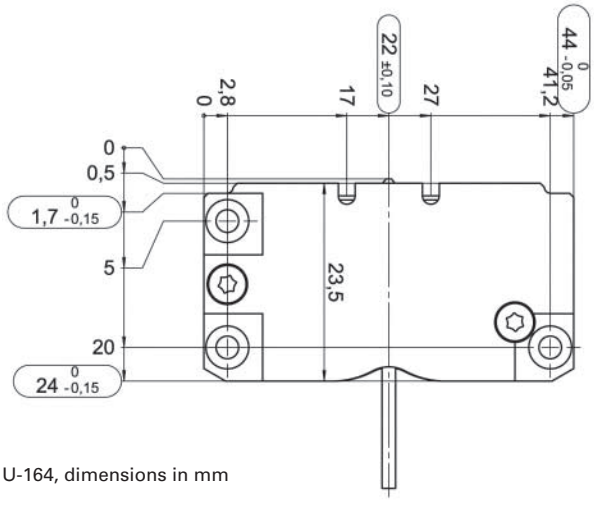
Maximum duty cycle depending on the ambient temperature with a control signal level of 100%



Force / velocity motor characteristic of a PILine® motor 6 N holding force. The percentages refer to the control signal level, which denotes the coupling of the electric power of the actuator



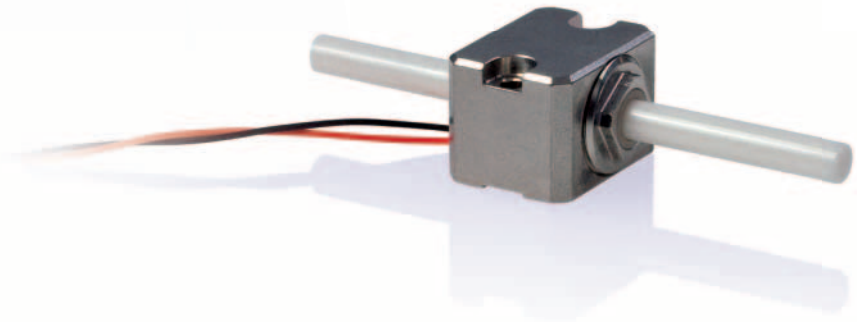
P-661, dimensions in mm



U-164, dimensions in mm

PIShift Piezo Inertia Drives

Cost-Efficient, Compact Linear Motors



- From OEM drives to integration into a multi-axis positioning system
- Basically unlimited travel ranges
- Easy mechanical integration
- Self-locking at rest
- Holding force up to 10 N
- Velocity of more than 5 mm/s
- Simple, cost-efficient control

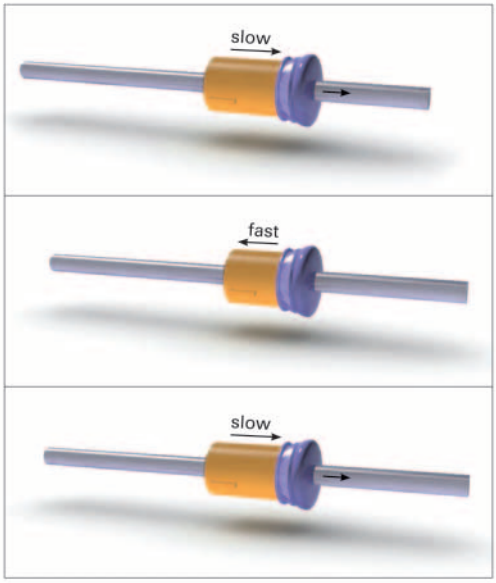
PIShift drives are space-saving and cost-efficient piezo-based drives with relatively high holding forces of up to 10 N and a basically unlimited travel range. They make use of the stick-slip effect (inertia effect) – a cyclical alternation of static and sliding friction between a moving runner and the drive element generated by the piezo element – for a continuous feed of the runner. With an operating frequency above 20 kHz, PIShift drives reach velocities of more than 5 mm/s.

Silent and Energy-Saving

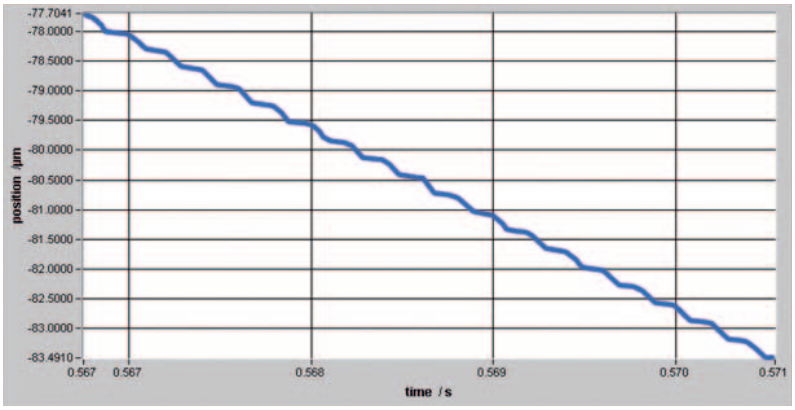
The drive works silently at this frequency. When at rest, the drive is self-locking and therefore requires no current and generates no heat. It holds the position with maximum force.

Easy Integration

For easy integration, the drive component is either mounted on a level surface or screwed in on the front. 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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