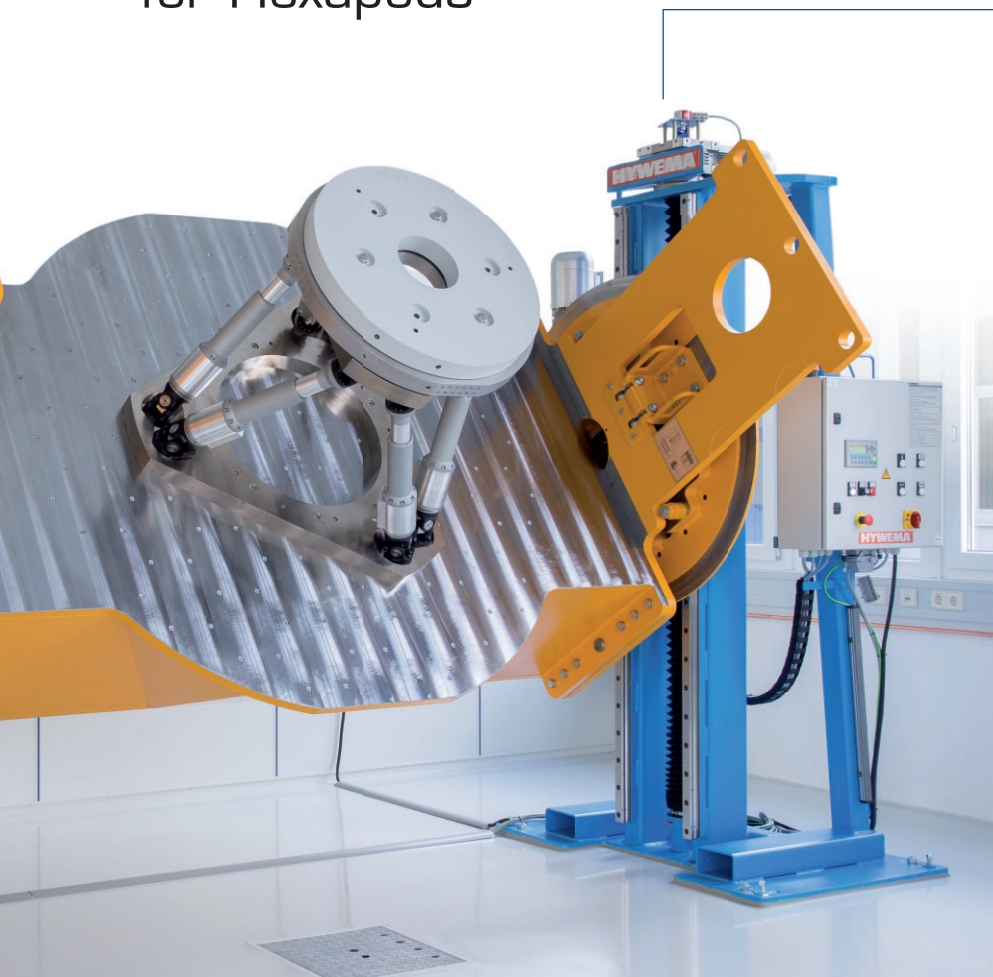


Completely Synchronous Operation

Fieldbus Activation for Hexapods



Controller by Beckhoff
with EtherCAT



millimeters. Even major loads can be positioned accurately to the micrometer using Hexapods.

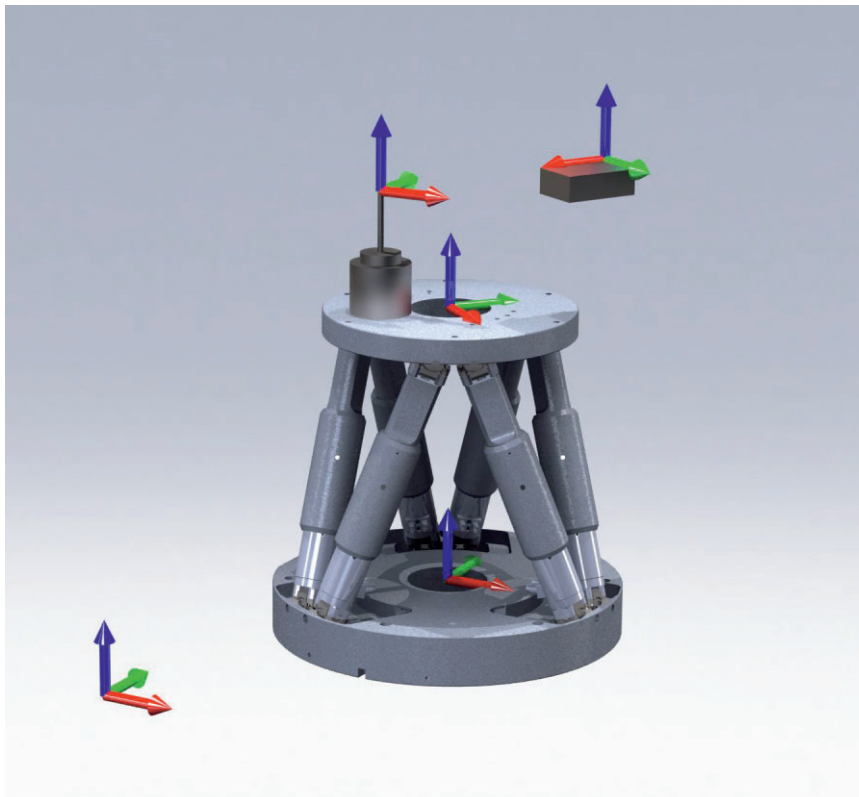
Clocked Communication for Synchronous Processes

For easily and quickly using the benefits of Hexapods in automation, PI now offers a Hexapod controller with integrated automation interface. The Hexapods communicate with parent PLC or CNC controls via exchangeable fieldbus modules and can work synchronously with other components in one automation line. The PLC acts as master and defines the target position or trajectories in Cartesian coordinates. In return, it gets the actual positions over the fieldbus interface. Complex calculations required to command the parallel-kinematic six-axis system are done by the Hexapod controller, i.e. transforming the target positions from Cartesian coordinates into drive commands for the individual drives. The cycle times for determining new positions, evaluating signals and synchronizing are between 1 and 3 ms.

PI offers a new controller for the easy and fast integration of high-precision six-axis positioning systems in automation lines

Machining, automatic feed, micro-assembly or complex bending processes in several axes and precise to the micrometer – these tasks are carried out by parallel-kinematic Hexapods with utmost precision and reliability. The travel ranges of Hexapods go normally from only a few to several hundred

Continued on page 2



Any coordinate system used as a reference for target values of the Hexapod may be defined

Hexapods from PI can currently be controlled via EtherCAT. Real-time Ethernet assures a fast and reliable connection to the overall system with short cycle times and low timing jitter for precise synchronization. On request, PI also offers control via fieldbus protocols, such as EtherNet/IP, Profinet, CANopen or SERCOS.

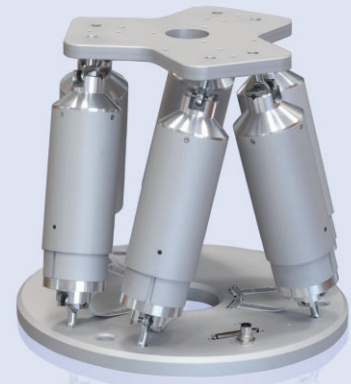
G-Code for Precise Trajectory Control

If there is no parent PLC or if synchronizing with other system components is not required, the Hexapod controller can now also control the trajectory based on G-code according to DIN 66025/ISO 6983. For this purpose, G-code is directly implemented in the controller as command language. The Hexapod system can then move a workpiece or tool smoothly and with high precision during machining without the mechanical system starting to vibrate.

Suitable for Any Coordinate System, Freely Definable Pivot Point

To adapt the trajectory perfectly to the requirements of the application, it is possible to define various coordinate systems with the controller, which refer, e.g. to the position of the workpiece or tool. The user can optimally position the Hexapod platform for the application and the controller gets its new reference system from the new position data. The pivot point is freely definable via software command. In extension, it can be handled as coordinate system, referring to a platform, or it can be set freely in space, thus allowing even more precise commanding of the Hexapod motion.

New Hexapods for Automation



A linear repeatability of 20 μm and 200 μrad in the tip/tilt or rotational axes – these are important features of the new H-820 Hexapod: It provides travel ranges of up to 100 mm in X and Y direction and 50 mm in the Z axis as well as rotational angles up to 60°. Thanks to the specially developed brushless torque motors, a load capacity of 20 kg and velocities of up to 20 mm/s can be achieved.



H-845 Hexapod for loads of up to one ton: The modular construction allows for fast adaptation to the application environment

Dynamic and Cost-Efficient Drive Solutions for Automation

PIMag™: Magnetic Direct Drives and Positioning Systems

In terms of dynamics and wear, magnetic direct drives offer advantages compared to common spindle-based technologies.

For this, PI adapts the system components such as stator, actuator or electronics to the specific requirements. With this individualization of the drive system, PI creates a substantial factor of success for piezo actuator systems in nanopositioning technology, that is also used for the PIMag™ series. PI's experience in nanopositioning technology results in the profound knowledge concerning selection and use of digital control technology, guiding systems or fast communication interfaces.

In automation, PI uses therefore magnetic direct drives if the application requires long travel ranges with high velocities or scanning frequencies, long operating times and long lifetime.

Lifetime: Almost Unlimited

The V-900KPIC linear actuator combines a direct magnetic linear drive with a flexure guiding system. The wear-free flexure guiding system is based on the elastic deformation of metal joints, a principle which prevents unintentional lateral motion of the mechanical output

and ensures high travel accuracy as well as a high lifetime. PI has been using this guiding system for a long time in piezo-based nanopositioning systems which are designed to perform several billion motion cycles in continuous operation, e.g. for dosing or focusing tasks with low requirements in terms of travel.

Position and Force Control

The PIMag™ VC linear actuators provide high dynamics and high velocities at a favorable price and are suited for applications in automation and handling technology. The V-273 features a position sensor and can be equipped with a force sensor which allows the application of defined forces. By using the digital C-413 PIMag™ motion controller for operation, tasks can be performed within automated production lines where both fast positioning in the range of a few micrometers and closed-loop force control are required.



Compact V-900KPIC PIMag™ linear actuator for high scanning frequencies and fast step-and-settle

V-900KPIC

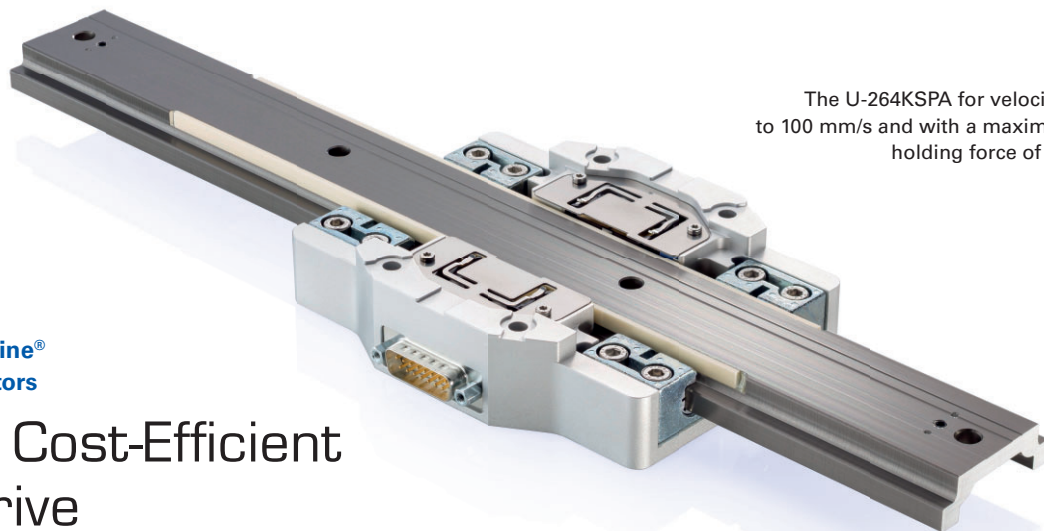
- Travel range 1.5 mm
- Compact dimensions: approx. 13.5 mm x 32 mm x 49 mm
- Integrated linear encoder with 0.1 µm resolution
- Wear-free flexure guides
- High dynamics

V-273

- Travel ranges of up to 20 mm
- Velocity up to 250 mm/s
- Integrated linear encoder with 0.1 µm resolution
- Optional force sensor with 5 mN resolution
- Optional: Weight force compensation



V-273 PIMag™ VC magnetic drive for high dynamics and velocity



The U-264KSPA for velocities to 100 mm/s and with a maximum holding force of 6 N

U-264KSPA with PLine® Ultrasonic Piezomotors

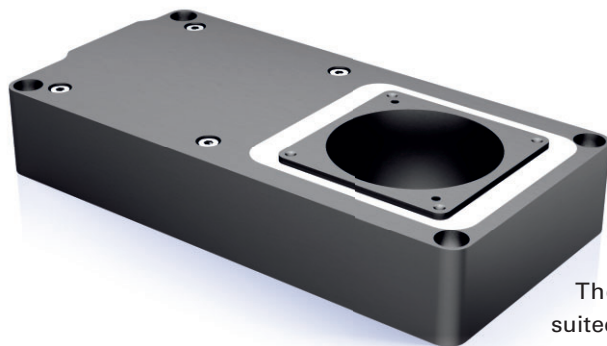
Fast and Cost-Efficient Linear Drive

When selecting suitable solutions for motion control systems, PI is not limited to one drive principle. Depending on the application, there may be no alternative to using piezomotor drive systems for automation in plants or scientific setups. This is the case e.g. with applications that require motion in high magnetic

fields or self-locking in currentless state and where at the same time mechanical components, such as gearhead or brakes, shall be avoided.

The U-264KSPA actuator with ultrasonic piezomotors is a customized direct drive that was optimized for being manufactured from engineering thermoplastics

for series production. An integrated linear encoder measures the position with 0.6 μm resolution, the drive technology allows for velocities (open-loop) up to 100 mm/s and a maximum holding force of 6 N.



Versatile nanopositioning system with high control dynamics and fast settling times

P-630 Piezo Nanopositioning System

Versatile, Fast and Compact with Large Clear Aperture

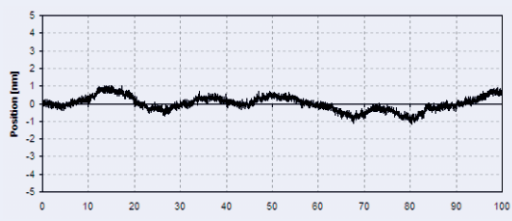
The P-630 stages are perfectly suited, e.g. for use in sensor heads or precision motion of objects in optical and tactile metrology as well as for microstructuring.

With travel ranges up to 80 μm and a direct piezo actuator drive, the compact positioning stages reach high scanning frequencies and settling times of only a few milliseconds. At a width of only 50 mm, their clear aperture is relatively large with a diameter of 30 mm.

The drive technology of the highly dynamic piezo nanopositioning systems is based on all-ceramic insulated PICMA® piezo actuators.

The P-630 stages achieve nanometer-precise positioning accuracy and stability using an integrated capacitive position sensor.

Optimum control properties are ensured via the high performance single-channel E709.CHG motion controller. Its digital technology allows for refined linearization algorithms to improve accuracy. The operating parameters can easily be optimized via software.



The positioning stability of the P-630 is in the nanometer range

Efficient and Unique

DuraAct Power: Composite Patch Transducer with Multilayer Ceramics Uses d_{33} Effect

The new P-878 DuraAct Power patch transducer from PI Ceramic uses a voltage of only –20 to 120 V; with this, it is the only one of its kind on the world market. As all other DuraAct elements, the P-878 can be used as piezo actuator, sensor or energy harvester.

The active layer of the patch transducer consists of a multilayer piezo element that is embedded in a glass-fibre reinforced plastic with a patented method. For deflection, the DuraAct Power uses the high-efficiency d_{33} effect.

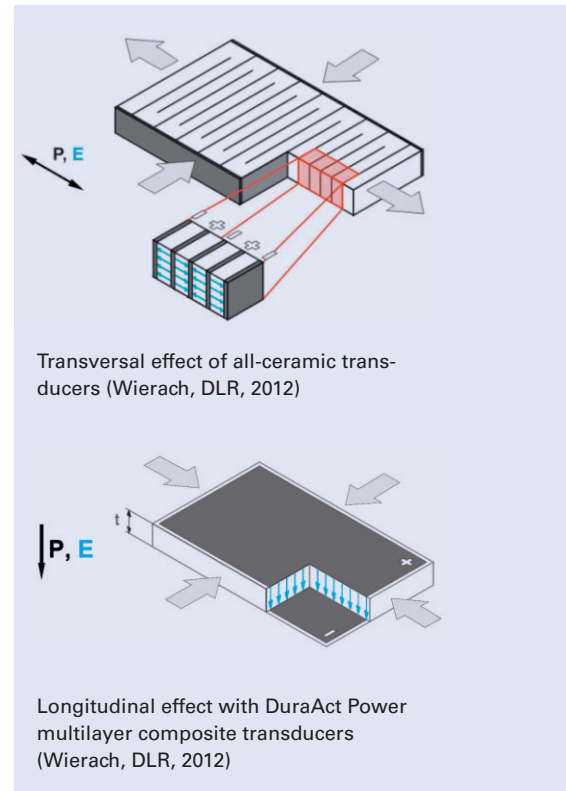


DuraAct Power: Composite patch transducer with multilayer ceramics uses efficient d_{33} effect

The composites are manufactured with a bubble-free injection method. The polymer coating simultaneously serves as electrical insulation and as mechanical preload, which makes the P-878 bendable.

d_{33} Effect: What Stands Behind DuraAct Power?

Previous all-ceramic transducers require high voltages of 250 to 1000 V. They use lateral contraction of the piezo element when applying the electrical voltage, the so-called transversal or d_{31} effect. In contrast, DuraAct Power multilayer patch transducers use the longitudinal or d_{33} effect, which describes an elongation parallel to the electric field E and the polarization direction of the piezo actuator. The d_{33} piezoelectric charge coefficients for longitudinal displacement are considerably higher than the d_{31} coefficients for transversal displacement, consequently the attainable displacement is higher too.



Transversal effect of all-ceramic transducers (Wierach, DLR, 2012)

Longitudinal effect with DuraAct Power multilayer composite transducers (Wierach, DLR, 2012)

Fast Stacking

P-080 PICMA® Stack Multilayer Ring Actuator

With the new ring actuator, composed of annular PICMA® chip multilayer piezo actuators, dimensions and travel ranges can be flexibly scaled.

For initial sampling or small quantities, PI Ceramic offers multilayer actuators that consist of PICMA® chip actuators. These miniature piezo actuators come in different dimensions and geometries and are glued together as required for the dimensions or travel ranges.

Thus, special lengths for the PICMA® multilayer actuators can be scaled quickly and flexibly – resulting in short delivery times.

The P-080 ring actuator is the first standard product of this series. At 36 mm length, it offers a travel range of 25 μm . Ring actuators achieve their maximum deflection already at low operating voltages of only 100 V. Here the resonant frequency of 40 kHz is very high which makes the actuator perfectly suitable for highly dynamic processes.

The Integration: All-Round Perfection

The round outer diameter fits e.g. perfectly into pre-manufactured case components made from semi-finished tubes. The inner hole can be used as aperture for optical applications or for applying a preload for dynamic applications.



Small Steps Leading to Great Results

NEXACT® Piezomotors – Nanopositioning over Long Travel Ranges

Various types of piezomotors exist; PI uses most of these types for different products and a wide range of applications.

But if the aim is to achieve uniform motion over long travel ranges with the highest possible accuracy, PI uses directly driven NEXACT® stepping drives.



Small size and high resolution: LPS-24 miniature stages with NEXACT® piezomotors are only 24 mm wide. They achieve a 0.5 nm resolution and a minimum incremental motion of 1 nm

Why NEXACT®?

Stepping drives with NEXACT® drive technology feature:

- Compact and cost-effective designs
- Variable travel ranges due to variable runner lengths
- Open-loop resolution to 10 pm for high positioning accuracy
- Position sensors with up to 0.5 nm resolution, minimum incremental motion of only a few nanometers
- Low operating voltage
- Self-locking at rest, no energy consumption, no heat generation
- Nonmagnetic and vacuum-compatible operating principle

and can be implemented in compact and precise positioning systems, e.g. for sample positioning or manipulation, for focusing or positioning diaphragms and optical components.

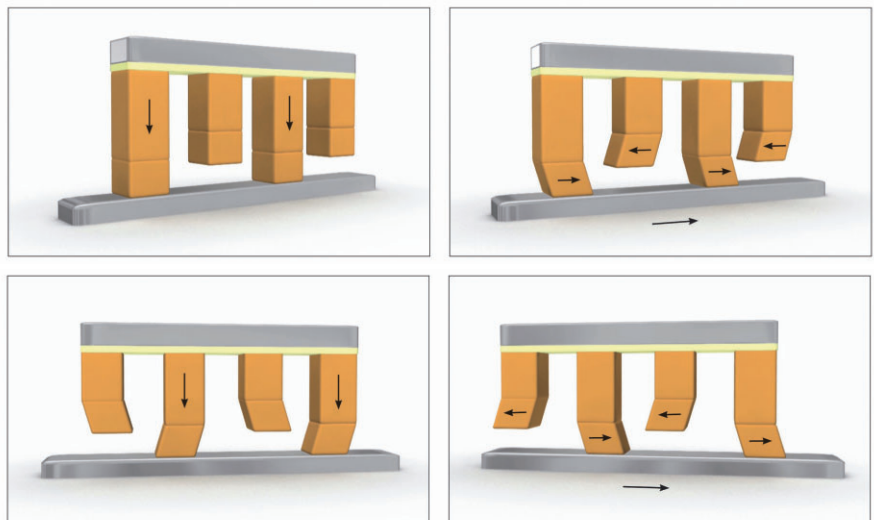
Piezo Actuators Move the Runner

As essential components of the NEXACT® drive technology, the NEXACT® stepping drives have at least four piezo actuators that are preloaded against a guided runner. During operation, the piezo actuators work in pairs as clamping and feed elements on a runner; cyclical, phase-shifted control induces the stepping motion of the actuators on the

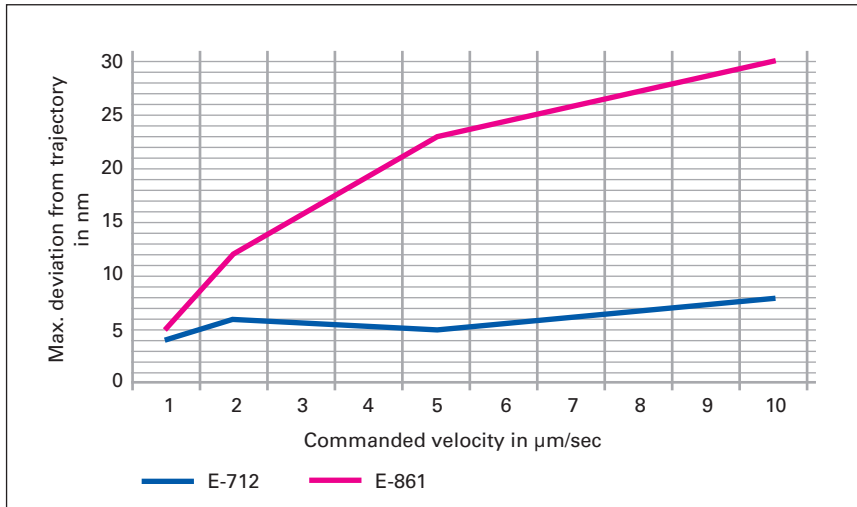
runner and the runner is moved forwards and backwards.

Precise to the Nanometer

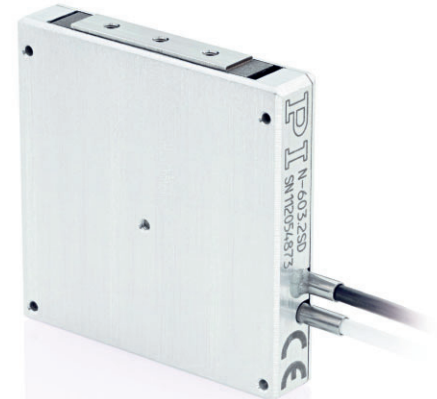
In a position-controlled system with NEXACT® drive, the motion is executed in nanostepping mode along a predefined motion profile to the target position. The nanostepping mode allows for a constant and smooth feed of the runner.



Functional principle of a piezo stepping drive as an example of NEXLINE® technology: Clamping and feed motion are distributed to separately driven longitudinal and shear actuators. NEXACT® drives use bending actuators for moving the runner



Maximum path deviation of an N-664 high-resolution linear stage with NEXACT® stepping drive, driven by an E-712 or E-861 controller



Only 7.5 mm wide and entirely nonmagnetic: The N-603 combines a NEXACT® stepping drive with titanium flexure guides and strain gauge sensor

This is achieved by an overlapping of the feed motion of the actuator pairs. Thanks to this functional principle, maximum positioning accuracy and path accuracy during the motion of the NEXACT® drives can be achieved.

The advantages of nanostepping mode are best visible at low velocities: Path deviation here is only 1 to 10 nm at velocities around 1 $\mu\text{m/s}$, depending on the sensor and the controller, feed velocity is constant at 1% and even better.

Smooth Operation

For the stepping motion, the individual bending actuators and the moving run-

ner always use stiction and never friction. This increases the lifetime of the drive and reduces wear and generation of particles to a minimum.

Simple Control

The E-861 single-channel controller supports the different types of motion of the piezo stepping drive and is tuned to the requirements of the mechanical system. As a result of the controller's networking capability, up to 16 controllers can be driven simultaneously via one computer interface.

Complex systems, such as NEXACT® Hexapods are driven by the modular

E-712 controller. Powerful algorithms optimize the nanostepping mode for sub-nanometer step sizes. In full-step mode, the E-712 achieves maximum velocity.

System Integration

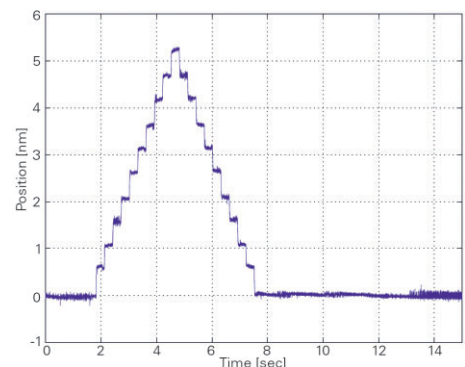
All parameters can be set and checked via software. For start-up and system configuration, the program PIMikroMove is included in the scope of delivery. Connection to custom software is possible via LabView drivers and DLLs.



Nanopositioning with travel ranges to 50 mm: Several NEXACT® drive modules with LPS-65 achieve a feed force of up to 10 N



2 mm travel range – 20 milliseconds settling time: New N-725 objective scanner with NEXACT® drive for 3D stacks with up to 1 mm depth



NEXACT® positioning system with 0.5 nm resolution

Award-Winning

PI as Exhibitor from the Very Beginning – 40 Years LASER World of PHOTONICS

Precision is the motto – back then and today. Since 1973, without interruption, PI has been an exhibitor at the LASER World of PHOTONICS.

Now the world's leading trade fair in the laser and photonics industry celebrated its 40-year anniversary and awarded PI with a prize for its long-term participation. In the early days, PI started as a

manufacturer of optical tables and accessories for laser beam steering. Today, PI presents products and complete system solutions for optical metrology and materials processing.



PI exhibition stand at the LASER World of PHOTONICS 2013

For the first time together with PI miCos, PI presented over 300 exhibits, including 25 product novelties, 18 SpaceFAB and Hexapod variants and 16 product lines with piezo drive. The PI stand was very popular and visitors showed keen interest in the exhibited products and systems. This success was largely due to the centrally arranged modular Hexapod, which was nearly one meter high and had a base platform with a diameter of 1.2 meters. But also the new video "The Graceful Elegance of Precision" made visitors stop at the stand and watch the 4 x 2.5 m² screen.



Video

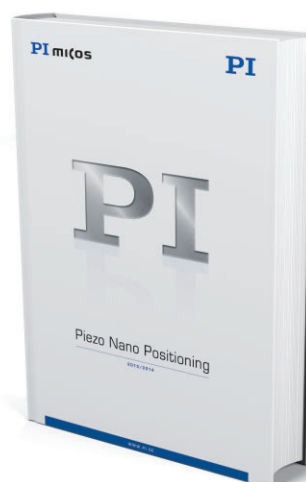
"The Graceful Elegance of Precision": www.youtube.com

PI Catalog – Finding the Right Solution, Quickly and Reliably

Request Now!

The PI catalog 2013/2014 displays the PI Group's technical expertise in all precision positioning sectors on 270 pages. Here PI presents its wide range of high-performance precision positioning systems: Different drive technologies based on piezo elements as well as electrical and magnetic principles and their integration into positioning systems with up to six axes.

Get important background knowledge: Technical tutorials give you detailed information about the technologies used in the broad and deep product portfolio of PI (Physik Instrumente), PI miCos and PI Ceramic, expert in piezo technology.



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