

Piezo Technology Made Affordable

**PiezoMove OEM Flexure Actuators:
Speed, Precision & Long Travel Ranges**



PI: Piezotechnology and Precision Motion Control

NanoAutomation®: Precision Positioning for Science and Industry



PI headquarters in Karlsruhe

Future Technology Solutions

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

- Semiconductor Technology
- Optical Metrology, Microscopy
- Biotechnology and Medical Devices
- Precision Automation and Handling
- Precision Machining
- Data Storage
- Photonics, Fiber Optics, Telecom
- Nano Technology
- Microsystems Technology
- Aerospace Engineering
- Astronomy



PI reception desk:
Our employees look forward to your visit

PI is market and technological leader for precision positioning systems with accuracies well under one nanometer. Nanometer-range motion control is the key to worlds where millions of transistors fit on one square millimeter, where molecules are manipulated, where thousands of “virtual slices” are made in the observation of living cells, or where optical fiber bundles no larger than a human hair are aligned in six degrees of freedom.

Worlds We Call NanoWorlds

Continuous innovation and reinvestment of profits over the decades has allowed PI to attain its present market status. This status is also based on long-term customer relationships and on the freedom to transform ideas into reality.

Over 30 Years Experience

When PI introduced piezo-electric nanopositioning technology more than 30 years ago, typical customers were research labs and universities working on laser cavity tuning, Fabry-Perot interferometers and filters. Few foresaw that

whole industrial sectors like semiconductor manufacturing or biotechnology would become dependent on progress in nanopositioning. Today, not even the precision machining industry can do without nanometer-level positioning systems.

Key Technologies In-House

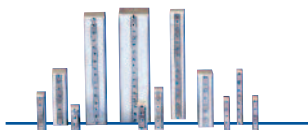
PI follows a vertical integration strategy designed to develop and maintain all key technologies in-house. We supervise each and every step from design to delivery in the following areas: software, precision mechanics, digital and analog control electronics, sub-nanometer capacitive position sensors, piezo ceramics and piezo actuators. This assures the highest quality and reduces cost.

Low-cost Piezo Systems with Various Levels of Integration

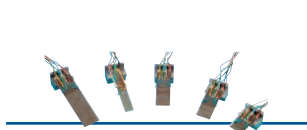
Product Overview

Piezo Actuator / Stage	Description	Travel Range up to	Guiding System	Mechanical Levels of Integrations	Positioning Sensor	Stiffness	Page
P-882 - P-888	PICMA® Multilayer Piezo Stack Actuators	30 µm	-	-	optional SGS	up to 200 N/µm	19
P-871	PICMA® Piezo Bender Actuator	1600 µm	-	-	optional SGS	0.02 N/µm	see PI hardbound catalog p. 1-84
P-842 - P-845	Preloaded Piezo 90 µm Actuators		-	case, mechanically preloaded	optional SGS	up to 200 N/µm	see PI hardbound catalog p. 1-76
P-601	PiezoMove Linear Actuator	400 µm	flexure guiding system prevents tip and tilt	motion amplifier, mechanically preloaded	optional SGS	up to 0.8 N/µm	6
P-602	PiezoMove Flexure Actuator with High Stiffness	1000 µm	flexure guiding system provides straight motion with no tip and minimum tilt	motion amplifier, mechanically preloaded	optional SGS	up to 2.3 N/µm	8
P-603	PiezoMove Linear Actuator	500 µm	flexure guiding system prevents tip and tilt	motion amplifier, mechanically preloaded	optional SGS	up to 0.36 N/µm	10
P-712, P-713	Low-Profile Piezo Scanner	30 µm in X, XY	flexure guiding system provides straight motion with no tip and minimum tilt	motion amplifier, mechanically preloaded, P-713 parallel-kinematics	optional SGS	up to 0.8 N/µm	see PI hardbound catalog p. 2-56
P-611	NanoCube® XYZ Piezo Stage	100 µm in XYZ up to 3 axes	flexure guiding system provides straight motion with no tip and minimum tilt	motion amplifier, mechanically preloaded, serial kinematics	optional SGS	up to 0.8 N/µm	see PI hardbound catalog p. 2-52

Controller	Function	Positioning Sensor	Number of Channels	Peak Output Current	Peak Output Power	Page
E-831	Piezo Amplifier	-	1	100 mA (< 8 ms)	2 W without heat sink, 5 W with additional heat sink	16
E-610.00	Piezo Amplifier	-	1	180 mA (< 15 ms)	18 W (< 15 ms)	14
E-610.S0	Motion Controller	SGS	1	180 mA (< 15 ms)	18 W (< 15 ms)	14
E-621.SR	Networkable Motion Controller Module	SGS	1, networkable up to 16	120 mA (< 5 ms)	12 W (< 5 ms)	see PI hardbound catalog p. 2-160



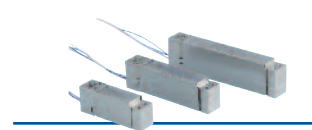
P-882 - P-888 PICMA® Multilayer Piezo Stack Actuators



P-871 PICMA® Piezo Bender Actuator



P-842 - P-845 Preloaded Piezo Actuators



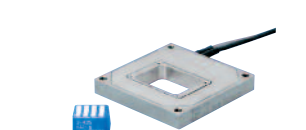
P-601 PiezoMove Linear Actuator



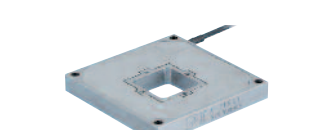
P-602 PiezoMove Flexure Actuator with High Stiffness



P-603 PiezoMove Linear Actuator



P-712 Low-Profile Piezo Scanner



P-713 Low-Profile Piezo Scanner



P-611 NanoCube® XYZ Piezo Stage



E-831 Piezo Amplifier



E-610 Piezo Amplifier/Motion Controller



E-621.SR Motion Controller Module

PiezoMove: Moving, Positioning, Scanning

Microfluidics, Biotechnology, Medical Engineering, Adaptronics

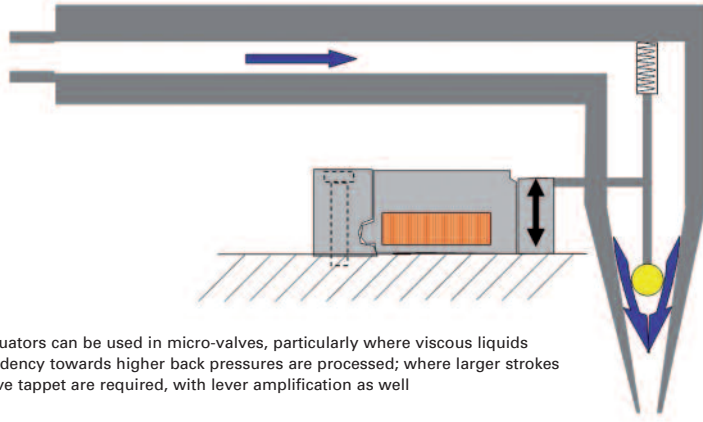
Piezo = nano = expensive?

Piezo actuators can do a lot more than “just” precision. Their excellent dynamics and high force play a crucial role in many areas, while the (nanometer) precision is of lesser importance: e.g. for fast switching, vibration cancellation, or to adjust tools in machines.

In these applications the piezo actuator is one – if not the only – solution and in the case of the new PiezoMove OEM actuators, at a very attractive price.

PiezoMove OEM actuators: Apply motion, how and where it is required

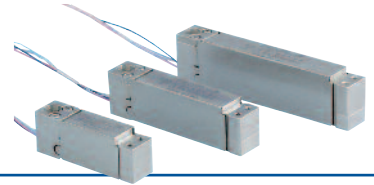
PiezoMove actuators combine guided motion and long travel ranges up to 1 mm and provide precision in the 10 nm range if ordered with the position sensor option. They are very compact, easy to integrate, require no maintenance and provide service life of Billions (10^9) of cycles.



Linear actuators can be used in micro-valves, particularly where viscous liquids with a tendency towards higher back pressures are processed; where larger strokes of the valve tappet are required, with lever amplification as well

PI supplies a variety of standard integration levels and also customized versions: From simple piezo stack components and preloaded linear actuators through to 6-axis positioning systems with sub-nanometer precision.

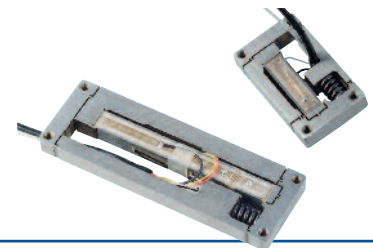
3 Actuator Families



P-601: Travel ranges to 400 μm , slight tilt



P-602: Travel ranges to 1000 μm , slight tip and tilt, high stiffness



P-603: Travel ranges to 500 μm , slight tilt, cost-optimized for high quantities

Application fields

Microfluidics:

Valves, pumps, microliter and nanoliter dosing

Biotechnology:

Cell manipulation, patch-clamp, microarrays, nanoliter dosing, dispensers, microstructuring with imprint processes

Medical engineering:

Diaphragm pumps, valves, dosing, injection, sample handling

Mechatronics, adaptronics:

Active structures, vibration isolation, active tools, structure deformation

Laser technology, metrology:

Cavity tuning, adjustment of optics or slit widths, sample positioning, beam control

PiezoMove: Travel Ranges to 1 mm

Easy Integration and Adaptation

Systems Thinking

PI provides a range of different control electronics for PiezoMove actuators.

These range from solderable OEM piezo driver modules to advanced digital motion controllers.

PI's wide range of actuators and control electronics allows for an optimum match of performance and cost for any application.

In addition to standard products, modified or completely custom engineered solutions are available at competitive prices. The following parameters can be modified to suit an application:

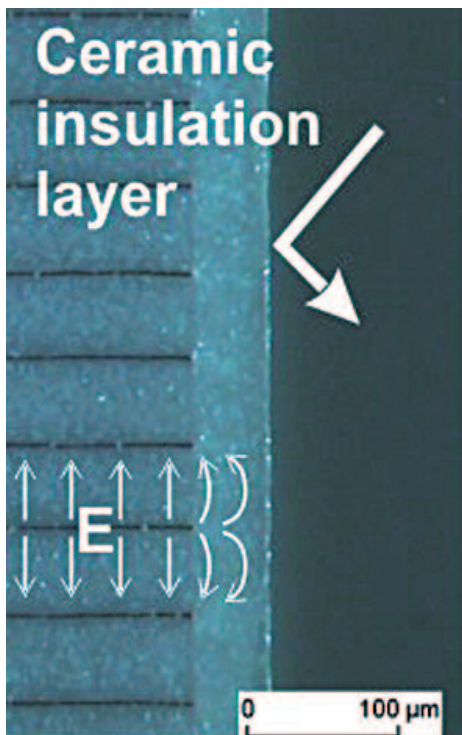
- Travel range
- Dynamics
- Force
- Precision



Levels of Integration: From Stack Actuator to 6-Axis Stage

	Stack actuators	Lever-amplified actuators	Positioning systems
Travel ranges	up to approx. 150 μm	up to 1 mm	up to 2 mm
Axes moved	one	one	up to three linear axes and three tip/tilt axes
Sensors	SGS optional	SGS optional	SGS or direct measuring capacitive sensors
Linearity	up to 99.8 %	up to 99.8 %	over 99.9 %
Guidance	none	flexures for rotations <10"	flexures for rotations <2"
Space required	low	low	depends on features
Price	low	low	depends on features
Integration effort	high	low	low

PI Actuators Offer Longer Service Life



The ceramic insulating layer prevents the penetration of water molecules and reliably protects the sensitive internal electrodes from mechanical damage and dirt

Different Piezo Solutions: Simple Piezo Components to Complex (Nano) Positioning Systems

Actuator: Piezo ceramic stack actuators are the driving force in many of PI's motion systems. Piezo actuators can move very rapidly due to their high stiffness; response times are as short as microseconds and scan frequencies up to several tens of kilohertz are feasible. The resolution is virtually unlimited, depending only on the electrical noise of the driver, making piezo actuators predestined for precision motion applications. The displacement of basic actuators is limited to a few tens of micrometers, however, and they need to be handled with care.

Preloading and Decoupling Against Lateral Forces: Encased piezo stacks can handle higher forces. The housing can decouple the piezo ceramics from lateral forces. Integrated mechanical preloading allows dynamic operation with higher loads.

Guiding System: Piezo ceramic stacks do not move in perfectly straight lines. For precise linear motion, a guiding system is required. Flexures guarantee the best performance because they provide frictionless, backlash-free motion and unlimited lifetime. If designed well, preloading and decoupling of unwanted forces can also be integrated without negative effects on the system stiffness.

Lever Amplification for Longer Travel Ranges:

The guiding system can be designed in such a way that it acts like a mechanical lever and increases the displacement of the piezo ceramic stack. Lever amplifiers reduce the system stiffness and this is where experience pays off. PI uses CAD modeling, FEA analysis and laser vibrometry for design optimization and testing. Based on 3 decades of experience with piezo flexure design PI actuators provide the best combination of lifetime, stiffness, precision and size.

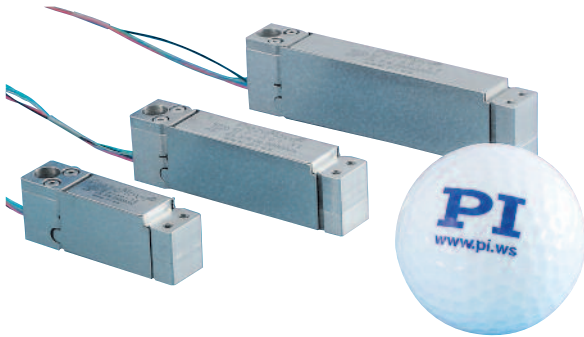
Sensor: Position feedback sensors are available when absolute position information is required. Strain gauge sensors (lower cost, accuracy to 0.5%) and capacitive sensors (higher precision to 0.01 %) are available.

Controller: The higher the demands placed on the system precision, the larger the role played by the motion controller. Open-loop actuators can be controlled directly via a voltage amplifier. To achieve maximum positional accuracy and scanning linearity, however, closed-loop control and digital control algorithms are indispensable.

Multi-Axis Positioners are constructed as parallel-kinematic systems for the highest possible precision, and controlled by advanced digital nanopositioning controllers.

P-601 PiezoMove Z-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 pre-loaded 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

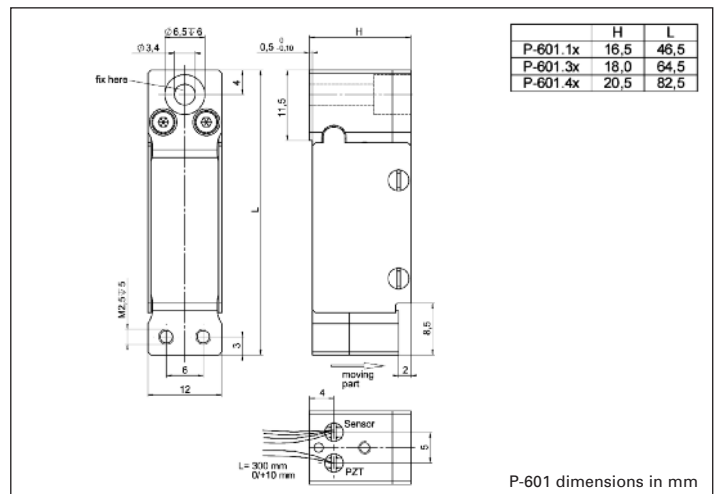
Highest possible reliability is assured by the use of award-winning PICMA® multilayer piezo actuators. PICMA® actuators are the only actuators on the market with ceramic-only insulation, which makes them resistant to ambient humidity and leakage-current failures. They are thus far superior to conventional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

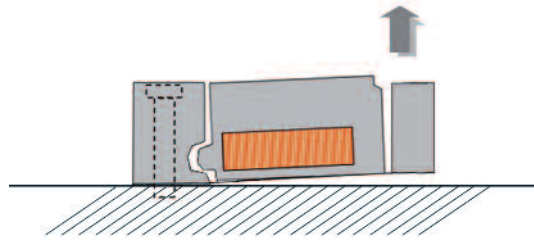
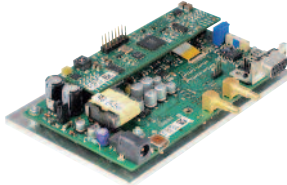
Ordering Information

- 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





The E-610 analog controller OEM module left or the E-609 digital OEM controller are available for closed-loop versions with position sensor

The flexure guiding system prevents tip and tilt at the drive head

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		
Motion and positioning						
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 θ_x, θ_y	20 / 10	20 / 10	20 / 10	as P-601.xS	µrad	typ.
Mechanical properties						
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.
Drive properties						
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 %
Miscellaneous						
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 Actuator with 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

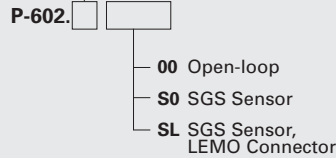
millimeter with high stiffness and very fast response. They do not contain any components that require maintenance or are subject to wear or tear. The flexure guides eliminate tip motion permitting only for a very slight tilt at the drive head. This design feature saves the cost for additional guiding 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

Ordering Information

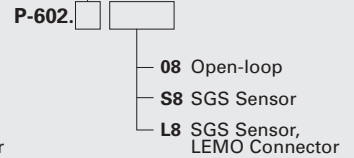
PiezoMove® OEM Linear Actuator with High Stiffness

- 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!

suit the customer's requirements. The 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

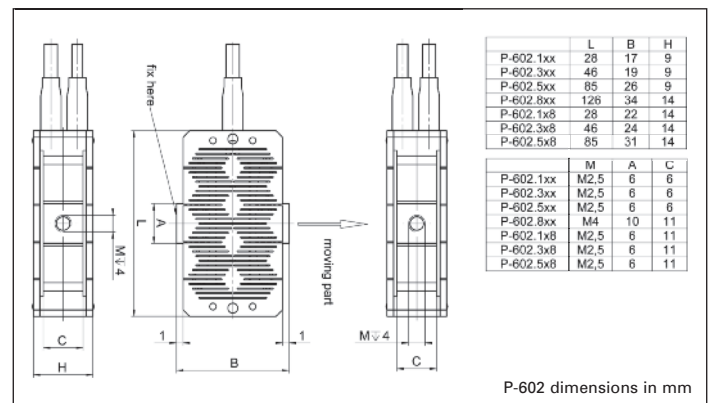
OEM controllers (see p. 2-110) to high-performance digital controllers (see p. 2-100ff). The great choice of actuators and controllers allows customers to select the optimum combination of performance and cost for their application.

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.

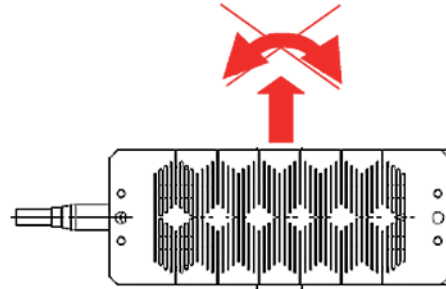
Application Examples

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





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



P-602: Flexure guides provide straight motion with no tip and minimum tilt

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		
Motion and positioning									
Integrated sensor	- / SGS / SGS	- / SGS / SGS	- / SGS / SGS	- / SGS / SGS	- / SGS / SGS	- / SGS / SGS	- / SGS / SGS		
Open-loop travel, -20 to +120 V	120	300	600	100	300	500	1000	µm	min. (+20%/-0)
Closed-loop travel	- / 100 / 100	- / 300 / 300	- / 500 / 500	- / 100 / 100	- / 300 / 300	- / 500 / 500	- / 1000 / 1000	µm	
Open-loop resolution	0.2	0.3	0.4	0.2	0.3	0.4	0.5	nm	typ.
Closed-loop resolution	- / 2 / 2	- / 3 / 3	- / 3 / 3	- / 2 / 2	- / 3 / 3	- / 3 / 3	- / 7 / 7	nm	typ.
Linearity, closed-loop	- / 0.5 / 0.5	- / 0.5 / 0.5	- / 0.5 / 0.5	- / 0.5 / 0.5	- / 0.5 / 0.5	- / 0.5 / 0.5	- / 1.5 / 1.5	%	typ.
Repeatability	- / 10 / 10	- / 20 / 20	- / 35 / 35	- / 10 / 10	- / 20 / 20	- / 35 / 35	- / 60 / 60	nm	typ.
Mechanical properties									
Stiffness in motion direction	0.8	0.35	0.3	2.3	0.75	0.65	0.4	N/µm	± 20%
Unloaded resonant frequency	1000	450	230	1000	450	230	150	Hz	± 20%
Blocking force	80	105	150	230	225	325	400	N	max.
Drive properties									
Ceramic type	PICMA® P-885	PICMA® P-885	PICMA® P-885	PICMA® P-888	PICMA® P-888	PICMA® P-888	PICMA® P-888		
Electrical Capacitance	1.5	3.1	6.2	6	13	26	39	µF	± 20%
Dynamic operating current coefficient	1.9	1.3	1.6	7.5	5	6	4	µA/(Hz·µm)	± 20%
Miscellaneous									
Operating temperature range	-20 to 80	-20 to 80	-20 to 80	-20 to 80	-20 to 80	-20 to 80	-20 to 80	°C	
Material	Stainless steel	Stainless steel	Stainless steel	Stainless steel	Stainless steel	Stainless steel	Stainless steel		
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		

Recommended controller / amplifier

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

P-603 PiezoMove Linear Actuator

Low-cost and with Large Travel Ranges



P-603 linear actuators with 500 and 100 μm travel range (from left to right). CD for size comparison

- Frictionless, High-Precision Flexure Guiding System
- Travel Ranges to 500 μm
- Cost-Effective Design
- Outstanding Lifetime Due to PICMA® Piezo Actuators
- Available with Integrated Position Sensor
- Ideal OEM Actuators for Precision Motion Control in Optics, Medical, Biotech and Microfluidics Applications
- Custom Designs with Larger Travel or Faster Response and Non-Magnetic Versions Feasible

P-603 PiezoMove flexure-guided piezo actuators integrate a frictionless high-efficiency motion amplifier to combine

Application Example

- Nanopositioning
- CCD / CMOS camera technology / Micro scanning
- Cell manipulation, biohandling
- Medical technology
- Micropumps
- Micro-dispensing
- Slit width adjustment
- Cavity Tuning
- Beam stabilization
- Photonics / integrated optics
- Switches

large travel ranges up to 500 μm with high stiffness and very fast response. The flexure guides reduce tip at the drive head to a minimum saving the cost for additional guiding systems when integrating these actuators in micro-dispensing devices, pumps or servo valves. The overall precision of 10s of nanometers also makes these devices ideal for nanomanipulation applications.

Options and Custom Versions

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

ding 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

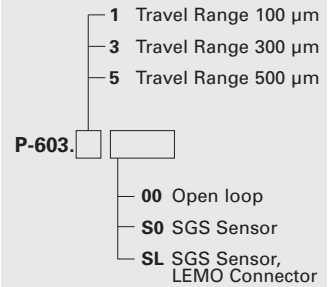
PI also supplies a variety of controllers to match the actuators. These range from simple amplifier modules (see p. 2-164) and analog closed-loop OEM controllers (see p. 2-110) to high-performance digital controllers (see p. 2-100ff). The great choice of actuators and controllers allows customers to select the optimum combination of performance and cost for their application.

Increased Lifetime Through Humidity Resistance

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

Ordering Information

PiezoMove® OEM Linear Actuator with High Stiffness



Ask about custom designs!

highly dynamic applications with small loads; depending on the load an external preload for dynamic applications is recommended. The high Curie temperature of 320° gives PICMA® 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 reduced travel range).



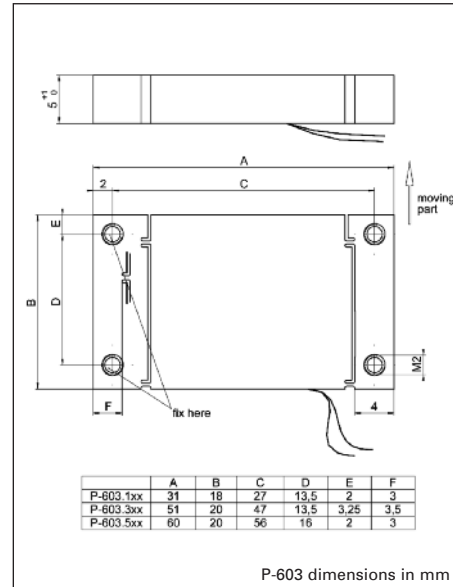
The flexure guiding system prevents tip and tilt at the drive head!



Levels of Integration: From Stack Actuator to 6-Axis Stage

	Stack actuators	Lever-amplified actuators	Positioning systems
Travel ranges	up to approx. 150 μm	up to 1 mm	up to 2 mm
Axes moved	one	one	up to three linear axes and three tip/tilt axes
Sensors	SGS optional	SGS optional	SGS or direct measuring capacitive sensors
Linearity	up to 99.8 %	up to 99.8 %	over 99.9 %
Guidance	none	flexures for rotations <10°	flexures for rotations <2°
Space required	low	low	depends on features
Price	low	low	depends on features
Integration effort	high	low	low

Flexure guided, lever-amplified actuators form a reasonably priced and easily integrated class of products between conventional piezo stack actuators and the complex piezo nanopositioning systems



Technical Data (preliminary)

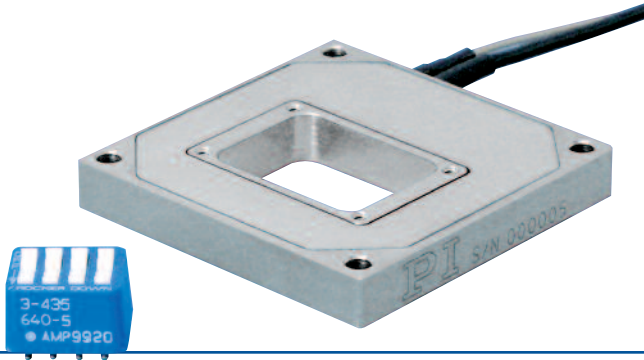
Model	P-603.1S0 P-603.1SL	P-603.3S0 P-603.3SL	P-603.5S0 P-603.5SL	P-603.x00 open-loop versions	Units	Tolerance
Active axes	X	X	X	X		
Motion and positioning						
Integrated sensor	SGS	SGS	SGS	–		
Open-loop travel, -20 to +120 V	100	300	550	as P-603.xS0	μm	min. (+20%/-0)
Closed-loop travel	100	300	500	–	μm	calibrated
Open-loop resolution	0.2	0.3	0.4	as P-603.xS0	nm	typ.
Closed-loop resolution	2	4	7.5	–	nm	typ.
Linearity, closed-loop	0.3	0.3	0.3	–	%	typ.
Repeatability	8	10	30	–	nm	typ.
Mechanical properties						
Stiffness in motion direction	0.25	0.14	0.06	as P-603.xS0	N/ μm	$\pm 20\%$
Unloaded resonant frequency	900	450	300	as P-603.xS0	Hz	$\pm 20\%$
Blocking force	20	35	25	as P-603.xS0	N	max.
Drive properties						
Ceramic type	PICMA® P-885	PICMA® P-885	PICMA® P-885	PICMA® P-885		
Electrical Capacitance	1.5	3.1	3.7	as P-603.xS0	μF	$\pm 20\%$
Dynamic operating current coefficient	1.9	1.3	1.6	as P-603.xS0	$\mu\text{A}/(\text{Hz}\cdot\mu\text{m})$	$\pm 20\%$
Miscellaneous						
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		
Dimensions	31x18x5	50x20x5	51x20x5	as P-603.xS0	mm	
Mass	0.02 / 0.031	0.032 / 0.043	0.038 / 0.049	as P-603.xS0	kg	$\pm 5\%$
Cable length	0.5	0.5	0.5	0.5	m	± 10 mm
Sensor / voltage connection	S-version: open leads SL-version: LEMO connector (SGS Sensor)	S-version: open leads SL-version: LEMO connector (SGS Sensor)	S-version: open leads SL-version: LEMO connector (SGS Sensor)	Open leads		

Recommended controller / amplifier

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

P-712 Low-Profile Piezo Scanner

Compact OEM System



P-712 piezo scanner with up to 40 μm travel range

- High Dynamic, to 5 ms Settling Time
- Travel Range up to 40 μm
- Resolution to 0.2 nm
- Compact Design with Low Profile, 40 x 40 x 6 mm
- Clear Aperture 25 x 15 mm
- PICMA® High-Power Actuators

P-712 piezo scanners are ideal for applications where limited space requires small-sized equipment. The high resonant frequency allows for fast linear scanning with 30 μm travel in one axis and provides settling times of about 5 ms. The P-712 linear scanner is offered in two versions, one with SGS position sensors for closed-loop operation, and one without sensors for open-loop.

Application Examples

- Optical path tuning
- Biotechnology
- Medical technology
- Image processing / stabilization
- CCD / CMOS camera technology

A similar XY version is available with product number P-713 / P-714 (see p. 2-56).

Excellent Guiding Accuracy

Flexures optimized with Finite Element Analysis (FEA) are used to guide the stage. FEA techniques are used to give the design the highest possible stiffness in, and perpendicular to, the direction of motion, and to minimize linear and angular runout. Flexures allow extremely high-precision motion, no matter how minute, as they are completely free of play and friction.

Electric discharge machining (EDM) with fine cutting wires is used to obtain the required precision for the flexures which make up the guidance system and determine the stiffness.

Optional Position Control

High-resolution, broadband, strain gauge sensors (SGS) are applied to appropriate locations on the drive train and measure the displacement of the moving part of the stage relative to the base indirectly. The SGS sensors assure optimum position stability in the nanometer range and fast response.

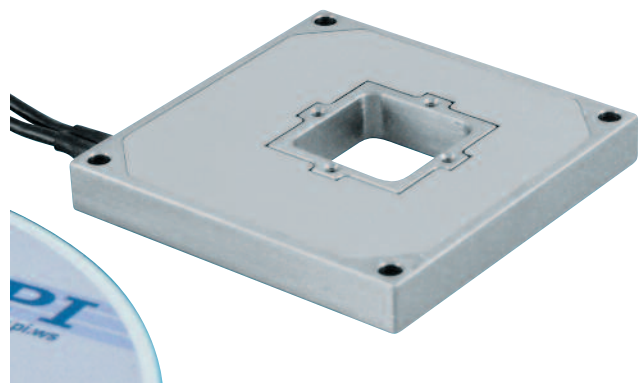
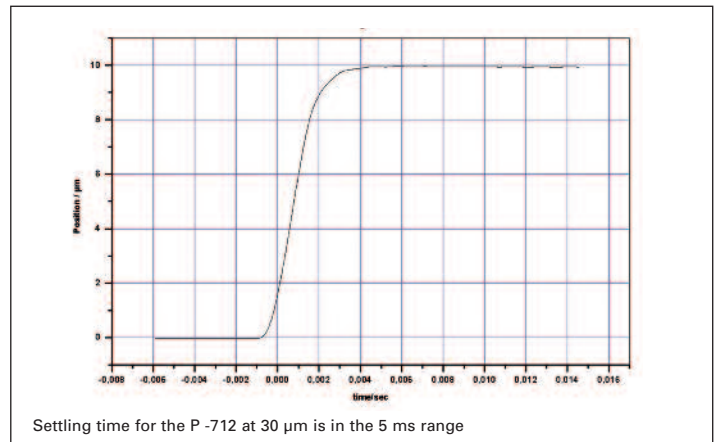
Ceramic Insulated Piezo Actuators Provide Long Lifetime

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

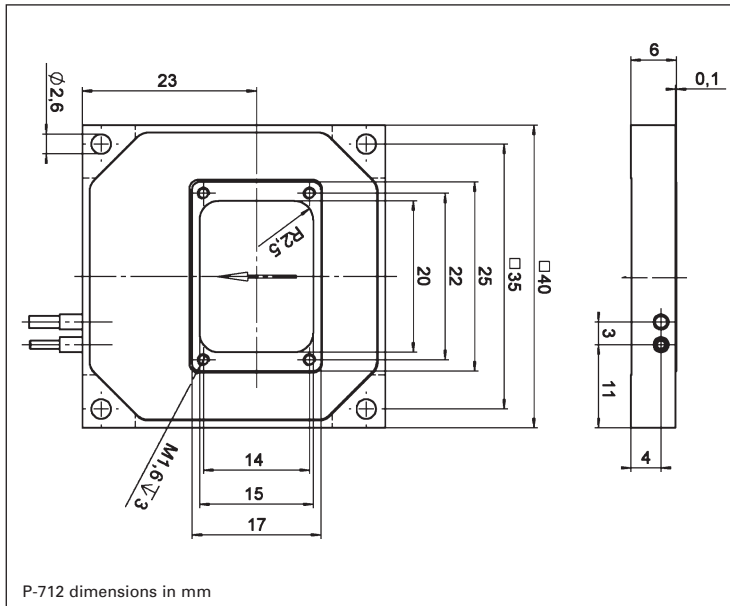
Ordering Information

- P-712.10L**
Low-Profile OEM Nanoscanner, 40 μm , Open-Loop
- P-712.1SL**
Low-Profile OEM Nanoscanner, 30 μm , SGS-Sensor

resistant to ambient humidity and leakage-current failures. They are thus far superior to conventional actuators in reliability and lifetime.



The P-713 XY-scanner is based on the same principle as the P-712 offering a travel range of 15 x 15 μm and a very high resonant frequency of over 2 kHz



Technical Data

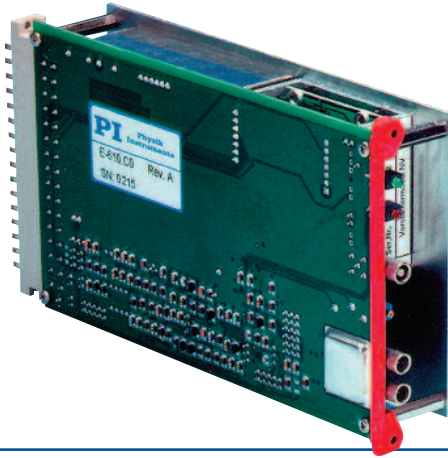
Model	P-712.1SL	P-712.10L	Units	Tolerance
Active axes	X	X		
Motion and positioning				
Integrated sensor	SGS	–		
Open-loop travel, -20 to +120 V	40	40	μm	min. (+20%/0%)
Closed-loop travel	30	–	μm	calibrated
Closed-loop resolution	2	–	nm	typ.
Open-loop resolution	0.2	0.2	nm	typ.
Linearity, closed-loop	0.3	–	%	typ.
Repeatability	±5	–	nm	typ.
Pitch	±5	±5	μrad	typ.
Yaw	±20	±20	μrad	typ.
Mechanical properties				
Stiffness in motion direction	0.6	0.6	N/μm	±20%
Unloaded resonant frequency	1550	1550	Hz	±20%
Resonant frequency under load	1090 (20 g)	1090 (20 g)	Hz	±20%
Push/pull force capacity in motion direction	6	6	N	Max.
Load capacity	5	5	N	Max.
Lateral Force	6	6	N	Max.
Drive properties				
Ceramic type	PICMA® P-882	PICMA® P-882		
Electrical capacitance	0.3	0.3	μF	±20%
Dynamic operating current coefficient	1.3	1.3	μA/(Hz • μm)	±20%
Miscellaneous				
Operating temperature range	-20 to 80	-20 to 80		
Material	Stainless steel	Stainless steel		
Dimensions	40 x 40 x 6	40 x 40 x 6	mm	
Mass	0.095	0.095	kg	±5%
Cable length	1.5	1.5	m	±10 mm
Voltage connection	LEMO	LEMO		
Sensor connector	LEMO	–		

Recommended controller / amplifier

Single-channel (1 per axis): E-610 servo controller / amplifier (p. 2-110), E-625 servo controller, bench-top (p. 2-114)

E-610 Piezo Amplifier / Controller

1-Channel OEM Piezo Driver Module with Optional Position Servo-Control



E-610 Single-channel OEM module with optional position servo control

- **Cost-Effective 1-Channel OEM Solution**
- **Closed-Loop and Open-Loop Versions**
- **Notch Filter for Higher Bandwidth**
- **Position Control with Strain Gauge or Capacitive Sensor**
- **18 W Peak Power**

The E-610 is an OEM amplifier & position servo-control board for low-voltage piezo actuators and positioning systems. It integrates a low-noise piezo amplifier which can output and sink peak currents of 180 mA in a voltage range of -20 to +120 V. Three versions are available: E-610.00 (only amplifier) and closed-loop versions E-610.S0 and E-610.C0 with additional components for position measurement and servo control.

Closed-Loop and Open-Loop Piezo Positioning

The units are designed to provide high-resolution operation of piezo actuators and positioning systems in voltage-controlled mode (open-loop) and in position-controlled mode (closed-loop).

In closed-loop position control mode, displacement of the piezo is highly linear and proportional to the analog signal. The servo modifies the amplifi-

er output voltage based on the position sensor signal. Thus, positioning accuracy and repeatability down to the sub-nanometer range is possible, depending on the piezo mechanics and on the sensor type.

PI employs proprietary position sensors for fast response and optimum positioning resolution and stability in the nanometer range and below. For high-end applications, capacitance sensors provide direct and non-contact position feedback (direct metrology). Strain gauge sensors (SGS) are available for cost-effective applications. The integrated notch filters (adjustable for each axis) improve the stability and allow high-bandwidth operation closer to the resonant frequency of the mechanics.

In open-loop (voltage-controlled) operation the output voltage is determined by an external analog signal. Open-loop operation is ideal for

applications where fast response and very high resolution with maximum bandwidth are essential. Here, commanding and reading the target position in absolute values is either not important or carried out by external position sensors (see p. 2-104).

Remote Control via Computer Interface

For digital-interface computer control, consider the E-621 (see p. 2-160) and E-625 (see p. 2-114) instead.

Alternatively control via PC using a D/A board is possible. PI offers a LabVIEW driver set which can be used with certain D/A boards from National Instruments.

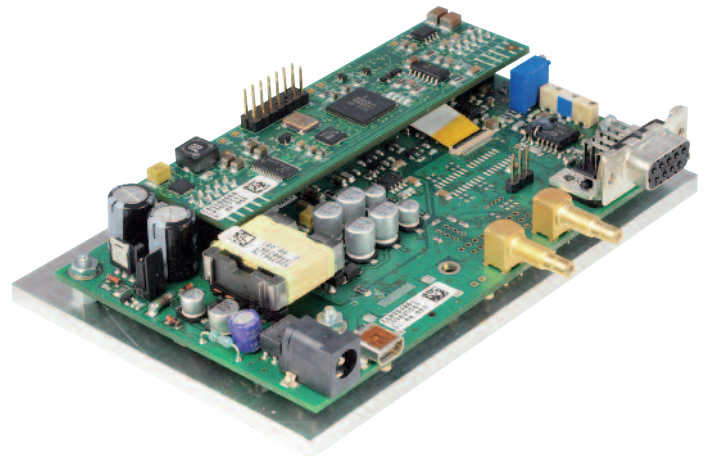
Operation / Contents of Delivery

A single stabilized voltage in the range of 12 to 30 V is sufficient to operate the E-610. An integrated DC/DC converter generates the piezo operating voltage and all other voltages

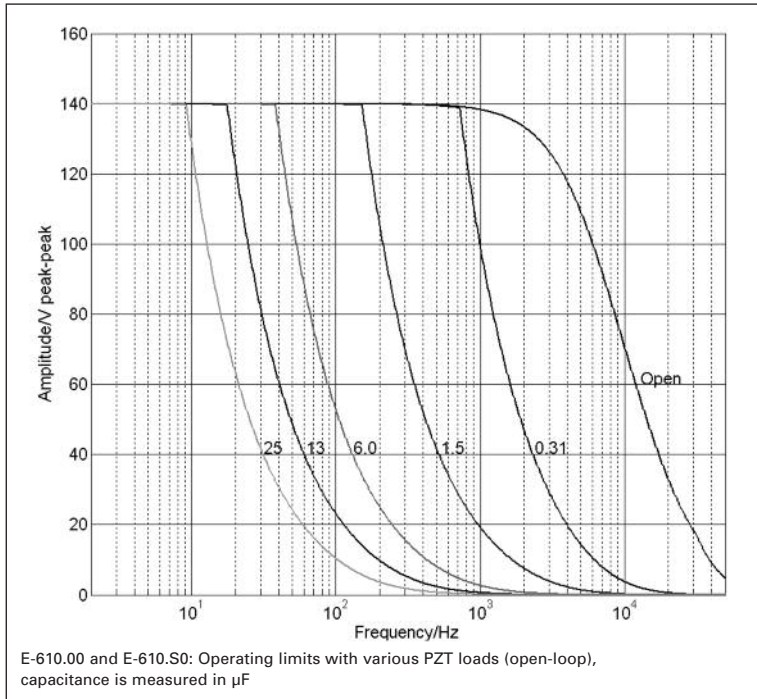
Ordering Information

E-610.00	Piezo Amplifier, 1 Channel, OEM Module, -30 to 130 V
E-610.C0	Piezo Amplifier / Servo-Controller, 1 Channel, OEM Module, -20 to 120 V, Capacitive Sensor
E-610.S0	Piezo Amplifier / Servo-Controller, 1 Channel, OEM Module, -30 to 130 V, SGS-Sensor
E-500.ACD	LabVIEW Driver Set for Analog Controllers
E-500.HCD	HyperBit™ Functionality for Enhanced System Resolution (Supports Certain D/A Boards)

used internally. All inputs and outputs (except capacitive sensor lines) are available on the male 32-pin rear connector. A matching female 32-pin connector is included in the contents of delivery to interface with your circuitry.



An OEM version with a digital controller is available – the E-609



Technical Data

Model	E-610.00	E-610.C0	E-610.S0
Function	Piezo Amplifier, 1 Channel, OEM Module	Piezo Amplifier / Servo-Controller, OEM Module	Piezo Amplifier / Servo-Controller, OEM Module
Sensor			
Servo characteristics	–	P-I (analog) + notch filter	P-I (analog) + notch filter
Sensor type	–	Capazitiv	SGS
Amplifier			
Control input voltage range	-2 to +12 V	-2 to +12 V	-2 to +12 V
Output voltage	-30 to 130 V	-20 to 120 V	-30 to 130 V
Peak output power	18 W (< 15 ms)	18 W (< 50 ms)	18 W (<15 ms)
Average output power	10 W	10 W	10 W
Peak current	180 mA (< 15 ms)	180 mA (< 50 ms)	180 mA (<15 ms)
Average current	100 mA	100 mA	100 mA
Current limitation	Short-circuit proof	Short-circuit proof	Short-circuit proof
Noise, 0 to 100 kHz	1.6 mV _{rms}	0.5 mV _{rms}	1.6 mV _{rms}
Voltage gain	10 ±0.1	10 ±0.1	10 ±0.1
Input independence	100 kΩ	100 kΩ	100 kΩ
Interfaces and operation			
Input / Output	32-pin (male) on rear panel (DIN 41612 / D)	32-pin (male) on rear panel (DIN 41612 / D)	32-pin (male) on rear panel (DIN 41612 / D)
Piezo connector	LEMO	LEMO	LEMO
Sensor connection	–	LEMO	LEMO
DC Offset	External potentiometer (not included), adds 0 to 10 V to Control In	External potentiometer (not included), adds 0 to 10 V to Control In	External potentiometer (not included), adds 0 to 10 V to Control In
Miscellaneous			
Operating temperature range	+5° to +50° C	+5° to +50° C	+5° to +50° C
Dimensions	7HP/3U	7HP/3U	7HP/3U
Mass	0.3 kg	0.35 kg	0.35 kg
Operating Voltage	12 to 30 V DC, stabilized	12 to 30 V DC, stabilized	12 to 30 V DC, stabilized
Current consumption, max.	2 A	2 A	2 A

E-831 Piezo Driver OEM Module, Power Supply for up to 3 Axes



E-831.03 amplifier module.

- Cost Effective Piezo Driver
- Small Size
- Low Noise, High Stability
- Easy-to-Use
- Full Overcurrent, Short-Circuit and Temperature Protection
- Power-up/down Without Voltage Spikes

The E-831.03 OEM piezo driver module is a very compact, cost-effective, single-channel, 4-quadrant power amplifier for low-voltage piezoelectric actuators.

It provides a peak output power of 12 W and average power of 2 W (expandable to 5 W with external heat sink). The E-831.03 is a high-precision amplifier with a fixed gain of 10.0 and outputs voltages in

the range of -20 to 120 V for control input signals ranging from of -2 to 12 V. The output is fully compensated for the capacitive loads of up to 10 μ F typical of PI's low-voltage PZTs such as PICMA[®] piezo actuators. For monitoring purposes, the output voltage is internally divided by 100 and provided at a special monitor pin.

Because piezo actuators require virtually no power in

steadystate operation and the power consumption depends on the operating frequency, high-powered amplifiers are not required for many applications. With a peak output current of 100 mA (sink/source) the E-831 is well-suited for switching applications and fast transitions where the capacitive load (the piezo actuator) needs to be charged as quickly as possible. The small-signal bandwidth is about 3 kHz.

Power Supplies for E-831.03

The E-841.05 (input voltage range 10 to 30V) and E-842.05 (input voltage range 30 V to 72 V) switched power supply modules provide all the operating voltages (± 15 V, -26 V and +127 V DC) required by the E-831.03 amplifier module. Both models supply enough power for up to three E-831.03 amplifiers with a total output power of 5 W.

A sync. input on the power supply allows synchronization of the internal switching frequency with an external clock (185 to 220 kHz) for elimination of interference in AC-driven position sensors or DACs.

Easy Implementation

E-831 and E-841/E-842 modules are enclosed in metal cases with solderable pins for PCB mounting. They are designed to work together without additional components.

Triple Safety

The E-831 amplifier is short-circuit proof with both a low-speed current limiter of 50 mA and a high-speed (8 msec) current limiter of 100 mA. When the case temperature rises above 70 °C (can be reached after a few minutes with maximum current) an internal temperature sensor shuts down

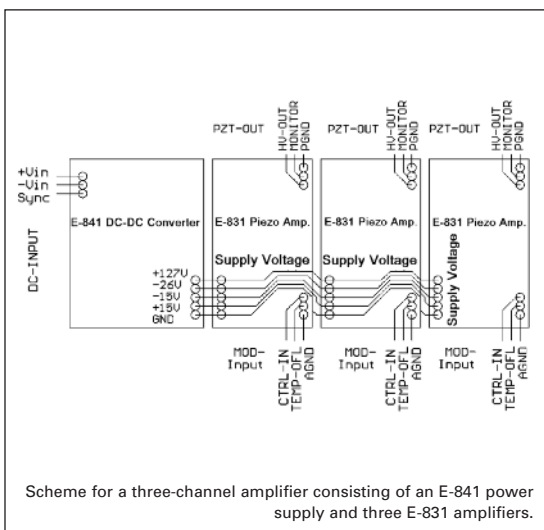
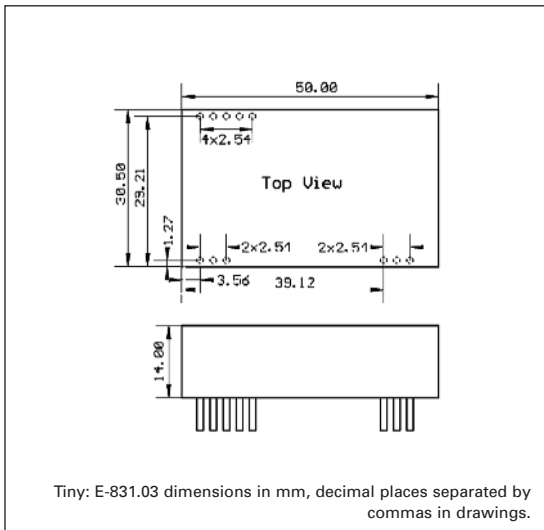
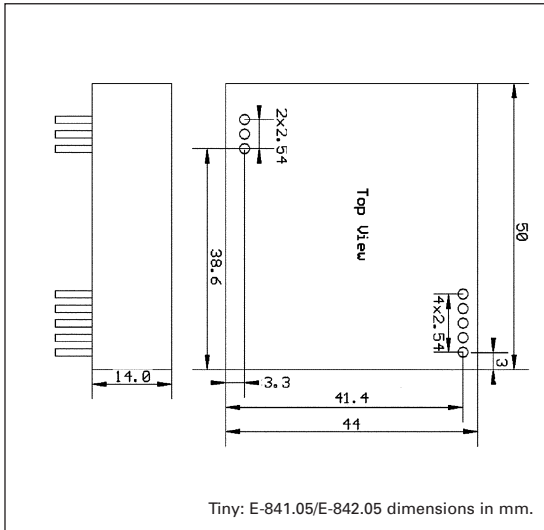
Ordering Information

- E-831.03**
Single-Channel Piezo Driver Module for LVPZTs
- E-841.05**
Power Supply Module for E-831, Input 10 to 30 V
- E-842.05**
Power Supply Module for E-831, Input 30 to 72 V

the output stage until the temperature drops below 60 °C. This operation mode is indicated by the active-high TEMP-OFL TTL status line.



E-841.05 power supply module



Technical Data E-831.03

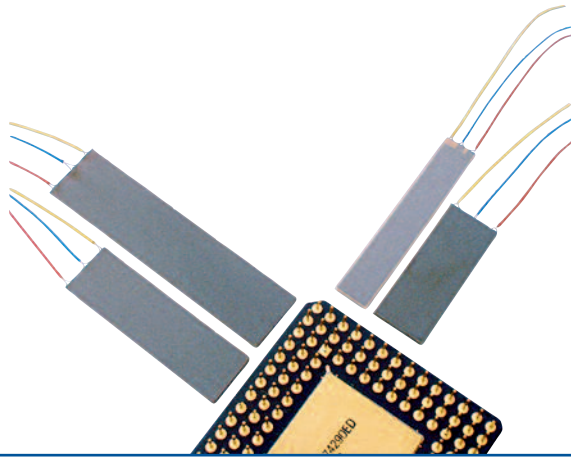
Models	E-831.03
Function:	Single-channel piezo amplifier module
Output voltage range:	from [U+ - 6 V] (121 V for U+ = 127 V) to [U- + 8 V] (-20 V for U- = 28 V)
Gain	10 ±0.1
Max. output current:	100 mA for 8 ms (sink/source)
Max. average current:	50 mA for 2 min without heatsink
Output protection:	short-circuit protected, the module is overload protected to 70 °C case temperature
Max. output power:	2 W without ext. heatsink 5 W with ext. heatsink or forced airflow
Control input range:	-2 to +12 V
Input impedance:	100 kΩ
Dynamic current requirements:	depend on load, amplitude and slew rate
Cut off frequency:	3.5 kHz, no load
Operating temperature range:	+5° to +50° Celsius
Operating voltages:	+15 V / 20 mA (14 to 16 V) (all currents without dynamic load) -15 V / 7 mA (-14 th -16 V) +127 V / 1.8 mA +125 to 135 V -26 V / 1.8 mA (-24 to -30 V)
Case	Metal shielded case, size: 50 x 30 x 14 mm
Soldering pins	1 mm diameter, 4 mm length

Technical Data E-84x.05

Models	E-841.05, E-842.05
Function:	Power Supply Module for E-831
Output voltages:	+127 V, 30 mA; -26 V, 30 mA; +15 V, 60 mA; -15 V, 20 mA
Max. output Power:	8 W
Max. average Power	8 W with forced air flow (5 W without)
Output protection:	short-circuit protected (1 min.)
Input voltage:	10 - 30 V (E-841.05); 30 - 72 V (E-842.05)
Quiescent current:	100 mA @15 V; 60 mA @30 V; 25 mA @72 V
Max. input current:	1000 mA (E-841.05 @ 10V); 200 mA (E-842.05 @ 72V)
Power-on, peak current:	1500 mA
Switching frequency	100 kHz typical
External clock frequency:	200 kHz (185 - 220 kHz possible)
Synchronization signal:	preferred TTL-level with duty cycle 50 %; operating from 1.8 V _{DD} and offsets within ±7 V
Output ripple:	<100 mV _{pp}
Operating temperature range:	5° to +50° Celsius (with power derating above 40 °C)
Case	Metal shielded case, size: 50 x 44 x 14 mm
Soldering pins	1 mm diameter, 4 mm length

PL112 · PL140 PICMA® Bender Actuators

Multilayer Piezo Bender Actuators with High Travel and Low Operating Voltage



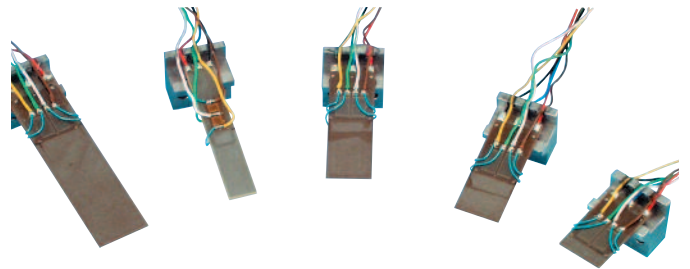
Bender actuators with optional wire leads (order number extension .x1); micro processor for size comparison

- Ceramic Encapsulation for Better Protection and Longer Lifetime
- Positioning Range up to 2 mm
- Fast Response (10 msec)
- Nanometer-Range Resolution
- Low Operating Voltage
- Vacuum-Compatible Versions to 10^{-9} hPa
- Available with Integrated Position Sensor
- Special OEM- and Bench-Top Amplifiers Available

PICMA® multilayer bender piezo actuators provide a deflection of up to 2 mm, forces up to 2 N and response times in the millisecond range. 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. The benders have two outer active areas and one central electrode network dividing the actuator in two segments of equal capacitance, similar to a classical parallel bimorph.

Advantages

PICMA® Bender piezo actuators offer several advantages over classic bimorph components manufactured by gluing together two ceramic plates (0.1 to 1 mm thick): faster response time and higher stiffness. The main advantage, however, is the drastically reduced (by a factor of 3 to 10) operating voltage of only 60 V. The reduced voltage allows smaller drive electronics and new applications, such as in medical equipment. Additionally, these devices offer improved humidity resistance due to the ceramic encapsulation.



Bender actuators with strain gauge positioning sensors are available with product number P-871

Technical Data / Product Order Numbers

Order number*	Operating voltage [V]	Nominal displacement [μm] $\pm 20\%$	Free length [mm]	Dimensions L x W x T [mm]	Blocking force [N]	Electrical capacitance [μF] $\pm 20\%$	Resonant frequency [Hz] $\pm 20\%$
PL112.10**	0 - 60 (± 30)	± 80	12	17.8 x 9.6 x 0.65	± 2.0	2 x 1.1	>1000
PL122.10	0 - 60 (± 30)	± 250	22	25.0 x 9.6 x 0.65	± 1.1	2 x 2.4	660
PL127.10	0 - 60 (± 30)	± 450	27	31.0 x 9.6 x 0.65	± 1.0	2 x 3.4	380
PL128.10**	0 - 60 (± 30)	± 450	28	35.5 x 6.3 x 0.75	± 0.5	2 x 1.2	360
PL140.10	0 - 60 (± 30)	± 1000	40	45.0 x 11.0 x 0.60	± 0.5	2 x 4.0	160

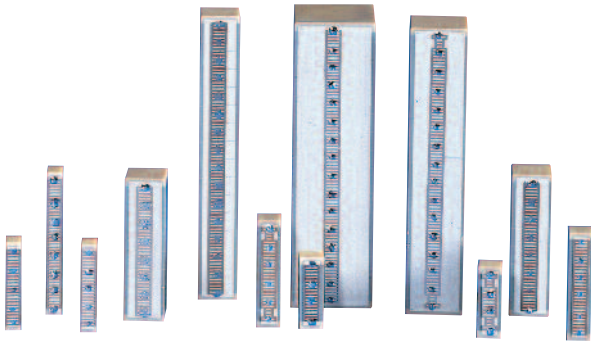
*For optional PTFE insulated wire leads change order number extension to .x 1 (e.g. PL112.11)
Operating temperature range: -20 to +85 °C;

**to +150 °C Resonant frequency at 1 V_{pp} , capacitance at 1 V_{pp} , 1 kHz

All parameters depend on actual clamping conditions and applied load.
Ask about custom designs and further specifications.

P-882 · P-888 PICMA® Multilayer Piezo Stack Actuators

Ceramic-Insulated High-Power Actuators



Improved reliability even for permanently high humidity or splash water by hermetic encapsulation with inert gas filling. Available on request.

- 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^{-9} hPa
- Sub-Millisecond Response / Sub-Nanometer Resolution
- Ideal for Dynamic Operation

Ideal for Closed-Loop Operation

PICMA® actuators achieve positioning resolutions in the sub-nanometer range and response times in the microsecond range. The ceramic surface of the actuators is excellently suitable for mounting sensors, such as strain gauges. In con-

trast to polymer-coated actuators, the sensor can be applied directly to the ceramic of the PICMA® actuator, allowing for higher stability, linearity and measuring accuracy.

Technical Data / Product Order Numbers

Order numbers*	Dimensions A x B x L [mm]	Nominal displacement [μm] (0 – 100 V)	Max. displacement [μm] (0 – 120 V)	Blocking force [N] (0 – 120 V)	Stiffness [N/ μm]	Electrical capacitance [μF] $\pm 20\%$	Resonant frequency [kHz] $\pm 20\%$
P-882.11	2 x 3 x 9	6.5 $\pm 20\%$	8 $\pm 20\%$	190	24	0.15	135
P-882.31	2 x 3 x 13.5	11 $\pm 20\%$	13 $\pm 20\%$	210	16	0.22	90
P-882.51	2 x 3 x 18	15 $\pm 10\%$	18 $\pm 10\%$	210	12	0.31	70
P-883.11	3 x 3 x 9	6.5 $\pm 20\%$	8 $\pm 20\%$	290	36	0.21	135
P-883.31	3 x 3 x 13.5	11 $\pm 20\%$	13 $\pm 20\%$	310	24	0.35	90
P-883.51	3 x 3 x 18	15 $\pm 10\%$	18 $\pm 10\%$	310	18	0.48	70
P-885.11	5 x 5 x 9	6.5 $\pm 20\%$	8 $\pm 20\%$	800	100	0.6	135
P-885.31	5 x 5 x 13.5	11 $\pm 20\%$	13 $\pm 20\%$	870	67	1.1	90
P-885.51	5 x 5 x 18	15 $\pm 10\%$	18 $\pm 10\%$	900	50	1.5	70
P-885.91	5 x 5 x 36	32 $\pm 10\%$	38 $\pm 10\%$	950	25	3.1	40
P-887.31	7 x 7 x 13.5	11 $\pm 20\%$	13 $\pm 20\%$	1700	130	2.2	90
P-887.51	7 x 7 x 18	15 $\pm 10\%$	18 $\pm 10\%$	1750	100	3.1	70
P-887.91	7 x 7 x 36	32 $\pm 10\%$	38 $\pm 10\%$	1850	50	6.4	40
P-888.31	10 x 10 x 13.5	11 $\pm 20\%$	13 $\pm 20\%$	3500	267	4.3	90
P-888.51	10 x 10 x 18	15 $\pm 10\%$	18 $\pm 10\%$	3600	200	6.0	70
P-888.91	10 x 10 x 36	32 $\pm 10\%$	38 $\pm 10\%$	3800	100	13.0	40

Standard piezo ceramic type: 252

Standard connection types: 100 mm pigtail

* For optional solderable contacts, change order number extension to .x0 (e.g. P-882.10)

Recommended preload for dynamic operation: 15 MPa

Maximum preload for constant force: 30 MPa

Resonant frequency at 1 V_{pp} , unloaded, free at both sides. The value is halved for unilateral clamping

Capacitance at 1 V_{pp} , 1 kHz

Operating voltage: -30 to +130 V; the lifetime depends on the voltage applied.

Operating temperature range: -40 to +150 °C

Standard mechanical interfaces: Ceramics

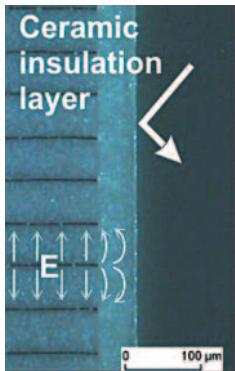
Available options: strain gauge sensors, special mechanical interfaces, etc.

Other specifications on request.

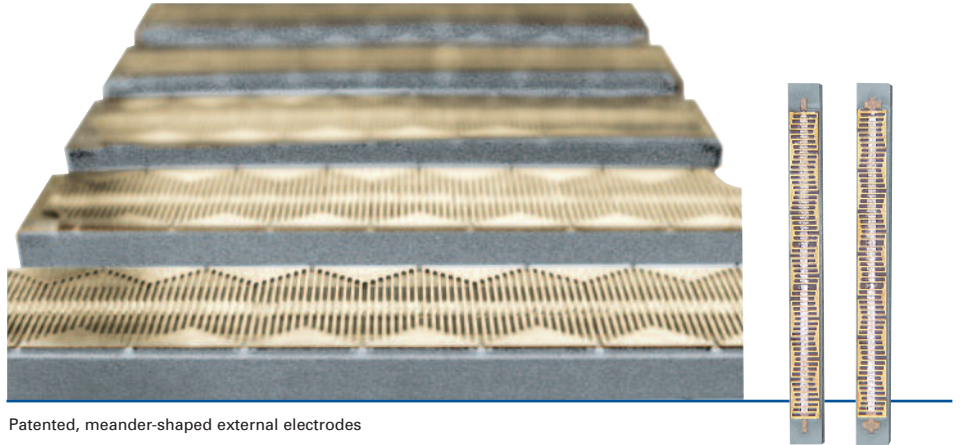
PICMA®: Reliability and Continuous Further Development

Ceramic-Insulated, Piezoelectric Actuators Offer Superior Lifetime

PICMA® multilayer piezo actuators are based on a special PZT (lead zirconate – lead titanate) ceramic, which ideally combines the desired characteristics of the components such as high stiffness, low electrical capacity, high specific displacement, low load and temperature dependence of the specifications and long lifetime.



The ceramic insulating layer prevents the penetration of water molecules and reliably protects the sensitive internal electrodes from mechanical damage and dirt



Patented, meander-shaped external electrodes

Contacts for Large Electric Currents

Research on the termination electrodes led to a further improved design. The patented, meandering form of the external electrodes supplies the electric current evenly to the internal electrodes (Fig. 2). The contact here is chosen so that it remains electrically stable and mechanically flexible even at high currents up to 20 A and more, thus providing particularly dynamic control. This improves the lifetime of the actuator in applications with rapidly changing fields.

Influences on the Lifetime of a Piezo-Ceramic Actuator

Three essential factors affect the lifetime of piezo ceramics in positioning applications: Humidity, operating voltage and temperature.

Penetrating moisture and the electric field applied can cause electrochemical transport processes in the component, which are accelerated by higher temperatures. The result is a short circuit between the electrodes, which can cause irreparable damage to the actuator.

The actual application determines the extent to which the individual factors have an impact.

The internal electrodes and the ceramic are jointly sintered (co-fired technology) to create a monolithic piezo-ceramic block (Fig. 1). This block is protected against humidity and damage from increased leak current by a ceramic insulation layer. Therefore, PICMA® actuators are far superior in terms of reliability and lifetime to conventional, polymer-coated, multilayer, piezoelectric actuators. The construction with the ceramic insulation layer results also in a high resonance frequency, making the actuators ideally suited for high-dynamics operation.

Large Temperature Range – Optimum UHV Compatibility – Minimal Outgassing – Neutral in Magnetic Fields

The particularly high Curie temperature of 320°C allows for a usable temperature range of up to 150°C, far beyond the 80°C limit of conventional multilayer actuators. This and the exclusive use of inorganic materials provide the optimum conditions for use in ultra-high vacuums: No outgassing and high bake-out temperatures.

PICMA® piezoelectric actuators work at a reduced travel even in the cryogenic temperature range.

Thanks to their construction that is based solely on non-ferromagnetic materials, the actuators have an extremely low residual magnetism in the order of a few nanotesla.

Low Operating Voltage

In contrast to most commercially available multilayer piezo actuators, PICMA® actuators achieve their nominal displacement at operating voltages significantly below 150 V. This is achieved by using a particularly fine-grained ceramic material which allows a lower depth of the internal layers.

The products described in this document are at least partially protected by the following patents:

- German patent no. 10021919
- German patent no. 10234787
- German patent no. 10348836
- German patent no. 102005015405
- German patent no. 102007011652
- US patent no. 7,449,077

Safety with PICMA®

Long-Term Tests Prove the Superior Reliability

In positioning applications, the piezoelectric actuator is typically operated at constant voltage to maintain one position over an extended period of time. Here, the lifetime of piezoelectric actuators is affected especially by the voltage and the humidity.

Protective Ceramic Layer

The most important feature which protects PICMA® actuators against ingressing moisture is the monolithic construction with the ceramic insulation layer. The penetration of water molecules is effectively suppressed, which is impressively documented by measurements of the leak current (Fig. 3). Increased values are a sign of deteriorating insulation resistance and thus of a decrease in lifetime, as can be seen with polymer-coated actuators.

Tests Under Realistic and Extreme Conditions

The high reliability makes it virtually impossible to experimentally measure the lifetime of PICMA® actuators under realistic operating conditions. To estimate the lifetime, tests under extreme conditions are used.

These tests are then confirmed in a long-term series of tests that are carried out under realistic conditions (see “Realistic study”).

Realistic Study

Voltage	Failure Rate of PICMA® Actuators with Ceramic Insulation	Failure Rate of Conventional, Polymer-Coated Actuators
100 V DC	0 % (calculated MTTF: $1.3 \cdot 10^6$ h)	75 %
120 V DC	0 % (calculated MTTF: 178,000 h)	100 %
135 V DC	0 % (calculated MTTF: 49,000 h)	100 %
150 V DC	25 % (calculated MTTF: 15,500 h)	100 %

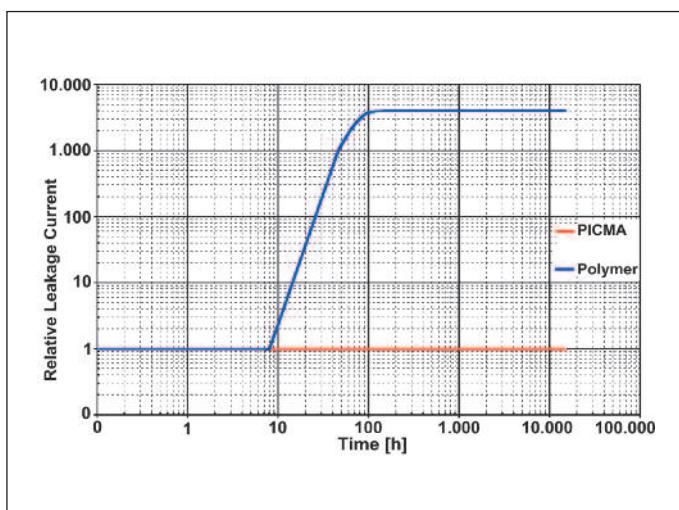
Tests under realistic conditions clearly confirm the high reliability of the ceramic-insulated PICMA® piezo actuators. Multilayer actuators were operated under conventional environmental conditions with different DC voltages. In this case, as well, PICMA® actuators with ceramic insulation convince by quite a margin: First failures occur only at 150 V, i.e. far above their specified nominal voltage, while after an 18-month test period only a small number of conventional polymer-insulated piezoelectric actuators are still functional. Test conditions: 22°C, 55% RH, testing period 18 months (13,400 h)

Accelerated Life Test

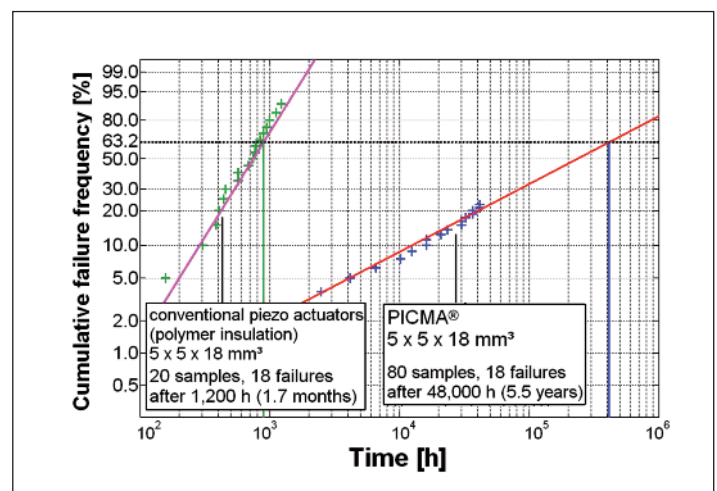
An increased relative humidity combined with high ambient temperatures and control voltages sometimes above the nominal voltage range leads here to an accelerated degradation of the piezo ceramics. The boundary conditions are subsequently corrected using a mathematical model and thus results in a specification for the average lifetime (Mean Time To Failure, MTTF) in a realistic application. Conventional,

polymer-coated piezoelectric actuators typically survive continuous use at increased humidity for about 30 days (Fig. 4), whereas PICMA® multilayer piezoelectric actuators are still working reliably after more than four years!

The results were obtained from a representative random sample of PICMA® 5 x 5 x 18 (P-885.50) and are typical for the complete PICMA® product range.



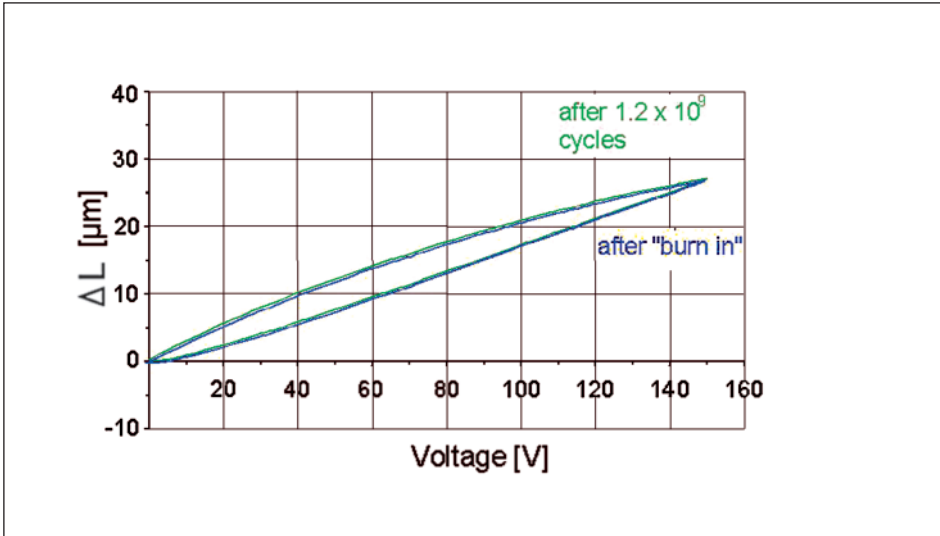
PICMA® piezoelectric actuators (bottom curve, red) compared to polymer-coated multilayer piezoelectric actuators. The high insulation resistance of the PICMA® actuators remains stable over several time decades, whereas conventional, polymer-coated actuators exhibit a significantly increased leak current after a few hours. (Test conditions: 100 V DC, 25°C, 70% relative humidity (RH))



Comparison of PICMA® and conventional piezo actuators insulated with a polymer coating. Results of an accelerated life test with increased humidity for accelerated aging (Test conditions: 100 V DC, 22°C, 90% RH). Statistical methods can be used to derive values under normal climatic operating conditions from this. The extrapolated average lifetime (MTTF) for PICMA® actuators is more than 400,000 h (approx. 45 years). All polymer-coated comparison samples fail, at the most, after only 1,600 hours (MTTF = 890 hours, about 1 month)

PICMA® Piezo Actuators under Permanent Cyclic Load

Dynamic Application: AC Voltage / AC Operation



Dynamic test series with eight PICMA® actuators 5 x 5 x 18 mm: Total number of cycles 4.0×10^9 cycles; 116 Hz sinusoidal control (1.0×10^7 cycles per day), 100 V unipolar operating voltage, 15 MPa preloading. Control measurements after each series of 10^6 cycles. Only insignificant decrease in the displacement.

Dynamic Continuous Operation

Cyclic demands with a rapidly alternating electrical field and high control voltages (typically > 50 Hz; > 50 V) are common conditions for multilayer piezoelectric actuators, for example when used in valves, pumps or ultrasonic transducers.

The lifetime of the piezo element is in this case dominated by different factors to those affecting DC operation:

The impact of the dynamic forces and the changing state of the mechanical stress increases. Therefore, this can lead to the

formation of cracks in the stack construction and hence to electrical discharges. The impact of the humidity, on the other hand, is negligible because it is reduced locally by the warming-up of the piezoceramic.

The most important factors affecting the lifetime are therefore the voltage and the type of the signal. In AC operation, the lifetime itself is not expressed as a time period but more sensibly as a number of cycles.

Extraordinarily Robust: 10¹⁰ Working Cycles

Due to the stability of the material behavior and their mechanical construction, PICMA® actuators exhibit no signs of wear even after many billions of load cycles (Fig. 6).

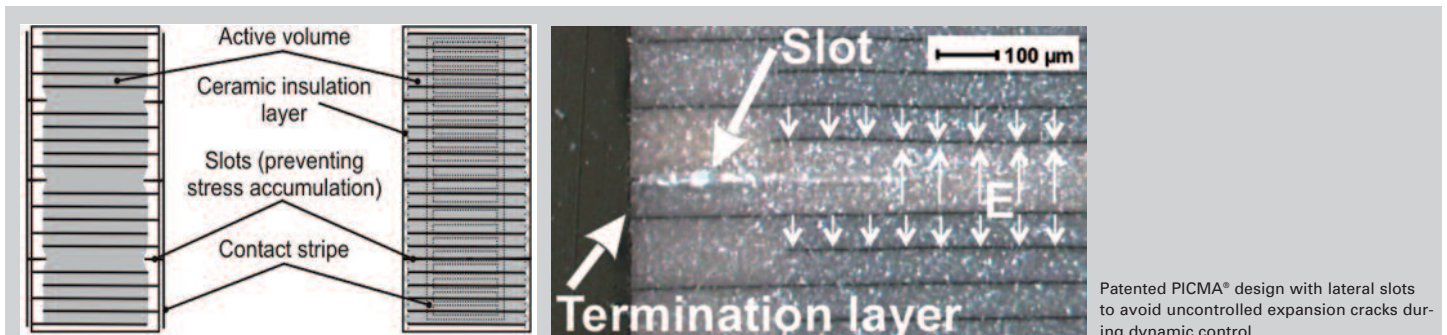
The target of 10^{10} working cycles is especially important for industrial use. The proof for the reliability of the PICMA® technology is obtained by means of a test with particularly high control frequency.

Preloaded PICMA® actuators with dimensions of 5 x 5 x 36 mm were loaded at room temperature and average humidity with a sinusoidal signal of 120 V unipolar voltage at 1,157 Hz. This amounts to 10^8 cycles per day! Even at this high voltage and frequency there was not a single failure and the actuators showed no significant changes in displacement.

Longer Operating Periods and Higher Control Frequencies

The dynamic operation of PICMA® piezo elements benefits significantly from the large range of operating temperatures of up to 150°C.

The intrinsic warming of the elements when dynamically controlled is proportional to the operating frequency. A higher operating temperature thus also allows higher control frequencies and longer periods of operation. Additionally, the displacement of the PICMA® piezoceramics exhibits only a low dependence on temperature.



Patented PICMA® design with lateral slots to avoid uncontrolled expansion cracks during dynamic control

Also Stable in the AC Field

PI reduces the probability of crack formation by using a particular patented design with lateral slots. These reliably prevent the mechanical tensile stresses in the stack from becoming too high and the formation of uncontrolled additional cracks (Fig. 7). Furthermore, the patented meander-shaped construction of the termination electrodes (see Fig. 2) ensures all internal electrodes have a stable electrical contact even at extreme dynamic loads.

The PI Group

High Quality and Strong Brands on a Global Scale



PI Ceramic—a PI Subsidiary—is a world-class supplier of high-performance piezoelectric actuator and transducer components and subassemblies.

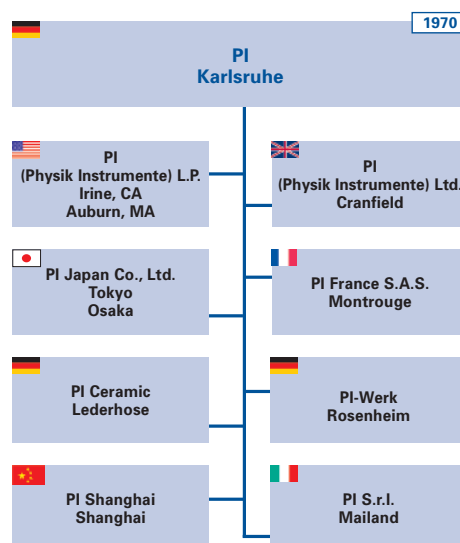
PI Ceramic also develops and produces all piezo ceramic drive systems employed in PI's precision positioning systems. This makes PI the only supplier of nanopositioning equipment in the world to manufacture its own piezo ceramic drives. This capability allows the flexibility to provide custom engineered piezo ceramic components. It also allows PI to offer the most reliable piezo stages in the world, based upon the award-winning PICMA® actuator technology and to develop innovative drive solutions such as PLine® ultrasonic ceramic motors and NEXLINE® high-force ceramic motors.

In the tradition of the former Keramische Werke Hermsdorf (KWH, until 1990), the PI Ceramic staff embodies knowledge and expertise in the field of piezo and ceramic technology. Since 1992, PI Ceramic has been developing and producing piezo ceramics, worldwide known as PIC: PI piezo Ceramics.

Quality and Brand Policy

We measure the quality and reliability of our products against the strictest of standards. ISO 9001 certification, which also emphasizes points like customer expectations and satisfaction, has been accorded in 1994, making PI the first manufacturer of nanopositioning technology following this standard. PI's Integrated Management System (IMS) includes also Environmental Protection and Job Safety (according to ISO 14001:2004 and OHSAS 18001:1999). This system assures legal conformity of all procedures as well as continuous optimization of the processes at all PI locations. PI brands and colors are well known throughout the high-tech world. PIFOC® is almost used as a synonym for objective positioners in general and PICMA® stands for the highest reliability in piezo actuator products.

PI stands for quality and precision – worldwide.





The current hardbound "Piezo-Nano-Positioning: Inspirations 2009" catalog from PI is available.

The 530 page publication is the most comprehensive reference book on the fundamentals of nanopositioning, piezo systems and micropositioning technology yet. The new catalog contains 200+ product families – 30% of them new – with more than 1000 drawings, graphs, images and technical diagrams.

The 530 page publication presents PI's state-of-the-art products and technologies-such as:

- Nanopositioning / Scanning Stages
- Scanning Microscopy Stages
- Steering Mirrors, Mirror Shifters
- Piezo Actuators
- Piezo Motors
- Piezo Controllers
- Motorized Stages & Actuators
- Motor Controllers
- Hexapod 6-Axis Alignment Systems

The catalog also contains a tutorial on piezo technology and application examples of nanopositioning products in the following industries:

- Biotechnology / Life Sciences
- Semiconductor Technology
- Data Storage Technology
- Nanotechnology
- Aeronautics
- Astronomy
- Adaptive Optics
- Metrology / Laser-Systems
- Precision Machining

Headquarters

GERMANY

Physik Instrumente (PI) GmbH & Co. KG
 Auf der Römerstraße 1
 76228 Karlsruhe
 Tel: +49 (721) 4846-0
 Fax: +49 (721) 4846-100
 info@pi.ws · www.pi.ws

PI Ceramic GmbH
 Lindenstraße
 07589 Lederhose
 Tel: +49 (36604) 882-0
 Fax: +49 (36604) 882-25
 info@piceramic.de
 www.piceramic.de

Subsidiaries

USA (East) & CANADA

PI (Physik Instrumente) L.P.
 16 Albert St.
 Auburn, MA 01501
 Tel: +1 (508) 832 3456
 Fax: +1 (508) 832 0506
 info@pi-usa.us
 www.pi-usa.us

USA (West) & MEXICO

PI (Physik Instrumente) L.P.
 5420 Trabuco Rd., Suite 100
 Irvine, CA 92620
 Tel: +1 (949) 679 9191
 Fax: +1 (949) 679 9292
 info@pi-usa.us
 www.pi-usa.us

JAPAN

PI Japan Co., Ltd.
 2-38-5 Akebono-cho
 Tachikawa-shi
 Tokyo 190-0012
 Tel: +81 (42) 526 7300
 Fax: +81 (42) 526 7301
 info@pi-japan.jp
 www.pi-japan.jp

PI Japan Co., Ltd.
 Hanahara Dai-ni-Building #703
 4-11-27 Nishinakajima,
 Yodogawa-ku, Osaka-shi
 Osaka 532-0011
 Tel: +81 (6) 6304 5605
 Fax: +81 (6) 6304 5606
 info@pi-japan.jp
 www.pi-japan.jp

CHINA

Physik Instrumente (PI Shanghai) Co., Ltd.
 Building No. 7-301
 Longdong Avenue 3000
 201203 Shanghai, China
 Tel: +86 (21) 687 900 08
 Fax: +86 (21) 687 900 98
 info@pi-china.cn
 www.pi-china.cn

UK & IRELAND

PI (Physik Instrumente) Ltd.
 Trent House
 University Way,
 Cranfield Technology Park,
 Cranfield,
 Bedford MK43 0AN
 Tel: +44 (1234) 756 360
 Fax: +44 (1234) 756 369
 uk@pi.ws
 www.physikinstrumente.co.uk

FRANCE

PI France S.A.S.
 244 bis, avenue
 Max Dormoy
 92120 Montrouge
 Tel: +33 (1) 55 22 60 00
 Fax: +33 (1) 41 48 56 62
 info.france@pi.ws
 www.pifrance.fr

ITALY

Physik Instrumente (PI) S.r.l.
 Via G. Marconi, 28
 20091 Bresso (MI)
 Tel: +39 (02) 665 011 01
 Fax: +39 (02) 610 396 56
 info@pionline.it
 www.pionline.it