

Piezo Actuators & Components

For Motion Control, Sensing, Energy Harvesting



Selection Guide: Piezo Actuators & Components

Great Variety: Flexure Guided, Preloaded, Stacks, Tubes, Benders, Shear Actuators

Piezo Actuators Overview

PI piezo actuators are designed to combine ultra-high performance with long lifetime in industrial and scientific applications. PI's piezo ceramic design and manufacturing division, PI Cera-

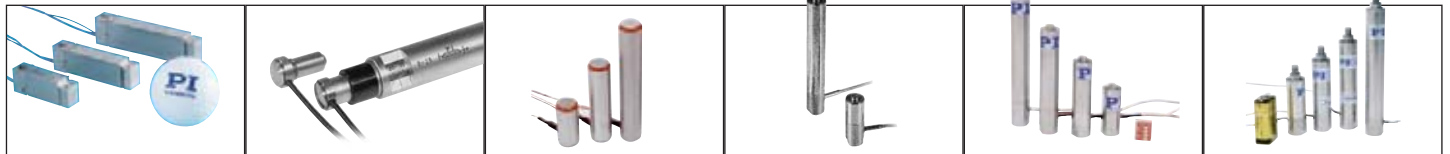
mic, provides the capability and flexibility to offer highly engineered custom sub-assemblies at a very attractive price. The patented PICMA® multilayer long-life piezo actuators with co-fired ceramic insulation provide

more than 10 times higher service life than conventional actuators. Integrated position feedback sensors are available for high linearity applications in closed-loop operation. All linear drives are intended for integra-

tion into a customer's system and feature no guidance. If off-axis motion cannot be tolerated external guidance is required.

Models	Description	Dynamics*	Push/Pull Force [N]	Travel [µm]	Voltage Range	Sensor	Page
P-601	Closed-loop, with flexure guidance	●●○○○	30 / 10	110, 300, 400	-20 to 120	SGS	1-68
P-855.20	Piezo tip for micrometer	●●●●○	100 / 5	20	-20 to 120	-	1-73
P-810-P-830	Only 6 mm diameter, ferromagnetic end pieces	●●●●○ / ●●●●○	50 / 1	15, 30, 45	-20 to 120	-	1-70
P-820	Smallest preloaded piezo translator	●●○○○	50 / 10	15, 30, 45	-20 to 120	-	1-72
P-840, P-841	Preloaded, optional ball tip	●●●●○	1000 / 50	15, 30, 45, 60, 90	-20 to 120	SGS	1-74
P-842, P-843 P-844, P-845	Preloaded, optional ball tip, optional water-proof case	●●●●○	800 / 300, 3000 / 700	15, 30, 45, 60, 90	-20-120	SGS	1-76
P-212, P-216 P-225, P-235	Preloaded, long travel ranges, very high forces	●●●●●	2000 / 300, 4500 / 500	15 to 120, 15 to 180	0 to 1000	SGS	1-78 1-80
PL022, /033, /055	PICMA® Chip. Smallest multilayer piezo actuators, from 2x2x2 mm	●●●●●	to 1000 / 5	3	-20 to 120	-	1-92
P-882-P-888	PICMA® multilayer stacks, ceramic encapsulation, extreme lifetime	●●●●●	to 4000 / 20	5, 9, 15, 30	-20 to 120	-	1-82
P-871	PICMA® multilayer bender actuators, co-fired ceramic encapsulation, low operating voltage, with position sensors	●●●●○	1 / 1	160 to 1600	±30	SGS	1-84
PL112-PL140	PICMA® multilayer bender actuators, co-fired ceramic encapsulation, low operating voltage, open-loop	●●●●○	1 / 1	500, 900, 2000	±30	-	1-94
P-876	DuraAct™ piezoelectric patch transducers: sensor, actuator & electrical charge generation	●●●●○	to 775	-	var.	-	1-96
P-007-P-056 P-010-P-056.xxP	PICA™ Stack piezo actuators, wide variety, high-force capacity.	●●●●●	to 80000 / 300	5 to 300	0 to 1000	Opt.	1-86 1-88
P-010, P-016, P-025.xxH	PICA™ Thru ring actuators combine the advantages of piezo tubes with the high forces of stack actuators	●●●●●	to 60000 / 250	5 to 300	0 to 1000	Opt.	1-90
PT120-PT140	PT-Tube piezo tube actuators, minimum tolerances	●●●●○	0,1 / 0,1	4, 6, 8	0 to 1000	-	1-100
P-111-P-151	PICA™ Shear shear-effect actuator: Compact, X, XY, XYZ, e.g. for scanning-microscopy, optional clear aperture	●●●●●	10 to 300	1 to 10x10x10	±250	-	1-98

*Relative to products in this class



P-601 Closed-loop, flexure guided, long travel

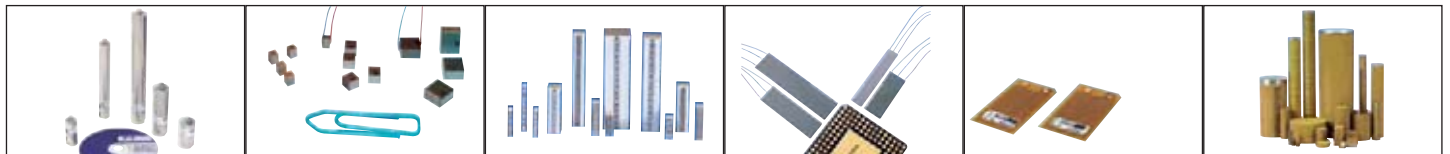
P-855.20 Piezo tip for micrometer

P-810 - P-830 Small (6 mm diam.) actuators

P-820 Smallest preloaded piezo actuators

P-840 - P-841 Preloaded actuators with optional ball tips

P-842 - P-842 Preloaded, opt. water-proof case



P-212, P-216, P-225, P-235 High force, preloaded, long travel

PL022, PL033, PL055 Multilayer miniature chip actuators

P-882 - P-888 Multilayer stacks, extreme lifetime

P-871, PL122-PL144 PICMA® multilayer bender actuators

P-876 Piezoelectric patch transducers

P-007-P-056 Stack piezo actuators. Version xxP for even higher dynamics



P-010.xxH, P-016.xxH, P-025.xxH PT120 PT-Tube piezo tube actuators

P-111 - P-151 Shear-effect actuator: Up to 3 axes, fast

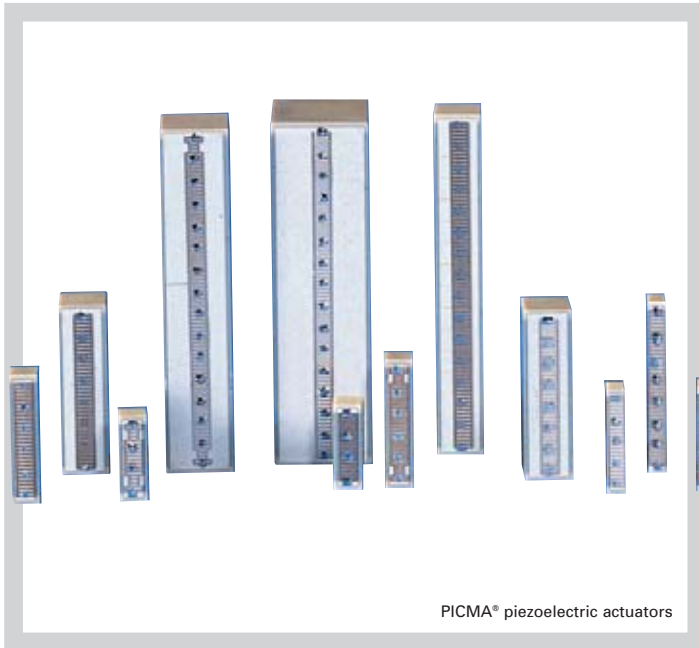
Options and Accessories see p. 1-102 ff

More Piezo Actuators and Piezo Motors: See p. 1-3 ff & 1-23 ff

Please follow the mounting guidelines on p. 1-67

Notes on Specifications see p. 1-106 ff

Piezoelectric Actuators and Components



Advantages of PI Piezoelectric Actuators:

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

Linear Actuators & Motors

PiezoWalk® Motors / Actuators

PILine® Ultrasonic Motors

DC-Servo & Stepper Actuators

Piezo Actuators & Components

Guided / Preloaded Actuators

Unpackaged Stack Actuators

Patches/Benders/Tubes/Shear..

Nanopositioning / Piezoelectrics

Nanometrology

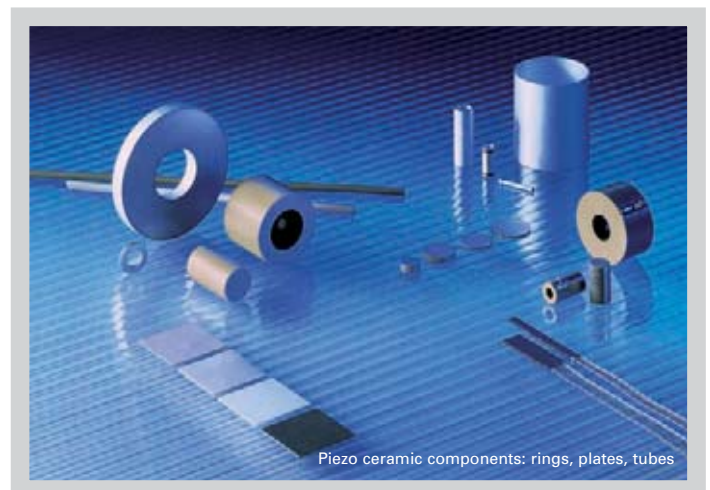
Micropositioning

Index

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



Variety of piezoceramic stacks



Piezoelectric Actuators and Components

Quality and Selection

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

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

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

High-Force Piezo Systems

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



Piezo-Electric All-Rounder—DuraAct™ Patch Transducers

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

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

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



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

Full-Ceramic Encapsulation & Patented Design

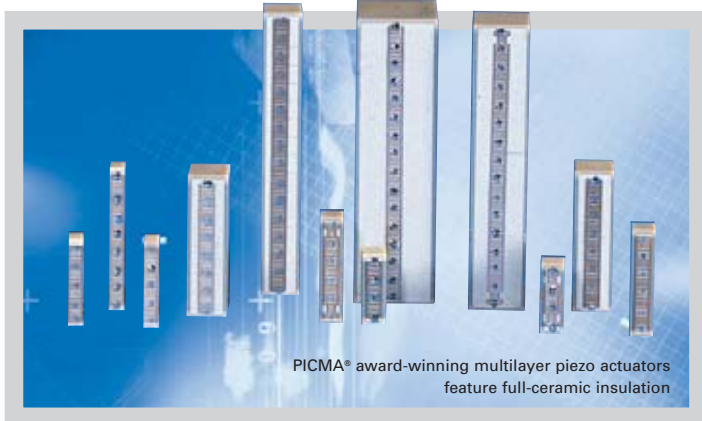
PI has 4 decades of experience with piezo ceramic actuators in motion control applications in industry and research. Currently PI employs more than 100 peo-

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

flexibility and worldwide leadership in piezo matters.

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

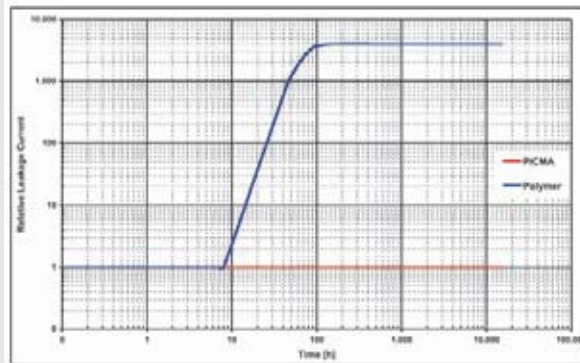
Maximum lifetime means highest possible reliability. PI's award-winning, patented PICMA® actuators are based upon the newest technology which reduces the failure rate by a factor 10 compared to conventionally designed multilayer actuators.



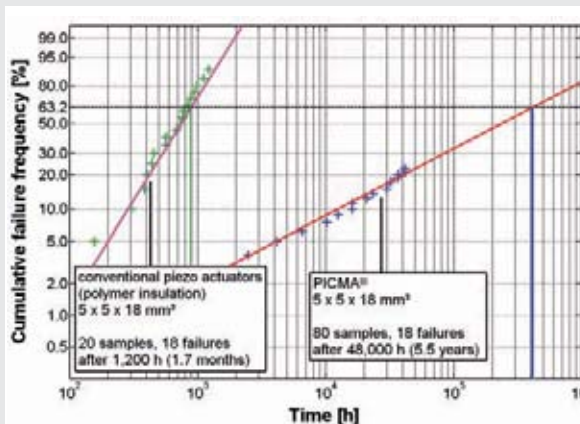
Long Term Tests Prove DC Reliability

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

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



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



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

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Guided / Preloaded Actuators

Unpackaged Stack Actuators

Patches/Benders/Tubes/Shear..

Nanopositioning / Piezoelectrics

Nanometrology

Micropositioning

Index

PICMA® Piezo Actuators

Continuous Dynamic Operation

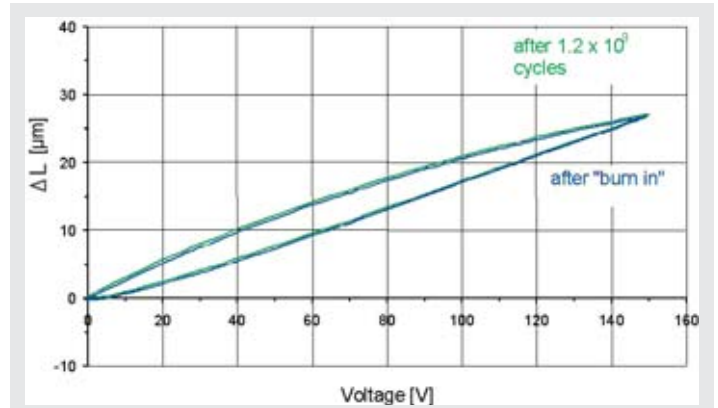
Here, the well-known lifetime-limiting factors of conventional designs are humidity, crack formation inside the ceramic leading to rising leakage currents and delamination of electrodes under extreme dynamic conditions.

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

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

Long-Term Test under Cryogenic Conditions

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



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

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

Large Operating Temperature Range , Optimum UHV Compatibility - Minimum Outgassing

Another advantage of fully ceramic-encapsulation PICMA®

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

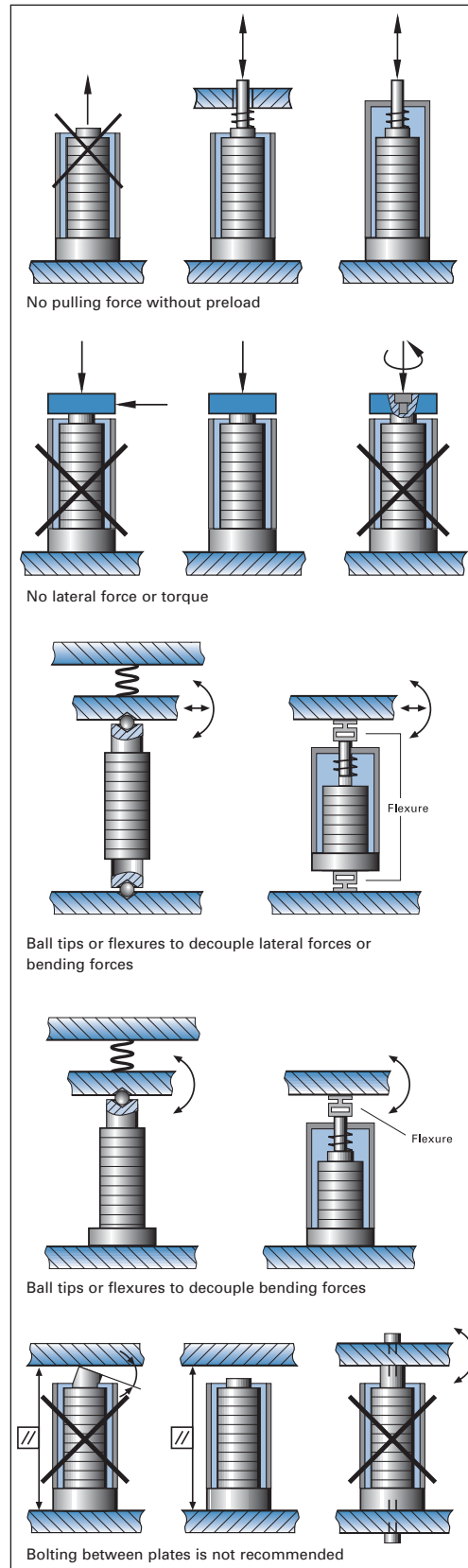
Mounting and Handling Guidelines

Adherence to the following guidelines will help you obtain maximum performance and lifetime from your piezo actuators: Do not use metal tools for actuator handling. Do not scratch the coating on the side surfaces. The following precautions are recommended during handling of piezoelectric actuators:

- I. Piezoelectric stack actuators without axial preload are sensitive to pulling forces. A preload of up to 50% of the blocking force is generally recommended.
- II. Piezoelectric stack actuators may be stressed in the axial direction only. The applied force must be centered very well. Tilting and shearing forces, which can also be induced by parallelism errors of the endplates, have to be avoided because they will damage the actuator. This can be ensured by the use of ball tips, flexible tips, adequate guiding mechanisms etc. An exception to this requirement is made for the PICA™Shear actuators, because they operate in the shear direction.
- III. Piezoelectric stack actuators can be mounted by gluing them between even metal or ceramic surfaces by a cold or hot curing epoxy, respectively. Ground surfaces are preferred. Please, do not exceed the specified working temperature range of the actuator during curing.
- IV. The environment of all actuators should be as dry as possible. PICMA® actuators are guarded against humidity by their ceramic coating. Other actuators must be protected by other measures (hermetic sealing, dry air flow, etc).

The combination of long-term high electric DC fields and high relative humidity values should be avoided with all piezoelectric actuators.

- V. It is important to short-circuit the piezoelectric stack actuators during any handling operation. Temperature changes and load changes will induce charges on the stack electrodes which might result in high electric fields if the leads are not shorted: Should the stack become charged, rapid discharging—especially without a preload—might damage the stack. Use a resistor for discharging.
- VI. Prevent any contamination of the piezo ceramic surfaces with conductive or corrosive substances. Isopropanol is recommended for cleaning. Avoid acetone and excessive ultrasonic cleaning at higher temperatures.



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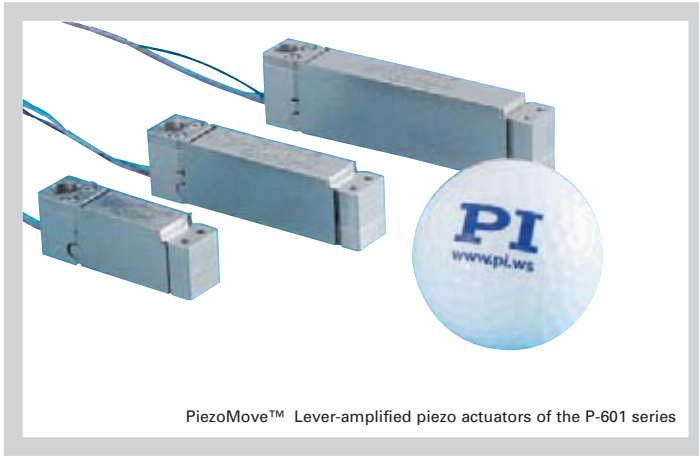
Nanometrology

Micropositioning

Index

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

OEM Actuator with Integrated Guidance

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

Ceramic Insulated Piezo Actuators Provide Long Lifetime

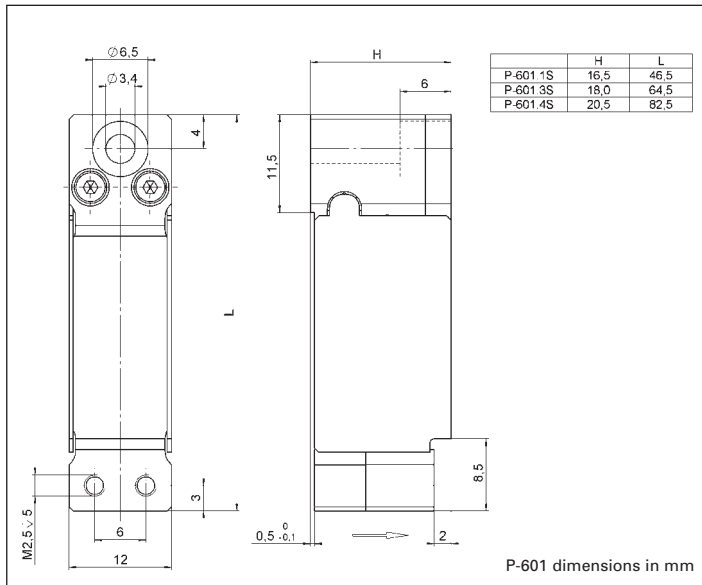
Highest possible reliability is assured by the use of award-winning PICMA® multilayer piezo actuators. PICMA® actuators are the only actuators on the market with ceramic-only insulation, which makes them resistant to ambient humidity and leakage-current failures. They are thus far superior to conventional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

Application Example

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

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



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)

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PLine® Ultrasonic Motors

DC-Servo & Stepper Actuators

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Guided / Preloaded Actuators

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Patches/Benders/Tubes/Shear..

Nanopositioning / Piezoelectrics

Nanometrology

Micropositioning

Index

P-810 • P-830 Piezo Actuators For Light and Medium Loads



P-810 & P-830 piezo actuators

- Outstanding Lifetime Due to PICMA® Piezo Ceramics
- Travel Range to 60 μm
- Pushing Forces to 1000 N
- Pulling Forces to 5 N
- Sub-Millisecond Response
- Sub-Nanometer Resolution

The P-810 and P-830 series translators are high-resolution linear actuators for static and dynamic applications. They provide sub-millisecond response and sub-nanometer resolution.

Application Examples

- Static and dynamic precision positioning
- Fiber positioning
- Laser tuning
- Patch-Clamp
- Nanotechnology

Design

These actuators consist of a highly reliable monolithic multilayer piezoceramic stack protected by a stainless steel case. PI offers a variety of pre-loaded translators for applications involving higher tensile loads (see the "Selection Guide" on p. 1-62).

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

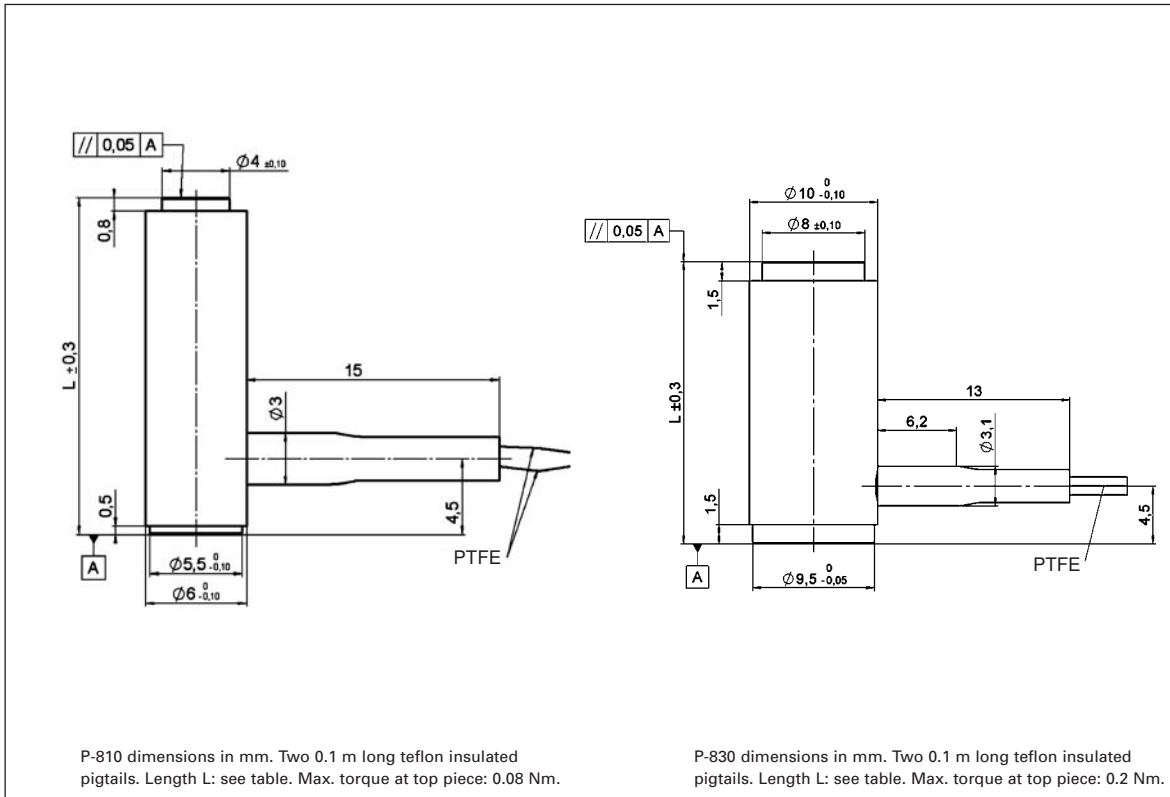
the market with ceramic-only insulation, which makes them resistant to ambient humidity and leakage-current failures. They are thus far superior to conventional actuators in reliability and lifetime.

Mounting

Attachment is realized via the ferromagnetic end surfaces, with epoxy or magnets. Read details in Mounting and Handling Guidelines (p. 1-67). For extensions, adapter cables and connectors, see "Accessories" (p. 1-104 ff).

Piezo Drivers, Controllers & Amplifiers

High-resolution amplifiers and servo-control electronics, both digital and analog, are described in the "Piezo Drivers / Servo Controllers" section (see p. 2-99 ff).


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Piezo Actuators & Components
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Patches/Benders/Tubes/Shear..

Nanopositioning / Piezoelectrics

Nanometrology

Micropositioning

Index

Technical Data and Product Order Numbers

Order number	Travel range for 0 to 100 V [μm] ±20 %	*Resolution [nm]	**Static large-signal stiffness [N/μm] ±20 %	Push- / pull force capacity [N]	Electrical capacitance [μF] ±20 %	Dynamic operating current coefficient [μA / (Hz · μm)]	Resonant frequency (unloaded) [kHz] ±20 %	Mass [g] ±5 %	Length L [mm] ±0.3
P-810.10	15	0.15	14	50 / 1	0.3	3.0	22	4	20
P-810.20	30	0.3	7	50 / 1	0.7	3.0	15	6	38
P-810.30	45	0.45	4	50 / 1	1.0	3.0	12	8	56
P-830.10	15	0.15	57	1000 / 5	1.5	12.5	23	10	22
P-830.20	30	0.3	27	1000 / 5	3.0	12.5	14	16	40
P-830.30	45	0.45	19	1000 / 5	4.5	12.5	10	21	58
P-830.40	60	0.6	15	1000 / 5	6.0	12.5	8.5	27	76

*The resolution of piezo actuators is not limited by stiction or friction. Value given is noise equivalent motion with E-503 amplifier p. 2-144

**Dynamic small-signal stiffness is ~ 30 % higher. Operating temperature range: -20 to 120° C. Case: non-magnetic steel; end pieces: stainless steel. Recommended preload for dynamic operation: 10–20 MPa.

Recommended amplifiers / controllers

One channel: E-831 amplifier (p. 2-164), E-610 amplifier / controller (p. 2-110)

Multi-channel: E-663 amplifier (p. 2-136)

P-820 Preloaded Piezo Actuators

For Light and Medium Loads



- Outstanding Lifetime Due to PICMA® Piezo Actuators
- Travel Range to 45 µm
- Pushing Forces to 50 N
- Pulling Forces to 10 N
- Sub-Millisecond Response
- Sub-Nanometer Resolution
- Optional Ball Tip

The P-820 series piezo translators are high resolution linear actuators for static and dynamic applications. They provide sub-millisecond response and sub-nanometer resolution.

Design

These actuators consist of a friction-free, preloaded monolithic piezo ceramic stack integrated in a stainless steel housing.

Ceramic Insulated Piezo Actuators Provide Long Lifetime

Highest possible reliability is assured by the use of award-

Application Examples

- Static and dynamic precision positioning
- Fiber positioning
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- Nanotechnology

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.

Mounting

Mounting is at the foot, with push/pull forces of less than 3 N, the actuator can be held by clamping the case. The optional ball tip (P-820.95) is intended to decouple torque and off-center forces from the piezo ceramic. The magnetic adapter P-176.30 is to be glued onto the top piece in order to provide magnetic coupling.

Read details in Mounting and Handling Guidelines (p. 1-67).

Factory Installed Options

P-820.95 Ball Tip

Accessories

P-176

Magnetic Adapter (see p. 1-103) For extensions, adapter cables and connectors, see "Accessories" in the piezo electronics chapter (see p. 1-168 ff).

Piezo Drivers, Controllers & Amplifiers

High-resolution amplifiers and servo-control electronics, both digital and analog, are des-

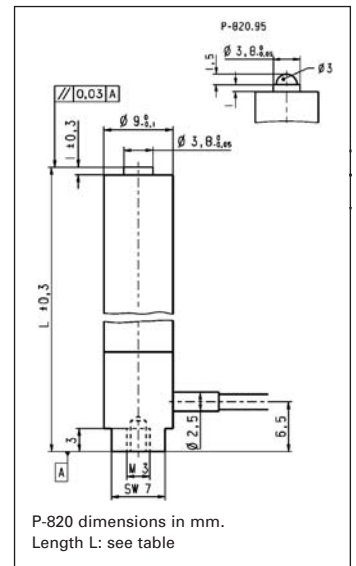
Ordering Information

P-820.10
Preloaded Piezo Actuator, 15 µm Travel range

P-820.20
Preloaded Piezo Actuator, 30 µm Travel range

P-820.30
Preloaded Piezo Actuator, 45 µm Travel range

cribed in the "Piezo Drivers / Servo Controllers" (see p. 2-99 ff) section.



Technical Data

Model	P-820.10	P-820.20	P-820.30	Units
Displacement at 0 to 100 V	15	30	45	µm ±20%
*Resolution	0.15	0.3	0.45	nm
**Static large-signal stiffness	13	7	4	N/µm µm ±20%
Push/pull force capacity	50 / 10	50 / 10	50 / 10	N
Max. torque limit (on tip)	0.08	0.08	0.08	Nm
Electrical capacitance	0.3	0.7	1.0	µF µm ±20%
Dynamic operating current coefficient (DOCC)	3.0	3.0	3.0	µA / (Hz • µm)
Unloaded resonant frequency fo	22	15	12	kHz µm µm ±20%
Operating temperature	-20 to +80	-20 to +80	-20 to +80	°C
Voltage connection	VL	VL	VL	
Mass	8	11	14	g ±5%
Material: case, end pieces	N-S	N-S	N-S	
Length L	26	44	62	mm ±0.3

*The resolution of piezo actuators is not limited by stiction or friction. Value given is noise equivalent motion with E-503 amplifier (p. 2-146)

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

Recommended amplifiers / controllers

One channel: E-610 controller / amplifier (p. 2-110)

Modular system E-500 (p. 2-142) with amplifier module E-503 (multi-channel) (p. 2-146)

Multi-channel: E-663 amplifier (p. 2-136)

P-855 Miniature Piezo Actuator

Micrometer-Mountable Open-Loop Piezo Translator



- Displacement 20 μm
- Mounts Inside Micrometer Tip
- Sub-msec Response
- Sub-nm Resolution

P-855 piezo translators are high-resolution linear actuators specially designed for integration in micrometer tips. They fit the M-227 DC-Mike motorized actuators (see p. 1-42), the M-168 Stepper Mike (see p. 1-55) motorized actuators and the M-631 to M-633 manual micrometers (see p. 1-56).

The piezo translators consist of a monolithic PICMA[®] piezo ceramic integrated in a stainless steel housing.

P-855 actuators provide sub-millisecond response and sub-nanometer resolution.

Application Examples

- Laser tuning
- Static and dynamic positioning of small parts
- Fiber positioning

Superior Lifetime with Ceramic-Encapsulated Piezos

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

Accessories

Extension cables, adapters & connectors: see in "Accessories" in the "Piezo Drivers / Servo Controllers" (see p. 2-168 ff) section.

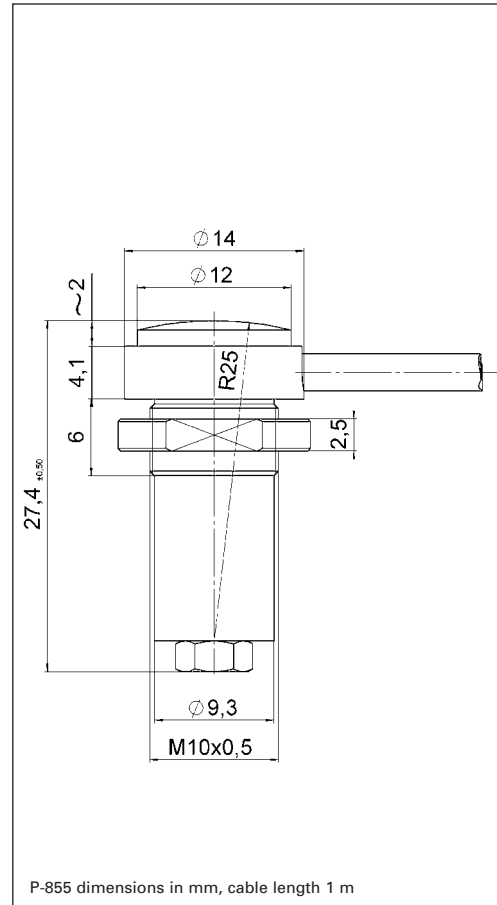
Notes

See the "Piezo Drivers / Servo Controllers" (see p. 2-99 ff) section for our comprehensive line of low-noise modular and OEM control electronics for computer and manual control.

Read details in Mounting and Handling Guidelines (p. 1-67).

Ordering Information

P-855.20
Piezo Actuator for Micrometer Drive



Technical Data

Model	P-855.20	Tolerance
Open-loop travel @ -20 to 120 V	20 μm	$\pm 20\%$
*Open-loop resolution	0.2 nm	
**Static large-signal stiffness	48 N/ μm	$\pm 20\%$
Push / pull force capacity	100 / 5 N	
Operating voltage range	-20 to 120 V	
Piezo ceramic type	PICMA [®]	
Electrical capacitance	1.5 μF	$\pm 20\%$
Dynamic operating current coefficient (DOCC)	12.5 $\mu\text{A}/(\text{Hz} \cdot \mu\text{m})$	
Unloaded resonant frequency	18 kHz	$\pm 20\%$
Operating temperature range	-40 bis +80 $^{\circ}\text{C}$	
Voltage connection	VL	
Mass	28 g	$\pm 5\%$
Recommended amplifier	E-610 (p. 2-110) E-500 System (p. 2-142)	

*Resolution of piezo actuators is not limited by friction or stiction.
Noise equivalent motion with E-505 amplifier
**Dynamic small-signal stiffness ~50% higher

Linear Actuators & Motors

PiezoWalk[®] Motors / Actuators

PLLine[®] Ultrasonic Motors

DC-Servo & Stepper Actuators

Piezo Actuators & Components

Guided / Preloaded Actuators

Unpackaged Stack Actuators

Patches/Benders/Tubes/Shear...

Nanopositioning / Piezoelectrics

Nanometrology

Micropositioning

Index

P-840 • P-841 Preloaded Piezo Actuators

Optional with Integrated Position Sensor



P-840, P-841 piezo translators (DIP switch for size comparison)

- Outstanding Lifetime Due to PICMA® Piezo Ceramic Stacks
- Travel Range to 90 µm
- Compact Case
- Pushing Forces to 1000 N
- Pulling Forces to 50 N
- Sub-Millisecond Response
- Sub-Nanometer Resolution
- Option: Ball Tip, Vacuum Version

The P-840 and P-841 series translators are high-resolution linear actuators for static and dynamic applications. They provide sub-millisecond response and sub-nanometer resolution.

Application Examples

- Static and dynamic Precision positioning
- Disc-drive-testing
- Adaptronics
- Smart structures
- Active vibration control
- Switches
- Laser tuning
- Patch-Clamp
- Nanotechnology

Design

These translators are equipped with highly reliable multilayer piezo ceramic stacks protected by a non-magnetic stainless steel case with internal spring preload. The preload makes them ideal for dynamic applications and for tensile loads as well.

Ceramic Insulated Piezo Actuators Provide Long Lifetime

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

Optimum UHV Compatibility - Minimum Outgassing

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

Mounting

Mounting is at the foot, with push/pull forces of less than 5 N, the actuator can be held by clamping the case. The optional ball tip (P-840.95) is intended to decouple torque and off-center forces from the piezo ceramic. The magnetic adapter P-176.20 is to be glued onto the top piece in order to provide magnetic coupling.

Read details in Mounting and Handling Guidelines (p. 1-67).

High Accuracy in Closed-Loop Operation

The standard model P-840 is designed for open-loop positioning. Version P-841 with integrated high-resolution strain gauge position sensors provides high precision for closed-loop operation (further details see p. 2-199).

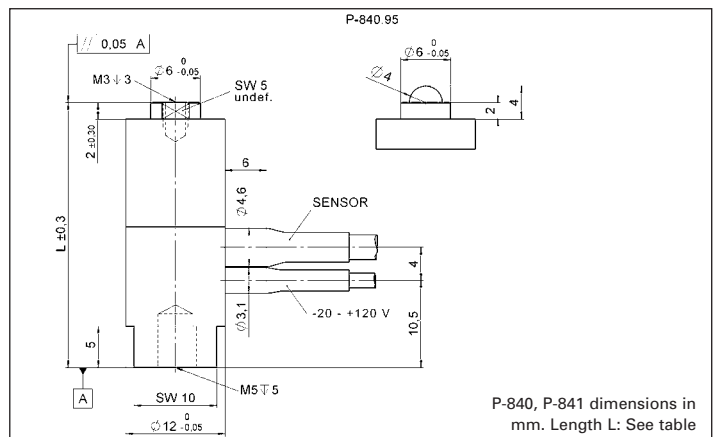
Piezo Drivers, Controllers & Amplifiers

High-resolution amplifiers and servo-control electronics, both

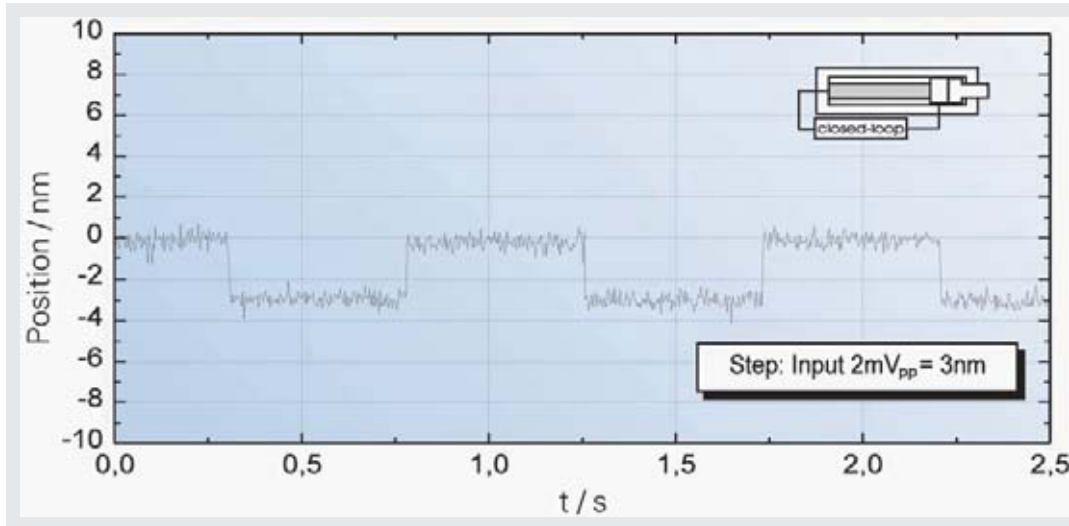
Ordering Information

- P-840.10**
Preloaded Piezo Actuator, 15 µm Travel range
- P-840.20**
Preloaded Piezo Actuator, 30 µm Travel range
- P-840.30**
Preloaded Piezo Actuator, 45 µm Travel range
- P-840.40**
Preloaded Piezo Actuator, 60 µm Travel range
- P-840.60**
Preloaded Piezo Actuator, 90 µm Travel range
- P-841.10**
Preloaded Piezo Actuator with SGS-Sensor, 15 µm Travel range
- P-841.20**
Preloaded Piezo Actuator with SGS-Sensor, 30 µm Travel range
- P-841.30**
Preloaded Piezo Actuator with SGS-Sensor, 45 µm Travel range
- P-841.40**
Preloaded Piezo Actuator with SGS-Sensor, 60 µm Travel range
- P-841.60**
Preloaded Piezo Actuator with SGS-Sensor, 90 µm Travel range

digital and analog, are described in the "Piezo Drivers / Servo Controllers" (see p. 2-99) section.



P-840, P-841 dimensions in mm. Length L: See table



Response of a P-841.10 to a 3 nm peak-to-peak square wave control input signal, measured with servo-control bandwidth set to 240 Hz and 2 msec setting time.

Technical Data

Model	P-841.10 P-840.10	P-841.20 P-840.20	P-841.30 P-840.30	P-841.40 P-840.40	P-841.60 P-840.60	Units
Open-loop travel @ 0 to 100 V	15	30	45	60	90	$\mu\text{m} \pm 20\%$
Closed-loop travel	15 / -	30 / -	45 / -	60 / -	90 / -	μm
Integrated feedback sensor*	SGS / -	SGS / -	SGS / -	SGS / -	SGS / -	
Closed-loop / open-loop resolution**	0.3 / 0.15	0.6 / 0.3	0.9 / 0.45	1.2 / 0.6	1.8 / 0.9	nm
Static large-signal stiffness***	57	27	19	15	10	$\text{N}/\mu\text{m} \pm 20\%$
Pushing forces to 1000 N	1000	1000	1000	1000	1000	N
Pulling forces to 50 N	50	50	50	50	50	N
Max. torque limit (on tip)	0.35	0.35	0.35	0.35	0.35	Nm
Electrical capacitance	1.5	3.0	4.5	6.0	9.0	$\mu\text{F} \pm 20\%$
Dynamic operating current coefficient (DOCC)	12.5	12.5	12.5	12.5	12.5	$\mu\text{A} / (\text{Hz} \cdot \mu\text{m})$
Unloaded resonant frequency f_0	18	14	10	8.5	6	$\text{kHz} \pm 20\%$
Operating temperature	-20 to +80	-20 to +80	-20 to +80	-20 to +80	-20 to +80	$^{\circ}\text{C}$
Voltage connection	LEMO	LEMO	LEMO	LEMO	LEMO	
Sensor connection	LEMO	LEMO	LEMO	LEMO	LEMO	
Mass without cables	20	28	46	54	62	$\text{g} \pm 5\%$
Material: case, end pieces	N-S	N-S	N-S	N-S	N-S	
Length L	32	50	68	86	122	$\text{mm} \pm 0.3$

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

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

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

Recommended amplifiers / controllers

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

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

Multi-channel: modular piezo controller system E-500 (p. 2-142) with amplifier module E-503 (three channels) (p. 2-146) or E-505 (1 per axis, high-power) (p. 2-147) and E-509 controller (p. 2-152) (optional)

Linear Actuators & Motors

PiezoWalk® Motors / Actuators

PLine® Ultrasonic Motors

DC-Servo & Stepper Actuators

Piezo Actuators & Components

Guided / Preloaded Actuators

Unpackaged Stack Actuators

Patches/Benders/Tubes/Shear..

Nanopositioning / Piezoelectrics

Nanometrology

Micropositioning

Index

P-842 – P-845 Preloaded Piezo Actuators

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



P-844 piezo actuators
(battery for size comparison)

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

Design

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

High Accuracy in Closed-Loop Operation

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

Application Examples

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

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

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

Ceramic Insulated Piezo Actuators Provide Long Lifetime

Highest possible reliability is assured by the use of award-winning PICMA® multilayer piezo actuators. PICMA® actuators are the only actuators on

Technical Data and Product Order Numbers

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

the market with ceramic-only insulation, which makes them resistant to ambient humidity and leakage-current failures. They are thus far superior to conventional actuators in reliability and lifetime.

Optimum UHV Compatibility - Minimum Outgassing

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

Mounting

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

Options

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

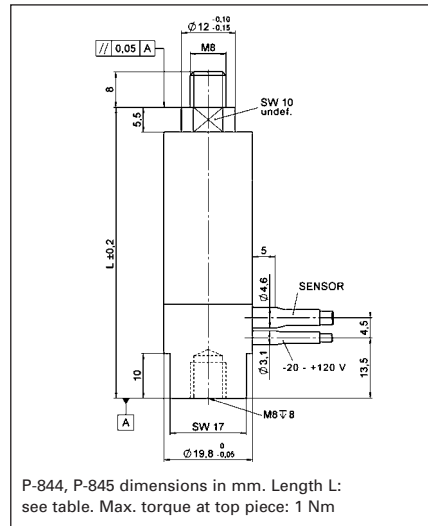
Accessories

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

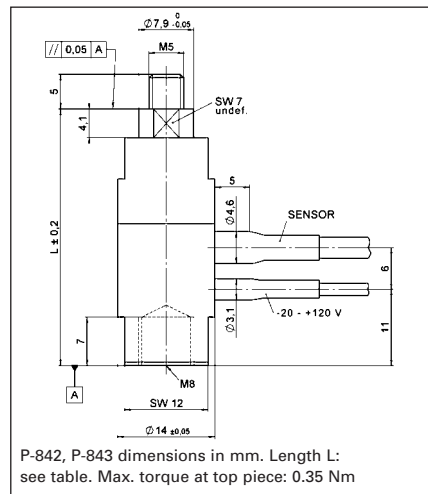
Piezo Drivers, Controllers & Amplifiers

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

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



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



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

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

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

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

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

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

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

Recommended amplifiers / controllers

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

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

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

Multi-channel: modular piezo controller system E-500 (p. 2-142) with amplifier module E-503 (three channels) (p. 2-146) or E-505 (1 per axis, high-power, see p. 2-147) and E-509 controller (p. 2-152) (optional)

Linear Actuators & Motors

PiezoWalk® Motors / Actuators

PILine® Ultrasonic Motors

DC-Servo & Stepper Actuators

Piezo Actuators & Components

Guided / Preloaded Actuators

Unpackaged Stack Actuators

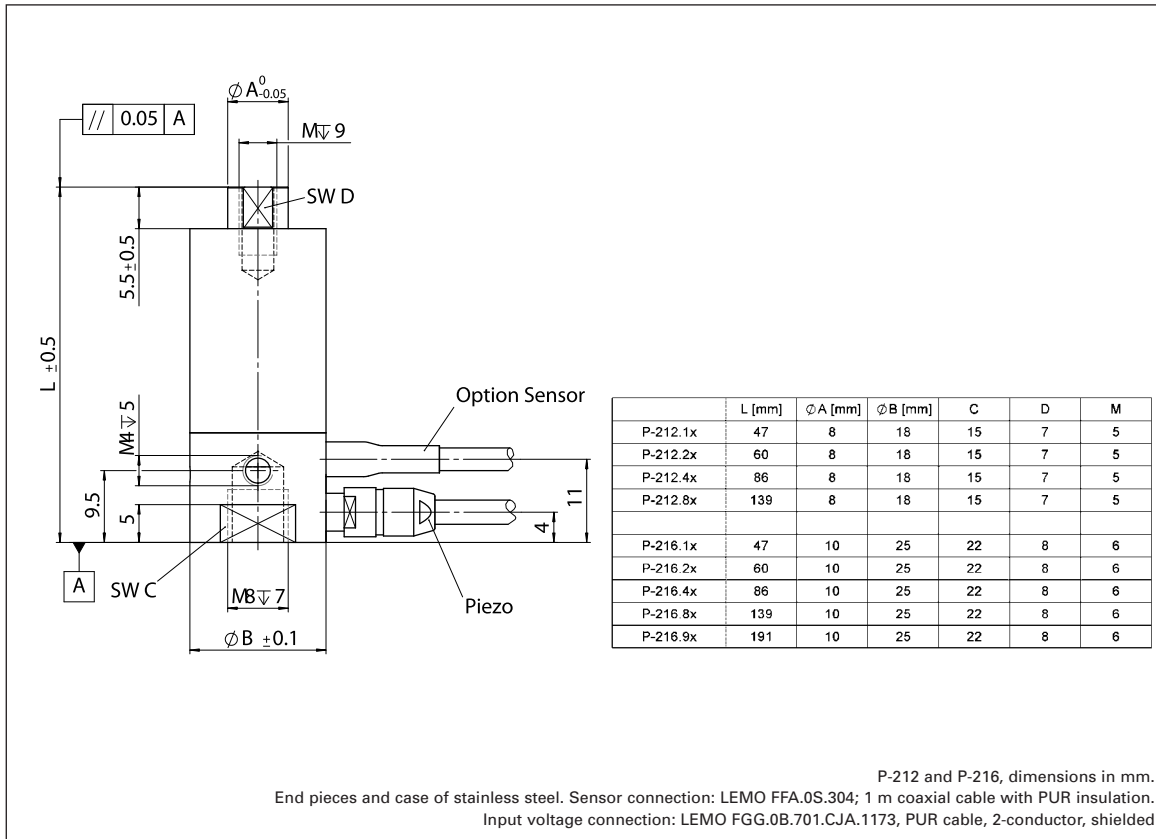
Patches/Benders/Tubes/Shear...

Nanopositioning / Piezoelectrics

Nanometrology

Micropositioning

Index



Linear Actuators & Motors

PiezoWalk® Motors / Actuators

PLine® Ultrasonic Motors

DC-Servo & Stepper Actuators

Piezo Actuators & Components

Guided / Preloaded Actuators

Unpackaged Stack Actuators

Patches/Benders/Tubes/Shear..

Nanopositioning / Piezoelectrics

Nanometrology

Micropositioning

Index

Technical Data

	P-212.10	P-212.20	P-212.40	P-212.80	P-216.10	P-216.20	P-216.40	P-216.80	P-216.90	Unit	Tolerance
Operating voltage	0 to 1000	0 to 1000	0 to 1000	0 to 1000	0 to 1000	0 to 1000	0 to 1000	0 to 1000	0 to 1000	V	
Motion and positioning											
Closed-loop travel*	15	30	60	120	15	30	60	120	180	μm	
Closed-loop resolution*/**	0.3	0.6	1.2	2.4	0.3	0.6	1.2	2.4	3.6	nm	typ.
Open-open resolution**	0.15	0.3	0.6	1.2	0.15	0.3	0.6	1.2	1.8	nm	typ.
Linearity*	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	%	typ.
Mechanical properties											
Static large-signal stiffness***	90	60	34	18	210	140	80	50	32	N/μm	±20%
Unloaded resonant frequency	17	12	7	4.5	17	12	7	4.5	3	kHz	±20%
Push/pull force capacity	2000/300	2000/300	2000/300	2000/300	4500/500	4500/500	4500/500	4500/500	4500/500	N	Max.
Shear force limit	15	10	10	10	60	36	23	23	23	N	
Torque limit (on tip)	0.5	0.5	0.5	0.5	1	1	1	1	1	Nm	
Drive properties											
Electrical capacitance	47	90	180	370	130	250	500	1000	1500	nF	±20%
Dynamic operating current coefficient	5	5	5	5	13	13	13	13	13	μA/(Hz • μm)	±20%
Miscellaneous											
Mass (with cable)	110	120	150	210	170	200	250	370	480	g	±5%

* Requires SGS sensor. SGS versions are shipped with performance reports

** Measured with an Interferometer. The resolution of piezo actuators is not limited by stiction or friction

*** Dynamic small-signal stiffness is ~50% higher

Piezo ceramic type: PICA™ Power

Operating temperature range: -40 to +80 °C

Recommended controller/driver see p. 2-100 ff

For maximum lifetime, voltages in excess of 750 V should be applied only for short durations

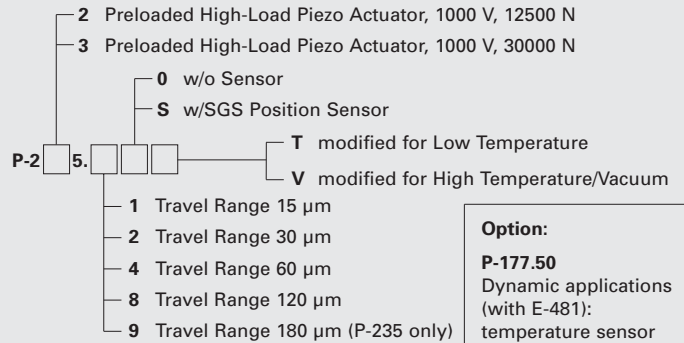
See Notes (Technical Data) for further information (p. 1-106 ff)

P-225, P-235 PICA™ Power Piezo Stack Actuators

Preloaded High-Load Piezo Actuators (HVPZT) w/ Sensor Option



Ordering Information



Please read "Options and Accessories" (page 1-102 ff) for further information.

Extensions cables, adapters & connectors: "Accessories" in the "Piezo Drivers / Servo Controllers" (see p. 2-168 ff) section.

Option:

P-177.50

Dynamic applications (with E-481): temperature sensor and protective air for PICA™ HVPZT

P-706.00

Water-resistant case

- **Extremely High Stiffness**
- **Pushing Forces to 30,000 N**
- **Pulling Forces to 3500 N**
- **Travel Ranges to 180 µm**
- **Options: Versions for Vacuum, High- and Low-Temperatures and with Water-Resistant Case**

P-225 and P-235 are preloaded, high-load piezo actuators (translators) for static and dynamic applications. They provide sub-millisecond re-sponse and sub-nanometer resolution.

These ultra-high-force linear

Application Examples

- Precision engineering / micromechanics
- Adaptive mechanics
- Active vibration damping
- Adaptronics
- Static and dynamic precision positioning
- Force generation / materials testing

actuators consist of PICA™ Power piezoelectric ceramic-stacks encapsulated in a stainless steel case with stainless steel end pieces and a frictionless internal spring preload. The high load capacity and preload makes them ideal for machining applications and active vibration cancellation.

High Displacement with Ultra-High Reliability

PICA™ Power actuators are optimized for high-temperature working conditions and high-duty-cycle dynamic applications.

All PICA™ piezo ceramics are specifically designed for high-duty-cycle applications. With PI's extensive applications knowledge, gained over sever-

al decades, performance does not come at the price of reliability. All materials used are specifically matched for robustness and lifetime. Endurance tests on PICA™ actuators prove consistent performance, even after billions (1,000,000,000) of cycles.

Open- and Closed-Loop Models for Optimum Dynamics and Linearity

The standard models are ideal for open loop positioning applications. In this mode the actuator displacement is roughly proportional to the applied voltage.

Open-loop operation is ideal for applications where the fastest response and the highest bandwidth are essential. Here, commanding and reading the target position in absolute values is either not important or carried out by an external feedback loop.

For highest positioning accuracy and repeatability, select the factory installed closed-loop option with integrated ultra-high-resolution strain gauge position sensors and operate with PI servo-control electronics. For more information, read

the tutorial "Piezoelectrics in Positioning" (see p. 2-169 ff).

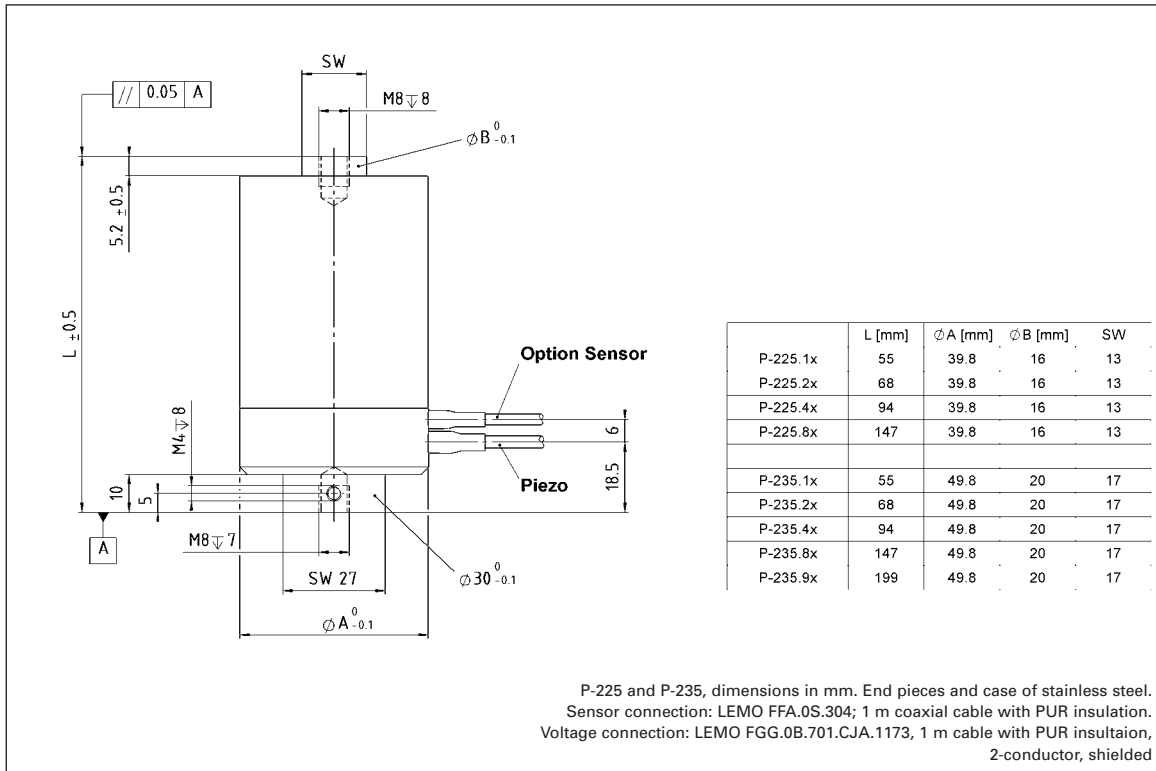
High Flexibility with PI Amplifiers, Drivers & Controllers

PI offers a wide range of control electronics for piezo actuators from economical, low-power piezo drivers to the E-481 high-performance amplifier / controller providing 2000 W of dynamic power.

For closed-loop operation a wide variety of analog and digital controllers is available. The E-500 modular system can be easily upgraded from an amplifier to a servo controller, including different interface / display modules.

Read details in Mounting and Handling Guidelines (p. 1-67).

High-resolution amplifiers and servo-control electronics, both digital and analog, see selection guide in the "Piezo Drivers / Servo Controllers" section (see p. 2-99 ff).



Linear Actuators & Motors

PiezoWalk® Motors / Actuators

PILine® Ultrasonic Motors

DC-Servo & Stepper Actuators

Piezo Actuators & Components

Guided / Preloaded Actuators

Unpackaged Stack Actuators

Patches/Benders/Tubes/Shear..

Nanopositioning / Piezoelectrics

Nanometrology

Micropositioning

Index

Technical Data

Model	P-225.10	P-225.20	P-225.40	P-225.80	P-235.10	P-235.20	P-235.40	P-235.80	P-235.90	Unit	Tolerance
Operating voltage	0 to 1000	0 to 1000	0 to 1000	0 to 1000	0 to 1000	0 to 1000	0 to 1000	0 to 1000	0 to 1000	V	
Motion and positioning											
Closed-loop travel*	15	30	60	120	15	30	60	120	180	µm	
Closed-loop resolution*/**	0.3	0.6	1.2	2.4	0.3	0.6	1.2	2.4	3.6	nm	typ.
Open-loop resolution**	0.15	0.3	0.6	1.2	0.15	0.3	0.6	1.2	1.8	nm	typ.
Linearity*	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	%	typ.
Mechanical properties											
Static large-signal stiffness***	480	330	200	110	860	600	380	210	150	N/µm	±20
Unloaded resonant frequency	14	10	7	4	14	10	7	3,9	2,8	kHz	±20 %
Push/pull force capacity	12500 / 2000	12500 / 2000	12500 / 2000	12500 / 2000	30000 / 3500	30000 / 3500	30000 / 3500	30000 / 3500	30000 / 3500	N	Max.
Shear force limit	255	152	84	73	707	420	232	147	147	N	
Torque limit (on tip)	1,5	1,5	1,5	1,5	2	2	2	2	2	Nm	
Drive properties											
El. capacitance	320	630	1300	2600	550	1100	2400	5100	7800	nF	±20 %
Dynamic operating current coefficient	33	33	33	33	65	65	65	65	65	µA/(Hz • µm)	±20 %
Miscellaneous											
Mass (with cable)	410	470	610	900	580	690	940	1400	1900	g	±5 %

*Requires SGS sensor. SGS versions are shipped with performance reports

**Measured with an interferometer. The resolution of piezo actuators is not limited by stiction or friction

***Dynamic small-signal stiffness is ~50 % higher

Piezo ceramic type: PICA™ Power

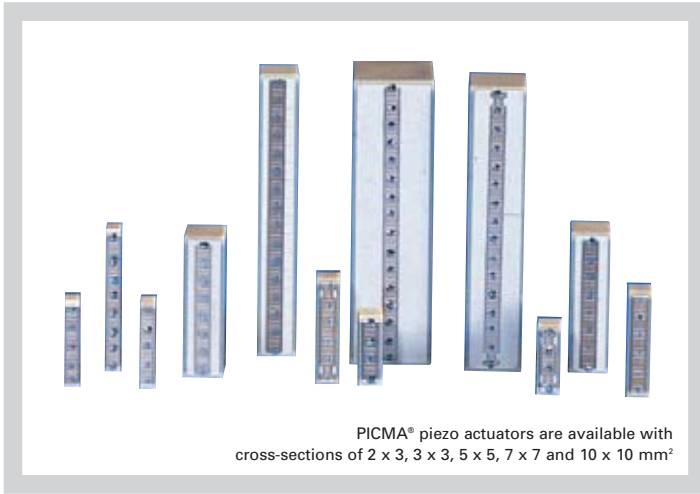
Operating temperature range: -40 to +80 °C

Recommended controller/driver see p. 2-100 ff

For maximum lifetime, voltages in excess of 750 V should be applied only for short durations

See Notes (Technical Data) for further information (see p. 1-106 ff)

P-882 • P-888 PICMA® Multilayer Piezo Stack Actuators Ceramic-Insulated High-Power Actuators



- 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 10⁹ hPa
- Sub-Millisecond Response / Sub-Nanometer Resolution
- Ideal for Dynamic Operation

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

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

New Production Process, Optimized Piezo Ceramics

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

Increased Lifetime Through Humidity Resistance

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

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

Optimum UHV Compatibility - Minimum Outgassing

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



PICMA® actuator with optional 0.1 m PTFE insulated wire leads and optional rounded top piece for decoupling lateral forces

Ideal for Closed-Loop Operation

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

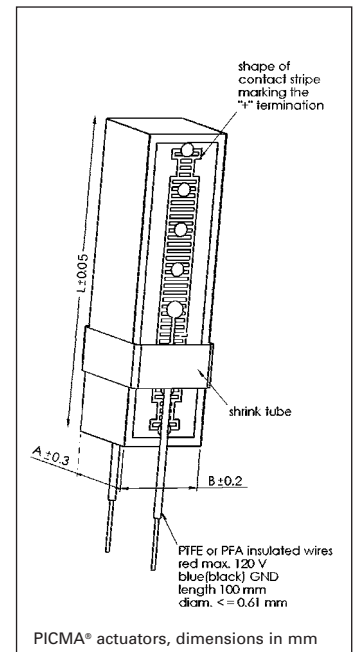
Piezo Drivers, Controllers & High-Voltage Amplifiers

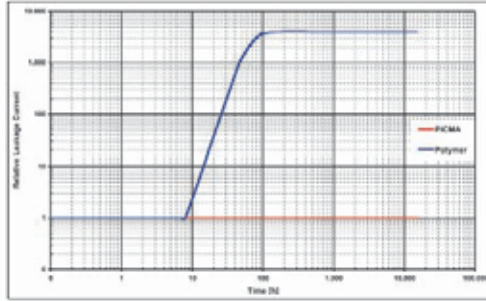
High-resolution amplifiers and servo-control electronics, both digital and analog, are described in the "Piezo Drivers / Servo Controllers" section.

Read more on PICMA® reliability on page 2-12 ff.

Application Examples

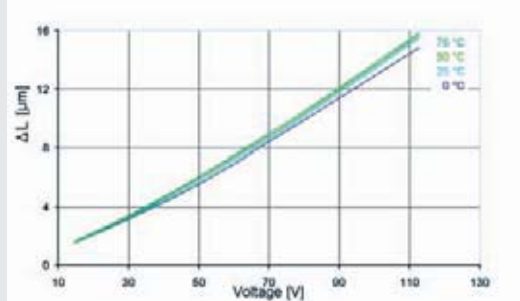
- Precision mechanics / -machining
- High-speed switching
- Active and adaptive Optics
- Active vibration damping
- Pneumatic & hydraulic valves
- Metrology / Interferometry
- Life science, Biotechnology
- Nanotechnology





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

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



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

Linear Actuators & Motors

PiezoWalk® Motors / Actuators

PLine® Ultrasonic Motors

DC-Servo & Stepper Actuators

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Patches/Benders/Tubes/Shear..

Nanopositioning / Piezoelectrics

Nanometrology

Micropositioning

Index

Technical Data / Product Order Numbers

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

Standard piezo ceramic type: 252

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

Recommended preload for dynamic operation: 15 MPa

Maximum preload for constant force: 30 MPa

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

Capacitance at 1 V_{pp}, 1 kHz

Operating voltage: -20 to +120 V

Operating temperature range: -40 to +150 °C

Standard Mechanical Interfaces: Ceramics

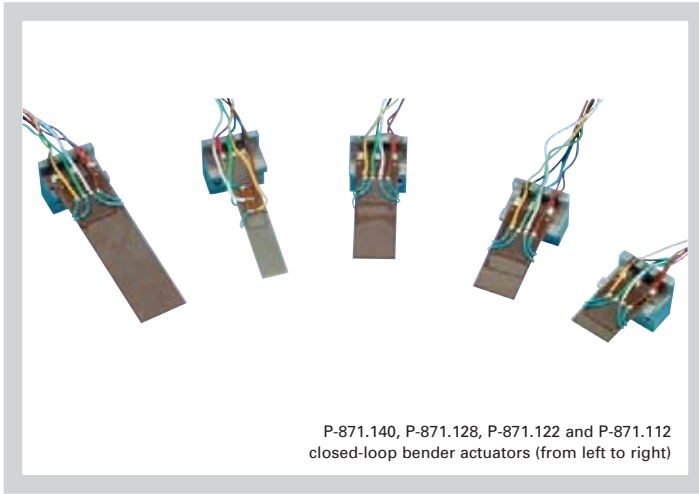
Standard Electrical Interfaces: Solderable pads

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

Other specifications on request.

P-871 PICMA® Piezo Bender Actuators

Low-Voltage Multilayer Piezo Bender Actuators with Position Sensor



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

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

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

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

Design

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

Closed-Loop Position Control for Higher Accuracy

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

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

Ceramic Insulated Piezo Actuators Provide Long Lifetime

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

Optimum UHV Compatibility - Minimum Outgassing

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

Ordering Information

P-871.112
PICMA® Multilayer Piezo Bender Actuator, 160 µm, 9.6 mm Width, SGS-Sensor

P-871.122
PICMA® Multilayer Piezo Bender Actuator, 400 µm, 9.6 mm Width, SGS-Sensor

P-871.127
PICMA® Multilayer Piezo Bender Actuator, 720 µm, 9.6 mm Width, SGS-Sensor

P-871.128
PICMA® Multilayer Piezo Bender Actuator, 720 µm, 6.3 mm Width, SGS-Sensor

P-871.140
PICMA® Multilayer Piezo Bender Actuator, 1600 µm, 11 mm Width, SGS-Sensor

Ask about custom designs

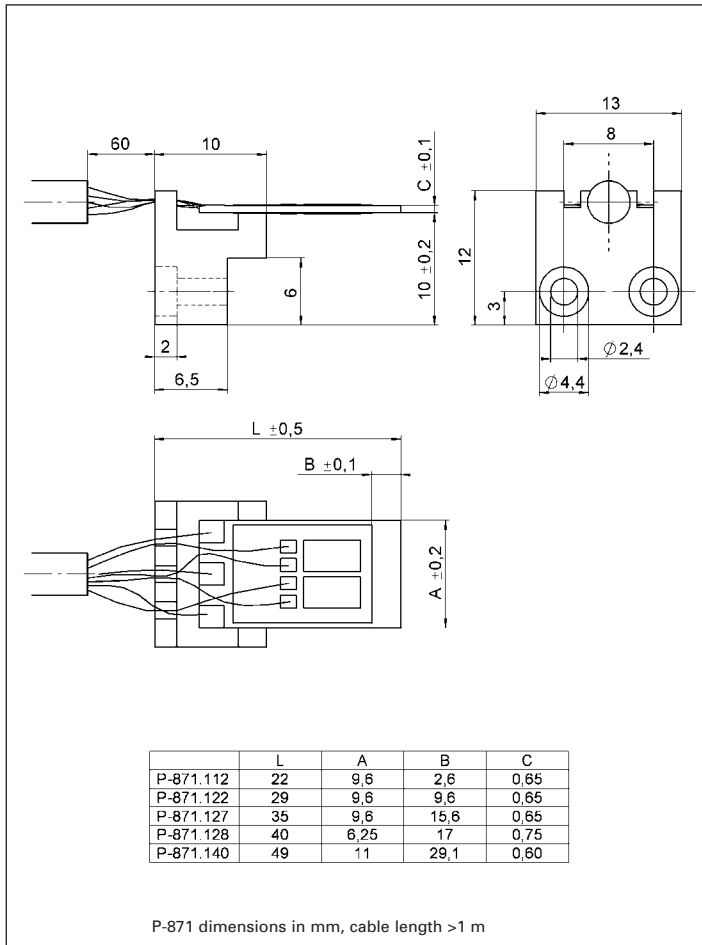
vacuum compatibility (no outgassing / high bakeout temperatures, up to 150 °C).

Amplifiers, Drivers & Controllers

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



E-651 2-channel and 1-channel controllers with P-871 bender actuators



Linear Actuators & Motors

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PLine® Ultrasonic Motors

DC-Servo & Stepper Actuators

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Guided / Preloaded Actuators

Unpackaged Stack Actuators

Patches/Benders/Tubes/Shear..

Nanopositioning / Piezoelectrics

Nanometrology

Micropositioning

Index

Technical Data

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

Operating voltage: 0 to 60 V (±30 V)

Recommended driver / controller: E-651 bench top / E-614 PCI card (p. 2-123)

Connector: 1 LEMO connector for both sensor and voltage supply

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

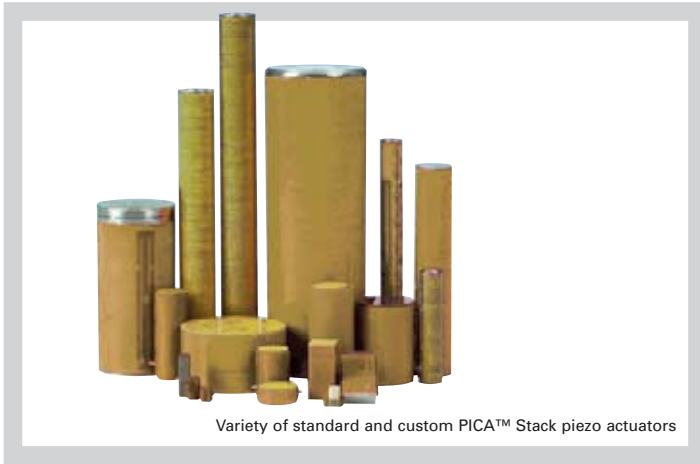
Resonant frequency at 1 V_{pp}, capacitance at 1 V_{pp}, 1 kHz

All specifications depend on the real clamping conditions and on the applied mechanical load.

Other specifications on request.

P-007 – P-056 PICA™ Stack Actuator

Piezo actuator for highly dynamic applications



Variety of standard and custom PICA™ Stack piezo actuators

- High Load Capacity to 100 kN
- High Force Generation to 80 kN
- Large Cross Sections to 56 mm Diameter
- A selection of Variety of Shapes
- Extreme Reliability >10⁹ Cycles
- Sub-Millisecond Response, Sub-Nanometer Resolution
- Vacuum-Compatible Versions

PICA™ Stack piezo ceramic actuators are offered in a large variety of standard shapes and sizes with additional custom designs to suit any application.

Ultra-High Reliability, High Displacement, Low Power Requirements

PICA™ piezo actuators are specifically designed for high-duty-cycle applications. With our extensive applications

Application Examples

- Nanopositioning
- High-load positioning
- Precision mechanics / -machining
- Semiconductor technology / test systems
- Laser tuning
- Switches
- Smart structures (Adaptronics)

knowledge, gained over several decades, we know how to build performance that does not come at the price of reliability. All materials used are specifically matched for robustness and lifetime. Endurance tests on PICA™ actuators prove consistent performance, even after billions (1,000,000,000) of cycles. The combination of high displacement and low electrical capacitance provides for excellent dynamic behavior with reduced driving power requirements.



Standard actuators are covered with heat-shrink tube, shown here is the model P-025.40



Flexibility / Short Leadtimes

All manufacturing processes at PI Ceramic are set up for flexibility. Should our standard actuators not fit your application, let us provide you with a custom design. Our engineers will work with you to find the optimum solution at a very attractive price, even for small quantities. Some of our custom capabilities are listed below:

- Custom Materials
- Custom Voltage Ranges
- Custom Geometries (Circular, Rectangular, Triangular, Layer Thickness ...)
- Custom Load / Force Ranges
- Custom Flat or Spherical Endplates (Alumina, Glass, Sapphire, ...)
- Extra-Tight Length Tolerances
- Integrated Piezoelectric Sensor Discs
- Special High / Low Temperature Versions
- Vacuum Compatible Versions

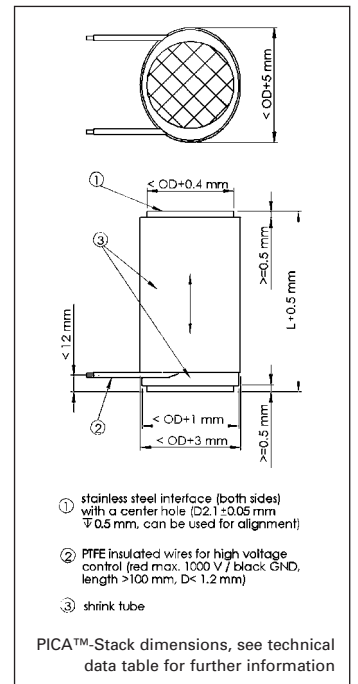
Because all piezoelectric materials used in PICA™ actuators are manufactured at PI Ceramic, leadtimes are short and quality is outstanding. All standard and custom actuators are delivered with performance test sheets.

Piezo Drivers, Controllers & High-Voltage Amplifiers

High-resolution amplifiers and servo-control electronics, both

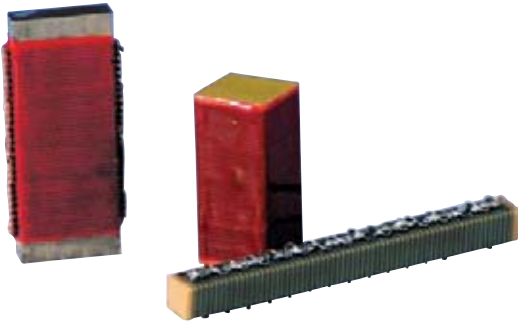


Custom PICA™ Stack actuator with 350 µm displacement

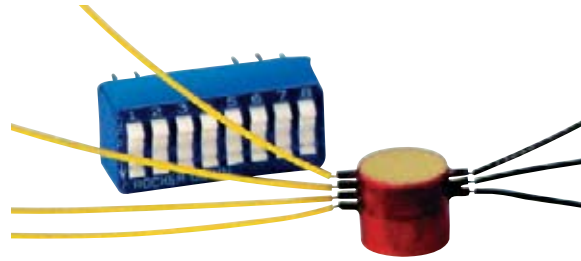


digital and analog, are described in the "Piezo Drivers / Servo Controllers" (see p. 2-99 ff) section.

PICA™ Stack piezo actuators are delivered with metal endcaps for improved robustness and reliability. For preloaded versions with steel casings (see p. 1-78, p. 1-80).



Custom PICA™-Stack actuators with rectangular cross-sections.



Custom PICA™-Stack actuator, each layer wired individually.

Technical Data / Product Order Numbers

Order number	Displacement [μm] -10/+20%	Diameter D [mm]	Length L [mm] ±0.5	Blocking force [N]	Stiffness [N/μm]	Capacitance [nF] ±20%	Resonant frequency [kHz]
P-007.00	5	7	8	650	130	11	126
P-007.10	15	7	17	850	59	33	59
P-007.20	30	7	29	1000	35	64	36
P-007.40	60	7	54	1150	19	130	20
P-010.00	5	10	8	1400	270	21	126
P-010.10	15	10	17	1800	120	64	59
P-010.20	30	10	30	2100	71	130	35
P-010.40	60	10	56	2200	38	260	20
P-010.80	120	10	107	2400	20	510	10
P-016.10	15	16	17	4600	320	180	59
P-016.20	30	16	29	5500	190	340	36
P-016.40	60	16	54	6000	100	680	20
P-016.80	120	16	101	6500	54	1300	11
P-016.90	180	16	150	6500	36	2000	7
P-025.10	15	25	18	11000	740	400	56
P-025.20	30	25	30	13000	440	820	35
P-025.40	60	25	53	15000	250	1700	21
P-025.80	120	25	101	16000	130	3400	11
P-025.90	180	25	149	16000	89	5100	7
P-025.150	250	25	204	16000	65	7100	5
P-025.200	300	25	244	16000	54	8500	5
P-035.10	15	35	20	20000	1300	700	51
P-035.20	30	35	32	24000	810	1600	33
P-035.40	60	35	57	28000	460	3300	19
P-035.80	120	35	104	30000	250	6700	11
P-035.90	180	35	153	31000	170	10000	7
P-045.20	30	45	33	39000	1300	2800	32
P-045.40	60	45	58	44000	740	5700	19
P-045.80	120	45	105	49000	410	11000	10
P-045.90	180	45	154	50000	280	17000	7
P-050.20	30	50	33	48000	1600	3400	32
P-050.40	60	50	58	55000	910	7000	19
P-050.80	120	50	105	60000	500	14000	10
P-050.90	180	50	154	61000	340	22000	7
P-056.20	30	56	33	60000	2000	4300	32
P-056.40	60	56	58	66000	1100	8900	19
P-056.80	120	56	105	76000	630	18000	10
P-056.90	180	56	154	78000	430	27000	7

Standard piezo ceramic type: PIC 151
 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 blocking force at 1000 V
 Operating voltage: 0 to 1000 V
 Operating temperature range: -20 to +85 °C
 Standard mechanical interfaces: steel plates, 0.5 to 2 mm thick (depends on model)
 Standard electrical interfaces: two PTFE-insulated wires, pigtail length 100 mm
 Available options: integrated piezo force sensor or strain gauge sensors, non magnetic, vacuum compatible, etc.
 Other specifications on request.

Linear Actuators & Motors

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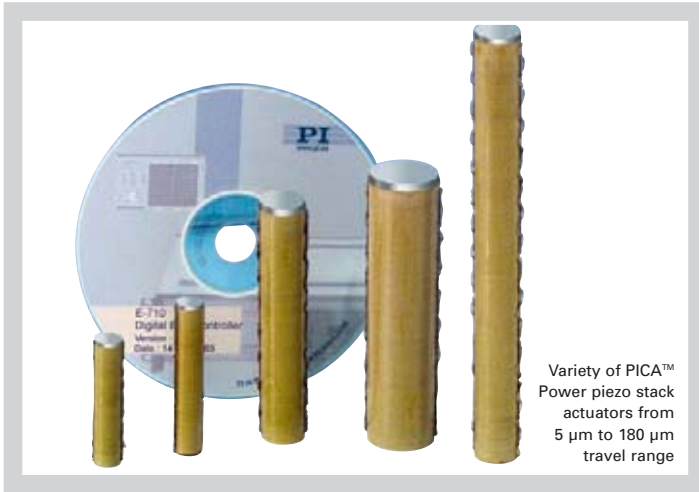
Nanopositioning / Piezoelectrics

Nanometrology

Micropositioning

Index

P-010.xxP – P-056.xxP PICA™ Power Actuator Piezo Stack Actuators for High-Level Dynamic Applications



Variety of PICA™ Power piezo stack actuators from 5 µm to 180 µm travel range

- Operating Temperature to 150 °C
- High Load Capacity to 80 kN
- High Force Generation to 70 kN
- Large Cross Sections to 56 mm Diameter
- Extreme Reliability >10⁹ Cycles
- Sub-Millisecond Response, Sub-Nanometer Resolution
- UHV Versions to 10⁻⁹ hPa
- Non-Magnetic Versions
- Temperature Sensor PT1000 Applied

PICA™ Power piezoceramic stack actuators are offered in a large variety of standard shapes and sizes, with additional custom designs to suit any application. Based on the PIC 255 material, PICA™ Stack

Power actuators are optimized for high-temperature working conditions and high-duty-cycle dynamic applications.

High Displacement with Ultra-High Reliability

PICA™ Power actuators are optimized for high-temperature working conditions and high-duty-cycle dynamic applications.

All PICA™ piezo ceramics are specifically designed for high-duty-cycle applications. With PI's extensive applications knowledge, gained over several decades, performance does not come at the price of reliability. All materials used are specifically matched for robustness and lifetime. Endurance tests on PICA™ actuators prove consistent performance, even after billions (1,000,000,000) of cycles.

Flexibility / Short Leadtimes

All manufacturing processes at PI Ceramic are set up for flexibility. Should our standard actuators not fit your application, let us provide you with a custom design. Our engineers will work with you to find the optimum solution at a very attractive price, even for small quantities. Some of our custom capabilities are listed below:

- Custom Materials
- Custom Voltage Ranges
- Custom Geometries (Circular, Rectangular, Triangular, Layer Thickness ...)
- Custom Load / Force Ranges
- Custom Flat or Spherical Endplates (Alumina, Glass, Sapphire, ...)
- Extra-Tight Length Tolerances
- Integrated Piezoelectric Sensor Discs
- Special High / Low Temperature Versions
- Vacuum Compatible Versions

Because all piezoelectric materials used in PICA™ actuators are manufactured at PI Ceramic, leadtimes are short and

quality is outstanding. All standard and custom actuators are delivered with performance test sheets.

Piezo Drivers, Controllers & High-Voltage Amplifiers

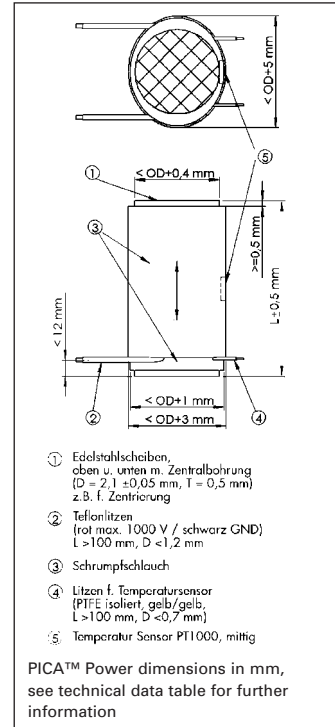
PI offers a wide range of piezo control electronics, from low-power drivers to the ultra-high-performance E-481 power amplifier delivering 2000 W of dynamic power. For closed-loop positioning applications, a variety of analog and digital controllers is also available. The modular E-500 system can be upgraded from an amplifier to a servo-controller and offers a variety of computer interfaces. Of course, PI also designs custom amplifiers and controllers (see p. 2-98 ff).



OEM-PICA™ Power piezo actuators are available with cross sections to 56 mm

Application Examples

- Nanopositioning
- Active vibration damping
- High-load positioning
- Precision mechanics / -machining
- Semiconductor technology / test systems
- Laser tuning
- Switches
- Smart structures (Adaptronics)
- Nanotechnology



Technical Data / Product Order Numbers

Order number	Displacement [μm] -10/+20%	Diameter D [mm]	Length L [mm] ±0.5	Blocking force [N]	Stiffness [N/μm]	Capacitance [nF] ±20%	Resonant frequency [kHz]
P-010.00P	5	10	9	1200	240	17	129
P-010.10P	15	10	18	1800	120	46	64
P-010.20P	30	10	31	2100	68	90	37
P-010.40P	60	10	58	2200	37	180	20
P-010.80P	120	10	111	2300	19	370	10
P-016.10P	15	16	18	4500	300	130	64
P-016.20P	30	16	31	5400	180	250	37
P-016.40P	60	16	58	5600	94	510	20
P-016.80P	120	16	111	5900	49	1000	10
P-016.90P	180	16	163	6000	33	1600	7
P-025.10P	15	25	20	9900	660	320	58
P-025.20P	30	25	33	12000	400	630	35
P-025.40P	60	25	60	13000	220	1300	19
P-025.80P	120	25	113	14000	120	2600	10
P-025.90P	180	25	165	14000	80	4000	7
P-035.10P	15	35	21	18000	1200	530	55
P-035.20P	30	35	34	23000	760	1200	34
P-035.40P	60	35	61	26000	430	2500	19
P-035.80P	120	35	114	28000	230	5200	10
P-035.90P	180	35	166	29000	160	7800	7
P-045.20P	30	45	36	36000	1200	2100	32
P-045.40P	60	45	63	41000	680	4300	18
P-045.80P	120	45	116	44000	370	8800	10
P-045.90P	180	45	169	45000	250	13000	7
P-056.20P	30	56	36	54000	1800	3300	32
P-056.40P	60	56	63	66000	1100	6700	18
P-056.80P	120	56	116	68000	570	14000	10
P-056.90P	180	56	169	70000	390	21000	7

Standard piezo ceramic type: PIC 255
 Recommended preload for dynamic operation: 15 MPa
 Maximum preload for constant force: 30 MPa
 Resonant frequency at 1 V_{ppr} unloaded. The value is halved for unilateral clamping
 Capacitance at 1 V_{ppr}, 1 kHz blocking force at 1000 V
 Operating voltage: 0 to 1000 V
 Operating temperature range: -20 to +150 °C
 Standard mechanical interfaces: steel plates, 0.5 to 2 mm thick (depends on model)
 Standard electrical interfaces: two PTFE-insulated wires, pigtail length 100 mm
 Available options: integrated piezo sensor or strain gauge sensors, non magnetic, vacuum compatible, etc.
 Other specifications on request.

Linear Actuators & Motors

PiezoWalk® Motors / Actuators

PLine® Ultrasonic Motors

DC-Servo & Stepper Actuators

Piezo Actuators & Components

Guided / Preloaded Actuators

Unpackaged Stack Actuators

Patches/Benders/Tubes/Shear..

Nanopositioning / Piezoelectrics

Nanometrology

Micropositioning

Index

P-010.xxH – P-025.xxH PICA™ Thru Actuator High-Load Piezo Stack Actuators with Aperture



PICA™ Thru piezo stack actuators with clear aperture

- Clear Aperture for Transmitted-Light Applications for Mechanical Preloading
- Extreme Reliability >10⁹ Cycles
- Large Cross Sections to 56 mm Diameter
- Variety of Shapes
- Sub-Millisecond Response, Sub-Nanometer Resolution
- Vacuum-Compatible Versions

PICA™ Thru actuators are hollow piezo stack actuators, offered in a large variety of standard shapes and sizes with additional custom designs to meet all customer requirements. They combine the advantage of a clear aperture with the strength and force generation of stack actuators. These tubular devices are high-resolution linear actuators for static and dynamic applications. The clear aperture facilitates transmitted-light applications.

Furthermore the electrical consumption is reduced due to the decreased electrical capacitance.

Ultra-High Reliability, High Displacement, Low Power Requirements

PICA™ piezo actuators are specifically designed for high-duty-cycle applications. With our extensive applications knowledge, gained over several decades, we know how to build performance that does not come at the price of reliability. All materials used are specifically matched for robustness and lifetime. Endurance tests on PICA™ actuators prove consistent performance, even after billions (1,000,000,000) of cycles. The combination of high displacement and low electrical capacitance provides for excellent dynamic behavior with re-

duced driving power requirements.

Flexibility / Short Leadtimes

All manufacturing processes at PI Ceramic are set up for flexibility. Should our standard actuators not fit your application, let us provide you with a custom design. Our engineers will work with you to find the optimum solution at a very attractive price, even for small quantities. Some of our custom capabilities are listed below:

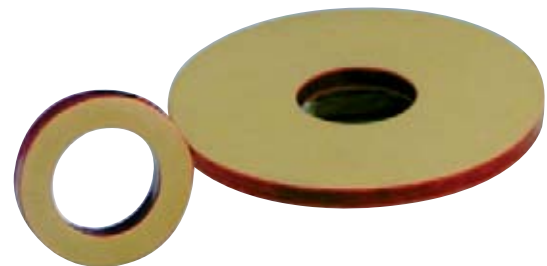
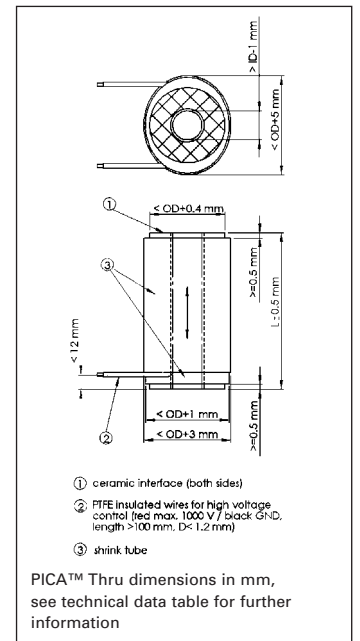
- Custom Materials
- Custom Voltage Ranges
- Custom Geometries (Circular, Rectangular, Triangular, Layer Thickness ...)
- Custom Load / Force Ranges
- Custom Flat or Spherical Endplates (Alumina, Glass, Sapphire, ...)
- Extra-Tight Length Tolerances
- Integrated Piezoelectric Sensor Discs
- Special High / Low Temperature Versions
- Vacuum Compatible Versions

Because all piezoelectric materials used in PICA™ actuators are manufactured at PI Ceram-

ic, leadtimes are short and quality is outstanding. All standard and custom actuators are delivered with performance test sheets.

Piezo Drivers, Controllers & High-Voltage Amplifiers

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



Customized PICA™ Thru actuator discs

Application Examples

- Optics
- Image stabilization
- Laser tuning
- Laser treatment
- Precision mechanics / -machining
- Confocal microscopy
- Nanopositioning



Custom PICA™ Thru piezo actuator with 56 mm outside diameter, 8 mm inner diameter, 250 μm displacement. Pen for size comparison

Technical Data / Product Order Numbers

Order numbers	Displacement [μm] -10/+20 %	Diameter OD [mm]	Diameter ID [mm]	Length L [mm] ± 0.5	Blocking force [N]	Stiffness [N/ μm]	Capacitance [nF] ± 20 %	Resonant frequency [kHz]
P-010.00H	5	10	5	7	1200	230	15	144
P-010.05H	10	10	5	12	1300	130	29	84
P-010.10H	15	10	5	15	1700	110	40	67
P-010.15H	20	10	5	21	1500	76	59	48
P-010.20H	30	10	5	27	1800	59	82	39
P-010.30H	40	10	5	40	1600	40	120	28
P-010.40H	60	10	5	54	1800	29	180	21
P-016.00H	5	16	8	7	2900	580	42	144
P-016.05H	10	16	8	12	3400	340	83	84
P-016.10H	15	16	8	15	4100	270	120	67
P-016.15H	20	16	8	21	3800	190	170	48
P-016.20H	30	16	8	27	4500	150	230	39
P-016.30H	40	16	8	40	4000	100	340	28
P-016.40H	60	16	8	52	4700	78	490	21
P-025.10H	15	25	16	16	7400	490	220	63
P-025.20H	30	25	16	27	8700	290	430	39
P-025.40H	60	25	16	51	9000	150	920	22
P-025.50H	80	25	16	66	9600	120	1200	17

Piezo ceramic type PIC 151
 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
 Blocking force at 1000 V
 Operating voltage range: 0 to 1000 V
 Operating temperature range: -20 to +85 °C
 Standard mechanical interface (top & bottom): ceramic, 0.5–2 mm thick (depends on model)
 Standard electrical interface: two PTFE-insulated wires, pigtail length 100 mm
 Available options: integrated force piezo sensor or strain gauge sensors, non-magnetic, vacuum compatible, etc.
 Ask about custom designs and further specifications.

Linear Actuators & Motors

PiezoWalk® Motors / Actuators

PLLine® Ultrasonic Motors

DC-Servo & Stepper Actuators

Piezo Actuators & Components

Guided / Preloaded Actuators

Unpackaged Stack Actuators

Patches/Benders/Tubes/Shear..

Nanopositioning / Piezoelectrics

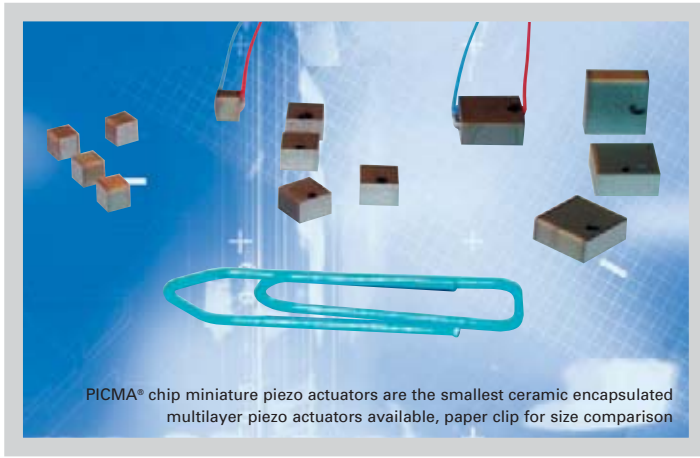
Nanometrology

Micropositioning

Index

PL022 · PL033 · PL055 PICMA® Chip Actuators

Miniature Multilayer Piezo Stack Actuators



PICMA® chip miniature piezo actuators are the smallest ceramic encapsulated multilayer piezo actuators available, paper clip for size comparison

- Superior Lifetime Even Under Extreme Conditions
- Ultra-Compact: from 2 x 2 x 2 mm
- Ideal for Dynamic Operation
- Sub-Millisecond Response
- Sub-Nanometer Resolution
- Vacuum Compatible to 10⁹ hPa
- High Humidity Resistance

Smallest Dimensions – High Performance

PICMA® Chip actuators sized from 2 x 2 x 2 mm are the smallest monolithic multilayer piezo stack actuators available. Providing sub-nanometer resolution and sub-millisecond response, they are ideally suited to high-level dynamic applications.

New Production Process, Optimized Piezo Ceramics

PICMA® actuators are made from a ceramic material in which the piezoceramic prop-

Application Examples

- Static and dynamic precision positioning
- Laser tuning
- Micro-dispensing
- Metrology / Interferometry
- Life science, Biotechnology
- Photonics

erties such as stiffness, capacitance, displacement, temperature stability and lifetime are optimally combined. Thus the actuators accomplish sub-nanometer resolution in positioning and sub-millisecond response!

Increased Lifetime Through Humidity Resistance

The monolithic ceramic-encapsulated design provides better humidity protection than 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 highly dynamic applications with small loads; depending on the load an external preload for dynamic applications is recommended. The high Curie temperature of 320 °C gives PICMA® actuators a usable temperature range extending up to 150 °C, far beyond 80 °C as is common for

conventional multilayer actuators. With conventional multilayer actuators, heat generation – which is proportional to operating frequency – either limits the operating frequency or duty cycle in dynamic operation, or makes ungainly cooling provisions necessary. At the low end, operation down to a few Kelvin is possible (with reduction in performance specifications).

Optimum UHV Compatibility – Minimum Outgassing

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

Piezo Drivers, Controllers & High-Voltage Amplifiers

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

Technical Data / Product Order Numbers

Order number*	Dimensions A x B x TH in mm	Nominal displacement [µm @ 100 V] ±20 %	Blocking force [N]	Electrical capacitance [nF] ±20 %	Resonant frequency [kHz]
PL022.30	2 x 2 x 2	2.2	>120	25	>300
PL033.30	3 x 3 x 2	2.2	>300	50	>300
PL055.30	5 x 5 x 2	2.2	>500	250	>300

* For optional PTFE insulated wire leads change order number extension to .x1 (e.g. PL022.31)

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: -20 to +100 V

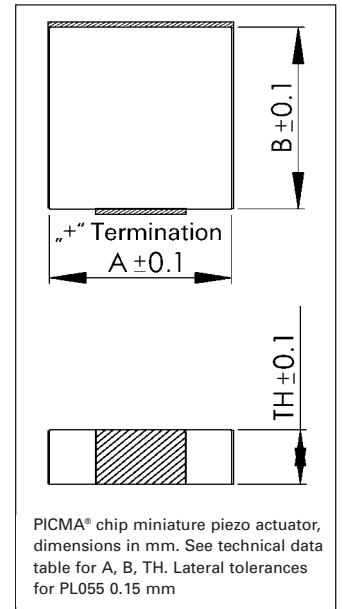
Operating temperature range: 150 °C

Standard electrical interfaces: Solderable pads

Other specifications on request.

Recommended preload for dynamic operation: 15 MPa

Maximum preload for constant force: 30 MPa



Piezoelectric Actuators & Components from PI Ceramic—Leading in Piezo Technology

PI Ceramic—a PI Subsidiary—is a long-standing, world-class supplier of high-performance piezoelectric actuator and transducer components and subassemblies. The award-winning PICMA® actuator technology is a result of PI Ceramic's research and development, and innovative drive solutions such as PLine® ultrasonic ceramic motors and NEXLINE® high-force ceramic motors are based on piezoelectric actuators from PIC.

PI Ceramic provides a wide range of standard piezoelectric actuator components and develops and produces all piezo ceramic drive systems employed in PI's precision positioning systems. Apart from the standard types a multitude of application-specific and custom-engineered modifications can be delivered.

Piezoceramic Materials & Components

Variety of materials:

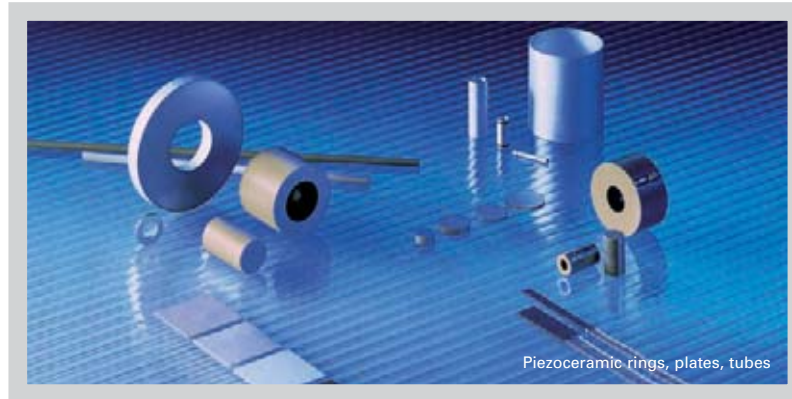
- lead zirconate titanate (PZT); barium titanate

Variety of shapes:

- discs (rod, block, custom design)
- rings, tubes
- shear elements (plates, rings)

Custom electrodes (material, shape)

Patch transducers, piezo composite materials



Linear Actuators & Motors

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Guided / Preloaded Actuators

Unpackaged Stack Actuators

Patches/Benders/Tubes/Shear..

Nanopositioning / Piezoelectrics

Nanometrology

Micropositioning

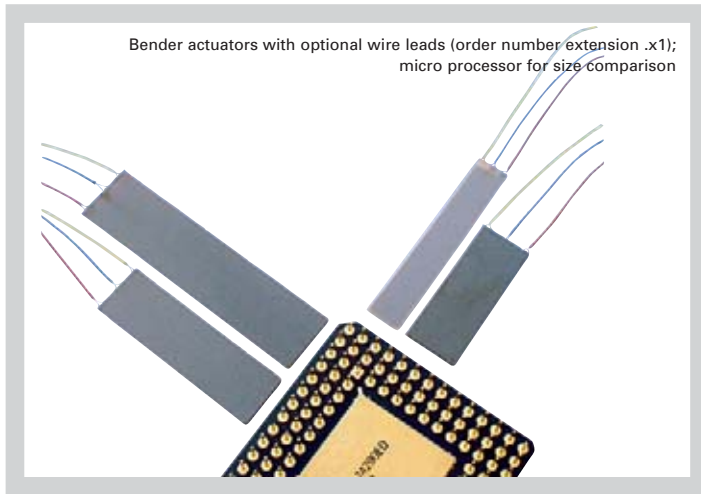
Index

For more information on piezoceramic materials and components, see the PI Ceramic catalogs and Website (www.piceramic.de).



PL112 · PL140 PICMA® Bender Actuators

Multilayer Piezo Bender Actuators with High Travel and Low Operating Voltage



- **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.

Application Examples

- Wire bonding
- Pneumatic valves
- Fiber optic switches
- (Laser)-Beam steering
- Micropositioning
- Acceleration sensors

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 highly dynamic applications with small loads; depending on the load an external preload for dynamic applications is recommended. The high Curie temperature of 320 °C gives PICMA® actuators a usable temperature range extending up to 150 °C, far beyond 80 °C as is common for conventional multilayer actuators. With conventional multilayer actuators, heat generation – which is proportional to operating frequency – either limits the operating frequency or duty cycle in dynamic operation, or makes ungainly cooling provisions necessary. At the low end, operation down to a few Kelvin is possible (with reduction in performance specifications).

Optimum UHV Compatibility – Minimum Outgassing

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

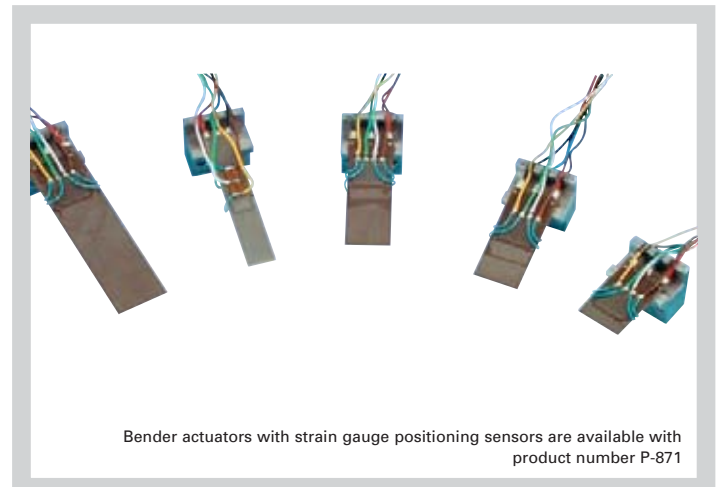
Closed-Loop Version

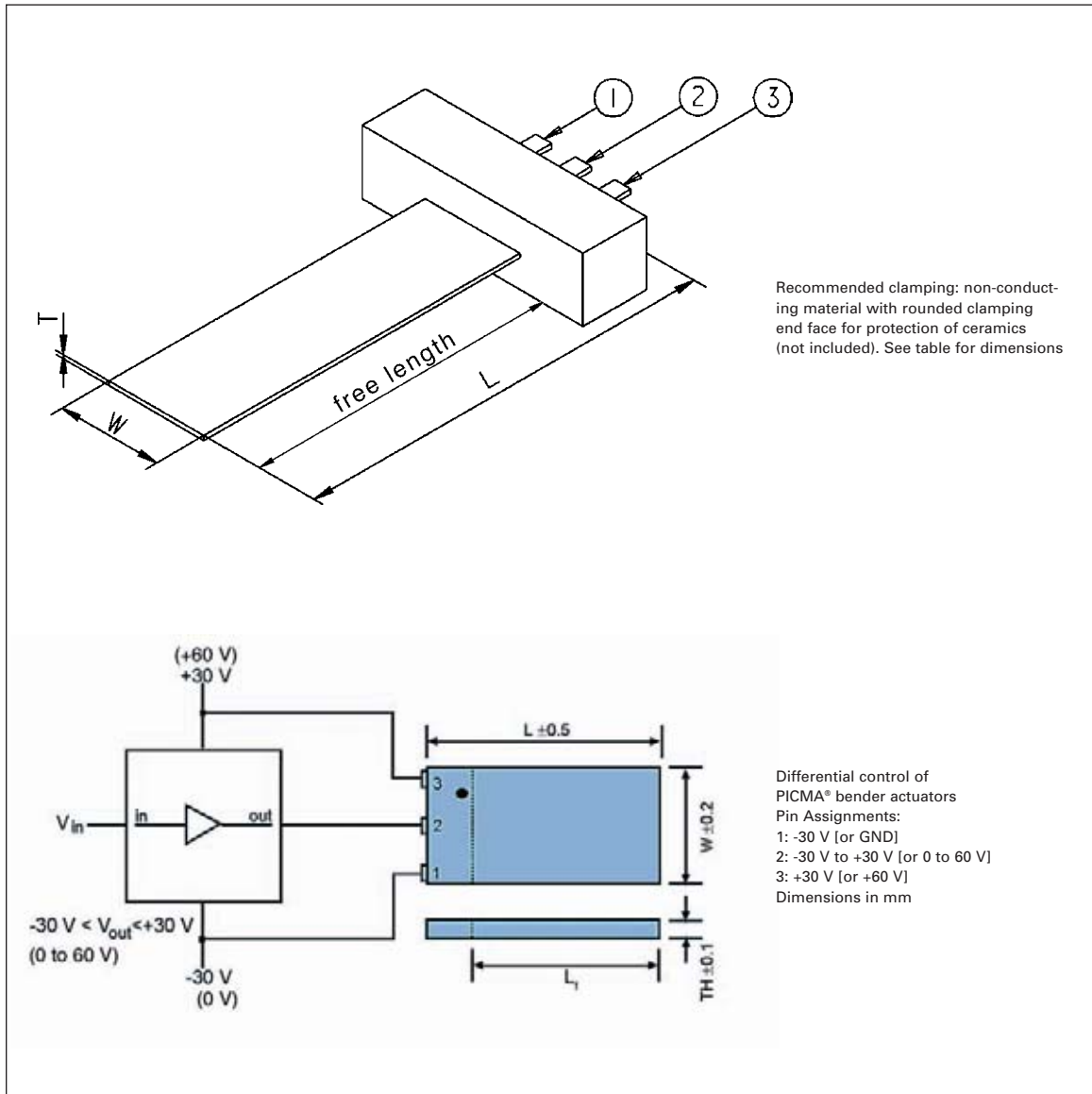
For closed-loop positioning the versions P-871 with integrated strain gauge sensors are available (see p. 1-84).

Drivers and Controllers

PI offers a wide selection of low noise amplifiers and controllers for piezo actuators (see section „Piezo Electronics“). Customized piezo electronics are developed on request.

The E-650.00 and E-650.0E piezo amplifiers (see p. 2-122) are especially designed for operating the PICMA® bender actuators.





Linear Actuators & Motors

PiezoWalk® Motors / Actuators

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DC-Servo & Stepper Actuators

Piezo Actuators & Components

Guided / Preloaded Actuators

Unpackaged stack Actuators

Patches/Benders/Tubes/Shear..

Nanopositioning / Piezoelectrics

Nanometrology

Micropositioning

Index

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-876 DuraAct™ Piezoelectric Patch Transducers



P-876.A12 and .A15 actuators. Golf ball for size comparison

- Actuator, Sensor or Energy Source
- Highly Formable Ceramics
- Can be Applied to Curved Surfaces
- Customized Solutions on Request
- Cost-Effective

P-876 DuraAct™ patch transducers offer the functionality of piezoceramic materials as sensors and actuators as well as for electrical charge generation and storage. Used as bender actuators, they allow high deflections of up to 0.8 mm with high force and high precision. Other possible operation modes of DuraAct™ transducers are as high-dynamics sensors (e.g. for structural health monitoring) or for energy harvesting.

Integration into Adaptive Systems

With their compact design, DuraAct™ transducers can be applied to structure areas where deformations are to be generated or detected. For this purpose the transducers can be affixed to the surfaces of structures or integrated as structural elements themselves. Whole areas can be monitored effectively by applying an array of several modules to a surface.

DuraAct™ patch transducers are ideally suited for active and adaptive systems. Embedded in a servo-control loop, they can reduce vibrations and control structures in the nanometer range.

Robust and Cost-Effective Design for Industrial Applications

The laminated design with piezoceramic plate and polymers provide a mechanically preloaded and electrically insulated device for easy handling. P-876 patch transducers feature

a rugged design with the mechanical stability of a structural material.

Energy Harvesting: Self-Sustaining Systems in a Small Package

One possible application of DuraAct™ patch transducers is in the field of energy harvesting. Transformation of mechanical vibrations of up to some kilohertz into the corresponding potential difference can yield electrical power in the milliwatt range. This power can supply miniature electronic devices like diodes, sensors or even radio transmitters for remote data control.

DuraAct™ transducers can be offered in highly customized versions:

Ordering Information

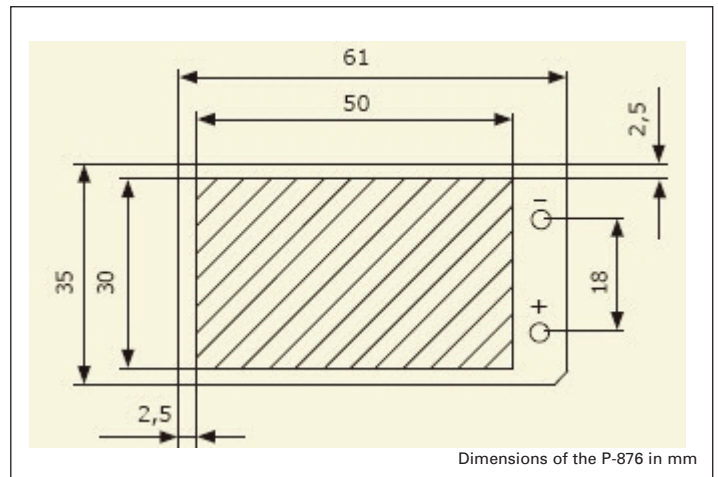
P-876.A11
DuraAct™ Patch Transducer,
61 x 35 x 0.4 mm

P-876.A12
DuraAct™ Patch Transducer,
61 x 35 x 0.5 mm

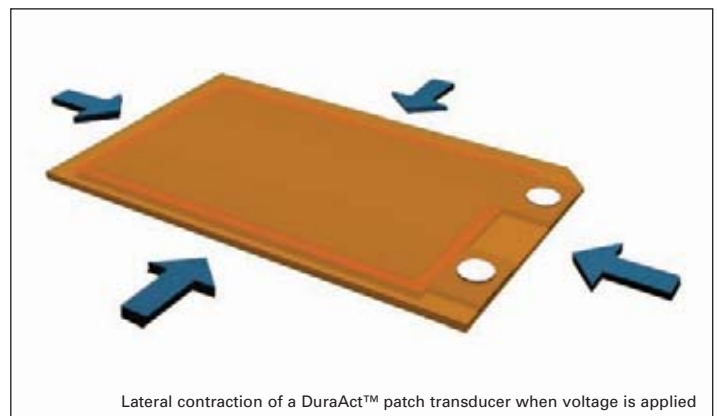
P-876.A15
DuraAct™ Patch Transducer,
61 x 35 x 0.8 mm

Ask for custom designs!

- Flexible choice of dimensions
- Flexible choice of thickness and bending properties
- Flexible choice of piezoceramic materials and operating temperature
- Various electrical connection designs
- Combining sensor and actuator functions (multiple ceramic layers)



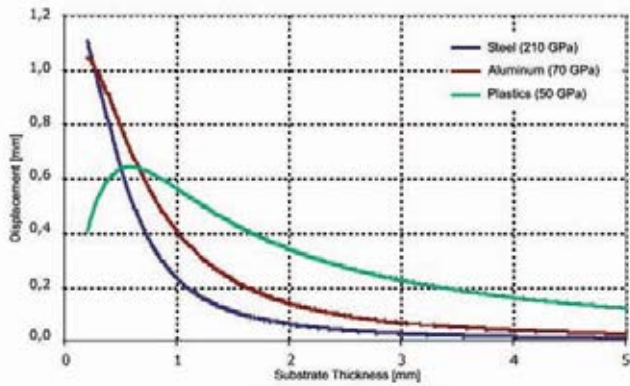
Dimensions of the P-876 in mm



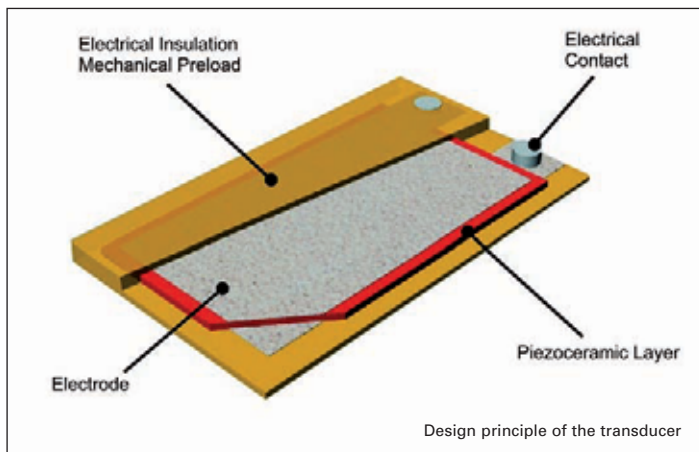
Lateral contraction of a DuraAct™ patch transducer when voltage is applied

Application Examples

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



Deflection of a bending transducer as a function of the substrate thickness for different materials. A bending transducer consists of a substrate with a P-876 actuator (here: P-876.A15) glued to one side. A contraction of the actuator effects a deflection W



Technical Data

Model	P-876.A11	P-876.A12	P-876.A15	Tolerances
Operating voltage	-50 to +200 V	-100 to +400 V	-250 to +1000 V	
Motion and positioning				
Lateral contraction, open-loop	400 $\mu\text{m}/\text{m}$ 1.6 $\mu\text{m}/\text{m}/\text{V}$	650 $\mu\text{m}/\text{m}$ 1.3 $\mu\text{m}/\text{m}/\text{V}$	800 $\mu\text{m}/\text{m}$ 0.64 $\mu\text{m}/\text{m}/\text{V}$	min.
Mechanical properties				
Blocking force	90 N	265 N	775 N	
Length	61 mm	61 mm	61 mm	± 0.5 mm
Width	35 mm	35 mm	35 mm	± 0.5 mm
Thickness	0.4 mm	0.5 mm	0.8 mm	± 0.05 mm
Bending radius	12 mm	20 mm	70 mm	max.
Drive properties				
Piezo ceramic type	PIC 252 Layer thickness: 100 μm	PIC 255 Layer thickness: 200 μm	PIC 255 Layer thickness: 500 μm	
Electrical capacitance	150 nF	90 nF	45 nF	± 20 %
Miscellaneous				
Operating temperature range	-20 to +150 (180) $^{\circ}\text{C}$	-20 to +150 (180) $^{\circ}\text{C}$	-20 to +150 (180) $^{\circ}\text{C}$	
Mass	2.1 g	3.5 g	7.2 g	± 5 %
Voltage connection	Solder pads	Solder pads	Solder pads	
Recommended controller/driver	E-413.D2 E-835	E-413.D2 (p. 2-120) E-835	E-508 (p. 2-150) E-835 (p. 2-166)	

Linear Actuators & Motors

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Piezo Actuators & Components

Guided / Preloaded Actuators

Unpackaged stack Actuators

Patches/Benders/Tubes/Shear..

Nanopositioning / Piezoelectrics

Nanometrology

Micropositioning

Index

P-111 • P-151 PICA™ Shear Actuators

Compact Multi-Axis Actuators Based on the Piezo Shear Effect



PICA™ Shear actuators are available in cross-sections from 3 x 3 mm to 16 x 16 mm

- Compact Single- and Multi-Axis Actuators
- X-, XY-, XZ- and XYZ-Versions
- High Resonant Frequencies
- Extreme Reliability >10⁹ Cycles
- Picometer-Resolution / Sub-Millisecond Response
- UHV Versions to 10⁹ hPa
- Non-Magnetic and Clear Aperture Versions

The unique PICA™ Shear piezo actuator series are exclusively available from PI. These devices are extremely compact and feature sub-nanometer resolution and ultra-fast response. They come in a variety of geometries providing displacements to 10 μm. Possible applications for these devices are e.g. scanning microscopy, or in motor drives.

Application Examples

- Nanopositioning
- Precision mechanics / -machining
- Active vibration damping
- Semiconductor technology / test systems
- Laser tuning
- Atomic force microscopy
- Switches
- Scanning applications
- Linear motors
- Nanotechnology

High Stiffness and High Displacement

PICA™ Shear actuators exhibit high stiffness, both parallel and perpendicular to the motion direction. Based on the piezoelectric shear effect, the PICA™ Shear X and XY actuators show almost twice the displacement amplitudes of conventional piezo actuators at the same electric field. Consequently they can be made smaller and have higher resonant frequencies. This results in reduced power requirements for a given induced displacement in dynamic X- and Y-axis operation.

High Reliability under High Duty Cycles, Low Power Requirements

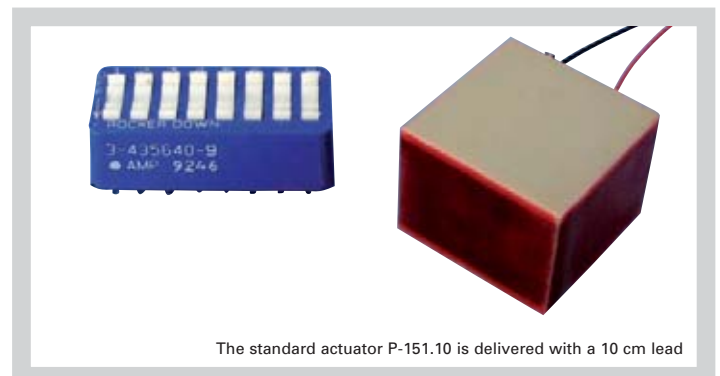
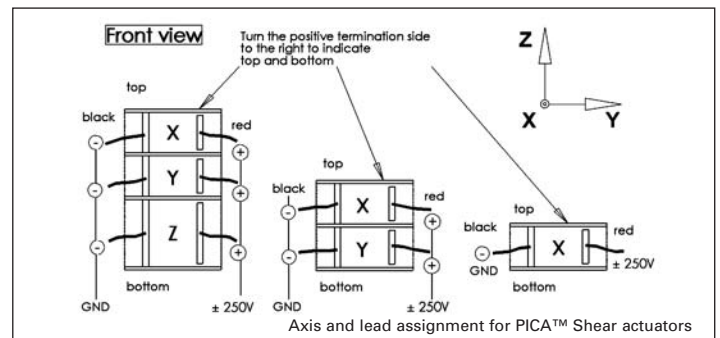
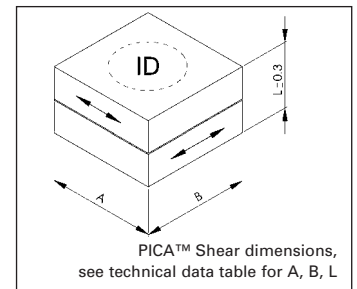
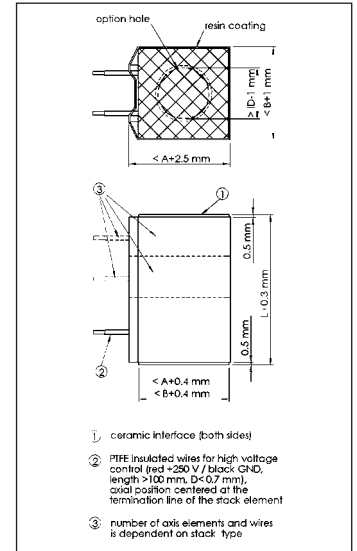
PICA™ Shear actuators are specifically designed for high-duty-cycle applications. All materials used are specifically matched for robustness and lifetime. Endurance tests proved consistent performance, even after billions (1,000,000,000) of cycles. The combination of high displacement

and low electrical capacitance provides for excellent dynamic behavior with reduced driving power requirements.

Short Leadtime for Standard & Custom Designs

All manufacturing processes at PI Ceramic are set up for maximum flexibility. Should our standard actuators not fit your application, let us provide you with a custom design. Our engineers will work with you to find the optimum solution at a very attractive price, even for small quantities. Some of our custom capabilities are listed below:

- Custom Materials
- Custom Voltage Range / Custom Displacement
- Clear Aperture
- Custom Load / Force Ranges
- Custom Flat or Spherical Endplates (Metal, Ceramics, Glass, Sapphire, ...) / Optical Surface Quality



- Extra-Tight Length Tolerances
 - Combination with Piezoelectric Shear Sensors (no Pyroelectric Effect)
 - Low-Temperature Designs, Down to Liquid-He
 - Vacuum Compatible and Non-Magnetic Versions
- Because all piezoelectric materials used in these actuators

are manufactured at PI Ceramic, leadtimes are short and quality is outstanding. All standard and custom actuators are delivered with performance test sheets.

Amplifiers and Controllers

The E-413.OE bipolar piezo driver is recommended for operating these actuators.

Other high-resolution amplifiers and servo-control electronics, both digital and analog, are described in the “Piezo Drivers / Servo Controllers” section.

Technical Data / Product Order Numbers

Order number	Active axes	Displacement [µm] -10/+20% for -250 to 250 V	Cross section A x B / ID [mm]	Length L [mm] ±0.3	Max. shear load [N]	Axial Stiffness [N/µm]	Capacitance [nF] ±20%	Resonant frequency [kHz]
P-111.01	X	1*	3 x 3	3.5	20	70	0.5	330
P-111.03	X	3*	3 x 3	5.5	20	45	1.5	210
P-111.05	X	5	3 x 3	7.5	20	30	2.5	155
P-121.01	X	1*	5 x 5	3.5	50	190	1.4	330
P-121.03	X	3*	5 x 5	5.5	50	120	4.2	210
P-121.05	X	5	5 x 5	7.5	40	90	7	155
P-141.03	X	3*	10 x 10	5.5	200	490	17	210
P-141.05	X	5	10 x 10	7.5	200	360	28	155
P-141.10	X	10	10 x 10	12	200	230	50	100
P-151.03	X	3*	16 x 16	5.5	300	1300	43	210
P-151.05	X	5	16 x 16	7.5	300	920	71	155
P-151.10	X	10	16 x 16	12	300	580	130	100
P-112.01	XY	1 x 1*	3 x 3	5	20	50	0.5 / 0.5	230
P-112.03	XY	3 x 3*	3 x 3	9.5	10	25	1.5 / 1.5	120
P-122.01	XY	1 x 1*	5 x 5	5	50	140	1.4 / 1.4	230
P-122.03	XY	3 x 3*	5 x 5	9.5	40	70	4.2 / 4.2	120
P-122.05	XY	5 x 5	5 x 5	14	30	50	7 / 7	85
P-142.03	XY	3 x 3*	10 x 10	9.5	200	280	17 / 17	120
P-142.05	XY	5 x 5	10 x 10	14	100	190	28 / 28	85
P-142.10	XY	10 x 10	10 x 10	23	50	120	50 / 50	50
P-152.03	XY	3 x 3*	16 x 16	9.5	300	730	43 / 43	120
P-152.05	XY	5 x 5	16 x 16	14	300	490	71 / 71	85
P-152.10	XY	10 x 10	16 x 16	23	100	300	130 / 130	50
P-123.01	XYZ	1 x 1 x 1*	5 x 5	7.5	40	90	1.4 / 1.4 / 2.9	155
P-123.03	XYZ	3 x 3 x 3*	5 x 5	15.5	10	45	4.2 / 4.2 / 7.3	75
P-143.01	XYZ	1 x 1 x 1*	10 x 10	7.5	200	360	5.6 / 5.6 / 11	155
P-143.03	XYZ	3 x 3 x 3*	10 x 10	15.5	100	170	17 / 17 / 29	75
P-143.05	XYZ	5 x 5 x 5	10 x 10	23	50	120	28 / 28 / 47	50
P-153.03	XYZ	3 x 3 x 3*	16 x 16	15.5	300	450	43 / 43 / 73	75
P-153.05	XYZ	5 x 5 x 5	16 x 16	23	100	300	71 / 71 / 120	50
P-153.10	XYZ	10 x 10 x 10	16 x 16	40	60	170	130 / 130 / 230	30
P-153.10H	XYZ	10 x 10 x 10	16 x 16 / 10	40	20	120	89 / 89 / 160	30
P-151.03H	X	3*	16 x 16 / 10	5.5	200	870	30	210
P-151.05H	X	5	16 x 16 / 10	7.5	200	640	49	155
P-151.10H	X	10	16 x 16 / 10	12	200	460	89	100

Standard piezo ceramic type: 255

* Tolerances ±30%

Unloaded (longitudinal) resonant frequency measured at 1 V_{pp}, capacitance at 1 V_{pp}, 1 kHz, unloaded, free at both sides

Capacitance at 1 V_{pp}, 1 kHz

Operating voltage: -250 V to +250 V

Operating temperature range: -20 to +85 °C

Standard mechanical interfaces: Ceramics

PTFE-insulated wires, pigtail length 100 mm

Available options: integrated piezo force sensors, non magnetic, vacuum compatible, free aperture etc.

Other specifications on request.

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DC-Servo & Stepper Actuators

Piezo Actuators & Components

Guided / Preloaded Actuators

Unpackaged stack Actuators

Patches/Benders/Tubes/Shear..

Nanopositioning / Piezoelectrics

Nanometrology

Micropositioning

Index

PT120 · PT140 PT Piezo Tube Actuators

Piezoceramic Tube Actuators with Small Tolerances and Various Options



A selection of PT piezoceramic tubes

- Standard & Custom Sizes
- Optional Quartered Electrodes for XYZ-Positioning & Scanning
- Sub-Nanometer Resolution
- Ideal for OEM-Applications

PT-series piezoceramic tubes are used in a wide range of applications from microdispensing to scanning microscopy. These monolithic components contract laterally (radially) and longitudinally when a voltage is applied between their inner and outer electrodes. Multi-electrode tubes are available to provide XYZ motion for use in manipulation and scanning microscopy applications. PI also provides

ultra-high linearity, closed-loop scanning stages for SPM and nanomanipulation.

Precision and Flexibility

PT piezo tubes are manufactured to the tightest tolerances. We can provide tubes with diameters as small as 0.8 mm and tolerances as tight as 0.05 mm. All manufacturing processes at PI Ceramic are set up for maximum flexibility. Should our standard actuators not fit your application, let us provide you with a custom design. Our engineers will work with you to find the optimum solution at a very attractive price, even for small quantities. Some of our custom capabilities are listed below:

- Custom Materials
- Custom Voltage Ranges / Displacement
- Custom Geometries
- Extra-Tight Tolerances
- Applied Sensors
- Special High / Low Temperature Versions

Application Examples

- Micropositioning
- Scanning microscopy (AFM, STM, etc.)
- Fiber stretching / modulation
- Micropumps
- Micromanipulation
- Ultrasonic and sonar applications

Short Leadtime

Because all piezoelectric materials used in PT tube actuators are manufactured at PI Ceramic, leadtimes are short and quality is outstanding.

Dimensions

max. L: 50 mm
max. OD: 80 mm
min. d: 0.30 mm

Electrodes

Fired silver-plated inside and outside as standard; thin film electrodes (e.g. copper-nickel or gold) as outer electrodes optional.

Options

Single or double wrapped, circumferential bands or quartered outer electrodes.

Polarization

Inner electrode positive potential

Tube actuators are not designed to withstand large forces (see PICA™ Thru actuators p. 1-90), but their high resonant frequencies make them especially suitable for dynamic operation with light loads.

Application examples are micro pumps, scanning microscopy, ink-jet printing, ultrasonic and sonar applications.

Piezo Drivers, Controllers & High-Voltage Amplifiers

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

Equations

The axial contraction and radial displacement of piezo tubes can be calculated as follows:

(Equation 1)

$$\Delta L \approx d_{31} \cdot L \cdot \frac{U}{d}$$

where:

d_{31} = strain coefficient (displacement normal to polarization direction) [m/V]

L = length of ceramic tube [m]

U = operating voltage [V]

d = wall thickness [m]

(Equation 2)

$$\Delta d \approx d_{33} \cdot U$$

where:

d = change in wall thickness [m]

d_{33} = strain coefficient (field and displacement in polarization direction) [m/V]

U = operating voltage [V]

Typical values for d_{31} and d_{33} are -200 pm/V and 500 pm/V, respectively.



XY scanning tubes with quartered outer electrodes; see table for specifications

The radial contraction is the superposition of the increase in wall thickness and the tangential contraction; it can be estimated by the following equation:

(Equation 3)

$$\frac{\Delta r}{r} \approx d_{31} \frac{U}{d}$$

where:

r = radius of piezo tube

d_{31} = strain coefficient (displacement normal to polarization direction) [m/V]

U = operating voltage [V]

d = wall thickness [m]

For a given division of the outer electrode of a piezo tube into four 90° sections the differential control ($\pm U$) of opposing electrodes results in bending of one of the ends, due to super-

position of radial and axial contraction. Such tubes are applied as XY scanner in scanning-probe microscopes such as atomic force microscopes. The scanning range can be evaluated as follows:

(Equation 4)

$$\Delta x \approx \frac{2\sqrt{2} \cdot d_{31} \cdot L^2 \cdot U}{\pi \cdot ID \cdot d}$$

where:

Δx = scanning range in X and Y (for symmetrical electrodes) [m]

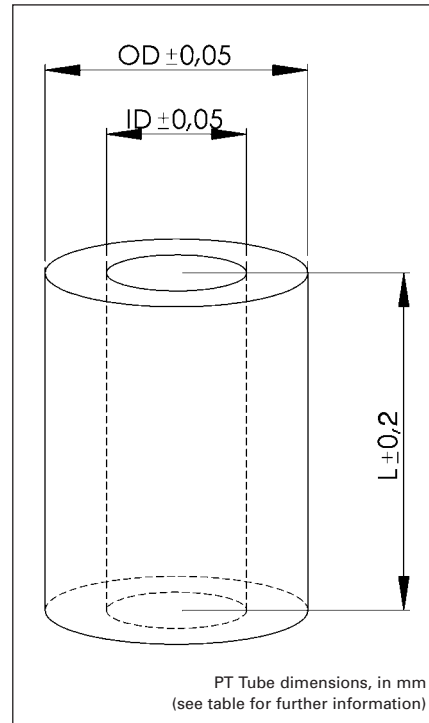
d_{31} = strain coefficient (displacement normal to polarization direction) [m/V]

U = operating voltage [V]

L = length [m]

ID = inner diameter [m]

d = wall thickness [m]



PT Tube dimensions, in mm
(see table for further information)

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Guided / Preloaded Actuators

Unpackaged stack Actuators

Patches/Benders/Tubes/Shear..

Nanopositioning / Piezoelectrics

Nanometrology

Micropositioning

Index

Technical Data / Product Order Numbers

Order number	Dimensions [mm] L x OD x ID**	Max. operating voltage [V]	Electrical capacitance [nF] $\pm 20\%$	Axial contraction [μm] @ max. V	Radial contraction [μm] @ max. voltage	XY deflection [μm] @ ± 200 V
PT120.00	20 x 2.2 x 1.0	500	3	5	0.7	-
PT130.00	30 x 3.2 x 2.2	500	10	9	0.9	-
PT130.90	30 x 3.2 x 2.2	500	12	9	0.9	-
PT130.94*	30 x 3.2 x 2.2	± 200	4 x 2.4	9	0.9	± 35
PT130.10	30 x 6.35 x 5.35	500	18	9	1.8	-
PT130.14*	30 x 6.35 x 5.35	± 200	4 x 3.8	9	1.8	± 16
PT130.20	30 x 10.0 x 9.0	500	36	9	3	-
PT130.24*	30 x 10.0 x 9.0	± 200	4 x 8.5	9	3	± 10
PT130.30	30 x 10.0 x 8.0	1000	18	9	3	-
PT130.40	30 x 20.0 x 18.0	1000	35	9	6	-
PT140.70	40 x 40.0 x 38.0	1000	70	15	12	-

*Quartered electrodes for XY deflection

**OD (outer diameter), ID (inner diameter) ± 0.05 mm. PT120 / PT130.00: ID ± 0.1 mm

Other specifications on request.

Options and Accessories

Factory Installed Options

Notes

The following options must be installed in the piezo translators during the manufacturing process. They must be ordered with the piezo actuator and cannot be added later. If necessary contact your local PI office for details on how to order modified translators.

Strain Gauge Position Sensor for HVPZT Stack Actuators

For positioning requiring high repeatability and accuracy, the strain gauge position sensor is available. See page 2-187 *ff.* and page 2-199 *ff.*, for more information on position sensors and closed-loop operation of piezos. Piezos with strain gauge sensors are equipped with a 1 m PUR cable with FFA.0S.304.CLAC32 LEMO connector in addition to the voltage cable.

Vacuum Options

All PI piezo translators can be safely used in a vacuum outside the range from 100 to 0.1 hPa (100 to 0.1 torr). See the tutorial "Piezoelectrics in Positioning" section, page 2-205 for discussion. For applications that require reduced outgassing, the P-703.10 and P-703.20 high-vacuum options are available.

P-703.10 High Vacuum (for non-preloaded PZTs)

The translators are delivered as bare ceramic stacks without a case. The PZTs can be baked up to 150 °C. The electrical connection is via two 50 cm long Teflon leads without connector. The nominal displacement of the PZT is reduced by about 20% (due to

the stiff insulation materials). P-703.10 includes high-temperature range if ordered with HVPZTs.

P-703.20 High Vacuum (for preloaded PZTs)

The piezo ceramics are enclosed in a stainless steel case with vent holes. The PZTs can be baked to 150 °C. The electrical connection is via two 50 cm Teflon leads without connector. The nominal displacement of the PZT is reduced by about 20% (due to the stiff insulation materials).

This option includes factory calibration of any PI servo-controller (see "Piezo Drivers & Nanopositioning Controllers" section) delivered along with the sensor-equipped piezo translator.

P-177.50 Dynamic applications (with E-481): temperature sensor and protective air for PICA™ HVPZT

The option for dynamic applications is recommended for the operation with the E-481 HVPZT Piezo Amplifier / Controller with energy recovery. Protective air and integrated temperature sensor prevent damage to the piezo ceramic by overtemperature.

P-706.00 Water-Resistant Case

The water-resistant case is recommended if PZTs are used in applications where spray of coolants, oil, water, etc. might

damage the piezo ceramics. It consists of a specially sealed steel case with integrated flexure zones. Please call for dimensions and further details. The following translators are available with water-resistant cases:

P-844.xx, P-845.xx, P-225.xx, P-235.xx.

P-176.30 Magnetic Adapter

To attach P-820 translators to various positioning units the P-176.30 magnetic adapters are available. The P-176.30 can be glued on the top piece of the P-820.

Cables and Cable Adapters

A variety of cables, extension cables and adapters are available. See "Accessories" page 2-168 *ff.* in the "Piezo Drivers / Servo Controllers" section for further details.

Extended Temperature Range

Standard HVPZTs work in the temperature range from -40 °C to 80 °C (-40 °F to +176 °F). For applications requiring an extended temperature range the following options are available:

High-Temperature Range and High Vacuum (only for HVPZTs)

-40 °C to +150 °C /
-40 °F to +302 °F /
233 K to 423 K

The piezo ceramics are enclosed in a stainless steel case with vent holes. Special electrical insulation materials are used. The nominal displacement of the PZT is reduced by about 20% (due to the stiff insulation materials). The electrical connection is via two 1,5 m Kapton leads with LEMO connector.

Low-Temperature Range

-273 °C to +80 °C /
-459 °F to +176 °F /
0 K to 353 K

Generally all PZT ceramics function down to zero kelvin. However, piezo translators are constructed of a combination of materials (ceramics, metal, insulating materials...) which makes the situation more complex.

To qualify the piezoelectric translators for cryogenic temperatures, special insulation material and adhesives must be used. The low-temperature translators are delivered as bare ceramic stacks without case and mechanical preload. The electrical connection is via two 50 cm Teflon leads without connectors.



P-176.30 magnetic adapter



P-176.10 magnetic adapter



P-176.60 flexible tip

Accessories

Accessories can be installed after manufacture.

P-176.Bxx Ball Tips

To avoid bending moments and shear forces on the PZT ceramics, a ball tip is available that can be screwed into the top piece of the individual translators.

- P-176.B12 Ball tip for P-212
- P-176.B16 Ball tip for P-216
- P-176.B25 Ball tip for P-225 and P-235

P-176.Fxx Flat Tips

Flat Tips are available and can be screwed into the top piece of the individual translators.

- P-176.F12 Flat tip for P-212
- P-176.F16 Flat tip for P-216
- P-176.F25 Flat tip for P-225
- P-176.F35 Flat tip for P-235

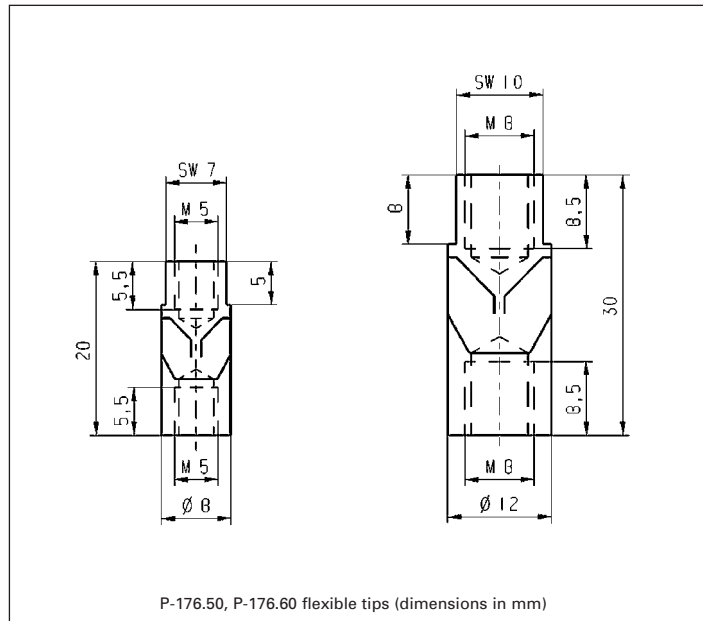
P-176.10/20 Magnetic Adapter

To attach P-840/1 and P-212 translators to various positioning units the P-176.10/20 magnetic adapters are available. The P-176.20 can be screwed into the top piece of the P-840/1. The P-176.10 can be screwed into the top piece of the P-212.

P-176.50/60 Flexible Tip

PZT ceramic stacks cannot withstand bending forces. The P-176.50/60 flexible tips are available for applications where it is not possible to avoid

those forces. They can be screwed into the standard top pieces of the P-842/3 and P-844/5 translators. See drawing.



P-176.50, P-176.60 flexible tips (dimensions in mm)

Technical Data

Model	P-176.50	P-176.60
Thread	M5/M5	M8/M8
Ø [mm]	8	12
L [mm]	20	30
Tilting angle [deg]	±0.5	±0.5
Axial stiffness [N/µm]	100	200
Bending stiffness [Nm/rad]	22	40

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Piezo Actuators & Components

Guided / Preloaded Actuators

Unpackaged Stack Actuators

Patches/Benders/Tubes/Shear..

Nanopositioning / Piezoelectrics

Nanometrology

Micropositioning

Index

Accessories (cont.)

Cables, Connectors & Adapters for PICA™ HVPZT Piezo Translators and Nanopositioning Systems

Notes

Unless stated otherwise, PI's preloaded PICA™ HVPZT piezo translators and nanopositioners are equipped with LEMO connectors and 1 m PVC cables. The voltage connector is an FGG.0B.701.CJL.1173. With integrated P-177.10 strain gauge, an additional sensor cable is installed. The length of the sensor cable is 1 m, the material PUR and the connector a LEMO FFA.0S.304.CLAC32 as shown on the P-892 cable.



P-202 PICA™ HVPZT cable

P-202.xx PICA™ HVPZT Cable LEMO plug / solderable end

Plug: FGG.0B.701.CJL.1173 (fits PICA™ HVPZT amplifiers, e.g. E-508.00)
Cable with PUR insulation, 2-conductor, shielded

This cable can be soldered to PZTs with pigtails

P-202.06	0.6 m
P-202.10	1 m
P-202.12	2 m
P-202.13	3 m
P-202.15	5 m



P-203 extension cable for PICA™ HVPZTs

P-203.xx PICA™ HVPZT Extension Cable

Plug: FGG.0B.701.CJL.1173
Socket: PHG.0B.701.CJL.1173
Cable: PUR-insulation, 2-conductor, shielded

P-203.01	1 m
P-203.02	2 m
P-203.03	3 m
P-203.05	5 m
P-203.10	10 m
P-203.15	15 m

Sensor Extension Cables



P-892.xx Sensor Extension Cable

For strain gauge sensors or LVDTs.

Plug (right):

FFA.0S.304.CLAC32

Socket (left):

PCA.0S.304.CLCC32

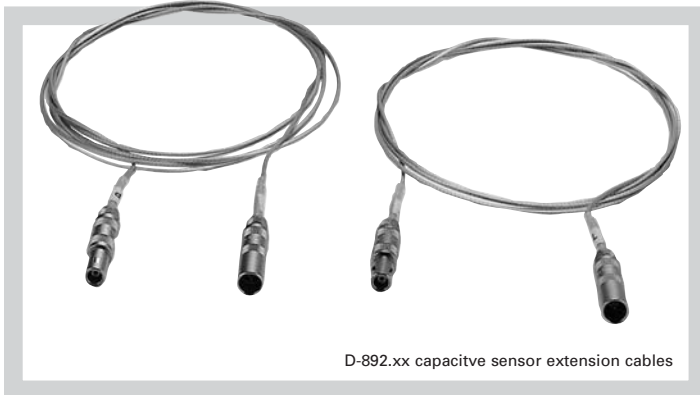
Cable: 4 wires; $\approx \varnothing 0.20$ mm;

#32 AWG (American)

\approx #35 SWG (British)

PVC-Isolation

P-892.01	1 m
P-892.02	2 m
P-892.03	3 m
P-892.05	5 m
P-892.10	10 m



D-892 Sensor Extension Cable Set

For capacitive sensors.

Set of two.

Plug (e.g., far left)

FFA.00.250.CTLC20

Socket (e.g., far right)

PCA.00.250.CTAC22

Cable: LSM 75 (Teflon)

D-892.01	1 m
D-892.02	2 m
D-892.03	3 m

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Piezo Actuators & Components

Guided / Preloaded Actuators

Unpackaged Stack Actuators

Patches/Benders/Tubes/Shear..

Nanopositioning / Piezoelectrics

Nanometrology

Micropositioning

Index

Notes on Specifications for Piezo Actuators and Components

Operating voltage

For PICMA® ceramic equipped piezo actuators: 0 to 100 V typ. Max. recommended operating voltage range is -20 to +120 V (extremes for short durations only).

For PICA™ ceramic equipped piezo actuators: 0 to 1000 V typ. Voltages in excess of +750 V should not be applied for long durations. Operation in the range of -200 to +750 V is recommended for maximum lifetime and displacement.

For shear and bender type piezo actuators, bipolar voltage is applied, ranging from ± 30 V up to ± 250 V typ.

Motion and Positioning

Performance specifications are valid for room temperature (22 ± 3 °C) and closed-loop systems are calibrated at this temperature (specifications for different operating temperatures on request). Recalibration is recommended for operation at a significantly higher or lower temperature. Custom designs for ultra-low or ultra-high temperatures on request.

Integrated feedback sensor

Absolute measuring capacitive and SGS sensors are used to provide position information to

the controller. For details see the tutorial "Piezoelectrics in Positioning" Section (see p. 2-187 ff).

Open-loop travel for PICMA® Ceramic Equipped Piezo Stages and Actuators

Minimum open-loop travel at 0 to 100 V operating voltage.

Open-loop travel for PICA™ Ceramic Equipped Piezo Actuators

Minimum open-loop travel of high-voltage piezo actuators at 0 to +1000 V operating voltage.

Closed-loop travel for PICMA® Ceramic Equipped Piezo Stages and Actuators

Travel provided in closed-loop operation. PI piezo amplifiers have an output voltage range of -20 to +120 V or -30 to +135 V to provide enough margin for the servo-controller to compensate for load changes, etc.

Open-loop / closed-loop resolution

Resolution of piezo actuators is basically infinitesimal because it is not limited by stiction or friction. Instead of

resolution, the noise-equivalent motion is specified. Values are typical results (RMS, 1σ), measured with E-503/E-508 amplifier module in E-500/501 chassis.

Mechanical Properties

Static large-signal stiffness

Typical tolerance $\pm 20\%$. Static large-signal stiffness of the stage in operating direction at room temperature. Small-signal stiffness and dynamic stiffness may differ because of effects caused by the active nature of piezoelectric material, compound effects, etc. For details see the tutorial "Piezoelectrics in Positioning" Section (see p. 2-189 ff)

Unloaded resonant frequency

Typical tolerance $\pm 20\%$. Lowest resonant frequency in operat-

ing direction (does not specify the maximum operating frequency). For details see the tutorial "Piezoelectrics in Positioning" Section (see p. 2-192 ff)

Push/pull force capacity (in operating direction)

Specifies the maximum forces that can be applied to the system along the active axis. Limited by the piezo ceramic material and the flexure design. If larger forces are applied, damage to the piezo ceramic, the flexures or the sensor can

occur. The force limit must also be considered in dynamic applications.

Example: the dynamic forces generated by sinusoidal operation at 500 Hz, 20 μm peak-to-peak, 1 kg moved mass, are approximately ± 100 N. For details see the tutorial "Piezoelectrics in Positioning" Section (see p. 2-192 ff)

Shear force limit

Maximum lateral force orthogonal to the operating direction. Limited by the piezo ceramics.

Torque limit (on tip)

Maximum torque that can be applied before damage occurs. Limited by the piezo ceramics.

Drive Properties

Electrical capacitance

Typical tolerance $\pm 20\%$. The piezo capacitance values indicated in the technical data tables are typical small-signal values (measured at 1 V, 1000 Hz, 20 °C, no load). Large-signal values at room temperature are 30 to 50% higher. The capacitance of piezo ceramics changes with amplitude, temperature, and load, up to 200% of the unloaded, small-signal capacitance at room temperature. For detailed information on power requirements, refer to the amplifier frequency-response graphs in the Piezo Drivers / Servo Controllers (p. 2-99 *ff*) Section of this catalog.

Dynamic Operating Current Coefficient (DOCC)

Typical tolerance $\pm 20\%$. Average electrical current (supplied by the amplifier) required to drive a piezo actuator per unit frequency and unit displacement (sine-wave operation). For example to find out if a selected amplifier can drive a given piezo stage at 50 Hz with 30 μm amplitude, multiply DOC coefficient by 50 x 30 and check if the result is smaller or equal to the output current of the selected amplifier. For details see the tutorial "Piezoelectrics in Positioning" Section (p. 2-195 *ff*).

Miscellaneous

Operating temperature range

The temperature range indicates where the piezo actuator may be operated without damage. Nevertheless, recalibration or zero-point-adjustment may be required if the system is operated at different temperatures. Performance specifications are valid for room temperature range.

Material

Housings are usually made of stainless steel. Small amounts of other materials may be used internally (for spring preload, piezo coupling, mounting, thermal compensation, etc.).

Al: Aluminum
 N-S: Non-magnetic stainless steel
 S: Ferromagnetic stainless steel
 I: Invar
 T: Titanium

See also "Options and Accessories" (p. 1-102 *ff*).

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Patches/Benders/Tubes/Shear..

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Nanometrology

Micropositioning

Index

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