Piezotechnology

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.

Application Examples

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

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

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]*

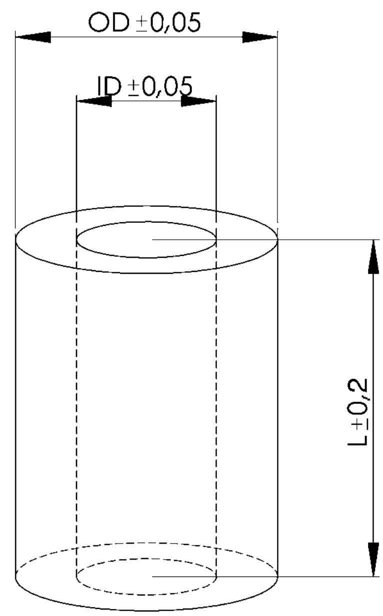
For a given division of the outer electrode of a piezo tube into four 90° sections the differential control (±U) of opposing electrodes results in bending of one of the ends, due to superposition of radial and axial contraction. Such tubes are applied as XY scanner in scanning-probe microscopes such 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)

Technical Data / Product Order Numbers

Order number	Dimensions [mm] L x OD x ID**	Max. operating voltage [V]	Electrical capacitance [nF] ±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

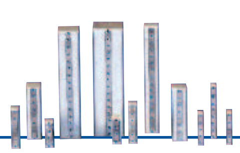
Other specifications on request.

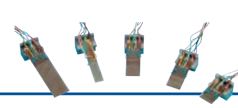
Low-cost Piezo Systems with Various Levels of Integration

For more information visit http://www.pi.ws

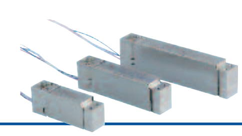
Piezo Actuator / Stage	Description	Travel Range up to	Guiding System	Mechanical Levels of Integrations	Positioning Sensor	Stiffness
P-882 - P-888	PICMA® Multilayer Piezo Stack Actuators	30 µm	-	-	optional SGS	up to 200 N/µm
P-871	PICMA® Piezo Bender Actuator	1600 µm	-	-	optional SGS	0.02 N/µm
P-842 -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

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


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

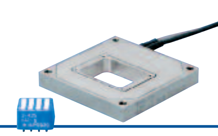

P-871 PICMA® Piezo Bender Actuator

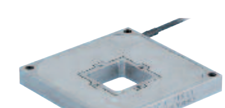

P-842 · P-845 Preloaded Piezo Actuators

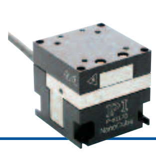

P-601 PiezoMove Linear Actuator


P-602 PiezoMove Flexure Actuator with High Stiffness


P-603 PiezoMove Linear Actuator


P-712 Low-Profile Piezo Scanner


P-713 Low-Profile Piezo Scanner


P-611 NanoCube® XYZ Piezo Stage


E-831 Piezo Amplifier


E-610 Piezo Amplifier/ Motion Controller


E-621.SR Motion Controller Module

Page numbers on the following pages refer to the hardbound 2009 PI catalog

PiezoMove: Moving, Positioning, Scanning

Microfluidics, Biotechnology, Medical Engineering, Adaptronics

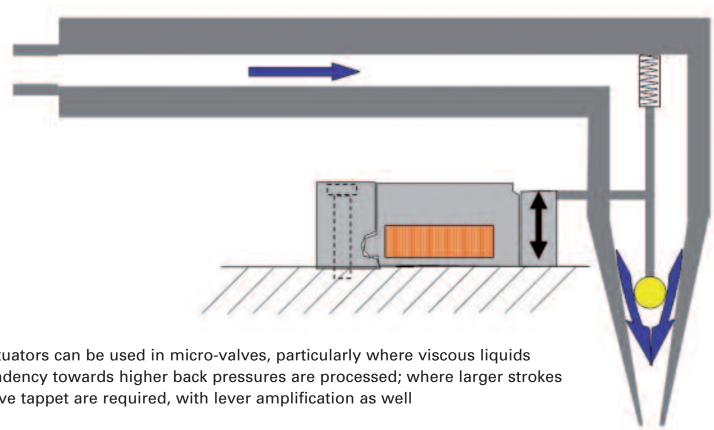
Piezo = nano = expensive?

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

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

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

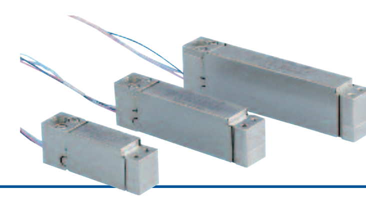
PiezoMove actuators combine guided motion and long travel ranges up to 1 mm and provide precision in the 10 nm range if ordered with the position sensor option. They are very compact, easy to integrate, require no maintenance and provide service life of Billions (10^9) of cyles.



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

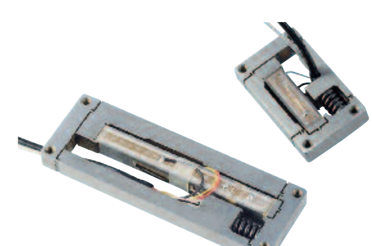
PI supplies a variety of standard integration levels and also customized versions: From simple piezo stack components and preloaded linear actuators through to 6-axis positioning systems with sub-nanometer precision.

3 Actuator Families



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

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



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

For more information visit http://www.pi.ws

Application fields

Microfluidics:

Valves, pumps, microliter and nanoliter dosing

Biotechnology:

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

Medical engineering:

Diaphragm pumps, valves, dosing, injection, sample handling

Mechatronics, adaptronics:

Active structures, vibration isolation, active tools, structure deformation

Laser technology, metrology:

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

PiezoMove: Travel Ranges to 1 mm

Easy Integration and Adaptation

Systems Thinking

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

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

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

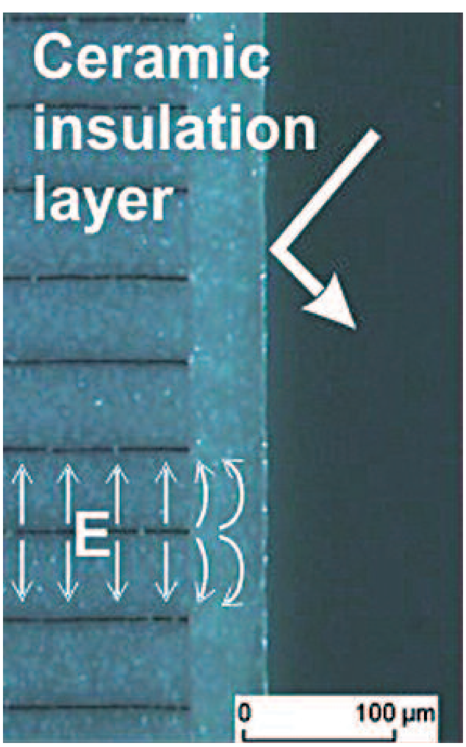
In addition to standard products, modified or completely custom engineered solutions are available at competitive prices. The following parameters can be modified to suit an application:

- Travel range
- Dynamics
- Force
- Precision

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

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

PI Actuators Offer Longer Service Life



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

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

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

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

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

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

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

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

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