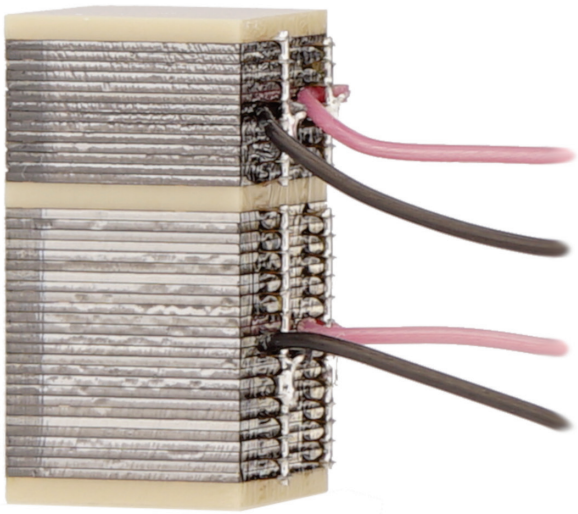
PZ284E

P-405 Piezo Actuator

User Manual

Version: 1.0.1 Date: 08.03.2019



This document describes the following products:

- **P-405**
  Picoactuator®
  Longitudinal and shear actuators with high linear displacement

This document also applies to custom products from the Picoactuator® piezoelectric crystal product line.

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Contents

1 About this Document

In this Chapter

1.1 Objective and Target Group of this User Manual

This user manual contains the information necessary for using the P-405.xx (x stands for the different models (p. 9)) as intended.

Basic knowledge of drive technologies and suitable safety measures is assumed.

The latest versions of the user manuals are available for download (p. 3) on our website.

1.2 Validity for Custom Products

This user manual also applies to custom products from the Picoactuator® piezoelectric crystal product line if nothing else is stated in their accompanying documentation.

The product line is stated on the delivery note of the custom product.

The properties of custom products may differ from those stated in this manual.

1.3 Symbols and Typographic Conventions

The following symbols and typographic conventions are used in this user manual:

DANGER

Imminently hazardous situation

If not avoided, the hazardous situation will result in death or serious injury.

➢ Measures for avoiding the risk.

CAUTION

Dangerous situation

If not avoided, the dangerous situation will result in minor injury or damage to the equipment.

➢ Measures for avoiding the risk.

NOTICE

Dangerous situation

If not avoided, the dangerous situation will result in damage to the equipment.

➢ Measures for avoiding the risk.

INFORMATION

Information for easier handling, tricks, tips, etc.

Symbol / Label	Meaning
	General hazard symbol
1. 2.	Action consisting of several steps whose sequential order must be observed
➢	Action consisting of one or several steps whose sequential order is irrelevant
▪	List item
p. 5	Cross-reference to page 5
RS-232	Labeling of an operating element on the product (example: socket of the RS-232 interface)

1.4 Figures

For better understandability, the colors, proportions, and degree of detail in illustrations can deviate from the actual circumstances. Photographic illustrations may also differ and must not be seen as guaranteed properties.

1.5 Other Applicable Documents

The devices and software tools from PI mentioned in this documentation are described in their own manuals.

The latest versions of the user manuals are available for download (p. 3) on our website.

1.6 Downloading Manuals

INFORMATION

If a manual is missing or problems occur with downloading:

➢ Contact our customer service department (p. 37).

INFORMATION

For products that are supplied with software (CD in the scope of delivery), access to the manuals is protected by a password. Protected content is only displayed on the website after entering the access data.

You need the product CD to get the access data.

For products with CD: Get access data

1. Insert the product CD into the PC drive.
2. Switch to the Manuals directory on the CD.
3. In the Manuals directory, open the Release News (file including ***releasenews*** in the file name).
4. Get the access data for downloading protected content in the "User login for software download" section of the Release News. Possible methods for getting the access data:
   - Link to a page for registering and requesting the access data
   - User name and password is specified
5. If the access data needs to be requested via a registration page:
   a) Follow the link in the Release News.
   b) Enter the required information in the browser window.
   c) Click ***Show login data*** in the browser window.
   d) Note the user name and password shown in the browser window.

Downloading manuals

If you have requested access data for protected contents via a registration page (see above):

➢ Click the links in the browser window to change to the content for your product and log in using the access data that you received.

General procedure:

1. Open the website **www.pi.ws**.
2. If access to the manuals is protected by a password:
   a) Click ***Login***.
   b) Log in with the user name and password.
3. Click ***Search***.
4. Enter the product number up to the period (e.g., P-405) or the product family (e.g., Picoactuator®) into the search field.
5. Click ***Start search*** or press the Enter key.
6. Open the corresponding product detail page in the list of search results:
   a) If necessary: Scroll down the list.
   b) If necessary: Click ***Load more results*** at the bottom of the list.
   c) Click the corresponding product in the list.
7. Click the ***Downloads*** tab.

   The manuals are shown under ***Documentation***.
8. Click the desired manual and save it to the hard disk of your PC or to a data storage medium.

2 Safety

In this Chapter

2.1 Intended Use

The P-405 is intended to be used in an environment which is free of dirt, oil, and lubricants.

In accordance with its design, the P-405 is intended for integration into a mechanics and for the following applications:

- Hysteresis-free positioning
- High dynamics scanning
- Vibration absorption

Depending on the version, the motion is performed as follows:

Model	Motion	Axis
P-405.05, P-405.08	In one axis vertically	Z
P-405.15, P-405.18	In one axis horizontally	X
P-405.28	In one axis horizontally and in one axis vertically	X, Z

The operator is responsible for standards-compliant integration of the P-405 into the overall system.

When mounting, the maximum shear load according to the data table (p. 39) may not be exceeded.

For operation of the P-405, suitable electronics that provide the required operating voltages are required. The electronics are not in the scope of delivery of the P-405. We recommend the use of suitable electronics (p. 12) from PI.

2.2 General Safety Instructions

The P-405 is built according to state-of-the-art technology and recognized safety standards. Improper use can result in personal injury and/or damage to the P-405.

- Only use the P-405 for its intended purpose, and only use it if it is in a good working order.
- Read the user manual.
- Immediately eliminate any faults and malfunctions that are likely to affect safety.

The operator is responsible for the correct installation and operation of the P-405.

Temperature changes and compressive stress can induce charges in the P-405 piezo actuator. After disconnection from the electronics, the piezo actuator can remain charged for several hours. Touching the live parts of the P-405 can result in minor injury from electric shock.

- Do not touch the piezo actuator unless it is discharged (p. 30).
- When handling the piezo actuator, wear powder-free nitrile or latex gloves.
- Keep the piezo actuator short-circuited (p. 31) when it is not connected to the electronics.

The system in which the P-405 is integrated (e.g., housing or surrounding mechanics) must be connected to a protective earth conductor. If the protective earth conductor is missing or not properly connected, dangerous touch voltages can occur in the overall system in the event of malfunction or failure of the system. If touch voltages exist, touching the overall system can result in serious injury or death from electric shock.

- Before startup, connect the overall system to a protective earth conductor in accordance with the applicable standards.
- Do **not** remove the protective earth conductor during operation.
- If the protective earth conductor has to be temporarily removed (e.g., for modifications), reconnect the overall system to the protective earth conductor before starting it up again.

During operation, the P-405 is subject to voltages up to 500 V. The protective polymer layer of the piezo actuator does **not** protect against electric shock. Touching the live parts of the P-405 can result in serious injury or death from electric shock.

- Do **not** touch the piezo actuator during operation.
- Before startup, insulate the piezo actuator electrically from the surrounding mechanics to prevent direct or indirect contact with live parts. Pay attention to the clearances and creepage distances required for the operating voltage as well as the standards applicable to your application.

Mechanical forces can damage the P-405.

- Avoid impacts that affect the P-405.
- Do **not** drop the P-405.
- Avoid torques and lateral forces on the P-405.
- Do **not** use metal tools during installation.
- Do **not** exceed the maximum permissible stress and load capacities according to the specifications (p. 39).
- Do **not** exceed the maximum compressive/tensile stress capacity (p. 40).

2.3 Organizational Measures

User manual

- Always keep this user manual available with the P-405.
  The latest versions of the user manuals are available for download (p. 3) on our website.
- Add all information from the manufacturer to the user manual, for example supplements or technical notes.
- If you give the P-405 to other users, also include this manual as well as all other relevant information provided by the manufacturer.
- Only use the device on the basis of the complete user manual. If your user manual is incomplete and is therefore missing important information, serious or fatal injury as well as damage to the equipment can result.
- Only install and operate the P-405 after you have read and understood this user manual.

Personnel qualification

The P-405 may only be installed, started up, operated, maintained and cleaned by authorized and appropriately qualified personnel.

3 Product Description

In this Chapter

3.1 Model Overview

Model	Description
P-405.05	Picoactuator® Z piezo actuator, 1 µm travel range, 5 mm × 5 mm × 12.5 mm
P-405.08	Picoactuator® Z piezo actuator, 1 µm travel range, 10 mm × 10 mm × 12.5 mm
P-405.15	Picoactuator® X piezo actuator, 1 µm travel range, 5 mm × 5 mm × 7.5 mm
P-405.18	Picoactuator® X piezo actuator, 1 µm travel range, 10 mm × 10 mm × 7.5 mm
P-405.28	Picoactuator® XZ piezo actuator, 1 µm × 1 µm travel range, 10 mm × 10 mm × 19 mm

3.2 Product View

The figure serves as an example and can differ from your model.

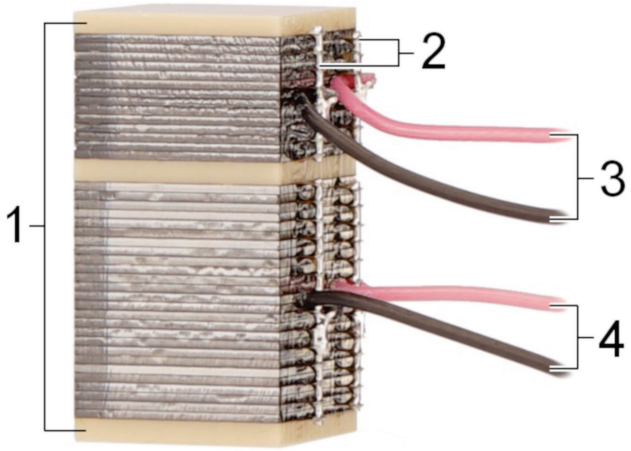

Figure 1: Example product view of a P-405.28 XZ actuator

1 Endpiece made of ceramic (passive PZT)
2 Soldering guide
3 Stranded wires for the X axis (shearing motion): Red wire for voltage (+) and black wire for ground (-)
4 Stranded wires for the Z axis (axial motion): Red wire for voltage (+) and black wire for ground (-)

The actuator's lateral surface consists of a protective polymer layer (epoxy resin).

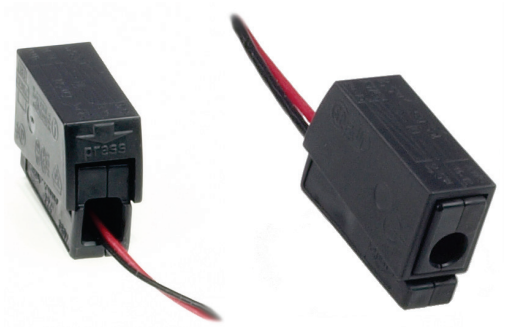

Figure 2: INYY-0005 shorting clamp: Front side for clamping the stranded wires (left) and rear side of the clamp (right)

3.3 Product Labeling

The product labeling is on a sticker that is affixed to the black stranded wire of the piezo actuator.

Labeling	Description
	Data Matrix code (example; contains the abbreviated batch number and the product number)
P-405.28	Product number (example), the digits after the period refer to the model The product number of custom products consists of nine digits (without identification of the model).
123456789	Serial number (example), individual for each P-405 Meaning of the places (counting from left): 1 = internal information 2 and 3 = year of manufacture 4 to 9 = consecutive numbers
PI	Manufacturer's logo
Country of origin: Germany	Country of origin
WWW.PICERAMIC.COM	Manufacturer's address (website)

3.4 Direction of Motion and Polarity

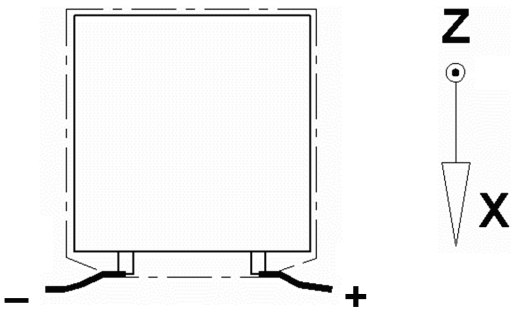

Figure 3: Example view from above: Directions of motion and the polarity of the actuator clamped to the bottom

–	Black stranded wire for ground (-)
+	Red stranded wire for voltage (+)
X	X direction of motion when applying positive voltage (X and XZ actuators only)
Z	Z direction of motion when applying positive voltage (Z and XZ actuators only)

3.5 Scope of Delivery

Product number	Description
P-405	Piezo actuator according to order (p. 9)
PZ257EK	Short instructions for piezo actuators without housing
INYY-0005	Shorting clamp, 2.5 mm^2 for the stranded wires of the piezo actuator (one shorting clamp per axis)

3.6 Suitable Electronics

You need electronics to operate a P-405. The device is selected depending on the type of application. The table below lists the suitable devices.

Product number	Description
E-500 • E-501	Modular piezo controller with E-508.00 HVPZT piezo amplifier module, 3 to 1100 V, 1 channel

The E-508.00 piezo amplifier module is suitable for medium bandwidths. For higher bandwidths to 20 kHz and lower noise, a customized version of the E-508 is available on request for Picoactuator® actuators with a capacity of 1 nF to 5 nF.

- ➢ To order, contact our customer service department (p. 37).
- ➢ Before selecting electronics, calculate the power requirements of your application (p. 29).

3.7 Operating Principle of a Shear Actuator

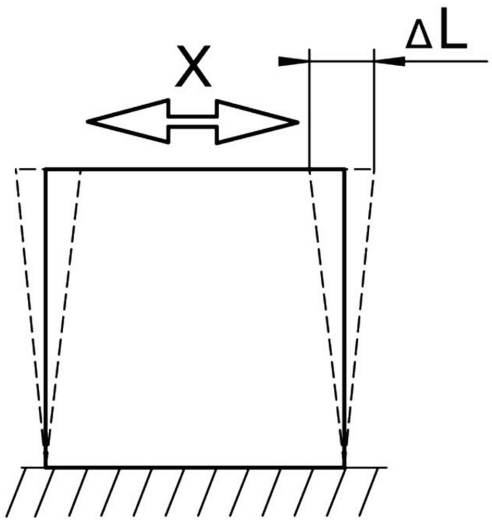

Figure 4: Principle of shear motion using the example of a P-405.1x. ΔL refers to the travel range.

3.8 Technical Features

Picoactuator® piezoelectric crystal

Picoactuator® longitudinal and shear actuators consist of a crystalline piezoelectric material. The specific displacement for shear actuators is ±0.02 % of the actuators length and ±0.01 % for longitudinal piezo actuators. This value is ten times lower when compared to piezo actuators made of lead zirconate titanate (PZT). The motion is highly linear and almost hysteresis-free.

4 Unpacking

NOTICE

Destruction of the piezo actuator due to contamination!

Contamination on the surface of the P-405 can result in the destruction of the piezo actuator by electric flashovers during operation.

- When handling the piezo actuator, wear powder-free nitrile or latex gloves.
- Prevent the piezo actuator from coming into contact with conductive liquids (e.g., finger sweat) and conductive materials (e.g., metal dust).
- If the piezo actuator has been accidentally contaminated, clean it in accordance with the instructions in "Cleaning the P-405" (p. 33).

1. Unpack the P-405 with care.
2. Compare the contents with the scope of delivery according to the contract and the delivery note.
3. Inspect the contents for signs of damage. If any parts are damaged or missing, contact our customer service department (p. 37) immediately.
4. Keep all packaging materials in case the product needs to be returned.

5 Installation

In this Chapter

5.1 General Notes on Installation

CAUTION

Dangerous voltage and residual charge in piezo actuators!

Temperature changes and compressive stress can induce charges in the P-405 piezo actuator. After disconnection from the electronics, the piezo actuator can remain charged for several hours. Touching the live parts of the P-405 can result in minor injury from electric shock.

- Do not touch the piezo actuator unless it is discharged (p. 30).
- When handling the piezo actuator, wear powder-free nitrile or latex gloves.
- Keep the piezo actuator short-circuited (p. 31) when it is not connected to the electronics.

NOTICE

Destruction of the piezo actuator due to rapid discharging!

If the piezo actuator is not connected to the electronics, it must be short-circuited to prevent it from charging during temperature changes or when it is subject to compressive stress. Unsuitable short-circuiting of a charged piezo actuator leads to abrupt contraction of the piezo actuator due to excessively fast discharging. Abrupt contraction can destroy the piezo actuator.

- Remove shorting clamps (p. 12) connected to the stranded wires only when this is required for installation or operation.
- If the shorting clamp was removed, discharge the piezo actuator (p. 30) before reattaching the shorting clamp.
- If the piezo actuator has a voltage connector, keep the piezo actuator short-circuited (p. 31) using a suitable shorting plug with a built-in 100 kΩ discharge resistor.

NOTICE

Destruction of the piezo actuator due to excessive loads!

Excessive loads can destroy the P-405.

- Do **not** exceed the maximum compressive stress of 15 MPa.
- Avoid tensile stress.

NOTICE

Destruction of the piezo actuator due to mechanical overload!

Torques, bending forces and lateral forces can destroy the piezo actuator.

- Avoid torques, bending forces and lateral forces on the piezo actuator.
- Do **not** exceed the maximum shear load according to the data table (p. 39).
- Establish contact over as large an area as possible on the endpieces of the piezo actuator, and select opposing surfaces with a flatness of only a few micrometers. Minor irregularities in flatness for example, can be compensated by full-surface gluing.

NOTICE

Damage due to tensile stress on the stranded wires of the piezo actuator!

Impermissible forces on the stranded wires can damage the piezo actuator.

- Avoid tensile stress on the stranded wires of the piezo actuator.

NOTICE

Damage due to scratches on the surface of the piezo actuator!

The surface of the piezo actuator is scratch-sensitive. Scratches on the surface can cause damage to the piezo actuator.

- Do not use metal tools to install the piezo actuator.
- Install the piezo actuator so that the polymer insulation and the end surfaces of the piezo actuator are not scratched during installation and operation.

NOTICE

Heating up of the P-405 during operation!

Emitted heat may adversely affect your application if you operate the P-405 at a higher frequency (in the kHz range).

- Install the P-405 so that your application is not affected by the dissipating heat.

INFORMATION

Ground loops can occur when a shielded connecting cable is connected to the P-405 and the shield of this cable is connected to an actuator housing grounded via a separate protective earth conductor.

➢ If a ground loop occurs, contact our customer service department (p. 37).

INFORMATION

A low preload (p. 40) is recommended for P-405 longitudinal actuators (Z actuators) to compensate for lateral forces.

Generally, P-405 shear actuators (X and XZ actuators) are not preloaded mechanically. A low preload (p. 40) could make sense.

➢ If preloading is required, contact our customer service department (p. 37).

Avoiding mounting errors

The following figures are to help you avoid mounting errors.

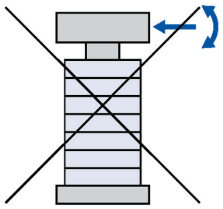

Figure 5: Prevention of lateral forces and torques

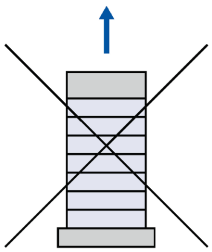

Figure 6: Avoiding tensile stress

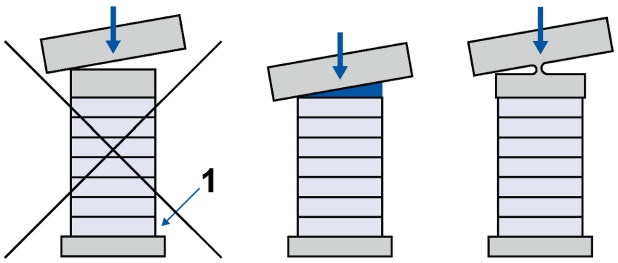

Figure 7: Prevention of an irregular load application (1: Tensile stresses)

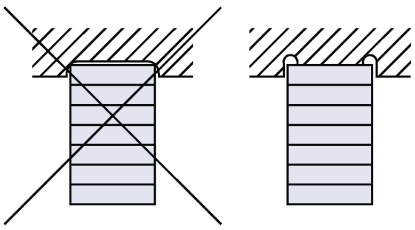

Figure 8: Full-area contact of the piezo actuator

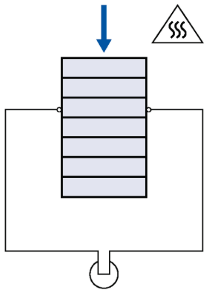

Figure 9: Mechanical or thermal loads electrically charge the piezo actuator. Mount only when short-circuited.

5.2 Mounting the P-405

P-405 piezo actuators are glued to metal or ceramic surfaces.

Requirements

- ✓ You have read and understood the general notes on installation (p. 17).
- ✓ The P-405 is discharged (p. 30) and short-circuited (p. 31).
- ✓ You have read and understood the user information of the manufacturer of the adhesive.

Tools and accessories

- Level surface that is dry, dust-free, and grease-free
- Suitable adhesive (e.g., cold-hardening epoxy resin adhesive)

Mounting the P-405

1. Glue the piezo actuator to the surface:
   - Apply the thinnest possible layer of adhesive.
   - During the hardening process, maintain the operating temperature range (p. 41) specified for the piezo actuator.
   - Observe the temperature expansion coefficients of the materials involved.
2. Press the piezo actuator until the adhesive has hardened.

5.3 Applying the Load

Depending on the application, mechanical coupling of the P-405 to a load is done by gluing the piezo actuator (p. 20) to the mechanics to be moved or to a flexure joint.

INFORMATION

Diagrams showing how to couple the P-405 to a load can be found in "General Notes on Installation" (p. 17).

Requirements

✓ You have read and understood the general notes on installation (p. 17).

✓ The P-405 is discharged (p. 30) and short-circuited (p. 31).

Tools and accessories

- Suitable adhesive (e.g., cold-hardening epoxy resin adhesive)
- When using a flexure joint: Suitable flexure joint

Applying the load

➢ Apply the load evenly.

If the piezo actuator is coupled in a milling pocket:

➢ Ensure that there is full-area contact at the endpiece of the piezo actuator. For this purpose, choose the dimensions of the milling pocket correspondingly or make free cuts in the milling pocket.

5.4 Connecting the P-405 to the Electronics

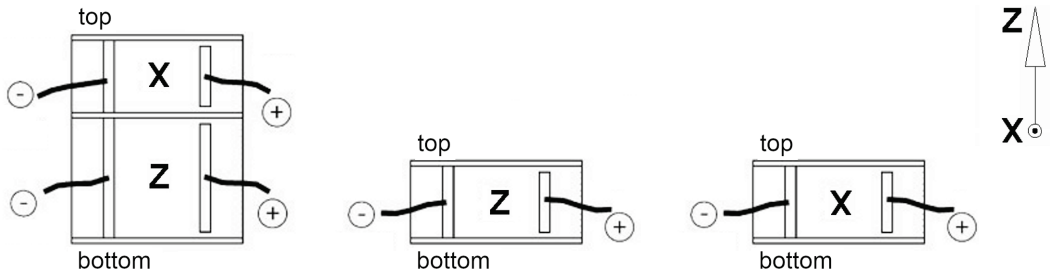

Figure 10: Model-dependent axis and cable assignment: XZ actuator (left), Z actuator (center), X actuator (right)

–	Black stranded wire for ground (-)
+	Red stranded wire for voltage (+)
X	X axis
Z	Z axis

Connecting the P-405 to electronics with LEMO socket

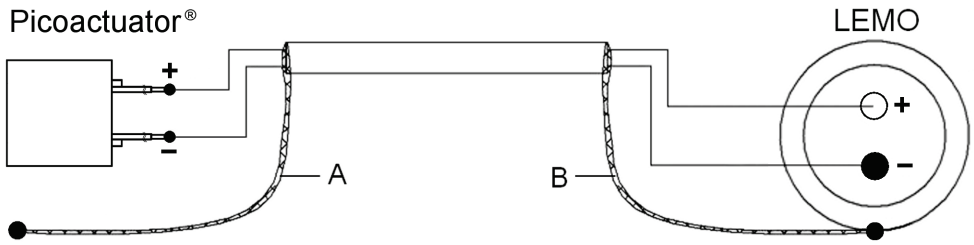

Figure 11: P-405 Picoactuator® (left) to LEMO connector (right)

Picoactuator®	P-405: Red stranded wire for voltage (+) Black stranded wire for ground (-)
LEMO	LEMO connector: Female contact for voltage (+) Male contact for ground (-)
A	Cable shield (actuator side)
B	Cable shield (connector side)

Requirements

- ✓ You have read and understood the general notes on installation (p. 17).
- ✓ If the P-405 is not short-circuited: The P-405 is discharged (p. 30).
- ✓ The electronics are **switched off**.

Tools and accessories

- One LEMO FGG.0B.701.CJA.1173 plug connector per axis (available on request)
- Shielded 2-wire cable (not in the scope of delivery) suitable for the voltage and current specifications of the electronics (p. 12) to be connected and fulfills the applicable standards for the application conditions
- Suitable soldering iron
- Suitable solder
- Suitable cable tools

Connecting the P-405 to electronics with LEMO socket

1. If the P-405 is short-circuited, separate the short-circuited stranded wires of the P-405 from each other. If a shorting clamp (p. 12) or a discharge resistor is connected, remove this component from the stranded wires.
2. Solder the stranded wires of the P-405 and the LEMO connector with the wires of the shielded cable as shown in the connection diagram above.
   – When soldering, pay attention to the polarity of the P-405: The red connection is positive in contrast to the other connection.
3. Connect the cable shield:
   a) Connect the cable shield on the actuator side (A) to the actuator housing. If there is no actuator housing, cut the shield on the actuator side and insulate it.
   b) Connect the cable shield on the connector side (B) to the connector shell.
4. Connect the connector of the P-405 to the corresponding connection on the electronics.

6 Startup and Operation

In this Chapter

6.1 General Notes on Startup and Operation

DANGER

Dangerous voltage in piezo actuators during operation!

During operation, the P-405 is subject to voltages up to 500 V. The protective polymer layer of the piezo actuator does **not** protect against electric shock. Touching the live parts of the P-405 can result in serious injury or death from electric shock.

- Do **not** touch the piezo actuator during operation.
- Before startup, insulate the piezo actuator electrically from the surrounding mechanics to prevent direct or indirect contact with live parts. Pay attention to the clearances and creepage distances required for the operating voltage as well as the standards applicable to your application.

DANGER

Risk of electric shock if the protective earth conductor is not connected!

The system in which the P-405 is integrated (e.g., housing or surrounding mechanics) must be connected to a protective earth conductor. If the protective earth conductor is missing or not properly connected, dangerous touch voltages can occur in the overall system in the event of malfunction or failure of the system. If touch voltages exist, touching the overall system can result in serious injury or death from electric shock.

- Before startup, connect the overall system to a protective earth conductor in accordance with the applicable standards.
- Do **not** remove the protective earth conductor during operation.
- If the protective earth conductor has to be temporarily removed (e.g., for modifications), reconnect the overall system to the protective earth conductor before starting it up again.

NOTICE

Destruction of the piezo actuator due to electric flashovers!

Using the P-405 in environments that increase the electrical conductivity can lead to the destruction of the piezo actuator by electric flashovers. Electric flashovers can be caused by moisture, high humidity, liquids, and conductive materials (e.g., metal dust). In addition, electric flashovers can also occur in certain air pressure ranges due to the increased conductivity of the air.

- Avoid operating the P-405 in environments that can increase the electrical conductivity.
- Only operate the P-405 within the permissible ambient conditions and classifications (p. 41).
- Prevent the piezo actuator from coming into contact with liquids.
- Protect the piezo actuator against moisture by means of hermetic sealing or the supply of dry air.
- In the air pressure range between 1 hPa and 500 hPa:
  Do **not** operate the P-405, or operate it only at reduced voltage (max. 200 V).
- When using in a vacuum under 0.1 hPa (P-405 vacuum-compatible custom products only):
  Do **not** operate the P-405 while evacuating or ventilating.
- If the P-405 is to be operated in a special gas atmosphere, contact our customer service department (p. 37).

NOTICE

Destruction of the piezo actuator due to dynamic forces!

During dynamic operation, dynamic forces can be generated that lead to mechanical overload of the piezo actuator. Dynamic forces can cancel preloading of preloaded piezo actuators. Dynamic operation at too high loads or dynamic operation without preloading can destroy the piezo actuator.

- Do **not** exceed the maximum compressive stress of 15 MPa.
- Avoid tensile stress.
- Do **not** exceed the maximum shear load according to the data table (p. 39).
- If preloading is required, contact our customer service department (p. 37).

NOTICE

Destruction of the piezo actuator due to excessive operating frequencies!

An excessive operating frequency can cause thermal and mechanical overloading that destroys the piezo actuator.

- ➢ Select the operating frequency so that the following conditions are met:
  - The operating frequency of the piezo actuator does not exceed one third of the resonant frequency. The resonant frequency according to the data table (p. 39) applies to unclamped operation without load. In an arrangement with unilateral clamping, the value must be halved.
  - Dynamic forces generated during operation do **not** exceed the maximum compressive stress capability of the piezo actuator of 15 MPa and do not result in tensile stress.
- ➢ Reduce the voltage at high frequencies or apply a low preload (p. 40) to avoid mechanical overload. If preloading is required, contact our customer service department (p. 37).
- ➢ If your application involves operation of the piezo actuator with greater loads, contact our customer service department (p. 37).

NOTICE

Damage due to steep edges in the control signal!

If the actuator does not have a preload, steep edges in the control signal can trigger strong dynamic forces which damage the piezo actuator. Steep edges can occur, for example, when digital wave generators are switched on.

- ➢ Avoid steep edges in the control signal on actuators with low preload.

NOTICE

Damage after reconnecting due to a charged piezo actuator!

The piezo actuator can remain charged when the connecting cable of the piezo actuator is pulled out of the electronics during operation. Reconnecting a charged piezo actuator to electronics during operation can cause a mechanical impulse that will damage the piezo actuator.

- ➢ Do **not** pull the connecting cable of the piezo actuator out of the electronics during operation.

If the connecting cable of the piezo actuator was accidentally pulled out of the electronics during operation:

- ➢ Discharge the piezo actuator accordingly before reconnecting (p. 30).
- ➢ Switch off the electronics before you reconnect the piezo actuator.

NOTICE

Reduced lifetime due to permanently high voltage and high air humidity!

Applying a high static voltage to piezo actuators continuously reduces the lifetime of the piezo ceramic. This applies in particular to operation in a humid environment.

- When the P-405 is not in use but the electronics remain switched on to ensure temperature stability, discharge the P-405 (p. 30).
- Reduce offset voltages to a minimum.
- Protect the piezo actuator against moisture by means of hermetic sealing or the supply of dry air.
- Make sure that the air humidity in the vicinity of the P-405 does not exceed the relative humidity specified in "Ambient Conditions and Classifications" (p. 41).

NOTICE

Operating voltage too high or incorrectly connected!

Operating voltages that are too high or incorrectly connected can cause damage to the P-405.

- Do **not** exceed the operating voltage range (p. 40) for which the P-405 is specified.
- Operate the P-405 only when the operating voltage is properly connected; see "Connecting the P-405 to the Electronics" (p. 22).

NOTICE

Destruction of the piezo actuator due to rapid cooling or heating!

Cooling down or heating up too quickly leads to a thermomechanical load that can destroy the piezo actuator.

- Allow the piezo actuator to cool down or warm up slowly.

NOTICE

Uncontrolled oscillation!

Oscillation can cause irreparable damage to the P-405. Oscillation is indicated by a humming noise and can be caused by the following:

- A change in the load and/or dynamics requires the operating parameters to be adjusted.
- The P-405 is operated near to its resonant frequency.

If you notice oscillation:

- Stop the P-405 immediately.

INFORMATION

The positive direction of motion (p. 11) corresponds to the expansion direction of the piezo actuator when a positive voltage is applied.

6.2 Calculating the Power Requirement for Sinusoidal Operation

- Calculate the average current requirement for sinusoidal operation using the following formula:

  $I_a \approx f \cdot C \cdot U_{p\text{-}p}$

- Calculate the peak current requirement for sinusoidal operation using the following formula:

  $I_{max} \approx f \cdot \pi \cdot C \cdot U_{p\text{-}p}$

Variable	Description	Notes
I_a	Required average current of the amplifier (source / sink) [A]	It is essential that the power supply can supply enough current.
I_{max}	Required peak current of the amplifier (source / sink) [A]	
f	Operating frequency [Hz]	The operating frequency may not exceed one third of the resonant frequency. The resonant frequencies specified in the data tables (p. 39) apply to operation of the piezo actuator when it is unloaded and not clamped on both sides. In an arrangement with unilateral clamping, the value must be halved.
C	Capacitance of the piezo actuator [F (= As/V)]	See "Data Table" (p. 39) for the capacitance of the piezo actuator.
$U_{p\text{-}p}$	Operating voltage (peak-to-peak) [V]	

6.3 Operating the P-405

INFORMATION

To determine the optimum operating parameters (e.g., operating frequency, operating voltage, operating time and load) for your application, contact our customer service department (p. 37).

Requirements

- ✓ You have read and understood the general notes on startup and operation (p. 25).
- ✓ You have installed (p. 17) the P-405 correctly and connected it to the electronics (p. 22).
- ✓ You have provided suitable electronics that can supply the required currents (p. 29).
- ✓ You have read and understood the user manual of the electronics used.

Operating the P-405

➢ For starting up and operating the P-405, follow the instructions in the manual for the electronics (p. 12) used.

6.4 Discharging the P-405

The P-405 must be discharged in the following cases:

- When the P-405 is not in use but the electronics remain switched on to ensure temperature stability
- If the stranded wires of the P-405 are to be short-circuited without discharge resistor, e.g., with a shorting clamp (p. 10)
- If the connecting cable of the P-405 is accidentally pulled out of the electronics during operation

Requirements

✓ You have read and understood the general safety instructions (p. 6).

Tools and accessories

If the P-405 is not connected to the electronics:

- For P-405 **without** connector only (delivery condition):
  - 100 kΩ discharge resistor (not in the scope of delivery); touchable parts must be adequately insulated for the operating voltage range (p. 40) of the actuator
- Only for P-405 **with** connector (p. 22):
  - Electronics (p. 12) from PI or a suitable shorting plug with built-in 100 kΩ discharge resistor (available on request)

Discharging a P-405 connected to the electronics

➢ Set the piezo voltage to 0 V on the electronics.

Discharging a P-405 not connected to the electronics

If the P-405 does **not** have a connector:

1. Ensure adequate protection against touching live parts.
2. Short-circuit the stranded wires of the P-405 for at least a few seconds using a **100 kΩ discharge resistor**.

If the P-405 has a connector (p. 22):

➢ Connect the voltage connector of the P-405 to the switched off PI electronics, which has an internal discharge resistor, for at least a few seconds.

➢ Alternative: Connect a suitable shorting plug with integrated discharge resistor to the voltage connector of the P-405 for at least a few seconds.

6.5 Short-Circuiting the P-405

The P-405 must be discharged (p. 30) and short-circuited before demounting (e.g., before cleaning and transporting the P-405) as well as for modifications.

Requirements

- ✓ You have read and understood the general safety instructions (p. 6).
- ✓ If a shorting clamp needs to be connected: You have discharged (p. 30) the P-405.
- ✓ You have disconnected the P-405 from the electronics.

Tools and accessories

- Only for P-405 **without** connector (delivery condition):
  - Supplied shorting clamp (p. 12)
- Only for P-405 **with** connector (p. 22):
  - Suitable shorting plug with built-in 100 kΩ discharge resistor (available on request)

Short-circuiting the P-405

If the P-405 does **not** have a connector:

- ➢ Short-circuit the stranded wires of the **discharged** P-405 with the shorting clamp supplied.

If the P-405 has a connector (p. 22):

- ➢ Connect a suitable shorting plug with integrated discharge resistor to the voltage connector of the P-405.

7 Maintenance

In this Chapter

7.1 General Notes on Maintenance

The P-405 is maintenance-free.

7.2 Cleaning the P-405

NOTICE

Destruction of the piezo actuator due to electric flashovers!

If it comes into contact with liquids, the piezo actuator can be destroyed by electric flashovers.

Before cleaning the P-405:

➢ Ensure that the P-405 is discharged (p. 30) and short-circuited (p. 31).

After cleaning the P-405:

➢ Dry the P-405 completely in a drying cabinet (recommended duration: 30 minutes at 40 °C).

NOTICE

Damage due to use of unsuitable cleaning agents!

Some cleaning agents may cause damage to the P-405.

➢ Do **not** use acetone and do **not** use water for cleaning.

Requirements

✓ The P-405 is discharged (p. 30) and short-circuited (p. 31).

✓ The P-405 is disconnected from the electronics.

Cleaning the P-405

- Touch the piezo actuator only with powder-free nitrile or latex gloves.
- When necessary, clean the surfaces of the P-405 with a lint-free cloth that is dampened with a mild cleanser (e.g., isopropyl alcohol or ethanol).
- When cleaning in an ultrasonic bath:
  - Reduce the energy input to the necessary minimum.
  - Use isopropyl alcohol or ethanol as cleaning fluid only.
  - Make sure that the cleaning time is 5 minutes.
- After cleaning, dry the P-405 completely in a drying cabinet (recommended duration: 30 minutes at 40 °C).

8 Troubleshooting

Problem	Possible causes	Solution
No or limited motion	Cable not connected correctly	➢ Check the cable connections.
	Excessive load	➢ Do **not** exceed the maximum compressive stress of 15 MPa. ➢ Avoid tensile stress.
Piezo actuator moves in the opposite direction (p. 11) to that specified when voltage increases	Reverse polarity of the piezo actuator	➢ To ensure correct polarity (p. 11), pay attention to the voltage and ground connections.

If the problem that occurred with your system is not listed in the table above or cannot be solved as described, contact our customer service department (p. 37).

9 Customer Service

You can contact PI Ceramic by telephone under +49 36604 882-0 or by email at the following address:

- For general questions or for orders:
  info@piceramic.com
- In the case of technical problems or faults:
  service@piceramic.com

➢ If you have any questions concerning your product, provide the following information:
  - Product and serial numbers of all products concerned
  - Firmware version of the electronics (if applicable)
  - Version of the driver or the software (if applicable)
  - Operating system on the PC (if applicable)

➢ If possible: Take photographs or make videos of your system that can be sent to our customer service department if requested

The latest versions of the user manuals are available for download (p. 3) on our website.

10 Technical Data

In this Chapter

10.1 Specifications

10.1.1 Data Table

	P-405.05	P-405.08	P-405.15	P-405.18	P-405.28	Unit
Active axes	Z	Z	X	X	XZ	
Dimensions A × B × L	5 mm × 5 mm × 12.5 mm	10 mm × 10 mm × 12.5 mm	5 mm × 5 mm × 7.5 mm	10 mm × 10 mm × 7.5 mm	10 mm × 10 mm × 19 mm	
Travel range*	1	1	1	1	1 / 1	µm
Axial stiffness	140	550	230	900	350	N/µm
Max. shear load	10	100	20	150	50	N
Electrical capacitance**	0.95	3.75	0.7	2.75	2.75 / 3.75	nF
Resonant frequency***	160	160	–	–	105	kHz
Piezo material	PIC050	PIC050	PIC050	PIC050	PIC050	
Operating voltage range	-500 to 500	-500 to 500	-500 to 500	-500 to 500	-500 to 500	V
Operating temperature range	-20 to 85	-20 to 85	-20 to 85	-20 to 85	-20 to 85	°C
Recommended electronics	E-508	E-508	E-508	E-508	E-508	

* At -500 to 500 V, tolerance ±20 %

** Measured at 1 V_{pp}, 1 kHz, RT, tolerance ±10 %

*** Measured at 1 V_{pp}, unloaded, unclamped. The value is halved for unilateral clamping.

Standard connections: PTFE-insulated wire leads, 100 mm, AWG 32, Ø 0.76 mm.

Standard end parts: Ceramics

Lateral surface: Epoxy resin

Ask about customized versions!

10.1.2 Maximum Ratings

P-405 piezo actuators are designed for the operating data specified in the table below.

Additional information on the maximum ratings table

- Maximum operating frequency without load:

The values apply to piezo actuators clamped unilaterally and are calculated as follows: A third of the resonant frequency or respectively the shear resonant frequency of the unloaded piezo actuator (not clamped on both sides) divided by two (clamped unilaterally). Higher operating frequencies are only possible at lower operating voltage amplitudes and when the P-405 is preloaded (p. 40).

- Maximum power consumption:

Power consumption of the unloaded, uncooled piezo actuator operated at a voltage of **1000 V peak-to-peak** with the specified operating frequency.

Piezo actuator	Maximum operating voltage range ⚠	Maximum operating frequency without load ⚠	Maximum power consumption ⚠
P-405.05	–500 V to 500 V	27 kHz	25 W
P-405.08	–500 V to 500 V	27 kHz	80 W
P-405.15	–500 V to 500 V	27 kHz	15 W
P-405.18	–500 V to 500 V	27 kHz	60 W
P-405.28	–500 V to 500 V	17 kHz	95 W (60 W in Z, 35 W in X)

10.1.3 Compressive/Tensile Stress Capacity and Preload

Type of mechanical stress	P-405*
Maximum compressive load capacity	15 MPa
Maximum tensile stress capacity without preload	None**
Preload	1 to 5 MPa

* 1 MPa corresponds to a pressure of 1 N per square millimeter of the base area of the piezo actuator (see "Dimensions" (p. 42)).

** Tensile stress can damage the piezo actuator and must be avoided.

If your application involves dynamic operation, contact our customer service department (p. 37).

10.1.4 Ambient Conditions and Classifications

The following ambient conditions and classifications for the P-405 must be observed:

Area of application	For indoor use only
Air pressure	>1 hPa ➢ Pay attention to the notes on electrical flashovers in "General Notes on Startup and Operation" (p. 25).
Relative humidity	Maximum relative humidity 50 % Continuous operation with high static voltage in humid environments significantly reduces piezo actuator lifetime. ➢ Pay attention to the notes on lifetime in "General Notes on Startup and Operation" (p. 25).
Operating temperature	–20 °C to 85 °C
Storage temperature	–20 °C to 80 °C
Transport temperature	–20 °C to 80 °C
Supply voltage fluctuations	Max. ±10 % of the nominal voltage
Overvoltage category	II
Degree of pollution	1

The P-405 is intended for installation in devices that fulfil the following classifications:

Protection class	I
Degree of protection according to IEC 60529	IP00

10.2 Dimensions

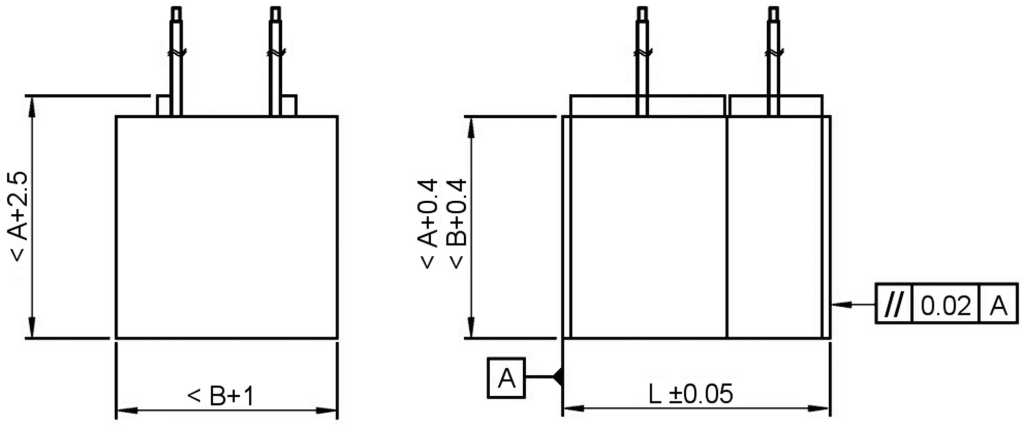

Figure 12: P-405, dimensions in mm. A, B, L see table.

Model	A	B	L	Unit
P-405.05	5	5	12.5	mm
P-405.08	10	10	12.5	mm
P-405.15	5	5	7.5	mm
P-405.18	10	10	7.5	mm
P-405.28	10	10	19	mm

11 Old Equipment Disposal

In accordance with EU law, electrical and electronic equipment may not be disposed of in EU member states via the municipal residual waste.

For disposal, observe the international, national, and local rules and regulations.

In order to fulfil the responsibility as the product manufacturer, PI Ceramic GmbH offers the environmentally correct disposal of PI products made available on the market after August 13, 2005, without charge.

Any product from PI Ceramic that is to be disposed of can be sent free of shipping costs to the following address:

PI Ceramic GmbH

Lindenstrasse

D-07589 Lederhose, Germany

12 EU Declaration of Conformity

An EU Declaration of Conformity was issued for the P-405 in accordance with the following European directives:

RoHS Directive

The applied standards certifying the conformity are listed below.

RoHS: EN 50581

If an electrical operating device is designed to be integrated into another electrical operating device: The operator is responsible for standards compliant integration of the electrical device into the overall system.