PZ266E

P-88x.x5 Piezo Actuator

User Manual

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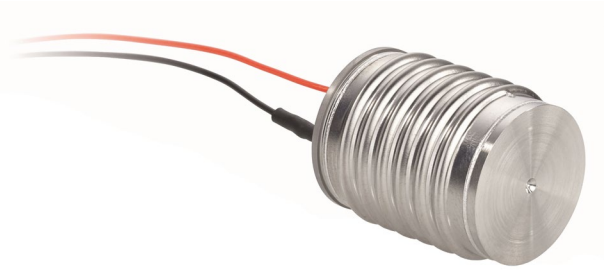

This document describes the following products:

- **P-885.55**
  Encapsulated PICMA® piezo actuator, 14 µm travel range, OD 11.2 mm × L 22.5 mm, stranded wires
- **P-885.95**
  Encapsulated PICMA® piezo actuator, 30 µm travel range, OD 11.2 mm × L 40.5 mm, stranded wires
- **P-888.55**
  Encapsulated PICMA® piezo actuator, 14 µm travel range, OD 18.6 mm × L 22.5 mm, stranded wires

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1 About this Document

In this Chapter

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Validity for Custom Products 1
Symbols and Typographic Conventions 1
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1.1 Objective and Target Audience of this User Manual

This user manual contains the necessary information for the intended use of the P-88x.x5 (x stands for the different models (p. 9)).

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

1.2 Validity for Custom Products

This user manual also applies to custom products from the "Encapsulated PICMA® Stack piezo actuators" 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.

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

1.3 Symbols and Typographic Conventions

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

CAUTION

Dangerous situation
Failure to comply could lead to minor injuries or damage to equipment.

➢ Precautionary measures for avoiding the risk.

NOTICE

Dangerous situation
Failure to comply could cause damage to equipment.

➢ Precautionary 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 with strict sequential order
➢	Action consisting of one or more steps without relevant sequential order
▪	List item
p. 5	Cross-reference to page 5
RS-232	Operating element labeling 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 separate manuals.

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

Product	Document
E-503 piezo amplifier module	PZ62E user manual
E-504 piezo amplifier module	PZ62E user manual
E-505 piezo amplifier module	PZ62E user manual
E-506 piezo charge amplifier	PZ62E user manual

Product	Document
E-610 piezo amplifier / servo controller	PZ72E user manual
	PZ70E user manual
E-617 high-performance piezo amplifier	PZ201E user manual
E-618 high-performance piezo amplifier / servo controller	PZ221E user manual
E-663 piezo amplifier	PZ69E user manual
E-831 piezo amplifier module	PZ191E user manual
	PZ235E user manual
E-836 compact piezo amplifier / OEM module	PZ250E user manual

1.6 Downloading Manuals

INFORMATION

If a manual is missing or problems occur with downloading:

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

Downloading Manuals

1. Open the website **www.pi.ws**.
2. Search the website for the product number (e.g., P-885) or the product family (e.g., PICMA® Stack).
3. Click the corresponding product to open the product detail page.
4. Click the ***Downloads*** tab.

   The manuals are shown under ***Documentation***. Software manuals are shown under ***General Software Documentation***.
5. Click the desired manual and fill out the inquiry form.

   The download link will then be sent to the email address entered.

2 Safety

In this Chapter

Intended Use 5
General Safety Instructions 5
Organizational Measures 7

2.1 Intended Use

The P-88x.x5 is intended for use in an environment where spray water or oil is possible or where high air humidity prevails.

In accordance with its design, the P-88x.x5 is intended for integration into a mechanical system and for the following applications:

- Positioning of loads
- Vibration damping
- Force generation

The following applications are only permitted after consultation with the customer service department (p. 37):

- Dynamic positioning
- Complete immersion into a liquid

The operator is responsible for standards-compliant integration of the P-88x.x5 into the overall system.

The motion of the P-88x.x5 takes place in one axis. When mounting without preload, avoid tensile stress (p. 41).

For operation of the P-88x.x5, suitable electronics that provide the required operating voltages are required. The electronics are not included in the scope of delivery of the P-88x.x5. We recommend the use of suitable electronics (p. 11) from PI.

2.2 General Safety Instructions

The P-88x.x5 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-88x.x5.

- ➢ Use the P-88x.x5 for its intended purpose only, and only when it is in perfect technical condition.
- ➢ Read the user manual.
- ➢ Eliminate any malfunctions that may affect safety immediately.

The operator is responsible for the correct installation and operation of the P-88x.x5.

Temperature changes and compressive stress can induce charges in the P-88x.x5 piezo actuator. The piezo actuator can remain charged for several hours after disconnecting the electronics. Touching the live parts on the P-88x.x5 can result in minor injury from electric shock.

- Touch the stranded wires only when the piezo actuator is discharged (p. 30).
- Keep the piezo actuator short-circuited (p. 31) when it is not connected to the electronics.
- Do **not** disassemble the piezo actuator.

The system into which the piezo actuator is integrated (e.g., housing or surrounding mechanical system) must be connected to a protective earth conductor. If the protective earth conductor is not or not properly connected, touching the system in which the piezo actuator was incorporated can lead to minor injury from electric shock in the case of a malfunction.

- 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 restarting.

Mechanical forces can damage the P-88x.x5.

- Avoid impacts that affect the P-88x.x5.
- Do **not** drop the P-88x.x5.
- Avoid torques and lateral forces on the P-88x.x5.
- 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. 41).

If the piezo actuator is to be used in a vacuum, attention must be paid to the corresponding cleanliness. At PI, all parts are cleaned before assembly. During assembly and calibration, powder-free gloves are worn. Afterwards, the piezo actuator is wiped clean once again and then shrink-wrapped in vacuum-compatible film.

- When handling the piezo actuator, wear powder-free nitrile or latex gloves.
- If necessary, wipe the piezo actuator clean after unpacking.

2.3 Organizational Measures

User manual

- Always keep this user manual together with the P-88x.x5.
  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-88x.x5 to a third party, include this user manual as well as other relevant information provided by the manufacturer.
- Do the work only if the user manual is complete. Missing information due to an incomplete user manual can result in minor injury and damage to equipment.
- Install and operate the P-88x.x5 only after you have read and understood this user manual.

Personnel qualification

The P-88x.x5 may only be installed, started, operated, maintained, and cleaned by authorized and appropriately qualified personnel.

3 Product Description

In this Chapter

Model Overview 9
Product View 10
Product Labeling 10
Scope of Delivery 11
Suitable Electronics 11
Accessories 12
Technical Features 12

3.1 Model Overview

Encapsulated PICMA® Stack multilayer piezo actuators with inert gas filling

Model	Description
P-885.55	Encapsulated PICMA® piezo actuator, 14 µm travel range, OD 11.2 mm × L 22.5 mm, stranded wires
P-885.95	Encapsulated PICMA® piezo actuator, 30 µm travel range, OD 11.2 mm × L 40.5 mm, stranded wires
P-888.55	Encapsulated PICMA® piezo actuator, 14 µm travel range, OD 18.6 mm × L 22.5 mm, stranded wires

3.2 Product View

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

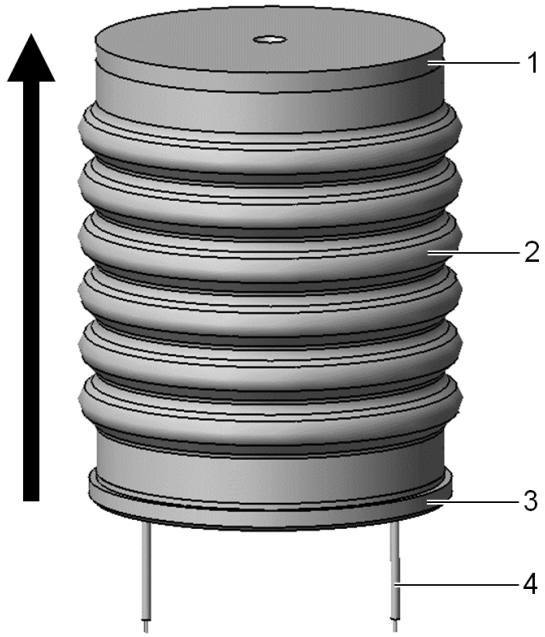

Figure 1: Exemplary product view: P-88x.x5

1: Stainless steel tip

2: Metal bellows

3: Stainless steel base

4: Stranded wire:
Red stranded wire: Voltage connection (+)
Black stranded wire: Connection for ground (-)

Arrow: Expansion direction of the piezo actuator when a positive voltage is applied

The tip (1), the metal bellows (2), and the base (3) form the stainless steel housing.

3.3 Product Labeling

Before delivery, each P-88x.x5 is vacuum-packed in an ESD protection bag that prevents the piezo actuator from becoming charged during transport. Larger actuators are additionally packed in tubes to protect them against breakage.

Every ESD protection bag has a sticker with the following information:

Labeling	Description
	Data Matrix code (example; contains the abbreviated batch number and the product number)

Labeling	Description
P-885.55	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).
16CEP0653128979	Batch number (example), individual for each P-88x.x5
PI	Manufacturer's logo
1 piece	Quantity
Country of origin: Germany	Country of origin
WWW.PICERAMIC.COM	Manufacturer's address (website)

3.4 Scope of Delivery

Product number	Description
P-88x.x5	Piezo actuator according to order (p. 9)
PZ264EK	Short instructions for PICMA® multilayer piezo actuators

3.5 Suitable Electronics

To operate a P-88x.x5, you need electronics. The device is selected depending on the type of application. The table below lists the suitable devices.

Product number	Description
E-503	Piezo amplifier module (for E-500 piezo controller system)
E-504	Piezo amplifier module (for E-500 piezo controller system)
E-505	Piezo amplifier module (for E-500 piezo controller system)
E-506	Piezo charge amplifier (for E-500 piezo controller system)
E-610	Piezo amplifier / servo controller
E-617	High-performance piezo amplifier
E-618	High-performance piezo amplifier / servo controller
E-663	Piezo amplifier
E-831	Piezo amplifier module
E-836	Compact piezo amplifier / OEM module

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

3.6 Accessories

Product number	Description
P-890.10	Cable for piezo voltage, LEMO connector/open end, 1 m
P-890.20	Cable for piezo voltage, LEMO connector/open end, 5 m
The P-890.xx cable is for connecting the P-88x.x5 to a low-voltage piezo amplifier. The cable is soldered on the actuator side. Connector: LEMO FFS.00.250.CTCE24, coaxial Cable: RG 178 (Teflon)	

➢ To order, contact our customer service department (p. 37).

3.7 Technical Features

PICMA® piezo actuators

PICMA® actuators have all-ceramic insulation and their performance and lifetime are therefore far superior to conventional actuators. The ceramic insulation layer protects the monolithic piezoceramic block against humidity and failure due to increased leakage current. In this way, an especially high reliability is achieved even under extreme ambient conditions.

Encapsulated PICMA® stack piezo actuators

Encapsulated PICMA® stack actuators are surrounded by inert gas and have a stainless steel housing. They can also be used when the application environment is characterized by oil, spray water or continuously high humidity.

4 Unpacking

INFORMATION

If the piezo actuator is to be used in a vacuum, attention must be paid to the corresponding cleanliness. At PI, all parts are cleaned before assembly. During assembly and calibration, powder-free gloves are worn. Afterwards, the piezo actuator is wiped clean once again and then shrink-wrapped in vacuum-compatible film.

- When handling the piezo actuator, wear powder-free nitrile or latex gloves.
- If necessary, wipe the piezo actuator clean after unpacking.

1. Unpack the P-88x.x5 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

General Notes on Installing 15
Mounting the P-88x.x5 19
Applying the Load 20
Connecting the P-88x.x5 to the Electronics 21

5.1 General Notes on Installing

CAUTION

Dangerous voltage and residual charge in piezo actuators!

Temperature changes and compressive stress can induce charges in the P-88x.x5 piezo actuator. The piezo actuator can remain charged for several hours after disconnecting the electronics. Touching the live parts on the P-88x.x5 can result in minor injury from electric shock.

- Touch the stranded wires only when the piezo actuator is discharged (p. 30).
- Keep the piezo actuator short-circuited (p. 31) when it is not connected to the electronics.
- Do **not** disassemble the piezo actuator.

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 in order to prevent the piezo actuator from becoming charged during temperature changes and compressive stress. Unsuitable short-circuiting leads to an abrupt contraction of the piezo actuator due to excessively fast discharging. Abrupt contraction can destroy the piezo actuator.

- As soon as you have removed the piezo actuator from the conductive original packaging, twist the stranded wires together.
- Only disconnect the short-circuit connection of the piezo actuator if this is necessary for installation or operation.
- If the piezo actuator is not short-circuited:
  - Ensure adequate protection against touching live parts.
  - Discharge the piezo actuator in a suitable way before short-circuiting again (p. 30).

NOTICE

Short-circuiting due to complete immersion in a liquid!

Complete immersion of the P-88x.x5 into a liquid can lead to short-circuiting at the stranded wires. A short-circuit can destroy the P-88x.x5 as well as the electronics connected.

- Avoid immersing the stranded wires into liquids. If your application requires complete immersion of the P-88x.x5 into a liquid, contact our customer service department (p. 37).

NOTICE

Damage to the piezo actuator due to excessive preloading!

Excessive preloading can mechanically depolarize the piezo actuator. Depolarization damages the piezo actuator.

- Only apply preloads that are just as high as necessary.
- Do **not** exceed the maximum preload (p. 41).

NOTICE

Destruction of the piezo actuator due to mechanical overload!

Torques, lateral forces, and excessive loads can destroy the piezo actuator.

- Do **not** exceed the maximum compressive/tensile stress capacity (p. 41).
- Avoid torques and lateral forces on the piezo actuator.
- Make sure that the center of load of the moving system is on the motion axis of the piezo actuator.
- Avoid an uneven load distribution by using suitable structures or guide elements (e.g., ball tips or flexure guides).
- Establish contact over as large an area as possible on the end surfaces of the piezo actuator, and select opposing surfaces with a flatness of only a few micrometers. Minor unevenness can be compensated by full-surface gluing, for example.

NOTICE

Damage to the piezo actuator due to sideways mounting!

Sideways mounting of the housing leads to deformation of the metal bellows of the piezo actuator and restricts its motion. The piezo actuator can be damaged when mounting the housing sideways.

- Do **not** mount the housing of the piezo actuator sideways.

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

Heating up of the P-88x.x5 during operation!
The heat produced during operation of the P-88x.x5 can affect your application.

➢ Install the P-88x.x5 so that your application is not affected by the dissipating heat.

INFORMATION

Ground loops can occur when the piezo actuator is installed in a housing that is grounded via the shield of the connecting cable of the piezo actuator as well as a separate protective earth conductor.

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

Avoiding mounting errors

Piezo actuators may only be loaded axially. Moreover, piezo actuators should be preloaded mechanically in order to avoid tensile stress. The following figures are to help you avoid mounting errors.

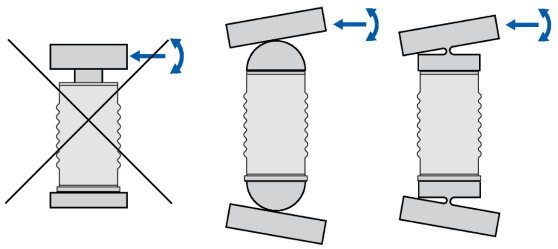

Figure 2: Prevention of lateral forces and torque

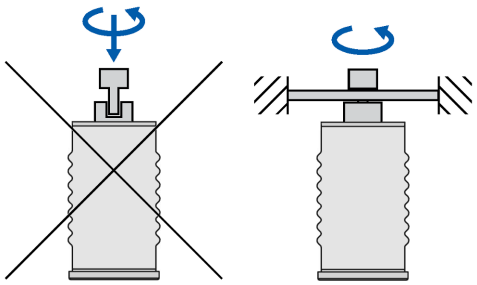

Figure 3: Prevention of torque

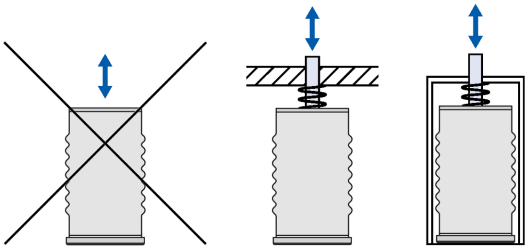

Figure 4: Prevention of tensile stress by means of a mechanical preload

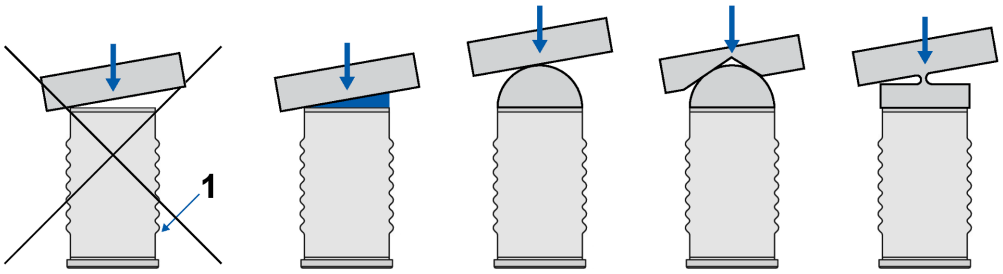

Figure 5: Prevention of an irregular load application (1: Tensile stress)

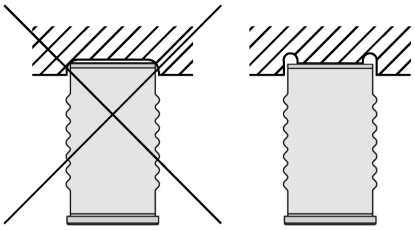

Figure 6: Full-area contact of the piezo actuator

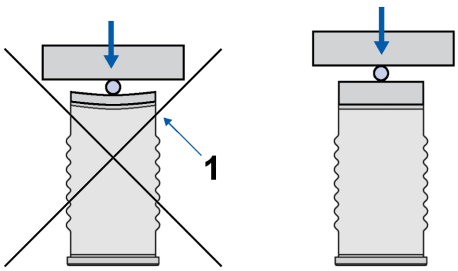

Figure 7: Proper dimensioning of the end pieces in the case of point contact (1: Tensile stress)

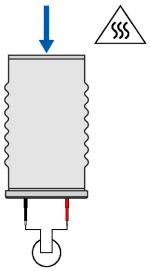

Figure 8: Mechanical or thermal loads electrically charge the piezo actuator. Mount only when short-circuited.

5.2 Mounting the P-88x.x5

P-88x.x5 piezo actuators are glued to metal or ceramic surfaces.

Requirements

- ✓ You have read and understood the general notes on installation (p. 15).
- ✓ The P-88x.x5 is discharged (p. 30) and short-circuited (p. 31).
- ✓ You have read and understood the user information of the manufacturer of the adhesive.
- ✓ The surface, onto which the piezo actuator is to be glued, has two holes (Ø ≥1.5 mm) for feeding the stranded wires of the piezo actuator through. See "Dimensions" (p. 42) for the gap between the stranded wires.

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-88x.x5

1. Glue the piezo actuator to the surface:
   - Apply the thinnest possible layer of adhesive and feed the stranded wires of the piezo actuator through the holes in the surface so that the stranded wires do not go between the actuator and the surface.
   - During the hardening process, maintain the operating temperature range (p. 41) specified for the piezo actuator.
   - Pay attention to the temperature expansion coefficients of the materials involved.
2. Press the piezo actuator until the adhesive has hardened.

5.3 Applying the Load

The P-88x.x5 can be coupled to a load in various ways, depending on the application:

- Gluing the piezo actuator (p. 19) into the mechanical system to be moved or into a flexure
- Using a ball tip:
  - Gluing a hardened ball tip, which establishes a single-point contact to an even surface
  - Gluing a hardened ball tip, which establishes a ring-shaped contact to a calotte

INFORMATION

Diagrams showing how to couple the P-88x.x5 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. 15).

✓ The P-88x.x5 is discharged (p. 30) and short-circuited (p. 31).

Tools and accessories

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

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 end surface of the piezo actuator. For this purpose, choose the dimensions of the milling pocket correspondingly or make free cuts in the milling pocket.

If a point load is applied to the end piece of the piezo actuator:

➢ Dimension the end piece so that its thickness corresponds to half the cross-sectional dimension in order to prevent tensile stress on the piezo actuator.

5.4 Connecting the P-88x.x5 to the Electronics

The P-88x.x5 piezo actuator is connected to a LEMO socket, a terminal, or soldering pins, depending on the electronics.

This section describes how the P-88x.x5 piezo actuator is connected with the P-890.xx coaxial cable to electronics with a LEMO coaxial socket.

- ➢ For connection to the electronics with other LEMO connectors, contact our customer service department (p. 37).
- ➢ If you use a self-made connecting cable instead of the P-890.xx coaxial cable, pay attention to the relevant standards as well as the assembly information of the manufacturer of the connector used.
- ➢ For connection to terminals or solder pins, refer to the manual of the respective electronics used (p. 2).

INFORMATION

The P-88x.x5 has color-coded stranded wires:

- Red stranded wire: Voltage connection (+)
- Black stranded wire: Ground (-)

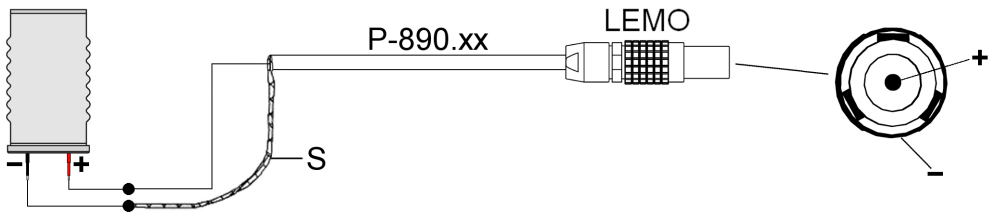

Figure 9: Connection of the P-88x.x5 piezo actuator to the P-890.xx coaxial cable

+	On the piezo actuator (left): Red stranded wire for voltage connection On the LEMO connector (right): Inner contact for voltage connection
-	On the piezo actuator (left): Black stranded wire for ground On the LEMO connector (right): Connector housing
S	Cable shield
LEMO	LEMO FFS.00.250.CTCE24 coaxial connector

Requirements

- ✓ You have read and understood the general notes on installation (p. 15).
- ✓ You have read and understood the user manual of the electronics used.
- ✓ If the P-88x.x5 is not short-circuited: The P-88x.x5 is discharged (p. 30).
- ✓ The electronics are **switched off**.
- ✓ The electronics have a suitable LEMO socket for the connector on the P-890.xx coaxial cable.

Tools and accessories

- P-890.xx coaxial cable (p. 12), LEMO to open end (can be ordered separately)
- Suitable soldering iron
- Suitable solder
- Suitable cable tools

Connecting the P-88x.x5 to the electronics

1. If necessary, shorten the wire and the cable shield of the coaxial cable to the correct length.
2. Make the stranded wires of the P-88x.x5 accessible:
   - If the stranded wires of the P-88x.x5 are short-circuited, sever the connection between the stranded wires.
   - Remove all aids and components that have been connected to the P-88x.x5 for short-circuiting or discharging (e.g., discharging resistor).
3. Solder the red stranded wire of the P-88x.x5 to the wire of the coaxial cable connected to the inner contact of the LEMO connector.
4. Solder the black stranded wire of the P-88x.x5 to the cable shield of the coaxial cable.
5. Insulate the soldered cable connections appropriately.
6. Connect the connector of the P-88x.x5 to the corresponding connection on the electronics.

6 Starting and Operating

In this Chapter

General Notes on Starting 23
Determining the Operating Parameters 26
Operating the P-88x.x5 29
Discharging the P-88x.x5 30
Short-Circuiting the P-88x.x5 31

6.1 General Notes on Starting

CAUTION

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

The system into which the piezo actuator is integrated (e.g., housing or surrounding mechanical system) must be connected to a protective earth conductor. If the protective earth conductor is not or not properly connected, touching the system in which the piezo actuator was incorporated can lead to minor injury from electric shock in the case of a malfunction.

- 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 restarting.

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.

- If your application involves dynamic operation, contact our customer service department (p. 37).
- 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 maximum compressive/tensile stress capacity (p. 41) of the piezo actuator is not exceeded.
  - The maximum permissible operating temperature of the piezo actuator is not exceeded. For details, see "Overview of Limiting Factors" (p. 26).
- Reduce the voltage at high operating frequencies to minimize the heating of the piezo actuator.
- If your application involves the operation of a piezo actuator which is not clamped on both sides, 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 of the piezo actuator due to permanently high voltage!

Applying a continuous high static voltage to piezo actuators reduces the lifetime of the piezo ceramic.

- When the P-88x.x5 is not in use but the electronics remain switched on to ensure temperature stability, discharge the P-88x.x5 (p. 30).
- If possible: Limit the maximum operating voltage during continuous operation.
- Reduce offset voltages to a minimum.

NOTICE

Operating voltage excessively high or incorrectly connected!

Operating voltages that are too high or incorrectly connected can cause damage to the P-88x.x5.

- Do **not** exceed the operating voltage range (p. 40) for which the P-88x.x5 is specified.
- Operate the P-88x.x5 only when the operating voltage is properly connected; see "Connecting the P-88x.x5 to the Electronics" (p. 21).
- If you have applied the operating voltage with the wrong polarity accidentally, contact our customer service department (p. 37).

NOTICE

Destruction of the piezo actuator due to overheating!

During the operation of the piezo actuator, dielectric losses that are converted into heat energy occur in the piezo ceramic due to ferroelectric polarization processes. Heat dissipation to the outside is reduced due to the inert gas filling of the piezo actuator. The thermal energy that is generated can overheat and destroy the piezo actuator, especially in dynamic operation. The maximum operating temperature can already be exceeded inside the piezo actuator, when the temperature measured on the outside is still within the permissible range.

- ➢ If your application involves dynamic operation, contact our customer service department (p. 37).
- ➢ Adjust the operating voltage, operating frequency, and/or operating time so that the maximum operating temperature of the piezo actuator is not exceeded; see "Ambient Conditions and Classifications" (p. 41), "Maximum Ratings" (p. 40), and "Determining the Operating Parameters" (p. 26).
- ➢ Cool the piezo actuator. Liquid cooling is only possible under certain conditions. If liquid cooling is to be used, contact our customer service department (p. 37).

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-88x.x5. Oscillation is indicated by a humming noise and can be caused by the following:

- A change in the load and/or dynamics requires the servo control parameters to be adjusted.
- The P-88x.x5 is operated near to its resonant frequency.

If you notice oscillation:

- ➢ In closed-loop operation, switch off the servo mode immediately.
- ➢ In open-loop operation, stop the P-88x.x5 immediately.

INFORMATION

The positive direction of motion (p. 10) corresponds to the expansion direction of the piezo actuator when a positive voltage is applied.

6.2 Determining the Operating Parameters

6.2.1 Overview of Limiting Factors

Limiting factors for the operation of the piezo actuator:

Resonant frequency:

The resonant frequency of the piezo actuator serves as a basis for calculating the operating frequency, which must **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.

For **loaded** piezo actuators that are clamped on one side, see "Calculating the Maximum Operating Frequency of the Loaded Piezo Actuator" (p. 27).

Maximum compressive/tensile stress capacity (p. 41):

The mass of the load to be moved, the preload, and the operating frequency of the piezo actuator must be selected so that the dynamic forces occurring during operation do not exceed the maximum compressive/tensile stress capacity of the piezo actuator. See "Calculating the Forces that Occur During Dynamic Operation" (p. 28).

Maximum permissible operating temperature of the piezo actuator (p. 41):

The greater the operating frequency, the operating voltage (peak-to-peak), and the capacitance of the piezo actuator, the greater the thermal power generated in the piezo actuator. The operating frequency, operating voltage and operating time must be selected so that the maximum permissible operating temperature of the piezo actuator is **not** exceeded. For the maximum permissible operating frequency without cooling, see column B of the table in "Maximum Ratings" (p. 40).

It is possible to avoid overheating of the piezo actuator by taking the following measures:

- Cooling: Taking measures for cooling increases the threshold values for operating frequency, operating voltage, and operating time.
- Dynamic operation at low frequency only: The maximum operating temperature on the inside of the piezo actuator can already be exceeded when the temperature measured on the outside is still within the permissible range.

Peak and average output current of the electronics (p. 11) used:

The electronics must be selected so that it fulfills the following requirements:

- The electronics can provide the required current. See "Calculating the Power Requirement for Sinusoidal Operation" (p. 29).
- The output current of the electronics does not exceed the maximum power consumption of the piezo actuator. See "Maximum Ratings" (p. 40).
- The control signal of the electronics does not have steep edges. See "General Notes on Startup and Operation" (p. 23).

6.2.2 Calculating the Effective Mass

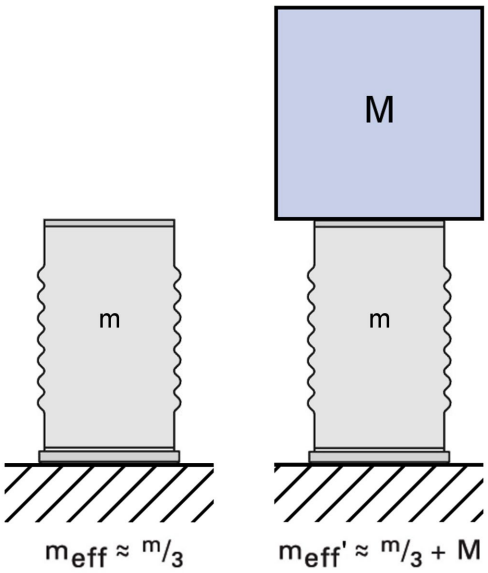

Figure 10: Calculation of the effective mass of a unilaterally clamped P-88x.x5 without load (left) and with additional load (right).

1. Determine the mass m of your piezo actuator.
2. Determine the additional load M.
3. Calculate the effective mass m_{eff} of the unloaded piezo actuator and m_{eff}' of the loaded piezo actuator using the formulas in the figure above.

6.2.3 Calculating the Maximum Operating Frequency of the Loaded Piezo Actuator

INFORMATION

In the following calculation, the maximum permissible operating temperature of the piezo actuator is **not** taken into account. During operation without cooling, the maximum operating temperature may already be exceeded when the operating frequency is still below the limit value calculated in the following.

➢ For the maximum permissible operating frequency without cooling, see column B of the table in "Maximum Ratings" (p. 40).

1. Calculate the resonant frequency of the loaded, unilaterally clamped piezo actuator using the following formula:

   $$f_0' = f_0 \sqrt{\frac{m_{eff}}{m_{eff}'}}$$

   f_0' = Resonant frequency of the loaded piezo actuator [Hz]

   f_0 = Resonant frequency of the unloaded piezo actuator [Hz]: 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.

   m_{eff} = Effective mass; approx. 1/3 of the mass of the piezo actuator [kg]

   m_{eff}' = Effective mass m_{eff} + additional load M [kg]

   See also "Calculating the Effective Mass" (p. 27).

2. Calculate the maximum operating frequency of the loaded, unilaterally clamped piezo actuator using the following formula:

   $f_{max} = f_0'/3$

   f_{max} = Maximum operating frequency of the loaded piezo actuator [Hz]

   f_0' = Resonant frequency of the loaded piezo actuator [Hz]

6.2.4 Calculating the Forces that Occur During Dynamic Operation

➢ Calculate the dynamic forces acting on the unilaterally clamped piezo actuator during sinusoidal operation at the frequency f using the following formula:

$$F_{dyn} \approx \pm 4\pi^2 \cdot m_{eff}' \left(\frac{\Delta L}{2}\right) f^2$$

F_{dyn} = Dynamic force [N]

m_{eff}' = Effective mass m_{eff} (approx. 1/3 of the mass of the piezo actuator) + additional load M [kg], see also "Calculating the Effective Mass" (p. 27)

ΔL = Displacement in the application (peak-to-peak) [m]

f = Frequency [Hz]

Example: The dynamic forces at 1000 Hz, 2 µm displacement (peak-to-peak) and 1 kg effective mass are approximately ±40 N.

6.2.5 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]	The provided peak current depends on the internal storage capacity of the amplifier.
f	Operating frequency [Hz]	Details on the operating frequency see "Overview of Limiting Factors" (p. 26).
C	Capacitance of the piezo actuator [F (= As/V)]	See "Data Table" (p. 39) for the small-signal capacitance of the piezo actuator. For large-signal conditions, a safety factor of 70 % should be added to the small-signal capacitance.
$U_{p\text{-}p}$	Operating voltage (peak-to-peak) [V]	Voltage difference between positive and negative peak voltage

6.3 Operating the P-88x.x5

Requirements

✓ You have read and understood the general notes on starting and operating (p. 23).

✓ You have determined the operating parameters for your application (p. 26).

✓ You have installed (p. 15) the P-88x.x5 correctly and connected it to the electronics (p. 21).

✓ 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-88x.x5

➢ For starting up and operating the P-88x.x5, follow the instructions in the manual for the electronics (p. 2) used.

6.4 Discharging the P-88x.x5

The P-88x.x5 must be discharged in the following cases:

- When the P-88x.x5 is not in use but the electronics remain switched on to ensure temperature stability
- If the P-88x.x5 has become accidentally charged due to thermal or mechanical loading
- If the connecting cable of the P-88x.x5 is accidentally pulled out of the electronics during operation

Requirements

✓ You have read and understood the general notes on installation (p. 15).

✓ You have read and understood the general notes on starting and operating (p. 23).

Tools and accessories

If the P-88x.x5 is not connected to the electronics:

- Only for P-88x.x5 **without** connector (condition as supplied):
  - 10 kΩ discharge resistor (not included in scope of delivery); touchable parts must be adequately insulated for the operating voltage range (p. 40) of the actuator
- Only for P-88x.x5 **with** connector (p. 21):
  - Electronics (p. 11) from PI or suitable shorting plug (available on request)

Discharging a P-88x.x5 connected to the electronics

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

Discharging a P-88x.x5 not connected to the electronics

If the P-88x.x5 does **not** have a connector:

1. Ensure adequate protection against touching live parts.
2. Short-circuit the stranded wires of the P-88x.x5 for at least a few seconds using a **10 kΩ discharge resistor**.

If the P-88x.x5 has a connector (p. 21):

➢ Connect the voltage connector of the P-88x.x5 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-88x.x5 for at least a few seconds.

6.5 Short-Circuiting the P-88x.x5

The P-88x.x5 must be discharged (p. 30) and short-circuited before demounting (e.g., before cleaning and transportation of the P-88x.x5) as well as for modifications.

Requirements

- ✓ You have read and understood the general notes on installation (p. 15).
- ✓ You have discharged (p. 30) the P-88x.x5 and disconnected it from the electronics.

Tools and accessories

- Only for P-88x.x5 **without** connector (condition as supplied):
  - Suitable shorting clamp (available on request)
- Only for P-88x.x5 **with** connector (p. 21):
  - Suitable shorting plug (available on request)

Short-circuiting the P-88x.x5

If the P-88x.x5 does **not** have a connector:

- ➢ Short-circuit the stranded wires of the **discharged** P-88x.x5 with a suitable shorting clamp or twist the stranded wires.

If the P-88x.x5 has a connector (p. 21):

- ➢ Connect a suitable shorting plug with integrated discharge resistor to the voltage connector of the P-88x.x5.

7 Maintenance

In this Chapter

General Notes on Maintenance 33
Cleaning the P-88x.x5 33

7.1 General Notes on Maintenance

The P-88x.x5 is maintenance-free.

7.2 Cleaning the P-88x.x5

Requirements

- ✓ The P-88x.x5 is discharged (p. 30) and short-circuited (p. 31).
- ✓ The P-88x.x5 is disconnected from the electronics.

Cleaning the P-88x.x5

- ➢ When using in a vacuum: Touch the piezo actuator only with powder-free nitrile or latex gloves.
- ➢ Depending on the application, clean the piezo actuator as follows:

  a) Clean with a lint-free cloth (only when using outside of the vacuum):

  - Clean the surfaces of the P-88x.x5 with a lint-free cloth that is dampened with a mild cleanser (e.g., isopropyl alcohol).

  b) Cleaning in an ultrasonic bath:

  - Reduce the energy input to the necessary minimum.
  - Only use isopropyl alcohol or ethanol as cleaning fluid.
  - Make sure that the cleaning time is 5 minutes.
  - After cleaning, dry the P-88x.x5 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/tensile stress capacity (p. 41).
	Piezo actuator is depolarized due to overheating or reverse polarity	➢ Contact our customer service department (p. 37).
Piezo actuator moves in the opposite direction to that specified when voltage increases	Reverse polarity of the piezo actuator	➢ Contact our customer service department (p. 37).

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

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Dimensions 42

Subject to change. You can find the latest product specifications on the product web page at www.pi.ws (https://www.pi.ws).

10.1 Specifications

10.1.1 Data Table

	P-885.55	P-885.95	P-888.55	Unit
Dimensions OD × L	11.2 mm × 22.5 mm	11.2 mm × 40.5 mm	18.6 mm × 22.5 mm	
Nominal travel range	14	30	14	µm
Maximum travel range	17	36	17	µm
Blocking force	850	900	3400	N
Stiffness	50	25	200	N/µm
Capacitance	1.5	3.1	6.0	µF
Resonant frequency	60	35	60	kHz
Mass	6.5	11.6	20.0	g
Recommended electronics	E-610, E-617, E-831, E-836	E-610, E-617, E-831, E-836	E-610, E-617, E-831, E-836	

Nominal travel range: At 0 to 100 V, tolerance ±10 %.

Maximum travel range: At 0 to 120 V, tolerance ±10 %.

Blocking force: At 0 to 120 V.

Electrical capacitance: Measured at 1 V_{pp}, 1 kHz, RT, tolerance ±20 %.

Resonant frequency: Measured at 1 V_{pp}, unloaded, unclamped. The value is halved for unilateral clamping, tolerance ±20 %.

Piezo ceramic type: PIC252.

Standard connections: PTFE-insulated stranded wires, UHV compatible, 100 mm, AWG 30, Ø 0.61 mm.

Operating voltage range: -20 to 120 V.

Operating temperature range: -40 to 150 °C.
The operating temperature range does **not** apply to dynamic operation. If your application involves dynamic operation, contact our customer service department (p. 37).

10.1.2 Maximum Ratings

P-88x.x5 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, without considering thermal aspects, column A:

  The values apply to unilaterally clamped piezo actuators and are calculated as follows: A third of the resonant frequency of the unloaded piezo actuator (operation when not clamped on both sides) divided by two.

- Maximum operating frequency without load, considering thermal aspects, column B:

  In order to prevent the maximum permissible operating temperature from being exceeded, the operating frequency of the unloaded, **uncooled** piezo actuator must not exceed the specified frequency when the operating voltage is **140 V peak-to-peak**. In the case of smaller amplitudes of the operating voltage and/or the use of cooling measures, higher operating frequencies are possible.

- Maximum power consumption:

  Power consumption of the unloaded, uncooled piezo actuator that is operated at a voltage of **140 V peak-to-peak** with the operating frequency from column B of this table.

Piezo actuator	Maximum operating voltage range	Maximum operating frequency without load		Maximum power consumption
		A: Without considering thermal aspects	B: Considering thermal aspects	Considering thermal aspects
P-885.55	-20 V to 120 V	5 kHz	200 Hz	5 W
P-885.95	-20 V to 120 V	5 kHz	200 Hz	10 W
P-888.55	-20 V to 120 V	5 kHz	200 Hz	22 W

10.1.3 Compressive/Tensile Stress Capacity and Preload

Piezo ceramic withstands a pressure of up to 250 MPa but starts to depolarize at significantly lower compressive loads. Since stacked piezo actuators are also made of different materials (piezo ceramic, metallic electrodes), the mechanical load capacity does not depend solely on the strength of the ceramic material. Consideration must be given to additional parameters such as slenderness ratio, bending, tilt and homogeneity of the force application.

Tensile stress can damage the piezo actuator and must be avoided. It is recommended to preload the actuators mechanically to reduce tensile stress during operation. The preload should be chosen only as high as necessary.

Compressive/tensile stress capacity and preload of the P-88x.x5

Type of mechanical stress	P-88x.x5*
Maximum compressive load capacity	10 MPa
Maximum tensile stress capacity without preload	None
Recommended preload for dynamic operation**	5 MPa
Maximum preload for constant force	10 MPa

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

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

10.1.4 Ambient Conditions and Classifications

Pay attention to the following ambient conditions and classifications for the P-88x.x5:

Area of application	For indoor use only
Air pressure	10^{-9} hPa to 1500 hPa
Relative humidity	0 to 100 %
Operating temperature	-40 °C to 150 °C The operating temperature does **not** apply to dynamic operation. ➢ If your application involves dynamic operation, contact our customer service department (p. 37).
Storage temperature	-40 °C to 80 °C
Transport temperature	-40 °C to 80 °C
Maximum bakeout temperature (when using in a vacuum)	150 °C
Overvoltage category	II
Degree of pollution	1

The P-88x.x5 is intended for installation in devices that fulfil the following classifications:

Protection class	I
Degree of protection according to IEC 60529	IP20

10.2 Dimensions

Dimensions in mm

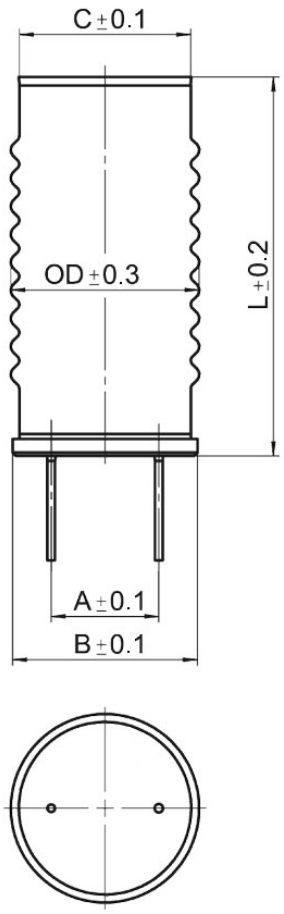

Figure 11: P-88x.x5: Dimensions

	A	B	C	OD	L
P-885.55	6.4 mm	11 mm	10.25 mm	11.2 mm	22.5 mm
P-885.95	6.4 mm	11 mm	10.25 mm	11.2 mm	40.5 mm
P-888.55	12 mm	17.5 mm	16.85 mm	18.6 mm	22.5 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.

Dispose of your old equipment according to international, national, and local rules and regulations.

In order to fulfil its responsibility as the product manufacturer, Physik Instrumente (PI) GmbH & Co. KG undertakes environmentally correct disposal of all old PI equipment made available on the market after 13 August 2005 without charge.

Any old PI equipment can be sent free of charge to the following address:

Physik Instrumente (PI) GmbH & Co. KG

Auf der Roemerstr. 1

D-76228 Karlsruhe, Germany

12 EU Declaration of Conformity

An EU Declaration of Conformity was issued for the P-88x.x5 in accordance with the following European directives:

RoHS Directive

The applied standards certifying the conformity are listed below.

RoHS: EN 50581 or EN IEC 63000

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.