

PZ256E
S-331 Piezo Tip/Tilt System
User Manual

Version: 1.0.0

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This document describes the following products:

- **S-331.2SH**
High-Dynamics Piezo Tip / Tilt System with High Stiffness, 3 mrad, SGS, Sub-D Connector
- **S-331.2SL**
High-Dynamics Piezo Tip / Tilt System with High Stiffness, 3 mrad, SGS, LEMO Connectors
- **S-331.5SH**
High-Dynamics Piezo Tip / Tilt System with High Stiffness, 5 mrad, SGS, Sub-D Connector
- **S-331.5SL**
High-Dynamics Piezo Tip / Tilt System with High Stiffness, 5 mrad, SGS, LEMO Connectors



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Subject to change without notice. This manual is superseded by any new release. The latest release is available for download (p. 3) on our website.

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1 About this Document

In this Chapter

Objective and Target Audience of this User Manual	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 information needed for the intended use of the S-331. Basic knowledge of servo systems, 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 Symbols and Typographic Conventions

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

CAUTION



Dangerous situation

If not avoided, the dangerous situation will result in minor injury.

- Actions to take to avoid the situation.

NOTICE



Dangerous situation

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

- Actions to take to avoid the situation.

INFORMATION

Information for easier handling, tricks, tips, etc.

Symbol/ Label	Meaning
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)
	Warning signs affixed to the product that refer to detailed information in this manual.

1.3 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.

1.4 Other Applicable Documents

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

Product	Document
E-727.3SD/E-727.3SDA digital multi-channel piezo controllers for SGS	E727T0005 Technical Note
E-509.S3 sensor/servo controller module	PZ77E User Manual
E-503.00S piezo amplifier module	PZ62E User Manual
E-505.00 piezo amplifier module	
E-505.00S offset voltage supply for tip/tilt mirror systems	
E-501.00 9.5" chassis for modular piezo controller system	
E-500.00 19" chassis for modular piezo controller system, 1 to 3 channels	
E-518.I3 interface module	E518T0001 Technical Note, PZ214E User Manual

1.5 Downloading Manuals

INFORMATION

If a manual is missing or problems occur with downloading:

- Contact our customer service department (p. 41).

INFORMATION

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

The password is included on the CD of the product.

For products with CD: Identify the password

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. Find the user name and the password in the section "User login for software download" in the Release News.

Downloading Manuals

1. Open the website <http://www.pi.ws>.
2. Click *Info*.
3. If you have a user name and password:
 - a) Click *Login*.
 - b) Log in with the user name and password.
4. Click >> *Product Downloads*.
5. In the *Product Files* area, click the corresponding product category.
6. On the right-hand side of the page, select the corresponding subcategory.
7. Navigate to the product code on the page.

The following manuals are displayed:

- Freely accessible manuals

- Manuals that are protected by a password
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

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Organizational Measures.....	6

2.1 Intended Use

The S-331 is a laboratory device as defined by DIN EN 61010-1. It is intended for indoor use and use in an environment that is free of dirt, oil, and lubricants.

In accordance with its design, the S-331 is intended for the precise positioning and alignment of a mirror in two orthogonal axes with a common pivot point (parallel kinematics). The S-331 is suitable for highly dynamic applications and can be mounted in any orientation.

The S-331 is delivered without a mirror and is intended for the attachment of a suitable mirror (p. 25). The models of the S-331 are equipped with strain gauge sensors (SGS).

The intended use of the S-331 is only possible in conjunction with suitable electronics (p. 13) that are available from PI. The electronics are not included in the scope of delivery of the S-331.

The electronics must provide the required operating voltages. To ensure proper performance of the servo-control system, the electronics must also be able to read out and process the signals from the strain gauge sensors.

2.2 General Safety Instructions

The S-331 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 S-331.

- Only use the S-331 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 S-331.

2.3 Organizational Measures

User manual

- Always keep this user manual available with the S-331. 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 S-331 to other users, also include this user manual as well as other relevant information provided by the manufacturer.
- Only use the device on the basis of the complete user manual. Missing information due to an incomplete user manual can result in minor injury and damage to equipment.
- Only install and operate the S-331 after you have read and understood this user manual.

Personnel qualification

The S-331 may only be installed, started up, operated, maintained, and cleaned by authorized and appropriately qualified personnel.

3 Product Description

In this Chapter

Model Overview..... 7
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 Control 14
 ID Chip..... 15
 Dynamic Behavior 15

3.1 Model Overview

Four standard versions of the S-331 piezo tip/tilt system are available.

Model	Description
S-331.2SH	High-Dynamics Piezo Tip / Tilt System with High Stiffness, 3 mrad, SGS, Sub-D Connector
S-331.2SL	High-Dynamics Piezo Tip / Tilt System with High Stiffness, 3 mrad, SGS, LEMO Connectors
S-331.5SH	High-Dynamics Piezo Tip / Tilt System with High Stiffness, 5 mrad, SGS, Sub-D Connector
S-331.5SL	High-Dynamics Piezo Tip / Tilt System with High Stiffness, 5 mrad, SGS, LEMO Connectors

- For further technical data, see the specifications (p. 43).

3.2 Product View



Figure 1: Product view of the S-331.2SH



Figure 2: Product view of the S-331.5SH

- 1 Protective earth connection
- 2 Housing
- 3 Motion platform with groove for gluing the mirror
- 4 M1.6 threaded hole for mounting a mirror mount
- 5 Cable exit

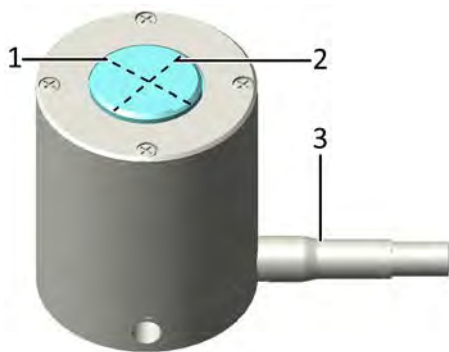


Figure 3: Schematic diagram of the axes of the S-331.2SH in relation to the cable exit, identical for further models of the S-331

- 1 Axis 1 (corresponds to axis 1 on the E-727.3SD/A controller)
- 2 Axis 2 (corresponds to axis 2 on the E-727.3SD/A controller)
- 3 Cable exit



Figure 4: Maximum displacement in the positive direction of motion around axis 1. At the connected channel 1 of the amplifier, the output voltage U_{Piezo} is 100 V. The displacement shown is strongly exaggerated for better understanding.



Figure 5: Maximum displacement in the positive direction of motion around axis 2. At the connected channel 2 of the amplifier, the output voltage U_{Piezo} is 100 V. The displacement shown is strongly exaggerated for better understanding.


3.3 Product Labeling

Labeling	Description
S-331.2SH	Product name (example), the characters following the period refer to the model
116010244	Serial number (example), individual for each S-331 Meaning of the places (counting from left): 1 = internal information, 2 and 3 = year of manufacture, 4 to 9 = consecutive numbers
	Manufacturer's logo
Country of origin: Germany	Country of origin
	Warning sign "Observe manual!"
	Old equipment disposal (p. 51)
	CE conformity mark
WWW.PI.WS	Manufacturer's address (website)
	Symbol for the protective earth conductor, marks the protective earth connection of the S-331 (p. 30)

S-331.xSH: Labeling of the Sub-D 37 (m) connector



Figure 6: Sub-D 37 (m) connector on the connection cable of the S-331.xSH

- 1  Warning sign "Residual Voltage": Notice of risk of electric shock (p. 5)

S-331.2SL, S-331.5SL: Labeling of the LEMO connection cables



Figure 7: Cable diagram for S-331.xSL

- 1 Sensor connection of axis 2, labeled **AXIS 2**
- 2 Sensor connection of axis 1, labeled **AXIS 1**
- 3 Piezo connection for 100 V fixed voltage, labeled **PZT 100V**
- 4 Piezo connection of axis 2, labeled **PZT2**
- 5 Piezo connection of axis 1, labeled **PZT1**

3.4 Scope of Delivery

Item number	Components
S-331	Piezo tip/tilt system according to the order
000036450	M4 screw set for protective earth, consisting of: <ul style="list-style-type: none"> ▪ 1 flat-head screw with cross recess, M4x8 ISO 7045 ▪ 2 safety washers ▪ 2 flat washers
PZ256E	User manual (this document) in printed form

3.5 Accessories

Order number	Description
Only S-331.xSL:	
E-518.I3	Interface Module, 3 Channels, TCP/IP, USB and RS-232 Interfaces
P-891.01	Extension Cable for Piezo Voltage, LEMO Connectors, 1 m
P-891.02	Extension Cable for Piezo Voltage, LEMO Connectors, 2 m
P-891.03	Extension Cable for Piezo Voltage, LEMO Connectors, 3 m
P-891.05	Extension Cable for Piezo Voltage, LEMO Connectors, 5 m
P-891.10	Extension Cable for Piezo Voltage, LEMO Connectors, 10 m
P-892.01	Extension Cable, for Strain Gauge Sensors, LEMO Connectors, 1 m
P-892.02	Extension Cable, for Strain Gauge Sensors, LEMO Connectors, 2 m
P-892.03	Extension Cable, for Strain Gauge Sensors, LEMO Connectors, 3 m
P-892.05	Extension Cable, for Strain Gauge Sensors, LEMO Connectors, 5 m
P-892.10	Extension Cable, for Strain Gauge Sensors, LEMO Connectors, 10 m

- To order, contact our customer service department (p. 41).

3.6 Suitable Electronics

Model	Controller	Amplifier	Housing	Interfaces
S-331.xSH	E-727.3SD Digital Multi-Channel Piezo Controller, 3 Channels, -30 to 130 V, Sub-D Connector, Strain Gauge		221 mm x 240.10 mm x 116.60 mm	-
	E-727.3SDA Digital Multi-Channel Piezo Controller, 3 Channels, -30 to 130 V, Sub-D Connector, Strain Gauge, Analog Inputs		221 mm x 240.10 mm x 116.60 mm	-
S-331.xSL	E-509.S3 Sensor / Piezo Servo-Control Module, SGS Sensors, 3 Channels	E-503.00S Piezo Amplifier Module, -30 to 130 V. Special Version, Modified for Tip/Tilt Systems with Differential Drive: One Fixed Voltage of +100 V, Two Variable Voltages	E-501.00 9½" Chassis for Modular Piezo Controller System, 1 to 3 Channels	Optional: E-518.I3 Interface Module, 3 Channels, TCP/IP, USB and RS-232 Interfaces
	E-509.S3 Sensor / Piezo Servo-Control Module, SGS Sensors, 3 Channels	2 x E-505.00 Piezo Amplifier Module, 2 A, -30 to 130 V, 1 Channel, 1 x E-505.00S Offset Voltage Supply for Tip/Tilt Systems, One Fixed Voltage of 100 V	E-500.00 19" Case for Modular Piezo Controller System, 1 to 3 Channels	Optional: E-518.I3 Interface Module, 3 Channels, TCP/IP, USB and RS-232 Interfaces

➤ To order, contact our customer service department (p. 41).

3.7 Control

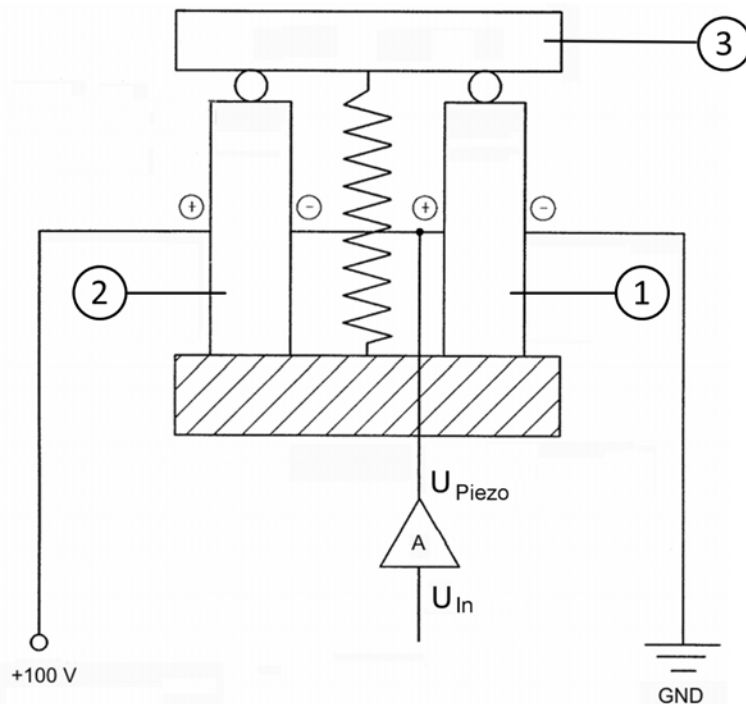


Figure 8: Differential drive of the piezo tip/tilt system, functional principle using the tilting of a single axis as an example

- 1 Piezo actuator 1 of the axis
- 2 Piezo actuator 2 of the axis
- 3 Motion platform

The S-331 is a piezo tip/tilt system with a differential piezo drive. Tip/tilt motions on two axes are realized by the pairwise interconnection of a total of four piezo actuators.

Both pairs of actuators are electrically switched so that when piezo voltage U_{Piezo} is changed, the voltage is increased to one actuator of a pair while the voltage to the other actuator is decreased by the same amount. The actuator with the increased voltage expands while the other actuator with the decreased voltage contracts. This produces the tip/tilt motion.

For a simplified representation of the functional principle, only one axis is shown in the figure above. The motion platform is shown with a tilt of 0° .

When the control input voltage U_{In} increases, piezo actuator 1 expands and piezo actuator 2 contracts. This produces a tilt in the positive direction.

Because of the way they are interconnected, both actuator pairs always move in opposite directions. It is thus **impossible** to command linear motions in the Z axis.

The position of the Z axis can change with temperature fluctuations, however: Due to the symmetrical design of the piezo tip/tilt system, temperature fluctuations do not cause the motion platform to tilt but cause the length of the piezo actuators to change evenly in the direction of the Z axis.

Most applications are not very sensitive to such deviations as long as the tip/tilt angle does not change.

Each of the four piezo actuators of the S-331.xSx models is equipped with a strain gauge sensor. Therefore, in addition to the amplifier channel, a servo loop with a sensor channel must be available for each actuator pair.

3.8 ID Chip

An ID chip is located in the Sub-D connector of the tip/tilt mirror. When the tip/tilt mirror is calibrated at the factory with digital electronics, the calibration data is saved together with specific product information on the ID chip. When switched on, digital electronics read the data from the ID chip of the connected tip/tilt mirror. Tip/tilt mirrors whose ID chip contains the calibration data can therefore be connected to any suitable digital electronics without a new calibration.

For more information on the ID chip, see the manual of the controller used.

3.9 Dynamic Behavior

The maximum operating frequency of a piezo tip/tilt system depends on the following factors:

- Bandwidth of amplifier, controller, and sensor
- Resonant frequency of the piezo tip/tilt system including mirror and possibly mirror mount

The resonant frequency is estimated in two steps:

- a) Calculating moments of inertia for mirror and mirror mount (p. 16)
- b) Calculating the resonant frequency of the piezo tip/tilt system including mirror and mirror mount (p. 19)

3.9.1 Calculating Moments of Inertia for Mirror and Mirror Mount

Calculating the distance from the axis through the center of gravity of the mirror to the rotational axis

Before the moment of inertia of the mirror is calculated, it is necessary to calculate the distance from the axis through the center of gravity of the mirror to the rotational axis of the platform. When a mirror mount is used, it must be included in the calculation.

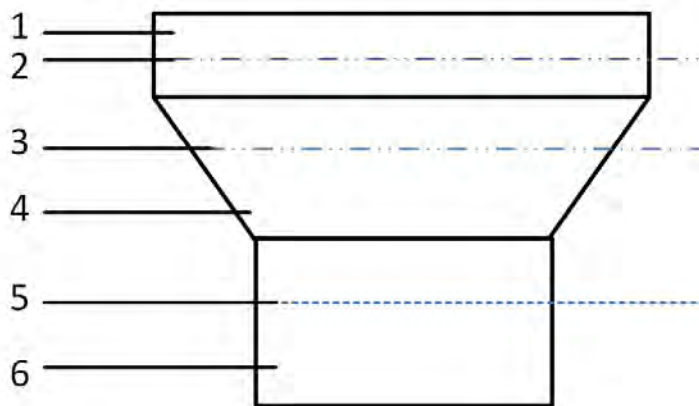


Figure 9: Example diagram: Platform with mirror mount and mirror

- 1 Mirror
- 2 Axis through the center of gravity of the mirror
- 3 Axis through the center of gravity of the mirror mount
- 4 Mirror mount (example of a geometry)
- 5 Axis through the pivot point of the platform of the S-331 ("rotational axis")
- 6 Platform

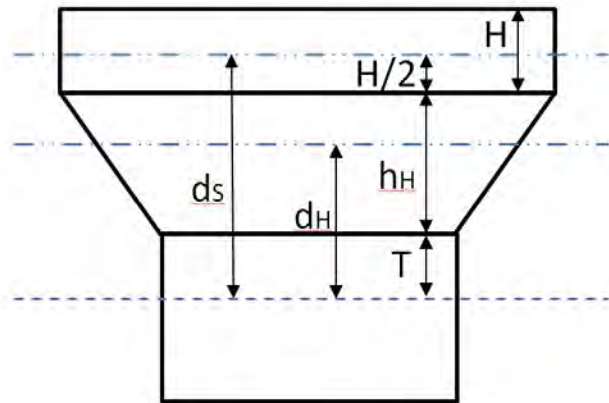


Figure 10: Example diagram: Platform with mirror mount and mirror; here with variables required for calculating the moments of inertia

- d_s Distance from the axis through the center of gravity of the mirror to the rotational axis
- d_H Distance from the axis through the center of gravity of the mirror mount to the rotational axis
- $H/2$ Half the mirror thickness
- h_H Thickness of the mirror mount
- T Distance from the rotational axis to the platform surface (see "Data Table" (p. 43))
- H Mirror thickness

Formula for calculating the distance from the axis through the center of gravity of the mirror to the rotational axis of the platform:

When a mirror is attached **without** a mirror mount:

$$d_s = \frac{H}{2} + T$$

When a mirror is attached **with** a mirror mount:

$$d_s = \frac{H}{2} + h_H + T$$

with:

d_s = Distance from the axis through the center of gravity of the mirror to the rotational axis [mm]

H = Mirror thickness [mm]

h_H = Thickness of the mirror mount [mm]

T = Distance from the rotational axis to the platform surface [mm], see "Data Table" (p. 43)

Calculating the moment of inertia of the mirror

Formula for calculating the moment of inertia of a rotationally symmetric mirror:

$$I_{S,P} = m_S \left[\frac{3R^2 + H^2}{12} + d_S^2 \right]$$

Formula for calculating the moment of inertia of a rectangular mirror:

$$I_{S,P} = m_S \left[\frac{L^2 + H^2}{12} + d_S^2 \right]$$

with:

$I_{S,P}$ = Moment of inertia of the mirror, in relation to the rotational axis [$\text{g} \cdot \text{mm}^2$]

m_S = Mirror mass [g]

R = Mirror radius [mm]

L = Mirror length perpendicular to the rotational axis [mm]

H = Mirror thickness [mm]

d_S = Distance from the axis through the center of gravity of the mirror to the rotational axis [mm]; for calculation see separate formulas (p. 16)

Calculating the moment of inertia of the mirror mount

$$I_{H,P} = I_H + m_H * (d_H)^2$$

with:

$I_{H,P}$ = Moment of inertia of the mirror mount, in relation to the rotational axis [$\text{g} \cdot \text{mm}^2$]

I_H = Moment of inertia of the mirror mount, dependent on the geometry of the mirror mount [$\text{g} \cdot \text{mm}^2$]

m_H = Mass of the mirror mount [g]

d_H = Distance from the axis through the center of gravity of the mirror mount to the rotational axis of the platform [mm], see above illustration (p. 16)

3.9.2 Calculating the Resonant Frequency of the Piezo Tip/Tilt System

Mirror without mirror mount

When the mirror is mounted without a mirror mount, the resonant frequency of the system is calculated with the following formula:

$$f' = \frac{f_0}{\sqrt{1 + \frac{I_{S,P}}{I_0}}}$$

with:

f' = Resonant frequency of the S-331 with mirror [Hz]

f_0 = Resonant frequency of the unloaded S-331 [Hz]; see "Data Table" (p. 43)

I_0 = Moment of inertia of the platform of the S-331 [$\text{g}\cdot\text{mm}^2$], see "Data Table" (p. 43)

$I_{S,P}$ = Moment of inertia of the mirror, in relation to the rotational axis, [$\text{g}\cdot\text{mm}^2$]; calculation see separate formulas (p. 18)

The resonant frequency of the system consisting of S-331, mirror, and mirror mount is calculated with the following formula:

$$f' = \frac{f_0}{\sqrt{1 + \frac{(I_{S,P} + I_{H,P})}{I_0}}}$$

with:

f' = Resonant frequency of the S-331 with mirror [Hz]

f_0 = Resonant frequency of the unloaded S-331 [Hz]; see "Data Table" (p. 43)

I_0 = Moment of inertia of the platform of the S-331 [$\text{g}\cdot\text{mm}^2$], see "Data Table" (p. 43)

$I_{S,P}$ = Moment of inertia of the mirror, in relation to the rotational axis, [$\text{g}\cdot\text{mm}^2$]; for calculation see separate formulas (p. 18)

$I_{H,P}$ = Moment of inertia of the mirror mount, in relation to the rotational axis, [$\text{g}\cdot\text{mm}^2$]; calculation see separate formulas (p. 18)

Further information on dynamic or static operation can be found in the PI catalog (CAT 130), in the section "Fundamentals of Piezo Technology". The catalog can be downloaded from our website <http://www.pi.ws> under **Info**.

Mirror with mirror mount

When the mirror is mounted with a mirror mount, the resonant frequency of the system is calculated with the following formula:

$$f' = \frac{f_0}{\sqrt{1 + \frac{(I_{S,P} + I_{H,P})}{I_0}}}$$

with:

f' = Resonant frequency of the S-331 with mirror and mirror mount [Hz]

f_0 = Resonant frequency of the unloaded S-331 [Hz]; see "Data Table" (p. 43)

I_0 = Moment of inertia of the platform of the S-331 [$\text{g}\cdot\text{mm}^2$], see "Data Table" (p. 43)

$I_{S,P}$ = Moment of inertia of the mirror, in relation to the rotational axis, [$\text{g}\cdot\text{mm}^2$]; for calculation see separate formulas (p. 18)

$I_{H,P}$ = Moment of inertia of the mirror mount, in relation to the rotational axis, [$\text{g}\cdot\text{mm}^2$]; calculation see separate formula (p. 18)

Further information on dynamic or static operation can be found in the PI catalog (CAT 130), in the section "Fundamentals of Piezo Technology". The catalog can be downloaded from our website <http://www.pi.ws> under **Info**.

4 Unpacking

1. Unpack the S-331 with care.
2. Compare the contents with the items listed in the contract and the packing list.
3. Inspect the contents for signs of damage. If parts are missing or you notice signs of damage, contact PI immediately.
4. Keep all packaging materials in case the product needs to be returned.

5 Installation

In this Chapter

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Mounting the Mirror on the S-331	25
Mounting the S-331	29
Connecting the S-331 to the Protective Earth Conductor	30
Connecting the S-331 to the Controller	31

5.1 General Notes on Installation

CAUTION



Dangerous voltage and residual charge in piezo actuators!

The S-331 is driven by piezo actuators. Temperature changes and compressive stresses can induce charges in piezo actuators. After being disconnected from the electronics, piezo actuators can also stay charged for several hours. Touching or short-circuiting the contacts in the connector of the S-331 can lead to minor injuries. In addition, the piezo actuators can be destroyed by an abrupt contraction.

- Do **not** open the S-331.
- Discharge the piezo actuators of the S-331 before installation:
Connect the S-331 to the switched-off PI controller, which is equipped with an internal discharge resistor.
- Do **not** pull the connector out of the electronics during operation.



Touching the contacts in the connector can lead to an electric shock (max. 120 V DC) and minor injuries.

- Do **not** touch the contacts in the connector.
- Use the screws to secure the connector of the S-331 against being pulled out of the controller.

NOTICE**Heating up of the S-331 during operation!**

The heat produced during operation of the S-331 can affect your application.

- Install the S-331 so that the application is not impaired by the dissipated heat.
- Ensure sufficient ventilation at the place of installation.
- Make sure that the complete bottom side of the S-331 is in contact with the surface on which the S-331 is mounted.

NOTICE**Destruction of the piezo actuator due to electric flashovers!**

Using the S-331 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 S-331 in environments that can increase the electric conductivity.
- Only operate the S-331 within the permissible ambient conditions and classifications (p. 45).

NOTICE**Destruction of the piezo actuator due to short-circuiting without a discharge resistor!**

When a charged piezo actuator is short-circuited without a discharge resistor, this can lead to a contraction shock and thus to the destruction of the piezo ceramic.

- Only discharge the S-331 according to the instructions in "Discharging S-331" (p. 35).

NOTICE**Warping of the S-331 due to mounting on uneven surfaces!**

Mounting the S-331 on an uneven surface can warp the S-331. Warping reduces the accuracy.

- Mount the S-331 on an even surface. The recommended evenness of the surface is $\leq 30 \mu\text{m}$.
- For applications with large temperature changes:
Only mount the S-331 on surfaces that have the same or similar thermal expansion properties as the S-331.

NOTICE

Damage due to unsuitable cables!

Unsuitable cables can damage the S-331 and the electronics.

- Only use cables provided by PI for connecting the S-331 to the electronics.

5.2 Mounting the Mirror on the S-331

You have the following options for mounting the mirror on the motion platform of the S-331:

- Gluing the mirror
- Screwing the mirror mount



Figure 11: Top view of the S-331

- 1 Motion platform
- 2 Housing
- 3 Groove for gluing
- 4 M1.6 threaded hole with 3 mm depth for screwing in a mirror mount

NOTICE

Impermissibly high forces and torques!

Impermissibly high forces and torques that are applied to the moving platform can damage the S-331.

- Avoid high forces and torques on the motion platform when mounting the mirror.

NOTICE**Reduced positioning accuracy due to improper mounting!**

Improper mounting can reduce the positioning accuracy of the piezo tip/tilt system.

- Avoid overtightening the mirror:
 - To glue the mirror, choose an adhesive that hardens at room temperature and contracts as little as possible during drying and hardening. Recommendation: Two-component adhesive made of epoxy resin that hardens in 24 hours at a temperature above 25 °C and is resistant to shearing forces.
 - In the case of applications with large temperature changes:
Make sure that the mirror and mirror mount have the same or similar thermal expansion properties as the motion platform of the S-331 (material of the platform: titanium).
- Make sure that there is no adhesive between the motion platform and the housing of the S-331 and in the hole in the middle of the platform; see figure above.

INFORMATION

If the mirror is to be replaceable, it is recommended to mount it with a mirror mount.

- Take the moment of inertia of the mirror mount into account when calculating the resonant frequency of the piezo tip/tilt system (p. 20).

INFORMATION

Recommended characteristics of the mirror:

- Diameter: 12.7 mm (0.5")
- Thickness: 3 mm
- Material: Glass such as borosilicate crown glass (BK7), e.g., whose moment of inertia matches the application (details see "Dynamic Behavior" (p. 15)) and whose thermal expansion coefficient is as similar as possible to that of titanium.



Figure 12: The three-arm groove (colored white here) on the motion platform is used for punctiform application of the adhesive.

INFORMATION

For gluing the mirror, it is recommended to use a suitable centering aid; for an example, see below.

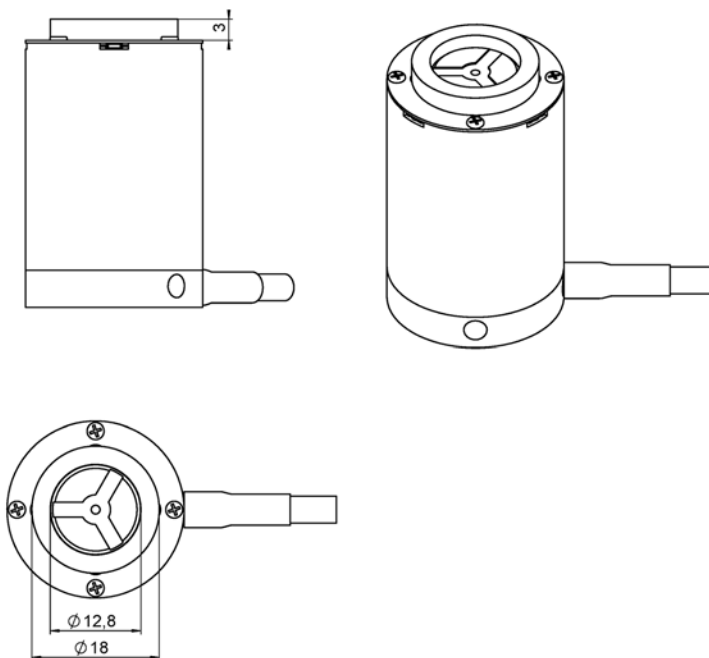


Figure 13: Example: S-331 with centering aid for a mirror with a thickness of 3 mm and $\varnothing 12.7$ mm

Requirements

- ✓ You have read and understood the general notes on installation (p. 23).
- ✓ The S-331 is **not** connected to the electronics.

Tools and accessories

- Suitable mirror, see above and "Dynamic Behavior" (p. 15)
- When the mirror is glued to the platform:
 - Suitable adhesive, see above
 - Option: Suitable centering aid
 - Cotton swab
 - Isopropanol
- When the mirror is mounted with a mirror mount:
 - Suitable mirror mount with M1.6 threaded pin or screw
- Powder-free gloves

Gluing the mirror to the S-331

1. Option: Carefully align the centering aid on the motion platform of the S-331 and fix it in a suitable manner.
2. Apply a small amount of adhesive to three points in the three-armed groove of the motion platform; see above figure. Only apply a pinhead-sized amount to each point.
3. Carefully place the mirror into the centering aid on the motion platform. Avoid touching the mirror surface.
4. Carefully and briefly press the mirror onto the motion platform with a cotton swab.
5. If necessary, remove the adhesive residue with a cotton swab and isopropanol.
6. Allow the adhesive to harden according to the instructions of the adhesive manufacturer.
7. Remove the centering aid.

Affix the mirror mount to the S-331

- Affix the mirror mount on the motion platform via the M1.6 threaded hole.
Maximum torque: 0.2 Nm
Maximum screw-in depth: 3 mm
- Affix the mirror on the mirror mount in a suitable manner.

5.3 Mounting the S-331

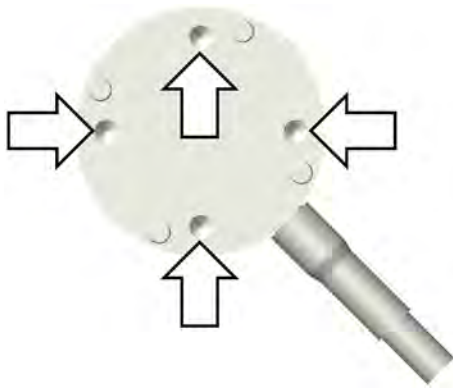


Figure 14: M3 holes of the S-331 for mounting on a surface

Requirements

- ✓ You have read and understood the general notes on installation (p. 23).
- ✓ The S-331 is **not** connected to the electronics.
- ✓ You have accounted for the space required to route cables without bending and according to regulations.

Tools and accessories

- For the dimensions of the S-331 and the position and depth of the M3 holes, see "Dimensions" (p. 47).
- You have provided a suitable surface:
 - Four through-holes for M3 screws are provided.
 - The evenness of the surface is $\leq 30 \mu\text{m}$.
- 4 M3 screws of suitable length (p. 47)
- Suitable tools

Mounting the S-331 on a surface

1. Align the S-331 on the surface so that the M3 holes in the S-331 and the surface overlap.
2. Insert the four screws through the holes in the surface into the base body of the S-331 from below.
3. Tighten the four screws.
 - Maximum screw-in depth: 4 mm
 - Maximum torque: 1.1 Nm
4. Check that the S-331 is affixed firmly.

5.4 Connecting the S-331 to the Protective Earth Conductor

INFORMATION

- Observe the applicable standards for mounting the protective earth conductor.

The S-331 has an M4 hole for mounting the protective earth conductor. This hole is marked with the symbol for the protective earth conductor \oplus (see "Dimensions" (p. 47)).

Requirements

- ✓ You have read and understood the general notes on installation (p. 23).
- ✓ The S-331 is **not** connected to the electronics.

Tools and accessories

- Suitable protective earth conductor: Cross-sectional area of the cable $\geq 0.75 \text{ mm}^2$
- Supplied M4 protective earth screw set (p. 11) for connecting the protective earth conductor
- Suitable screwdriver

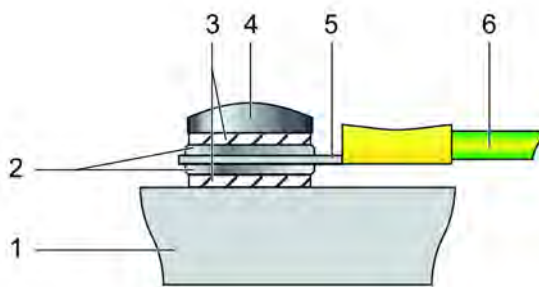


Figure 15: Mounting of the protective earth conductor (profile view)

- 1 Base body of the S-331
- 2 Flat washer
- 3 Safety washer
- 4 Screw
- 5 Cable lug
- 6 Protective earth conductor

Connecting the S-331 to the protective earth conductor

1. If necessary, attach a suitable cable lug to the protective earth conductor.
2. Affix the cable lug of the protective earth conductor using the M4 screw on the protective earth connection of the S-331 as shown in the profile view.
3. Tighten the M4 screw with a torque of 1.2 Nm to 1.5 Nm.
4. Make sure that the contact resistance at all connection points relevant for mounting the protective earth conductor is $<0.1 \Omega$ at 25 A.

5.5 Connecting the S-331 to the Controller

INFORMATION

Systems consisting of an S-331 and controller are calibrated at the factory to achieve optimum performance.

- Note the assignment of the axes to the controller channels, which is specified on the calibration label of the piezo servo controller.

Requirements

- ✓ You have read and understood the general notes on installation (p. 23).
- ✓ You have installed a suitable controller (p. 13).
- ✓ You have read and understood the user manual of the controller.
- ✓ The controller is switched off.

Connecting the S-331.xSH to the E-727.3SD controller

1. Plug the connector of the S-331.xSH into the corresponding socket of the controller (see user manual of the controller).
2. Use the integrated screws to secure the connection against accidental disconnection.

Connecting the S-331.xSL to E-50x modules

1. Connect the piezo connectors of the S-331.xSL with the piezo amplifier modules as follows.

If you use an E-503.00S module:

- **PZT1** to **PZT** for channel 1 (**CH1**)
- **PZT2** to **PZT** for channel 2 (**CH2**)
- **PZT 100V** to **PZT** for channel 3 (**CH3**)

If you use two E-505.00 modules for variable voltages and an E-505.00S module for 100 V fixed voltage:

- **PZT1** to **PZT** of an E-505.00 module
 - **PZT2** to **PZT** of the second E-505.00 module
 - **PZT 100V** to **PZT** of the E-505.00S module
2. Connect the sensor connections of the S-331.xSL to the E-509.S3 servo-controller module as follows:
- **AXIS 1** to **SENSOR** for channel 1 (**SERVO 1**)
 - **AXIS 2** to **SENSOR** for channel 2 (**SERVO 2**)

6 Start-Up and Operation

In this Chapter

General Notes on Start-Up and Operation	33
Operating the S-331	35
Discharging the S-331	35

6.1 General Notes on Start-Up and Operation

CAUTION



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

If a protective earth conductor is not or not properly connected, dangerous touch voltages can occur on the S-331 in the case of malfunction or failure of the system. If touch voltages exist, touching the S-331 can result in minor injuries from electric shock.

- Before start-up, establish contact between the S-331 and the protective earth conductor.
- Do **not** remove the protective earth conductor during operation.
- Make sure that the contact resistance at all connection points relevant for mounting the protective earth conductor is $<0.1 \Omega$ at 25 A.
- If the protective earth conductor has to be temporarily removed (e.g., for modifications), reconnect the S-331 to the protective earth conductor before starting it up again.

NOTICE



Destruction of the piezo actuator due to electric flashovers!

Using the S-331 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 S-331 in environments that can increase the electric conductivity.
- Only operate the S-331 within the permissible ambient conditions and classifications (p. 45).

NOTICE**Reduced lifetime of the piezo actuator due to permanently high voltage!**

The permanent application of a high static voltage to piezo actuators leads to a considerable reduction in the lifetime of the piezo ceramic of the S-331.

- When the S-331 is not used but the controller remains switched on to ensure temperature stability, discharge the S-331 (p. 35).

INFORMATION

Systems consisting of an S-331 and controller are set at the factory so that optimum performance can be achieved when a mirror with the recommended characteristics is glued onto the S-331 (p. 25).

- Only adjust the notch filter and the servo-control parameters of the controller when the moved mass and thus the resonant frequency of the piezo tip/tilt system changes considerably. Possible reasons:
 - The used mirror strongly deviates from the recommended characteristics (p. 25).
 - A mirror mount is used.

Only when system components have been replaced:

- Perform a recalibration of the axis displacement (see controller manual) or contact our customer service department (p. 41).
- Adjust the notch filter and servo-control parameters of the controller (see controller manual).

INFORMATION

Depending on the amplitude and frequency of the piezo voltage, the S-331 heats up during operation.

- Select the amplitude and frequency of the piezo voltage so that the maximum permissible operating temperature of the S-331 is not exceeded. For details, see "Recommended Control Signals for Dynamic Operation" (p. 46).

INFORMATION

Sound and vibration (e.g., footfall, impacts) can be transmitted to the S-331 and can affect its performance with regard to position stability.

- Avoid sound and vibration during operation of the S-331.

INFORMATION

The expansion of the piezo actuators depends on the ambient temperature and can vary by up to 10 % in the given temperature ranges (p. 45).

6.2 Operating the S-331

Requirements

- ✓ You have read and understood the general notes on start-up and operation (p. 33).
- ✓ You have read and understood the user manual of the controller.
- ✓ You have properly installed the S-331 (p. 23).
- ✓ The controller and the required PC software have been installed. All connections with the controller have been established (see user manual of the controller).

Operating the S-331

- For start-up and operation of the S-331, follow the instructions in the manual of the controller used.

6.3 Discharging the S-331

The S-331 must be discharged in the following cases:

- Before installation
- If the S-331 is not used but the controller remains switched on to ensure temperature stability
- Before pulling out the connector (e.g., before cleaning and transport of the S-331 and for modifications in the application)

The S-331 is discharged through the internal discharge resistor of the controller from PI.

Discharging a S-331 that is connected to the controller

1. Switch the controller off.
2. Wait at least 10 seconds before pulling out the connector.

Discharging a S-331 that is not connected to the controller

- Connect the S-331 to the switched-off controller from PI.

7 Maintenance

In this Chapter

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Cleaning the S-331	37

7.1 General Notes on Maintenance

NOTICE



Misalignment due to loosening screws!

The S-331 is maintenance-free and achieves its positioning accuracy as a result of the optimum alignment of mechanical components and piezo actuators. Loosened screws cause a loss in positioning accuracy.

- Only loosen screws according to the instructions in this manual.
- Do **not** open the S-331.

7.2 Cleaning the S-331

Requirements

- ✓ You have discharged the piezo actuators of the S-331 (p. 35).
- ✓ You have disconnected the S-331 from the controller.

Cleaning the S-331

- Clean the surfaces of the S-331 with a cloth that is slightly dampened with a mild cleanser or disinfectant (e.g., ethanol or isopropanol).
- Do **not** use ultrasonic cleaners.

8 Troubleshooting

Problem	Possible causes	Solution
No or uncontrolled motion	<ul style="list-style-type: none"> ▪ Cable not connected correctly ▪ Controller defective ▪ Cable defective ▪ Piezo ceramic defective after electric flashover 	<ul style="list-style-type: none"> ➤ Check the cable connections (p. 31). ➤ Contact our customer service department (p. 41).
Reduced accuracy	Warped base body	<p>Only mount the S-331 on surfaces with the following characteristics:</p> <ul style="list-style-type: none"> ▪ Evenness of at least 30 μm ▪ The thermal expansion properties are similar to those of the S-331 (e.g., surfaces made of steel)
	Adhesive has run into the M1.6 threaded hole or between the platform and the housing of the S-331	<ul style="list-style-type: none"> ➤ Contact our customer service department (p. 41).
	S-331 or controller has been replaced	<p>After the S-331 or controller has been replaced, it is necessary to recalibrate the axis displacement.</p> <ul style="list-style-type: none"> ➤ Perform a recalibration of the axis displacement (see controller manual) or contact our customer service department (p. 41).
	Mirror and mirror mount have been replaced	<p>The change in the mass that has to be moved by the S-331 influences the dynamic characteristics such as the resonant frequency of the piezo tip/tilt system.</p> <ul style="list-style-type: none"> ➤ Adjust the notch filter and servo-control parameters of the controller; see controller manual.
	Operating temperature outside of the permissible range (p. 43)	<ul style="list-style-type: none"> ➤ Contact our customer service department (p. 41).

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. 41).

9 Customer Service

For inquiries and orders, contact your PI sales engineer or send us an email (info@pi.ws).

- If you have questions concerning your system, have the following information ready:
 - Product codes and serial numbers of all products in the system
 - Firmware version of the controller (if present)
 - Version of the driver or the software (if present)
 - Operating system on the PC (if present)
- 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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10.1 Specifications

10.1.1 Data Table

	S-331.2SL / S-331.2SH	S-331.5SL / S-331.5SH	Unit	Tolerance
Active axes	θ_x, θ_y	θ_x, θ_y		
Motion and Positioning				
Integrated sensor	SGS	SGS		
Open-loop tip/tilt angle in θ_x, θ_y at -20 to 120 V	4.2	7	mrad	min.
Closed-loop tip/tilt angle in θ_x, θ_y	3	5	mrad	
Open-loop resolution in θ_x, θ_y	0.05	0.1	μ rad	typ.
Closed-loop resolution in θ_x, θ_y	0.1	0.25	μ rad	typ.
Linearity error in θ_x, θ_y	0.4 * 0.1 **	0.4 * 0.1 **	%	typ.
Repeatability in θ_x, θ_y , 10% tilt angle	0.3	0.5	μ rad	typ.
Repeatability in θ_x, θ_y , 100% tilt angle	3	5	μ rad	typ.
Mechanical Properties				
Resonant frequency, unloaded in θ_x, θ_y	10	6	kHz	± 20 %

	S-331.2SL / S-331.2SH	S-331.5SL / S-331.5SH	Unit	Tolerance
Resonant frequency, unloaded in θ_x , θ_y (with glass mirror, \varnothing 12.7 mm, thickness 3 mm)	6	4	kHz	± 20 %
Distance of pivot point to platform surface	4	4	mm	± 1 mm
Platform moment of inertia	30	30	$g \times mm^2$	± 20 %
Drive Properties				
Ceramic type	PICMA®	PICMA®		
Electrical capacitance	0.96/axis	1.44/axis	μF	± 20 %
Miscellaneous				
ID chip functionality	S-331.2SH	S-331.5SH		
Operating temperature range	-20 to 80	-20 to 80	$^{\circ}C$	
Material housing	Steel	Steel		
Material platform	Titanium	Titanium		
Mass	0.13	0.14	kg	± 5 %
Cable length	2	2	m	± 10 mm
Sensor/voltage connection	LEMO (S-331.2SL), Sub-D 37-pin (m) (S-331.2SH)	LEMO (S-331.5SL), Sub-D 37-pin (m) (S-331.5SH)		

* In combination with analog E-5xx controller modules

** In combination with digital controllers




Recommended controllers/amplifiers

Versions with LEMO connectors: E-500 modular piezo controller system with E-503.00S amplifier module (three channel) or 1 x E-505.00S and 2 x E-505.00 (highly dynamic applications) and E-509 controller.

Versions with Sub-D connector (m): E-727-3SD/E-727.3SDA digital multi-channel piezo controller for SGS.

10.1.2 Maximum Ratings

The models of the S-331 are designed for the following operating data:

Model	Maximum operating voltage 	Maximum operating frequency ¹ (without load, at 100 V _{pp}) 	Maximum power consumption ² 
S-331.2SH S-331.2SL	-20 to +120 V	1.75 kHz	21 W/axis
S-331.5SH S-331.5SL	-20 to +120 V	1.5 kHz	25 W/axis

¹ To ensure stable operation, the maximum operating frequency has been defined as around one third of the mechanical resonant frequency. To calculate the resonant frequency of the system of S-331 and mirror, see "Dynamic Behavior" (p. 15).

² The heat that is generated by the piezo actuator during dynamic operation limits the value for maximum power consumption.

Details can be found at the following website:

<http://piceramic.com/piezo-technology/properties-piezo-actuators/electrical-operation.html>

10.1.3 Ambient Conditions and Classifications

The following ambient conditions and classifications must be observed for the S-331:

Area of application	For indoor use only
Maximum altitude	2000 m
Air pressure	1100 hPa to 0.1 hPa (equivalent of roughly 825 Torr to 0.075 Torr)
Relative humidity	Highest relative humidity 80 % for temperatures up to 31 °C Decreasing linearly to 50 % relative humidity at 40 °C
Storage temperature	-20 °C to 80 °C
Transport temperature	-25 °C to 85 °C
Overvoltage category	II
Protection class	I
Degree of pollution	1
Degree of protection according to IEC 60529	IP20

10.1.4 Recommended Control Signals for Dynamic Operation

The maximum permissible operating temperature for the piezo actuators of the S-331 is 80 °C. During dynamic continuous operation of a single axis, this temperature value is achieved at an ambient temperature of approx. 20 °C for the following characteristics of a sinusoidal piezo voltage signal and then remains constant.

Model	Amplitude	Operating frequency
S-331.2SH	20 V _{pp}	2.5 kHz
S-331.2SL	50 V _{pp}	2.5 kHz
	100 V _{pp}	1.75 kHz
S-331.5SH	20 V _{pp}	2 kHz
S-331.5SL	50 V _{pp}	2 kHz
	100 V _{pp}	1.5 kHz

At a higher ambient temperature and when both axes are operated, the maximum permissible operating temperature can already be achieved at a lower amplitude and/or lower operating frequency.

10.2 Dimensions

Dimensions in mm. Note that the decimal places are separated by a comma in the drawings.

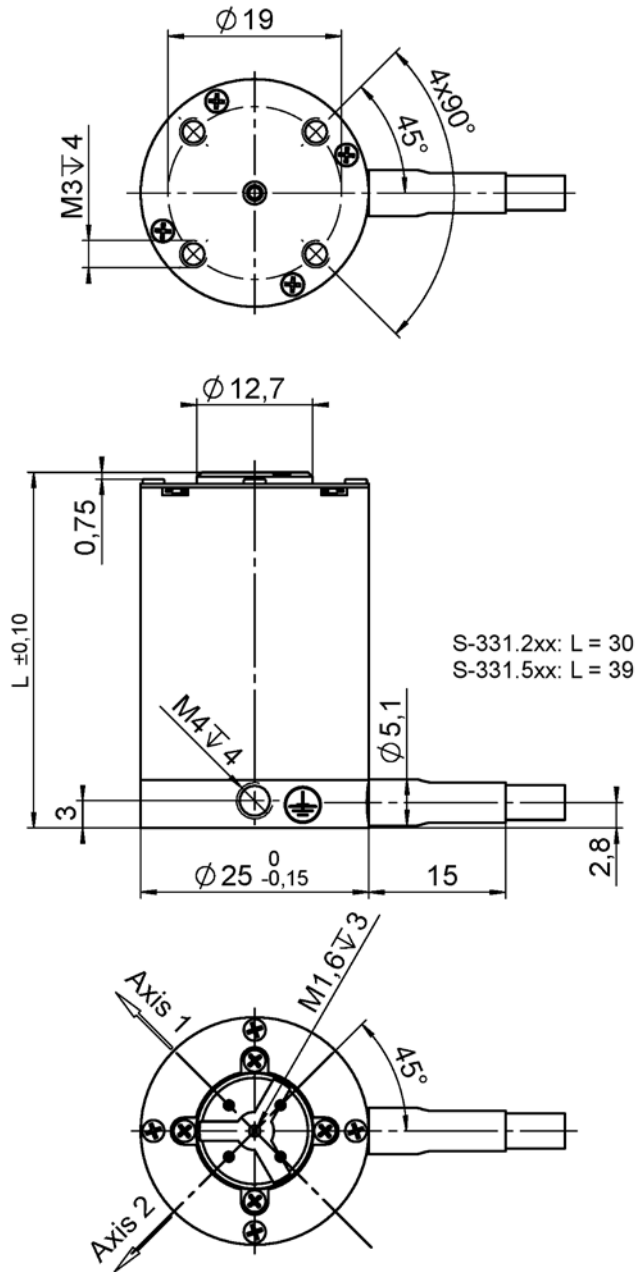


Figure 16: S-331.xSH

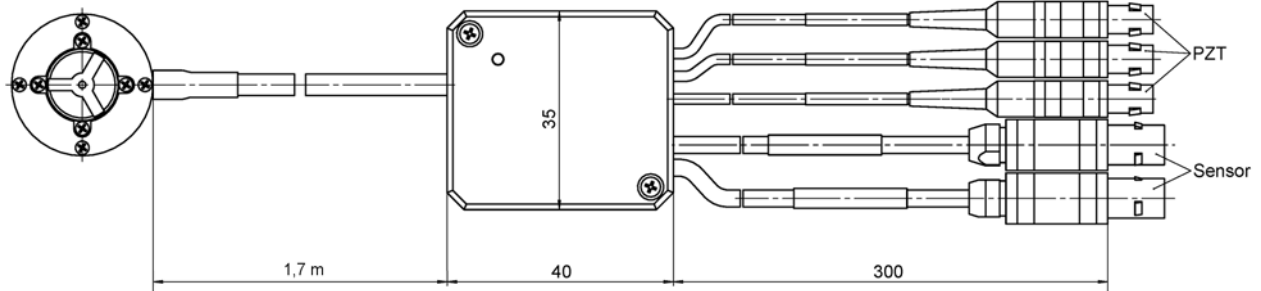


Figure 17: S-331.xSL: Position and dimensions of the cable splitter box

10.3 Pin Assignment

10.3.1 S-331.xSH: Sub-D 37 (m) Piezo and Sensor Connection



Figure 18: Sub-D 37 (m) piezo and sensor connection

Pin	Signal*	Function
1	-	-
2	GND	Ground
3	ID chip CH2	Data, ID chip axis 2
4	-	-
5	ID chip GND	Ground, ID chip
6	-	-
7	GND	Ground
8	-	-
9	GND	Ground
10	SGS CH2+	SGS signal axis 2 (positive)
11	GND	Ground
12	SGS CH1+	SGS signal axis 1 (positive)
13	GND	-

Pin	Signal*	Function
14	Reserved	Reserved
15	Reserved	Reserved
16	Piezo CH1+	Piezo voltage, axis 1 (positive)
17	Piezo CH2+	Piezo voltage, axis 2 (positive)
18	Piezo CH3+	100 V fixed voltage
19	-	-
20	-	-
21	ID chip CH1	Data, ID chip axis 1
22	ID chip GND	Ground, ID chip
23 to 27	-	-
28	SGS CH2-	SGS signal axis 2 (negative)
29	SGS CH2 Ref	SGS reference axis 2
30	SGS CH1-	SGS signal axis 1 (negative)
31	SGS CH1 Ref	SGS reference axis 1
32	Reserved	Reserved
33	Reserved	Reserved
34	Piezo CH1-	Piezo voltage, axis 1 (negative)
35	Piezo CH2-	Piezo voltage, axis 2 (negative)
36	Piezo CH3-	Ground 100 V fixed voltage
37	-	-

* The "-" sign indicates that the corresponding pin has not been assigned.

10.3.2 S-331.xSL: LEMO Piezo and Sensor Connections



Figure 19: Sensor connection: LEMO connector FFA.0S.304.CLAC32Y, contact side

Pin	Signal	Function
1	SGS Ref	SGS reference
2	SGS-	SGS signal (negative)
3	SGS+	SGS signal (positive)
4	SGS GND	Ground SGS signal

PZT

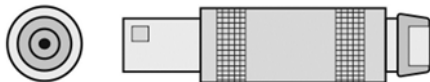


Figure 20: Piezo connector

Signal	Function	Connector Shell
PZT	Piezo Voltage	Ground

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 EC Declaration of Conformity

For the S-331, an EC Declaration of Conformity has been issued in accordance with the following European directives:

Low Voltage Directive

EMC Directive

RoHS Directive

The applied standards certifying the conformity are listed below.

Safety (Low Voltage Directive): EN 61010-1

EMC: EN 61326-1

RoHS: EN 50581

