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User Manual PZ 107E

S-330

Tip/Tilt Platform

Release 1.1.1



Product Description
and
Operating Notes

This Document is valid for the following products:

S-330.10	**Piezo Tip/Tilt Platform, ±1 mrad, Closed-Loop**
S-330.P10	**Piezo Tip/Tilt Platform, ±1 mrad, Closed-Loop with PICMA Ceramic**
S-330.30	**Piezo Tip/Tilt Platform, ±1 mrad**

Release: *1.1.1*
Release Date: *2003-09-09*

© Physik Instrumente (**PI**) **GmbH & Co. KG**
76228 Karlsruhe, Germany **FAX: (+49)721-4846-100**
EMail: info@pi.ws **www.pi.ws**

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0 Manufacturer Declarations

0.1 Quality and Warranty Clauses

Certification

Physik Instrumente GmbH & Co. KG (**PI**) certifies that this product met its published specifications at the time of shipment. The device was calibrated and tested before shipment.

Warranty

This Physik Instrumente product is warranted against defects in materials and workmanship for a period of one year from date of shipment. Duration and conditions of warranty for this product may be superseded when the product is integrated into (becomes a part of) other Physik Instrumente products. During the warranty period, Physik Instrumente will, at its option, either repair **or** replace products which prove to be defective.

Limitation of Warranty

The foregoing warranty shall not apply to defects resulting from improper or inadequate maintenance by the Buyer, Buyer supplied products or interfacing, unauthorised modification or misuse, operation outside of the environmental specifications for the product, or improper site preparation or maintenance.

The design and connection of any circuitry to this product is the sole responsibility of the Buyer. **PI** does not warrant the Buyer's circuitry or malfunctions of **PI** products that result from the Buyer's circuitry. In addition, **PI** does not warrant any damage that occurs as a result of the Buyer's circuit or any defects that result from Buyer-supplied products.

No other warranty is expressed or implied. Physik Instrumente specifically disclaims the implied warranties of merchantability and fitness for a particular purpose.

0.2 Safety Precautions

Warning: Be careful when mounting the platform

Never use the hole on the platforms surface for mounting an object.

Never put anything in the flexure gaps of the body.

Do not clamp the body since this can block the flexure guiding system.

Warning: Resonance Can Cause Permanent Damage

The system must never be operated close to the resonant frequency or permanent damage can result. If you hear or see resonant behavior, switch off the unit immediately.

1 Introduction

The S-330 tip/tilt platform is an active tip/tilt stage system based on the differential-piezo-drive design incorporating two pairs of LVPZT (low voltage piezoelectric translator) actuators. The system is designed for fast and precise laser beam steering in two axes and for stabilizing and correcting optical axes or paths.

1.1 Features

- Sub-µrad Resolution
- For Mirrors to 50 mm ∅
- Closed-Loop Versions
- Differential Design for Excellent Temperature Stability



Fig. 1. S-330 tip/tilt mirror

1.2 Design

The tip/tilt platform is mounted on four LVPZT stacks, located at the corners of a square. Tilting around one axis requires synchronized movement of two diagonally opposite LVPZT actuators. To ensure that one actuator will contract by exactly the same amount as the other expands, the actuator pairs are individually matched at the factory. The actuators in each pair are then connected electrically in differential push-pull mode, eliminating Z-axis freedom.

Note that with this design the pivot point is fixed and the same for both rotation axes. Whether you choose to measure the angles in vertical planes or in planes perpendicular to the platform depends on the requirements of your application.

1.3 Models Available

S-330.10 PZT Tip/Tilt Platform, 2 Axes, ±1 mrad, Closed-Loop

S-330.P10 same as S-330.10 but with PICMA ceramic actuator

S-330.30 PZT Tip/Tilt Platform, 2 Axes, ±1 mrad, Open-Loop

2 Quick Start

2.1 Mounting

You can mount the object to be positioned (for example, a mirror) on the platform using glue.

Warnings

Never use the hole on the platform surface for mounting an object.

Never put anything in or across the gaps (flexure guiding system) of the body.

Do not clamp the body since this can block the flexure guiding system.

The platform can be mounted in any orientation. If you mount it on a vertical plane, however, the maximum “sideways” force limitation of 1 N will limit the load capacity accordingly.

By default, the platform metal case is not connected electrically. You should ground the mechanics if so required.

2.2 Connecting to Controller and Starting

The following instructions describe starting the S-330 tip/tilt platform using PI’s E-500-series control electronics (E-500 or E-501 chassis including E-503.00S amplifier module and, when using the closed-loop model, E-509.S3S servo-control module). If you use other modules from the E-500 series the steps are the same, but the connections details may differ. In this case please consult “Drive Electronics” Section on p. 8 for further information.

1. Make sure the control electronics is switched off.
2. Closed-loop models (S-330.10 and S-330.P10) only: Connect the S-330 tip/tilt mirror to the E-509.S3S servo-control module.

   The sensor cable of the S-330, which has a 4-pin connector and is labeled “CH1”, must be plugged into the corresponding socket of the servo-control module (labeled “SERVO 1”). This cable carries sensor signals from channels 1 and 2.
3. Connect the S-330 tip/tilt platform to the E-503.00S amplifier module.

   The supply voltage cables of the S-330 have brown connectors and are labeled “CH 1”, “CH 2” and “CH 3”. They must be plugged into the corresponding output sockets of the amplifier module.

   Note: Do not mix up the cables while connecting, since the amplifier channels are connected internally so as to supply the platform channels 1 and 2 with variable drive signals, while channel 3 is supplied with a constant and very stable voltage of +100 volts.

   Warning: Resonance Can Cause Permanent Damage

   The system must never be operated close to the resonant frequency or permanent damage can result. If you hear or see resonant behavior, switch off the unit immediately.

   See “Dynamic Behavior” Section on p. 9 for more details.
4. Switch on the control electronics.

   Consult the E-500 User Manual, and, if you have an E-516 interface module installed, the E-516 E-User Manual for information on commanding the S-330 tip/tilt platform. If

you have the closed-loop model, see also the User Manual of the servo-control module (E-509) for details on servo-control settings.

3 Working Principle

The S-330 contains two pairs of PZT actuators. The actuators in each pair are connected in differential push-pull mode: any change in the operating voltage causes one actuator of the pair to see a voltage increase, the other to see a decrease of the exact same magnitude.

Because the symmetrical design of the tip/tilt platform system, temperature changes will not effect the angular orientation but only the Z-axis position (axial thermal drift). Most applications are much less sensitive to this kind of instability as long as the angular orientation remains stable.

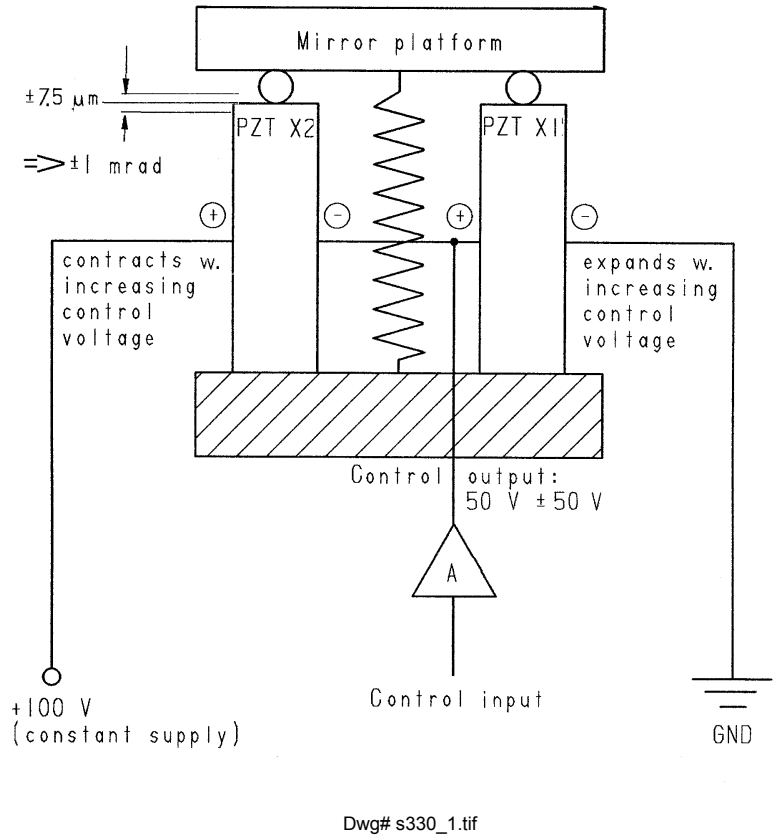


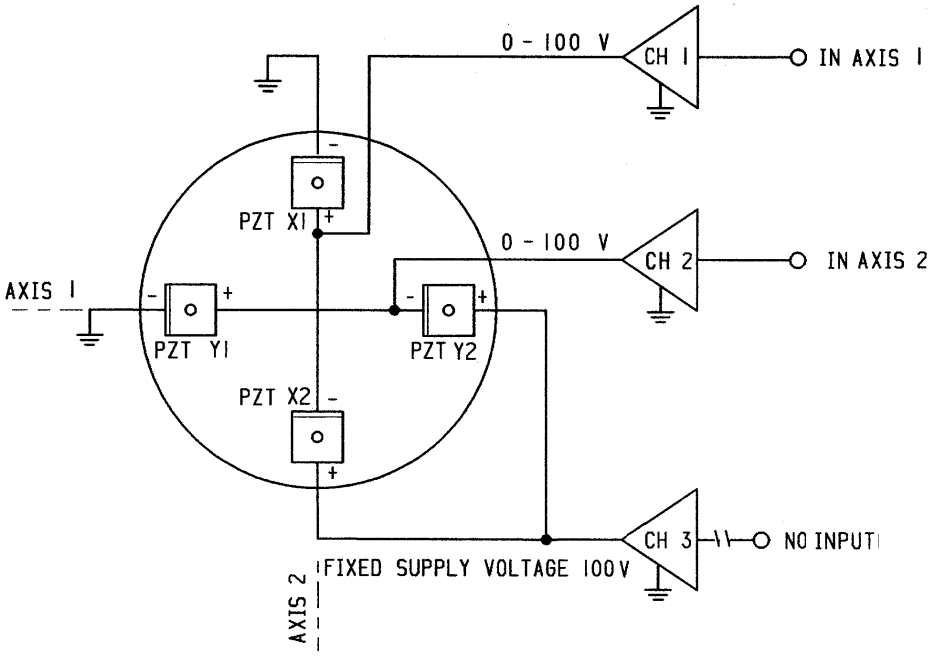
Fig. 2. S-330 Differential-drive tip/tilt platform, working principle (only Axis-1 tip motion shown)

3.1 Operating Voltages

Each tilt axis of the tip/tilt platform system requires one controlled operating voltage in the range of 0 to +100 volts and one constant voltage of +100 V. At the zero position (tilt angle zero) both actuators of a pair are expanded to 50% of their maximum expansion (i.e. to 7.5 µm). Control voltages below 50 volts cause tilting in one direction, above 50 volts, tilting in the other. A 0 to 10 V control input thus covers the full tilt range. Operation over an extended range of -20 to +120 V is possible with certain limitations.

3.2 Motion Polarities

The diagram below shows the relative positions of the four PZT stacks and makes the relative rotation polarities clear.



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Fig. 3. S-330 viewed from above with Axis 1 (controlled by channel 1) running left and right.

Keeping in mind that the grounded PZTs expand with increasing input, it can be seen that if after a positive Axis 1 tilt, you look “uphill” across the platform, a subsequent positive Axis 2 tilt would go up to the left and down to the right. Conversely, facing “uphill” after a positive Axis 2 tilt, a positive Axis 1 tilt would go down to the left and up to the right. The “handedness” of an open-loop system (with no sensor cable) can thus be inverted by interchanging the axes and rotating the unit 90°.

3.3 Position Sensors

The closed-loop versions, S-330.10 and S-330.P10, are equipped with two pairs of strain gauge position feedback sensors operated in a bridge circuit for ultra-high resolution and angular stability. These sensors permit angular movements to be executed with sub-µrad resolution and repeatability.

The S-330.10 and S-330.P10 use strain gauge sensors in a half-bridge configuration.

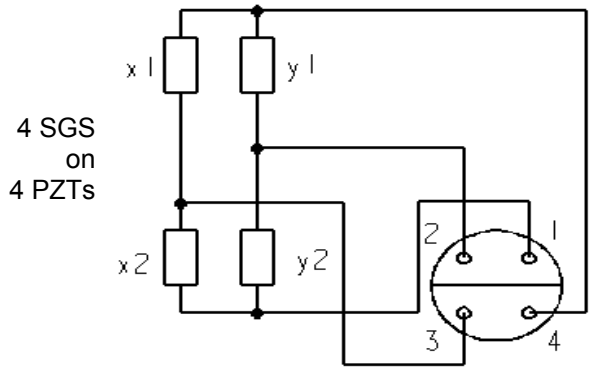


Fig. 4. S-330 sensor cable connections and pinout. X1, Y1,... refer to the PZT on which the respective sensors are mounted (see Fig. 3)

Note that both sensor channels are routed over a single sensor connector. If using an E-509.S3S controller, connect this cable to the CH1 socket. The CH2 and CH3 sockets are not connected.

4 Drive Electronics

The S-330 tip/tilt platform system can be controlled by electronics of the E-500 series:

Amplifier (choice of the following, always required):

E-503.00S	Amplifier module special connected for differential-drive LVPZT tip/tilt platforms; 2 channels with variable drive signals (output sockets “CH1” and “CH2”) plus 100 V fixed output (output socket “CH3”)
2 x E-505.00 1 x E-505.00S	Single Channel modules. With two E-505.00 modules on the left and one E-505.00S on the right, “CH1” of the platform must be connected to the leftmost module, “CH2” to the center module and “CH3” to the E-505.00S

Note: On amplifiers for tip/tilt mirrors, the DC-offset potentiometer for channel 3, if present at all, is disabled and the output is clamped internally to +100 volts. The analog input of this channel is also disabled. External control voltages thus must be supplied to the CONTROL INPUT sockets of CH1 and CH2.

Controller (required in addition to amplifier for closed-loop operation):

E-509.S3S	Position servo-control module for SGS sensors; channel 1 (labeled “SERVO 1”) must be used with the platforms sensor cable, second and third channel (input sockets “SERVO 2” and “SERVO 3”) are not used. **Note:** This controller has the same front panel as a regular 3-channel version, but with the CH3 controls/connections deactivated and sensor channels 1 and 2 both routed through the CH1 sensor socket.

Display Module (displays position or voltage of axes, not required):

E-515.03	3½-digit LED position or voltage display for each of 3 channels (channel 3 not used)
E-515.01	3½-digit LED position or voltage display, 1 channel (2 modules needed for 2-axis display)

Computer Interface and Display Module (replaces display above, required for computer-controlled operation):

E-516.i3*	Computer Interface and Display Module, 3 channels, (channel 3 not used)

*The discontinued E-515.i3 can also be used.

5 Dynamic Behavior

In addition to the amplifier, controller and sensor bandwidths, the maximum operating frequency of a tilt platform depends on its mechanical resonant frequency. To estimate the effective resonant frequency of the tilt mirror system (platform + mirror), the moment of inertia of the mirror substrate must first be calculated.

Moment of inertia of a rotationally symmetric mirror:

$$I_m = m\left[\frac{3R^2 + H^2}{12} + \left(\frac{H}{2} + T\right)^2\right]$$

Moment of inertia of a rectangular mirror:

$$I_m = m\left[\frac{L^2 + H^2}{12} + \left(\frac{H}{2} + T\right)^2\right]$$

where:

m = Mirror mass [g]

I_M = Moment of inertia of the mirror [g·mm^2]

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

H = Mirror thickness [mm]

T = Distance, pivot point to platform surface (see technical data table for individual model) [mm]

R = Mirror radius [mm]

Using the resonant frequency of the unloaded platform (see Technical Data table) and the moment of inertia of the mirror substrate, the system resonant frequency is calculated according to the following equation:

Resonant frequency of a tilt platform / mirror system:

$$f' = \frac{f_0}{\sqrt{1 + I_M / I_0}}$$

where:

f' = Resonant frequency of platform with mirror [Hz]

f_0 = Resonant frequency of unloaded platform [Hz]

I_0 = Moment of inertia of the platform (see technical data table) [g·mm^2]

I_M= Moment of inertia of the mirror [g·mm^2]

For more information on static and dynamic behavior of piezo actuators, see the "Tutorial" section of the PI Catalog, in particular pages 4-27 *ff.*

6 S-330 Technical Data

Models	S-330.30 (open-loop)	S-330.10 / S-330.P10 (closed-loop)	Units
Active axes (fixed orthogonal tilt axes)	2	2	
Tip/tilt range 0 to 100 V[1]	±1	±1	mrad ±20%
Closed-loop tilt angle ≥	–	±1	mrad
Integrated feedback sensor	–	4 x strain gauge	
Open-loop / closed-loop resolution[2] ≤	0.05	0.1	µrad
Closed-loop linearity (typ.)	–	±0.2	%
Full-range repeatability (typ.)[3]	–	±2	µrad
Electrical capacitance[4]	3.6 per axis	3.6 per axis	µF ±20%
Dynamic operating current coefficient (DOCC)[5]	0.22 per axis	0.22 per axis	µA/(Hz x µrad)
Resonant frequency (f_0) without mirror[6]	3.3	3.3	kHz ±20%
Resonant frequency w/ Ø 25 x 8 mm glass mirror[7]	2.4	2.4	kHz ±20%
Distance, pivot point to platform surface	6	6	mm
Platform moment of inertia	1530	1530	g·mm^2
Operating temperature range[8]	-20 to 80	-20 to 80	°C
Voltage connection	3 x Lemo fem. 2m cable	3 x Lemo fem. 2m cable	
Sensor connection	–	1 x Lemo, 2m cable	
Weight (w/o cables)	200	200	g ±5%
Material	Stainless steel case, Invar platform	Stainless steel case, Invar platform	
PICMA ceramic actuator[9]	no	no / yes	

Notes:

[1] Range: Operation over a -20 to +120 V range is possible if excursions to the limits are of short duration. See “Lifetime of PZTs” in the PI Catalog for more information. Special open-loop version with ± 2.5 mrad for 0-100 V is available on request.

[2] Resolution of PZT tip/tilt platforms is not limited by friction or stiction. Value is typical (RMS, 1σ) noise-equivalent motion with E-503 amplifier module.

[3] Full-Range Repeatability: Typical values, closed-loop mode. Since repeatability is a percentage of angle traveled, repeatability is significantly better for small ranges.

[4] Temperature Range: Small-signal value (measured at 1 V, 1000 Hz, 20 °C, no load); large-signal values at room temperature are 30 to 50% higher. The capacitance of PZT ceramics changes with amplitude, temperature, and load up to 200% of the unloaded, small-signal capacitance at room temperature. For detailed information on power requirements, refer to the amplifier frequency response curves in the "PZT Control Electronics" section of the PI Catalog.

[5] Dynamic Operating Current Coefficient in µA per hertz and µrad. Example: Sinusoidal scan of 100 µrad at 10 Hz requires approximately 0.22 mA drive current.

[6] Unloaded Resonant Frequency: Lowest tilt resonant frequency around an active axis without mirror (well above the maximum operating frequency). For more resonance considerations, see p. 4-28 in the PI Catalog.

[7] Resonant Frequency with Mirror: Example of how a load (mirror) affects the (calculated) resonant frequency.

[8] Standard range, other temperature ranges on request. Closed-loop systems are calibrated for optimum performance at room temperature. Recalibration is recommended if operation is at a significantly higher or lower temperature.

[9] PICMA™ ceramics offer extended lifetime and compatibility with harsh conditions.

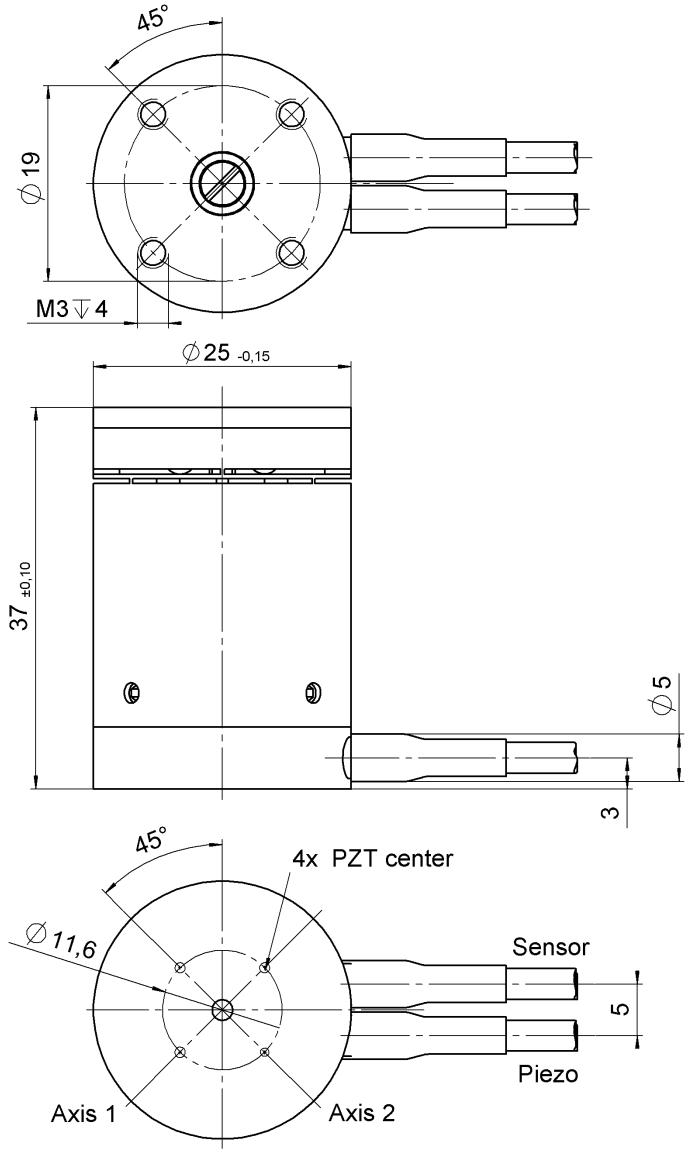
6.1 Connectors

The S-330 tip/tilt platform is equipped with three cables for supply voltage and and one cable for the sensor signals. Its LEMO connectors match the amplifier and servo controller modules.

The supply voltage cables of the S-330.xx are labeled “CH 1”, “CH 2” and “CH 3”.

The sensor cable of the S-330.10 and S-330.P10 (with 4-pin connector) is labeled “CH 1”. It carries sensor signals for both channels 1 and 2 (see Section 3.3, p. 7)

6.2 Dimensions



S-330 dimensions in mm, decimal places separated by a comma in drawings

Note: On the open-loop model (S-330.30) the unused sensor cable outlet is plugged with silicon.

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