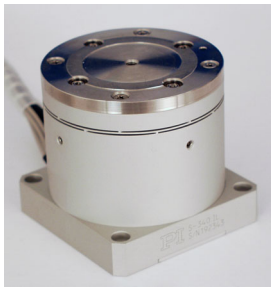
User Manual PZ 75E

S-340

Tip/Tilt Platform

Release 2.2.0



Product Description
and
Operating Notes

This document is valid for the following products:

S-340.x0	**Tip/Tilt Platform**
S-340.xL	**Tip/Tilt Platform with LVDT sensors**

Release: *2.2.0*
Release Date: *2003-05-22*

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0. Quality and Warranty Clauses

Certification

Physik Instrumente (**PI**) certifies that this product met its published specifications at the time of 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 Duration and conditions of warranty for this product may be superseded when the product is integrated into (becomes a part of) other Physik Instrumente products.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.

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1. Introduction

The S-340 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.

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.

Fig. 1. S-340 tip/tilt platform with connectors

1.1. Models Available:

S-340.T0 PZT Tip/Tilt Platform, 2 Axes, Material: Titanium
S-340.A0 PZT Tip/Tilt Platform, 2 Axes, Material: Aluminum
S-340.i0 PZT Tip/Tilt Platform, 2 Axes, Material: Invar
S-340.S0 PZT Tip/Tilt Platform, 2 Axes, Material: Steel
S-340.TL PZT Tip/Tilt Platform, 2 Axes, Material: Titanium, LVDT sensors
S-340.AL PZT Tip/Tilt Platform, 2 Axes, Material: Aluminum, LVDT sensors
S-340.iL PZT Tip/Tilt Platform, 2 Axes, Material: Invar, LVDT sensors
S-340.SL PZT Tip/Tilt Platform, 2 Axes, Material: Steel, LVDT sensors

Note: *Material* refers to platform interface material

2. Electrical Design

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.

The closed-loop versions (S-340.xL) are equipped with two pairs of LVDT position feedback sensors operated in a bridge circuit for ultra-high resolution and angular stability. These sensors have 10 nm linear resolution and permitangular movements to be executed with 5 µrad resolution.

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.

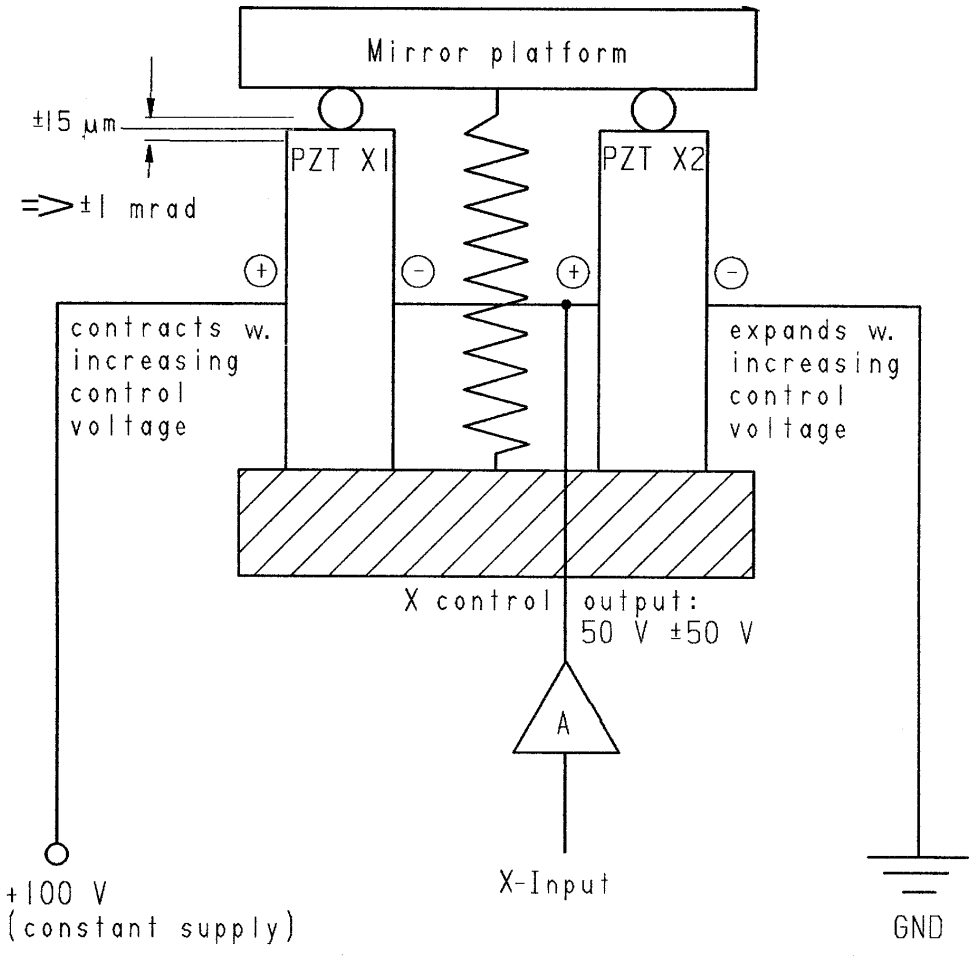

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Fig. 2. S-340 differential-drive tip/tilt platform, working principle (X-axis tip motion shown)

3. 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 at 50% of their maximum expansion (i.e. at 15 µm expansion). 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).

The diagram below shows the relative positions of the four PZT stacks and makes the relative rotation polarities clear. Please note: To ease the understanding of the working principle, the tilt axes and the corresponding PZTs are labeled X and Y. In fact the user is free to assign x- and y-axis of an orthogonal coordinate system to the tilt axes of the platform.

The handedness of the system can be inverted by interchanging the axes and rotating the unit 90° (on closed-loop versions sensor cables must also be interchanged).

S-340 LVPZT Actuator Layout and Wiring

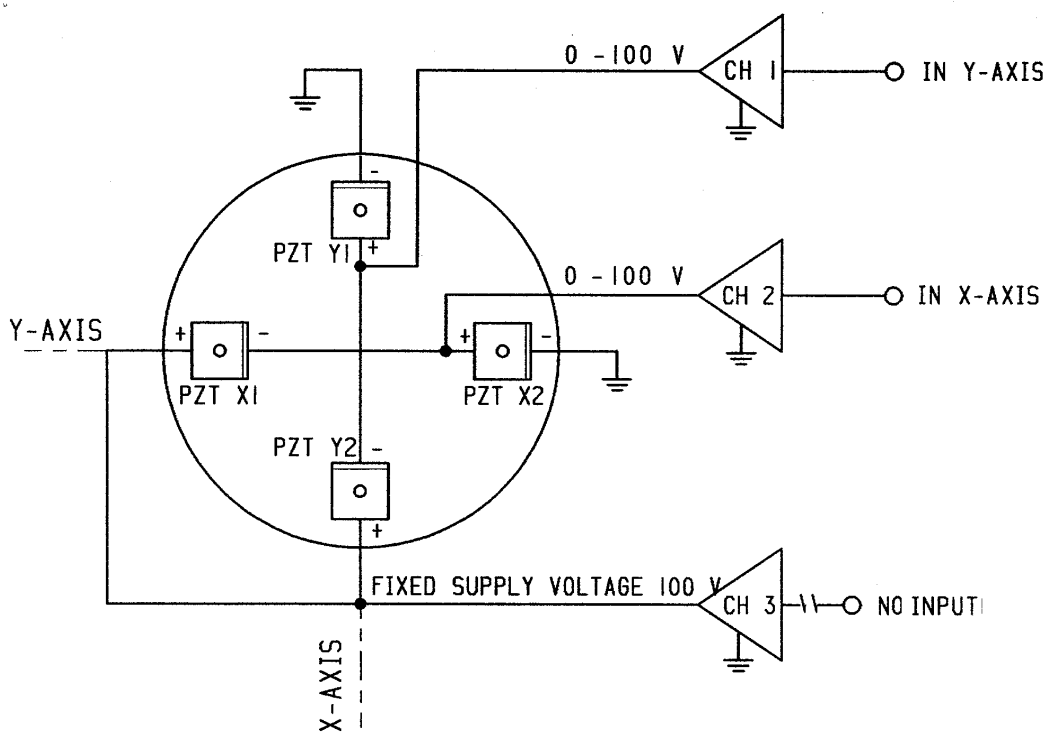

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Fig. 3. S-340 viewed from above with Y-axis running left and right. PZT stacks connected to the fixed 100 V supply contract with increasing input, grounded stacks expand.

4. Operating Instructions

The S-340 tip/tilt platform is equipped with cables for power and sensor signals and LEMO connectors to match the driver and controller modules.

The supply voltage cables labeled CH1, CH2 and CH3 must be plugged into the corresponding output sockets of the amplifier/controller. Channel 1 and 2 outputs are the variable drive signals, while channel 3 supplies a constant voltage of +100 volts. This channel has no manual DC-offset potentiometer and the output is clamped internally to +100 volts. The analog input of this channel is also disabled.

The sensor cables (black cables with 4-pin LEMO connector) are labeled Sensor CH1 and Sensor CH2 have to be plugged into the corresponding sockets of the controller module. Channel 3 of the control module must not be used.

External control voltages must be supplied to the inputs CH1 and CH2 on the amplifier modules.

5. Drive Electronics

The S-340 tip/tilt platform system is controlled by electronics of the E-500 series (described in separate manuals):

Amplifier (choice of the following, always required):

E-503.00S or specially connected E-503.00	Amplifier module for differential-drive LVPZT tip/tilt platforms (2 channels plus 100 V fixed output)
E-505.00	1-Channel Amplifier module for LVPZTs (3 modules required)

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

Specially connected E-509.L3	Position Servo-Control Module for LVDT Sensors, 3 channels (channel 3 not used)

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.

6. 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.*

7. S-340.xx Technical Data

Models	S-340.A0 / S-340.AL open-loop/closed-loop	Units
Active axes	2 fixed orthogonal tilt axes	
Design	Differential-piezo drive (4 LVPZT stacks)	
Tip/tilt range 0 to 100 V[1]	±1	mrad ±20%
Closed-loop tilt angle ≥	– / ±1	mrad
Integrated feedback sensor	– / 4 x LVDT	
Sensor linear resolution	– / 10	nm
Open-loop / closed-loop resolution[2] ≤	0.1 / 0.5	µrad
Closed-loop linearity (typ.)	– / ±0.1	%
Full-range repeatability (typ.) [3]	– / ±1	µrad
Electrical capacitance[4]	7.2 / axis	µF ±20%
Dynamic operating current coefficient (DOCC) [5]	0.45 / axis	µA/(Hz·µrad)
Resonant frequency (f_0) without mirror[6,7]	1.4	kHz ±20%
Resonant frequency w/ Ø 50 x 15 mm glass mirror[6,8]	0.9	kHz ±20%
Resonant frequency w/ Ø 75 x 22 mm glass mirror[6,8]	0.4	kHz ±20%
Distance, pivot point to platform surface	7.5	mm
Platform moment of inertia	18000	g·mm^2
Operating temperature range[9]	-20 to 80	°C
Voltage connection	3 x Lemo fem. 1 m cable	
Sensor connection	– / 2 x Lemo, 1 m cable	
Weight (w/o cables)	335	g ±5%
Material	Case: aluminum Platform: depends on version	

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.

[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 0.45 mA drive current.

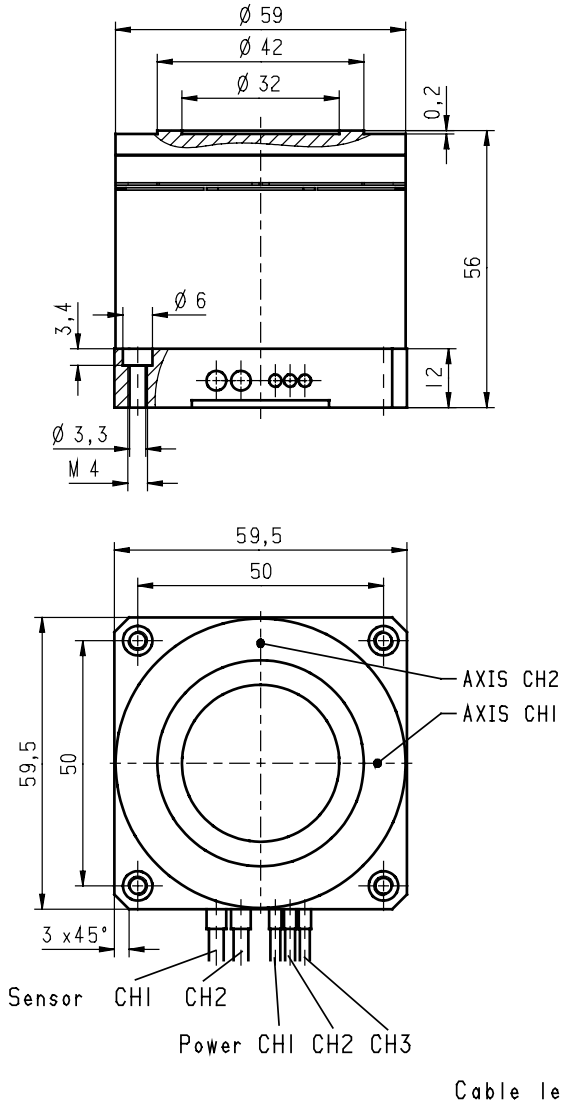
[6] Resonant frequency values for aluminum top plate. Frequencies are lower for other versions due to higher moment of inertia: titanium +60%, invar +200%, steel +190%.

[7] 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.

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

[9] 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.

8. Drawings



Dimensions in mm, decimal places separated by comma in drawings

Fig. 4. S-340 dimensions

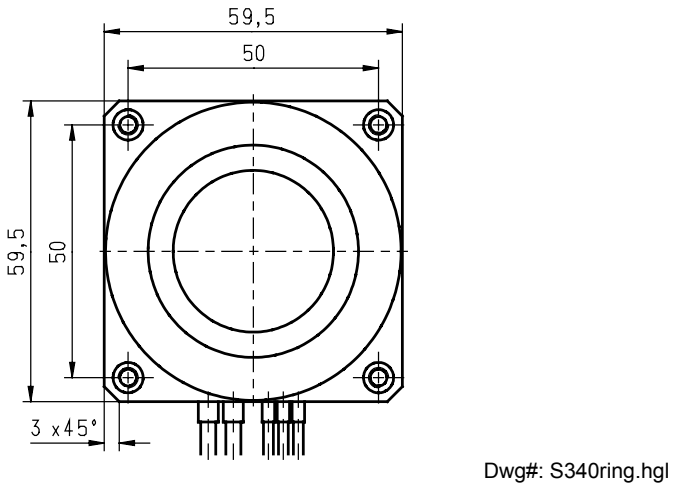


Fig. 5.Mounting flat with a ring elevation for mirror attachment