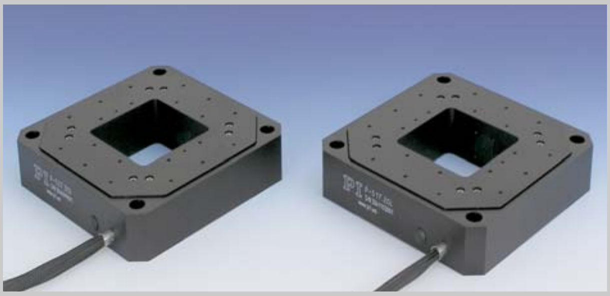
Piezo · Nano · Positioning

PZ 82E User Manual

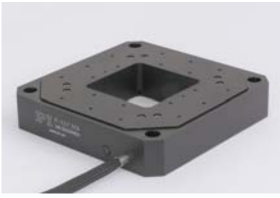
P-500 Series **PZT Flexure Stages**

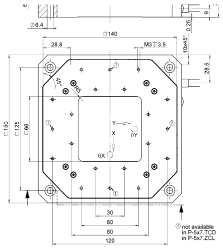
Release: 2.2.1 Date: 2005-10-24



This document describes the following products:

- **P-517.2CL, P-517.3CD**
  XY Stage, 100 x 100 µm
- **P-517.3CL**
  XYZ Stage, 100 x 100 x 20 µm, LEMO Connectors
- **P-517.RCD**
  X,Y,θ_Z Stage, 100 x 100 µm, ±1 mrad, Sub-D Connector
- **P-527.2CL**
  XY Stage, 200 x 200 µm, LEMO Connectors
- **P-527.3CD, P-527.3CL**
  XYZ Stage, 200 x 200 x 20 µm
- **P-527.RCD**
  X,Y,θ_Z Stage, 200 x 200 µm, ±2 mrad, Sub-D Connector
- **P-518.TCD**
  Z-Axis and Tip-Tilt (θ_X, θ_Y) Flexure Stage, 100 µm x 1.12 mrad, Sub-D Connector
- **P-518.ZCD, P-518.ZCL**
  Z-Axis Stage, 100 µm
- **P-528.TCD**
  Z-Axis and Tip-Tilt (,θ_X ,θ_Y) Flexure Stage, 200 µm x 2.26 mrad, Sub-D Connector
- **P-528.ZCD, P-528.ZCL**
  Z-Axis Stage, 200 µm
- **P-558.TCD**
  Z-Axis and Tip-Tilt (,θ_X ,θ_Y) Flexure Stage, 50 µm x 0.56 mrad, Sub-D Connector
- **P-558.ZCD, P-558.ZCL**
  Z-Axis Stage, 50 µm





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0. Manufacturer Declarations

Physik Instrumente (PI) certifies that this product met its published specifications at the time of shipment. The device was calibrated and tested with the PZT actuators specified.

0.1. Handling Notes

Caution: Avoid Damage

Read Before Operating PI Piezoelectric Nanopositioners and Nanoautomation® Stages

- Do not operate the positioner at higher voltages or different polarity than stated in the data sheet. For optimum performance, and to avoid damage resulting from incorrect supply voltages, we strongly recommend operation with PI controllers only.
- PZTs are sensitive to moisture, high relative humidity, liquids and any other conductive material such as metal dust. Operating piezoelectric translators (PTZs) under environmental conditions of increased conductivity, electric discharges that can destroy the piezoelectric element can occur.
- For the same reason, it is not possible to operate the piezoelectric translators (PZT) at pressures between 100 hPa and 0.1 hPa (1.45 psi to 0.0014 psi). Under such conditions, the increased conductivity of air can cause electric discharges (corona effect). When operating in a vacuum below 0.1 hPa, the piezo must therefore not be operated while the pressure is being reduced.
- Do not disassemble the piezoelectric translator (PZT)!
  During operation PZT drives are under high voltages which can remain even after operation.
- A PZT system achieves its high accuracy by the proper matching of the mechanics and the drive. Disassembly will result in loss of the specified accuracy as well as voiding the warranty.
- Do not exceed the maximum push/pull forces stated in the catalog or data sheets. Doing so can result in damage to the PZT elements or deadjustment of the mechanics.
- Do not drop the stage or subject it to any kind of mechanical shock. Doing so can result in damage to the PZT elements or deadjustment of the mechanics.
- Attach the positioning stage only at the mounting holes provided for that purpose. Attach loads only at the threaded holes provided for that purpose. Follow the mounting instructions provided.
- Do not operate outside the temperature range given. The displacement range of the PZT depends on the ambient temperature and can vary by up to 20% within the ranges given (see also discussion of temperature effects in the PI catalog)
- Shorting the leads of a loaded piezo element must be done through a resistance of at least 10 kΩ in order to limit the discharge current. If this is not done, the resulting contraction shockwave can destroy the element.

0.2. Warnings and Safety Notices

Warning

The amplifiers and controllers used with these products are high-voltage devices capable of generating high output currents. They may cause serious or even lethal injury if used improperly.

We strongly advise you to never touch any part that might be connected to the high-voltage output.

Take special care if connecting to products from other manufactures. Follow the General Accident Prevention Rules!

Working with high-voltage amplifiers requires adequately trained operating personnel.

Caution: Actuator Damage

The piezo actuators in these stages connected to the E-710 can be destroyed by uncontrolled oscillation near the mechanical resonant frequency. If you observe resonance while configuring your system, switch off power to the actuators concerned immediately and check the settings and servo-control parameters.

1. General Description

This operating manual describes the functionality and the use of
P-500 Series of Multi-Axis Piezo Flexure NanoPositioners and Scanners

Features:

- Precision Trajectory Control
- 6-Axis Versions on Request
- Travel Ranges to 200 µm (per axis)
- Clear Aperture to 66 x 66 mm
- Integrated Capacitive Displacement Sensors
- Optional Active Error Compensation for Enhanced Trajectory Control

P-500 series positioners are low-profile, high-resolution, piezoelectrically driven multi-axis flexure stages providing motion in up to 6 degrees of freedom. Linear travel ranges to 200 x 200 x 20 µm and rotation ranges to ± 2 mrad are available. The 66 x 66 mm clear aperture is ideal for transmitted-light applications. The low cost and versatility of the P-500-series stages are made possible by their unique single-module design concept.

State-of-the-art trajectory control is achieved in the P-527.6C. This stage incorporates 6-axis active error compensation to force sub-nm and sub-µrad straightness and flatness (more information available on request).

Application examples:

Metrology, lithography, nanopositioning, scanning microscopy, disk drive testing, optics, laser technology, micromanufacturing

Working principle:

Low-voltage PZTs (0 to 100 V) and flexures are employed as the drive and guiding system. The flexures provide zero stiction/friction, ultra-high resolution and exceptional guiding precision. Integrated capacitive position feedback sensors provide sub-nm resolution and stability in closed-loop operation (with PI electronics).

P-527.xx PZT Flexure Stage

2. Model Survey

All models are piezo flexure stages equipped with capacitive position feedback sensors. The models differ in travel range, type of connectors and active axis combinations. The following can be inferred from the model numbers:

P-51 | 7. | 2 | C | L

"D" at the end:	sub-D connectors
"L" at the end:	LEMO connectors
"2" after the dot:	2 active axes
"3", "T" or "R" after dot:	3 active axes
"Z" after the dot:	Z axis only
"7" before the dot:	no tip-tilt axes (θ_X, θ_Y)
"8" before the dot:	no X, Y, θ_Z axes
"P-51" at the beginning:	travel ranges based on 100 µm
"P-52" at the beginning:	travel ranges based on 200 µm
"P-55" at the beginning:	travel ranges based on 50 µm

The available models are as follows. Special combinations, including 6-axis stages, are available on request.

P-517.2CL	XY Stage, 100 x 100 µm, LEMO Connectors
P-517.3CD	XYZ Stage, 100 x 100 x 20 µm, Sub-D Connector
P-517.3CL	XYZ Stage, 100 x 100 x 20 µm, LEMO Connectors
P-517.RCD	X,Y,θ_Z Stage, 100 x 100 µm, ±1 mrad, Sub-D Connector
P-527.2CL	XY Stage, 200 x 200 µm, LEMO Connectors
P-527.3CD	XYZ Stage, 200 x 200 x 20 µm, Sub-D Connector
P-527.3CL	XYZ Stage, 200 x 200 x 20 µm, LEMO Connectors
P-527.RCD	X,Y,θ_Z Stage, 200 x 200 µm, ±2 mrad, Sub-D Connector
P-518.TCD	Z-Axis and Tip-Tilt (θ_X, θ_Y) Flexure Stage, 100 µm x 1.12 mrad, Sub-D Connector
P-518.ZCD	Z-Axis Stage, 100 µm, Sub-D Connector
P-518.ZCL	Z-Axis Stage, 100 µm, LEMO Connectors
P-528.TCD	Z-Axis and Tip-Tilt (,θ_X ,θ_Y) Flexure Stage, 200 µm x 2.26 mrad, Sub-D Connector
P-528.ZCD	Z-Axis Stage, 200 µm, Sub-D Connector
P-528.ZCL	Z-Axis Stage, 200 µm, LEMO Connectors
P-558.TCD	Z-Axis and Tip-Tilt (,θ_X ,θ_Y) Flexure Stage, 50 µm x 0.56 mrad, Sub-D Connector
P-558.ZCD	Z-Axis Stage, 50 µm, Sub-D Connector
P-558.ZCL	Z-Axis Stage, 50 µm, LEMO Connectors

3. Working Principle

3.1. General

Low-voltage PZTs (0 to +100 V) and flexures are employed as the drive and guiding system. The flexures provide for zero-backlash motion and excellent guiding accuracy. The 3-axis versions add direct-drive PZT actuators for vertical motion. Integrated capacitive displacement sensors measure the position of the moving frame with resolution on the order of 1 nm.

3.2. Travel Range Restrictions for Tip-Tilt Stages

Positions obeying following condition are reachable with the E-5x8.TCD tip-tilt models:

$2 \cdot |Z - ½ L_Z| + 89\ \text{mm}\ (|\text{rot } X| + |\text{rot } Y|) \leq L_Z$

where:

L_Z nominal travel range in Z

Z, rotX, rotY: position values in respective directions (Z, units in µm, rotation axis positions in mrad)

4. Mechanical Design

Four piezoelectric actuators are used for movements in the XY plane. Linear movements are accomplished by equal displacements of a pair of actuators.

One sensor (LVDT or capacitive) is installed for each linear axis.

Rotational movements are be accomplished by simultaneous operation of all 4 actuators, with the displacements controlled by the E-710.3CD digital PZT controller. Rotary stages have three sensors, capacitive only.

Stages with LEMO connectors can be used with either analog or digital controllers (E-500 and E-710 series electronics), while stages with sub-D connectors must be used exclusively with E-710 digital controllers.

5. Technical Data

Models (XY, XYZ,θ_Z)	P-517.2CL	P-527.2CL	P-517.3CL	P-527.3CL	P-517.3CD	P-527.3CD	P-517.RCD	P-527.RCD	Units	Notes
Active axes	X,Y	X,Y	X,Y,Z	X,Y,Z	X,Y,Z	X,Y,Z	X,Y, θZ	X,Y, θZ		
Open-loop travel @ 0 to 100 V	100 X 100	200 X 200	100 X 100 X 20	200 X 200 X 20	100 X 100 X 20	200 X 200 X 20	100 ± 1 mrad	200 ±2 mrad	µm ±20%	A2
Closed-loop travel ≥	100 X 100	200 X 200	100 X 100 X 20	200 X 200 X 20	100 X 100 X 20	200 X 200 X 20	100 ±1 mrad	200 ±2 mrad	µm	A5
Number of cap. sensors	2	2	3	3	3	3	3	3		
Closed- / open-loop*** resolution ≤	1	2	X,Y: 1; Z: 0.1	X,Y: 2; Z: 0.1	X,Y: 1; Z: 0.1	X,Y: 2; Z: 0.1	X,Y: 1; θ_Z: 0,3 µrad	X,Y: 2; θ_Z: 0,3 µrad	nm	C1
Closed-loop linearity (typ.)	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	%	
Full-range repeatability (typ.)	±5	±10	X,Y: ±5; Z: ±1	X,Y:±10; Z: ±1	X,Y: ±5; Z: ±1	X,Y:±10; Z: ±1	X,Y: ±5; µrad	X,Y: ±10; µrad	nm	C3
Stiffness	2	1	X,Y: 2; Z: 15	X,Y: 1; Z: 15	X,Y: 2; Z: 15	X,Y: 1; Z: 15	2	1	N/µm ±20%	D1
Push/pull force capacity (in operating direction)	200 / 30	200 / 30	200 / 30; Z: 50 / 30	200 / 30; Z: 50 / 30	200 / 30; Z: 50 / 30	200 / 30; Z: 50 / 30	200 / 30	200 / 30	N	D3
Max. (±) normal load	5	5	5	5	5	5	5	5	kg	D4
*Electrical capacitance	11 / axis	11 / axis	X,Y: 11; Z: 7.2	X,Y: 11; Z: 7.2	X,Y: 11; Z: 7.2	X,Y: 11; Z: 7.2	X,Y: 11	X,Y: 11	µF ±20%	F1
*Dynamic operating current coefficient (DOCC)	13.7 / axis	6.9 / axis	X,Y: 13.7; :Z: 75	X,Y: 6.9; :Z: 75	X,Y: 13.7; :Z: 75	X,Y: 6.9; :Z: 75	X,Y: 13.7	X,Y: 6.9	µA/(Hz x µm)	F2
Unloaded resonant frequency	450	350	450; Z: 1100	350; Z: 1100	450; Z: 1100	350; Z: 1100	X,Y: 450; θ_Z: 400	X,Y: 350; θ_Z: 300	Hz ±20%	G2
Resonant frequency @ 500 g load	250	190	X, Y: 250	X, Y: 190	X, Y: 250	X, Y: 190	X,Y 250	X, Y: 190	Hz ±20%	G3
Resonant frequency @ 2500 g load	140	110	X, Y: 140	X, Y: 110	X, Y: 140	X, Y: 110	X,Y 140	X, Y: 110	Hz ±20%	G3
Operating temperature range	- 20 to 80	- 20 to 80	- 20 to 80	- 20 to 80	- 20 to 80	- 20 to 80	- 20 to 80	- 20 to 80	°C	H2
**Voltage connection	2 x VL	2 x VL	3 x VL	3 x VL	D	D	D	D		J1
**Sensor connection	4 x C	4 x C	6 x C	6 x C	D	D	D	D	J2	
Weight (with cables)	1400	1400	1450	1450	1460	1460	1400	1400	g ±5%	
Body material	Al	Al	Al	Al	Al	Al	Al	Al		L
Recommended Amplifier/Controller****	H, F, L, K	H, F, L, K	H, F, L	H, F, L	K	K	K	K		

Models (Z,$\theta_X\theta_Y$):	P-558.ZCD	P-518.ZCD	P-528.ZCD	P-558.ZCL	P-518.ZCL	P-528.ZCL	P-558.TCD	P-518.TCD	P-528.TCD	Units	Notes
Active axes	Z	Z	Z	Z	Z	Z	Z, θ_X, θ_Y	Z, θ_X, θ_Y	Z, θ_X, θ_Y		
Open-loop travel @ 0 to 100 V	50	100	200	50	100	200	50, (±0.28 mrad)♣	100, (±0.56 mrad) ♣	200, (±1.13 mrad) ♣	µm ±20%	A2
Closed-loop travel ≥	50	100	200	50	100	200	50, (±0.25 mrad) ♣	100, (±0.5 mrad) ♣	200, (±1.0 mrad) ♣	µm	A5
Number of cap. sensors	1	1	1	1	1	1	3	3	3		
Closed-loop / open-loop*** resolution ≤	0.5	0.5	1	0.5	0.5	1	0.5, (50 nrad)	0.5, (50 nrad)	1, (100 nrad)	nm	C1
Closed-loop linearity (typ.)	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	%	
Full-range repeatability (typ.)	±5	±5	±10	±5	±5	±10	±5, (±0.1 µrad)	±5, (±0.1 µrad)	±10, (±0.1 µrad)	nm	C3
Stiffness	Z: 4.0	Z: 2.7	Z: 1.5	Z: 4.0	Z: 2.7	Z: 1.5	Z: 4.0	Z: 2.7	Z: 1.5	N/µm ±20%	D1
Push/pull force capacity (in operating direction)	Z: 100/50	Z: 100/50	Z: 100/50	Z: 100/50	Z: 100/50	Z: 100/50	Z: 100/50	Z: 100/50	Z: 100/50	N	D3
Max. (±) normal load	5	5	5	5	5	5	5	5	5	kg	D4
* Electrical capacitance	8	11	15	8	11	15	Z: 8	Z: 11	Z: 15	µF ±20%	F1
* Dynamic operating current coefficient (DOCC)	20	13.7	9.5	20	13.7	9.5	Z: 20	Z: 13.7	Z: 9.5	µA/	F2
Unloaded resonant frequency	570	500	350	570	500	350	Z: 570 θ_X, θ_Y: 610	Z: 500 θ_X, θ_Y: 530	Z: 350 θ_X, θ_Y: 390	Hz ±20%	G2
Resonant frequency load @ 500 g	410	350	210	410	350	210	Z: 410 θ_X, θ_Y: 430	Z: 350 θ_X, θ_Y:370	Z: 210 θ_X, θ_Y: 250	Hz ±20%	G3
Resonant frequency @ 2500 g load	240	190	115	240	190	115	Z: 240 θ_X, θ_Y: 245	Z: 190 θ_X, θ_Y:200	Z: 115 θ_X, θ_Y: 130	Hz ±20%	G3
Operating temperature range	- 20 to 80	- 20 to 80	- 20 to 80	- 20 to 80	- 20 to 80	- 20 to 80	- 20 to 80	- 20 to 80	- 20 to 80	°C	H2
**Voltage connection	D ***	D ***	D ***	VL	VL	VL	D ***	D ***	D ***		J1
**Sensor connection	D ***	D ***	D ***	2 x C	2 x C	2 x C	D ***	D ***	D ***		J2
Weight (with cables)	1380	1400	1420	1380	1400	1420	1380	1400	1420	g ±5%	
Body material	Al	Al	Al	Al	Al	Al	Al	Al	Al		L
Recommended Amplifier/Controller****	M	M	M	H, F, L	H, F, L	H, F, L	K	K	K		

5.1. Notes to Technical Data Tables

* **Capacitance and DOCC** of rotational axes cannot be stated because θ_Z is based on differential X and Y motion rather than on motion of a dedicated rotational drive.
Dynamic Operating Current Coefficient of linear axes is in µA per hertz and µm.
Example P-527.2xx: Sinusoidal scan of 30 µm at 10 Hz requires approximately 2.1 mA drive current.

** **Cable length:** 1.5 m. Versions P-5xx.xxD with one Sub-D special connector for sensor and operating voltage.
Versions P-5xx.xxL with LEMO connectors.

*** **Resolution** of PZT NanoPositioners is not limited by friction or stiction. Noise equivalent motion with E-710, E-503.

****** Recommended Amplifier/Controller Codes:** For most PI PZT Actuators and PZT Nano-Positioning systems more than one amplifier/controller combination is available. The best choice depends on the application and personal preference. A low-level dynamic application does not require a high-power amplifier. In OEM applications, there may not be enough space for rackmount amplifiers/controllers. The information below is a general guide; please refer to the PI Catalog or Web site for each amplifier/controller for details, and call your local PI representative if you need further assistance.

♣ **Travel Range Restrictions:** The travel ranges of the individual coordinates (Z, θ_X and θ_Y) are interdependent. The data in this table show maximum travel (where one axis is totally extended). If motion from a particular starting point or in more than one axis is desired, the available travel may be less. For the calculation of the available travel range see Section 3.2 on p. 6.

F: E-610.C0* OEM amplifier/controller module
H: Low- & Medium-Power Applications:
E-500 (E-501) chassis +E-503 (3-channel amp.) +E-509.ab controller (a: sensor type; b: # axis +optional E-515/E-516 display/interface
H: High-Power Applications:
E-500 chassis +E-505 (1-channel amp.) +E-509.ab controller (a: sensor type; b: # axes) +optional E-515/E-516 display/interface
K: E-710.3CD digital controller. Sub-D special connector for operation voltage and sensors.
L: E-710.4CL digital controller. LEMO connectors for operating voltage and sensors..
L: E-501.10/E-612.C0 or E-661.CP high-speed parallel port NanoAutomation® controller.
M: E-750.CP digital controller, special sub-D connector for operating voltage and sensor signal.*

* *Depending on the number of axes (channels) to be driven, more than one module may be required.*

Lettered Notes

A2 Open-loop travel
@ 0 to 100 V
Typical open-loop travel at 0 to 100 V operating voltage. Max. operating voltage range is -20 to +120 V (extremes for short durations only).

A5 Closed-loop travel
Travel provided in closed-loop operation. PI LVPZT amplifiers have an output voltage range of -20 to +120 V to provide enough margin for the controller to compensate for load changes, etc.

C1 Closed-loop / open-loop resolution
Resolution of piezo flexure stages is basically infinitesimal because it is not limited by stiction and friction. Instead of resolution, the noise equivalent motion is specified. Values are typical results (RMS, 1σ), measured with E-503 amplifier module in E-500/501 chassis.

C3 Full-range repeatability (typ.)
Typical values in closed-loop mode. Repeatability is a percentage of the total travel. For small ranges, repeatability is significantly better.

D1 Stiffness
Static large-signal stiffness of the stage in operating direction at room temperature. Small-signal stiffness and dynamic stiffness may differ because of effects caused by the active nature of piezo material, compound effects, etc. Further details see the "Tutorial: Piezoelectrics in Positioning" section of the PI catalog or Web site.

D3 Push/pull force capacity (in operating direction)
Specifies the maximum force that can be applied to the system. Limited by the PZT ceramic material and the flexure design. If larger forces are applied, damage to the PZT, the flexures or the sensor can occur. The force limit must also be considered in dynamic applications.
Example: the dynamic forces generated by sinusoidal operation at 500 Hz, 20 µm peak-to-peak, 1 kg moved mass, are approximately ±100 N. Further more information, see the "Tutorial: Piezoelectrics in Positioning" section of the PI catalog or Web site.

D4 Max. (+/-) normal load
Maximum vertical load, when the stage is mounted horizontally. Limited by the flexures or the load capacity of the piezo actuators.

F1 Electrical capacitance
The PZT capacitance values indicated in the technical data table are small-signal values (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 informationon power requirements, refer to the amplifier frequency- response graphs in the "PZT Control Electronics" section of the catalog or Web site.

F2 Dynamic Operating Current Coefficient (DOCC)
Average electrical current (supplied by the amplifier) required to drive a piezo actuator per unit frequency and unit displacement (sine-wave operation). E.g. to find out if a selected amplifier can drive a given piezo stage at 50 Hz with 30 µm amplitude, multiply DOC coefficient by 50 X 30 and check if the result is smaller or equal to the output current of the selected amplifier. For details see link ff. in the "Tutorial: Piezoelectrics in Positioning" section of the PI catalog or Web site.

G2 Unloaded resonant frequency
Lowest resonant frequency in operating direction (does not specify the maximum operating frequency). For more information, see the "Tutorial: Piezoelectrics in Positioning" section of the PI catalog or Web site.

G3 Resonant frequency with xx g load
Resonant frequency of the loaded system.

H2
Performance specifications are valid for room temperature (22 °C +/-5 °C) and closed-loop systems are calibrated for optimum performance in this range (specifications for other operating temperatures on request). Recalibration is recommended for operation at a significantly higher or lower temperature. Custom designs for ultra-low or ultra-high temperatures on request.

J1 Voltage connection
Standard operating voltage connectors are LEMO-type connectors.
VL (Voltage Low): LEMO FFA.00.250, male. Cable: coaxial, RG 178, Teflon coated, 1m.
D: Sub-D special connector
For extension cables and adapters, see "Accessories" in the "PZT Control Electronics" section of the PI catalog or Web site.

L Body material
Flexure stages are usually made of anodized aluminum or stainless steel. Small amounts of other materials may occur internally (for spring preload, piezo coupling, mounting, thermal compensation, etc.)
Al: Aluminum.
N-S Non-magnetic stainless steel
S: Ferromagnetic stainless steel
I: Invar

5.2. Connector Pinouts

The P-500-series stages are all equipped with either special sub-D or LEMO connectors.

5.2.1. Sub-D Special Connector

The sub-D special connector has 2 coax lines and 5 single pins:

Pin		**Signal**
Coax inner lines (shielded):		
A1		PZTOUT (LV)
A2		Signal Probe
Standard pins		
3		PZTGND
	1	DOW
4		+ 15 V Supply for external devices
	2	AGND Target and ID gnd
5		Target

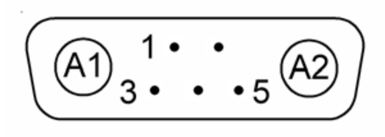


Fig. 1: Sub-D special connector with 2 coax lines and 5 single pins

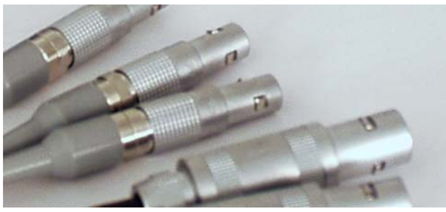
Note:

Probe and *Target* are capacitive sensor connections.

PZTOUT line carries PZT drive voltage of up to 130 V.

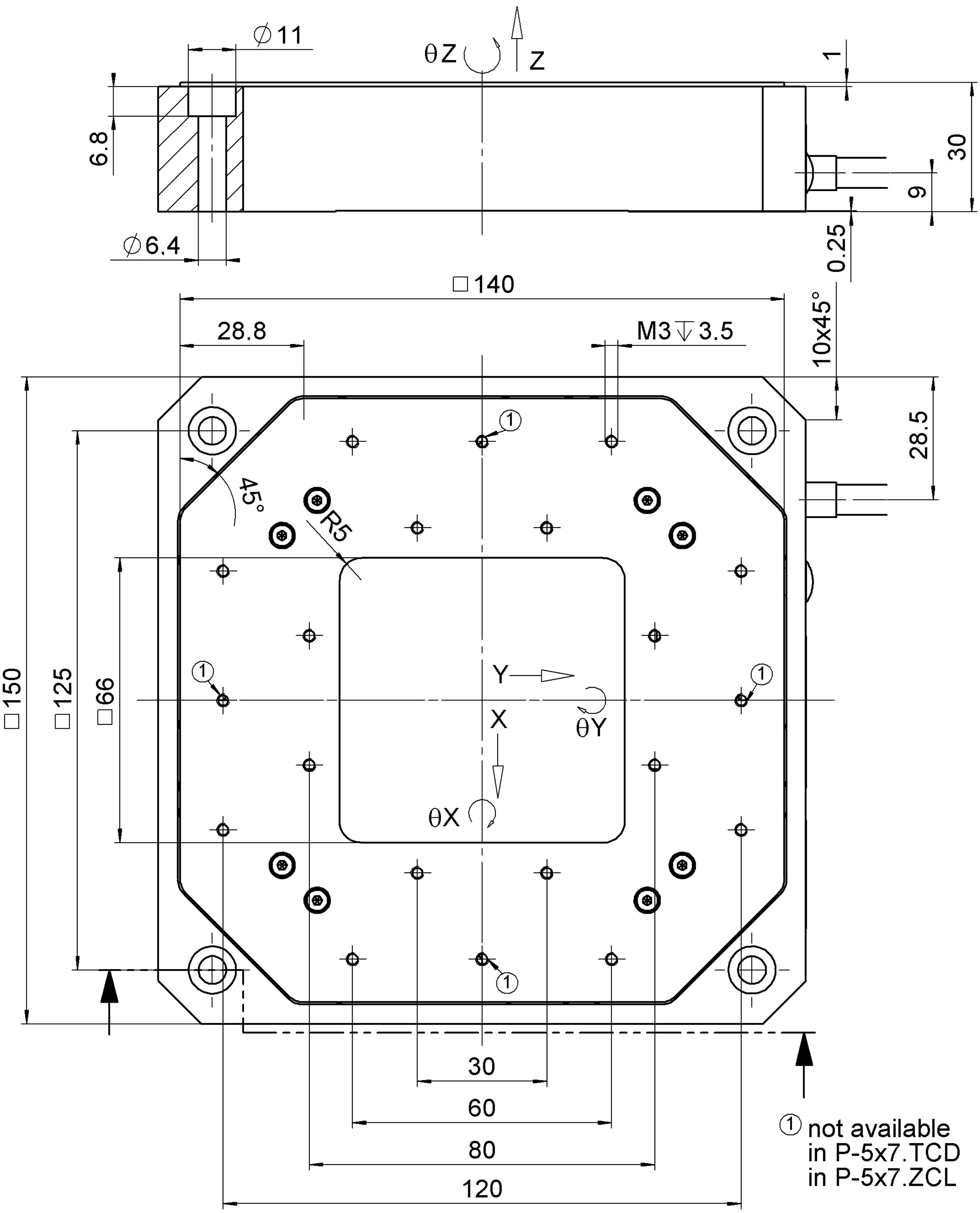
5.2.2. LEMO Connectors

The models with LEMO connectors use one cable for the PZT drive cable and two cables per sensor, one for the target and one for the probe. Each sensor cable/connector has its own shield. If target and probe connectors are interchanged, specified accuracy will not be maintained.



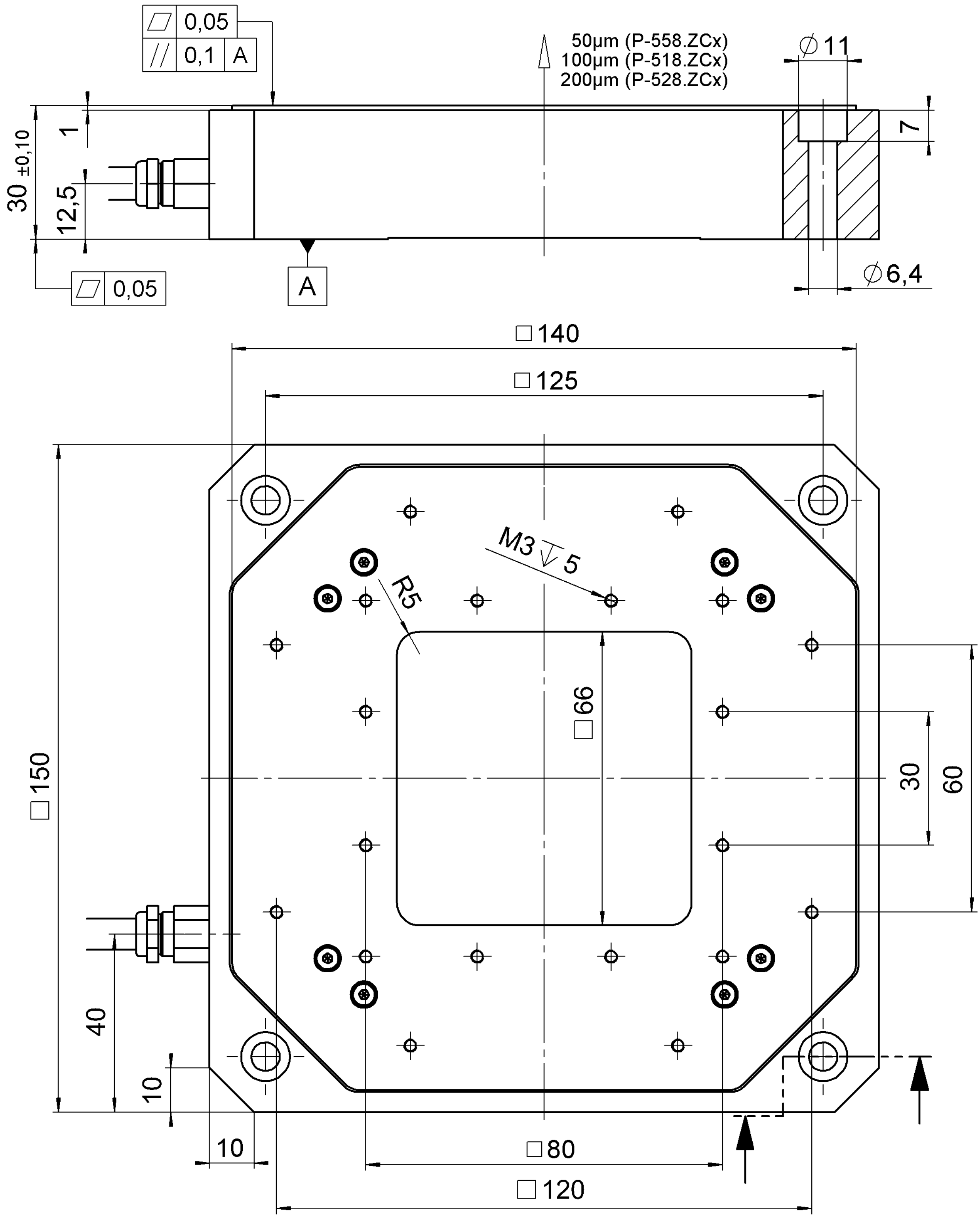
The drive cables/connectors carry voltages of up to 130 V. The positive voltage is on the inner conductor.

5.3. P-5x7.xx Dimensions*



*in mm

5.4. P-5x8.xx Dimensions*



* in mm, decimal places separated by commas