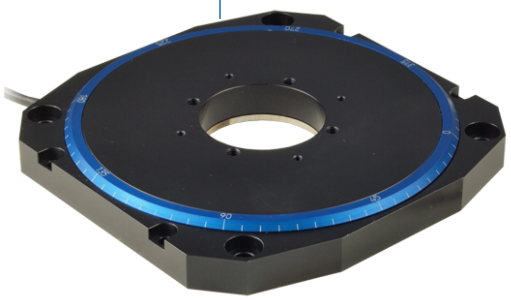
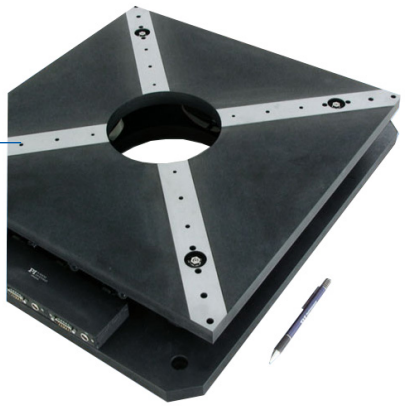
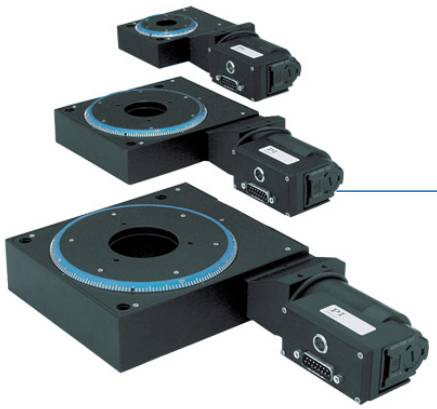
High Precision Rotation Stages

PRECISE



HIGH LOAD





FAST

Ultra-Low Profile Rotation Table with fast Piezo-Motor

High-Speed Positioning, High Resolution & Accuracy, 14 mm, 720 deg/sec.

The M-660 PILine® rotation stage allows high positioning speeds of up to 2 full turns/sec. The 36 mm Ø clear aperture offers flexible usage

- **Low Profile: Only 14 mm in Height**
- **Direct Metrology Encoder, up to 4 µrad Resolution**
- **Self-Locking Ceramic Direct Drive: Energy Saving & High Position Stability**
- **PILine® Direct Drive: Non-Magnetic and Vacuum-Compatible Working Principle**
- **Compact Combinations with Linear Stages**
- **Unlimited Travel Range**
- **Max. Velocity 720 °/s**

M-660 precision rotation stages use PILine® ultrasonic piezo motors that act on a ceramic friction ring to drive the platform. This direct drive principle allows for the compact design and low profile of the stage. An integrated incremental encoder offers precision position control with up to 4 µrad resolution. The integrated U-164 PILine® linear motors provide a maximum torque of 0.3 Nm, independent from the direction of motion, and a maximum velocity of up to 720 °/sec. The maximum load is 2 kg.

M-660s can be built in different sizes or with other specifications, and they are available upon request as vacuum-compatible versions.

Applicatotion Examples

- Biotechnology
- Micromanipulation
- Microscopy
- Quality assurance testing
- Metrology
- Mass storage device testing
- R&D
- Photonics packaging

Advantages of PILine® Micropositioning Systems

Positioning systems equipped with ceramic ultrasonic drives of the PILine® series provide several advantages over positioners that apply classic drive technology:

- Smaller dimensions
- Higher holding force when powered down; no holding current
- Increased acceleration of up to 5 g
- Increased velocity of up to 500 mm/s or 720 °/s, resp.
- No leadscrews, gears or other mechanical components, no wear or maintenance
- No lubricants
- Non-magnetic and vacuum-compatible operating principle

Optimized Controller and Drive Electronics

For optimum performance, the highly specialized C-867 motion controller (s. p. 4-116) is recommended. This dedicated piezo motor controller also integrates the drive electronics which PILine® motors require to generate the ultrasonic oscillations on the piezoceramic element.

Furthermore, the controller has a number of special characteristics to address the requirements of ultrasonic motors, such as continuous automatic drive frequency adjustment, dynamic parameter switching for optimized high-speed motion and settling behavior. The broad-band encoder input (50 MHz) supports the outstanding high accelerations and velocities of PILine® drives at high resolutions.

Ordering Information

M-660.55
PILine® Rotation Stage, Ø 108 mm, 360°, 34 µrad Resolution

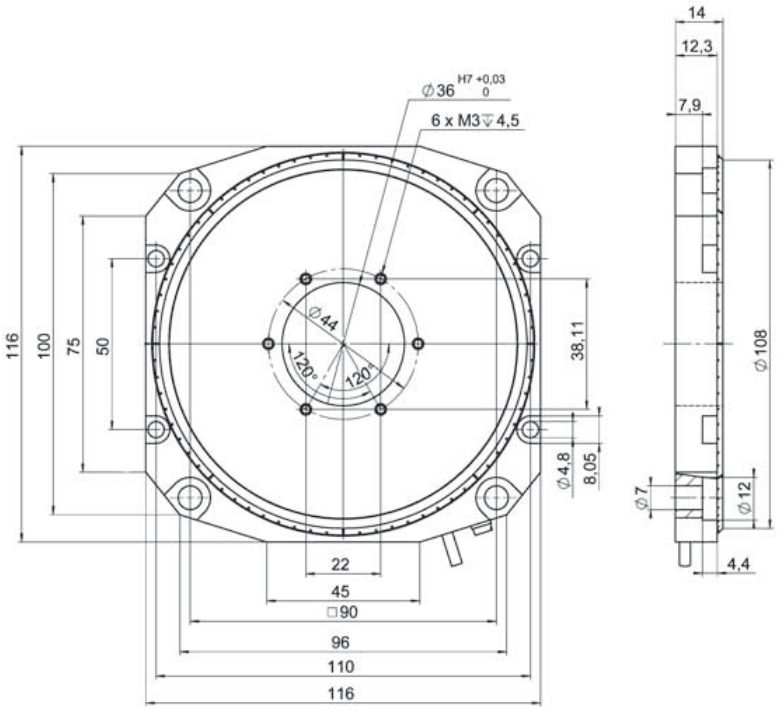
M-660.45
PILine® Precision Rotation Stage, Ø 108 mm, 360°, 4 µrad Resolution

Ask about custom designs!

Patented Technology

The products described in this document are in part protected by the following patents:
US Pat. No. 6,765,335
German Patent No. 10154526

© Physik Instrumente (PI) GmbH & Co. KG 2011. Subject to change without notice. All data are superseded by any new release. The newest release for data sheets is available for download at www.pi.ws. R2 11/03/29.0



M-660.55, dimensions in mm

Technical Data

Model	M-660.55 / M-660.45	Units	Tolerance
Active axes	Theta Z		
Motion and positioning			
Rotation range	No limit	°	
Integrated sensor	Incremental encoder		
Design resolution	34 (0.00195) / 4 (0.00023)	µrad (°)	typ.
Min. incremental motion	34 / 12	µrad	typ.
Bidirectional repeatability	±68 / ±24	µrad	
Max. velocity	720	°/s	
Mechanical properties			
Load capacity / axial force	20	N	max.
Holding force	0.3	Nm	max.
Max. torque cw/ccw (θ Z)	0.3	Nm	max.
Drive properties			
Motor type	2 x U-164 PILine® ultrasonic piezo drive		
Operating voltage	60 (RMS)*	V	
Current consumption**	0.3 (2 max.)	A	
Reference switch	optical		
Miscellaneous			
Operating temperature range	-20 to +50	°C	
Material	Al (black anodized)		
Mass	470	g	±5%
Cable length	1.3	m	±10 mm
Connector	MDR, 14-pin		
Recommended controller / driver	C-867 single-axis controller / driver		

* The operating voltage is supplied by the drive electronics
** For drive electronics

Fast Rotation Stage with Small Footprint

WITH ULTRASONIC PIEZO MOTOR

U-628

- Side length 50 mm
- Integrated position encoder
- High velocity >1000°/s
- Unlimited rotation range

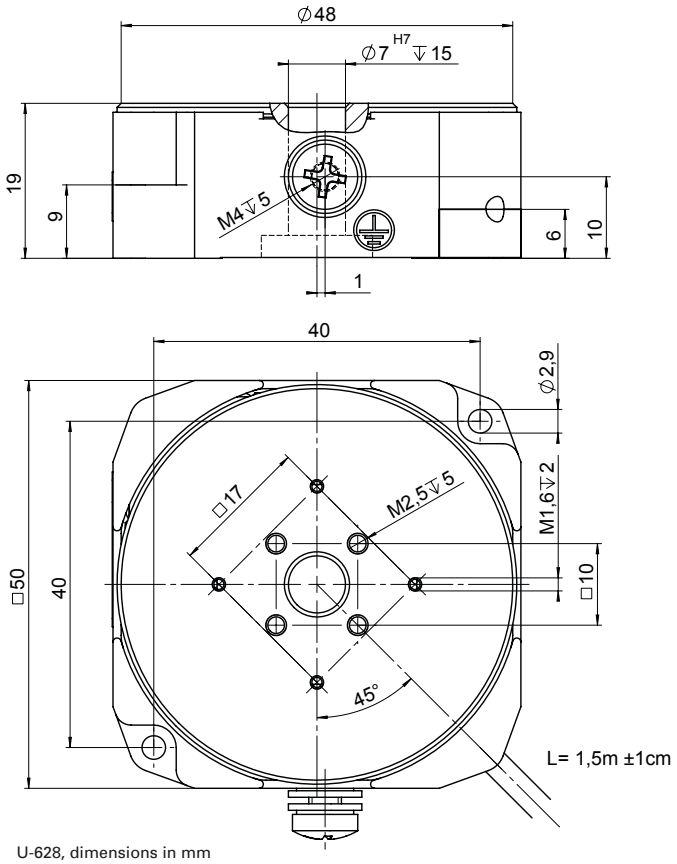
Precision-class rotation stage
Integrated optical encoder for direct metrology. Unlimited rotation range. Reference point switch. Central clear aperture with 7 mm diameter

PILine® ultrasonic piezo motor
Oscillating piezoceramic actuators act directly on the ring-shaped runner. High velocity, holding torque 0.1 Nm

Fields of application
Sample handling and positioning in research and industry for installations limited in space. Vacuum version as option

Physik Instrumente (PI) GmbH & Co. KG 2013. Subject to change without notice. Latest releases available at www.pi.ws. 13/04/29.0

Preliminary data	U-628.03	Unit	Tolerance
Active axes	θ_z		
Motion and positioning			
Rotation range	No limit		
Integrated sensor	Optical encoder, direct position metrology, interpolator integrated in stage		
Design resolution	35 (2)	µrad (m°)	
Min. incremental motion	105 (6)	µrad (m°)	typ. ±3 cts
Bidirectional repeatability	±105 (6)	µrad	
Velocity	1080	°/s	max.
Mechanical properties			
Load capacity / axial force	5	N	max.
Holding force	0.1	Nm	max.
Torque clockwise/counterclockwise (θ_z)	0.1	Nm	max.
Drive properties			
Motor type	2× U-161 PILine® ultrasonic piezomotors		
Reference point switch	Optical		
Miscellaneous			
Operating temperature range	-20 bis 50	°C	
Material	Aluminium		
Mass	Approx. 300	g	±5 %
Recommended controller/driver	C-867 PILine® Motion Controller		



U-628, dimensions in mm

Physik Instrumente (PI) GmbH & Co. KG 2013. Subject to change without notice. Latest releases available at www.pi.ws. 13/04/29.0

Fast Miniature Rotation Stage

WITH ULTRASONIC PIEZO MOTOR

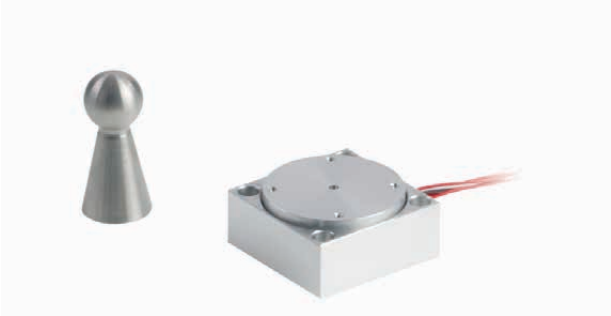
U-624

- Only 30 mm in side length
- Integrated position encoder
- High velocity >720°/s
- Unlimited rotation range

Small, precision-class rotation stage
Integrated optical encoder for direct metrology. Unlimited rotation range. Reference point switch

PILine® ultrasonic piezo motor
The piezoceramic ring-shaped motor acts directly on the rotational platform. High velocity, holding torque 0.01 Nm

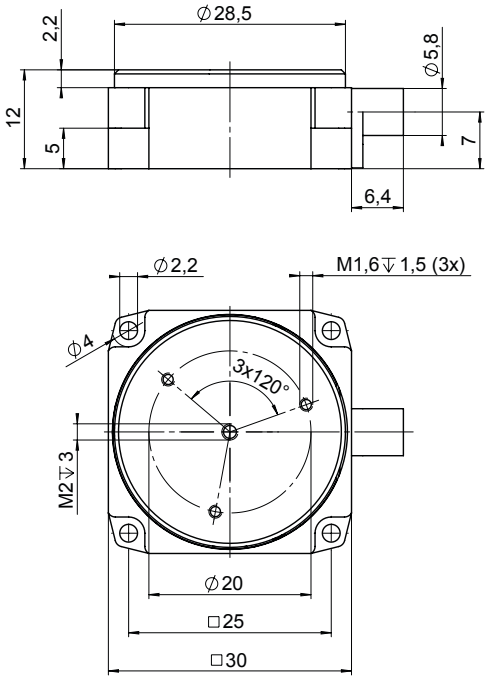
Fields of application
Sample handling and positioning in research and industry for installations limited in space. Vacuum version as option



Even smaller with 20 mm side length:
Open-loop customized version of the U-624

Physik Instrumente (PI) GmbH & Co. KG 2013. Subject to change without notice. Latest releases available at www.pi.ws. 13/04/29.0

Preliminary data	U-624.03
Active axes	Θ_z
Motion and positioning	
Rotation range	No limit
Integrated sensor	Optical encoder, position metrology
Design resolution	52 µrad
Min. incremental motion	approx. 150 µrad
Bidirectional repeatability	<500 µrad
Velocity	>720°/s
Mechanical properties	
Load capacity / axial force	1 N
Holding force	0.01 Nm
Torque clockwise/counterclockwise (Θ_z)	0.01 Nm
Drive properties	
Motor type	Piezoceramic ring-shaped motor
Reference point switch	Optical
Miscellaneous	
Dimensions	30 mm × 30 mm × 12 mm
Operating temperature range	-20 to 50 °C
Material	Aluminium
Cable length	1.5 m
Recommended controller/driver	C-867 PILine® Motion Controller



U-624, dimensions in mm

Physik Instrumente (PI) GmbH & Co. KG 2013. Subject to change without notice. Latest releases available at www.pi.ws. 13/04/29.0

Technical Progress with Ultrasonic Piezomotors

Leica Geosystems AG benefits from PILine® ultrasonic motors employed in their newest generation of surveying instruments for geodesy. The requirements for the drive of the new "Leica TS30" total station were, amongst others, higher speeds, shorter positioning times and a very high positioning accuracy when moving the measuring optics.

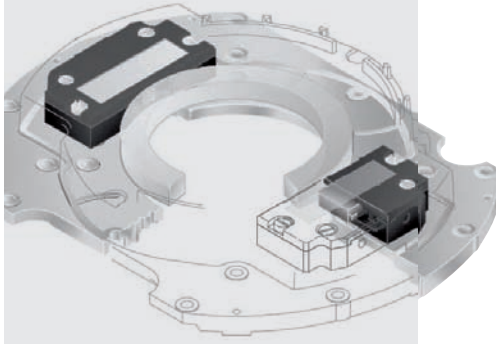
These requirements were exceeded by far through the employment of PILine® ultrasonic motors. PI's U-164 piezomotor was chosen for the vertical as well as the horizontal movement of the measuring optics. Rotations are produced by two such motors which are preloaded against a pivot mounted friction ring doubling as a brake when at rest. In operation, the ceramic piezomotors oscillate with ultrasonic frequencies. Generating a feed motion of the friction ring. This principle of operation provides unrivalled speeds of >180 °/sec and high accelerations of up to 360 °/s² and an angular measuring accuracy of 0.5". The drive also improves starting and stopping behavior and reduces power consumption. The maintenance-free motors are self locking, i.e.

Fast, Compact & Energy Efficient

OEM Ultrasonic Piezo Motors

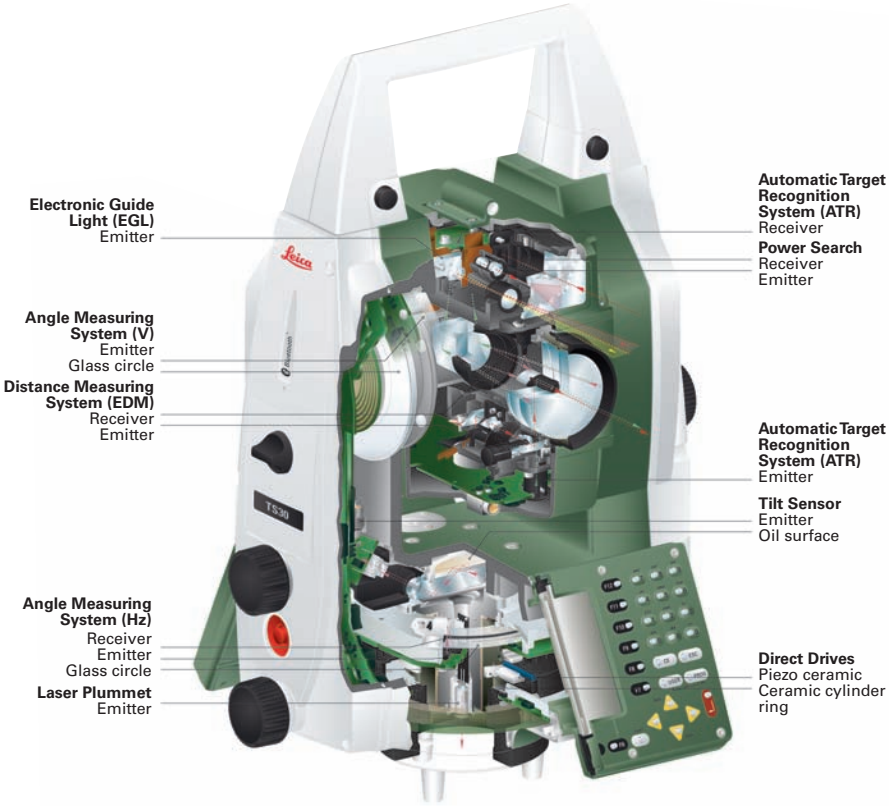
U-164 ultrasonic piezo motors are particularly compact, reliable and maintenance-free drives which are self-locking when at rest and intrinsically non-magnetic and vacuum-compatible. In the application, they provide as yet unrivalled speeds and accelerations while offering a high positioning resolution and low power consumption.

With its PILine® series PI offers a broad range of positioning systems with piezo ultrasonic motors: From simple motors to fully integrated custom solutions.



The rotations are produced by two U-164 ultrasonic motors that are preloaded against a friction ring. (Photo: Leica Geosystems AG/ Physik Instrumente (PI))

NUZ40/E/11/09/8 Subject to change without notice © Physik Instrumente (PI) GmbH & Co. KG



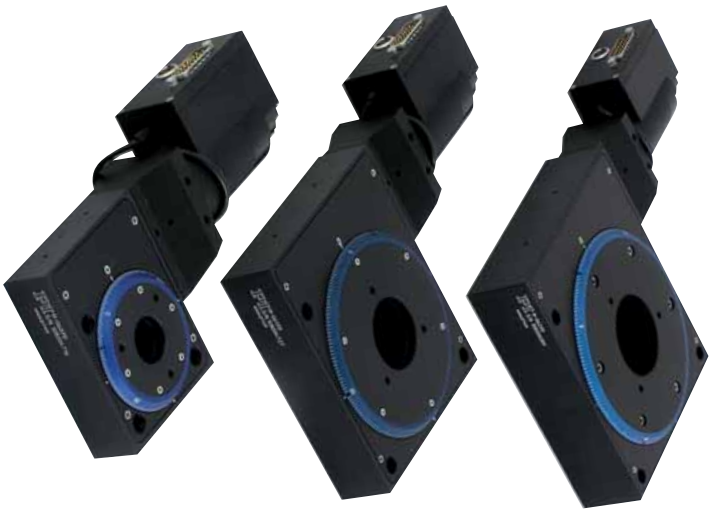
The cross-section of the total station shows the limited installation space available for the drives
(Photo: Leica Geosystems AG, Switzerland)

they generate high holding forces even when no electrical power is applied, they run extremely quiet and operate at ambient temperatures between –20 °C and + 50 °C.

NUZ40/E/11/09/8 Subject to change without notice © Physik Instrumente (PI) GmbH & Co. KG

M-06x Precision High-Resolution Rotation Tables

Unlimited Travel Range



- **Continuous Rotation Range**
- **Ultra-High Resolution**
- **Max. Velocity 90 deg/sec**
- **Preloaded Worm Drive for Zero Backlash**
- **ActiveDrive DC-Servo, Stepper-Motor and Manual Drives**
- **Direction-Sensing Reference Switch**

M-06x series rotation stages are equipped with ultra-precise, ultra-low-friction, spring-preloaded worm gear drives allowing unlimited rotation in either direction. Models M-060 feature a 60 mm diameter turntable, models M-061, a 100 mm table and models M-062, a 120 mm table.

DC-Motor and Stepper-Motor Drive

One manual drive and three motor drives (four with M-062 models) are available:

Application Examples

- R&D
- Semiconductor testing
- Mass storage device testing
- Metrology
- Photonics packaging
- Quality assurance testing

M-06x.PD with ActiveDrive

This version features a direct-coupled motor/encoder. For superior dynamic performance, we integrated our unsurpassed ActiveDrive system. The ActiveDrive design, developed by PI, features a high-efficiency PWM (pulse width modulation) servo-amplifier mounted side-by-side with the DC-Motor and offers several advantages:

- Increased efficiency, by eliminating power losses between the amplifier and motor
- Reduced cost of ownership and improved reliability, because no external driver is required
- Elimination of PWM amplifier noise radiation, by mounting the amplifier and motor together in a single, electrically shielded case

M-06x.DG with Zero-Backlash DC-Motor/Gearhead Drive

The M-06x.DG are equipped with 3-watt DC motors with zero-backlash gearhead and shaft-mounted encoders (2048 counts/rev.). The gear ratio of 29.6:1, provides higher resolution than the direct drive motors.

M-60x.2S Stepper-Motor Drive

The M-060x.2S models feature a cost-effective direct-drive, 2-phase stepper-motor, providing very smooth operation and a resolution of 6400 steps/rev.

Non-Contact Limit and Reference Switches

Motorized models are equipped with an integrated Hall-effect origin switch. To protect your equipment and increase versatility in automation applications, the rotary stage can optionally be equipped with Hall-effect limit switches. Travel can be limited to a range between 0° and 268° ±2°.

Coarse position can be read from an adjustable scale ring on the outer edge of the turntable graduated in 2 degree increments. The manual versions also feature a drive-shaft-mounted indicator with 0.1-degree graduations.

Ordering Information

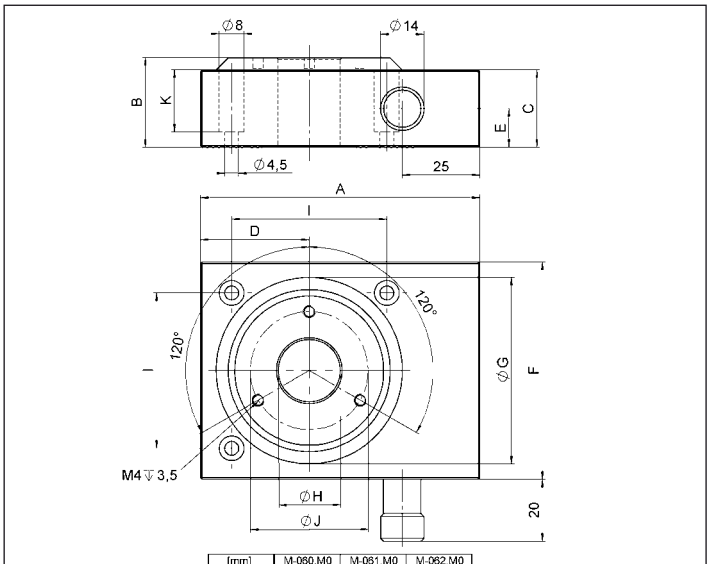
Precision Rotation Stage, 360°

M-06 .

- **0 =** Ø 60 mm
- **1 =** Ø 100 mm
- **2 =** Ø 120 mm

- **PD =** ActiveDrive DC Motor
- **DG =** Closed-Loop DC Motor Gearhead
- **2S =** 2-Phase Stepper Motor
- **M0 =** Manual Drive
- **V =** Vacuum Compatible to 10^{-6} hPa

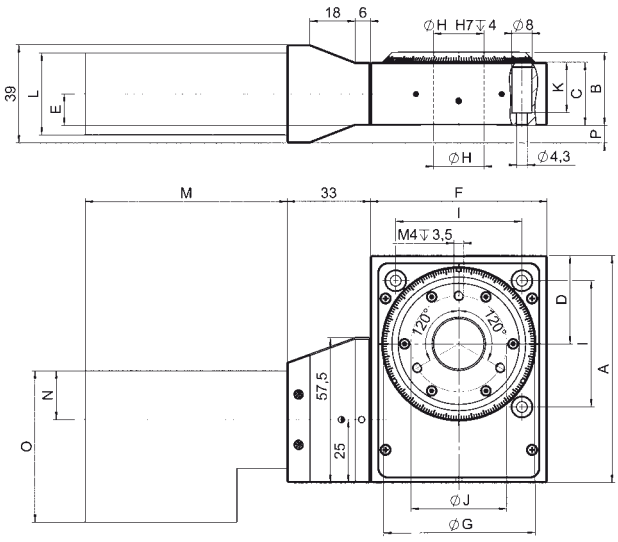
Ask about custom designs!



[mm]	M-060.M0	M-061.M0	M-062.M0
A	90	130	150
B	29	34	42
C	25	30	38
D	35	55	65
E	12,5	15	21,5
F	70	110	130
G	60	100	120
H	20	35	45
I	50	90	110
J	38	50	60
K	20	20	28

M-060.MO, M-061.MO, M-062.MO rotation stages, with manual drive, dimensions in mm

© Physik Instrumente (PI) GmbH & Co. KG 2008. Subject to change without notice. All data are superseded by any new release. The newest release for data sheets is available for download at www.pi.ws. R1 11/04/12.0



DIMENSIONS	M-060.PD	M-060.DG	M-060.2S	M-061.PD	M-061.DG	M-061.2S	M-062.PD	M-062.DG	M-062.2S
A	90	90	90	130	130	130	150	150	150
B	29	29	29	34	34	34	42	42	42
C	25	25	25	30	30	30	38	38	38
D	35	35	35	55	55	55	65	65	65
E	12,5	12,5	12,5	15	15	15	21,5	21,5	21,5
F	70	70	70	110	110	110	130	130	130
G	60	60	60	100	100	100	120	120	120
H	20	20	20	35	35	35	45	45	45
I	50	50	50	90	90	90	110	110	110
J	38	38	38	50	50	50	60	60	60
K	20	20	20	20	20	20	28	25	25
L	39	34	39	39	34	39	39	34	39
M	80,8	83,8	81	80,8	83,8	81	80,8	83,8	81
N	19	15	18,5	19	15	18,5	19	15	18,5
O	59,3	51	52,5	59,3	51	52,5	59,3	51	52,5
P	7	7	7	4,5	4,5	4,5	-	-	-

Motorized M-060, M-061, M-062 rotation stages, dimensions in mm

Technical Data

Model	M-060.M0 / M-061.M0 / M-062.M0	M-060.PD / M-061.PD / M-062.PD	M-060.DG / M-061.DG / M-062.DG	M-060.2S / M-061.2S / M-062.2S	Units
Active axes	Rotation	Rotation	Rotation	Rotation	
Motion and positioning					
Rotation range	>360	>360	>360	>360	°
Integrated sensor	–	Rotary encoder	Rotary encoder		
Sensor resolution	–	4000	2000		Cts./rev.
Design resolution	–	32 (0.0018) / 17.5 (0.001) / 15 (0.0008)	2.1 (0.00012) / 1.2 (6.9 x 10^{-5}) / 0.96 (5.5x10^{-5})	19.7 (0.0011) / 10.9 (0.00063) / 8.9 (0.00051)*	µrad (°)
Min. incremental motion	–	32 / 17.5 / 15	6.3 / 6 / 5	40 / 20 / 18*	µrad
Backlash	–	200 / 200 / 240	200 / 200 / 240	200 / 200 / 240	µrad
Unidirectional repeatability	–	50 / 50 / 60	50 / 50 / 60	50 / 50 / 60	µrad
Max. velocity	–	90	16 / 9 / 7.3	36 / 20 / 16	°/s
Mechanical properties					
Worm gear ratio	50:1 / 90:1 / 110:1	50:1 / 90:1 / 110:1	50:1 / 90:1 / 110:1	50:1 / 90:1 / 110:1	
Gear ratio	–	–	$(28/12)^4$:1 ≈ 29.6:1	–	
Motor resolution	–	–	–	6400*	steps/rev.
Axial force	±500 / ±550 / ±650	±500 / ±550 / ±650	±500 / ±550 / ±650	±500 / ±550 / ±650	N
Max. torque θ_X, θ_Y	±6 / ±6 / ±7	±6 / ±6 / ±7	±6 / ±6 / ±7	±6 / ±6 / ±7	Nm
Max. torque θ_Z	±4 / ±6 / ±8	±4 / ±6 / ±8	±4 / ±6 / ±8	±4 / ±6 / ±8	Nm
Drive properties					
Motor type	–	ActiveDrive DC-Motor	DC-Motor, gearhead	2-phase Stepper-Motor**	
Operating voltage	–	24 (PWM)	12 differential	24	V
Electrical power	–	30	3	–	
Reference switch	Hall-effect	Hall-effect	Hall-effect	Hall-effect	
Miscellaneous					
Operating temperature range	-20 to +65	-20 to +65	-20 to +65	-20 to +65	°C
Material	Aluminum	Aluminum	Aluminum	Aluminum	
Mass	0.42 / 1.36 / 2.24	0.94 / 1.88 / 2.76	0.94 / 1.88 / 2.76	0.96 / 1.9 / 2.78	kg
Recommended controller/driver		C-863 single-axis C-843 PCI board, for up to 4 axes	C-863 single-axis (p. 4-114) C-843 PCI board (p. 4-120), for up to 4 axes	C-663 single-axis (p. 4-112)	

*with C-663 stepper-motor controller
**2-phase stepper-motor, 24 V chopper voltage, max. 0.8 A/phase, 400 full steps/rev
Data for vacuum versions may differ.

Precision Miniature High-Resolution Rotation Table

Compact, Multi-Axis Combinations with M-110 Translation Stage Series

M-116.DG micro rotary stage

- **Compact Design**
- **Continuous Rotation Range**
- **Encoder Resolution 2.5 µrad**
- **Clear Aperture**
- **Max. Velocity 20 degrees/second**
- **Preloaded Worm Drive for Zero Backlash**
- **Fits Directly on M-110 Micro Translation Stages**
- **Non-Contact Reference Switch**
- **Repeatability to ±10 µrad**

M-116 rotation stages are equipped with low-friction, spring-preloaded worm gear drives allowing unlimited rotation in either direction in an extremely compact package.

Stepper and Servo Motors

Both drive options provide a cost-effective solution for industrial and OEM environments. A miniature DC or stepper motor actuates motion via a spring-preloaded worm gear drive and zero-backlash (with M-116.xxH versions) gearhead.

To meet the most critical positioning demands, the DC motor is equipped with a high-resolution encoder featuring resolution of 2 048 counts per revolution. The combination of the extremely low-stiction/low-friction construction and high-resolution encoder allows for minimum incremental motion of 25 µrad at speeds up to 20 degrees/second.

Multi-Axis Combinations

M-116 rotary stages can be combined with the M-110, M-111 and M-112 micro linear stages without an additional adapter plate to keep the total height at a minimum.

Clear Aperture, Lens Adapter

The M-116 is designed with a clear aperture for extended versatility in optics applications. The M-116.AL1 lens adapter is available to accommodate 0.5" optics such as polarizers.

Non-Contact Limit and Reference Switches

Motorized models are equipped with an integrated Hall-effect origin switch. To protect your equipment and increase versatility in automation applications, the rotary stage can optionally be equipped with Hall-effect limit switches. Travel can be limited to a range between 0° and 330° ±2°.

For ease of operation and setup, all models come with a scale ring on the outer edge of the turntable.

Application Examples

- R&D
- Laser technology
- Metrology
- Adjustment of optics
- Photonics packaging
- Quality assurance testing

Ordering Information

M-116.DG
Rotation Stage, 360°, Closed-Loop DC Motor Gearhead

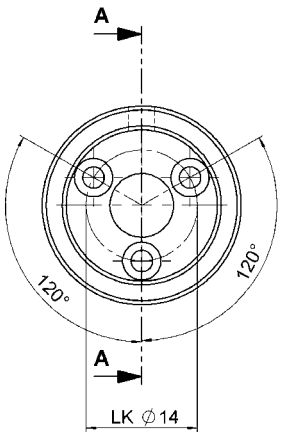
M-116.DGH
Rotation Stage, 360°, Closed-Loop Backlash-Free DC Motor Gearhead

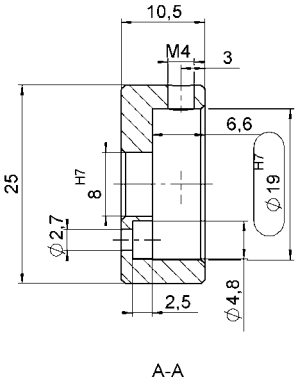
M-116.2SH
Rotation Stage, 360°, 2-Phase Stepper Motor with Backlash-Free Gearhead

M-116.AL1
Lens Adapter for 0.5" Optics

Ask about custom designs!

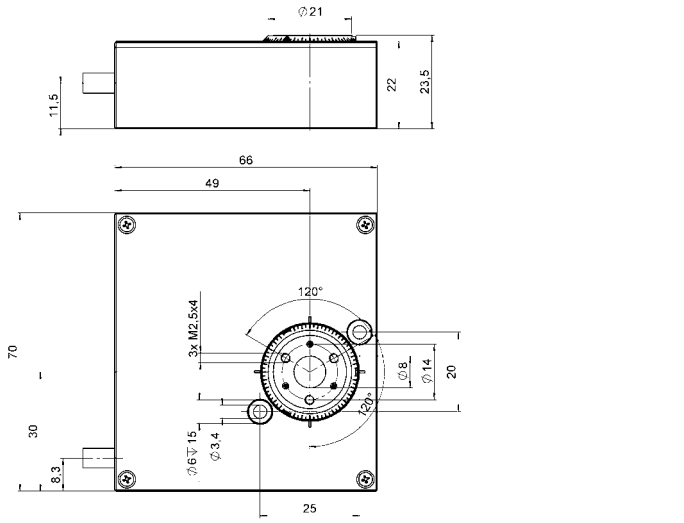
XY θ_z micropositioning combination consisting of (from top to bottom) M-116 micro rotary stage and two M-111 translation stages (M-110.01 adapter for mounting the M-111 on a honeycomb breadboard with M6 on 25 mm centers)





Dimensions of the M-116.AL1 lens adapter for 0.5" optic devices such as polarizers

© Physik Instrumente (PI) GmbH & Co. KG 2008. Subject to change without notice. All data are superseded by any new release. The newest release for data sheets is available for download at www.pi.ws. Cat120E Inspirations2009 08/10.18



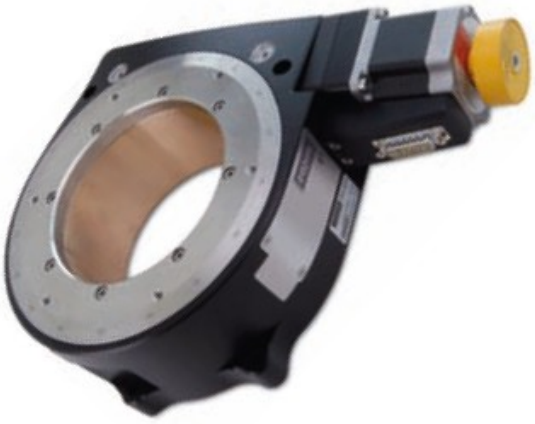
M-116 dimensions in mm, 0.5 m cable included, 15-pin sub-D connector

Technical Data

Model	M-116.DG	M-116.DGH	M-116.2SH	Units
Active axes	Rotation	Rotation	Rotation	
Motion and positioning				
Rotation range	>360	>360	>360	°
Integrated sensor	Rotary encoder	Rotary encoder	–	
Sensor resolution	2048	2048	–	Cts./rev.
Design resolution	2.45 (0.00013)	3.16 (0.00018)	16.9* (0.00097)	µrad (°)
Min. incremental motion	50	25	30	µrad
Backlash	1000	500	500	µrad
Unidirectional repeatability	12	10	10	µrad
Max. velocity	20	20	20	°/s
Mechanical properties				
Worm gear ratio	44:1	44:1	44:1	
Gear ratio	28.444:1	22.0335:1	22.0335:1	
Motor resolution	–	–	384*	steps/rev.
Axial force	±15	±15	15	N
Max. Torque (θ_X, θ_Y)	±1.5	±1.5	±1.5	Nm
Max. Torque clockwise (θ_Z)	0.4	0.4	0.4	Nm
Max. torque counterclockwise (θ_Z)	0.8	0.8	0.8	Nm
Drive properties				
Motor type	DC-motor, gearhead	DC-motor, gearhead	2-phase stepper motor*	
Operating voltage	0 to ±12	0 to ±12	24	V
Electrical power	1.75	1.75		W
Reference switch	optical	optical	optical	
Miscellaneous				
Operating temperature range	-20 to +65	-20 to +65	-20 to +65	°C
Material	Aluminum	Aluminum	Aluminum	
Mass	0.4	0.4	0.4	kg
Recommended controller/driver	C-863 single-axis C-843 PCI board, for up to 4 axes	C-863 single-axis (p. 4-114) C-843 PCI board (p. 4-120), for up to 4 axes	C-663 single-axis (p. 4-112)	

*2-phase stepper motor, 24 V chopper voltage, max. 0.25 A/phase, 24 full steps/rev., motor resolution with C-663 stepper motor controller

PI miCos High Precision Rotation Stages



M-880 Rotation + XY Stage: Planar 3-Axis Precision Positioner

XY-Rot-Z Parallel Kinematics System with Very High Holding Force

- Travel Ranges 20 x 20 mm / 8°
- Static Load Capacity to 150 kg
- ActiveDrive Servo Motors
- Low Profile through Parallel Kinematics
- Min. Incremental Motion to 0.75 µm
- Large Clear Aperture
- Sophisticated Controller Included

M-880.PD for planar load positioning up to 20 kg with submicron accuracy

Model	Active Axes	Travel range	Max. velocity	Stiffness (linear axes)	Dynamic load capacity	Static load capacity
M-880.PD	X, Y, θ_Z	±10 mm, ±4°	20 mm/s	5 N/µm	200 N	1500 N

Parallel Kinematic Tripod / Goniometer Rotation + Z-X Stage

Precision Positioning in X, Z, θ_Y

- Goniometer Z Stage with Freely Selectable Pivot Point
- Travel Ranges ±25 mm / ±25 mm / ±30°
- Load Capacity to 4 kg
- Min. Incremental Motion to 0.1 µm
- ActiveDrive Servo Motors
- Compact Design with Parallel Kinematics

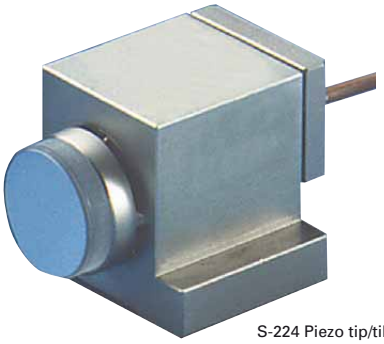
The parallel-kinematics tripod is designed for precision positioning, offering elevation, translation and tilt motion around the (horizontal) y-axis, with a user-defined pivot point

Model	Travel ranges	Max. velocity	Stiffness	Dimensions
Tripod Goniometer-Stage	±25 mm (X, Z), ±30° (θ_Y)	10 mm/s (linear)	50 N/µm	223,2 x 110 x 192 mm

© Physik Instrumente (PI) GmbH & Co. KG 2008. Subject to change without notice. All data are superseded by any new release.
The newest release for data sheets is available for download at www.pi.ws. R1 10/06/30.0

Rotation with 50 Nano-Radian Resolution: Piezo Mirror Tilter

Fast Steering Mirror Combines Highest Dynamics and Compact Design



S-224 Piezo tip/tilt mirror for high-speed beam steering tasks and image stabilization applications

- **Optical Beam Deflection to 4.4 mrad**
- **Sub-µrad Resolution, Sub-Millisecond Response**
- **Frictionless, High-Precision Flexure Guiding System**
- **Includes BK7 Mirror**
- **Optional Position Feedback Sensor**
- **Outstanding Lifetime Due to PICMA® Piezo Actuators**

Model	Active axes	Open-loop tilt angle @ 0 to +100V	Closed-loop/ open-loop resolution	Unloaded resonant frequency
S-224.00 (open-loop)/ S-226.00 (closed-loop)	θ_X	2.0 / 2.2 mrad	0.1 / 0.05 µrad	9 kHz

Rotation with 50 Nano-Radian Resolution Piezo Z/Tip/Tilt Platform

High Dynamics & Stability Nanopositioning System with Direct Metrology

The S-323 Z/tip/tilt platform integrates capacitive sensors for highest resolution and stability

- **Optical Beam Deflection to 6 mrad**
- **Sub-µrad Resolution for High Positioning Stability**
- **Position Servo-Control with Capacitive Sensors**
- **Frictionless, High-Precision Flexure Guiding System**
- **System Combination with Digital Controllers for Highest Linearity**

Model	Active axes	Travel range	Resolution	Unloaded resonant frequency
S-323.3CD	Z, θ_X, θ_Y	30 µm, ±1.5 mrad	0.1 nm, ±0.05 µrad	1.7 kHz

© Physik Instrumente (PI) GmbH & Co. KG 2008. Subject to change without notice. All data are superseded by any new release. The newest release for data sheets is available for download at www.pi.ws. R1 09/07/29.0

2-Axis Rotational Piezo Mirror Positioner

Fast Steering Mirror with up to 120 mrad Deflection

S-334 Tip/Tilt Mirror System / Scanner Provides Optical Deflection Angle up to 120 mrad

- **Miniature Design**
- **Optical Beam Deflection to 120 mrad (~ 6.8°)**
- **Coplanar Axes & Fixed Pivot Point; Eliminate Polarization Rotation**
- **Factory Installed Mirror**
- **Millisecond Response, Resolution to 0.2 µrad**
- **Closed-loop Position Servo-Control for High Accuracy**
- **For Mirrors up to 12.5 mm (0.5") Diameter**
- **Frictionless, High-Precision Flexure Guiding System**
- **Parallel Kinematics for Enhanced Dynamics and Better Multi-Axis Accuracy**

S-334 piezo tip/tilt mirrors / scanners provide extremely large deflection angles in a miniaturized package. These fast steering mirror systems are based on a sophisticated parallel-kinematics design with two coplanar, orthogonal axes and a fixed pivot point.

Large Tip/Tilt Ranges with Excellent Motion Characteristics

The novel flexure/lever design with minimized inertia allows for the exceptionally large tip/tilt range of 60 mrad (50 mrad in closed-loop operation, which is equivalent to 100 mrad optical beam deflection) and very fast response in the millisecond range. These parameters make the system unique in the market of piezo driven tip/tilt mirror systems.

Sub-Microradian Resolution

In addition to the large angles and the high dynamics the S-334 provides sub-microradian resolution. The integrated high-resolution, full-bridge strain gauge sensors (SGS) provide absolute position control, excellent repeatability and high linearity, typically better than 0.05 % over the entire travel range.

Differential Drive for Improved Stability and Dynamics

The S-334 is based on a parallel-kinematics design with coplanar axes and a single moving platform. Two pairs of differentially-driven piezo actuators are employed to provide the highest dynamics and position stability over a wide temperature range.

Compared to stacked, (two-stage), piezo or galvo scanners, the single-platform design provides several advantages: smaller package size, identical dynamic performance in both axes, faster response and better linearity. It also prevents polarization rotation.

High Reliability and Long Lifetime

The compact S-334 systems are equipped with preloaded PICMA® high-performance piezo actuators which are integrated into a sophisticated, FEA-modeled, flexure guiding system. The PICMA® actuators feature cofired ceramic encapsulation and provide better performance and reliability than conventional piezo actuators. Actuators, guidance and sensors are maintenance-free, not subject to wear and offer extraordinary reliability.

Ordering Information

S-334.1SD
High-Dynamics Piezo Tip/Tilt Platform, 25 mrad, SGS, Sub-D Connector, incl. Mirror

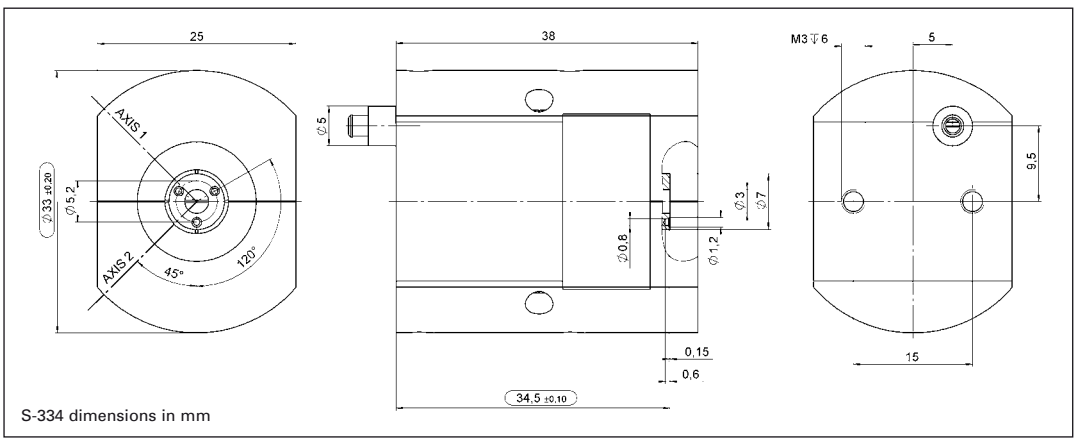
S-334.1SL
High-Dynamics Piezo Tip/Tilt Platform, 25 mrad, SGS, LEMO Connector, incl. Mirror

S-334.2SD
High-Dynamics Piezo Tip/Tilt Platform, 50 mrad, SGS, Sub-D Connector, incl. Mirror

S-334.2SL
High-Dynamics Piezo Tip/Tilt Platform, 50 mrad, SGS, LEMO Connector, incl. Mirror

Application Examples

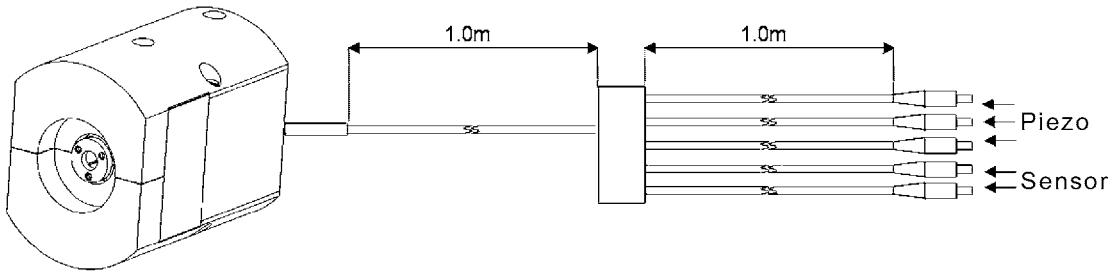
- Image processing / stablilization
- Interlacing, dithering
- Laser scanning / beam steering
- Optics
- Optical filters / switches
- Scanning microscopy
- Beam stabilization



S-334 dimensions in mm

© Physik Instrumente (PI) GmbH & Co. KG 2008. Subject to change without notice. All data are superseded by any new release. The newest release for data sheets is available for download at www.pi.ws. R1 10/04/07.0

Factory Installed Mirror
The S-334 is equipped with a factory-installed mirror 10 mm in diameter and 2 mm thick (flatness λ/5, reflectivity >98 % from 500 nm to 2 µm).



S-334.2SL cable configuration

Technical Data

Model	S-334.1SL S-334.1SD	S-334.2SL S-334.2SD	Units	Tolerance
Active Axes	θ_X, θ_Y	θ_X, θ_Y		
Motion and positioning				
Integrated sensor	SGS	SGS		
*Open-loop tilt angle at -20 to +120 V	30	60	mrad	min. (+20 %/-0 %)
*Closed-loop tilt angle	25	50	mrad	
Open-loop resolution	0.2	0.5	µrad	typ.
Closed-loop resolution	1	5	µrad	typ.
Linearity	0.05	0.05	%	typ.
Repeatability	2	5	µrad	typ.
Mechanical properties				
Resonant frequency underload (with standard mirrors)	3.0	1.0	kHz	±20 %
Load capacity	0.2	0.2	N	Max.
Distance of pivot point to platform surface	6	6	mm	±1 mm
Platform moment of inertia	1530	1530	g • mm²	±20 %
Standard mirror (mounted)	diameter: 10 mm, thickness: 2 mm; BK7, λ/5, R > 98 % (λ = 500 nm to 2 µm)	diameter: 10 mm, thickness: 2 mm; BK7, λ/5, R > 98 % (λ = 500 nm to 2 µm)		
Drive properties				
Ceramic type	PICMA® P-885	PICMA® P-885		
Electrical capacitance per axis	3	3	µF	±20 %
Miscellaneous				
Operating temperature range	-20 to 80	-20 to 80	°C	
Material casing	Titanium	Titanium		
Mass	0.065	0.065	kg	±5 %
Cable length	2	2	m	±10 mm
Sensor / voltage connection	LEMO connector / 25-pin sub-D connector	LEMO connector / 25-pin sub-D connector		

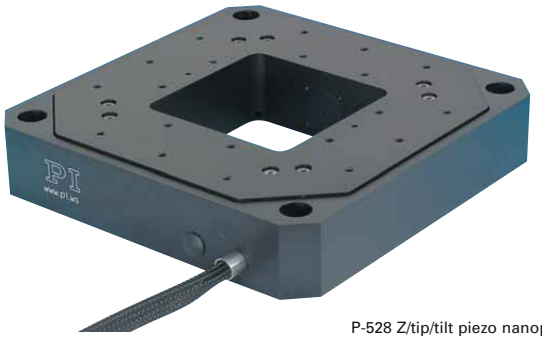
Recommended controller / amplifier
Closed-loop versions with D-sub connector: E-616 controller for tip/tilt mirror systems (p. 2-132);
Open-loop versions with LEMO connector: Modular piezo controller system E-500 (p. 2-142) with amplifier module E-503.00S (three channels) (p. 2-146) or 1 x E-505.00S and 2 x E-505 (high speed applications) (p. 2-147) and E-509 servo controller (p. 2-152 / 3-16)
Open-loop: E-663 three channel amplifier (p. 2-136)

Resolution of PI piezo tip/tilt platforms is not limited by friction or stiction. Noise equivalent motion with E-503 amplifier, (p. 2-146).

*Mechanical tilt, optical beam deflection is 120 mrad (open loop) and 100 mrad (closed-loop), respectively.

Precision Piezo Z/Tip/Tilt Stage: 2 x Rotation + Z

20 Nano-Radian Rotational Resolution, High-Dynamics + Large Clear Aperture



P-528 Z/tip/tilt piezo nanopositioning system

- **1- and 3-Axis Versions**
- **Closed-Loop Vertical / Tilt Range to 200 µm / 2 mrad (Open-Loop to 240 / 2.4)**
- **Parallel Kinematics / Metrology for Enhanced Responsiveness & Multi-Axis Precision**
- **Frictionless, High-Precision Flexure Guiding System**
- **Outstanding Lifetime Due to PICMA® Piezo Actuators**
- **Clear Aperture 66 x 66 mm**
- **Capacitive Sensors for Highest Linearity**

P-5x8 series, Z/tip/tilt nanopositioners / scanners are open-frame, high-resolution, piezo-driven stages providing motion to 240 µm and 2.4 mrad with resolutions of up to 0.5 nm and 50 nrad. The 66 x 66 mm clear aperture is ideal for transmitted-light applications.

XY and XYZ multi-axis versions in the same form factor are also offered as P-517, P-527 (see p. 2-70) models with six degrees of freedom are available upon request.

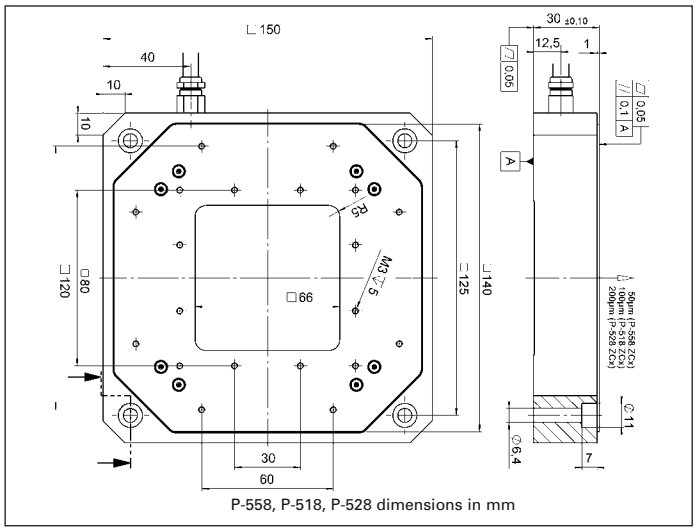
Capacitive Position Sensors for Higher Accuracy

PI's proprietary capacitive sensors measure position directly and without physical contact. They are free of friction and hysteresis, a fact which, in combination with the positioning resolution of well under 1 nm, makes it possible to achieve very high levels of linearity. A further advantage of direct metrology with capacitive sensors is the high phase fidelity and the high bandwidth of up to 10 kHz.

Excellent Guiding Accuracy

Flexures optimized with Finite Element Analysis (FEA) are used to guide the stage. FEA techniques are used to give the design the highest possible stiffness in, and perpendicular to, the direction of motion, and to minimize linear and angular runout. Flexures allow extremely high-precision motion, no matter how minute, as they are completely free of play and friction.

Flatness and Straightness is further enhanced by active trajectory control: Multi-axis nanopositioning systems equipped with both parallel kinematics and parallel direct metrology are able to measure platform position in all degrees of freedom against one common fixed reference. In such systems, undesirable motion from one actuator in the direction of another (cross-talk) is detected immediately and actively compensated by the servo-loops. This Active Trajectory Control Concept can keep deviation from a trajectory to under a few nanometers, even in dynamic operation.



P-558, P-518, P-528 dimensions in mm

Application Examples

- Metrology
- Interferometry
- Optics
- Lithography
- Scanning microscopy
- Mass storage device testing
- Laser technology
- Micromachining

Higher Precision in Periodic Motion

The highest dynamic accuracy in scanning applications is

Ordering Information

P-558.ZCD
Precision Nanopositioning Z-Stage, 50 µm, Direct Metrology, Capacitive Sensors, Sub-D Connector

P-558.ZCL
Precision Nanopositioning Z-Stage, 50 µm, Direct Metrology, Capacitive Sensors, LEMO Connector

P-518.ZCD
Precision Nanopositioning Z-Stage, 100 µm, Direct Metrology, Capacitive Sensors, Sub-D Connector

P-518.ZCL
Precision Nanopositioning Z-Stage, 100 µm, Direct Metrology, Capacitive Sensors, LEMO Connector

P-528.ZCD
Precision Nanopositioning Z-Stage, 200 µm, Direct Metrology, Capacitive Sensors, Sub-D Connector

P-528.ZCL
Precision Nanopositioning Z-Stage, 200 µm, Direct Metrology, Capacitive Sensors, LEMO Connector

P-558.TCD
Precision Nanopositioning Z/Tip/Tilt Stage, 50 µm, 0.6 mrad, Parallel Metrology, Capacitive Sensors, Sub-D Connector

P-518.TCD
Precision Nanopositioning Z/Tip/Tilt Stage, 100 µm, 1.4 mrad, Parallel Metrology, Capacitive Sensors, Sub-D Connector

P-528.TCD
Precision Nanopositioning Z/Tip/Tilt Stage, 200 µm, 2.4 mrad, Parallel Metrology, Capacitive Sensors, Sub-D Connector

© Physik Instrumente (PI) GmbH & Co. KG 2008. Subject to change without notice. All data are superseded by any new release. The newest release for data sheets is available for download at www.pi.ws. Cat120E Inspirations2009 08/10.18

made possible by the DDL algorithm, which is available in PI's modern digital controllers. DDL eliminates tracking errors, improving dynamic linearity and usable bandwidth by up to three orders of magnitude!

Ceramic Insulated Piezo Actuators Provide Long Lifetime

Highest possible reliability is assured by the use of award-winning PICMA® multilayer piezo actuators. PICMA® actuators are the only actuators on the market with ceramic-only insulation, which makes them resistant to ambient humidity and leakage-current failures. They are thus far superior to conventional actuators in reliability and lifetime.

Technical Data

Model	P-558.ZCD/ P-558.ZCL	P-558.TCD	P-518.ZCD/ P-518.ZCL	P-518.TCD	P-528.ZCD/ P-528.ZCL	P-528.TCD	Units	Tolerance
Active axes	Z	Z, θ_x, θ_y	Z	Z, θ_x, θ_y	Z	Z, θ_x, θ_y		
Motion and positioning								
Integrated sensor	Capacitive	Capacitive	Capacitive	Capacitive	Capacitive	Capacitive		
Open-loop travel, -20 to +120 V	60	60	140	140	240	240	µm	min. (+20 %/-0 %)
Open-loop tip/tilt angle, -20 to +120 V	–	±0.3 mrad	–	±0.7 mrad	–	±1.2 mrad	mrad	min. (+20 %/-0 %)
Closed-loop travel	50	50	100	100	200	200	µm	
Closed-loop tip/tilt angle	–	±0.25 mrad	-	±0.5 mrad	–	±1 mrad	mrad	
Open-loop resolution	0.2	0.2	0.2	0.4	0.6	0.6	nm	typ.
Open-loop tip/tilt angle resolution	–	0.02	–	0.04	–	0.06	µrad	typ.
Closed-loop resolution	0.5	0.5	0.8	0.8	1	1	nm	typ.
Closed-loop tip/tilt resolution	–	0.05	–	0.05	–	0.1	µrad	typ.
Linearity θ_x, θ_y	–	0.03	–	0.03	–	0.03	%	typ.
Repeatability	±5	±5	±5	±5	±10	±10	nm	typ.
Repeatability θ_x, θ_y	–	±0.03	–	±0.05	–	±0.1	µrad	typ.
Runout θ_z (Z motion)	<10	<10	<10	<10	<20	<20	µrad	typ.
Runout θ_x, θ_y (Z motion)	<50	<50	<50	<50	<100	<100	µrad	typ.
Mechanical properties								
Stiffness	4	4	2.7	2.7	1.5	1.5	N/µm	±20 %
Unloaded resonant frequency (Z)	570	570	500	500	350	350	Hz	±20 %
Unloaded resonant frequency (θ_x, θ_y)	-	610	-	530	-	390	Hz	±20 %
Resonant frequency @ 30 g in Z	410	410	350	350	210	210	Hz	±20 %
Resonant frequency @ 500 g in X, Y	-	430	-	370	-	250	Hz	±20 %
Resonant frequency @2500 g in Z	245	245	200	200	130	130	Hz	±20 %
Resonant frequency @ 2500 g θ_x, θ_y	-	240	-	190	-	115	Hz	±20 %
Push/pull force capacity	100 / 50	100 / 50	100 / 50	100 / 50	100 / 50	100 / 50	N	Max.
Drive properties								
Ceramic type	PICMA® P-885	PICMA® P-885	PICMA® P-885	PICMA® P-885	PICMA® P-885	PICMA® P-885		
Electrical capacitance	6	6	8.4	8.4	14.8	14.8	µF	±20 %
Dynamic operating current coefficient	15	15	10.5	10.5	9.2	9.2	µA/ (Hz•µm)	±20%
Miscellaneous								
Operating temperature range	-20 to 80	-20 to 80	-20 to 80	-20 to 80	-20 to 80	-20 to 80	°C	
Material	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum		
Dimensions	150 x 150 x 30	150 x 150 x 30	150 x 150 x 30	150 x 150 x 30	150 x 150 x 30	150 x 150 x 30	mm	
Mass	1380	1380	1400	1400	1420	1420	g	±5 %
Cable length	1.5	1.5	1.5	1.5	1.5	1.5	m	±10 mm
Sensor / voltage connection	CD-version: Sub-D special CL-version: LEMO	Sub-D Special	CD-version: Sub-D special CL-version: LEMO	Sub-D Special	CD-version: Sub-D special CL-version: LEMO	Sub-D Special		

Resolution of PI Piezo Nanopositioners is not limited by friction or stiction. Value given is noise equivalent motion with E-503 (p. 2-146) or E-710 controller (p. 2-128)
Recommended controller
CD-Versions:
Single-channel (1 per axis): E-610 servo controller / amplifier (p. 2-110), E-625 servo controller, bench-top (p. 2-114)
Single-channel digital controller: E-753 (bench-top) (p. 2-108)
CL-Versions:
Single-channel: E-500 modular piezo controller system (p. 2-142) with E-505 (p. 2-147) high-power amplifier module and E-509 servo-controller (p. 2-152)
Multi-channel versions:
Multi-channel digital controllers: E-710 bench-top (p. 2-128), E-712 modular (p. 2-140), E-725 high-power (p. 2-126), E-761 PCI board (p. 2-130)

M-811 Vacuum-Hexapod: 3 x Rotation + XYZ = 6 DOF

High Precision and Very Versatile

The M-811.STV vacuum-compatible Hexapod comes complete with software and a highly specialized Hexapod controller. It combines small size with high-load capacity and high accuracy.

- **Vacuum-Compatible Miniature Hexapod**
- **Complete with Specialized Hexapod Controller and Software**
- **Travel Ranges 34 x 32 x 13 mm, Rotation to 42 Degrees**
- **Load Capacity to 5 kg**
- **Actuator Resolution 40 nm**
- **Min. Incremental Motion to 200 nm**
- **Repeatability up to ±0.2 µm**
- **Velocity to 10 mm/s**

The M-811.STV is PI's smallest standard vacuum-compatible Hexapod. Despite its size it can handle loads up to 5 kg (2.5 kg in any orientation) and achieves velocities up to 10 mm/sec. With a diameter of only 130 mm and a height of 115 mm it provides travel ranges up to 35 mm in the XY-plane and up to 13 mm in the Z-direction. In combination with the large tilting angles of 20° around the X and Y axis and up to 40° around the vertical axis it allows for complex motion profiles with particularly flexible placement of the load – a great advantage in restricted areas (such as beam lines) and small vacuum chambers.

Each individual strut has a positioning resolution of 40 nm; multi-axis motion can be accomplished with sub-micron repeatability. In addition to controlling all axes in Cartesian coordinates, a software command allows the user to select the center of rotation (pivot point) freely anywhere inside or outside the system envelope.

Application Examples

- Biotechnology
- Semiconductor technology
- Micromachining
- Micromanipulation
- X-ray diffraction measurements
- Tool control

Hexapod vs. Serial Kinematics Systems

The Hexapod is driven by six high-resolution actuators all connected directly to the same moving platform. This design provides a high system stiffness and a large clear aperture. Because of the low mass of the moving platform, positioning operations can be performed with far lower settling times than with conventional, stacked multi-axis systems. In such systems, runout, guiding errors, and the friction and inertia of moving cables all accumulate to limit accuracy and repeatability—problems which do not affect parallel kinematic systems like the Hexapod.

Fixed Virtual Pivot Point

For optics and other alignment tasks, it is important to be able to define a fixed pivot point. The sophisticated Hexapod controller allows choosing any point in space as the pivot point for the rotation axes by software command. The pivot point remains fixed relative to the platform.

Ordering Information

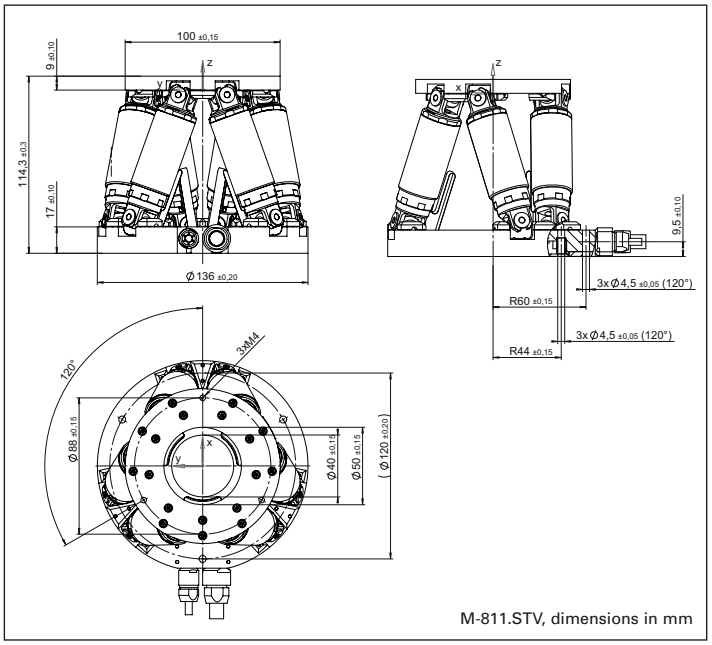
M-811.STV
Miniature Hexapod Microrobot with Controller, Direct Drive, 5 kg Load, Vacuum Compatible to 10^{-6} hPa

Ask about custom designs!

Target positions in 6-space are entered in user-friendly coordinates and reached by smooth vectorized motion.

Open Architecture

Control of the Hexapod is facilitated by the controller's open interface architecture, which provides a variety of high-level commands and includes a macro language for programming and storing command sequences.



M-811.STV, dimensions in mm

© Physik Instrumente (PI) GmbH & Co. KG 2011. Subject to change without notice. All data are superseded by any new release. The newest release for data sheets is available for download at www.pi.ws. 11/05/06.0

Technical Data

Model	M-811.STV
Active axes	X, Y, Z, θX, θY, θZ
Motion and positioning	
*Travel range X, Y, Z	±17, ±16, ±6.5 mm
*Travel range θX, θY, θZ	±10°, ±10°, ±21°
Actuator drive	Brushless DC motor, ActiveDrive
Single-actuator design resolution	0.04 µm
Integrated sensor	Rotary encoder
Sensor resolution	12800 cts./rev.
**Min. incremental motion X, Y	0.5 µm
**Min. incremental motion Z	0.2 µm
**Min. incremental motion θX, θY, θZ	10 µrad
Repeatability X, Y	±0.5 µm
Repeatability Z	±0.2 µm
Repeatability θX, θY, θZ	±2 µrad
Backlash X, Y	1 µm
Backlash Z	0.2 µm
Max. velocity X, Y, Z	10 mm/s
Max. velocity θX, θY, θZ	250 mrad/s
Typ. velocity X, Y, Z	5 mm/s
Typ. velocity θX, θY, θZ	120 mrad/s
Mechanical properties	
Stiffness X, Y	0.2 N/µm
Stiffness Z	3.6 N/µm
Load (baseplate horizontal / any orientation)	5 / 2.5 kg
Miscellaneous	
Operating temperature range	0 to +50 °C
Material	Stainless steel, aluminum
Mass	2.2 kg
Controller	
Operating voltage	100-240 VAC, 50/60 Hz

* The travel ranges of the individual coordinates (X, Y, Z, θX, θY, θZ) are interdependent. The data for each axis in this table shows its maximum travel, where all other axes are at their zero positions. If the other linear or rotational coordinates are not zero, the available travel may be less.

** Six-axis move. No moving cables (unlike serial-kinematic stacked systems). Eliminates bending, inertia and friction, improving accuracy.

Technical data are specified at 20 ±3 °C. Data for vacuum versions may differ.

Program Overview

- Piezo Ceramic Actuators & Motors
- Piezo Nanopositioning Systems and Scanners
- Active Optics / Tip-Tilt Platforms
- Capacitive Nanometrology Sensors
- Piezo Electronics: Amplifiers and Controllers
- Hexapod 6-Axis Positioners / Robots
- Micropositioning Stages & Actuators
- Photonics Alignment Systems, Solutions for Telecommunications
- Motor Controllers
- Ultrasonic Linear Motors

Request or download the complete PI Nanopositioning & Piezo Actuator Catalog

USA (East) & CANADA

PI (Physik Instrumente) L.P.
16 Albert St.
Auburn, MA 01501
Tel: +1 (508) 832 3456
Fax: +1 (508) 832 0506
info@pi-usa.us
www.pi-usa.us

USA (West) & MEXICO

PI (Physik Instrumente) L.P.
5420 Trabuco Rd., Suite 100
Irvine, CA 92620
Tel: +1 (949) 679 9191
Fax: +1 (949) 679 9292
info@pi-usa.us
www.pi-usa.us

JAPAN

PI Japan Co., Ltd.
Akebono-cho 2-38-5
Tachikawa-shi
J-Tokyo 190
Tel: +81 (42) 526 7300
Fax: +81 (42) 526 7301
info@pi-japan.jp
www.pi-japan.jp

PI Japan Co., Ltd.
Hanahara Dai-ni Building, #703
4-11-27 Nishinakajima,
Yodogawa-ku, Osaka-shi
J-Osaka 532
Tel: +81 (6) 6304 5605
Fax: +81 (6) 6304 5606
info@pi-japan.jp
www.pi-japan.jp

CHINA

Physik Instrumente (PI Shanghai) Co., Ltd.
Building No. 7-301
Longdong Avenue 3000
201203 Shanghai, China
Tel: +86 (21) 687 900 08
Fax: +86 (21) 687 900 98
info@pi-china.cn
www.pi-china.cn

UK & IRELAND

PI (Physik Instrumente) Ltd.
Trent House
University Way,
Cranfield Technology Park,
Cranfield,
Bedford MK43 0AN
Tel: +44 (1234) 756 360
Fax: +44 (1234) 756 369
uk@pi.ws
www.physikinstrumente.co.uk

FRANCE

PI France S.A.S
244 bis, avenue Max Dormoy
92120 Montrouge
Tel: +33 (1) 55 22 60 00
Fax: +33 (1) 41 48 56 62
info.france@pi.ws
www.pi-france.fr

ITALY

Physik Instrumente (PI) S.r.l.
Via G. Marconi, 28
I-20091 Bresso (MI)
Tel: +39 (02) 665 011 01
Fax: +39 (02) 873 859 16
info@pionline.it
www.pionline.it

GERMANY

Physik Instrumente (PI) GmbH & Co. KG
Auf der Römerstr. 1
D-76228 Karlsruhe/Palmbach
Tel: +49 (721) 4846-0
Fax: +49 (721) 4846-100
info@pi.ws · www.pi.ws