

P-725 PIFOC® Long-Travel Objective Scanner

High-Precision Positioner / Scanner for Microscope Objectives



P-725.2CL with QuickLock option
P-721.12Q for W0.8 x 1/36" threads and objective (QuickLock adapter and objective not included)

- Travel Ranges to 460 μm
- Significantly Faster Response and Higher Lifetime than Motorized Z-Stages
- Scans and Positions Objectives with Sub-nm Resolution
- Direct Metrology with Capacitive Sensors for Highest Linearity
- Parallel Precision Flexure Guiding for Better Focus Stability
- Compatible with MetaMorph Imaging Software
- Outstanding Lifetime Due to PICMA® Piezo Actuators
- QuickLock Adapter for Easy Attachment
- Clear Aperture up to 29 mm \varnothing

P-725 PIFOC® nanofocus systems are long-travel (up to 460 μm), high-speed, piezo-driven microscope objective nanofocusing/scanning devices. The innovative, frictionless, flexure guiding system provides enhanced precision for superior focus stability with fast response for rapid settling and scanning. Despite the larger travel range, they are 20 % shorter than P-721 units (p. 2-25) while providing sub-nanometer reso-

lution. For applications which require a particularly high resolution, such as the two photon spectroscopy, there are versions which allow a free aperture of up to 29 mm in diameter.

Superior Accuracy With Direct-Metrology Capacitive Sensors

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. Further advantages of direct metrology with capacitive sensors is the high phase fidelity and the high bandwidth of up to 10 kHz.

Open-loop models are available for applications where fast response and very high resolution are essential. Here, specifying or reporting absolute position values is either not required or

Ordering Information

P-725 PIFOC® Piezo Nanofocusing Z-Drive for Long Scanning Ranges

- 1 Travel Range 100 μm (closed-loop)
 - 2 Travel Range 250 μm (closed-loop)
 - 4 Travel Range 400 μm (closed-loop)
- P-725.
- CA Capacitive Sensor, Sub-D Connectors, for Large Aperture QuickLock Thread Adapters
 - CD Capacitive Sensor, Sub-D Connectors, for QuickLock Thread Adapters
 - CL Capacitive Sensor, LEMO Connector, for QuickLock Thread Adapters
 - 0L No Sensor, LEMO Connectors, for QuickLock Thread Adapters, Travel Range see Data Table

Accessories

QuickLock Thread Adapters s. fig.,
Extension Tubes for Objectives s. www.pi.ws

is handled by external sensors, such as interferometers, a vision system or photodiode PSD (position sensitive detector). These models retain the inherent piezo advantages such as high resolution and speed.

Open-loop models are available for applications where fast response and very high resolution are essential. Here, specifying or reporting absolute position values is either not required or is handled by external sensors, such as interferometers, vision system or photodiode PSD (position sensitive detector). These models retain the inherent piezo advantages as high resolution and speed.

Simple Installation with QuickLock Thread Options

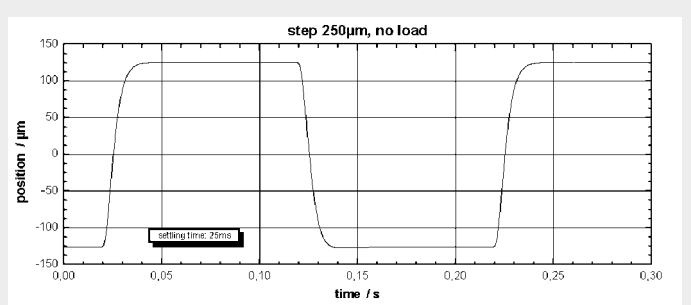
The PIFOC® is mounted between the turret and the objective with the QuickLock thread adapter. After threading the adapter into the turret, the QuickLock is affixed in the desired position. Because the PIFOC® body need not to be rotated, cable wind-up is not an issue.

High Reliability and Long Lifetime

The compact PIFOC® 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

Application Examples

- 3D-Imaging
- Screening
- Interferometry
- Metrology
- Disc-drive-testing
- Autofocus systems
- Confocal microscopy
- Biotechnology
- Semiconductor testing



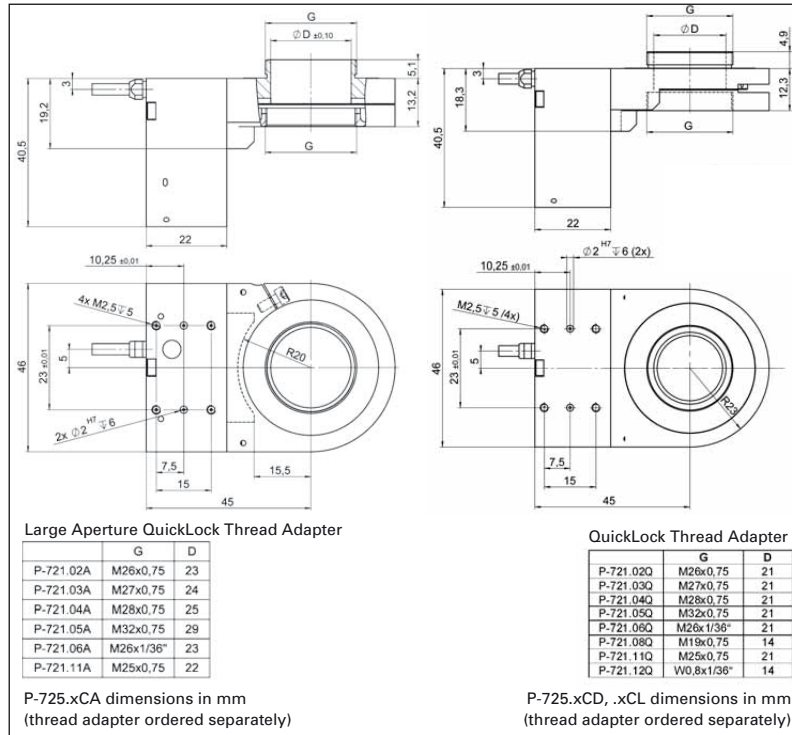
Fastest step and settle: The P-725.2CL can perform a 250 μm step to 1 % accuracy in only 25 ms (no load; 50 ms with a load of 150 g. With E-665.CR controller)

cofired ceramic encapsulation and thus offer better performance and reliability than conventional piezo actuators. Actuators, guidance and sensors are maintenance-free and not subject to wear, and thus offer an extraordinary reliability.

Scanner for Higher Dynamics and Higher Loads

PI offers a series of related PIFOC® objective scanners with different specifications. For higher loads and dynamic scanning applications the models P-726 (s.p. 2-32) and P-725.DD (s.p. 2-30) featuring a stroke of up to 100 µm are available.

Alternatively, the sample can be moved into focus: The P-737 piezo Z-nanopositioner features a large aperture to hold a variety of sample holders.



Technical Data

| Model | P-725.1CL P-725.1CD P-725.1CA | P-725.2CL P-725.2CD P-725.2CA | P-725.4CL P-725.4CD P-725.4CA | P-725.x0L open-loop version | Units | Tolerance |
|--|--|--|--|-----------------------------------|--------------|-----------------|
| Active axes | Z | Z | Z | Z | | |
| Motion and positioning | | | | | | |
| Integrated sensor | Capacitive | Capacitive | Capacitive | - | | |
| Open-loop travel, -20 to +120 V | 150 | 330 | 460 | as P-725.xCL | µm | min. (+20%/-0%) |
| Closed-loop travel | 100 | 250 | 400 | - | µm | calibrated |
| Open-loop resolution | 0.3 | 0.4 | 0.5 | as P-725.xCL | nm | typ. |
| Closed-loop resolution | 0.65 | 0.75 | 1.25 | - | nm | typ. |
| Linearity, closed-loop | 0.03 | 0.03 | 0.03 | - | % | typ. |
| Repeatability | ±5 | ±5 | ±5 | - | nm | typ. |
| Runout Θ_x | 1 | 6 | 10 | as P-725.xCL | µrad | typ. |
| Runout Θ_y | 20 | 45 | 45 | as P-725.xCL | µrad | typ. |
| Crosstalk in X | 20 | 20 | 60 | as P-725.xCL | nm | typ. |
| Crosstalk in Y | 20 | 40 | 60 | as P-725.xCL | nm | typ. |
| Mechanical properties | | | | | | |
| Stiffness in motion direction | 0.23 | 0.17 | 0.12 | as P-725.xCL | N/µm | ±20% |
| Unloaded resonant frequency | 470 | 330 | 230 | as P-725.xCL | Hz | ±20% |
| Resonant frequency @ 150 g | 185 | 140 | 120 | as P-725.xCL | Hz | ±20% |
| Push/pull force capacity in motion direction | 100 / 20 | 100 / 20 | 100 / 20 | as P-725.xCL | N | Max. |
| Drive properties | | | | | | |
| Ceramic type | PICMA® P-885 | PICMA® P-885 | PICMA® P-885 | as P-725.xCL | | |
| Electrical capacitance | 4.2 | 6.2 | 6.2 | as P-725.xCL | µF | ±20% |
| Dynamic operating current coefficient | 5.2 | 3.1 | 1.9 | as P-725.xCL | µA/(Hz • µm) | ±20% |
| Miscellaneous | | | | | | |
| Operating temperature range | -20 to 80 | -20 to 80 | -20 to 80 | -20 to 80 | °C | |
| Material | Aluminum | Aluminum | Aluminum | Aluminum | | |
| Max. objective diameter | 39 | 39 | 39 | 39 | mm | |
| Mass | 0.215 | 0.23 | 0.23 | as P-725.xCL | kg | ±5% |
| Sensor / voltage connection | CL-version: LEMO others: Sub-D special | CL-version: LEMO others: Sub-D special | CL-version: LEMO others: Sub-D special | LEMO (no sensor) | | |

Recommended controller / amplifier
 CL-versions:
 E-610 servo controller / amplifier (p. 2-110); E-500 modular piezo controller system (p. 2-142) with E-505 high-performance amplifier module (p. 2-147) and E-509 controller (p. 2-152)
 CD/CA-versions:
 E-621 controller module (p. 2-160), E-625 servo controller, bench-top (p. 2-114), E-665 display servo controller, with digital interface, bench-top (p. 2-116)
 Single-channel digital controller: E-753 (bench-top) (p. 2-108), E-709

PIFOC® Long Range Objective Scanning System

High-Dynamics Sub-Nanometer Piezo Drive; Controller & Software



PIFOC® long range objective scanning system with QuickLock thread adapter and controller (objective not included)

- **Complete System with Controller: High Performance Digital Servo Software Configurable Parameters**
- **Travel Ranges to 400 µm**
- **Scans and Positions Objectives with Sub-nm Resolution**
- **Frictionless, High-Precision Flexure Guiding System for Better Focus Stability**
- **Higher Linearity and Stability Through Digital Control and Direct Metrology with Capacitive Sensors**
- **Clear Aperture up to 29 mm Ø, QuickLock Adapter for Easy Attachment**
- **Interfaces: USB, RS-232 and Analog**
- **Extensive Software Support, Compatible with MetaMorph Imaging Software**

The PIFOC® piezo objective scanner systems include a high precision piezo mechanism and a custom-tuned compact digital controller. This combination

provides higher performance at reduced costs. The piezo mechanisms combine large travel ranges of up to 400 µm with extreme position stability. The in-

tegrated, frictionless and stiff piezo flexure guiding system and the sophisticated digital servo, ensure high stiffness, fast response and minimal settling times. Highly parallel motion with minimum tilt improve image quality. Nevertheless, the focusing systems are extremely compact. The settling time of less than 20 ms increases the throughput and allows rapid Z-stack acquisition.

For applications which need a particularly large clear aperture a version with a 29 mm diameter threaded insert is available.

Digital Controller for Automated Scans

Included in the delivery is a digital controller which opens up the possibilities of digital control for piezo-driven nanopositioning systems for the same price as analog controllers. The advantage: higher precision and simpler operation. The controller can also be used for applications which provide analog control signals: as a standard, a broadband analog input is provided as well as the two digital interfaces.

Flexibility: Software Configurable Servo Parameters

All servo controllers require

Ordering Information

PD72Z2CAA
Fast PIFOC® Piezo Nanofocusing Z-Drive, 250 µm, Capacitive Sensor, M32 Large Aperture QuickLock Thread Adapters, Digital Controller with USB, RS-232

PD72Z2CAQ
Fast PIFOC® Piezo Nanofocusing Z-Drive, 250 µm, Capacitive Sensor, M25 QuickLock Thread Adapters, Digital Controller with USB, RS-232

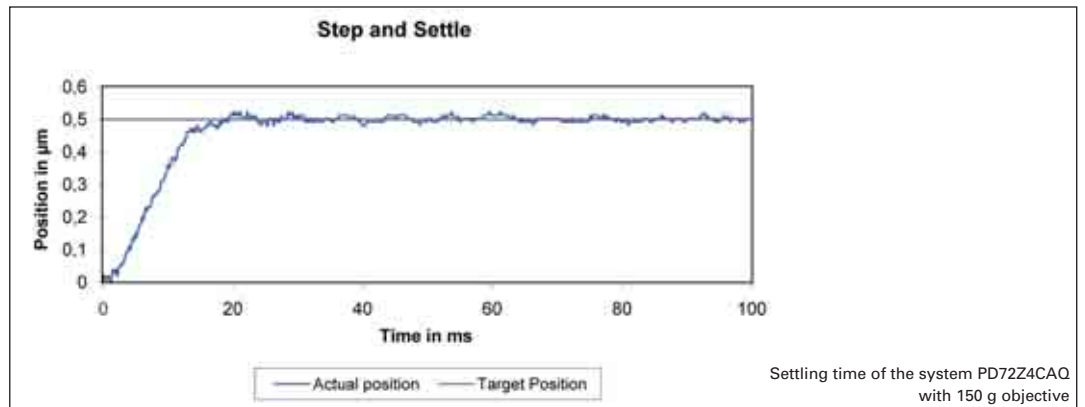
PD72Z4CAA
Fast PIFOC® Piezo Nanofocusing Z-Drive, 400 µm, Capacitive Sensor, M32 Large Aperture QuickLock Thread Adapters, Digital Controller with USB, RS-232

PD72Z4CAQ
Fast PIFOC® Piezo Nanofocusing Z-Drive, 400 µm, Capacitive Sensor, M25 QuickLock Thread Adapters, Digital Controller with USB, RS-232

tuning and adjustment of servo parameters for optimum performance (e.g. as a result of changes to the load or the motion profile). With a digital controller, all adjustments are carried out by simple software commands and the resulting motion or transient characteristics can be viewed, analyzed and further optimized immediately with the provided software. It is also possible to switch between previously

Application Examples

- Microscopy
- Confocal microscopy
- 3D Imaging
- Screening
- Autofocus systems
- Surface analysis
- Wafer inspection
- Multi-Photon Spectroscopy



found sets of parameters when the controller is in operation. Since jumpers and potentiometers no longer have to be set manually, system integration becomes much more straightforward.

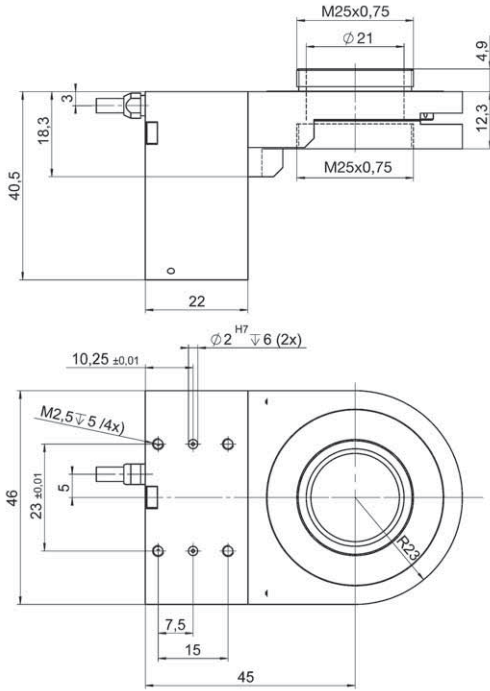
Easy System Setup, Comprehensive Software

All parameters can be set and checked by software. System setup and configuration is done with the included user-interface

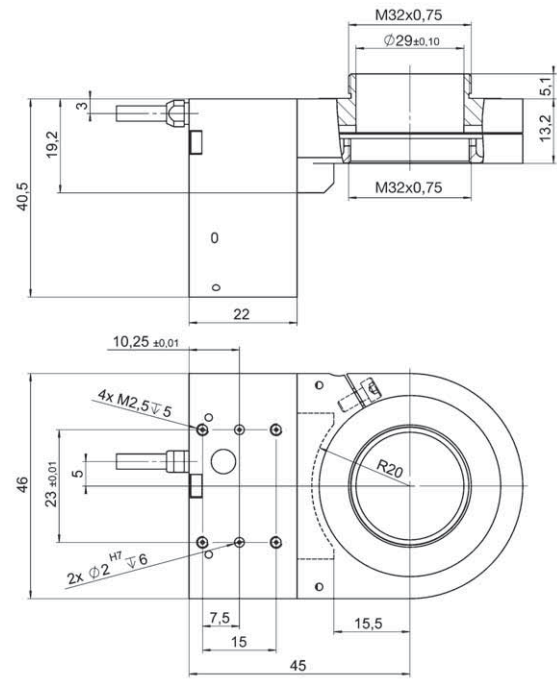
software. Interfacing to custom software is facilitated with included LabVIEW drivers and DLLs. Drivers for MetaMorph and μ Manager are available.

Technical Data

| Model | PD72Z2CAA PD72Z2CAQ | PD72Z4CAA PD72Z4CAQ | Units | Tolerance |
|--|---|------------------------|------------------|------------|
| Active axes | Z | Z | | |
| Motion and positioning | | | | |
| Integrated sensor | Capacitive | Capacitive | | |
| Closed-loop travel | 250 | 400 | μm | |
| Closed-loop resolution | 1.5 | 2.5 | nm | typ. |
| Linearity, closed-loop | 0.06 | 0.06 | % | typ. |
| Repeatability | ± 5 | ± 5 | nm | typ. |
| Runout θ_X | 6 | 10 | μrad | typ. |
| Runout θ_Y | 45 | 45 | μrad | typ. |
| Crosstalk in X | 20 | 60 | nm | typ. |
| Crosstalk in Y | 40 | 60 | nm | typ. |
| Settling time (0.5 μm step to 5 % accuracy, 150 g) | 15 | 20 | ms | typ. |
| Mechanical properties | | | | |
| Stiffness in motion direction | 0.17 | 0.12 | N/ μm | $\pm 20\%$ |
| Unloaded resonant frequency | 330 | 230 | Hz | $\pm 20\%$ |
| Resonant frequency @ 150 g | 140 | 120 | Hz | $\pm 20\%$ |
| Push/pull force capacity in motion direction | 100 / 20 | 100 / 20 | N | Max. |
| Drive properties | | | | |
| Ceramic type | PICMA® P-885 | PICMA® P-885 | | |
| Controller | | | | |
| | Digital controller for single-axis piezo nanopositioning systems | | | |
| Processor | DSP 32-bit floating point, 150 MHz | | | |
| Communication interfaces | USB, RS-232 | | | |
| Linearization | 5th order polynomials | | | |
| Amplifier power | 10 W (<5 ms); 5 W (>5 ms) | | | |
| I/O Connector | HD-Sub-D 26-pin, 1 Analog input 0 to 10 V, 1 Sensor monitor 0 to 10 V, 1 digital input (LVTTTL, programmable), 5 digital outputs (LVTTTL, 3 predefined, 2 programmable) | | | |
| User software | PIMikroMove, NanoCapture | | | |
| Software drivers | LabVIEW drivers, DLLs | | | |
| Supported functionality | Digital setting of the control parameters, wave generator, data recorder, auto zero, trigger I/O; Compatible to MetaMorph, μ Manager | | | |
| Display | Status LED, overflow LED | | | |
| Miscellaneous | | | | |
| Operating temperature range | 10 to 50 °C | | | |
| Material scanner | Aluminum | | | |
| Weight | 0.23 kg (scanner), 0.5 kg (controller) | | | $\pm 5\%$ |
| Cable length to controller | 1.5 m | | | |
| Dimensions controller | 160 x 96 x 33 mm | | | |



PD72ZxCAQ with M25 QuickLock thread adapters, dimensions in mm



PD72ZxCAA with M32 large aperture QuickLock thread adapters, dimensions in mm

PIFOC® Long Range Objective Scanning System

1000 µm Travel, with PiezoWalk® Drive, Controller & Software



The microscopy package: Objective nanofocusing system with 1 mm travel range and adapters for M25 threads. The controller comes with an extensive software package e. g. for automation and also supports manual control via joystick

- **High Force and Long Travel Range: 10 N / 1 mm**
- **Dynamic Fine Positioning, Typical Step and Settle: 20 ms**
- **Drive Resolution < 1 nm, Linear Encoder Resolution 20 nm**
- **Self Locking at Rest, no Heat Generation, No Servojitter**
- **Compact Design: Ø 48 mm, 40.5 mm Height**
- **Frictionless, High-Precision Flexure Guiding System for Better Focus Stability**
- **Complete System with Controller**
- **Non-Volatile Macro Storage for Stand-Alone Functionality with Autostart Macro**
- **I/O for Automation, Joystick for Manual Operation**

The NEXACT® objective scanner provides significantly more travel range than other piezo-driven objective positioners due to its unique PiezoWalk® linear motor drive. This drive combines high stiffness, quick step-and-settle, large travel ranges and extreme position stability.

Application Examples

- Two-photon microscopy
- Confocal microscopy
- 3-D Imaging
- Screening
- Autofocus systems
- Surface analysis
- Wafer inspection

The long travel range of 1 mm is the main reason why the objective scanner offers decisive advantages for applications with large optical penetration depth such as two-photon microscopy. The focusing plane can be selected as desired over the total working range of the objective without any changes to the mechanical system. In conjunction with a step-and-settle time of less than 20 ms this increases the through-put and allows rapid Z-stack acquisition.

Simple Installation with Quick-Lock Thread Options

The PIFOC® is mounted between the turret and the objective with the QuickLock thread adapter. After threading the

adapter into the turret, the QuickLock is affixed in the desired position. Because the PIFOC® body need not to be rotated, cable wind-up is not an issue.

Controller for Manual Control and Automated Scans

The system comes with a proprietary closed-loop controller for NEXACT® piezomotor linear drives. A joystick can be connected as a manual control. Its non-volatile memory supports macro programming, e.g. to speed up automation tasks. A user-programmable „Auto-start“ macro allows for stand-alone-functionality without the need for external communication. The system includes an extensive software package to facilitate integration into com-

Ordering Information

ND72Z9LAQ

PIFOC® Piezo Nanofocusing Z-Drive with NEXACT® Linear Motor, 1 mm, Linear Encoder, 20 nm Resolution, M25 QuickLock Thread Adapters, Including Controller

Accessories:

P-721.91Q

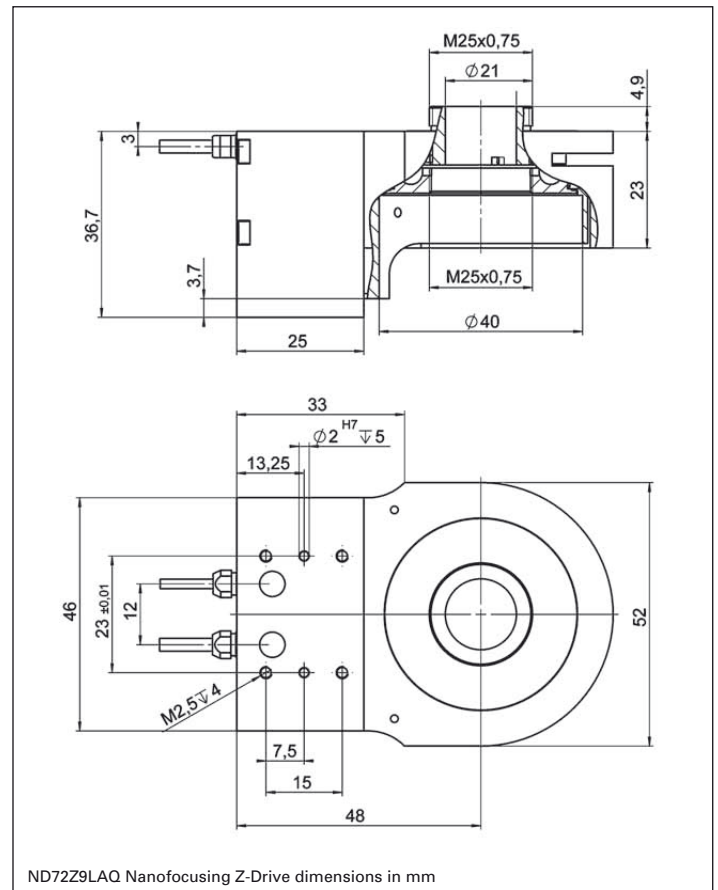
Extens. Tube, 12.5 mm, Thread M25 x 0.75

C-819.20

2-Axis Analog Joystick

plex imaging applications and also allows manual control via a joystick.

In addition, four input and four output lines are provided for easy synchronization of motion with internal or external trigger signals.



Easy System Set-up, Comprehensive Software Package

All parameters can be set and checked via software. For system setup and configuration the versatile PIMikroMove user-interface software is included. Interfacing to custom software is facilitated with LabView drivers and DLLs.

Scanners for Higher Resolution and Larger Loads

PI offers a range of related PIFOC® objective scanners with different specifications. The P-725 models e.g. (s.p. 2-28) offer resolutions of less than one nanometer. For larger loads

and dynamic scanning applications the models P-726 (s.p. 2-32) and P-725.DD (s.p. 2-30) are also available with travel ranges of up to 100 µm.

NEXACT® PiezoWalk® Technology

See page 1-12 for further information.

The products described in this document are in part protected by the following patents:
German Patent No. P4408618.0

Technical Data

| | |
|---------------------------------|---|
| Model | ND72Z9LAQ |
| | Long-travel objective scanning system, incl. controller |
| Active axes | Z |
| Motion and positioning | |
| Travel range | 1 mm |
| Integrated sensor | Linear encoder |
| Sensor resolution | 20 nm |
| Linearity, closed-loop | 0.1 % |
| Bidirectional repeatability | 50 nm |
| Runout (X, Y) typ. | 15 µrad / 100 µm |
| Step and settle (200 nm) typ. | 20 ms |
| Max. velocity | 10 mm/s |
| Mechanical properties | |
| Stiffness in motion direction | 0.5 N/µm |
| Max. push / pull force (active) | 10 N |
| Drive resolution | < 1 nm |
| Drive properties | |
| Drive type | NEXACT® linear drive |
| Controllers | |
| Communication interfaces | USB 1.0, RS-232 (9-pin (m) sub-D) |
| I/O ports | 4 analog/digital in, 4 digital out (TTL) |
| User software | PIMikroMove®, PI Terminal |
| Software drivers | GCS-DLL, LabVIEW Driver |
| Supported functionality | Digital setting of the control parameters on-the-fly; start-up macro; data recorder for recording parameters such as motor input voltage, velocity, position or position error; internal safety circuit: watchdog timer |
| Miscellaneous | |
| Operating temperature range | 0 to 50 °C |
| Material Scanner | Aluminum |
| Weight | 440 g (scanner), 1.1 kg (controller) |
| Cable length to controller | 1.5 m |
| Dimensions controller | 206 x 130 x 66 mm (including mounting rails) |