Ultrasonic Motors for Fast and Precise Positioning

Latest Catalogs: www.pi.ws
Ultrasonic Motor Applications

Nanotechnology, Nanofabrication, NanoAutomation®
- Precision positioning of components (linear and rotation)
- Precision actuation
- Microgrippers
- Manipulators

Semiconductor Technology
- Long-range placement and positioning

Microscopy/Imaging
- Fast sample positioning
- XY-stages
- Long range scanning

Biotechnology, Life Science
- Microdosing
- Dispensing
- Nano/microliter pumps
- Fast positioning
- Bio-handling

Medical Design, Medical Technology
- Screening
- Fast positioning
- Cell penetration, microdosing
- Handling
- Non-magnetic actuators
PI Line® Ultrasonic Piezomotors

PI. Ultrasonic piezomotors are based on a novel, patented ultrasonic drive developed by PI. At the heart of the system is a rectangular monolithic piezoceramic plate (the stator), segmented on one side by two electrodes. Depending on the desired direction of motion, the left or right electrode of the piezoceramic plate is excited to produce high-frequency eigenmode oscillations at tens to hundreds of kilohertz. An alumina friction tip (pusher) attached to the plate moves along an inclined linear path at the eigenmode frequency. Through its contact with the friction bar, it provides microimpulses that drive the moving part of the mechanics (slider, turntable, etc.) forward or backwards. With each oscillatory cycle, the mechanics executes a step of a few nanometers; the macroscopic result is smooth motion with a virtually unlimited travel range. The driving force is taken from the energy in the longitudinal oscillation component. The transverse component serves to increase/decrease the pressure of the friction tip against the friction bar. The transverse oscillation energy determines the maximum frictional force and hence the holding and driving force of the motor. State-of-the-art ultrasonic motors can produce accelerations to 10 g and velocities to 500 mm/s.

Ultrasonic motors cannot provide the unlimited resolution of linear piezo actuators and flexure-guided piezo positioning stages. These motors transfer motion through friction, which is why their repeatability is limited to about 50 nm. Much higher resolution and holding forces can be achieved with PiezoWalk® piezomotors/drv.

PI Line® Levels of Integration

PI Line® ultrasonic drive products are offered in three different levels of integration. The drive electronics and controller can be chosen accordingly.

- P-661 and P-664 OEM motors require the greatest amount of care at the customer’s site. Motor and friction bar – the length depends on the travel range – have to be integrated into a mechanical setup. Operation requires preload of the motor against the friction bar, guiding and, if necessary, the servo-loop.
- RodDrives can replace classical drive elements like rotary motor/leadscrew assemblies, or magnetic linear drives integrated into a micropositioner or handling device. Integration requires guiding and – if necessary – the servo-loop.
- Linear positioning stages represent the highest level of manufacturer integration. The piezomotor is integrated completely in a high-quality mechanical setup including if necessary the servo-loop with direct-metrology linear encoders.

PI Line® levels of integration: OEM motor, RodDrive, linear positioning stage.
Features and Advantages of PILine® Ultrasonic Piezomotors

- **Compact Size:** the direct-drive principle allows the design of ultra-compact translation stages. The M-662, for example, provides 20 mm travel in a 28 x 28 x 8 mm package.

- **Low inertia, high acceleration, speed and resolution:** PILine® drives achieve velocities to 500 mm/s and accelerations to 10 g. They are also very stiff, a prerequisite for their fast step-and-settle times – on the order of a few milliseconds – and provide resolution to 0.05 µm. The lack of a leadscrew means no lubricant flow or material relaxation to cause submicron creep. There is also no rotational inertia to limit acceleration and deceleration.

- **Excellent Power-to-Weight Ratio:** PILine® drives are optimized for high performance in a minimum package. No comparable drive can offer the same combination of acceleration, speed and precision.

- **Safe:** The minimum inertia of the moving platform together with the “slip clutch” effect of the friction drive provide better protection of precision fixtures/devices than leadscrew-driven stages. Despite the high speeds and accelerations, there is a much lower risk of pinching fingers or other injuries than with conventional drives. This means users may not need interlocks, light curtains or other measures to keep them safe.

- **Self-Locking Feature:** PILine® drives create a braking force when not energized without the position shift common with conventional mechanical brakes. Other benefits of the self-locking are the elimination of servo dither and steady-state heat dissipation.

- **Vacuum Compatibility:** Vacuum compatible versions of PILine® drives are available.

- **Negligible EMI:** PILine® drives do not create magnetic fields nor are they influenced by them, a decisive advantage in many applications.

- **Custom Solutions / Flexibility for OEMs:** PILine® drives are available in open-loop and closed-loop translation stages and as OEM components. PI develops and manufactures all piezo ceramic components in-house. This gives us the flexibility to provide custom motors (size, force, environmental conditions) for OEM and research applications.

- **Quality, Lifetime, Experience:** Based on PI’s 30+ years of experience with piezo nano-positioning technology, PILine® drives offer exceptional precision and reliability with an MTBF of >20,000 hours. Rotating components such as gears, shafts and moving cables that are prone to failure in conventional motion systems, are not part of the PILine® design.
Fast and Self-Locking with PILine® Piezomotors

Self-locking Instead of Quiescent Current

PILine® piezo motors are based on a new, patented, ultrasonic drive principle developed by PI. The core piece of the system is a piezoceramic plate, which is excited with high-frequency eigenmode oscillations. A friction tip attached to the plate moves along an inclined linear path at the eigenmode frequency. Through its contact with the friction bar, the moving part of the mechanics drives forward or backwards. With each oscillatory cycle, the mechanics executes a step of a few nanometers; the macroscopic result is smooth motion with a virtually unlimited travel range.

The ceramic plate is preloaded against the runner and thus generates the holding force when the drive is at rest.

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

Ordering Information

M-272
PILine® Linear Actuator with Ultrasonic Motor and Linear Encoder, 50 mm, 8 N

Application Examples

- Automation
- Handling
- Micromanipulation
- Metrology

PILine® piezoceramic ultrasonic drives offer an affordable alternative to motor-leadscrew combinations and electromagnetic linear motors when small dimensions and/or high speed are important. With velocities of up to 200 mm/s, these drives are fast, compact, and are readily integrated. In addition, PILine® motors are self-locking when at rest with zero heat generation, and doing away with the need for an additional motor brake.

The novel M-272 closed-loop linear drive combines motor, actuator, linear encoder, guiding system and brake functionality in a very compact package. Due to the integrated guiding system a payload can be easily attached to the drive rod of the M-272 drive. The drive can also function as a drop-in-replacement for motor- leadscrew drives facilitating assembly and reducing the number of components significantly. Due to the integrated linear encoder, positioning can be done precisely and repeatably.
Watch Video at http://www.youtube.com/watch?v=w9FOJemtvQ

Cost-effective combination: M-272 closed-loop linear pusher and C-867.OE controller card

<table>
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<tr>
<th>Technical Data (Preliminary Data)</th>
<th>Latest Specs: <a href="http://www.pi.ws">www.pi.ws</a></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Model</strong> M-272</td>
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<tr>
<td><strong>Active axes</strong> X</td>
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<tr>
<td><strong>Motion and positioning</strong></td>
<td></td>
</tr>
<tr>
<td>Travel range 50 mm</td>
<td></td>
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<tr>
<td>Integrated sensor Linearencoder</td>
<td></td>
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<tr>
<td>Sensor resolution 5 µm</td>
<td></td>
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<tr>
<td>Design resolution 5 µm typ.</td>
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<tr>
<td>Min. incremental motion 10 µm typ.</td>
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<td>Backlash 5 µm typ.</td>
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<tr>
<td>Unidirectional repeatability 10 µm typ.</td>
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<tr>
<td>Velocity 200 mm/s max.</td>
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<tr>
<td><strong>Mechanical properties</strong></td>
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<tr>
<td>Guiding Ball bearings</td>
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<tr>
<td>Push/pull force 8 N max.</td>
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<tr>
<td>Holding force 8 N max.</td>
<td></td>
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<tr>
<td>Lateral force 5 N max.</td>
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<tr>
<td><strong>Drive properties</strong></td>
<td></td>
</tr>
<tr>
<td>Motor type U-164 PiLine® ultrasonic piezomotor</td>
<td></td>
</tr>
<tr>
<td>Current 800 mA</td>
<td></td>
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<tr>
<td>Reference switch Hall-effect</td>
<td></td>
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<tr>
<td><strong>Miscellaneous</strong></td>
<td></td>
</tr>
<tr>
<td>Operating temperature range -20 to +50 °C</td>
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<tr>
<td>Material Aluminum</td>
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<tr>
<td><strong>Dimensions</strong></td>
<td></td>
</tr>
<tr>
<td>Mass 0.5 kg ± 5%</td>
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<tr>
<td>Cable length 0.5 m ± 10 mm</td>
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</tr>
<tr>
<td>Connector MDR, 14-pin</td>
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</tbody>
</table>

Recommended controller/driver: C-867.OE

* Power for the motor is supplied by the drive electronics, which requires 12 VDC.

** For drive electronics
Ultrasonic Motor OEM Controller

Affordable OEM Piezo Motor Controller with CAN Interface

Typical for ultrasonic piezomotors, the controller has a number of advanced features, including dynamic control parameter adaption. By automatically switching between gainsets for dynamic and static operation an optimized settling behavior within a couple of 10 milliseconds is achieved. The broadband encoder input (50 MHz) allows high-resolution encoders to be used with the outstandingly high accelerations and velocities that PILine® drives deliver.

The C-867 OEM card is a cost-effective motion controller for closed-loop positioning systems equipped with PILine® ultrasonic piezo motors. The controller card integrates both the servo controller / communication hardware and the driver electronics for the ultrasonic piezo motors. For seamless integration in industrial automation environments, the controller can be operated via RS-232 and CAN interfaces. In addition, an analog (joystick) interface and non-volatile macro command memory make stand-alone operation possible.

Application Examples

- Biotechnology
- Microscopy
- Fiber positioning
- Automation
- Photonics / integrated optics
- Quality assurance testing
- Testing equipment

Ordering Information

C-867.OE
OEM Driver / Controller Card for PILine® Ultrasonic Motors, 1 Channel

Ask about custom designs!

The C-867 is based on a highly specialized DSP (Digital Signal Processor) that handles the PID servo-control algorithm as well as other system functions. Because of the motion properties

Software / Programming

In addition to the user software for setup, system optimization and operation, comprehensive LabVIEW and DLL libraries are provided. The PIMikroMove user software provides the Pi Tuning Tool for optimizing system performance. Graphic displays show the system’s behaviour and facilitate parameter setting.

Highest Stability and Reliability with Automatic Frequency Control

The integrated piezomotor drive electronics supports all types of PILine® ultrasonic piezomotors currently available. Variations in the resonant frequency of the motor caused by temperature or load changes are automatically compensated for by a frequency-control loop which adjusts the operating frequency of the driving voltage. This leads to higher stability of the motor output force and velocity and to higher position accuracy.

In addition to the user software for setup, system optimization and operation, comprehensive LabVIEW and DLL libraries are provided. The PIMikroMove user software provides the Pi Tuning Tool for optimizing system performance. Graphic displays show the system’s behaviour and facilitate parameter setting.

Controller C-867.OE for piezo linear drives
**Technical Data**

<table>
<thead>
<tr>
<th><strong>Model</strong></th>
<th>C-867.OE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Function</strong></td>
<td>Controller and drive electronics for PILine® piezomotors/systems</td>
</tr>
<tr>
<td><strong>Drive type</strong></td>
<td>PILine® motors, single and dual drives with P-661, P-664, U-161, U-164 and U-264</td>
</tr>
<tr>
<td><strong>Channels</strong></td>
<td>1</td>
</tr>
</tbody>
</table>

**Motion and control**

| **Servo characteristics** | Programmable PID V-ff filter, parameter changes on-the-fly |
| **Trajectory profile modes** | Trapezoidal |
| **Encoder input** | A/B differential signals, 50 MHz |
| **Stall detection** | Servo off, triggered by programmable position error |
| **Limit switches** | 2 TTL (programmable) |
| **Reference switches** | 1 TTL (active high/low, programmable) |

**Electrical properties**

| **Max. output power** | 15 W |
| **Max. output voltage** | 200 $V_{pp}$ |

**Interfaces and operation**

| **Communication interfaces** | RS-232, CAN, input/output 32-pin (male) on rear panel (DIN 41612/D) |
| **Motor connector** | MDR14 |
| **Command set** | PI General Command Set (GCS) |
| **User software** | PiMikroMove |
| **Software drivers** | GCS-DLL, LabVIEW drivers |

**Supported functionality**

| **Start-up macro, macro, data recorder for recording parameters as motor input voltage, velocity, position or position error** |

**Miscellaneous**

| **Operating voltage** | 24 VDC from external power supply (not included) |
| **Current** | 150 mA + motor current (2 A max.) |
| **Operating temperature range** | +5 °C to +40 °C |
| **Mass** | 420 g |
| **Dimensions** | 175 x 100 x 38 mm (connectors included) |
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 34 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.

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

Unlimited Travel Range
Max. Velocity 720 °/s
Low Profile: Only 14 mm in Height
Self-Locking Ceramic Direct Drive: Energy Saving & High Position Stability
Direct Metrology Linear Encoder, 34 µrad Resolution
PILine® Direct Drive: Non-Magnetic and Vacuum-Compatible Working Principle
Compact Combinations with Linear Stages

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.

Optionally, the C-185 analog drive electronics (stand-alone unit) (s. p. 1-36) is available for use with third party servo controllers. It accepts an analog ±10 V signal to control the motor velocity. For optimum performance, the driver must be tuned together with the mechanics and should be ordered at the same time as the motor / stage.

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

Ordering Information

M-660.55
PILine® Rotation Stage, Ø 108 mm, 360°, 34 µrad Resolution
Ask about custom designs!

Applicaton Examples

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

www.ultrasonic-motor.com

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www.pi.ws
Technical Data

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<tr>
<th>Model</th>
<th>M-660.55</th>
<th>Units</th>
<th>Tolerance</th>
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<tbody>
<tr>
<td>Active axes</td>
<td>Theta Z</td>
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</table>

**Motion and positioning**

- **Rotation range**: No limit °
- **Integrated sensor**: Incremental encoder
- **Design resolution**: 34 µrad typ.
- **Min. incremental motion**: 34 µrad typ.
- **Bidirectional repeatability**: 34 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
- **Electrical power**: 0.2 W nominal
- **Current consumption**: 0.3 (2 max.) A
- **Reference switch**: optical

**Miscellaneous**

- **Operating temperature range**: -20 to +50 °C
- **Material**: Al (black anodized)
- **Mass**: 0.4 kg ±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

Latest Specs: www.pi.ws

Watch Video at http://www.youtube.com/watch?v=loAhRLFFPNk&NR=1
**PILine® Linear Motors – Small, Fast, Highly Effective**

Despite their small size, PILine® linear motors generate high driving and holding forces. Because the ceramic stator is pressed against the slider, holding forces are generated when the motor is powered down. The result is very high position stability without the heat dissipation common in conventional linear motors.

**Accessories for Easy Integration**

PILine® piezomotors require a special drive electronics to generate the ultrasonic oscillations for the piezoceramic element. The drive electronics is available as OEM board, stand-alone device or integrated controller and therefore not included in the delivery. PI offers friction bars with different lengths.

**Long Lifetime**

PI has over 30 years experience with piezo technology and nanopositioning. PILine® drives offer high precision and reliability, with over 20,000 hours MTBF. This is because PILine® piezo linear motor drives have no mechanical components such as shafts and gears which can cause failures in conventional motors.

**Application Examples**

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

**Ordering Information**

P-661.P01
PILine® Miniature Linear Piezomotor, 2 N

**Accessories:**

P-661.B01
Friction Bar for P-661 PILine® Miniature Linear Piezomotor, 15 mm

P-661.B02
Friction Bar for P-661 PILine® Miniature Linear Piezomotor, 25 mm

P-661.B05
Friction Bar for P-661 PILine® Miniature Linear Piezomotor, 55 mm

C-184.161
Analog OEM Driver Board for PILine® P-661 Motors

C-185.161
Analog Stand-Alone Drive Electronics with Power Supply for PILine® P-661 Motors

Controller for closed-loop operation are available as C-867 s. p. 4-116.
Model: P-661.P01

<table>
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<tr>
<th>Motion and positioning</th>
<th>Units</th>
<th>Tolerance</th>
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<tbody>
<tr>
<td>Travel range</td>
<td>No limit*</td>
<td>mm</td>
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<tr>
<td>Minimum incremental motion, open-loop</td>
<td>0.05**</td>
<td>µm</td>
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<td>Max. velocity</td>
<td>500</td>
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<th>Mechanical properties</th>
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<td>Stiffness when powered down</td>
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<td>Holding force when powered down</td>
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<td>Preload on friction bar</td>
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<td>Resonant frequency</td>
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<td>Motor voltage range</td>
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<td>Operating voltage drive electronics</td>
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<td>Electrical power drive electronics</td>
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<th>Miscellaneous</th>
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<td>Body material</td>
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<tr>
<td>Mass</td>
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<tr>
<td>Cable length</td>
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<tr>
<td>Connector</td>
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<td>Recommended controller/driver</td>
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<tr>
<td>Dimensions</td>
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<tr>
<td>MTBF</td>
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</table>

* The travel range of piezo linear motors is virtually unlimited and depends on the length of the friction bar, which is available separately.
** The minimum incremental motion is a typical value that can be achieved in the open-loop mode of a piezomotor stage. To reach the specs it is important to follow the mounting guidelines of the OEM-motors.

Note
The products described in this document are in part protected by the following patents:
US Pat. No. 6,765,335
German Patent No. 10154526
PILine® Linear Motors—Small, Fast, Highly Effective

Despite their small size, PILine® linear motors generate high driving and holding forces. PILine® piezo motors have a new, patented, ultrasonic drive developed by PI. The core piece of the system is a piezoceramic plate, which is excited with high-frequency eigenmode oscillations. A friction tip attached to the plate moves along an inclined linear path at the eigenmode frequency. Through its contact with the friction bar, the moving part of the mechanics drives forward or backwards. With each oscillatory cycle, the mechanics executes a step of a few nanometers; the macroscopic result is smooth motion with a virtually unlimited travel range.

Long Lifetime
PI has over 30 years experience with piezo technology and nanopositioning. PILine® drives offer high precision and reliability. This is because PILine® piezo linear motor drives have no mechanical components such as shafts and gears which can cause failures in conventional motors.

Accessories for Easy Integration
The PILine® motors require a special drive electronics to generate the ultrasonic oscillations for the piezoceramic element. The drive electronics is available as OEM board, stand-alone device or integrated inside a controller and therefore not included in the delivery. PI offers friction bars with different lengths.

Long Lifetime
PI has over 30 years experience with piezo technology and nanopositioning. PILine® drives offer high precision and reliability. This is because PILine® piezo linear motor drives have no mechanical components such as shafts and gears which can cause failures in conventional motors.

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

High Speed and Acceleration
PILine® piezomotor drives can provide accelerations of up to 5 g and speeds of up to 500 mm/s, together with high resolution and high holding force. Because the ceramic stator is pressed against the slider, holding forces are generated when the motor is powered down. The result is very high position stability without the heat dissipation common in conventional linear motors.

Ordering Information
U-164.01
PILine® Piezo Linear Motor, 4 N
Accessories:
P-664.B01
Friction Bar for PILine® Miniature Linear Piezomotor, 15 mm
P-664.B02
Friction Bar for PILine® Miniature Linear Piezomotor, 25 mm
P-664.B05
Friction Bar for PILine® Miniature Linear Piezomotor, 55 mm
C-184.164
Analog OEM Driver Board for PILine® Motors
C-185.164
Analog Stand-Alone Drive Electronics with Power Supply for PILine® Motors

Controllers for closed-loop operation are available as C-867 (see p. 4-116).

Ask about custom designs!

Patent Information
The products described in this document are in part protected by the following patents:
US Pat. No. 6,765,335
German Patent No. 10154526
M-674K Ultrasonic Z Drive
Ceramic PILine® Motor and Linear Encoder for High Speed & Precision

- High Speed to 100 mm/sec
- High Push/Pull Force to 7 N
- Extremely Slim Design, Matched with Standard Multiwell Plates
- Stackable
- Integrated Linear Encoder for Highest Accuracy
- Self Locking at Rest
- Non-Magnetic and Vacuum-Compatible Working Principle

<table>
<thead>
<tr>
<th>Model</th>
<th>Travel</th>
<th>Push/pull force</th>
<th>Velocity</th>
<th>Resolution</th>
<th>Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>M-674KCPP</td>
<td>50 mm</td>
<td>7 N</td>
<td>100 mm/s</td>
<td>0.1 µm</td>
<td>120 x 40 x 9 mm</td>
</tr>
</tbody>
</table>

Equipped with two ultrasonic piezo-motors, the slim M-674KCPP offers up to 7 N push and pull force. The 9 mm width is matched to standard multiwell plate sizes, ideally suited to automation tasks in biotechnology.

M-664K Ultrasonic Z Array
High-Speed, Compact, Cost-Effective, Stackable PILine® Actuator

- High Speed to 100 mm/sec
- Slim Design, Matched with Standard Multiwell Plates
- Travel range 50 mm
- Cost-Effective Design
- Stackable
- Non-Magnetic and Vacuum-Compatible Working Principle
- Self Locking at Rest

<table>
<thead>
<tr>
<th>Model</th>
<th>Travel</th>
<th>Push/pull force</th>
<th>Max. closed-loop velocity</th>
<th>Resolution</th>
<th>Dimensions</th>
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<tbody>
<tr>
<td>M-664KCEP</td>
<td>50 mm</td>
<td>5 N</td>
<td>100 mm/s</td>
<td>0.5 µm</td>
<td>120 x 40 x 9 mm</td>
</tr>
</tbody>
</table>

Stack of 8 M-664KCEP linear actuators, shown with well plate. The integrated ceramic piezomotor provides high speeds to 100 mm/sec. The low-profile design with only 9 mm width allows stacking for multi-channel dispensing in bio-automation tasks.

M-682K Non-Magnetic Ultrasonic Motor Stage
Low-Profile, High-Speed with Piezo Ceramic Motor

- Integrated Non-Magnetic PILine® RodDrive
- Travel Range 50 mm
- Integrated Linear Encoders with 0.1 µm Resolution
- Up to 6 N Force Generation
- Closed-Loop Velocity up to 100 mm/s
- Low Profile, Small Footprint

<table>
<thead>
<tr>
<th>Model</th>
<th>Travel</th>
<th>Load capacity</th>
<th>Max. push/pull force</th>
<th>Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>M-682KNMS</td>
<td>50 mm</td>
<td>50 N</td>
<td>6 N</td>
<td>110 x 110 x 20 mm</td>
</tr>
</tbody>
</table>

Custom non-magnetic M-682KNMS linear stage with integrated RodDrive linear motor.
Ultrasonic Motor Pusher

Integrated Fast Ultrasonic Piezo Drives

PLine® RodDrives represent a level of integration between PLine® OEM piezo linear motors such as P-664 (see p. 1-28) and guided micropositioning systems such as the M-682 (see p. 4-32) series stages. RodDrives may replace classical drive elements like rotary motor/leadscrew assemblies, or magnetic linear drives integrated into a micropositioner.

Advantages of PLine® Micropositioning Systems

- They consist of a rod which is preloaded by piezo linear motors from two sides. Depending on the way of integration, either the rod or the motor block is coupled to the moving platform.
- They offer higher accelerations, up to 5 g.
- They provide speeds up to 500 mm/s.
- They have a small form factor.
- Self-locking when powered down.
- No shafts, gears or other rotating parts.
- Non-magnetic and vacuum compatible drive principle.

Variety of Drivers / Controllers

PLine® piezomotors require a drive electronics for exciting the ultrasonic oscillations. The drive electronics is available as OEM board, stand-alone device or integrated inside a closed-loop motion controller and therefore not included in the delivery.

Closed-Loop Operation: Optimized for High Velocity and Rapid Step/Settling

Together with a position sensor, RodDrives can be operated in closed-loop with the C-867.D64 (see p. 4-116) piezo motor controller. This specialized servo-controller also integrates the motor drive electronics and enables highly constant speeds up to 350 mm/s with very short settling times (tens of milliseconds). RodDrives can also be operated with conventional servo-controllers. In this case, the C-185 (see p. 1-36) (to be ordered separately) external drive electronics is required which accepts a ±10 V analog signal from the controller.

Note

The products described in this document are in part protected by the following patents:

US-Pat. No. 6,765,335
German Patent No. 10154526

Application Examples

- System integration for micropositioning products
- Automation
- Handling
- Micromanipulation
- Biotechnology
- Metrology

Latest Specs: www.pi.ws
M-661 and M-662 PILine® translation stages offer accelerations to 5 g with millisecond response and velocities to 500 mm/sec in an extremely compact package. Providing travel ranges to 20 mm, they are among the smallest motorized translation stages currently on the market. Both models are designed for open-loop operation (a similar closed-loop stage with linear encoder is available as model M-663). The M-662, with its square footprint, is also suitable for use in XY configurations. For applications where the smallest dimensions are essential, the P-652 micro stage is offered.

Working Principle
PILine® piezo motors use a new, patented, ultrasonic drive developed by PI. A the heart of the system is a piezo ceramic plate, which is excited with high-frequency eigenmode oscillations. A friction tip attached to the plate moves along an inclined linear path at the eigenmode frequency. Through its contact with the friction bar, the moving part of the mechanics drives forward or backwards. With each oscillatory cycle, the mechanics execute a step of a few nanometers; the macroscopic result is smooth motion with a virtually unlimited travel range.

Advantages of PILine® Micropositioning Systems
The ultrasonic piezoceramic drives used in PILine® micropositioners have a number of advantages over classical drives:
- Higher Accelerations, up to 5 g
- Speeds up to 500 mm/s
- Small Form Factor
- Self-Locking When Powered Down
- No Shafts, Gears or Other Rotating Parts
- Non-Magnetic and Vacuum-Compatible Drive Principle

Choice of Drive Electronics
Special driver electronics are required to create the ultrasonic oscillations for PILine® piezo-motors. The driver controls the motor speed as a function of an analog ±10 V signal. The driver is not included, as it is available in different versions, from the low-priced C-184.161 OEM-board to the C-185.161 bench-top unit. The stage and the driver electronics, however, must be ordered together, so that they can be tuned to one-another for optimum performance.

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

<table>
<thead>
<tr>
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<th>M-661.370</th>
<th>M-662.470</th>
<th>Units</th>
<th>Tolerance</th>
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<tr>
<td><strong>Motion and positioning</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Travel range</td>
<td>18</td>
<td>20</td>
<td>mm</td>
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</tr>
<tr>
<td>Min. incremental motion</td>
<td>0.05*</td>
<td>0.05*</td>
<td>µm</td>
<td>typ.</td>
</tr>
<tr>
<td>Max. velocity</td>
<td>500</td>
<td>500</td>
<td>mm/s</td>
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<td><strong>Mechanical properties</strong></td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Max. load</td>
<td>5</td>
<td>5</td>
<td>N</td>
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<td>Max. push/pull force</td>
<td>1</td>
<td>1</td>
<td>N</td>
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<td>Max. holding force</td>
<td>2</td>
<td>2</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td><strong>Drive properties</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motor type</td>
<td>P-661 PILine® ultrasonic piezomotor drive</td>
<td>P-661 PILine® ultrasonic piezomotor drive</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operating voltage</td>
<td>120 (Peak-Peak)** 42 (RMS)**</td>
<td>120 (Peak-Peak)** 42 (RMS)**</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Electrical power</td>
<td>5***</td>
<td>5***</td>
<td>W</td>
<td>nominal</td>
</tr>
<tr>
<td>Current</td>
<td>400***</td>
<td>400***</td>
<td>mA</td>
<td></td>
</tr>
<tr>
<td><strong>Miscellaneous</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
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<td>Operating temperature range</td>
<td>-20 to +50</td>
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<td>°C</td>
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<td>Al (black anodized)</td>
<td>Al (black anodized)</td>
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<tr>
<td>Dimensions</td>
<td>30 x 23 x 10</td>
<td>28 x 28 x 8</td>
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<td>Mass</td>
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<td>kg</td>
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<td>Cable length</td>
<td>1.5</td>
<td>1.5</td>
<td>m</td>
<td>±10 mm</td>
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<tr>
<td>Connector</td>
<td>LEMO connector</td>
<td>LEMO connector</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recommended controller/driver</td>
<td>C-184.161 OEM board</td>
<td>C-184.161 OEM board</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>C-185.161 Bench-top</td>
<td>C-185.161 Bench-top (p. 1-36)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*The minimum incremental motion is a typical value that can be achieved in the open-loop mode of a piezomotor stage.

**To obtain it, it is important to follow the mounting guidelines in the motor documentation.

***The stage supply power is drawn from the drive electronics, which runs on 12 VDC.

***For drive electronics.
Ultrasonic Motor Closed Loop Linear Piezo Motor Stage

Compact, Fast, with Ultrasonic Piezo Linear Drives, Direct Position Measurement

With each oscillatory cycle, the mechanics executes a step of a few nanometers; the macroscopic result is smooth motion with a virtually unlimited travel range.

Advantages of PILine® Micropositioning Systems

The ultrasonic piezoceramic drives used in PILine® micropositioners have a number of advantages over classical drives:

- Higher Accelerations, up to 5 g
- Speeds up to 500 mm/s
- Small Form Factor
- Self-Locking When Powered Down
- No Shafts, Gears or Other Rotating Parts
- Non-Magnetic and Vacuum-Compatible Drive Principle

Optimized Controller and Drive Electronics

PILine® motors require a special drive electronics to generate the ultrasonic oscillations for piezoceramic element. For optimum performance the highly specialized C-867 (see p. 4-116) motion controller is recommended. This sophisticated controller also integrates the drive electronics. Furthermore, the controller has a number of special features, including dynamic parameter switching for an optimized high-speed motion and settling behavior to take into account the motion characteristics typical of piezomotors. The broad-band encoder input (50 MHz) supports the outstanding high accelerations and velocities of PILine® drives at high resolutions.

Optionally, for use with third party servo controllers, the C-185 analog drive electronics (stand-alone unit) is available. It controls the motor speed by an analog ±10 V signal. For optimum performance the driver must be tuned together with the mechanics and should be ordered at the same time as the motor/stage.

Note

The products described in this document are in part protected by the following patents:

US Pat. No. 6,765,335
German Patent No. 10154526

Application Examples

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

Ordering Information

M-663.465
PILine® Translation Stage, 19 mm, Linear Encoder, 0.1 µm Resolution

M-663.165
PILine® Translation Stage, 19 mm, Linear Encoder, 0.1 µm Resolution, turned cable outlet, XY mountable

M-663.16V
PILine® Translation Stage, 19 mm, Linear Encoder, 0.1 µm Resolution, Vacuum Compatible to 10-6 hPa

Accessories:

C-867.161
Piezomotor Controller with Drive Electronics, 1 Channel, for PILine® Systems with P-661 Motors

Driver for use with separate controller:

C-185.161
Analog Stand-Alone Drive Electronics with Power Supply for PILine® P-661 Motors

Ordering Information

M-663.465
PILine® Translation Stage, 19 mm, Linear Encoder, 0.1 µm Resolution

M-663.165
PILine® Translation Stage, 19 mm, Linear Encoder, 0.1 µm Resolution, turned cable outlet, XY mountable

M-663.16V
PILine® Translation Stage, 19 mm, Linear Encoder, 0.1 µm Resolution, Vacuum Compatible to 10-6 hPa

Accessories:

C-867.161
Piezomotor Controller with Drive Electronics, 1 Channel, for PILine® Systems with P-661 Motors

Driver for use with separate controller:

C-185.161
Analog Stand-Alone Drive Electronics with Power Supply for PILine® P-661 Motors

PILine® M-663 micropositioning systems offer high velocities of up to 400 mm/s and travel ranges of 19 mm in a compact package. The M-663 is the smallest closed-loop translation stage with piezomotor drives currently on the market. Its square footprint makes it suitable for use in compact XY configurations.

Working Principle

PILine® motors have a new, patented, ultrasonic drive developed by PI. The core piece of the system is a piezoceramic plate, which is excited to produce high-frequency eigenmode oscillations. A friction tip attached to the plate moves along an inclined linear path at the eigenmode frequency. Through its contact with the friction bar, the moving part of the mechanics drives forward or backwards.
Technical Data

<table>
<thead>
<tr>
<th>Model</th>
<th>M-663.465</th>
<th>Units</th>
<th>Tolerance</th>
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</thead>
<tbody>
<tr>
<td>Active axes</td>
<td>X</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Motion and positioning**
- Travel range: 19 mm
- Integrated sensor: Linear encoder
- Sensor resolution: 0.1 µm
- Min. incremental motion: 0.1 µm typ.
- Bidirectional repeatability: ±0.3 µm typ.
- Unidirectional repeatability: 0.2 µm typ.
- Pitch: 300 µrad typ.
- Yaw: 300 µrad typ.
- Max. velocity: 400 mm/s
- Reference switch repeatability: 1 µm typ.

**Mechanical properties**
- Max. load: 5 N
- Max. push/pull force: 2 N
- Max. holding force: 2 N

**Drive properties**
- Motor type: P-661 PiLine® ultrasonic piezomotor
- Motor voltage range: 120 (peak-peak)* 42 (RMS)* V
- Electrical power: 5** W nominal
- Current: 400** mA
- Reference switch: Hall-effect

**Miscellaneous**
- Operating temperature range: -20 to +50 °C
- Material: Al (black anodized)
- Dimensions: 35 x 35 x 15 mm
- Mass: 40 g ±5%
- Cable length: 1.5 m ±10 mm
- Connector: MDR, 14-pin

Recommended controller/driver:
- C-867.161 Single-axis controller/driver (p. 4-116)
- C-185.161 Drive electronics (p. 1-36)

---

*A Power is supplied by the drive electronics which runs on 12 V DC

**For drive electronics

Latest Specs: www.pi.ws

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PIEZO NANO POSITIONING | WWW.PI.WS
Ultrasonic Motor Linear Piezo Stage
Low-Profile High-Speed with Ultrasonic Piezo Linear Drives & Direct Position Measurement

M-664 micropositioning systems are low-profile, high-accuracy translation stages with linear encoders. The M-664 stage is next-larger in the series of piezomotor-driven stages of which the M-663 (see p. 4-28) is the smallest. For improved guiding accuracy, the M-664 uses two crossed roller bearings mounted on ground aluminum profiles. The integrated P-664 PILine® linear motor can generate forces up to 4 N and maximum closed-loop velocities to 400 mm/s over a 25 mm travel range.

Advantages of PILine® Micropositioning Systems

The ultrasonic piezoceramic drives used in PILine® micropositioners have a number of advantages over classical drives:

- Higher Accelerations, up to 5 g
- Speeds up to 500 mm/s
- Small Form Factor
- Self-Locking When Powered Down
- No Shafts, Gears or Other Rotating Parts

M-664 dimensions in mm

Application Examples

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

Ordering Information

M-664.164
PILine® Micro Positioning Stage with P-664 Piezo Linear Motor, 25 mm, 4 N
Ask about custom designs!

Optionally, for use with third party servo controllers, the C-185 analog drive electronics (stand-alone unit, see p. 1-36) is available. It controls the motor speed by an analog ±10 V signal. For optimum performance this driver must be tuned together with the stage and should be ordered at the same time as the motor/stage.

Notes

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

<table>
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<td>Active axes</td>
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### Motion and positioning

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<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel range</td>
<td>25 mm</td>
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<tr>
<td>Integrated sensor</td>
<td>Linear encoder</td>
</tr>
<tr>
<td>Sensor resolution</td>
<td>0.1 µm</td>
</tr>
<tr>
<td>Min. incremental motion</td>
<td>0.3 µm typ.</td>
</tr>
<tr>
<td>Bidirectional repeatability</td>
<td>0.2 µm typ.</td>
</tr>
<tr>
<td>Unidirectional repeatability</td>
<td>0.2 µm typ.</td>
</tr>
<tr>
<td>Pitch</td>
<td>±50 µrad typ.</td>
</tr>
<tr>
<td>Yaw</td>
<td>±50 µrad typ.</td>
</tr>
<tr>
<td>Max. velocity</td>
<td>400 mm/s</td>
</tr>
<tr>
<td>Reference switch repeatability</td>
<td>1 µm typ.</td>
</tr>
</tbody>
</table>

### Mechanical properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. load</td>
<td>25 N</td>
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<tr>
<td>Max. push/pull force</td>
<td>4 N</td>
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<tr>
<td>Max. holding force</td>
<td>3 N</td>
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### Drive properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor type</td>
<td>P-664 PiLine® ultrasonic piezo drive</td>
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<tr>
<td>Operating voltage</td>
<td>168 V (peak-to-peak) * 60 V (RMS) *</td>
</tr>
<tr>
<td>Electrical power</td>
<td>10 W ** nominal</td>
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<tr>
<td>Current</td>
<td>800 mA **</td>
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<tr>
<td>Limit and reference switches</td>
<td>Hall-effect</td>
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### Miscellaneous

<table>
<thead>
<tr>
<th>Property</th>
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<tbody>
<tr>
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<td>Material</td>
<td>Al (black anodized)</td>
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<td>Dimensions</td>
<td>90 x 60 x 15 mm</td>
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<td>Mass</td>
<td>0.190 kg ±5 %</td>
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<td>Cable length</td>
<td>1.5 m ±10 mm</td>
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<tr>
<td>Connector</td>
<td>MDR, 14-pin</td>
</tr>
<tr>
<td>Recommended controller/driver</td>
<td>C-867.164 single-axis controller/driver C-185.164 drive electronics</td>
</tr>
</tbody>
</table>

---

*The stage supply power is drawn from the drive electronics, which runs on 12 V.

**For drive electronics
M-683 precision micropositioning stages make use of PILine® ultrasonic piezo linear motors enabling a compact design and low profile. An integrated linear encoder enables closed-loop control with 0.1 µm resolution. The stages can be arranged to form compact XY systems. If an additional Z-axis is required, the M-110 micro-stage series (see page 4-22) is recommended due to its higher holding force. The M-683 design is scalable and can be extended to provide longer travel ranges to 300 mm.

Vacuum-compatible versions are also available on request.

Limit and Reference Switches
For the protection of your equipment, non-contact limit and reference switches are installed. The reference switch supports advanced automation applications with high precision.

Advantages of PILine® Micro Positioning Systems
PILine® ultrasonic ceramic drives provide several advantages over classical motors and drivers:
- Higher Accelerations, up to 5 g
- Speeds up to 500 mm/s
- Small Form Factor
- Self-Locking when Powered Down
- No Shafts, Gears or Other Rotating Parts
- No Lubricants
- Non-Magnetic and Vacuum Compatible Operating Principle

Optimized Controller and Drive Electronics
For optimum performance the highly specialized C-867 motion controller (see page 4-116) is recommended. This dedicated piezo motor controller also integrates the drive electronics which PILine® motors require to generate the ultrasonic oscillations for the piezoceramic element.

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

Optionally, for use with third party servo controllers, the C-185 analog drive electronics (stand-alone unit) (see page 1-36) is available. It accepts an analog ±10 V signal to control the motor velocity. For optimum performance the driver must be tuned together with the mechanics and should be ordered at the same time as the motor/stage.

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

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

Ordering Information
M-683.2U4
PILine® High-Speed Linear Stage, 50 mm, 6 N

Accessories:
M-110.05
Adapter bracket for vertical mount of M-110 stages on M-683 stages
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<th>Model</th>
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**Motion and positioning**

<table>
<thead>
<tr>
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<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Travel range</td>
<td>50 mm</td>
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<tr>
<td>Integrated sensor</td>
<td>Linear encoder</td>
</tr>
<tr>
<td>Sensor resolution</td>
<td>0.1 µm</td>
</tr>
<tr>
<td>Min. incremental motion</td>
<td>0.3 µm typ.</td>
</tr>
<tr>
<td>Bidirectional repeatability</td>
<td>±1 µm typ.</td>
</tr>
<tr>
<td>Unidirectional repeatability</td>
<td>0.2 µm typ.</td>
</tr>
<tr>
<td>Pitch</td>
<td>±150 µrad typ.</td>
</tr>
<tr>
<td>Yaw</td>
<td>±50 µrad typ.</td>
</tr>
<tr>
<td>Max. velocity</td>
<td>350 mm/s</td>
</tr>
<tr>
<td>Reference switch repeatability</td>
<td>1 µm typ.</td>
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</table>

**Mechanical properties**

<table>
<thead>
<tr>
<th>Parameter</th>
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<tbody>
<tr>
<td>Max. load capacity</td>
<td>50 N</td>
</tr>
<tr>
<td>Max. push / pull force</td>
<td>6 N</td>
</tr>
<tr>
<td>Max. holding force</td>
<td>6 N</td>
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**Drive properties**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor type</td>
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<tr>
<td>Operating Voltage</td>
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<tr>
<td>Electrical power</td>
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<td>Power consumption</td>
<td>1.5 A**</td>
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<td>Reference Switch</td>
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<td>Limit Switches</td>
<td>Hall-effect</td>
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**Miscellaneous**

<table>
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<th>Value</th>
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<tr>
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<td>0 to +50 °C</td>
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<td>Material</td>
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<td>Dimensions</td>
<td>130 x 95 x 21 mm</td>
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<td>Mass</td>
<td>0.65 kg ±5%</td>
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<td>Cable length</td>
<td>1.5 m ±10 mm</td>
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<td>Connector</td>
<td>MDR, 14-pin</td>
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<tr>
<td>Recommended controller / driver</td>
<td>C-867.160 single-axis controller / driver</td>
</tr>
<tr>
<td></td>
<td>C-185.D64 drive electronics</td>
</tr>
</tbody>
</table>

*Power to the motor is supplied by the drive electronics, which runs on 12 V DC, or by the controller (24 V).

**For drive electronics**
Ultrasonic Motor XY Stage

Fast, Low Profile and Large Aperture with Direct Position Measurement

M-686 open-frame piezomotor stages are mainly designed for automated positioning applications in microscopy. The optimized form factor with a low profile height of only 32 mm and the standardized mounting pattern allows the combination with many PI standard nanopositioning systems.

Space Saving Piezomotors

Compared to conventional motorized translation stages, the M-686 provides a lower profile and smaller footprint. The compact PILine® piezoelectric linear motors and high-resolution linear encoders make both, the lead screw duct and the flanged, bulky stepper motor employed in traditional stages obsolete. In addition, the piezomotors are self-locking at rest and hold the stage in a stable position without heating up.

Compatibility to PI Nanopositioning and Scanning Stages

A number of standard PI piezo flexure stages (150 x 150 mm footprint) can be mounted directly on the M-686 open-frame stage. Depending on the application, these highly specialized, ultra-precise nanopositioning systems are available as fast XY scanners (for fluorescence microscopy), as vertical Z positioners (3D imaging), or with up to 6 degrees of freedom.

Limit and Reference Switches

For the protection of your equipment, non-contact Hall-effect limit and reference switches are installed. The direction-sensing reference switch supports advanced automation applications with high precision.

Advantages of PILine® Micropositioning Systems

The ultrasonic piezoceramic drives used in PILine® micropositioners have a number of advantages over classical drives:

- Higher Accelerations, up to 5 g
- Speeds up to 500 mm/s
- Small Form Factor
- Self-Locking When Powered Down
- No Shafts, Gears or Other Rotating Parts
- Non-Magnetic and Vacuum-Compatible Drive Principle

Notes

Nanopositioning stages that fit directly on the M-686:

P-561 to P-563
PIMars™ XYZ Nanopositioning systems with up to 300 µm travel

P-541.2 to P-542.2
Low-profile microscopy XY scanners

P-541.2
Low-profile Z/tip/tilt piezo nanopositioning stages for microscopy

Application Examples

- Biotechnology
- Microscopy
- Scanning microscopy
- Confocal microscopy
- Semiconductor testing
- Handling
Technical Data

Model: M-686.D64
Active axes: XY

Motion and positioning
Travel range: 25 x 25 mm
Integrated sensor: Linear encoder
Sensor resolution: 0.1 µm
Design resolution: 0.1 µm
Min. incremental motion: 0.3 µm
Bidirectional repeatability: 0.3 µm
Pitch / yaw: ±50 µrad
Max. velocity: 100 mm/s

Mechanical properties
Load Capacity*: 50 N
Max. push/pull force: 7 N
Max. lateral force: 4 N

Drive properties
Motor type: 2 x PILine® P-664 per axis
Operating voltage: 190 V (Peak-Peak)**
67 V (RMS)**
Electrical power: 10 W / axis***

Miscellaneous
Operating temperature range: -20 to +50 °C
Material: Aluminium (black anodized)
Mass: 1.2 kg
Cable length: 1.5 m
Connector: 2 x MDR connector, 14-pin
Recommended controller/driver: 2 x C-867.D64 single-axis controller / driver
2 x C-185.D64 single-axis drive electronics for external servo-controllers (p. 4-116, p. 1-36)

*10 N for max. velocity
**The operating voltage or the piezomotor is supplied by the drive electronics which requires 12 VDC
***For drive electronics

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M-686.D64, dimensions in mm. The minimum aperture is 66 x 66 mm with both axes at the maximum position.

Customized M-686 stage with a bigger footprint, to sink the piezo Z scanner. The system height together with the P-541 piezo scanner is reduced to only 33 mm.

M-686 open-frame stage with P-541.2DD piezo scanner on top, providing a resolution of 0.1 nm and a scanning range of 30 x 30 µm. The system height of the combination with the P-541 XY (or Z) piezo scanner is only 48 mm.

0.3 µm steps performed by M-686
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
- No leadscrews, gears or other mechanical components, no wear or maintenance
- No lubricants
- Non-magnetic and vacuum-compatible operating principle

Because of the motion properties typical for ultrasonic piezomotors, the controller has a number of advanced features, including dynamic control parameter adaption. By automatically switching between gainsets for dynamic and static operation an optimized settling behavior within a couple of 10 milliseconds is achieved. The broadband encoder input (50 MHz) allows high resolution encoders to be used with the outstandingly high accelerations and velocities that PILine® drives deliver.

Highest Stability by Frequency Control

The integrated piezomotor drive electronics support all PILine® ultrasonic piezomotors used for the M-66x to M-69x positioning stage series.

Drift in the mechanical frequency of the motor caused by temperature or load changes is automatically compensated by a frequency-control loop which adjusts the operating frequency of the driving voltage. This leads to the highest stability in pushing force, velocity and closed-loop control.

Software / Programming

In addition to the user software for setup, system optimization and operation, comprehensive LabVIEW and DLL libraries are provided.

The C-867 controller is especially designed for closed-loop positioning systems equipped with PILine® piezo linear motor drives. A compact case contains both drive electronics for the piezo ceramic motors and components for controlling and communication.

The controller can be operated from a host PC either via a USB port or an RS-232 interface. Alternatively, a stand-alone operation is possible. Here, stored macro commands can be executed, or manual control by joystick or pushbutton box is possible.

Two models are available: C-867.160 is used to operate single-axis positioning systems, the two-channel C-867.260 is used with XY scanning stages.

The C-867 is based on a highly specialized DSP (Digital Signal Processor) that handles the PID servo-control algorithm as well as other system functions.
The two-channel C-867.260 ultrasonic motor controller operates XY scanning stages, here:

a customized M-686 stage for microscopy

### Technical Data

<table>
<thead>
<tr>
<th>Model</th>
<th>C-867.160</th>
<th>C-867.260</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Function</strong></td>
<td>Controller and drive electronics for PILine® piezomotors / systems</td>
<td>PILine® motors, single and dual drives with P-661, P-664, U-161 or U-164</td>
</tr>
<tr>
<td><strong>Channels</strong></td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

### Motion and control

| **Servo characteristics** | Programmable PID V-ff filter, parameter changes on the fly |
| **Trajectory profile modes** | Trapezoidal |
| **Encoder input** | A/B differential signals, 50 x 10⁶ impulses/s |
| **Stall detection** | Servo off, triggered by programmable position error |
| **Limit switch** | 2 x TTL per channel (programmable) |
| **Reference switch** | 1 x TTL per channel (active high / low, programmable) |

### Electrical properties

| **Max. output power / channel** | 15 W |
| **Max. output voltage / channel** | 200 Vpp |

### Interfaces and operation

| **Communication interfaces** | USB, RS-232 |
| **Motor connector** | MDR14, 2 x MDR14 |
| **Controller network** | Up to 16 units on single interface |
| **I/O ports** | 4 analog/digital in, 4 digital out (Mini-DIN, 9-pin) digital: TTL analog: 0 to 5 V |
| **Command set** | PI General Command Set (GCS) |
| **User software** | PIMikroMove |
| **Software drivers** | GCS-DLL, LabVIEW drivers |
| **Supported functionality** | Start-up macro; macro; data recorder for recording parameters as motor input voltage, velocity, position or position error |
| **Manual control** | Pushbutton box, joystick, Y-cable for control of 2 axes with joystick |

### Miscellaneous

| **Operating voltage** | 24 VDC from external power supply (included) |
| **Current consumption** | 300 mA + motor current (2 A max.) 600 mA + motor current (4 A max.) |
| **Operating temperature range** | +5 °C to +40 °C |
| **Mass** | 1.0 kg 2.4 kg |
| **Dimensions** | 206 x 130 x 66 mm (including mounting rails) 320 x 150 x 80.5 mm (including mounting rails) |

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Products and Technologies
- Nanopositioning / Scanning Stages
- Scanning Microscopy Stages
- Steering Mirrors, Mirror Shifters
- Piezo Actuators
- Piezo Motors
- Piezo Controllers
- Motorized Stages & Actuators
- Motor Controllers
- Hexapod 6-Axis Alignment Systems

Fields of Applications
- Biotechnology / Life Sciences
- Semiconductor Technology
- Data Storage Technology
- Nanotechnology
- Aeronautics
- Astronomy
- Adaptive Optics
- Metrology / Laser-Systems
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