Ultrasonic Motor Positioners

COMPACT DRIVES, FAST AND SELF-LOCKING
PILine® Ultrasonic Piezomotors

COMPACT DRIVES, FAST AND SELF-LOCKING

Direct-driven PILine® linear motors
These linear drives dispense with the mechanical complexity of classical rotary motor/gear/leadscrew combinations. These components can be very susceptible to wear, especially in miniaturized systems.

The simplicity of the ultrasonic linear motor promotes its precision, reliability and cost efficiency. An integral part of the ultrasonic piezomotor is a piezo ceramic that is preloaded against a moving runner with a coupling element. The piezo element is electrically excited to produce high-frequency oscillations that cause the runner to move.

Piezomotors are self-locking
The preload of the piezoceramic actuator against the runner ensures that the drive self-locks at rest and when powered down. As a result, it does not consume any power, it does not heat up and keeps the position stable mechanically. Applications with a short duty cycle, that are battery-operated or heat-sensitive benefit from these characteristics.

Lifetime and reliability
The motion of the piezoceramic actuator is based on crystalline effects and is not subject to any wear. The coupling to the runner, on the other hand, is subject to friction effects. Depending on the operating mode, running distances over 2000 km or a MTBF of 20000 hours are achieved.

Dynamics in use
The stiff design, direct coupling and fast response of the piezo ceramics to electric inputs allows for very fast start/stop behavior and velocities to hundreds of mm/sec.

Patented technology
The products described in this document are in part protected by the following patents:
US Pat. No. 6,765,335B2
European Patent No. 1267425B1
Piezomotors for all applications – e. g. in vacuum environments and strong magnetic fields

Piezomotors from PI are intrinsically vacuum-compatible and suitable for operation in strong magnetic fields. Special versions are offered for this purpose. Nanometer resolution or forces up to several 100 N can be achieved with PiezoWalk® linear motors.

The benefit of the low profile PILine® drives becomes apparent with positioning systems such as the M-660 rotation stage (left, 14 mm high) or the M-687 microscopy XY stage (right, 25 mm high): a consistently flat design without lead screw ducts or flanged motors.

The piezoceramic actuator is excited with a high frequency electric signal (100 to 200 kHz). The deformation of the actuator leads to a periodic diagonal motion of the coupling element to the runner. The created feed is roughly 10 nm per cycle; the high frequencies lead to the high velocities.

PILine® integration levels (left to right): OEM motor, U-284 RodDrive low-profile actuator (unguided) and M-272 closed-loop, guided linear actuator.
Rotation Stage with Direct Drive

LOW PROFILE, FAST

M-660

- Low profile: Only 14 mm height
- Direct position measurement with up to 4 µrad resolution
- Max. velocity 720 °/s
- Compact combinations with translation stages are possible
- Vacuum versions to 10⁻⁶ hPa

Precision-class rotation stage
With fast direct drive; unlimited slewing range. A vacuum-compatible version down to 10⁻⁴ hPa is available

PLine® piezo ultrasonic drive
Self-locking, no heat generation at rest. Excellent start/stop dynamics. Non-contact reference point switch

Direct measuring principle
Non-contact measuring, optical linear encoder. Variants with different resolutions. High repeatability

Valid patents
US Patent No. 6,765,335B2
European Patent No. 1267425B1

Application fields
Research and industry. For micromanipulation, automation, optical metrology

Related products
M-060 • M-061 • M-062 Precision Rotation Stage
M-116 Micro Rotation Stage
C-867 PLine® Motion Controller
## M-660.45, M-660.55 Specifications

<table>
<thead>
<tr>
<th>Active axes</th>
<th>Motion and positioning</th>
<th>Unit</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rotation range</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Integrated sensor</td>
<td></td>
<td>Incremental encoder</td>
</tr>
<tr>
<td></td>
<td>Design resolution</td>
<td>4 (0.00023)</td>
<td>34 (0.00195)</td>
</tr>
<tr>
<td></td>
<td>Min. incremental motion</td>
<td>12</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td>Bidirectional repeatability</td>
<td>±24</td>
<td>±68</td>
</tr>
<tr>
<td></td>
<td>Velocity</td>
<td>720</td>
<td>720</td>
</tr>
</tbody>
</table>

### Mechanical properties

- **Load capacity/axial force**: 20 N max. 20 N max.
- **Holding force**: 0.3 Nm max. 0.3 Nm max.
- **Torque cw/ccw (θz)**: 0.3 Nm max. 0.3 Nm max.

### Drive properties

- **Motor type**: U-164 PILine® ultrasonic piezomotor U-164 PILine® ultrasonic piezomotor
- **Reference point switch**: Optical Optical

### Miscellaneous

- **Operating temperature range**: -20 bis 50 °C
- **Material**: Al (black anodized) Al (black anodized)
- **Mass**: 470 g ±5 % 470 g ±5 %
- **Cable length**: 1.3 m ±10 mm 1.3 m ±10 mm
- **Connector**: MDR, 14-pin MDR, 14-pin
- **Recommended controller/driver**: C-867 PILine® Motion Controller C-867 PILine® Motion Controller

Vacuum versions to 10⁻⁶ hPa are available under the following order number: M-660.x5V.

Ask about custom designs!
XY Stage with Piezoceramic Linear Motors

HIGH STABILITY AND SPEED, LOW-PROFILE, DIRECT POSITION MEASUREMENT

M-686

- Higher stability with self-clamping linear motors
- Max. velocity 100 mm/s
- Very low profile of only 32 mm, no protruding parts
- Travel range 25 x 25 mm
- 100 nm, optical linear encoders provide excellent repeatability and accuracy

Precision-class XY stage
With fast direct drive. Clear aperture 78 x 78 mm, 65 x 65 mm at full displacement

PLLine® piezo ultrasonic drive
Self-locking, no heat generation at rest. Excellent start/stop dynamics. Flat supporting surface, no lead screw ducts or flange-mounted motors. Crossed roller guide for higher running accuracy and load capacity. Non-contact limit and reference point switches

Direct measuring principle
Non-contact, direct-measuring, optical linear encoder per axis. High repeatability

Valid patents
US Patent No. 6,765,335B2
European Patent No. 1267425B1

Application fields
Research and industry. For microscopy, biotechnology, laboratory automation. Special versions for standard light microscopes available on request

The following stages fit directly
P-561 • P-562 • P-563 PIMars Nanopositioning Stage
P-541.2 • P-542.2 Piezo XY Stage
P-541.Z Vertical Nanopositioning Stage

Related products
M-683 Dynamic Micropositioning Stage
M-545 Microscopy Stage
M-686.D64, dimensions in mm. At an extreme displacement, the aperture still is 65 x 65 mm

M-686.D64, open-frame long-travel stage combined with P-541.2DD high-speed piezo scanner (0.1 nanometer resolution). The system height of the combination with the P-541 XY (or Z) piezo scanner is only 48 mm

Ask about custom designs!
* 10 N for maximum velocity.

Series of 0.3 µm steps performed by M-686 shows excellent equidistance and repeatability; measured with laser interferometer.

The two-channel C-867.260 controller serves to control XY scanning stages, as in this case a customized M-686 stage for microscopy.
Dynamic Micropositioning Stage

LOW PROFILE, LINEAR ENCODER

Precison-class micropositioning stage
Integrated piezoceramic direct drive. A vacuum-compatible version down to 10⁻⁶ hPa is available

PLINE® piezo ultrasonic drive
Self-locking, no heat generation at rest. Excellent start/stop dynamics. Crossed roller guides. Non-contact limit and reference point switches

Direct-metrology linear encoder
Excellent linearity and repeatability

Application fields
Research and industry. For biotechnology, micromanipulation, test equipment

Related products
M-605 High-Accuracy Translation Stage
N-661 Miniature Linear Stage with NEXACT® Drive

Valid patents
US Patent Nr. 6,765,335B2
European Patent Nr. 1267425B1

M-683
- Piezoceramic linear drive with excellent dynamics
- Max. velocity 350 mm/s
- Low profile: only 21 mm
- Travel range 50 mm
- Encoder resolution 0.1 µm
## M-683.2U4

<table>
<thead>
<tr>
<th>Active axes</th>
<th>X</th>
</tr>
</thead>
</table>

### Motion and positioning

<table>
<thead>
<tr>
<th>Travel range</th>
<th>50 mm</th>
</tr>
</thead>
<tbody>
<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>Velocity</td>
<td>350 mm/s max.</td>
</tr>
<tr>
<td>Reference point switch repeatability</td>
<td>±1 µm typ.</td>
</tr>
</tbody>
</table>

### Mechanical properties

<table>
<thead>
<tr>
<th>Guiding</th>
<th>Crossed-roller bearings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load capacity</td>
<td>50 N max.</td>
</tr>
<tr>
<td>Push / pull force</td>
<td>6 N max.</td>
</tr>
<tr>
<td>Holding force</td>
<td>6 N max.</td>
</tr>
</tbody>
</table>

### Drive properties

<table>
<thead>
<tr>
<th>Motor type</th>
<th>PILine® U-164 (dual motor)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference point switch</td>
<td>Optical</td>
</tr>
<tr>
<td>Limit switches</td>
<td>Hall-effect</td>
</tr>
</tbody>
</table>

### Miscellaneous

| Operating temperature range | 0 to +50 °C |
| Material | Al (black anodized) |
| Dimensions | 130 × 95 × 21 mm |
| Mass | 0.65 kg ±5% |
| Cable length | 1.5 m ±10 mm |
| Connector | MDR, 14-pin |
| Recommended controller | C-867 PILine® controller incl. driver |

M-683.2V4: Delivery includes 1 m cable (vacuum), feedthrough and 1.5 m cable (air). Specifications for vacuum versions can differ. Ask about custom designs!

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### Diagrams

- **M-683.2U4, dimensions in mm**

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Compact Linear Positioning Stage

**FAST LINEAR MOTOR, LINEAR ENCODER**

**M-663**
- Max. velocity 400 mm/s
- Travel range 19 mm
- 0.1 µm linear encoder
- XY combinations without adapter plate possible

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**Precision-class micropositioning stage**
Integrated piezoceramic direct drive. A vacuum-compatible version down to 10⁻⁶ hPa is available

**PILine® piezo ultrasonic drive**
Self-locking, no heat generation at rest. Excellent start/stop dynamics. Centered ball bearings. Non-contact reference point switch

**Direct measuring principle**
Non-contact, optical linear encoder. High linearity and repeatability

**Valid patents**
US Patent No. 6,765,335B2
European Patent No. 1267425B1

**Application fields**
Research and industry. For optical metrology, laser technology, micromanipulation, biotechnology, photonics, packaging

**Related products**
M-110 • M-111 • M-112 Compact, Cost-Efficient Linear Stage
M-122 Compact, Fast Linear Stage
M-683 Fast Micropositioning Stage
C-867 PILine® Motion Controller
Appendix

Linear Stages

Translation (X)  Nanometrology Hexapod System  Nanopositioning & Piezoelectrics

Linear Actuators & Motors

M-663.465 Unit Tolerance

Active axes

X

Motion and positioning

Travel range

19 mm

Integrated sensor

Linear encoder

Sensor resolution

0.1 µm

Min. incremental motion

0.3 µm typ.

Unidirectional repeatability

0.2 µm typ.

Bidirectional repeatability

≤0.3 µm

Pitch / yaw

±300 µrad typ.

Velocity

400 mm/s max.

Reference point switch repeatability

1 µm typ.

Mechanical properties

Load capacity

5 N max.

Push / pull force

2 N max.

Holding force

2 N max.

Drive properties

Motor type

P-661 PILine® ultrasonic piezomotor

Reference point switch

Optical

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 PILine® Motion Controller

Vacuum versions to 10⁻⁶ hPa are available under the following ordering number: M-663.46V.

A version with 90 deg. shifted cable exit for XY mounting is available as the M-663.Y65

Step and settle example:

An M-663 positioner loaded with 100 g can execute a 100 µm step and settle to within 0.1 µm in only 10 ms.

Performed with a C-867 PILine® motion controller

1-mm step performed by an M-663 stage and a C-867 controller. The stage is loaded with 300 g and reaches the target position in less than 40 ms

M-663.465, dimensions in mm
Linear Drive for Automation

FAST AND SELF-LOCKING WITH PILINE® PIEZOMOTOR

Compact standard-class linear drive
Fast, maintenance-free and easy to integrate. Integrated ball bearing guidance

PILine® ultrasonic drive
Cost effective alternative to the conventional combination of electric motor and spindle. Ceramic direct drive, self-locking at rest, no heat generation

Integrated linear scale encoder
Reliable position control, repeatable accuracy. Optical reference point switch

Application fields
Automation, handling, micromanipulation, metrology

M-272
- Velocity up to 150 mm/s
- Self-locking at rest
- Integrated linear encoder
- Integrated linear guiding system

Related Products
N-310 NEXACT® OEM Miniature Linear Motor / Actuator
M-664 Precision Stage with Linear Drive
M-228 • M-229 Linear Actuator Series with Stepper Motor
C-867 Controller for PILine®
C-867.OE Controller Board for PILine®
<table>
<thead>
<tr>
<th>Active axes</th>
<th>X</th>
</tr>
</thead>
</table>

### Motion and positioning

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel range</td>
<td>50 mm</td>
</tr>
<tr>
<td>Integrated sensor</td>
<td>Linear encoder</td>
</tr>
<tr>
<td>Sensor resolution</td>
<td>0.6 µm</td>
</tr>
<tr>
<td>Min. incremental motion</td>
<td>1.8 µm typ.</td>
</tr>
<tr>
<td>Unidirectional repeatability</td>
<td>2 µm typ.</td>
</tr>
<tr>
<td>Bidirectional repeatability</td>
<td>3 µm typ.</td>
</tr>
<tr>
<td>Velocity</td>
<td>150 mm/s max.</td>
</tr>
</tbody>
</table>

### Mechanical properties

<table>
<thead>
<tr>
<th>Guiding</th>
<th>Ball bearings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Push/pull force</td>
<td>8 N max.</td>
</tr>
<tr>
<td>Holding force</td>
<td>8 N max.</td>
</tr>
<tr>
<td>Lateral force</td>
<td>10 N max.</td>
</tr>
</tbody>
</table>

### Drive properties

<table>
<thead>
<tr>
<th>Motor type</th>
<th>U-164 PILine® ultrasonic piezo drive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current consumption</td>
<td>800 mA*</td>
</tr>
<tr>
<td>Reference point switch</td>
<td>Optical</td>
</tr>
</tbody>
</table>

### Miscellaneous

| Operating temperature range      | -20 to +50 °C                      |
| Material                         | Aluminum                            |
| Mass                             | 0.47 kg ± 5%                        |
| Cable length                     | 1.5 m ± 10 mm                       |
| Connector                        | MDR, 14-pin                         |

Recommended controller/driver: C-867.OE

Power for the motor is supplied by the drive electronics, which requires 24 V DC.

* For drive electronics
PILine® Motion Controller
FOR ULTRASONIC PIEZOMOTORS, 1 AND 2 AXES

C-867
■ For PILine® ultrasonic piezo linear motors
■ 50-MHz encoder inputs for high velocity and position resolution
■ USB, RS-232 and analog interfaces (e.g. for a joystick)

Servocontroller and power amplifier
One and two channels, bench top, proprietary PID control for ultrasonic motors, network-compatible with up to 16 units per interface

For PILine® ultrasonic linear motors
Power amplifier for PILine® drives and stages with up to two piezomotors per channel. Automated frequency tracking for improved servo performance

Incremental encoders
Differential signal transmission (A/B). Evaluation of TTL signals for limit and reference point switches

Digital communication
USB, RS-232 and analog interfaces (e.g. for a joystick). Data recorder. Powerful macro programming language, e.g. for standalone operation. Extensive software support, e.g. LabVIEW, shared libraries for Windows and Linux
<table>
<thead>
<tr>
<th><strong>Function</strong></th>
<th>C-867.160: Controller for single-axis positioning or scanning stages</th>
<th>C-867.260: Controller for XY positioning or scanning stages</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Drive type</strong></td>
<td>PLine® motors, single and dual drives with P-661, P-664, U-161 and U-164</td>
<td></td>
</tr>
<tr>
<td><strong>Channels</strong></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td><strong>Motion and control</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Servo characteristics</strong></td>
<td>Programmable PID filter, parameter changes on the fly</td>
<td></td>
</tr>
<tr>
<td><strong>Trajectory profile modes</strong></td>
<td>Trapezoid</td>
<td></td>
</tr>
<tr>
<td><strong>Encoder input</strong></td>
<td>A/B (quadrature) differential, 50 MHz</td>
<td></td>
</tr>
<tr>
<td><strong>Stall detection</strong></td>
<td>Servo off, triggered by programmable position error</td>
<td></td>
</tr>
<tr>
<td><strong>Limit switches</strong></td>
<td>2 TTL (programmable) per channel</td>
<td></td>
</tr>
<tr>
<td><strong>Reference point switch</strong></td>
<td>1 TTL per channel (active high/low, programmable)</td>
<td></td>
</tr>
<tr>
<td><strong>Electrical properties</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Max. output power per channel</strong></td>
<td>15 W</td>
<td></td>
</tr>
<tr>
<td><strong>Max. output voltage per channel</strong></td>
<td>200 Vpp</td>
<td></td>
</tr>
<tr>
<td><strong>Interface and operation</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Communication interfaces</strong></td>
<td>USB, RS-232</td>
<td></td>
</tr>
<tr>
<td><strong>Motor connector</strong></td>
<td>MDR14</td>
<td>2 × MDR14</td>
</tr>
<tr>
<td><strong>Controller network</strong></td>
<td>Up to 16 units on single interface</td>
<td></td>
</tr>
<tr>
<td><strong>I/O ports</strong></td>
<td>4 analog/digital in 4 digital out (Mini-DIN, 9-pin) Digital: TTL Analog: 0 to 5 V</td>
<td></td>
</tr>
<tr>
<td><strong>Command set</strong></td>
<td>PI General Command Set (GCS)</td>
<td></td>
</tr>
<tr>
<td><strong>User software</strong></td>
<td>PMikroMove</td>
<td></td>
</tr>
<tr>
<td><strong>Software drivers</strong></td>
<td>GCS-DLL, LabVIEW driver</td>
<td></td>
</tr>
<tr>
<td><strong>Supported functionality</strong></td>
<td>Start-up macro, macro, data recorder for recording parameters as motor input voltage, velocity, position or position error</td>
<td></td>
</tr>
<tr>
<td><strong>Manual control</strong></td>
<td>Pushbutton box, joystick (for two axes), Y cable for 2-D motion</td>
<td>Pushbutton box, joystick (for two axes)</td>
</tr>
<tr>
<td><strong>Miscellaneous</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Operating voltage</strong></td>
<td>24 VDC from external power supply (included)</td>
<td></td>
</tr>
<tr>
<td><strong>Max. operating current</strong></td>
<td>300 mA plus motor current (max. 2 A)</td>
<td>600 mA plus motor current (max. 4 A)</td>
</tr>
<tr>
<td><strong>Operating temperature range</strong></td>
<td>5 to 40°C</td>
<td></td>
</tr>
<tr>
<td><strong>Mass</strong></td>
<td>1 kg</td>
<td>2.4 kg</td>
</tr>
<tr>
<td><strong>Dimensions</strong></td>
<td>206 × 130 × 66 mm (incl. mounting rails)</td>
<td>320 × 150 × 80.5 mm (incl. mounting rails)</td>
</tr>
</tbody>
</table>

Ask about custom designs!

The two-channel C-867.260 controller serves to control XY scanning stages, as in this case a customized M-686 stage for microscopy.
Different integration levels offer flexibility
PILine® allow the design of positioning systems with higher dynamics and smaller dimensions. PI offers various integration levels of PILine® drives for easier integration into customer designs:

- Complete positioning stages with integrated PILine® motors are available in custom designs for OEMs,
- Linear actuators move the load via a guided rod. Position feedback is available as an option,
- RodDrives are unguided and open-loop linear drives that replace motor-leadsscrew combinations. They can easily be coupled to a guided positioning platform,
- The integration of OEM motors requires more experience and technical knowledge because the optimal preload between runner and actuator has to be set-up by the customer.

Drive electronics
To produce the ultrasonic oscillations in the piezo actuator, special drive electronics are required that are also provided by PI. These range from OEM boards to integrated servo controllers for closed-loop systems.

<table>
<thead>
<tr>
<th>PILine® Piezo Linear Drive</th>
<th>P-661</th>
<th>U-164</th>
<th>Unit</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Motion and positioning</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Travel range*</td>
<td>No limit</td>
<td>No limit</td>
<td>mm</td>
<td></td>
</tr>
<tr>
<td>Min. incremental motion, open-loop**</td>
<td>0.05</td>
<td>0.05</td>
<td>µm</td>
<td>typ.</td>
</tr>
<tr>
<td>Open-loop velocity</td>
<td>500</td>
<td>500</td>
<td>mm/s</td>
<td>max.</td>
</tr>
<tr>
<td><strong>Mechanical properties</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stiffness, de-energized</td>
<td>0.7</td>
<td>3</td>
<td>N/µm</td>
<td>±10 %</td>
</tr>
<tr>
<td>Holding force, de-energized</td>
<td>1.5</td>
<td>3</td>
<td>N</td>
<td>max.</td>
</tr>
<tr>
<td>Push / pull force</td>
<td>2</td>
<td>4</td>
<td>N</td>
<td>max.</td>
</tr>
<tr>
<td>Optimum preload on runner</td>
<td>9</td>
<td>18</td>
<td>N</td>
<td>±10 %</td>
</tr>
<tr>
<td><strong>Drive properties</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resonant frequency</td>
<td>210</td>
<td>155</td>
<td>kHz</td>
<td>±2 kHz</td>
</tr>
<tr>
<td>Motor voltage</td>
<td>42 V_{rms} (120 V_{pp})</td>
<td>60 V_{rms} (170 V_{pp})</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Miscellaneous</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operating temperature range</td>
<td>-20 to +50</td>
<td>-20 to +50</td>
<td>°C</td>
<td></td>
</tr>
<tr>
<td>Casing material</td>
<td>Al (black anodized)</td>
<td>Al (black anodized)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass</td>
<td>10</td>
<td>20</td>
<td>g</td>
<td>±5 %</td>
</tr>
</tbody>
</table>

* The travel range of piezo linear motors is practically unlimited and it only depends on the length of the runner
** The minimum incremental motion is a typical value which can be reached in open-loop operation. However, it is important to follow the installation guidelines for the motors
Open-loop step sequence of a PILine® based translation stage. Steps of approx. 300 nm shown. For repeatable increments closed-loop operation is recommended, because the step size depends on the force applied from outside.

PILine® ultrasonic linear motors provide excellent dynamic properties. They provide acceleration to several g and can achieve step and settle of a few 10 ms for small distances.

Maximum duty cycle depending on the ambient temperature with a control signal level of 100 %

Force / velocity motor characteristic of a U-164 PILine® motor. The percentages refer to the control signal level, which denotes the coupling of the electric power of the actuator.

P-661, dimensions in mm

U-164, dimensions in mm
Vertical Drive for Bio-Automation

- Actuator with PiLine® piezomotor
- Compact and cost-effective design
- Stackable
- Non-magnetic and vacuum-compatible operating principle
- Self-locking at rest

<table>
<thead>
<tr>
<th></th>
<th>Travel range</th>
<th>Max. push/pull force</th>
<th>Max. closed-loop velocity</th>
<th>Resolution</th>
<th>Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>M-664KCEP compact PiLine® positioner</td>
<td>50 mm</td>
<td>5 N</td>
<td>100 mm/s</td>
<td>0.5 µm</td>
<td>120 × 40 × 9 mm</td>
</tr>
</tbody>
</table>

Z Actuator for Bio-Automation

- Extremely slim design, matched with standard multiwell plates
- Stackable
- Integrated linear encoder for highest accuracy
- Self-locking at rest
- Non-magnetic and vacuum-compatible operating principle

<table>
<thead>
<tr>
<th></th>
<th>Travel range</th>
<th>Max. push/pull force</th>
<th>Max. closed-loop velocity</th>
<th>Resolution</th>
<th>Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>M-674KCPP compact PiLine® positioner</td>
<td>50 mm</td>
<td>7 N</td>
<td>100 mm/s</td>
<td>0.1 µm</td>
<td>120 × 40 × 9 mm</td>
</tr>
</tbody>
</table>

Micro Linear Stage

- Smallest micropositioning stages with linear motor drive
- Acceleration 5 g
- Push / pull force 1 N
- XY combination possible
- MTBF 20,000 h
- Vacuum-compatible versions to 10⁻⁷ hPa
- Self-locking at rest

<table>
<thead>
<tr>
<th></th>
<th>Travel range</th>
<th>Max. load</th>
<th>Max. velocity</th>
<th>Min. incremental motion</th>
<th>Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>M-661.370</td>
<td>18 mm</td>
<td>5 N</td>
<td>500 mm/s</td>
<td>50 nm</td>
<td>30 × 23 × 10 mm</td>
</tr>
<tr>
<td>M-662.470</td>
<td>20 mm</td>
<td>5 N</td>
<td>500 mm/s</td>
<td>50 nm</td>
<td>28 × 28 × 8 mm</td>
</tr>
</tbody>
</table>
RodDrive Piezomotor Direct Drive

LOW PROFILE, HIGH SPEED, EASY INTEGRATION

Fast OEM linear drive
For integration into guided systems

RodDrive direct drive with integrated and preloaded
PILine ultrasonic piezo drives
Self-locking, no heat generation at rest. Excellent start/stop dynamics. Easy integration by coupling the rod to a guided payload (e.g. a linear slide)

Application fields
OEM drives for automation. For handling and high-precision positioning systems

Related Products
M-272 Linear Drive for Automation
N-310 NEXACT OEM Miniature Linear Motor / Actuator
C-872 Driver for PLine® Ultrasonic Piezomotors

U-264
- Velocity up to 250 mm/s
- Travel ranges up to 150 mm
- Linear drive for integration
- Generated force up to 15 N

RodDrive integrated in a micro stage
### Motion and positioning

<table>
<thead>
<tr>
<th>U-264.10/20/30</th>
<th>U-264.11/21/31</th>
<th>Units</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel range</td>
<td>50 / 100 / 150</td>
<td>mm</td>
<td></td>
</tr>
<tr>
<td>Open-loop step size</td>
<td>0.1*</td>
<td>μm</td>
<td>typ.</td>
</tr>
<tr>
<td>Open-loop velocity</td>
<td>250</td>
<td>mm/s</td>
<td>max.</td>
</tr>
</tbody>
</table>

### Mechanical properties

<table>
<thead>
<tr>
<th></th>
<th>U-264.10/20/30</th>
<th>U-264.11/21/31</th>
<th>Units</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stiffness when powered down</td>
<td>1.5</td>
<td>N/μm</td>
<td>±10 %</td>
<td></td>
</tr>
<tr>
<td>Holding force when powered down</td>
<td>8</td>
<td>N</td>
<td>max.</td>
<td></td>
</tr>
<tr>
<td>Push/pull force</td>
<td>7 (at 50 mm/s)</td>
<td>N</td>
<td>max.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 (at 250 mm/s)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>12 (at 50 mm/s)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 (at 200 mm/s)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Drive properties

<table>
<thead>
<tr>
<th></th>
<th>U-264.10/20/30</th>
<th>U-264.11/21/31</th>
<th>Units</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resonant frequency</td>
<td>158</td>
<td>kHz</td>
<td>±2 kHz</td>
<td></td>
</tr>
<tr>
<td>Motor voltage</td>
<td>200 V_{pp}</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>65 V_{rms}</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Input impedance</td>
<td>40 to 80**</td>
<td>Ω</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>50 to 100**</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Miscellaneous

<table>
<thead>
<tr>
<th></th>
<th>U-264.10/20/30</th>
<th>U-264.11/21/31</th>
<th>Units</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating temperature range</td>
<td>0 to 40</td>
<td>°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Material case</td>
<td>Al (black anodized)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass</td>
<td>0.08 / 0.09 / 0.1 kg</td>
<td></td>
<td>±5 %</td>
<td></td>
</tr>
<tr>
<td>Connector</td>
<td>D-Sub 15 (m)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recommended controller/driver</td>
<td>C-872.160 driver, C-867 motion controller/driver</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dimensions</td>
<td>57 x 63 x 10.2 plus rod mm</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* pulsed operation, 1 msec ON time, 50 % duty cycle

** at resonant frequency

---

![U-264.11/21/31, velocity (open-loop) vs. dynamic force (push/pull force) at various drive signal amplitudes](image)

![U-264, dimensions in mm](image)

PILine RodDrive with variable travel ranges
All-purpose driver for all PILine® single and dual drives
OEM board with analog control input. Suitable for PILine® ultrasonic piezomotors P-661, U-161, U-164 and PILine® RodDrive U-264

PILine® ultrasonic piezomotors and drives
High velocity. Self-locking, no heat generation at rest. Excellent start/stop dynamics

Resonance tracking
Automatically adjusts the driving frequency for maximum motor performance and efficiency (can be switched off)

Related products
U-264 RodDrive Piezomotor Direct Drive
M-272 Ceramic Linear Drive for Automation
C-867.OE Controller Board PILine®

**Preliminary Data**

<table>
<thead>
<tr>
<th>Data</th>
<th>C-872.160</th>
<th>Unit</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Function</td>
<td>Driver for PILine® ultrasonic piezomotors / single and dual drives with P-661, U-161, U-164 and U-264</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Channels</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control In</td>
<td>±10 V defines the velocity, polarity defines the direction of motion, 12-bit A/D converter</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Electrical properties</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output power</td>
<td>50</td>
<td>W</td>
<td>max.</td>
</tr>
<tr>
<td>Output voltage</td>
<td>240 (AC voltage, amplitude and frequency depending on motor selection)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current limitation</td>
<td>2.5 (short-circuit-proof)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Interface and operation</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DIP switches</td>
<td>Motor selection, frequency control activated/deactivated</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motor connector</td>
<td>MDR14 and sub-D 15 (f)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I/O ports</td>
<td>Sub-D 15 (m)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1x frequency control activated/deactivated</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Looped through: 3x signals for limit and reference point switches (TTL), 4x encoder signal (A/B, differential)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Miscellaneous</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operating voltage</td>
<td>24 VDC, 50 W, from external power supply (not included)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current consumption</td>
<td>2.5</td>
<td>A</td>
<td>max.</td>
</tr>
<tr>
<td>Operating temperature range</td>
<td>5 to 40</td>
<td>°C</td>
<td></td>
</tr>
<tr>
<td>Mass</td>
<td>0.125</td>
<td>kg</td>
<td></td>
</tr>
<tr>
<td>Dimensions</td>
<td>172 x 100 x 20 (incl. connector)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

For all PILine® motors
Analog control input
Automatic frequency control
Minimum heat generation
PILine® Motion Controller

OEM BOARD, COST-EFFECTIVE, WITH CAN INTERFACE

C-867.0E

- For PILine® ultrasonic piezomotors
- 50-MHz encoder inputs for high velocity and position resolution
- CAN, RS-232 and analog interfaces (e.g. for a joystick)

**Servocontroller and power amplifier**
One channel, proprietary PID control for ultrasonic motors, standard Eurocard size

**For PILine® ultrasonic linear motors**
Power amplifier for PILine® drives and stages. Automated frequency tracking for improved servo performance

**Incremental encoders**
Differential signal transmission (A/B). TTL inputs for limit and reference point switches

**Digital communication**
CAN, RS-232 and analog interfaces (e.g. for a joystick). Data recorder. Powerful macro programming language, e.g. for standalone operation. Extensive software support, e.g. for LabVIEW, shared libraries for Windows and Linux

Cost-effective combination: M-272 closed-loop linear pusher and C-867.0E motion controller

**Related Products**
C-867 PILine® Motion Controller
<table>
<thead>
<tr>
<th><strong>Function</strong></th>
<th>C-867.OE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Drive type</strong></td>
<td>Controller and drive electronics for PILine® piezomotors/systems</td>
</tr>
<tr>
<td><strong>Channels</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>Motion and control</strong></td>
<td>1</td>
</tr>
<tr>
<td><strong>Servo characteristics</strong></td>
<td>Programmable PID filter, parameter changes on the fly</td>
</tr>
<tr>
<td><strong>Trajectory profile modes</strong></td>
<td>Trapezoid</td>
</tr>
<tr>
<td><strong>Encoder input</strong></td>
<td>A/B (quadrature) differential, 50 MHz</td>
</tr>
<tr>
<td><strong>Stall detection</strong></td>
<td>Servo off, triggered by programmable position error</td>
</tr>
<tr>
<td><strong>Limit switches</strong></td>
<td>2 TTL (programmable)</td>
</tr>
<tr>
<td><strong>Reference point switch</strong></td>
<td>1 TTL (active high/low, programmable)</td>
</tr>
<tr>
<td><strong>Electrical properties</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Max. output power</strong></td>
<td>15 W</td>
</tr>
<tr>
<td><strong>Max. output voltage</strong></td>
<td>200 Vpp</td>
</tr>
<tr>
<td><strong>Interface and operation</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Communication interfaces</strong></td>
<td>RS-232, CAN, Input / output 32-pin (male) on rear panel (DIN 41612 / D)</td>
</tr>
<tr>
<td><strong>Motor connector</strong></td>
<td>MDR14</td>
</tr>
<tr>
<td><strong>Command set</strong></td>
<td>PI General Command Set (GCS)</td>
</tr>
<tr>
<td><strong>User software</strong></td>
<td>PIMikroMove</td>
</tr>
<tr>
<td><strong>Software drivers</strong></td>
<td>GCS-DLL, LabVIEW driver</td>
</tr>
<tr>
<td><strong>Supported functionality</strong></td>
<td>Start-up macro, macro, data recorder for recording parameters as motor input voltage, velocity, position or position error</td>
</tr>
<tr>
<td><strong>Miscellaneous</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Operating voltage</strong></td>
<td>24 VDC from external power supply (not included)</td>
</tr>
<tr>
<td><strong>Max. operating current</strong></td>
<td>150 mA plus motor current (max. 2 A)</td>
</tr>
<tr>
<td><strong>Operating temperature range</strong></td>
<td>5 to 40°C</td>
</tr>
<tr>
<td><strong>Mass</strong></td>
<td>420 g</td>
</tr>
<tr>
<td><strong>Dimensions</strong></td>
<td>175 × 100 × 38 mm (incl. connector)</td>
</tr>
</tbody>
</table>
PI (Physik Instrumente) is the leading supplier of piezo-based positioning systems with accuracies in the range of a few nanometers.

The extensive product portfolio is based on a wide range of technologies with electromotive or piezoelectric drives for up to six motion axes. Hexapods, nanometer sensors, control electronics as well as software and are supplemented by customized solutions.

All key technologies are developed in-house. This means that every phase from the design right down to the shipment can be controlled: The precision mechanics and the electronics as well as the position sensors and the piezo ceramics or actuators. The latter are produced by the subsidiary company PI Ceramic.

PI is, therefore, the only manufacturer of nanopositioning technology which employs the piezoelectric drives it produces. This ensures a high degree of flexibility for developing customized piezoceramic components.

More than 100 patents and patents applied for stand for more than 40 years of experience and pioneering work. PI products are employed wherever technology in industry and research is pushed forward – worldwide.

With four German factories and ten subsidiaries and sales offices abroad, the PI group is represented internationally.

PI stands for quality in products, processes and service. The ISO-9001 certification which focuses not only on product quality but also on customer expectations and satisfaction was achieved back in 1994.

PI is also certified according to the ISO 14001 (environmental management) and OHSAS 18001 (occupational safety) standards, which taken together form an Integrated Management System (IMS).
1970  PI founding year
1977  PI moved its headquarters to Waldbronn, Germany
1987  Foundation of a subsidiary in the USA
1991  Foundation of a subsidiary in Japan
1991  Market launch of 6-axis parallel-kinematics positioning systems (Hexapods)
1992  Foundation of PI Ceramic, Thuringia, Germany; crucial step towards market leadership in nanopositioning
1993  Foundation of subsidiaries in the UK and in France
1994  Market launch of capacitive position sensors
1995  Foundation of a subsidiary in Italy
1998  Market launch of digital control electronics
2001  Market launch of PILine® ultrasonic piezomotors
2001  New company building in Karlsruhe, Germany
2002  PI Ceramic company building extended
2002  Foundation of a subsidiary in China
2002  Market launch of PICMA® multilayer piezo stack actuators
2004  Market launch of NEXLINE® high-performance piezo linear drives
2007  Market launch of NEXACT® piezo linear drives
2010  Acquisition of the expansion site next to the PI headquarters
2011  Foundation of a subsidiary in Korea
2011  Foundation of a subsidiary in Singapore
2011  Acquisition of the majority shares of miCos GmbH
2012  Extension of the PI headquarters company building in Karlsruhe
PI General Catalog

Request it now!

The 530 page hardbound catalogue from PI is the most comprehensive reference book on the fundamentals of nanopositioning, piezo systems and micro-positioning technology yet. The catalog contains 200 product families, with more than 1000 drawings, graphs, images and technical diagrams.

---

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**PIEZO NANO POSITIONING**

PI

www.pi.ws

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"PIEZOCERAMIC INTEGRATION"

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