This document describes the following products:

- **U-521.23**
  PILine® linear stage, 2 N drive force, 18 mm travel range, incremental encoder, 0.4 µm resolution, Sub-D connector (m)

- **U-521.23V**
  PILine® linear stage, 2 N drive force, 18 mm travel range, incremental encoder, 0.4 µm resolution, Sub-D connector (m), vacuum compatible to $10^{-6}$ hPa

- **U-521.24**
  PILine® linear stage, 2 N drive force, 18 mm travel range, incremental encoder, 0.1 µm resolution, Sub-D connector (m)

- **U-521.24V**
  PILine® linear stage, 2 N drive force, 18 mm travel range, incremental encoder, 0.1 µm resolution, Sub-D connector (m), vacuum compatible to $10^{-6}$ hPa
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1 About this Document

In this Chapter

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1.1 Objective and Target Audience of this User Manual

This manual contains information necessary for the intended use of the U-521.
It assumes that the reader has a fundamental understanding of basic servo systems as well as
motion control concepts and applicable safety procedures.
The latest versions of the user manuals are available for download (p. 3) on our website.

1.2 Symbols and Typographic Conventions

The following symbols and typographic conventions are used in this user manual:

**CAUTION**

Dangerous situation
If not avoided, the dangerous situation will result in minor injury.
- Actions to take to avoid the situation.

**NOTICE**

Dangerous situation
If not avoided, the dangerous situation will result in damage to the equipment.
- Actions to take to avoid the situation.

**INFORMATION**

Information for easier handling, tricks, tips, etc.
1.3 Definition of Terms

<table>
<thead>
<tr>
<th>Term</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load capacity</td>
<td>Maximum load capacity in the vertical direction when the stage is mounted horizontally. The contact point of the load is in the center of the motion platform.</td>
</tr>
<tr>
<td>Linear encoder</td>
<td>The linear encoder is an incremental sensor for capturing changes in position. Signals from the sensor are used for axis position feedback. After switching on the controller a reference point definition must be performed before absolute target positions can be commanded and reached.</td>
</tr>
</tbody>
</table>

1.4 Figures

For better understandability, the colors, proportions, and degree of detail in illustrations can deviate from the actual circumstances. Photographic illustrations may also differ and must not be seen as guaranteed properties.
1.5 Other Applicable Documents

The devices and software tools that are mentioned in this documentation are described in their own manuals.

<table>
<thead>
<tr>
<th>Description</th>
<th>Document</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-867.1U PILine® controller</td>
<td>MS223E user manual</td>
</tr>
<tr>
<td>C-867.2U2 PILine® controller</td>
<td>MS231E user manual</td>
</tr>
<tr>
<td>C-877.1U11 PILine® controller</td>
<td>MS232E user manual</td>
</tr>
<tr>
<td>C-877.2U12 PILine® controller</td>
<td>MS233E user manual</td>
</tr>
<tr>
<td>C-867.10C885 PILine® controller module</td>
<td>C867T0017 user manual</td>
</tr>
<tr>
<td>PIMikroMove</td>
<td>SM148E software manual</td>
</tr>
<tr>
<td>PILine® stages</td>
<td>MP121EK short instructions</td>
</tr>
</tbody>
</table>

1.6 Downloading Manuals

**INFORMATION**

If a manual is missing or problems occur with downloading:

- Contact our customer service department (p. 37).

**INFORMATION**

For products that are supplied with software (CD in the scope of delivery), access to the manuals is protected by a password. Protected manuals are only displayed on the website after entering the password.

The password is included on the CD of the product.

**For products with CD: Identify the password**

1. Insert the product CD into the PC drive.
2. Switch to the Manuals directory on the CD.
3. In the Manuals directory, open the Release News (file including releasenews in the file name).
4. Find the user name and the password in the section "User login for software download" in the Release News.
1 About this Document

**Downloading manuals**

1. Open the website [www.pi.ws](http://www.pi.ws).
2. If access to the manuals is protected by a password:
   a) Click *Login*.
   b) Log in with the user name and password.
3. Click *Search*.
4. Enter the product number up to the period (e.g., P-882) or the product family (e.g., PICMA® Bender) into the search field.
5. Click *Start search* or press the *Enter* key.
6. Open the corresponding product detail page in the list of search results:
   a) If necessary: Scroll down the list.
   b) If necessary: Click *Load more results* at the end of the list.
   c) Click the corresponding product in the list.
7. Scroll down to the *Downloads* section on the product detail page. The manuals are displayed under *Documentation*.
8. Click the desired manual and save it to the hard disk of your PC or to a data storage medium.
2 Safety

In this Chapter

Intended Use ................................................................. 5
General Safety Instructions ............................................. 5
Organizational Measures .................................................. 6

2.1 Intended Use

The U-521 is a laboratory device as defined by DIN EN 61010-1. It is intended for indoor use and use in an environment that is free of dirt, oil, and lubricants.

In accordance with its design, the U-521 is intended for single-axis positioning, adjusting and shifting of loads at various velocities in interval operation. The U-521 is not intended for applications in areas in which a failure would present severe risks to human beings or the environment.

The intended use of the U-521 is only possible when completely mounted and connected.

The U-521 uses a PILine® ultrasonic piezo linear motor as a drive and has to be operated with a suitable controller (p. 10). The controller is not included in the scope of delivery of the U-521.

2.2 General Safety Instructions

The U-521 is built according to state-of-the-art technology and recognized safety standards. Improper use can result in personal injury and/or damage to the U-521.

- Only use the U-521 for its intended purpose, and only use it if it is in a good working order.
- Read the user manual.
- Immediately eliminate any faults and malfunctions that are likely to affect safety.

The operator is responsible for the correct installation and operation of the U-521.

Piezomotors are driven by piezo actuators. After disconnection from the electronics, piezo actuators can remain electrically charged for several hours. Temperature changes can also induce charges in piezo actuators. Touching charged parts of the U-521 can cause slight injuries from electric shock.

- Do not open the U-521.
- Do not touch the contacts in the connector of the U-521.
If a protective earth conductor is not or not properly connected, dangerous touch voltages can occur on the U-521 in the case of malfunction or failure of the system. If touch voltages exist, touching the U-521 can result in minor injuries from electric shock.

- Connect the U-521 to a protective earth conductor (p. 16) before start-up.
- Do not remove the protective earth conductor during operation.
- If the protective earth conductor has to be removed temporarily (e.g., in the case of modifications), reconnect the U-521 to the protective earth conductor before starting it up again.

Mechanical forces can damage or misalign the U-521.

- Avoid impacts that affect the U-521.
- Do not drop the U-521.
- Do not exceed the maximum permissible stress and load capacities (p. 39).

### 2.3 Organizational Measures

#### User manual

- Always keep this user manual available with the U-521. The latest versions of the user manuals are available for download (p. 3) on our website.
- Add all information from the manufacturer to the user manual, for example supplements or technical notes.
- If you give the U-521 to other users, also include this user manual as well as other relevant information provided by the manufacturer.
- Only use the device on the basis of the complete user manual. Missing information due to an incomplete user manual can result in minor injury and damage to equipment.
- Only install and operate the U-521 after you have read and understood this user manual.

#### Personnel qualification

The U-521 may only be installed, started up, operated, maintained, and cleaned by authorized and appropriately qualified personnel.
3 Product Description

In this Chapter

Model Overview ................................................................. 7
Product View ........................................................................ 8
Product Labeling ................................................................. 8
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Suitable Controllers ............................................................. 10
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3.1 Model Overview

The U-521 is available in the following versions:

<table>
<thead>
<tr>
<th>Model</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>U-521.23</td>
<td>Small linear stage with PILine® ultrasonic piezomotors, 35 mm width, 2 N drive force, 18 mm travel range. Direct position measurement with</td>
</tr>
<tr>
<td></td>
<td>incremental encoder, 0.4 µm resolution, Sub-D connector</td>
</tr>
<tr>
<td>U-521.23V*</td>
<td>Small linear stage with PILine® ultrasonic piezomotors, 35 mm width, 2 N drive force, 18 mm travel range. Direct position measurement with</td>
</tr>
<tr>
<td></td>
<td>incremental encoder, 0.4 µm resolution, Sub-D connector, vacuum compatible to 10⁻⁶ hPa</td>
</tr>
<tr>
<td>U-521.24</td>
<td>Small linear stage with PILine® ultrasonic piezomotors, 35 mm width, 2 N drive force, 18 mm travel range. Direct position measurement with</td>
</tr>
<tr>
<td></td>
<td>incremental encoder, 0.1 µm resolution, Sub-D connector</td>
</tr>
<tr>
<td>U-521.24V*</td>
<td>Small linear stage with PILine® ultrasonic piezomotors, 35 mm width, 2 N drive force, 18 mm travel range. Direct position measurement with</td>
</tr>
<tr>
<td></td>
<td>incremental encoder, 0.1 µm resolution, Sub-D connector, vacuum compatible to 10⁻⁶ hPa</td>
</tr>
</tbody>
</table>

* Vacuum versions available on request
### 3.2 Product View

![U-521 product view](image)

Figure 1: U-521 product view

1. Cable exit
2. Motion platform
3. Base body

Double arrow: Direction of motion of the stage

### 3.3 Product Labeling

![U-521: Position of the product labeling](image)

Figure 2: U-521: Position of the product labeling (example view)
### 3 Product Description

#### Position | Labeling | Description
--- | --- | ---
A | U-521.23 | Product name (example), the characters following the period refer to the model
A | 116007748 | Serial number (example), individual for each U-521
|  | Meaning of the places (counting from left):
|  | 1 = internal information
|  | 2 and 3 = year of manufacture
|  | 4 to 9 = consecutive numbers
A+B | WWW.PI.WS | Manufacturer's address (website)
A | | Data matrix code (example; contains the serial number)
B | PI | Manufacturer's logo
B | PILine® | Brand name
B | Country of origin: Germany | Country of origin
B | | CE conformity mark
B | | Old equipment disposal (p. 49)
B | | Warning sign "Observe manual!"
B | | Symbol for the protective earth conductor (p. 16)

![Achtung! Restspannung](image)

Figure 3: "Residual Voltage" warning sign on the connector of the U-521
Warning sign "Residual voltage": Notice of risk of electric shock (p. 5)

### 3.4 Scope of Delivery

<table>
<thead>
<tr>
<th>Product number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>U-521</td>
<td>Stage according to order (p. 7)</td>
</tr>
</tbody>
</table>
| 000055389 | Screw set:
| | - 4 socket head screws, M1.6x8 ISO 4762
| | - 1 hex key |
| MP121EK | Short instructions for PILine® stages |
3.5 Suitable Controllers

<table>
<thead>
<tr>
<th>Product number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-867.1U</td>
<td>Piezomotor controller, networkable, 1 axis, for PILine® systems</td>
</tr>
<tr>
<td>C-867.2U2</td>
<td>Piezomotor controller, networkable, 2 axes, for PILine® systems</td>
</tr>
<tr>
<td>C-877.1U11</td>
<td>Compact, inexpensive piezomotor controller / driver, 1 axis, for PILine® systems with low power consumption</td>
</tr>
<tr>
<td>C-877.2U12</td>
<td>Compact piezomotor controller / driver, 2 axes, for PILine® systems</td>
</tr>
<tr>
<td>C-867.10C885</td>
<td>Motion controller module for PILine® piezomotor systems with Sub-D connector, 1 axis, for PImotionMaster</td>
</tr>
</tbody>
</table>

➢ To order, contact our customer service department (p. 37).

3.6 Accessories

<table>
<thead>
<tr>
<th>Product number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-815.VF</td>
<td>Vacuum feedthrough, Sub-D 15-pin, including C815T0003 technical note</td>
</tr>
<tr>
<td>U-600.A01</td>
<td>Extension cable for PILine®, Sub-D 15-pin, 1 m*</td>
</tr>
<tr>
<td>U-600.A03</td>
<td>Extension cable for PILine®, Sub-D 15-pin, 3 m*</td>
</tr>
<tr>
<td>U-600.A05</td>
<td>Extension cable for PILine®, Sub-D 15-pin, 5 m*</td>
</tr>
</tbody>
</table>

* Other cable lengths available on request.

➢ To order, contact our customer service department (p. 37).

3.7 Technical Features

3.7.1 Linear Encoder

The U-521 is equipped with an optical linear encoder. For the resolution, refer to the table in the "Specifications" section (p. 39).

Optical linear encoders measure the actual position directly (direct metrology). Therefore, errors occurring in the drivetrain such as nonlinearity, backlash or elastic deformation, cannot influence the measurement of the position.
3.7.2 Reference Point Switch

The U-521 is equipped with a direction-sensing reference point switch, which is located at about the midpoint of the travel range. This sensor transmits a TTL signal that indicates whether the stage is on the positive or negative side of the reference point switch.

See the controller user manual and/or associated software manuals for the commands that make use of the reference point signal.

For more information, see "Reference Point Switch Specifications" (p. 40).

3.7.3 ID Chip

The connector of the U-521 stages contains an ID chip. Information on the stage (e.g., type, serial number, date of manufacture, version of the hardware) is stored in parameters on the ID chip.

When switched on or rebooted, controllers from PI read the data from the ID chip.

For more information on the ID chip recognition, see the manual of the controller used.
4 Unpacking

INFORMATION

When handling the vacuum version of the stage, attention must be paid to appropriate cleanliness. At PI, all parts are cleaned before assembly. During assembly and measurement, powder-free gloves are worn. In addition, the stage is wipe cleaned afterwards and then shrink-wrapped twice in vacuum-compatible film.

- Only touch the stage with powder-free gloves.
- If necessary, wipe the stage clean after unpacking.

1. Unpack the U-521 with care.
2. Compare the contents with the items listed in the contract and the packing list.
3. Inspect the contents for signs of damage. If parts are missing or you notice signs of damage, contact PI immediately.
4. Keep all packaging materials in case the product needs to be returned.
5 Installation

In this Chapter

General Notes on Installation ................................................................. 15
Mounting the U-521 on a Surface and Connecting It to a Protective Earth Conductor .......... 16
Affixing the Load to the U-521 .................................................................. 21
Setting Up a Multi-Axis System ................................................................. 22
Connecting the Vacuum Version to the Controller ........................................ 25

5.1 General Notes on Installation

CAUTION

Dangerous voltage and residual charge on piezo actuators!
Piezomotors are driven by piezo actuators. After disconnection from the electronics, piezo actuators can remain electrically charged for several hours. Temperature changes can also induce charges in piezo actuators. Touching or short-circuiting the contacts in the connector of the U-521 can lead to minor injuries from electric shock.

➢ Do not touch the contacts in the connector of the U-521.

NOTICE

Lubricants, dirt, condensation!
Dirt, oil, lubricants and condensation will render the motor/drive inoperable.

➢ Ensure that the piezomotor of the U-521 does not come into contact with lubricants.
➢ Keep the U-521 free from dirt and condensation.

NOTICE

Heating up of the U-521 during operation!
The heat produced during operation of the U-521 can affect your application.

➢ Install the U-521 so that your application is not affected by the dissipating heat.
### NOTICE

**Unsuitable cables!**

Unsuitable cables can cause damage to the controller and affect the performance of the U-521.

- Only use genuine PI parts to connect the U-521 to the controller.
- If you need longer cables, use extension cables from PI (p. 10).

### INFORMATION

For optimum repeatability, all components must be firmly affixed to each other.

### INFORMATION

When moving the motion platform in a power off state manually, differences in the holding force may be noticeable across the travel range.

There are mechanical reasons for fluctuations in the holding force and they have no influence on the function of the stage.

- If possible, simulate the stage motions with a mounted load or make suitable calculations in order to identify collisions or unfavorable center of gravity constellations.
- If necessary, take suitable constructive measures to avoid collisions and instabilities in the overall system.
- Avoid or mark danger zones that result from the installation of the stage and the application in accordance with the legal regulations.

For more information on operating conditions, refer to the "Motor Power" section (p. 43).

### 5.2 Mounting the U-521 on a Surface and Connecting It to a Protective Earth Conductor

### NOTICE

**Protruding screw heads!**

Protruding screw heads can damage the U-521.

- Ensure that the screw heads do not protrude from countersunk holes so that they do not interfere with the stage motion.
NOTICE

Screws that are too long!
Mounting from below: Screws that are inserted too deeply can damage the U-521.
- Observe the depth of the mounting holes in the base body of the U-521 (p. 47).
- Only use screws of the correct length for the respective mounting holes.

Warping of the base body!
Incorrect mounting can warp the base body. Warping of the base body will increase wear and reduce accuracy.
- Mount the U-521 on an even surface. The recommended flatness of the surface is 10 µm.
- For applications with large temperature changes:
  Only affix the U-521 to surfaces that have the same or similar thermal expansion properties as the U-521 (e.g., surfaces made of aluminum).

INFORMATION

Contact of the U-521 with the protective earth conductor is made as follows:
- Three mounting holes in the base body of the U-521
- Suitable conductive screws (p. 9)
- Protective earth conductor connected to the surface on which the U-521 is mounted

INFORMATION

- Observe the applicable standards for connecting the protective earth conductor.

INFORMATION

The directions of motion of the U-521 are indicated in the product view (p. 8).
Possible uses for the mounting holes

The three mounting holes in the base body of the U-521 are intended for the following mounting possibilities:

<table>
<thead>
<tr>
<th>Mounting possibility</th>
<th>View of the mounting holes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Default:</td>
<td><img src="image" alt="Countersunk holes for mounting with M1.6 screws" /></td>
</tr>
<tr>
<td>▪ Mounting with M1.6 screws from above; M1.6 threaded holes must be made in the surface</td>
<td><img src="image" alt="U-521, view from above: Countersunk holes for mounting with M1.6 screws" /></td>
</tr>
<tr>
<td>Alternative:</td>
<td><img src="image" alt="Threaded holes for mounting with M2 screws" /></td>
</tr>
<tr>
<td>▪ Mounting with M2 screws from below; the M2 threads of the mounting holes of the U-521 are used</td>
<td><img src="image" alt="U-521, view from below: Threaded holes for mounting with M2 screws" /></td>
</tr>
</tbody>
</table>

Possible orientations of the U-521

The U-521 can be mounted on a surface in different orientations.

<table>
<thead>
<tr>
<th>Optimum:</th>
<th>Optimum:</th>
</tr>
</thead>
<tbody>
<tr>
<td>g = gravity</td>
<td>g = gravity, 1 = guide</td>
</tr>
<tr>
<td>Horizontal mounting of the stage</td>
<td>Vertical mounting with horizontal orientation of the motion axis; the guide points upwards.</td>
</tr>
</tbody>
</table>
### Not recommended:

| g = gravity, 1 = guide | g = gravity  
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical mounting with horizontal orientation of the motion axis: The increased load on the guide can reduce the lifetime of the U-521.</td>
<td>Vertical orientation of the motion axis: The increased load on the motor can reduce the lifetime of the U-521. Gravity compensation is required depending on the load (see below).</td>
</tr>
</tbody>
</table>

### INFORMATION

With a vertically oriented motion axis, the U-521 can reliably move a maximum load of 100 g without gravity compensation. The velocity is correspondingly reduced; see "Velocity and Dynamic Force" (p. 44).

For operating the U-521 with a vertically oriented motion axis and load >100 g:

- Mount suitable gravity compensation. Contact our customer service department (p. 37) for details on gravity compensation.

### Requirements

- You have read and understood the general notes on installation (p. 15).
- You have provided a suitable surface (for the required position and depth of the holes for accommodating the screws, see "Dimensions", p. 47).
  - The surface must be connected to the protective earth conductor.
  - When mounting from above: Three M1.6 holes are provided with a thread depth of at least 5 mm.
  - When mounting from below: Three through holes are provided for M2 screws.
  - The holes for accommodating the screws have to be sufficiently conductive to ensure the proper functioning of the protective earth conductor.
  - The flatness of the surface is ≤10 µm.
  - For applications with large temperature changes: The surface should have the same thermal expansion properties as the U-521 (e.g., surface made of aluminum).
5 Installation

✓ You have accounted for the space required to route cables without bending and according to regulations.
✓ The U-521 is not connected to the controller.

Tools and accessories

- Suitable protective earth conductor: Cross-sectional area of the cable \( \geq 0.75 \text{ mm}^2 \)
- Mounting accessories in the scope of delivery (p. 9):
  - 3 M1.6 screws
  - Hex key
- Alternative (not in the scope of delivery):
  - 3 electrically conductive M2 screws of appropriate length (p. 47)
  - Suitable screwdriver

Mounting the U-521 onto a surface and connecting it to a protective earth conductor

1. Align the U-521 on the surface so that the corresponding holes in the U-521 and the surface overlap.
2. Mount the U-521 onto the surface from above or from below:
   Mounting from above with three M1.6x5 screws:
   a) Manually move the motion platform of the U-521 until one of the three countersunk holes in the base body is accessible.
   b) Insert a screw from above into the countersunk hole in the base body of the U-521.
   c) Tighten the screw with a torque of 16 Ncm.
   d) Make sure that the screw head does not protrude from the countersunk hole.
   e) Manually move the motion platform of the U-521 until the other two countersunk holes in the base body are accessible.
   f) Insert two screws from above into the countersunk holes in the base body of the U-521.
   g) Starting with the screw that is diagonally opposite to the screw already tightened, tighten the two screws with a torque of 16 Ncm each.
   h) Make sure that the screw heads do not protrude from the countersunk holes.
   Mounting from below with three M2 screws:
   a) Insert the three screws through the holes in the surface into the base body of the U-521 from below.
   b) Tighten the three screws with a torque of 20 Ncm each.
   c) Make sure that the screws do not interfere with the motion of the platform of the U-521.
3. Make sure that the contact resistance at all connection points relevant for attaching the protective earth conductor is \(<0.1 \Omega \text{ at } 25 \text{ A.} \)
4. Check that the U-521 is affixed firmly to the surface.
5.3 Affixing the Load to the U-521

**NOTICE**

**Impermissibly high forces and torques!**
Impermissibly high forces and torques that are applied to the motion platform can damage the stage.

- For affixing type and mass of the load, observe the maximum permissible forces according to the specifications (p. 39).
- When the motion axis of the stage is oriented vertically, ensure that the installed load is lower than the holding force of the drive (see "Data Table" (p. 39) and "Influence of Downtimes on the Static Holding Force" (p. 46)).
- Avoid tilting torques on the motion platform.

**NOTICE**

**Screws that are too long!**
The U-521 can be damaged by screws that are too long.

- Note the depth of the mounting holes in the motion platform (p. 47).
- Only use screws of the correct length for the respective mounting holes.

**INFORMATION**

With a vertically oriented motion axis, the U-521 can reliably move a maximum load of 100 g without gravity compensation. The velocity is correspondingly reduced; see "Velocity and Dynamic Force" (p. 44).

For operating the U-521 with a vertically oriented motion axis and load >100 g:

- Mount suitable gravity compensation. Contact our customer service department (p. 37) for details on gravity compensation.

---

![Figure 6: U-521, M1.6 holes for affixing the load](image-url)
5 Installation

Requirements

- You have read and understood the general notes on installation (p. 15).
- You have properly mounted the U-521 onto a surface.
- The U-521 is not connected to the controller.
- You have prepared the load so that it can be affixed to the mounting holes on the motion platform:
  - The distance between the center of gravity of the load and the center of the motion platform is as small as possible in all directions.
  - At least three points are provided for affixing the load on the motion platform.

Tools and accessories

- At least three M1.6 screws of suitable length (p. 47)
- Suitable tools for tightening the screws

Affixing the load

1. Align the load on the U-521 so that the mounting holes in the load and the holes in the motion platform overlap.
2. Affix the load with at least three screws.
3. Check that the load is affixed firmly to the motion platform of the U-521.

5.4 Setting Up a Multi-Axis System

5.4.1 General Information on Setting Up a Multi-Axis System

NOTICE

Impermissibly high forces and torques!
Impermissibly high forces and torques that are applied to the motion platforms of the stages in a multi-axis system can damage the stages.

- Include the mass of the stage that is moved in the calculation of the load to be moved.
- With respect to the mass and the mounting type, observe the maximum permissible forces for each individual stage according to the specifications (p. 39).
- Avoid tilting torques on the motion platforms: Make sure that the distance between the center of gravity of the load and the center of the motion platform is as small as possible in all directions for the individual stages.
- When the motion axis of the stage is oriented vertically, make sure that the installed load is lower than the holding force of the drive.
NOTICE

Screws that are too long!
Screws that are inserted too deeply can damage the lower stage.

- Observe the depth of the mounting holes in the motion platform (p. 47) of the lower stage.
- Only use screws of the correct length for the respective mounting holes.

- Only install and operate the multi-axis system after you have read and understood the user manuals for all components of the multi-axis system.
- If you need special mounting adapters, contact our customer service department (p. 37).

5.4.2 Setting Up an XY System
Two linear positioning stages can be stacked to form an XY system as shown below:

Figure 7: Example of a stacked XY system

Requirements

✓ You have read and understood the general notes on installation (p. 15).
✓ You have read and understood the general notes on setting up a multi-axis system (p. 22).

Tools and accessories

- 3 electrically conductive M1.6 screws of suitable length (p. 47) (screws not included in the scope of delivery)
- Suitable tool for tightening the screws
Mounting the U-521 on the U-521

1. Position the upper U-521 offset by 90° on the lower U-521 so that the following conditions are met:
   - The base body of the upper U-521 exactly covers the motion platform of the lower U-521.
   - The holes in the base body of the upper U-521 cover the corresponding holes in the motion platform of the lower U-521.
   It is possible to rotate the cable exit by 180°.
2. Manually move the motion platform of the upper U-521 until one of the three countersunk holes in the base body is accessible (see hatched arrow in illustration).
3. Insert a screw into the countersunk hole in the base body of the upper U-521.
4. Tighten the screw with a torque of 16 Ncm.
5. Make sure that the screw head does not protrude from the countersunk hole.
6. Manually move the motion platform of the upper U-521 until both other countersunk holes in the base body are accessible.
7. Insert two screws into the countersunk holes in the base body of the upper U-521.
8. Starting with the screw that is diagonally opposite to the screw already tightened, tighten the two screws with a torque of 16 Ncm each.
9. Make sure that the screw heads do not protrude from the countersunk holes.
5.5 Connecting the Vacuum Version to the Controller

For the vacuum version of the U-521, it is necessary to install a vacuum feedthrough (p. 10).

Requirements

- You have read and understood the general notes on installation (p. 15).
- The controller is switched off.
- You have connected the U-521 to the protective earth conductor (p. 16).
- You have read and understood the C815T0003 technical note for the C-815.VF vacuum feedthrough.

Tools and accessories

- C-815.VF vacuum feedthrough (p. 10), Sub-D 15
- U-600.A0x (p. 10) PILine® extension cable, Sub-D 15, 1 m to 5 m, air-side
- Suitable tools for installing the vacuum feedthrough

Installing the vacuum feedthrough

1. The dimensions of the vacuum feedthrough are in the C815T0003 technical note (see "shell size 2").
2. Provide a suitable opening for the vacuum chamber.
3. Install the vacuum feedthrough so that the Sub-D 15 (f) socket is in the vacuum chamber.

Connecting the vacuum version to the controller

- Connect the U-521 ("stage"), vacuum feedthrough and controller as shown in the connection diagram below.
  - Observe the assignment that is given by the labeling on the sockets, connectors and cables.

![Connection Diagram](image)

Figure 9: Connection of the vacuum version to the controller
6 Startup and Operation

In this Chapter

General Notes on Startup and Operation................................................................. 27
Starting up the U-521............................................................................................... 30

6.1 General Notes on Startup and Operation

**CAUTION**

Risk of electric shock if the protective earth conductor is not connected!
If a protective earth conductor is not or not properly connected, dangerous touch voltages can occur on the U-521 in the case of malfunction or failure of the system. If touch voltages exist, touching the U-521 can result in minor injuries from electric shock.

- Connect the U-521 to a protective earth conductor (p. 16) before start-up.
- Do not remove the protective earth conductor during operation.
- If the protective earth conductor has to be removed temporarily (e.g., in the case of modifications), reconnect the U-521 to the protective earth conductor before starting it up again.

**NOTICE**

Damage if an incorrect controller is connected!
Connecting a stage to an unsuitable controller can cause damage to the stage or controller.

- Only connect stages with PILine® ultrasonic piezomotors to PILine® controllers (p. 10).

**NOTICE**

Operating voltage too high or incorrectly connected!
Operating voltages that are too high or incorrectly connected can cause damage to the U-521.

- Only operate the U-521 with controllers/driver and original accessories from PI.
- Do not exceed the operating voltage range (p. 41) for which the U-521 is specified.
- Only operate the U-521 when the operating voltage is properly connected; see "Pin Assignment" (p. 48).
**NOTICE**

Unintentional motion!

Unintentional motion of the stage is possible when connecting the U-521 to the controller. Defective software or wrong operation of the software can also result in unintentional motion.

- Do not place any objects in areas where they can be caught by moving parts.
- Before connecting the U-521, check whether a macro is defined as the start-up macro in the controller and cancel the selection of the start-up macro if necessary.

---

**NOTICE**

Damage due to collisions!

Collisions can damage the stage, the load to be moved, and the surroundings.

- Make sure that no collisions are possible between the stage, the load to be moved, and the surroundings in the motion range of the stage.
- Do not place any objects in areas where they can be caught by moving parts.
- Stop the motion immediately if a controller malfunction occurs.
- If possible, adapt the travel range limits of your mechanical system in the software that you use for commanding the motion.

---

**NOTICE**

Uncontrolled oscillation!

Your application can be damaged by uncontrolled oscillation of the U-521. If you encounter noise during operation:

- Immediately switch off the servo-control system of the affected axes.
- Check the settings of the servo-control parameters.

---

**NOTICE**

Collision of the motion platform with the hard stop!

The collision of the motion platform of the U-521 with the hard stop can lead to damage or considerable wear on the U-521.

- Prevent motion in open-loop operation.
- If motions in open-loop operation are necessary with the controller (p. 10):
  - Set the control value with the `SMO` command so that the axis moves with low velocity.
  - Stop the axis in time. For this purpose, use the `#24, STP` or `HLT` command, or set the control value to zero with the `SMO` command.
- Ensure that the end of the travel range is approached at low velocity.
- Only make changes to the velocity, acceleration, deceleration, and load in small steps.
NOTICE

Overheating during continuous operation!
The highest dynamic force and holding force are achieved at maximum motor power; however, the U-521 may overheat during continuous operation.

- Observe the recommended motor power depending on the duty cycle and the ambient temperature (p. 45).

NOTICE

Damage or considerable wear due to high accelerations!
High accelerations can cause damage to or considerable wear on the mechanical system.

- Stop the motion immediately if a controller malfunction occurs.
- Determine the maximum velocity for your application.
- Observe the information in the "Motor Power" section (p. 43).

INFORMATION

Although the U-521 operates quietly in theory, noise levels of up to 50 dB (A) are possible during operation. The ultrasonic drive of the U-521 can also generate higher noise levels at frequencies between 100 and 500 kHz.

INFORMATION

For maximum force generation, a run-in procedure is necessary during the start-up of the U-521 and after longer downtimes; see also "Influence of Downtimes on the Static Holding Force" (p. 46). After run-in, the U-521 will generate its maximum dynamic force.

- For run-in, command a few motion cycles at low velocity over the entire travel range.

INFORMATION

In a vacuum, there is no heat dissipation via convection.

- Operate the vacuum version of the U-521 with 20 % lower motor power than specified in "Motor power and lifetime" (p. 45) or reduce the duty cycle.

INFORMATION

The directions of motion of the U-521 are indicated in the product view (p. 8).

For more information on operating conditions, refer to the "Motor Power" section (p. 43).
6.2 Starting up the U-521

**NOTICE**

Incorrect parameter settings!

If you use the software that is included in the scope of delivery of the controller (p. 10), the operating parameters of the U-521 can be loaded from a stage database. The stage database contains the default parameter values of your stage for performing initial test motions during start-up. Depending on the application, using the default parameter values (e.g., for P term, I term, D term, acceleration and velocity) can cause damage to the stage, especially when operated with heavy loads.

- If possible: Perform the first start-up without a load.
- Always install the latest version of the stage database onto your PC.

For start-up with a load:

- Before start-up, make sure that the U-521 has been properly installed (p. 15).
- For optimum performance of the moving axis, adjust the operating parameters of the controller (e.g., P term, I term, D term, acceleration, velocity; see controller manual).
- Save the new parameter values to a stage database on the PC or to the nonvolatile memory of the controller for future use (see controller manual and PIMikroMove manual).

**INFORMATION**

If the total cable length between the stage and the controller is more than 3 m, it is necessary to adjust the parameter values in the controller for optimum motor power. The default parameter values in the stage database are suitable for a total cable length of 3 m.

**Total cable length of 3 m to 6.5 m:**

1. Adjust the value of the Frequency Shift parameter (ID 0x64) in the controller. Possible values: 20, 15, 10, 5, 0, -5, -10, -15, -20.
2. Repeat step 1 until the U-521 has reached optimum motor power.
3. Save the new parameter values to a stage database on the PC or the nonvolatile memory of the controller for future use (see controller manual and PIMikroMove manual).

**Total cable length >6.5 m:**

- Contact our customer service department (p. 37).

**Requirements**

- You have read and understood the general notes on start-up and operation (p. 27).
- You have read and understood the user manual of the controller (p. 3).
- In the case of start-up with a load: The U-521 has been properly installed (p. 15).
- The controller (p. 10) and the required software have been installed. All connections on the controller have been set up (see controller manual).
Starting up the U-521

- Start up the axis (see controller manual).

Start-up involves the following steps:

- Selecting the stage type
- Defining the reference point of the axis
- Commanding initial motions in closed-loop operation for testing and for run-in of the mechanical system

The controller manual describes start-up using the PIMikroMove program.
7 Maintenance

In this Chapter

- General Notes on Maintenance ................................................................. 33
- Performing a Maintenance Run ................................................................. 33
- Cleaning the U-521 ................................................................................. 34

7.1 General Notes on Maintenance

**NOTICE**

Damage due to improper maintenance!

Improper maintenance can result in the failure of the U-521.

- Only loosen screws according to the instructions in this manual.
- Ensure that the piezomotor of the stage does not come into contact with lubricants.

7.2 Performing a Maintenance Run

Depending on the operating conditions and the period of use of the U-521, the following maintenance measures are required:

**Maintenance Run**

The maintenance run is performed to distribute the existing lubricant on the guides of the U-521.

- To evenly distribute the existing lubricant on the stage guidings, perform a run across the entire travel range after 500 hours of operation or after 1 year at the latest.
- If you move the U-521 continuously over a small working range (<20 % of the entire travel range) in industrial operation, perform a run across the entire travel range every 5000 motion cycles.

**Lubrication**

Under laboratory conditions, the guides of the U-521 only need to be lubricated in exceptional cases. For continuous industrial use, the lubrication intervals must be defined individually.

- If you have any questions on relubricating, contact our customer service department (p. 37).
- Make sure that the piezo motor of the U-521 does not come into contact with lubricants.
7.3 Cleaning the U-521

Requirements

✓ You have disconnected the stage from the controller.

Cleaning the stage

Only when the stage is not used in vacuum:

➢ If necessary, clean the surfaces of the stage with a cloth that is dampened with a mild cleanser or disinfectant.

Only when the stage is used in vacuum:

➢ Only touch the stage with powder-free gloves.
➢ If necessary, wipe the stage clean.
# Troubleshooting

<table>
<thead>
<tr>
<th>Problem</th>
<th>Possible causes</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noise during operation</td>
<td>Uncontrolled oscillation of the U-521</td>
<td>➢ Immediately switch off the servo-control system of the affected axes.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>➢ Check the settings of the servo-control parameters.</td>
</tr>
<tr>
<td>Stage positions inaccurately</td>
<td>Settling window around the target position is too large</td>
<td>➢ Reduce the settling window by changing the parameter values for the settling window limits on the controller. See the controller user manual (p. 3) for details.</td>
</tr>
<tr>
<td>Reaching the target position takes too long</td>
<td>Settling window around the target position is too small</td>
<td>➢ Enlarge the settling window by changing the parameter values for the settling window limits on the controller. See the controller user manual (p. 3) for details.</td>
</tr>
<tr>
<td>Increased wear</td>
<td>Warped base body</td>
<td>➢ Mount the U-521 on an even surface. The recommended flatness of the surface is 10 µm.</td>
</tr>
<tr>
<td>Reduced accuracy</td>
<td></td>
<td>➢ For applications with large temperature changes: Only mount the U-521 on surfaces that have the same or similar thermal expansion properties as the U-521 (e.g., surfaces made of aluminum).</td>
</tr>
<tr>
<td>No or limited motion</td>
<td>Excessive load</td>
<td>➢ For horizontally aligned motion axis: Reduce the load (see &quot;Data Table&quot;, p. 39).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>For vertically aligned motion axis: Reduce the load to a maximum of 100 g.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>If you want to operate the U-521 with a vertically aligned motion axis with a load of &gt;100 g:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>➢ Mount suitable gravity compensation. Contact our customer service department (p. 37) for details on gravity compensation.</td>
</tr>
</tbody>
</table>
### Troubleshooting

<table>
<thead>
<tr>
<th>Problem</th>
<th>Possible causes</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>The default parameter values are not suitable for operation with high</td>
<td>- Adjust the operating parameters according to the description in &quot;Starting</td>
<td>- Adjust the operating parameters according to the description in &quot;Start-</td>
</tr>
<tr>
<td>loads</td>
<td>loads</td>
<td>up the U-521&quot;.</td>
</tr>
<tr>
<td>The default parameter values are not suitable for a total cable length</td>
<td></td>
<td></td>
</tr>
<tr>
<td>of more than 3 m</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

If the problem that occurred with your system is not listed in the table above or cannot be solved as described, contact our customer service department (p. 37).
9 Customer Service

For inquiries and orders, contact your PI sales engineer or send us an email (service@pi.de).

- If you have questions concerning your system, have the following information ready:
  - Product and serial numbers of all products in the system
  - Firmware version of the controller (if present)
  - Version of the driver or the software (if present)
  - Operating system on the PC (if present)
- If possible: Take photographs or make videos of your system that can be sent to our customer service department if requested.

The latest versions of the user manuals are available for download (p. 3) on our website.
10 Technical Data

In this Chapter

Specifications ............................................................................................................................... 39
Ambient Conditions and Classifications ....................................................................................... 42
Motor Power ................................................................................................................................ 43
Dimensions .................................................................................................................................. 47
Pin Assignment .......................................................................................................................... 48

10.1 Specifications

10.1.1 Data Table

<table>
<thead>
<tr>
<th>Motion and positioning</th>
<th>U-521.23</th>
<th>U-521.24</th>
<th>Unit</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active axes</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Travel range</td>
<td>18</td>
<td>18</td>
<td>mm</td>
<td></td>
</tr>
<tr>
<td>Velocity, closed loop</td>
<td>200</td>
<td>200</td>
<td>mm/s</td>
<td>max.</td>
</tr>
<tr>
<td>Minimum incremental motion</td>
<td>2</td>
<td>0.3</td>
<td>µm</td>
<td>typ.</td>
</tr>
<tr>
<td>System resolution</td>
<td>0.4</td>
<td>0.1</td>
<td>µm</td>
<td></td>
</tr>
<tr>
<td>Bidirectional repeatability</td>
<td>±2</td>
<td>±0.2</td>
<td>µm</td>
<td></td>
</tr>
<tr>
<td>Linearity error (over the entire travel range)</td>
<td>8</td>
<td>4</td>
<td>µm</td>
<td></td>
</tr>
<tr>
<td>Pitch</td>
<td>±300</td>
<td>±300</td>
<td>µrad</td>
<td></td>
</tr>
<tr>
<td>Yaw</td>
<td>±300</td>
<td>±300</td>
<td>µrad</td>
<td></td>
</tr>
<tr>
<td>Sensor</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sensor type</td>
<td>Incremental encoder</td>
<td>Incremental encoder</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measurement principle</td>
<td>Optical</td>
<td>Optical</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measuring method</td>
<td>Direct measuring</td>
<td>Direct measuring</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sensor resolution</td>
<td>0.4</td>
<td>0.1</td>
<td>µm</td>
<td>typ.</td>
</tr>
<tr>
<td>Mechanical load capacity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Push force capacity</td>
<td>2</td>
<td>2</td>
<td>N</td>
<td>max.</td>
</tr>
<tr>
<td>Pull force capacity</td>
<td>2</td>
<td>2</td>
<td>N</td>
<td>max.</td>
</tr>
</tbody>
</table>
# Technical Data

## Drive properties

<table>
<thead>
<tr>
<th></th>
<th>PILine® ultrasonic piezomotor, performance class 1</th>
<th>PILine® ultrasonic piezomotor, performance class 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor type</td>
<td>PILine® ultrasonic piezomotor, performance class 1</td>
<td>PILine® ultrasonic piezomotor, performance class 1</td>
</tr>
<tr>
<td>Drive force</td>
<td>2 N max.</td>
<td>2 N max.</td>
</tr>
<tr>
<td>Holding force</td>
<td>2 N max.</td>
<td>2 N max.</td>
</tr>
</tbody>
</table>

## Connectors

<table>
<thead>
<tr>
<th></th>
<th>1 × Sub-D, 15-pin (m)</th>
<th>1 × Sub-D, 15-pin (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor/Sensor</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## Miscellaneous

<table>
<thead>
<tr>
<th></th>
<th>Optical</th>
<th>Optical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference point switch</td>
<td>Optical</td>
<td>Optical</td>
</tr>
<tr>
<td>Operating temperature</td>
<td>0 to 40 °C</td>
<td>0 to 40 °C</td>
</tr>
<tr>
<td>Material</td>
<td>Aluminum, anodized</td>
<td>Aluminum, anodized</td>
</tr>
<tr>
<td>Mass (stage without cable and connector (m))</td>
<td>40 g</td>
<td>40 g</td>
</tr>
<tr>
<td>Mass (stage with cable and connector (m))</td>
<td>160 g</td>
<td>160 g</td>
</tr>
<tr>
<td>Cable length</td>
<td>1.5 m typ.</td>
<td>1.5 m typ.</td>
</tr>
</tbody>
</table>

Specifications determined with the C-867.1U controller.
All specifications based on room temperature (22 °C ±3 °C).
Vacuum versions to 10⁻⁶ hPa available on request. Specifications for vacuum versions can differ.
Ask about custom designs!

### 10.1.2 Reference Point Switch Specifications

<table>
<thead>
<tr>
<th></th>
<th>Optical sensor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply voltage</td>
<td>+5 V/GND, supply via the motor connector</td>
</tr>
<tr>
<td>Signal output</td>
<td>TTL level</td>
</tr>
<tr>
<td>Signal logic</td>
<td>Direction sensing by means of different signal levels on the left and right side of the reference point switch: The signal level changes from 0 to +5 V when the reference point switch is passed.</td>
</tr>
<tr>
<td>Hysteresis</td>
<td>0.2 to 0.4mm (when approaching from a positive or negative direction)</td>
</tr>
</tbody>
</table>
10.1.3 Maximum Ratings

U-521 stages are designed for the following operating data:

<table>
<thead>
<tr>
<th>Maximum operating voltage</th>
<th>Operating frequency</th>
<th>Maximum power consumption*</th>
</tr>
</thead>
<tbody>
<tr>
<td>160 V&lt;sub&gt;pp&lt;/sub&gt; or 57 V&lt;sub&gt;eff&lt;/sub&gt;</td>
<td>210 to 225 kHz</td>
<td>10 W</td>
</tr>
</tbody>
</table>

* Typical power consumption with de-energized motor (cable length: approx. 1.5 meter):
  - U-521.23: 0.5 W
  - U-521.24: 0.8 W

10.1.4 Specifications for Vacuum-Compatible Versions

The following vacuum-compatible components are used for the vacuum version of the U-521:

<table>
<thead>
<tr>
<th>Component</th>
<th>Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical parts</td>
<td>Aluminum (blank), aluminum (anodized, black, matt), steel, ceramic (PIC181, Al&lt;sub&gt;2&lt;/sub&gt;O&lt;sub&gt;3&lt;/sub&gt;), PEEK, PTFE</td>
</tr>
<tr>
<td>Cable</td>
<td>FEP; ribbon cable (FFC) from Axon Kabel GmbH</td>
</tr>
<tr>
<td>Shrink tubing</td>
<td>PVDF (Kynar)</td>
</tr>
<tr>
<td>Connector</td>
<td>Sub-D 15 (m)</td>
</tr>
<tr>
<td>Insulation</td>
<td>KU-THE-150</td>
</tr>
<tr>
<td>Lubricant</td>
<td>Molykote HP-300</td>
</tr>
<tr>
<td>Sealant</td>
<td>Scotch Weld</td>
</tr>
<tr>
<td>Adhesives</td>
<td>Epoxy resin-based adhesive</td>
</tr>
</tbody>
</table>

Bakeout temperature: 80°C (176°F)
Bakeout time: 3 hours
10.2 Ambient Conditions and Classifications

The following ambient conditions and classifications for the U-521 must be observed:

<table>
<thead>
<tr>
<th>Area of application</th>
<th>For indoor use only</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum altitude</td>
<td>2000 m</td>
</tr>
<tr>
<td>Air pressure</td>
<td>1100 hPa to 0.1 hPa</td>
</tr>
<tr>
<td>Relative humidity</td>
<td>Highest relative humidity 80 % for temperatures up to 31 °C  Decreasing linearly to 50 % relative humidity at 40 °C</td>
</tr>
<tr>
<td>Operating temperature</td>
<td>0 °C to 40 °C</td>
</tr>
<tr>
<td>Storage temperature</td>
<td>-20 °C to 75 °C</td>
</tr>
<tr>
<td>Transport temperature</td>
<td>-20 °C to 75 °C</td>
</tr>
<tr>
<td>Overvoltage category</td>
<td>II</td>
</tr>
<tr>
<td>Protection class</td>
<td>I</td>
</tr>
<tr>
<td>Degree of pollution</td>
<td>1</td>
</tr>
<tr>
<td>Degree of protection according to IEC 60529</td>
<td>IP20</td>
</tr>
</tbody>
</table>
10 Technical Data

10.3  Motor Power

10.3.1  Motor Power and Operating Voltage

**INFORMATION**

The operating voltage is limited by the controller using the *Maximum Motor Output (V)* (ID 0x7c) parameter. If you load the operating parameters of the U-521 from the stage database, the parameter is set to the maximum permissible value.

The following table shows the relationship between the operating voltage and the motor power of the U-521. The operating voltage is output by the controller and depends on the actual control value. The polarity sign of the control value determines the direction of motion.

<table>
<thead>
<tr>
<th>Motor power</th>
<th>Operating voltage* (rounded)</th>
<th>Corresponding control value on the controller**</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 %</td>
<td>0 V&lt;sub&gt;eff&lt;/sub&gt;</td>
<td>0</td>
</tr>
<tr>
<td>25 %</td>
<td>14 V&lt;sub&gt;eff&lt;/sub&gt;</td>
<td>8192 or -8192</td>
</tr>
<tr>
<td>50 %</td>
<td>29 V&lt;sub&gt;eff&lt;/sub&gt;</td>
<td>16384 or -16384</td>
</tr>
<tr>
<td>75 %</td>
<td>43 V&lt;sub&gt;eff&lt;/sub&gt;</td>
<td>24575 or -24575</td>
</tr>
<tr>
<td>100 %</td>
<td>57 V&lt;sub&gt;eff&lt;/sub&gt; (max.)</td>
<td>32767 or -32767</td>
</tr>
</tbody>
</table>

* Exceeding the maximum value in the *Maximum Motor Output (V)* (ID 0x7c) parameter is not permitted and can damage the motor.

** Generated in closed-loop operation via the control algorithm or set in open-loop operation via the *SMO* command.

For further information, see the user manual of the controller (p. 3) used to operate the U-521.
10.3.2 Velocity and Dynamic Force

The following figure can be used to estimate the velocity and force of the U-521 with different motor powers. Motion is possible starting at a motor power of approx. 30 %.

Figure 10: Relationship between velocity and force of the U-521 with different motor power levels
10.3.3 Motor Power and Lifetime

Motor power, duty cycle and ambient temperature influence the lifetime of the stage. In order to prevent overheating and high wear, the motor power and the duty cycle should not exceed the limits given in the following graph. A load cycle corresponds to a positioning run and includes the acceleration, motion, deceleration as well as downtime (break). The motor should only sporadically be operated at peak power; the peak power serves as a control reserve.

**INFORMATION**

In a vacuum, there is no heat dissipation via convection.

- Operate the vacuum version of the U-521 with a 20 % lower motor power than given in the graph, or reduce the duty cycle.

Figure 11: U-521: Recommended duty cycle and motor power depending on the ambient temperature
10.3.4 Influence of Downtimes on the Static Holding Force

Figure 12: Static holding force of the U-521 depending on the downtime of the motor
10.4 Dimensions

Dimensions in mm. Note that the decimal places are separated by a comma in the drawings.

Figure 13: U-521
## 10.5 Pin Assignment

**Connector: Sub-D 15 (m)**

![Sub-D 15 connector](image)

*Figure 14: Front view of the Sub-D 15 connector*

<table>
<thead>
<tr>
<th>Pin</th>
<th>Signal</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>NC</td>
<td>Not connected</td>
</tr>
<tr>
<td>2</td>
<td>USM_P1</td>
<td>Input: Piezo 57 VAC (RMS)</td>
</tr>
<tr>
<td>3</td>
<td>USM_P2</td>
<td>Input: Piezo 57 VAC (RMS)</td>
</tr>
<tr>
<td>4</td>
<td>VDD</td>
<td>Input: +5 V</td>
</tr>
<tr>
<td>5</td>
<td>NC</td>
<td>Not connected</td>
</tr>
<tr>
<td>6</td>
<td>ID_CHIP</td>
<td>Bidirectional: Data line for ID chip</td>
</tr>
<tr>
<td>7</td>
<td>ENCA-</td>
<td>Output: Encoder channel A (inverted), RS-422</td>
</tr>
<tr>
<td>8</td>
<td>ENCB-</td>
<td>Output: Encoder channel B (inverted), RS-422</td>
</tr>
<tr>
<td>9</td>
<td>USM_P1</td>
<td>Input: Piezo 57 VAC (RMS)</td>
</tr>
<tr>
<td>10</td>
<td>GND</td>
<td>0 V</td>
</tr>
<tr>
<td>11</td>
<td>USM_P3</td>
<td>Input: Piezo 57 VAC (RMS)</td>
</tr>
<tr>
<td>12</td>
<td>NC</td>
<td>Not connected</td>
</tr>
<tr>
<td>13</td>
<td>REFSWITCH</td>
<td>Output: Reference point switch</td>
</tr>
<tr>
<td>14</td>
<td>ENCA+</td>
<td>Output: Encoder channel A, RS-422</td>
</tr>
<tr>
<td>15</td>
<td>ENCB+</td>
<td>Output: Encoder channel B, RS-422</td>
</tr>
</tbody>
</table>
11 Old Equipment Disposal

In accordance with EU law, electrical and electronic equipment may not be disposed of in EU member states via the municipal residual waste.

Dispose of your old equipment according to international, national, and local rules and regulations.

In order to fulfil its responsibility as the product manufacturer, Physik Instrumente (PI) GmbH & Co. KG undertakes environmentally correct disposal of all old PI equipment made available on the market after 13 August 2005 without charge.

Any old PI equipment can be sent free of charge to the following address:

Physik Instrumente (PI) GmbH & Co. KG
Auf der Roemerstr. 1
D-76228 Karlsruhe, Germany
For the U-521, an EU Declaration of Conformity has been issued in accordance with the following European directives:

- Low Voltage Directive
- EMC Directive
- RoHS Directive

The applied standards certifying the conformity are listed below.

- Safety (Low Voltage Directive): EN 61010-1
- EMC: EN 61326-1
- RoHS: EN 50581