PI

MP138E
U-521 Linear Stage
User Manual

Version: 1.3.0   Date: 02.12.2020

This document describes the following products:

▪ **U-521.23**
Small linear stage with PILine® ultrasonic piezo motors, 35 mm width, 2 N drive force, 18 mm travel range, incremental encoder, 0.4 µm resolution, D-sub connector

▪ **U-521.23V**
Small linear stage with PILine® ultrasonic piezo motors, 35 mm width, 2 N drive force, 18 mm travel range, incremental encoder, 0.4 µm resolution, D-sub connector, vacuum compatible to 10^{-6} hPa

▪ **U-521.24**
Small linear stage with PILine® ultrasonic piezo motors, 35 mm width, 2 N drive force, 18 mm travel range, incremental encoder, 0.1 µm resolution, D-sub connector

▪ **U-521.24V**
Small linear stage with PILine® ultrasonic piezo motors, 35 mm width, 2 N drive force, 18 mm travel range, incremental encoder, 0.1 µm resolution, D-sub connector, vacuum compatible to 10^{-6} hPa

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Subject to change without notice. This manual is superseded by any new release. The latest release is available for download (p. 3) on our website.

Contents

1 About this Document

In this Chapter

1.1 Objective and Target Audience of this User Manual

This user manual contains the information required for using the U-521 as intended.

It assumes that the reader has a fundamental understanding of basic servo systems as well as motion control concepts and applicable safety procedures.

1.2 Symbols and Typographic Conventions

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

CAUTION

Dangerous situation
Failure to comply could lead to minor injury.

➢ Precautionary measures for avoiding the risk.

NOTICE

Dangerous situation
Failure to comply could cause damage to equipment.

➢ Precautionary measures for avoiding the risk.

INFORMATION

Information for easier handling, tricks, tips, etc.

Symbol/Label	Meaning
1. 2.	Action consisting of several steps with strict sequential order
➢	Action consisting of one or more steps without relevant sequential order.
▪	Bullet
p. 5	Cross-reference to page 5
RS-232	Label on the product indicating an operating element (example: RS-232 interface socket)
⚠ ⚡	Warning signs attached to the product that refer to detailed information in this manual.

1.3   Definition of Terms

Term	Explanation
Load capacity	Maximum load capacity in the vertical direction when the positioner is mounted horizontally. The contact point of the load is at the center of the platform.
Linear encoder	The linear encoder is an incremental sensor for detecting changes in position. Signals from the sensor are used for axis position feedback. After switching the controller on, referencing must be done before absolute target positions can be commanded and reached.

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 from PI mentioned in this documentation are described in separate manuals.

Description	Document
C-867.1U PILine® Controller	MS223E User Manual
C-867.2U2 PILine® Controller	MS231E User Manual
C-877.1U11 PILine® Controller	MS232E User Manual
C-867.10C885 PILine® Controller Module	C867T0017 User Manual
PIMikroMove	SM148E Software Manual
PILine® Positioners	MP121EK Short Instructions

1.6   Downloading Manuals

INFORMATION

If a manual is missing or problems occur with downloading:
➢ Contact our customer service department (p. 37).

Downloading Manuals

1. Open the website **www.pi.ws**.

2. Search the website for the product number (e.g., U-521) or the product family (e.g., PILine®).

3. Click the corresponding product to open the product detail page.

4. Click the *Downloads* tab.

   The manuals are shown under *Documentation*. Software manuals are shown under *General Software Documentation*.

5. Click the desired manual and fill out the inquiry form.

   The download link will then be sent to the email address entered.

2 Safety

In this Chapter

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 where failure could lead to considerable risk to people or the environment.

It is only possible to use the U-521 as intended when it is installed and connected properly.

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.

➢ Use the U-521 for its intended purpose only, and only when it is in perfect technical condition.

➢ Read the user manual.

➢ Eliminate any malfunctions that may affect safety immediately.

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

Piezo motors are driven by piezo actuators. Piezo actuators can remain electrically charged for several hours after disconnecting the electronics. 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.

PI

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 there are touch voltages, touching the U-521 can result in minor injuries from electric shock.

> ➢ Connect the U-521 to a protective earth conductor (p. 16) before starting.

> ➢ 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 restarting.

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 together 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 a third party, include this user manual as well as other relevant information provided by the manufacturer.

> ➢ Do the work only if the user manual is complete. Missing information due to an incomplete user manual can result in minor injury and damage to equipment.

> ➢ Install and operate the U-521 only after you have read and understood this user manual.

Personnel qualification

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

3 Product Description

In this Chapter

3.1 Model Overview

The U-521 is available in the following versions:

Model	Description
U-521.23	Small linear stage with PILine® ultrasonic piezo motors, 35 mm width, 2 N drive force, 18 mm travel range. direct position measurement with incremental encoder, 0.4 µm resolution, D-sub connector
U-521.23V*	Small linear stage with PILine® ultrasonic piezo motors, 35 mm width, 2 N drive force, 18 mm travel range. direct position measurement with incremental encoder, 0.4 µm resolution, D-sub connector, vacuum compatible to 10^{-6} hPa
U-521.24	Small linear stage with PILine® ultrasonic piezo motors, 35 mm width, 2 N drive force, 18 mm travel range. direct position measurement with incremental encoder, 0.1 µm resolution, D-sub connector
U-521.24V*	Small linear stage with PILine® ultrasonic piezo motors, 35 mm width, 2 N drive force, 18 mm travel range. direct position measurement with incremental encoder, 0.1 µm resolution, D-sub connector, vacuum compatible to 10^{-6} hPa

* Vacuum versions available on request

3.2   Product View
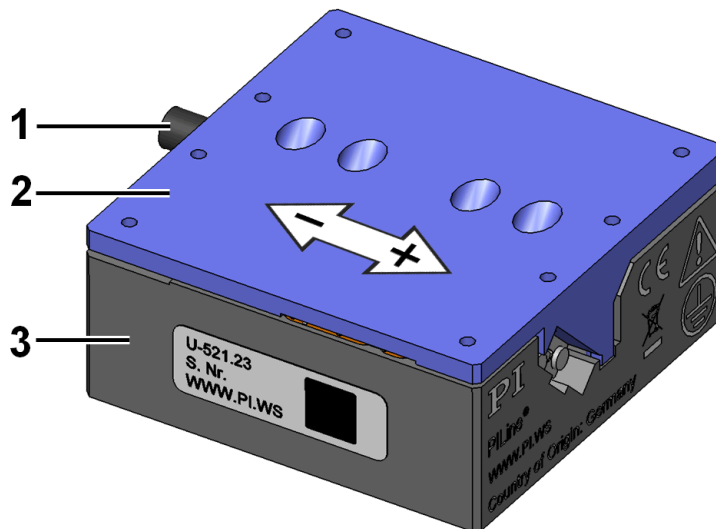
Figure 1:   U-521 product view

      1   Cable exit
      2   Motion platform
      3   Base body
      Double arrow: Direction of positioner motion

3.3   Product Labeling
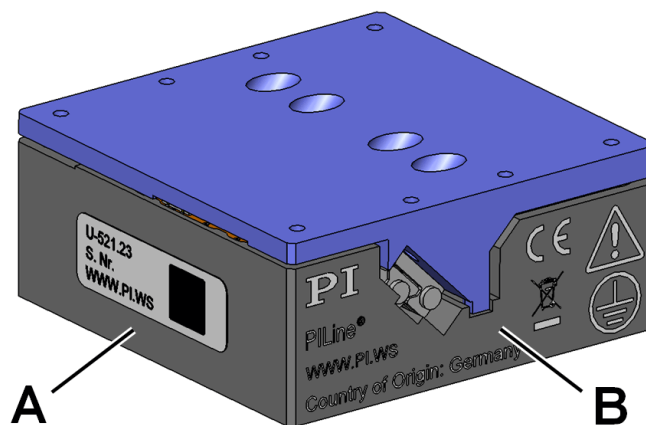
Figure 2:   U-521: Position of the product labeling (example view)

Position	Labeling	Description
a	U-521.23	Product name (example), the characters following the period refer to the model
a	123456789	Serial number (example), individual for each U-521 Meaning of each position (from the left): 1 = internal information 2 and 3 = year of manufacture 4 to 9 = consecutive number
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	C€	CE conformity mark
B	⌧	Old equipment disposal (p. 49)
B	⚠	Warning sign "Pay attention to the manual!"
B	⏚	Symbol for the protective earth conductor (p. 16)

Achtung!
Restspannung
Attention!
Residual Voltage

Figure 3: "Residual Voltage" warning sign on the connector of the U-521

Warning sign "Residual Voltage": Indicates risk of electric shock (p. 5)

3.4 Scope of Delivery

Product number	Description
U-521	Positioner according to order (p. 7)
000055389	Screw set: ▪ 4 socket head screws, M1.6x8 ISO 4762 ▪ 1 hex key
MP121EK	Short instructions for PILine® positioners

3.5 Suitable Controllers

Product number	Description
C-867.1U	Piezo motor controller for PILine® systems, 1 axis, USB, RS-232, SPI, I/O, analog joystick, networkable via daisy chain
C-867.2U2	Piezo motor controller for PILine® systems, 2 axes, USB, RS-232, TCP/IP, SPI, I/O, analog or digital joystick, networkable via daisy chain
C-877.1U11	Compact, inexpensive piezo motor controller / driver, 1 axis, for PILine® systems with low power consumption
C-867.10C885	Motion controller module for performance class 1 and 2 PILine® piezo motor systems, 1 axis, D-sub 15, for PIMotionMaster, PID controller

3.6 Accessories

Product number	Description
C-815.VF	Vacuum feedthrough, D-sub 15 (m/f), including C815T0003 technical note
U-600.A01	Extension cable for PILine®, D-sub 15-pin, 1 m*
U-600.A03	Extension cable for PILine®, D-sub 15-pin, 3 m*
U-600.A05	Extension cable for PILine®, D-sub 15-pin, 5 m*

* Other cable lengths available on request.

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 Switch

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

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

Refer to "Reference Switch Specifications" (p. 40) for more information.

3.7.3 ID Chip

The U-521 positioners have a connector with an ID chip. Information on the positioner (e.g., type, serial number, date of manufacture, hardware version) is stored in parameters on the ID chip.

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

You will find further information on ID chip recognition in the manual for the controller.

4 Unpacking

INFORMATION

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

➢ Touch the positioner only with powder-free gloves.

➢ If necessary, wipe the positioner clean after unpacking.

1. Unpack the U-521 with care.

2. Compare the contents with the scope of delivery according to the contract and the delivery note.

3. Inspect the contents for signs of damage. If any parts are damaged or missing, contact our customer service department (p. 37) immediately.

4. Keep all packaging materials in case the product needs to be returned.

5 Installation

In this Chapter

5.1 General Notes on Installing

CAUTION
Dangerous voltage and residual charge on piezo actuators!
Piezo motors are driven by piezo actuators. Piezo actuators can remain electrically charged for several hours after disconnecting the electronics. 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 piezo motor 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 connected firmly together.

INFORMATION

When moving the 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 positioner.

➢ If possible, simulate the positioner 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 positioner 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 onto an Underlying 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 motion.

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NOTICE

Excessively long screws!

Mounting from below: Screws inserted too deeply could damage the U-521.

➢ Pay attention to 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.

NOTICE

Warping the base body!

Incorrect mounting can warp the base body. A warped base body will increase wear and reduce accuracy.

➢ Mount the U-521 onto a flat surface. The recommended flatness of the surface is 10 µm.
➢ For applications with large temperature changes:
Only fix 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

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INFORMATION
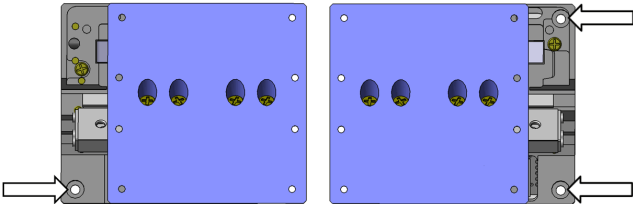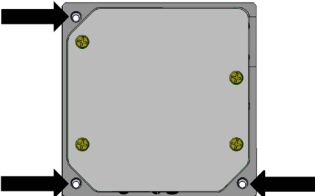
➢ Pay attention to the applicable standards for connecting the protective earth conductor.

INFORMATION

The U-521's direction of motion is indicated in the product view (p. 8).
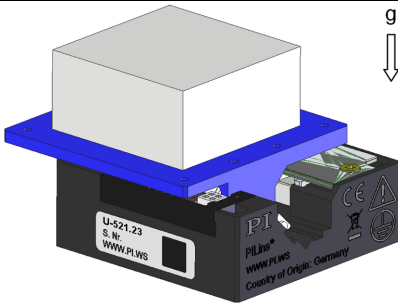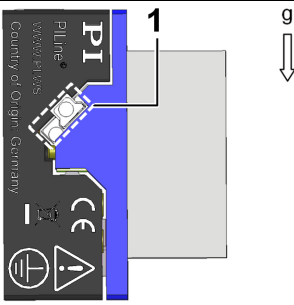
Possible uses for the mounting holes
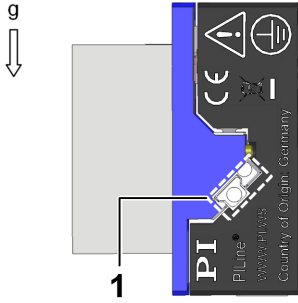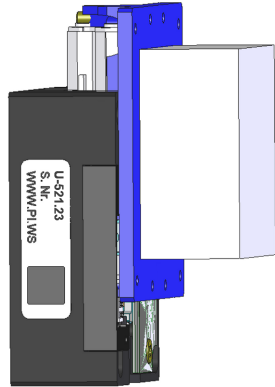
The three mounting holes in the base body of the U-521 are intended for the following mounting possibilities:

Mounting possibility	View of the mounting holes
Default: ■ Mounting with M1.6 screws from above; M1.6 threaded holes must be made in the surface	Figure 4: U-521, view from above: Countersunk holes for mounting with M1.6 screws
Alternative: ■ Mounting with M2 screws from below; the M2 threads of the mounting holes of the U-521 are used	Figure 5: U-521, view from below: Threaded holes for mounting with M2 screws

Possible orientations of the U-521

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

Optimum:	Optimum:
g = gravity Horizontal mounting of the positioner	g = gravity, 1 = guide Vertical mounting with horizontal orientation of the motion axis; the guide points upwards.

Not recommended:	Not recommended:
g = gravity, 1 = guide	g = gravity
Vertical mounting with horizontal orientation of the motion axis: The increased load on the guide can reduce the lifetime of the U-521.	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).

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 underlying surface (see "Dimensions" (p. 47) for the required position and depth of the holes for the screws).

  – 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 surface flatness 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).

✓ 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 ≥0.75 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 an underlying surface and connecting it to a protective earth conductor

1. Align the U-521 on the underlying surface so that the corresponding holes in the U-521 and underlying surface are in line.

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 Ω at 25 A.

4. Check that the U-521 is fixed firmly to the surface.

5.3   Fixing 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 positioner.

➢ For affixing type and mass of the load, pay attention to the maximum permissible forces according to the specifications (p. 39).
➢ When the motion axis of the positioner 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

Excessively long screws!

The U-521 could be damaged by screws inserted too deeply.

➢ Pay attention to the depth of the mounting holes in the platform (p. 47).
➢ Use screws of the correct length for the respective mounting holes only.

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.
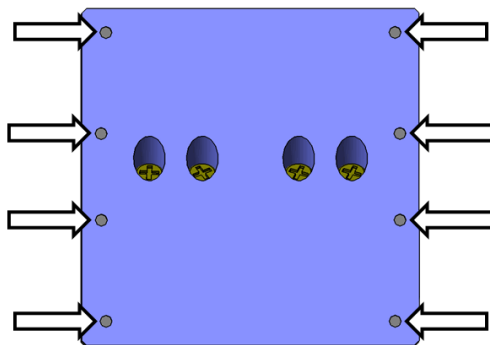
Figure 6:   U-521, M1.6 holes for affixing the load

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 fixed 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 fixing 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

Fixing 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. Fix the load with at least three screws.
3. Check that the load is fixed firmly to the motion platform of the U-521.

5.4 Building a Multi-Axis System

5.4.1 General Information on Building a Multi-Axis System

NOTICE

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

- ➢ Include the mass of the positioner that is moved in the calculation of the load to be moved.
- ➢ With respect to the mass and the mounting type, pay attention to the maximum permissible forces for each individual positioner 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 positioners.
- ➢ When the motion axis of the positioner is oriented vertically, make sure that the installed load is lower than the holding force of the drive.

	NOTICE
(!)	**Excessively long screws!** Screws inserted too deeply can damage the lower positioner. ➢ Pay attention to the depth of the mounting holes in the motion platform (p. 47) of the lower positioner. ➢ 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 Building an XY System

Two linear stages can be stacked to form an XY system as shown below:
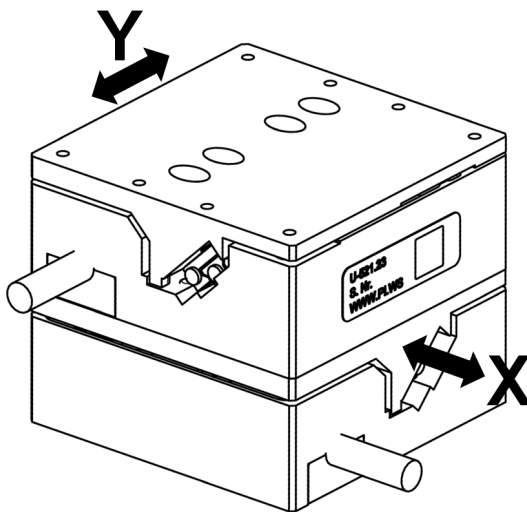
Figure 7:   Example of a stacked XY system

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

▪ Three 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
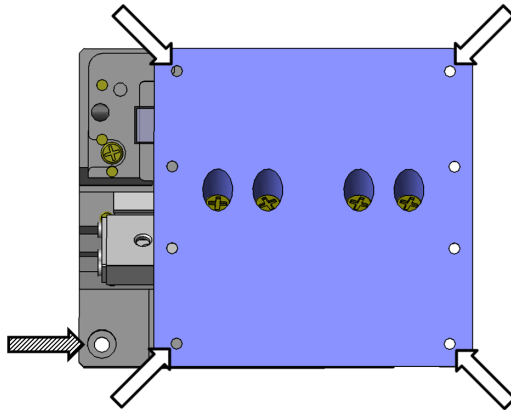
Figure 8:   Threaded holes in the motion platform for mounting stacked systems (white arrows) and one of three countersunk holes in the base body of the U-521 (hatched arrow)

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. Move the platform of the upper U-521 by hand 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. Move the motion platform of the upper U-521 by hand until the other two 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

It is necessary to install a vacuum feedthrough (p. 10) for the vacuum version of the U-521.

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

Installing the vacuum feedthrough

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

Connecting the vacuum version to the controller

- ➢ Connect the U-521 ("positioner"), vacuum feedthrough, and controller as shown in the connection diagram below.
   - – Pay attention to the assignment specified on the labeling of the sockets, plug connectors, and cables.
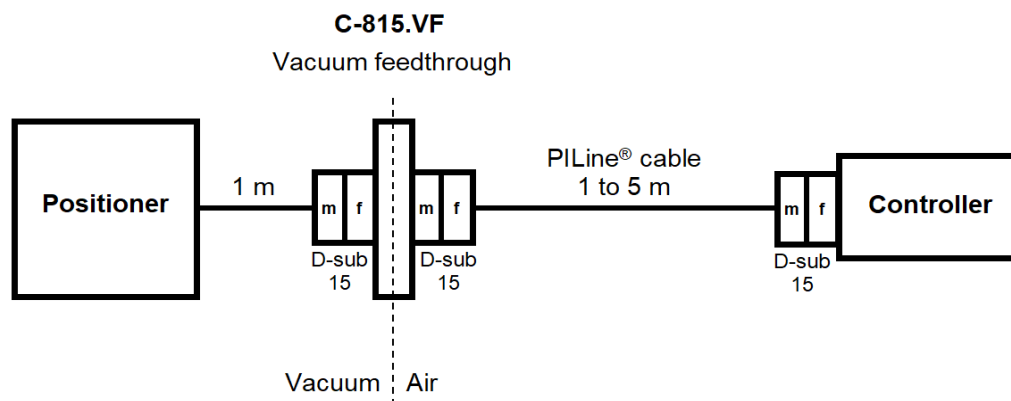
Figure 9:   Connection of the vacuum version to the controller

6 Starting and Operating

In this Chapter

6.1 General Notes on Starting

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 there are touch voltages, touching the U-521 can result in minor injuries from electric shock.

➢ Connect the U-521 to a protective earth conductor (p. 16) before starting.

➢ 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 restarting.

NOTICE

Destruction of the piezo motor due to electric flashovers!

Using the U-521 in environments that increase the electrical conductivity could lead to the destruction of the piezo motor by electric flashovers. Electric flashovers can be caused by moisture, high humidity, liquids, and conductive materials (e.g., metal dust). In addition, electric flashovers are also possible as a result of increased conductivity in certain air pressure ranges.

➢ Avoid operating the U-521 in environments that can increase the electrical conductivity.

➢ Operate the U-521 only under permissible ambient conditions and classifications (p. 42).

➢ When using in a vacuum under 0.1 hPa:
Do **not** operate the U-521 while evacuating or ventilating.

NOTICE

Damage if the wrong controller is connected!

Connecting a positioner to an unsuitable controller can damage the positioner or controller.

➢ Connect a positioner with PILine® ultrasonic piezo motors to a PILine® controller only (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.

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

HINWEIS

Short-circuiting due to condensation!

Condensation can lead to short-circuiting and failure of the U-521.

➢ Wait for a sufficient period of time to allow the U-521 to reach room temperature in the following cases:
  – After unpacking or before starting for the first time
  – If the U-521 has been brought from a cold into a warm environment or from a warm into a cold environment
➢ Keep the U-521 free of condensation.

NOTICE

Unintentional motion!

The U-521 may move unintentionally when connecting it to the controller. Faulty software and incorrect operation of the software may also cause unintended movements.

➢ 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 startup macro in the controller and cancel the selection of the startup macro if necessary.

NOTICE

Damage due to collisions!

Collisions can damage the U-521, the load to be moved, and the surroundings.

➤ Make sure that no collisions are possible between the U-521, the load to be moved, and the surroundings in the motion range of the U-521.
➤ 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.

➤ Pay attention to 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.
> - ➢ Pay attention to 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, it is necessary to run the U-521 in when starting and after longer downtimes; refer also to "Influence of Downtimes on the Static Holding Force" (p. 46). After running in, the U-521 will generate its maximum dynamic force.
> - ➢ Command several motion cycles at low velocity over the entire travel range to run in.

> **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 U-521's direction of motion is indicated in the product view (p. 8).

Refer to the "Motor Power" section (p. 43) for more information on operating conditions.

6.2   Starting and Operating the U-521

NOTICE

Wrong 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 positioner database. The positioner database contains the default parameter values of your positioner for doing initial motion testing during starting. 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 positioner, especially when operated with heavy loads.

➢   If possible: Start without a load first.

➢   Always install the latest version of the positioner database onto your PC.

For starting with a load:

➢   Before starting, make sure that the U-521 has been properly installed (p. 15).

➢   For optimal performance of the moving axis, adjust the operating parameters of the controller (e.g., P term, I term, D term, acceleration, velocity; refer to the controller manual).

➢   Save the new parameter values to a positioner database on the PC or to the nonvolatile memory of the controller for future use (refer to the controller manual and the PIMikroMove manual).

Requirements

✓   You have read and understood the general notes on starting and operating (p. 27).

✓   You have read and understood the user manual of the controller (p. 3).

✓   When starting 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 made (refer to the controller manual).

Starting the U-521

➢   Start the axis (refer to the controller manual).
    Starting involves the following steps:

   –   Selecting the positioner type

   –   Defining the reference point of the axis

   –   Commanding initial motion in closed-loop operation for testing and for running the mechanics in

The controller manual describes startup using the PIMikroMove program.

6.3 Adjusting Parameter Values when Using Extension Cables

INFORMATION

It may be necessary to optimize the motor performance when using extension cables. The parameter values in the controller must be adjusted if the total cable length exceeds 3 m (between positioner and controller).

➢ If the total cable length between the positioner and the controller exceeds 6.5 m, contact our customer service department (p. 37).

Adjusting parameter values when using extension cables

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 optimal motor power.

3. Save the new parameter values to a positioner database on the PC or the nonvolatile memory of the controller for future use (refer to the controller manual and the PIMikroMove manual).

7 Maintenance

In this Chapter

7.1 General Notes on Maintenance

> **NOTICE**
>
> **Damage due to improper maintenance!**
> Improper maintenance can result in failure of the U-521.
>
> ➢ Loosen screws only when instructed in this manual.
> ➢ Make sure that the piezo motor of the U-521 does not come into contact with lubricants.

7.2 Doing 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 guides, do a maintenance run across the entire travel range after 500 hours of operation or at least after 1 year.

➢ 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.

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7.3   Cleaning the U-521

Requirements

- ✓ You have disconnected the positioner from the controller.

Cleaning the positioner

Only when the positioner is **not** used in vacuum:

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

Only when the positioner is used in vacuum:

- ➢ Touch the positioner only with powder-free gloves.
- ➢ If necessary, wipe the positioner clean.

8 Troubleshooting

Problem	Possible causes	Solution
Noise during operation	Uncontrolled oscillation of the U-521	➢ Immediately switch off the servo control system of the affected axes. ➢ Check the settings of the servo control parameters.
Inaccurate positioning	Settling window around the target position is too large	➢ Reduce the settling window by changing the parameter values for the settling window limits on the controller. Refer to the controller manual (p. 3) for details.
Reaching the target position takes too long	Settling window around the target position is too small	➢ Enlarge the settling window by changing the parameter values for the settling window limits on the controller. Refer to the controller manual (p. 3) for details.
Increased wear Reduced accuracy	Warped base body	➢ Mount the U-521 onto a flat surface. The recommended flatness of the surface is 10 µm. ➢ 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).
No or limited motion	Excessive load	For horizontally aligned motion axis: ➢ Reduce the load (see "Data Table" (p. 39)). For vertically aligned motion axis: ➢ Reduce the load to a maximum of 100 g. If you wish to operate the U-521 with a vertically aligned motion axis with a load of >100 g: ➢ Install suitable gravity compensation. Contact our customer service department (p. 37) for details on gravity compensation.

Problem	Possible causes	Solution
	The default parameter values are not suitable for operating with high loads	➢ Adjust the operating parameters according to the description in "Starting and operating the U-521".
	The default parameter values are not suitable if the overall cable length exceeds 3 m	➢ Adjust the operating parameters according to the description in "Adjusting Parameter Values when Using Extension Cables" (p. 32).

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 any questions concerning your system, provide the following information:
  - − Product and serial numbers of all products in the system
  - − Firmware version of the controller (if applicable)
  - − Version of the driver or the software (if applicable)
  - − Operating system on the PC (if applicable)
- ➢ 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

10.1   Specifications

10.1.1   Data Table

Motion	U-521.23	U-521.24	Unit	Tolerance
Active axes	x	x		
Travel range	18	18	mm	
Velocity, closed loop	200	200	mm/s	Max.
Minimum incremental motion	2	0.3	µm	Typ.
System resolution	0.4	0.1	µm	
Bidirectional repeatability	±2	±0.2	µm	
Linearity error (over the entire travel range)	8	4	µm	
Pitch	±300	±300	µrad	
Yaw	±300	±300	µrad	

Positioning	U-521.23	U-521.24	Unit	Tolerance
Sensor type	Incremental encoder	Incremental encoder		
Measuring principle	Optical	Optical		
Measuring method	Direct measuring	Direct measuring		
Sensor resolution	0.4	0.1	µm	Typ.

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Mechanical properties	U-521.23	U-521.24	Unit	Tolerance
Push force capacity	2	2	N	Max.
Pull force capacity	2	2	N	Max.

Drive properties	U-521.23	U-521.24	Unit	Tolerance
Motor type	PILine® ultrasonic piezo motor, performance class 1	PILine® ultrasonic piezo motor, performance class 1		
Drive force	2	2	N	Max.
Holding force	2	2	N	Max.

Connectors	U-521.23	U-521.24	Unit	Tolerance
Motor / sensor	1 × D-sub 15 (m)	1 × D-sub 15 (m)		

Miscellaneous	U-521.23	U-521.24	Unit	Tolerance
Reference switch	Optical	Optical		
Operating temperature	0 to 40	0 to 40	°C	
Material	Aluminum, anodized	Aluminum, anodized		
Mass (positioner without cable and connector)	40	40	g	
Mass (positioner with cable and connector)	160	160	g	
Cable length	1.5	1.5	m	+200 mm/ -0 mm
Recommended electronics	C-867.1U	C-867.1U		

Specifications determined with the C-867.1U controller.

Vacuum versions to 10^{-6} hPa available on request. Specifications for vacuum versions can differ.

10.1.2   Reference Switch Specifications

Type	Optical sensor
Supply voltage	+5 V/GND, supply via the motor connector
Signal output	TTL level
Signal logic	Direction sensing by means of different signal levels on the left- and right-hand side of the reference switch: The signal level changes from 0 to +5 V when the reference switch is passed.
Hysteresis	0.2 to 0.4 mm (when approaching from a positive or negative direction)

10.1.3 Maximum Ratings

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

Maximum operating voltage	Operating frequency	Maximum power consumption*
⚠	⚠	⚠
160 V_{pp} or 57 V_{eff}	210 to 225 kHz	10 W

* 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:

Component	Material
Mechanical parts	Aluminum (blank), aluminum (anodized, black, matt), steel, ceramic (PIC181, Al_2O_3), PEEK, PTFE
Cable	FEP; ribbon cable (FFC) from Axon Kabel GmbH
Shrink tubing	PVDF (Kynar)
Connector	D-sub 15 (m)
Insulation	KU-THE-150
Lubricant	Molykote HP-300
Sealant	Scotch Weld
Adhesives	Epoxy resin-based adhesive

Bakeout temperature: 80°C (176°F)

Bakeout time: 3 hours

10.2   Ambient Conditions and Classifications

Pay attention to the following ambient conditions and classifications for the U-521:

Area of application	For indoor use only	
Maximum altitude	2000 m	
Air pressure	All models except vacuum-compatible models: 1100 hPa to 0.1 hPa	Vacuum-compatible models: 1100 hPa to 10^{-6} hPa
Relative humidity	Highest relative humidity 80 % for temperatures up to 31 °C Decreasing linearly to 50 % relative humidity at 40 °C	
Operating temperature	0 °C to 40 °C	
Storage temperature	-20 °C to 75 °C	
Transport temperature	-20 °C to 75 °C	
Overvoltage category	II	
Protection class	I	
Degree of pollution	1	
Degree of protection according to IEC 60529	IP20	

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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 positioner 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.

Motor power	Operating voltage* (rounded)	Corresponding control value on the controller**
0 %	0 V_{eff}	0
25 %	14 V_{eff}	8192 or -8192
50 %	29 V_{eff}	16384 or -16384
75 %	43 V_{eff}	24575 or -24575
100 %	57 V_{eff} (max.)	32767 or -32767

* 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.

Refer to the user manual of the controller (p. 3) used to operate the U-521 for further information.

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 %.
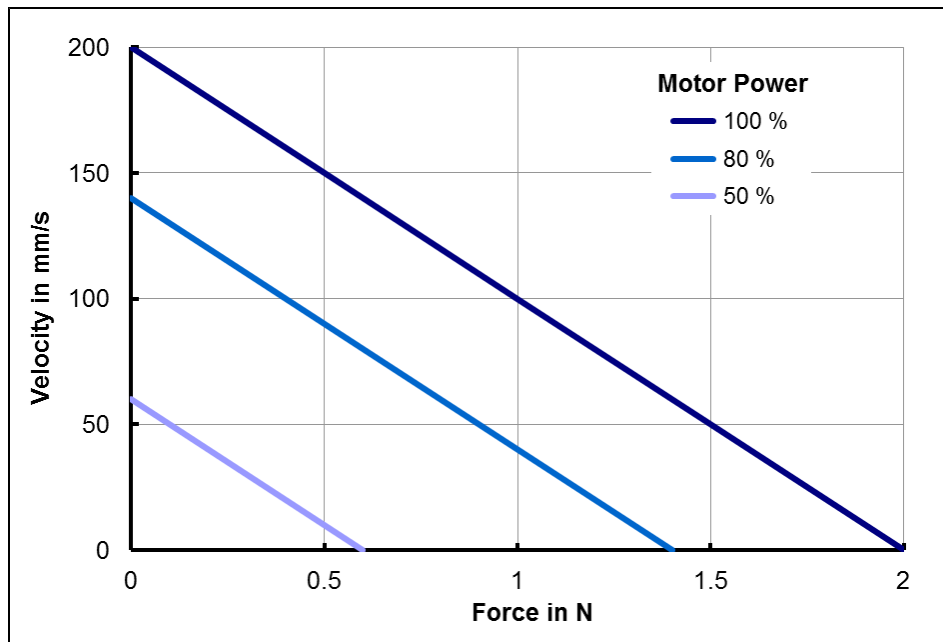

Figure 10: Relationship between velocity and force of the U-521 with different motor power levels

10.3.3 Motor Power and Lifetime

Motor power, duty cycle and ambient temperature influence the lifetime of the positioner. 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.
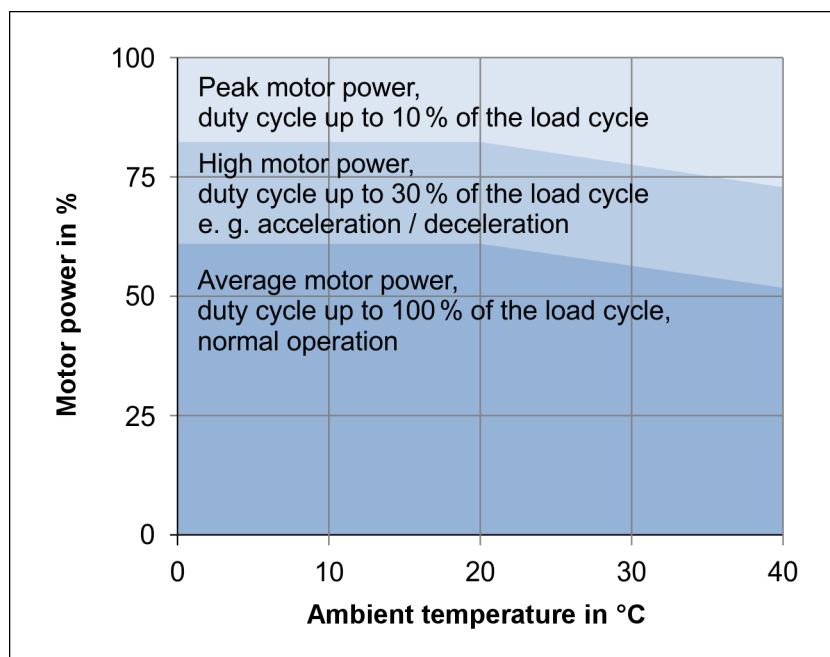

Figure 11:   U-521: Recommended duty cycle and motor power depending on the ambient temperature

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10.3.4   Influence of Downtimes on the Static Holding Force
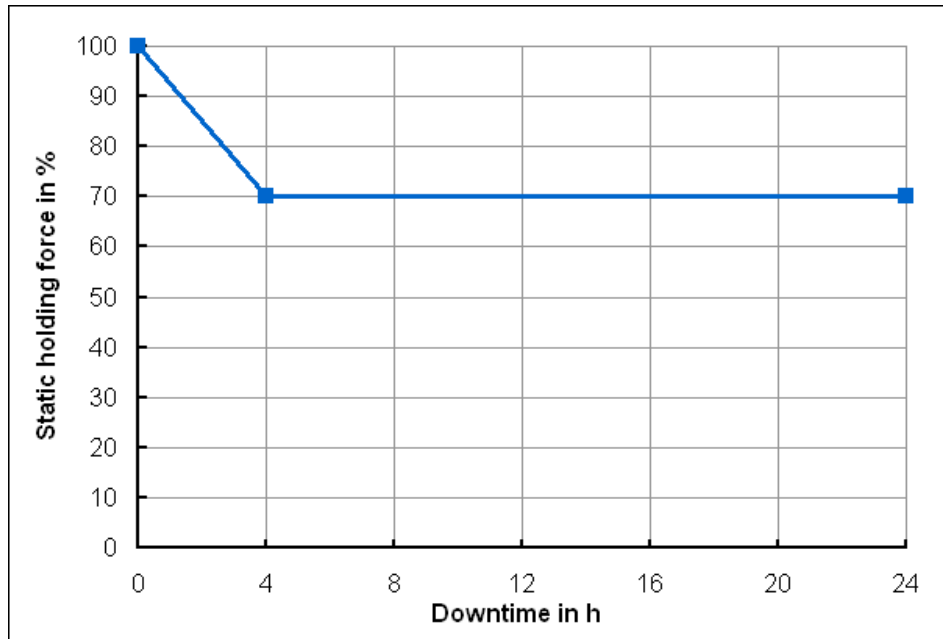

Figure 12:   Static holding force of the U-521 depending on the downtime of the motor

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10.4   Dimensions

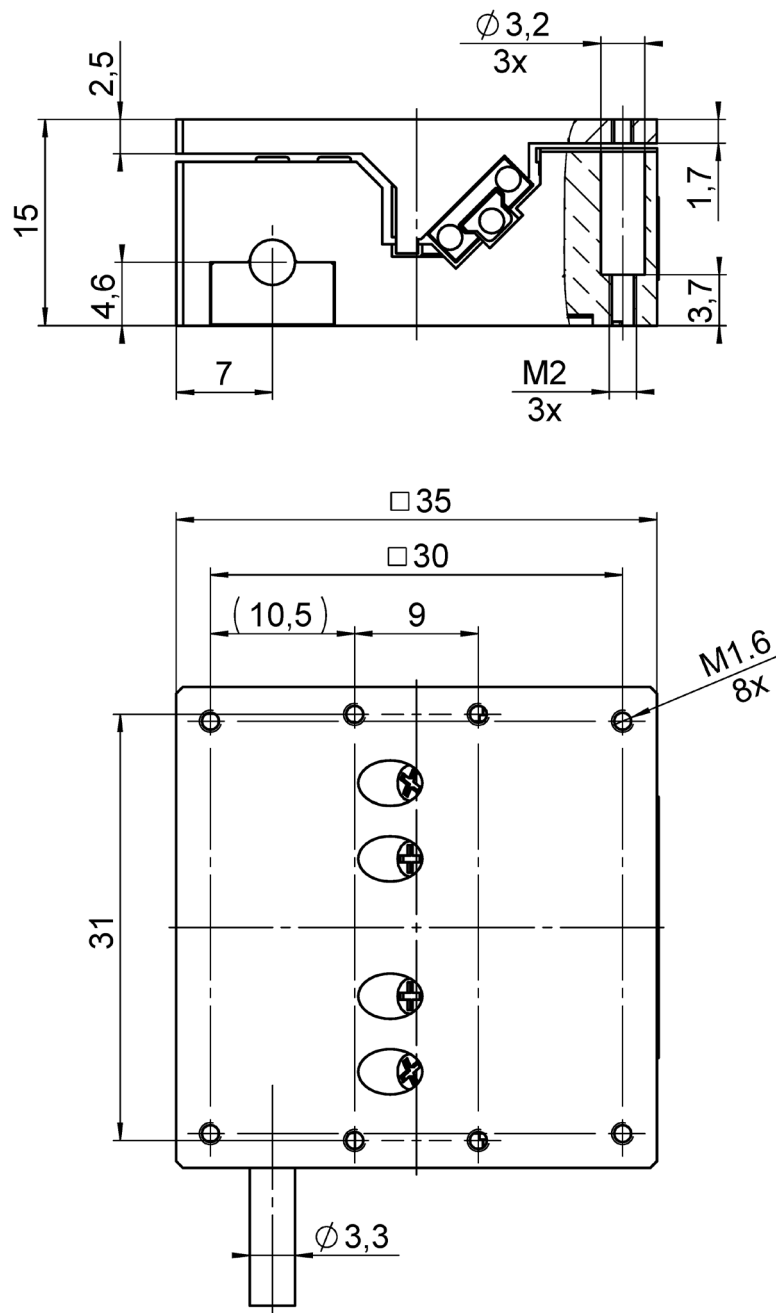Dimensions in mm. Note that the decimal points are separated by a comma in the drawings.

Figure 13:   U-521
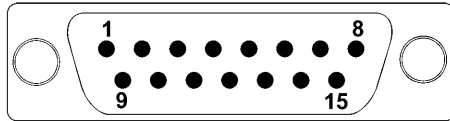

10.5   Pin Assignment

Connector: D-sub 15 (m)

Figure 14:   Front view of the D-sub 15 connector

Pin	Signal	Function
1	NC	Not connected
2	USM_P1	Input: Motor voltage ground
3	USM_P2	Input: Piezo 57 VAC (RMS)
4	VDD	Input: +5 V
5	NC	Not connected
6	ID_CHIP	Bidirectional: Data line for ID chip
7	ENCA-	Output: Encoder channel A (inverted), RS-422
8	ENCB-	Output: Encoder channel B (inverted), RS-422
9	USM_P1	Input: Motor voltage ground
10	GND	0 V
11	USM_P3	Input: Piezo 57 VAC (RMS)
12	NC	Not connected
13	REFSWITCH	Output: Reference switch
14	ENCA+	Output: Encoder channel A, RS-422
15	ENCB+	Output: Encoder channel B, RS-422

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

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12   EU Declaration of Conformity

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 or EN IEC 63000