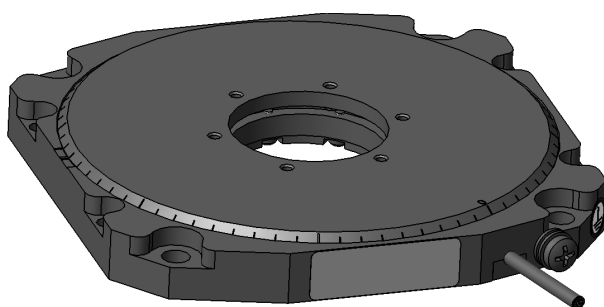


MP136E U-651 Rotation Stage User Manual

Version: 1.3.0

Date: 02.12.2020



This document describes the following products:

- **U-651.03**
Rotation stage with low profile and PISLine® ultrasonic piezo motors, >360° rotation range, velocity 540 °/s, incremental encoder, resolution 9 µrad, D-sub connector
- **U-651.03V**
Rotation stage with low profile and PISLine® ultrasonic piezo motors, >360° rotation range, velocity 540 °/s, incremental encoder, resolution 9 µrad, D-sub connector, vacuum compatible to 10⁻⁶ hPa
- **U-651.04**
Rotation stage with low profile and PISLine® ultrasonic piezo motors, >360° rotation range, velocity 540 °/s, incremental encoder, resolution 4 µrad, D-sub connector
- **U-651.04V**
Rotation stage with low profile and PISLine® ultrasonic piezo motors, >360° rotation range, velocity 540 °/s, incremental encoder, resolution 4 µrad, D-sub connector, vacuum compatible to 10⁻⁶ hPa



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The patents held by PI are found in our patent list: <https://www.physikinstrumente.com/en/about-pi/patents>

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Original instructions

First printing: 02.12.2020

Document number: MP136E, CBo, Version 1.3.0

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 This manual is superseded by any new release.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.

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1 About this Document

In this Chapter

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Symbols and Typographic Conventions	1
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1.1 Objective and Target Audience of this User Manual

This user manual contains the information required for using the U-651 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.

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

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.	Action consisting of several steps with strict sequential order
2.	
➤	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 rotation stage is mounted horizontally. The contact point of the load is at the center of the platform.
Rotary encoder	The rotary 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, 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 PLine® Controller	MS223E User Manual
C-867.2U2 PLine® Controller	MS231E User Manual
C-867.10C885 PLine® Controller Module	C867T0017 User Manual
PIMikroMove	SM148E Software Manual
PLine® 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. 33).

Downloading Manuals

1. Open the website **www.pi.ws**.
2. Search the website for the product number (e.g., U-651) or the product family (e.g., PLine®).
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

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

2.1 Intended Use

The U-651 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 and realization, the U-651 is intended for single-axis positioning, adjusting and rotation of loads in at different velocities in interval operation. The U-651 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-651 as intended when it is installed and connected properly.

The U-651 uses PLine® ultrasonic piezo motors as a drive and must be operated with a suitable controller (p. 10). The controller is not included in the scope of delivery of the U-651.

2.2 General Safety Instructions

The U-651 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-651.

- Use the U-651 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-651.

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-651 can cause slight injuries from electric shock.

- Do **not** open the U-651.
- Do **not** touch the contacts in the connector of the U-651.

If a protective earth conductor is not or not properly connected, dangerous touch voltages can occur on the U-651 in the case of malfunction or failure of the system. If there are touch voltages, touching the U-651 can result in minor injuries from electric shock.

- Connect the U-651 to a protective earth conductor (p. 17) 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-651 to the protective earth conductor before restarting.

Mechanical forces can damage or misalign the U-651.

- Avoid impacts that affect the U-651.
- Do **not** drop the U-651.
- Do **not** exceed the maximum permissible stress and load capacities (p. 35).

2.3 Organizational Measures

User manual

- Always keep this user manual together with the U-651.
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-651 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-651 only after you have read and understood this user manual.

Personnel qualification

The U-651 may only be installed, started, operated, maintained, and cleaned by authorized and appropriately qualified personnel.

3 Product Description

In this Chapter

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Product Labeling.....	8
Scope of Delivery	10
Suitable Controllers	10
Accessories.....	10
Technical Features	11

3.1 Model Overview

The U-651 is available in the following versions:

Model	Description
U-651.03	Rotation stage with low Profile and PLine® ultrasonic piezo motors, >360° rotation range, velocity 540 °/s. direct position measurement with incremental encoder, 9 µrad resolution, D-sub connector
U-651.03V	Rotation stage with low Profile and PLine® ultrasonic piezo motors, >360° rotation range, velocity 540 °/s. direct position measurement with incremental encoder, 9 µrad resolution, D-sub connector, vacuum compatible to 10 ⁻⁶ hPa
U-651.04	Rotation stage with low Profile and PLine® ultrasonic piezo motors, >360° rotation range, velocity 540 °/s. direct position measurement with incremental encoder, 4 µrad resolution, D-sub connector
U-651.04V	Rotation stage with low Profile and PLine® ultrasonic piezo motors, >360° rotation range, velocity 540 °/s. direct position measurement with incremental encoder, 4 µrad resolution, D-sub connector, vacuum compatible to 10 ⁻⁶ hPa

3.2 Product View

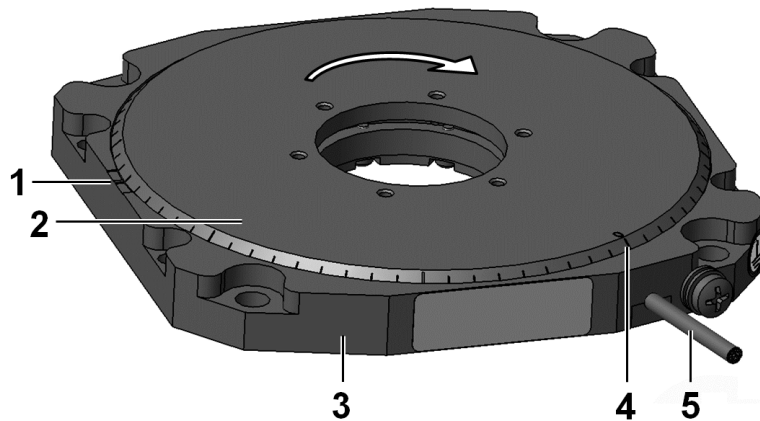


Figure 1: U-651 product view

- 1 0° mark* in the base body
- 2 Platform
- 3 Base body
- 4 0° mark* of the platform
- 5 Cable exit

The arrow in the figure shows the positive direction of motion.

*0° mark:

The 0° mark of the platform is at the 0° mark in the base body after the U-651 does a reference move.

3.3 Product Labeling

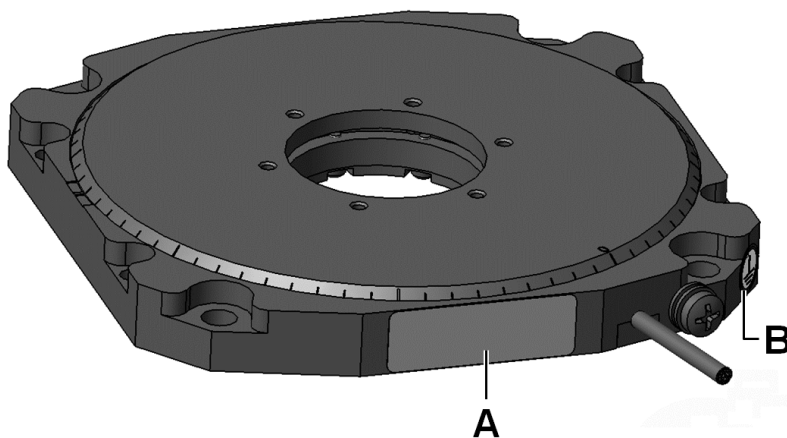


Figure 2: U-651: Position of the product labeling (example view)







Position	Labeling	Description
A		Manufacturer's logo
A		CE conformity mark
A		Warning sign "Pay attention to the manual!"
A	U-651.03	Product name (example), the characters following the period refer to the model
A	123456789	Serial number (example), individual for each U-651 Meaning of each position (from the left): 1 = internal information 2 and 3 = year of manufacture 4 to 9 = consecutive number
A	WWW.PI.WS	Manufacturer's address (website)
A		Data matrix code (example; contains the serial number)
A		Old equipment disposal (p. 45)
A	Country of origin: Germany	Country of origin
B		Symbol for the protective earth conductor, marks the protective earth connector of the U-651 (p. 17)



Figure 3: "Residual Voltage" warning sign on the connector of the U-651

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

3.4 Scope of Delivery

Product number	Description
U-651	Rotation stage according to order (p. 7)
000036450	M4 screw set for protective earth, consisting of: <ul style="list-style-type: none"> ▪ 1 flat-head screw with cross recess, M4x8, ISO 7045 ▪ 2 lock washers ▪ 2 flat washers
000055390	Screw set for mounting the U-651, consisting of: <ul style="list-style-type: none"> ▪ 5 socket head screws, M6x20 ISO 4762 ▪ 1 hex key, AF 5.0
MP121EK	Short instructions for PLine® positioners

3.5 Suitable Controllers

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

➤ To order, contact our customer service department (p. 33).

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 PLine®, D-sub 15-pin, 1 m*
U-600.A03	Extension cable for PLine®, D-sub 15-pin, 3 m*
U-600.A05	Extension cable for PLine®, D-sub 15-pin, 5 m*

* Other cable lengths available on request.

➤ To order, contact our customer service department (p. 33).

3.7 Technical Features

3.7.1 Rotary Encoder

The U-651 is equipped with an optical rotary encoder. For the encoder resolution, refer to the table in the "Specifications" section (p. 35).

Optical rotary 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-651 has an optical reference switch (refer to "Reference Switch Specifications" (p. 36)).

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

The red dot on the platform is above the 0° mark in the base body after the U-651 has done a reference move.

3.7.3 ID Chip

The U-651 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 rotation stage, 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 rotation stage is wipe cleaned afterwards and then shrink-wrapped twice in vacuum-compatible film.

- Touch the rotation stage only with powder-free gloves.
- If necessary, wipe the rotation stage clean after unpacking.

1. Unpack the U-651 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. 33) immediately.
4. Keep all packaging materials in case the product needs to be returned.

5 Installation

In this Chapter

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Fixing the Load to the U-651.....	20
Connecting the Vacuum Version to the Controller	22

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-651 can lead to minor injuries from electric shock.

- Do **not** touch the contacts in the connector of the U-651.

NOTICE



Lubricants, dirt, condensation!

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

- Make sure that the piezo motors of the U-651 do not come into contact with lubricants.
- Keep the U-651 free from dirt and condensation.

NOTICE



Heating up of the U-651 during operation!

The heat produced during operation of the U-651 can affect your application.

- Install the U-651 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-651.

- Only use genuine PI parts to connect the U-651 to the controller.
- If you need longer cables, use extension cables from PI (p. 10).

NOTICE**Unwanted changes in position when mounted vertically!**

The platform could move unexpectedly if the load exceeds the rotation stage's drive torque when the U-651 is mounted vertically (e.g., due to pulling forces on the cable of the load). Unwanted changes in the position of the platform can damage the drive, the load or the surroundings.

- Take suitable measures to make sure that the load is lower than the drive torque (p. 35) when the rotation stage is mounted vertically, e.g., the cables connected to the load should have sufficient strain relief.

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 rotation stage.

- If possible, simulate the rotation 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 rotation stage and the application in accordance with the legal regulations.

For more information on operating conditions, refer to the "Motor Power" section (p. 38).

5.2 Connecting the U-651 to the Protective Earth Conductor

INFORMATION

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

On the U-651, there is an M4 hole next to the cable exit for connecting the protective earth conductor. In the following figure, this hole is marked with the symbol for the protective earth conductor ⚡.

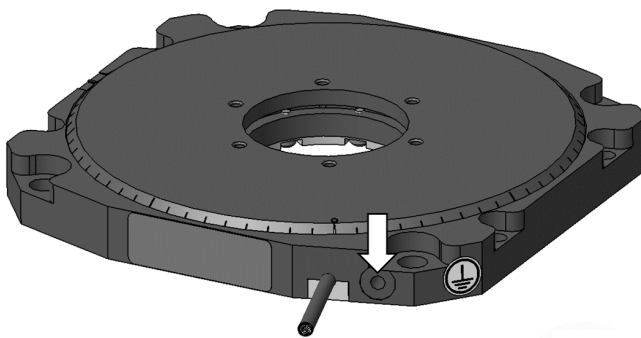


Figure 4: M4 threaded hole for connecting the protective earth conductor

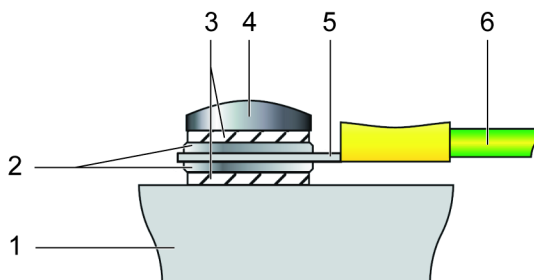


Figure 5: Connecting the protective earth conductor (profile view)

- 1 Base body of the U-651
- 2 Flat washer
- 3 Lock washer
- 4 Screw
- 5 Cable lug
- 6 Protective earth conductor

Requirements

- ✓ You have read and understood the general notes on installation (p. 15).
- ✓ The U-651 is **not** connected to the controller.

Tools and accessories

- Suitable protective earth conductor: Cross-sectional area of the cable $\geq 0.75 \text{ mm}^2$
- M4 screw set supplied for connecting the protective earth conductor (p. 10)
- Suitable screwdriver

Connecting the U-651 to the protective earth conductor

1. If necessary, attach a suitable cable lug to the protective earth conductor.
2. Use the M4 screw (together with the flat and lock washers) to attach the cable lug of the protective earth conductor to the threaded hole in the U-651 as shown in the profile view.
3. Tighten the M4 screw with a torque of 1.2 Nm to 1.5 Nm.
4. Make sure that the contact resistance at all connection points relevant for connecting the protective earth conductor is $< 0.1 \Omega$ at 25 A.

5.3 Mounting the U-651 onto a Surface

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-651 onto a flat surface. The recommended flatness of the surface is $10 \mu\text{m}$.
- For applications with large temperature changes:
Only fix the U-651 to surfaces that have the same or similar thermal expansion properties as the U-651 (e.g., surfaces made of aluminum).

INFORMATION

The positive direction of motion of the U-651 is shown in the product view (p. 8).

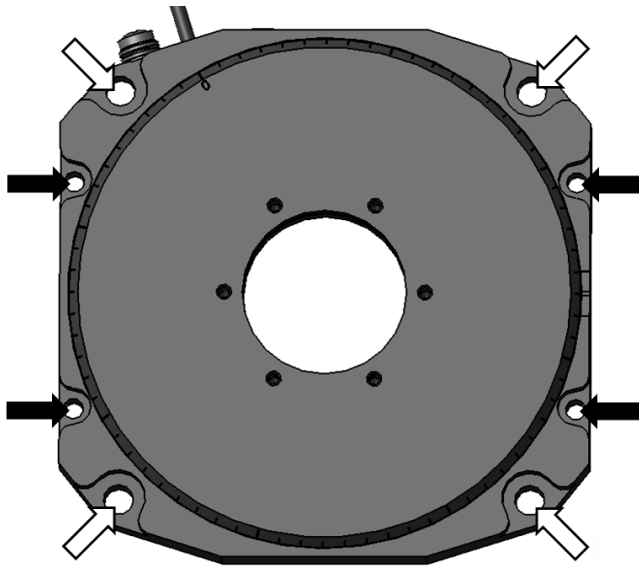


Figure 6: U-651: Holes in the base body for M6 screws (white arrows) or M4 screws (black arrows)

Requirements

- ✓ You have read and understood the general notes on installation (p. 15).
- ✓ You have provided a suitable underlying surface (see "Dimensions" (p. 42) for the required position of the holes for the screws).
 - Four M6 or M4 holes are provided with a thread depth of at least 13 mm.
 - The surface flatness is $\leq 10 \mu\text{m}$.
 - For applications with large temperature changes: The surface should have the same thermal expansion properties as the U-651 (e.g., surface made of aluminum).
- ✓ You have accounted for the space required to route cables without bending and according to regulations.
- ✓ The U-651 is **not** connected to the controller.

Tools and accessories

- Mounting accessories in the scope of delivery (p. 10):
 - Four M6 screws
 - Hex key
- Alternative (not in the scope of delivery):
 - Four M4 screws of suitable length
 - Suitable screwdriver

Mounting the U-651 onto a surface

1. Align the U-651 on the underlying surface so that the holes selected in the U-651 (see arrows in the figure) are in line with the corresponding holes in the underlying surface.
2. Insert four suitable screws into the selected holes in the base body of the U-651.
3. Tighten each of the four screws with the following torque:
 - M6 screws: 7.1 Nm
 - M4 screws: 2.1 Nm
4. Check that the U-651 is fixed firmly to the surface.

5.4 Fixing the Load to the U-651**NOTICE****Impermissibly high forces and torques!**

Impermissibly high forces and torques that are applied to the platform can damage the U-651.

- For fixing type and mass of the load, pay attention to the maximum permissible forces according to the specifications (p. 35).
- Avoid tilting torques >0.5 Nm on the platform.

NOTICE**Excessively long screws!**

The U-651 could be damaged by screws inserted too deeply.

- Pay attention to the depth of the mounting holes in the platform (p. 42).
- Use screws of the correct length for the respective mounting holes only.

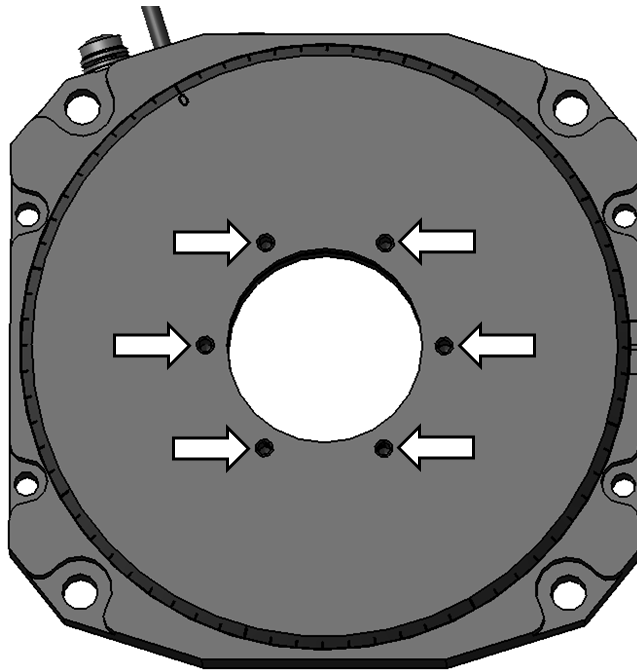


Figure 7: U-651, M3 holes for fixing the load

Requirements

- ✓ You have read and understood the general notes on installation (p. 15).
- ✓ You have mounted the U-651 onto an underlying surface (p. 18) properly.
- ✓ The U-651 is **not** connected to the controller.
- ✓ You have prepared the load so that it can be fixed to the mounting holes in the platform:
 - The gap between the center of gravity of the load and the center of the platform is as small as possible in all directions.
 - At least three points are provided for fixing the load on the platform.

Tools and accessories

- At least three M3 screws of suitable length (p. 42)
- Suitable tool for tightening the screws

Fixing the load

1. Align the load on the U-651 so that the mounting holes in the load and the holes in the platform are in line.
2. Fix the load with at least three screws.
3. Check that the load is sitting firmly on the platform of the U-651.

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-651.

Requirements

- ✓ You have read and understood the general notes on installation (p. 15).
- ✓ The controller is **switched off**.
- ✓ You have connected the U-651 to the protective earth conductor (p. 17).
- ✓ 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)
- PLine® 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-651 ("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.

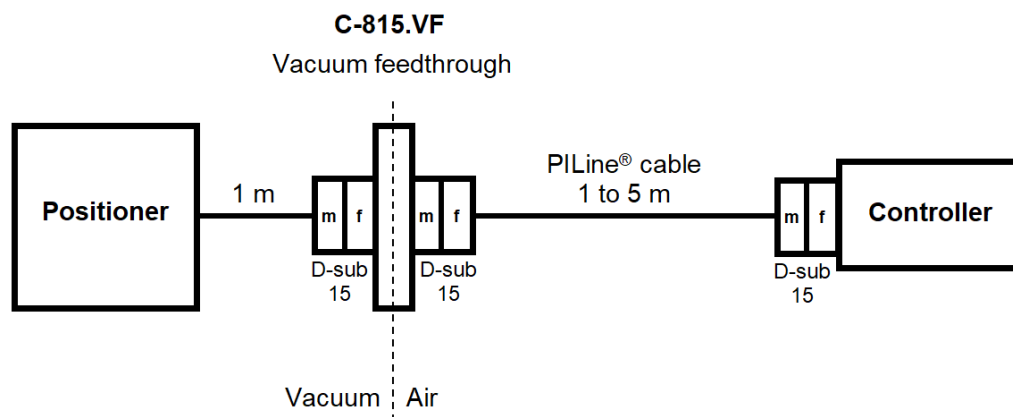


Figure 8: Connection of the vacuum version to the controller

6 Starting and Operating

In this Chapter

General Notes on Starting	23
Starting and Operating the U-651	26
Adjusting Parameter Values when Using Extension Cables	27

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-651 in the case of malfunction or failure of the system. If there are touch voltages, touching the U-651 can result in minor injuries from electric shock.

- Connect the U-651 to a protective earth conductor (p. 17) 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-651 to the protective earth conductor before restarting.

NOTICE



Destruction of the piezo motor due to electric flashovers!

Using the U-651 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-651 in environments that can increase the electrical conductivity.
- Operate the U-651 only under permissible ambient conditions and classifications (p. 37).
- When using in a vacuum under 0.1 hPa:
Do **not** operate the U-651 while evacuating or ventilating.

NOTICE**Damage if the wrong controller is connected!**

Connecting a rotation stage to an unsuitable controller can damage the rotation stage or controller.

- Connect a rotation stage with PLine® ultrasonic piezo motors to a PLine® 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-651.

- Operate the U-651 only with controllers/drivers and original accessories from PI.
- Do **not** exceed the operating voltage range (p. 36) for which the U-651 is specified.
- Operate the U-651 only when the operating voltage is properly connected; see "Pin Assignment" (p. 43).

HINWEIS**Short-circuiting due to condensation!**

Condensation can lead to short-circuiting and failure of the U-651.

- Wait for a sufficient period of time to allow the U-651 to reach room temperature in the following cases:
 - After unpacking or before starting for the first time
 - If the U-651 has been brought from a cold into a warm environment or from a warm into a cold environment
- Keep the U-651 free of condensation.

NOTICE**Unintentional motion!**

The U-651 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-651, 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-651, the load to be moved, and the surroundings.

- Make sure that no collisions are possible between the U-651, the load to be moved, and the surroundings in the motion range of the U-651.
- 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-651.

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**Overheating during continuous operation!**

The highest torque or holding force is reached at maximum motor power; however, the U-651 may overheat during continuous operation.

- Pay attention to the recommended motor power depending on the duty cycle and the ambient temperature (p. 40).

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. 38).

INFORMATION

Although the U-651 operates quietly in theory, noise levels of up to 50 dB (A) are possible during operation. The ultrasonic drive of the U-651 can also generate higher noise levels at frequencies between 100 and 500 kHz.

INFORMATION

The positive direction of motion of the U-651 is shown in the product view (p. 8).

INFORMATION

To generate the maximum force, it is necessary to run in when starting the U-651 and after longer downtimes; refer also to "Influence of Downtimes on the Torque" (p. 41). The U-651 reaches its maximum torque after running in.

- Command several motion cycles at low velocity to run in. The motion cycles should include as many full rotations as possible.

INFORMATION

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

- Operate the vacuum version of the U-651 with 20 % lower motor power than specified in "Motor power and lifetime" (p. 40) or reduce the duty cycle.

Refer to the "Motor Power" section (p. 38) for more information on operating conditions.

6.2 Starting and Operating the U-651

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-651 can be loaded from a positioner database. The positioner database contains the default parameter values of your rotation stage 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 rotation stage, 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-651 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. 23).
- ✓ You have read and understood the user manual of the controller (p. 3).
- ✓ When starting with a load: The U-651 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-651

- 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. 33).

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-651 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

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7.1 General Notes on Maintenance

NOTICE



Damage due to improper maintenance!

Improper maintenance can result in the failure of the U-651.

- Loosen screws only according to the instructions in this manual.
- Make sure that the piezo motors of the U-651 do 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-651, a maintenance run may be required. The maintenance run is performed to redistribute the existing lubricant in the bearing of the U-651. The stage must rotate by at least one full revolution during the maintenance run.

- To evenly distribute the existing lubricant in the stage bearing, perform a maintenance run after 500 hours of operation or after 1 year at the latest.
- If you move your U-651 over a small working range (<20°) in continuous industrial operation, perform a maintenance run after every 5000 motion cycles.

7.3 Cleaning the U-651

Requirements

- ✓ You have disconnected the rotation stage from the controller.

Cleaning the rotation stage

Only when the rotation stage is **not** used in vacuum:

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

Only when the rotation stage is used in vacuum:

- Touch the rotation stage only with powder-free gloves.
- If necessary, wipe the rotation stage clean.

8 Troubleshooting

Problem	Possible causes	Solution
Noise during operation	Uncontrolled oscillation of the U-651	<ul style="list-style-type: none"> ➤ 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	Warped base body	<ul style="list-style-type: none"> ➤ Mount the U-651 onto a flat surface. The recommended flatness of the surface is 10 µm. ➤ For applications with large temperature changes: Only mount the U-651 on surfaces that have the same or similar thermal expansion properties as the U-651 (e.g., surfaces made of aluminum).
Reduced accuracy		
No or limited motion	Excessive load	<ul style="list-style-type: none"> ➤ Reduce the load (see "Data Table" (p. 35)). ➤ When the rotation stage is mounted vertically, make sure that the installed load is lower than the maximum torque of the drive (p. 35).
	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-651".
	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. 27).

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. 33).

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

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10.1 Specifications

10.1.1 Data Table

Motion	U-651.03 / U-651.03V	U-651.04 / U-651.04V	Unit	Tolerance
Active axes	θ_z	θ_z		
Rotation range	>360	>360	°	
Velocity, closed loop	540	540	°/s	max.
Minimum incremental motion	27	12	μrad	typ.
Bidirectional repeatability	± 54	± 24	μrad	
Positioning	U-651.03 / U-651.03V	U-651.04 / U-651.04V	Unit	Tolerance
Sensor type	Incremental encoder	Incremental encoder		
Sensor resolution	9	4	μrad	
Mechanical properties	U-651.03 / U-651.03V	U-651.04 / U-651.04V	Unit	Tolerance
Load capacity / axial force	20	20	N	max.
Holding force	0.3	0.3	Nm	max.

Drive properties	U-651.03 / U-651.03V	U-651.04 / U-651.04V	Unit	Tolerance
Motor type	PILine® ultrasonic piezo motor, performance class 2	PILine® ultrasonic piezo motor, performance class 2		
Drive torque clockwise / counterclockwise (θ_z)	0.3	0.3	Nm	max.
Connectors	U-651.03 / U-651.03V	U-651.04 / U-651.04V	Unit	Tolerance
Motor / sensor	1 × D-sub 15 (m)	1 × D-sub 15 (m)		
Miscellaneous	U-651.03 / U-651.03V	U-651.04 / U-651.04V	Unit	Tolerance
Reference switch	Optical	Optical		
Operating temperature	0 to 40	0 to 40	°C	
Material	Anodized aluminum	Anodized aluminum		
Mass	500	500	g	±5 %
Cable length	1.5 (model .03) 1.0 (model .03V)	1.5 (model .04) 1.0 (model .04V)	m	Cable length 1.5 m: +200 mm Cable length 1.0 m: +20 mm
Recommended electronics	C-867.1U	C-867.1U		




Ask about customized versions.

10.1.2 Reference Switch Specifications

Type	Optical sensor
Supply voltage	+5 V/GND, supply via the motor connector
Signal output	TTL level

10.1.3 Maximum Ratings

The U-651 rotation stages are designed for the following operating data:

Maximum operating voltage	Operating frequency	Maximum power consumption
		
200 V _{pp} or 71 V _{eff}	152 to 165 kHz	30 W

10.1.4 Specifications for Vacuum-Compatible Versions

The following vacuum-compatible components are used for the vacuum version of the U-651:

Component	Material
Mechanical parts	Aluminum (blank), aluminum (anodized, black, matt), steel, ceramic (PIC181, Al ₂ O 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-651:

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	

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-651 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-651. 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 %	18 V _{eff}	8192 or -8192
50 %	36 V _{eff}	16384 or -16384
75 %	53 V _{eff}	24575 or -24575
100 %	71 V _{eff} (max.)	32767 or -32767

* 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-651 for further information.

10.3.2 Velocity and Torque

The following figure can be used to estimate the velocity and torque of the U-651 with different motor powers. Motion is possible starting at a motor power of approx. 30 %.

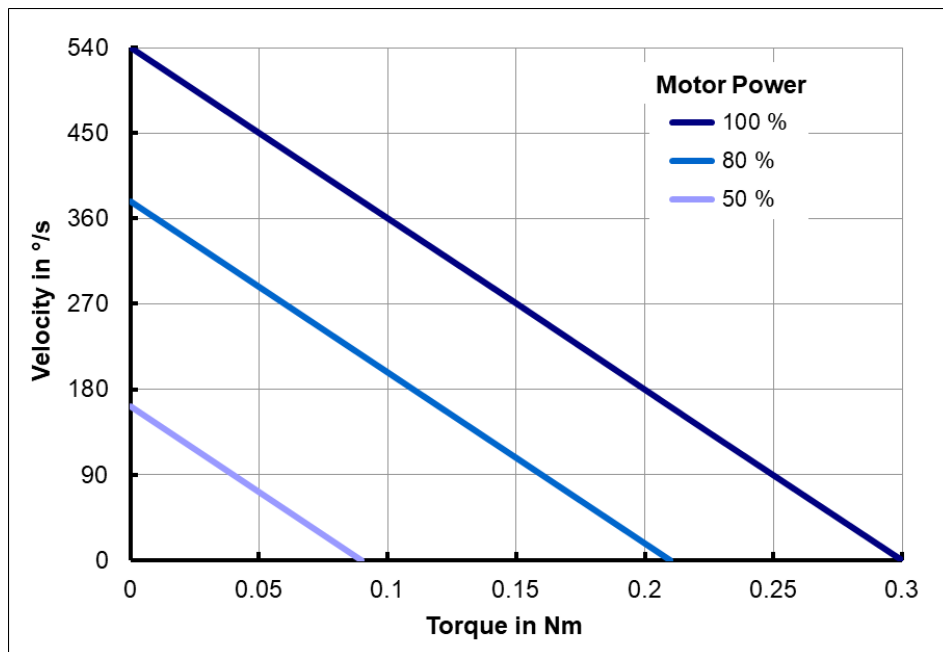


Figure 9: Relationship between velocity and torque of the U-651 with different motor power levels

10.3.3 Motor Power and Lifetime

Motor power, duty cycle and ambient temperature influence the lifetime of the rotation 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-651 with a 20 % lower motor power than given in the graph, or reduce the duty cycle.

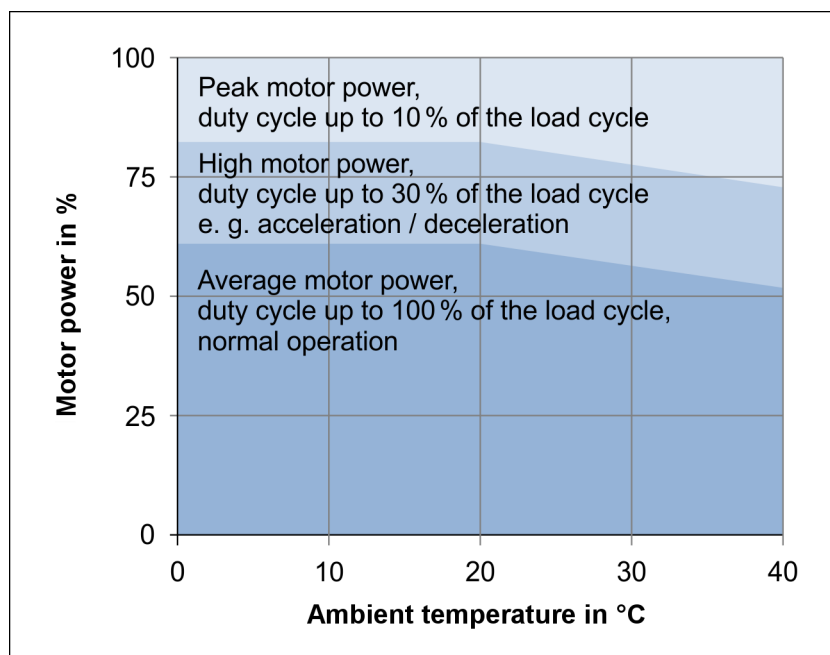


Figure 10: U-651: Recommended duty cycle and motor power depending on the ambient temperature

10.3.4 Influence of Downtimes on the Torque

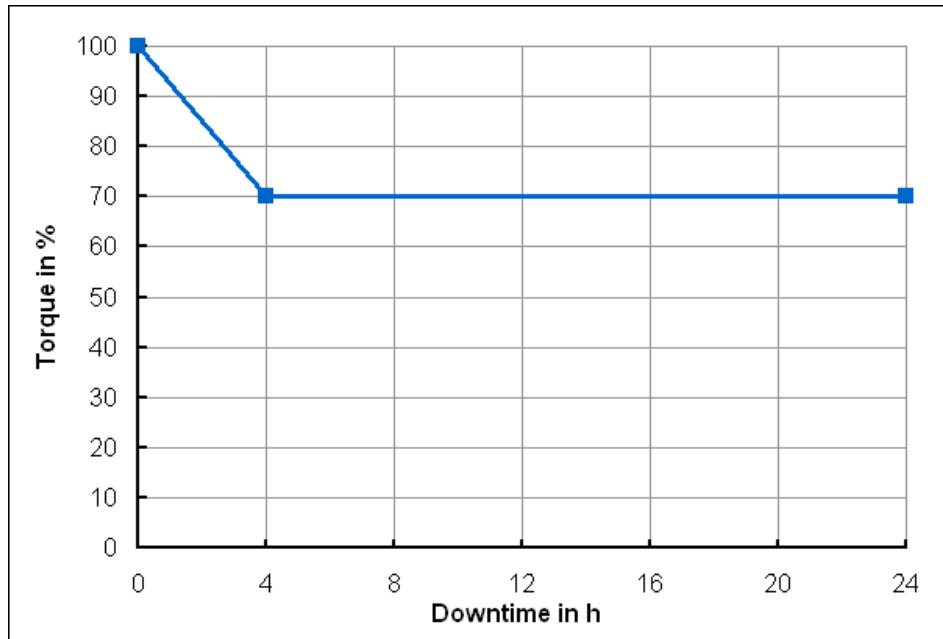


Figure 11: Torque of the U-651 depending on the downtime of the motor

10.4 Dimensions

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

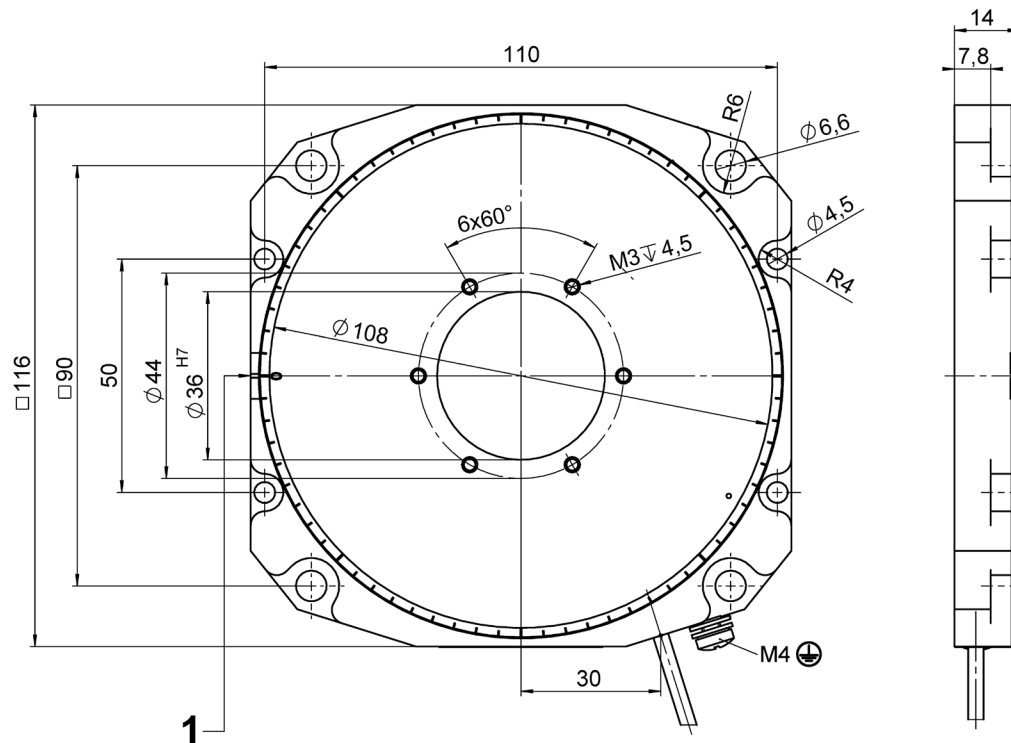


Figure 12: U-651: Dimensions and position of the 0° mark [1] after referencing

10.5 Pin Assignment

Connector: D-sub 15 (m)

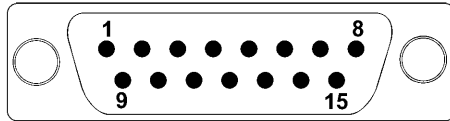


Figure 13: Front view of the D-sub 15 connector

Pin	Signal	Function
1	NC	Not connected
2	USM_P1	Input: Motor voltage ground
3	USM_P2	Input: Piezo 71 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 71 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



12 EU Declaration of Conformity

For the U-651, 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

