THORLABS

PD1(/M)
Piezo Inertia Drive Stage

User Guide

Table of Contents

Chapter 1 Warning Symbol Definitions

Below is a list of warning symbols you may encounter in this manual or on your device.

Symbol	Description
	Direct Current
	Alternating Current
	Both Direct and Alternating Current
	Earth Ground Terminal
	Protective Conductor Terminal
	Frame or Chassis Terminal
	Equipotentiality
	On (Supply)
	Off (Supply)
	In Position of a Bi-Stable Push Control
	Out Position of a Bi-Stable Push Control
	Caution: Risk of Electric Shock
	Caution: Hot Surface
	Caution: Risk of Danger
	Warning: Laser Radiation
	Caution: Spinning Blades May Cause Harm

Chapter 2 Safety

2.1. Safety Information

For the continuing safety of the operators of this equipment, and the protection of the equipment itself, the operator should take note of the Warnings, Cautions and Notes throughout this manual and, where visible, on the product itself.

The following safety symbols may be used throughout the manual and on the equipment itself.

SHOCK WARNING

A shock warning is given when there is a risk of injury from electrical shock.

WARNING

A warning is given when there is danger of injury to users.

CAUTION

A caution is given when there is a possibility of damage to the product.

NOTE

This is a clarification of an instruction or additional information.

2.2. General Warnings

WARNING

If this equipment is used in a manner not specified by the manufacturer, the protection provided by the equipment may be impaired. In particular, excessive moisture and/or dust may impair operation.

Spillage of fluid, such as sample solutions, should be avoided. If spillage does occur, clean up immediately using absorbent tissue. Do not allow spilled fluid to enter the internal mechanism.

The equipment is for indoor use only.

The equipment is not designed for use in an explosive atmosphere.

When running custom move sequences, or under fault conditions, the stage may move unexpectedly. Operators should take care when working inside the moving envelope of the stage.

2.3. General Cautions

CAUTION

Dust and debris can reduce the lifetime of the stage. If left running unattended for extended periods of time, the application should be covered where possible.

If the clamping force onto the moving platform is too high, this can cause reduced stepping performance and possible stalling of the stage.

The stage's screws are well adjusted and fixed. Loosening or removing any screws will change the performance and invalidate the warranty, except where instructed to do so in this manual.

2.4. General Notes

NOTE

The slip-stick function of the mechanism uses a very short pulse width.

Continuous stepping of the stage results in an audible noise at a typical level of 60 to 70 dB.

The step size is defined as the distance moved in one step or pulse. This distance can be increased by up to about 30% by changing the piezo drive voltage. The actual step size achieved for a given drive voltage will be dependent on the application. Due to the open loop design, piezo hysteresis, component variance, and application conditions, the achieved step size of the system may vary by over 20% and is not normally repeatable.

Chapter 3 Overview

3.1. Introduction

The PD1(/M) stage features a piezo inertia motor that uses friction and inertia to translate the platform in discrete cycles. Each cycle consists of a relatively slow piezo expansion step accompanied by a rapid piezo contraction step. During the expansion step, the moving platform moves in the same direction as the piezo element due to friction, while the rapid piezo contraction causes the moving platform to slip and remain immobile due to inertia. Continuous motion is achieved through repetition ("continuous stepping") of this cycle and reverse travel is achieved by performing the cycle in reverse.

The PD1(/M) stage has a 20 mm travel range and open loop operation. When driven by the KIM101 Inertial Piezo Controller, the PD1(/M) stage offers continuous long term stepping as well as periodic position and hold mode with 3 N clamping/holding force. The stage can achieve a typical step size of 1 µm using different rise and fall voltage rates that depend on the load.

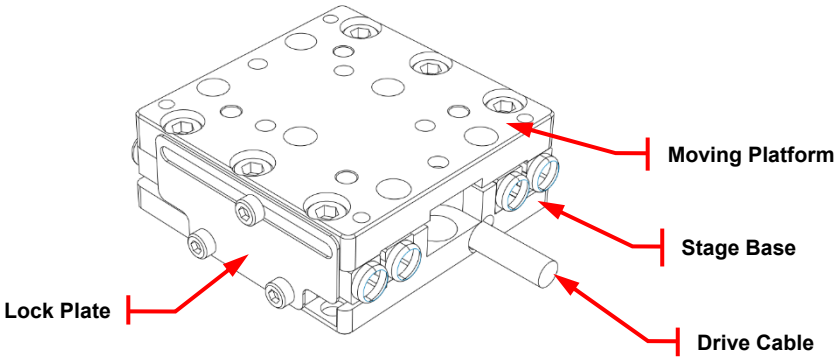


Figure 1 Stage Features

3.2. Included Components

The PD1(/M) stage is delivered with the following components:

- Quick Start Card
- 8-32 (M4) Cap Screws, 6 mm Long, 2 Pieces
- 2-56 (M2) Cap Screws, 4 mm Long, 2 Pieces
- Ø2 mm Dowel Pin, 3 mm Long, 2 Pieces
- 9/64" (3.0 mm) Hex Key
- 5/64" (1.5 mm) Hex Key
- 1.3 mm Hex Key

3.3. Unpacking

NOTE

Unpack the stage with care. Check the contents for signs of damage. If there is any sign of damage or missing parts, contact Thorlabs immediately. The lock plate and corresponding M1.4 screws are used to lock the stage during transportation or storage.

Unlock the upper M1.4 screw indicated by the note card using the included 1.3 mm hex key and remove the note card before first use. Leave the M1.4 screw loosened during use.

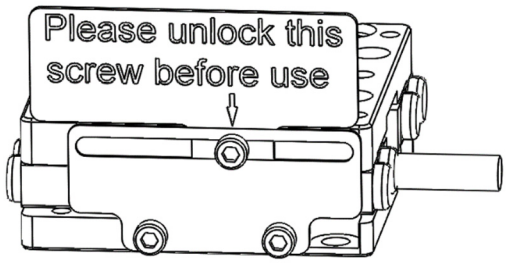


Figure 2 Loosen the lock screw and remove the note card before use.

3.4. Accessories

The PD1B(/M) adapter provides a flat surface for mounting the PD1(/M) stage.

The PD1T(/M) adapter plate features a central 8-32(M4) tapped hole, both imperial and metric versions have four 4-40 tapped holes spaced for 16 mm cage systems.

The PD1U(/M) adapter plate features four 6-32 and four 8-32 tapped holes (or eight M4 tapped holes) in a cross pattern. The bottom surface features five #8 (M4) counterbores, providing a convenient means of attaching a load to the stage.

The PD1Z(/M) right-angle bracket allows the stage to be mounted in an XYZ configuration.

The PAA101 1.5 m extension cable and T5026 male adapter can be used to extend the drive cable length to 2.5 m.

CAUTION

Do not mount an imperial accessory to a metric stage or a metric accessory to an imperial stage.

Chapter 4 Installation

4.1. Mounting

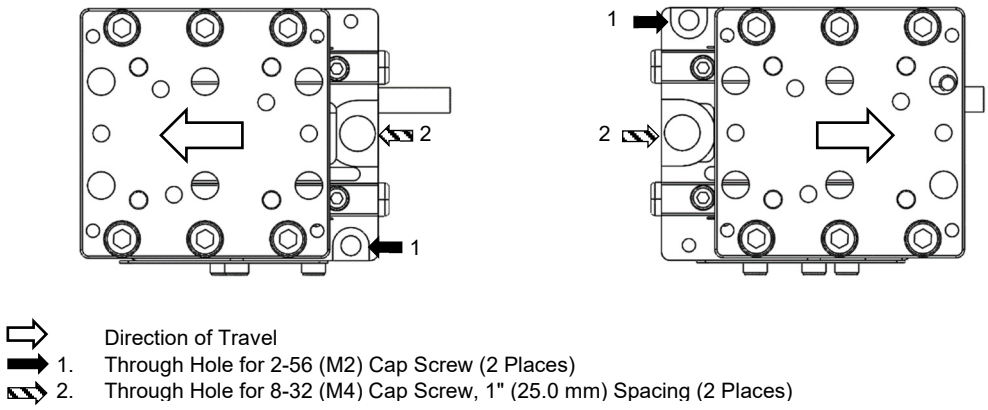
4.1.1. General

Mount the PD1(/M) stage on an even surface. The recommended flatness of the surface is ≤5 µm.

For applications with large temperature changes, only mount the PD1(/M) stage on a surface that has the same or similar thermal expansion properties as the stage.

The mounting holes are accessible when the moving platform is at the ends of the translation range. The stage can be mounted using two 2-56 (M2) screws near the corners with a maximum of 0.35 N·m torque. Alternatively, two 8-32 (M4) screws can be used on either end of the stage with up to 0.55 N·m torque.

Take care to mount the stage before attaching components to the stage's moving platform.



Direction of Travel
1. Through Hole for 2-56 (M2) Cap Screw (2 Places)
2. Through Hole for 8-32 (M4) Cap Screw, 1" (25.0 mm) Spacing (2 Places)

Figure 3 Mounting Holes

CAUTION

Mounting the PD1(/M) stage on an uneven surface can warp the stage, degrading the performance and possibly damaging the stage.

When mounting close to other equipment, ensure that the travel of the carriage is not obstructed. If movement is obstructed the stage will stall, which could cause excessive wear and premature failure.

When using the stage in the proximity of other objects or equipment, ensure that movement of cables connected to the moving carriage is not impeded.

Avoid touching the ceramic bar under the carriage plate.

Thorlabs offers a mounting baseplate, PD1B(/M), to provide a flat surface for mounting and 1.00" (25.0 mm) long #8 (M4) counterbored slot for attaching to table.

1. Firstly mount the PD1B(/M) to a breadboard or base plate or table using two 8-32 (M4) cap screws via 1.00" (25.0 mm) long #8(M4) counterbored slot. Washers are recommended to be used under the 8-32 (M4) cap screws to enhance the mounting and reduce damage to the plate by the screws.

2. Insert two 8-32 (M4), 6 mm long cap screws through the stage to the mounting plate. 8 mm long 8-32 (M4) screws can also be used here. Two 2-56 (M2), 4 mm long screws can also be used to mount the stage to the mounting plate.

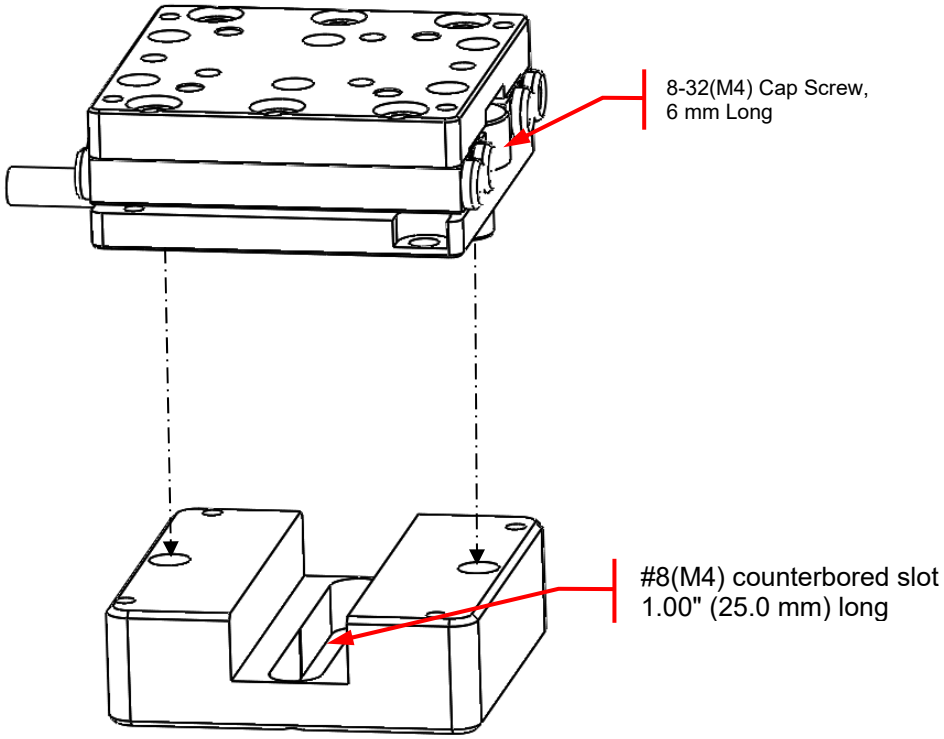


Figure 4 Mounting Adapter PD1U(/M) on Moving Platform

4.1.2. Setting Up an XY & XYZ Stage Configuration

CAUTION

In a multi-axis system, upper stage(s) and any mounting adapters must also be moved and should be considered as part of the load.

Do not exceed the load capacity for any of the stages in a multi-axis system.

When a stage is mounted vertically, make sure that the installed load is lower than the push/pull force of the stage.

Screws and locating dowel pins that are inserted too deep into the stage will damage it. Do not thread screws into the top plate with excessive force as they may break through the terminating lip at the base of each threaded hole.

To set up an XY system:

1. Insert two Ø2 mm, 3 mm long dowel pins into the lower stage's two slots in diagonal corners.
2. Rotate the upper stage by 90° relative to the lower one and mount the two stages by the alignment of the two dowel pins.
3. Insert two 2-56 (M2), 4 mm long cap screws through the upper stage to the lower one.

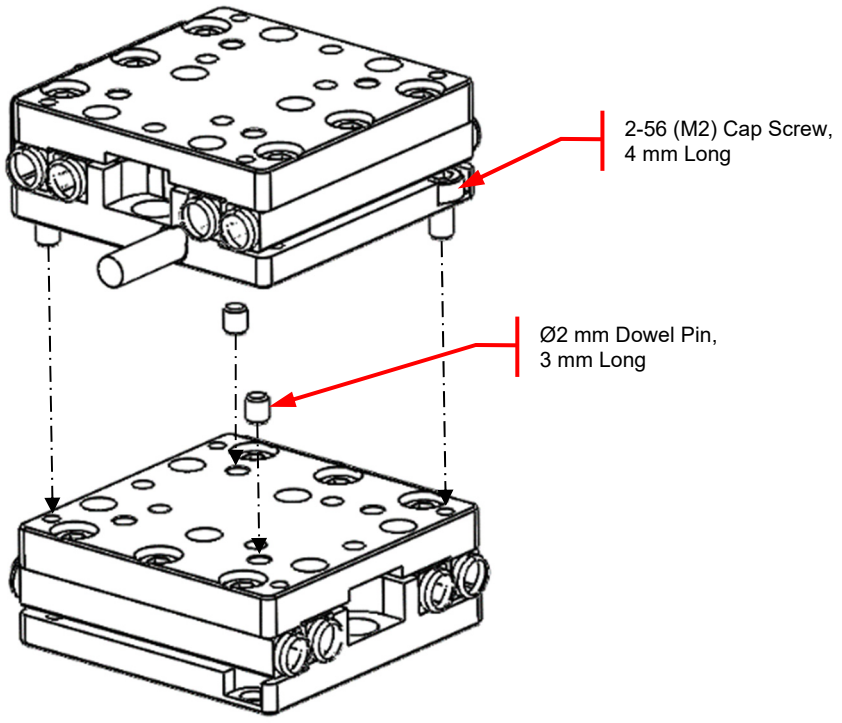


Figure 5 Setting Up an XY Configuration

To set up an XYZ-axis system, firstly build the XY-axis system as above and then use an adapter plate. Thorlabs offers a right-angle bracket adapter plate, PD1Z(/M), to mount the PD series stage vertically.

1. Insert two Ø2 mm, 3 mm long dowel pins into the lower stage's two slots in diagonal corners.

2. Align the PD1Z(/M) bracket with vertical plane to the stage's side face and parallel to stage's cable direction and mount the Z bracket to the stage by the alignment of the two dowel pins.

3. Insert two 2-56 (M2), 4 mm long cap screws through the right-angle bracket to the stage on the rear corners from the vertical plane.

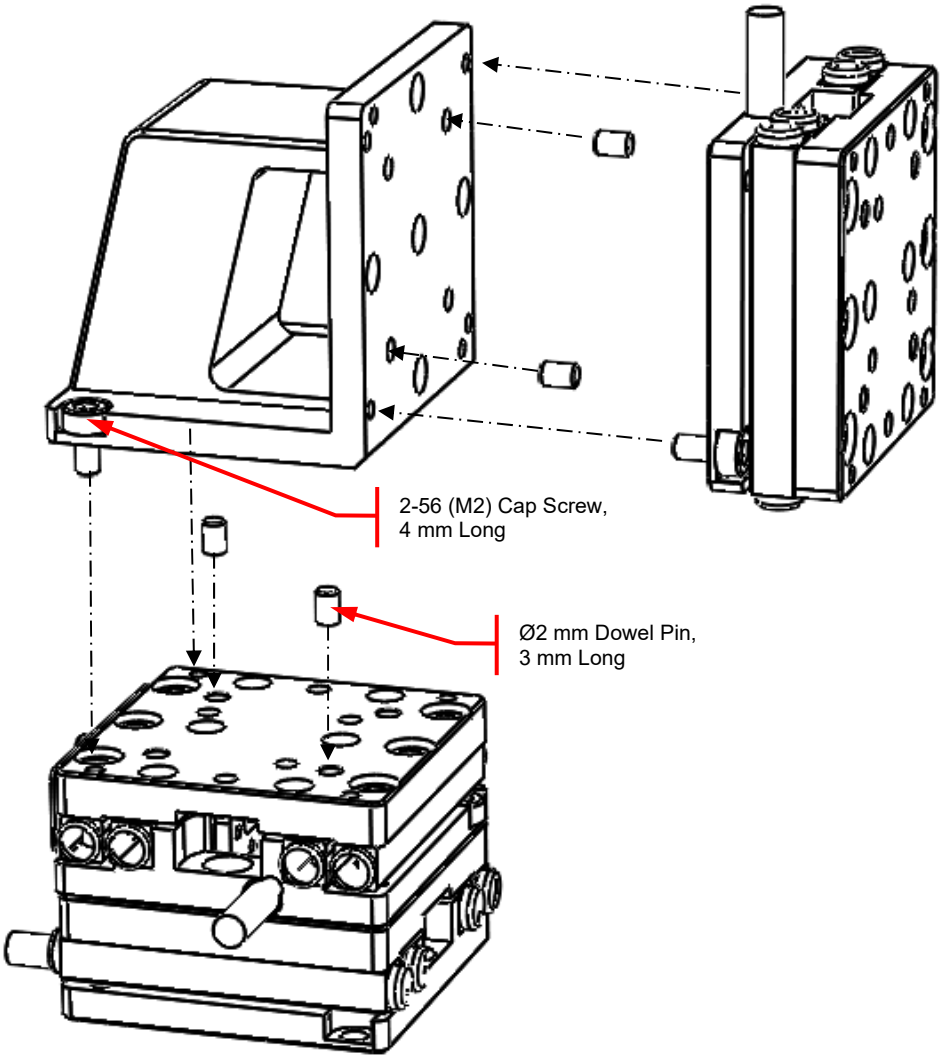


Figure 6 Setting Up an XYZ Configuration

4. Insert another two Ø2 mm, 3 mm long dowel pins into the vertical plane's two slots in diagonal corners.

5. Align the Z stage to the vertical plane with its cable vertically and away from the lower stage, mount the Z stage to the Z bracket by the alignment of the two dowel pins.

6. Insert two 2-56 (M2), 4 mm long cap screws through the Z stage to the vertical plane, as shown in Figure 6. Alternatively, two 8-32 (M4), 6mm long cap screws can also be used to mount the Z stage to the vertical plane.

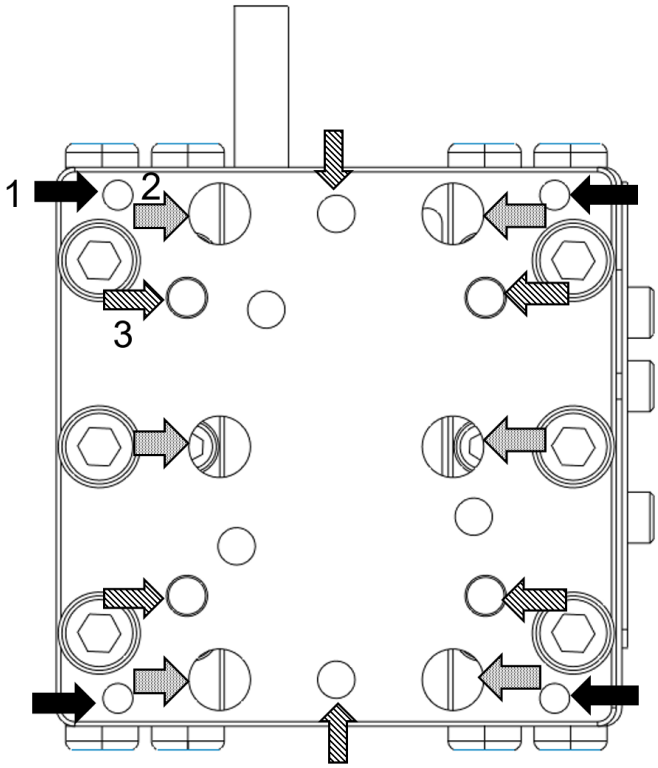
4.1.3. Mounting Components to the Stage

CAUTION

Do not exceed the load capacity specified in Chapter 6.

The load's center of mass should be over the platform.

Do not use screws and dowel pins that protrude past the maximum hole depth.



1. 2-56 (M2) Threaded Hole, 3 mm Deep (4 Places)
2. 8-32 (M4) Threaded Hole, 3 mm Deep, 1" (25.0 mm) Spacing (6 Places)
3. Ø2 mm Dowel Pin Hole, 1.5 mm Deep (6 Places)

Figure 7 Mounting Holes on Moving Platform

Attach the load using screws and check that it is secure. We recommend aligning the load with a set of dowel pins opposite each other relative to the center of the stage, as well as ensuring the load's center of mass is over the platform before driving the stage.

Thorlabs offers a thin mounting adapter plate, PD1T(/M), to provide a convenient means of attaching load to the PD series stages by a central 8-32(M4) tapped hole and other 4-40(M2 & M3) tapped holes. Both the imperial and metric versions have four 4-40 tapped holes spaced for 16 mm cage systems. Following is the example to show how to mount PD1T(/M) to a PD1(/M) stage.

1. Insert two Ø2 mm, 3 mm long dowel pins into the moving platform's two slots along the travel direction.
2. Mount the adapter plate to the stage by the alignment of the two dowel pins.
3. Insert two 2-56 (M2), 4 mm long cap screws through the adapter plate to the stage.

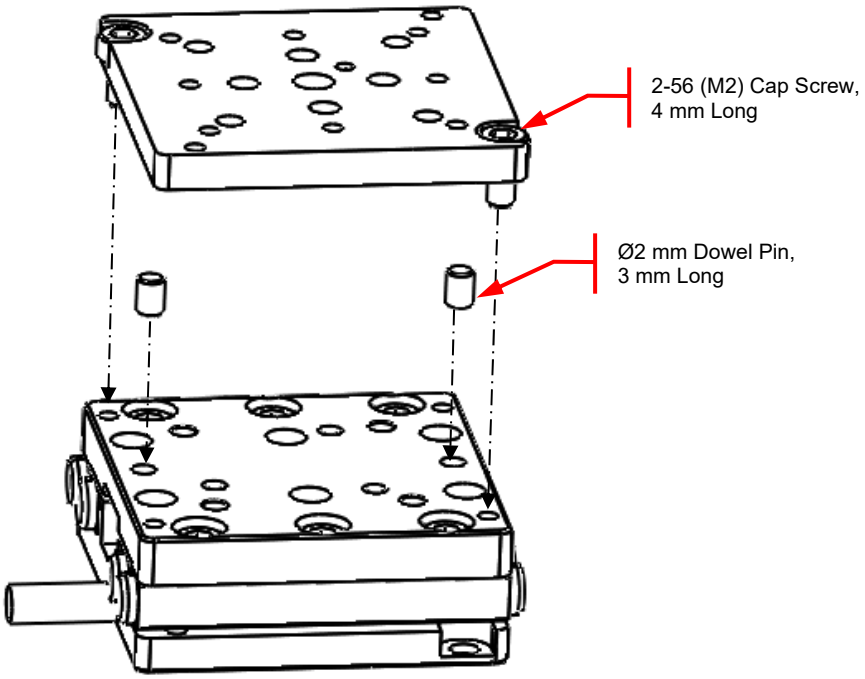


Figure 8 Mounting Adapter PD1U(/M) on Moving Platform

Thorlabs also offers a thick mounting adapter plate, PD1U(/M), to provide a convenient means of attaching load to the PD series stages by five #8 (M4) counterbores. As shown in Figure 8:

1. Use the five #8 (M4) counterbores to mount the load from down up. Notice that the load should not cover the two counterbores for the 2-56(M2) cap srews on the top surface.
2. Insert two Ø2 mm, 3 mm long dowel pins into the moving platform's two slots along the travel direction.
3. Mount the adapter plate to the stage by the alignment of the two dowel pins.
4. Insert two 2-56 (M2), 8 mm long cap screws through the adapter plate to the stage.

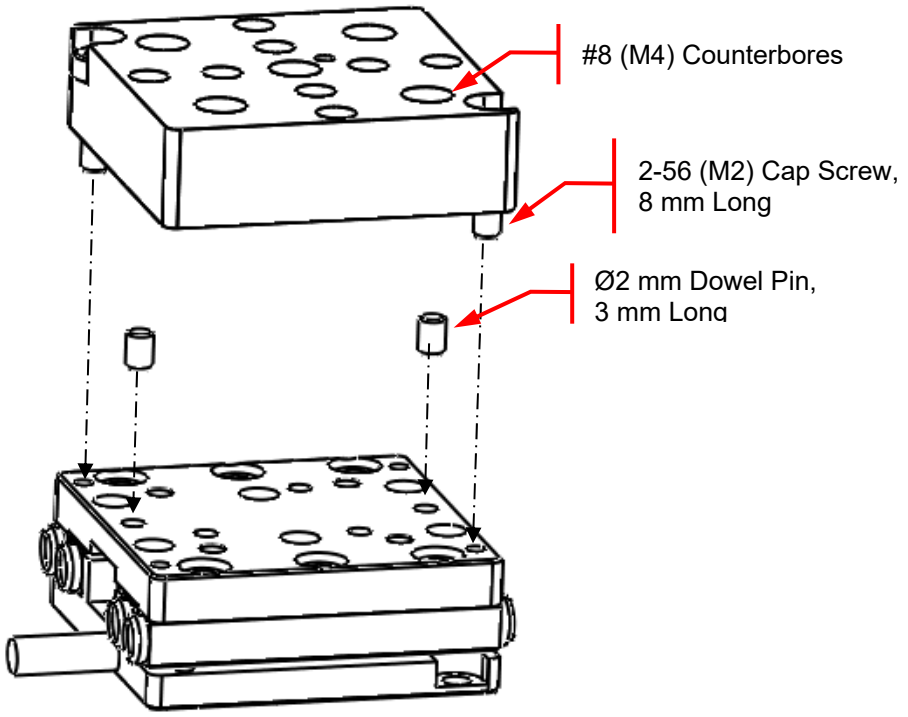


Figure 9 Mounting Adapter PD1U(/M) on Moving Platform

4.2. Electrical Connections

CAUTION

The PD1(/M) stage must be driven by a Thorlabs KIM101 controller with 2019 or newer version and firmware revision 010004 or higher. Earlier versions of the KIM101 controller or those with older firmware will not function properly and may cause failure of the stage and/or the controller. The previous-generation TIM101 controller is not compatible.

The stage is shipped with a 1 m (3.3 ft) cable that is terminated in an SMC connector. Connect the PD1(/M) stage to one of the MOT (motor) terminals on the rear panel of the KIM101 controller - see the KIM101 controller manual for pin out details.

Before driving the PD1(/M) stage, the configuration of the KIM101 must be set correctly, since the KIM101 controller is configured by default to drive our piezo inertia actuators. Using the joystick and menu button, select the “Set stage” option and change it from “PIA” to “PD(R)”, then restart the KIM101 controller. The display will show “Stage is PD(R)” and the configuration will be changed to drive the PD1(/M) stage. Alternatively, using Kinesis software with revision 1.14.18 or higher could also switch the configuration by choosing the stage type. See the KIM101 controller manual for additional front panel configuration details.

CAUTION

The KIM101 controller is configured by default to drive Thorlabs PIA series actuators. The configuration must be changed to “PD(R)” before using the controller to drive the PD1(/M) stage, or else the stage may experience degraded performance or damage may be caused to either the controller, the stage, or both.

Confirm the configuration has been switched to PD(R) stage before using the KIM101 controller with the PD1(/M) stage.

Thorlabs offers a 1.5 m extension cable (PAA101) and male adapter (T5026) to extend the drive cable length to 2.5 m, see www.thorlabs.com.

Due to the capacitance of the cables, do not use cables longer than 2.5 m in total.

Chapter 5 Operation

5.1. General

CAUTION

Confirm the configuration of the KIM101 controller has been switched to "PD(R)" stage.

WARNING

The piezo actuators in this product use high voltages. Voltages up to 125 V may be present at the SMC connector. This is hazardous and can cause serious injury. Appropriate care should be taken when using this device. Persons using the device must understand the hazards associated with using high voltages and the steps necessary to avoid risk of electrical shock.

The piezo controller must be switched OFF before the stage is connected or disconnected. Failure to switch the controller off may result in damage to either the controller, the stage, or both.

For a complete tutorial on driving the stage, see the manual supplied with the KIM101 controller. Basic steps in controlling the stage are as follows:

1. Mount the PD1(/M) stage as detailed in Section 4.1.

2. Make electrical connections as detailed in Section 4.2.

NOTE

During operation, the stage makes a high pitch noise and may generate some heat. This is normal behavior in the performance of the device and does not indicate a fault condition.

3. Run the software and click the 'zero' button on the GUI panel. This establishes a datum at the current position, from which subsequent positional moves can be measured.

4. The stage can now be moved using the controls on the KIM101 unit, the GUI panel, or by sending commands to move each axis – see the manual supplied with the KIM101 controller, and the help file supplied with the software for more information.

NOTE

The PD1(/M) stage is an open loop device that has been designed to offer relative positioning which can be commanded via the number of steps.

CAUTION

If the stage is driven to the end of its travel range, do not drive it further. Instead, stop or reverse the driving direction to avoid excessive wear at the end stops.

Using a small working range permanently increases the wear in this area. Select another part of the travel range for the working range if possible to spread the wear evenly and extend stage life.

5.2. Maintenance

Periodically perform a maintenance run by driving the stage to travel back and forth across the entire travel range. The frequency of this will depend on usage. In applications involving continuous use or where a small travel range is used at a high duty cycle, the maintenance run should be performed often to ensure optimal performance of the stage.

Due to the stick-slip (friction-inertia) nature of the mechanism, wear of the friction parts occurs during its lifetime. Periodic maintenance helps to ensure the optimum stepping performance during its lifetime.

NOTE

The PD1(/M) stage is assembled with rust preventative oil. Don't wipe the stage with organic solvent. When necessary, clean the surfaces of the stage with a dry, dust-free cloth.

5.3. Transportation

CAUTION

When packing the unit for shipping, use the original packaging and lock the moving platform of the stage using the lock plate and M1.4 screws. If the original packaging is not available, use a strong box and surround the unit with at least 20 mm of shock absorbent material.

Chapter 6 Specifications

Item #	PD1(/M)
Travel Range	20 mm (0.78")
Typical Step Size[1]	1 µm
Maximum Step Size[2]	<3 µm
Step Size Adjustability[2]	Up to 30%
Maximum Step Frequency	2 kHz
Velocity (Typical Max, Continuous Stepping)[3]	3 mm/s
Average Velocity Variation Over Travel Range[3]	±10%
Horizontal Load Capacity	3 kg (6.61 lbs)
Vertical Load Capacity[4]	100 g (3.5 oz)
Clamping / Holding Force	3 N
Pitch / Yaw Over Travel Range	200 µrad
XY Stacked Orthogonality	<5 mrad
Lifetime*	>10 Billion Steps
Connector Type	SMC Female
Cable Length	1 m (3.3 ft) Cable Included
Piezo Capacitance	170 nF
Max Operating Voltage	125 V
Operating Temperature	10 to 40 °C
Dimensions	32.5 mm x 32.0 mm x 11.5 mm (1.28" x 1.26" x 0.45")
Weight (Including Cable)	76 g (2.68 oz)

Note: all specifications are measured using the KIM101 controller and with the stage mounted on a surface with flatness ≤5 µm.

*When mounted vertically, long term usage (>3 billion steps) may cause creep of the rails, leading to decreased travel range. To avoid this, return the stage to a horizontal position and run it back and forth over the full range several times after approximately 1 billion steps in a vertical orientation.

[1] *This can vary by 20% due to component variance, change of direction, and application conditions.*
[2] *This is adjusted by changing the piezo drive voltage and frequency - see the KIM101 controller manual for more details.*
[3] *Specified at 2 kHz Step Frequency*
[4] *This is equivalent to the push/pull force along the axial/travel direction, which is 1 N.*

Chapter 7 Frequently Asked Questions

How does a piezo inertia motor work?

A piezo inertia stage uses friction and inertia (“stick” and “slip”) to drive the moving platform. The piezo stack is driven by a sawtooth voltage waveform. As the voltage is ramped up, the piezo will extend and push the moving platform (stick). When the voltage is dropped to zero, the piezo returns to its original length. By using different rates of voltage rise and fall, the moving platform travels more in one direction than the other due to inertia and different frictional coefficients, resulting in residual linear travel.

What applications can they be used for?

Any ‘set-and-forget’ application, particularly where space is tight. The primary function of the PD1(/M) stage is relative position and hold. The step size is dependent upon preload, and will differ between stages and applications. They are not suitable where repeatable step size is required.

What is the lifetime of a typical piezo inertial motor?

The piezo stack of the actuator is rated for a service life of over 10 billion steps. With proper maintenance (see Section 5.2), the wear performance of the stage’s friction parts should endure for this lifetime, however the speed variation could change by up to 50% or more over time.

What driver can I use?

The PD1(/M) stage must be driven by a Thorlabs KIM101 controller version must be 2019 or newer (per the S/N label) with a firmware revision of 010003 or higher (indicated when the controller is powered on). Earlier versions of the KIM101 controller or those with older firmware will not function properly and may cause failure of the stage and/or the controller. The previous-generation TIM101 controller is not compatible.

Ensure the controller’s stage mode is set to “PD(R)”.

What is the maximum length of cable?

The stages are shipped with 1 m (3.3 ft) of cable. Thorlabs offer 1.5 m (PAA101) extension cables and male adapters (T5026) to extend this length to 2.5 m, see www.thorlabs.com. Due to the capacitance of the cables, do not use cables longer than 2.5 m in total.

Chapter 8 Mechanical Drawings

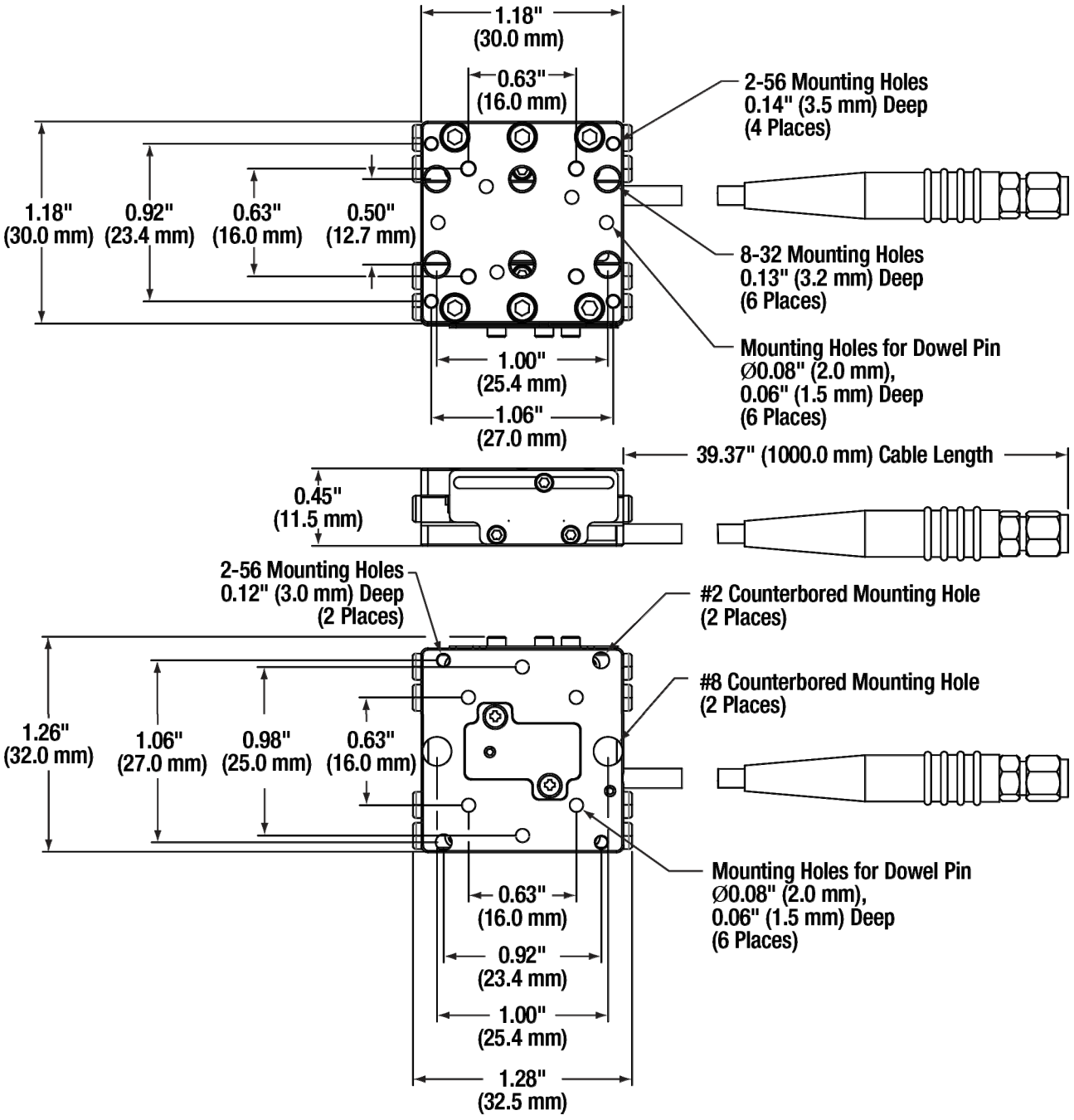


Figure 10 PD1 Imperial Stage Drawing

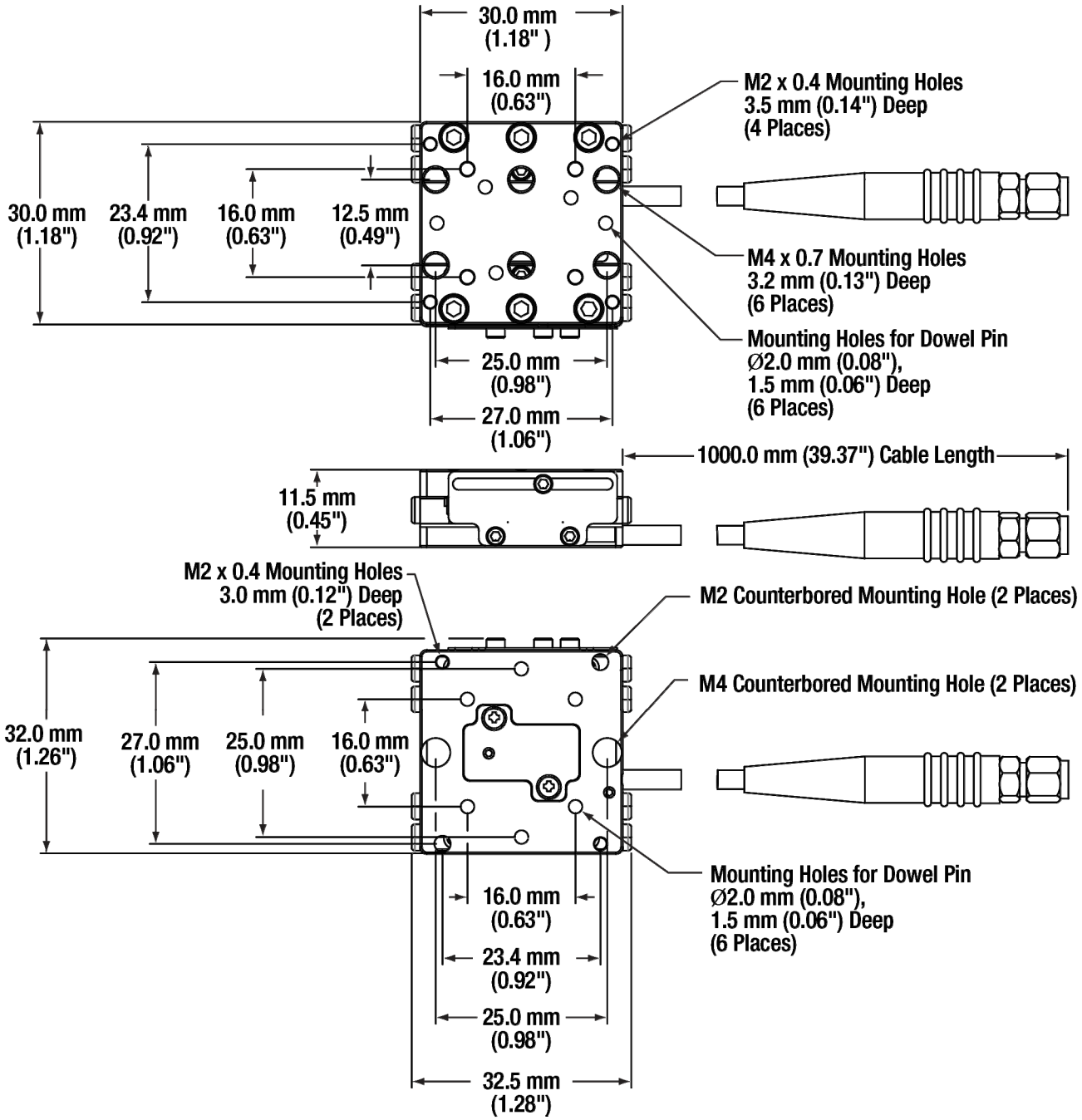
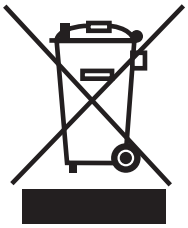


Figure 11 PD1/M Metric Stage Drawing

Chapter 9 Regulatory

As required by the WEEE (Waste Electrical and Electronic Equipment Directive) of the European Community and the corresponding national laws, Thorlabs offers all end users in the EC the possibility to return “end of life” units without incurring disposal charges.



- This offer is valid for Thorlabs electrical and electronic equipment:
- Sold after August 13, 2005
- Marked correspondingly with the crossed out “wheelie bin” logo (see right)
- Sold to a company or institute within the EC
- Currently owned by a company or institute within the EC
- Still complete, not disassembled and not contaminated

As the WEEE directive applies to self-contained operational electrical and electronic products, this end of life take back service does not refer to other Thorlabs products, such as:

- Pure OEM products, that means assemblies to be built into a unit by the user (e. g. OEM laser driver cards)
- Components
- Mechanics and optics
- Left over parts of units disassembled by the user (PCB’s, housings etc.).

If you wish to return a Thorlabs unit for waste recovery, please contact Thorlabs or your nearest dealer for further information.

Waste Treatment is Your Own Responsibility

If you do not return an “end of life” unit to Thorlabs, you must hand it to a company specialized in waste recovery. Do not dispose of the unit in a litter bin or at a public waste disposal site.

Ecological Background

It is well known that WEEE pollutes the environment by releasing toxic products during decomposition. The aim of the European RoHS directive is to reduce the content of toxic substances in electronic products in the future.

The intent of the WEEE directive is to enforce the recycling of WEEE. A controlled recycling of end of life products will thereby avoid negative impacts on the environment.

Chapter 10 Declaration of Conformity

CE

Declaration of Conformity

We: Thorlabs Optical Electronic Technology (Shanghai) Co., Ltd
of: Room A101, No.100, Lane 2891, South Qilianshan Rd, Shanghai

In accordance with the following Directive(s):

2014/35/EU	Low Voltage Directive (LVD)
2011/65/EU	Restriction of Use of Certain Hazardous Substances (RoHS)

hereby declare that:

Model: ***PD1, PD1/M***
Equipment: ***Piezo Inertia Drive Stage***

Is in conformity with the applicable requirements of the following documents:

EN 61010-1: 2010 (Third Edition) + A1: 2019

and which, issued under the sole responsibility of Thorlabs, is in conformity with Directive 2011/65/EU of the European Parliament and of the Council of 8th June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment, for the reason stated below:

does not contain substances in excess of the maximum concentration values tolerated by weight in homogenous materials as listed in Annex II of the Directive.

I hereby declare that the equipment named has been designed to comply with the relevant section of the above referenced specifications, and complies with all applicable Essential Requirements of the Directives.

Signed:  on: 5th Jan. 2021

Name: Shanshan Song
Position: General Manager

Chapter 11 Thorlabs Worldwide Contacts

For technical support or sales inquiries, please visit us at **www.thorlabs.com/contact** for our most up-to-date contact information.

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UNLEASHED