



PFM450E

Piezo Focus Mount and Controller

Kinesis User Guide



Original Instructions

Contents

- Chapter 1 Overview 1**
 - 1.1 Introduction 1**
 - 1.2 Software Overview 3**
 - 1.2.1 Introduction 3
 - 1.2.2 Kinesis Server 3
 - 1.2.3 Software Upgrades 4

- Chapter 2 Safety 5**
 - 2.1 Safety Information 5**
 - 2.2 General Warnings and Cautions 5**

- Chapter 3 Installation 6**
 - 3.1 Unpacking 6**
 - 3.2 Mounting 7**
 - 3.2.1 General 7
 - 3.3 Installing the Focus Mount 7**
 - 3.4 Fitting/Changing the Objective 9**
 - 3.4.1 Angular Rotation 10
 - 3.5 Installing the Controller 11**
 - 3.5.1 Siting 11
 - 3.5.2 Environmental Conditions 11
 - 3.6 Installing the Software 12**
 - 3.7 Electrical Connection 12**
 - 3.7.1 Connecting To The Supply 12
 - 3.7.2 Connecting The Hardware 13
 - 3.7.3 Powering Down The Controller 14
 - 3.7.4 Rear Panel Connections 15
 - 3.8 Front Panel Controls and Indicators 17**
 - 3.9 Controller Schematic Diagram 18**

Continued...

Chaper 4	PC Operation - Tutorial	20
4.1	Introduction	20
4.2	Using the Kinesis Software	20
4.3	Introduction to Open and Closed Loop Operation	22
4.4	Tuning	22
4.5	Limitations on the Displayed Position Values	23
4.6	Moving the Piezo Mount	24
4.6.1	Setting the Zero Position	24
4.6.2	Entering the piezo position	24
4.6.3	Jogging the Piezos	25
4.7	Using the Controller as a Piezo Amplifier	26
4.8	Thermal Shutdown	27
4.9	Using the MZF001 Joystick	27
4.10	Load Response	28
Chaper 5	Software Reference	29
5.1	GUI Panel	29
5.2	Settings Panel	30
5.2.1	Persisting Settings to the Hardware	30
5.2.2	Advanced tab.	31
5.2.3	Filters tab.	33

Appendices

Appendix A	Rear Panel Connector Pinout Detail	39
Appendix A	Preventive Maintenance	45
Appendix B	Specifications and Associated Parts	46
Appendix C	Piezo Operation - Background	49
Appendix D	Regulatory	52
Appendix E	Thorlabs Worldwide Contacts	55

Chapter 1 Overview

1.1 Introduction

Thorlabs' PFM450E Piezo-Driven Focus Mount System provides 600 μm of travel in open loop and 450 μm in closed loop and is designed specifically for visualizing specimens or samples in applications such as confocal microscopy and 3D imaging. The PFM450 Objective Mount is sold as a matched pair with the PPC001 closed-loop, precision piezo controller for controlled focussing and active location feedback.

The stage offers a monolithic flexure made from hardened tool steel. It houses a precision geometry capacitive feedback sensor that uses ultra-stable electrode plates (rigid substrates coated with precious metal alloy layers). These sensors give correct positioning with submicron repeatability and resolution on the order of 1 nm in open loop and 3 nm in closed loop, making this product ideal for applications that require highly accurate positioning control.

The system also provides active feedback to compensate for thermal changes and other factors that might lead to drift and is ideally suited for use in laser scanning microscopy setups among others.

The supplied PPC001 controller is designed for use in critical alignment applications where nanometer level motion control is required. These high power units deliver up to 150V/150mA per channel.

The unit combines the latest highspeed digital signal processors (DSP) with low-noise analog electronics and ActiveX® software technology for effortless single-axis motion. Additional axes can be driven by connecting one or more benchtop units via a standard USB hub.



Fig. 1.1 PFM450 Piezo Focus Mount

The piezo controller is supplied with a full suite of software support tools. An intuitive graphical instrument panel allows immediate control and visualization of the operation of the piezo controller, and any other controllers that are installed in the system. See Section 1.2. for a full description of the system software.

The piezo unit operation is fully configurable (parameterized) with key settings exposed through the associated graphical interface panel. Open or closed loop operating modes can be selected 'on the fly', and in both modes the display can be changed to show drive voltage or position (in microns). In the closed loop operation mode, the P I D (proportional, integral and derivative) components of the feedback control loop can be altered to adjust the servo loop response. A notch filter can also be adjusted for fine tuning. For convenience and ease of use, adjustment of many key parameters is possible through direct interaction with the graphical panel. For example, the output drive voltage or position can be adjusted by entering a value in the display window (see the tutorial in Chapter 4 for further details). Note that all such settings and parameters are also accessible through the programmable interfaces. See Section 1.2. for a full description of the system software.

The key innovation of the controllers and associated mechanical products is the ease and speed with which complete automated alignment systems can be engineered at both the hardware and software level. All controllers in the Kinesis range are equipped with USB connectivity. The 'multi-drop' USB bus allows multiple units to be connected to a single controller PC using commercial USB hubs and cables. In the remainder of this handbook, the Tutorial section (Chapter 4) provides a good initial understanding on using the unit, and the reference section (Chapter 5) covers all operating modes and parameters in detail.



Fig. 1.2 Single Channel Precision Piezo Controller (PPC001)

1.2 Software Overview

1.2.1 Introduction

The PPC001 piezo controller features USB connectivity (allowing multiple units to be used together on a single PC), fully featured Graphical User Interface (GUI) panels, and extensive software function libraries for custom application development.

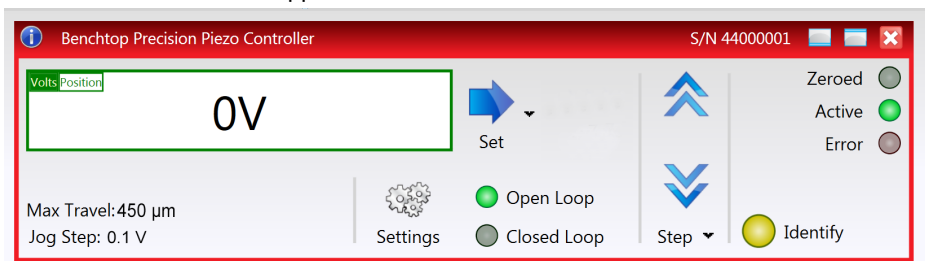
The Kinesis software suite provides a flexible and powerful PC based control system both for users of the equipment, and software programmers aiming to automate its operation.

The User Interface allows full control of all settings and operating modes enabling complete 'out-of-box' operation without the need to develop any further custom software. It provides all of the necessary system software services such as generation of GUI panels, communications handling for multiple USB units, and logging of all system activity to assist in hardware trouble shooting. The Kinesis server is also used by software developers to allow the creation of advanced automated positioning applications very rapidly and with great ease. The server is described in more detail in the following section.

1.2.2 Kinesis Server

With the Kinesis system, .Net Controls are deployed to allow direct control over (and also reflect the status of) the range of electronic controller units, including the Piezo controller. Software applications that use .Net Controls are often referred to as 'client applications'. A .Net Control is a language independent software component. Consequently the controls can be incorporated into a wide range of software development environments for use by client application developers. Development environments supported include Visual Basic, Labview, Visual C++, C++ Builder, HPVee, Matlab, VB.NET, C#.NET and, via VBA, Microsoft Office applications such as Excel and Word.

Consider the control supplied for the PPC001 controller.



The system provides a separate control for each piezo drive channel to allow the piezo unit to be manually operated, as well as a complete set of software functions to allow all parameters to be set and operations to be automated by a client application. The instrument panel reflects the current operating state of the driver unit to which it is associated (e.g. such as piezo drive voltage). Updates to the panel take place automatically when a user (client) application is making software calls into the same

Control. For example, if a client application instructs the associated Piezo Control to move an actuator, the progress of that move is reflected automatically by changing position readouts on the graphical interface, without the need for further programming intervention.

The Kinesis Controls collection provides a rich set of graphical user panels and programmable interfaces allowing users and client application developers to interact seamlessly with the Kinesis hardware. Each of the Kinesis controllers has an associated .Net Control and these are described fully in the handbooks associated with the controllers.

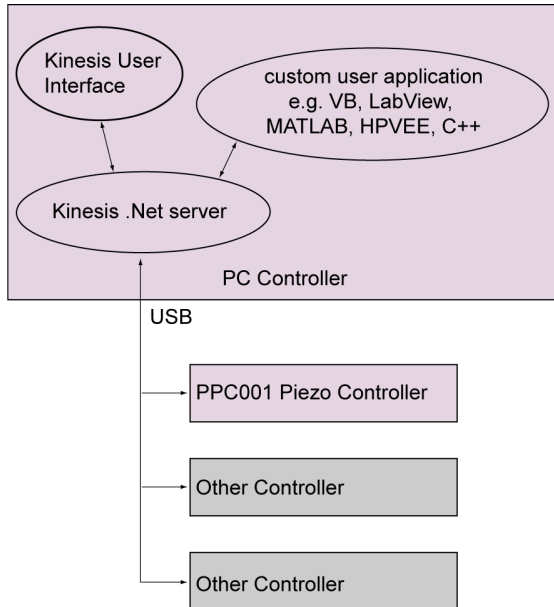


Fig. 1.3 System Architecture Diagram

Refer to the main Kinesis Software online help file, for a complete programmers guide. This is available either by pressing the F1 key when running the Kinesis server, or via the Start menu, Start\Programs\Thorlabs\Kinesis\Kinesis Help.

1.2.3 Software Upgrades

Thorlabs operate a policy of continuous product development and may issue software upgrades as necessary.

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 handbook and, where visible, on the product itself.

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



Warning: Risk of Electrical Shock

Given when there is a risk of injury from electrical shock.



Warning

Given when there is a risk of injury to users.



Caution

Given when there is a risk of damage to the product.

Note

Clarification of an instruction or additional information.

2.2 General Warnings and Cautions



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 may impair operation.

Spillage of fluid, such as sample solutions, should be avoided. If spillage does occur, clean up immediately using absorbant 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.



Caution

If your PC becomes unresponsive (e.g due to an operating system problem, entering a sleep state condition, or screen saver operation) for a prolonged period, this will interrupt communication between the Software and the hardware, and a communications error may be generated. To minimize the possibility of this happening it is strongly recommended that any such modes that result in prolonged unresponsiveness be disabled before the software is run. Please consult your system administrator or contact Thorlabs technical support for more details.

Chapter 3 Installation

3.1 Unpacking



Caution

Once removed from its packaging, the stage can be easily damaged by mishandling. The unit should only be handled by its base, not by any attachments to the moving part.

The equipment contains no user servicable parts. Do not remove any screws securing the covers or attempt any repairs or adjustments as this will affect the calibration and invalidate the warranty. Adjustments are confined to loosening and tightening of the clamping screws - see Fig. 3.2 and Fig. 3.3.

Note

Retain the packing for use in future transportation.

PFM450 Box Contents

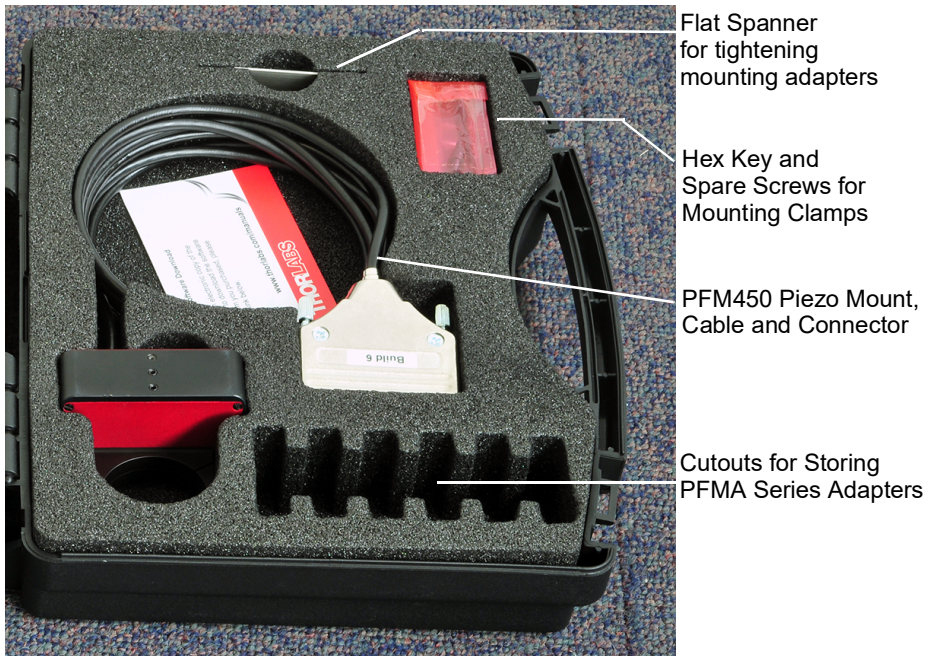


Fig. 3.1 PFM450 Contents

3.2 Mounting

3.2.1 General



Caution

The controller and objective mount are calibrated at the factory and are sold as a matched pair. The matched pair can be identified by the serial number label that appears on both units.

Unsatisfactory performance is likely to result if the objective mount is driven by a different controller, or if the controller is used to drive other objective mounts.



Caution

When mounting the focus mount on the microscope, ensure that the travel is not obstructed. If the mount is driven against a solid object, damage to the internal mechanism could occur.

The range of travel is 450 μm in closed loop but can be up to 600 μm in open loop.

Ensure that the cable is not under vibration as this can effect the stability of positioning by pulling the moving world away from the fixed world - see Fig. 3.2.

When considering movement in the proximity of other objects or equipment, ensure that movement of cables connected to the focus mount is not impeded.

Note

This handbook has been compiled to support the PFM450E piezo mount and controller as a standalone system. For assistance with integration into third part microscopes and systems, please contact tech support.

3.3 Installing the Focus Mount

The PFM450 can be mounted to most inverted or upright microscopes from major manufacturers, or independently in "home built microscopes or set ups. A mounting adapter is first fitted to the microscope. The piezo objective mount is then fitted to the adapter and secured by a clamping ring as shown in Fig. 3.2.

A range of microscope adapters are available separately as detailed below.

Description	Part Number
Microscope Adapter, External M32 x 0.75 Thread	PFMA01
Microscope Adapter Extended, External M32 x 0.75 Thread	PFMA01E
Microscope Adapter, External M32 x 0.75 Thread	PFMA03
Microscope Adapter, External M25 x 0.75 Thread	PFMA05
Microscope Adapter, External RMS (0.800"-36) Thread	PFMA07
Microscope Adapter, External SM1 (1.035"-40) Thread	PFMA09
Microscope Adapter, External M26 x 0.706 Thread	PFMA11

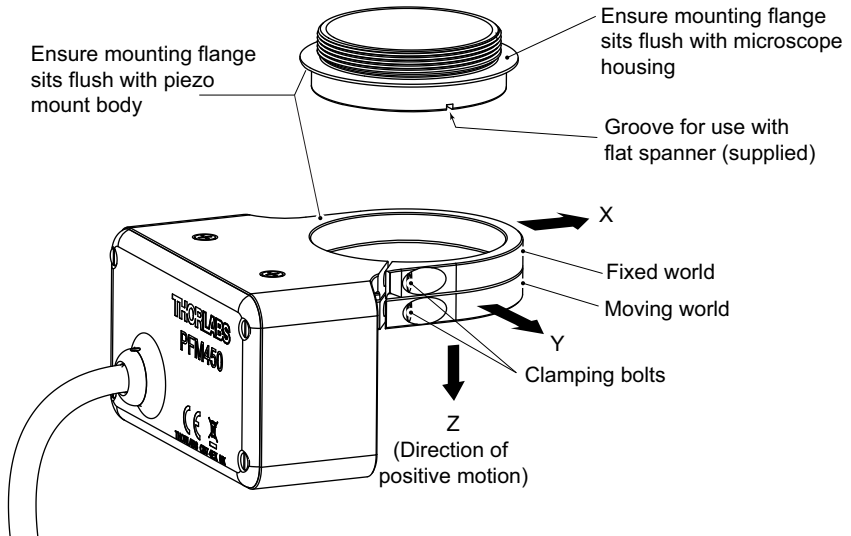


Fig. 3.2 Fitting the Focus Mount



Caution

Proper alignment and positioning is crucial to correct functioning of the piezo mount. When fitting, ensure that the mounting faces of the adapters fit flush with the microscope and piezo mount.

- 1) Fit the appropriate adapter to the microscope. Ensure that the threads are not crossed, and that the mounting flange sits flush against the microscope housing. Use the flat spanner supplied to tighten the adapter taking care not to overtighten.
- 2) Using the hex key supplied, loosen the upper clamping bolt. Fit the focus mount to the adapter ensuring that the mounting flange on the adapter sits flush against the body of the piezo mount. Re-tighten the clamp bolt until resistance is felt then a further 1/4 turn.

Note

The stability of the piezo mount is affected directly by the stability of the microscope. For best performance, it is recommended that the microscope is mounted on a surface isolated from external vibrations.

3.4 Fitting/Changing the Objective



Caution

Fit the objective to the adapter ring before the adapter ring and objective are fitted to the piezo mount. Fitting or removing the objective whilst the adapter ring is fitted to the piezo mount can exert excessive torsional force and damage the internal flexures.

The objective screws onto an adapter which is then fitted to the piezo mount and secured by a clamping ring as shown in Fig. 3.3. The objective/adapter can be removed/fitted without removing the mount from the microscope.

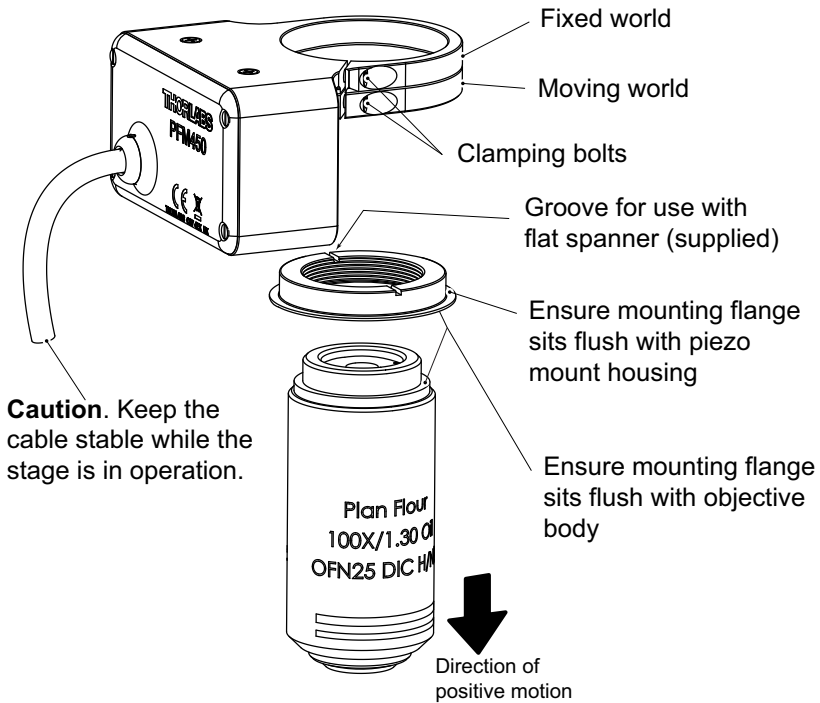


Fig. 3.3 Fitting the objective

- 1) Fit the appropriate adapter to the microscope objective. Ensure that the threads are not crossed, and that the mounting flange sits flush against the objective housing. Use the flat spanner supplied to tighten the adapter taking care not to overtighten.
- 2) Using the hex key supplied, loosen the lower clamping bolt. Fit the adapter to the focus mount, ensuring that the mounting flange on the adapter sits flush against the body of the piezo mount. Re-tighten the clamp bolt until resistance is felt then a further 1/4 turn.

**Caution**

Due to its inherent capacitance, movement or vibration of the cable may affect the stability of the stage. Where possible, arrange the cable in such a way to minimize movement and vibration while the stage is in operation.

A range of objective adapters are available separately as detailed below.

Description	Part Number
Objective Adapter, Internal M32 x 0.75 Thread	PFMA02
Objective Adapter, Internal M27 x 0.75 Thread	PFMA04
Objective Adapter, Internal M25 x 0.75 Thread	PFMA06
Objective Adapter, Internal RMS (0.800"-36) Thread	PFMA08
Objective Adapter, Internal SM1 (1.035"-40) Thread	PFMA10
Objective Adapter, Internal M26 x 0.706 Thread	PFMA12

3.4.1 Angular Rotation

Certain microscopes can operate with the objective rotated such that it is not perpendicular with the vertical plane. It is recommended that the PFM450 piezo mount is operated with a pitch rotation. Yaw rotation (as shown below) is possible with certain limitations - contact tech support for more details.

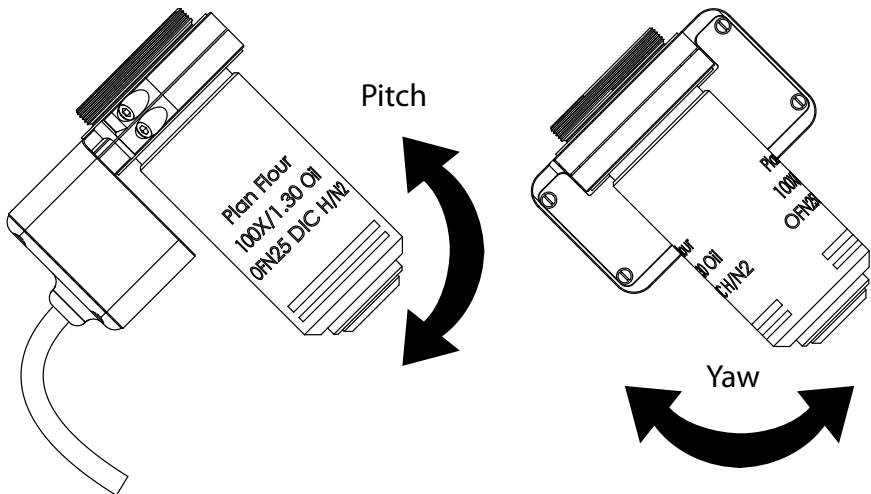


Fig. 3.4 Angular rotation

3.5 Installing the Controller

3.5.1 Siting

The unit is designed to be mounted free standing on a shelf, benchtop or similar surface.



Caution

Ensure that proper airflow is maintained to the sides of the unit.

3.5.2 Environmental Conditions



Warning

Operation outside the following environmental limits may adversely affect operator safety.

Location Indoor use only

Maximum altitude 2000 m

Temperature range 5°C to 40°C

Maximum Humidity Less than 80% RH (non-condensing) at 31°C

To ensure reliable operation the unit should not be exposed to corrosive agents or excessive moisture, heat or dust.

If the unit has been stored at a low temperature or in an environment of high humidity, it must be allowed to reach ambient conditions before being powered up.



Caution

In applications requiring the highest level of accuracy and repeatability, it is recommended that the stage and the controller unit are powered up for at least 30 minutes before use, in order to allow the internal temperature to stabilize.

For maximum precision, the unit should be operated in a thermally stabilised environment, e.g. an air-conditioned room.

When the stage is not in use for a long period (e.g. over a week) the controller should be switched off. Leaving the stage under a high voltage (e.g. over 100V) for a prolonged period can reduce the lifetime of the internal piezo stack.

3.6 Installing the Software



Caution

Thorlabs often releases updated firmware for bug fixes and support for new features. We recommend all users to download the latest version of Kinesis software and use the included firmware update utility. Failure to do this could result in stages not being recognized by the latest controllers.

Some PCs may have been configured to restrict the users ability to load software, and on these systems the software may not install/run. If you are in any doubt about your rights to install/run software, please consult your system administrator before attempting to install.

If you experience any problems when installing software, contact Thorlabs on +44 (0)1353 654440 and ask for Technical Support.

Note

When operating via a PC, direct user interaction with the unit is accomplished through intuitive graphical user interface panels (GUIs), which expose all key operating parameters and modes. The user can select multiple panel views displaying different information about a particular hardware unit. The multitasking architecture ensures that the graphical control panels always remain live, showing all current hardware activity.

DO NOT CONNECT THE CONTROLLER TO YOUR PC YET

- 3) Go to Services/Downloads at www.thorlabs.com and download the Kinesis Software.
- 4) Run the .exe file and follow the on-screen instructions.

3.7 Electrical Connection

3.7.1 Connecting To The Supply



Warning: Risk of Electrical Shock

The controller unit must be connected only to an earthed fused supply of 24V 2A DC.

Use only power supply cable and power supply provided with the unit, other cables/PSUs may not be rated to the same current. The unit is shipped with appropriate power cables for use in the UK, Europe and the USA. When shipped to other territories the appropriate power plug must be fitted by the user. Cable identification is as follows:

Brown Live

Blue Neutral

Green/Yellow Earth/Ground



Warning: Risk of Electrical Shock

Piezo actuators are driven by high voltages. Voltages up to 150V may be present at the rear panel 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 focus mount is plugged in or unplugged. Failure to switch the controller off may result in damage to either the controller, the focus mount or both.

3.7.2 Connecting The Hardware

- 1) Install the software - see Section 3.6.



Caution

The controller and objective mount are calibrated at the factory and are sold as a matched pair. The matched pair can be identified by the serial number label that appears on both units.

Unsatisfactory performance is likely to result if the objective mount is driven by a different controller, or if the controller is used to drive other objective mounts.

- 2) Connect the focus mount to the Controller unit - see Fig. 3.6

Note

Ensure that the mating faces of the connectors are properly aligned. Misalignment can cause connection problems.

Tighten the securing screws to ensure that the connectors do not become disconnected during use.

- 3) Using the USB cable provided, connect the Controller unit to your PC.
- 4) Connect the Controller unit to the power supply and switch 'ON' by pressing the POWER button on the front panel.

Note

The USB cable should be no more than 3 metres in length. Communication lengths in excess of 3 metres can be achieved by using a powered USB hub).

- 5) Windows™ should detect the new hardware. Wait while Windows™ installs the drivers for the new hardware - see the Getting Started guide for more information
- 6) Run the Kinesis software - Start/Programs/Thorlabs/Kinesis/Kinesis.

- 7) Check that the Graphical User Interface (GUI) panel appears and is active.

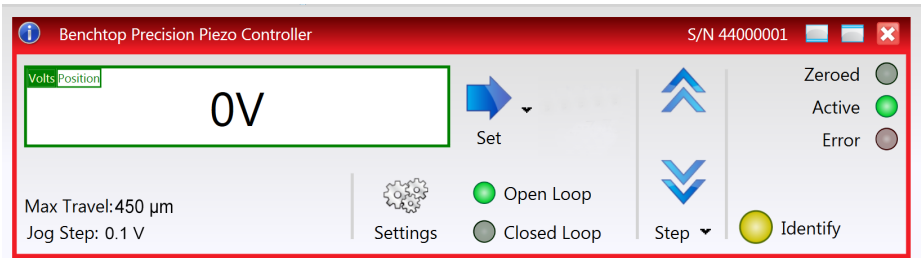


Fig. 3.5 GUI panel showing jog and ident buttons

- 8) Click the 'Identify' button. The POWER LED on the front panel of the controller flashes. This is useful in multi-channel systems for identifying which controller is associated with which GUI.
- 9) Click the jog buttons on the GUI panel to move the piezo or axis connected to the controller. The position display for the associated GUI should increment and decrement accordingly.

Follow the tutorial described in Chapter 4 for further guidance on basic operation.

Note

The 'Simulator' utility can be used to set up simulated hardware configurations and place the Kinesis Server into simulator mode. In this way it is possible to create any number and type of simulated (virtual) hardware units in order to emulate a set of real hardware. This is a particularly useful feature, designed as an aid to application program development and testing. Any number of 'virtual' control units are combined to build a model of the real system, which can then be used to test the application software offline. See the Kinesis Simulator helpfile for detailed instructions.

3.7.3 Powering Down The Controller



Warning

The controller may cause drive voltage spikes on power down. In applications requiring the highest sensitivity, the piezo drive voltage should be set to zero before the unit is powered down.

When power is applied, do not disconnect the piezo mount from the unit.

3.7.4 Rear Panel Connections

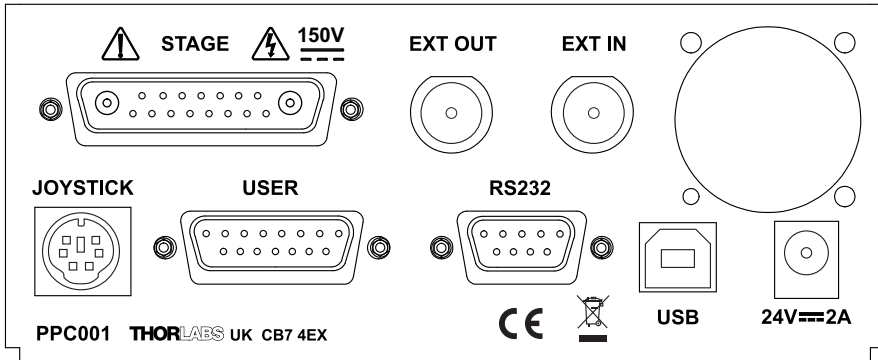


Fig. 3.6 Rear panel connections

STAGE - Provides the drive signal to the piezo actuator, -30 V to 150 V, 0 to 150 mA.

Note

Ensure that the mating faces of the connectors are properly aligned. Misalignment can cause connection problems.

Tighten the securing screws to ensure that the connectors do not become disconnected during use.

EXT IN (BNC connector) – Used to control the piezo mount from an external source (10V to 10V). When in open loop the EXT IN controls the voltage, when in closed loop it controls the position. The input impedance is 10 kΩ load.

0 to 10V gives 0 to 450um in closed loop, and -2V to 10V gives -30V to 150V in open loop.

In cases where there is a software contribution, -10V to 10V can be used. For example, if you command 225um from software GUI, then input a ±5V sinewave, this will cause the stage to swing up and down from 0 to 450um.

**Caution**

Before the input can be used, the Drive Input Source must be set to a BNC (+SW) option in the Settings panel (see Section 5.2.2.) or in software by calling the appropriate message.

When driving the piezo mount from an external source, the external signal is added to the software input (GUI panel or SetVoltOP software method) and, if connected and selected, the Joystick.

The max stepping frequency depends on the shape of the waveform. E.g. for a staircase waveform with a step size up to 25 μm , the minimum period for each step can be as small as the settling time, i.e. 25 ms or stepping frequency of 40 Hz. However it will take a few ms to capture an image. For large periodic waveforms, e.g. over 200 μm peak to peak sine wave signal, the operational frequency is recommended to be as follows:

Loads up to 150g - less than 25 Hz

Loads 150 g to 250 g - less than 20 Hz

Loads 250 g to 400 g - less than 15 Hz

Loads 400 g to 500 g - less than 10 Hz

EXT OUT (BNC connector) – Used to monitor the piezo actuator on an oscilloscope or other device. The output can be set to monitor the piezo Drive Voltage, the Linearized Position, or the Unprocessed Position, as set in the Output Signal parameter in the settings panel - see Section 5.2.2., or in software by calling the appropriate message.

JOYSTICK - Provides connection for the MZF001 Joystick - see Section 4.9. and Section A.4.

USER - This female 15-Pin D-type connector exposes a number of internal electrical signals. For convenience, a number of logic inputs and outputs are included, thereby eliminating the need for extra PC based IO hardware. Using the software, these user programmable logic lines can be deployed in applications requiring control of external devices such as relays, light sources and other auxilliary equipment - see Section A.2. for further details.

RS232 – Provides connection for serial port communication - see Section A.3.

USB - USB port for system communications.

Note

The USB cable length should be no more than 3 metres unless a powered USB hub is being used.

3.8 Front Panel Controls and Indicators

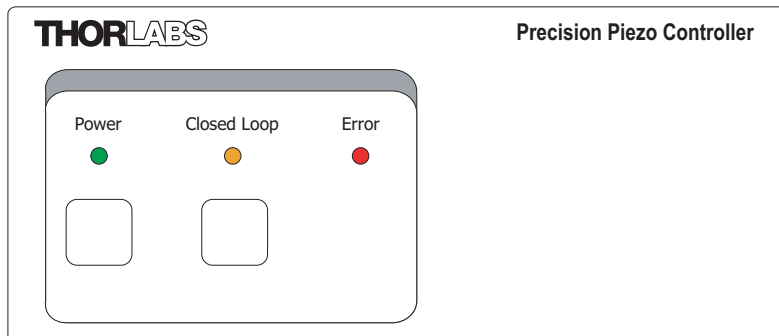


Fig. 3.7 Front panel controls and indicators

Power Button and LED – Applies and removes power to the controller. Power is applied when the LED is lit.

Note

The brightness of the front panel LEDs can be adjusted (Full, Dim or Off) to match the ambient light conditions and avoid stray light problems in sensitive applications - see Section 5.2.2.

Closed Loop Button and LED – Switches the unit to closed loop operation. When the LED is lit, the unit is operating in Closed Loop mode. If the LED is not lit, the unit is operating in open loop.

Error LED – Lit when one of the following fault conditions occur:

- 1) One or more power supply voltages are out of range.
- 2) Closed loop mode is selected but the associated piezo is disconnected.
- 3) An overtemp condition has occurred - see Section 4.8.

3.9 Controller Schematic Diagram

The PPC001 controller and PFM450 focus mount is a closed-loop position control system with a digital PID controller and dual notch filters. The PFM450 actuator contains a capacitive position sensor for accurate position measurement. The sensor is driven from a sine wave generator, the AC output signal of the actuator is demodulated and sampled by a precision 18 bit A/D converter. The output from the capacitive sensor is linearized in the digital domain and for maximum accuracy the linearizing curve is individually matched to the sensor. The setpoint position is maintained by a PID controller whose coefficients can be tuned to optimize system response. The PID controller is followed by a dual notch filter that, when enabled, dampens the natural mechanical resonance exhibited by the mass and elasticity of the actuator.

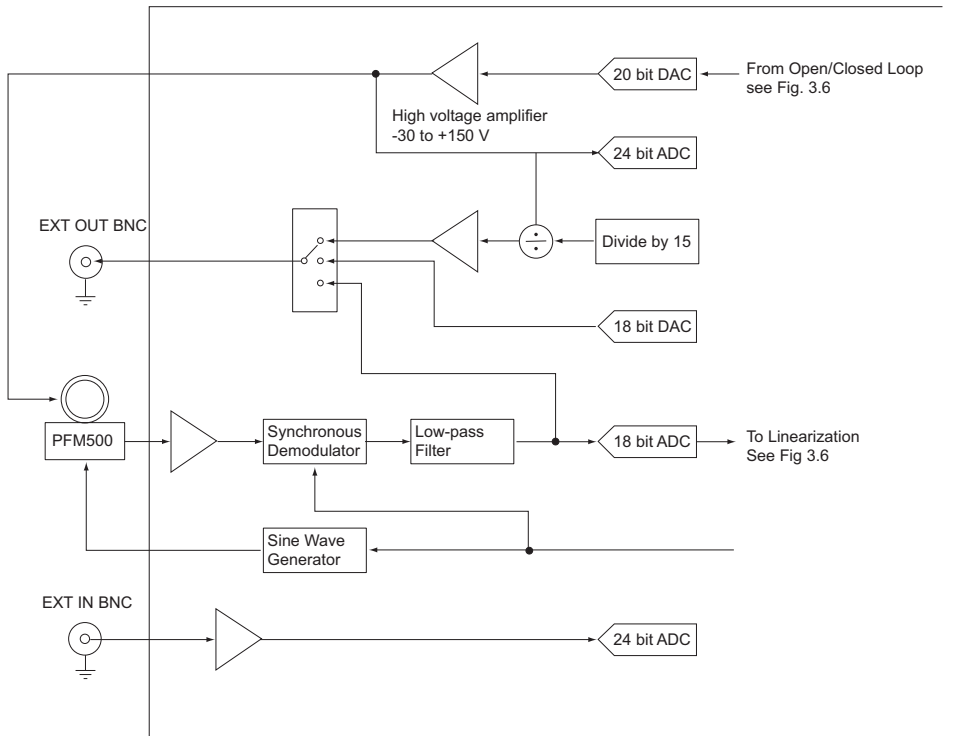


Fig. 3.8 System Schematic - Part 1

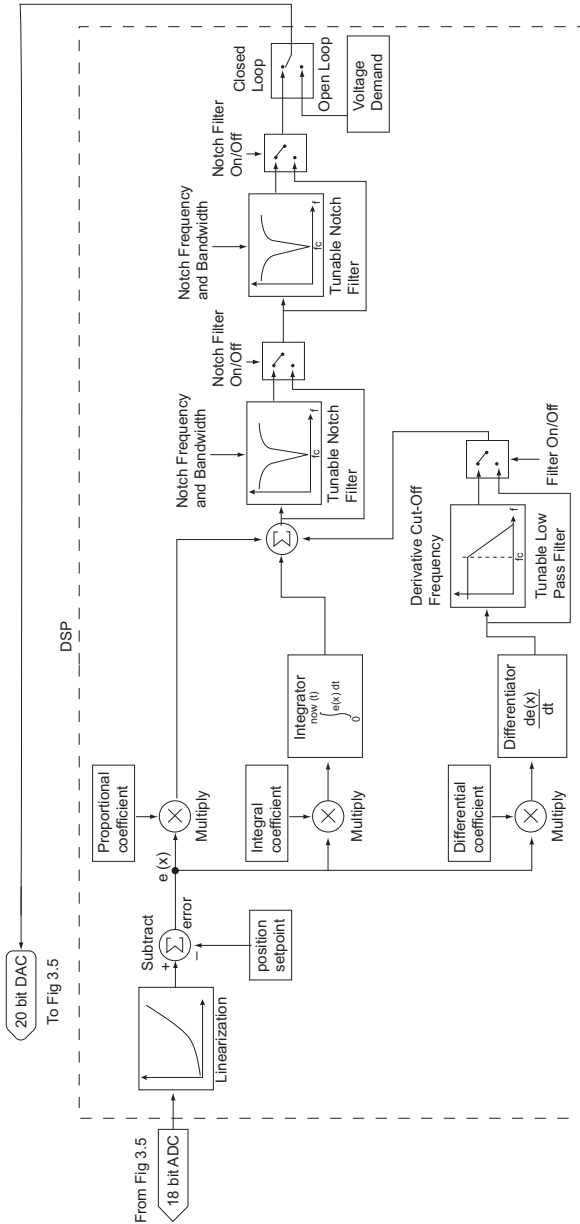


Fig. 3.9 System Schematic - Part 2

Chapter 4 PC Operation - Tutorial



Warning: Risk of Electrical Shock

Piezo actuators are driven by high voltages. Voltages up to 150V may be present at the STAGE connector on the rear panel. 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 focus mount is plugged in or unplugged. Failure to switch the controller off may result in damage to either the controller, the stage or both.

4.1 Introduction

The following brief tutorial guides the user through a typical series of actions and parameter adjustments performed using the Kinesis software. It assumes that the unit is electrically connected as shown in Section 3.7.4. and that the software is already installed - see Section 3.6. It also assumes that a piezo-actuated stage is connected to the 'STAGE' connector on the rear panel.

4.2 Using the Kinesis Software

The Kinesis application allows the user to interact with any number of hardware control units connected to the PC USB Bus (or simulated via the Simulator utility). This program allows multiple graphical instrument panels to be displayed so that multiple units can be controlled. All basic operating parameters can be set through this program, and all basic operations (such as piezo moves) can be initiated. Hardware configurations and parameter settings can be saved to a file, which simplifies system set up whenever the software is run up.

This tutorial shows how the Kinesis application provides all of the functionality necessary to operate the hardware.

- 1) Fit the focus mount to the microscope and install the hardware as detailed in Chapter 3.
- 2) Switch ON the controller.
- 3) Power up the hardware, and wait until the PPC001 has finished booting up, then run the software - Start/All Programs/Thorlabs/Kinesis/Kinesis. The software registers automatically the units connected on the USB bus and displays the associated GUI panels as shown in Fig. 4.1.

- 4) Notice how the total travel for the associated piezo is displayed in the 'Travel' window - see Fig. 4.1.

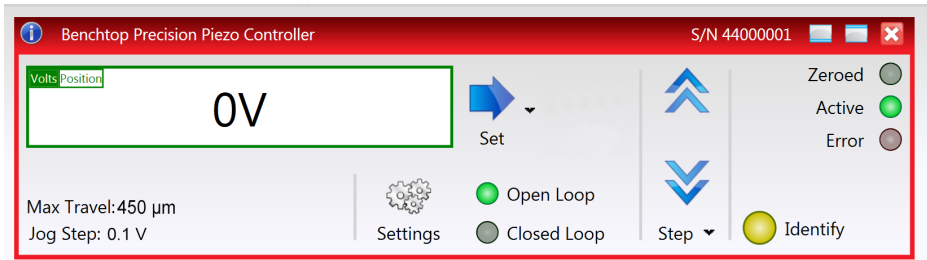


Fig. 4.1 Piezo Controller Software GUI .



Caution

The PFM450 Focus Mount contains a capacitive feedback sensor and can be driven only by the Thorlabs PPC001 150V Piezo Controller.

The controller and objective mount are calibrated at the factory and are sold as a matched pair. The matched pair can be identified by the serial number label that appears on both units.

Unsatisfactory performance is likely to result if the objective mount is driven by a different controller, or if the controller is used to drive other objective mounts.



Warning: Risk of Electrical Shock

The piezo actuators in this product use high voltages. Voltages up to 150V may be present at the STAGE connector on the rear panel. 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 focus mount is plugged in or unplugged. Failure to switch the controller off may result in damage to either the controller, the focus mount or both.

4.3 Introduction to Open and Closed Loop Operation

The PPC001 Precision Piezo Controller has two distinct modes of operation: open and closed loop mode. In open loop mode, the output voltage is controlled directly, using a joystick, the external BNC input, the GUI or a combination of these. The output voltage is proportional to the controlling source. This voltage controls the expansion of the piezo actuator, turning the voltage into a certain amount of displacement.

The need for a closed loop mode of operation arises from the fact that the displacement produced by the piezo actuator is not a linear function of the driving voltage. All piezo actuators show a certain amount of nonlinearity, hysteresis, temperature dependence and aging - see Appendix D for more details.

In precision positioning applications this can seriously limit the accuracy and repeatability of the system. This problem can however be eliminated when closed loop control is used. Closed loop mode assumes that the piezo actuator is fitted with a position sensor, usually a strain gauge, that is capable of reading the actual position and this signal is fed back to the piezo controller. Rather than outputting a constant voltage, the piezo controller continuously monitors the position signal and, if necessary, adjusts the output voltage to maintain the required position.

4.4 Tuning

Note

The PPC001 controller and PFM450 focus mount are a matched pair that have been calibrated together for maximum accuracy. On power up, the controller checks that it is connected to the PFM450 with which it was calibrated. If there is a mis-match, the controller sends an error message to the server. Operating a controller with an unmatched stage is possible, but the position readings will not be accurate. Mismatched units can be returned to the factory for re-calibration, contact tech support for more details.



Caution

Default PID values have already been optimized and stored within the stage/controller pair, and these are loaded on power up.

If problems are encountered (e.g. stability of the closed loop position control) the position PID parameters can be adjusted to tune the stage for the given application. Normally, only minor adjustment of the Proportional, Integral and Derivative parameters should be necessary, and some trial and error will be required before the ideal settings for a specific application are achieved.

In general, adjust the notch filter settings to achieve stable performance, then make minor adjustment to the PID parameters to optimize the performance.

See Section 5.2.3. for more details on these parameters.

The following section describes details a typical tuning procedure

- 1) Measure and record the objective mass.
- 2) Fit the PFM450 to the microscope - see Section 3.3.
- 3) Fit the objective to the microscope - see Section 3.4.
- 4) Switch on the controller and leave to warm up for at least 30 minutes.
- 5) Run Kinesis and switch to Open Loop mode.
- 6) In the Settings panel, ensure that the Notch Filter 1, Notch Filter 2 and Derivative LP Cut OFF are all ticked as "Enabled" - see Section 5.2.3.
- 7) Set the notch filter central frequency as explained in Section 5.2.3.
- 8) Set the PID parameters as explained in Section 5.2.3.
- 9) Switch to closed loop mode.
- 10) The stability of position display should be better than $\pm 0.02 \mu\text{m}$ with a stable microscope system. While monitoring the position display on the GUI, reduce P, I and D parameters one at a time, by 10% steps to optimise display jittering.
- 11) To ensure the settling time is optimised, increase P, I and D with 10% increments until position display indicates a large ringing effect, in the range of microns. Consider this point as threshold for stability.
- 12) Reduce the threshold values by 10% to 20%, to ensure a safe margin and a fast response is guaranteed.
- 13) In case of a high level ringing, e.g. amplitude in order of 10s of microns (especially if it is audible), switch to Open Loop mode, set parameters as explained above, then switch back to Closed Loop. In such situations, it is advisable to have starting P, I and D parameter values well below the last set of values that caused ringing.

4.5 Limitations on the Displayed Position Values

The controller can report small negative position values and the software can display these; however negative position values below approximately 4% of the full travel range (i.e. more negative than -32 μm for a 800 μm stage / -18 μm for a 450 μm stage) might be clipped and therefore incorrect. Position values above the maximum travel range are clipped to the maximum travel. In other words, the position display is clipped to -4% to +100% of the maximum travel range.

4.6 Moving the Piezo Mount

The piezo mount can be manually positioned in two ways: by entering a voltage/position, or by clicking the 'Jog' buttons.

4.6.1 Setting the Zero Position

Upon power up, the controller is set to 0V and open loop. Typical operation involves moving to a position visually in open loop and then switching to closed loop, which maintains the stage position to that achieved at the moment of switch over. Due to factors such as objective mass, piezo mount orientation, and environmental temperature, the position of the mount with 0V applied can vary by tens of microns. Therefore a true position of 0 μm (or a required offset position value) must be set before the position attained by a specific applied voltage and the position attained by a corresponding specified distance can be rationalized. This is particularly important when operating in open loop via the GUI Output control to find an area of interest, and then switching to closed loop and exploring this area using an external voltage source.

To adjust the zero position:

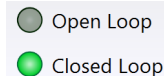
- 1) Ensure that any external signal (External BNC input or joystick) is set to 0V, then in the GUI panel, select 'Closed Loop' mode.
- 2) Move the stage to 0 μm as detailed in Section 4.6.2.

4.6.2 Entering the piezo position

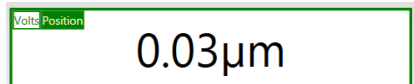
Note

The piezo position can be entered only when operating in 'Closed Loop' mode.

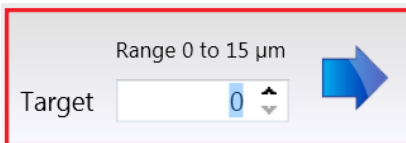
- 1) Click the 'Closed Loop' button.



- 2) Click the 'Position' button in the Main Display..



- 3) Click the Set Arrow  to display the Target window..



- 4) Enter a position, e.g. 10.00. This can be entered directly into the field, or by clicking on the up/down arrows.

- 5) Click the arrow to save the change. Notice that the position display counts up to 10.00 to indicate a move to a position 10 μ m from the Zero datum.

4.6.3 Jogging the Piezos

When the Step buttons are pressed, the piezo moves by the step size specified in the Jog Step Size parameter.

- 1) Click the Step Button **Step** \downarrow to display the Step Size window..

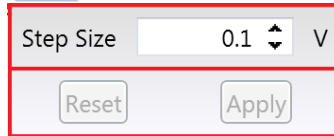


Fig. 4.2 Target Voltage Popup Window

- 2) In the 'Step Size' field, enter a step size in the range 0.1 V to 10 V. This can be entered directly into the field, or by clicking on the up/down arrows.
- 3) Click 'Apply' to save the settings and close the window. To cancel the change click Reset.
- 4) Click the upper Jog arrow on the GUI panel to jog the piezo. Notice that the voltage display increments by the value entered every time the button is clicked.
- 5) Click the lower Jog arrow on the GUI panel. Notice that the voltage display decrements by the value entered every time the button is clicked.

The jog step size can also be set in th Setting panel, see Section 5.2.2.

4.7 Using the Controller as a Piezo Amplifier

Certain applications may require the piezo to be driven by a voltage generated from an external source (e.g. 0 to 10V output). To achieve this, the controller must handle the amplification from 10V to 75V.

The following procedure explains how to configure the unit as a piezo amplifier.

- 1) Connect a 0 - 10V external source to the EXT IN (+) or EXT IN(-) connector on the rear panel.
- 2) In the GUI panel, click the 'Settings button to display the settings panel.

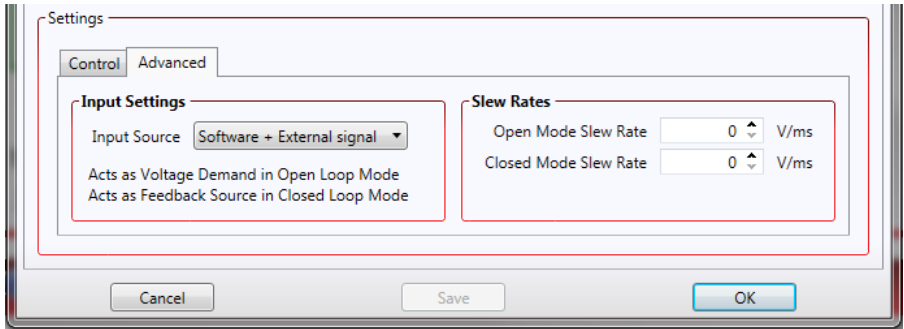


Fig. 4.3 Piezo settings panel

- 3) Select the 'General' tab.
- 4) In the 'Input Source' field, select '*Software + External Signal*'.
- 5) Click 'OK' to save the settings and close the window.

Any voltage on the rear panel BNC connector is now amplified by the unit and presented at the HV OUT (piezo drive) connector and the position of the piezo actuator can be controlled by varying the 0-10V external source.



Caution

When driving the piezo mount from an external source, the external signal is added to the software input (GUI panel or SetVoltOP software method) and, if connected and selected, the Joystick.

In closed loop a drive voltage of 120V gives around 450 μm travel, in open loop the drive voltage can be as high as 150 V with a travel of 600 μm . When using an external source and switching from open loop to closed loop, care must be taken that the travel range is not pushed to its limit. If closed loop is selected with excessive drive voltages applied, the stage may jump position and/or drift.

4.8 Thermal Shutdown

In order to protect the piezo driver card from overheating due to abnormal load conditions, the electronics contains thermal protection circuitry. When the protection is activated, the HV output is shut down, limiting the maximum output current to a few milliamps, and the 'Error' LED on the GUI panel lights, warning the user of the fault condition. If the overtemp condition occurs, turn off the controller and allow 10 minutes for the unit to cool down.

4.9 Using the MZF001 Joystick

The MZF001 joystick console has been designed for microscope users, to provide intuitive, tactile, manual positioning. It is used in conjunction with a PPC001 piezo controllers. Furthermore, if the parameter settings are saved (persisted) to the controller, the controller need not be connected to a host PC, thereby allowing remote operation.

- 1) Connect the stage to the controller.
- 2) Using the lead supplied, connect the CONTROLLER/EXT IN terminal on the joystick console to the JOYSTICK connector on the rear panel of the Controller unit.



Fig. 4.1 Connections

- 3) Switch ON the controller.
- 4) Wait until the red warning LED on the joystick console stop flashing (~3s). This indicates that initialisation is complete.
- 5) Run the software and set the Drive Input Source to one of the 'Joystick' options - see Section 5.2.2.
- 6) The stage can now be moved using the joystick. The rate of change is proportional to the rotation of the Rate potentiometer.

4.10 Load Response

The response of the PPC001 to varying load and frequencies is shown below.

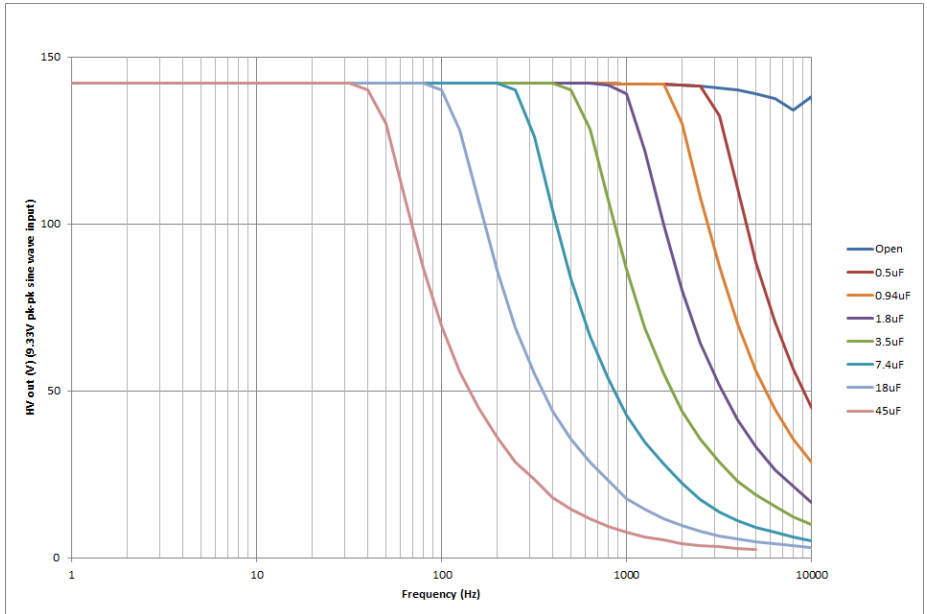


Fig. 4.4 Response of PPC001 to Varying Loads and Frequencies

Chapter 5 Software Reference

5.1 GUI Panel

The following screen shot shows the graphical user interface (GUI) (one panel per card fitted) displayed when accessing the controller using the software.

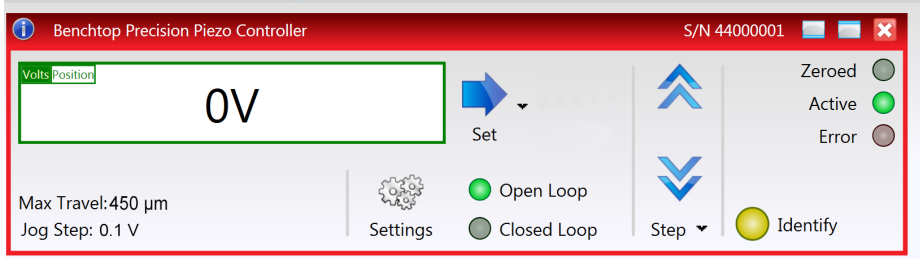
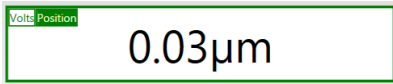


Fig. 5.1 PPC001 Piezo Driver Software GUI

Note

The serial number of the PPC001 unit associated with the GUI panel, is displayed in the top right hand corner. This information should always be provided when requesting customer support.



Main Display - Shows the voltage applied to the piezo, or the position (in microns), as determined by the feedback signal (if equipped). The display mode is set via the

'Volts' and 'Position' buttons in the top left corner of the display.



Set Arrow - Opens the settings window, so that the target drive voltage or position can be entered - see Section 4.6.2.



Step Arrows - used to increment or decrement the output voltage or position. When the buttons are clicked, the piezo is driven in the selected direction, one step per click. The step size is set by clicking the Step Button **Step** - see Section 4.6.3.

Max Travel: 450 μm
Jog Step: 0.1 V


Parameters Display - shows the maximum working voltage of the associated piezo actuator and the present setting for the step size


Settings - Displays the 'Settings' panel, which allows the operating parameters to be entered for the motor drive - see Section 5.2.




Settings

Open Loop and Closed Loop LEDs - When Open Loop or Closed Loop mode is selected, the corresponding LED is lit.


 Open Loop

 Closed Loop


Identify - when this button is pressed, the main display on the front panel of the associated hardware unit will flash for a short period.

 Identify

Active - lit when the unit is operating normally and no error condition exists.

Active 

Error - lit when a fault condition occurs.

Error 

5.2 Settings Panel

When the 'Settings' button on the GUI panel is clicked, the 'Settings' window is displayed. This panel allows data such as jog step size and input sources to be entered. Note that all of these parameters have programmable equivalents accessible through the functions on this Control (refer to the *Kinesis API helpfile* for further details).

5.2.1 Persisting Settings to the Hardware

Many of the parameters that can be set for the PPC001 Piezo Controller can be stored (persisted) within the unit itself, such that when the unit is next powered up these settings are applied automatically. This is particularly important when the controller is being used manually in the absence of a PC and USB link. The *Analogue Input Channel* and *Closed Loop Operation* parameters are good examples of settings that can be altered and then persisted in the driver for use in absence of a PC.

To save the settings to hardware, check the 'Persist Settings to Hardware' checkbox before clicking the 'OK' button.



Caution

The 'Persist Settings' functionality is provided to simplify use of the unit in the absence of a PC. When the unit is connected to a PC and is operated via the Kinesis software, the default settings will be loaded at boot up, even if the 'Persist Settings' option has been checked.

5.2.2 Advanced tab.

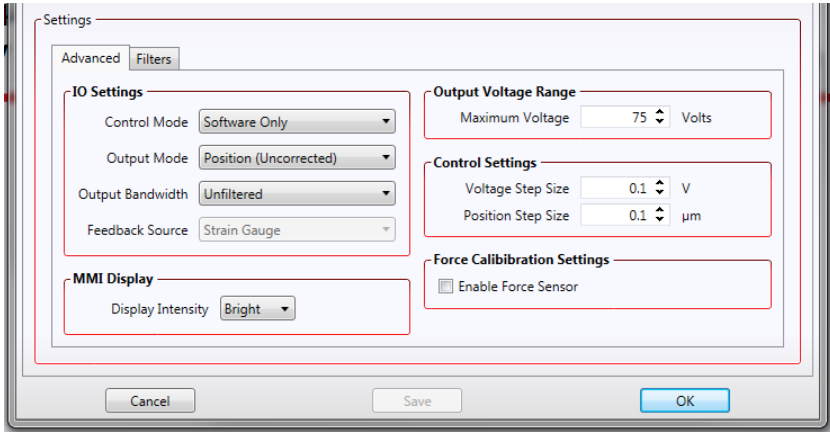


Fig. 5.2 Piezo Settings panel - Advanced tab

IO Settings

Control Mode - determines the input source(s) which control the output from the HV amplifier circuit (i.e. the drive to the piezo actuators).

Software Only - the unit responds only to software inputs and the piezo drive output is that set using the Software message calls (or the GUI panel).

Software + External BNC - the unit sums the signal on the rear panel EXT IN BNC connector with the voltage set using the software (or the GUI panel).

Software + Joystick - the unit sums the signal from the joystick control with the voltage set using the software (or the GUI panel).

Software + Joystick + BNC - the unit sums all three signals.



Caution

When driving the piezo mount from an external input source, the external signal is summed with the software input (GUI panel or SetVoltOP software method) and, if connected and selected, the Joystick.

In closed loop a smaller drive voltage than 150V is required to give 450 μm travel. However, in open loop the drive voltage can be set from

-30 V to 150 V with a typical travel of over 600 μm. When using an external source and switching from open loop to closed loop, care must be taken that the travel range is not pushed to its limit. If closed loop is selected with excessive drive voltages applied, the stage may jump position and/or drift.

If absolute positioning is required use closed loop mode only

Output Mode - the EXT OUT BNC connector on the rear panel can be used to monitor the piezo actuator on an external device, e.g. oscilloscope. This can be a useful

means of monitoring the position stability and fine tuning the settings. This parameter sets the type of signal being monitored - see also Section 3.9.

If *High Voltage Output* is selected, the signal driving the EXT OUT (Monitor) BNC is a scaled down version of the piezo output voltage, with 150 V piezo voltage corresponding to 10V.

If *Position Uncorrected* is selected, the signal driving the EXT OUT (Monitor) BNC is the output voltage of the position demodulator. This signal shows a slight nonlinearity as a function of position and a small offset voltage. As a result it is not as accurate as the linearized position. However, having not undergone any digital processing it is free of any potential digital signal processing effects and can be more advantageous for loop tuning and transient response measurement.

If *Position Corrected* is selected, the signal driving EXT OUT is linearized and scaled so that the 0 to full range corresponds to 0 to 10 Volts.

Output Bandwidth - Unfiltered or 200 Hz. A low pass filter can be switched on to limit the output bandwidth to the range of interest in most closed loop applications, i.e. 200Hz..

Feedback Source - the type of feedback associated with the actuator being driven, either Capacitive or Strain Gauge. The PFM450 piezo mount has a capacitive sensor and this parameter is locked.

MMI Display

Display Intensity - In some applications, the light from the front panel of the unit may cause unwanted light pollution. This parameter allows the brightness of the front panel LED display to be adjusted, either Full, Dim or OFF.

Output Voltage Range - used to set the maximum output voltage of the piezo controller. The piezo actuator connected to the controller has a specific maximum operating voltage range and this parameter is used to set a corresponding value for the maximum output voltage. Additionally, in some applications it can be useful to restrict the output voltage range to a lower value. For example, during loop tuning the actuator might become unstable; lowering the maximum output voltage imposes a lower limit on the amplitude of any oscillation and can be used to protect sensitive optical components.

Any voltage can be entered in the range 0 to 150 V.

Control Settings

Voltage Step Size - the distance to move when a jog command is initiated in open loop mode. The step size is measured in Volts.

Position Step Size - the distance to move when a jog command is initiated in closed loop mode. The step size is measured in microns.

Force Calibration Settings - Not currently implemented. For future use with force sensing devices.

5.2.3 Filters tab.

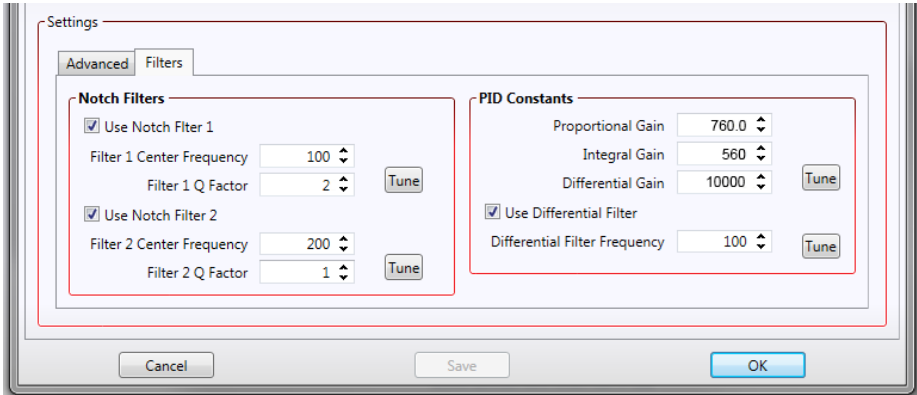


Fig. 5.3 Piezo Settings panel - Loop Tuning tab

When operating in Closed Loop mode, the proportional, integral and differential (PID) constants can be used to fine tune the behaviour of the feedback loop to changes in the output voltage or position. While closed loop operation allows more precise control of the position, feedback loops need to be adjusted to suit the different types of focus mount assemblies that can be connected to the system. Due to the wide range of objectives that can be used with the PFM450 and their different masses, some loop tuning may be necessary to optimize the response of the system and to avoid instability, however the default parameters should offer stable operation for most small and medium size objectives.

To adjust the PID constants, enter a value in the associated window as follows:

Proportional Gain- The Proportional parameter makes a change to the output which is proportional to the current error value. A high proportional gain results in a large change in the output for a given error. If set too high, the system can become unstable.

It accepts values in the range 0 to 10000 (default 760)

Integral Gain - The Integral parameter accelerates the process towards the demanded set point value, ensuring that the positional error is eventually reduced to zero. If set too high, the output can overshoot the demand value.

It accepts values in the range 0 to 10000. (default 560).

Derivative Gain - The Derivative parameter damps the rate of change of the output, thereby decreasing the overshoot which may be caused by the integral term. However, the differential term also slows down system response. If set too high, it could lead to instability due to signal noise amplification.

It accepts values in the range 0 to 10000 (default 10,000).

Please see Fig. 5.4 for guidance on Proportional and Integral settings for different loads. The Differential value does not normally need adjustment.

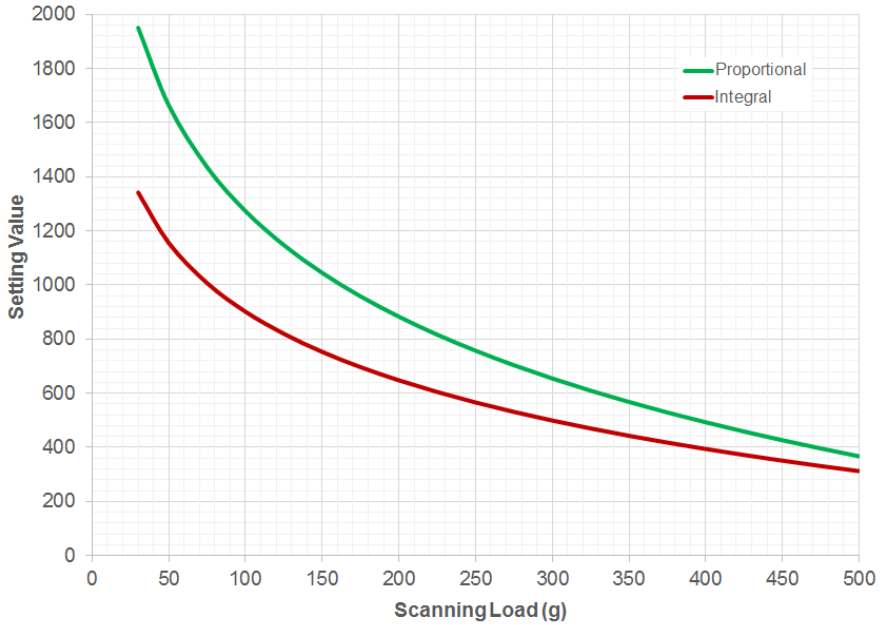
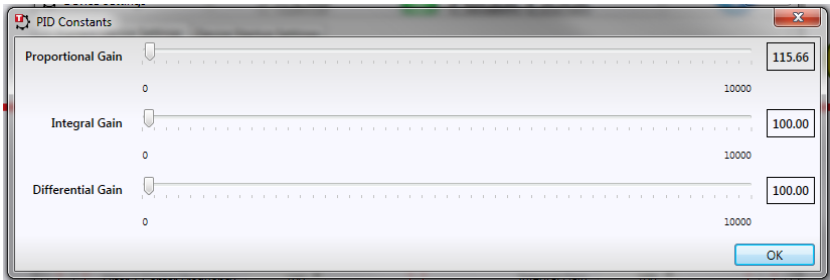


Fig. 5.4 P and I parameter values v load

It is also possible to tune the PID loop using slider controls. To display these controls click the Tune button.



These slider controls adjust the settings for the PID parameters, and any changes are applied immediately. In this way, the window can be left open and adjustments made whilst observing the effect on the system.

Once satisfactory performance is obtained, click OK to save the settings.



Warning

High amplitude oscillation due to inappropriate PID/Notch filter parameter settings can cause damage to the piezo mount. If such oscillation is apparent, switch immediately to open loop or disable the mount.

Note

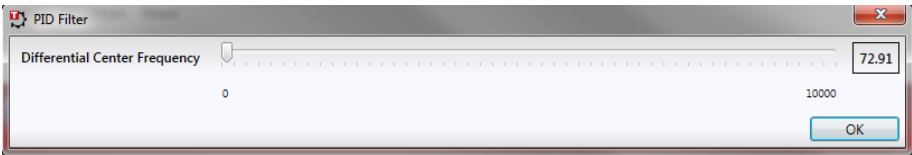
The default values have been optimized to work with the PFM450 mount shipped with the controller.

Due to the type of load the PFM450 presents to the PPC001 controller, the system is most sensitive to the integral (Int) tuning parameter and the notch filter settings. In most applications the derivative parameters can be left at their default values.

Differential Filter Frequency- The output of the derivative (differential) part of the PID controller can be passed through a tuneable low pass filter. Whilst the derivative component of the PID loop often improves stability (as it acts as a retaining force against abrupt changes in the system), it is prone to amplifying noise present in the system, as the derivative component is sensitive to changes between adjacent samples. To reduce this effect, a low pass filter can be applied to the samples. As noise often tends to contain predominantly high frequency components, the low pass filter can significantly decrease their contribution, often without diminishing the beneficial, stabilizing effect of the derivative action. In some applications enabling this filter can improve the overall closed loop performance.

The settings appear when the 'Use Differential Filter' box is checked.

The frequency is specified in Hz in the range 0 to 10000. (default 1000). Alternatively, click the Tune button to display a slider control which can be used to make adjustments and monitor the effect on the system.



Notch Filter Settings - Due to their construction, most actuators are prone to mechanical resonance at well-defined frequencies. The underlying reason is that all spring-mass systems are natural harmonic oscillators. This proneness to resonance can be a problem in closed loop systems because, coupled with the effect of the feedback, it can result in oscillations. With some actuators, the resonance peak is either weak enough or at a high enough frequency for the resonance not to be troublesome. With other actuators the resonance peak is very significant and needs to be eliminated for operation in a stable closed loop system. The notch filter is an

adjustable electronic anti-resonance that can be used to counteract the natural resonance of the mechanical system.

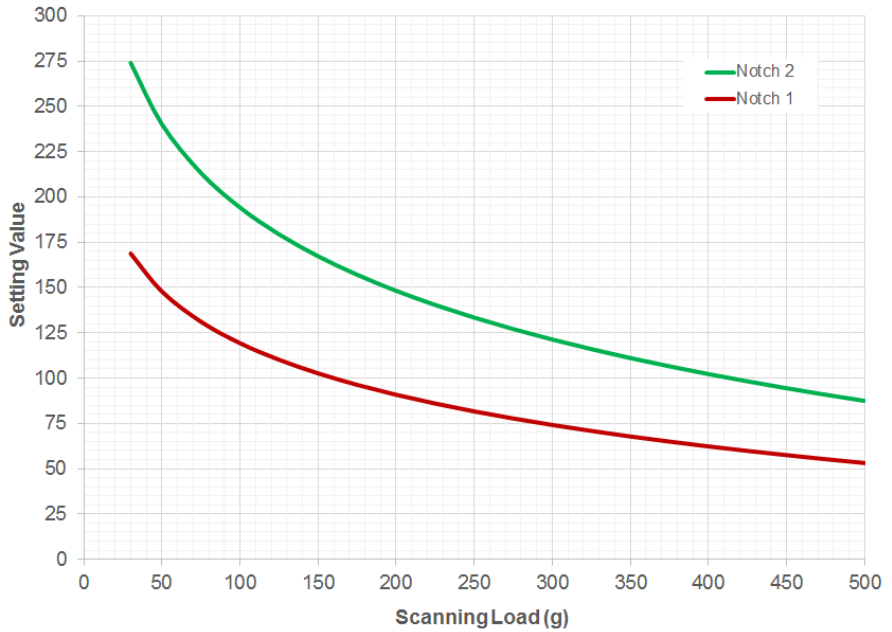
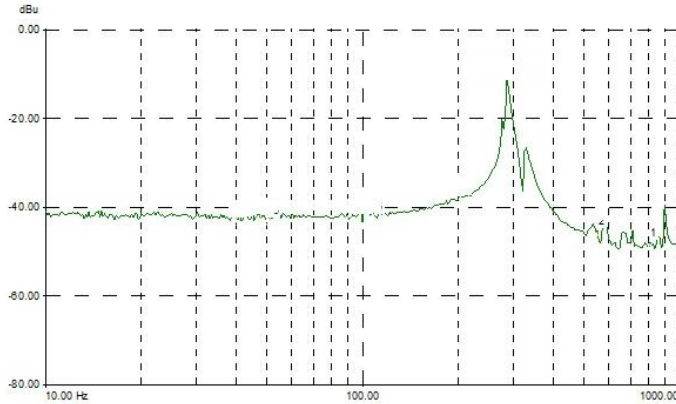
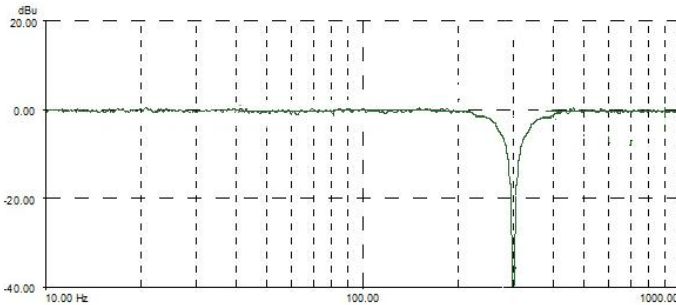


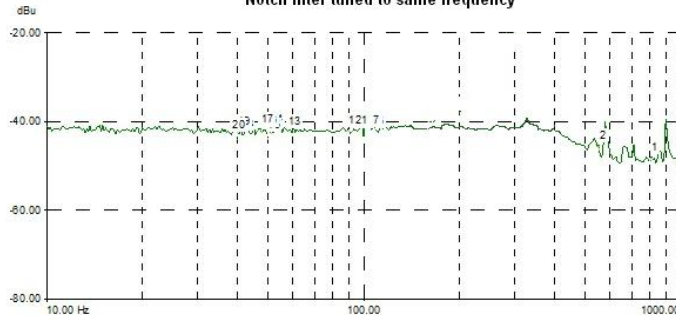
Fig. 5.5 Notch filter settings v load



Frequency response of a typical actuator showing resonance peak



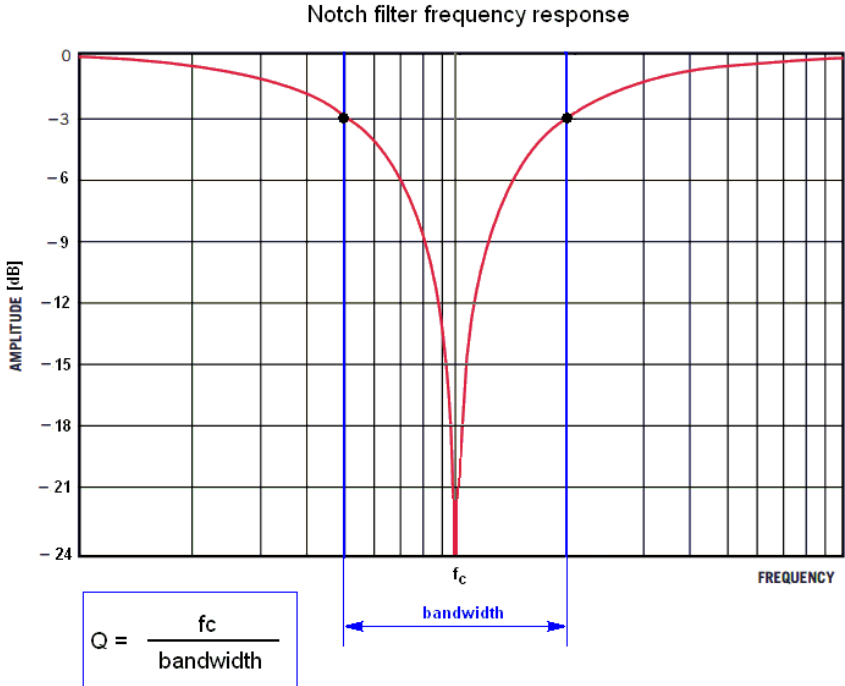
Notch filter tuned to same frequency



The resonance is largely eliminated

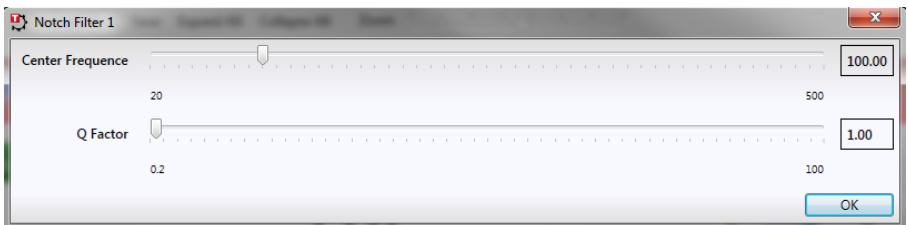
As the resonance frequency of actuators varies with load in addition to the minor variations from product to product, the notch filter is tuneable so that its characteristics can be adjusted to match those of the actuator. In addition to its centre frequency, the bandwidth of the notch (or the equivalent quality factor, often referred to as the Q-factor) can also be adjusted. In simple terms, the Q factor is the center frequency/

bandwidth, and defines how wide the notch is, a higher Q factor defining a narrower ("higher quality") notch.



Either one or two notch filters can be used, and the settings appear when the 'Use Notch Filter' boxes are checked.

The center frequency is specified in Hz in the range 20 to 500. (default 100). Alternatively, click the Tune button to display a slider control which can be used to make adjustments and monitor the effect on the system.



Optimizing the Q factor requires some experimentation but in general a value of 2 to 10 is in most cases a good starting point.

The *Center Frequency* is specified in Hz in the range 20 to 500.

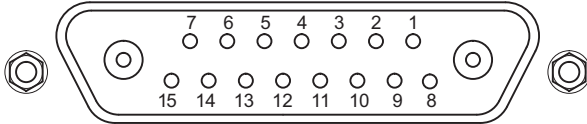
The *Q Factor* is specified in the range 0.2 to 100.

To enable the notch filter settings check the associated box.

Appendix A Rear Panel Connector Pinout Detail

A.1 Rear Panel STAGE Connector

This Female Combination D-Sub connector provides 15 signal pins, and 2 power connections for both the piezo drive signal and the feedback signal of the piezo actuator. The pin functions are detailed in Fig. A.1.



Pin	Description	Pin	Description
1	High Voltage Ground (Return)	8	High Voltage Ground (Return)
2	Unused	9	Unused
3	Unused	10	Stage ID *
4	Sinewave Excitation Output	11	Low Voltage Ground
5	Unused	12	Low Voltage Ground
6	+15 V (Preamplifier Supply) †	13	Piezo ID (Legacy Stages) *
7	Low Voltage Ground	14	Position Sense Input (Strain Gauge)
Coaxial Female	High Voltage Output	15	-15 V Preamplifier Supply) †
Coaxial Male	Position Sense Input (Capacitive)		

Note

† Power supply for the piezo actuator feedback circuit. It must not be used to drive any other circuits or devices.

* This signal is applicable only to Thorlabs actuators. It enables the system to identify the piezo extension associated with the actuator.

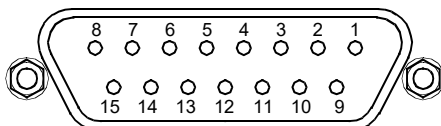
Fig. A.1 STAGE Connector Pin Identification

A.2 Rear Panel USER Connector

A.2.1 Pin Identification

This female 15-pin D-Type connector exposes a number of internal electrical signals. For convenience, a number of logic inputs and outputs are included, thereby eliminating the need for extra PC based IO hardware. Using the software, these user programmable logic lines can be deployed in applications requiring control of external devices such a relays, light sources and other auxilliary equipment.

The pin functions are detailed in in Fig. A.2 .



Pin	Description	Return	Pin	Description	Return
1	Digital O/P 1	5, 9, 10	9	Digital Ground	
2	Digital O/P 2	5, 9, 10	10	Digital Ground	
3	Digital O/P 3	5, 9, 10	11	For Future Use (Trigger Out)	5, 9, 10
4	Digital O/P 4	5, 9, 10	12	For Future Use (Trigger IN)	5, 9, 10
5	Digital Ground		13	Digital I/P 4	5, 9, 10
6	Digital I/P 1	5, 9, 10	14	5V Supply Output	5, 9, 10
7	Digital I/P 2	5, 9, 10	15	5V Supply Output	5, 9, 10
8	Digital I/P 3	5, 9, 10			



Warning

Do not, under any circumstances attempt to connect the digital I/O to any external equipment that is not galvanically isolated from the mains or is connected to a voltage higher than the limits specified in Section A.2.2. to Section A.2.6.. In addition to the damage that may occur to the controller there is a risk of serious injury and fire hazard.

Note

The "Trigger In" pin on the USER D-type connector is assigned the function of Open Loop / Closed Loop switchover, effectively replicating the function of the Closed Loop button on the front panel. This is useful in applications where the PPC001 is incorporated in equipment and the front panel is not easily accessible. If required, open loop / closed loop switchover can be accomplished by connecting an external button (normally open, momentary closed switch) between this pin and ground. A 5 Volt logic signal can also be used.

Fig. A.2 USER Connector Pin Identification

A.2.2 Digital Outputs

All digital outputs are of the open-collector type, with a 330 Ohm series resistor. When the output is set to a logic zero (which is also the default state), it behaves as open circuit. When it is a logic one, it behaves as a 330 Ohm resistor connected to ground.

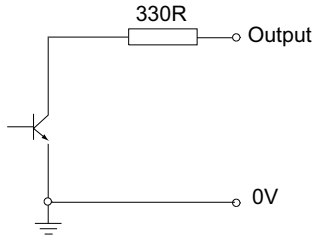


Fig. A.3 Digital Output Schematic

In some applications, the digital outputs may be required to control external equipment that has optocoupler type inputs (such as PLCs). The digital outputs used here can be used to directly drive most optocouplers and the +5V supply available on pins 14 and 15 can be used to provide power for the optocouplers.

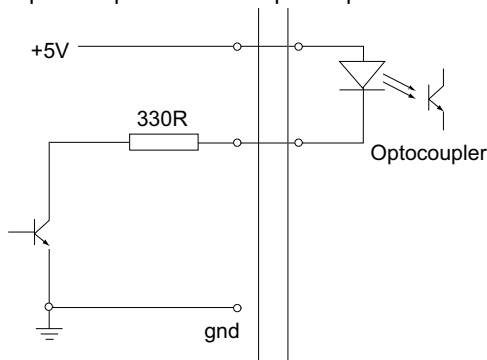


Fig. A.4 Application Example: Connection to Optocoupler Inputs

The digital outputs can also be used to interface to external logic circuitry (a pull-up resistor may be needed if the external logic does not contain it) or control other types of inputs.



Caution

The voltage that external equipment applies to the digital outputs must be within the range 0 V and +5 V DC, or damage to the outputs may occur.

Please see the Kinesis helpfile for details on software calls used to control these logic IO.

A.2.3 Digital Inputs

The digital inputs used in the controller are of the standard CMOS logic gate type with TTL compatible input levels and a built-in pull-up resistor (10 kOhm to +5V). They can be connected directly to mechanical switches, open-collector type outputs or most type of logic outputs.

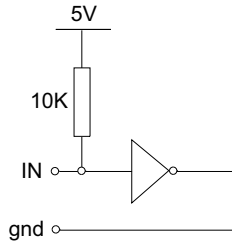


Fig. A.5 Digital Input Schematic (protection circuitry not shown)

When connected to a switch, the inputs will read as logic LOW if the switch is open circuit and HIGH if the switch is closed. When connected to a logic output, or any other voltage source, the input is guaranteed to read LOW if the voltage is above 2.4V and HIGH when the output is below 0.8 V. Please see the Kinesis helpfile for details on software calls used to control these logic IO.



Caution

The voltage applied to the digital inputs must be within the range 0 V to +7V DC, or damage to the inputs may occur.

A.2.4 Trigger Output

The trigger output is different from the rest of the digital outputs in that it is a 5V CMOS logic gate with a series 1 kOhm resistor for protection. It behaves as +5V voltage source with 1 kOhm in series when the outputs is a logic HIGH, and 1 kOhm to ground when it is a logic LOW. The 1 kOhm resistor limits the current to 5 mA maximum for any load as long as the output is not connected to voltages outside the 0 V to +5V range.

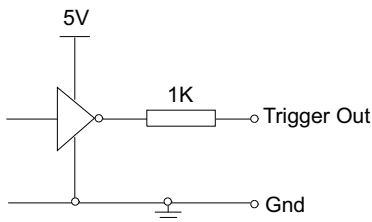


Fig. A.6 Trigger Output Schematic

As this output is actively driven, it can be connected, for example, to an oscilloscope without a need for an external pull-up resistor. It can also be used to drive most optocouplers.

A.2.5 Trigger Input

The Trigger inputs are electrically identical to the digital inputs (i.e. a standard CMOS logic gate type with TTL compatible input levels and a built-in pull-up resistor, 10 kOhm to +5V). They can be connected directly to mechanical switches, open-collector type outputs or most type of logic outputs.

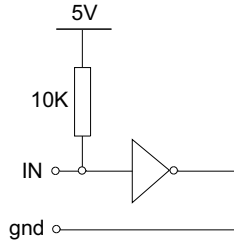


Fig. A.7 Trigger Input Schematic (protection circuitry not shown)

When connected to a switch, the inputs will read as logic LOW if the switch is open circuit and HIGH if the switch is closed. When connected to a logic output, or any other voltage source, the input is guaranteed to read LOW if the voltage is above 2.4V and HIGH when the output is below 0.8 V.



Caution

The voltage applied to the trigger inputs must be within the range 0V to +7V DC, or damage to the inputs may occur.

A.2.6 +5 Volt Supply

A +5 V, 250 mA supply is provided for interfacing to external circuits that require a power source.



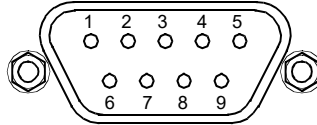
Caution

Do not exceed the 250 mA maximum output current. For applications requiring higher currents an external power supply must be used.

A.3 Rear Panel RS232 Connector

The RS232 terminal is a Male 9-Pin D-type connector exposes internal electrical signals for use with serial communications. This allows control of the device using the low level protocol in software environments that bypass Kinesis server. A 9-way female-to-female crossover (zero modem) cable is required for connecting to a host PC.

The pin functions are detailed in in Fig. A.8

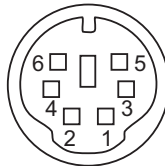


Pin	Description
1	Not Connected
2	RX (controller input)
3	TX (controller output)
4	Not Connected
5	Ground
6	Not Connected
7	Not Connected
8	Not Connected
9	Not Connected

Fig. A.8 RS232 Connector Pin Identification

A.4 Rear Panel Joystick Connector

Provides connection to the MZF001 joystick. The pin functions are detailed in Fig. A.9



Pin	Description
1	RX (controller input)
2	Ground
3	Ground
4	+5V , 100 mA Supply for Joystick
5	TX (controller output)
6	Ground

Fig. A.9 HANDSET Connector Pin Identification

Appendix B Preventive Maintenance



Warning: Risk of Electrical Shock

The equipment contains no user servicable parts. There is a risk of electrical shock if the equipment is operated with the covers removed. Only personnel authorized by Thorlabs Ltd and trained in the maintenance of this equipment should remove its covers or attempt any repairs or adjustments. Maintenance is limited to safety testing and cleaning as described in the following sections.

B.1 Safety Testing

PAT testing in accordance with local regulations, should be performed on a regular basis, (typically annually for an instrument in daily use).

B.2 Cleaning



Warning

Disconnect the power supply before cleaning the unit.

Never allow water to get inside the case.

Do not saturate the unit.

Do not use any type of abrasive pad, scouring powder or solvent, e.g. alcohol or benzene.

The fascia may be cleaned with a soft cloth, lightly dampened with water or a mild detergent.

Appendix C Specifications and Associated Parts

C.1 Objective Mount Specifications

Parameter	Value
Drive Voltage	-30 V to 150 V
Open Loop Travel Range	600 μm \pm 10%
Closed Loop Travel Range	450 μm
Feedback Transducer Type	Capacitive
Open Loop Resolution	1 nm
Closed Loop Resolution	3 nm
Typical Settling Time for 1 to 100 μm Step	25 ms
Position Linearity Error	\pm 0.05%
Resonant Frequency for 150 g Load	120 Hz \pm 20%
Max Load (any direction)*	500g (1.1 lb)
Tilt Angle	Yaw \pm 35 $\mu\text{radians}$ Pitch \pm 15 $\mu\text{radians}$
Max Objective Diameter	\varnothing 38.4 mm
Max Clear Aperture †	\varnothing 29.0 mm
Capacitance	8.0 μF \pm 15%
Cable Length	2 m (6.6')
Connector	Male 15-Way Mixed Signal Combination D-sub
Available Thread Adapters (Sold Separately)	M32 X 0.75 M27 X 0.75 M25 X 0.75 RMS (0.8"-36) SM1 (1.035" - 40)
Dimensions (X, Y, Z)	69 mm x 60 mm x 35 mm (2.72" x 2.36" x 1.38")
Weight (stage only)	380 g (0.84 lb)
Monolithic Flexure Housing Structure	Hardened Tool Steel
Surface Finish	Black Hard PVD Coated

Notes

* It is recommended that the centre of mass is as close as possible to the stage

† When the M32 adapters (PFMA01 and PFMA02) are attached to the stage.

C.2 Controller Specifications

Parameter	Value
Piezoelectric Output (Mixed Signal Combination D-Sub Connector)	
Voltage Output	-30 V to 150 V DC
Output Current	150 mA
Voltage Stability	100ppm over 24 hours (after 30 mins warm up time)
Noise	<0.5 mV RMS (Bandwidth 20 Hz to 100 kHz)*
Typical Piezo Capacitance	1 to 10 μ F
External Input (BNC)	
Input Type	Single Ended
Input Impedance	10 k Ω
Input Voltage Range	-10 V to 10 V DC
Absolute Maximum Input Voltage	\pm 20 V DC
Input Voltage for Full Range	10 V DC \pm 2%
External Output (BNC)	
Output Voltage Range	0 to 10 V nominal for full range (output can swing negative in certain scenarios)
Output Impedance	100 Ω
Minimum Recommended Load Impedance	10 k Ω
Protection	Protected against short circuit
Scaling Factor (HV Monitor)	1/15 (10V for a piezo voltage of 150 V)
User Input/Output (D-type 15 Pin Female)	
4 Digital Inputs	TTL Levels
4 Digital Outputs	Open Collector
Trigger Input	TTL
Trigger Output	TTL, 5 V Logic
User 5V	100 mA Max
Input Power Requirements (IEC Connector)	
Voltage	24 V DC \pm 5%
Supply Current	<2 A (ignoring power on transient)
Protection	Internal Fuse, 3 A Slow Blow

Notes

* HP3458A, statistical measurements

Parameter	Value
General	
USB	Version 2.0 Full Speed Compatible
RS-232	3-wire Interface (RX, TX, GND) via 9-way D-type male connector
Joystick	Compatible with Thorlabs MZF001 Joystick
Closed Loop Algorithm	Digital PID with Dual Tuneable Notch Filter
Processor	DSP 32-bit Floating Point, 160 MHz (ARM Cortex M4F)
Servo Update Interval	50 μ s
EXT IN ADC Resolution	24 Bits
Position ADC Resolution	18 Bits
HV DAC Resolution	20 Bits
Housing Dimensions (incl. feet, excl. connectors)	147 mm x 205 mm x 68.3 mm (5.79" x 8.07" x 2.69")
Weight	1.65 kg (3.63 lb)

Appendix D Piezo Operation - Background

D.1 Piezoelectric Controller

D.1.1 The Piezoelectric Effect

Piezoelectricity is the effect whereby certain types of crystal expand reversibly when subjected to an electric field.

Although the amount of expansion is usually very small (corresponding to less than 1% strain in the material) it can be controlled extremely finely by varying the strength of the electric field. Piezoelectric materials therefore form the basis of very high precision actuators. The resolution of these actuators is effectively only limited by the noise and stability of the drive electronics. Moreover, the force generated by the expanding piezo is very large, typically hundreds of newtons.

Perhaps the most useful property of these actuators is their ability to produce oscillating motion at considerable frequencies, usually limited by the mechanical system driven rather than by the piezo actuator itself. This ability is used to advantage in the NanoTrak control system, for example.

The electric field gradient needed to produce a useful amount of expansion is quite large. Thus to avoid excessive drive voltages, the actuator is constructed as a stack, consisting of lamina of active material sandwiched among electrodes – see Fig. D.1. In this way, the distance from positive to negative electrodes is very small. A large field gradient can therefore be obtained with a modest drive voltage (75 V or 150 V in the case of Thorlabs actuators).

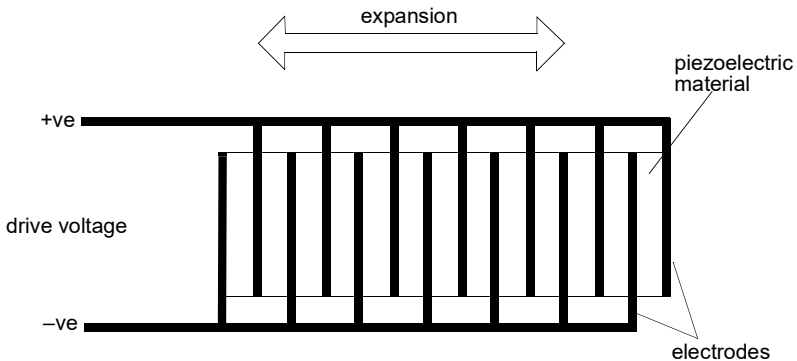


Fig. D.1 Piezo-electric actuator schematic diagram

D.1.2 Hysteresis

Despite the very high resolution of piezoelectric actuators, an inherent problem is the significant amount of hysteresis they exhibit, (i.e., the tendency of the actuator to reach a final position that lags behind the demand position).

If a cyclic voltage is applied to the actuator the positions reached on the upward sweep are smaller than those achieved on the downward sweep. If position is plotted against voltage, the graph describes a hysteresis loop – see Fig. D.2.

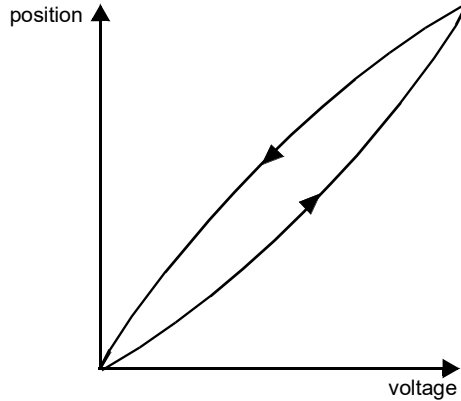


Fig. D.2 Piezo-electric hysteresis

D.1.3 Position Sensing and Feedback Control

Hysteresis can be eliminated by using a position sensor and feedback loop, i.e., the sensor measures the position, the circuit subtracts the measured position from the demand position to get the error, and a proportional-integral feedback loop adjusts the voltage to the actuator until the error is virtually zero.

Some Thorlabs nanopositioning actuators have position sensing, others do not. The Piezoelectric control module allows both types to be controlled.

To control an actuator with position sensing, the Piezoelectric control module should be set to closed-loop mode. To control an actuator without position sensing, the Piezoelectric Control module should be set to open-loop mode.

Note

An actuator with position sensing can also be driven in open-loop mode if desired, since the feedback part of the circuit can be switched off. An advantage of open-loop mode is the greater bandwidth of the system.

Block diagrams for both modes of operation are shown in Fig. D.1.

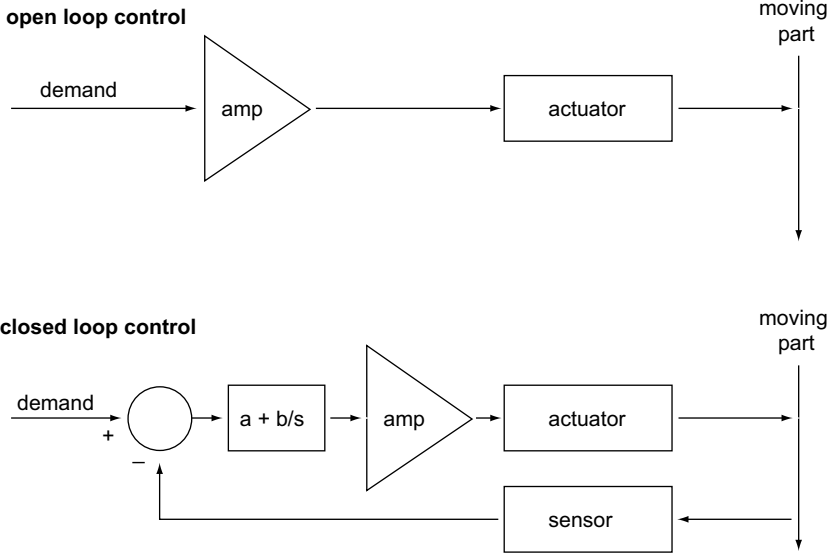


Fig. D.3 Open loop and closed loop control

The result of using closed-loop control is a linear relationship between demand (voltage) and measured position – see Fig. D.4, in contrast to open loop control – see Fig. D.2.

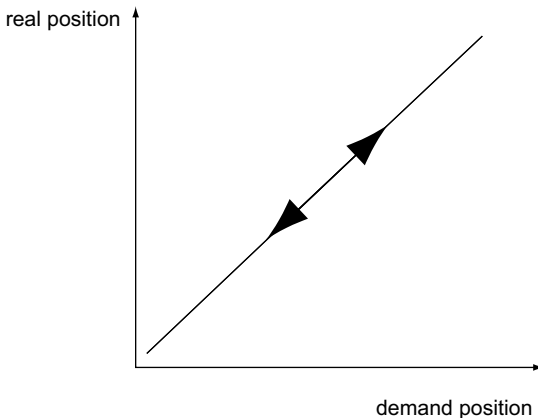


Fig. D.4 Closed loop response

Appendix E Regulatory

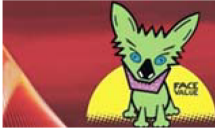
E.1 Declarations Of Conformity

E.1.1 For Customers in Europe
See Section E.2.

E.1.2 For Customers In The USA

This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense. Changes or modifications not expressly approved by the company could void the user's authority to operate the equipment.

E.2 CE Certificate



THORLABS

www.thorlabs.com

EU Declaration of Conformity

in accordance with EN ISO 17050-1:2010

We: Thorlabs Ltd.
Of: 1 St. Thomas Place, Ely, CB7 4EX, United Kingdom

in accordance with the following Directive(s):

2006/42/EC	Machinery Directive (MD)
2004/108/EC	Electromagnetic Compatibility (EMC) Directive
2011/65/EU	Restriction of Use of Certain Hazardous Substances (RoHS)

hereby declare that:

Model: **PFM450**
Equipment: **Piezo Focus Objective Mount – 450um Capacitive Closed Loop**

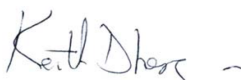
is in conformity with the applicable requirements of the following documents:

EN ISO 12100	Safety of Machinery. General Principles for Design. Risk Assessment and Risk Reduction	2010
EN 61326-1	Electrical Equipment for Measurement, Control and Laboratory Use - EMC Requirements	2013

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

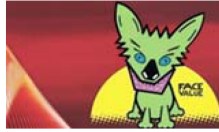
I hereby declare that the equipment named has been designed to comply with the relevant sections of the above referenced specifications, and complies with all applicable Essential Requirements of the Directives.

Signed:  On: 18 January 2016

Name: Keith Dhese
Position: General Manager

EDC - PFM450 -2016-01-18





THORLABS
www.thorlabs.com

EU Declaration of Conformity

in accordance with EN ISO 17050-1:2010

We: Thorlabs Ltd.
Of: 1 St. Thomas Place, Ely, CB7 4EX, United Kingdom

in accordance with the following Directive(s):

2006/95/EC	Low Voltage Directive (LVD)
2004/108/EC	Electromagnetic Compatibility (EMC) Directive
2011/65/EU	Restriction of Use of Certain Hazardous Substances (RoHS)

hereby declare that:

Model: **PPC001**

Equipment: **1 Channel Piezo Controller**

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

EN 61010-1	Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory Use.	2010
EN 61326-1	Electrical Equipment for Measurement, Control and Laboratory Use - EMC Requirements	2013

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 sections of the above referenced specifications, and complies with all applicable Essential Requirements of the Directives.

Signed:  On: 15 January 2016

Name: Keith Dhese

Position: General Manager

EDC - PPC001 -2016-01-15

CE 16

Chapter 6 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.



USA, Canada, and South America

Thorlabs, Inc.
sales@thorlabs.com
techsupport@thorlabs.com

Europe

Thorlabs GmbH
europe@thorlabs.com

France

Thorlabs SAS
sales.fr@thorlabs.com

Japan

Thorlabs Japan Inc.
sales@thorlabs.jp

UK and Ireland

Thorlabs Ltd.
sales@uk.thorlabs.com
techsupport.uk@thorlabs.com

Scandinavia

Thorlabs Sweden AB
scandinavia@thorlabs.com

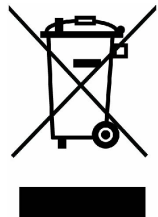
Brazil

Thorlabs Vendas de Fotônicos Ltda.
brasil@thorlabs.com

China

Thorlabs China
chinasales@thorlabs.com

Thorlabs verifies our compliance with the WEEE (Waste Electrical and Electronic Equipment) directive of the European Community and the corresponding national laws. Accordingly, all end users in the EC may return "end of life" Annex I category electrical and electronic equipment sold after August 13, 2005 to Thorlabs, without incurring disposal charges. Eligible units are marked with the crossed out "wheelie bin" logo (see right), were sold to and are currently owned by a company or institute within the EC, and are not disassembled or contaminated. Contact Thorlabs for more information. Waste treatment is your own responsibility. "End of life" units must be returned to Thorlabs or handed to a company specializing in waste recovery. Do not dispose of the unit in a litter bin or at a public waste disposal site.



UNLEASHED



THORLABS
www.thorlabs.com
