THORLABS

This legacy APT manual is provided for reference only. Our APT software was discontinued on July 1, 2024, and no updates have been made to this document since then. The latest product specifications are contained within the item-specific documentation at www.thorlabs.com

PGM1SE

Closed Loop Piezo Gimbal Mount and Controller

APT User Guide

Original Instructions

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Appendices

Chapter 1 Overview

1.1 Introduction

The PGM1SE kit comprises the PGM1S closed loop piezo gimbal mount and the PPC102 precision piezo controller. The design of the PGM1S mount includes a true gimbal feature, i.e. the axes of rotation are at the center of the front surface of the optic and do not move when the optic is rotated.

The mount delivers a high angular range of adjustment in two axes (30 mrad (±15 mrad) in open loop and 20 mrad (±10 mrad) in closed loop) and offers the option of using lenses as well as mirrors. A mechanically-amplified piezo-flexure mechanism provides the actuation required for the high angular adjustments. In addition, the design provides a maximum bandwidth of 50 Hz with a fine resolution of better than 0.05 µrad in open loop and 0.14 µrad in closed loop. The housing provides flexibility to be integrated as part of a 30 mm cage system as well as a post system assembly. In addition to accepting 1" optics of 2.5 ~ 10 mm thick, adapters are available for smaller and thinner optics.

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 and beam steering applications among others.

The mount is driven by the included PPC102 controller. This 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 for effortless dual-axis motion.

Fig. 1.1 PGM1S Closed Loop Piezo Gimbal Mount

The PPC102 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 APT system software.

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 mrad). 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. Two notch filters can also be adjusted for fine tuning of the resonance frequency of the system according to the scanning loads.

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 rotating a "software-panel" control knob (see the tutorial in Chapter 4 for further details). Note that all such settings and parameters are also accessible through the ActiveX programmable interfaces. See Section 1.2. for a full description of the APT system software and background on the advantages of the ActiveX Control technology.

Using the controllers and associated mechanical products, complete automated alignment systems can be engineered with ease at both the hardware and software level. All controllers in the APT range are equipped with USB connectivity. The 'multi-drop' USB bus allows multiple APT units to be connected to a single controller PC using commerical 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 Dual Channel Precision Piezo Controller (PPC102)

1.2 APT PC Software Overview

1.2.1 Introduction

As a member of the Thorlabs range of controllers, the PPC102 piezo controller shares many of the associated software benefits. This includes 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 APT software suite supplied with all APT controllers provides a flexible and powerful PC based control system both for users of the equipment, and software programmers aiming to automate its operation.

For users, the APTUser (see Section 1.2.2.) and APTConfig (see Section 1.2.3.) utilities allow full control of all settings and operating modes enabling complete 'out-of-box' operation without the need to develop any further custom software. Both utilities are built on top of a sophisticated, multi-threaded ActiveX 'engine' (called the APT server) which provides all of the necessary APT 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. It is this APT server 'engine' that is used by software developers to allow the creation of advanced automated positioning applications very rapidly and with great ease. The APT server is described in more detail in Section 1.2.4.

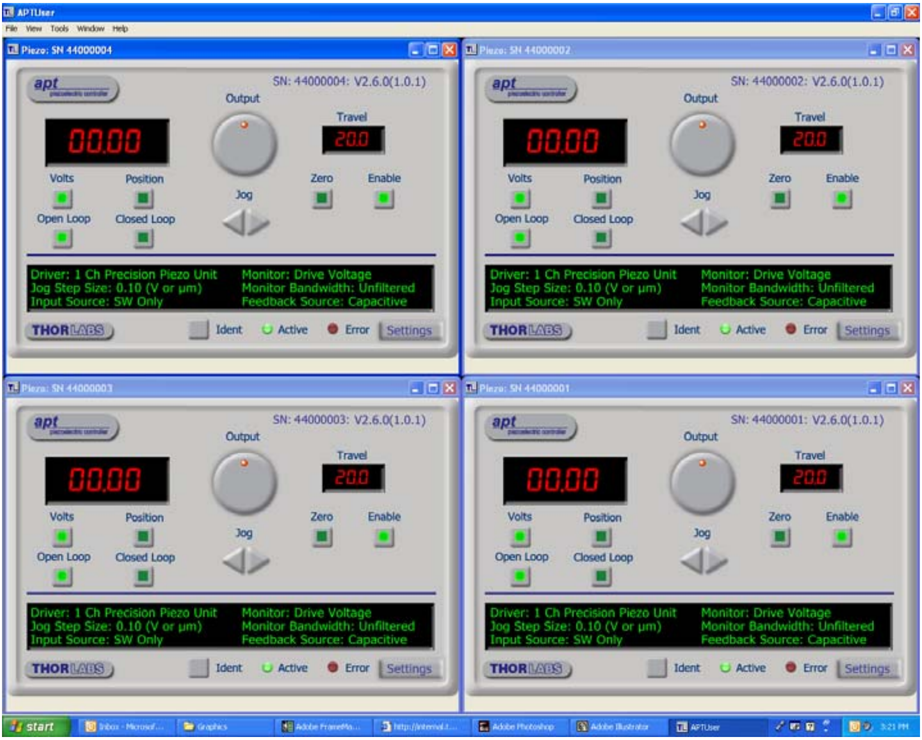
Aside

ActiveX®, a Windows®-based, language-independent technology, allows a user to quickly develop custom applications that automate the control of APT system hardware units. Development environments supported by ActiveX® technology include Visual Basic®, LabView™, Borland C++ Builder, Visual C++, Delphi™, and many others. ActiveX® technology is also supported by .NET development environments such as Visual Basic.NET and Visual C#.NET.

ActiveX controls are a specific form of ActiveX technology that provide both a user interface and a programming interface. An ActiveX control is supplied for each type of APT hardware unit to provide specific controller functionality to the software developer. See Section 1.2.4. for further details.

1.2.2 APTUser Utility

The APTUser application allows the user to interact with a number of APT hardware control units connected to the host PC. This program displays multiple graphical instrument panels to allow multiple APT units to be controlled simultaneously.



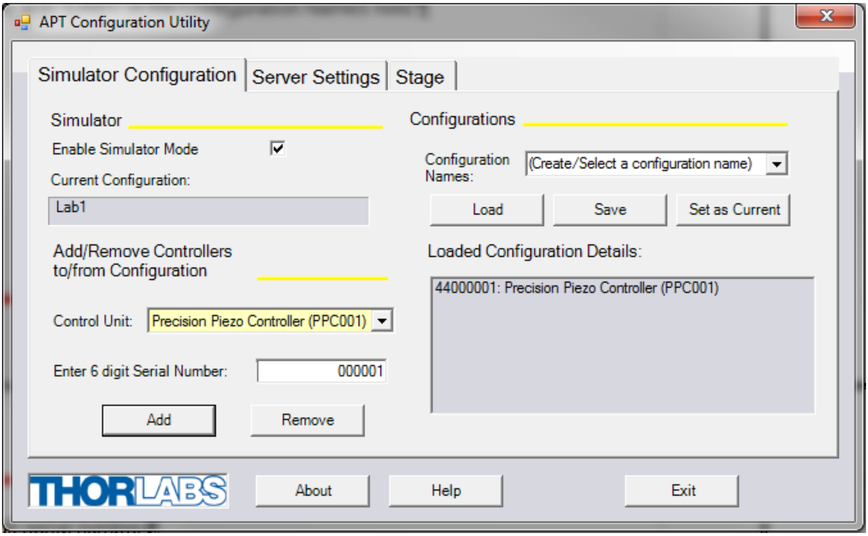
All basic operating parameters can be altered and, similarly, all operations (such as piezo moves) can be initiated. Settings and parameter changes can be saved and loaded to allow multiple operating configurations to be created and easily applied.

For many users, the APTUser application provides all of the functionality necessary to operate the APT hardware without the need to develop any further custom software. For those who do need to further customise and automate usage of the controller (e.g. to implement a positioning algorithm), this application illustrates how the rich functionality provided by the APT ActiveX server is exposed by a client application.

Use of the APT User utility is covered in the PC tutorial (Chapter 4) and in the APTUser online help file, accessed via the F1 key when using the APTUser utility.

1.2.3 APT Config Utility

There are many system parameters and configuration settings associated with the operation of the APT Server. Most can be directly accessed using the various graphical panels, however there are several system wide settings that can only be made 'off-line' before running the APT software. These settings have global effect; such as switching between simulator and real operating mode and incorporation of calibration data.



The APTConfig utility is provided as a convenient means for making these system wide settings and adjustments. Full details on using APTConfig are provided in the online help supplied with the utility.

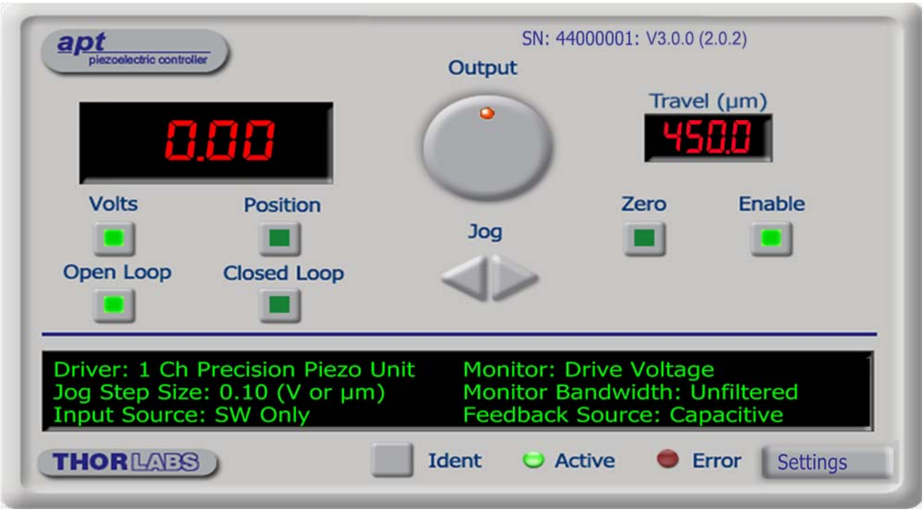
Use of the APT Config utility is covered in the PC tutorial (Chapter 4) and in the APTConfig online help file, accessed via the F1 key when using the APTConfig utility.

1.2.4 APT Server (ActiveX Controls)

ActiveX Controls are re-usable compiled software components that supply both a graphical user interface and a programmable interface. Many such Controls are available for Windows applications development, providing a large range of re-usable functionality. For example, there are Controls available that can be used to manipulate image files, connect to the internet or simply provide user interface components such as buttons and list boxes.

With the APT system, ActiveX Controls are deployed to allow direct control over (and also reflect the status of) the range of electronic controller units, including the PPC102 piezo controller. Software applications that use ActiveX Controls are often referred to as 'client applications'. Based on ActiveX interfacing technology, an ActiveX Control is a language independent software component. Consequently ActiveX 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 ActiveX Control supplied for the PPC102 APT piezo controller unit.



This Control provides a complete user graphical instrument panel to allow the Piezo unit to be manually operated, as well as a complete set of software functions (often called methods) to allow all parameters to be set and Piezo control operations to be automated by a client application. The instrument panel reflects the current operating state of the controller unit to which it is associated (e.g. such as piezo travel). 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 to a particular position, progress is monitored automatically by changing position readout on the graphical interface, without the need for further programming intervention.

The APT ActiveX Controls collection provides a rich set of graphical user panels and programmable interfaces allowing users and client application developers to interact seamlessly with the APT hardware. Each of the APT controllers has an associated ActiveX Control and these are described fully in system online help. Note that the APTUser and APTConfig utilities take advantage of and are built on top of the powerful functionality provided by the APT ActiveX Server (as shown in Fig. 1.3).

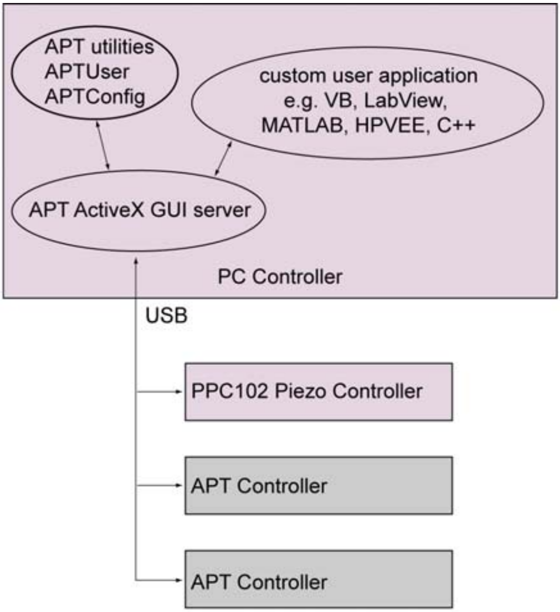


Fig. 1.3 System Architecture Diagram

Refer to the main APT Software online help file, *APTServer.hlp* (available from the Windows Start menu), for a complete programmers guide and reference material on using the APT ActiveX Controls collection. Additional software developer support is provided by the APT Support pages included on the software installation CD supplied with every APT controller. This CD contains a complete range of tutorial samples and coding hints and tips, together with handbooks for all the APT controllers.

1.2.5 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 in the handbook, 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.

Warning

This device uses voltages up to 150V at the rear panel CHANNEL connectors (piezo output). This is hazardous and can cause serious injury. Appropriate care should be taken when using this device.

Persons using this device must understand the hazards associated with using high voltages and the steps necessary to avoid risk of electrical shock.

If the unit is used in a manner not specified by Thorlabs, the protective features provided by the product may be impaired.

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 APT 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 APT 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.

3.2 Installation

The PGM1S can be mounted on an optical post via the 8-32 (M4) mounting hole on two of the side faces, as shown below. Alternatively, it can be mounted in a 30 mm cage system. Please search PGM1SE at www.thorlabs.com for detailed dimension drawings.

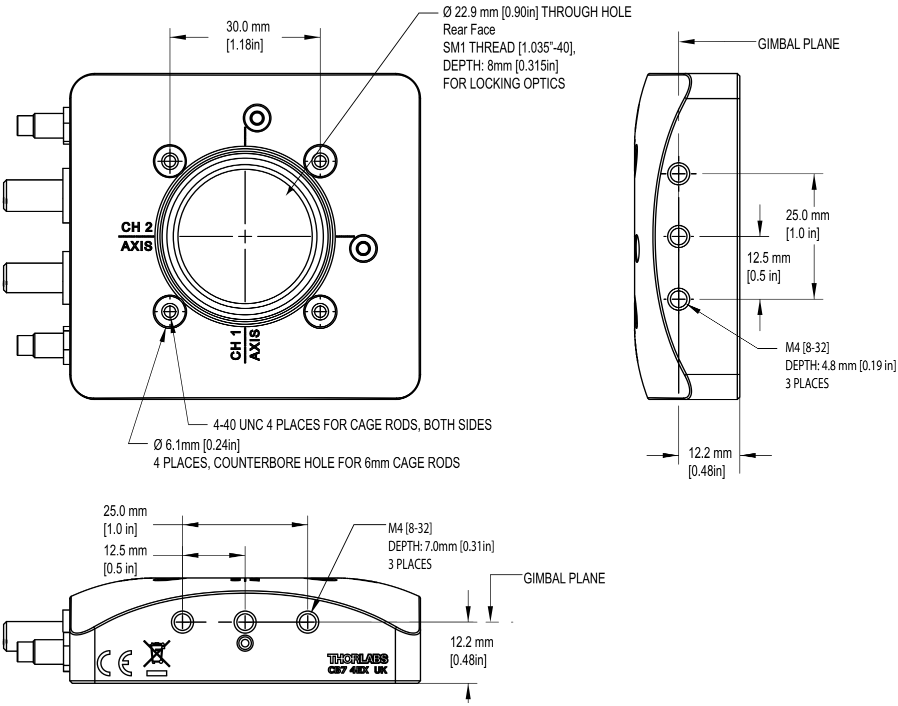


Fig. 3.1 Mounting Options

3.3 Fitting/Changing the Optic

The optic is fitted from the rear face, and is secured with an SM1 retaining ring as shown in Fig. 3.2. The retaining ring can be removed/fitted using the SM1 spanner wrench part number SPW602.

Caution

Securing the optic should require a tightening torque of 25.0 N.cm (2.2 lb.in) .

The maximum tightening torque should be limited to 35 N.cm (3.1 lb.in) to avoid damage to the gimbal flexure mechanism.

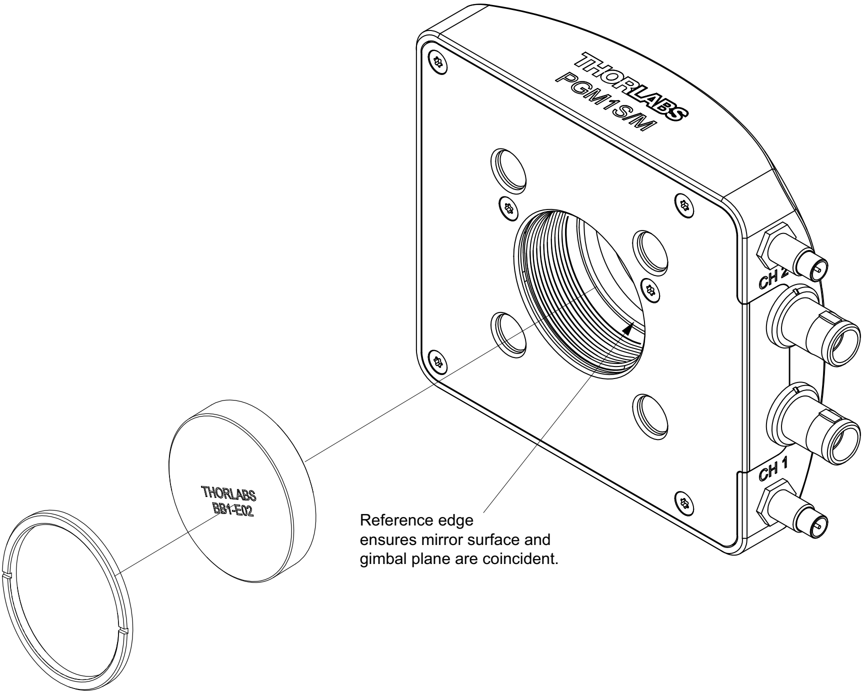


Fig. 3.2 Fitting the optic

3.4 Maximum Beam Incident Angle

The face of the mirror or lens fitted to the PGM1S mount is recessed from the front face of the device by around 9.0 mm (0.35"). This is to match the gimbal axes of rotation with the optic surface and side/bottom mounting holes.

The maximum incident angle at which the laser beam can strike the optic varies with beam diameter but for a typical 2.5 mm dia. beam, the maximum angle is 55° as shown in Fig. 3.3

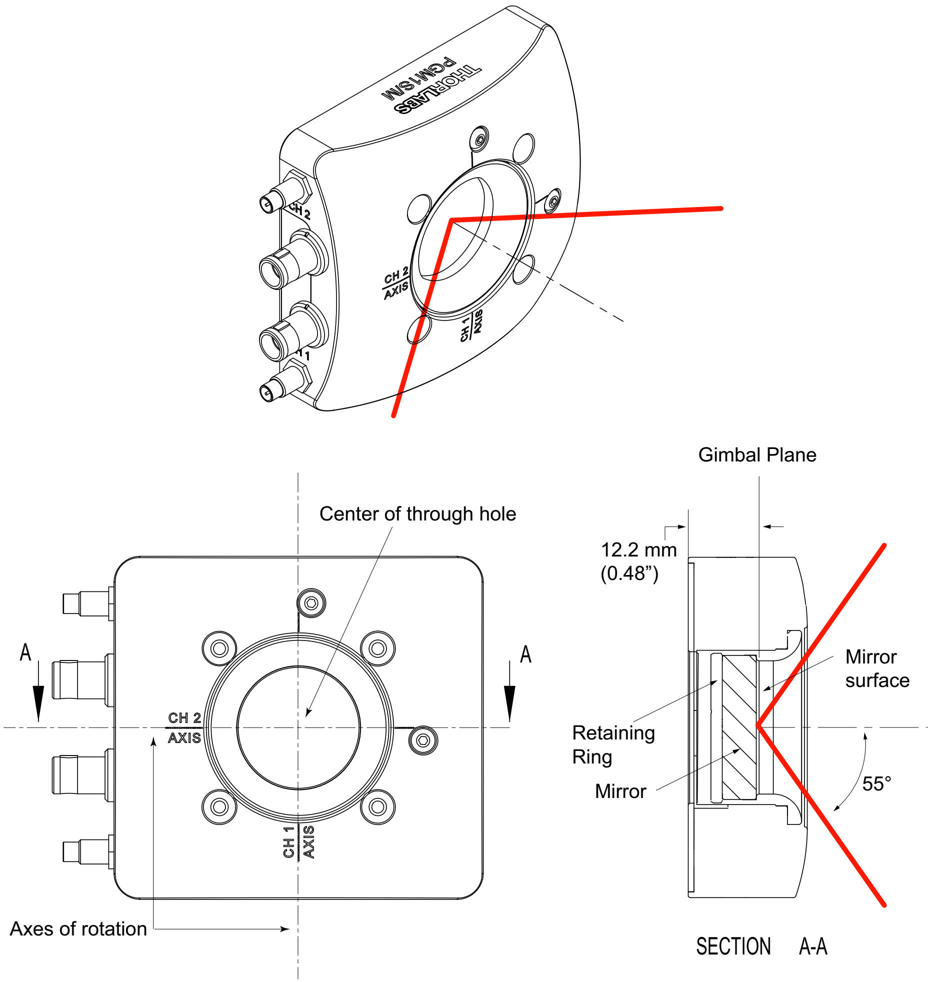


Fig. 3.3 Maximum beam incident angle

3.5 Installing the Controller

Caution

The PGM1S Gimbal Mount and PPC102 150V Piezo Controller 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.

Furthermore, the cables provided are part of paired bundle. Channel connections should according to the channel labels, otherwise a serial number mis-match error massage will not allow operation of the stage.

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

Caution

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

Location	Indoor use only
Maximum altitude	2000 m
Temperature range	5^{o}C to 40^{o}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 prelonged period can reduce the lifetime of the internal piezo stack.

3.6 Installing APT Software

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.

Caution

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.

DO NOT CONNECT THE CONTROLLER TO YOUR PC YET

1) Go to Services/Downloads at www.thorlabs.com and download the APT Software.
2) 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 4A 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 gimbal mount is plugged in or unplugged. Failure to switch the controller off may result in damage to either the controller, the gimbal mount or both.

3.7.2 Connecting The Hardware

1) Install the software - see Section 3.6.

Caution

The PGM1S Gimbal Mount and PPC102 150V Piezo Controller 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.

Furthermore, the cables provided are part of paired bundle. Channel connections should be made according to the channel labels, otherwise a serial number mis-match error message will not allow operation of the stage.

2) Connect the gimbal mount to the Controller unit - see Fig. 3.5 and 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 to not become disconnected during use.

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

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 APTUser utility
   Start/All Programs/Thorlabs/APT/APT User.

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

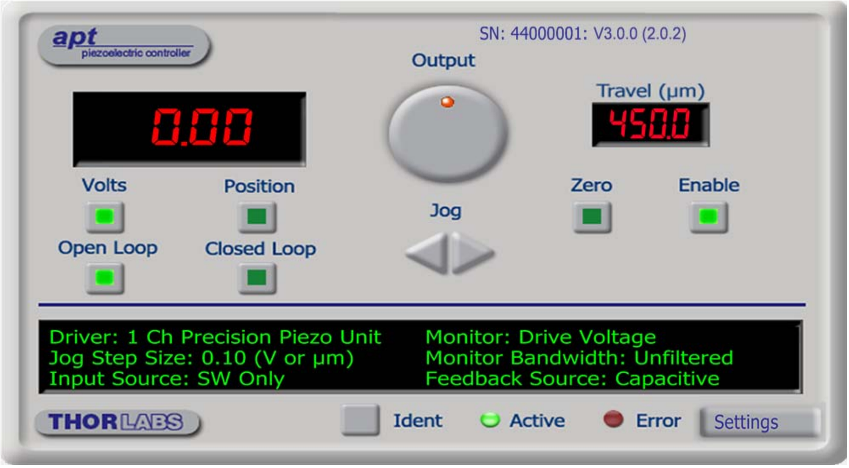


Fig. 3.4 GUI panel showing jog and ident buttons

8) Click the 'Ident' 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 'APT Config' utility can be used to set up simulated hardware configurations and place the APT 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. If using real hardware, ensure that Simulator Mode is disabled. If using a simulated setup, enable Simulator Mode and set up a 'Simulated Configuration' - see Section 4.9. or the APTConfig 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

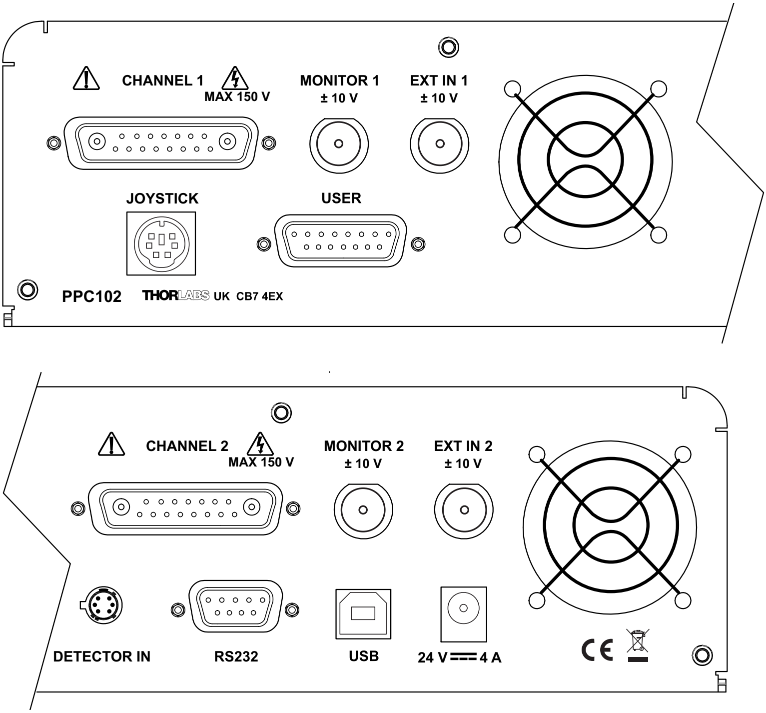


Fig. 3.5 Rear panel connections

CHANNEL 1/CHANNEL 2 - Provides the drive signal to the piezo actuator connected to the associated channel, -30 V to 150 V, 0 to 150 mA.

Caution

The PGM1S Gimbal Mount and PPC102 150V Piezo Controller 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.

Furthermore, the cables provided are part of the paired bundle. Channel connections should be made according to the channel labels, otherwise a serial number mis-match error message will not allow operation of the stage.

Ensure that the mating faces of the connectors on the cables and the rear panel of the unit are properly aligned. Misalignment can cause connection problems.

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

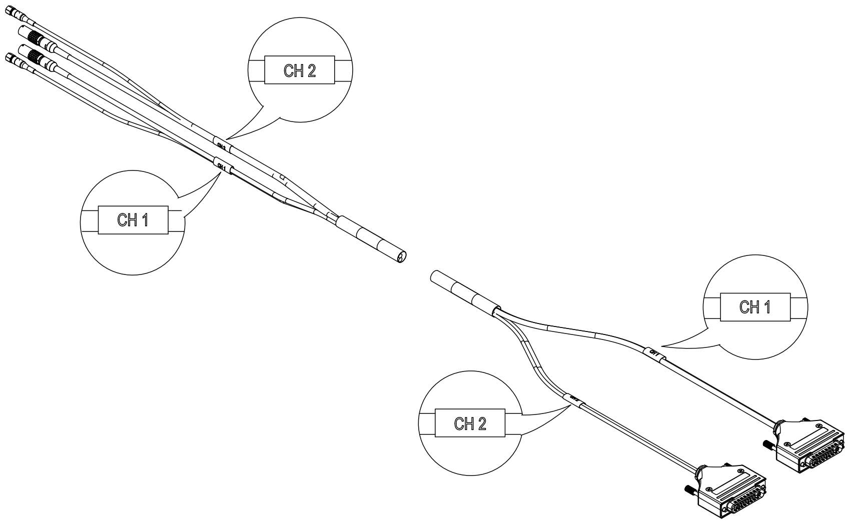


Fig. 3.6 Cable Connection Details

EXT IN (BNC connector) – Used to control the piezo mount from an external source. When in open loop the EXT IN controls the voltage, when in closed loop it controls the position. This input allows a -10V to 10V input to drive the output to its full scale. This gives a gain of 15 for the 150V range. The input impedence is 10 kΩ load.

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 5.2.1.) or in software by calling the SetPPCIOSettings method (see the APTServer helpfile available from the Windows 'Start' menu).

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.

MONITOR (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 5.2.1., or in software by calling the SetPPCIOSettings method (see the *APTServer helpfile* available from the Windows 'Start' menu).

JOYSTICK - Not used in the PGM1SE

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 APT support 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 - see Section A.2. for further details.

DETECTOR IN - Not Implemented. For future use.

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

USB - USB port for system communications.

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.

3.8 Front Panel Controls and Indicators

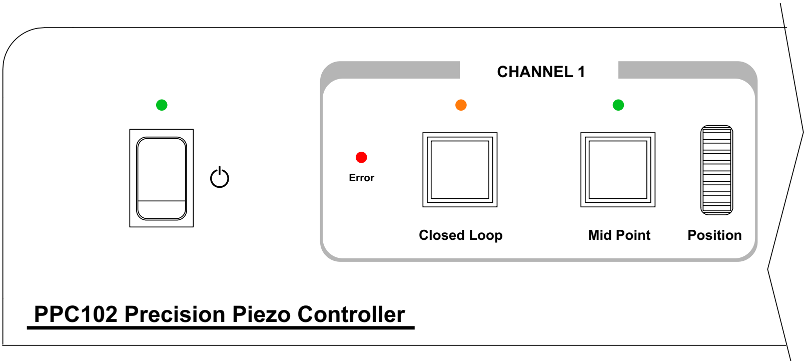


Fig. 3.7 Front panel controls and indicators

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 5.2.1.

The front panel includes two sets of identical controls, one set for each channel. The function of these controls is detailed below.

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.

Mid Point Button and LED - When this button is pressed, the associated channel moves to it's mid point position. In open loop, the drive voltage is adjusted to 60V, i.e. midway between -30V and 150V. In closed loop, the channel moves to the actual midpoint, i.e. 0 mrad. The LED is lit when at the mid point, if the position or voltage is adjusted thereafter, the LED is extinguished and the button must be pressed again to return to the mid point.

Position Wheel - Adjusts the drive voltage and/or position. A 'joystick' option must be selected in the settings panel (see Section 5.2.1.) in order for the wheel to function.

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 4.7.

3.9 Controller Schematic Diagram

The PPC102 controller and PGM1S gimbal mount is a closed-loop position control system with a digital PID controller and dual notch filters. The PGM1S mount contains a strain gauge 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 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 exhibitied by the mass and elasticity of the actuator.

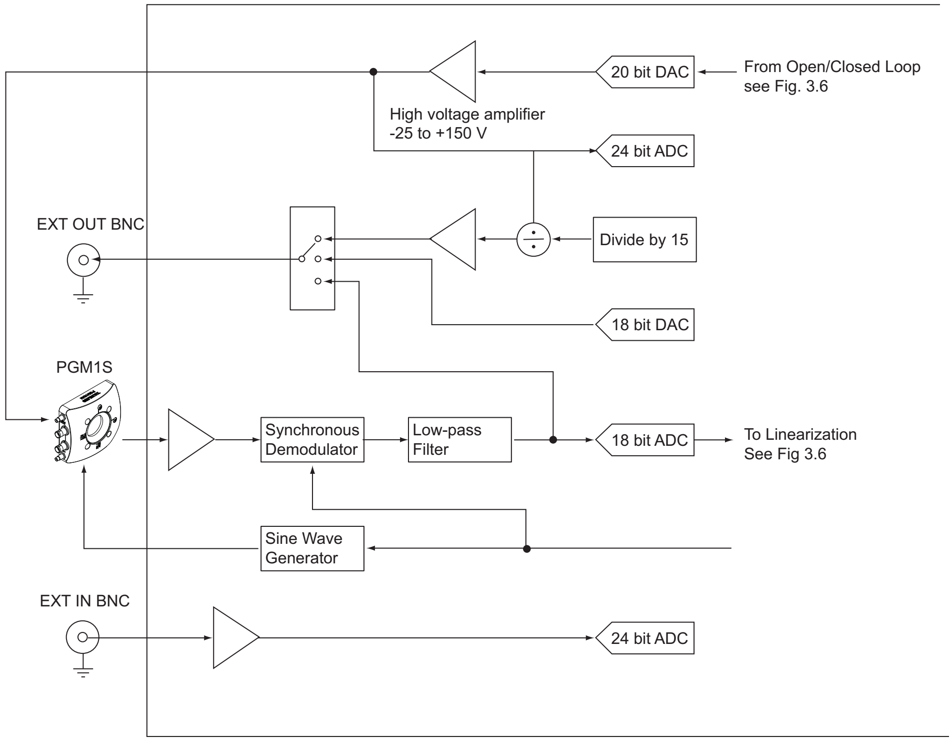


Fig. 3.8 System Schematic - Part 1

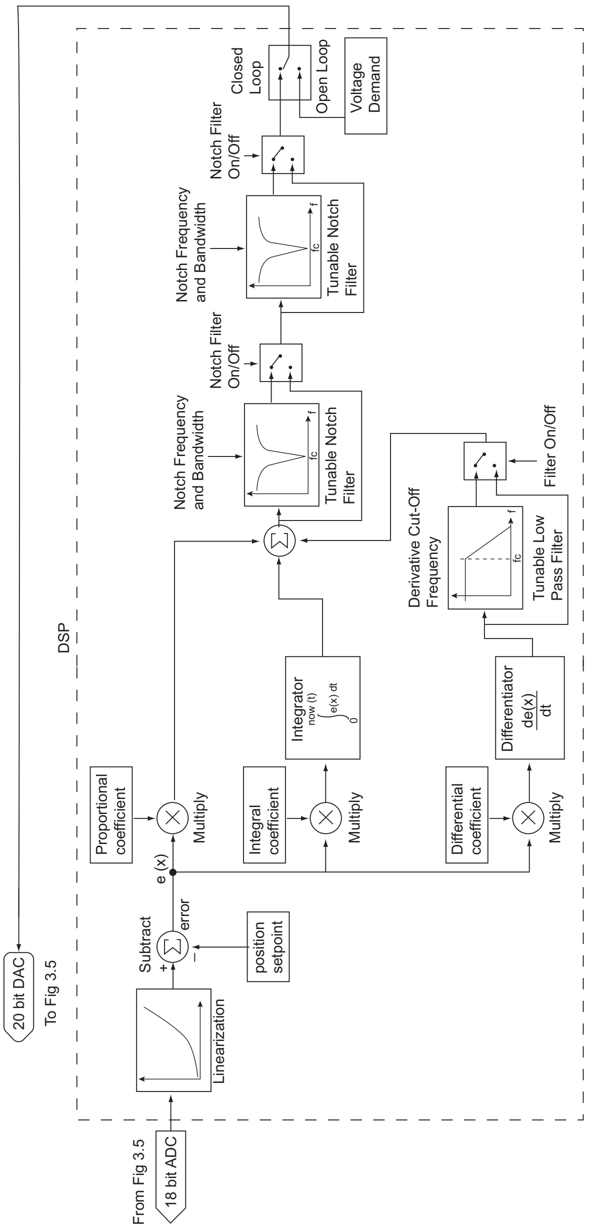


Fig. 3.9 System Schematic - Part 2

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 rear panel CHANNEL connectors. 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 gimbal mount is plugged in or unplugged. Failure to switch the controller off may result in damage to either the controller, the gimbal mount or both.

4.1 Introduction

The following brief tutorial guides the user through a typical series of actions and parameter adjustments performed using the PC based APT software. It assumes that the unit is electrically connected as shown in Section 3.7.4. and that the APT 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 APT User Utility

The APT User.exe application allows the user to interact with any number of APT hardware control units connected to the PC USB Bus (or simulated via the APTConfig utility). This program allows multiple graphical instrument panels to be displayed so that multiple APT 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 APTUser is run up.

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

1) Fit the gimbal mount and install the hardware as detailed in Chapter 3.
2) Run the APT User program - Start/All Programs/Thorlabs/APT User/APT User. The APT server registers automatically the units connected on the USB bus and displays the associated GUI panels as shown in Fig. 4.1.

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

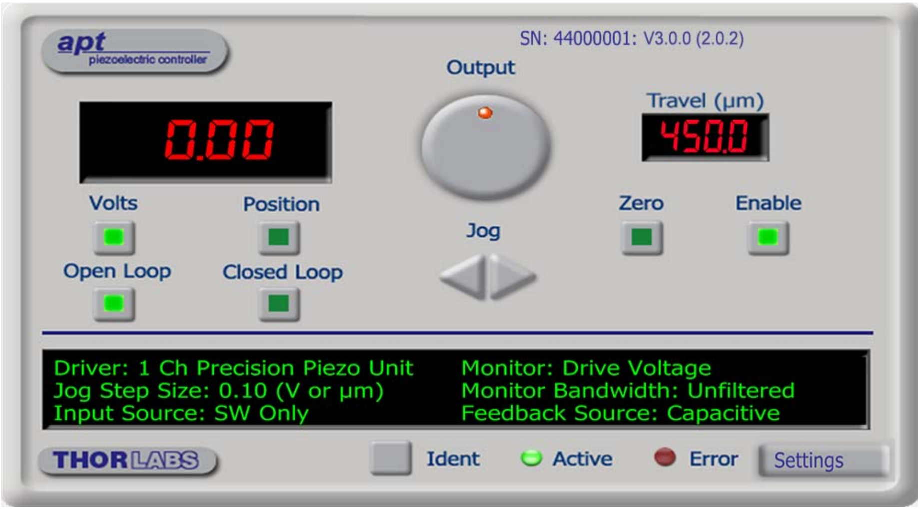


Fig. 4.1 Piezo Controller Software GUI .

Caution

The PGM1S Gimbal Mount should be driven by the Thorlabs PPC102 150V Piezo Controller supplied. Other controllers may not deliver the best performance and/or full range of travel.

Warning: Risk of Electrical Shock

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

4.3 Introduction to Open and Closed Loop Operation

The PPC102 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 E 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 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 PPC102 controller and PGM1S Gimbal 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 PGM1S unit with which it was calibrated. If there is a mis-match, the controller sends an error message to the APTServer. 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 5.2.2. for more details on these parameters.

The following section describes a typical tuning procedure

1) Fit the PGM1S into the application - see Section 3.
2) Switch on the controller and leave to warm up for at least 30 minutes.
3) Run APT and switch to Open Loop mode.
4) 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 5.2.2.
5) Set the notch filter central frequency as explained in Section 5.2.2.
6) Set the PID parameters as explained in Section 5.2.2.
7) Switch to closed loop mode.
8) The stability of position display should be better than ± 0.005 mRad with a stable microscope system. While monitoring the position display on the APT GUI, reduce P, I and D parameters one at a time, by 10% steps to optimise display jittering.
9) 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.
10) Reduce the threshold values by 10% to 20%, to ensure a safe margin and a fast response is guaranteed.
11) 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 Moving the Piezo Mount

The piezo mount can be manually positioned in three ways: by entering a voltage/ position, by using the ‘Output’ potentiometer or by clicking the ‘Jog’ buttons.

4.5.1 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 optic mass, piezo mount orientation, and environmental temperature, the position of the mount with 0V applied can vary by tens of µrad. Therefore a true position of 0 mrad (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 4.5.2.

4.5.2 Entering the Gimbal Position

Note

The gimbal position can be entered only when operating in ‘Closed Loop’ mode.

1) Click the ‘Closed Loop’ button.
2) Click the ‘Position’ button.
3) Click the main display.

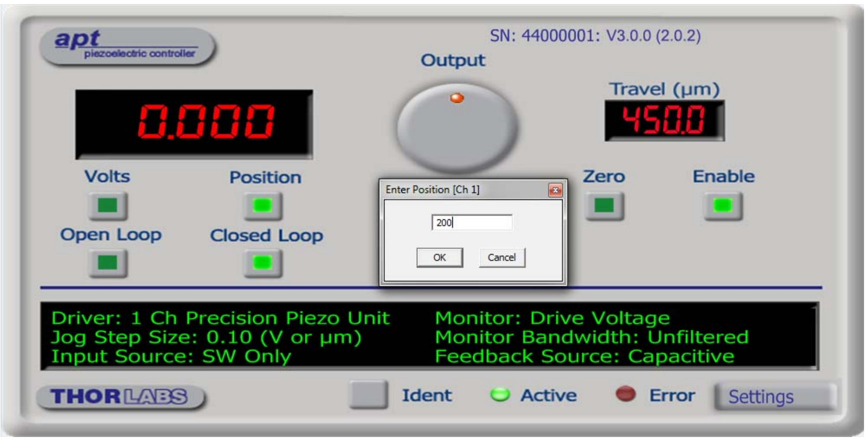


Fig. 4.2 Position Popup Window

4) Enter 5.000 into the pop up window
5) Click ‘OK’. Notice that the position display counts up to 5.000 to indicate a move to a position 5.0 µRad from the Zero datum.

4.5.3 Entering the Piezo Voltage (Open Loop)

1) Click the ‘Open Loop’ button.
2) Click the ‘Volts’ button.
3) Click the main display.

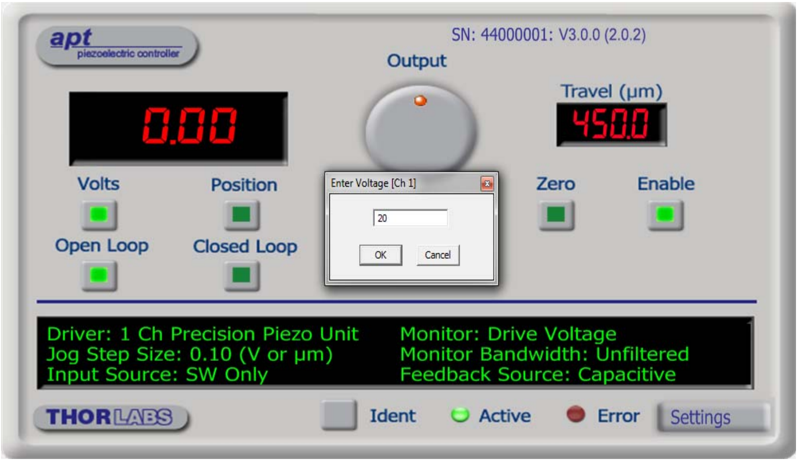


Fig. 4.3 Voltage Popup Window

4) Enter 20.0 into the pop up window
5) Click ‘OK’. Notice that the position display counts up to 20.00 to indicate a drive voltage of 20 V being applied to the piezo.

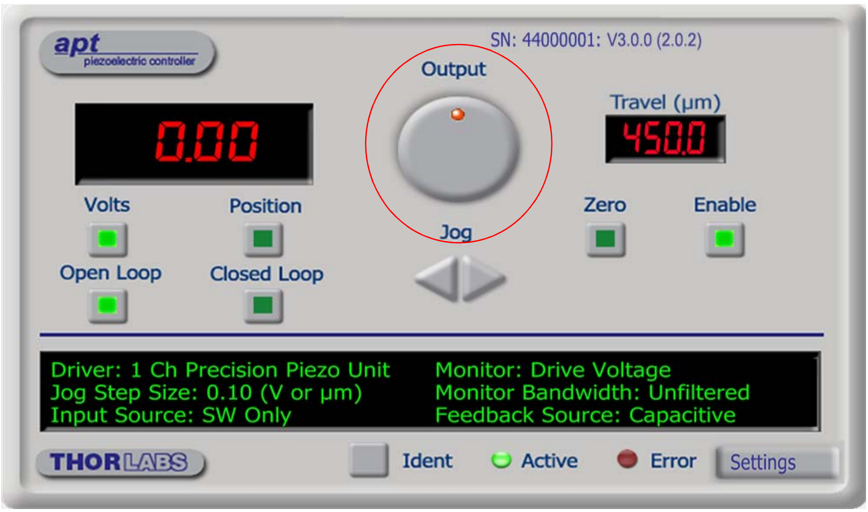
4.5.4 Moving the Piezo using the 'Output' control

The 'Output' control is used to adjust and set the voltage or position output as displayed in the main digital display. If the channel is in closed loop mode (set using the 'closed loop' button on the panel) then this control can be used to adjust position output. If open loop mode is selected (using the 'open loop' button) then the control is used to adjust the voltage output.

1) Click the 'Closed Loop' button.
2) Click the 'Position' button.
3) Rotate the 'Output' control clockwise. Notice how the position display increments to show the increasing piezo position.
4) Rotate the 'Output' control anticlockwise. Notice how the position display decrements to show the decreasing piezo position.
5) Click the 'Voltage' button. Notice how the display changes to show the voltage associated with the current piezo position.

Note

The read out in the main digital display is independent of the operating mode (open or closed loop) selected for the particular channel. If the 'Volts' button is selected, then the read out is in volts, even if the channel is in closed loop mode and the Output control is being used to adjust position. Similarly, if the 'position' button is selected, the read out is in microns, derived from the position feedback signal, even if the channel is operating in open loop.



4.5.5 Jogging the Piezos

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

1) Click the 'Settings' button to display the Settings panel.

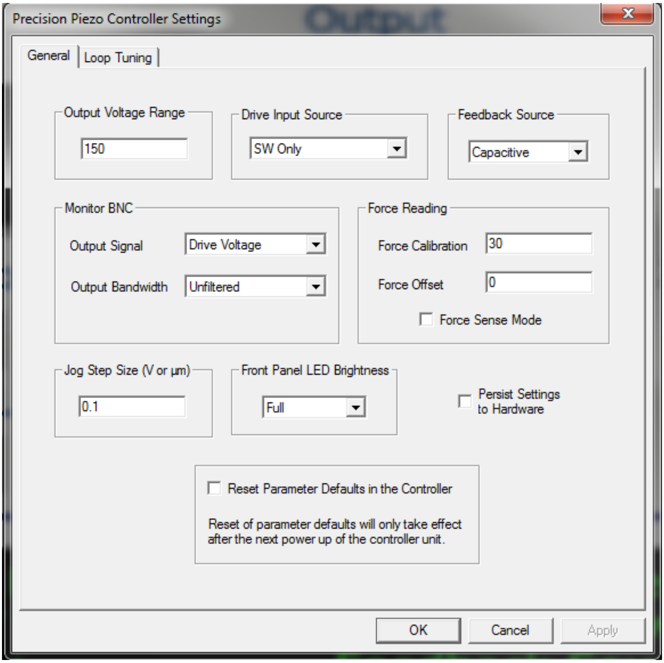


Fig. 4.4 Piezo settings panel

2) Select the General tab as shown in above.
3) In the 'Jog Step Size' field, enter 0.1
4) Click 'OK' to save the settings and close the window.
5) Click the upper Jog arrow on the GUI panel to jog the piezo. Notice that the display increments 0.1 µm (or Volts) every time the button is clicked.
6) Click the lower Jog arrow on the GUI panel. Notice that the display decrements 0.1 µm (or Volts) every time the button is clicked.

4.6 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 150V.

Caution

When using the controller as an amplifier, the performance of the piezo mount will be affected directly by the performance of the external source (e.g. accuracy and stability).

As an example, the following procedure explains how to configure the unit as a piezo amplifier.

1) Connect a ±10V external source to the EXT IN connector on the rear panel.
2) In the GUI panel, click the ‘Settings’ button to display the settings panel.

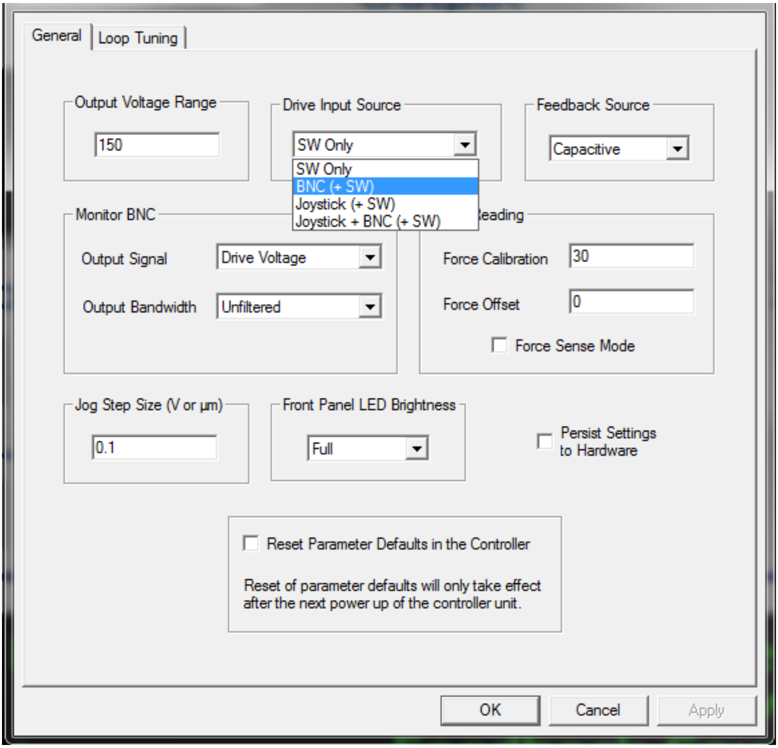


Fig. 4.5 Piezo settings panel

3) Select the ‘General’ tab.
4) In the ‘Drive Input Source’ field, select ‘*BNC (+SW)*’.
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 STAGE (drive) connector. The position of the piezo mount can be controlled by varying the ±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.

4.7 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 its 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.

4.8 Load Response

The response of the PPC102 to varying load and frequencies is shown below.

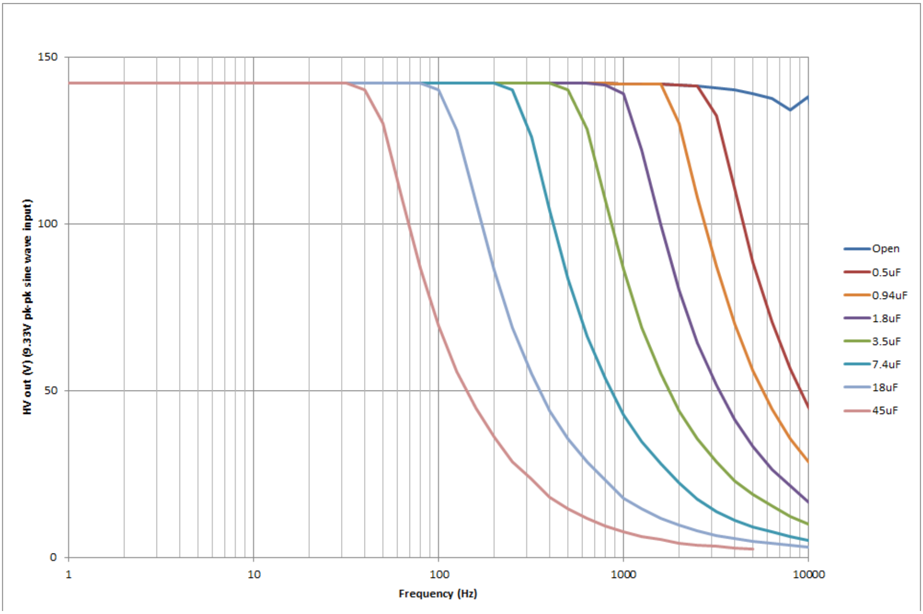


Fig. 4.6 Response of PPC102 to Varying Loads and Frequencies

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 APTUser utility.

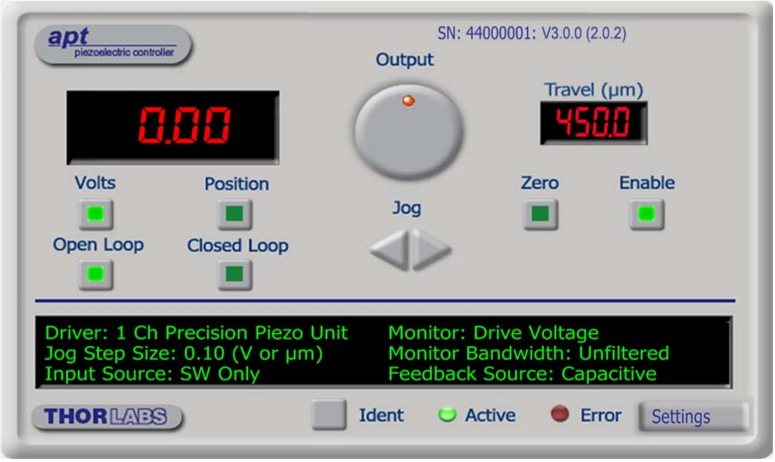


Fig. 5.1   PPC102 Piezo Driver Software GUI

> **Note**
>
> The serial number of the PPC102 unit associated with the GUI panel, the APT server version number, and the version number (in brackets) of the embedded software running on the unit, are displayed in the top right hand corner. This information should always be provided when requesting customer support.

Output Control - used to adjust and set the voltage or position output as displayed in the main digital display. If the channel is in closed loop mode (set using the 'closed loop' button on the panel) then this control can be used to adjust position output. If open loop mode is selected (using the 'open loop' button) then the control is used to adjust the voltage output. Note that the read out in the main digital display is independent of the operating mode (open or closed loop) selected for the particular channel. If the 'Volts' button is selected, then the read out is in volts, even if the channel is in closed loop mode and the Output control is being used to adjust position. Similarly, if the 'position' button is selected, the read out is in microns, derived from the feedback signal, even if the channel is operating in open loop.

Jog - used to increment or decrement the piezo position. When the button is clicked, the piezo is driven in the selected direction, one step per click. The step size can be set in the 'Settings' panel or by using the SetJogStepSize method.

Travel - the range of travel (in µm) of the piezo actuator.

Zero - **Not used on the PPC102 controller**.

Enable - enables or disables the HV channel's output voltage. With the piezo enabled, the LED in the button is lit. When disabled, the LED is unlit, the output voltage on the HV amp channel is set to zero volts and the piezo is disconnected from the HV amplifier.

Digital 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.

Volts and Position - push button controls used to toggle the display between volts and position modes - see Section 4.3.. The corresponding button LED is lit when selected.

Open Loop and Closed Loop - push button control used to toggle between open loop and closed loop modes. The corresponding button LED is lit when selected.

Settings display - shows the following user specified settings:

Jog Step Size - the distance to move when a jog command is initiated. If in closed loop mode, the step size is measured in microns; if in open loop mode, the step size is measured in Volts. The step size can be set either via the Settings panel or by calling the SetJogStepSize method.

Input Source - displays the input source associated with the selected channel. The input source can be set either via the 'Settings' panel or by calling the SetPPCIOSettings method - see Section 5.2.1.

Monitor - 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 parameter shows the signal being monitored, Drive Voltage, Unprocessed Position or Linearised Position.

Monitor Bandwidth - 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.

Settings button - Displays the 'Settings' panel, which allows the tuning parameters to be entered - see Section 5.2.

Ident - when this button is pressed, the main digital display on the unit associated with the GUI panel will flash for a short period.

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

Error - lit when one of the following fault condition occurs:

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 4.7.

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 ActiveX methods and properties on this Control (refer to the *Programming Guide* in the *APTServer helpfile* (accessed via the Windows 'Start' menu) for further details and to Section 1.2.4. for an overview of the APT ActiveX controls).

5.2.1 General tab.

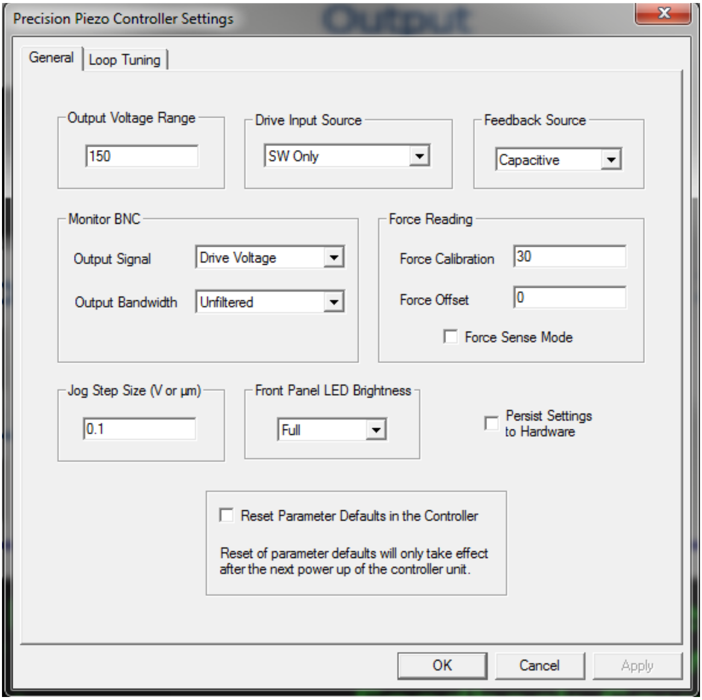


Fig. 5.1 Piezo Settings panel - General tab

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.

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

SW Only - the unit responds only to software inputs and the piezo drive output is that set using the SetVoltOutput method (or the GUI panel 'Output' control).

BNC (+ SW) - the unit sums the signal on the rear panel EXT IN BNC connector with the voltage set using the SetVoltOutput method (or the GUI panel 'Output' control).

Joystick (+ SW) - the unit sums the signal from the joystick control with the voltage set using the SetVoltOutput method (or the GUI panel 'Output' control).

Joystick + BNC (+ SW) - the unit sums all three signals signal.

Caution

When driving the piezo mount from an externall 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

Feedback Source - the type of feedback associated with the actuator being driven, either Capacitive or Strain Gauge. The PGM1S piezo mount has a strain gauge sensor and this parameter is locked.

Monitor BNC - 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.

Output Signal - the signal being monitored, Drive Voltage, Unprocessed Position or Linearised Position - see also Section 3.9.

If *Drive Voltage* 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 *Unprocessed Position* 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 *Linearized Position* 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.

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

Jog Step Size - the distance to move when a jog command is initiated. If in closed loop mode, the step size is measured in mrads; if in open loop mode, the step size is measured in Volts.

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

Persist Settings to Hardware - Many of the parameters that can be set for the PPC102 controller can be stored (persisted) within the unit itself, such that when the unit is next powered up these settings are applied automatically. The Output Voltage Range and Drive Input Source parameters described previously are good examples of settings that can be altered and then persisted in the driver for later use.

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

5.2.2 Loop Tuning tab.

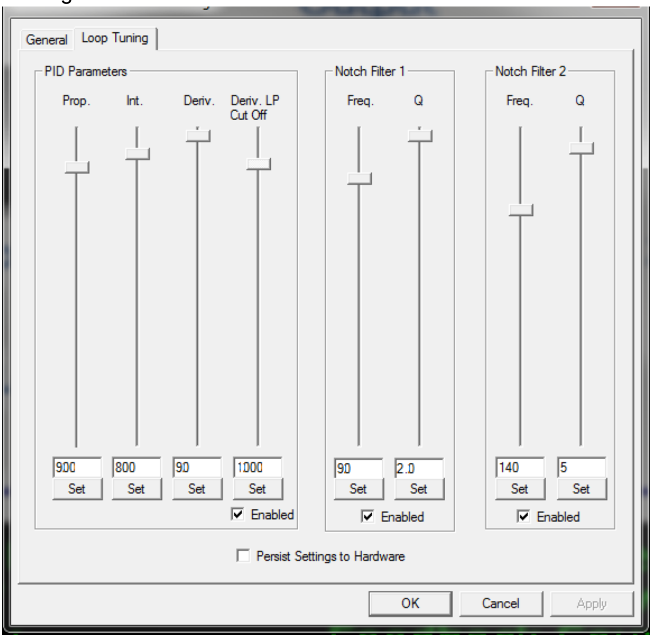


Fig. 5.2 Piezo Settings panel - Loop Tuning tab

Loop Tuning - 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 gimbal mount assemblies that can be connected to the system. Due to the wide range of mirrors and lenses that can be used with the PGM1S 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.

These slider controls adjust the settings for the PID parameters, and any changes are applied immediately after clicking the Set button. 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, or cancel to discard the changes. Click OK to close the window.

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 optimised to work with the specific PGM1S mount shipped with the controller.

Due to the type of load the PGM unit presents to the PPC102 controller, the system is most sensitive to the integral (Int) tuning parameter and the notch filter settings. In most applications the deriviative parameters can be left at their default values.

Prop- 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 900)

Int - 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 800).

Deriv - 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 90).

General Tuning Procedure Example

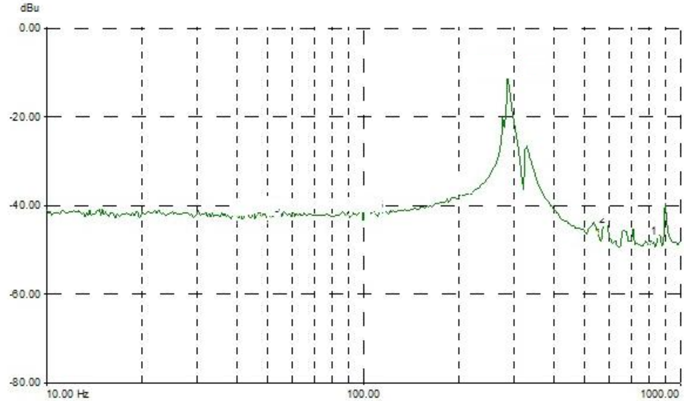
The default parameters have been set for a default load (M0) of 5.0g. If the actual load (M1) is 15.0 g, then the default PID parameter values should be multiplied by M0/M1. Therefore P = 300, I = 266 and D = 30.

Further optimization can be achieved by increasing/decreasing the values by 10% to find the balance between settling time and stability - see Section 4.4. for more details.

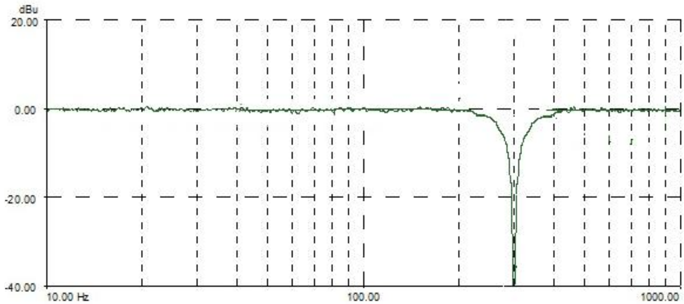
Deriv. LP Cut Off- The output of the derivative (differential) part of the PID controller can be passed through a tuneable low pass filter. Whilst the derivative component of the PID loop often improves stability (as it acts as a retaining force against abrupt changes in the system), it is prone to amplifying 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 *Cut Off Frequency* is specified in Hz in the range 0 to 10000. (default 1000).

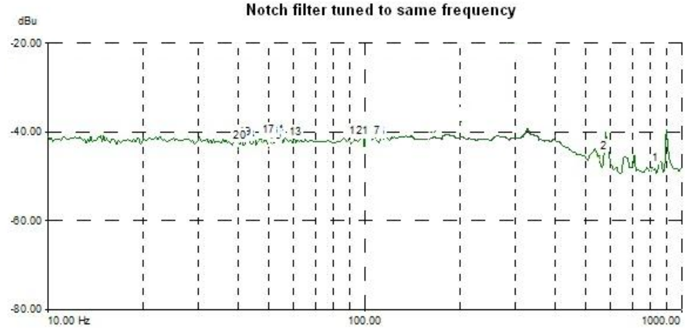
Notch Filter Settings - Due to their construction, most actuators are prone to mechanical resonance at well-defined frequencies. The underlying reason is that all spring-mass systems are natural harmonic oscillators. This proneness to resonance can be a problem in closed loop systems because, coupled 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.



Frequency response of a typical actuator showing resonance peak

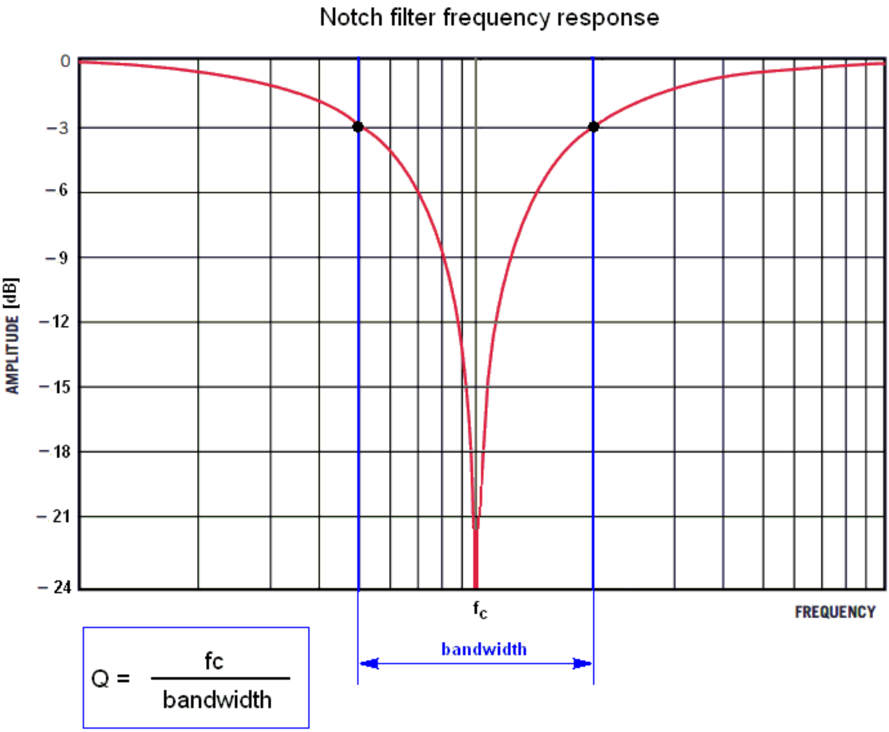


Notch filter tuned to same frequency



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.



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 rage 0.2 to 100.

To enable the notch filter settings check the Enable box.

General Tuning Procedure for Notch Filter Center Frequency

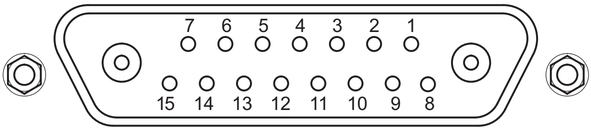
The default parameters have been set for a default load (M0) of 5.0g. If the actual load (M1) is 15 g, then the default frequency values should be multiplied by square root of M0/M1. In this case, the notch frequencies should be changed from 90 and 140 to 52 and 81.

Further optimization can be achieved by increasing/decreasing the values by 10% to find the balance between settling time and stability.

Appendix A Rear Panel Connector Pinout Detail

A.1 Rear Panel CHANNEL 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 (Strain Gauge)		

Notes

† 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.

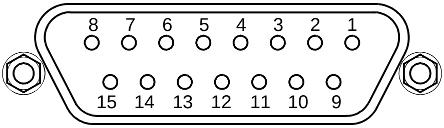
Fig. A.1 CHANNEL Connector Pin Identification

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 APT support 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 PPC102 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.

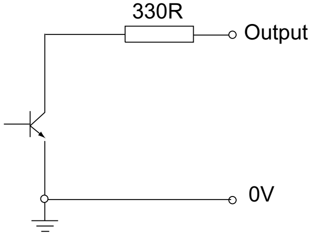


Fig. A.3 Digital Output Schematic

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.

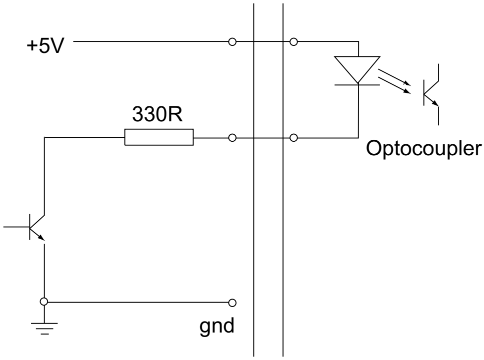


Fig. A.4 Application Example: Connection to Optocoupler Inputs

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 APTServer 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.

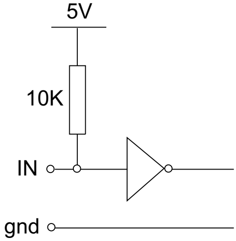


Fig. A.5 Digital Input Schematic (protection circuitry not shown)

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 APTServer 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.

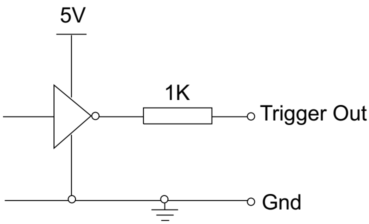


Fig. A.6 Trigger Output Schematic

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.

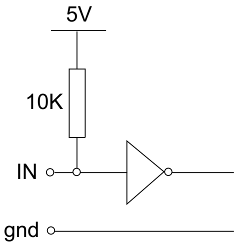


Fig. A.7 Trigger Input Schematic (protection circuitry not shown)

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

0 V 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.

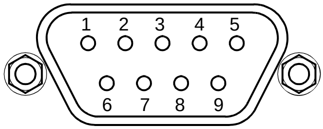
Caution

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 APT 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



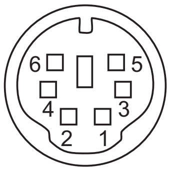
Pin	Description
1	Not Connected
2	RX (controller input)
3	TX (controller output)
4	Not Connected
5	Ground
6	Not Connected
7	Not Connected
8	Not Connected
9	Not Connected

Fig. A.8 RS232 Connector Pin Identification

A.4 Rear Panel JOYSTICK Connector

THE FUNCTIONALITY FOR THIS CONNECTOR IS NOT IMPLEMENTED AT PRESENT

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

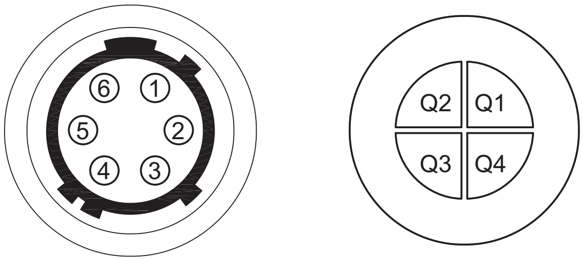
Fig. A.9 HANDSET Connector Pin Identification

A.5 Rear Panel DETECTOR IN Connector

THE FUNCTIONALITY FOR THIS CONNECTOR IS NOT IMPLEMENTED AT PRESENT

The DETECTOR IN connector on the rear panel is a HIROSE HR10A-7R-6S connector, which mates with the connector on the sensor cable.

Fig. A.10 shows the pin configuration as viewed by looking at the rear panel of the controller..



DETECTOR IN Photodiode Detail

Pin 1 - X-axis [Q2 + Q3] - [Q1 + Q4] (-10 to +10V)
Pin 2 - Y-axis [Q1 + Q2] - [Q3 + Q4] (-10 to +10V)
Pin 3 - SUM [Q1 +Q2 + Q3 + Q4] (0 to +10V)
Pin 4 - +V (+15V,15mA Max)
Pin 5 - Common
Pin 6 -V (-15V,15mA Max)

Fig. A.10 DETECTOR IN 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 Piezo Gimbal Mount Specifications

Parameter	Value
Open Loop Angular Scanning Range	30 mrad ± 15%
Closed Loop Angular Scanning Range	20 mrad (i.e. ±10 mrad about center point)
Bidirectional Repeatability	0.32 mrad
Bidirectional Accuracy	0.49 mrad
Crosstalk	0.56 mrad
Orthogonality Ch1 (X) to Ch2 (Y)	1.85°
Angular Resolution	0.05 µrad in Open Loop, 0.14 µrad in Closed Loop [a]
Resonant Frequency (7.0 g load)	360 Hz ±15% [b]
Max Load	50 g
Max Recommended Operating Bandwidth	50 Hz
Tilting concept	Gimbal [c]
Feedback Type	Strain Gauge Sensor
Maximum Incident Angle	55° typical [d]
Piezo Input Voltage	-25 to 150 V [e]
Capacitance (per axis)	3.5 µF ±15%
Closed Loop Stability	±5.0 µrad
Mirror/Lens Diameter	25.4 mm (1.0”)
Optic Interchangability	Yes (SM1 Ring Supplied)
Through Hole Aperture Diameter	22.9 mm (0.9”)
Acceptable Mirror Thickness	2 mm to 7.5 mm
Optic Mounting	SM1 Retaining Ring (included)
Cage Rod System Compatibility	Yes, 6 mm Cage Rod, 30 mm Spacing
Post Mount Thread	M4 or 8-32 UNC, Bottom and Side Mount

Notes

[a] With PPC102 piezo controller and defined by the smallest command voltage signal size, based on 18 bit ADC used in these controllers.

[b] With 2mm thick 1" mirror typically.

[c] Varies with beam diameter. Values quoted are typical for a 2.5 mm (0.1”) diameter beam - see Fig. 3.3.

[d] Mirror center point on gimbal tilting center. Based on two axes tilting with four point contact, all on the same plane with gimbal tilting center on the mirror center point. See Fig. 3.2 and Fig. 3.3 for more details.

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 µF
External Input (BNC)	
Input Type	Single Ended
Input Impedance	10 kΩ
Input Voltage Range	-10 V to 10 V DC
Absolute Maximum Input Voltage	±20 V DC
Input Voltage for Full Range	10 V DC ±2%
External Output (BNC)	
Output Voltage Range	0 to 10 V nominal for full range (output can swing negative in certain scenarios)
Minimum Recommended Load Impedance	10 kΩ
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 ±5%
Supply Current	<4 A (ignoring power on transient)
Protection	Internal Fuse, 4 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 connecvtor
Joystick	Reserved for future use
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 µs
EXT IN ADC Resolution	24 Bits
Position ADC Resolution	18 Bits
HV DAC Resolution	20 Bits
Housing Dimensions (incl. feet, excl, connectors)	249.9 mm x 299.8 mm x 80.2 mm (9.84” x 11.8” x 3.16”)
Weight	2.9 kg (6.38 lb)

Appendix D Piezo Control Method Summary

The 'Piezo' ActiveX Control provides the functionality required for a client application to control one or more of the APT series of piezo controller units. This range of controllers covers both open and closed loop piezo control in a variety of formats including compact Cube type controllers, benchtop units and 19" rack based modular drivers.

To specify the particular controller being addressed, every unit is factory programmed with a unique 8-digit serial number. This serial number is key to the operation of the APT Server software and is used by the Server to enumerate and communicate independently with multiple hardware units connected on the same USB bus. The serial number must be specified using the HWSerialNum property before an ActiveX control instance can communicate with the hardware unit. This can be done at design time or at run time. Note that the appearance of the ActiveX Control GUI (graphical user interface) will change to the required format when the serial number has been entered.

The Methods and Properties of the Piezo ActiveX Control can be used to perform activities such as selecting output voltages, reading the strain gauge position feedback, operating open and closed loop modes and enabling force sensing mode. A brief summary of the methods and propertys applicable to the PPC102 unit is given below, for more detailed information and individual parameter descriptiond please see the on-line help file supplied with the APT server.

Methods

DeleteParamSet	Deletes stored settings for specific controller.
DisableHWChannel	Disables the drive output.
DoEvents	Allows client application to process other activity.
EnableEventDlg	Enables or disables the event dialog box.
EnableHWChannel	Enables the drive output.
GetControlMode	Gets the loop operating mode (open/closed).
GetForceSenseParams	Gets the force sensing mode parameters.
GetJogStepSize	Gets the jogging step size.
GetMaxTravel	Gets the maximum travel of a strain gauge equipped piezo actuator
GetMaxOPVoltage	Gets the value for the maximum output in the range 0 to 150 V.
GetOutputLUTParams	Gets the output voltage waveform (LUT) operating parameters.

GetOutputLUTTrigParams	Gets the output voltage waveform (LUT) triggering parameters.
GetOutputLUTValue	Gets a specific voltage output value in the voltage waveform (LUT) table.
GetParentHWInfo	Gets the identification information of the host controller.
GetPosOutput	Gets the piezo actuator extension in closed loop mode.
GetPPCIOSettings	Gets the Input and Output parameters for the rear panel BNC connectors.
GetPPCNotchParams	Gets parameters for the notch filters.
GetPPCPIDParams	Gets the PID parameters.
GetSlewRates	Gets the limits set for the rate of change of the drive voltage.
GetVoltOutput	Gets the HV output voltage.
GetVoltPosDispMode	Gets the GUI display mode (voltage or position).
Identify	Identifies the controller by flashing unit LEDs.
LLGetDigIPs	Gets digital input states encoded in 32 bit integer.
LLGetStatusBits	Gets the controller status bits encoded in 32 bit integer.
LLGetHostStatusBits	Gets the controller status bits encoded in 32 bit integer.
LLSaveHWDefaults	Allows the current settings of the operation parameters to be saved into the onboard 'Flash' memory of the hardware unit.
LLSetGetDigOPs	Sets or Gets the user digital output bits encoded in 32 bit integer.
LLSetGetHostDigOPs	Sets or Gets the user digital output bits encoded in 32 bit integer.
LoadParamSet	Loads stored settings for specific controller.
SaveParamSet	Saves settings for a specific controller.
SetAmpFeedbackSig	Sets the feedback signal type (AC or DC).
SetControlMode	Sets the loop operating mode (open/closed).
SetForceSenseParams	Sets the force sensing mode parameters.
SetHWMode	Sets Piezo Amp or NanoTrak operating mode.
SetJogStepSize	Sets the jogging step size.
SetMaxOPVoltage	Sets the value for the maximum output in the range 0 to 150 V.
SetOutputLUTParams	Sets the output voltage waveform (LUT) operating parameters.

SetOutputLUTTrigParams	Sets the output voltage waveform (LUT) triggering parameters.
SetOutputLUTValue	Sets a specific voltage output value in the voltage waveform (LUT) table.
SetPosOutput	Sets the piezo actuator extension in closed loop mode.
SetPPCIOSettings	Sets the Input and Output parameters for the rear panel BNC connectors.
SetPPCNotchParams	Sets parameters for the notch filters.
SetPPCPIDParams	Sets the PID parameters.
SetSlewRates	Sets the limits for the rate of change of the drive voltage.
SetVoltOutput	Sets the HV output voltage.
SetVoltPosDispMode	Sets the GUI display mode (voltage or position).
ShowEventDialog	Shows the event dialog when it has previously been disabled using the EnableEventDlg method
StartCtrl	Starts the ActiveX Control (starts communication with controller)
StartOutputLUT	Starts outputting the voltage waveform (LUT).
StopCtrl	Stops the ActiveX Control (stops communication with controller)
StopOutputLUT	Stops outputting the voltage waveform (LUT).
ZeroPosition	Nulls the strain gauge reading to take out offset errors.

Properties

APTHelp	Specifies the help file that will be accessed when the user presses the F1 key. If APTHelp is set to 'True', the main server helpfile MG17Base will be launched.
HWSerialNum	specifies the serial number of the hardware unit to be associated with an ActiveX control instance.

Appendix E Piezo Operation - Background

E.1 Piezoelectric Controller

E.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.

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. E.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).

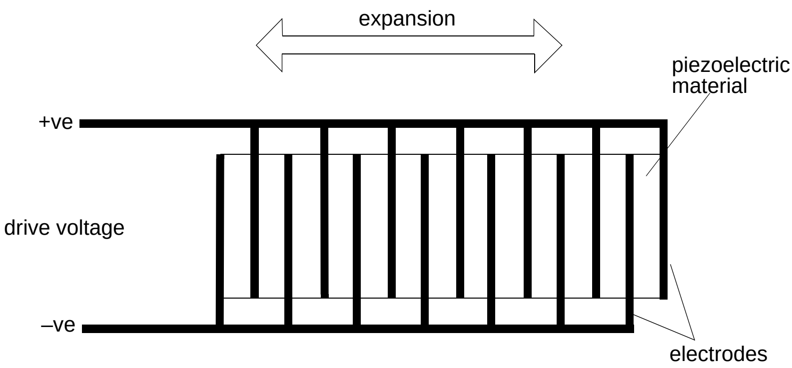


Fig. E.1 Piezo-electric actuator schematic diagram

E.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. E.2.

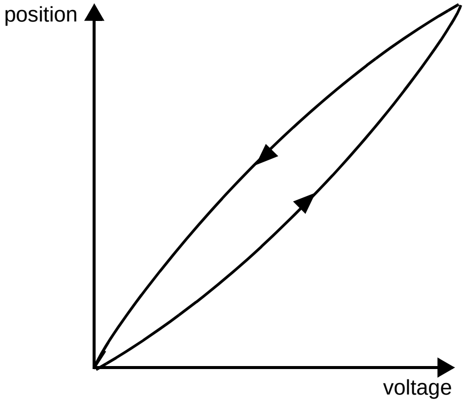


Fig. E.2 Piezo-electric hysteresis

E.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. E.1.

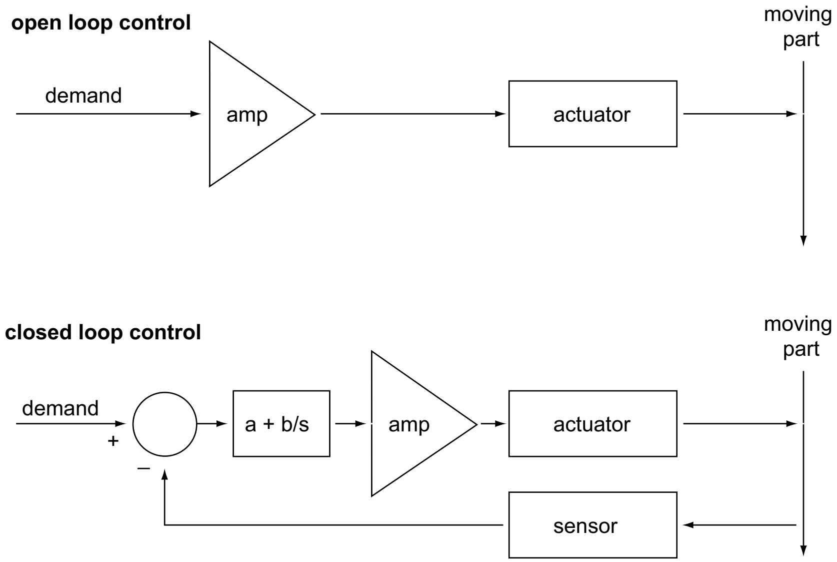


Fig. E.3 Open loop and closed loop control

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

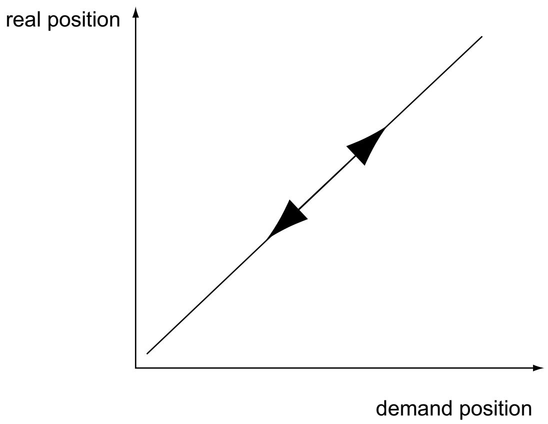


Fig. E.4 Closed loop response

Appendix F Regulatory

F.1 Declarations Of Conformity

F.1.1 For Customers in Europe

See Section F.2.

F.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, persuant 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.

F.2 CE Declaration

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)
2014/30/EU	Electromagnetic Compatibility (EMC) Directive
2011/65/EU	Restriction of Use of Certain Hazardous Substances (RoHS)

hereby declare that:

Model: ***PGM1SE and PGM1SE/M***

Equipment: ***Piezo-actuated Gimbal Mount and Controller***

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: Keith Dhese *On:* 16 July 2018

Name: Keith Dhese

Position: General Manager

EDC - PGM1SE and PGM1SE/M -2018-07-16

CE

Appendix G 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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Thorlabs, Inc.
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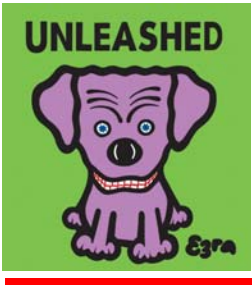
sales@thorlabs.jp

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 dissembled 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.



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