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

# BPC301

# Benchtop Piezo Controller

# User Guide


Original Instructions

*HA0248T*

# Contents



Continued...

## Appendices

# Chapter 1 Overview

## 1.1 Introduction

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/500mA per channel and are compatible with all piezo-actuated nanopositioning actuators & stages in the Thorlabs range.

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.

Manual controls are located on the front face of the unit to allow manual adjustment of the piezo position using the digitally encoded adjustment pot. The display is easy to read and can be set to show either applied voltage or position in microns. Open or closed loop control , maximum drive voltage, and zeroing of the piezo can also be selected from the front panel.


**Fig. 1.1 APT Single Channel Piezo Controller (BPC301)**

The APT 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.

The APT 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, both the P & I (proportional and integral) components of the feedback control loop can be altered to adjust the servoloop response. 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 which allow the user to build automated alignment routines. See Section 1.2. for a full description of the APT system software and background on the advantages of the ActiveX Control technology.

The key innovation of the APT range of 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 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. When planning an alignment application, simply add up the number and type of drive channels required and connect together the associated number of APT controllers. 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.

## 1.2 APT PC Software Overview

### 1.2.1 Introduction

As a member of the APT range of controllers, the BPC301 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.

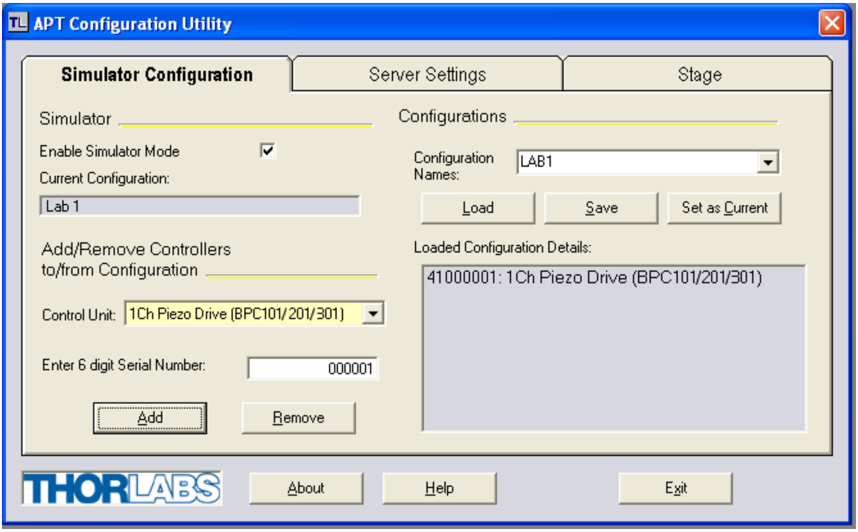

All basic operating parameters can be altered and, similarly, all operations (such as piezo moves) can be initiated. Settings and parameter changes can be saved and loaded to allow multiple operating configurations to be created and easily applied.

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.

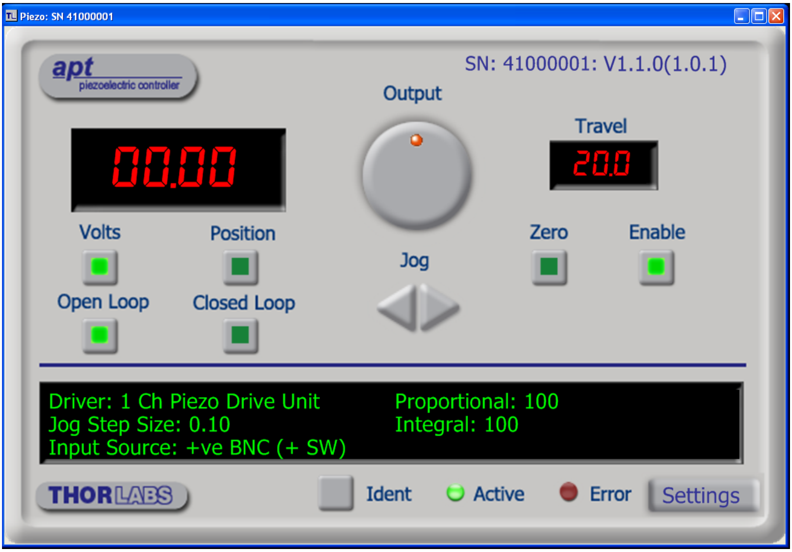
Use of the APT Config utility is covered in the PC tutorial (Chapter 4) and in the APTConfig online help file, accessed via the F1 key when using the APTConfig utility.

### 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 BPC301 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 BPC301 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. 1.2).

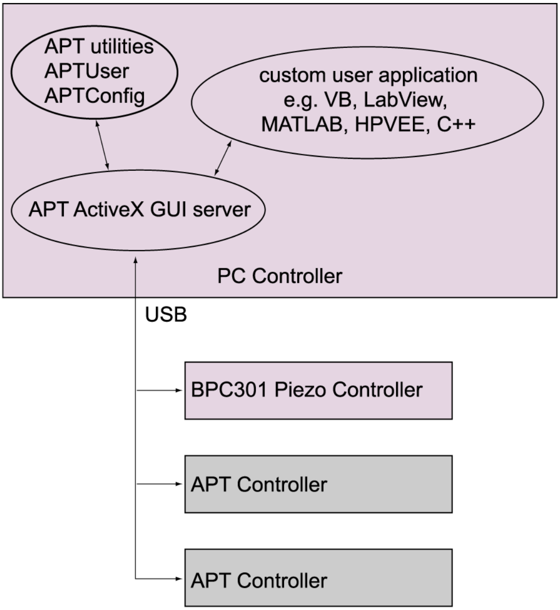



**Fig. 1.2 System Architecture Diagram**

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 Overview

## 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

**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.

# Chapter 3 Getting Started

## 3.1 Installing APT Software

**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.

**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.

## 3.2 Mechanical Installation

### 3.2.1 Siting

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

**Caution**

When siting the unit, it should be positioned so as not to impede the operation of the rear panel power supply switch.

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

### 3.2.2 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 controller unit is powered up approximately 30 minutes before use, in order to allow the internal temperature to stabilize.

## 3.3 Electrical Installation

### 3.3.1 Connecting To The Supply

**Warning: Risk of Electrical Shock**

The unit must be connected only to an earthed fused supply of 85V to 264V.

Use only power supply cables supplied by Thorlabs, other cables 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**

Piezo actuators are driven by high voltages. Voltages up to 150V may be present at the SMC connector. This is hazardous and can cause serious injury. Appropriate care should be taken when using this device.

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

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

### 3.3.2 Fuses

Two T 3.15A/250V a.c. antisurge ceramic fuses are located on the back panel, one for the live feed and one for the neutral.

When replacing fuses:

1) Switch off the power and disconnect the power cord before removing the fuse cover.
2) Always replace broken fuses with a fuse of the same rating and type.

### 3.3.3 Powering Down The Unit

**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, and the HV cable disconnected before the unit is powered down.

### 3.3.4 Rear Panel Connections

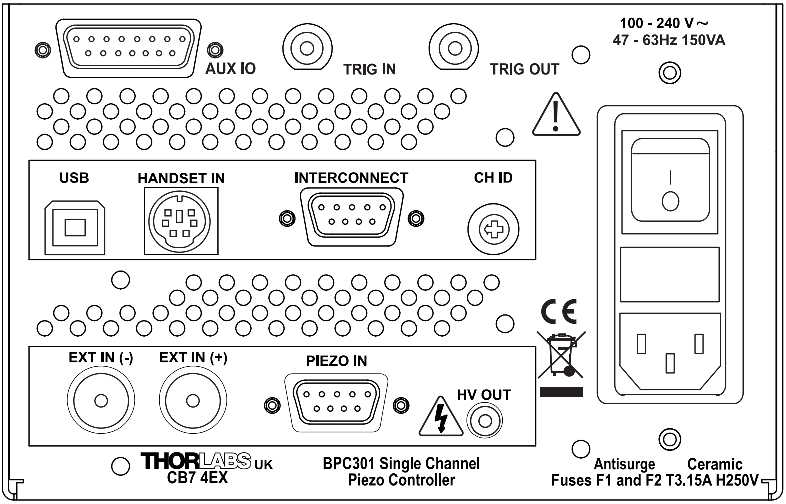



**Fig. 3.1 Rear panel connections**

**AUX IO** - 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.

**TRIG IN** – Reserved for future use, not implemented at this time.

**TRIG OUT** – Reserved for future use, not implemented at this time.

**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.

**HANDSET IN -** Provides connection for the MZF001 Jopystick - see Section 4.8. and Section A.4.

**INTERCONNECT** - For Future Use.

**CH ID -** For channel selection when using the MZF001 joystick - see Section 4.8.

**EXT IN (+) and EXT IN (-) (BNC connector)** – Used to control the output voltage (open loop) or position of the piezo actuator(closed loop) from an external source. These inputs allow a 0V to 10V input to drive the output to its full scale. This gives a gain of 7.5 on the 75V range, 10 on the 100V range and 15 on the 150V range. The gain values are predefined with a tolerance of +/- 2%. The input impedence is 20kΩ load.

The exact bandwidth achievable is dependent on a variety of factors, such as the load capacitance but in general is a few kHz in open loop mode and about 200 Hz in closed loop.

Before they can be used, these inputs must be enabled in the Settings panel (see Section 5.2.) or in software by calling the Piezo SetIPSource method (see the *APTServer helpfile* available from the Windows 'Start' menu).

The difference between the two signals is amplified internally before being routed to the HV OUT connector. The high voltage amplifier output will be 0V when the positive input is equal to the negative input, and will be at full scale (75V, 100V or 150V depending on the voltage range selected) when the positive input minus the negative input equals 10V. If either input is unconnected, it contributes 0V. The differential nature of these inputs can be useful in some applications, as they reject unwanted common mode signals. Although they are differential, these inputs can also be used in single-ended mode. In this configuration, the +ve input can be considered as non-inverting and the -ve input as inverting. The unused input can simply be left unconnected.

**PIEZO IN** – This Female 9-Pin D-type connector receives the signal from the position sensor (strain gauge) of the piezo actuator to provide the feedback for the control loop - see Section A.1. for pin out details.

**HV OUT** (SMC connector) – 0 to 150V, 0 to 500mA. Provides the drive signal to the piezo actuator.

**Caution**

It is recommended that only cables supplied by Thorlabs are used to connect the piezo drive outputs. Other cables may not be rated to the same specification. If using third party cables for the high voltage output, the HV cable used must have insulation able to withstand 200V DC / 150V AC.

## 3.4 Front Panel Controls and Indicators

The front panel controls of the BPC301 piezo controller allow the unit to be operated as a standalone unit, without the need to connect to a PC.

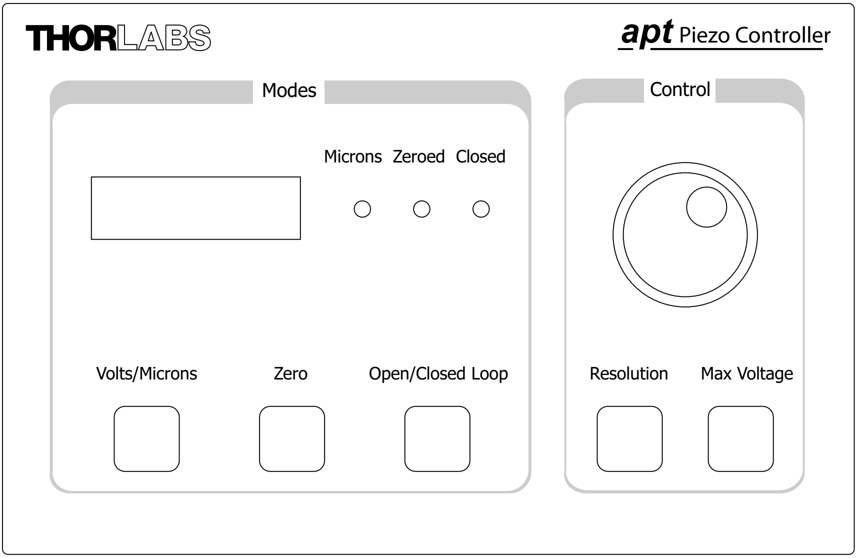



**Fig. 3.2 Front panel controls and indicators**

**Digital Display** – Shows the voltage applied to the piezo actuator/stack or the position (in microns).

**Note**

The main digital display will flash when the 'Ident' button is clicked on the APT Software GUI panel - see Section 5.1. for further details.

**Microns LED** – Indicates that the display is showing the piezo position in microns. If the LED is not lit, the display is showing the output voltage in Volts.

**Zeroed LED** – Indicates that the piezo has been zeroed. This LED flashes during the zeroing operation.

**Closed LED** – Indicates that the unit is operating in Closed Loop mode. If the LED is not lit, the unit is operating in open loop.

**Volts/Microns Button** – Selects either Volts or Microns to be displayed.

**Open/Closed Loop Button** – Selects Open or Closed Loop mode.

**Zero Button** – Initiates the zeroing routine - see Section 3.5.2.

**Note**

The ‘Zero’ and ‘Open/Closed Loop’ buttons perform the same function as their respective equivalents on the software GUI panel. If a control PC is connected, pressing these buttons has the same effect as pressing the correspondingGUI button. Similarly, the ‘Zeroed’ and ‘Closed’ LEDs correspond to the virtual button lights on the GUI.

The ‘Volts/Microns’ button is similar in function to the ‘Volts’ button on the GUI but it operates independently. For example, it is possible to display microns on the GUI but volts on the front panel

**Control Potentiometer** – Used to adjust the voltage applied to the piezo actuator/ stack.

**Resolution Button** – Toggles the ‘Control’ potentiometer between ‘Coarse’ and ‘Fine’ adjustment and ‘Parked’ mode - see Section 3.5.1.

**Max Voltage Button** – Used to adjust the maximum drive voltage output - see Section 3.5.3.

## 3.5 Button Operation

### 3.5.1 Resolution Button

The resolution button cycles the behaviour of the Control potentiometer between ‘Coarse’ and ‘Fine’ adjustment, and ‘Parked’ mode.

In ‘Coarse’ mode, one revolution of the pot varies the output by a factor of 10 greater than in ‘Fine’ mode. In ‘Open loop’ mode, the full voltage range corresponds to about 12 turns of the pot in ‘Coarse’ mode. In ‘Parked’ mode, the ‘Control’ potentiometer is disabled, and turning it has no effect.

At power up, the resolution defaults to ‘Coarse’.

### 3.5.2 Zero Button

The position sensor is a strain gauge fitted to the piezo actuator. Due to limitations in manufacture, the strain gauge may give a small signal when the actuator is at zero position with zero volts applied. This ‘offset’ signal must be removed before the position attained by a specific applied voltage and the position attained by a corresponding specified distance can be rationalized.

Each actuator has a unique offset value. Therefore the offset should be adjusted whenever an actuator is replaced. Temperature and prolonged use can affect the performance of the strain gauge and therefore the offset value. It is good practice to adjust the offset value whenever the unit is powered up.

To adjust the offset zero:

1) Click the ‘Zero’ button. Notice that the ‘Zeroed’ led flashes to indicate that zeroing is in progress.

2) When the zeroing move has been completed, the 'Zeroed' LED is lit and the controller switches to closed loop mode.

#### 3.5.3 Max Voltage Button

The Max Voltage button sets the max limit of the drive output voltage. When the button is pressed and released, the present limit flahes on the main display. The voltage may be cycled through 75 V, 100 V and 150 V by turning the control potentiometer. The new limit is saved by pressing and releasing the Max Voltage button again..

**Note**

Legacy piezo stages (i.e. those fitted with an ident resistor) are driven by 75 V. The server will detect automatically if such a stage is fitted and in this case will limit the max voltage to 75 V.

## 3.6 Control Potentiometer Operation

The 'Control' potentiometer is an infinite turn encoder, used to adjust and set the voltage or position output as displayed in the main digital display. To increase the drive voltage, turn the potentiometer clockwise - once the maximum voltage (75V) is attained, subsequent clockwise turns do not effect the output, however the voltage decreases immediately the control is turned anticlockwise. Similarly, once the voltage has been decreased to 0V, subsequent anticlockwise turns do not effect the output, but the voltage increases immediately the control is turned clockwise.

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.

#### 3.6.1 Moving the Piezo using the 'Control' Potentiometer

1) Press the 'Open/Closed Loop' button until the 'Closed' LED is lit. The unit is now in Closed Loop mode.
2) Press the 'Volts/Microns' button until the 'Microns' LED is lit. The display now shows the piezo position in microns.
3) Rotate the 'Control' potentiometer clockwise. Notice how the position display increments to show the increasing piezo position.
4) Rotate the 'Control' anticlockwise. Notice how the position display decrements to show the decreasing piezo position.
5) Press the 'Volts/Microns' button until the 'Microns' LED is extinguished. Notice how the display changes to show the voltage associated with the current piezo position.

## 3.7 Adjusting the Display Brightness

The display brightness can be adjusted in relation to the ambient light conditions.

To adjust the brightness:

1) Press and hold the Resolution button and turn the Control potentiometer.

## 3.8 Connecting The Hardware

1) Connect the piezo actuator to the Controller unit.
2) Connect the Controller unit to the power supply and switch 'ON'.
3) 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.

4) Windows™ should detect the new hardware. Wait while Windows™ installs the drivers for the new hardware - see the Getting Started guide for more information
5) Run the APTUser utility
   Start/All Programs/Thorlabs/APT/APT User.
6) Your APT Piezo Controller is now ready for use.
   See the Getting Started Guide supplied with the controller or Chapter 4 of this manual, for a brief tutorial on operation of the unit.

## 3.9 Verifying Software Operation

### 3.9.1 Initial Setup

1) Install the APT software as detailed in Section 3.1.
2) Connect the controller to the actuators (see Section 3.3.4.) and the PC, then switch ON. Wait approximately 5 seconds for the system to settle.

**Caution**

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

3) Run the APTUser utility and check that the Graphical User Interface (GUI) panel appears and is active.

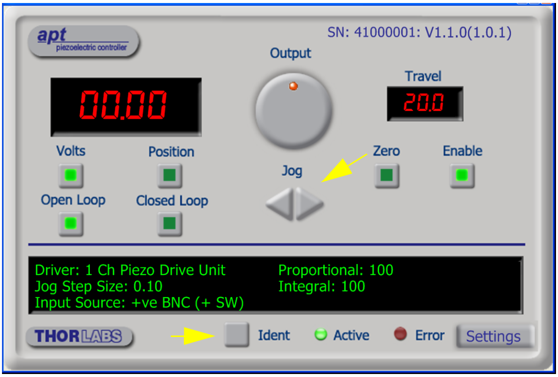



**Fig. 3.3 Gui panel showing jog and ident buttons**

4) Click the 'Ident' button. The min digital display on the front panel of the controller flashes. This is useful in multi-channel systems for identifying which channel is associated with which GUI.
5) 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 4.10. or the APTConfig helpfile for detailed instructions.

# Chapter 4 PC Operation - Tutorial

**Warning**

Piezo actuators are driven by high voltages. Voltages up to 150V may be present at the SMC connector. This is hazardous and can cause serious injury. Appropriate care should be taken when using this device.

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

The piezo controller must be switched OFF before the piezo actuator 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 PC based APT software. It assumes that the unit is electrically connected as shown in Section 3.3.4. and that the APT Software is already installed - see Section 3.1. It also assumes that a piezo-actuated stage is connected to the 'HV OUT and PIEZO IN' connectors 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 APT User is run up.

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

1) 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.


**Fig. 4.1 Typical APT User Screen**

2) Notice how the total travel for the associated piezo is displayed in the 'Travel' window - see Fig. 4.2.

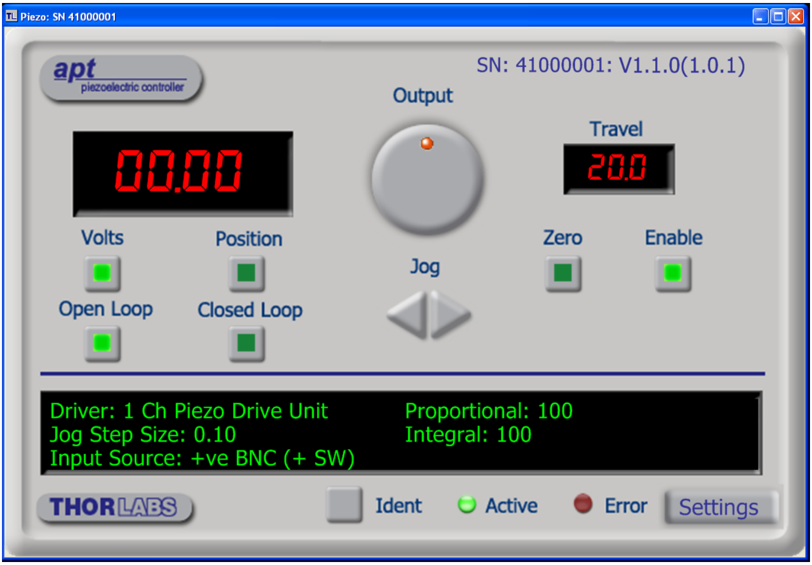



**Fig. 4.2 Piezo Controller Software GUI**

The APT User utility will be used throughout the rest of this tutorial to interface with the piezo controller.

## 4.3 Setting the Position Sensor Zero

The position sensor is a strain gauge fitted to the piezo actuator. Due to limitations in manufacture, the strain gauge may give a small signal when the actuator is at zero position with zero volts applied. This 'offset' signal must be removed before the position attained by a specific applied voltage and the position attained by a corresponding specified distance can be rationalized.

Each actuator has a unique offset value. Therefore the offset should be adjusted whenever an actuator is replaced. Temperature and prolonged use can affect the performance of the strain gauge and therefore the offset value. It is good practice to adjust the offset value whenever the unit is powered up.

To adjust the offset zero:

1) In the GUI panel, click the 'Zero' button. Notice that the led in the button flashes to indicate that zeroing is in progress and the displayed position counts down towards zero (but may not reach zero).
2) When the zeroing move has been completed, the 'Zero' LED is lit and the controller switches to closed loop mode.

## 4.4 Moving the Piezo

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

### 4.4.1 Entering the piezo position

**Note**

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

The position of the actuator is relative to the minimum position set for the arrangement using the 'Zero' button. The extension of the actuator will be displayed as a position in microns.

1) Click the 'Closed Loop' button.
2) Click the 'Position' button.
3) Click the position display.

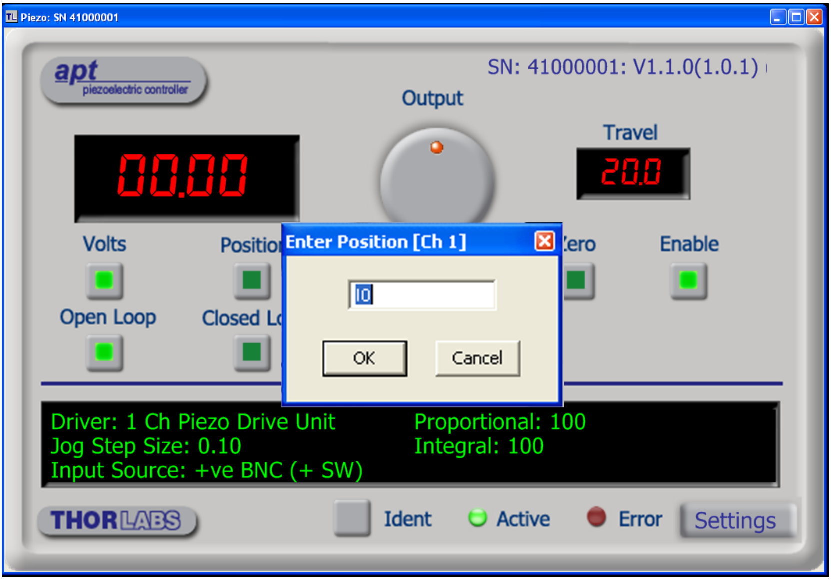



**Fig. 4.3 Position Popup Window**

4) Enter 10.0 into the pop up window
5) Click 'OK'. Notice that the position display counts up to 10.00 to indicate a move to a position 10μm from the Zero datum.

### 4.4.2 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 strain gauge feedback signal, even if the channel is operating in open loop.

### 4.4.3 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.

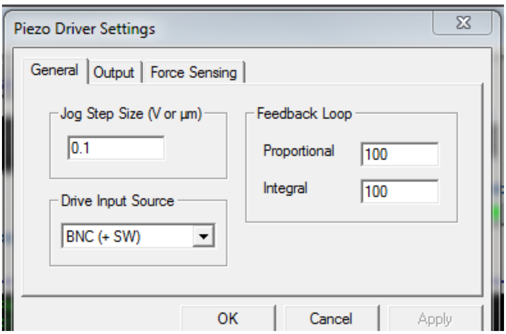



**Fig. 4.4 Piezo settings panel**

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 position display increments 0.1µm every time the button is clicked.
6) Click the lower Jog arrow on the GUI panel. Notice that the position display decrements 0.1µm every time the button is clicked.

## 4.5 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, 100V or 150V.

As an example, 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.

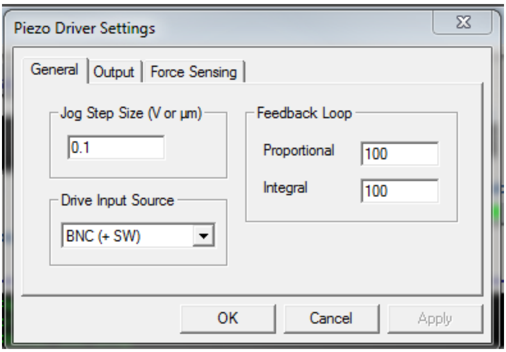



**Fig. 4.5 Piezo settings panel**

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 HV OUT (piezo drive) connector and the position of the piezo actuator can be controlled by varying the 0-10V external source.

## 4.6 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, disconnect the load and allow 10 minutes for the unit to cool down.

## 4.7 Using the Controller with a Force Sensor

The controller unit can also be used to control a force sensor.

1) In the GUI panel, click the ‘Settings button to display the settings panel and select the Force Sensing tab.

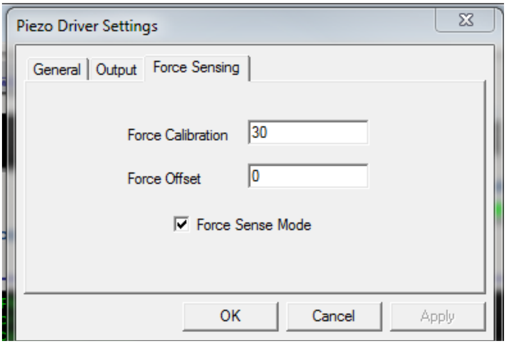



**Fig. 4.6 Piezo settings panel**

2) Check the *Force Sense Mode* box to select Force Sensing Mode.
3) Enter the calibration factor for the type of force sensor being used. For example, if set to 1, the GUI digital display shows a detected force of 0 to 1. The default setting for this parameter is 30, to be compatible with our FSC102 force sensor, which is specified to read forces up to 30N.
4) The force sensor may display an offset when no contact is apparent. The *Force Offset* parameter is used to remove any latent offset, such that the sensor only detects a force when contact is experienced. Enter the required value to remove any offset from the force sensor output.

In Force Sensor mode, an 'F' is displayed next to the digital display on the GUI panel.

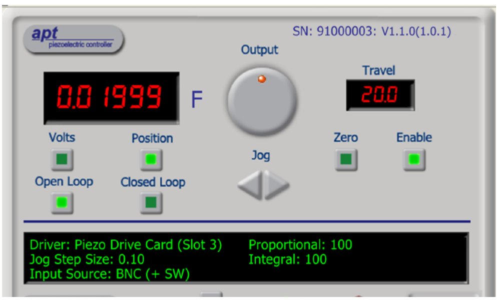



**Fig. 4.7 GUI Display - Force Sensor Mode**

The system defaults to 'Position' (Force) display mode and the digital display shows the force detected by the sensor. The units of force are dependent upon the type of force sensor used.

## 4.8 Using the MZF001 Joystick

The MZF001 joystick console has been designed for microscope users, to provide intuitive, tactile, manual positioning of the MZS500 stage. It is used in conjunction with a BPC30X series piezo controllers. Up to 3 joysticks can be connected to each other, interfacing neatly into a multi-channel control application. 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 as detailed in the handbook supplied with the stage and controller unit.
2) Using the lead supplied, connect the CONTROLLER/EXT IN terminal on the joystick console to the HANDSET IN connector on the rear panel of the Controller unit.


**Fig. 4.1 Connections**

In order to establish control over a particular axis, the joystick axes must be associated with the corresponding channels of the related controller. This is achieved by setting the joystick ID switch, located on the underside of the joystick console, and the channel ident switches on the rear panel of the BPC controller to the same number.

For example, if the joystick switch is set to '1', then the channel ID switch on the controller must also be set to ‘1’ as shown in Fig. 4.2.


**Fig. 4.2 ID switch setings**

3) Using a small, flathead screwdriver, set the joystick console ID switch and the controller channel ID switch as described in the preceding paragraph.

**Caution**

Do not set the switches to 'E' or 'F' as this is reserved for factory use and testing.

4) Switch ON the controller.
5) Wait until the red warning LED on the joystick console stop flashing (~3s). This indicates that initialisation is complete.
6) Press and hold the ‘High/Low’ button for 2 seconds, then release to zero the stage. When zeroing is complete, the green LED stops flashing.
7) The stage can now be moved using the joystick, GUI panel, or by setting commands to move by relative and absolute amounts – see the helpfile supplied with the APT server for more information.

## 4.9 Load Response

The response of the BPC301 to varying load and frequencies is shown below.

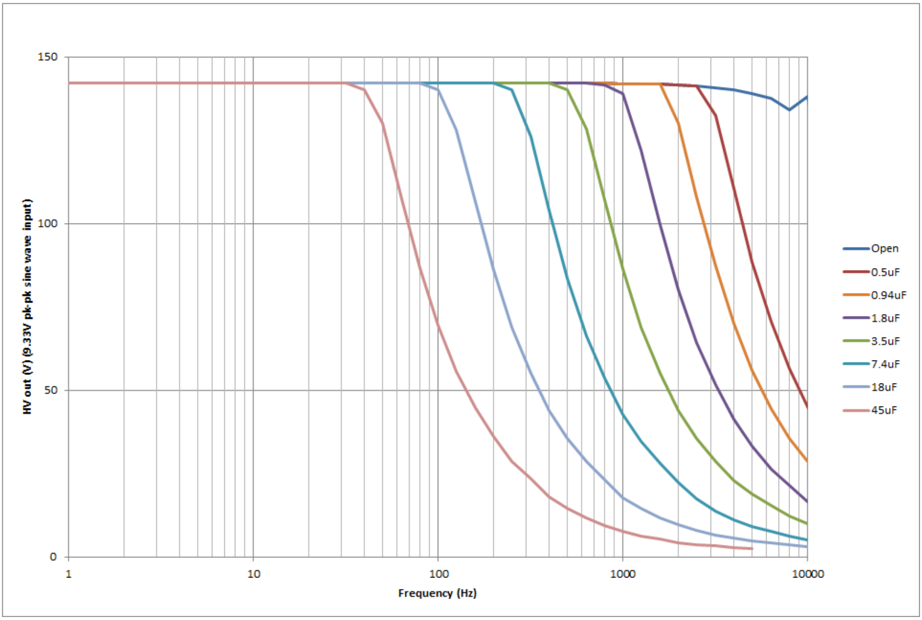



**Fig. 4.8 Response of BPC301 to Varying Loads and Frequencies**

## 4.10 Creating a Simulated Configuration Using APT Config

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 learning how to use the APT software and as an aid to developing custom software applications 'offline'.

Any number of 'virtual' control units can be combined to emulate a collection of physical hardware units For example, an application program can be written, then tested and debugged remotely, before running with the hardware.

To create a simulated configuration proceed as follows:

1) Run the APT Config utility - Start/All Programs/Thorlabs/APT/APT Config.
2) Click the 'Simulator Configuration' tab.

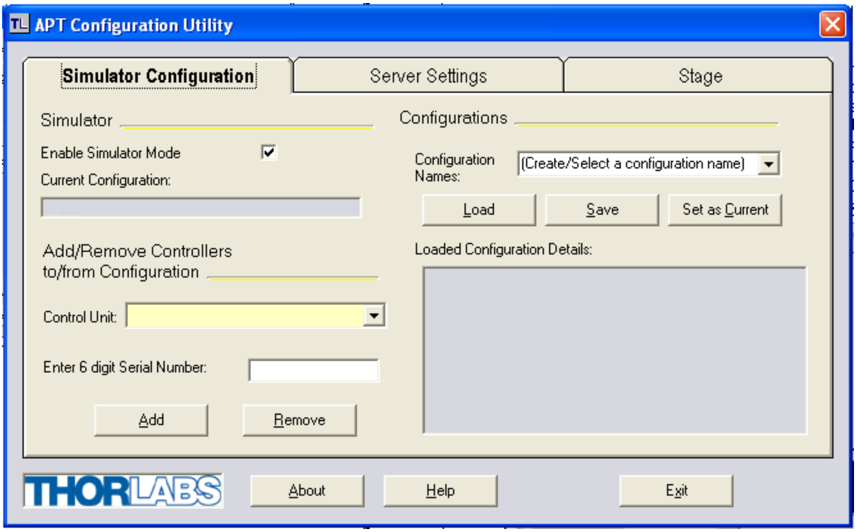
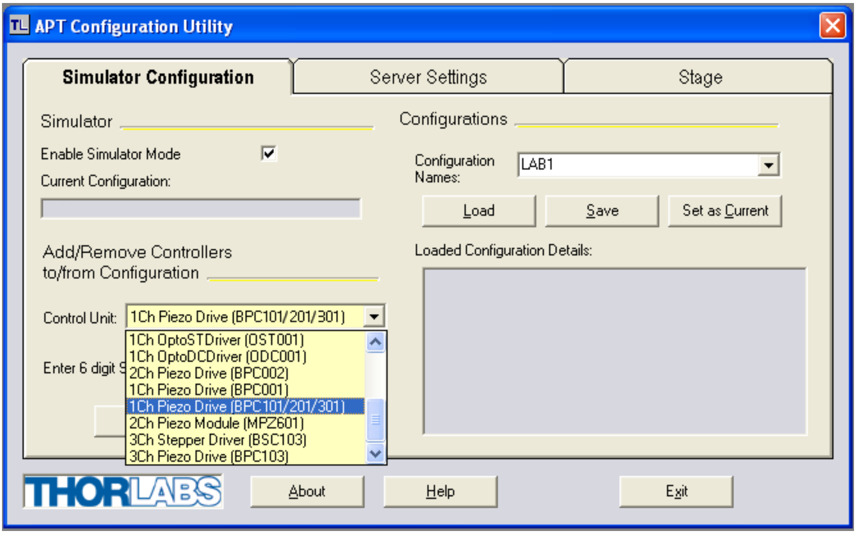


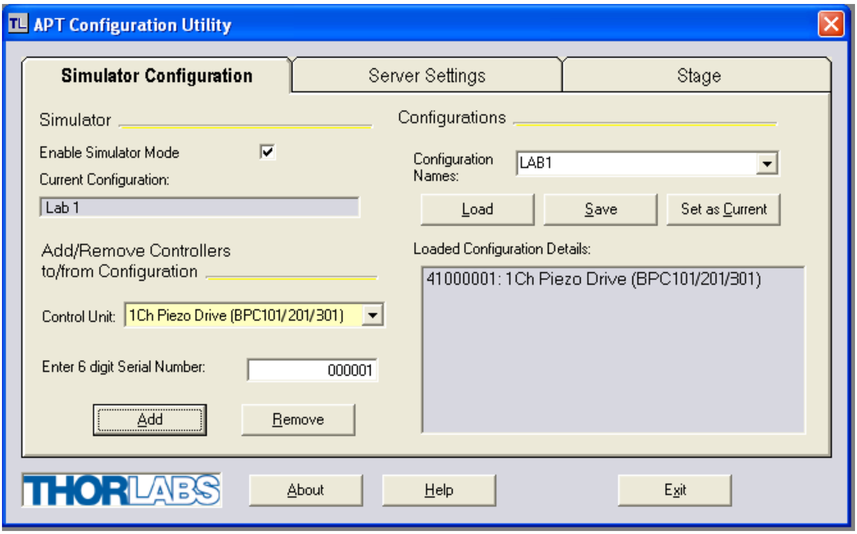

**Fig. 4.9 APT Configuration Utility - Simulator Configuration Tab**

3) Enter 'LAB1' in the Configuration Names field.

4) In the 'Simulator' field, check the ‘Enable Simulator Mode’ box. The name of the most recently used configuration file is displayed in the 'Current Configuration' window.




5) In the ‘Control Unit’ field, select ‘1 Ch Piezo Driver (BPC301)’.



6) Enter a 6 digit serial number.

**Note**

Each physical APT hardware unit is factory programmed with a unique 8 digit serial number. In order to simulate a set of 'real' hardware the Config utility allows an 8 digit serial number to be associated with each simulated unit. It is good practice when creating simulated configurations for software development purposes to use the same serial numbers as any real hardware units that will be used. Although serial numbers are 8 digits (as displayed in the 'Load Configuration Details' window), the first two digits are added automatically and identify the type of control unit.

The prefixed digits relating to the BPC301 piezo controller are:

41xxxxxx - Benchtop APT Single Channel Piezo Controller

When the APT Software is next run up, the system automatically creates 3 simulated single channel piezo drive cards.

7) Click the 'Add' button.
8) Repeat items (1) to (7) as required. (A unit can be removed from the configuration by selecting it in the 'Loaded Configuration Details' window and clicking the 'Remove' button or by right clicking it and selecting the 'Remove' option from the pop up window).
9) Enter a name into the 'Configuration Names' field.
10) Click 'Save'.
11) Click 'Set As Current' to use the configuration.

# 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.

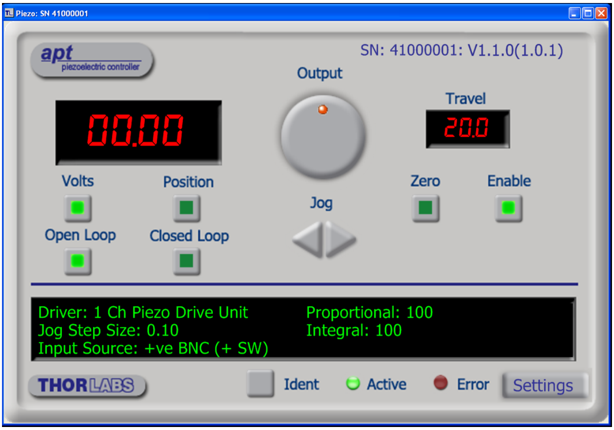



**Fig. 5.1 BPC301 Piezo Driver Software GUI**

**Note**

The serial number of the BPC301 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 strain gauge 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** - used to zero the position sensor (strain gauge) when operating in 'Closed Loop mode' - see Section 5.2.4. Setting The Position Sensor Zero.

**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 and the output voltage on the HV amp channel is set to zero volts.

**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 5.2.5.. 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 SetIPSource method - see Section 5.2.1.

*Proportional* - displays the proportional feedback loop constant for the selected channel (0 to 255).

*Integral* - displays the integration feedback loop constant for the selected channel (0 to 255).

**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 4.6.

## 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.

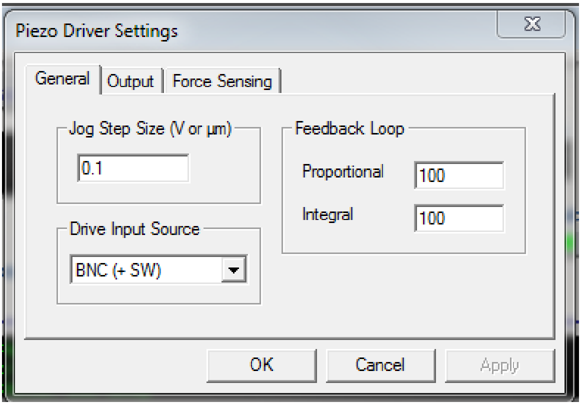



**Fig. 5.3 Piezo Settings panel - General tab**

*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.

*Feedback Loop* - these parameters determine the response characteristics when operating in closed loop mode. In general, the default values should not be altered.

*Proportional* - sets the proportional feedback loop constant for the selected channel (0 to 255).

*Integral* - sets the integral feedback loop constant for the selected channel (0 to 255).

*Input Source* - determines the input source(s) which controls 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 HV amp output is that set using the SetVoltOutput method (or the GUI panel ‘Output’ control).

BNC (+ SW) - the unit sums the differential signal on the rear panel EXT IN (+) and EXT IN (-) BNC connectors with the voltage set using the SetVoltOutput method (or the GUI panel ‘Output’ control).

Pot (+ SW) - the unit sums the voltage set using the front panel ‘Control’ potentiometer, with the voltage set using the SetVoltOutput method (or the GUI panel ‘Output’ control).

Pot + BNC (+ SW) - the unit sums the voltage set using the front panel ‘Control’ potentiometer, with the differential signal on the rear panel EXT IN (+) and EXT IN (-) BNC connectors and the voltage set using the SetVoltOutput method (or the GUI panel ‘Output’ control).

5.2.2 Output tab.

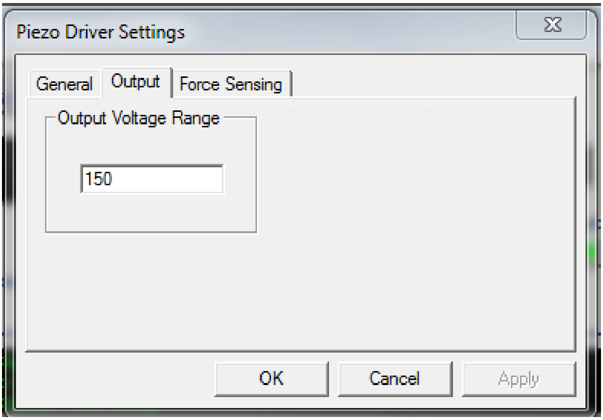



**Fig. 5.4 Piezo Settings panel - General tab**

*Output Voltage Range* - the piezo actuator connected to the controller has a specific maximum operating voltage range. This parameter sets a value for the maximum output voltage; 75V, 100V or 150 V. If any other value is entered, the unit will default to the nearest of these three settings.

**Note**

Legacy piezo stages (i.e. those fitted with an ident resistor) are driven by 75 V. The server will detect automatically if such a stage is fitted and in this case will limit the max voltage to 75 V.

### 5.2.3 Force Sensing tab

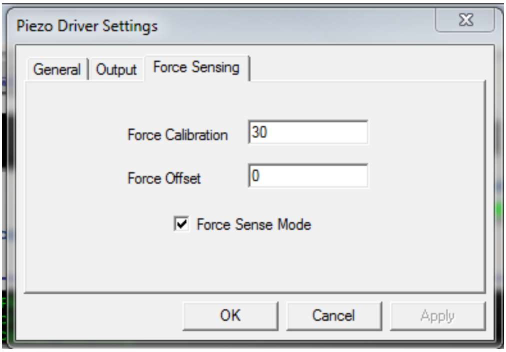



**Fig. 5.2 Piezo Settings panel - Force Sensing tab**

*Force Sense Mode* - Check this box to select Force Sensing Mode.

*Force Calibration* - This parameter specifies the calibration factor for the type of force sensor being used. For example, if set to 1, the GUI digital display shows a detected force of 0 to 1. The default setting for this parameter is 30, to be compatible with our FSC102 force sensor, which is specified to read forces up to 30N.

*Force Offset* - The force sensor may display an offset when no contact is apparent. This parameter is used to remove any latent offset, such that the sensor only detects a force when contact is experienced.

### 5.2.4 Setting the Position Sensor Zero

The position sensor is a strain gauge fitted to the piezo actuator. Due to limitations in manufacture, the strain gauge may give a small signal when the actuator is at zero position with zero volts applied. This 'offset' signal must be removed before the position attained by a specific applied voltage and the position attained by a corresponding specified distance can be rationalized. The offset is removed by clicking the 'Zero' button in the GUI panel or by calling the 'ZeroPosition ' method in the application software.

Each actuator has a unique offset value. Therefore the offset should be adjusted whenever an actuator is replaced. Temperature and prolonged use can affect the performance of the strain gauge and therefore the offset value. It is good practice to adjust the offset value whenever the unit is powered up.

### 5.2.5 Choice of Display Mode

It is possible to set the GUI to display either the voltage applied to the actuator or the position measured by the sensor (in microns). Even if the module is in open-loop mode, the signal from the position sensor can still be displayed.

In the case of actuators with position feedback, there are 4 modes of operation in total;

1) Open-loop, display voltage applied to actuator
2) Closed-loop, display position (microns) measured by sensor
3) Closed-loop, display voltage applied to actuator
4) Open-loop, display position (microns) measured by sensor

**Note**

These options can be selected through the GUI 'Settings' panel or by calling the SetVoltPosDispMode method from the application software.

The controller unit can also be used to control a force sensor. This is achieved either by calling the SetForceSenseParams method (see the APTServer Helpfile, accessed via the F1 key) or by checking the Force Sensing box in the settings panel (see Section 5.2.3.).

When checked, an 'F' is displayed next to the digital display on the GUI panel.

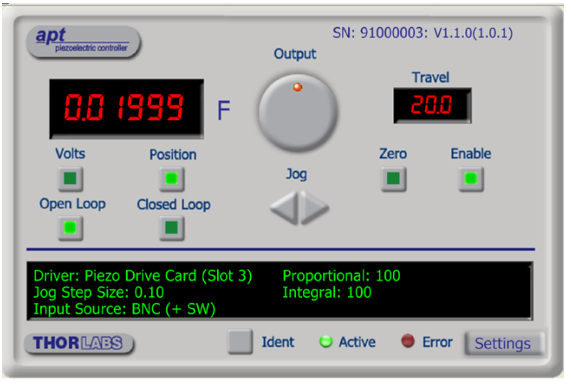



**Fig. 5.3 GUI Display - Force Sensing Mode**

The system defaults to 'Position' (Force) display mode and the digital display shows the force detected by the sensor. The units of force are dependent upon the type of force sensor used.

### 5.2.6 Detection of Range of Travel

In the case of actuators with position feedback, the Piezoelectric driver can detect the range of travel of the actuator, since this information is programmed in the electronic circuit inside the actuator.

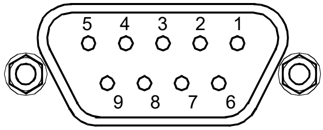
It is possible to get the range of travel of the actuator from the application software by calling the *GetMaxTravel* method – *see the APTServer Help File* (accessed via the Windows 'Start' menu).

This feature is not present in actuators without position sensing.

# Appendix A Rear Panel Connector Pinout Detail

## A.1 Rear Panel PIEZO IN Connectors

This Female 9-Pin D-Type connector receives the signal from the position sensor (strain gauge) of the piezo actuator to provide the feedback for the control loop. The pin functions are detailed in Fig. A.1.




| Pin | Description |
|---|---|
| 1 | Strain Gauge excitation |
| 2 | † +15V out |
| 3 | † -15V out |
| 4 | Ground |
| 5 | AC Feedback IN |
| 6 | Ground |
| 7 | * Actuator ID signal |
| 8 | Reserved for future use |
| 9 | Reserved for future use |

**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.

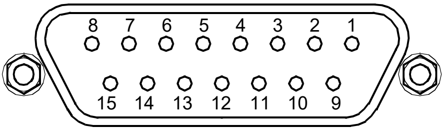
**Fig. A.1 PIEZO IN Connector Pin Identification**

## A.2 Rear Panel AUX I/O 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.

**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.

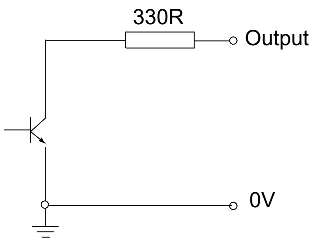



**Fig. A.3 Digital Output Schematic**

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.

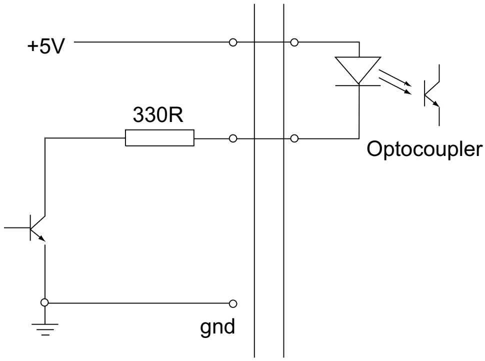



**Fig. A.4 Application Example: Connection to Optocoupler Inputs**

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.

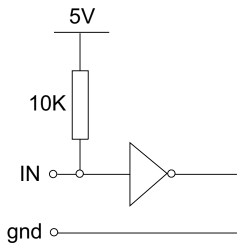



**Fig. A.5 Digital Input Schematic (protection circuitry not shown)**

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 +5 Volt Supply

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

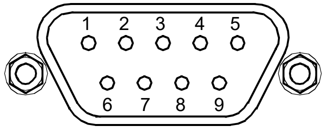
**Caution**

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 INTERCONNECT Connector

Although this Male 9-Pin D-type connector exposes internal electrical signals for use with serial communications or an external remote control handset, no firmware support is available at present.

The pin functions are detailed in in Fig. A.6 .

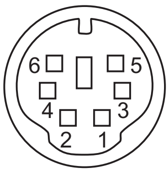



| Pin | Description |
|---|---|
| 1 | Not Connected |
| 2 | RX (controller input) |
| 3 | TX (controller output) |
| 4 | Not Connected |
| 5 | Ground |
| 6 | Not Connected |
| 7 | Not Connected |
| 8 | Not Connected |
| 9 | Not Connected |

**Fig. A.6 iNTERCONNECT Connector Pin Identification**

## A.4 Rear Panel HANDSET Connector

Provides connection to the MZF001 joystick. The pin functions are detailed in in Fig. A.7




| 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.7 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).

**Caution**

The instrument contains a power supply filter. Insulation testing of the power supply connector should be performed using a DC voltage.

## 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

## C.1 Specifications

| Parameter | Value |
|---|---|
| **Piezoelectric Output (SMC Male)** | |
| Voltage Output | 75 V, 100 V, and 150 V DC/channel |
| Output Current | 500 mA |
| Voltage Stability | 100ppm over 24 hours (after 30 mins warm up time) |
| Noise | <3m V RMS |
| Typical Piezo Capacitance | 1 to 10 µF |
| Bandwidth | 10 kHz (1 µF Load, 1 $V_{p-p}$ ) |
| **External Input (BNC)** | |
| Input Type | Differential or Single Ended |
| Input Voltage for Full Range<br>(i.e. 75 V, 100 V or 150 V) | 10 V ±2% |
| Max Output | 75 V Range: -10V to 90 V DC<br>100 V Range: -10V to 115 V DC<br>150 V Range: -10 V to 159 V DC |
| **Position Feedback (9-Pin D-Type Female)** | |
| Feedback Transducer Type* | Strain Gauge or Capacitive Sensor |
| Detection Method | AC Bridge (18 kHz Excitation) |
| Typical Resolution | 5 nm (for 20 µm Actuator e.g. PAZ005) |
| Auto-Configure | Ident Resistance or Stage ID EEPROM in Actuator |
| **User Input/Output (D-type 15 Pin Female)** | |
| 4 Digital Inputs | TTL Levels |
| 4 Digital Outputs | Open Collector |
| Trigger Input/Output | TTL |
| Trigger Input Functionality | Triggered Voltage Ramps/Waveforms |
| Trigger Output Functionality | Trigger Generation during Voltage Ramps Output |
| User 5V (with Ground) | 250 mA Max |
| **Input Power Requirements (IEC Connector)** | |
| Voltage | 85-264 VAC |
| Power | 150 VA |
| Fuse | 3.15 A |
| USB Port | Version 2.0 Full Speed Compatible |

| Parameter | Value |
|---|---|
| **General Data** | |
| Housing Dimensions (W x D x H) | 152 x 244 x 104 mm (6 x 9.6 x 4.1 in.) |
| Weight: | 3.18 kg (7 lbs) |

* The controller measures a conditioned signal from the feedback sensor. For details of circuitry please contact Tech Support.

## C.2 Associated Products

| Product Name | Part Number |
|---|---|
| Drive Cable for Piezoelectric Actuators (3.0 m) | PAA100 |
| Drive Cable for Piezoelectric Actuators (1.5 m) | PAA101 |
| Piezoelectric Feedback Cable, Male D-type to Female LEMO converter (3.0 m) | PAA622 |
| Z Focus Joystick | MZF001 |
| Strain Gauge Pre Amp circuit for use with third party closed loop piezos | AMP002 |

# 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. Note one additional product, the TSG001 T-Cube Strain Gauge reader is another member of the APT controller range - and can also be accessed using the Piezo ActiveX Control.

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 BPC301 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. |
| GetIPSource | Gets the HV amplifier input source. |
| 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. |
| 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. |
| SetIPSource | Sets the HV amplifier input source. |
| 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. |
| 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. 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. 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 in the case of Thorlabs actuators).

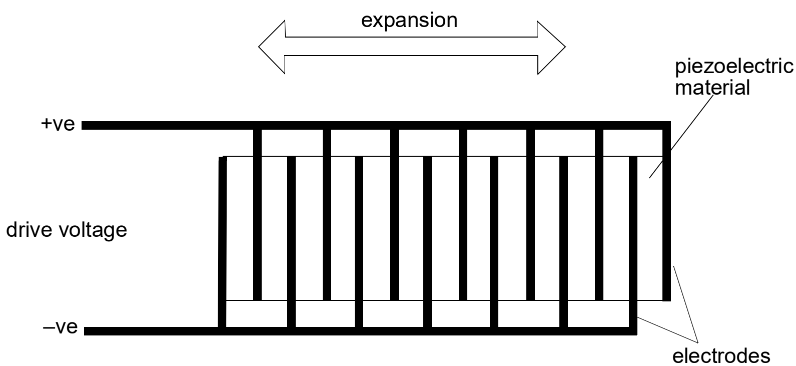



**Fig. E.1 Piezo-electric actuator schematic diagram**

### 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.

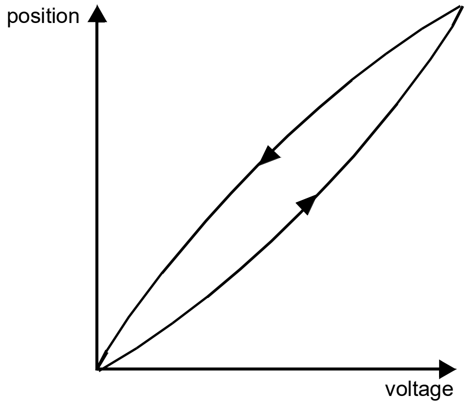



**Fig. E.2 Piezo-electric hysteresis**

### 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.

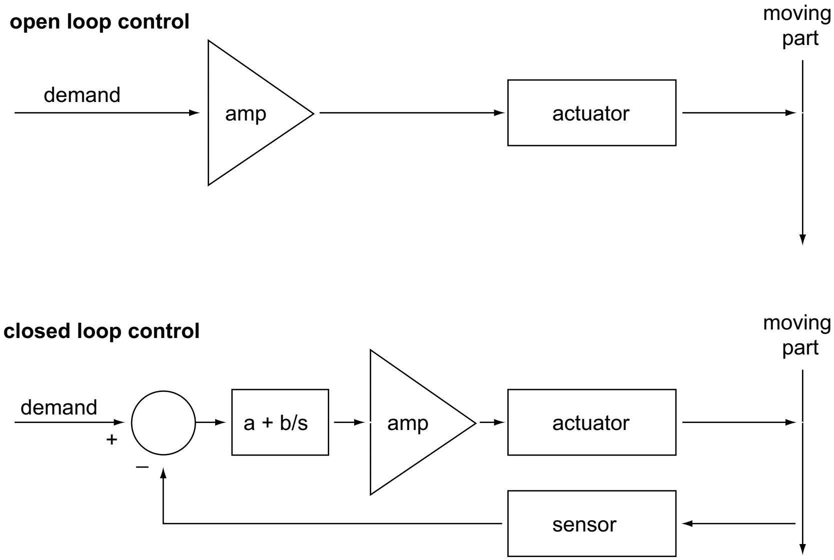



**Fig. E.3 Open loop and closed loop control**

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.

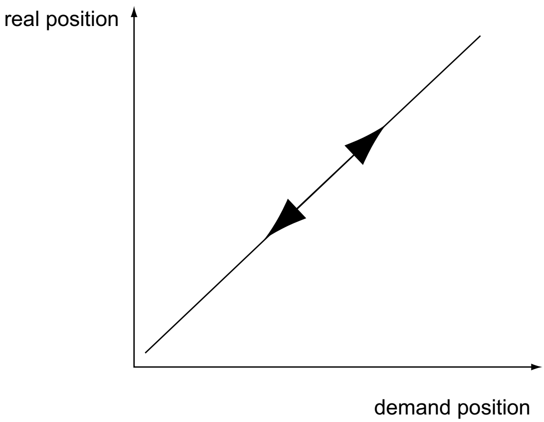



**Fig. E.4 Closed loop response**

# 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 Certificate

THORLABS
www.thorlabs.com

# *EU Declaration of Conformity*

*in accordance with EN ISO 17050-1:2010*

| | |
|---|---|
| *We* | Thorlabs Ltd. |
| *Of* | 1 Saint Thomas Place, Ely, Cambridgeshire, CB7 4EX |

*in accordance with the following Directive(s):*

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

*hereby declare that:*

*Model:* ***BPC30X***

*Equipment:* ***Benchtop Piezo Controller 150V (Single or Multi-Channel)***

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

| | | |
|---|---|---|
| EN61010 -1 | Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory Use. | 2010 |
| EN61326-1 | Electrical Equipment for Measurement, Control and Laboratory Use - EMC Requirements | 2013 |

*and which 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:*

A 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:* 23 April 2014

*Name:* Keith Dhese

*Position:* General Manager

*EDC - BPC30X -2014-04-23*

CE 14

# 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.

**USA, Canada, and South America**
Thorlabs, Inc.
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**UK and Ireland**
Thorlabs Ltd.
sales@uk.thorlabs.com
techsupport.uk@thorlabs.com

**Europe**
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scandinavia@thorlabs.com

**France**
Thorlabs SAS
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**Brazil**
Thorlabs Vendas de Fotônicos Ltda.
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**Japan**
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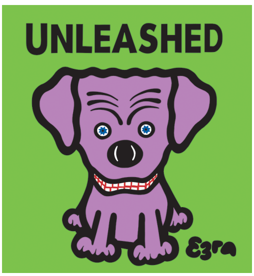
**China**
Thorlabs China
chinasales@thorlabs.com

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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