THORLABS

KBD101

K-Cube Brushless DC Servo Driver

APT User Guide

Original Instructions

Contents

  Appendices

Chapter 1   Safety

1.1   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.

Shock Warning
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.

1.2   General Warnings

Warnings
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 absorbent tissue. Do not allow spilled fluid to enter the internal mechanism.

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 2   Overview and Setup

2.1   Introduction

The KBD101 Brushless DC Motor K-Cubes are ideal for motion control applications demanding high speed (100s of mm/s) and high encoder resolution (<100 nm) operation. These single channel drivers offer high-precision motion control in a wide range of applications, and in particular when used along with our DDSM100 fast translation stage where speeds of up to 500 mm/sec can be achieved. Designed using latest digital and analog techniques and with high-bandwidth high-power servo control circuitry, these new drivers are capable of driving a range of rotary and linear brushless 3-phase DC motors of up to 2 Amp peak coil current.

Integrated into the apt family of products, it offers Thorlabs standard control and programming interface, allowing easy integration into the customer's own automated motion control applications. These units are cable of being reprogrammed in-field, allowing the option of upgrading the units with future firmware releases as soon as new programming interfaces (such as microscopy standard command sets) are added.

Fig. 2.1   K-Cube Brushless DC Servo Motor driver (KBD101)

Operation of the KBD101 brushless DC motor unit is fully configurable (parameterized) with key settings (e.g. PID settings, min and max position values, and joystick response) exposed through the associated graphical interface panels.

PID control loop values can be adjusted for a particular application, minimum and maximum position values can be entered to suit different stages as required, and the response of the key pad joystick can be adjusted for speed or precision. Moreover, relative and absolute moves can be initiated with move profiles set using velocity profile parameters. Similarly, home sequences have a full set of associated parameters that can be adjusted for a particular stage or actuator. For simplicity of operation, the apt™ software incorporates pre-configured settings for each of the Thorlabs stages and actuators, while still exposing all parameters individually for use with other DC motor driven systems.

For convenience and ease of use, adjustment of many key parameters is possible through direct interaction with the graphical panel. For example a move to the next position can be initiated by clicking directly on the position display and entering a new value (see the tutorial in Chapter 5 for further details). Furthermore, all such settings and parameters are also accessible through the ActiveX® programmable interfaces for automated alignment sequences.

In the remainder of this handbook, the Tutorial section (Chapter 5) provides a good initial understanding on using the unit, and the reference sections (Chapter 6) covers all operating modes and parameters in detail.

2.2   Power Options

A single way wall plug KPS201* power supply for powering a single K-Cube Driver is available.

* The previous-generation KPS101 power supply is also compatible and can be used to power a single K-Cube Driver.

As a further level of convenience when using the new K-Cube Controllers Thorlabs also offers the 3-channel and 6-channel K-Cube Controller Hubs (KCH301 and KCH601). These products have been designed specifically with multiple K-Cube operation in mind in order to simplify issues such as cable management, power supply routing, multiple USB device communications and different optical table mounting scenarios.

The K-Cube Controller Hub comprises a slim base-plate type carrier with electrical connections located on the upper surface to accept the K-Cubes.

Internally the Controller Hub contains a fully compliant USB 2.0 hub circuit to provide communications for all K-Cubes – a single USB connection to the Controller Hub is all that is required for PC control. The Controller Hub also provides power distribution for the K-Cubes, requiring only a single power connection.

2.3 APT PC Software Overview

2.3.1 Introduction

As a member of the APT range of controllers, the KBD101 Brushless DC motor driver 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, including the KBD101 drivers, 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 2.3.2.) and APTConfig (see Section 2.3.3.) 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 2.3.4.

⚠	**Caution**	⚠
	On start up, wait until the initialization sequence is completed before running the APT software - see Section 3.4.	

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 2.3.4. for further details.

THOR LABS

2.3.2   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.
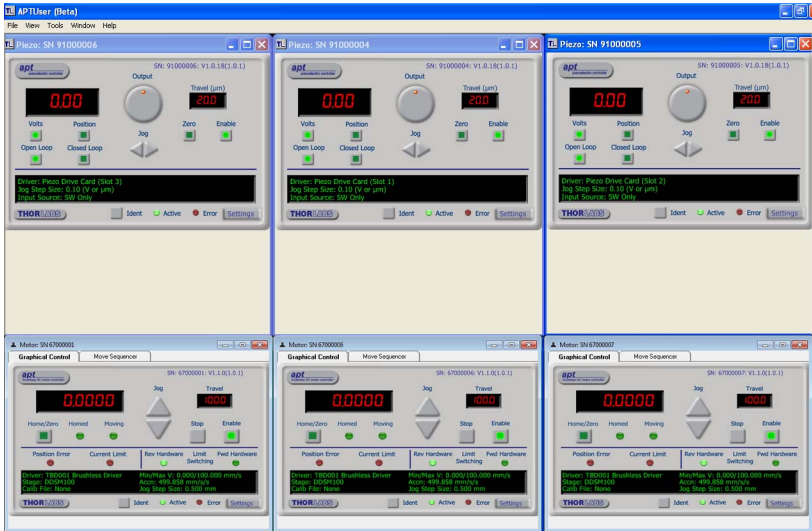
All basic operating parameters can be altered and, similarly, all operations (such as motor moves) can be initiated. Settings and parameter changes can be saved and loaded to allow multiple operating configurations to be created and easily applied.

 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 customize and automate usage of the driver (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 5) and in the APTUser online help file, accessed via the F1 key when using the APTUser utility.

Caution
On start up, wait until the initialization sequence is completed before running the APT software - see Section 3.4.

2.3.3   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 be made 'off-line' before running the APT software. These settings have global effect; such as switching between simulator and real operating mode, and associating third party mechanical stages to specific motor actuators.
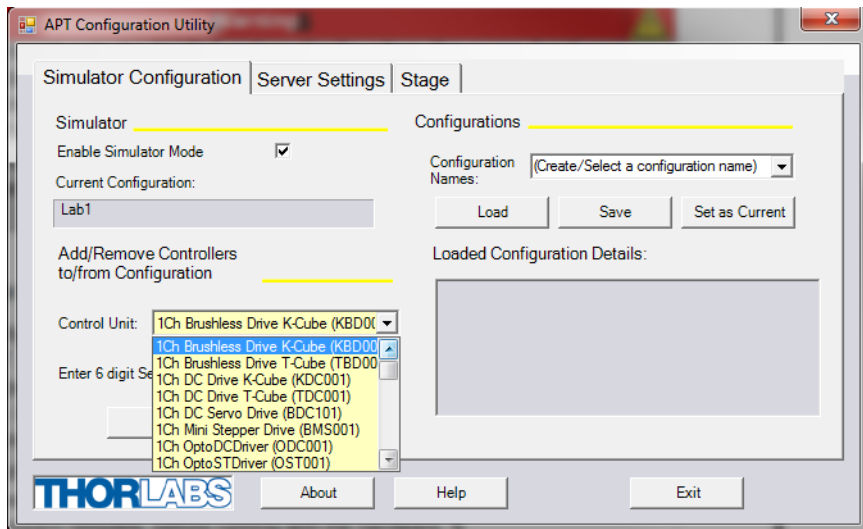
If a KBD101 driver is used with the DDSM100 Direct Drive Translation stage, all stage-associated settings are made automatically when the stage is connected to the driver.

The APTConfig utility is provided as a convenient means for making these system wide settings and adjustments for third party brushless DC motor driven stages. An overview of APTConfig is provided in Section 2.3.3. Full details are contained in the online help supplied with the utility.

2.3.4   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 KBD101 DC motor drivers. 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 KBD101 APT Brushless DC Servo driver unit.
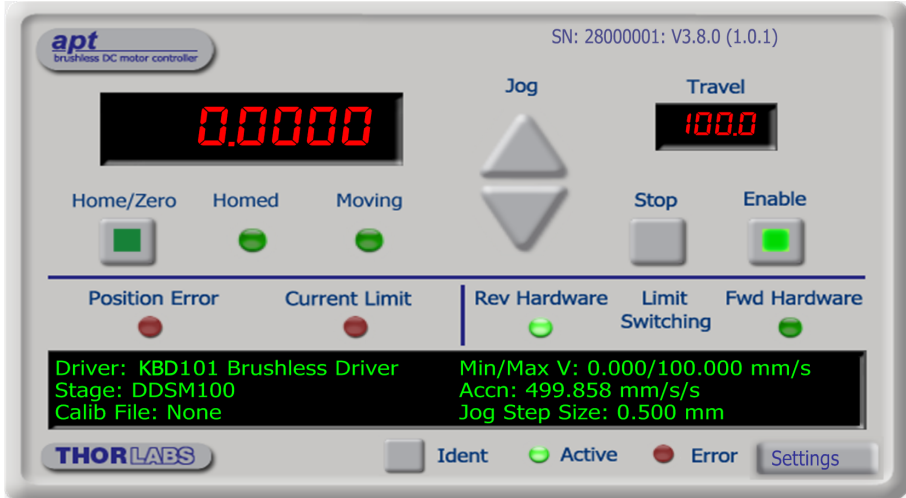
This Control provides a complete user graphical instrument panel to allow the motor unit to be manually operated, as well as a complete set of software functions (often called methods) to allow all parameters to be set and motor operations to be automated by a client application. The instrument panel reflects the current operating state of the driver unit to which it is associated (e.g. such as motor position). 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 DC motor Control to move a motor, the progress of that move is reflected automatically by changing position readouts 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 or the handbooks associated with the controllers. 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. 2.2).
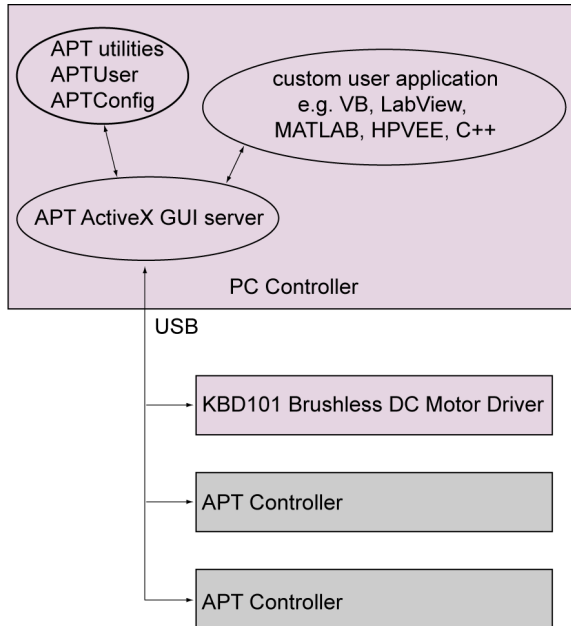
Fig. 2.2 System Architecture Diagram

Refer to the main APT Software online help file, for a complete programmers guide and reference material on using the APT ActiveX Controls collection. This is available either by pressing the F1 key when running the APT server, or via the Start menu, Start\Programs\Thorlabs\APT\APT Help.

2.3.5 Software Upgrades

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

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 STAGE TO YOUR PC YET

1) Download the software from www.thorlabs.com.
2) Locate the downloaded setup.exe file and move to a suitable file location.
3) Double-click the setup.exe file and follow the on-screen instructions.

3.2 Mechanical Installation

3.2.1 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.

3.2.2 Mounting Options

The K-Cube Brushless DC Driver is shipped with a baseplate, for use when fitting the unit to a breadboard, optical table or similar surface.

For multiple cube systems, a 3-channel and 6-channel K-Cube Controller Hub (KCH301 and KCH601) are also available - see Section 2.2. for further details. Full instructions on the fitting and use of the controller hub are contained in the handbook available at www.thorlabs.com

⚠	**Caution**	⚠
	When siting the unit, it should be positioned so as not to impede the operation of the control panel buttons. **Ensure that proper airflow is maintained to the rear of the unit.**	

3.2.3 Using the Baseplate

The baseplate must be bolted to the worksurface before the K-Cube is fitted, as shown below. The K-cube is then located on two dowels in the baseplate and secured by two clips.
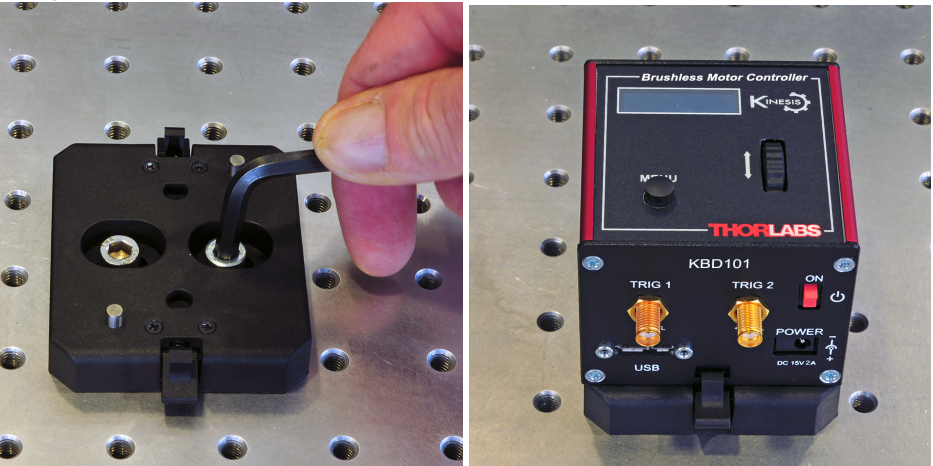
Fig. 3.1   Using The Baseplate

3.3   Electrical Installation

3.3.1   Rear Panel
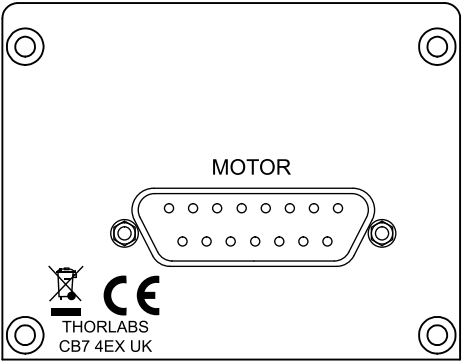
Fig. 3.2   Rear Panel Connections

The unit is supplied with a female 15 pin D-type connector as shown above, which is compatible with the DDSM100 brushless DC driven translation stage (refer to Appendix A   for details of pin outs)**.**

3.3.2 Front Panel
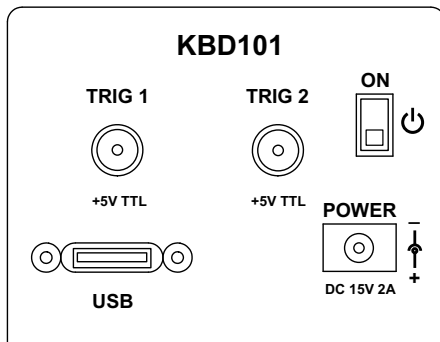
Fig. 3.3 Front Panel Connections

⚠	Shock Warning	⚠
	The unit must be connected only to a DC supply of 15V, 2A regulated. Connection to a supply of a different rating may cause damage to the unit and could result in injury to the operator.	

POWER - A Standard 3.5 mm front panel jack connector for connecting the unit to a regulated DC power supply of 15 V, 2A - 2.66A.

A single way wall plug KPS201* supply for powering a single Driver K-Cube is available.

*The previous-generation KPS101 power supply is also compatible.

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.

ON - Power ON/Standby switch. When in the ON position, the unit is fully powered up. When the switch is turned to the Standby position, the unit initiates a controlled power down sequence, saving all user-adjustable parameters to non-volatile memory before turning off the power. For the first few seconds, the shutdown can be cancelled by turning the switch on again, in which case the unit will save the parameters but will remain powered up. In a powered down (Standby) state, the logic circuits are powered off and the unit will draw only a small quiescent current. The switch should always be used to power down the unit.

TRIG 1 and TRIG 2 - SMA connectors for use with external trigger input and output signals (5V TTL levels). The function is set to trigger IN or OUT via the settings panel - see Section 4.5. and Section 6.3.5.

3.4   Connect The Hardware

1) Perform the mechanical installation as detailed in Section 3.2.
2) Install the APT Software.

⚠	**Caution**	⚠
	During items (3) to (6) the instructions should be followed strictly in the order stated. Problems may occur if the process is not performed in the correct sequence.	

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) Connect the DC servo motor actuator to the driver unit - see Section 3.3.1.

⚠	**Caution**	⚠
	During item (5) ensure the power switch on the front panel of the unit is switched off before connecting power to the K-Cube. Always power up the K-Cube unit by its ON switch. DO NOT connect the K-Cube unit to a 'live' external power supply. Doing so (i.e. "hot plugging") carries the risk of PERMANENT damage to the unit. Similarly, to power down the unit, turn the power switch off before disconnecting the power supply.	

5) Connect the driver unit to the power supply - see Section 3.3.2.
6) Connect the PSU to the main supply.
7) Switch 'ON' the unit using the switch on the front panel.

The unit takes about 5 seconds from power application until warm up is finished, and phase initialization is complete. During this time the following screens are displayed.

```
Thorlabs KBD101
SwRev 10002
```

```
Stage connected:
DDSM100
```

```
Phase init
Please wait...
```

```
Phase init
completed
```

```
At 0.0000 mm
Disabled        V
```

.

Note
If any problems are encountered during the connection and power up process, power cycle the unit, which should clear the error.

Note
3-phase brushless DC motors are commutated electronically, i.e. the controller drives the coils with a precisely controlled waveform, that depends on the position of the rotor (or, with linear motors, the position of the coil housing). On power up, the position of the rotor is not known. The controller establishes this by energising the coils and measuring the resulting movement. This is why on power up, the stage (motor) makes a slight buzzing noise and moves about slightly for a few seconds. Phase initialisation can only take place if the motor can move unobstructed during this time.

8) Windows® should detect the new hardware. Wait while Windows® installs the drivers for the new hardware.

Note
After initial start up, the drive channel must be enabled before the stage can be driven - see Section 4.4.2.

THORLABS

Chapter 4   Standalone Operation

4.1   Introduction

The Brushless DC Driver K-Cube has been designed specifically to operate with the range of Thorlabs Brushless DC motorized opto-mechanical products. The unit offers a fully featured motion control capability including velocity profile settings, limit switch handling, homing sequences and, for more advanced operation, adjustment of PID settings, allowing support for many different actuator configurations. These parameters can be set via the APT Server software - see Chapter 5. Furthermore, many of these parameters are automatically set to allow "out of the box" operation with no further "tuning" required.

The following brief overview explains how the front panel controls can be used to perform a typical series of motor moves.

4.2   Control Panel Buttons and Indicators
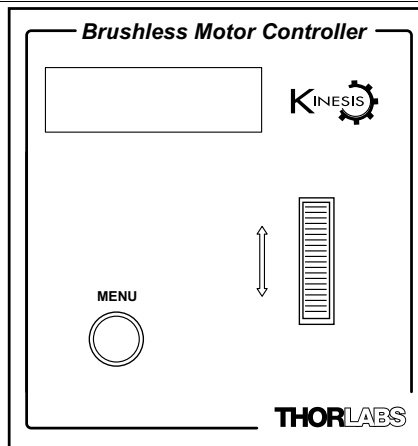
Fig. 4.1   Panel Controls and Indicators

MOVE Controls - These controls allow all motor moves to be initiated.

Velocity Wheel - Used to drive the motor at a varying speed in either forward or reverse directions for full and easy motor control - see Section 4.3.

Digital Display - The display shows the menu options and settings, accessed via the menu button - see Section 4.4. When the Ident button on the associated GUI panel is clicked, the display will flash for a short period.

MENU - used to access the settings menu - see Section 4.4. Also used to stop a move when the stage is in motion.

4.2.1   Digital Display - Operating Mode

During normal operation, the digital display shows the current position (in millimeters or degrees) and the current state of the motor (Stopped or Moving). If the stage being driven has been homed, the display will also show 'Homed'.
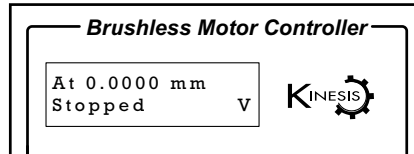
Fig. 4.2   Digital Display - Normal Operation

For rotation stages, the position display will be restricted to the "Equivalent Angle" display mode (see Section 6.3.7. for more details), so the position displayed will always be a positive number between 0 and 360 degrees. If set to Total Angle in the settings panel, the LED display will still show the equivalent 0 to 360° value but the GUI screen will show the total rotation.

4.3   Velocity Wheel Operation

The velocity wheel is a sprung potentiometer, such that when released it returns to its central position. In this central position the motor is stationary. Different types of move can be initiated by the wheel, depending on its mode setting. The mode can be set either via the GUI Settings panel, see Section 6.3.3. or via the top panel display menu, see Section 4.4. The various operating modes are described in Section 4.3.1. to Section 4.3.3.

4.3.1   Homing

A 'Home' move is performed to establish a datum from which subsequent absolute position moves can be measured (see Section 5.4.) for further information on the home position).

To initiate a 'Home' see Section 4.4.4.

4.3.2   Go to Position

In 'Go To Position' mode, two preset position values can be specified, such that the motor moves to position 1 when the wheel is moved down and to position 2 when it is moved up. These 'taught' positions can be set through the software GUI - see Section 6.3.3. or via the display menu, see Section 4.4.8.

This mode of operation is enabled by setting the 'Wheel Mode' to 'Go To Position' through the software GUI - see Section 6.3.3. or via the display menu, see Section 4.4.6.

Note for Rotation Stage Users

If the current absolute position is outside the 0 to 360 degree range, then "go to position" will result in a move to the correct angular position within the same 0..360 degree full turn "segment". This means that the move will always stay in the current full turn segment, and from this point of view it is not always the quickest position move. For example, if you are at 350 degrees and you enter a "go to" position of 10 degrees, the stage will rotate anticlockwise 340 degrees and not clockwise 20 degrees.

4.3.3   Jogging

The top panel wheel can also be configured to 'jog' the motor. This mode of operation is enabled by setting the 'Wheel Mode' parameter to 'Jogging' through the software GUI - see Section 6.3.3. or via the display menu, see Section 4.4.6.

Once set to this mode, the jogging parameters for the wheels are taken from the 'Jog' parameters on the 'Move/Jogs' settings tab - see Section 6.3.1. or via the display menu, see Section 4.4.7.

4.3.4   Velocity Moves

The wheel can also be used to initiate a move at a specified velocity. As the wheel is moved away from the centre, the motor begins to move. Bidirectional control of the motor is possible by moving the wheel in both directions. The speed of the motor increases by discrete amounts as a function of wheel deflection, up to a maximum as set in through the software GUI - see Section 6.3.3. or via the display menu, see Section 4.4.5. The move stops when the wheel is returned to its centre position.

4.4   Settings Menu

```
At 0.0000 mm
Stopped        V
```
MENU

4.4.1   Overview

Press the MENU button

```
Menu options
Use wheel
```

Use the wheel to scroll through the menu options
Press the MENU button to enter a particular option

```
Menu options
1 Disable
```

Disable the stage - see Section 4.4.2.

```
Menu options
2 Go to position
```

Move the stage to an absolute position - see Section 4.4.3.

```
Menu options
3 Start homing
```

Move the stage to the Home position - see Section 4.4.4.

```
Menu options
4 Velocity
```

Set the Max Velocity - see Section 4.4.5.

```
Menu options
5 Joystick mode
```

Set the joystick wheel mode - see Section 4.4.6.

```
Menu options
6 Jog step size
```

Set the Jog Step Size - see Section 4.4.7.

```
Menu options
7 Teach position
```

Set the teach positions - see Section 4.4.8.

```
Menu options
8 Brightness
```

Set the display brightness - see Section 4.4.9.

```
Menu options
9 Disp.Timeout
```

Set the display timeout period - see Section 4.4.10.

```
At 0.0000 mm
Disabled        V
```
MENU

```
Menu options
Use wheel
```

```
Menu options
1 Enable
```

```
At 0.0000 mm
Stopped         V
```

4.4.2 Menu Option - Enable/Disable

After initial start up the drive channel is disabled, and must be enabled before the stage can be driven.

Press the MENU button, then use the wheel to scroll through the menu options.

Press the MENU button to enter the Enable option.

Press the MENU button to store the selection and return to the main display.

4.4.3   Menu Option - Go to position
This mode is used to move to an absolute position.

```
At 0.0000 mm
Stopped         V
```
↓ MENU

```
Menu options
Use wheel
```

Press the MENU button, then use the wheel to scroll through the menu options.

Press the MENU button to enter the Go to position option.

```
Menu options
2 Go to position
```

Use the wheel to adjust the position value, (within the travel range for linear stages, or 0 to 360 ° for rotation stages) then press the MENU button to store the selection.

```
P = 0.00 mm
↕ adjust Pos
```

Note for rotation stages. If the current absolute position is outside the 0 to 360 degree range, then "go to position" will result in a move to the correct angular position within the same 0..360 degree full turn "segment". This means that the move will always stay in the current full turn segment, and from this point of view it is not always the quickest position move. For example, if the stage is at 350 degrees and you enter a "go to" position of 10 degrees, the stage will rotate anticlockwise 340 degrees and not clockwise 20 degrees.

The stage moves to the position entered, and the display shows the change in position.

```
At 2.0000 mm
Stopped         V
```

To stop the move, press the MENU button.
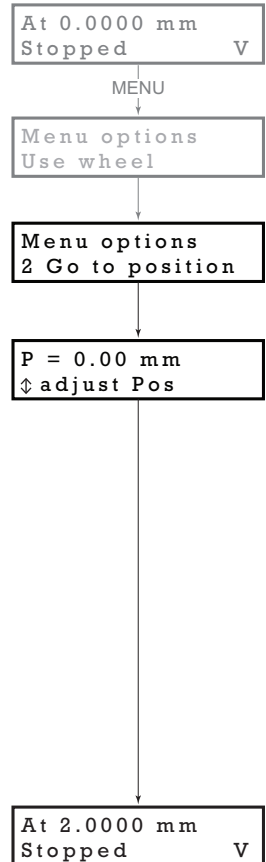
```
At 2.0000 mm
Stopped        V
```
           MENU
```
Menu options
Use wheel
```

```
Menu options
3 Start homing
```

```
At 2.0000 mm
Homing         V
```

```
At 0.0000 mm
Homed Stopped V
```

4.4.4 Menu Option - Start homing
This mode is used to home the stage.

Press the MENU button, then use the wheel to scroll through the menu options.

Press the MENU button to enter the Start Homing option.

The display shows a decreasing position count while the stage is homing.

Once homing is complete, the display shows the position at 0.0000 mm and 'Homed' is displayed.

To stop the move, press the MENU button.

```
At 0.0000 mm
Homed Stopped V
```
           MENU
```
Menu options
Use wheel
```

```
Menu options
4 Velocity
```

```
1.680 mm/s
↕ adjust MaxVel
```

```
At 0.0000 mm
Homed Stopped V
```

4.4.5 Menu Option - Velocity
This mode is used to move to set the max velocity.

Press the MENU button, then use the wheel to scroll through the menu options.

Press the MENU button to enter the Velocity option.

Use the wheel to adjust the max velocity, e.g. 1.68 mm/s, then press the MENU button to store the setting.

Subsequent moves will be performed at the velocity entered.

4.4.6 Menu Option - Joystick Mode

This mode is used to set the operating mode of the joystick wheel.

```
At 0.0000 mm
Homed Stopped V
```
MENU

Press the MENU button, then use the wheel to scroll through the menu options

```
Menu options
Use wheel
```

Press the MENU button to enter the Joystick mode option. Use the wheel to scroll through the options, then press MENU when the required option is displayed.

```
Menu options
5 Joystick Mode
```

In *Velocity control mode*, deflecting the wheel starts a move with the velocity proportional to the deflection. The maximum velocity (i.e. velocity corresponding to the full deflection of the joystick wheel) is set in the preceding *3 Velocity* option. The move will stop when the wheel is released.

```
Velocity control
⇕ to select
```

In *Jog to positions mode*, deflecting the wheel starts a move from the current position to one of the two predefined "teach" positions. The teach positions are specified in option *6 Teach Position*.

```
Jog to positions
⇕ to select
```

In *Jog in steps mode*, deflecting the wheel initiates a jog move, using the parameters specified by the *3 Velocity* and *5 Jog step size* options. Keeping the wheel deflected repeats the move automatically after the current move has completed.

```
Jogging in steps
⇕ to select
```
MENU

Use the wheel to display the required option, then press MENU to store the selection and return to the main display.

```
At 0.0000 mm
Homed Stopped V
```

The selected mode is indicated at the right hand side of the bottom line:

V = Velocity mode

P = Jog to position mode

J = Jog in steps mode

```
At 0.0000 mm
Homed Stopped V
```
```
Homed Stopped P
```
```
Homed Stopped J
```
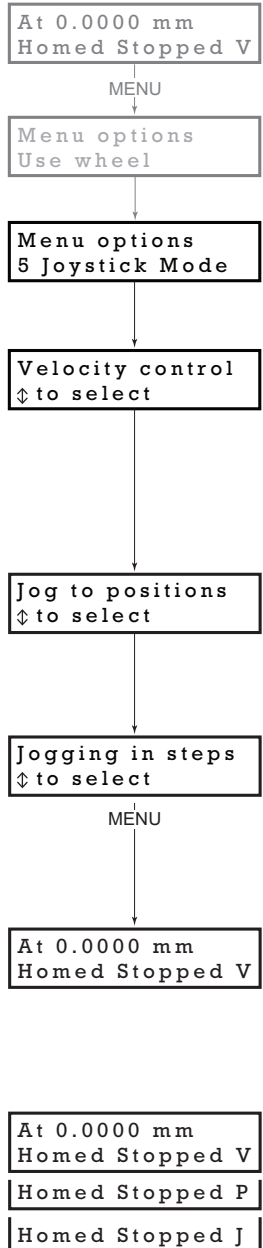
```
At 0.0000 mm
Homed Stopped V
```
          MENU
```
Menu options
Use wheel
```

```
Menu options
6 Jog step size
```

```
S = 0.10 mm
↕ adjust JogStep
```

```
At 0.0000 mm
Homed Stopped V
```

4.4.7   Menu Option - Jog Step Size
This mode is used to set the jog step size.

Press the MENU button, then use the wheel to scroll through the menu options.

Press the MENU button to enter the Jog step size option.

Use the wheel to adjust the step size, e.g. 0.10 mm, then press the MENU button to store the selection.

When *Jog in steps* mode is selected in the *Joystick mode* option (see Section 4.4.6.), subsequent moves will be performed at the step size entered.

4.4.8 Menu Option - Teach Position

This mode is used to set the teach positions, used when the *Joystick mode* option is set to *Jog to positions* mode - see Section 4.4.6.

To set Teach Position 1...

Move the stage to the position to use as teach position 1.

```
At 10.0000 mm
Homed Stopped V
```
MENU

Press the MENU button, then use the wheel to scroll through the menu options.

```
Menu options
Use wheel
```

Press the MENU button to enter the Teach position option.

```
Menu options
7 Teach position
```

Use the wheel to select P1, then press the MENU button to store the current position as teach position 1 and return to the main display.

```
P1 = 10.0000 mm
⇕num ⇕store
```

```
At 10.0000 mm
Homed Stopped V
```

To set Teach Position 2...

Move the stage to the position to use as teach position 2.

```
At 5.0000 mm
Homed Stopped V
```
MENU

Press the MENU button, then use the wheel to scroll through the menu options.

```
Menu options
Use wheel
```

Press the MENU button to enter the Teach position option.

```
Menu options
7 Teach position
```

Use the wheel to select P2, then press the MENU button to store the current position as teach position 2 and return to the main display.

```
P2 = 5.0000 mm
⇕num ⇕store
```

When *Jog to position* mode is selected in the *Joystick mode* option (see Section 4.4.6.), a downwards deflection of the wheel moves the stage to position 1, and an upwards deflection moves to position 2.

```
At 5.0000 mm
Homed Stopped V
```

THORLABS

```
At 0.0000 mm
Homed Stopped V
```
MENU
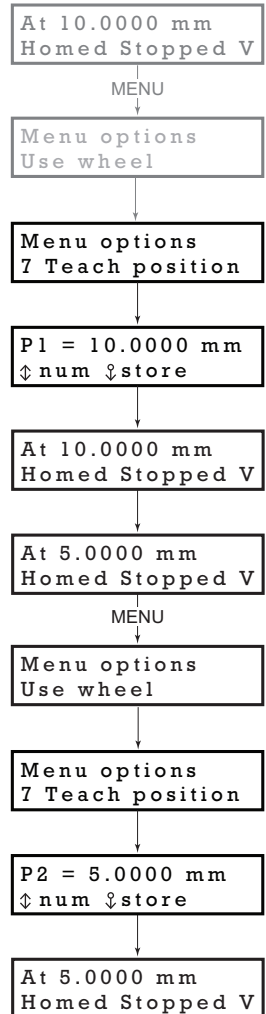
```
Menu options
Use wheel
```

```
Menu options
8 Brightness
```

```
Brightness = 67
↕ to adjust
```

```
At 0.0000 mm
Homed Stopped V
```

4.4.9 Menu Option - Brightness

In certain applications, it may be necessary to adjust the brightness of the LED display. The brightness is set as a value from 0 (Off) to 100 (brightest). The display can be turned off completely by entering a setting of zero, however, pressing the MENU button on the top panel will temporarily illuminate the display at its lowest brightness setting to allow adjustments. When the display returns to its default position display mode, it will turn off again.

Press the MENU button, then use the wheel to scroll through the menu options.

Press the MENU button to enter the Brightness option.

Use the wheel to adjust the brightness, then press the MENU button to store the selection and return to the main display.

```
At 0.0000 mm
Homed Stopped V
```
MENU
```
Menu options
Use wheel
```

```
Menu options
9 Disp.Timeout
```

```
After 2 min
↕ to adjust
```

```
At 0.0000 mm
Homed Stopped V
```

4.4.10 Menu Option - Disp.Timeout

'Burn In' of the display can occur if it remains static for a long time. To prevent this, the display is automatically dimmed after a specified time interval.

Press the MENU button, then use the wheel to scroll through the menu options.

Press the MENU button to enter the Disp.Timeout option.

The time out interval is specified in minutes in the range 1 to 480. The adjustment is done in steps of 1 minute if the timeout is between 1 to 10 minutes, 10 minute steps between 10 minutes and 1 hour, and 30 minute steps above, up to a maximum of 480 minutes. After 480 minutes there is an option for Never.

The dim level can only be adjusted via the Settings panel - see Section 6.3.3.

Press the MENU button to store the selection and return to the main display.

4.5 External Triggering

External triggering is facilitated by the 'TRIG 1' and 'TRIG 2 connectors on the front panel of the unit - see Section 3.3.2.. These connectors are controlled via the APT software (see Section 6.3.4.) and provide a 5V logic level input/output that can be configured to support triggering from and to external devices.

4.5.1 Trigger In
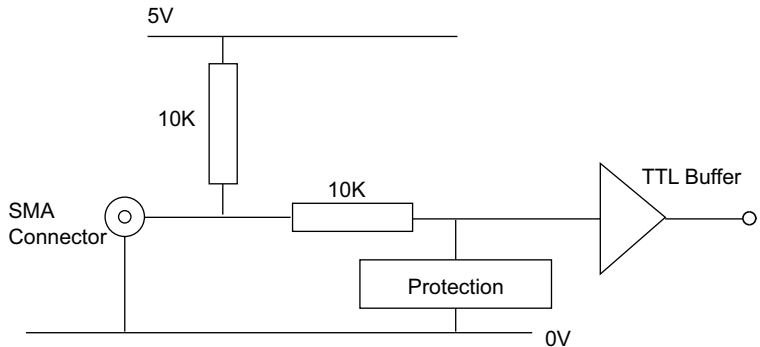
Fig. 4.3   TRIG IN Connection Detail

The TRIG Input contains a pull up resistor to an internal +5V supply, allowing it to be operated by passive devices (e.g. a switch or relay contact) as well as standard logic outputs. The protection circuit also allows the external signal to be in the ±10 V voltage range.

The input logic threshold levels are compatible with most TTL and CMOS logic circuits (input <0.8V is low and >2.4 V is high). Do not exceed the maximum voltage range of -10V to 10V.

4.5.2 Trigger In Latency

The trigger input will not accept another trigger request until the current move has completed, which imposes a restriction on how frequently moves can be triggered. In addition, there is a communications latency between the micro controller and the motion processor of up to 100 msec. This means that the maximum frequency at which triggered moves can be commanded is approximately 100 msec plus the duration of the move itself.

2

4.5.3 Trigger Out
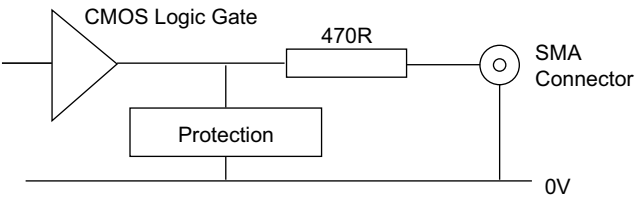
Fig. 4.4   TRIG OUT Connection Detail

The TRIG output is the output of a standard 5V CMOS logic gate in series with a 470Ω resistor. The resistor provides protection against accidentally short circuiting to ground by limiting the current to approx 10 mA maximum.

Do not connect the output to any voltage level outside the 0 to 5V range. It is recommended that the output is only used to drive external devices or equipment that has a high input resistance (>10 kΩ).

4.5.4 Trigger Out Latency
The detection of whether a trigger condition has occurred is carried out periodically at 102 μs intervals. As a result, there is a maximum 102 μs delay between the condition occurring and the trigger output being updated. The following timing diagram illustrates this latency:

Fig. 4.5   Triggering Latency

Chapter 5   PC Operation - Tutorial

5.1   Introduction

The following brief tutorial guides the user through a typical series of moves and parameter adjustments performed using the PC based APT software. It assumes that the unit is electrically connected as shown in Section 3.3.1.   that the APT Software is already installed - see Section 3.1. and that the stage being driven is the Thorlabs DDSM100 Direct Drive Translation stage.

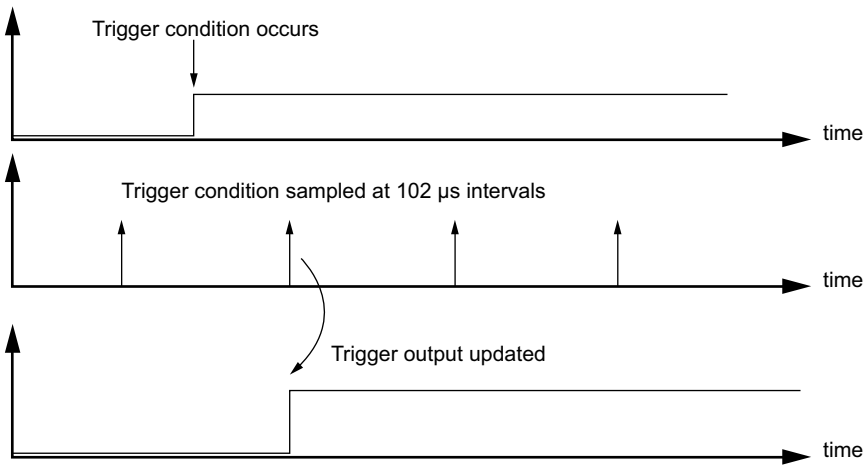| Warning |
|---|
| The APTServer includes built in safety features which prevent the user from performing a move before the actuators being driven have been 'homed'. If a custom software application, which operates outside of the APTServer, is being used to position the actuator, then these safety features will not be implemented. In this case, it is the responsibility of the user to home the motors before performing any further moves. Failure to home the motors will cause an error in positional information which could result in damage to the unit and possible injury to personnel operating the equipment. |

Caution
The maximum velocity at which the encoder can operate is approximately 600 mm/sec. Above this speed, encoder pulses may be lost and, as a result, the position readout becomes incorrect. This renders normal operation impossible because phase commutation of the motor is also based on the encoder reading.
When the stage is controlled by the KBD101 driver, the maximum velocity is limited to safe values. However, if the output is disabled (with the driver connected and monitoring the position) and the stage is moved manually at high speeds, it is possible to exceed this limit. If the KBD101 driver is subsequently used again to move the stage, the incorrect encoder reading will cause incorrect operation, often resulting in sudden uncontrolled moves. It is therefore important not to move the stage excessively quickly when it is moved manually.
The TBD driver has fault monitoring to detect the loss of encoder pulses. If this fault occurs, an error message will be generated and the driver must be powered down and re-started so that correct phasing and commutation can be established.

5.2 Verifying Software Operation

5.2.1 Initial Setup

The APT Software should be installed (Section 3.1.) and the power up procedure performed (Section 3.3.) before software operation can be verified.

1) Run the APTUser utility and check that the Graphical User Interface (GUI) panel appears and is active.
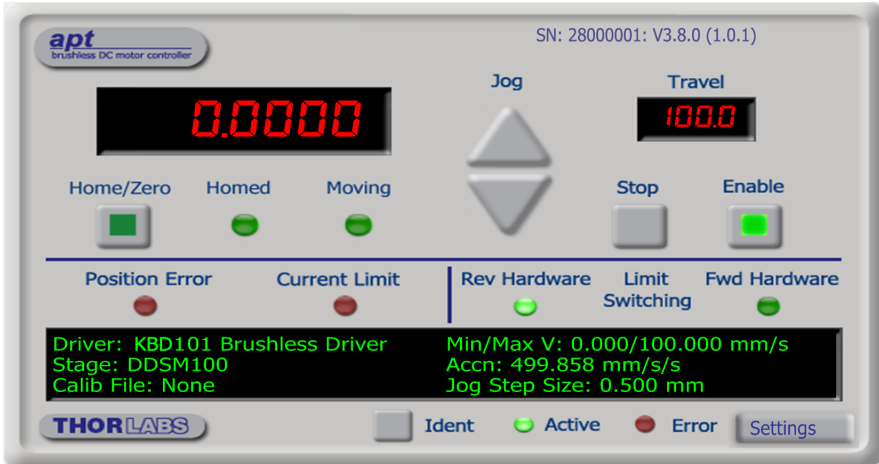
Fig. 5.1 GUI panel showing jog and ident buttons

2) Click the 'Ident' button. The ENABLE LED on the front panel of the associated driver flashes. This is useful in multi-channel systems for identifying which driver unit is associated with which GUI.

3) Click the 'Home/Zero button on the GUI panel and check that the motor or axis connected to the driver moves. See Section 5.4. for further details on homing.

Follow the tutorial steps described in Chapter 5 for further verification of 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 5.11. or the *APTConfig* helpfile for detailed instructions.

5.3   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 motor 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.
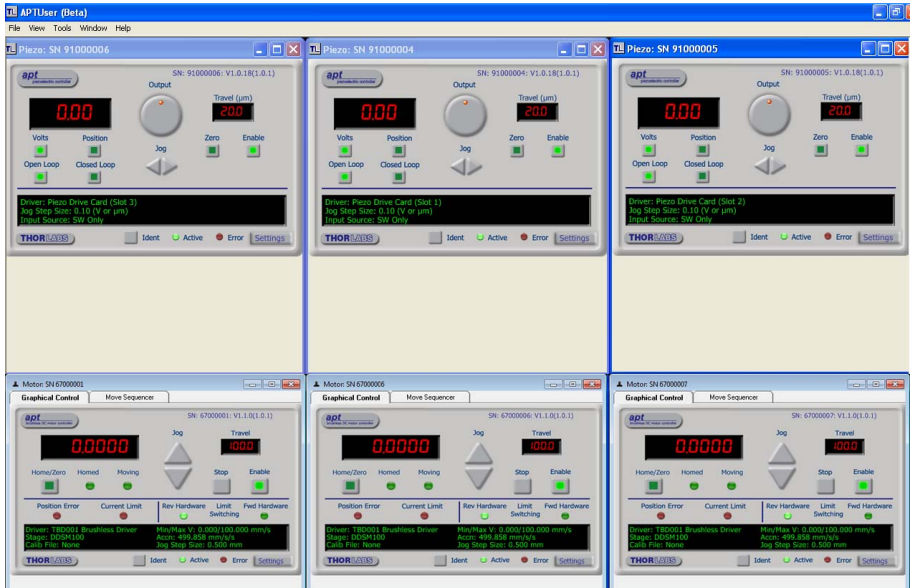
Fig. 5.2   Typical APT User Screen

1) Run the APT User program - Start/All Programs/Thorlabs/APT User/APT User.

5.4   Homing Motors

The need for homing comes from the fact that on power up the motor (stage) is at a random position, so the value of the position counter is meaningless. Homing involves moving the motor to a known reference marker and resetting the position counter to the associated absolute value. This reference marker can be one of the limit switches or can be provided by some other signal. The DDSM series stages use an electronic reference marker and therefore the limit switches are not used for reference.
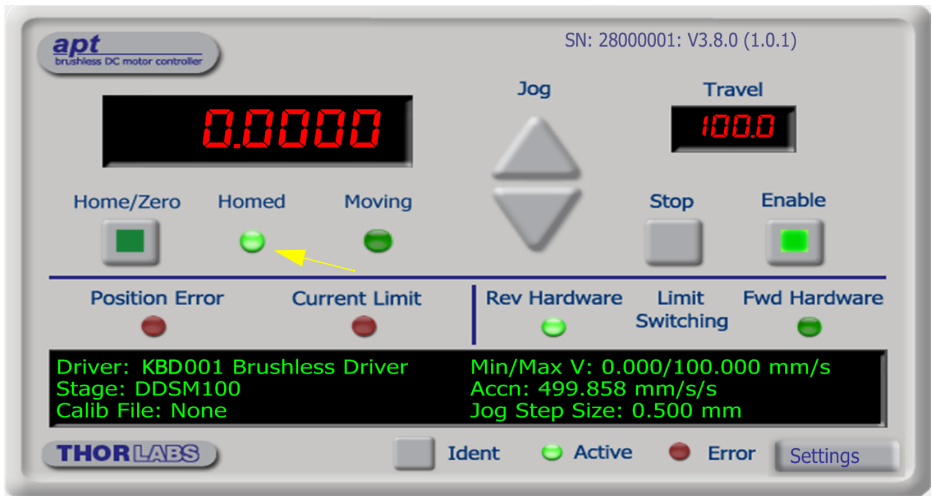
Fig. 5.3   Motor Controller Software GUI

1) Click the 'Home' button. Notice that the led in the button lights to indicate that homing is in progress.
2) When homing is complete, the 'Homed' LED is lit as shown above.

Note
If a move is demanded on a particular axis, before the axis has been 'Homed' then a Windows 'Event Information' panel is displayed, telling the user that the axis must be homed before operation.

5.5   Moving to an Absolute Position

Absolute moves are measured in real world units (e.g. millimetres), relative to the Home position.

1) Click the position display.
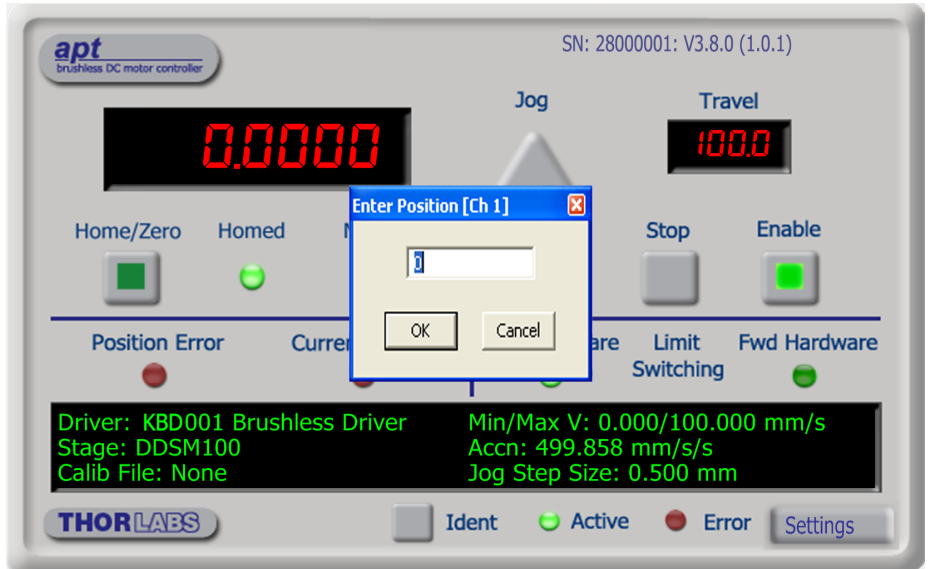
Fig. 5.4   Absolute Position Popup Window

2) Enter 3.0 into the pop up window
3) Click 'OK'. Notice that the position display counts up to 3.000 to indicate a move to the absolute position 3.00 mm.

5.6 Changing Motor Parameters

Note
Moves are performed using a Trapezoidal or S-Curve velocity profile (see Section 6.3.4.). The velocity settings relate to the maximum velocity at which a move is performed, and the acceleration at which the motor speeds up from zero to maximum velocity.

1) On the GUI panel, click the 'Settings' button (bottom right hand corner of the display) to display the Settings panel.
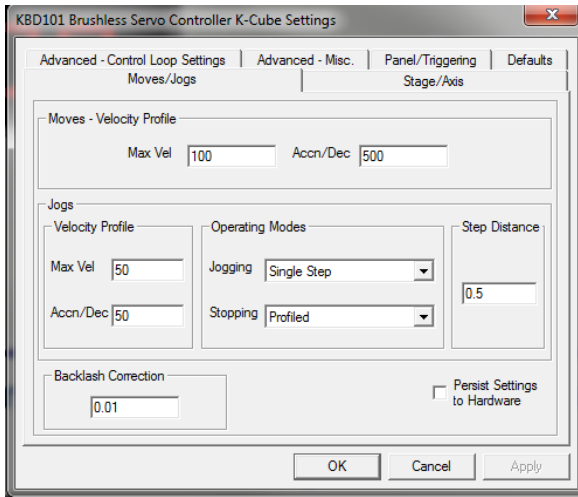
Fig. 5.5   Settings Panel - Move/Jogs Tab

2) Select the Move/Jogs tab as shown in Fig. 5.5.
3) In the 'Moves' field, change the parameters as follows:
   'Max. Vel' - '100'
   'Accn/Dec' - '500'
4) Click 'OK' to save the settings and close the window.
5) Any further moves initiated will now be performed at a maximum velocity of 100 mm per second, with an acceleration of 500 mm/sec/sec.

5.7   Jogging

During PC operation, the motor actuators are jogged using the GUI panel arrow keys. There are two jogging modes available, 'Single Step' and 'Continuous'. In 'Single Step' mode, the motor moves by the step size specified in the Step Distance parameter each time the key is pressed. In 'Continuous' mode, the motor actuator will accelerate and move at the jog velocity while the button is held down.

1) On the GUI panel, click the 'Settings' button to display the Settings panel.
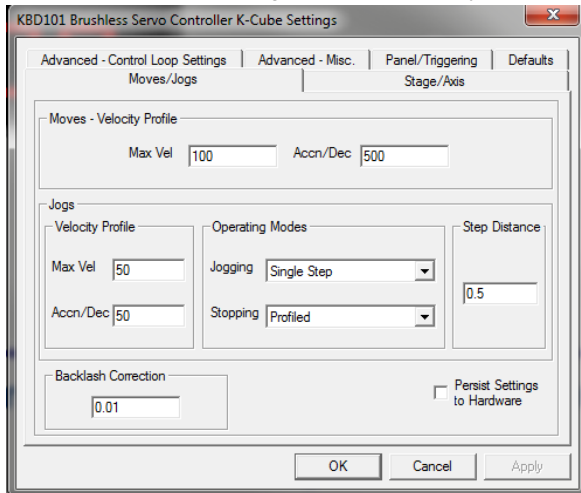
Fig. 5.6   Settings Panel - Move/Jogs Tab

2) Select the Move/Jogs tab as shown in Fig. 5.6.
3) In the 'Jogs' field, enter parameters as follows: (see Section 6.3.1. for details of these parameters).
    'Max. Vel' - '50'
    'Accn/Dec' - '50'

    Operating Modes
    'Jogging' - 'Single Step'
    'Stopping' - 'Profiled'

    'Step Distance' - '0.5'
4) Click 'OK' to save the settings and close the window.
5) Click the Jog Arrows on the GUI panel to jog the motor. Notice that the position display increments 0.5 mm every time the button is clicked.

![THORLABS]

5.8 Graphical Control Of Motor Positions (Point and Move)

The GUI panel display can be changed to a graphical display, showing the position of the motor channel(s). Moves to absolute positions can then be initiated by positioning the mouse within the display and clicking.

To change the panel view to graphical view, right click in the screen and select 'Graphical View'.

Fig. 5.7 KBD101 driver GUI Panel - Graphical View

Consider the display shown above for a KBD101 Motor Driver.

The right hand display shows the channel and motor unit parameters; i.e. controller unit type and serial number, associated stage and actuator type, minimum and maximum positions, current position, units per grid division and cursor position. All units are displayed in real world units, either millimetres or degrees.

Note
The channel functionality of the KBD101 driver is accessed via a single channel GUI panel, so the settings for channel 2 are greyed out.

The left hand display shows a circle, which represents the current position of the motor associated with the specified controller (absolute position data is displayed in the 'Chan Pos' field).

The vertical divisions relate to the travel of the stage/actuator being driven by the controller. For example, the screen shot above shows the parameters for a DDSM100 stage. The graph shows 10 divisions in the X axis, which relates to 100 mm of total travel (10 mm per division).

The graphical panel has two modes of operation, 'Jog' and 'Move', which are selected by clicking the buttons at the bottom right of the screen.

Move Mode

When 'Move' is selected, the motors move to an absolute position which corresponds to the position of the cursor within the screen.

To specify a move:

1) Position the mouse within the window. For reference, the absolute motor position values associated with the mouse position is displayed in the 'Cursor Position field.

2) Click the left hand mouse button to initiate the move.

Jog Mode

When 'Jogging' mode is selected, the motors are jogged each time the left mouse button is clicked.

The Jog direction corresponds to the position of the cursor relative to the circle (current motor position), e.g. if the cursor is to the left of the circle the motor will jog left. The Jog Step size is that selected in the Settings panel - see Section 6.3.

Stop

To stop the move at any time, click the 'Stop' button.

Returning to Panel View

To return to panel view, right click in the graphical panel and select 'Panel View'.

5.9   Loading Parameter Settings

Normally, when the APTServer is run up, the default settings for the system (e.g. move velocitiy, phase currents etc) are loaded. These values have been chosen to be suitable for the majority of applications. However, for applications where these settings need to be changed, the values can be saved to a 'Settings Group', which can be uploaded on subsequent start up. This is achieved via the APTUser utility, please see Section 6.3. for more details.

5.10   Setting Move Sequences

This section explains how to set move sequences, allowing several positions to be visited without user intervention.

For details on moving to absolute positions initiated by a mouse click – see Section 5.8.

1) From the Motor GUI Panel, select 'Move Sequencer' tab to display the Move Sequencer window.

Fig. 5.8 Move Sequencer Window

2) Right click, in the move data field to display the pop up menu.

Fig. 5.9 Move Sequencer Pop Up Menu

3) Select 'New' to display the 'Move Editor' panel.
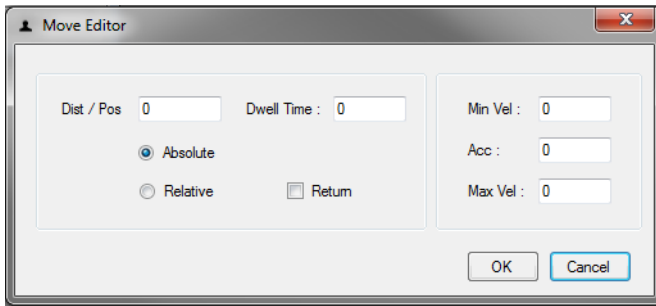
Fig. 5.10 Move Editor Window

Move data is entered/displayed as follows:

Dist/Pos: - the distance to move from the current position (if 'Relative' is selected) or the position to move to (if 'Absolute' is selected) (values entered in mm).

Dwell Time: - after the move is performed, the system can be set to wait for a specified time before performing the next move in the sequence. The Dwell time is the time to wait (in milliseconds).

Return - if checked, the system will move to the position specified in the Dist/Pos field, wait for the specified Dwell time, and then return to the original position.
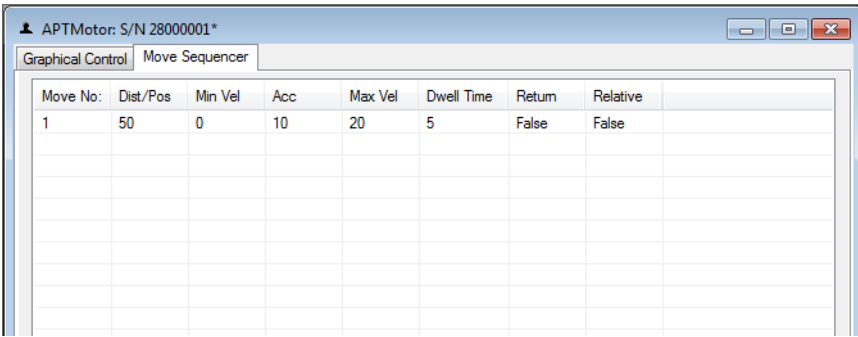
Min Vel: Acc: and Max Vel: - the velocity profile parameters for the move (velocity parameters are entered in mm/sec, acceleration in mm/sec/sec).

Note
In current versions of software, the 'Min Vel' parameter is locked at zero and cannot be adjusted.

The motor accelerates at the rate set in the Acc field up to the speed set in the Max Vel field. As the destination approaches, the motor decelerates again to ensure that there is no overshoot of the position.

4) Enter the required move data into the Move Editor and click OK. The move data is displayed in the main window as shown below.

Fig. 5.11 Main Window with Move Data

5) Repeat step 4 as necessary to build a sequence of moves. Move data can be copied, deleted, cut/pasted and edited by right clicking the data line(s) and selecting the appropriate option in the pop up menu (shown below).

Fig. 5.12 Pop Up Options

6) To run a single line of data, right click the appropriate data and select 'Run' from the pop up menu (shown above).

7) To run the entire sequence, click the 'Run' button (shown below). A Home move can also be performed from this panel by clicking the 'Home' button.
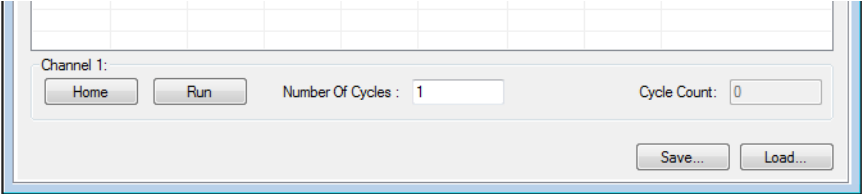
Fig. 5.13 Home and Run Buttons

8) To save data to a file, or load data from a previously saved file, click the 'Save' or 'Load' button and browse to the required location.

5.11 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.
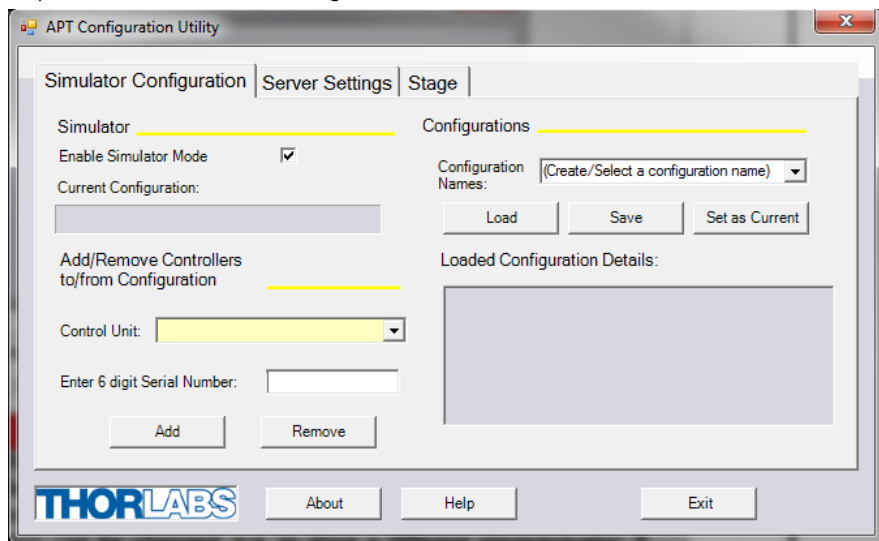
Fig. 5.14 APT Configuration Utility - Simulator Configuration Tab

3) Enter a name (e.g. '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.
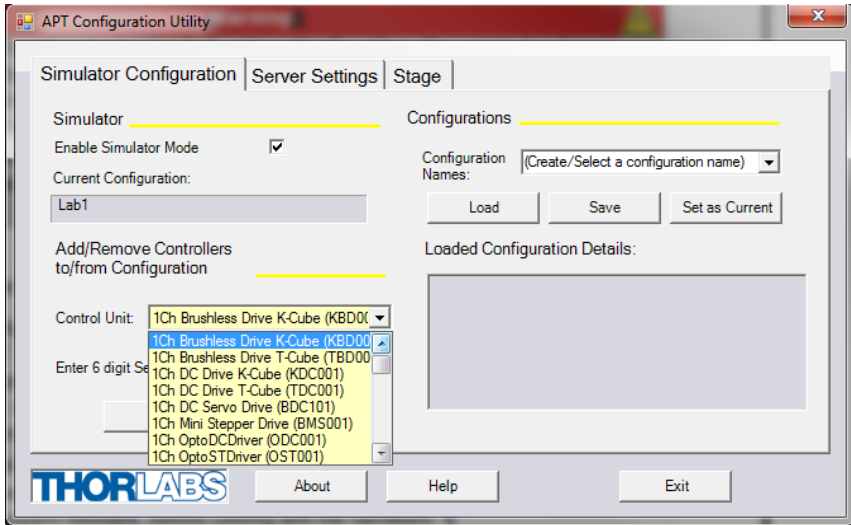
Note
Each physical APT hardware base unit is factory programmed with a unique 8 digit serial number. In order to simulate a set of 'real' hardware the Config utility allows an 8 digit serial number to be associated with each simulated unit. It is good practice when creating simulated configurations for 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 for the KBD101 Brushless DC Motor K-Cube are 28xxxxxx.

5) In the 'Control Unit' field, select '1 Ch Brushless Drive K-Cube (KBD101)'.
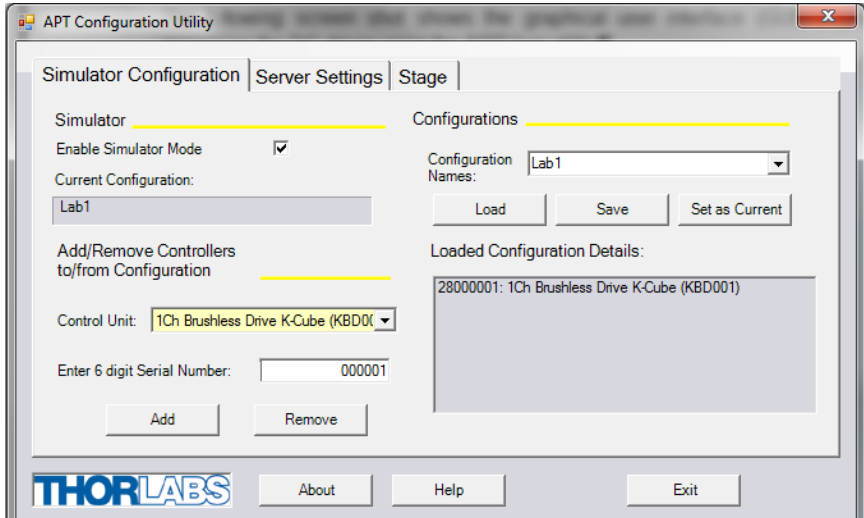
6) Enter a 6 digit serial number.
7) Click the 'Add' button.
8) Repeat items (1) to (7) to build the required system. (A unit can be removed from the configuration by selecting it in the 'Loaded Configuration Details' window and clicking the 'Remove' button or by right clicking it and selecting the 'Remove' 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 6 Software Reference

6.1 Introduction

This chapter gives an explanation of the parameters and settings accessed from the APT software running on a PC. For information on the methods and properties which can be called via a programming interface, see Appendix D   .

6.2 GUI Panel

The following screen shot shows the graphical user interface (GUI) displayed when accessing the DC driver using the APTUser utility.
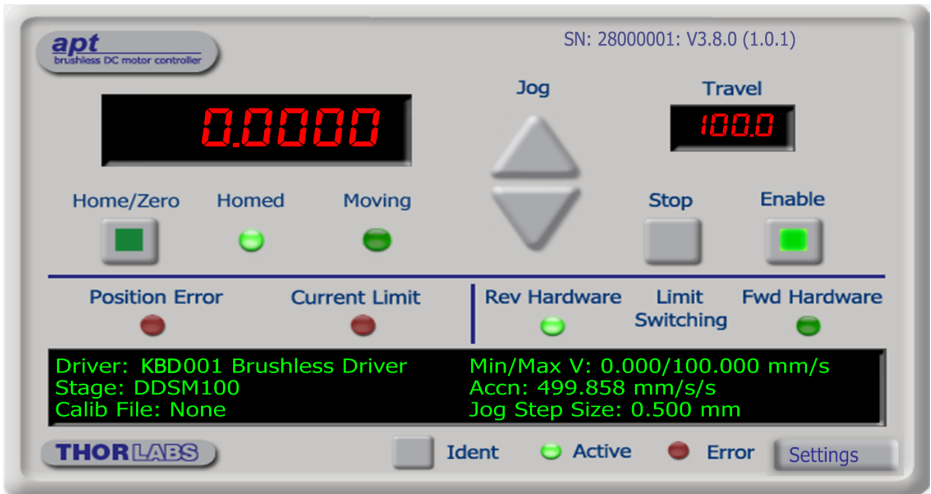
Fig. 6.1   Motor driver Software GUI

Note
The serial number of the driver 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.

Jog - used to increment or decrement the motor position. When the button is clicked, the motor is driven in the selected direction at the jog velocity one step per click. The step size and jog velocity parameters are set in the 'Settings' panel (see Section 6.3.).

Travel - the travel (in mm or degrees) of the actuator associated with the GUI panel.

Digital display - shows the position of the stage in millimetres (or degrees in the case of a rotation stage). The motor must be 'Homed' before the display will show a valid position value, (i.e. the displayed position is relative to a physical datum).

Home/Zero - sends the motor to its 'Home' position - The LED in the button is lit while the motor is homing.

Homed - lit when the motor has previously been 'Homed' (since power up).

Moving - lit when the motor is in motion.

Stop - halts the movement of the motor.

Enable - applies power to the motor. With the motor enabled, the associated Channel LED on the front panel is lit.

Position Error - lit when the associated axis has exceeded the position error limit setting - see Section 6.3.3.

Current Limit - lit when an 'current foldback' condition exists - Section 6.3.4.

Limit switches - the LEDs are lit when the associated limit switch has been activated.

Settings display - shows the following user specified settings:

Driver - the type of control unit associated with the specified channel.

Stage - the stage type and axis associated with the specified channel.

Note
The software automatically associates the stage/actuator type on bootup.

Calib File - the calibration file associated with the specified channel.

Note
Calibration files are not applicable for the Thorlabs Brushless DC motor stages such as the DDSM100.

Min/Max V - the minimum velocity at which a move is initiated, and the maximum velocity at which the move is performed. Values are displayed in real world units (mm/s or degrees/s), and can be set via the 'Settings' panel (see Section 6.3.).

Accn - the rate at which the velocity climbs to, and slows from, maximum velocity, displayed in real world units (mm/s/s or degrees/s/s). The acceleration can be set via the 'Settings' panel (see Section 6.3.) and is used in conjunction with the Min/Max velocity settings to determine the velocity profile of a motor move.

Jog Step Size - the size of step (mm or degrees) taken when the jog signal is initiated. The step size can be set either via the Settings panel or by calling the SetJogStepSize method.

Settings button - Displays the 'Settings' panel, which allows the motor drive's operating parameters to be entered - see Section 6.3.

Ident - when this button is pressed, the LED (on the front panel of the unit) associated with the selected channel will flash for a short period.

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

Error - lit when a fault condition occurs.

6.3   Settings Panel

When the 'Settings' button on the GUI panel is clicked, the 'Settings' window is displayed. This panel allows motor operation parameters such as move/jog velocities, and stage/axis information to be modified. 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* for further details and to Section 2.3.4. for an overview of the APT ActiveX controls). The various parameters are described below.

6.3.1   Moves/Jogs tab
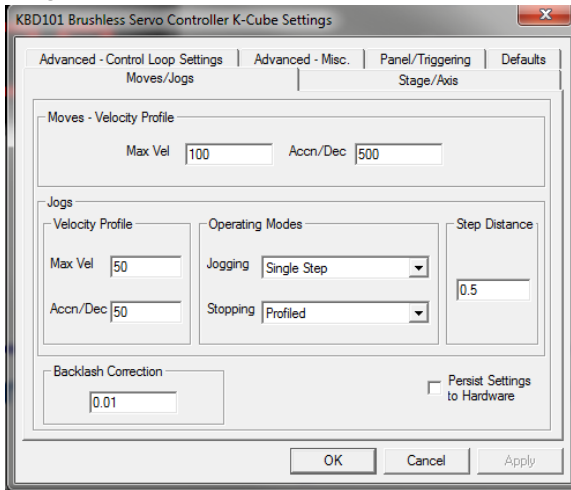
Fig. 6.2   Move/Jog Settings

Moves - Velocity Profile

Moves can be initiated via the GUI panel by entering a position value after clicking on the position display box (see Section 5.5.) or by calling a software function (see the APTServer helpfile). The following settings determine the velocity profile of such moves, and are specified in real world units, millimetres or degrees.

MaxVel - the maximum velocity (in mm/sec) at which to perform a move.

Accn/Dec - the rate at which the velocity climbs from zero to maximum, and slows from maximum to zero (in mm/sec^2).

Note

Under certain velocity parameter and move distance conditions, the maximum velocity may never be reached (i.e. the move comprises an acceleration and deceleration phase only).

The limits for the max velocity or acceleration parameters are dependent on the stage being driven. They can be obtained by calling the *GetVelParamLimits* method.

The move is also affected by the 'Profile' and 'Jerk' settings in the Advanced - Misc. tab.

Jogs

Jogs are initiated by using the 'Jog' buttons on the GUI panel (see Section 5.7.).

Velocity Profile (specified in real world units, i.e. millimetres)

MaxVel - the maximum velocity at which to perform a jog.

Accn/Dec - the rate at which the velocity climbs from zero to maximum, and slows from maximum to zero.

Note

The limits for the max velocity or acceleration parameters are dependent on the stage being driven. They can be obtained by calling the *GetVelParamLimits* method.

Operating Modes

Jogging - The way in which the motor moves when a jog command is received (i.e. GUI panel button clicked).

There are two jogging modes available, 'Single Step' and 'Continuous'. In 'Single Step' mode, the motor moves by the step size specified in the Step Distance parameter, each time the jog key is pressed - see Fig. 6.3. In 'Continuous' mode, the

motor actuator will accelerate and move at the jog velocity while the button is held down..
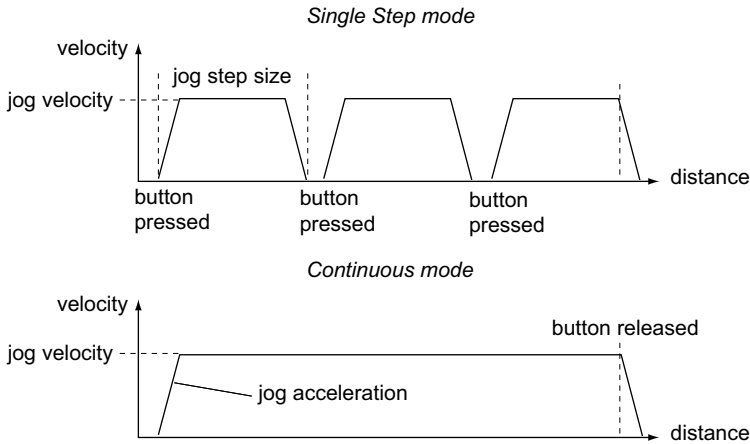
Single Step mode

Fig. 6.3 Jog Modes

Single Step - the motor moves by the step size specified in the Step Distance parameter.

Continuous - the motor continues to move until the jog signal is removed (i.e. jog button is released).

Stopping - the way in which the jog motion stops when the demand is removed.

Immediate - the motor stops quickly, in a non-profiled manner

Profiled - the motor stops in a profiled manner using the jog Velocity Profile parameters set above.

Step Distance - The distance to move when a jog command is initiated. The step size is specified in real world units (mm).

Backlash Correction - Backlash is a term used to describe the errors inherent in motors which use a leadscrew. Brushless linear DC motors have no leadscrew and therefore this parameter is normally set to 0.

For motors which do incorporate a leadscrew, when this parameter is set the system will overshoot the demanded set point by the specified amount, and then reverse.

This ensures that during absolute or relative moves, the target position is always approached in a forward direction. The Backlash Correction Distance is specified in real world units (millimeters).

To remove backlash correction, this value should be set to zero.

Note. Setting a negative value for backlash correction also results in zero correction.

Persist Settings to Hardware - Many of the parameters that can be set for the KBD101 series drivers can be stored (persisted) within the unit itself, such that when the unit is next powered up these settings are applied automatically. This is particularly important when the driver is being used manually via the top panel, in the absence of a PC and USB link. The *Move and Jog* 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.

6.3.2 Stage/Axis tab
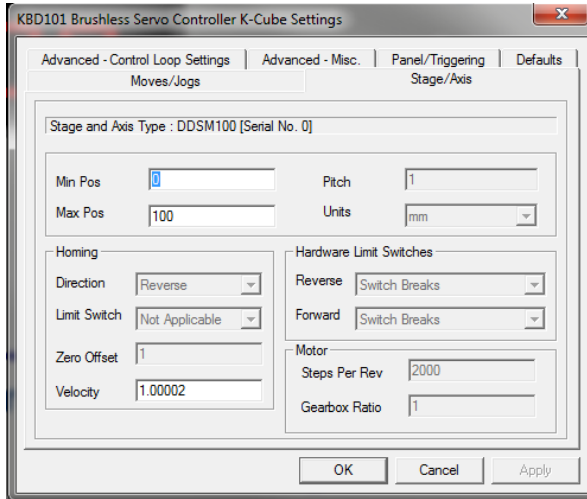
Fig. 6.4   Stage/Axis Settings

Note
This tab contains a number of parameters which are related to the physical characteristics of the particular stage being driven. They need to be set accordingly such that a particular stage is driven properly by the system.
For Thorlabs stages, the APT server will automatically apply suitable defaults for the parameters on this tab during boot up of the software. Most of these parameters cannot subsequently be altered as it may adversely affect the performance of the stage and they are greyed out. Description of these parameters is included for information only.

Stage and Axis Type - The stage type and serial number are displayed. This information should always be quoted when requesting technical support.

⚠ Caution ⚠
Extreme care must be taken when modifying the stage related settings that follow. Some settings are self consistent with respect to each other, and illegal combinations of settings can result in incorrect operation of the physical motor/stage combination being driven. Consult Thorlabs for advice on settings for stage/actuator types that are not selectable via the APTConfig utility.

Min Pos - the stage/actuator minimum position (typically zero).

Max Pos - the stage/actuator maximum position.

Note

The *Min Pos* and *Max Pos* parameters can be used to restrict the working range of the stage to a particular area of interest.

Pitch - the pitch of the motor lead screw (i.e. the distance (in mm or degrees) travelled per revolution of the leadscrew). Not applicable to DDSM100 stages and preset to '1'.

Units - the 'real world' positioning units (mm or degrees).

Note

***For DDSM100 users*. The Homing, Limit Switch and Motor parameters described on the next two pages are not applicable for the DDSM100 stages because the stage does not use a limit switch as a reference point for homing. Instead, it uses a special reference marker pulse from the encoder. Homing on these stages involves a search for this reference marker. Initially, the stage moves in the forward direction and if the reference marker is found before the stage hits the forward limit switch, then homing is completed. If not, the stage reverses direction and continues to search for the reference marker. Due to the different method used, only the Homing Velocity parameter can be adjusted, although normally the default value is suitable for nearly all applications. All other parameters are greyed out.**

Homing

When homing, a stage typically moves in the reverse direction, (i.e. towards the reverse limit switch). The following settings allow support for stages with both Forward and Reverse limits.

Note

Typically, the following two parameters are set the same, i.e. both Forward or both Reverse.

Direction - the direction sense to move when homing, either *Forward* or *Reverse*.

Limit Switch - The hardware limit switch associated with the home position, either *Forward HW or Reverse HW*.

Zero Offset - the distance offset (in mm or degrees) from the limit switch to the Home position.

Velocity - the maximum velocity at which the motors move when Homing.

Note

The minimum velocity and acceleration/deceleration parameters for a home move are taken from the existing move velocity profile parameters

---

Hardware Limit Switches

These parameters are inherent in the design of the associated stage or actuator. Default values are loaded on boot up and are not adjustable. The parameters notify the system to the action of the switches when contact is made, i.e. Rev Switch or Fwd Switch as required.

Switch Makes - The switch closes on contact
Switch Breaks - The switch opens on contact
Ignore/Absent - The switch is missing, or should be ignored.
Not Applicable - Limit switches are not applicable.

Motor

These parameters are used to set the 'resolution' characteristics of the DC motor connected to the selected channel. The resolution of the motor, combined with other characteristics (such as gearbox ratio) of the associated actuator or stage, determines the overall resolution.

Steps Per Rev - The number of encoder counts per revolution of the DC servo motor (minimum '1', maximum '10,000').

For linear stages (e.g. DDSM100) this parameter is set to '1' and cannot be adjusted.

Note
The *Gearbox Ratio* parameter is applicable only to motors fitted with a gearbox.

Gearbox Ratio - The ratio of the gearbox. For example, if the gearbox has a reduction ratio of X:1 (i.e. every 1 turn at the output of the gearbox requires X turns of the motor shaft) then the Gearbox Ratio value is set to X. (minimum '1', maximum '1000').

For linear driven stages with no gearbox (e.g. DDSM100) this parameter is set to '1' and cannot be adjusted.

Note
The 'Steps Per Rev' and 'Gearbox Ratio' parameters, together with the 'Pitch' and 'Units' parameters are used to calculate the calibration factor for use when converting real world units to encoder counts.
The correct default values for Steps Per Rev and Gearbox Ratio are applied automatically when the software is booted up.

Persist Settings to Hardware - Many of the parameters that can be set for the KBD101 series drivers can be stored (persisted) within the unit itself, such that when the unit is next powered up these settings are applied automatically. This is particularly important when the driver is being used manually via a joystick, in the absence of a PC and USB link. The *Min Pos, Max Pos, and Velocity* 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.

6.3.3   Advanced - Control Loop SettingsTab
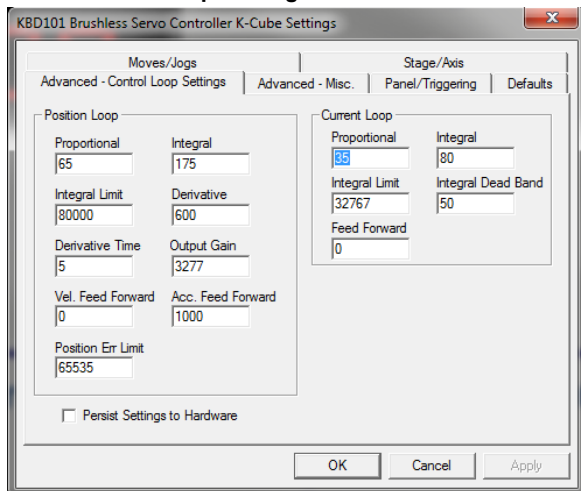
Fig. 6.5 Advanced Control Loop Settings

Position Loop Control Settings

The motion processors within the KBD101 driver uses a position control loop to determine the motor command output. The purpose of the position loop is to match the actual motor position and the demanded position. This is achieved by comparing the demanded position with the actual encoder position to create a position error, which is then passed through a digital PID-type filter. The filtered value is the motor command output.

Caution
The PID and other closed loop parameters must be set according to the stage or actuator type associated with the driver, the load being positioned and the speed/duty cycle of operation. Default values have already been optimized and stored within the stage, and these are loaded into the controller on power up. If problems are encountered (e.g. stability of the closed loop position control, lost motion or incomplete moves) the position PID parameters should 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 cases where further adjustment of the control loop parameters is required, the following guidelines are provided in order to assist in the tuning process.

Proportional term - Increasing the proportional (Prop) term will increase the amount of effective torque used to correct a given position error. Typically this is used to minimize the amount of position error when an impulse event affects current target position during motion. i.e. sticksion, vibration etc.If the proportional term is too high

this can lead to overshoot and general instability. If this is too low it can result in a sloppy response. It accepts values in the range 0 to 32767.

Integral term - Increasing the integral (Int) term minimises following error and final position error. If Integral is too high this will typically lead to motion overshoot during and at end of move. If the integral term is too low final position may take a long time to reach, if at all. It accepts values in the range 0 to 32767.

Integral limit - Limits the wind up limit for the integral term such that excessive overshoots are prevented. Typically used to prevent runaway integral calculations due to stiction and other such physical forms of random forces. Normally set as low as possible, but high enough that with the given integral term final position can be reached. It accepts values in the range 0 to 32767. If set to 0 then the integration term in the PID loop is ignored.

Derivative term - Increasing the derivative (Deriv) term decreases the rate of change of driver output. Typically this is used to reduce the overshoot from a given motion. If derivative is too high it can become sensitive to noise from the measured position error. If derivative is too low, velocity fluctuations may arise during motion. It accepts values in the range 0 to 32767.

Derivative Time–Time over which derivative is calculated. Under normal circumstances, the derivative term of the PID loop is recalculated at every servo cycle. However, it may be desirable to increase the sampling rate to a higher value, in order to increase stability. The *Derivative Time* parameter is used to set the sampling rate. For example if set to 10, the derivative term is calculated every 10 servo cycles. The value is set in cycles, in the range 1 to 32767 (1 cycle = 102.4 µs). Typically increasing the derivative time increases sensitivity to noise.

Output Gain – This parameter is a scaling factor applied to the output of the PID loop. It accepts values in the range 0 to 65535, where 0 is 0% and 65535 is 100%. Typically used to tighten a control loop for increased positional performance at the expense of stability.

Vel. Feed Forward and *Acc. Feed Forward* – These parameters are velocity and acceleration feed-forward terms that are added to the output of the PID filter to assist in tuning the motor drive signal. They accept values in the range 0 to 32767.

Position Err. Limit – Under certain circumstances, the actual encoder position may differ from the demanded position by an excessive amount. Such a large position error is often indicative of a potentially dangerous condition such as motor failure, encoder failure or excessive mechanical friction. To warn of, and guard against this condition, a maximum position error can be set in the *Position Err. Limit* parameter, in the range 0 to 65535. The actual position error is continuously compared against the limit entered, and if exceeded, the Motion Error bit (bit 15) of the Status Register is set, the associated axis is stopped and the GUI panel Position Error LED is lit.

Note
The position error limit is monitored only when the motor is enabled (i.e. the feedback loop is active)..

Position PID Settings Summary

Stage overshoots the intended position - reduce Int and increase Deriv and Prop terms.

Stage doesn't attain final position - increase the Int and Prop terms.

Motion is unstable - reduce Prop and Int, increase Deriv.

Stage sounds noisy - reduce Deriv.

Current Loop Control Settings

The motion processor within the TBD driver uses digital current control as a technique to control the current through each phase winding of the motors. In this way, response times are improved and motor efficiency is increased. This is achieved by comparing the required current with the actual current to create a current error, which is then passed through a digital PI-type filter. The filtered current value is used to develop an output voltage for each motor coil. The following parameters allow this signal to be tuned for a fast response and low error when moving to the demanded position.

Note
These parameters are specific to the motor within the stage. Default values are set at the factory and under normal circumstances do not need to be changed.

Proportional – This term drives the motor current to the demand value, reducing the current error. It accepts values in the range 0 to 32767.

Integral – This term provides the 'restoring force' that grows with time, ensuring that the current error is zero under a constant torque loading. It accepts values in the range 0 to 32767.

Integral Limit – This term is used to cap the value of the Integrator to prevent an excessive build up over time of the 'restoring force', thereby causing runaway of the integral sum at the output. It accepts values in the range 0 to 32767. If set to 0 then the integration term in the PI loop is ignored.

Note
The following two parameters assist in fine tuning the motor drive current and help reduce audible noise and/or oscillation when the stage is in motion. A certain amount of trial and error may be experienced in order to obtain the optimum settings.

Integral Dead Band – This parameter allows an integral dead band to be set, such that when the error is within this dead band, the integral action stops, and the move is completed using the proportional term only. It accept values in the range 0 to 32767.

Feed Forward – This parameter is a feed-forward term that is added to the output of the PI filter. It accept values in the range 0 to 32767.

Persist Settings to Hardware - Many of the parameters that can be set for the KBD101 series drivers can be stored (persisted) within the unit itself, such that when the unit is next powered up these settings are applied automatically. This is particularly important when the driver is being used manually via a joystick, in the absence of a PC and USB link. The *Position and Current Loop* 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.

6.3.4   Advanced - Misc. Tab
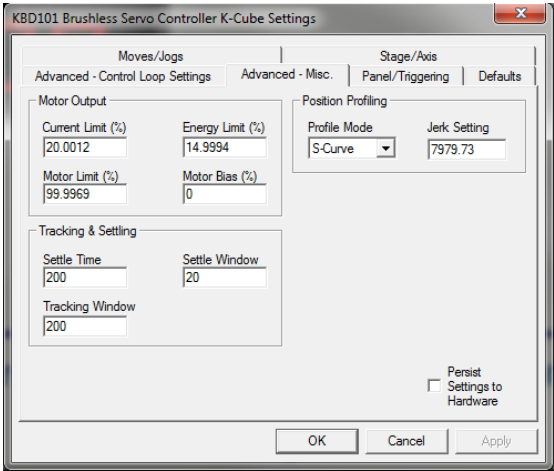
Fig. 6.6 Advanced Miscellaneous Settings

Motor Output Settings

⚠	Caution	⚠
	The default values programmed into the APT software will give acceptable performance in most cases. The following parameters are set according to the stage or actuator type associated with the driver and have already been optimized. Changing these parameters can result in control instability and possible damage. Use extreme caution if adjusting these parameters.	

Current Limit – The system incorporates a current 'foldback' facility, whereby the continuous current level can be capped. The *Current Limit* parameter, accepts values as a percentage of maximum peak current, in the range 0% to 100%, which is the default maximum level set at the factory (this maximum value cannot be altered).

Energy Limit – When the current output of the drive exceeds the limit set in the *Current Limit* parameter, accumulation of the excess current energy begins. The *Energy Limit* parameter specifies a limit for this accumulated energy, as a percentage of the factory set default

maximum, in the range 0% to 100%. When the accumulated energy exceeds the value specified in the *Energy Limit* parameter, a 'current foldback' condition is said to exist, and the commanded current is limited to the value specified in the *Current Limit* parameter. When this occurs, the Current Foldback status bit (bit 25) is set in the Status Register and the 'Current Limit' LED on the GUI panel is lit. When the accumulated energy above the *Current Limit* value falls to 0, the limit is removed and the status bit is cleared.

Motor Limit – This parameter sets a limit for the motor drive signal and accepts values in the range 0 to 100% (32767). If the system produces a value greater than the limit set, the motor command takes the limiting value. For example, if the *Motor Limit* is set to 30000 (91.6%), then signals greater than 30000 will be output as 30000 and values less than -30000 will be output as -30000.

Motor Bias – When an axis is subject to a constant external force in one direction (such as a vertical axis pulled downwards by gravity) the servo filter can compensate by adding a constant DC bias to the output. This bias is set in the *Motor Bias* parameter, which accepts values in the range -32768 to 32767. The default value is 0. Once set, the motor bias is applied while the position loop is enabled.

Tracking & Settling Settings

Moves are generated by an internal profile generator, and are based on either a trapezoidal or s-curve trajectory (see Section 6.3.3.). A move is considered complete when the profile generator has completed the calculated move and the axis has 'settled' at the demanded position.

The system incorporates a monitoring function, which continuously indicates whether or not the axis has 'settled'. The 'Settled' indicator is bit 14 in the Status Register and is set when the associated axis is settled. Note that the status bit is controlled by the processor, and cannot be set or cleared manually.

The axis is considered to be 'settled' when the following conditions are met:

- the axis is at rest (i.e. not performing a move),
- the error between the demanded position and the actual motor position is less than or equal to the specified number of encoder counts (0 to 65535) set in the *Settle Window* field,
- the above two conditions have been met for a specified number of cycles (1 cycle = 102.4 µs), set in the *Settle Time* field (range 0 to 32767).

The above settings are particularly important when performing a sequence of moves. If the PID parameters (see Section 6.3.3.) are set such that the settle window cannot be reached, the first move in the sequence will never complete, and the sequence will stall. The settle window and settle time values should be specified carefully, based on the required positional accuracy of the application. If positional accuracy is not a major concern, the settle time should be set to '0'. In this case, a move will complete when the motion calculated by the profile generator is completed, irrespective of the actual position attained, and the settle parameters described above will be ignored.

The processor also provides a 'tracking window' which is used to monitor servo performance outside the context of motion error. The tracking window is a programmable position error limit within which the axis must remain, but unlike the

Position Err Limit parameter set in the *Advanced - Control Loop Settings* tab, the axis is not stopped if it moves outside the specified tracking window.

This function is useful for processes that rely on the motor's correct tracking of a set trajectory within a specific range. The tracking window may also be used as an early warning for performance problems that do not yet qualify as motion error.

The size of the tracking window (i.e. the maximum allowable position error while remaining within the tracking window) is specified in the *Tracking Window* field, in the range 0 to 65535. If the position error of the axis exceeds this value, the Tracking Indicator status bit (bit 13) is set to 0 in the Status Register. When the position error returns to within the window boundary, the status bit is set to 1 - see the *APTServer helpfile* for details on accessing the status register.

Position Profiling

To prevent the motor from stalling, it must be ramped up gradually to its maximum velocity. Certain limits to velocity and acceleration result from the torque and speed limits of the motor, and the inertia and friction of the parts it drives.

The system incorporates a trajectory generator, which performs calculations to determine the instantaneous position, velocity and acceleration of each axis at any given moment. During a motion profile, these values will change continuously. Once the move is complete, these parameters will then remain unchanged until the next move begins.

The specific move profile created by the system depends on several factors, such as the profile mode and profile parameters presently selected, and other conditions such as whether a motion stop has been requested.

Profile Mode – This field is used to set the profile mode to either *Trapezoidal* or *S-curve.* In either case, the velocity and acceleration of the profile are specified using the *Velocity Profile* parameters on the *Moves/Jogs tab.*

The *Trapezoidal* profile is a standard, symmetrical acceleration/deceleration motion curve, in which the start velocity is always zero.

In a typical trapezoidal velocity profile, (see Fig. 6.7.), the stage is ramped at acceleration '*a*' to a maximum velocity '*v*'. As the destination is approached, the stage is decelerated at '*a*' so that the final position is approached slowly in a controlled manner.
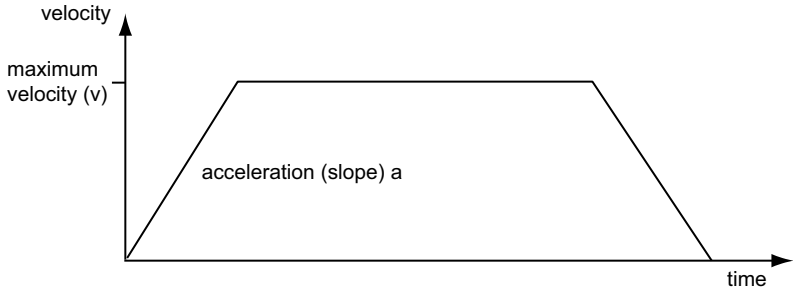
Fig. 6.7   Graph of a trapezoidal velocity profile

The *S-curve* profile is a trapezoidal curve with an additional 'Jerk' parameter, which limits the rate of change of acceleration and smooths out the contours of the motion profile.

Jerk Setting – This parameter is specified in mm/s^3 and accepts values in the range 0 to 46566139. It is used to specify the maximum rate of change in acceleration in a single cycle of the basic trapezoidal curve.

In this profile mode, the acceleration increases gradually from 0 to the specified acceleration value, then decreases at the same rate until it reaches 0 again at the specified velocity. The same sequence in reverse brings the axis to a stop at the programmed destination position.

Example
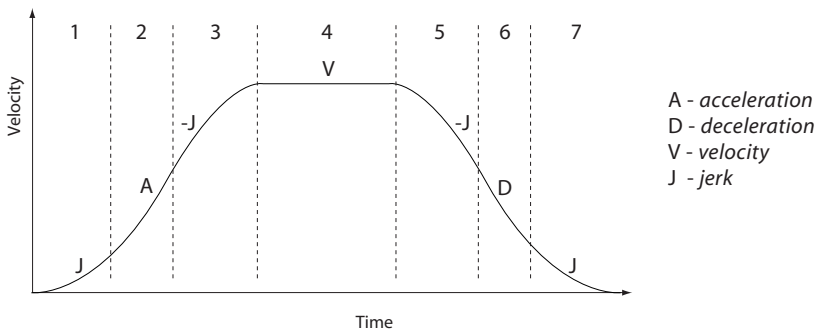
Fig. 6.8   Typical S-Curve Profile

The figure above shows a typical S-curve profile. In segment (1), the S-curve profile drives the axis at the specified jerk (J) until the maximum acceleration (A) is reached. The axis continues to accelerate linearly (jerk = 0) through segment (2) . The profile then applies the negative value of jerk to reduce the acceleration to 0 during segment (3). The axis is now at the maximum velocity (V), at which it continues through segment (4). The profile then decelerates in a similar manner to the acceleration phase, using the jerk value to reach the maximum deceleration (D) and then bring the axis to a stop at the destination.

6.3.5 Panel/Triggering Tab
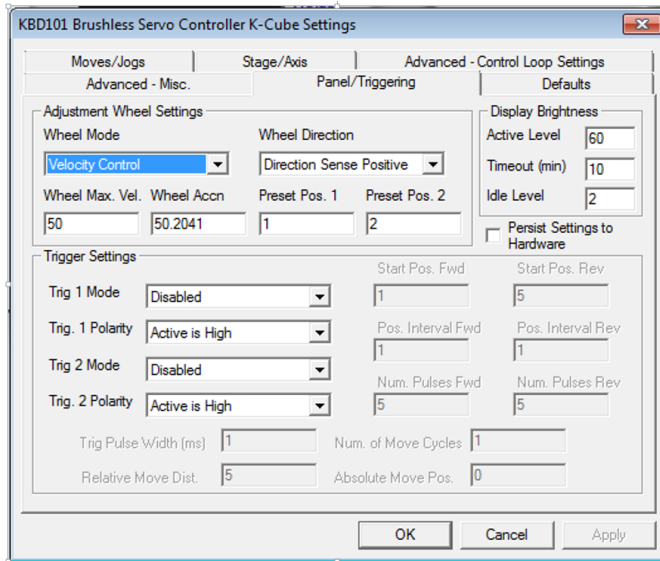
Adjustment Wheel Settings

The velocity wheel is sprung such that when released it returns to it's central position. In this central position the motor is stationary. As the wheel is moved away from the center, the motor begins to move; the speed of this movement increases as the wheel deflection is increased. Bidirectional control of motor moves is possible by moving the wheel in both directions.

Wheel Mode

> *Velocity Control* - Deflecting the wheel starts a move with the velocity proportional to the deflection. The maximum velocity (i.e. velocity corresponding to the full deflection of the joystick wheel) and acceleration are set in the *Max Wheel Vel.* and *Wheel Accn.* parameters.

> *Position Jogging* - Deflecting the wheel initiates a jog move, using the parameters specified by the Move/Jogs tab. Keeping the wheel deflected repeats the move automatically after the current move has completed.

> *Go To Position* - Deflecting the wheel starts a move from the current position to one of the two predefined "teach" positions. The teach positions are specified in the *Preset Pos. 1* and *Preset Pos. 2* parameters, and are measured in number of steps from the home position.

Wheel Direction

The direction of a move initiated by the velocity wheel is specified as follows:

Disabled - The wheel is disabled to remove any unwanted motion due to accidental movement of the wheel.

Direction Sense Positive - Upwards rotation of the wheel results in a positive motion (i.e. increased position count).

Note. The following option applies only when the Wheel Mode is set to Velocity Control. If set to Position Jogging or Go to Position Mode, the following option is ignored.

Direction Sense Negative - Upwards rotation of the wheel results in a negative motion (i.e. decreased position count).

Disp. Brightness

In certain applications, it may be necessary to adjust the brightness of the LED display on the top of the unit. The brightness is set in the *Active Level* parameter, as a value from 0 (Off) to 100 (brightest). The display can be turned off completely by entering a setting of zero, however, pressing the MENU button on the top panel will temporarily illuminate the display at its lowest brightness setting to allow adjustments. When the display returns to its default position display mode, it will turn off again.

Furthermore, 'Burn In' of the display can occur if it remains static for a long time. To prevent this, the display is automatically dimmed after the time interval specified in the *Timeout (min)* parameter has elapsed. The time interval is specified in minutes in the range 0 (never dimmed) to 480. The dim level is set in the *Idle Level* parameter, as a value from 0 (Off) to 10 (brightest) but is also limited by the *Active Value* parameter if this is lower.

Persist Settings to Hardware - Many of the parameters that can be set for the DC Driver K-Cube can be stored (persisted) within the unit itself, such that when the unit is next powered up these settings are applied automatically. This is particularly important when the driver is being used manually in the absence of a PC and USB link. The wheel, and trigger parameters described here are good examples of settings that can be altered and then persisted in the driver for use in absence of a PC. To save the settings to hardware, check the 'Persist Settings to Hardware' checkbox before clicking the 'OK button.

Caution

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

Triggering Introduction

The K-Cube motor controllers have two bidirectional trigger ports (TRIG1 and TRIG2) that can be used to read an external logic signal or output a logic level to control external equipment. Either of them can be independently configured as an input or an output and the active logic state can be selected High or Low to suit the requirements of the application. Electrically the ports output 5 Volt logic signals and are designed to be driven from a 5 Volt logic.

When the port is used in the input mode, the logic levels are TTL compatible, i.e. a voltage level less than 0.8 Volt will be recognized as a logic LOW and a level greater than 2.4 Volt as a logic HIGH. The input contains a weak pull-up, so the state of the input with nothing connected will default to a logic HIGH. The weak pull-up feature allows a passive device, such as a mechanical switch to be connected directly to the input.

When the port is used as an output it provides a push-pull drive of 5 Volts, with the maximum current limited to approximately 8 mA. The current limit prevents damage when the output is accidentally shorted to ground or driven to the opposite logic state by external circuity.

Warning: do not drive the TRIG ports from any voltage source that can produce an output in excess of the normal 0 to 5 Volt logic level range. In any case the voltage at the TRIG ports must be limited to -0.25 to +5.25 Volts.

Input Trigger Modes

When configured as an input, the TRIG ports can be used as a general purpose digital input, or for triggering a relative, absolute or home move. When used for triggering a move, the port is edge sensitive. In other words, it has to see a transition from the inactive to the active logic state (Low->High or High->Low) for the trigger input to be recognized. For the same reason a sustained logic level will not trigger repeated moves. The trigger input has to return to its inactive state first in order to start the next trigger. The mode is set in the *Trig 1 Mode* and *Trig 2 Mode* parameters as follows:

Disabled - The trigger IO is disabled

Digital Input - General purpose logic input (read through status bits using the LLGetStatusBits method).

Trig In Rel. Move - Input trigger for relative move.

Trig In Abs. Move - Input trigger for absolute move.

Trig In Home - Input trigger for home move.

When the trigger mode is selected to *Trig In Rel Move* or *Trig In Abs Move*, the relative distance or absolute position to move, can be entered in the *Relative Move Dist* and *Absolute Move Pos*. parameters.

Output Trigger Modes

When the *Trig 1 Mode* and *Trig 2 Mode* parameters are configured as outputs, the TRIG ports can be used as a general purpose digital output, or to indicate motion status or to produce a trigger pulse at configurable positions as follows:

Digital Output - General purpose logic output (set using the LLSetGetDigOPs method).

Trig Out In Motion - Trigger output active (level) when motor 'in motion'. The output trigger goes high (5V) or low (0V) (as set in the Trig 1. Polarity and Trig. 2 Polarity parameters) when the stage is in motion.

Trig Out Max Vel - Trigger output active (level) when motor at 'max velocity'.

Trig Out Pos. Steps Fwd - Trigger output active (pulsed) at pre-defined positions moving forward. Only one Trigger port at a time can be set to this mode. See Trigger Out Position Steps for further details.

Trig Out Pos. Steps Rev - Trigger output active (pulsed) at pre-defined positions moving backwards. Only one Trigger port at a time can be set to this mode. See Trigger Out Position Steps for further details.

Trig Out Pos. Steps Both - Trigger output active (pulsed) at pre-defined positions moving forwards and backward. Only one Trigger port at a time can be set to this mode. See Trigger Out Position Steps for further details.

Trigger Out Position Steps

Note
If the trigger mode is not set to one of the three position modes described previously, then the following parameters are not applicable and will be greyed out.

In the last three modes described above, the controller outputs a configurable number of pulses (set in the *Num. Pulses Fwd* and *Num. Pulses Rev* parameters), of configurable width (*Trig Pulse Width*), when the actual position of the stage matches the position values configured as the Start Position and Position Interval (*Start Pos. Fwd* and *Start Pos. Rev*. These modes allow external equipment to be triggered at exact position values.

The position pulses are generated by dedicated hardware, allowing a very low latency of less than 1 usec. The low latency of this triggering mode provides a very precise indication of a position match (assuming a stage velocity of 10 mm/sec, the less than 1 usec latency would in itself only result in a 10 nm position uncertainty, which is normally well below the accuracy limitations of the mechanics.)

Using the last three modes above, position triggering can be configured to be unidirectional (*Trig Out Pos. Steps Fwd* or *Trig Out Pos. Steps Rev*) or bidirectional (*Trig Out Pos. Steps Both*). In bidirectional mode the forward and reverse pulse sequences can be configured separately. A cycle count setting (*Num. of Move*

Cycles) allows the uni- or bidirectional position triggering sequence to be repeated a number of times.
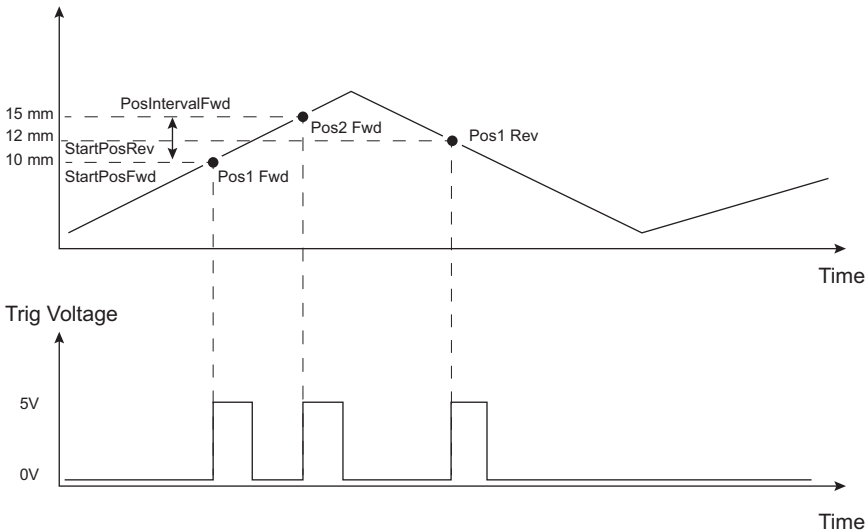
Fig. 6.9   Position Steps Triggering

Example for a move from 0 to 20 mm and back.

In forward direction: The first trigger pulse occurs at 10 mm (StartPosFwd), the next trigger pulse occurs after another 5 mm (PosIntervalFwd), the stage then moves to 20 mm.

In reverse direction: The next trigger occurs when the stage gets to 12 mm.

Note that position triggering can only be used on one TRIG port at a time, as there is only one set of position trigger parameters.

Triggering Polarity

The polarity of the trigger pulse is specified in the *Trig. 1 Polarity* and *Trig 2 Polarity* parameters as follows:

> *Active is High* - The active state of the trigger port is logic HIGH 5V (trigger input and output on a rising edge).

> *Active is Low* - The active state of the trigger port is logic LOW 0V (trigger input and output on a falling edge).

6.3.6 Triggering Latency

The detection of whether a trigger condition has occurred is carried out periodically at 102 µs intervals. As a result, there is a maximum 102 µs delay between the condition occurring and the trigger output being updated. The following timing diagram illustrates this latency:
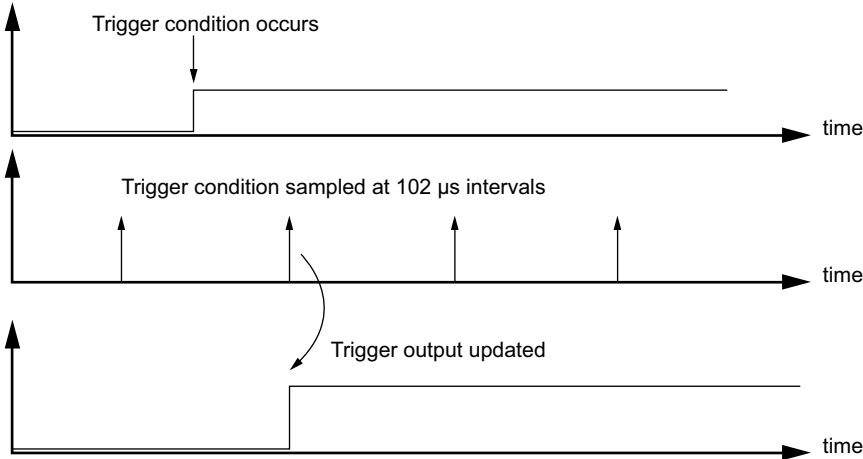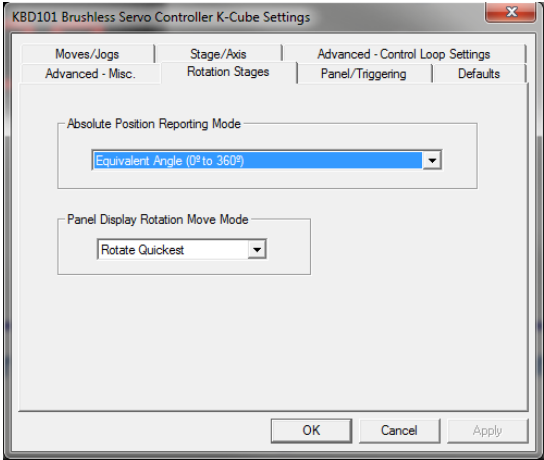

Fig. 6.10   Triggering Latency

6.3.7 Rotation Stages Tab

Absolute Position Reporting Mode

This setting relates to the way in which the angular position is displayed on the GUI panel. There are two options:

Equivalent Angle 0 to 360 degrees – The maximum displayed position is 359.99°. If a stage is driven past the 360° rotation point, the display reverts back to zero and counts up to 360° again.

Total Angle (360 x Num Revs + Angular Offset) – The total angular rotation is displayed, e.g. for a movement of two full rotations plus 10°, the display will show 730°.

Note. The following parameters are applicable only if the Absolute Position Reporting Mode is set to 'Equivalent Angle 0 to 360 degrees'.

Panel Display Rotation Move Mode

This setting specifies the move direction. There are three options:

Rotate Positive – The move is performed in a positive direction

Rotate Negative - The move is performed in a negative direction

Rotate Quickest - The move is performed in the quickest direction

6.4   Troubleshooting and Restoring Default Parameters

⚠️ **Caution** ⚠️

The PID and other closed loop parameters must be set according to the stage or actuator type associated with the driver, the load being positioned and the speed/duty cycle of operation. Default values have already been optimized and stored within the stage, and these are loaded into the driver on power up.

If problems are encountered (e.g. stability of the closed loop position control, lost motion or incomplete moves) the position PID parameters should 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 cases where further adjustment of the control loop parameters is required, the following guidelines are provided in order to assist in the tuning process.

Position PID Settings Summary

Stage overshoots the intended position - reduce the integral term, and increase the derivative and proportional terms.

Stage fails to attain final position - increase the integral and proportional terms.

Motion is unstable - reduce the prop and int terms, increase the derivative term.

Stage sounds noisy - reduce the derivative term.

See Section 6.3.3. for further information.

If adjustment of the parameter values previously described has resulted in unstable or unsatisfactory system response, this tab can be used to reset all parameter values to the factory default settings.

To restore the default values:

1) Select the 'Defaults' tab.

2) Click the 'Reset Parameter Defaults in the Controller' check box,

3) Click OK.

4) The driver must then be power cycled before the default values can take effect
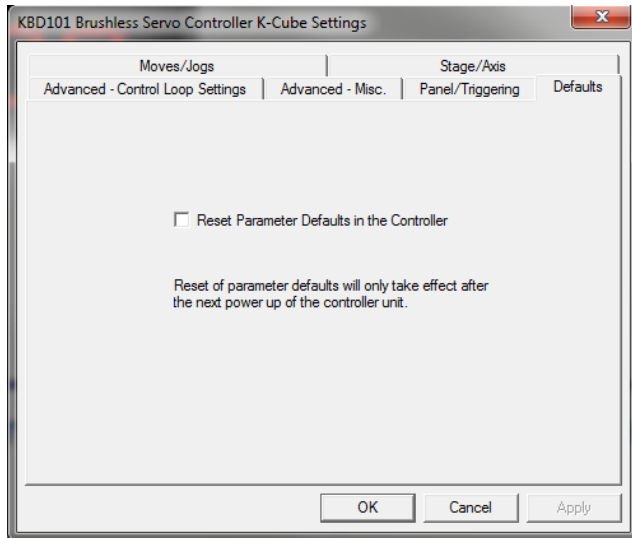
Fig. 6.11   Defaults tab

Appendix A   Rear Panel Connector Pinout Details

A.1   Rear Panel MOTOR Connectors

The 'MOTOR DRIVE' connector is a female, 15-pin D-Type and provides drive connection to the motors. The pin functions are detailed in Fig. A.1.
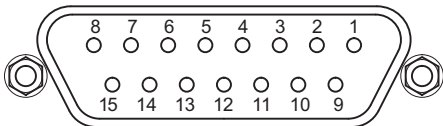
Pin	Description	Pin	Description
1	Quadrature A-	9	GND
2	Quadrature A+	10	Motor Phase C
3	Quadrature B+	11	Motor Phase A
4	Quadrature B-	12	Motor Phase B
5	Encoder Index I-	13	+5 V
6	Encoder Index I+	14	GND
7	Negative Limit	15	Stage ID
8	Positive Limit		

Notes

Quadrature X+/-: Differential quadrature pulses of the encoder

Encoder Index I -/+: The differential Index pulse used for homing

Limit -/+: Positive and negative limit switch signals

Stage ID: Unique Thorlabs communication interface signal used to identify the stage connected.

Fig. A.1 MOTOR DRIVE **connector pin identification**

Appendix B   Preventive Maintenance

Shock Warning
The equipment contains no user serviceable 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.

THORLABS

Appendix C   Specifications

C.1   Specifications

Parameter	Value
Drive Connector	15-Pin D-Type, Female (Motor Phase Outputs, Stage ID Input)
Peak Current Output	2A
PWM Frequency	40 kHz
Operating Modes	Position, Velocity
Control Algorithm	16-bit Digital PID Servo Loop with Velocity and Acceleration Feed forward
Velocity Profile	Trapezoidal/S-Curve
Position Count	32 Bit
Position Feedback	Incremental Encoder
Encoder Bandwidth	2.5 MHz/ 10 M Counts/sec
Encoder Supply	5V
Input Power Requirements	
Voltage	14.5 - 15.5 V Regulated DC
Current	2A Peak
General	
Housing Dimensions (W x D x H) (excluding buttons and baseplate)	60 x 60 x 47 mm (2.36" x 2.36" x 1.85")
USB Connector Type	USB 3.0
USB Connection Speed	USB 1.1 Full Speed (12 Mbps)
Instrument Weight	160 g (5.5 oz)
Compatible Motors	
Type	• 3-Phase DC Brushless Motors
Rated Phase Currents (Nominal)	100mA to 2A

Appendix D   Motor Control Method Summary

The 'Motor' ActiveX Control provides the functionality required for a client application to control one or more of the APT series of motor controller units.

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 Motor ActiveX Control can be used to perform activities such as homing stages, absolute and relative moves, and changing velocity profile settings. A brief summary of each method and property 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.
EnableHWChannel	Enables the drive output.
GetAbsMovePos	Gets the absolute move position.
GetAbsMovePos_AbsPos	Gets the absolute move position (returned by value).
GetBLashDist	Gets the backlash distance.
GetBLashDist_BLashDist	Gets the backlash distance (returned by value).
GetCtrlStarted	Gets the ActiveX Control started flag.
GetDCCurrentLoopParams	Gets the Current servo loop PID parameter settings applied when the unit is moving
GetDCPositionLoopParams	Gets the Position servo loop PID parameter settings
GetDCMotorOutputParams	Gets the limits that are applied to the motor drive signal
GetDCTrackSettleParams	Gets the settings for the Track and Settle windows
GetDCProfileModeParams	Gets the settings for the profile mode
GetDCJoystickParams	Gets the settings for the joystick max velocity and acceleration

GetDCSettledCurrentLoopParams

> Gets the Current servo loop PID parameter settings applied when the unit is 'settled'.

GetDCTriggerParams	Gets the present Trigger Mode settings.
GetDispMode	Gets the GUI display mode.
GetHomeParams	Gets the homing sequence parameters.
GetHomeParams_HomeVel	Gets the homing velocity parameter (returned by value).
GetHomeParams_ZeroOffset	Gets the homing zero offset parameter (returned by value).
GetHWCommsOK	Gets the hardware communications OK flag.
GetJogMode	Gets the jogging button operating modes.
GetJogMode_Mode	Get the jogging button operating mode (returned by value).
GetJogMode_StopMode	Gets the jogging button stopping mode (returned by value).
GetJogStepSize	Gets the jogging step size.
GetJogStepSize_StepSize	Gets the jogging step size (returned by value).
GetJogVelParams	Gets the jogging velocity profile parameters.
GetJogVelParams_Accn	Gets the jogging acceleration parameter (returned by value).
GetJogVelParams_MaxVel	Gets the jogging maximum velocity parameter (returned by value).
GetMotorParams	Gets the motor gearing parameters.
GetParentHWInfo ;	Gets the identification information of the host controller.
GetPosition	Gets the current motor position.
GetPosition_Position	Gets the current motor position (returned by value).
GetPositionEx	Gets the current motor position.
GetPositionEx_UncalibPosition	Gets the current uncalibrated motor position (returned by value).
GetPositionOffset	Gets the motor position offset.
GetRelMoveDist	Gets the relative move distance.
GetRelMoveDist_RelDist	Gets the relative move distance (returned by reference).
GetStageAxis	Gets the stage type information associated with the motor under control.
GetStageAxisInfo	Gets the stage axis parameters.

GetStageAxisInfo_MaxPos	Gets the stage maximum position (returned by value).
GetStageAxisInfo_MinPos	Gets the stage minimum position (returned by value).
GetStatusBits_Bits	Gets the controller status bits encoded in 32 bit integer (returned by value).
GetVelParamLimits	Gets the maximum velocity profile parameter limits.
GetVelParams	Gets the velocity profile parameters.
GetVelParams_Accn	Gets the move acceleration (returned by value).
GetVelParams_MaxVel	Gets the move maximum velocity (returned by value).
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.
LLSetGetDigOPs	Sets or Gets the user digital output bits encoded in 32 bit integer.
LoadParamSet	Loads stored settings for specific controller.
MoveAbsolute	Initiates an absolute move.
MoveAbsoluteEnc	Initiates an absolute move with specified positions for encoder equipped stages.
MoveAbsoluteEx	Initiates an absoloute move with specified positions.
MoveAbsoluteRot	Initiates an absolute move with specified positions for rotary stages.
MoveHome	Initiates a homing sequence.
MoveJog	Initiates a jog move.
MoveRelative	Initiates a relative move.
MoveRelativeEnc	Initiates a relative move with specified distances for encoder equipped stages.
MoveRelativeEx	Initiates a relative move with specified distances.
MoveVelocity	Initiates a move at constant velocity with no end point.
SaveParamSet	Saves settings for a specific controller.
SetAbsMovePos	Sets the absolute move position.
SetBLashDist	Sets the backlash distance.
SetDCCurrentLoopParams	Sets the Current servo loop PID parameter values applied when the unit is moving
SetDCPositionLoopParams	Sets the Position servo loop PID parameter values

SetDCMotorOutputParams	Sets the limits that are applied to the motor drive signal
SetDCTrackSettleParams	Sets the parameters for the Track and Settle windows
SetDCProfileModeParams	Sets the parameters for the profile mode
SetDCJoystickParams	Sets the values for the joystick max velocity and acceleration
SetDCSettledCurrentLoopParams	
	Sets the Current servo loop PID parameter settings applied when the unit is 'settled'.
SetDCTriggerParams	Sets the Trigger Mode parameters.
SetDispMode	Sets the GUI display mode.
SetHomeParams	Sets the homing sequence parameters.
SetJogMode	Sets the jogging button operating modes.
SetJogStepSize	Sets the jogging step size.
SetJogVelParams	Sets the jogging velocity profile parameters.
SetPositionOffset	Sets the motor position offset.
SetRelMoveDist	Sets the relative move distance.
SetStageAxisInfo	Sets the stage axis parameters.
SetVelParams	Sets the velocity profile parameters.
ShowSettingsDlg	Display the GUI Settings panel.
StartCtrl	Starts the ActiveX Control (starts communication with controller)
StopCtrl	Stops the ActiveX Control (stops communication with controller)
StopImmediate	Stops a motor move immediately.
StopProfiled	Stops a motor move in a profiled (decelleration) manner.

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.
DisplayMode	Allows the display mode of the virtual display panel to be set/read.
HWSerialNum	specifies the serial number of the hardware unit to be associated with an ActiveX control instance.

Appendix E   Regulatory

E.1   Declarations Of Conformity

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

E.1.2   For Customers In The USA
This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

Changes or modifications not expressly approved by the company could void the user's authority to operate the equipment.

E.2 CE Certificate

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):

2004/108/EC   Electromagnetic Compatibility (EMC) Directive

2011/65/EU   Restriction of Use of Certain Hazardous Substances (RoHS)

hereby declare that:

Model: **KBD101**

Equipment: **Kinesis Brushless Motor Controller**

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

| EN 61326-1 | Electrical Equipment for Measurement, Control and Laboratory Use - EMC Requirements | 2013 |

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

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

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

Signed: *On:*   17 December 2015

Name: Keith Dhese

Position: General Manager   *EDC - KBD101 -2015-12-17*

C E

Appendix F   Thorlabs Worldwide Contacts

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

USA, Canada, and South America
Thorlabs, Inc.
sales@thorlabs.com
techsupport@thorlabs.com

Europe
Thorlabs GmbH
europe@thorlabs.com

France
Thorlabs SAS
sales.fr@thorlabs.com

Japan
Thorlabs Japan Inc.
sales@thorlabs.jp

UK and Ireland
Thorlabs Ltd.
sales@uk.thorlabs.com
techsupport.uk@thorlabs.com

Scandinavia
Thorlabs Sweden AB
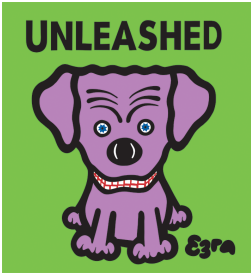scandinavia@thorlabs.com

Brazil
Thorlabs Vendas de Fotônicos Ltda.
brasil@thorlabs.com

China
Thorlabs China
chinasales@thorlabs.com

Thorlabs verifies our compliance with the WEEE (Waste Electrical and Electronic Equipment) directive of the European Community and the corresponding national laws. Accordingly, all end users in the EC may return "end of life" Annex I category electrical and electronic equipment sold after August 13, 2005 to Thorlabs, without incurring disposal charges. Eligible units are marked with the crossed out "wheelie bin" logo (see right), were sold to and are currently owned by a company or institute within the EC, and are not 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.