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

BBD301, BBD302, & BBD303 Brushless DC Motor Controllers

APT User Guide

Original Instructions

Contents

Continued...

Appendices

Chapter 1 For Your 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.

Chapter 2 Overview and Setup

2.1 Introduction

The BBD30x is a family of three Brushless DC Motor Controllers that are ideal for motion control applications demanding high speed (100s of mm/s) and high encoder resolution (<100 nm) operation:

BBD301 Single Channel Controller

BBD302 Two Channel Controller

BBD303 Three Channel Controller

These controllers offer high-precision motion control in a wide range of applications, and in particular when used along with our DDS series fast translation stages, where speeds of up to 300 mm/ sec can be achieved. Designed using the latest digital and analog techniques and with high-bandwidth high-power servo controlcircuitry, these new controllers are capable of driving a range of rotary and linear brushless 3-phase DC motors at 2.5 Amps continuous current (4 Amps peak), and up to 5.2 Amps maximum in total.

It offers Thorlabs standard control and programming interface, allowing easy integration into the customer's own automated motion control applications. These units are capable 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 APT Three Channel Brushless DC Servo Motor Controller (BBD303)

Operation of the BBD30x Series Controllers is fully configurable (parameterized) with key settings (e.g. PID settings, min and max position values, and limit switch operation) 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 limit switch configuration is accommodated through a flexible set of limit switch logic settings. 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. The units are also fully supported by Thorlabs Kinesis® software – see separate manual.

For convenience and ease of use, movement of stages and adjustment of many key parameters is possible either through direct interaction with the front panel controls (see Chapter 4), or via a PC and virtual graphical panel (see Chapter 5). Furthermore, all such settings and parameters are also accessible through the APT and Kinesis programmable interfaces for automated alignment sequences.

The reference section (Chapter 6) covers all operating modes and parameters in detail.

Finally, an Ethernet port is included in the rear panel for connection of the controller to a computer, but at present is not supported by APT. For use of this port, please refer to the Kinesis version of the BBD3* controller.

2.2 APT PC Software Overview

2.2.1 Introduction

As a member of the APT range of controllers, the BBD30x DC motor controllers share 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 BBD30x series, 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 2.2.2.) and APTConfig (see Section 2.2.3.) utilities allow full control of all settings and operating modes enabling complete 'out-of-box' operation without the need to develop any further custom software. Both utilities are built on top of a sophisticated, multi-threaded ActiveX 'engine' (called the APT server) which provides all of the necessary APT system software services such as generation of GUI panels, communications handling for multiple USB units, and logging of all system activity to assist in hardware trouble shooting. It is this APT server 'engine' that is used by software developers to allow the creation of advanced automated positioning applications very rapidly and with great ease. The APT server is described in more detail in Section 2.2.4.

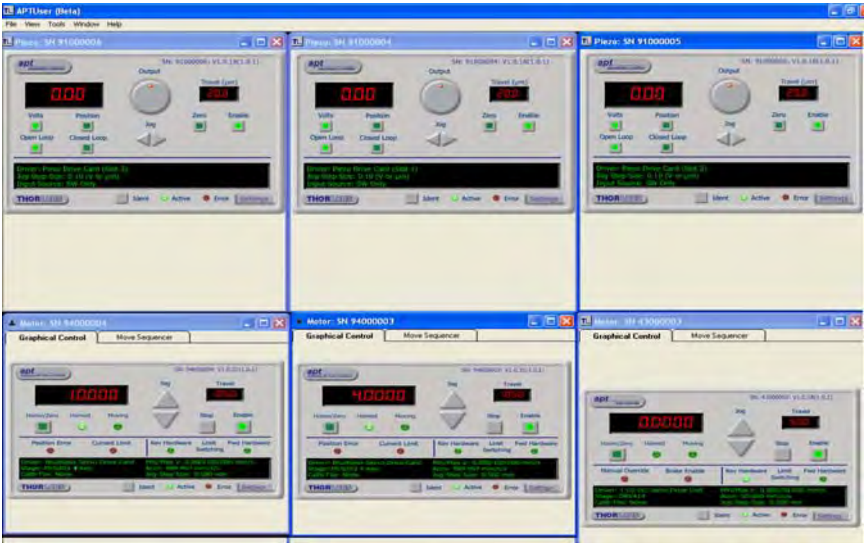
Aside

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

ActiveX controls are a specific form of ActiveX technology that provide both a user interface and a programming interface. An ActiveX control is supplied for each type of APT hardware unit to provide specific controller functionality to the software developer. See Section 2.2.4. for further details.

2.2.2 APTUser Utility

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



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 customise and automate usage of the controller (e.g. to implement a positioning algorithm), this application illustrates how the rich functionality provided by the APT ActiveX server is exposed by a client application.

Use of the APT User utility is covered in the PC tutorial (Chapter 5) and in the APTUser online help file, accessed via the F1 key when using the APTUser utility.

2.2.3 APT Config Utility

There are many system parameters and configuration settings associated with the operation of the APT Server. Most can be directly accessed using the various graphical panels, however there are several system wide settings that can 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.

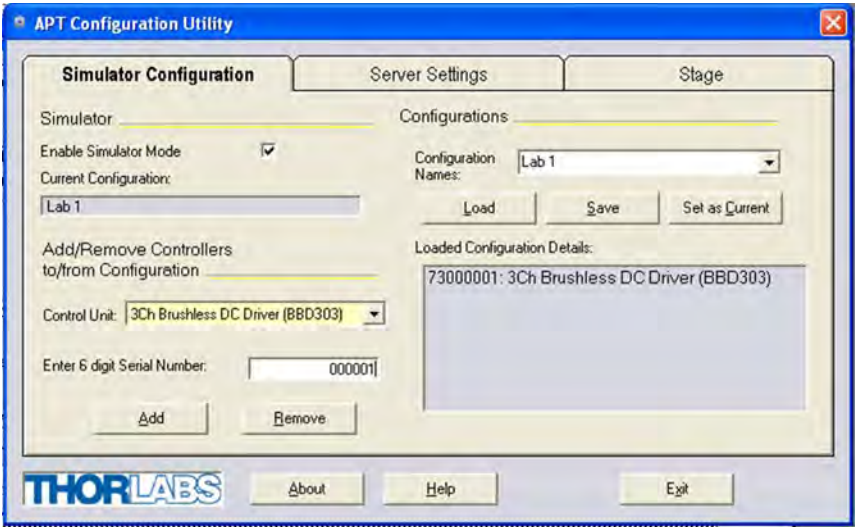
If a BBD series controller is used with the MLS203 microscopy scanning stage, all stage-associated settings are made automatically when the stage is connected to the controller.

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 2.2.3. Full details are contained in the online help supplied with the utility.

2.2.4 APT Server (ActiveX Controls)

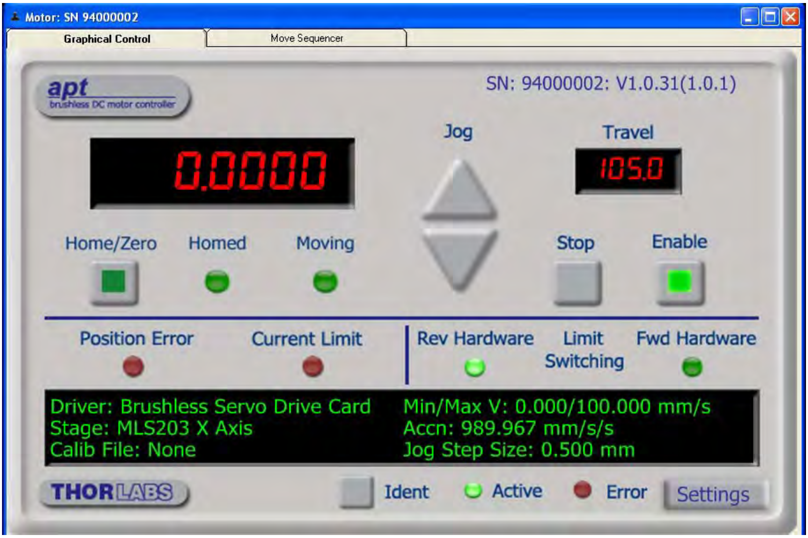
ActiveX Controls are re-usable compiled software components that supply both a graphical user interface and a programmable interface. Many such Controls are available for Windows applications development, providing a large range of re-usable functionality. For example, there are Controls available that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

With the APT system, ActiveX Controls are deployed to allow direct control over (and



also reflect the status of) the range of electronic controller units, including the BBD302 and BBD303 DC motor controllers. 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 one channel of the BBD303 APT Brushless DC Servo Controller 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 controller 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).

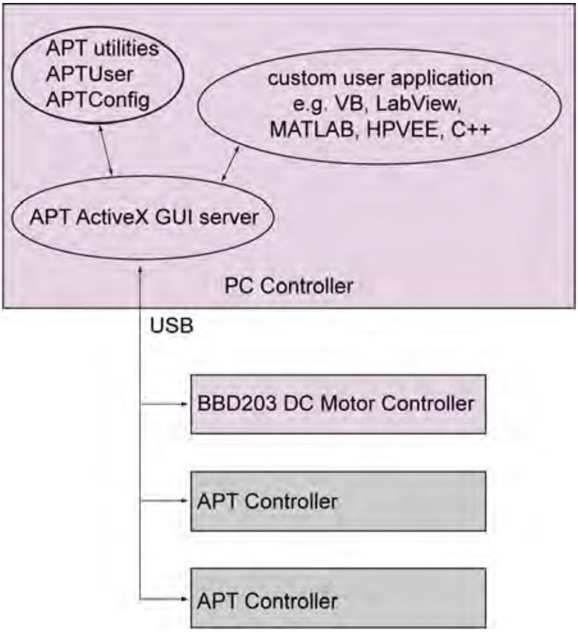


Fig. 2.2 System Architecture Diagram

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

2.2.5 Software Upgrades

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

Detailed instructions on installing upgrades are included on the APT Software CD ROM.

Chapter 3 Getting Started

3.1 Installing APT Software

Note

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

Caution

Some PCs may have been configured to restrict the user's 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) Go to Services/Downloads at www.thorlabs.com and download the APT software.
2) Run the .exe file and follow the on-screen instructions.

3.2 Mechanical Installation

3.2.1 Siting

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

Caution

When siting the unit, it should be positioned so as not to impede the operation of the rear panel power supply switch.
Ensure that proper airflow is maintained to the rear of the unit.

3.2.2 Environmental Conditions

Warning

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

Location	Indoor use only
Maximum altitude	2000 m
Temperature range	5^oC to 40^oC
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.

3.3 Electrical Installation

Warning

The safety of any system incorporating this equipment is the responsibility of the person performing the installation.

3.4 Connecting To The Supply

Shock Warning

The unit must be connected only to an earthed fused supply of 110 to 230 V.

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

Brown Live
Blue Neutral
Green/Yellow Earth/Ground

3.5 Fuses

Two T 3.15A/250V A.C. anti-surge ceramic fuses are located in the fuse drawer on the mains inlet panel, one for the live feed and one for the neutral as follows:

Fuse	Rating	Type	Fused Line
F1	T 3.15 A	ceramic; anti-surge	Live feed
F2	T 3.15 A	ceramic; anti-surge	Neutral feed

When replacing fuses:

1) Switch off the power and disconnect the power cord before removing the fuse cover.
2) Always replace broken fuses with a fuse of the same rating and type. It is good practice to replace both fuses when a fuse blows.

3.5.1 Rear Panel Connections BBD301

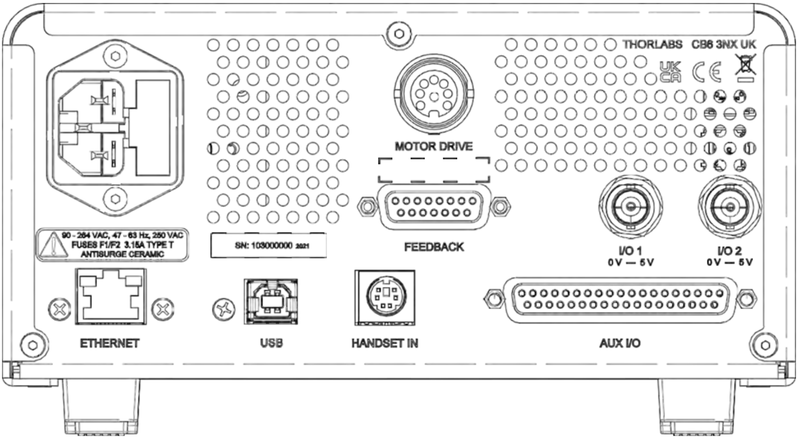


Fig. 3.1 BBD301 rear panel connections

MOTOR DRIVE - Provides all phase current drive connections to the DC motor actuators, via a female 8-pin DIN connector - see Section A.1.

FEEDBACK - 15-pin female D Connector. Provides connection for the position encoder feedback signals - see Section A.2.

I/O 1 and I/O 2 – BNC connectors for use with external trigger input and output signals (5V TTL levels) or as monitor outputs. The function is set to trigger IN, trigger OUT or Monitor via the settings panel - see Section 6.4.4.

ETHERNET - For use in Ethernet communications.

USB - USB port for system communications.

Note

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

HANDSET IN - Provides connection, via a female Mini-DIN, for the MJC001 2-Axis Joystick - see Section A.4.

AUX I/O - 37-pin female DIN Connector. The AUX I/O connector exposes a number of internal electrical signals. For convenience, a number of logic inputs and outputs are included, thereby negating the need for extra PC based IO hardware.Using the APT support software, these user programmable logic lines can be deployed in applications requiring control ofexternal devices such a relays, light sources and other auxiliary equipment. - see Section A.3. for further details.

3.5.2 Rear Panel Connections for BBD302 and BBD303

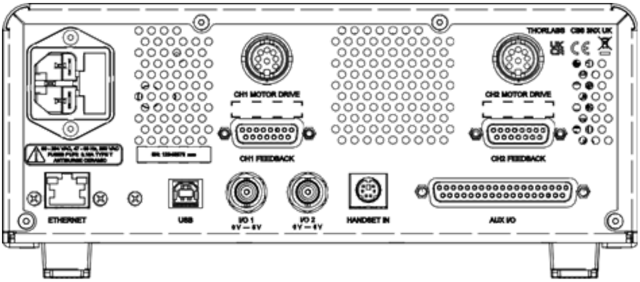


Fig. 3.2a BBD302 Rear Panel Connections

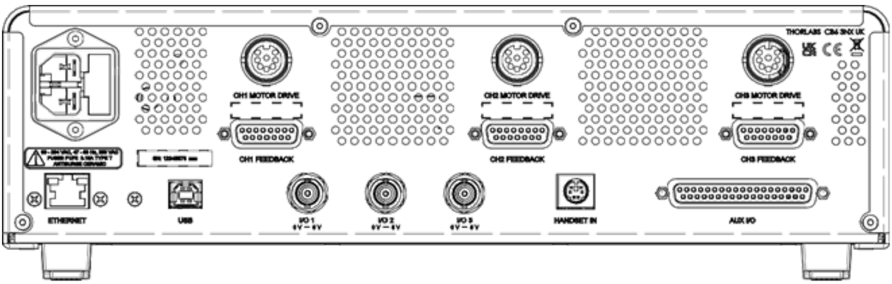


Fig. 3.2b BBD303 Rear Panel Connections

3.6 Front Panel Controls and Indicators

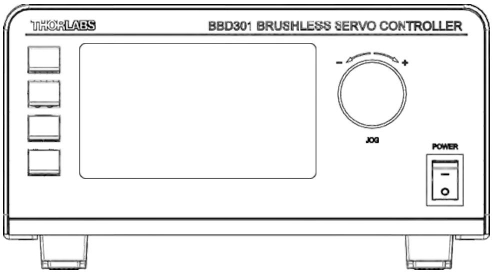


Fig. 3.3a BBD301 Front panel controls and indicators

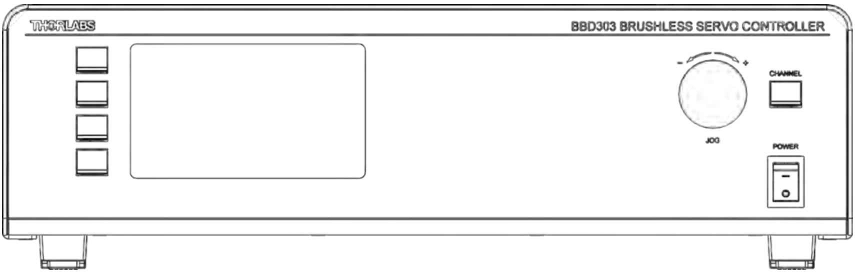


Fig. 3.3b BBD303 Front Panel Controls and Indicators

Power - Rocker switch to turn power ON and OFF.

Jog Knob - Used to initiate moves in normal operation. In set-up mode the knob is used to make changes to parameter settings.

Main Display - In normal operation the display shows channel information, such as axis position and stage type connected. In set-up mode the display allows various parameter settings to be changed - see Chapter 4.

Buttons – The buttons on the left are used to manually communicate with the BBD30x via information provided in the corresponding position on the screen - see Chapter 4.

Channel – BBD302 and BBD303 only; located above the power switch. Used to toggle between the various channels connected.

3.7 Connecting The Hardware and Powering Up

Follow the set procedure for powering up, as described below. **Specifically, a stage must only be connected to and disconnected from a controller that is powered down.**

1) Install the APT Software - see Section 3.1.
2) Connect the stage to the Controller unit.
3) Connect the Controller unit to your PC.

Note

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

4) Connect the Controller unit to the power supply and switch 'ON'. Windows™ should detect the new hardware. Wait while Windows™ installs the drivers for the new hardware - see the Getting Started guide for more information
5) Wait for 10 seconds for the initialization phase to complete.

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.

6) Run the APTUser utility and click the 'Home' button on each GUI panel. The front panel of the controller indicates when homing is complete.
7) The stage can now be moved using the GUI panel, or by sending commands to move each axis by relative and absolute amounts – see the helpfile supplied with the APT server for more information.
8) See Chapters 4 & 5 of this manual, for a brief tutorial on the operation of the unit via the controller front panel and software, respectively.

3.8 Verifying Software Operation

3.8.1 Initial Setup

The APT Software should be installed (Section 3.1.) and the power up procedure performed (Section 3.7.) before software operation can be verified.

1) Run the APTUser utility and check that the Graphical User Interface (GUI) panels appear and are active (one panel for each channel of operation).

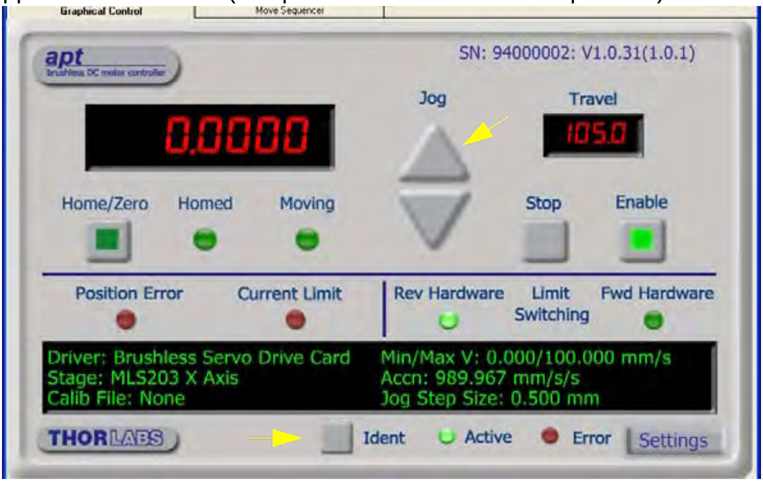


Fig. 3.4 GUI panel showing jog and ident buttons

2) Click the ‘Ident’ button. The screen on the front panel of the controller flashes. This is useful in multi-channel systems for identifying which driver unit is associated with which GUI.
3) Click the jog buttons on the GUI panel and check that the motor or axis connected to the controller moves. The position display for the associated GUI should increment and decrement accordingly.

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 5.12. or the *APTConfig* helpfile for detailed instructions.

Chapter 4 Operation from the Front Panel

4.1 Introduction

The BBD30x can be used to drive attached stages directly via the front panel controls and display screen, without the specific need of a computer connection and its peripheral software; only a mains power connection is needed, together with electrical connections to each stage (15-pin D plug, and 8-pin DIN plug for each stage). However, the fullest functionality is available ifthe front panel is used in conjunction with APT software - described in more detail in Chapter 5 - and this will need a USB connection to the computer.

This section describes the functionality and use of stage control via the front panel of the BBD30x controller. Throughout thechapter, examples are given assuming linear stages are being addressed. For rotary stages, the same functionality is available (so replace linear speed/acceleration/position with their angular counterparts). Any differences are specifically addressed in section 4.9.

Caution

There is maximum stage velocity at which the encoder can operate (which is motor-dependent). 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 BBD30x controller, the maximum velocity is limited to safe values. However, if theoutput is disabled (with the controller connected and monitoring the encoder position) and the stage is moved manually at high speeds, it is possible to exceed this limit. If the controller 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 BBD controller has fault monitoring to detect the loss of encoder pulses. If this fault occurs, an error message willbe generated, and the controller must be powered down and re-started so that correct phasing and commutation can be re-established.

4.2 Front Panel Menu Index

The front panel main page, active on startup, allows intuitive access to an array of sub-pages that provide information on thesystem status and parameters, the possibility to set and change parameters, and the ability to control the attached stages. Fig. 4.1 below provides an index of these pages (and where they can be accessed). More details can be found in sections 4.3 to 4.8.

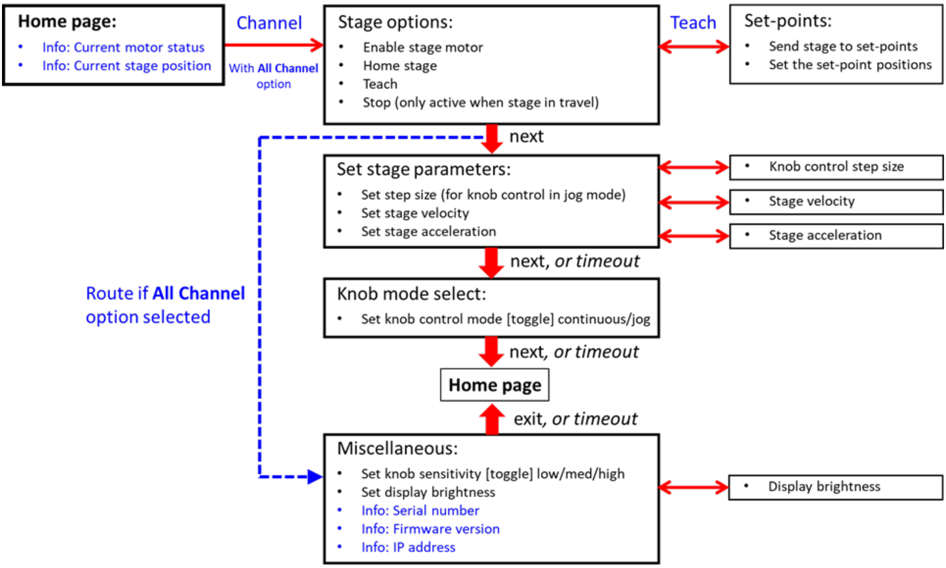


Fig. 4.1 Front Panel Display Pages Map

4.3 System Startup

On powering up the controller for the first time, the BBD30x first initializes (Fig. 4.2a) and retrieves information from the stages connected, which is then displayed in the appropriate channel on the front panel home page. An example is shown in Fig. 4.2b for a Thorlabs DDS220 linear stage. Where more stages are attached (for example when using a BBD302 or BBD303), information is also displayed in the Ch 2 and Ch 3 spaces. Note that any stage motor will be disabled at this juncture, and manual intervention is required to both enable and home it. For individual motors, this can be done by first pressing the appropriate panel button to select the motor required, which brings up the control screen for that stage (Fig. 4.2c). Where multiple channels are in use, all of these can be initialized together by pressing the "Ch All" button at the bottom of the panel, as shown in Fig. 4.2b.

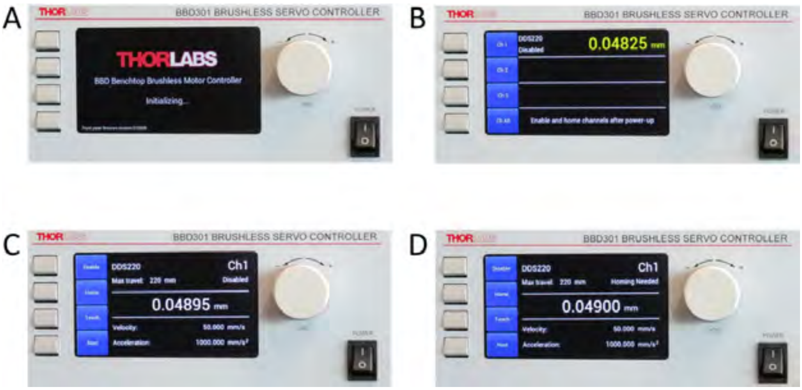


Fig. 4.2 Startup Sequence for BBD301 under Front Panel Control

To enable the motor(s), press the top left-hand button; this is a toggle switch, so if needed, the motor(s) can be disabled by pressing again. The panel now updates with the message "Homing Needed", (Fig. 4.2d) which is achieved by pressing the second button down on the panel, next to "Home".

During the homing process, the stage(s) first travel to their encoder calibration position, typically an end switch (Fig. 4.3a), followed by a move to the preset home position (Fig. 4.3b). At this point, the stage(s) is/are now set and ready for use, with the correct calibrated position indicated on the display.

Fig. 4.3 Homing in Operation

Note

During the homing process when the stage is in motion, a red "STOP" sign is illuminated on the display (Fig. 4.3a) and pressing the corresponding panel button will immediately stop the stage's motion; for example, this might be needed in case there is an observed obstruction to the stage's travel. The same applies whenever a motor is in motion. If there are 2 or more motors/axes, each axis must be selected and stopped separately.

Important: The stage stops traveling when the “STOP” button is released, not when it is depressed.

Additional information appears on the screen once a particular motor channel is selected, including:

Maximum travel

Velocity

Acceleration

These are default values read from the firmware. The maximum travel is factory set according to the stage being driven, but the velocity and acceleration can be changed via the controller front panel at any time: see Section 4.4.

4.4 Setting Motor Velocity and Acceleration

Individual motor speed and acceleration can be set by first selecting the appropriate channel (which produces a screen similar to Fig. 4.3b) then scrolling to the next page by pressing the lowest control panel button adjacent to "Next". This brings up a screen similar to Fig. 4.4a, where Step Size, Velocity and Acceleration can all be changed. Step Size relates to stage movement when the knob control is operating in jog mode - see Section 4.5. for further details. However, in all cases, the method of changing the parameters is the same: select what needs to be altered (e.g. Velocity in Fig. 4.4b), then use "+/-" buttons to increment/decrement the number indicated by the cursor. The cursor position is changed by the Resolution button at the bottom. When finished, press Enter (top button).

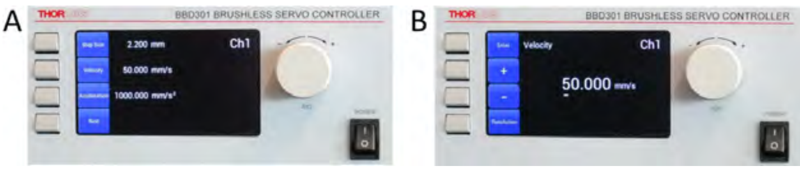


Fig. 4.4 Changing Motor Parameters

Note: This page times out after 20 second of inactivity.

Note: The controller will prevent the inputting of parameters that are outside the permitted range of the device in question. If required, these parameters can be viewed via the PC GUI described in Chapter 5.

4.5 Moving the Stage

Manually moving motorized stages using the BBD30x is simple, and can be done via two methods:

1) By using pre-selected positions (up to 3) found under the "Teach" tab. In this mode, the stage travels directly to the requested position at the speed/acceleration currently loaded into the firmware. Simply press the button corresponding to Position 1/2/3 to send the stage to that point. See Section 4.6. on how to change these set-points.
2) By using the control knob on the front panel to increment/decrement the stage position. There are two options for how this is done:

   Jog Mode, whereby turning the control knob allows motion in either direction, one step at a time: keep turning the knob for further steps. Allow the knob to return to its zero potion, and twist again for more steps.

   Continuous Mode, whereby the stage will continuously move whilst the control knob is rotated in the "+" or "-" direction. The further the knob is rotated, the faster it moves - up to the maximum velocity that has been set for the motor.

See Section 4.7. for how the control knob functionality can be changed.

4.6 The Teach Facility: Inputting Stage Set-Points

On the title page of any chosen motor channel, the Teach facility is directly available (3rd button down - see Fig. 4.3b). Pressing this reveals a page similar to that shown in Fig. 4.5a, where the current set-points are indicated. Pressing Pos1/Pos2/ Pos3 will send the stage to those points.

However, if an alternative set-point position is required, use the control knob to place the stage at the required position (the current position is indicated on the screen on the right-hand side, even when moving), then hold down the button corresponding to the position that needs to be set. Wait for the white progress bar in the bottom right-hand corner to complete (see Fig. 4.5b), and the button can now be released. The new set-point should then appear on the panel, and this will now have been loaded into the firmware for future use. When finished, press 'Exit'.

Note that if precise calibration positions are required, this may be better achieved through the APT software control option, described in Chapters 5 and 6.

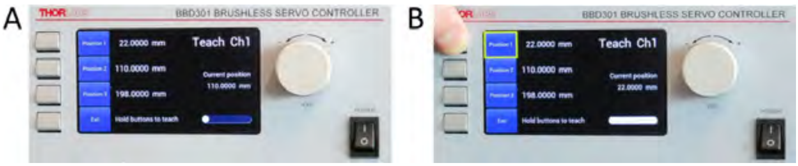


Fig. 4.5 Stage position Set-points and Changing them via Teach

4.7 The Knob Control: Setting Functionality

As noted in Section 4.5. the knob can control the motor stage position in either continuous-motion or jog mode; speed is set in the Set Stage parameters page (Fig. 4.4a). The choice of continuous vs. jog action is set via toggle action in the knob select page (Fig. 4.6a) and the knob sensitivity is set in the final Miscellaneous page (Fig. 4.6b), again by toggle action (low/medium/ high).

As seen from the page index overview (Fig. 4.1), the knob function (continuous vs. jog mode) must be set for individual motors and cannot be set for all stages simultaneously.

Note: this page times out after 20 second of inactivity.

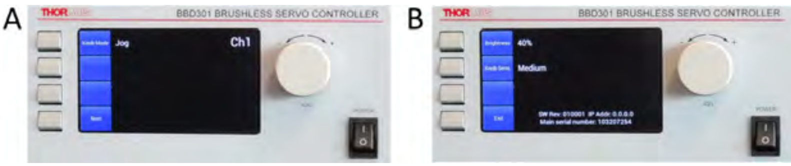


Fig. 4.6 Setting the Front Panel Knob Control Function

4.8 Miscellaneous: Screen Brightness, Knob Sensitivity, Firmware Version, IP Address, Serial Number

The final Miscellaneous screen (Fig. 4.6b) allows setting of the knob sensitivity (toggle between low, medium, and high); as this is applied to all stages, the page can only be accessed via the All Channels route (see page index in Fig. 4.1).

The screen brightness (1-100%) control is also found on this page, and is useful for operating the controller in a variety of lighting conditions. Selecting the button next to Brightness allows the change to be made in similar fashion to stage velocity (Fig. 4.4b).

The screen also provides information on:

Firmware version currently uploaded
Controller Serial Number
IP address of the controller.

Note: this page times out after 20 second of inactivity.

4.9 Comments on Rotary Stages

For rotary sages, most of the functionality of the front panel resembles that of linear stages, except:

º	replaces mm
º/s	replaces mm/s
$º/s^2$	replaces mm/s^2

The final difference is that, if the knob control is used to move the stage, there is no upper/lower hardware limit to motion; the stages can freely rotate continuously. However, the recorded angle reverts to 0º once 360º is passed (i.e., 370º is read as 10º) and any setting (e.g., in Teach) must be between 0º and 360º.

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 3.5.1. that the APT Software is already installed - see Section 3.1. and that the stage being driven is the Thorlabs MLS203 microscopy scanning 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 400 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 BBD30x controller, the maximum velocity is limited to safe values. However, if the output is disabled (with the controller connected and monitoring the position) and the stage is moved manually at high speeds, it is possible to exceed this limit. If the BBD30x controller 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 BBD controller has fault monitoring to detect the loss of encoder pulses. If this fault occurs, an error message will be generated and the controller must be powered down and re-started so that correct phasing and commutation can be established.

If this fault occurs when the stage is being controlled via the MJC001 joystick, in the absence of a PC, the red LED on the joystick console is lit, and all operation is suspended until the controller is shut down and rebooted.

5.2 Using the APT User Utility

The APT User.exe application allows the user to interact with any number of APT hardware control units connected to the PC USB Bus (or simulated via the APTConfig utility). This program allows multiple graphical instrument panels to be displayed so that multiple APT units can be controlled. All basic operating parameters can be set through this program, and all basic operations (such as 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.

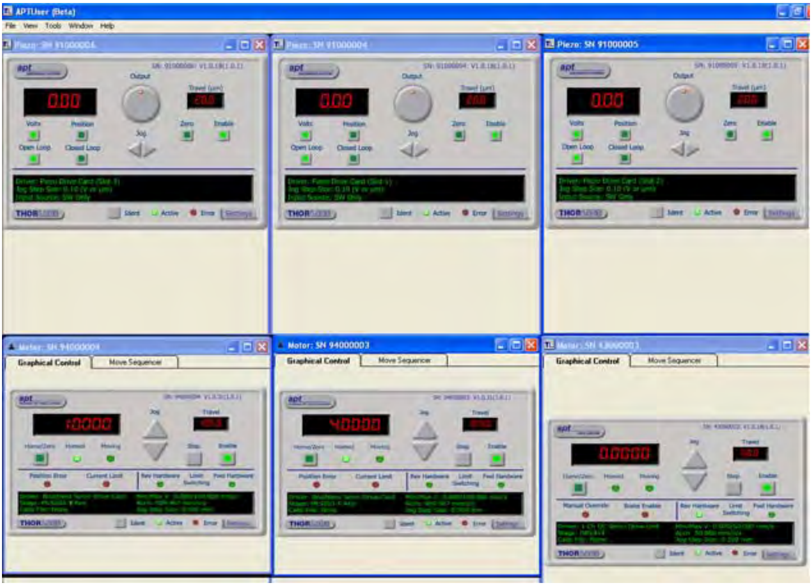


Fig. 5.1 Typical APT User Screen

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

5.3 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 MLS series stages use an electronic reference marker and therefore the limit switches are not used for reference.

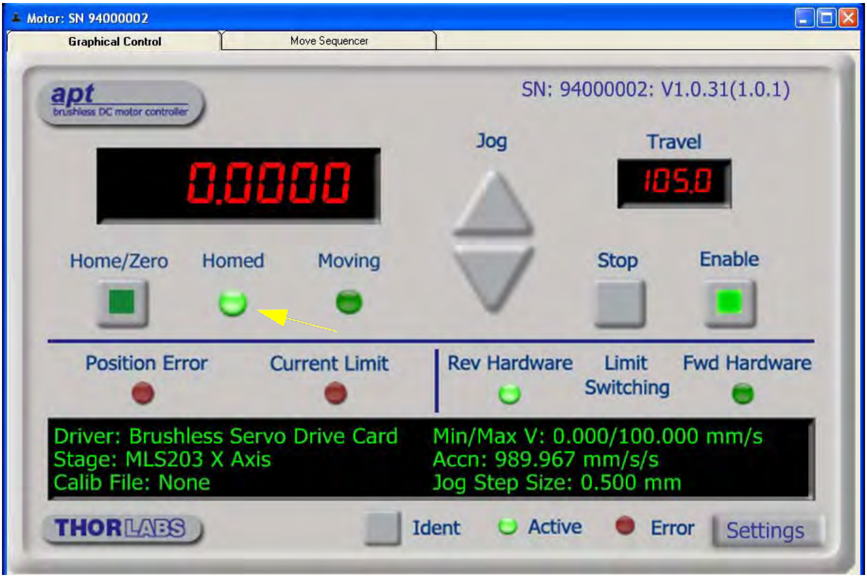


Fig. 5.2 Motor Controller Software GUI

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.

5.4 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.

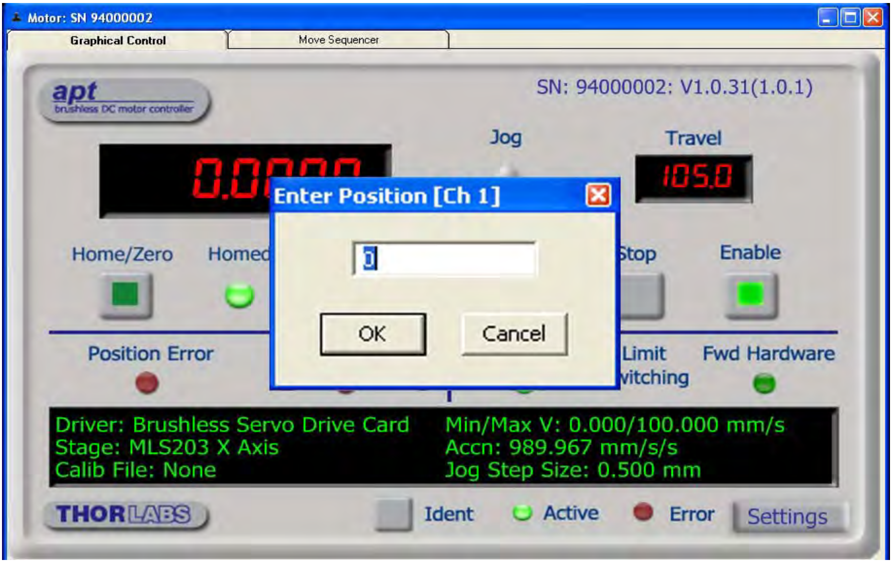


Fig. 5.3 Absolute Position Popup Window

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 3.00mm.

5.5 Stopping the Stage

The drive channel is enabled and disabled by clicking the ‘Enable’ button on the GUI panel or the front panel of the unit. The green indicator is lit when the drive channel is enabled. Disabling the channel removes the drive power and allows the stage/ actuator to be positioned manually.

During operation, the stage can be stopped at any time by clicking the ‘Stop’ button on the GUI panel. Using this button does not remove power to the drive channel.

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.

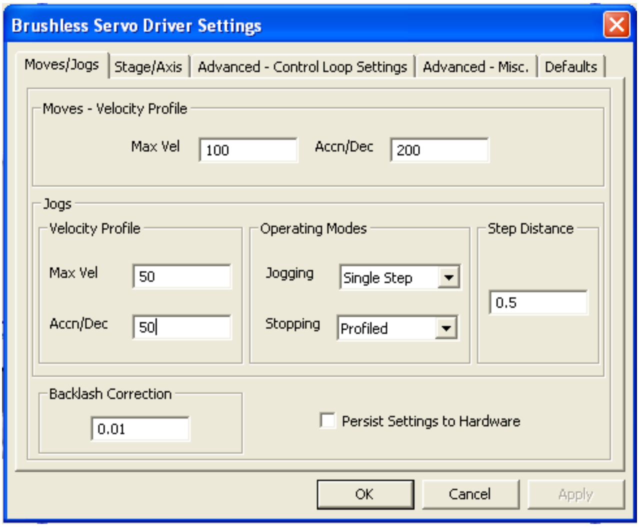


Fig. 5.4 Settings Panel - Move/Jogs Tab

2) Select the Move/Jogs tab as shown in Fig. 5.4.
3) In the 'Moves' field, change the parameters as follows:
   'Max. Vel' - '100'
   'Accn/Dec' - '200'
4) Click 'OK' to save the settings and close the window.
5) Any further moves initiated on channel 1 will now be performed at a maximum velocity of 100 mm per second, with an acceleration of 200 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.

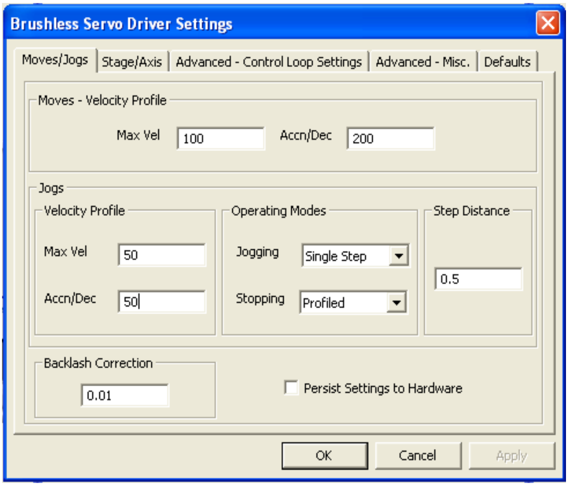


Fig. 5.5 Settings Panel - Move/Jogs Tab

2) Select the Move/Jogs tab as shown in Fig. 5.5.
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.

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'.

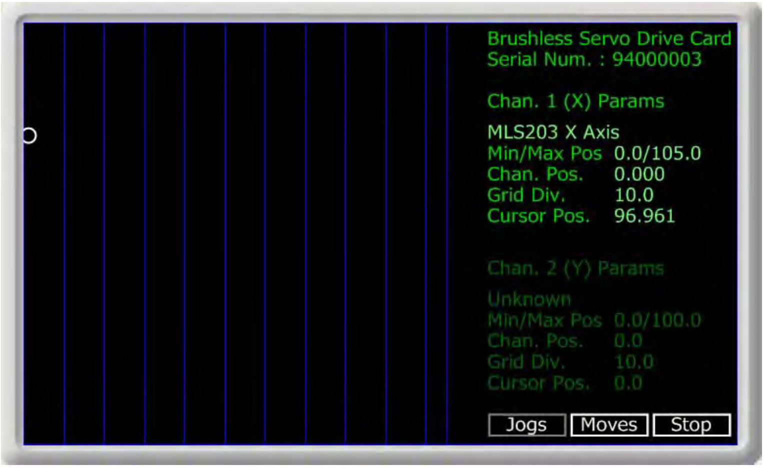


Fig. 5.6 DC Controller GUI Panel - Graphical View

Consider the display shown above for a DC Motor Drive Card.

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 BBD302/303 controller is accessed via a single channel GUI panel, one panel for each motor drives fitted.

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 the X-axis of an MLS203 stage. The graph shows 11 divisions in the X axis, which relates to 105mm of total travel (10 mm per division with the last division being 5 mm).

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 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 5.12.

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

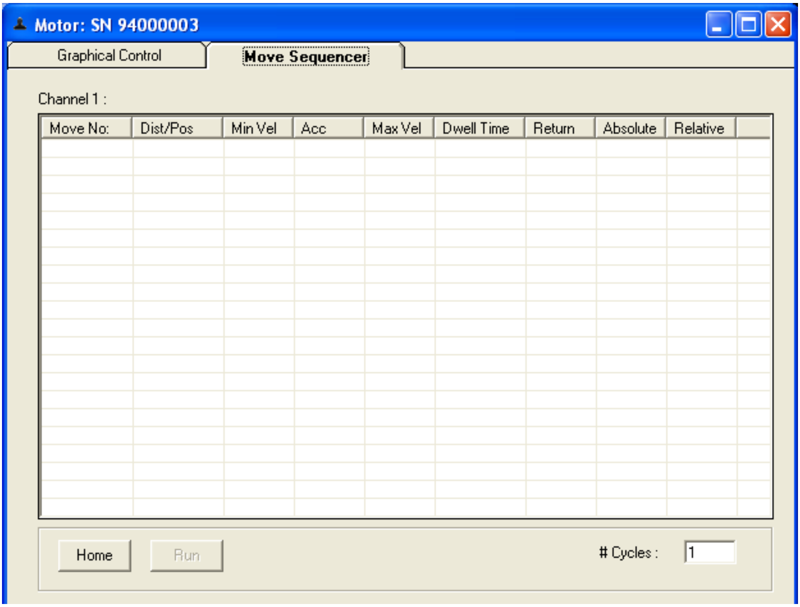


Fig. 5.7 Move Sequencer Window

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

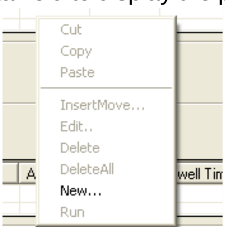


Fig. 5.8 Move Sequencer Pop Up Menu

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

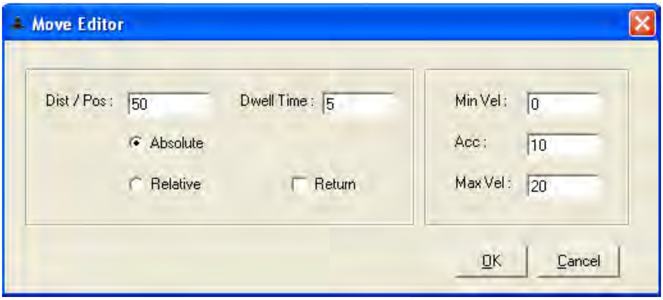


Fig. 5.9 Move Editor Window

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.

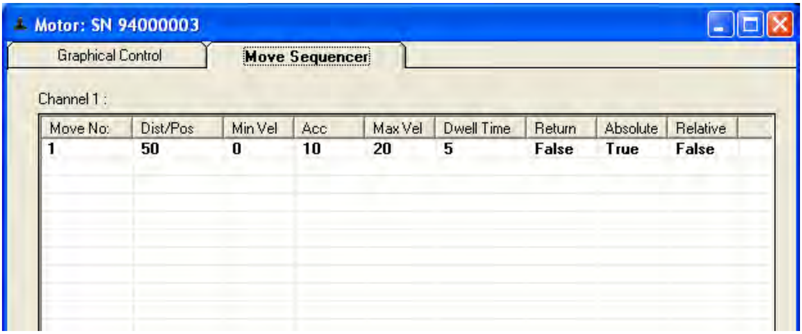


Fig. 5.10 Main Window with Move Data

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. 5.11 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.

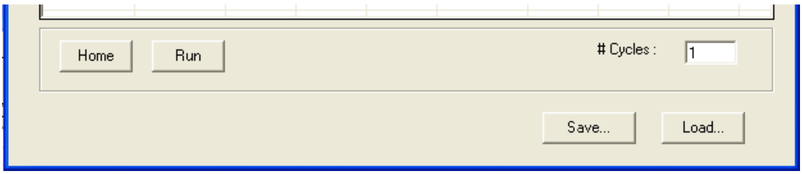


Fig. 5.12 Home and Run Buttons

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.

5.10 Using A Joystick Console

The MJC001 joystick console has been designed for microscope users, to provide intuitive, tactile, manual positioning of the stage. The console features a two-axis joystick for XY control. Up to 3 joysticks can be connected to each other, interfacing neatly into a multi-channel control application. Furthermore, if the parameter settings are persisted to the controller (see Section 6.3.) the controller need not be connected to a host PC, thereby allowing remote operation.

Note

The default parameter values loaded at the factory should be acceptable for most applications, and in this case, it is not necessary to connect the controller to a PC running the APT software. If these parameter values subsequently require adjustment, this can only be performed by running the APT software - see Section 3.1. and Section 6.3. for more information.

1) Connect the stage to the Controller unit.
2) Connect the joystick console to the HANDSET IN connector of the controller.
3) Switch ON the controller.
4) Wait until the red led on the joystick console and the Channel Enable LEDs on the controller front panel stop flashing (~3s). This indicates that phase initialisation is complete.
5) Press and hold the ‘High/Low’ button for 2 seconds to home the stage. When homing is complete, the green LED stops flashing.

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

The joystick ID switch assigns the selected number to the X axis of the joystick and the next sequential number to the Y axis. The channel ident switches on the controller unit must then be set to match these joystick axis numbers.

For example, if the joystick switch is set to '1', then the X axis channel ID switch on the controller must be set to ‘1’ and the Y axis ID switch must be set to ‘2’ as shown in Fig. 5.1.

Fig. 5.1 ID switch settings

6) Set the joystick console ID switch and the controller channel ID switches as described in the preceding paragraph.

Caution

Do not set the switches to identical numbers as this may result in lack of joystick control. Also, do not set the channel ID switches to 'E' or 'F' as this is reserved for factory use and testing.

7) The stage can now be moved using the joystick, GUI panel, or by setting commands to move each axis by relative and absolute amounts – see the helpfile supplied with the APT server for more information.

5.11 External Triggering

External triggering is facilitated by BNC connectors on the rear panel of the unit.

These connectors provide a 5V logic level input and output that can be configured to support triggering from and to external devices - see Section 6.3.4. further details.

Currently, the BNCs are configured for Trigger Input only, with only a single Trigger per motor (meaning that for BBD301, only one of the two BNCs present is functional). Full functionality will be available at a later date with firmware/software updates.

5.12 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.

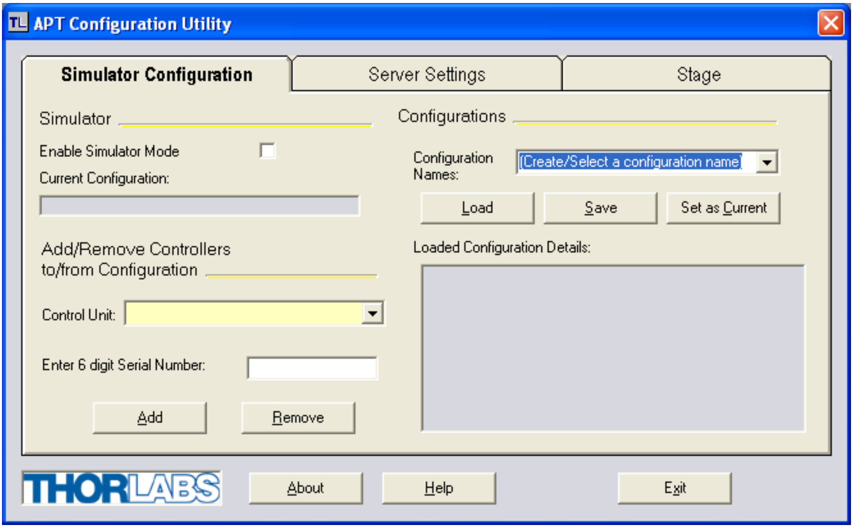
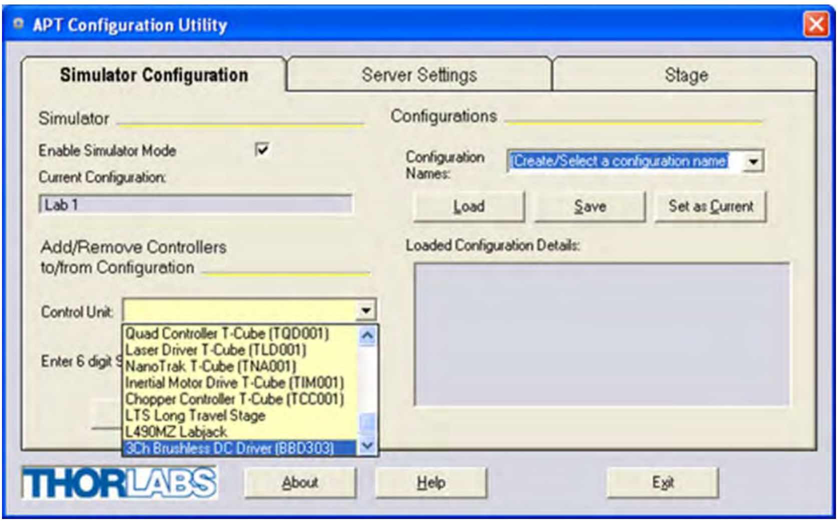


Fig. 5.13 APT Configuration Utility - Simulator Configuration Tab

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

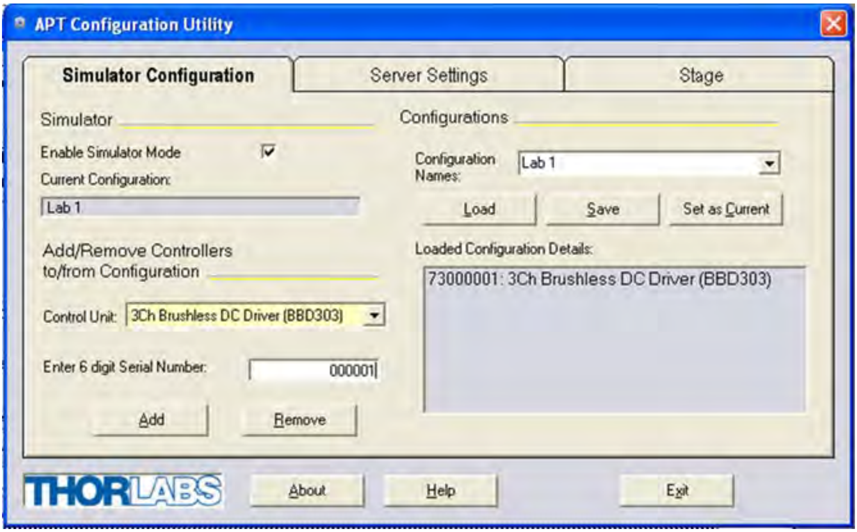
Each physical APT hardware base unit is factory programmed with a unique 8 digit serial number. In order to simulate a set of 'real' hardware the Config utility allows an 8 digit serial number to be associated with each simulated unit. It is good practice when creating simulated configurations for software 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 relating to the BBD302 and BBD303 stepper controllers are:

73xxxxxx - 3 Channel Brushless DC Driver (BBD303)

Note. The '73' prefix described above is applicable only to the base units. The serial number of the individual driver cards is prefixed by '94' - see Section 6.2.

5) In the 'Control Unit' field, select '3 Ch Brushless DC Driver (BBD303)'.



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 E .

6.2 GUI Panel

The following screen shot shows the graphical user interface (GUI) displayed when accessing the DC controller using the APTUser utility.

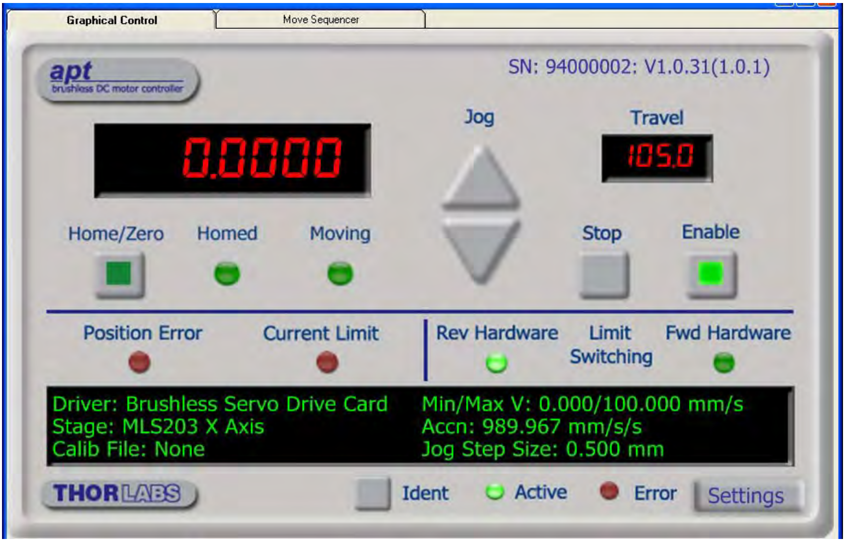


Fig. 6.1 Motor Controller Software GUI

Note

The serial number of the single channel driver cards is derived from the base unit serial number, with the '73' prefix being replaced with '94' and the subsequent 6 digit number incremented by '1' for each card in the system, e.g. a 2-channel unit with a base serial number 73123456 will have card serial numbers 94123457 and 94123458.

The serial number of the driver card 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 degs) of the actuator associated with the GUI panel.

Digital display - shows the position (in millimetres or degrees) of the motor. 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, the limit switch).

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 - During operation, the stage can be stopped at any time by clicking the ‘Stop’ button. Using this button does not remove power to the drive channel.

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 MLS203.

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 degs/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 degs) 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 2.2.4. for an overview of the APT ActiveX controls). The various parameters are described below.

6.3.1 Moves/Jogs tab

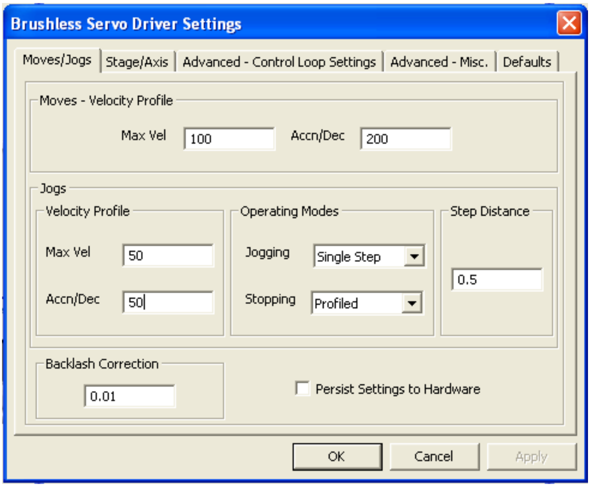


Fig. 6.2 Move/Jog Settings

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 5.4.) 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

Note. All jog moves are performed using either a trapezoidal or an S-curve profile, depending on which mode is selected in the 'Advanced-Misc. Tab - see Section 6.3.4.

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. mm or degrees).

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.

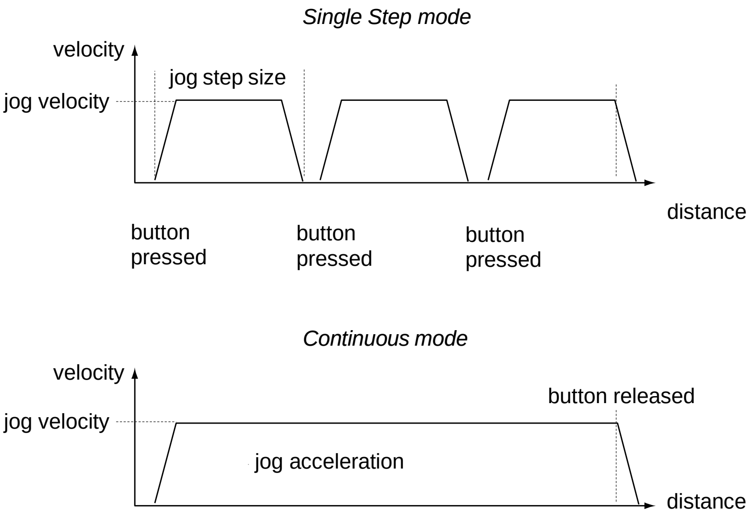


Fig. 6.3 Jog Modes

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 or degrees).

Backlash Correction - Backlash is a term used to describe the errors inherent in motors which use a leadscrew. Brushless linear DC motors that 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 BBD30x 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 *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

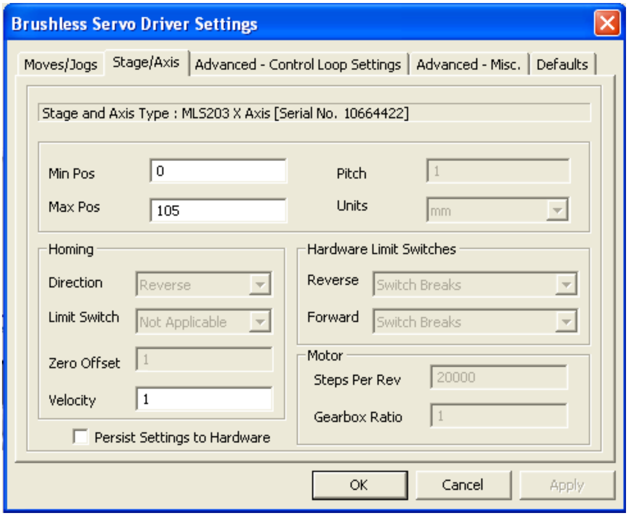


Fig. 6.4 Stage/Axis Settings

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, serial number, and axis 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 MLS203 and DDS220 stages and preset to ‘1’.

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

Note

***For DDS220 and MLS203 users*. The Homing, Limit Switch and Motor parameters described on the next two pages are not applicable for the DDS220 and MLS203 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

The operation of the limit switches is inherent in the design of the associated stage or actuator. The following parameters notify the system to the action of the switches when contact is made. Select Rev Switch or Fwd Switch as required, then select the relevant operation.

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 driven stages (e.g. MLS203) 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. MLS203) 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 BBD30x 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

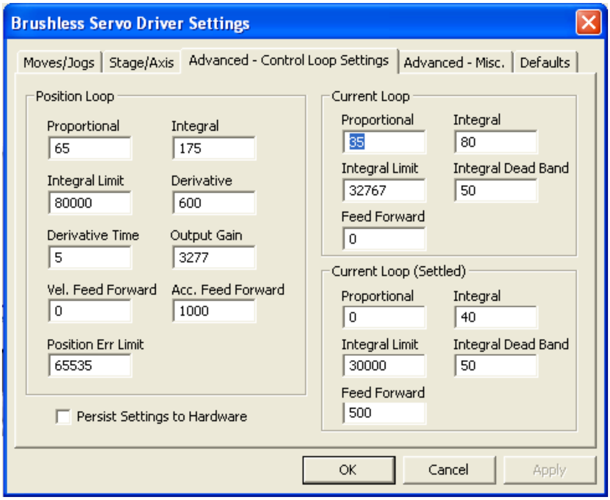


Fig. 6.5 Advanced Control Loop Settings

Position Loop Control Settings

The motion processors within the BBD series controllers use 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 minimise 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 controller 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.

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 processors within the BBD series controllers use 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 accepts 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 accepts values in the range 0 to 32767.

Current Loop (Settled) Control Settings

The following parameters are designed to assist in maintaining stable operation and reducing noise at the demanded position. They allow the system to be tuned such that errors caused by external vibration and manual handling (e.g. loading of samples) are minimized, and are applicable only when the stage is settled, i.e. the Axis Settled status bit (bit 14) is set - see Section 6.3.4.

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 near the target position. 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 accepts 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 accepts values in the range 0 to 32767.

Persist Settings to Hardware - Many of the parameters that can be set for the BBD30x 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

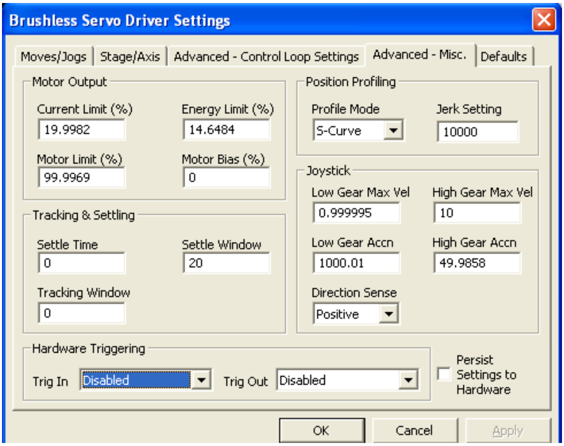


Fig. 6.6 Advanced Miscellaneous Settings

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.

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.

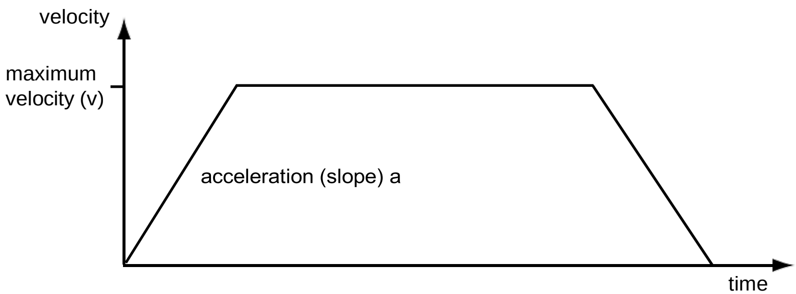


Fig. 6.7 Graph of a trapezoidal velocity profile

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. If the jerk value is set to ‘0’ then the profile is trapezoidal.

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.

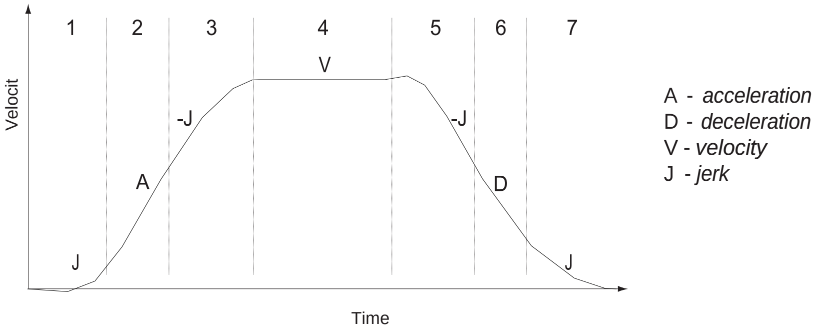


Fig. 6.8 Typical S-Curve Profile

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.

Joystick

If the optional Thorlabs joystick console is being used (MJC001) the following parameters are used to set the velocity and acceleration limits and the direction sense of any moves initiated from the joystick.- see Section 4.10. for more details on joystick use.

Low Gear Max Vel – The max velocity of a move when low gear mode is selected.

High Gear Max Vel – The max velocity of a move when high gear mode is selected.

Low Gear Accn – The acceleration of a move when low gear mode is selected.

High Gear Accn – The acceleration of a move when high gear mode is selected.

Direction Sense – The actual direction sense of any joystick initiated moves is dependent upon the application. This parameter can be used to reverse the sense of direction for a particular application and is useful when matching joystick direction sense to actual stage direction sense.

Note

Joystick controlled moves always use a trapezoidal velocity profile.

Persist Settings to Hardware - Many of the parameters that can be set for the BBD30x 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 *Motor Output, Position Profiling Tracking & Settling, and Joystick* 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.

Triggering

External triggering is facilitated by BNC connectors on the rear panel of the unit. These connectors will eventually allow the connection of external TTL compatible signals to initiate moves (Trigger In) and generate a hardware signal when certain motion related conditions are met (Trigger Out). They will provide a 5V logic level input and output that can be configured to support triggering from and to external devices. Note that at present (firmware/software update pending), for each motor only a single BNC Trigger Input is catered for via the BNCs: see the AUX I/O for further options (Appendix A.3).

It is possible to configure a particular controller to respond to trigger inputs, generate trigger outputs or both simultaneously. For those units configured for both input and output triggering, a move can be initiated via a trigger input while at the same time, a trigger output can be generated to initiate a move on another unit.

The trigger settings can be used to configure multiple units in a master–slave setup, thereby allowing multiple channels of motion to be synchronized. Multiple moves can then be initiated via a single software or hardware trigger command.

Trigger In

The Trigger In input can be configured to initiate a relative, absolute or homing home, either on the rising or falling edge of the signal driving it. As the trigger input is edge sensitive, it needs to see a logic LOW to HIGH transition ("rising edge") or a logic HIGH to LOW transition ("falling edge") for the move to be started. Additionally, the move parameters must be downloaded to the unit prior to the move using the relevant relative move or absolute move software methods as described following. A move already in progress will not be interrupted; therefore external triggering will not work until the previous move has been completed.

In order to avoid unexpected moves being executed on start-up, the trigger input settings cannot be persisted and will default to the input being disabled on power-up.

Even when input triggering is disabled, the state of the Trigger In input can be read at any time by using the LLGetStatusBits software method to read the status register bit 1. This allows application software to use the Trigger In input as a general-purpose digital input - see the *APTServer helpfile* for details on using the LLGetStatusBits method and the status register.

Trigger In options are set as follows:

Disabled – triggering operation is disabled

Rel Move (Trig Rise) – a relative move (specified using the latest MoveRelative or MoveRelativeEx method settings) is initiated on the specified channel when a rising edge input signal is received on the TRIG IN connector.

Rel Move (Trig Fall) – as above, but the relative move is initiated on receipt of a falling edge signal.

Abs Move (Trig Rise) – an absolute move (specified using the latest MoveAbsolute or MoveAbsoluteEx method settings) is initiated on the specified channel when a rising edge input signal is received on the TRIG IN connector.

Abs Move (Trig Fall) – as above, but the absolute move is initiated on receipt of a falling edge signal.

Home Move (Trig Rise) – a home move (specified using the latest MoveHome method settings) is initiated on the specified channel when a rising edge input signal is received on the TRIG IN connector.

Home Move (Trig Fall) – as above, but the home move is initiated on receipt of a falling edge signal.

Trigger Out

The Trigger Out output can be configured to be asserted to either logic HIGH or LOW as a function of certain motion-related conditions, such as when a move is in progress (In Motion), complete (Move Complete) or reaches the constant velocity phase on its trajectory (Max Vel). The logic state of the output will remain the same for as long as the chosen condition is true. The logic state associated with the condition can be selected to be either LOW or HIGH.

The Trigger Out output settings can be persisted and the persisted settings will be automatically applied once phase initialisation has completed after the next power-up. Whilst this can be advantageous of in some applications, please note that immediately after power-up, while the unit is going through its normal boot-up and initialisation process, the state of the Trigger Out output may not be its expected state.

In addition to the trigger out options listed above, it is also possible to set or clear the Trigger Out output under software-only control. As with the Trigger In input, this allows application software to use the Trigger Out output as a general-purpose digital output. To use this option, select the Trigger Out option to be Disabled and use the LLSetGetDigOPs method to control the state of the output directly - see the *APTServer helpfile* for details on how to use the LLSetGetDigOPs method.

Trigger Out options are set as follows:

Disabled – triggering operation is disabled

In Motion (Trig HI) – The output trigger goes high (5V) when the stage is in motion.

In Motion (Trig Lo) – The output trigger goes low (0V) when the stage is in motion.

Move Complete (Trig HI)

Move Complete (Trig HI) - The output trigger goes high (5V) when the current move is completed.

Move Complete (Trig LO) – The output trigger goes low (0V) when the current move is completed.

Max. Vel. (Trig HI) – The output trigger goes high (5V) when the stage reaches max velocity (as set using the SetVelParams method).

Max. Vel. (Trig LO) – The output trigger goes low (0V) when the stage reaches max velocity (as set using the SetVelParams method).

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 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.

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 proportional and integral 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, the ‘Defaults’ 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 controller must then be power cycled before the default values can take effect.

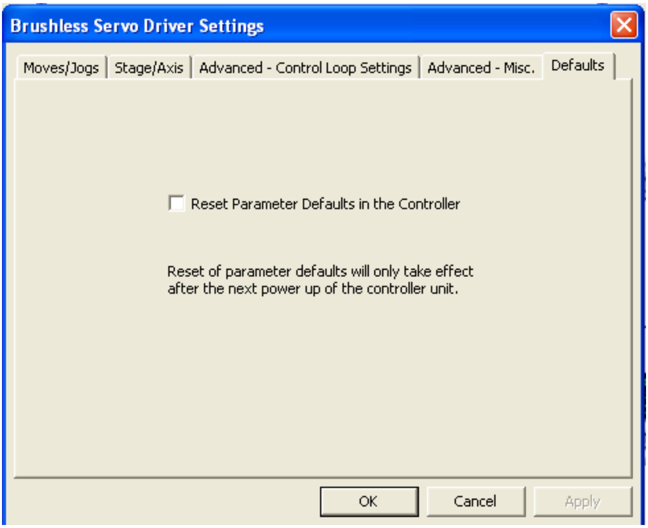


Fig. 6.9 Defaults tab

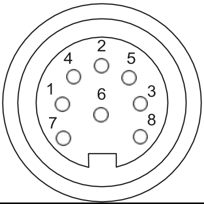
Changing the parameters under the "Advanced" tabs can cause the motor to become unstable or uncontrollable. If these settings are persisted, the unit may not be able to phase initialise the axis correctly the next time it powers up and, as a result, APT will not display some or any of the panels. If this occurs, the unit can be set to a special mode where the persisted settings are ignored and the default (safe) operating parameters are loaded after power-up.

To enter this mode, power down the unit and set the rear panel ‘CH1 ID’ switch to 'D'. When the unit is powered up, it will load the default set of operating parameters for all channels. In this mode parameters can still be persisted but they will not be loaded on start-up as long as the "CH1 ID" switch is set to 'D'. Moving the CH1 ID switch back to its original position will re-enable the operating parameters that were last persisted.

Appendix A Rear Panel Connector Pinout Details

A.1 Rear Panel MOTOR DRIVE Connectors

The 'MOTOR DRIVE' connector is a female, round 8-pin DIN type and provides drive connection to the motors. The pin functions are detailed in Fig. A.1.



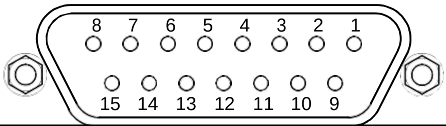
Pin	Description	Pin	Description
1	Motor Phase B	5	Stage ID
2	GND	6	Enable
3	Unused (Motor Phase D)*	7	Motor Phase C
4	Motor Phase A	8	+5 V*

* The signal present on Pins 3 and 8 are not used by brushless controllers

Fig. A.1 MOTOR DRIVE connector pin identification

A.2 Rear Panel FEEDBACK Connector

The 'FEEDBACK' connector is a female, 15 pin D-Type and supplies connection for the motor encoder feedback lines.



Pin	Description	Pin	Description
1	Not Connected	9	GND
2	GND	10	Limit Switch +
3	Not Connected	11	Limit Switch -
4	Index -	12	Index +
5	QB -	13	QB +
6	QA -	14	QA +
7	* 5 V	15	Not Connected
8	* 5 V		

***** Pins 7 and 8 are short circuit internally

Fig. A.2 FEEDBACK connector pin identification

A.3 Rear Panel AUX I/O Connector

A.3.1 Pin Identification

The AUX I/O connector is a female, 37 pin D-Type exposes a number of internal electrical signals. For convenience, a number of logic inputs and outputs are included, thereby negating the need for extra PC based IO hardware. Using the APT support software, these user programmable logic lines can be deployed in applications requiring control of external devices such a relays, light sources and other auxiliary equipment. The easy access BNC terminals currently allow for motor trigger inputs (one per motor; for BBD301, the second BNC present is not currently used).

The pin functions are detailed in the table associated with Fig. A.3 – see next page.

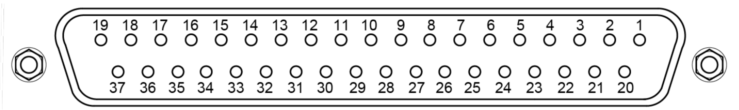


Fig. A.3 AUX I/O Connector Pin Identification

Warning

Do not, under any circumstances attempt to connect the digital I/O to any external equipment that is not galvanically isolated from the mains or is connected to a voltage higher than the limits specified in Section A.2.to Section A.4. In addition to the damage that may occur to the controller there is a risk of serious injury and fire hazard.

37-way D-type pin	Signal	BBD301	BBD302	BBD303	Comments
1	RS232 TX	Serial RS-232 communication port			Used for communication via RS-232
2	RS232 RX	Serial RS-232 communication port			
3	Ground	Ground			
4	Differential I/P 2+	reserved for future use			
5	Differential I/P 2-	reserved for future use			
6	Differential I/P 1-	reserved for future use			
7	Differential I/P 1+	reserved for future use			
8	User Digital O/P 12-			Motor #3 Trigger Out-	Trigger outputs. These can be configured to be set/cleared by motion related events, (e.g motion complete).
9	User Digital O/P 12+			Motor #3 Trigger Out+	
10	User Digital O/P 11-		Motor #2 Trigger Out-		
11	User Digital O/P 11+		Motor #2 Trigger Out+		
12	User Digital O/P 10-	Motor #1 Trigger Out-			
13	User Digital O/P 10+	Motor #1 Trigger Out+			
14	User Digital O/P 9-		Motor #2 Encoder IX-		Buffered encoder outputs, these can be used to monitor the state of the Motor #2 encoder inputs
15	User Digital O/P 9+		Motor #2 Encoder IX+		
16	User Digital O/P 8-		Motor #2 Encoder B+		
17	User Digital O/P 8+		Motor #2 Encoder B-		
18	User Digital O/P 7-		Motor #2 Encoder A-		
19	User Digital O/P 7+		Motor #2 Encoder A+		
20	+5V	+5V			
21	+5V	+5V			
22	User Digital I/P 3				The command MGMSG_RACK_REQ_STATUSBITS can be used to read the state of these inputs
23	User Digital I/P 2				
24	User Digital I/P 1				
25	User Digital I/P 0				
26	User Digital O/P 0				The command MGMSG_RACK_SET_DIGOUTPUTS can be used to set the state of these outputs
27	User Digital O/P 1				
28	User Digital O/P 2				
29	User Digital O/P 3				
30	Ground	Ground			
31	User Digital O/P 4+	Motor #1 Encoder A+			Buffered encoder outputs, these can be used to monitor the state of the Motor #1 encoder inputs
32	User Digital O/P 4-	Motor #1 Encoder A-			
33	User Digital O/P 5+	Motor #1 Encoder B+			
34	User Digital O/P 5-	Motor #1 Encoder B-			
35	User Digital O/P 6+	Motor #1 Encoder IX+			
36	User Digital O/P 6-	Motor #1 Encoder IX-			
37	Ground	Ground			
BNC #1	I/O #1	Motor #1 Trigger In			Trigger inputs. These can trigger motion related actions (e.g. absolute move).
BNC #2	I/O #2		Motor #2 Trigger In		
BNC #3	I/O #3			Motor #3 Trigger In	

<u>Notes:</u>

Pins 1 & 2 are used for RS232 communications. This allows control of the device using the low level communications protocol, or other software environments such as micromanager.

Pins 22-29 are single ended inputs and outputs - see Section A.3.3. and Section A.3.4.

Pins 8-19 are differential outputs - see Section A.3.2.

Pin 20-21 is a +5 V supply, see Section A.3.5.
Pins 4-7 are currently not useable; a firmware/software update will allow for future use.

A.3.2 Differential Outputs

All differential outputs (QA, QB and IX/Ref) are driven by an AM26C31 line driver, with a 130 Ω resistor between the output of the line driver and the connector pin. When the stage is being controlled by a joystick, in the absence of a PC, these outputs could be connected to an oscilloscope or custom circuit to facilitate monitoring of the position output.

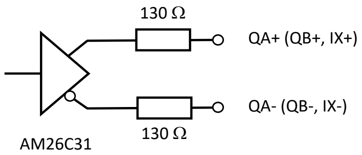


Fig. A.4 Differential Output Schematic

A.3.3 Digital Outputs

The digital outputs are via a 5V CMOS logic gate with a 330 Ω series resistor for protection (see Figure A.5). They behave as +5 V voltage sources with 330 Ω in series when the outputs are logic HIGH, and 330 Ω to ground when logic LOW. The resistor limits the current to a 15 mA maximum for any load, provided the output is not connected to voltages outside the 0 to +5 V range.

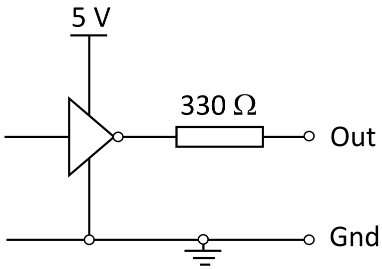


Fig. A.5 Digital Output Schematic

In some applications, the digital outputs may be required to control external equipment that has optocoupler type inputs (such as PLCs). As the outputs are actively driven, they can be used here to directly drive most optocouplers and the +5 V supply available on pins 20 and 21 can be used to provide power for these.

Caution

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

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

A.3.4 Digital Inputs

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

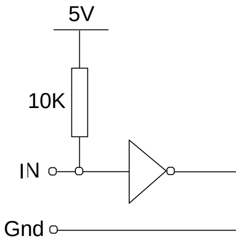


Fig. A.6 Digital Input Schematic (protection circuitry not shown)

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

Caution

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

A.3.5 +5 Volt Supply

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

Caution

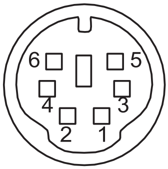
Do not exceed the 250 mA maximum output current. For applications requiring higher currents an external power supply must be used.

A.4 Rear Panel HANDSET Connector

A.5.1 Pin Identification

The HANDSET connector is a female, 6 pin mini DIN connector that exposes internal electrical signals for use with the external remote control handset (MJC001).

The pin functions are detailed in in Fig. A.7 .



Pin	Description
1	RX (controller input)
2	Ground
3	Ground
4	Supply Voltage for Handset 5V
5	TX (controller output)
6	Ground

Fig. A.7 HANDSET Connector Pin Identification

Note

Pins 2, 3 and 6 are common (connected) ground connections.

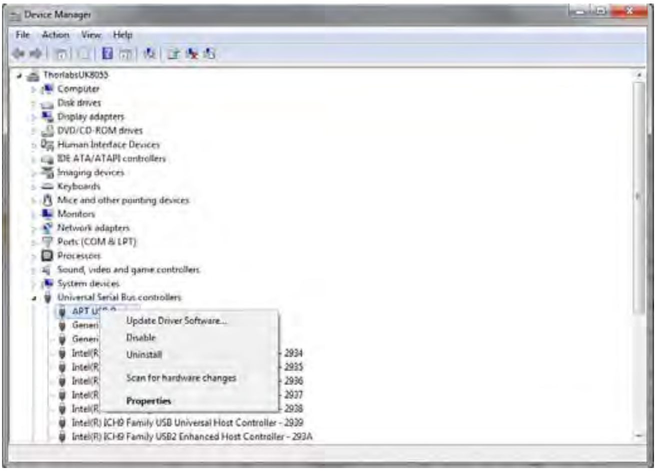
Pin 4 is for use only with Thorlabs joystick MJC001. It should not be used to power any other device.

Appendix B Using the RS232 or Virtual Comm Port

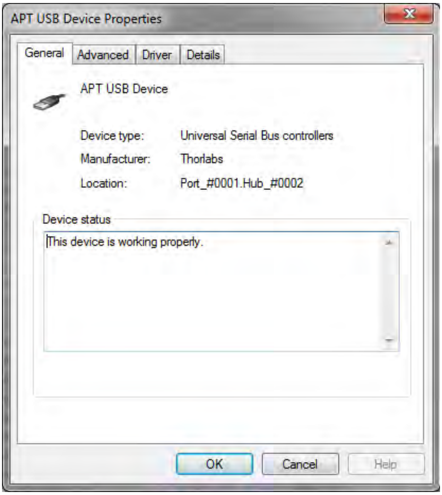
When using the low level communications protocol messages to develop client applications outside of the APT software, communication with the device is facilitated by using the RS232 comms pins on the rear panel AUX I/O connector – see Section A.3. Alternatively, a virtual comms port can be configured as follows:

1) Open the device manager by selecting Start/Control Panel/Device Manager/

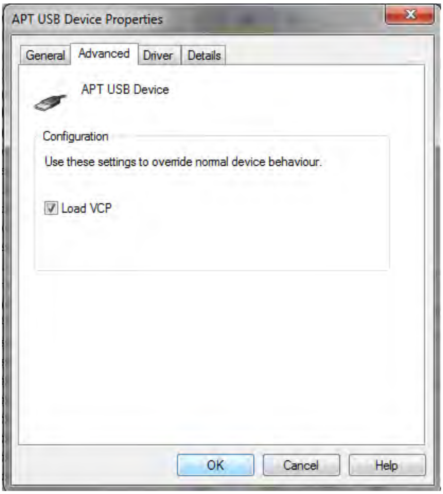
2) Click 'USB Serial Bus Controllers' and select the APT USB Device to be configured, then right click and select 'Properties'.



3) The 'USB Device Properties' window is displayed.

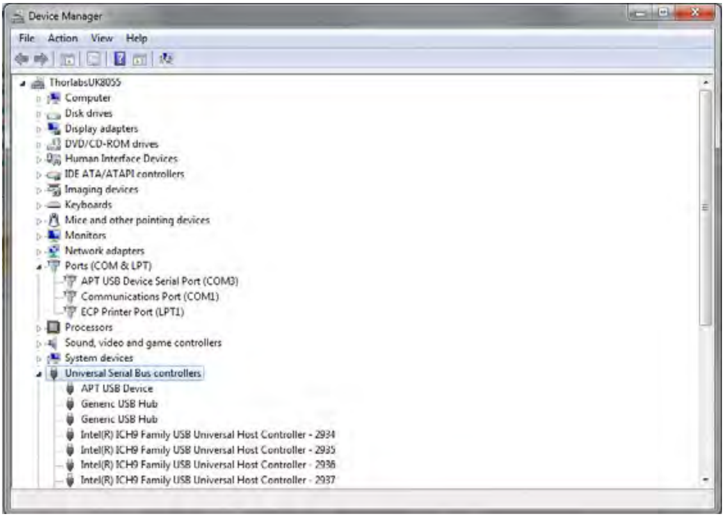


4) Select the 'Advanced' tab, and check the 'Load VCP' box.



5) Click OK, then power cycle the device being configured.

6) In the device manager, click 'Ports (COM & LPT)', and note the 'APT USB Device Serial Port' COM port number (e.g. COM3).



This COM port can then be used by the client application to communicate with the device using the low level protocol messages.

Appendix C Preventive Maintenance

Shock Warning

The equipment contains no user serviceable parts. There is a risk of severe 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.

C.1 Safety Testing

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

Caution

The instrument contains a power supply filter. Insulation testing of the power supply connector should be performed using a DC voltage. Repeated application of 'flash' test may damage the insulation.

C.2 Fuses

Two T 3.15 A /250 V a.c. anti-surge ceramic fuses are located on the back panel, onefor the live feed and one for the neutral as follows:

Fuse	Rating	Type	Fused Line
F1	T 3.15 A	ceramic; anti-surge; 20mm	Live feed
F2	T 3.15 A	ceramic; anti-surge; 20mm	Neutral feed

When replacing fuses:

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

C.3 Cleaning

Warning

Disconnect the power supply before cleaning the unit.
Never allow water to get inside the case.
Do not saturate the unit.
Do not use any type of abrasive pad, scouring powder or solvent, e.g. alcohol or benzene.

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

Appendix D Specifications and Associated Parts

D.1 Specifications

Parameter	Value
Drive Connector	8-Pin DIN-Type, Female (Motor Phase Outputs, Stage ID Input)
Feedback Connector	15-Pin D-Type, Female
AUX Control Connector	37-Pin D-Type Female (User Digital IO, 5 V O/P)
Brushless Continuous Output	2.5 A per channel (5.2A max. total output)
Brushless Peak Output	4.0 A per channel (5.2 A max. total output)
PWM Frequency	40 kHz
Operating Modes	Position, Velocity
Control Algorithm	16-bit Digital PID Servo Loop with Velocity and Acceleration Feedforward
Velocity Profile	Trapezoidal/S-Curve
Position Count	32 Bit
Position Feedback	Incremental Encoder
Encoder Bandwidth	2.5 MHz/ 10 M Counts/sec
Encoder Supply	5 V
Front Panel Display	Full colour LCD display, 4.3", 480 x 272 pixels
Input Power Requirements	
Voltage	100 to 240 V AC
Power	250 VA
Frequency	47 to 63 Hz
General	
Housing Dimensions (W x D x H)	BBD301: 199.8 x 229.1 x 108.8 mm (7.87" x 9.02" x 4.28") BBD302: 250.0 x 279.1 x 108.8 mm (9.84" x 10.99" x 4.28") BBD303: 350.0 x 279.1 x 108.8 mm (13.78" x 10.99" x 4.28")
Weight	BBD301: 1.20 kg (2.65 lbs) BBD302: 1.70 kg (3.75 lbs) BBD303: 2.20 kg (4.85 lbs)
Compatible Motors	3-Phase DC Brushless Motors Peak Powers: 100 W Coil Resistance: 0.1 to 100 Ω Coil Inductance (Nominal): 1 to 100 mH Rated Phase Currents (Nominal): 100 mA to 5 A

Appendix E   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 serial number of the single channel driver cards is derived from the base unit serial number, with the ‘73’ prefix being replaced with ‘94’ and the subsequent 6 digit number incremented by ‘1’ for each card in the system, e.g. a 2-channel unit with a base serial number 73123456 will have card serial numbers 94123457 and 94123458.

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 descriptions 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.
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.
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.
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'.
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'.

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 F Regulatory

F.1 Declarations Of Conformity

F.1.1 For Customers in Europe; CE certificate

THORLABS
www.thorlabs.com

EU Declaration of Conformity

in accordance with EN ISO 17050-1:2010

We: Thorlabs Ltd.

Of: 204 Lancaster Way Business Park, Ely, CB6 3NX, UK

in accordance with the following Directive(s):

2014/35/EU	Low Voltage Directive (LVD)
2014/30/EU	Electromagnetic Compatibility (EMC) Directive
2011/65/EU	Restriction of Use of Certain Hazardous Substances (RoHS)

hereby declare that:

Model: **BBD30X**

Equipment: ***Benchtop Brushless Motor Controller***

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

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

and which, issued under the sole responsibility of Thorlabs, is/are 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:

contains no 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:* 12 May 2021

Name: Keith Dhese

Position: General Manager *EDC - BBD30X -2021-05-12*

CE

F.1.2 For Customers In The USA

This equipment has been tested and found to comply with the limits for a Class A digital device, 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.

Appendix G Thorlabs Worldwide Contacts

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

USA, Canada, and South America
Thorlabs, Inc.
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

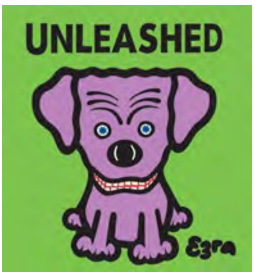
UK and Ireland
Thorlabs Ltd.
sales@uk.thorlabs.com
techsupport.uk@thorlabs.com

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 "endof 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 litterbin or at a public waste disposal site.



THORLABS

www.thorlabs.com