THORLABS

BBD301, BBD302, & BBD303 Brushless DC Motor Controllers

Kinesis User Guide

Original Instructions

Contents

Chapter 1   Overview

1.1   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 of up to 2.5 Amp peak coil current.

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. 1.1 BBD303 Three Channel Brushless DC Servo Motor Controller

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 Kinesis® software incorporates pre-configured settings for each of the Thorlabs stages and actuators, while still exposing all parameters individually for use with other DC motor driven systems.

For convenience and ease of use, 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 Kinesis programmable interfaces for automated alignment sequences.

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

1.2   Kinesis Software Overview

1.2.1   Introduction

As a member of the Thorlabs range of controllers, the BBD30x series 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 Kinesis software suite provides a flexible and powerful PC based control system both for users of the equipment, and software programmers aiming to automate its operation.

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

1.2.2   Kinesis Server

Kinesis 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 Kinesis system, .Net Controls are deployed to allow direct control over (and also reflect the status of) the range of electronic controller units, including the BSC301 series controllers. Software applications that use .Net Controls are often referred to as 'client applications'. A .Net Control is a language independent software component. Consequently, the controls can be incorporated into a wide range of software development environments for use by client application developers. Development environments supported include Visual Basic, LabVIEW, Visual C++, C++ Builder, HPVEE, MATLAB, VB.NET, C#.NET and, via VBA, Microsoft Office applications such as Excel and Word.

Consider the control supplied for the BBD30x Brushless DC Servo Controller unit (Fig.1.2):
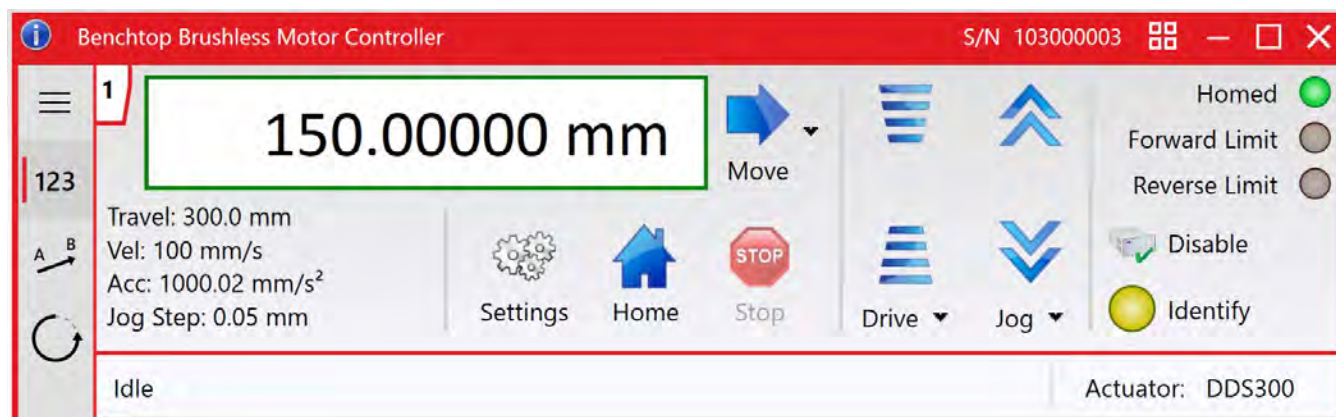
Fig. 1.2 Standard PC GUI with Kinesis

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 Kinesis controls collection provides a rich set of graphical user panels and programmable interfaces allowing users and client application developers to interact seamlessly with the hardware. Each of the controllers has an associated .Net Control and these are described fully in the handbooks associated with the controllers. See Fig 1.3.
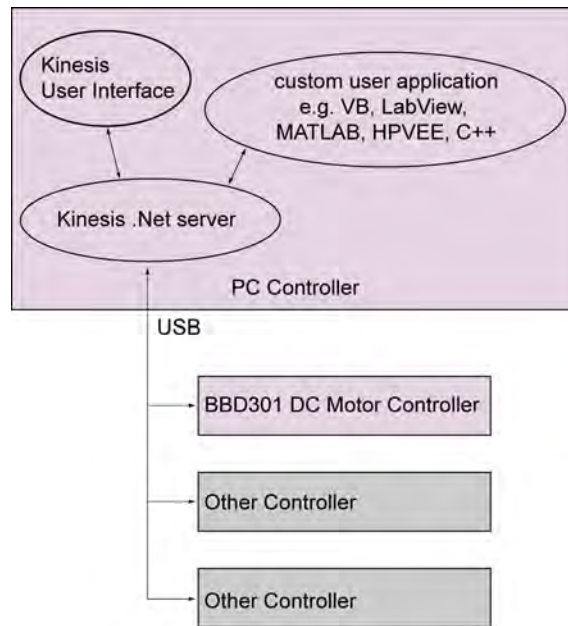
Fig. 1.3 System Architecture Diagram

Refer to the main Kinesis Software on-line help file, for a complete programmer's guide and reference material on using the Kinesis Controls collection. This is available either by pressing the F1 key when running the Kinesis server, or via the Start menu, Start\Programs\Thorlabs\Kinesis\Kinesis Help.

1.2.3   Software Upgrades
Thorlabs operate a policy of continuous product development and may issue software upgrades as necessary. The latest software can be downloaded from the 'services' section of www.thorlabs.com.

Chapter 2 Safety

2.1 Safety Information

For the continuing safety of the operators of this equipment, and the protection of the equipment itself, the operator should take note of the **Warnings, Cautions** and **Notes** throughout this handbook and, where visible, on the product itself.

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

Warning: Risk of Electrical Shock

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

Warning

Given when there is a risk of injury to users.

Caution

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

Note

Clarification of an instruction or additional information.

2.2 General Warnings

Warning

If this equipment is used in a manner not specified in the handbook, the protection provided by the equipment may be impaired. In particular, excessive moisture may impair operation.

Spillage of fluid, such as sample solutions, should be avoided. If spillage does occur, clean up immediately using absorbent tissue. Do not allow spilled fluid to enter the internal mechanism.

The equipment is for indoor use only.

When running custom move sequences, or under fault conditions, the stage may move unexpectedly. Operators should take care when working inside the moving envelope of the stage.

Chapter 3 Installation

3.1 Installing the 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 Kinesis 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 or the control panel buttons.

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 $^{\circ}$C to 40 $^{\circ}$C
Maximum Humidity	Less than 80% RH (non-condensing) at 31°C

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

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

The unit must not be used in an explosive environment.

3.3 Electrical Installation

> ⚠️ **Warning**
>
> The safety of any system incorporating this equipment is the responsibility of the person performing the installation.

3.3.1 Connecting To The Supply

> ⚠️ **Warning: Risk of Electrical Shock**
>
> The unit must be connected only to an earthed fused supply of 100 to 240 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:
>
> <div align="center">
>
> Brown Live
>
> Blue Neutral
>
> Green/Yellow Earth/Ground
>
> </div>

3.3.2 Fuses

Two T 3.15A/250VAC 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; Antisurge	Live Feed
F2	T 3.15 A	Ceramic; Antisurge	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.
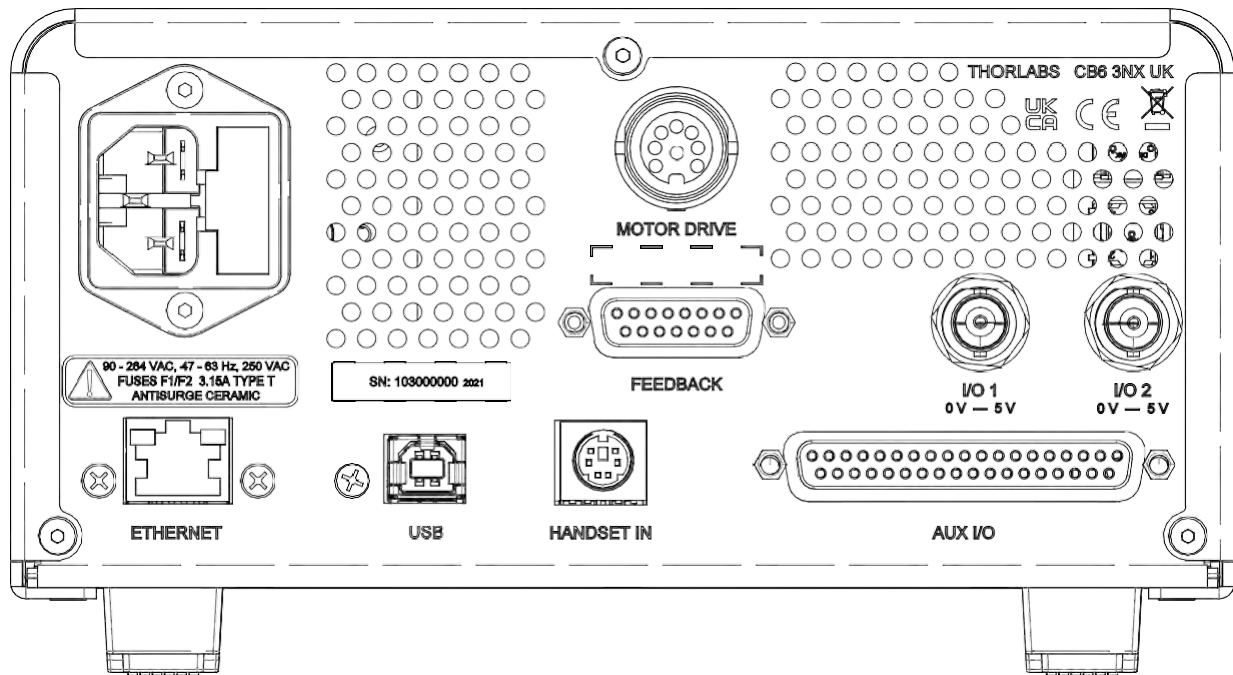
3.3.3   Rear Panel Connections BBD301

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 Kinesis 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. - see Section A.3. for further details.
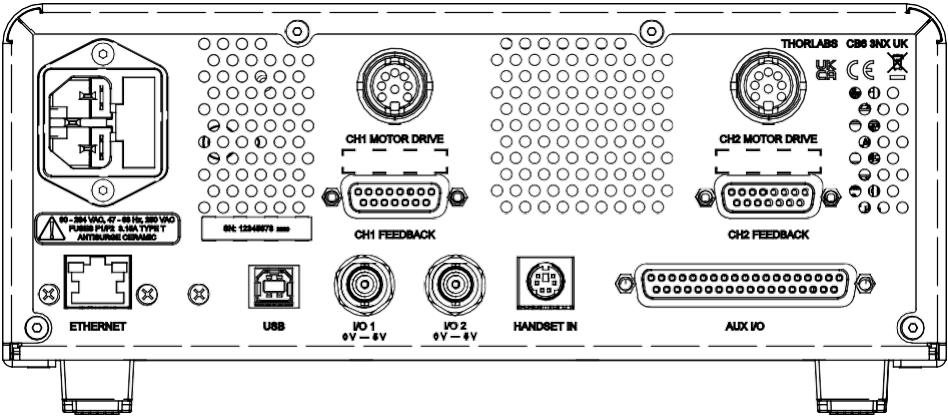
3.3.4   Rear Panel Connections BBD302 and BBD303
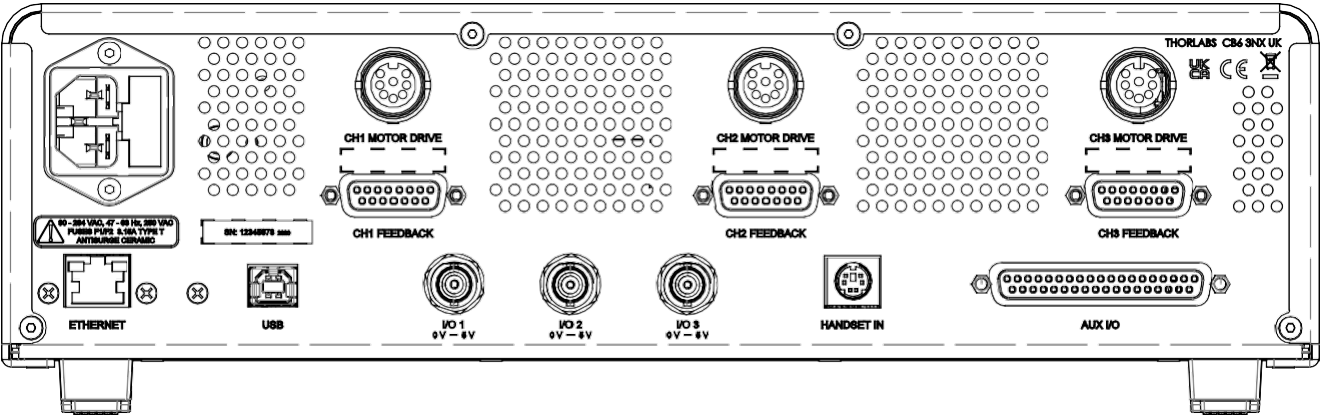

Fig. 3.2a BBD302 Rear Panel Connections

Fig. 3.2b BBD303 Rear Panel Connections

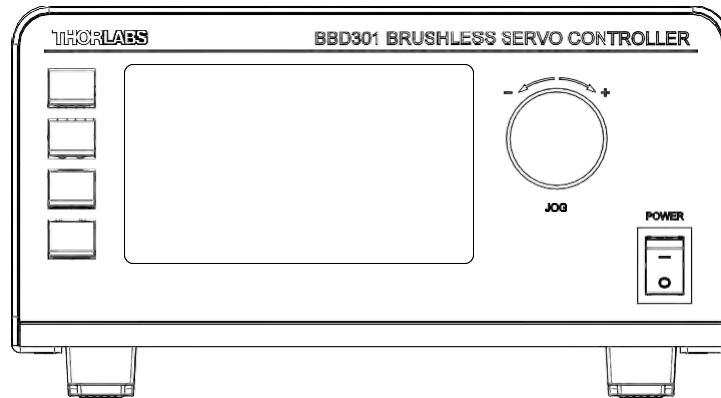## 3.4   Front Panel Controls and Indicators

Fig. 3.3a BBD301 Front Panel Controls and Indicators
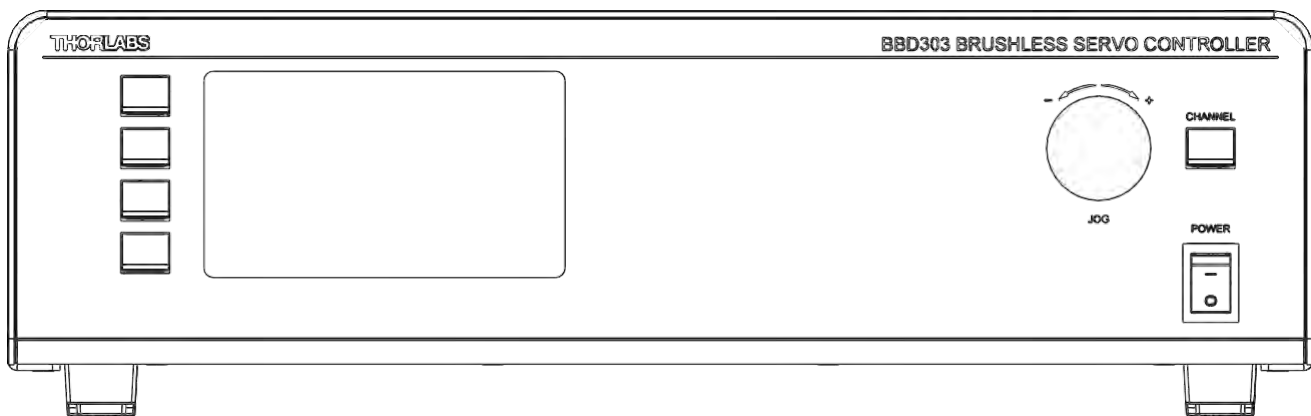

Fig. 3.3b BBD303 Front Panel Controls and Indicators

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.

3.5   Connecting the Hardware and Powering Up

1) Install the 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^{TM} should detect the new hardware. Wait while Windows^{TM} installs the drivers for the new hardware - see the Getting Started guide for more information
5) Wait for around 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 energizing 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 initialization can only take place if the motor can move unobstructed during this time.

6) Run the software and click the 'Home' button on each GUI panel. When homing is complete, the Channel Enable LEDs on the controller GUI front panel stop flashing.
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 help-file supplied with the Kinesis server for more information.

3.6   Verifying Software Operation

3.6.1   Initial Setup

The Software should be installed (Section 3.1) and the power up procedure performed (Section 3.5) before software operation can be verified.

1)   Run the software and check that the Graphical User Interface (GUI) panel appears and is active.
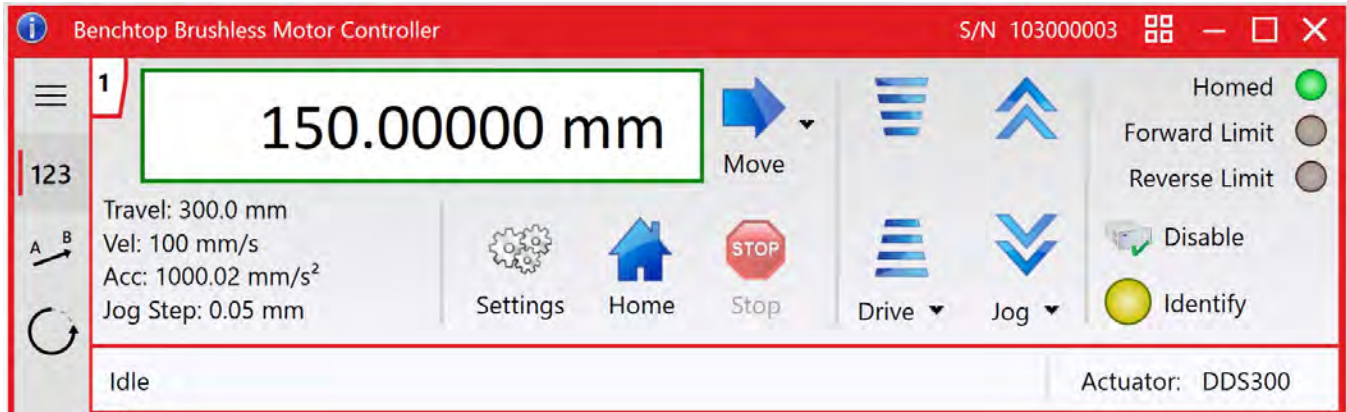
Fig. 3.4 GUI Panel Showing Jog and Ident Buttons

2)   Click the 'Identify' button. The display on the front panel of the associated 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.

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 if the front panel is used in conjunction with Kinesis 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 the chapter, 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 the output 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 will be 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 the system 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.
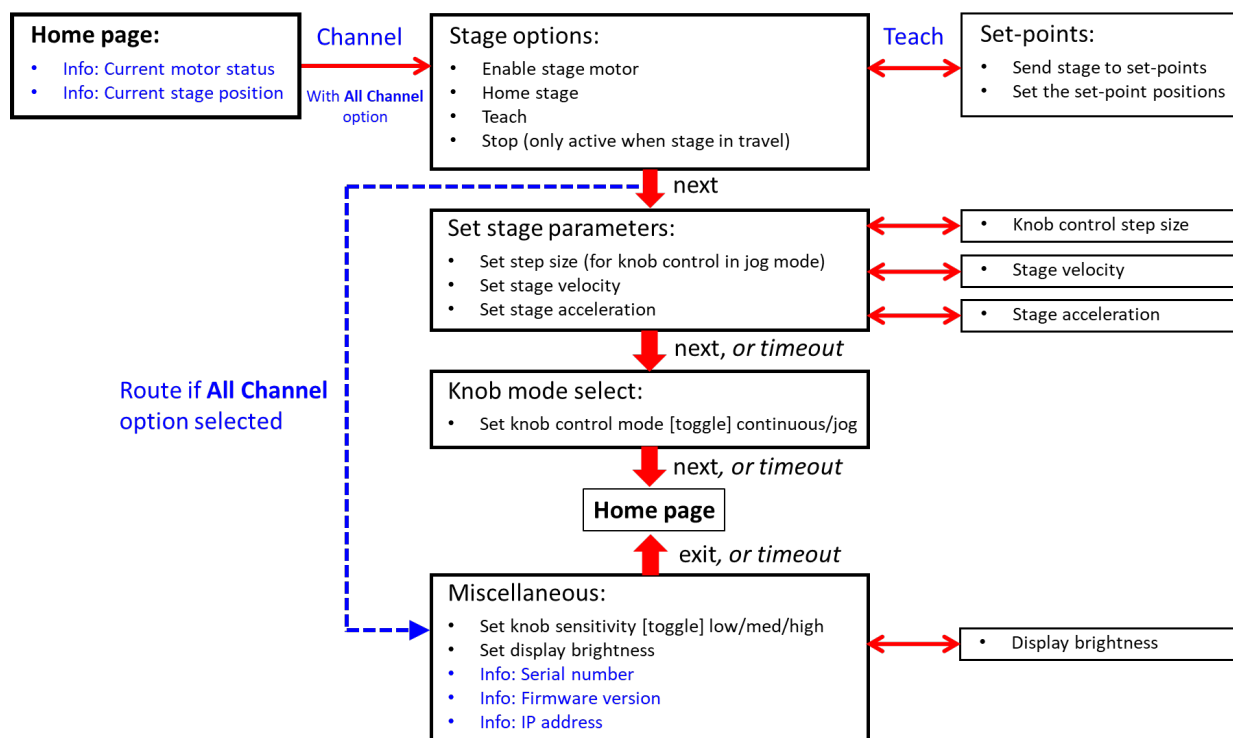

Fig. 4.1   Front Panel Display Pages Map

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.
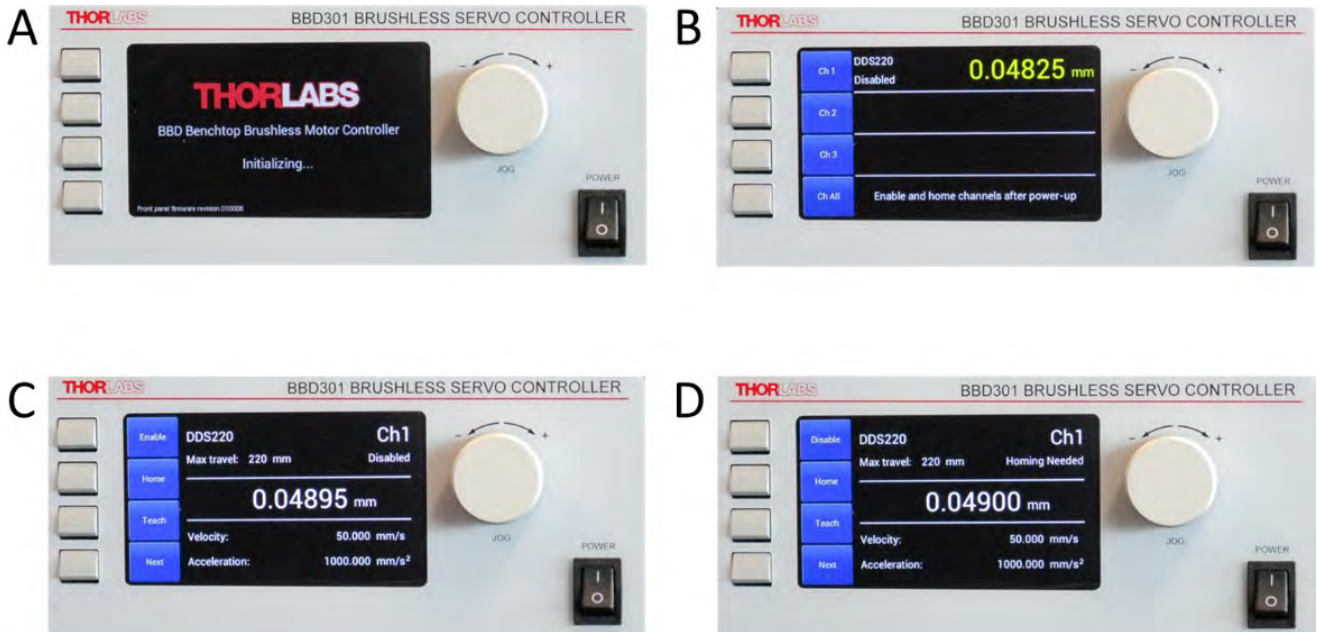

Fig. 4.2   Startup Sequence for BBD301 under Front Panel Control

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.
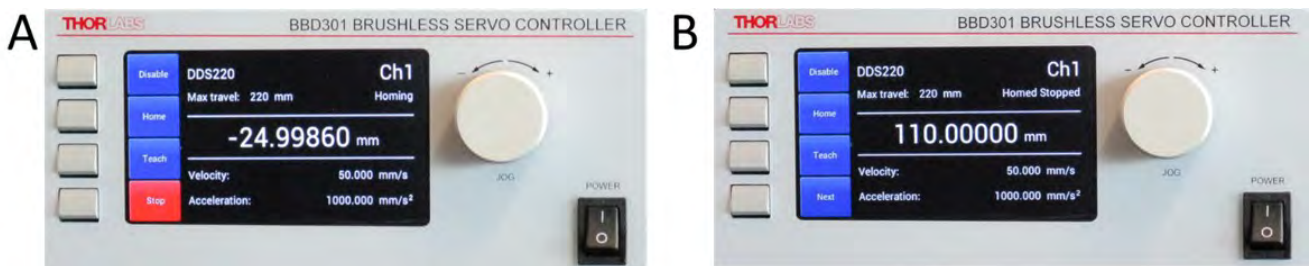

Fig. 4.3   Homing in Operation

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).

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.
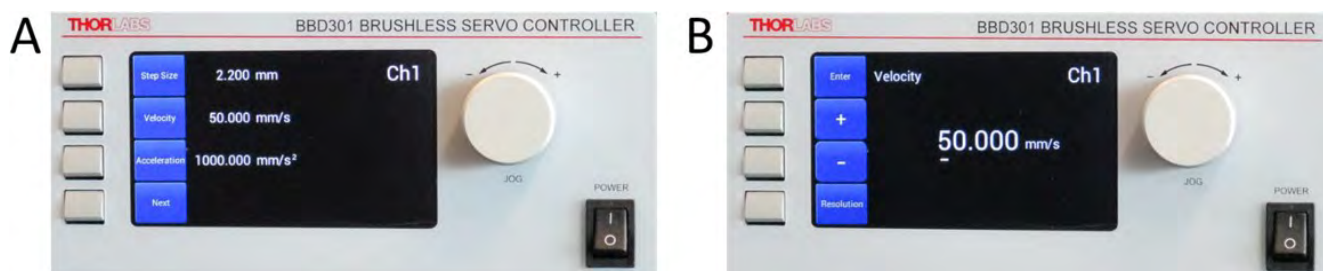

Fig. 4.4   Changing Motor Parameters

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 Kinesis software control option, described in Chapters 5 and 6.
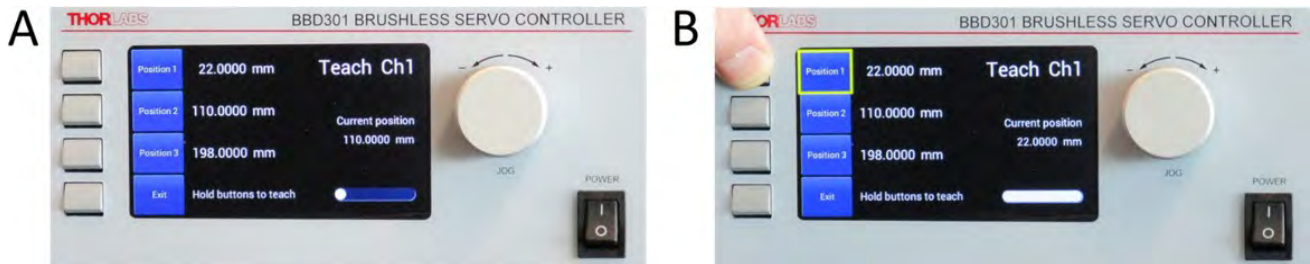

Fig. 4.5   Stage position Set-points and Changing them via Teach

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.

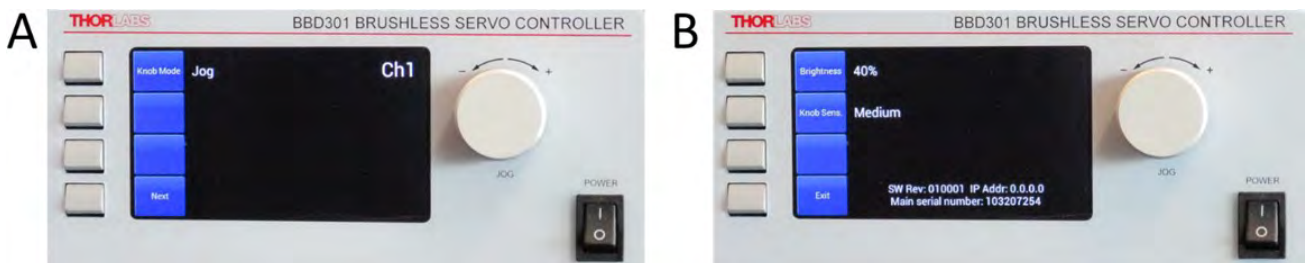Note: this page times out after 20 second of inactivity.

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

1) The following brief tutorial guides the user through a typical series of moves and parameter adjustments performed using the Kinesis software. It assumes that the unit is electrically connected as shown in Section 3.3.3, that the Software is already installed (see Section 3.1), and that the stage being driven is the Thorlabs DDS300 Direct Drive Translation stage.

> ⚠️ **Warning**
>
> The Kinesis software 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 kinesis software, 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**
>
> 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 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 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 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 DDS series stages use an electronic reference marker and therefore the limit switches are not used for reference.
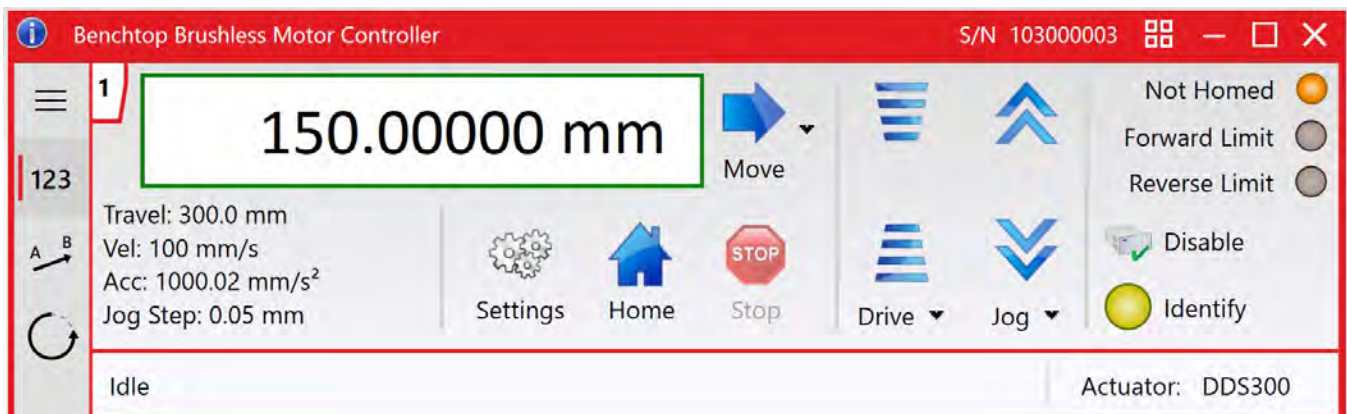

Fig. 5.1 Motor Controller Software GUI

1) Click the 'Home' button. Notice that the 'Not Homed' LED changes to 'Homing' and flashes green to indicate that homing is in progress.
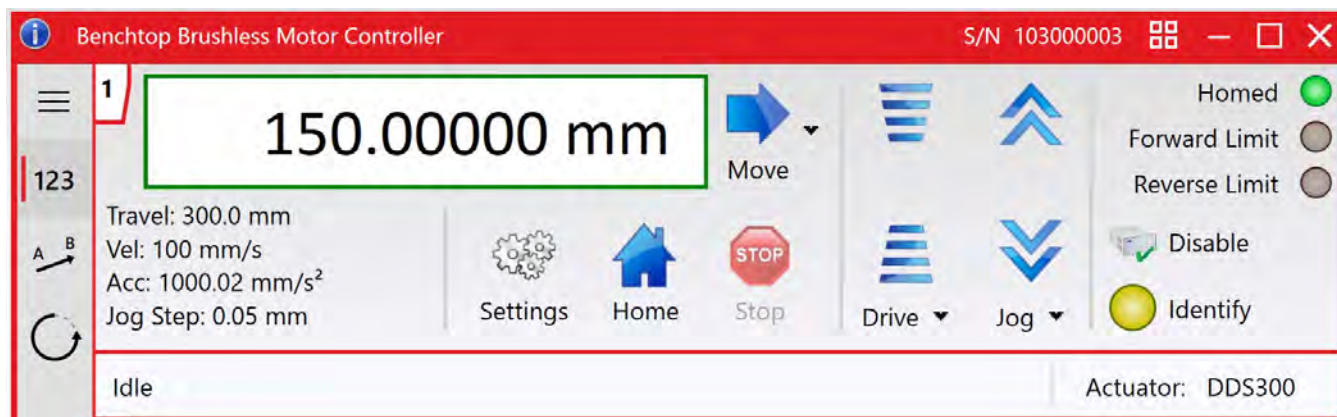
2) When homing is complete, the 'Homed' LED is lit green.

Fig. 5.2 BBD30x GUI - Homed

> **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.

5.3 Changing Motor Parameters and Moving to an Absolute Position

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

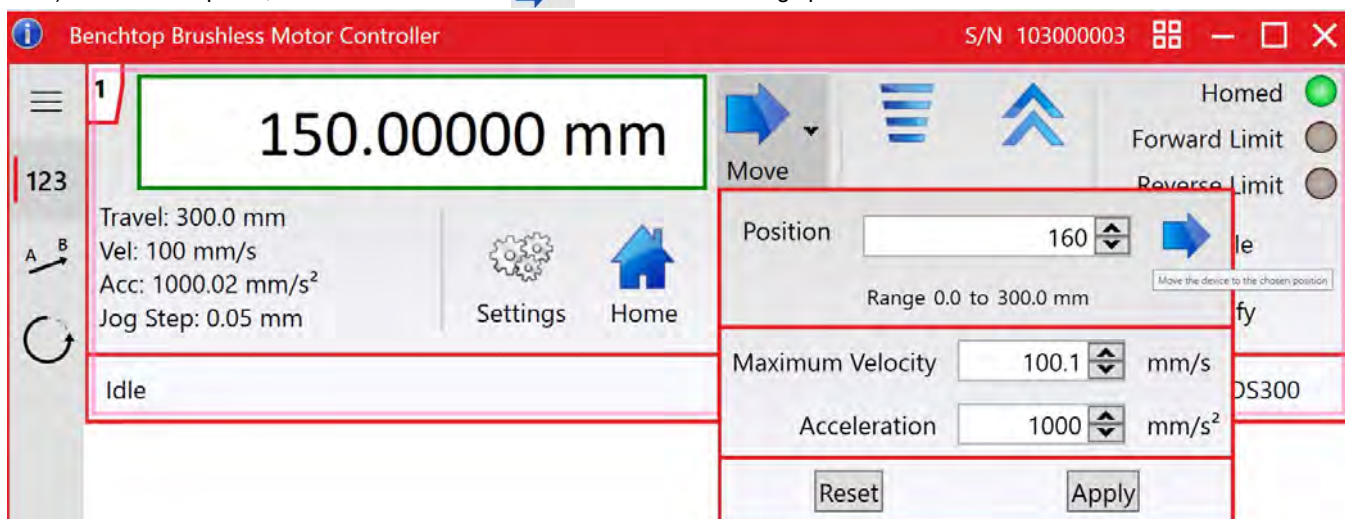1) On the GUI panel, click the Move arrow ➡ ▾ to show the Settings panel.

Fig. 5.3 Absolute Position Popup Window

2) Enter the required absolute position and/or parameter values.

3) To move to the position entered click the arrow ➡

4) Click 'Apply' to save the parameter settings and close the window, click Reset to return to the previously saved values.

5.4 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.

5.5   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.

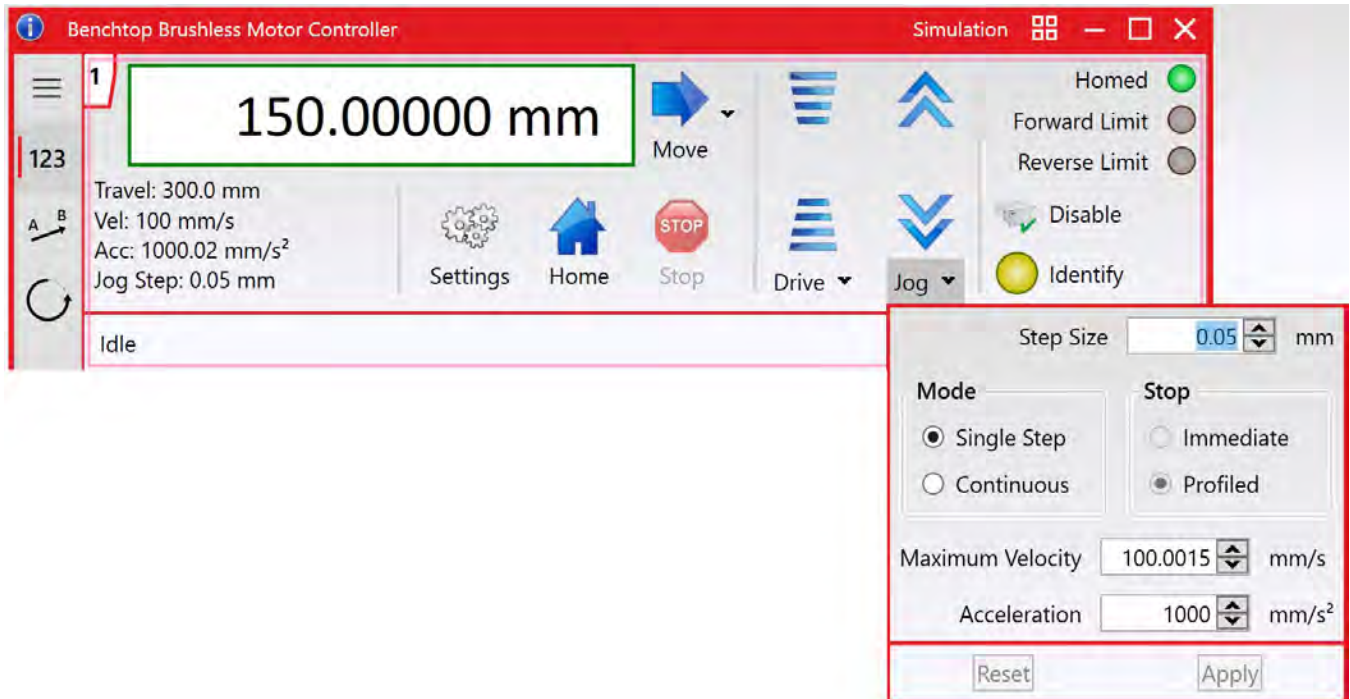1) On the GUI panel, click the word 'Jog' Jog ▾ to display the Settings panel

Fig. 5.4 Settings Panel - Move/Jogs Tab

2) Make parameter changes as required.
3) Click 'Apply' to save the settings and close the window, click Reset to return to the previously saved values.

5.6   Setting Move Sequences

The Kinesis software allows move sequences to be programmed, allowing several positions to be visited without user intervention. For more details and instructions on setting move sequences, please see the *Kinesis Help-file*.

5.7   Changing and Saving Parameter Settings

During operation, certain settings (e.g. max velocity, jog step size etc.) can be changed as required. Other settings (e.g. PID parameter values) cannot be changed so easily. When the Kinesis Server is run up and the stage/actuator association made, suitable default settings are loaded and these values have been chosen to provide safe performance in the majority of applications. However, for applications where these settings need to be changed, a new set of Device Start Up settings', must be created which can then be applied and/or uploaded on subsequent start up. See the *Kinesis Help-file* for more details.

5.8 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, and if the parameter settings are persisted to the controller (see Section 6.4.) 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 Kinesis software. If these parameter values subsequently require adjustment, this can only be performed by running the Kinesis software - see Section 3.1. and Section 5.3. 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 stops flashing (~3 s) and for the controller phase initialization to 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 to '0'.

> **Note**
>
> The other settings 1 to F are not required for operation with the BBD30x series, and are reserved for use with earlier, legacy BBD units.

Fig. 5.1 ID switch settings

6) Set the joystick console ID switch to '0' as shown above.
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 help-file supplied with the Kinesis server for more information.

Chapter 6 Software Reference

6.1 Introduction

This chapter gives an explanation of the parameters and settings accessed from the Kinesis software running on a PC.

6.2 GUI Panel

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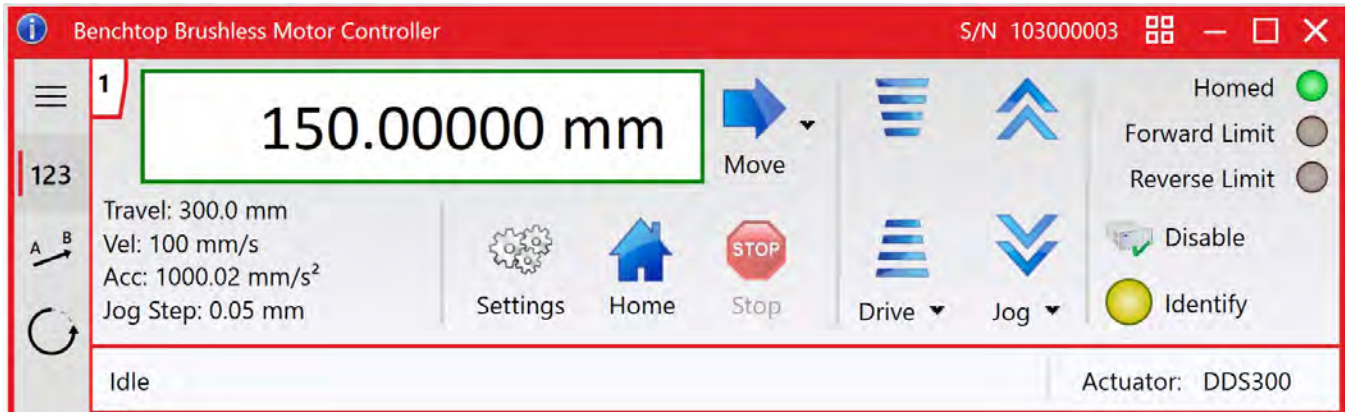

Fig. 6.1 Motor Controller Software GUI

> **Note**
>
> The serial number of the driver card associated with the GUI panel is displayed in the top right hand corner. This information should always be provided when requesting customer support.

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

Move - Opens the settings window, so that position data and velocity parameters can be entered - see Section 5.3. Moves are performed using the current velocity parameters which can be changed in the same panel. The present settings are displayed below the window.

Velocity Parameters - the present setting for the move velocity parameters and the jog step size. The travel range of the associated stage/actuator is also displayed.

These settings can be adjusted as described previously, or by clicking the Settings button to display the settings window, see Section 6.4.1.

Jog Controls - used to increment or decrement the motor position. The controls comprise a bar graph and a set of jog arrows.

Each division of the bar graph represents a different velocity. The velocities are entered in the settings panel which is displayed by clicking 'Drive' or the small down arrow.

When the arrows are clicked, the motor is driven in the selected direction at the jog velocity, one step per click. The step size and jog velocity parameters can be changed by clicking 'Jog' or the small down arrow to display the settings panel.

Homed/Not Homed - lit when the motor has not been 'Homed' since power up. When the home button is clicked, the caption changes to 'Homed' and the LED flashes while the home move is being performed. The LED is lit green once the move is complete.

Limit Switch - lit when a Forward or Reverse limit switch is activated, i.e. the motor is at its end stop.

Enable/Disable - applies and removes power to the motor. With the motor enabled, only the Disable button is visible, and with the motor disabled only the Enable button is visible.

Identify - when this button is pressed, the display on the front panel of the associated hardware unit will flash for a short period.
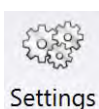
Settings - Displays the 'Settings' panel, which allows the operating parameters to be entered for the motor drive - see Section 6.4.

Home - sends the motor to its 'Home' position - see Section 5.2.

**Stop** - halts the movement of the motor.

Lower Display - Shows the present state of the motor, e.g. Idle, Moving, or Homing.

Also shows the part number of the associated actuator or stage.

6.3 Synchronized Moves

On BBD302 2-Axis and BBD303 3-Axis controllers, it is possible to perform synchronized moves by clicking the ⊞ button to 'group' the channels. When this button is clicked, the Vector button and the path button become active.

6.3.1 Entering Positions for a Synchronized Move

The Vector button displays the channels in a vector window, allowing multi-channel moves to be performed simultaneously in a synchronized fashion.

Fig. 6.2 Vector Window

For each required channel, enter the absolute positions to move on the right hand side, then click the Move arrow.

6.3.2   Synchronized Moves
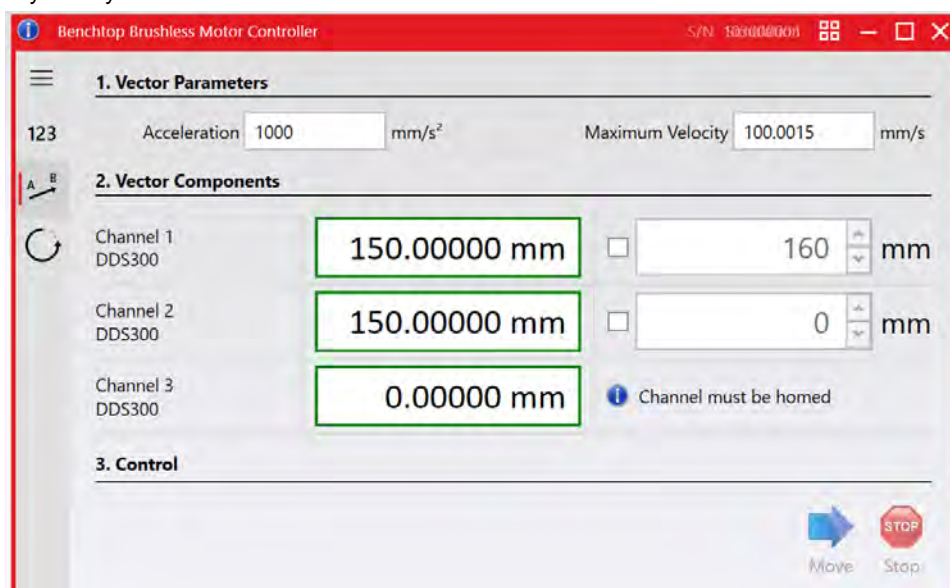
At the heart of nearly all motion control algorithms a trajectory generator is used to generate the position points where the motor is required to be at any one time. The trajectory (position target) values output by the trajectory generator are fed to the position loop controller which compares the target position to the actual position and adjusts the motor current, always trying to maintain the target position. Thus when a move is commanded, the corresponding parameters are sent to the trajectory generator, which then calculates the position target values required to execute the move.

The path button ⟳ displays a window which allows the user to upload a trajectory generator in the form of a .csv file.
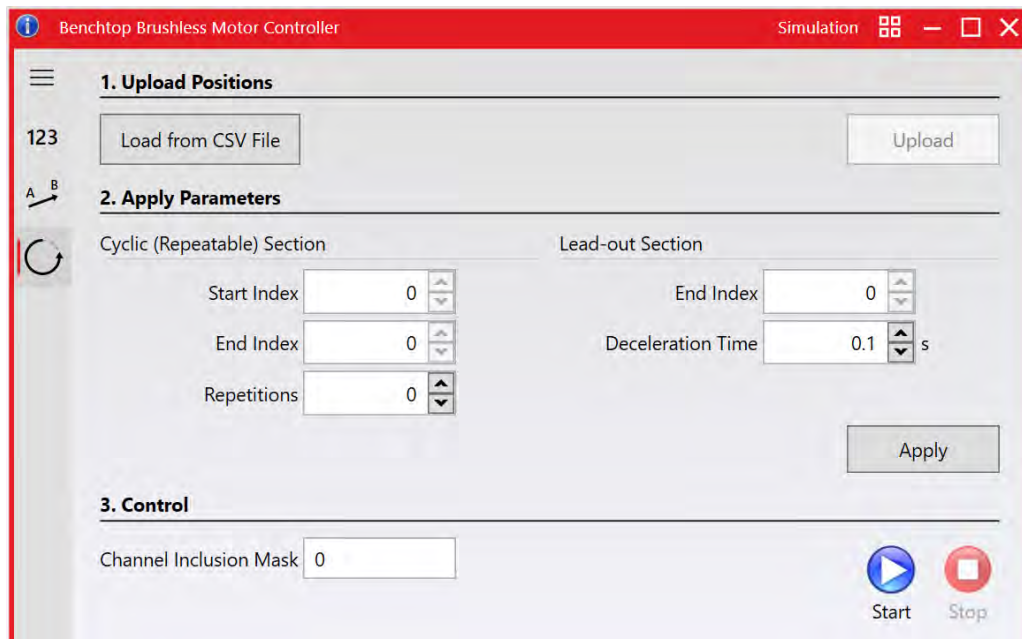

Fig. 6.3 Path Window

A time-position array contains a Leading Section, a Repeated Section and a Trailing Section and the Path window allows these parameters to be entered. Thus the time-position array will be output with the repeated section beginning at *Start Index*, and finishing at *End Index*, and repeating the number of times entered in the *Repetitions* parameter.

Normally the time-position array leading and trailing sections contain a smooth transition from stationary to moving state and then back to stationary again, as the multi-axis synchronized move is assumed to describe a complete move sequence. However, if the move needs to be interrupted and stopped, the parameter *Deceleration Time* will be applied to bring the various moving axes to standstill.

Click the Load from CSV File button and navigate to the location of the required file.

Start Index: The start index of the repeated (cyclic) part of the trajectory.

End Index: The end index of cyclic part.

Repetitions: The number of times the cyclic part is repeated.

End Index: The end index of the complete synchronized move sequence (i.e. total number of time-position array elements).

Deceleration Time: The deceleration time if the move is stopped before completing all points

Channel Inclusion Mask: The number of channels included in the sequence.

For an introduction to multi-axis synchronized moves, please see Appendix E.

6.4 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 (refer to the *Kinesis Server help-file* for further details.

6.4.1 Moves/Jogs tab

Fig. 6.4 Move/Jog Settings

Position Display

By default, the GUI will display position in mm. If required, the units can be changed so that the display shows other positional units (cm, μm, or in.).

Use Device Units -

Units - the positioning units used on the GUI display.

Factor - the scaling factor associated with the selected units*.*

Decimal Places - the number of decimal places to show on the GUI display.

The Apply and Options buttons relate to user defined or custom units created for a specific application, as described on the following page.

It is also possible to create user defined or custom units specific for a particular application.

To do this, click the Options button to display the Configure Units window.

Enter a name for the new units, and a factor for conversion to millimetres, then click Add.

The new units are added to the list and can now be selected in the Units parameter described previously. Once selected, click the Apply button to apply the new units.

Velocity Parameters

Moves can be initiated via the GUI panel by entering a position value after clicking on the position display box (see Section 5.3.), or by calling a software function (see the Kinesis Server help-file). The following settings determine the velocity profile of such moves, and are specified in millimetres.

Maximum Velocity - the maximum velocity at which to perform a move.

Acceleration - the rate at which the velocity climbs from zero to maximum, and slows from maximum to zero.

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).

Jog Parameters

Jogs are initiated by using the 'Jog' keys on the GUI panel (see Section 5.5.), or the Jog Buttons on the front panel of the unit.

Step Size - The distance to move when a jog command is initiated. The step size is specified in mm).

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

There are two jogging modes available, 'Jog' and 'Continuous'. In 'Jog' mode, the motor moves by the distance specified in the Step Size parameter. If the jog key is held down, single step jogging is repeated until the button is released - see Fig. 6.5. In 'Continuous' mode, the motor actuator will accelerate and move at the jog velocity while the button is held down.
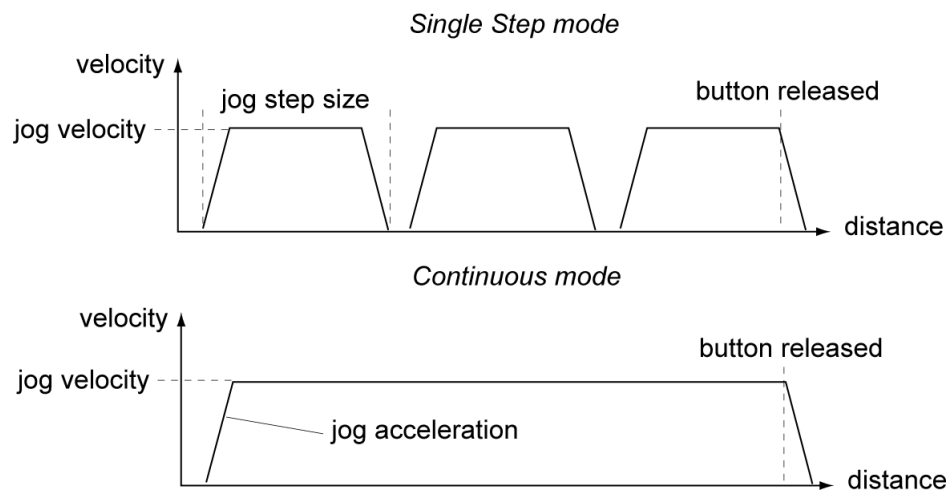

Fig. 6.5 Jog Modes

Jog - the motor moves by the distance specified in the Step Size parameter.

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

Stop - 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.

Maximum Velocity - the maximum velocity at which to perform a move.

Acceleration - the rate at which the velocity climbs from zero to maximum, and slows from maximum to zero.

Backlash

Distance - The system compensates for lead screw backlash during reverse direction moves, by moving passed the demanded position by a specified amount, and then reversing. This ensures that positions are always approached in a forward direction. The Backlash Distance is specified in millimeters. To remove backlash correction, this value should be set to zero.

Enable Restricted Settings - This checkbox enables settings that should not be changed unless the user fully understands the impact of the changes. Under normal circumstances, this box should remain unchecked, and the default values should offer satisfactory performance in most cases.

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.

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

6.4.2   Stage/Axis tab

Fig. 6.6 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 Kinesis 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.
>
> In the event that these settings need to be changed, the user can create a custom settings group - see the Kinesis Help-file for more information.

Stage Axis Settings - 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.

Actuator Name - The name (part number) of the stage or actuator connected.

Serial Number - The serial number of the stage or actuator connected.

Stage ID - The ID number of the stage or actuator connected. This number is used by the server to assign stage specific parameter values at start up.

Counts per mm - The number of encoder counts per millimeter of travel of the DC servo motor (minimum '1', maximum '10,000').

Homing Settings.

> **Note**
>
> For Thorlabs brushless motor-driven stages, 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.

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.

Enable Restricted Settings - This checkbox enables settings that should not be changed unless the user fully understands the impact of the changes. Under normal circumstances, this box should remain unchecked, and the default values should offer satisfactory performance in most cases.

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.

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

6.4.3 Advanced Tab

Fig. 6.7 Advanced Control Loop Settings

Position Loop

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.

There are 3 sets of PID parameters, one for each stated move type, stationary, accelerating and constant velocity. This is an advanced feature for users who want to refine and optimize the controller's behavior in very sensitive applications.

Proportional Gain - Increasing the proportional (Prop) term will increase the amount of effective torque used to correct a given position error. Typically this is used to minimize the amount of position error when an impulse event affects current target position during motion, i.e. sticktion, 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 Gain - Increasing the integral (Int) term minimizes 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.

Derivative Gain - Increasing the derivative (Deriv) term decreases the rate of change of driver output. Typically this is used to reduce the overshoot from a given motion. If Deriv is too high, it can become sensitive to noise from the measured position error; if too low, velocity fluctuations may arise during motion. 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 it is set as low aspossible, but high enough that with the given integral term, the 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 Recalculation 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.

Velocity Feed Forward and *Acceleration 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 Error 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 Error 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.

Tune Buttons - These buttons open a window with slider controls, to allow the parameter to be adjusted graphically, rather than by entering numbers.

Positioning problems arising from 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

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.

> **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.

Dead Error 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.

Integral Gain – 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.

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

Current Loop (Settled)

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 6.4.4.

> **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.

Dead Error 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.

Integral Gain – 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.

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

Motor Output

> **Caution**
>
> The default values programmed into the Kinesis 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.

Continuous 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).

Excess 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 Signal 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.

Track Settle

Moves are generated by an internal profile generator and are based on either a trapezoidal or s-curve trajectory (see Section 6.4.4.). 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 6.4.3.) 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 *Time* parameter 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 Error Limit* parameter set in the *Position Loop Settings* group, 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.

Enable Restricted Settings - This checkbox enables settings that should not be changed unless the user fully understands the impact of the changes. Under normal circumstances, this box should remain unchecked, and the default values should offer satisfactory performance in most cases.

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.

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

6.4.4   Advanced - Misc. Tab

Fig. 6.8 Advanced Miscellaneous Settings

Velocity Profile Settings

To prevent the motor from stalling, its velocity must be ramped up gradually to the required maximum. Certain limits to velocity and acceleration result from the torque and speed limits of the motor itself, 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.

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

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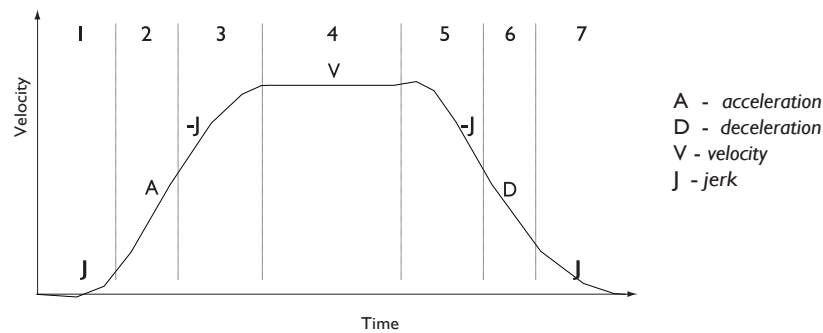
Example

Fig. 6.9 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.

Profile – 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. 6.10.), 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*.*
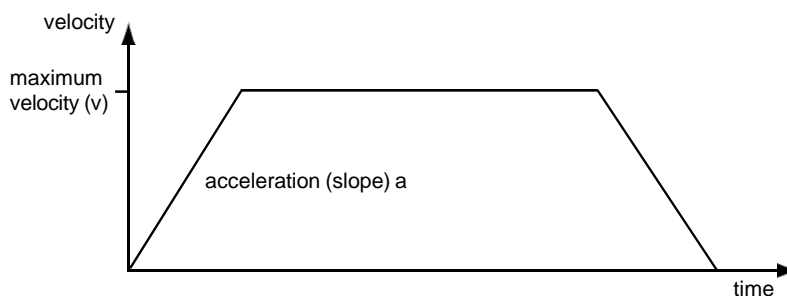

Fig. 6.10   Graph of a trapezoidal velocity profile

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.

Joystick Settings

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 5.8 for more details on joystick use.

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

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

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

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

Direction – 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.

Triggering

External triggering is facilitated by the two BNC connectors on the rear panel of the unit. These connectors 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 provide a 5V logic level input and outputthat can be configured to support triggering from and to external devices.

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.

Input Triggers

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 are not retained in memory 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 a software method to read the status register bit 1 (see the server *help-file* for more details). This allows application software to use the Trigger In input as a general-purpose digital input - see the *help-file* for details on using the software messages and the status register.

Input Trigger options are set as follows:

Disabled – triggering operation is disabled

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

Relative Move (Rise) – a relative move (specified using the latest GUI panel settings) is initiated on the specified channel when a rising edge input signal is received on the TRIG IN connector.

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

Absolute Move (Rise) – an absolute move (specified using the latest GUI panel settings) is initiated on the specified channel when a rising edge input signal is received on the TRIG IN connector.

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

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

Output Triggers

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 retained in memory and the settings will be automatically applied once phase initialization 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 initialization process, the Trigger Out output may not be in 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 software messages to control the state of the output directly - see the *helpfile* for details on using the software messages.

Output Trigger options are set as follows:

Disabled – triggering operation is disabled

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

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

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

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

At maximum velocity (High) – The output trigger goes high (5V) when the stage reaches max velocity.

At maximum velocity (Low) – The output trigger goes low (0V) when the stage reaches max velocity.

Drive Array Velocities

These parameters relate to the velocity for moves initiated by the DRIVE bar graph. Each specifies a velocity to apply when the associated bar is clicked. These settings are applicable in either direction of pot deflection, i.e. 4 possible velocity settings in the forward or reverse motion directions.

> **Note**
>
> It is acceptable to set velocities equal to each other to reduce the number of speeds.

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.

LCD Display Control

Jog Parameters

Mode - The way in which the motor moves when a jog command is received via the front panel controls.

> *Jog* - the motor moves by the distance specified in the Step Size parameter.
>
> *Continuous* - the motor continues to move until the jog signal is removed (i.e. jog button is released).

Step Size - The distance to move when a jog command is initiated. The step size is specified in mm).

Maximum Velocity - the maximum velocity at which to perform a move.

Acceleration - the rate at which the velocity climbs from zero to maximum, and slows from maximum to zero.

Preset Position for Wheel Actions -

Enable Restricted Settings - This checkbox enables settings that should not be changed unless the user fully understands the impact of the changes. Under normal circumstances, this box should remain unchecked, and the default values should offer satisfactory performance in most cases.

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.

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

6.5   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.

Positioning problems arising from 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 6.4.3. for further information.
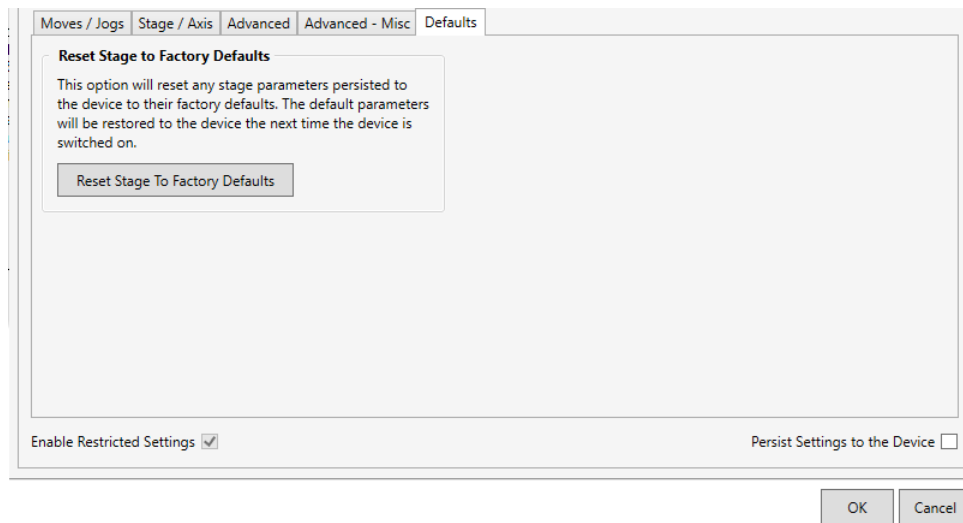
6.5.1   Defaults **Tab**

Fig. 6.11 BBD30x - Defaults Tab

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

To restore the default values, click the 'Reset Stage to Factory Defaults' Button, then click OK.

The controller must then be power cycled before the default values can take effect.

6.5.2   Rotation Stages Tab
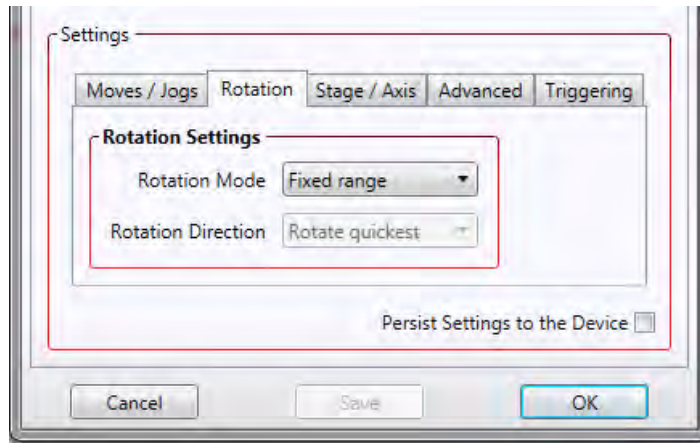
Fig. 6.12 Rotation Stages Tab

Note

This tab is visible only if a rotation stage (e.g. DDR100) is being driven.

Rotation Mode

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

Fixed Range - The angular rotation is limited to 360° i.e. one revolution.

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

Total Angle – The total angular rotation is displayed, e.g. for a movement of two full rotations plus 10°, the display will show 730°.

Note

The following parameters are applicable only if the Rotation Mode is set to 'Equivalent Angle'.

Rotation Direction

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

*Rotate Forwards* – The move is performed in a positive direction

Rotate Reverse - The move is performed in a negative direction

Rotate Quickest - The move is performed in the quickest direction

Appendix A   Rear Panel Connector Pin-out 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.
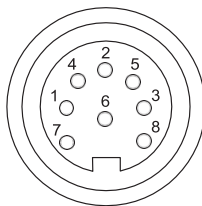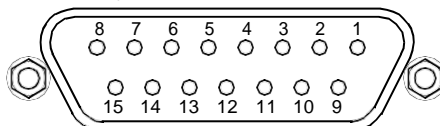

Pin	Description	Pin	Description
1	Motor Phase V	5	Stage ID
2	GND	6	GND
3	Temp Sensor (Not Used)	7	Motor Phase W
4	Motor Phase U	8	Enable

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 circuited 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 Kinesis 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 pin functions are detailed in Fig. A.3 .

Pin	Description	Pin	Description	Pin	Description	Pin	Description
1	RS232 TX	10	User Digital O/P 11-	19	User Digital O/P 7+	28	User Digital O/P 2
2	RS232 RX	11	User Digital O/P 11+	20	+5 V	29	User Digital O/P 3
3	Ground	12	User Digital O/P 10-	21	+5 V	30	Ground
4	Differential I/P 2+	13	User Digital O/P 10+	22	User Digital I/P 3	31	User Digital O/P 4+
5	Differential I/P 2-	14	User Digital O/P 9-	23	User Digital I/P 2	32	User Digital O/P 4-
6	Differential I/P 1-	15	User Digital O/P 9+	24	User Digital I/P 1	33	User Digital O/P 5+
7	Differential I/P 1+	16	User Digital O/P 8-	25	User Digital I/P 0	34	User Digital O/P 5-
8	User Digital O/P 12-	17	User Digital O/P 8+	26	User Digital O/P 0	35	User Digital O/P 6+
9	User Digital O/P 12+	18	User Digital O/P 7-	27	User Digital O/P 1	36	User Digital O/P 6-
						37	Ground

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

Notes:

RS-232 TX and RS-232 RX expose electrical signals for use in RS232 communications. This allows control of the device using the low level communications protocol, or other software environments such as micromanager.

USER_IN0 to USER_IN3 and USER_OUT0 to USER_OUT3 are single ended inputs and outputs - see Section A.3.3. and Section A.3.4.

USER_OUT6 to USER_OUT12 are differential outputs and are user configurable to various functions - see Section A.3.2.

DIFF_IN1 and DIFF_IN2 are differential inputs.

+5 V is a supply, see Section A.3.5.

> **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.

A.3.2   Differential Outputs

All differential outputs (QA, QB and IX/Ref) are driven by an AM26C31 line driver, with a 100 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.
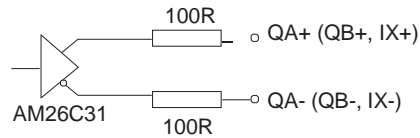

Fig. A.4 Differential Output Schematic

A.3.3   Digital Outputs

All digital outputs are of the open-collector type, with a 330 Ω series resistor. When the output is set to a logic zero (which is also the default state), it behaves as open circuit. When it is a logic one, it behaves as a 330 Ω resistor connected to ground.
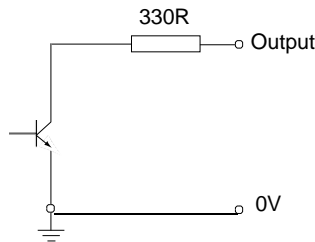
Fig. A.5 Digital Output Schematic

In some applications, the digital outputs may be required to control external equipment that has optocoupler type inputs (such as PLCs). The digital outputs used here can be used to directly drive most optocouplers and the +5 V supply available on pins 14 and 15 can be used to provide power for the optocouplers.
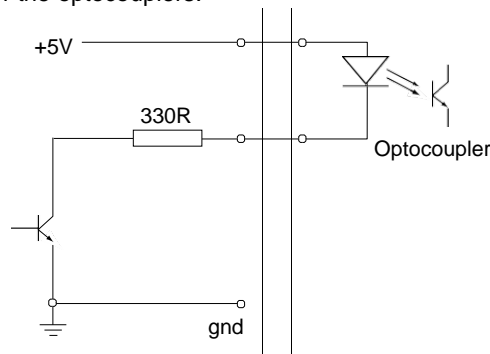
Fig. A.6 Application Example: Connection to Optocoupler Inputs

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

⚠ **Caution**

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

Please see the Kinesis Server help-file 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 +5V). They can be connected directly to mechanical switches, open-collector type outputs ormost type of logic outputs.
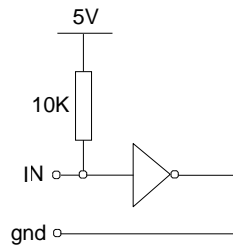

Fig. A.7 Digital Input Schematic (protection circuitry not shown)

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 Kinesis Server help-file 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 V Supply

This is a +5 V, 250 mA supply, 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.4.1   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 Fig. A.8.
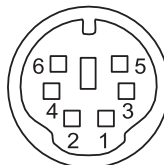
Pin	Description
1	RX (controller input)
2	Ground
3	Ground
4	Supply Voltage for Handset 5 V
5	TX (controller output)
6	Ground

**Fig. A.8 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 Kinesis 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:
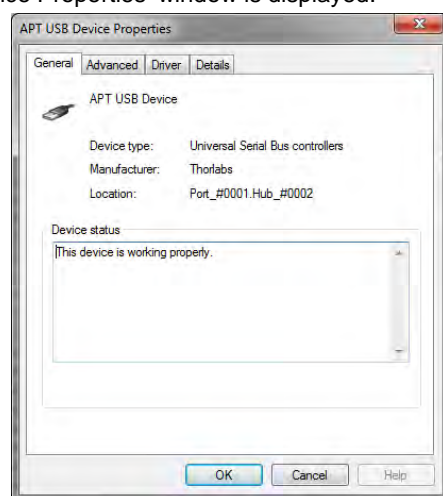
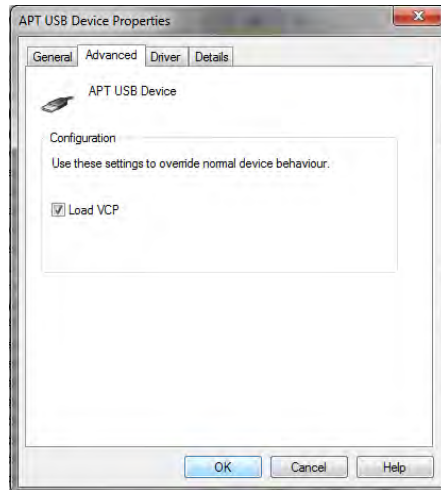1) Open the device manager by selecting Start/Control Panel/Device Manager/
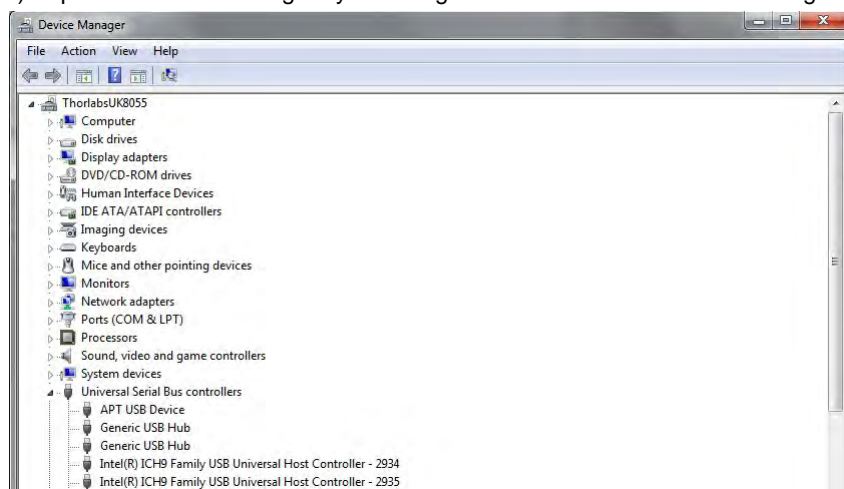
2) Click 'USB Serial Bus Controllers' and select the USB Device to be configured, then right click and select 'Properties'.
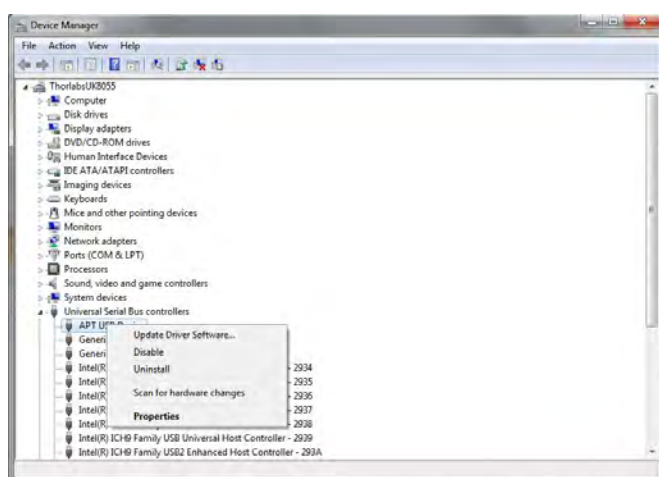
3) The 'USB Device Properties' window is displayed.

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 'USB Device Serial Port' COM port number (e.g. COM3).
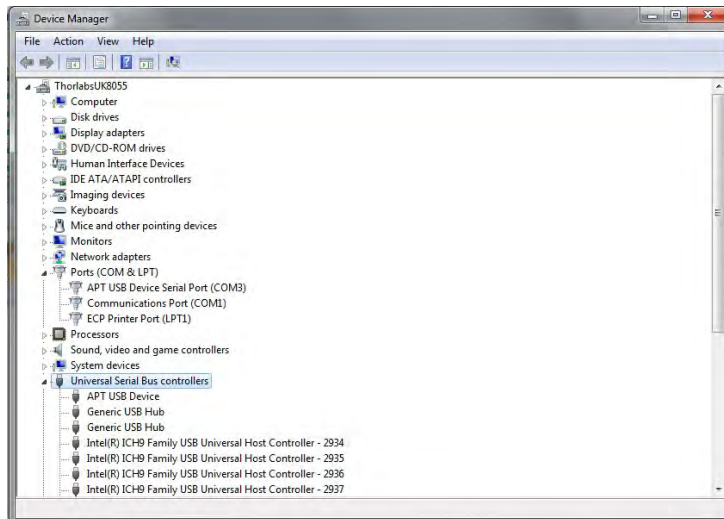
This COM port can then be used by the client application to communicate with the device using the low level protocol messages.

Appendix C Preventive Maintenance

> **Warning: Risk of Electrical Shock**
>
> 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 3.15A/250V a.c. Antisurge Ceramic fuses are located on the back 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; 20 mm	Live Feed
F2	T 3.15 A	Ceramic; Anti-surge; 20 mm	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

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 An Introduction to Multi-Axis Synchronized Moves

E.1 Introduction

This section describes the implementation of multi-axis synchronized moves on the Thorlabs BBD30x series controllers.

In order to give developers a better understanding of the underlying principles of multi-axis synchronized moves, the relevant building blocks of the BMC10X controller are shown below:
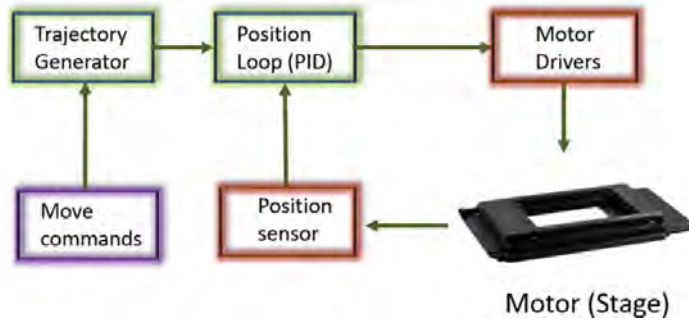

Fig. E.1 Multi-Axis Synchronized Moves Schematic

At the heart of nearly all motion control algorithms a trajectory generator is used to generate the position points where the motor is required to be at any one time. The trajectory (position target) values output by the trajectory generator are fed to the position loop controller which compares the target position to the actual position and adjusts the motor current, always trying to maintain the target position. Thus when a move is commanded, the corresponding parameters are sent to the trajectory generator, which then calculates the position target values required to execute the move.

E.2 Trapezoidal Move Profiles

Simple linear point-to-point moves (which are also the most commonly used moves) are conveniently described by the end position, acceleration and maximum velocity values.
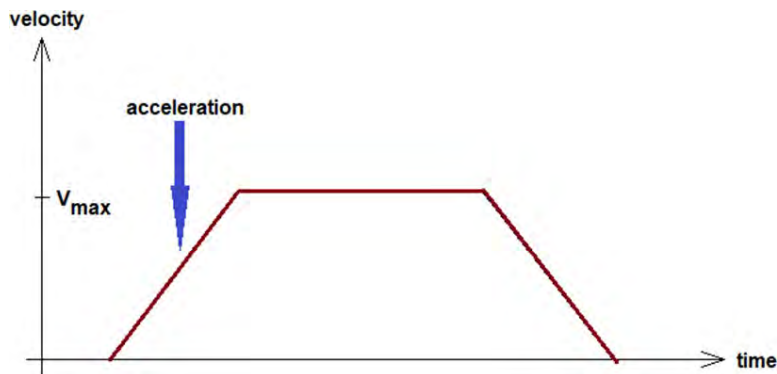
Fig. E.2 Trapezoidal Move Trajectory

At the start of the move, the motor accelerates to the specified maximum velocity, travels at that velocity and then decelerates to zero velocity and reaches that at exactly the target position.

For simple multi-axis moves, the trapezoidal move scheme can easily be extended to two or more dimensions.

If we want to move from position (x1, y1) to position (x2, y2) with acceleration Acc and velocity Vel, then the moves for the individual axes will be effectively the vector projections of the overall 2-D move.

Thus from the 2-D move parameters we can calculate the move parameters for each axis by simply multiplying Acc and Vel with the scaling factors:

$$Scale_x = \frac{x_2 - x_1}{\sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}}$$

and

$$Scale_y = \frac{y_2 - y_1}{\sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}}$$

Thus:

$Acc_x = Acc * Scale_x$ and $Acc_y = Acc * Scale_y$

$Vel_x = Vel * Scale_x$ and $Vel_y = Vel * Scale_y$

E.3   Complex Move Shapes

The trapezoidal move profile is impractical for describing more complex move shapes, such as an arc or circle. For these, a different approach is used and the move is described as a time-position array that defines the position targets the trajectory has to output at the predefined time points. For the time points in-between the specified points the trajectory generator uses linear interpolation.
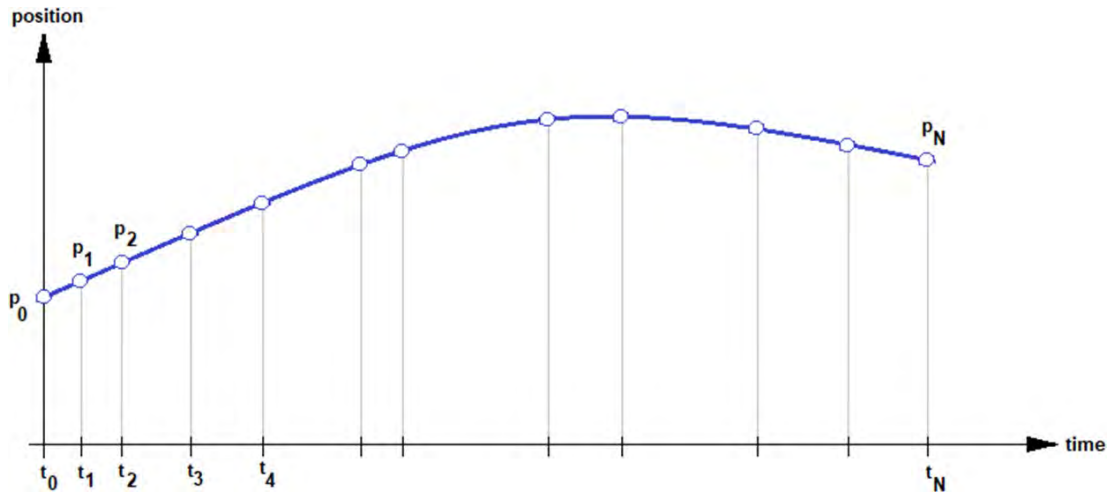

Fig. E.3 Curved Move Trajectory

The figure above shows the approach: the shape of the curve is described as a time-position array

$(t_0, p_0), (t_1, p_1) \dots (t_N, p_N)$

The interval between the time points does not need to be equal. In fact, as linear interpolation is used between adjacent points, the algorithm effectively moves in a straight line between points, so more linear sections of the shape do not need to be described with the same frequency as more curved sections.

With this definition of the move trajectory the acceleration and velocity values are no longer predefined parameters but instead are implicit in the time-position difference between adjacent points. This also means that the user must pay attention to the velocity and acceleration limitations of the controller and the stage. With simple trapezoidal move profiles, the acceleration and velocity are normally set to values that are supported by the controller and with reasonable values they result in smooth motion. The time-position array, on the other hand, allows the user more freedom but as a result also opens up the possibility of move definitions that the controller cannot execute. For example, a large position change in a very short time can translate into excessive velocity and/or acceleration values.

Whilst the approach can be used to define single axis moves, it is more useful for multi-axis synchronized moves. For these the time-position array contains the position points for each axis. Thus, the array defines the position of all axes involved in the move at the same time points. Assuming 2 dimensional (x, y) coordinates, the array becomes:

$(t_0, x_0, y_0), (t_1, x_1, y_1) \dots (t_N, x_N, y_N)$

Obviously, the scheme can be extended to any number of axes that the controller supports.

E.4   Repeated Patterns

To make the scheme more flexible, a section of the curve can also be repeated for a number of times. With this extension, the array can be considered as having a leading, a repeated and a tailing section. This is useful for applications where, for example, the repeated pattern needs to be preceded by an acceleration phase and then completed by deceleration to standstill.

In the illustration below the section p_K to p_L is repeated.
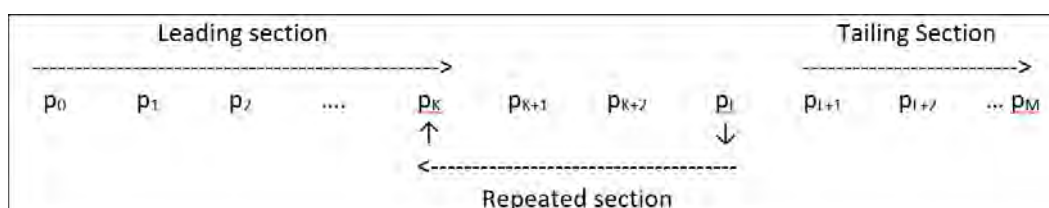
E.5   Starting a Synchronized Trajectory

The user must take into account the initial position of the stage when the trajectory is started. In almost all usage scenarios the stage will be at standstill when the synchronous move is started and immediately afterwards there will be a move to the first point in the time-position array. This can result in a large jump. The easiest way of avoiding this is by moving the stage to the first point defined in the time-position array prior to starting the synchronized trajectory.

To define the multi-axis synchronized moves, the time-position array and the corresponding parameters must be loaded into the controller. This is achieved by uploading a .CSV file via the GUI panel - see Section 6.3.2.

Appendix F Regulatory

F.1   Declarations of Conformity

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

F.1.2   For Customers in the USA
This equipment has been tested and found to comply with the limits for a Class A digital device, 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.

F.2   CE Certificate

Appendix G Thorlabs Worldwide Contacts

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

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