LTS150C(/M), LTS300C(/M), LTS450C(/M) and LTS600C(/M)
Long Travel Stages

User Guide



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Chapter 1 Introduction

1.1 Intended Use

The LTS Series stages are a range of stepper-motor driven long travel stages with ranges of:

- 150 mm
- 300 mm
- 450 mm
- 600 mm

They are optimized for applications requiring high load capacity and high resolution, such as measurement and inspection. They are highly suited to applications such as interferometry and M2 measurements and are compatible with our range of optomech and translation stages. The heavy-duty aluminum construction and small moving platform height (40 mm for LTS150 and LTS300, 45 mm for LTS450 and LTS600) makes this stage ideal for applications where space is limited.

They are intended for indoor use only and can be used in for example, optical, robotics and instrumentation environments. They should not be used in explosive, humid or dirty environments. To ensure reliable operation, the unit should not be exposed to corrosive agents or excessive moisture, heat or dust.

NOTICE

Impairment of protection and warranty
If this equipment is used in a manner not specified by the manufacturer, its protection may be impaired. The product may only be used in accordance with the instructions described in this manual. Any other use will invalidate the warranty.

1.2 Explanation of Safety Warnings

⚠WARNING Warning indicates a hazard with a medium level of risk that, if not avoided, could result in death or serious injury.

⚠CAUTION Caution indicates a hazard with a low level of risk that, if not avoided, could result in minor or moderate injury.

NOTICE Indicates information considered important, but not hazard-related, such as possible damage to the product.

CE
UK CA

The CE/UKCA markings on the product are the manufacturer's declaration that the product complies with the essential requirements of the relevant European health, safety, and environmental protection legislation.

The symbol on the product, the accessories or packaging indicates that this device must not be treated as unsorted municipal waste but must be collected separately.

1.3 Description

The LTS Series stages are designed to be light-weight, compact and robust with high performance over the full travel range. Features include:

- A Load Capacity Of Up To 15 kg Horizontally and 4 kg Vertically
- Integrated Magnetic Limit Switches To Allow For Homing As Well As Overdriving Protection in Both Directions
- A Precision-Ground Lead Screw Delivering Smooth, Virtually Noise-Free Movement

The power supply provided with the stage operates with 90 - 264 VAC input voltages (47 - 63 Hz) and is shipped with a location-specific power cord.

The stages are inclusive of the drive electronics which can either be driven via a PC with Thorlabs' Kinesis® or XA software applications or can be controlled manually via the buttons and velocity potentiometer on the control keypad.



Figure 1 LTS150C, LTS300C, LTS450C and LTS600C Long Travel Stages

1.4 Kinesis Software Overview

The LTS series stages share many of the benefits of the Thorlabs range of motor controllers. These include 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 LTS stages are fully compatible with Thorlabs' Kinesis and XA software applications. The remainder of this manual describes the use of the controllers with Kinesis software. For information about operation using Thorlabs' XA software, refer to the XA User Guide.

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 GUI 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 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 troubleshooting. The Kinesis server is also used by software developers to allow the creation of advanced automated positioning applications very rapidly and with great ease.

1.4.1 Kinesis Server

Kinesis controls are re-usable compiled software components that supply both a Graphical User Interface (GUI) 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 reflect the status of the range of electronic controller units, including the LTS series stages. 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 LTS300C integrated stage as shown in Figure 2.

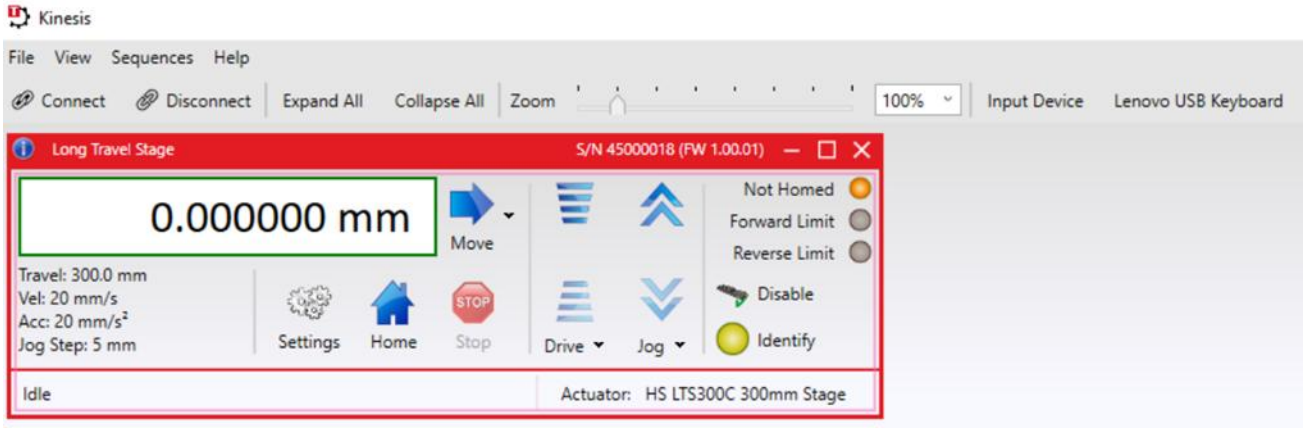


Figure 2 LTS300C Kinesis Server

This control provides a complete GUI instrument panel to allow the stage 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 (for example, a 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 stage to move, the progress of that move is reflected automatically by changing position readouts on the GUI, without the need for further programming intervention.

The Kinesis controls collection provides a rich set of GUI user panels and programmable interfaces allowing users and client application developers to interact seamlessly with the Kinesis hardware. Each of the Kinesis controllers has an associated .Net control and these are described fully in the handbooks associated with the controllers.

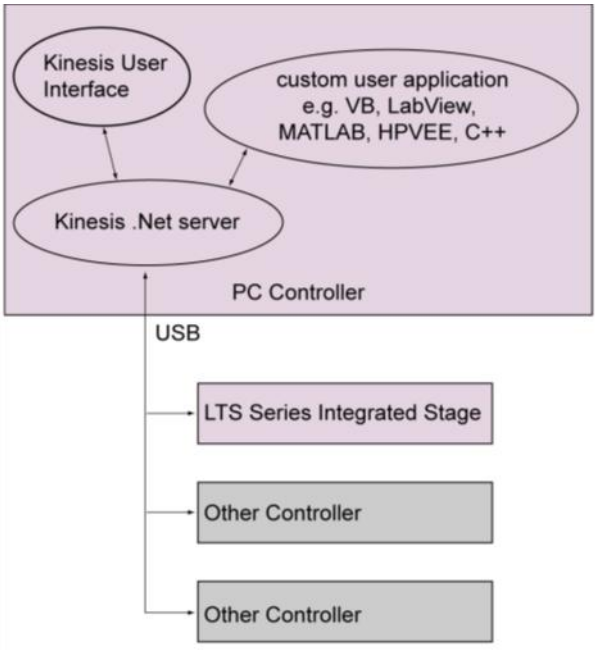


Figure 3 System Architecture Diagram

Refer to the main Kinesis Software online 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**.

1.4.2 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.

1.5 Technical Data

1.5.1 Controller Specifications

Item #	Value
Microsteps per Full Step	2048
Microsteps per Revolution of Motor	409,600 (for 200 step motor)
Motor Drive Voltage	24 V
Motor Drive Power	Up to 25 W (Peak)/ 12.5 W (Avg)
Motor Speeds	Up to 3000 RPM (200 Full Step Motor)

1.5.2 Stage Specifications

Item #	Value			
	LTS150C(/M)	**LTS300C(/M)**	**LTS450C(/M)**	**LTS600C(/M)**
Bidirectional Repeatability	< ±2 µm			
Calibrated On - Axis Accuracy	< ±5 µm			
Backlash	2 µm			
Maximum Horizontal Acceleration	50 mm/sec^2		35 mm/sec^2	
Maximum Vertical Acceleration	5 mm/sec^2			
Maximum Horizontal Velocity	50 mm/s			35 mm/s
Maximum Vertical Velocity	3 mm/s			
Velocity Stability	± 1 mm/sec			
Max Load Capacity	15 kg Horizontal, 4 kg Vertical			
Recommended Horizontal Load Capacity	< 12 kg			
Minimum Achievable Incremental Movement	0.1 µm			
Minimum Repeatable Incremental Movement	4 µm			
Home Location Accuracy	±0.6 µm			
Pitch	<0.016° (279 µrad)	<0.022° (384 µrad)	<0.014° (250 µrad)	<0.020° (350 µrad)
Yaw	<0.050° (873 µrad)	<0.060° (1047 µrad)	<0.032° (550 µrad)	<0.046° (800 µrad)
Construction	Aluminum with precision, recirculating linear bearings			
Weight	2.28 kg (5.03 lbs)	3 kg (6.61 lbs)	4.8 kg (10.58 lbs)	5.7 kg (12.62 lbs)
USB Cable Length	1.5 m (4.92')			

NOTICE

The max velocity and acceleration values quoted are achievable with lighter loads. As the load increases, the velocity and acceleration decreases. For a maximum 15 kg load, the velocity reduces to either 15 mm/s with an acceleration of 3 mm/s^2 or 12 mm/sec with an acceleration of 5 mm/s^2, depending upon whether speed or acceleration is more important for the intended application.

1.5.3 Motor Specifications

Item #	Value
Step Angle	1.8°
Step Accuracy	5%
Rated Phase Current	0.85 A
Phase Resistance	5.4 Ohms
Phase Inductance	5.6 mH
Holding Torque	20 N·cm
Detent Torque	2.0 N·cm
Operating Temperature	-20°C to +40°C (Motor Specification Only)

1.5.4 Parts List

Item #	Value
LTS150C and LTS150C/M	Long Travel Stage with 150 mm travel
LTS300C and LTS300C/M	Long Travel Stage with 300 mm travel
LTS450C and LTS450C/M	Long Travel Stage with 450 mm travel
LTS600C and LTS600C/M	Long Travel Stage with 600 mm travel
LTSP1 and LTSP1/M	XY Mounting Adapter Plate
LTSP2 and LTSP2/M	Vertical (Z-axis) Mounting Plate for LTS150C
LTSP3 and LTSP3/M	Vertical (Z-axis) Mounting Plate for LTS300C
HA0203T	Handbook

1.5.5 Mechanical Drawings

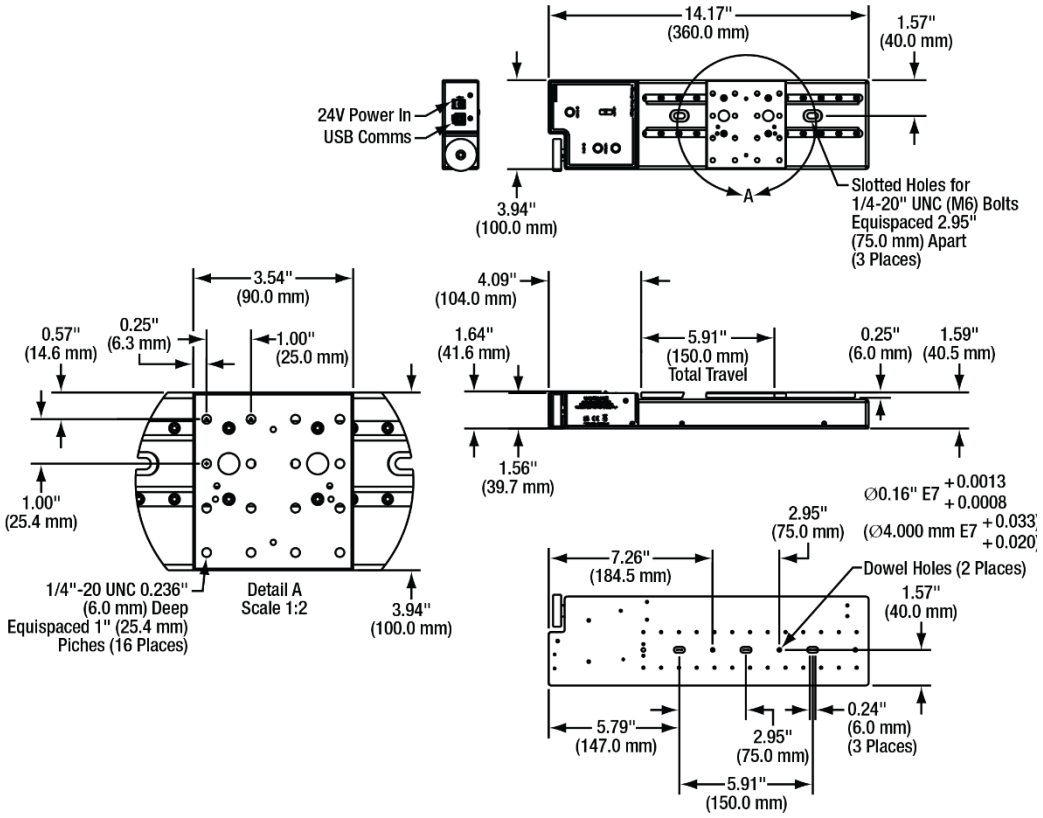


Figure 4 LTS150 Imperial Mechanical Drawing

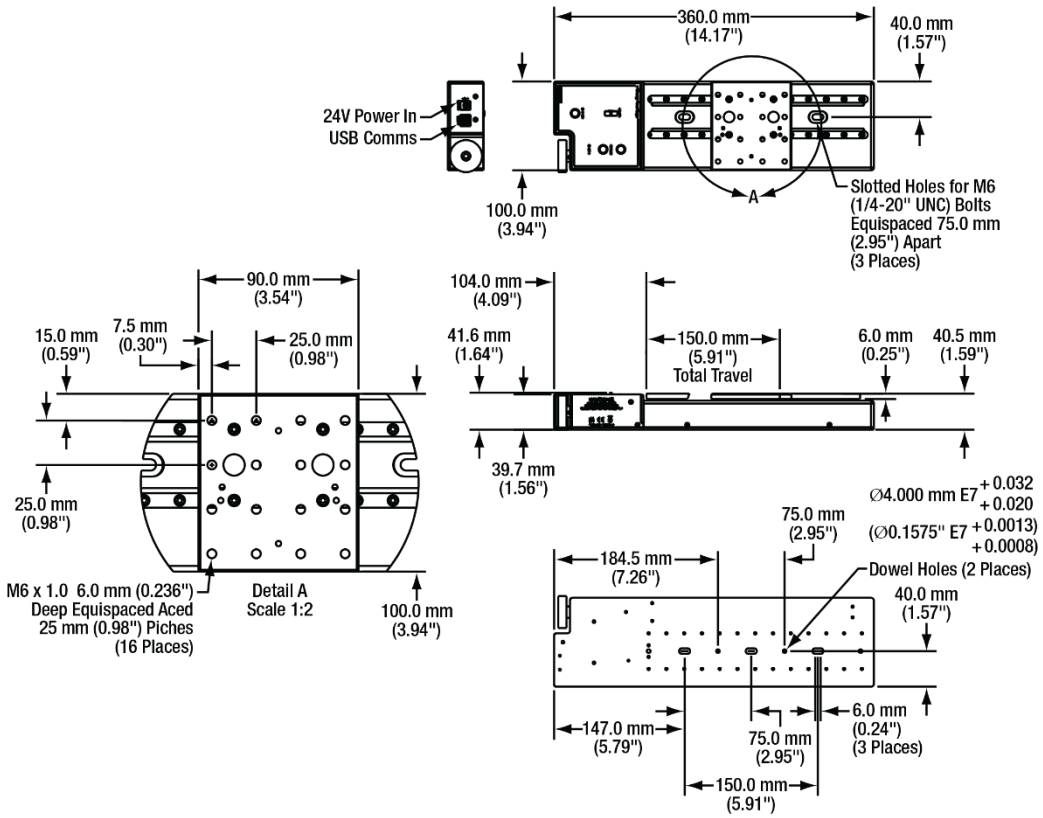


Figure 5 LTS150 Metric Mechanical Drawing

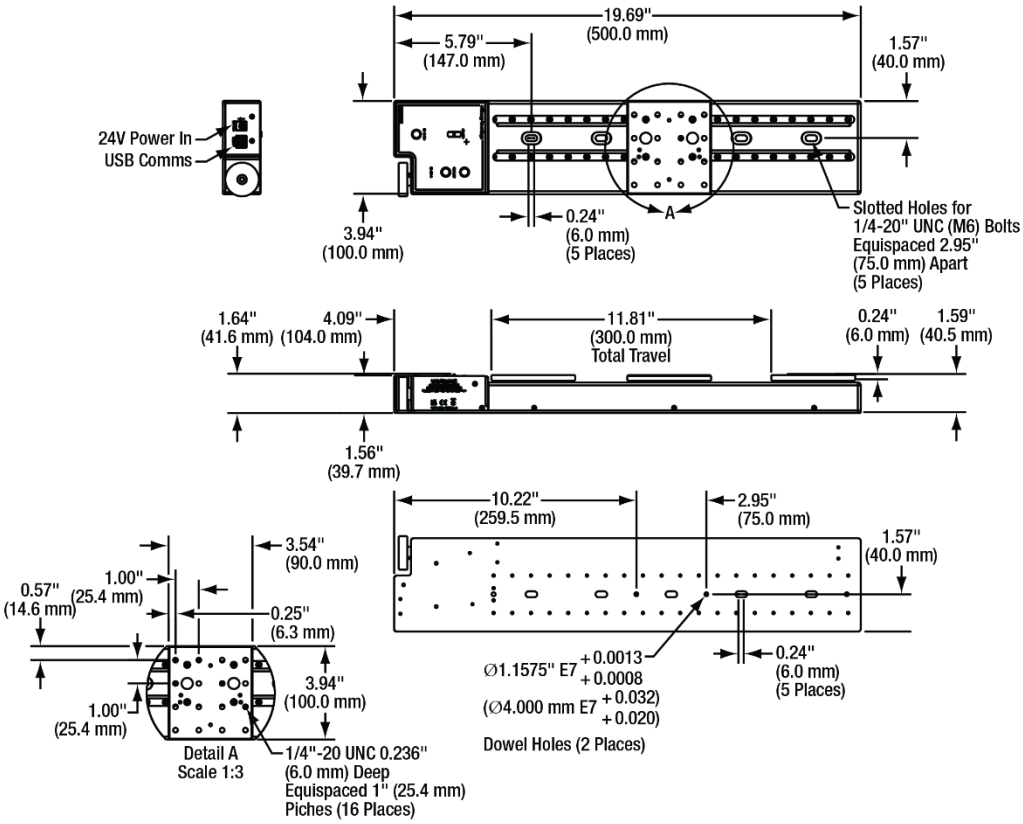


Figure 6 LTS300 Imperial Mechanical Drawing

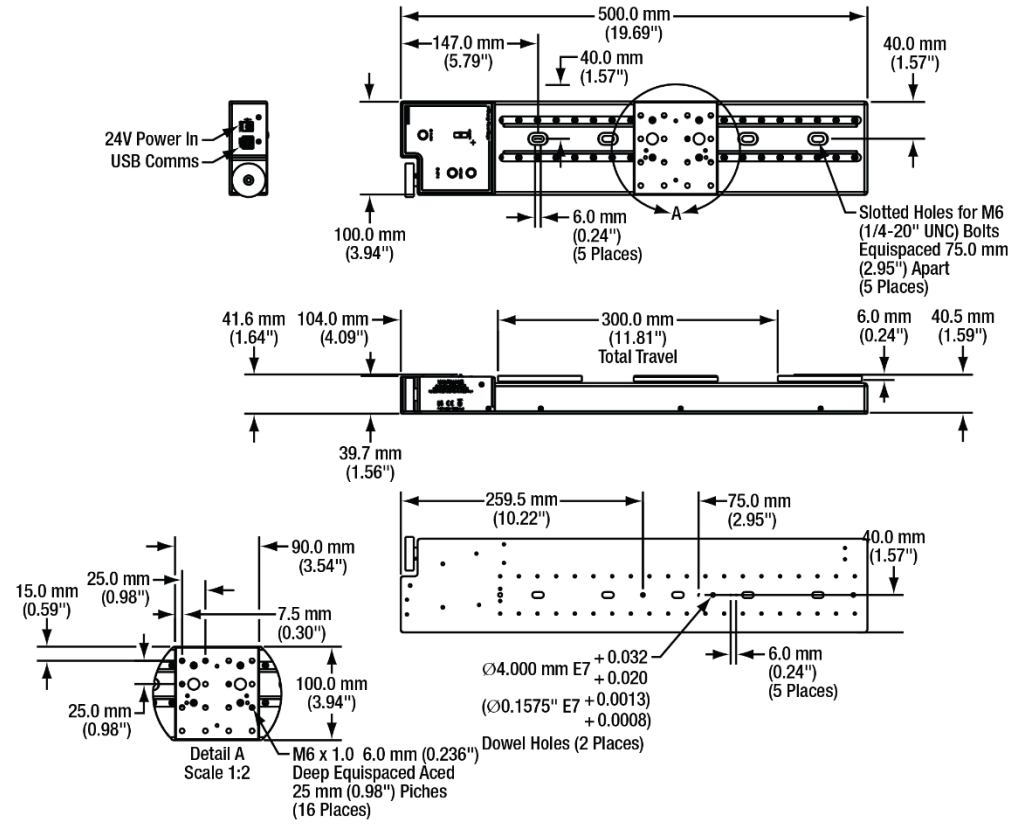


Figure 7 LTS300 Metric Mechanical Drawing

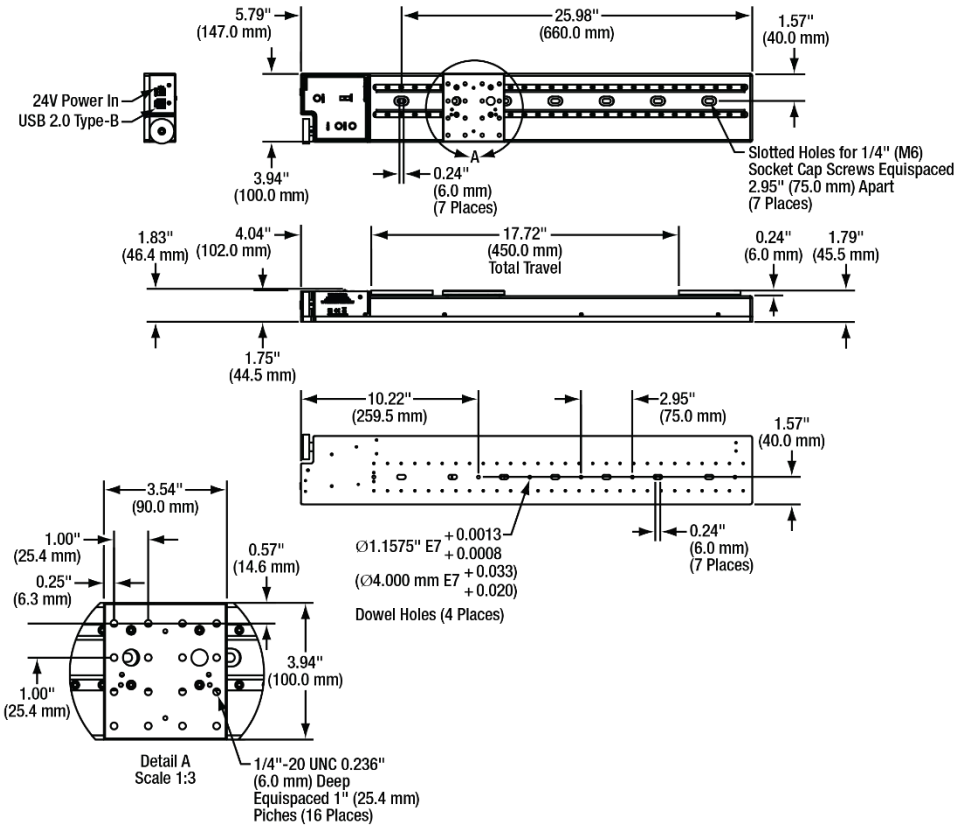


Figure 8 LTS450 Imperial Mechanical Drawing

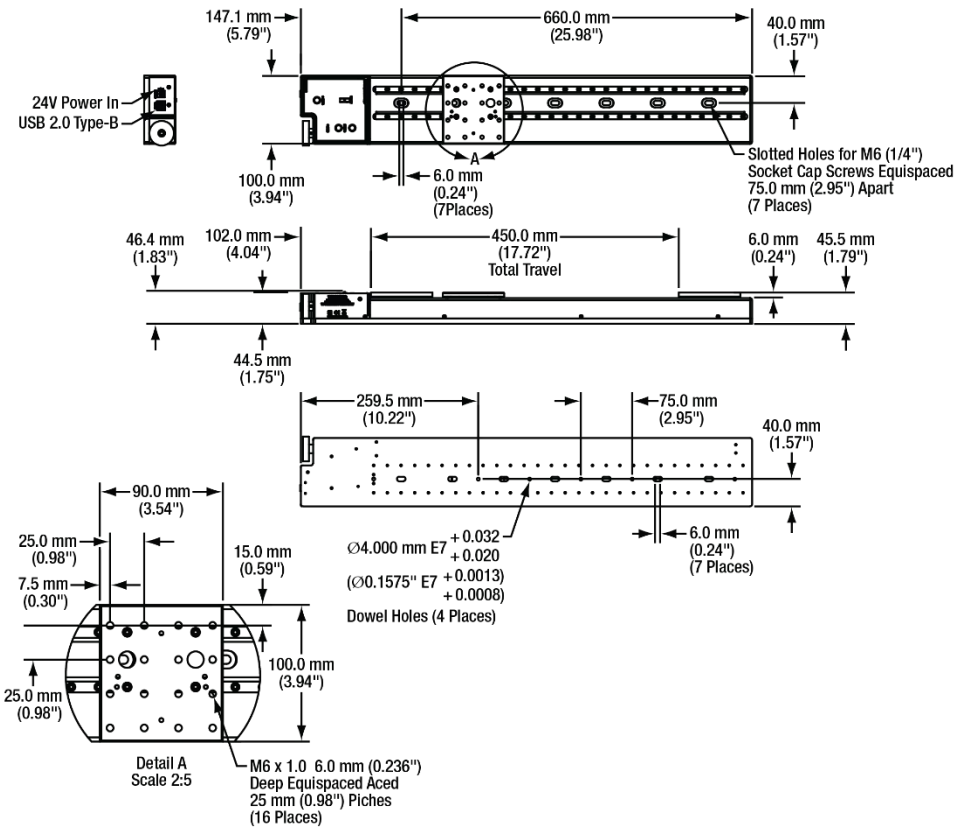


Figure 9 LTS450 Metric Mechanical Drawing

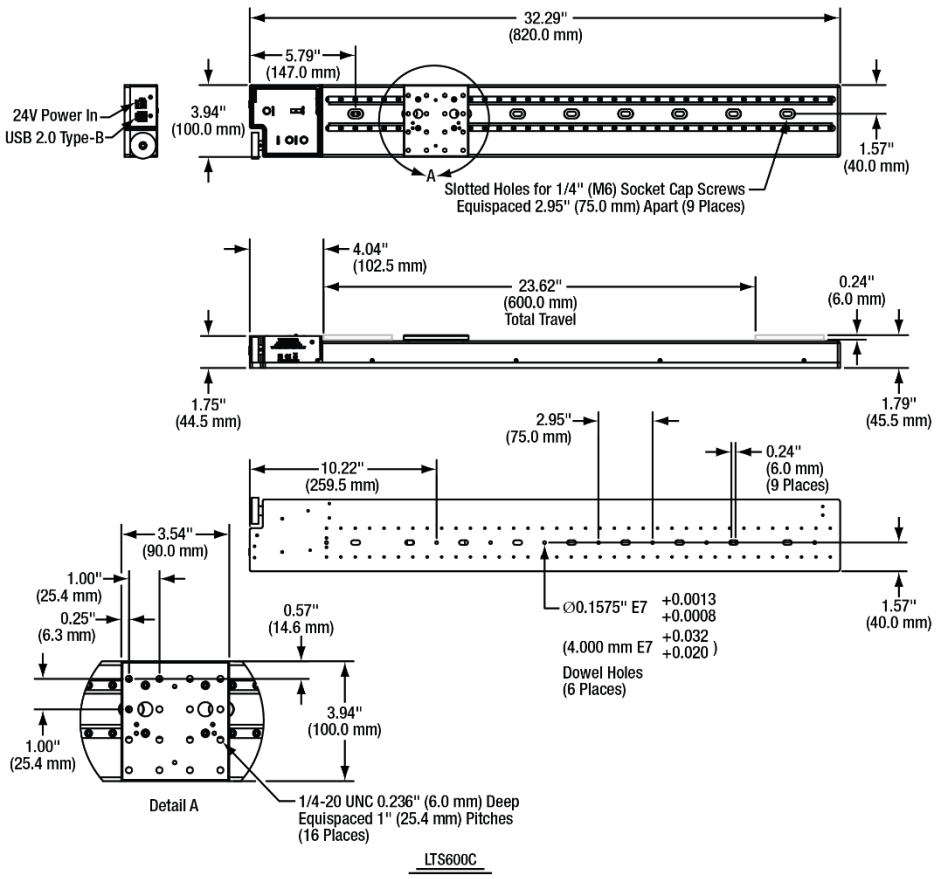


Figure 10 LTS600 Imperial Mechanical Drawing

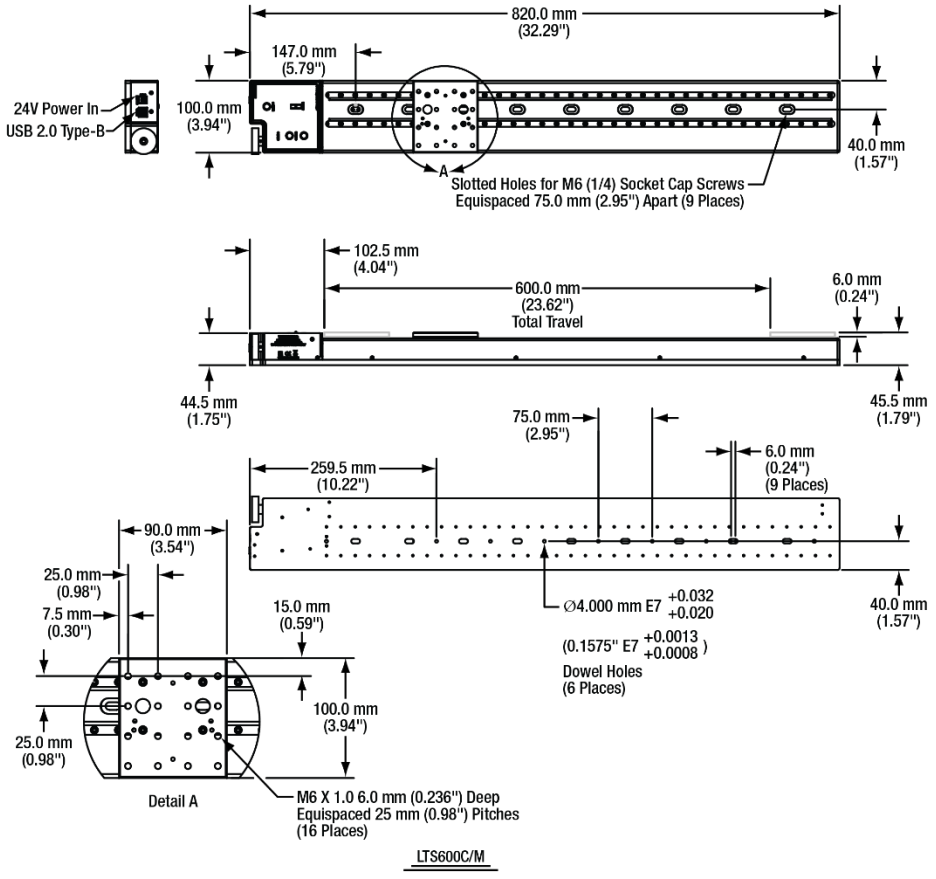
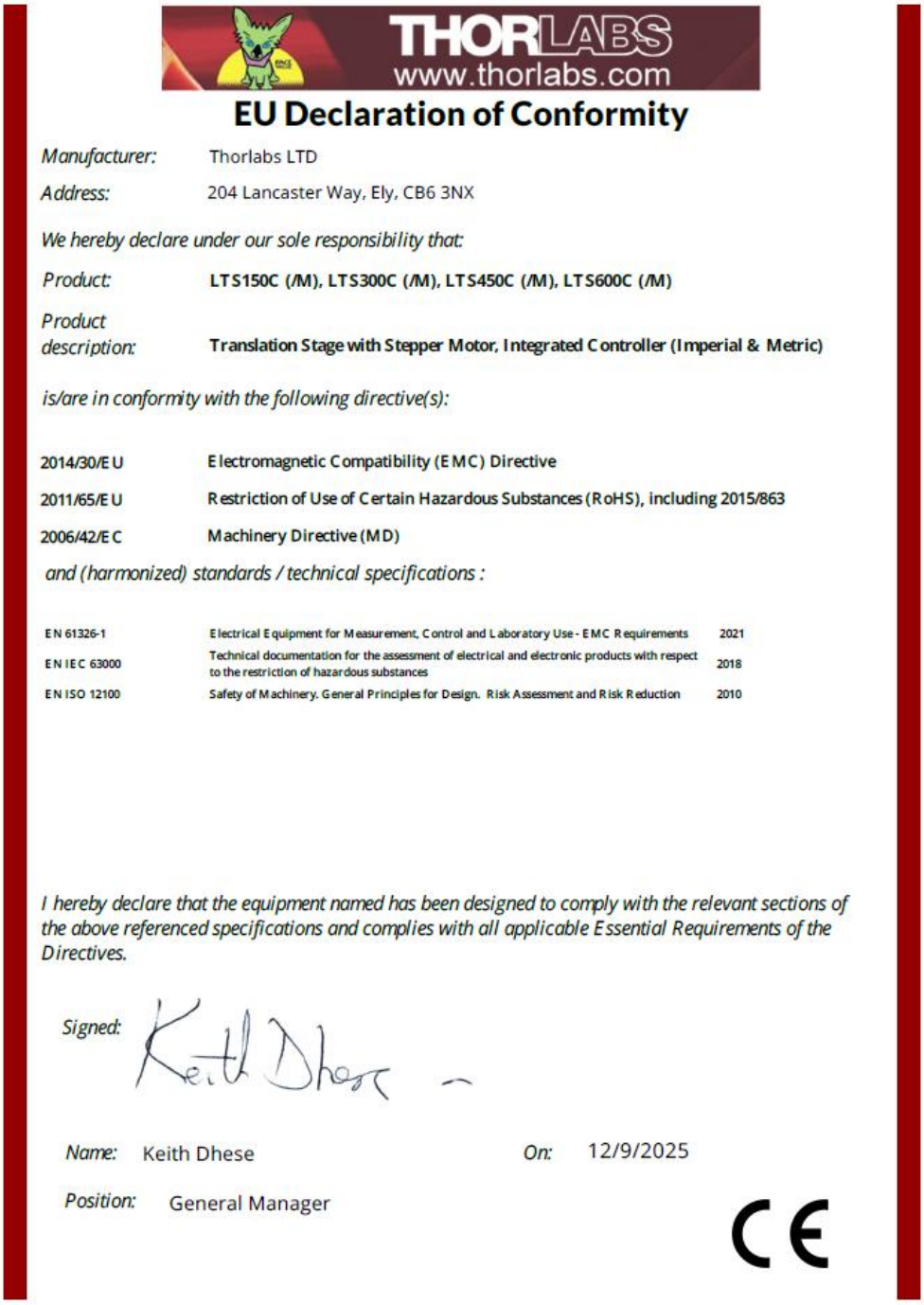


Figure 11 LTS600 Metric Mechanical Drawing

1.6 Simplified Declaration of Conformity



THORLABS
www.thorlabs.com

EU Declaration of Conformity

Manufacturer: Thorlabs LTD

Address: 204 Lancaster Way, Ely, CB6 3NX

We hereby declare under our sole responsibility that:

Product: **LTS150C (/M), LTS300C (/M), LTS450C (/M), LTS600C (/M)**

Product description: **Translation Stage with Stepper Motor, Integrated Controller (Imperial & Metric)**

is/are in conformity with the following directive(s):

2014/30/EU	Electromagnetic Compatibility (EMC) Directive
2011/65/EU	Restriction of Use of Certain Hazardous Substances (RoHS), including 2015/863
2006/42/EC	Machinery Directive (MD)

and (harmonized) standards / technical specifications :

EN 61326-1	Electrical Equipment for Measurement, Control and Laboratory Use - EMC Requirements	2021
EN IEC 63000	Technical documentation for the assessment of electrical and electronic products with respect to the restriction of hazardous substances	2018
EN ISO 12100	Safety of Machinery. General Principles for Design. Risk Assessment and Risk Reduction	2010

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

Signed: Keith Dhese

Name: Keith Dhese *On:* 12/9/2025

Position: General Manager

CE

1.7 FCC Designation

Class A FCC Designation

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.

Chapter 2 Safety

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.

NOTICE

Impairment of Operation and Damage to Equipment
If this equipment is used in a manner not specified by the manufacturer, the protection provided by the equipment may be impaired.

Impairment of Operation and Damage to Equipment
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.

Indoor Usage Only
The equipment is for indoor use only

Damage to Equipment
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.

Damage to Equipment
The unit should not be exposed to corrosive agents, heat or dust.

Damage to Equipment
The unit is not designed to be used in explosive environments.

⚠CAUTION

Risk of Injury
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

NOTICE

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

3.1 Warranty Information

This precision device is only serviceable if returned and properly packed into the complete original packaging including the complete shipment plus the cardboard insert that holds the enclosed devices. If necessary, ask for replacement packaging. Refer servicing to qualified personnel.

3.2 Unpacking

NOTICE

Once removed from its packaging, the LTS stage is easily damaged by mishandling. The unit should only be handled by its base, not by the motor or any attachments to the moving platform.
Retain the packing in which the unit was shipped, for use in future transportation.

3.3 Mounting to a Work Surface

NOTICE

When siting the unit, it should be positioned so as not to impede the operation of the control panel buttons.
Make sure that proper airflow is maintained to the unit.
Remove power from the unit before bolting or unbolting from the work surface.
When mounting the LTS stage close to other equipment, ensure that the travel of the moving platform is not obstructed. If equipment mounted on the moving platform is driven against a solid object, damage to the internal mechanism could occur. The range of travel for each model is as follows:

- LTS150C: 150 mm
- LTS300C: 300 mm
- LTS450C: 450 mm
- LTS600C: 600 mm

Do the following:

1. Place the LTS stage in the required position on a flat surface.
2. Attach to the surface using the supplied 1/4-20 (M6) screws which fit through the base. The number of screws provided for each stage is as follows:

Stage	Number of Screws
LTS150C	3 (three)
LTS300C	5 (five)
LTS450C	7 (seven)
LTS600C	9 (nine)

NOTICE The mounting holes are accessed from the top of the stage.

NOTICE Sleeves are fitted in the moving platform to allow the bolts to pass through from the top surface (the mounting hole locations for the LTS300C are shown in Figure 12).

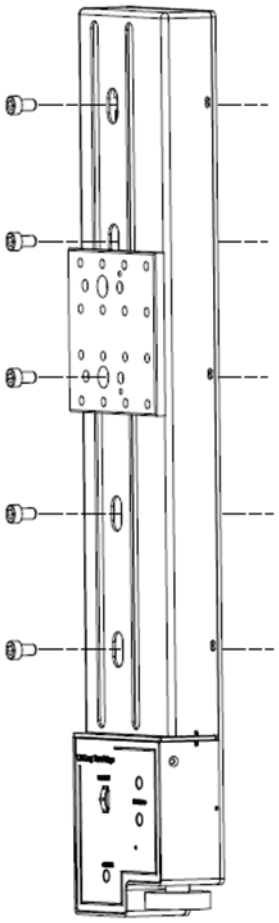


Figure 12 Mounting Hole Locations (LTS300C)

3.4 Mounting in a Multi-Axis Configuration

⚠CAUTION Make sure that any devices and components attached to the moving platform are securely fastened. Incorrectly attached components could come loose when the stage is operated.

The LTS series stages can be mounted in XY configurations using the LTSP1 spacer plate. The LTSP2 and LTSP3 angle brackets allow the LTS150C and LTS300C stages respectively to be mounted vertically in Z axis configurations.

NOTICE LTSP2 and LTSP3 angle brackets are **NOT** suitable for the LTS450C and LTS600C. To mount either the LTS450C and LTS600C vertically, bolt it to a sturdy upright bracket that has capacity to house all screws.
When mounted in a vertical (Z-axis) orientation, the maximum load capacity is 4 kg and the maximum velocity is 3 mm/sec.

For more information about installation with adaptor plates, refer to the documentation supplied with them.

⚠CAUTION For safety reasons, set the Max Vel parameter in the software **Settings** panel to 3 mm/sec – see Section 8.3.2. for more details.

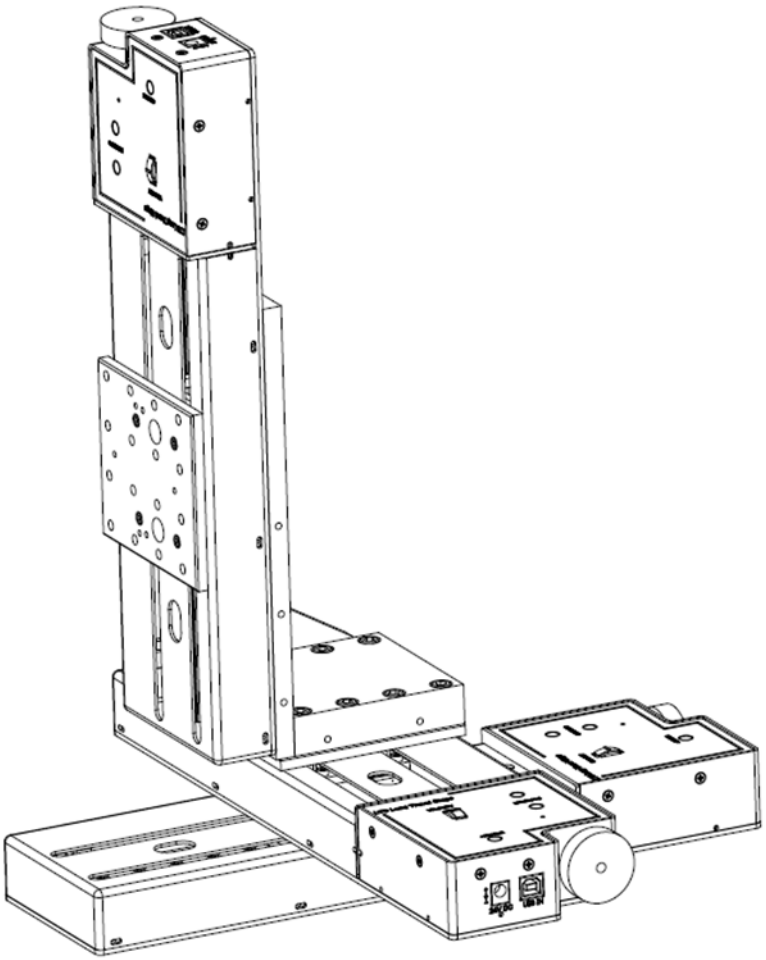


Figure 13 Typical XYZ Configuration (3 x LTS150Cs, LTSP1 and LTSP2)

3.5 Calibrating the Motor Drives

Calibration enables the server to correct for any mechanical errors inherent in the system. Mechanical components, such as the leadscrew and linkages, can be machined only within a certain tolerance, e.g., the leadscrew may be nominally 1 mm but actually 1.0005 mm, giving a 0.5 micron error. In practice, these errors accumulate from several sources, however they are repeatable and therefore, can be compensated.

During calibration, the total positional error is measured at many points and these errors are stored as a look up table (LUT). The LUT is saved as a calibration file, one file for each stage. The file is then linked to the appropriate stage using the Kinesis software. Whenever the stage is moved, the LUT is consulted to ascertain the precise movement required to achieve the demanded position.

The use of a calibration file is optional. Without it, the repeatability and resolution of the stage are unaffected, but no compensation is made to enhance the accuracy.

Calibration files can be downloaded from the support documents section on the product web page, one file for each serial number.

Details on assigning a calibration file are contained in Section 8.3.3.

3.6 Attaching Equipment and Devices

NOTICE

When attaching equipment or devices to the top platform, do not use bolts with a fixing thread longer than 6 mm (0.24”). Bolts of longer length protrude into the unit and could damage the internal mechanism.

3.7 Transporting the Unit

NOTICE

When packing the unit for shipping, use the original packing. If this is not available, use a strong box and surround the unit with at least 100 mm of shock absorbent material.

3.8 Installing the Software

NOTICE

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.

NOTICE

Do not connect the stage to your PC yet.

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

3.9 Connecting the Hardware

WARNING

Risk of electrical shock

The PSU unit must be connected only to an earthed fused supply of 90 - 264 VAC (47 - 63 Hz).

Use only the power supply supplied by Thorlabs, other units may not be rated to the same current.

The unit is shipped to the UK, Europe, and the USA, with the appropriate power plug already fitted. When shipped to other territories the appropriate power plug must be fitted by the user. Cable identification is as follows:

- Brown: Live
- Blue: Neutral
- Green/Yellow: Earth/Ground

When connecting the power and USB cables, ensure they are routed clear of the moving platform.

1. Make sure the mechanical installation as described in Sections 3.3 to 3.6 is complete.
2. Make sure the software has been installed according to the instructions in Section 3.8.
3. Connect one end of the supplied USB cable to the stage unit (see Figure 14).

NOTICE

If a communication length of more than 3 m is required, use a powered USB hub.

4. Connect the other end of the USB cable to the PC.
5. Connect the stage unit to the power supply.
6. Connect the PSU to the mains power outlet and switch on.
7. Wait for the unit to initialize (about 5 s). Do not press any controls during this time. The ENABLE LED is lit when the unit is ready for use.
8. Wait until Windows® installs the drivers for the new hardware.

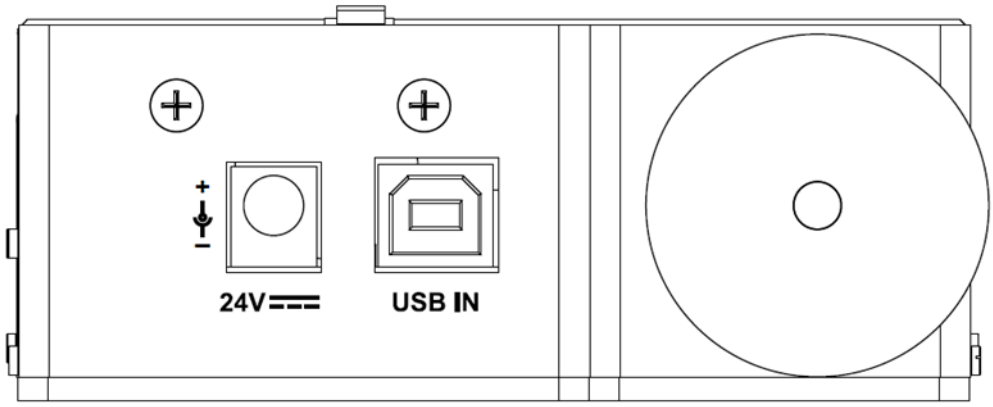


Figure 14 Power and USB Connectors

3.10 Verify Software Operation

Perform the following for the initial setup:

1. Run the Kinesis software and check that the Graphical User Interface (GUI) appears and is active.

NOTICE

If the Kinesis software does not recognize the unit, switch the power off but leave the Kinesis software running and the USB connected. Wait around 30 s then switch the power back on. Kinesis will load the unit.

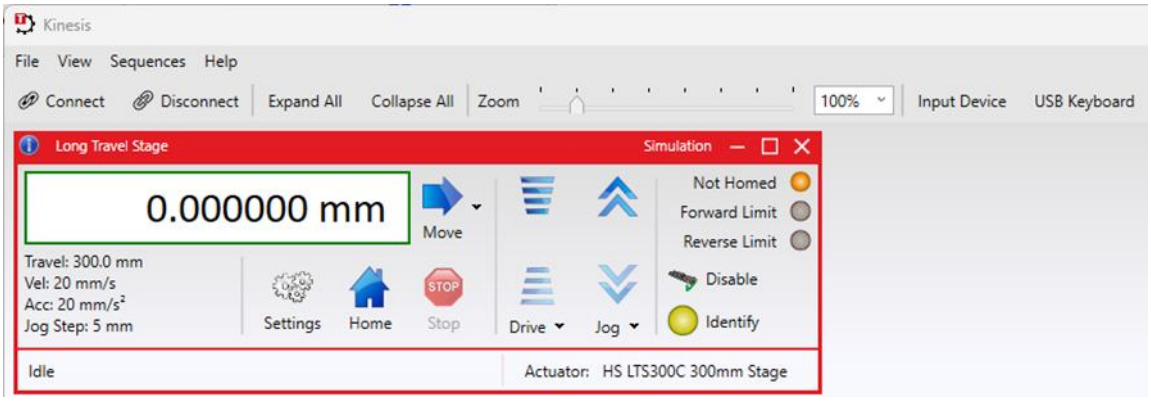


Figure 15 GUI Panel

2. Select **Identify**. The **ACTIVE** LED on the control keypad flashes. This is useful in multi-channel systems for identifying which driver is associated with which GUI.
3. Using the **Jog** buttons on the GUI panel, check the associated stage moves. The position display for the associated GUI should increment and decrement accordingly.

Chapter 4 Operation

4.1 Standalone Operation

The LTS series of integrated long travel stages offer a fully featured motion control capability including velocity profile settings, limit switch handling and homing sequences. When the unit is connected to the PC, these parameters are automatically set to allow 'out-of-the-box' operation with no further 'tuning' required. However, further adjustment is possible via the Kinesis software - see Section 4.2.

The following brief overview explains how the top panel controls can be used to perform a typical series of motor moves, however it also may be useful to read the background on stepper motor operation contained in Chapter 9.

4.1.1 Control Keypad

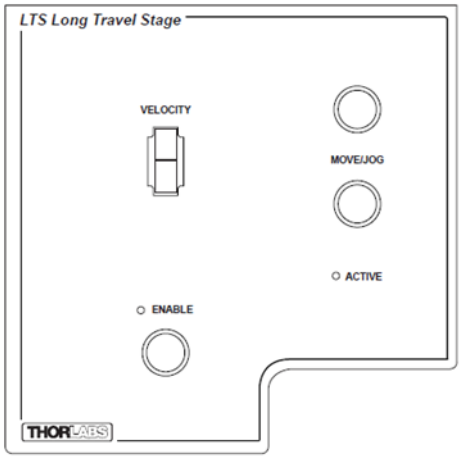


Figure 16 Front Panel Controls and Indicators

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

Control	Description
Jog Buttons	Used to jog the motors and make discrete position increments in either direction. See Section 0 for more details.
Slider Potentiometer	Used to drive the motor at a pre-defined speed in either forward or reverse directions for full and easy motor control. see Section 4.1.2 for more details.
ACTIVE LED	Flashes when the motor reaches a forward or reverse limit switch and is lit when the motor is moving.
ENABLE button	Used to enable/disable channel functionality. Disabling the channel removes the drive power and allows the motor actuator to be operated manually.
ENABLE LED	When the stage is enabled, this LED is lit. Furthermore, this LED will flash when the **Identify** button is clicked on the Software GUI panel.

4.1.2 Potentiometer Operation

The potentiometer slider is sprung such that when released it returns to its central position. In this central position the motor is stationary. As the slider is moved away from the center, the motor begins to move. Bidirectional control of the motor is possible by moving the slider in both directions.

The velocity of this move is set in real world units (mm) in the **Potentiometer Settings** parameter in the **Settings > Advanced** tab (see Section 8.3.5) and is limited to a maximum of 20 mm/sec.

4.1.3 Button Operation

The buttons on the front of the unit (see Figure 16) can be used to control the motor in several ways:

Homing

A 'Home' move is performed to establish a datum from which subsequent absolute position moves can be measured (see Section 4.2.2 and Section 9.2.2 for further information on the home position).

To initiate a 'Home' move, press, and hold both **MOVE/JOG** buttons for 2 seconds.

Go To Position

Each button can be programmed with a different position value, such that the controller will move the motor to that position when the specific button is pressed.

This mode of operation is enabled by setting the **Button Control Settings Mode** parameter to **Go To Position** on the **Advanced settings** tab (see Section 8.3 for further information).

In addition to entering values in the **Settings > Advanced** tab, when operating in Go To Position mode, it is also possible to save the current position as the 'Go To Position' value from the front panel **MOVE/JOG** buttons.

To save the current position as the 'Go To Position' value, press and hold either **MOVE/JOG** button for 2 seconds.

NOTICE

The value set by the **FW** button cannot be greater than the value set by the **BW** button. Conversely, the value set by the **BW** button must be less than that set by the **FW** button.

Jogging

The front panel buttons can also be configured to 'jog' the motor. This mode of operation is enabled by setting the **Button Control Settings Mode** parameter to **Jogging** in the **Settings > Advanced** tab (see Section 8.3.5). Once set to this mode, the jogging parameters for the buttons are taken from the **Jog Parameters** on the **Moves/Jogs** settings tab (see Section 8.3.3).

Switching Between Button Modes

The button mode can only be changed in the **Actuator Settings** panel (see Section 8.3.5).

4.1.4 Stopping the Stage

The drive channel is enabled and disabled by selecting **Enable** on the GUI panel or the top 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 selecting Stop on the GUI panel. Using this button does not remove power to the drive channel.

4.2 PC Operation

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 described in Section 3.9 and that the software is installed as described in Section 3.8. For information about operation using Thorlabs' XA software, refer to the XA User Guide.

4.2.1 Using the Kinesis Software

The Kinesis software application allows the user to interact with any number of hardware control units connected to the PC USB Bus. This program allows multiple graphical instrument panels to be displayed so that multiple units can be controlled. All basic operating parameters can be set through this program, and all basic operations (such as motor moves) can be initiated. Parameter settings can be saved, which simplifies system set up whenever the software is run.

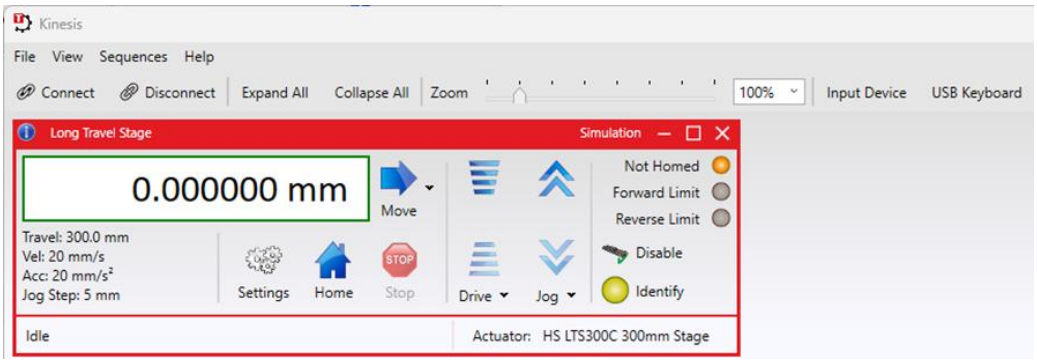


Figure 17 Typical User Screen

Run the Kinesis software (for example, by selecting **Start/All Programs/Thorlabs/Kinesis/Kinesis**).

NOTICE

If the Kinesis software does not recognize the unit, switch the power off but leave the Kinesis software running and the USB connected. Wait around 30 s then switch the power back on. Kinesis will load the unit.

4.2.2 Homing Motors

Homing the motor moves the actuator to the home limit switch and resets the internal position counter to zero. The limit switch provides a fixed datum that can be found after the system has been powered up.

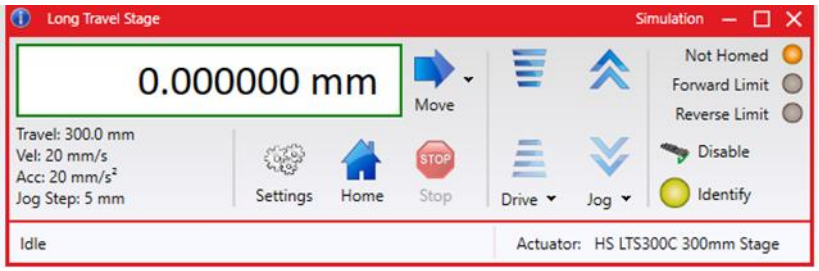


Figure 18 Motor Controller Software GUI

Select Home. The LED labeled **Not Homed** changes to **Homing** and when homing is complete, changes again to **Homed** and the LED indicator becomes green. The displayed position counts down to 0 (the home position).

NOTICE

Homing can also be performed at the unit, by holding down both front panel buttons for around 2 s.

Refer to Section 9.2.2 for background information on the home position.

4.2.3 Changing Motor Parameters and Moving to an Absolute Position

Absolute moves are measured in real world units (for example, millimetres), relative to the home position.

Moves are performed using a trapezoidal velocity profile (refer to Section 9.1.3). The velocity settings relate to the maximum velocities at which a move is performed, and the acceleration at which the motor speeds up from zero to maximum velocity.

Do the following:

1. On the GUI panel, select **Move** .

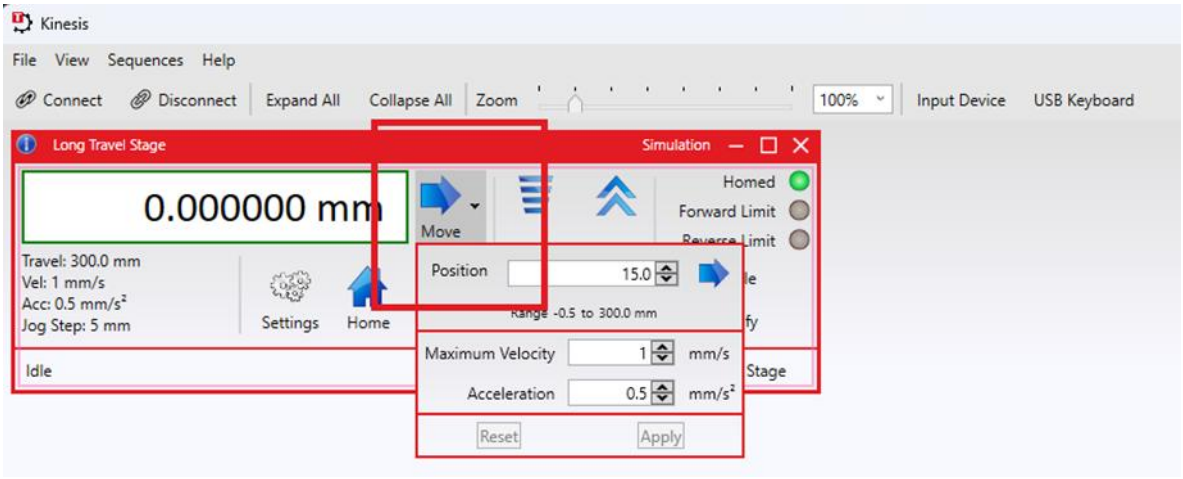


Figure 19 Move Settings Panel

2. In the pop-up window, enter the required absolute position and /or parameter values.
3. To move to the position entered, select .
4. Select **Apply** to save the parameter settings and close the window. Select **Reset** to return to the previously saved values.

4.2.4 Stopping the Stage

The drive channel is enabled and disabled by selecting **Enable** on the GUI panel or **ENABLE** on the top 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 selecting **Stop** on the GUI panel. Using this button does not remove power to the drive channel.

4.2.5 Jogging

During PC operation, the motor actuators are jogged using the GUI panel arrow keys. There are two jogging modes available:

- **Single Step**
  The motor moves by the step size specified in the **Step Size** parameter. If a **Jog** button is held down, single-step jogging is repeated until the button is released (see Figure 23).
- **Continuous**
  The motor actuator will accelerate and move at the jog velocity while the button is held down.

Do the following:

1. On the GUI panel, select **Jog**.

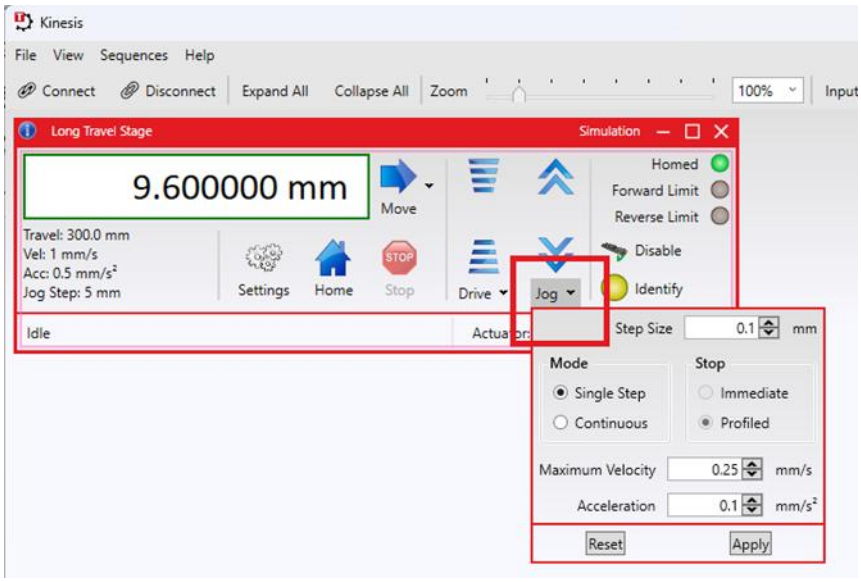


Figure 20 Jog Settings Panel

2. In the pop-up window, make the parameter changes as required.

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

3. Select **Apply** to save the settings and close the window. Select Reset to return to the previously saved values.

4.2.6 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, see the *Kinesis Helpfile*.

4.2.7 Changing and Saving Parameter Settings

During operation, certain settings can be changed, while other settings cannot be changed easily. When the Kinesis server is running and the stage/actuator association made, suitable default settings are loaded, and these values have been chosen to provide safe performance in most 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. For more details and instructions on setting Device Start Up settings, see the *Kinesis Helpfile*.

Chapter 5 Maintenance and Cleaning

NOTICE

The equipment contains no user serviceable parts.
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.

5.1 Safety Testing

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

5.2 Cleaning

WARNING

Danger of death or serious injury

- Disconnect the power supply before cleaning the unit.
- Never allow water to get inside the unit.
- Do not saturate the unit.
- Do not use any type of abrasive pad, scouring powder or solvent (for example, alcohol or benzene).

Clean the external surface with a soft cloth, lightly dampened with water or a mild detergent.

Chapter 6 Troubleshooting and Repair

If an unexpected obstruction to the stage motion is encountered, the motor may stall, and the home position may be lost. After the obstruction has been removed, the associated channel of the controller should first be homed to re-establish a datum zero point.

In the event of a breakdown, or malfunction of the product please contact Thorlabs Tech Support. Contact details are contained in Chapter 10.

Chapter 7 Disposal



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. It is the user’s responsibility to delete all private data stored on the device prior to disposal.

Chapter 8 Software Reference

8.1 Introduction

This chapter explains the parameters and settings accessed from the Kinesis software running on a PC.

8.2 GUI Panel

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

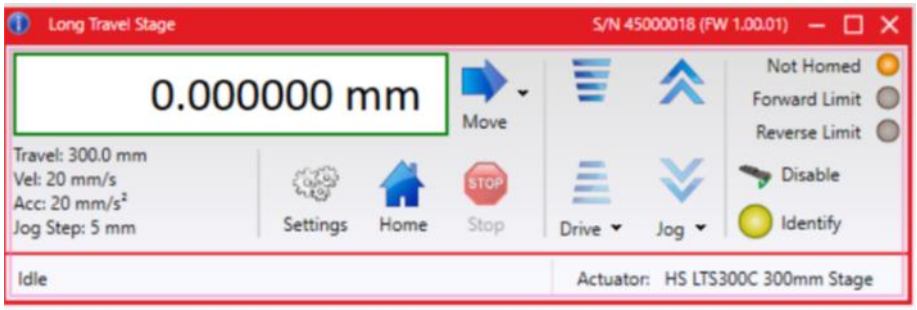
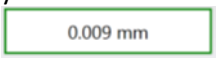


Figure 21 LTS Stage Software GUI

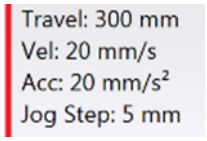
NOTICE

The serial number of the LTS Stage 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, the limit switch). 



Move - Opens the settings window, so that position data and velocity parameters can be entered - see Section 4.2.3. 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 8.3.2.

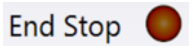


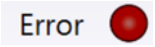
Jog Controls - used to increment or decrement the motor position. The controls comprise a bar graph and a set of jog arrows.

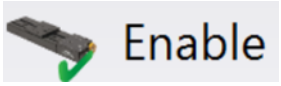
Each division of the bar graph represents a different velocity. The velocities are entered in the settings panel which is displayed by clicking 'Drive' or the small down arrow.

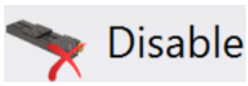
When the arrows are clicked, the motor is driven in the selected direction at the jog velocity, one step per click. The step size and jog velocity parameters can be changed by clicking 'Jog' or the small down arrow to display the settings panel.

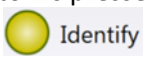
Homed/Not Homed - lit when the motor has not been 'Homed' since power up. When the home button is clicked, the caption changes to 'Homed' and the LED flashes while the home move is being performed. The LED is lit green once the move is complete. 

End Stop - lit when a limit switch is activated, i.e., the motor is at its end stop. 

Error - lit when a fault condition occurs. 

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 ACTIVE LED 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 8.3. 

Home - sends the motor to its 'Home' position – refer Section 9.2.2

Stop - halts the movement of the motor. 

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

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

8.2.1 Keyboard Shortcuts

Certain functionality can also be accessed via PC keyboard shortcuts as follows:

Jog Forwards	'Ctrl' + 'F', 'Ctrl' + '+'
Jog Backwards	'Ctrl' + 'B', 'Ctrl' + '-'
Home	'Ctrl' + 'H', 'Ctrl' + 'Home'
Stop	'Ctrl' + '0'
Jog Forward1	'LeftCtrl' + '1' (Hold to move)
Forward2	'LeftCtrl' + '2' (Hold to move)
Forward3	'LeftCtrl' + '3' (Hold to move)
Forward4	'LeftCtrl' + '4' (Hold to move)
Backward1	'RightCtrl' + '1' (Hold to move)
Backward2	'RightCtrl' + '2' (Hold to move)
Backward3	'RightCtrl' + '3' (Hold to move)
Backward4	'RightCtrl' + '4' (Hold to move)
Go To	'Enter' (On target position box)

8.3 Settings Panel

When the 'Settings' button on the GUI panel is clicked, the 'Settings' window is displayed. This panel allows motor operation parameters such as move/jog velocities, and stage/axis information to be modified. Note that all these parameters have programmable equivalents (refer to the *Kinesis Helpfile* for further details).

8.3.1 Persisting Settings to Hardware

Many of the parameters that can be set for the LTS Stage can be stored (persisted) within the unit itself, such that when the unit is next powered up these settings are applied automatically. This is particularly important when the driver is being used manually in the absence of a PC and USB link. The Velocity Profile and Jogging parameters described previously are good examples of settings that can be altered and then persisted in the driver for use in absence of a PC. To save the settings to hardware, check the 'Persist Settings to the Device' checkbox before clicking the 'OK button.

⚠CAUTION

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

8.3.2 Moves/Jogs Tab

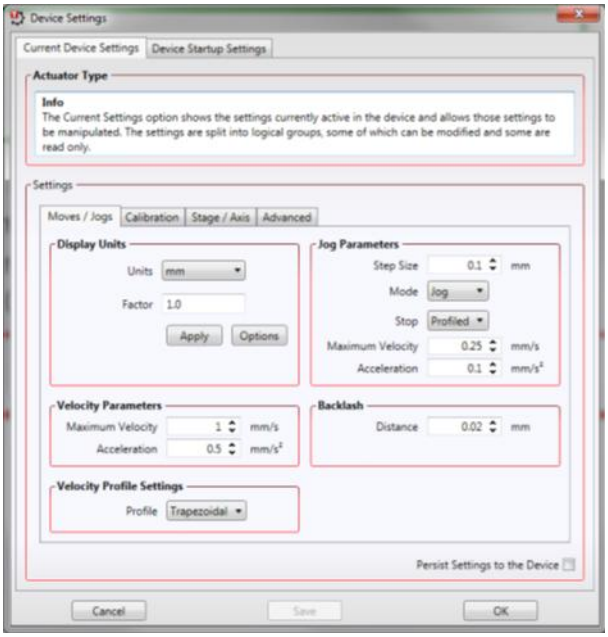


Figure 22 LTS Series Stage – Move/Jog Settings

Display Units

By default, the unit will display position in real world units (mm or degrees). If required, the units can be changed to so that the display shows other positional units (cm, µm, µrad etc.).

Units - the positioning units used on the GUI display.

Factor - the scaling factor associated with the selected units.

Jog Parameters

Jogs are initiated by using the 'Jog' keys on the GUI panel (see Section 0), 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 real world units (mm or degrees dependent upon the stage).

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 Figure 23. In 'Continuous' mode, the motor actuator will accelerate and move at the jog velocity while the button is held down.

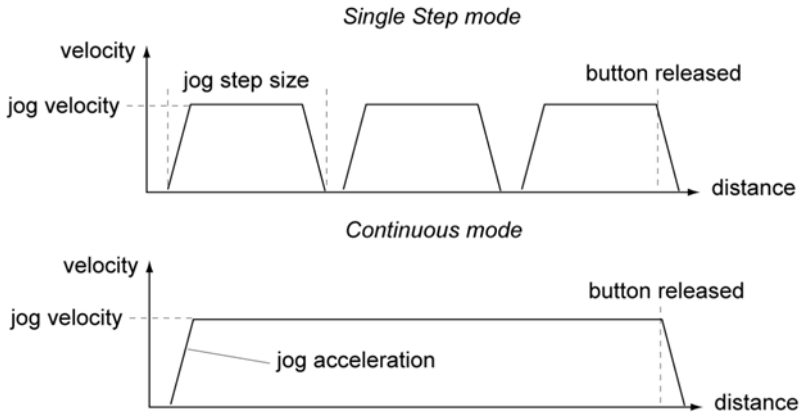


Figure 23 Jog Modes

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.

Velocity Parameters

Moves can be initiated via the GUI panel by entering a position value after clicking on the position display box (see Section 4.2.3), or by calling a software function (refer to the Kinesis Helpfile for further details). The following settings determine the velocity profile of such moves, and are specified in real world units, millimeters or degrees.

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.

NOTICE

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).

Backlash

Velocity Profile settings are described in detail in Section 9.1.3.

The Profile 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.

8.3.3 Calibration Tab

NOTICE This section is applicable only to NRT100, NRT150, LTS150C, LTS300C, LTS450C and MLJ050 series stages, DRV013 and DRV014 actuators.

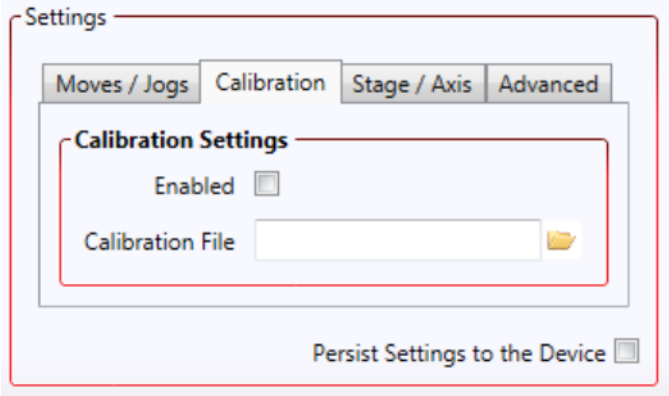


Figure 24 LTS Series Stage – Calibration Settings

Calibration enables the server to correct for any mechanical errors inherent in the system. Mechanical components, such as the leadscrew and linkages, can be machined only within a certain tolerance, e.g., the leadscrew may be nominally 1 mm but actually 1.0005 mm, giving a 0.5 µm error. In practice, these errors accumulate from several sources, however they are repeatable and therefore, can be compensated.

During calibration, the total positional error is measured at many points and these errors are stored as a look up table (LUT). The LUT is saved as a calibration file, one file for each stage. Whenever the stage is moved, the LUT is consulted to ascertain the precise movement required to achieve the demanded position.

The use of a calibration file is optional. Without it, the repeatability and resolution of the stage are unaffected, but no compensations are made to enhance the accuracy.

Calibration files can be downloaded from the support documents section on the product web page, one file for each serial number.

To assign a calibration file:

1. Click the ‘Enabled’ checkbox.
2. Click the folder icon and navigate to the location of the required calibration file.
3. Select the file so that the file name is displayed in the ‘Calibration File’ field.
4. Click OK.

8.3.4 Stage/Axis Tab

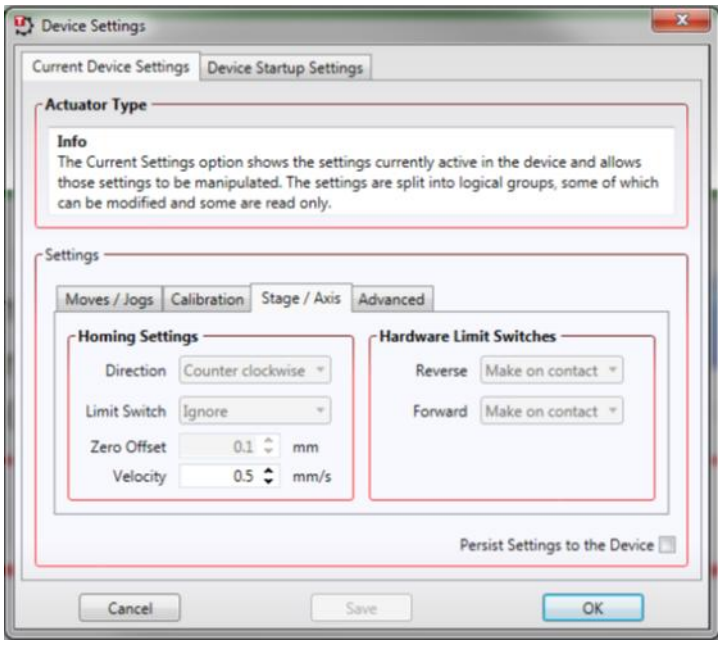


Figure 25 LTS Series Stage – Stage/Axis Settings

NOTICE

This tab contains several parameters which are related to the physical characteristics of the stage being driven. They need to be set accordingly such that a particular stage is driven properly by the system.
For LTS stages, the Kinesis software will automatically apply suitable defaults for the parameters on this tab during boot up of the software and these parameters should not normally be altered subsequently as it may adversely affect the performance of the stage. Descriptions are provided for information only.
For custom stage types not available using the Kinesis software, the stage details must be entered manually - see the software overview for more details.

Homing Settings

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.

NOTICE

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

Direction - the direction sense that the motor moves when homing, either *Clockwise* or *Counterclockwise*.

Limit Switch - The hardware limit switch associated with the home position, either Ignore, *Clockwise* or *Counterclockwise*.

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.

For further information on the home position, see Section 9.2.2.

Hardware Limit Switches

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

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 Reverse or Forward 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.

8.3.5 Advanced Tab

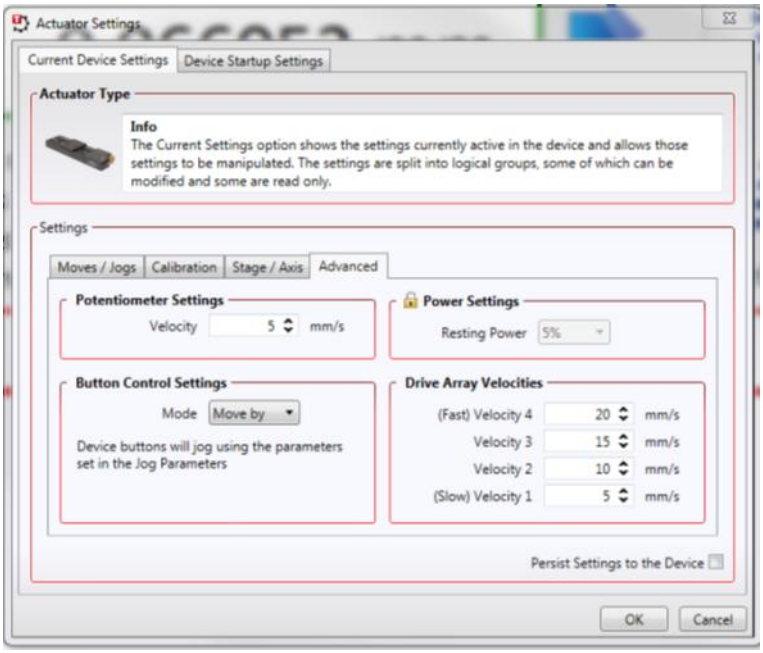


Figure 26 LTS Series Stages – Advanced Settings

Potentiometer Settings

The potentiometer slider is sprung such that when released it returns to its central position. In this central position the motor is stationary. As the slider is moved away from the centre, the motor begins to move. Bidirectional control of motor moves is possible by moving the slider in both directions. The speed of the motor increases up to the value set in the Velocity parameter.

The velocity profile is derived from the 'Velocity Profile' settings in the 'Move/Jogs' settings tab.

Power Settings

The LTS Stage is designed to vary the phase powers (current) in the motor coils depending on the operating state of the motor - moving or stationary. Typically, when a stepper motor is at rest it is advisable to reduce the phase (holding) currents so that the motor does not overheat. When moving, these phase currents are boosted to provide sufficient motor torque and minimize the possibility of stalling (missed steps) The moving phase powers are set automatically by the unit and cannot be adjusted.

The Resting Power is entered as a percentage of full power.

NOTICE The default values applied by the software have been selected based on the type of stage or actuator associated with the motor drive. Modify these values with caution (particularly the rest power) as the risk of damage to the motor due to overheating is significant.

Button Control Settings

The buttons on the front of the unit can be used either to jog the motor, or to perform moves to absolute positions.

Mode: This setting determines the type of move performed when the front panel buttons are pressed.

Move By: Once set to this mode, the move parameters for the buttons are taken from the 'Jog' parameters on the 'Move/Jogs' settings tab.

Move To: In this mode, each button can be programmed with a different position value, such that the controller will move the motor to that position when the specific button is pressed.

NOTICE The following parameters are applicable only if 'Move To' is selected in the 'Mode' field.

Left/Top Button Pos.: The position to which the motor will move when the top button is pressed.

Right/Lower Button Pos.: The position to which the motor will move when the bottom button is pressed.

NOTICE A 'Home' move can be performed by pressing and holding both buttons for 2 seconds. This function is irrespective of the 'Button Mode' setting.

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.

NOTICE It is acceptable to set velocities equal to each other to reduce the number of speeds.

Chapter 9 Stepper Motor Operation

9.1 How a Stepper Motor Works

9.1.1 General Principle

Thorlabs' actuators use a stepper motor to drive a precision lead screw.

Stepper motors operate by using attractive and repulsive magnetic fields to convert digital pulses into mechanical shaft rotation. The amount of rotation achieved is directly proportional to the number of input pulses generated and the speed is proportional to the frequency of these pulses. A basic stepper motor has a permanent magnet and/or an iron rotor, together with a stator. The torque required to rotate the stepper motor is generated by switching (commutating) the current in the stator coils as illustrated in Figure 27.

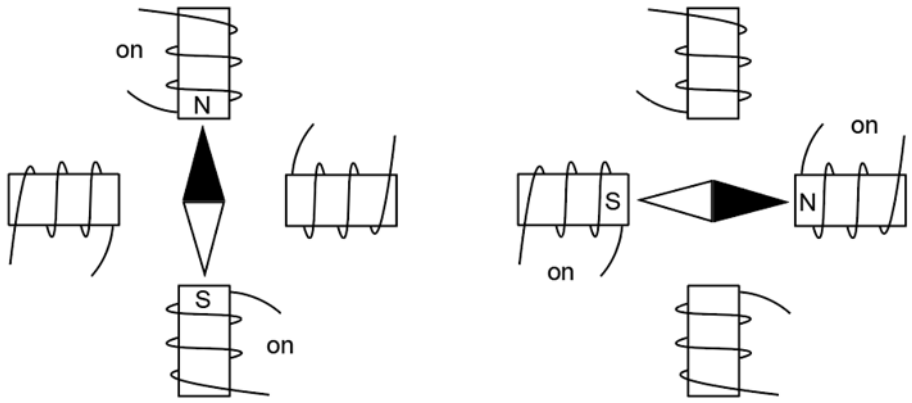


Figure 27 Simplified Concept of Stepper Motor Operation

Although only 4 stator poles are shown above, there are numerous tooth-like poles on both the rotor and stator. The result is that positional increments (steps) of 1.8 degrees can be achieved by switching the coils (i.e., 200 steps per revolution). If the current through one coil is increased as it is decreased in another, the new rotor position is somewhere between the two coils and the step size is a defined fraction of a full step (microstep).

The size of the microstep depends on the resolution of the driver electronics. The integral driver of the LTS stages gives a smallest angular adjustment of 0.00088 degrees (i.e. 1.8/0.00088 = 2048 microsteps per full step), resulting in a resolution of 409,600 microsteps per revolution of the motor.

In practice, the mechanical resolution achieved by the system may be coarser than a single microstep, primarily because there may be a small difference between the orientation of the magnetic field generated by the stator and the orientation in which the rotor comes to rest.

9.1.2 Positive and Negative Modes

Positive and *negative* are used to describe the direction of a move. A positive move means a move from a smaller absolute position to a larger one, a negative move means the opposite.

In the case of a linear actuator, a positive move takes the platform of the stage further away from the motor.

In a rotational stage, a positive move turns the platform clockwise when viewed from above.

9.1.3 Velocity Profiles

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

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

The specific move profile created by the system depends on several factors, such as the profile mode and profile parameters presently selected, and other conditions such as whether a motion stop has been requested. The profile mode can be set to 'Trapezoidal' or 'Bow Index'.

The *Trapezoidal* profile is a standard, symmetrical acceleration/deceleration motion curve, in which the start velocity is always zero. This profile is selected when the *Bow Index* field is set to '0'.

In a typical trapezoidal velocity profile, (see Figure 28), 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.

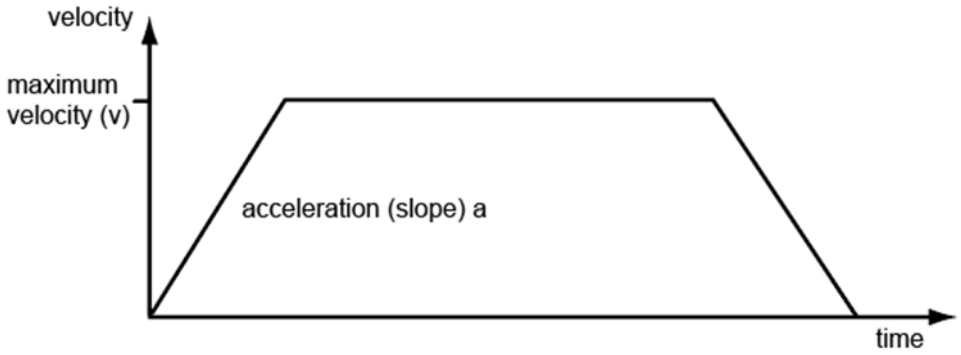


Figure 28 Graph of a Trapezoidal Velocity Profile

The *S-curve* profile is a trapezoidal curve with an additional '*Bow Value*' parameter, which limits the rate of change of acceleration and smooths out the contours of the motion profile. The *Bow Value* is specified in mm/s^3 and is derived from the Bow Index field as follows:

The *Bow Value* is applied in mm/s^3 and is derived from the Bow Index field as follows:

Bow Value = $2^{(\text{Bow Index } -1)}$ within the range 1 to 262144 (Bow Index 1 to 18).

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

Example

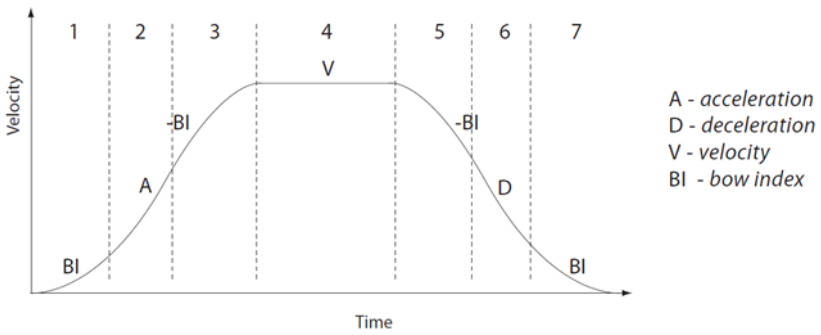


Figure 29 Typical S-Curve Profile

The figure above shows a typical S-curve profile. In segment (1), the S-curve profile drives the axis at the specified Bow Index (BI) until the maximum acceleration (A) is reached. The axis continues to accelerate linearly (Bow Index = 0) through segment (2). The profile then applies the negative value of Bow Index 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 Bow Index to reach the maximum deceleration (D) and then bring the axis to a stop at the destination.

NOTICE

The higher the Bow Index, then the shorter the BI phases of the curve, and the steeper the acceleration and deceleration phases. High values of Bow Index may cause a move to overshoot.
Conversely, low values of Bow Index result in much shallower (longer duration) acceleration and deceleration curves. When these are combined with high velocities, the average power consumption increases, and some heating may be apparent.

9.2 Positioning a Stage

9.2.1 General

Whenever a command is received to move a stage, the movement is specified in motion units, (e.g., millimetres). This motion unit value is converted to microsteps before it is sent to the stage. If operating the unit by the front panel (local mode) this conversion is performed internally by the controller. If operating via a PC (remote mode) then the conversion is performed by the software.

Each motor in the system has an associated electronic counter in the controller, which keeps a record of the net number of microsteps moved. If a request is received to report the position, the value of this counter is converted back into motion units.

9.2.2 Home Position

When the system is powered up, the position counters in the controller are all set to zero and consequently, the system has no way of knowing the position of the stage in relation to any physical datum.

A datum can be established by sending all the motors to their ‘Home’ positions. The ‘Home’ position is set during manufacture and is determined by driving the motor until the negative limit switch is reached and then driving positively a fixed distance (zero offset). When at the Home position, the counters are reset to zero thereby establishing a fixed datum that can be found even after the system has been switched off.

See Section 4.2.2 for details on performing a Home move.

9.2.3 Limit Switches

A linear stage moves between two stops, and movement outside these limits is physically impossible. Linear stages can include stages that control the angle of a platform within a certain range, although the movement of the platform is not linear but angular. Rotary stages can rotate indefinitely, like a wheel.

Linear and rotary stages both contain microswitches that detect certain positions of the stage, but they differ in the way these switches are used.

All linear stages have a –ve limit switch, to prevent the stage from accidentally being moved too far in the –ve direction. Once this switch is activated, movement stops. The switch also provides a physical datum used to find the Home position. Some linear stages and actuators also have a +ve limit switch, whereas others rely on a physical stop to halt the motion in the positive direction. A rotary stage has only one switch, used to provide a datum so that the Home position can be found.

Movement is allowed right through the switch position in either direction.

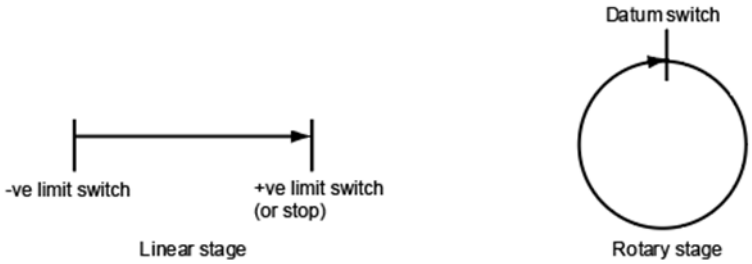


Figure 30 Stage Limit Switches

9.2.4 Minimum and Maximum Positions

These positions are dependent upon the stage or actuator to which the motors are fitted and are defined as the minimum and maximum useful positions of the stage relative to the 'Home' position - see Figure 31.

The distance from the Minimum position to the Maximum position is the 'useful travel' of the stage. It is often the case that the Minimum position is zero. The Home and Minimum positions then coincide, with movement always occurring on the positive side of the Home position.

Rotary stages have effectively no limits of travel. The Minimum and Maximum positions are conventionally set to 0 and 360 degrees respectively. When the position of a rotary stage is requested, the answer will be reported as a number between 0 and 360 degrees, measured in the positive direction from the Home position.

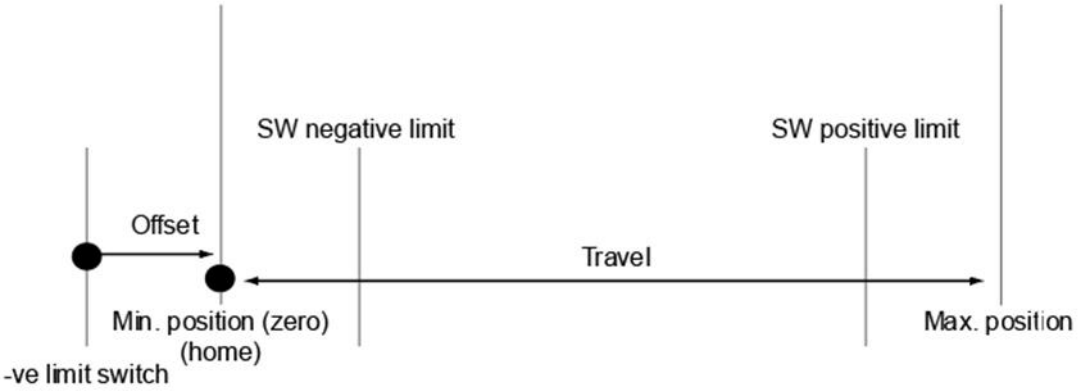


Figure 31 Minimum and Maximum Positions

9.2.5 Power Saving

The current needed to hold a motor in a fixed position is much smaller than the current needed to move it, and it is advantageous to reduce the current through a stationary motor to reduce heating. Although this heating does not harm the motor or stage, it is often undesirable because it can cause thermal movements through expansion of the metal of the stage.

For this reason, power saving is implemented by default from the software drivers.

When a motor is moving, the 'Move Power' is applied. When a motor is stationary, the 'Rest Power' is applied. See 'Phase Powers' in Section 8.3.5 for more details on these power settings.

9.3 Error Correction

Backlash Correction

The term *backlash* refers to the tendency of the stage to reach a different position depending on the direction of approach.

Backlash can be overcome by always making the last portion of a move in the same direction, conventionally the positive direction. Consider the situation in Figure 32, a positive move, from 10 to 20 mm, is carried out as one simple move, whereas a negative move, from 20 to 10 mm, first causes the stage to overshoot the target position and then move positively through a small amount.

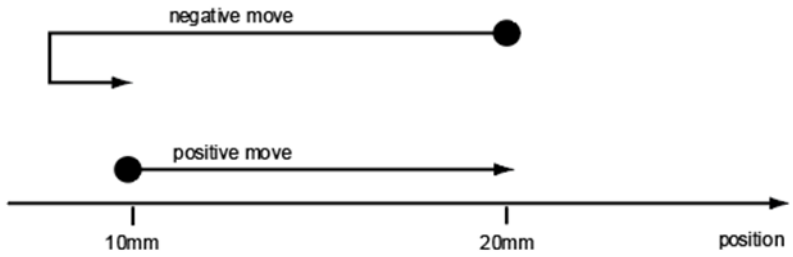


Figure 32 Backlash Correction

The controller has this type of 'backlash correction' enabled as its default mode of operation, but it can be overridden if the overshoot part of the move is unacceptable for a particular application.

See Section 8.3.2 for details on setting the backlash correction.

Chapter 10 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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