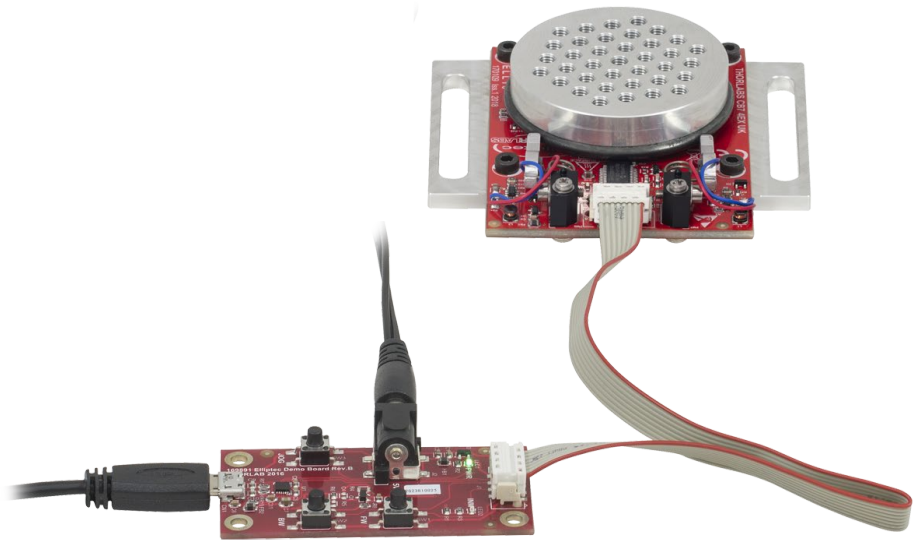
THORLABS

ELL18 and ELL18K

Rotation Stage Kit

Operating Manual



Original Instructions

Table of Contents

Chapter 1 Introduction

The ELL18 Rotation Stage is part of the Thorlabs series of resonant piezo motor circuits and bare modules for OEM applications. The resonant piezo design of these motors offers fast response times and precise positioning, and are therefore particularly useful in scanning applications.

The high-speed digital signal processing (DSP) architecture supports a multi-drop serial communication protocol, and a set of digital IO lines allows the user to control the movement and state manually by switching the lines high (5V) or low (0V).

The stage is designed for closed loop applications requiring rotational positioning with 43.0 µrad of resolution. The stage delivers a travel range of 360° continuous rotation, however the displayed position and requested position commands are in the range 0 to 359.99°.

Homing is achieved using a combination of a reflecting optical sensor (IR) for coarse (0.5 to 1.0 mm) positioning, then a magnetic sensor for fine (1.0 µm resolution) positioning. Using the ELLO software, the user can modify the offset value to shift the homing position (up to a ¼ of turn). Furthermore, coarse homing can be selected in a clockwise (CW) or counter clockwise (CCW) direction (fine homing is always performed in a CCW direction to guarantee repeatability).

The module is powered via an external 5V power supply supplied in the kit.

A hand-held controller is supplied with the ELL18K/M evaluation kit to allow homing and manual jogging and/or positioning. The unit can also be driven remotely via PC-based software, downloaded from **www.thorlabs.com**. A compatible USB driver and source code are included in the software download package.

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.

Warning: Risk of Electrical Shock
Given when there is a risk of electrical shock.

Warning
Given when there is a risk of injury to the user.

Caution
Given when there is a possibility of damage to the product.

Note
Clarification of an instruction or additional information.

2.1. General Warnings and Cautions

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

The equipment is susceptible to damage from electrostatic discharge. When handling the device, anti-static precautions must be taken and suitable discharge appliances must be worn.

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.

If the device is operated over a prolonged time period, the motor housing may become hot. This does not affect motor operation but may cause discomfort if contacted by exposed skin.

Do not bend the PCB. A bending load in excess of 500 g applied to the board may cause the PCB to deform, which will degrade the performance of the controller.

Do not expose the stage to magnetic fields as this could affect the positioning and homing sensor operation. An external magnetic field close to the sensor should be below +/- 5mT.

Chapter 3 Description

3.1. Environmental Conditions

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

Location	Indoor use only
Maximum altitude	2000 m
Temperature range	15°C to 40°C
Maximum Humidity	Less than 80% RH (non-condensing) at 31°C

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

Do not expose the stage to magnetic fields as this could affect the positioning and homing sensor operation.

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 is not designed to be used in explosive environments.

The unit is not designed for continuous operation. Lifetime will depend on several factors, e.g. load, number of homing operations, number of frequency searches etc. The minimum lifetime is 100 km. See Chapter 4 for more details.

3.2. Mounting

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

Caution
Although the module can tolerate up to 8kV of air discharge, it must be treated as ESD sensitive device. When handling the device, anti-static precautions must be taken and suitable discharge appliances must be worn.

Do not expose the stage to magnetic fields as this could affect the positioning and homing sensor operation. An external magnetic field close to the sensor should be below +/- 5mT.

When handling the stage, take care not to touch the wires to the motors.

Do not bend the wires over the motor spring as this affects the performance of the unit.

Do not allow the wires to contact other moving parts.

The recommended mounting orientation is horizontal. Two mounting brackets are shipped with the ELL18K/M kit to allow mounting to a standard 1” or 25 mm pitch optical table or breadboard.

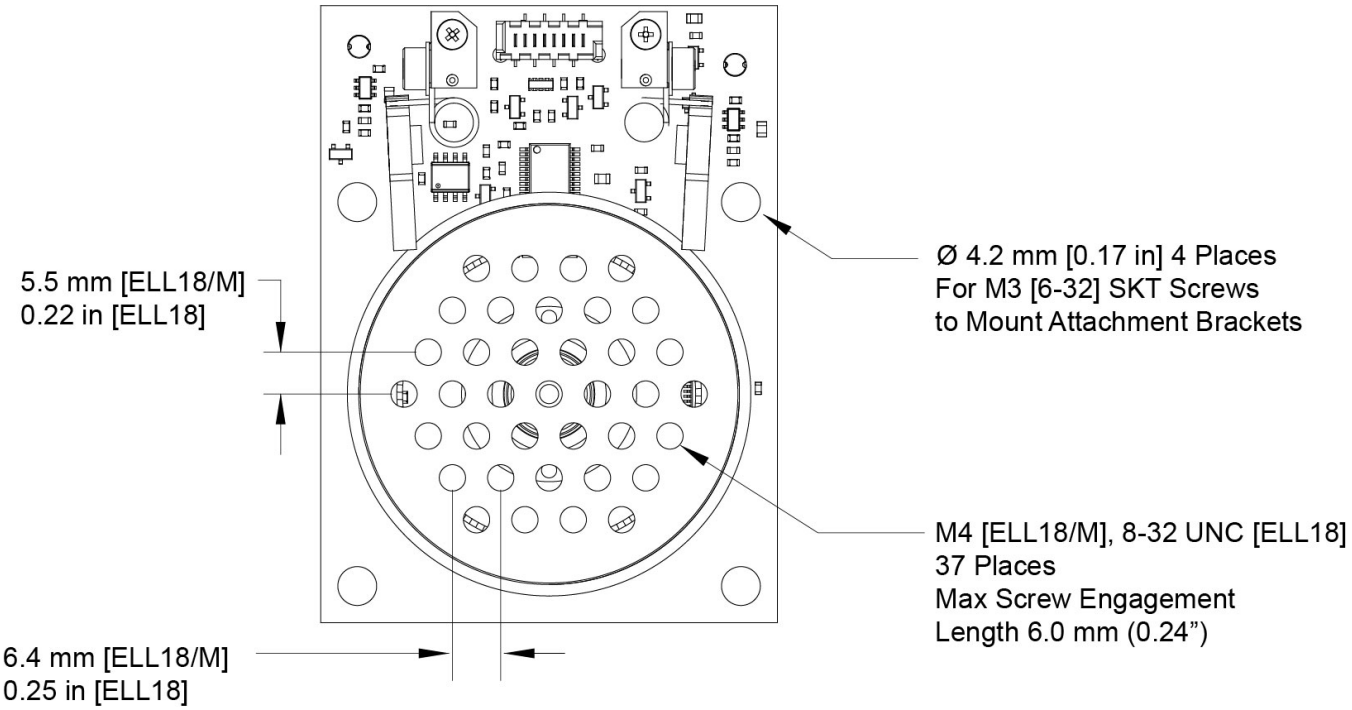


Figure 1 ELL18 rotation stage

The image below shows a diffraction grating mounted on the stage, with the diffracted light being incident on the slit located to the right.

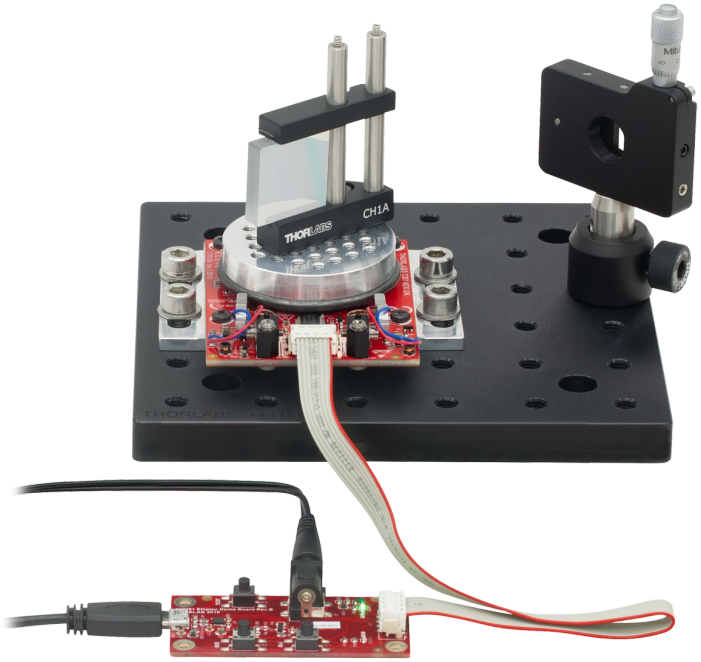


Figure 2 ELL18 with components fitted

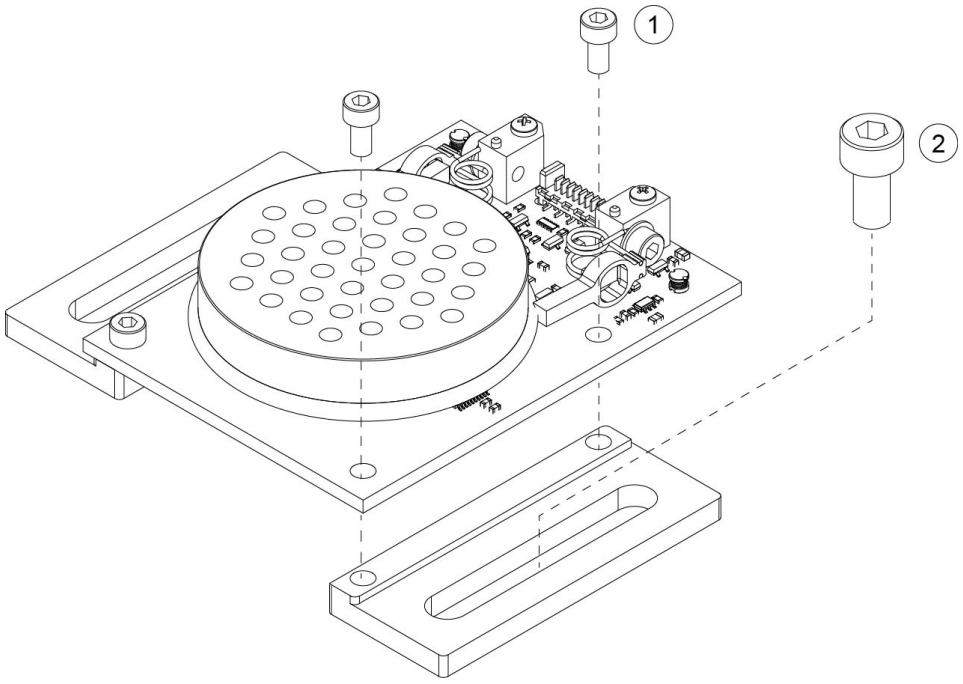


Figure 3 Fixing the ELL18K to the work surface

1. Using the M3 x 6 mm (6-32 x ¼") bolts supplied, fix the mounting brackets to the circuit board as shown above.
2. Attach the mounting brackets to the work surface using appropriate standard fixings (not supplied).

Chapter 4 Operation

4.1. Getting Started

Caution
Although the module can tolerate up to 8kV of air discharge, it must be treated as ESD sensitive device. When handling the device, anti-static precautions must be taken and suitable anti-discharge appliances must be worn.

Do not expose the stage to magnetic fields as this could affect the positioning and homing sensor operation.

When power is applied, do not connect or disconnect the ribbon cable connecting the handset to the stage PCB. Always remove power before making connections.

Warning
If the device is operated over a prolonged time period, the motor housing may become hot. This does not affect motor operation but may cause discomfort if contacted by exposed skin.

1. Perform the mechanical installation as detailed in Section 3.2
2. Connect the handset to the stage if required.

Caution
The unit is easily damaged by connections with incorrect polarity. Pin 1 of the connector on the PCB is marked with an arrow (see Figure 4 and Figure 5.) which should be adjacent to the red wire in the connecting cable.

3. Connect the stage to a 5V supply and switch ‘ON’. (A 5V PSU is supplied with the ELL18K/M).
4. Connect the unit to your PC if required, and wait for the drivers to be installed.
5. Home the stage. Homing is necessary to align the sensor and establish a datum from which all future moves are measured.

4.1.1. Homing

Homing is achieved using a combination of a reflecting optical sensor (IR) for coarse (0.5 to 1.0 mm) positioning, then a magnetic sensor for fine (1.0 µm resolution) positioning (the magnetic sensor is also used for positioning during subsequent moves). Using the ELLO software, the user can modify the offset value to shift the homing position (up to a ¼ of turn). Furthermore, coarse homing can be selected in a clockwise or counter clockwise direction (the switch between coarse to fine homing is always performed in the same direction to guarantee repeatability).

4.1.2. Position Error Compensation

The stage has a positioning error compensation algorithm. When moving from one position to another, the stage detects the error between the requested and actual positions and will calculate an error compensation value, which is then applied to the next movement. The calculation is applied automatically and is continually updated, but generally the optimum value is calculated within 2 to 6 motions.

4.2. Controlling the Stage

The stage can be controlled in three ways; via the handset, by the Elliptec software running on a PC, or by writing a custom application using the messages described in the communications protocol document. Homing and Jogging functionality can also be accessed by applying voltages to the digital lines on Connector J1. The modes of control are described in the following sections.

Caution
In all modes, the angular position is requested and displayed from 0 to 359.99°. If a stage is driven past the 359.99° rotation point, the display reverts back to zero and counts up to 359.99° again. Furthermore, the unit will not respond to requests for a move to a position greater than 359.99° and an error message will be generated.

4.2.1. Hand-held Controller

Caution
On power up the stage will move while the unit checks the sensors and then searches for the home position.

The hand-held controller supplied with the ELL18K Evaluation Kit features two buttons (marked FW and BW) that allow control of the stage position. The handset also provides for connection to the host PC and to the external 5V power supply. The external PSU connector allows the stage to be used in the absence of a PC, with control being achieved via the handset buttons.
LED1 (green) is lit when power is applied to the unit. LED2 (red) is lit when the device being driven is in motion.

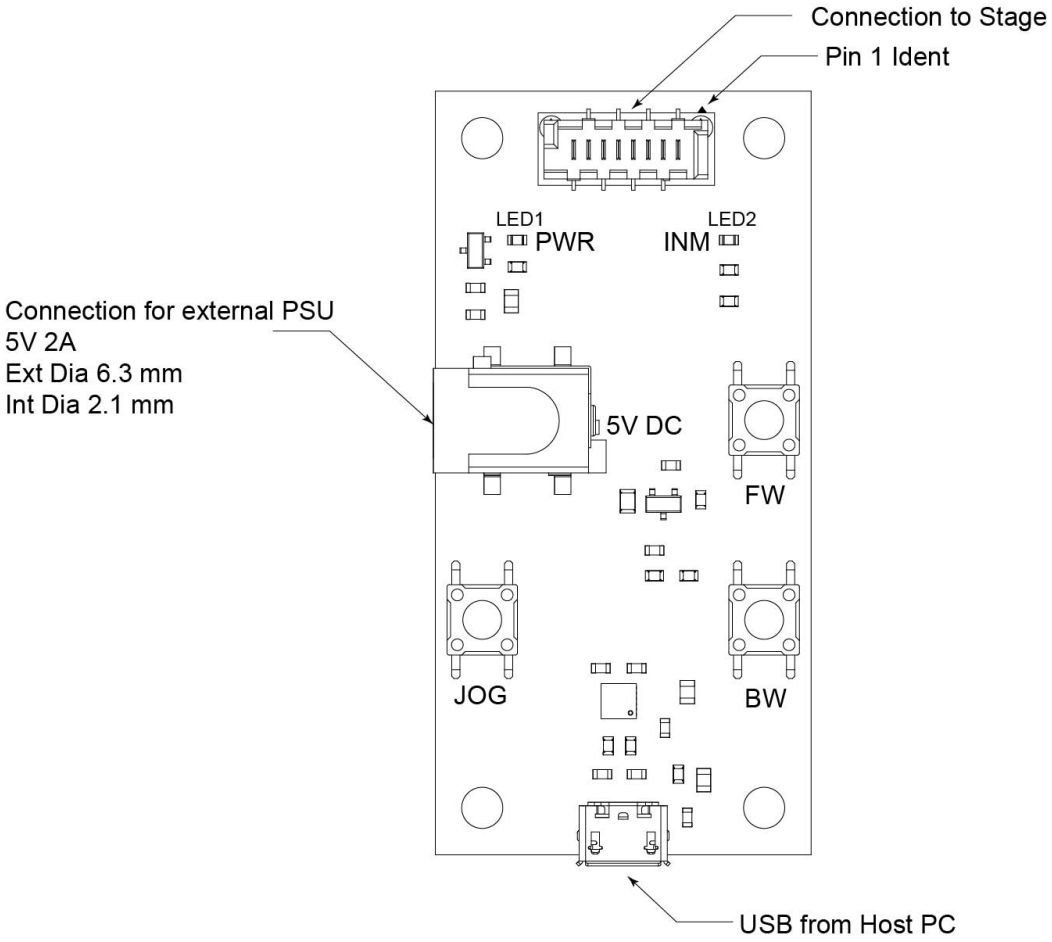


Figure 4 Handset details

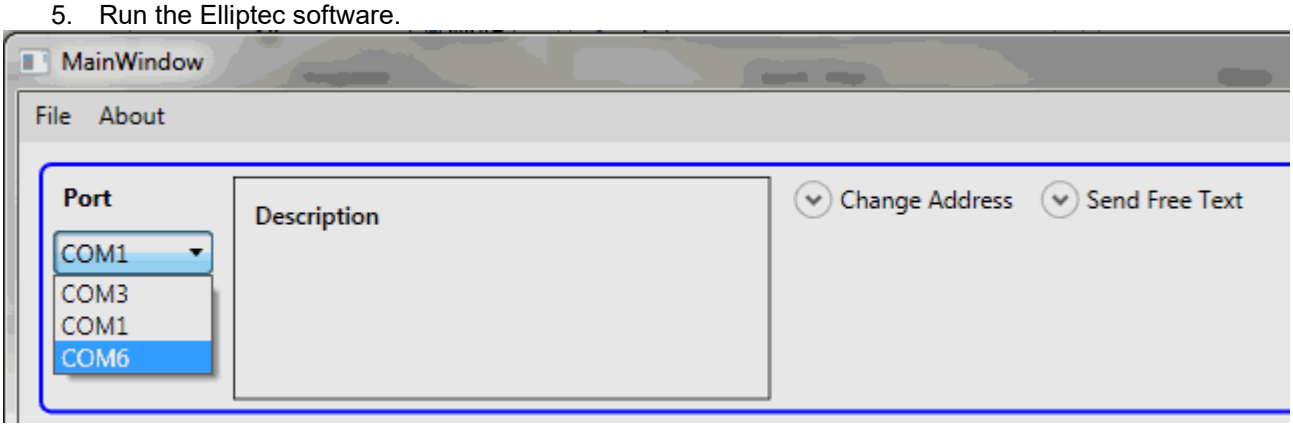
Caution
The stage must be homed before performing any Jog moves.

1. Home the stage by pressing the BW button.
2. To jog forward, press and hold JOG and then press FW. The default jog step value is 45 degrees. The jog step size can be changed in the software GUI, see the helpfile for details.
3. To jog backward, press and hold JOG and then press BW.

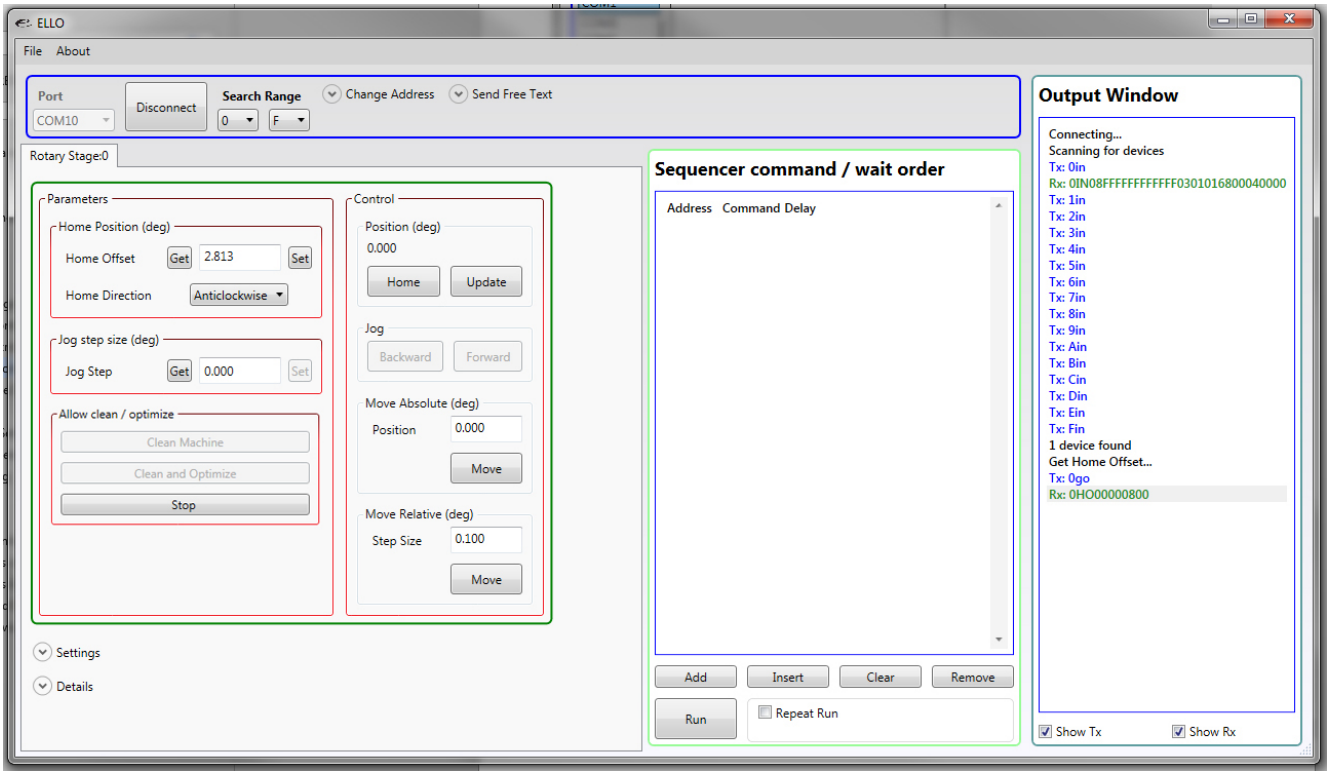
4.2.2. Software Control

When connected to the host PC, the stage can be controlled remotely, via the Elliptec software.

1. Download the Elliptic software from the downloads section at www.thorlabs.com. Double click the saved .exe file and follow the on-screen instructions.
2. Connect the hand-held controller to the stage unit.
3. Connect the hand-held controller to the 5V Power Supply and switch on.
4. Connect the hand-held controller to the PC USB port and wait for the drivers to be installed.
5. Run the Elliptec software.



6. In the top left of the GUI panel displayed, select the COM port to which the device is connected, and click ‘Connect’. The software will search the comms bus and enumerate the device.
7. Click the Home Offset ‘Get’ button, then click ‘Home’ to home the stage.
8. The GUI and device are now ready for use. See the helpfile supplied with the software for more information.



4.2.3. Communications Protocol

Custom move applications can be written in languages such as C# and C++.
The communication bus allows multi-drop communication with speeds at 9600 baud, 8 bit data length, 1 stop bit, no parity.
Protocol data is sent in ASCII HEX format, while module addresses and commands are mnemonic character (no package length is sent). Modules are addressable (default address is “0”) and addresses can be changed and/or saved using a set of commands. Lower case commands are sent by user while upper case commands are replies by the module.
Please refer to the communications protocol manual for more detail about commands and data packet formats.

4.2.4. Connecting Multiple Devices

When a device is first connected to the PC, it is assigned the default address '0'. The software can run multiple devices; however, before more than one device can be recognised, each device must be assigned a unique address. See below for a brief overview; detailed instructions are contained in the help file supplied with the software.

Connect the first device to the PC USB port, then run the Elliptec software and load the device.

Change the address of the first device.

Connect the next device to the first device.

Change the address of the second device.

Multiple devices can be controlled individually, either via the Elliptec software or by a third party application written using the messages detailed in the protocol document. Control via the handset is applied to all devices simultaneously.

4.2.5. Controlling the Stage without the handset

Caution
During normal operation each motor is protected with a time out of 2.5 seconds to prevent overheating. Do not override this protection or drive the motors continuously.

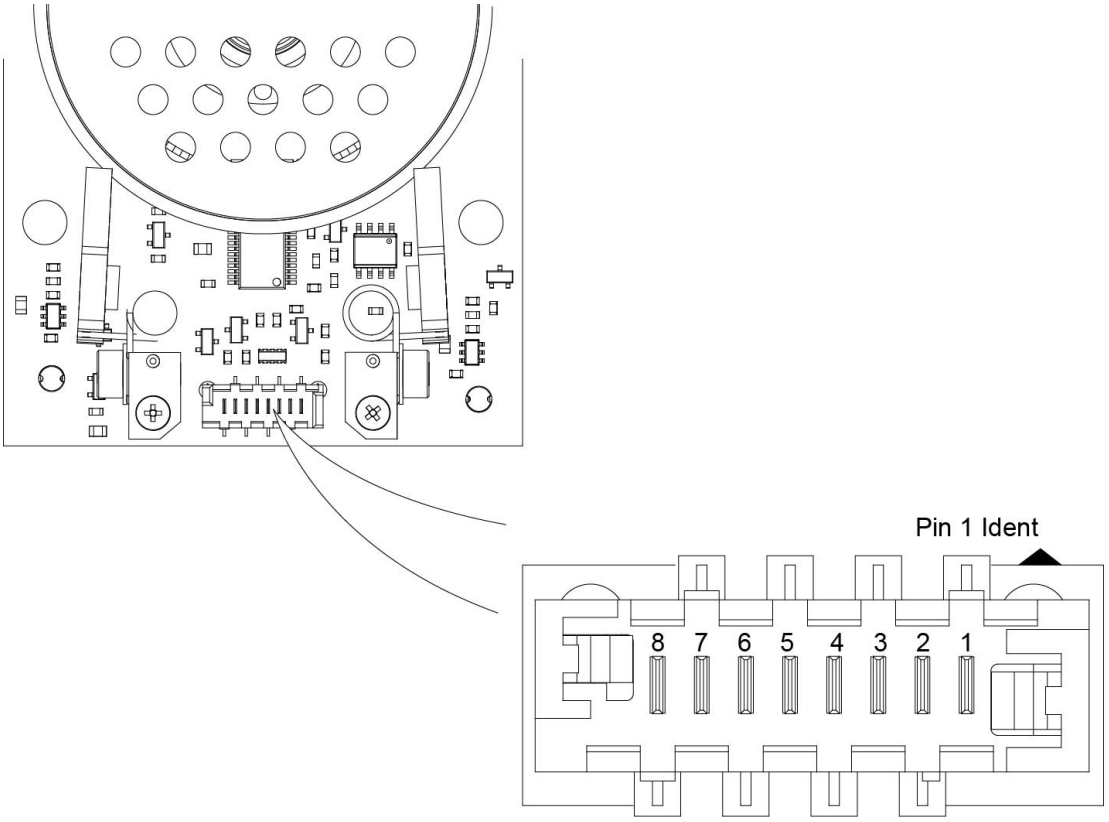
In the absence of the handset, the stage is controlled via digital lines: forward, backward and mode (J1 pins 7, 6 and 5) by shorting the corresponding line to ground (pin 1).

When the stage is moving, the open drain IN MOTION digital line (pin 4) is driven low (active low) to confirm movement. The IN MOTION line goes high (inactive) when the move is completed or the maximum time-out (2.5 seconds) is reached.

Warning
Do not exceed the voltage and current ratings stated in Figure 5.

Do not reverse polarity.

Connector J1 Pin Out



PIN	TYPE	FUNCTION
1	PWR	Ground
2	OUT	ODTX - open drain transmit 3.3V TTL RS232
3	IN	RX receive - 3.3V TTL RS232
4	OUT	In Motion, open drain active low max 5mA
5	IN	JOG/Mode, active low max 5V
6	IN	BW Backward , active low max 5V
7	IN	FW Forward, active low max 5V
8	PWR	VCC +5V +/-10% 800mA

Connector model number MOLEX 90814-0808 Farnell order code 1518211

Mating connector model number MOLEX 90327-0308 Farnell order code 673160

Figure 5 Connector J1 pin out details

4.3. Frequency Search

Due to load, build tolerances and other mechanical variances, the default resonating frequency of a particular motor may not be that which delivers best performance. A frequency search can be performed using the Main GUI Settings panel in the ELLO software, or by using the serial communication line (SEARCHFREQ_MOTORX message), which offers a way to optimize the operating frequencies for backward and forward movement.

This search can also be performed manually by restoring the factory settings as follows.

4.4. Periodic Cycling of Devices Over Full Range of Travel

Caution
Periodically, devices should be moved over the full range of travel, from one end to the other. This will help minimize the build up of debris on the track and will prevent the motors digging a groove over the most used area of contact. Typically, a travel cycle should be performed every 10K operations.

4.5. Restoring Factory Settings

Factory settings can be restored during the start up (calibration) test as follows:

1. Remove power from the rotator and disconnect the USB cable.
2. Press and hold the BW button (do not release until item 5).
3. POWER UP and reconnect the USB cable.
4. WAIT for red led to switch on.
5. Release BW. The unit will reboot and load the default factory values.

4.6. Simultaneous Movement of Devices

If more than one device is connected to the comms bus, movement of the devices can be synchronized. This can be achieved either by using the handset, or by software. See the protocol document for details on how to use the ‘ga’ message to synchronize moves. If using the handset, synchronized movement is hard wired, so if multiple devices are connected, pressing the FWD or BWD buttons will move all devices.

Chapter 5 Troubleshooting and FAQ

5.1. Frequently Asked Questions

Stage is moving back and forth after power up
If the digital line “bw” is driven low before powering up the stage, the module will go into calibration mode. Remove power to exit calibration mode. Keep line tight up to 3.3V or 5V rail during power up or use a serial communication line instead.

Stage not moving
Check power supply lines ratings (polarity, voltage drop or range, available current) or reduce cable length.

Check module is not in boot loader mode (power cycle the module to exit boot loader) consumption must be higher than 36mA at 5V.

Stage does not complete homing commands
Power cycle the unit.

Perform a frequency search on both motors.

Stage switching time increased / max load decreased
Check power supply voltage provided on J1 connector, increase voltage within specified limits if voltage drop along cable goes below 5V during system operation.

Clean the moving surfaces. To avoid grease contamination, do not touch the moving parts.

Temperature change may affect the stage performance. Using the software to perform a frequency search will compensate frequency as needed (required current could reach 1.2A during frequency search, use an addition 5V 1A power supply and a USB connection).

Integrators should search for optimal frequency on every power up sequence (commands “s1”, “s2” see ELLx protocol document).

How do I restore the factory (default) settings
Factory settings can be restored during the start up (calibration) test – see Section 3.5.

Motor optimization does not work.

The optimization may fail if the device is damaged, if the load is heavily unbalanced or changed in position during the optimization, or if the power supply is not stable.

> **Note**
> Do not run more than one device optimization at the same time on the same bus and power supply.
>
> The current drawn can overload the power supply. Allow 20 minutes of cool down between consecutive optimizations on the same device.

If the optimization fails, the device will try to reload the previous settings. If this reload fails, perform a frequency search (see section 4.3) to reload the settings.

The unit is not responding after power up

During the power up sequence, if the user holds down the JOG, BW and FW lines to ground, the module will go into a bootloader (firmware update) mode.

Power cycle the unit again without pressing the 3 buttons at the same time to exit from the bootloader mode.

The device is not responding during cleaning or optimization

This is normal.

The cleaning and the optimization routines block a device and the associated communication bus for several minutes. When one of these routines is initiated, the bus is unavailable until the routine is completed, and the device replies busy '0GS09' to all commands except the stop command '0st' (for a unit at address 0). The stop request can take up to 5 seconds to abort the operation.

During these routines, the unit may increase in temperature by several degrees. Because of this inherent temperature increase, consecutive cleaning and optimization routines should be avoided.

After optimization or cleaning, allow a 20 min cool down period before use.

What is the typical product life time?

ELL18 product life time is restricted by the wearing of moving surfaces and the motor contact as motion is started (due to resonance build up) and performed (due to friction), and is expressed in km travelled. Lifetime will depend on several factors (e.g. load, number of homing operations, number of frequency searches etc.) and users must take into account all these factors when considering life time. For example, homing requires more travel than a simple motion, and a frequency search may not generate any motion at all, but still energizes the motors fully.

The unit is not designed for continuous operation. Users should aim for a duty cycle of less than 40% wherever possible, and never exceed a duty cycle of 60% for longer than a few seconds. Furthermore, it is good practice to move in the shortest path, so from position 350° to 5° it is better to move CW 15° (relative move) rather than CCW 345° (absolute move).

A typical lifetime is more than 100 km or 600,600 revolutions.

Handling

The stage and interface board are robust to general handling. To ensure reliable operation, keep the surface of the plastic track contacted by the motors free of oils, dirt, and dust. It is not necessary to wear gloves while handling the linear stage, but avoid touching the track to keep it free of oils from fingerprints. If it is necessary to clean the track, it may be wiped with isopropyl alcohol or mineral spirits (white spirit). Do not use acetone, as this solvent will damage the plastic track.

5.2. Notes on Making a Picoflex Cable for Use when Daisy Chaining Devices

The multi-drop communications bus offers the option of connecting the stage to a hybrid network of up to 16 Elliptec resonant motor products and controlling the connected units with a device such as a microprocessor. When multiple units are connected to the same interface board, all can be controlled simultaneously using either the software or the buttons on the interface board.

When making a cable to operate multiple devices it is important to observe the correct pin orientation. The following procedure offers guidance in making such a cable.

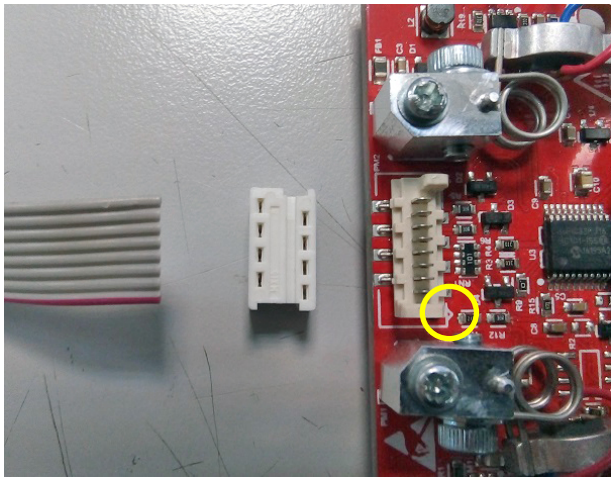
1. Gather together the parts required.

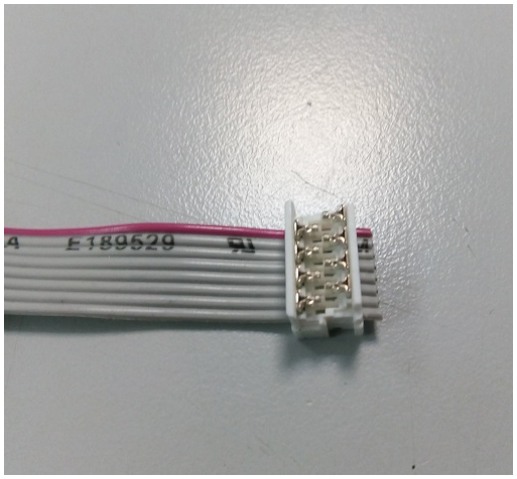
   a) Ribbon cable 3M 3365/08-100 (Farnell 2064465xxxxx).

   b) Female crimped connectors as required - model number MOLEX 90327-0308 (Farnell order code 673160) (Qty 1 female connector above is shipped with each stage unit).

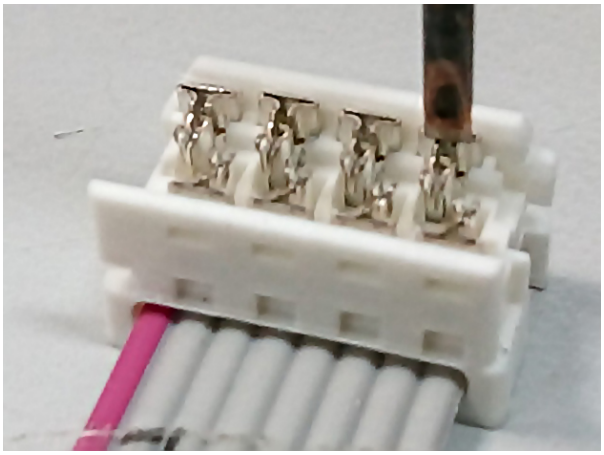
   c) Suitable screwdriver and scissors or other cutting tool.

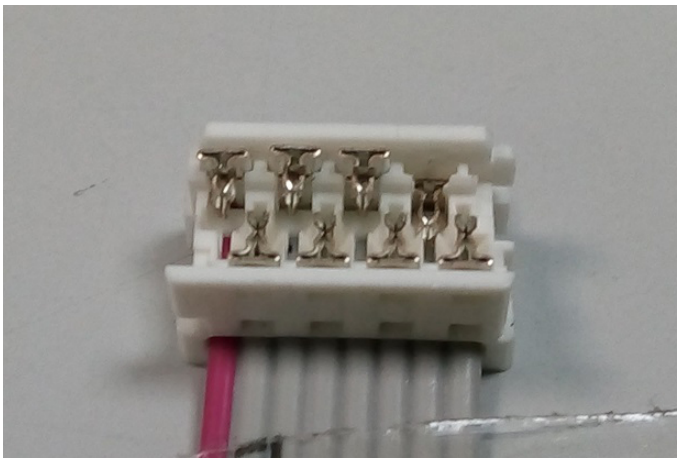
2. Orientate the first connector correctly to mate with the connector on the stage, then arrange the ribbon cable as shown with the red wire aligned with pin 1 (identified on the pcb by a small triangle). Slide the connector onto the ribbon cable as shown.



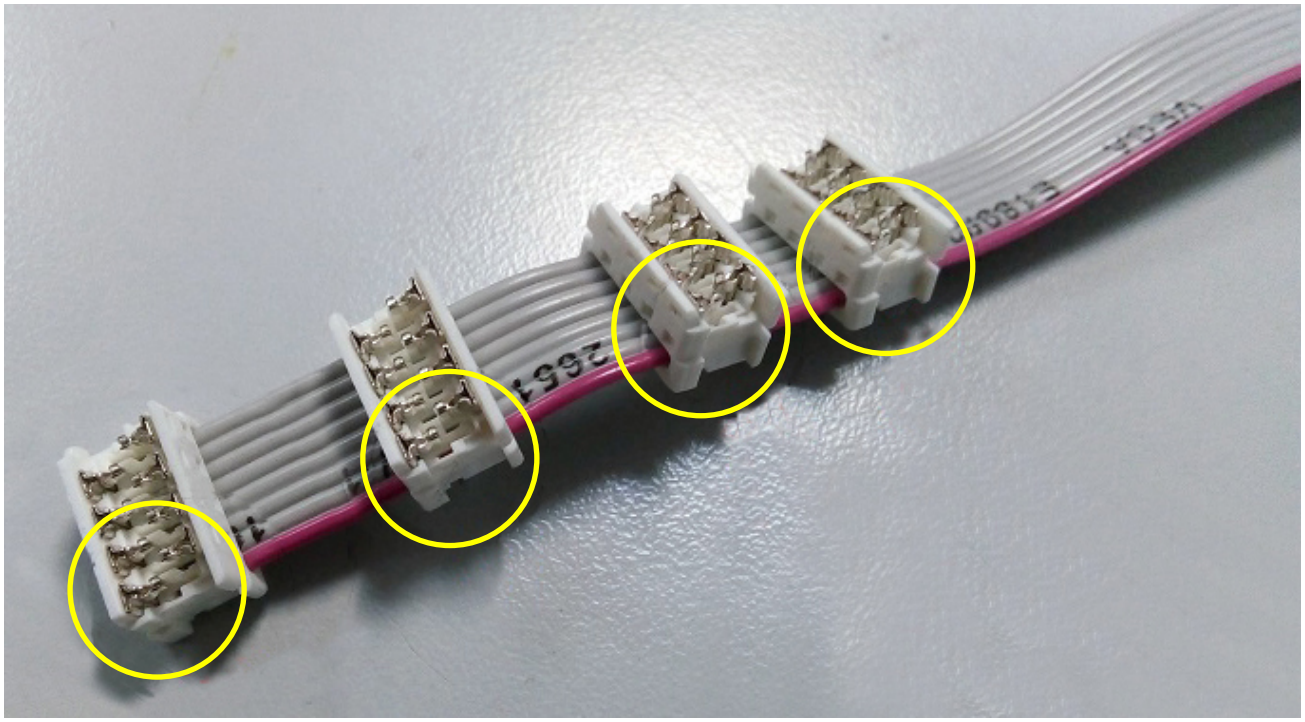


3. Using a screwdriver or other suitable tool, push down the crimp of each pin to make connection with the ribbon cable.





4. If other connectors are required they should be fitted at this point. Slide each connector onto the cable, paying attention to the orientation as shown below, then crimp as detailed in step (3).



5. Fit the terminating connector which will mate with the interface board, taking care to align the cable red wire with pin 1 as detailed in step (2).

Chapter 6 Specifications

General Specifications[a]	
Travel	360° Continuous[b]
Minimum Life Time	100 km (600,600 revolutions).
Max Speed[c]	430 °/s
Bidirectional Repeatability[d]	0.05 °
Homing Repeatability	0.25 °
Bidirectional Accuracy[e]	0.4 °
Backlash	0.013 °
Encoder Resolution	143360 Counts/rev
Minimum Incremental Motion	0.002 °
Minimum Motor Holding Torque (both motors engaged)	0.015 N•m
Axis Wobble[f]	0.019 °
Max Load	200 g (centered*)
Limit Switches	None
Mounting	4.2 mm (0.17") holes through PCB for attachment brackets (supplied)
Rated Voltage	4.5 to 5.5 V
Typical Current Consumption During Movement	800 mA
Standby Current	0.05 A
Motor Type	Elliptec Resonant Piezo
8-Conductor Ribbon Cable Length (Supplied)	250 mm
8-Conductor Ribbon Cable Length (Maximum)	3 m
Operating Temperature Range	15 to 40 °C (59 to 104 °F)
Dimensions (with Brackets fitted)	81.0 x 86.4 x 21.5 mm (3.19” x 3.72” x 0.85”)
Weight (Stage plus Brackets)	90 g
Weight (Stage Only)	80 g

[a] All values measured with a load of 64 g and a moment of inertia of 6600 g.mm^2

[b] duty cycle of 15 secs running, followed by a 20 sec cooling down period. If the running time is shorter, then so is the required cool down time.

[c] Some natural variability in the maximum speed may be experienced. Max speed will increase with usage.

[d] Maximum difference between clockwise and anticlockwise movement to the same position

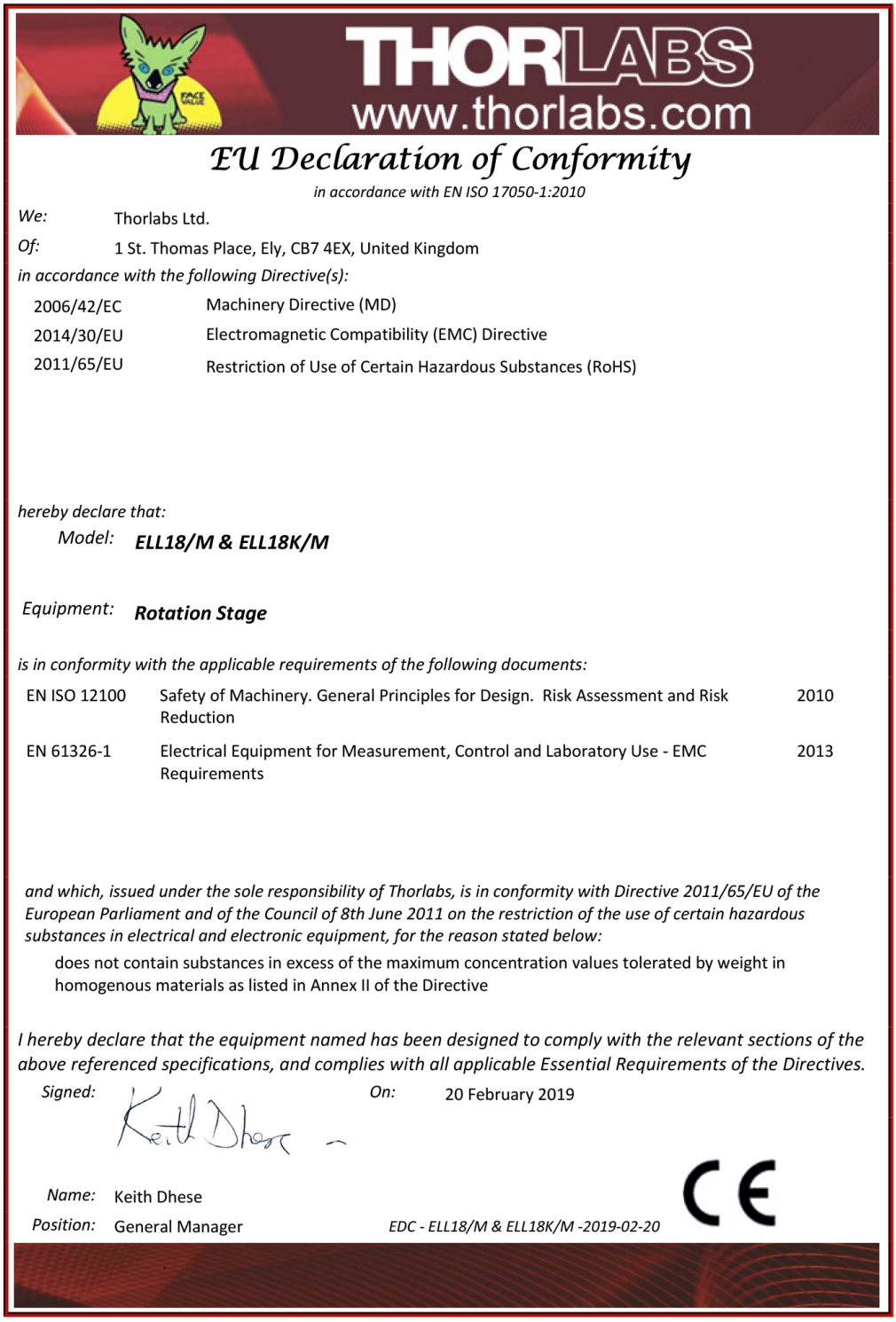
[e] Maximum deviation from true

[f] Max deviation from centre of rotation

Chapter 7 Regulatory

7.1. Declarations of Conformity

7.1.1. For Customers in Europe



THORLABS
www.thorlabs.com

EU Declaration of Conformity

in accordance with EN ISO 17050-1:2010

We: Thorlabs Ltd.

Of: 1 St. Thomas Place, Ely, CB7 4EX, United Kingdom

in accordance with the following Directive(s):

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

hereby declare that:

Model: ***ELL18/M & ELL18K/M***

Equipment: ***Rotation Stage***

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

EN ISO 12100	Safety of Machinery. General Principles for Design. Risk Assessment and Risk Reduction	2010
EN 61326-1	Electrical Equipment for Measurement, Control and Laboratory Use - EMC Requirements	2013

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

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

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

Signed: Keith Dhese *On:* 20 February 2019

Name: Keith Dhese

Position: General Manager

EDC - ELL18/M & ELL18K/M -2019-02-20

CE

7.1.2. For Customers In The USA

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

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

Chapter 8 Thorlabs Worldwide Contacts

USA, Canada, and South America
Thorlabs, Inc.
56 Sparta Avenue
Newton, NJ 07860
USA
Tel: 973-300-3000
Fax: 973-300-3600
www.thorlabs.com
www.thorlabs.us (West Coast)
Email: sales@thorlabs.com
Support: techsupport@thorlabs.com

UK and Ireland
Thorlabs Ltd.
1 Saint Thomas Place, Ely
Cambridgeshire CB7 4EX
Great Britain
Tel: +44 (0)1353-654440
Fax: +44 (0)1353-654444
www.thorlabs.de
email: sales@uk.thorlabs.com
Support: techsupport.uk@thorlabs.com

Europe
Thorlabs GmbH
Hans-Böckler-Str. 6
85221 Dachau
Germany
Tel: +49-(0)8131-5956-0
Fax: +49-(0)8131-5956-99
www.thorlabs.de
Email: europe@thorlabs.com

Scandinavia
Thorlabs Sweden AB
Bergfotsgatan 7
431 35 Mölndal
Sweden
Tel: +46-31-733-30-00
Fax: +46-31-703-40-45
www.thorlabs.com
Email: scandinavia@thorlabs.com

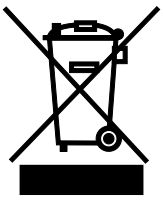
France
Thorlabs SAS
109, rue des Côtes
78600 Maisons-Laffitte
France
Tel: +33 (0) 970 444 844
Fax: +33 (0) 825 744 800
www.thorlabs.com
Email: sales.fr@thorlabs.com

Brazil
Thorlabs Vendas de Fotônicos Ltda.
Rua Riachuelo, 171
São Carlos, SP 13560-110
Brazil
Tel: +55-16-3413 7062
Fax: +55-16-3413 7064
www.thorlabs.com
Email: brasil@thorlabs.com

Japan
Thorlabs Japan, Inc.
3-6-3 Kitamachi,
Nerima-ku, Tokyo 179-0081
Japan
Tel: +81-3-6915-7701
Fax: +81-3-6915-7716
www.thorlabs.co.jp
Email: sales@thorlabs.jp

China
Thorlabs China
Room A101, No. 100
Lane 2891, South Qilianshan Road
Putuo District
Shanghai 200331
China
Tel: +86 (0) 21-60561122
Fax: +86 (0)21-32513480
www.thorlabschina.cn
Email: chinasales@thorlabs.com

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



Annex I

THORLABS

www.thorlabs.com