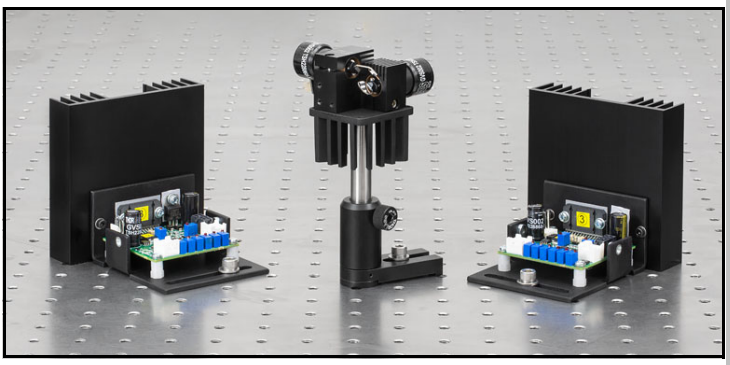
THORLABS

# GVS001 and GVS002
# GVS101 and GVS102
# GVS201 and GVS202
# GVS301 and GVS302

## Scanning Galvo Systems

## User Guide



Original Instructions

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# Chapter 1 Overview

## 1.1 Introduction

The GVS series scanning galvo systems are board level, mirror positioning systems, designed for integration into OEM or custom laser beam steering applications. The single axis systems consists of a motor and mirror assembly, a mounting bracket, a tuned driver card and a heat sink. The dual axis systems comprises two mirror and motor assemblies, an X-Y mounting bracket, two driver cards and two heat sinks. The driver cards feature a small footprint, fixings for easy mounting to a heatsink and a simple analog command signal interface.

A choice of mirror coating is available as follows:

*GVS001 and GVS002: Single- and Dual-Axis Systems with Protected Silver Mirrors*

*GVS101 and GVS102: Single- and Dual-Axis Systems with Protected Gold Mirrors*

*GVS201 and GVS202: Single- and Dual-Axis Systems with 400-750 nm Broadband Dielectric Mirrors*

*GVS301 and GVS302: Single- and Dual-Axis Systems with High Power Dual Band (532 and 1064 nm) Nd: YAG Mirrors*

Typical applications include laser scanning, laser microscopy, and laser marking.

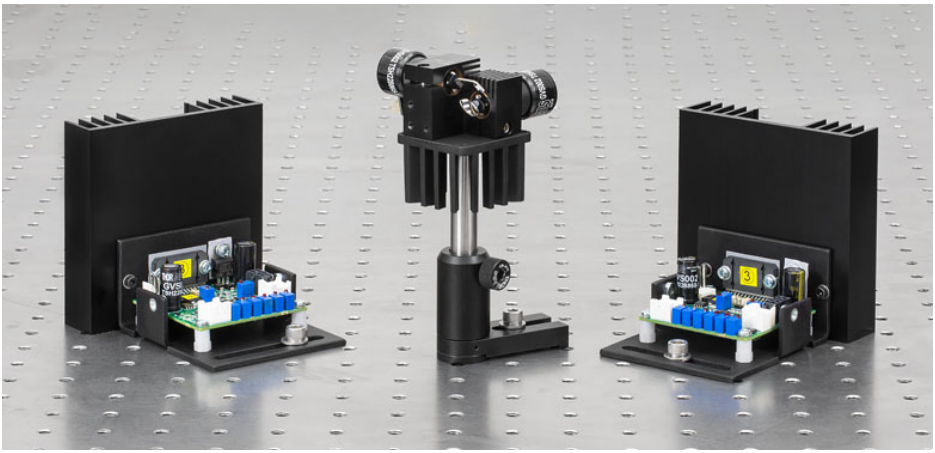


**Fig. 1.1 GVS002 2-Axis Galvo System (Post Adapter and post not included)**

## 1.2 System Description

### 1.2.1 Introduction

Galvo Scanners are widely used in applications such as laser etching, confocal microscopy, and laser imaging.

A galvanometer is a precision motor with a limited travel, usually much less than 360 degrees, whose acceleration is directly proportional to the current applied to the motor coils. When current is applied, the motor shaft rotates through an arc. Motion is stopped by applying a current of reverse polarity. If the current is removed, the motor comes to rest under friction.

Typically, the term 'Galvo' refers only to the motor assembly, whereas a 'Galvo Scanner' would include the motor, together with a mirror, mirror mount and driver electronics.

A description of each component in the system is contained in the following sections.

### 1.2.2 The Galvanometer

The galvanometer consists of two main components: a motor that moves the mirror and a detector that feeds back mirror position information to the system.

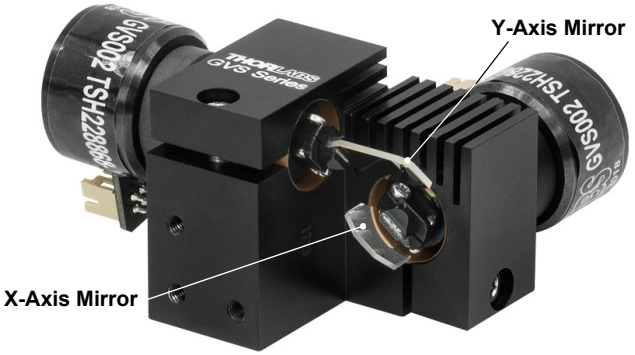



**Fig. 1.2 GVS002 Dual Axis Galvo/Mirror Assembly**

Our galvo motor features a moving magnet, which means that the magnet is part of the rotor and the coil is part of the stator. This configuration provides faster response and higher system-resonant frequencies when compared to moving coil configurations.

Mirror position information is provided by an optical position detector, which consists of two pairs of photodiodes and a light source. As the galvo and mirrors are moved, differing amounts of light are detected by the photodiodes and the current produced is relative to the galvo actuator position.

### 1.2.3 The Mirror

The mirror assembly is attached to the end of the actuator, and deflects the light beam over the angular range of the motor shaft. Scanning galvo applications demand high speed and frequencies of the shaft rotation, and so the inertia of the actuator and mirror assembly can have a profound effect on the performance of the system. High resonant frequencies and enhanced stiffness in the mirror assembly also add to system performance by increasing bandwidth and response times.

Wavelength ranges and damage threshold of the different mirror coatings are details below:

| Part No | Coating | Wavelength | Damage Threshold |
|---|---|---|---|
| GVS00x | Silver | 500 nm - 2.0 µm | 3 J/cm$^2$ at 1064 nm, 10 ns pulse |
| GVS10x | Gold | 800 nm - 20.0 µm | 2 J/cm$^2$ at 1064 nm, 10 ns pulse |
| GVS20x | E02 | 400 nm - 750 nm | 0.25 J/cm$^2$ at 532 nm, 10 ns pulse |
| GVS30x | K13 | 532 nm and 1064 nm | 5 J/cm$^2$ at 1064 nm, 10 ns pulse |




**Fig. 1.3 Mirror Assembly Detail**

### 1.2.4 Servo Driver Board

The servo circuit interprets the signals from the position detector, then uses positional error, speed and integral of current terms to output control voltages to drive the actuator to the demanded position.

The scanner uses a non-integrating, Class 0 servo, which enables higher system speeds compared to integrating servo systems, and is ideal for use in applications that require vector positioning (e.g. laser marking) or raster positioning (printing or scanning laser microscopy). It can also be used in some step and hold applications.

Furthermore, the proportional derivative circuit gives excellent dynamic performance and includes an additional current term to ensure stability at high accelerations. The diagram below shows the architecture of the driver in more detail.

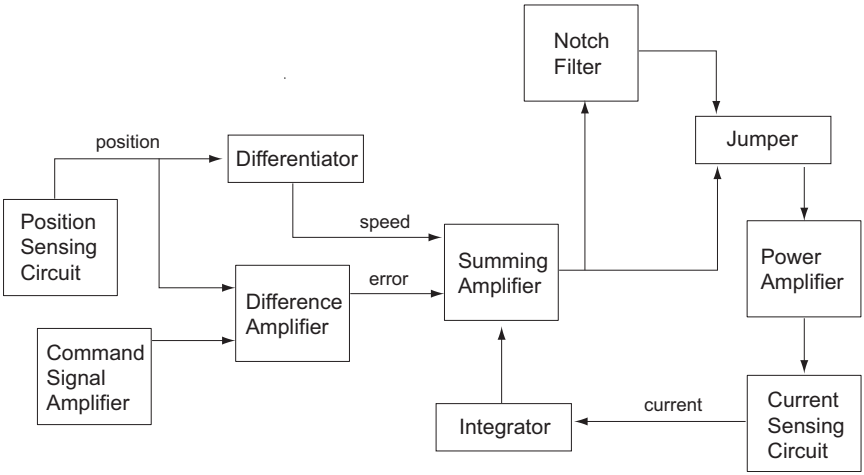



**Fig. 1.4 Servo Driver Board Schematic Diagram**

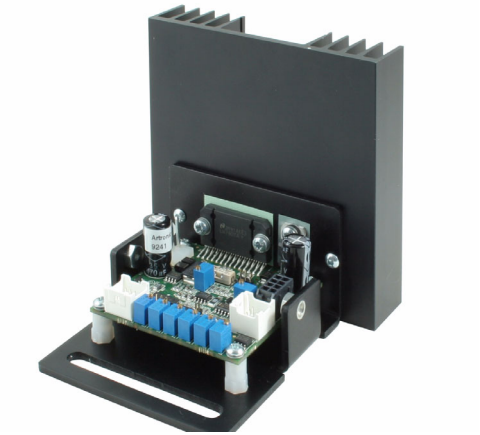


**Fig. 1.5 Servo Driver Circuit Board**

# Chapter 2 Safety

## 2.1 Safety Information

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

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



**Warning: Risk of Electrical Shock**

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



**Warning**

Given when there is a risk of injury to users.



**Caution**

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

**Note**

Clarification of an instruction or additional information.

## 2.2 General Warnings



**Warning**

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

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

Although the unit does not emit radiation, it does redirect laser radiation emitted from other devices. Operators must follow all safety precautions provided by the manufacturer of any associated laser devices.



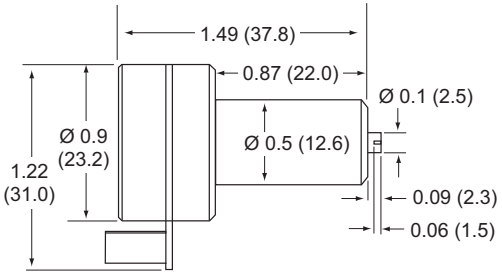
**Caution**

When connecting the driver boards and motors use only the cables supplied. Do not extend the cables. The driver boards and motors are calibrated with these cables. Using different cables will affect the performance of the system.

# Chapter 3 Installation & Initial Set Up

## 3.1 Dimensions

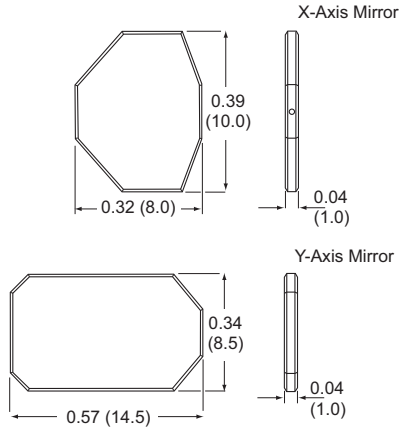
### 3.1.1 Motor Assembly Dimensions




*all dimensions in inches (mm)*

**Fig. 3.1 Motor Dimensions**

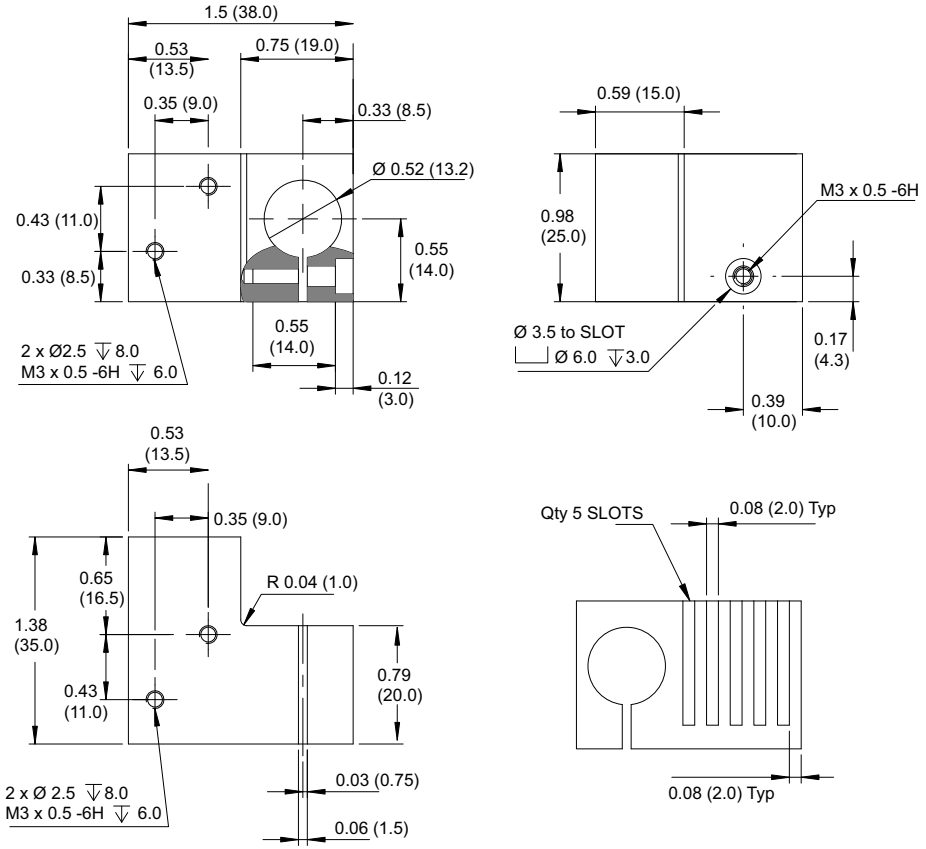
### 3.1.2 Mirror Dimensions




*all dimensions in inches (mm)*

**Fig. 3.2 Mirror Dimensions**

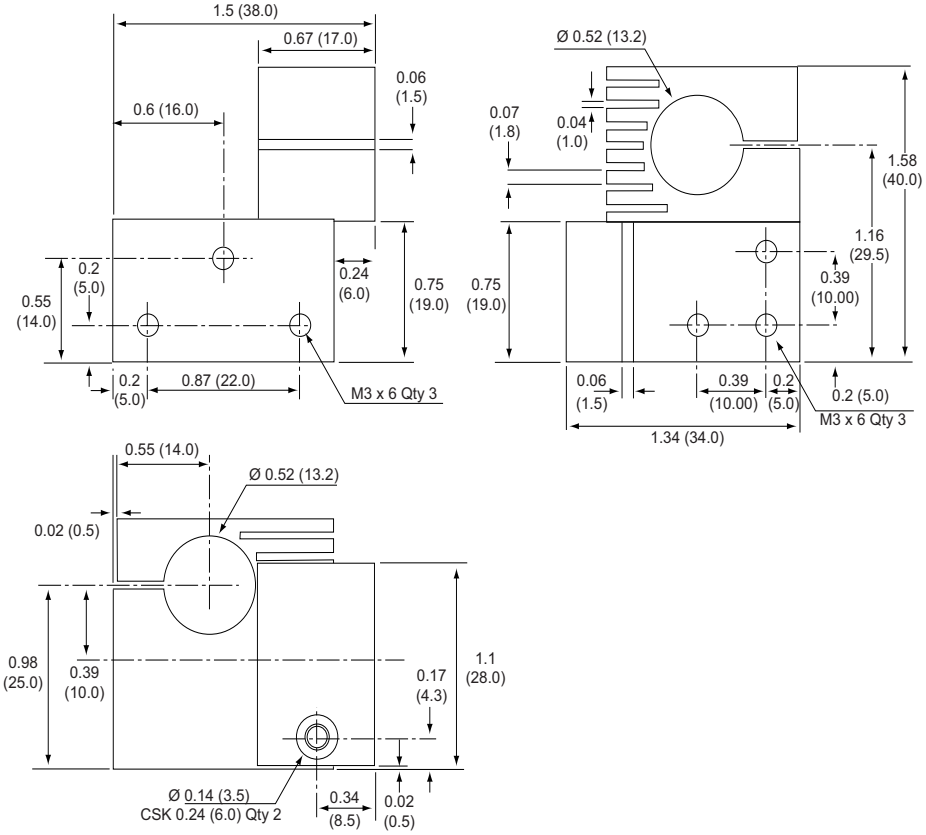
### 3.1.3 Single Axis Mount Dimensions




*all dimensions in inches (mm)*

**Fig. 3.3 Single Axis Mounting Bracket Dimensions**

### 3.1.4 XY Mount Dimensions




*all dimensions in inches (mm)*

**Fig. 3.4 XY Mounting Bracket Dimensions**

### 3.1.5 Heatsink Dimensions

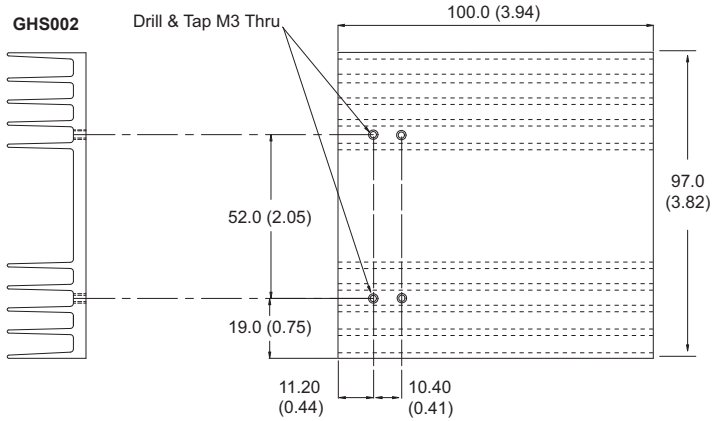



**Fig. 3.5 Heatsink Dimensions**

### 3.1.6 Servo Driver Board Baseplate Dimensions

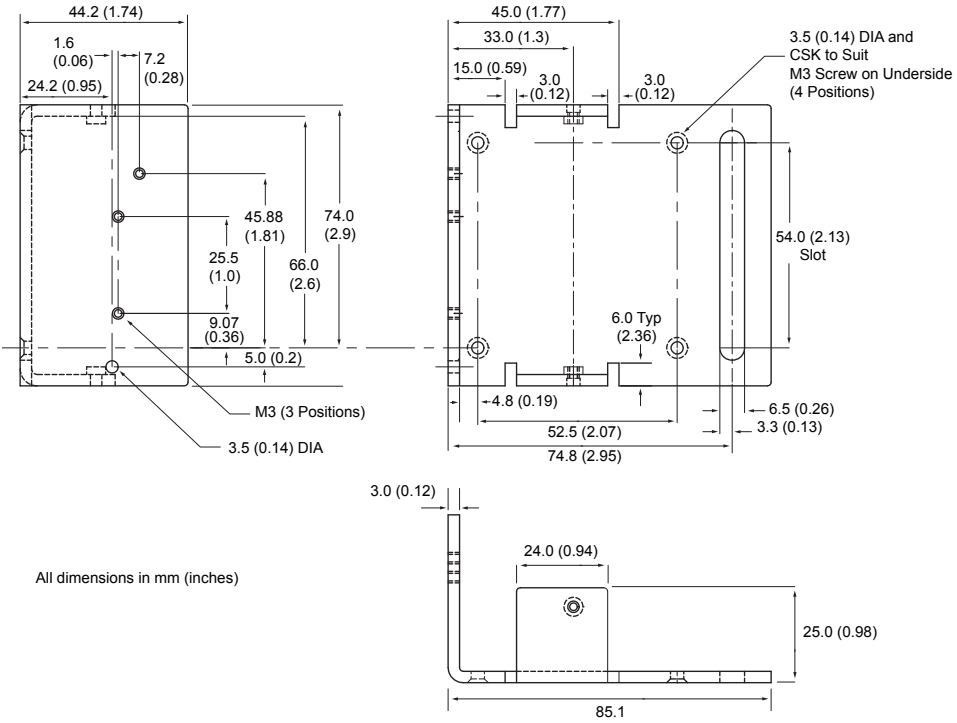



**Fig. 3.6 Servo Driver Board Baseplate Dimensions**

## 3.2 Mechanical Installation

### 3.2.1 Introduction

**Caution**

The galvo motor assembly and associated driver board are tuned at the factory before they are shipped and further adjustment is not normally necessary. If the accuracy of the system is in doubt, e.g due to accidental adjustment of trim pots, contact Thorlabs for information on the tuning procedure.

During Installation, ensure that the motors are connected to the driver card to which they were tuned. Both the motor and the driver card should carry the same serial number.

The location of the serial number labels is shown below.

.

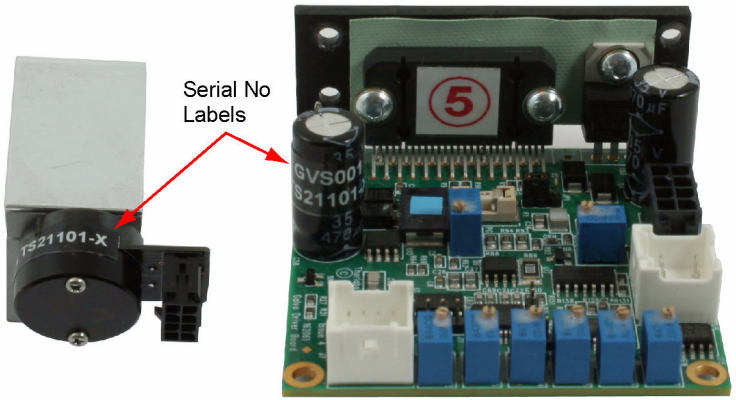



**Fig. 3.7 Serial Number Label Location**

It is essential that the user mounts heatsinks to the driver board and motor mounts which are suitable for their intended application. If this is not done the devices will overheat and permanent damage may occur. The choice of heatsink will primarily be determined by the power which the devices dissipate, a value which is dependant on the average speed at which the user moves the scanners. The larger the power the heatsink must dissipate the larger the heatsink will need to be.

### 3.2.2 Fitting The Heatsinks

*Servo Driver Board Heatsink*

The servo driver board is supplied complete with a large heatsink, suitable for all applications, even those involving more vigorous usage and rapidly changing drive waveforms.

1) Secure the heatsink bracket to the heat sink using two M3 x 8 screws and two plain M3 washers (arrowed in the photo below).

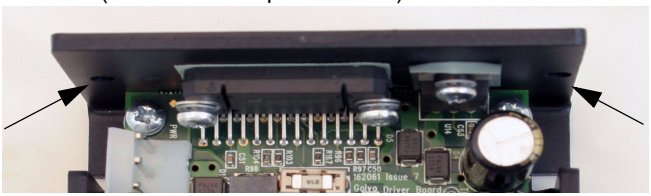


**Fig. 3.8 Driver Board Heatsink Screws**

*Motor/Mirror Mount Heat Sink*

**Caution**

Due to the large torque to weight ratio, thermal managment is crucial to the successful operation of galvo motors. Consequently the galvo motors must be kept cool (<50 °C).

For most applications, the mounting bracket will provide adequate heat sinking, however for more vigorous applications, it may be necessary to fit some heatsinking in addition to the galvo motor mount. Thorlabs supply a combined post adapter and heatsink (GHS003) suitable for both single and dual axis applications.

If using a third party heatsink, please see Appendix B for details on how to calculate the power dissipation in the motor.

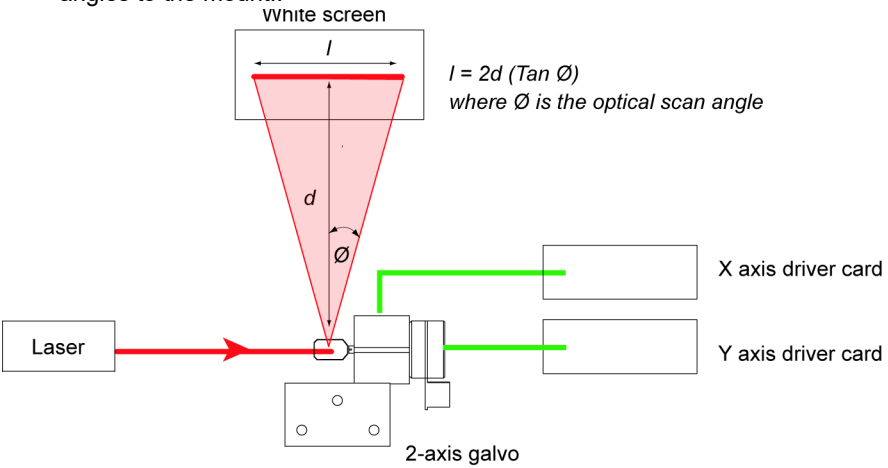
1) Secure the heatsink to the motor/mirror mount using the two M3 x 5 screws supplied.



**Fig. 3.9 XY Mount Heatsink Screws**

3.2.3 Typical System Set Up

1) Fit a GHS003 post adapter to the XY mounting block
2) Fit a lens post into the bottom of the post adapter and clamp it to the breadboard.
3) Arrange a beam steering system such that a laser beam shines on to the X axis mirror, at right angles to the mount and is then reflected onto a screen, also at right angles to the mount..




Typical example: If the optical scan angle Ø = ±25°

l = 2d x Tan 25° (Note. In this case, the mechanical scan angle is ±12.5°)

**Fig. 3.10 Typical Beam Steering System**

## 3.3 Electrical Installation

3.3.1 Choosing A Power Supply

Thorlabs recommends using the GPS011 linear power supply to power the galvo controller board(s) as this power supply has been specifically designed for this purpose. The GPS011 can power up to two driver cards under any drive conditions and is supplied with all the cables required to connect to the driver cards.

However, customers also have the option of using a third-party power supply or incorporate the boards into their existing system. In this case care must be taken to ensure that the power supply voltage and current ratings are within the limits specified.

The drive electronics require a split rail DC supply in the range ±15V to ±18V. The cards do not require an accurately regulated supply as the boards themselves have their own regulators. The maximum current drawn by the driver cards will not exceed 1.2 A rms on each rail. In addition to this, for optimum performance the supply should be able to provide peak currents of up to 5A on either rail.

**Caution**

Both switching and linear power supplies can be used with the Thorlabs galvo systems, however it is important to limit the inrush current when the power supply is turned on, in order to ensure that the power supply reservoir capacitors on the board are not damaged by the large surge currents that can occur on power-up. Most power supplies naturally “soft start” when they are switched on at the mains side and provide inrush current limiting. If, however, the power supply is turned on at the output (DC) side, it can output its peak current instantaneously. In this case it is important to limit this peak current to less than 2 Amps.

### 3.3.2 Using the GPS011 Linear Power Supply

The unit is supplied with a variety of mains power cords.

1) Select the power cord appropriate for your territory.
2) Connect the power cord to the socket on the rear panel of the unit - see Fig. 3.11.
3) Select the correct voltage range for your region.

**Caution**

Selecting the incorrect voltage range will damage the unit.

4) Plug the power cord into the wall socket.




**Fig. 3.11 Power Supply Unit Rear Panel**

### 3.3.3 Electrical Connections

**Caution**

During the electrical installation, cables should be routed such that power and signal cables are separated so that electrical noise pick up is minimized.

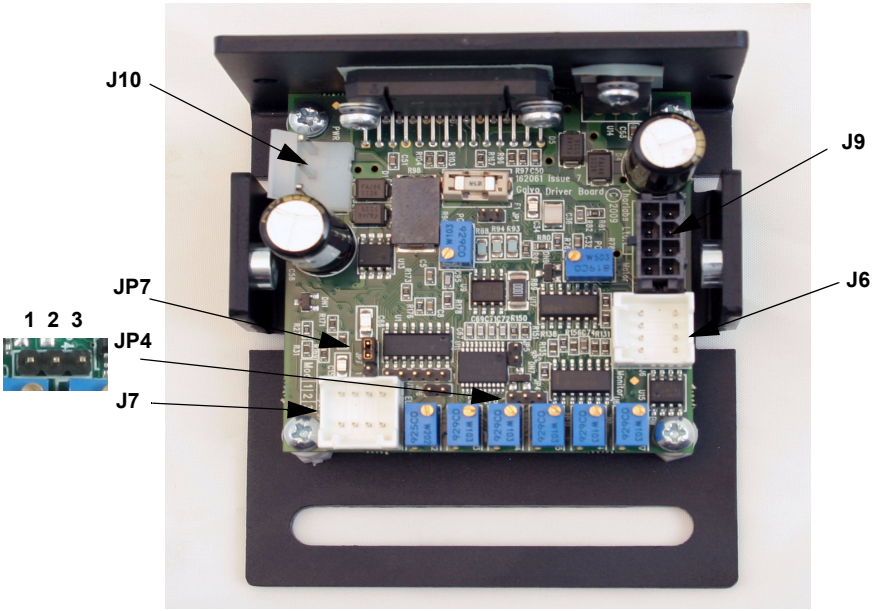



**Fig. 3.12 Connector Identification**

1) Identify connector J10 on each driver board, and make power connections as shown below. Thorlabs supply a suitable PSU (GPS011) for powering a single or dual axis system (see Section 3.3.1.). A bare cable, crimp connectors (Molex Pt No 2478) and housings for use with general lab PSUs is supplied with each driver board.

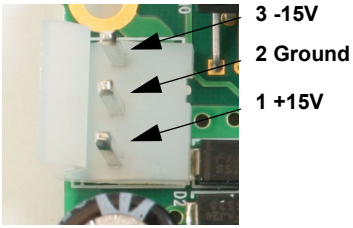
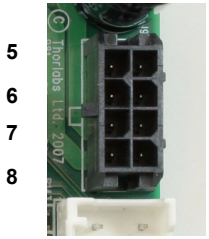



**Fig. 3.13 J10 Power Connector Pin Identification**

**Caution**

During item (2) and (3) use only the cables supplied. Do not extend the cables. The driver boards and motors are calibrated with these cables. Using different cables will affect the performance of the system. Longer cables are available as a custom part but the units will require re-calibration if these are not specified at time of order. Contact tech support for more details.

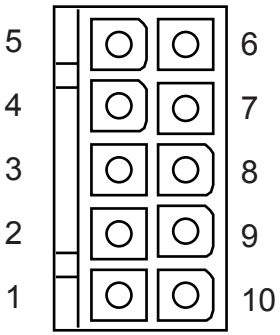
2) Connect the motor cable to the connector J9 on each driver board as shown below.




Pin 1 Position Sensor A Current
Pin 2 Position Sensor Ground
Pin 3 Position Sensor Cable Shield
Pin 4 Drive Cable Shield
Pin 5 Position Sensor B Current
Pin 6 Position Sensor Power
Pin 7 Motor + Coil
Pin 8 Motor -Coil

**Fig. 3.14 J9 Motor Connector Pin Identification.**

3) Note the serial numbers of the galvo motors and driver boards, then connect the galvo motors to their associated driver boards. If using a custom cable, the pin outs for the connectorson the Driver PCB and the Motor connector are detailed in Fig. 3.14 and Fig. 3.15 respectively.




Pin 1 Motor + Coil (power shield floating)
Pin 2 Motor -Coil (power shield floating)
Pin 3 Not Used
Pin 4 Not Used
Pin 5 Position Sensor B Current
Pin 6 Position Sensor Ground
Pin 7 Position Sensor A Current
Pin 8 Position Sensor Power
(Automated Gain Control)
Pin 9 Position Sensor Cable Shield
Pin 10 Not Used

**Fig. 3.15 Galvo Assembly Motor Connector Pin Identification**

4) Connect a command input (e.g. function generator) to J7 of each driver board as shown in Fig. 3.16. J7 accepts Molex pins Pt No 56134-9100.

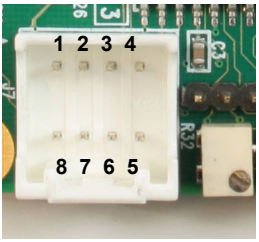
**Note**

The scanner accepts a differential analog command input. If the scaling is 0.8 Volt per degree mechanical movement (see Section 3.3.5.), -10 V to +10 V gives -12.5 to +12.5 degrees mechanical movement. The driver will attempt to set the mirror position to the command input value.

Pin 3 (DRV_OK) is an open collector output that is low when the board is operating normally and floating if a fault occurs. To use Pin 3 as a fault indicator, connect a pull-up resistor to give a high signal when the fault occurs. DRV_OK limits are 30 mA 30 V.

Do not connect a relay to this output.

.




Pin 1 Command Input +ve
Pin 2 Command Input -ve
Pin 3 DRV OK
Pin 4 External Enable
Pin 5 -12V Output (low impedence O/P)
Pin 6 +12V Output (low impedence O/P)
Pin 7 Ground
Pin 8 Ground

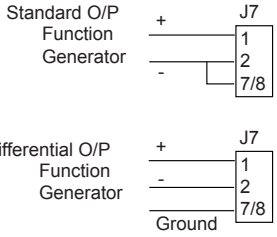
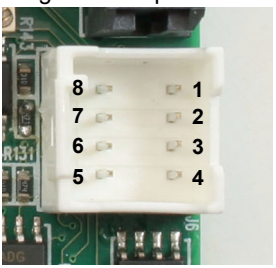



**Fig. 3.16 J7 Command Input Connector Pin Identification**

5) Using a suitable cable, connect the Diagnostic Terminal J6 to the diagnostic device (e.g. oscilloscope) in your application. Pin identification is givem below, signal descriptions are detailed in the next section.




Pin 1 Scanner Position
Pin 2 Internal Command Signal
Pin 3 Positioning Error x 5
Pin 4 Motor Drive Current
Pin 5 Not Connected
Pin 6 Test Input (NC)
Pin 7 Motor + Coil Voltage / 2
Pin 8 Ground

**Fig. 3.17 J6 Diagnostics Connector Pin Identification**

**Note**

All diagnostic signals from J6 have 1 KW output impedance except Pin 7 (Motor Coil Voltage/2) which has 5 KW.

**J6 Diagnostics and J7 Command Input Mating Connector Details**

*Mating Connector body*: Manufacturer: Molex, Mfr. P/N: 513530800

Example Vendor: Farnell, Vendor P/N: 1120387

*Crimps (22-26AWG)*: Manufacturer: Molex, Mfr. P/N: 56134-8100

Example Vendor: Farnell, Vendor P/N: 1120545

*Crimps (22-28AWG)*: Manufacturer: Molex, Mfr. P/N: 56134-9100

Example Vendor: Farnell, Vendor P/N: 1120546

### 3.3.4 Diagnostic Signal Descriptions

*Scanner Position* - This signal is proprotional to the position of the scanner mirror, with a scaling of 0.5 Volts per degree of mechanical movement.

*Internal Command Signal* - The command signal following amplification by the input stage. The scaling is 0.5 Volt per degree of mechanical movement.

**Note**

The Scanner Position and Internal Command signals are scaled internally by the driver circuit and are essentially equivalent to the input signal /2.

*Positioning Error x 5* - This signal is proportional to the difference between the demanded and the actual positions - (Position - Command) x 5 (i.e. (Pin 1 - pin 2) x 5).

*Motor Drive Current* - The drive current of the motor (2V per A), i.e. if drive signal is 2V, the drive current is 1 A.

*Motor + Coil Voltage /2* - This pin outputs the drive voltage to the "+" side of the motor coil. It is scaled down by a factor of 2. The drive voltage determines the current, which then determines the acceleration. It is not required if the user only wants to monitor position.

### 3.3.5 Setting the Volts/Degree Scaling Factor

Servo driver cards manufactured after October 2015 have a jumper which is used to set the Volts per Degree scaling factor. The cards are shipped with the scaling set to 0.8 V/°, where the max scan angle is ±12.5°, and is compatible with driver cards manufactured before October 2009. To set the scaling factor to 1 V/° and the maximum scan angle to ±10°, proceed as follows:

1) Identify JP7 as shown in Fig. 3.18.
2) Set the jumper position for the corresponding scaling factor as shown below.

**Note**

The 0.5V/° scaling factor is provided to allow the full scan angle to be achieved using small input signals. In this case, the input voltage should be limited to ±6.25 V max

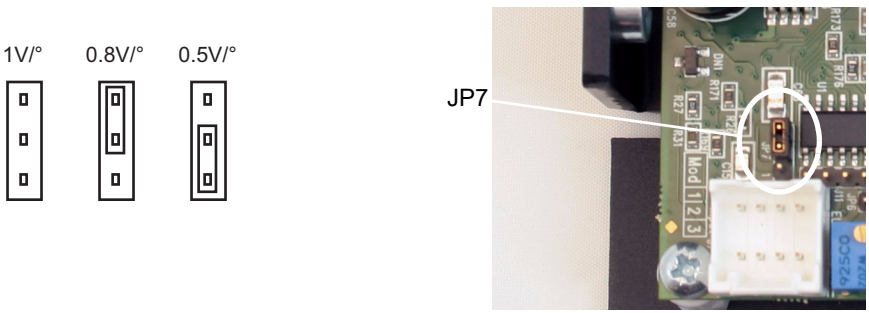



**Fig. 3.18 Setting the Volts/Degree Scaling Factor**

# Chapter 4 Operation

## 4.1 General Operation

1) Connect the system as described in Section 3.3.
2) Apply power to the driver boards.
3) Input a command signal to each driver board to obtain the desired behviour.

**Note**

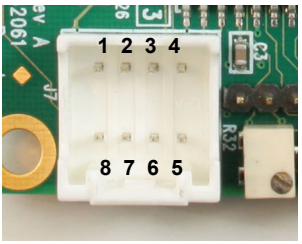
After powering the boards, there may be a delay of up to 10 seconds before the motors start to follow the command signal.

## 4.2 External Enabling of the driver board

1) The drive electronics can be configured for external enabling by placing a jumper across pins 2 and 3 of JP4.




2) Once this has been done the user can enable or disable the drive electronics by applying a 5V CMOS signal to J7 pin 4.




Pin 1 Command Input +ve
Pin 2 Command Input -ve
Pin 3 No Connect
Pin 4 External Enable
Pin 5 -12V Output
Pin 6 +12V Output
Pin 7 Ground
Pin 8 Ground

**Fig. 4.1 J7 Command Input Connector Pin Identification**

If a logic high or no signal is applied, the drive electronics will be enabled. If a logic low signal is applied then the driver will be disabled.

## 4.3 Using a DAQ Card

Typically, users will deploy a DAQ card with DAC analogue outputs in order to drive the servo drivers supplied with the galvos. The minimum recommended specifications for the DAC outputs are:-

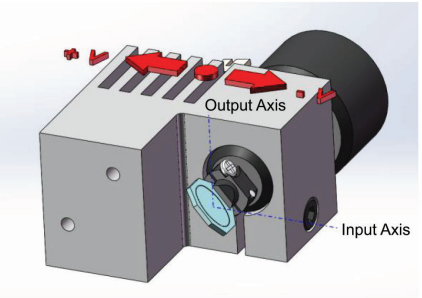
Dual bipolar -10V to 10V DAC analogue output channels (differential).

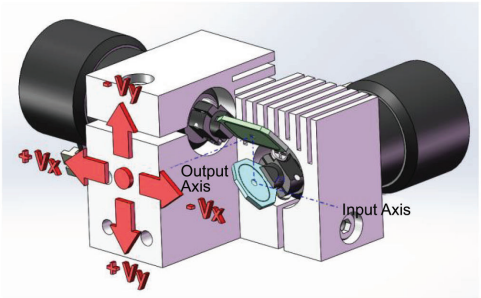
DAC clocking frequency higher than 20kS/s (Kilo Samples/Second), higher sampling frequencies like 100 kS/s are recommended (inputs have a 7 kHz low pass filter).

16 Bit DAC resolution and low out impedance (<= 50 Ω).

## 4.4 Recommended Scanning Angles

The ideal scanning angle is dependent upon a number of conditions. Firstly, the larger the diameter of the input laser beam, the smaller the achievable scanning angle. Secondly, the applied input voltage causes the laser beam to move away from the center of the mirrors. The larger the input voltage then the greater the movement from the center, as shown below.




Lastly, on dual-axis systems, there is an offset alignment between the X and Y axis mirrors that also limits the scan angle.

The table below gives recommended scanning angles for various beam diameters.

| GVS001, GVS101, GVS201 and GVS301, | | |
|---|---|---|
| **Input Beam Diameter** | **Mechanical Scan Angle** | **Optical Scan Angle** |
| 4 mm and less | ± 12.5° | ± 25° |
| 5 mm | + 10°, -12.5° | + 20°, -25° |

| GVS002, GVS102, GVS202 and GVS302, | | | | |
|---|---|---|---|---|
| **Input Beam Diameter** | **Mechanical Scan Angle X** | **Optical Scan Angle X** | **Mechanical Scan Angle Y** | **Optical Scan Angle Y** |
| 1 mm | + 11.0°, - 12.5° | + 22.0°, - 25° | ± 12.5° | ± 25° |
| 2 mm | + 10°, - 11.5° | + 20°, - 23° | ± 12.5° | ± 25° |
| 3 mm | + 9.5°, - 10° | + 19°, - 20° | ± 12.5° | ± 25° |
| 4 mm | ± 8.5° | ± 17° | ± 12.5° | ± 25° |
| 5 mm | ± 8° | ± 16° | + 12.5°, -3° | + 25, -6° |

# Chapter 5 Troubleshooting

## 5.1 Common Problems

Some of the more common problems encountered when using galvanometers are details below.

**Motor fails to respond to the command signal**

This can occur for a number of reasons. The most likely are:

1) power is not correctly applied to the board
2) one of the cables is faulty or not connected properly
3) a fault has been triggered
4) the device has been disabled either by placing a jumper across JP4 pins 1 and 2 or by placing a jumper across JP4 pins 2 and 3 and pulling J7 pin 4 to ground.

**Note**

After powering the boards, there may be a delay of up to 10 seconds before the motors start to follow the command signal.

**Instability of the scanner**

If uncontrolled, instability of the scanner will cause a whistiling or schreeching noise and uncontrolled movement of the scanner. It will also cause large current to be drawn by the motor and the motor will move spontaneously and unpredictably. If this occurs the user should turn off power to the driver boards immediately to prevent damage to the scanners.

However under normal circumstances the instability should be detected by the fault control circuitry. In this case the behaviour most likely to be observed by the user is the following: The mirror will suddenly jump from one position to another (probably with a short burst of whistling) and stop and remain still. After a delay of a few seconds the mirror will jump to another position and so on. Here when the mirror is stopped a fault has been triggered and the driver board is disabled. The only movement is during the brief period when the fault control circuitry tries to resume normal operation.

Instability can occur for a number of reasons. The most common is if the driver board is incorrectly tuned to the motor. This can occur if the board is connected to a different motor to the one it was originally sold with or if one of the potentiometers have been tampered with. Another common cause for instability is if the motor is driven at large amplitudes and high frequencies then the electronics may be unable to control the scanner.

**Mirror periodically shoots off to one side and then stops**

If the mirror suddenly shoot off to one side and then stops it is likely that either the position sensing circuitry is not functioning correctly or the motor cable is incorrectly wired. When this happens most likely either the drive electronics will output a constant drive voltage or the loop feedback will be positive. Consequently the motor jumps to one extreme and an overposition fault is triggered. Once the drive electronics is disabled the scanner will bounce freely backwards and come to rest. After a delay the electronics will attempt to resume operation and the process will repeat.

**Galvo mostly behaves normally but periodically becomes unstable**

If the galvo driver card is incorrectly tuned it is possible that the galvo system can appear to be behaving correctly most of the time, but with a brief period where the system suddenly becomes unstable repetitively occuring. This can be caused if the maximum error signal value is exceeded. The fault control circuitry responds by lowering the error gain which may cause the system to behave normally. However, once the system tries to resume normal operation the system is likely to become unstable again and the process will repeat.

**Oscillation in the galvo motor current**

If the galvo system is drawing more current than expected, if the scanners or the driver cards are overheating, if the scanners are making a hissing noise or if the position accuracy is less than expected, this may be due to oscillations in the galvo motor current. This can be identified by viewing the coil current signal J6 pin 4 on an oscilloscope. The problem will manifest itself as a high frequency (>1kHz) sinusoidal oscillation in the current, unrelated to the position signal. Normally the scanner will still appear to be correctly following the command signal, but the oscillation may show up in the position signal if the effect is very strong.

This effect is normally caused by crosstalk between the position sensing circuitry and the motor drive current. Repositioning the motor drive cable will normally help to avoid this problem. If the user replaces the motor cables with their own cables they should ensure that they keep the wires as short as possible and use separate shielded cables for the position sensing and motor drive signals.

**Cross talk between axes**

Cross talk between the two motors will normal show up as a slight movement in one axis when one motor is moved quickly. This typically occurs if both the motors are run off a same power supply and the power supply cannot deliver the peak currents demanded by the galvos. There will then be a drop in the power supply voltage which will then affect the behaviour of the remaining axis. Choosing a different power supply with sufficient peak drive current capability should solve this problem.

**Overshoot in position signal which grows over time**

It is possible that the position of the motor may show an overshoot when driven with a large square wave or similar, and that this overshoot will grow with time until a fault is triggered. There is usually a certain frequency and amplitude above which this starts to occur. This behaviour is caused by choosing a power supply which cannot deliver enough current for the intended application. The oscillation builds up because the power supply voltage is dropping on the rising edge of the position signal and effecting the board's behaviour. With every rising edge the effect becomes slightly greater as the overshoot grows.

## 5.2 Galvanometer Faults

The driver electronics monitor numerous signals to ensure the scanners operate safely and the fault protection circuitry will normally prevent any damage.

However, the user should be aware that the galvanometer may become permanently damaged if the system becomes unstable (manifested by a screeching noise, self excitation and unpredicable movement of the scanner). In addition the user should also be aware that the system has no protection against the galvanometer scanners overheating, and it is left to the user to ensure that they are fitted to an adequate heatsink (see Section 3.2.1.).

It is worth noting that a fault state may be triggered on applying power to the driver boards and the power amplifier will be disabled. However in this case the board will commence normal operation after a delay of a few seconds. The table below shows the various faults states which can be triggered in the fault control circuitry.

Table 5.1 Galvo System Faults and Associated Fault Protection Circuit Action

| Fault | Possible Causes | Action Taken by Fault Control Circuit |
|---|---|---|
| Maximum scanner position exceeded | Drive signal too large, instability of scanner | Power amplifier turned off |
| Maximum peak current Exceeded | Incorrect tuning, instability of the scanner or overly vigorous drive waveforms | Power amplifier turned off |
| Maximum postion error exceeded | Incorrect tuning, instability of the scanner or overly vigorous drive waveforms | Loop gain reduced |
| AGC voltage out of normal range | Broken motor position sensor, problem with motor cable connection | Power amplifier turned off |
| Power supply voltage drops below minimum value | Poor choice of power supply | Power amplifier turned off |
| Maximum RMS coil current exceeded | Incorrect tuning, instability of the scanner or overly vigorous drive waveforms | Power amplifier turned off |
| Maximum junction temperature of power amplifier IC exceeded | Inadequate heatsinking of driver board | Power amplifier turned off |

# Appendix A Specifications and Associated Parts

## A.1 Specifications

| Parameter | Value |
|---|---|
| **Mirror** | |
| Maximum Beam Diameter | 5 mm |
| Finish | GVS00x: Protected Silver Coated<br>GVS10x: Protected Gold Coated<br>GVS20x: Broadband, E02<br>GVS30x: Dual Band Hi Power, K13 |
| Damage Threshold* | GVS00x: 3 J/cm$^2$at 1064 nm, 10 ns pulse<br>GVS10x: 2 J/cm$^2$ at 1064 nm, 10 ns pulse<br>GVS20x: 0.25 J/cm$^2$ at 532 nm, 10 ns pulse<br>GVS30x: 5 J/cm$^2$ at 1064 nm, 10 ns pulse |
| **Motor & Position Sensor** | |
| Linearity | 99.9%, range ±20° |
| Scale Drift | 40PPM/°C(Max) |
| Zero Drift | 10 µRad/°C(Max) |
| Repeatability | 15 µRad |
| Resolution<br>With GPS011 Linear PSU<br>With standard switch mode PSU | <br>0.0008° (15 µRad)<br>0.004° (70 µRad) |
| Average Current | 1 A |
| Peak Current | 5 A |
| Load Mirror Aperture | 5 mm |
| Coil Resistance: | 2.2 Ω±10% |
| Coil Inductance: | 150µH ±10% |
| Rotor Inertia: | 0.02gm per cm$^2$ |
| Maximum Scan Angle (Mechanical Angle) | ±12.5° (with 0.8V/° scaling factor) |
| Motor Weight (inc cables, excl bracket) | 50 g |
| Operating Temperature Range | 0 ~ 40° C |
| Optical Position Sensor Output Range | 40 to 80 µA |

**Note**

*The way our mirrors are tested is continually updated, please consult www.thorlabs.com for more information.

**Drive Electronics**

| Parameter | Value |
|---|---|
| Full Scale Bandwidth* | 100 Hz Square wave,<br>250 Hz Sinewave<br>175 Hz Saw Tooth<br>175 Hz Triangular |
| Small Angle (±0.2°) Bandwidth* | Typ. 1kHz with Sinewave |
| Small Angle Step Response | 300 µs |
| Power Supply | +/-15V to +/-18V dc<br>(1.25 A rms, 5A peak MAX) |
| Analog Signal Input Resistance | 20K±1%Ω (Differential Input) |
| Position Signal Output Resistance: | 1K±1%Ω |
| Analog Position Signal Input Range | ±10V |
| Mechanical Position Signal Input Scale Factor | switchable: 0.5V/°, 0.8V/° or 1.0V/° |
| Mechanical Position Signal Output Scale Factor | 0.5V/° |
| Operating Temperature Range | 0 ~ 40°C |
| Servo Board Size (L x W x H) | 85 mm × 74 mm × 44 mm<br>(3.35” x 2.9” x 1.73”) |

* Using heat sink to keep temp <50°C (see Section 3.2.2.).

## A.2 Associated Products

| Product Name | Part Number |
|---|---|
| 2D Galvo System - Protected Silver Mirrors | GVS002 |
| 1D Galvo System - Protected Silver Mirror | GVS001 |
| 2D Galvo System - Protected Gold Mirrors | GVS102 |
| 1D Galvo System - Protected Gold Mirror | GVS101 |
| 2D Galvo System - Broadband E02 Mirrors | GVS202 |
| 1D Galvo System - Broadband E02 Mirror | GVS201 |
| 2D Galvo System - Dual Band High Power K13 Mirrors | GVS302 |
| 1D Galvo System - Dual Band High Power K13 Mirror | GVS301 |
| Motor Assembly Heatsink | GHS003(/M) |
| Galvo Power Supply | GPS011 |
| Servo Driver Card Cover | GCE001 |
| 1D Galvo Cage System Mount | GCM001 |
| 2D Galvo Cage System Mount | GCM002 (/M) |
| Tip/Tilt Mount Adapter | GTT001 |

# Appendix B Calculating the Power Dissipation

## B.1 Motor Heatsink

The power dissipated in the motor can be estimated by measuring the RMS current drawn from the PSU and then using the following equation:

$P_{mot} = R_{mot} \times [(I_{rms+} + I_{rms-} - I_{q+} - I_{q-}) / 2]^2$

Where $P_{mot}$ is the power dissipated in the motor, $R_{mot}$ is the motor coil resistance (2.2Ω), $I_{rms+}$ is the rms current drawn from the positive supply rail, $I_{rms-}$ is the rms current drawn from the negative supply rail, $I_{q+}$ is the quiescent current drawn on the +ve rail (0.15A under all circumstances) and $I_{q-}$ is the quiescent current drawn on the -ve rail (0.10A under all circumstances).

The power dissipated in the driver boards can be calculated using the following equation:

$P_{drv} = (V_+ \times I_{rms+}) + (V_- \times I_{rms-}) - Pmot$

Where $P_{drv}$ is the power dissipated in the driver boards, $V_+$ is positive supply voltage and $V_-$ is the negative supply voltage.

### 2.1.1 Calculating the Required Thermal Conductivity

The ability of a heatsink to transfer heat to its surroundings is parameterised either by its thermal conductivity, k or its thermal resistance, Ø. The lower the thermal resistance the more effectively the heatsink can transfer heat. The required thermal resistance can be calculated from the following equation:

$Ø = 1/k = (T_{hs} - T_a) / P_{max}$

In the above equation $T_{hs}$ is the maximum permissible heatsink temperature, $T_a$ is the ambient temperature and $P_{max}$ is the maxium power the device being cooled will dissipate. For the motors it is desireable to keep $T_{hs}$ below 45°C.

The following equation can be used to calculate $T_{hs}$ for the driver IC:

$T_{hs} = T_j - P_{max} \times Ø_{jhs}$

Here, $Ø_{jhs}$ is the thermal resistance between the semiconductor junction of the power amplifier IC and the heatsink. $T_j$ is the maximum temperature allowable at the junction, about 150°C (although the lifetime of the driver IC will be longer if the junction is kept at a lower temperature). The value of $Ø_{jhs}$ is 1.3 °C/W.

# Appendix C Reasons For Image Distortion

The deflection of a laser beam with a two-mirror system results in three effects:

(1) The arrangement of the mirrors leads to a certain distortion of the image field – see Fig. C.1 below.

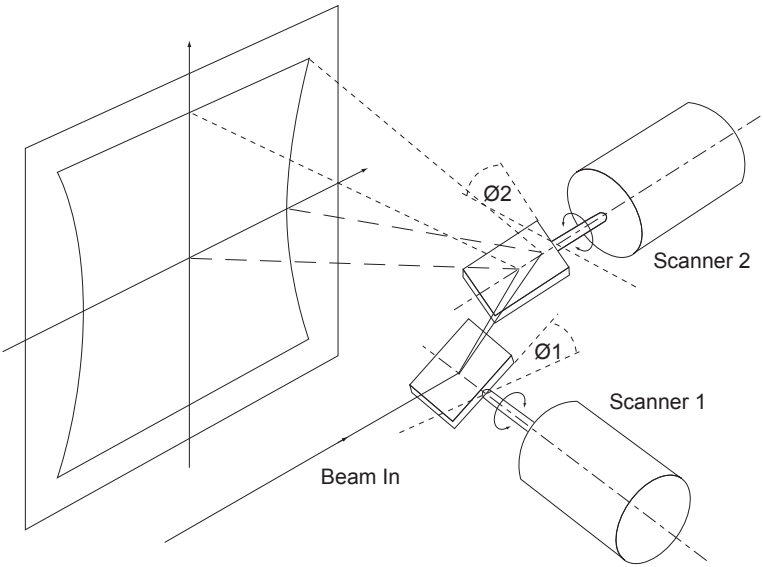



**Fig. C.1 Field Distortion in a Two-way Mirror Deflection System**

This distortion arises from the fact that the distance between mirror 1 and the image field depends on the size of the mechanical scan angles of mirror 1 and mirror 2. A larger scan angle leads to a longer distance.

(2) The distance in the image field is not proportional to the scan angle itself, but to the tangent of the scan angle. Therefore, the marking speed of the laser focus in the image field is not proportional to the angular velocity of the corresponding scanner.

(3) If an ordinary lens is used for focusing the laser beam, the focus lies on a sphere. In a flat image field, a varying spot size results.

As a result, you will find the scanning field turn out to be a "pillow-shaped" image, see Fig. C.2 below.

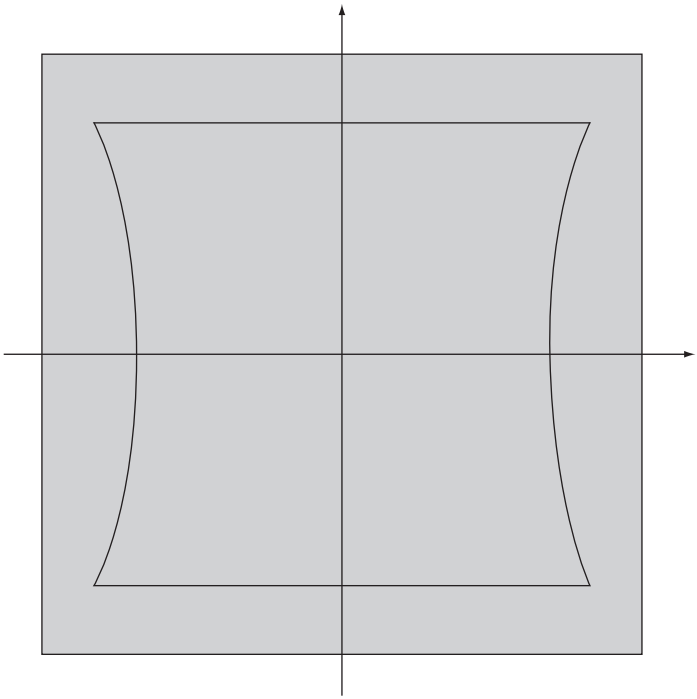


**Fig. C.2 Pillow-shaped Field Distortion Caused by the Arrangement of Mirrors**

# Appendix D Regulatory

## D.1 Declarations Of Conformity

D.1.1 For Customers in Europe

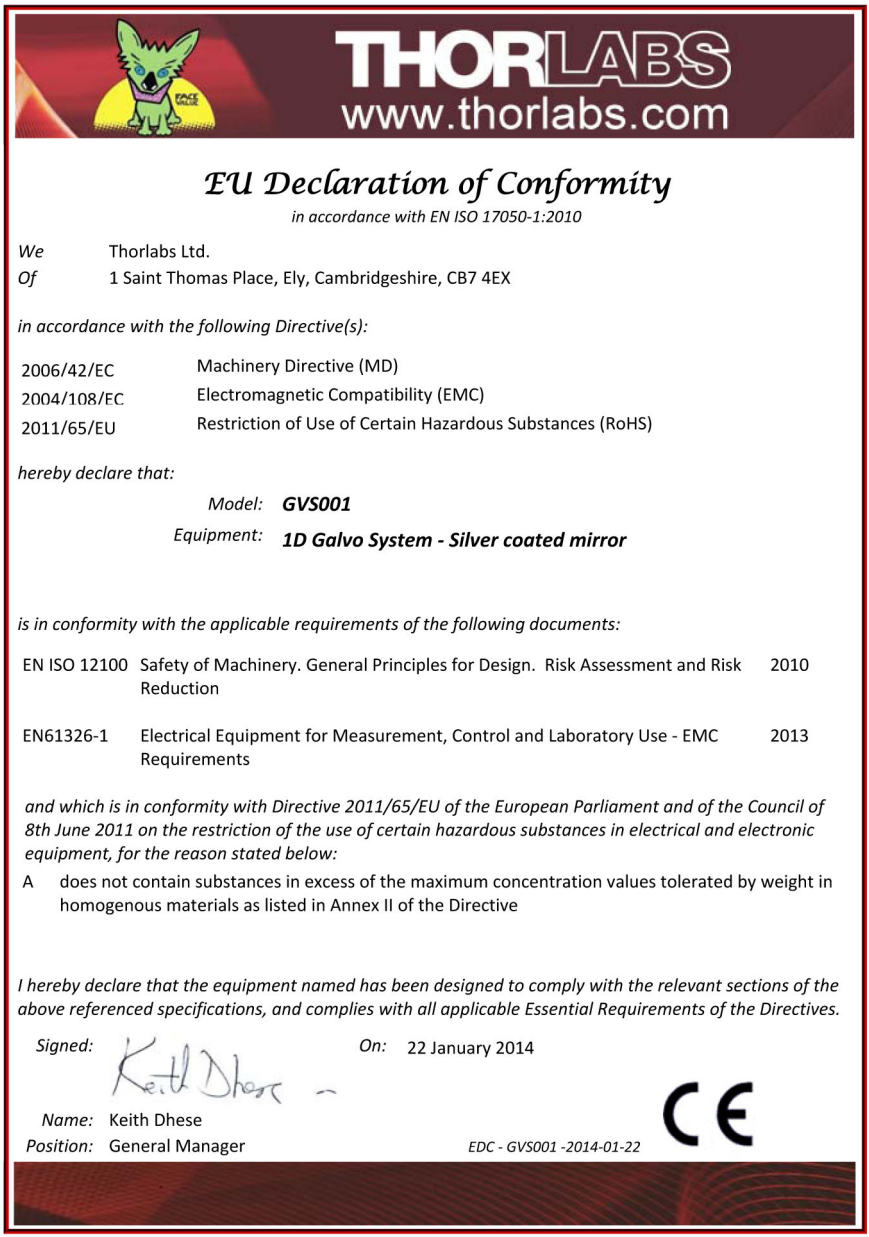
See Section D.2.

D.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.

## D.2 CE Certificates



THORLABS
www.thorlabs.com

# EU Declaration of Conformity

*in accordance with EN ISO 17050-1:2010*

*We* Thorlabs Ltd.
*Of* 1 Saint Thomas Place, Ely, Cambridgeshire, CB7 4EX

*in accordance with the following Directive(s):*

| | |
|---|---|
| 2006/42/EC | Machinery Directive (MD) |
| 2004/108/EC | Electromagnetic Compatibility (EMC) |
| 2011/65/EU | Restriction of Use of Certain Hazardous Substances (RoHS) |

*hereby declare that:*

*Model:* ***GVS001***
*Equipment:* ***1D Galvo System - Silver coated mirror***

*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 |
| EN61326-1 | Electrical Equipment for Measurement, Control and Laboratory Use - EMC Requirements | 2013 |

*and which 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:*

A 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:* 22 January 2014

*Name:* Keith Dhese
*Position:* General Manager

*EDC - GVS001 -2014-01-22*

CE

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www.thorlabs.com

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*Of* 1 Saint Thomas Place, Ely, Cambridgeshire, CB7 4EX

*in accordance with the following Directive(s):*

| | |
|---|---|
| 2006/42/EC | Machinery Directive (MD) |
| 2004/108/EC | Electromagnetic Compatibility (EMC) |
| 2011/65/EU | Restriction of Use of Certain Hazardous Substances (RoHS) |

*hereby declare that:*

*Model:* ***GVS002***

*Equipment:* ***2D Galvo System - Silver coated mirror***

*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 |
| EN61326-1 | Electrical Equipment for Measurement, Control and Laboratory Use - EMC Requirements | 2006 |

*and which 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:*

A 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:* 22 January 2014

*Name:* Keith Dhese
*Position:* General Manager

CE

*EDC - GVS002 -2014-01-22*




# EU Declaration of Conformity

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|---|---|
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| 2004/108/EC | Electromagnetic Compatibility (EMC) Directive |
| 2011/65/EU | Restriction of Use of Certain Hazardous Substances (RoHS) |

*hereby declare that:*

*Model:* ***GVSM00X Series***

*Equipment:* ***1D or 2D Galvo System with accessories or metric accessories***

*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 |
| EN61326-1 | 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:* 22 January 2014

*Name:* Keith Dhese

*Position:* General Manager

*EDC - GVSM00X Series -2014-01-22*

CE




# EU Declaration of Conformity

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*Of* 1 Saint Thomas Place, Ely, Cambridgeshire, CB7 4EX

*in accordance with the following Directive(s):*

| | |
|---|---|
| 2006/42/EC | Machinery Directive (MD) |
| 2004/108/EC | Electromagnetic Compatibility (EMC) |
| 2011/65/EU | Restriction of Use of Certain Hazardous Substances (RoHS) |

*hereby declare that:*

*Model:* ***GVS101***

*Equipment:* ***1D Galvo system - Gold coated mirror***

*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 |
| EN61326-1 | Electrical Equipment for Measurement, Control and Laboratory Use - EMC Requirements | 2006 |

*and which 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:*

*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:* 23 January 2014

*Name:* Keith Dhese
*Position:* General Manager

CE

*EDC - GVS101 -2014-01-23*




# EU Declaration of Conformity

*in accordance with EN ISO 17050-1:2010*

*We* Thorlabs Ltd.
*Of* 1 Saint Thomas Place, Ely, Cambridgeshire, CB7 4EX

*in accordance with the following Directive(s):*

| | |
|---|---|
| 2006/42/EC | Machinery Directive (MD) |
| 2004/108/EC | Electromagnetic Compatibility (EMC) |
| 2011/65/EU | Restriction of Use of Certain Hazardous Substances (RoHS) |

*hereby declare that:*

*Model:* ***GVS102***

*Equipment:* ***2D Galvo system - Gold coated mirrors***

*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 |
| EN61326-1 | Electrical Equipment for Measurement, Control and Laboratory Use - EMC Requirements | 2006 |

*and which 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:*

A 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:* 23 January 2014

*Name:* Keith Dhese
*Position:* General Manager

*EDC - GVS102 -2014-01-23*

CE




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*Of* 1 Saint Thomas Place, Ely, Cambridgeshire, CB7 4EX

*in accordance with the following Directive(s):*

| | |
|---|---|
| 2006/42/EC | Machinery Directive (MD) |
| 2004/108/EC | Electromagnetic Compatibility (EMC) |
| 2011/65/EU | Restriction of Use of Certain Hazardous Substances (RoHS) |

*hereby declare that:*

*Model:* ***GVS201 & GVS202***

*Equipment:* ***1D & 2D Galvo system - Broadband mirror 400-750 nm***

*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 |
| EN61326-1 | Electrical Equipment for Measurement, Control and Laboratory Use - EMC Requirements | 2013 |

*and which 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:*

A 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:* 03 April 2014

*Name:* Keith Dhese
*Position:* General Manager

CE

*EDC - GVS201 & GVS202 -2014-04-03*




# 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) |
| 2004/108/EC | Electromagnetic Compatibility (EMC) Directive |
| 2011/65/EU | Restriction of Use of Certain Hazardous Substances (RoHS) |

*hereby declare that:*

*Model:* ***GVS30X Series***

*Equipment:* ***1D & 2D Galvo system - Dual Band mirror 532/1064nm***

*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 |
| EN61326-1 | 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:* 03 September 2014

*Name:* Keith Dhese

*Position:* General Manager

*EDC - GVS30X Series -2014-09-03*

CE

# Appendix E  Thorlabs Worldwide Contacts

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



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

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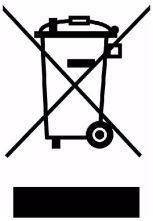
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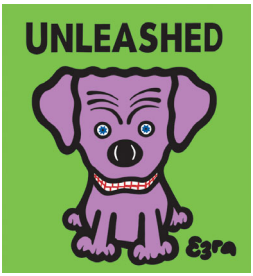
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Thorlabs verifies our compliance with the WEEE (Waste Electrical and Electronic Equipment) directive of the European Community and the corresponding national laws. Accordingly, all end users in the EC may return "end of life" Annex I category electrical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






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