



GVS001 and GVS002

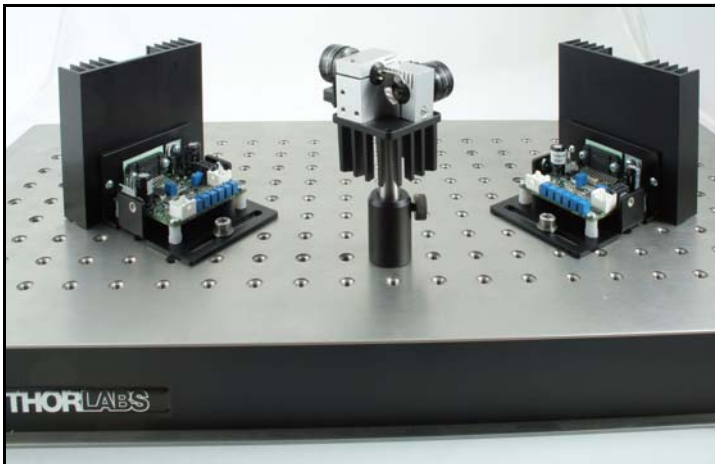
GVS101 and GVS102

GVS201 and GVS202

GVS301 and GVS302

## Scanning Galvo Systems

### User Guide



Original Instructions

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# Chapter 1 Safety

## 1.1 Safety Information

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

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



### Shock Warning



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



### Warning



Given when there is a risk of injury to users.



### Caution



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

### Note

Clarification of an instruction or additional information.

## 1.2 General Warnings



### Warnings



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

Spillage of fluid, such as sample solutions, should be avoided. If spillage does occur, clean up immediately using 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.

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## Chapter 2 Overview

### 2.1 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. 2.1 GVS002 2-Axis Galvo System (Post Adapter and post not included)**

## 2.2 System Description

### 2.2.1 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.

### 2.2.2 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. 2.2 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.

2.2.3 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 $\mu$ m	3 J/cm <sup>2</sup> at 1064 nm, 10 ns pulse
GVS10x	Gold	800 nm - 20.0 $\mu$ m	2 J/cm <sup>2</sup> at 1064 nm, 10 ns pulse
GVS20x	E02	400 nm - 750 nm	0.25 J/cm <sup>2</sup> at 532 nm, 10 ns pulse
GVS30x	K13	532 nm and 1064 nm	5 J/cm <sup>2</sup> at 1064 nm, 10 ns pulse



Fig. 2.3 Mirror Assembly Detail

### 2.2.4 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.

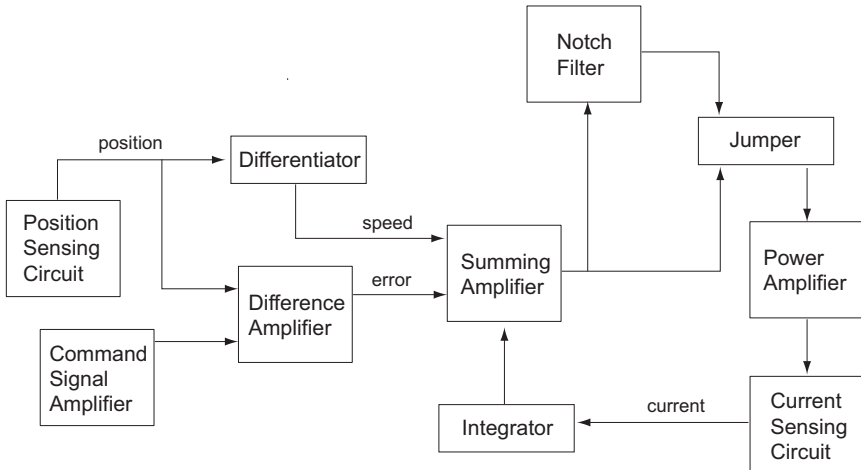


Fig. 2.4 Servo Driver Board Schematic Diagram

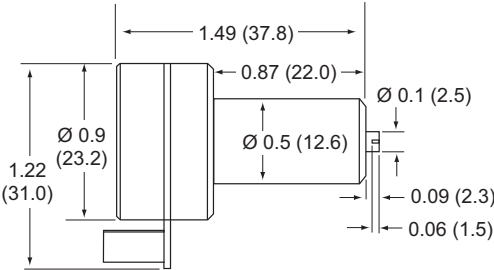


Fig. 2.5 Servo Driver Circuit Board

# Chapter 3    Installation & Initial Set Up

## 3.1    Dimensions

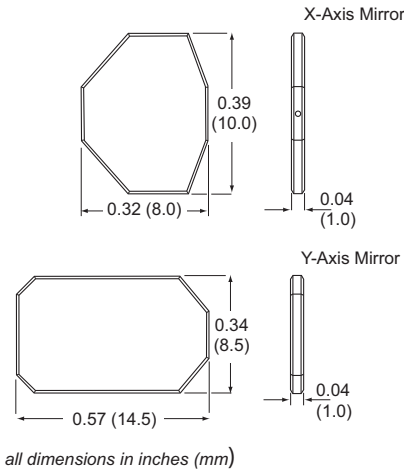
### 3.1.1    Motor Assembly Dimensions



*all dimensions in inches (mm)*

**Fig. 3.1    Motor Dimensions**

### 3.1.2    Mirror Dimensions

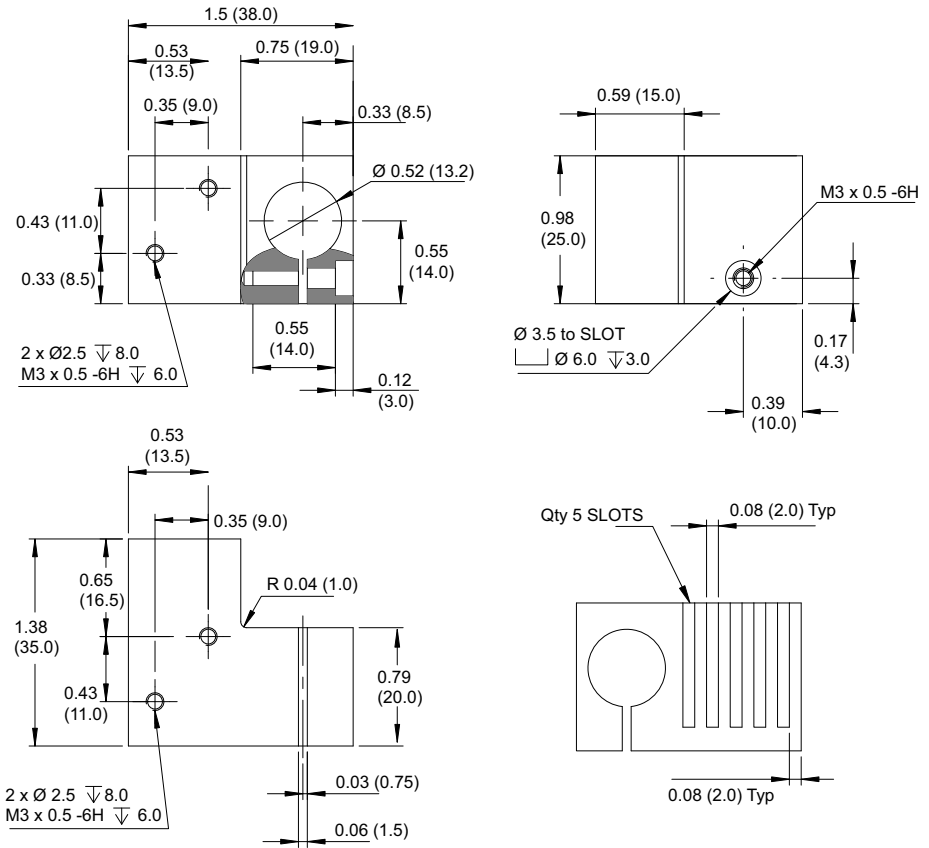


*all dimensions in inches (mm)*

**Fig. 3.2    Mirror Dimensions**



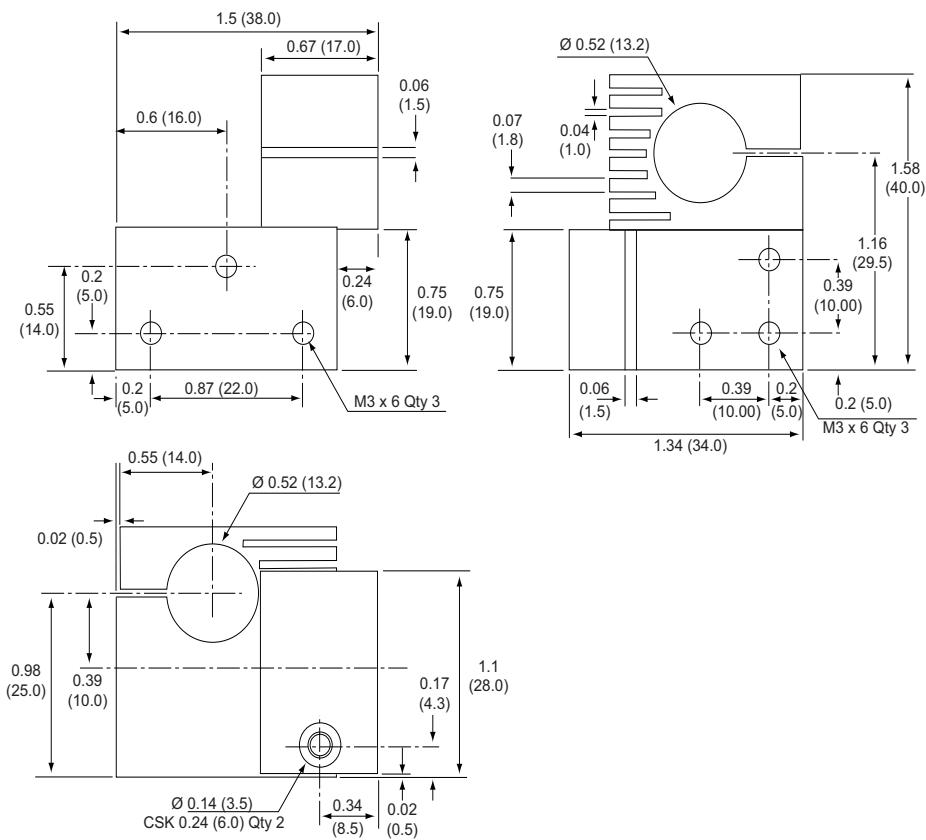
### 3.1.3 Single Axis Mount Dimensions



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

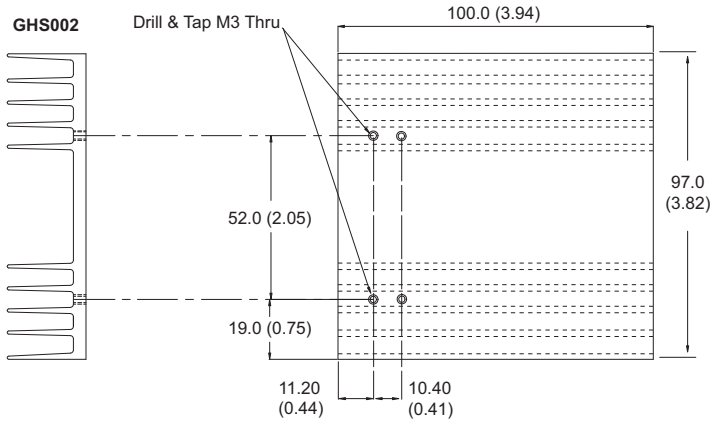


Fig. 3.5 Heatsink Dimensions

### 3.1.6 Servo Driver Board Baseplate Dimensions

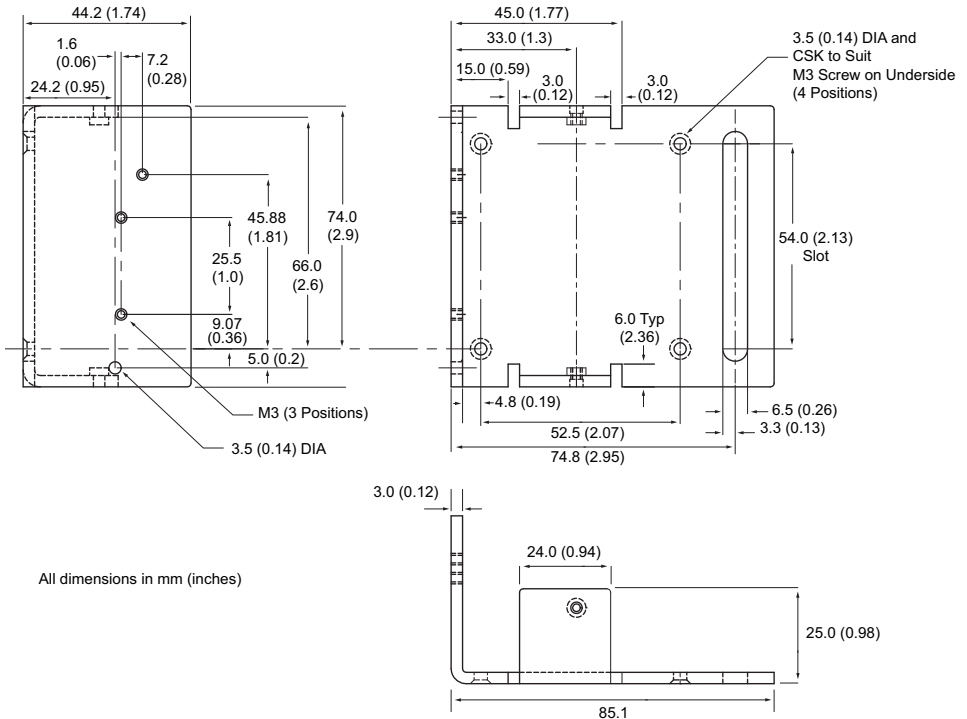


Fig. 3.6 Servo Driver Board Baseplate Dimensions

## 3.2 Mechanical Installation

### 3.2.1 Introduction



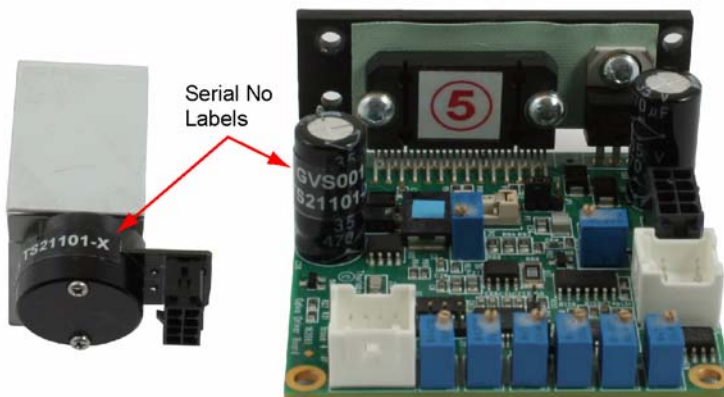
#### Caution



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 management 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.

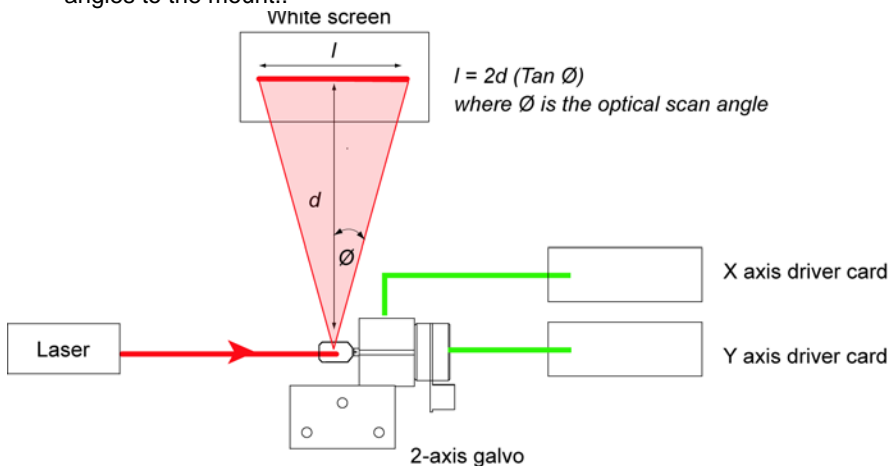
- 1) Secure the heatsink to the motor/mirror mount using the two M3 x 5 screws supplied.



**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  $\varnothing = \pm 25^\circ$

$l = 2d \times \tan 25^\circ$  (Note. In this case, the mechanical scan angle is  $\pm 12.5^\circ$ )

**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  $\pm 15V$  to  $\pm 18V$ . 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

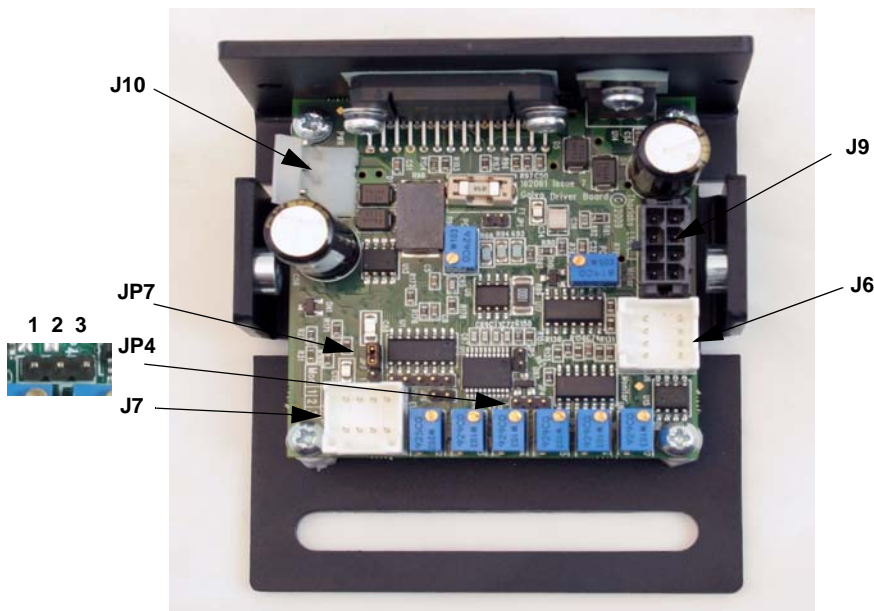


Fig. 3.12 Connector Identification

- 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.

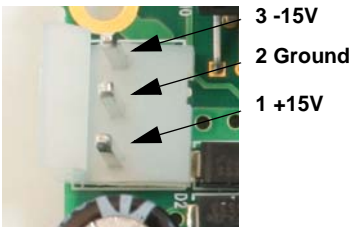
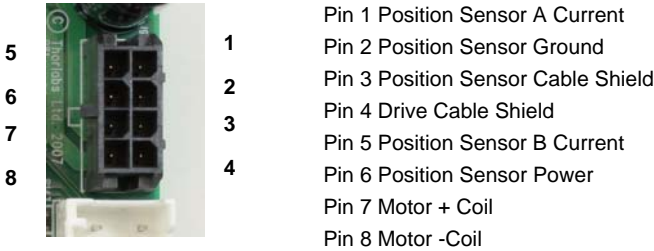


Fig. 3.13 J10 Power Connector Pin Identification

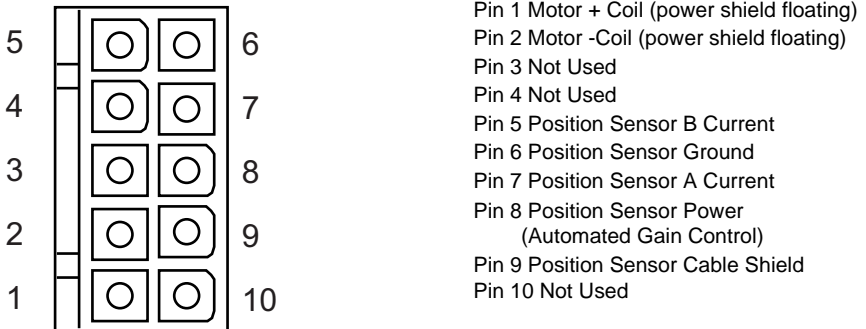


- 2) Connect a motor cable to the connector J9 on each driver board as shown below.



**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 connectors on the Driver PCB and the Motor connector are detailed in Fig. 3.14 and Fig. 3.15 respectively.



**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.

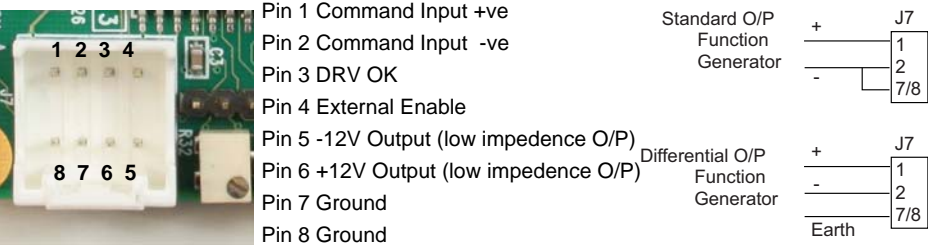


Fig. 3.16 J7 Command Input Connector Pin Identification

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

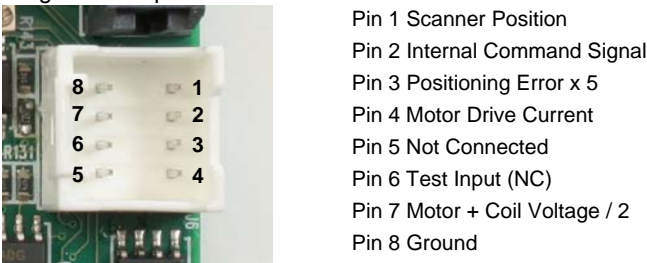


Fig. 3.17 J6 Diagnostics Connector Pin Identification

**Note**

All diagnostic signals from J6 have 1 K $\Omega$  output impedance except Pin 7 (Motor Coil Voltage/2) which has 5 K $\Omega$

**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 proportional 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.

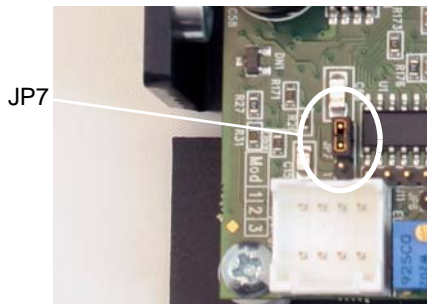
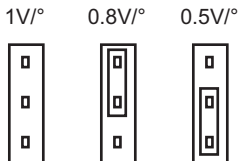
### 3.3.5 Setting the Volts/Degree Scaling Factor

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  $\pm 12.5^\circ$ , and is compatible with driver cards manufactured before October 2009. To set the scaling factor to 1 V/° and the maximum scan angle to  $\pm 10^\circ$ , 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  $\pm 6.25$  V max**



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

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## Chapter 4 Operation

### 4.1 General Operation

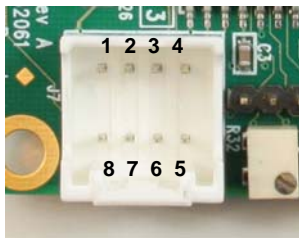
- 1) Connect the system as described in Section 3.3.
- 2) Apply power to the driver boards.
- 3) Input a command signal to each driver board to obtain the desired behaviour.

#### 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:-

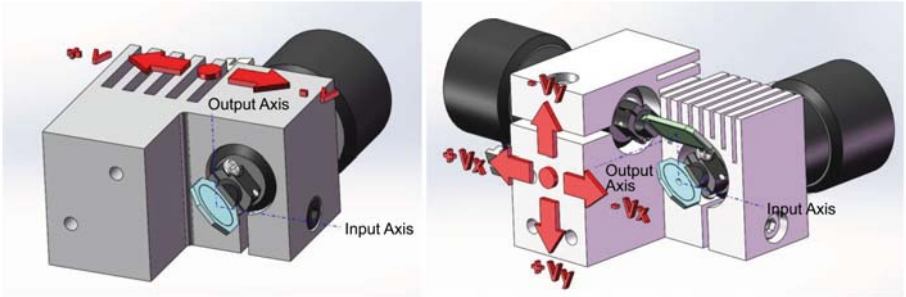
Dual bipolar -10V to 10V DAC analogue output channels (differential).

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 ( $\leq 50 \Omega$ ).

#### 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	$\pm 12.5^\circ$	$\pm 25^\circ$
5 mm	$+ 10^\circ, -12.5^\circ$	$+ 20^\circ, -25^\circ$

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	$+ 11.0^\circ, - 12.5^\circ$	$+ 22.0^\circ, - 25^\circ$	$\pm 12.5^\circ$	$\pm 25^\circ$
2 mm	$+ 10^\circ, - 11.5^\circ$	$+ 20^\circ, - 23^\circ$	$\pm 12.5^\circ$	$\pm 25^\circ$
3 mm	$+ 9.5^\circ, - 10^\circ$	$+ 19^\circ, - 20^\circ$	$\pm 12.5^\circ$	$\pm 25^\circ$
4 mm	$\pm 8.5^\circ$	$\pm 17^\circ$	$\pm 12.5^\circ$	$\pm 25^\circ$
5 mm	$\pm 8^\circ$	$\pm 16^\circ$	$+ 12.5^\circ, -3^\circ$	$+ 25, -6^\circ$

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# 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 whistling 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 occurring. 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 unpredictable 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

<b>Fault</b>	<b>Possible Causes</b>	<b>Action Taken by Fault Control Circuit</b>
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 position 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
<b>Mirror</b>	
Maximum Beam Diameter	5 mm
Finish	GVS00x: Protected Silver Coated GVS10x: Protected Gold Coated GVS20x: Broadband, E02 GVS30x: Dual Band Hi Power, K13
Damage Threshold*	GVS00x: 3 J/cm <sup>2</sup> at 1064 nm, 10 ns pulse GVS10x: 2 J/cm <sup>2</sup> at 1064 nm, 10 ns pulse GVS20x: 0.25 J/cm <sup>2</sup> at 532 nm, 10 ns pulse GVS30x: 5 J/cm <sup>2</sup> at 1064 nm, 10 ns pulse
<b>Motor &amp; Position Sensor</b>	
Linearity	99.9%, range $\pm 20^\circ$
Scale Drift	40PPM/ $^\circ$ C(Max)
Zero Drift	10 $\mu$ Rad/ $^\circ$ C(Max)
Repeatability	15 $\mu$ Rad
Resolution	
With GPS011 Linear PSU	0.0008 $^\circ$ (15 $\mu$ Rad)
With standard switch mode PSU	0.004 $^\circ$ (70 $\mu$ Rad)
Average Current	1 A
Peak Current	5 A
Load Mirror Aperture	5 mm
Coil Resistance:	2.2 $\Omega \pm 10\%$
Coil Inductance:	150 $\mu$ H $\pm 10\%$
Rotor Inertia:	0.02gm per cm <sup>2</sup>
Maximum Scan Angle (Mechanical Angle)	$\pm 12.5^\circ$ (with 0.8V/ $^\circ$ scaling factor)
Motor Weight (inc cables, excl bracket)	50 g
Operating Temperature Range	0 ~ 40 $^\circ$ C
Optical Position Sensor Output Range	40 to 80 $\mu$ A

#### Note

\*The way our mirrors are tested is continually updated, please consult [www.thorlabs.com](http://www.thorlabs.com) for more information.

## Drive Electronics

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

\* Using heat sink to keep temp <50 $^\circ$ 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

### 2.1 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:

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

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

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

Where  $P_{\text{drv}}$  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,  $\theta$ . The lower the thermal resistance the more effectively the heatsink can transfer heat. The required thermal resistance can be calculated from the following equation:

$$\theta = 1/k = (T_{\text{hs}} - T_a) / P_{\text{max}}$$

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

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

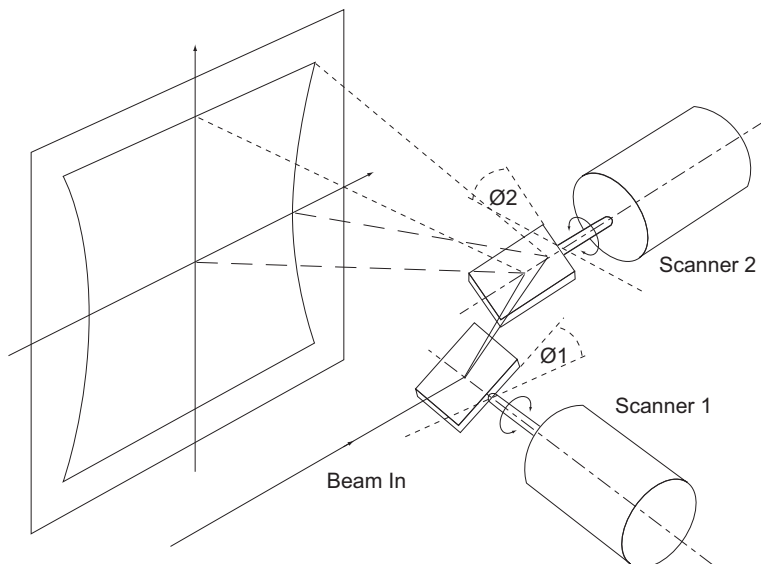
$$T_{\text{hs}} = T_j - P_{\text{max}} \times \theta_{\text{jhs}}$$

Here,  $\theta_{\text{jhs}}$  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  $150^\circ\text{C}$  (although the lifetime of the driver IC will be longer if the junction is kept at a lower temperature). The value of  $\theta_{\text{jhs}}$  is  $1.3^\circ\text{C/W}$ .

## 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.



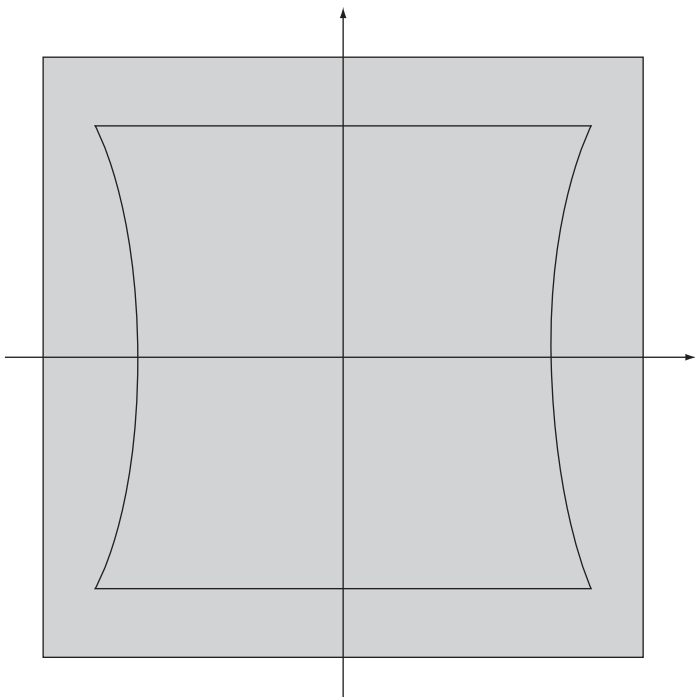
**Fig. C.1 Field Distortion in a Two-way Mirror Deflection System**

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**

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## Appendix D Regulatory

### D.1 Declarations Of Conformity

#### D.1.1 For Customers in Europe

This equipment has been tested and found to comply with the EC Directives 2006/42/EC Machinery Directive (MD)

2004/108/EC Electromagnetic Compatibility (EMC) Directive

2011/65/EU Restriction of Use of Certain Hazardous Substances (RoHS).

Compliance was demonstrated by conformance to the following specifications which have been listed in the Official Journal of the European Communities:

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

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

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

### D.2 Waste Electrical and Electronic Equipment (WEEE) Directive

#### D.2.1 Compliance

As required by the Waste Electrical and Electronic Equipment (WEEE) Directive of the European Community and the corresponding national laws, we offer all end users in the EC the possibility to return "end of life" units without incurring disposal charges.

This offer is valid for electrical and electronic equipment

- sold after August 13th 2005
- marked correspondingly with the crossed out "wheelie bin" logo (see Fig. 1)
- sold to a company or institute within the EC
- currently owned by a company or institute within the EC
- still complete, not disassembled and not contaminated



**Fig. 4.1 Crossed out "wheelie bin" symbol**

As the WEEE directive applies to self contained operational electrical and electronic products, this "end of life" take back service does not refer to other products, such as

- pure OEM products, that means assemblies to be built into a unit by the user (e. g. OEM laser driver cards)
- components
- mechanics and optics
- left over parts of units disassembled by the user (PCB's, housings etc.).

If you wish to return a unit for waste recovery, please contact Thorlabs or your nearest dealer for further information.

#### D.2.2 Waste treatment on your own responsibility

If you do not return an "end of life" unit to the company, you must hand it to a company specialized in waste recovery. Do not dispose of the unit in a litter bin or at a public waste disposal site.


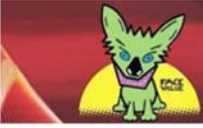
#### D.2.3 Ecological background

It is well known that WEEE pollutes the environment by releasing toxic products during decomposition. The aim of the European RoHS directive is to reduce the content of toxic substances in electronic products in the future.

The intent of the WEEE directive is to enforce the recycling of WEEE. A controlled recycling of end of life products will thereby avoid negative impacts on the environment.



### D.3 CE Certificates



**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: **GV5001**  
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.*

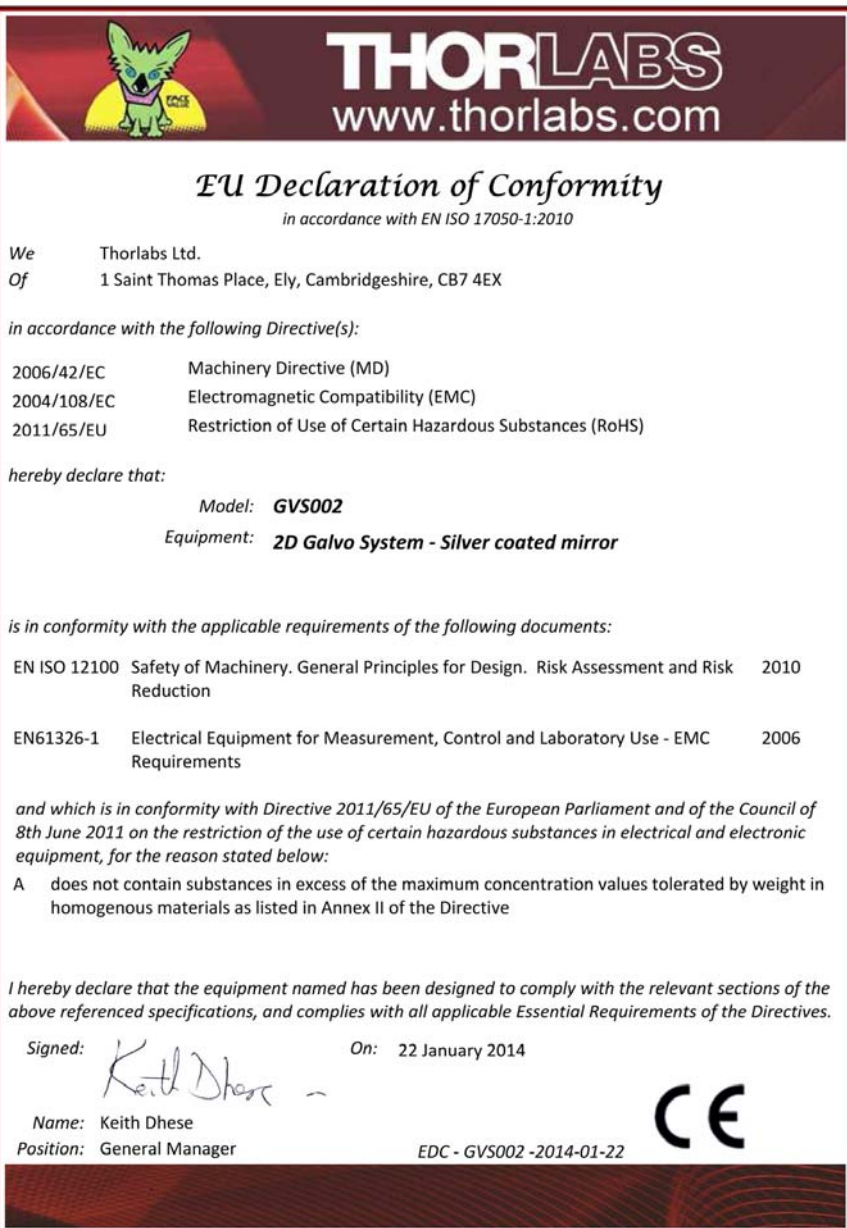
Signed:  On: 22 January 2014


Name: Keith Dhesse  
Position: General Manager

EDC - GV5001 -2014-01-22



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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: **GVSM00X Series**  
Equipment: **1D or 2D Galvo System with accessories or metric accessories**

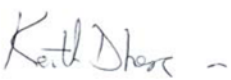
is in conformity with the applicable requirements of the following documents:

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


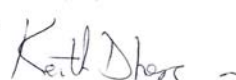

I hereby declare that the equipment named has been designed to comply with the relevant sections of the above referenced specifications, and complies with all applicable Essential Requirements of the Directives.

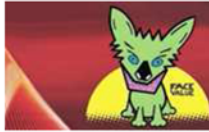
Signed:  On: 22 January 2014

Name: Keith Dhese  
Position: General Manager

EDC - GVSM00X Series -2014-01-22



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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:		<b>GVS101</b>	
Equipment:		<b>1D Galvo system - Gold coated mirror</b>	
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: 		On: 23 January 2014	
Name: Keith Dhese			
Position: General Manager			
		EDC - GVS101 -2014-01-23	



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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:




On: 23 January 2014

Name: Keith Dhese

Position: General Manager

EDC - GVS102 -2014-01-23



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<b>EU Declaration of Conformity</b> <i>in accordance with EN ISO 17050-1:2010</i>			
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: <b>GVS201 &amp; GVS202</b>			
Equipment: <b>1D &amp; 2D Galvo system - Broadband mirror 400-750 nm</b>			
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:		On:	03 April 2014
Name:	Keith Dhese		
Position:	General Manager		
		EDC - GVS201 & GVS202 -2014-04-03	
			





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*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:  On: 03 September 2014

Name: Keith Dhese  
Position: General Manager

EDC - GVS30X Series -2014-09-03



---

## Appendix E Thorlabs Worldwide Contacts

### USA, Canada, and South America

Thorlabs, Inc.  
56 Sparta Ave  
Newton, NJ 07860  
USA  
Tel: 973-579-7227  
Fax: 973-300-3600  
www.thorlabs.com  
www.thorlabs.us (West Coast)  
email: feedback@thorlabs.com  
Support: techsupport@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

### 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

### France

Thorlabs SAS  
109, rue des Côtes  
78600 Maisons-Laffitte  
France  
Tel: +33 (0) 970 444 844  
Fax: +33 (0) 811 381 748  
www.thorlabs.de  
email: sales.fr@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.de  
email: scandinavia@thorlabs.com

### Japan

Thorlabs Japan Inc.  
Higashi Ikebukuro  
Q Building 1st Floor 2-23-2  
Toshima-ku, Tokyo 170-0013  
Japan  
Tel: +81-3-5979-8889  
Fax: +81-3-5979-7285  
www.thorlabs.jp  
email: sales@thorlabs.jp

### China

Thorlabs China  
Oasis Middlering Centre  
3 Building 712 Room  
915 Zhen Bei Road  
Shanghai  
China  
Tel: +86 (0)21-32513486  
Fax: +86 (0)21-32513480  
www.thorlabs.com  
email: chinasales@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

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Thorlabs Inc.  
56 Sparta Avenue  
Newton, NJ07860  
USA  
Tel: +1 973 579 7227  
Fax: +1 973 300 3600  
www.thorlabs.com

Thorlabs Ltd.  
Saint Thomas Place, Ely  
Cambridgeshire CB7 4EX,  
UK  
Tel: +44 (0) 1353 654440  
Fax: +44 (0) 1353 654444  
www.thorlabs.com