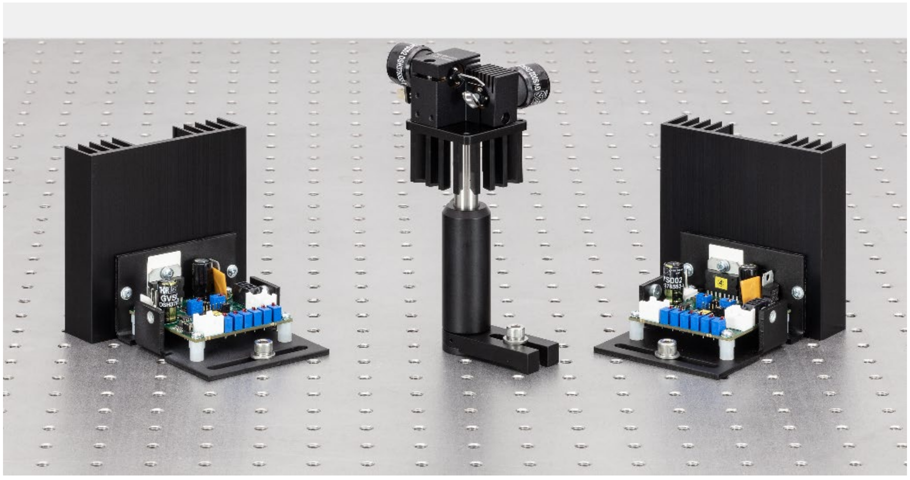
GVS001 and GVS002
GVS101 and GVS102
GVS201 and GVS202

Small Beam Diameter Scanning Galvo Systems

User Guide



Original Instructions

Table of Contents

Chapter 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.

Warning: Risk of Electrical Shock

Given when there is a risk of electrical shock.

Warning

Given when there is a risk of injury to users.

Caution

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

Note

Clarification of an instruction or additional information.

1.1 General Warnings and Cautions

Warning

If this equipment is used in a manner not specified by the manufacturer, the equipment might malfunction. Excessive moisture may impair operation.
Spillage of fluid, such as sample solutions, should be avoided. If spillage does occur, clean up immediately using absorbent tissue. Do not allow spilled fluid to enter the internal mechanism.
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.

Caution

The driver circuit board is shipped calibrated and ready for use. The only adjustments necessary are setting the Volts/Degree Scaling factor (see section 3.4.5 and if required, setting the device for external enabling see section 4.2).

Do not attempt to make any other adjustments or remove/fit any other jumpers than those explicitly described in the following sections as this could invalidate the warranty.

Warning

Please install the metal covers GCE001 to prevent any damage to the motors and PCBs as the galvo boards contain electrostatic discharge-sensitive components.

1.2 EMC Compatibility and ESD Precautions

Caution

Galvos must be shielded from external interference, ground loops, and electrostatic discharge because they are components and not finished goods. If the covers are not used, a 4 kV ESD can touch the PCB and harm it. Please install covers to shield the boards from ESD.

Note

The customer must adhere to EMC and ESD best practices when integrating any galvo parts into their systems.

Motors can be sensitive to external radio frequency signals; the customer should protect the galvo and the PCB with shielding and/or ferrite beads if radio frequency signals are present in the system.
For instance, a Würth Elektronik ferrite 742 711 31 S placed over the motor cable of the large galvo system can improve immunity between 105 and 115 MHz.

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 consist of a motor and mirror assembly, a mounting bracket, a tuned driver card and a heat sink. The dual axis systems comprise 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

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

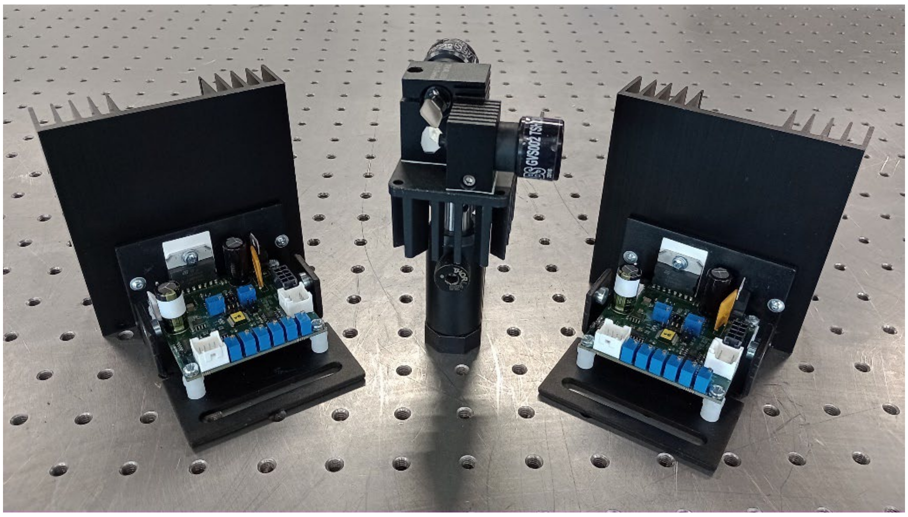


Figure 1 GVS002 Dual-Axis Galvo System (Post Adapter and Post Not Included)

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.

Figure 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 detailed below:

Table 1 Wavelength Ranges and Damage Threshold

Part Number	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

Figure 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.

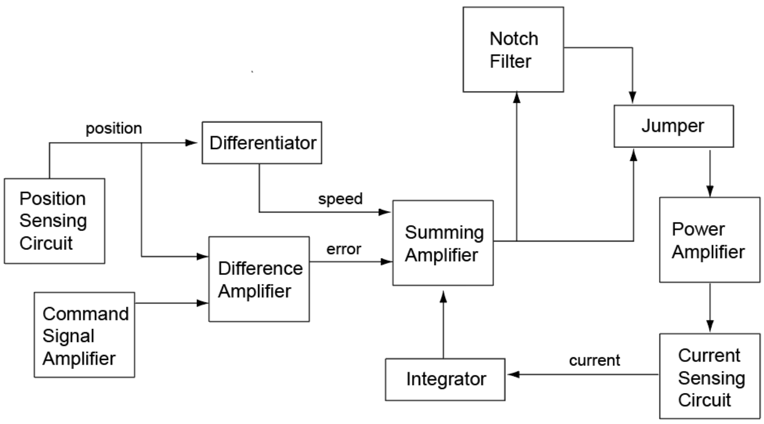


Figure 4 Servo Driver Board Schematic Diagram

Figure 5 Servo Driver Circuit Board

Chapter 3 Installation and Initial Setup

3.1 Environmental Conditions

Warning

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

The unit is designed for indoor use only.

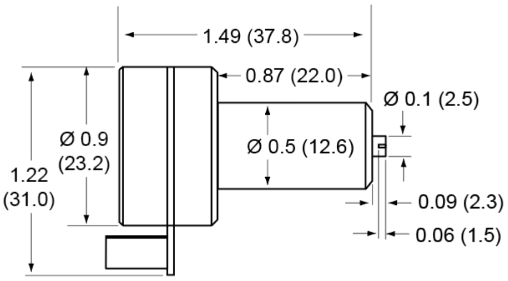
To ensure reliable operation, the unit should not be exposed to corrosive agents or excessive moisture, heat, or dust.

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

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

3.2 Dimensions

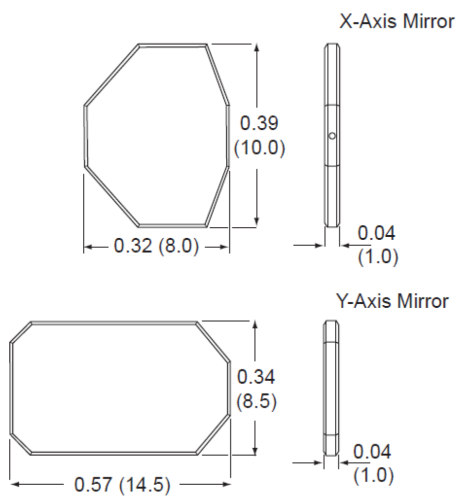
3.2.1 Motor Assembly Dimensions



all dimensions in inches (mm)

Figure 6 Motor Dimensions

3.2.2 Mirror Dimensions



all dimensions in inches (mm)

Figure 7 Mirror Dimensions

3.2.3 Single Axis Mount Dimensions

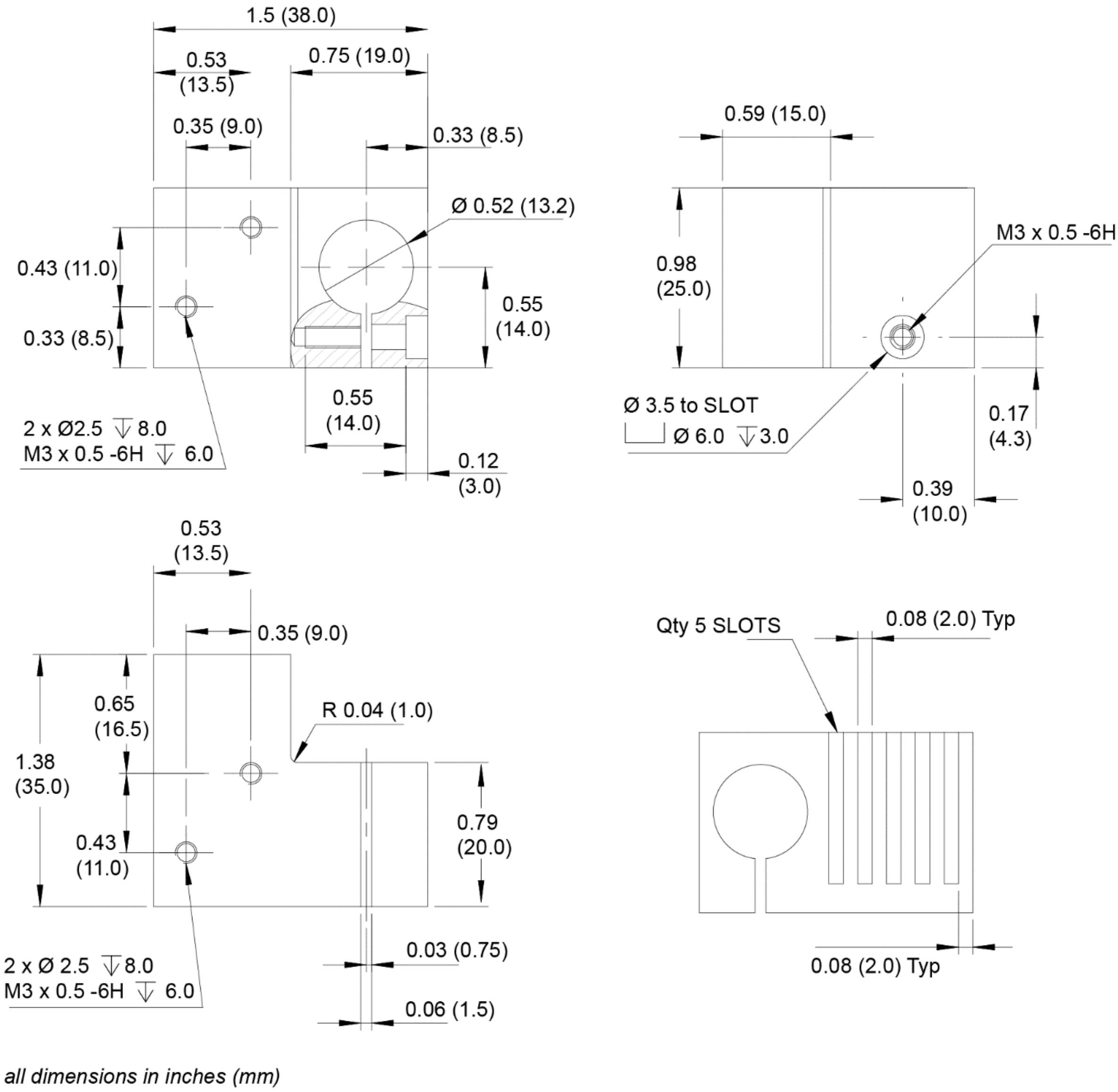
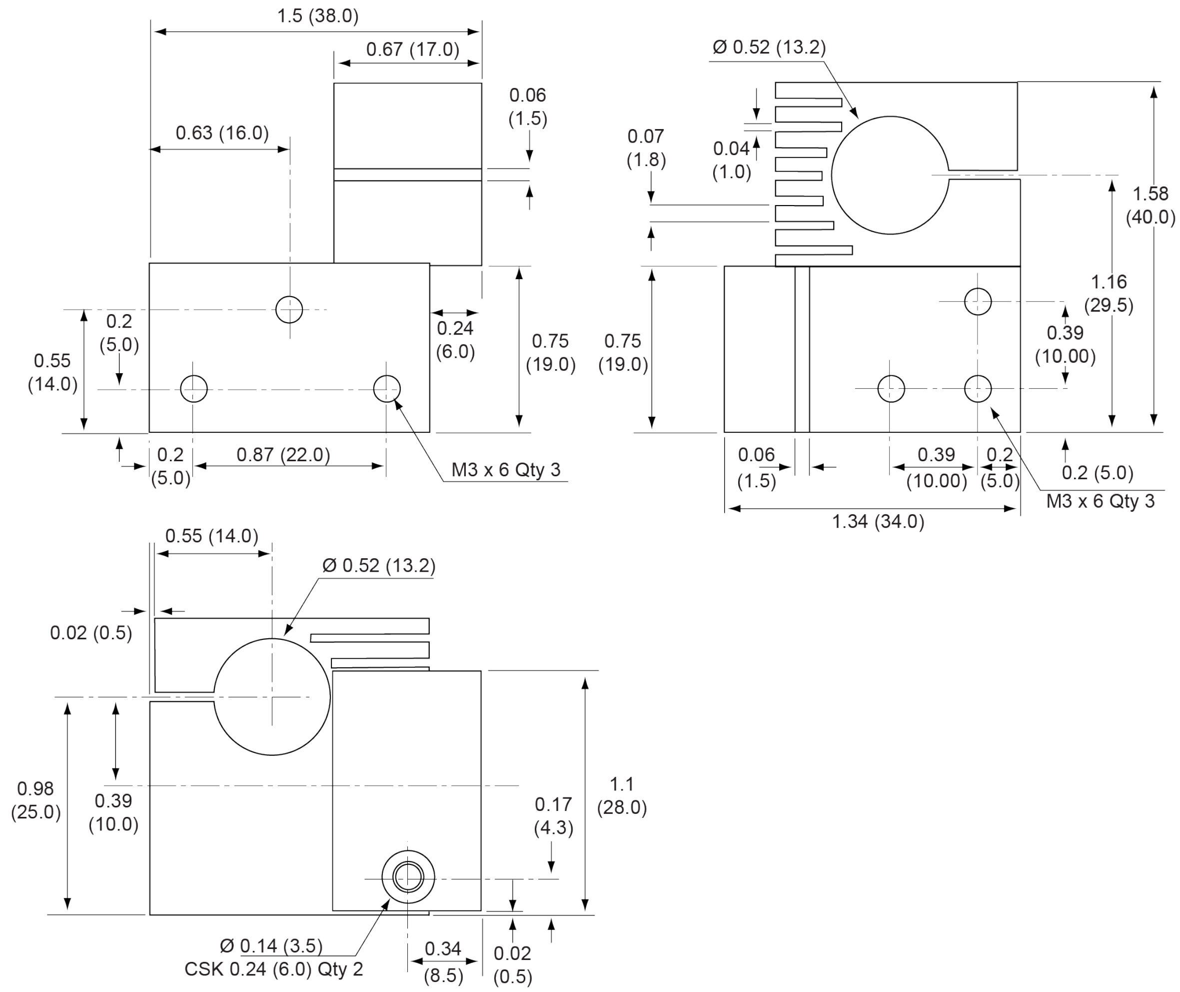


Figure 8 Single Axis Mounting Bracket Dimensions

3.2.4 XY Mount Dimensions



all dimensions in inches (mm)

Figure 9 XY Mounting Bracket Dimensions

3.2.5 Heatsink Dimensions

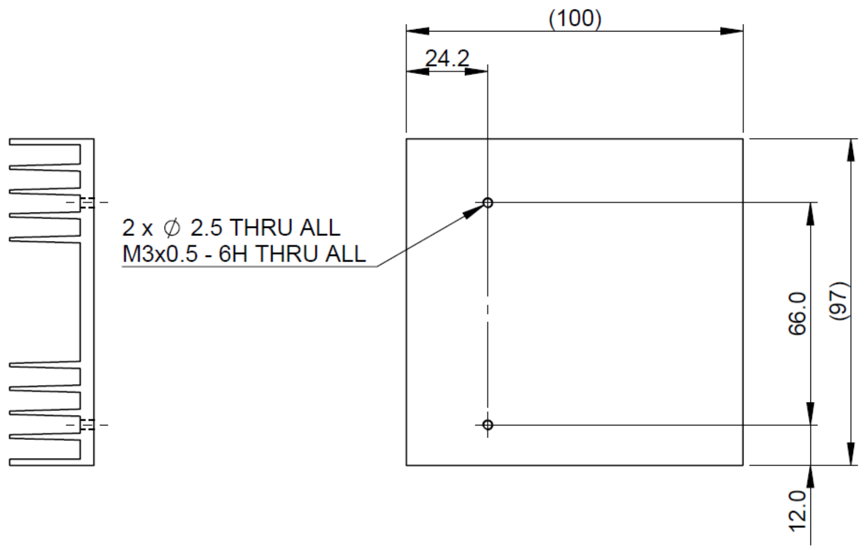


Figure 10 Heatsink Dimensions

3.2.6 Servo Driver Board Baseplate Dimensions

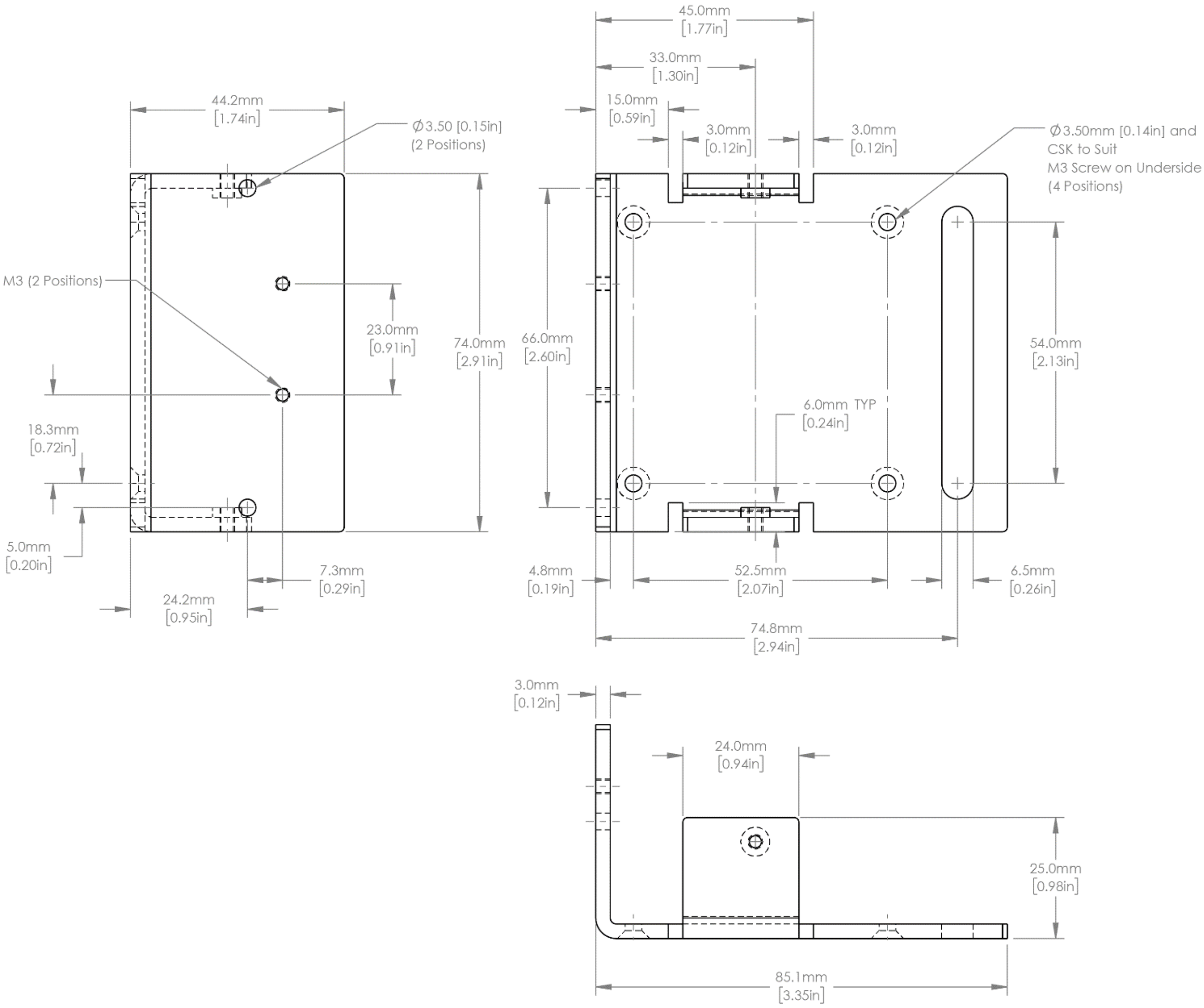


Figure 11 Servo Driver Board Baseplate Dimensions

3.3 Mechanical Installation

3.3.1 Introduction

Caution

The galvo motor assembly associated driver board and connecting cables 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. Do not extend the cables as this will affect the system calibration.

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.

Figure 12 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 dependent 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.

3.3.2 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.

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

Figure 13 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 supplies a combined post adapter and heatsink (GHS003) suitable for both single and dual axis applications.

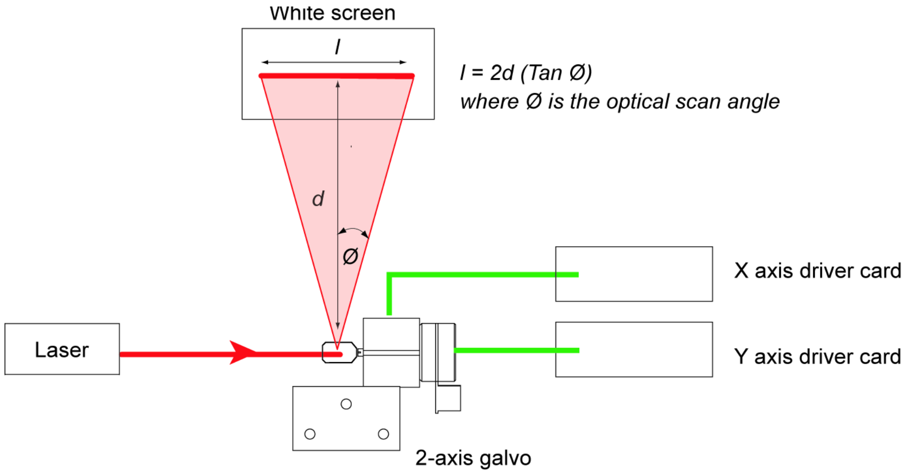
If using a third party heatsink, please refer Chapter 7 for details on how to calculate the power dissipation in the motor.

Secure the heastsink to the motor/mirror mount using the two M3 X 5 screws supplied.

Figure 14 XY Mount Heatsink Screws

3.3.3 Typical System Setup

1. Fit a GHS003 post adaptor 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 the 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°)

Figure 15 Typical Beam Steering System

3.4 Electrical installation

3.4.1 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 ±15 V to ±18 V. The maximum current drawn by the driver cards will not exceed 1.25 A rms on each rail (the current depends on the application). In addition to this, for optimum performance the supply should be able to provide peak currents of up to 5 A 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, 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. The unit can be damaged if the polarity of the power rails is reversed.

3.4.2 Using the GPS011 Linear Power Supply

The unit must be connected only to an earthed (grounded) mains power outlet.

Note

The unit is supplied with the input voltage and fuses configured to be compatible in the region to which it was shipped. No further adjustment should be necessary.

1. Connect the power cord to the socket on the rear panel of the unit. Refer to Figure 16.

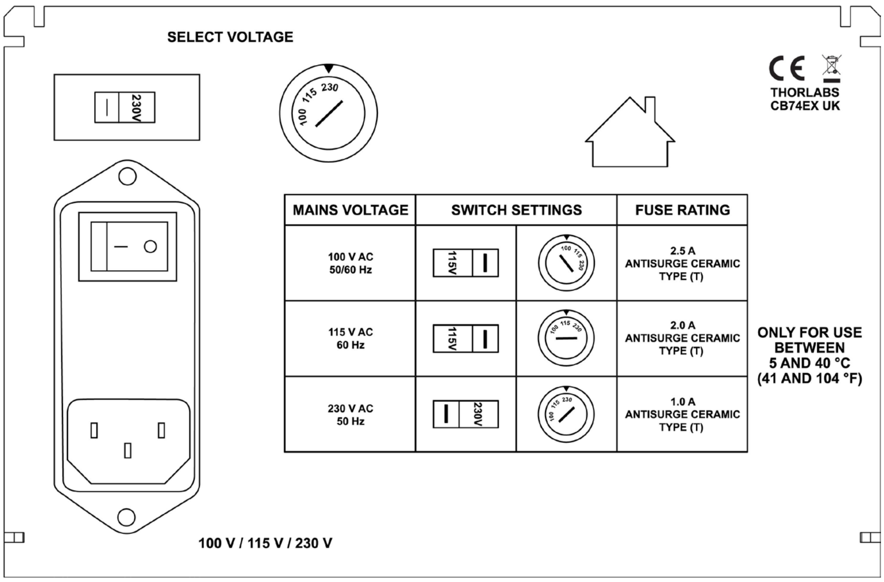


Figure 16 Rear Panel

2. Ensure that the correct voltage range and fuse rating for your region is selected.

Caution

Selecting the incorrect voltage range or fuse will damage the unit. Ensure that both switches are set to the correct position for your region and that the fuse fitted is of the correct rating, as indicated by the screen print on the rear panel.

3. Plug the power cord into the wall socket.

3.4.3 Electrical Connections

Caution

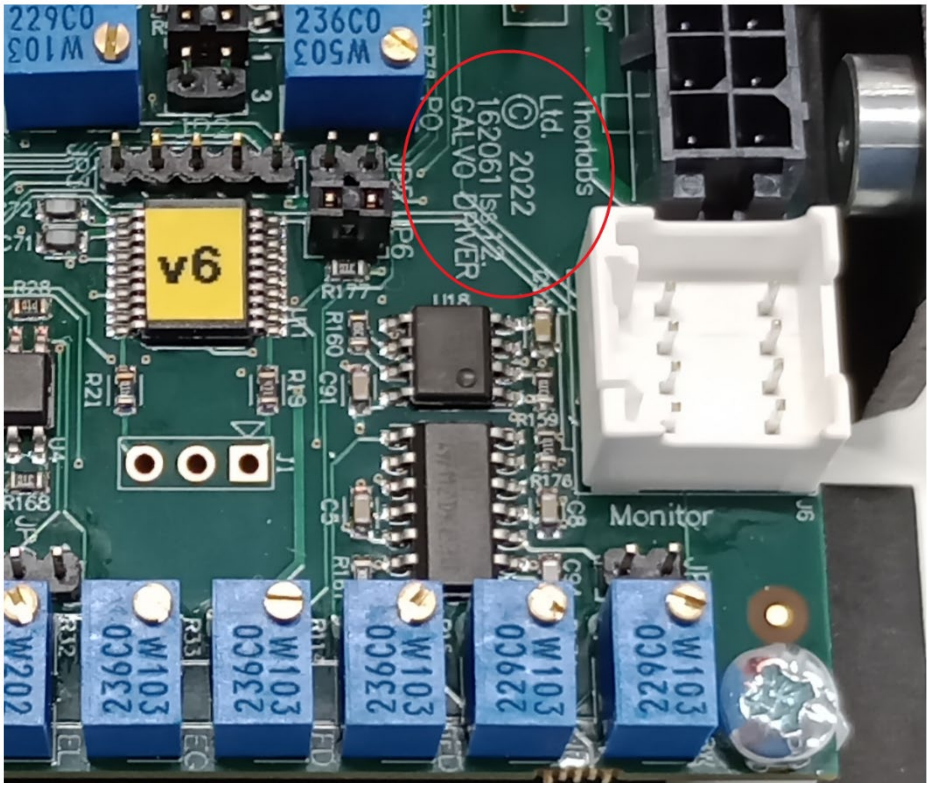
During the electrical installation, cables should be routed such that power and signal cables are separated so that electrical noise pick up is minimized.

Caution

This section is applicable only to driver card units, with a PCB at rev 11 or later.

PCB revisions can be identified as follows:

Up to and including issue 10.



Steps (1) to 3) are applicable only if using the Thorlabs GPS011 PSU.

1. Ensure the correct voltage range is selected on the PSU. Refer section 3.4.2.

2. The circular 3-pin connector on the power output cable and the OUTPUT socket on the PSU are fitted with alignment keyways to ensure connection in correct orientation. Make connection as referred in Figure 17.

3. Screw the outer casing of the plug clockwise until the connector is fully fastened.

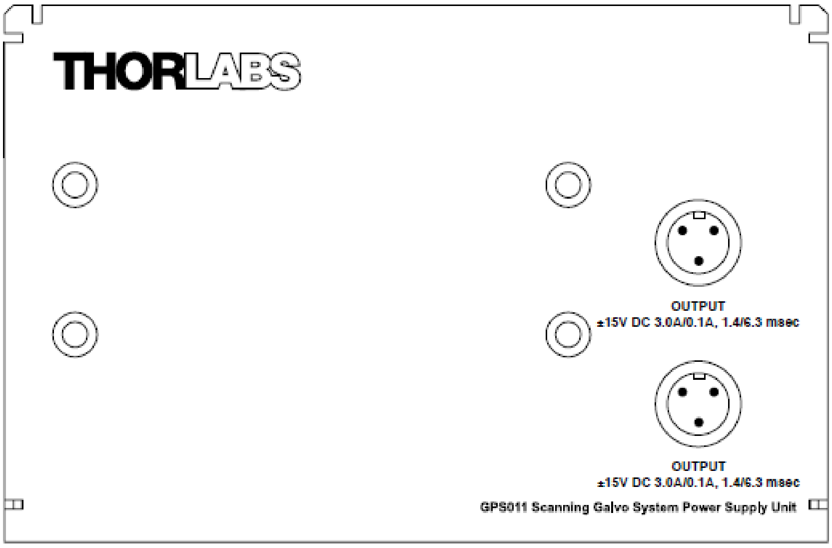


Figure 17 Connecting the Power Supply to the PSU

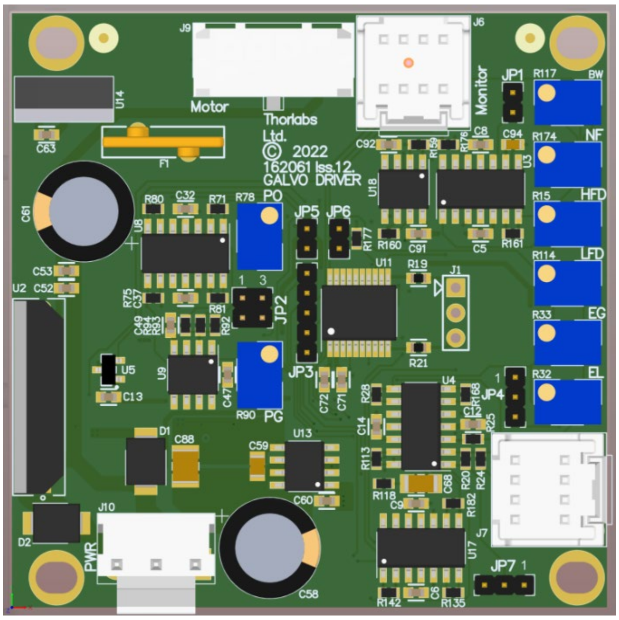


Figure 18 Connector Identification

4. Identify connector J10 on each driver board and make power connections as shown below. Thorlabs supplies a suitable PSU (GPS011) for powering a single or dual axis system (refer section 3.4.1). A bare cable, crimp connectors (Molex Pt No 2478) and housings for use with general lab PSUs is supplied with each driver board. The unit can be damaged if the polarity of the power rails is reversed.

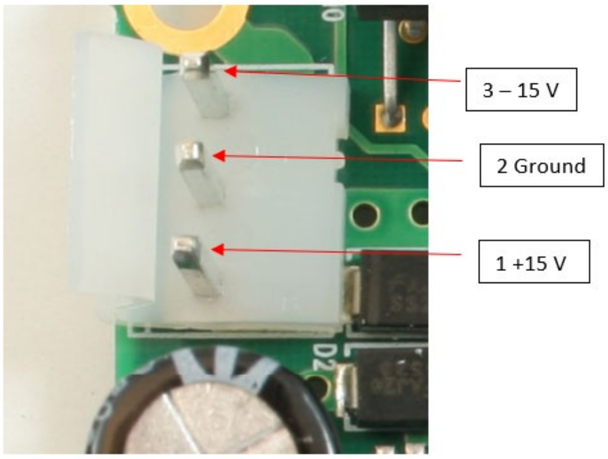
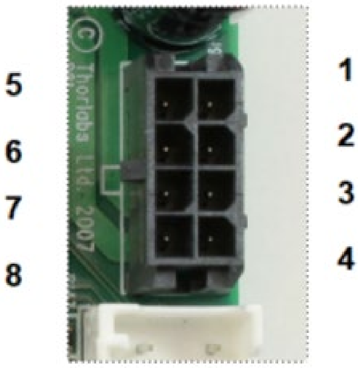


Figure 19 J10 power Connector Pin Identification

> **Caution**
>
> During steps (5) and (6) 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.

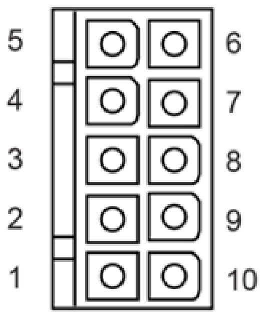
5. Connect a motor cable to the connector J9 on each driver board as shown below.



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

Figure 20 J9 Motor Connector Pin Identification

6. Note the serial numbers and then connect the galvo motors to their associated driver boards.



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

Figure 21 Galvo Assemble Motor Connector Pin Identification

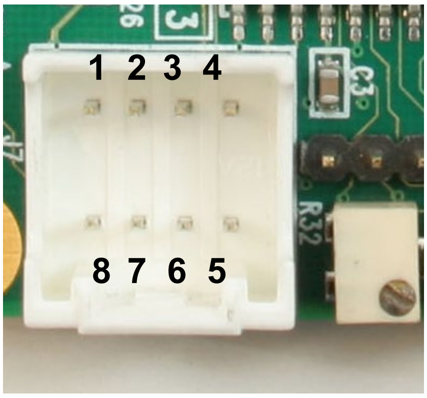
7. Connect the command input (e.g., function generator) to J7 of each driver board as shown in Figure 22. J7 accepts Molex pins Pt No 56134-910

Note

The scanner accepts a differential analog command input. If the scaling is 0.8 Volt per degree mechanical movement (see section 3.4.5), -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 active low, i.e., 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 +positive
Pin 2 Command Input -negative
Pin 3 DRV OK (Active Low)
Pin 4 External Enable
Pin 5 -12 V output (Low Impedance O/P)
Pin 6 +12 V output (Low Impedance O/P)
Pin 7 Ground
Pin 8 Ground

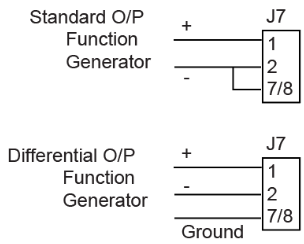
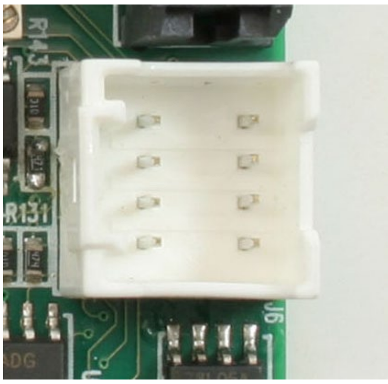


Figure 22 J7 Command Input Connector Pin identification

8. 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 added 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

Figure 23 J6 Diagnostics Connector Pin identification

Note

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

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

3.4.4 Diagnostic Signal Descriptions

Scanner Position - This signal is proportional to the position of the scanner mirror, with a scaling of 0.5 Volt 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 (2 V per A), i.e., if drive signal is 2 V, 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.

3.4.5 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 Figure 24 .
2. Set the jumper position for the corresponding scaling factor as shown below.

> **Note**
>
> The 0.5 V/° 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.

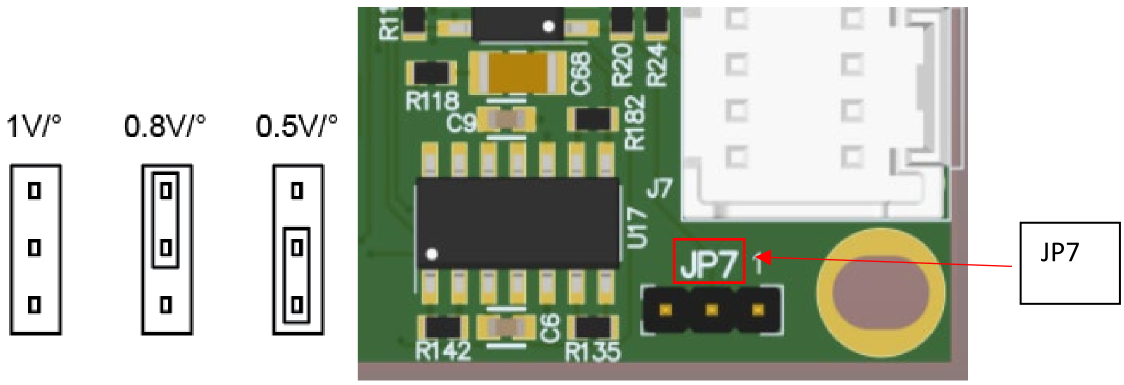


Figure 24 Setting the Volts/Degree Scaling Factor

Chapter 4 Operation

4.1 General Operation

Perform the following installation steps:

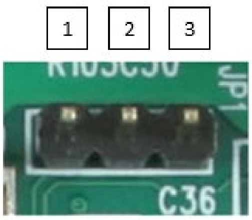
1. Connect the system as described in section 3.4.
2. Apply power to the driver boards.
3. Input a command signal to each driver board to obtain the desired behavior.

> **Note**
>
> After applying power to the boards, there may be a delay of up to 10 seconds before the motors start to follow the command signal.

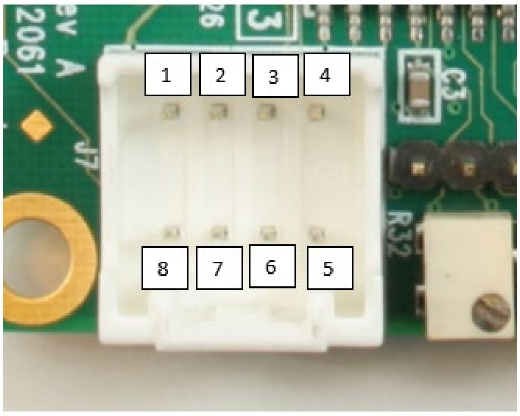
4.2 External Enabling of the Driver Board

Perform the following installation steps:

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 5 V CMOS signal to J7 pin 4.



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

Figure 25 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 to drive the servo drivers supplied with the galvos. The specifications of the DAC depend on speed and resolution of the application. The minimum recommended specifications for the DAC outputs are: -

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

DAC clocking frequency higher than 20 kS/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.

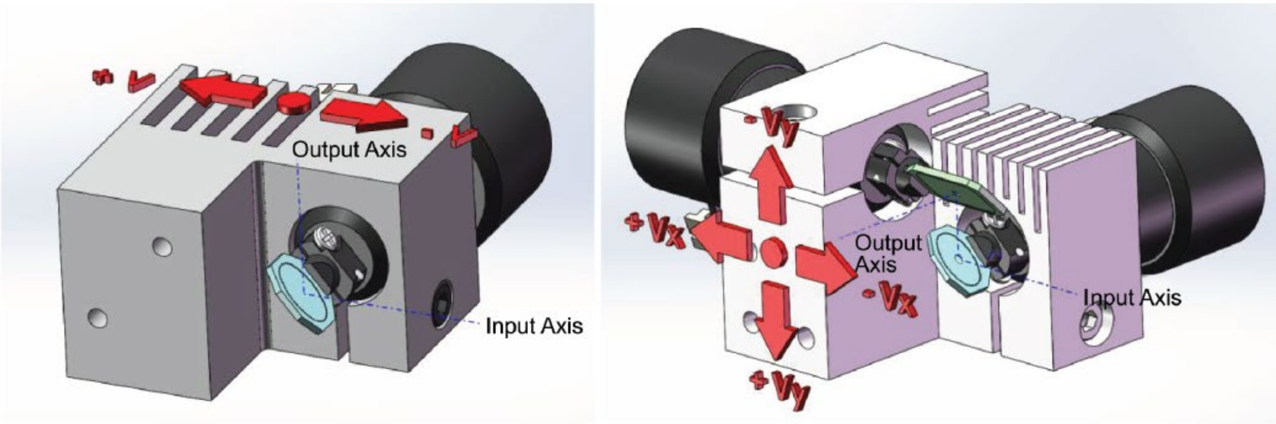


Figure 26 Scanning Angles

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

GVS002, GVS102, and GVS202				
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°

Table 2 Recommended Scanning Angles

Chapter 5 Troubleshooting

5.1 Common Issues

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

Scanner fails to respond to the command signal due to several reasons. The most common are:

1. Power is not 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 applying power to 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 screeching 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 behavior 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 several 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 shoots 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 over position fault is triggered. Once the drive electronics are 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 behave properly most of the time, but with a brief period where the system suddenly becomes unstable and it occurs repetitively. This can be caused if the maximum error signal value is exceeded.

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 (>1 kHz) 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 behavior 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 behavior 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 behavior. 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 damages.

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 3.3.1). A base firmware thermal protection is implemented from revision 5 (see the label on the PCB). It disables the motors if a persistent and high current is detected. The higher the current the earlier it acts by disabling the motor for 4 seconds.

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.

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
Power supply voltage drops below minimum value of 14 V or rises above maximum limit of 20 V[a]	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[b]	Inadequate heatsinking of driver board. A short circuit could be present in motor or motor cable	Power amplifier turned off

Table 3 Galvo System Faults and Associated Fault Protection Circuit Action

5.3 Diagnostic

The diagnostic connector J1 on the galvo driver board revision 12 has the following pinout (see image below).

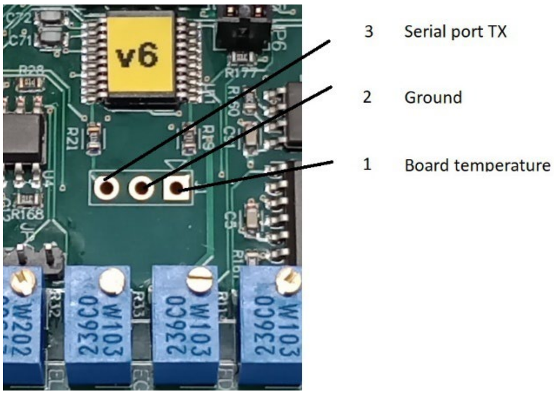


Figure 27 J1 Connector

Pin 3 of J1 is a 5 V serial port (UART) transmit line that is connected to the micro through a 1 kΩ resistor.

The data transmission rate is 9600 baud/s with an 8-bit data size, one start bit, and one stop bit. The line requires a level translator if it is connected to a standard RS232C serial port. The line is intended for diagnostics in the event of a fault, and it shouldn't be left connected permanently to prevent ground loop interference or harm from current from other items connected to the galvo. These dangers are minimized by connecting to the micro's serial port or using an isolated level translator for the RS232C.

The board's firmware revision, the Galvo model, and other error messages can all be sent over the serial ports. Below are some examples:

Positive rail (VCC) under voltage!
Positive rail (VCC) over voltage!

[a] *If the power rails are out of specifications (+/-14 V to +/-20 V) the board shuts down for 1 second*
[b] *This is a severed hardware protection which means that the board experienced a lot of voltage beyond its range or there is short circuit. The unit can be damaged.*

Negative rail (VEE) under voltage!
Negative rail (VEE) over voltage!
Thermal protection!
AGC out of range!
PCB temperature too high!
PCB temperature too low!
Overcurrent!

When the PCB temperature rises above 65 to 70 °C or falls below 0 °C, a temperature sensor on the PCB shuts off the board for 16 seconds. The diagnostic signal is accessible via pin 3, however it shouldn't be loaded, shorted, forced to a signal, or left connected to other devices (otherwise, the thermal shutdown may trip and disable the power stage).

To prevent ground loops or board damage, the maximum relevant load should be greater than 100 kΩ, and it should be measured by an insulated interface like a multimeter.

The typical sensor response is: 19.5 mV/°C with an output voltage of 400 mV at 0 °C.

5.4 Resettable Fuse

The board has a resettable fuse that, after tripping, can be reset by shutting off the power and allowing for the component to cool. The fuse should return to its original state in less than 10 seconds at 20 °C. If the resettable fuse trips, it indicates a problem with the board's motor or power stage.

Temperature affects the time protection: at low temperatures the protection trip occurs later than it does at high temperatures.

Please contact Thorlabs if the fuse trips continuously: the motor or the board might have issues.

5.5 Error codes

The shut down time of the board is the error code.

A 16-second shut down could indicate that the PCB temperature is too high and at least one voltage rail is out of range.

1 second

Positive rail (VCC) under voltage

Positive rail (VCC) over voltage

Negative rail (VEE) under voltage

Negative rail (VEE) over voltage

2 seconds

Overcurrent

4 seconds

AGC out of range

8 seconds

Thermal protection

16 seconds

PCB temperature too high

PCB temperature too low

Chapter 6 Specifications and Associated Parts

Item #	GVS001, GVS002, GVS101, GVS102, GVS201, GVS202
Mirror	
Maximum Beam Diameter	5 mm
Finish	GVS00x: Protected Silver Coated GVS10x: Protected Gold Coated GVS20x: Broadband, E02
Damage Threshold[c]	GVS00x: 3 J/cm^2 at 1064 nm, 10 ns pulse GVS10x: 2 J/cm^2 at 1064 nm, 10 ns pulse GVS20x: 0.25 J/cm^2 at 532 nm, 10 ns pulse
Motor & Position Sensor	
Linearity	99.9%, range ±20°
Scale Drift	40 ppm/°C (Max)
Zero Drift	10 µRad/°C (Max)
Repeatability	15 µRad
Resolution **with GPS011 Linear PSU** **with Standard Switch Mode PSU**	0.0008° (15 µRad) 0.004° (70 µRad)
Average Current	<1.25 A rms
Peak Current	5 A
Load Mirror Aperture	5 mm
Coil Resistance	2.2 Ω ±10%
Coil Inductance	150 µH ±10%
Rotor Inertia	0.02 g per cm^2
Maximum Scale Angle (Mechanical Angle)	±12.5° (with 0.8 V/° scaling factor)
Motor Weight **(Including Cables, Excluding Bracket)**	50 g
Operating Temperature Range	0 – 40 °C

Note

The lowest scale drift for the small beam galvo is generally achieved around 5 - 10 °C, stabilizing the temperature of the motor and of the PCB will keep the drift sensitivity under control.

The maximum speed is achieved when using triangular waveforms with 50% of duty cycle. If the signal has a different duty cycle (sawtooth) the maximum achievable speed is lower and determined by the slew rate. Max power bandwidth is measured with a 20 Vpp sinewaves when the output swing drops off -3 dB on the Y axis.

Drive Electronics

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

Item #	Value
Full Scan Bandwidth[d]	100 Hz Square wave, 250 Hz Sine wave 175 Hz Sawtooth 175 Hz Triangular
Small Angle (±0.2°) Bandwidth[e]	Typically, 1 kHz with Sine wave
Small Angle Step Response	300 µs
Power Supply	± 15 V to ± 18 V DC (1.25 A rms, 5 A peak MAX)
Analog Signal Input Resistance	20 kΩ ±1% (Differential Input)
Position Signal Output Resistance	1 kΩ ±1%
Analog Position Signal Input Range	±10 V
Mechanical Position Signal Input Scale Factor	switchable: 0.5 V/°, 0.8 V/° or 1.0 V/°
Mechanical Position Signal Output Scale Factor	0.5 V/°
Operating Temperature Range	0 - 40 °C
Servo Board Size (L x W x H)	85 mm × 74 mm × 44 mm (3.35" x 2.9" x 1.73")

6.1 Associated Products

Item #	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
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

[d] *Using heatsink to keep temp <50 °C (see section 3.3.2)*
[e] *Using heatsink to keep temp <50 °C (see section 3.3.2)*

Chapter 7 Calculating the Power Dissipation

7.1 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 (2.2 Ω), 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 (0.15 A under all circumstances) and I_{q-} is the quiescent current drawn on the -ve rail (0.10 A 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.

Overheating can short the life of the motors or trip the thermal protection in the board.

7.1.1 Calculating the Required Thermal Conductivity

The ability of a heatsink to transfer heat to its surroundings is parameterized 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 maximum power the device being cooled will dissipate. For the motors it is desirable 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.

Chapter 8 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 Figure 28 below.

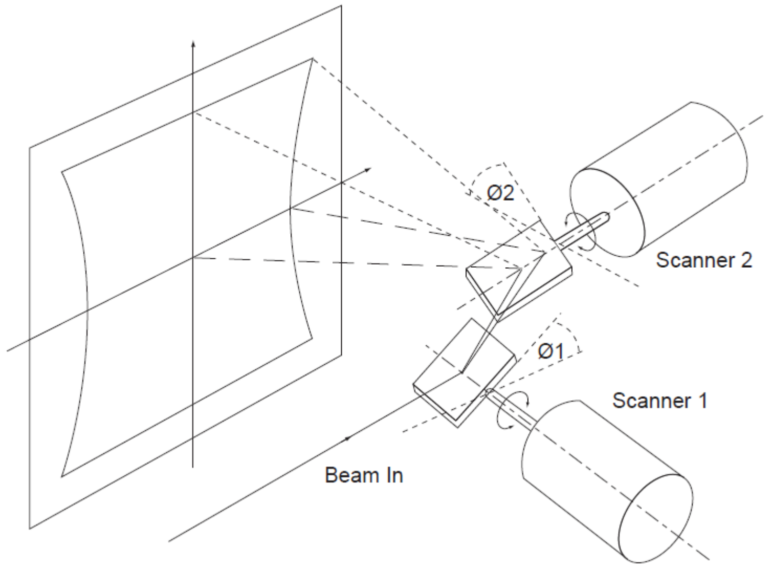


Figure 28 Field Distortion in a Two-way Mirror Deflection System

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 will result.

As a result, you will find the scanning field turns out to be a "pillow-shaped" image. Refer to Figure 29.

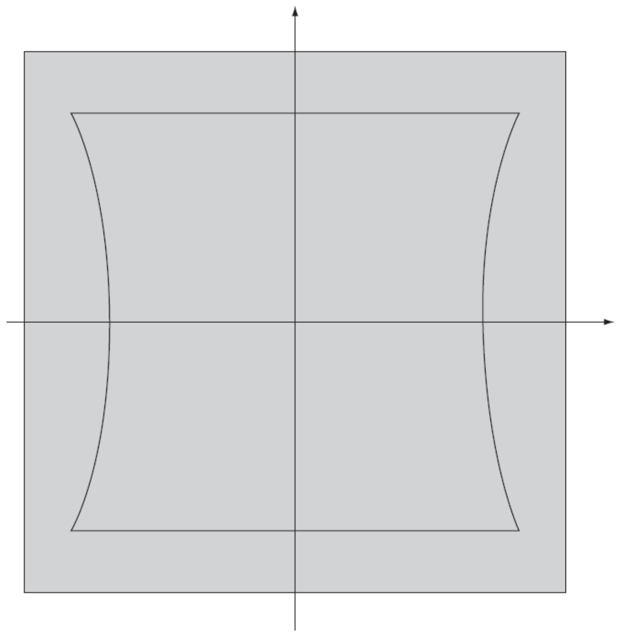


Figure 29 Pillow Shaped Field Distortion Caused by the Arrangement of Mirrors

Chapter 9 Certifications and Compliance

THORLABS
www.thorlabs.com

EU Declaration of Conformity

in accordance with EN ISO 17050-1:2010

We: Thorlabs Ltd.

Of: 204 Lancaster Way Business Park, Ely, CB6 3NX, UK

in accordance with the following Directive(s):

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

hereby declare that:

Model: **GVSM00X Series**

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

is/are 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

Authorised to compile the technical file: Thorlabs GmBH
Münchner Weg1, 85232 Bergkirchen, Deutschland

EN 61326-1	Electrical Equipment for Measurement, Control and Laboratory Use - EMC Requirements	2013
EN 63000	Technical documentation for the assessment of electrical and electronic products with respect to the restriction of hazardous substances	2018

and which, issued under the sole responsibility of Thorlabs, is/are 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:* 22 January 2014

Name: Keith Dhese

Position: General Manager *EDC - GVSM00X Series -2014-01-22*

CE

Chapter 10 Thorlabs Worldwide Contacts

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

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