MPower Motors
User's Manual

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Revision A

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1 IMPORTANT INFORMATION

1.1 ESD WARNING

The OEM electronics that *General Scanning* manufactures - including scanner motors and servo drivers - are electrostatic discharge (ESD) sensitive. Improper handling could therefore damage these electronics. *General Scanning* has implemented procedures and precautions for handling these devices and we encourage our customers to do the same. Upon receiving your components, you should note that it is packaged in an ESD-protected container with the appropriate ESD warning labels. The equipment should remain sealed until the user is located at a proper static control station*.

Note: Any equipment returned to the factory must be shipped in anti-static packaging.

(*) A proper static control station **should** include:

1. A soft grounded conductive tabletop or grounded conductive mat on the tabletop.
2. A grounded wrist strap with the appropriate (1 Meg) series resistor connected to the tabletop mat and ground.
3. An adequate earth ground connection such as a water pipe or AC ground.
4. Conductive bags, trays, totes, racks or other containers used for storage.
5. Properly grounded power tools.
6. Personnel handling ESD items should wear ESD protective garments and ground straps.

1.2 Warranty Information

The Customer shall examine each shipment within 10 days of receipt and inform General Scanning of any shortage or damage. If no discrepancies are reported, General Scanning shall assume the shipment was delivered complete and defect free. General Scanning warrantees products against defects up to 1 year from manufacture date, barring unauthorized modifications or misuse. Repaired product is warranted 90 days after the repair is made, or one year after manufacture date - whichever is longer.
Contact Customer Service to obtain a Return Materials Authorization number *before returning any product for repair*.
All orders are subject to the General Scanning Terms and Conditions and Limited Warranty. Visit our website for the latest version of these documents and other useful information.

IMPORTANT: Optical Scanners are normally tuned, serialized and warranted as a matched set for optimized performance. Mismatched components negatively affect performance and void the warranty. A matched set typically consists of galvanometer motor, mirror load, electronic driver board and interface cable.

1.3 Customer Support

General Scanning has support services to address your questions or concerns with either the product or manual you are using. Before calling for assistance, be sure to refer to any appropriate sections in the manual that may answer your questions. Call General Scanning's Customer Service Department Monday through Friday between 8 A.M. and 5 P.M. local time (GMT –05:00 Eastern Time (US & Canada)).

The customer service personnel will be able to give you direct assistance and answers to your questions.

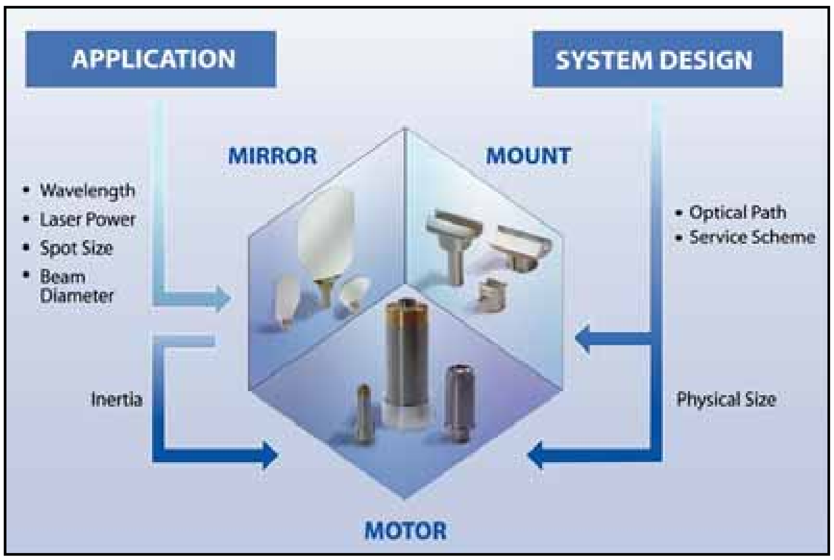
2 INTRODUCTION

2.1 Overview

General Scanning invented the optical scanner over thirty years ago. Since that time, we have been improving and refining our designs. Now, we have achieved another breakthrough in motor design that will enable higher performance and greater throughput for your applications. We call it the MPower Motor design strategy.

A scanner is not simply a motorized mirror, it is a complex system whose performance can only be optimized when all of the inertial elements, the motor, the mount and the mirror, are designed and tested as an integrated working unit.

With the MPower Motor strategy, there is no need to search for the best combination of mirror, mount and motor, because we've done all the testing and analysis for you.



High Performance Laser Quality Mirrors

MPower Motor selection begins with the component that is closest to your application, the mirror. Considerations such as wavelength, power, beam diameter and spot size will dictate the best mirror for your application.

Low inertia is essential for beam-steering mirrors to attain the highest accelerations, while high stiffness is needed to achieve adequate servo bandwidth. The reality, however, is that a balance must be struck between adequate stiffness and acceptable inertia. That means selecting the best alternative from a large array of mirror designs, or creating a custom mirror that matches your performance requirements.

In our thirty years of industry leadership, General Scanning has developed both. We have a complete line of optimized mirror designs in a clear aperture range of 4mm to 50mm.We also offer innovative mirror designs based on Beryllium and Silicon-Carbide substrates to achieve the highest stiffness-to-inertia ratio. And of course, we offer a custom mirror design capability to OEM customers.

Another patent-pending innovation from General Scanning is the high-power mirror. This mirror design is intended for use in applications with beam power levels up to 10 times higher than conventional laser mirrors. Most importantly, this design does not require active cooling. Regardless of your application requirements, the chances are we have the ideal mirror.

Innovative Mirror Mounting Designs

Once the mirror for the MPower Motor has been selected, mounting options can be considered. For example, does the optical path require a special mirror orientation? Should the mounting scheme accommodate mirror replacement in the field?

General Scanning has developed several innovative mirror mounting designs for outstanding performance and flexibility. Options include direct mounting to the rotor shaft, a sleeve-mount design, our patent-pending tapered-mount design, and an integrated mirror-mount design. All of these configurations will provide you with the best balance of low inertia and high mechanical stiffness.

Optimized Motor Designs

The last aspect of our MPower Motor concept is the motor itself. The power transfer path in an optical scanner motor flows from the motor's stator to the rotor (Motor Efficiency) and from rotor to the load (Inertia Matching & mounting scheme).The ideal design combines a compact, high efficiency stator design and a rigid, low-inertia rotor-mount-mirror assembly.

Another important consideration is power transfer losses that are converted to heat. This heat must then be conducted to the case of the motor so it can be dissipated before the motor is overheated and damaged.

General Scanning's family of 4th-generation motors was designed with optimized coil winding and forming techniques to improve both motor efficiency (power transfer to the rotor) and heat transfer (coil-to-case conductivity).This optimization also provides the best balance of torque and response-time.

The MPower Motor Advantage

Increasing a scanner's performance, while reducing its power requirement in rapid motion applications, demands a motor solution with the lowest total inertia (rotor inertia + load inertia). But optimal performance, or power transfer from rotor to load, can only occur when the load inertia and the rotor inertia are similar. As a result, an efficient motor by itself does not insure optimal performance, but matching the motor to the load does. And that is what the MPower Motor strategy is all about. General Scanning's wide variety of integrated MPower Motor solutions is sure to provide you with the best performance* for your application.

* MPower Motors perform best when coupled with General Scanning's analog or digital servo drivers.

2.2 Configurations

The MPower Motors are designed to work with either the Miniature Single Axis (MiniSAX) servo driver or the dual axis Low-Noise Intelligent (LN-ISD) Servo Driver.

Each motor is recommended for use with specific mirrors sizes out of our selection of standard mirrors, or within a range of load inertias.

2.3 Accessories & Assemblies

Developer's Kits

An additional test / tuning kit may be purchased for each of General Scanning's drivers that will allow the user to customize the servo tuning for a specific application. These kits include a test interface board and serial interface to tuning software (where applicable). Please contact the sales representative in your area for additional information.

XY Open Heads

General Scanning is an experienced component as well as sub-assembly builder. Therefore, much thought has already been put into creating two-axis systems, where mirrors and XY galvo-blocks are designed to optimize performance per aperture, maximizing speed and reducing geometric distortions. Additional information is available through General Scanning's website www.gs-scanner.com

Please note that when using scanners in two axis configurations, some geometric phenomena, such as "pincushion effect" and "cosine distortion" will occur. (Refer to "7OM-1143 XY-Series Manual" for details).

3 MIRRORS AND LOADS

3.1 Standard Mirrors

For best results, we recommend using standard General Scanning mirrors when possible. General Scanning offers a line of mirrors designed specifically to optimize scanning performance and motor lifetime. All General Scanning's mirrors introduce a low inertia design (without compromising flatness or stiffness), which supports a variety of industry standard coatings.

Custom mirror coatings are available for OEM applications. Please contact the General Scanning Customer Service department for more information on available mirror coatings.

Table 1: Mirror Size and Scan Angles

Standard Mirrors (clear aperture)*	**Maximum Scan Angle****
20mm	±22º Optical
25mm	±15º Optical
28mm	±15º Optical
30mm	±20º Optical

(*) The above mirrors are supported by the MPM-20A motor.
High-power designs and larger aperture sizes are supported by the MPM-30A motor.

(**) Larger angular displacement will cause part of the beam to fall out of the mirror area.

General Scanning's mirrors are available in both performance-class (machined back) and value-class (slab) options to address your required price / performance needs.

3.2 Custom Loads

When designing a custom load, several factors must be considered. A common oversight is to disregard the adverse effect of an improperly balanced mirror / load. An unbalanced mirror / load can shorten the life span of the motor as it causes cross-axis excitation of the mirror-rotor assembly, leading to premature bearing failure. In the event that standard General Scanning mirrors do not meet your application's requirement, the following mirror design guidelines should be observed:

1) Mirror mass and inertia should be minimized
2) Mirror should be mounted as close as possible to the top bearing of the motor.
3) Mirror / load's center of gravity must be on the axis of rotation.
4) Principal axis of the mirror / load and mount must be aligned with the scanner axis as closely as possible.

3.3 Mirror Assembly Mounting

If the MPower Motor has already been mounted in an open frame XY bracket, this section does not apply. Do not remove or realign mirrors or mechanical stops as they have been set specifically at the factory to avoid mirror collision. If the mirror needs cleaning or is damaged please contact customer service to have the unit repaired.

If the MPower Motor is being used in single-axis or custom multi-axis systems, this section may apply if the entire motor can only be mounted in a specific orientation.

Before mounting the mirror assembly to the rotor shaft, or realigning the mirror position, it is advisable to find the motor's electrical zero position to create a reference position when it is used in a system.

Command the rotor to electrical zero by applying power and a 0 VDC command signal to the servo driver connected to the motor. This will cause the rotor to torque to its zero position as described above. **If the servo driver was factory tuned, it may be necessary to slightly de-tune the servo to avoid any destructive oscillations that may occur when the mirror is removed**. (See the servo driver user's manual for information on tuning.)
When mounting the mirror, take special precautions to prevent damage to the mirrors. If possible use latex gloves or finger cots, to avoid fingerprints on the mirror. It may be helpful to put a piece of tack-free tape over the mirror during any mounting procedures to guard against nicks and scratches. If the mirror does become dirty refer to the cleaning procedure in the following section.

3.3.1 Attaching Mirror Mounts To Motor

1) Clean the motor shaft end inside and out with acetone using cotton or foam swabs.
2) Clean the mirror mount with acetone and inspect for any foreign matter or epoxy that may have become attached to the taper surface during mirror bonding.
3) Place Shrink Ring on a tissue, hold it in place with a wooden stick and spray with freeze spray long past the point when frost forms on the ring.
4) Bring the shaft end of the scanner into the ring. If it does not fit, cool the ring more, with the scanner shaft holding down the ring.

5) Lift the scanner with the ring in place (a wooden tool may help here).

6) Position the mirror/mount assembly in place quickly and orient as required. Press the mirror into the tapered shaft end to seat it firmly (approximately 5 to 10 lbs. force).

7) The ring will start warming up and shrinking in size to grip the assembly.

8) The location of the shrink ring must be such that it is flush with the end of the rotor. (Nominal gap between the ring and the stop is 0.5 mm.) Adjust the ring position using a wooden tool or a plastic shim 0.5 mm thick.

9) Allow the ring and shaft end to warm up to room temperature. By the time the frost melted, the assembly is locked together and can be set aside.

3.3.2 Removing the Mirror Mount From The Motor

1) Hold the motor so the axis is horizontal and the mirror surface is facing away.

2) Direct the freeze spray onto the shrink ring and chill it until it becomes free.

3) Pull the mirror with mount out of the shaft taper; it may take some force to pull it out.

4) Remove the ring from the galvo while it is still free to move. If it is not free, apply more freeze spray.

5) Let all parts warm up to room temperature.

3.4 Mirror Mechanical Stops

The MPower Motors use an adjustable mechanical stop to limit the maximum angular excursion of the mirror. The stop is slipped around the outer diameter of the top motor body. Should the motor become unstable during operation, or be commanded to excessively large scan angles, the rotor tab will hit the stop, thus preventing the rotor from spinning all the way around. The stop design provides enough friction to keep the stop in place, yet still allows the user to adjust its position relative to the mirror and therefore adjust the maximum angular peak excursion of the mirror. The stop is required in two axis applications to prevent the mirrors of an XY system from crashing into each other. In single axis applications, the stop helps keep the position detector within the necessary range of operation, for proper servo control.

Mechanical stop insertion procedure:

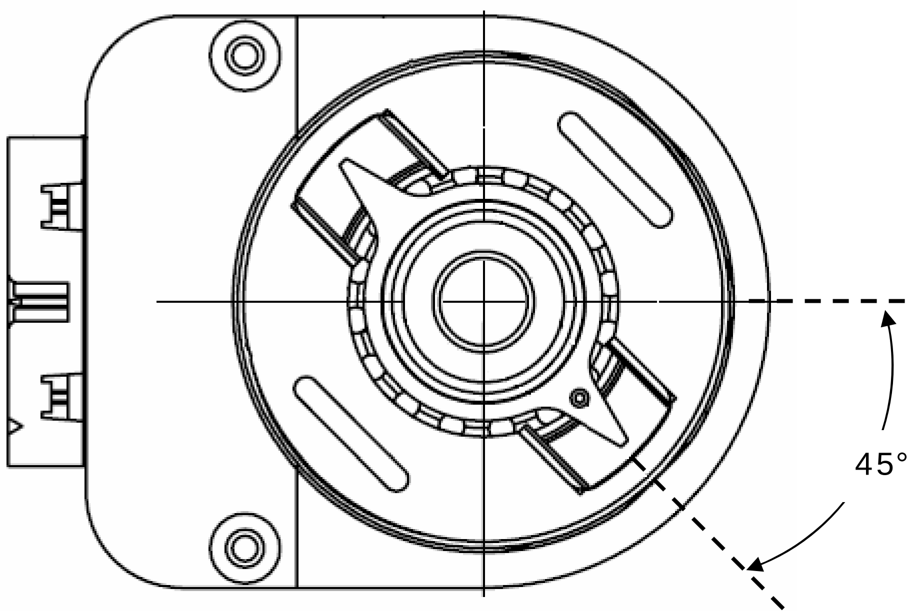
1) Remove the mirror and press the stop ring into the top of the motor so that it rests flush against the edge of the body. Be sure the ring sits as far down into the motor as possible.

2) Mount the mirror / load by carefully following the instructions in section 3.3.

3) To adjust the stop, insert a flat-head screwdriver into the slot and rotate clockwise or counterclockwise. The stop can be adjusted with or without the scanner enabled. It may be helpful to have the mirror in its zero or maximum deflection angle for reference. Recheck that the stop is still flush with the galvanometer and the mirror mount is not rubbing against it.

Stop-flag orientation:

For proper operation of the position detector, the mark on the stop flag should be positioned as shown below (see also Appendix A – "Principles of Operation"):



3.5 Mirror Cleaning/Maintenance

General Scanning does not recommend cleaning front surface mirrors. Mirrors damaged by cleaning are **not covered by the warranty**. The surface of these mirrors damage easily. It is difficult to prevent hard dust particles from being entrained in the process and causing scratches. In many cases, small defects in the mirror's surface may be less harmful than the surface damage resulting from continued cleaning. Cleaning requires special equipment typically not available to customers.

There are times, however, when cleaning the mirror becomes a necessity, e.g. stains such as fingerprints must be removed immediately to prevent permanent etching of the reflective surface. The information below includes general recommendations for those special occasions when mirrors must be cleaned.

- Remove lint from mirrors with a jet of low-pressure clean air or nitrogen. Blowing on front surface of mirrors with mouth, deposits moisture that may stain the finish.
- A thin overcoating of silicon monoxide protects most mirrors from oxidation. Like many optical coatings, it is easily damaged when attempts are made to clean the mirror surface with a dry tissue.
- The safest method of cleaning is to place a piece of lens tissue on the mirror surface and wet it with reagent grade (highly pure) alcohol or acetone (If you use acetone, take precautions regarding possible health and fire hazards). Grasp an overhanging corner of the tissue and gently agitate it several times, then slide the tissue off. This should remove the problem blemishes.
- If the mirror surface is still contaminated, use a highly pure solvent such as alcohol or acetone and generously wet the mirror surface with a sterile cotton swab or lens tissue. Gently wipe the dirty areas. Turn your cotton swab or tissue with each stroke so that a clean area is exposed.

4 GALVO MOUNTING CONSIDERATIONS

When designing a motor mount, the following aspects should be considered –

4.1 Mechanical

Rigidity of the mounting surface is important in minimizing vibrations and unwanted oscillations or beam movement. Rigidity becomes even more critical when operating the motor with high inertial loads. Sources of structural vibration should be investigated so that they do not include significant relative displacement between the motor and the target.

Clamping force on the motor should be tight enough to prevent the motor from moving or turning within the mounting hole. Excessive or uneven (pinching) clamping force may induce stress on the ball bearings of the motor, thus hindering performance and significantly reducing the lifetime of the motor.

4.2 Electrical

The position detector of the MPower Motor is electrically isolated from the motor body. Performance testing of the MPower Motor has verified minimum electrical noise to exist on the position signal when the body of the motor is well grounded to servo driver ground. Therefore to achieve optimum performance, the motors must be in good electrical contact with the servo driver ground. This may be done through the mount fixture or additional ground cabling between the scanner and servo.

4.3 Thermal

4.3.1 Heatsinking

In most vector applications, power dissipation in the motor is minimal, and therefore the motor requires little heat sinking. In raster or other high duty cycle applications, optimum heat sinking is desired to maximize the scan frequency and prevent damage to the motor caused by overheating. When mounting a MPower Motor in your system, the thermal relationship between the motor and its environment should be considered.

Caution: Insufficient heat sinking can cause irreparable damage to the motor. The internal temperature of the motor should never exceed 100ºC. When using a static heatsink, this corresponds to an external case temperature of 70°C.

To maximize heat flow from the motor case to the heat sink, the surface area of the mount should contact as much of the motor as possible. Surface finishes should not exceed 0.8um or 32 microinches in roughness. If the mounting surface is too rough thermal grease between the two surfaces should be used.

4.3.2 Thermal Control

The MPower Motors construction does not include thermal sensor, hence thermal control of these motors is not available.

4.3.3 Cooling Options

There is an optional Water Cooling sleeve available for the MPower Motors. Call your region's sales manager for details.

5 APPLICATION NOTES

5.1 Galvo Motor Lifetime

Galvo motor lifetime will vary depending on many conditions, and is limited in most cases by bearing wear. Environment, command waveform, load inertia, load balance, and required resolution among other things will all play a role in dictating the number of usable cycles. Although difficult to predict, experience has provided us with some basic guidelines that can help the user maximize motor lifetime.

Maximum lifetime of the MPower Motors *will be achieved if:*

a. The motor is operated so that it makes random moves over the full scan field. Commanding repetitive, small angle rotations of any ball bearing device will likely lower the usable lifetime because bearing lubrication is not adequately distributed.
b. Mirror / load inertia and mass are minimized.
c. Large signal commands are structured to limit acceleration and cross-axis wobble.
d. Storage and operation are in a low humidity, dust free environment. The output shaft should not be cleaned with solvents that could flow into the bearings and remove lubrication.

5.2 Command Waveforms

To avoid unnecessary stresses to the motor structure, as well as improving performance, it is recommended that structured waveforms be used when running the scanner at higher frequencies and wider angles to limit the galvanometer's acceleration needs. This includes rounding the corners on triangular waveforms, creating sinusoidal retraces on saw tooth waveforms and micro-vectoring large step signals.

Structuring the command waveform will help reducing cross axis resonance (minimizing wobble), thus improving performance and increasing scanner longevity.

5.3 Maximal Angle

The MPower motors are equipped with a mechanical stop that prevents the motor from exceeding its maximal allowable angle. The standard stop allows ±30º (optical) of rotation, and should not be adjusted more then 10º from the original zero position, to ensure the position detector is within its linear active range.

APPENDIX A: PRINCIPALS OF OPERATION

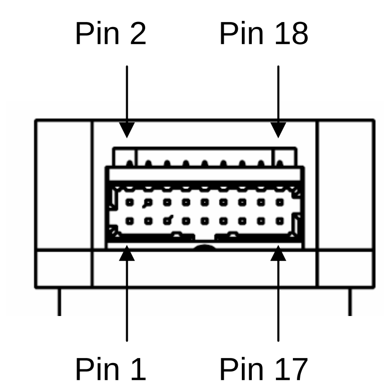
A.1 General Characteristics

General Scanning's MPower Motors are enabled for servo control using an advanced optical detector summarized by the following characteristics:

- High current transfer ratios (up to 3 times higher than industry standards), giving superior signal to noise ratios.
- Efficient LED and excellent thermal properties of the design allow the LED to be run at 50ma with an expected lifetime of greater than 12 years.
- Very linear over a range of ±22º mechanical.
- Typical Common Mode Current is 0.8mA.
- Typical sensitivity is equal to 53µA/Degree (3.06mA/Radian).

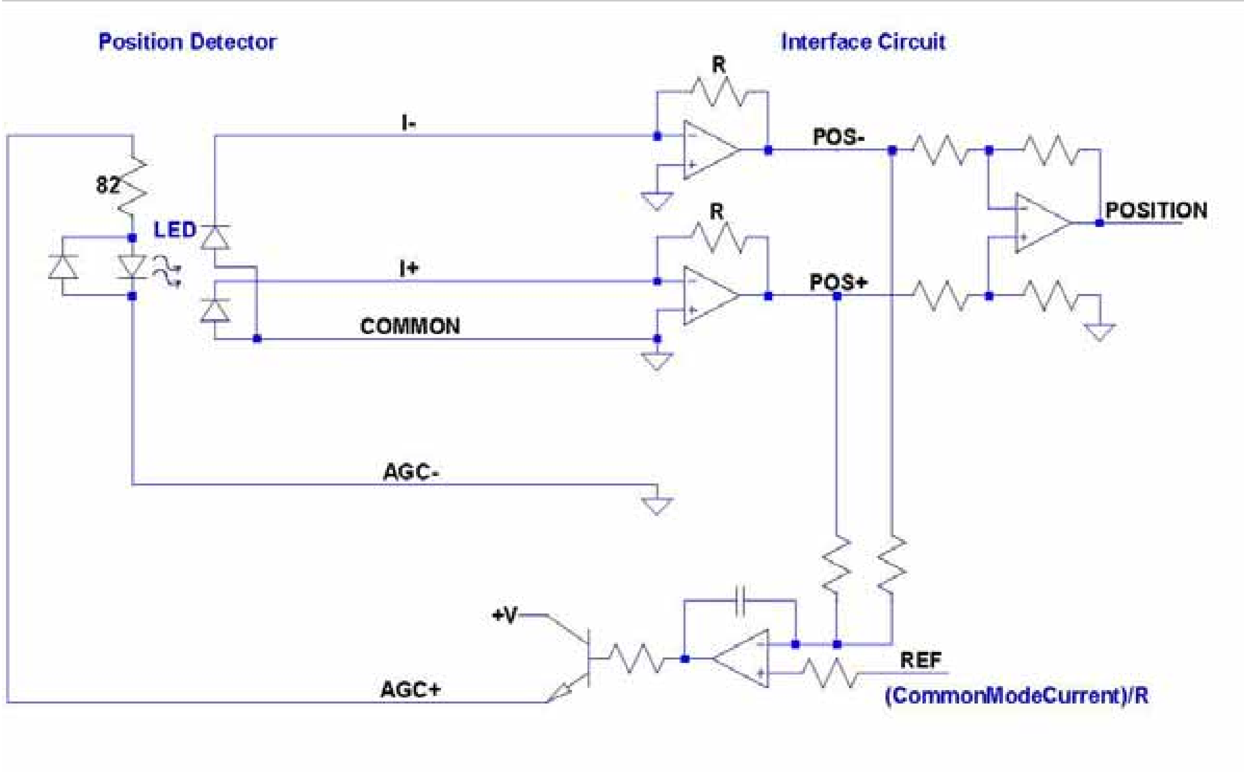
A.2 Connector Pinout

Pin #	Signal
1	I +
2	I -
3	COM
4	Shield
5	AGC +
6	AGC -
7	Not Used
8	Not Used
9	Not Used
10	Not Used
11	Motor Coil 0 [+]
12	Motor Coil 0 [-]
13	Motor Coil 0 [+]
14	Motor Coil 0 [-]
15	Motor Coil 1 [+]
16	Motor Coil 1 [-]
17	Motor Coil 1 [+]
18	Motor Coil 1 [-]



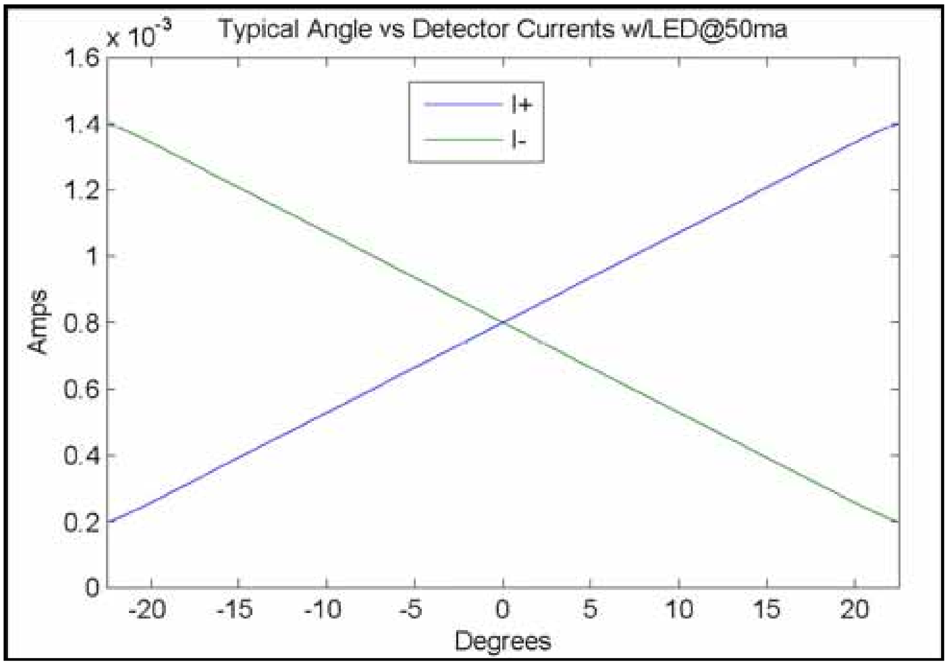
A.3 Detection Circuit

The position of the rotor indicated by the detector is equal to ((I+)-(I-))/((I+)+(I-)). If the denominator is held at a constant level, the division operation is not necessary as shown in the following simplified circuit:



The integrator controlling the **AGC+** voltage will integrate the difference between ((**POS+**)+(**POS-**)) and **REF** so that the difference approaches zero. **REF** should be set to the desired Common Mode Current divided by **R**. The Common Mode Current is defined as the average current for **I+** and **I-**. The sensitivity is defined by how much the differential current changes with respect to angle.

For the example shown on the following page, the Common Mode Current is 0.8mA. The resulting sensitivity is equal to 1.2mA/22.5 degrees or 53µAmp/degree (3.06mAmp/Radian).



A current limiting resistor and protection diode inside the position detector ensure that the diode cannot be damaged by transient events, faulty cables, or malfunctioning interface circuits.

A.4 Cabling and Grounding

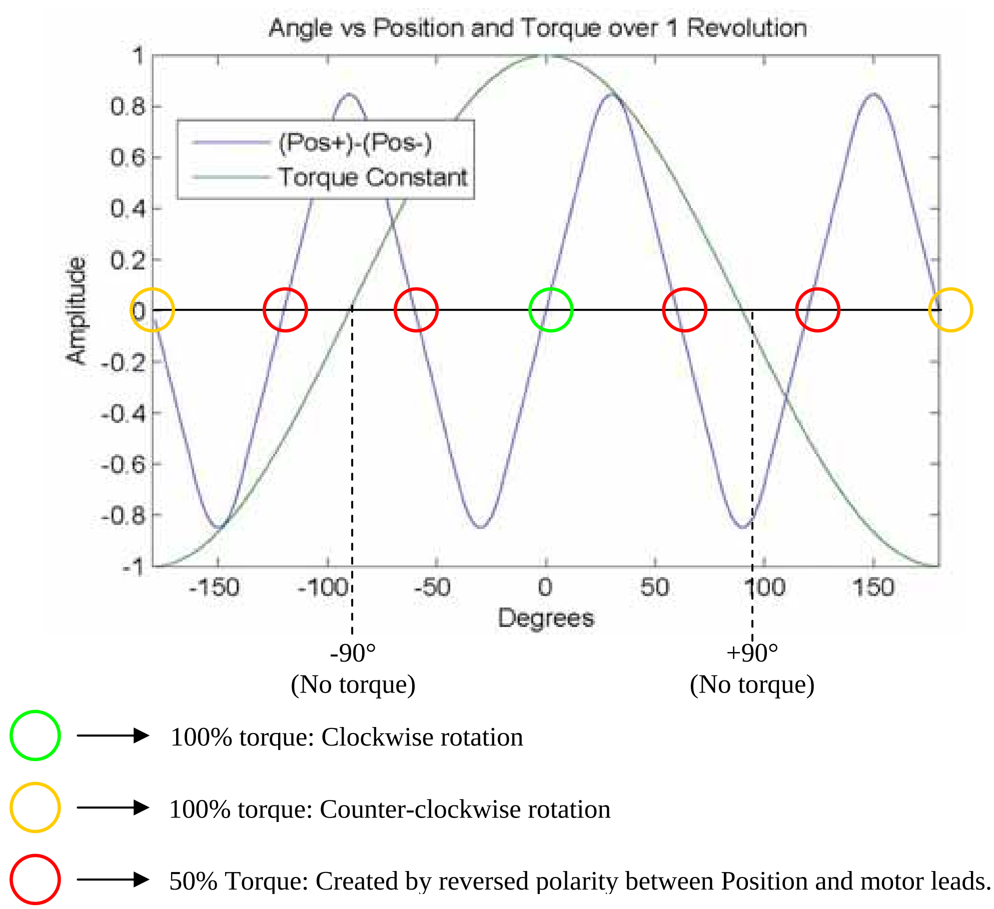
To minimize noise in the system, twisted pairs are recommended for the **I+ / I-, AGC+ / AGC-,** and **Motor+ /Motor-** signals. The Motor cable shield should be terminated to the Shield wire on the motor Connector and / or Chassis. The AGC and Common / I signals should be shielded with a different shield, and terminated to either the Interface circuit Ground or Chassis.

A.5 Motor Winding Alignment

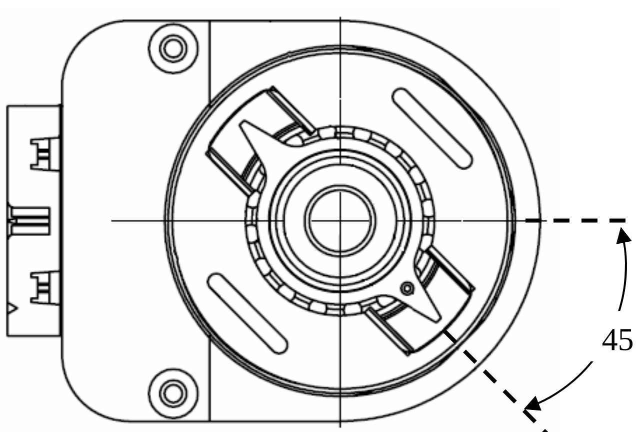
The motor is aligned such that the maximum torque is at the point where the currents from both detector set are equal. The motor will move clockwise with a positive voltage. If the stops are removed and the motor is moved to a position 180 degrees from zero, the motor will be stable since both the polarity of the EMF and the slope of the detector are inverted, but will operate in the reverse direction.

The correct orientation is set at manufacturing, and secured with the stop tab and ring

The Torque constant and Position signal for an entire revolution are shown in the following figure:



For proper operation of the position detector (100% torque: Clockwise rotation), the mark on the stop flag should be positioned as shown below:



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