User Manual

LM9, Standard Options, Revision A

Document Notice

This manual contains pertinent safety information for the proper integration, use, maintenance, and decommissioning of certain LM9 motion products provided by Griffin Motion, LLC. Please first verify the applicability of this manual to the equipment in use prior to following its guidance. If you have any questions, please contact a Griffin Motion representative.

Document Title: User Manual, LM9, Standard Options
Document Number: 37668
Current Revision: A
Revision Date: 16 October, 2024

This manual is subject to change without notice and is superseded by any new revision. All previous and current revisions of this manual may be made available upon request.

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Copyright Information

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2 SCOPE

This manual covers a wide range of products under the "LM9" designation. To keep the manual concise, most illustrations and figures depict a standard configuration (Griffin Motion Part Number: LM9-300-LM-V-U-S-F-00) with features applicable across the entire product lineup. When significant deviations exist, notes or additional figures are included. If you have any questions about the information provided or its relevance to your product or requirements, please contact Griffin Motion.

Griffin Motion continually improves its products and may update ordering options or make minor specification changes without notice. If you are a previous customer, refer to the documentation provided with your stage at the time of delivery for the most accurate reference.

2.1 INTENDED USE

This manual is intended for use by qualified technicians or experienced system integrators.

The LM9 series linear stages are designed for laboratory or light industrial applications. They operate best in temperature-controlled environments free of dirt, oil, and condensing moisture.

The primary function of the LM9 is to provide dynamic, high-precision positioning of externally mounted loads within its design limits. Typical applications include microscope inspection, laser processing, additive manufacturing, automatic dispensing, and general-purpose positioning. This manual provides safety guidance and installation procedures specific to the LM9's positioning capabilities, not its end-use applications.

In its standard configuration, the LM9 is designed to be mounted on a flat, horizontal surface. Some sub-models may also be suitable for vertical use—contact Griffin Motion for details.

For optimal safety, performance, and longevity, appropriate controls and cabling must be selected or manufactured. The LM9 is designed for integration into a control system for hands-free operation. Simply following the hazard and caution notices in this manual may not be sufficient to meet regulatory requirements for your specific application.

For questions regarding controls or cabling, please contact Griffin Motion.

2.2 HAZARDS AND WARNINGS

This manual provides instructions for the safe installation, operation, and maintenance of the LM9 stage. Users must strictly follow the guidelines outlined in this manual and conduct risk assessments for applications not specifically covered. If any information is unclear, please contact Griffin Motion.

Below is a list of identified safety hazards for both users and the LM9 stage. While this manual offers guidance on these hazards, it may not fully address the risks associated with specific applications. Users are responsible for conducting a risk assessment based on the intended application and ensuring compliance with applicable local safety standards.

Specific hazardous locations on the stage are shown in Section 3.4.2.

DANGER: This product may contain potentially harmful voltages. To reduce the risk of shock to a human operator, the following precautions must be followed:

1. The associated controls and cables must be fully de-energized before connecting to the LM9.
2. De-energize and disconnect power sources before servicing.
3. Use an appropriate grounding scheme to preclude accidental shock during fault conditions.
4. Install a control system that can detect fault voltages and raise alarm.
5. Where the potential for human contact is expected during operation, install additional non-conductive safety guards or power interruption equipment (ex. sensor curtain) to de-energize the equipment as required.
6. Create and post operating instructions and warning labels on the final equipment.

DANGER: This product contains crushing and shearing hazards. To reduce the risk of crushing or shearing, the following precautions must be followed:

1. Install equipment as outlined in the Mechanical Installation chapter.
2. Where potential for touching is expected during operation, consider additional protection such as:
   a. Install additional warning labels.
   b. Install additional guards or enclose the equipment.
   c. Install a power interruption system (ex. sensor curtain) to de-energize the equipment.
3. Consider lowering motor current limits as low as is practicable for your application.
4. Create and post operating instructions and warning labels on the final equipment.

Attention: This product may produce potentially hazardous temperatures. To reduce the risk of burns to a human operator, the following precautions must be followed:

1. Where potential for touching is expected during operation, consider additional protection such as:
   a. Install temperature warning signs on motor housings.
   b. Install temperature monitoring equipment or additional thermal guards.
2. Consider lowering motor current limits as low as is practicable for your application.
3. Create and post operating instructions and warning labels on the final equipment.

CAUTION: This product may emit electromagnetic radiation. To reduce the risk of interference with other electrical equipment, the following guidance may apply:

1. Assess the motor amplifier topology in your control system.
2. Construct shielded motor and feedback cables as outlined in Section 5.6.
3. Create RF shields for any other sensitive equipment in the vicinity of the stage.
4. Contain final equipment in RF conducting meshes or enclosures.
5. Utilize filters, transformers, or other impedance equipment to mitigate radiation from power sources as outlined in the manual of the associated controller.

ATTENTION: This product may emit uncomfortable noise levels depending on how it is operated. To reduce the discomfort level due to radiated noise, the following guidance may apply:

1. Change the motor amplifier topology.
2. Re-tune the current control loop gains in the amplifier.
3. Isolate the equipment with a sound barrier.
4. Turn off machines that are not required to be in operation.
5. Limit the amount of time the operator is in the vicinity of the equipment.

ATTENTION: This product is intended to be incorporated as part of a complete control system; some, but not all, of the key operating factors are listed:

1. Warn the user of abnormal machine operation.
2. Remove power to the machine when an unsafe condition exists.
3. Arrest or halt motion as required.
4. Prevent unexpected start-up or motion.

3 PRODUCT OVERVIEW

The LM9 is the largest linear stage (as of 2024) in the Griffin Motion product lineup. As standard, it is based around an ironless DC linear motor, profile rails, and linear encoder. Side seals also come as standard. The LM9 can be stacked at the factory to create XY motion. Full cable management is available for stacked systems.

3.1 ORDERING OPTIONS

The LM9 can be ordered in many different standard configurations. Standard ordering options and the most common custom ordering options are shown below in Table 1:

Table 1. LM9 Ordering Options

Example Part Number: LM9-300-LM-V-U-S-F-00							
Product Series	Nominal Stage Travel (mm)	Drive Technology	Motor Type	Encoder Type	Precision Level	Additional Features	Custom Features
LM9	300, 400, 500, 600, 800, 1000	LM- Linear Motor	V- Ironless Linear BLDC, 300V Winding	U-Linear Sinusoidal (1Vpp), 40µm Signal Period	S- Standard, 1.0µm Bi-Directional Repeatability	0- No Additional Options	00- No Custom Features
				CC- Linear Quadrature (RS422), 0.1µm	P- High Precision, 0.5µm Bi-Directional Repeatability	F-Silicone Side Seals	01-99: Custom Feature Designation

Supplemental to Table 1, Table 2 is provided to explain the ordering options in further detail:

Table 2. LM9 Ordering Guide

Product Series	With a 280mm width, the LM9 is the widest profile linear stage (as of 2024) in Griffin Motion's product lineup. It is intended for payloads that may be too heavy for smaller profile stages such as the LM3 or LM7.
Nominal Stage Travel	Nominal travel indicates the distance between limit switches. The limit switch locations may be altered at the factory to shorten the nominal travel. This change will be reflected in the "Custom Features" designation, rather than the "Nominal Stage Travel" value. For example, an LM9-500 shortened to 425mm of travel may be designated "LM9-500-LM-V-U-S-F-01" rather than "LM9-425-LM-V-U-S-F-00". Travels longer than 1000mm are not currently available due to manufacturing constraints.
Drive Technology	At the time of this document's creation, ballscrew-driven variants of the LM9 are not available. Contact Griffin Motion if a ballscrew variant of the LM9 would be desirable for your application.
Motor Type	Other ironless linear motor winding offerings may be available upon request. The motor may be driven at less than 300V, but may be force or velocity-limited.
Encoder Type	The sinusoidal encoder may be interpolated to similar or higher resolutions than the quadrature encoder within controls. They may also be more susceptible to signal interference. Top speed of the "U" sinusoidal encoder is often limited by the control electronics connected to it. Quadrature encoders are recommended for many laser applications, as many controls require square wave signals for position-based event triggers. The "CC" Quadrature encoders are more resistant to electrical noise but are limited to 900 mm/s. Other encoder options (like absolute encoders) may be available (as a custom feature) upon request.
Precision Level	Standard precision is used for a majority of LM9 applications. Before purchasing the high-precision "P" LM9, the application should be carefully considered to ensure that the additional performance and cost are justified. Contact Griffin Motion for assistance with the evaluation. Other specifications such as accuracy, pitch, yaw, straightness, and flatness may also be improved by purchasing the "P" variant of the LM9.

Additional Features	Side seals are recommended for most applications. Cleanroom applications may not require them.
Custom Features	Common custom features include cleanroom preparation, custom nominal travel, and additional holes. A custom part number may also be applied if the stage if it is intended to be used as part of an X-Y stacked system.

3.2 ENVIRONMENTAL SPECIFICATIONS

To prevent damage to the LM9 stage, the specifications in Table 3 must be adhered to.

Table 3. Environmental Specifications

Ambient Temperature (Operating)	Indoor controlled temperature environment between 17˚C to 27˚C. Positioning performance only tested at 20°C, will vary at different temperatures.
Ambient Temperature (Non-Operating)	Indoor long-term exposure to temperatures between 10˚C and 35˚C in original packaging.
Humidity	15% to 85% relative humidity, non-condensing
Altitude	0ft to 6000ft above sea level
Vibration	Low Vibration Environment
Protection Rating	IP00
Use	Partly assembled machine intended for indoor use, properly integrated as part of a control system; no direct contact expected while in operation. Used by a trained operator or integrator.

Every LM9 is machined, assembled, and tested at or around 20°C, and is intended to be used at the same temperature. As the stage has a multi-metal construction, thermal conditions will directly impact the positioning performance of the stage.

While the available side seals assist with preventing moisture and particulate ingress, the LM9 is not tested or rated to any IEC Ingress Protection ratings.

3.3 BASIC SPECIFICATIONS

The specifications contained in Table 4 pertain to standard LM9 configurations with the standard “S” precision grade (as shown in Table 1). All accuracy, repeatability, pitch, and yaw specifications are measured for each stage via laser interferometer, with the retroreflector mounted 30-50mm above the surface of the LM9 tooling plate (shown in 3.4.1). Accuracy, pitch, and yaw values are defined to be “zero” at the stage’s center position; the specified values indicate the total indicator reading or “TIR” measurement. Test reports for a stage’s accuracy, repeatability, pitch, and yaw are provided with each LM9 stage.

Straightness and flatness are (optionally) measured as defined by Renishaw White Paper TE325, as “fixed reflector” measurements, with endpoints fitted. Flatness does not indicate running parallelism with the bottom surface of the stage. Straightness does not indicate running parallelism with the sides of the stage base. Additional charges may apply to certify straightness and flatness measurements.

Each LM9 is tested while affixed to a metrology-grade granite table, in a thermally stable room at 20°C. To achieve similar precision, the LM9 should be used in similar conditions. Mounting surface flatness requirements are specified in 4.2.1.

Table 4. LM9 General Specifications

Nominal Stage Travel (mm)	300	400	500	600	800	1000
Mechanical Accuracy (µm)[1]	±8.0	±10.0	±12.0	±14.0	±16.0	±18.0
Calibrated Accuracy (µm)[2]	±2.0					
Bi-Directional Repeatability (µm)[1]	±1.0					
Maximum Velocity (mm/s)	2,000 (“U” Encoder), 900 (“CC” Encoder)					
Continuous Motor Force, (N)	199					
Peak Motor Force (N)	990					
Maximum Load, Y Direction (N)[3]	1500					
Maximum Load, Z Direction(N)[3]	2000					
Maximum Moment About X (Nm)[3]	400					
Maximum Moment About Y (Nm)[3]	750					
Maximum Moment About Z (Nm)[3]	250					
Moving Mass (kg)	12.0					
Flatness (Z Motion) (µm)[3] Straightness (Y Motion) (µm)[3]	±3.0	±4.0	±5.0	±6.0	±8.0	±10.0
Pitch Motion (about Y) (arc-sec)[1 3] Yaw Motion (about Z) (arc-sec)[1 3]	±5.0	±6.0	±7.0	±9.0	±12.0	±15.0
Stage Mass (kg)	56.5	62.5	68.5	74.5	87	98.5

1. Specification is verified via laser interferometer for each stage as standard. Other specifications may be verified upon request.
2. Calibration must be performed and verified by Griffin Motion. Calibration is typically performed with simulated conditions of each application, which must be agreed upon before purchase.
3. See the coordinate convention below in Figure 1.

Figure 1 is provided below to define the coordinate convention of the LM9. The positive direction of motion is defined in 5.5.1.

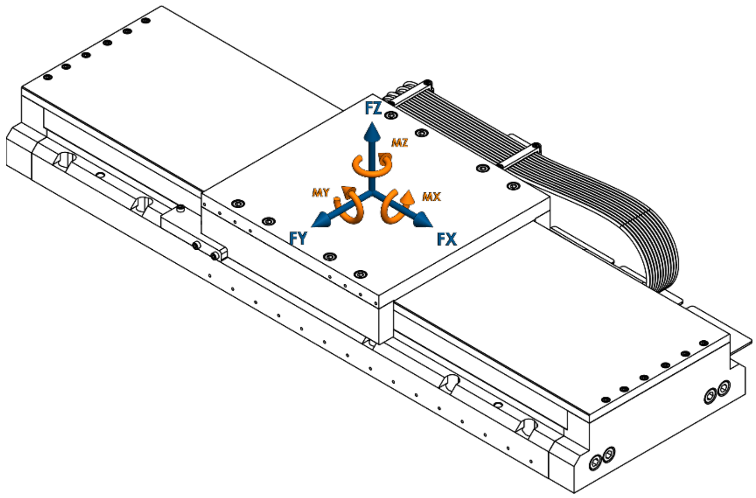


Figure 1. LM9 Coordinate Convention

3.4 PRODUCT VIEWS AND LABELS

Figure 2 identifies the major external components of the LM9. Stage travels above (but not including) 500mm will feature a cable track to support the Silicone Ribbon Cable.

3.4.1 GENERIC VIEW

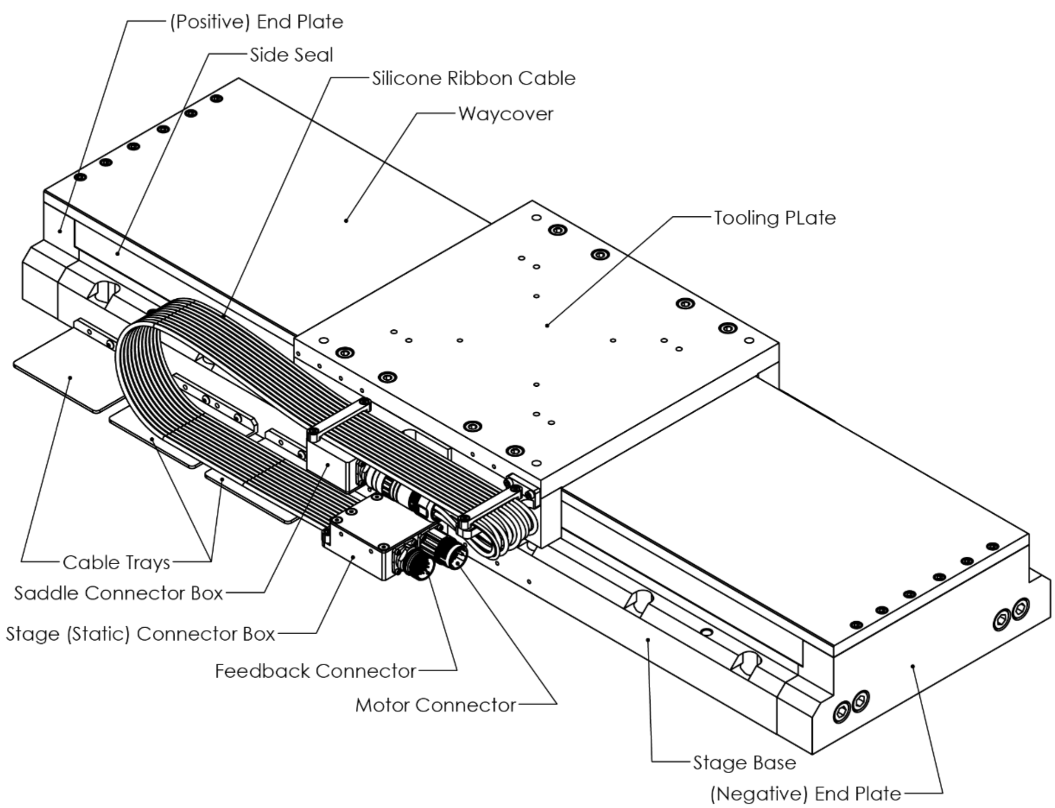


Figure 2. LM9 External Components

3.4.2 VIEW OF HAZARDS

As shown in Figure 3, the primary shearing hazard is located between the (static) connector box and the saddle connector box. During operation, the saddle connector will sweep about 36mm above the top of the static connector box below. Strategies to prevent injury due to shearing are described in 2.2.

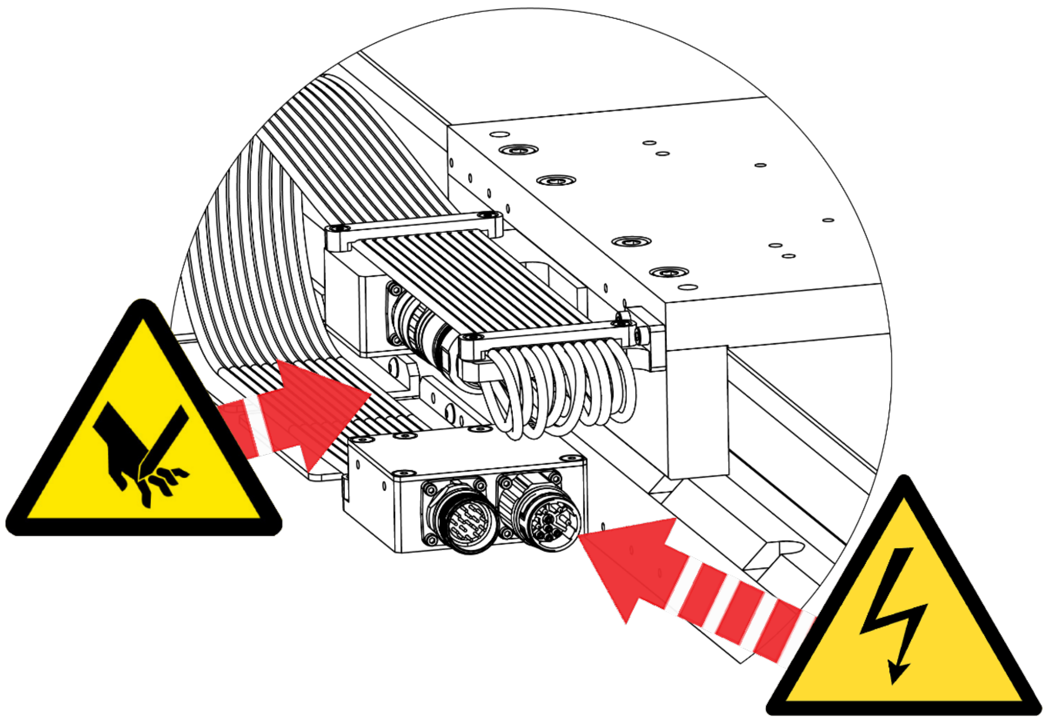


Figure 3. LM9 Shearing and Voltage Hazard Locations

Even while the stage is unplugged, harmful voltages may be present at the motor connector if the stage is manually pushed or "back driven". Strategies for safely back driving the stage are described in 5.4. Operators should be careful to keep fingers away from the motor connector unless the unplugged stage is impeded from moving.

3.5 GENERAL DIMENSIONS

This section aims to provide the critical user-facing dimensions of the LM9 stage. These include mounting holes, overall size, lifting points and tooling plate specifics. Other dimensions may be measured from the LM9 3D CAD models, which are available for download on the website. More detailed information, such as tolerances, may be available by contacting Griffin Motion.

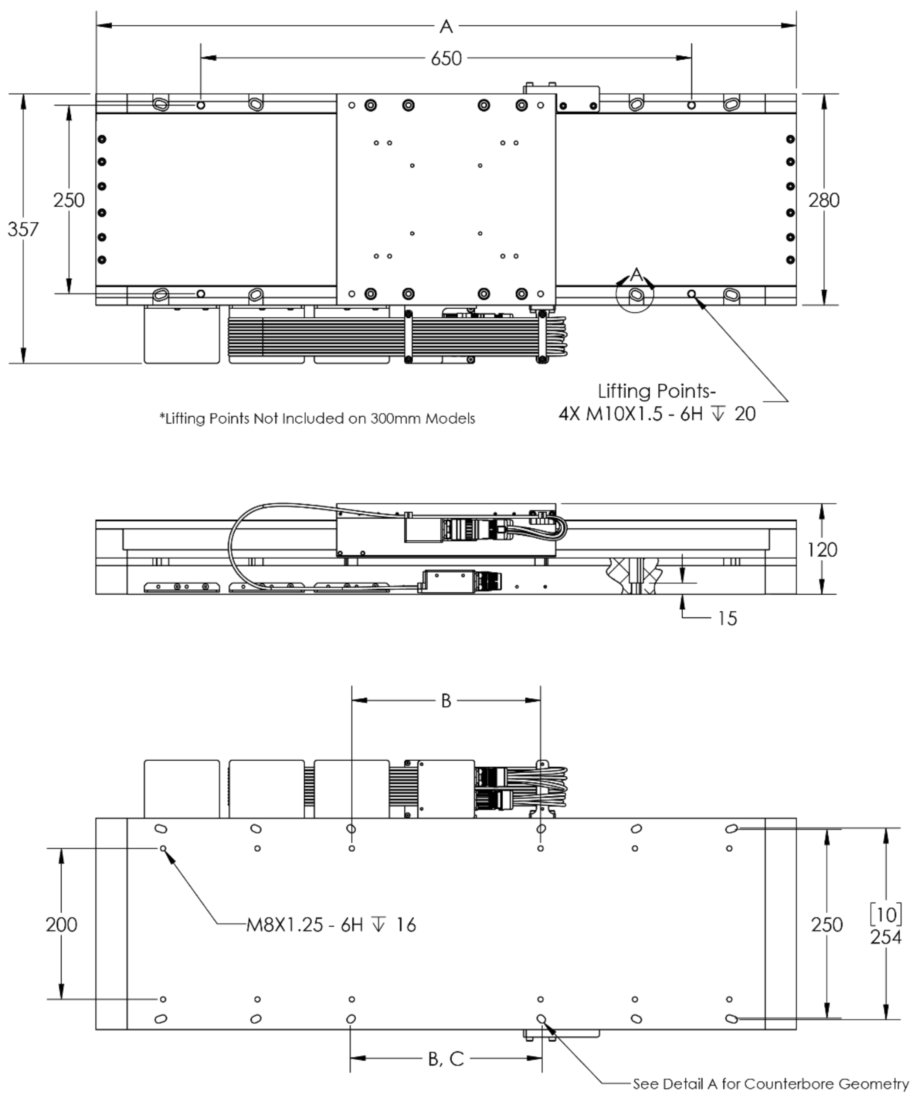


Figure 4. LM9 General Dimensions

Table 5. LM9 Stage Length and Mounting Hole Spacing

Stage	Dimension "A" (mm)	Metric Spacing "B" (mm)	Inch Spacing "C" (mm(in))
LM9-300	928	250, 500	254 (10), 508 (20)
LM9-400	1028	250, 500	254 (10), 508 (20)
LM9-500	1128	250, 500, 750	254 (10), 508 (20), 762 (30)
LM9-600	1228	250, 500, 750	254 (10), 508 (20), 762 (30)
LM9-800	1428	250, 500, 750, 1000	254 (10), 508 (20), 762 (30), 1016 (40)
LM9-1000	1628	250, 500, 750, 1000, 1250	254 (10), 508 (20), 762 (30), 1016 (40), 1270 (50)

As detailed above in Figure 4 and Table 5, each stage has mounting counterbores available at both metric and inch spacings. There are no “inch” or “metric” versions of the LM9, as all stages have both spacings. The geometry of these counterbores is detailed in Figure 5. These counterbores are intended to be used with either an M8 or 5/16” socket-head cap screws.

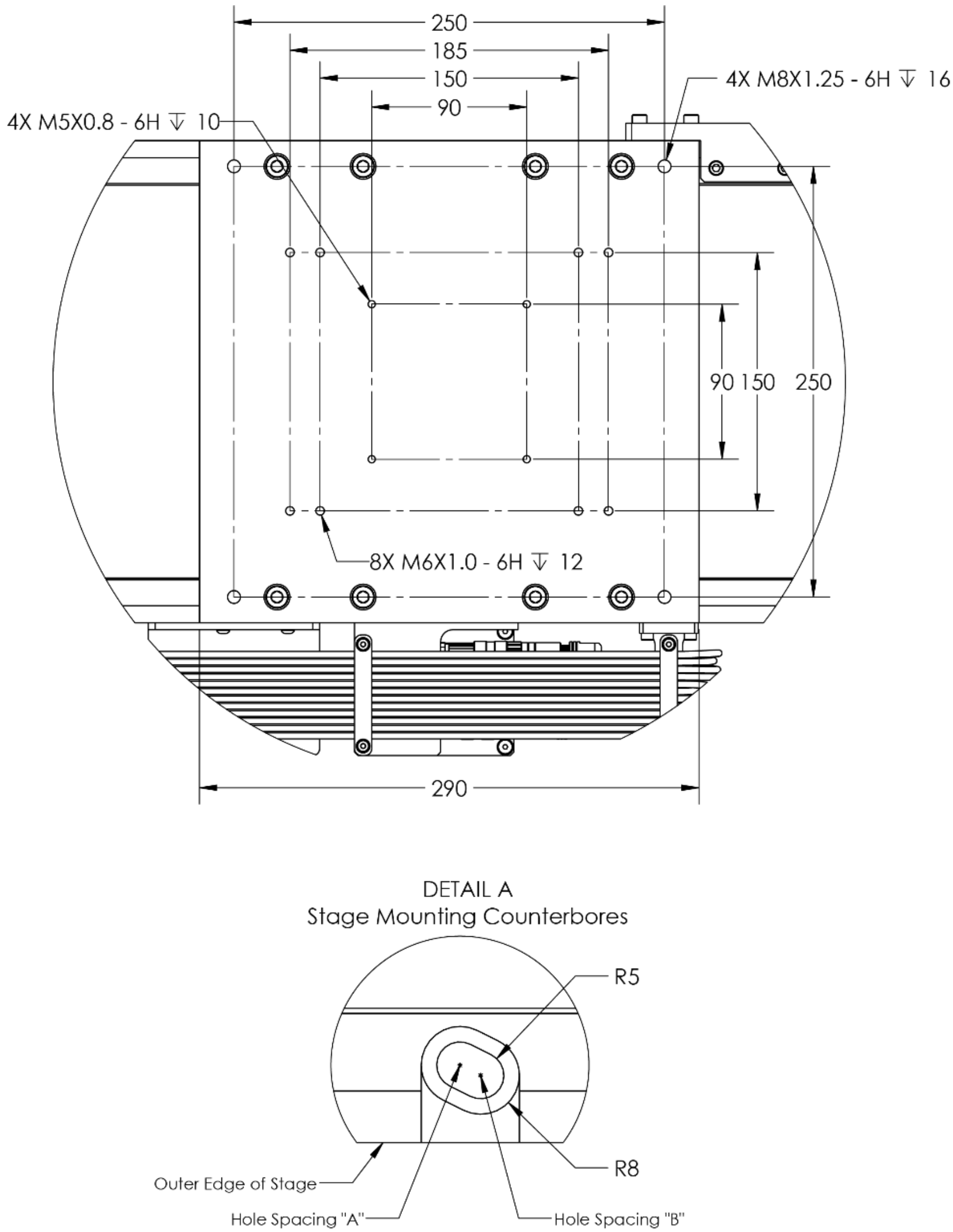


Figure 5. LM9 Tooling Plate and Counterbore Dimensions

3.6 ELECTRICAL SPECIFICATIONS

This section will provide all necessary electrical specifications required to determine compatibility and configure a servo drive to the LM9. If assistance is needed with drive selection or compatibility, contact Griffin Motion.

3.6.1 MOTOR SPECIFICATIONS

Table 6. LM9 Motor Specifications

Motor Type	3φ Brushless, Linear, DC
Maximum Continuous Current ($\boldsymbol{A_{pk}}$)	2.27
Peak Current ($\boldsymbol{A_{pk}}$)	11.3
Maximum Voltage ($\boldsymbol{V_{dc}}$)	300
Back EMF Constant ($\boldsymbol{V_{pk}/m/s}$)	101
Force Constant ($\boldsymbol{N/A_{pk}}$)	88
Electrical Time Constant ($\boldsymbol{ms}$)	1.8
Pin to Pin Resistance (Ω)	15.8
Pin to Pin Inductance ($\boldsymbol{mH}$)	28
Pole Pair Length (mm)	57 (N-N)
$\boldsymbol{A_{pk}}$ refers to Amperes-peak-of-sine which is the maximum current in one phase during the full electrical cycle.	

Please note that all motor current values are called out in Table 6 as peak-of-sine rather than RMS. Failure to distinguish between peak-of-sine and RMS may result in thermally unsafe motor conditions, which could cause motor failure. Equation 1 shows the relationship between peak-of-sine current and RMS current.

Equation 1. Peak-of-Sine to RMS Current Conversion

$$A_{pk} = \frac{A_{rms}}{\sqrt{2}}$$

3.6.2 FEEDBACK SPECIFICATIONS

Both standard encoder options, displayed in Table 7 and Table 8, are based around the same linear encoder platform and therefore produce similar positioning performance. The differences in the 2 encoders are based on the output signal types only.

Table 7. LM9 Feedback Specifications- "U" Encoder Option

Supply Voltage (V)	5.0±10%
Supply Current (mA)	250
Encoder Type	Incremental
Encoder Output	1Vpp Sin & Cos and Z, Differential Pairs
Encoder Signal Period	40µm Signal Period
Encoder Resolution	Determined by Controls Hardware
Hall Switch Output Type	CMOS
Hall Switch Output Current (mA)	±20.0
Limit Switch Output Type	CMOS
Limit Switch Output Current (mA)	±20.0
Index Pulse(s)	One, at the Center of Travel
Maximum Counting Rate (mm/s)	2,000
Over Temp Switch Output Type	CMOS

Over Temp Switch Output Current (mA)	±20.0

When using a 1Vpp (Sine and Cosine) encoder, like the "U" encoder detailed in Table 7, the 40µm signal period must be divided into encoder counts within the servo drive. At a minimum, this signal must be divided 4x to achieve a resolution of 10µm. This is referred to as 1x interpolation. In some scenarios, a servo drive may be able to interpolate the 40µm signal period up to an additional 200x, resulting in a resolution of 0.05µm (50nm). Interpolation beyond 200x is not recommended. Increased encoder resolution will likely not affect stage accuracy or repeatability.

Table 8. LM9 Feedback Specifications- "CC" Encoder Option

Supply Voltage (V)	5.0±10%
Supply Current (mA)	250
Encoder Type	Incremental
Encoder Output	Square Wave Quadrature, RS422 Compatible, A, B, and Z, Differential Pairs
Encoder Signal Period	40µm Signal Period
Encoder Resolution	0.1µm (100x)
Hall Switch Output Type	CMOS
Hall Switch Output Current (mA)	±20.0
Limit Switch Output Type	CMOS
Limit Switch Output Current (mA)	±20.0
Index Pulse(s)	One, at the Center of Travel
Maximum Counting Rate (mm/s)	900
Over Temp Switch Output Type	CMOS
Over Temp Switch Output Current (mA)	±20.0

The index pulse on both encoders is a highly repeatable pulse that occurs in the middle of the stage's travel. This is the most repeatable absolute position marker on the LM9. Most servo drives can use this index pulse for homing routines upon power-up.

Two limit switches are provided at the ends of travel. The limit switches will be pulled low throughout the travel range of the stage. The output will swing high at the end of travel and remain high until the mechanical limit of the stage is reached. The locations and operation of the limit switches are detailed further in Chapter 5.

The over temp sensor in the LM9 monitors the temperature at a single point within the motor coil. Logic high indicates that the motor coil has exceeded a safe temperature. Logic low indicates normal operating temperatures. Chapter 5 contains more information about the operation and limitations of this sensor.

4 MECHANICAL INSTALLATION

This chapter outlines how to inspect and unpack the LM9 upon arrival, as well as the basic installation requirements for both the mounting surface and payload.

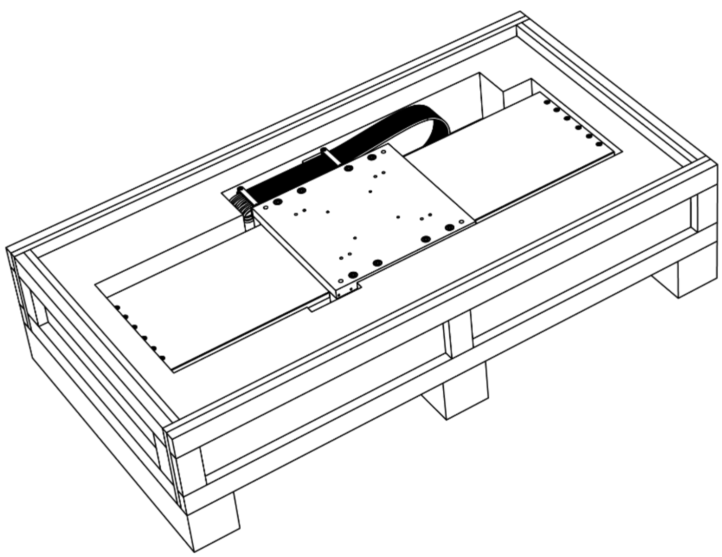
4.1 UNPACKING AND HANDLING

4.1.1 RECEIPT INSPECTION

CAUTION: The LM9 stage is a sensitive device! Handle with great care to minimize the risk of damage to the precision surfaces, rail alignments, and feedback mechanisms.

CAUTION: Do not disassemble any portion of the equipment unless specifically directed by this user manual. Improper installation will cause the stage to no longer hold the promised accuracy specifications or cause damage rendering the device inoperable.

Before removing the LM9 stage from its packaging, please check the integrity of the crate in which it was shipped. Any excessive dirt or debris, crushed corners, or general weathering may indicate improper handling during shipment. After inspection, please verify the contents of the package for any missing materials.



Items included the crate:

1. The LM9 Stage
2. Cut-to-Size Foam
3. Performance Test Reports
4. Instruction Manual*
5. Other Data Sheets*

Should any of these materials be missing, please contact a Griffin Motion Representative so we may convey them.
*Items 4 and 5 may be sent electronically

Figure 6. LM9 Packaging Material List

Please do not dispose of the crate for a reasonable period. For warranty or service requests, the custom crate provided is required to ensure safe shipping back to Griffin Motion. Purchase of a replacement crate may be required if the original is not available.

4.1.2 REMOVAL FROM PACKAGING AND HANDLING

CAUTION: Do not pick up or move the stage by any other means than the stage base. Other components may be fragile or critically aligned. As shown in Figure 4, M10 tapped holes are provided for the installation of lifting eyebolts. Lifting the stage via the eyebolts is the recommend method. Figure 7 shows the installation of the eyebolts.

CAUTION: Do not remove the shipping lock until after the stage is affixed to its final surface and payload. Further detail on the shipping lock is provided in 4.4.

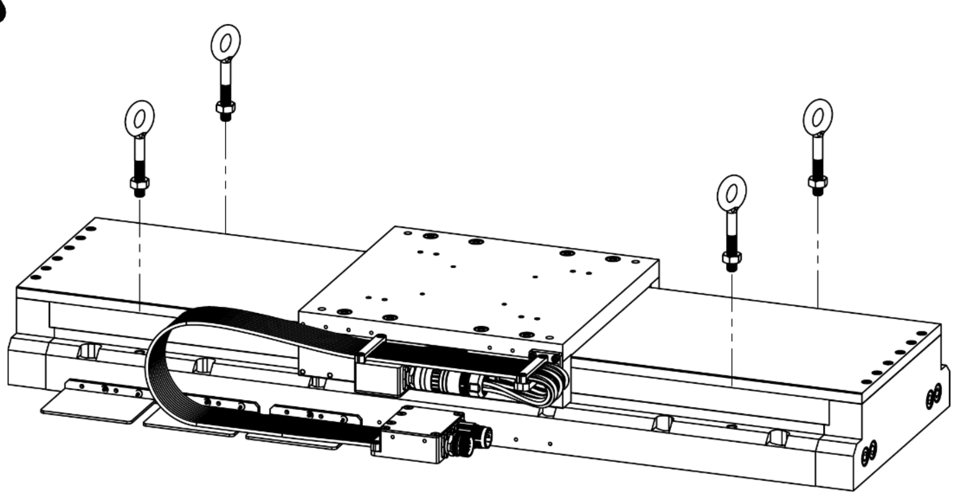


Figure 7. LM9 Lifting Eyebolt Installation

At the factory, McMaster Part Number 3032T85 eyebolts are used for lifting LM9 stages. Once all four eyelets are securely threaded into the stage base, a strap or rope can be run through each eyelet. These can then be lifted by means such as a forklift or winch.

WARNING: Take great care as to not strike or gouge the LM9 while handling. Damage to critical surfaces such as the tooling plate or stage base may result in diminished stage performance or even render the stage inoperable.

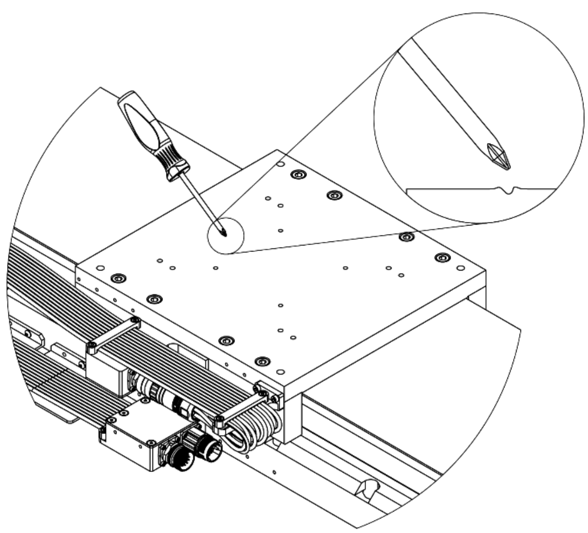


Figure 8. Potential Damage to LM9 Critical Surfaces

4.2 MOUNTING REQUIREMENTS

The LM9 is a high precision device; proper consideration for mounting surfaces must be considered prior to the delivery of the LM9. Failure to do so will result in diminished performance or even damage to the stage.

4.2.1 MOUNTING SURFACE REQUIREMENTS

As a general rule, a stage will conform to the shape of the surface this is it affixed to. A precision stage needs to be bolted to a precision surface to achieve satisfactory results. A visual representation of a stage warping to the shape of its mounting surface is displayed in Figure 9.

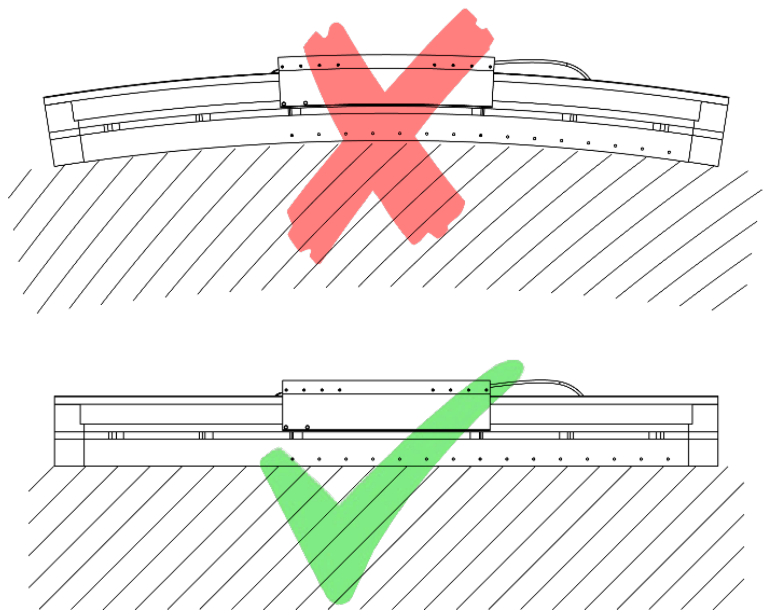


Figure 9. LM9 Warping to Contour of Mounting Surface

Common examples of suitable mounting surfaces include but are not limited to: lapped granite, ground metal, and lapped metal. Flatness requirements are shown below in Table 9.

Table 9. LM9 Mounting Surface Flatness Requirements

<table>
<tr><th>Stage</th><th>Local Flatness (µm/100mm)</th><th>Total Flatness (µm)</th></tr>
<tr><td>LM9-300</td><td rowspan="6">5.0</td><td rowspan="2">8.0</td></tr>
<tr><td>LM9-400</td></tr>
<tr><td>LM9-500</td><td rowspan="2">9.0</td></tr>
<tr><td>LM9-600</td></tr>
<tr><td>LM9-800</td><td>10.0</td></tr>
<tr><td>LM9-1000</td><td>12.0</td></tr>
</table>

Machined mounting surfaces can be used as well, but often lack the requisite flatness. Some specialty machine shops may be able to provide a high precision machined surface for mounting the LM9.

Lastly, both the bottom surface of the stage base and the mounting surface must be made clear of dust and debris prior to mounting the LM9. Small dust and debris may have large impacts on stage performance.

4.2.2 MOUNTING HARDWARE INSTALLATION

The LM9 may be affixed to its mounting surface via the M8 (and 5/16) counterbores on the top side, or via the M8x1.25 tapped holes on the back side. Regardless of which mounting method, the installer should adhere to the following procedure:

Table 10. LM9 Mounting Hardware Installation

1	Select the correct hardware.	• A minimum thread engagement of 2x the diameter of the thread. For example, and M8 screw should have at least 16mm of thread engagement. Coarse thread screws are recommended.
2	Loosely install all mounting screws.	• Loose enough to not impede adjustment of the stage position. • Order of screw installation is not yet critical. • After all accessible screws are loosely installed, remove the shipping lock to push the saddle assembly to access the most central counterbores. Be cautious of the voltage and crushing hazards shown in Figure 3.
3	Align the stage as required.	• Alignment requirements may differ for each application.
4	Tighten screws to the final torque.	• For M8 or 5/16" socket head cap screws, Griffin Motion recommends 210 in-lbs for stainless screws, and 300 in-lbs for alloy steel screws. • Use an inside-to-outside alternating-side tightening order. An example of this order can be seen in Figure 10.
5	Reinstall shipping lock.	• The shipping lock should be installed prior to payload installation if stability is required.

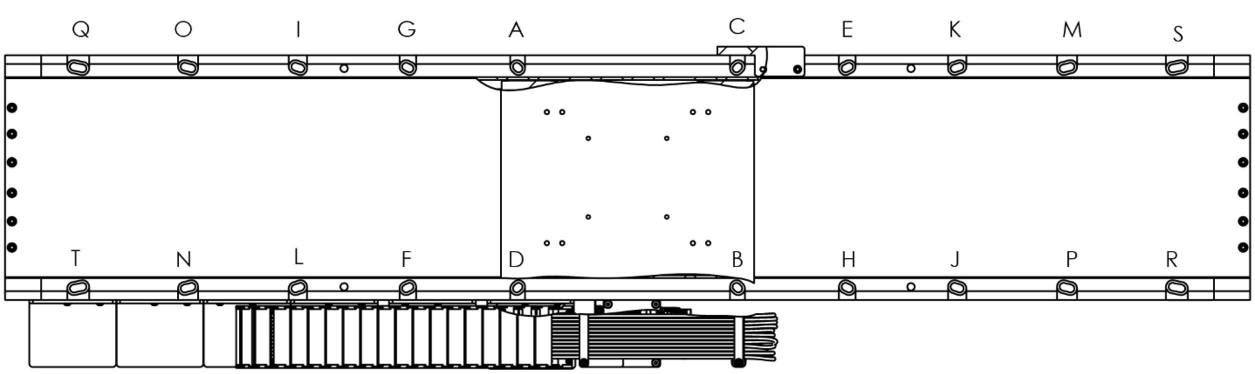


Figure 10. LM9 Mounting Screw Tightening Order

Figure 10 displays an example of a proper inside-to-outside, alternating-side tightening order. Other inside-to-outside, alternating-side tightening orders may be acceptable.

4.3 MOUNTING OF PAYLOADS

After the stage is securely mounted, aligned and the shipping lock is re-installed, the payload may be installed on the tooling plate. The LM9 is a high precision device; proper consideration for payload mounting must be considered prior to the delivery of the LM9. Failure to do so will result in diminished performance or even damage to the stage. Both the top of the LM9 tooling plate as well as the mating surface on the payload should be clean and dust-free prior to installation.

4.3.1 PAYLOAD REQUIREMENTS

Just as a warped mounting surface may cause poor stage performance or damage, the same is true when mounting a payload to the LM9 tooling plate. Table 11 details the flatness requirement for the mating face of a payload to be affixed to the LM9 tooling plate.

Table 11. LM9 Payload Flatness Requirements

Stage	Total Flatness (µm)
LM9-All	10.0

In addition to flatness, payload rigidity should be evaluated. If a payload shows excessive oscillation, it may lack adequate stiffness, which could lead to difficulties with servo tuning.

All payloads should adhere to the load ratings (Fy, Fz, Mx, My, Mz) as listed in Table 4. Contact Griffin Motion if assistance with this evaluation is needed.

4.3.2 PAYLOAD MOUNTING TORQUE

Recommended torque specs and thread engagement for the tapped holes on the tooling plate are shown in Table 12. Failure to adhere to these specifications may result in stage damage or insecure payloads. These torque specs only apply to socket-head cap screws with a standard head height.

Table 12. Tooling Plate Mounting Screw Installation Specifications

Screw Size	Minimum Thread Engagement (mm)	Maximum Thread Engagement (mm)	Recommended Torque, Alloy Steel Screws (in-lbs)	Recommended Torque, Stainless Steel Screws (in-lbs)
M5	10	19	45	32
M6	12	19	130	90
M8	16	18	300	210

4.4 SHIPPING LOCK REMOVAL AND INSTALLATION

Each LM9 stage comes with a red-anodized "shipping lock," which is designed to prevent stage motion during transportation. Failing to install the shipping lock prior to transport or handling could result in damage to the stage or injury to the handler. Do not dispose of the shipping lock, even after the stage is permanently installed.

The shipping lock should be removed only after the stage is securely attached to the stationary mounting structure and the payload is firmly fixed to the tooling plate. Figure 11 below shows the location of the shipping lock and the hardware to secure the lock.

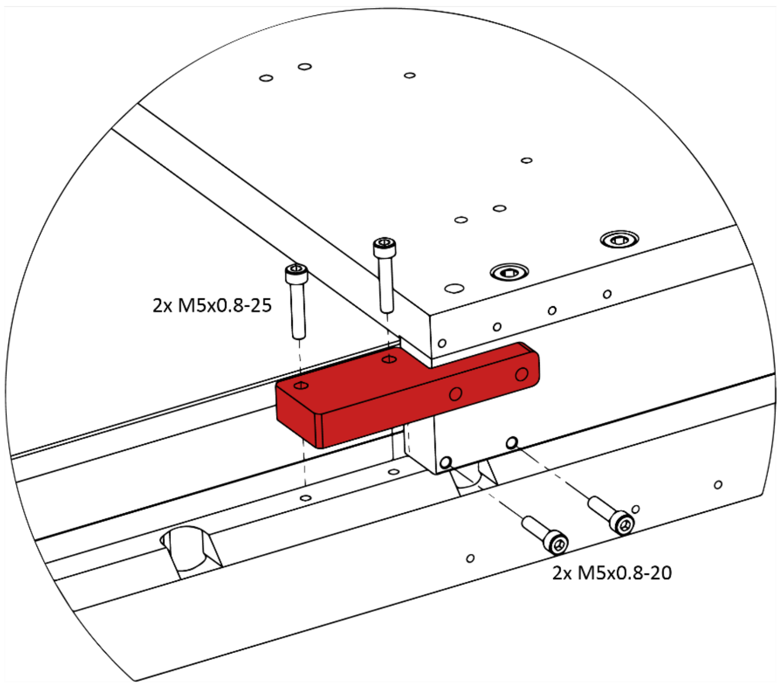


Figure 11. LM9 Shipping Lock

Figure 11 displays that the shipping lock is secured by four M5 cap screws. These screws use a 4mm hex (Allen) key, and should be tightened to the torque shown in Table 13, according to the material of the cap screws.

Table 13. Shipping Lock Screw Torque

Screw Size	Installation Torque, Alloy Screws (in-lbs)	Installation Torque, Stainless Screws (in-lbs)
M5x1.25-20	45	32
M5x1.25-25		

When the time comes to operate the stage, ensure the shipping lock is removed, as it will inhibit all motion.

5 ELECTRICAL INSTALLATION

Electrically, the LM9 contains a motor and 4 primary feedback systems: an optical encoder, limit switches, a Hall Effect sensor, and a motor over-temp switch. This chapter covers the connections, wiring, and function of these systems.

5.1 MOTOR AND FEEDBACK CONNECTIONS

The electrical connections are divided up into 2 connectors: a 9-pin motor connector and a 17-pin feedback connector. The layout of the motor and feedback connectors is shown in Figure 12. Not every pin shown in Figure 12 is populated. See the complete pinout in Table 14 and Table 15.

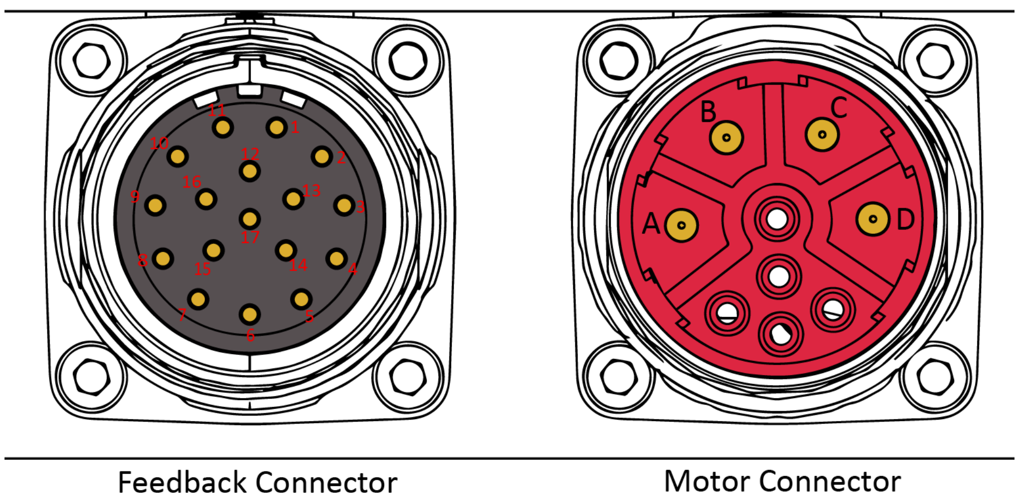


Figure 12. LM9 Motor and Feedback Connector Interface

Table 14. LM9 Feedback Connector Pinout

Pin	Signal, Sin-Cos Encoder "U"	Signal, A quad B Encoder "CC"
1	SIN+	A+
2	SIN-	A-
3	COS+	B+
4	COS-	B-
5	Z+ (Center Index+)	
6	Z- (Center Index-)	
7	LIM+ (Positive End of Travel)	
8	LIM- (Negative End of Travel)	
9	+5VDC	
10	GND	
11	*	
12	*	
13	TEMP	
14	*	
15	HALL A	
16	HALL B	
17	HALL C	
*	Reserved, Leave Disconnected	

Table 15. LM9 Motor Connector Pinout

Pin	Signal
A	PHASE A (U)
B	PHASE B (V)
C	PHASE C (W)
D	PE GROUND
E	*
F	*
G	*
H	*
L	*
*	Reserved

Mating connectors and pins are provided in Table 16.

Table 16. LM9 Mating Connectors and Pins

Component	Part Number	Manufacturer	Description
Mating Motor Connector	MB1CKN0900	Amphenol	9 Position Connector
Mating Motor Pin	SC000045		2mm Female Pin
Mating Feedback Connector	MA1CAP1700		17 Position Connector
Mating Feedback Pin	SC000044		1mm Female Pin

Other mating connectors and pins may be suitable but have not been evaluated by Griffin Motion.

5.2 WIRING OVERVIEW

This section elaborates on the basic electronic interface requirements. Example supporting circuit elements expected from the user's controller are also shown.

5.2.1 MOTOR ELECTRICAL DIAGRAM

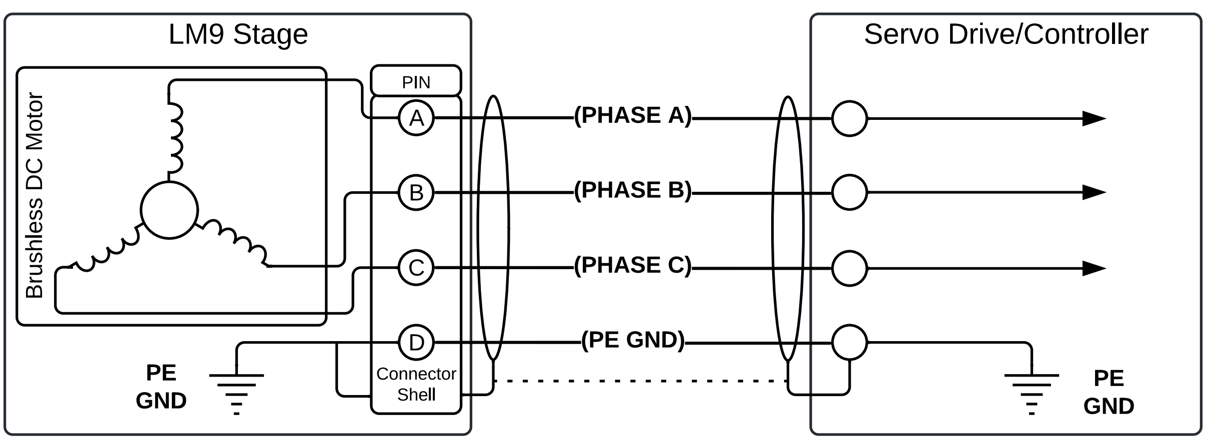


Figure 13. LM9 Motor Wiring Diagram

5.2.2 FEEDBACK ELECTRICAL DIAGRAM

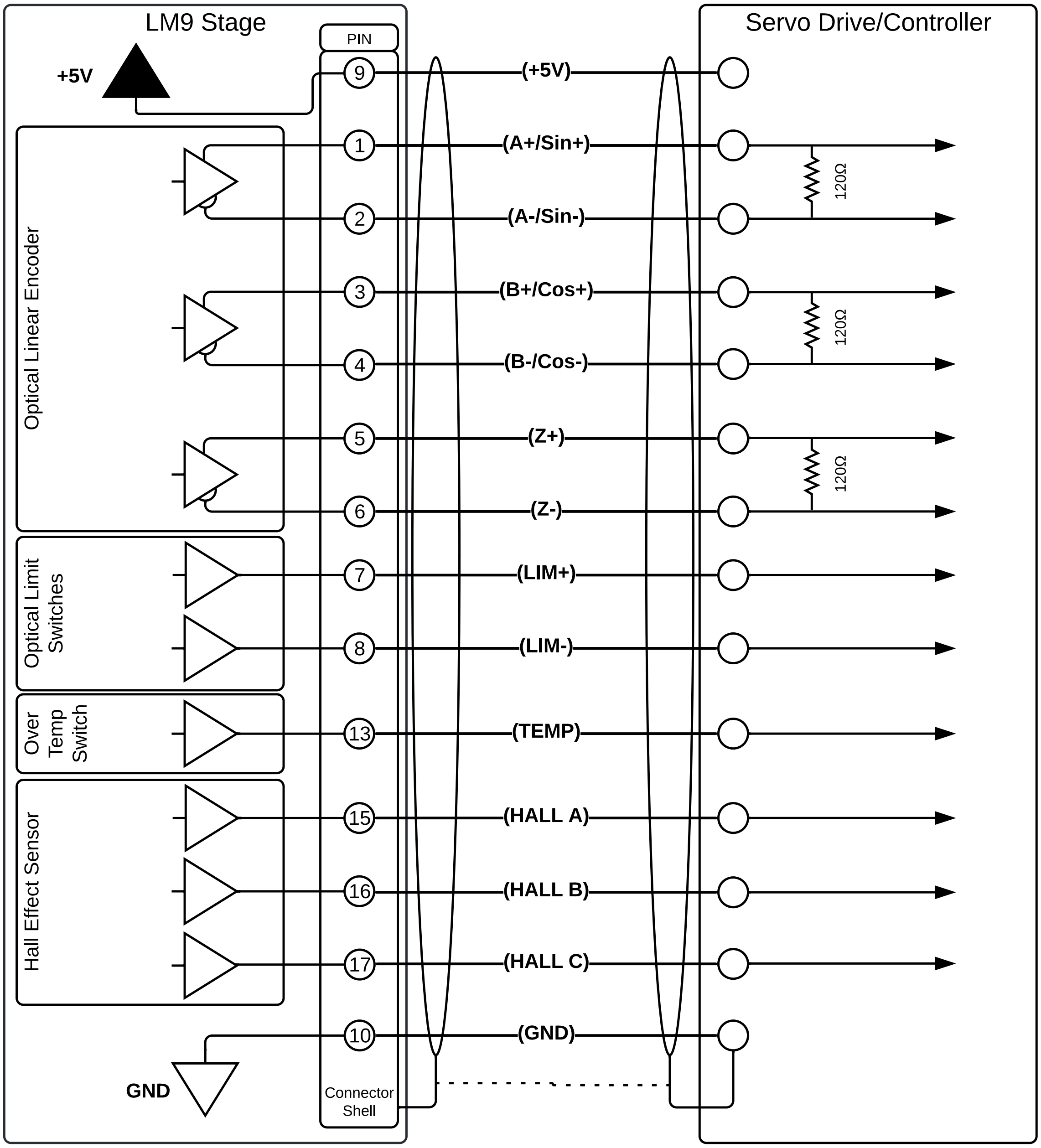


Figure 14. LM9 Feedback Wiring Diagram

5.3 SHIELDING AND GROUNDING

The linear motor within the LM9 is a high-voltage device. To best mitigate danger caused by motor fault conditions, a protective earth (PE) grounding point is provided on PIN D of the motor connection.

To provide a grounded terminal for stage cable shielding, both the motor and feedback connector shells are properly grounded.

For proper operation, the user must connect the cable shielding and protective earth to the points shown in Figure 15. Example electrical wiring diagrams are shown in Section 5.2. This will ensure safety to the user and high reliability of the motor and feedback systems to achieve optimal performance.

CAUTION: The user should not attempt to use any tapped hole not labeled "PE" if additional grounding is desired.

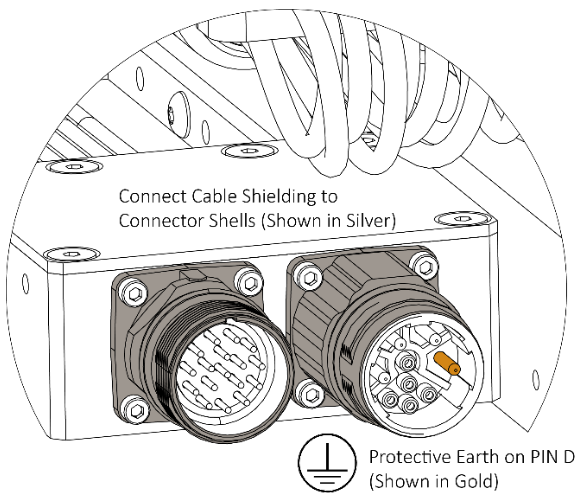


Figure 15. LM9 PE Ground and Shielding Connection Locations

5.4 BACKDRIVING THE STAGE

Manually pushing, or *back driving*, the stage motor will generate electrical current via back EMF. If a motor cable is installed, this current will be delivered to the servo drive, potentially causing damage. If a motor cable is not installed, the user may be exposed to dangerous electrical power at the motor connection. Adhere to the following warnings and procedures to prevent injury or device damage:

CAUTION: Never handle or push the stage saddle when connected to a controller. This is to preclude accidental shock to the user, and to avoid potentially damaging the controller amplifier due to the BEMF generated by the motor.

DANGER: When back driving, move the stage slowly and in a controlled manner. The BEMF generated by the motor may be higher than the permitted safety limits if the motor speed is sufficiently high. Connection of a temporary shunt network to the motor connector may be used to limit generated voltages.

LM9 stages may be slowly back-driven, when not connected to controls, to allow access to mounting holes without the need to power the stage. As discussed in previous sections, follow the precautions listed below when manipulating the stage by hand:

1. Never touch the stage under servo control, de-energize and disconnect first.
2. When back driving the stage, apply slow gradual pressure by hand.
3. Do not strike the stage or slam it into the hard stops.
4. Minimize contact and maintain cleanliness of mounting surfaces prior to installation.
5. Consider covering the motor connector to prevent accidental contact with the pins. Amphenol P29687 may be used for this purpose.

5.5 FEEDBACK DEVICE FUNCTION AND SIGN CONVENTION

The function and sign convention of the motor, Halls, encoder, limit switches and index are described in this chapter.

5.5.1 MACHINE DIRECTION

As standard, the encoder, limit switches, and Hall Effect sensor are wired such that the direction of positive motion is as defined below Figure 16.

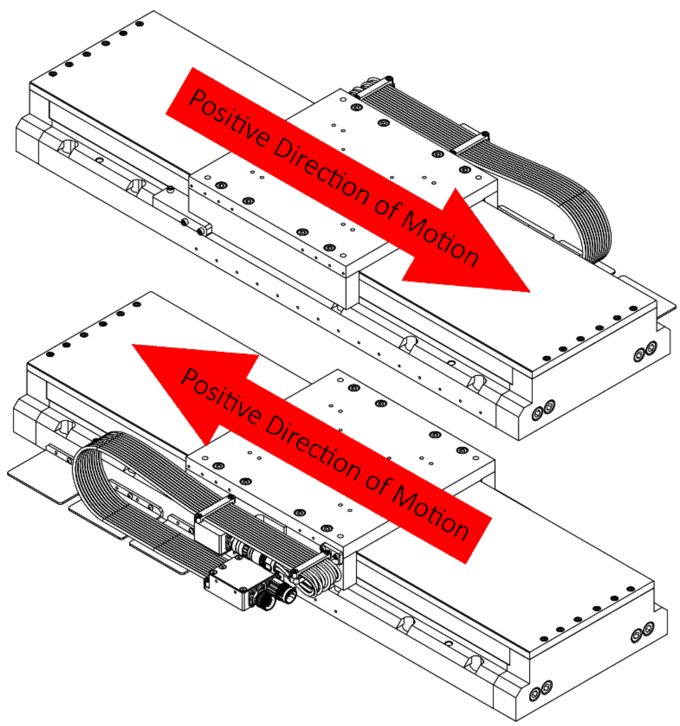


Figure 16. LM9 Positive Direction of Motion

5.5.2 MOTOR ELECTRICAL CYCLE AND HALL PHASING

Figure 17 details the Motor BEMF with respect to the Hall Effect Sensor outputs in the sequence that would be observed in the Positive Direction of Motion. BEMF waveforms are referenced to the respective phases, and the Hall signal levels are shown as pulled up by an external resistor and referenced to ground.

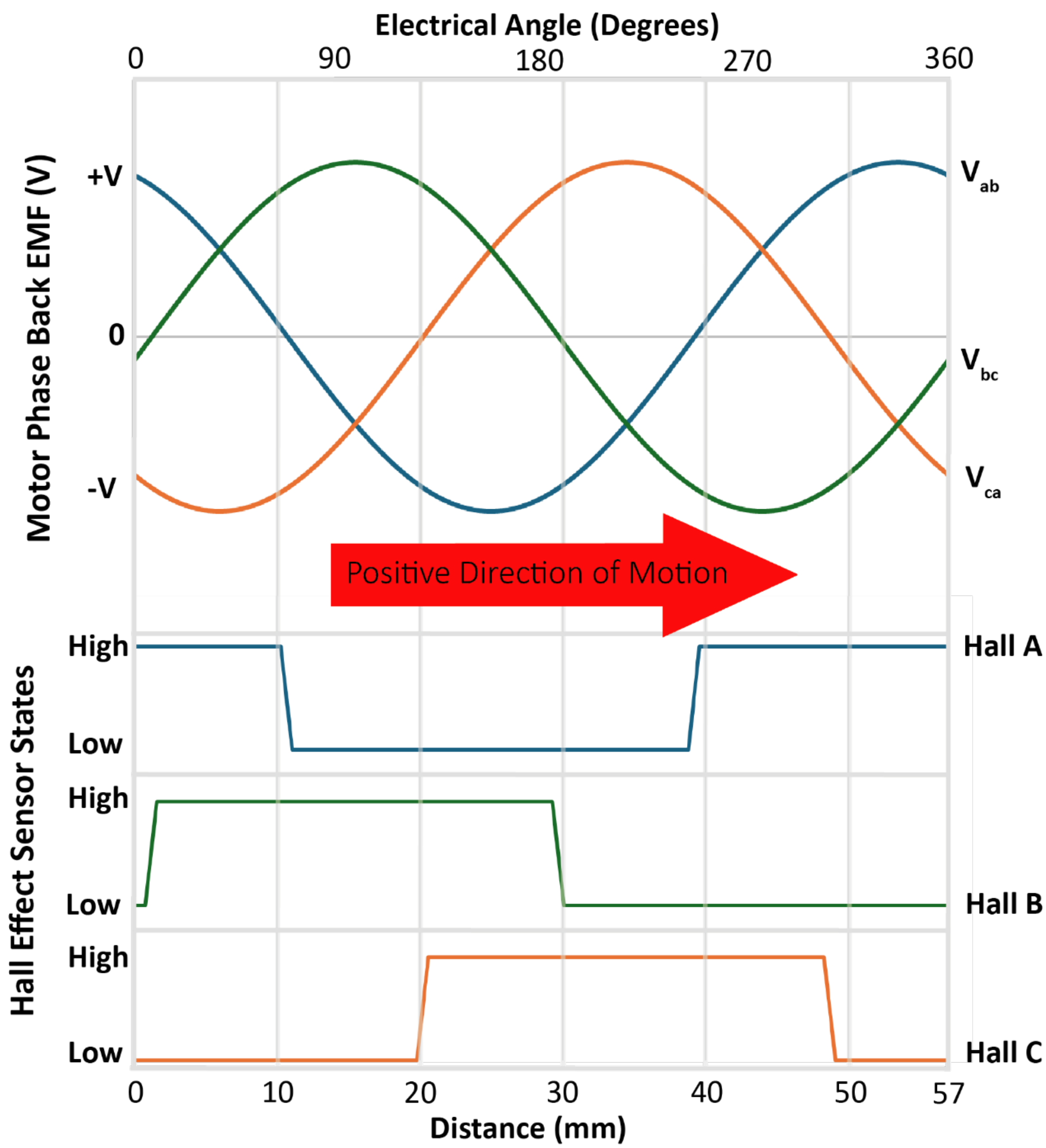


Figure 17. LM9 Electrical Cycle, Motor and Halls

The electrical signals shown in Figure 17 describe the behavior of motor Back EMF and the associated hall states across an arbitrary 57mm span within the stage travel. 57mm is the pole pitch of the LM9 motor and is equivalent to 1 full 360° electrical cycle. The motor electrical cycle is not phased with the encoder signals, the home index, or the limit switches.

5.5.3 LINEAR ENCODER OUTPUT WAVEFORMS

As standard, the LM9 can be ordered with a digital quadrature "CC" or an analog Sin-Cos "U" encoder. Both encoder options use the same scale, which has a 40µm period. Figure 18 (CC) and Figure 19 (U) detail the output waveforms of both options.

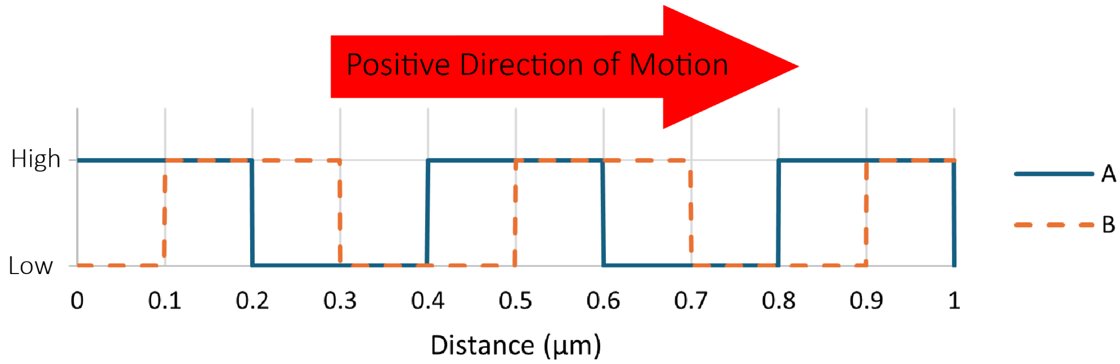


Figure 18. Digital Quadrature Encoder "CC" Output Signals

As seen in Figure 18, the "CC" quadrature encoder produces 2 square waves, A and B, offset by a 90° phase angle. The waveforms shown above represent the differential voltage between the positive signal (A+ or B+) and its inverse counterpart (A- or B-). Each signal has a wavelength of 0.4µm (100x interpolation). Every 0.1µm, one of the two signals rises or falls; this can be interpreted by the servo drive/controller as a single encoder count.

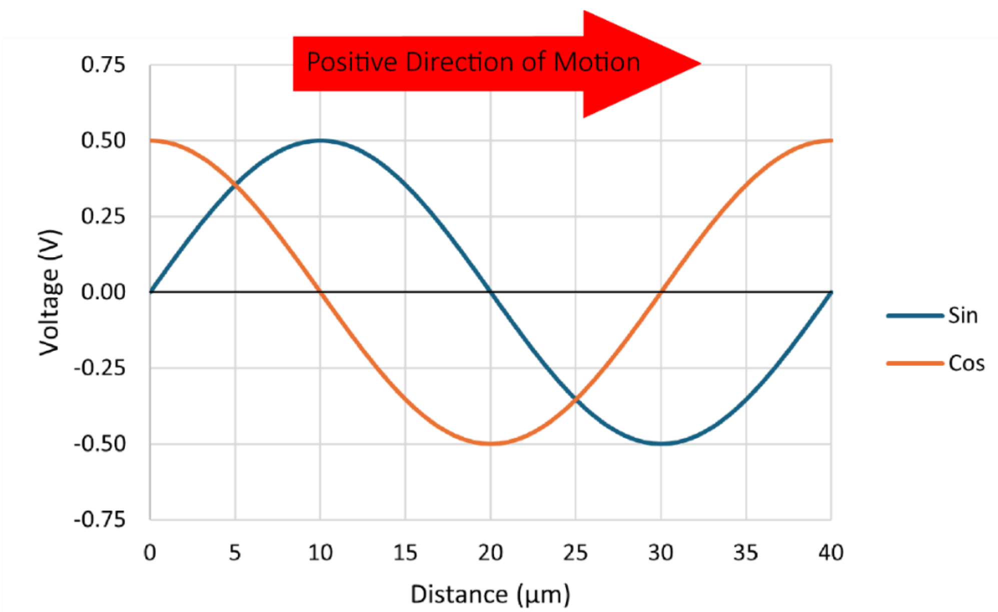


Figure 19. 1Vpp Encoder "U" Output Signals

As seen in Figure 19, the "U" quadrature encoder produces 2 sinusoidal waves, Sin and Cos (offset by a 90° phase angle). The waveforms shown above represent the differential voltage between the positive signal (Sin+ or Cos+) and its inverse counterpart (Sin- or Cos-). Each signal has a wavelength of 40µm. Each signal must be interpolated into encoder counts within the servo drive/controller. Interpolation beyond 200x (0.05µm) is not recommended.

5.5.4 LINEAR ENCODER MARKERS AND HARDSTOPS

Figure 20 shows the locations of the LM9's limit switches and hard stops relative to the Home Index. Table 17 details their specific locations for each LM9 travel.

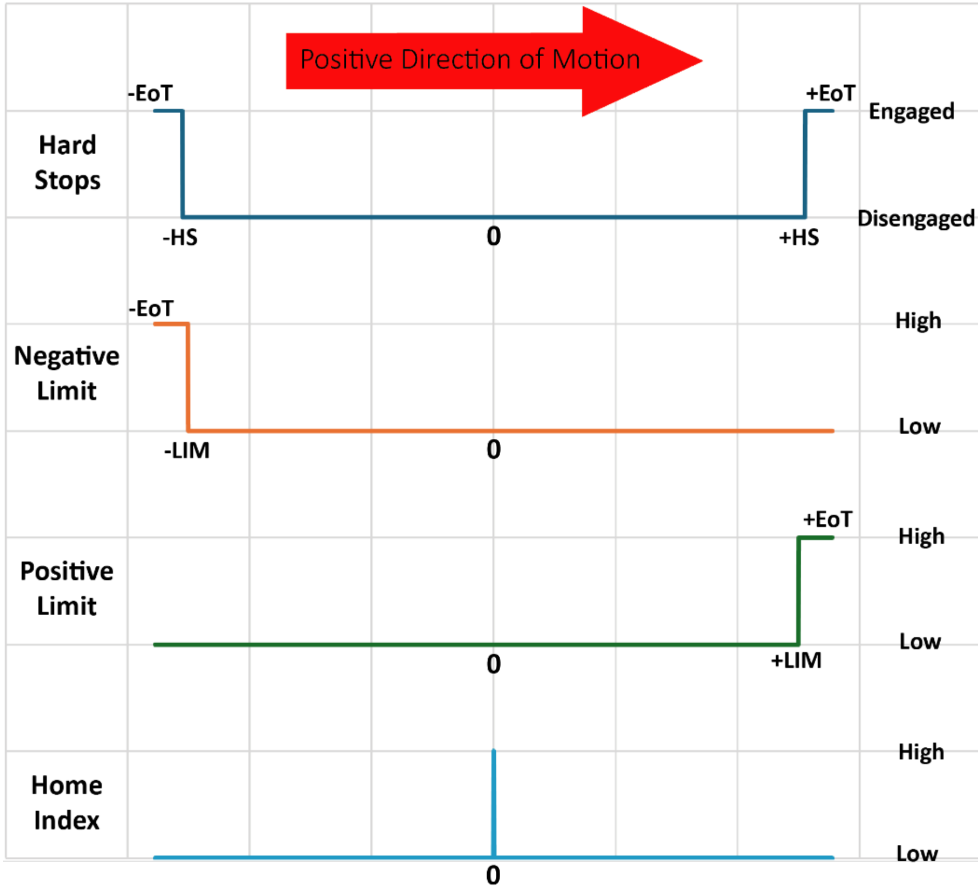


Figure 20. LM9 Hard Stop, Limit and Index States

Table 17. LM9 Limit Switch and Hard Stop Locations

Stage	Limit Location "LIM"	Hard Stop Location "HS"	End of Travel "EOT"
LM9-300	±150mm	±155mm	±177.5mm
LM9-400	±200mm	±205mm	±227.5mm
LM9-500	±250mm	±255mm	±277.5mm
LM9-600	±300mm	±305mm	±327.5mm
LM9-800	±400mm	±405mm	±427.5mm
LM9-1000	±500mm	±505mm	±527.5mm

The distance between the limit switches defines the nominal travel of the LM9. At the limit locations, the appropriate limit switch logic will swing high. The limit switch logic will remain high throughout the remainder of the stage overtravel until the End-of-Travel is reached.

The LM9 has spring-loaded hard stops, designed to dissipate the stage's kinetic energy before the End-of-Travel. The springs will first contact the moving saddle at the position ±HS. The springs will bottom out at the End-of-Travel location, where the metal saddle will contact the metal end plate (shown in Figure 2). Great care should be taken to prevent contact with the hard stops or collision with the end plate.

5.5.5 OVER-TEMP SENSOR

The CMOS motor temp sensor will remain low during normal operation and swing high when the motor reaches an over-temperature condition, as defined by Griffin Motion. The motor temp sensor alone will not prevent motor damage in all situations. It can only detect and prevent damage when temperature rise is much slower than the motors' thermal response time. The sensor has a maximum response of 4.5°/s. I^2T (a common feature in modern servo drives) protection should be used if commanding higher than continuous motor current.

5.6 CABLE CONSTRUCTION CONSIDERATIONS

To achieve the highest stage reliability, several simple considerations should be made when designing cables for the LM9. Griffin Motion can provide cables for many servo drives including but not limited to Galil, ACS, Copley, Aerotech and Polaris.

5.6.1 MOTOR CABLE CONSIDERATIONS

To ensure safe transmission of motor current, use a wire with a gauge of at least 16 AWG (1.3mm conductor diameter).

Ensure that the PE ground pin is connected and terminated to the appropriate PE ground connection on the drive/controller.

Shielding is recommended for all motor cables. This will minimize interference with sensitive signals within the adjacent feedback cable. The shielding should be bonded to the connector shells on both the drive and stage sides of the cable.

5.6.2 FEEDBACK CABLE CONSIDERATIONS

All differential signals (±A, ±B, ±SIN, ±COS, ±Z) should be transmitted via shielded twisted pairs to increase noise immunity. These signals should be terminated at an appropriate differential input channel on the drive/controller.

Minimize the length of the feedback cable. This reduces signal drop and potential for inference.

5.7 CONTROL SYSTEM CONSIDERATIONS

Many suitable controllers on the market today can control and drive the Griffin Motion LM9 stage. Listed below are a few common fault and limit functions that should be implemented to maintain the safe and efficient operation of the stage:

Continuous and Peak Current Limits – The servo drive/controller is solely responsible for implementing safe current limitations. Do not set the continuous current limit above the value specified in Table 6. In some applications, greater than continuous current is required for short periods. Motor protection algorithms such as I^2T should be implemented in these applications. It is recommended that the current limits should not be set higher than is necessary to achieve the desired force/acceleration.

Verification and Tuning—It is highly recommended that the installer first verify the stage's operation with the controller of their choice, no payload, in a horizontal orientation. After that, dummy payloads (similar mass and geometry to the final payload) can be used to tune the system and verify requirements prior to installing any sensitive payload equipment.

Velocity Limit – To prevent a damaging metal-on-metal collision occurrence at the end of travel, the maximum velocity of the LM9 should be limited to the values displayed in Table 18, based on the mass of the customer payload. These velocities are calculated based on the energy capacity of the spring-loaded hard stops. When applying the full continuous braking force of 199N, the LM9 will require approximately 100mm to achieve a complete stop at these speeds. Keep this in mind when designing motion profiles.

The following recommendations are based solely on the kinetic energy of the system. In some cases, maximum velocity is limited by encoder type and or bus voltage. Be sure to observe these limits as well when setting maximum stage velocity.

Table 18. LM9 Velocity Limit

Payload (kg)	Recommended Velocity Limit (mm/s)
0	1775
10	1300
20	1075
30	950
40	850
50	775
60	725
70	675
80	625
90	600
100	575
110	550
120	525
140	500
160	475
180	450
200	425

Position Error Limit – Many controllers actively monitor the distance between the commanded position and measured positions (as reported by the encoder). This feature can prevent runaway conditions should a cable, feedback mechanism, or current control fail to operate as desired. It can also serve as a collision detection feature.

Determining the best value for this safety variable takes time and some experience with the process. The machine integrator should consider the behavior of the control system and stage should this value be exceeded

Software End-of-Travel Limits – Normal stage operation should never occur beyond the electrical limit switches. The velocities in Table 18 require about 100mm to stop using the full 199N braking force.

Software limits may be implemented short of the limit switches to signal that full braking force is necessary to prevent a hard stop collision.

6 MAINTENANCE

The LM9 is intended to be a maintenance-free device. Regular inspections should still be completed.

6.1 INSPECTION

Depending on the cleanliness of your operating environment or system process, the inspection frequency may need to increase. For normal laboratory usage (little to no debris), the following minimum inspection interval and criteria are suggested.

Inspection Interval: Monthly
Inspection Criteria:

- Check Cables for:
    - Jacket fraying
    - Loose connections.
    - Check the resistance of protective earth bonding to the controller.
- Check the stage for:
    - Excessive debris on the stage.
    - Silicone side seal fraying

6.2 CLEANING AND LUBRICATION

Clean the accessible surfaces with a lint-free cloth dampened with denatured alcohol.

Avoid ingress of cleaning agents or water beyond the side seals, as this will break down the lubricants, embed contaminants into seals and crevices, and ultimately affect machine life.

Cleaning and lubricating components such as the precision rails require disassembly beyond the scope of this document and is not recommended to be attempted.

Keep cleaning agents and water away from electronic components.

Lubricants used in the assembly of Griffin Motion LM9 stages are intended to last the usable life of the device, given that the cleanliness of the environment is maintained consistently with the expected use.

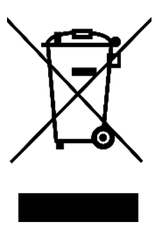
6.3 TROUBLESHOOTING

Some general troubleshooting guidance is listed below in Table 19.

Table 19. General Troubleshooting

Problem	Root Cause and/or Propose Solution
Stage will not move (unpowered)	• Check that the shipping lock is removed.
Stage will not move (powered)	• Verify motor pinout from controller to stage. • Hall phase order may be incorrect. • Hall sensor may not be detected, check schematic implementation. • Motor failure, check pin-to-pin resistance to verify. • Controller requirements to servo may not be met.
Stage Runaway or erratic behavior	• Encoder feedback wrong direction • Encoder failure or disconnection. • Improper current or servo tune loop gains. • Improper shielding of feedback cable causing erroneous encoder or Hall effect sensor signals.
Missing or additional feedback counts	• Improper shielding of feedback cable or motor cable. • Loose connection on feedback cable. • Machine velocity too high; missing counts. • Encoder failure or disconnection.
Stage power lower than expected	• Check current gains and monitor current admitted to motor. • Motor current phase angle offset is incorrect.
Excessive Vibration	• Servo or current tune loop gains need adjustment. • System setup has a resonant frequency that must be damped.
High force required during normal operation	• Contamination in ball screw or precision rails.
Stage cannot reach electrical limit	• Stage obstructed, check pinch points. • Electrical limit or cabling has failed.
Intermittent failure or operation	• Loose cable connections. • Amplifier VBUS unstable or too low. • Encoder read head damaged. • Motor Hall Effect sensors damaged. • Motor winding damaged.
Motor noise during operation	• Current loop gains set too high • Contamination of precision rails • Rubbing noise from power-off brake.

6.4 SCRAPPING AND DISPOSAL



The LM9 Stage qualifies as electronic equipment that should be disposed of properly. Dispose of old equipment following the appropriate international, national, and local rules and regulations.

If you need assistance in proper disposal, or would like to send the machine back to Griffin Motion for disposal, please reach out to a representative for RMA (Return Material Authorization) information.

7 SERVICE AND SUPPORT

7.1 SERVICE

If you need any assistance regarding product integration, application, identification, inspection, repair, or new business opportunities, please contact Griffin Motion. Contact information is displayed at the beginning of this document.

7.2 GENERAL WARRANTY

Griffin Motion, LLC [hereafter GM] warrants that, for a period of one year from the date a [machine] is delivered to the Buyer, such [machine] will be free from material defects in workmanship and materials provided by GM. Buyer's sole and exclusive remedy for a breach of this warranty will be, at GM's option, either (i) credit in the amount of the purchase price of the defective [machine], or (ii) repair or replacement, at GM's expense, of the defective [machine] within [twenty (20)] days after receipt by GM of written notice of the defect from Buyer. Costs in connection with GM's repair or replacement of any defective [machine], including, parts, labor, cost of standard return transport from GM to buyer, will be borne by GM. If available, GM will provide Buyer a temporary loaner [machine] while repairs are made to any defective [machine]. This warranty will continue as to the repaired or replaced [machines] for the remainder of the original 1-year warranty period. This warranty will not apply to defects arising from neglect, accidental damage, repair or maintenance not performed by GM, or use of the [machine] for any purpose other than the purpose for which it was designed. GM DISCLAIMS ANY AND ALL OTHER WARRANTIES, WHETHER EXPRESS OR IMPLIED, WITH RESPECT TO THE [MACHINES]. GM WILL HAVE NO LIABILITY FOR CONSEQUENTIAL, INDIRECT, SPECIAL, INCIDENTAL, EXEMPLARY, OR SIMILAR DAMAGES ARISING OUT OF OR RELATING TO THE [MACHINE] OR THE USE THEREOF BY BUYER, INCLUDING, WITHOUT LIMITATION, DAMAGES FOR LOSS OF PROFITS, BUSINESS INTERRUPTION, OR OTHER PECUNIARY LOSS, EVEN IF GM HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES.