USERS' MANUAL

LINEAR MOTORS

UM-102 Revision F
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Model Numbers

4020 5020

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Table of Contents:

1. Safety:

The Moog motor is capable of producing high forces and velocities. Always follow appropriate safety precautions when installing and applying these motors. Equipment should be designed and utilized to prevent personnel from coming in contact with moving parts that could potentially cause injury.

Read all cautions, warnings and notes before attempting to operate this device.

Follow all applicable codes and standards.

2. Warnings, Cautions and Notes:

The following conventions are used on the equipment and found in this manual. Please read all equipment labels and manuals before attempting to use Moog Linear Motors.

> **WARNING:** Identifies information about practices or circumstances that can lead to personal injury, property damage, or loss of life if not correctly followed.

A WARNING identifies information that is critical for identifying and avoiding a hazard that could lead to serious personnel injury or equipment damage.

> **CAUTION:** Identifies information about practices or circumstances that can lead to severe equipment damage.

A CAUTION identifies information that is critical to prevent permanent equipment damage.

> **NOTE:** Identifies information that is critical for successful application and understanding of the product.

A NOTE identifies information that is critical for successful application and understanding of the product.

The following is a list of warnings and cautions that must be observed when working with Moog High Force Linear Motors.

WARNING: Only those familiar with linear motors and associated machinery should plan or implement the installation, startup, and subsequent maintenance of the system. Failure to comply can result in personnel injury and/or equipment damage.

WARNING: This equipment contains HIGH ENERGY PERMANENT MAGNETS. Do not attempt to disassemble. Serious damage to property or injury to person may result. Keep ferrous materials away from the motor.

WARNING: Improper Servo tuning can cause uncontrolled motion of the Moog motor. Do not allow the system to oscillate uncontrolled during the tuning process, and keep all personnel and body parts away from moving equipment.

WARNING: This system produces extremely strong magnetic and electric fields that can interfere with other equipment. Use extreme caution when using motor near any type of medical device or equipment.

WARNING: Do not use drives powered by voltages greater than 480 VAC.

WARNING: Keep fingers and limbs clear of the motor and moving parts when power is applied to the motor.

WARNING: This system produces very high forces and rapid motion. Under no circumstances should it be operated when hands, fingers or clothing are in, on, or near the motor. Guards should be installed to prevent such items from coming into contact with the motor or other moving parts.

WARNING: Moog End-Stops are not designed for large loads.

WARNING: A qualified electrician should install all electrical components to assure safe operation and to meet all regulations.

WARNING: Do not step onto or apply lateral Loads to the Linear Position Sensor Housing.

CAUTION: Do not move the Moog linear motor's shaft without proper mechanical End-Stops. It is possible to over-travel a motor without End-Stops and cause damage to the motor.

CAUTION: Do not attempt to insert or realign the shaft into the bearings if it has been moved beyond the bearings. If this occurs, the shaft will be pulled to the stator side and locked in place. The motor must then be returned to Moog for repair.

CAUTION: An incorrectly applied or installed motor can result in equipment damage or a reduction in product life. Wiring or application errors, such as under-sizing the motor, using incorrect or inadequate AC supply, or using the motor in excessive ambient temperatures can result in malfunction or permanent damage to the motor.

CAUTION: Poor ground or shield connections or wiring can cause unpredictable motion, and damage the motor, control system or machine.

CAUTION: Only use Anderol 465. Other lubricants could break down prematurely and cause permanent damage to the motor and contaminate the bearings.

CAUTION: The Moog Linear Motor Bearing System is not designed to support large lateral loads. Lateral loading of the shaft during movement will limit bearing life.

CAUTION: The Moog Linear Position Sensor contains electronic circuitry that can be damaged by misapplication of electrical power, or by applying electrical power of the wrong voltage or polarity. To avoid damaging the Linear Position Sensor, always use the correct Moog – approved cable intended for the Drive in use. Ensure correct sensor power supply voltage and that all custom sensor cables are properly wired before applying power.

CAUTION: The Linear Encoder is not designed to be removed, aligned, adjusted, disassembled or installed by the user.

CAUTION: When pigtail Linear Position Sensor cables are used (EC series) do not leave stripped wire ends unprotected. Shorting of the wire ends will damage the Encoder.

CAUTION: Do not apply more than 5.5 VDC to the encoder. The encoder will be damaged if the maximum rated voltage is exceeded.

3. Scope:

This manual provides the necessary information for installation of standard Moog 4020/5020 C&D Series Linear Motors. The LPA position sensor is an integral part of standard motors. For technical support, application assistance and sizing information, contact Moog's Application Engineering at: 610-328-4000, Toll Free 877-474-2854, Fax 610-605-6216, or email to mcg@moog.com

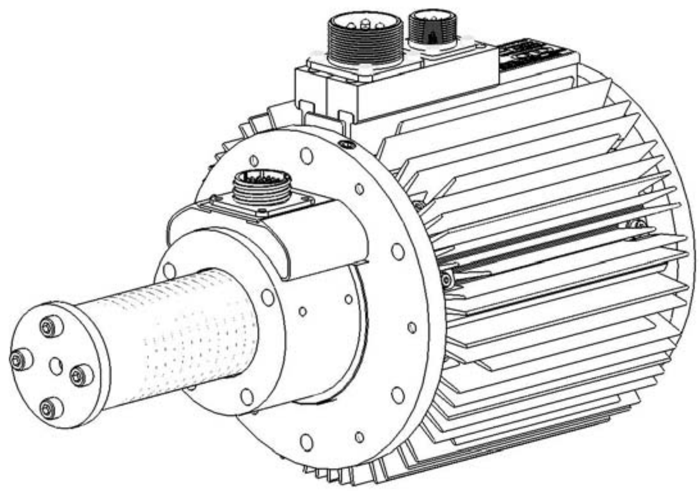


Fig 3-1 Moog Linear Servo Motor with LPA Position Sensor

4. Introduction:

The Moog motor is designed to be the driving part of a servo control system. To ensure that the motor performs with precision and reliability, it is important to follow the instructions contained in this manual.

The Moog motor is only one component of a motion system. A motion system also includes the load, position measuring device (usually supplied with the Moog motor), power regulation device (amplifier) and a control system (Servo controller). All of these components must be properly specified and work together to achieve optimum system performance and accuracy.

The linear encoder is provided as an integral part of the linear servo motor. It provides the required position feedback and commutation data to a control system.

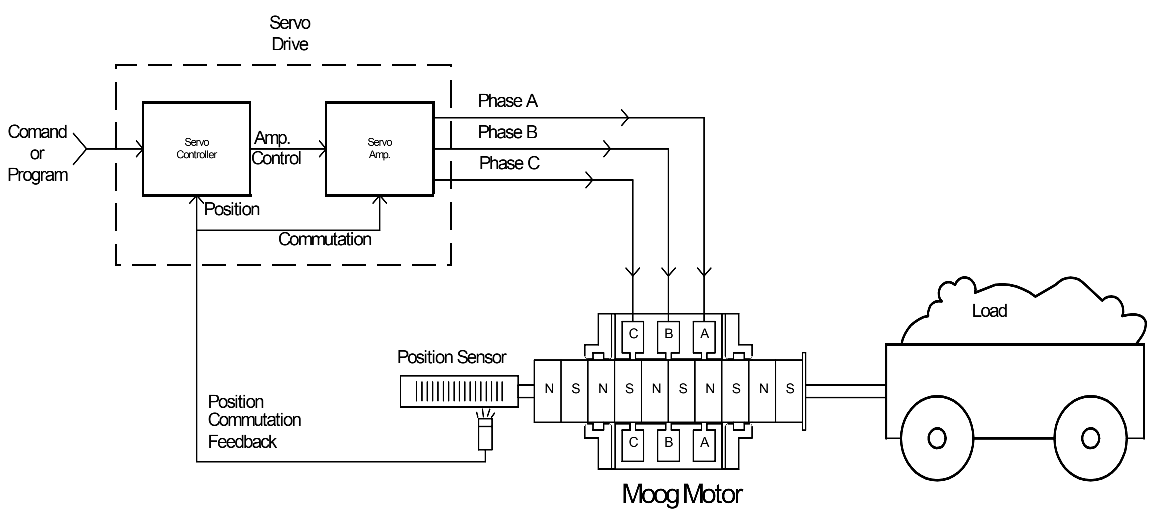


Fig 4-1 Typical Servo System with Moog Motor:

The Moog motor has several options and accessories that are not addressed in this manual. For detailed technical information on these components, please reference relevant Moog interface control drawings and device manuals.

5. Commissioning:

Use the following sequence when installing a Moog linear motor:

1. Read all of this manual's warnings, cautions, and notes (Section 1).
2. Properly mount the motor (Section 6).
3. Ensure tight coupling to the feedback device if it is not an installed option from Moog (Section 8.2).
4. Make the Motor Feedback cable connections (Section 7.5).
5. Interconnect the motor power to the control system (Section 7.3).
6. Interconnect the motor temperature switch to the control system (Section 7.4).
7. Ensure good electrical shielding and grounding throughout the system (Section 7.6).
8. Configure Encoder position signals and Commutation signals to indicate positive motion consistent with positive Drive effort and positive shaft movement (Section 9.1).
9. Initialize the motor with the control system, including appropriate motor parameters and limits. (See the manuals for the control system being implemented).
10. Attach the load in a manner that does not induce or cause binding when the motor is stationary or moving (Section 6).
11. Tune the system for desired performance and accuracy (Section 9.4).

6. Mechanical Mounting:

It is important that the mounting of the motor and load are designed to handle the forces created. The mounting needs to allow the motor shaft to move freely while under load without binding or creating additional loading of the bearings. If the mounting is not secure and true, poor motion quality and reduced life will most likely result. Insufficiently stiff mounting will result in low tuning gains and an inability to achieve optimal precision and control of the servo system. Tolerance information is contained in the Moog motor interface control drawings.

6.1. Face Mounting:

Single-face mounting is recommended by Moog. The mounting face is the face on the end opposite the electrical connections. When mounting the motor, it is important that the motor mounting face (Datum A), is perpendicular to the direction of motion, and that it maintains this orientation when the motor is under load (Refer to motor ICD for bolt pattern).

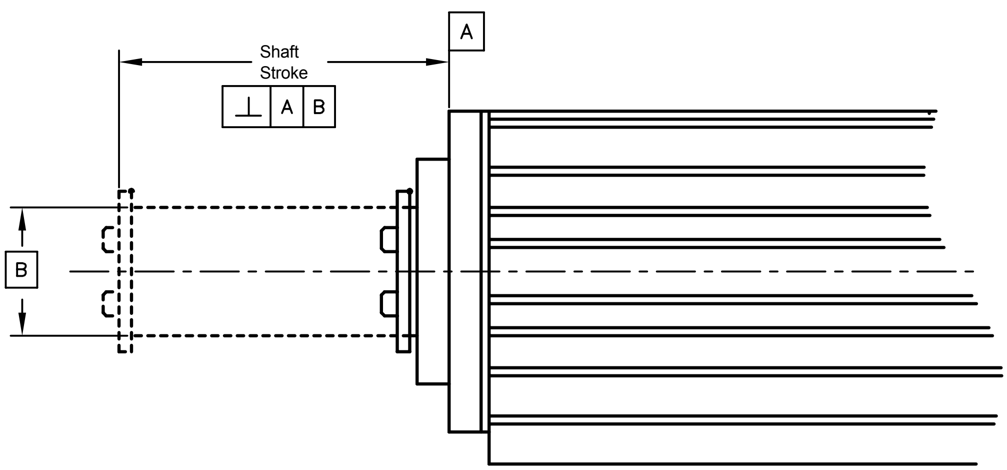


Fig 6-1 Single Face Motor Mounting

Dual- face mounting is not recommended by Moog. Dual-face Mounting can be utilized only without an integral Moog position sensor. With a dual face mounting configuration, the motor mounting will need to accommodate variation in the motor length that occurs with varying temperature. Dual face mounting is difficult and is rarely required.

6.2. Coupling to the Load:

The load is typically coupled with the four ¼ - 20 threaded mounting holes on the end of the shaft, or with the use of an optional Moog end-stop. It is extremely important that the load be coupled with as little compliance as possible in the direction of force and motion. Poor coupling will result in diminished system performance.

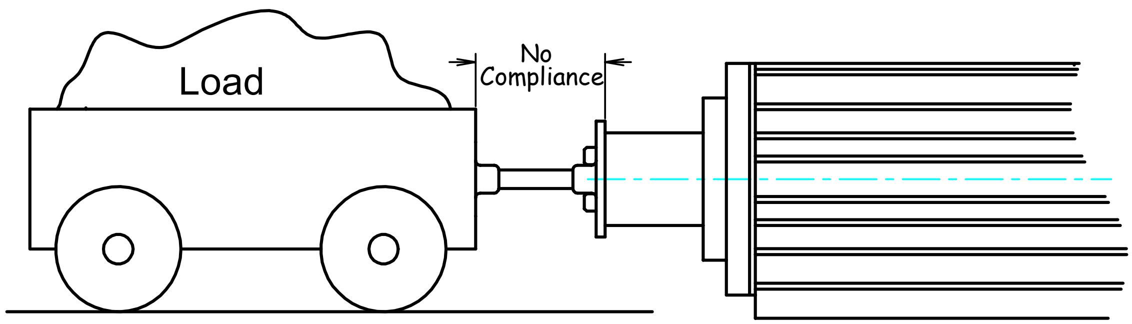


Fig 6-2 Load Coupling

6.2.1. End-Stops:

It is necessary to mechanically prevent the motor shaft from retracting past the bearings on both ends of the motor. Moog motors are shipped with end stops to prevent over-travel of the shaft during transport and commissioning. When attaching tooling or load to the shaft, use ¼ -20 hardened screws with ½" of thread engagement.

WARNING: Keep fingers and limbs clear of the motor and moving parts when power is applied to the motor.

CAUTION: Do not move the Moog linear motor's shaft without proper mechanical End-Stops. It is possible to over travel a motor without End-Stops and cause damage to the motor.

CAUTION: Do not attempt to insert or realign the shaft into the bearings if it has been moved beyond the bearings. If this occurs, the shaft will be pulled to the stator side and locked in place. The motor must then be returned to Moog for repair.

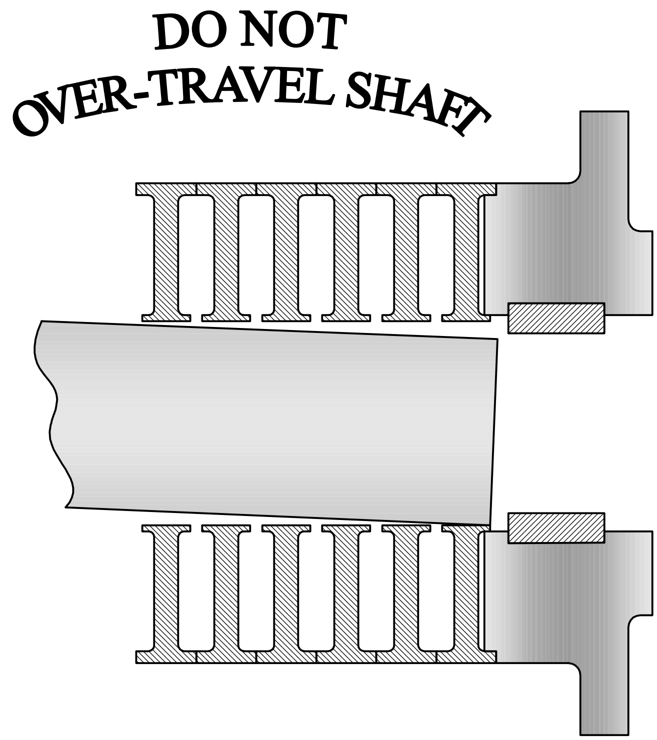


Fig 6-3 Shaft Over-travel

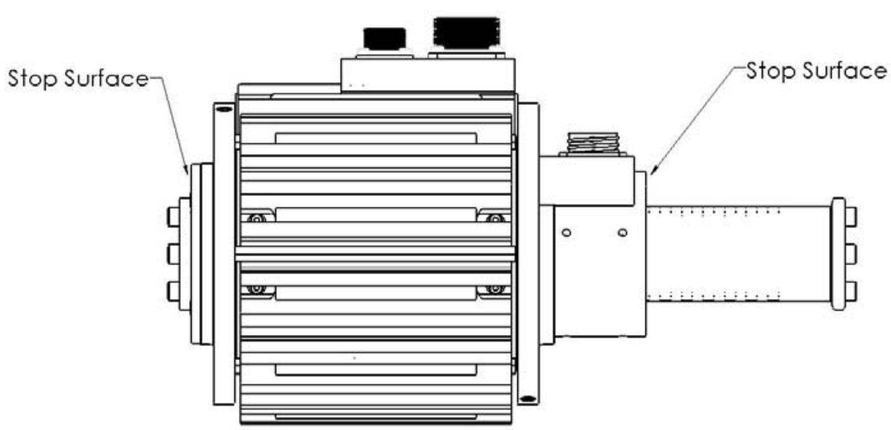


Fig 6-4 End-Stops

WARNING: Moog End-Stops are not designed for large loads.

6.2.1.1. Standard End-Stop:

Moog's standard end-stop prevents the shaft from being retracted into the motor. It is not designed for interconnection to a load. An end-stop is provided on each end of the motor shaft.

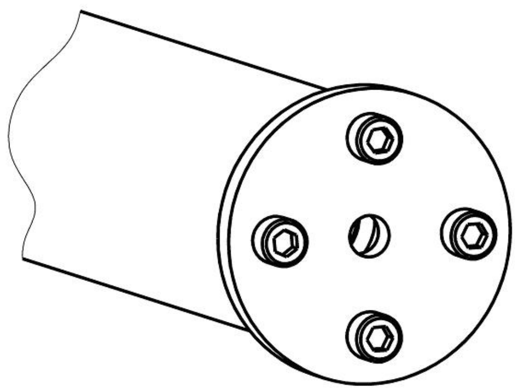


Fig 6-5 Standard End-Stop

6.2.1.2. Loads without End-Stops (option):

When attaching loads to the end of the shaft without using a Moog provided end stop, ensure that the stopping mechanism is capable of withstanding the forces exerted by the motor and load.

1. Use four ¼-20 hardened screws with ½ inch of engagement to attach the load to the motor shaft.
2. Ensure a flat flange of 2¼" diameter minimum to extend 1/8" beyond the shaft diameter.
3. Ensure that nothing is protruding inside the flange area that could damage the shaft seal.

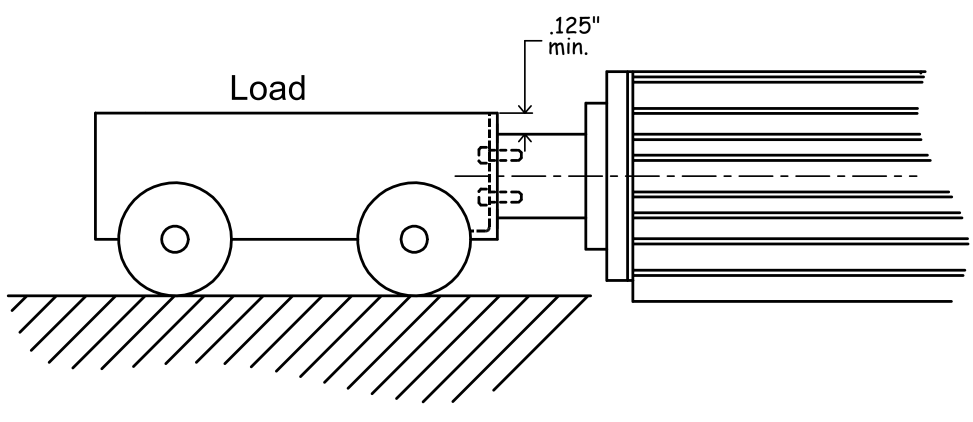


Fig 6-6 Loads Serving as End Stops

6.2.2. <u>Trueness of Load:</u>

Loads mounted to the Moog motor must to be mounted so the forces and motion are in line with the shaft. The Moog motor is not designed for offset loads that can cause additional loading or binding of the bearings.

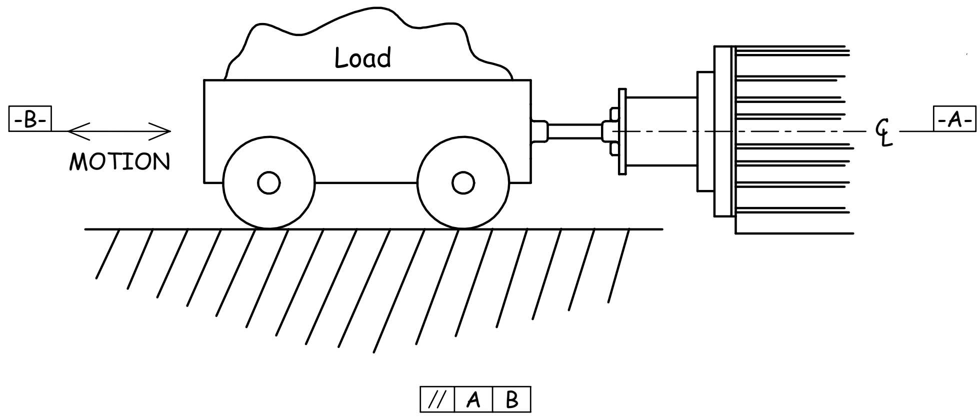


Fig 6-7 True Load

6.2.3. <u>Overhung Loads:</u>

The Moog motor is not designed for overhung loads greater than 25 lbs. Overhung loads cause additional, unpredictable bearing wear, and additional drag.

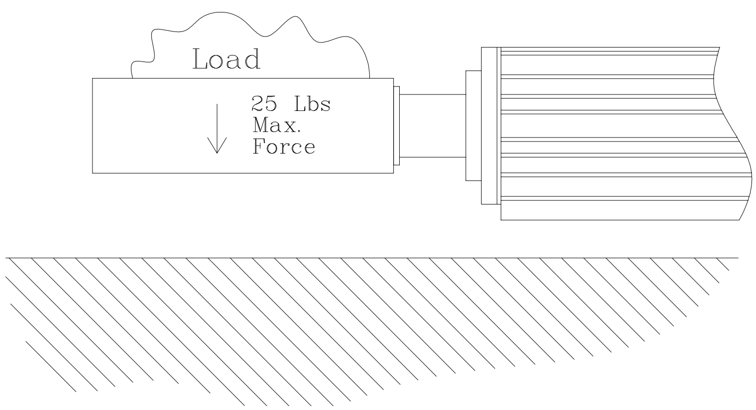


Fig 6-8 Overhung Load

6.2.4. <u>Shaft Rotation:</u>

Shaft rota tion is typically limited only by the load constraints. The Moog servo motor shaft has nothing preventing it from rotating unless an optional “LC” series feedback sensor is attached. The standard “LP” sensor allows rotation. If shaft rotation is not acceptable, provisions need to be taken to prevent the load from rotating.

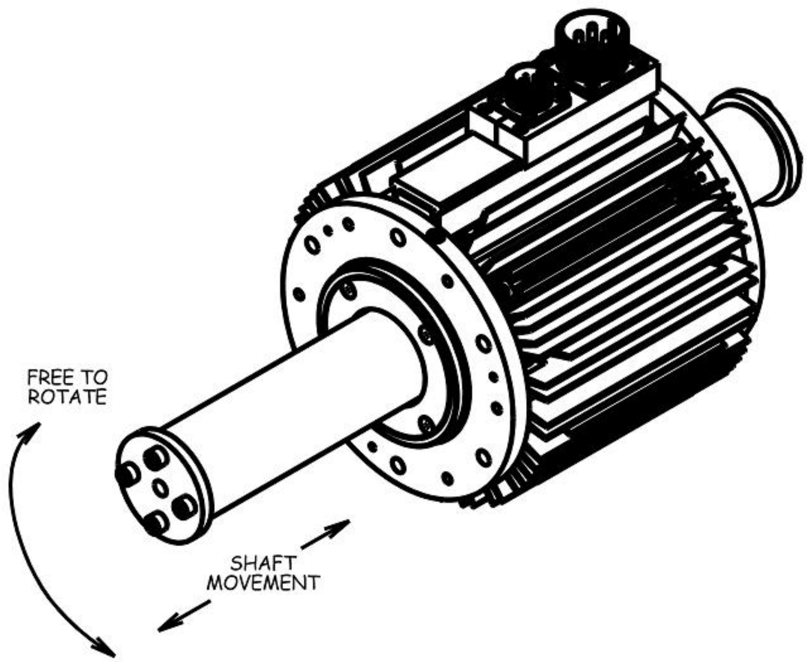


Fig 6-9 Shaft Rotation

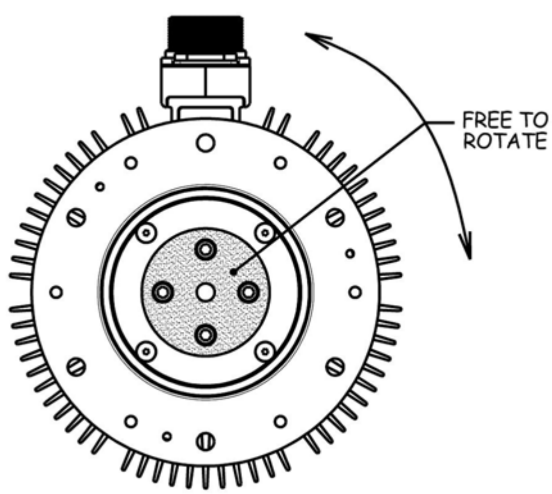


Fig 6-10 Shaft Free to Rotate

7. <u>Electrical Connections:</u>

Control component and system manufacturers use differing nomenclatures in their wiring conventions. When inserting the Moog motor into a system, be sure to consider this, and carefully examine the Moog conventions and those of the control system manufacturer to ensure proper compatibility.

Motor current and Motor power need to be limited by the amplifier or drive to not exceed the ratings given by the motor specification sheet. A thermal cutout should be employed by the system to ensure that the maximum rated temperature of the motor is not exceeded.

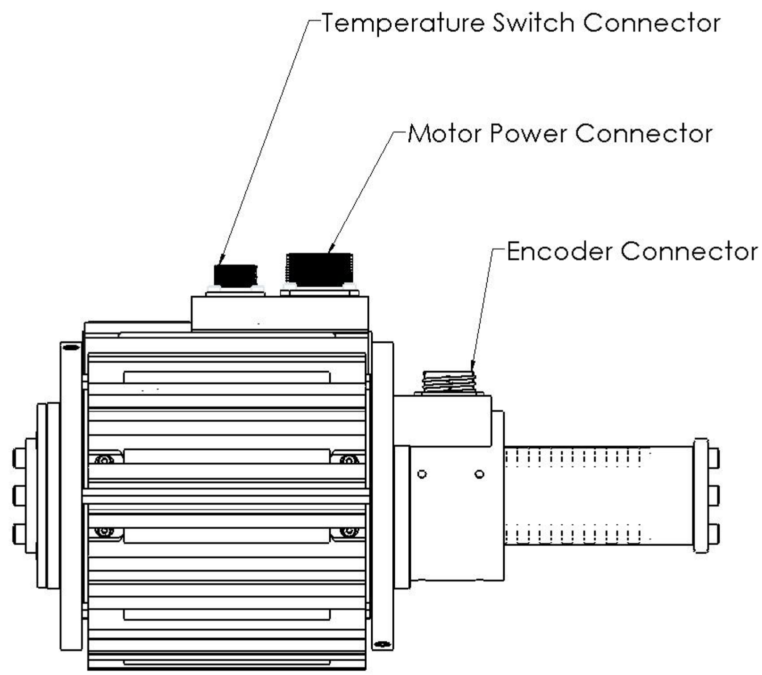


Fig 7-1 Motor Connectors

> **<u>Note:</u>** It is important to use good grounding and shielding practices for any servo systems that use this motor to minimize electrical interference.

7.1. Servo Drives:

Moog motors require a servo drive system to control the position of the motor. The motors are designed for use with drives meeting the following requirements:

Drive Requirements:

Powered by 208 – 480 VAC. In some cases 115 VAC is acceptable.
Sinusoidal Commutation
Current rating depends on motor chosen and loading. Typical peak current requirement is in the 30 -100 amp range.

The servo drive system should be selected and specified to match the specific application. The following factors are important considerations when selecting a drive for use with Moog motors for any application:

- □ Does the drive have sufficient programmability? Moog motors can be only as flexible and programmable as the drive will allow.
- □ Is the intended line voltage sufficient for obtaining the peak speed? Maximum motor speed for a given force can be limited by the line voltage. Check the application with the speed force curve for a given voltage. Reference the appropriate motor data sheet.
- □ Is the intended line voltage sufficient for obtaining the needed dynamic response? Higher line voltages result in snappier motion and more precise positional accuracy.
- □ Is the drive output current sufficient? The force that any given motor can produce is proportional to drive output current as defined by it's force sensitivity value.
- □ Is the drive of the correct basic type? Moog motors are all synchronous AC servo motors which mean that they will need a drive that produces sinusoidal commutation.
- □ Is the drive compatible with Moog's servo motor feedback type? Moog feedback sensors are incremental position sensors with six step hall signal commutation.

7.2. Servo Drive Input Voltage:

The input voltage to the servo drive has a significant impact on the motion system performance. Higher voltages provide higher speed capability. When selecting the voltage input to the servo drive, the force velocity curves of the Moog servo motors should be consulted to determine that the motor will perform at the required speeds under all loading conditions. Reference the appropriate motor data sheet.

WARNING: Do not use drives powered by voltages greater than 480 VAC.

7.3. Motor Power Connections:

It is recommended that a Moog Motor Power Cable be used to connect the motor to the power amplifier or drive. Moog power cables have integrated the necessary power components, connectors and shielding to make a good electrical power connection to the motor.

Moog produces standard 10 ft. motor power cables (MPC-XX-10-6) and 25ft motor power cables (MPC-XX-25-6) for use with Moog C&D series motors.

7.3.1. Motor Power Filter:

A common mode choke should be used in series with the motor power leads. This choke will help minimize ground currents associated with PWM amplifiers and drives typically used with this type of motor. The choke presents a high impedance to capacitively-coupled ground currents from the PWM transitions. The Motor Power Filter provided by Moog includes a common mode choke. The Motor Power Filter leads should be connected directly to the amplifier/drive lugs. The Motor Power Filters are included with the Motor Power Cables (Moog P/Ns MPC- XX-10-6 and MPC-XX-25-6) which should be purchased for use with Moog motors.

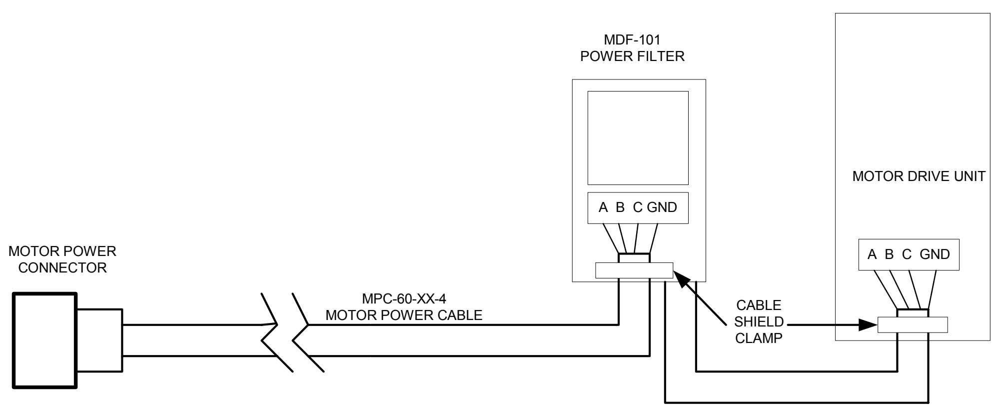


Fig 7-2 Motor Power Filter Connection

7.3.2. Motor Power Cable and Motor Power Filter Connections:

The motor power cable and Motor Power Filter are used to connect the power output of the drive to the motor. These devices carry currents and voltages that could cause severe injury if improperly connected. An electrician should ensure that these connections are performed safely and in accordance with all relevant codes and regulations.

WARNING: A qualified electrician should install all electrical components to assure safe operation and to meet all regulations.

7.3.2.1. Motor Power Filter Connection to Drive:

Connect the Motor Power Filter to the amplifier in the following manner. If the appropriate feature is available on the motor drive, install the bare portion of the cable shield securely with a clamp on the drive as depicted in Figure 6-4. Connect the green wire to chassis ground. Connect the phase wires from the cable end of the Motor Power Filter labeled Phase A, Phase B, and Phase C to the drive outputs typically labeled U, V, W , or A, B, C or R, S, T or 1, 2, 3. Connect the wire labeled GND to Ground.

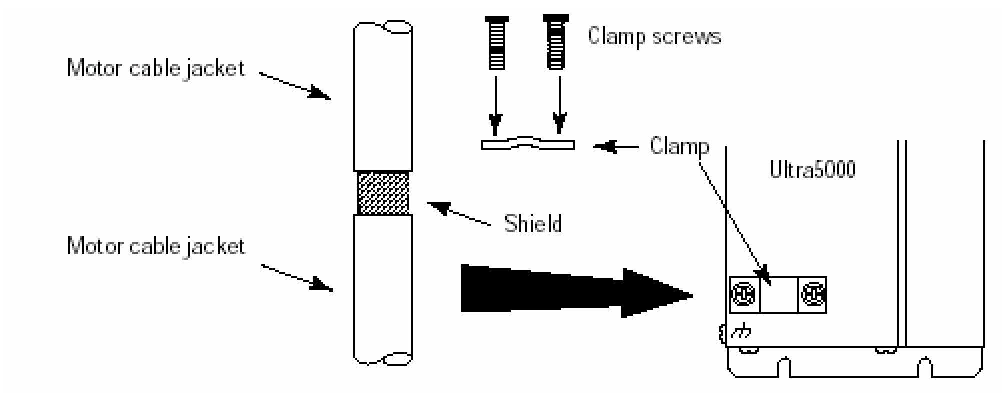


Fig. 7-3 Motor Power Filter Shield Connection to Servo Drive

7.3.2.2. Motor Power Cable Connections :

The motor power cable is interconnected between the motor's power connector and the Motor Power Filter. Attach the connector end of the cable to the motor power connector. On the Motor Power Filter loosen the cable clamp and install the cable under the clamp so that the exposed portion of the cable shielding is under the clamp. Install the wire labeled A into the terminal marked A, the wire labeled B to the terminal marked B, the wire labeled C to the terminal marked C and the yellow wire with green stripe marked Gnd to the terminal marked Gnd. Tighten the cable clamp over the exposed portion of the cable shield.

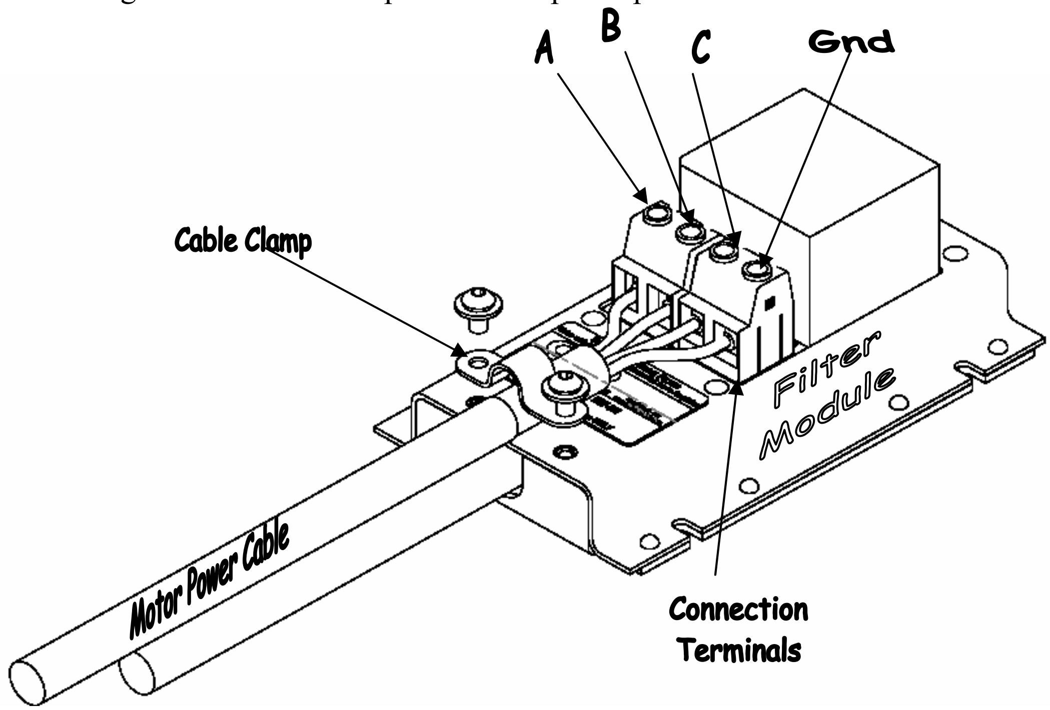


Fig 7-4 Motor Power Filter Connection

7.4. Over Temperature Protection:

Thermal protection of the Moog motors is achieved through the use of thermal switches incorporated in the motor. The thermal switches should always be considered the primary indication of a motor over temperature condition, as the thermal switches are sensitive to the temperatures of the windings.

7.4.1. Thermal Switches:

The over-temperature protection is three series connected normally closed thermal switches located close to the motor windings. The purpose of these switches is to signal the control system that the temperatures of the windings have reached the maximum rating of the motor. The switches indicate this by opening.

Moog recommends that thermal shutdown be incorporated into any control system used to drive the Moog motor. If a dedicated or compatible thermal shutdown is not a standard feature of the control system, the thermal switches should be monitored continually by a digital input and programming logic to safely shut down the system if the switches open (indicating a maximum temperature condition).

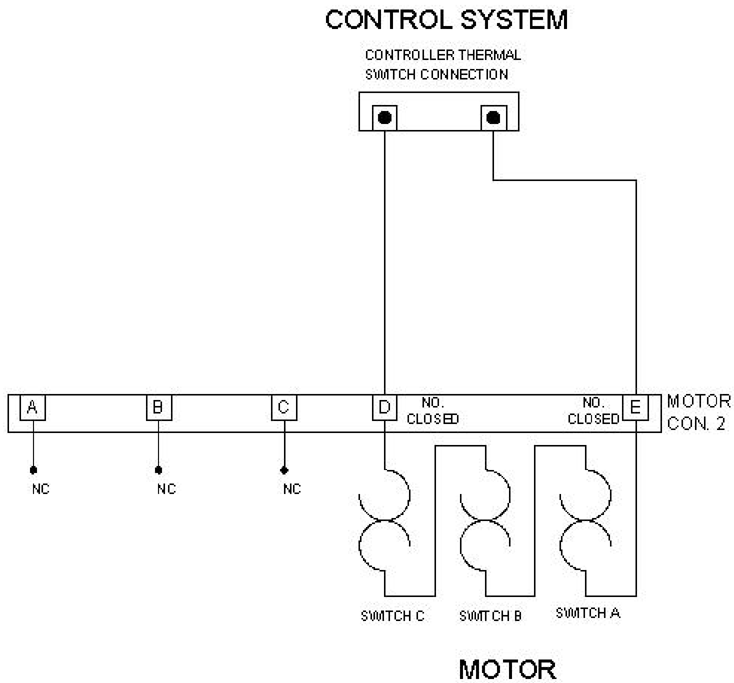


Fig 7-5 Temperature Switch Connections

7.5. Motor Feedback Connections:

Connect motor feedback to drive using Moog provided cables (or equivalent). Wiring diagrams for connecting the motor to a drive are on the Interface Control Drawings of the appropriate Moog cables. The following diagram shows the signal location on the 28 pin AMP motor feedback connector.

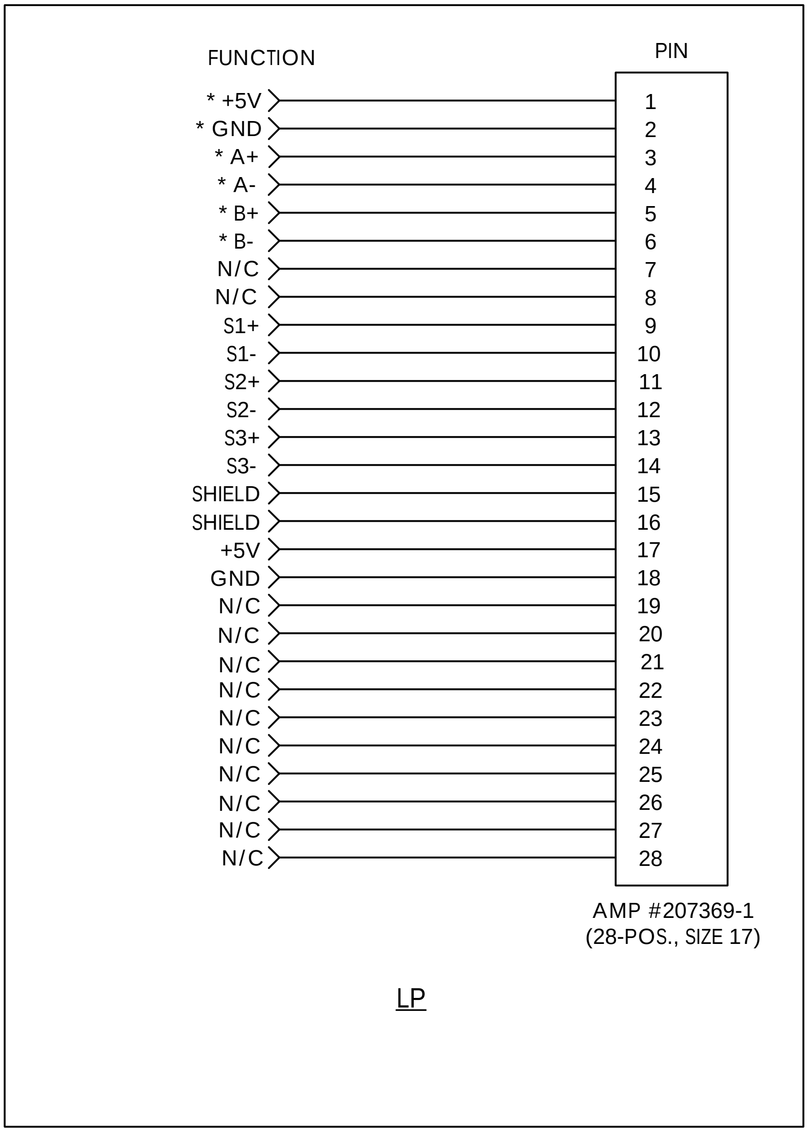


Fig 7-6 Motor Feedback Connections

7.6. Grounding and Shielding:

It is important that the motor and interconnection cables are well-grounded and shielded. The motor grounding should be to a central system ground as well as to the amp and controller.

CAUTION:	Poor ground or shield connections or wiring can cause unpredictable motion, and could damage the motor, control system or machine.

8. Position Feedback:

A position feedback signal is required for proper operation of Moog motors. The position feedback signal supplies the control system with the motor's position for control and commutation. Position sensors other than the Moog sensors can be used, but will require additional integration into the system. The type of position sensor is a system consideration and needs to be determined during system design.

8.1. Moog Position Sensors:

Moog produces several position feedback devices for use with its motors: Individual feedback device options have different resolutions, signal types, and compatibility. The LPA position sensor is considered the standard position sensor on Moog linear motors. Therefore, this manual includes the function and use of the LPA sensor. For other position sensors, separate manuals and interface control drawings for the feedback option contain the relevant information and specifications.

The motor part number specifies the linear position sensor option.

Example P/N 40202D06F-**LPA**- CV

LPA is the standard option

8.1.1. LPA Position Sensor

The LPA position sensor is an integral part of standard Moog motors. Its function is dependent on other features in the Moog linear motors. Therefore it can not operate independently of the motor.

8.1.1.1. LPA Basic Specifications

Position Signal:	Digital A Quad B output (Quadrature Incremental)
Commutation Signal:	120 deg. Six step digital
Resolution:	5 micron (5080cts/inch)
Repeatability:	10 micron
Maximum Speed:	200 in/s (5 m/s)
Linearity (zero based):	0.005 inch
Input Voltage:	5 VDC +/- 5%
Input Current:	160 mA

CAUTION: Do not apply more than 5.5 VDC to the encoder. The encoder will be damaged if the maximum rated voltage is exceeded.

8.1.1.2. Digital Quadrature Incremental Signals A and B:

Encoder option LPA provides Differential Mode Digital Quadrature Incremental Encoder data lines A+, A-, B+ and B-. These 0 to 5V (TTL level) signals connect to both single ended and Differential mode "A quad B" inputs and are electrically compatible with the industry standard RS-422 transmission protocol using the 26LS31 Buffer IC.

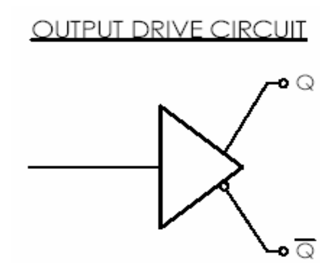
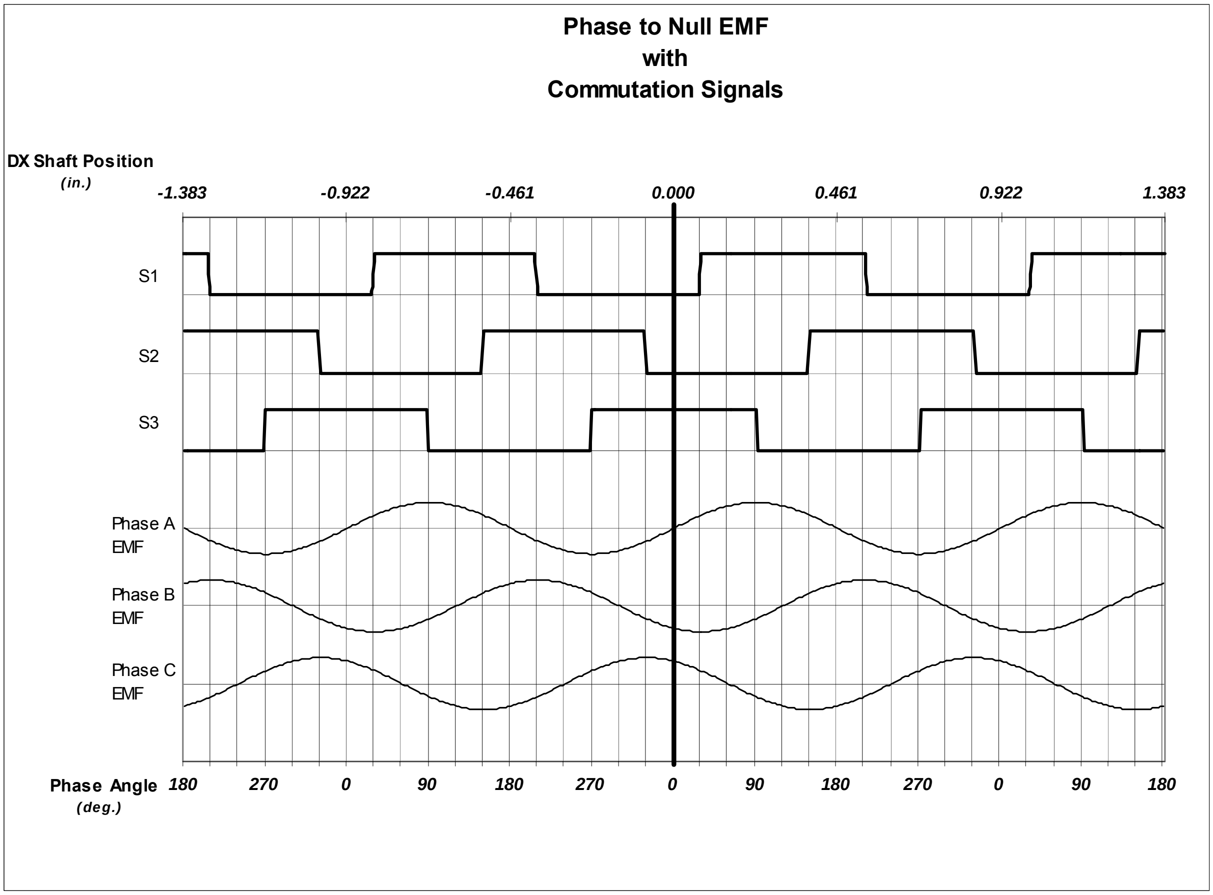


Fig 8-1 Digital Quadrature Signals

8.1.1.3. Commutation (Hall Sensor) Signals:

0 to 5V (TTL level) Differential mode Hall sensor signals are electrically compatible with the industry standard RS-422 transmission protocol using the 26LS31 Buffer IC. These signals are compatible with Drive Hall sensor inputs equipped with or without pull up resistors.



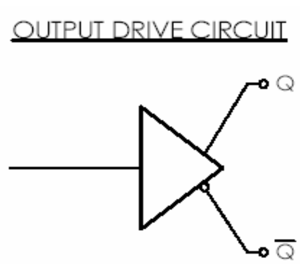


Fig 8-2 Motor Commutation Output Signals

8.2. Using a 3rd Party Position Sensor:

When using a position sensor other than one supplied by Moog, it is important to meet the following criteria in addition to those determined during system design:

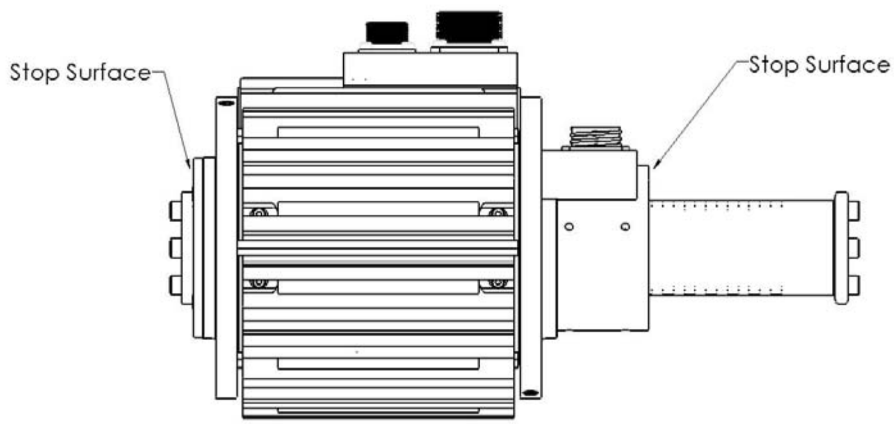
- Proportional coupling between motor linear position and output signal.
- A means of commutating the motor.
- Tight mechanical coupling between the sensor, motor shaft and motor.
- Sensor latency less than 20msec.

9. Control Conventions:

When using the Moog motor in a servo system, specific information always needs to be known and accounted for by the control system. The system always needs to have a directionality reference established, where positive direction or force sensed by the feedback device corresponds to that commanded by the amplifier and control system. A commutation method with a cycle pitch and reference angle must be established. Many feedback devices supply commutation signals, but if they are devices other than one supplied with the motor, a phase reference position will have to be established with the control system. See the installation manual of the control system (drive) used for establishing a phase reference position.

9.1. Directional Reference:

For the motor and control system to work properly together, a directional reference will need to be established for the system. Moog motors will generate positive force and motion, and cause the shaft to extend on the power connector side of the motor when the 3-phase wave-form shown in Fig. 9-2 is applied.



Direction of Positive Motion →

Fig 9-1 Positive Motion

9.2. <u>Cycle Pitch:</u>

As with other sinusoidal brushless motors, the Moog motor is commutated relative to the shaft position within an electrical cycle. The repetition distance of the cycle is known as the cycle pitch. The cycle pitch on the C&D Series motors is .922 inches.

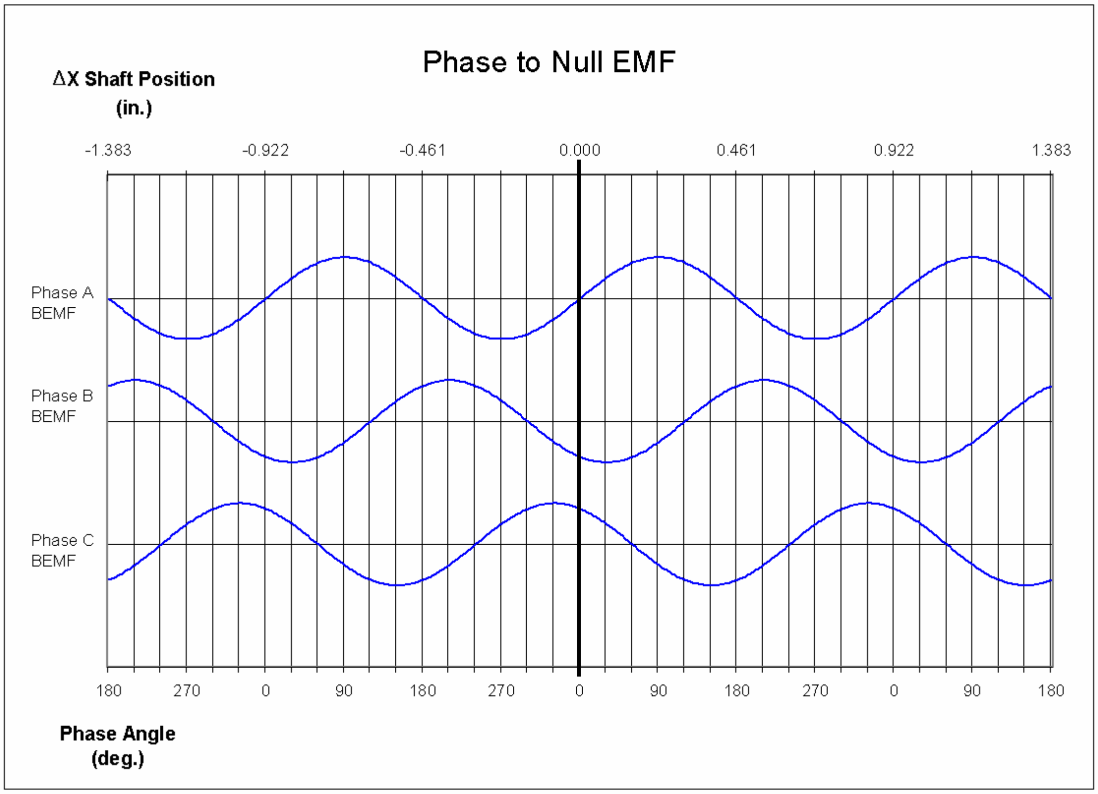


Fig 9-2 Electrical Cycle Diagram

9.3. Commutation Reference:

When using a sinusoidal brushless motor without a Moog-supplied commutation feedback device, it is necessary to set the commutation in the control system. Some control systems have procedures for setting the commutation.

9.4. Tuning a Servo System:

The servo system that includes the Moog motor will likely require some form of tuning. Follow the drive and control system manufacturer's recommendations for tuning of the system.

WARNING: Improper servo tuning can cause uncontrolled motion of the Moog motor. Do not allow the system to oscillate uncontrolled during the tuning process, and keep all personnel and body parts away from moving

10. Motor Cooling:

Motor cooling is an important facet of the motor's operation. Depending on the load capacity and ambient air temperature, a cooling system may be required. It is important to keep in mind that like any other motor, the Moog motor produces heat when it operates. It must have the opportunity to dissipate this heat or it will eventually overheat and fail. It may dissipate heat through natural convection (natural flow of air), conduction (attaching to a larger cool object), or one of the Moog cooling options. The more heat a motor can dissipate, the cooler the motor will run, and the longer it will last.

10.1. Fan Cooling (option):

The Moog motor can be supplied with five fans that force air over the motor and keep it cool. It is important that the fans and the motor are kept clean, and that cool air is allowed to move freely around the motor. Buildup of excessive dirt and debris on the motor's cooling fins will cause the cooling system to work inefficiently and could lead to overheating the motor.

10.1.1. Fan Interconnections (option):

Connect the fan to a 220 VAC single-phase supply for optimum cooling. Fans will run at lower voltages with less than the designed airflow. Follow applicable local wiring codes and regulations for interconnections.

10.2. Liquid Cooling (option):

The Moog motor can be supplied in some models with a liquid cooling jacket which draws heat from the motor without the space and ventilation constraints of a fan cooling option. The cooling jacket as supplied is fabricated from aluminum. It is extremely important that proper coolant selection and coolant circulation system be chosen.

> **CAUTION:** Use only those Coolants and cooling system components recommended by the cooling jacket manufacturer LYTRON. The use of inappropriate coolants or heat exchanger components will result in rapid galvanic corrosion and failure of the cooling system.

Aluminum water jackets, while providing effective heat transfer, are subject to galvanic corrosion if not filled with the appropriate coolant. In particular, factors which can cause rapid deterioration of the aluminum water jacket include the use of tap water of uncontrolled pH, galvanically incompatible metals in the coolant flow source or sink (generally, anything other than aluminum should be suspect), and jacket storage time prior to beginning active use, if this occurred after initial filling of the heat exchanger with tap water; short operational life of the cooling jacket may occur if preceded by storage time with initial Tap Water fill.

If Glycol - based coolant is not typically used in the installation, it is recommended that the user consider purchasing a recirculating chiller made for operation with aluminum water jackets, and precharged with glycol based coolant. A chiller which should be adequate for most installations is a standard product made by LYTRON as well as by other manufacturers. For applications information, Genesis can call Sue Shea at LYTRON, at (781) 993-7300.

11. Motor Care and Maintenance:

It is important to keep the motor clean and free of dirt and chemicals to prevent damage and ensure long motor life. The Moog motor is not designed for wash-down or exposure to most cleaning chemicals. When cleaning the motor, use a clean dry cloth when removing dirt and debris from the motor. Clean shaft as described in Shaft Cleaning section.

11.1. Environmental Considerations:

The Moog motor is designed for use in an indoor industrial environment. The motor is not designed to be washed down, exposed to weather, corrosive, or abrasive elements. Ambient temperatures should be between 1°C and 30°C (33°F and 85°F). If the motor is to be used in an ambient temperature greater than 30°C (85°F), the motor's power rating will need to be decreased.

11.2. Motor Bearing Care:

The bearings in the C&D series of Moog motors are not field replaceable. The bearing oil should be added periodically, approximately every 100,000,000 linear inches of shaft travel or if the shaft seems dry or has burnt oil residue. Ensure no foreign materials or residues are on the shaft when the motor is run. Keep the shaft clean and free of debris.

11.2.1. Bearing Lubrication:

Each of the motors bearings is equipped with an oil port for adding additional oil to the bearing reservoir. The oil ports are threaded for a 1/16NPT-27 pipe fitting. Anderol 465 oil can be added through this fitting with a small positive pressure until the bearing reservoir is full.

> **CAUTION:** Use Only Anderol 465. Other lubricants could break down prematurely and cause permanent damage to the motor and contaminate the bearings.

11.3. Shaft Care:

The exterior of the motor shaft is carbon steel that will corrode if subjected to corrosive agents. Take care in keeping it clean and free of contaminants that could cause corrosion. The shaft should be maintained with a thin film of Moog-specified oil only. In corrosive environments, the motor shaft will need to be protected from elements.

11.3.1. Shaft Cleaning:

The Moog motor shaft is self-lubricated by oil that is contained in a reservoir in the bearing assembly. Additional oil should not need to be applied to the shaft. If the bearing reservoir runs out of oil, the reservoir should be refilled as described in the Bearing Lubrication section. When cleaning the shaft, use a clean rag lightly oiled with Anderol 465.

Appendix-A: Specifications

Moog Motors - Data Sheet

Parameter	Units	Model 5020						Model 4020						
		2C	2D	4C	4D	6C	6D	1C	2C	2D	4C	4D	6C	6D
Peak Force (1 sec)	lb	360	360	780	780	1100	1100	205	410	410	850	850	1180	1180
Peak Force (3 sec)	lb	300	300	680	680	970	970	155	310	310	660	660	1020	1020
Peak Current (1 sec)	A	50	100	50	100	50	100	45	45	90	45	90	45	90
Peak Current (3 sec)	A	30	60	30	60	30	60	25	25	50	25	50	25	50
Continuous Static Force (nat. convection)	lbf	160	160	320	320	450	450	40	80	80	170	170	260	260
Continuous Static Force (forced air)	lbf	n/a	n/a	490	490	710	710	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Motor Constant	lb/sqrt(watt)	10.6	10.6	17.3	17.3	20.4	20.4	6.5	9.2	9.2	13.2	13.2	17.1	17.1
Force Sensitivity (at 50% of 3 sec Peak Curr)	lb/A	11.7	5.8	26.9	13.4	38.7	19.3	6.8	13.7	6.8	27.7	13.8	44.1	22.0
Back EMF Const. ph-ph	V_{pk}/(in/sec)	1.94	0.97	4.04	2.02	6.04	3.02	1.05	2.09	1.05	4.08	2.04	6.44	3.22
DC Winding Resistance ph-ph at 25 deg C	ohms	1.6	0.4	3.2	0.8	4.8	1.2	1.5	2.9	0.7	5.9	1.5	8.8	2.2
Winding Inductance ph-ph	mH	19.6	4.9	39.2	9.8	58.1	14.5	10.2	20.5	5.1	40.3	10.1	60.5	15.1
Detent Force (peak)	lbf	10	10	10	10	10	10	20	10	10	10	10	10	10
Thermal Resistance (nat. Convection)	deg. C/W	0.23	0.23	0.13	0.13	0.09	0.09	0.5	0.28	0.28	0.19	0.19	0.13	0.13
Thermal Resistance (forced air)	deg. C/W	n/a	n/a	0.06	0.06	0.04	0.04	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Moog Positional Feedback - Data Sheet

Parameter	Units	Model LP	Model LC (Renishaw)			
		A	A	B	C	D
Resolution	microns	5.0	5.0	1.0	0.5	0.1
Repeatability	microns	+/- 10	Not Published by Renishaw			
Linearity (zero based)	inch	+/- 0.005	Not Published by Renishaw			
Compensated Accuracy*	inch	+/- 0.007	Not Published by Renishaw			
Uncompensated Accuracy	% of measured stroke	+/- 0.4	Not Published by Renishaw			
Maximum Stroke	inch	N/A	12	12	8	8
Maximum Speed (may be further limited by control system)	in/s	200	472	236	N/A	236
Temperature - Storage	°F	0 to 250	-4 to 158			
Temperature - Operating	°F	32 to 200	32 to 131			
Humidity - Storage	% Relative non-condensing	95	95			
Humidity - Operating	% Relative non-condensing	95	80			
Acceleration	G	N/A - not moving	50			
Shock	G	100	100			
Power Supply	VDC	5 +/- 5%***	5 +/- 5%**			

* Compensation consists of externally applied scale factor supplied by Moog.

** 5 V± 5% 120 mA (typical) NOTE: For digital outputs, current consumption figures refer to unterminated readheads/ interfaces. A further 25 mA per channel pair (eg A+, A-) will be drawn when terminated with 120 Ω.

*** 5 V± 5% 160 mA (typical) NOTE: For digital outputs, current consumption figures refer to unterminated readheads/ interfaces. A further 25 mA per channel pair (eg A+, A-) will be drawn when terminated with 120 Ω.

Appendix-B: (Revision History)

ECO #	***Revision***	***Change***	***Date***
0103	A	Initial Release	October 31, 2002
0141	B	Add Motor Power Filter and delete AD590 option	February 11, 2005
0186	C	Add LPA as standard option	June 1, 2007
0199	D	Add Appendix A – Specifications	October 10, 2007
0204	E	Add section 10.2 – Liquid Cooling Option	January 22, 2008
0205	F	Remove Ref Mark Z in fig 8-1.	February 8, 2008