LIN ENGINEERING
MOTOR SPECIALISTS IN MOTION
A MOONS' COMPANY

Frameless BLDC
Mounting and Installation Guidelines

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1. Storage, Operation and Transportation Guidelines

1.1 Storage Condition

Climate category	1K4 in accordance with IEC 60721-3-1, EN 61800-2
Storage Temperature	-20°C to +100°C
Humidity	Relative humidity from 5% to 95%, with no condensation
Storage time	Unlimited

NOTE

Store motors exclusively in the original packaging provided by the manufacturer or distributor.

1.2 Operation Condition

Operating Temperature (at specified ratings)	-30°C to +155°C for altitudes up to 1000 m above sea level
Allowable Humidity (at specified ratings)	95% relative humidity, without condensation
Power Reduction (current and torque limits)	No power reduction required for altitudes above 1000 m, provided the temperature is decreased by 10°C for every 1000 m. Ensure that the winding temperature does not exceed 155°C.

NOTE

Consult with LIN Engineering for any operating conditions beyond the specified range.

1.3 Transportation Condition

Climate category	2K3 in accordance with IEC 60721-3-2, EN61800-2
Storage Temperature	-20°C to +100°C, with a maximum fluctuation of 20°C per hour
Humidity	Relative humidity from 5% to 95%, with no condensation

NOTE

Avoid impacts. If the packaging is compromised, inspect the motor components for any visible damage. Notify the carrier and, if necessary, the manufacturer or distributor.

1.4 Unpacking Information

The Rotor and Stator are customarily packaged together, either as individual units or in bulk. For customers with specific needs, custom bulk packaging can be arranged. To prevent any adverse interaction due to their strong magnetic forces, the Rotor and Stator are separated by protective packing materials. During unpacking, it is imperative to handle these components with care, ensuring they remain apart and that the magnetized rotor does not come into contact with other objects.

In cases where hall sensor devices are integrated into the Stator, it is important to note that these components are highly sensitive to static electricity. To protect them during transit, Stators with hall devices are enclosed in ESD (Electrostatic Discharge) protective bags. We strongly recommend that appropriate ESD precautions are maintained during the unpacking process to avoid any potential damage to these sensitive devices.

2. Mounting and Installation Guidelines

The guidance provided in this LIN Engineering manual is intended as general advice for installation and should be used solely as a reference. LIN Engineering accepts no liability for any errors in applying these methods, the responsibility for correct implementation rests entirely with the user.

2.1 Responsibilities Related to User Interface

The user is responsible for designing the mounting interface or system, which includes the rotor shaft, stator enclosure, and bearing system. This guide from LIN Engineering is intended to help ensure the motor's performance and reliability when integrated into the system, but it is for reference purposes only. Calculations for fit and tolerance analysis should be tailored to the specific requirements of the intended application and remain the sole responsibility of the user.

2.1.1 Bearings

The bearing system supplied by the user must be sufficiently rigid to maintain a stable and uniform gap between the rotor and stator during all operating conditions. This stable gap (refer to section **2.1.6 Air Gap Clearance**) should adhere to the requirements for runout and concentricity between the rotor and stator [Figure 1].

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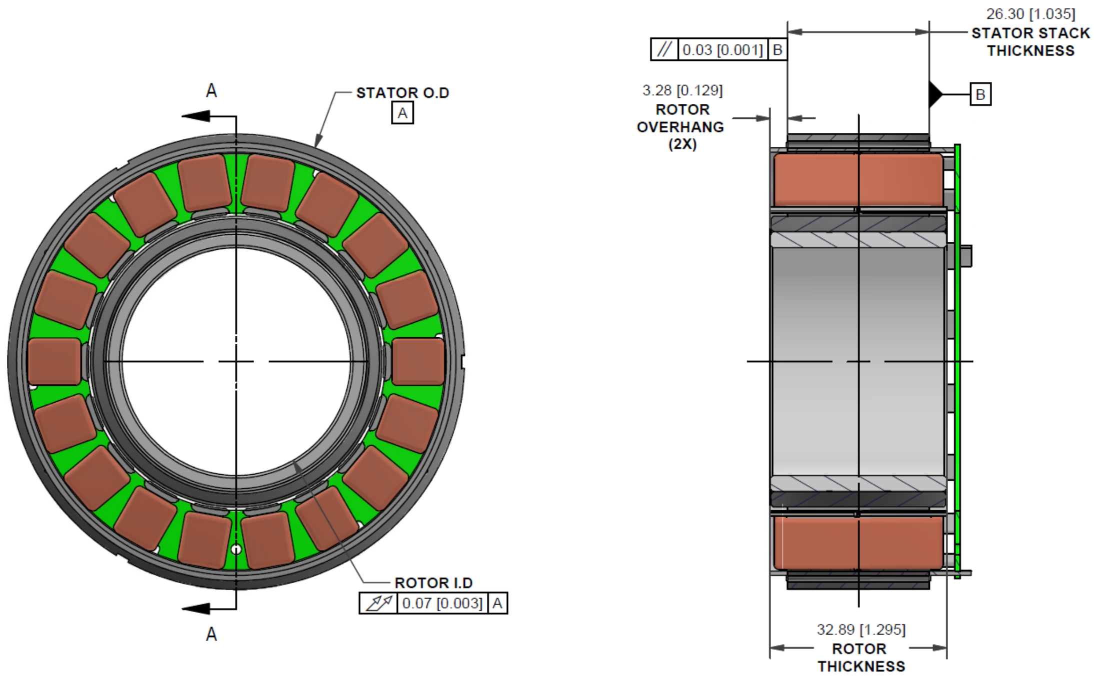

Figure 1. *LIN's 85mm Frame Size Motor Outline*

2.1.2 Material Suggestion for Stator Mounting

- A metal housing or clamp structure is recommended for securely mounting the stator to ensure optimal heat dissipation and structural integrity. Aluminum alloys are preferred due to their excellent thermal conductivity and favorable strength-to-weight ratio. Stainless steel alloys (300 series or similar) are also acceptable for applications where thermal performance is less critical but will require continuous torque to be derated (consult factory for additional information).

- Carbon steel, cast iron, 400 series stainless alloys, and other ferrous metals that conduct magnetic flux are less ideal for stator mounting. If these metals must be used, please consult LIN Engineering for in-depth guidance.

- Plastics or similar thermally insulating materials are not recommended, as they significantly impair heat dissipation and may necessitate substantial derating of the motor's performance.

2.1.3 Material Suggestion for Rotor Mounting

The magnetized rotor can be mounted onto any metallic shaft selected by the user. While carbon steel and stainless steel are the most frequently used materials for shafts, aluminum alloys can also be utilized if they are appropriately designed for the required torque and thermal conditions. The method of attaching the rotor to the shaft may affect the selection of optimal materials and tolerances for the shaft.

NOTE
The shaft does not need to conduct flux or be part of the magnetic circuit to achieve the specified performance with a LIN Engineering brushless motor.

2.1.4 Grounding

When installing the stator, ensure that the laminated stack (or metal outer sleeve) is grounded to the same electrical potential as the system and servo drive chassis. Inadequate grounding can result in electrical interference and pose a risk of electrical shock, especially with high pole-count motors that have significant capacitance. Usually, if the stator is mounted with conductive metal components, a reliable ground connection between the stator laminations and the machine chassis is naturally established.

LIN Engineering recommends verifying this ground connection through a continuity test before powering up the motor system. Depending on the specific mounting arrangement and materials used, an additional grounding strap may be required. In such instances, the user is responsible for ensuring proper installation and verification of the ground path.

2.1.5 Standard Assembly Instructions

HANDLE WITH CARE	LIN Engineering's frameless series and other frameless brushless motors are equipped with high-performance magnets. Exercise extreme caution when handling or transporting these components to prevent injury and avoid damage. The magnetic forces between the rotor and nearby metal objects can be very strong, leading to sudden, unanticipated impacts if not handled properly. Additionally, the powerful magnetic field may interfere with nearby electronic devices, including computers, display screens, and storage media. To mitigate these risks, keep the rotor in its original shipping container or well-protected until it is ready for installation. This helps to prevent accidents and reduces the risk of contamination from metallic particles or debris that may adhere to the magnet.

The following is a general assembly procedure for installing a Rotor (Field Assembly) into a Stator (Armature Assembly):

1. Firmly attach the customer-supplied housing to a stable surface to avoid any unintended movement.
2. Insert the stator into the housing and secure it using either bonding or clamping methods, as detailed in section **2.2 Stator Mounting Instructions**.
3. Position the rotor onto the customer-supplied shaft and secure it using either bonding or clamping techniques, as outlined in section **2.3 Rotor Mounting Instructions**.

CAUTION	
	Rare earth magnets are prone to cracking and chipping. It is essential to exercise caution to prevent dropping the magnets or subjecting them to impacts during the installation of the rotor onto the shaft.

4. Before inserting the Rotor/Shaft Assembly into the Stator/Housing Assembly, Lin Engineering advises placing a thin layer of shim material, such as Mylar® film, inside the inner bore of the stator.

*The Mylar film can either be installed as a single piece wrapped entirely around the circumference of the stator bore or as multiple pieces placed axially at evenly spaced intervals. The ideal film thickness and the number of shim layers required will depend on the gap clearance between the rotor and stator for the specific motor size being installed. Refer to the section **2.1.6 Air Gap Clearance** chart below for guidance.

CAUTION	
⚠	As the rotor is being installed, the magnetic attraction between the rotor's outer surface and the stator's inner bore may cause the rotor to adhere to the closest point within the stator. This interaction can result in friction during insertion, which may lead to potential damage to the rotor band, magnets, protective coatings, or the stator bore surfaces.

2.1.6 Air Gap Clearance

LIN's Frameless motors											
Stator Lamination Outer Diameter (mm)		**040**	**052**	**060**	**070**	**077**	**085**	**100**	**127**	**137**	**160**
Nominal Air Gap Clearance (Radially)	**mm**	0.500	0.300	0.43	0.44	0.70	0.35	0.75	0.51	0.70	1.00
	in.	0.020	0.012	0.017	0.017	0.028	0.014	0.030	0.020	0.028	0.039

NOTE

The user must take into account the concentricity/run-out specifications outlined in the model-specific LIN Engineering drawings. It is recommended to select bearings with minimal friction and high-quality lubricants to reduce system friction and ensure the motor operates at peak efficiency.

Axial alignment control is vital when implementing the frameless motor into any system and is commonly achieved through machined shoulders or grooves at the customer's discretion.

2.2 Stator Mounting Instructions

LIN Engineering recommends several installation methods for the motor stator, taking into account factors such as torque, vibration, and the thermal properties of the application. Additionally, considerations include cost, ease of assembly, and the level of serviceability required by the user. The following guidelines are provided as a reference.

Surface Preparation

Before bonding the stator to the housing, it is essential that both surfaces are meticulously cleaned to ensure optimal adhesion. The cleaning process should be carried out in accordance with the recommendations provided in the adhesive's data sheet, which will specify the appropriate techniques based on the material of the housing.

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Proper surface preparation is critical for:

- Achieving a strong, reliable bond that meets the application's torque, vibration, and thermal requirements. The cleaning procedure should adhere to the specific recommendations for the materials involved, which can be found in the relevant technical documentation or manufacturer guidelines.
- Avoiding issues such as slippage or uneven mounting, which could impact the performance and reliability of the assembly.

2.2.1 Stator Bonding

*This method is highly recommended for applications with high peak torque values.

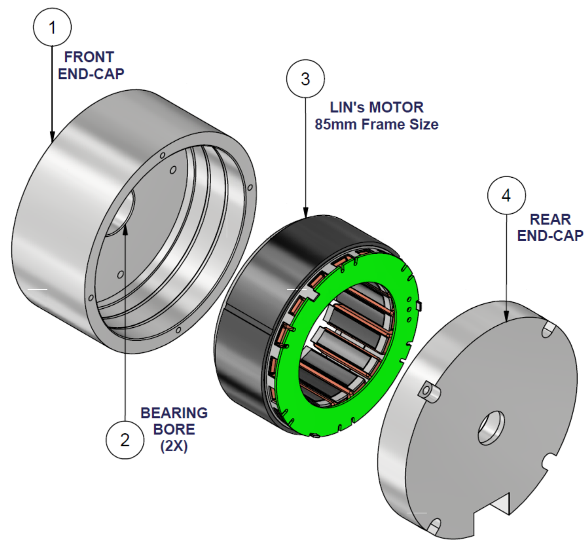

Figure 2. *Exploded view of Stator to Housing Assembly with Bonding Method*

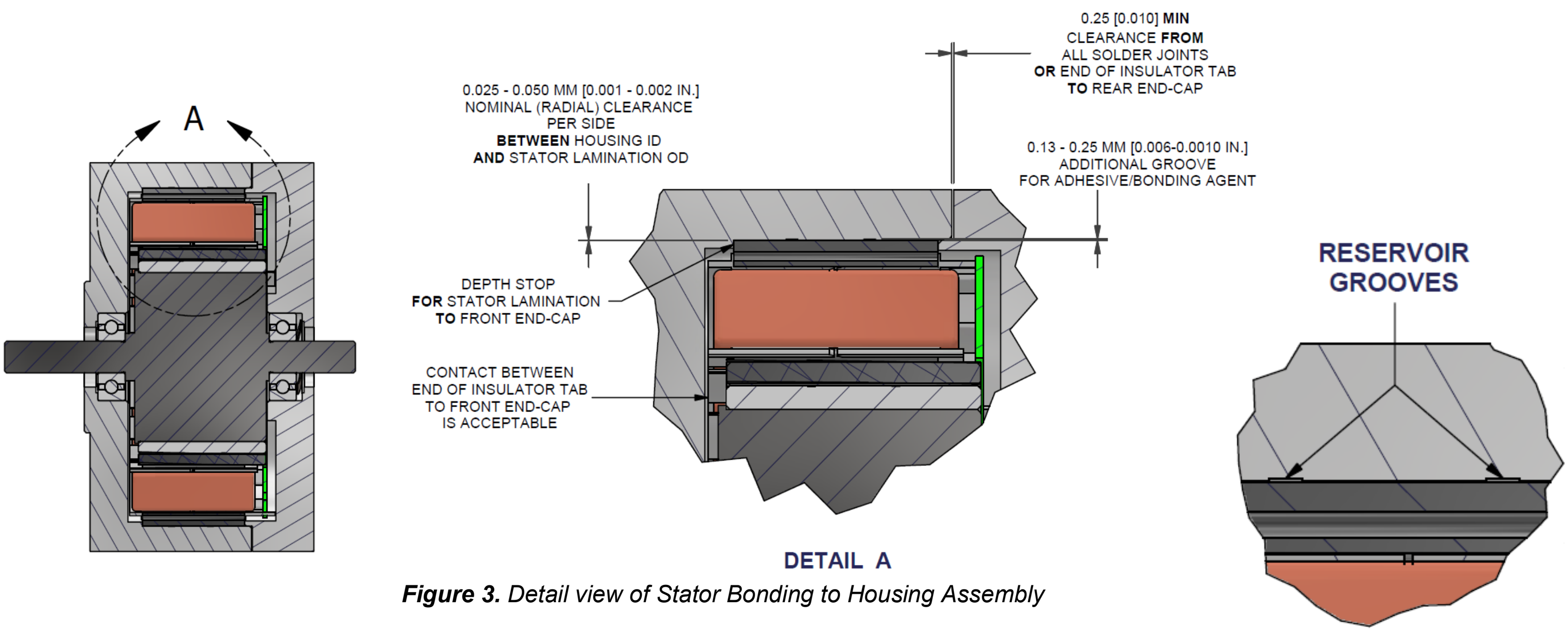

Figure 3. *Detail view of Stator Bonding to Housing Assembly*

2.2.1.1 Bonding Material

Bonding is a preferred and permanent installation technique for all LIN's frameless stators, particularly in applications where peak torque values fall within the shearing range of structural epoxy adhesives. For motors with high peak torque, the stator can be securely bonded in place using a structural epoxy such as 3M™ Scotch-Weld™ 2214 or other similar adhesives.

2.2.1.2 Design Consideration

To effectively utilize adhesive bonding, the stator enclosure should be designed as a cylindrical cup and should include a small shoulder at one end for axial positioning, with the opposite end remaining open. The shoulder serves as a stop for the stator during insertion, ensuring proper alignment, and should accommodate the maximum outer diameter of the winding end-turn, as specified in the outline drawing. Sharp corners of the stator laminations require corner reliefs, and a small internal chamfer at the open end of the housing is recommended to facilitate stator insertion.

Temperature fluctuations can present challenges due to the differing expansion coefficients of materials, such as steel laminations and aluminum housing. To mitigate these issues, the user should consult the adhesive manufacturer for guidance on proper bond line thickness, application procedures, and curing instructions. The grooves shown in the inner diameter of the housing serve as adhesive reservoirs, enhancing torsional strength across a broad temperature range. For thick structural epoxies, the housing cup's inner diameter should be approximately 0.05 mm to 0.1 mm larger than the stator's maximum outer diameter [Figure 3]. These measures ensure that, when applied according to the manufacturer's guidelines, the bonding agents deliver excellent durability and strength over time.

Should a retaining compound such as LOCTITE® 640™ or an equivalent adhesive be chosen instead of structural epoxy, it is essential to ensure a tighter clearance between the housing's inner diameter and the stator's outer diameter to achieve the correct bond line thickness. It is recommended that users consult the adhesive manufacturer's guidelines for detailed instructions.

2.2.1.3 Assembly Process

During assembly, it is ideal to lay the stator housing flat, with the rotation axis vertical. This orientation allows the hydrostatic pressure of the structural adhesive to assist in self-centering the stator within the housing. While adhesive bonding is effective, there may be potential perpendicularity issues between the stator and housing. However, these can be mitigated by incorporating shoulder features and chamfers, which aid in precise insertion and location.

NOTICE

The user is responsible for ensuring the appropriate selection of adhesive and for designing housing dimensions that account for the anticipated thermal expansion rates under the application's temperature extremes. Additionally, it is critical that adhesive curing temperatures remain below 155°C to avoid potential damage to the motor stator.

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2.2.2 Stator Axial Clamping

*This method is suitable for applications with low to moderate torque requirements or where periodic removal of the stator is necessary.

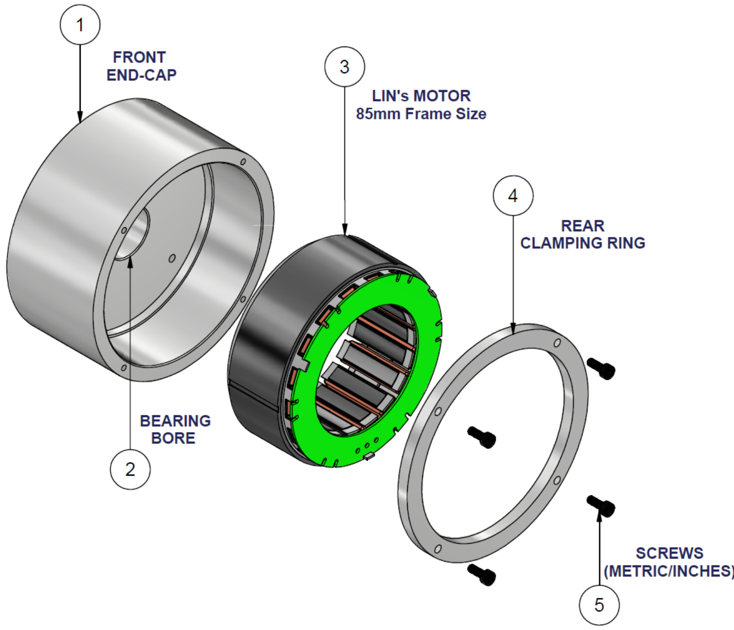

Figure 4. *Exploded view of Stator to Housing Assembly with Axial Clamping Method*

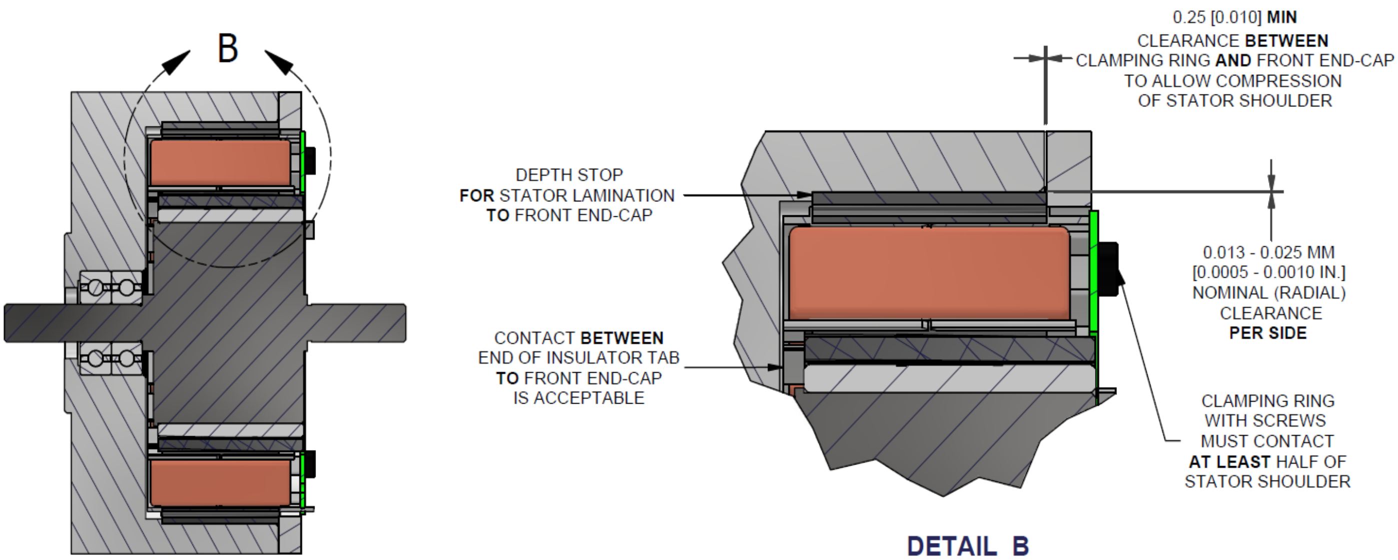

Figure 5. *Detail view of Stator Axial Clamping to Housing Assembly*

2.2.2.1 Design Consideration

LIN Engineering recommends that the inner diameter of the housing cup be approximately 0.013 mm to 0.025 mm larger than the stator's maximum outer diameter [Figure 5]. For enhanced thermal conduction, the radial gap between the stator and housing can be filled with a thermal compound. A machined shoulder feature should be included to act as a stop and location point during stator insertion. At the opposite end, a clamp ring must be used and bolted to the housing with 4 to 12 evenly spaced fasteners. It is critical to ensure that the clamping ring contacts the stator core before engaging the housing to achieve adequate clamping forces.

It is also recommended to incorporate locating features and stops to secure the stator in position (consult with LIN Engineering for in-depth guidance). Additionally, the clamping pressure should be maintained within a range of 5 to 20 MPa (725 to 2900 psi). Excessive clamping pressures can result in increased core losses during high-speed operation, while insufficient pressure may lead to improper mounting.

2.2.2.2 Assembly Process

During the clamping process, ensure that the housing bore depth is designed so that the clamping ring engages the stator before making contact with the housing, avoiding any potential issues with insufficient clamping force. To maintain proper clamping, ensure adequate preload on the clamping bolts and consider using a removable thread locker to prevent loosening during extended operation.

2.3 Rotor Mounting Instructions

Surface Preparation

Before bonding, it is essential to meticulously clean the surfaces of the shaft and rotor inner diameter (ID) to achieve optimal adhesion. Consult the adhesive's data sheet for specific cleaning methods appropriate to the housing material.

Lin Engineering provides critical rotor inner diameter (I.D) dimensions and alignment specifications in model-specific drawings, available online. Adherence to these dimensions is vital for the optimal design of the rotor shaft assembly and bearing system.

2.3.1 Rotor Bonding with Adhesive

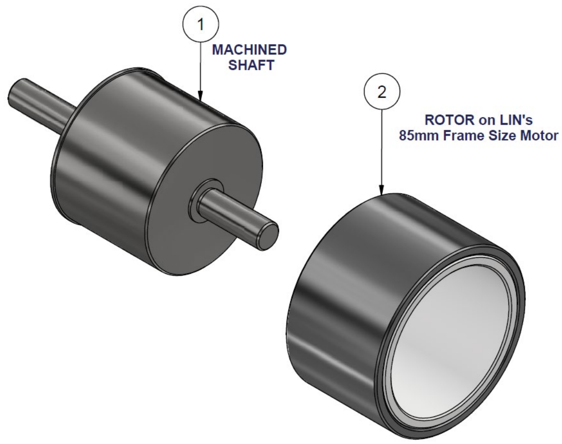

Figure 6. *Exploded view of Rotor Bonding to Shaft Assembly*

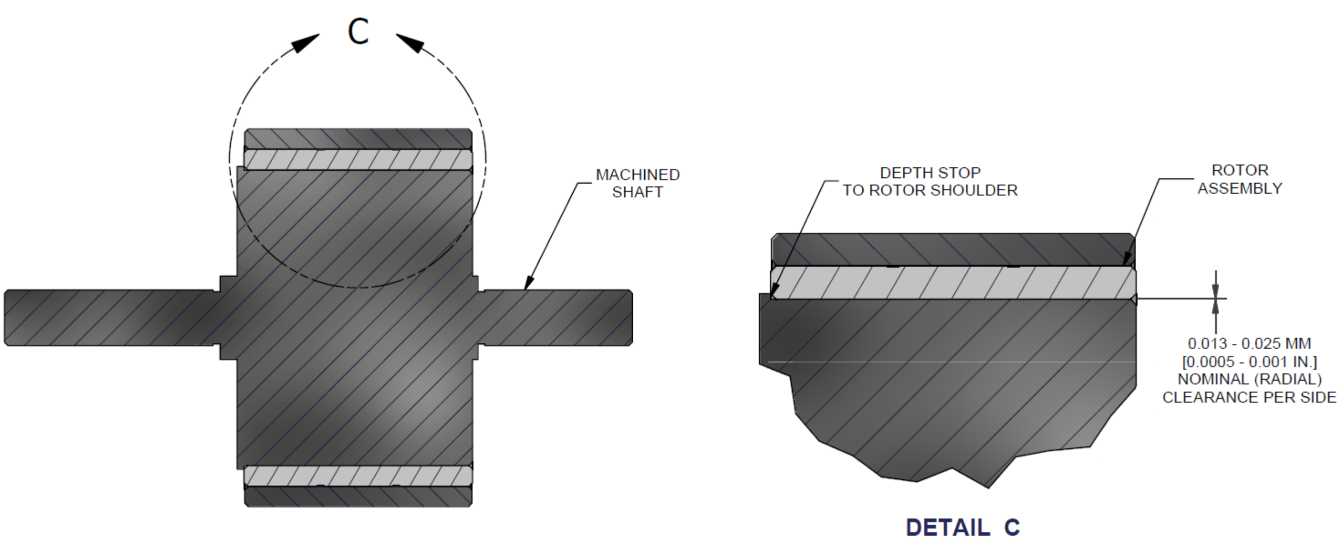

Figure 7. *Detail view of Rotor Shaft Assembly*

2.3.1.1 Bonding Material

For peak torques up to 750 Nm, bonding the rotor to carbon steel or stainless-steel shafts is effective. Retaining compounds like LOCTITE® 640™ require tight fit tolerances (0.013 mm - 0.025 mm). Structural epoxies may require slightly larger gaps and benefit from grooves or textured surfaces for better adhesion. Always consult the adhesive manufacturer for proper application and curing guidelines.

2.3.1.2 Design Consideration

Multiple methods exist for securing the rotor to the shaft or rotary output, though bolting is rarely used. Ensuring precise axial alignment during mounting is essential, as misalignment can significantly impact motor performance. Consideration of the thermal environment and material selection is also crucial.

2.3.2 Optional Rotor Mountings

2.3.2.1 Rotor Mounted with Knurled Shaft

When mounting a rotor to a shaft using knurling, it is important to choose the appropriate knurling pattern (straight or diamond) based on torque and load requirements. The knurl depth, typically between 0.001 to 0.005 inches (0.025 to 0.127 mm), must be optimized to ensure sufficient grip without damaging components.

Ensure the rotor bore is slightly smaller than the knurled shaft for an interference fit, typically ranging from 0.025 to 0.127 mm. The assembly can be aided by heating the rotor or cooling the shaft. Proper alignment during the press-fit is critical to avoid misalignment or damage. Post-assembly checks, such as torque tests and runout inspection, should be performed to ensure a secure fit and smooth operation. Material compatibility, stress distribution, and the use of lubrication during assembly are also key factors to consider.

2.3.2.2 Rotor Bonding with Adhesive and Knurled Shaft

For applications requiring enhanced torque transfer, combining knurling with adhesive bonding offers a robust solution. The knurled shaft provides mechanical grip, while the adhesive fills any remaining gaps, ensuring both a frictional and chemical bond. The knurl depth should be optimized for sufficient grip without damaging the rotor, typically in the range of 0.025 mm to 0.127 mm.

Adhesives such as LOCTITE® 640™ or structural epoxies can be used alongside knurling, with epoxies particularly benefiting from the textured surface created by knurling for improved adhesion. Adhesive bonding requires close fit tolerances, typically between 0.013 mm and 0.025 mm, and proper curing. This hybrid approach enhances the assembly's ability to handle higher torque while minimizing the risk of slippage or misalignment, making it ideal for applications demanding both mechanical and chemical retention.

NOTE
The above technique is provided for reference. For detailed guidance, please consult LIN Engineering.

CAUTION	
⚠	To prevent rotor demagnetization, avoid curing rotor/shaft bonds at temperatures above 110°C unless the rotor is within the stator or surrounded by a ferrous metal fixture. Special care should be taken when bonding rotors to aluminum shafts, potentially requiring a highly flexible adhesive with broad thermal properties. Consult with LIN Engineering if the operating/storing condition beyond the mentioned temperature.

2.4 Motor (Rotor-Stator) Mounting Instructions

2.4.1 Sensor-less version

When mounting a sensor-less motor, it is best to align the axial center of the rotor with the axial center of the stator for optimal performance [Figure 8]. This alignment ensures complete magnetic coupling, allowing for maximized torque and full motor efficiency.

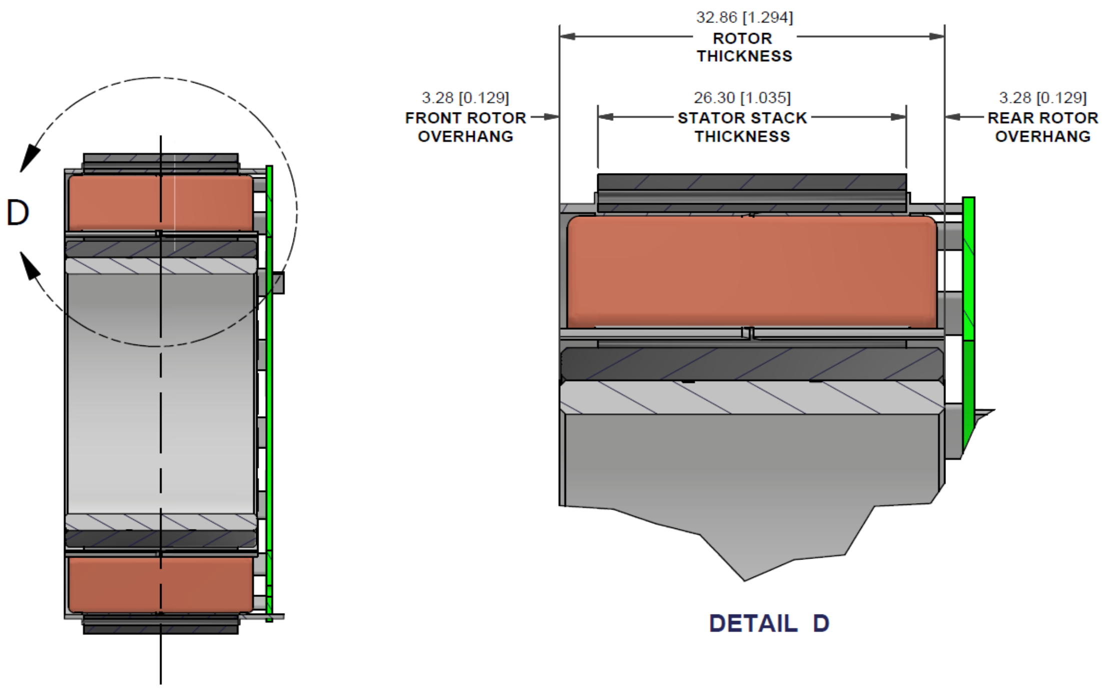

Figure 8. *Detail view of Rotor to Stator Alignment on Sensor-less Motor version*

Additionally, proper alignment ensures uniform force distribution, which balances electromagnetic forces, minimizing wear and tear of system components and reducing vibration.

2.4.2 Hall-sensor version

To ensure and accurate triggering of Hall devices, LIN Engineering's outline drawing specifies a precise mounting dimension between the face of the lamination stack and the edge of the yoke ring, as illustrated in Figure 9. This dimension ensures that the magnet material adequately covers the lamination stack and extends axially to trigger the Hall devices. Figure 9 shows the mounting dimension for the LIN's 85 mm frame size, measured from the left edge of the lamination stack to the left edge of the yoke material (excluding the magnet).

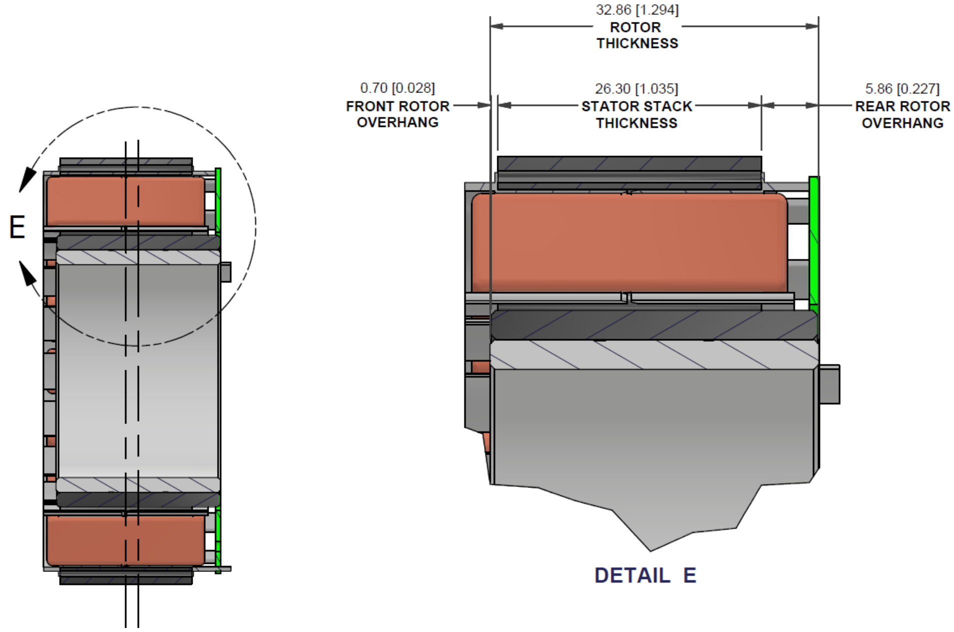

***Figure 9.** Detail view of Typical Rotor to Stator Alignment on Hall-sensor Motor version*

If it is more desirable to determine the rotor offset on the opposite side of the lamination stack, this dimension can be calculated as follows:

Rear Overhang (mm, nominal) = “Rotor Thickness” – “Stator Stack Thickness” – 0.70 mm

Example:

Rear Overhang (mm, nominal) = “32.86” – “26.30” – 0.70 mm = 5.86 mm

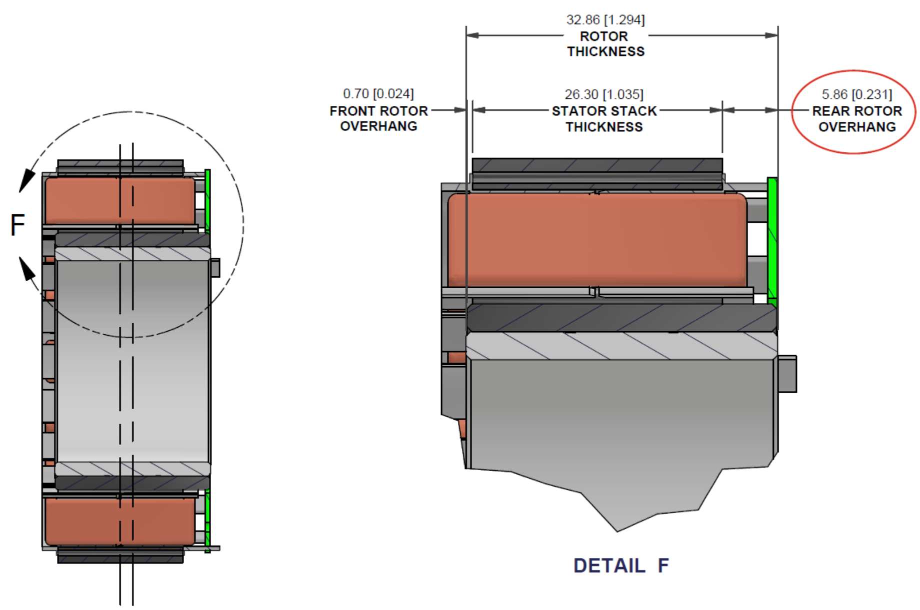

***Figure 10.** Detail view of Alternative Rotor to Stator Alignment on Hall-sensor Motor version*

2.5 Electrical Connection Option

For the Frameless series motors provided by LIN Engineering, the following guidelines apply to the use of UL-compliant un-terminated flying lead wires:

1. **Lead Wire Routing and Connection**:
   - Ensure all lead wires are routed and connected in accordance with the diagrams provided on LIN Engineering drawings.
   - Avoid positioning wires across sharp edges, corners, or other potential pinch points where the insulation could be pierced or damaged.
2. **Securing Wire Bundles in High-Vibration Environments**:
   - Secure wire bundles with clamps or appropriate fasteners in high-vibration applications to prevent contact with surfaces that may cause abrasion.
   - Maintain wire bundles away from moving or vibrating parts to avoid wear on insulation.
3. **Strain Relief and Bend Radius**:
   - Implement strain relief for all wire bundles to protect against mechanical stress.
   - Allow for a generous bend radius to reduce strain on the wires and prevent damage.
4. **Additional Electrical Interface Enhancements**:
   - The user is responsible for any additional modifications or enhancements to the wiring beyond the configuration specified in the LIN's motor outline drawing. This may include:
     - Connector installation
     - Crimping or soldering
     - Shielding or sleeving

Standard Lead Wiring Chart

STANDARD WIRING CHART #1	
Function	**Color**
Phase A (U)	Yellow
Phase B (V)	Red
Phase C (W)	Black

STANDARD WIRING CHART #2	
Function	**Color**
Phase A (U)	Yellow
Phase B (V)	Green
Phase C (W)	Blue

OPTIONAL ADDED-IN HALL SENSOR	
Function	**Color**
Hall A (U-V)	Blue
Hall B (V-W)	Green
Hall C (W-U)	White
Hall +5 VDC	Red/White
Hall Ground	Black/White

OPTIONAL ADDED-IN THERMISTOR	
Function	**Color**
Thermal Sensor (+)	Red
Thermal Sensor (-)	Blue

* Alternative color code options are available based on customer requirements.

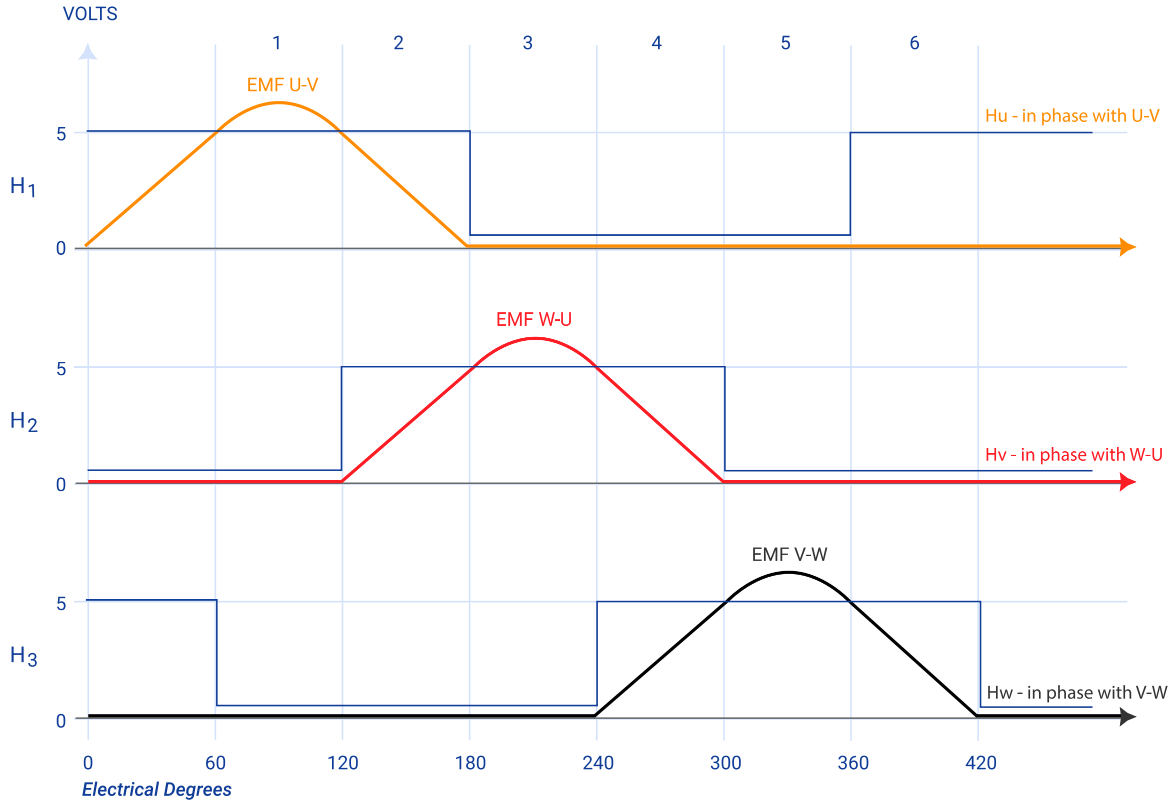

Figure 11. *Hall Sensors Commutation Diagram*

SIX STATE COMMUTATION CHART			
STEP	**PHASE A (U)**	**PHASE B (V)**	**PHASE C (W)**
1	+	-	
2	+		-
3		+	-
4	-	+	
5	-		+
6		-	+

* Counter-Clockwise rotation viewed from PCB/Lead-end.