thin gap

INNOVATION IN MOTORS

INTEGRATION GUIDE

This Integration Guide is intended to be a comprehensive document with a wide range of information on handling, integrating, and supporting ThinGap's motor kits.

Info@thingap.com | www.thingap.com

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I. Overview

ThinGap is a leading designer and maker of slotless motor kits based on its proprietary technology, ability to provide engineered solutions, and capability to provide US-made motor kits. In most cases, ThinGap's slotless motor kits are sold as a frameless set comprised of a stator and a rotor. While framed and housed versions are offered for a number of its motor kits, the ability to deeply integrate ThinGap products into an application is an important aspect of effectively utilizing a frameless part set.

ThinGap's standard product lines can be divided into two distinct groups: the LS Series of high precision, torquer-motor kits, and the TG Series of high-speed ironless core motor kits. In addition to these standard products, ThinGap has developed a wide range of custom, modified, and application-specific motors and generators.

LS SERIES

TG SERIES

This document is intended to provide useful information on integrating ThinGap motor kits, ranging from handling, housing designs and considerations for choosing electrical components for the motor kits. It should be noted that, while the LS and TG Series of motor kits have similar requirements for electrical components, their housing design considerations and mounting techniques can be significantly different.

Product Selection and Options

As indicated above, ThinGap has two standard product lines, as well the ability to develop custom, modified, and application-specific designs. Standard products range in size, from as small as 25 mm Outer Dimeter (OD) to 300 mm OD, as well as custom sizes that are larger. Torque specifications for each motor are indicated in newton-meter (N-m) and usually with a stated continuous and peak torque value.

Datasheets, performance specifications, and STEP-files of the mechanical envelopes of all standard products are available at www.thingap.com. A Speed and Torque Curve calculation tool is available upon request.

Framed and housed motor assemblies are available for a limited number of standard motor kits. Hall-effect sensors are an option for many, but not all, motor kits. Special requirements, including supporting Space-rated or MIL-STD requirements, are possible with all motor kits as a special or modification to the standard part set.

For certain mission critical applications, a redundant Stator design is possible. Other modifications include, wiring and interconnect changes to accommodate Voltage input levels, an altered number of electrical phases, or enhanced magnet retention to the Rotor for overspeed operation.

Please contact ThinGap Sales and Applications for additional information.

II. Mechanical Integration

Packaging and Handling

ThinGap motor kits are packaged with both the Stator and Rotor in individual bags surrounded in foam. The Stator and Rotor can either be in the same box or in separate ones depending on how many motor kits are being shipped. If a motor kit is purchased with a pre-built frame, the whole assembly will be shipped as one piece.

The TG Series motor kits are ironless and do not have an attractive force between the Rotor and Stator. The LS Series motor kits have ferrous material in the lamination stack and the Stator and Rotor will be attracted to one another when in close proximity. This can lead to a collision which can damage the Rotor as well as the Stator or even personal injury from pinching. CAUTION SHOULD ALWAYS BE USED WHEN HANDLING THE ROTOR SINCE IT USES PERMANENT MAGNETS AND REPRESENTS A PINCH OR COLLISION HAZARD. IN ADDITION, STRONG MAGNETIC FORCES CAN INTERFERE WITH PACEMAKERS AND IMPLANTABLE MEDICAL DEVICES. Good practice when unpacking either type of motor kit is to keep the Stator and Rotor at least 2 feet apart from one another and away from any magnetically sensitive material when not properly housed or installed to avoid accidental collision. Always avoid close proximity to any sensitive device, such as pacemakers and implantable medical devices.

Cleanliness and foreign object damage are important considerations in the handling and storge of any permanent magnet motor. It is important to make sure that the Rotors for both the LS Series and TG Series are clean of any particulates which may have been attracted to them. When not in use, and if not assembled into a housing, the Rotor and Stator should be stored in sealed bags and kept at least 2 feet apart from one another and in an area that meets the temperature ranges found in the below table. When removing the motor kit from storage, make sure that the Rotor and Stator are taken out of the sealed bags in a clean environment. Exposed parts are susceptible to rust or oxidation and should be inspected after periods of storage and improper handling.

Recommended Storage and Operational Temperatures

Motor Type	Storage Ambient		Operation Ambient		Operation	
	Lower (°C)	Upper (°C)	Lower (°C)	Upper (°C)	Stator (°C)	Rotor (°C)
TG Series Motors	-60	80	-60	50*	-60 to 130	-60 to 85
LS Series Motors	-40	80	-40	50*	-40 to 130	-40 to 85

* 50 degree C is a general guideline. Actual upper ambient temperature will depend on mounting and thermal conditions. Motor performance in ThinGap published Datasheets assumes a 20 degree C ambient condition.

Housing Design

ThinGap motor kits are normally sold as a Stator and Rotor, unless otherwise stated or promoted. This means that a housing will need to be designed for the motor kit so that it can be properly retained and integrated into its intended application. In a limited number of cases, ThinGap offers a framed version of the TG Series and a housed Direct Drive Assembly for the LS Series (see section IV. Supplemental Images). These standard offerings, along with the potential for custom designed motor housings are available for an addition NRE charge.

Provided below are some general tips for designing housings or frames for both the LS Series and TG Series. **While the two motor Series use the same core technology, the methods for mounting the motor kits vary widely.**

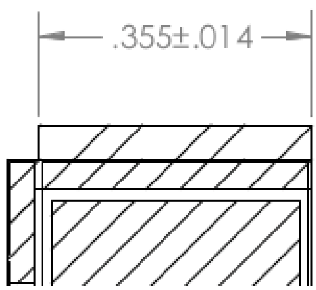
LS Series

1. **Part Configuration:** The LS Series of torquer motor kits are based on an industry-standard Stator and Rotor pair. For LS Series parts starting with “LSI”, such as the LSI 25-10, the “I” indicates an in-runner design, with the Rotor being located on the inside of the Stator. Similarly, for parts starting with “LSO”, such as the LSO 220-16, the “O” indicates an out-runner design, with the Rotor being located on the outside of the Stator. Most standard LS Series parts are in-runners.

2. **Contact Points:** When designing the housing for a LS motor kit, said housing should only be in contact with the lamination stack of the stator and the rotor iron of the rotor. If the housing interfaces with the stator’s coil or rotor’s magnets, it can negatively affect performance of the motor kit. It is recommended that there is at least 2 mm of clearance between the motor coil and housing in the axial direction.

3. **Tolerances:** ThinGap motor kits have tight tolerances of only a few thousandths of an inch for the Stator and Rotor, including a very narrow air gap between the two. It is important that the housing has tolerances that are similar to that of the motor kit in order to make sure that recommended concentricity and axial position tolerances are held.

   Due to how the lamination stack for the LS Series motor kits are manufactured, the lamination stack has a wider tolerance than the other parts of the motor kit. This should be considered when designing the housing given the lamination stack is the main contact point between the housing and the Stator.



Ex. Dimensions for the lamination stack for an LSI 25-10. Due to how it is manufactured, it has wider tolerances than the rest of the motor.

   AS A GENERAL WARNING, ANY CONTACT BETWEEN THE STATOR AND ROTOR DURING OPERATION (REFERRED TO AS A “TOUCH DOWN”) WILL LIKELY RESULT IN CATASTROPHIC DAMAGE TO THE MOTOR.

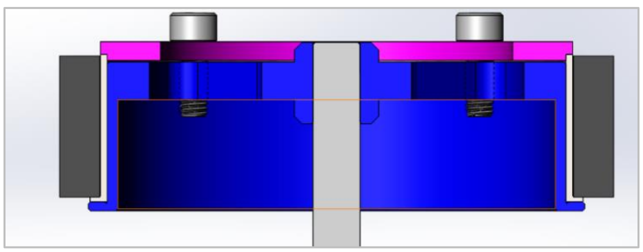
4. **Assembly:** When assembling the motor, it is important to avoid impacts with the work surface, housing, and other pieces of the motor. It is good practice to keep the part set separated during installation into the housing since the Stator and Rotor for the LS Series motor kits are attracted to one another. In some cases, non-metallic shims can be used to prevent contact between the Stator and Rotor while being assembled.

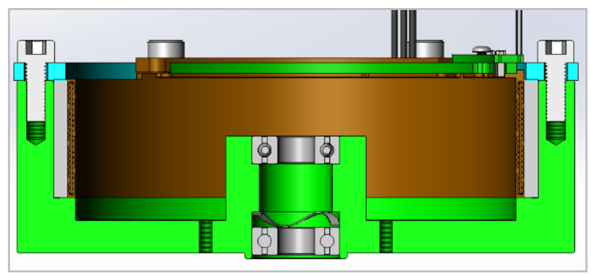
There are many ways to design a housing for an LS Series motor kit; **with regards to retention methods, ThinGap generally recommends either clamping or adhesive bonding.** The clamping method works by tightening two sections of the housing to the rotor and stator in order to hold it together. Clamping is often times used to accommodate disassembly, especially in prototype units. Adhesive bonding attaches the housing to the motor kit using an aforementioned adhesive and is considered to be a better method for high-volume applications. Knowledgeable customers may design alternative methods for integrating the motor into the housing.

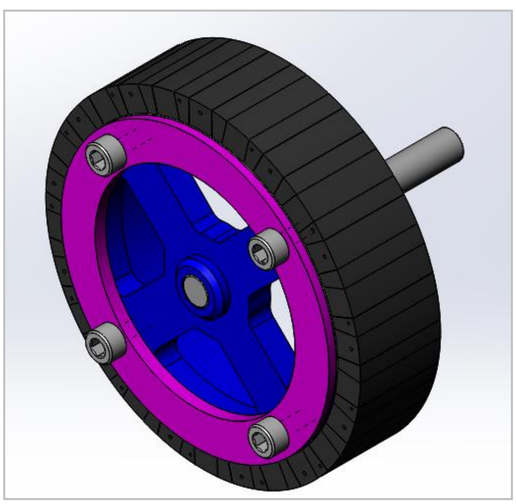
Clamping: The clamping method is useful for when the motor kit will likely need to be dissembled, such as in prototype builds or applications that require rapid replacement. Below are some general tips for designing a housing using the clamping method.

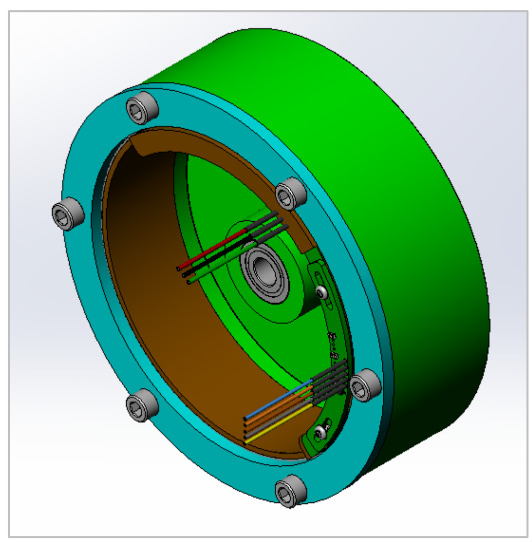
1. **Tightening:** When tightening the screws that will hold the housing together, it is advised to partially tighten each screw in a star shaped pattern as to **avoid applying to much pressure to one area which can cause warping either the lamination stack or rotor iron.** The warping or flexure caused by this can lead to the magnets breaking away from the rotor iron. **A clamping ring is highly recommended** to help evenly distribute the force evenly during installation.

2. **Thermal Management:** The stator's lamination stack on the LS Series is the main thermal path by which the motor coil dissipates heat. Since heat is the main limiting factor for motor performance, and the lamination stack in a LS motor kit is uneven and does not create a perfect matting surface with the housing, it is suggested that a thermal grease be used between the lamination stack and the housing to help with heat management.









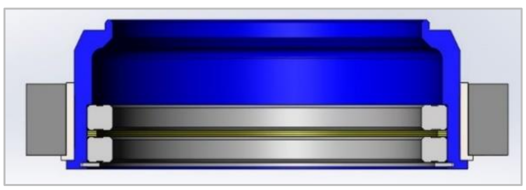
A general example of a mounted LS Series Rotor and Stator assembly using the clamping method.
Note: The housing should **not** interface with the magnets on the Rotor or coil on the Stator.

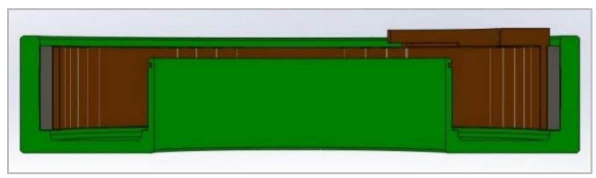
Adhesive: Adhesive bonding is an effective solution for a housing that is intended for long-term use in applications that are not going to need to be disassembled. As a recommendation, 3M's DP420 series of two-part epoxy is a good adhesive for bonding the rotor and stator in place, though any adhesive that can withstand the forces and heat from the motor should work.

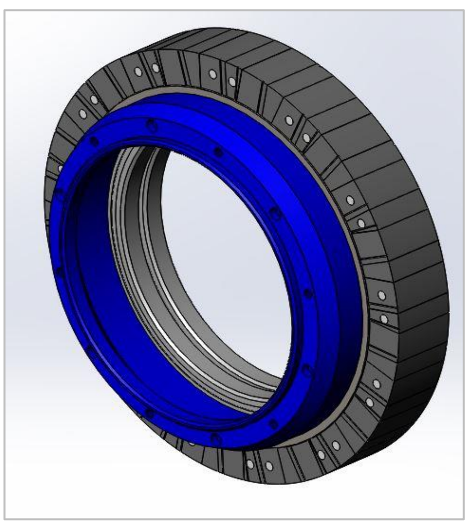
Below are some general tips for designing a housing using adhesive bonding.

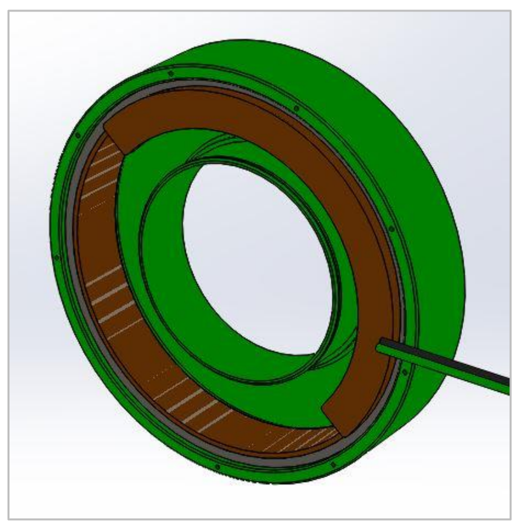
1. **Thermal Management:** Standard ThinGap stators are rated to operate up to 130 °C and the rotors are rated to 85 °C. If the motor kit is going to be run near its maximum capabilities, it is important to make sure that the adhesive used can survive the elevated temperatures. Since heat is the main limiting factor for motor performance, and the lamination stack in a LS motor kit is uneven and does not create a perfect matting surface with the housing, it is suggested that a thermal grease be used between the lamination stack and the housing to help with heat management.

2. **Housing Bonding:** It is recommended to clamp the housing to the motor while the adhesive cures so that the two pieces remain aligned properly.







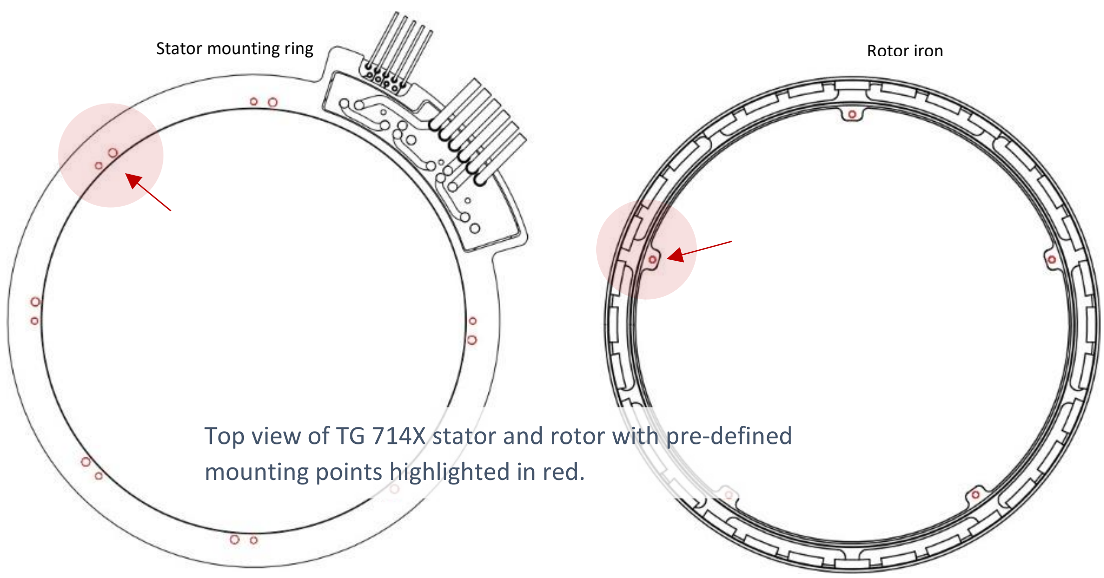


A general example of a mounted LS Series rotor and stator assembly using the adhesive method.
Note: The housing should **not** interface with the magnets on the Rotor or coil on the Stator.

TG Series

1. **Part Configuration:** The TG Series of high-speed motor kits use a unique mechanical architecture, with the Stator being retained by mounting holes and the rotor using a channel design with the potential for magnets to be located on the inside or outside of the rotor iron (and in some cases, on both).

2. **Contact Points:** Unlike the LS Series which requires the housing of the motor kit to conform to the stator's lamination stack and the rotor iron, **the TG Series has pre-defined mounting holes on the stator and mounting tabs on the rotor.** These mounting features can act as a starting point for a housing design or ignored in favor of using an adhesive to bond the housing to the motor kit. ThinGap recommends using the provided mounting features when designing a housing. Custom mounting features on the Stator or Rotor are available for modified designs.



Top view of TG 714X stator and rotor with pre-defined mounting points highlighted in red.

3. **Tolerances:** ThinGap motors have tight tolerances of only a few thousandths of an inch for the stator and rotor, including a very narrow air gap between the two. It is important that the housing has tolerances that are similar to that of the motor kit in order to make sure that recommended concentricity and axial position tolerances are held.

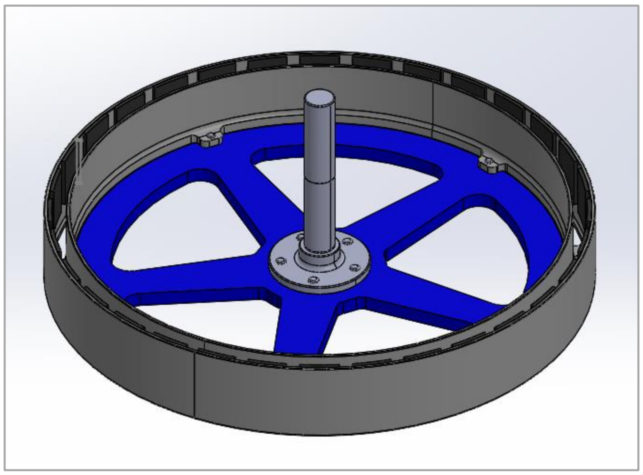
   AS A GENERAL WARNING, ANY CONTACT BETWEEN THE STATOR AND ROTOR DURING OPERATION (REFERRED TO AS A "TOUCH DOWN") WILL LIKELY RESULT IN CATASTROPHIC DAMAGE TO THE MOTOR.

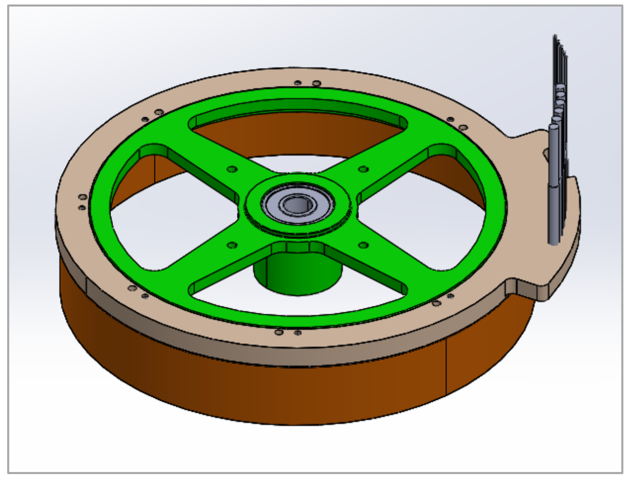
4. **Assembly:** When assembling the motor, it is important to avoid impact with work surfaces, the housing, and other pieces of the motor. It is good practice to keep the stator and rotor separated when installing the frame since, while the TG Series' Rotor and Stator are not attracted to one another, ferromagnetic material in the frame are still attracted to the permanent magnets in the Rotor.

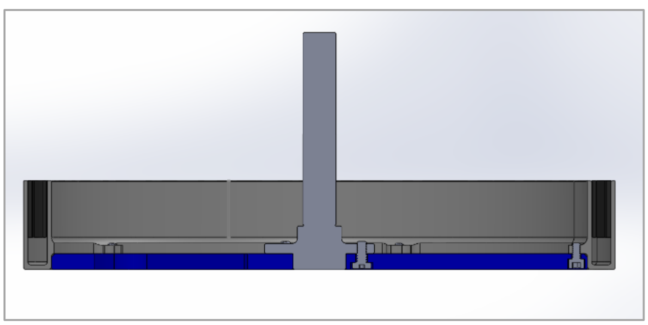
Due to the presence of the mounting features on most of the standard TG Series motor kits, it is recommended to incorporate these features into a housing design. ThinGap can provide frames for most of its standard TG Series motor kits, but most applications require some kind of custom housing to effectively integrate a motor kit.

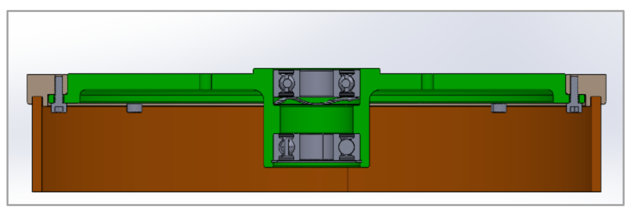
Below are some general tips for designing a housing for the TG Series motor kits.

1. **Air Flow:** The TG Series is mainly convectively cooled during operation, which allows for increased torque and power outputs at higher speeds. This design feature does, however, mean that allowing for air flow over the magnets and coil is important factor in achieving peak performance. Most Rotors have cutouts on the underside to allow for increased airflow. **It is recommended that any housing design avoid blocking these air vent cutouts.**









An example of the standard off the shelf frame for the TG-7 Series which uses the provided mounting features.

Bearings and Shaft

Additional mechanical components to consider when integrating a ThinGap motor kit include how the bearings and shaft are going to be added to the design. This part of the integrated mechanical design is highly dependent on the application that the motor is going to be used in. In general, deep groove radial ball bearings work well with ThinGap motor kits if the axial loading on the assembly is minimal. If the application is going to apply axial load to the system, it is suggested to look into angular contact or duplex pairs of bearings rated to handle the calculated loading. In any case, the bearing will require preload to work effectively in an application.

With respects to the interface between a shaft and the bearing, it is important to know the radial tolerance for whatever bearing is chosen before finalizing the shaft dimensions. This will avoid fret wear from a loose fit between the shaft and the bearing.

III. Electrical Integration

ThinGap mainly sells high precision motor kits and does NOT make, design, or supply motor Drive Electronics (also referred to as a “Controller”) or high precision position sensors (commonly referred to as “Encoders”). Most ThinGap motor kits do however include an option for a Hall-effect sensor.

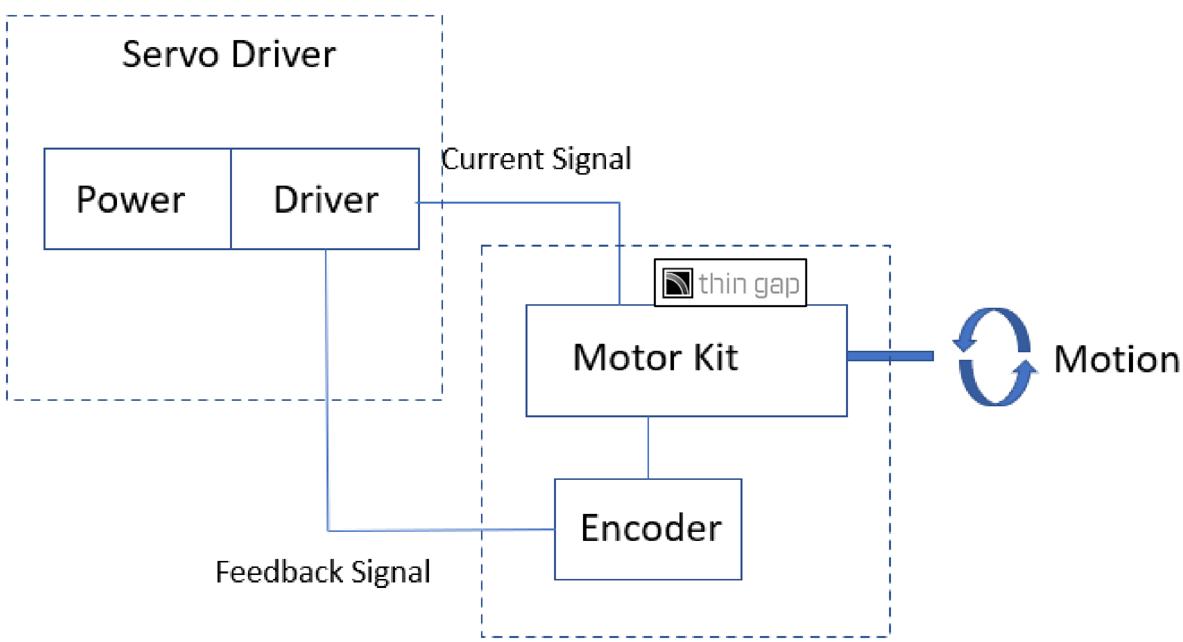
All ThinGap motor kits offer zero-cogging motion, a highly desired feature. In order to achieve the optimal coggless motion, **ThinGap motor kits are best operated by three-phase, sinusoidal-drive electronics.** In addition, ThinGap’s motor architecture is inherently low inductance. Likewise, drive electronics should us a high PWM frequency to achieve the best performance.

Voltage input and Current ratings for ThinGap motor kits range by product, but generally speaking are from 24 to 285 Volts. Custom and modified Stator wire selection and winding configurations are available.

In all cases, **for high-speed and precision applications, some form of a sensor of the motor’s position is needed to commutate the drive Current**. In addition, many applications desire or require motor position feedback. Two common methods to address these needs are Hall-effect sensors and Encoders. Additional information is provided below under Position Control.

In order to help with the integration of ThinGap motor kits, a general list of required components, as well as recommendations for how to choose these components is provided. The objective is to provide direction when integrating a ThinGap motor kit.

Motor Solution Block Diagram



Position Control

Most ThinGap motor kits generally include an option for a Hall-effect sensor. Hall-effect sensors are integrated into the motor kit's part set and are usually a less expensive solution for sensing position, however, these sensors are only accurate within ±10 electrical degrees, which makes them ineffective in precision applications. More precise position and commutation performance can be accomplished with either a standalone Magnetic, Optical, or Absolute Encoder.

There are multiple options available when looking for an Encoder for use with a ThinGap motor kit. In order to generate motion in a three-phase motor, there must be switching between the phases to energize the appropriate windings. The process of switching between the phases is called commutation.

For any Encoder, the following are important factors to think about when choosing a solution to integrate with a ThinGap motor kit.

1. **Optical vs. Magnetic:** The two most commonly used Encoders for ThinGap motor kits are the Optical and Magnetic Encoders. Optical Encoders tend to have higher resolution than Magnetic Encoders but are only effective in clean environments. Magnetic Encoders are capable of working effectively in particulate dense environments but have their own set of operating temperature and EMI limitations.

2. **Absolute vs. Incremental:** Absolute Encoders are preferred in most applications due to their lack of need to find a start point during start-up. Incremental Encoders can measure things such as distance, speed, and position, but do require the need for a known position at start up.

Driver Choice

In order to achieve the optimal cogless motion, ThinGap motor kits are best operated by three-phase, sinusoidal-drive electronics and a high PWM drive frequency.

ThinGap motor kits do not come with Driver Electronics, so customers need to design their own electronics or select a solution available from a third-party vendor. As with all electronics, Driver Electronics are not one-size-fits-all and specifications should be checked against the requirements of the motor kit before purchase or design. For additional information on recommended third-party Drive Electronics vendors, please contact ThinGap Sales and Applications.

Below are important factors to keep in mind when selecting Drive Electronics for use with a ThinGap motor kit:

1. **Phase Count:** The slotless motor kits best perform with a three-phase electrical input. A driver with an incorrect number of phases **will not** work with the motor kit. ThinGap motor kit designs can be modified to support more or less phases.

2. **Commutation Type:** The motor kit will work with either a sinusoidal or trapezoidal commutation. While both are able to drive the motor, the sinusoidal commutation will provide smoother motion when driving the motor due to the < 1% total harmonic distortion offered by ThinGap's architecture. The trapezoidal commutation is only suggested if speed is the main focus for the application and precision is of little importance.

3. **Voltage and Current:** It is important to make sure that the driver can provide the required Voltage and Current for the motor kit. All datasheets for ThinGap motor kits provide the needed constants to calculate an estimate for the Voltage input. The Current input can be estimated by dividing the torque by the torque constant.

$$Voltage = RPM * K_e * \frac{\pi}{30} + \frac{\tau}{K_t} * R$$

K_e = Voltage Constant (V/rad/s)

K_t = Torque Constant (N-m/A)

R= Resistance (Ω)

4. **Commutation Frequency:** The Commutation Frequency (also called the maximum Encoder frequency) acts as an upper limit to how fast a driver can run a motor. ThinGap motor kits, specifically the TG series, have a high pole count and therefore, require a high commutation frequency to reach top speeds. In order to make sure that a driver has the required commutation frequency to run a motor kit, divide the commutation frequency by half of the motor kit's pole count.

Example: The LSI 51-13 has 18 poles. The commutation frequency for a potential driver is 45,000 electrical revolutions per pole pair.

$$Max\ Driver\ Speed = \frac{45{,}000\ Electrical\ Revolutions}{1\ min} * \frac{1\ Mechanical\ Revolution}{9\ Electrical\ Revolutions} = 5{,}000\ RPM$$

5. **Pulse Width Modulation (PWM) Frequency:** The PWM frequency effects the current ripple when operating the motor kit. ThinGap motor kits feature low inductance which means that a high PWM frequency is key to maintaining smooth motion when operating the motor kit. A low PWM frequency driver can have external inductance added to improve performance. PWM frequencies above 40kHz typically do not requiring external inductors.

IV. Supplemental Images

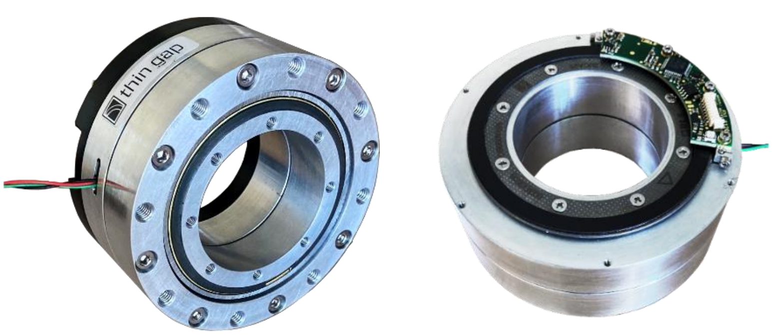
These supplemental images and part descriptions are provided to further demonstrate design and features for consideration in integrating ThinGap motor kits.

TG Series Motor Products

TGD-260 | 10-inch application-specific motor kit for HALE aircraft propulsion.

TG-71xx | 7-inch, high-speed motor kit with frame, shaft and bearing. Used in both Rection Wheel and Starter-Generator applications.

LG Series Motor Products



H-LSI 75-12 | Direct Drive Motor assembly using the LSI 75-12 torque motor.
ID: 51mm | OD: 98.5 mm | Ht.: 49.6mm.

[END DOCUMENT]