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How to Mount an Inductive Rotary Encoder

REV201308

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OVERVIEW

This paper discusses mechanical design considerations and the process of properly mounting an IncOder. It also explains how incorrect encoder mounting can impact measurement performance. A comparison of installing other angular position sensor technologies is explored.

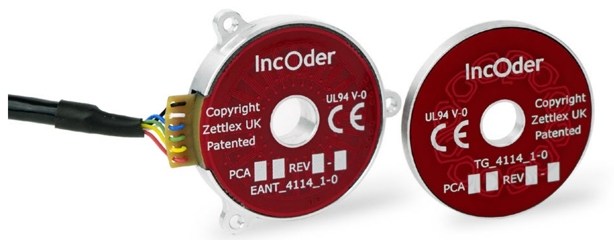

Figure 1 – 37 mm inductive rotary encoder

ROTARY ENCODER FORMATS

When selecting an encoder for an application, the following attributes may be considered:

- Functional performance – for example: accuracy and resolution
- Environmental requirements – for example: operating temperature and IP-rating
- Mechanical format – for example: size and mounting features

Often, an overlooked factor is how performance is impacted by the quality of installation and how to achieve correct installation. This is largely dependent on the sensing technology and encoder package chosen. Physical encoder packages can vary from kit encoders, which typically include sensor head and measurement scale (or coded track) sub-components, to fully packaged shafted encoders, where the sensor is contained within a sealed electro-mechanical assembly around a bearing. When considering the package type, integrators must weigh the benefits of reduced mass and more mechanical design control in the system, with increased installation and alignment complexity.

Some of the most popular types of encoder packages are shaft, hub shaft and ring (bearingless) encoders. The IncOder product is a range of inductive ring encoders, also available in a shaft or hub shaft package. Shaft and hub shaft encoders are designed to directly couple to the end of a shaft, typically through means of a servo-grade flexible coupling. The sensor is contained around a bearing, therefore alignment of the sensor is achieved during assembly. The disadvantage is limited locations where the encoder can be located. Additionally, the bearing axial load is restricted, and the motor/load shaft must be well aligned to the encoder. Integrating with a flexible coupling will also increase the system height and cost.

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Ring format IncOders, such as the Mini, Midi and Maxi series, contain no bearings and are supplied as a rotor and stator pair. This format enables greater freedom in locating the sensor. The rotor-stator pair can be mounted along or at the end of a load shaft. The IncOder housing supports low profile form factors, large bore diameters, and a range of mounting formats enabling simple installation. While customers need to ensure that the device is mounted correctly, it is straightforward to design in an IncOder for direct mounting based on the rotor/stator bore diameter.

DESIGNING MOUNTING FEATURES

The IncOder product requires little design effort to be correctly installed. Customers are required to design mechanical features for mounting the IncOder in a system to the prescribed installation tolerances. If the IncOder is mounted within these tolerances, it will operate to the specified sensor accuracy.

Standard IncOder	Gap	Non-concentricity
Mini 37 mm OD	0.5 +/- 0.2 mm	0.2 mm
Mini 58 mm OD	1.0 +/- 0.2 mm	0.2 mm
Midi (75-300 mm OD)	1.1 +/- 0.35 mm	0.25 mm
Maxi (325-595 mm OD)	1.1 +/- 0.35 mm	0.25 mm

Ultra IncOder	Gap	Non-concentricity
Mini Ultra 37 mm OD	0.5 +/- 0.1 mm	0.1 mm
Mini Ultra 58 mm OD	1.0 +/- 0.1 mm	0.1 mm
Midi Ultra (75-300 mm OD)	1.1 +/- 0.1 mm	0.1 mm

Table 1 – IncOder installation tolerances

A range of mechanical format options and sensor sizes from 37-595 mm OD enable various installation scenarios (installation examples are detailed in the IncOder product guides). The mechanical format will determine the IncOder mounting features and installation type, for example, screw mount fixings. As shown in Table 2 below, engineers have the flexibility to combine stator and rotor mechanical formats. Different diameters cannot be combined.

Mechanical Format Combinations	Screw Mount Stator	Servo Clamp Stator	External Mount Stator	Duplex Stator
Screw Mount Rotor	INC-3	INC-9	INC-13	
Set Screw Rotor	INC-7	INC-4	INC-15	
Plain Rotor	INC-8	INC-6	INC-14	
Shaft Clamp Rotor		INC-11		
Duplex Rotor				INC-10

Table 2 – Ring IncOder mechanical format options

MOUNTING AN INCODER

1. Care should be taken when designing features to secure the IncOder rotor and stator in place. This will depend on the IncOder size, connector type and mounting format. When mounting the IncOder, ensure the stator and rotor are co-located to the prescribed installation tolerances for gap and radial offset, and that the red printed circuit board sensor surfaces are facing one another.

2. If required, align the rotor and stator to angular position zero.

   The zero-point is the datum from which angle is measured. As supplied, the IncOder carries a factory zero-point setting. The zero-point is within 5° of the "O" within the screen printed "IncOder" labeled name printed on the rotor, aligned with the same respective feature on the stator. For INC-3 and INC-10 products, the dowel positions (near the "O" of the labeled name) can also be used to identify the zero-point within the same specified range. You can confirm zero position by reading position of the encoder through your servo drive or a position counter.

   The zero-point can be changed using the zero set and zero reset lines on the IncOder electrical interface. The zero set signal will set the current position as the zero-point. Zero reset signal will reset the zero-point to the factory setting.

3. Apply power to the IncOder. Once powered, position can be read from the DATA terminals. A CLOCK signal may be required dependent on the sensor communication protocol.

Note: A software calibration procedure is not required due to the relaxed installation requirements of the IncOder product. Provided that you are within the prescribed installation tolerances, the specified accuracy will be achieved.

HOW IS SENSOR PERFORMANCE IMPACTED BY ALIGNMENT?

If the IncOder product is mounted within the prescribed installation tolerances, the specified sensor resolution, repeatability and accuracy will be achieved. If the IncOder stator-rotor pair are not mounted correctly, then the static accuracy will not be as specified. If the IncOder is grossly mis-aligned, an error signal will be generated.

Mounting error in rotary IncOder products can be derived from three degrees of freedom. These are defined as axial gap (or ride height), non-concentricity (or radial offset), and tilt. Each component of alignment error will contribute its own characteristic change in sensor performance, described below.

AXIAL GAP

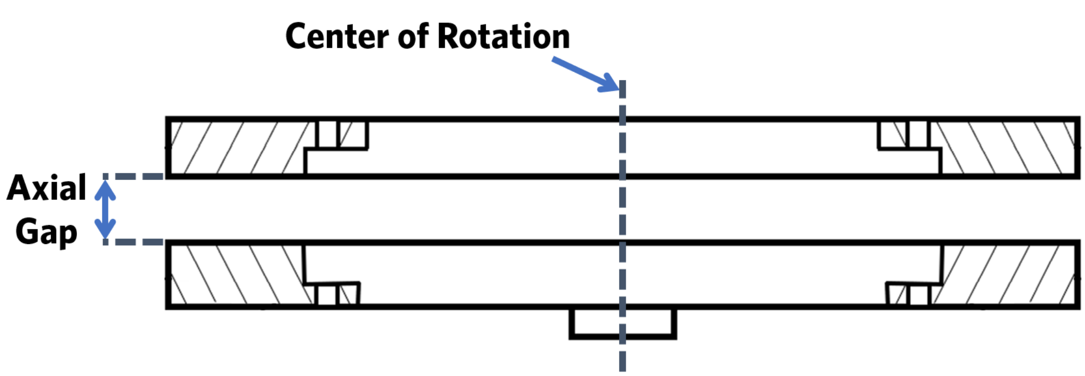

Figure 2 – Axial gap diagram

Axial gap is prescribed to optimize measurement performance of the sensor and avoid contact between the stator and rotor. Gap has the smallest impact on accuracy of each alignment axis. A change in gap is characterized by an increase in position error across the full rotation of the sensor. This increase is seen in Figure 3 below. Within the installation limits, the increase in sensor accuracy is not significant.

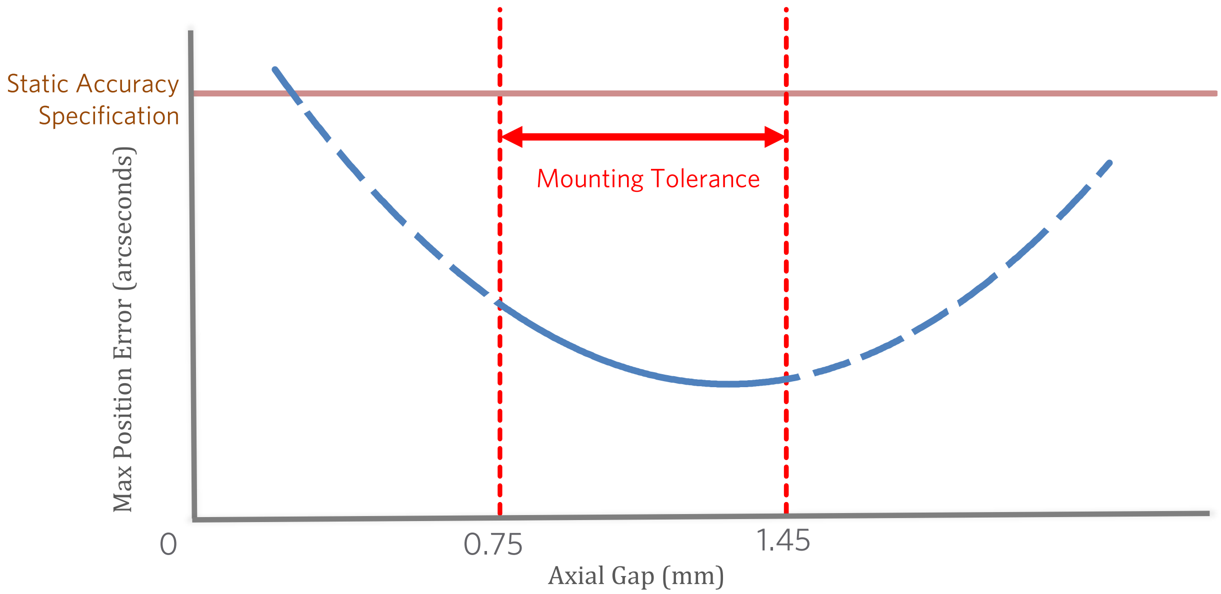

Figure 3 – Variation of static accuracy based on change in axial gap. Data taken from a sample 75 mm IncOder. Static accuracy is guaranteed within the prescribed installation tolerances.

NON-CONCENTRICITY

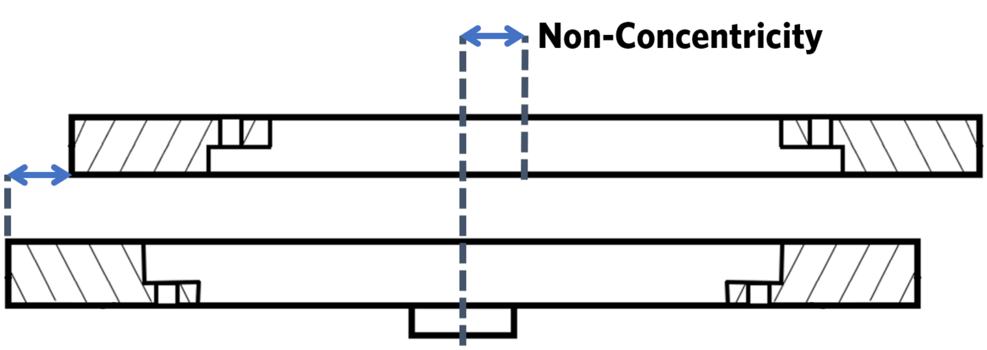

Figure 4 – Non-concentricity diagram

Non-concentricity is the error in radial offset of the rotor in relation to the stator. It has a greater impact on static accuracy than gap, which is why this tolerance is generally more restricted. Non-concentricity in practice can mean the following:

- The axis of the rotor is offset from the axis of rotation.
- The axis of the stator is offset from the axis of rotation.
- The axis of both the rotor and stator is offset from the axis rotation.

As is the case for gap, a square relationship exists between non-concentricity in rotor alignment and static accuracy. For all cases above, non-concentricity will superimpose a single cycle sine wave position error component across the full measurement scale. The amplitude of this error component will increase as radial offset increases. The location of the peak and trough will change dependent on the angle of this offset and which portion of the sensor is offset from the axis of rotation.

Measurement data is collected over the full face of the sensor and averaged for the detrimental effects of eccentricity to be nulled out, therefore this reduction in accuracy performance is less severe than off-axis sensor formats.

TILT

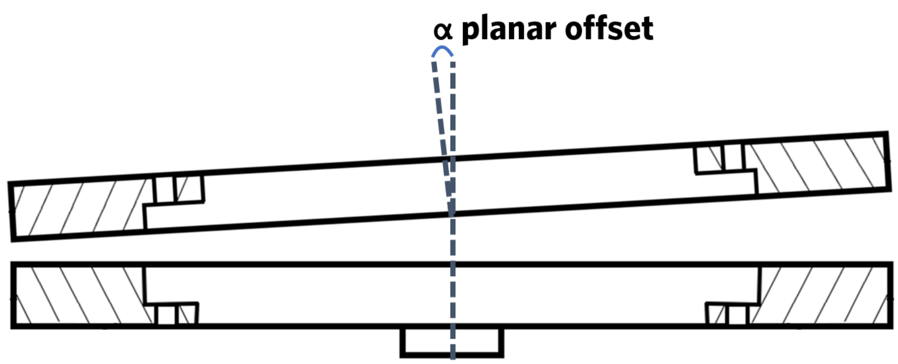

Figure 5 – Tilt diagram

Tilt occurs when the rotor is non-planar from the axis of rotation. This means that one portion of the sensor rotor will be closer to the stator than the other. The effects of tilt are comparable to non-concentricity, as it is more impactful than planar gap variation and will induce a non-uniform error profile.

When combining sources of error, the sensitivity to one source of error (tilt) can be higher if another source of error (concentricity) is introduced at the same time, making it difficult to derive the sensor accuracy.

By mounting the IncOder product within the specified installation tolerances, static accuracy will be achieved. Users hoping to improve accuracy of the IncOder should consider selecting an Ultra IncOder position sensor.

ULTRA INCODER

Users may want to improve the accuracy performance of a standard IncOder product by installing it to tighter tolerances than those which are prescribed. While this may be possible, this cannot be guaranteed.

The Ultra IncOder series is pre-calibrated and offers a 50% increase in accuracy, providing the slightly tighter installation tolerances are met.

OTHER ROTARY ENCODER TECHNOLOGIES

ECCENTRICITY

Optical and magnetic encoders typically employ a readhead on the circumference of a scale, as shown in Figure 6 below. This approach is more sensitive to eccentricity error which causes the scale to move elliptically, relative to the readhead. The readhead sees a longer or shorter arc depending on its position on the circumference.

As an example, inductive and capacitive encoders are tolerant to ± 0.1 mm of eccentricity error. For a magnetic or optical encoder with a 50 mm diameter scale, this would result in a large angular error.

Angular error = arctan (0.1/25) = 0.23 degrees = 828 arcsec

In reality, steps are taken to significantly reduce eccentricity error. Encoder manufacturers are very proficient in mounting scales with minimal eccentricity. For the highest levels of performance, angular error can be essentially eliminated by mounting a second readhead opposite the original readhead. As one readhead sees a longer arc, the opposite readhead sees a shorter arc. The two readings can be combined for an average reading, effectively free of eccentricity error. This does increase system cost, but is frequently used when the highest levels of precision are required. Some encoders provide eccentricity calibration, typically requiring that the scale be rotated at a constant speed.

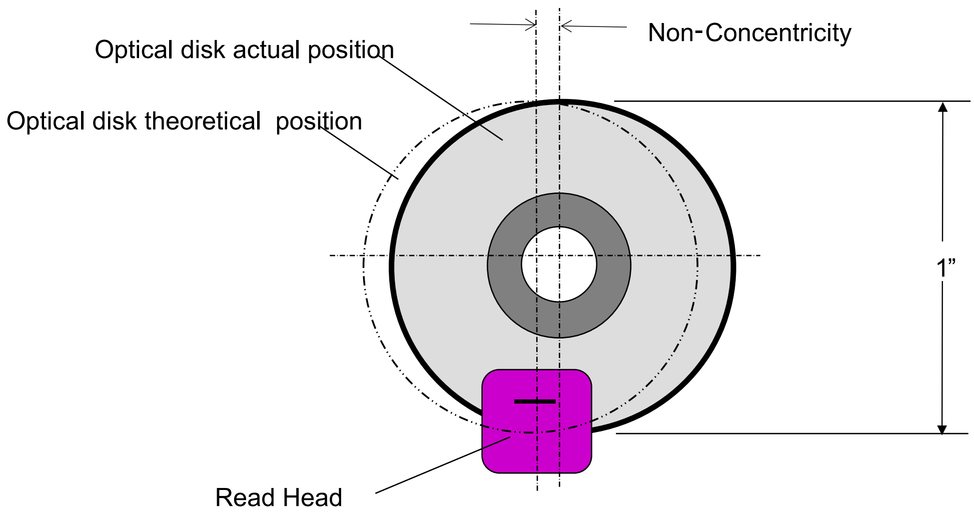

Figure 6 – Non-concentric optical disk and read head

ALIGNMENT

Ease of alignment is critical in many applications. Very narrow air gaps with tight tolerance can cause problems in system commissioning. It can be difficult to compare alignment tolerances across technologies. For example, the pitch, roll and yaw specifications for an optical or magnetic readhead, localized at a specific position on the scale, do not translate to the ring design of an inductive or capacitive sensor. One common parameter which is a good measure of overall tolerances is fly height or air gap, and the associated Z tolerance. See the Table 3 below:

Technology	Ride Height (mm)	Tolerance ± mm
Magnetic	0.20	0.10
Optical Interferential	1.00-2.40	0.15
Inductive	1.00	0.35
Capacitive	0.60	0.10

Table 3 – Typical Z-tolerances across rotary encoder technologies. Note: The tolerances in the chart are for devices with similar resolutions (excluding interferential optical).

CONCLUSION

Minimal effort is needed to design in an IncOder for direct mounting based on the rotor/stator bore diameter. Mechanical features should be designed for mounting the IncOder in a system to the prescribed tolerances and to ensure correct installation. Various installation scenarios are available and are detailed in the IncOder product guides. If the IncOder is mounted within the prescribed installation tolerances, the specified sensor resolution, repeatability and accuracy will be achieved. Properly mounting an encoder can have great effect on device accuracy, this is why correct installation is important to overall system performance.