

# How Inductive Encoders Work

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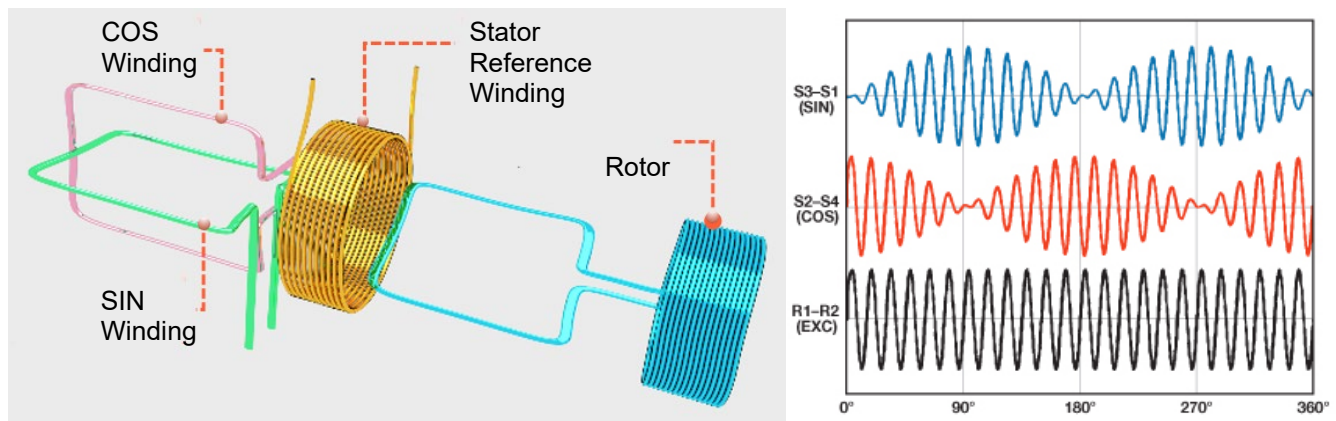
## INTRODUCTION

This article explains the technology of the inductive encoder. This device is closely based on the resolver. It is instructive to discuss the resolver before exploring the inductive encoder.

## RESOLVERS

Resolvers are based on the principle of electromagnetic induction - an alternating current in one conductor generates a changing magnetic field around the conductor. This magnetic field can induce an alternating current in an adjacent conductor. The magnitude of coupling from one conductor to another depends on the rate of change of magnetic field and the relative position and geometry of the conductors.

As shown below, a 5kHz (typ.) sinusoidal reference voltage in the stator induces a sinusoidal voltage in the rotor winding. A second, axial, rotor winding then induces a voltage in two axial signal windings displaced by 90° back on the stator. The amount of coupling into the stator windings is a function of the relative position of the rotor which effectively amplitude modulates the stator signals as shown.

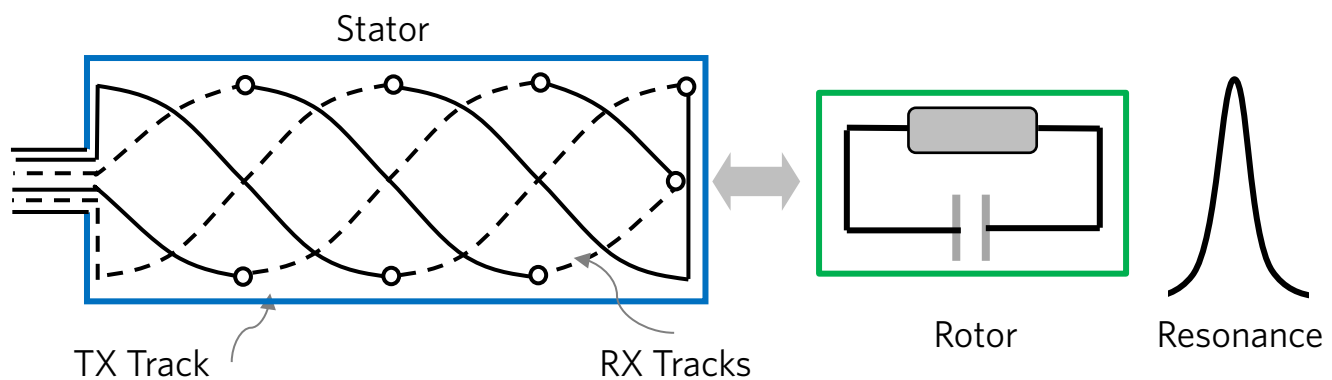


In the illustration on the previous page, the rotor is shown outside the stator for clarity. The radial windings on the stator interact with only the radial windings on the rotor. In turn, the axial windings on the rotor interact with only the axial windings on the stator. This is to avoid the stator reference winding coupling to the stator signal windings. Winding a resolver is not trivial and the end result is a heavy, bulky device. The resolver does, however, have unmatched ruggedness as there are no electronics or fragile parts in the device.

Resolvers are available in various "speeds". A single speed resolver has one electrical sinewave cycle per rev and provides absolute position information with limited resolution. A "multi-speed resolver" is wound

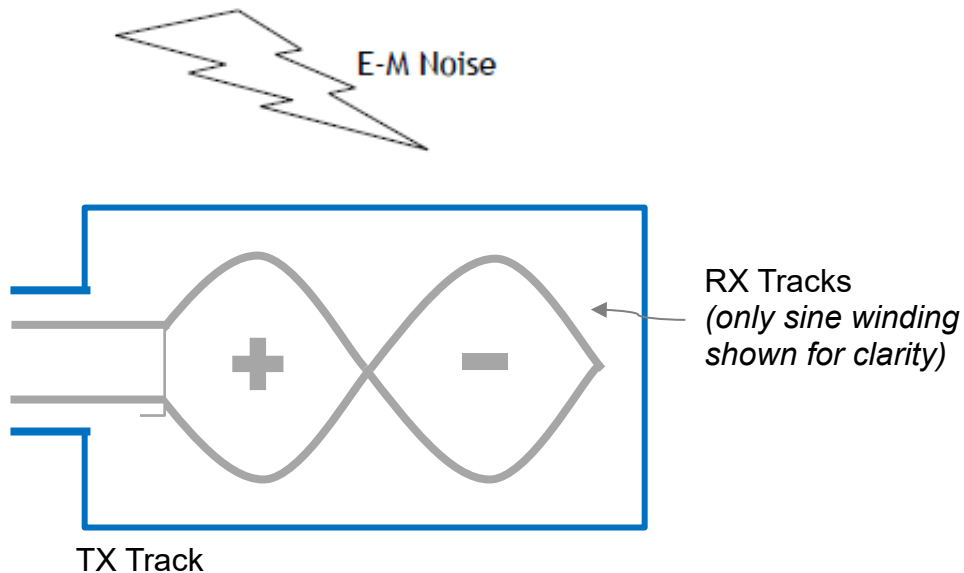
for a higher number of electrical cycles per rev improving resolution. The higher ratio of electrical to mechanical cycles also helps minimize the effects of mechanical error sources. Multi-speed resolvers are no longer absolute and are more expensive and typically even more bulky.

## INDUCTIVE ENCODER



The absolute inductive encoder is based on the same electromagnetic induction principle as the resolver but uses PCB traces rather than coil windings. The TX track on the stator is excited by specific frequency in the range 1-10MHz. This signal inductively couples into target with a resonant LC circuit. The target magnetic field induces a sinusoidal current in stator RX track. The RX track is sinusoidal in shape which effectively amplitude modulates the induced signal. A second RX track displaced by 90° carries a cosine signal. The sin/cos signals are interpolated and output as BiSS-C, SSI or in some versions AqB signals.

The RX tracks on the stator are analogous to a twisted pair wire. The balanced dipole effect cancels electric fields induced in the RX tracks from the changing magnetic field on the TX track. The RX track responds to changing magnetic field on the target only. The RX tracks also reject external electromagnetic interference. Undesirable induced stator currents are also rejected based on frequency and phase.



The main RX tracks with one sin/cos cycle per rev defines absolute position. A secondary track with multiple cycles enhances resolution. More typically the main TX track has multiple cycles (9 for example) combined with a secondary track with a number of cycles not a multiple of 3 – every position within one rev is defined by two unique readings.

The use of PCB traces versus the resolver’s windings brings significant advantages including: reduced cost, size and weight; form factor flexibility including curvilinear; elimination of inaccuracies from the winding process; for safety-related applications multiple sensors can be located in the same space by using multi-layer circuit boards.

The PCB material is environmentally very stable. The option for remote electronics further increases ruggedness. The 360° sensor improves eccentricity error tolerance.

## TECHNOLOGY COMPARISON

Resolvers and inductive encoders deliver superior precision combined with exceptional environmental ruggedness. As discussed, the inductive encoder has numerous advantages versus the resolver particularly size, weight and ease of customization.