TECHNICAL WHITE PAPER

Optical Versus Inductive Encoders

Author: Mark Howard, General Manager, Zettlex UK Ltd
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Optical Vs. Inductive Encoders

Introduction

Optical encoders have been a popular choice of position sensor for equipment manufacturers since the 1970s. They are widely available from a range of manufacturers and can be found in a variety of industrial machines such as printers, CNC machine tools and robots. Traditional inductive positions sensors, such as resolvers and linearly variable differential transformers (LVDTs), have been around since the 1940s but are less widely used. They tend to be used in harsh environment or safety related applications in the aerospace, defence and petrochemical sectors, where their strengths of reliability and robustness outweigh their high cost, bulk and weight. However, a new type of device, the inductive encoder or ‘incoder’, is gaining market share and changing the traditional balance. Incoders can be thought of as a hybrid of the inductive and optical technologies.

With so many position technologies to choose from it is unsurprising that design engineers have difficulty in selecting the right kind of sensor for their project. This article explains how optical and inductive encoders work and examines their relative strengths and weaknesses.

What’s an Encoder?

First, let’s start with some explanation of terminology. An encoder is a device that converts position or motion to an electrical signal - usually a digital code. Confusingly, they can also be referred to as rotary encoders, shaft encoders, angle encoders, angular encoders or even angle sensors, angle transmitters – the list goes on. For the purposes of this paper we will simply use the term encoder.

Encoders can be rotary or linear. They can also be absolute or incremental and this is an important distinction. If we consider a simple absolute rotary encoder then its electrical output indicates the current angular position of the shaft immediately following power up. The output of incremental encoders provides information about the motion of the shaft. In other words, the output from an incremental encoder only changes when there is movement. Some incremental encoders are equipped with a reference mark so that the encoder can use this as a datum from which signals increment or decrement.

There are more incremental encoders than absolute encoders but this is gradually changing with time as the cost premium for absolute devices reduces. Further, many markets – notably robotics and automated systems - are less willing for the equipment to go through a calibration routine at start up so that the position encoders can work out where they are.

The most frequent electrical output from incremental encoders is A/B pulses. This refers to 2 or more streams of low voltage pulses in quadrature that change from high or low status as position changes. Rotation detection is determined by whether the A stream of pulses lead the B stream of pulses or vice versa. The most frequent output from absolute encoders is SSI (Synchronous Serial Interface) which is a digital communications protocol whose various bit values indicate absolute position.
What’s an Optical Encoder?

Encoders use a number of sensing techniques with the most common being optical. In an optical encoder, a source shines light onto or through a grated optical disk so that the light passes through or is blocked. An optical detector or read head senses the light’s passage and generates a corresponding electrical signal. Optical gratings are arranged as a series of markings which can be used to measure angle or motion. The scale of the markings can be very fine – down to microns – enabling many optical encoders to measure with high levels of precision.

The packaged shaft encoder is a common format, in which the encoder’s shaft is mechanically connected to the host system. The encoder’s shaft runs in a bearing assembly and carries an optical disk which, in turn, runs in close relationship to the optical detectors. Electrically, the connection is usually a multicore cable which supplies DC power and carries the encoder’s position output data. The simple electrical interface combined with their widespread availability makes them easy to specify and deploy. Their major weakness is that they simply cannot cope with harsh environments that might include vibration, shock, foreign matter or extreme temperatures. There is little or no warning of imminent failure which may result in a worst case scenario of incorrect position data output or – in a best case – an error message. Typically, the reporting of the wrong position (with no error message) is a much more serious failure mode than no reading at all, since the result can be catastrophic.

With larger diameter or ring encoders, the datasheet small print often specifies extremely tight tolerances for the position of the read head to the optical disc or grating in order to achieve the stated measurement performance. Such unpackaged ring encoders are particularly susceptible to foreign matter given the tiny size of the optical features compared with the similarly sized dust or dirt particles.

Unsurprisingly, optical encoders are typically not a preferred choice for high reliability or safety related applications.

<table>
<thead>
<tr>
<th>Strengths</th>
<th>High resolution, widely available, high accuracy possible</th>
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<tr>
<td>Weaknesses</td>
<td>Delicate, susceptible to foreign matter, catastrophic failure modes, limited temperature range (-20 to +70°C)</td>
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What’s an Inductive Encoder?

An inductive encoder – often referred to as an incoder - uses inductive or transformer principles to measure the position of a target or rotor relative to a stator. Incoders use the same fundamental physics as traditional inductive devices such as brushless resolvers or LVDTs but their electrical interface is similar to an optical encoder - a simple DC power supply and digital electrical signal as an output.

Most traditional resolvers look rather like an electric motor - with copper windings on the stator which cooperate with a metal rotor or target. The inductive or transformer coupling between the stator’s windings varies according to the position of the rotor. Rather than wound transformer constructions, incoders use printed circuit boards for their rotor and stator, making them less bulky, more accurate and less costly to manufacture.

Since their use in military aircraft in WWII, resolvers and LVDTs have established a well-earned reputation for accuracy, robustness and reliability, thus often making them the automatic choice for high-reliability and safety related applications. This is because transformer principles of operation are generally unaffected by harsh environmental conditions including the presence of dirt, water and ice.

Incoders are as easy to specify and deploy as optical encoders, because they too only require a DC supply and output a digital signal representing position. This means that incoders have all the advantages of resolvers but with none of their disadvantages.

Because incoders do not use delicate optical components, they are not susceptible to foreign matter and do not only operate in limited temperature ranges. Further, accurate position measurement does not depend on the accurate alignment of the moving and stationary elements – allowing generous installation tolerances and a ‘bearingless’ approach. The eradication for the need for bearings has led to thin annular constructions with low axial height and a large bore – making them easy to integrate in to equipment with tight size or weight constraints such as gimbals, robotic arms and actuators.
Incoders are available in a wide range of sizes up to 600mm diameter and have been used extensively and successfully in a variety of machine tools, gimbal systems, aerospace, defence and medical equipment.

<table>
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<tr>
<th>Strengths</th>
<th>High resolution, accurate, reliable, robust, long life, tolerant to misalignment</th>
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</thead>
<tbody>
<tr>
<td>Weaknesses</td>
<td>Temperature range (-100 to +125°C) is greater than optical but not as great as resolvers</td>
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Further Information / Contact

For more information about Zettlex inductive position sensing technology, or to discuss your application with a position sensor expert, please contact Zettlex directly or speak with your nearest local representative.

UK Head Office

Zettlex UK Ltd
Newton Court, Newton, Cambridge, CB22 7ZE, United Kingdom
Sales Contacts: Mark Howard or Darran Kreit

Email: info@zettlex.com
Telephone: +44 1223 874444
Web: www.zettlex.com

International

Zettlex has a worldwide network of resellers and distributors. To find your local representative please visit www.zettlex.com