TECHNICAL WHITE PAPER

The CAD Jockey's Guide to Ring Encoders

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Introduction

The Chief Engineer says "we'll need a ring encoder for this project" and you respond with "absolutely boss – great idea!" but you're thinking "what's a ring encoder? And, more importantly, how do I find out without looking like an idiot?" Don't worry - this article's for you. It will tell you all you need to know about ring encoders without blinding you with science or talking to you like an 8 year-old.

What's a ring encoder?

Let's start with some terminology. Confusingly, some people use the term 'ring encoder' while others use 'hollow shaft encoder', 'through bore angle sensor', 'ring sensor', or even 'big bore angular displacement transducer'. In reality, all such terms can – and usually do - mean the same thing. For the purposes of simplicity, we will just use the term ring encoder in this article.

Ring encoder refers to a device which:

- measures angular position or angular speed
- has a large through hole (usually > 50mm or >2")
- produces an electrical signal proportional to angle.

Ring encoders, rather than the more usual shaft encoders, are used when there's a need to either

- measure the angle of large shafts
- pass hydraulic pipes, electrical cables etc. through the middle of the encoder
- minimize axial height
- maximise accuracy
- eliminate bearings.

How does a ring encoder work?

We can group ring encoders in to 2 main types – incremental and absolute encoders. Incremental encoders measure *change* in angular position. Typically, they produce a series of pulses as angle changes – sometimes with a reference pulse which is generated once per revolution. Incremental encoders are often used to measure angular speed.

Absolute encoders report angle straight after power up without any motion. Typically, they produce either an analogue signal or a digital data stream which is unique over the measurement range. Absolute encoders are most often chosen when a calibration step after power up must be avoided.

Both types may be further grouped according to the basic physics that they utilise:-

Potentiometers

Although there is a marked trend towards non-contact angle encoders, potentiometers ('pots') remain common. They measure a voltage drop as a contact(s) slides along a resistive track. Accuracies of <0.01% are possible by laser trimming the resistive tracks but <0.5% is more typical. Potentiometers operate well in applications with modest duty cycles, benign environments and relaxed performance. Unfortunately, they are susceptible to wear and foreign particles such as dust or sand which act as a kind of grinding paste. Higher quality devices quote long life in terms of the number of cycles, but this often ignores the effects of vibration.

Strengths: Low cost; simple; compact; lightweight. Can be made accurate.
Weaknesses: Wear; vibration; foreign matter; extreme temperatures.

Optical ring encoders

Optical encoders are what most people think of when they think of a ring encoder. They can range from simple devices that cost <100 US dollars through to precision units that cost >10,000 US dollars. The basic principles are pretty much the same: a stationary read head shines light through or onto a grating on the rotating ring. The read head detects the resulting optical signal and a position signal generated. If the read head's lens or the grating becomes obscured by dirt, swarf or water, measurements will fail. Condensation is a notorious problem in outdoor equipment. With optical encoders, remember that if the encoder is quoted as having 1,000 counts per revolution, this does not mean that it is accurate to 1/1000th of a revolution. Data sheets need to be read carefully, as the small print may require very tight installation tolerances. There may also be a requirement to ensure no contamination during assembly, installation and operation.

Strengths: High resolution; good accuracy if mounted precisely; wide availability.
Weaknesses: foreign matter; catastrophic failure; shock; extreme temperatures.

Magnetic ring encoders

Magnetic ring encoders feature a read head which measures the field generated by a magnetic pattern carried by a rotating disk. As the magnet or magnetic patterns displaces relative to the read head, the magnetic field changes in proportion to their relative displacement and an output signal generated. Magnetic sensors overcome many of the drawbacks associated with optical devices, as they are more tolerant to foreign matter. Nevertheless, these sensors are rarely used for high accuracy applications due to magnetic hysteresis and large thermal drift. A further consideration is the proximity of magnetic materials or electrical cables which will distort the field. Magnets may attract some foreign particles and one source of failure is the build-up of swarf or particulates over time.

Strengths: Fairly robust; most liquids have no effect.
Weaknesses: Temperature; hysteresis; precision mechanical engineering; nearby steel/DC sources and poor impact/shock performance.

Traditional inductive - resolvers

Ring encoders which use traditional inductive (or transformer) techniques are more usually known as pancake resolvers or slab resolvers. Resolvers use three wire spools: a primary which is energised with an AC signal and two secondaries arranged around a stator. As a magnetically permeable or conductive rotor spins, it varies the electromagnetic coupling between the primary and secondary windings. The ratio of the induced signals in the windings indicates the position of the rotor relative to the spools. This ratiometric technique is key to the resolver's high stability and measurement performance. Pancake or slab resolvers have a good reputation for reliability and are often chosen for safety-related applications in aerospace, military, nuclear and industrial sectors. Whereas optical and magnetic encoders need electronics adjacent to the sensing point, inductive sensors can displace the electronics, allowing the resolver to be placed in harsh environments with the electronics in more benign locations.

Strengths: High accuracy; reliable; robust; extreme environments; widely available.
Weaknesses: Expensive; bulky; heavy.

Inductive encoders or Incoders

Inductive encoders (often referred to as incoders) use the same basic principles as resolvers, so they offer good, non-contact measurement performance in harsh environments. Rather than transformer constructions or bulky spools of wire, incoders use printed circuits. This means reduced cost, size and weight but increased accuracy and measurement performance in harsh conditions. They are a relatively new form of ring encoder but they have a good reputation and incoders are being used in lots of aerospace, medical, military and heavy industry applications. Incoders are available with incremental, absolute and analogue voltage outputs.

Strengths: High accuracy; reliable; robust; multiple geometries; compact; lightweight.
Weaknesses: More expensive than potentiometers.

How do I specify a ring encoder?

We're basically talking about a measurement device and so the key aspect of the specification is measurement performance. It's important you're clear about what's needed because it can make a big difference to cost, size and weight. The main parameters are:-

- ***Resolution*** - the smallest increment or decrement in angle that the encoder can measure and reliably report
- ***Repeatability*** - the difference in angle that the encoder would report for the same position over multiple cycles. This is tantamount to ***Precision -*** or the encoder's degree of reproducibility.
- ***Linearity*** – or more scientifically ***Non-linearity*** - is the difference between the encoder's output to actual angle. If we ignore any offsets, it is tantamount to ***Accuracy.*** A perfectly linear angle encoder is also perfectly accurate.

We can explain the difference between accuracy and precision using the analogy of an arrow fired at a target. Accuracy describes how close an arrow is to the bullseye. If many arrows were shot, precision equates to the size of the arrow cluster. If all arrows are grouped together, the cluster is considered precise.

Think carefully about what's required for your project. You may be surprised that accuracy is not so important for your project but repeatability is. If you're using a term like 'fairly accurate' then you've not thought hard enough. Also remember that most angle encoders will be marketed and promoted using counts per rev (cpr) or resolution (usually specified in bits e.g. 10bits = 1024counts). Note that this is resolution – not linearity or accuracy.

What kind of ring encoder is right for my project?

The first step in selecting a suitable angle encoder for your project is to be absolutely clear about what you need, particularly with respect to sensor resolution, repeatability and linearity. Over-specifying any of these attributes will cause unnecessary expense. The trick is to find a sensor that is fit-for-purpose at minimum cost.

The second step is to match the encoder types described earlier (e.g. incremental optical or absolute inductive encoder etc.) with the nature of your design. As a very general guide

- Don’t use a potentiometer in harsh, dirty, wet or vibrating environments
- Don’t use a magnetic sensor for high accuracy measurements
- Don’t use an optical ring encoder in a dirty or wet environment or where precision installation might prove difficult
- Don’t use a traditional pancake or slab resolver if there’s tight limits on cost, weight or size.

If you get stuck – give me a shout, I’ll be happy to help out.

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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.

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