Technicle White Paper

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Choosing the right Position Sensor

With such a bewildering array of position sensors to choose from these days, how do design engineers ensure they select the right one? Mark Howard, General Manager at Zettlex UK Ltd, outlines the main types of sensor and their respective strengths and weaknesses.

Position sensors are used in a wide variety of industrial and commercial applications, from military, aerospace and defence, through to automotive, process manufacturing, nuclear and other safety-related installations. In fact, after temperature measurement, position (or displacement) measurement is the second most common property that we need to measure in our lives.

A key step in selecting a suitable position sensor for an application is to be absolutely clear about what is needed, 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.

Potentiometers

Although there is a trend towards non-contact position sensors, potentiometers ('pots') are the most common position sensor. These sensors measure a voltage drop as a contact(s) slides along a resistive track.

Pots are available in rotary, linear or curvilinear forms and are generally compact and lightweight. A simple device will cost pennies, whereas a high precision version may cost upwards of 200 US dollars. Linearities of less than 0.01 per cent are possible by laser trimming the resistive tracks.

Potentiometers operate well in applications with modest duty cycles, benign environments and relaxed performance. Unfortunately, pots are susceptible to wear and foreign particles such as dust or sand. Higher quality devices quote long life in terms of the number of cycles, but this often ignores the effects of vibration.

It must also be noted that potentiometers often quote ‘infinite resolution’. Whilst theoretically true, many control systems require digital data and so actual resolution will be that of the analogue to digital converter (which needs to be included in any costings).

Strengths: Low cost; simple; compact; lightweight. Can be made accurate.
Weaknesses: Susceptible to wear; vibrations; foreign matter; extreme temperatures.

Optical

Optical encoders are a common form of position sensor, ranging from simple devices that cost less than 10 US dollars through to precision units that cost 10,000 US dollars or more.

The fundamental principle is pretty much the same: a light beam is shone through or onto a grating, which is then measured electronically and a position signal generated. Packaged, rotary encoders are widely available, typically with 100-5,000 counts per revolution.

If the lens or grating system becomes obscured by foreign particles such as dirt, swarf or water, then measurements will fail.

In selecting an optical encoder, it is important to note 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. The data sheet for the sensor will need to be read very carefully, particularly with encoder kits or ring encoders. These devices require the user to mount the sensor accurately and ensure no contamination is present during measurements. If the encoder has a glass disk, the unit will have limited shock resistance.

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

Magnetic

Magnetic sensors all use a similar measuring principle: as a magnet displaces relative to a magnetic detector, the magnetic field changes in proportion to their relative displacement. Hall Effect devices are often used in automotive applications with modest measurement performance.

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 the need for precision mechanical engineering. Any magnetic sensor’s data sheet will need to be studied carefully with respect to the temperature coefficient and limits of the sensor.

A second consideration is the proximity of magnetic materials or electrical cables. Magnets may attract some foreign particles and one source of failure is the build up of swarf or particulates over time.

Magnetic sensors are typically not chosen for applications with harsh impact or shock conditions since magnets are notoriously brittle.

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

Magnetostrictive

These sensors use an unusual phenomenon called 'magnetostriction', which is present in some materials. When a magnet approaches the material it causes energy passing along the material to reflect. Position can be measured from the time it takes a pulse of energy to move along and back a strip of magnetostrictive material.

The strip must be carefully held in a housing such as an aluminium extrusion. The housing means that magnetostrictive devices are robust and suffer no wear or lifetime issues. Each sensor needs to be calibrated by the manufacturer and this, combined with the precision housing, makes magnetostrictive sensors relatively expensive.

The technique is sensitive to any other influences on the time of flight – most notably temperature. Magnetostrictive data sheets often quote accuracy at constant temperature, so design engineers will need to do their own calculations using the quoted temperature coefficient.

Strengths: Robust; well suited to high pressures; percentage accuracy increases with length.
Weaknesses: Relatively expensive; temperature effects; inaccurate over short distances (less than 100mm).

Capacitive

A capacitor is an electrical device that accumulates charge. Typically, it has two conductive plates separated by an insulator. The amount of charge the capacitor can store varies according to the size of the plates, their percentage overlap, their separation and the permeability of the material between the plates. In its simplest form, a capacitive position sensor measures plate separation. Displacements are typically over ranges of less than 1mm for load, strain and pressure measurement.

Another form is used for rotary or linear position sensing in which a series of plates are cut or etched along the measurement axis. As another plate moves across them, the capacitance of the circuits along the axis varies indicating the relative position of the two parts.

Capacitive position sensors are uncommon and rarely used in safety related applications. Unfortunately, as well as overlap of the plates etc., capacitance also varies with temperature, humidity, surrounding materials and foreign matter, which makes engineering a stable, high accuracy position sensor challenging.

Strengths: Compact; low power.
Weaknesses: Significant temperature and humidity coefficients; sensitive to foreign matter.

Traditional Inductive

Linear inductive position sensors are commonly referred to as variable reluctance or linearly variable differential transformers (LVDTs). Rotary forms are known as synchros or resolvers. These all work on inductive or transformer principles and have been used for more than 100 years.

LVDTs use at least three wire spools: a primary and two secondaries. As the rod moves, it varies the electromagnetic coupling between the primary and secondary spools. The ratio of the induced signals indicates the position of the rod relative to the spools. This ratiometric technique is key to the LVDT's high stability and measurement performance.

Zettlex
Precision in the Extreme

Traditional inductive sensors have a reputation for reliability and are typically chosen for safety-related applications in aerospace, military, nuclear and industrial sectors.

Whereas optical and magnetic sensors require electronic circuitry adjacent to the sensing point, inductive sensors can displace the electronics away from the sensing area, which enables the sensor to be located in harsh environments with the electronics in more benign locations.

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

New Generation Inductive

New generation inductive sensors – such as those made by Zettlex - use the same principles as traditional inductive sensors, so they offer good, non-contact measurement performance irrespective of the operating environment. However, rather than use bulky spools of wire, these sensors use printed circuits on flexible or rigid substrates.

The transition to printed windings brings other specific advantages:

- A large reduction in production cost, size and weight
- Greater flexibility in form factor
- Eradication of sources of inaccuracy from the winding process
- Complex measurement geometries such as curvilinear, 2D & 3D position sensing
- Multiple sensors can be located in the same space by using multi-layer circuit boards (e.g. redundant sensors in safety-related applications).

EMC performance is generally as good as that of resolvers or LVDTs. This is evidenced by selection of new generation inductive devices for aerospace and military applications.

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

For more information on new generation inductive sensors, please telephone Zettlex (UK) Ltd on 01223 874 444 or visit the website at www.zettlex.com or email mark.howard@zettlex.com

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Editor's Notes:

About Zettlex (UK) Ltd:

Zettlex is a sensors company. The company's range of sensors measure position or speed accurately and reliably, even in harsh conditions.

Zettlex designs and manufactures its own sensors and supplies sensor components and integrated circuits. The company also offers custom designed and manufactured sensors for specific customer applications.

Unique technology and laminar, printed designs, enables Zettlex to manufacture sensor solutions that have no contacts, no bearings, no delicate parts and zero maintenance, just accurate measurements.

Zettlex sells directly to OEMs and system integrators across a broad range of industry sectors. Applications include position measurement, servo and motor controls, and user interfaces. Around 50 per cent of the company's business is safety-related or safety-critical.

Zettlex is ISO 9001 and BS EN 13980 certified for the manufacture of electromagnetic sensors, including sensors for intrinsically safe (ATEX) environments.

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