TECHNICAL WHITE PAPER

Why Some Encoders Don't Like Winter

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Introduction

There are a number of signs telling us that winter is drawing to a close and spring is just around the corner. New born lambs; trees suddenly coming in to bud and lots of Zettlex sales enquiries starting with "…this last winter's been really tough – have you got something that can replace our optical encoders?" This article investigates why optical and capacitive encoders aren't suited to winter conditions and suggests some possible solutions and alternatives.

When they go wrong

Optical and capacitive encoders have an unfortunate habit of going wrong in the cold. This can be a major issue for manufacturers of outdoor equipment, and, even worse, a major source of career limiting embarrassment for the design engineer who specified the encoders in the first place. Yes, the data sheet said they were good to -20^{o}Celsius but it's not necessarily the low temperatures that cause the problems, rather what the low temperatures bring with them.

There is every chance that you have seen these effects first hand during winter. In the summer months, defrosting or demisting your car windscreen on your way to work is something that doesn't cross your mind. However, during winter, this is an early morning or late afternoon chore that you could really do without. You have an advantage over optical and capacitive sensors because when you are defrosting your car you can estimate how much difficulty you're having seeing through the windscreen before you set off on your travels. The best an optical or capacitive encoder can do in such a scenario is give out an error flag to indicate that something's wrong. The worst it can do is report a wrong angle with potentially catastrophic results.

Thankfully, such problems are rare for low resolution devices of less than say 8bits (around 250 counts per rev) because their feature sizes are relatively large and so the optical contrast measurements are fairly easy. However, for high resolution (12bits or higher) optical encoders, their optical features can be microscopically small and therefore sensing the optical contrast of such tiny marks through mist, condensation or ice is often difficult and sometimes impossible. The key here is that to an optical sensor a few, small particles of hoarfrost or beads of condensation on its lens either mask or looks like the optical features that it's trying to detect. You can prove this for yourself – spray one of those house plant water atomisers on the lens of an optical sensor and see what happens. Logic might suggest that OEM-kit or ring type, bearingless encoders would be more prone to such effects than their housed counterparts because the lens systems on ring encoders are more open. Feedback from customers indicates that both formats are prone to icing difficulties although the packaged devices tend to suffer fewer problems with foreign matter such as swarf, dust, sand, hair or fluff.

For a capacitive encoder, their basic physics means that moisture greatly affects the sensor's main measured parameter (electrical capacitance) and as such they can suffer from big moisture coefficients. A droplet of condensation on the plates of a capacitive encoder can produce wildly inaccurate measurements.

The nemesis - condensation

Condensation or misting can be a rather complex and confusing issue because its formation depends on a number of (inter-related) factors including atmospheric pressure, altitude, temperature, time, surface 'wettability' and absorbency. Condensation can be thought of as the reverse of evaporation – it is the change of state from gas phase into liquid phase. For our purposes, it can be defined as the change in the state of water vapour to liquid water when in contact with a surface. When the transition happens from the gaseous phase into the solid phase directly, the change is called deposition – usually resulting in ice. For those of us of a certain age, the formation of ice on the *inside* of our bedroom windows will be a distant but familiar memory. Condensation is initiated by the formation of atomic or molecular clusters within its gaseous volume—like rain drop or snow flake formation within clouds—or at the contact between such gas and a surface. Condensation occurs when a vapour is cooled and/or compressed to its saturation limit when the molecular density in the gas phase reaches its maximal threshold. For outdoor equipment, the most common mechanism is when relatively warm air inside the equipment meets a chilled surface such as the aluminium or steel casework. In some cases this will lead to the formation of mist, then droplets and then condensate streams which, under gravity, will form pools of water at the lower points of the equipment. Condensation within outdoor equipment is a common, natural and usually unwanted phenomenon for design engineers. Other than the failure of optical or capacitive encoders, condensation may also cause or accelerate a number of effects such as corrosion, electrical shorting, mold, fungal growth and rotting of fabric or cellular materials.

What are the solutions?

Traditionally, there have been a number of solutions. The first is either lots of through ventilation and/or a heater inside the equipment so that the internal air doesn't chill sufficiently to condense on cold surfaces. Forcibly ventilating electrical enclosures can, in practice, cause more problems than it solves in some moisture or particle laden environments (most notably with potentially explosive environments). A heater solution is more easily said than done and any heating system will tend to add complexity, extend start up times, increase energy consumption and in some cases exacerbate matters in unexpected ways. Next time you've got a misted up windscreen, see what happens when you blow warm rather than cold air on to it. Issues such as differential thermal expansion, thermal gradients/stress, mold and fungal growth must also be taken into account.

The second solution is to use a hermetically sealed unit and to fill the cavity with a gas which contains no water vapour, such as pure nitrogen. This is often the defacto solution for systems such as electro-optical assemblies, missile seekers, camera or infrared detectors. Important here, is the use of the word 'hermetic' - in other words, airtight. Importantly, O-rings and shaft seals are typically environmental rather than hermetic seals. In other words, they do not prevent the passage of air in and out of the equipment's internal cavities. They may slow the passage of air, but even a modest pressure differential across a shaft seal will lead to air flow. This phenomenon is well known to aerospace engineers – especially with regards to 'cavity pumping' caused by changes in pressure from the ascent or descent of aircraft and this is why the use of hermetically sealed cavities is often a basic requirement for avionics. For most equipment designers, the position for encoders is typically where there are shafts and moving components and so by definition, they do not lend themselves to being hermetically sealed. This solution is seldom applicable to rotating shaft and encoder arrangements.

The third solution is to use a desiccant to remove water vapour from the internal environment. This can be a good method but requires periodic service for replacement or refill. Equipment users invariably don't like this solution.

An alternative approach

Perhaps the most sensible solution is not to use equipment that is sensitive to condensation. Optical and capacitive encoders are not included in this category. Such an approach may seem obvious to some but it seems that the difficult lessons learned by an older generation of engineers has not necessarily been learned by a newer generation. Resolvers, synchros, Inductosyns™ and inductive encoders (or 'incoders') are included in this category. Such devices use inductive or transformer principles to measure angular displacement or velocity and are generally unaffected by changes in temperature, humidity or even immersion in fluids. Inductive devices are the traditional choice of seasoned design engineers in the aerospace, defence, utility and petrochemical sectors where reliable outdoor operation over long periods is a key requirement.

An example of an incoder

Synchros and Inductosyns™ are seldom specified nowadays because of the difficult requirement to supply power to the rotating element. Brushless resolvers are more common but because of the rarity of resolver manufacturers they are increasingly expensive and are generally not considered by younger engineers because of their requirement to be paired with analogue supply and digital conversion circuitry. Incoders offer the best of both worlds – the robustness and reliability of traditional inductive devices coupled with the simple electrical interface of the optical encoder. Incoders are typically supplied with a DC power supply and produce a variety of simple digital outputs such as SSI, SPI or A/B pulses in high resolution formats up 22bits (4millions counts per rev). Such devices are winning an increasing market share from applications which require reliable and precise measurements in difficult environments such as defence, aerospace, and petrochemical environments.

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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