Technicle White Paper

Zettlex
Precision in the Extreme

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Why do engineers dislike potentiometers?

Potentiometers have been around for a long time and are still, by far, the most commonly used position sensor. So why does every design engineer seem to be looking for a non-contact alternative? Mark Howard from Zettlex Ltd. examines this phenomenon and explains the pros and cons of potentiometers.

Potentiometers – still the most common choice

There are more potentiometers sold than any other form of position sensor. They are simple, inexpensive, widely available and compact. Laser trimmed potentiometers offer high accuracy measurement and, unlike their more complex, non-contact counterparts, there are practically no issues of long term component obsolescence. In terms of value for money, potentiometers – usually referred to as 'pots' – are an excellent choice for many applications and this is likely to remain the case for the foreseeable future.

Fig. 1 – Potentiometers – why don't we like them anymore?

So why is it that every design engineer seems to be looking for a non-contact alternative?

Certainly, over the past 20 years, there has been a massive swing towards non-contact position sensing. This has increased to such an extent that when potentiometers are nowadays proposed as part a technical solution, there is a good chance of raised eyebrows, sucking of teeth and pointed questions about reliability and life-time. So what's caused this? Is this some mild form of mass hysteria among engineers or is the swing to non-contact position sensing really justified?

Potentiometers – where they work well

Clearly, there are many, many applications where potentiometers will work perfectly well and offer trouble free operation over long periods. The very desk on which I write this article carries a radio of 1970s vintage whose volume is elegantly and smoothly controlled with a good old potentiometer behind the Bakelite fascia.

Consider a potentiometer measuring a linear displacement once every 5 minutes or so – the kind of typical application and duty cycle for a piece of factory automation such as an actuator or valve. A good quality potentiometer might typically be rated for 500,000 cycles.

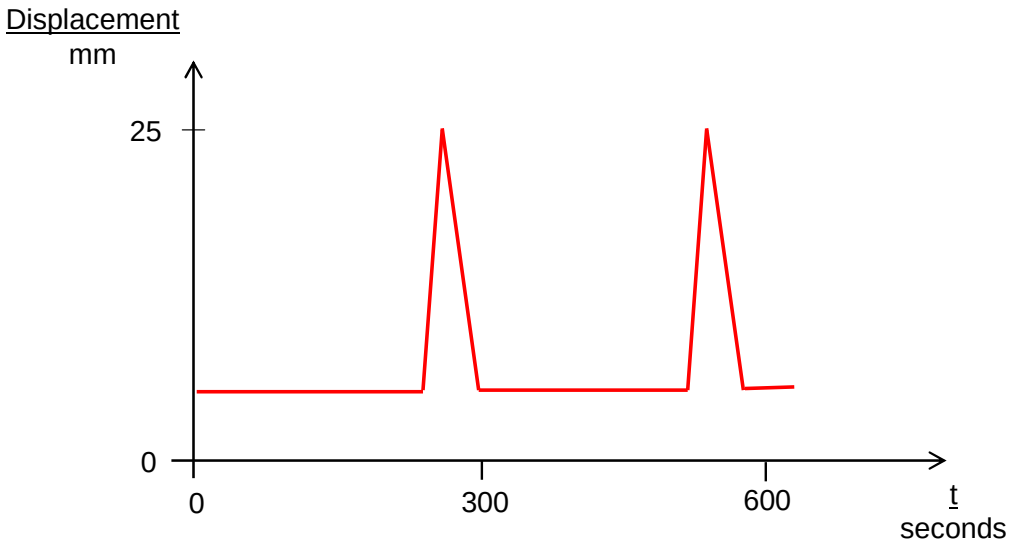

Fig. 2 – Duty cycle of a potentiometer

At 500,000 cycles this potentiometer should be good for 5 years even with constant use 24 hours a day, 7 days a week.

Potentiometers – where they might let you down

It appears that all potentiometers have been classed as unreliable because of a relatively small number, but seemingly notorious, failures in harsh environments. Now 'harsh environments' come in all sorts but there seems to be 3 particular aspects that cause problems for pots – vibration; foreign matter and extreme climates.

Potentiometers are vulnerable in applications with any significant vibration. Let us consider the previous application more closely but in a vibrating environment such as a road vehicle, heavy plant or aircraft system.

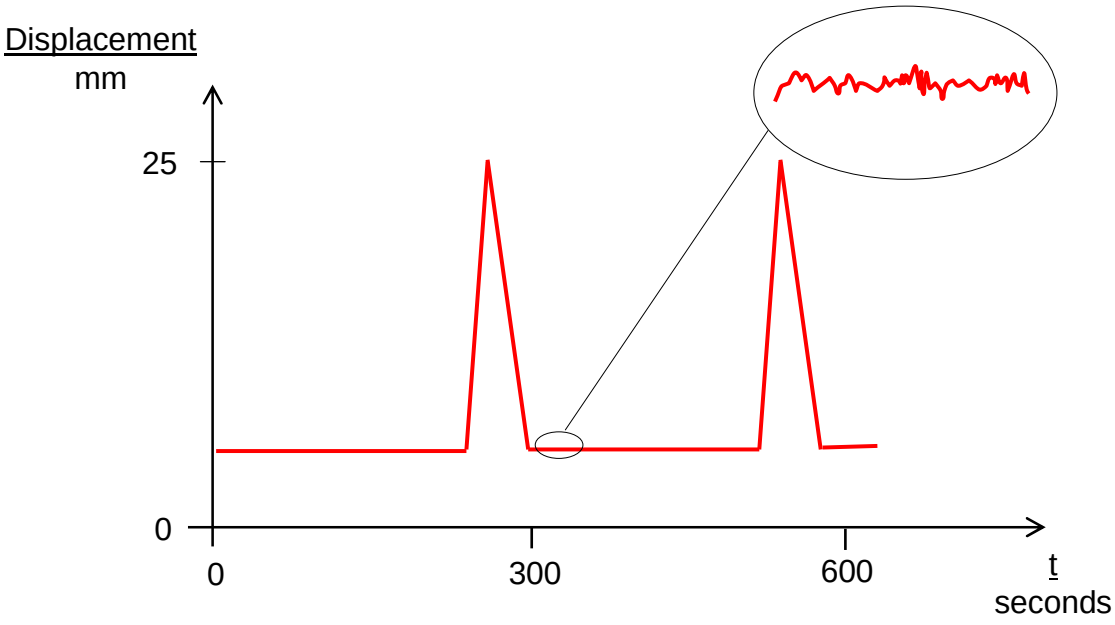

Fig. 3 – Duty cycle of a potentiometer in a vibrating environment

When we look closely at the displacement we can see that there are frequent ‘micro displacements’ caused by the vibration. At this microscopic level, the potentiometer’s conductive track cannot differentiate between a full cycle and a vibration induced ‘micro cycle’. Furthermore, because the potentiometer’s wiper is at the same point for most of the time, the same part of the track is subject to most of the wear. Just like a pot hole *(pun intended)* in a road, a microscopic wear point on a potentiometer’s tracks grows quickly – resulting in a discontinuity or ‘flat spot’ with no electrical response. Operation is severely, usually terminally, effected. Whereas 500,000 cycles previously equated to a lifetime of 5 years, in this example even at a modest vibration cycle of 1Hz, the lifetime reduces to less than 10 days!

Ingress of foreign matter can also be a source of accelerated failure. Again at a microscopic level the potentiometer’s wiper should normally ride over the conductive track’s molecular surface. When it’s just the track and the wiper this works well. Introduce even tiny particulates between track and wiper and the effect is the same as an abrasive – rapidly accelerating the wear of the conductive track surface. Wind blown desert sand is notoriously abrasive and problematic. Unfortunately, the application of a lubricant can bring the law of unintended consequences in to play, since the lubricant can act as an attractant or binder to the particulates and so accelerate still further the rate of wear.

Extreme environments per se, are not a root cause of failure for potentiometers but rather the generation of tiny micro climates in the immediate vicinity of the wiper and tracks. For example humid air, when cooled, may result in condensation on the wiper and ultimately corrosion or, as with some lubricants, the condensation attracts and retains foreign particles.

Market Perception

In summary, there are some applications where potentiometers will work well and there are others – notably in harsh environments – where potentiometers can prove unreliable. The unfortunate consequence of these high profile, harsh environment failures is that they have overshadowed the more benign applications where potentiometer operation has been reliable. This has led to a more widespread perception by engineers and technical buyers that potentiometers are the cheap, low quality option for position measurement. This widespread perception can put equipment manufacturers on the back foot when they are selling equipment that relies on potentiometers - since they are often forced to defend or justify the reliability and quality of their product. Consequently, many equipment builders are looking to replace potentiometers with non-contact solutions for marketing, rather than strictly technical, reasons. The unfortunate reality is that partially ill-founded market perception as a driving force for change is just as real and just as brutal as any technical reason.

Why isn't everyone changing to non-contact?

The reason that not everyone is changing to non-contact is that it's not straightforward. Firstly, there is the issue of cost. Most of industry still works from simplistic bill of material costings and these will always favour pots over non-contact. It takes a more sophisticated cost analysis to include break-downs, warranty, spares, maintenance and service costs, to show that non-contact solutions are the less costly alternative in harsh environments. Similarly, the sophistication required to show that product sales prices can be maintained when non-contact solutions are used, rather than a potentiometer, is usually beyond most hard-nosed industrial companies.

Just as importantly, there is the knock on engineering caused by replacing potentiometers with a non-contact alternative. Non-contact devices tend to produce a digital electrical output whereas potentiometers produce a simple analogue output.

Changing from analogue to digital will require the host electrical system to be re-engineered, re-tested and re-qualified. Similarly, potentiometers are compact and so the space previously occupied by a potentiometer will usually be too small or not quite the right shape for its non-contact alternative. Such a change may require a complete mechanical redesign and hence re-testing and re-qualification.

New Generation Inductive

Where potentiometers are being swopped for a non-contact alternative, a common replacement is one of the new generation inductive sensors. These new sensors work in a similar way to traditional resolvers or linear transformers but are just as compact as a potentiometer. Rather than a traditional inductive sensor's wire spools, these new generation devices use printed, laminar windings to generate the inductive fields. These sensors can also generate a high accuracy voltage or current analogue output to mimic a potentiometer and hence avoid re-engineering the host control system. They are well suited to harsh environments with operating temperature s between -55 to +230Celsius and can be encapsulated for long term submersion or operation in explosive environments. Since they are lightweight and non-contact, vibration and shock have negligible effect.

Fig. 5. – Next generation inductive sensors are as compact as pots and mimic their analogue output

For more information on Zettlex's new generation of inductive position sensors, please telephone Zettlex UK Ltd on 01223 874 444 or visit the website at www.zettlex.com or email info@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 sensors; supplies sensor components and integrated circuits. The company offers bespoke sensor design and development for specific customer applications.

Unique technology and laminar, printed designs, enables Zettlex to manufacture sensors that have no contacts, no bearings, no delicate parts and zero maintenance.

Zettlex sells directly to OEMs and system integrators across a broad range of industry sectors. Applications include position measurement, servos, 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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