INNOVATIVE ENCODERS FOR DEMANDING APPLICATIONS

As tools for measuring rotary motion in machinery, magnetic rotary encoders have a lot to offer. They are compact, robust and relatively inexpensive. For these reasons, simple magnetic rotation detection devices are often used in high-volume applications such as anti-lock braking systems for motor vehicles. However, for more demanding applications, more sophisticated devices are needed. POSITAL, a business unit of the German-based FRABA group, has developed a new family of magnetic rotary encoders that retain the mechanical simplicity, toughness and cost effectiveness of magnetic devices, while adding the features needed for high-performance motion control applications such as industrial automation systems, medical equipment, heavy construction machinery, elevator systems, automated doors, etc.

Figure 1: POSITAL MAGNETOCODE rotary encoder

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The absolute, multi-turn advantage

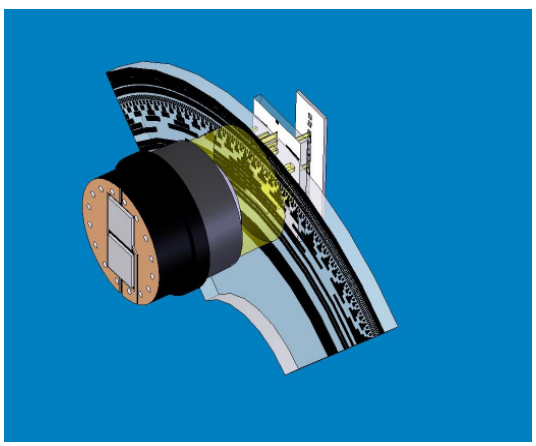
For an application like automotive ABS, it is usually sufficient to detect the rate at which wheel is rotating. This means that simple incremental rotary encoders will usually do the job. (Incremental encoders simply send out a pulse each time the shaft moves a certain amount.) However, for many motion control applications, the control system needs to 'know' the exact position of each drive shaft at all times (and, by extension, the position of the machinery driven by that shaft). This means having an accurate measurement of both the angular rotation of the shaft, plus a count of complete rotations.

If a simple incremental encoder is used, responsibility for keeping track of shaft position during equipment operations must be assumed by the control system. However, this can lead to problems: if the equipment undergoes some movement during a shutdown or power outage, then the control system will 'loose track' of the absolute position of components of the mechanism. Loss of position knowledge can also occur if the data transmission is interrupted or disturbed while machinery is in motion. If the control system's knowledge of the position of any of the components under its control is lost or corrupted, it is typically necessary to re-zero the system by moving all the parts back to established starting positions and re-initializing the system. Moreover, serious safety issues can arise when position data is lost or corrupted, since the system might attempt to move mechanical components outside of safe limits or allow collisions to occur.

Encoders that measure absolute shaft angle termed 'absolute encoders'. 'Single turn' absolute encoders measure angles between 0 and 360°. Encoders that also keep track of the number of complete rotations that the shaft has undergone, they are termed 'multi-turn absolute encoders'. Such devices can obviously be very useful in motion control applications since they can always be relied on to report their absolute position to the control system.

Understanding Optical Encoders

The current high-performance champs for multi-turn absolute rotary encoders are sophisticated optical encoders, such as POSITAL's OPTOCODE encoders. These devices have a transparent disk attached to the shaft, positioned between a light source and an array of photoreceptors. There is a pattern of clear and opaque areas printed on the disk, so that as the shaft turns, the photoreceptors are switched on and off, providing a digital readout of the shaft position. High performance optical encoders have resolutions as high as 65,536 (2^{16}) increments per turn and reliable accuracies as high as one part in 16,384 (2^{14}). For multi-turn encoders, one or more secondary disks are connected via a gear train that moves these disks forward or back with each complete rotation of the shaft. For a device with a 14-bit counter, the range would be 16,384 (2^{14}) rotations.



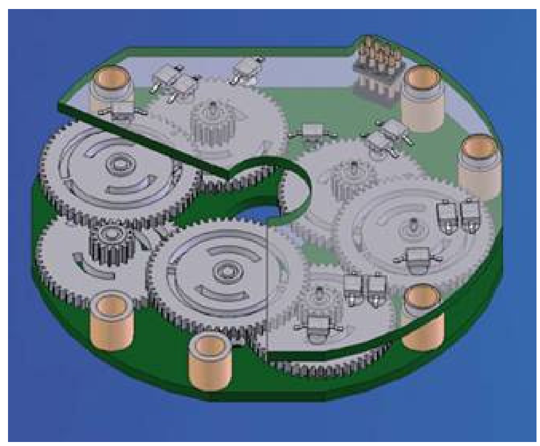


Figure 2: Inside a multi-turn absolute optical encoder

Upgrading the magnetic encoder

When the POSITAL designers set out to create the new MAGNETOCODE (MCD) family of absolute rotary encoders, their objective was to combine the functionality of the optical encoders with the simplicity, robustness and cost effectiveness of magnetic encoders.

The technology used to detect shaft position is fairly typical of magnetic encoders: there is a permanent magnet attached to the device's shaft and a 2-axis Hall effect sensor mounted on the encoder casing. As the shaft and magnet rotate, the Hall effect sensor measures changes in the magnetic field and reports the angular measurement to the control system. Because MCD encoders are individually calibrated before they are shipped, they can also provide higher accuracy (around one part in a thousand) than is typical with magnetic rotary encoders.

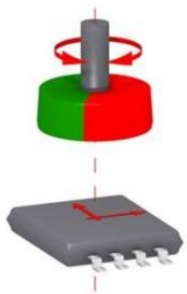


Figure 3: Hall effect sensor for an absolute magnetic encoder

What makes the MCD family of encoders special is the ingenious technology used to record the number of rotations that the device experiences. There were several obvious ways of providing this capability, but these have drawbacks. One possible approach would have been to use a gear train to drive a second magnet that would move one increment with each rotation of the shaft, similar to the system used in multi-turn optical encoders. The problem of this approach is that it would add significant complexity, size and cost to the device, largely undermining the advantage of using the magnetic sensor technology. Another possibility would have been to add an electronic counter with a battery backup. Batteries however must be checked periodically and occasionally replaced, which adds to maintenance costs. Moreover, batteries can prove to be unreliable under hot and harsh industrial conditions, while 'dead' batteries are a form of hazardous waste that can be a problem to dispose of.

The solution that the POSITAL designers developed avoids these drawbacks with elegant simplicity. The key feature of the multi-turn MCD encoders is that the turn counter mechanism is self-powered. That is, the encoder harnesses the rotation of the shaft to generate enough electrical energy to trigger the turn counter and to record the event in non-volatile memory. However, this is not a conventional 'bicycle generator' type dynamo! Such dynamos, while simple and inexpensive, have a serious drawback in that the voltage produced depends on the turning speed. At very low speeds, the voltage would be too low to reliably trigger the turn counter, which is unacceptable. Instead, the core technology of the MCD rotation counter is based on the use of the "Wiegand effect".

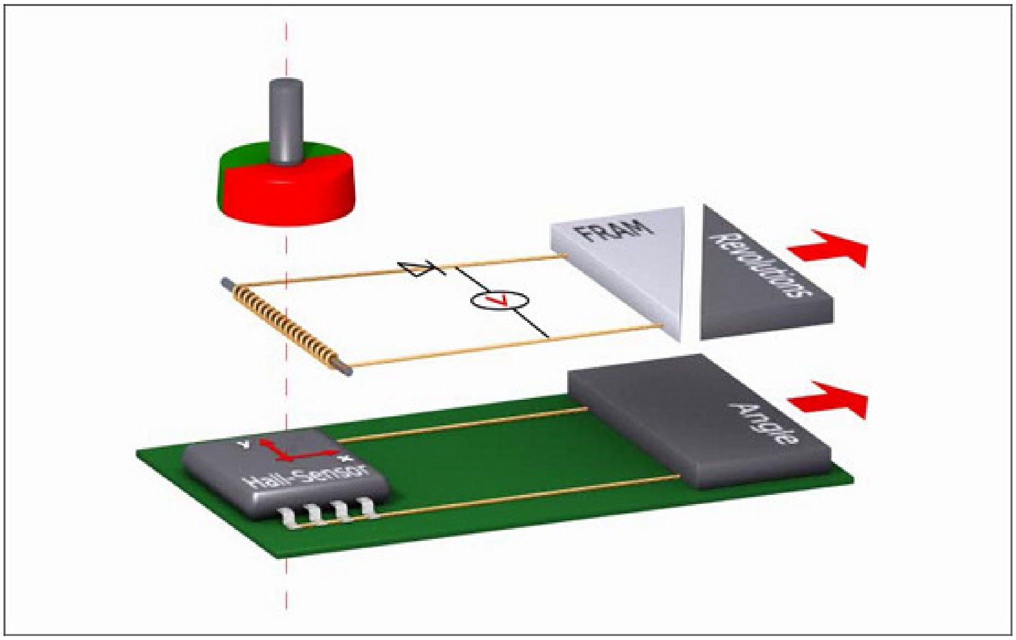


Figure 4: Hall sensor, plus Wiegand effect turn counter.

A 'Wiegand wire' is a small cylinder of ferromagnetic material that has been specially conditioned so that it experiences sudden changes to its magnetic polarity when it is subjected to an alternating external magnetic field. This rapid change in magnetic polarity creates a short, sharp pulse of electric power in a tiny coil wrapped around the cylinder.

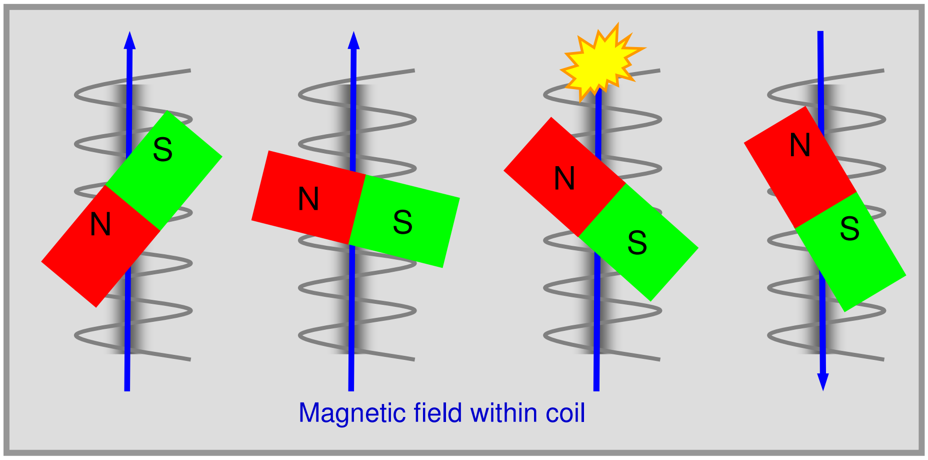


Figure 5: Wiegand effect: as the external magnetic field changes, a sudden change in the polarity of the ferromagnetic material is triggered

(The sudden change in polarity within the Wiegand wire is independent of the rate of change of the magnetic field, so that the strength of the electrical pulse is effectively the same, regardless of the speed of rotation of the magnet that triggers the polarity jump in the Wiegand wire.)

In the MCD multi-turn encoder, these pulses are used to power a Hall effect sensor (to detect the direction of rotation) and an electronic counter that increments or decrements the number of rotations recorded in a non-volatile memory. All of this occurs without any need for external power, so that changes in the absolute position of the shaft (number of turns plus angular displacement) are registered, even if there has been rotation of the shaft during a shutdown or power outage. Since the internal memory of the encoder is always up-to-date the absolute position information reported to the control system is always correct.

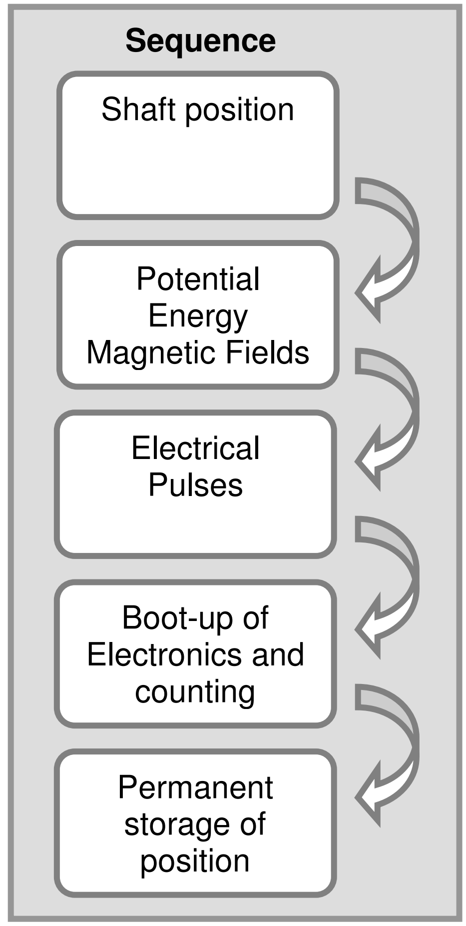


Figure 6: Turn-counting powered by the Wiegand effect.

Optical or magnetic?

While POSITAL MAGNETOCODE multi-turn absolute rotary encoders are an excellent choice for many applications, they should not be seen as a substitute for their 'big brother', the OPTOCODE optical encoders in all situations. The relative advantages and trade-offs of these devices are summarized as follows:

Accuracy: OPTOCODE encoders provide a maximum of resolution and accuracy. However, MCD encoders with their 13-bit resolution meet the requirements of most motion control applications.

Harsh conditions: MCD encoders are available with sealing levels up to IP69K, which makes them suitable for damp and dirty conditions.

Size: MCD encoders, at 36.5 mm diameter, are relatively compact. OPTOCODE encoders are larger, with a diameter of 58 mm.

Cost: MCD encoders are generally significantly less expensive than their optical counterparts.

About FRABA Inc.

FRABA Inc. is the North American unit of the FRABA Group, a producer of specialized industrial sensor equipment for sophisticated manufacturing applications. The company traces its roots back to 1918 when its predecessor, Franz Baumgartner elektrische Apparate GmbH, was established to manufacture relays. Today, the group consists of six independent companies that develop and produce advanced industrial sensor technology and safety equipment.

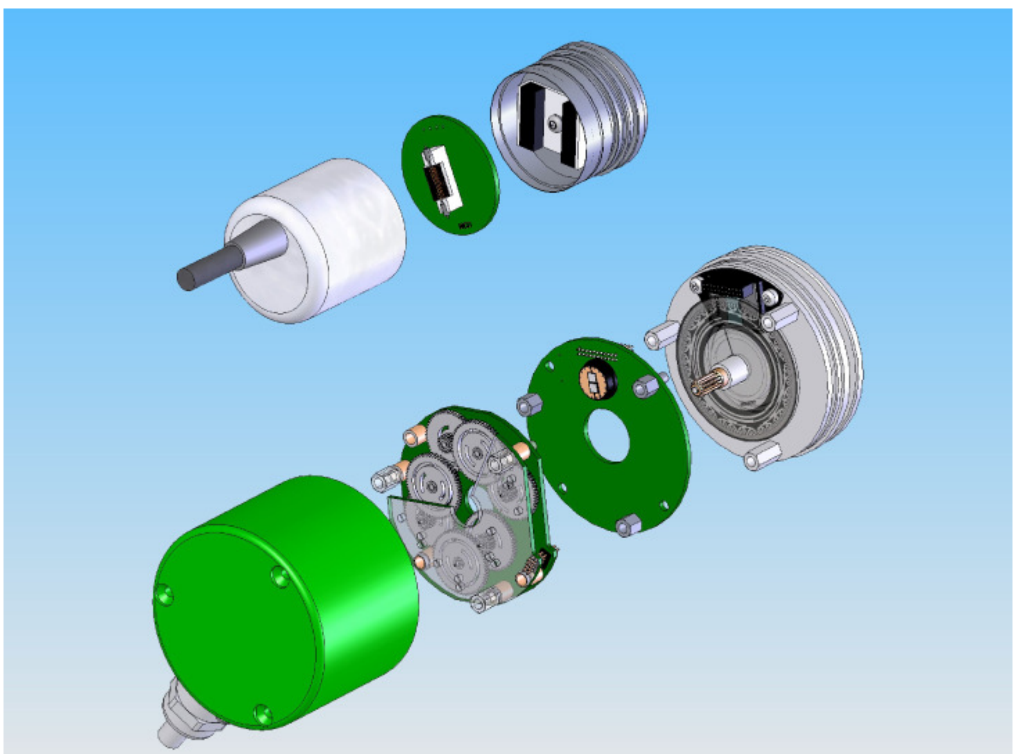


Figure 7: 'Exploded' view comparison of Magnetic (top) vs Optical (bottom) Absolute Multi-Turn Rotary Encoders

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