Even Without Power You can count on it…

How To Substantially Reduce Encoder Cost While Gaining Functionality With **44-Turn** Multi-Turn Rotary Position Sensors

WhitePaper

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Multi-Turn Rotary Position Sensors

Many applications require rotation counters that can measure angles greater than 360º. However the low-cost 10-turn potentiometers most design engineers are familiar with can't always meet user requirements for resolution– which can be less than 0.1%. As an alternative, optical absolute encoders are too expensive for many applications– typically costing 8 times higher cost than potentiometric technology products. They can also fall short on reliability due to contaminants like dust and liquids and desired durability in some applications. These solutions require a continuous power supply or they will lose count when power is restored. Also, geared technology/rotation counters are subject to significant wear.

Technology adapted from the computer industry can be applied to multi-turn rotary position sensors to address this unfilled engineering need. Position sensors built on an enhanced giant magnetic resistance effect can provide substantial cost savings (¼ of the cost compared to optical encoders), maintain reliability and accuracy with resolution to 16-bits and independent linearity to ± 0.25%, plus they offer additional useful features.

Developing New Technology

Magnetoresistance is a phenomenon in quantum mechanics that occurs in thin film structures when two ferromagnetic layers are separated by a thin non-magnetic film. It is a technology used in hard disk drives used in computers and other microprocessor-based applications. When the two magnetic layers are parallel, resistance drops to a minimal value. As the magnetic layers are turned so they are no longer in parallel alignment, electrical resistance increases. This increase can be used to measure absolute position values, e.g. full rotations.

Minimum resistance

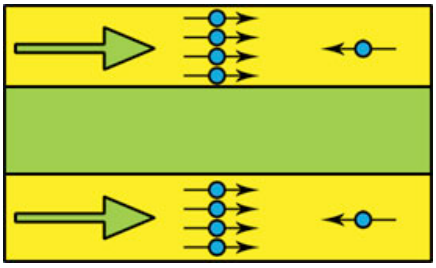

Figure 1a

Increased resistance

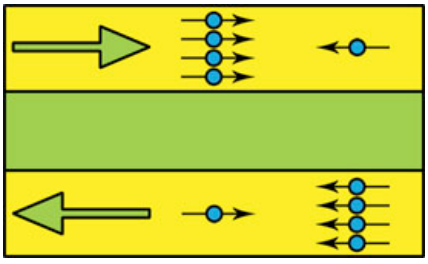

Figure 2a

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How It Works

By optimizing this technology for encoder and positioning applications, a combined multi-turn rotation counter and position sensor that senses without contact or power. The sensed count can be held without power for years.

Block Diagram of Multiturn Angle Sensor

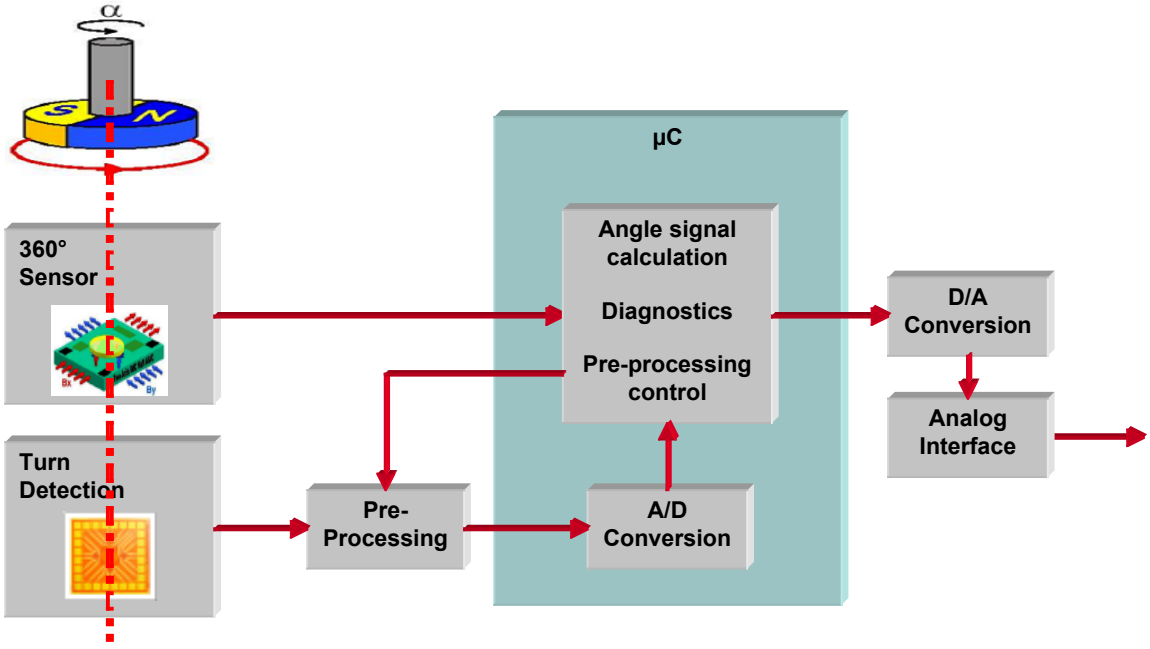

Figure 2

The physics of this sensor technology is simply described in three elements. The first, is called a Domain Wall Generator (DWG) A magnetic DWG is a group of atoms that are aligned in parallel to magnetic north and south. The second element is a specific number of ferro-magnetic sensor tracks arranged in layers, separated by a thin non-magnetic spacer layer. The sensor tracks begin at the DWG. The third element is a reference track that is another ferromagnetic layer placed above or below, and parallel to, the sensor track layer.

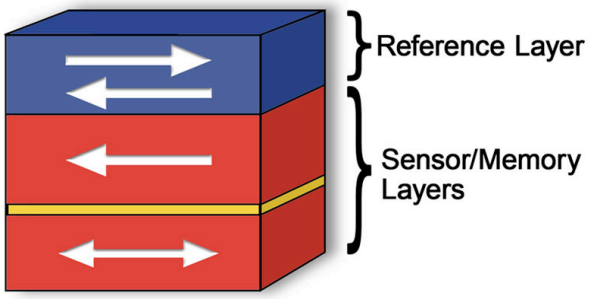

Figure 3

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Think of it as a pool of fish all swimming in the same direction in the DWG, and they head in to a narrow “tunnel” (the sensor track segments) so that once in the “tunnel”, their alignment can’t change until a nearby magnetic field interacts with the DWG. If their alignment is changed in the “tunnel”, it can only be 0° or 180°. The reference layer has a fixed magnetization direction that doesn’t change.

The narrow track segments are arranged in a spiral structure and the reason the sensing/memory layer limits magnetization direction to only 0° or 180° is due to an effect called *shape anisotropy*. The DWG that is labeled DWG “pool” above has a large enough area such that *shape anisotropy* cannot occur there and therefore the magnetization direction in the DWG is the same direction as the rotating magnet’s magnetic field.

As the magnet passes over a segment, the the DWG “pumps” out “groups” of magnetic *domains* causing magnetization, aligned to either 0° or 180°, of the first segment depending on the position of the magnet. One alignment, say 0° is the same direction to the reference layer. This would mean the 180° alignment would be an opposing direction to the reference layer.

Figures 4a through 4f on next page depict domain directions in DWG and track segments as well as magnetic field orientation– all with respect to the reference layer. Figure 4c is shown here to explain what each element in figures 4a - 4f represent:

The reference layer’s magnetic orientation is represented by a big green arrow. The gray arrow in the center of each diagram represents the application sensing magnet. The arrows in the DWG ‘pool’ reflect the orientation of the sensing magnet. Tracks with higher resistance are represented with a yellow rectangle and a domain wall is drawn as yellow or white ‘elbows’ at the turn of two track segments.

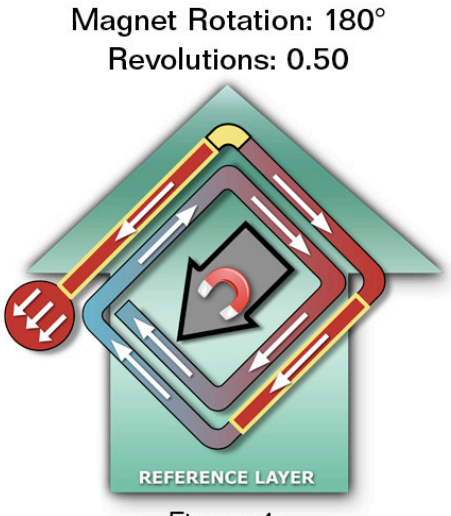

Figure 4c

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As the magnet passes clockwise from 0° up to 180° from a starting point of 0°, the alignment of all segments is in the same direction (figure 4a). At each 90° turn, the DWG pumps more domain walls through causing the magnetized

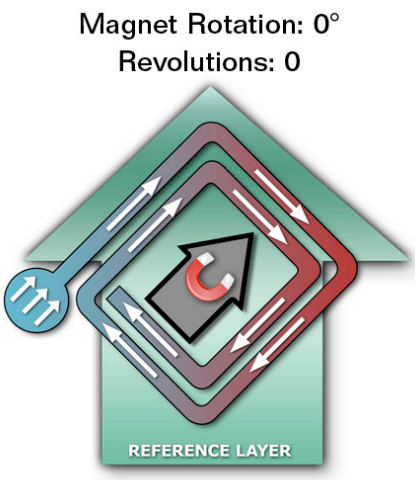

Figure 4a

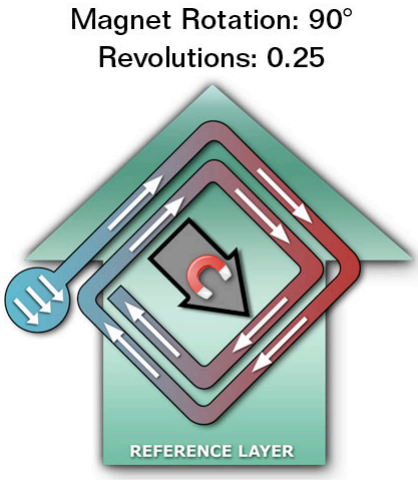

Figure 4b

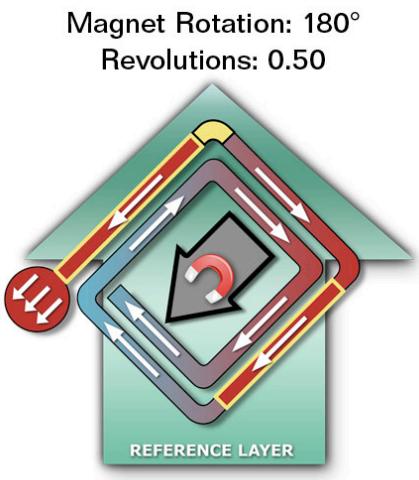

Figure 4c

segments to advance one segment each to the next segment (figure 4b). However, as the magnet is rotated through a position of 180° from the start, its magnetic alignment forces a 180° change in the direction of the domains the DWG produces causing the first segment to be magnetically aligned in the opposite direction to the prior segments (figure 4c). This creates what is known

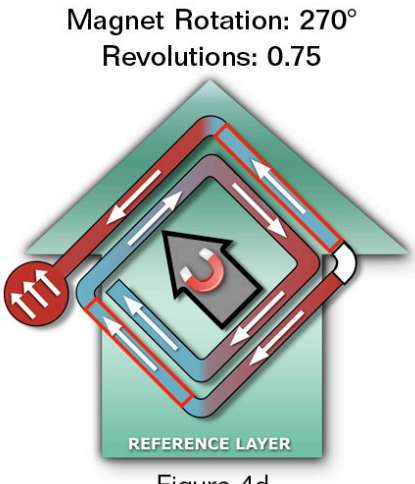

Figure 4d

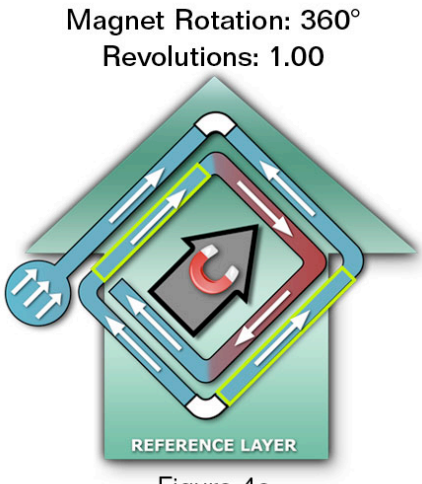

Figure 4e

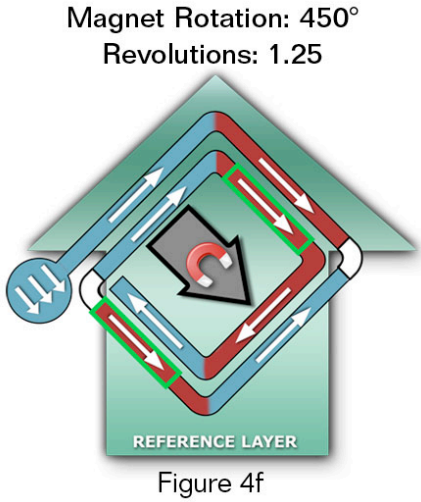

Figure 4f

as a *domain wall* between segments 1 and 2. This situation repeats at 270° (figure 4d), creating a second opposing direction domain wall. Then the cycle starts again at 360° except that the second (inner) spiral segments are affected.

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In this way, the resistance suddenly and measurably increases or decreases across segments. The resistance across the segments is measured and processed. Since the tri-level (or trinary– low, medium or high) resistances produced by specific segments depends on parallel and anti-parallel domain wall combinations as well as the number of rotations, the count can be accurately determined.

Because these are purely magnetic phenomena, this process occurs and information is stored in the segments whether there is any power applied or not!

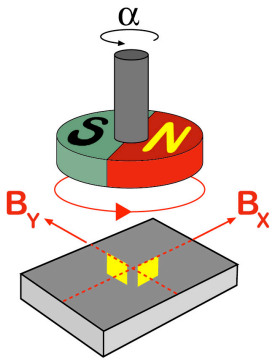

Figure 5

By measuring the resistance of the structure, a custom integrated circuit stores the changes of resistance and applies a pre-determined offset to count the number of turns.

The number of spiral tracks determines the number of rotations that can be detected.

A second 360° sensor is used to determine the specific angle in a single-turn range and combined with the count sensor just described, this technology can determine the angle and number of turns- even tracking when no power is present. More on that benefit later.

Implementation Of This Technology

In an implementation of this technology, a sensor with two multi-turn elements are offset by 90º in a diamond pattern (Figure 5). With this structure, a clear rotation value can be derived in any angular position using a corresponding evaluation algorithm.

These sensors are true “power on” systems that provide these measured values immediately following start-up. This technology eliminates the need for the gears or the external power supply required in conventional rotation encoders. This results in very compact multi-turn sensors that can be easily integrated into a wide variety of applications. Prior technology could measure angles up to

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44 turns and supply absolute position values over 360° without mechanical gearing or a buffer.

This implementation can support devices with resolution to 16-bits and independent linearity to ± 0.25% and measures up to 15,840º. This technology supports a true power on sensor. This means a sensor counts revolutions even with power off, and no battery is required. Plus, even when power is restored, after a power disruption, it can respond with the last position upon powering up again– even months or years later.

Opening New Applications

Multi-turn sensors based on this technology can be used in an extremely broad range of linear or rotary actuators to detect the position of drive spindles over several turns. In many industrial applications this enables control systems to monitor and actuate compact, low cost drives for valves and electro-mechanical devices without a mechanical gear.

This technology also opens new possibilities in conveyor technology where a sensor can be integrated with a winding drum.

Off-highway vehicles have many applications for positioning moving and extending/retracting sections.

In an automotive application, sensors can be used to determine the actual vehicle steering angle over several rotations of the steering wheel.

In warehouse applications sensors can be used to detect the different opening positions of a roll-up door as well as forklift vertical and horizontal mast positions.

Novotechnik understands this technology extremely well and has applied it by developing patented technology called novoturn™. It is optimized for rotary position sensing and turn-tracking applications.

Now with the addition of the MB1, MC1 and MZ1 to the RSM 2800, the number of applications that can benefit from this multi-turn technology for rotation counting and angle measurement is substantially increased.

This magnetoresistance technology features true power-on functionality. They count revolutions even with power off, and no battery is required. When power is restored, after a power disruption, the MB1, MC1, MZ1, RMB and RSM 2800 Series retain the last turn count and position upon powering up again.

These multi-turn series of sensors feature 16 or 44 maximum turn count, linearity as tight as ±0.04% and ingress protection as high as IP69K— depending on model.

Output interface options include voltage, current, IO-Link, CANopen ,CAN SAE J1939, SSI and SPI— again, depending on model.

MB1 and RMB Series also feature solid shaft or semi-hollow-shaft versions, repeatability of less than ± 0.1° in a galvanized steel housing with stainless steel shaft and coupling.

For more information including our Multi-Turn and MZ1 brochures,
visit our website at:

https://novotechnik.com/rotary-multi-turn/ or email info@novotechnik.com.