How RedRock® TMR Magnetic Sensors Work in Typical Device Applications

IoT • Wake-Up • Security • Medical
Level Sensing • Metering • Motor Control

Offering ultra-low power consumption, high sensitivity, miniature package size and short lead times, Coto's RedRock® series of analog and digital TMR (Tunneling Magnetoresistance) magnetic sensors are ideally suited to the demands of next generation security, metering, medical, automotive, instrumentation, and industrial markets. Target applications include fluid level detection, open-close detection, proximity sensing, rotary sensing and any application where the device or product needs to wake up, turn on and perform – thus providing a true "out-of-the-box" experience.

RedRock™
TMR Magnetic Sensing Technology
by Coto Technology

1 General Magnet/Sensor Configurations and Orientations

There are several ways that a magnet can be presented to a RedRock® TMR magnetic sensor. Some general rules are illustrated in Figure 1. Imaginary field lines can be envisaged, looping from the North pole to the South pole of a magnet. Provided these field lines are linked to the RR TMR sensor in the right direction, and the magnetic field strength exceeds B_{OP}, the sensor will operate. For example, in Figure 1, Frame A, a bar magnet is placed parallel to and above the top of a SOT-23-3 RR sensor. The field lines loop through the sensor, causing it to activate. In Frame C, the same thing occurs except the bar magnet is placed at the side of the sensor, not above its top surface. Frame B presents an interesting case; if the magnet is offset slightly to one side of the top center of the sensor, it will operate normally, though there is a null if the magnet is placed directly on the vertical (Z) axis of the sensor. This displacement allows RedRock® TMR sensors to replace Hall sensors, which only have sensitivity in the Z-axis.

Some other common applicable geometries can be classified as: Head on, Parallel, Pass By and Rotating Diametrically Polarized magnet configurations, illustrated in Figure 2, Figure 3, Figure 4, and Figure 5.

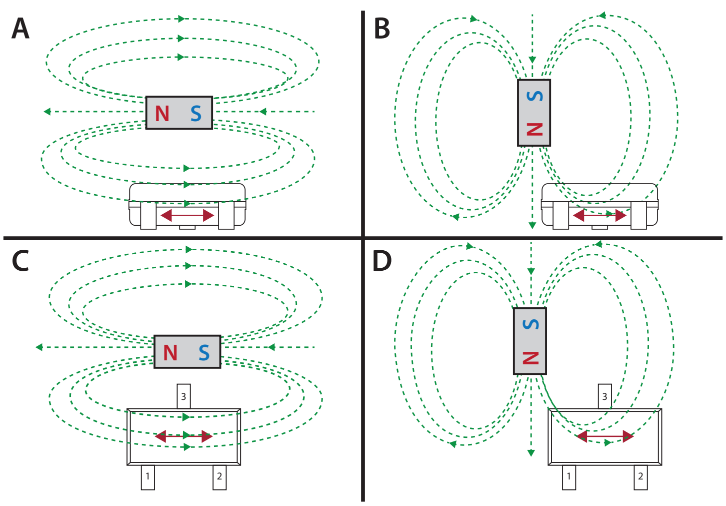

Figure 1: Alternative ways to configure a permanent magnet to a RedRock® TMR sensor

2 Methods for Applications Assessment

2.1 Laboratory Testing

Most design engineers want to fully test a new sensor application under conditions that closely correspond to the end use. It is far less costly to do the testing early, rather than encounter problems in production that are very expensive to correct. Such testing should use test samples of the exact model of sensor that has been selected, with the magnet of choice, with the air gap that will be used, in a ferromagnetic environment that includes potentially interfering magnetic fields and ferrous objects that might perturb the magnetic field near the sensor.

To develop magnetic fields with accurately known magnitude, a Helmholtz (HH) coil can be used. HH coils, in fact, have two wire coils in series, with their radii equal to their spacing. A Helmholtz coil displays an interesting property – it generates an almost uniform magnetic field within its volume, and the magnitude of that field depends solely on the electric current flowing through the coils. A typical coil might have a conversion factor of 8.0 Gauss per amp. Run 2.00 amps through the coil (measured with a NIST traceable ammeter), and you can be certain the field in the coil is 16 Gauss, plus or minus maybe 1%. Figure 6 shows a Helmholtz coil with an angle-adjustable test card in its center. This particular test was being conducted to determine the angular response of a sensor in XYZ-space.

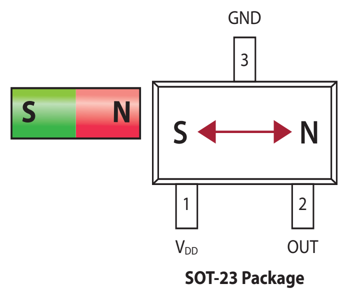

Figure 2: Head-on operation

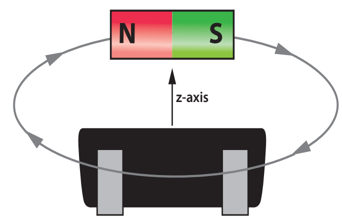

Figure 3: Parallel operation

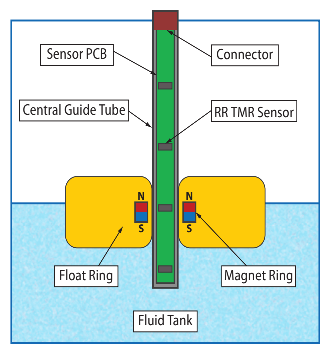

Figure 4: Pass-by operation

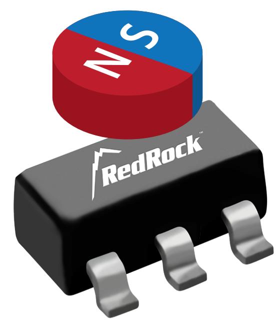

Figure 5: Rotating diametrically polarized magnet operation

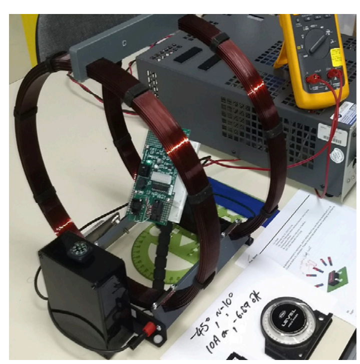

Figure 6: Helmholtz coil used to measure magnetic sensor response

One common disruption to lab testing is that the exact magnet proposed for use may not be available, only one that is "similar." Custom-designed magnets have long lead-times, so it is important to get the magnet design right. Another limitation of lab testing is that the ferromagnetic environment may be difficult to emulate under test lab conditions. That's when simulation becomes cost-effective.

2.2 Simulation

Magnetic simulation software allows the response of a magnetic sensor to a magnet to be estimated, either by using closed-form analytically calculable equations or by using finite element analysis (FEA). There are well-established formulas that can calculate the on- and off-axis magnetic field from a magnet given its material of construction, dimensions and magnetic remanence. The magnetic field at the sensor position can then be estimated, and converted to the estimated operate and release distance. However, in real-world applications, the influence of other ferrous components on the magnetic field reaching the sensor must be taken into account in a three-dimensional environment, and FEA becomes vital for simulation accuracy. Most commercial magnetic simulation software allow the direct import of CAD files followed by assignment of the magnetic characteristics of any ferrous components. After running an automated FEA solution, the result is an accurate estimate of the sensor's response, fully corrected for the magnetic environment in which it will be operating. Simulation also helps predict the performance from a specific magnet, based on its magnetic material characteristics and its size and shape, especially where a non-stock magnet unavailable from a magnet vendor is available. Different types and sizes can be rapidly evaluated at relatively low cost before a custom magnet is ordered. Simulation also allows visualization of the magnetic environment surrounding the sensor, via magnetic field contour and vector plots.

Coto Technology uses JMag ® [1] and FEMM [2] simulation software. JMag is a commercial full 3D simulator, and FEMM is 2.5D open source.

Figure 7 and Figure 8 illustrate the usefulness and accuracy of simulations in the case of a rotation-counting application. The figures illustrate a common applications problem: how much might a ferrous body, such as a steel-cased battery adjacent to a magnetic sensor, influence the magnetic field reaching the sensor? To investigate this effect, a diametrically-polarized magnet was rotated at high speed near a RedRock® analog sensor, and the analog voltage output was recorded on a digital oscilloscope. Using the sensor's transfer curve, these voltages were converted to magnetic field strength. A 3D model of the sensor and magnet was built in JMag that allowed the magnetic field to be predicted and converted to the expected sensor output, using the sensor's transfer curve. Two geometries were simulated; the first geometry was simply a magnet and sensor (Figure 7), and the second geometry was a model with a lithium coin cell positioned close to the sensor (Figure 8). Will the battery's steel case shunt away the magnetic field and reduce its strength at the sensor? The blue and orange traces in Figure 9 show the variation in field strength over time predicted by the simulator. The slightly noisy black traces show the actual measurements recorded by the oscilloscope. The simulator agrees extremely well with the experimental measurements and correctly predicts a drop in field strength at the sensor when the battery is present due to the battery case shunting magnetic field away from the sensor.

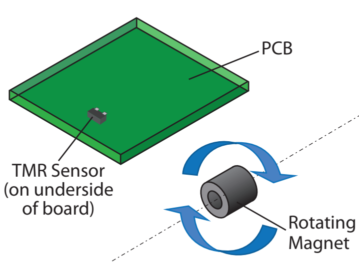

Figure 7: Rotating magnet application with no battery present

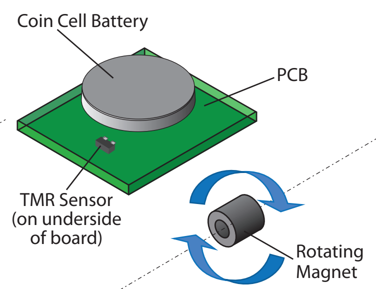

Figure 8: Rotating magnet application with CR2032 battery present

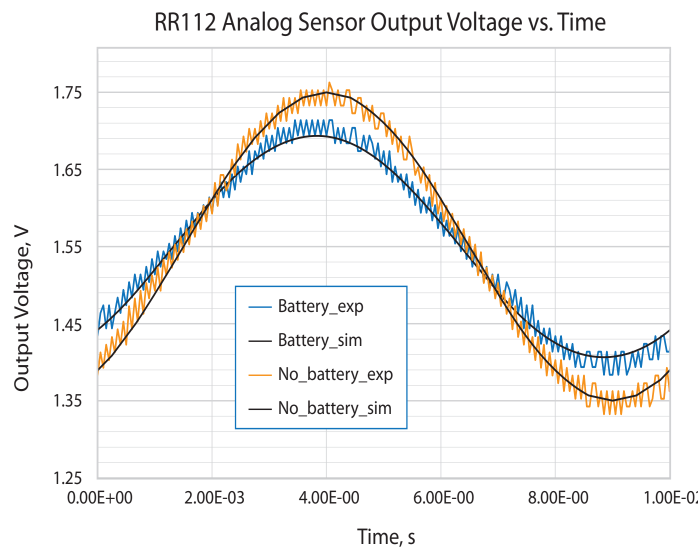

Figure 9: Rotating magnet application; simulation vs. actual measurements, showing experimental vs. simulated magnetic field vs. time

3 Common Applications

3.1 Wake-up Applications

A wake-up application requires a magnetic sensor that consumes extremely low power in a deep "sleep" mode, until a magnetic field turns it on (or off) so that it can then control another circuit such as a microcontroller. Unboxing a medical device, such as a capsule endoscope, is an example. A capsule endoscope contains a battery, a microcontroller, one or more video cameras, an array of LED's to illuminate its path, and possibly a radio transmitter (Figure 10). All these components must be enclosed within a capsule small enough to swallow. Combined, the components consume a hefty current, but must be driven by a tiny battery. While the capsule only needs to operate for a few hours after a patient swallows it, the endoscope itself may sit on a physician's office shelf for many months before being used. For obvious reasons, the device has to be sealed. So, how does one turn the device on just before it is to be swallowed?

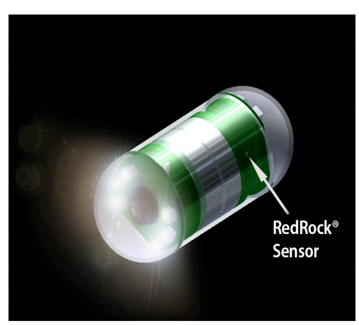

Figure 10: A capsule endoscope

The answer is to use an ultra-low

power sensor such as a 2Hz RedRock® sensor that consumes 18nA when powered at 3V. An LGA package with 1.45mm x 1.45mm footprint minimizes the sensor volume inside the capsule's sealed shell. The small Silver Oxide batteries normally used in the capsule can deliver this level of current for several years. After assembly and sealing, the capsule is enclosed in a package with a small permanent magnet mounted inside the lid. The magnet keeps the sensor closed, and the corresponding sensor low signal tells a microcontroller to turn off the lights, cameras, radio etc. until the package is opened, immediately before the patient swallows the endoscope. In this way the capsule can "sleep" for months before its few hours of useful but heavy current draw.

For more information on the use of RedRock® sensors in capsule endoscope applications, see **RedRock TMR Magnetic Sensors in Capsule Endoscopy.**

3.2 Security Sensor

Typical security sensors protect a building by having the doors and windows wire in a loop of normally-open sensors (traditionally reed switches) held closed by a nearby magnet on the door or window frame. If the conductivity of the loop is broken by opening a door or window, a central control unit registers an alarm. This system works well, but the wiring is costly, so many security system manufacturers have changed to battery-powered wireless transmitters at each sensor location that transmit back to a control station.

Most of these wireless transmitters still use reed switches, which have the advantage of zero power requirement, but have still the inherent disadvantages of reed switches: fragility during manufacturing installation and in the field (unless plastic-encapsulated reed switches are used), relatively high cost, long lead times and a limited number of worldwide manufacturers. Reed switches, first introduced around WWII to modernize telephone exchanges, are now an aging technology.

Up until now, solid state magnetic sensors would have been a perfect replacement for reed switches but for one flaw; they consume too much power for satisfactory battery life to be achieved. This is a situation where the ultra-low power consumption of RedRock® TMR sensors becomes attractive. High-speed sampling of the magnetic environment is not needed, so a 2Hz sensor can be used as the maximum sampling wait time is only 0.5 seconds before an alarm is transmitted. Consider that the average current consumption of a 2Hz RedRock® digital sensor running with the 3V supply from a CR2012 lithium cell is only 18nA. If the battery did not have a limited shelf life, it could power this sensor for hundreds of years. For more information, see **RedRock TMR Sensors for Security Applications.**

3.3 Level, Distance and Proximity Sensing Applications

Traditionally, level sensors are produced using a reed switch ladder. As a floating magnet sweeps past a series of reed switches, the sequential closing of each switch shorts out a chain of resistors, producing a varying resistance that can be converted to a varying voltage corresponding to the fluid level. Though widely used, there are several disadvantages to such a scheme. First, reed switches are relatively large, limiting the resolution of a reed-based level sensor to about 15mm when using 5mm molded reed switches. Second, reed switches are prone to multiple closures as a magnet passes by, complicating the algorithms needed to decode the switch closures. Third, reed switches are mechanical devices that have a limited lifetime before the contacts fail. Therefore, it is desirable to provide a solid state solution that has higher spatial resolution and reliability.

It is simple to replace reed switches with a solid state TMR sensor such as the RedRock® RR132. Figure 11 shows a suitable circuit, and Figure 12 shows the implementation into a demonstration circuit board with ten RR132 open-drain sensors spaced 4 mm apart. The sensors' MOSFET's are sequentially shorted to ground through the chain of 470Ω resistors as the magnet sweeps by. By fitting a calibration curve of switch number (y) vs. V_{OUT} (x), it is possible to predict the closest switch number for any subsequent V_{OUT} measurement, thereby predicting the fluid level to a resolution of 10%.

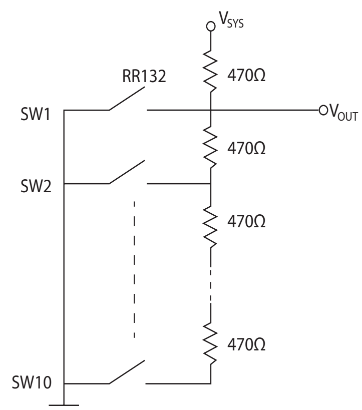

Figure 11: Level sensor circuit schematic using resistor ladder

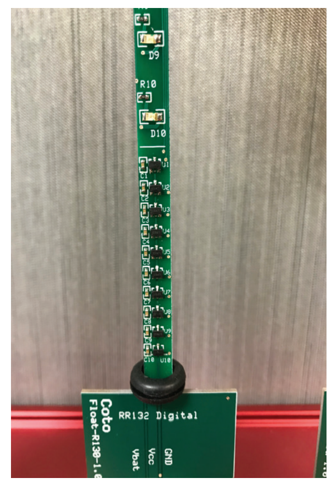

Figure 12: Level sensing ladder prototype

Setting V_{SYS} to 3.00V resulted in the following values (Figure 13 and Figure 14) for V_{OUT} as each switch is successively turned on.

It is also feasible to use RedRock® analog sensors such as the RR112 for level sensing. A floating ring magnet moves up and down, constrained by a vertical post. (Figure 15) The analog output varies with the height of the ring magnet, and has a useful range of about 30mm. This method is therefore suitable for measuring the depth of fluid in shallow reservoirs such as detergent dispensers in white goods applications, and is cost-effective since only one sensor is required. This system can be adapted to greater fluid depths by providing a chain of analog sensors spaced about every 25 to 30mm.

For further information see **Improving Level Sensor Design.**

V_{OUT}	Switch Closed (actual)	Switch No. Predicted	Switch No, Predicted (Rounded to 1 decimal point)
0.2810	1	1.0501	1.0
1.6094	2	2.0322	2.0
2.0625	3	2.9842	3.0
2.3125	4	4.0244	4.0
2.4513	5	4.9900	5.0
2.5469	6	5.9776	6.0
2.6094	7	6.8663	7.0
2.6719	8	8.0654	8.0
2.7188	9	9.2808	9.0
2.7344	10	9.7719	10.0

Figure 13: Measured V_{OUT} (left hand column) and corresponding predicted switch number calculated from curve shown in Figure 14.

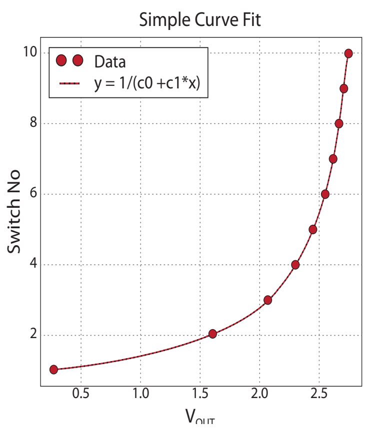

Figure 14: Calibration curve of switch number (y-axis) vs. V_{OUT}.

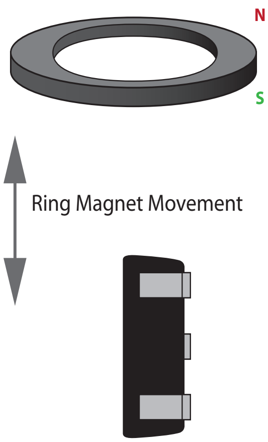

Figure 15: Level sensing with a single RedRock® analog sensor has a useful range of 30mm.

3.4 Rotation Sensing Applications

A very common application is measuring a rotating device such as a motor shaft. The required measurement can be as simple as counting the total number of revolutions, counting the number of revolutions in a given time (i.e. RPM), counting both RPM and direction of rotation, or measuring the angle to which a shaft has been rotated. All of these measurements can be made with one or more TMR sensors.

Counting the total number of revolutions or measuring RPM can be accomplished simply by mounting a magnet on a rotating shaft, with a RedRock® digital sensor at an air gap distance where the rotating magnetic field will turn the sensor on for each revolution of the shaft, provided the sensor has a fast enough response time to keep up with the rotation speed. By adding a timing gate, RPM can be derived easily. However, this simple method cannot determine the direction of rotation. For that, two sensors are required, using a scheme called "quadrature detection".

First let's discuss the required sensor response frequency. Consider a shaft rotating 4 times per second. Clearly a 2Hz sensor (for example) won't be able to sample fast enough since it samples once every 0.5 seconds, and in that time the shaft has revolved twice. The sensor will falsely report a rotation speed of about 2 revolutions per second. The rule for determining the minimum sensor response time for a given rotation speed can be found from the Nyquist theorem [3], which states that in order to accurately sample a periodic signal (in this case the periodic fluctuations of a magnetic field), the signal must be sampled at no less than twice the highest frequency of the signal. So for our shaft rotating 4 times per second, the magnetic field must be sampled at least 8 times per second, and preferably somewhat faster than that. A 10Hz sensor would be ideal.

The other consideration in selecting a sensor for a rotation application is whether the direction of rotation must be known. Consider a gas meter, for example, that has a revolving vane with a magnet mounted on it, activating a magnetic sensor. If the vane is rotating one way, gas is flowing from a vendor to a customer who will be charged for the volume of gas represented by the number of revolutions of the meter. But what if the gas goes into reverse flow and the vane starts rotating backwards? Does the customer get a credit? To solve this apparent measurement anomaly, the direction of rotation can unambiguously be determined with a system called quadrature detection.

Two sensors are required for quadrature detection. The basic requirement for this method to work is that the sensors (let's call them A and B) must be mounted relative to a rotating magnet so that there are four sequential sensor pair states: A and B both OFF; A OFF, B ON; A and B both ON; A ON, B OFF; and back to A and B both OFF. One common way to achieve this is to use the layout shown in Figure 16. Two digital sensors are used, mounted orthogonally to each other. A diametrically polarized magnet is mounted on the end of a rotating shaft; the sinusoidal magnetic field variations from the magnet reaching each sensor position are shown at the top of Figure 17. The digital outputs from the two sensors as the magnet revolves, periodically turning

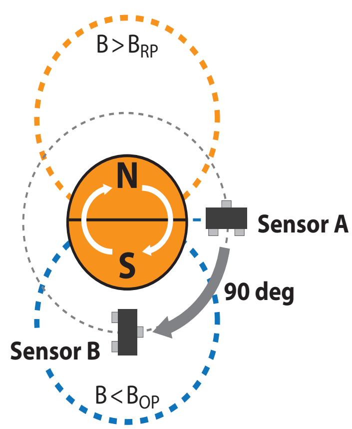

Figure 16: Typical arrangement for measuring rotational speed and direction

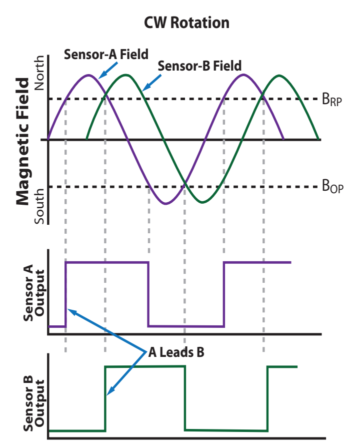

Figure 17: Rotational field profiles and corresponding sensor responses

each sensor ON and OFF, are also shown in Figure 17. In this case, clockwise rotation (viewed from the top) causes Sensor A to lead Sensor B. Conversely for anticlockwise rotation, Sensor A lags Sensor B (or put another way, Sensor B leads Sensor A.)

A simple logic circuit using a D-type flip flop, fed with the signals from Sensors A and B, can then determine both the direction of rotation and the rotation speed, as shown in Figure 18. Other more sophisticated methods may be appropriate to provide noise immunity and high speed sensing. They include the use of digital state machines such as FPGA's or PLD's, or the use of a high frequency oversampling clock that only confirms the state of Sensors A and B after multiple clock cycles agree. For further information, see **Speed and Direction Estimation in Rotating Systems**

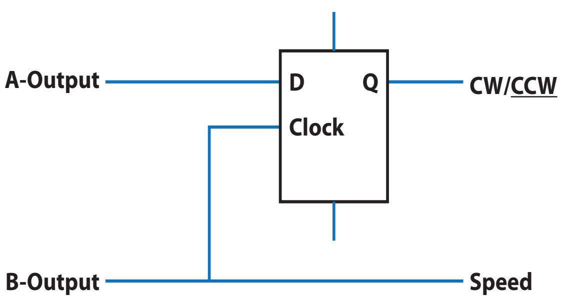

Figure 18: D-type flip flop circuit for detecting rotational speed and direction

3.5 Motor Control

Conventional DC motors get current into their rotating coils via brushes rubbing against a commutator. A commutator has two or more split copper rings electrically connected to coils on the rotor, which revolve inside a cage of external magnets. The commutator ensures that the current flowing through each of the rotor coils generates a field of the required polarity at the right rotation angle, so the coils get pushed at the right time to spin the motor.

Commutated DC motors such as those used in electric hand tools have a serious disadvantage; the carbon brushes wear down due to dirt, friction and sparking until the motor won't run any more. Worn out electric drills litter transfer stations worldwide, since few people know how to replace a $10 set of brushes.

Brushless DC (BLDC) motors (Figure 19) eliminate the mechanical unreliability of a commutator with an electronic solution. A BLDC motor is "inside-out" compared to a conventional DC motor. Magnets are mounted on the rotor, surrounded by a system of stationary coils. The magnetic field from the rotating magnets triggers magnetic sensors that activate electronic circuitry, which in turn, send current to each coil at just the right time to push the motor round with peak efficiency. The need to get current into rotating coils via an unreliable commutator/carbon brush system is eliminated, because the magnetic field rotates instead of the coils.

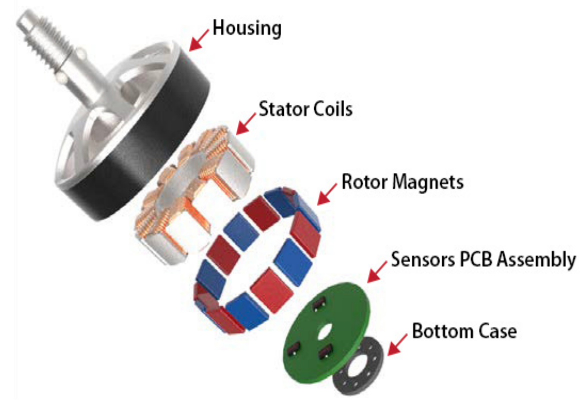

Figure 19: Typical BLDC motor structure. Rotor magnets may be outside or inside stator coils, depending on design.

The key to efficient BLDC motor control is the magnetic sensors. They must be small, since electric motors are shrinking at almost a Moore's law [4] pace. They must be low power, since many motor applications are battery operated. They must be sensitive, to allow the use of smaller magnets or larger air gaps. They must couple efficiently with the rotating field generated by the magnets. Finally, they must have uniform magnetic sensitivity and sampling frequency from part to part, to make sure the rotor magnets get the right kick from the stator coils at precisely the same time. Coto Technology's TMR sensors are a good match to these performance requirements compared to the Hall sensors commonly used in BLDC motors, since their high operate sensitivity allows the use of either smaller (and therefore less expensive) magnets, or larger airgaps. Furthermore, the axis of sensitivity of a RedRock® sensor is along its long axis compared to the Z-axis sensitivity of a Hall sensor (Figure 20), enabling efficient coupling to, and closer location of, the RedRock® sensor to the rotating magnets. This eliminates the need to rotate the sensor the way a Hall sensor needs to be rotated to point its sensitive Z axis at the magnets. For a more extensive discussion comparing RedRock® TMR sensors to Hall sensors, see **Evolution from Hall Effect to Tunneling Magnetoresistance (TMR).**

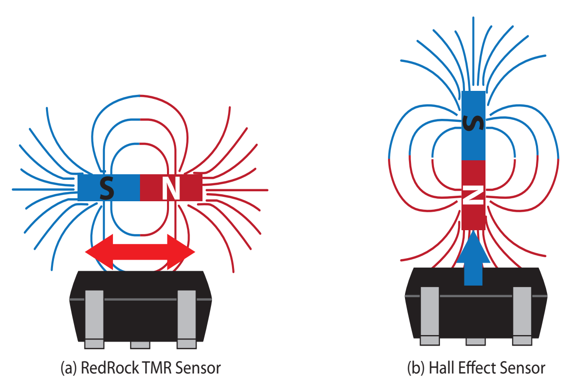

Figure 20: Magnetically sensitive axes of a RedRock® TMR sensor compared to a Hall sensor

3.6 Angle Sensing Applications

Angle sensing with discrete RedRock® TMR sensors can be shown in principle with two analog sensors mounted at right angles, and a diametrically polarized magnet, as shown in Figure 21. To obtain the graph shown in Figure 22, the voltages output by the two sensors were normalized to a range of -1 to +1, then their ratio at each angle was converted to an angle using the MS Excel ATAN2() function.

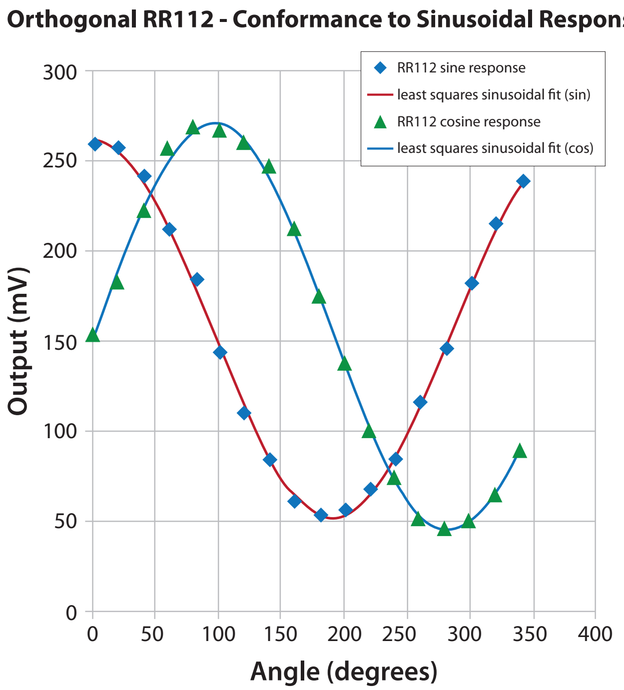

Figure 21: Outputs from two orthogonally mounted RR112 sensors in the field of a rotating diametrically polarized magnet

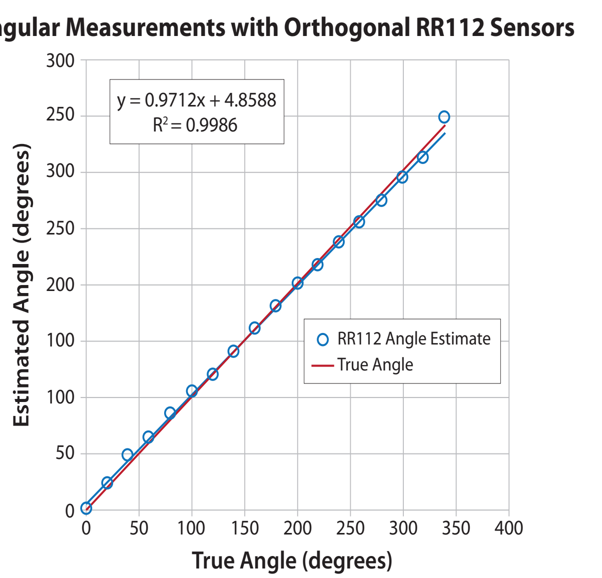

Figure 22: Estimated angle calculated using MS Excel ATAN2() function

3.7 Current sensing

The amplitude of the magnetic field at a specific distance from a long current-carrying conductor follows an inverse relationship. The field can be determined by the following equation:

$$B = \frac{(\mu o * \mu r * I)}{(2\pi * R)}$$

Where:

- ***B*** is the amplitude of the magnetic field in Tesla
- ***I*** is the amplitude of the current in Amperes
- ***μo*** is the magnetic permeability of free space in H/m ($4\pi \times 10^{-7}$ H.m^{-1})
- ***μr*** is the relative permeability of the surrounding material (1 for air)
- ***R*** is the radius (or distance) from the center of the conductor in meters

This formula shows that the magnetic field from a long current-carrying conductor is inversely proportional to the distance from its center. The field gets weaker as the distance from the conductor increases. (Deviations from this rule occur at high frequencies where skin effects force current to the conductor's surface.) Figure 23 shows the field strength vs. distance for a conductor carrying 10A. Figure 24 shows the direction of the magnetic field lines surrounding the conductor. A RedRock® analog sensor (shown in black outline on a green PCB) is well suited to detect the magnetic field since its sensitive axis couples efficiently with the direction of the magnetic field lines, and it can be mounted close to the conductor to obtain the maximum possible sensitivity. In contrast, a sensor with its sensitive axis through the short axis of the part would be much more difficult to mount close to the conductor.

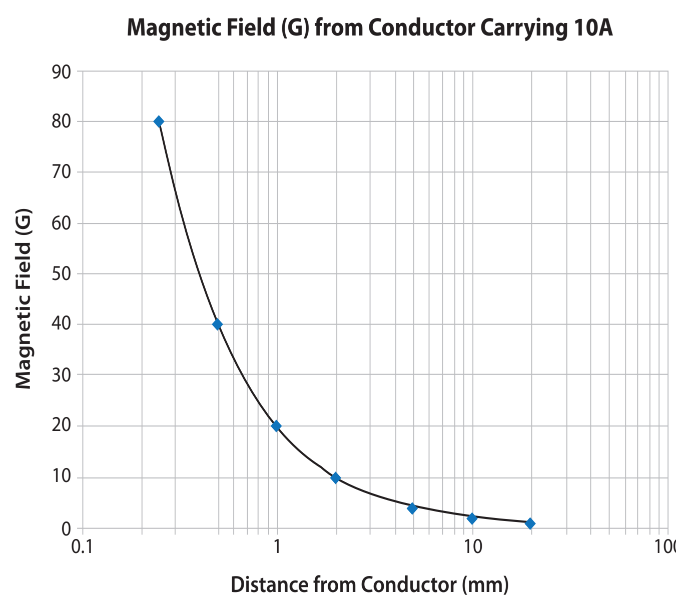

Figure 23: Magnetic field from a conductor carrying 10A

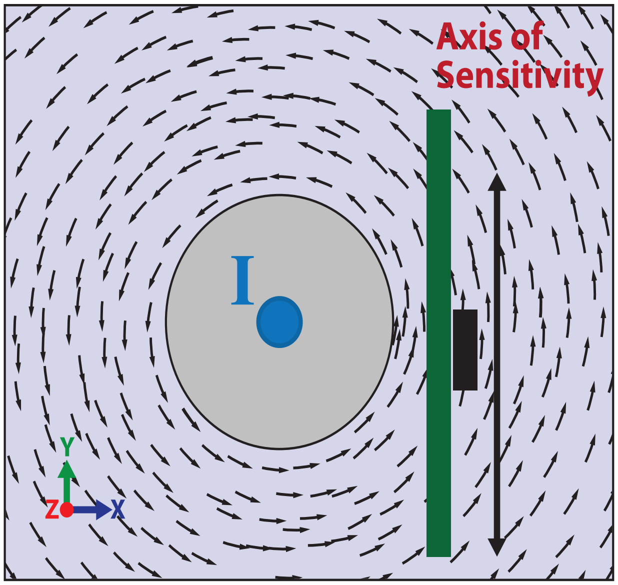

Figure 24: Orientation of an analog RedRock® sensor relative to a current carrying conductor.

4 Miscellaneous Technical Notes

4.1 Undervoltage Lockout Protection (UVLO)

RedRock® sensors have a voltage at which they stop operating, called the undervoltage lockout (UVLO) threshold. This feature is particularly important for battery-powered devices that need to turn off gracefully when the battery is nearing depletion. UVLO thresholds are listed in the data sheets for each sensor type. UVLO for a falling V_{DD} supply is typically about 50mV lower than UVLO for a rising value of V_{DD}. This hysteretic behavior is designed into the part to prevent "bouncing" if V_{DD} is close the UVLO threshold. However if the power supply impedance is relatively high, when V_{DD} is restored to the rising UVLO threshold, the start-up current surge from the sensor may pull the supply back down below the UVLO falling threshold, causing the sensor to go into stop-start oscillation. The solution for this problem is either to supply a stiffer, lower impedance power supply or to use a higher capacitance decoupling capacitor between V_{DD} and ground, placing the capacitor as close as possible to the sensor. The capacitor acts as a charge reservoir, buffering the current demand from the sensor as it starts up.

4.2 Decoupling Capacitor Guidelines

Using a bypass capacitor between V_{DD} and ground is important for the reason first discussed in 4.1

To be effective in preventing start-up oscillation, the capacitance should be no less than 1µF, placed as close as possible to the sensor, and certainly no farther away than 10mm. The capacitor supplies energy to prevent V_{DD} from drooping during the few microsounds when the sensor starts up. If oscillation does occur during the development of an application, the circuit shown in Figure 25 can be used to investigate the amplitude and width of the start-up current pulse. The current generates a corresponding voltage across a 10Ω sense resistor, which is recorded by an oscilloscope vs. time. The area under the peak can be estimated from the scope plot in amp·seconds, and converted to Joules by multiplying by the supply voltage. The stored energy a charged capacitor is:

$$J = 0.5C \cdot V^2$$

Where J = stored energy in volt-amp-seconds, C = capacitance (in Farads) and V = voltage

Solving for C then gives the required capacitance to store the charge in the start-up peak, and is a good indicator of the minimum capacitance needed. Multiplying the capacitance by a safety factor of two would add a safety margin.

It is also good practice to place a higher value capacitor such as a 100µF tantalum further back from the sensor for low-frequency smoothing; this capacitor may serve several sensors depending on the circuit design. But in all cases, a non-polarized ceramic decoupling capacitor should be placed as close as possible to each sensor.

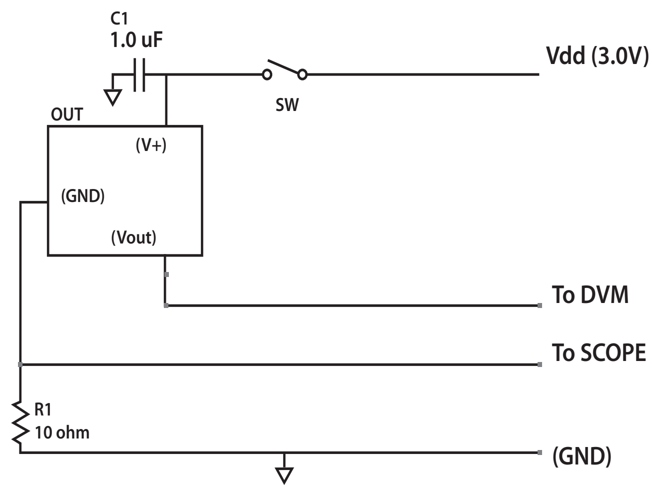

Figure 25: Circuit for measuring sensor start-up pulse energy

4.3 Troubleshooting (or Avoiding Trouble)

Here are three factors that can cause problems when using RedRock® sensors

4.3.1 Missing Decoupling Capacitor, or Capacitor Value Too Low.

This is by far the most common problem reported by RedRock® sensor users. A user contacts Coto Tech Support, noting that their sensors are oscillating or drawing heavy current. In almost all cases, we find that the wrong decoupling capacitor has been used, or it is missing. It is mandatory to place a decoupling capacitor with no less than 1µF capacity as close as possible to the sensor. The preferred maximum distance is 10mm. The capacitor will fix the problem.

4.3.2 Damage Due to High Magnetic Fields.

If a RedRock® sensor is exposed to a magnetic field greater in magnitude than the fields used to set the TMR sensor layers during manufacture, then transient or even permanent changes in magnetic sensitivity can occur. The problem is exacerbated at high temperatures. Coto recommends that RedRock® sensors should not be exposed to magnetic fields greater than +/- 2000 Gauss. (Please consult product data sheets.)

4.3.3 Magnetic Sensitivity Too Low

A user sometimes reports that the magnetic sensitivity of a part is lower than what is reported in the data sheet. This occasionally happens with users migrating from Hall sensors (q.v.) to RedRock® TMR sensors. Our engineers frequently find that the magnet is not oriented correctly relative to the sensor, resulting in apparent low sensitivity. Hall sensors are sensitive to magnetic fields perpendicular to the Hall sensor plate (the Z-axis), but RedRock® sensors are sensitive through their plane. The solution is to rotate the RedRock® sensor or the magnet appropriately to ensure the magnetic field lines pass through the plane of the sensor.

4.3.4 Damage Due to Electrostatic Discharge (ESD)

RedRock® sensors withstand up to +/- 4000V, verified by the JESD22-A114 HBM (Human Body Model) test [5]. For RR sensors used in medical devices, there is a possibility that during electron beam (E-Beam) sterilization, surface charges could build up that exceed 4000V. No user has ever reported problems with RedRock® sensors during E-Beam sterilization, but if you plan to use this method of sterilization, you should contact Coto Technology first. (redrock@cotorelay.com)

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RedRock® TMR Magnetic Sensors by Coto Technology

Offering **ultra-low power consumption, high sensitivity, miniature package size and short lead times,** Coto's RedRock® series of analog and digital TMR magnetic sensors are ideally suited to the demands of next generation security, metering, medical, automotive, instrumentation, and industrial markets. Target applications include fluid level detection, open-close detection, proximity sensing, rotary sensing and any application where the device or product needs to wake up, turn on and perform – thus providing a true "out-of-the-box" experience.

A handy RedRock® TMR magnetic sensor Selector Guide can be downloaded from Coto's Website. In addition to providing the primary specifications for each sensor type, the guide provides valuable reference and application information.

Coto's website also provides an extensive Resource Library with Application Notes, Videos and Product Datasheets. Content is growing, so check back often. Here are just a few App Notes you might like:

- How to Pair a Magnetic Sensor with the Right Magnet for a Cost-Effective Solution
- Magnetic Sensing for Open and Anti-Tamper Detection
- Improving Metering Performance with TMR
- Powering ON Your Battery-Operated Medical or IoT Device
- Magnetic Sensors in IoT Devices
- Overcoming Battery Life Anxiety with Active Magnetic Sensors

Coto's Application Engineers are readily available to answer questions specific to your device design.

Contact us today for Applications Support. | Samples are available.