Benefits
From Using Output Diagnostics
Of Rotary Position Sensors
For Your Application
Part I

More Applications Can Benefit By Using Better Control Inputs

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Benefits From Rotary Sensors' Analog Output Diagnostics

Overview

Non-contact rotary position sensors with independent magnet markers have great advantages over their shafted cousins. Mechanical wear, the necessity to seal moving shafts or use additional shaft couplings are eliminated. Reduced cost at higher reliability levels is often a benefit of non-contacting sensors over mechanically-linked sensors.

Diagnostic technology that is integrated into some non-contacting rotary sensors can provide even more benefits to users. These benefits include signaling operational status, confirming in-range operation as well as safety-based functioning of the sensor.

Non-Contact rotary sensors have the additional user's design task of properly choosing and aligning the magnetic marker with the sensor for best possible function. Some manufacturers like Novotechnik provide the information to make that task readily doable. It is important to keep in mind that magnetic rotary position sensors, in general, need to maintain specified limits to magnet position relative to the sensor for the part to realize its specifications.

Novotechnik supports their customers by providing all information about magnet mounting options (see the Sensor Tip article in our newsletter Mechatronics Sense volume 4, issue 2.)

An electronic function can be turned on that will monitor and signal if the magnet is 'lost' as well as validate other functionality of the sensor.

Novotechnik rotary position sensor with magnetic marker

While other magnetic rotary sensors may have part or all of the functionality described in this white paper, it is necessary to use a specific part to explain the details in a clear manner.

The Novotechnik RFC 4850 Series is available with a sensor diagnostics feature. It can be ordered with diagnostics turned on or off. Users can benefit from knowing what this feature does and how it can make their product more reliable.

This white paper describes what functions diagnostics perform and offers recommendations on when and how to use them.

One of the main considerations of a sensor diagnostics system is safety. Design engineers, system integrators and other technical users can best determine whether the rotary sensor will need diagnostics or not for their application. In cases where a sensor will be used in a safety relevant function, sensor diagnostics are definitely required. Some of the relevant standard for reference is ISO 13849.

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In cases where these safety standards are not relevant, the diagnostics still can be very useful. A user might want to be able to detect broken sensor wires and the 'loss' of the magnet marker.

Analog Output Options with Diagnostics

There are four analog output options of Novotechnik's RFC48 Series that are available with diagnostics:

- Ratiometric voltage output 0.5 to 4.5 V or 0.25 to 4.75 V output. (Ratiometric in this context means that small variations on the supply voltage side will change the output voltage proportionally.)
- Industrial standard voltage output: Absolute output 0.1 to 10 V (independent of specified variations of supply voltage)
- Mobile standard voltage output: Absolute output 0.5 to 4.5 V or 0.25 to 4.75 V (independent of specified variations of supply voltage)
- Current output 4 to 20mA (independent of specified variations of supply voltage)

The diagnostic functions available for these output options are the same, however the diagnostics "watchdog" output types differ. Here's the explanation. Ratiometric versions of the RFC4850 Series use defined percentages of the supply voltage as diagnostic levels. The absolute outputs use defined voltages and the current outputs reference specific current levels.

Sensor With Diagnostics Turned Off

The RFC4850 Series sensor – without diagnostics turned on - will work well outside the defined distance range of the magnetic marker under normal conditions, e.g. in the lab. In fact, the sensor might work in distances as far as twice the recommended distance and one may wonder, "why is this not specified?"

The reason is that the ranges are limited in order to secure long-term stability and to withstand extreme temperatures, while working flawlessly. Shaft bearing tolerances on the customers' machine may increase mechanical play, further reducing the magnetic field strength as the magnet distance increases. Angular precision, signal stability and low noise levels can only be guaranteed when the magnet is within the range specified in a product's data sheet.

Sensor With Diagnostics Turned On

All four analog output versions of the RFC48 Series have a clearly defined operating output range that does not reach down to a zero output level. Output levels during operation within the defined range state that everything is working fine. A part of this range below the minimum output is defined as the Diagnostics Range. If the sensor system detects an error the output signal will switch immediately into this range:

- Ratiometric voltage output: below 2% of supply voltage
- Absolute voltage output industrial standard CE: below 50mV
- Absolute voltage output mobile electronics standard: below 100mV
- Absolute current output: below 3.5mA

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Diagnostics Triggers

Extremely rare internal sensor chip errors due to malfunction of components of the circuitry can activate the diagnostics as well as a weak magnet.

The Hall-effect sensor system designed into the RFC 48 series functions solely on the orientation of the magnetic field of the magnetic marker mounted to the user´s rotary application. This way, the specified function is guaranteed within a wide range of the magnetic field strength which the permanent magnetic marker transmits to the sensor.

For ease of mechanical integration, the Novotechnik magnetic markers come with a defined distance range instead of hard-to-measure magnetic field strength specifications.

There is a chart showing the recommended distance range for each of the standard magnets available for the RFC 48 series. Smaller magnet markers usually work in smaller distance ranges than larger magnets.

Activated diagnostics limit the sensor in order to work within the specified magnetic field range and a bit beyond. If the magnetic field is too low or too high, the output drops into the previously described diagnostics range. The diagnostics range is a bit larger than the specified distance range to compensate for possible tolerances. Therefore, the diagnostics cannot be used for distance adjustments between marker and sensor. The distance should be adjusted using shims or gauges. The diagnostics cannot detect off-center misalignment of the position marker, therefore correct alignment is key.

Working distances (mm)

Series	Interface	Z-RFC-___ P30	P03	P04 / P23 / P31 / P20	P02 / P08	P41 / P47	P43	P22	P18	P19
RFC-4801/4802 4853/4854 4861/4862	analog single SPI	0 ... 1.5		0 ... 4		0 ... 2.7		-	0 ... 4.5	0 ... 2.2
RFC-4801/4802 4853/4854 4861/4862	analog redundant	0 ... 1.5		0 ... 4		0 ... 2.3		-	0 ... 4	0 ... 1.7
RFC-4801/4802	SSI / Incremental	-		0 ... 1.4		-		-	-	-
RFC-4851/4852	analog single CAN single IO-Link single	0.7 ... 2.2		2.3 ... 5		0 ... 2.7		4.4 ... 9.2	0 ... 4.5	0 ... 2.2
RFC-4851/4852	analog redundant CAN redundant	0.3 ... 1.8		1.9 ... 4.5		0 ... 2.3		4.8 ... 8.8	0 ... 4	0 ... 1.7
RFC-4863/4864	analog single	0.7 ... 2.2		2.3 ... 5		0 ... 2.7		-	0 ... 4	0 ... 2.2
RFC-4863/4864	analog redundant	0.3 ... 1.8		1.9 ... 4.5		0 ... 2.3		-	0 ... 3.5	0 ... 1.7
RFD-4021/4031	analog single	1.2 ... 2.7	1 ... 3	2.8 ... 6.2	-	-	0.9 ... 3.4	6.1 ... 10.9	0 ... 5	0 ... 2.8
RFD-4021/4031	analog redundant	0.7 ... 2.3	0.6 ... 2.6	2.8 ... 6.2	-	-	0.5 ... 2.9	5.6 ... 10.4	0 ... 4.5	0 ... 2.3
RFX-6901	analog single / redundant CAN redundant	-	-	0.3 ... 3.5		-		2.6 ... 7.3	0 ... 2.5	-
RFX-6901	CAN single	-	-	0.8 ... 4		-		2.9 ... 7.7	0 ... 3	-
RFE-3201	analog single CAN single	0.4 ... 1.9	-	2 ... 4.7	-	-	0 ... 2.4	4.1 ... 8.9	0 ... 4	0 ... 1.8
RFE-3201	analog redundant CAN redundant	0.5 ... 1.5	-	1.6 ... 4.2	-	-	0 ... 2	3.6 ... 8.4	0 ... 3.5	0 ... 1.3

Magnet/Sensor Working Distances (mm)

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Additional Linearity Error (°) From Radial Displacement (mm)

Series	Interface	Z-RFC-P02 / P04 / P08 / P20 / P23 / P31			Z-RFC-P41 / P43 / P47			Z-RFC-P03 / P30			Z-RFC-P18			Z-RFC-P19			Z-RFC-P22		
		0.5 mm	1 mm	2 mm	0.5 mm	1 mm	2 mm	0.5 mm	1 mm	2 mm	0.5 mm	1 mm	2 mm	0.5 mm	1 mm	2 mm	1 mm	2 mm	4 mm
RFC-48 _ _ RFD-4021 RFE-3201 RFX-6901	analog single* SPI CANopen single IO-Link single	0.4	1.1	3.5	0.4	1.1	3.5	1.4	3.7	-	0.7	1.3	3.3	1.3	2.6	-	0.8	1.8	5.4
RFC-48 _ _ RFD-4021 RFE-3201 RFX-6901	analog redundant* CANopen redundant	0.7	1.8	5.2	0.7	1.8	5.2	2.5	6.4	-	1.1	2	4.6	2.3	4.5	-	1.1	2.4	6.7
RFX-6901	analog single analog redundant	0.7	1.8	5.2	0.7	1.8	5.2	-	-	-	1.1	2	4.6	-	-	-	1.1	2.4	6.7
RFC-48 _ _	SSI Incremental	0.4	0.7	2.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

*) exept RFX

The magnet markers are well protected against loss of magnetic field strength. Should for whatever reason the distance in the application change or external forces like rocks or gravel destroy the sensor magnet completely, the sensor output will jump to the diagnostics level. Likewise, if the screws of either sensor or magnet marker were not tightened correctly causing the sensor to fall off, the diagnostic level output will be triggered.

When to Use the Diagnostics

The diagnostics are useful if the user wants to add another level of safety during integration of the sensor in an actuator closed loop application or in a simple angle display function. The diagnostics definitely help to increase the machine system's safety in cases where the jump of the output signal into the diagnostics range is handled by the system to stop the macine or transition into a safe mode.

Many applications require only the information that one or more wires are broken or that the signal is lost completely and therefore simply being out of the defined range provides enough information to let the control system switch the machine into a safe mode.

When Not To Use the Diagnostics

Applications where it is better and acceptable to work with a signal that might be slightly deteriorated, might not require diagnostics. This is especially the case when the complete loss of signal would have a more negative impact.

Adding Redundancy To the Diagnostics

Many Novotechnik sensors are also available as fully redundant position sensor systems. These can be programmed with custom output characteristics, e.g. different angles, different output gradients and orientation and also with diagnostics individually turned on or off. The available options can provide common-mode error detection on the control system side.

Digital SSI, IO-link, J1939 and CANopen versions of these sensors are also available with diagnostics, some even with a wider array of options. We will discuss these versions in a separate *Output Diagnostics Part II* white paper.

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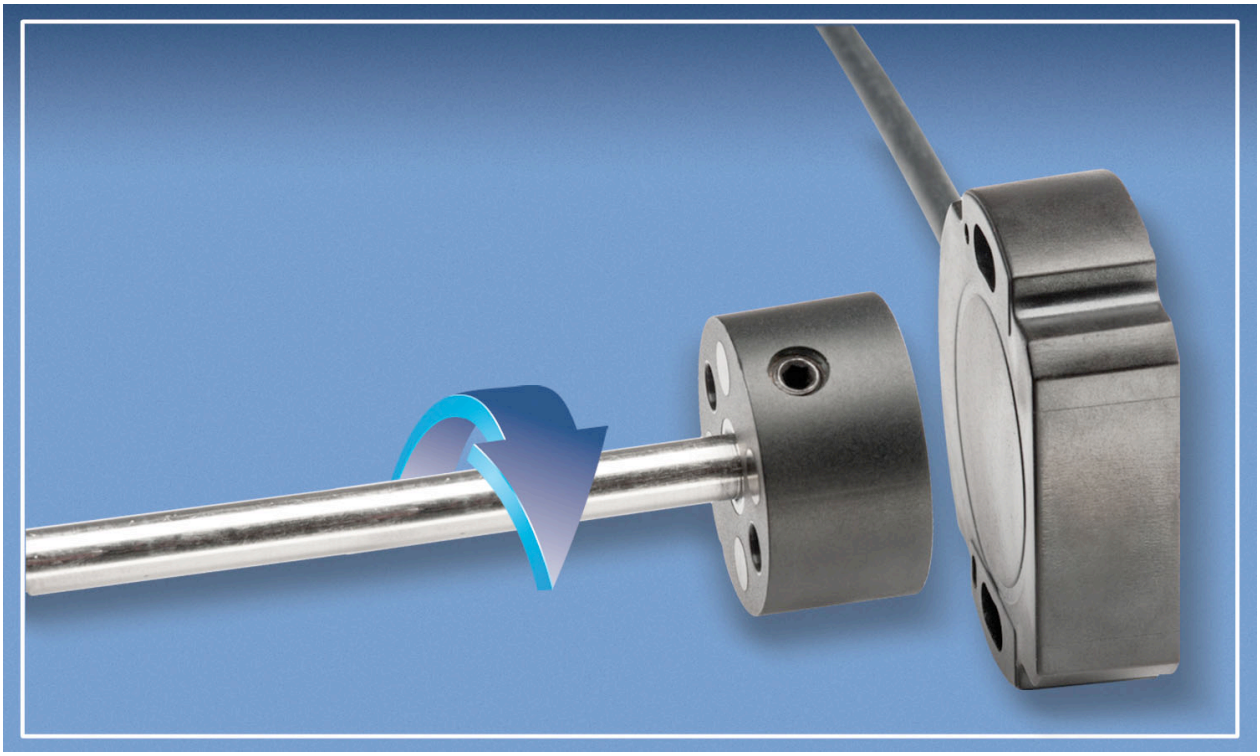
Conclusion

By selecting a magnetic rotary position sensor with diagnostics capability, users can add features to the machine they are designing. These features can have substantial benefits to your customers including sensor operation status as well as safety or smooth limp-home modes should a wire break, an application's rotating part goes out of alignment or gap-spacing is altered, or the sensor fails.

Manufacturers with tables and guidelines can make selecting and applying the optimum magnet and sensor for a particular application a relatively easy task.

With safety related applications or functional safety applications it is always advisable to follow the instruction manuals and to contact the manufacturer's application engineers for further information.

Lear more about the RFC 4800 Series angle sensors at www.novotechnik.com.



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