Application Note 01 - The Electric Encoder™

DF Product Lines - Angular Position Sensors

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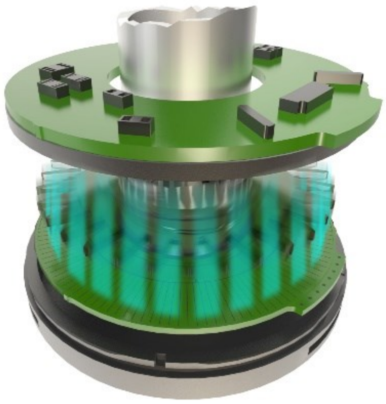
Netzer Precision Motion Sensors Ltd.
Misgav Industrial Park, P.O. Box 1359
D.N. Misgav, 20179
Israel
Tel: +972 4 999 0420
Fax: +972 4 999 0432
www.netzerprecision.com
global-info@netzerprecision.com



1. The Electric Encoder™ | A Perspective

The patented, leading edge **Electric Encoder™** technology provides a mix of performance features unmatched by any competing technology, optical, magnetic, or otherwise. The rotary **Electric Encoder™** implements using either one of two topologies: "**3-plate**" and "**2-plate**," both include a space/time modulated electric field inside a shielded space. The total field integrates and converts into a signal current, processed by on-board electronics to provide DC output signals proportional to the sine and cosine of the rotation angle. In the 3-plate topology (**Figure 1.a**), a dielectric rotor's rotation angle influences the field between stationary transmitter and receiver plates. In the 2-plate topology (**Figure 1.b**), the field confines between a stationary transmitter/receiver plate and a conductively patterned rotor.

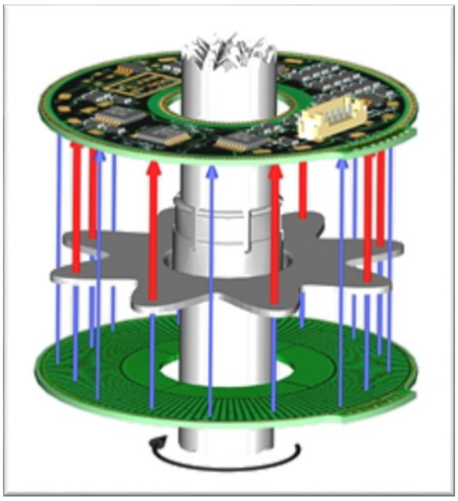


Figure 1a.

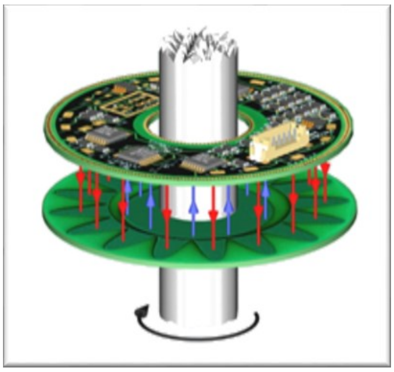


Figure 1b.

The **Electric Encoder™** has two operation modes selectable by a logic level command; the **coarse** mode has **M** sine/cosine periods/revolution, and generates a corresponding number of electrical-cycle/revolution (EC/R). On system startup—in combination with fine-mode data—this mode is accurate enough to help identify the initial absolute position. The **fine channel** has **N** EC/Rs and provides the accuracy and resolution of the computed absolute angle data. **M** typically ranges from one to seven and **N** from 16 to 128, depending on the specific design. To provide an unambiguous reading over 360˚ mechanical degrees (i.e., each angular position has a unique pair of **fine** and **coarse** electrical angles), **M** and **N** have no common denominator. In practice, the coarse mode is needed only on system startup, after which the encoder is permanently switched to fine mode. Signal conditioning is based on digitizing and processing the output analog signals.

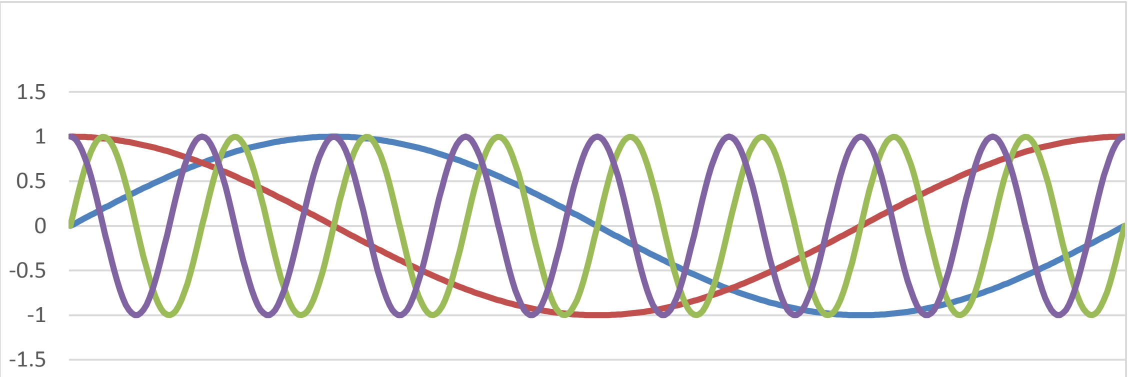


Figure 2.

Figure 2 illustrates the output signals of an **Electric Encoder™** with **M**=1 and **N**=8, as a function of the rotation angle. Compared with an optical sin/cos encoder, the **Electric Encoder™** generates much fewer EC/Rs; however, the sine/cosine output signals are near perfect, resulting in high accuracy and resolution. Other advantages of the **Electric Encoder™**:

- Hollow, floating shaft (no bearings)
- Very low power consumption
- Immunity to magnetic and electric interference
- Low profile
- High mechanical durability
- High tolerance to mechanical installation errors
- Wide temperature operation range
- Simple mechanical and electrical interface

2. The "Holistic" Rotor

The many **Electric Encoder™** advantages result from its holistic rotor - see **Figure 3**. Unlike other encoders, the whole area of the **Electric Encoder™** rotor participates in signal generation, i.e., multiple spatial periods integrate; this results in two powerful mechanisms.

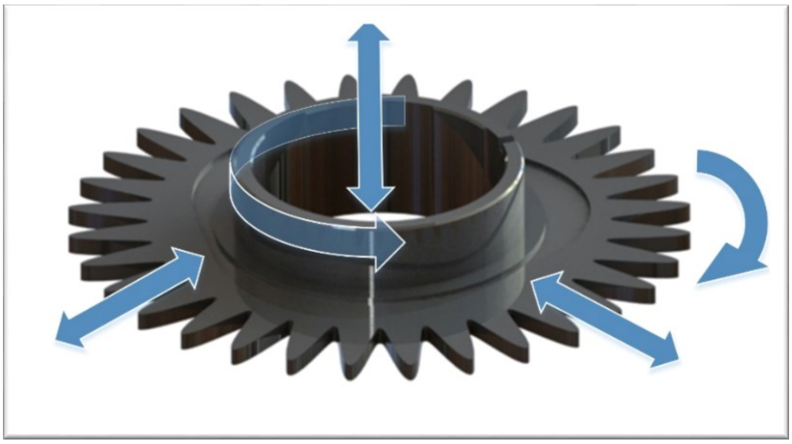


Figure 3.

2.1. **Geometrical compensation** - each two opposing regions of the encoder react oppositely to tilt, and the **Electric Encoder™** rotor plane translation—shown by white arrows—is also insensitive to axial motion—shown by the red arrow. Thus, it approaches the “ideal” in being sensitive only to rotation, closer than any other encoder is. One practical outcome is that unlike optical encoders with comparable accuracy, no internal ball bearings are necessary, and the rotor can directly mount on the host shaft without flexible shaft coupling or soft stator mounting. This unique floating, hollow shaft results in the lowest possible axial space requirements but also enhances reliability by eliminating the major long-term degradation mechanism. **Figure 4** illustrates the significantly fewer errors induced by rotor eccentricity of the **Electric Encoder™** compared with an optical encoder of the same diameter.

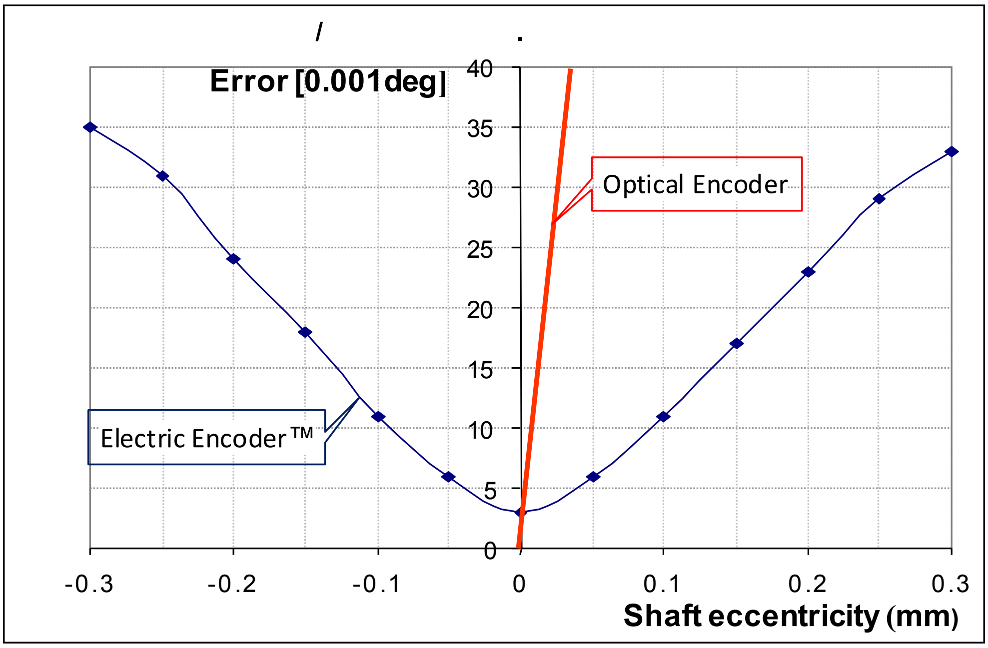


Figure 4.

2.2. **Averaging** - the output signals are the integrated sum of multiple periods, any effect due to geometrical errors, temperature variations, contamination, etc., tends to average out, in proportion to the number of poles.

2.3. **Common signal processing chain** - the rotation induced signals are processed in an analog channel—shown as a block diagram in **Figure 5** where most of the blocks are common to the sine and the cosine signals—then separated by unity-gain demodulators and filtered by unity-gain low-pass filters. Therefore, the two output amplitudes tightly match, irrespective of component tolerances or temperature influence. In addition, since the processed signals are AC, offset voltages are nearly eliminated.

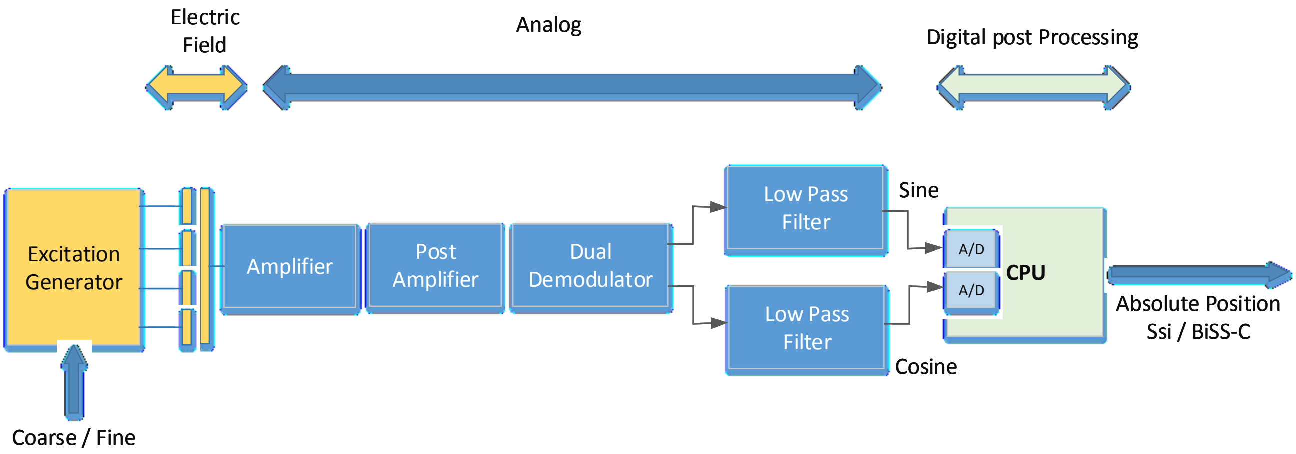


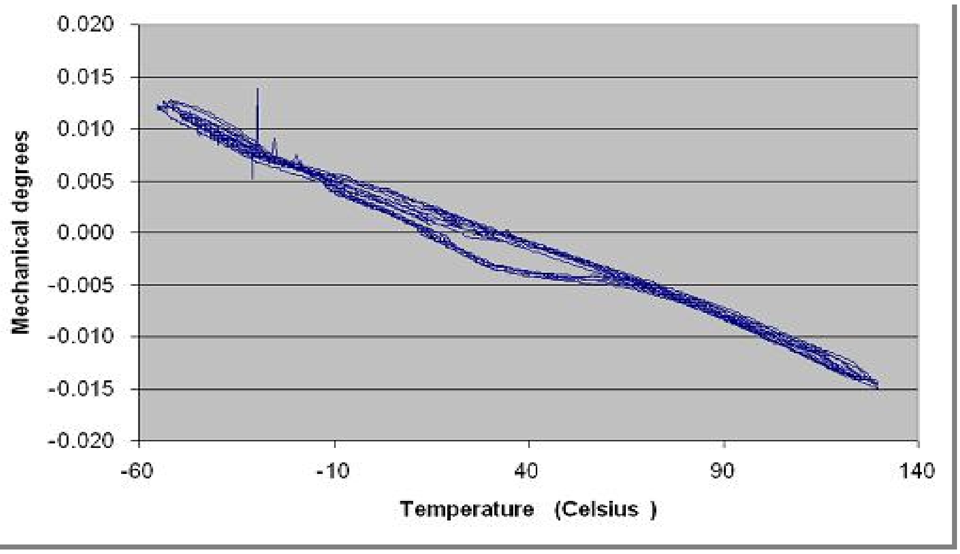
Figure 5.

3. Environmental Compatibility

Unique feature of the **Electric Encoder™** is the low frequency range (typically under 1 kHz) of the output signals. This is due to the low number of EC/Rs, and enables the signals to be carried over long distances, even in noisy environments, since coupled interferences such as PWM are, in most cases, of much higher frequencies and can be easily filtered out prior to digitization.

The **Electric Encoder™** is unusually immune to contaminants and moisture conditions and has proven to perform not only immersed in oil but even in humid and condensing conditions. This immunity is especially noticeable in the **3-plate** topology that, in addition to having a holistic rotor, has a three dimensional construction largely uninfluenced by foreign material deposit.

Because of its robust construction, the **Electric Encoder™** not only survives extreme shock and vibration, it also performs under harsh conditions. The temperature stability of the output signals results from its construction materials, the holistic rotor, and the unique signal conditioning, as described above. The encoder can be designed to operate from cryogenic temperature up to 125˚C and above. **Figure 7** illustrates a typical plot of the readout angle of a premium DS-58 encoder cycled over temperature.



4. Resolver Comparison

The output signals of the **Electric Encoder™** are proportional to the sine/cosine of the rotation angle, i.e., they are DC signals at any fixed angle and are sinusoidal only at constant rotation speeds. This is in contrast to the resolver, where the signals are modulated on an AC carrier whose frequency is limited by the inductance to typically 10 kHz; the effective servo bandwidth is usually further limited by the resolver-to-digital converter (R/DC). The excitation frequency of the **Electric Encoder™** is nearly unlimited, which results in potentially unlimited servo bandwidth - 1 kHz in the standard products, and much higher in customized versions. **Table 1**. compares the two technologies.

	Parameter	**Resolver**	**Electric Encoder™**
1	Operating temp. range	-55˚ to +150˚	-55˚ to +125˚
2	Weight/Diameter	Larger	Smaller
3	Profile	Larger	Smaller
4	Rotor	Active	Passive
5	Electrically floating rotor	Adds axial length	Inherent
6	Sensitivity to magnetic field	Only if shielded	Inherently insensitive
7	Power consumption	Several watts	Typically 30mW
8	Mounting tolerance	Relatively tight	Relatively loose
9	Power supply	AC	DC
10	Cost/performance	Higher	Lower
11	Accuracy/diameter	Lower	Higher
12	Servo bandwidth	Medium	High
13	Absolute position output	Yes	Yes
14	Number of wires	6	6
15	Redundancy option	Yes	Yes

Table 1. Resolver/Electric Encoder™ Comparison