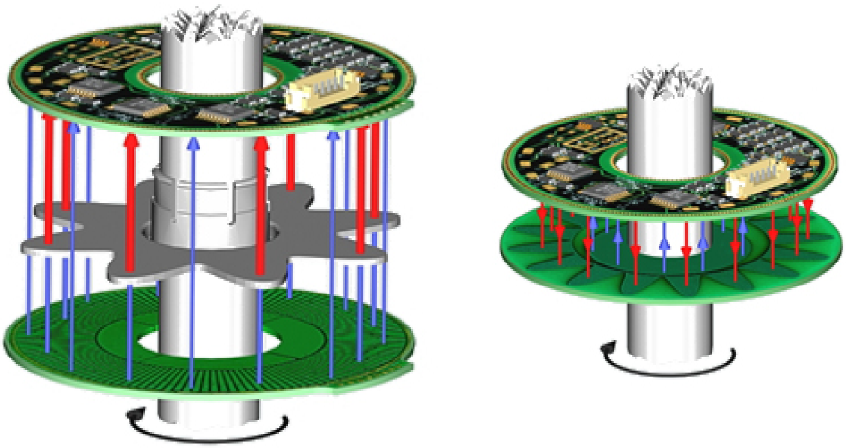
Application Note 01 - The Electric Encoder™

Electric Encoder™ - Angular Position Sensors

1. The Electric Encoder™ - a perspective

The patented, state of art, **Electric Encoder™** technology provides a mix of performance features unmatched by any competing technology, optical, magnetic or otherwise. The rotary **Electric Encoder™** is implemented using either of two topologies: "**3-plate**" and "**2-plate**", both include a space/time modulated electric field inside a shielded space. The total field is integrated and converted into a signal current which is processed by on board electronics to provide DC output signals proportional to the sine and cosine of the rotation angle (space qualified versions) or different formats of digital interfaces. In the 3-plate topology, shown in **Figure 1-a** a dielectric rotor whose rotation angle influences the field between stationary transmitter and receiver plates. In the 2-plate topology, shown in **Figure 1-b**, the field is confined between a stationary transmitter/receiver plate and a conductively patterned rotor.

Figure – 1 (a) (b)



The **Electric Encoder™** has two measurement channels selectable by a logic level command; The **Coarse** channel has **M** sine/cosine periods/revolution, and generates a corresponding number of Electrical-Cycle/Revolution (EC/R). This mode is accurate enough to help identify, upon system power-up, in combination with the Fine-mode data, the initial absolute position. The **Fine channel** has **N** EC/Rs and provides the accuracy and resolution of the readout angle. M typically ranges from one to 7 and **N** from 16 to 128 - depending on the specific design. In order for each position to have a unique combination of coarse and fine readings, **M** and **N** have no common denominator. In practice the coarse channel is needed only upon system turn on, after which the encoder is permanently switched to the Fine mode. Signal conditioning of the analog versions is based on digitizing and processing the output signals using factory supplied code and provides high-accuracy absolute position information.

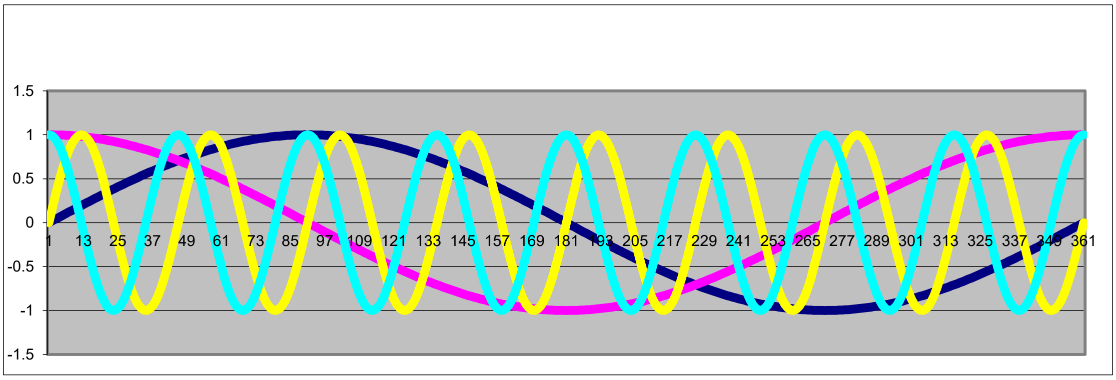


Figure -2

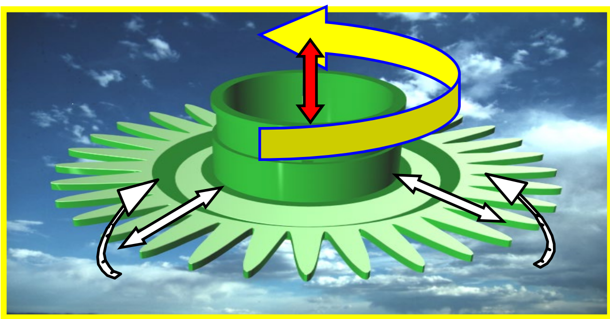
Figure 2 illustrates the output signals an **Electric Encoder™** with **M**=1 and **N**=16, as a function of the rotation angle. Compared to an optical Sin/Cos encoder the **Electric Encoder™** generates much less EC/Rs, however, the Sine/Cosine output signals are near-perfect, resulting in high accuracy and resolution. Other advantages of the **Electric Encoder™** are:

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

2. The “Holistic” rotor

Many of the advantages of the **Electric Encoder™** result from its “holistic” rotor - see **Figure 3**. Unlike in other encoders, the whole area of the **Electric Encoder™** rotor participates in signal generation, i.e., multiple spatial periods are integrated. This results in two powerful mechanisms:

Figure 3



1. Geometrical compensation - each two opposing regions of the encoder react oppositely to both tilt and translation of the rotor plane – shown by white arrows, the **Electric Encoder™** is also tolerant to axial mounting –shown by the red arrow; it thus approaches the “ideal” closer than any other encoder by essentially being sensitive to rotation only. One practical outcome is that, unlike optical encoders with comparable accuracy, no internal ball bearings are needed and the rotor can be directly mounted on the host shaft without flexible shaft coupling or soft stator mounting. This unique floating hollow shaft results in very low profile and enhanced reliability by eliminating the major long-term degradation mechanism. **Figure 4** illustrates the significantly lower error typically induced by rotor eccentricity of the **Electric Encoder™** compared to an optical encoder of the same diameter.

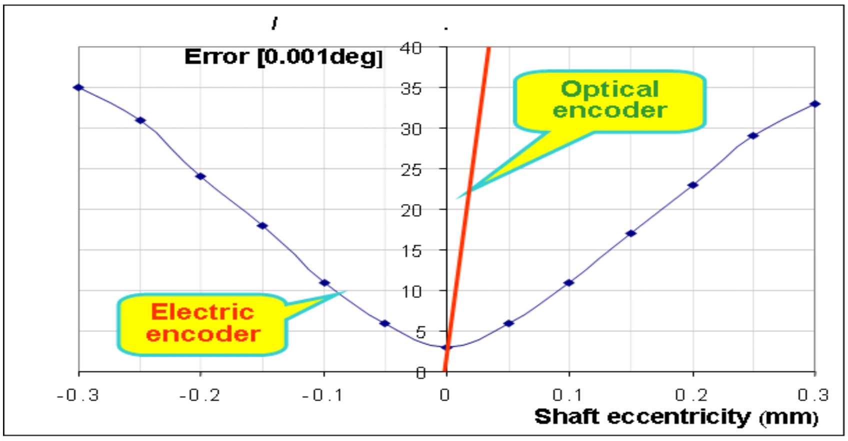


Figure 4

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 periods/revolution.

In addition, a common signal processing chain handles the rotation-induces Sine/Cosine signals – shown schematically for the analog version in **Figure 5**. Sine and the Cosine signal components are separated by unity gain demodulators and filtered by unity gain low pass filters. The two output amplitudes are therefore tightly matched, irrespective of component tolerances, or temperature influence. In addition, since the processed signals are AC, offset voltages are nearly eliminated.

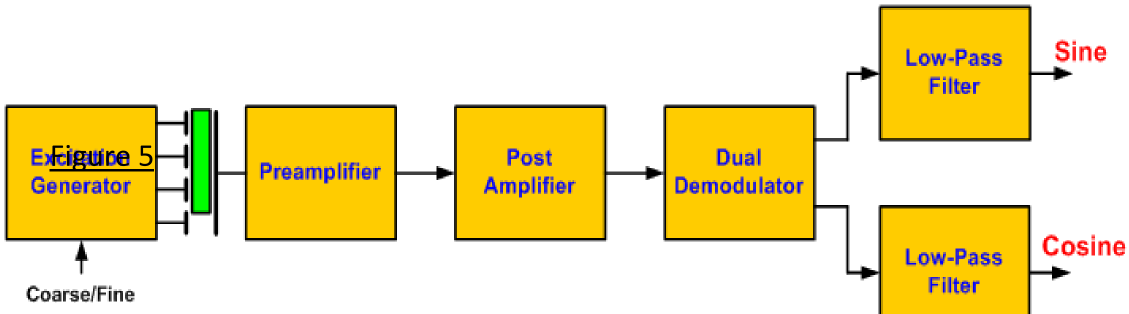


Figure 5

3. Environmental compatibility

Figure 6 illustrates (in red) the built-in electrostatic shield of the **Electric Encoder™**, the shield comprises ground layers and can be grounded by conductive labyrinth which allows mechanical attachment to the rotor while blocking potential parasitic coupling from the host shaft. The physics of the **Electric Encoder™** provides inherent insensitivity to magnetic fields; therefore, no magnetic shield is required, even when mounted inside electric motors. The **Electric Encoder™** also has virtually no magnetic signature; a critical feature in special applications.

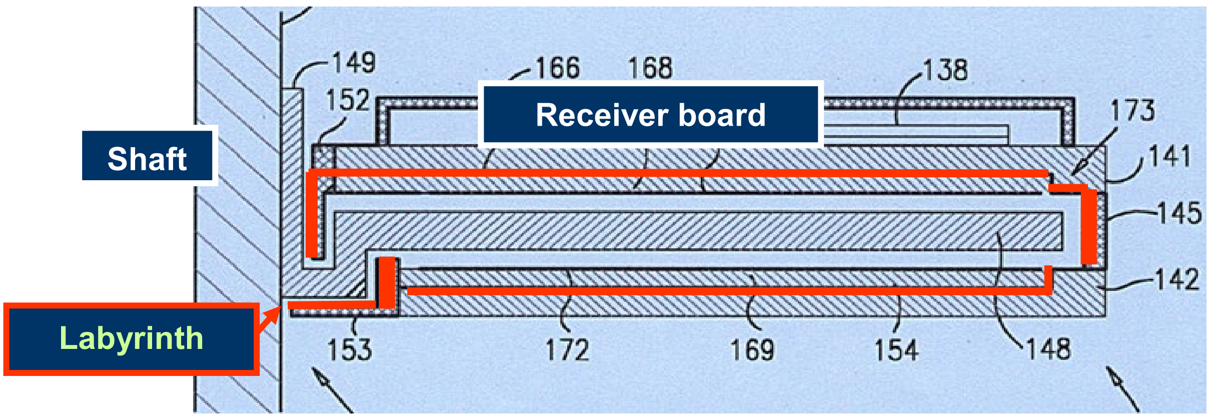
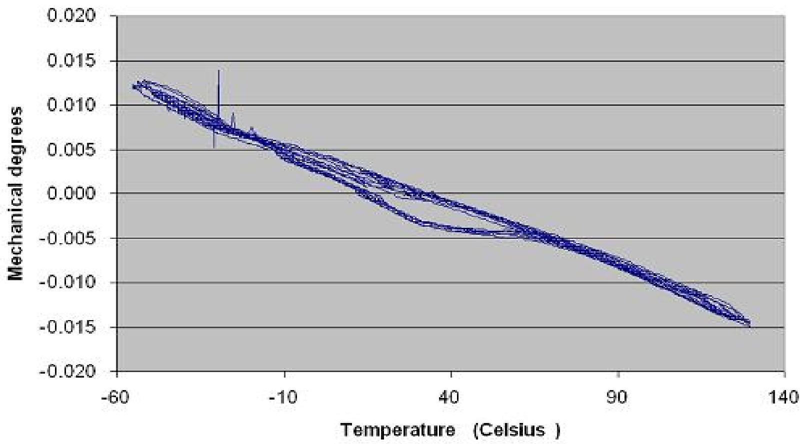


Figure 6

Extreme shock and vibrations. 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 adapted to operate from cryogenic temperature up to 125˚C and above. **Figure 7** illustrates a typical plot of the read out angle of a premium DS-58 encoder cycled over temperature.

Figure 7



4. Comparison with the resolver

The output signals of the analog **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 with 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. The following table compares the two technologies.

	Parameter	Resolver	Electric encoder™
1	Operating temp. range	-55^0 to $+150^0$	-55^0 to $+125^0$
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	Down to 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

5. Electric Encoder™ interface

The veteran, legacy analog versions provide Sine / Cosine of the Coarse and Fine signals (electric angle). However, most others have digital outputs generated either internally or converted from analog signals by an external module.