Optical position encoders enable high-reliability applications

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A new approach implements optical position encoders based on a mass-replicable micro-optical technology.

Conventional optical encoders were introduced more than thirty years ago in the factory automation market, and they have evolved little since then. Although their performance is acceptable for today’s industrial requirements, there is room for improvement, especially in making them applicable to high-reliability applications. In addition to addressing their sensitivity to external factors and improving signal read-out speed, other important concerns include cost and integration and packaging challenges that are linked to tight assembly tolerances.

The majority of position encoding applications currently use incremental or absolute rotational encoders. ‘Signal on demand’ in hybrid absolute/incremental rotational encoders is becoming more and more desirable for industry and will make up a new sector of the encoding market, as well as integrated multidimensional position encoders (x/y or more complex 2D/3D position encoding). We have developed an optical encoder technology that addresses all of these applications (see Figure 1).

Our research resulted in optical encoders that cost less and require looser tolerances during integration and packaging than conventional encoders. In addition, they are less sensitive to external influences such as fast and extreme temperature changes, strong vibrations, shocks, scratches and dust or particle contamination.

The technology implemented in our optical encoders is inherently a parallel optical-position read-out process, based on a mass-replicable micro-optical technology. In contrast, the vast majority of existing position-encoding architectures (based on optical, inductive, magnetic, or mechanical technologies) are serial read-out processes.

Figure 2 shows a photograph of our encoder channel taken under a microscope. Note that this technology is not related to the traditional grating (single or dual) interference patterns that are usually used to build up high-cost and high-resolution glass incremental linear encoders.

The positional read-out frequency of our encoders is higher than that of conventional ones because the optical pulses (both in incremental and absolute read-out schemes) are pure native pulses: they do not require any signal processing time, which avoids errors and extensive computation.

Our research found that this type of optical encoder also supports high-resolution absolute encoding with lower quality shafts as well as “wear-out monitoring.” These attributes combine to support a highly-reliable, fault-tolerant architecture that allows for fault prediction and measurement in motors.

Developing these optical encoders depended upon some enabling technologies. First, we needed the ability to design and generate master disks with conventional IC microfabrication techniques. Second, we had to be able to replicate these disks in volume using a custom injection-molding process. The result is a low-cost transparent or reflective plastic encoder disk that replaces the high-priced metallic or metal-on-glass encoder disks used in conventional encoders. Figure 3 shows examples of some plastic injection-molded encoder disks.

Our technology incorporates automatic optical compensation for temperature variations, which requires no signal processing,

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electronic, software, or mechanical compensation. This enables the encoders to be incorporated into applications that require high reliability such as automotive, aviation, space, and military equipment, without having to bear the cost burden usually linked to such applications.

We also developed a series of integrated optical read-out heads customized for the diffractive disks, which allows further reduction of the encoder’s size and weight. Since the planar micro-optical components are already aligned in the fabrication process, the integrated optical read-out heads do not require precise alignment during assembly.

Current and future development work is focusing on hybrid incremental and absolute encoders to enable a ‘signal on demand’ read-out (with fast incremental read-out and absolute read-out up to 14 bits). We are also developing incremental encoders with resolutions ranging from 500 pulses per revolution to 5000 pulses per revolution, and absolute incremental encoders with resolution from 8 bits to 14 bits in grey code or natural binary code. We plan to integrate multidimensional encoding in both $x – y$ and $r – \theta$ formats (in absolute and hybrid incremental/absolute modes) and more complex 3D positioning sensing encoders.

**Figure 2.** Microscope photograph of microstructures in the encoders.

**Figure 3.** Plastic replicated (injection-molded) transmissive and reflective encoder disks.

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**References**