WiSys Ref: T130018

HIGH ACCURACY ANGLE MEASURING DEVICE FOR INDUSTRIAL, MEDICAL, SCIENTIFIC, OR RECREATIONAL USE

Background

The ability to accurately measure movement of rotating components is crucial in many industrial, medical, and recreational applications. Devices used to measure such movement are called rotary position encoders (RPE), which represent a North American market worth over $500m. An absolute encoder (a RPE subtype), is desirable because it is able to determine present position angle, even if the device has been turned off and on again. However, a strong limitation to using these encoders is cost, with a high-end (±0.4 arc seconds accuracy) absolute RPE costing as much as $20k. In addition, systems currently in use suffer from large, bulky components and they often experience measurement errors resulting from mechanical imperfections.

Technology

A UW-Stout researcher has developed a high-accuracy angle measurement system that addresses the problems inherent to existing RPE systems. In this device, a high accuracy optical RPE, controlled by a microprocessor, consists of rotating optical disks and sensors precisely formed and placed to read angles with 0.001 arc second sensitivity (average) and better than ±0.1 arc second accuracy (single readings), which is comparable to the accuracy of the high-end encoders currently on the market. This accuracy is made possible by a compact, novel design that combats mechanical sources of error which are problematic in other devices. Beyond high accuracy and portability, the cost of this improved system is much lower than a high-end commercial system because it is easily constructed from readily available industrial grade components, bringing the production cost to roughly $2,000. Strikingly, this cost is comparable to the advertised price of other rotary position encoders that are less than one tenth as accurate. Its high accuracy, low cost, and portability make this new angle measurement system a strong option for use in virtually any of the current applications for absolute rotary encoders.

Research and Development Status and Commercialization Needs

Prototypes have been developed and tested for principle of operation, accuracy, and sensitivity. Further refinement through mechanical and electrical engineering would be needed to take this product to market. Additional software development may be needed to interface the device to other equipment depending on desired end-use. Both engineering and development would benefit from industry collaborations and WiSys is currently seeking a strategic partner to further develop, manufacture, market, and distribute this device.

Applications and Key Benefits

- Astronomical telescope mounts, land surveying, industrial inspection and calibration, machine tools, magnetic resonance imaging (MRI) and computerized tomography (CT) machines, robotics
- High single reading accuracy of ±0.1 arc seconds with high average reading sensitivity of 0.001 arc seconds
- Excellent inherent accuracy obviates need for calibration in most applications
- Small angular changes can be measured with high accuracy because residual error is a slowly varying function of angle
- Low production cost; easily constructed from readily available standard industrial level components
- Compact and portable design

Intellectual Property

A U.S. Patent Application has been issued for this technology. For more information on partnering opportunities please contact us at licensing@wisys.org.

Supplementary Information

Operating Principle

The present technology utilizes a novel system for angle measurement called the Shifted Delta Sum Angle Measurement System (SDSAMS). The SDSAMS uses one or more rotating marked disks rigidly mounted to rotate together on a common rotating shaft. Two sets of one or more sensors are used, one set on a fixed base and a second set that moves through the angle to be measured. The movable sensors rotate about the same axis as the rotating disks. The measured angle is calculated based on the times when marks on the rotating disk(s) are sensed by the set of movable sensors compared to the times when marks are sensed by the set of fixed sensors.

The main mechanical components of the current prototype consist of a rotating top platform and a fixed lower assembly. The rotating platform houses an upper encoder disk and encoder sensor modules. The assembly of this platform, including the sensors, rotates independently of the disk. Within the fixed lower assembly is a lower encoder disk and fixed sensors. Also fixed in place is a custom designed efficient, low power, frameless brushless three phase drive motor, driven by a three phase sensorless brushless DC motor driver.

For signal analysis and data output, the current prototype uses a multi-core microprocessor to provide hard real-time performance, with I/O timing accuracy and latency of approximately 10 nanoseconds. The prototype sends the measurements and diagnostic information as a clear text stream of characters over wired or wireless ethernet, though other formats could be easily incorporated. Alternative circuitry could also be used to enhance computation power and potentially increase the timing resolution. In testing the current prototype, rotation rates of 300-2000 rpm have been studied. At 450 rpm, the device provided the average angular position over the previous 133 milliseconds approximately every 100 milliseconds with an average standard deviation of 0.0026 arc-seconds for groups of 10,000 successive measurements. At 2000 rpm, the device provided the average angular position over the previous 30 milliseconds approximately every 50 milliseconds with an average standard deviation of 0.0087 arc-seconds for groups of 10,000 successive measurements.

Additional Information: Speed Control Loop

The integrated circuit of the motor driver changes the currents supplied to the coils based on phasing information derived from voltages across the coils, but the motor is essentially driven ”open loop” without fine position or velocity feedback from an encoder. In early tests, motor and driver combinations that included closed loop speed control diminished performance, with much larger variation in the angle measurement on successive revolutions of disks. The larger variation in measured angle values when using ”closed loop” speed control may have been due to the servo system making frequent adjustments to the rotation rate as the motor rotated. However, these “closed loop” tests were preliminary, and further testing would be needed to determine the cause(s) of the high variation, as well as whether alternative “closed loop” system configurations could further optimize performance.