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Original Article

A Novel Concept to Monitor Speed, Position, Direction of Rotation and Fault Detection using Multi Color / Multi-Material Encoder Disc and a Single Channel Sensor in an Embedded System

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Abstract *- Encoder system is widely used in rotational measurements in embedded systems. These encoder systems use a bicolor encoder disc/wheel and at least two channel sensors connected to a microcontroller for rotational measurements. The novel theoretical concept in this article discloses a system to measure the speed of rotation, position of rotation, direction of rotation and fault detection using a multi-colour / multi-material encoder disc and a single-channel sensor in embedded systems. The system is used to measure the shaft rotation, a measure which finds applications in various fields like automotive, power tools, medical devices, manufacturing, etc. The system is useful due to its compactness.*

Keywords *- Encoder disc, Multi color encoder disc, Multi material encoder disc, Optical encoder, Rotary encoder.*

1. Introduction

Many industrial applications involve rotational movements and related measurements. The measurement of these rotational movements is essential in determining the performance of these applications and controlling the inputs which drive the rotation. Without these rotational measurements and control feedback loops, these applications will not perform as intended, and sometimes, these will result in catastrophic failures.

The importance of these rotational measurement can be easily understood with the automatic cruise control feature in the car as an example. When the automatic cruise control feature with a set speed is enabled in the car, the application measures the wheel rotation speed and determines the gap between the set speed and the measured speed. When the measured speed is less than the set speed, the driving force of the wheel is increased so that the measured speed can trend towards the set speed. Without the rotational measurement, the control feedback loop of the automatic cruise control is not possible.

Several technologies are available for rotational measurements. In these technologies, the two most common technologies employed are optical and magnetic. In optical technology, encoder systems are widely used to measure the speed of rotation, position of rotation and direction of rotation. These encoder systems use a bicolor encoder wheel/disc and at least two channel sensor/s to detect the direction of rotation and fault conditions [1-2]. These sensors work by either reflection or transmission. In the case of transmission type, a light source projects the light onto the rotating encoder wheel from one side, and a receiver placed on the other side detects the light. As the encoder wheel rotates, light will pass through the transparent slot in the encoder wheel while no light passes through the opaque slot in the encoder wheel. With this phenomenon, the speed of rotation can be measured. But to measure the direction of rotation, a single channel sensor will not suffice as the receiver will see the same pattern of light when the encoder wheel rotates in either direction. A second receiver placed in such a way that the pattern of light is slightly offset by 90° between the two receivers will support the measurement of rotation direction.

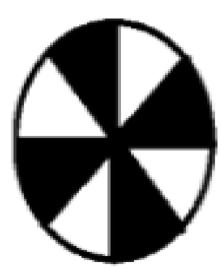

Fig. 1 Bi-colour slot encoder disc

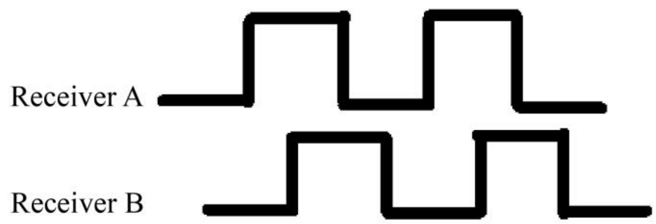

Fig. 2 Clockwise rotation Receiver inputs

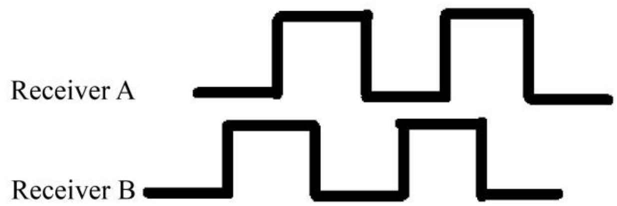

Fig. 3 Counterclockwise rotation receiver inputs

From the above discussion it is clear that current optical encoder systems require an encoder wheel and at least two sensors to work. The mounting space requirement and the cost requirement are also more for the current optical encoder systems.

A new novel theoretical optical encoder system is discussed in this article, which will require an encoder wheel and only one sensor to work, which can measure the speed of rotation, position of rotation and direction of rotation. The new novel optical encoder system is cost-effective and compact when compared to existing systems.

2. Literature Review

Several forms of Optical Encoder systems are widely used to measure rotational movements where the environment is dust-free and noise-free (in terms of light energy).

Method [3] shows a single light source and three receivers/output signals as a standard. Receiver signals A and Receiver signal B are identical to A but 90° displaced, and Receiver signal Z as a marker output, which acts as a reference point for identification of the completion of a full cycle of rotation.

Method [4] shows three light sources and three receivers/output signals as a standard. Receiver signal A for Light source A, Receiver signal B(identical to Receiver A but 90° displaced) for Light source B and Receiver signal Z for Light source Z, which acts as a reference point for identification of the completion of a full cycle of rotation.

Method [5] shows five light sources and five receivers/output signals as a standard. Each receiver has its own light source.

The novel optical encoder system discussed in this article, in contrast, provides a rotational measurement solution using a single receiver and a single multi-colour / multi-material encoder disc.

3. Concept

The concept is based on a novel theoretical rotational measurement technique using a multi-colour / multi-material encoder disc and a single-channel sensor. The concept can measure the speed, position and direction of rotation and can also provide fault detection. The basic structure of the measurement tool uses a tricolor slot encoder disc in a single-channel optical sensor, which is connected to a microcontroller. As a whole, the system works as an incremental encoder and it measures the shaft rotation. This measure finds applications in various fields like automotive, power tools, medical devices, manufacturing, etc.

The encoder used in this method can operate in two modes: Reflective type and transmission type encoders.

3.1. Reflective Type Encoder

For the reflective variant, the encoder disc used contains slots which are tricolored. The three colors are white, grey and black, all chosen because of their distinctive reflective properties. The encoder disc is connected to a rotating shaft connected to a motor. The placement of the mechanism must be done such that the light hitting the encoder disc will reflect straight back to the optical sensor for analysis of the speed. Another mandatory consideration is that the focus area of the light which hits the encoder disc should be less than the slot area of the encoder disc.

Based on the sensor feedback, the software running in the microcontroller detects the black, white and grey color of the disc based on how much light is reflected back, and using the sequence of black, white and grey on the encoder disc, the software can determine the direction of rotation by incrementing or decrementing the position value. By finding out the time needed for a transition in color, the speed of the rotation can also be determined. A larger range of colors can be chosen, provided there is a substantial gap in their reflectivity. When the change in colors is erroneous, i.e., when a shift of white to black is expected, and a white to grey is observed, the software will detect that a fault exists, which can then be modified to remove the error.

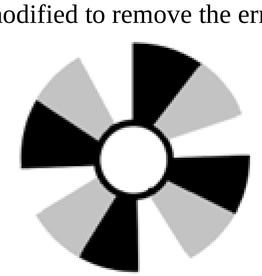

Fig. 4 Tri-color slot Encoder Disc

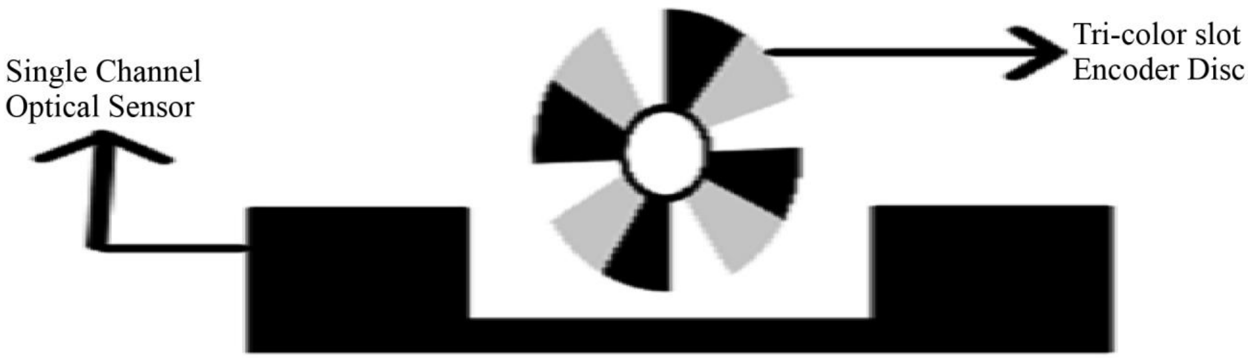

Fig. 5 Tri-color slot encoder disc in optical sensor

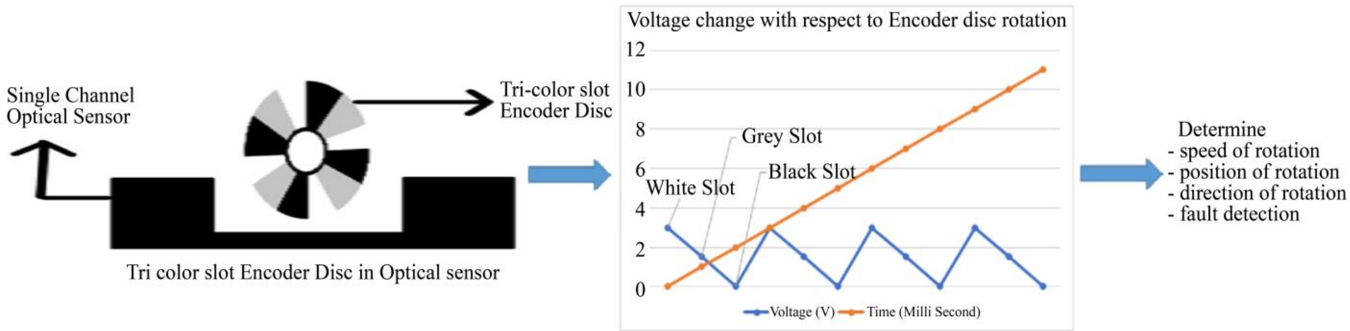

Fig. 6 Encoder Disc slot correlation to the voltage level

3.2. Transmission Type Encoder

The transmission variant of the system works on the transparency of materials, not their reflectivity. The Tri-colored disc used here constituted three materials with varying levels of transparency, i.e. one material is opaque, the other translucent and the final one transparent. The system set-up is similar to the reflective type, but this time, the sensor will receive transmitted light from one side, and based on how much light is received, the software receiving the sensor feedback can determine what material of the disc the light is passing through. Using similar mathematics to the previous system, this software/system will be able to determine the direction of the rotation, the speed of rotation, the position and fault detection of any sort.

4. Discussion and Benefits

4.1. Optical Encoder Channel Insights

Current optical encoder systems use a wide array of channel choices, including one-channel, two-channel, four-channel and more than eight channels. The two-channel choice is widely used [6].

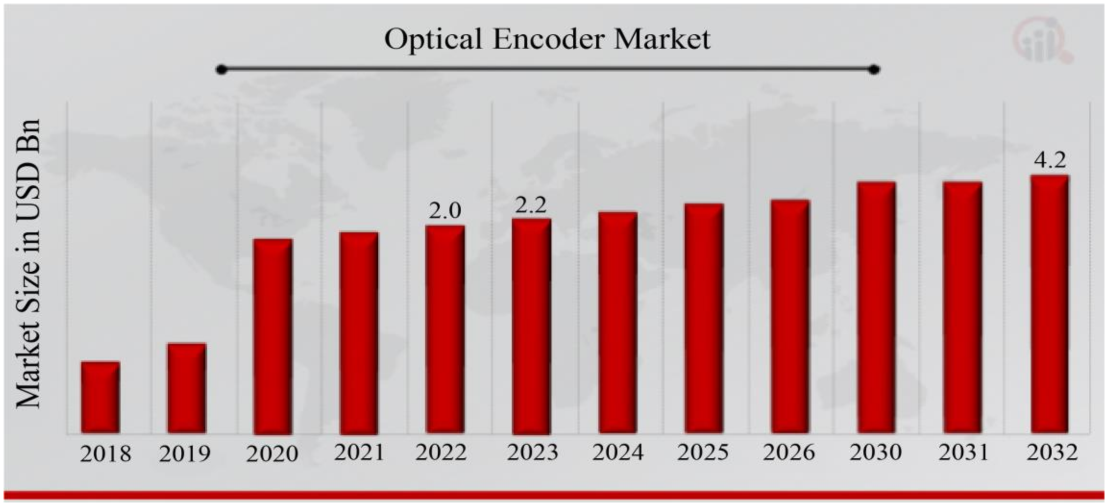

Fig. 7 Optical encoder systems global market growth [6]

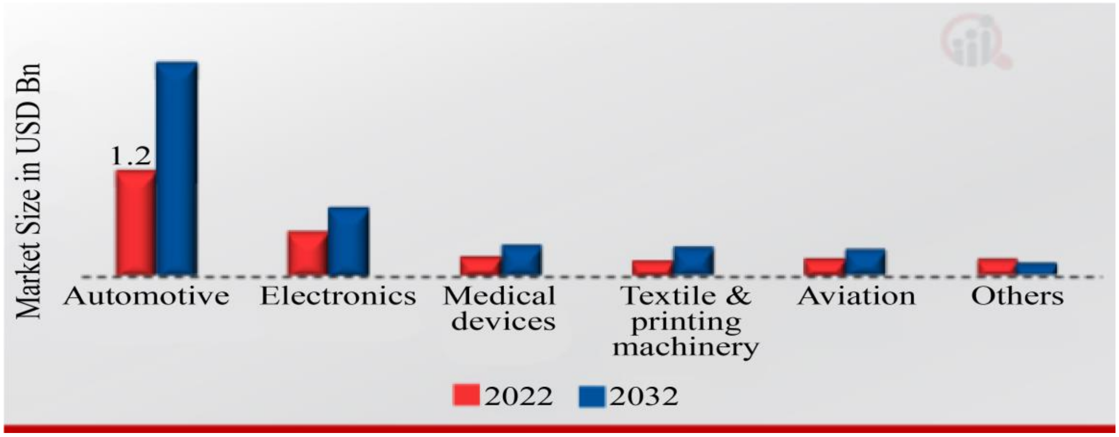

Fig. 8 Optical Encoder Systems industrial sector market growth [6]

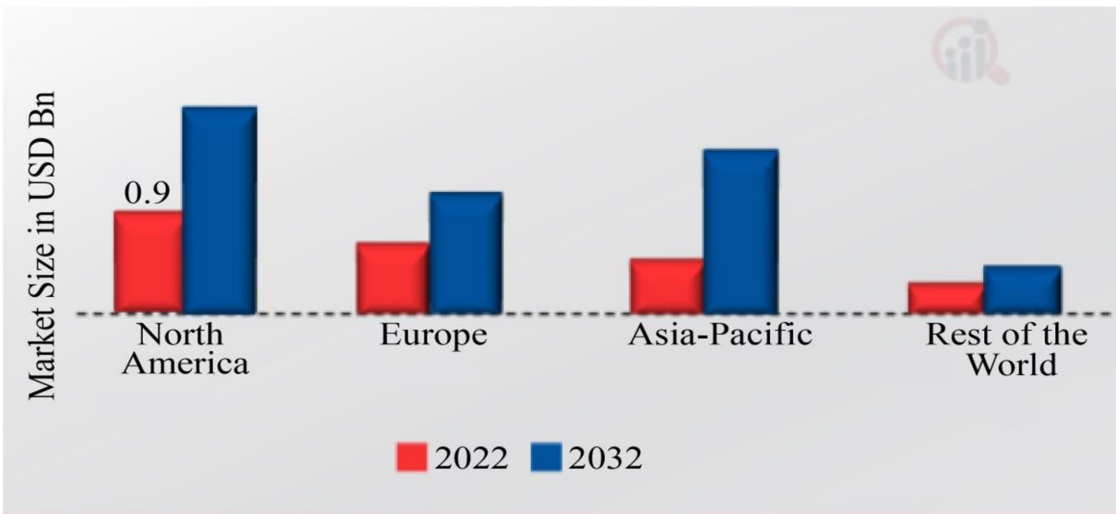

Figure 9 Optical Encoder Systems regional revenue [6]

4.2. Optical Encoder Industrial applications

Optical encoder systems usage is growing steadily as several applications increase their demand for advanced motion control systems. Some sectors where this can be seen are automotive, power tools, medical devices, electronics, manufacturing, aviation, textile, and printing machinery [6].

4.3. Optical Encoder Market Growth

From 2023 to 2032, the optical encoder systems market is expected to grow at a compound annual growth rate (CAGR) of 8.70% from USD 2.2 billion to USD 4.2 Billion [6]. This growth is expected to happen in several application sectors, with automotive and electronics leading the chart [6]. Among regional geographies, growth is expected in all the world regions [6].

4.4. Results

With such huge market growth forecasted for the Optical encoder systems, the proposed novel concept can be adapted in many applications. The proposed novel concept uses a single-channel sensor instead of multiple-channel sensors. This will result in cost savings, thereby benefiting the end customer.

The proposed novel concept shows better results than a single channel 2-slot encoder disc measurement method (fault detection is impossible due to its operating principles). It is useful due to its compactness compared with existing systems, indicating that it could be used when space constraints exist.

Overall, the proposed novel concept is versatile, finding applications in various domains, and has two variants depending on the availability of specific optical sensor technologies.

5. Conclusion

The novel theoretical concept described can be further subjected to experimental studies with different colours in the encoder disc, different materials in the encoder disc and the outcome analysed for each combination. Experimental studies can be conducted in several applications that are seeing an increasing usage of advanced motion control systems. The results of the experimental studies can be analysed and published.

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