IMPROVED RELIABILITY OF PSEUDORANDOM OPTICAL ROTARY ENCODER

Goran Miljković, Ivana Ranđelović, Dragan Denić, Milan Simić

University of Niš, Faculty of Electronic Engineering
Aleksandra Medvedeva 14, 18000 Niš, Serbia

Abstract

Modern servo systems rely on position information for their quality and reliability of operation. Optical rotary encoders are mainly used when reliable, high-resolution position information is required. The paper presents a pseudorandom optical rotary encoder that has been improved with introducing two phase-shifted pseudorandom code tracks and using two reading heads that are in line and one against the other in relation to the disc encoder. This type of code reading offers a number of advantages in terms of improving the reliability and redundancy of encoder operation.

Keywords: absolute pseudorandom position encoder, code scanning, redundancy, reliability

INTRODUCTION

Modern devices and industrial systems are increasingly demanding regarding certain parameters of position information, such as its resolution, accuracy, reliability, etc. That increase in demand must be accompanied by optical position encoders, which are often used to measure the position of a motor within a moving system. Classical absolute position encoders have the number of code tracks that depends on the resolution of the encoder, and the paper will present an improved pseudorandom absolute encoder that has one code track. This encoder has serially arranged code words along one code track, whereby the operation of the encoder exploits some convenient properties of the pseudorandom binary sequence [1, 2, 3, 4, 7, 11]. Pseudorandom absolute encoders are suitable for the application of various methods of detecting code reading errors, which contribute to the overall reliability of the encoder. Also, with these encoders, it is possible to implement algorithms that facilitate mounting the encoder on the motor shaft and easier definition of the zero position [6].

The disc of pseudorandom optical rotary encoders usually contains a synchronization track and at least one code track, side by side. Signals from the synchronization track are used to define the moment of reading pseudorandom bits from the code track, then to determine the direction of rotation of the encoder, and sometimes to increase its resolution [2, 8]. Reading bits from the code track can be implemented as serial with one or more reading heads or in parallel when the number of heads depends on the resolution of the pseudorandom code [1, 4]. In order for the position information to be suitable for further processing, transmission and presentation, it is necessary to convert the pseudorandom code into a natural code. Different types of code converters can be implemented that differ in conversion time, complexity and cost of the hardware used [1, 4, 9, 10]. Three types of converters can be distinguished: fast parallel converters that use fast memory, then slower but simpler serial converters that use a pseudorandom binary sequence generator, and there are also serial-parallel converters that are a compromise solution applicable to high-resolution encoders.

In the first part of the paper, an improved layout of the pseudorandom encoder disc is presented, which contains synchronization and two phase-shifted code tracks. Next, the practical realization of reading the encoder disk with two optical modules, which are located opposite each other, is described. At the end, the working principle of such an encoder and the possibilities for increasing its redundancy and reliability in operation were discussed.

PSEUDORANDOM OPTICAL ENCODER WITH SERIAL READING

Reading of the pseudorandom code from the code track of the encoder disc can be realized as serial by means of a single reading head. This is possible thanks to the fact that adjacent code words differ in one bit. Reading a pseudorandom code using a single head is shown in Fig. 1, where the read bits are placed into a bidirectional shift register that is a buffer for forming the read code word. Two heads, AUT and VER, are needed to obtain signals from the synchronization track, and they are used to synchronize the readings of the pseudorandom code track and to determine the direction of rotation.

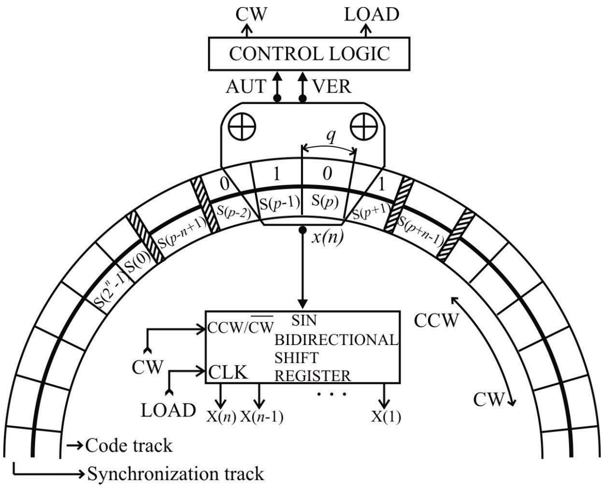

***Fig. 1** Serial reading of pseudorandom code with one reading head*

However, single-head pseudorandom code reading faces the problem of losing position information when changing the direction of rotation. A more elegant and advanced solution is reading with two heads that are at a distance of nq, where n is pseudorandom code resolution. The code words that are formed after changing the direction of movement now correspond to the current positions of the encoder disc, Fig. 3. Also, the continuity of the formation of code words is achieved even in case of possible oscillation of the moving system in the direction of movement. This method of reading the code enables the application of continuous verification of the correctness of the formed code words.

Serial reading of the pseudorandom code that will be applied in this paper is based on the use of two code reading heads along with two pseudorandom code tracks carrying the same PRBS code but phase shifted for $2n$-1+n-1 bits, Fig. 2. The sensor heads are located opposite each other, on a straight line passing through the center of the encoder disc. First code reading head reads pseudorandom bit $S(p)$ from first code track and other code reading head bit $S'(p+n)$ from the shifted code track. Compared to the previous solution, the sensor heads read bits from two different code tracks, they are easier to mount and adjust. This arrangement of code tracks and their reading has the continuity of the formation of code words, Fig. 3, as well as the possibility of applying error detection techniques for code reading. If the error detection method described in reference [5] were applied to the this encoder solution, the main code word would be formed from bits from one code track, and the control code word from bits from a phase-shifted code track. In this way, a more reliable reading of the pseudorandom code is obtained in industrial operating conditions.

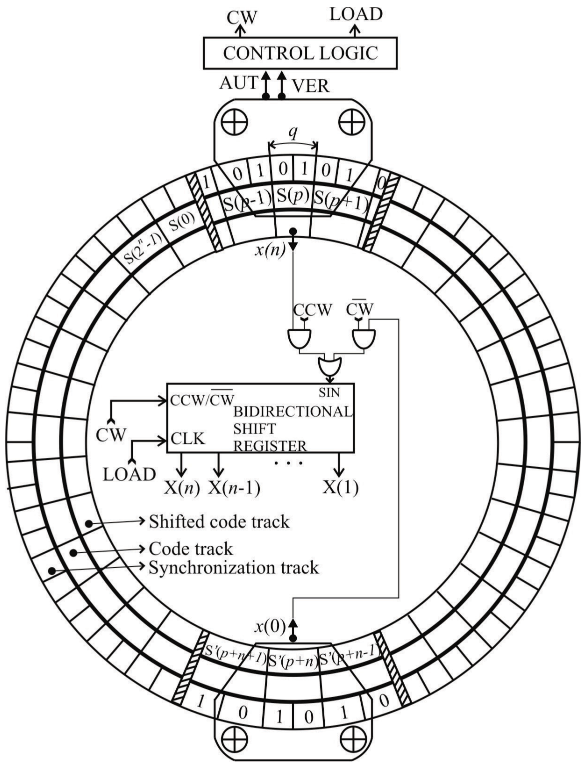

***Fig. 2** Improved serial reading of pseudorandom code*

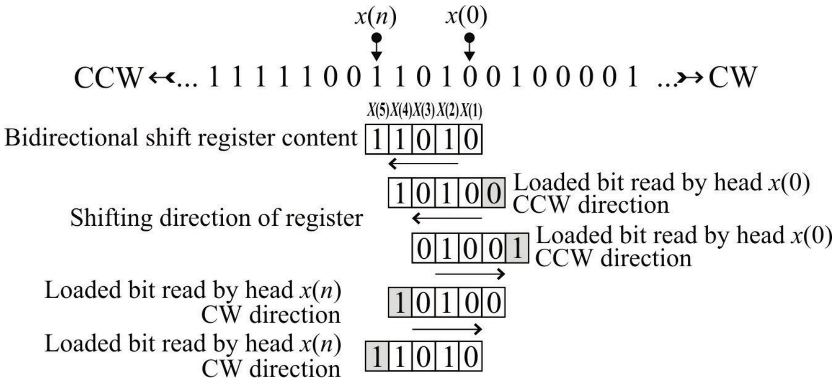

Fig. 3 *Code word forming in bidirectional shift register in case of reading with two heads*

PRACTICAL IMPLEMENTATION OF PSEUDORANDOM OPTICAL ENCODER

The presented pseudorandom code reading solution was practically tested using the experimental setup shown in Fig. 4. In this experimental setup, the encoder plastic disc with a diameter of ϕ 45 mm has an 11-bit synchronization track (2048 slits), 10-bit pseudorandom code track (1024 slits), and another same but phase shifted 10-bit pseudorandom code track. 10-bit pseudorandom binary code obtained by linear feedback shift register (LFSR) with feedback set [10, 3] for maximum length sequence is printed on two pseudorandom code tracks. This arrangement of code tracks as well as the use of a pseudorandom code enabled the use of ready-made optical modules for reading, which can be found on the market for use with incremental encoders. An optical encoder module M832-1024-6T-U manufactured by Dynapar is used and the width of the tracks is customized for this concrete reader. Also, the encoder module must be selected for the appropriate incremental track resolution. Fig. 4 shows a magnified photo of a code disc, from which it can be observed that each pseudorandom code track has its inverted version beside it due to differential scanning.

One encoder module is used to read the synchronization track (signals A and B) and the first pseudorandom code track (PRBS1), while the other is used to read the shifted pseudorandom code track (PRBS2), Fig. 5. The index sensor head of the applied encoder module was used to read the pseudorandom code track. One encoder module is positioned closer to the center of the disc so that the index sensor head reads a pseudorandom track closer to the center of the disc.

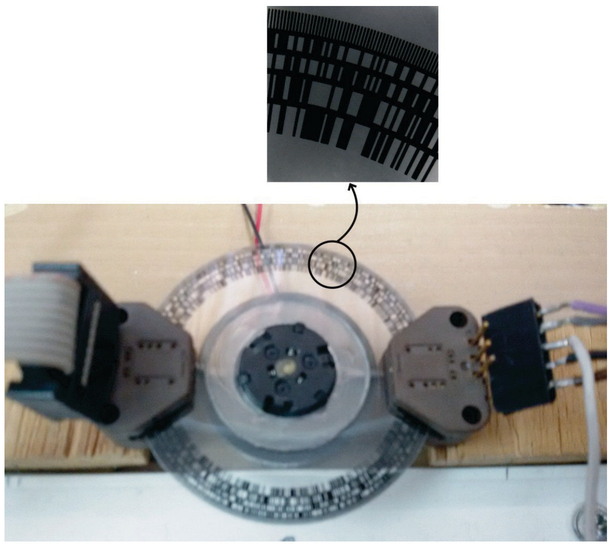

Fig. 4 *Encoder disc with two optical modules*

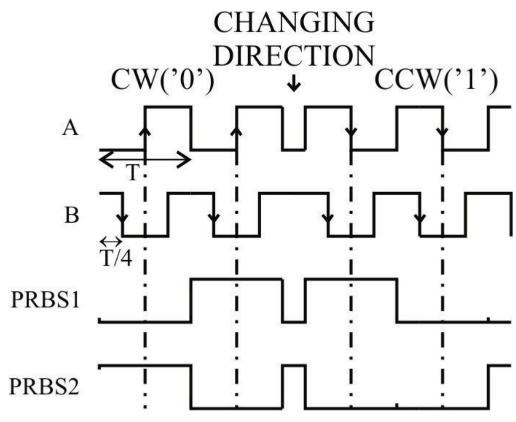

Fig. 5 *Output signal from reading heads*

After the initialization of the system, this encoder must form the first valid pseudorandom code word and determine the absolute position after that. The accepted initial code word stays the same for both code tracks. After initialization and forming the first code word, the reading a new bit from the corresponding code track depending on the direction of rotation is followed. The accuracy of the read bit is checked according to method [5].

If there was no error reading the code, the encoder continues to operate in normal 10-bit mode. The absolute position is determined after the pseudorandom/natural code conversion of pseudorandom code word. In 12-bit mode, between two read code words from a pseudorandom code track and their conversion, position is determined using two quadrature signals from the synchronization track. For both, 10-bit and 12-bit, operation modes it is necessary to form a main code word to determine the position and control code word in order to detect a code reading error, [5].

In the worst case, when the error of the read bits has occurred in both code tracks, the encoder can continue to work in the incremental mode. This is provided by rising and falling edges of signals A and B from synchronization track.

However, if the bit read errors occurred in a single code track, due to failure of one encoder module or due to the contamination of one code track, the encoder can continue to operate in mode of reduced reliability with a single code track. As possibility, if only part of the code track is damaged or contaminated, the encoder can only operate in that part in reduced reliability mode. In this way, the reliability of the position encoder operation is significantly increased. As a code reading error can occur due to some immediate external influence, such as vibration, temperature, it can be introduced a testing procedure whether the error occurs again in the same place in the subsequent reading of these same bits.

CONCLUSION

Arrangement of the synchronization and code reading heads provides reliable code reading and checking of code reading errors in presented pseudorandom encoder. In the event of a code reading head failure or contamination of one code track, the encoder can continue to operate with reduced reliability. Experimental results verify the validity of the implemented solutions and operation modes in presented encoder.

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