Encoder Solution for Testing Pseudo-Random Code

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ABSTRACT: *For industries and robot applications the transducers of angular and linear positions with pseudo-random encoders are used. A possible improvement in this feature is the use of two pseudo-random code heads which is now employed. We found during testing that it is easy for practical work and bring improved performance, redundancy and reliability. In the proposed encoder solution, the checking methods of pseudo-random code can ensure reliable position.*

Keywords: Position Measurement, Pseudorandom Position Encoder, Code Reading, Code Reading Correctness

Received: 27 May 2022, Revised 3 September 2022, Accepted 22 September 2022

DOI: 10.6025/jism/2022/12/4/98-104

1. Introduction

The optical absolute position encoders which have single code track based on pseudorandom binary sequences are good solution for precise positioning of various movable systems. The position measurement at pseudorandom position encoders is based on property of n-bit pseudorandom binary sequence (PRBS) that each sliding window of length n, which passed along a sequence, will extract unique code word in every moment [1, 2]. One code track is necessary at these encoders, no matter how many digits the code word includes, but the tolerance against yaw-angle errors becomes significantly smaller. Additional property, which makes possible serial code reading at absolute encoder, is that last (n-1) bits of the current code word are equivalent to the first (n-1) bits of the subsequent code word. Pseudorandom binary sequences are, besides at absolute position encoders, also used in cryptography, bit-error-rate measurements, wireless communication systems, audio applications, etc.

Each designer of new pseudorandom position encoder need to develop following functional parts: the code reading system [3, 4], where can be used different solutions with one, two or more code reading heads, code scanning methods in the sense of reliable code reading moment defining [5], pseudorandom/natural code conversion [6] and error detection methods [7], which increase reliability of encoder. Code scanning methods are based on using of one external synchronization track or internal incrementally encoded wheel or by additional coding of pseudorandom code bits [5].

Pseudorandom binary code is not suitable for direct application in digital electronics, and so different methods for pseudorandom/natural code conversion are developed and they can be separated on three distinct groups: parallel [8], serial [2] and serial–parallel code conversion [2]. Parallel solution for code conversion is fast, but expensive and impractical for long PRBS. Serial code conversion is developed as one simple and cheap way for conversion of long PRBS. However, conversion time is critical for one absolute position measurement cycle. Development of different solutions of serial code converters has the main goal in reducing of conversion time. Serial–parallel code conversion is one compromise solution, which combines serial and parallel conversion techniques. During mounting on the shaft pseudorandom encoder provides possibility of direct zero position adjustment without a significant change of hardware, [9].

In the first part of the paper existing serial pseudorandom code reading methods are explained, and then one new improved solution is proposed. Then, it is presented implementation of pseudorandom code reading correctness checking method and reliable zero position adjustment method. Checking of pseudorandom code reading correctness is explained through one concrete example of low resolution pseudorandom encoder code disk.

2. The Serial Pseudorandom Code Reading Methods

The pseudorandom binary code provides possibility of serial code reading with one sensor head and one bidirectional shift register, Fig. 1, which is not possible at classical absolute encoders. Code word is formed in the shift register and later converted to more convenient natural code. This solution has one disadvantage because it is needed initial moving of n bits for forming of the first valid pseudorandom code word. Also, it occur problem of losing position information at any change of movement direction, and solving of this problem requires additional hardware in encoder realization.

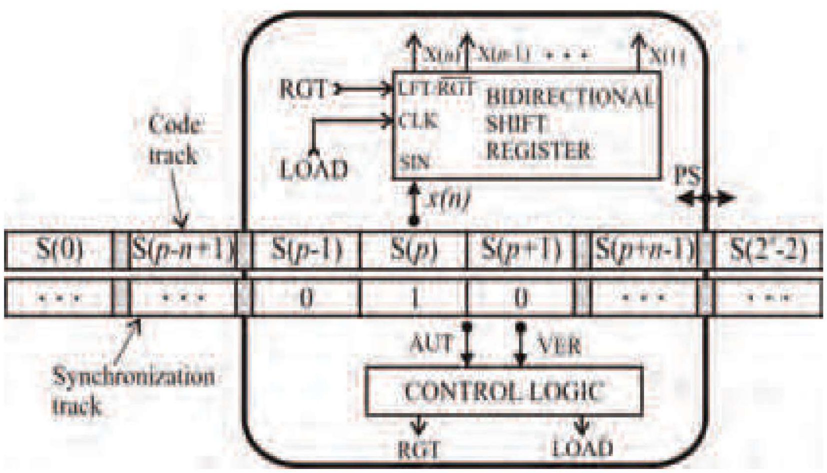

Figure 1. Serial pseudorandom code reading with one reading head

So, the code reading method that eliminates drawbacks in previously described solution [3] and enables additional possibilities is shown in Fig. 2. This solution is based on introducing one more reading head at distance of nq, where q is value of code track quantization step. A multiplexer 2/1 consisted from two AND and one OR logic gate is used for selection one of two code reading heads depend on moving direction. When system is moving to the left shift register is loaded with bits from reading head x(n), and when moving to the right bits are loaded from reading head x(0). Presented solution provides continuity in pseudorandom code word forming and now loosing of position information during change of moving direction would not occurred. Also, this solution provides a reliable method for permanent checking of the code reading correctness, which significantly improves reliability of position encoder. But, this code reading method requires correction of position information for one moving direction and this arrangement of code reading heads is not suitable for practical encoder realization.

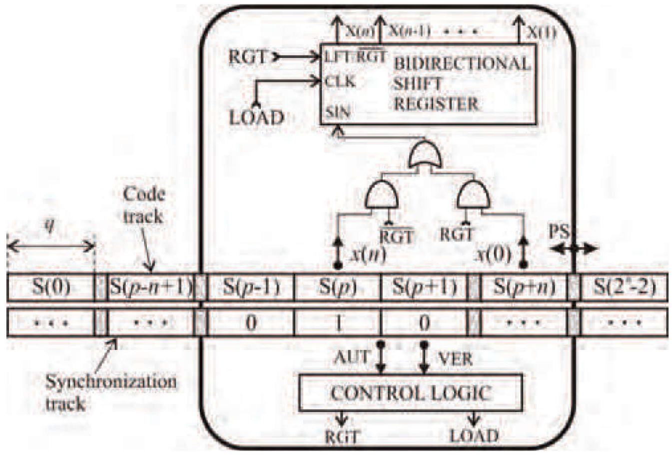

Figure 2. Serial pseudorandom code reading with two reading heads

The code scanning in pseudorandom position encoder shown in Fig. 2 is solved by using an external synchronization track next to the pseudorandom code track. The sensor heads AUT and VER provide the synchronization pulses and information about the movement direction (RGT = "moving to the right"). Formed pseudorandom n-tuples code words are then converted to natural code using pseudorandom/natural code converter [6].

However, practical application of previous solution at high resolution encoders is difficult because two sensors need to be on very little distance from each other. Also, different environmental conditions such as temperature and vibrations can bring variations in distance between sensor heads, and this would cause code reading errors. In this paper is proposed improved solution with introducing of one additional pseudorandom code track, which would be same as the first code track, but shifted for (n-1) bits, Fig. 3. Application of this code reading method is especially convenient in systems where oscillations of movable system can occur.

Now, each pseudorandom code track would have one code reading head and they will be arranged in line as at classical absolute position encoders. Most of previous solution practical problems are solved on this way, but price is introducing of one more code track. This improved solution also provides continuity in code word forming, simpler hardware realization, and increasing redundancy of systems and also realization of very good code reading error detection method

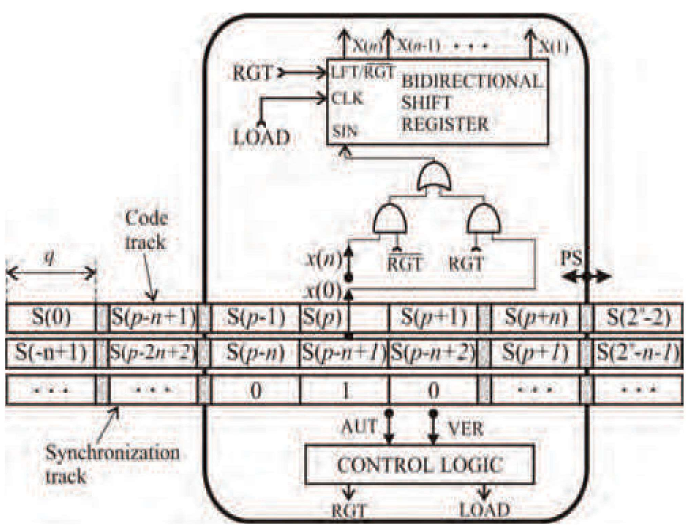

Figure 3. Improved serial pseudorandom

On the market can be found high speed and high sensistive optical sensors, which are normally used for incremental encoders, but also can be used for proposed solution of pseudorandom encoder. One chip with 9 silicon P/N photodiode is shown in Fig 4, where active area of each photodiode is 0,236 mm2. This chip can be used for previously described solution where depend of disk diameter and concrete resolution need to apply a separate reticle.

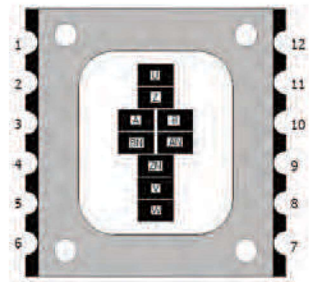

Figure 4. MO-PMD09 optical sensor for encoder (www.micropto.com)

3. Code Reading Error Detection Method

The proposed solution of pseudorandom encoder enables implementation of reliable code reading error detection method, which will be explained below on the example of 4-bit resolution pseudorandom absolute position encoder, which code disk and arrangement of code reading heads is shown in Figure 5. In this example is used 4-bit pseudorandom binary sequence 111101011001000. There are one synchronization code track and two pseudorandom code tracks shifted for three bits from each other. The synchronization track can be also used for increasing resolution of encoder.

There are multiple sources of errors in pseudorandom absolute encoder: quantization error (due to digitalization), assembly errors (eccentricity), structural limitations (ellipticity of disc, disc deformations due to loading), manufacturing tolerances (inaccurately imprinted code patterns, positioning of code reading sensors) and ambient influences (temperature, vibration, contamination, light noise, humidity, etc.).

The sensor heads AUT and VER provide the synchronization pulses and sensor heads x(0) and $x(n)$ are used for pseudorandom code reading from two code tracks. The two code reading heads $x(0)$ and $x(n)$ [3, 7] can form two code words which should be on the same distance, and this fact enables implementation of procedure for checking of the code reading correctness, Figure s6. So, one code reading head is used to form the main pseudorandom n-bit code word (corresponding to the current position), and the other code reading head is used to form the control pseudorandom n-bit code word. The loading of the code bits into the main code assembly register X (bidirectional shift register for forming the main pseudorandom code word) and into the control register Y, depends on the movable system moving direction, and it is shown in Figure 6.

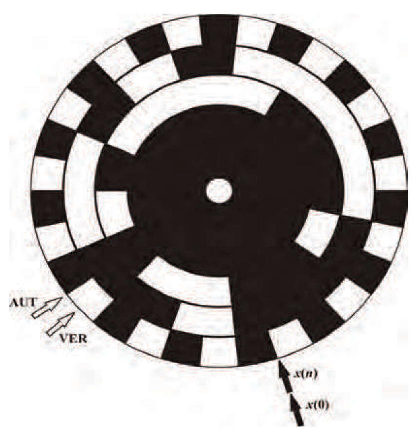

Figure 5. Pseudorandom absolute position encoder code disc

After reading of each code bit, the checking for code reading errors is performed according to the following procedure. Firstly, the content of register Y is shifted n times to the left using the direct generation law of pseudorandom binary sequence (PRBS) (for movement of the MS to the right) or n times to the right using the reverse generation law of pseudorandom binary sequence (for movement of the MS to the left). Selection of direct or reverse generation law can be done on the same way as selection of code reading heads, where simple logic is shown in Fig. 1. Finally, the equality of the obtained code word and the content of register X is examined.

Previously described principle can not be applied in the first n-quantization steps q right after the MS direction changing, because it starts with forming of the new control code word.

However, during this time the bits which were been in the register Y immediately before the MS direction changing, are read from the code track and loaded to the main shift register X. Also, the bits which were been in the register X immediately before the MS direction changing are loaded into the control shift register Y.

These bits can be used for checking the code reading correctness right after the MS direction changing and further to the moment when the complete control code word is formed again. After the each read code bit the checking equality of bit which was loaded in the main shift register X with bit which just stop to belong to content of control register Y. This can be realized by additional memorizing of that bit. Also, it is necessary to check equality of bit which was loaded in the control shift register Y with the memorized bit which just occurred on the serial output of register X.

Let the MS moves to the left, and the current content of code assembly registers is {X = 0110} and {Y = 0010} (Fig. 6).

After the MS moving direction changing, the new bits provided by the code reading heads x(0) = 0 and x(n) = 1 are loaded into the x(1) and y(1) stages of the code assembly registers X and Y, respectively. Obviously, in the moment when the new bit is loaded into the register X its correct value is in the stage y(4) of the control register Y. In the moment when the new bit is loaded into the control register Y its correct value is in the stage x(4) of the main register X.

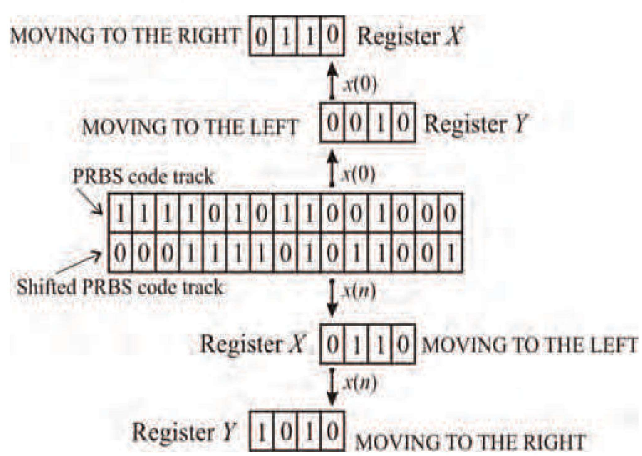

Figure 6. Code reading error detection with two code reading heads

Because the previous contents of the registers are simultaneously shifted to the left, in the moment of new bits loading in the main and control register, their correct value will be again in y(4) and x(4) stages. Similar consideration of the case when MS moving direction is to the right and occurs change of moving direction, gives conclusion that in the moment of new bits loading in the main and control register, their correct value will be always in y(1) and x(1) stages.

4. Zero Position Adjustment Method

The important functional part of pseudorandom absolute position encoders is zero position adjustment process. This adjust ment process is usually performed right after mounting of encoder to the rotating shaft. The direct zero position adjustment procedure for the proposed pseudorandom position encoder can be performed according to algorithm which is detailed explained and shown in reference [10]. The direct zero position adjustment process is usually done only one time during encoder mounting on the motor shaft, and in the end of algorithm some special parameters about finishing of this process are memorized in the encoder flash memory. That means, when encoder is later restarted these parameters stay memorized in encoder memory, so in further functioning of encoder algorithm for zero position adjustment is skipped. So, this algorithm does not further increase measurement time of absolute position.

In algorithm, firstly are read n bits using code reading heads and loaded to n-bit shift register. These n bits represent first formed code word, which will be accepted for zero position of encoder, if error detection procedure which will be performed to next read n bits does not find some errors in code reading. Accurate determination of zero position is essential for further functioning of pseudorandom absolute position encoder. In the error detection procedure are examined next read n bit for reading errors using procedure which was explained in Fig. 6. Before accepting and memorizing the content of n-bit shift register in flash memory, whole procedure must be executed without errors.

After procedure of direct zero position adjustment the encoder can start with absolute position measurements according to adequate algorithm. The pseudorandom absolute position encoders have advantage that any accurate read code word can be accepted as zero position. The pseudorandom/natural code converter now performs conversion process in relation to memorized zero position.

5. Conclusion

The two methods of serial pseudorandom code reading with one and two code reading heads are detailed explained. Then, one modified method of serial pseudorandom code reading with two code reading heads and with two pseudorandom code tracks is proposed and explained. With this modification easier practical realization of pseudorandom code reading process is obtained, better reliability and redundancy. Also method for checking of the code reading correctness for modified method of serial pseudorandom code reading is presented and detailed explained. This method significantly increases reliability of encoder in the process of absolute position measurement.

Method for direct zero position adjustment in described encoder which minimally increase measurement time, much less than in the case of using of correction factor at each absolute position measurement cycle, is also proposed. For pseudorandom code reading in proposed encoder can be used optical sensors which are normally used for incremental encoders, it is no need for custom solutions of optical sensors which would increase price of encoder.

Acknowledgment

Research activities presented in this paper, are supported by funds of the Ministry of Science and Technological Development of Republic of Serbia, having the reference project number TR32045.

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