Pseudorandom Position Encoder With Direct Zero Position Adjustment

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***Abstract*— Pseudorandom position encoder which uses two reading heads for serial code reading is described in the first part of this paper. This code reading method solves the problems of absolute position measurement in the case of moving direction changing and provides advanced methods of error detection. Then one method for direct zero position adjustment after mounting of the pseudorandom position encoder on the shaft is presented. The advanced method of error detection is used for reliable zero position adjustment.**

Keywords-pseudorandom position encoder; error detection; zero position adjustment

I. INTRODUCTION

The absolute position encoders are used in many applications that require precise shaft rotation, including industrial controls, robotics, computer input devices, rotating radar platforms, etc. Pseudorandom position encoders, as one of the latest innovations in this field of research, are introduced one code track for absolute position measurement which is their big advantage. They use property of pseudorandom binary sequence that sliding window of length n, which passes along a sequence, will extract unique code word in every moment [1]. Longitudinally arranged code words along a code track are overlapping, in such a manner that the first (n-1) bits of such a code word are identical to the last (n-1) bits of the previous code word. The essential functional parts of pseudorandom position encoder are the code reading system [2, 3, 4], code scanning [4, 5], error detection [6], and pseudorandom/natural code conversion [3, 7, 8].

The code reading system can be realized as parallel with sensor array or serial with using of one, two or more reading heads. The reliable code reading moment is defined using code scanning method which can use external synchronization track, internal synchronization using incremental encoded wheel or additional encoding of pseudorandom code bits, etc. The code reading error detection method increase reliability of pseudorandom position encoder. Pseudorandom/natural code converters can be realized as parallel, serial or serial/parallel. The fastest are parallel, but hardware expensive for high resolution encoders. Serial code converters require less hardware, but they are time expensive solution. The compromise between two opposite request, hardware cost and conversion time, can be fund in the serial-parallel code converters.

II. SERIAL CODE READING WITH TWO READING HEADS

Pseudorandom binary sequence provides a new way of code reading at absolute encoders using only one detector [2, 6, 8]. This serial code reading method uses a shift register for code word forming. Only one bit is read for each new position and along with (n-1) bits of the previous code word forms code word for new position. Disadvantage of this encoder is necessity of n bits initial moving for forming of first valid code word, loading of the shift register. Serial code reading with one head loses information about position when occurs any change of movement direction.

The code reading method that eliminates this drawback and enables a reliable method for permanent checking of the code reading correctness is presented in Fig. 1. This solution is based on introducing one more reading head at distance of nq, where q is value of code track quantization step. A simple logic (multiplexer 2/1) consisted from two AND and one OR logic gate [2] 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 $x(0)$. So, on that way does not occur loosing of position information during change of moving direction. This reading method requires correction of position information for one moving direction.

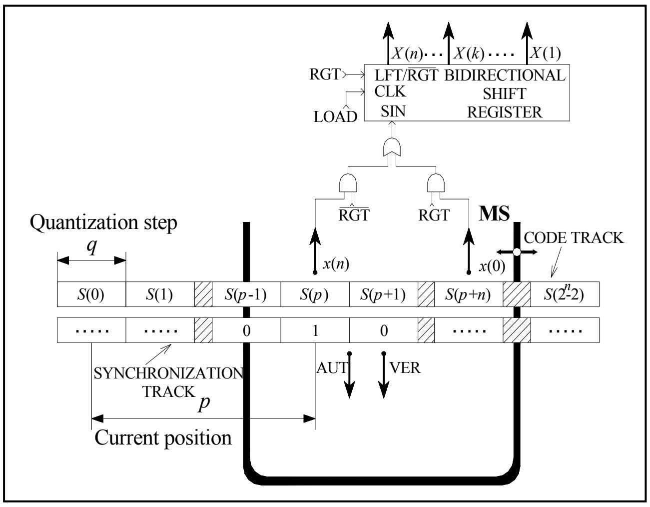

Figure 1. Serial pseudorandom code reading with two reading heads

Now, the continuity in forming the pseudorandom *n*-tuples code word is achieved even for the possible oscillations of movable system (MS) along the movement course. Application of this code reading method is especially convenient in systems where oscillations of movable system can occur.

The code scanning in pseudorandom position encoder shown in Fig. 1 is solved by using an external synchronization track next to the pseudorandom code track. Synchronization occurs only at the borders of the synchro signals in synchronization track, that is achieved in reality by shifting of two heads by the half of a quantization step. 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 [3, 7].

III. Error Detection with Two Code Reading Heads

The code reading error detection method 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 Fig. 2.

The constant distance between two code reading heads of $n{\cdot}q$ [2, 6] is a reference that enables checking of the code reading correctness, Fig. 3. According to this error detection method, 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 Fig. 3.

After the each read 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) [8] (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).

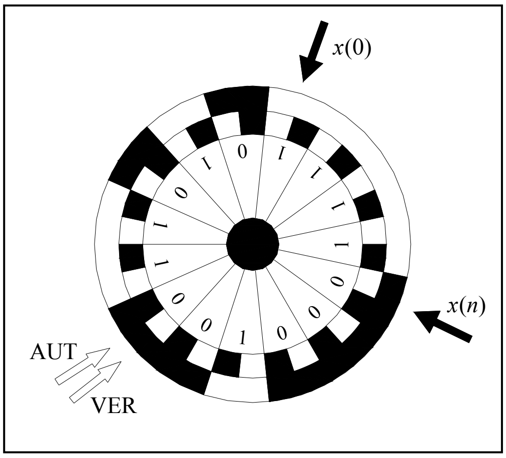

Figure 2. Pseudorandom absolute position encoder code disc

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* = *1011*} and {*Y* = *0010*} (Fig. 3). After the MS moving direction changing, the new bits provided by the code reading heads $x(0) = 0$ and $x(n) = 0$ are loaded into the $x(1)$ and $y(1)$ stages of the code assembly registers *X* and *Y*, respectively.

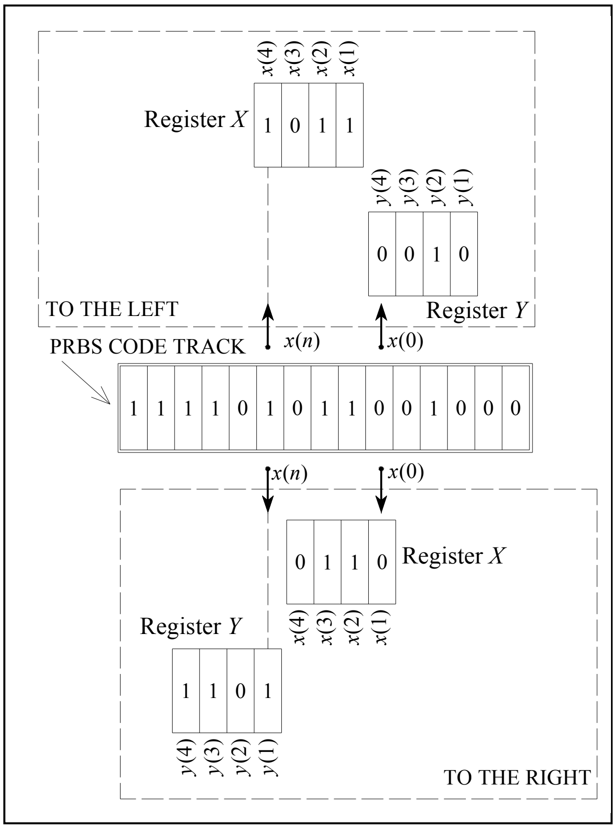

Figure 3. Error detection with two code reading heads

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*.

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.

IV. DIRECT ZERO POSITION ADJUSTMENT METHOD

The zero position adjustment is important functional part of pseudorandom absolute position encoders, as reference code word can be formed and used in measurements of absolute position. This adjustment is usually performed right after mounting of encoder to the rotating shaft. The direct zero position adjustment procedure is explained in form of algorithm, shown in Fig. 4. In presented algorithm in Fig. 4, the direct zero position adjustment is done for parameter values “Z=0“, while parameter “T=1“ is related to pushbutton, did it pressed. If parameter “Z=1“ the zero position is already determined. Firstly, the parameters T and Z are putted in flesh memory of encoder itself, and on the end of procedure are permanently stored. That means, when encoder is restarted parameters T and Z stay memorized in encoder memory, so in further functioning of encoder algorithm from Fig. 4 is skipped. So, this algorithm does not further increase measurement time of absolute position.

If procedure of zero position adjustment isn’t performed yet then pushbutton is pressed (“T=1“), and follows execution of algorithm for zero position determination. In algorithm, firstly counter *p* is reset to zero, then are read next *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 next error detection procedure 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. 3. Before accepting and memorizing the content of n-bit shift register in flash memory, whole procedure must be executed without errors. If error detection method, which uses information from both code reading heads, does not find errors in *n* consecutive bits, then content of shift register is memorized to flash memory as zero position. Also, parameters “Z=1“, and “T=0“ are stored to the flash memory.

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. Disadvantage of pseudorandom absolute position encoders is necessity for initial movement of encoder before starting of absolute position measurement process, which is not the case at classical absolute encoders. Procedure of direct zero position adjustment eliminate need for correction of each read position value. Now, the correction factor does not exist, which would be added or subtracted from current read value in process of position measurement.

The pseudorandom encoder with applied method of parallel code reading has relatively easier procedure of zero position determination [9]. This encoder uses integrated circuit which has linear photodetector array for simultaneously reading of all *n* bits on pseudorandom code track. Here, for zero position determination, firstly reading of the photodetector array is performed, and then follows adoption of read code word for initial code word.

A necessity for using of permanent memory does not significantly increase complexity of needed hardware for realization of encoder electronic block.

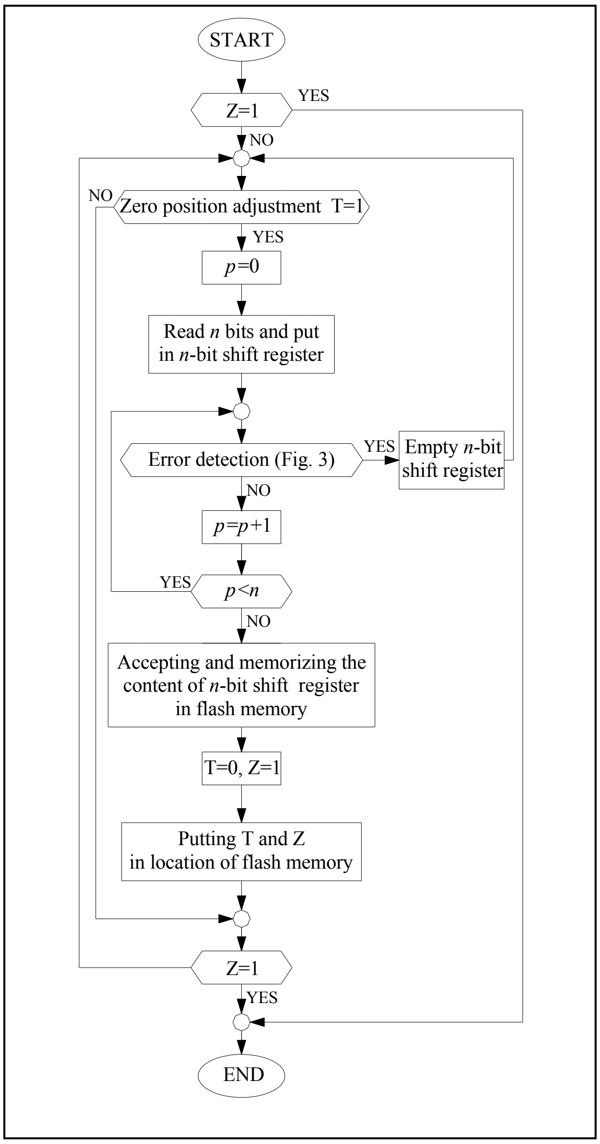

Figure 4. Direct zero position determination method

Encoder will be in the future one intelligent sensor when standard will dictate that the encoder memory element will have permanently stored information, such as factory number, parameters for processing of measured data, identification of address, receiving of command/data, generating and transmitting of data/command, autocalibration procedure, zero and offset adjustment, autotesting, etc. Furthermore, from the modern encoders is or will be requested an independence in deciding at control systems, local data processing and statistics. Therefore, the introducing of memory element is or will be necessary in the future standards. The proposed solution of direct zero adjustment is useful and needed feature of modern encoder.

V. Conclusion

Today, the pseudorandom absolute position encoders become competitive to classical absolute encoders. In the paper are explained method for pseudorandom code reading with two code reading heads and also method for checking of the code reading correctness. These methods significantly increase reliability of encoder in the process of absolute position measurement. In the second part of the paper is presented method for direct zero position adjustment which minimally increases measurement time and eliminates using of correction factor at each absolute position measurement cycle. This method requests memory element for hardware realization for storing of code word which is adopted as zero position. One disadvantage of pseudorandom absolute position encoders is need for very small initial movement of the movable system before starting of absolute position measurement process.

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