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VIRTUAL INSTRUMENT FOR ANGULAR POSITION AND VELOCITY MEASUREMENT BASED ON IMPROVED PSEUDORANDOM BINARY ENCODER

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Abstract
Signals from realized improved pseudorandom binary encoder, which have two mutually shifted pseudorandom code tracks and one synchronization track, were brought to the inputs of the acquisition card and exploited in virtual instrument for angular velocity and position determination. This encoder enabled the application of advanced code reading error control techniques, as well as the operation in case of failure of a single code track or one code reading head. This system can be used in many applications where it is necessary to reliable and accurately measure the angular position and velocity.

Keywords: pseudorandom binary sequence, absolute pseudorandom position encoder, virtual instrument, LabVIEW

INTRODUCTION

Modern industrial automation systems require reliable and accurate position transducers for achieving excellent control. Optical encoder is often used for this purpose. In the paper is used new pattern of code disc, based on pseudorandom binary sequences, with the aim of improving resolution and reliability of absolute optical encoder.

Concept of virtual instrumentation is used for implementation of operation algorithm for proposed angular position and velocity measurement [1, 2]. Virtual instrument acquires signals from encoder through USB acquisition card and determines position and speed information in an algorithm implemented in LabVIEW software. This instrument is easy to upgrade and change, in order to get an optimal working algorithm. The main sources of measurement uncertainty in the virtual instrument [3] are in transducers, circuits for signal conditioning, data acquisition hardware, application software for measurement and computer.

Pseudorandom absolute position encoders use property of pseudorandom binary sequence (PRBS) that window of width *n*, which moves along the *n*-bit sequence can extract a unique code word for absolute position determination [4, 5]. Code words are arranged longitudinally on the pseudorandom code track, and two successive code words differ in only one bit. These encoders have one code track, regardless of resolution, and can apply serial code reading, which is a significant advantage over classical absolute encoders. Also, the advantage of these encoders in comparison to the classical ones may be due to the possibility of applying advanced techniques for code reading error detection.

Pseudorandom position encoder must have a code reading system [5, 6], the synchronization system [5, 7, 8], the pseudorandom/natural code converter [5, 8, 10], and it is preferable the code reading error detection system [9]. The code reading can be implemented with one or two sensor heads, but also with a linear array of photodetectors.

Synchronization method is usually implemented using external synchronization track. In order to get the natural code, pseudorandom/natural code conversion is done, serial, slower method or parallel, faster but hardware more expensive method, and can also compromise solution over serial / parallel converters.

Virtual instruments for measurement of angular position and angular velocity based on the signals from incremental encoders can be found in the literature [11]. In this paper is presented virtual instrument for measuring the angular position and velocity based on the signals from the code disk of pseudorandom absolute position encoder.

REALIZED PSEUDORANDOM ABSOLUTE POSITION ENCODER

First, it was designed and printed code disk of encoder with diameter 50 mm on plastic foil, with synchronization and two mutually shifted 10-bit pseudorandom code tracks. The disk is centered on the motor shaft, and the reading is done with MO-PMD09 optical sensor (www.micropto.com), Fig. 1. Separate reticle for guidance of infrared light beam is also designed specially for this disk.

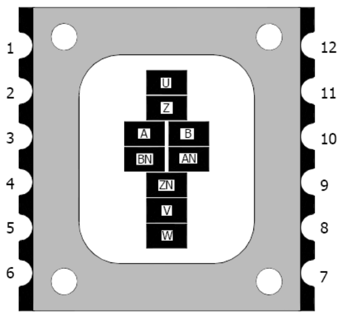

Fig. 1. *MO-PMD09 optical sensor for encoder*

Electronic system for the code disc reading of this pseudorandom absolute position encoder is also realized, Fig. 2. Four diodes (A, AN, B, and BN) from the MO-PMD09 chip are used for differential scanning of the synchronisation track, one diode ZN for scanning of the pseudorandom code track, and also one diode W for scanning of shifted pseudorandom code track. The photodiodes are inversely polarized and used in a "photoconductive" mode, their internal P/N junction capacitance is then smaller, which assures higher operating frequencies. The quad CMOS rail-to-rail input and output MCP6024 operational amplifiers (made by „Microchip“) are used for the photodiodes' current-to-voltage conversion. The obtained quasi-sine wave are then shaped into digital (TTL) signal.

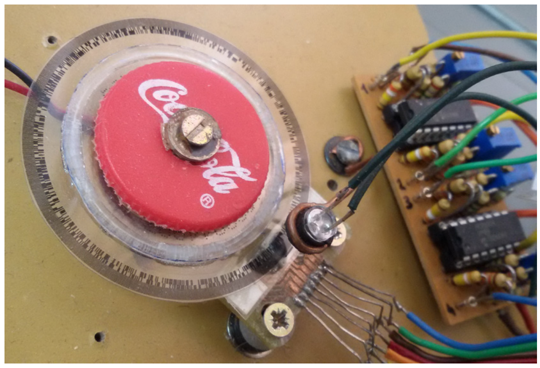

Fig. 2. *The code disk with an electronic system of code reading*

The implemented system provides four signals, two with a synchronization track and two with two pseudorandom code tracks. These signals are channeled into four digital inputs of the USB acquisition card NI USB-6341. This acquisition card has 16 analog inputs with sampling rate 500 kS/s, 2 analog outputs, 24 digital inputs/outputs, 4 counters, etc. So, four inputs signals can be sampled with a maximum of 125 kS/s, which is enough for this realization.

The two signals obtained from synchronization track are phase shifted for 90° and are used to determine the direction of rotation as well as to accurate determine the moment of pseudorandom code reading. Also, one signal from synchronization track is used for angular velocity determination using counters in acquisition card. Pseudorandom code tracks are mutually shifted for 9 bits, so read bits from one pseudorandom code track is used for forming a code word when rotation is in clockwise direction, and read bits from the shifted pseudorandom code track for opposite direction.

VIRTUAL INSTRUMENT FOR ANGULAR POSITION AND VELOCITY MEASUREMENT

Based on signals, read bits, from pseudorandom code tracks the 10-bit code word is formed in the shift register of virtual instrument. When the encoder starts, initial time is needed until the first 10-bit code word is formed, or until the first valid position is determined, which is a consequence of the serial code reading. The problem of determining a position when changing the direction of rotation, which exists in the case of using one code reading head, is solved by introducing another code reading head for shifted pseudorandom code track. After forming the first valid 10-bit code word, with each subsequent read bit, the virtual instrument gets new 10-bit code word that is compared to the previous code word differs only in one bit.

The formed pseudorandom code word from previously read 10 bits is stored in the shift register in the block diagram of the virtual instrument. The code word is then converted from pseudorandom to natural code using a serial code converter based on the Fibonacci generator of PRBS [10]. The code word which was adopted as the initial code word is determined during mounting process of encoder to the motor shaft, where some properties of PRBS can be exploited for easier solution of this problem. This initial code word is used as a reference with which to compare the read code word, and the generated code words of the Fibonacci generator in each clock period. The binary counter is used to determine the required number of steps to equalize the initial code word with the contents of the Fibonacci generator registry. On this way is obtained information about absolute position. The feedback configuration of Fibonacci generator in code converter must be compatible with configuration which is used during generation of 10-bit PRBS.

Front panel of realized virtual Instrument, Fig. 3, displays real time signals with a synchronization (channel A and B), as well as with two shifted pseudorandom code tracks (PRBS1 and PRBS2). Also, on the front panel there is information about the direction of rotation, then a part of the read PRBS sequences (LED array indicator), as well as information about angular position and velocity. Determined absolute position is displayed in digital form using waveform chart, where the position changes in the range 1-1024. Acquisition parameters (sampling rate, buffer size) of input signals can be changed in the front panel of the virtual instrument.

The angular velocity is determined using the direct counting method shown in reference [12], using pulses in one signal from the synchronization track. This acquisition card has two general purpose 32-bit counters which are used for angular velocity measurement. Applied simple method is based on counting of pulses from synchronization track in fixed time interval. Realized encoder has 2048 pulses from synchronization track per one rotation, which can be increased by detecting each transition (rising and falling edges) of both signals from synchronization track, when resolution is bigger by a factor of four.

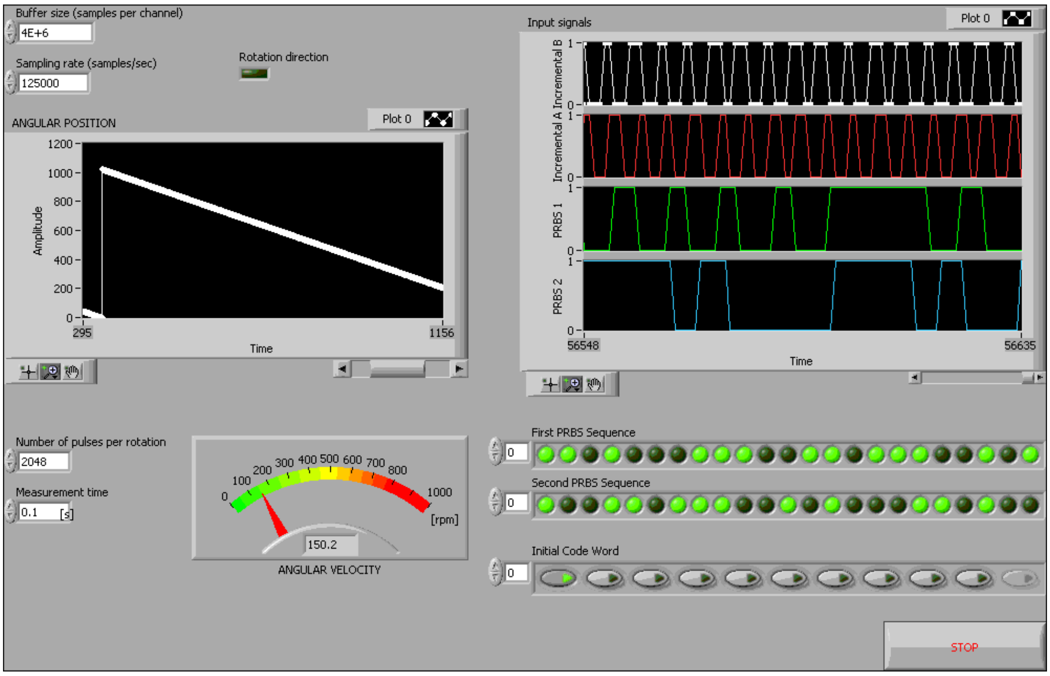

Fig. 3. Front panel of realized virtual instrument

The accuracy of the read code bit is checked and based on this the further operation of the encoder is determined [9]. If no code reading error has occurred, the absolute position is determined by applying pseudorandom/natural code conversion. The procedure for checking the accuracy of the read bits makes it possible to determine whether the error occurred in one code track or in both. If the error of the read bits has occurred in both code tracks, the encoder continues to operate in the incremental mode, where the increment or decrement of the value of the position is made based on the direction of rotation. However, if the bit read error occurred in a single code track, the encoder continues to operate in a reduced reliability mode with a single code track.

Electronic block of encoder is usually realized using the microprocessor or programmable FPGA, and realized operation algorithm of presented encoder can be transfered to this circuits.

CONCLUSION

It is presented one reliable absolute position 10-bit encoder with disc diameter 50 mm based on pseudorandom binary sequence. Working algorithm is implemented using virtual instrumentation concept which is one modular and adaptive system for measuring angular position and velocity. Based on the signals obtained from the electronic system for code reading a reliable position and velocity information is obtained. Advanced code reading error detection techniques have been implemented, as well as work in the event of failure of one reading head for code track or contamination a part of the code track. So, encoder can work with two code tracks, the most reliable working regime, then with one code track, working mode with reduced reliability, or in worst case scenario as incremental encoder using synchronization track.

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