Application of Virtual Instrumentation for Measuring the Angular Position and Velocity

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Abstract – **Accurate measurement of angular position and velocity is required in many modern movable systems in industry and everyday life. Realized virtual instrument for measuring the angular position and velocity is tested and presented in this paper. It uses signals at the output of the electronic system for optical code reading from a glass code disc of 10-bit pseudorandom encoder, which has two code (pseudorandom) and one synchronization track. Presented virtual instrument is modular and adaptable, and can be modified and upgraded some of its elements. The use of computer and modular hardware, as well as the USB interface defines the limit frequency of the instrument.**

Keywords – **position measurement, pseudorandom position encoder, velocity measurement, virtual instrument**

I. Introduction

Virtual instrument is a combination of hardware and software elements, the most commonly used with a PC, which is accomplished classical instrument function [1, 2]. Functionally, virtual instruments, as computer-based instruments, can perform the tasks of measuring, monitoring, acquisition, simulation, testing, and so on.

Virtual instruments, usually designed in LabVIEW software environment, have properties of good flexibility, easy modification, hierarchy and modularity, easy connectivity with other instruments, the Internet, various data presentations, etc. Such an instrument could be later adapted, repaired, and extended its functionality. The three main parts of the virtual instrument software are the front panel, the block diagram, and the icon with the connector. Using graphical programming in realization of virtual instrument was removed some difficulties related to programming with textual programming languages, and shorten the time of realization of an instrument. Sources of measurement uncertainty with virtual instruments [3] that need to be addressed when determining the measurement uncertainty are: transducers, signal conditioning circuits, data acquisition, application software for measurement, computer.

Absolute pseudorandom position encoders can be used to accurately measure the angular position and additionally the angular velocity in various fields of industry (machinery, motors, conveyors), elevators, telescopes, antennas, computer peripherals (printers, mice), and so on. The window of length n, which slides along the n-bit pseudorandom binary sequence (PRBS) allocates a unique code word at any time, which is used to determine the absolute position of the pseudorandom absolute position encoder [4, 5]. Unlike conventional absolute encoders, code words are now longitudinally arranged on the code track; with two consecutive code words differ in only one bit. Some of the advantages of absolute pseudorandom position encoders compared to conventional absolute encoders are they only have one code track on the code disk, regardless of the resolution encoder; then they are more reliable due to the possibility of using the method for detecting code reading errors; code reading can be implemented using one or two sensor heads as a serial code reading, etc.

The main functional parts of a pseudorandom absolute position encoder are code reading system [5, 6], the code scanning method [5, 7, 8], the code reading error detection methods [9] and the pseudorandom/natural code conversion methods [5, 8, 10]. The pseudorandom/natural code conversion can be done as parallel, which is the fastest way, serial or a combination of these two methods.

Angular velocity is an important parameter which usually needs to be regulated or monitored in different servo, mechatronic, robotic and precise production systems. One signal from synchronization track is used for angular velocity measurement. There are different methods for velocity measurement, and here is used the direct counting method (or M method) [11]. This method is based on counted pulses from the encoder in fixed-time intervals.

In the literature we can find realized virtual instruments for measuring the angular position and velocity based on the application of the incremental encoder signals, whereby the principle of determining the angular position considerably simpler than in the case of pseudorandom position encoder [12]. This paper presents a virtual instrument for measuring the angular position and velocity, based on signals from the code disk of pseudorandom absolute position encoder.

II. Functional parts of virtual instrument

The signals that are used for measuring the angular position and velocity in realized virtual instrument were obtained using an electronic system for optical reading from glass code disk of realized pseudorandom position encoder, Fig. 1. The code disk of pseudorandom position encoder has synchronization and two phase shifted 10-bit pseudorandom code tracks. The

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signals obtained with an electronic system of optical code reading are fed to USB multifunction data acquisition card NI USB-6341, which is shown in Fig. 2. The two phase shifted signals from synchronization track are used to determine the direction of rotation as well as the determination of the moment reading pseudorandom code on two pseudorandom code tracks. One signal from synchronization track is also use for measuring the angular velocity. Signal from one pseudorandom code track is used to form a code word during movement in one direction, while the other signal, phase-shifted, from another pseudorandom code track is used for the second direction of movement of the shaft encoder.

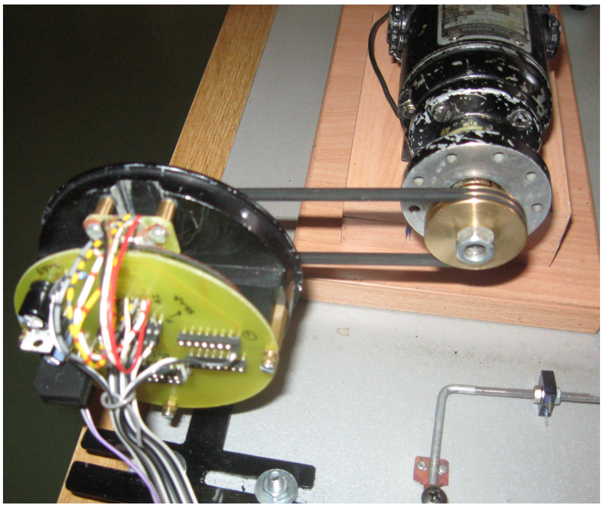

Fig. 1. The code disk with an electronic code reading system

Fig. 2. The external appearance of acquisition cards X series (made by National Instruments)

NI USB-6341 acquisition card has 16 analog inputs of 16-bit resolution with a sampling rate 500 kS/s, 2 analog outputs, 24 digital inputs / outputs, 4 counters, etc. The signals at the output of the electronic system for code reading are also observed and analyzed on a digital oscilloscope, Fig. 3. The first two digital TTL signals are from synchronization track, and the other two from two phase shifted pseudorandom code tracks.

M method or direct counting method is simple and widely used method for angular velocity measurement, and it is based on counting of pulses in fixed time interval. C_P denotes the number of counted pulses in fixed sampling period T_S. The measured velocity ω is estimated using

$$\omega = \frac{60C_P}{PT_S}[rpm], \tag{1}$$

where P denotes the number of encoder pulses per rotation, and it can be changed in the front panel of the realized virtual instrument, which depends on the applied encoder type. Measurement time is equal to the sampling period T_S, and it can be changed in the front panel. One counter is used for determination of sampling period and the other counter is used for counting the encoder pulses. This method has good accuracy at high speed.

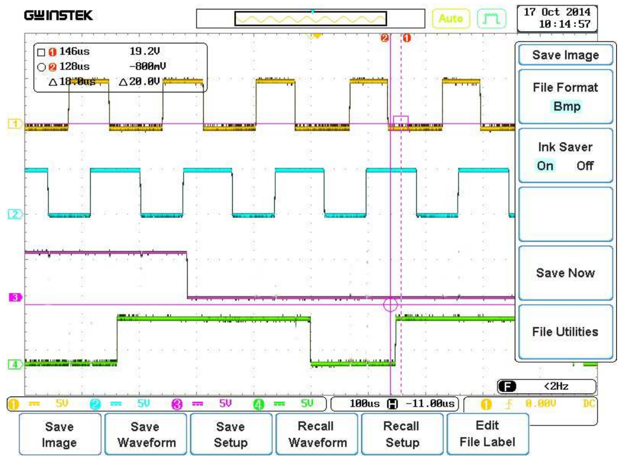

Fig. 3. Pseudorandom encoder signals on the screen of the digital oscilloscope

Using two phase shifted signals from synchronization track obtained information on the direction of rotation of the encoder using the same method as for incremental encoders. Based on the signals from pseudorandom code tracks the read 10-bit code word is formed in a bidirectional shift register, within virtual instrument block diagram. This code word is used for determination of position information, Fig. 4. Signal from one pseudorandom code track is used for one direction of rotation of the shaft encoder, and a second signal for the opposite direction of rotation of the shaft encoder. The disadvantage of using serial reading of pseudorandom binary code is that the after system initialization it takes some initial time until a first valid pseudorandom code word is formed. After that with each clock period gets new 10-bit code word that is compared to the previous code word differs only in one bit.

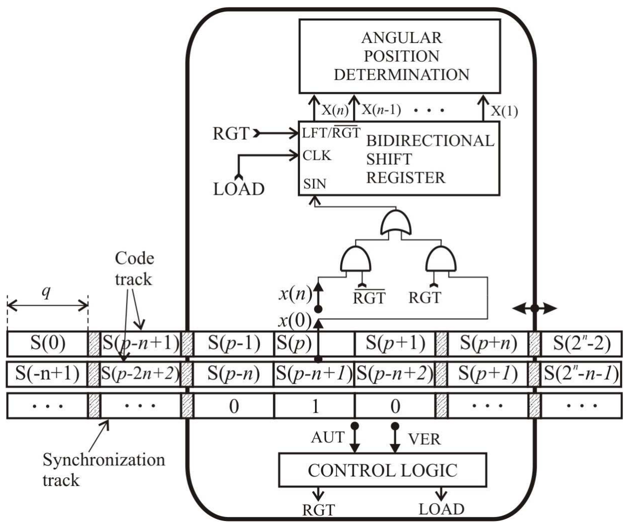

Fig. 4. Forming read code word in the registry

The read 10-bit pseudorandom code word formed in the bidirectional shift register in the block diagram of the virtual instrument, is converted from a pseudorandom to natural code using serial code converter based on the Fibonacci generator of 10-bit PRBS, Fig. 5. The code word, which was adopted as the initial code word is used as a reference with which to compare the read code word and the code word generated in the Fibonacci generator in each clock period. When the initial code word equalize with code word in Fibonacci generator of PRBS the 10-bit counter is stopped, and at its output provides information about the position in natural code. The feedback configuration of the Fibonacci generator is defined for 10-bit PRBS and can be found in the literature. This conversion process is here realized in the block diagram of virtual instrument and his speed depends on computer configuration.

III. Front Panel of the Virtual Instrument

Realized virtual instrument, Fig. 6, on its front panel displays in real time the signals from the synchronization track (channels A and B), as well as two signals from the pseudorandom code tracks (channels C and D). Information about angular position and angular velocity is also displayed. Angular position obtained in the opposite direction of rotation of the shaft encoder has a negative sign. The indication of the direction of the shaft rotation is also given. The input signals are recorded on the hard disk of the computer, for eventual their later processing or analysis, and on the front panel can be changed location and name of the recorded file. Also, parameters for input signal acquisition (buffer size, sampling rate) can be changed in the front panel.

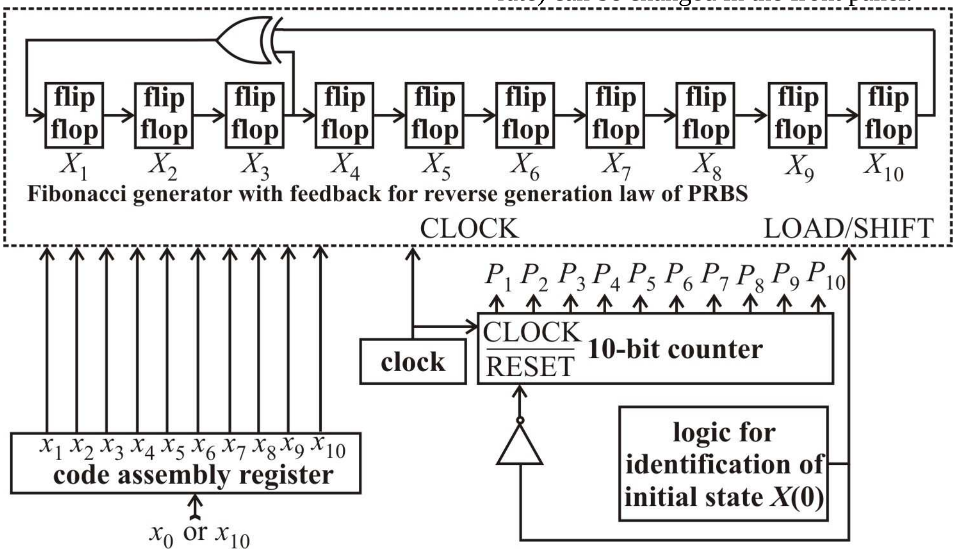

Fig. 5. The serial pseudorandom/natural code converter

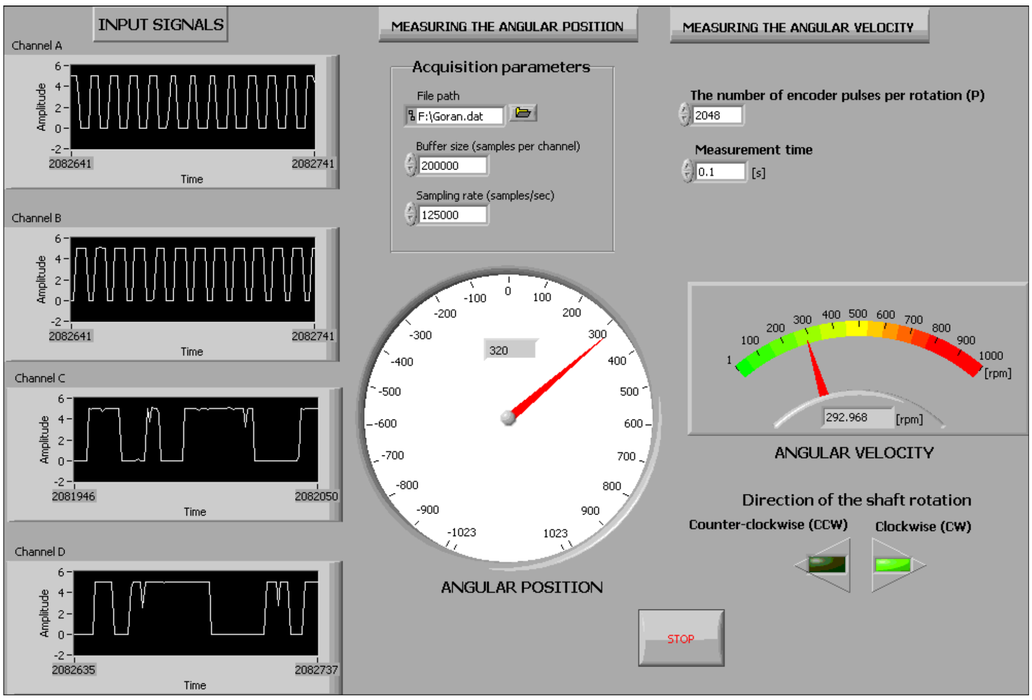

Fig. 6. Virtual instrument for measuring the angular position and velocity

Parameters, the number of encoder pulses per rotation, P, and measurement time, T_S, which are used for angular velocity determination can be also changed in the front panel of virtual instrument. This realized virtual instrument can be subsequently modified and changed, depending on the specific application, input signals, etc. This instrument is portable in case of using laptops. Its performance depends on the used acquisition card, as well as the used computer configuration. Electronic block of encoder is usually made using a microprocessor or programmable FPGA circuits for maximum performance. However, and this is realized measuring the angular position and velocity may very well find its practical application in various areas where you need precise positioning of different machines, robots, telescopes, cranes, etc. Graphical programming significantly reduces the time required for the implementation of such a system.

IV. Conclusion

Presented virtual instrument for measuring angular position and velocity represents a modern, modular, adaptive system which uses signals from code disk of pseudorandom position encoder. Realized virtual instrument uses a modular hardware, computer software, which allows you to expand the variety and upgrading performance. This virtual instrument allows the measurement of angular position and velocity based on the signals obtained from the electronic system of reading the code with encoder code disk and storing these signals, adjust the signal acquisition and observation signals in real time on the front panel of the instrument. The virtual instrument performance depends on the used computer configuration and modular hardware.

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