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A SOFTWARE SOLUTION FOR DETECTION OF MOTION DIRECTION

NICOLAE PĂTRĂȘCOIU[1], COSMIN RUS[2], CECILIA ROȘULESCU[3]

Abstract: This paper presents a software solution to implement a detection of a movement direction for a mobile moving in a linear or circular direction. For this, are determined logical functions using the principles of Moore automata sequential and these logical functions are implemented using LabVIEW graphical programming elements. It is thus possible to achieve a virtual instrument to control the operation of a data acquisition boards, for general use like PCI-6024E, by which is possible to determine the amount and direction of linear or angular movement.

Keywords: incremental sensor, direction, virtual instrument, data acquisition board.

1. INTRODUCTION

Movement is defined as a physical quantity of a mechanical change through is possible to provide information about position of a material point or mobile against a reference system. In many applications the displacement is considered as a vector so it is necessary to calculate both size and direction for this quantity.

Usual procedure for calculating the size of this quantity is to use incremental displacement sensor that generates a pulse train by counting of these pulses acquired from sensor.

Same incremental displacement sensor can be used to detect the direction of movement if it provides two trains of pulses shifted by one quarter of the period, in which case it is named quadrature encoder. A quadrature encoder can have up to three channels – channels A, B, and Z. There are data acquisition boards that accept at their counters signals provided by encoder quadrature signals such as the NI 622x, NI 625x, and NI 628x (M series devices) but there are also data acquisition boards that not accept such signals like the NI PCI-6024 (E series devices) [6]. In this case it is necessary to achieve a logical system to detection the direction of motion. Such a system can be achieved through structure hardware but also can be done by a software

[1] *Associate Prof. Eng. Ph.D. at the University of Petroşani, nicolaepatrascoiu@upet.ro*
[2] *Eng.,Ph.D. student at the University of Petroşani, cosminrus@upet*
[3] *Professor, Grigore Geamănu School*

solution using digital inputs of the data acquisition board.

Data acquisition board PCI-6024E has 8 digital inputs and two of them will be used to detect the direction and two counters that will be used to determine the size of displacement in one direction or another.

2. DETERMINING OF THE LOGICAL FUNCTION

To make a determination either linear or angular displacement is first necessary to determine its direction. After that, it can control the counting direction for the counter through which is determined the value of displacement by counting the train of pulses.

To measure angular displacement, we use PCI-6024E, a data acquisition board from National Instruments that has 8 digital I/O (DIO0 … DIO7) lines (TTL/CMOS) and two 24-bit counter/timers without having the dedicated inputs to connect a quadrature encoder. Control the operation of the data acquisition boards is achieved through a program written in LabVIEW graphical programming language and called virtual instrument.

To achieve the determination of displacement direction is needed in these conditions to be used two digital inputs to connect to the signals A and B carried over from the quadrature encoder. Displacement value is obtained by counting the pulses A or B, and its direction is determined by counting purposes, otherwise said, by increment or decrement the counter value [5].

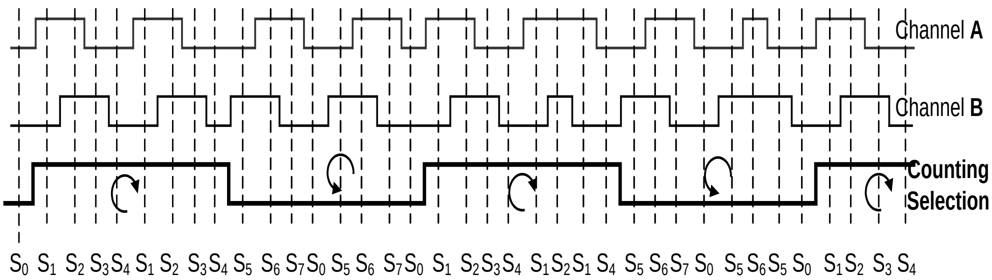

Fig. 1. Signals chart that identify the direction of displacement

To realize the virtual instrument for angular displacement measurement based on two trains of pulses shifted by one quarter of period is necessary to synthesize a control command for counting direction.

For synthesizing the command control signal called Counting Selection is considered a chart signals (Fig.1.) that identify all the possibilities of combining the two pulse trains according to the direction of rotation.

Following the diagram signals depicted in Fig. 1, 8 distinct states denoted by Si (i = 0 ... 7) can be identified, corresponding to 8 possible combinations of logic levels for both Channel A and Channel B signals and output signal Counting Selection. Based on this chart states is constructed the states transition graph shown in Fig. 2.

It consists of nodes represented by the 8 states previously identified and arcs represented by binary combinations of both Channel A and Channel B signals through which made the transition between states. Each node is characterized by the logical level of the signal Counting Selection and has an arc with logical combination of both Channel A and Channel B signals for which do not change the status for state of respectively node.

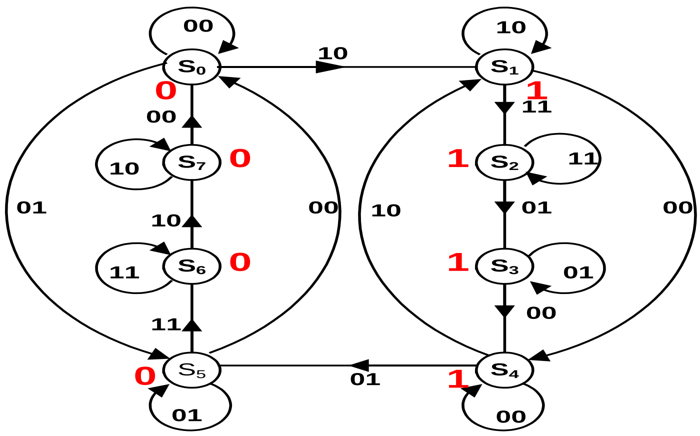

Fig. 2. Transition graph of states

Based on the transition graph is built the primitive matrix that contain on the columns the input signals Channel A and Channel and on the rows contains all possible transitions from one internal stable state. This is accompanied by full matrix of the output that contains the values of output variable during both states and transitions. Columns are cyclic coded so that from one column to another does not change more than one input variable and therefore is used Gray code. Primitive matrix of states is presented in Fig. 3.

States					**Counting Selection**
AB	00	01	11	10	
S_0	$\mathbf{S_0}$	S_5	-	S_1	0
S_1	S_4	-	S_2	$\mathbf{S_1}$	1
S_2	-	S_3	$\mathbf{S_2}$	-	1
S_3	S_4	$\mathbf{S_3}$	-	-	1
S_4	$\mathbf{S_4}$	S_5	-	S_1	1
S_5	S_0	$\mathbf{S_5}$	S_6	-	0
S_6	-	S_5	$\mathbf{S_6}$	S_7	0
S_7	S_0	-	-	$\mathbf{S_7}$	0

Fig. 3. Primitive matrix of states and output

To identify a minimal configuration of the sequentially system is built a reduced matrix of states. Technique used to reduce the number of states from primitive matrix, is based only on the equivalence from the theory of sequential automatic and reduction of state is through merger or annexation in compliance with specific rules [1]. Applying these rules it can obtain the reduced matrix of states and the corresponding output shown in Fig. 4.

x_1x_2 \ AB	States 00	01	11	10	Counting Selection
00	**S_0**	S_5	-	S_1	0
01	S_4	**S_3**	**S_2**	**S_1**	1
11	**S_4**	S_5	-	S_1	1
10	S_0	**S_5**	**S_6**	**S_7**	0

Fig. 4. Encoding reduced states

To obtain the excitation functions of the sequentially system is required to encode the reduced matrix states. It notes the existence of 4 reduced states so that would be necessary to encrypt them by two state variables i.e. x_1 and x_2, Fig. 4. To take account of hazard that occurs due to simultaneous change of more than one input variable during transition between two states is used the Gray code.

To construct the excitation functions, represented by logic functions for states x_1 and x_2 is necessary to build matrices of transition for reduced states and their number must be equal to the number of state variables. These matrices are shown in Fig.5 respectively Fig. 6 in which notation X means states impossible during operation.

x_1x_2 \ AB	State x_1 00	01	11	10	Counting Selection
00	0	1	x	0	0
01	1	0	0	0	1
11	1	1	x	0	1
10	0	1	1	1	0

Fig. 5. State transition matrix for x_1

x_1x_2 \ AB	State x_2 00	01	11	10	Counting Selection
00	0	0	x	1	0
01	1	1	1	1	1
11	1	0	x	1	1
10	0	0	0	0	0

Fig. 6. State transition matrix for x_2

Applying the method of synthesis of logical functions based on Karnaugh diagrams it can identify the logical functions of the excitation variables (states) x_1, x_2 respectively for function of output signal Counting Selection as follows:

$$\begin{aligned} &x_1 = B \cdot x_1 + \overline{A} \cdot \overline{B} \cdot x_2 + B \cdot \overline{x_1} \cdot \overline{x_2} + A_1 \cdot x_1 \cdot \overline{x_2} \\ &x_2 = \overline{x_1} \cdot x_2 + A_1 \cdot \overline{x_1} + \overline{B} \cdot x_2 \\ &Counting\ Selection = x_2 \end{aligned} \qquad (1)$$

From equations (1) can be seen that the output signal is identical to the state x_2. From equations (1) can be seen that the output signal is identical to the state x1, which simplifies implementation with logic gates for the scheme that generate the control signal for counting direction.

Based on logical functions (1) can create a logical diagram of the system through which make selection for direction of counting, shown in Fig.7.

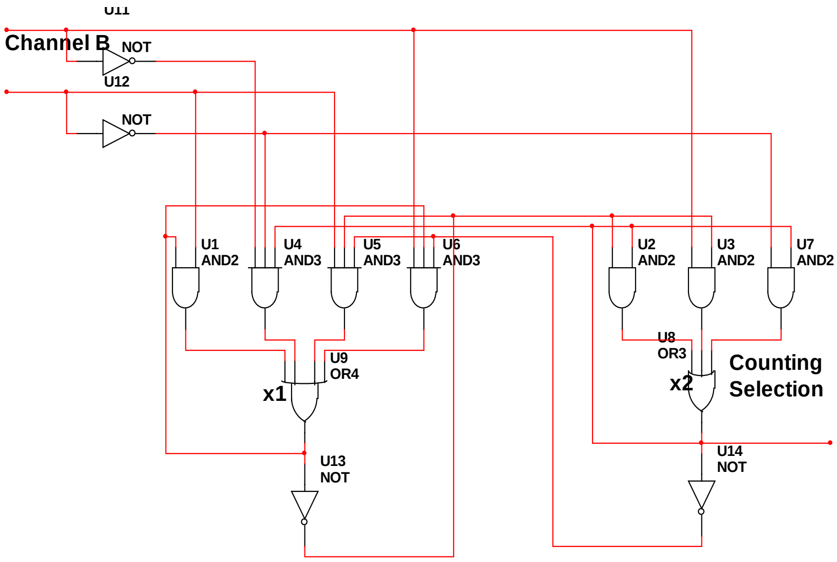

Fig.7. Logical diagram of the system

Checking the correctness of system operation was achieved in the first phase, by simulation and for this was used Multisim® program from National Instruments [7]. Based on simulation results presented in Fig.8 it can observe that selection signal changes logical levels in according to the direction of rotation given by the sequence of pulse trains Channel A, Channel B, respectively.

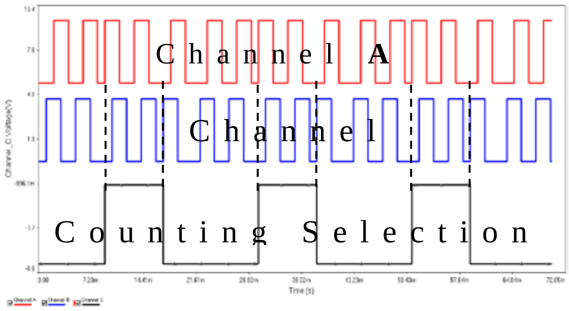

Fig.8. System simulation results

3. THE LOGICAL FUNCTION IMPLEMENTATION BY VIRTUAL INSTRUMENT

A program developed in LabVIEW is called a virtual instrument (VI) and it has two components the block diagram that represent program itself and the front panel that is user interface. Through such a virtual instrument can be controlled the operation of the data acquisition board PCI-6024 whose digital inputs DIO0 and DIO1 are used for acquisition of Channel A and Channel B signals from incremental sensor.

To achieve virtual instrument is used DAQ Assistant function that creates, edits, and runs tasks using NI-DAQmx that is data acquisition driver. Read through this function is an array with eight boolean components corresponding to the eight digital inputs of the data acquisition board and through Index Array function are selected components with index 0 and 1 that correspond to digital inputs DIO0 respectively DIO1. Thus the two components will be the inputs Channel A and Channel B of the system developed for determining the direction of displacement, system that generates the output signal Counting Selection.

In Fig.9 is shown the structure of this system built with logical functions based on the logical diagram presented in Fig.7. Are used Compound Arithmetic/Logic functions through which can select basic arithmetic or logic operations with two or more variables.

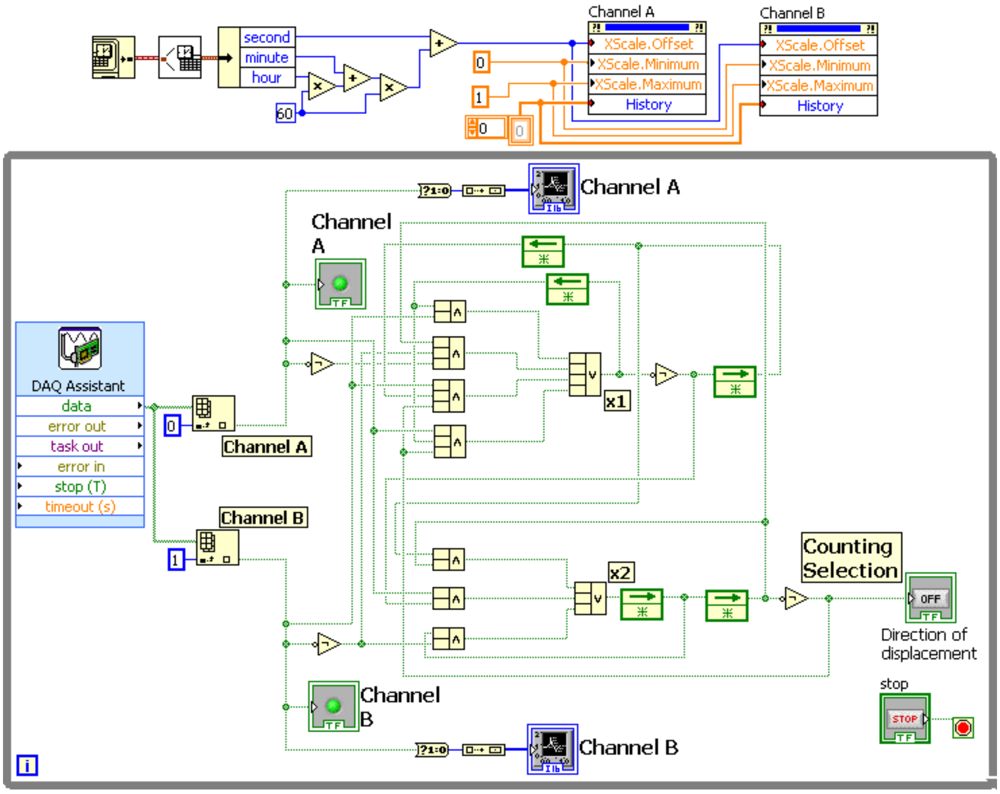

Fig.9. Diagram bloc of the virtual instrument

To observe the two signals are used two waveform chart indicators. For these charts were created **Property Nodes** through which is achieved offset, scaling and history for time axis [3].

In the next two figures is shown the front panel for the two situations corresponding to two states of operation for the virtual instrument [4].

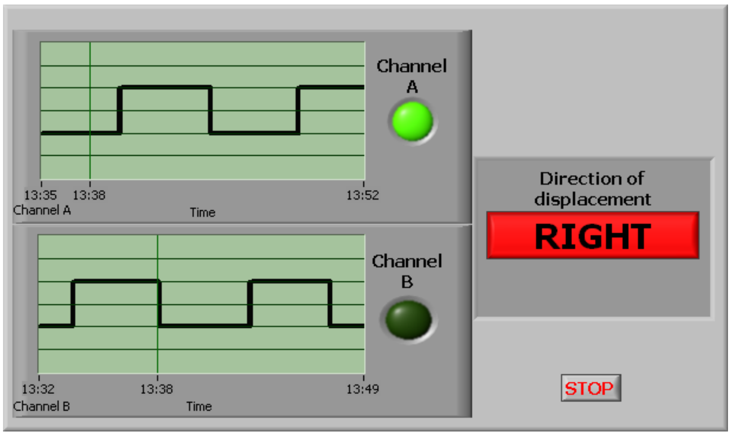

Fig.10. Front panel corresponding to the displacement in right direction

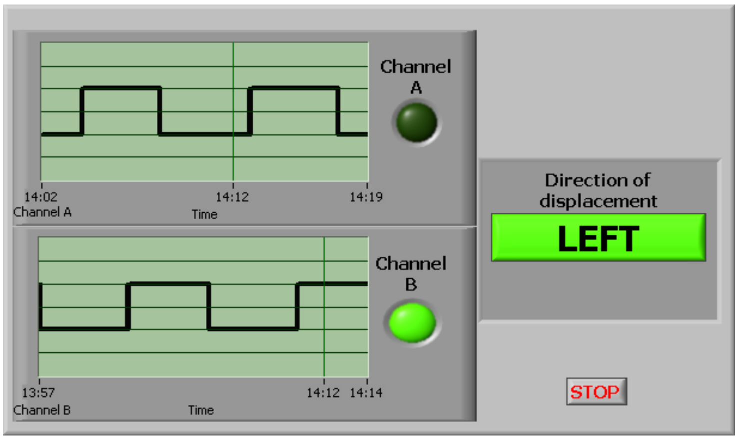

Fig.11. Front panel corresponding to the displacement in left direction

Can be observed in the two figures, that direction is determined by the order of movement succession of the two trains of pulses Channel A and Channel B, which means the phase shift between them.

4. CONCLUSIONS

Using the virtual instrument in this form do not have a very high interest, but its use becomes essential when becomes a control system for a reversible counter, in which case it is used as an SubVI into instrument structure which measure displacement or angular velocity.

Function testing was done both for only direction displayed and by its integration into the structure of a system for measuring displacement or angular velocity. Tests were performed using quadrature encoders with 4, 200 (E6A2-CW5C) respectively 500 (HEDS – 5500) pulses/revolution for a wide range of speeds, connected to digital inputs of the PCI – 6024E and USB – 6008 data acquisition systems

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