HARDWARE AND SOFTWARE USED FOR THE STUDY OF ANGULAR MOTION BY REMOTE CONTROL

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Abstract: This work is part of a project that includes methods for studying automation elements' functionality. From this project, I chose to present, in this paper, the hardware and software structure used for the study of angular motion. The generation of movement in the sense of controlling the spinning direction and amplitude is achieved by a DC motor. The Discovery Studio module, a Digilent product, controls the motor through the L298N DC motor driver module. The movement parameters are measured through an experimental incremental transducer through a National Instruments data acquisition module. The software created in LabVIEW allows both the control of the motor and the determination of the spinning direction and amplitude. The user has an interface with movement control elements and visualization of measurement results, for various operating conditions.

Key words: incremental sensors, DC motor control, LabVIEW, DiscoveryStudio, remote control

1. INTRODUCTION

The development of virtual tools like virtual instruments that can be used in education processes or in research activities offer a number of advantages over hardware structures based on measuring devices with manual data logging, including:

- the generation of signals with very precise shapes and amplitudes and at very well-determined moments of time,
- automatic data retrieval and processing,
- graphical interfaces that allow users to effectively control the computer or device they interact with,
- virtual instruments through their interfaces offer the user:
  - ✓ clarity, that's means recognizable features and elements that are intuitive to interact with,
  - ✓ consistency which helps the users feel at ease and in control of their actions,
  - ✓ accessibility which makes all users feel comfortable, at ease, and in control when using a software product.

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LabView is a graphical programming language that allows users in various fields to develop and implement interactive programs that will enable the acquisition of data from different technical equipment and also analysis and data processing and then displaying the obtained results in different forms like reports, graphs, or charts. The LabView programming environment provides the user with many functions, programming structures, libraries, and routines that allow the creation of virtual tools that can be used in many branches of engineering [1]. The facilities offered by the LabVIEW software by generating virtual laboratory instruments along with the corresponding hardware enable the development of student's abilities to conduct experiments with dynamic systems to study their responses [2], [3].

Motion can be defined as a physical quantity of a mechanical change that can provide information about the position of a material point or mobile against a reference system. Quantities derived from this, which may be considered, are: position, distance or speed [4]. In many applications, all these quantities are considered vectors, so measuring both size and direction for this quantity is necessary.

The usual procedure for obtaining the size of these quantities is by counting the pulses acquired from an incremental sensor that generates a pulse train [5]. The same incremental sensors 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.

In order to understand the operation and use of incremental sensors, it is necessary to use a rotation mechanism whose angular displacement and rotation speed can be set. The DC motor can fulfill this role if it is possible to control the supply voltage.

2. THE HARDWARE STRUCTURE OF THE LABORATORY STAND

The purpose of this paper is to present the physical structure and virtual instrument that allows automatic control and acquisition from the experiments in the study of angular motion. This hardware structure and virtual instrument are part of interactive and low-cost tools used for students' training systems.

The following elements were used to create the laboratory stand:

1. DC motor Un=9V;
2. Interface L298N DC Motor Driver Module;
3. Incremental encoder with 4 slits and D=80 mm, necessary choice to be able to visually observe the rotation movement and its sense;
4. Two transmissive optical sensors with phototransistor output TCST1103 (Vishay Semiconductors);
5. A trigger-type signal adapter module made with the Hex Non-Inverting Buffer CD4050 integrated circuit;
6. Analog Discovery Studio module (Digilent);
7. USB-6008 data acquisition module (National Instruments);

The block diagram of the entire system is shown in Figure1

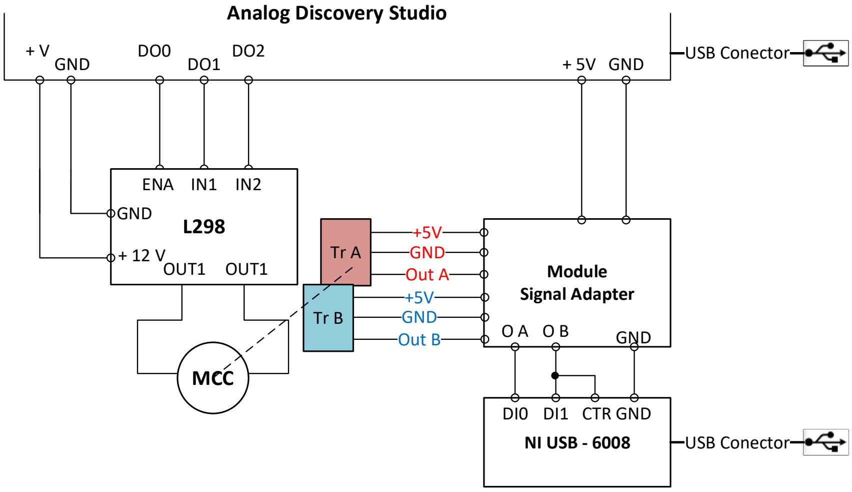

Fig.1. Laboratory stand block diagram

The elements component of the of this system are arranged like shown in Figure 2. The generation of the values of the rotation speed as well as its direction is carried out by means of the Analog Discovery Studio and L298N DC Motor Driver modules respectively.

The Analog Discovery Studio is a fully functional, portable test and measurement device that can turn any cross-functional space into a pop-up electronics laboratory. This equipment includes the Power Suppliers and other 13 instruments including 16 channels digital I/O lines with input logic standard: LVCMOS (1.8/3.3 V, 5 V tolerant) and output logic standard: LVCMOS (3.3 V, 12 mA). From this device is used the Variable Power Supply for which the generation, with a resolution of 12 bits, of a programmable voltage in the range (0 ... 5) V, the 5 V Fixed Power Supply, and digital channels D0 to D2 like output lines [6].

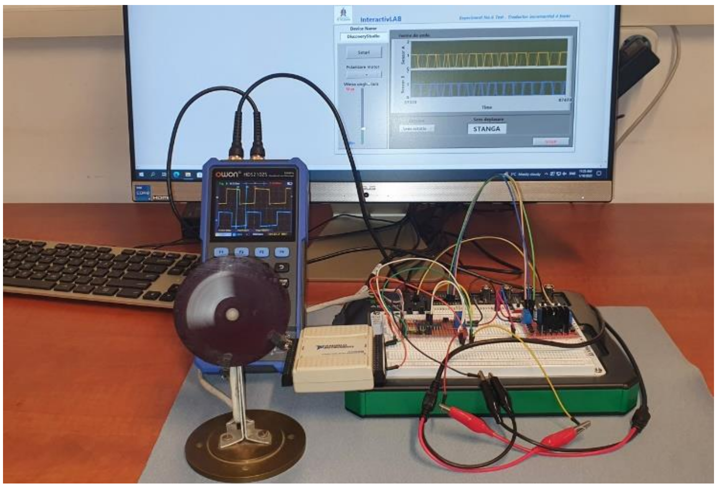

Fig.2. Setting up the laboratory stand

The Variable Power Supply and the three digital channels are used to control the angular movement of the DC motor through the L298N DC Motor Driver. Thus, the output lines DO1 and DO2 are connected to motor A input pins IN1 and IN2 which are used to control the spinning direction of the DC motor. Line DO0 is connected to the ENA pin that enables the PWM signal for the DC motor. The Variable Power Supply is connected to input from DC power Source at the L298N module and the 5 V Fixed Power Supply is used to supply power for the switching logic circuitry inside L298N integrated circuit.

The DC motor is connected to the output OUT1 and OUT2 pins.

The two transmissive optical sensors TrA and TrB with phototransistor output TCST1103 are mechanically fixed relative to the incremental encoder such the output signals of these must be two pulse trains Out A and Out B in quadrature. By using a relatively large encoder disk together with the two optical sensors, students are given the opportunity to observe and understand the operation of incremental rotary transducers as well.

The Out A and Out B signals taken from the transducers are processed in order to improve the transitions between their logical levels by using two gates from the CD4050B CMOS Noninverting Buffer and Converter. This operation is performed by the Signal Adapter Module.

The two pulse trains Out A and Out B in quadrature are used to measure the DC motor spinning value and direction. These signals are connected to the digital I/O lines and also to the counter input line on the N USB-6008 data acquisition module. Thus, are used the digital inputs DI0 and DI1 for the spinning direction identification, and the PFI0 for spinning value measurement.

The NI USB-6008 is a low-cost, bus-powered, all-in-one data acquisition (DAQ) module with a USB connection. Along with the functionalities related to the acquisition or generation of voltages, as analog quantities, this module also includes two ports with 12 digital I/O lines and a 32-bit counter. Each of these digital channels can be individually programmed as input or output and is compatible with TTL, LVTTL, and CMOS logic levels. The counter is a 32-bit resolution up-counter, which counts the falling-edges of pulses with frequencies up to 5 Mhz [7].

3. VIRTUAL INSTRUMENT IMPLEMENTATION

The virtual instrument that is proposed in this paper is built in the LabVIEW graphical programming environment. This virtual instrument consists of the front panel which is the user interface and the diagram block which is the actual program for controlling the laboratory stand.

3.1 Front panels of the virtual instrument

The front panel of the virtual instrument, shown in Figure 3 include two sections.

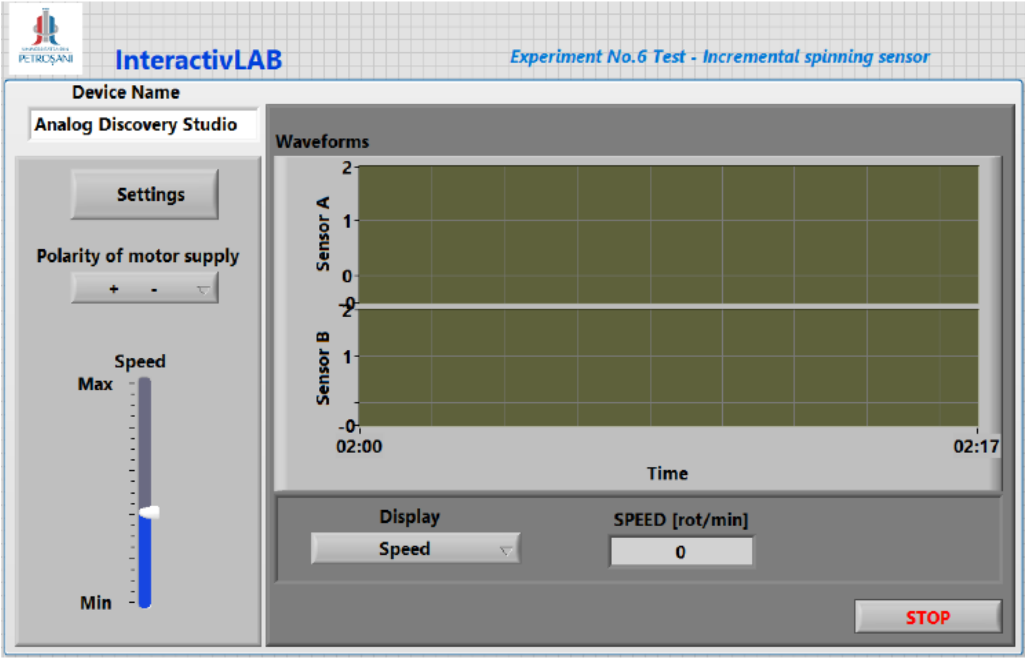

Fig.3. Front panel of the virtual instrument

The first section is used to sets the movement parameters, thus from the controls here the user can set the polarity (Polarity of the motor supply) and the value (Speed) of the power supply for the DC motors. For both input type elements that generate the rotation movement (polarity of the DC motor supply voltage and its PWM control) the parameters used to set this movement are not measured and are not available on the front panel to the user.

The second section is used to display the waveforms of the Out A and Out B signals taken from the transducers and also to display direction of motor spinning or speed value. The information that will be displayed about spinning direction or speed (in rev/min) can be selected through the selector control, Display, placed on this section.

3.2. Block diagrams of the virtual instrument

The block diagram of the virtual instrument, which represents its operating program, consists of two While loops that work independently, their only common element being the STOP command to stop the program. Block diagram used to read electrical values.

The loop used to control the movement of the DC motor is shown in Figure 4.

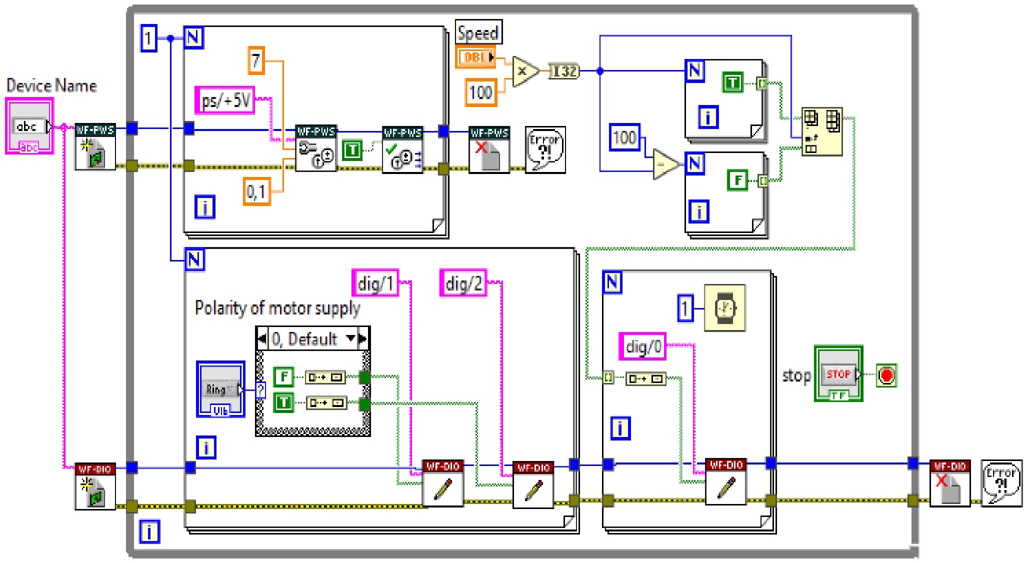

Fig4. The part of the block diagram used for control

This contains, in addition to typical LabVIEW programming functions and structures, functions from the Digilent WF VIs library used for DC motor power supply and setting its spinning direction.

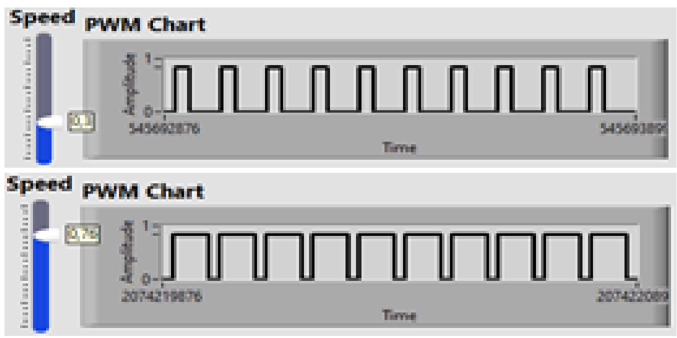

Fig.5. PWM waveform generation

Thus, the function DWF PS Configure Voltage Output is used to configures a voltage output on the +5 channel for a max 7 V voltage and max 100 mA current. The validation of this function is performed through the DWF PS Enable function which enables or disables all outputs on all channels of the instrument. By means of two For loops whose number of cycles is controlled by the Speed control, a PWM type waveform is generated, Figure 5. The width of the pulses is determined in relation to the unitary value of 100% by setting the value N and respectively 100-N of the number of loops of the two For structures.

The PWM signal is obtained at the digital output DO0 of the Analog Discovery Studio module and it is applied to the ENA input of the L298N driver and for this the DWF Dig Write function is used. This function writes data to the specified lines.

Bidirectional control of the motor is established by the logical combination of inputs IN1 and IN2 of the L298N as follows [8]:

Table 1. ***L298 motor control***

Inputs		Function
ENA=H	IN1=H ; IN2=L	Forward
	IN1=L ; IN2=H	Reverse
	IN1= IN2	Fast motor stop
ENA=L	IN1=x; IN2=x	Free running

The logic levels are transmitted, by selection with the Polarity of motor supply control, to the outputs DO1 and DO2 of the Analog Discovery module using the same DWF Dig Write function with the arguments dig/1 and dig/2.

The second While loop is used to display the spinning direction or the speed of rotation. The choice of one of the two options is made from the front panel through the Display control and a Case structure.

In the case of selecting the display of the direction of rotation, which corresponds to case 0 which is shown in Figure 6, the signals from the DI0 and DI1 inputs of port 0 of the NI USB-6008 low cost data acquisition module are read through the DAQ Assistant function.

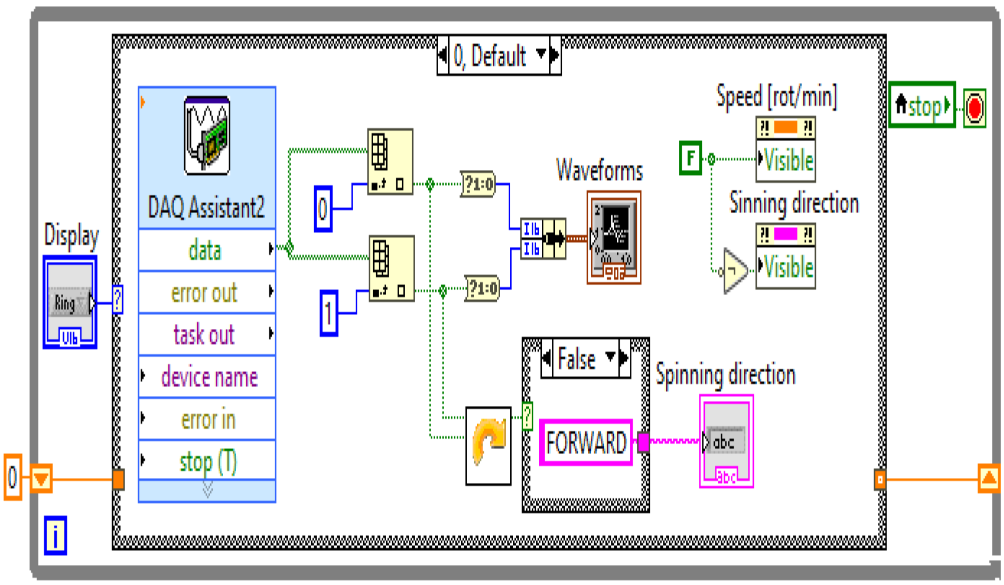

Fig.6. The part of the block diagram used for display spinning direction

These signals are displayed in their dynamic development on the Waveforms chart indicator. These also represent the input variables of a SubVI which is a representation in LabVIEW of a sequential logic circuit through which the logic functions necessary to identify the spinning direction are implemented [9]. In Figure 7 is shown the logic configuration of this SubVI.

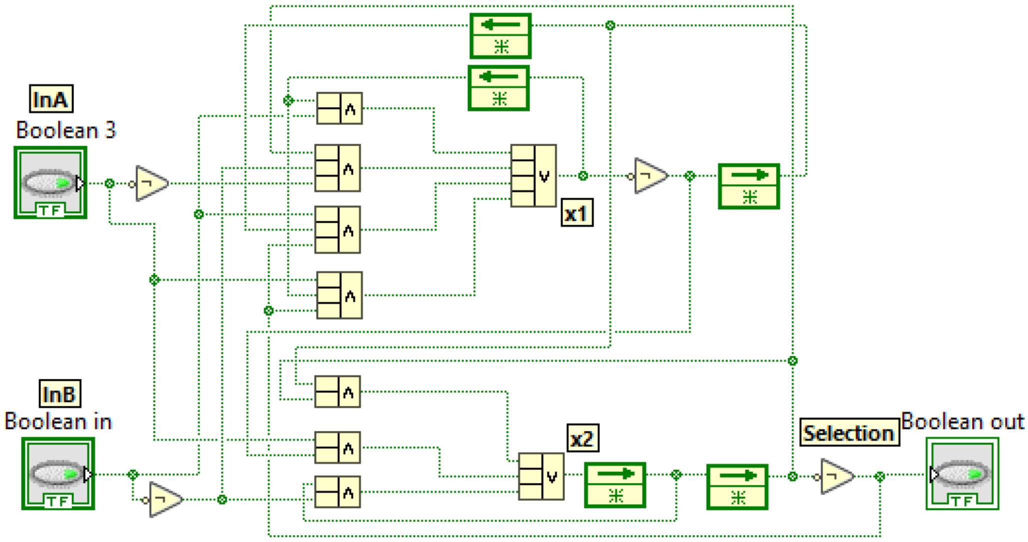

Fig.7. The logic configuration for spinning direction identification

In the case of selecting the display of the speed of rotation, which corresponds to case 1 which is shown in Figure 8, one of the signals to the digital inputs is passed also on the counter input PFI0 of the same NI USB-6008module.

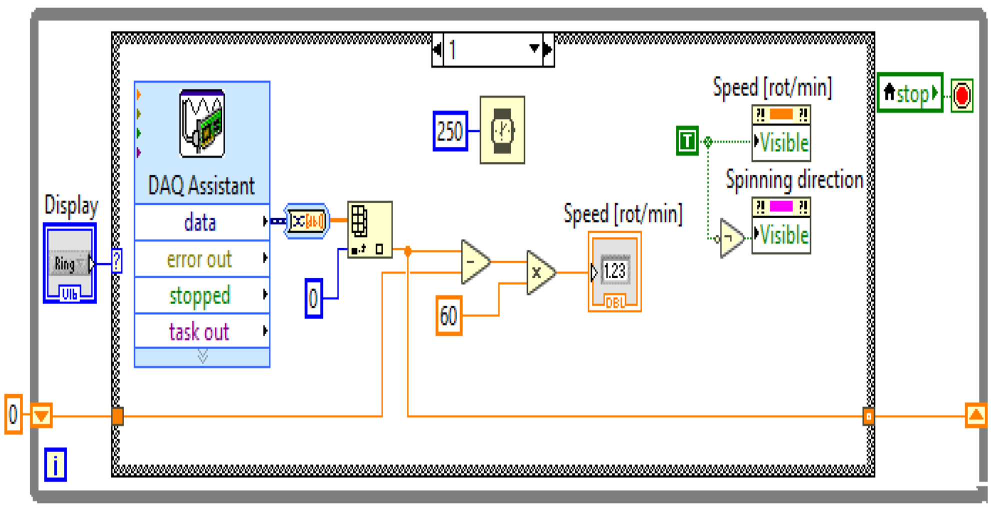

Fig.8. The part of the block diagram used for display speed of rotation

Since a coding disc with only 4 slots was chosen, it can be said that its resolution is 4 Pulses Per Revolution (PPR). By measuring the frequency of the pulses generated on the counting input PFI0, the rotation speed of the disk and implicitly of the DC motor axis can also be expressed. To express it in rev/min, the expression is used:

$$Speed\ [rev/min] = \frac{N}{PPR} \times time[sec] \times 60 \tag{1}$$

where N represents the counted number of pulses between two successive cycles of the While loop and the resolution is PPR=4.

Thus, the duration of the measurement is reduced to 250 msec, which means that the number N of pulses by multiplying by 60 will represent the rotation speed expressed in rev/min.

The simultaneous stopping of the two While loops and implicitly of the motor control program and measurement of the movement parameters is done by the STOP button on the front panel.

4. CONCLUSIONS

This paper presents one of the applications created in LabView that allows the realization of several experiments related to different topics from the educational plan of electrical engineering students. The other experiments are used to study force sensors (strain bridge) or temperature sensors (RTD, thermistor) or semiconductor devices like diode and transistor.

This laboratory stand and the experiment is used to verify the operation of both a direct current motor whose control is achieved through the rotor circuit and angular motion incremental transducers. Students are given the opportunity, on the one hand, to study the principles of control (direction and speed) of a direct current motor and, on the other hand, to study the operating principle of an incremental transducer.

The experiment benefits from its own command and control panel and both the hardware configuration and the virtual tool proposed in this work were made and tested in the laboratory.

I consider this application can be the starting point for creating a system based on virtual laboratories that can be accessed via an internet connection from anywhere in the world. In this sense, we intend to complete the tools created with G Web Development Software interfaces. The G Web programming environment helps programmers to create web-based user interfaces for test and measurement applications.

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