Acquisition of U/I characteristics of electric motors with permanent magnet using LabView software

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Abstract – **This paper deals with creating user interfaces and software for measurement, recording and playback of U/I characteristics of electric motors with permanent magnet in real time, using application called LabView of the National Instruments company. Paper deals with measuring and displaying these characteristics under different engine loads, as well as measuring its speed. The realization of these tasks implied the design and the construction of an additional hardware realized by microcontroller, whose task is to convert an analog voltage with an acquisition card with the PWM signal thereby adjusting the engine design needs in order to record and display its characteristics.**

Keywords – **USB, PWM, DAQ, CASE, AD, USB-6009**

I. Introduction

The paper describes a software solution to adjust and control data acquisition and display of data within experimental methods for the determination of UI features of the electric motor over a wide load range. Apart from the software, written in a programming package LabVIEW, an example of its application is displayed together with the results in a separate chapter.

Development of the software supported system, applied to testing of instruments for monitoring and analysis of the basic UI and speed parameters is presented in this paper. This acquisition system includes two functionally connected parts. First part involves generation of the standard waveforms, including possibility for simulation of the various signals typical for electrical UI power and speed acquisitions. Software support of this procedure performs graphical presentation of the previously generated and recorded signal waveforms. Second part of this procedure includes real-time recording and presentation.

System is supported by virtual instrumentation concept, which includes control software application in LabVIEW environment and data acquisition card USB-6009.

Data acquisition (DAQ) is the process of measuring an electrical or physical phenomenon such as voltage, current, temperature, pressure, or sound with a computer. A DAQ system consists of sensors, DAQ measurement hardware, and a computer with programmable software. Compared to traditional measurement systems, PC-based DAQ systems exploit the processing power, productivity, display, and connectivity capabilities of industry-standard computers providing a more powerful, flexible, and cost-effective measurement solution. An example is given in Fig 1.

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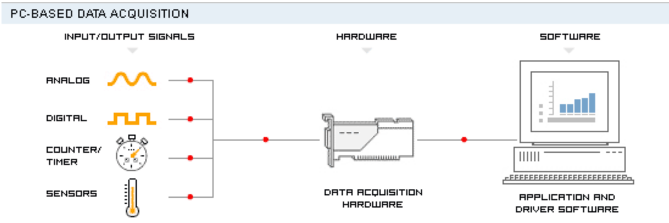

Fig. 1. Data acquisition system

The parts of the system are:

- Physical input/output signals
- DAQ (Data Acquisition) device/hardware
- Driver software
- Application software

Hardware component used in this paper is a USB-6009 card of the National Instruments company. A block diagram of the card is shown in Fig 2.

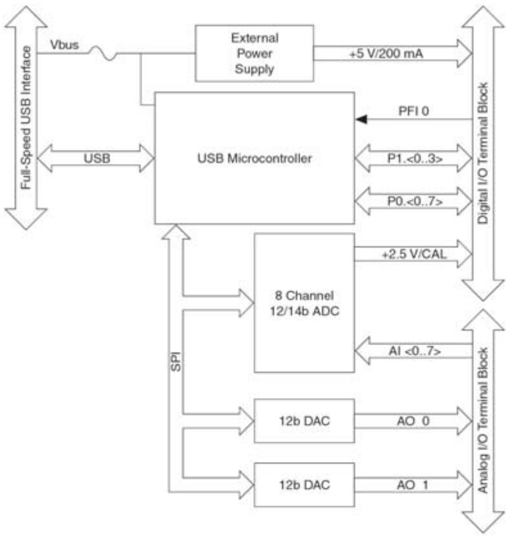

Fig. 2. Block diagram of the card USB-6009

Card USB-6009 includes:

- Four analog inputs of the differential relation (14-bit resolution, maximum sample rate 48KS/s, the input voltage at the junction of up to ± 10 V)

- Two analog outputs (12-bit resolution, voltage 0-5 V, current up to 5mA, refreshing outputs with 150 Hz)
- Twelve digital inputs/outputs (there are two ports, port P0 has 8 lines that can be individually defined program as input/output marked with P0 - P7 and P1 port that has four lines that can be individually defined program as input/output, marked with P1 - P3.
- 32-bit counter with full speed USB interface (activated on the falling edge of the signal, counting only the advance, the maximum input frequency of 5 MHz).

Hardware components of the printed circuit board were created with the aim of controlling the speed of rotation of DC motors with permanent magnet. Electronics is realized using a microcontroller whose primary task is to convert an analog voltage of 0 - 5V, which is obtained from one of the two analog outputs of the USB 6009 card defined in the programme, into the corresponding PWM (Pulse Wide Modulation) signal with a ratio of 0 - 100% of the value which is proportional to the analog voltage dependent upon referrential voltage of the card. The microcontroller is programmed so that it can generate three different periods of the PWM signal while the choice available via buttons on the printed circuit board can select a range of 15.6 KHz, 3.8 KHz or 980Hz in the full range of 0 - 100% depending on the selected electric motor.

The load circuit consists of transistors and amplifiers responsive to a programmed digital outputs on the USB - 6009 card. Four relays are inserted through the load as active loads of different ohmic resistance through which electric generators indirectly charge.

A hardware block diagram of the complete part is shown in Fig 3.

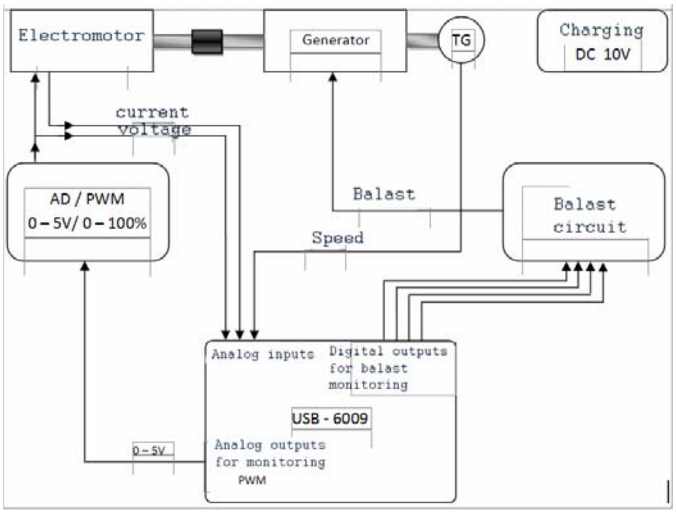

Fig. 3. Block diagram of the complete hardware part

Unlike other programming languages, LabVIEW uses a graphical programming language "G" to create programs in the form of block diagrams. LabVIEW uses terminology, icons, and ideas close to scientists and engineers and relies on graphical symbols rather than textual languages to describe the actions of the program as part of CASE tools. For lovers of C, LabVIEW has left open the possibility of programming in text mode commands. Programming of these possibilities has just been used in this paper. LabVIEW contains a huge number of functions and subroutines for most programming requirements that may occur in practice. In addition to Windows, LabVIEW supports the work of the Macintosh, Sun and Linux OS and developed its own OS. Fig 4 is showing Front Panel work tools and structures that contain Block Diagram.

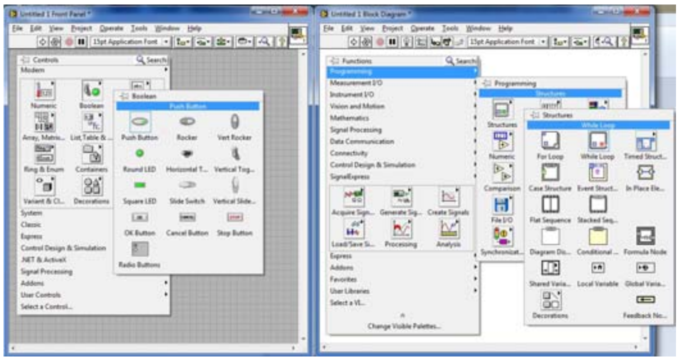

Fig. 4. Front panel

II. Creating a Program for Measuring the U/I Characteristics of the Motor

The program is designed as a whole in one window, where there will be two oscilloscope displays, one which will display waveform voltage to the engine Fig 5 - mark 1 and the other which will display the current flowing through the engine in real time Fig 5 - mark 2. Regulation of the output analog voltage 0 - 5V cards with USB - 6009 (exit A00) was performed programmatically by virtual vertical slider, the respective slider on the right side of the window labeled with PWM, Fig 5 - mark 5. This voltage is directly led to the input of the hardware part of the microcontroller whose task is to measure the AD voltage converter and generate a PWM signal which is in direct proportion to that voltage. Practically, the analog voltage whose value ranges from 0 - 5V has proportional PWM signal 0 - 100% and therefore the motor rotation speed control from 0 - 100%.

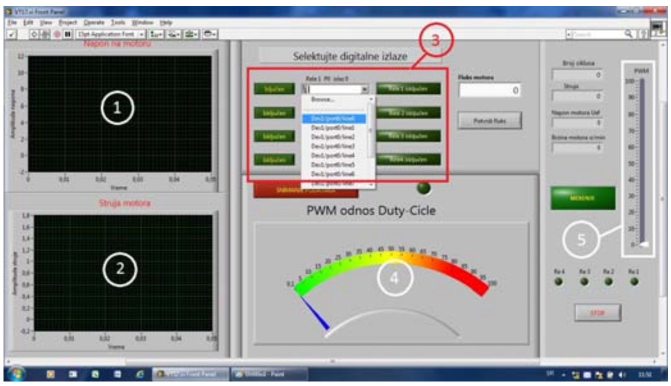

Fig. 5. The appearance of the user interface

The part of the program that deals with selecting digital outputs on the USB - 6009 card, enables that charging can be connected to any of the outputs, which is made possible by a drop-down list in the framework of Fig 5 - mark 3 in which the channels are selected thus becoming physically connected. Programming makes it possible to isolate each of these digital outputs which can be at any time switched on or off via the corresponding switch on the left drop-down list, as well as to indicate the relay activity at any time, allowing a visual overview of the current state of the relay involved, ie ohmic load. Vertical slider or slider, Fig 5 - mark 5, defines compliance with PWM signal or voltage that is entered to the motor.

A. Defining analog input channels

The procedure for defining the analog inputs is as follows: it is necessary to have a connected USB card - 6009 via a USB port that we could access or to define the analog inputs. In the block diagram, right-click on the desktop opens the pop-up menu from which we choose the icon DAQ Assist in Fig 6.

Fig. 6. Defining the analog inputs

We can define three analog channels: voltage_0, voltage_1, voltage_2, an rename them too, through which we measure speed, voltage and current of the motor, Fig 7.

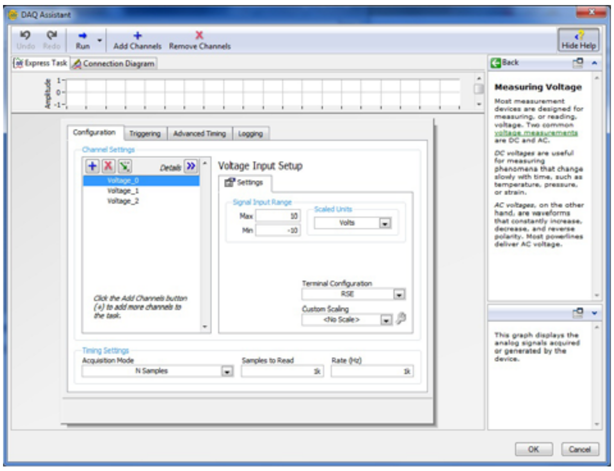

Fig. 7. Adjusting the selected channels

B. Defining analog outputs channels

Defining the analog output to generate a voltage of 0-5 V, which we use to manage PWM is performed as follows. Right click on the desktop block diagram opens the menu shown in Fig 8.

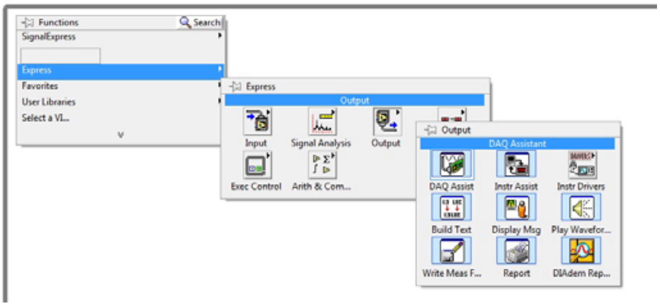

Fig. 8. Defining the analog outputs

The next activity is to define the scope of the output voltage, which is entered so that the minimum voltage value is 0V and 5V maximum value (which is the largest value of the output voltage which can be defined for this card).

The procedure of definition of the analog outputs is similar to the procedure of defining analog inputs.

C. Creating a graphic (oscilloscope) display

For the oscilloscope signal display it is needed to add Waveform graph of voltage and current in the Front panel.

To show the effective voltage value of the system, it is necessary to perform an expression that defines the effective value of the PWM signal that has a form used in this paper.

Effective voltage value is defined by the equations Eq. 1.

$$U_{ef} = \sqrt{\frac{1}{T}\int_0^T u^2(t)dt} \tag{1}$$

Since in our case the signal - pause can have any value, we need to define the effective value of the signal in every possible case. This is necessary in order to programme the system to display the correct values for any given voltage of PWM signal.

Fig 9 shows the PWM signal, which in general can have any signal-pause relationship, and variable is defined by variable k within the periods which can be defined at any time.

Calculation of the effective value during periods start from the equations Eq. 2.

$$U_{ef} = \sqrt{\frac{1}{T}\int_0^T u^2(t)dt} = \sqrt{\frac{1}{T}\int_0^T U^2{}_{\max}(t)dt} = \sqrt{\frac{1}{T}\left[\int_0^{kT} U^2{}_{\max}(t)dt + \int_{kT}^{T} 0(t)dt\right]}$$

$$U_{ef} = \sqrt{\frac{U^2_{\max}}{T} \cdot \Big|_0^{kT} t} = \sqrt{\frac{U^2_{\max}}{T}\left[kT - 0\right]} = \sqrt{\frac{U^2_{\max}}{T} kT} = U_{\max}\sqrt{k} \qquad (2)$$

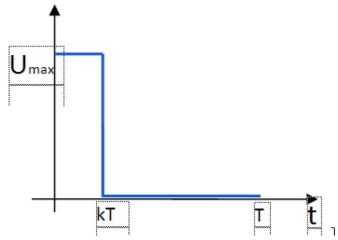

Fig. 9. PWM signal

The resulting expression is entered in the program to help that displaying the correct effective value of the supply voltage. Fig 10.

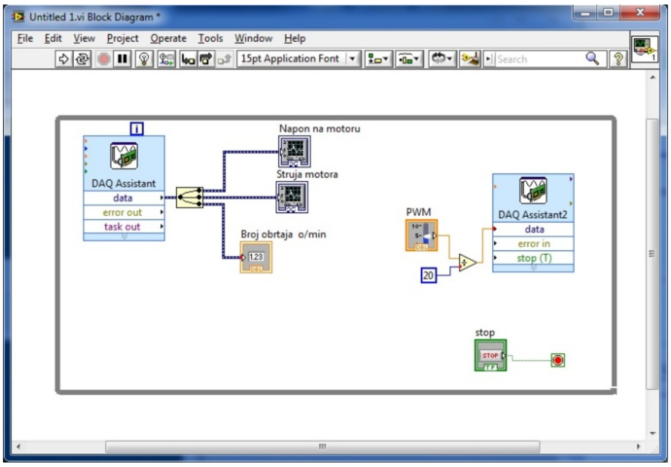

Fig. 10 System block diagram

D. Defining the digital outputs

Program is defined by CASE structure (central rectangular part of the Fig 11.) which allows the inclusion or exclusion of each digital output individually.

In the same way, the other three digital outputs that form a functional unit with the rest of the software program are defined.

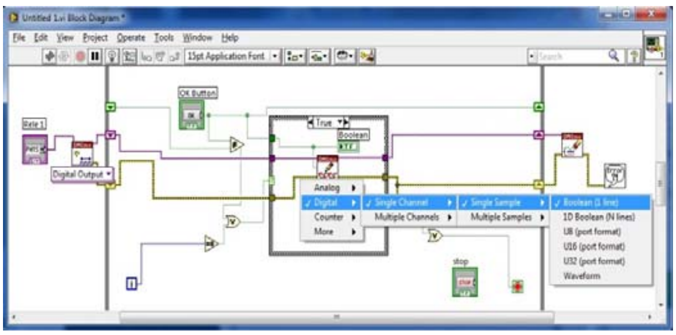

Fig. 11 Defining the digital outputs

Programming the connection and disconnection of individual relay which will include the active resistors is generated in C language.

The final look of the front panel is shown in Fig 12 where we can see all the possibilities that are built into the program and we can also record the signal voltage and current on the motor during operation under load.

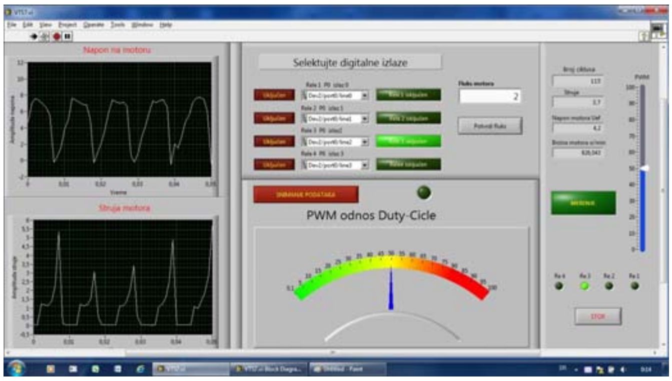

Fig. 12. The final look of the front panel

III. Conclusion

This paper describes the intelligent controller designed and developed in LabVIEW for measurement the U/I characteristics and motor speed of electric motors with permanent magnet in real time.

One benefit of LabVIEW over other development environments is the extensive support for accessing instrumentation hardware. Drivers and abstraction layers for many different types of instruments and buses are included or are available for inclusion. These present themselves as graphical nodes. The abstraction layers offer standard software interfaces to communicate with hardware devices. The provided driver interfaces save program developments.

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