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## DIGITAL CONTROL OF BRUSHLESS DC SERVOMOTOR ELECTRICAL DRIVE SYSTEMS OPEN-LOOP CONTROL

BY

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**Abstract.** This paper presents the open-loop control of a Brushless DC (BLDC) servomotor. The dsPICDEM MC1 development system (with dsPIC30F6010A microcontroller) and the dsPICDEM MC1L power module, manufactured by Microchip Company, were used.

The control program was developed in C programming language and adapted for microcontroller with MPLAB platform. The graphical user interface, realized in LabVIEW 8.6 graphical programming language, presents the following facilities: the speed profiling (step variation), operating regime selection (constant load or overload), visualization of the prescribed/measured speed, and angular position.

**Key words:** BLDC servomotor; digital control; open-loop control.

### 1. Introduction

Used in servodrives, the most of BLDC servomotors are designed into integrated version with digital control systems (Tae-Hyung *et al.*, 2006;

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D'Souza, 2004; Mathapati, 2007). The regulation within large limits of speed/position requires electrical drive systems (EDS) with high level of automation. Speed/position digital control can be implemented on systems with microcontrollers. Microcontrollers, due to high operation speeds, the low cost, the large number of peripheral devices, etc., represent the „intelligent” elements from EDS.

Using microcontrollers in electrical drive control circuits is also justified by Hintz & Taback, 1993; Peatmenn, 1998; Cazacu *et al.*, 2010; Ursanu *et al.*, 2010 namely: possibility to implement evolved digital control algorithms, reducing control circuits time response, improving control performances by consideration of some functionality nonlinearity conditions, improving control accuracy by reducing some analogical components which can depreciate in time, etc.

Considering the above mentioned aspects, the paper presents the open-loop digital control of the BLDC servomotor speed.

## 2. Hardware Aspects

The EDS block diagram is presented in Fig. 1. The system contains

a) an integrated electrical drive system (IEDS) which includes a BLDC servomotor with rotor position transducer (RPT) realized with Hall sensors, a resolver, an encoder with resolution of 4096 PPR, and an electromagnetic brake (EB);

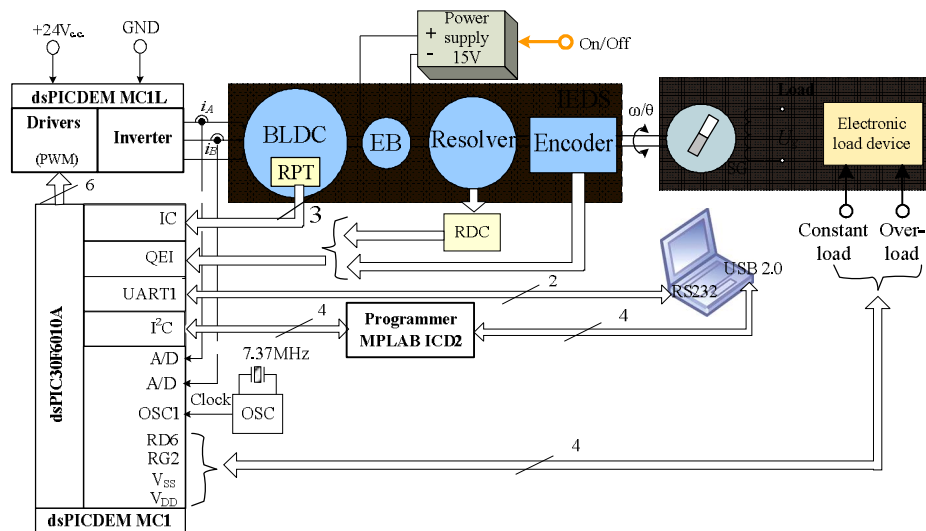


Fig. 1 – EDS block diagram for open-loop control.

b) dsPICDEM MC1 development system;

- c) dsPICDEM MC1L power module;
- d) a load controlled device that offers the ability to load the BLDC servomotor with a resistant torque in constant load or overload regime;
- e) MPLAB ICD2 programmer/debugger.

Dedicated for EDS control, dsPICDEM MC1 development system generally is designed to operate with dsPIC30F digital controllers family (www.Microchip.com, 2003). The development system has all of the peripheral devices that are needed to be integrated in digital control of an EDS. The interconnection with the rotor position feedback of BLDC servomotor is realized either by the interface with logical signals provided by RPT with Hall sensors, either by encoder's interface (QEI module – *Quadrature Encoder Interface*). dsPICDEM MC1 development system's clock is provided by a quartz oscillator (7.37 MHz frequency). The block diagram of dsPICDEM MC1 development system is shown in Fig. 2.

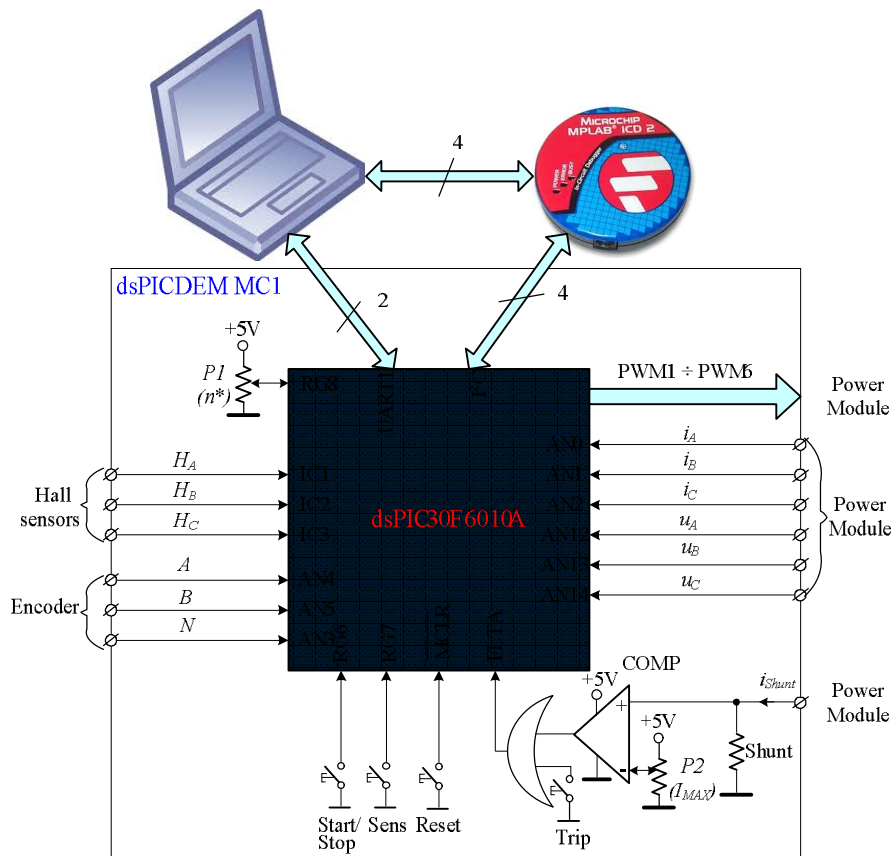


Fig. 2 – dsPICDEM MC1 development system block diagram.

The development system has as processor the digital controller (16

bits), with signal processor features, dsPIC30F3010A. Its most important characteristics are (www.Microchip.com, 2005):

- a) Harvard modified architecture, optimized for C programming language;
- b) 144 Kb program memory (Flash), 8Kb RAM and 4 Kb EEPROM;
- c) large number of interrupt sources (44);
- d) internally clock with a frequency of 7.37 Hz;
- e) dual data fetch;
- f) 2 serial ports (RS232 and RS485);
- g) 2 CAN modules;
- h) 8 PWM channels to command the inverter;
- i) 4 modules to generate dead time;
- j) 3 inputs for encoder;
- k) 16 bits counter related to encoder interface;
- l) software possibilities to increase encoder signal resolution;
- m) programmable digital noise filters on inputs;
- n) 10-bit Analog-to-Digital Converter (A/D);
- o) 16 A/D channels.

The human intervention on the unfolding process control is assured by the following elements: the START/STOP, SENS, RESET push buttons, two potentiometers for speed and maximum current, drawn by BLDC servomotor, the UART1 computer serial interface and CAN interface.

To feed the BLDC servomotor, dsPICDEM MC1L power module includes an inverter made by 6 MOSFET transistors. Also, dsPICDEM MC1L driver contains a reverse voltage protection circuit and a brake chopper (www.Microchip.com, 2003).

### 3. Software Aspects

The open loop control program was developed in C programming language and adapted for microcontroller with MPLAB platform (MPLAB 7.3 software and MPLAB ICD 2 programmer/debugger). The flowchart of open-loop control program is presented in Fig. 3, and in Fig. 4 is described the flowchart of the interrupt routine.

To obtain the real speed of BLDC servomotor was used the QEI module of microcontroller which is connected to the signals generated by the encoder. QEI module performs the multiplication with 4 of the information provided by the encoder. The measured speed value is computed with (Cazacu *et al.*, 2010; Ursanu *et al.*, 2010)

$$n = \frac{N}{\Delta} \cdot \frac{60}{4R_{ENC}} = \frac{N}{\Delta} \cdot \frac{15}{R_{ENC}}, \text{ [rev./min.],} \quad (1)$$

where:  $N$  is the number of pulses in  $\Delta$  measurement range;  $R_{ENC}$  – the transducer's resolution (including the multiplication by 4 realized by microcontroller).

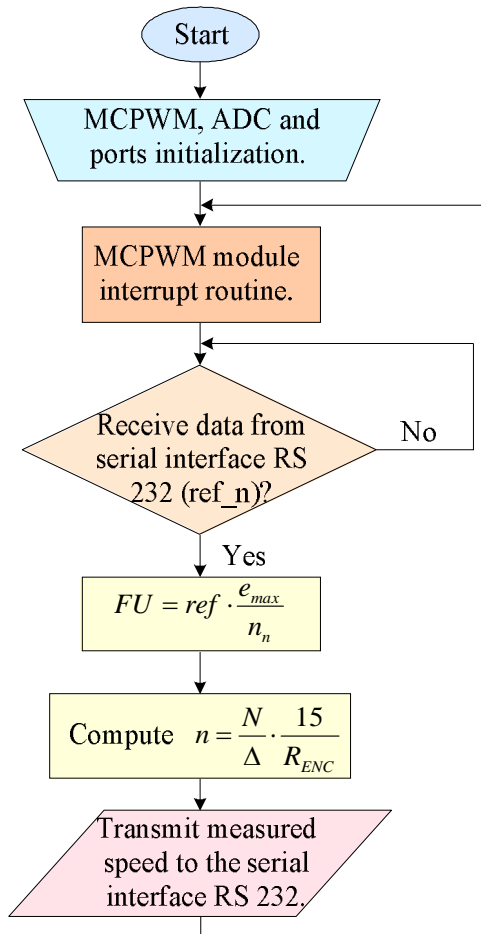


Fig. 3 – Flowchart of main program (open-loop control).

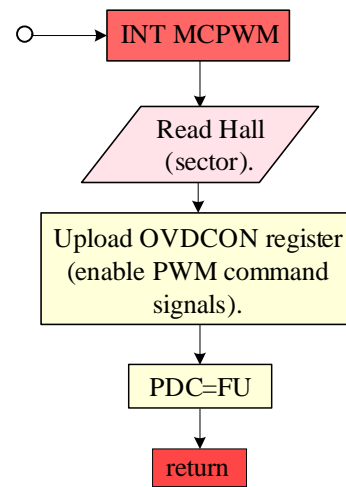


Fig. 4 – Flowchart of interrupt routine.

The graphical user interface was realized in LabVIEW 8.6 graphical programming language, its LabVIEW diagram being presented in Fig. 5. The realized graphical user interface is presented in Fig. 6. It offers the following facilities:

- speed profiling (step variation);
- operating regime selection (constant load or overload);
- visualization of the prescribed and measured speed, and position.

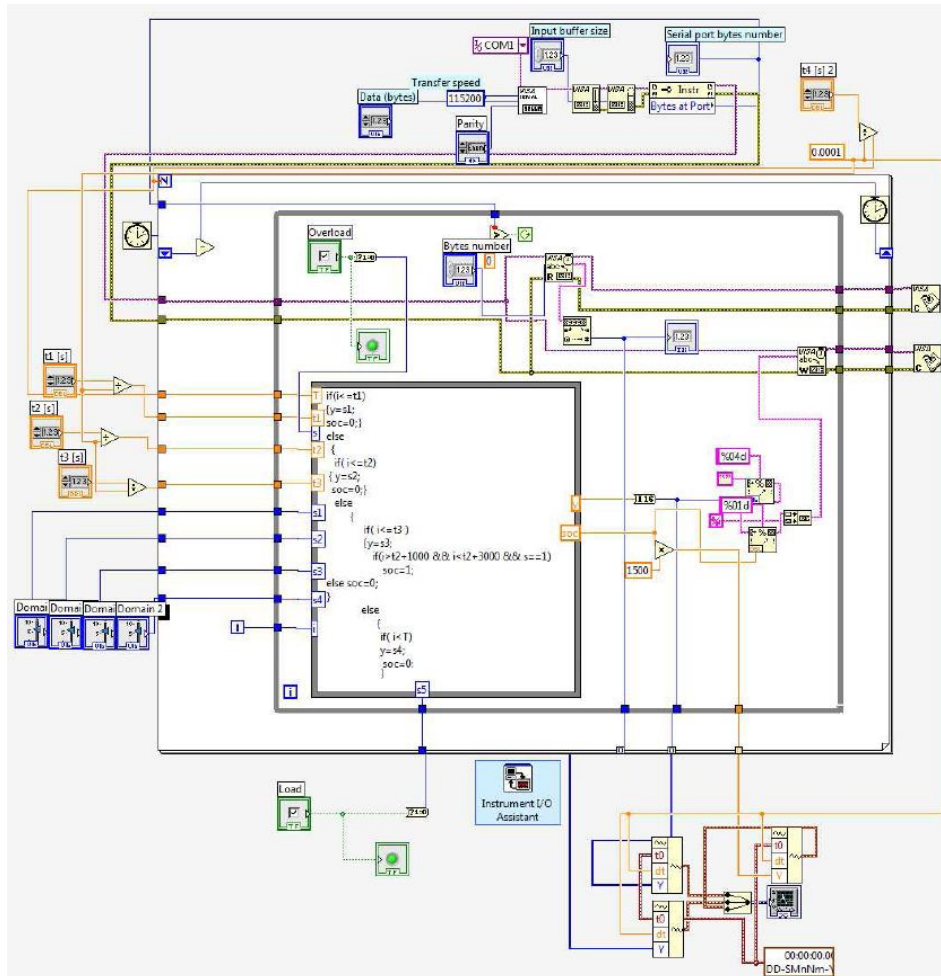


Fig. 5 – LabVIEW diagram for open-loop control.

#### 4. Experimental Results

The experimental research was performed in the Electrical Drives Laboratory of „Gheorghe Asachi” Technical University from Iași. The general view of test bench is presented in Fig. 7.

The BLDC servomotor from IEDS is three phased in star connection with 9 slots on stator and 10 poles on rotor. Its nominal parameters are presented in Table 1.

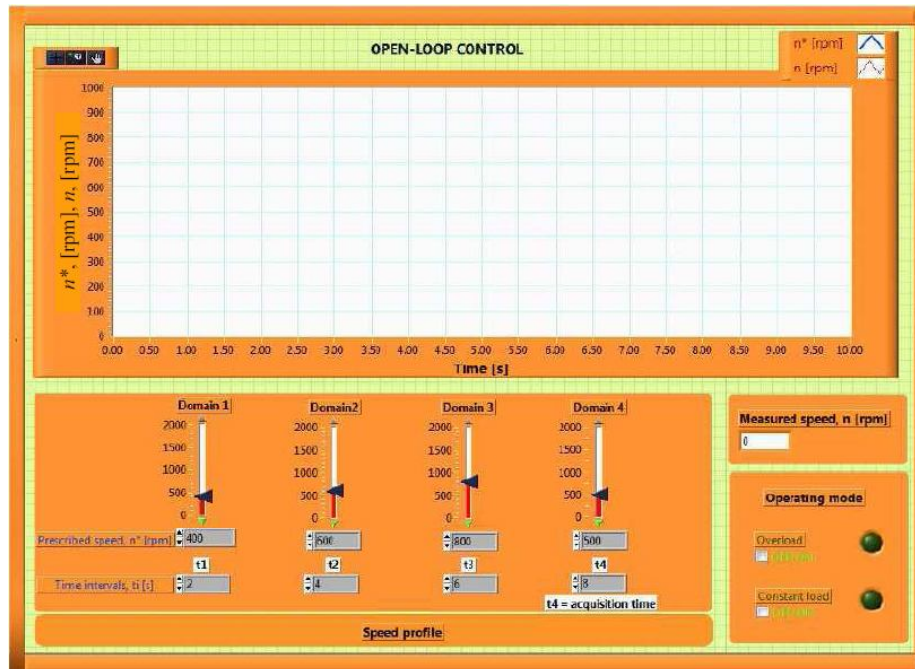


Fig. 6 – Graphical user interface for open-loop control.

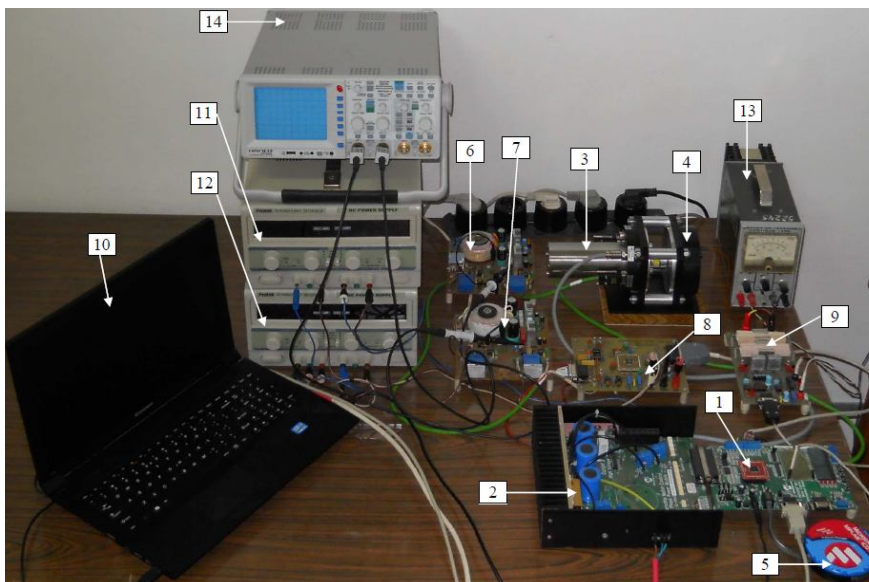


Fig. 7 – General view of the test bench: 1 – development system; 2 – power module; 3 – IEDS; 4 – SG; 5 – MPLAB ICD2 programmer/debugger; 6 – current transducers interface; 7 – voltage transducers interface; 8 – RDC; 9 – electronic load device; 10 – PC; 11, 12, 13 – power supplies; 14 – oscilloscope.

**Table 1**  
*Nominal Parameters of BLDC Servomotor*

Parameter	Value	Unit
Rated voltage, $U_n$	24	V <sub>cc</sub>
Nominal current, $I_n$	3.5	A <sub>cc</sub>
Rated speed, $n_n$	1,725	rpm
Rated torque, $M_n$	0.35	N.m
Rated power, $P_n$	63.5	W
Winding resistance, $R$	0.7	$\Omega$
Winding inductance, $L$	1.3	mH
Constanta t.e.m., $k_e$	0.07	V/(rad/s)
Rated efficiency, $\eta_n$	73	%

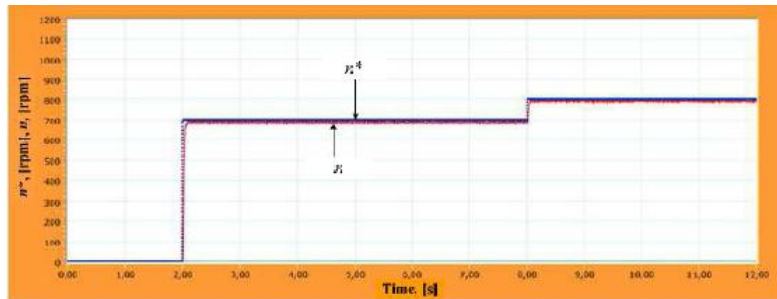
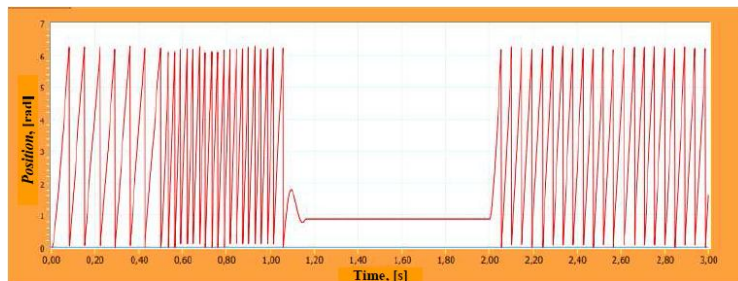
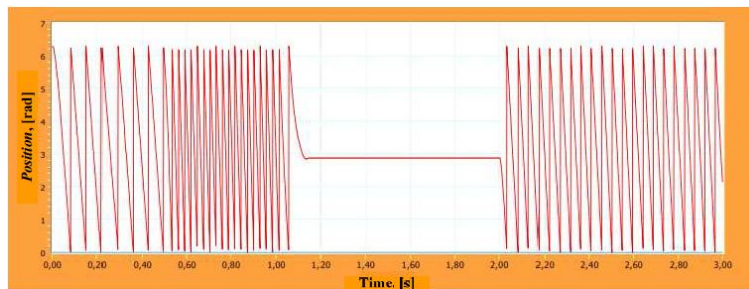


Fig. 8 – System response for speed step variation, clockwise.



a – Counter-clockwise.



b – Clockwise.

Fig. 9 – Time diagram of position for prescribed speed step variation.



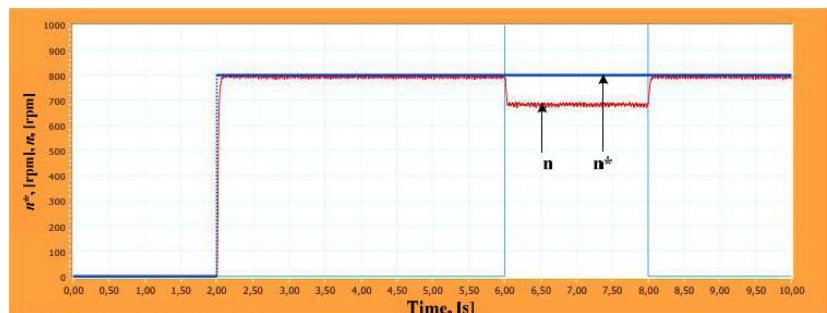


Fig. 10 – System response for overload.

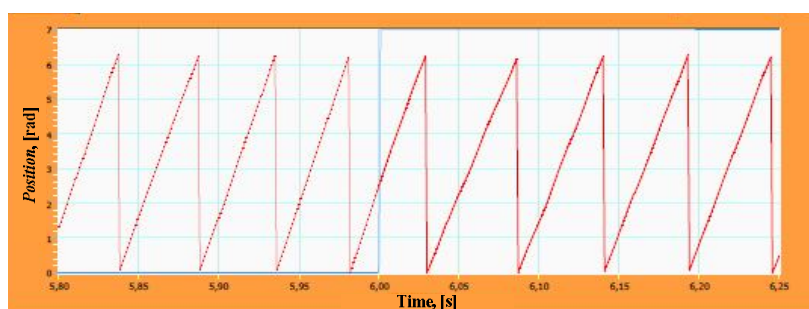


Fig. 11 – Time diagram of position for overload, counter-clockwise (looking glass).

To load the servomotor, a load formed by an electronic load device and a single-phase synchronous generator (SG) was used. Position and speed signals were provided by the encoder manufactured by Allied Motion – Computer Optical Products Inc. Company (resolution of 4096 pulses/rev.).

The experimental results were obtained in the following working conditions: step variation of prescribed speed, overload.

In Figs. 8 and 9 is presented system response at prescribed speed step variation. Therewith, in Figs. 10 and 11 is shown system response at disturbance step variation, for both rotation direction. Overload was applied in 6...8 s interval. In this interval it can be observed that speed drops due to mechanical characteristic of BLDC servomotor. The absence of speed controller makes these servomotors sensitive at disturbances caused by load.

## 5. Conclusions

The digital system above presented is a good solution for open-loop and closed-loop control with microcontroller of a BLDC servomotor. The realized system is the first step for research closed-loop control with microcontroller of BLDC servomotor.

## REFERENCES

- Cazacu M., Ursanu Gh., Băluță Gh., *Open- Loop Control of a DC Servomotor*. Bul. Inst. Politehnic, Iași, **LVI (LX)**, 3, s. Electrot., Energ., Electron., 31-70 (2010).
- D'Souza S., *Sensored BLDC Motor Control Using dsPIC30F2010*, Appl. Note AN957, Microchip Inc, 2004.
- Hintz J. K., Taback D., *Microcontroller. Architecture, Implementation and Programming*. McGraw Hill, New York, 1993.
- Mathapati S., *Implementation of Dynamically Reconfigurable Control Structures on a Single FPGA Platform*. Proc. of Power Electron. a. Appl. Conf., 2007, 1-9.
- Peatmenn B. J., *Design with Microcontrollers*. McGraw Hill, New York, 1998.
- Tae-Hyung K., Hyung-Woo L., Parsa L., Mehrdad E., *Optimal Power and Torque Control of a Brushless DC (BLDC) Motor/Generator Drive in Electric and Hybrid Electric Vehicles*. Proc. of Ind. App. Conf. – IAS, 2006, 1276-1281.
- Ursanu Gh., Diaconescu Cristina, Băluță Gh., *Closed Loop Control of a DC Servomotor*. Bul. Inst. Politehnic, Iași, **LVI (LX)**, 4, s. Electrot., Energ., Electron., 117-125 (2010).
- \* \* \* *dsPIC30F6010A Data Sheet*. www.Microchip.com, 2005.
- \* \* \* *dsPICDEM<sup>TM</sup> MC1L 3-Phase Low Voltage Power Module User's Guide*, DM300022. www.Microchip.com, 2003.

CONTROLUL NUMERIC AL SISTEMELOR DE ACȚIONARE ELECTRICĂ A  
UNUI SERVOMOTOR DE CURENT CONTINUU FĂRĂ PERII  
Comanda turației în circuit deschis

(Rezumat)

Se prezintă comanda în circuit deschis a turației unui servomotor de c.c. fără perii (Brushless DC-BLDC). Au fost utilizate sistemul de dezvoltare dsPICDEM MC1 (cu microcontrolerul dsPIC30F3010A) și modulul de putere dsPICDEM MC1L fabricate de Compania Microchip.

Totodată, a fost realizat un program de comandă a turației în limbajul de programare C și care a fost adaptat microcontrolerului cu ajutorul platformei de programe MPLAB (mediul de programare MPLAB 7.3 și programatorul / depanatorul MPLAB ICD 2).

Interfața grafică cu operatorul uman, realizată în limbajul de programare grafică LabVIEW8.6, oferă posibilitatea stabilirii profilului de turație, a regimului de lucru (cu sarcină constantă sau șoc de sarcină) și vizualizarea principalelor mărimi (turația prescrisă și cea măsurată, poziția).