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Speed Digital Control of Brushless DC Motor Using dsPIC Controller

This paper presents the digital control of the Brushless DC motor (BLDCM) speed. The dsPICDEM MC1 development system (with the dsPIC30F6010A microcontroller) and the dsPICDEM MC1L power module, manufactured by Microchip Company, were used. The control program was developed in C programming language. The graphical user interface was realized in LabVIEW 8.6 graphical programming language. For speed control, a digital controller PI type was implemented. Due to digital controller well chosen and well tuned, the system response at speed step variation is very good. Therewith, the experimental results obtained also show a good compensation of disturbance which does not happen in open-loop control.

Keywords: brushless machine, microcontrollers, digital control, speed control

1. Introduction

The most of BLDCMs are used in servodrives, so they designed into integrated version with digital control systems which provide speed/position/torque control [1], [2], [3]. 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. High operation speeds, the low cost, the large number of peripheral devices, etc. make microcontrollers to represent the „intelligent" elements from EDS.

Using microcontrollers in electrical drive control circuits is also justified by [4], [5] and [7]:

-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 and require corrections, etc.

Taking into account the above mentioned aspects, the paper presents the digital control of the BLDCM speed.

2. EDS's Structure

The EDS block diagram is presented in Figure 1. The system contains:

-an integrated electrical drive system (IEDS) which includes a BLDC motor with Rotor Position Transducer (RPT) realized with Hall sensors, a resolver, an encoder with resolution of 4096 pulses/rev., and an Electromagnetic Brake (EB);

-dsPICDEM MC1 development system;

-dsPICDEM MC1L power module;

-a load controlled device that offers the possibility to load the BLDCM with a resistant torque in constant load or overload regime;

-MPLAB ICD2 programmer/debugger.

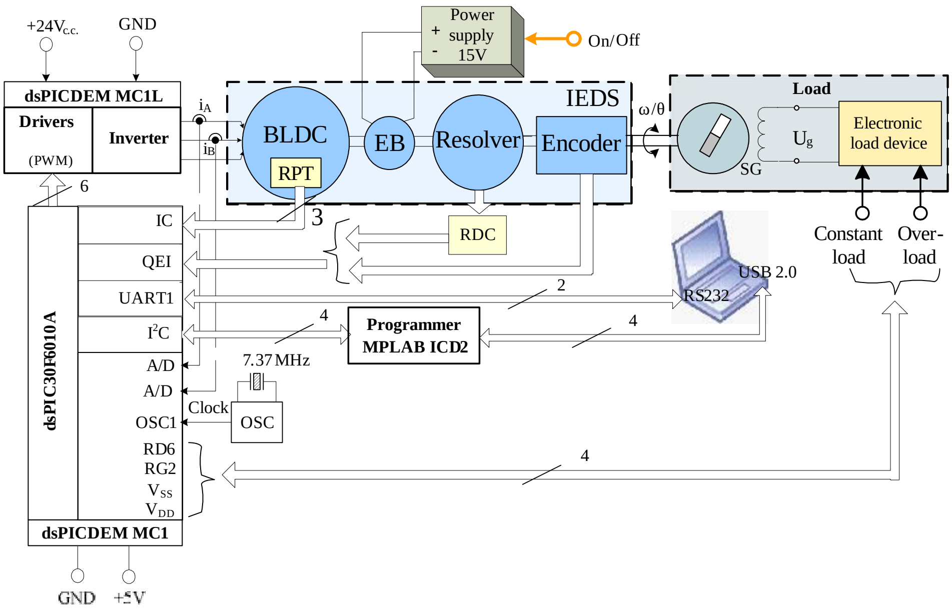


Figure 1. EDS block diagram.

Dedicated for EDS control, dsPICDEM MC1 development system generally is designed to operate with dsPIC30F digital controllers family [9]. The development system has all of peripheral devices that are needed to be integrated in digital control of an EDS, the inverter being independent of it. The interconnection with the rotor position feedback of BLDCM is realized either by the interface with logical signals provided by RPT with Hall sensors, either by encoder's interface (QEI module). The block diagram of dsPICDEM MC1 development system is shown in Figure 2.

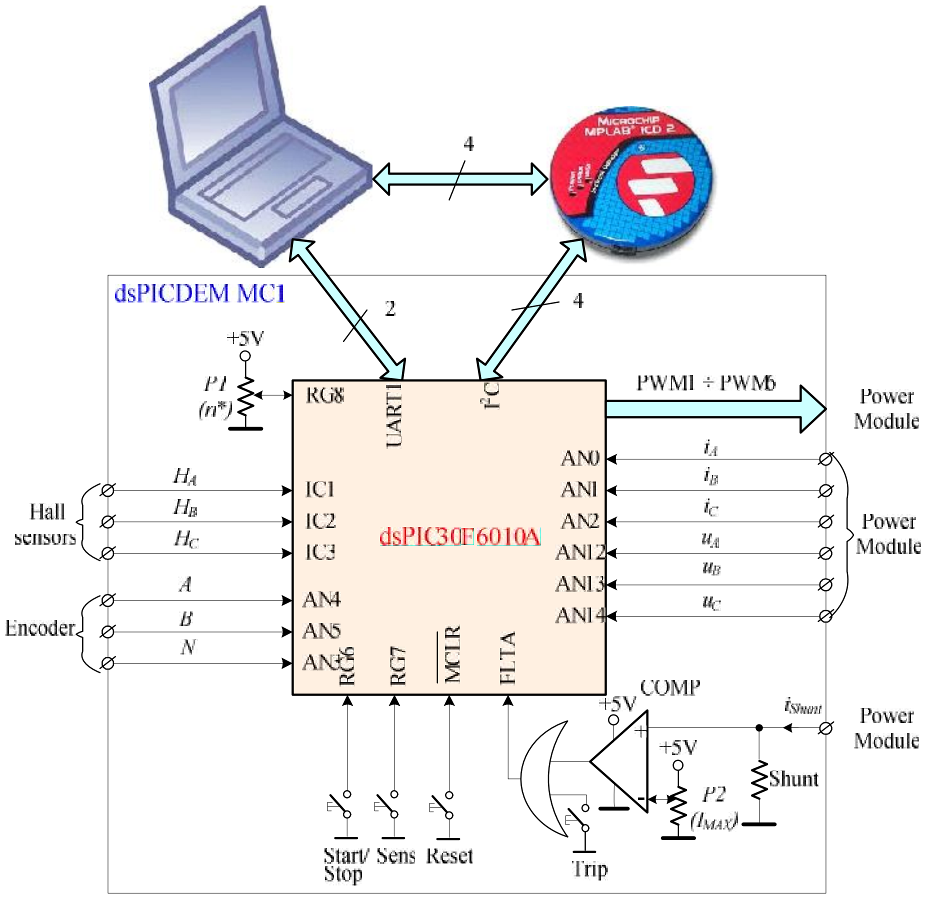


Figure 2. dsPICDEM MC1 development system block diagram.

The essential element of the development system is the digital controller (16 bits), with signal processor features, dsPIC30F3010A. Its most important characteristics are [10]:

-84 base instructions;

-144 Kb program memories (Flash), 8Kb RAM, 4 Kb EEPROM;

-internally clock with a frequency of 7.37 MHz;

-2 serial ports (RS232, RS485), 2 CAN modules, 8 PWM channels to command the inverter, 10-bit A/D Converter (1 Msps conversion rate);

-4 modules to generate dead time;

-3 inputs for encoder, 16 bits counter related to encoder interface (software possibilities to increase encoder signal resolution);

-programmable digital noise filters on inputs.

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

dsPICDEM MC1L power module that feeds the BLDCM includes an inverter made by 6 MOSFET transistors. Also, dsPICDEM MC1L driver contains a reverse voltage protection circuit and a breake chopper [10].

3. Speed Digital Control of BLDCM

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

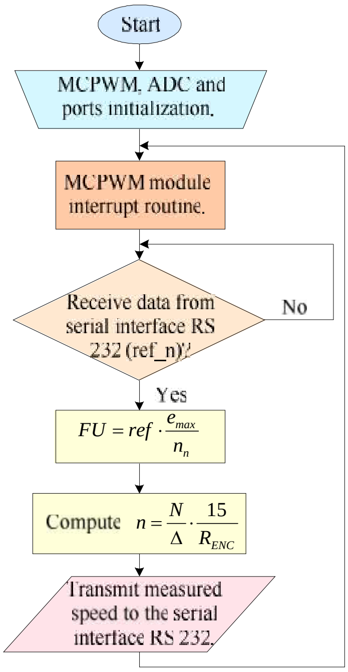


Figure 3. Flowchart of main program.

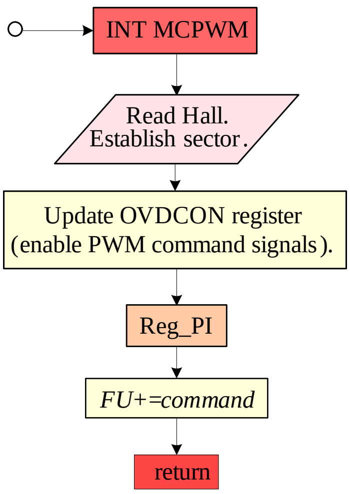


Figure 4. Flowchart of interrupt routine.

The digital controller algorithm is PI type and it assures a good dynamic response and a zero error in the steady state [6]:

$$u(k)=u(k-1)+K_P\cdot\left(\frac{T_s}{T_i}+1\right)\cdot e(k)-K_P\cdot e(k-1)\,, \qquad (1)$$

where:

- u(k) and e(k) are the command quantity and error from actual sample step;
- u(k-1) and e(k-1) are the same quantities from last sample step;
- K_p is the proportionality constant;
- T_s is sample time;
- T_i is the integration time.

The flowchart of PI digital controller is shown in Figure 5.

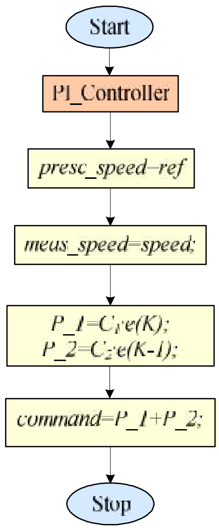


Figure 5. Flowchart of PI digital controller.

The real speed of BLDCM was obtained by using the QEI module of microcontroller which is connected to the signals generated by the incremental transducer. QEI module performs the multiplication with 4 of the information provided by the incremental transducer. The n [rpm] measured speed value is computed with [7], [8]:

$$n=\frac{N}{a}\cdot\frac{60}{4\cdot R_{ENC}}=\frac{N}{a}\cdot\frac{15}{R_{ENC}}\,, \qquad (2)$$

where:

- N is the number of pulses in Δ measurement range;

- R_{ENC} is the encoder's resolution (including the multiplication by 4 realized by microcontroller).

The graphical user interface was realized in LabVIEW 8.6 graphical programming language, its LabVIEW diagram being presented in Figure 6.

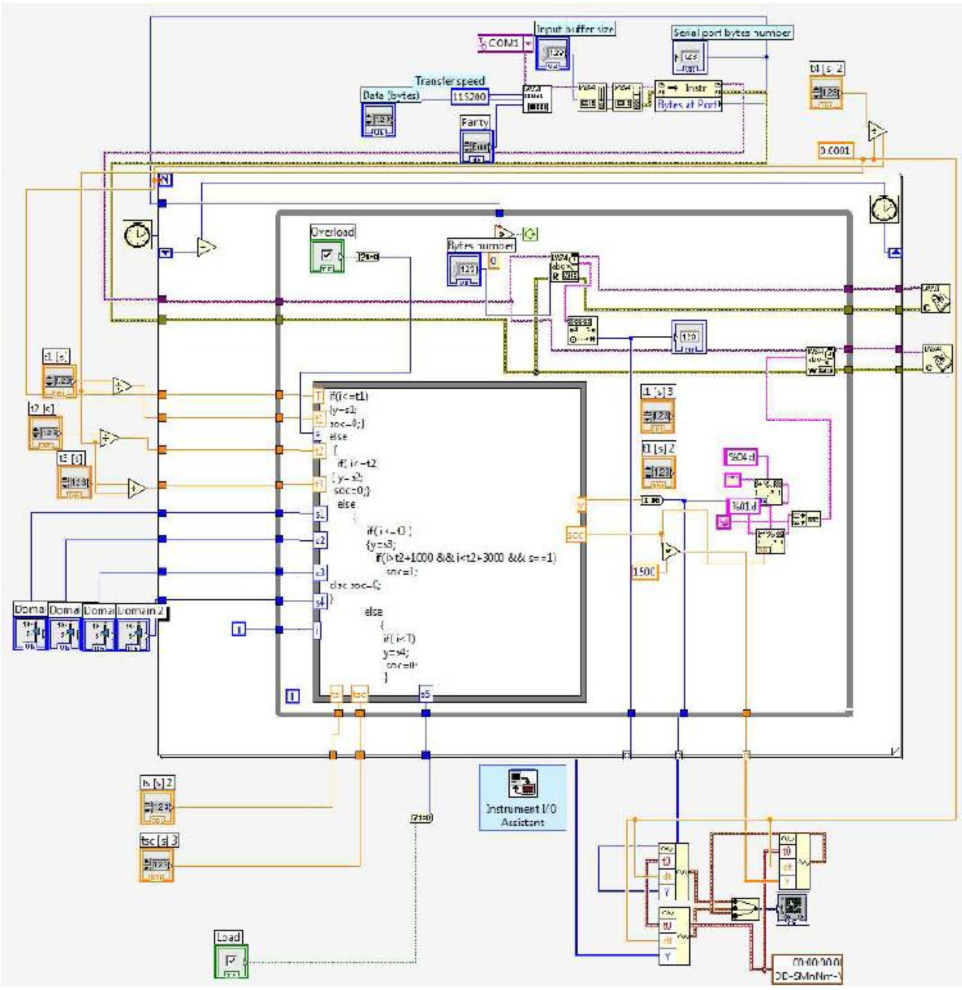


Figure 6. LabVIEW diagram for speed digital control.

The realized graphical user interface offers the following facilities:

- setting of speed controller parameters;
- speed profiling (step variation);

- establishing of operating regime (constant load or overload).
- visualization of the prescribed/measured speed and command quantity.

4. Experimental Results. Conclusions

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

The BLDCM 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.

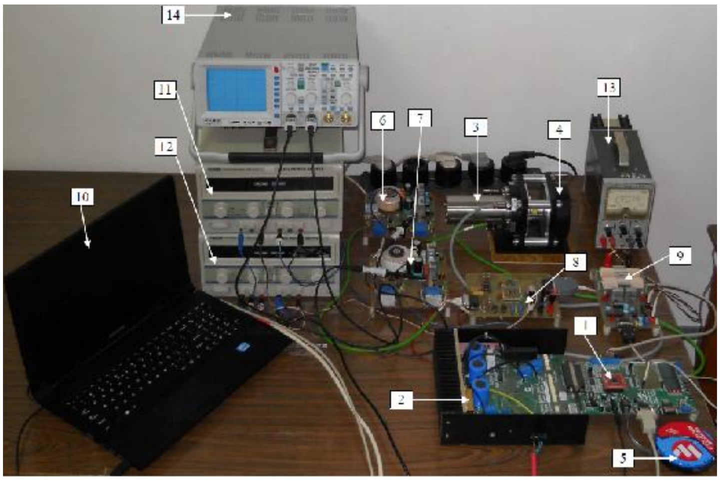


Figure 7. General view of the test bench: 1–development system, 2–power module, 3–IEDS, 4–SG, 5–MPLAB ICD2 programmer/debugger, 6–current transducers interface, 7–voltage transducers interface, 8–RDC, 9–electronic load device, 10–PC, 11, 12, 13–power supplies, 14–osciloscope.

Table 1. Rated parameters of the BLDCM.

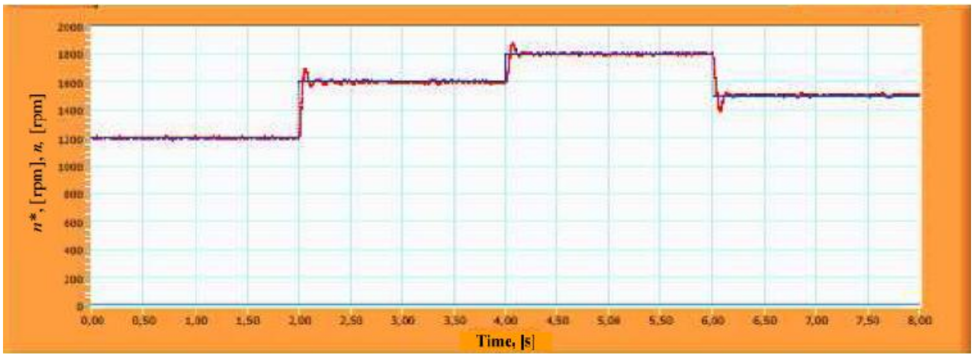
Parameter	Value	Unit
Voltage, U_n	24	V
Current, I_n	3.5	A
Speed, n_n	1725	rpm
Torque, M_n	0.35	Nm
Power, P_n	63.5	W
Winding resistance, R	0.7	Ω
Winding inductance, L	1.3	mH
Voltage constant, k_e	0.07	V/(rad/s)

To load the motor, a load formed by an electronic load device an a single-phase Synchronous Generator (SG) was used. Position and speed signals were provided by the incremental transducer manufactured by Allied Motion-Computer Optical Products Inc. Company (resolution of 4096 pulses/rev.).

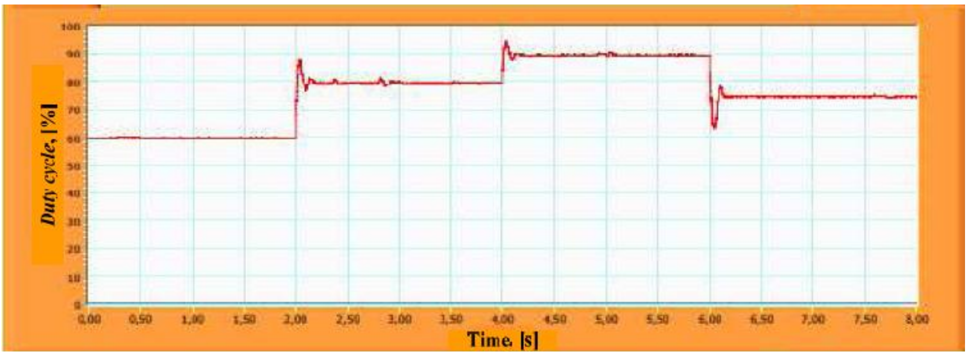
The experimental results were obtained in the following working conditions:

- prescribed speed step variation;
- disturbance (overload) step variation.

In Fig. 8 is presented the system response at prescribed speed step variation. Due to fact that digital controller was corectly chosen and tuned, system response is very good (good dynamic response and a zerro error in the stationary state).



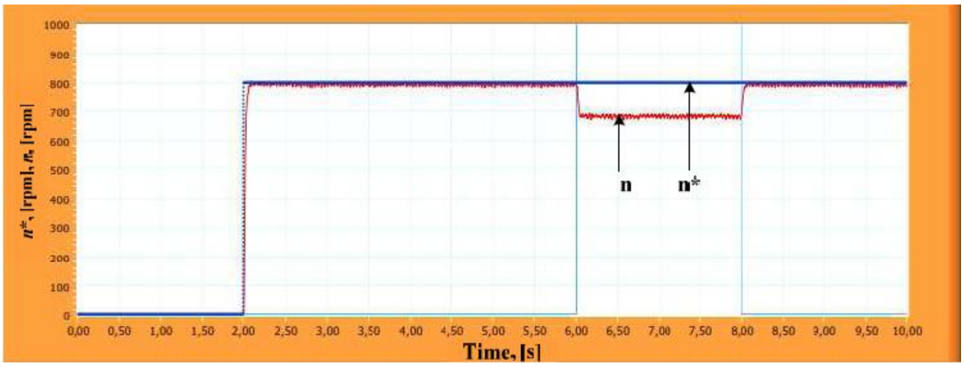
a. Prescribed and measured speed.



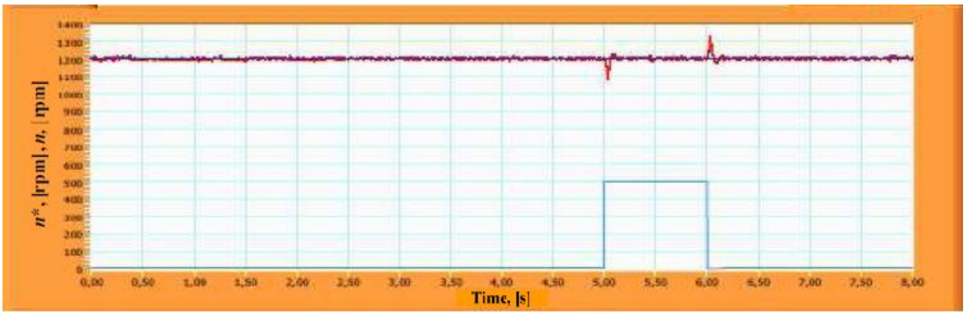
b. Duty cycle.

Figure 8. System response for prescribed speed step variation.

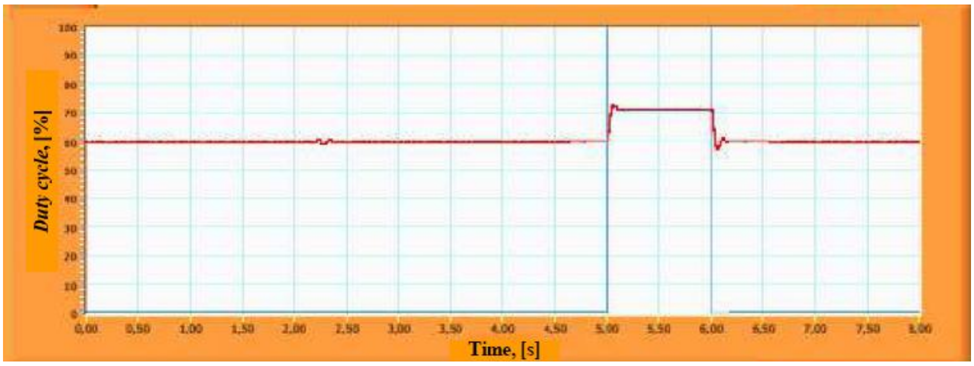
In Fig. 9 is presented the system response at disturbance (load torque) step variation (overload). The overload was imposed in [5÷6]s interval. The experimental results were obtained for a sample period T_s = 0.0001s. The controller parameters which led to this results are K_p = 1.21, T_i = 0.0141s and were obtained in an experimentally mode.



a. Prescribed and measured speed (open-loop control).



b. Prescribed and measured speed (closed-loop control).



c. Duty cycle.

Figure 9. System response for disturbance step variation.

The experimental results obtained also show a good compensation of disturbance.

The system presented is a good solution for digital control (open-loop and closed-loop) with microcontroller of a BLDC motor.

Due to well chosen and well tunned controller, the system response at speed step variation is very good. Therefore, the experimental results obtained also show a good compensation of disturbance (load torque) which does not happen in open-loop control.

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