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DEVELOPMENT OF A CONTROL PROGRAM FOR DC MOTORS USING PID CONTROL AND LOW-PASS FILTER

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Abstract: DC motors are used in a wide range in many engineering applications since are inexpensive compared to servo motors. In order to achieve precise positioning, DC motors are difficult to control, so in applications where precise positioning is required, servo motors are used. This research aims to build a program for precise control for DC micro motors to be actuated for precise positioning. For this, an inexpensive magnetic encoder was attached to the shaft at the end of the DC micromotor, and the control program used the Proportional-Integral-Derivative (PID) algorithm and a low-pass filter used for cut the frequency in speed control, allowing for smooth and precise positioning. In order to be able to actuate the DC micromotors in an easy way, the user interface was created with the help of the Visual Studio development program, and for the communication amongst microcontroller and computer, a communication protocol(serial) was developed in which the data transmission is done in a short period of time.

Key words: micro DC motors, magnetic encoder, PID control, low-pass filter, user interface.

1. INTRODUCTION

In the operation of a direct current (DC) motor, a conversion by transforming electrical power into mechanical power is made [1]. The DC motor principle is used in several types of motors, such as: brushless DC (BLDC) motor [2], stepper motor [3]. DC motors are preferred over AC motors because they have features of easy control [4], good performance and low power [5]. The applications of this type of motor are very diverse, such as: electric vehicles [6], rehabilitation robot [7], industrial robot [8][9][10], drone [11], pendulum [12] and so on.

The main difficulty of this type of motor is to control the position and angular velocity for a certain reference even if there is uncertainty or disturbance [13]. In order to be able to set the position of a DC motor, it is necessary to attach an encoder and the angular speed is established by means of the pulse width modulation (pwm) signal coming from the microcontroller port. Also, in order to be able to control the DC

motors, it is necessary to use a driver that is linked to the microcontroller.

Various controllers are implemented for DC motor, such as: PID controller [14], PI controller [15], Fuzzy Logic controller [16][17], model reference adaptive control (MRAC) [18] and so on. In a real hardware system the most known of the controllers is the PID controller because it is simple to implement [19].

The article is written in the following manner: Section 2 is dedicated to related works, and section 3 presents the description of the actuation and control system. Section 4 presents the user interface, after which it continues with conclusions and references.

2. RELATED WORK

In [20] a way to optimize the angular velocity for a DC motor has been proposed. This angular velocity is measured using a low-cost rotary magnetic encoder which is attached to the DC motor. This proposed technique was monitored and validated by obtaining a reduction in the

angular rotation rate estimation ripple of: 4.93%, 59.43%, 76.49% and 86.75%. The advantage of this improvement is that it does not introduce delays or increase the total cost of the rotary encoder. Ma'arif et al. [21] researched for tracking control in a DC motor an integral state feedback design using Matlab Simulink simulation and hardware implementation with Arduino. Then the results were compared with the PID controller implementation. Then the results were compared with the PID controller implementation where it was seen that the integral state feedback controller can cope with the system to succeed in reaching the set point with good performance in simulations, including with changing different setpoints and poles. Based on the result, the controller can reach the setpoint stably with oscillations, and when compared with the PID controller, it is observed that the integral state feedback controller has an improved response. In [22] is approached the robust problem of predictive speed control of DC motors that are controlled of a DC-DC converter, using a discrete-time model predictive control algorithm with output feedback. The efficiency of this algorithm is demonstrated with the help of testing by obtaining positive results. Patel et al. [23] proposes a technique that aims to develop closed-loop speed control for the brushless DC motor through use the modified sinusoidal pulse width modulation. By using a Proportional Integral (PI) controller for a speed control loop, closed-loop control is achieved, accurate detection of the rotor position and speed is achieved by using a magnetic encoder that is attached to the motor shaft. Shouran et al. [24] analyzes how the parameters of the Proportional Integral Derivative (PID) control can be adjusted by applying different optimization techniques for the DC motor. To get the optimal gains of the PID controller, the proposed algorithms for use are: teaching learning-based optimization (TLBO), Bees Algorithm (BA) and Particle swarm optimization (PSO). Through simulations, results were obtained that show that the DC motor responses obtained from the application of the PID tuned by TLBO have acceptable control performance in terms of establishment time, rise time and exceed.

3. DESCRIPTION OF THE CONTROL AND ACTUATION SYSTEM

Figure 1 shows a block diagram of the control and actuation system of DC motors.

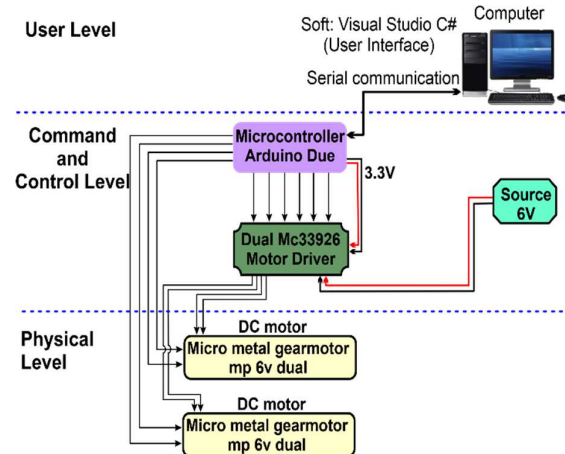


Fig. 1. The control and actuation system diagram

The control and actuation system is organized as follows:

- ✓ User Level;
- ✓ Command and Control Level;
- ✓ Physical Level.

User Level: include a computer equipped with the Visual Studio development program, using the C Sharp programming language (C#) for the programming part. The **user interface** has been created in this development program (Figure 13, 14). The communication amongst the microcontroller and the computer is done via the serial communication protocol.

Command and Control Level contains:

- microcontroller development board;
 - motor DC driver.
- The name of the microcontroller development board is Arduino DUE (Figure 2). This development board is based on the SAM3X8E microchip which has the Arm Cortex-M3 model processor. This microcontroller contains 54 pins. The processor works at a frequency of 84 MHz, having 4 UARTs (i.e., hardware serial ports).

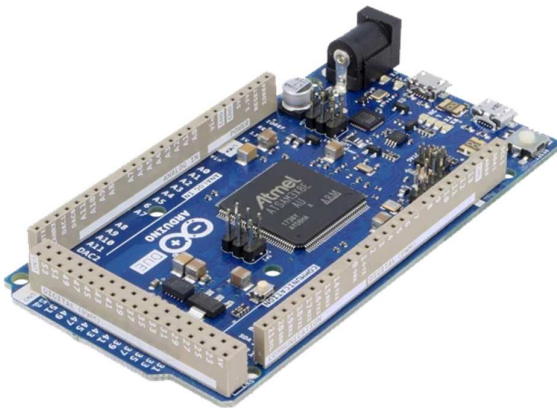


Fig. 2. Development board - Arduino DUE

- The motor DC driver, model Dual MC33926 (Figure 3) is based on Freescale's MC33926 full H-bridge, having the following specifications: channels: 2; minimum voltage: 5 V; maximum voltage: 28 V; current per channel: 2.5 A; PWM frequency: 20 kHz; Minimum logic voltage: 2.5 V; Maximum logic voltage: 5.5 V.

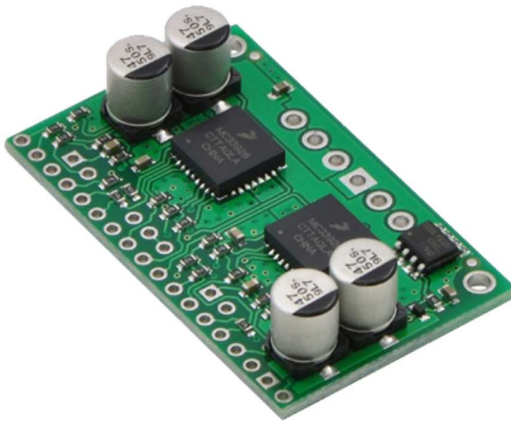


Fig. 3. Motor DC driver - Dual MC33926

The physical command and control system can be seen in the Figure 4. We can see in this system, motor DC driver (Figure 4, 1) and development board (Figure 4, 2). The DC motor driver is powered from the DC power supply (Figure 5) with 6.26V, and from the development board with a logic voltage of 3.3V.

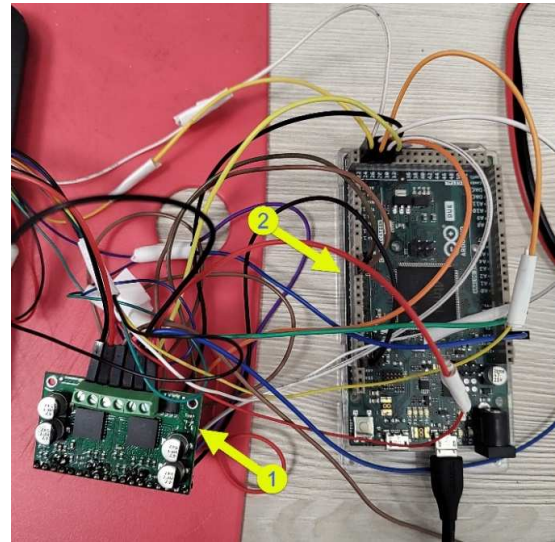


Fig. 4. Command and control system

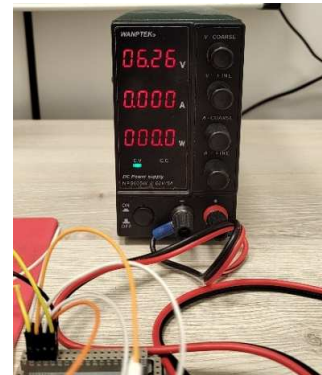


Fig. 5. DC power supply

Physical Level - contains DC micro metal motor (Figure 6) with the following specifications:

- Shaft diameter: 3 mm;
- Supply voltage: 6V;
- Transmission: 298:1;
- Nominal transmission rotations 73 rot./min;
- Torque: 235 mNm.



Fig. 6. DC micro metal motor - 298:1

For position control, an encoder was attached to the motor shaft (Figure 7) which has the following specifications:

- Minimum voltage 2.7V;
- Maximum voltage: 18V;
- Connector: with entry through the upper part, male, 6 pins, type JST SH;
- Generates 12 pulses/rotation (12CPR).

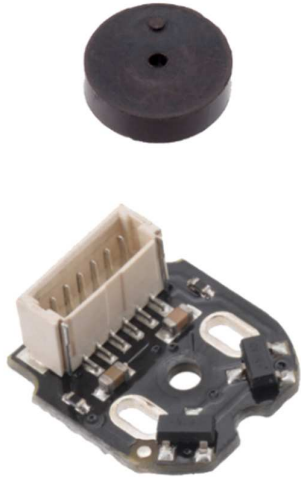


Fig. 7. Quadrature encoder

3.1 PID control and low pass filter

The Proportional Integral and Derivative (PID) controller is used in a large number to control the system for the desired reference point in the process industries, being the most flexible and simple method and therefore it can be said to be the most popular among all control methods.

For this application we use the PID control method to make a better and smooth positioning. A closed loop was used to control the motor position. (Figure 8).

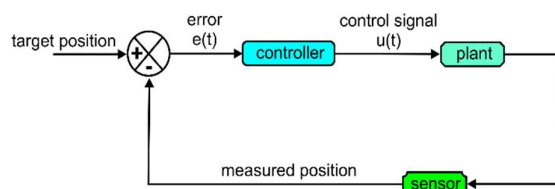


Fig.8. Closed control loop

In a closed control loop, the components that provide control are often called the installation (system), here being the motor driver and the motor. A sensor called an encoder is used to measure the position. A target position must be provided to control the motor position, and then the difference between the target position and the measured position is taken, the error being the result for this measurement. After calculating this error, a controller signal is sent to the plant. The control signal is configured to try to reduce the error. In this application we'll use the PID control algorithm to create the control signal: $k_p e(t) + k_i \int e(t) dt + k_d \frac{de}{dt}$.

The proportional term ($k_p e(t)$) it is fundamental because it is responsible for reducing the error, the derivative ($k_i \int e(t) dt$) and integral ($k_d \frac{de}{dt}$) terms are usually used to smooth the response of the control system. The constants k_p, k_i and k_d determine how resistant each term in the control loop is represented, we can adapt these constants to tune our response and we can evaluate the integral and derivative of the error using the simple finite difference approximation: $\int e(t) dt \approx c_{int} + e \Delta t$ $\frac{de}{dt} \approx \frac{e - e_{prev}}{\Delta t}$. The derivative calculates how quickly the error changes, while the integral term accumulates the error over time.

After the code was written in the Arduino language and loaded on the "Arduino DUE" microcontroller, tests were made to reach the desired goal using the PID control algorithm. On Figure 9 we can see the raw result of a signal in which no values were added to the three constants ($k_p = 0$; $k_i = 0$ and $k_d = 0$) in the PID algorithm. We can see here the motor that spins too much and has to reverse the direction to reach the target position because an overtaking is done after reaching the target.

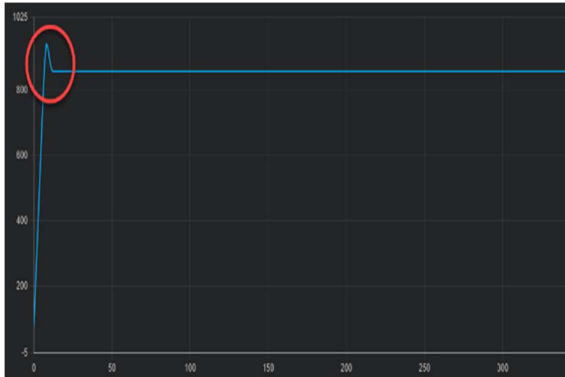


Fig.9. Tests using raw signal in the PID algorithm

By adding the following values to the constants $k_p = 1$; $k_i = 0$ and $k_d = 0.025$ the desired result could be obtained, as can be seen in Figure 10.

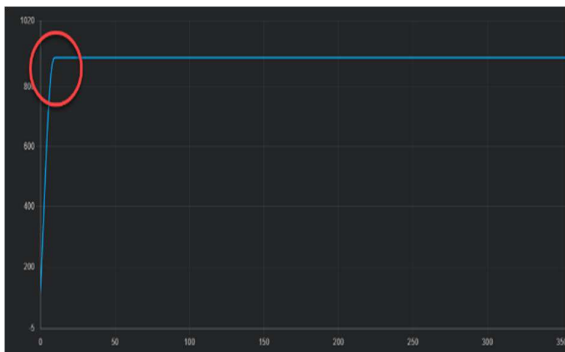


Fig.10. Tests using processed signal in the PID algorithm

During DC motor operation the speed is coarse due to the discrete steps of the encoder, and as the speed changes there are high frequency oscillations between the discrete levels. Applying a low pass filter will remove these high frequencies and produce an improved speed estimate, this will be important for our application in speed control. To design a low-pass filter it is necessary to specify a cut-off frequency. For this application, a cut-off has been made at 25 hertz. To create the discrete implementation of the filter we used the Matlab program. To create the low pass filter we used the transfer function and the discrete time transfer function. After obtaining the results from the discrete transfer function in the Matlab program, they are used in the Arduino program to facilitate cutting the frequency to 25 hertz. On Figure 11 we can see an raw signal (1) where

low-pass filter was not used and a processed signal (2) where the frequency was cut-off at 25 hertz with the help of the low-pass filter. From here we can see the importance of using the low-pass filter when the signal is processed to be used for speed.

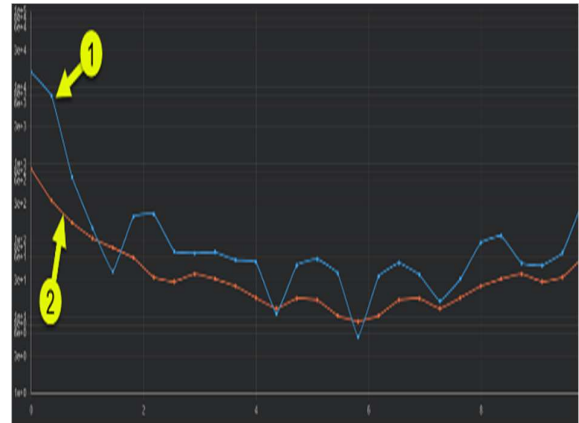


Fig.11. Tests using raw signal and processed signal

4. THE USER INTERFACE

In order to be able to interact with DC motors (Figure 12), a simple user interface has been developed.



Fig.12. Actuation of DC motors

When the user interface is opened, through a serial port, an automatic connection between the microcontroller and the computer is created. When creating this connection, the button "PortConn" displays status "On", on a yellow background.

The user interface is divided into two control modes, as follows:

- ✓ In the first control mode (Figure 13) the DC motors can be controlled individually with the help of cursors. First, we select the number of motors that we want to control by

means of radio buttons (M1, M2, All M), then by means of three sliders (Speed, Acceleration, Position) we will set the speed, acceleration and position. In the example from Figure 13, both motors (Figure 12, 1, 2) were selected to be controlled. In the fields "Encoder pos." we can see the position of the motors.

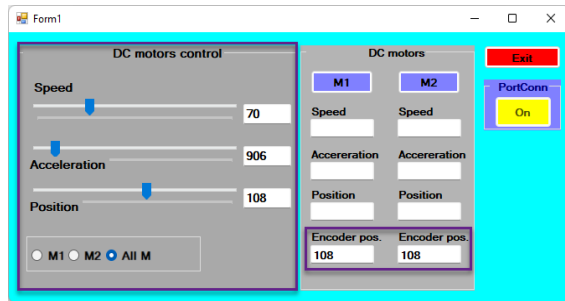


Fig.13. User interface - first control mode

- ✓ In the second control mode (Figure 14) the DC motors can be controlled individually by pressing some buttons (M1, M2), after the values for speed, acceleration and position have been entered. In Figure 14 we can see an example in which a single motor is controlled (Figure 12, 1).

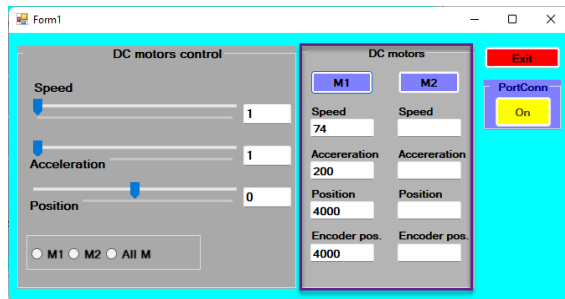


Fig.14. User interface - second control mode

5. CONCLUSION

This article presents the development of a control program for DC motors. In the control program, the PID controller was used to make a correct and smooth positioning of the DC motors. Also in this control the low pass filter was used to cut the high frequencies from the signal to produce an improved estimate in the speed control. As part of the control system, a detailed representation of the user interface is

made. The performance of the system was validated through several laboratory tests.

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DEZVOLTAREA UNUI PROGRAM DE CONTROL PENTRU MOTOARELE DE CURENT CONTINUU FOLOSIND CONTROLUL PID SI FILTRUL TRECE-JOS

Rezumat: Motoarele de curent continuu sunt utilizate într-o gamă largă în multe aplicații de inginerie deoarece sunt ieftine în comparație cu servomotoarele. Pentru a obține o poziționare precisă, motoarele de curent continuu sunt greu de controlat, așa că în aplicațiile în care este necesară o poziționare precisă, se folosesc servomotoare. Această cercetare își propune să construiască un program de control precis al micromotoarelor de curent continuu care urmează să fie acționate pentru o poziționare precisă. Pentru acest lucru pe axul de la capătul micromotorului de curent continuu a fost atașat un encoder magnetic ieftin, iar în programul de control au fost folosite algoritmul de control Proportional-Integral-Derivat (PID) și un filtru trece jos folosit pentru a tăia frecvența în controlul vitezei, permitând o poziționare lină și precisă. Pentru a putea acționa micromotoarele de curent continuu într-un mod ușor, a fost dezvoltată o interfață cu utilizatorul folosind programul de dezvoltare Visual Studio, iar pentru comunicarea dintre calculator și microcontroler a fost dezvoltat un protocol de comunicare serială în care transmiterea datelor se realizează într-o perioadă scurtă de timp.

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