

Embedded System Based Real Time Position Control Of A Dc Motor Using Matlab

Osman ULKIR¹, Ishak ERTUGRUL², Nihat AKKUS³

^{1,2,3}Department of Mechatronics Engineering, Marmara University, Istanbul, 34722, Turkey

Abstract

In this study, a permanent magnet DC motor has been controlled in real time by PID controller. The position of the motor is being controlled to the desired value using fixed and variable reference signals using as input to the motor. An embedded system is designed by Matlab and Simulink in order to control the position of a DC motor. Normally, a Data Acquisition Card (DAQ) is required to collect data through Matlab for real time control by the cost of using this system is very expensive. For that reason an open source system based ARDUINO MEGA 2560 electronic card is being used for this study.

Keywords: PID Control, Dc Motor, Matlab&Simulink, Embedded System.

1. Introduction

With the advancement in technology, DC motor has found its uses in many fields in the industry with robotics being at the top of this list. DC motor is available in many different sizes and prices but when compared with an AC motor, it is really cheap. In addition, a DC motor can be controlled by the mean of a very basic control system. Other advantages of DC motor include high efficiency and high starting torque for sudden increase in load [1].

Years ago, many of the servo motors, which are used for the position control, are based on AC motor. The control of AC motor is very difficult and due to the dominance of its non-linear properties, DC motor is being preferred in many applications over the AC motor. In contrast, the maintenance of brush and commutator is difficult and money consuming [2]. Because of those problems, brushless DC motor has begun to take the place of traditional DC motors in today's age.

Nowadays, not only the speed and position control of DC motor is being made feasible but a variety of different techniques have been developed for it [3]. Some example of those techniques are traditional P, PI, PID, fuzzy logic

based, nonlinear, adaptive variable structure, Neural Networks, Feed forward networks etc. [4].

Proportional-Integral-Derivative (PID) control technique has been commonly used for the control of dynamic systems. Almost 85% of dynamic control systems are based on PID control. In spite of having a basic construction, the need of having a mathematical model and to give unsuccessful result in nonlinear systems is the disadvantages of this type of control method [5].

PID control with pulse width modulation (PWM) switching is the most widely used position control technique for DC motors. It can be easily implemented on analog or digital components because it is well understood, simple, and in practice for a fairly long period of time.

In this study, a DC motor's position is controlled by Matlab and Simulink software and Arduino Mega 2560 programming card. The system's efficiency has been increased by developing a PID control algorithm. The designed controller, the impact on the system behavior has been observed by applying different gain rates and optimal PID parameters have been determined. The motor is being controlled at the desired position by comparing the output signal with the motor's current position and then feed backing it to the system' input. In order to learn the motor's position, a potentiometer is being as a feedback element in Simulink. Required amount of PWM is being applied by the comparing the results from the potentiometer and motor's position which help in deciding the values for PID parameters. By applying PWM on driver circuit, the motor is being kept at the desired position.

2. Arduino Card

Arduino is an open source development card. Because it is cheap and easily programmable, it is popular among users in its users every day. Arduino, a product of Atmel, has its own software named Wiring but it can also be programmed using C language. Due to the fact that it can be easily

communicated with Matlab and Labview and other control software, it has been very commonly used.

Arduino Mega 2560 can be operated by a battery or USB port or through an adaptor. The power source is selected automatically. It can be operated using a power source with 6-20V range. When used with voltages of more than 12 volts, it can cause damage to the card due to excessive heating. For this reason, voltages between 7 to 12 volts are preferred.

Arduino has Arduino Mega Atmega 2560 processor. It has 54 digital inputs/output pins, 14 out of 54 can be used as PWM output. It has 16 analog input pins. Besides that, it has 16 MHz crystal oscillator, a USB port, ICSP port and a reset button. It can be programmed through serial port using computer's USB port. Figure 1 shows the detail of all its operations with its input and output pins.

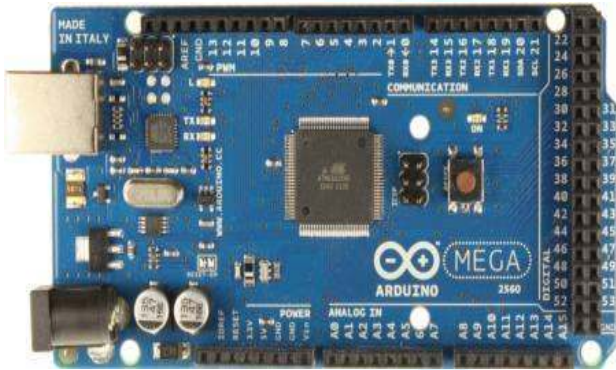


Figure 1: Arduino mega card

3. Designing Driver

In this study, the nominal value of 24V supply DC motor, which is used. A 40 W, 24V, 1800 rpm DC motor with the below parameters was used. Table 1 shows the motor parameters.

Table 1: Parameters of dc motor

Parameter	Symbol	Value
Motor inertia	J	0.01171(kgm ²)
Motor resistance	R	6.5 (Ω)
Motor inductance	L	0,673 (H)
Torque constant	Ki	0.038 (Nm/A)
Back emf constant	Kb	0.038 (Vs/rad)
Viscous friction	B	0.00143 (Nms/rad)

For this study, in order to drive a DC motor, an L298 driver is being used. It consists of 8 transistors which can rotate the motor in both reverse and forward directions. The usage voltage can rise up to 46 V. Total current consumption can rise up to 4 A. As it has low saturation voltage it can resist heating problems. It has a 0 logic till 1.5 V. It has A and B driver circuits. The driver designed for this study is shown in Figure 2.

When L298 motor driver integrated card used in a micro controlled circuit, Vsp and Vss pins should be connected to positive pole of DC motor supply, and the positive (+5V) voltage supply of microcontroller respectively. Meanwhile enable pins are used to activate the A and B driver circuits.



Figure 2: Driver circuit

4. PID Control

PID is the most used control system nowadays. It has been extensively used in the industrial applications [6]. Because of it being basic and due to the fact that it can be easily applied to the motor control, it has been widely used. The general block diagram has been shown in Figure 3.

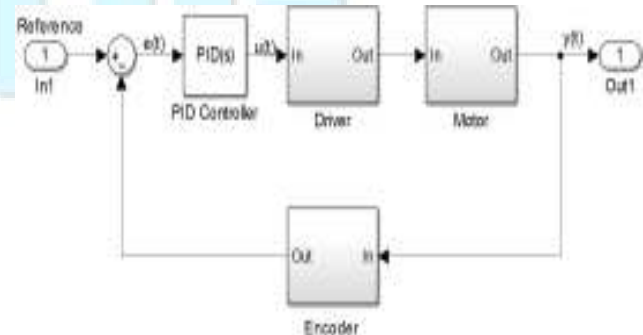


Figure 3: Block diagram of PID control

As shown in Figure 3, the difference between determined reference value and the value of systems current position received from the encoder, is transmitted to the controller as the error value. Controller processes the error data and gives an output, and consequently output provide to generate PWM. The engines move logical by PWM which applied to the motor with the proper drivers.

PID control forming proportional, integral and derivative gains each of the acts in various ways to the operation of the system. Proportional controller (K_p) is effective in reducing the rise time, but doesn't remove the steady state error. Integral controller (K_i) is effective in removing the steady state error, but transient response can be worse. Derivative controller (K_d) is effective for the increase in system stability, in the reduction of the overshoot and the improvement transient response. PID controller output:

$$u(t) = K_p e(t) + K_i \int e(t) + K_d \frac{de(t)}{dt} \quad (1)$$

$$e(t) = r(t) - y(t) \quad (2)$$

Where, $u(t)$ shows control signal, $e(t)$ shows error signal, $y(t)$ shows output signal. In PID control algorithm, for system output to track the desired reference value, K_p , K_d and K_i gains has to be determined properly. In this method, K_p gain product with $e(t)$, control output $u(t)$ obtained by K_i gain product with integral of $e(t)$ and K_d gain product with derivative of $e(t)$ and then all products added with each other [7].

PID control is applied on the position information, which is collected from the potentiometer, by Matlab and Simulink in order to provide output as close to the desired position as possible. The system model which is built in Simulink is shown in Figure 4. The reference signal input from the Arduino and PID controller and PWM signals, which are important for positional controlling, are shown.

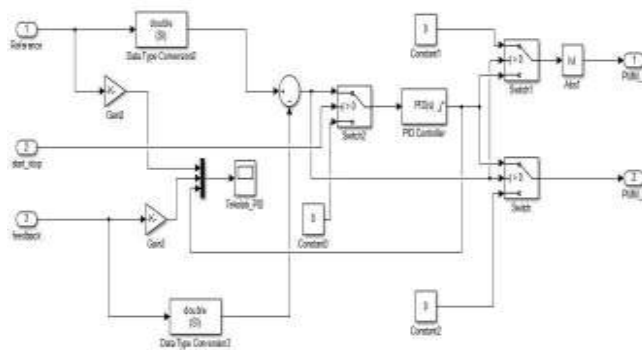


Figure 4: Simulink model of dc motor

In this study, the values for PID's parameter K_p , K_i and K_d are selected to be 8,4 and 7 accordingly using the trial and error method. Those values provide the best output result.

5. Communication of Arduino with Matlab

Arduino Mega Card has Atmega2560 integrator. This integrator has protocols which allow it to communicate with Matlab etc. Because of this, Arduino Mega programmable card can communicate with Matlab through USB port. After connecting Arduino card with Computer, the required drivers can be downloaded which will help the communication process between the two devices.

In order to make the communication between Arduino and Matlab possible, it is necessary to install Simulink toolbox in Matlab first. After the installation, the Arduino card can be selected from the menu in Simulink.

6. Experimental Results and Discussion

The position control of a DC motor in real time is done using an experimental set in University's laboratory. The experimental setup is shown in Figure 5. In order to move the motor to the desired position of user, the PID controller is being used. The reference signal to the system is done using two methods. The other method is by using a potentiometer. The values of the PID controller are $K_p=8$, $K_i=4$ and $K_d=7$. This configuration gives the best results possible.

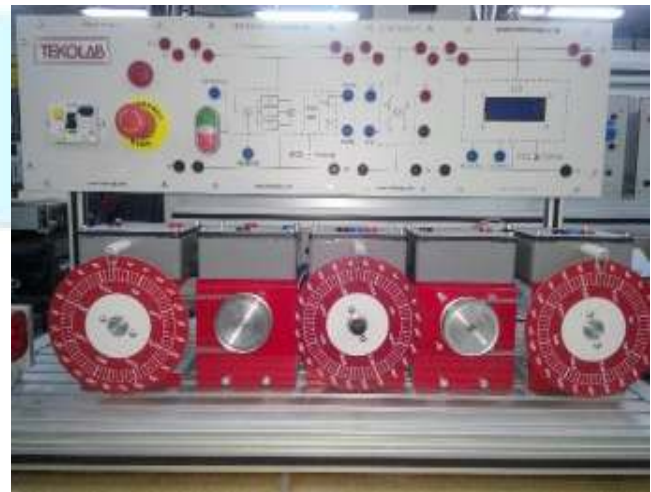


Figure 5: Experimental setup

The results collected from the system are shown in this section. Using the different input reference signals, the behavior of the system was being observed. At first, 350° reference input was being fed to the system's input. The result of that signal was shown in Figure 6. Afterwards, the motor was requested to turn 180°.

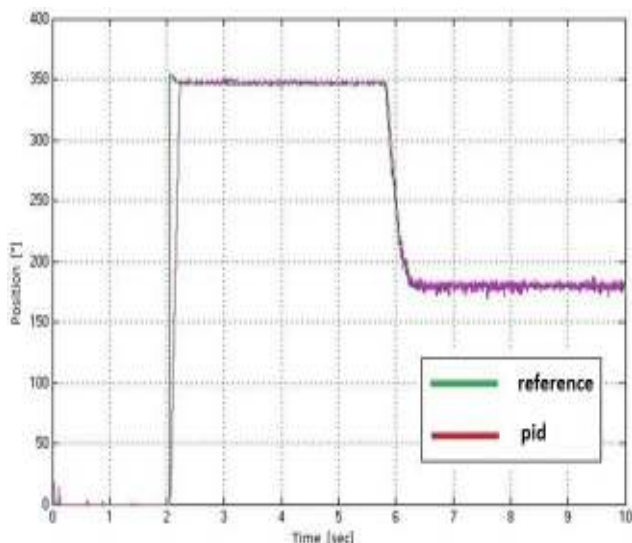


Figure 6: Variable reference signals and pid results

At second, 90° reference input was being fed to the system's input. The result of that signal was shown in Figure 7. Afterwards, the motor was requested to turn to 180°.

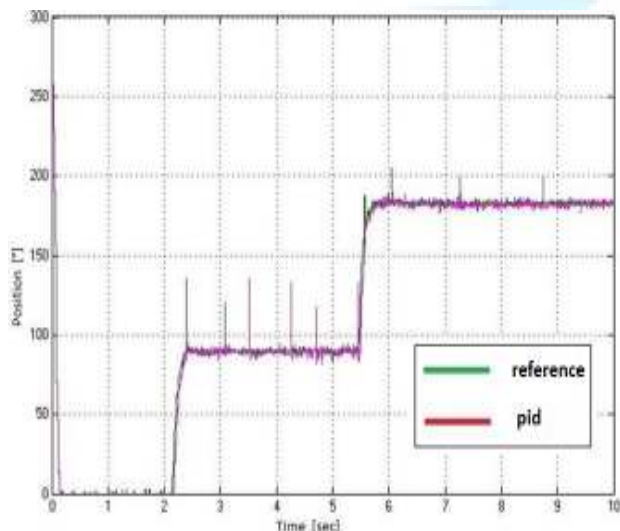


Figure 7: Fixed reference signals and pid results

Using the different input reference signal, the response of the system was being observed. According to the result, it is clear that this PID parameters gives the most precise result and catch the system reference values.

7. Conclusions

In this study, the position of DC motor is being controlled by PID controller in real time. The inputs and output to the system is being done using Matlab and Simulink on Computer. In order to increase the efficiency of the system, PID controller's values are being manipulated. Arduino is being preferred over the DAQ card because it is much cheaper. In addition, Arduino is able to use USB port for communication, and it provides a fast transfer of data in addition to its ease of programming.

It is well known that production is very much dependent on automation systems. In this study, a DC motor, which is one of the most basic element in automation system, is controlled in real time by a PID controller.

References

- [1] Ibrahim, H. E. A., F. N. Hassan, and Anas O. Shomer. "Optimal PID control of a brushless DC motor using PSO and BF techniques." *Ain Shams Engineering Journal* 5.2 (2014): 391-398.
- [2] Lee, J. B., et al. "Design and implementation of integrated drive circuit for a small BLDC motor." *Electrical Machines and Systems, 2003. ICEMS 2003. Sixth International Conference on*. Vol. 2. IEEE, 2003.
- [3] Lucas, Caro, Danial Shahmirzadi, and Nima Sheikholeslami. "Introducing BELBIC: brain emotional learning based intelligent controller." *Intelligent Automation & Soft Computing* 10.1 (2004): 11-21.
- [4] Aydemir, Seda, Serkan Sezen, and H. Mertin Ertunc. "Fuzzy logic speed control of a DC motor." *Power Electronics and Motion Control Conference, 2004. IPEMC 2004. The 4th International*. Vol. 2. IEEE, 2004.
- [5] Ang, Kiam Heong, Gregory Chong, and Yun Li. "PID control system analysis, design, and technology." *IEEE transactions on control systems technology* 13.4 (2005): 559-576.
- [6] Zhang, Jiasheng, Dingwen Yu, and Shiqing Qi. "Structural research of fuzzy PID controllers." *2005 International Conference on Control and Automation*. Vol. 2. IEEE, 2005.
- [7] Meshram, P. M., and Rohit G. Kanojiya. "Tuning of PID controller using Ziegler-Nichols method for speed control of DC motor." *Advances in Engineering, Science and Management (ICAESM), 2012 International Conference on*. IEEE, 2012.