OPEN ACCESS
Saudi Journal of Engineering and Technology
Abbreviated Key Title: Saudi J Eng Technol
ISSN 2415-6272 (Print) |ISSN 2415-6264 (Online)
Scholars Middle East Publishers, Dubai, United Arab Emirates
Journal homepage: https://saudijournals.com

Original Research Article

Real-Time PID Controller for a DC Motor Using STM32F407

Nguyen Le Thai[1*], Nguyen Thi Kieu[1]

[1]Faculty of Engineering & Technology, Nguyen Tat Thanh University, Ho Chi Minh City, Vietnam

DOI: 10.36348/sjet.2022.v07i08.007 | **Received:** 20.08.2022 | **Accepted:** 13.09.2022 | **Published:** 20.09.2022

***Corresponding author:** Nguyen Le Thai
Faculty of Engineering & Technology, Nguyen Tat Thanh University, Ho Chi Minh City, Vietnam

Abstract

This paper presents a real - time model of the DC motor speed control system. The PID controller is used to estimate the error between the actual speed and the set speed to adjust the Pulse - width modulation (PWM) inverter. The actual speed is measured through the encoder that provides training and testing data for PID controller. Simulation results are compared with the real-time results to address advantages and disadvantages of the system.

Keywords: PID Controller; DC motor; Speed control; Real-time model.

1. INTRODUCTION

DC motors are widely used in machine tools, printing presses, ans, pumps, hoists, robotics, Small DC motors are mainly used in control devices and servo motors for positioning and tracking. DC motors are also used in many high- precision industrial applications such as robot control, position control, steel mining and paper and textile industries. Therefore, the study of motor speed control methods has received great attention in recent years [1-3].

The proportional-integral-derivative (PID) controller is widely used in industrial control processes because of their simple structure and robust performance. The design of a PID controller depends on three parameters which are proportional gain *Kp*, integral time constant *Ki* and derivative time constant *Kd* [4]. Many authors have used the Fuzzy Logic controller to automatically detect the parameters of *Ki*, *Kp* and *Kd* of the PID controller [5-7]. However, the use of fuzzy controller will increase the complexity of the system leading to increase product costs. In this experiment, we detect the parameters *Kp*, *Ki* and *Kd* of the PID controller corresponding to the used DC motor.

In this paper, we first build a simulation model of DC motor speed using PID controller by Matlab Simulink. And then we use Kit STM32F407, DC motor servo encoder and the necessary equipment to conduct experiments.

The remainder of the paper is organized as follows. Section 2 describes theoretical basis of the PID controller and the Mathematical Model of DC Motor. Section 3 presents the simulation results of the model. Experimental results are given in Section 4 and conclusions are summarized in Section 5.

2. MODEL DESIGN

The model of DC Motor speed is presented in Figure 1. Where, *r(t)* is desired speed, *u(t)* is the actual speed of motor that is measured from speed sensor, *e(t)* is the error between desired speed and real speed that is transmitted to PID controller to stabilize the speed of the motor.

2.1 PID Controller

The PID controller is defined by the following relationship between the controller input *e(t)* and the controller output *u(t)* that is applied to the motor as follows:

$$y(t) = k_p e(t) + k_i \int_0^t e(\tau)d\tau + k_d \frac{de(t)}{d(t)} \qquad (1)$$

Laplace transform of the equation (1) gives the transfer function G(s) as follows:

$$G(s) = \frac{u(t)}{e(t)} = k_p + \frac{k_i}{s} + k_d s \qquad (2)$$

The discrete-time equation (2) expression is given as:

$$y(k) = k_p e(k) + k_i s T_s \sum_{i=1}^{n} e(i) + \frac{k_d}{T_s}\Delta e(k) \quad (3)$$

Here, u(k) is the control signal, e(k) is the error, Ts is the sampling period for the controller, and $\Delta e(k) \approx e(k) - e(k-1)$.

Citation: Nguyen Le Thai & Nguyen Thi Kieu (2022). Real-Time PID Controller for a DC Motor Using STM32F407. *Saudi J Eng Technol*, *7*(8): 472-478.

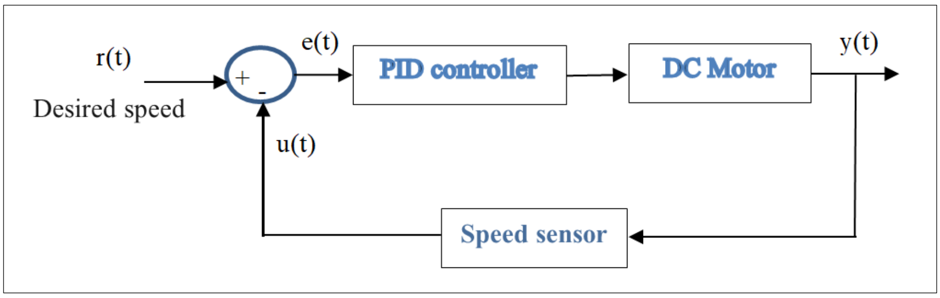


Figure 1: The model of DC motor speed control using PID controller

2.2 Mathematical Model of DC Motor

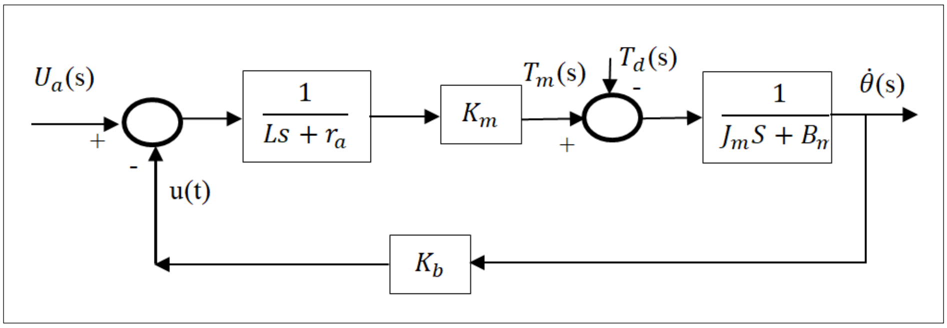


Figure 2: Block diagram of DC motor

The dynamic behavior of DC motor is given by following set of relations [8] and its block diagram is shown in Figure 2. A simplified linear model is presented for this work ignoring the nonlinearities like the backlash and dead zones to simplify the application of metaheuristic techniques. Consider

$$T_m(s) = K_m I_s(s) \quad (4)$$

$$U_a(s) = (r_a + Ls)I_a(s)_m + U_b(s) \quad (5)$$

$$U_b(s) = K_b\dot{\theta}(s) \quad (6)$$

$$I_a(s) = \frac{U_a - K_b\dot{\theta}(s)}{r_a + Ls} \quad (7)$$

$$T_l(s) = J_m s^2\theta(s) + B_m s\theta(s) \quad (8)$$

$$T_l(s) = T_m(s) + T_d(s) \quad (9)$$

Where, Ua is armature applied voltage, Ub is back-emf, Km is motor constant, Kb is back emf constant, Jm is inertia of rotor, Bm is viscous damping, Tm is developed motor torque, Tl is torque delivered to load, Td is disturbance torque, ra is armature resistance, L is armature inductance, Ia is armature current, and s is s-plane.

By using (1) the transfer function of DC motor is

$$\frac{\dot{\theta}(s)}{U_a(s)} = \frac{K_m}{(r_a+Ls)(J_m s+B_m s)+K_m+K_b} \quad (10)$$

3. SIMULATION

In this section, simulation results are given to verify the convergence of the PID controller. The simulation model is shown as Figure 3.

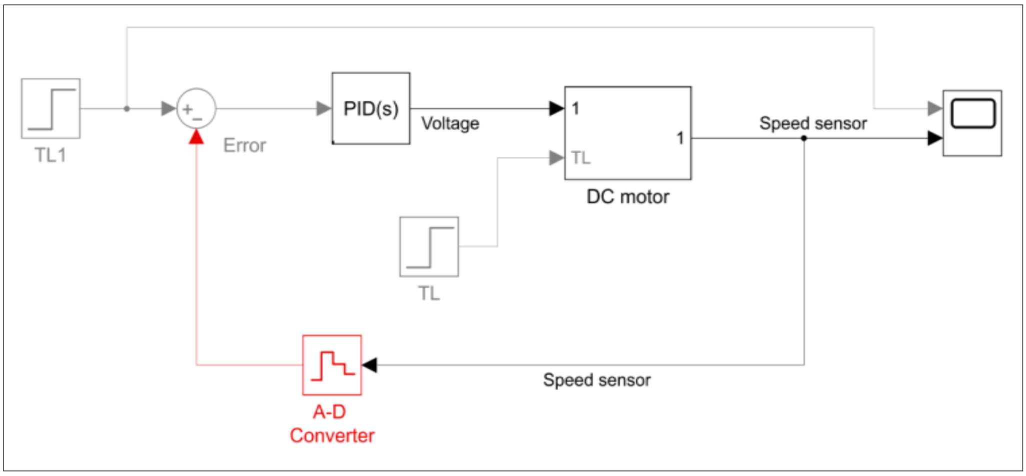


Figure 3: PID controller simulation model

The simulation parameters of DC motor are shown in Table 1.

Table 1: Parameters of DC motor

Parameter	***Values and Unit***
R	1 Ω
K_b	0.023 Kg-m/A
K_t	0.023 Vs/Rad
L	0.5 H
J_m	0.01Kgms^2/Rad
B_m	0.00003Kgms/Rad

The simulation parameters of PID controller are shown in Table 2.

Table 2: Parameters of PID controller

Parameter	***Values and Unit***
Ki	12
Kp	50
Kd	0.75
N	100

In this simulation, the speed motor is selected 200 rpm and 300 rpm. Figure 4 and Figure 5 show simulation results of PID controller.

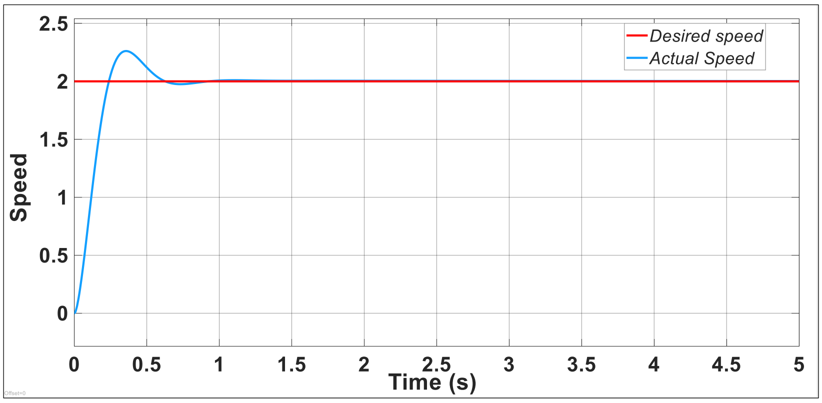


Figure 4: Simulation result at 200rpm

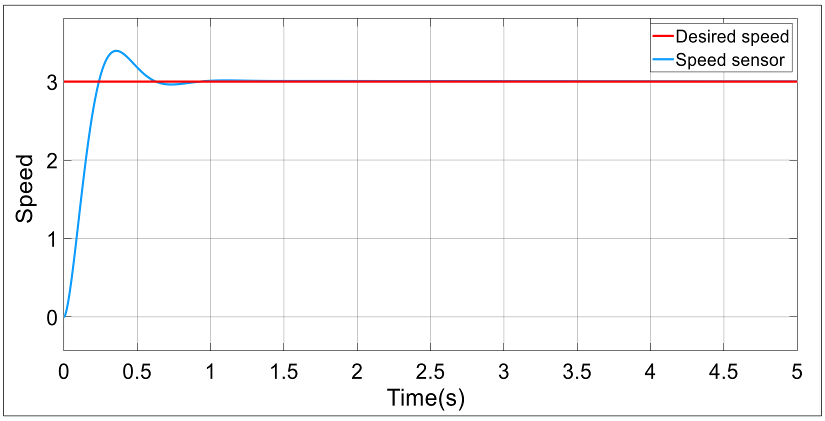


Figure 5: Simulation result at 300 rpm

4. EXPERIMENTAL RESULTS

4.1 Experimental Model

Experimental model is shown in Figure 6. Where, microcontroller is selected STM32F407. The encoder DC motor is selected GA37 and driver DC motor is used L298. The parameters of the PID controller are selected at Table 3 and the control software using waijung library in matlab simulink R2020b as shown in Appendix.

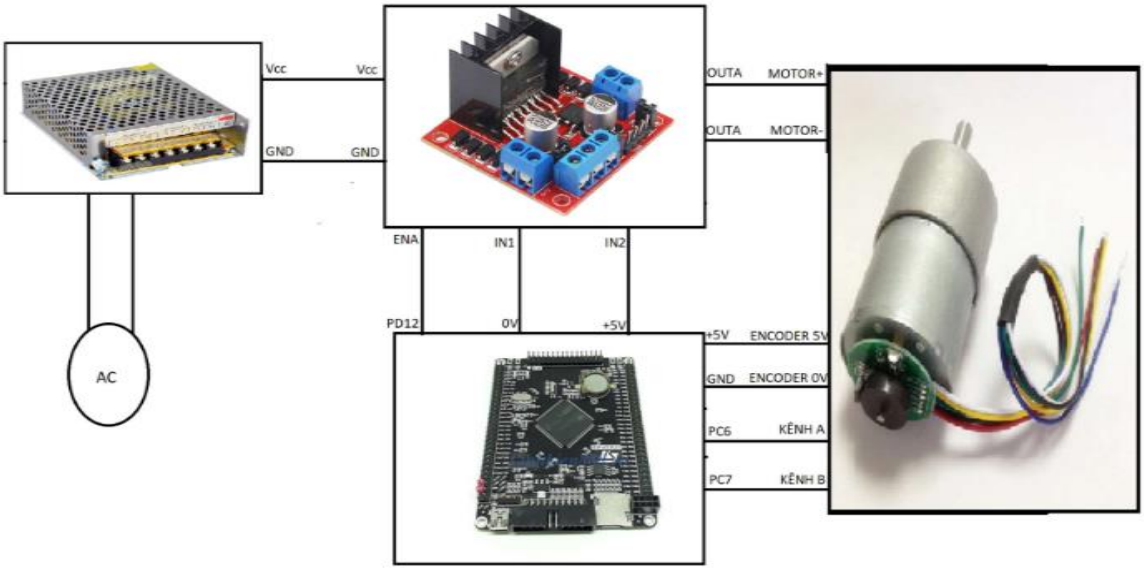


Figure 6: Experimental model: Missing

Table 3: Parameters of Discrete PID controller

Parameter	***Values and Unit***
Ki	12
Kp	50
Kd	0.75
Ts	0.01

4.2 Experimental Results

The experimental results are shown in Figure 7, Figure 8, Figure 9 and Figure 10. Figure 7 and Figure 8 show results of PID control performance with two different speeds of 200 rpm and 300 rpm, respectively.

Figure 9 provides the test results at the speed increasing from 400 rpm to 500 rpm. Figure 10 shows the test results at the speed increasing from 450 rpm to 550 rpm.

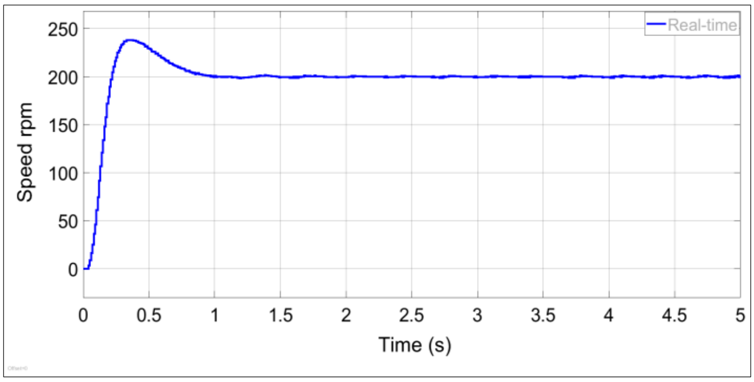


Figure 7: Experimental results for speed 200 rpm

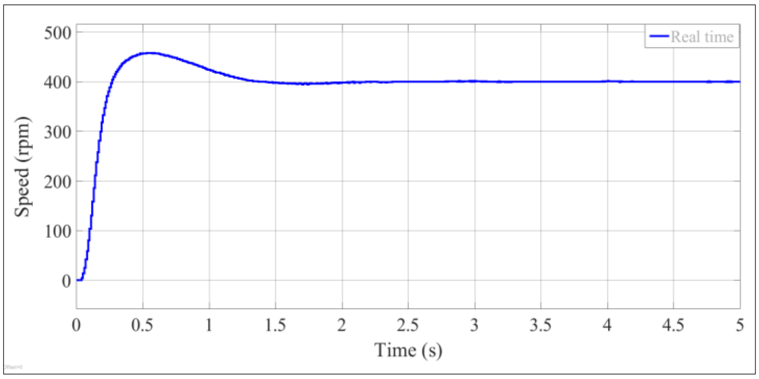


Figure 8: Experimental results for speed 400 rpm

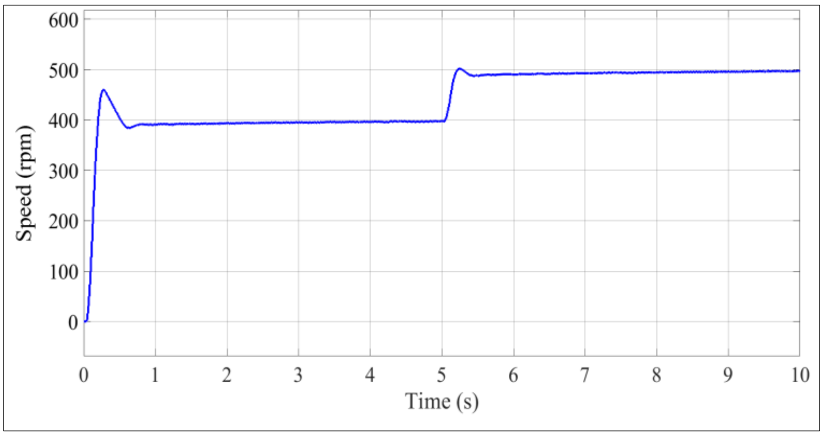


Figure 9: Experiment results for speed from 400 rpm to 500 rpm

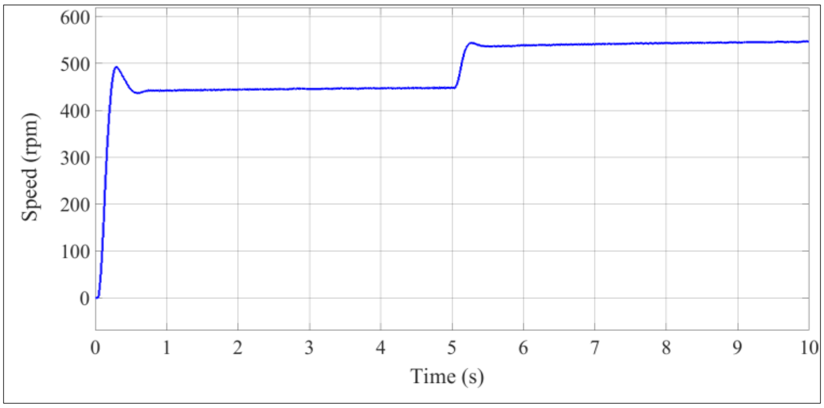
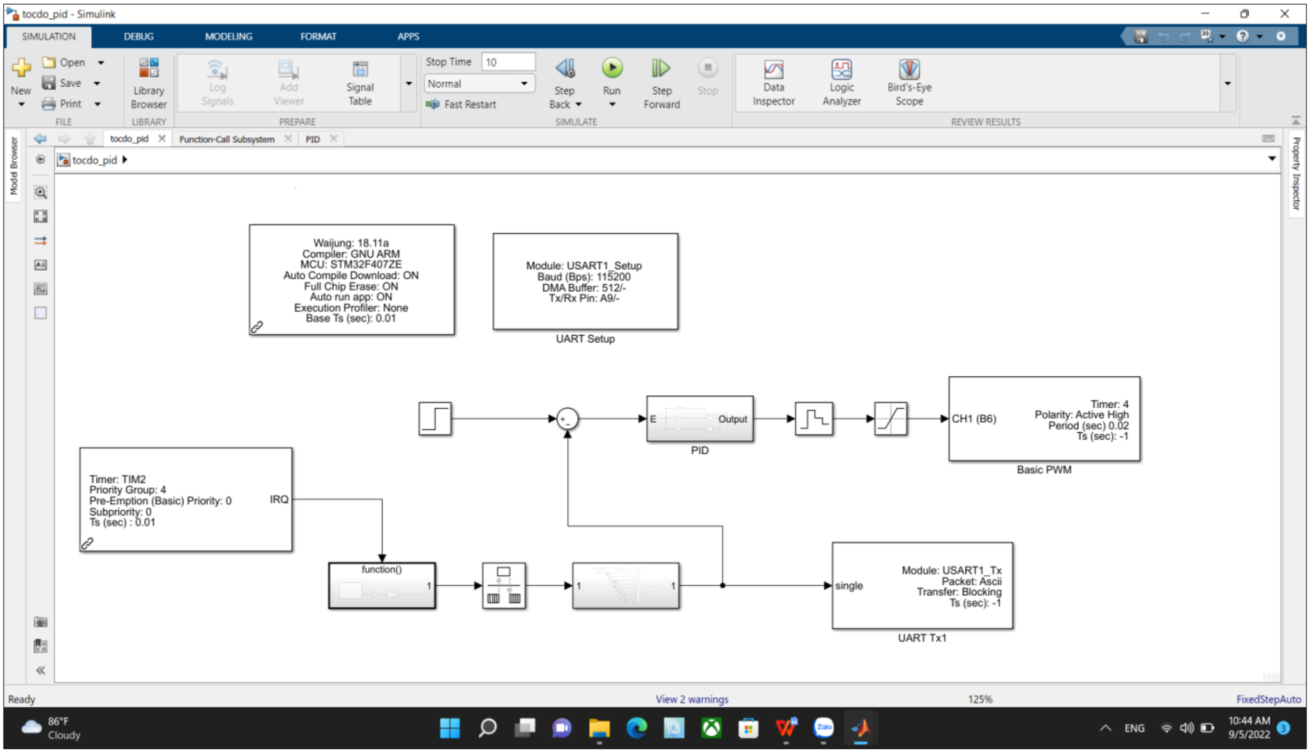


Figure 10: xperiment results for speed from 450 rpm to 550 rpm

APPENDIX

A. *Control program using waijung library.*



Waijung: 18.11a
Compiler: GNU ARM
MCU: STM32F407ZE
Auto Compile Download: ON
Full Chip Erase: ON
Auto run app: ON
Execution Profiler: None
Base Ts (sec): 0.01

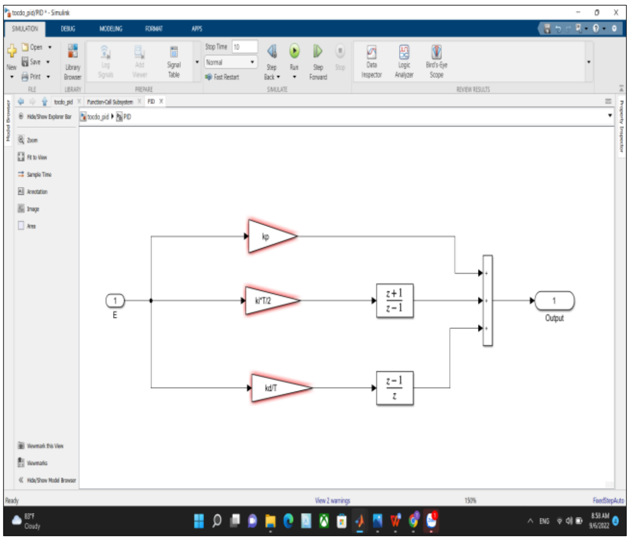
Module: USART1_Setup
Baud (Bps): 115200
DMA Buffer: 512/-
Tx/Rx Pin: A9/-

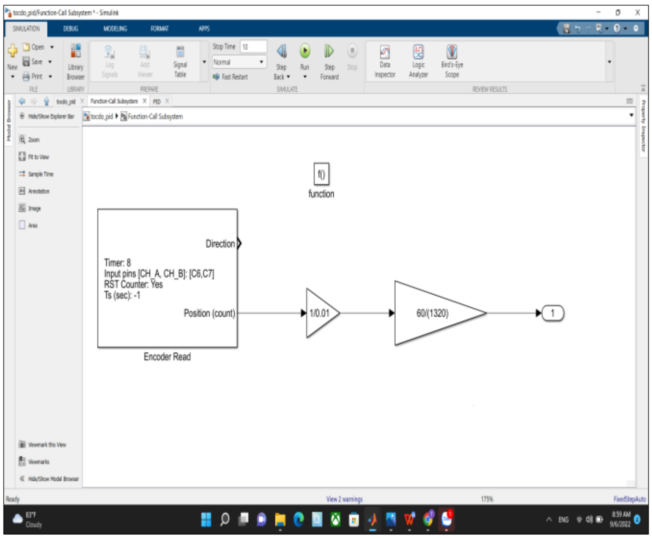
Timer: 4
Polarity: Active High
Period (sec) 0.02
Ts (sec): -1

Timer: TIM2
Priority Group: 4
Pre-Emption (Basic) Priority: 0
Subpriority: 0
Ts (sec) : 0.01

Module: USART1_Tx
Packet: Ascii
Transfer: Blocking
Ts (sec): -1

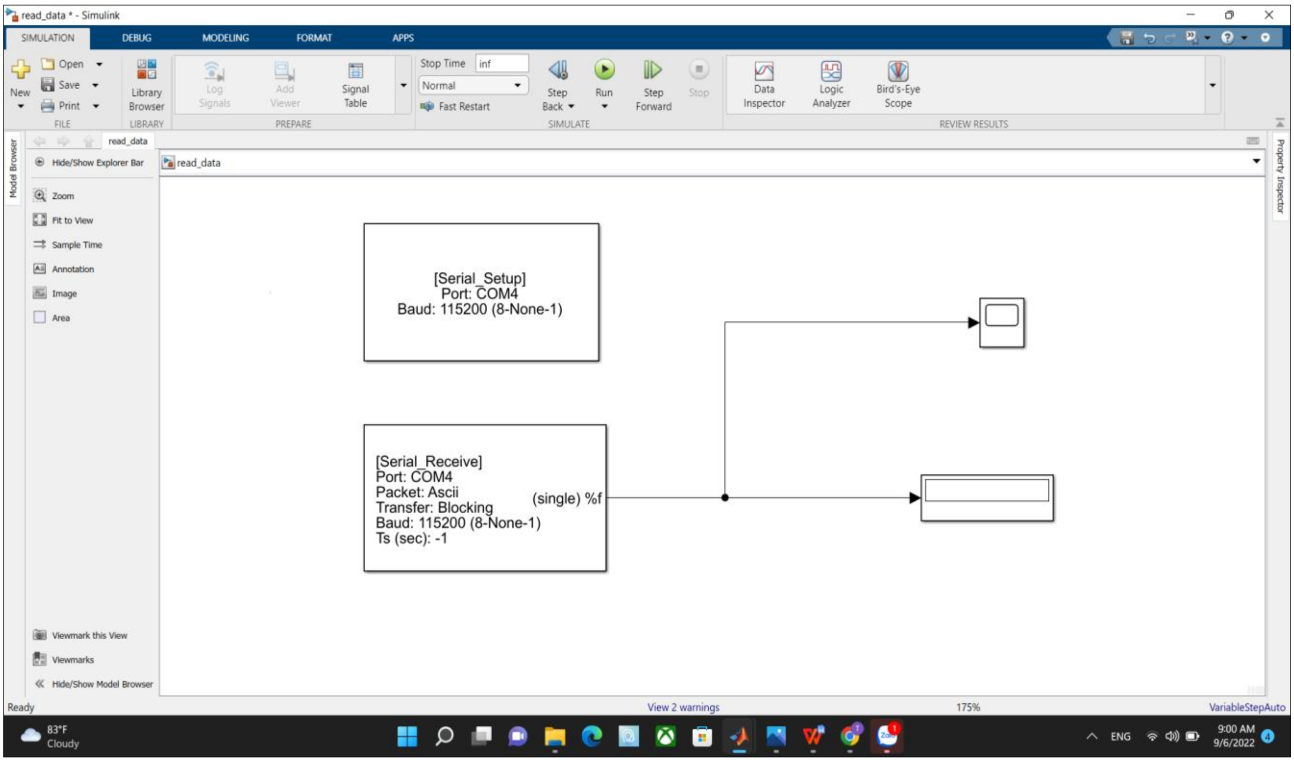
B. *Discrete PID Controller and Encoder reading function.*





Timer: 8
Input pins [CH_A, CH_B]: [C6,C7]
RST Counter: Yes
Ts (sec): -1

C. Program to read real speed of DC motor



[Serial_Setup]
Port: COM4
Baud: 115200 (8-None-1)

[Serial_Receive]
Port: COM4
Packet: Ascii
Transfer: Blocking
Baud: 115200 (8-None-1)
Ts (sec): -1

5. CONCLUSIONS

This paper introduces a DC motor speed control model using the PID controller. The main object of the paper lies in checking the actual speed of the DC motor using Kit STM32F407 and waijung libraty. Experimental results show that the system works stably for controlling small DC motors.

REFERENCES

1. Frayyeh, H. F., Mukhlif, M. A., Abbood, A. M., & Kercam, S. S. (2019). Speed control of direct current motor using Mechanical Characteristics. *Journal of Southwest Jiaotong University*, 54(4), 1-9.
2. Hassan, A. A., Al-Shamaa, N. K., & Abdalla, K. K. (2017). Comparative study for DC motor speed control using PID controller. *International Journal of Engineering and Technology*, *9*(6), 4181-4192.
3. Mohammed, J. A. (2011). Modeling, Analysis and Speed Control Design Methods of a DC Motor. *Eng. & Tech. Journal*, *29*(1), 141-155.
4. Anderson, K. L., Blankenship, G. L., & Lebow, L. G. (1998). A rulebased adaptive PID controlleR. In *Proc. 27th IEEE Con J Decision, Control*, 564-569.
5. Akbari-Hasanjani, R., Javadi, S., & Sabbaghi-Nadooshan, R. (2015). DC motor speed control by self-tuning fuzzy PID algorithm. *Transactions of the Institute of Measurement and Control*, *37*(2), 164-176.

6. Wang, T., Wang, H., Hu, H., Lu, X., & Zhao, S. (2022). An adaptive fuzzy PID controller for speed control of brushless direct current motor. *SN Applied Sciences*, *4*(3), 1-16.
7. Jaya, A., Purwanto, E., Fauziah, M. B., Murdianto, F. D., Prabowo, G., & Rusli, M. R. (2017, September). Design of PID-fuzzy for speed control of brushless DC motor in dynamic electric vehicle to improve steady-state performance. In *2017 International Electronics Symposium on Engineering Technology and Applications (IES-ETA)* (pp. 179-184). IEEE.
8. Richard, R. H. B., & Dorf, C. (2008). Modern Control Systems, Pearson, *11th edition*.
9. Mishra, A. K., & Narain, A. (2012). Speed control of dc motor using particle swarm optimization. *International Journal of Engineering Research and Technology*, *1*(02), 2278-0181.