

Real-time Speed Control of DC Motor Using LabVIEW

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Abstract The control of DC motors is required in many sectors, including unmanned vehicles and the robot industry. The primary goal of this work is to provide an efficient and straightforward method for controlling the speed and direction of the motor. The suggested technique is to create a system that can control and monitor the speed and direction of motion using a graphical user interface (GUI). This paper describes a LabVIEW-based PID controller implementation for controlling a DC motor's speed. LabVIEW is the software used to create the controller. The process is separated into two sections: software development and hardware implementation. The simulation calculates the DC motor transfer function in software development to determine the PID parameter values and construct the software controller. To find the values of K_p , K_i , and K_d . Finally, NI my-Rio will be used as a real-time controller on which the PID was built to control the speed of the motor. Furthermore, an easy-to-use user interface has been made in the LabVIEW environment.

Keywords: LabVIEW, PID, and DC motor.

I. INTRODUCTION

A direct current motor, sometimes known as a DC motor, is an electrical machine that converts electrical energy into mechanical energy by producing a magnetic field generated by a direct current. Each type of DC motor has advantageous properties that must be considered before purchase and use. One of the primary advantages of direct current (DC) motors over alternating current (AC) motors is their ease of installation and low maintenance. DC Motors has a wide usage like Diesel Electric Locomotives, Electric Vehicles, Electric Vehicles, Ceiling, Fans, and Pump Drives [1,2].

The design and development of PID controllers are commonly supported by simulation tools such as Matlab Simulink and LabVIEW control design and simulation toolkit; for example, once the controller is modeled, its physical implementation can be carried out directly in software such as microprocessors and microcontrollers [3, 4]. LabVIEW is the shortcut “laboratory virtual instrumentation engineering workbench,” and it’s a high-level graphical language that consists of 3 main components the front panel, the block (or wiring) diagram, and Icon/connector.

The PID (Proportional-Integral-Derivative) controller is a typical control loop feedback mechanism used in industrial applications. It calculates an error value continuously as the

difference between a planned setpoint and a measured process variable. By adjusting a control variable to a new value defined by a weighted sum, the controller aims to reduce error over time.

In many applications, the ability to adjust the speed of a DC motor is essential. DC motors Due to their superior performance, DC motors have long been employed in the industry control sector so widely used in unmanned vehicles, such as ROVs and USVs, where the vehicles' motion may be controlled by adjusting the speed of the motors.

A real time PID controller was implemented on MY RIO1900 embedded device using the National Instruments LabVIEW software environment for controlling the speed and direction of the motor based on the encoder feedback .

The key contributions of this paper are summarized as: section II is a description of DC motor mathematical model ,In section III description of PID controller while section IV represents the transfer function extraction using LabVIEW. In section V simulation results are show , In section VI Hardware setup are shown and finally, section VII represents the conclusion of the project

II. DC MOTOR MATHEMATICAL MODEL

A DC motor system is an independently excited DC motor that is frequently used for velocity and position control. Fig 1 depicts the equivalent circuit of a DC motor using the armature voltage control method:

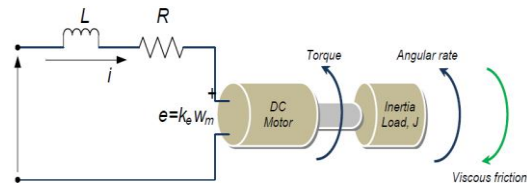


Fig 1 Equivalent circuit of the DC motor.

The electromechanical system of a DC motor equation may be expressed using Kirchoff's Voltage Law as:

$$e = -Ri - L \frac{di}{dt} + V_s \quad (1)$$

According to Newton's second law of motion, the mechanical characteristics of the system arranged in Fig 1 are the product

of the inertia load (J) and the rate of angular velocity (ω_m), which is equal to the total of all torques, as indicated by eqn.2 and eqn.3, respectively [5].

$$J \frac{d\omega_m}{dt} = \sum T_i \quad (2)$$

$$T_e = K_f \omega_m + J \frac{d\omega_m}{dt} + T_L \quad (3)$$

Where the electrical torque and the back emf can be written as $e = K_e \omega_m$ and $T_e = K_t \omega_m$

Therefore, re-writing equations 1 and 2, the equations 4 and 5 are obtained as,

$$\frac{di}{dt} = -i \frac{R}{L} - \frac{K_e}{L} \omega_m + \frac{1}{L} V_s \quad (4)$$

$$\frac{d\omega_m}{dt} = -i \frac{K_t}{J} - \frac{K_f}{J} \omega_m + \frac{1}{J} T_L \quad (5)$$

The following equations are derived correctly by applying the Laplace transform to assess equations 4 and 5. For the equation 4,

$$L \left\{ \frac{di}{dt} = -i \frac{R}{L} - \frac{K_e}{L} \omega_m + \frac{1}{L} V_s \right\} \quad (6)$$

This implies,

$$si = -i \frac{R}{L} - \frac{K_e}{L} \omega_m + \frac{1}{L} V_s \quad (7)$$

For equation 5,

$$L \left\{ \frac{d\omega_m}{dt} = -i \frac{K_t}{J} - \frac{K_f}{J} \omega_m + \frac{1}{J} T_L \right\} \quad (8)$$

This implies,

$$s\omega_m = -i \frac{K_t}{J} - \frac{K_f}{J} \omega_m + \frac{1}{J} T_L \quad (9)$$

From these, the transfer function could be derived accordingly as follows

$$G(s) = \frac{\omega_m}{V_s} = \frac{K_t}{s^2 J L + s(K_f L + R J) + K_e K_t} \quad (10)$$

The above equation represents the transfer function of a BLDC motor, which is connected to rotational speed and supply voltage.

As the friction constant is small, that is, K_f tends to 0, which implies that

$$R J \gg K_f L \text{ and } K_e K_t \gg R K_f$$

And the negligible values are zero and the transfer function is finally written as,

$$G(s) = \frac{\omega_m}{V_s} = \frac{K_t}{s^2 J L + R J s + K_e K_t} \quad (10)$$

To extract the DC Motor Transfer function, MathScript tool in labVIEW has been used for implementation of motor transfer function in eqn 10 as shown in Fig 2 by enter the Parameters of the Motor in the Inputs shown in table 1.

Parameters	Value
Armature inductance (H)	L=0.00584H
Armature resistance (ohm)	R=3.8 Ω

Rotor inertia (Kgm ²)	J=8.86E-6 Kgm ²
Armature voltage (Volt)	Va(t)=240 V
Viscous friction coefficient (NmS/rad)	Bm=0.002753 (NmS/rad)
Motor torque constant (Nm/A)	Kt=0.034 Nm/A
Back emf constant (Vs/rad)	Ke=0.027 Vs/rad
Speed	W=1000 rpm

Table 1 DC motor Parameters

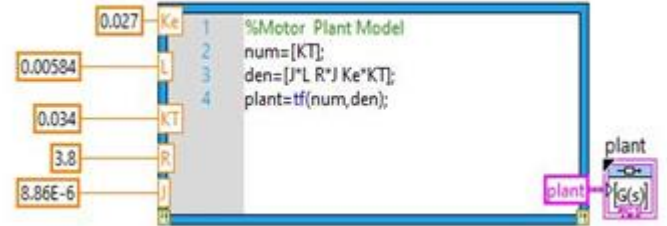


Fig 2 the implementation of motor transfer function on mathscript

The following transfer function was obtained from the tool.

Fig 3 the transfer function on LabVIEW

III. PID CONTROLLER

PID controller is a generic feedback control loop mechanism which is widely used in industrial control systems. A PID controller calculates an "error" value as the difference between a measured process variable (PV) and a desired set point (SP). The development of PID control theories has already started in early sixties. PID control has been one of the control system design methods of the longest history. PID controller is mainly to adjust an appropriate proportional gain (K_p), integral gain (K_i), and differential gain (K_d) to achieve PID Controller will reduce any process's steady state error by integral action on error and expectation output changes through derivative action on error with regard to the process's set point [6].

The following equation connects the output $y(t)$ and error input $e(t)$ of the PID Controller algorithm.

$$y(t) = K_p e(t) + K_i \int e(t) dt + K_d \frac{de(t)}{dt} \quad (11)$$

Where, K_p =Proportional gain; $K_i = \frac{1}{T_i}$ = Integral gain

and $K_d = T_d$ = Derivative gain

There are several methods available for tuning the three mode controller parameters (K_p , K_i and K_d). Presently, In order to adjust the system to the desired response the parameters of three mode (P + I + D) controllers has to be changed by the manual tuning methods like Ziegler Nichols method for closed loop system and Process reaction curve method for open loop system [7].

A general PID controller system block diagram is shown in Fig4:

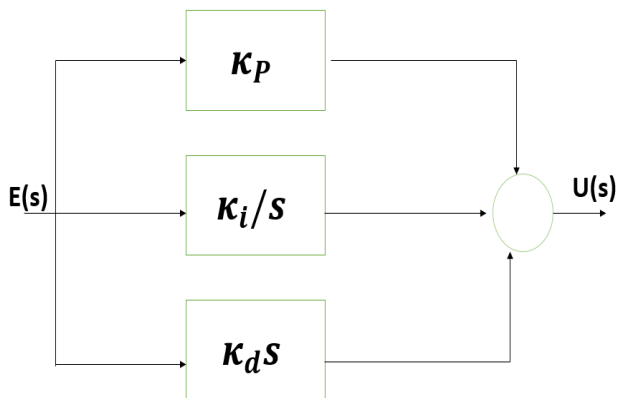


Fig 4 general PID controller system block diagram

A popular method for tuning P, PI, and PID controllers is the Ziegler–Nichols method. This method starts by zeroing the integral and differential gains and then raising the proportional gain until the system is unstable. The value of K_p at the point of instability is called K_{MAX} ; the frequency of oscillation is f_0 . The method then backs off the proportional gain a predetermined amount and sets the integral and differential gains as a function of f_0 [8].

To design PID Controller Following Steps are used to improve the response of system:

To decrease rise time Proportional Gain is used, for less overshoot and less settling time Derivative Gain is used and to maintain the error as less as possible integral gain is used[9].

Using some tuning methods, the following gains are obtained

$$K_p = 0.2667$$

$$K_i = 28.073684$$

$$K_d = 0.000633412$$

The Fig represents block diagram window of simulation of PID Speed control of DC motor. It represents designed motor model parameters as transfer function to get parameters proportional gain (K_p), integral time (T_i) and derivative time (T_d)

IV. SIMULATION RESULTS

The simulator-designed PID controller was tested using the unit step input, viewing the output, and doing analyses on it. This is explained as follows in Fig (6).

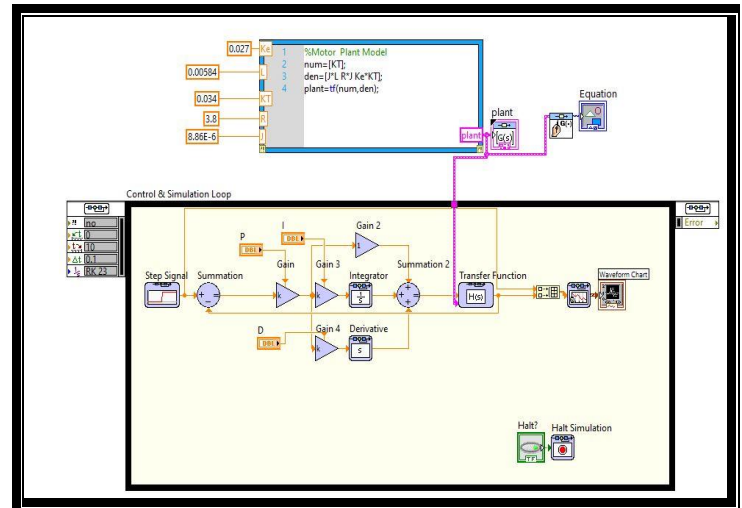


Fig 5 the PID code on LabVIEW

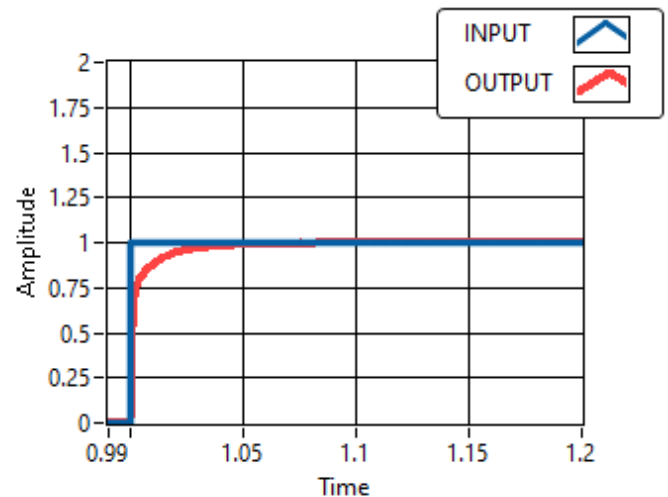


Fig 6 simulation result for unit step input

The simulation mathematical analyses are shown in the following table:

Response specification	Results for PID controller
damping ratio	0.21
peak value	1.004
peak time (s)	0.0119722
rise time	0.0049
settling time	0.08241

Table 2 the simulation results

V. REAL TIME IMPLEMENTATION

The developed controller is validated using the NI MY RIO1900 embedded device, which is a real-time controller that receives feedback from the optical encoder and generates a PWM value to regulate the speed of the motor depending on the speed to be attained and the value of the encoder's actual speed. As seen in Fig 6,

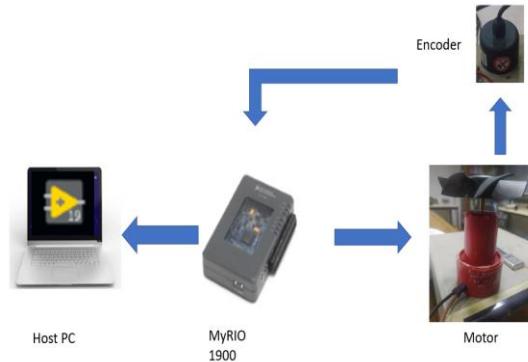


Fig 6 Process flow of the system

The user can easily change the gains values from the user interface on the host PC.

VI. CONCLUSION

It is determined from the LabVIEW Platform-based simulation and hardware results that a PID controller has been created to control the speed of a DC motor. The parameters are fine-tuned to fulfill the requirements, which are evaluated using experimental results and shortlisted over various set point speed ranges. As a result, it may practically adjust the parameters by altering the other governing parameters and variables K_p , K_i , and K_d . The motor model was created with LabVIEW software, and the controller was designed with the NI MY RIO1900 embedded device. Finally, controlling the speed and direction of the motor became achievable.

VII. REFERENCES

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