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Thème

**Contrôle de vitesse du moteur à courant continu basé sur
MATLAB Interface avec Arduino et
L298N H-Bridge**

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List of Abbreviation and Symbols

PMDC : Permanent Magnet Direct Current

PID : Proportionnal Integral Derivation

VI : virtual instrument

FTDI : Future Technology Devices International

LIFA : Matlab Interface for Arduino

ICSP : in-circuit serial programming

PWM : Pulse Width Modulation

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ABSTRACT

The aim of this project is to show Permanent Magnet DC motor (PMDC motor) can be controlled by using a PI controller in Matlab. PMDC motor will be interfaced with Matlab using an Arduino and L298N H-Bridge. The methodology during the project is divided into two parts which is software development and hardware implementation. The works in software development are calculation of PMDC motor transfer function, and developing the software controller. Ziegler-Nichols Open-Loop Method is used to obtain the value for K_p and K_i . The last part is to interface the controller with the hardware.

Introduction General

1. Background

DC motor have been widely use in high-performance electrical drives and servo system [1]. There are various differences DC motors in the market and all with it good and bad attributes. Such bad attribute is the lag of efficiency. In order to overcome this problem a Proportional–Integral–Derivative (PI) controller is introduce to the system. PI controller is a generic control loop feedback mechanism widely used in industrial control systems [1]. A PI controller attempts to correct the error between a measured system variable and a desired set point by calculating and then outputting a corrective action that can adjust the system accordingly. So, by integrating the PI controller to the DC motor were able to correct the error made by the DC motor and control the speed of the DC motor to the desired speed.

2. Objective

The objectives of this project are:

- i. To explorer and apply the knowledge gain in lectures into practical applications.
- ii. to derive mathematical model of PMDC motor and develop PI controller for the motor,
- iii. To control the speed of PMDC motor with PID controller interfaced with Matlab using an Arduino board.
- iv. Analysis the experimental result using the actual motor.

3. Scope of Work

The scope of this project is;

- i. Design and modeling of the PI controller with the PMDC motor
- ii. Implementation of the PI controller with an actual PMDC motor
- iii. The experimental results with the actual PMDC motor

4. Problem Statement

The problem encountered when dealing with a PMDC motor is the lag of efficiency and losses. In order to eliminate this problem, a PI controller is introduced for the PMDC motor. This is because a PI controller helps get the output, where we want it in a short time, with minimal overshoot and little error.

5. Thesis Organization

This thesis is organized with the Overview of DC motors, including the equations that represent torque, rotor speed, field and armature currents and voltages, covered in Chapter II.

Quick and simple start guide for using and exploring an L298N Dual H-Bridge Motor Controller module with an Arduino are detailed in Chapter III. Test setup and results for each test is presented and performance is explained in detail.

Results of the testing and conclusions about the Speed Control of PMDC Motor performance are addressed in Chapter IV. Recommendations on future work are suggested for additional research regarding PMDC motor controlled.

Date sheets for equipment used, Matlab code are detailed in the Appendixes.

Chapter I

PMDC Motor Overview

1. Introduction to DC Motors

To understand how to control output speed of a DC motor, a review some of the basics of PMDC motor operations and their types and construction was introduced in this section.

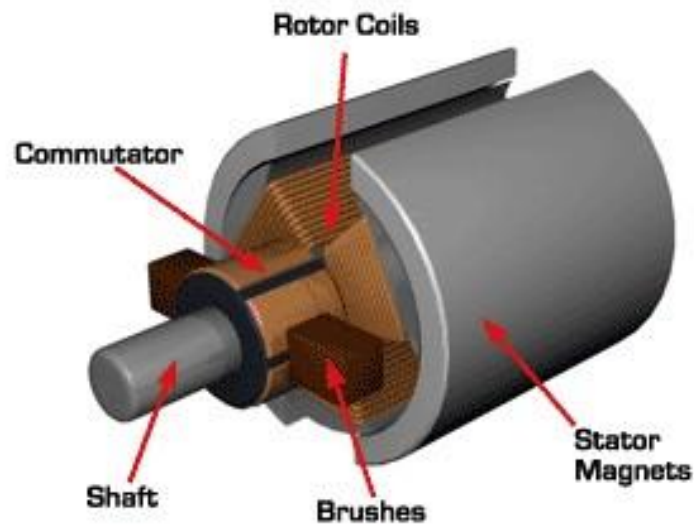


Figure 1: PMDC motor [2]

In a DC motor, an armature rotates inside a magnetic field. Basic working principle of DC motor is based on the fact that whenever a current carrying conductor is placed inside a magnetic field, there will be mechanical force experienced by that conductor. All kinds of DC motors work in this principle only. Hence for constructing a DC motor it is essential to establish a magnetic field. The magnetic field is obviously established by means of magnet. The magnet can be any type i.e. it may be an electromagnet or it can be a permanent magnet (PM). When a permanent magnet is used to create a magnetic field in a DC motor, the motor is referred to as a permanent magnet DC motor or PMDC motor. Have you ever uncovered any battery-operated toy, if you

did, you had obviously found a battery operated motor inside it. This battery operated motor is nothing but a PMDC motor. These types of motor are essentially simple in construction. These motors are commonly used as starter motor in automobiles, windshield wipers, washer, for blowers used in heaters and air conditioners, to raise and lower windows, it also extensively used in toys. As the magnetic field strength of a permanent magnet is fixed it cannot be controlled externally, field control of this type of DC motor cannot be possible. Thus permanent magnet DC motor is used where there is no need of speed control of motor by means of controlling its field. Small fractional and sub fractional kW motors now constructed with permanent magnet, [2].

2. Construction of PMDC Motor

A PMDC motor mainly consists of two parts.

1) Stator: A stator and an armature. Here the stator which is a steel cylinder. The magnets are mounted in the inner periphery of this cylinder. The permanent magnets are mounted in such a way that the N - pole and S - pole of each magnet are alternatively faced towards armature as shown in the figure below. That means, if N – pole of one magnet is faced towards armature then S – pole of very next magnet is faced towards armature. In addition to holding the magnet on its inner periphery, the steel cylindrical stator also serves as low reluctance return path for the magnetic flux. Although field coil is not required in PMDC motor but still it is sometimes found that they are used along with permanent magnet. This is because if permanent magnets

lose their strength, these lost magnetic strengths can be compensated by field excitation through these field coils. Generally, rare earth hard magnetic materials are used for this permanent magnet.

2) Rotor: The rotor of pmdc motor is similar to other DC motor. The rotor or armature of permanent magnet DC motor also consists of core, windings and commutator. Armature core is made of number of varnish insulated, slotted circular lamination of steel sheets. By fixing these circular steel sheets one by one, a cylindrical shaped slotted armature core is formed. The varnish insulated laminated steel sheets are used to reduce eddy current loss in armature of permanent magnet dc motor. These slots on the outer periphery of the armature core are used for housing armature conductors in them. The armature conductors are connected in a suitable manner which gives rise to armature winding. The end terminals of the winding are connected to the commutator segments placed on the motor shaft. Like other DC motor, carbon or graphite brushes are placed with spring pressure on the commutator segments to supply current to the armature.

The image below shows the construction of Permanent Magnet DC Motor.

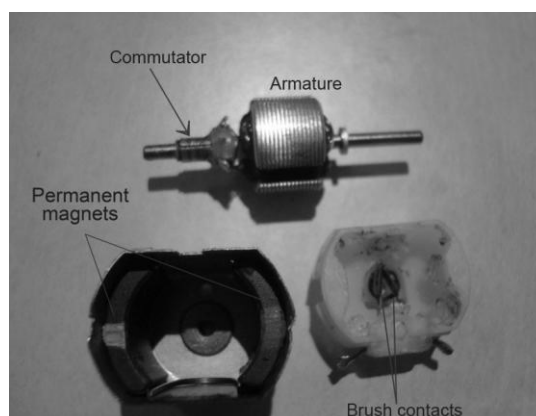


Figure 2 : DC motor construction [4]

3. Operation principle of PMDC Motor

As we said earlier the working principle of PMDC motor is just similar to the general working principle of DC motor. That is when a carrying conductor comes inside a magnetic field, a mechanical force will be experienced by the conductor and the direction of this force is governed by Fleming's left hand rule. As in a permanent magnet DC motor, the armature is placed inside the magnetic field of permanent magnet; the armature rotates in the direction of the generated force. Here each conductor of the armature experiences the mechanical force $F = B \cdot I \cdot L$ Newton where, B is the magnetic field strength in Tesla ($\text{weber} / \text{m}^2$), I is the current in Ampere flowing through that conductor and L is length of the conductor in metre comes under the magnetic field. Each conductor of the armature experiences a force and the compilation of those forces produces a torque, which tends to rotate the armature.

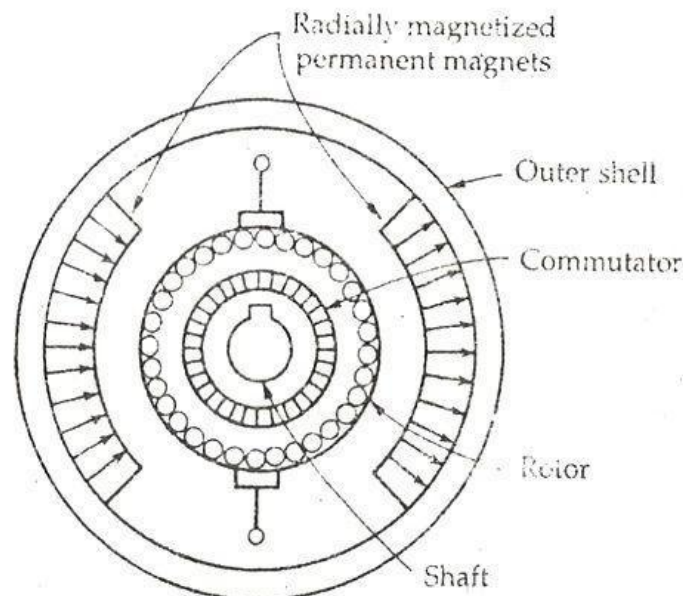


Figure 3 : Cross-section of DC motor [3]

4. Equivalent Circuit of PMDC Motor

As in PMDC motor the field is produced by permanent magnet, there is no need of drawing field coils in the equivalent circuit of permanent magnet DC motor.

The circuit diagram of the PMDC is shown below.

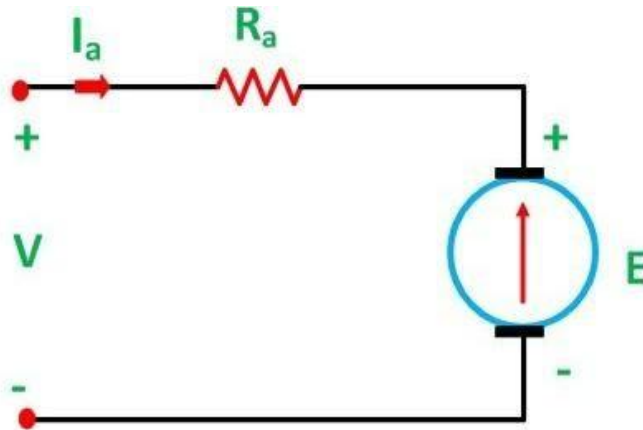


Figure 4 : Equivalent Circuit of PMDC Motor [3]

In conventional DC motor, the generated or back EMF is given by the equation shown below.

The electromagnetic torque is given as

In Permanent Magnet DC motor, the value of flux is constant. Therefore, the above equation (1) and (2) becomes

Considering the above circuit diagram the following equations are expressed.

Putting the value of E from the equation (3) in equation (5) we get

$$E = k_1 \omega$$

Where $k_1 = k$ and is known as speed-voltage constant or torque constant. Its value depends upon the number of field poles and armature conductors, [3].

The speed control of the PMDC motor cannot be controlled by using flux control method as the flux remains constant in this type of motor. Both speed and torque can be controlled by armature voltage control, armature rheostat control, and chopper control methods. These motors are used where the motor speed below the base speed is required as they cannot be operated above the base speed, [3].

5. Characteristics

Characteristics of PMDC motors are similar to the characteristics of dc shunt motor in terms of torque, speed and armature current. However, speed-torque characteristics are more linear and predictable in PMDC motors, [4].

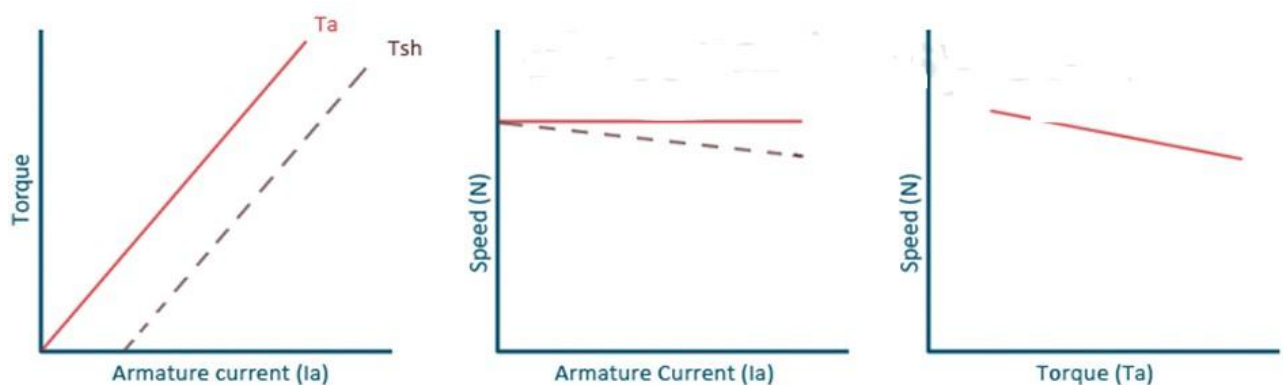


Figure 5 : Characteristics of PMDC motors,[4].

6. Types of Permanent Magnet Materials

There are three types of Permanent Magnet Materials used in PMDC Motor. The detailed information is given below, [3].

1) Alnicos

Alnicos has a low coercive magnetizing intensity and high residual flux density. Hence, it is used where low current and high voltage is required.

2) Ferrites

They are used in cost sensitive applications such as Air conditioners, compressors, and refrigerators.

3) Rare earths

Rare earth magnets are made of Samarium cobalt, neodymium-iron-boron. They have a high residual flux and high coercive magnetizing intensity. The rare earth magnets are exempted from demagnetizing problems due to armature reaction. It is an expensive material.

The Neodymium iron boron is cheaper as compared to Samarium cobalt. But it can withstand higher temperature. Rare earth magnets are used for size-sensitive applications. They are used in automobiles, servo industrial drives and in large industrial motors, [3].

7. Applications of the Permanent Magnet DC Motor

The PMDC motors are used in various applications ranging from fractions to several horsepower. They are developed up to about 200 kW for use in various industries.

The following applications are given below, [3].

- PMDC motors are mainly used in automobiles to operate windshield wipers and washers, to raise the lower windows, to drive blowers for heaters and air conditioners etc.
- They are also used in computer drives.
- These types of motors are also used in toy industries.
- PMDC motors are used in electric toothbrushes, portable vacuum cleaners, food mixers.
- Used in a portable electric tool such as drilling machines, hedge trimmers etc.

8. Advantages of the Permanent Magnet DC Motor

Following are the advantages of the PMDC Motor.

- They are smaller in size.
- For smaller rating Permanent Magnet reduces the manufacturing cost and thus PMDC motor are cheaper.
- As these motors do not require field windings, they do not have field circuit copper losses. This increases their efficiency.

9. Disadvantages of the Permanent Magnet DC Motor

The disadvantages of the PMDC motor are given below

- Permanent magnets cannot produce a high flux density as that as an externally supplied shunt field does. Therefore, a PMDC motor has a lower induced torque per ampere turns of armature current than a shunt motor of the same rating.
- There is a risk of demagnetization of the poles which may be caused by large armature currents. Demagnetization can also occur due to excessive heating and also when the motor is overloaded for a long period of time.
- The magnetic field of PMDC motor is present at all time, even when the motor is not being used.
- Extra ampere turns cannot be added to reduce the armature reaction.

10. Speed regulation

A motor which is able to maintain its speed at constant level when a variable load is applied to it, it has good speed regulation. It is a built in characteristic of a motor and remains the same as long as the applied voltage kept constant. Speed regulation of a motor is a comparison of its no load speed to its full-load speed and is usually expressed in a percent as follows:

$$\text{Percent speed regulation} = \frac{(\text{no load speed}) - (\text{full load speed})}{\text{full load speed}} \times 100 \%$$

The lower of the speed-regulation percent of a motor, the better is the speed regulation. If the speed –regulation percent is high, then its speed regulation is poor.

1) Motor losses

The losses of a PMDC motor may be divided into two types mechanical and copper losses.

a) Copper losses ($I^2 R$), are present in the windings. This resistance may be found by the ammeter – voltmeter method; they are then multiplied by the currents squared to obtain the copper losses .

b) Mechanical or rotational losses are divided into two groups: the iron (or core losses), and friction losses. Iron losses consist of the eddy current loss and hysteresis losses.

2) Equipment Setup for Performance Testing of Theory

Some of the components used in this experiment. The equipment used for this experiment and shown in Figure 7 and detailed: Arduino UNO, L298 H Bridge, DC Power Supply, 4W permanent magnet d.c. motor, sensor speed (encoder), and Computer with Matlab Software, Oscilloscope and Multimeters.

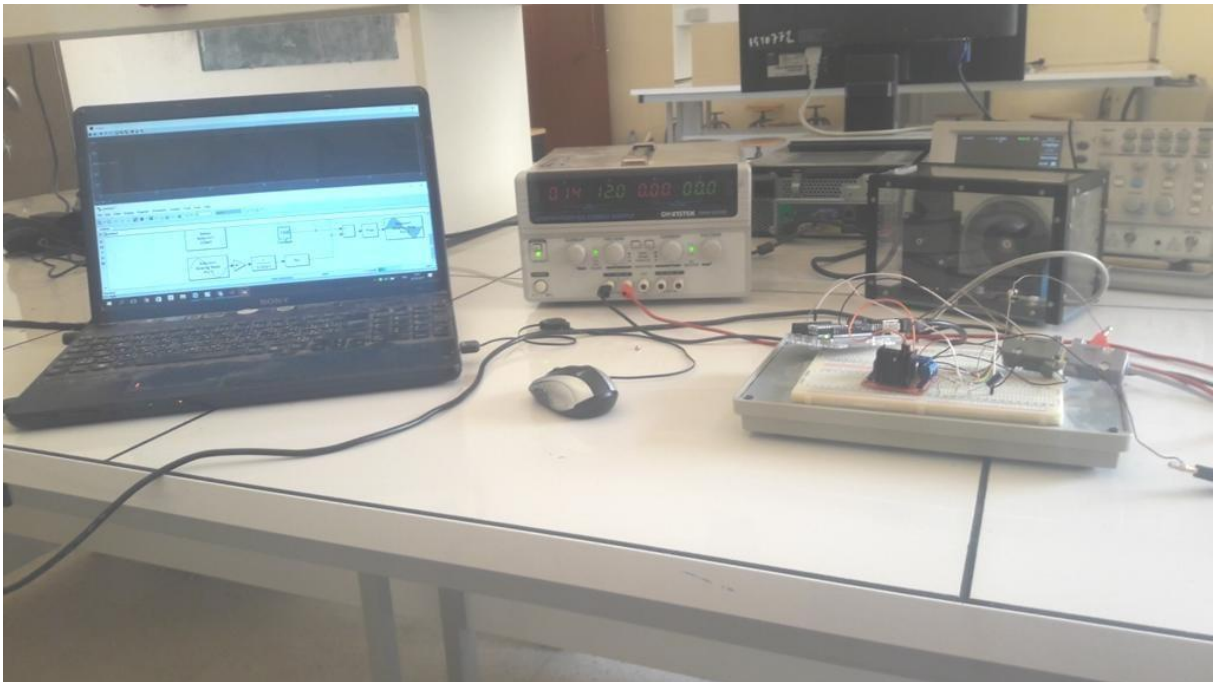


Figure 6 Photograph of equipment used.

In Figure 6, a schematic diagram of the equipment setup for this experiment is shown.

The present experiment, built around a small permanent magnet d.c. motor, is designed to bring out the salient features of such a system. Facilities are available to directly measure the principal performance factors of the speed control system, steady state error and load disturbance rejection, as a function of the forward path gain. In addition, the experimental work involves the determination of the motor transfer function and the characteristics of the tachogenerator. An important feature of the unit is the built-in absolute speed measurement through optical pickup from a slotted disk followed by a frequency counter. The 4-digit speed display is therefore completely independent of the tachogenerator characteristics. The high accuracy of speed reading is due to a built-in crystal oscillator. Another interesting design feature

is the use of an 'electronic tachogenerator' - a frequency to voltage converter, for the generation of speed feedback signal. This highly linear, non-contact transducer is ideally suited for the small D.C. motor being used in the unit. Variable loading of the motor is achieved by a built-in eddy current brake. This brake has superior characteristics compared to friction brake especially for a small motor. The motor unit, housed in a cabinet with transparent panels, provides a good view of the mechanical arrangements. In addition, a 3½ digit DVM is available on the panel for the measurement of various D.C. signals.

Chapter II

Identification and PID Controller of a 1st Order DC Motor Model

1. Objective

The response of a first order DC Motor depends on its DC gain, K , and time constant, τ . Both K and τ are function of DC Motor parameters. The objective of this chapter is to model a first-order DC Motor and investigate the effect of DC Motor parameters on its response to a step input.

We choose to experiment with an armature controlled DC motor, which behaves as a first-order machine when the armature voltage is the input and the angular speed is the output. We obtain the transfer function of the DC motor and identify specific parameters of the system that affect system response. Specifically, we identify system parameters that individually affect the DC gain and the time constant and vary these parameters to experimentally verify the change in system response, [5].

2. Background

2.1. First-order systems

The standard form of transfer function of a first-order system is:

$$G(s) = \frac{Y(s)}{U(s)} = \frac{K}{(\tau s + 1)} \quad (3.1)$$

where $Y(s)$ and $U(s)$ are the Laplace transforms of the output and input variables, respectively, K is the DC gain, and τ is the time constant. For a unit step input

$U(s) = 1/s$, the response of the system is:

$$Y(s) = \frac{Y(s)}{U(s)} U(s) = \frac{K}{(\tau s + 1)} \frac{1}{s} = \frac{K}{s(\tau s + 1)} \quad (4.2)$$

The inverse of the resulting Laplace transform can be easily found (see the Appendix in your text). Typically the inverse is available in standard tables. In this case,

$$y(t) = L^{-1} \left[\frac{K}{s(\tau s + 1)} \right] = K \left\{ L^{-1} \left[\frac{1}{s(\tau s + 1)} \right] \right\} = K(1 - e^{-t/\tau}) \quad (4.3)$$

It is clear from (3)) that $y \rightarrow K$ as $t \rightarrow \infty$. The DC gain can therefore be interpreted as the final value of the output for a unit step input. The time constant is the time required for $y(t)$ to reach 63.2% of its final value. Indeed, at $t = \tau$, $y(t) = 0.632K$ for a unit step input. For a unit step input, the change in input is one (1). In general, for a step input of magnitude A , at $t = \tau$, $y(t) = 0.632 KA$. The response of the first-order system to a unit step input is shown in Fig.1a for two cases. For a system gain $K < 1$, the system's output change is less than the input change applied. For a system gain $K > 1$, the system's output change is more than the input change applied. The results plotted are for a system operating for small positive input and output deviations from zero (the origin) [5].

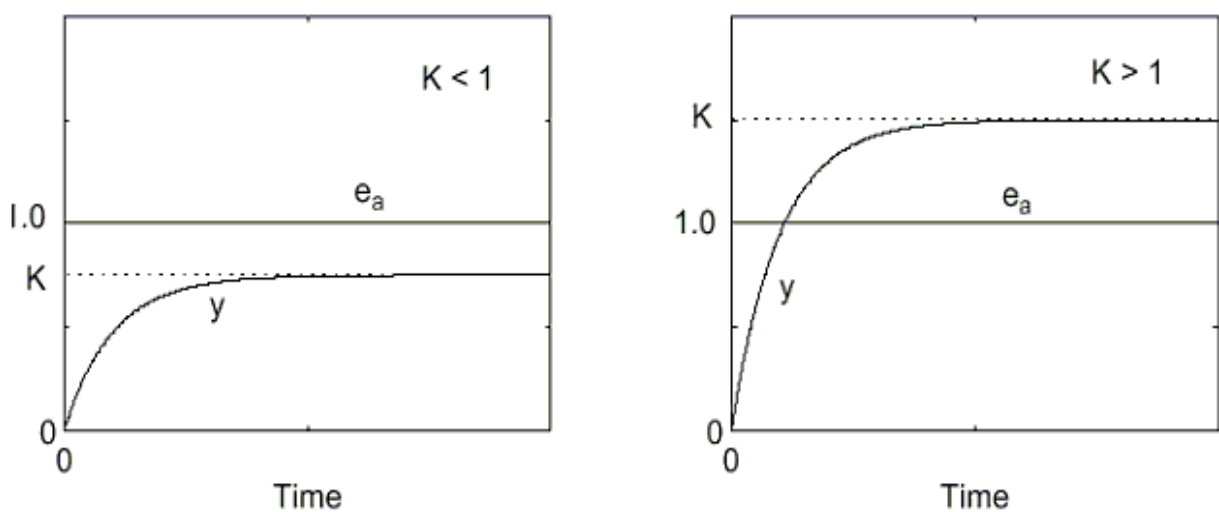


Figure 7: First-Order System Step Response

The step response of the DC motor will be evaluated with a square wave input composed of a series of positive and negative steps. As shown in Figure 7, these steps produce repeated positive and negative changes in a 1st order system's output. Assuming the positive system's response reaches steady-state for each positive and negative input, the gain and time constant parameters can be separately evaluated for both positive and negative input changes. The specific values for the gain and time constant parameters for the above systems are computed below. Notice that the system gains are equal but that the positive and negative change time constants are not. For both parameters, an average is typically used as a representative value. The variation from the average indicates the repeatability of the measurement, [5].

1.2DC Servo Motor System

An experimental schematic diagram of an armature controlled DC motor is shown in Figure 8. The system variables include:

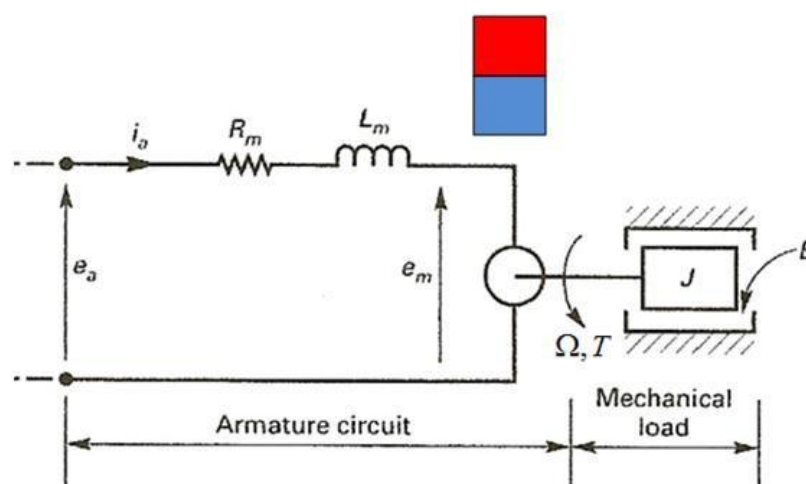


Figure 8: The PMDC motor (Phillips and Harbor) [5]

e_a : Armature drive potential (volts).

e_m : Back emf potential (volts)

i_a : armature current (Amps)

T : torque produced by motor (N-m)

θ : angular position of motor shaft (radians)

$\Omega = d\theta/dt$: angular velocity of motor shaft (rad/sec)

The parameters of the system include:

R_m : Armature resistance (Ohms)

L_m : armature inductance (Henry)

J : moment of inertia of motor shaft (Kg-m²)

B : coefficient of viscous friction (N-m-sec/rad)

The system parameters not shown in Fig.8 include:

K_T : Torque constant (N-m/Amp)

K_b : motor back emf constant (volt-sec/rad)

The torque constant K_T models the relationship between the electric current i_a input and motor torque T output.

$$T(s) = K_T i_a(s) \quad (3.4)$$

The back EMF constant K_b models the relationship between the motor speed Ω input and the electrical back emf e_b produced by the DC motor,

$$e_m(s) = K_b \Omega(s) \tag{3.5}$$

The transfer function of the servomotor, with armature drive potential e_a as input and motor speed $\Omega = s\theta(s)$ as output, can be written as (Phillips and Harbor, Section 2.72)

$$G(s) = \frac{\Omega(s)}{e_a(s)} = \frac{K_T}{JL_m s^2 + (BL_m + JRm)s + (BR_m + K_T K_b)} \tag{3.6}$$

Typically, the inductance of the motor armature is relatively small. Neglecting the armature inertia L_m , yields the low speed approximation for the DC servo motor transfer function

$$G(s) = \frac{\Omega(s)}{e_a(s)} = \frac{K_T}{JR_a s + (bR_a + K_T K_b)} \tag{3.7}$$

Rewriting (3.7) is the standard 1st order transfer function form (1) yields

$$G(s) = \frac{\omega(s)}{e_a(s)} = \frac{K_T / (bR_a + K_T K_b)}{[JR_a / (bR_a + K_T K_b)]s + 1} \tag{3.8}$$

and comparing it with (1), we obtain the expression for the motor DC gain:

$$K_m = \frac{K_T}{(bR_a + K_T K_b)} \tag{3.9}$$

and the DC motor time constant:

$$\tau_m = \frac{JR_a}{(bR_a + K_T K_b)} \tag{3.10}$$

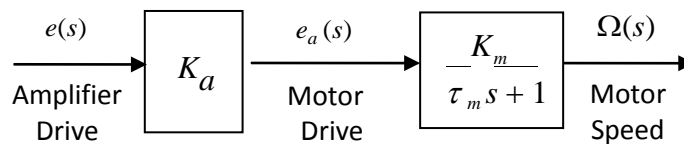


Figure 9: Block Diagram of the Motor and Amplifier System.[5]

An amplifier is often used to generate the power required to drive the armature voltage on the motor. A block diagram showing an amplifier connected to the motor transfer function is shown in Fig. 18. The amplifier modeled as a constant gain κ_a , is also shown. Together, the motor and the amplifier can be modeled as a single first-order system with steady-state (DC) gain:

$$K = \frac{K_a K_T}{(bR_a + K_T K_b)} \quad (3.11)$$

and the time constant:

$$\tau = \frac{JR_a}{(bR_a + K_T K_b)} \quad (3.12)$$

Comparing (3.9) and (3.11), the DC gain κ of the motor and amplifier system is the product of the motor DC gain κ_m and the gain of the amplifier κ_a .

$$K = K_a * K_m \quad (3.13)$$

A comparison of (3.10) and (3.12) indicates that the time constant τ of the motor plus amplifier system is the same as the motor time constant τ_m alone. One of the primary objectives of this experiment is to study those effects that vary the system's DC gain and the time constant. Although it is possible to vary the system's DC gain κ by varying the amplifier gain κ_a , we will not vary κ_a in this experiment. We will vary the system's time constant τ by changing the inertia of the motor shaft J by mounting an inertia disk on the motor shaft. The above analysis shows that we expect these two changes to have independent effects on the motor system response.

1.3 Experimental Procedure:

The overall experimental setup is shown schematically in Figure 10



Figure 10 Basic Equipment Setup

According to the experimental result below, the gain of the DC Motor is = 2500 rpm,
the time constant of the DC Motor is = 0.5 s

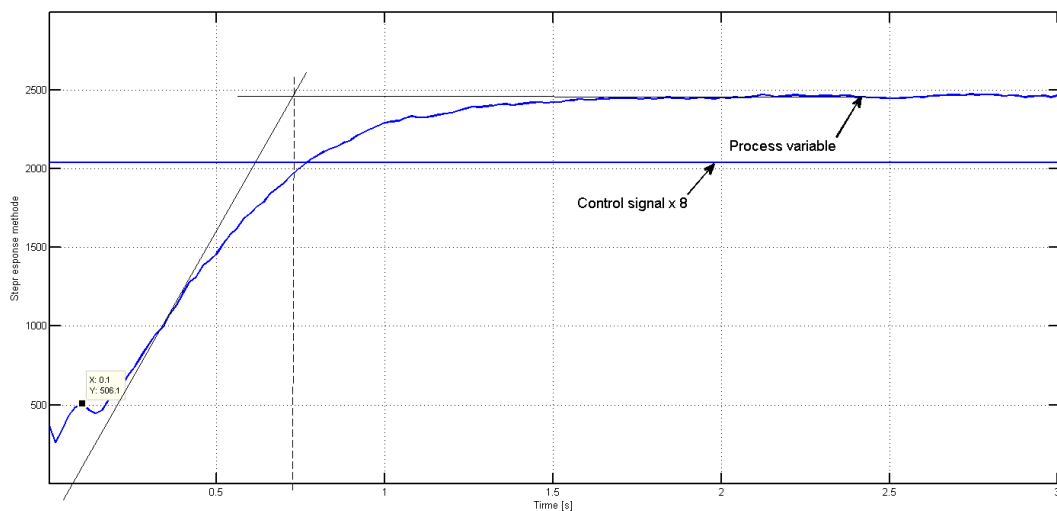


Figure 11 Step response methode.

The first-order system below is composed of an amplifier and a plant. Find the system transfer function in standard first-order form, $K/(\tau s+1)$.

2. Experimental Tuning of PID Controllers via Ziegler-Nichols Methods

Until 1941, the engineers, John Ziegler and Nathaniel Nichols have changed the whole control industry by their tuning method. John Ziegler was the practical one of the pair with a lot of experience in process applications, and who performed all the simulator tests that led to the methods they were seeking. Nathaniel Nichols was the mathematician and who reduced all of the mathematics to a few simple relationships that could be understood by technicians and operators. The results were the now famous "Ziegler-Nichols" methods of tuning controllers - methods that survived the slings and arrows of its early detractors, withstood the test of time, and works just as well as many of the later more sophisticated optimizing forms on a great majority of process applications.[6]

3.1 The step response method

The Ziegler-Nichols step response method is based on a step response of the DC motor. A step input is made in the control signal to the DC Motor and the response is logged for analysis Figure 12.

The DC Motor characteristics which have determined from the DC Motor in the following way:[6]

- i. Locate the point on the DC Motor response curve where the slope is greatest, and draw the tangent to the curve through this point.

- ii. Find the points at which this tangent cuts the two lines which give the stationary values of the DC motor variable before and after the step disturbance respectively.
- iii. Reading off the times for these two points, the dead-time ($L=100$ ms, see fig.11) and the dominant time constant ($T=640$ ms, see fig.11) for the DC Motor. The dead-time is defined as that time it took from when the step disturbance was made until the DC Motor signal began to react. With the Ziegler-Nichols method for determining dead-time, the estimated dead-time is often longer than it is in real life. This is correct, and it is due to the very simple model of the DC Motor which is used since high-order dynamics also appear in the step response as an additional dead-time. In other words, the dead-time L and the time constant T have to describe a DC Motor which may comprise one dead-time and several time constants. This is approximated with a slightly longer dead-time and a dominant time constant.

3. Experimental Tuning of PID Controllers via Ziegler-Nichols Methods

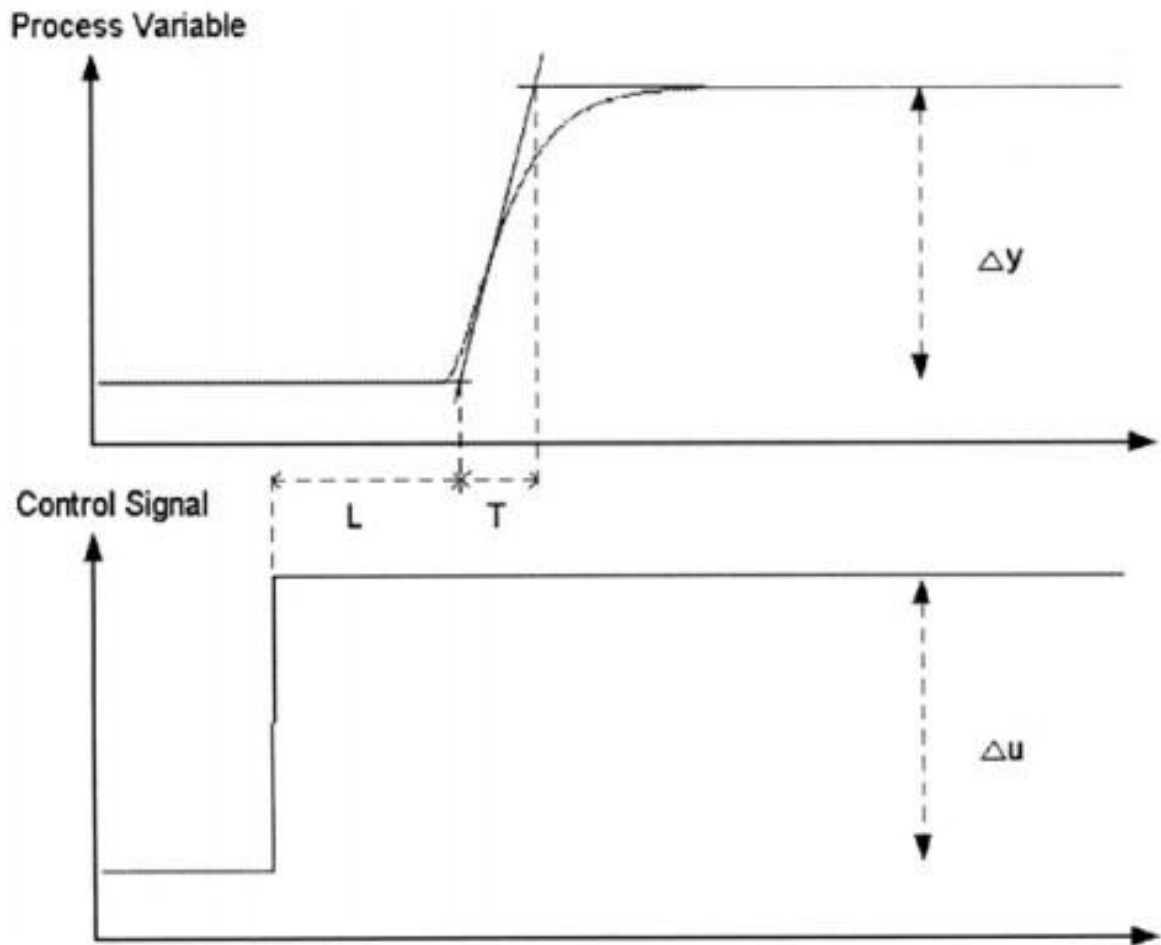


Figure 12 Step response method

- iv. The static gain K_p of the DC Motor is estimated by taking the ratio between the process variable change and the control signal change:

$$K_p = \frac{\Delta y}{\Delta u}$$

Based on these three parameters L , T and K_p determined from the step experiment (see figure 11), the Ziegler-Nichols step response method can now provides the

controller parameters such as in table 1. In order to simplify the table, the relationship between the dead-time and the time constant has been designated by L , where

$$L = \frac{T_d}{T_c}$$

The constant is known as the normalized dead-time. The Ziegler-Nichols table was originally drawn up for the PID controller in its parallel design type.

Tableau 1 PID parameters according to Ziegler-Nichols step response method.

Controller	K	T_i	T_d
PI	—	$3L=0.3$	-

In the table, the controller gain is inversely proportional to the static gain of the DC motor and the normalized dead-time.

Both the integral and derivative times are proportional to the dead-time of the DC motor. This is also sensible, because the time parameters of the controller have to lie in the same range as the DC motor time scale.

3.2 Advantage of the Ziegler-Nichols

The main advantage of the Ziegler-Nichols step response method is in its simplicity as only a step experiment is required. The disadvantage is that the method is relatively sensitive to load disturbances and other disturbances in the frequency range of interest during the experimental phase and a large step input may be necessary to obtain a good signal-to-noise ratio. On the other hand, use of a large

input is restricted by the non-linear modes of the DC motor as well as important safety operational limits [6].

Chapter III

Speed Control of DC Motor

1. Overview

Here in this chapter terminal voltage control method is employed. A control system is an interconnection of components forming a system configuration that will provide a desired system response. A controlled DC motor is developed allowing Arduino hardware which acts as the interface between the computer Matlab and the outside world via L298 H Bridge Driver. It primarily functions as a device that digitizes incoming analog signals so that the Matlab can interpret them. The user interface was developed in an Arduino environment. The aim is to control the speed of the dc motor using the Low Cost data acquisition board i.e. the Arduino board interfaced with PI Controller in Matlab.

2. Arduino Uno Board

The Arduino Uno is a microcontroller board based on the ATmega328. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started, [7].

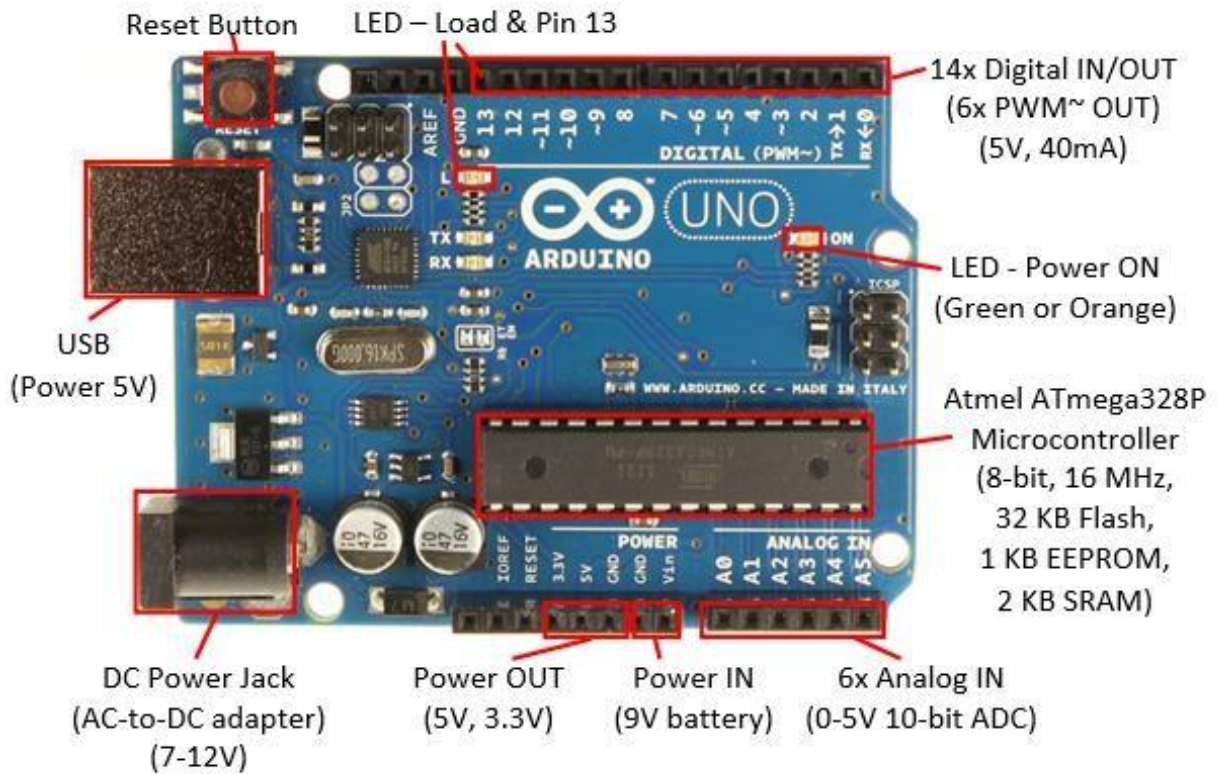


Figure 13: Arduino Uno Front and Back

The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega16U2 (Atmega8U2 up to version R2) programmed as a USB-to-serial converter.

A sketch for the Arduino microcontroller acts as an I/O engine that interfaces with the Matlab Vis through a serial connection. This helps to move information from Arduino to Matlab without adjusting the communication, synchronization or even a single line of code. Using the Open, Read/Write, Close convention in Matlab we can access the digital, analog and pulse width modulated signals of the Arduino microcontroller. The Arduino microcontroller must be connected to the computer with the Matlab through a USB.

3. Matlab Interface for Arduino

Arduino programming is supposed to be fun but can become frustrating and time consuming for tasks such as plotting sensor data or incorporating advanced math, signal processing, or controls routines into your projects.

MATLAB and Simulink address several challenges with traditional Arduino programming. The products support two primary workflows[8]:

- Read, write, and analyze data from Arduino sensors
- Develop algorithms that run standalone on the Arduino device

Read, write, and analyze data from Arduino sensors

MATLAB support package for Arduino lets you write MATLAB programs that read and write data to your Arduino and connected devices such as Adafruit motor shield, I2C, and SPI devices. Because MATLAB is a high level interpreted language, programming with it is easier than with C/C++ and other compiled languages, and you can see results from I/O instructions immediately – no compiling. MATLAB includes thousands of built-in math, engineering, and plotting functions that you can use to quickly analyze and visualize data collected from your Arduino.



Figure 14 : Read, write, and analyze data from Arduino sensors[8]

With MATLAB support package for Arduino, the Arduino is connected to a computer running MATLAB. Processing is done on the computer with MATLAB.

Benefits of using MATLAB for Arduino programming [8]:

- Read and write sensor data interactively without waiting for your code to compile
- Analyze your sensor data using thousands of pre-built functions for signal processing, machine learning, mathematical modeling, and more
- Quickly visualize your data using MATLAB's vast array of plot types

Develop algorithms that run standalone on the Arduino

Simulink support package for Arduino lets you develop algorithms in Simulink, a block-diagram environment for modeling dynamic systems and developing algorithms, and run them standalone on your Arduino. The support package extends Simulink with blocks for configuring Arduino sensors and reading and writing data

from them. After creating your Simulink model, you can simulate it, tune algorithm parameters until you get it just right, and download the completed algorithm for standalone execution on the device. With the MATLAB Function block, you can incorporate MATLAB code into your Simulink model, [8].

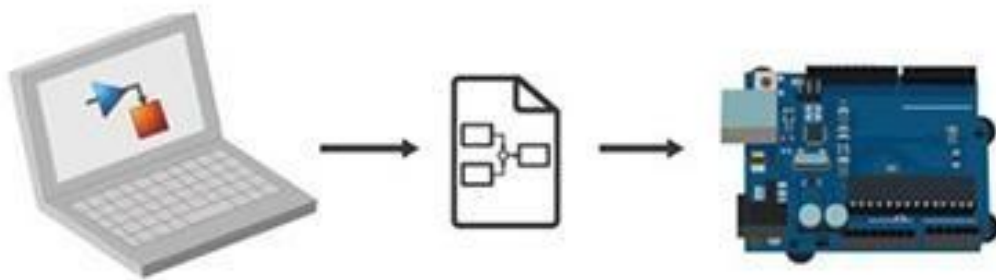


Figure 15 : Develop algorithms that run standalone on the Arduino

With Simulink support package for Arduino, you develop the algorithm in Simulink and deploy to the Arduino using automatic code generation. Processing is then done on the Arduino.

Benefits of using Simulink for Arduino programming [8]:

- Develop and simulate your algorithms in Simulink and use automatic code generation to run them on the device
- Incorporate signal processing, control design, state logic, and other advanced math and engineering routines in your hardware projects

- Interactively tune and optimize parameters as your algorithm runs on the device
- Easily modify algorithms to run on other low-cost and commercial hardware platforms

Belows is the Block diagram of the Closed-Loop System is as shown in Figure 26:

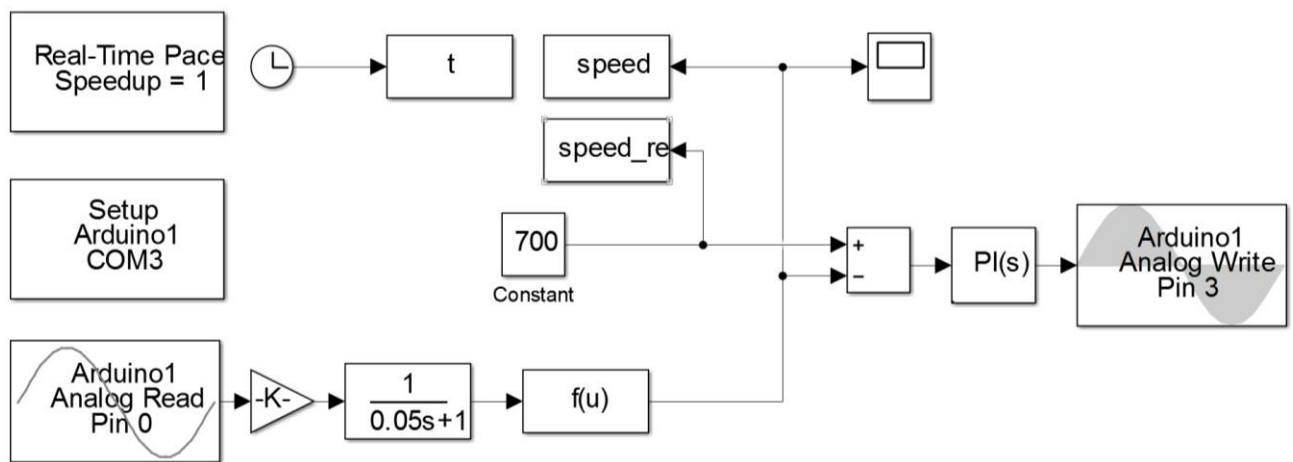


Figure 16 Block diagram of control part

PI controller will compare the setpoint value with the value received from the Arduino. Arduino receives this value from tachometer. Encoder measures the revolutions of the DC motor. If the two values are not same, PID controller will try to minimize this error and bring the DC Motor to the desired speed.

4. Result and discussion

Figures 17 - 18 below shows the speed control of DC motor with PID controller. The value at which the speed is obtained at $K=0.59$ and $T_i=0.3$.

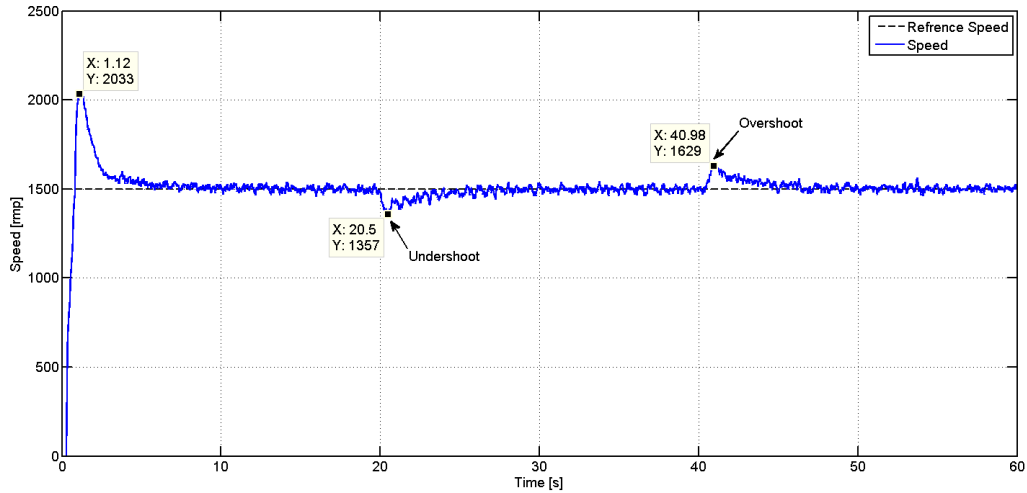


Figure 17 Speed Response with various values of torque load

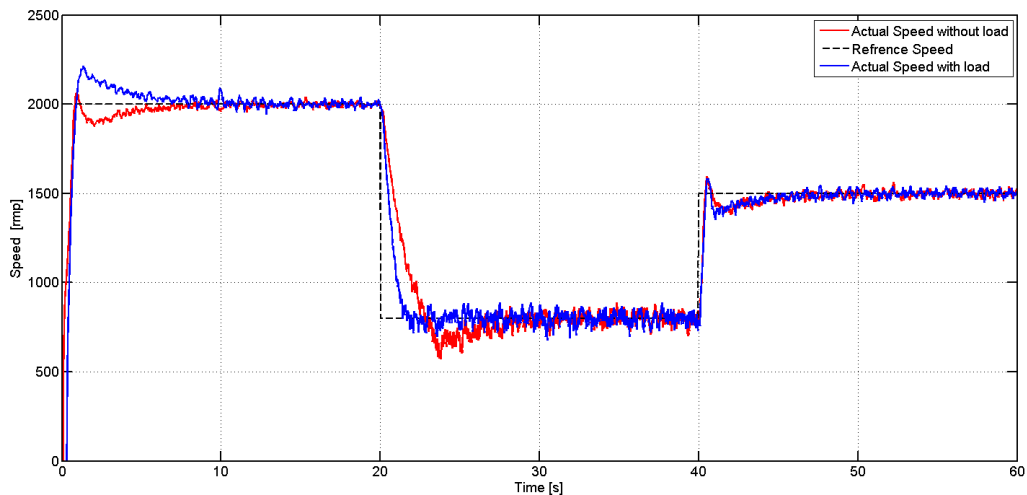


Figure 18 Speed Response without and with torque load

Experimental results are shown in Fig. 17 and Fig. 18 for step response for speed change from 0 rad/sec to 2000 rpm and from 2000 rpm to 700 rpm and from 700 rpm to 1500 rpm at different of rated motor load. These figures clarify the soft start of the motor and the operation of the current limit as well as the satisfactory transient response.

The speed of a DC motor has been successfully controlled by using L298 H bridge driver and PI type Speed controller based on closed loop system model. Initially a simplified closed loop model for speed control of DC motor is considered and requirement of speed controller is studied. Then a generalized modeling of dc motor is done. After that a complete layout of DC drive system is obtained. Then designing of speed controller is done. The optimization of speed control loop is achieved through Ziegler-Nichols methode. A DC motor specification is taken and corresponding parameters are found out from derived design approach. The expermental results under varying reference speed and varying load are shown above. The test shows good results under all conditions employed during simulation.

General Conclusion

Electric motors are used to provide mechanical work in industries. The DC motors is considered to be a basic electric machine. The DC motors are one of the electrical drives that are rapidly gaining popularity, due to their high efficiency, good dynamic response and low maintenance. The DC motors and drives have grown significantly in recent years in the appliance industry and the automotive industry. DC drives are very preferable for compact, low maintenance, and high reliability system [17].

In this work, an overview of PMDC motors, including the equations that represent torque, rotor speed, field and armature currents and voltages is developed. Identification and PI Controller of a 1st Order DC Motor Model is discussed. The Results of the testing about the Speed Control of DC Motor performance are analyzed. A PI controller has been employed for speed control of DC motor by Matlab interfaced with Arduino. The speed controller has been designed successfully for closed loop operation of the DC motor and the motor runs nearly to the reference speed. The expermental results under varying reference speed and varying load are shown above. The test shows good results under all conditions employed during simulation.

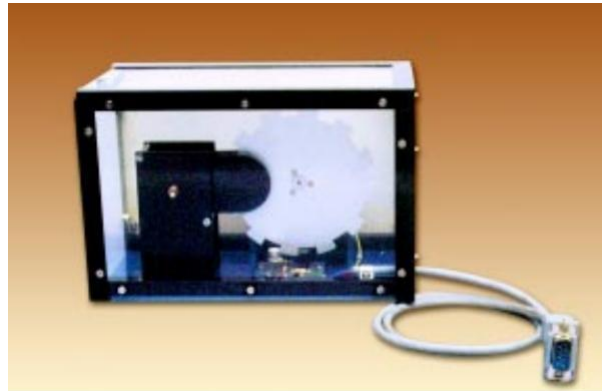
1. Future Scope

Tuning of PI controller for position control using Artificial Intelligence techniques such as : Neural Network and Fuzzy approach ...

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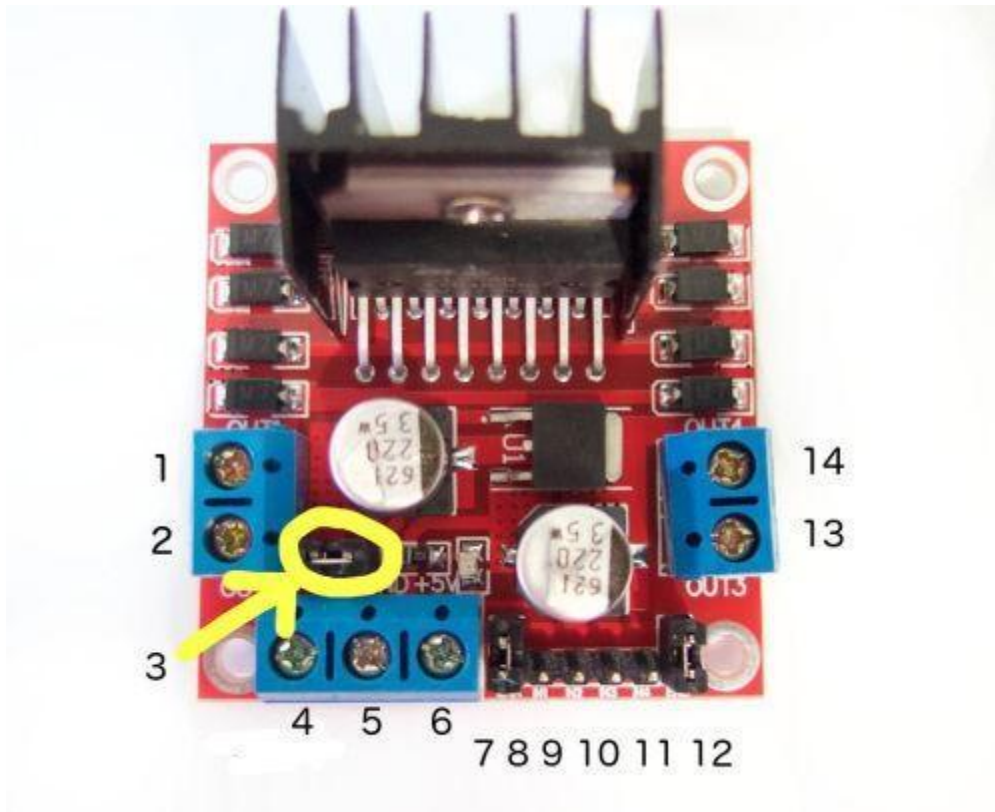
Motor unit



Features & Specifications

- Speed Control of a 12V, 4W permanent magnet dc motor
- Speed Range: 0 to 2000 rpm (typical)
- Opto-interrupter based speed sensing
- 4-digit speed display in rpm
- Electronic tachogenerator for feedback
- Separate unit for motor in a see-through cabinet
- Smooth, non-contact eddy current brake for loading
- Built-in 3½ digit DVM for signal measurements
- 220V±10%, 50Hz mains operation
- Supporting literature and patch cords included
- Essential accessory – a CRO

L298 Module Connections



First we'll run through the connections, then explain how to control DC motors then a stepper motor. At this point, review the connections on the L298N H-bridge module.

Consider the image – match the numbers against the list below the image:

1. DC motor 1 “+” or stepper motor A+
2. DC motor 1 “-” or stepper motor A-
3. 12V jumper – remove this if using a supply voltage greater than 12V DC. This enables power to the onboard 5V regulator
4. Connect your motor supply voltage here, maximum of 35V DC. Remove 12V jumper if >12V DC

5. GND

6. 5V output if 12V jumper in place, ideal for powering your Arduino (etc)

7. DC motor 1 enable jumper. Leave this in place when using a stepper motor.

Connect to PWM output for DC motor speed control.

8. IN1

9. IN2

10.IN3

11.IN4

12.DC motor 2 enable jumper. Leave this in place when using a stepper motor.

Connect to PWM output for DC motor speed control

13.DC motor 2 “+” or stepper motor B+

14.DC motor 2 “-” or stepper motor B-