DEVELOPMENT OF P RESONANT CURRENT CONTROL FOR DC MOTOR BY USING ARDUINO

FARIH BIN DERAMAN

A project report submitted in partial
fulfillment of the requirement for the award of the
Master of Electrical Engineering

Faculty of Electrical and Electronic Engineering
Universiti Tun Hussein Onn Malaysia

JULY 2014

ABSTRACT

The DC motors have been popular in the industry control area for a long time because DC motors have many good features. Generally, DC motor speed is controlled by using potentiometers, variable resistors, and pulse-width-modulation. Speed control also can be achieved by variable battery tapping, variable supply voltage, resistors or electronic controls. But the problems in applying this conventional control method are the effects of nonlinearity in a DC motor. This project presents the development of Proportional Resonant (PR) current control for DC Motor. P Resonant (PR) type controller has been proposed to overcome the problem using MATLAB/Simulink software. This technique was called current control technique by comparing the actual current with the reference current at PR controller. Then, the Simulink model downloaded into Arduino to generate PWM signal. This signal was used to trigger the MOSFET at the rectifier circuit in order to control the current at DC motor. A set of hardware was designed and developed to demonstrate the validity of this approach. The observation and experimental results were explained in this report base on the PWM output and output current at DC motor.

ABSTRAK

DC motor telah lama digunakan di dalam bidang industri kawalan motor kerana kelebihan yang ada padanya. Secara umumnya, DC motor dikawal dengan menggunakan ‘potentiometer’, perintang boleh ubah, dan ‘Pulse Width Modulation’. Kelajuan DC motor juga boleh dikawal dengan mengubah bateri, megubah voltan bekalan, perintang ataupun kawalan elektronik. Tetapi masalah dalam menggunakan kaedah kawalan konvensional ini adalah tidak linear kepada kelajuan DC motor. Pengawal PR dicadangkan untuk mengatasi masalah ini menggunakan perisian MATLAB / Simulink. Teknik ini dipanggil teknik kawalan arus dengan membandingkan arus sebenar dengan arus rujukan pada pengawal PR. Setelah itu, model Simulink ini dimuat turun ke dalam Arduino untuk menjana isyarat PWM. Isyarat ini pula akan digunakan untuk mengaktifkan MOSFET di litar penerus untuk mengawal arus pada DC motor. Satu set perkakasan telah direka dan dibangunkan untuk menunjukkan kesahihan pendekatan ini. Pemerhatian dan keputusan eksperimen yang diterangkan di dalam laporan ini adalah mengenai keluaran PWM dan keluaran arus pada DC motor.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

AC	-	Alternating Current
DC	-	Direct Current
PID	-	Proportional Integral Derivative
ADC	-	Analog Digital Controller
PWM	-	Pulse Width Modulation
PR	-	Proportional Resonant

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

The DC motors have been popular in the industry control area for a long time because they have many good features, for example the high start torque characteristic, high response performance, easier to be linear control and etc.[1]. DC motors used in many such as in steel rolling mills, electric trains and robotic manipulators that require current and speed controllers to perform tasks [2].

A DC motor's speed and torque characteristics varies according to three different magnetization sources, separately excited field, self-excited field or permanent-field, which are used selectively to control the motor over the mechanical load's range. The principal advantage of a DC motor is that its speed can be changed over a wide range by a variety of methods. In fact, fine speed control is one of the reasons for the strong competitive position of DC motors in the modern industrial applications.

In the new era of power electronic technology, power electronic converter is generally used in power system, general industry, transportation and new energy field. But most converters need a rectifier section to get the DC voltage [3]. Rectifier is one of the main parts that are functioning to get the required DC voltage for DC motor. Rectifier in this project is controlled by the PWM signal through the gate driver from the Arduino board.

There are several methods to control the speed of DC motor. In this project, the speed of the DC motor will be controlled by vary the current through the entire circuit. This control method using the Arduino board integrated with the MATLAB Simulink Toolbox. Arduino is a single-board microcontroller to make the use of electronics in multidisciplinary projects more accessible. The hardware consists of an open-source hardware board designed around an 8-bit Atmel AVR microcontroller, or a 32-bit Atmel ARM. The software consists of a standard programming language compiler and a boot loader that executes on the microcontroller. The choosing of the Arduino board because it is an open source based where is extremely accessible with MATLAB Software and very flexible to be customized.

The proposed of the block diagram of this project as below.

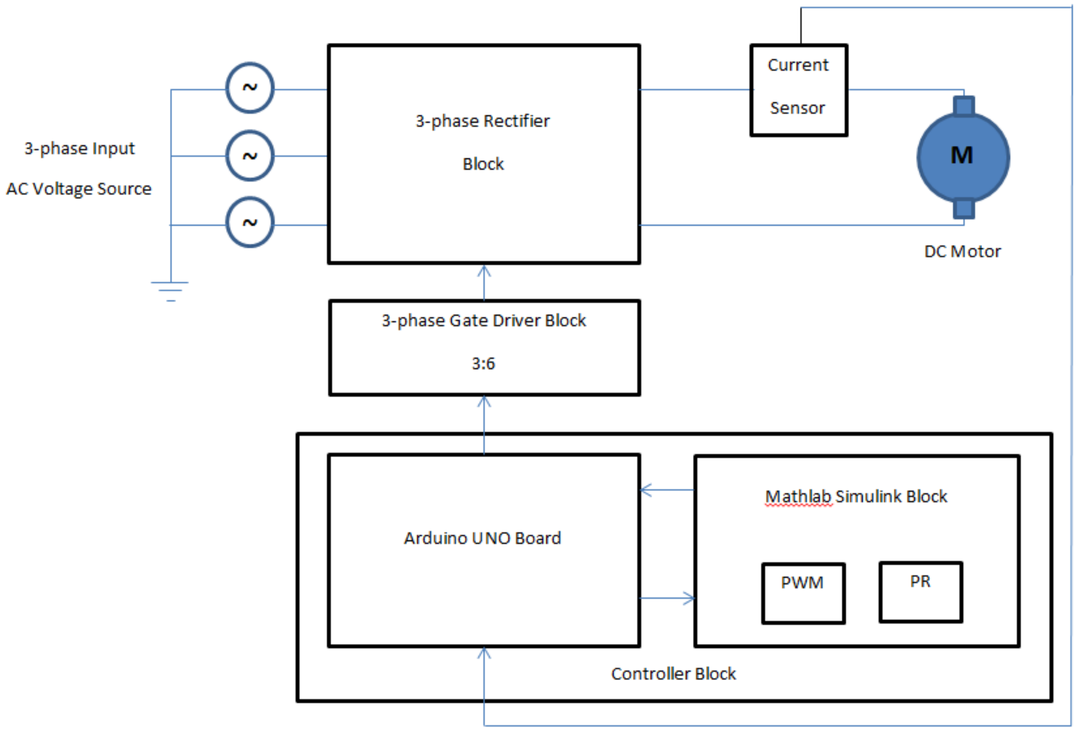


Figure 1.1: Block diagram of the project

1.2 Problem Statements

In controlling DC motor speed, there are several ways can be used. Generally, DC motor speed is controlled by using potentiometers, variable resistors, and pulse-width-modulation. Speed control also can be achieved by variable battery tapping, variable supply voltage, resistors or electronic controls. Major problems in applying this conventional control method are the effects of nonlinearity in a DC motor [2]. The nonlinear characteristics such as friction and saturation could degrade the performance of DC motor hence lag of efficiency and slow response.

DC motors also widely used in traction and application that required high starting torque. Due to the inherent characteristic possessed by the dc motor system, such as the complexity of the nonlinear system, unavailability of an accurate and precise mathematical model, the use of conventional PI or PD become a suitable solution. However, the capabilities of these controllers are limited and the performance is not the best possible [4]. Besides, a few of the method is not make use the using of DSP which is better in giving response.

Most of rectifier sections consist of uncontrolled rectifying circuits with diodes or phase-controlled rectifying circuits with thyristors. In this process, harmonics and reactive power will be into the power network, which can affect to power network [3]. A major problem in the design and operation of the three- phase voltage rectifier is the high switching loss which limits maximum switching frequency for a given power rating [5]. These converters have the inherent drawbacks that the power factor decreases when the firing angle increases and the harmonics of the line current are relatively high.

1.3 Project Objectives

- To develop a proportional-resonant (P-Resonant) current controller using MATLAB Simulink.
- To build up a three phase rectifier circuit for the DC motor.
- To design the gate driver for the rectifier circuit.
- To communicate the Arduino board with the MATLAB software.

1.4 Project Scopes

- The rectifier will be utilized for converting the AC source supply to the DC source supply.
- The gate driver will be developed is for 3 inputs and six (6) outputs to accommodate the number of MOSFET used in the rectifier circuit.
- The Proportional-Resonant (P-Resonant) current controller will be developed by using MATLAB Simulink Toolbox.
- The Arduino Uno Rev3 board is a microcontroller based board will be used to working with the MATLAB software. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button.

CHAPTER 2

LITERATURE REVIEW

2.1 DC Motor

DC motor can be classified according to the electrical connections of the armature winding and the field windings. The different ways in which these windings are connected lead to machines operating with different characteristics. The field winding can be either self-excited or separately-excited. The terminals of the winding can be connected across the input voltage terminals or fed from a separate voltage source. Further, in self-excited motors, the field winding can be connected either in series or in parallel with the armature winding. The types of electric motors are illustrated by the figure as below.

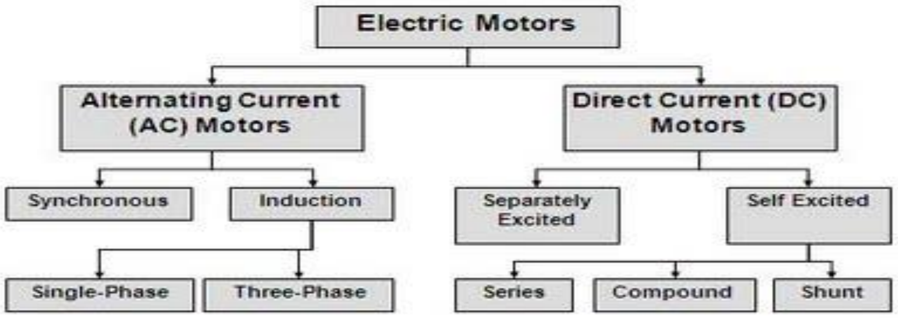


Figure 2.1: Types of Electric Motors

2.1.1 Separately Excited

The DC motor is the obvious proving ground for advanced control algorithms in electric drives due to the stable and straight forward characteristic associated with it [6]. In a DC motor, the electromagnetic torque is produced by the interaction of the field flux and the armature current. A back emf, or speed voltage, is produced when the motor is rotating [4].

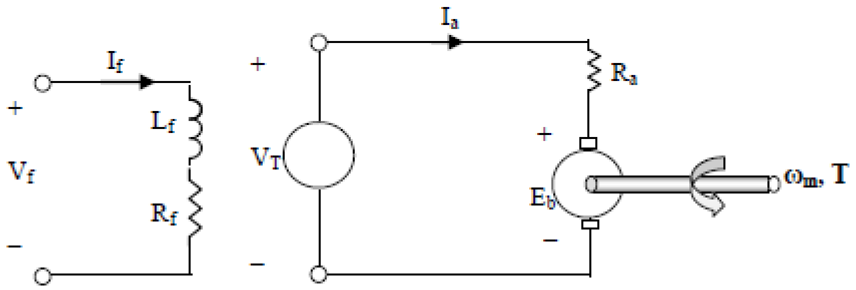


Figure 2.2: Separately Excited DC motor

For the Separately Excited DC motor, the rotor and stator are each connected from a different power supply, this gives another degree of freedom for controlling the motor over the shunt. Nowadays, a close loop controller for separately excited DC motor is suggested with boost converter [6].

2.1.2 Self Excited

In Self Excited machines, instead of a separate voltage source, the field winding is connected across the main voltage terminals. As illustrated in the figure 2.1, Self-Excited DC Motor can be divided into three categories which are Series DC Motor, Shunt DC Motor and Compound DC Motor. Each of these categories has its own characteristics.

2.1.2.1 Series DC Motor

DC series motors are widely used in traction and application that required high starting torque [4]. In this motor, the field coil and armature windings are connected in series to the power source. The field coil is wound with a few turns of heavy gauge wire. The magnetic field is produced by the current flowing through the armature winding with the result that the magnetic field is weak when the motor load is light (the armature winding draws a minimum current). The magnetic field is strong when the load is heavy (the armature winding draws a maximum current). The armature voltage is nearly equal to the line voltage (just as in the shunt wound motor if we neglect the small drop in the series field). Consequently, the speed of the series wound motor is entirely determined by the load current [7]. The speed is low at heavy loads, and very high at no load. In fact, many series motors will, if operated at no load, run so fast that they destroy themselves. The high forces, associated with high speeds, cause the rotor to fly apart, often with disastrous results to people and property nearby.

The torque of any DC motor depends upon the product of the armature current and the magnetic field. For the series wound motor this relationship implies that the torque will be very large for high armature currents, such as occur during start-up. The series wound motor is, therefore, well adapted to start large heavy-inertia loads, and is particularly useful as a drive motor in electric buses, trains and heavy duty traction applications. Compared to the shunt motor, the series DC motor has high starting torque and poor speed regulation.

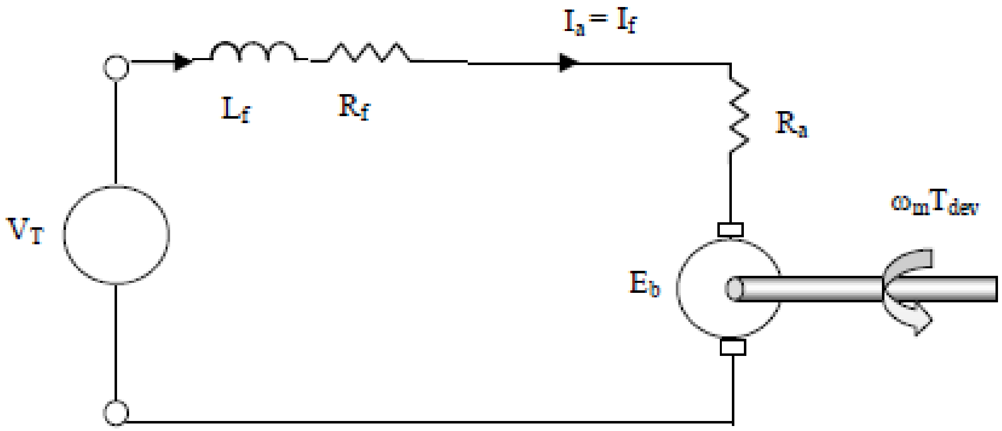


Figure 2.3: Series DC Motor

2.1.2.2 Compound DC Motor

Compound motor consists two parts of the magnetizing flux, one depending on the parallel or shunt current and one function of the armature current [8]. The high torque capability of the series wound DC motor is somewhat compromised by its tendency to over speed at light loads. This disadvantage can be overcome by adding a shunt field, connected in such a way as to aid the series field. The motor then becomes a cumulative compound machine. Paper [9] defines the new torque-speed characteristic determination technique, the system analysis, and experiment results, for a DC compound motor. Again, in special applications where DC motors are used in conjunction with flywheels, the constant speed characteristic of the shunt wound motor is not entirely satisfactory since it does not permit the flywheel to give up its kinetic energy by an appropriate drop in motor speed.

The series field can also be connected so that it produces a magnetic field opposing that of the shunt field. This produces a differential compound motor, which has very limited application, principally because it tends to be unstable. As the load increases, the increases armature current is increasing the strength of the series field. Since it acts in opposition to the shunt winding, the total flux is reduced, with the result that the speed increases. An increase in speed will generally further increase the load, which raises the speed and could cause the motor to run away.

Figure 2.4: DC Multifunction Machines

The shunt field winding places a practical limit on maximum no-load speed and it may be operated at no load. The shunt coil also provides for better speed regulation than a series motor; while the series coil provides for greater starting torque than a shunt motor. After the motor is started, the series coil is shorted out for better speed regulation. Cumulative compound motors are used where fairly constant speed under irregular loading is needed.

2.1.2.3 Shunt Motor

In paper [10] mentioned that the field coil and the armature windings are connected in shunt is parallel across the power source. Shunt DC motor mathematical model is nonlinear, with polynomial type nonlinearities. It consists of three state variables and one input. It was mention that for comparison of the nonlinear control methods both position and speed control are considered. It allows one to study some important differences in the properties of the control arrangements even the model of the shunt DC motor is quite simple[11].

The armature winding consists of relatively few turns of heavy gauge wire. The voltage across two windings is the same but the armature draws considerably more current than the field coil. Torque is caused by the interaction of the current caring armature winding with the magnetic field produced by the field coil. If the DC line voltage is constant, the armature voltage and the field strength will be constant. The speed regulation is quite good; the speed is a function of armature current and is not precisely constant. As the armature rotates within the magnetic field, an EMF is induced in its wining. This EMF is in the direction opposite to the source EMF and is called the counter EMF (CEMF), which varies with rotational speed. It was reported in [12] that the main advantage of such methods is their strength for a wide range of operating circumstances.

Finally, the current flow through the armature winding is a result of the difference between source EMF and CEMF. When the load increases, the motor tends to slow down and less CEMF is induced, which in turn increases the armature current providing more torque for the increased load. Motor speed is increased by inserting resistance into the field coil circuit, which weakens the magnetic field.

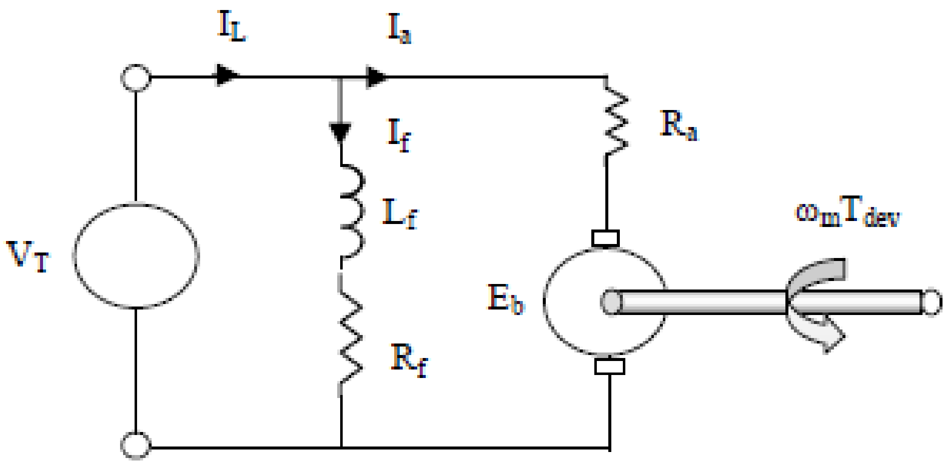


Figure 2.5: Shunt DC Motor

Therefore, the speed can be increased from “basic” or full-load, full-field value to some maximum speed set by the electrical and mechanical limitations of the motor. The power difference between the motor input and the output is dissipated in form of heat and constitutes to the losses of the machine. These losses increase with load, since the motor heats up as it delivers mechanical power.

2.2 Three Phase Rectifier

Rectifiers are widely employed in industrial fields and consumer products thanks to advantages of low cost, simple structure, robustness and absence of control [13]. A rectifier is an electrical device that converts alternating current (AC), which periodically reverses direction, to direct current (DC), which flows in only one direction. The process is known as rectification. Conventionally, DC motor drives have widely employed thyristor – based phase controlled rectifiers, which supply adjustable terminal voltage for speed control. However, since the SCRs in AC-DC converters are switched at the AC supply line frequency, significant torque and speed ripple can result, especially with low inertia motor load set- ups [6].

The rectifier produced can reduce the harmonics, increase power factor, possess of both rectifying and regenerating abilities with fast responses that can improve the dynamic performance of the whole system [14]. The schematic circuit of the converter is shown in figure below.

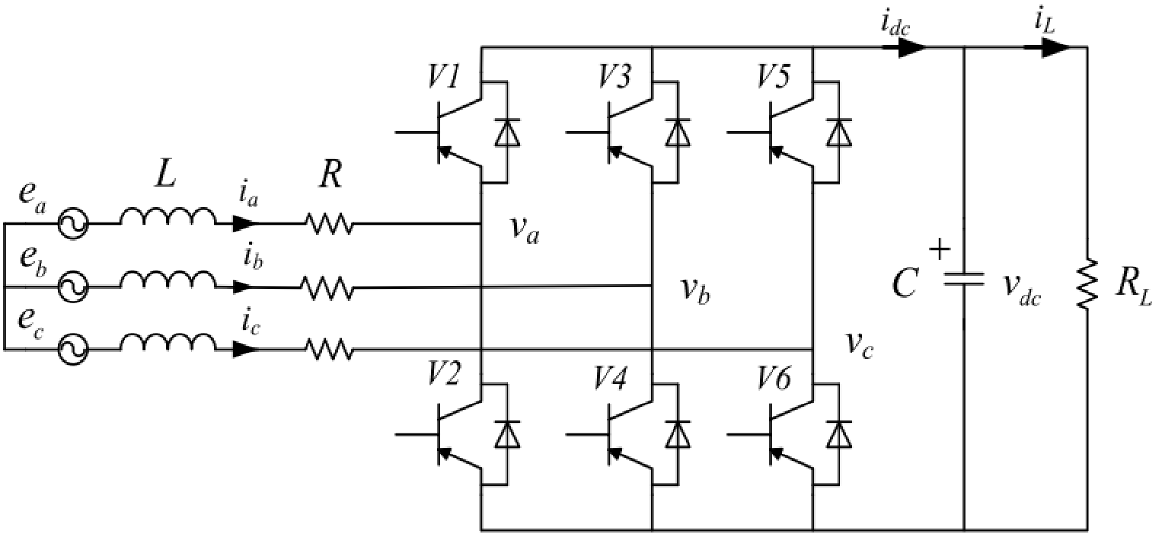


Figure 2.6: Main Circuit of the three-phase rectifier

In the figure 2.6, La, Lb, Lc, are the three phase input reactance respectively; S1, S2, S3, S4, S5. S6 are controllable switches such as insulated gate bipolar transistors; V1, V2, V3, V4, V5, V6 are free-wheeling diodes that were parallel connected with the controllable switches, and a capacitance C is connected to the dc bus of the bridge circuit. In this paper the six fully controlled switches are replaced with a MOSFET and the MOSFET is controlled using PWM. The PWM signals are generated from the gate driver in order to control the switching of the MOSFET. The PWM rectifier can ride with unity power factor[3].

2.3 Controller

The important characteristic of modern control theory is that the controller and estimator depend on the model of the controlled plant [15]. Controller is a device, which monitors and decides the operating conditions of a given dynamical system. There are two major groups' categories of controller which are Adaptive and Passive. PID, Fuzzy, and P-Resonant are the example of Adaptive controller. Hysteresis, Relay and Sliding Mode Control are the example of the passive controller.

2.3.1 PI and PID controller

Proportional–integral (PI) control is frequently used in the stationary reference frame for current-controlled inverters [16]. Conventional proportional and integral (PI) controllers are very easy to implement for the grid side inverter, but they cannot track non dc current references without errors between the sinusoidal reference currents and output current through the LC or LCL filters [17]. Thus, when the attenuation and resonant frequency of the filter varies significantly, they will be unstable for the control system. To solve these problems, feed-forward PI current controllers with two current loops have been proposed in [16]. But, these controllers not only have poor dynamic response to track a sinusoidal reference without steady-state error, but also lack capability in disturbance rejection. A standard PID controller transfer function is generally written in 2.1.

$$G(s) = K_p + K_i \frac{1}{s} + K_d s \qquad (2.1)$$

PID has been one of the controller system design method that extensively used until today [18]. The design are discussed in many references such as [19]. PID represents the grouping of three elements known as Proportional (P) +Integral (I) +Derivative (D). In industrial applications, PID control algorithm is the most widely used controller [20]. Figure 2.7 shows the commonly implementation of PID.

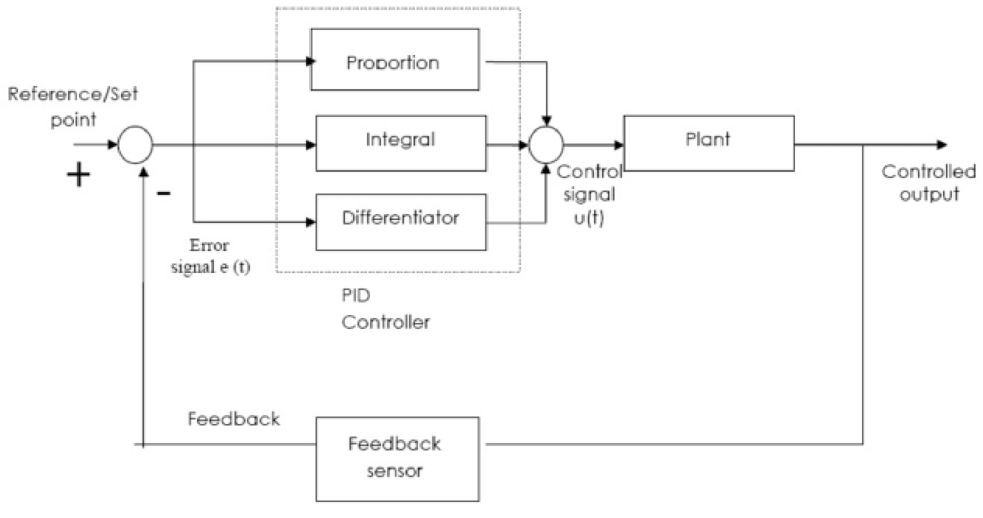


Figure 2.7: PID implementation

PID controller is normally to adjust the value of proportional gain Kp, integral gain Ki, and differential gain Kd to get the ideal control performance setting. This function has been sufficient to the most control processes.

2.3.2 Fuzzy logic

The fuzzy set theory was introduced in the 1970's to design controllers for systems that are difficult to model [21] . Fuzzy logic-based controllers have recently gained large acceptance in many applications due to their robust performance and good dynamic response. The marvel of fuzzy logic is that it facilitates computation with words rather than with numbers and does not necessitate a detailed model of the plant to be controlled [13].

In fuzzy logic, linguistic expressions; e.g. small, medium, big are used to describe situations as well as the actions –governed by if/then rules- to be taken upon the current situation. Fuzzy logic is capable of describing situations and actions in a manner close to the human brain thinking while achieving satisfactory results in real time applications. A detailed mathematical model is not essential in case of fuzzy control which simplifies the design process; however, good knowledge and experience of the inspected system are required. Fuzzy logic is a method used to make the machines thinkable to reason in a fuzzy manner like humans [22]. Generally, there was five components characteristic or rule of a Fuzzy controller.

Components of fuzzy rule system;

- Preprocessing
- Fuzzification
- Rule base
- Defuzzification
- Post processing

Paper [18] presented the speed control of DC motor using fuzzy logic based on Labview. The author conclude that fuzzy logic have an advantages compared to the other commonly used controller. Fuzzy logic has simplicity in control, low cost and the possibility to design without depth knowledge in mathematical model of the process.

2.3.3 P- resonant controller

The proportional resonant (PR) controller has been proposed in many recent works, as an effective controller for this application. It does not introduce any phase delay into the control loop at the resonant frequency. Also, it has infinite gain at the resonant frequency, which ensures zero steady-state error in a stationary frame, resulting in minimization of the load current distortion and harmonic content in the inverter.

A proportional–resonant (PR) controller introduces an infinite gain at a selected resonant frequency to eliminate steady-state error or current harmonic at that frequency. However, the harmonic compensators of the PR controller are limited to several low-order harmonics due to system instability when the compensated frequency is out of the bandwidth of the system [16]. Passive damping is often used to maintain system stability, but it is limited by cost, losses, and degradation of the filter performance. The use of active damping by means of control may seem attractive, but it is often limited by a complex tuning procedure of the controllers. This controller gives an advantage in performance at the fundamental frequency and ignore other frequency [23]. The transfer function of PR controller is given by 2.2.

$$G_{AC}(s) = k_p + \frac{k_i s}{s^2+\omega_0^2} \tag{2.2}$$

Proportional-resonant (PR) controllers were introduced to overcome the shortcomings of the stationary-frame PI- controllers as well as the complexity related to the synchronous-frame controllers [21]. PR controllers associated with the PR controllers is the possibility of implementing certain harmonics compensation without requiring excessive computational resources [24].

As a conclusion, PR controller has some superior performance over the other controller especially Proportional-Integral-Derivative (PID) controller such as PR controller is performed in a stationary frame and there is no need for frame transformations. As a result the response is faster and it has high computational efficiency. This controller has less dependence on the system model, so there is no need for the exact model of the system. PR controller has good robustness against system parameters variations.

2.4 Arduino Uno Rev3 Board

Microcontrollers have become quite affordable in recent years due to the fast growth of integrated electronics [25]. Arduino is an open-source platform used for building electronics projects. Arduino consists of both a physical programmable circuit board (often referred to as a microcontroller) and a piece of software, or IDE (Integrated Development Environment) that runs on the computer, used to write and upload computer code to the physical board. The Arduino platform has become quite popular with people just starting out with electronics, and for good reason it is open sourced. Unlike most previous programmable circuit boards, the Arduino does not need a separate piece of hardware (called a programmer) in order to load new code onto the board. Thus, it covers everything needed to support the microcontroller[26].

The use and selection of this development board is based on the few considerations. This is important to make sure the system functioning and running without any problems.

2.4.1 Performance

This project needs almost real-time response to estimate and correct the current immediately. Hence, the development board must provide a processing speed that is sufficiently fast to perform the processing tasks, including data acquisition, control computation and signal output, within the sampling time. The Arduino Uno Rev3 development board is equipped with the ATmega328 processor, which features a maximum clock rate of 16 MHz with 32 KB Flash Memory which is sufficient for the project.

2.4.2 I/O Pins

Another issue is the number of I/O pins available. On this project, current sensors are deployed to obtain measurements beside the tachometer to measure speed of the motor. In addition, a motor control board is interfaced with the development board for delivery of PWM signals.

Base on the pin-outs of these sensors and the motor control board, it has been determined that at least three I/O pins are needed. The Arduino Uno Rev3 features 14 general-purpose digital I/O pins of which 6 provide PWM output. Some of the digital I/O pins also support serial communication such as I2C and SPI, as well as interrupt handles. The board also features 6 analog inputs for 0-5V input, giving a quantization limit of 4.9mV.

2.4.3 Open Sources

Another advantage of this device is the multisource of programming language. To alleviate difficulties in programming, a user-friendly development environment, useful function libraries and references are preferred. These requirements are well met by the Arduino development environment which is based on the C language. User-contributed function libraries like PWM control, I2C and SPI communication reduce difficulties in learning to program the Arduino boards. Most importantly, Arduino is open-source with a large user community and up-to-date discussion forums. This allows users to study other users' codes, compare results, and make modifications according to the project's needs [15]. This project makes use the function on MATLAB Simulink Toolbox as a programming method for the controller.

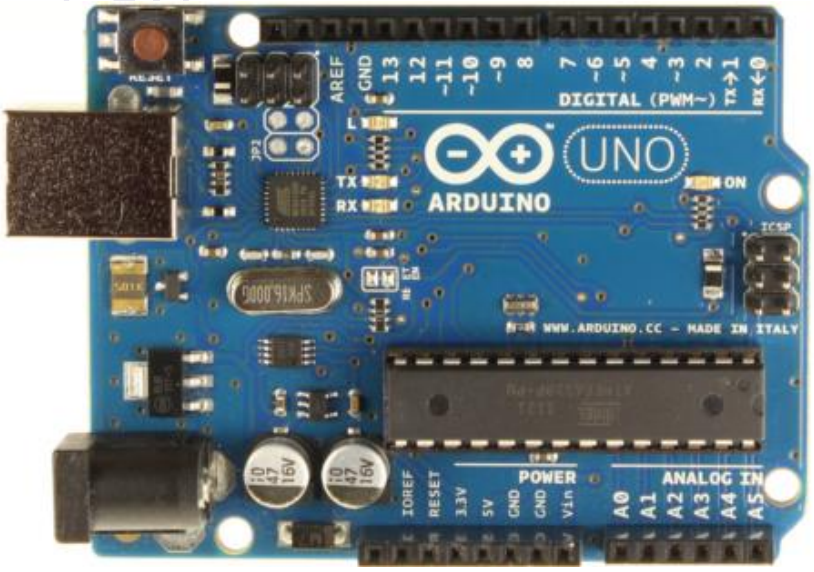


Figure 2.8: Arduino Uno Rev3 Board

Summary of Arduino Uno Rev3 Board:

Microcontroller	ATmega328
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	6
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (ATmega328)
SRAM	2 KB (ATmega328)
EEPROM	1 KB (ATmega328)
Clock Speed	16MHz

CHAPTER 3

METHODOLOGY

Chapter 3 consist of methodology of the project which is divided into two main sections which is software and hardware developments. The software development section includes the familiarization with the MATLAB Simulink Toolbox as well as Proportional Resonant (PR) Controller. Besides, the uses of the Arduino board were explained in detail in this section. Section two is for hardware development which consist of selection of DC motor, design and development of gate driver and three phase rectifier circuit.

3.1 Block Diagram

Figure 3.1 shows the block diagram of this project, it consist of four important elements which is three phase rectifier circuit, gate driver, load and the Arduino controller board. The input supply of this block diagram is the three phase AC voltage source. The rectifier consist of a number of MOSFET that controlled by the PWM signal at the gate driver. Controller part of this project represent by the Arduino board where all the Simulink model was embedded into it.

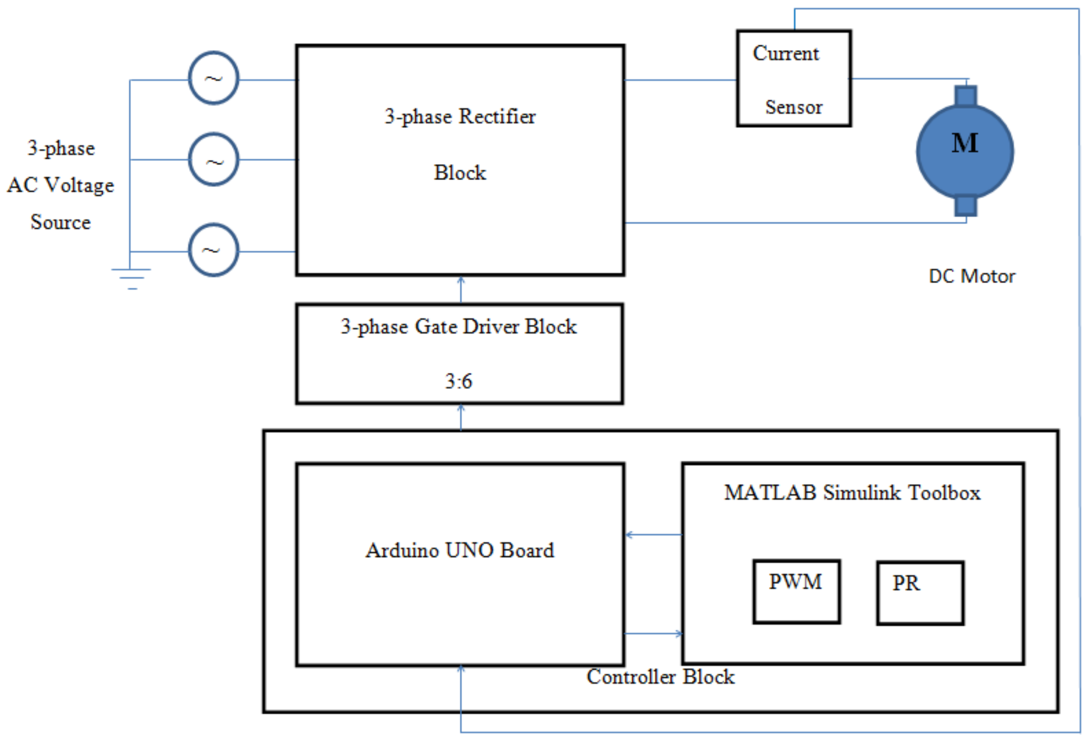


Figure 3.1: Block diagram of the project

3.2 Flow Chart

Figure 3.2 shows the flow chart of this project, at the starting point the reference current value must be set for the PR controller. After that the system can be switched ON to run the DC motor. At the time, current sensor takes it role to send data to the Arduino. Arduino receives the data and compare the data with the reference value. If the data reach the reference value the motor will continue running until the system shut down. If not, the data will be analysed by the PR controller and the result will be send back to the gate driver for correction, this role will continue running until the system reach the reference current.

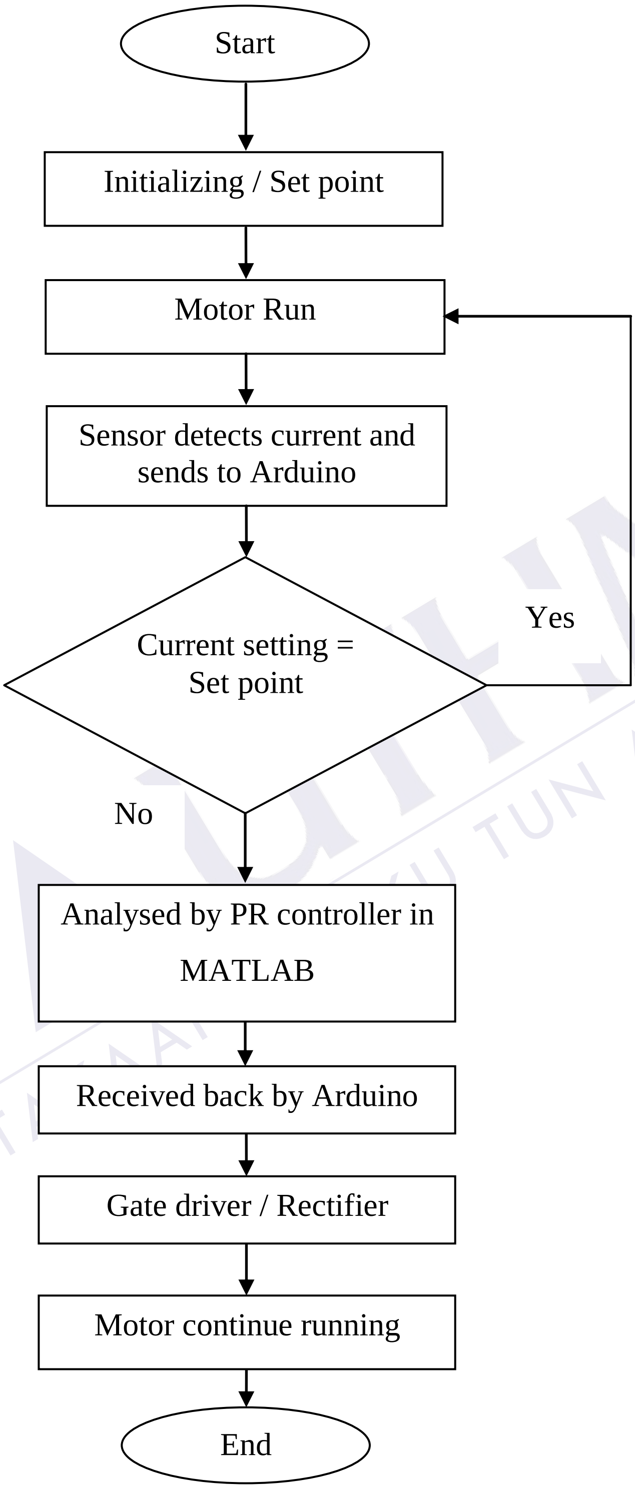


Figure 3.2: Flow Chart

3.3 Software Development

MATLAB is a high-level language and interactive environment for numerical computation, visualization, and programming. It is used to analyse data, develop algorithms, and create models and applications. The language, tools, and built-in math functions enable you to explore multiple approaches and reach a solution faster than with spreadsheets or traditional programming languages. Although MATLAB is intended primarily for numerical computing, an additional package, Simulink, adds graphical multi-domain simulation and Model-Based Design for dynamic and embedded systems.

3.3.1 MATLAB Simulink Toolbox

For controlling DC motor, a MATLAB program has been develop using “Simulink” toolbox and Arduino Support Package libraries in order to generate the command instruction. The MATLAB program sends the proper commands to Arduino which control the motor through the gate driver and three phase rectifier, then send back the sensory feedback to computer via Arduino for correction and analysis. A conversion function that converts the desired function from MATLAB to Arduino commands is developed. Arduino was programmed to read MATLAB’s commands [27], thus the user can generate any function in MATLAB or close the loop to control the DC motor by adding a Proportional Resonant or any type of controller in MATLAB.

3.3.2 Proportional Resonant Controller

To improve the system performance and achieve the precise sinusoidal current tracking, PR type controller have been proposed initially for the control at fundamental supply frequency and then at harmonic frequencies. The transfer function of PR controller can be expressed by [24]:

$$G_{AC}(s) = k_p + \frac{k_i s}{s^2+\omega_0^2} \tag{3.1}$$

Where the ω_0 is the fundamental frequency (grid/resonant frequency) and K_p and K_i represent proportional and resonant gains respectively. For K_p, it is tuned in the same way as for a PI controller, and it basically determines the dynamics of the system in terms of bandwidth, phase and gain margin and K_i could be tuned for shifting the magnitude response vertically but this does not give rise to a significant variation in bandwidth [17].

For fundamental frequency component, the PR control for the ac quantity in the stationary frame is equal to the PI control for the dc quantity in the synchronous frame. Figure 3.2 shows the block diagram representation of PR controller, the designed controller was divided into three main parts which is input, controller contains of proportional gain (Kp), integration gain (Ki), transfer function (ω = 2πf where f = 50Hz.) and lastly output. The input of this controller will be the analog input from Arduino which is the current sensor feedback voltage. The current sensor will measure the line current that flow to the DC motor.

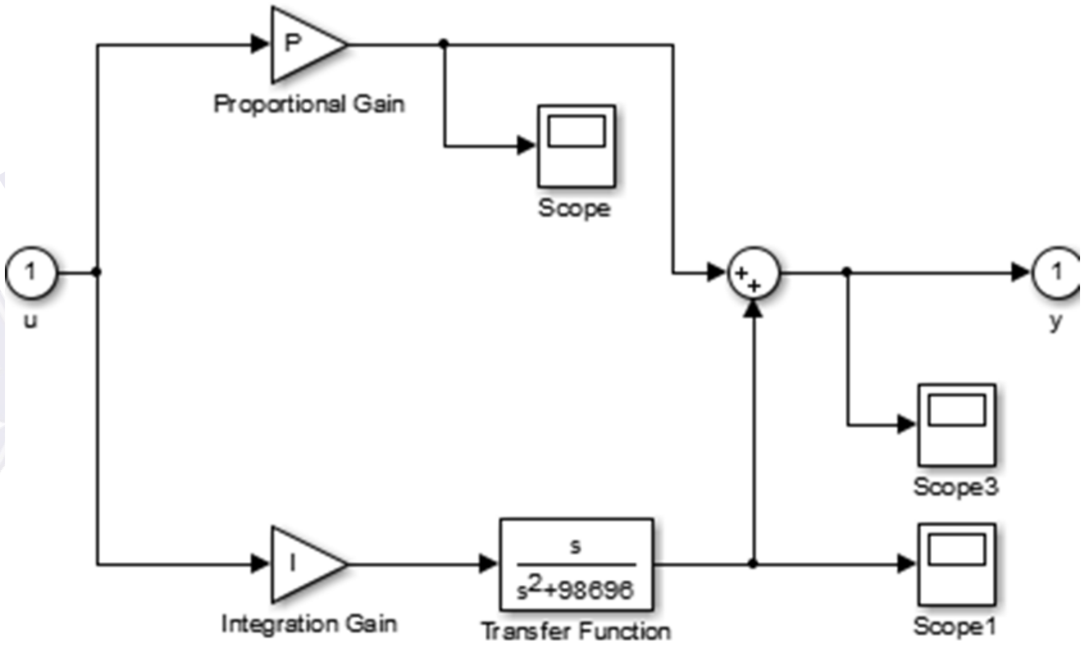


Figure 3.3: PR controller design

Figure 3.3 represent the PR controller model in the MATLAB Simulink. The model consists of proportional gain block, integration gain block and transfer function block. Based on the equation 3.1, ω_0^2 was replaced by the value 98696 where the calculation as follow.

$$\omega = 2\pi f \tag{3.2}$$
$$where\ f = 50Hz$$

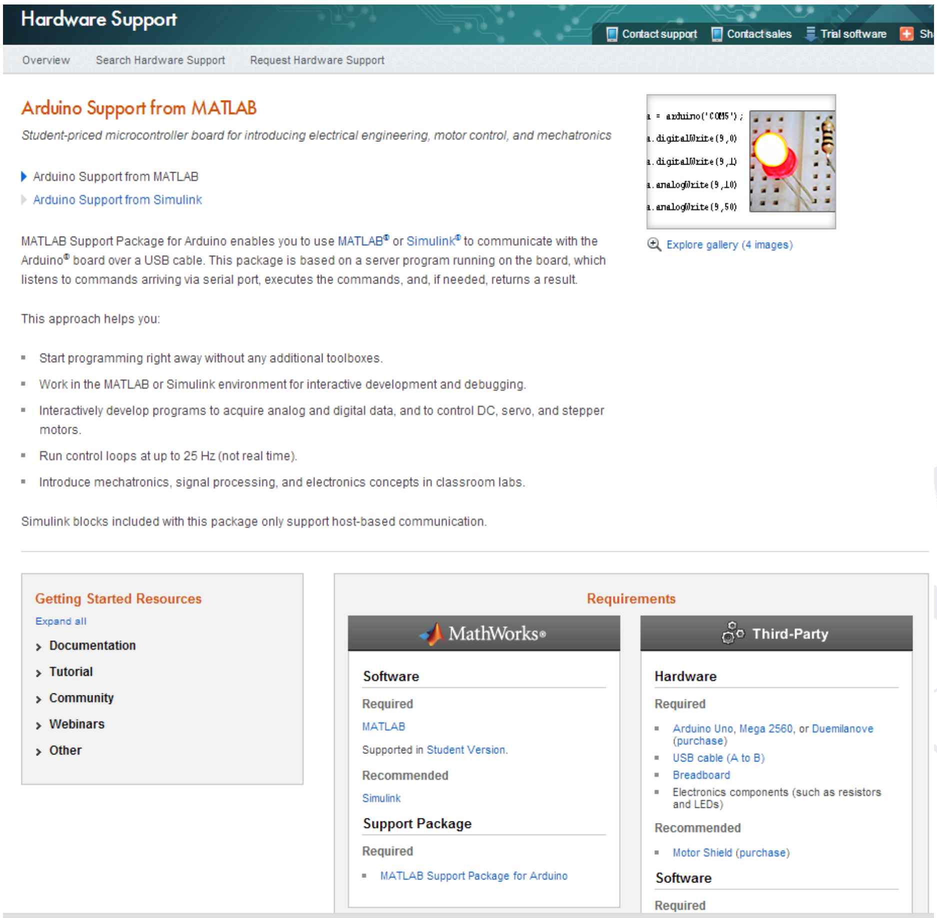
Therefore,

$$\begin{aligned} \omega_0^2 &= (2\pi\ \times 50)^2 \\ &= 314.16^2 \\ &= \mathbf{98696} \end{aligned} \tag{3.3}$$

3.3.3 Arduino Board

The Arduino Uno R3 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 32 KB Flash Memory of which 0.5 KB used by boot loader, 2 KB SRAM, 1 KB EEPROM. Moreover, it has 10 bits A/C converter, which allows 1024 resolution. Thus, it contains everything needed to support the microcontroller.

Arduino has its own open- source programming language basing on C/C++. It can be simply connect to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started. For this project, the compilation of a program is prepared on computer PC using MATLAB and implemented on the Arduino board. In order to communicate the Arduino with MATLAB, a few setting must be configured to ensure the communication is successful. As shown in Figure 3.4, MATLAB Support Package for Arduino available in the mathworks website for user to communicate MATLAB with Arduino.



Arduino Support from MATLAB

Student-priced microcontroller board for introducing electrical engineering, motor control, and mechatronics

- Arduino Support from MATLAB
- Arduino Support from Simulink

MATLAB Support Package for Arduino enables you to use MATLAB® or Simulink® to communicate with the Arduino® board over a USB cable. This package is based on a server program running on the board, which listens to commands arriving via serial port, executes the commands, and, if needed, returns a result.

This approach helps you:

- Start programming right away without any additional toolboxes.
- Work in the MATLAB or Simulink environment for interactive development and debugging.
- Interactively develop programs to acquire analog and digital data, and to control DC, servo, and stepper motors.
- Run control loops at up to 25 Hz (not real time).
- Introduce mechatronics, signal processing, and electronics concepts in classroom labs.

Simulink blocks included with this package only support host-based communication.

Getting Started Resources

Expand all

- Documentation
- Tutorial
- Community
- Webinars
- Other

Requirements

MathWorks®

Software

Required

MATLAB

Supported in Student Version.

Recommended

Simulink

Support Package

Required

- MATLAB Support Package for Arduino

Third-Party

Hardware

Required

- Arduino Uno, Mega 2560, or Duemilanove (purchase)
- USB cable (A to B)
- Breadboard
- Electronics components (such as resistors and LEDs)

Recommended

- Motor Shield (purchase)

Software

Required

Figure 3.4: MATLAB Support Package for Arduino

3.4 Hardware Development

Hardware development on this project consists on selection of the DC motor besides the design and development of gate driver and three phase rectifier. The gate driver that will attach on the circuit is the three phase circuit driver with 3 inputs and 6 outputs. The rectifier circuit was designed to receive the three phase input supply and convert it to required DC output which is accommodate the DC motor used which is 220VDC. All of the circuit and PCB layout are designed using the Proteus 8 Professional software.

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