DEVELOPMENT OF SMART LIBRARY SYSTEM USING RFID

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“I hereby declare that I have read this project entitle “Development of Smart Library System using RFID” and that is has comply the partial fulfilment for awarding the degree of Bachelor of Electrical Engineering (Control, Instrumentation and Automation)”.

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Date : ……………………………………

I declare that this report entitle "Development of Smart Library System using RFID" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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ABSTRACT

RFID is the newest and latest technology that has been used in library management system nowadays. With this research, the main aim is to develop the prototype of smart library system with additional features which is returning the books into the bookshelf in order to improve efficiency of the flow in library. RFID is radio frequency identification, readers and tags will communicate with each other through radio frequency. With RFID system, the operation system can be improved, operation cost will be decreased and the data of an item are useful for searching by users. The two design systems are about returning the book to the bookshelf in vertical motion and rotational motion. Two drawings are designing and comparing in order to make the best choice for the design for smart library system in the term of cost, space and number of flow of process. The technical problems and characteristics on the components which are going to use need to be consider and undergo the testing process when building the prototype, such as range of sensor to detect, performance of RFID, speed of DC motor and position of servo motor . The motor, such as DC motor and servo motor are going to use in the project. The control method, PWM control is applied for DC motor to determine the performance of speed of DC motor. The PID controller is designed for the servo motor with load and without load in order to improve the transient response. Ziegler-Nichols method is used for PID controller to perform the best accuracy of position of servo motor in the condition of clockwise direction. The components, such as IR sensor, DC motor, servo motor and RFID reader that used in the project will undergo a testing process to make sure the project runs successfully. The range for the IR sensor reflect on object is about 1 cm until 7cm. By using the PID, the servo motor can achieved the best accuracy of position but PI controller is not suitable for load condition due to PI controller causes unstable to the system. The prototype is developed with successful, but there have some technical problems occurred in hardware design. This research is useful and the technical problems need to be considered all the time and the corrective actions are needed to take when the hardware design is failed to run.

ABSTRAK

RFID adalah teknologi yang terbaru dan terkini yang telah digunakan dalam sistem pengurusan perpustakaan pada masa kini. Dengan kajian ini, tujuan utama adalah untuk membangunkan prototaip sistem perpustakaan pintar dengan memulangkan buku-buku ke rak buku untuk meningkatkan kecekapan aliran dalam perpustakaan. Dengan sistem RFID, sistem operasi boleh diperbaiki, kos operasi akan dikurangkan dan data item berguna untuk mencari oleh pengguna. Kedua-dua sistem reka bentuk akan kembali buku ke rak buku dalam gerakan tegak dan gerakan putaran. Dua lukisan bentuk dan membandingkan untuk membuat pilihan yang terbaik untuk reka bentuk untuk sistem perpustakaan pintar .Masalah teknikal dan ciri-ciri pada komponen yang akan menggunakan perlu mempertimbangkan dan menjalani proses ujian apabila membina prototaip, seperti pelbagai sensor untuk mengesan, prestasi RFID, kelajuan DC motor dan kedudukan motor servo. Motor, seperti DC motor dan motor servo akan menggunakan dalam projek itu. PID pengawal direka untuk motor servo dengan beban dan tanpa beban untuk meningkatkan sambutan fana. kaedah Ziegler-Nichols digunakan untuk pengawal PID untuk melaksanakan ketepatan terbaik kedudukan motor servo dalam keadaan mengikut arah jam. Komponen, seperti sensor IR, DC motor, motor servo dan pembaca RFID yang digunakan dalam projek ini akan melalui proses ujian untuk memastikan projek ini berjalan dengan jayanya. Julat untuk sensor IR merenung objek adalah dalam 1 cm sehingga 7 cm. Dengan menggunakan PID, motor servo boleh mencapai ketepatan yang terbaik kedudukan tetapi PI pengawal tidak sesuai untuk keadaan beban kerana PI pengawal menyebabkan tidak stabil kepada sistem. prototaip ini dibangunkan dengan berjaya, tetapi ada mempunyai beberapa masalah teknikal dalam reka bentuk perkakasan. Kajian ini adalah berguna dan masalah teknikal perlu dipertimbangkan sepanjang masa dan tindakan pembetulan yang diperlukan untuk mengambil apabila reka bentuk perkakasan itu menjalani gagal untuk menjalankan.

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RFID	-	Radio Frequency Identification
PID	-	Proportional–Integral–Derivative
PWM	-	Pulse Width Modulation
PID	-	Proportional-integral-derivative
P	-	Proportional
Z-N	-	Ziegler-Nichols

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CHAPTER 1

INTRODUCTION

1.1 Overview

This chapter will cover the introduction, motivation, problem statement, objective and scope of the research on implementation of smart library system using RFID.

1.2 Introduction

Library is the place where storing the information resources and it provides borrowing service for the library members. The 1st libraries discovered in temple room, located at Sumer with the proving of earliest style of writing. [1] Nowadays, the number of books is increasing in library from time to time in order to affect the people are wasting the time to search the books. Because of many books are arranging in bookshelf, misplaced of books will occur. Automation is growing rapidly recently and it is in order to solve the problem occurred in library which is mentioned. Before the automated returning book system is designed for library, the first thing need to consider is what type of Automatic Identification and Data Capture which called as AIDC is going to use. AIDC is the method to identify and specify the information for the objects. Generally, AIDC is divided into 2 types which are printed and encoded. For AIDC in library, the most common use is barcode and RFID. An analysis will be done for the comparison between RFID system and barcode system. Picking the suitable components for the phase design and analysing the characteristics on the components is important when developing a system. Researching on the past studies which is related to the topic is necessary to build an automation system in library. Experiment for the components used is going to setup and running along in the research to make sure the system build successful.

1.3 Motivation

RFID is a smart technology that is widely used in the world. For example, RFID is used in supermarket at case and pallet levels such as Wal-Mart, Best-Buy and Target in order to reduce the cost associated with this technology nowadays [2]. RFID is also provides great potential for library system such as broadening access and security. The data of a product can be identified through RFID, it make the mostly industries consider RFID first for tagging their product which can be tracked easily. From the Figure 1.1, the RFID is growing rapidly from the early year. RFID will take over barcode system in one day. Passive RFID technology has greater potential in the future if compared with active RFID due to the price is very cheap. RFID is chosen because it can improve the efficiency in management, production line and industry.

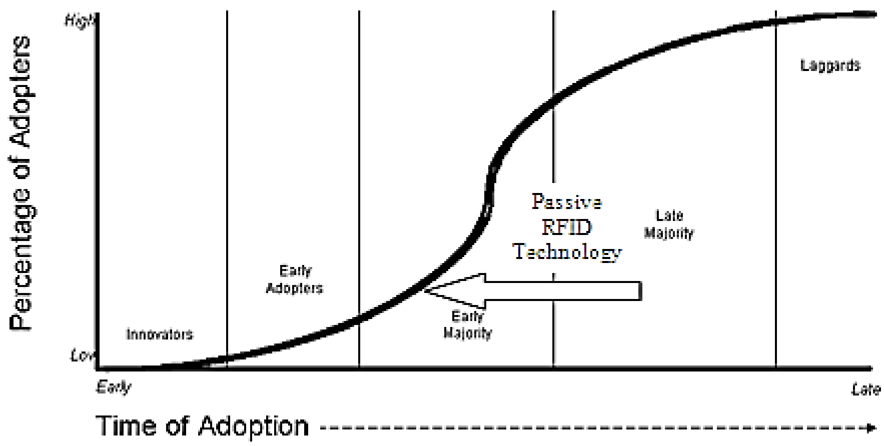


Figure 1.1: Diffusion in RFID Technology (Rogers, 1962)

Automation is useful and growing rapidly recently. For example, some of the restaurant in Japan are applying automation with conveyor belt sushi. The research had mentioned that automation is able to increase the efficiency of library system. [3] Automation is providing great potential and bring convenience to people around the world. Because of too much books on library, the higher and larger of bookshelf is needed to occupy the number of books. A chair and ladder is needed to pick up or put back the books into the bookshelf. With the smart automation, the injuries case can be reduced or prevented. The injuries case happened which is mentioned in The Brown Daily Herald. [4] Alexandra Ulmer had mentioned that Pereira who is a library technician is needed to a surgery on shoulder and elbow after he had serviced 28 years for the shelving books at Brown with the proven by lawyer. Therefore, this research will determine the possibility of applying automation in library management system.

1.4 Problem Statement

There are some technical problem on RFID, which the tag is not detected by the reader [2]. When the tag is moving on conveyor belt, the reader performance will be affected by speed of conveyor belt. The tags also will be influenced by the arrangement of tag on the item surface. The aim of the study evaluate result of various type of the variable, speed of conveyor belt, tag placement and the distance between unit tag and RFID reader and antennas that will affect the readability of RFID tag. Another one is regarding IR sensor due to IR sensor is divided into many types, every IR sensor has their own detecting range for the obstacles. IR sensor has the different detection range for the obstacle due to the colour of the obstacle and the voltage supply to the sensor. The aim of the research is carried out an experiment to determine distance of reflective object in different of colour with the difference values of input voltage to the sensor. The design of the conveyor belt for the sensor to detect the object will based on the results get from the experiment setup. The speed of conveyor belt will be affected by the weight of the item, the length of belt and frictional forces of the belts. To make sure the system is running smoothly, control of speed for conveyor belt system is necessary. The research had mentioned that servo motor is losing control and position without the close loop system. [4] A controller is needed to design to control the position of servo motor with accurately.

1.5 Objective

The main purpose of introducing this project is to design an intelligent smart library system based on RFID Technology with automated system which is returning books to bookshelves and determine the possibility of applying automation system in library for improving the efficiency for library management system. In order to achieve the purpose of the project and to solve the problem occur, the objectives are to design a prototype that able to apply microcontroller technology. The objectives have been listed below must be achieved in completing this project.

a) To design small prototype of smart library system with automated book return system.

b) To examine the performance of RFID tag with different placement.

c) To determine the distance of IR line tracking sensor to reflective object in 5 colours- red, orange, yellow, green and blue with the range of input voltage

d) To analyse the transient response of position for servo motor using PID controller.

1.6 Scope

To achieve the objectives, the scope of project as followed. Two drawings will be designed and analysed to order to make the choices on the design for smart library system. Implementation of a smart library system which is more focused on the conveyor belt system for returning the books to proper area of bookshelf by using Arduino Mega 2560 as a controller with RFID technology for provide more efficient management. The type of DC geared motor which is going to use is SPG 50-60K. The experiment for DC motor is only included open loop system for PWM analysis. The close loop system for PWM analysis of DC motor is not covered for the research. While the IR line tracking sensor is going to apply is model of IR Line Tracking Sensor (Single Bit). For PID to control the accuracy of 6 positions for Tower Pro MG995 in clockwise direction is using Ziegler-Nichols Tuning Rules.

1.7 Organization of the Project

This report will be conducted into five chapters and each of the chapter stated as below. Chapter 1 is regarding about Introduction. This chapter will cover the overview of the project such as general information, motivation, problem statement, objective and scope. Chapter 2 is about Literature Review. This chapter will discuss project background and the past studies related to the project research from the journal and conference paper. Chapter 3 is discussing about Research Methodology. All relevant experiments and techniques that used in the project will discuss in chapter 3. The flowchart for the system design with explanation will show in this chapter. Chapter 4 is about Results& Discussions. The result of the project from the experiment will record and interpret in chapter 4.Chapter 4 is also will analyse and discuss the data which get through the experiment. Chapter 5 is talking about conclusion. This chapter discuss the conclusion and recommendation for the project.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

This chapter is about the literature review for the case study which is related to the research. Project background for the research is included in this chapter. The theory on automatic identification and data capture, barcode, RFID, object detection system and system which is to control the DC motor and DC servo motor are included in this chapter.

2.2 Project Background

RFID which stands for Radio Frequency Identification system was created and invented in the years of 1948, but it was not used for the commercial application until the year of 1980[2]. Antenna, transceiver is called as reader, transponder is also as a tag are components in RFID system. Through RFID system, readers and tags will communicate with each other through radio frequency. RFID is widely used in worldwide today because it can be used to identify and track the item either in shopping, library, industry and various place by radio waves. Issues like misplaced and missing item are common problem that occurred in library nowadays. 1995 study shows that 12 percent of all library books in Ohio were missing [6].Based on the research, Singapore libraries are applying RFID Technology as management system in library [7]. To make the system to be more efficient, the automated shelving system need to add on to prevent issues like misplaced and missing item occurred in library.

2.3 Automatic Identification and Data Capture (AIDC)

AIDC stands for Automatic Identification and data capture is the method to identify and track the information products by automatically, the data is collected through the process and the data is directly recording in the computer world [8]. Barcodes and RFID are example of smart technologies in AIDC. AIDC is provided some benefits, such as reducing the labour cost, improving the efficiency of management system and also improving customer service in wide variety of operation system. The data collection is included the comparison between barcodes and RFID and explanation about the reason that RFID is stand more advantage over barcodes technology. The literature review for the barcode technology and RFID technology will discuss afterward.

2.3.1 Barcode

Barcode technologies was invented in early year of 1950[9]. Barcode is made up of lines and spaces. Barcodes can be represented by number and letter and it can be scanned by barcode reader to identify the type of an item. Figure 2.1 shows the symbol of barcode.

Figure 2.1: Symbol of Barcode

There are two types of barcode. One is linear barcodes and another is matrix barcodes. Linear barcodes also called as one dimension barcodes. It is made up with several lines and spaces which is shown Figure 2.1. Linear barcodes can used to represent the item in post offices, libraries and industries. For the matrix barcodes (2D barcodes) is shown in Figure 2.2 is same function with the linear barcodes but 2D barcodes able to present the more data per unit area. There are some different codes for the barcode, such as Codabar, Code 39 and Code 128. Several libraries in Lebanese are applying Code 39 to their library management system due to Code 39 can be widely used in the worldwide and it is the easiest alpha-numeric barcode.

Figure 2.2: Matrix Barcodes

Barcode is scanned by barcode reader in order to read the barcode data tagged on the item. It needs light source that transferring the optical impulses into electrical form. Barcode reader only can sense or read one barcode at once.

2.3.2 Barcode Technology Replaced by RFID

Before the RFID was invented, the libraries in worldwide are using barcodes technology. Nowadays, some of the library in US, China and Taiwan are applying RFID technology by replace the barcode system in library management system due to the limitation of barcode technology [10] [11]. The limitation of barcode system is its read range to the barcode reader is about several inches, the read rate only can be read at a time, the barcodes cannot be read if the barcode is dirtied by chemical and the system need to manually that is require a human to operate for the management. By using barcode technology, the labour cost will be increased and the time is wasted to wait the book one by one to scan by the barcode reader.

2.3.3 RFID Technology

In the year of 1800, the combination between radio broadcast and radar is called as RFID [11]. RFID's energy is come from electromagnets. Michael Faraday was proposed that light and radio waves are playing the one of the role in electromagnetic energy in the year of 1846. The signal of radio waves can be transmitted and received in the year of 1887 through the Hertz's effort [11]. It was the first used that acts as espionage tool to spy the others secret information by Soviet's in the year of 1945. The vast potential of RFID Technology was explored by Harry Stockman in a 1948 paper [10]. RFID is widely to use and it becomes some a part of life in every day since 1990.

RFID is a wireless technology that can read or write data into tag and data can be read by RFID reader. Tag reader as transceiver, RFID tag as transponder and antenna are the main components in RFID system [12]. RFID tag as function to carry data on the object which is identified while the RFID reader is able to read and write the tag data. RFID has bigger capacity in memory, wider in reading ranges from the reader to tag and faster speed for data processing than the barcode system. Table 2.1 shows the comparison between the characteristic of barcode system and RFID system.

Table 2.1: Characteristic of Barcode System and RFID System

Characteristics	Barcode	RFID
Read Range	Several inches to feet from tag which is read by reader.	From 30 feet up to 100 feet depend on the type of tag.
Read/ Write	It can only read.	It can read and write.
Updating	Cannot be updated.	It can be updated from time to time.
Automation	It needs human to operate.	It does not need human labour to operate.
Line of site	It is required.	Does not required.
Information Capacity	Less.	More than barcode system

It can be concluded that the reasons of some libraries are decided that RFID should replace the barcode system for the automatic identification and data capture in the management system.

2.3.3.1 RFID Tag

There are two types of RFID tag, which passive tags and active tags is [9] [13] [14]. The tag can be locate to the things, such as items, high value products and vehicles. The active tags have internal power source while the passive tags without internal power source. Table 2.2 shows the comparison between the characteristic of active tag and passive tag. The selection of the RFID tag will be chose after comparing two types of tag in the term of cost, size and read range.

Table 2.2: Characteristic of Active Tag and Passive Tag

Characteristic	**Active Tag**	**Passive Tag**
Cost	More expensive than passive tag. Price from RM30	Cheaper if compared with active tag. Price from RM0.60
Size of the tag	Bigger than passive tag.	Smaller than active tag.
Maintenance	It needs maintenance.	Does not need any maintenance.
Read range	Range is up to 100m	Range is up to 3m.
Memory storage	It is up to 512K.	It is up to 16K.
Life	Depend on battery life.	Up to 20 years.

From the research, mostly the libraries are using the passive tags instead of active tag for the transceiver. The passive tags are used to attach on the books in library because it is lighter than active tag and it can stay longer life. Although some of the characteristic of the active tag is better than passive tag, lastly the better choice is passive tags more suit to used library system.

The frequency bands for the passive tags will be discussed and the frequency bands which suits the library management system will be selected after the comparison. There are 4 types of frequency bands, LF, HF UHF and microware. LF stands for low frequency, HF is high frequency and UHF is about ultra-high frequency. The frequency bands for the passive tags is important to choose due to it will affect read range, data speed and memory capacity in the specific application. Table 2.3 shows the frequency ranges of RFID passive tag.

Table 2.3: Frequency Ranges of RFID Passive Tag

Frequency Band	**Range**	**Coupling**	**Read Range**	**Data Speed**	**Memory Capacity**
LF	125kHz	Inductive	Less than 5cm	Low	64 bits
HF	13.56 MHz	Inductive	Between 10cm and 1m.	Low to Moderate.	2048 bits
UHF	433.868-928MHz	Backscatter	Between 3m and up to 7m.	Moderate to high.	96 bits
Microwave	2.45&5.8GHz	Backscatter	Between 10m and up to 15m.	High.	32 bits

High frequency of RFID is chose for library system because it has greater flexibility for the placement for reader and tag. It has high processing speed and accuracy. This frequency range have bigger memory capacity which is shown in Table 2.3.

2.4 Automated Return System

An automated system is involving such activities as handling, storing, returning and controlling of materials by automated machinery and equipment is called as automated material handling system [15]. AMHs is able to increase the efficiency and speed of system and reduces the human done the activities manually. Automated return system is the system which is moving materials which is scanned by RFID tags or barcodes and transport it into original location.

2.4.1 Case study 1: Robotic Library systems

Research on Robotic library systems has been conducted by Tomizawa and co-workers, the University of Tsukuba, Japan, based on the project from the Johns Hopkins University [16], Comprehensive Access to Print Material (CAPM), who had built a robot limited to extract books from a bookshelf. The service robot contains of a gripper that can move right and left and it function as to search the book on bookshelves and pick the books up to specific location which is shown in Figure 2.3.

Figure 2.3: Service Robot

This robot is unable to be used for automatic library book returning system because it cannot pick the books up to higher position due to the robot has a limited range which is between 400mm and 1100mm above the floor. This problem can be solved by using the stepper motor which is connected to the thread load.

2.5 Object Detection System

Infrared sensor and ultrasonic sensor are the sensors used to detect the distance for middle range [17]. The applications of sensor are including object detection and distance of measurement. Both of the sensor are selected for object detection due to light weight, inexpensive and faster response time. Table 2.4 shows the comparison for the technical specification between IR sensor (Sharp GP2Y0A2YK0F) and ultrasonic sensor (MAXSONAR LV EZ1).

Table 2.4 Technical Specification of the Sensors

Characteristics	IR Sensor	Ultrasonic Sensor
Range	0.15-6.45m	0.2-1.5m
Resolution	2.54cm	1cm
Weight	4.3g	4.8g

IR sensor is chose although ultrasonic sensor can measure the distance with high precision if compared. The system design is only need detect the presence of the object in conveyor belt so does not need sensor with high precision. Infrared sensor is more suitable because it is high resolution, low price and faster response time. Resolution is the ability to detect the small changes for measured value. The components of IR sensor are including IR LED emitter and photo sensitive transistor.

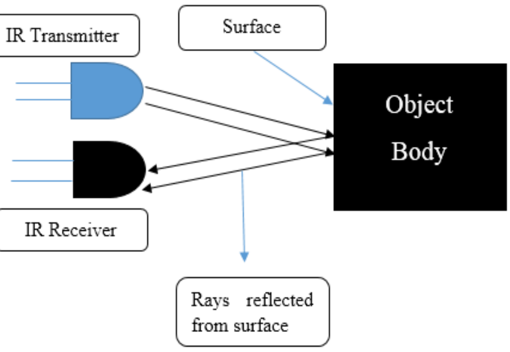


Figure 2.4: Principle Working of IR Sensor

IR transmitter function as emits radiation. When the radiation reaches the object and the radiation will reflect back to the IR receiver.

2.6 Method to Control of a DC Motor

Pulse width modulation is a method to control for DC Motor [18]. It is needed to use to drive a conveyor belt. By changing the time interval during the control signal has the logic value 1 which is t_{ON}, motor rpm variation can be performance. The motor is in maximum rpm at a 100% duty cycle. $T_{on}=T_{off}$ when the motor have half the rated rpm. The motor will stop at a 0% of duty cycle. The duty cycle can be calculated as shown in Eq. 2.1.

$$Duty\ Cycle = \frac{t_{ON}}{t_{ON+}t_{OFF}}\ [\%] \qquad \text{Eq. (2.1)}$$

PWM signals is required to generate by microcontrollers. The block diagram of the DC Motor is controlled by H-bridge is shown in Figure 2.5.

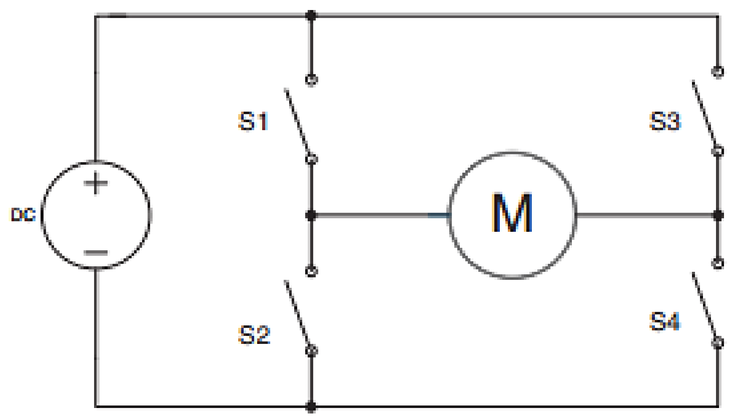


Figure 2.5: Block Diagram of the H-bridge

The operation as followed, a positive voltage is supplied and the motor is rotated in clockwise direction when the circuit breakers S1 and S4 are switching ON and the circuit breakers S2 and S3 in off state. The voltage polarity is reversed and the motor is rotated in counter-clockwise direction when the circuit breakers S2 and S3 are switching ON and the circuit breakers S1 and S4 in off state.

The block diagram of a PWM power controller is shown in Figure 2.6. Control signal can be analog or digital signal to the PWM controller. Information on the how much the power is applied to the load is contained in control signal. PWM controller functioned as accepts the control signal and adjust the duty cycle for PWM signal. Therefore, PWM method for DC motor is going to study through experiment setup.

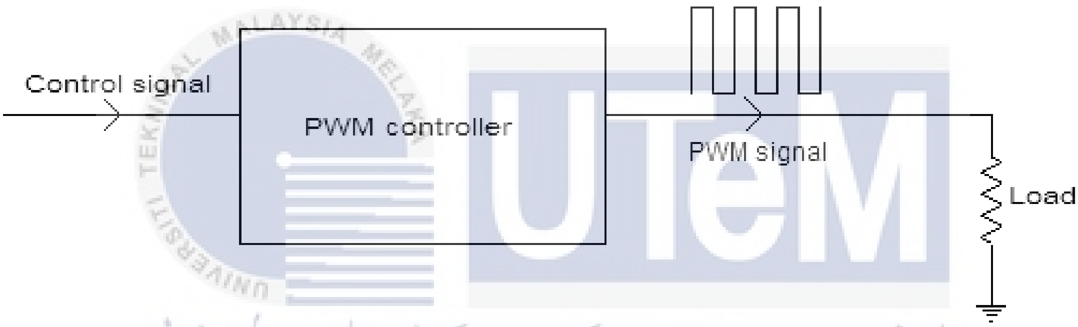


Figure 2.6: Block Diagram of a PWM Controller

2.7 PID Controller for DC Servo Motor

A servo motor is a rotary actuator that are used in industrial purposes. It is also including precision positioning as well as speed control [19]. A feedback controller has the ability to control the speed and positon of servomotor. PID controller is the popular to use for the real-world servo system [20]. The proportion gain K_p, the integral gain K_I and the derivative gain K_D need to be carefully to determine.

A DC servo motor is shown in Figure 2.7. Relationship between the shaft angular position and voltage input to the DC motor can be derived from physical laws. DC servo motor as SISO plant in the control system [18]. The field coil is parallel with the armature. So, the current in the field coil is not dependent on the current on armature. It can mean that DC servo motor have excellent speed and position control.

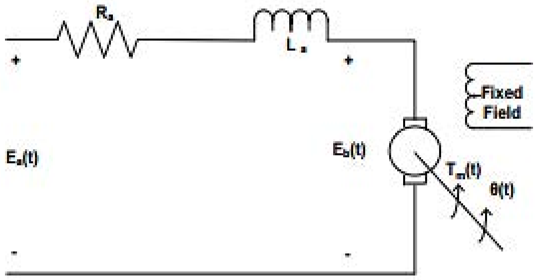


Figure 2.7: Schematic Diagram of DC Servo Motor

The following equation in block diagram as shown in Figure 2.8 which is related to dynamic behaviour of the DC motor as shown in Eq. 2.2 to Eq. 2.5.

$$E_a(s) = R_a I_a(s) + L_a\, S I_a + E_b(s) \qquad \text{Eq. (2.2)}$$

$$T_m = K_t I_a(s) \qquad \text{Eq. (2.3)}$$

$$E_b(s) = k_b\, S\Theta\,(s) \qquad \text{Eq. (2.4)}$$

$$T_m(s) = (J_m S^2 + D_m s)\theta(s) \qquad \text{Eq. (2.5)}$$

The R_a is armature resistance in ohm, L_a is the armature inductance in ohm, I_a is the armature current in ampere, e_a is the armature voltage, e_b is the back EMF, Kb is the back EMF constant, K_t is Torque constant, T_m is the torque which is developed by the motor, θ (t) is the angular displacement of shaft in radians, J is the moment of inertia of the motor and load and where D_m is the frictional constant of motor and load.

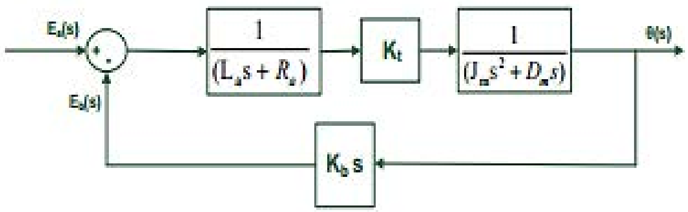


Figure 2.8: Block Diagram of DC Servo Motor

The transfer function for θ(s)/ E_b(s) as followed, which is shown in Eq.2.6 to Eq. 2.7.

$$G(s) = \frac{K_t}{(L_a s+R_a)(J_m s^2+D_m s)} \quad \text{Eq. (2.6)}$$

$$G(s) = \frac{K_t}{L_a J_m s^3+(R_a J_m+L_a D_m)s^2+(k_b k_t+R_a D_m)s} \quad \text{Eq. (2.7)}$$

Simply the G(s) with a_1, a_2 and a_3 shown in Eq.2.8.

$$G(s) = \frac{K_t}{(a_3)S^3+(a_2)S^2+(a_1)S} \quad \text{Eq. (2.8)}$$

Where $a_3= L_aJ_m$, $a_2= R_aJ_m+L_aD_m$ and $a_3= K_bK_t+R_aD_m$

The transfer function for PID controller is shown in Eq.2.9.

$$c(s) = K_p + \frac{K_I}{S} + K_D S \quad \text{Eq. (2.9)}$$

Figure 2.9 shows the block diagram for the DC servo motor with PID controller.

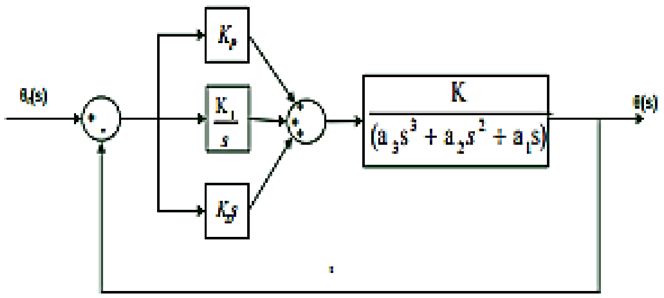


Figure 2.9: Block Diagram of DC Servo motor with PID Controller

The overall of transfer function for Figure 2.9 can be written as Eq.2.10.

$$T(s) = \frac{G(S)C(S)}{1+G(S)C(S)} \qquad \text{Eq. (2.10)}$$

The different values of proportion gain K_p, the integral gain K_I and the derivative gain K_D will be analysed through the experiment setup for control the servo motor to achieve accurate and precise position.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Project Overview

The Gantt chart for Final Year Project 1 for week 1 until week 16 is shown in Table 3.1. The activities are listed out in the Table 3.1 while Table 3.2 shows the Gantt chart for the Final Year Project 2. The list of experiment is shown in Table 3.3 while Table 3.4 shows the list of design for prototype.

Table 3.1: Gantt chart for Final Year Project 1

Activities	**Week**															
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Attend Briefing by J/K FYP	■															
Attend Briefing at Motion Control Lab	■															
Decide Topic for FYP	■	■														
Progress Meeting		■			■				■			■				
Literature Review		■	■	■	■	■	■	■	■	■	■	■	■			
Drawing Design A										■	■	■	■			
Experiment Setup 1										■	■	■	■			
Experiment Setup 2										■	■	■				

Table 3.2: Gantt chart for Final Year Project 2

Activities	**Week**															
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Drawing Design B																
Experiment Setup 3																
Experiment Setup 4																
Design Coding																
Design Hardware																
Progress Meeting																

Table 3.3: List of Experiment Setup

No	**Experiment Setup**
1	Reflection Object versus Colour
2	Effect of PWM to Motor Speed
3	Performance of RFID Reader
4	Positioning of Servo Motor

Table 3.4: List of Design

No	**Design**
A	Vertical System
B	Rotary System

This paper discussed in detail about the development of software and hardware of the smart library system using RFID technology. It will include the information explanation for flow of methodology that is being used to complete this project. The drawing designs, system design and the test procedure for experiment setup will be listed.

The flow of methodology will divide into several phases, such as planning, designing, purchasing, experimental setup and testing. Researching and studying for the related system on the journal and conference paper was done which is shown in literature review. The designing phases are included the drawing designs and the flowchart of the system design. There will have 4 experiment setup will be set and tested. The data get from the experiment setup will be discussed in the result part. Figure 3.1 shows the flowchart of methodology for the research. The experiment setup 1 and 2 are related to the components of IR line tracking sensor and DC motor. The experiment 3 and 4 will focus on RFID reader and servo motor. The software (coding design) and hardware design will implement through the research. The testing on the hardware design with the coding will be done. The overall design will be analysed at the end of research.

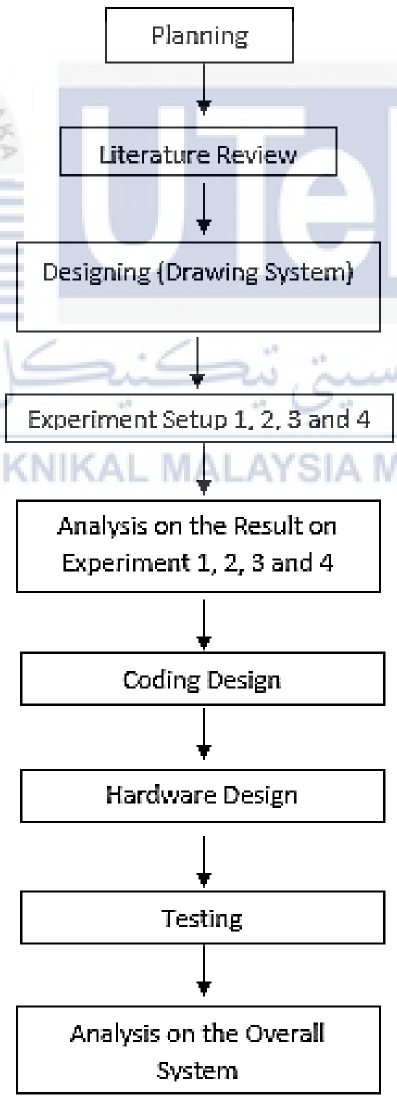


Figure 3.1: Flowchart of Methodology

3.2 Design A: Vertical System

There are two drawing designs (Design A and Design B) for the system is done by AutoCAD software. Based on this two designs, one of the designs will be chosen for the system based on number of process flow, budget and conveniently. Figure 3.2 shows the Drawing Design A for the smart library system.

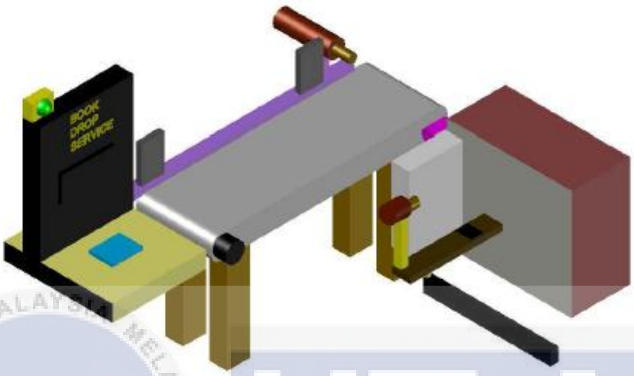


Figure 3.2: Design A

Figure 3.3 shows the overall drawing Design A for the smart library system using RFID. The Figure 3.3 is divided into 2 portion and will be discussed below. The drawing design is designed through AutoCAD Software.

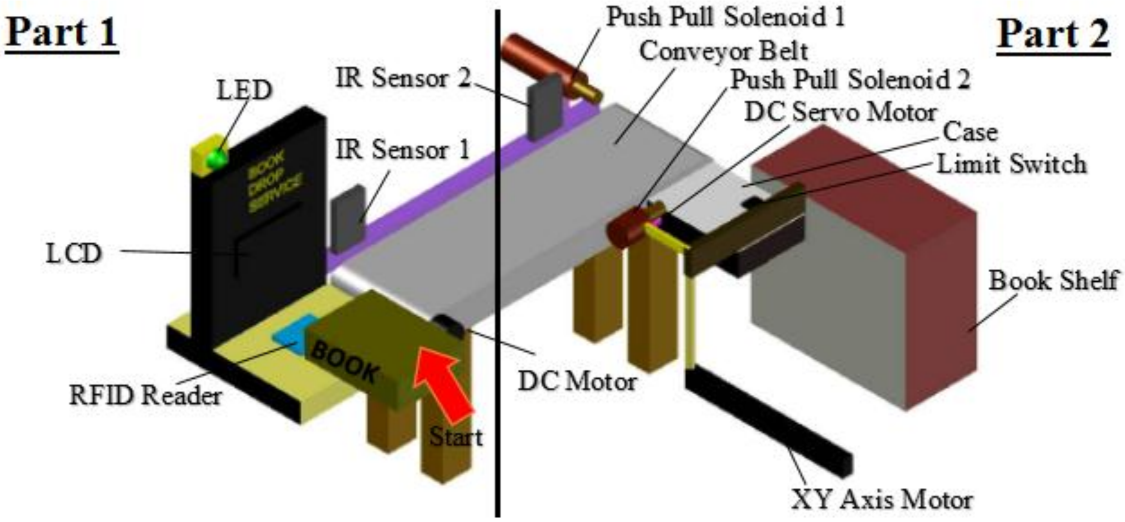


Figure 3.3: Overall Drawing Design A

For the part 1, the system is starting from platform book drop service. When the user need to return the book, the book is needed to scan by RFID reader. After the LCD is displaying "Returned" and LED is becoming green, the user put the book on the conveyor belt. When the IR sensor 1is sensing the book, the DC motor will start run and conveyor belt will start to move.

For the part 2, the push pull solenoid is on when the IR sensor 2 is detecting the book on the conveyor belt. The limit switch which is located inside the rectangular case is triggered when the book is reaching at the rectangular case. The servo motor is starting to move the case from the horizontal into vertical motion when the limit switch is triggered. Then, the hard case will move through the XY axis motor to reach the location of book in the bookshelf. The push pull solenoid 2 will start to push the book into the bookshelf when the case is reaching the location of the books on the bookshelf. The solenoid will be pull back when the limit switch is not trigged.

Figure 3.4 shows the overall dimension for the top view of drawing design A. All of the unit for drawing design A is in millimetre.

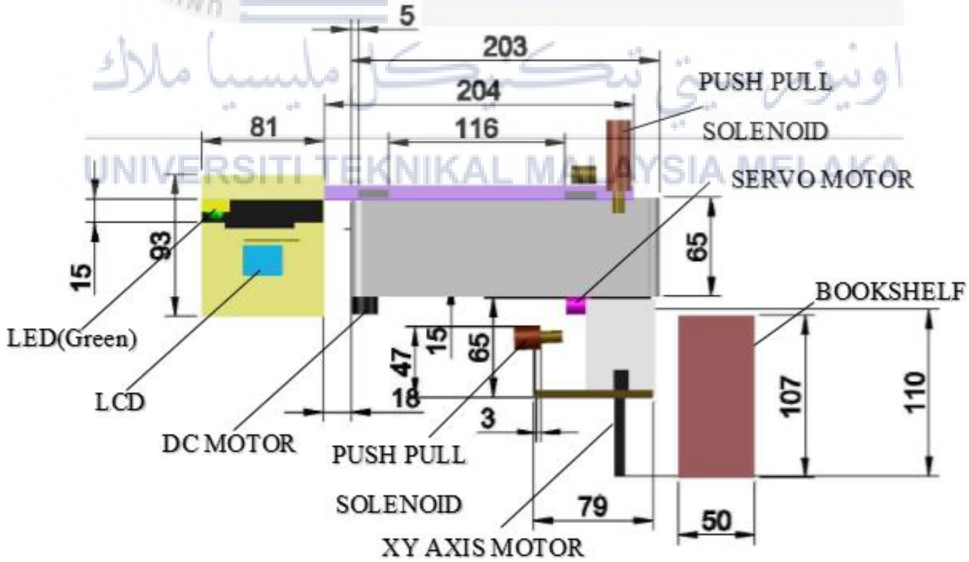


Figure 3.4: Overall Dimension for Drawing Design A

3.3 Design B: Rotary System

Figure 3.5 shows the Drawing Design B for the smart library system. While Figure 3.6 shows the overall drawing Design B for the smart library system using RFID. The drawing design is designed through AutoCAD Software.

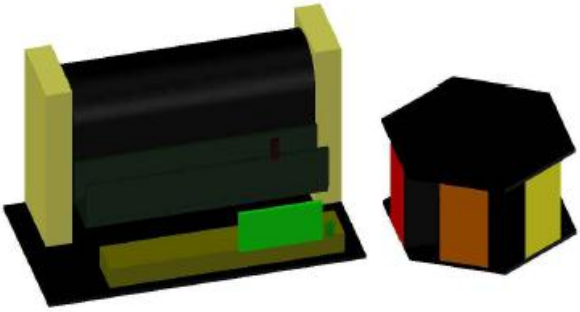


Figure 3.5: Design B

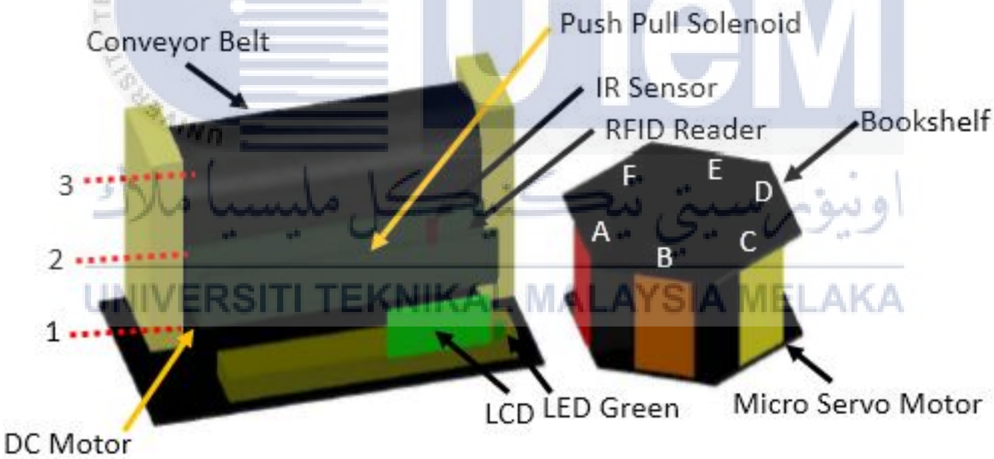


Figure 3.6: Overall Drawing Design B

When the user need to return the book, the user need to put book into the holder. The book is detect by the IR sensor and scan by RFID reader. After the LCD is displaying “Returned” and LED is becoming green, the DC motor will start run and conveyor belt will start to move. When the DC motor reach the specific location 2or 3, the DC motor will stop. The servo motor will rotate the bookshelf based on the book data in RFID tag. The push pull solenoid will push the books into the hole of bookshelf when it is in the right position. After that, the solenoid will pull back into original direction and the location of bookshelf and conveyor belt also will back in initial position 1.

Figure 3.7 shows the overall dimension for the top view of drawing design B while Figure 3.8 shows the overall dimension for the left view of Drawing Design B. All of the unit for drawing design is in centimetre.

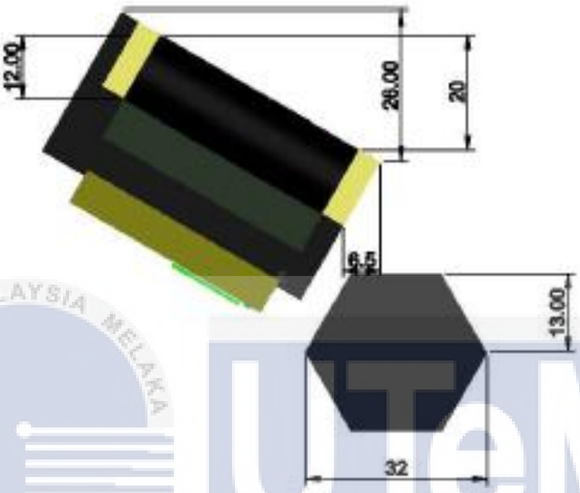


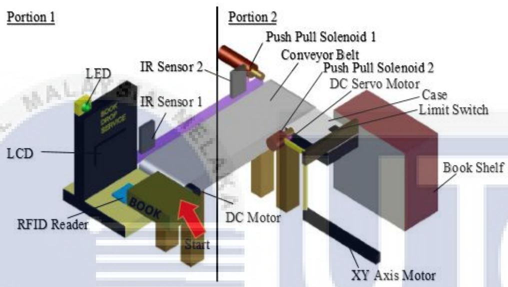
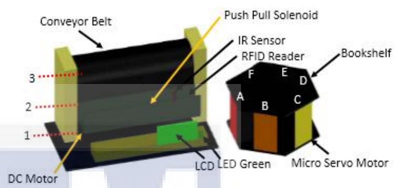
Figure 3.7: Overall Dimension for Drawing Design B (Top View)

Figure 3.8: Overall Dimension for Drawing Design B (Left View)

3.4 Comparison between Design A and Design B

One of the designs will be chosen after the comparison is made between the two designs. Table 3.5 shows the comparison between Design A and Design B. The system for Design A is returning the book in vertical system while Design B is a returning the book in rotary system.

Table 3.5: Comparison between Design A and Design B.

Design	**A**	**B**
System	Vertical	Rotary
Drawing		
Cost	Expensive	Cheap
Space Saving	No	Yes
Process Flow	Difficult	Easy

From Design A, it can be seen that there are more components need to build so it costed more expensive than Design B. In term of space spacing, Design B can save more space than Design A because the bookshelf in Design B is rotatable while Design A is in fixed. Table 3.6 shows the detail for the shape design for the bookshelf. From Design A, the system is difficult because it has more process flow than Design B. With using rotary motion, the process flow can be reduced. Therefore, Design B which is in rotary system will be chose for the smart library system.

Due to the Design B is chose, the bookshelf is designed specially. When the bookshelf is rotating, the space to rotate also need consider carefully. Table 3.6 shows the shape design for the bookshelf in square and hexagon.

Table 3.6: Shape Design for the Bookshelf

Shape	**Square**	**Hexagon**
Extra space		
Explanation	It is clear to show that square shape will waste more space if rotating.	Hexagon will save the space.

3.5 Reflection Object versus Colour

The main objective is to determine the distance of reflective object in different of colour. With different type of colours, the range for the distance IR sensor to reflective object can be more accurate. 5 colours is tested because it is main colour and it has own wavelength. The equipment used in the experiment are including IR Line Tracking Sensor, Arduino Mega, testing board, Arduino USB, Analog Multimeter, 10KΩ potentiometer, testing board and jumpers. Figure 3.9 shows the IR Line Tracking Sensor.

Figure: 3.9 IR Line Tracking Sensor

The schematic diagram 1 which is shown in Figure 3.10 is connected in the testing board. Arduino microcontroller is connected to the computer with Arduino USB. The program code is loaded to Arduino Integrated Development Environment (IDE). The input voltage for the sensor is adjusted by potentiometer and it is measured by Analog Multimeter which is shown in Figure 3.11. 5 different colours of objects which is shown in the Figure 3.12 is tested in the experiment with the adjusting the input voltage of sensor in the range of 0V-5V. The distance to reflective object for the 5 types of colour is measured by using ruler in cm with the adjusting the voltage in the range of 0V-5V with repeatability in 3 times which is shown in Figure 3.13. The experiment results will be discussed in result part.

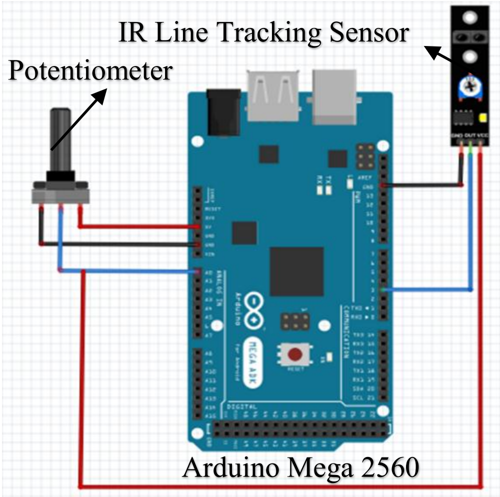


Figure 3.10: Schematic Diagram 1

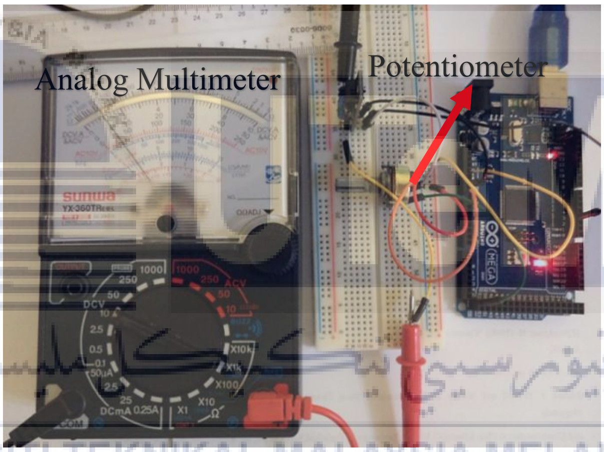


Figure 3.11: Measuring the Input Voltage by Analog Multimeter

Figure 3.12: Different of Colours

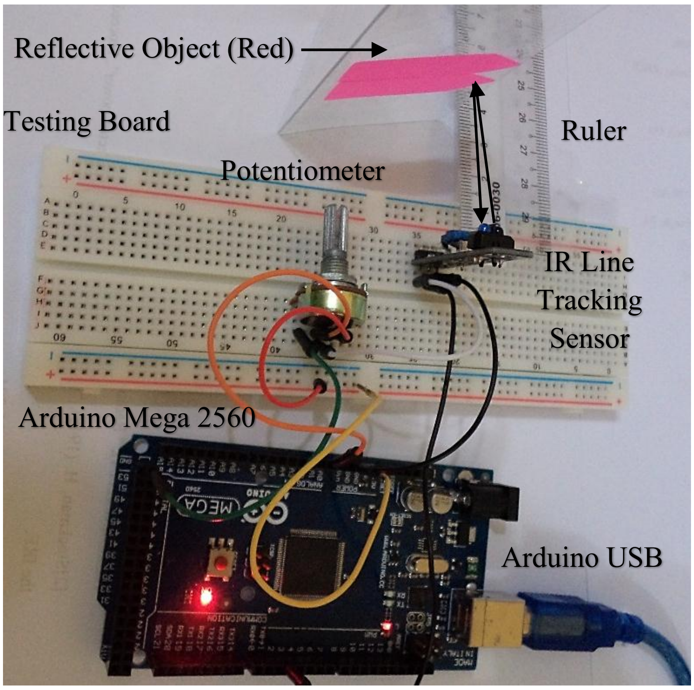


Figure 3.13: Measuring Distance to Reflective Object

3.6 Effect of PWM to Motor Speed

The main objective is to determine the characteristic of PWM for controlling the DC motor. The equipment used in the experiment are Arduino Mega, testing board, potentiometer, Arduino USB, Digital Multimeter, DC Geared Motor SPG 50-60K, testing board and jumpers.

The schematic diagram 2 which is shown in figure 3.14 is connected in the testing board. Arduino microcontroller is connected to the computer with Arduino USB. The program code is loaded to Arduino Integrated Development Environment (IDE). The duty cycle for 0%, 25%, 50%, 75% and 100% for the motor is adjusted by potentiometer. The output voltage of DC motor is measured with the Digital Multimeter with the duty cycle for 0%, 25%, 50%, 75% and 100%. The experiment results will be put and discussed in result part.

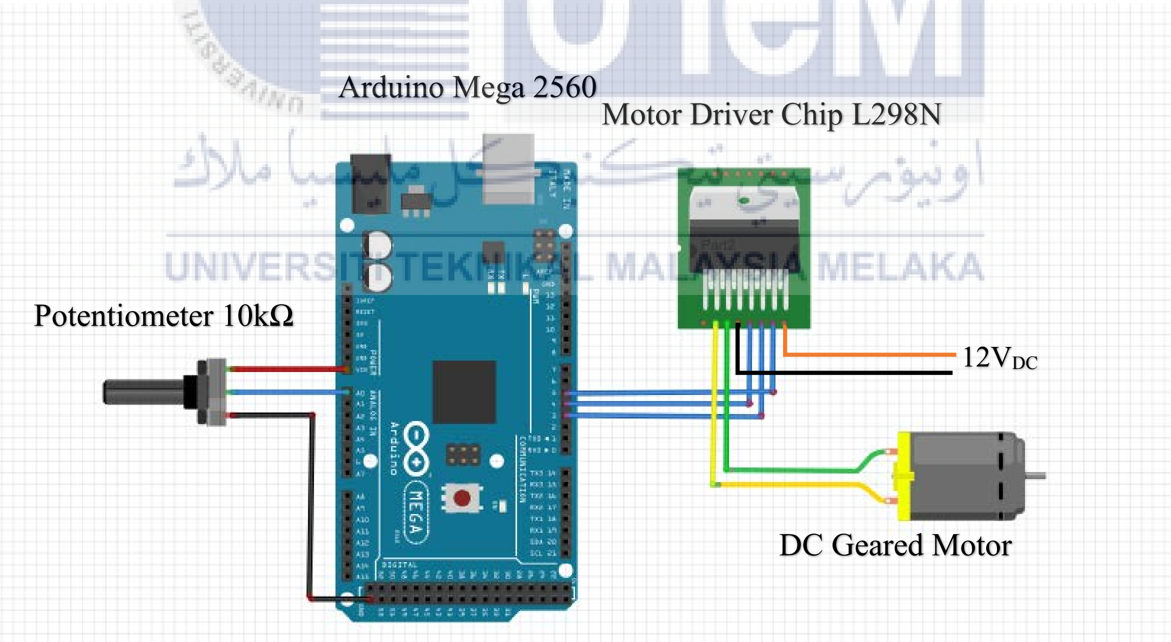


Figure 3.14: Schematic Diagram 2

3.7 Performance of RFID Reader

The main objective is to determine the performance of RFID reader (13.56MHz). The equipment used in the experiment are Arduino Mega, testing board, potentiometer, Arduino USB, Digital Multimeter and RFID reader (13.56MHz).

The schematic diagram 3 which is shown in Figure 3.15 is connected in the testing board. Arduino microcontroller is connected to the computer with Arduino USB. The program code is loaded to Arduino Integrated Development Environment (IDE). Ranges of input voltage: 0V-5V is measured by Analog Multimeter which is shown in Figure 3.16. The tag placement is put into vertical or horizontal side shown in Figure 3.17. The maximum distance between RFID tags which is scanned by reader is determined by ruler which is shown in Figure 3.18. (Repeatability: 3 Times)

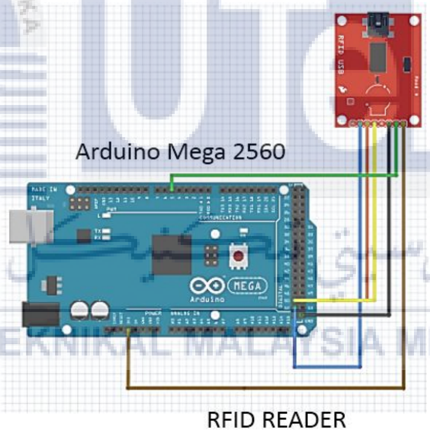


Figure 3.15: Schematic Diagram 3

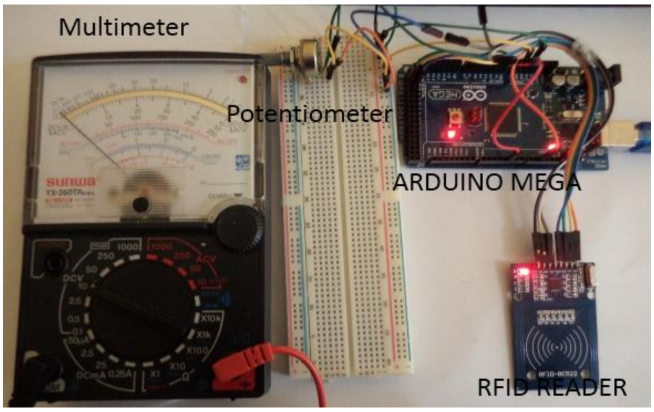


Figure 3.16: Measuring the Input Voltage by Analog Multimeter (A)

Figure 3.17: Placement for RFID Tag

Figure 3.18: Measuring Distance between RFID Reader and RFID Tag

3.8 Positioning of Servo Motor

The main objective is to perform the system (servo motor signal) based on the positions (A, B, C, D, E and F) of MG995 TowerPro servo motor by using PID with Ziegler-Nichols method and auto-tuning. The equipment used in the experiment are Arduino Mega, testing board, potentiometer, Arduino USB, MG995 TowerPro Servo Motor.

The schematic diagram 4 which is shown in Figure 3.19 is connected in the testing board. Arduino microcontroller is connected to the computer with Arduino USB. The program code is loaded to Arduino Integrated Development Environment (IDE). Ranges of input voltage: 4.7V is measured by Analog Multimeter. The length of the pulse for full cycle in bookshelf is get from experiment. Length of the pulse for 6 positions when reaching the point for 2 cycles (A-C-E-F-B-D) in clockwise direction of servomotor in bookshelf are collected which is shown in Figure 3.20. The experimental data and actual data is copied into Microsoft excel. The excel file is imported into MATLAB in order to get transfer function of the system. A PID controller is designed for servo motor to get more accurate positions in condition of load with the weight of 2g and no load. Figure 3.21 shows the condition without load while Figure 3.22 shows the condition with load.

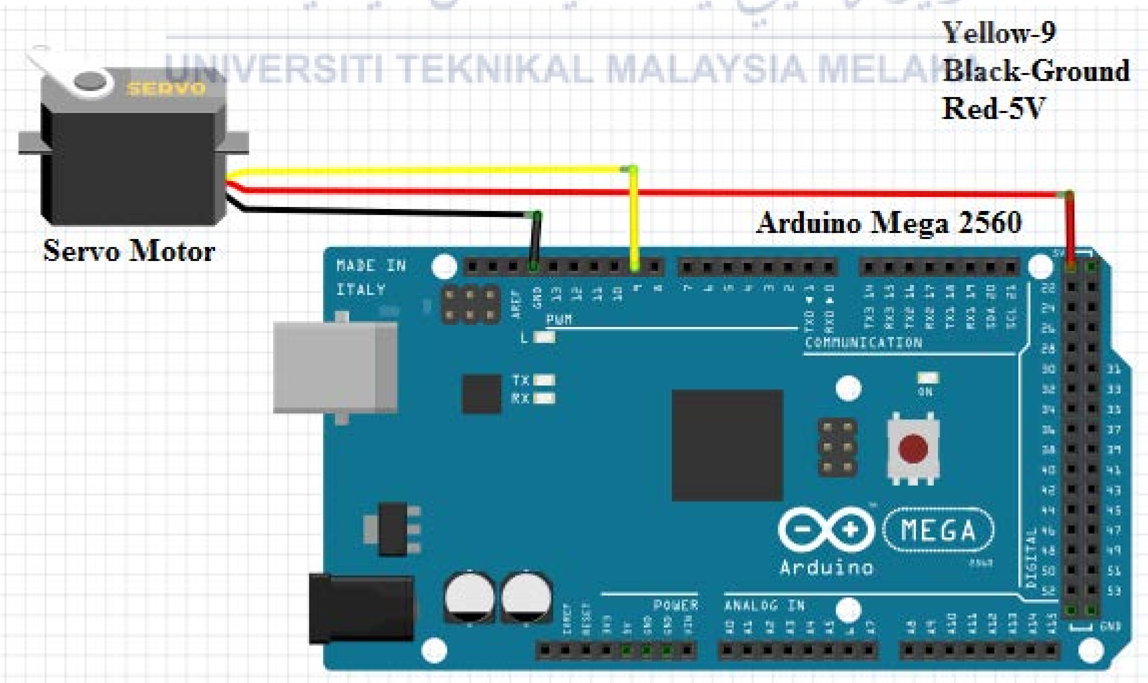


Figure 3.19: Schematic Diagram 4

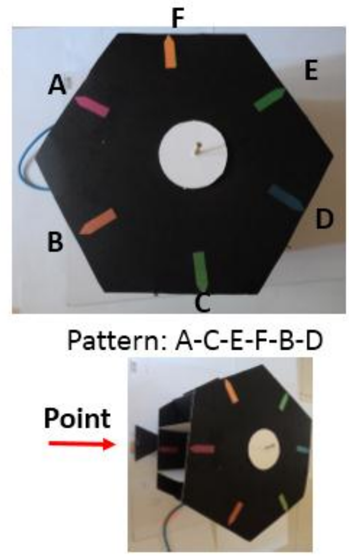


Figure 3.20: Signal of Servo Motor in 6 Positions

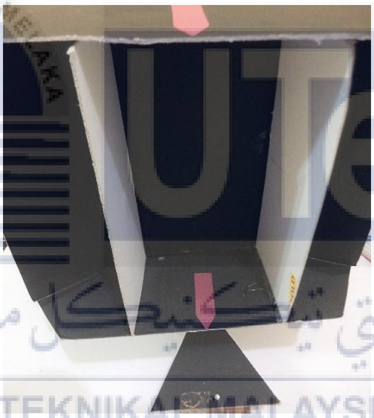


Figure 3.21: Condition without Load

Figure 3.22: Condition with Load

3.9 Coding Design and Hardware Design

When the design drawing is chose, coding is designed for the smart library system based on the design. The coding design is using Arduino Software. The hardware will be done based on the Design B and operated with the coding design by using Arduino. Table 3.7 shows the components list for hardware design.

Table 3.7: Components List for Hardware Design.

No	Components	Unit
1	Arduino Mega 2560	1
2	LCD 2x16	1
3	LED Green	1
4	RFID Reader (13.56Mhz)	1
5	RFID tag	6
6	MG 995 Tower Pro Servo Motor	1
7	DC Geared Motor SPG 50-60K	1
8	IR Sensor (single bit)	1
9	DC Motor Driver (L298N)	1
10	Potentiometer	3
11	Push Pull Solenoid	1

Figure 3.23 shows the flowchart for coding design for the Design B while Figure 3.24 Figure 3.24 shows the prototype of smart library system. All components are labelled in the Figure 3.24.

There have 12 process flow for the rotary system which is shown in Figure 3.23.

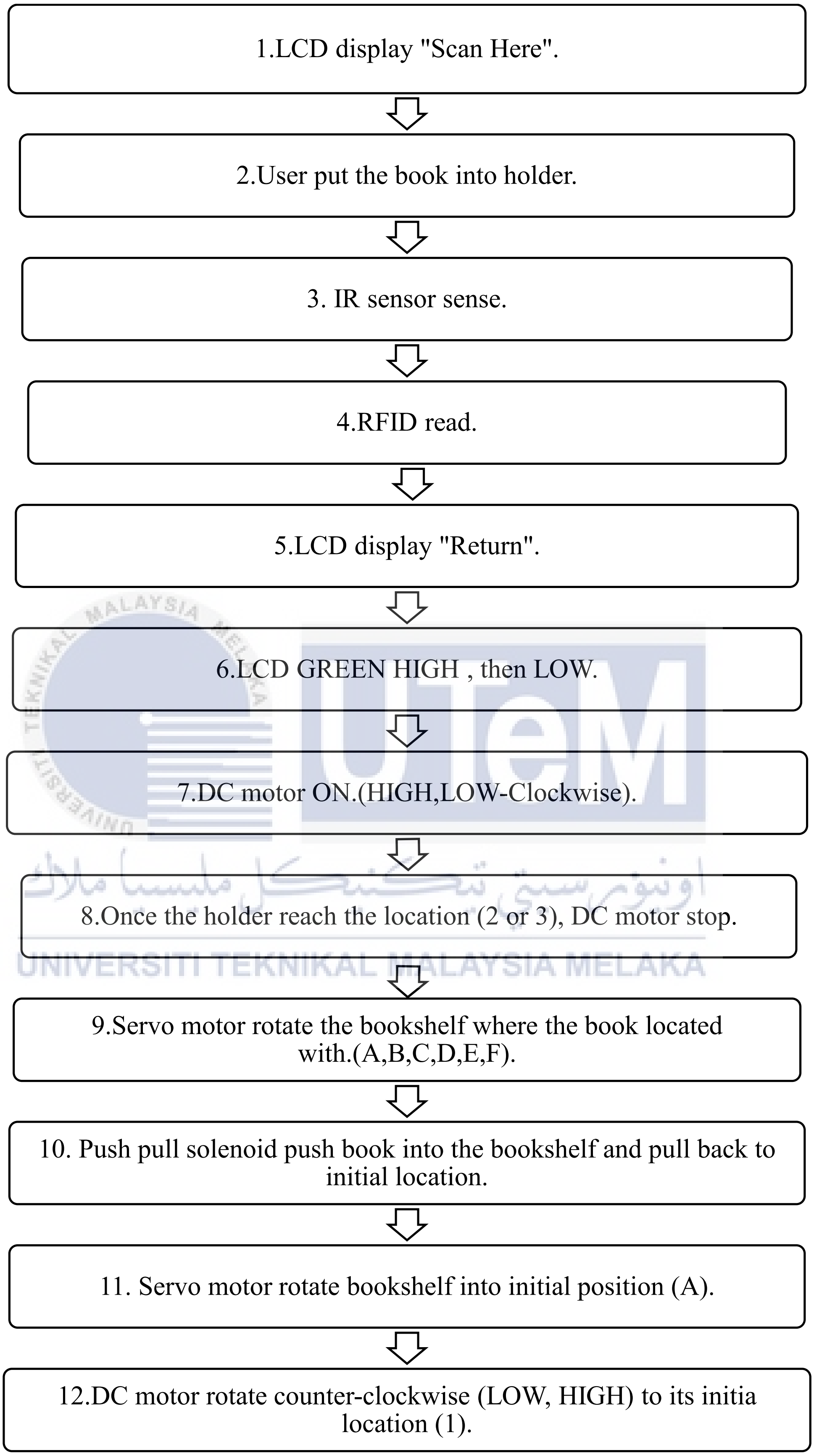


Figure 3.23: Flowchart of Coding Design Smart Library System

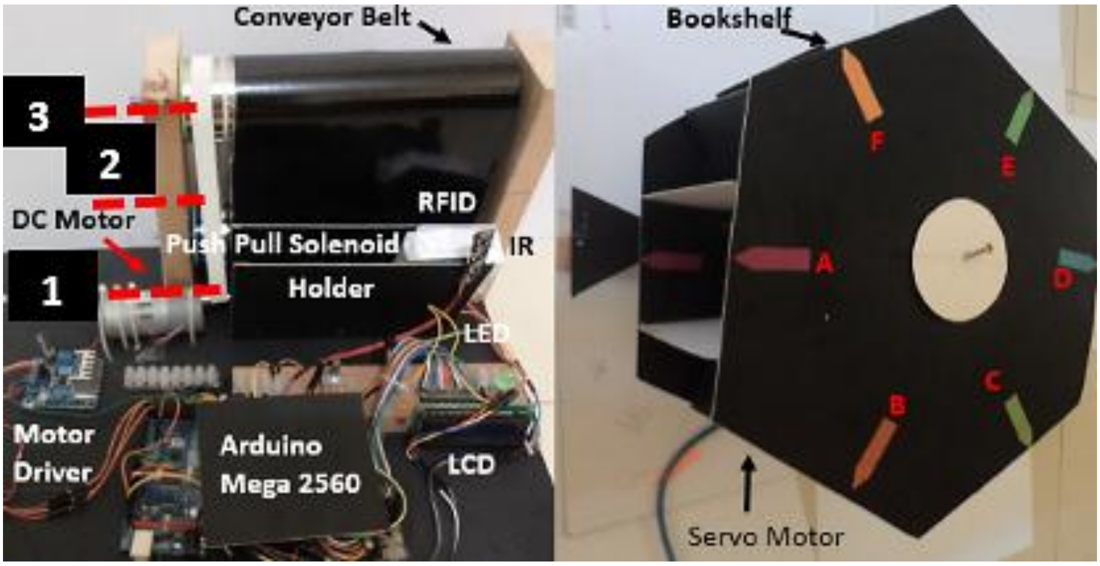


Figure 3.24: Prototype of Smart Library System

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Overview

The results for the experiment setup shown in Chapter 3 will be discussed in this chapter. The data which is obtained from the experiment will be compile in table and graph form. An analysis will be done through the results of experiment and overall design for software and hardware parts.

4.2 Results for Reflection Object versus Colour

The result is about the distance of IR line tracking sensor to reflective object in 5 colours- red, orange, yellow, green and blue with the range of input voltage from 0V-5V. The measured data will be collect repeatability in experiment to get an accuracy result. Table 4.1 shows the data which is being measured in experiment. The measured data is keyed in Microsoft Excel in order to make the data with more detail. The calculation for mean and standard deviation are calculated through the calculator in Microsoft Excel. The reading for the input voltage can't reach 5V from power supply Arduino USB due to the Arduino Mega board is not stable. No results for the input voltage for 1V and 2V for 5 type of colours of reflective object because the IR line tracking sensor is operating from 3V.

Table 4.1: Measured Data for Reflection Object versus Colour

	Distance to Reflective Object (cm)				
Input Voltage(V)	**Red**	**Orange**	**Yellow**	**Green**	**Blue**
1,2	-	-	-	-	-
	-	-	-	-	-
	-	-	-	-	-
Mean	-	-	-	-	-
Standard Deviation	-	-	-	-	-
3	0.6	0.3	0.3	0.1	0.2
	0.5	0.2	0.2	0.2	0.1
	0.6	0.3	0.3	0.1	0.1
Mean	0.57	0.27	0.27	0.13	0.13
Standard Deviation	0.06	0.06	0.06	0.06	0.06
4	0.6	0.4	0.4	0.3	0.2
	0.5	0.3	0.3	0.2	0.1
	0.6	0.4	0.4	0.3	0.1
Mean	0.57	0.37	0.37	0.27	0.13
Standard Deviation	0.06	0.06	0.06	0.06	0.06
4.5	0.7	0.5	0.5	0.5	0.4
	0.8	0.6	0.6	0.4	0.3
	0.7	0.5	0.5	0.4	0.4
Mean	0.73	0.53	0.53	0.43	0.37
Standard Deviation	0.06	0.06	0.06	0.06	0.06

Figure 4.1 shows the relationship between the input voltage and distance to reflective object for red colour. Figure 4.2 shows the relationship between the input voltage and distance to reflective object for orange colour while Figure 4.3 is for yellow colour. Figure 4.4 shows the relationship between the input voltage and distance to reflective object for green colour while Figure 4.5 is for blue colour.

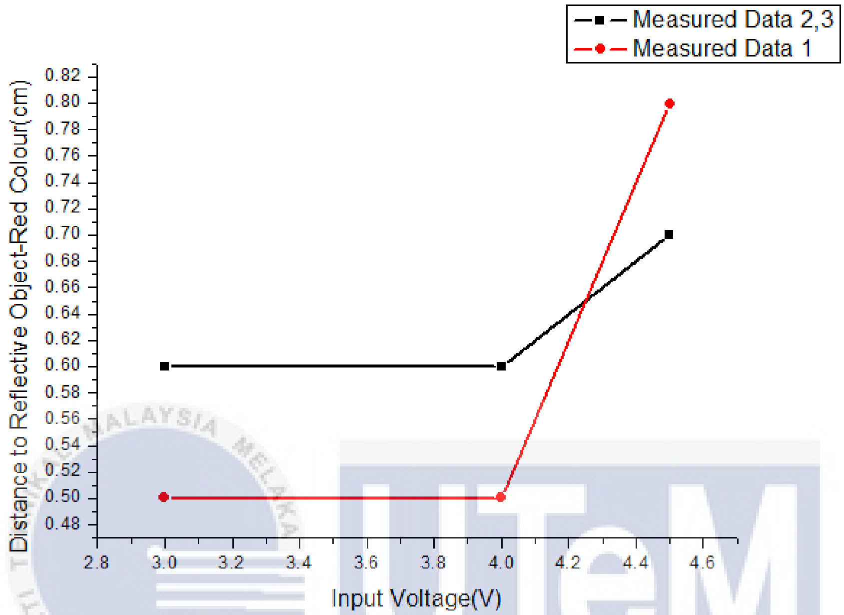


Figure 4.1: Input voltage and Distance to Reflective Object for Red Colour.

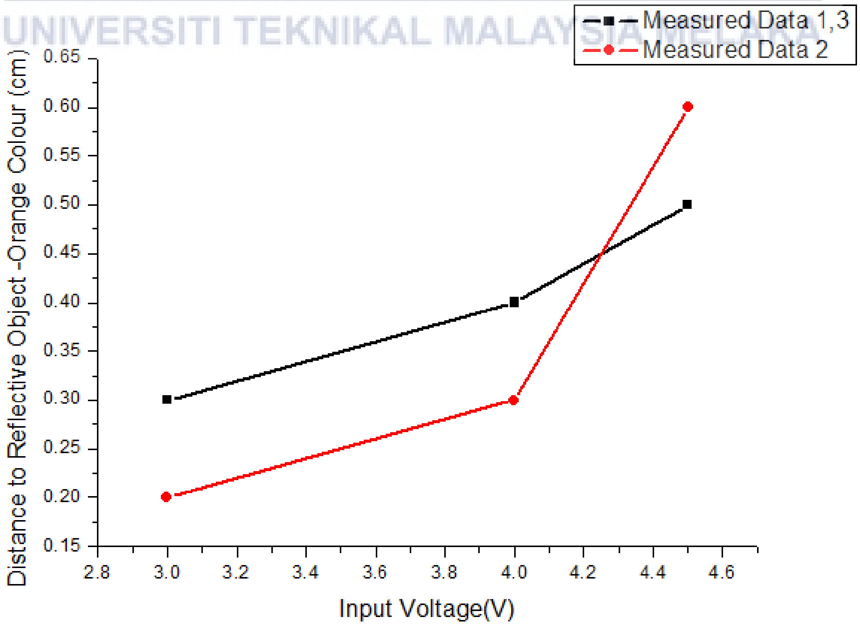


Figure 4.2: Input voltage and Distance to Reflective Object for Orange Colour

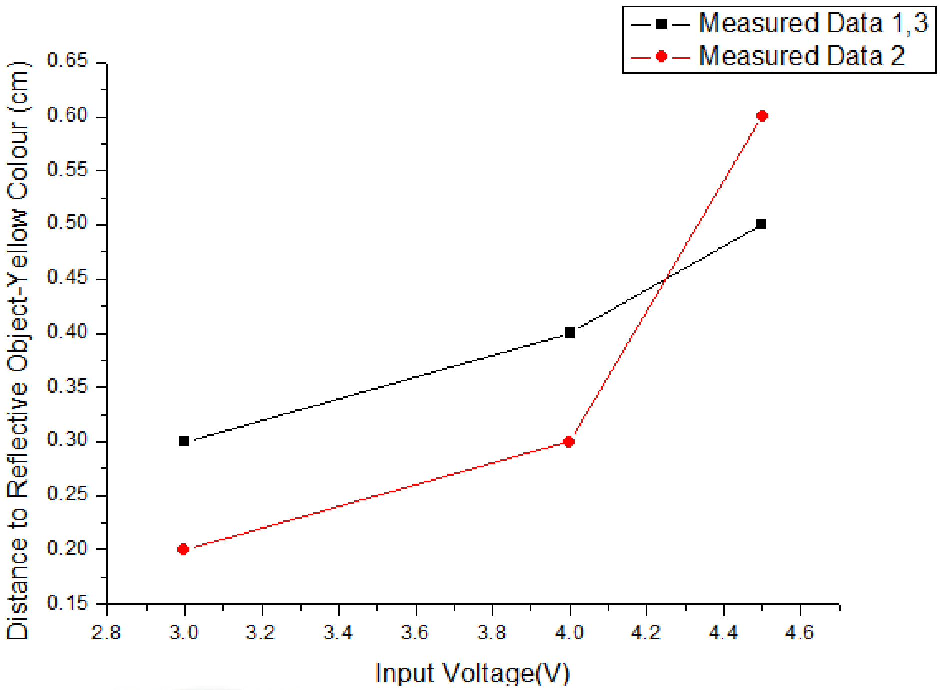


Figure 4.3: Input Voltage and Distance to Reflective Object for Yellow Colour

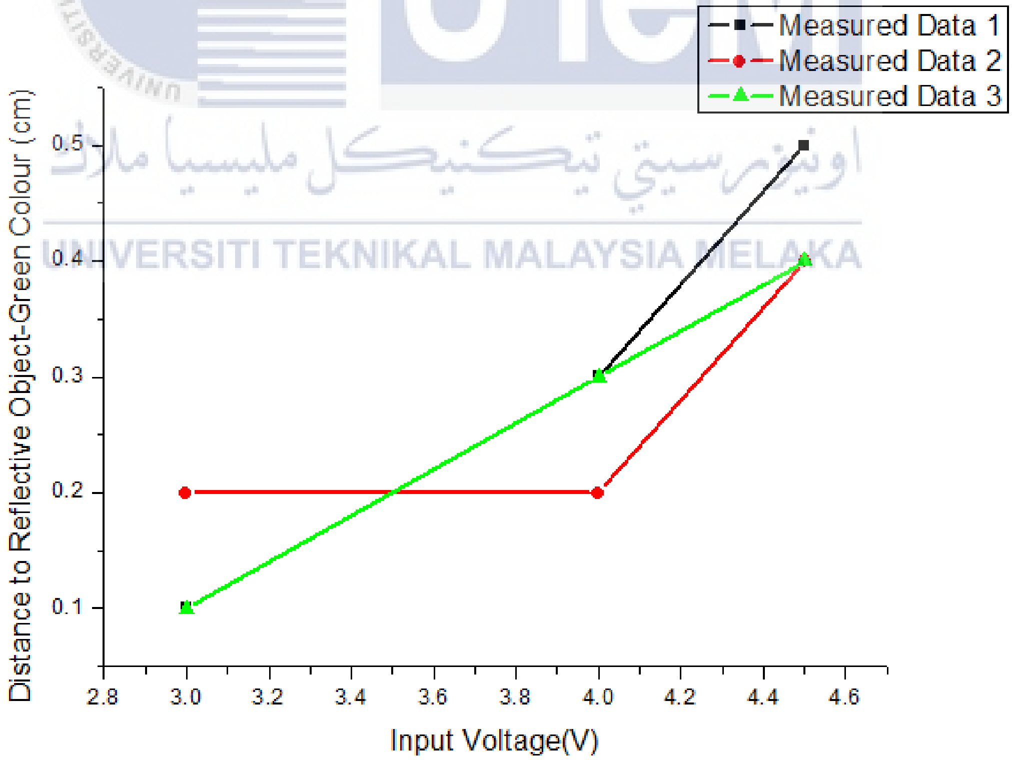


Figure 4.4: Input Voltage and Distance to Reflective Object for Green Colour

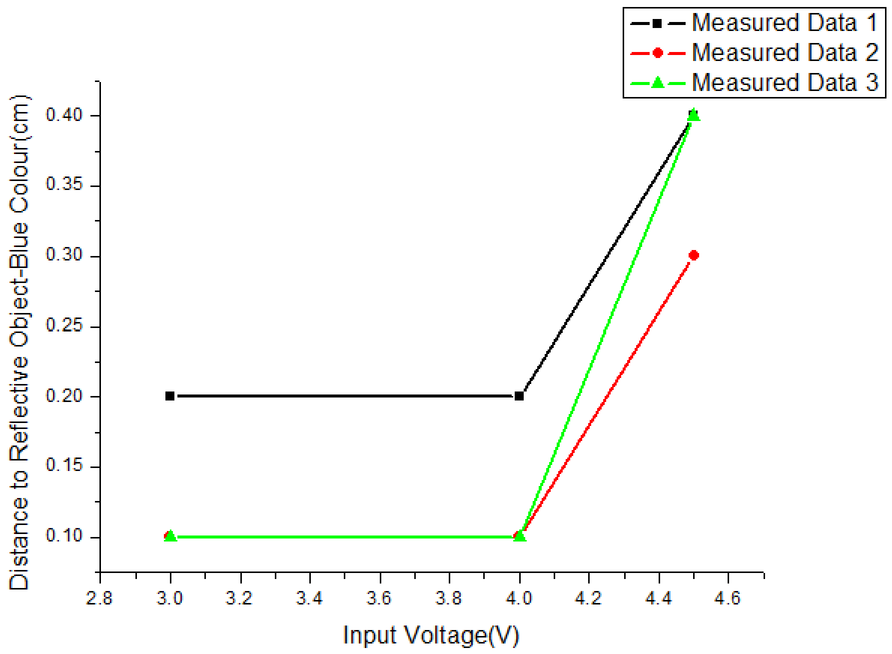


Figure 4.5: Input Voltage and Distance to Reflective Object for Blue Colour

4.2.1 Discussion for Reflection Object versus Colour

All of the data are collected from experiment and it is compiled in Figure 4.6. Figure 4.6 shows the mean distance for the IR line tracking sensor to reflect object for 5 type of colours.

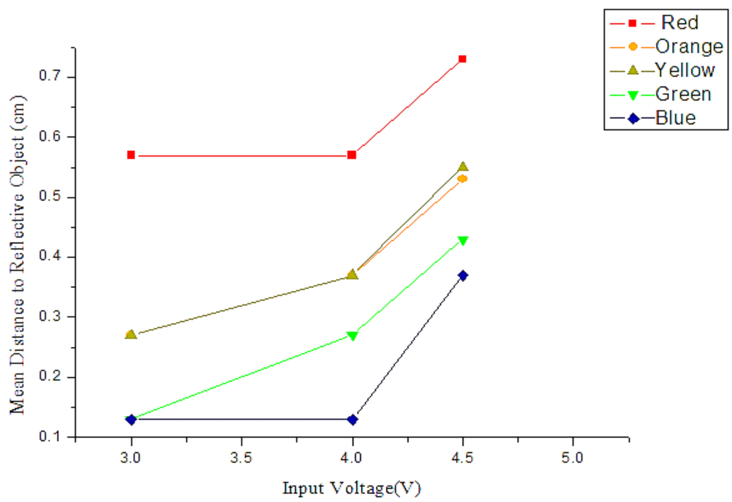


Figure 4.6: The Input Voltage and Mean Distance to Reflective Object.

From the Figure 4.6, it can be seen that the input voltage which is supplied in IR sensor increase, the distance for IR line tracking sensor to reflective object also increased. The distance for sensor to detect the presence of an object can be adjusted through potentiometer. Therefore, user no need to adjust the distance with the potentiometer which is located inside the IR line sensor because the potentiometer will easily get damaged shown in Figure 4.7.

Figure 4.7: The Potentiometer for Distance Control

Based on the Figure 4.6, the distance IR tracking line sensor can detect the object-red colour in far range of distance because the wavelength of red is more near to infrared if compared with other colour. Red colour is more visible to IR line tracking sensor. IR line tracking sensor is reflecting on an object based on the wavelength, temperature, brightness of colour. Repeatability for taking the result with the same instrument is necessary in order to get more accuracy results.

4.3 Results for Effect of PWM to Motor Speed

The result is about the pulse width modulation for DC motor control. Table 4.2 shows the measured voltage of DC motor based on the reading from digital multimeter for duty cycle for 0%, 25%, 50%, 75% and 100% which is adjusted by potentiometer. The measured data will be collect repeatability in experiment to get an accuracy result. The calculation for the voltage through the theoretical knowledge about on PWM will be compared with the measured voltage of DC motor in discussion part. The potentiometer is unable to adjust to 0% of duty cycle due to the position of wiper turns. The solution can be done in future, which is to calibrate the potentiometer to get the more accurate the position of wiper turns.

Table 4.2: Measured Data from Experiment Setup 2

Duty Cycle (%)	**Output Voltage (V)**		
0	-	-	-
0.6	0.23	0.2	0.24
25	2.4	2.64	2.63
50	5.28	5.28	5.25
75	8.16	8.4	8.3
100	11.04	11.16	11.16

Figure 4.8 shows the relationship between the duty cycle and the output voltage which is measured from multimeter.

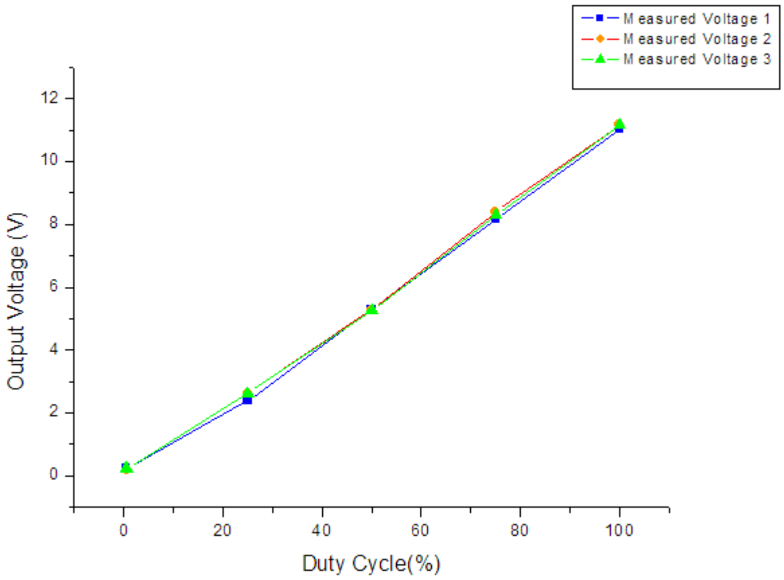


Figure 4.8: The Relationship between Duty Cycle and Output Voltage (1)

4.3.1 Discussion for Effect of PWM to Motor Speed

All of the data is collected from experiment and it is compiled in Table 4.3. Figure 4.9 shows the relationship between duty cycle and output voltage for the actual voltage which is theoretical value and the average measured data for voltage in the experiment setup 2.

Table 4.3: Data Analysis for Experiment Setup 2

Duty Cycle (%)	**Actual voltage (V)**	**Average Measured Voltage(V)**	**Error (%)**
0	0	-	-
0.6	0.36	0.26	27.78%
25	3	2.56	14.68%
50	6	5.27	12.17%
75	9	8.29	7.9%
100	12	11.12	7.3%

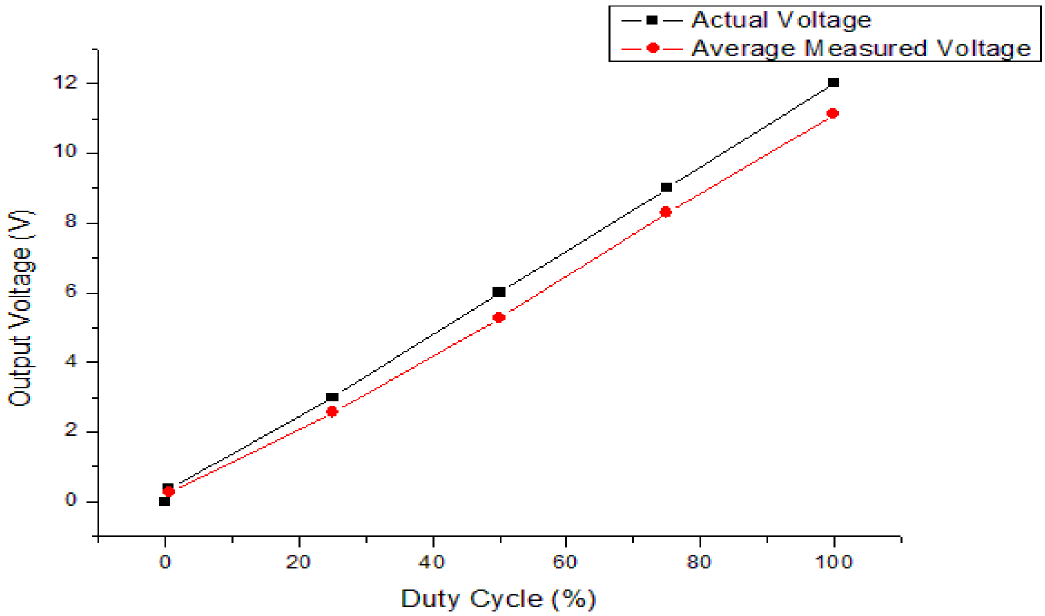


Figure 4.9: The Relationship between Duty Cycle and Output Voltage (2)

Based on the graph Figure 4.9, the percentage of duty cycle increase, the output voltage for the motor increase and speed of motor also be increased. The motor is running full speed when the duty cycle is in 100% while it is coasting in 0% of duty cycle and it is running half speed in 50% duty cycle. The output voltage for DC motor is not accurate as the actual voltage based on theoretical knowledge on PWM method due to the effect of frictional losses in DC geared motor.

4.4 Results for Performance of RFID Reader

The result is about the performance of RFID reader 13.56MHz. The distance of RFID reader to detect RFID tag of books for 2 placements which is in horizontal and vertical is measured through the experiment with the range of input voltage from 0V-5V. The measured data will be collect repeatability for 3 times in experiment to get an accuracy result. Figure 4.10 shows the data which is being measured in experiment for horizontal placement while Figure 4.11 shows the data which is being measured in experiment for vertical placement.

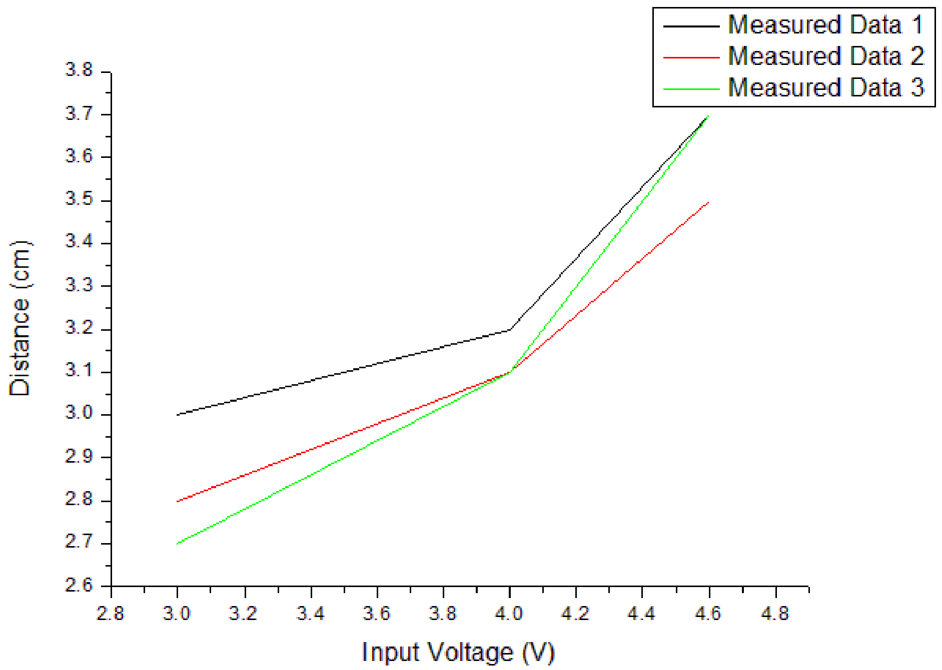


Figure 4.10: The Relationship between Input Voltage and Distance (Horizontal)

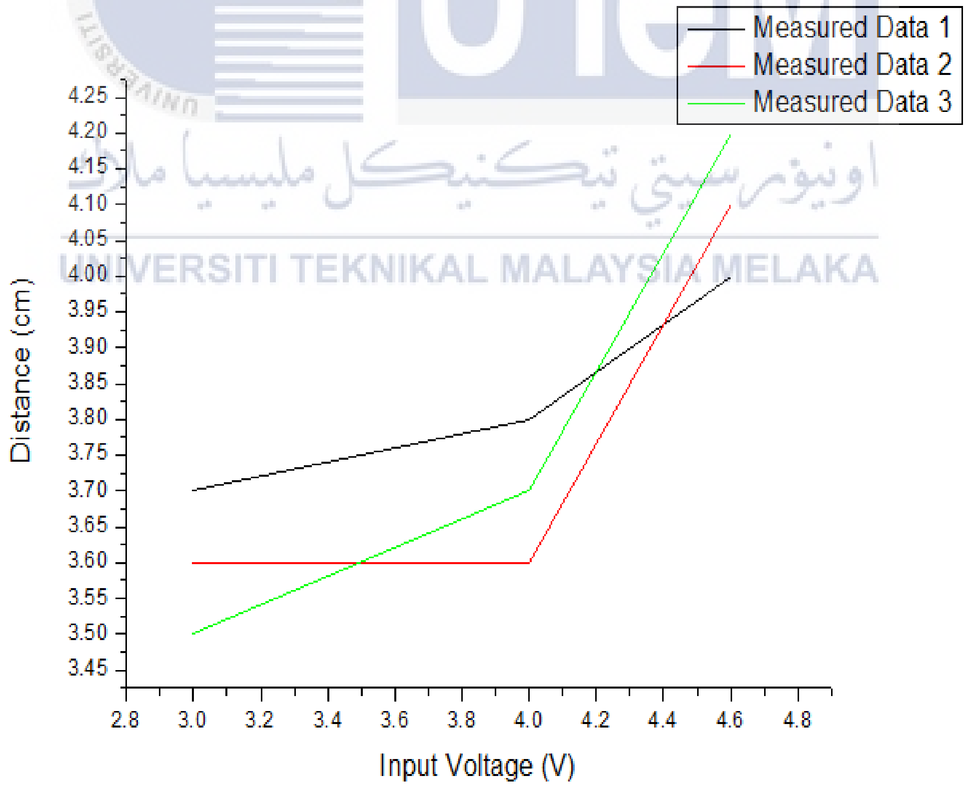


Figure 4.11: The Relationship between Input Voltage and Distance (Vertical)

4.4.1 Discussion for Performance of RFID Reader

The calculation for mean for the data collected for placements vertical and horizontal are calculated through the calculator in Microsoft Excel and plotted in OriginPro 7 software which is shown in Figure 4.12. No results for the input voltage for 1V and 2V for experiment setup 3 because RFID reader 13.56MHz is operating from 3V.

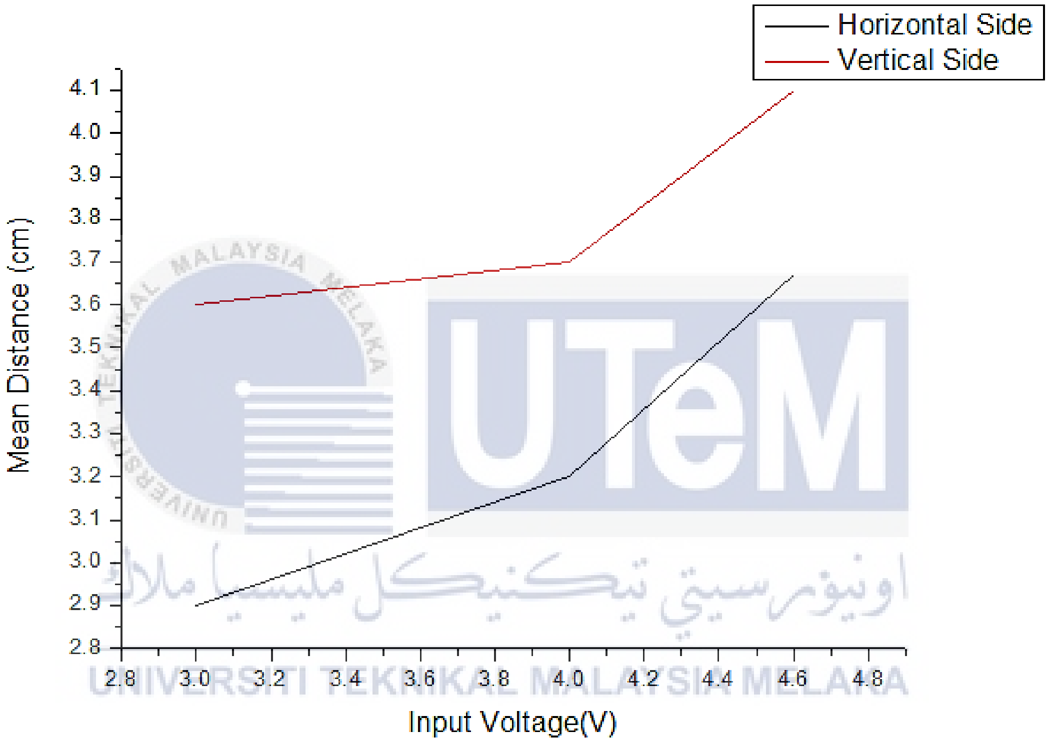


Figure 4.12: The Overall Result for Experiment Setup 3

From Figure 4.12, it can be shown that the horizontal side of placement of RFID Tag can only detect short distance if compared with vertical side by RFID reader. Therefore, vertical side of RFID tag will be consider to put on the book to detect by reader because it can be detected more far than horizontal side.

4.5 Results for Positioning of Servo Motor

The result is about the controlling the position of servo motor with PID controller. The data for serial monitor (Arduino) six positions of bookshelf when reaching the point which is collected. The experiment of the range input voltage set as 4.7V.

The data for condition without load is collected and plotted with Origin Pro 7 which is shown in Table 4.4. 2 cycles for clockwise direction with the pattern (A-C-E-F-B-D) in Figure 3.6 are collected for no load condition.

Table 4.4: Data Collected for Position of Bookshelf (No Load Condition)

Position	Actual Length of the Pulse (milliseconds)	Experimental Length of the Pulse (milliseconds)	Actual Angle (degree)	Experimental Angle (degree)	Error (%)
A	0	0	0	0	0
C	533.33	700	120	157.50	31.25
E	1066.67	1400	240	314.00	31.25
F	1333.34	1750	300	393.74	31.25
B	266.67	350	60	78.75	31.25
D	800	1050	180	236.25	31.25
A	1600	2100	360	472.50	31.25

The length of the pulse for whole cycle (Position A to Position A) is 1600 milliseconds. The actual length of the pulse for (Position A to Position B) is 266.67ms by dividing the length of the pulse (milliseconds) into 7 part. When 266.67ms is wrote to the servo motor by Arduino Mega 2560, the bookshelf did not achieve the results from Position A to Position B. It can be resulted there have error on the position of servo motor. Based on the Table 4.4, the bookshelf rotate from Position A to Position B for the length of the pulse for 350ms. Figure 4.13 shows the results between actual angle and experimental angle based the Position for no load condition.

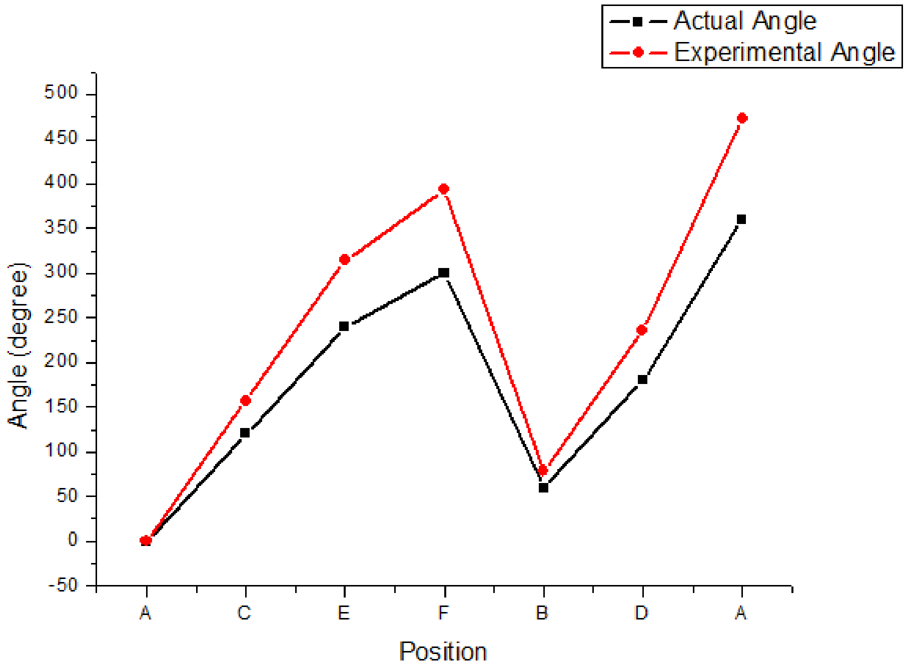


Figure 4.13: Actual Angle and Experimental Angle based the Position (No Load)

Data 1 in Table 4.5 is imported into MATLAB in order to get transfer function of the system which is shown in Eq. 4.1.

Table 4.5: Data 1

Cycle 1: Experimental Angle (degree)	Cycle 2: Experimental Angle (degree)	Actual Angle (degree)
0	0	0
157.50	157.50	120
314.00	314.00	240
393.74	393.74	300
78.75	78.75	60
236.25	236.25	180
472.50	472.50	360

Data 1 is imported into System Identification Tool and get the transfer function. The input variable is set as actual angle while the output variable is set as experimental angle.

Transfer function model is used, number of poles is set to three while the number of zero is set to zero for continuous time shown in Figure 4.14. Transfer function 1 is generated and estimated through MATLAB in Figure 4.15.

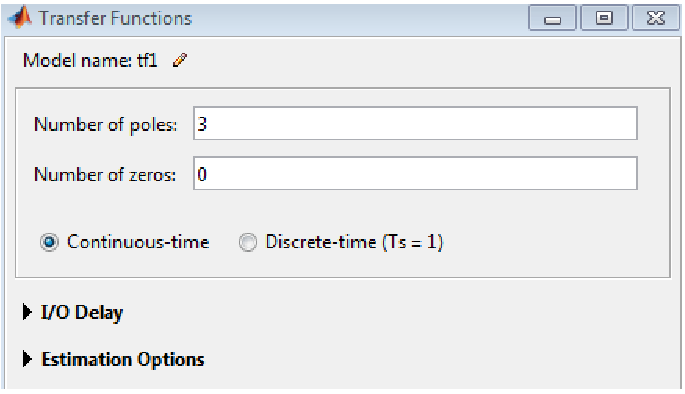


Figure 4.14: Transfer Function Estimation

```
From input "u1" to output "y1":
                416
---------------------------------
s^3 + 43.19 s^2 + 212.2 s + 380.4
Name: tf1
Parameterization:
   Number of poles: 3   Number of zeros: 0
   Number of free coefficients: 4
   Use "tfdata", "getpvec", "getcov" for parameters and their uncertainties.

Status:
Estimated using TFEST on time domain data "mydata".
Fit to estimation data: -22.83% (simulation focus)
FPE: 5.527e+04, MSE: 2.882e+04
```


Figure 4.15: Transfer Function 1

The Eq. 4.1 is the Transfer Function of servo motor without the load condition.

$$G(s) = \frac{416}{s^3+43.19s^2+212.2s+380.4} \qquad \text{Eq. (4.1)}$$

The PID is designed for the transfer function which is generated from MATLAB for servo motor to get more accurate position. Figure 4.16 shows the PID controller for the system without load in Simulink.

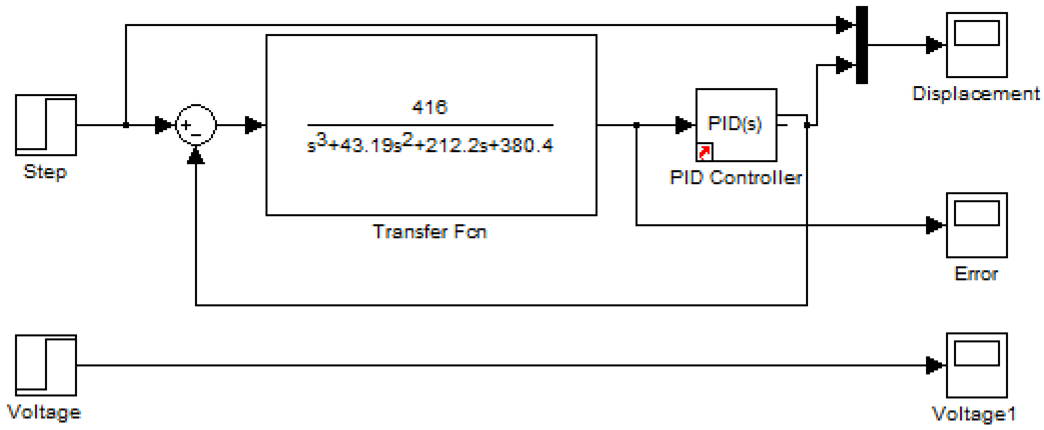


Figure 4.16: PID Controller for TF1 (No-Load Condition)

The data for condition with load is collected and plotted with Origin Pro 7 which is shown in Table 4.6. 2 cycles for clockwise direction with the pattern (A-C-E-F-B-D) in Figure 3.6 are collected for load condition.

The length of the pulse for whole cycle (Position A to Position A) is 1600 milliseconds. The actual length of the pulse for (Position A to Position B) is 266.67ms by dividing the length of the pulse (milliseconds) into 7 part. When 266.67ms is wrote to the servo motor by Arduino Mega 2560, the bookshelf did not achieve the results from Position A to Position B. It can be resulted there have error on the position of servo motor. Based on the Table 4.5, the bookshelf rotate from Position A to Position B for the length of the pulse for 340ms. Figure 4.17 shows the results between actual angle and experimental angle based the Position for load condition.

Table 4.6: Data Collected for the Position of Bookshelf (Load Condition)

Position	Actual Length of the Pulse (milliseconds)	Experimental Length of the Pulse (milliseconds)	Actual Angle (degree)	Experimental Angle (degree)	Error (%)
A	0	0	0	0	0
C	533.33	680	120	153.00	27.5
E	1066.67	1360	240	305.00	27.5
F	1333.34	1700	300	382.50	27.5
B	266.67	340	60	76.50	27.5
D	800	1020	180	229.50	27.5
A	1600	2040	360	459.00	27.5

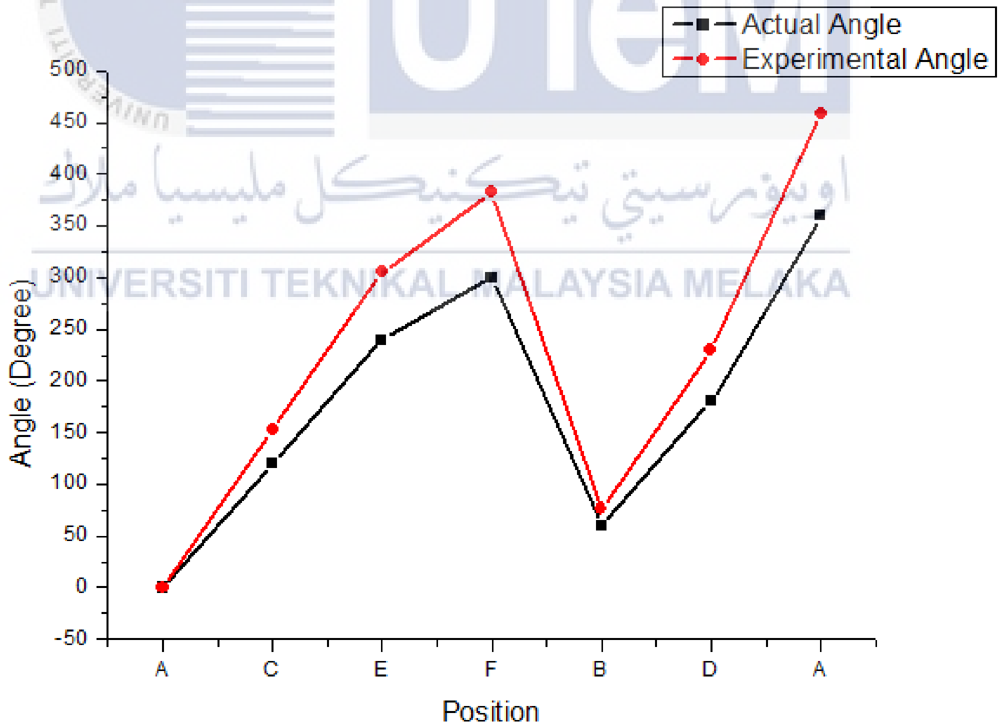


Figure 4.17: Actual Angle and Experimental Angle based the Position (Load)

Data 2 in Table 4.7 is imported into MATLAB in order to get transfer function of the system which is shown in Eq. 4.2.

Table 4.7: Data 2

Cycle 1: Experimental Angle (degree)	Cycle 2: Experimental Angle (degree)	Actual Angle (degree)
0	0	0
153.00	153.00	120
305.00	305.00	240
382.50	382.50	300
76.50	76.50	60
229.50	229.50	180
459.00	459.00	360

Data 2 is imported into System Identification Tool and get the transfer function. The input variable is set as actual angle while the output variable is set as experimental angle. Transfer function model is used, number of poles is set to three while the number of zero is set to zero for continuous time shown in Figure 4.14. Transfer function 2 is generated and estimated through MATLAB in Figure 4.18.


```
From input "u1" to output "y1":
              93.15
---------------------------------
s^3 + 13.34 s^2 + 48.88 s + 71.13
Name: tf3
Parameterization:
   Number of poles: 3   Number of zeros: 0
   Number of free coefficients: 4
   Use "tfdata", "getpvec", "getcov" for parameters and their uncertainties.

Status:
Estimated using TFEST on time domain data "mydata".
Fit to estimation data: -30.45% (simulation focus)
FPE: 8.557e+04, MSE: 4.542e+04
```

Figure 4.18: Transfer Function 2

$$K(s) = \frac{93.15}{s^3+13.34s^2+48.88s+71.13} \qquad \text{Eq. (4.2)}$$

The PID is designed for the transfer function which is generated from MATLAB for servo motor to get more accurate position. Figure 4.19 shows the PID controller for the system with load condition in Simulink.

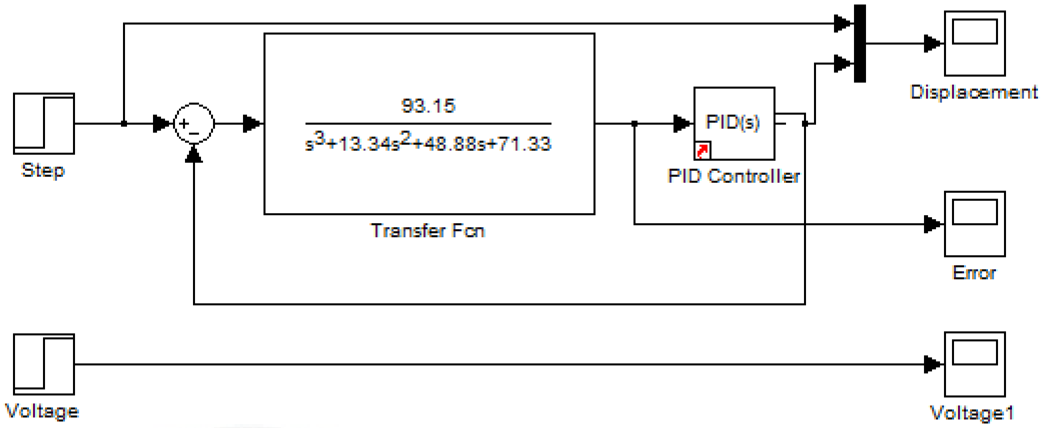


Figure 4.19: PID Controller for TF2 (No-Load)

Ziegler-Nichols Method is using for PID design of servo motor in order to get more accurate position for load condition and no load condition.. Table 4.8 shows the Ziegler-Nichols Method.

Table 4.8: Ziegler-Nichols Method

Control Type	K_p	K_i	K_d
P	0.50 K_u	-	-
PI	0.45 K_u	$\frac{1.2K_p}{T_u}$	-
PID	$0.60K_u$	$\frac{2K_p}{T_u}$	$\frac{K_pT_u}{8}$

4.5.1 Discussion for Positioning of Servo Motor for No-Load Condition

The integral and derivate is set to zero. K_p is increased from zero until it reaches the ultimate gain, which the output of the control loop has stable and consistent oscillations. Figure 4.20 shows the proportional gain with the values with 9. Based on the graph, it can be seen that the value of 9 achieves the system with stable and consistent oscillation. K_p is set to 9, then K_u is equal to 18,

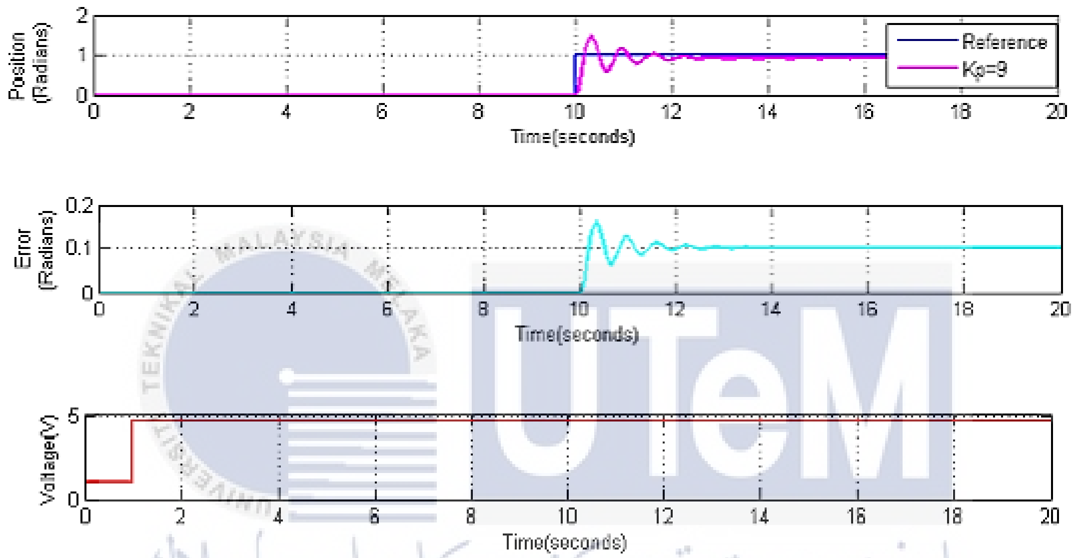


Figure 4.20: Result for P-controllers (No-Load)

Table 4.9 shows the effects of increasing K_p on the performance and robustness of the system by inserted the values of 7,8 and 9. The performance and robustness of the system can be obtained from the window in PID tuner.

Table 4.9: Effects of Increasing K_p (No-Load)

K_p	7	8	9
Rise time (seconds)	0.136	0.126	0.119
Settling time(seconds)	2.24	2.44	2.88
Overshoot (%)	52	59.2	63.1
Peak	1.37	1.43	1.48
Closed-loop stability	Stable	Stable	Stable

The simulated data in Table 4.9 will be computed with the theoretical data. Table 4.10 shows the performance and robustness of theoretical and simulated data of proportional action on the system.

Table 4.10: Effect of Increasing K_p (Simulated data and theroritical data) (No-Load)

Performance	Theoretical	Simulated	Accuracy
Rise Time	Decrease	Decrease	Yes
Overshoot	Increase	Increase	Yes
Settling Time	Small Change	Small Change	Yes
Steady State Error	Decrease	Decrease	Yes

It can be concluded that, increasing the proportional gain reduces steady state errors. Proportional controller gives an action on output signal proportional to the size of the error.

Based on the Table 4.8, the values for K_p, K_u and T_u is substituted into the formula to find integral control. Table 4.11 shows the values for PI controller based on Ziegler-Nichols Method.

Table 4.11: Values for PI Controller based on Ziegler-Nichols Method (No-Load)

Control Type	K_p	K_i	K_d
PI	8.1	10.8	-

Figure 4.21 shows the result for PI controller on the transfer function. The values for K_i are set as 10.8 the K_p is set as 8.1 based on Ziegler-Nichols Method.

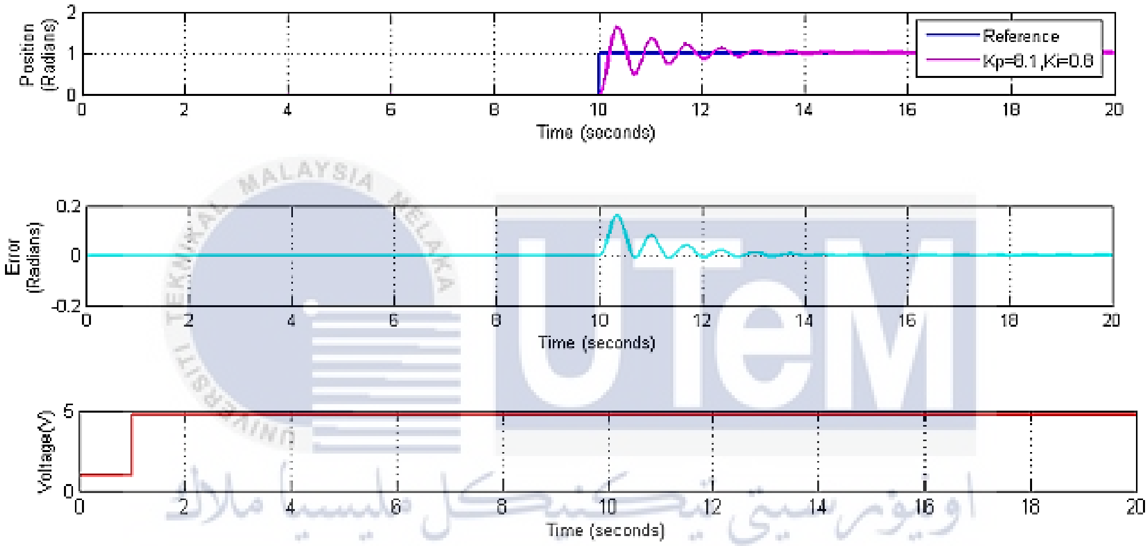


Figure 4.21: Result for PI-controllers (No-Load)

Table 4.12 shows the effects of increasing K_i on the performance and robustness of the system by inserted the values of 7.8,9.8 and 10.8. The performance and robustness of the system can be obtained from the window in PID tuner.

Table 4.12: Effects of Increasing K_i (No-Load)

K_i	7.8	9.8	10.8
Rise time (seconds)	0.129	0.127	0.127
Settling time(seconds)	3.47	4.09	4.13
Overshoot (%)	59.4	63.4	65.3
Peak	1.59	1.63	1.65
Closed-loop stability	Stable	Stable	Stable

The simulated data in Table 4.12 will be computed with the theoretical data. Table 4.13 shows the performance and robustness of theoretical and simulated data of integral action on the system.

Table 4.13: Effect of Increasing K_i (Simulated data and theroritical data) (No-Load)

Performance	Theoretical	Simulated	Accuracy
Rise Time	Small Change	Small Change	Yes
Overshoot	Increase	Increase	Yes
Settling Time	Decrease	Increase	No
Steady State Error	Small Change	Small Change	Yes

Integral control is able to provide robust reduction in steady-state error and it makes the system unstable.

Table 4.14 shows the values for PID controller based on Ziegler-Nichols Method.

Table 4.14: Values for PID Controller based on Ziegler-Nichols Method (No-Load)

Control Type	K_p	K_i	K_d
PID	10.8	18	1.125

Figure 4.22 shows the result for PID controller on the transfer function. The values for K_d is set as 1.12 while the K_p is set as 10.8 and K_i is set as 1.12 based on Ziegler-Nichols Method.

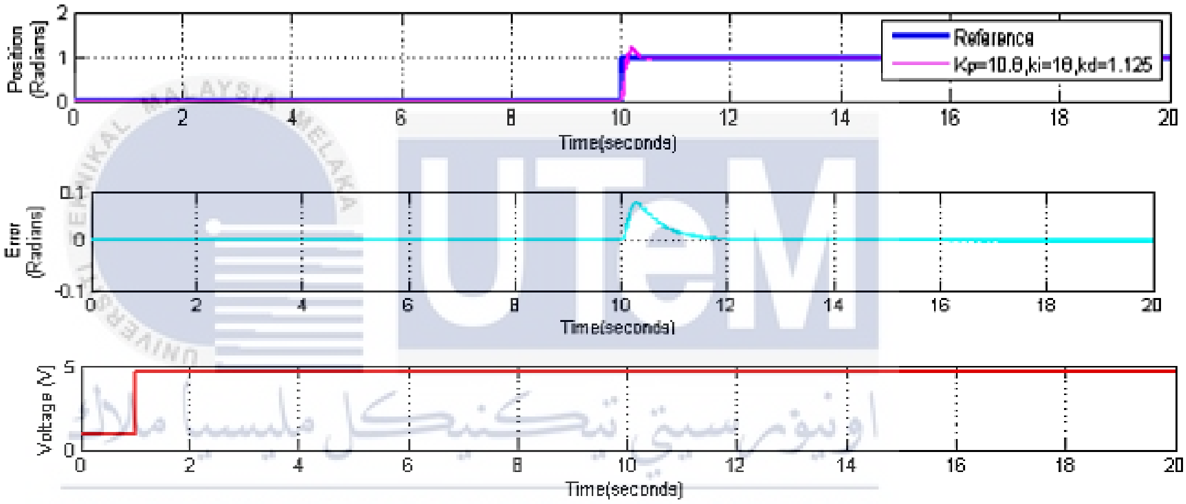


Figure 4.22: Result for PID-controllers (No-Load)

Table 4.15 shows the effects of increasing K_d on the performance and robustness of the system. by inserted the values of 0.0125,0.125 and 1.125. The performance and robustness of the system can be obtained from the window in PID tuner.

Table 4.15: Effects of Increasing K_d (No-Load)

K_d	0.0125	0.125	1.125
Rise time (seconds)	0.106	0.107	0.0818
Settling time(seconds)	8.59	3.59	0.358
Overshoot (%)	80.2	68.7	20.8
Peak	1.8	1.69	1.21
Closed-loop stability	Stable	Stable	Stable

The simulated data in Table 4.15 will be computed with the theoretical data. Table 4.16 shows the performance and robustness of theoretical and simulated data of derivative action on the system.

Table 4.16: Effect of Increasing K_d (Simulated data and theroritical data) (No-Load)

Performance	Theoretical	Simulated	Accuracy
Rise Time	Decrease	Decrease	Yes
Overshoot	Increase	Increase	Yes
Settling Time	Increase	Decrease	No
Steady State Error	Eliminate	Eliminate	Yes

Damping control increases damping and improves stability. Figure 4.23 shows the overall results of P, PI and PID controller for the system.

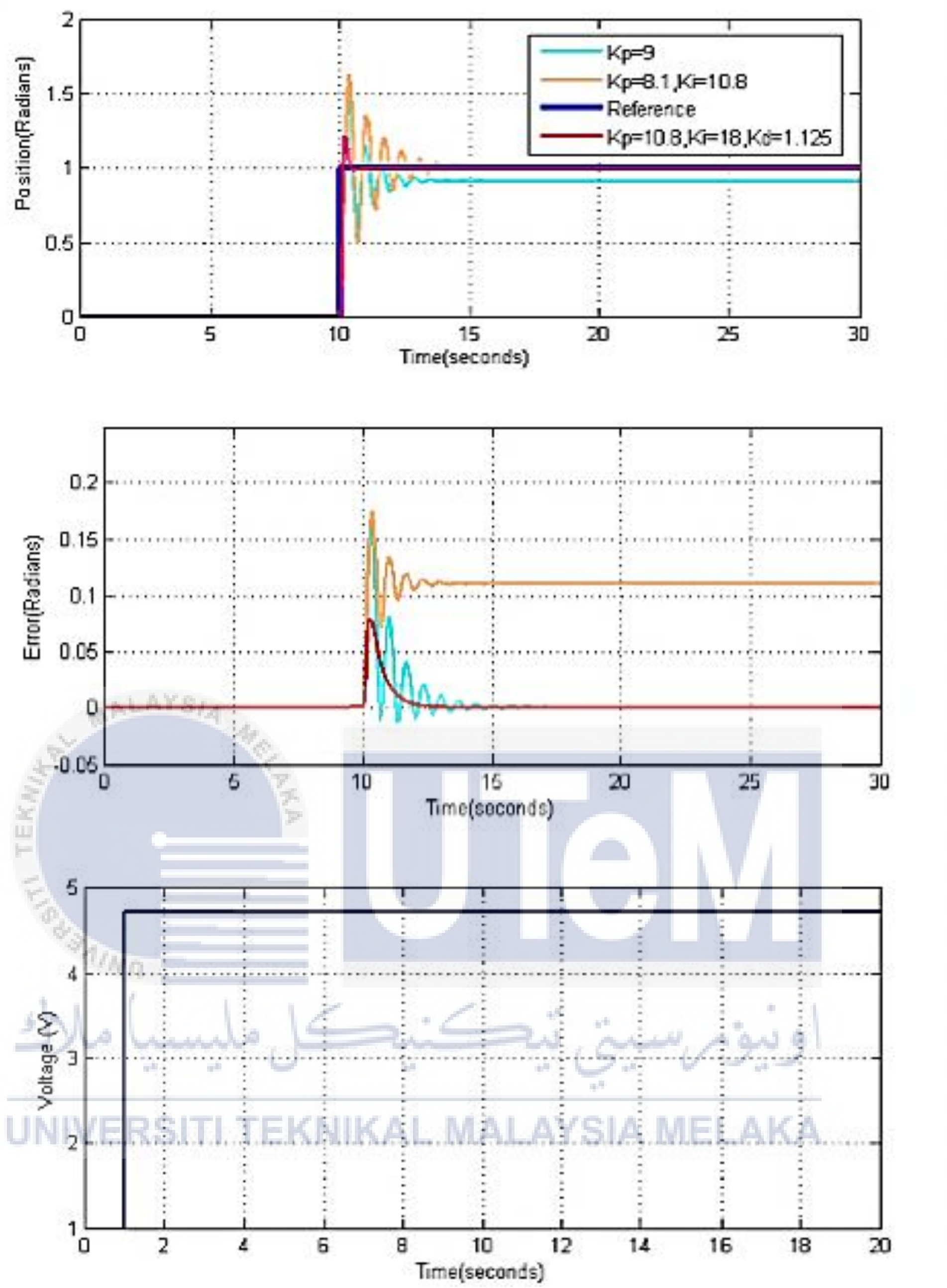


Figure 4.23: Overall Results of P, PI and PID Controller for the System (No-Load)

From the Figure 4.23, it can be seen that Ziegler-Nichols method is a good method to control the position of servo motor with no load condition.

4.5.2 Discussion for Positioning of Servo Motor for No-Load Condition

The integral and derivate is set to zero. K_p is increased from zero until it reaches the ultimate gain, which the output of the control loop has stable and consistent oscillations. Figure 4.24 shows the proportional gain with the value of 5 in load condition. Based on the graph, it can be seen that 5 achieves the system with stable and consistent oscillation. K_p is set to 5, then K_u is equal to 10.

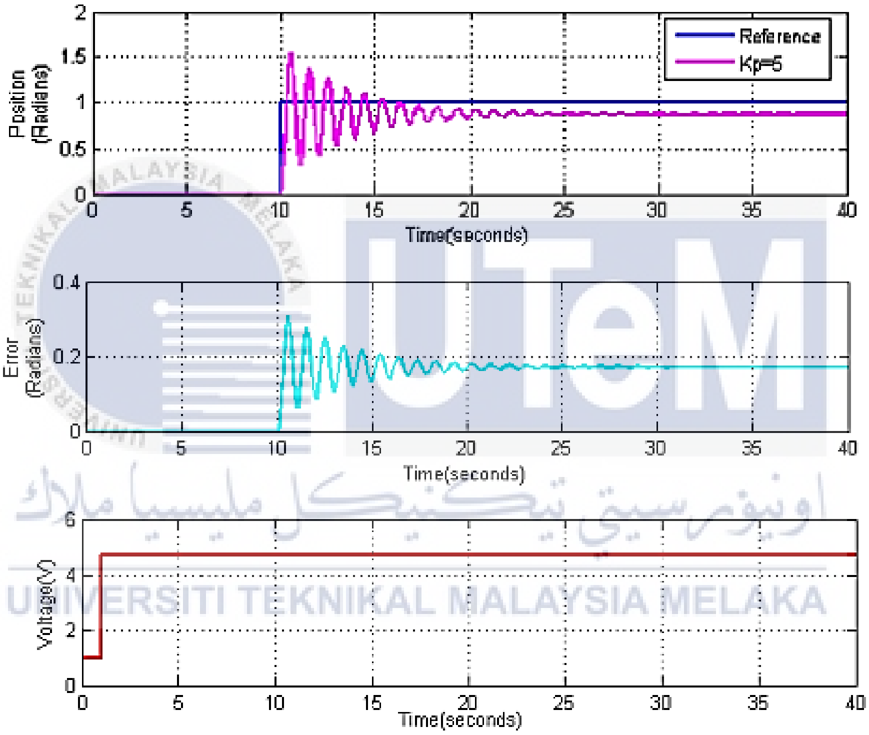


Figure 4.24: Result for P-controllers (Load Condition)

Table 4.17 shows the effects of increasing K_p on the performance and robustness of the system with the values of 3,4 and 5 with load condition.

Table 4.17: Effects of Increasing K_p (Load Condition)

K_p	3	4	5
Rise time (seconds)	0.239	0.208	0.187
Settling time(seconds)	4.79	7.02	13.7
Overshoot (%)	56.1	68	78
Peak	1.24	1.41	1.54
Closed-loop stability	Stable	Stable	Stable

The simulated data in Table 4.17 will be computed with the theoretical data. Table 4.18 shows the performance and robustness of theoretical and simulated data of proportional action on the system.

Table 4.18: Effect of Increasing K_p (Simulated data and theroritical data) (Load Condition)

Performance	**Theoretical**	**Simulated**	**Accuracy**
Rise Time	Decrease	Decrease	Yes
Overshoot	Increase	Increase	Yes
Settling Time	Small Change	Small Change	Yes
Steady State Error	Decrease	Decrease	Yes

It can be concluded that, increasing the proportional gain reduces steady state errors. Proportional controller gives an action on output signal proportional to the size of the error.

Based on the Table 4.8, the values for K_p, K_u and T_u is substituted into the formula to find integral control. Table 4.19 shows the values for PI controller based on Ziegler-Nichols Method.

Table 4.19: Values for PI Controller based on Ziegler-Nichols Method (Load Condition)

Control Type	K_p	K_i	K_d
PI	4.5	6	-

Figure 4.25 shows the result for PI controller on the transfer function. The values for K_i are set as 6 the K_p is set as 4.5 based on Ziegler-Nichols Method.

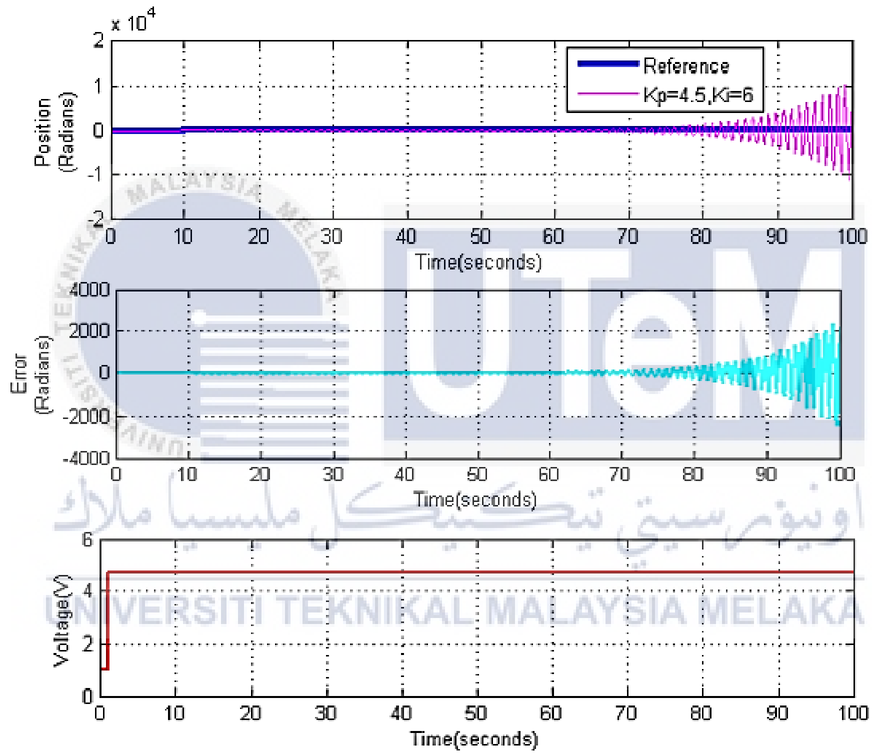


Figure 4.25: Result for PI-controllers (Load Condition)

Due to the close system with applying PI-controllers is unstable, the performance and robustness of the aystem cannot be analyzed.

Table 4.20 shows the values for PID controller based on Ziegler-Nichols Method.

Table 4.20: Values for PID Controller based on Ziegler-Nichols Method (Load Condition)

Control Type	K_p	K_i	K_d
PID	6	10	0.625

Figure 4.26 shows the result for PID controller on the transfer function. The values for K_d is set as 0.625 while the K_p is set as 6 and K_i is set as 10 based on Ziegler-Nichols Method.

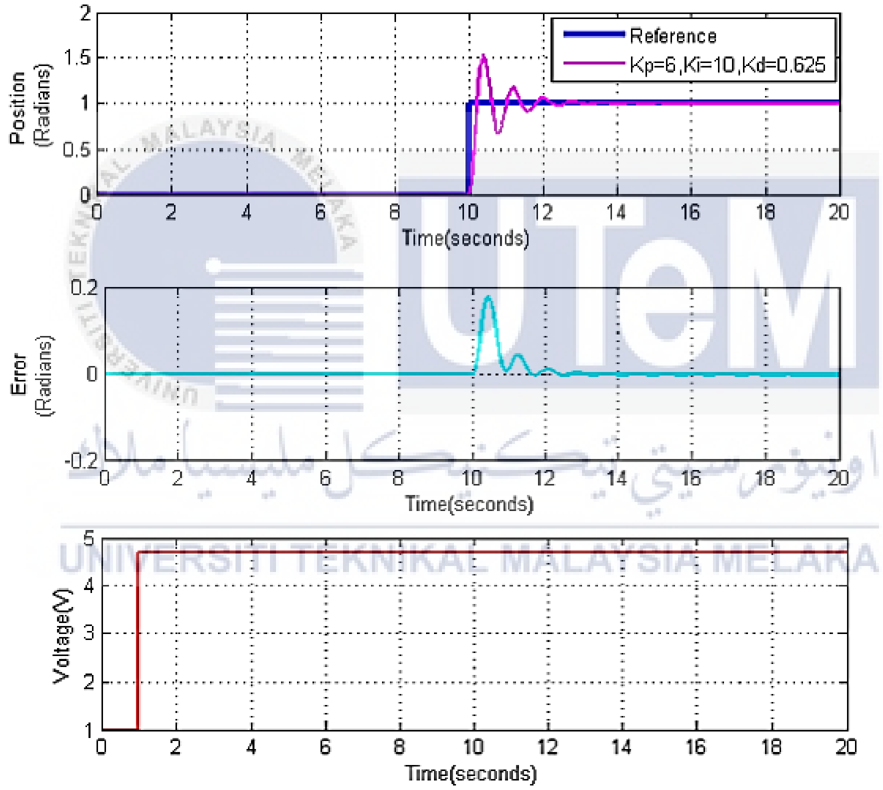


Figure 4.26: Result for PID-controllers (Load Condition)

Table 4.21 shows the effects of increasing K_d on the performance and robustness of the system with the values of 0.225,0.425 and 0.625 with load condition.

Table 4.21: Effects of Increasing K_d (Load Condition)

K_d	0.225	0.425	0.625
Rise time (seconds)	0.166	0.159	0.125
Settling time(seconds)	67.4	5.23	2.52
Overshoot (%)	83.1	65.9	53.9
Peak	1.83	1.66	1.54
Closed-loop stability	Stable	Stable	Stable

The simulated data in Table 4.21 will be computed with the theoretical data. Table 4.22 shows the performance and robustness of theoretical and simulated data of derivative action on the system.

Table 4.22: Effect of Increasing K_d (Simulated data and theroritical data) (Load Condition)

Performance	Theoretical	Simulated	Accuracy
Rise Time	Decrease	Decrease	Yes
Overshoot	Increase	Decrease	No
Settling Time	Increase	Decrease	No
Steady State Error	Eliminate	Eliminate	Yes

Damping control increases damping and improves stability. Figure 4.27 shows the overall results of P, PI and PID controller for the system.

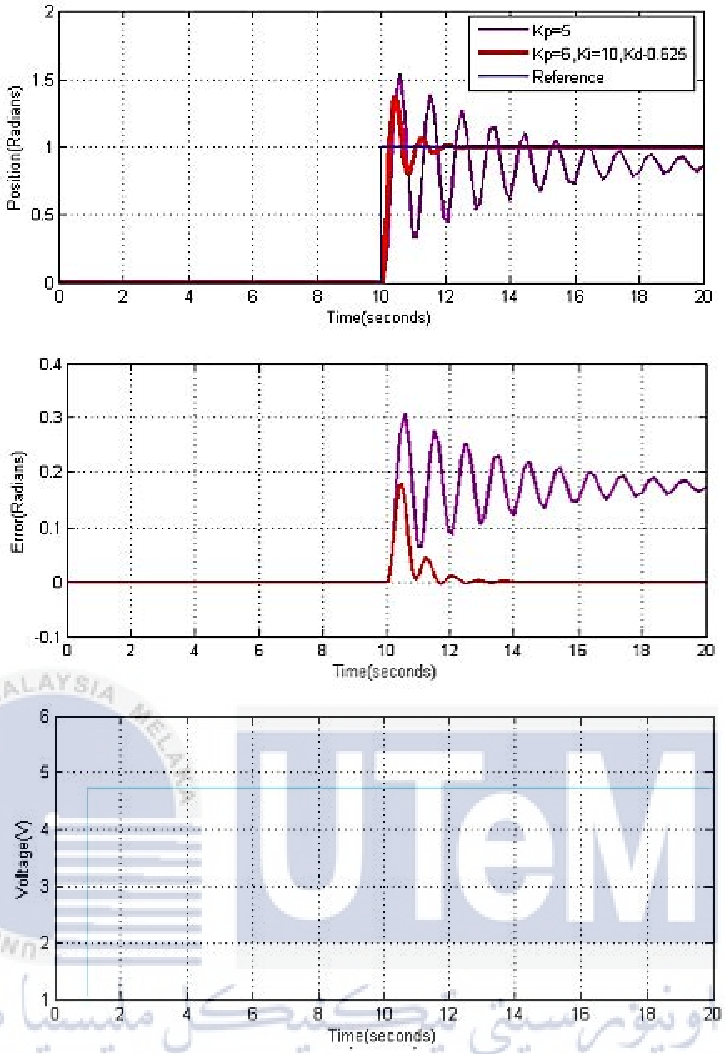


Figure 4.27: Overall Results of P, PI and PID Controller (Load Condition)

From the Figure 4.27, it can be seen that Ziegler-Nichols method is efficiency to control the position of servo motor.

4.6 Testing

The first testing was done for small prototype of smart library system. The information of sample 1 in Table 4.23 is tested and took in video for proving.

Table 4.23: Sample 1

RFID TAG	149
BOOK	HISTORY
LOCATION	A
LEVEL	2

The sample of location of servo motor is shown in Figure 4.24 also undergo a testing process and the process is taking in video for proving.

Table 4.24: Sample of Location

No	Starting	Ending
1	Location A	Location A
2	Location A	Location C
3	Location A	Location E
4	Location A	Location B
5	Location A	Location D
6	Location A	Location F

4.7 Testing Problem

After undergo many times testing, some technical problems are occurred. Corrective action need to take when something happen on the hardware. The DC motor is failed to pull up the holder from position “1” to position “2”. The reason is the belt is too smooth so it is unable to pull up the holder. The belt need to exchange with a rough surface so it can pull up the holder from position “1” to position “2”.

Another problem is existed in testing 1 is on push pull solenoid. The components used for push pull solenoid is DC 12V Push-Pull Type Open Frame Solenoid Electromagnet. It is not strong to push the books into bookshelf. By solving this problem, the suggestion is change the components push pull solenoid to 5/2 push pull valve with pneumatic control.

Figure 4.28 shows the problem 1 existed in testing process while Figure 4.29 shows the problem 2 existed in testing process.

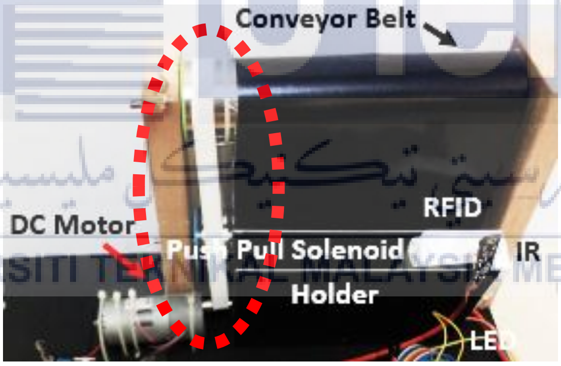


Figure 4.28: Testing Problem 1

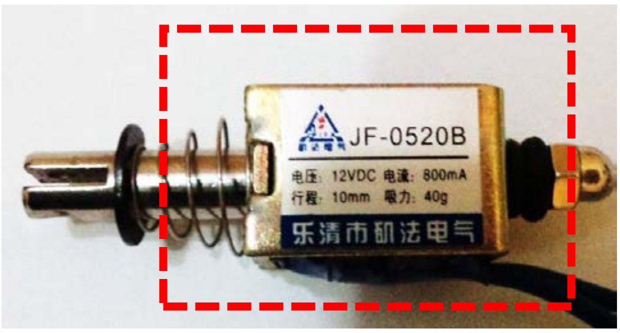


Figure 4.29: Testing Problem 2

CHAPTER 5

CONCLUSION

5.1 Overview

The conclusion part and recommendations for the future are explained and elaborated in this chapter.

5.2 Conclusion and Recommendation

The testing procedures on the components which is going to use in the project is done in order to study and determine the specification and characteristic of the components. The range of distance for IR sensor is about 0.1 cm until 0.8cm for the input voltage (3V-4.7V). The vertical placement of RFID tag can detect more far by RFID reader than horizontal placement. It can be concluded that PWM is a great and easy way to control the speed of motor. Z-N method is suitable to use for PID controller to get the accurate position of servo motor due to it still has error there. 4 experiments setup are done successfully .The objectives are achieved in the research. A small prototype of smart library system is built in the research.

For the recommendation, it is needed to study for causes which make the prototype of smart library system failure to run in some of the components. More research need to be done to make sure the system to run efficiency and safe. This is the starting of development smart library system by building the hardware. The corrective action is needed to done from time to time on the hardware design.

REFERENCE

[1] Wellisch, H.W, Ebla: the world's oldest library, Journal of Library History, Vol.16, (3), No. 3, pp488-500, 1981

[2] Singh, J., Deupser, C., Olsen, E., Singh, S. P. , An Examination of the Variables Affecting RFID Tag Readability in a Conveyer Belt Environment, Journal of Applied Packaging Research, Vol. 2, No. 2., 2007

[3]`D.M.I.E.T.R, Sawangi (m), Wardha, Automated Library System Using Robotic Arm, International Journal of Advanced Research in Computer Science and Software Engineering , Volume 5, Issue 2, February 2015

[4]K R Mulla, M Chandrashekara, "Application of RFID in Libraries for Physical Information Security- a View", presented at 4th International Convention CALIBER-2006, Gulbarga, 2006

[5] Shien-Chiang Yu, RFID implementation and benefit in libraries, The Electronic Library, Vol.25 Iss1 pp.54-64, 2001

[6]O'Neill, E.T. and W. L. Boomgaarden, Book deterioration and loss: Magnitude and characteristics in Ohio libraries. Library Resources and Technical Services." 38(4):pp394-pp408, 1995

[7]Kho Hao Yuan; Ang Chip Hong; Ang, M.; Goi Sio Peng, Unmanned library: An Intelligent Robotic Books Retrieval & Return System Utilizing RFID tags, Vol4, Iss1 pp.3, 2002

[8]Wei-Sheng Chen; Kai-Wen Chen; Hui-Sheng Ni; Yung-Yao Chen., A novel barcode system for intelligent automation industry, presented at International Conference on Advanced Robotics and Intelligent Systems (ARIS) on 2015, pp. 1,2015

[9] Society of Motion Picture and Television Engineers, RP 156:1999 - Bar Code Labelling for Type D-1 Component and Type D-2 Composite Cassette Identification, ICS 33.160.01 (Nov. 5 1999), pp.1-8, 1999

[10]Electrical and Computer Engineering (CCECE), Comparison of RFID system and barcode reader for manufacturing processes, presented at IEEE Conference (3-6 May 2015-Halifax, NS), pp 502-506, 2015

[11] Preradovic, S.; Balbin, I.; Karmakar, N.C.; Swiegers, G., A Novel Chipless RFID System Based on Planar Multiresonators for Barcode Replacement RFID, presented at IEEE International Conference on 2008,pp 289-296, 2008

[12]Cheng Feng (2010), Research for application of RFID in library, presented at International Conference on 2010, pp262-264, 2010

[13]Stockman, H. ,Communication by means of reflected power , Proceedings of the IRE, Vol.36 No.10, pp. 1196-204, 1948

[14] Qu, B.; Liu, H.; Ye, Q.; Geng, Y.; Ren, T., A novel MEMS-based 13.56 MHz micro antenna for RFID application, presented at Magnetics Conference (INTERMAG) on 2015, pp1-1, 2015

[15] Wright, D.R.; Riley, N., Common AMHS myths [automated material handling systems], presented IEEE International Symposium on 2015, pp 277-280, 2015

[16]Corina Monica Pop, Gheorghe Leonte Mogan*, ROBOTIC GRIPPERS FOR HANDLING BOOKS IN LIBRARIES. Presented at INTERNATIONAL CONFERENCE of SCIENTIFIC PAPER AFASES (Brasov, 28-30 May 2015), 2015

[17] Mustapha, B.; Zayegh, A.; Begg, R.K., Ultrasonic and Infrared Sensors Performance in a Wireless Obstacle Detection System, IEEE Conference (2013), pp487-492, 2013

[18]Agung, I.G.A.P.R.; Huda, S.; Wijaya, I.W.A., Speed control for DC motor with pulse width modulation (PWM) method using infrared remote control based on ATmega16 microcontroller, IEEE Conference paper for Smart Green Technology in Electrical and Information Systems (ICSGTEIS), 2014, International Conference (2014),pp 108-112, 2014

[19] Bindu R, Mini K. Namboothiripad, using of PID Controller for DC Servo Motor using Genetic Algorithm, International Journal of Emerging Technology and Advanced Engineering, Volume 2, Issue 3, 2012

[20] Wahyunggoro, Oyas; Saad, Nordin, Evaluations of fuzzy-logic-based self-tuning PI controller and fuzzy-scheduled PID controller for DC servomotor", presented at ITSim on 2008

APPENDIX A

Building Cost for Design A and B

Design	A	B
DC Motor	RM60	RM60
RFID Reader	RM26	RM26
LCD	RM18	RM18
IR SENSOR	RM24	RM12
XY-AXIS MOTOR	RM200	-
SERVO MOTOR	-	RM20
PUSH PULL SOLENOID	RM40	RM20
TOTAL	RM368	RM156

APPENDIX B

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