pick and place robot with
Mohd Firdaus Rusli.

DEVELOPMENT OF SERVO MOTOR PICK AND PLACE ROBOT WITH PIC16F877A MICROCONTROLLER

MOHD FIRDAUS BIN RUSLI

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DEVELOPMENT OF SERVO MOTOR PICK AND PLACE ROBOT WITH PIC16F877A MICROCONTROLLER

MOHD FIRDAUS BIN RUSLI

This Report Is Submitted In Partial Fulfillment Of Requirements For The Degree of Bachelor In Electrical Engineering (Industry Power)

Faculty Of Electrical Engineering
Universiti Teknikal Kebangsaan Malaysia

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"I hereby declared that I have read through this report and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Industrial Power)"

Signature	:	
Supervisor's Name	:	Mr. Hyreil Anuar Bin Hj. Kasdirin
Date	:	7/5/08

"I hereby declared that this report is a result of my own work except for the excerpts that have been cited clearly in the references."

Signature : 

Name : Mohd Firdaus Bin Rusli

Date : 7/5/08

To my dearest mother, Rossenani Bte Jaslan and sisters, Norafifi, Norafidah and Norafirah for their encouragement and blessing. Special to my supervisors, Mr. Hyreil Anuar Bin Hj. Kasdirin for his fully support and caring from PSM 1 until PSM 2. To my entire beloved course mate for their support.

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Thank You.

ABSTRACT

In this paper, Development of Servo Motor Pick and Place Robot With Microcontroller project is being proposed. A robot will be build that would function as a tool to pick and place object. A small robot arm assembly simulating shoulder movement of a human arm to be built to pick and place object from point A to B. The arm has two of freedom so the hand is able to reach and pick object from any three dimensional point. Electric motors will be used as the actuator for the robot that are controlled by microcontroller. The project encompasses all design areas required to make a hand able to move and pick an object, including hardware design, analysis, electronic controller circuit design and controller program. The controller circuit will use PIC16F877A microcontroller as 'the brain' of the robot.

ABSTRAK

Dalam laporan ini, Pembangunan Robot Motor Servo Angkat dan Letak Bersama Pengawal Mikro adalah dicadangkan. Sebuah robot yang akan berfungsi sebagai satu alat untuk mengangkat dan meletak sesebuah objek. Sebuah robot lengan kecil yang menyerupai pergerakan bahu manusia akan dibina untuk mengangkat dan meletak objek dari titik A ke titik B. Lengan tersebut mempunyai dua darjah kebebasan agar robot tersebut dapat mencapai dan mengambil objek dari mana-mana titik tiga dimensi. Motor servo akan digunakan sebagai penggerak yang akan dikawal oleh pengawal mikro. Projek ini mempunyai bahgian-bahagian rekabentuk yang diperlukan agar lengan tersebut dapat berfugsi untuk mengangkat objek, termasuk rekabentuk perkakasan, analisis, rekabentuk litar kawalan elektronik dan program pengawal. Litar pengawal tersebut akan menggunakan pengawal mikro PIC16F877A sebagai 'otak' kepada robot itu nanti.

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LIST OF ABBREVIATION

2D - 2 Dimension

DC - Direct Current

HDPE - High Density Polyethylene

PWM - Pulse Width Modulation

PIC - Peripheral Integrated Circuit

IC - Integrated Circuit

PID - Proportional Integral Derivative

DOF - Degree of Freedom

EOA - End of Arm Tooling

CCW - Counterclockwise

CW - Clockwise

USB - Universal Serial Bus

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CHAPTER I

INTRODUCTION

1.1 PROJECT OVERVIEW

Pick and place robot work cells are among the most popular material handling systems. It provide dependable solutions for production lines. Pick and place robot work cells perform tedious, repetitive tasks with ease, speed and accuracy. Nowadays robots play many important roles in industrial sector. More robots mean less workers needed by companies to run their production lines. So, engineers in the future need to take a step to learn as much as can about robotics so can add new skills and develop knowledge about robotics. So this project can help in understanding basic knowledge about robotics.

PIC microcontrollers are popular with developers and hobbyists alike due to their low cost, wide availability, large user base, extensive collection of application notes, availability of low cost or free development tools, and serial programming (and re-programming with flash memory) capability. The name PIC initially referred to "Programmable Interface Controller", but shortly thereafter was renamed "Programmable Intelligent Computer". Today they can be found in almost any complex electronic device - from portable music devices to washing machines to car. They are programmable, cheap, small, can handle abuse, require almost zero power, and there are so many varieties to suit every need. This is what makes them so useful for robotics - they are like tiny affordable computers that be can put right onto robot.

Servo motors are extremely useful in robotics. The motors are small, have built in control circuitry, and are extremely powerful for their size. A standard servo such as the Cytron C36S has 1.96 kg/inches of torque, which is pretty strong for its size. It also draws power proportional to the mechanical load. A lightly loaded servo, therefore, doesn't consume much energy. Their precision positioning makes them ideal for robot arms and legs, rack and pinion steering, and sensor scanners to name a few. Since servos are fully self contained, the velocity and angle control loops are very easy to implement.

This thesis explains about designing a pick and place robot that can pick certain size and form. A gripper were designed to grip the wanted object. Servo motors are used as the actuators for the robot mainly because of their size, easy to control and implemented to the robot chassis. PIC microcontroller will control the servo motors by generating square wave pulse width to the motors. The pulse will depend on the program that burned into the microcontroller.

1.2 PROJECT OBJECTIVES

The objectives of this project are as follows:-

i. To design and build a prototype of pick and place robot that can pick up an object and move it from point A-to-B.
ii. To learn how to make program for microcontroller using certain software.
iii. To learn how to use microcontroller to control behavior of servo motors.
iv. To do analysis about the pick and place robot's performance, reliability and others.

1.3 SCOPE OF WORK

There are limitation tasks that is called scope of work. For this project, the scopes of work are:

i. Design a prototype of pick and place robot.
ii. Build controller circuit for the pick and place robot.
iii. Write a program that control the robot.

1.4 PROBLEM STATEMENT

A pick and place robot need to be design that contain a base, an arm, a gripper and a controller circuit. Servo motors were choose as actuators for the robot. A controller circuit must be build to control each servo motors and the robot overall. That circuit must contain PIC microcontroller that would generate pulse to the servo motors.

1.5 METHODOLOGY

At the beginning, the project title and the functions must be understand. This is very important to make sure the objectives of this project can be achieved. Then, literature review need to be conducted to learn the basic knowledge and theory about this project. This can help in understanding and give early views before taking this project to next level.

Next, basic design of the pick and place robot will be done to give early impression of the robot. Then, circuit of robot controller will be design and simulated to make sure it is functioning according to the design. The circuit will be modified if it is not suitable with hardware of did not same with what are expected. After that, the robot can start to be built according to the design. Changes of the design and of the robot will be made if necessary. Then, the prototype will be test about its functioning and performance. The pick and place robot will undergo modifying process if it did not functioning as expected. Analysis about the robot's function and performance will be conducted and will be reported in final report.

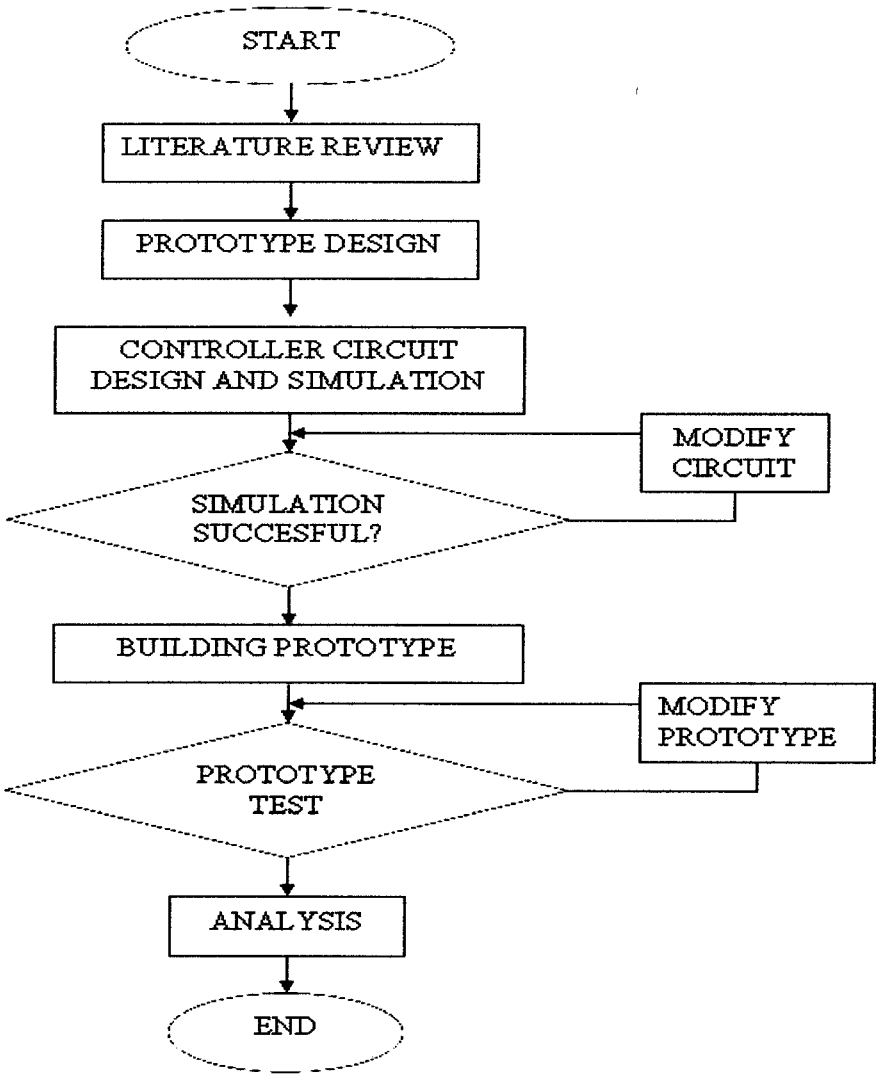

Figure 1.1: Flow Chart of Methodology

1.6 THESIS LAYOUT

This thesis report were divided into six main chapters which are Introduction, Theory of Robot Arm And Servo Motor Control, Project Hardware, Simulation And Analysis, Future Works And Applications and lastly Conclusion. The previous pages including this thesis layout are in the first chapter. The rest of the project's chapters are organized as follows:-

Chapter 2 gives overview about the theory of robot arm and servo motor control. This chapter will explain about basic principles of building a robot arm. It focus mainly on the robot arm mechanisms that need to be considered to get an efficient robot. Then, there are explanation of how to control servo motor rotation using microcontroller.

Chapter 3 review the hardware part of the project. There will be explanation of hardware components that were required to complete this project such as servo motors, microcontroller, electronic components and others. The designing and building process of the robot chassis will be explained in this chapter.

Chapter 4 discuss about the analysis of the robot. There will be discussion about controlling the rotation of servo motor using source code using a few method and the simulation tools and process. There will be calculation for servo motor selection and location of end effector.

Chapter 5 discuss future works that to improve this project and applications that can be made with this project while Chapter 6 will provide the conclusion that were made regarding the project.

CHAPTER II

THEORY OF ROBOT ARM AND SERVO MOTOR CONTROL

There are some theory that needed before starting to built a pick and place robot. Even though it is not compulsory, this information surely will help a lot in building any pick and place robot. This chapter will explain about degrees of freedom and its connection with robot workplace. It is essential to understand about arm sagging problem that may effect the efficiency of the robot. There will be explanation of basic servo motor characteristics from its connection with microcontroller to pulse needed to rotate the servo.

2.1 THEORY OF ROBOT ARM

There are some important features of pick and place robot:

- Able to pick object at any three dimensional point: The hand is able to lift any object placed at any three dimensional point locaters within the range of the hand.
- Cheap and light weight: The robot consists of minimum number of motors. The material used for the frame of the body is light and strong.
- Can be programmed easily for different situations: The mechanism is simple and can be controlled and regulated easily.
- Good stability and coordination: The robot weight completely acts on the base of the hand which gives it a great stability and support.
- Automation can be done very easily: Since the hand uses the servo motors for the motion of the links, it can be very easily controlled by the microcontroller, also due to microcontroller the use of the infrared and touch sensors is very easy.

To help achieve a good robot pick and place robot, there are a few things need to be known as bare minimum of information to build an effective robot arm. This will be discussed in the next pages.

2.1.1 Degrees of Freedom (DOF)

The degrees of freedom, or DOF, is a very important term to understand. Each degree of freedom is a joint on the arm, a place where it can bend or rotate or translate. The number of degrees of freedom can typically identified by the number of actuators on the robot arm. Now this is very important - when building a robot arm we want as few degrees of freedom allowed for your application because each degree requires a motor, often an encoder, and exponentially complicated algorithms and cost. Three degrees of freedom are sufficient to bring the end of a robot arm to any point within its workspace, or work envelope, in three dimensions. Thus, in theory, we might think that a robot should never need more than three degrees of freedom. But the extra possible motions, provided by multiple joints, give a robot arm versatility that it could not have with just three degrees of freedom.

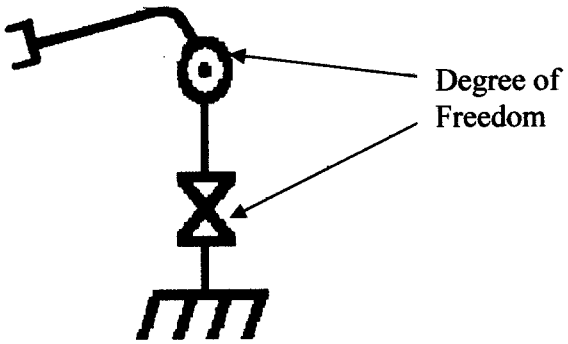

Figure 2.1: 2 Degree of Freedom

2.1.2 Robot Workspace

The robot workspace (sometimes known as reachable space) is all places that the end effector (gripper) can reach. The work space is dependent on the DOF angle/translation limitations, the arm link lengths, the angle at which something must be picked up at, etc. The work space is highly dependent on the robot configuration. Now lets assume that all joints rotate a maximum of 180 degrees, because most servo motors cannot exceed that amount. To determine the workspace, trace all locations that the end effector can reach as in the image below.

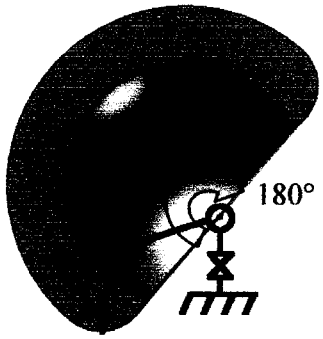

Figure 2.2: All locations that the end effector can reach

Rotating that by the base joint another 180 degrees to get 3D, we have this workspace image. Remember that because it uses servos, all joints are limited to a max of 180 degrees. This creates a workspace of a shelled semi-sphere. If we change the link lengths you can get very different sizes of workspaces, but this would be the general shape. Any location outside of this space is a location the arm cant reach. If there are objects in the way of the arm, the workspace can get even more complicated.

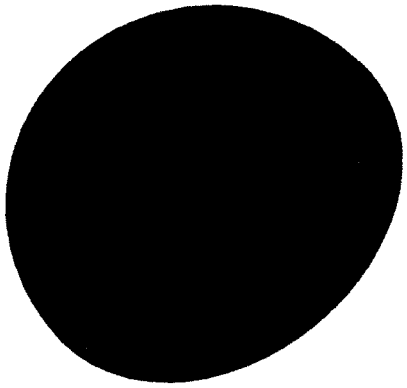

Figure 2.3: Workspace at 180 degrees in 3D

2.1.3 Arm Sagging

Arm sagging is a common affliction of badly designed robot arms. This is when an arm is too long and heavy, bending when outwardly stretched. When designing robot arm, make sure the arm is reinforced and lightweight and do a bending stress analysis. Keep the heaviest components, such as motors, as close to the robot arm base as possible. It might be a good idea for the middle arm joint to be chain/belt driven by a motor located at the base (to keep the heavy motor on the base and off the arm).

2.1.4 End-Effector

A robotic end-effector is any object attached to the robot flange (wrist) that serves a function. This would include robotic grippers, robotic tool changers, robotic collision sensors, robotic rotary joint, robotic press tooling, compliance device, robotic paint gun, robotic deburring tool, robotic arc welding gun, robotic transgun, etc. Robot end effectors are also known as robotic peripherals, robotic accessories, robot tools or robotic tools, end of arm tooling (EOA), or end-of-arm devices.

2.1.5 Kinematical Analysis

The kinematical analysis gives the relationship between the rotation of the servo motors and the rotation of the base plate, shoulder and arm. This analysis also gives an empirical relationship between coordinates of any point in the three dimensional space and the angle of rotation of the servo motor. This helps the arm to reach a particular point in the space with the help of the servo motors. The empirical formulas also help in the development of the software for the control of the robotic arm.

i. Forward Kinematics

Forward kinematics is the method for determining the orientation and position of the end effector, given the joint angles and link lengths of the robot arm. To calculate forward kinematics, all we need is trig and algebra.

ii. Inverse Kinematics

Inverse kinematics is the opposite of forward kinematics. This is when you have a desired end effector position, but need to know the joint angles required to achieve it.

2.2 THEORY OF MOTOR CONTROL

Before building the robot, the way to control motor that will be used as the actuators must be learned to ease the process of building the robot later.

2.2.1 Pulse Width Modulation (PWM) To Servo Motor

There are three wires leads to a servo motor. Two leads are for power, +5V and Ground. The third lead feeds a position control signal to the motor. The position control signal is a single variable-width pulse. The pulse can be varied from 1 to 2ms. The width of the pulse controls the position of the servo motor shaft. A 1-ms pulse rotates the shaft to counterclockwise (CCW) position (-45°). A 1.5-ms pulse places the shaft in a neutral midpoint position (0°). A 2-ms pulse rotates the shaft to the clockwise (CW) position (+45°). The pulse width is sent to the servo motor approximately 50 times a second (50Hz).

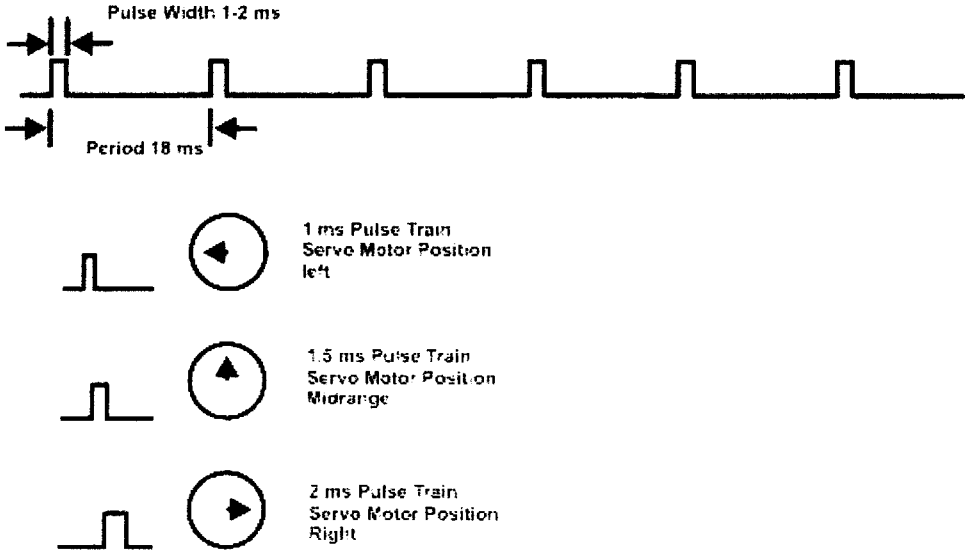

Figure 2.4: Relationship of pulse width to servo motor armature position

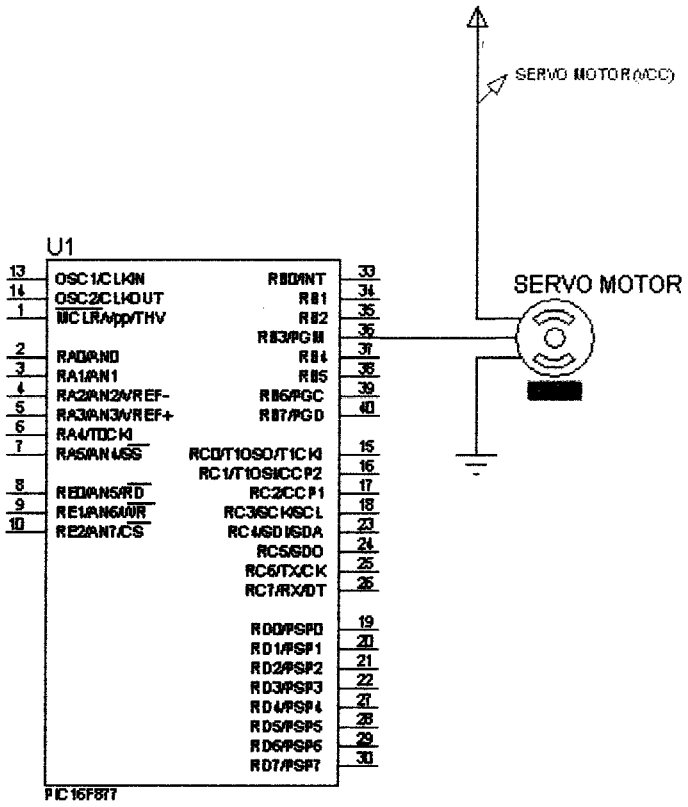

Figure 2.5: Schematic of servo motor connection with PIC16F877

A pulse-width variance from 1 to 2 ms will provide a full 90° of rotation. To extend this range up to 180°, we need to use pulses smaller than 1 ms and greater than 2 ms. If we decide to extend the rotational movement from the servo, we should be aware of certain problems that may arise. In particular, the servo motor has end stops that limit how far the shaft can rotate in either direction. If the PIC is sending a signal to the servo motor that is past either end stop, the motor will continue to fight against the end stop. In this stalled condition, the servo motor will draw increased current and generate greater wear on the gearing inside the motor, neither of which is desirable.

2.3 SUMMARY

This chapter has gathered all relevant information that need to be known to build an effective pick and place robot. The information about the characteristic of servo motor rotation also will help when designing the robot later. This will be used in the next chapter that will discuss about building the pick and place robot and the hardware requirement for this project.

CHAPTER III

PROJECT HARDWARE

This chapter will discuss about designing process of robot chassis. Then there will be explanation of the materials used in this project, dimension of the parts of the robot and the gripper mechanism. There will be specification of Cytron C36S servo motor that was used as the actuators for the robot. The important component in the circuit that control the robot will be explain at the latter part of this chapter.

3.1 DESIGN OF ROBOT CHASSIS

Planning is very important before doing anything. This means plan out everything, such as what material to build the robot out of, where to put every screw, how to you will attach the servos and others. This will save money and time, and will have a better constructed robot too. To do this, all robot parts were drawn out to dimension, mark the holes, and understand how all the parts connect.

The fewer parts the robot has, and the simpler they are, there will have less things to design, make, and pay for. One thing that need to be considered when designing the parts is how these parts will actually be manufactured. Unnecessary or over complicated features were avoided to make sure it is not really hard to make. Fewer and simpler parts also mean a smaller chance for mistakes in the design.

At the early stage of designing, a few basic designs of the robot were made based on other robot arm project as in literature review. After comparing the designs that mainly based on material to use and the complexity of the mechanism, a layout of the robot arm were made

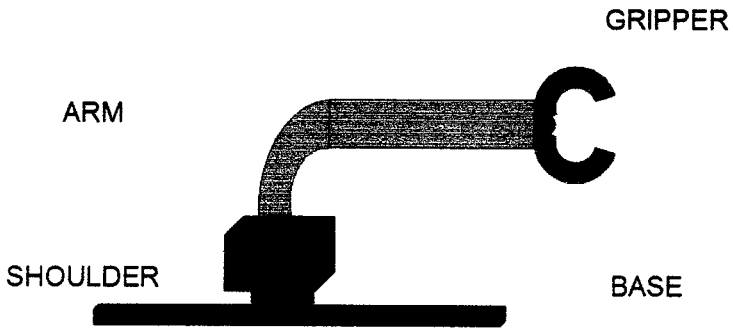

Figure 3.1 : The layout of robot arm

3.2 MATERIALS OF ROBOT CHASSIS

The robot use a few part from a lorry toy as the main part for the gripper and the arm. This is because the shape and size of those parts are suitable to be modified as a gripper and arm for this project. Building the gripper and arm from scratch will make this project harder and more complicated. It also does not cost too much and can save time too.

Plastic piece was used to built the base and servo mounter. This material was choose because it is cheap, light and have higher strength to weight ratio compare to metal. It also easy to fabricate such as cut, shape and drill. It usually used by advertising company to build signboard.

Aluminum was used to strengthen some part of the robot Although it is not as strong as steel, and rarely as cheap, it was choose over metal because aluminum has a much higher strength to weight ratio. This means that for a mass of aluminum and an equal mass of steel, aluminum would be much stronger.

Screws ands nuts were used to attach and tighten the robot chassis. This make the robot parts easier to be attach and disassemble for repairing and modifying.

3.3 THE ACTUATORS

In this project, servo motors were choose as the actuators of the robot because of their precision positioning that makes them ideal for robot arms such in this project. 3 Cytron C36S were used, each for gripper, shoulder and base of the robot. Actually servo motors are DC motors, only with built in gearing and feedback control loop circuitry.

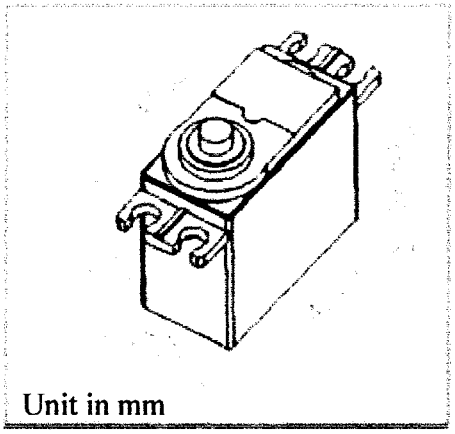

Figure 3.2 : Dimension of Cytron C36S servo motor

At 4.8V	Speed (s/60°)	0.16
	Torque (Kg.cm)	3.50
At 6V	Speed (s/60°)	0.14
	Torque (Kg.cm)	4.50
Gear Material		Plastic
Weight (g)		36

Table 3.1 : Specifications of Cytron C36S servo motor

To attach the servo motors to the robot chassis, plastic pieces were used as the mounter of the servos. The plastic pieces were cut according to the size of the servos and the location where the servos will be attached.

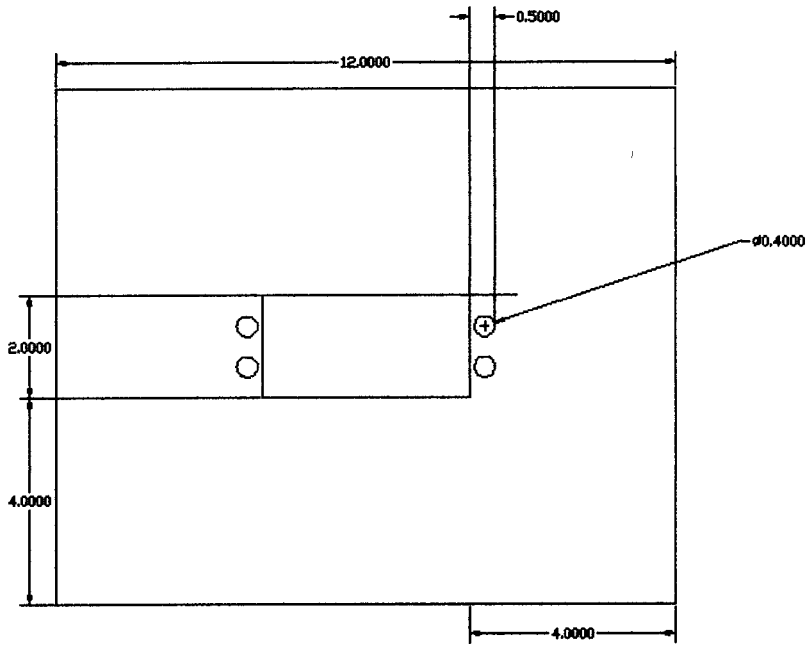

Figure 3.3 : Dimension of robot base

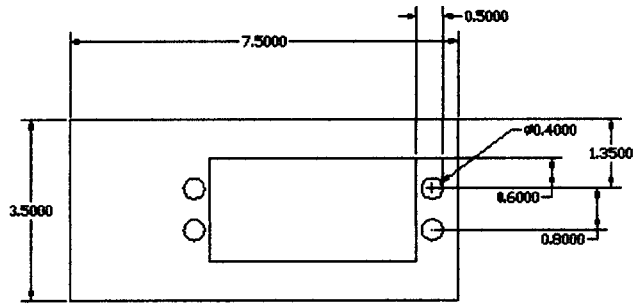

Figure 3.4 : Dimension of mounter for servo of gripper

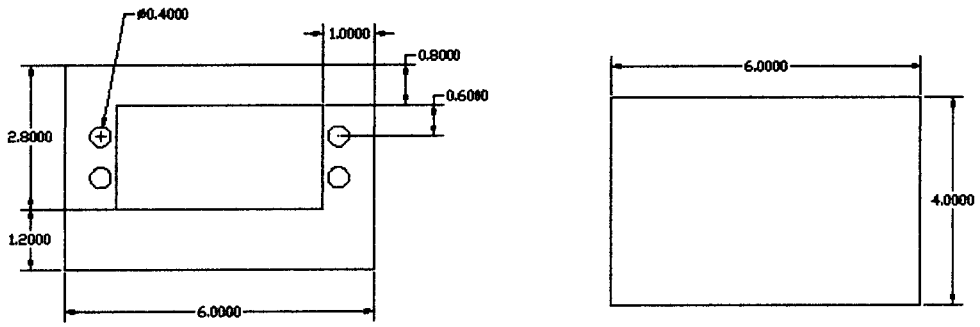

Figure 3.5 : Dimension of mounter for servo of robot's shoulder

(Note : All units are in mm)

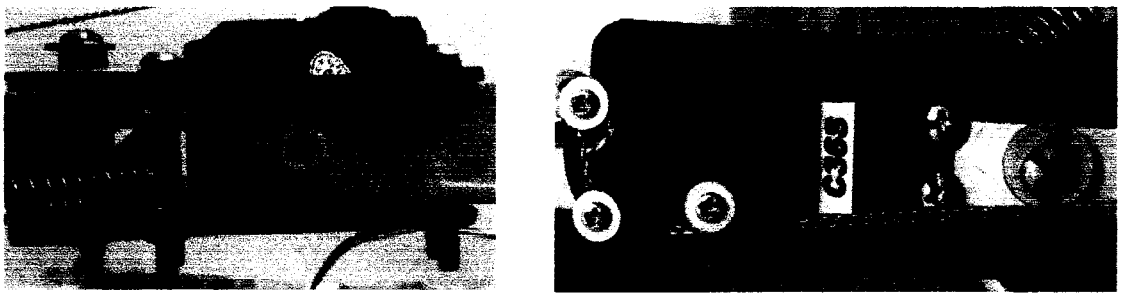

Figure 3.6 : Servo for gripper

Figure 3.7 : Servo motor for robot's shoulder

3.4 THE ARM

The arm chassis were made from a part of lorry toy. It were choose for the arm part because of its light weight and its shape that make the process to mount the servo for gripper easier. The arm contains 2 identical part that were put side by side to make the arm stronger. Short metal spacers were screwed between those part to strengthen it.

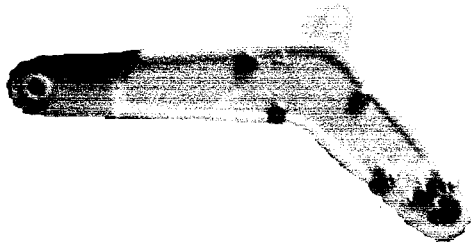

Figure 3.8 : The arm of robot

3.5 GRIPPER MECHANISM

Same as the arm, the gripper also use parts of lorry toy as the main part. Servo motor was used to pull a wire that attached to the gripper part. when the servo turns clockwise, the gripper will open. A pair of springs were used to counter the movement of the gripper that caused by the servo. Each were put at both side of the gripper. That will help to open the gripper when the servo turns to counter-clockwise. A piece of magic mat that usually used on car dashboard was glued to both end of the gripper. This to increase the grip of the gripper to object that would be pick later.

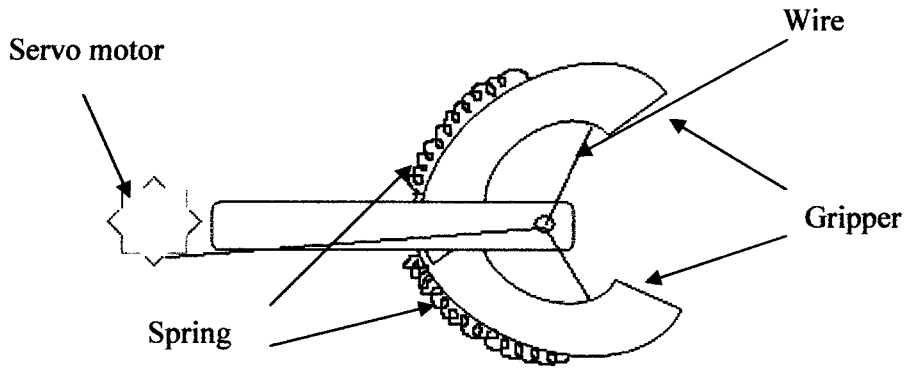

Figure 3.9 : Layout of gripper

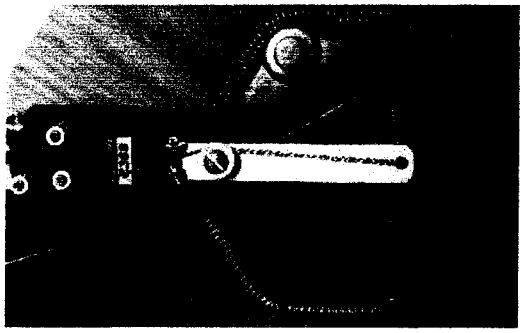

Figure 3.10 : The mechanism of gripper

3.6 PROGRAMMING AND RUNNING CIRCUIT

By using this circuit, both programming and running process of microcontroller can be done on the same circuit without moving the PIC. This circuit only use 5 volt of DC to operate. To program a PIC, this circuit can be connected to computer via Universal Serial Bus (USB).

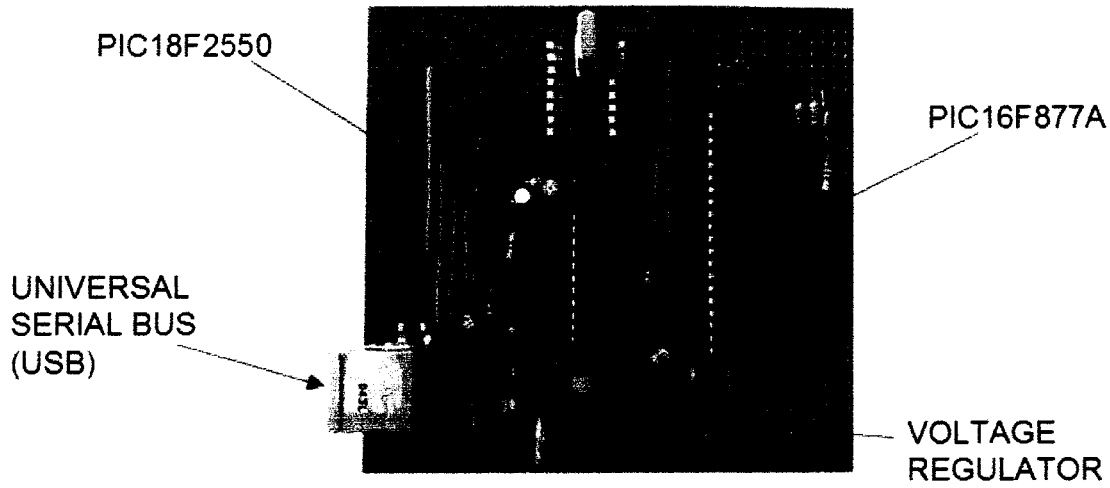

Figure 3.11 : PIC microcontroller programming and running circuit

The PIC18F2550 is functioning as an interface between the circuit and computer. When programming a microcontroller, the circuit can use power from the computer via USB to operate. When the circuit are in running mode and did not connected to computer, the circuit need external power source to operate such as battery. The LM7805 voltage regulator can regulate voltage ranging from 9 to 15 volt and produce 5 volt as the output for the operational of the circuit. 2 DIP switch are used to change the circuit mode from programming to running. PIC16F877A is the most important part in the circuit where all programs and instructions. It will execute the program by giving out 5V pulse to the servo motors art certain port that determined by the program. The schematic diagram of the circuit is shown at the next page.

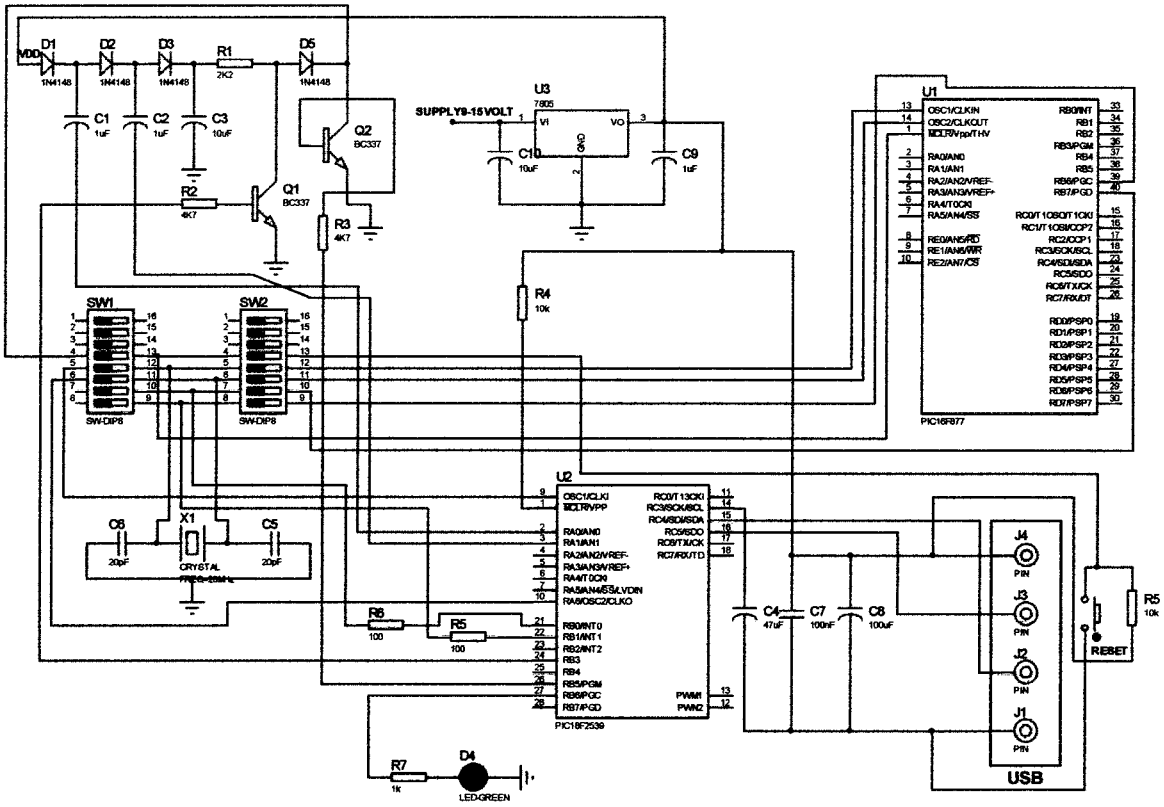

Figure 3.12 : Schematic diagram of programming and running circuit for microcontroller