SOLAR POWERED MICRO MOUSE

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A project report submitted in partial fulfilment of the requirements for the award of Bachelor of Engineering (Hons.) Electrical & Electronic Engineering

Faculty of Engineering and Science
Universiti Tunku Abdul Rahman

September 2012

DECLARATION

I hereby declare that this project report is based on my original work except for citations and quotations which have been duly acknowledged. I also declare that it has not been previously and concurrently submitted for any other degree or award at UTAR or other institutions.

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APPROVAL FOR SUBMISSION

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Specially dedicated to

my beloved family, lecturer, friends and those who have guided and inspired me throughout my journey of education

ACKNOWLEDGEMENTS

I would like to thank everyone who had contributed to the successful completion of this project. I would like to dedicate my deepest appreciation to my research supervisor, Dr Balamuralithara A/L Balakrishnan for his invaluable advice, guidance, encouragement, critics, friendship and his enormous patience throughout the development of the research.

In addition, I would also like to express my gratitude to my loving parents for their moral support, love and encouragement given to me. I would also like to extend my gratitude to my housemates and friends for their continuous moral support throughout the research. Finally thanks to God, His blessing made it possible for the completion of my research and more importantly my undergraduate degree.

SOLAR POWERED MICRO MOUSE

ABSTRACT

The micro mouse, also called a small autonomous mobile robot, which the goal is to navigate through an unknown maze and locate the centre. The overall capability of micro mouse are judged by the time it takes them to locate the centre. In this project, the Solar Powered Micro Mouse is developed to run using solar energy as its primary source to solve the maze. The components that are being used in this project are power, sensors, control, and drive train. The power system consists of 3 solar panels and a rechargeable battery pack in the circuit. The sensors are the means through which the micro mouse detects walls and traverses the maze with proper alignment in the centre of a pathway. The drive train includes the motors and motor controller, which produce the motion of the robot. The control unit is responsible for controlling each of the other components. Finally, a modified wall following algorithm has been developed to enable the micro mouse locate the centre of the maze, which is the main aim of this project. Each of these parts in the project has undergone a thorough process of design, analysis and component selection. The micro mouse is developed to be powered by solar energy, which can be improved to solve unmanned tasks in future. A Solar Powered Micro Mouse has been successfully built based on the initial design, meeting the objectives of this project.

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LIST OF SYMBOLS / ABBREVIATIONS

PCB – Printed Circuit Board

PWM – Pulse Width Modulator

MOSFET – Metal-Oxide-Semiconductor Field-Effect Transistor

EMI – Electromagnetic Interference

SMD – Surface Mount Device

IEEE – Institute of Electrical and Electronics Engineers

US – United States

IR – Infrared

DC – Direct Current

AC – Alternating Current

PIC – Peripheral Interface Controller

USA – United States of America

CCD – Charge-Coupled Device (type of image sensor)

UK – United Kingdom

Ni-MH – Nickel-Metal Hydride

Ni-Cad – Nickel-Cadmium

RC – Resistance-Capacitance

PN –Positive Negative Junction

DPDT – Double Pole Double Throw

SPST – Single Pole, Single Throw

EEPROM – Electrically Eraseable Programmable Read Only Memories

Vss – Voltage Source Source

LCD – Liquid Crystal Display

Vdd – Voltage Drain Drain

Vcc – Voltage Collector Collector

k – Kilo

μ – Micro

LED – Light-Emitting Diode

m – Mili

CMOS – Complementary Metal Oxide Semiconductor

p – Pico

F – Farad

A – Ampere

V – Voltage

W – Watt

Wh – Watt per hour

BJT – Bipolar Junction Transistor

RDS – Resistance Drain Source

EMF – Electromagnetic Field

NPN – Negative - Positive - Negative

IC – Integrated Circuit

MCUs – Microcontroller Unit

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Introduction

Autonomous robots have wide reaching applications, from bomb sniffing to find humans in wreckage to human automation. For many years, engineers have been facing power and reliable sensing mechanism problems in unfamiliar terrains robotic competitions which have inspired in the development of new technology to overcome those issues. Competitions are being held all around the world based on autonomous robots. One of the competitions with the richest history is the micro mouse. In May 1977, the micro mouse was introduced to the world. IEEE Spectrum Magazine came up with the concept of a self-contained robot that navigates through a complicated maze (IEEE Micromouse Competition Rules, 2007).

The micro mouse competition has now become a famous event which is held in different colleges around the world. The same rules applied at each event. Contestants are given 15 minutes to solve the maze by using the micro mouse to locate the centre. Little is known about the maze before the competition begins. The maze is a squared shaped; 12 feet x 6 feet element structure where each element is 30 cm x 30 cm. The side of the walls are painted white and the top of the wall is red. The dimensions of the walls are 10 cm high and 1.3 cm thick. This gives a 28.8 cm x 28.8 cm passageway between the walls. The final destination is the centre of the maze and the initial point is from any one of the four corners. Specifications are also placed on the robot. It must be self-contained and the dimension of the robot must not be larger than 30 cm x 30 cm. There is no height or weight restriction. These basic rules are the foundations for the competition (IEEE Micromouse Competition Rules, 2007).

1.2 Problem Statement

There are many problems that arouse in building the Solar Powered Micro Mouse. Previously, from 1972 to 2006, a problem that frequently appeared in the construction of a micro mouse was for it being too big, with some even reaching the height of 50 cm. Size does matters in a micro mouse. The smaller the micro mouse is, the faster the mobility of the micro mouse will be. The lower the point of gravity, the more stable the micro mouse will be. A micro mouse has to be fit in a 30 cm x 30 cm maze. The height is not fixed since when the shorter the mouse, the more stable it is to move. In order to solve this problem, proper designing of the circuits should be used. The circuits should be able to work and all necessary components should be compact within a circuit.

The other major problem aroused is in the power supply system. The micro mouse requires a lot of current which alkaline batteries could not provide in the required current for a long time. In order to solve this problem, renewable energy such as wind energy or solar energy has to be considered in this project. Solar energy is more preferable because it is not possible to build wind energy in a micro mouse as it requires a turbine. Solar panels are cheap for smaller scale design and it supplies the micro mouse with sufficient power. Furthermore, the introduction of rechargeable battery in this project will enable the storage of energy from the solar panel. In this case, the micro mouse will be able to work in the dark as well.

1.3 Project Aim and Objectives

Aim

The aim of this project is to design a self-contained, autonomous, solar powered vehicle called as ‘Solar Powered Micro Mouse’, which will be able to navigate through a path to the centre of the maze.

Objectives

These are the main objectives of the Solar Powered Micro Mouse:

- To design a solar panel circuit to obtain the solar energy as the power source for this project.
- To design a motor control circuit by using power devices to control the motors.
- To develop a software for the microcontroller to analyse and find a way to the centre of the maze autonomously.
- To design a maze for the Solar Powered Micro Mouse.
- To determine the movement of Solar Powered Micro Mouse without collision between walls in the maze.

1.4 Project Outline

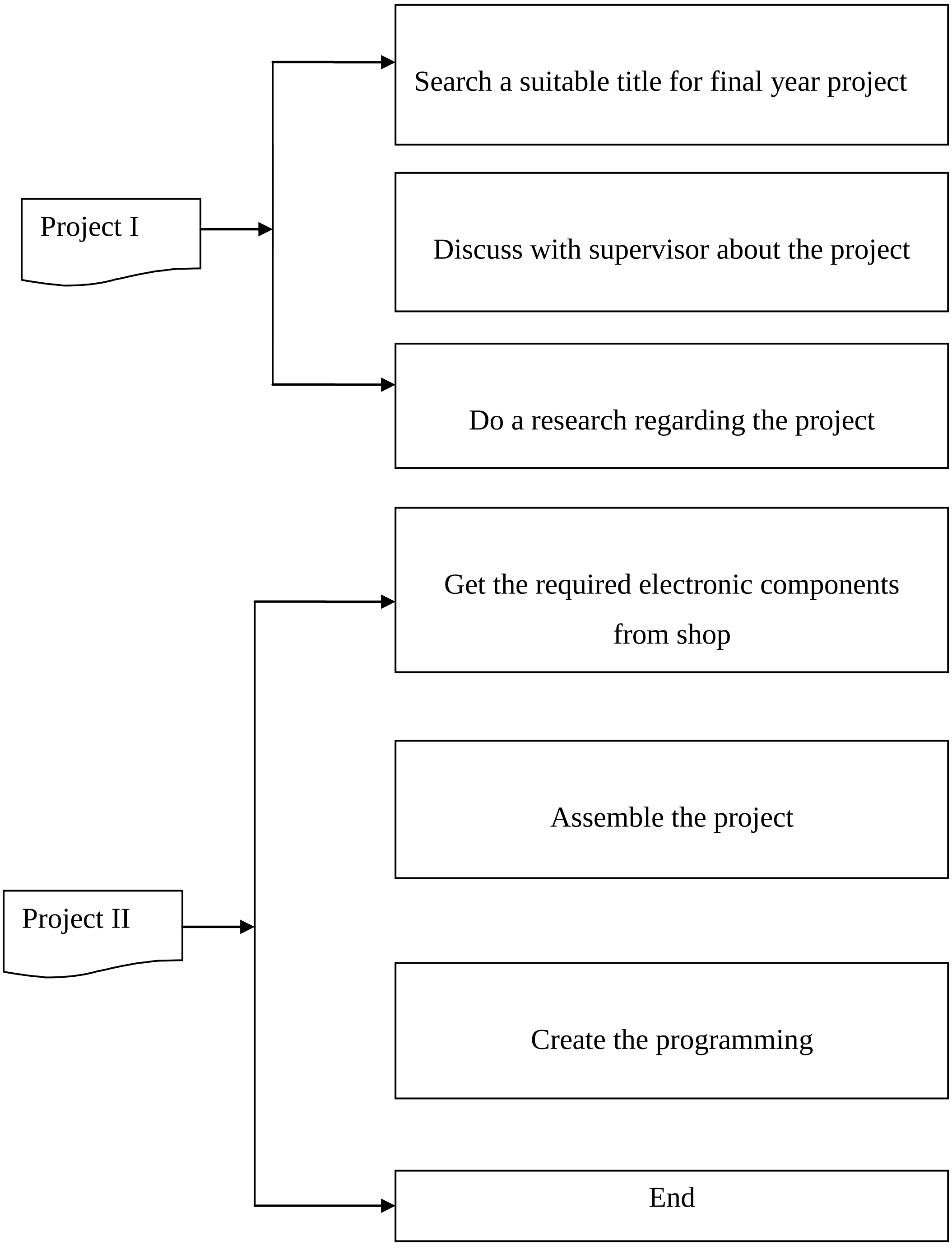


Figure 1.1: Flowchart of the Whole Planning for Project I & II

1.5 Project Overview and Expected Outcome

Solar Powered Micro Mouse is an intelligent autonomous robot which solves maze by using solar energy as its power supply. It uses microcontroller for processing and sensors to detect obstacles. A wooden maze is made up of 6 x 6 grids of cells and the micro mouse must find its way from a predetermined starting position to the central area of the maze. The following diagram shows the physical design sketch which is the outcome for this project.

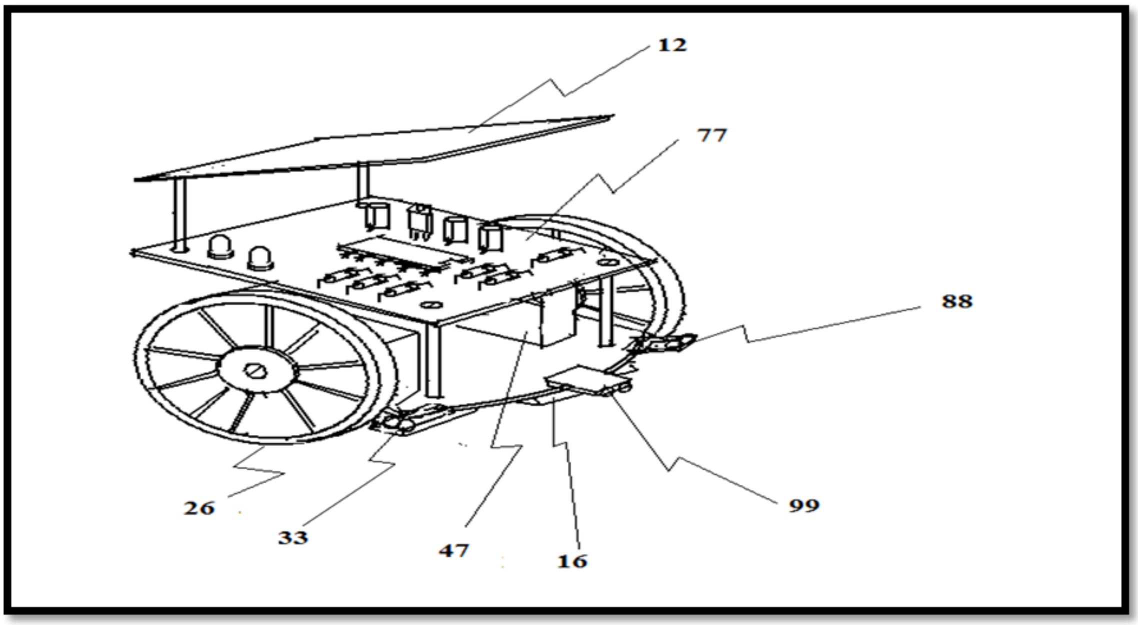


Figure 1.2: The Sketch of Micro Mouse

Figure 1.2 shows a sketch of micro mouse. As seen in Figure 1.2, the mouse comprises a set of wheels (26), side IR sensors (33) (88), a front IR sensor (99), a line sensor (16), DC motors (47), a control board (77) and solar panels (12).

The operation of the said Figure 1.2 begins when said (12) receives solar energy that will be used to charge the battery. When the said Figure 1.2 is moving, its direction is automatically controlled by (33), (99) and (88). The bottom (16) functions as line detection. As long as the line is detected, the robot can move accordingly.

1.6 Thesis Outline

This report consists of five chapters; it contains information from initial motivation for the project until the intended design aspect of the Solar Powered Micro Mouse.

Chapter 1 illustrates the project collective methods. It presents the background information necessary for the reader to gain a proper understanding of the reasons behind the perusal of this project. It also explains about the problem statement, overview and the objectives of the project.

Chapter 2 explains about the literature review which discusses the theoretical aspects leading to the implementation of the project. This involves the basic idea of this project. This chapter also presents about basic concepts of software that is used in this project.

Chapter 3 contain detailed descriptions on the techniques used where it explains clearly about the block diagram and so on. The design and implementation of the components in this project and project evaluation of hardware explains more about the hardware to be built in this project as well as the software used to design the circuit and PCB design.

Chapter 4 summaries the final result obtained from the project problems encountered. This chapter also discusses about the critical analysis and the alterations of some of the components in this project.

Chapter 5 is the final chapter that explains the conclusion for the project besides a several suggestions to increase the capability of the system of the project.

CHAPTER 2

LITERATURE REVIEW

2.1 Micro Mouse History

The first mechanical micro mouse was designed in 1972 which appeared in a magazine entitled " Machine Design " which sponsored a contest to see the mouse stamina by spring-powered mechanism against another mouse by travelling in the longest distance down the track. The winner of the contest was the "mouse mobile" which was the one that travelled up to 825.3 feet (Le Mouse 5000, 1972).

The concept of Micro Mouse by using microprocessor-controller was revealed in 1977 by the IEEE Spectrum magazine. The mouse was able to decipher and navigate a complicated maze because it is imbued with the intelligence. The Spectrum announced the first US Amazing Micro Mouse Maze Contest in May 1977, which dated in June 1979, at New York. Surprisingly just only 15 micro mice competed out of 6000 entries received. This was due to common problems such as "brain failure" and other claimant being the mouse to "blow-up". In addition, the competition get tougher as the interest in the design and construction of an intelligent micro mouse has spiked than what most people would have imagined (Micromouseonline, 2010).

At Euro mice 80's century, the European version of such contest was launched at the Euro mice '80 in London, but unfortunately none of the 18 micro mice was able to solve the maze. The first All-Japan Micro Mouse Contest was launched in Japan by the spectators that were from the Japan Education and Science.

They took the rules back to Tokyo and subsequently organised the contest (Sunshines, 2010).

The history continues as in August 1985, in Tsukuba, Japan, which was where the First World Micro Mouse Contest was held. Since all of the Micro mouse came from all over the western countries such as from Europe and the USA, it have been employed with sensors ranging from infra-red to ultrasonic to CCD, and driving mechanisms from stepper motors to DC servo motors. Even so, every top prizes were seized by the micro mice from Japan with Noriko-1emerging as the world champion (Micromouseonline, 2010).

The Institution of Electrical Engineers held another World Micro Mouse Championship, in London on 1987; with exactly 13 micro mice competed for top place honours. The winner of the competition was David Otten from the Massachusetts Institution of Technology (MIT), USA. He won the first and second prizes with his two entries, by the name of the mouse Mitee Mouse I and Mitee Mouse II. On top of that, a new system of scoring was also implied, designed to reward the intelligence, efficiency of maze-solving and self-reliance of the micro mouse (Micromouseonline, 2010).

Unbelievably, a Singaporean team won in July 1989 from the 2nd Singapore Micro Mouse Contest which was held in London. The best part is that the Singapore entries clinched 6 of the top 8 prizes in the contest. Sadly, David Otten's Mitee Mouse III was relegated to 2nd place whereas Enterprise from UK took the 5th place (Sunshines, 2010).

Since the initial US contest which was organised in 1977, there has been no turning back. Not only does the micro mouse get smarter and smarter from year to year, but so does the maze designers (Sunshines, 2010).

2.2 Literature Review

The Solar Powered Micro Mouse has one main advantage compared to the rest of the micro mouse created; it uses solar power as a renewable energy. There has never been a Micro Mouse that was created or used in any IEEE competition by using any sorts of natural renewable energy. In support of the Global Green Campaign, solar panels have been installed to charge up the rechargeable batteries.

The motors chosen for the Solar Powered Micro Mouse is DC geared motor. It gives a faster speed and also stability to the robot compared to stepper motor. Besides that, DC motor is much smaller and thus it fits well into the robot chassis. The usage of stepper motor will have to include a separate circuit to send pulses to the motor. In other words, a stepper motor requires a large amount of space and a bigger chassis. Micro Mouse Edgar in year 2006 as shown in Figure 2.1 uses stepper motor as its mobility drive. The usage of stepper motor in robot Edgar has also made it a very high power consumption robot. However, it does not support the Global Green Campaign. It requires up to 12 AA batteries with each giving out 1.5 V. Fitting 12 AA batteries does not only make the structure of the robot to be big but it also makes it too compact, by not allowing heat to disperse into the environment as there is no proper air flow within the robot. This will only put the robot into the risk of short circuit. Finally, the robot will look unorganized and the motor will not be able to move as fast as it requires since it needs proper current controlled drivers (Edgar, 2006).

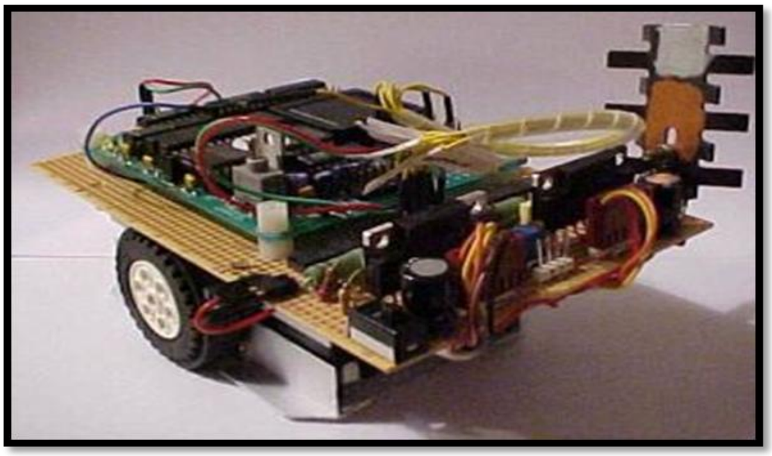


Figure 2.1: Micro Mouse Edgar (Edgar, 2006)

The first micro mouse as shown Figure 2.2 was created by Johan de Boer. The name of the micro mouse was Cybernetic Mouse. It was created around 1968. Its driven system works like a car. Two servo motor are used in this mouse. One servo motor is placed below the body, connecting a wheel at each end. This means the back wheels are stagnant and only moves forward. The other servo is placed in the front wheel, working as a steering wheel. This only allows the robot to turn at a very large angle. The body of the mouse is connected with bumper sensors to send signals to the microcontroller if there is collision. This means the robot has 80 percent chances of colliding with the maze (Boer, 1968).

The robot doesn’t have any algorithm so it uses two sensitive cells that direct the robot to the centre of the maze which has a light bulb connected to it. The robot moves around the maze according to the level of light sensitivity it receives from the light bulb. This robot can only work in a room with very less ambient light as ambient light can disrupt the light sensitivity it receives, giving wrong information to the robot. The Solar Powered Micro Mouse has many advantages compared to Cybernetics Mouse. Firstly, Solar Powered Micro Mouse uses DC motor which is faster than the servo motor. Solar Powered Micro Mouse has two DC motors that are connected to two wheels and two castors to support the front and back (Boer, 1968).

The turning angle of Solar Powered Micro Mouse is very small compared to Cybernetics Mouse. It’s forward, right, left and u-turn movements are all controlled by a motor controller circuit. Solar Powered Micro Mouse uses infrared sensors as eyes to direct the robot to the centre of the maze. The infrared sensors are placed at the front, left and right. The sensors will detect if there is a wall blocking the path of the micro mouse before the micro mouse bumped into the maze. This results in zero collision. Solar Powered Micro Mouse operates based on an algorithm. The usage of any transmitter is not necessary so that the mouse could find the centre of the maze autonomously (Boer, 1968).

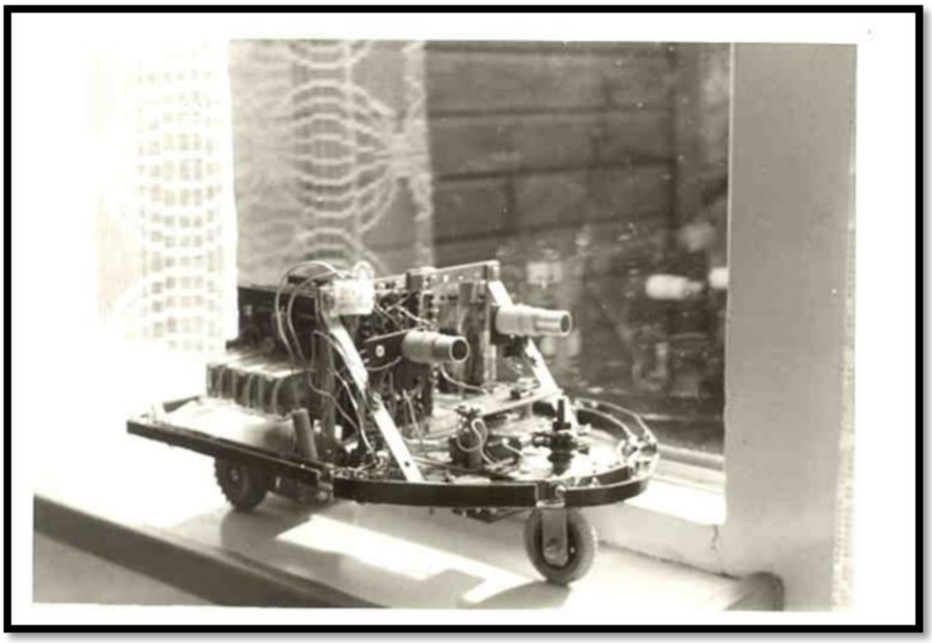


Figure 2.2: Cybernetic Mouse (Boer, 1968)

In 1982, David Buckley who is one of the famous scientists in the field of Robotics has created a micro mouse called Quester as shown in Figure 2.3. Quester is a better robot than Cybernetics Mouse. It runs on 6V DC motor. It also has bumped sensors only as back up sensors. Its major sensors are 12 phototransistors for obstacle detection and ultrasonic transducers for range finding. The program that was created for Quester is not of a complex program. The robot is able to start, go forward and backward, turn through various angles, approach an obstacle and stop at a given distance. This robot will not able to solve any maze as it does not use any algorithm whereas the Solar Powered Micro Mouse uses a modified wall following algorithm to move through the maze (Buckley, 1982).

Figure 2.3: Micro Mouse Quester (Buckley, 1982)

In 1979, Arthur Boland created the first micro mouse that was able to solve the maze. In his time, he has created three micro mice, Moonlight Special, Moonlight Express and Moonlight Flash as shown in Figure 2.4. All three mice use right wall hugger or right wall following algorithm. However, there are some trouble-shootings whereby the mouse could not execute the algorithm perfectly. Thus, the robot takes a lot of time to solve the maze. Compared to Solar Powered Micro Mouse, the right wall following algorithm was modified giving preference to forward view instead of right view. This allows the mouse to solve the maze faster. Besides that, the Solar Powered Micro Mouse uses Ni-MH batteries instead of the batteries which were used by the Moonlight which was Ni-Cad batteries. Ni-MH batteries last longer, weighs lighter and most importantly provides more current rather than Ni-Cad batteries (Boland, 1979).

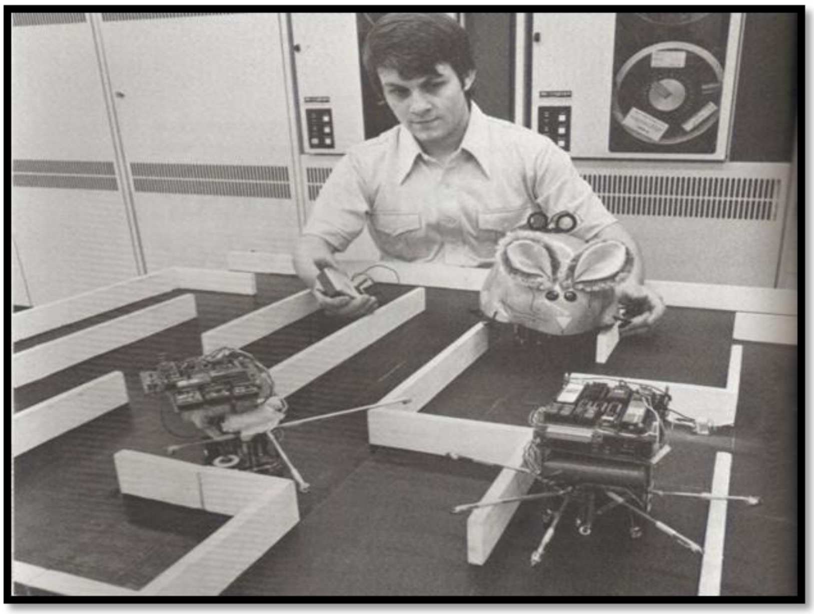


Figure 2.4: Micro Mice Moonlight Special, Moonlight Express and Moonlight Flash (Boland, 1979)

Rooter, a micro mouse maze solving robot of Figure 2.5 was created in 2006 by Bob Clough. It uses a stepper motor as its driving system. Stepper motor requires a lot more circuitry. A high power driver chip is needed, along with a method of sequencing the output. As size is very important in this project, having extra circuits is not an option. The Solar Powered Micro Mouse uses DC geared motor as its driving system. DC motors are much faster compared with stepper motors. Solar Powered Micro Mouse uses L293 and optocoupler as its switching devices. This will be explained more in Chapter 3 (Clough, 2006).

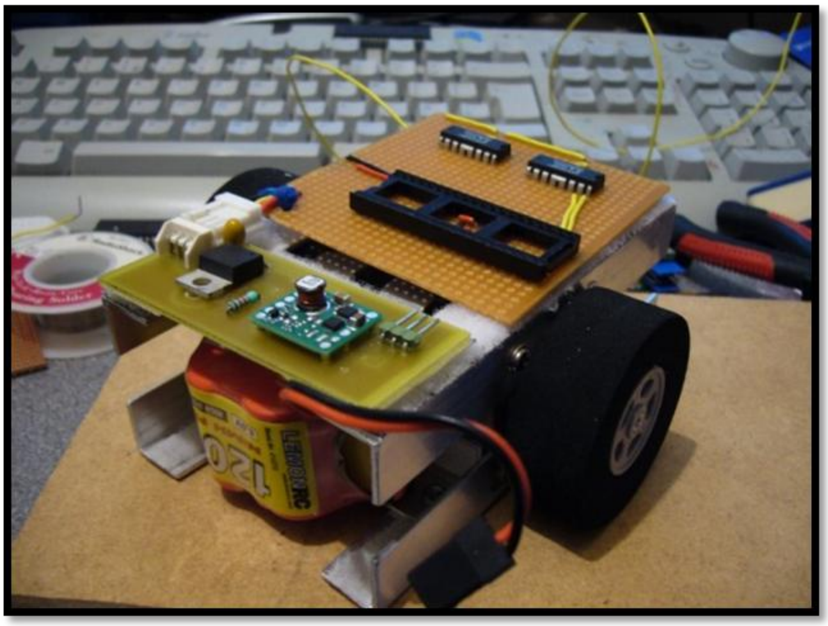


Figure 2.5: Micro Mouse Rooter (ThinkL33T , 2007)

In the year 2006, students from the University of Moratuwa created a wall following robot as shown in Figure 2.6. The robot uses an ultrasonic sensor to detect the obstacle in the front and bumper switches to give signal to the microcontroller if the robot hits the wall. The Solar Powered Micro Mouse uses IR sensors and it could detect the wall in the front, left and right. It is much cheaper and the wall collision is minimized compared to the wall following robot created by the students of University of Moratuwa (University of Moratuwa, 2006).

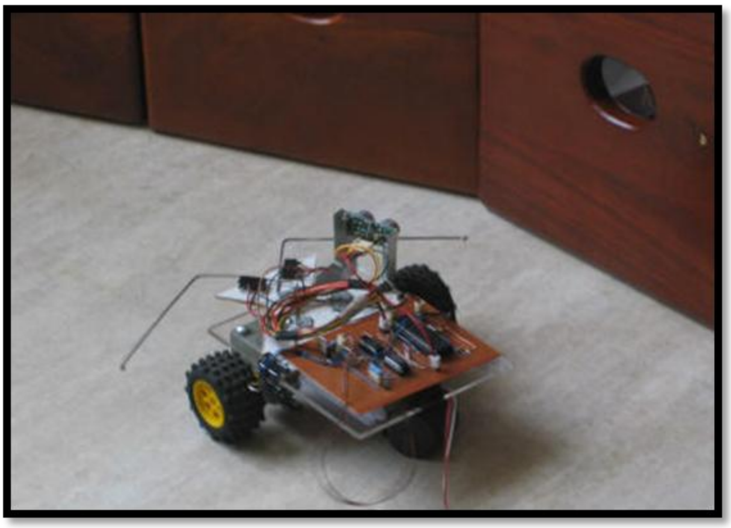


Figure 2.6: Wall Following Robot (University of Moratuwa, 2006)

2.3 Micro Mouse Algorithm

In many micro mice working system, there is always a sensor installed to prevent bumping of mouse to the obstacles. To control the micro mouse motion without hitting any obstacle, an algorithm design is very important. The algorithms that are analyzed in detail are Wall Following, Depth-First Search and Flood-Fill.

The source code to implement the algorithm can be in C or assembly language. No matter which language the system used, the basic control of algorithm should have read, write and making decision.

The read command is used to detect various signals from the sensors. Such signals can be analogue or digital. As such, in many microcontrollers there is a need to declare the signal either digital or analogue in the ADC ports.

The write command is used to send digital HIGH or LOW signals out to control external peripherals connected. These peripherals most properly are the DC motor. When the digital HIGH signal is send out, the DC motor will be activated. When the digital LOW signal is send out, the DC motor will stop working.

The decision making is used for compare the input read value with the pre-programmed value. Decision making is important to make the mouse robot turn left, right, move forward or backward.

The general algorithm for most of the micro mouse is shown in Figure 2.7. This algorithm is a basic algorithm that moves the mouse forward, turn left and right automatically without hitting an obstacle.

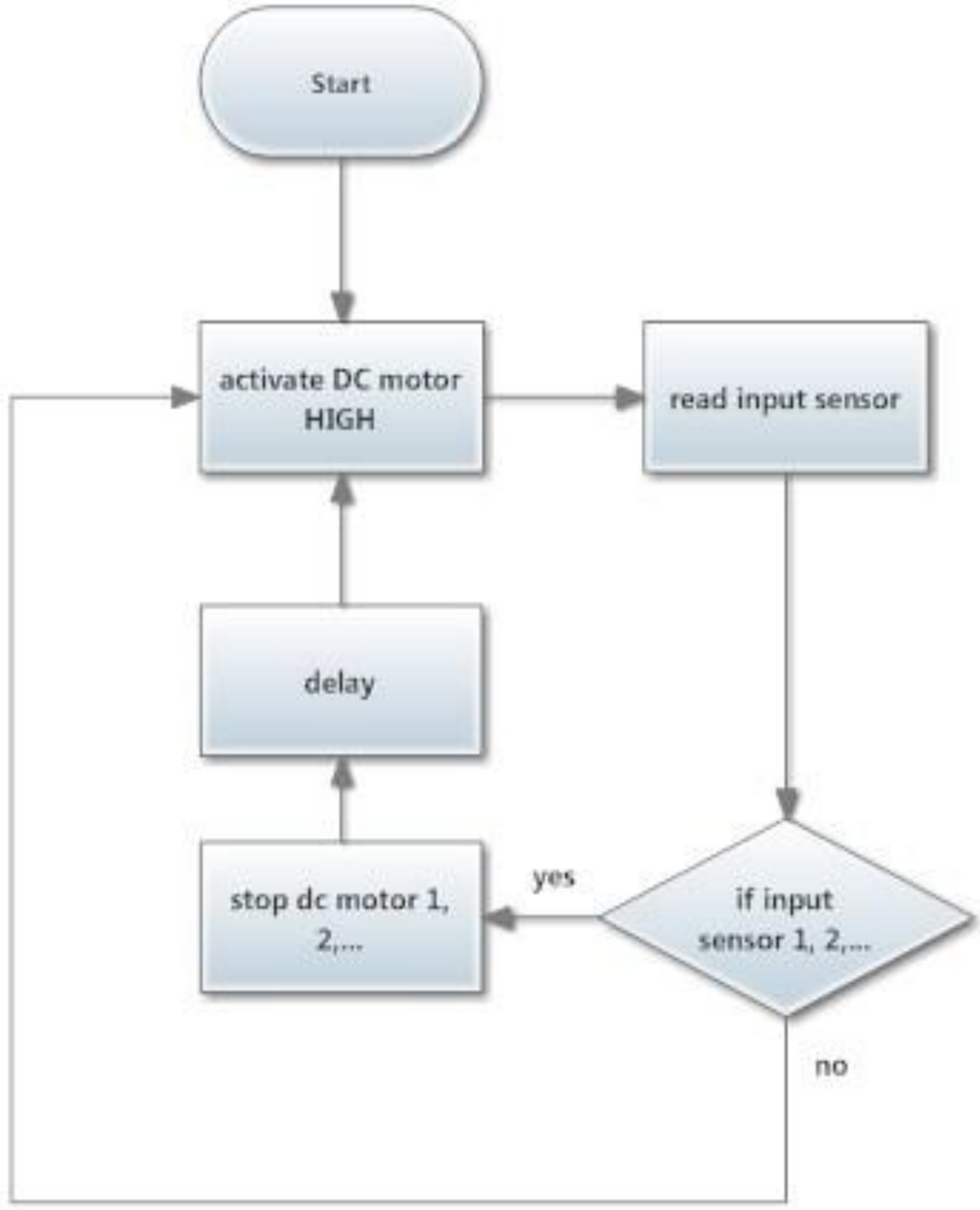


Figure 2.7: General Basic Algorithm for Micro Mouse Motion

From Figure 2.7, the infinite loop function is a “while”, “do” or “for” functions. These functions are in C language which causes the microcontroller continue reads and detect the input signals.

The reads command can have many and depends on the micro mouse design itself. All the read signal will be compared with the pre-programmed value in the “if” decision making function. The “if” function acts as logic function which response according to condition TRUE or NOT TRUE. If the condition in the “if” decision making is TRUE, the program will continue execute the next lines. Otherwise it will bypass the TRUE condition and jump to NOT TRUE which using “else if” function.

Apart from the decision making, the delay also plays an important role in the algorithm design. Delay can make the micro mouse motor stop and make decision on time. It also can control the mouse motion accurately turn left and right. Without delay, the micro mouse is hard to control its turning.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter presents the complete methodology on how the solar powered micro mouse is fabricated. The general methodology to complete the solar powered robot can be seen and summarized into a flow chart shown in Figure 3.1.

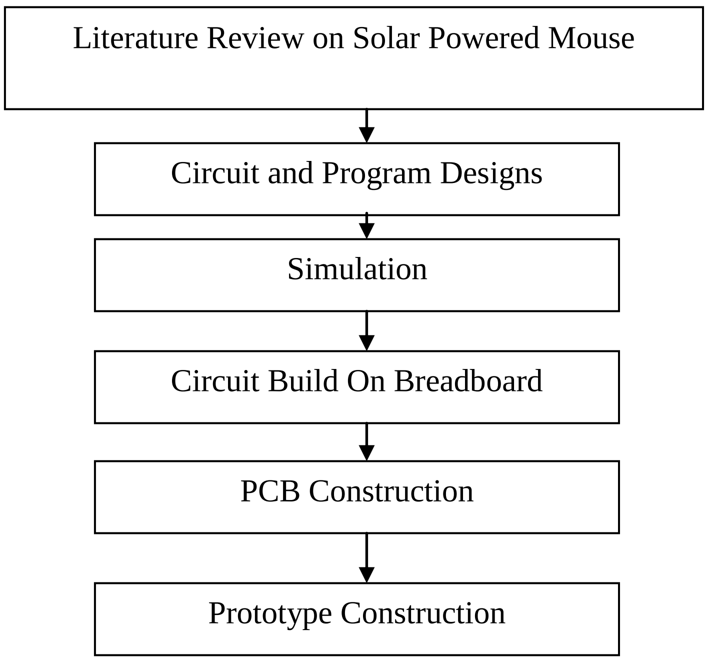


Figure 3.1: Summary on Methodology to Complete the Solar Powered Micro Mouse Project

In this whole project, literature review plays an important role to get started. Literature review enables the collection of information related with the project. Without enough information, a complete project cannot be achieved.

For this solar powered micro mouse project, the information was obtained from:

1. Internet
2. Textbooks
3. Conference paper
4. Journal
5. Advice from the experts
6. Guideline from lecturers
7. Past final year project report

Internet is a vast electronic library. Internet contains plenty of information that can be found which is related to micro mouse project. There are two powerful search engines, Google and Yahoo which are useful to seek information. However, the content of texts in this report was not plagiarized from the internet. Only pictures obtained from the internet were used in the report. References for each picture are recorded.

Textbook is another useful resource to look for information related with Solar Powered Micro Mouse especially on circuit explanation as well as the mathematical tools to describe the results. Many electronic and electrical textbooks found to have plenty of explanation on current flows, voltage drops and power consume in the circuit. Some equations such as Ohm's law and Kirchhoff's law were found useful to explain the current flows in the circuit. Other textbooks like calculus and statistic were useful to explain the results in mathematical form.

Conference and journal papers provide useful information which comprises up to current research works for Solar Powered Micro Mouse. These papers provide latest technology related information for the project. However, the disadvantage of conference and journal papers is that they do not provide much technical details in the design of the system.

Getting advice from experts regarding the technical design of the micro mouse project is also useful to obtain the relevant information. Robotic experts sometimes will show the guideline on how to build a robot. As from the experts in electronics, guidance in components used in the project is obtained.

Last but not least is the information source obtained from crucial past year's final year project report. Since micro mouse is not new in the scene, there were many universities and colleges by which the engineering students had come across it. Thus, there are a good number of brilliantly written documents regarding the project. Past final year project reports normally can be found in libraries or digital libraries. The following shows that digital libraries kept the past E&E final year project reports since year 1999 (Scott, 2008).

Once the information has been collected, studied and when the working principles have been understood, the next step of doing the project is to prepare a design of a circuit to control the mouse. The circuit is then tested by using either simulation or by constructing the circuit on breadboard.

Finally, PCB layout is designed and printed which is ready to make the PCB. PCB enables the circuit to firmly stick on the board and work in a stable mode.

3.2 Components Selection

Selecting the right component to build the control circuit is extremely important. Wrong selection of components may result in the robot not to move or damages other neighbouring components. This section presents some important components that are necessary to build a solar powered micro mouse.

3.2.1 Solar Panel

Figure 3.2: Solar Panel (Kyocera, 2012)

Table 3.1: Technical information about the solar panel used in the project

Parameters	Technical information
Output power	1mW
Output voltage	12V
Output current	0.45mA
Size	10cm x 5cm
Weight	20g

Solar panel is the main component used to charge the battery of the micro mouse. The solar panel will be mounted on top of the micro mouse so that it can receive more solar energy. Typical specification of a solar panel includes it to be light in weight so it will not have much loading effect toward the mouse.

3.2.2 LM358 IC

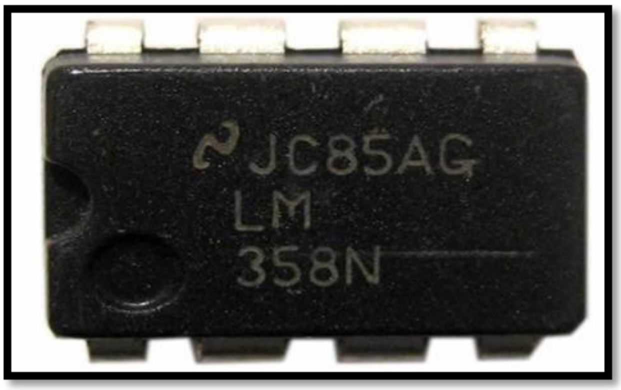


Figure 3.3: LM358 Op-amp IC (Freaklabs, 2012)

Table 3.2: Technical information about the LM358 IC

Parameters	Technical information
Operating voltage	± 5V DC
Maximum operating current	1A
Gain	120
No. of pins	8
Type	DIP Through hole
Maximum power dissipation	1W

The LM358 IC is an operational amplifier IC. This IC has 8 pins and it is mainly used to amplify a small signal. The IC normally reads the signal from sensor output and amplifies it before sending it to the next stage of the circuit.

3.2.3 4013N IC

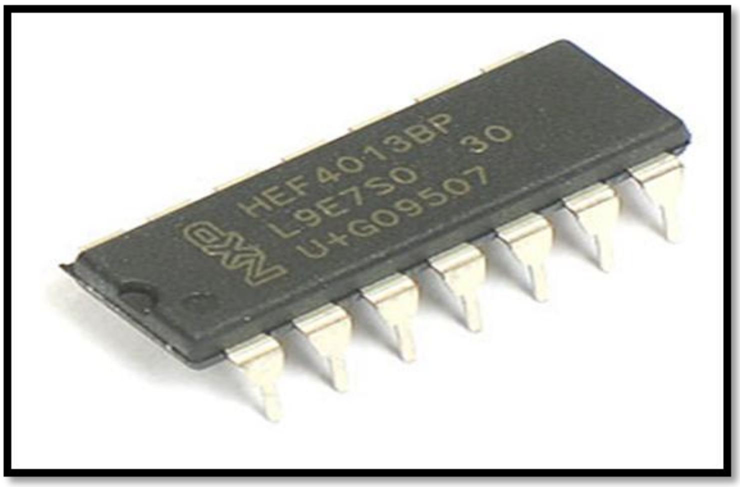


Figure 3.4: 4013IC (4013-IC, 2012)

Table 3.3: The technical information about 4013 IC

Parameters	Technical information
Operating voltage	5V ~ 12V DC
Current	1 – 1.5A
Power	1W
No. of pins	14

4013N IC is a dual D type flip-flop. This type of IC used in the project is to charge the battery. The reason to use this IC is because it can control the charging rate by turning it ON and OFF. Typical IC can be seen in solar charger circuit.

3.2.4 IRF9530 MOSFET

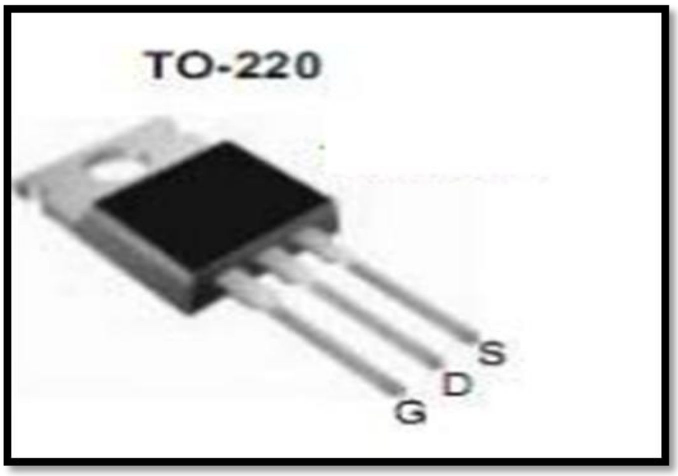


Figure 3.5: IRF9530 Power MOSFET (HEXFET, 2012)

Table 3.4: Technical information about the IRF9530

Parameters	Technical information
I_{DSS} maximum	20A
V_{GS}	-50V
Maximum power	3W
$Turn_{ON}$ time	5μs
Type	N channel

This IRF9530 is a power MOSFET. It is used in the solar charger circuit to draw a current so that it can charge higher rating of battery. The reason for choosing this MOSFET is that it can handle higher current and gives better control when charging the battery.

3.2.5 LM7805 Voltage Regulator

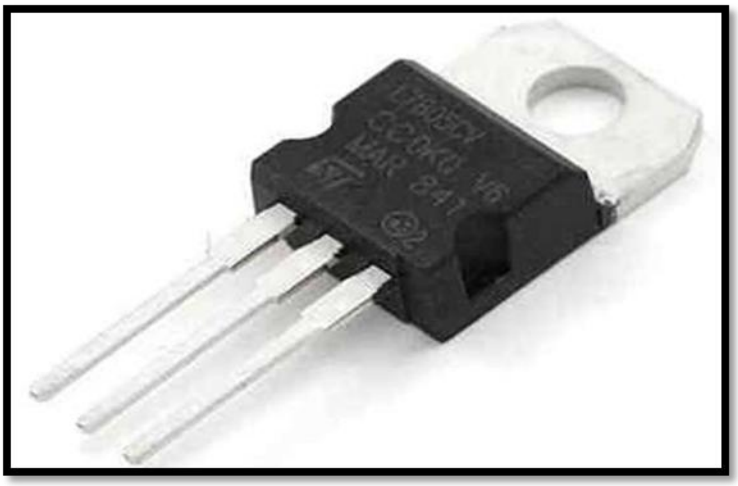


Figure 3.6: LM7805 Voltage Regulator (LM7805, 2012)

Table 3.5: Technical information about the LM7805 voltage regulator

Parameters	Technical information
Maximum power rating	1W
Maximum current	1.5A
Minimum input voltage	5V
Maximum input voltage	13V
Maximum output voltage	5V

A voltage regulator is used to reduce the higher voltage down to desired voltage level. For LM7805, it regulates the voltage down to 5V as the output. The output voltage is then supplied to other IC and microcontroller.

3.2.6 Transistor 2N3904

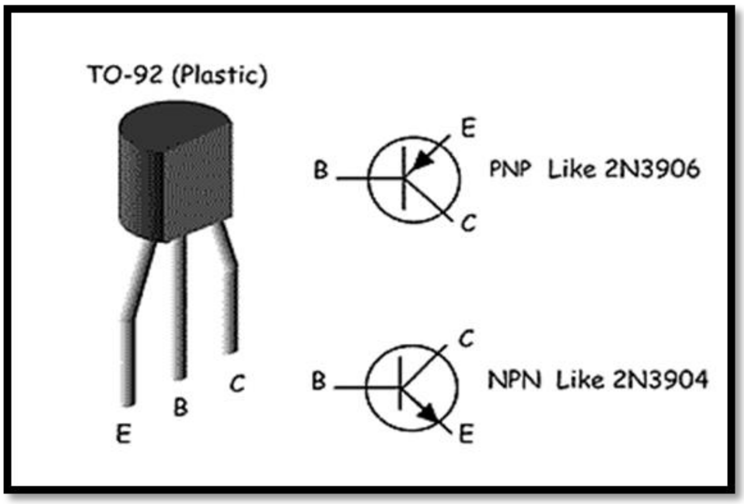


Figure 3.7: 2N3904 Transistor (2N3904, 2010)

Table 3.6: Technical information about the 2N3904 transistor

Parameters	Technical information
Vce	15V
Ic maximum	2A
I_B maximum	500μA
Vcc	20V
DC gain	40

The 2N3904 transistor is of NPN silicon type. It is used to amplify the collector current so that it can be used to control the MOSFET in the charger circuit. The reason for choosing this kind of transistor is to provide suitable current gain which will not bring the output voltage to go into saturation.

3.2.7 IR Transmit and Receive Sensors

(a) IR transmit sensor **(b) IR receive sensor**

Figure 3.8: IR Transmit and Receive Sensor (Kytron, 2011)

Table 3.7: Technical information about the IR transmit and receive sensor

Parameters	Technical information
Power dissipation	1mW
Maximum current	5mA
Maximum voltage	3.7V
Junction breakdown	5V

The IR sensor is an optical device used to sense an obstacle. The working principle is that when the transmit sensor sends the IR light, the receiver will detect the reflected IR light. If the IR light reflected can be detected, a HIGH voltage is produced at the receiving sensor. This indicates that an obstacle is detected.

3.2.8 PIC16F877A Microcontroller

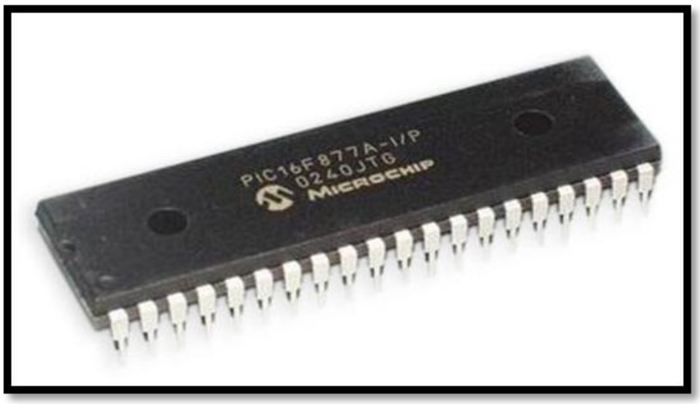


Figure 3.9: PIC16F877A Microcontroller (PIC16F877A, 2003)

Table 3.8: Technical information of PIC16F877A microcontroller

Parameters	Technical information
Package	40 pins
Number of bits	8
Operating voltage	5V DC
Operating current	0.5mA ~ 20mA
Number of PORTS	A, B, C, D, E
Operating clock frequency	DC ~ 20MHz
Memory	368kB

PIC16F877A microcontroller is used in the project to detect the IR signal and thus to make decision to control the motor in the wheel. PIC16F877A was chosen because of the following:

1. High memory
2. Low in cost
3. Available in the market
4. Stable in operation

3.2.9 L293 Motor Driver

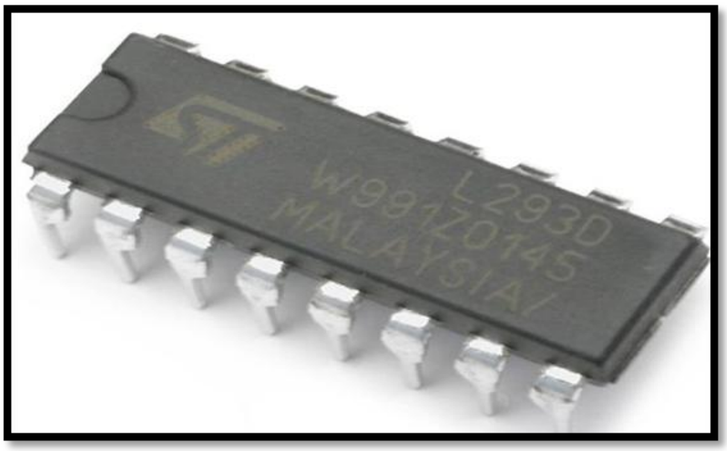


Figure 3.10: Motor Driver IC (L293, 2002)

Table 3.9: Technical information about L293D motor driver

Parameters	Technical information
Maximum current	2A
Maximum voltage	12V
Maximum power dissipation	1.5W
Breakdown current	> 2A
Control motor	Forward and reverse direction

Motor driver is very useful to control the motor turning direction. The turning of the motor can be done by reversing the pulse amplitude. Hence, the motor driver is only suitable to control the DC motor.

3.2.10 PC817 Optocoupler

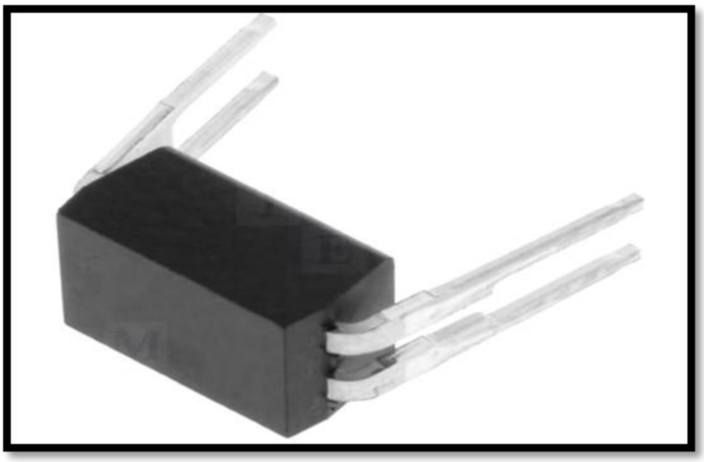


Figure 3.11: PC817 Optocoupler (PC817, 2012)

Table 3.10: Technical information about the Optocoupler

Parameters	Technical information
Maximum operating voltage	5V
Operating current	100mA
Power dissipation	1W

Optocoupler is used to isolate high current and low current circuit. It is mainly used to control the current in the DC motor.

3.2.11 DC Motor

Figure 3.12: DC Motor (DC Motor, 2012)

Table 3.11: Technical information of DC motor

Parameters	**Technical information**
Input voltage	12V
Operating current	1.5A
Power dissipation	0.6W

The DC motor will be used to run the robot. The DC motor is mounted on the two side of the wheel. The DC motor will be controlled by the microcontroller.

3.2.12 Line Following Sensor

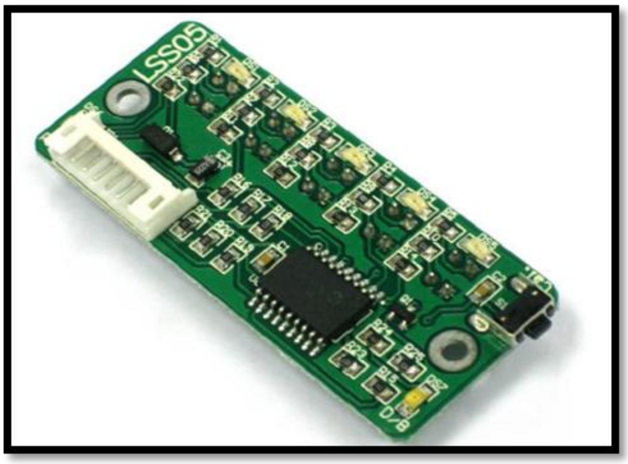


Figure 3.13: Line Sensor (Line Sensor, 2012)

Table 3.12: Technical information about the line sensor

Parameters	**Technical information**
Operating voltage	5V
Maximum current	20mA
Sensing distance	1 – 4cm

Line sensing sensor is used to sense the existing line on the floor. The robot movement and its ability to solve the maze depend on the line which is inside of the maze. When the line is sensed, the robot will auto adjust so that it always follows the line to the destination.

3.3 Design of the Solar Powered Micro Mouse

Figure 3.14 shows the technical block diagram for the solar powered mouse circuit design.

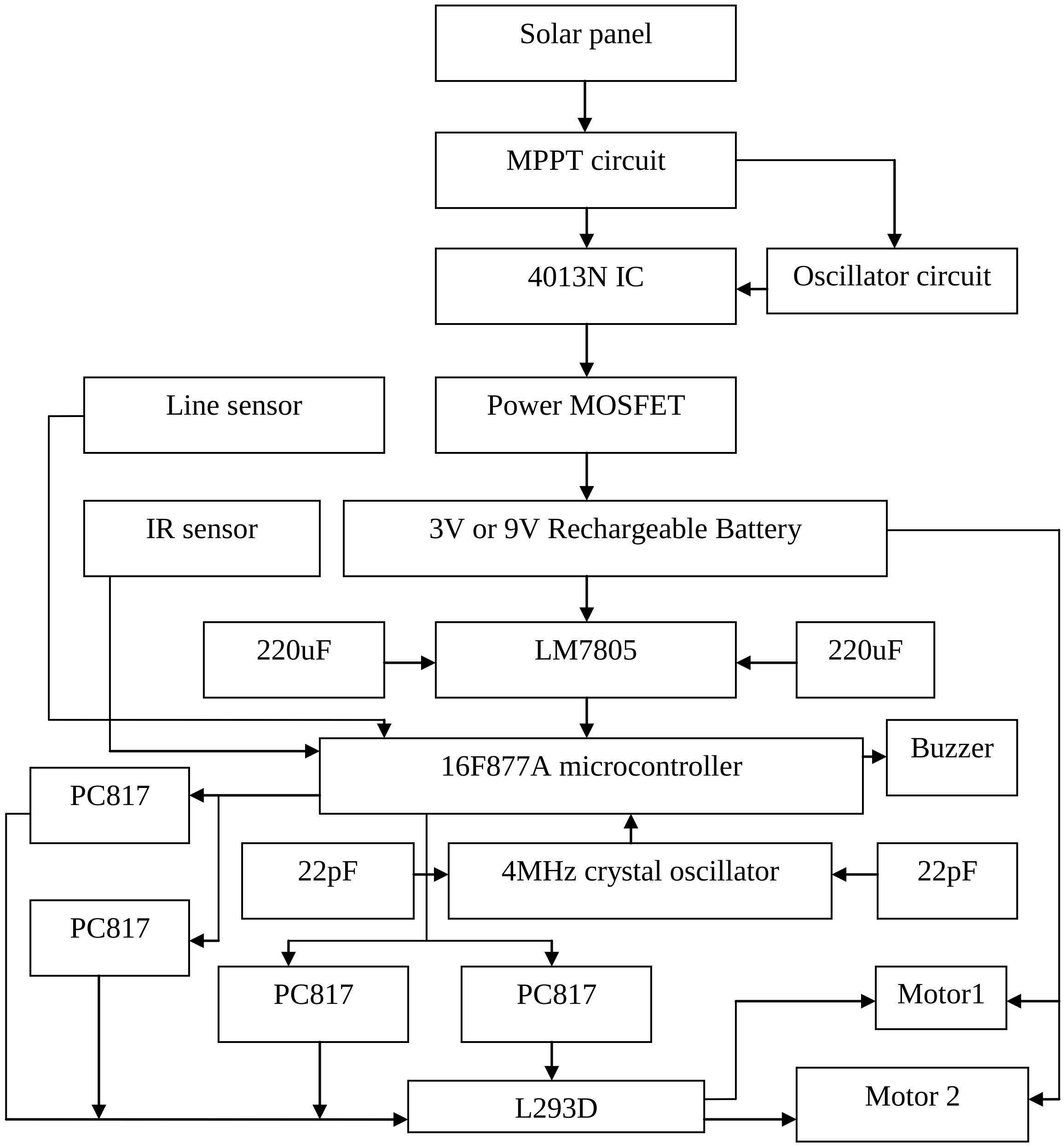


Figure 3.14: Design of the Solar Powered Micro Mouse Circuit

Figure 3.14 shows the complete block diagram designed for the solar powered micro mouse. As seen in Figure 3.14, the solar panel receives the solar energy and is converted into electrical energy to charge a rechargeable battery through a solar charger control circuit.

The solar charger control circuit consists of maximum power point tracking circuit (MPPT), 4013N IC, oscillator and power MOSFET.

The main component in MPPT is the regulator. It keeps a constant voltage at the output so that it can be used to charge the battery. The 4013N IC together with oscillator provides a charging rate control. The MOSFET controls the charging current so that it will not exceed to charge a battery and also prevents the battery current flows back to the charger.

Once the battery is charged, it is then used to power up the motor. The microcontroller used is PIC16F877A and it is supported by 4MHz crystal oscillator. The microcontroller will constantly read the input signals from the sensor and make decision to control DC motor 1 and 2. The control of DC motor was done using L293D motor driver as mentioned before.

In general, the micro mouse working mechanism for the entire project is shown below:

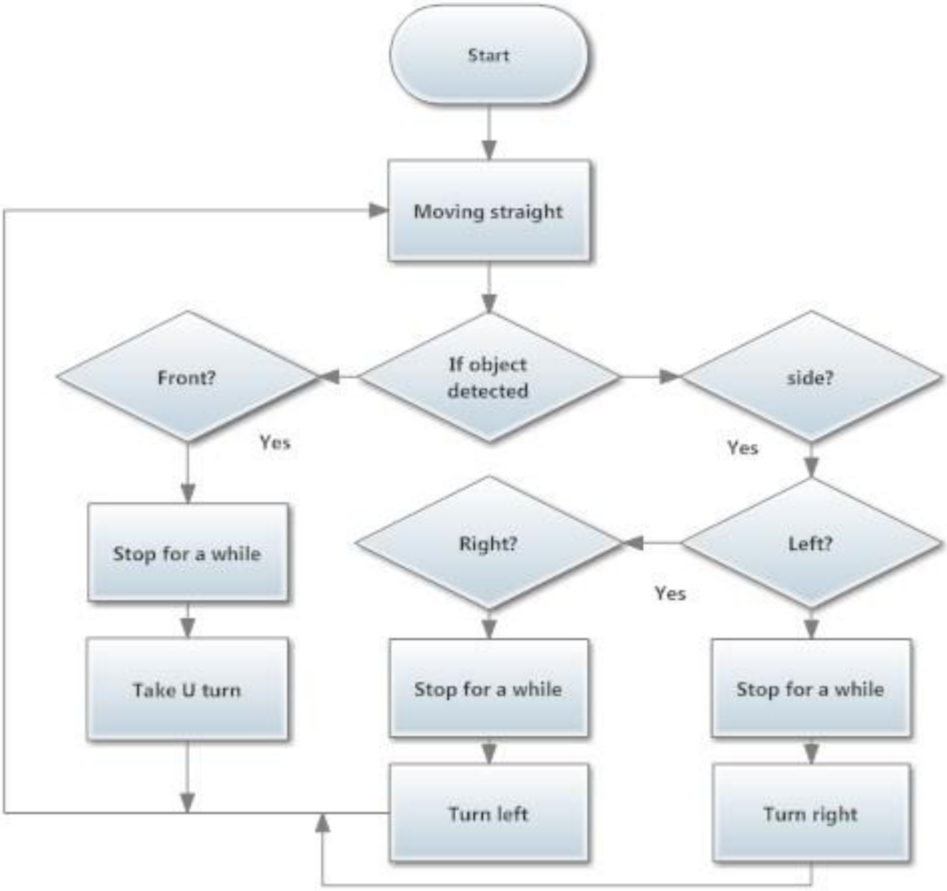


Figure 3.15: The Working Mechanism of the Micro Mouse

In case the micro mouse does not use solar energy, the battery can support operation of the micro mouse. Under this condition, the block diagram is shown in Figure 3.16.

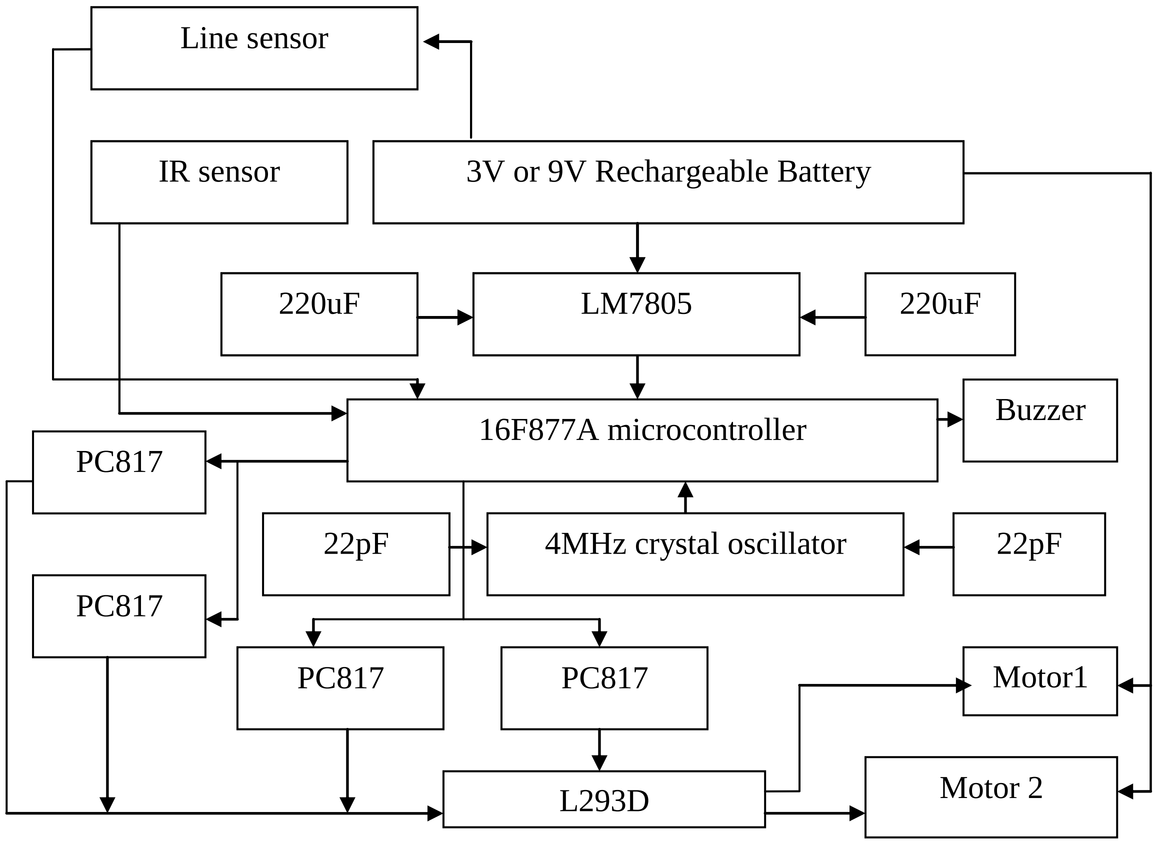


Figure 3.16: Operation of Micro Mouse without Using Solar Energy

From Figure 3.15 switch to Figure 3.16 can be achieved using the power MOSFET as a switching device. Therefore, even if solar energy not available, the robot still will be able to move by sourcing power from the battery.

3.3.1 Solar Charger Circuit

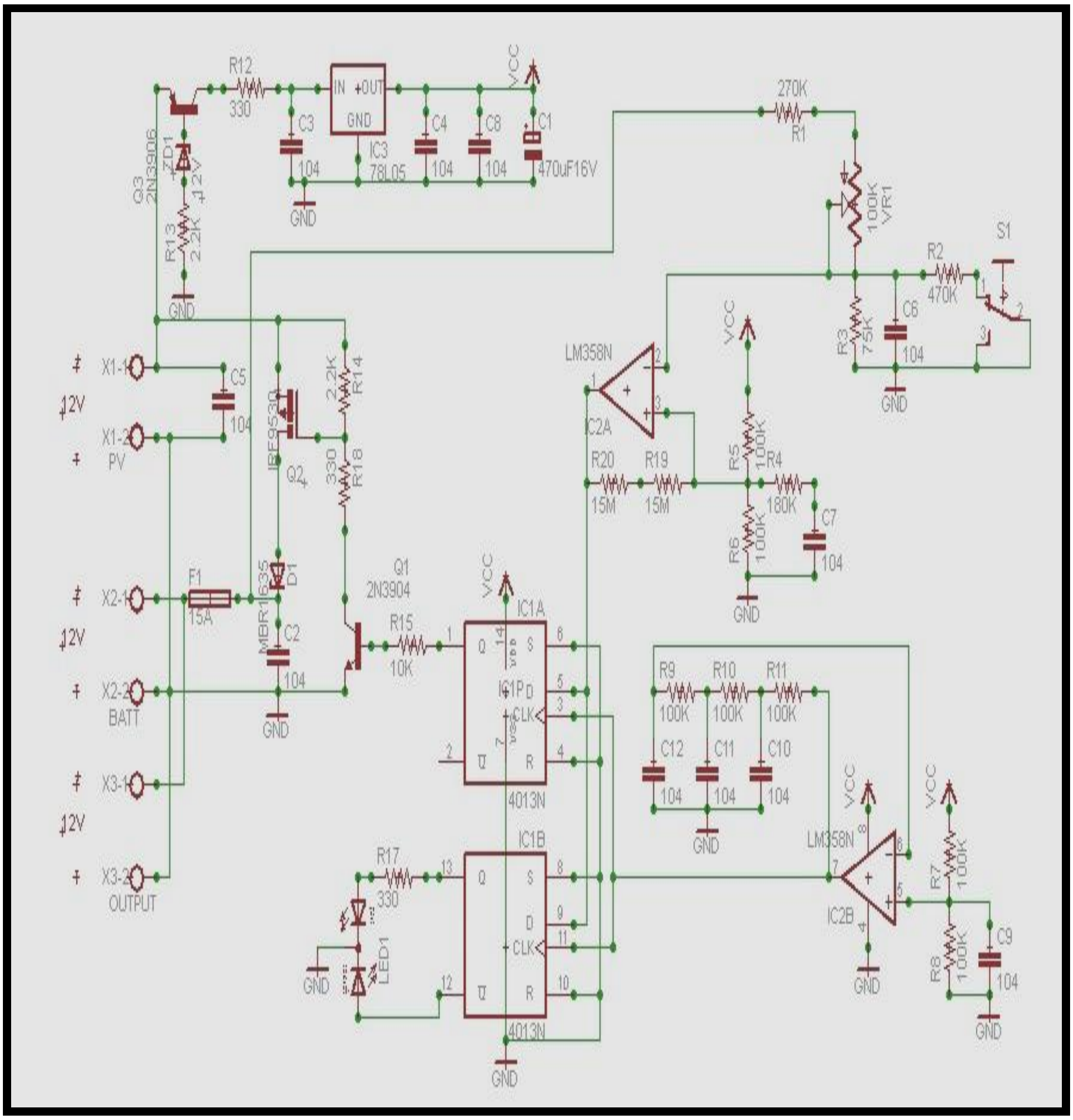


Figure 3.17: Solar Charger Circuit

Figure 3.17 shows the charger circuit design based on block diagram in Figure 3.14. As seen in the schematic diagram, X1-1 and X1-2 are the two points connected to 12V solar panel (not shown). The other two points X2-1 and X2-2 are connected to battery for charging.

The charging of the battery begins when the solar panel deliver voltage across 104 capacitor. This capacitor was used to prevent a rush of voltage or sudden increase of input voltage. The charging current will then flows into transistor 2N3906

PNP. This transistor turns on only when the voltage of solar panel output reaches 12V. The switching on of transistor 2N3906 is controlled by 12V zener diode. As such, when the output voltage reaches 12V, the current produced to the input of the LM7805 is:

$$I = 12V/330$$
$$= 0.036A$$

The 104 capacitor is once again used to prevent sudden rush of voltage from going into LM7805 voltage regulator. With another two 104 capacitor and 470uF, a further constant voltage can be produced no matter how the solar panel output voltage fluctuated.

There is also a switch S1 where it is used to turn on the charger. As the switch is pressed and in position 1, the voltage from the battery will be fed into LM358 via the resistor R1, VR1, R3, 104 and R2. When this happens, the L358N acts as comparator circuit. Hence, the voltage bias to the input pin 2 of LM358 is:

$$V_{Bias} = (75k/(270k + 100k + 75k))\times 12$$
$$= 2.02V$$

The voltage at pin 3 of LM358 is:

$$V_{pin\ 3} = (100k//180k/(100k//180k + 100k) \times 12V$$
$$= 4.69V$$

Since the 2.02V < 4.69V, the LM358 produce output is HIGH and this indicates that it needs to charge the battery. The two 15MΩ are used to control the gain of the LM358.

When the output of LM358 is HIGH, it triggers the 4013N flip-flop where the output will be a square wave to turn in the LED1.

The flip-flop operation is controlled by phase shift oscillator using LM358 op-amp as shown in the schematic diagram. The frequency of phase shift oscillator is given by:

$F = 1/2\pi\times100k\times0.01uF$
$= 159Hz$

Hence, the LEDs blink according to these values and the charging time will be:

$T = 1/159Hz$
$= 6.3ms$ approximately

At the output of the flip-flop, it is connected to the MOSFET charger circuit where it controls the N-channel or the gate of the MOSFET through transistor 2N3904. The two resistors R14 and R18 control the Vgs across the MOSFET and diode D1 forces the current to charge the battery and avoid the current from returning back to the circuit.

Figure 3.18 shows the simulation for the circuit in Figure 3.17 using Proteus. Simulation is needed for that particular circuit to ensure that it works.

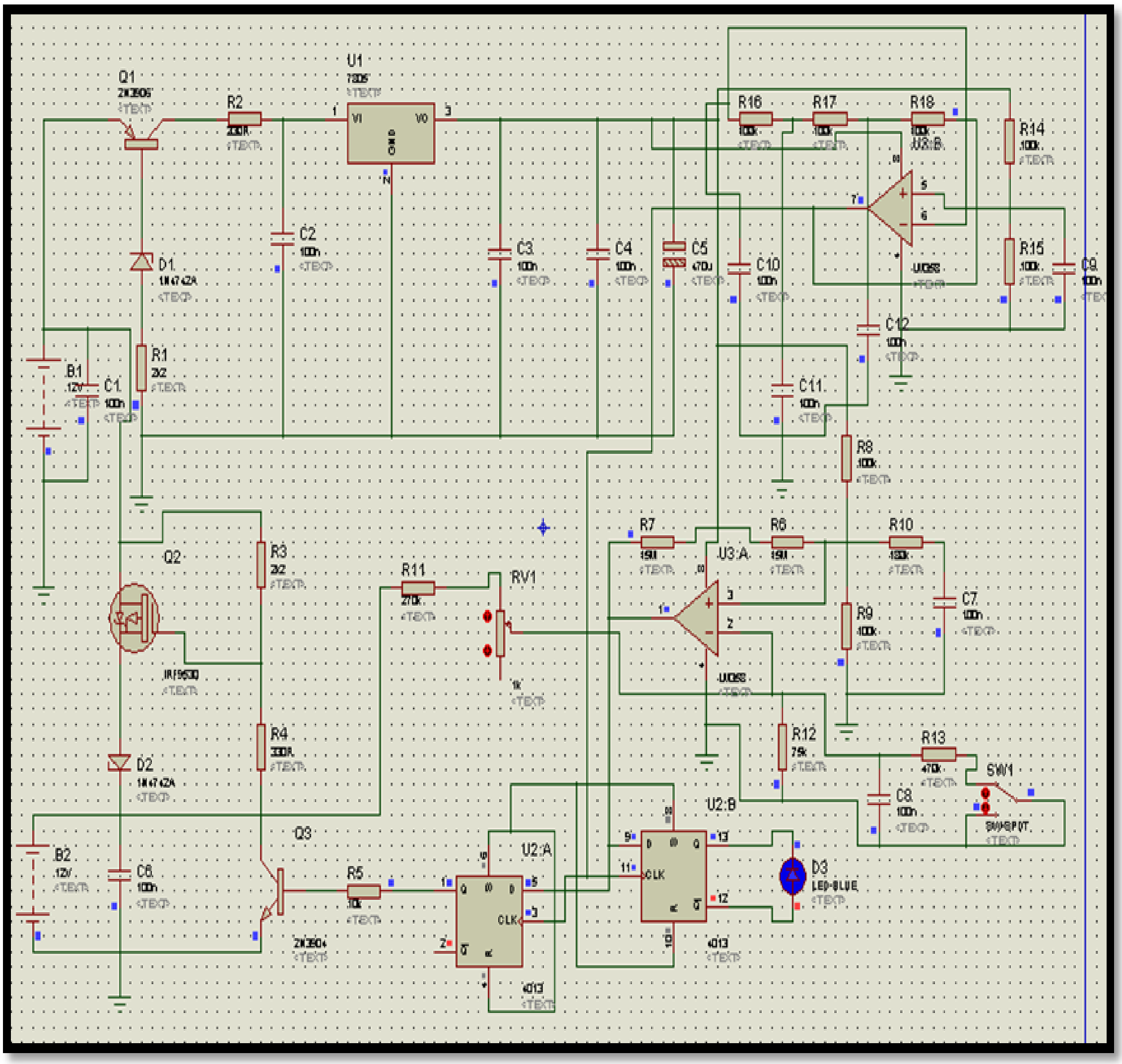


Figure 3.18: Simulation Result for the Solar Charger

As seen in Figure 3.18, the blue LED is lighted up and this indicates that the charging is in progress. Hence, the circuit design in Figure 3.17 works.

3.3.2 IR Sensor Circuit

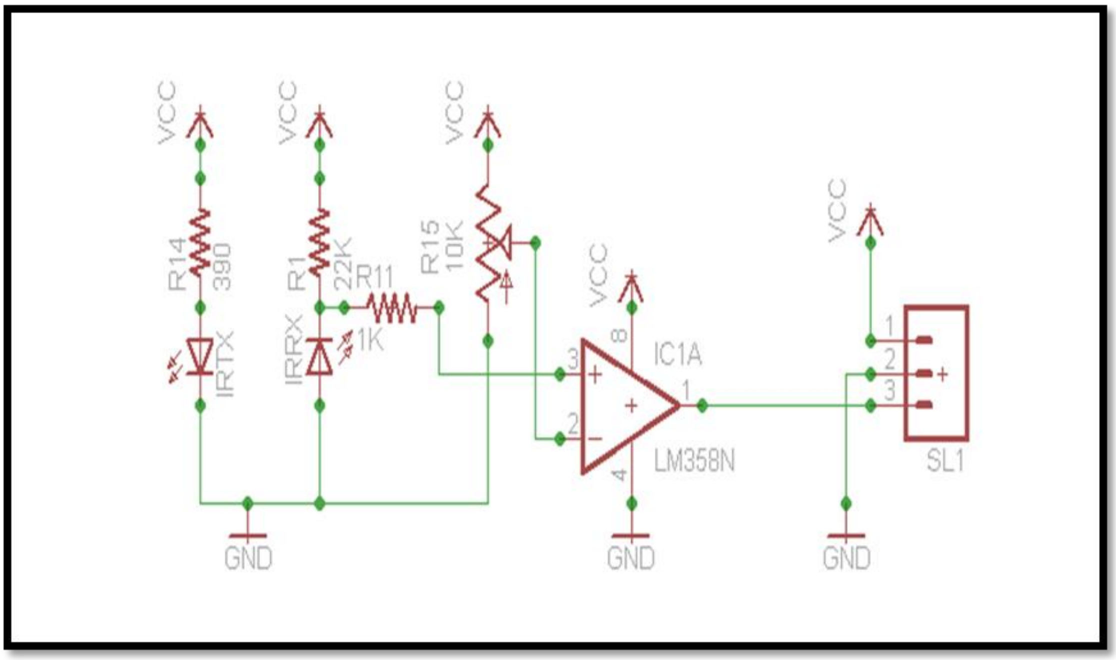


Figure 3.19: IR Sensor

Another circuit like IR sensor circuit was also build on the robot. This IR sensor circuit consists of transmitter and receiver of IR sensors. The schematic of such circuit is shown in Figure 3.19.

From the diagram, the IRTX is transmitting sensor where it obtains 5V Vcc from the supply. For the transmit circuit, a current:

$$I = \frac{5V}{390\Omega}$$
$$= 0.0128A$$

will flow into the sensor and transmit optical light. At the receiver, a current of:

$$I = \frac{5V}{22k \,//\, 1k}$$
$$= 5.23mA$$

will flow into LM358 when an optical light is detected. Notice that the reason to use 22k and 1k resistance is because of that 5mA is needed by the LM358 Op-amp.

At the input of LM358 (pin 2), there is a potentiometer with 10k maximum of resistance being used. This 10k potentiometer is used to adjust the sensitivity of the receiving IR sensor. By varying the resistance, the voltage across pin 2 will be changed and it will be compared with the voltage in pin 3.

As such, if the voltage at pin 2 and 3 are the same, the LM358 will generate output voltage at 1. Thus, indirectly, the circuit becomes a comparator circuit.

3.3.3 The Solar Powered Micro Mouse Control Circuit

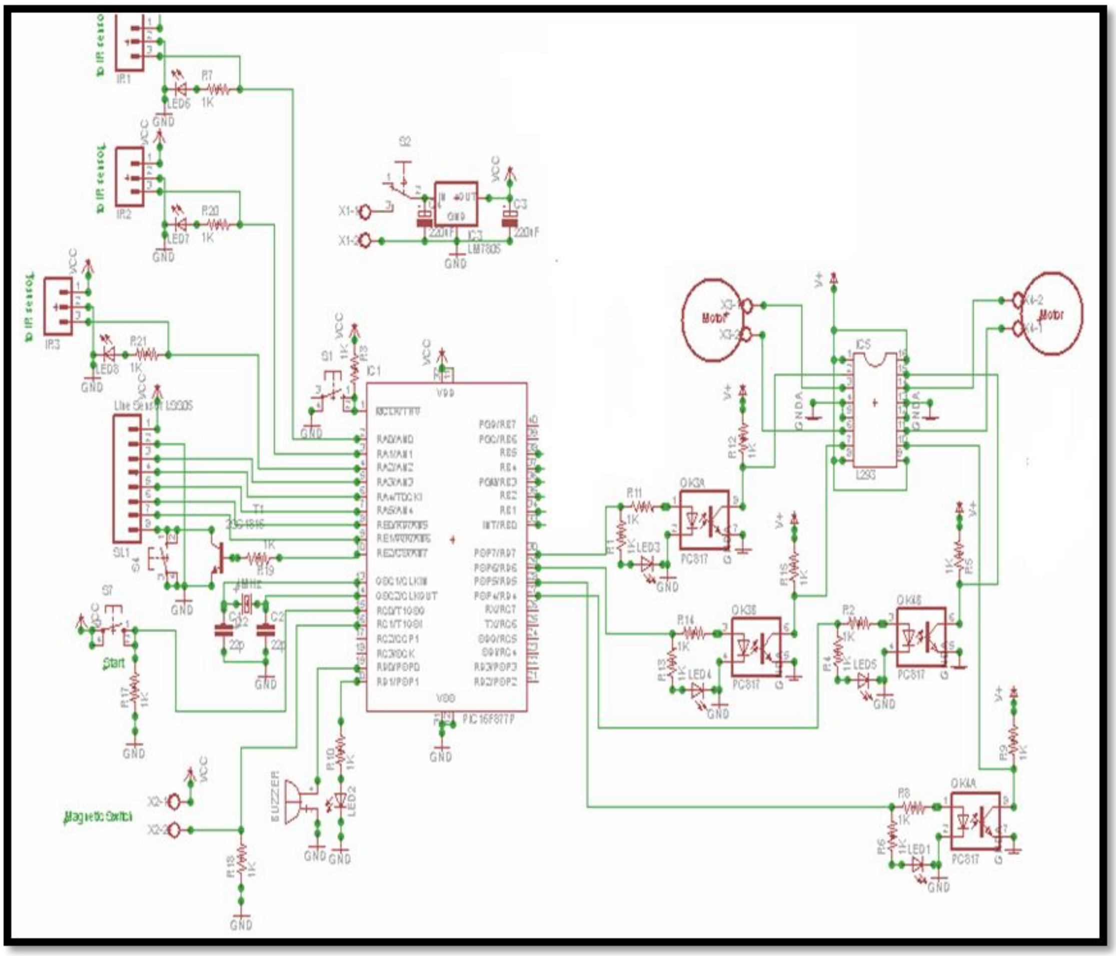


Figure 3.20: The Solar Powered Micro Mouse Control Circuit

The heart of the circuit shown in Figure 3.20 is the PIC16F877A microcontroller. From the microcontroller point of view, pin 1 is a reset pin and it is connected to switch S1. If the switch is pressed, a reset of program will happen. This is because, the current is forced into the ground. However, if the switch S1 is not pressed, the current that goes into pin 1 of the PIC16F877A microcontroller will be:

$$I = 5V/1k$$
$$= 5mA$$

Selection of 1kΩ resistor is needed because pin 1 could only accept 5mA to 15mA of current input.

When pin 1 receives a current of 5mA, it starts to execute the program inside the microcontroller.

Pin 2 to 3 are programmed to be connected to three IR transceiver sensors. Each sensor was installed with an LED for power indication. Pin 4 to 10 are programmed to be connected to line sensor LSS05. These pins serve as input pins.

Pin 13 and 14 are connected to 4MHz crystal oscillator. The 22pF capacitors are used to attenuate the overshoot of oscillation frequency. When these two capacitors connected in shunt, the resonance will become in parallel rather than in series. The microcontroller needs 4MHz as a reference frequency to execute the data.

Pin 19 is connected to buzzer to give out alert when obstacle is detected while pin 20 is connected to LEDs for indication of buzzer when it is turned on.

Pin 27 to 30 are the output pins that are connected to Optocouplers IC. These pins are basically produces digital HIGH 5V so that Optocoupler can be turned on to drive the L293 motor driver IC.

The current flow into each Optocoupler is:

$$I = 5mA$$

When the Optocoupler output is turned ON, a voltage of:

$$V_{drop} = 12V – 5mA \times 1k$$
$$= 7V$$

will be fed into L293D to control the motor direction. One motor will need two Optocouplers to drive. The control of motor to turn left, right, forward, stop and ‘U’ turn is based on the output voltage as shown below:

Table 3.13: The control of robot motion from the L293 motor driver

Input voltage from pin 27 and 28 of PIC16F877 to L293D (V)	**Input voltage 2 from pin 29 and 30 of PIC16F877 to L293D (V)**	**Output voltage 1 from L293D (V)**	**Output voltage 2 from L293 (V)**	**Condition of the robot**
7	7	12	12	Move forward
0	7	0	12	Turn left
7	0	12	0	Turn right
0	0	0	0	Stop
-7	7	-12	-12	U turn

Figure 3.21 depicts the waveform to describe the motion of the robot when L293 motor drivers change its voltage level under the control of PIC16F877A microcontroller.

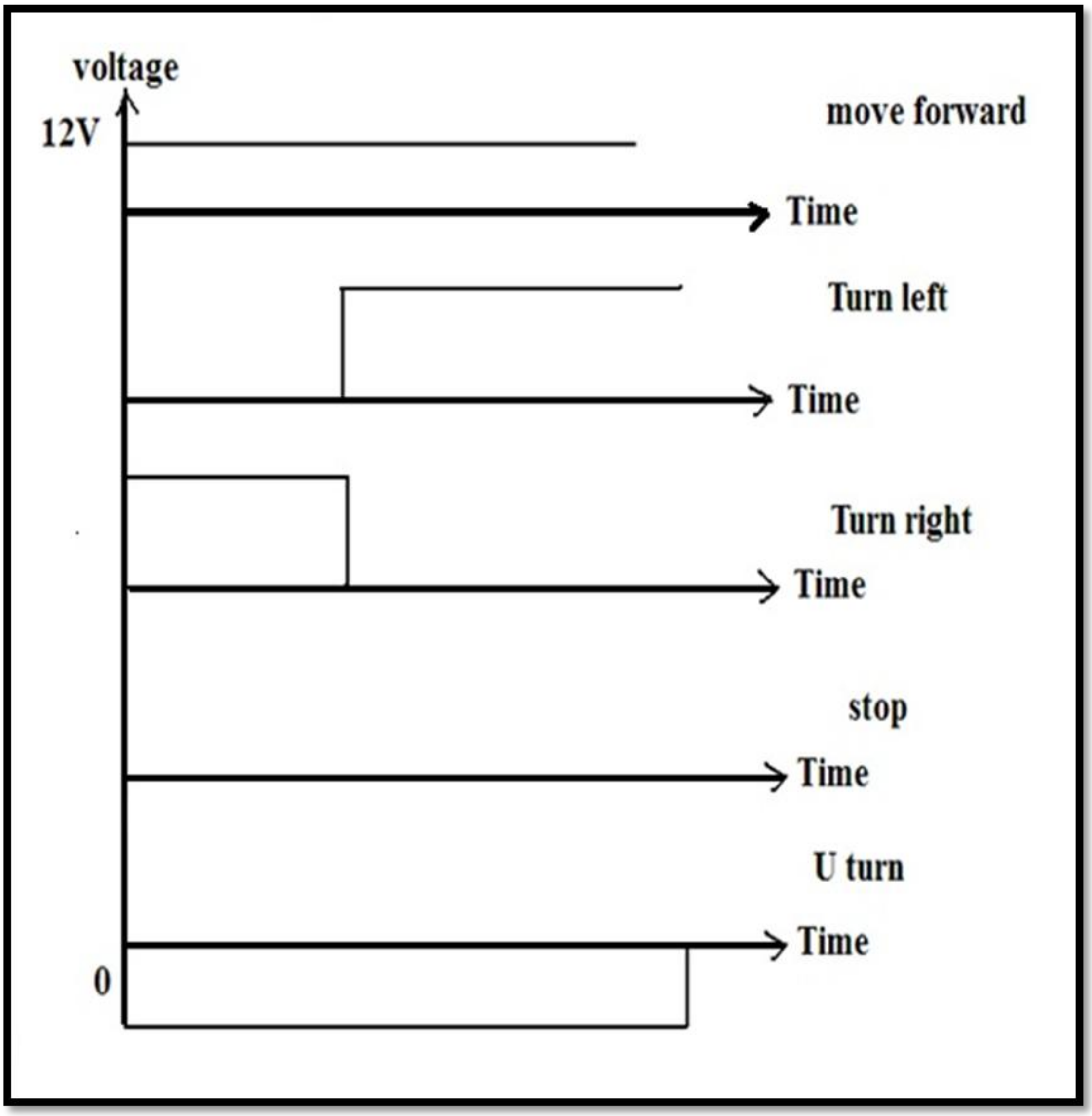


Figure 3.21: Waveform to Control the Motion of the Robot

The voltage level actually gives the power to the DC motor so that it works to move the robot. However, the duration needed for the DC motor to work is controlled by the time. The time control of voltage output can be done in the programming.

3.4 PIC Flow Chart

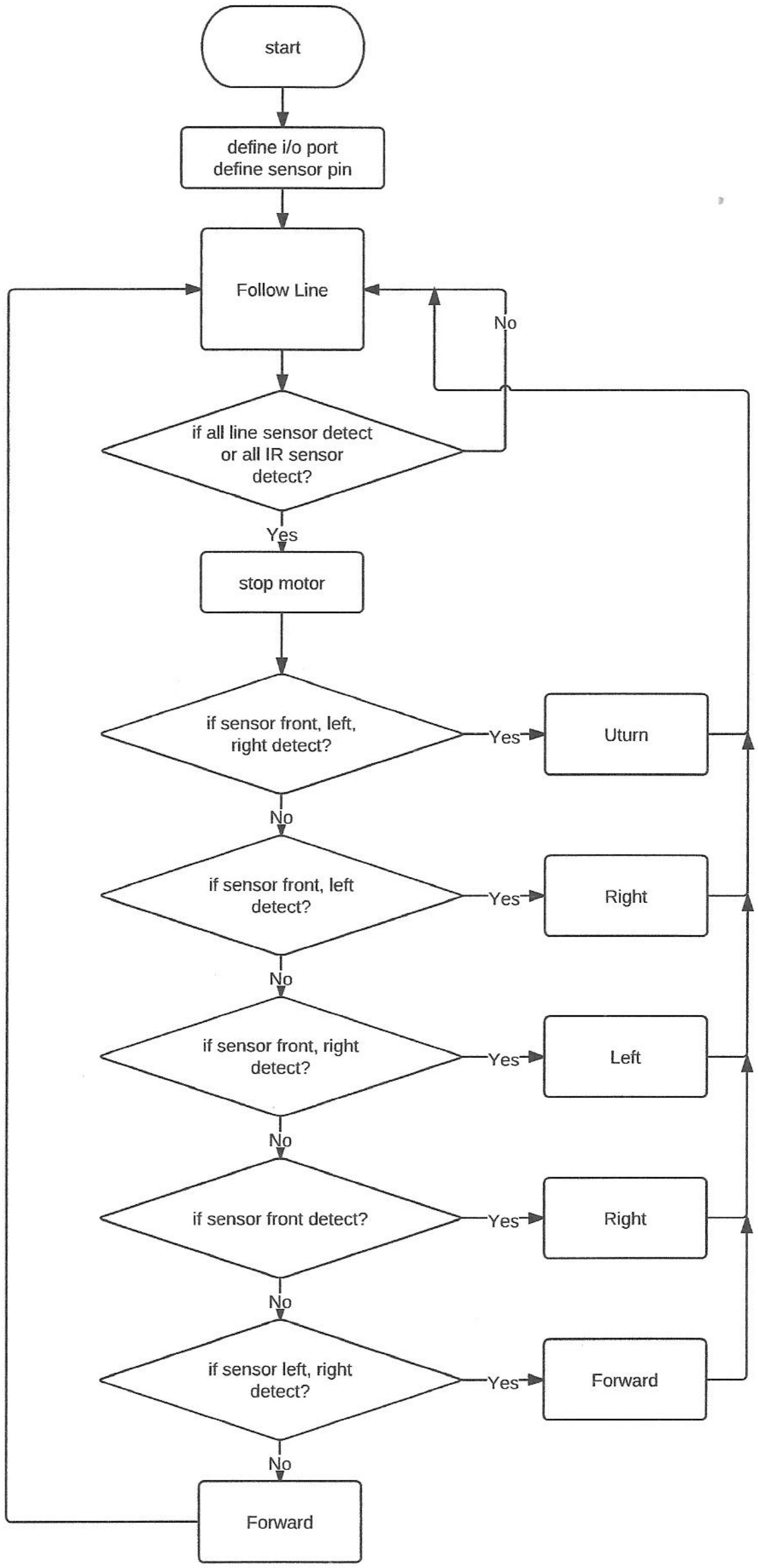


Figure 3.22: PIC Program Flow Chart to Control the Mouse Motion

From the flow chart, the programming designed to control the mouse motion begins from I/O port configuration. This was necessary because the microcontroller should know which pins are for input and which are for output.

When the system is turned ON, the microcontroller will check the line sensor and IR sensors. If all the sensors give signal to the microcontroller, the microcontroller will then stop the DC motor and hence stop the mouse motion.

However, if the IR sensor which is located at front, left and right gives signal to the microcontroller, the microcontroller will trigger the motor in a way it goes “U” turn.

If IR sensor at front and left gives input signal to the microcontroller, the robot then will turn right. To turn left, the front IR sensor and right IR sensor should be activated.

However, if only front sensor is detected, the robot moves right or if only left and right sensor gives out signal to the microcontroller, the robot will then move forward. The complete operation of the program is written in C and it can be seen in the appendix.

3.5 Maze Design

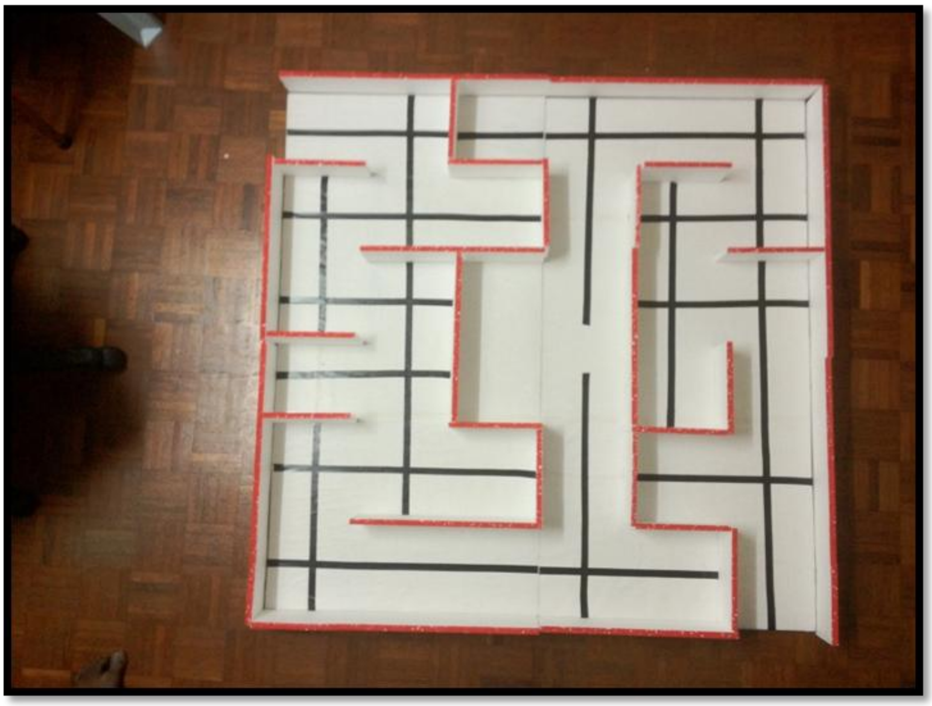


Figure 3.23: Maze Design

The maze is designed to have a total of 17 grids of cells, 9 turns and 1 “U” turn from left starting point. The design is mainly for different speed observation.

The right starting in the maze has a total of 14 grids of cell, 6 turns and 1 “U” turn. The design is to show the different speed compared to the left starting point.

In general, the total size of the maze design is 6×6 grids of cell by which each grid is 20cm × 20cm large. The base is built from 2 plank wood with the length of 4 feet and the width of 2 feet each. Then the wood is covered by white sheets of paper. The wall was built by using polyester. The top of the wall is painted red. The wall is 10 cm height with half an inch in thickness.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Technical and Physical Features of the Solar Powered Micro Mouse

Table 4.1: Technical features of the Solar Powered Mouse

Parameters	Requirements
Input voltage to the control board	9V
Solar panel	12V @ 5mA
Types of microcontroller	16F877A
IR sensors	1mW, 500mA
Motor drives	Use motor driver circuit

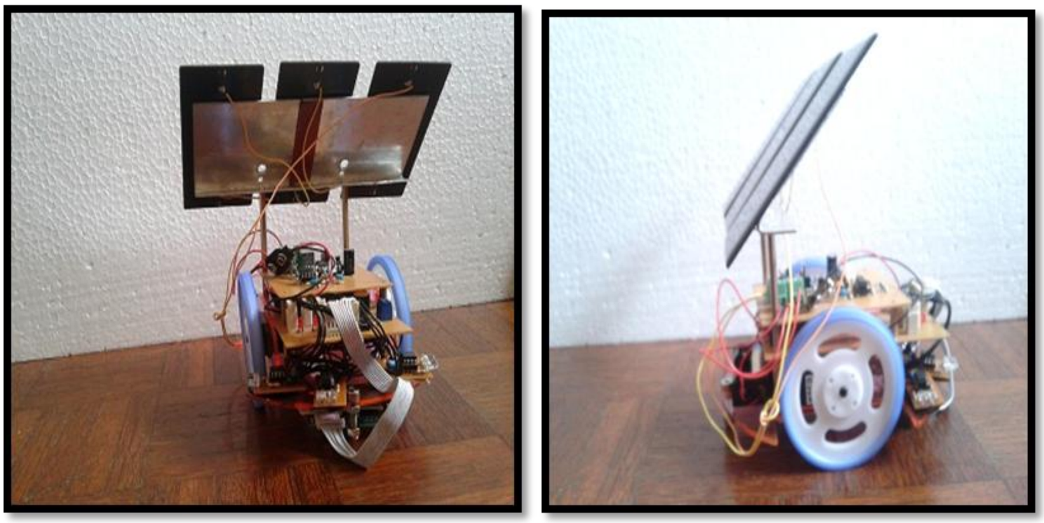


Figure 4.1: Front and Side View of Solar Powered Micro Mouse

4.2 The Route of the Robot Move In the Maze

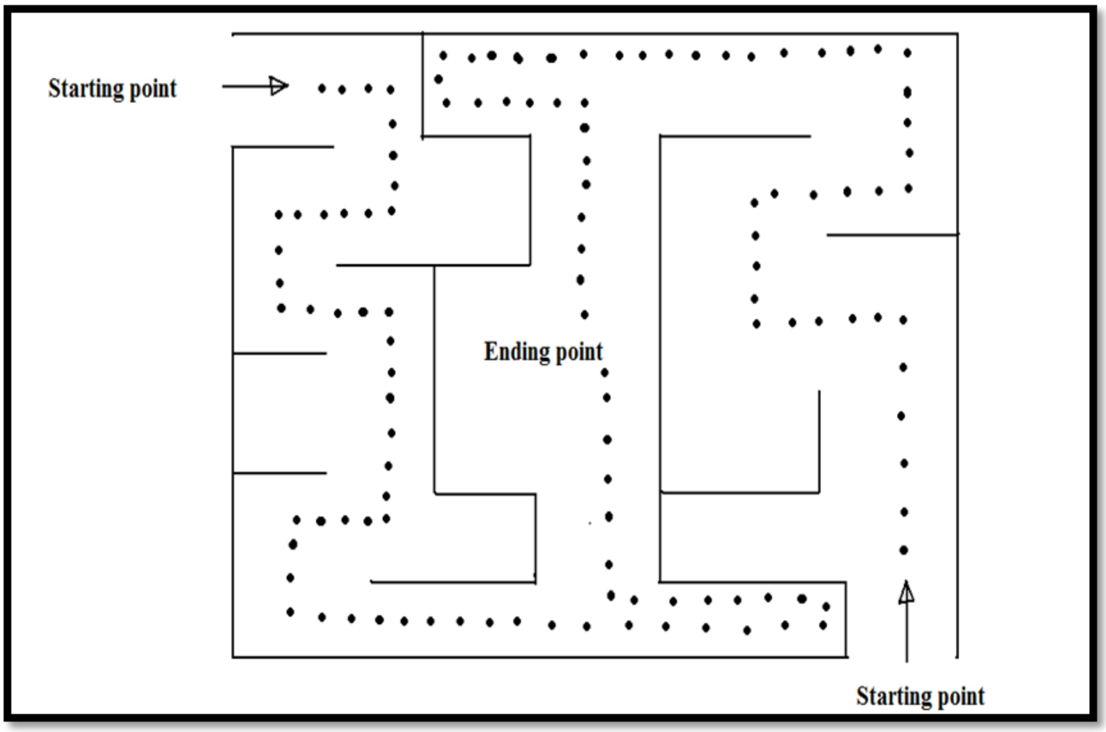


Figure 4.2: The Robot Route inside the Maze

Figure 4.2 shows the maze designed for the robot to complete the route. The designed maze has two entrance points as shown in the Figure 4.2. The dotted line represents the robot route that has been tested to come to the end point. There are two points where the robot need to "U" turn before it comes to the end point. These points were created where the sensor sense the obstacle in far distance. As such, the robot will move forward until the next obstacle is sensed and return back by means of "U" turn.

4.3 Infrared Distance Testing

According to the datasheet, the photodiode is supposed to detect objects in the range of 1 cm to 15 cm away. To verify this statement and to gain additional insight into how the sensor functions, several laboratory tests were performed on the sensor.

The IR sensor was placed facing a white sheet of paper upright and the output voltage is measured at several incremental distances from the sheet of paper by using a ruler. Table 4.1 shows the result of the three trials conducted, as well as an average of the three:

Table 4.1: Testing with white paper

Distance (cm)	Voltage (Trial 1) (V)	Voltage (Trial 2) (V)	Voltage (Trial 3) (V)	Voltage (Average of Trials) (V)
3	1.917	1.882	2.011	1.937
3.5	2.187	2.266	2.029	2.161
4	2.811	2.876	2.560	2.749
4.5	3.083	3.084	3.058	3.075
5	3.031	3.003	3.067	3.034
5.5	2.811	2.777	2.909	2.832
6	2.577	2.543	2.671	2.597
6.5	2.369	2.369	2.437	2.392
7	2.222	2.205	2.266	2.231
7.5	2.064	2.046	2.117	2.076
8	1.918	1.907	1.972	1.932
8.5	1.811	1.793	1.846	1.817
9	1.703	1.684	1.721	1.703
9.5	1.592	1.592	1.629	1.604
10	1.501	1.501	1.538	1.513
11	1.368	1.350	1.387	1.368
12	1.239	1.239	1.257	1.245
13	1.127	1.127	1.146	1.133
14	1.064	1.046	1.064	1.058
15	0.988	0.988	0.988	0.988

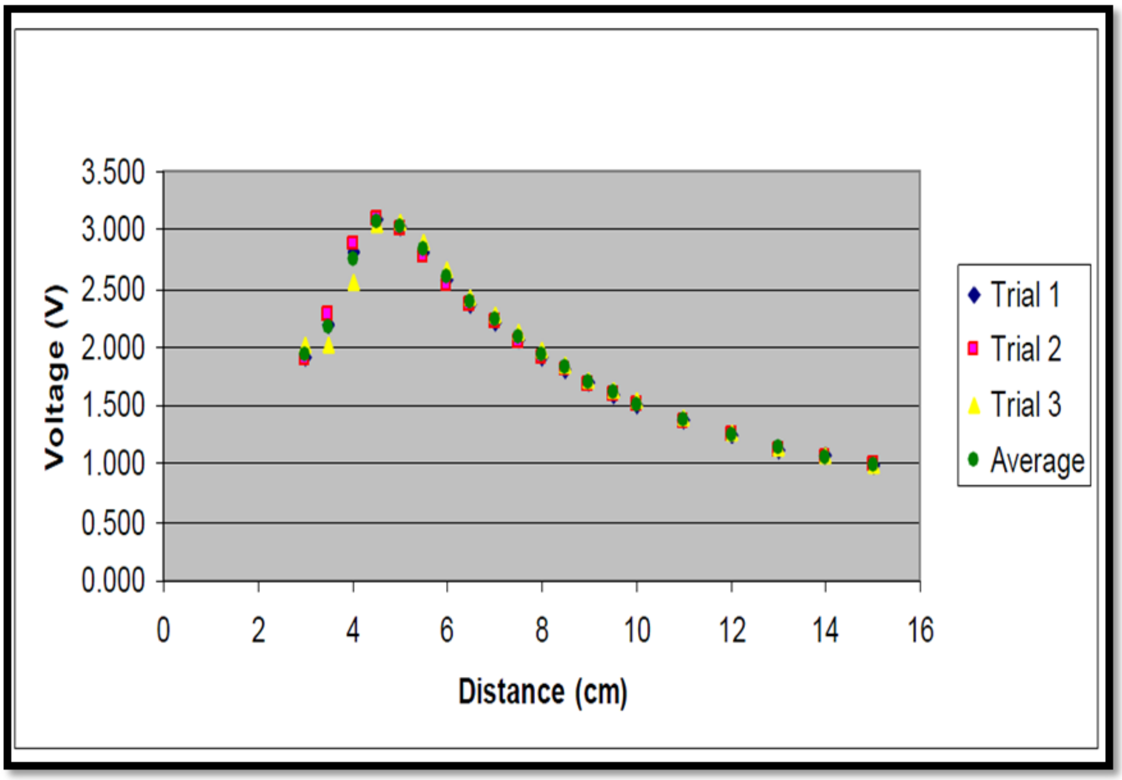


Figure 4.3: Voltage vs Distance Graph

Using the results from Table 4.1, the following voltage versus distance graph is plotted in Figure 4.3. From the graph, it is obvious that the output from the sensor is non-linear. This is due to the basic trigonometry within the triangle from the emitter to the ilumination spot to the detector. Moreover, as expected from the the device specifications, there is a range, mainly when it is close than 4cm to the wall, where the distance can be accurately measured.

4.4 Discussion on the Robot Move inside the Real Maze with Solar Panel

There are twelve figures that describes on how the Solar Powered Micro Mouse solves the maze.

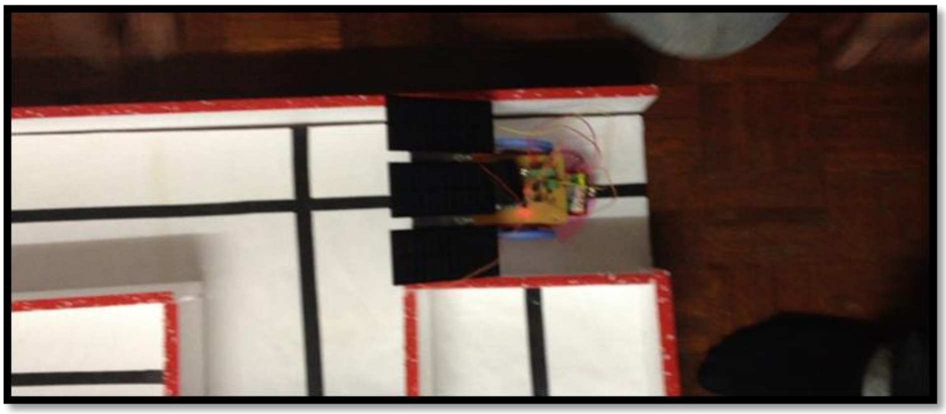


Figure 4.4: Picture of Micro Mouse Solving Maze Part 1

Figure 4.4 shows the robot start to move at the right side of starting point. In this situation, the robot power and the solar panel is turned on.

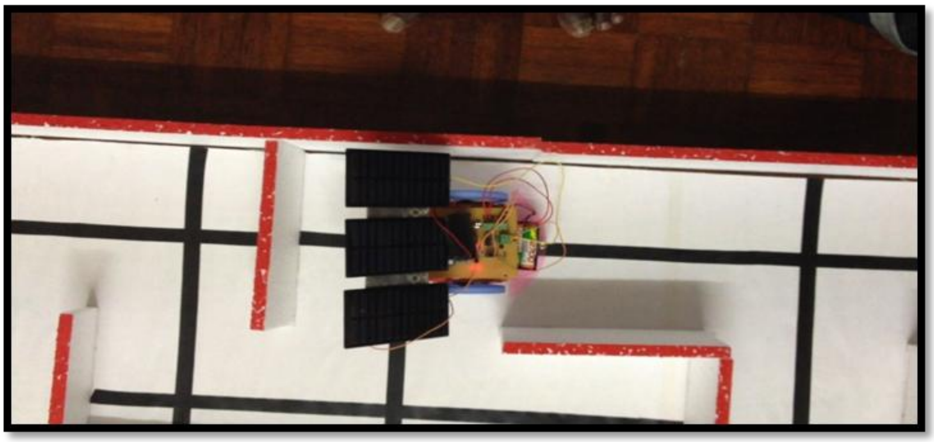


Figure 4.5: Picture of Micro Mouse Solving Maze Part 2

Figure 4.5 shows the robot reaches the first obstacle and begins to turn. Just before it turns, the robot will stop for a while. This is because the microcontroller needs time to make decision and scan for the next obstacle.

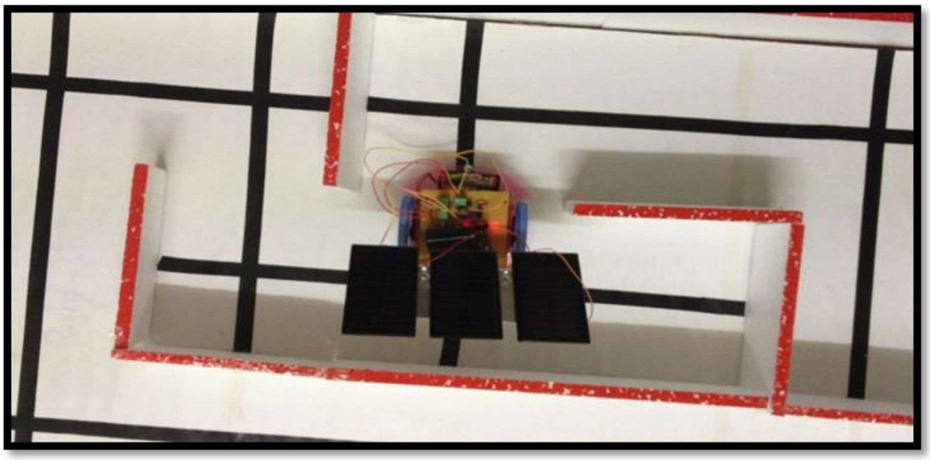


Figure 4.6: Picture of Micro Mouse Solving Maze Part 3

Figure 4.6 shows the robot has already solved the first obstacle and then it moves straight. In the second obstacle, the robot makes detection and thus made a turning.

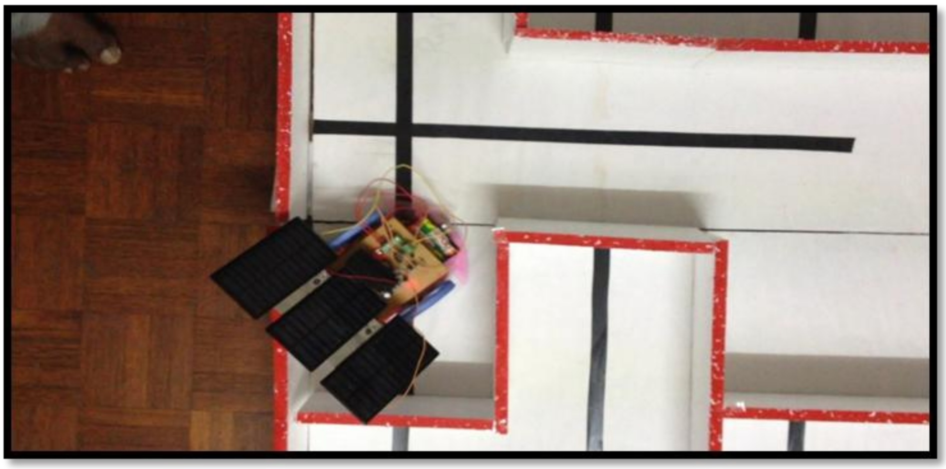


Figure 4.7: Picture of Micro Mouse Solving Maze Part 4

Figure 4.7 shows the robot reaching the “U” point. At this point, the front and the two sides of the robot have obstacles, but its back does not have any obstacles. Therefore the robot turns in “U” motion to move back and seek for another exit point.

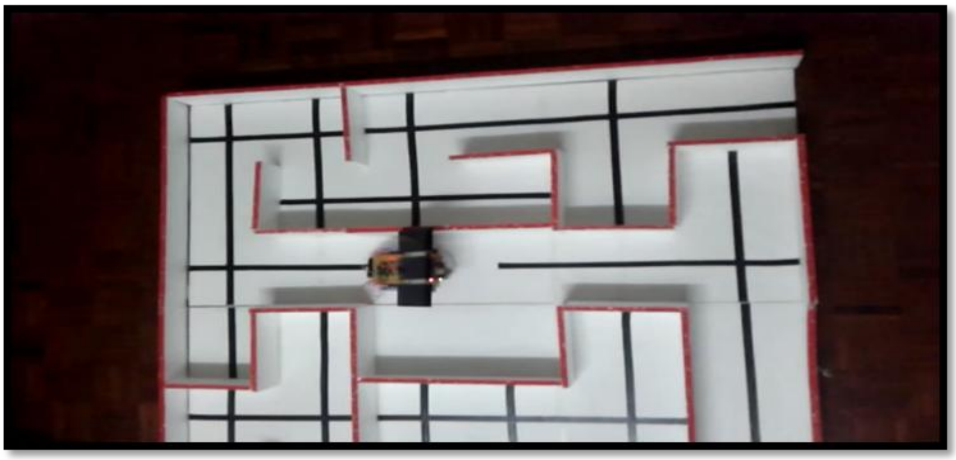


Figure 4.8: Picture of Micro Mouse Solving Maze Part 5

Figure 4.8 shows the robot reaching the end point successfully and stop at the point.

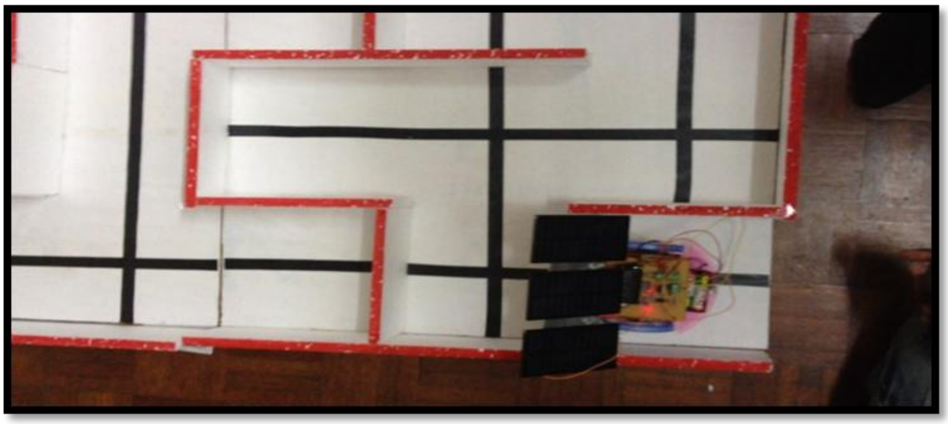


Figure 4.9: Picture of Micro Mouse Solving Maze Part 6

Figure 4.9 shows the robot solves the maze at the left side of starting point. This point has eight obstacles.

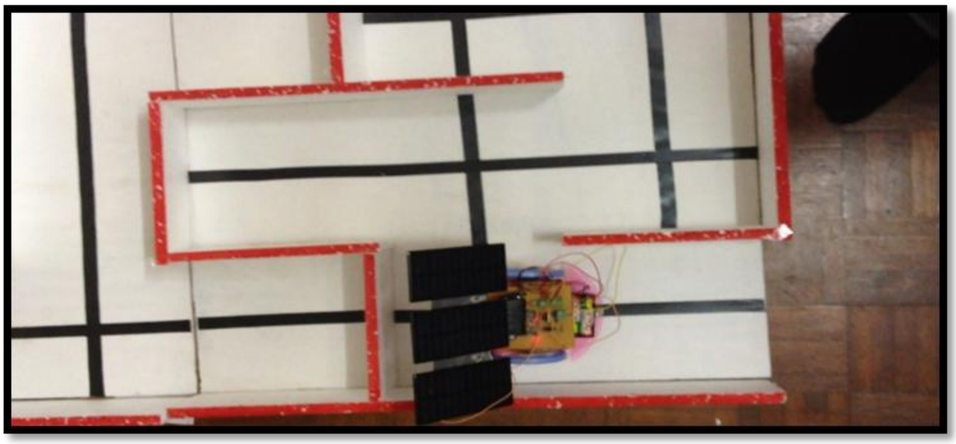


Figure 4.10: Picture of Micro Mouse Solving Maze Part 7

Figure 4.10 shows the robot solves for the first obstacle and moves forward. The sensor at this point is actively detecting the side and front object.

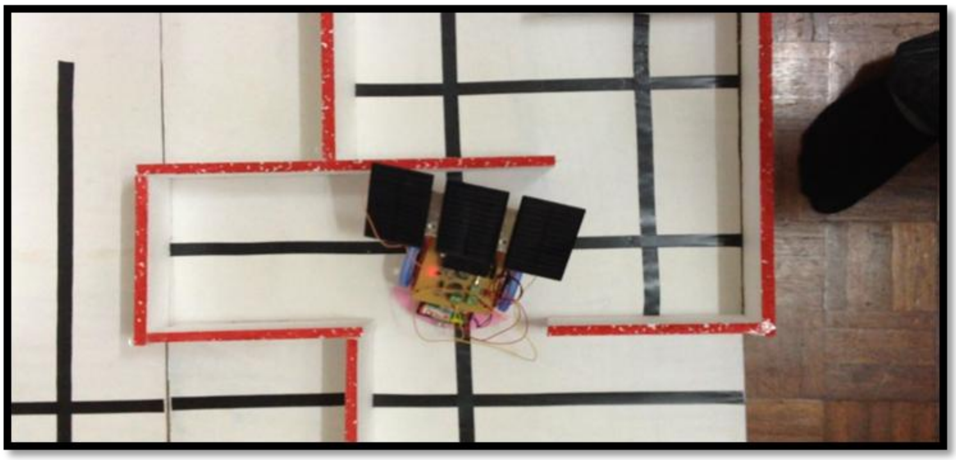


Figure 4.11: Picture of Micro Mouse Solving Maze Part 8

Figure 4.11 shows the robot solves for second obstacle. At this point, the robot turns right, left, left again and then right, right and left again to come out from the obstacle.

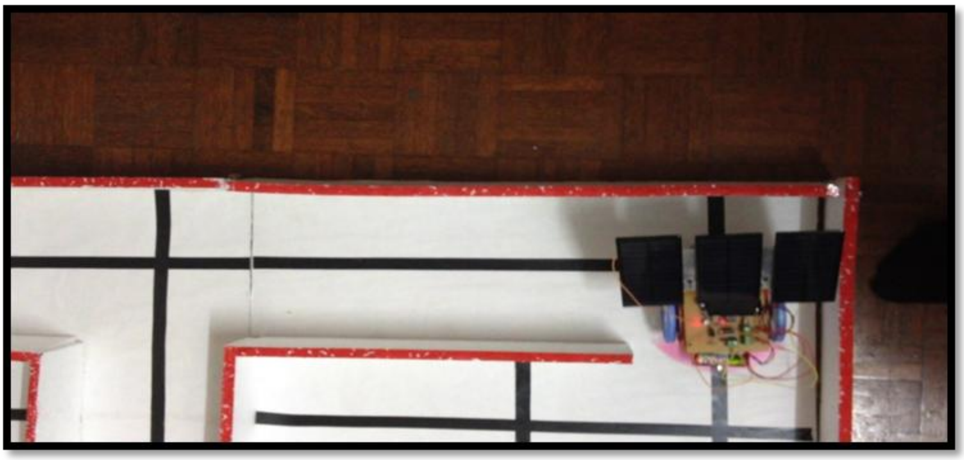


Figure 4.12: Picture of Micro Mouse Solving Maze Part 9

Figure 4.12 shows the robot is reaching the last obstacle and turn left.

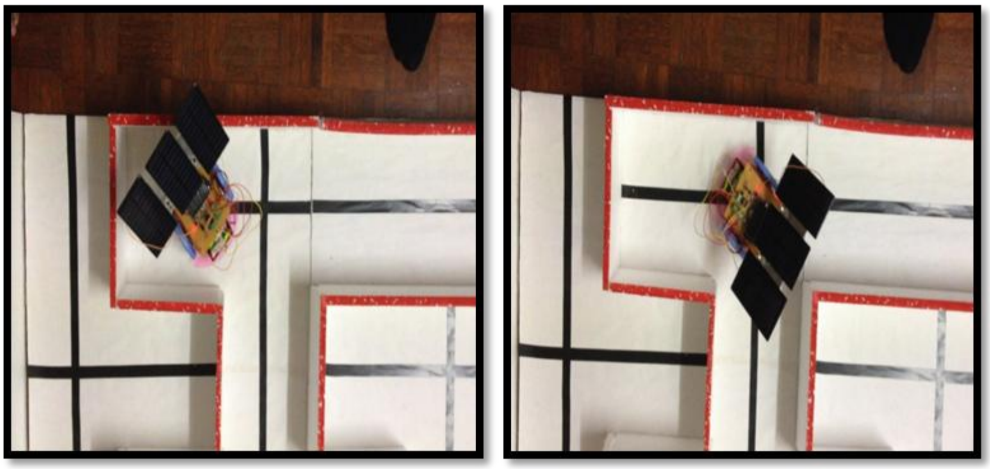


Figure 4.13: Picture of Micro Mouse Solving Maze Part 10

Figure 4.13 shows that at this point, the robot moves straight to the “U” turn point. Again the robot turns 180° and move back. After reaching the exit point it turns right.

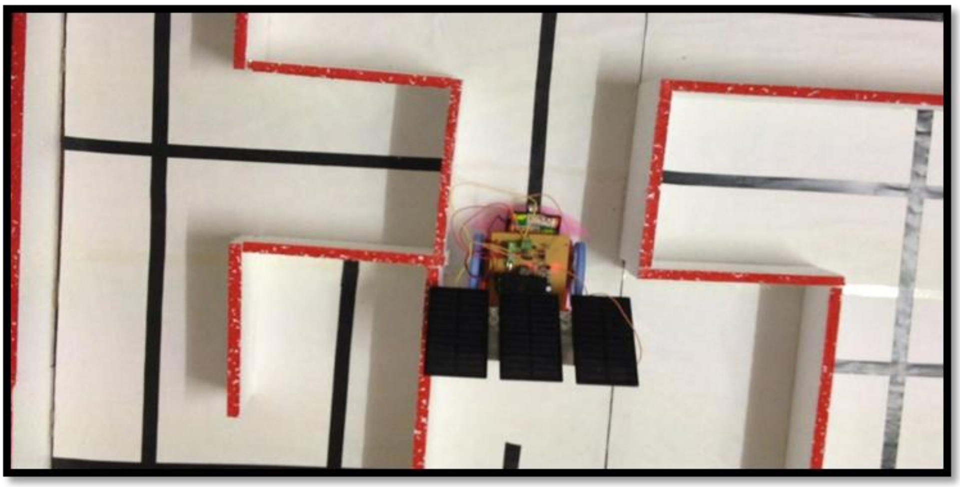


Figure 4.14: Picture of Micro Mouse Solving Maze Part 11

Figure 4.14 shows the robot has successfully reached the end point.

From the experimental test, it shows that without a solar panel, when the robot starts at left starting point, it takes approximately about 1 minute 61 second for it to reach the end point. The total distance traveled is 335cm. The speed of the robot is:

$$Speed = \frac{3.35}{121}$$

$$= 0.027 m/s$$

From the right starting point, the time for the robot to reach the end point was 51 seconds with a total distance traveled of 279cm. The speed of the robot under this case is:

$$Speed = \frac{2.79}{51}$$

$$= 0.055 m/s$$

When the solar panel was installed, the robot that starts at left starting point takes 109s to reach the end point. The distance traveled is 335cm. The speed under this is:

$$\text{Speed} = \frac{3.35}{109}$$

$$= 0.03\text{m/s}$$

From the right starting point being with solar panel installed, the time for the robot to reach the end point is 89 second. The speed is:

$$\text{Speed} = \frac{2.79}{89}$$

$$= 0.0313\text{m/s}$$

From the speed results, it can be seen that when the panel is installed, the robot moved slower. This is because the robot is heavy under loading condition. However, the robot was observed to move faster without the panel.

This particular developed robot can be used in space exploration to explore the surfaces of the planets by using solar energy. Besides, this robot can also be applied to power up ships and thus reduce the dependency on fuel. Moreover, this robot can also be used as land transportation such as bus by powering up the shuttle so that it can be used as a normal shuttle to carry the passengers. All these applications can be achieved by designing this robot in a bigger scale.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The ultimate goal of this project is to design and build a fully functional Solar Powered Micro Mouse. In this project, a self-contained, autonomous, solar powered vehicle called a “Solar Powered Micro Mouse”, which is able to navigate through a path to the centre of a maze was built. A fully functional Solar Powered Micro Mouse has been successfully built based on the initial design. This basic micro mouse can be improved in future to suit any requirements for solving a task.

5.2 Future Recommendations

Firstly, the circuit should be designed by using the SMD components and to make it more compact on PCB. This can reduce the total power consumption of the robot and thus save the input energy.

Firstly the power supply should be increased so that the Solar Powered Micro Mouse can last longer. The Solar Powered Micro Mouse should be small in size so that it can go through tight mazes or sharp angles in unknown terrain. However, the battery capacity used in Solar Powered Micro Mouse can be increased. The solar panel should have a power of at least 1W and above it with at least 900mA of current. This can effectively power up the DC motor of the robot.

The other parts which can be explored are the IR sensors. Currently the IR sensors that are used are the normal IR transmitter and photo diode. Instead of using normal IR sensors, Sharp GP2D12 IR sensor can be used to replace them. This is the most popular Sharp reflective IR distance sensor. It provides an analog voltage which the value is proportional to the distance of the detected object. This will give an accurate value of distance to the Solar Powered Micro Mouse to maintain its distance from the wall. Another type of sensor that can be used is the ultrasonic sensor. It can also be used to measure the distance of the robot from the wall. Furthermore it is not affected by ambient light. With this feature, the Solar Powered Micro Mouse can work under the sunlight.

Another improvement that can be done is upgrading the drive system. Currently, Solar Powered Micro Mouse uses a DC geared motor. The drive system can be upgraded by using a faster and smaller DC motor. Introducing the PWM circuit will be able to control the speed of the DC motor. In this way, the Solar Powered Micro Mouse will be able to solve the maze faster.

Finally, to speed up the processing of microcontroller, the 4MHz crystal can be upgraded into 20MHz crystal. When microcontroller encounters higher frequency of clock, it can make decision faster compared to 4MHz crystal oscillator.

REFERENCES

[Journals]

Mishra, Bande, S. (2008), 'Maze Solving Algorithms for Micro Mouse', *Signal Image Technology and Internet Based Systems,* IEEE International Conference, pp. 86-93.

Solar Energy, Vol.56, No.1 (1996), pp. 111-118

Tanaka, T. (2002), '*A comparative study of advanced MOSFET concepts*', Electron Devices, IEEE Transactions on, Vol.43, No.10, pp. 1742-1753

Wang, D. (2008), *Audio, Language and Image Processing,* International Conference on In Audio, Language and Image Processing, pp. 784-787

[Online]

2N3904 (2010), *NPN General Purpose Amplifier*. Retrieved July 18, 2012, from http://www.fairchildsemi.com/ds/2N/2N3904.pdf

4013-IC (2012). Retrieved July 18, 2012, from www.electronickitsbychaneyelectronics.com/4013-IC

Azooz A.A., Sulayman J.M. (2005), *Electronic Control Circuit*

For Solar Battery Charging. Retrieved January 14, 2012, from http://rrp.infim.ro/2007_59_1/art07Azooz.pdf

Boer J. D. (1968), *Cybernetics Zoo.* Retrieved January 8, 2012, from http://cyberneticzoo.com/?p=4045

Boland A. (1979), *Cybernetics Zoo.* Retrieved January 12, 2012, from http://cyberneticzoo.com?cat=535

Buckley D. (1982), *Quester*. Retrieved January 8, 2012, from http://davidbuckley.net/DB/Quester.htm

Clough B. (2006), *Rooter.* Retrieved January 12, 2012, from http://think133t.co.uk/uploads/diss/ Writeup/Dissertation.pdf

DC Motor (2012). Retrieved July 18, 2012, from http://www.nskelectronics.in/servo_motor.html

Edgar (2006), *Micromouse Online*. Retrieved January 8, 2012, from http://www.micromouseonline.com/ book/micromouse-book/actual-mice/edgar

Electric Motors (2003). Retrieved January 14, 2012, from http://www.electricmotors.machinedesign.com/

Freaklabs S. (2012), *LM358 Single Supply Op Amp* . Retrieved July 16, 2012, from http://www.freaklabsstore.com/index.php?main_page=product_info&products_id=114

HEXFET (2012), *Power MOSFET*. Retrieved July 18, 2012, from http://pdf1.alldatasheet.com/datasheet-pdf/view/199104/IRF/IRF9530PBF.html

IEEE Micromouse Competition Rules (2007), *Region 2 Student Activities Conference - 2007*. Retrieved January 8, 2012, from http://www.ieee.uc.edu/main/files/sac2007/mm_rules.pdf

Introduction to Power MOSFETs and Their Applications (1988). Retrieved January 14, 2012, from http://bitsavers.org/pdf/national/_appNotes/AN-0558.pdf

Introduction to Solar Electricity (2011). Retrieved January 14, 2012, from http://www.altestore.com/howto/Renewable-Energy-Energy-Efficiency/Introduction-to-Solar-Electricity/a89/

Kyocera S.P. (2012), *Installing Low Maintenance Kyocera Solar Panels*. Retrieved July 16, 2012, from http://kyocerasolarpanels.net/

Kytron E. (2011), *Infrared Sensor*. Retrieved July 18, 2012, from http://kytron.blogspot.com/2011/11/sensor-optical-infrared-sensor.html

L293 (2002). Retrieved July 18, 2012, from http://idmax.free.fr/Aide/Stepper/l293.pdf

Le Mouse 5000 (1972), *Machine Design LeMouse-5000, Chicago, IL 1972*. Retrieved January 10, 2012, from http://www.sciencephotography.com/andy/mousecar.htm

Line Sensor (2012). Retrieved July 18, 2012, from www.cytron.com.my

LM7805 (2012). Retrieved July 18, 2012, from http://www.fairchildsemi.com/ds/LM/LM7805.pdf

Micromouse Contest (2011), *The Micromouse Contest In The Beginning*. Retrieved January 10, 2012, from http://www.ee.cityu.edu.hk/~rtbrad/micromouse.html

Micromouseonline (2010), *History*. Retrieved January 10, 2012, from http://www.micromouseonline.com/micromouse-book/history/?doing_wp_cron=1345610400.7872860431671142578125#axzz24DFffvwA

Motha, K. (2009), *H-Bridge Circuit*. Retrieved January 14, 2012, from http://kartikmohta.com/wiki/Tech/ HBridge

Omkar (2008), *How to Make IR Sensor Modules*. Retrieved January 17, 2012, from http://electrom.wordpress.com/2008/02/19/how-to-make-simple-infrared-sensor-modules/

PC817 (2012). Retrieved July 18, 2012, from http://www.datasheetcatalog.org/datasheet/Sharp/mXruvuu.pdf

PIC16F877A (2003). Retrieved July 18, 2012, from http://ww1.microchip.com/downloads/en/devicedoc/39582b.pdf

Placek D, Gonski P (2007), Smart Solar Battery Charger. Retrieved January 14, 2012, from http://courses.engr.illinois.edu/ece445/projects/spring2007/project4_design_review.doc solar battery recharge circuit

Roman (2012), *DC Motors Direction and Speed Control*. Retrieved January 14, 2012, from http://letsmakerobots.com/files/MotorDriverL293Dnet.pdf

Scott P.C (2008), *Senior Design*. Retrieved July 18, 2012, from http://courses.engr.illinois.edu/ece445/?f=Projects&sem=fall2006

Sunshines. S. (2010), *Micro Mouse History*. Retrieved January 14, 2012, from http://www.shiningsunshines.com/micromousehistory/

ThinkL33T (2007), *R1V2-Rooter Version 2-Worklog Part 1*. Retrieved July 14, 2012, from http://thinkl33t.co.uk/tag/micromouse/page/4

University of Moratuwa (2006), *Wall following robot*. Retrieved January 13, 2012, from http://ent.mrt.ac.lk/ iml/projects/2006/2k6EN407P3/index.htm

APPENDICES

APPENDIX A: PIC Program Coding

```
//define pin used
#define sensor_f PORTA.F1
#define sensor_l PORTA.F2
#define sensor_r PORTA.F0

//motor pins
#define m_lf_fw PORTD.F4
#define m_lf_rw PORTD.F5
#define m_rf_fw PORTD.F6
#define m_rf_rw PORTD.F7

//line sensor
#define l5 PORTA.F3
#define l4 PORTA.F4
#define l3 PORTA.F5
#define l2 PORTE.F0
#define l1 PORTE.F1

//led & buzzer
#define led PORTC.F0
#define buzzer PORTD.F0

//variable
char x;

//subroutine
void forward(void);
void reverse(void);
void turn_left(void);
void turn_right(void);
void stop(void);
void u_turn(void);
void beep(void);
void left(void);
void right(void);
void follow(void);
```

```
//main loop
void main(void)
{
 ADCON1=0x06;
 TRISA=0xFF;                    //porta is input
 TRISB=0x00;                    //portb is output
  TRISC=0x00;                   //portc is output
  TRISD=0x00;                   //portd is output
 TRISE=0b00000111;              //porte is input
 INTCON=0xA0;
 PORTA=PORTB=PORTC=PORTD=0x00;
 beep();                        //beep 2x
 beep();

//main loop
 do
 {
  follow();                     //call follow loop
  if((l1 && l2 && l3 && l4 && l5) || (!sensor_f && !sensor_l && !sensor_r))

//when all sensor detect line or all sensor front left & right detect
  {
   stop();
                                                  //stop motor
   if(!sensor_f && !sensor_l && !sensor_r)        //when all 3 sensor detct then uturn
    {
     u_turn();
    }


    else if(!sensor_f && !sensor_l && sensor_r)   //when forward and left detect then
                                                    turn right
    {
     turn_right();
    }

    else if(!sensor_f && sensor_l && !sensor_r)     //when forward and right detect
                                                      then tuen left
    {
     turn_left();
    }

    else if(!sensor_f && sensor_l && sensor_r)      //when forward only then turn
                                                      right
    {
     turn_right();
    }
```

```
   else if(sensor_f && !sensor_l && !sensor_r)       //when left and right detect then
                                                       forward
   {
    forward();
   }

   else if(sensor_f && !sensor_l && sensor_r)        //when only left detect then
                                                       forward
   {
    forward();
   }

   else if(sensor_f && sensor_l && !sensor_r)       //when only right detect then
                                                     forward
   {
    forward();
   }

   else                                             //if none of above the forward
   {
    forward();
   }
  }


 }while(1);

}

//**********************************************************************
//follow the line
void follow(void)
{
 if(!l1 && l2 && l3 && !l4 && !l5)      //when sensor2 & 3 detect will forward
 {
  forward();
 }
 else if((!l1 && !l2 && l3 && !l4 && !l5)|| (!l1 && !l2 && l3 && l4 && !l5))

//when sensor3 or sensor 3&4 then turn left
 {
  left();
 }
 else if((!l1 && l2 && !l3 && !l4 && !l5) || (l1 && l2 && !l3 && !l4 && !l5))

//when sensor2 or sensor 1&2 then turn right
 {
  right();
 }
 else if(!l1 && !l2 && !l3 && !l4 && !l5)     //else no sensor detect then stop
```

```
 {
  stop();
 }
}

void forward(void)                    //routine for foward
{                                    // 1010
 m_lf_fw=1;
 m_lf_rw=0;
 m_rf_fw=1;
 m_rf_rw=0;
 delay_ms(50);
}
                                      //left 1000
void left(void)
{
 m_lf_fw=1;
 m_lf_rw=0;
 m_rf_fw=0;
 m_rf_rw=0;
 delay_ms(50);
}

void right(void)                      //right 0010
{
 m_lf_fw=0;
 m_lf_rw=0;
 m_rf_fw=1;
 m_rf_rw=0;
 delay_ms(50);
}


void turn_left(void)                  //at junction 0010 at 1.2sec
{
 m_lf_fw=0;
 m_lf_rw=0;
 m_rf_fw=1;
 m_rf_rw=0;
 delay_ms(1200);
 while(1)
 {
  if(l2 && l3)break;
 }
}

void turn_right(void)               //at junction 1000 at 1.2 sec
{
 m_lf_fw=1;
 m_lf_rw=0;
```

```
 m_rf_fw=0;
 m_rf_rw=0;
 delay_ms(1200);
 while(1)
 {
  if(l2 && l3)break;
 }
}
                                        //reverse 0101
void reverse(void)
{
 m_lf_fw=0;
 m_lf_rw=1;
 m_rf_fw=0;
 m_rf_rw=1;
 delay_ms(300);
}
                                        //uturn function
void u_turn(void)
{
 stop();                                //stop motor
 for(x=0;x<=5;x++)                      //beep 5x
 beep();
 stop();
 stop();                                //make uturn 1001
 m_lf_fw=1;
 m_lf_rw=0;
 m_rf_fw=0;
 m_rf_rw=1;
 delay_ms(2000);
 while(1)                               //uturn until line sensor 2& 3 detect
 {
  if(l2 && l3)break;
 }
 stop();
 while(1)                               //start to follow again
 {
  follow();
  if(l1 && l2 && l3 && l4 && l5)        //when junction detect
  {
   stop();                              //stop & turn right
   turn_right();
  }
 }
}

void stop(void)                         //stop routine 0000
{
 m_lf_fw=0;
 m_lf_rw=0;
```

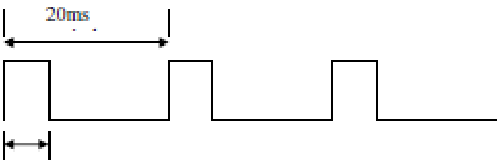
```
 m_rf_fw=0;
 m_rf_rw=0;
 delay_ms(200);
}

void beep(void)                              //beep buzzer
{
 buzzer=1;
 led=1;
 delay_ms(100);
 buzzer=0;
 led=0;
 delay_ms(100);
}
```

APPENDIX B: RC Servo Motor-C36R

2. HOW RC SERVO MOTOR WORKS

Servos are controlled by sending them a pulse of variable width. The signal wire is used to send this pulse. The parameters for this pulse are that it has a minimum pulse, a maximum pulse, and a repetition rate. Given the rotation constraints of the servo, neutral is defined to be the position where the servo has exactly the same amount of potential rotation in the clockwise direction as it does in the counter clockwise direction. It is important to note that different servos will have different constraints on their rotation.



Pulse Width (0.5ms-2.5ms)

The angle is determined by the duration of a pulse that is applied to the signal wire. This is called Pulse Width Modulation. The servo expects to see a pulse every 20 ms. The length of the pulse will determine how far the motor turns. For example, a 1.5 ms pulse will make the motor turn to the 90 degree position (neutral position). However, the **exact correspondence between pulse width and servo varies from one servo manufacturer to another. 1.5ms is not necessarily neutral or middle position.**

The position pulse must be repeated to instruct the servo to stay in position. When a pulse is sent to a servo that is less than 1.5 ms the servo rotates to a position and holds its output shaft some number of degrees counterclockwise from the neutral point. When the pulse is wider than 1.5 ms the opposite occurs. The minimal width and the maximum width of pulse that will command the servo to turn to a valid position are functions of each servo. Different brands, and even different servos of the same brand, will have different maximum and minimums. Generally the minimum pulse will be about 1 ms wide (some servo is 0.5ms) and the maximum pulse will be 2 ms wide (some servo is 2.5ms).

Caution: Over range of the pulse will damage the servos.

3. PRODUCT SPECIFICATION

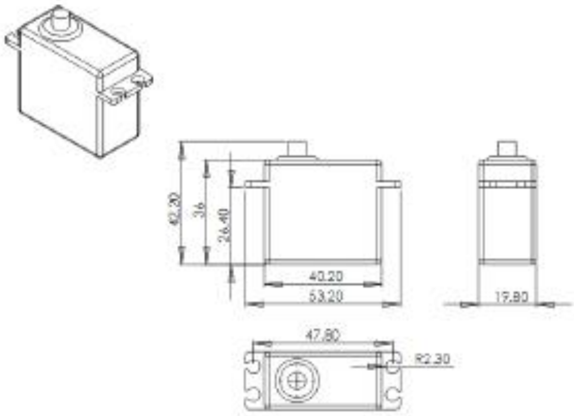
Cytron Technologies offer great range of RC servo motor. With the combination of various gear type, speed, torque and voltage, users are free to choose the suitable RC servo for project development. Of course, it can also be used for RC application. Below is product specification for Cytron RC Servo motor.

RC Servo Code		C36R	C40R	C55S
4.8V	**Speed (s/60°)**	0.16	0.19	0.22
	Torque (Kg.cm)	3.50	6.00	9.00
6.0V	**Speed (s/60°)**	0.14	0.16	0.20
	Torque (Kg.cm)	4.50	7.00	11.0
7.2V	**Speed (s/60°)**	-	-	0.17
	Torque (Kg.cm)	-	-	13.0
Pulse Width Range (ms)		0.5ms to 2.35ms	0.546ms to 2.4ms	0.582ms to 2.5ms
Weight (g)		36	38	55
Gear material		Plastic	Plastic	Metal
Servo type		Standard	Standard	Standard

*** Pulse width range is for reference only; please start the servo calibration at 1.5ms.**

4. DIMENSION DRAWING (unit in mm)

C36R RC Servo



APPENDIX C: Microcontroller-PIC16F877A

MICROCHIP

PIC16F87XA

28/40/44-Pin Enhanced Flash Microcontrollers

Devices Included in this Data Sheet:

- PIC16F873A
- PIC16F874A
- PIC16F876A
- PIC16F877A

High-Performance RISC CPU:

- Only 35 single-word instructions to learn
- All single-cycle instructions except for program branches, which are two-cycle
- Operating speed: DC – 20 MHz clock input
DC – 200 ns instruction cycle
- Up to 8K x 14 words of Flash Program Memory, Up to 368 x 8 bytes of Data Memory (RAM), Up to 256 x 8 bytes of EEPROM Data Memory
- Pinout compatible to other 28-pin or 40/44-pin PIC16CXXX and PIC16FXXX microcontrollers

Peripheral Features:

- Timer0: 8-bit timer/counter with 8-bit prescaler
- Timer1: 16-bit timer/counter with prescaler, can be incremented during Sleep via external crystal/clock
- Timer2: 8-bit timer/counter with 8-bit period register, prescaler and postscaler
- Two Capture, Compare, PWM modules
  - Capture is 16-bit, max. resolution is 12.5 ns
  - Compare is 16-bit, max. resolution is 200 ns
  - PWM max. resolution is 10-bit
- Synchronous Serial Port (SSP) with SPI™ (Master mode) and I²C™ (Master/Slave)
- Universal Synchronous Asynchronous Receiver Transmitter (USART/SCI) with 9-bit address detection
- Parallel Slave Port (PSP) – 8 bits wide with external $\overline{RD}$, $\overline{WR}$ and $\overline{CS}$ controls (40/44-pin only)
- Brown-out detection circuitry for Brown-out Reset (BOR)

Analog Features:

- 10-bit, up to 8-channel Analog-to-Digital Converter (A/D)
- Brown-out Reset (BOR)
- Analog Comparator module with:
  - Two analog comparators
  - Programmable on-chip voltage reference (V_{REF}) module
  - Programmable input multiplexing from device inputs and internal voltage reference
  - Comparator outputs are externally accessible

Special Microcontroller Features:

- 100,000 erase/write cycle Enhanced Flash program memory typical
- 1,000,000 erase/write cycle Data EEPROM memory typical
- Data EEPROM Retention > 40 years
- Self-reprogrammable under software control
- In-Circuit Serial Programming™ (ICSP™) via two pins
- Single-supply 5V In-Circuit Serial Programming
- Watchdog Timer (WDT) with its own on-chip RC oscillator for reliable operation
- Programmable code protection
- Power saving Sleep mode
- Selectable oscillator options
- In-Circuit Debug (ICD) via two pins

CMOS Technology:

- Low-power, high-speed Flash/EEPROM technology
- Fully static design
- Wide operating voltage range (2.0V to 5.5V)
- Commercial and Industrial temperature ranges
- Low-power consumption

Device	Program Memory		Data SRAM (Bytes)	EEPROM (Bytes)	I/O	10-bit A/D (ch)	CCP (PWM)	MSSP		USART	Timers 8/16-bit	Comparators
	Bytes	# Single Word Instructions						SPI	Master I²C			
PIC16F873A	7.2K	4096	192	128	22	5	2	Yes	Yes	Yes	2/1	2
PIC16F874A	7.2K	4096	192	128	33	8	2	Yes	Yes	Yes	2/1	2
PIC16F876A	14.3K	8192	368	256	22	5	2	Yes	Yes	Yes	2/1	2
PIC16F877A	14.3K	8192	368	256	33	8	2	Yes	Yes	Yes	2/1	2

1.0 DEVICE OVERVIEW

This document contains device specific information about the following devices:

- PIC16F873A
- PIC16F874A
- PIC16F876A
- PIC16F877A

PIC16F873A/876A devices are available only in 28-pin packages, while PIC16F874A/877A devices are available in 40-pin and 44-pin packages. All devices in the PIC16F87XA family share common architecture with the following differences:

- The PIC16F873A and PIC16F874A have one-half of the total on-chip memory of the PIC16F876A and PIC16F877A
- The 28-pin devices have three I/O ports, while the 40/44-pin devices have five
- The 28-pin devices have fourteen interrupts, while the 40/44-pin devices have fifteen
- The 28-pin devices have five A/D input channels, while the 40/44-pin devices have eight
- The Parallel Slave Port is implemented only on the 40/44-pin devices

The available features are summarized in Table 1-1. Block diagrams of the PIC16F873A/876A and PIC16F874A/877A devices are provided in Figure 1-1 and Figure 1-2, respectively. The pinouts for these device families are listed in Table 1-2 and Table 1-3.

Additional information may be found in the PICmicro® Mid-Range Reference Manual (DS33023), which may be obtained from your local Microchip Sales Representative or downloaded from the Microchip web site. The Reference Manual should be considered a complementary document to this data sheet and is highly recommended reading for a better understanding of the device architecture and operation of the peripheral modules.

TABLE 1-1: PIC16F87XA DEVICE FEATURES

Key Features	PIC16F873A	PIC16F874A	PIC16F876A	PIC16F877A
Operating Frequency	DC – 20 MHz	DC – 20 MHz	DC – 20 MHz	DC – 20 MHz
Resets (and Delays)	POR, BOR (PWRT, OST)	POR, BOR (PWRT, OST)	POR, BOR (PWRT, OST)	POR, BOR (PWRT, OST)
Flash Program Memory (14-bit words)	4K	4K	8K	8K
Data Memory (bytes)	192	192	368	368
EEPROM Data Memory (bytes)	128	128	256	256
Interrupts	14	15	14	15
I/O Ports	Ports A, B, C	Ports A, B, C, D, E	Ports A, B, C	Ports A, B, C, D, E
Timers	3	3	3	3
Capture/Compare/PWM modules	2	2	2	2
Serial Communications	MSSP, USART	MSSP, USART	MSSP, USART	MSSP, USART
Parallel Communications	—	PSP	—	PSP
10-bit Analog-to-Digital Module	5 input channels	8 input channels	5 input channels	8 input channels
Analog Comparators	2	2	2	2
Instruction Set	35 Instructions	35 Instructions	35 Instructions	35 Instructions
Packages	28-pin PDIP 28-pin SOIC 28-pin SSOP 28-pin QFN	40-pin PDIP 44-pin PLCC 44-pin TQFP 44-pin QFN	28-pin PDIP 28-pin SOIC 28-pin SSOP 28-pin QFN	40-pin PDIP 44-pin PLCC 44-pin TQFP 44-pin QFN

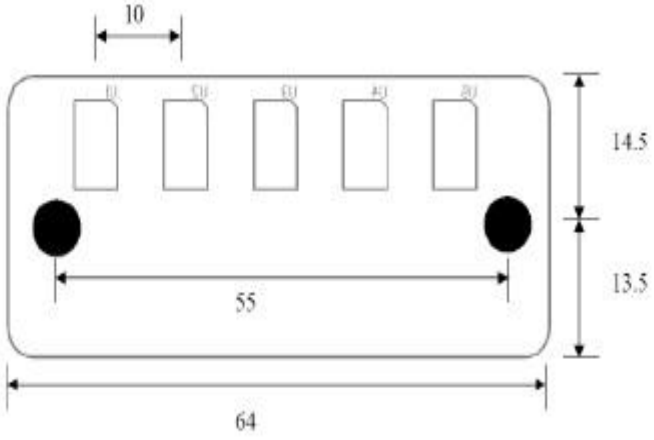
APPENDIX D: Line Following Sensor

Cytron Technologies

ROBOT . HEAD to TOE
Product User's Manual – LSS05

3. PRODUCT SPECIFICATION AND LIMITATIONS

Dimensions



Specifications

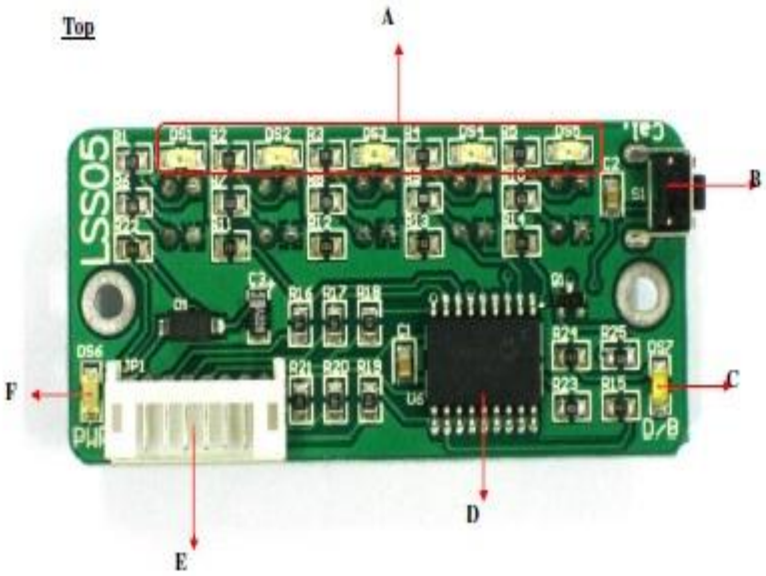
Parameter	Min	Typical	Maximum	Unit
IR Emission (peak wavelength)		940		nm
Input signal, V_{IH}	2		5	V
Input signal, V_{IL}	0		0.8	V
Output Signal			5	V

Absolute Maximum Rating

Parameter	Minimum	Typical	Maximum	Unit
Operating voltage			5	V
Maximum Current (I/O signal pins)			20	mA
Sensing distance	1	2	4	cm

4. BOARD OR PRODUCT LAYOUT

Top



Label	Function	Label	Function
A	Sensor indicator LEDs	D	PIC16F819
B	Calibration button	E	Power and output signal connector
C	Mode indicator LED	F	Power indicator LED

A – Sensor indicator LEDs (red) will light up showing that it detects line.

B – Calibration button is used to enter different modes. Press once to enter the calibration mode. Press twice to set the line sensor bar into dark line following mode and press 3 times to set the line sensor bar into bright line mode.

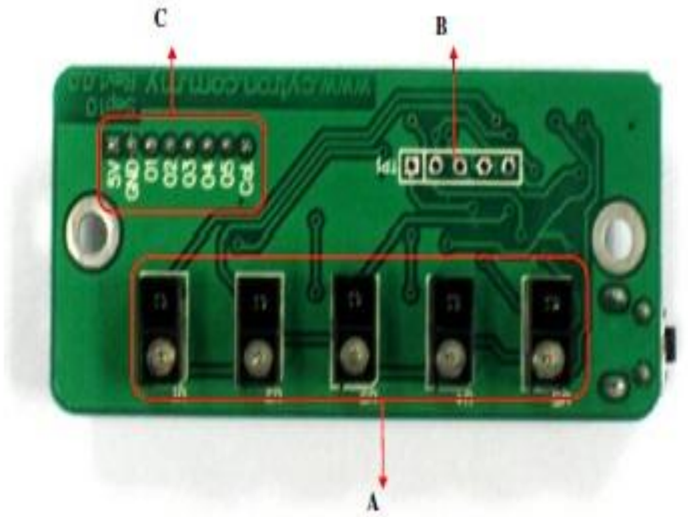
C – Mode indicator LED (orange) is for indication of the mode. LED will light up if LSS05 is in bright line detection mode. Otherwise, it is off.

D – PIC16F819 PIC microcontroller for data processing.

E – Power and output signal connector

F – Power indicator LED (green) showing the board is supplied with power. Maximum input power is 5V.

Bottom



Label	Function
A	Pairs of IR sensor
B	Manufacturing Test Points
C	Input/output signal label

A – Pairs of IR sensor which consist IR transmitter and IR receiver.

B – It is reserved for Manufacturing Test Point. Please **DO NOT** short or connect wire to any of these pins.

C –Input/output signal label showing the Power (5V, GND), output signal pins (O1-O5) and calibration signal (Cal.).

APPENDIX E: IR Transmitter and Receiver Sensor

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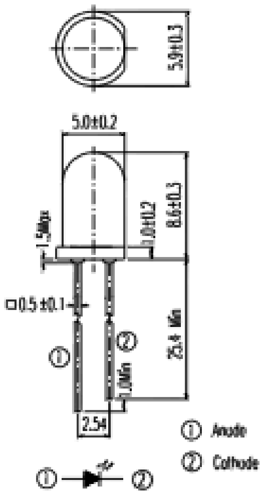
Package Dimensions



Notes: 1.All dimensions are in millimeters
2.Tolerances unless dimensions ±0.25mm

Absolute Maximum Ratings (Ta=25℃)

Parameter	Symbol	Rating	Units
Continuous Forward Current	I_F	100	mA
Peak Forward Current	I_{FP}	1.0	A
Reverse Voltage	V_R	5	V
Operating Temperature	T_{opr}	-40 ~ +85	℃
Storage Temperature	T_{stg}	-40 ~ +85	℃
Soldering Temperature	T_{sol}	260	℃
Power Dissipation at(or below) 25℃Free Air Temperature	P_d	150	mW

Notes: *1:I_{FP} Conditions--Pulse Width≦100 μs and Duty≦1%.
*2:Soldering time≦5 seconds.

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Device No：DIS-033-082 Prepared date：07-20-2004 Prepared by：Jaine Tsai

Electro-Optical Characteristics (Ta=25℃)

Parameter	Symbol	Condition	Min.	Typ.	Max.	Units
Radiant Intensity	E_e	I_F=20mA	7.8	20	--	mW/sr
		I_F=100mA Pulse Width≤100μs and Duty≤1%	--	90	--	
		I_F=1A Pulse Width≤100μs and Duty≤1%	--	900	--	
Peak Wavelength	λp	I_F=20mA	--	875	--	nm
Spectral Bandwidth	Δλ	I_F=20mA	--	80	--	nm
Forward Voltage	V_F	I_F=20mA	--	1.3	1.6	V
		I_F=100mA Pulse Width≤100μs and Duty≤1%	--	1.4	1.8	
		I_F=1A Pulse Width≤100μs and Duty≤1%	--	2.6	4.0	
Reverse Current	I_R	V_R=5V	--	--	10	μA
View Angle	2θ1/2	I_F=20mA	--	20	--	deg

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SIR333-A

Typical Electro-Optical Characteristics Curves

Fig.1 Forward Current vs.
Ambient Temperature

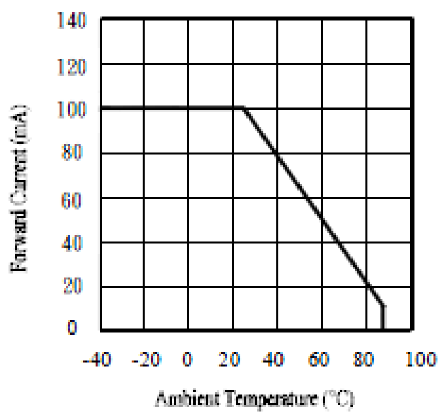


Fig.2 Spectral Distribution

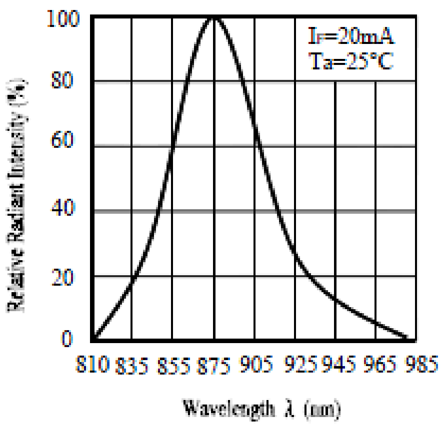


Fig.3 Peak Emission Wavelength
Ambient Temperature

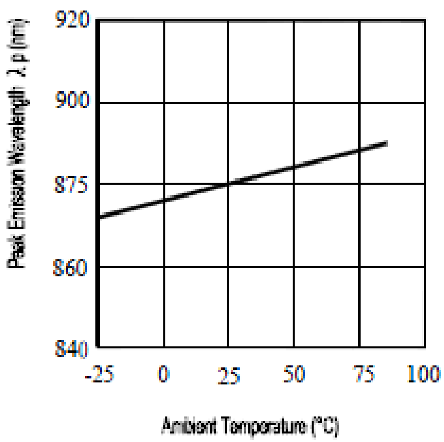
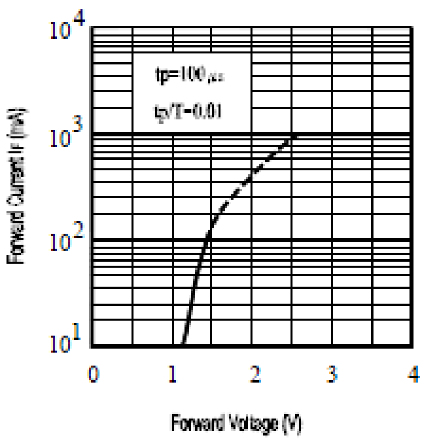


Fig.4 Forward Current
vs. Forward Voltage



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SIR333-A

Typical Electro-Optical Characteristics Curves

Fig.5 Relative Intensity vs. Forward Current

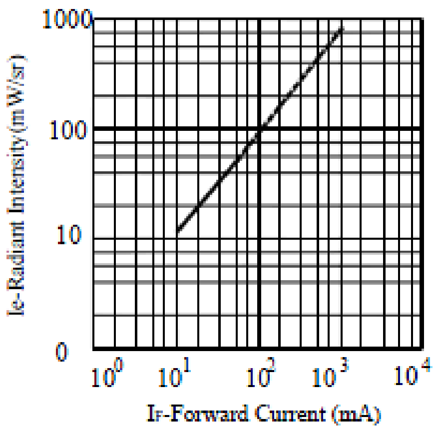


Fig.6 Relative Radiant Intensity vs. Angular Displacement

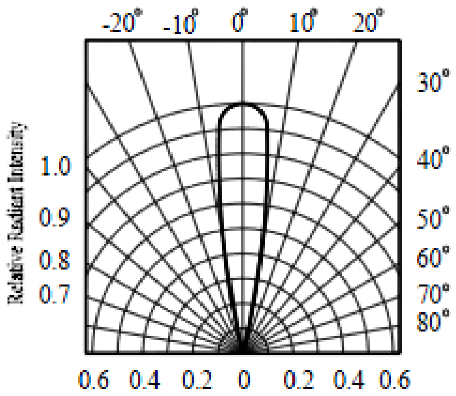


Fig.7 Relative Intensity vs. Ambient Temperature(°C)

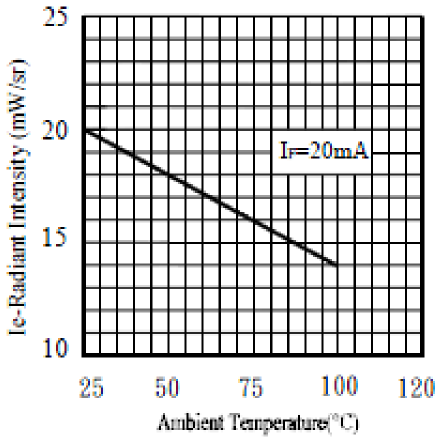
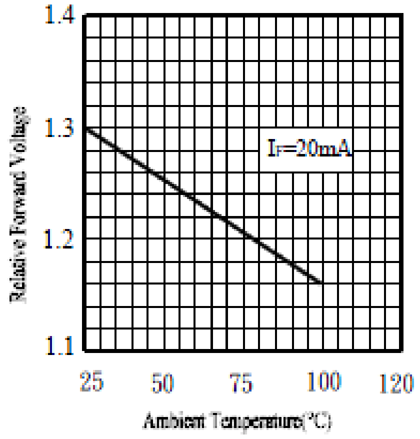
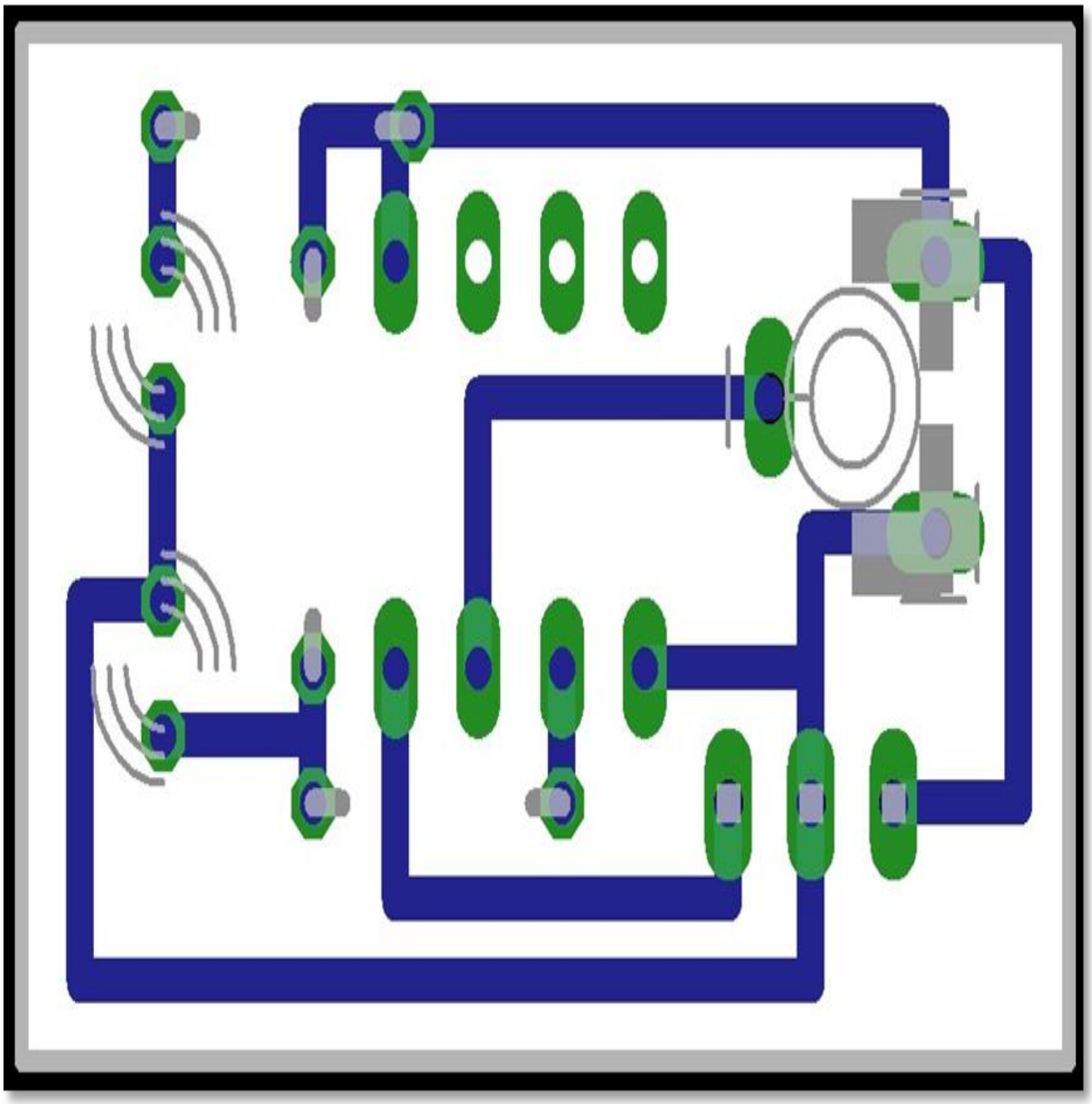


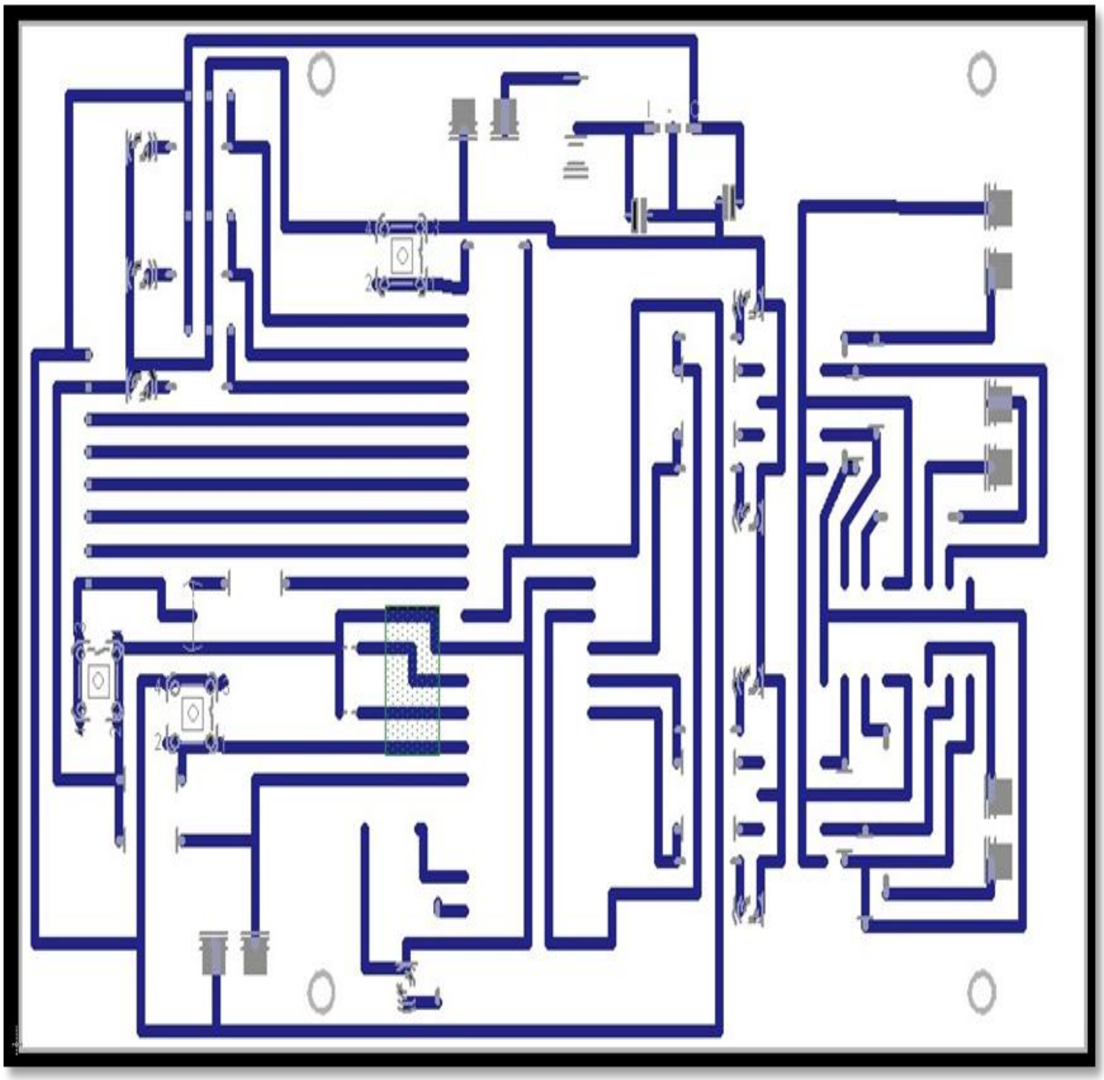
Fig.8 Forward Voltage vs. Ambient Temperature(°C)



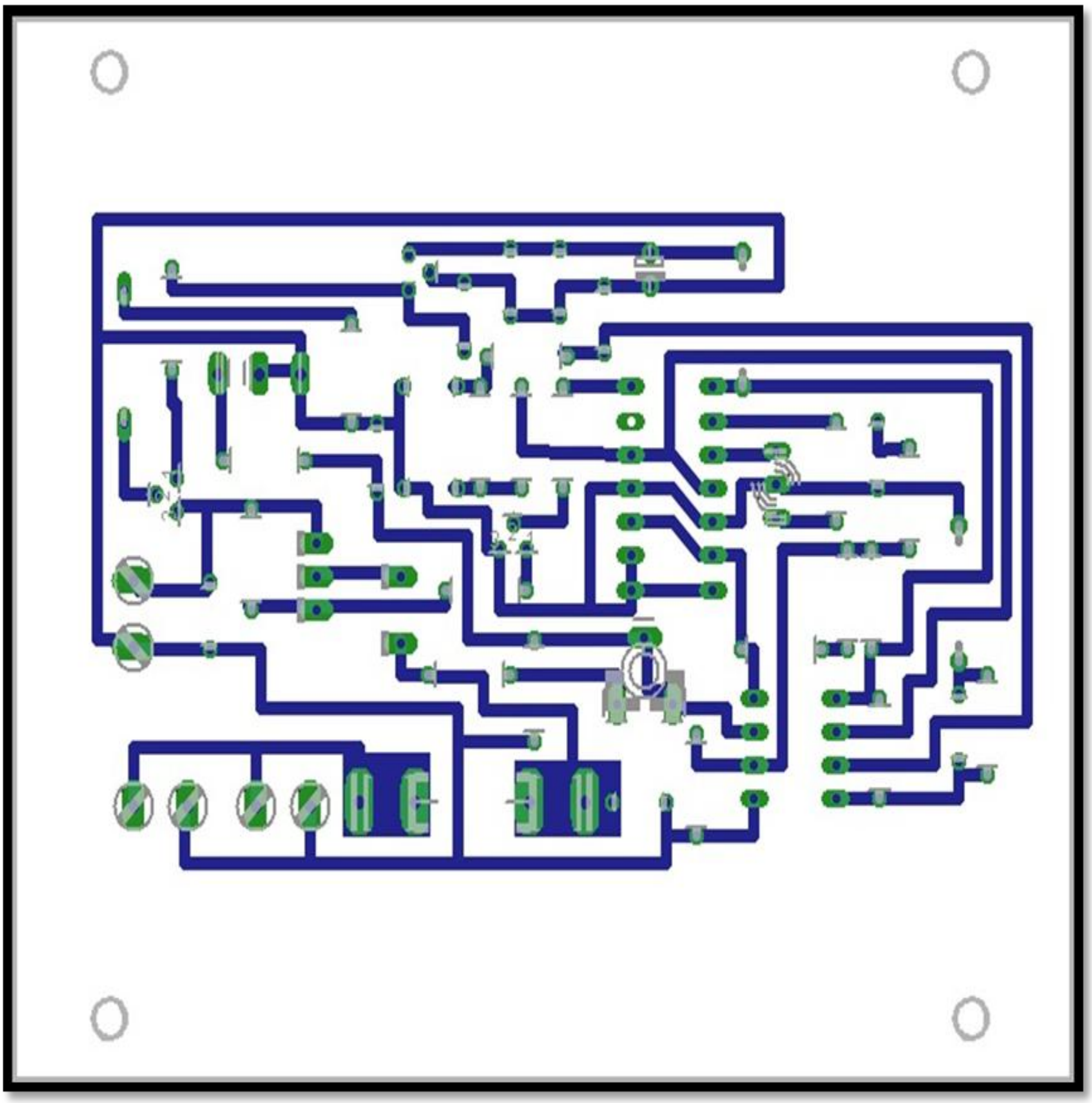
APPENDIX F: PCB



IR Sensor Circuit



Control Circuit



Solar Charger Circuit