Maze Mouse

By

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Dissertation submitted in partial fulfillment of
the requirements for the
Bachelor of Engineering (Hons)
(Electrical & Electronics Engineering)

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Electrical & Electronics Engineering Programme
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June 2004

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

[Asmalilah Binti Abdul Rahim]

ABSTRACT

This dissertation discusses fundamental issues in the development of a micromouse, utilizing the knowledge in electronic circuits, sensors and the microcontroller. The objective of this project is to develop a maneuverable micromouse that has the capability to navigate in the maze and find its way out of maze. A detail design of the micromouse systems is presented. A maze solver for demonstrating the maneuverability of the micromouse has also been developed.

A micromouse is a miniature electro-mechanical robot, typically consisting of three main subsystems: the drive system, an array of sensors and the control system. To illustrate the integration of the three systems in the micromouse, a general block diagram has been constructed. The first block is the sensory systems which generate the input to the microcontroller systems. The selected sensor is the IR detector that uses the reflective motion in order to detect the mouse position. This kind of sensor is sensitive enough for the project and commonly used for IEEE Micro Mouse Competition .The second block is the microcontroller systems that obtain the input signal from input pins and determine the appropriate algorithm for the output systems. The chosen microcontroller is Intel 8031 and had to be programmed by using the ASM51.The third block is the stepper motor. The reason for choosing the stepper motor is that we can easily adjust the direction and the speed by programming. The final product is the combination all the three block systems.

This report describes on the fundamental concepts required for micromouse design which are the infrared sensor systems, Intel 8051 microcontroller system and stepper motor drive systems. Focus of the project is primarily on the infrared sensor system and maze solving algorithm which are the critical part of this project.

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CHAPTER 1

INTRODUCTION

Micromouse is a miniature electro-mechanical robot, typically consisting of three main subsystems which are the drive system, sensory systems and the control system. This project has been developed since 1980s and has become on of the great event of IEEE. In previous years, the development of this project is emphasized on the mechanical aspects especially for sensory systems and driver systems. An analogue system is more preferable in solving the maze algorithm rather than microcontroller programming. However, with the advance innovation in microcontroller systems, people starts to make interesting program to control the micromouse.

The focus of author in this project is to develop all the systems involve in Maze Mouse development. Typically, the author plays around with a lot hardware and software development which requires knowledge in electronic and mechanical systems. The author is not using any high level artificial intelligent (AI) systems for the Maze Mouse development. However, this project can be enhanced with this technology in the future and more functions can be added to the mouse architecture.

1.1 BACKGROUND OF STUDY

Robotic is one of the preferred technologies in industrial application especially in manufacturing and automation fields. The innovation of robots helps the industry to perform more difficult and dangerous task efficiently. In fact sometimes, this production rates can further be improved by using this technology.

Micromouse is using almost likely the same idea as in the robotic system. Some engineers and designers termed it as the electro-mechanical robot. Micromouse is a maneuverable prototype that has the capability to detect its position in the maze and finds its way to the its intended position. The intended position here can means out of maze or to a specific location in the maze. Micromouse is a device that is very sensitive to the environment and that always deciding the next position that it will move as it sees wall or barrier in front of it.

The Maze Mouse project can be divided into three main parts; the sensory systems (detection devices), microcontroller systems (for intelligent/programming systems) and the stepper motor driver systems (the devices that will move the Maze Mouse as it gets the signal from the microcontroller). These systems must functions well before integration since they are dependable on each other.

A good product of micromouse shall have a very sensitive array of sensors so that the control system can has reliable signals inputs during navigation and performs it task efficiently. Failure to indicate a correct position in the maze will cause the mouse to move to an inaccurate position and hence might fail to reach the desired end location. The control system is the microcontroller that is programmed by using the suitable software. This program is used to determine how the driver systems (output) will work.

1.2 PROBLEM STATEMENT

In a particular industrial workplace or plants, there are lots of divisions or area. Some of these areas are not easily accessible by all personal due to certain conditions such as hazardous zone, complex arrangement of equipment and so on. In order to make these places easily accessible, engineers have come out with many solutions. One of the solutions is to have an intelligent device that is capable to detect its surrounding objects, disturbance or any abnormal changes as it enters these places.

Based on the above problem, the author has come out with a design project called Maze Mouse. This project has the potential to be implemented at those areas if we manage to enhance the development. This includes by adding more complex functions, advancing the microcontroller systems with artificial intelligent and a powerful driver systems that is capable to change speed at the appropriate location.

Micromouse can be enhanced to do specific functions as follows:

- Preliminary inspection and investigation at hazardous area in plants/workplace.
- Detect failures /abnormal condition of equipment in the factory.
- Record the data/reading of instruments that are located in the area that is hardly accessible.

However, to implement the above mentioned task, a complex programming tools and additional devices might be required. Since this is a one- year project, the author had narrowed down the constraints to suit the project with the given time frame. For this project, the design will be based on three main parts, which have been described in Section 1.1. The constraints for this project are:

i. The prototype must have the capability to maneuver in the maze and find its way out from the maze.

ii. The sensory systems for this project will utilize the infrared sensor as a detector.

iii. There microcontroller systems for this project is the Intel 8031 which is from the 8051 family.

iv. The driver system for this project is the stepper motor driver which can move in forward and reverse direction.

The accomplishment of this project will be product (micromouse) that is capable to navigate inside the maze and finds its way out of the maze.

1.3 OBJECTIVE AND SCOPE OF STUDY

The objectives of the project are:

1.3.1 To develop a maneuverable micromouse that can find its route out of maze

1.3.2 To integrate three workable systems in order to produce micromouse (i.e. sensory systems, control systems and driver systems).

1.3.3 To identify and troubleshoot the hardware tools (i.e. sensory systems, microcontroller circuit and the stepper motor.)

The scope of study of this project will mainly cover the all the three parts mentioned above (sensory systems, microcontroller systems and driver systems). It should involve the hardware construction and the software development and programming.

CHAPTER 2
LITERATURE REVIEW AND THEORY

2.1 HISTORY OF MICROMOUSE

The first World Maze Mouse or Micromouse Competition was held in Tsubuka, in Japan, in August 1985, and was open to contestants from Europe and the USA. The mice were now becoming quite sophisticated, using infra-red or ultrasonic sensors, stepper or DC servo-motors. The champion this year was the Japanese Noriko-1, with the best non-Japanese contestant being Dave Woodfield's Enterprise at the 7th position. [5]

The 1987 edition was hosted by the Institution of Electrical Engineers in London, with 13 competitors. David Otten, from MIT, won the two first prizes with Mitee Mouse I and II. This year a new scoring was introduced to reward mice able to solve the maze completely independently: 10 seconds were deducted to the run time if the mouse was never touched from start to finish. [5]

Singaporean micromouse competitions started in 1987, sponsored by the IES, the Institution of Engineers of Singapore. In 1988, MIR3+ from Nanyang Technological Institute won third place, and in July 1989 in London, the Singaporean team got 6 of the top 8 prizes. David Otten's Mitee Mouse III finished 2nd, while Dave Woodfield's Enterprise came in 5th. The three best mice were within a half second of each other. [5]

In October that same year, IES hosted their first International Micromouse Competition, and the local team once again won five of the top seven places against mice from the UK, the USA, Japan, Taiwan and Australia.[5]

2.2 MAZE SOLVER

Previously, the author had made used lots of theories by Nick Smith, where he had emphasized on the Maze Solver. Nick Smith's method had focused more on the electronic and mechanical systems rather than on the programming. However, since this project is also dealing with the programming, the author had also made extra research especially on the software and programming items.

A mouse must be fast and intelligent. For this section, the author the method to do the maze solver is described. The main objective of the maze-solving algorithm is to quickly determine from the current position of the mouse, where it has to go next in order to get to the centre of the maze and back. It uses wall information stored during the exploration of the maze to determine the quickest route from the start-square to the centre of the maze and back.

2.2.1 Lee's Algorithm

The Lee's algorithm is a popular maze solver to the micromouse contestants and has been used by several world championship-winning mice. The standard Lee's algorithm solves the maze for the shortest route, but this is not always the quickest. To find the quickest route to the centre of the maze it is necessary to use an advanced form of the Lee's algorithm, which floods with time instead of distance. The advanced Lee's algorithm is based upon the following: [2]

1. No internal maze walls exist except those specified in the competition rules; normally just the outside perimeter.[2]
2. The target square(s) is/are numbered 0. The squares joining the target square(s), with no separating walls, are numbered by the time taken to travel there from the target square(s).[2]
3. The squares joining the above squares, with no separating walls, are also numbered by the time taken to travel there from the target square(s).[2]

4. The flooding stops when the square being renumbered is the current mouse position.[2]
5. The mouse makes the best move from the current mouse position by selecting the lowest flooding number.[2]
6. If the mouse encounters a situation where there are two possible routes, with the same Lee's number, then the mouse will select the route with the following priority: straight ahead, east, west, north or south.[2]

2.2.2 Lee's Algorithm Program Structure

The steps below describe the Lee's Algorithm program structure:

i. Determines the next position of the mouse from its current position. It primarily uses information from the Bellman flooding array, along with the mouse's current direction. It only starts this step when the mouse is nearing its required destination. [2]

ii. The task of driving the Maze Mouse to the new position determined in the last step. Although this is not strictly the task of the maze-solving algorithm, it must inform the Motor Control sub-system where to go. [2]

iii. To update the wall information on the move, this is automatically done by the sensors and sensor sub-system. The sensor sub-system sets a flag if any new wall information is obtained. [2]

iv. This step is only executed if the wall information has changed during the movement of the Maze Mouse to its required destination. This cuts down the time to process the next position. [2]

v. This is the last step in the process and checks whether the Maze Mouse has reached its ultimate destination. The easiest way to achieve this is to check the current Bellman number for the current mouse's position. If this value is zero, then the flooding direction must be switched. [2]

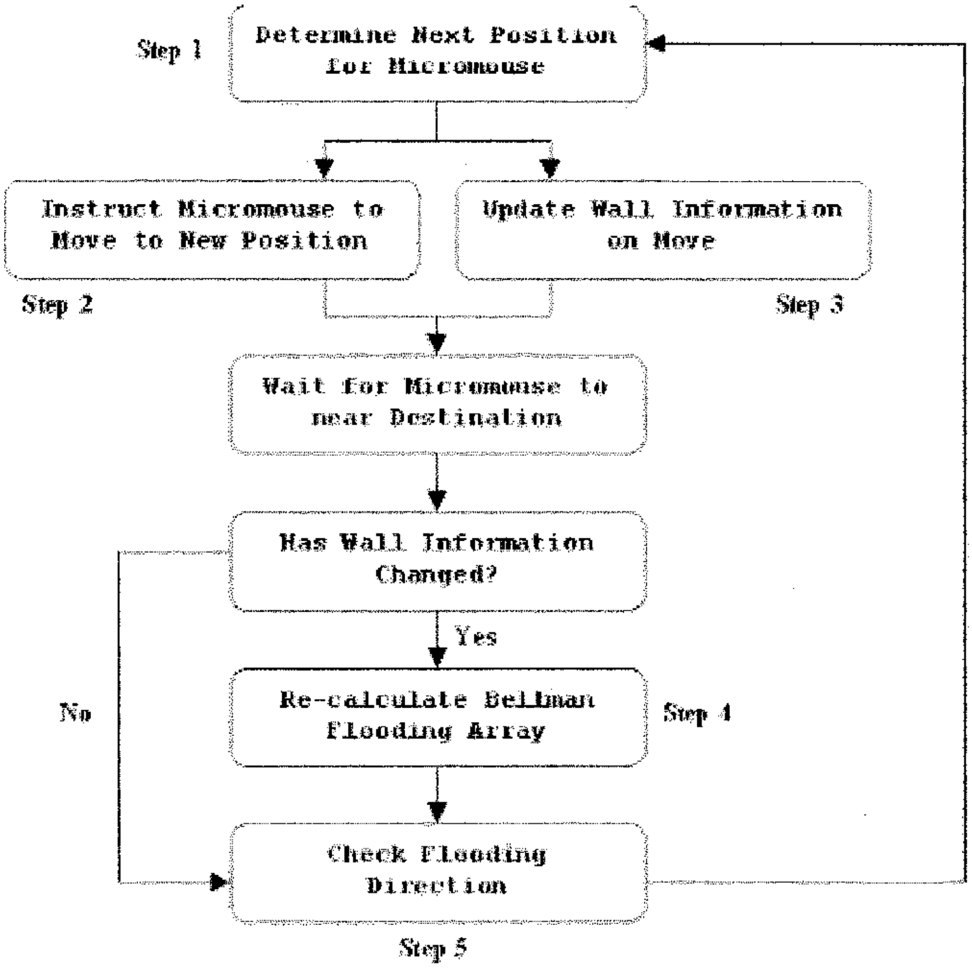


Figure 2.1 Block Diagram for the Bellman Flooding Algorithm [2]

2.3 SENSORY SYSTEMS

Sensors have two purposes - to detect the presence or absence of walls to the sides and front, and, in some designs, to provide feed-back about the motion of the wheels. Wall-sensors need to be mounted ahead of the centre of the micromouse for steering purposes. The reason for this becomes clear if we consider the effect on wall sensors if the micromouse is rotated within the maze by, say, ten degrees. If the sensors are mounted ahead of the micromouse, they can see a difference in wall position with respect to the micromouse and corrective action on steering is possible. If the sensors are near the centre of the micromouse little difference in apparent wall position can be seen. To achieve reliable steering we must control direction, not position. [4]

2.3.1 Infra-red sensors

Infrared sensor was claimed to operate much faster than mechanical switches. They are reliable when adjusted correctly, but may suffer interference from massive doses of IR from filament lamps used to illuminate Maze Mouse mazes during public exhibitions, and from flash-bulbs, though flash photography is prohibited during competition runs. [4]

The common form of IR wall-sensor is a row of IR-emitting diodes shining down onto the walls on each side of the Maze Mouse, and a set of about five IR-sensitive diodes on each side looking downwards to determine the presence and position of the walls to the left and right. If these are mounted ahead of the centre of the Maze Mouse they can also detect the presence of a wall in front, or a separate sensor may be used. To reduce power consumption and the effects of interference, emitters are usually pulsed during sensing cycles with power far above the nominal continuous rating. Sensors to detect and measure wheel motion must be fast to achieve good position resolution at high speed. Such sensors use reflective or slotted disks on driven or non-driven wheels. Most electronic catalogues list items designed for such use, containing an emitter and a receiver in one assembly. [4]

2.4 DRIVER SYSTEMS

The driver system is the output of the micromouse systems where that drive the micromouse to the intended position based on the input signal sensed. Common drivers that always being used are the servo motor control and stepper motor control. Below are some of the motors that ever been used in the micromouse construction:

2.4.1 Stepper motor

Stepper motor consists of a motor and a driver PCB. Ex-equipment items can be bought for less. The driver chips are operated by two signals. One signal determines the direction of rotation, plus for forward and minus for backwards. The other moves the stepper by one step each time it goes from minus to plus. [5]

2.5 APPLICATION OF OPERATIONAL AMPLIFIER (LM 339)

Non inverting amplifier is not the commonly used constant gain amplifier. However, for the sensory systems in this project, this type of amplifier is used instead of the inverting amplifier. The output is obtained by multiplying the input by a fixed or constant gain, set by the input resistor (R1) and feedback resistor (Rf). This output is not inverted from the input. The output voltage is determined by using the equation below: [11]

$$Vo = \frac{Rf}{R1} V1$$

In this particular project, the output voltage is taken to be 0V or 5V for which 0V represents the LOW output value and 5V represents the HIGH output value. The main concern in this project is to determine the correct input voltage that should be applied in order to realize the correct output. Referring to Figure 2.1, the calculation of the input voltage is determined as follows:

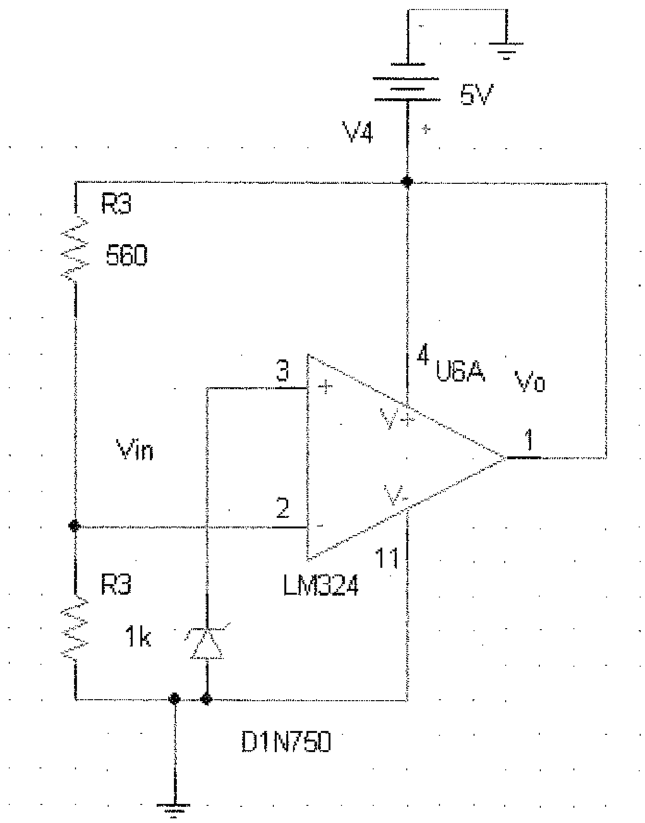


Figure 2.2 Non inverting Operational Amplifier

From Figure 2.2, the calculation for the input voltage Vin is as follows:

$$Vin = \frac{Rc}{Rc + Rf} Vo$$

$$Vin = \frac{560\Omega}{560\Omega + 1k\Omega} \times 5V$$

$$Vin = 1.8V$$

The reference voltage, Vref must be twice the input voltage. In this project, the reference voltage is taken to be 3.3 V. This is done by placing a zener diode that has a value of 3.3 V. Therefore, the determination of the output voltage is as follows:

$$V_o = 5V \text{ if } V_{in} > V_{ref}$$

$$= 0V \text{ if } V_{in} < V_{ref}$$

CHAPTER 3

METHODOLOGY AND PROJECT WORK

3.1 METHODOLOGY

The accomplishment of this project requires some strategies to be implemented. These are described as follows:

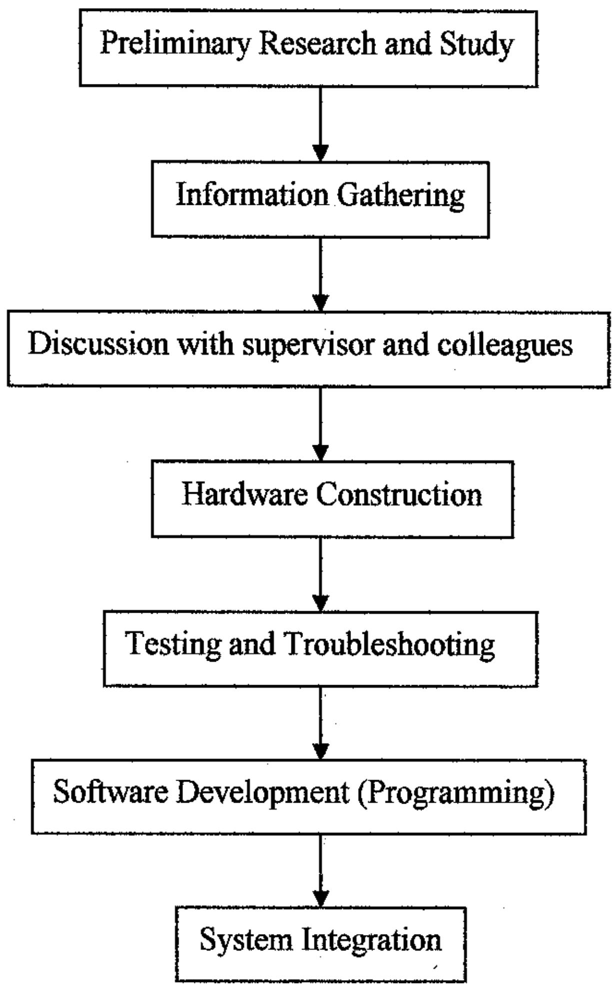


Figure 3.1 General Flowchart of the Methodology used for Maze Mouse Project

1. Preliminary Research and Study

This is the initial stage of the Maze Mouse Project. At this stage the author had spent the time for conceptual analyses on the constraints of the project. The author had started the study by identifying the items required for the project development and what are the systems involve in this project. An initial proposal or preliminary report has been produced to illustrate the gist of the project and the expected achievement that the author needs to accomplish. This conceptual study involves the description of the three systems used for the micromouse; sensory systems, microcontroller systems and the stepper motor driver systems. The list of equipment for this project is shown as per attachment in Appendix B.

2. Information Gathering

There are a lot of sources has been used for information gathering. The methods involved are as follows:

- Observation

The author had made some observation on some models of robot available at website and university. This is because the micromouse is using the general systems as in robot construction which is the sensory systems and control systems and the driver systems. However, the author had only focus on the sensory systems, especially on the detection process and the mechanism involve in determining the obstacles in front of the robot. The other systems are more complicated as compared to the micromouse specification. Besides, some of the previous paper work regarding micromouse is also referred.

- Technical Reference and Journals

The technical reference here refers to the books that have been referred during project construction. This reference has been used at the initial stage and also during literature review as a guideline to the project basis. The main reference is the Ayala's (1995) which provide a detail explanation on the 8051 programming for a beginner. The journals are also being referred especially to identify the specification of the components involve in this project to ensure that an accurate implementation is done. These references are as shown in the reference list.

- Internet Browsing

This is the most favorite method during project ongoing process. There are lots of website that provides technical reference and enhancement in this project. Most of the micromouse in the websites are the product that has been used for International competition or part of the lab project in other university.

3. Hardware Construction

The hardware construction is done based on the schematic diagrams generated for each system involve. For the sensory systems, the circuit was constructed on the bread board prior to the PCB or veroboard implementation for troubleshooting purpose. Besides the sensory systems, the author had also need to construct microcontroller circuit and the stepper motor systems. The schematic diagram for the sensory system, microcontroller systems and driver systems are shown in Appendix C, Appendix D and Appendix E.

4 Programming Developments

The programming can be developed once the hardware part is ready. All systems will be integrated when there is no error in the microcontroller board. If other system like the sensory system or the stepper motor system is not ready, a simulation input and output signal can be used to test the programming functionality.

5. Testing and Troubleshooting

The testing and troubleshooting is done after the system has been assembled to ensure the correctness of the interconnection between circuits workable. The author is required to do a number of testing to make sure the hardware construction is reliable.

6. Systems Assembly

If the systems work as intended the author can starts assembling all systems which involve the three parts described above, micro controller board, sensor interfacing and the mouse mechanical system. This stage focuses on testing the workability of the programming.

3.2 PROJECT WORK

The scope of work for this project will be divided into three main parts. This section will further explain on sub systems required to develop this project.

3.2.1 Maze Development

The author had designed few patterns for maze. The routes of the maze are as shown in Figure 3.2.

3.2.1.1 Routing Strategies

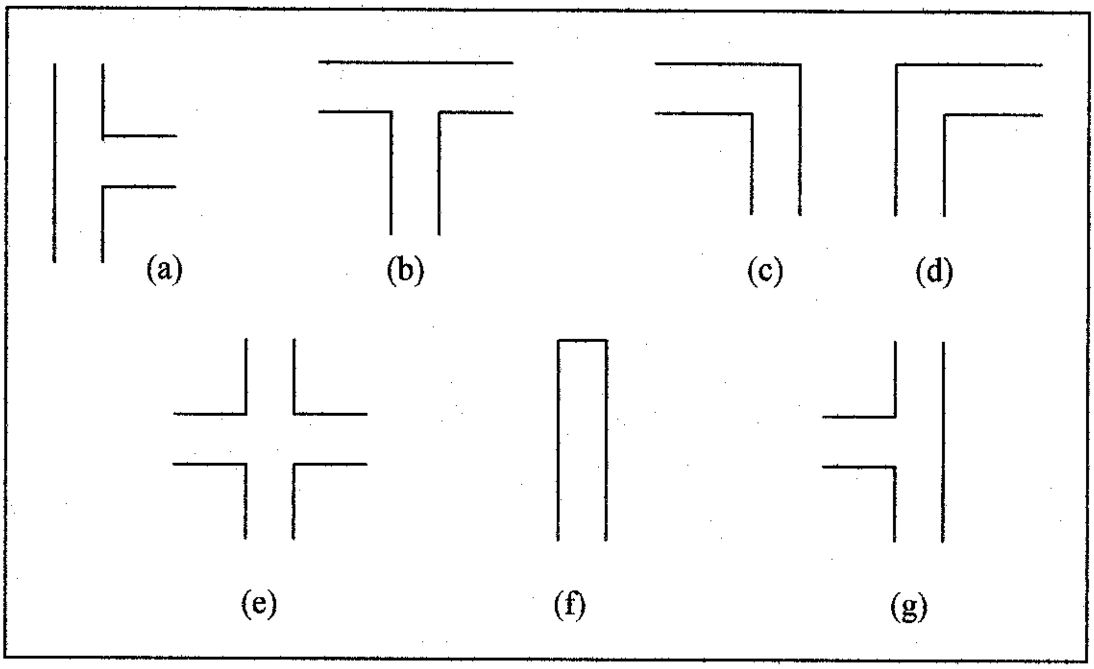


Figure 3.2 the Maze Mouse Routing

Figure 3.2 shows seven possible types of maze pattern that the mouse shall face during the navigation. In order to develop the flowchart, a specific direction is specified to drive the mouse for the next movement. The arrow in Figure 3.3 will described the way that the mouse should be directed when its sees a particular condition in the maze.

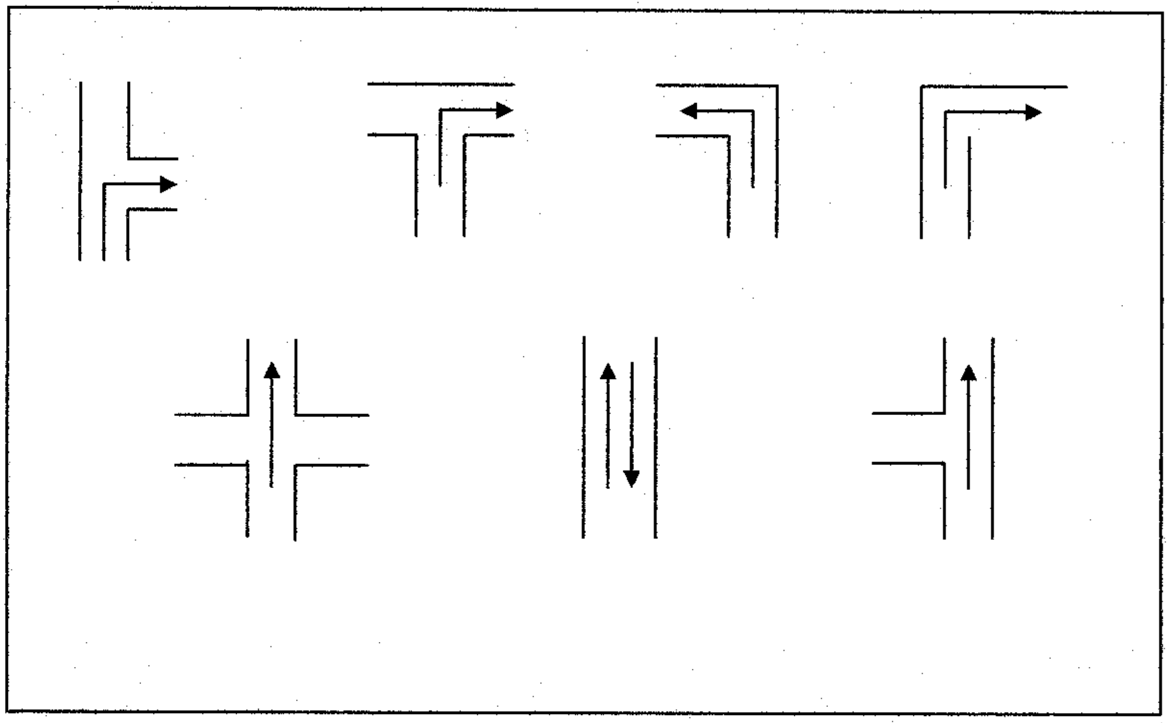


Figure 3.3 Mouse Directions in the Maze

Figure 3.3 shows the direction that the mouse will be directed from the programming command. In order to determine the above condition, a specific direction is defined based on the output indicated by the sensor. The next step is to design the maze design and maze algorithm.

3.2.1.2 Maze Algorithm

As noted, three areas will be sensed, right, forward and left. The condition for each of this sensor is summarized as in Table 3.1:

Table 3.1 Mouse Decision Matrix

Left Sensor	**Forward sensor**	**Right sensor**	**Routing**	**Decision**
Low	High	High	Left corner	Turn Left
High	High	Low	Right corner	Turn Right
High	Low	High	Straight line	Forward
Low	Low	Low	4 Junction	Forward
High	High	High	Dead End	Reverse
Low	Low	High	T Left Junction	Turn Left
High	Low	Low	T Right Junction	Forward
Low	High	Low	T Junction	Left

Based on Decision Matrix in Table 3.1, there are two possible conditions that the sensor should represent either High or Low. The High output tells the user that the receiver has received the reflection signal from the infrared signal. The Low output will indicates that the receiver has not received the reflection of the infrared signal.

Based on the output above, logic functions or maze solver is determined as follows:

i. Microcontroller receive input from the receiver
ii. Microcontroller will compare the input bits to the stored bits in the register.
iii. Input signal: [1 1 1] In this case three input signal is treated as 3 representation of binary digit. The most significant bit represents the left receiver signal. The least significant bits represent the right receiver signal.
iv. Each address will hole each binary representation of the microcontroller logic.

As described by the maze solver above (i- iv) the sensor must be able to define all conditions of the sensor so that it can identify the accurate position of the mouse. There must be three input signal received by the microcontroller in binary form. This three input signal represents the High or Low signal of the sensor (0 or 1). By having this input signal, the microcontroller is able to know the current position of the mouse and determined its next path. Table 3.2 represents the binary form of the input signals:

Table 3.2 Input Signal Representation

Input Signal	Position
000	4 Junction
001	T Left Junction
010	T Junction
011	Left corner
100	T Right Junction
101	Straight Line
110	Right Corner
111	Dead End

Table 3.2 represents the binary input signals to the microcontroller. This table is generated based on the decision matrix defined in Table 3.1. The signal received by the microcontroller will be compared with the input signal with the data store in the addressed. If the data input is the same with the data store, it will perform the specific function which will determine what is the next action of the mouse.

Each address, which represents the condition, will give the output to the motor. This condition will refer to different addresses, which contain the instruction for the motor. At the end of the logic, the microcontroller will perform checking function, which will check whether the final position of the mouse correct.

To demonstrate the flow of programming writing, the flow charts for each routing pattern is developed. Refer to Appendix F- Appendix M.

3.2.2 Sensor Interfacing

An experiment has been conducted to evaluate the performance of the sensor circuit. Below is the procedure for the sensor circuit:

i. The circuit as shown in Figure 3.4 is constructed. This circuit represents part of the left sensor circuit.

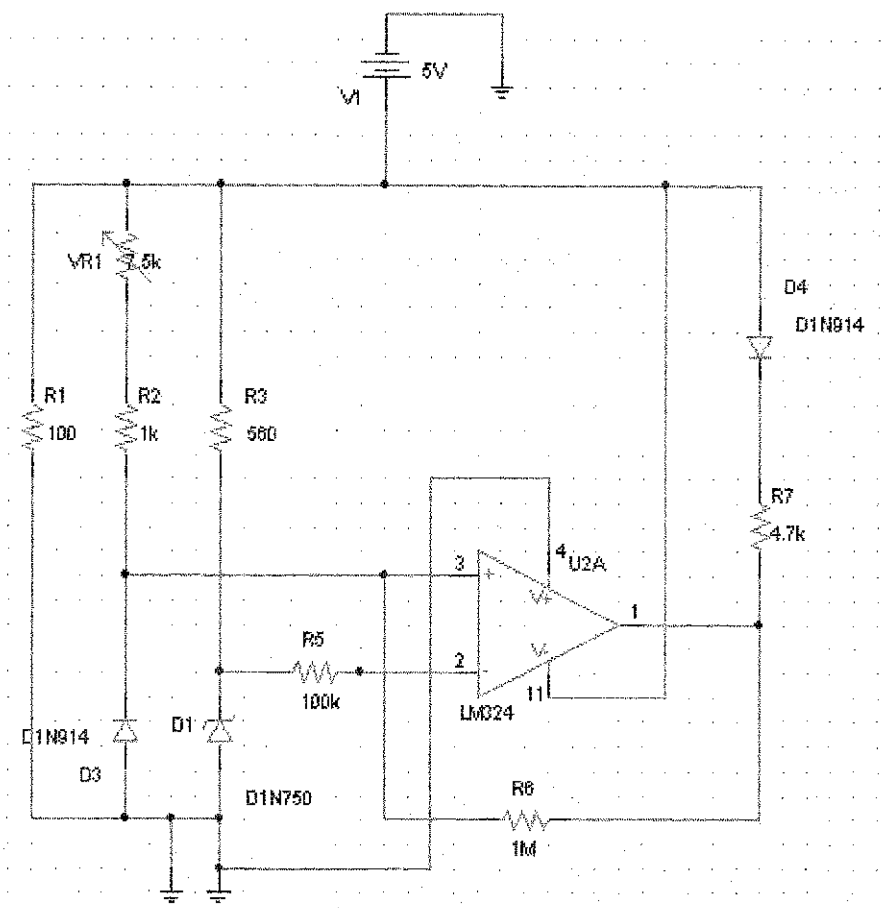


Figure 3.4 Infrared Sensor Circuit.

ii. A 2V voltage is applied to the input signal, Vin.

iii. The functionality of the sensor circuit is tested by using the black cardboard. The black cardboard represents the absence of routing in the maze.

iv. The output voltage of the operational amplifier is measured. The LED indicator is observed.

v. Comparison is made between the calculated value and the measured value.

vi. The measurement is repeated for three times.

vii. Step iii until step v is repeated for white cardboard. The white cardboard represents the presence of the routing in the maze.

The experiment is done to test the functionality of the infrared sensor. This experiment is repeated for three times in order to compare result obtained from this testing and the calculation from the theory. The findings from this experiment are discussed under Chapter 4: Result and Discussion.

3.2.3 Micro Controller Systems

The author had finished assembled all the integrated circuit for the microcontroller systems which consist of:

i. 2 x 8 pin header
ii. Microcontroller 80C31
iii. EPROM 6116
iv. RAM 2732A
v. Nand gate 74LS400
vi. Crystal Oscillator
vii. Voltage Regulator circuit.
viii. Latch 74LS373

All this ICs are shown in general block diagram below:

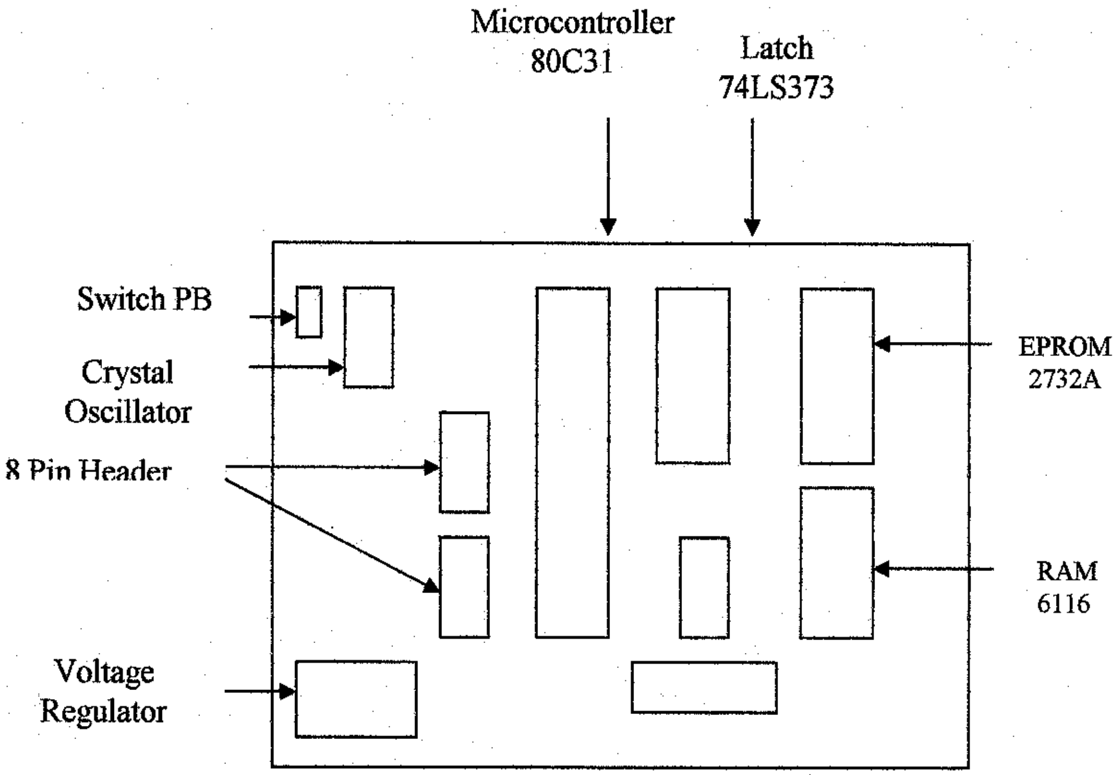


Figure 3.5 General Block Diagram of Microcontroller Systems Assembly

Figure 3.5 shows the location of ICs as had been constructed for the microcontroller systems. The 8 pin header is used to connect the input and output signals to microcontroller systems. The first 8 pin header is the inputs from the sensory systems which will be connected to Port 3 of the microcontroller. The second 8 pin header is the output port from microcontroller (Port 1) which is connected to the driver systems.

The programming will be written on the EPROM 2732A. The microcontroller will get the functions and command from RAM 6116. As the microcontroller runs the program, the latch will remains the current input in the storage. The latch shall be the most reliable device to ensure a correct output is generated. The NAND gate is used to compare the received input with the stored program. The program will continuously running as long as there are changes in the storage bits.

3.2.4 Stepper Motor Interfacing

The output of the microcontroller will be used to drive the stepper motor driver. Refer to Figure 3.6:

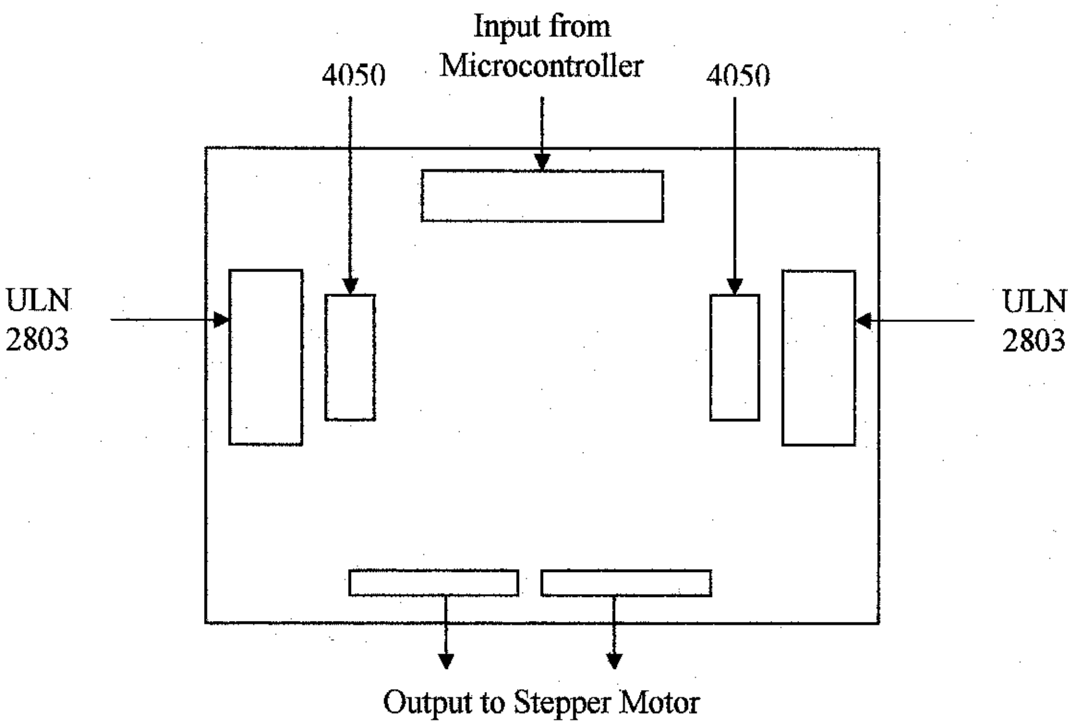


Figure 3.6 Motor Driver Circuit

The stepper motor is a DC motor that rotates through a cycle or through part of cycle in response to an electrical pulse. The type of stepper motors used for this project is the common stepper with four stator windings that are paired with a center tapped common.

The center tap allows a change of current direction in each of two coils when a winding is grounded, thereby resulting in a polarity change of the stator. While a conventional motor shaft runs freely, the stepper motor shaft moves in a fixed repeatable increment which allows one to move it to a precise position. This repeatable fixed movement is possible as result of basic magnetic theory where poles of the same polarity repel and opposite poles attract.

The direction of the rotation is dictated by the stator poles. The stator poles are determined by the current sent through the wire coils. As the direction of the current is changed, the rotor motion will be reversed. The stepper motor discussed here has a total of six leads; four leads representing the four stator windings and two commons for the center tapped leads. As the sequence of power is applied to each stator winding, the rotor will rotate.

3.3 TOOLS AND EQUIPMENT

3.3.1 Hardware Development

The hardware development refers to all circuits construction required for this project. This is referred to the sensor circuits, microcontroller circuit and the stepper motor circuit. The circuits is constructed on the breadboard prior to on veroboard implementation. The reason is for convenient testing and troubleshooting.

3.3.2 Software Development

The software development starts with the development of flowcharts so that the author can identify what are the sequences that should be defined in order to control the microcomuse. Software part is a significance aspect for programming and assembly language writing. The software that will be used for programming is the ASM51.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 RESULT AND FINDINGS

This section will cover the results from the effort that the author has put during the project development. Three main components will be discussed as described in previous section.

4.1.1 Sensor Interfacing

The project requires three IR sensors on the left, three IR sensors on the right and two IR sensors at front. Prior to sensor circuit construction, a sample circuit has been constructed by taking part of the sensor for testing. The circuit construction is as shown in Figure 3:

This circuit represents one of the sensors at the left side of the micromouse. The circuit operates by using the principle of an amplifier. The reference voltage Vref of the operational amplifier LM 339 is taken to be 3.3 V. The use of operational amplifier is to compare the signals between the input and the reference voltage Vref. The input signal of this circuit is identified by the infrared sensor. The infrared will detect the presence or absence of routing in the maze. In this case, the absence of routing is indicated by the black surface whereas the presence of the infrared sensor in indicated by the white surface. The significance of these two surfaces is described as follows:

- If light is transmitted to the black surface, the light will be absorbed by the surface.
- If light is transmitted to the white surface, the light will be reflected by the surface.

This is illustrated in Figure 4.1 below:

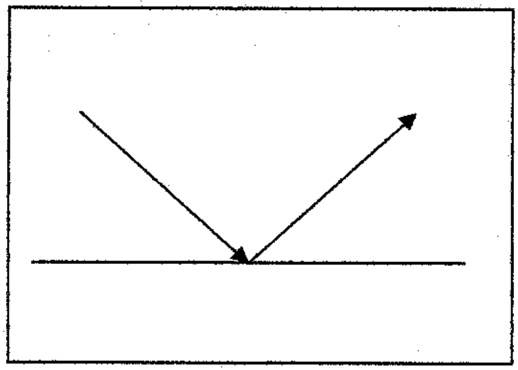


Figure 4.1(a) White surface

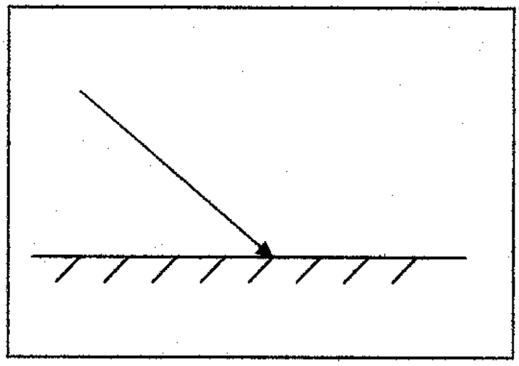


Figure 4.1(b) Black surface

Figure 4.1 Testing Cardboard for Infrared Sensor Circuit

The experiment is carried out by supplying the circuit with a 5V power supply. The functionality of the circuit is identified by using the white surface and the black surface. As describe in by the procedure in Section 3.2.2 the output voltage of the operational amplifier is measured. The result is as shown in Table 4.1:

Table 4.1: Result of Sensor Interfacing Experiment

Experiment	Surface	Measured Output Voltage (V)	Theoretical Output Voltage (V)	LED Output Indicator
1	Black	6.2	0	HIGH
	White	5.3	5	HIGH
2	Black	5.3	0	HIGH
	White	6.1	5	HIGH
3	Black	5.3	0	HIGH
	White	4.7	5	HIGH

The result from Table 4.1 had shown the measured output voltages are different from the theoretical value. The LED Output Indicator also does not changing even though the different surfaces have been tested on the infrared transmitter and infrared receiver. The result from this experiment will be further discussed under Section 4.2.

4.1.2 Maze Solver

Besides developing the hardware part of the Maze Mouse the author also need to plan the maze solver. The maze solver will be the preliminary part towards microcontroller programming. There are lot of method can be chosen to develop the maze solver. The author had chosen to use the Lee's Algorithm since this is the most convenient and common method used by the Maze Mouse designer before.

The first criterion required in the maze design is to have all the routing strategies in the maze. The proposed maze design is as shown in Figure 6:

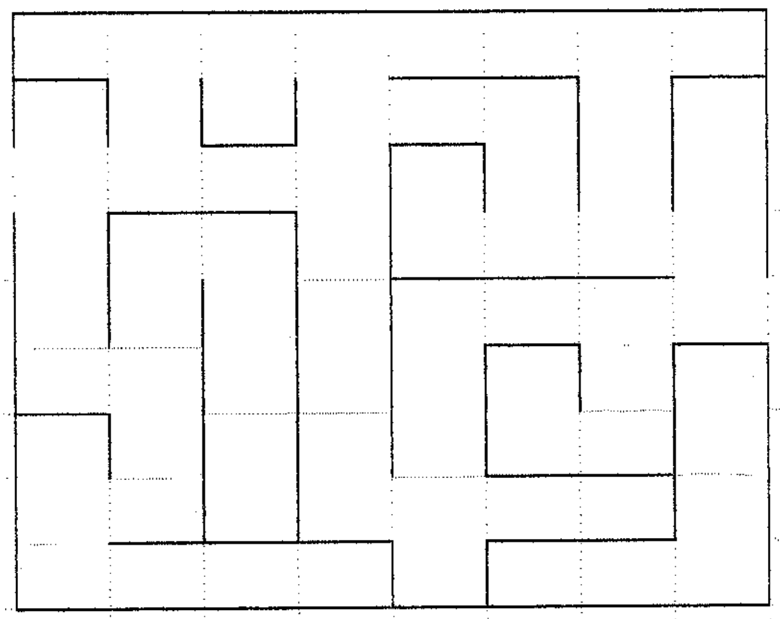


Figure 4.2 Maze Design

Figure 4.2 shows the Maze design for this project. As can be seen, all seven routing strategies are indicated in the maze design.

By using the Lee's Algorithm, the routing strategies developed in Section 3.2.1.1 is arranged. This method will be focused on the priority route that the mouse will follow when there are few possible routes to move. The algorithm is developed as described in Section 2.1.1. However, the author does not utilize all the concepts introduced for Lee's algorithm. The algorithm is modified in order to fulfill the requirement follows:

- The maze must perform all the routings defined in Section 3.2.1.1. The micromouse must counter all the seven routings as defined in that section.
- The traveling time is not the primary concern during navigation. Therefore, the resulted routing from this project might not possibly be the shortest path taken to complete the navigation.

The maze needs to be numbered to determine the priority path that the mouse will follow when it sees more then one potential route. The numbering process is as shown below:

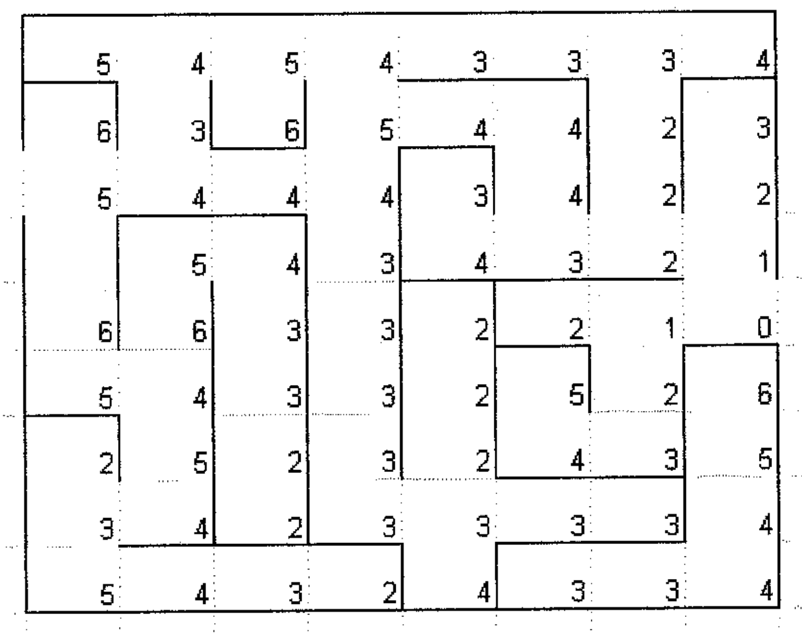


Figure 4.3 Numbered Maze (Lee's Algorithm)

The operation of the Lee's Algorithm worked as follows. From the start position, the mouse should move to a square with a number one less. Continue doing this until the target (numbered 0) is reached. Assuming that the bits array that will be developed in this program is 5, then the maze algorithm as in Figure 4.3 can be developed.

In this case, the mouse will start at the indicated at column 1 row number 3. The mouse shall move to a square with a number one less. The arrow in Figure 8 will describe the actual route that the mouse should move if we programmed the mouse by using the Lee's Algorithm.

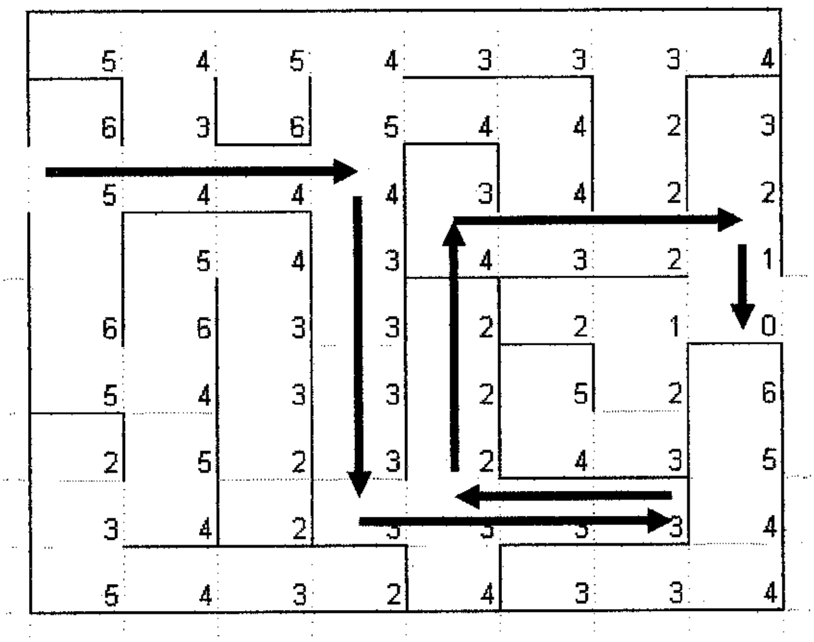


Figure 4.4 Traveling Direction of the Maze Mouse

There may be more than one possible route, but if so they will all is of equal length. However in this particular design, the mouse need to find the exact path that it should follow since any possible two routes will be indicated by two different numbers. Therefore, the mouse needs to follow the indicated route as shown in Figure 4.4.

In real practice, the maze solver can be designed to have a choice between two possible routes. However, since the author had defined the direction as described in Section 3.2.2.1, an exact path is used for this Lee's Algorithm. This part of the algorithm could be enhanced to give preference to long, straight runs because the robot can traverse those faster, even though they may be the same number of squares to the center.

Theoretically, the implementation of Lee's Algorithm requires two arrays: one for the Lee numbers and the other for the map, which records where the walls or distractions are in the maze. The Lee's algorithm array contains integer numbers that represent the minimum number of squares required to travel between the current square and the target. The map array contains bytes where a bit is used to represent the presence or the absence of a wall in each of the four directions N, S, E, W. When making decisions as to which way to go, the processor uses information from both arrays: the mouse moves to the adjacent square that has the lowest Lee number, which should be one less than the current value.

4.1.3 Microcontroller Board

The author had managed to construct the microcontroller that will be used for the microcontroller 8051 programming. This microcontroller board consists of the following items:

i. 2 x 8 pin header
ii. Microcontroller 80C31
iii. EPROM 6116
iv. RAM 2732A
v. Nand gate 74LS400
vi. Crystal Oscillator
vii. Voltage Regulator circuit.
viii. Latch 74LS373

Prior to programming, the circuit needs to be tested in the lab to ensure that there is no short circuit in between the nodes of the veroboard. All non connected pins should be separated. A plan is needed to make sure that the arrangement of the integrated circuit (IC) will functions well and at the same time minimized the size of the microcontroller circuit.

4.2 DISCUSSION

4.2.1 Sensor Interfacing

Based on the result obtained in Section 4.2.1, the author identified that the infrared sensor circuit does not functions well since the indicator do not change with respect for both surfaces (black and white) tested . The output voltage obtained from the experiments were also differs from the theoretical calculations.

There are few factors that cause the failure of this experiment. Below are some of the major factors that the author had identified:

i. The disturbance from surrounding- The infrared sensor might be affected by the source of light from the surrounding. This will cause the infrared receiver to always receive the light and hence the non-inverting input is always pulled to the HIGH input. Therefore, a HIGH output will be indicated by the operational amplifier. The absence or presence of the cardboard is very difficult to be recognized.

ii. The zener diode voltage does not indicate a value of 3.3 V. Hence, the inverting input cannot be pulled at a LOW position when it does not receive the signal from the infrared receiver.

iii. No current flowing at the non inverting input. High resistance might have occurred at this pin.

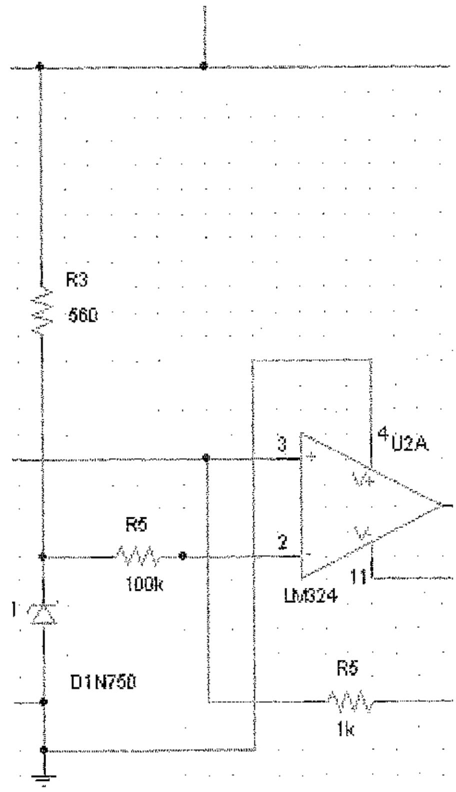


Figure 4.5 Node 3 of the Infrared Sensor Circuit

$$R2 = \frac{3.3V}{5.5V} \times (R1 + R2)$$

$$R2 = 0.66 \times (R1 + R2)$$

$$R2 - 0.66R2 = 0.66 \times (560\Omega)$$

$$R2 = \frac{369.6\Omega}{0.34}$$

$$R2 = 1087.06\Omega$$

$$R2 \approx 1k\Omega$$

By implementing the above modifications, the author managed an improvement for the sensor circuit.

4.2.2 Maze Solver

At the initial stage, the author had defined the path that should be taken by the mouse when it sees few possible routes that it can follow. The Lee's Algorithm is just being implemented when the author found that its implementation provide a more efficient guide to the micromouse. Another advantage of the Lee's Algorithm is that it can be programmed to make the mouse travels in a faster mode. A faster mode travel is very important during the micromouse competition.

The author had not emphasized on this algorithm since a predefined path has been done. The main focus of author while implementing this algorithm is the numbering systems. However, the array and memory map as described before can also be emphasized while doing the microcontroller programming.

CHAPTER 5
CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

This research of micromouse is intended for technical and non technical readers. It includes a wide area of electrical especially on the control systems. It includes substantial coverage on the sensory systems, microcontroller system and the driver systems. The author had covered all these three components in general. However, due to the technical problems occurred during project development, special attentions had been given on the sensory systems and the maze solver development.

In this study, the author had focused on developing the sensory systems. In a particular micromouse system, the sensory systems play a major role in identifying the position and potential routes for the micromouse. Thus, the systems need to be developed as a redundancy systems to ensure that an accurate position in sensed while the mouse is searching its way out of the maze. For this project, the infrared sensor has been chosen as the device that will detect the presence or absence routing in the maze. Based on the experiment developed in this project, the author had identified that the sensory system is one of the difficult part to be developed. The infrared sensor is a very sensitive device to light and hence it is not easy to sense the correct position.

The second part of the system is the microcontroller systems. An assembly language is required to be programmed for the microcontroller Intel 80C31. Prior to programming stage (software part), the microcontroller circuit will first need to be constructed and tested as described in Chapter 4. Failure to have a smooth circuit will cause problem while uploading the written program from the software.

Through this project, the author had made a lot of research regarding the previous micromouse that has been developed before. A lot of method has been by previous designer and most of this method is a standard practice for IEEE. The author had also tried some of this work with some modification to suite with the requirement of this project.

In general, the author had covered all parts involve in developing the micromouse systems. However, more effort and improvement shall be made so that a final integrated product of Maze Mouse can be produced. Therefore, it can be said that the author has partially complete this project within the research schedule. Finally, the author hopes that this research will meet Final Year Project requirement and complies with UTP FYP standard guideline.

5.2 RECOMMENDATIONS

For further knowledge on the microcontroller programming, the author would like to study deeper into the algorithm and assembly language techniques writing. This is because the successfulness of this product will rely on the programming and technical jargons of the microcontroller. Lack of knowledge in programming writing had caused the programming part cannot be completed within the time constraint. The author found that, the programming part is the most technical aspect of the microcontroller systems.

For the sensory systems, the author would like to suggest one type of infrared sensor. This sensor generally is similar to the one that has been used for this project except for the infrared receiver which is shiny as compared to the used infrared receiver. This is shown in Figure 5.1 below:

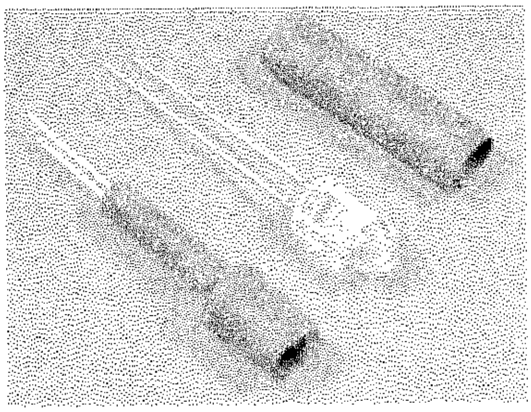


Figure 5.1 TSOP1740 Infrared Pair

Figure 5.1 shows the TSOP1740 Infrared photodiode. This infrared pair is equipped with an insulator that is used to avoid disturbance from the surrounding. The author had also tried to get this type of infrared sensor for the project. However, this kind of infrared was not available during the circuit construction. The main reason for suggesting this type of infrared sensor is because this sensor is the common IR pair that has being used for micromouse project. A more accurate output is possible for the sensory system.

The Maze Mouse project is not just a simple robot. Its application can be emphasized by enhancing the microcontroller programming. The artificial intelligent element can be added to the systems so that more complex functions and task can be operated by Maze Mouse in the future. By adding more complex functions and algorithm to the Maze Mouse systems, its application can further be enhanced in other field such as industry and robotic.

REFERENCES

1. Kenneth J. Ayala, (1995), *The 8051 Microcontroller Architecture, Programming & Applications*, New York, Wes Publishing Company [1]

2. Department of Electrical and Electronic Engineering Loughborough University,(1991) "*Welcome to Micromouse Loughborough*", Available at http:www.lboro.ac.uk/departments/el/robotics/MouseLab.pdf, 1991, last update 31st March 1991 [2]

3. WGM Consulting, (1990) "*Robots 8051 Microcontroller Software*", Available at www.lboro.ac.uk/departments/el/robotics/MouseLab.pdf., last update 17th October 1990.[3]

4. Rentron, (2003), "*Infrared Object Detection and Navigation*", Available at http://www.rentron.com/Micro-Bot/index.htm, last update 4th June 2003.[4]

5. Micromouse@tic(2004),"*Micromouse Competition 2004*", Available at http://www.tic.ac.uk/micromouse/index.asp, last update 26th January 2004.[5]

6. John Kopplin,(2002-03) "*8051 Simulator*", Available at www.computersciencelab.com, last update 27th May 2003.[6]

7. OPUS, (2000) "*Infrared Sensors – BV5E Sensor*", Available at www.**micromouse**info.com/links/mmouse.ppt, last update 17th July 2000[7]

Bibliography Reference

8. Weng-Seng Chia, Soo Lee, Chua Wei-Han, Lee Kai-Ee Wong, " Micromouse Project Development Overview", (2000).[8]

9. Travis Puderbaugh, Lorin Mueller, Lee Wetherel, Nathan Hansen, "MicroPanzer", (1999)[9]

10. PseudoCorp, " PseudoSam Assembler Manual Level 1", (1988)[10]

11. Metalink Corporation, " 8051 Cross Assembler-User Manual", (1990)[11]

APPENDICES

APPENDIX A

No.	Activities	Duration	Start Date	End Date	Remarks
1.	Requirement Study • Understand Problem • Identifying the components and equipment used • Procurement (tools and component)	7 days	06/08/2003	13/08/2003	Done
2.	Analysis • Conceptual Design • Information Gathering • Circuit Analysis	14 days	14/08/2003	28/08/2003	Produce initial idea from problem definition
3.	Design • Circuit construction • Components assembly	14 days	29/08/2003	11/09/2003	Put the problem definition into problem statement and application model.
4.	Testing • Sensory systems testing • Microcontroller circuit testing	48 days	12/09/2003	14/10/2003	Conducting experiment and identifying the problem encountered during testing and troubleshooting.
5.	Development • Maze solver • Sensory Systems • Programming Tools	60 days	01/03/2004	30/04/2004	Developing the maze solver and enhancing the sensory systems.
4.	Result Analysis • Experiment • Troubleshooting	3 days	01/05/2004	03/05/2004	Identifying the potential recommendation for future work.

LIST OF COMPONENTS

1. Voltage Regulator Circuit
   IC:
   7805 (voltage regulator)
   Components:
   Voltage Regulator
   0.1 uF (x4)
   IN400(x2)
   100 uF(x1) – electrolytic

2. Stepper motor driver circuit
   4050 9(x2)
   ULN2803(x2)

3. System microcontroller circuit
   IC:
   80C31 (microcontroller)
   74LS373 (Latch)
   74LS00 (Nand Gate)
   2732A (RAM)
   6116 (EPROM)

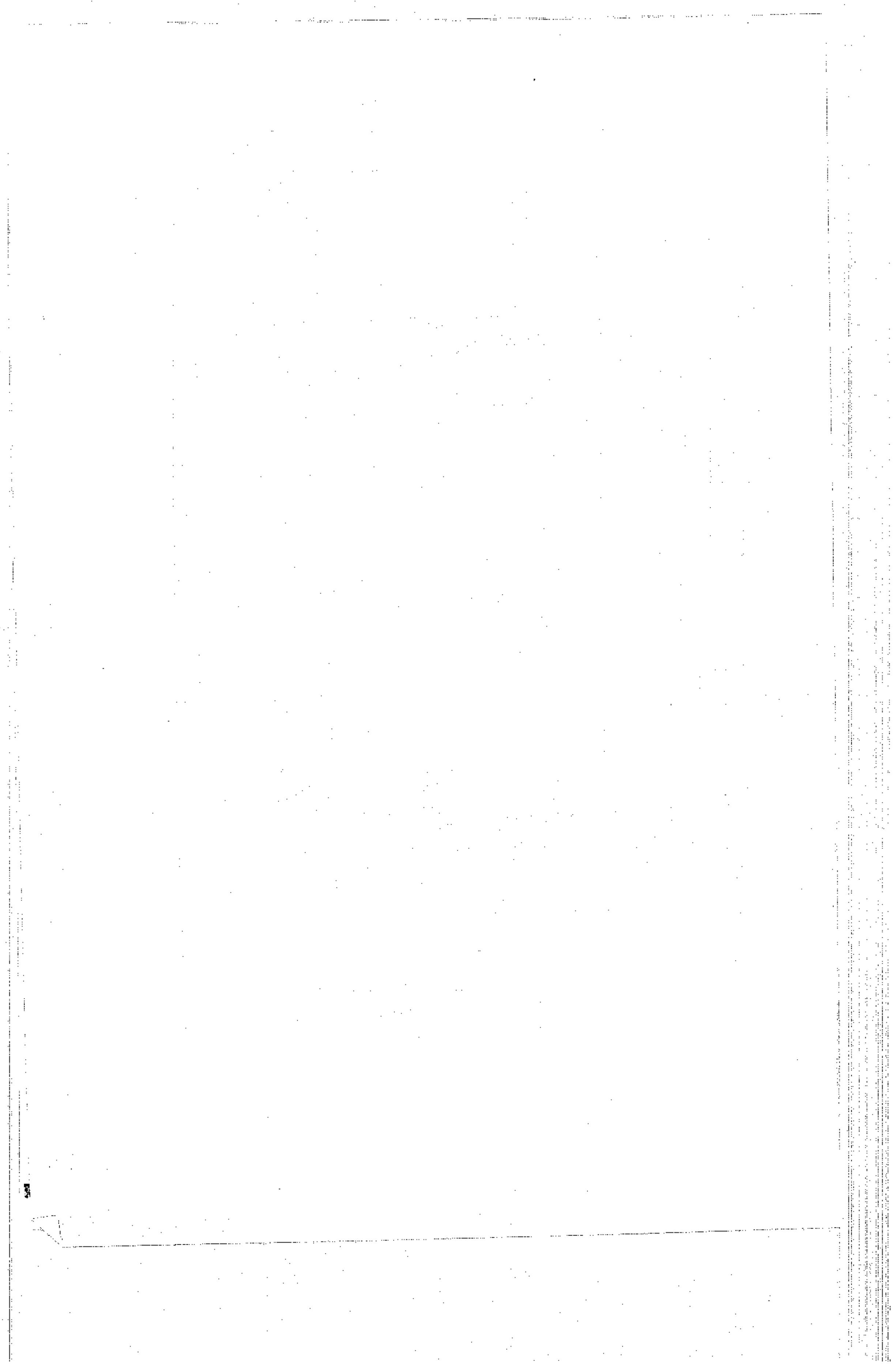
   7805 (voltage regulator)
   0.1 uF (x4)
   30 pF (x2)
   4.7 uF (x1) – electrolytic

   12 MHz (crystal oscillator)
   8 pin header (x2)
   Switch DIP (x4)
   4.7k (x@0
   10k (x1)
   Push Button Switch (x1)

4. Micromouse sensor circuit
   LM 339 (x2)
   Infrared sensor (x5)
   Photodiode (x8)
   LED (x8)
   7805 (x1)
   Variable resistor (x8)
   Resistors

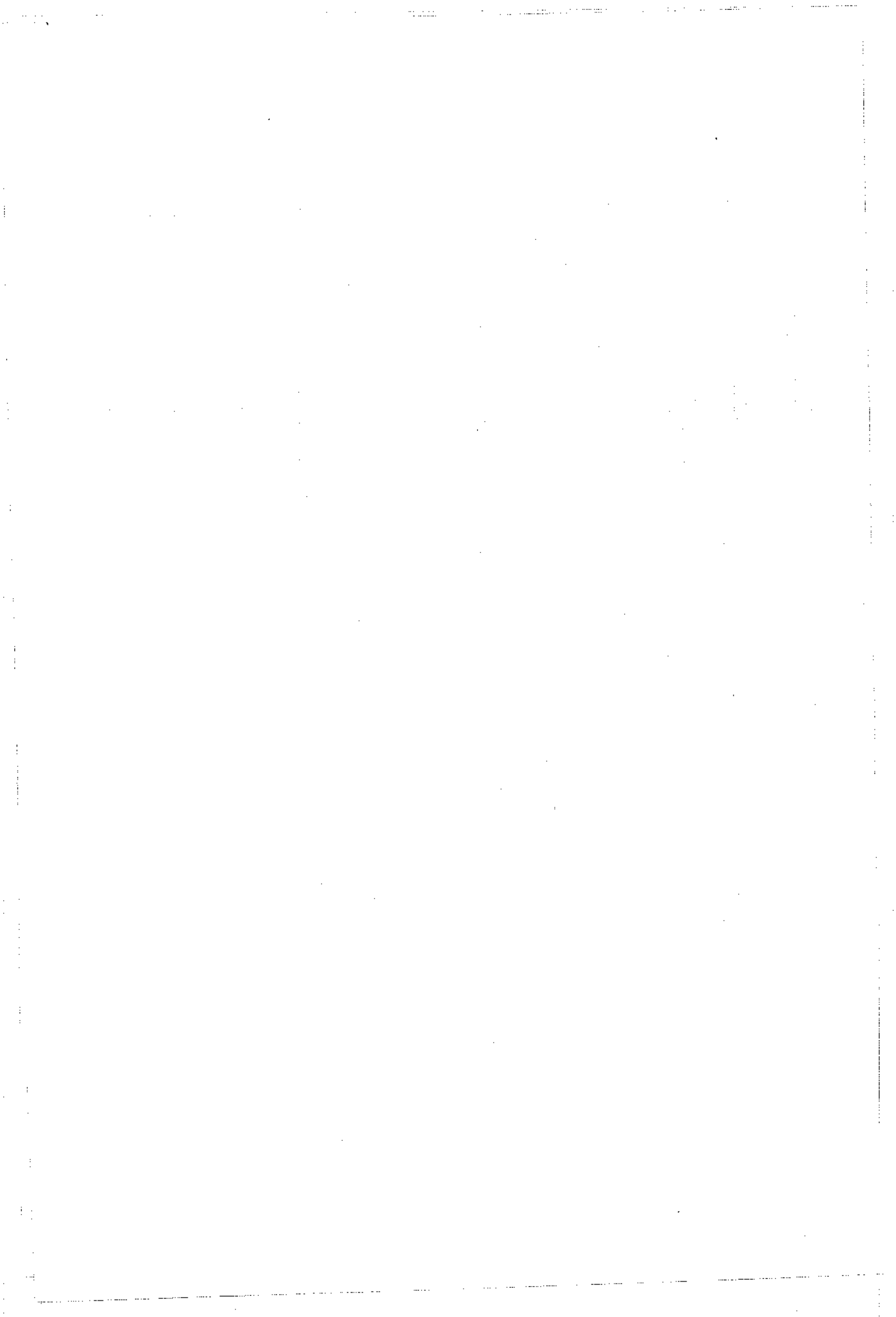
APPENDIX C

Schematic Diagram For Sensor Circuit [Sources : Project Supervisor]



APPENDIX D

Schematic Diagram for Microcontroller Circuit [Sources: Project Supervisor]

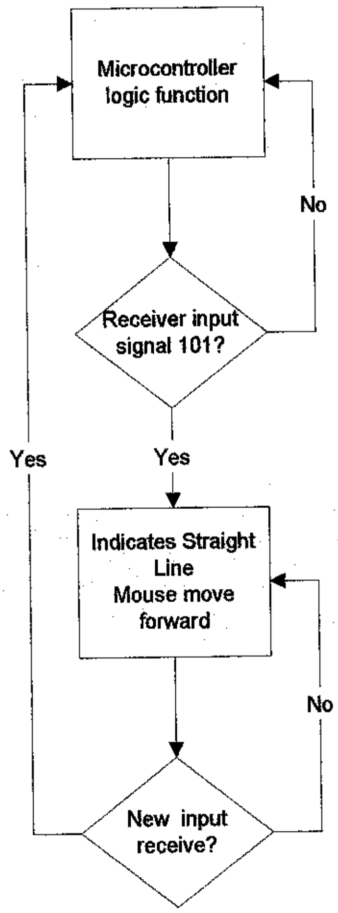


APPENDIX E

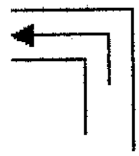
Schematic Diagram For Driver Circuit [Sources : Project Supervisor]

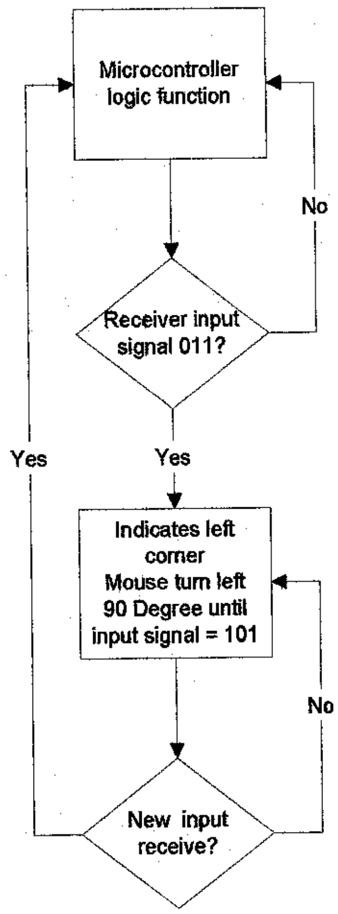
APPENDIX F

Straight logic

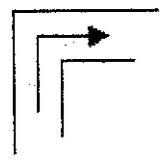


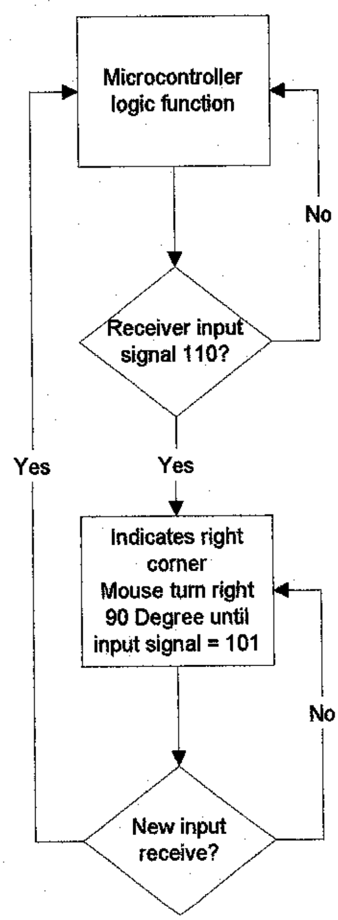
Left corner




Microcontroller logic function
No
Receiver input signal 011?
Yes
Yes
Indicates left corner Mouse turn left 90 Degree until input signal = 101
No
New input receive?

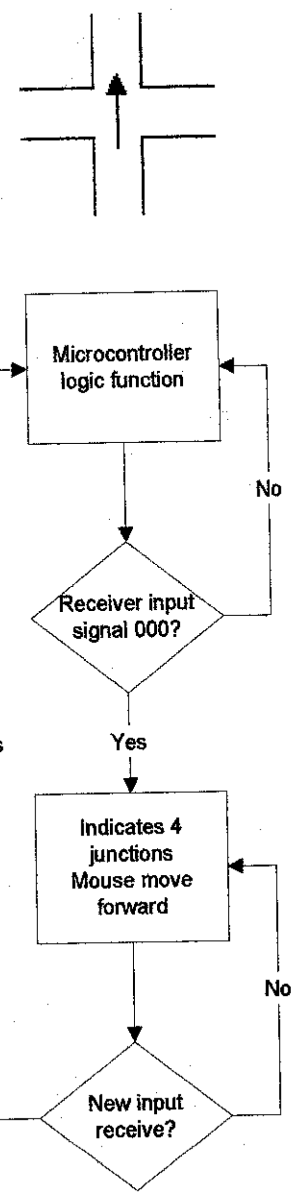
Right Corner



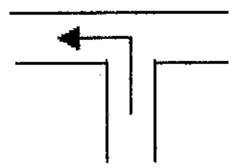


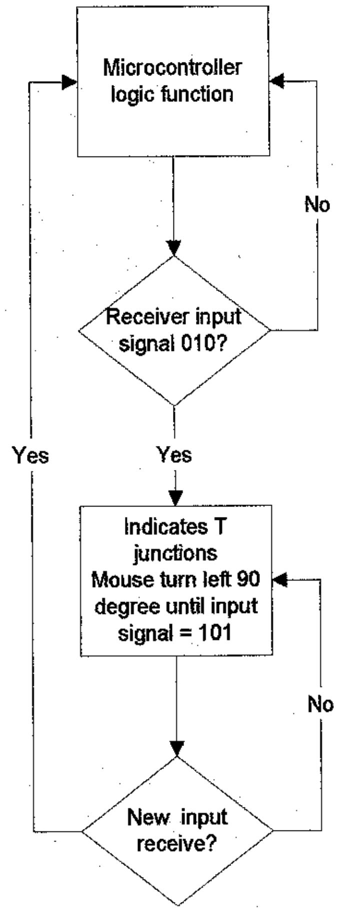
APPENDIX I

4 Junctions

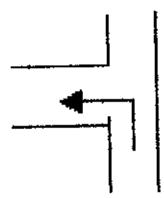


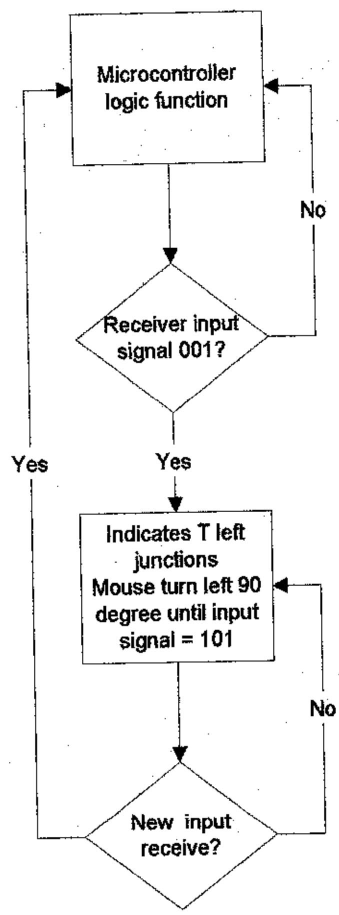
T Junction



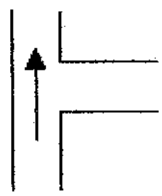

Microcontroller logic function
Receiver input signal 010?
No
Yes
Yes
Indicates T junctions Mouse turn left 90 degree until input signal = 101
No
New input receive?

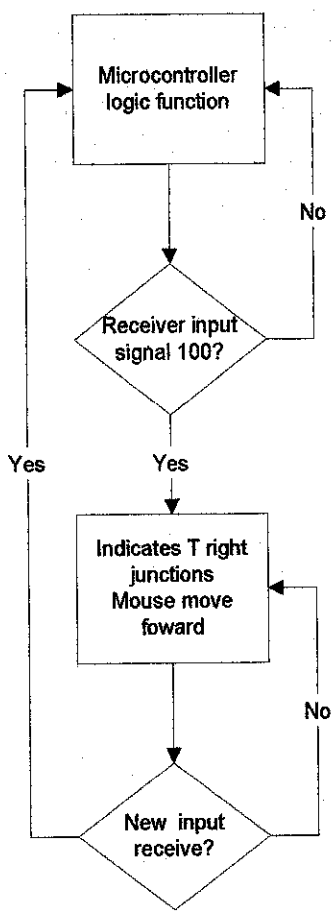
T Left Junction



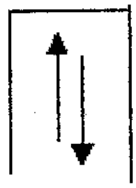


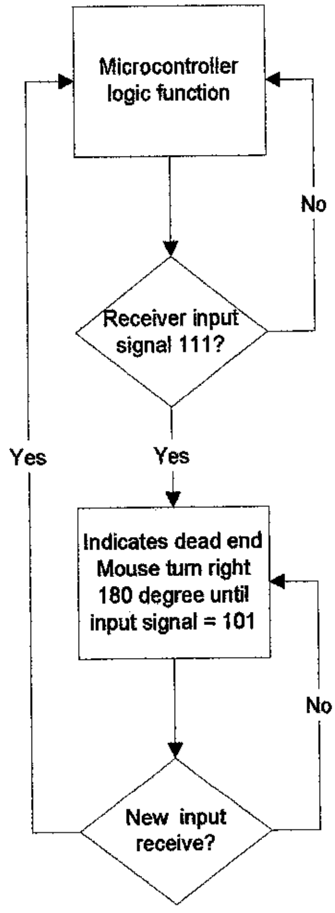
T right junction





Dead End




Microcontroller logic function
No
Receiver input signal 111?
Yes
Yes
Indicates dead end Mouse turn right 180 degree until input signal = 101
No
New input receive?