Interim Design Report

Micromouse Sensing Subsystem

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Declaration

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Date

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Chapter 1

Introduction

1.1 Problem Description

Design and manufacture the hardware of a micro-mouse which must be able to move around a maze and detect its distance from the maze walls. The greater project entails this robot, not only to move and detect walls, but also to solve the maze intelligently, as quickly as possible. This project concentrates on the design and manufacture of the hardware of the sensing subsystem of the micro-mouse with the aim of designing a PCB that can efficiently sense the presence and proximity of a maze wall.

1.2 Scope and Limitations

1.2.1 Scope

The sensor must be able to detect objects in front of and on the sides of the micro-mouse. The size of the PCB should not limit the locomotion of the micro-mouse. It must fit onto the pin headers of the motherboard. This project does not entail designing algorithms and programming the micro-mouse to actually solve the maze.

1.2.2 Limitations

The limitations of the micromouse sensing module are described in Table 1.1.

Table 1.1: Limitations of sensing module of micro-mouse design project.

Limitation	Description
Time	The design of the board must be completed within 2 weeks.
Budget	The total order should cost no more than $30.
Availability	Only components available on https://jlcpcb.com/parts may be used.
Power	Low power components should be used
Testing	Size of multimeter and oscilloscope probes are too large to test directly. Alternate testing measures must be incorporated into the design.
Developement	Only one version (V0) of the PCB can be manufactured.

1.3 GitHub Link

https://github.com/sharonjomon/Micromouse-Project-EEE3088F

Chapter 2

Requirements Analysis

2.1 Requirements

The requirements for a micro-mouse sensing module are described in Table 2.1.

Table 2.1: Requirements of the sensing subsystem.

Requirement ID	Description
Components	Only use components available on https://jlcpcb.com/parts.
Detection	Must detect objects in front of and on the sides of the micro-mouse.
Output	Must have a signal-based output connected to the microcontroller's ADC pins.
Power	Must operate on the voltage provided by the LiPo 800mAh 3.7V battery.
	Must not drain the battery before the maze is solved.
	Must have switching means to save power.
Human indicator	Must code microcontroller to indicate wall detection.
Dimensions	Must be an appropriate size to allow for fluid movement.
	Must fit onto the pin headers on the motherboard.
Budget	The final cost must be less than $30.

2.2 Specifications

The specifications, refined from the requirements in Table 2.1, for the micromouse power module are described in Table 2.2.

Table 2.2: Specifications of the sensing subsystem derived from the requirements in Table 2.1.

Specification ID	Description
Output	Signal must be between 0V and 3.3V.
	It should be low when an object is far and high when an object is near.
Power	To implement switching, the PWM of the microcontroller is used to switch the sensor on and off to save power.
Human indicator	The analogue output voltage signal is fed into the ADC. When the signal is between 0V and 1.65V, the ADC outputs 0 and no LED is turned on. When the signal is between 1.65V and 3.3V, the ADC ouputs 1 and an LED is turned on.
Dimensions	PCB width must be less than 85mm.
	2x14 (2.54mm pin pitch) pin headers should be used.
Budget	Use few extended parts and more basic parts.

2.3 Testing Procedures

A summary of the testing procedures detailed in chapter 4 is given in Table 2.3.

Table 2.3: CAPTION

Acceptance Test ID	**Description**
AT01	Power Supply
AT02	PWM
AT03	BJT base voltage
AT04	Voltage across receiver
AT05	ADC
AT06	Board dimensions

2.4 Traceability Analysis

The show how the requirements, specifications and testing procedures all link, Table 2.4 is provided.

Table 2.4: Requirements Traceability Matrix

#	Requirements	Specifications	Acceptance Test
1	Detection	Output, Human indicator	AT05
2	Output	Output	AT04, AT05
3	Power	Power	AT01, AT02
4	Dimensions	Dimensions	AT06

2.4.1 Traceability Analysis 1

From the detection requirement the output and human indicator specifications can be derived because in order to show that the sensor is detecting, the descriptions of the Output and Human indicator specifications in Table 2.2 need to be met. These can be tested through AT05 which tests the values of the voltage signal at the output of the sensor.

2.4.2 Traceability Analysis 2

From the output requirement, the output specification can be derived because the output specification specifies what range the signal-based output should be in. This is tested by AT04 and AT05 which tests the voltage across the receiver and at the output.

2.4.3 Traceability Analysis 3

The power specification specifies that the power requirements are achieved through switching, by using the PWM of the microcontroller. The PWM is tested through AT02 and the power supply is tested through AT01.

2.4.4 Traceability Analysis 4

The dimension specification specifies that the board width must be less than 85mm to meet the dimensions requirement. It also specifies that 2x14 (2.54mm pin pitch) pin headers should be used to fit onto the motherboard. This is tested through AT06 which physically makes these connections and places the board onto the motherboard of the micro-mouse.

Chapter 3

Subsystem Design

3.1 Design Decisions

3.1.1 Final Design

Component Selection

Emitter

Table 3.1: Emitter selection tradeoffs

Name	Power	Forward Voltage	Availability	Price
SFH 4544	200mW	1.6V	1355	$0.57
IR333-A	150mW	1.5V	1132	$0.0446
IR333C	150mW	1.5V	166	$0.0339

Table 3.1 shows that IR333-A is the best option for the emitter because it has a lower power consumption and forward voltage than the SFH 4544. It is slightly more expensive than the IR333C however, it is significantly more in stock and is therefore, a better option.

Receiver

Table 3.2: Receiver selection tradeoffs

Name	Power	Wavelength of Peak Sensitivity	Price
TEFD4300F	215mW	950nm	$0.3143
PD333-3B/H0/L2	150mW	940nm	$0.1518

Table 3.2 shows that PD333-3B/H0/L2 is the best option for the receiver because it has a lower power consumption and its wavelength of peak sensitivity is a better match for the emitter selected above. It is also cheaper than the TEFD4300F.

BJT
Since the emitter and receiver selected above are extended parts, it is important that the BJT is a basic part, to stay within the budget. Only a handful of basic BJTs are available on JLCPCB, of which the MMBT3904 has the lowest power rating of 200mW hence, it is selected.

Resistors
$V_{R1} = 3.3V - 1.5V = 1.8V$
$R_1 = 1.8V/18mA = 100$ ohms
The other resistor and capacitor values can only be finalised after testing.

Solution Description

The sensing PCB consists of three sensor units, one in front and one on either side of the rectangular PCB. The receiver of each sensor, picks up the light which is emitted by the emitter and reflected from the wall. As the micro-mouse moves closer to the wall the current through the receiver increases and the output voltage across R_7 increases. The capacitor stabilises the output signal by removing the AC components by pulling it to ground. The output voltage is connected to the ADC pin of the micro-controller via the appropriate connector pins on the sensing module. If the ADC reads a voltage above 1.65V it outputs a 1 and switches the relevant LED on because it is close to a wall. If the ADC reads a voltage below 1.65V it outputs a 0 and switches the relevant LED off because the wall is not near. The emitter of the sensor is connected to a BJT, which is connected to the PWM pin of the micro-controller. Hence, the sensor can be programmed to turn on and off at certain intervals, to save power. For example, when the micro-mouse is far from a wall, the sensor is programmed to switch off until it is closer to a wall.

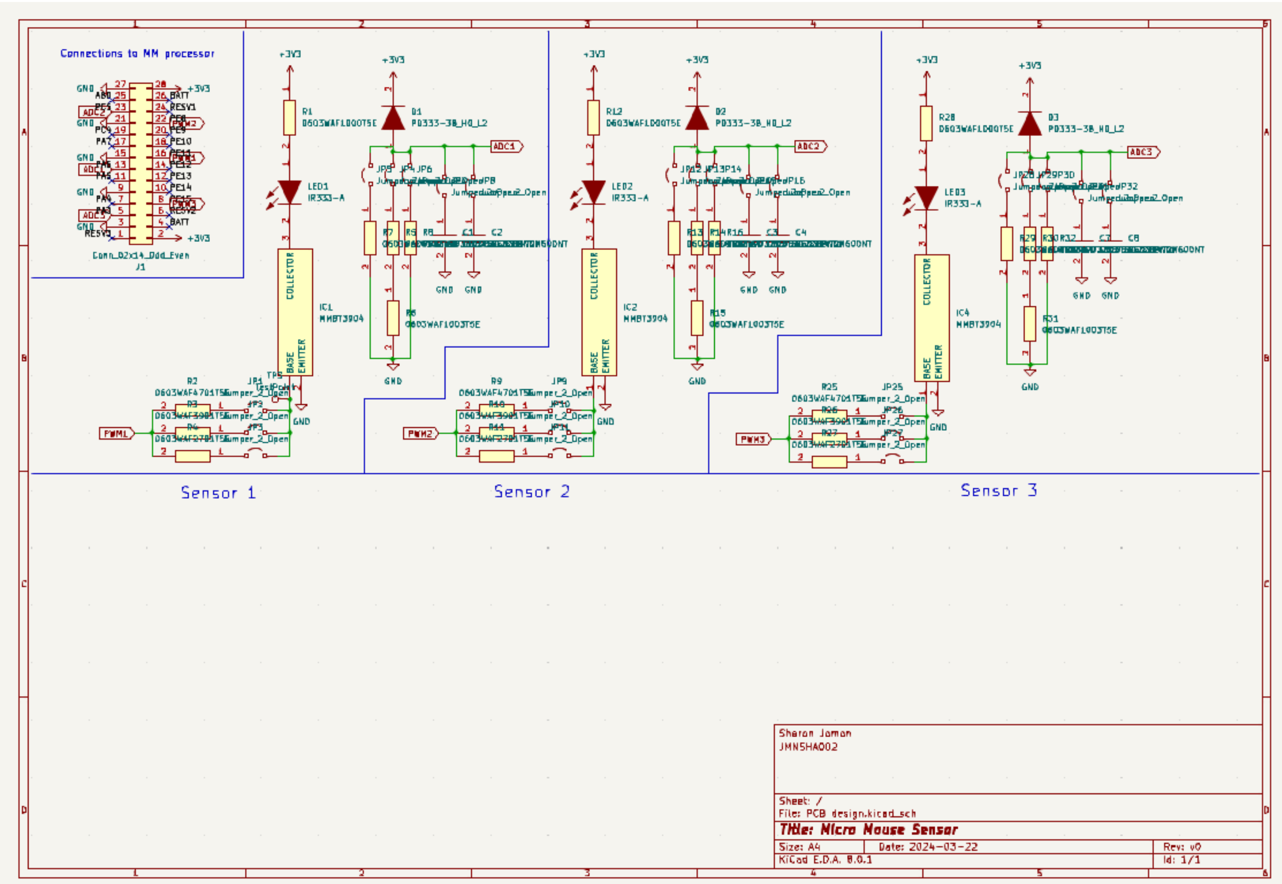
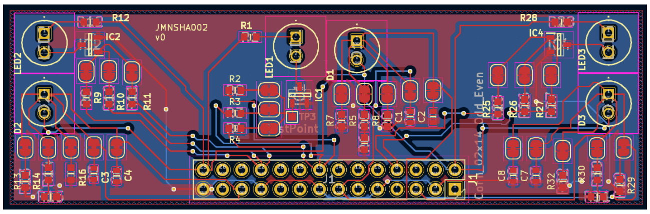
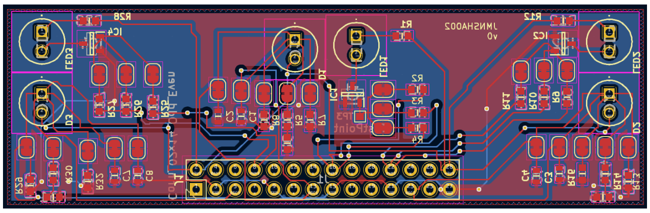


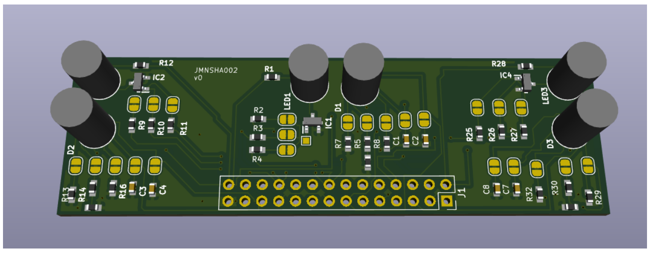
Figure 3.1: Schematic



(a) Front PCB



(b) Back PCB



(c) 3D PCB

Figure 3.2: PCB

Design Motivation

This design is implemented because it is a very simple circuit compared to other designs. It only makes use of one emitter and receiver in each sensing unit thus, it has fewer components which saves both space and money.

3.2 Failure Management

Table 3.3: Failure Management Processes

Name	Description
Electrical Rules Checker	Checks that all components, wires and labels are placed correctly on the schematic.
Design Rules Checker	Checks that all of the components, traces and fills are placed correctly on the PCB.
Component Search Engine	This is an online tool, which is used to import footprints of the specific components used from JLCPCB. This ensures that the dimensions of the footprints are more accurate.
JLCPCB Tools	Used to generate all of the production files which are uploaded onto JLCPCB when ordering the board. This tool saves time and is more accurate than manual compilation.

3.3 System Integration and Interfacing

To integrate the subsystem with the rest of the system, 2x14 (2.54mm pin pitch) pin headers are used. Table 3.4 shows what the pins connect to and how they interface with the rest of the micro-mouse system. Figure 3.3 is a high level interfacing diagram which shows how the sensing subsystem fits into the larger system.

Table 3.4: Interfacing specifications

Interface	Description	Pins/Output
ADC	Reads the voltage signal and converts it into a discrete value of 1 or 0. Sensor to connector to STM32L476 micro-controller	• Pin 5, 13 and 23 from sensor to connector. • Connector to STM PA3, PA6 and PC5 (pin 41, 40 and 36) respectively.
PWM	Used to control when the sensor switches on and off. STM32L476 micro-controller to connector to sensor.	• Pin 8, 16 and 22 from connector to sensor. • STM PE15, PE11 and PE8 (pin 24, 28 and 32) respectively to connector.
Ground	Electrical ground	• Pin 3, 9 , 15, 21 and 27 from sensor to connnector. • Connector to STM GND pins.
Power Supply	Provides a regulated DC power supply to the sensing module. STM32L476 micro-controller to connector to sensor.	• Pin 2 and 28 from connector to sensor. • STM 3V3 pins to connector.

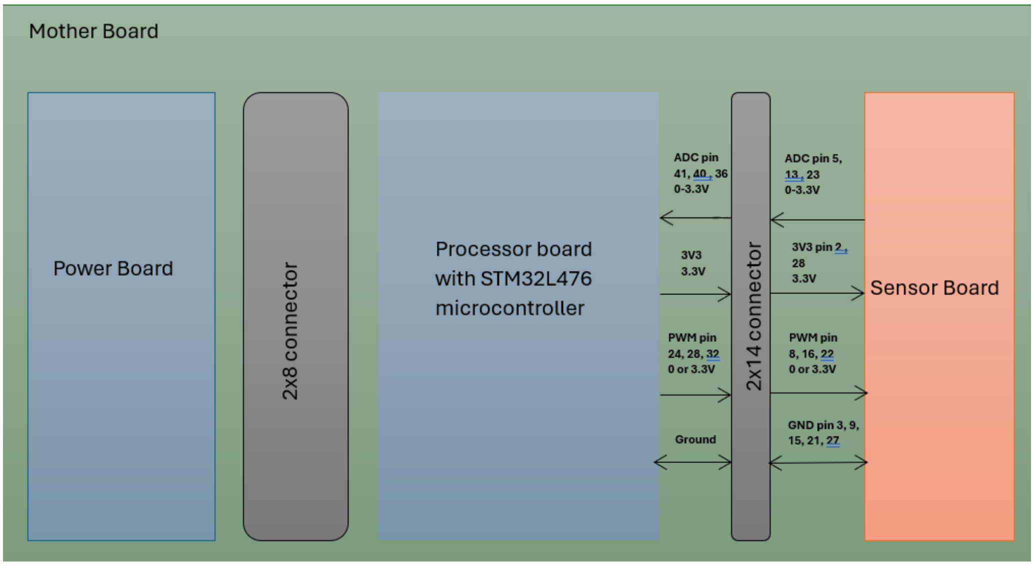


Figure 3.3: High Level Interfacing Diagram

Chapter 4

Acceptance Testing

4.1 Tests

Table 4.1: Subsystem acceptance tests

Test ID	Description	Testing Procedure	Pass/Fail Criteria
AT01	Powers supply	• Use a multimeter with one probe at the 3V3 pin of the connector and the other at ground.	• Pass = 3.3V • Fail = if the voltage is less than 3.3V the sensor will not work. If the voltage is slightly greater than 3.3V the sensor will still work but if it is substantially greater than 3.3V the components may get damaged.
AT02	PWM	• Use a multimeter with one probe at the PWM pin of the connector and the other at ground. Repeat the test for all of the PWM pins which are connected.	• Pass = 0V when sensor should be off and 3.3V when sensor should be on. • Fail = if the PWM does not work as expected, switching will not be possible and the battery will drain quickly.
AT03	BJT base voltage	• A test point pad has been placed at the base of the bjt of one sensor unit. A multimeter is used to test the voltage at this point. This voltage is used to determine which resisor should be used at the base of the bjt. 3 options for resistors are provided with jumpers.	• Pass = the voltage must be greater than 0.7V to turn the BJT on. • Fail = the voltage value is not suitable for the resistor values on the board. Switching may not work.

Test ID	Description	Testing Procedure	Pass/Fail Criteria
AT04	Voltage across receiver	• Jumper pads have been place after the receiver for 3 possible resistor options. Use these jumper pads and a multimeter to test the voltage across the receiver.	• Pass = unstable voltage from 0V to 3.3V according to the distance from a wall. • Fail = if the voltage does not change with distance, the sensor does not work.
AT05	ADC	• Use a multimeter with one probe at the ADC pin of the connector and the other at ground. Repeat the test for all of the ADC pins which are connected.	• Pass = stable voltage between 1.65V and 3V when the sensor is close to a wall and stable voltage between 0V and 1.65V when the sensor is far from a wall. • Fail = if the voltages at the ADC pin are changing with distance but are not in the specified range, the sensor may still work but with a smaller resolution. If the voltages are not changing at all the sensor does not work.
AT06	Board dimensions	• Use male or female pin headers to connect the sensor board to the processor and the motherboard.	• Pass = the connectors fit properly and the sensor board fits snuggly onto the motherboard with a little bit over the edge, in front. • Fail = the holes for the connectors are not the right size or the width of the board is too big. The sensor PCB will not fit onto the motherboard.

4.2 Critical Analysis of Testing

Table 4.2: Subsystem acceptance test results

Test ID	Description	Result
AT01	Powers on	

4.2.1 AT01

This worked, this did not work. I suspect that is because of x y and z.

Chapter 5

Conclusion

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5.1 Recommendations

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Bibliography

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