Interim Design Report

Micromouse: Sensing Subsystem

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May 17, 2024

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Introduction

1.1 Problem Description

A micro-mouse is a blend of both hardware and software, with its main goal of solving a maze using its different components and subsystems, these include: The motherboard which provides the base of the micro-mouse and allows all the other components to connect. The processor subsystem handles decision-making, the power subsystem provides the power needed for operation and the sensing subsystem is responsible for detecting the environment this project centers on developing the sensing subsystem, which is the 'eyes' of the micro-mouse. The sensor subsystem uses infrared light to detect the distance from the walls in the maze in front and to the side of the mouse sending real-time feedback to the processor. This report discusses how the sensing subsystem was designed and implemented, addressing key requirements such as wall detection, power management, and integration with the other systems of the micro-mouse. The objective is to design and make a reliable sensing solution that allows the micro-mouse to go through the maze.

1.2 Scope and Limitations

1.2.1 Scope

- The project focuses on designing and developing the sensing subsystem used to detect walls at a certain distance utilising infrared light.
- This project does not extend to the development of any other subsystem.
- The project involves designing the hardware for the sensing subsystem, which includes the sensor integration onto a PCB which will be further integrated with the rest of the micro-mouse components.
- The project involves programming the processor to interpret information on whether there is a wall and to alert the micro-mouse when it needs to rotate to escape the maze.

1.2.2 Limitations

- Due to the strict budget the project will be limited in terms of the components that can be used.
- The use of JLCPCB, a PCB production service, components will be limited based to what they have in stock.
- The battery being used to power the micro-mouse can only last two hours this will affect the design of the circuit.
- Time constraints will affect how well the testing of the PCB's will be completed.

1.3 GitHub Link

Below is the GitHub repository where information for both the sensing and power system can be found.
GitHub repository

Requirements Analysis

2.1 Requirements

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

Table 2.1: Requirements of the sensing subsystem.

Requirement ID	Description
RQ01	The subsystem needs to be able to detect an obstacle in front and on the left and right sides of the subsystem.
RQ02	The subsystem needs to integrate with the rest of the micro-mouse components.
RQ03	The subsystem needs to fit onto the micro-mouse whilst not restricting movement.
RQ04	The subsystem needs to combat the effect of the ambient light on the overall system.
RQ05	The subsystem needs to use the LiPo 800mAh battery as the input power source.
RQ06	The subsystem needs to have a means of switching power to save the battery life.
RQ07	The subsystem needs to be programmable to interface with the processor.
RQ08	The subsystem needs to be within the specified budget.
RQ09	The subsystem PCB design needs to be JLCPCB compliant.

2.2 Specifications

The specifications, refined from the requirements in Table 2.1, for the micro-mouse sensor 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
SP01	The subsystem needs to be able to detect an obstacle at a distance of at least 10cm.
SP02	The subsystem PCB board needs to ensure that the pin headers align with that of the motherboard.
SP03	The subsystem needs to be no greater than 85mm in length to fit in between the wheelbase and needs to be short in width so that rotation of the micro-mouse is not hindered.
SP04	The subsystem needs to use infrared light to detect an obstacle, photo-diodes or photo-transistors should be utilised.
SP05	The subsystem needs to be powered by 3.7 V provided by the battery ensuring the rest of the circuit has enough power.
SP06	The subsystem needs to works with a PWM (Pulse width modulator) signal.
SP07	The subsystem needs to have code that will turn on the LEDs to show that a wall is detected.
SP08	The subsystem PCB boards (5) need to cost below a total of $30.
SP09	The subsystem PCB design needs to use JLCPCB components that have more than 1000 units in stock.

2.3 Testing Procedures

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

Table 2.3: Testing procedure to verify that the requirements and specifications are met.

Acceptance Test ID	Type	Description
AT01	Operational testing	Measure voltage drop across the photo-transistors (output). To check the ability to detect a wall.
AT02	Unit testing	Checking alignment of pin headers and integration with the micro-controller.
AT03	Unit testing	Measuring the dimensions of the PCB.
AT04	Unit testing	Checking continuity across components and placement of components.
AT05	Unit testing	Ensuring that the power requirements are met for the subsystem.
AT06	Unit testing	Checking that the subsystem works with a PWM (Pulse width modulator) signal.
AT07	White box testing	Using the 2nd Year STM to verify code correctness .
AT08	Business acceptance testing	Using JLCPCB to review cost of the PCB.
AT09	Business acceptance testing	Checking whether the boards have arrived with all the correct components.

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	RQ01	SP01	AT01
2	RQ02	SP02	AT02, AT07, AT01
3	RQ03	SP03	AT03
4	RQ04	SP04	AT04
5	RQ05	SP05	AT05
6	RQ06	SP06	AT06, AT05
7	RQ07	SP07	AT07
7	RQ08	SP08	AT08
7	RQ09	SP09	AT09

Traceability Analysis 1

To meet the requirement RQ01 and specification SP01, test AT01 is done to ensure that a wall can be detected at a suitable distance (in this case 10 cm). This is crucial as this requirement is fundamentally the 'eyes' of the micro-mouse. To achieve AT01, AT05 and AT06 have to be passed.

Traceability Analysis 2

To meet the requirement RQ02 and specification SP02, test AT02 is done to rest the alignment of pin headers and integration with the micro-controller, ensuring physical and electrical compatibility. If

AT01 and AT07 are met then AT02 is passed as these two tests need to work in order to show that integration is complete.

Traceability Analysis 3

To meet the requirement RQ03 and specification SP03, test AT03 is done by measuring the PCB dimensions to ensure they meet the specified size constraints, confirming that the subsystem will physically fit within the micro-mouse and not impede its movement.

Traceability Analysis 4

To meet the requirement RQ04 and specification SP04, test AT04 is done to check continuity across components and the placement of IR LEDs and photo-diodes/transistors. This test ensures that the subsystem's design to use IR light is correctly implemented, addressing the requirement to mitigate ambient light effects.

Traceability Analysis 5

To meet the requirement RQ05 and specification SP05, test AT05 ensures the subsystem meets power requirements, verifying that it operates correctly with the battery voltage. This confirms the subsystem's compatibility with the specified power source.

Traceability Analysis 6

To meet the requirement RQ06 and specification SP06, test AT06 checks the subsystem's response to PWM signals, ensuring it can manage power efficiently. This is done in tandem with AT05 which confirms correct operation with the specified power requirements.

Traceability Analysis 7

To meet the requirement RQ07 and specification SP07, test AT07 uses the STM32F0 to verify the code's correctness. This test directly checks the programmability and functional response of the subsystem.

Traceability Analysis 8

To meet the requirement RQ08 and specification SP08, test AT08 reviews the cost using JLCPCB receipts, ensuring that the project stays within budget constraints. confirming the economic feasibility of the subsystem.

Traceability Analysis 9

To meet the requirement RQ09 and specification SP09, test AT09 ensures that the correct components are used and match the PCB design submitted.

Subsystem Design

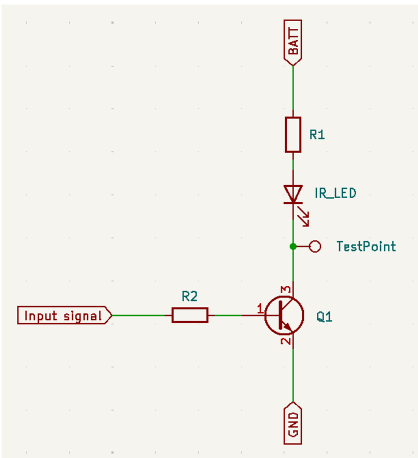
3.1 Design Decisions

3.1.1 Initial circuit and design

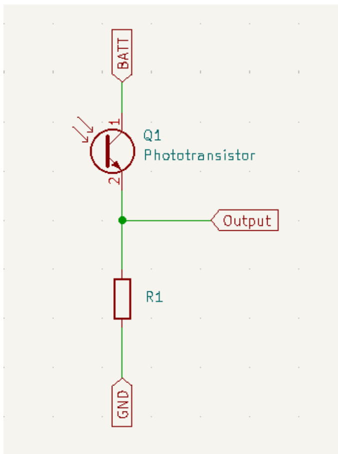
The sensing module is the 'eyes' of the micro-mouse thus it is essential to get all components and circuit design correct. The fundamental purpose of the sensing subsystem is to detect a wall at a certain distance away from the micro-mouse on either side and in front of it using infrared light, and then send a signal to the processor board that will tell the micro-mouse when to turn so that it can make its way through the maze. Since the micro-mouse is powered by a battery, another important function is that the sensing module has to switch power to the circuit to save the battery life. The solution can be split into two main parts, the first being the IR emitter circuit and the second being the IR receiver circuit, once these two are combined an effective and simple solution to the sensing module is created.

The IR emitter circuit contains 2 important components. The IR LED is used to emit infrared light and a NPN transistor which will act as a switch to save power when the circuit is not in operation. The resistors are used to limit the current flowing through the respective components. Look at Figure 3.1a below to see the initial circuit design.

The IR receiver circuit takes power from the battery and uses a photo-transistor to measure the reflected IR light produced by the IR Emitter bouncing of the wall. Resistor R1 is used to create a voltage divider so that the output can be fed back into the processor. Look at Figure 3.1b below to see the initial circuit design.



(a) Initial IR Emitter circuit



(b) Initial IR Receiver circuit

Figure 3.1: Initial circuit design for sensing module

3.1.2 Component selection

Based on the initial circuit design the components that were needed were an IR LED, an NPN transistor, and a form of either a Photo-diode or Photo-transistor (a device to receive IR light). Below is Table 3.1

showing the pros and cons of each component that was under consideration for the solution.

Table 3.1: Comparison of Component Options

Type	**Component**	**Pros**	**Cons**
Transistor	MMBT3904	• Small and compact SOT-23 package. • Short delay time. • Low total cost of \$0.0618.	• Moderate collector power dissipation (200 mW).
IR LED	IR383-A	• High radiant intensity of 90 mW/sr. • Wide 20° viewing angle.	• Insufficient units in stock. • High total cost of \$2.0032.
IR Emitting Diode	TSAL6200	• Low forward voltage. • Sufficient units in stock. • Moderate total cost of \$1.31048.	• Moderate radiant intensity of 72 mW/sr. • Narrow 17° viewing angle.
Photo-transistor	SFH309 FA	• Wide spectral range of sensitivity of 730 to 1120 nm. • High total cost of \$2.0466. • Has a half angle of 12°.	• Small radiant sensitive area of 0.038 mm^2.
Photo-diode	SFH205 F	• large radiant sensitive area of 7.02 mm^2.	• High total cost of \$5.596. • Has a half angle of 60°. • Insufficient units in stock.

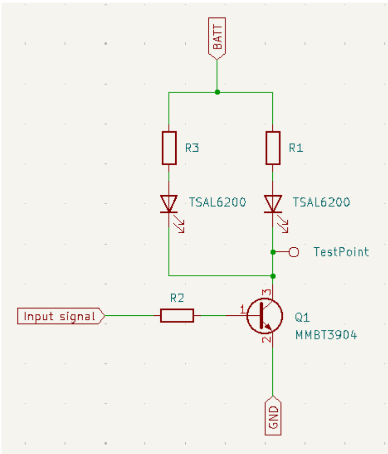
Based on Table 3.1 the components that have been selected are the MMBT3904 transistor, the TSAL6200 IR emitting diode, and the SFH309 FA Photo-transistor. The main reason for the selection of these components was the price and availability of stock whilst still having good specifications.

3.1.3 Evaluation of design

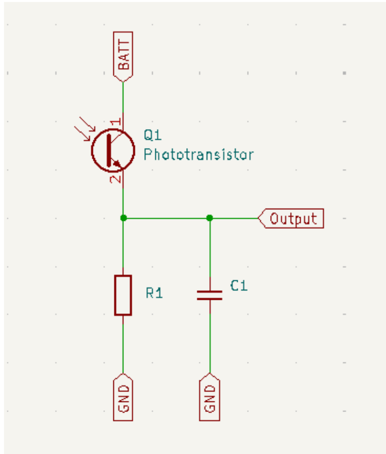
Building on the initial circuit designs shown in Figure 3.5 the following improvements and developments were made. The IR emitter circuit in Figure 3.1a had some modifications made, initially six of these circuits would be placed on the PCB, two for each IR Receiver circuit of which there will be three one placed in the front of the PCB and the other two on the left and right side respectively.

The changes that were made are now two IR LEDs would be placed in parallel to produce more IR light whilst only using one transistor. This solution is more cost-effective and will take up less space on the PCB. Look at Figure 3.2a below to see these changes.

The IR receiver circuit in Figure 3.1b had some modifications as well, since the voltage was being fed back into the processor a capacitor was added before the output so that the signal would be smoother and easier for the processor to detect whether there is a wall or not, it also creates a bit of a delay whilst the capacitor is charging. Look at Figure 3.2b below to see these changes.



(a) IR Emitter circuit v1.1



(b) IR Receiver circuit v1.1

Figure 3.2: Modified circuit design for sensing module

3.1.4 Calculations

All specified values were taken from the components' respective data sheets which can be found here

Referring back to Figure 3.2a the following resistor values were calculated:
The input signal is taken from the processor and is a PWM having a high of 3V3 and a low of zero therefore to calculate R_2 we use KVL from the input signal to ground.
Take $I_c = 100mA$ therefore $I_B = 3.33mA$ this was due to the DC gain = 30. $V_{\text{BE(sat)}} = 0.95V$
Therefore $R_2 = (3.3 - 0.95)/3.33mA = 705.71\Omega$ using E12 values $R_2 = 680\Omega$.
The power provided to the circuit is from the battery which has a rated voltage of 3.7V and the typical voltage drop over the IR LED is $V_F = 1.35V$. $V_{\text{CE(sat)}} = 0.3V$. The current $I_c = 100mA$ is split over the two branches. Thus using KVL R_3 and R_1 can be calculated.
Therefore $R_1 = (3.7 - 1.35 - 0.3)/50mA = 41\Omega = R_3$ using E12 values $R_1 = R_3 = 47\Omega$.

Referring back to Figure 3.2b the following resistor and capacitor values were calculated: The power provided to the circuit is from the battery which has a rated voltage of 3.7V and the maximum voltage over the photo-transistor is 35V. Thus for choosing R_1 any appropriate E12 resistor value will work to create a good voltage divider. Hence $R_1 = 8.2\text{k}\Omega$.
Any appropriate capacitor value can be chosen $C_1 = 10\mu\text{F}$.

Additional resistance and capacitors were added using jumpers, which will allow for troubleshooting the circuit: The values were chosen to satisfy the maximum ratings of the components and used E12 values. This will be seen in subsection 3.1.5.

3.1.5 Final Design

In the initial circuit and design phase, the primary objective was to develop a reliable sensing subsystem for the micro-mouse, enabling it to detect walls effectively using infrared light and provide the processor with a signal for navigation. Divided into IR emitter and receiver circuits, the former utilised an IR LED and NPN transistor for power-efficient operation, while the latter employed a photo-transistor to measure reflected IR light. Component selection was crucial, with careful consideration of factors such as size, cost, and availability. After evaluating various options, including transistors, IR LED's, and photo-devices, the MMBT3904 transistor, TSAL6200 IR emitting diode, and SFH309 FA photo-transistor were chosen for their favorable attributes. Subsequent design iterations involved enhancements to both emitter and receiver circuits, such as parallel IR LED configuration for increased light output and capacitor integration in the receiver circuit for smoother signal transmission to the processor. Calculations for resistor and capacitor values were performed to optimize circuit performance and ensure compatibility with component specifications, resulting in a refined and efficient sensing module design as seen in Figure 3.4.

See Figure 3.5 for the front and back of the PCB and see Figure 3.6 for a 3D view of the PCB. Images will be placed at the end of the chapter to make it more visible.

3.2 Failure Management

Table 3.2: Failure Management Processes for PCB Design

Process	**Description**
Design for Manufacturing (DFM)	Ensuring the manufacturing process of the board is fairly simple this can be achieved by avoiding complex shapes, reducing the number of vias, and optimising component placement so that if any errors arise it is easy to find a solution. The use of thicker traces to ensure all components receive power and reduce continuity errors.
Troubleshooting design	Including jumpers so that if there are component failures the PCB will have a backup component that could be soldered into place with the use of the jumpers added.
Circuit testing	Adding test points at various locations so that if there is an issue it will be easier to identify where the problem is being caused, also used to test the condition of the components and if they are working correctly.
Thermal Management	Ensuring that the PCB design includes adequate heat dissipation mechanisms by adding copper pours, to prevent overheating and ensure long-term reliability of the components.
Signal Integrity Analysis	Performing signal integrity analysis to identify potential issues with high-speed signals, ensuring that traces are properly routed and terminated to avoid issues such as cross-talk, and signal degradation.

3.3 System Integration and Interfacing

Below Figure 3.3 shows how the subsystems of the micro-mouse work together and how the pins are connected. Table 3.3 gives a more detailed description of what the connections do and how it relates to the project as a whole.

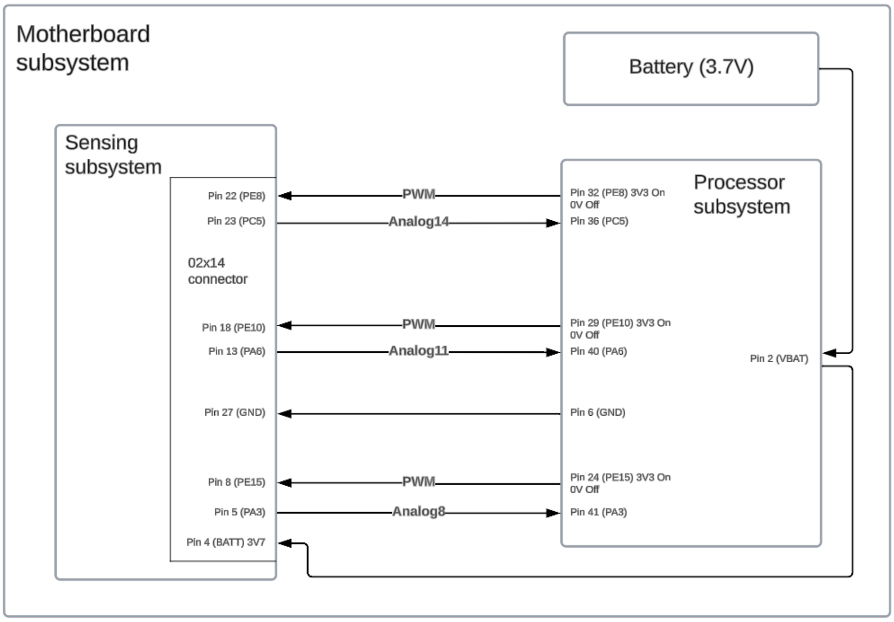


Figure 3.3: Interfacing diagram showing pin connections

Table 3.3: Interfacing specifications

Interface	Description	Pins/Output
I001	This provides the IR emitter circuit with a pulse (3V3 as high and then 0 V as low) this feeds into the transistor which will act as a switch to save the battery life.	• PWM: STM PE8 to connector pin 22 • PWM: STM PE10 to connector pin 18 • PWM: STM PE15 to connector pin 8
I002	Takes the analog signal provided by the IR Receiver and will be processed by the STM and code will be written to interpret the signal.	• Analog14: connector pin 23 to STM PC5 • Analog11: connector pin 13 to STM PA6 • Analog8: connector pin 5 to STM PA3
I003	Provides a ground connection to the sensing subsystem.	• GND: STM GND to connector pin 27
I004	Supplies the battery voltage to the processor and then the sensing subsystem. BATT has a voltage rating of 3.7 V.	• BATT: Battery to STM VBAT to connector pin 4 (BATT)

3.3.1 Images for final design

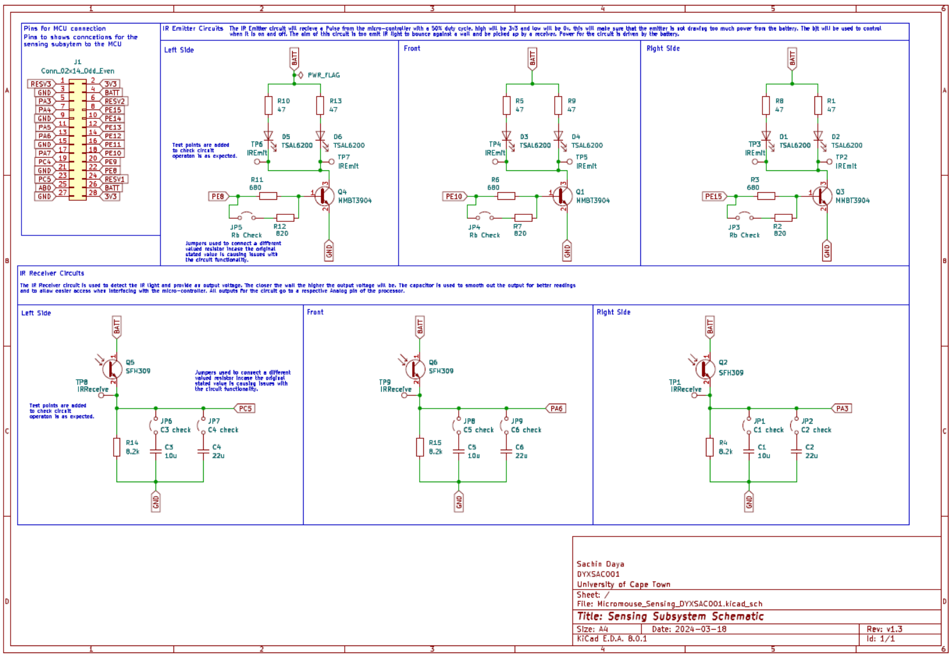
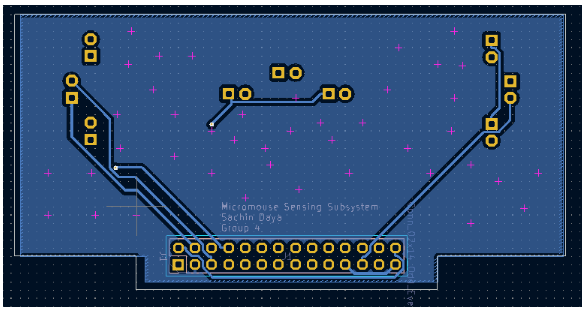
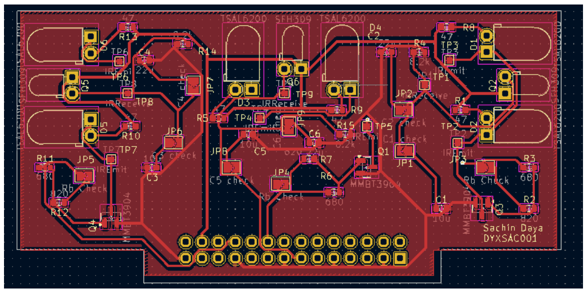


Figure 3.4: Sensing module schematic



(a) Back PCB



(b) Front PCB

Figure 3.5: PCB

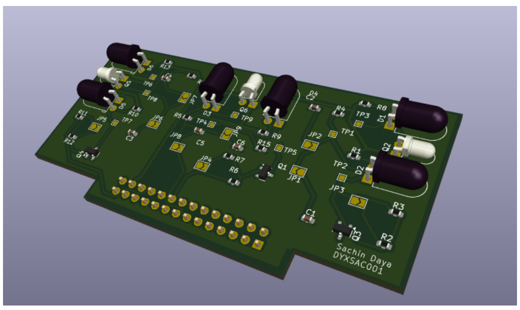


Figure 3.6: 3D PCB view

Acceptance Testing

4.1 Tests

Table 4.1 explains the procedures on how the subsystem will be tested to ensure all requirements and specifications are met. Note the tests are not presented in order of how they were executed.

Table 4.1: Subsystem acceptance tests

Test ID	Description	Testing Procedure	Pass/Fail Criteria
AT01	Operational testing: Measure voltage drop across the photo-transistors (output). To check ability to detect a wall.	• Connect the DC supply to the BATT Pin providing 3.7V. • Use the digital oscilloscope to provide a PWM and to read the output across the photo-transistor using the respective test points. • Simulate a wall and test each side of the board.	• Pass: If a wall is present the voltage should read 1.1 V or higher, and no wall voltage should be close to 0 V. • Fail: Voltage is below 1.1 V when a wall is present.
AT02	Unit testing: Checking alignment of pin headers and integration with the micro-controller.	• Obtain a 2x14 pin header from White Lab. • Solder into allocated space. • Use connecting wires to join the relative pins as shown in Figure 3.3 to the Micro-controller.	• Pass: Once connections are made check both AT07 and AT01 are passed. • Fail: If either AT07 or AT01 is not passed.
AT03	Unit testing: Measuring the dimensions of the PCB.	• Use a ruler and measure the dimensions of the PCB	• Pass: Length is 85 mm or less. • Fail: Length is greater than 85 mm.
AT08	Business acceptance testing: Using JLCPCB to review the cost of the PCB.	• Look at the order receipt	• Pass: Total price for 5 boards (2 populated, 3 not) is $30 or less. • Fail: Total price for 5 boards (2 populated, 3 not) is over $30.
AT09	Business acceptance testing: Checking whether the boards have arrived with all the correct components.	• Match the components with what is on the PCB editor. • If a mismatch is found check if the correct files were submitted.	• Pass: All components are on the board and match the PCB design. • Fail: Components missing or placed in the wrong position.

Test ID	Description	Testing Procedure	Pass/Fail Criteria
AT06	Unit testing: Checking that the subsystem works with a PWM signal.	• Provide 3.7 V to the circuit using a DC power supply. • Supply a PWM signal (Square Wave) using a signal generator. • Use probes to measure the output across the photo-transistor. • Use the Oscilloscope to get a reading.	• Pass: The photo-transistor is not constantly at a high or low. • Fail: The photo-transistor does not indicate a high or low voltage reading.
AT07	White box testing: Using the 2nd Year STM to verify the correctness of the code.	• Use Visual Studios and the required extensions to set up the STM. • Debug any errors in the code as they arise. • Connect the subsystem to the necessary pins and test using the mock maze and its different configurations.	• Pass: Each LED on the STM32F0 turns on for the respective configuration of the walls of the maze. • Fail: Respective LEDs do not turn on or turn on for the incorrect input.
AT04	Unit testing: Checking continuity across components and placement of components.	• Set the multi-meter to do a diode check. • Use the test points after the IR LED and monitor if there is a voltage drop when the positive lead is placed on the Test point. • Set the multi-meter to do a continuity test and place the probes at the corresponding terminals of each component.	• Pass: There is a forward voltage drop across the IR-LED and when doing the continuity check a beep is heard from the multi-meter. • Fail: There is no voltage drop across the IR LED and the multi-meter doesn't beep.
AT05	Unit testing: Ensuring that the power requirements are met for the subsystem.	• Provide 3.7 V to the circuit using a DC power supply and a PWM signal from a signal generator. • Use the test points placed after the IR LEDs to measure the voltage drop. • Use the test points after the photo-transistor to measure the voltage drop. • Use the test points after the photo-transistor to measure the voltage drop.	• Pass: The voltage drop across the IR LED is 1.2 V or more, and the voltage drop of the photo-transistor is between 0.5 to 3.2 V • Fail: The voltage requirements mentioned above aren't met.

4.2 Critical Analysis of Testing

Upon receiving the boards the testing of the subsystem began. This section will discuss the 5 most important tests that needed to be completed to have a functional sensing subsystem. The order in which the tests will be described represents the order in which the subsystem was being tested.

The analysis of the testing is only shown for the PCB that was used during the demo. Note the other PCB also went through the testing procedures for each test.

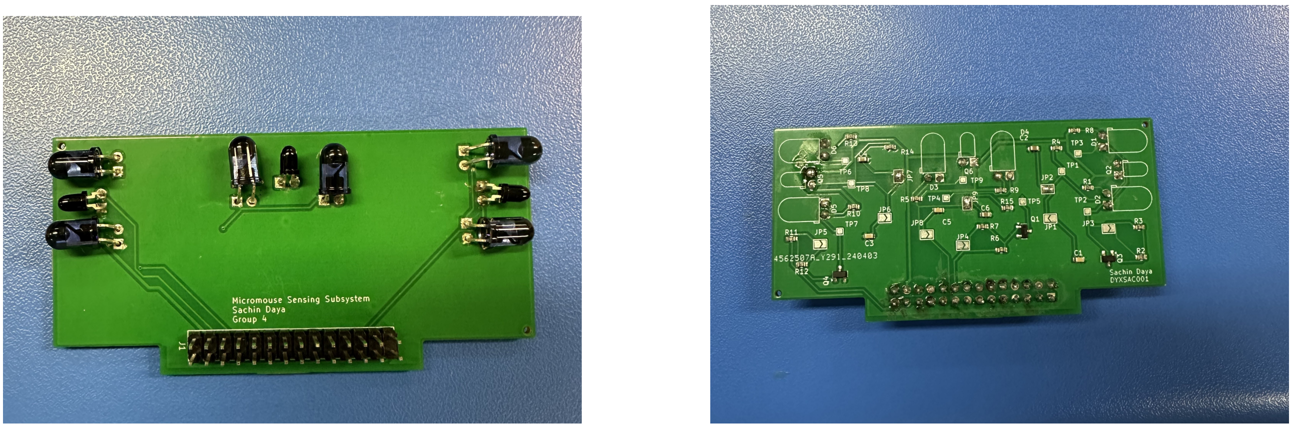
AT04

Initial results from conducting test AT04: **Fail**.

AT04 was done to check whether all the components were correctly placed onto the PCB. Following the testing procedure, after completing the diode check it was found that the IR LEDs (TSAL 6200) were placed the wrong way around for each side (Left, Front, and Right) of the PCB. This meant that it was acting in reverse to how the schematic in Figure 3.2a displays it. The effect of this error meant that the IR LED was not emitting any IR light.

Continuing with the testing procedure, the next step was to check continuity across the other components mainly the photo-transistor (SFH309 FA) as this was key to providing the detection of a wall. Another issue was encountered each photo-transistor was placed the wrong way around thus allowing no current to flow through therefore not being able to receive any IR light and produce an output that could be read.

To solve the issues arising from AT04 the components were removed using a soldering iron and a desoldering pump. Since the configuration of the components was all bent at 90 degrees this made it difficult to bend them the other way without the pins snapping, which resulted in the components being soldered onto the underside of the PCB as shown in Figure 4.1.



(a) Back PCB

(b) Front PCB

Figure 4.1: Modified PCB after conducting AT04.

Once the corrections were made the testing procedure was completed again this time all the criteria were met to pass AT04.

AT05

Initial results from conducting test AT05: **Pass**.

The next crucial step in testing the subsystem is to check whether or not the circuit can handle the power requirements. This is important as the components have maximum ratings of the voltage they can handle thus this step will simultaneously prove that the circuit is functional at the rated voltage while proving the calculations done for the resistors and capacitors are correct.

Following the testing procedure a DC power supply was used to act as the LiPo 800 mAh battery. The oscilloscope acted as the PWM provided by the micro-controller, a square wave with the following parameters shown in Figure 4.2. Using the test points placed at different points of the circuit. The locations of the test points can be checked in Figure 3.4. With the test points the voltage drop across the relative components can be measured.

A multi-meter was used to check the voltages across the components. The drop across the IR LEDs was approximately 1.3 V. This is what was expected. With the voltage across the IR LED being this high enough IR light was being transmitted to help the photo-transistor detect a wall at a further distance (approximately 10 cm).

Next, the photo-transistor was checked using a multi-meter, as long as it experienced some voltage drop from 0.5 to 3.2 V it was deemed to be working and could handle the supply voltage. This was the case. The readings displayed showed that the circuit could handle the 3.7 V provided by the DC power supply thus showing it can handle the battery that will be used to power the micro-mouse.

Monitor the power supply as it will show how much current is being drawn by the circuit. This is normally shown in Amperes. Thus the value needs to stay below 0.4 A. Thus we can conclude that the circuit will not drain a significant amount of the battery power during operation.

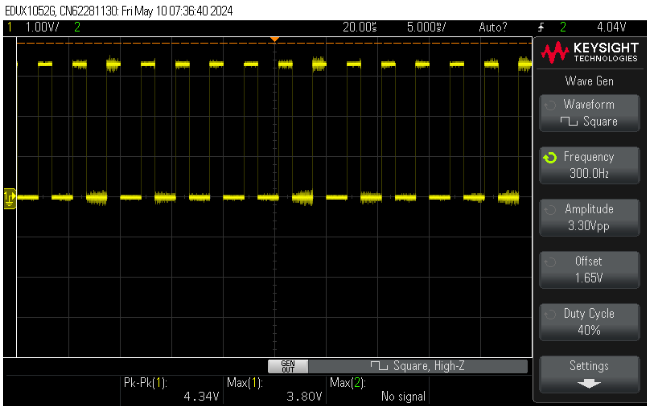


Figure 4.2: Oscilloscope signal generator providing a square wave in place of a PWM.

AT06

Initial results from conducting test AT06: **Pass**.

The following test works in tandem with AT05 to make sure that the circuit can handle the power requirements and has a means of switching power.

Following the testing procedure, again the DC power supply is connected to the circuit, and the digital oscilloscope is used to simulate the PWM signal that will be produced by the micro-controller.

The reason for the PWM is to provide a means of switching for the circuit so that the battery is not drained. To verify that this is true the photo-transistor output is not constantly at a high or low when a wall is placed in front of it and not respectively. It does not always sense a wall as it will quickly change between high (3V3) and low (0 V). The rate at which this change occurs depends on the parameters set by the PWM concerning its duty cycle and the frequency of the signal. Figure 4.3 shows that the photo-transistor responds to the PWM signal.

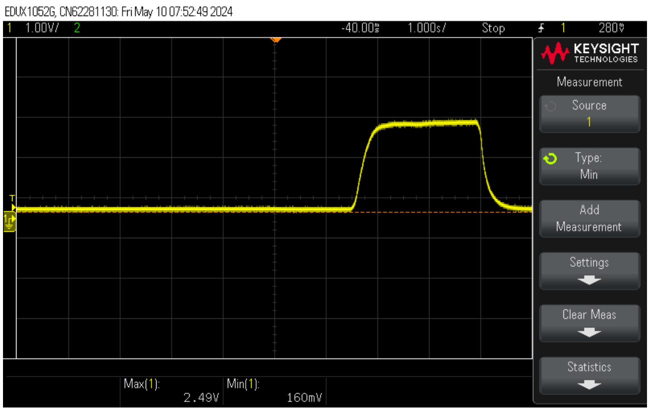


Figure 4.3: Oscilloscope showing the output across the photo-transistor.

AT01

Initial results from conducting test AT01: **Pass**.

AT01 is the most crucial test as if the criteria were not met there would be no means of sensing any wall at all. This test determines whether the 'eyes' of the micro-mouse can see.

To test the operation of the subsystem the following procedures were followed the DC power supply was connected and the PWM produced by the oscilloscope was also fed into the circuit. Once all the connections are made a probe is connected to measure the output across the phot-transistor which is read by an oscilloscope. The following results captured during testing are shown in Figure 4.4, Figure 4.5, and Figure 4.6 below.

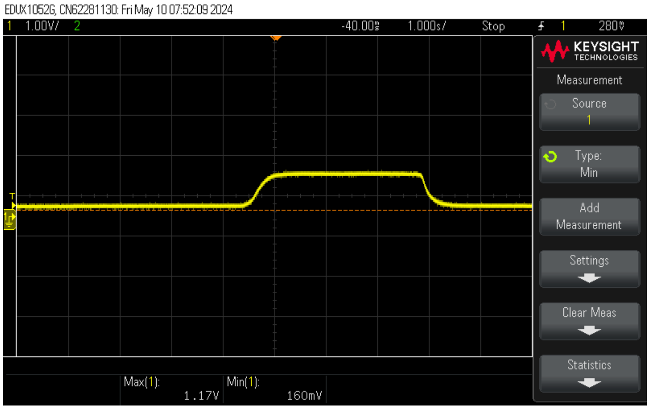


Figure 4.4: Voltage across photo-transistor on the left side of the PCB.

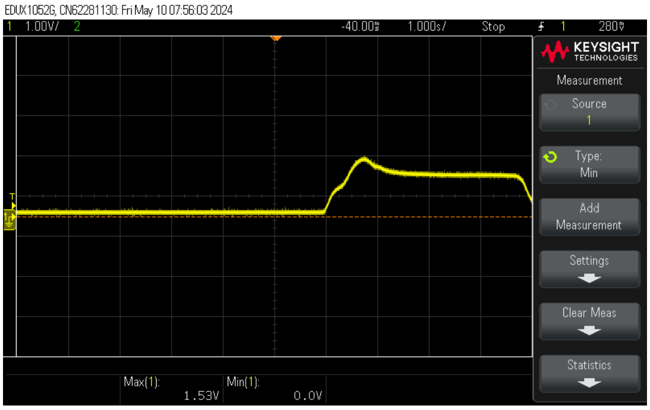


Figure 4.5: Voltage across photo-transistor on the front of the PCB.

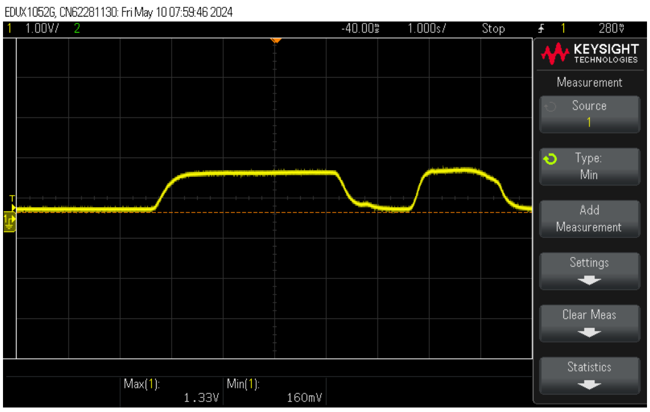


Figure 4.6: Voltage across photo-transistor on the right side of the PCB.

Table 4.2 shows the following results that were achieved at each side of the PCB.

Table 4.2: Results from AT01.

Side	Wall present at 10 cm	No wall present
Left	1.17 V	0.16 V
Front	1.53 V	0 V
Right	1.33 V	0.16 V

The results show that the subsystem is capable of detecting a wall on each side of the PCB (Left, Front, and Right) at a reasonable distance of 10 cm giving the micro-mouse enough time and distance to rotate following the configuration when put in a real-life maze.

AT02

Initial results from conducting test AT02: **Pass**.

Following the test procedure a problem was encountered, the subsystem required a 2x14 pin header, the only pin headers available from White Lab was a 2x13 header. To resolve the issue two sets of pin headers were requested and then 7 rows were taken from each set to create a 2x14 set. This was then soldered onto the board, all the pins matched up.

Next, all the pins were connected to the STM32F0 according to the interfacing diagram depicted in Figure 3.3.

Once all the necessary connections were made, power was supplied to the STM and the circuit, and as a check, the voltage was read across the respective photo-transistors and checked whether the LEDs on the STM (PB7, PB6, and PB5) turned on when there were walls placed in front of the photo-transistors. Figure 4.7 shows the testing done for verifying that the subsystem integrates with the micro-controller.

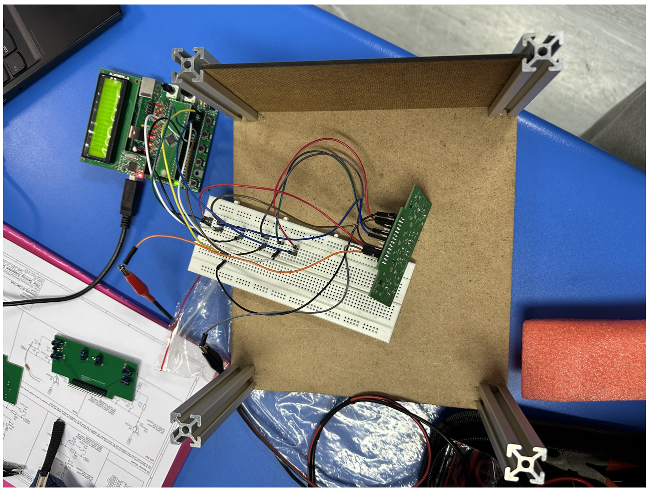


Figure 4.7: Showing that the subsystem interacts with the micro-controller.

Overall testing of the subsystem went smoothly, The acceptance testing procedures were followed thus making it easy to find problems with the board and hence allowing for quick and simple solutions to be found.

Conclusion

The development and testing of the sensing subsystem for the micro-mouse have been largely successful. This shows that the design decisions taken to use certain components, the components included the TSAL6200 IR emitting diode, the SFH309 FA photo-transistor, and the MMBT3904 transistor. The calculations used to determine the capacitor and resistor values were provided to be valuable and correct.

Demonstrating its ability to meet the requirements for effective maze navigation. The subsystem's ability to detect walls through the use of IR LEDs and photo-transistors was validated through a series of acceptance tests. For instance, test AT01 confirmed that the voltage readings were 1.17 V, 1.53 V, and 1.33 V for the left, front, and right sides respectively when a wall was present at a distance of 10 cm and close to 0 V when no wall was present, indicating a reliable detection mechanism.

Additionally, the subsystem passed tests AT04 and AT05, ensuring that all components were correctly placed and that the circuit could handle the power requirements without significant battery drain. The final integration with the micro-controller was also successful, as evidenced by the proper functioning of the LEDs on the STM32F0 when walls were detected. Overall, these results indicate that the subsystem is robust and capable of meeting its design objectives.

In conclusion, the sensing subsystem has successfully addressed the primary engineering challenges, demonstrating reliable wall detection and integration with the micro-mouse's control system.

5.1 Recommendations

To further enhance the functionality and reliability of the subsystem, two key areas for future work are suggested. First, enhancing the sensing range by exploring different types of IR LEDs and photo-transistors could provide the micro-mouse with greater flexibility in detecting walls at various distances and under different environmental conditions. Testing components with higher sensitivity and different wavelengths could optimise performance.

Secondly, optimising the placement and soldering of components could be achieved by employing automated soldering methods. This would reduce human error and improve the reliability and consistency of the subsystem, ensuring a more dependable performance.

The above improvements could significantly enhance the overall capability and efficiency of the micro-mouse's sensing subsystem.