Final Design Report

Micromouse Sensing Subsystem

Prepared by:
Aaron Isserow

Prepared for:
EEE3088F
Department of Electrical Engineering
University of Cape Town

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Chapter 1

Introduction

1.1 Problem Description

The micro-mouse project involves creating a system that can find its way through a maze. The project is divided into four modules: the processor, motherboard, sensing and power. The sensing subsystem is crucial because it allows the micro-mouse to understand its surroundings and decide where to go next. This report entails a step by step procedure on the calculations and thereafter the design in developing this sesning subsystem. This report also focuses on the design of the PCB board.

The challenge for the sensing subsystem is to select and place sensors in a way that the system can effectively sense walls and navigate through the maze. This involves choosing the right type of sensors, arranging them correctly on the PCB board, and making sure they work well with the rest of the system. It has to work within a tight budget and consume as little power as possible, all while being reliable and accurate in detecting walls.

1.2 Scope and Limitations

The scope of this project is to design and build a sensing board that involves selecting suitable IR emitters and IR detectors that balance effectiveness with cost and power consumption. Thereafter integrating these components (along with resistors, capacitors and transistors) into a system (on a PCB board) that fits within the micro-mouse's limited space. A fixed budget restricts the range and type of sensors and components available for use. Power consumption is another critical factor, as the subsystem must operate within the energy limits provided by the robot's battery (3.6V), emphasising the need for efficient energy use. The physical space available on the micro-mouse for mounting sensors is limited, requiring a compact and efficient design. The choice of components and their respective layout on the PCB board needs to be carefully thought out to satisfy the need for compactness.

Testing procedures are detailed in the Requirements Analysis of this report and are elaborated moreover in the Acceptance Testing section. An important test includes the ability for the sensors to emit and detect Infrared light which is tested with a multimeter at specific positions on the PCB board. The design of the system is detailed in the Design section where components are compared for efficiency. Thereafter calculations are performed using these selected components to design a functional circuit to incorporate into the sensing subsystem.

1.3 GitHub Link

https://github.com/AaronIsserow/Micro-mouse-Project

Chapter 2

Requirements Analysis

2.1 Requirements

The requirements for the micro-mouse sensing subsystem are described in Table 2.1.

Table 2.1: Functional requirements of the sensing subsystem.

Req ID	Description
FR01	PCB board must fit in limited space provided on micro-mouse.
FR02	Use a battery (the LiPo 800mAh 3.7V from Micro Robotics) as power source to power the entire system.
FR03	Voltage/signal-based output at a particular distance from the wall.
FR04	Detect whether there is a wall in front of or on the sides of the micro-mouse at various distances (6cm and 2cm).
FR05	The output should be repeatable and reliable.
FR06	Use IR light to sense and detect walls in the maze.
FR07	Output voltage signal should have a minimal or no change with small changes in angles. The output voltage signal should vary significantly when there are major changes in its angle relative to the wall.
FR08	It is necessary to include a switching mechanism to conserve power.
FR9	Must adhere to a strict budget and only use components available on JLCPCB which are in stock.

2.2 Specifications

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

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

Spec ID	Description
SP01	Comply with a strict size constraint of 80mm in width and 30mm in length to ensure the PCB board does not interfere with the micro-mouse's wheels or collide with the maze walls.
SP02	Use the microcontroller's 3V3 pin to power the sensing subsystem.
SP03	Output signal must be between 200mV and 3V (depending on the systems distance to a wall).
SP04	The sensor should not detect the maze wall at 25cm (not in the presence of a wall) and should detect the maze wall at 6cm; when the sensor's output signal is around 2.4V, it indicates proximity of roughly 6cm from the wall. The output voltage should increase to 3.3V at 2cm away from the wall.

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Table 2.2: Specifications of the sensing subsystem (continued)

Spec ID	Description
SP05	The output should be the exact same of the previous output voltage at a precise distance and orientation from the wall.
SP06	Emitters of the IR light should produce light with a wavelength of 940nm which corresponds to the wavelength of the detectors.
SP07	The sensor must not be sensitive to small changes in angle (±15 degrees); nothing greater than 100mV change in output signal should be observed during this condition. The sensor must be sensitive to significant changes in angle; greater than 100mV from the front detectors and side detectors should affect the micro-mouses output signal to the processor.
SP08	Use the PWM pin on the microcontroller and NPN bipolar junction transistors to enable switching. Operate the IR LED at 80% duty cycle to save power.
SP9	Starting allowance is $30. $13.5 is being used to manufacture a standard sized simple board. Components used should thus not total more than $16.5.

2.3 Testing Procedures

Table 2.3: Summary of acceptance testing procedures.

Test ID	Description
AT01	Use a ruler to measure the PCB dimensions.
AT02	Measure voltage and current post IR emitter and photodiode using a multimeter.
AT03	Test photodiode output voltage at a distinct distance from the wall using a multimeter.
AT04	Test wall detection accuracy at 6cm and 25cm distances at the output using a multimeter.
AT05	Verify repeatability of output voltage at various maze positions using a multimeter.
AT06	Detect IR light emission using an Android phone camera and by measuring thw output voltage directly after the IR emitter.
AT07	Assess minor and major angular sensitivity by measuring output voltage at a 15-degree angle and 30-degree angle to the wall.
AT08	Check PWM signal integrity and duty cycle with an oscilloscope.
AT9	Ensure PCB and components cost does not exceed $30.

2.4 Traceability Analysis

Table 2.4: Requirements Traceability Matrix

#	Req	Spec	Test
1	FR01	SP01	AT01
2	FR02	SP02	AT02
3	FR03	SP03	AT03
4	FR04	SP04	AT04
5	FR05	SP05	AT05
6	FR06	SP06	AT06
7	FR07	SP07	AT07
8	FR08	SP08	AT08

Continued on next page

#	Req	Spec	Test
9	FR09	SP09	AT09

2.4.1 Traceability Analysis Summary

Analysis	**Summary**
1	PCB fitting within micro-mouse (FR01 to SP01, tested by AT01). Ensures no obstruction or collision with maze walls.
2	Specific battery usage (FR02 to SP02), power delivery confirmed by voltage and current measurements (AT02).
3	Voltage/signal output within limits for navigation (FR03 to SP03), verified by varied position testing (AT03).
4	Obstacle detection at set distances (FR04 to SP04), accuracy confirmed by distance-based sensor testing (AT04).
5	Consistent output within 5% variance (FR05 to SP05), reliability checked by repeated measurements (AT05).
6	IR light detection by wavelength (FR06 to SP06), operational integrity checked using an Android camera (AT06).
7	Minor angle stability in sensor output (FR07 to SP07), validated by minor angle adjustments (AT07).
8	Power-efficient operation using PWM control (FR08 to SP08), duty cycle verified with oscilloscope (AT08).
9	Budget adherence for component costs (FR9 to SP9), financial compliance verified (AT9).

Chapter 3

Subsystem Design

3.1 Design Decisions

3.1.1 Component Comparison

Table 3.1: Comparison of IR Emitters

Feature	TSAL4400	TSAL6100	QRD1114 (Embedded)
Wavelength (nm)	940	940	940
Angle of Half Intensity	±25°	±10°	N/A
Forward Current (mA)	100	100	50
Voltage Drop (V)	1.35	1.35	1.7
Available on JLCPCB	Yes	Yes	Yes
JLCPCB Stock	918	0	5
Minimum Order	1	88	6
Price ($)	0.1646	0.0981	1.5795
Pros	Large angle, cheap	Cheap, low voltage	Compact, low power
Cons	High current	No stock, large min order	Expensive, limited stock

Table 3.2: Comparison of Detectors

Feature	BPW34	PD333	SFH205
Wavelength (nm)	900	940	950
Angle of Half Intensity	65°	80°	60°
Dark Current (nA)	2	30	2
Light Current (µA)	50	35	28
Design	Flushed	Pin	Pin
Available on JLCPCB	Yes	Yes	No
JLCPCB Stock	2658	3422	N/A
Minimum Order	1	1	N/A
Price ($)	0.5505	0.1518	N/A
Pros	Available, no min. order	Good design, high light current, large angle	Good design, low dark current
Cons	Flat, expensive	High dark current	Not available, low light current

Table 3.3: Comparison of Switches

Feature	2N3904	P2N2222A
Description	General-purpose amplifier and switch	NPN switching transistors
Available on JLCPCB	Yes	No
JLCPCB Stock	8249	N/A
Minimum Order	1	N/A
Pros	In stock, cheap	Switching capability
Cons	None	Not available on JLCPCB

3.1.2 Evaluating Multiple Solutions

The QRD's integration of emitter and detector components offers a space-saving solution beneficial for compact applications like the micro-mouse, but its cost is prohibitive given budget limitations. Conversely, using separate emitters and detectors, despite introducing greater complexity and potential signal issues, provides essential design flexibility. This flexibility is vital for customising functionality to specific project needs, making it the preferred choice despite the higher complexity and potential for interference, given the tight budget constraints.

Table 3.4: Comparing Possible Solutions

Design Description	Pros	Cons
Using QRD	Compact design, integrates emitter and detector, conserves power	More expensive, budget constraints
Separate IR components	Flexible design, customizable sensing range and sensitivity	Increases complexity, potential for signal interference

3.1.3 Component Selection

Table 3.5: Component Selection Reasoning

Component	Selected For	Reasoning
Emitter: TSAL4400	General sensitivity and cost	Cost-effective with no min. order; broad emission angle reduces need for precise alignment.
Detector: PD333	Optimal detection	Non-flush mounting enhances flexibility; high availability and light sensitivity compatible with emitter wavelength.
Switch: 2N3904	Efficiency	Affordable and available, suitable for efficient power management in switching applications.

3.1.4 Final Design

IR Emitter With Switching Capabilities Circuit

Components used: TSAL4400 IR emitter, 2N3904 transistor and resistors. The 3V3 pin of the microcontroller will power the branch connected to the collector of the IR emitter. Whereas the PWM pin from the microcontroller will power the base of the transistor, in turn switching it on and off to save power (when the voltage at the base is approximately less than 0.8V, the transistor will be reverse biased and switch off - no collector current will flow). The input where PWM is provided is connected to the pins on the micro-controller, specifically pins 8, 10, and 12.

The following information was extracted and/or derived from respective datasheets relating to the components used. These datasheets are included in the github link in the introduction of the project. Operating the IR emitter with a current of 100mA maximizes its performance efficiency. At this current, the voltage drop across the IR emitter is 1.35V, and across the transistor, it is 1V. Using Kirchhoff's Voltage Law (KVL) and Ohm's Law, the equation $3.3 - 1.35 - R(100mA) - 1 = 0$ leads to a required series resistor value of 10 ohms, connected to the transistor's collector.

Additionally, selecting an appropriate base resistor for the transistor is crucial. The transistor's gain, which varies inversely with the collector current, ranges from 30 to 100. If the collector current drops below 100mA, the gain increases, potentially altering the transistor's performance. This variation must be considered when determining the base resistor values. Three resistors with different values are included at the base of the transistor. Variations and combinations of these resistors will be tested and thereafter the most ideal combination will be chosen. When Ic=100mA: $Ib = Ic/b = 100mA/30 = 3.33mA$. Since Vbe= 0.8V, $3.3 - (3.33mA)(R) - 0.8 = 0$, from ohm's law and using KVL. Solving yields R = 750 ohms. However when the gain is equal to 100, $Ib = Ic/b = 100mA/100 = 1mA$. Since Vbe= 0.8V, $3.3 - (1mA)(R) - 0.8 = 0$, R = 2700 ohms. When the gain is equal to 70, which is somewhere in the middle of the minimum and maximum expected gain, Ib = $Ic/b = 100mA/70 = 1.4mA$. Since Vbe= 0.8V, $3.3 - (3.33mA)(R) - 0.8 = 0$, R = 1750 ohms.

IR Detector Circuit

Key components include the PD333 photodiode along with various resistors and capacitors. These PD333 circuits draw power from the 3V3 pin on the microcontroller and are arranged in a reverse bias configuration. The reverse current of the PD333 varies, ranging from 30nA without IR illumination to 35uA when exposed to intense IR light. This current is proportionate to the IR light's intensity it captures. Consequently, near a wall that reflects significant IR light, the voltage across a connected resistor can be deduced with Ohm's Law: $V = IR = (35\mu)(R)$. Away from a wall, the voltage is minimal, as 30nA is substantially less than 35uA.

Selecting the correct resistor value for series connection with the photodiode is crucial to prevent the voltage across it from exceeding 3.3V, which would disable the photodiode. It's also important that the resistor is large enough to ensure a distinct and significant output voltage signal, reflecting changes due to varying currents. Using a 75k ohm resistor helps manage this, limiting the maximum output voltage to $V = (35\mu)(75k) = 2.625V$, below the 3.3V power supply. The lowest output voltage approaches zero. For safety and adaptability, a 47k ohm resistor is added in parallel, configured with solder jumpers to address any unexpected currents or voltage fluctuations.

The PWM modulation of the IR emitters results in light intensity variations at kHz frequencies, thus causing similar frequency fluctuations in the voltage across the resistor. To counteract these fluctuations and stabilize the output voltage, a low pass filter is implemented by attaching a capacitor parallel to the resistor. A 100nF capacitor establishes a cut-off frequency of $f_c = \frac{1}{2\pi RC} = \frac{1}{2\pi(75k)(100n)} = 21.22$Hz, much lower than the PWM frequency. In alignment with previous adjustments for potential failures, another capacitor is added in parallel to the first, set via solder jumpers. This setup ensures that only frequencies below the cut-off are transmitted, thereby stabilizing the output.

This output is connected to the general-purpose input/output pins on the microcontroller, specifically targeting pins 5, 7, and 11. This configuration helps manage the signal integrity effectively.

3.1.5 Final notes

Three IR Emitter circuits will be used with their corresponding photodiode circuits. Circuit 1 will work with circuit 4. Circuit 2 will work with Circuit 5. Circuit 3 will work with Circuit 6. The respective circuits will be placed in close physical proximity to its counterpart (on the pcb board) for optimal and effective operation of the sensing subsystem.

The aim of the IR Emitter circuit is to project IR light towards the wall, whereas the aim of the photodiode circut is to detect this light. The varying output from the photodiode circuit will send signals to the microcontroller in order to detect walls in the maze. The intelligence incorporated into the microcontroller will allow the micro-mouse to navigate its way through the maze.

All grounding points are connected to one of the following pins on the microcontroller, pins 3, 9, 15, 21, 27.

Please see Micro-mouse-Project/Sensing /Kicad Design/KicadDesignPDF on my GitHub link for a higher resolution schematic .

3.2 Failure Management

Table 3.6: Failure Management Techniques

Name	Description
Solder Jumpers	Enable isolation or bypass of circuit sections for troubleshooting without PCB redesign. Include exposed copper points for measurement, strategically placed for easy configuration or disconnection based on testing needs.
Multiple Resistors in Parallel	Enhance flexibility in post-production by allowing adjustable resistance values. This setup supports precise control over circuit characteristics by varying the combination of parallel resistors.

3.3 Interfacing Specifications

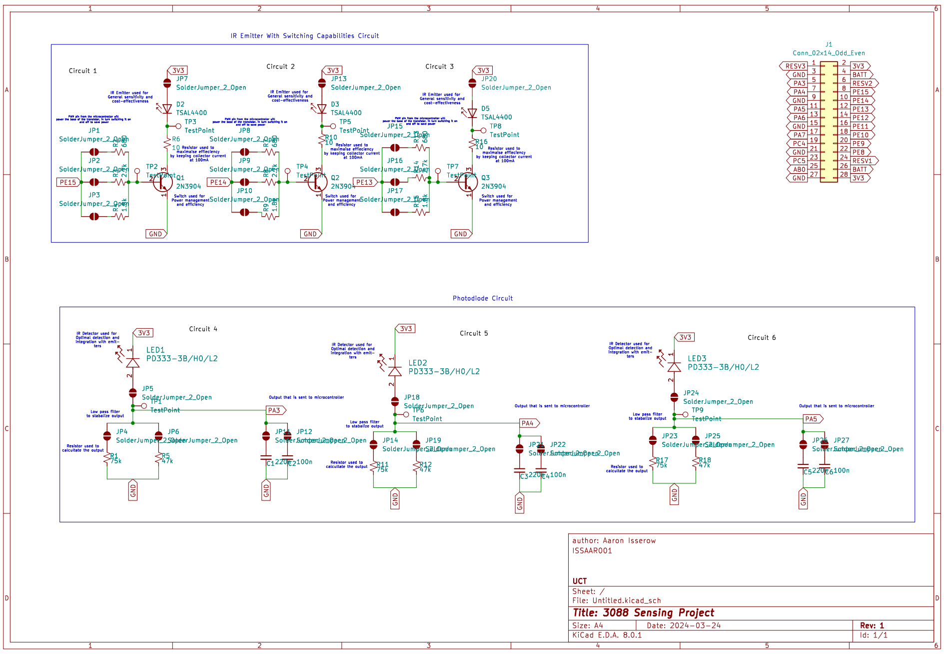
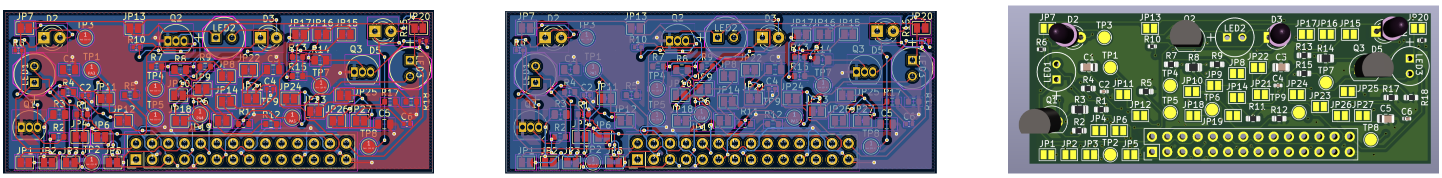


Figure 3.1: Schematic



(a) Front PCB (b) Back PCB (c) 3D PCB

Figure 3.2: PCB

Table 3.7: Interfacing Specifications

Interface ID	Description	Pin/Output
ID1	Emitter sub-circuit with PWM enabled for power conservation, 50% duty cycle.	PE13 (PWM PIN 12)
ID2	Emitter sub-circuit with PWM enabled for power conservation, 50% duty cycle.	PE14 (PWM Pin 10)
ID3	Emitter sub-circuit with PWM enabled for power conservation, 50% duty cycle.	PE15 (PWM PIN 8)
ID4	Powers all 6 subcircuits in the sensing system.	3V3 (PIN 2 and PIN 28)
ID5	Output for subcircuit 3.	PA3 (GPIO PIN 5)
ID6	Output for subcircuit 4.	PA4 (GPIO PIN 7)
ID7	Output for subcircuit 5.	PA5 (GPIO PIN 11)
ID8	Common ground for the circuit.	GND (PIN 3, PIN 9, PIN 15, PIN 21, PIN 27)

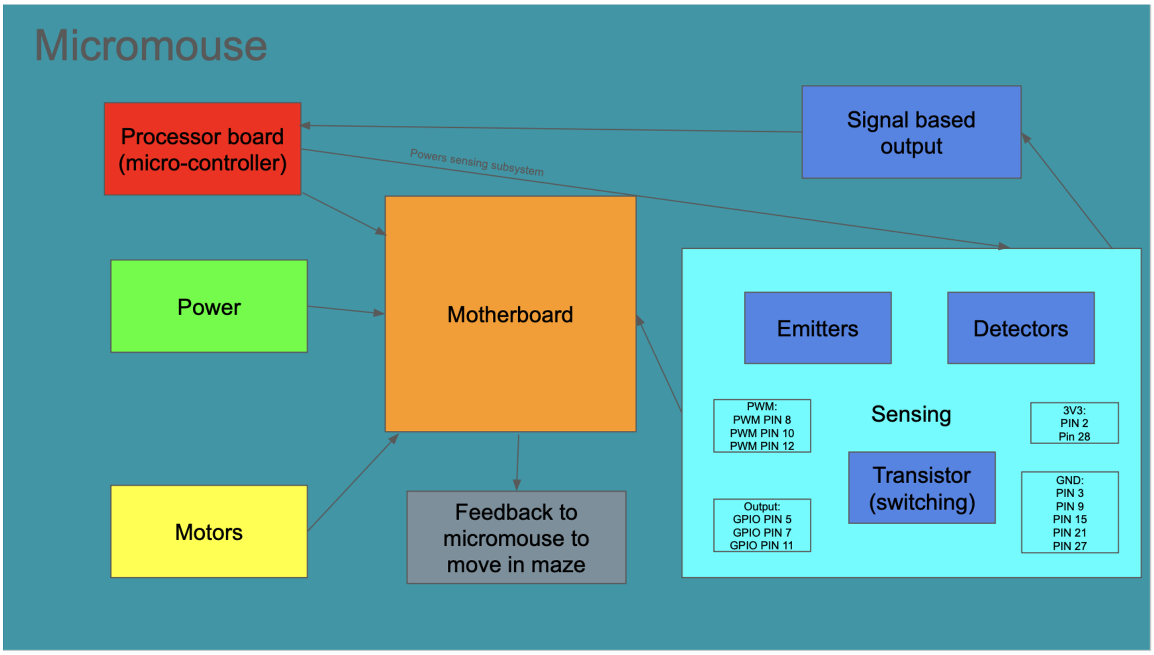


Figure 3.3: High Level Diagram

Chapter 4

Acceptance Testing

4.1 Tests

Table 4.1: Subsystem Acceptance Tests

Test ID	Description	Testing Procedure	Pass/Fail Criteria
AT01	Size limit	Use a ruler to measure the dimensions of the PCB board.	Width is 80mm and length is 30mm.
AT02	Power on	Use a multimeter at the test point/solder jumper directly after the IR emitter to measure the voltage at this point. Use a solder jumper directly after the photodiode and measure the current.	The voltage following the IR emitter should be below 1.95V. When the photodiode is directed at a wall, it conducts a current greater than zero.
AT03	Output voltage signal range at a distinct distance from the wall (6cm)	Once the board is turned on via the 3V3 and PWM pins. Measure the output voltage at a distinct position from the wall.	When the system is not in the presence of a wall (i.e. in open space), the output voltage should tend to 0V. When the system is placed in front of a wall (i.e. there are walls surrounding the system), the output voltage should reach a voltage in the range of 2.625V.
AT04	Distance sensing capabilities	Position the system so that the front sensor of the system faces the wall. Place the system 6cm away from the wall and measure the output voltage. Move the system to 2cm from the wall and now measure the output voltage. Repeat this process for the left sensor and the right sensor.	The output voltage should be in the range of 2.6V when 6cm away from the wall. The current flowing through the photodiode and thus also the resistor is directly dependent on the amount of IR light the photodiode is receiving. Therefore, it can be estimated the output voltage could be in the range of 2.6V at 6cm. The output voltage should be closer to 3.3V when 2cm away as the current flowing into the pull-down resistor will be greater.
AT05	Repeatable outputs for the same distance to a wall	Place the system at a distinct position and measure the output voltage. Remove the system and place it in the same position as before and measure the output voltage.	We expect the exact same output voltage at a distinct position from a wall. This will prove that the system has reliability in its design.

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Subsystem Acceptance Tests (continued)

Test ID	Description	Testing Procedure	Pass/Fail Criteria
AT06	Determining if the Infrared emitter is emitting light	Power the circuit using the 3V3 and PWM pins. Using the testing points (TP3, TP5, and TP8) measure the voltage at this point with respect to ground. Or use an Android phone camera to detect the IR light from the emitter.	A 3.3V supply is being supplied to this branch of the circuit. Thus to determine if the IR emitter is emitting light, we can use two methods. The first method is using an android phone, it is possible to see the IR light on the camera. This will clearly show if the LEDs are on or off. Another method I applied was to measure the voltage drop over this component which should be 1.6V.
AT07	Output voltage at small and large changes in angle from the wall	Position the system at a 15-degree angle from the wall. Measure the respective output voltage. Now position the system at a 30-degree angle from the wall and measure its output voltage.	At a 15-degree angle from the wall, the output voltage should not deviate (deviations of 100mv will be accepted). However, at a 30-degree angle, the output voltage should deviate significantly. A drop of around 500mV should be seen across the output.
AT08	Power saving	Connect the PWM pins to an oscilloscope and measure the output voltage across the resistor/capacitor parallel branch.	The output signal is a square wave that rapidly oscillates between 0V and 3.3V.
AT09	Budget analysis (This is not a technical ATP)	Calculate the price of the board and compare with the budget.	The price of the PCB is less than $30.

4.2 Critical Analysis of Testing

Upon the arrival of the PCB boards, it was obvious that the IR emitters and detectors were facing upwards (not directed outwards as desired). When the KiCad schematic was checked, it was clear that the wrong footprint had been used. Therefore, these components were desoldered and resoldered to properly emit and detect light reflected off a wall.

To fix this, the IR emitters and IR detectors were laid flat on the board, so the tops faced the wall. After making these changes, it was realized that the components had been resoldered incorrectly, swapping the detectors and emitters. Consequently, the components were desoldered and resoldered again in their correct positions.

Figure 4.1: Physical PCB after alterations

As seen in Figure 4.1, the blue LEDs are the emitters (TSAL4400 from JLCPCB) and the black LEDs are the detectors (PD333 from JLCPCB). When the phrase output resistor is mentioned below, this refers to the resistor after the photodiode and before ground, the output voltage is taken above this resistor.

Once the components were in the right spots, the board was tested. However, the system showed a high output voltage when it wasn't near a wall, which wasn't what was expected. After discussing the problem with tutors and classmates, it was concluded that the photodiode was forward biased instead of reverse biased, causing a constant voltage drop of 0.7V across the photodiode. This meant the distance to the wall didn't affect the output.

The photodiodes for the left, front, and right-hand side sensing circuits were reversed. This helped, but the output was still too low even when the sensors were close to a wall. The output resistor value was too low, so the resistance was increased from 75k ohms to 110k ohms. This adjustment was made by placing a resistor over a solder jumper that was put in series with the already existing output resistor. The original purpose of this solder jumper was to connect or disconnect a branch that contained a 75k ohm or a 35k ohm resistor via a small piece of solder. These values were however too low and thus an additional 75k ohm resistor was placed of the solder jumper connecting the 35k ohm resistor. Thus, effectively producing a 110k ohm resistor. This solution required problem solving as this solder jumper was not initially desired to contain a resistor but was rather thought to just connect or disconnect a branch with a small piece of solder. After this adjustment, a larger change in the output between when a wall was present and when it wasn't was observed. This final change improved the sensing system, making it easier to detect changes in distance to a wall.

A common theme in testing the system is measuring the output voltage. When output voltagei s referenced, the following method is applied: Use a multimeter to measure the output voltage with respect to ground via the three circuits respective test points (TP1, TP6 and TP9). These test points were placed directly after the photodiode and before the output resistor. Therefore, this is where one can measure the output of the interactions between the IR emitter circuits and the photodiode circuits. This method was used in initial testing of the system to figure out potential problems. Another method of determining the output voltage is to connect an oscilloscope directly to PA3, PA4 or PA5 (left, front or right) of the pin headers. I will be using the second method to show results of testing.

Table 4.2: Subsystem acceptance test results

Test ID	**Description**	**Result**
AT04	Distance sensing capabilities: Measures the output voltage at 6cm and 2cm from the wall, showing how the photodiode is reverse biased and behaves as expected.	Passed
AT05	Repeatable outputs for the same distance to a wall: Verifies the system's ability to produce consistent output when positioned at a fixed distance from the wall multiple times.	Passed
AT07	Output voltage at small and large changes in angle from the wall: Assesses how the output voltage varies when the system is angled at different degrees from a wall.	Passed
AT06	Determining if the Infrared emitter is emitting light: Confirms the functionality of the IR emitter by checking the voltage drop, which should match the expected value from the datasheet.	Passed

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Table 4.2 – continued from previous page

Test ID	Description	Result
AT03	Output voltage signal range at a distinct distance from the wall (6cm): Tests the output voltage for left, right, and front sensors both in the absence and presence of a wall.	Passed

4.2.1 AT04

The output voltage for both the 6cm distance and 2cm distance was as expected and was 2.25V and 3.2V respectively (varying slightly between left, right and front sensors). This shows the photodiode is reverse biased and is acting accordingly.

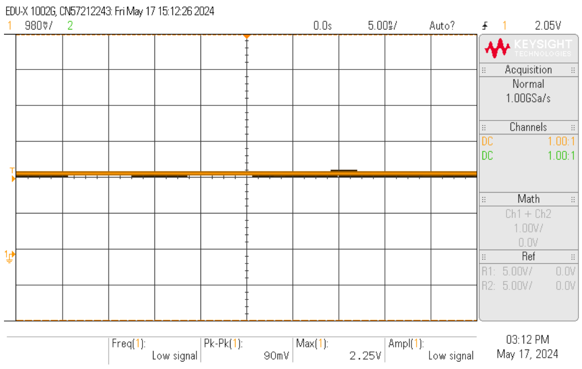

Figure 4.2: Output voltage when 6cm away from the wall

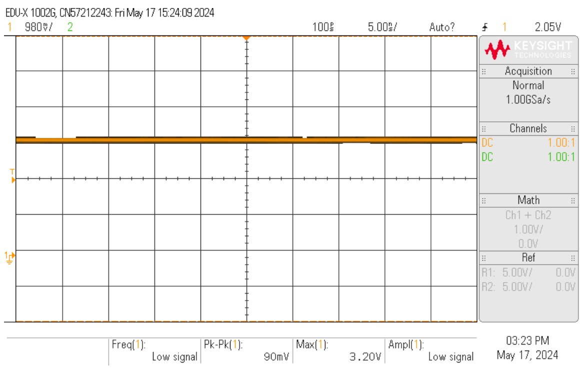

Figure 4.3: Output voltage when 2cm away from the wall

4.2.2 AT05

The system proved itself to consistently show repeatable output results. This was tested at 6cm away from the wall where in both iterations an output voltage of 2.25V was observed (see figure 4.2).

4.2.3 AT07

The output voltage did not change when the angle was 15-degrees from the wall. Where as a clear change in voltage (from 2.25v to 1.07V) was detected when the system was initially placed at a 0-degree angle to the wall compared at a 30-degree angled to the wall.

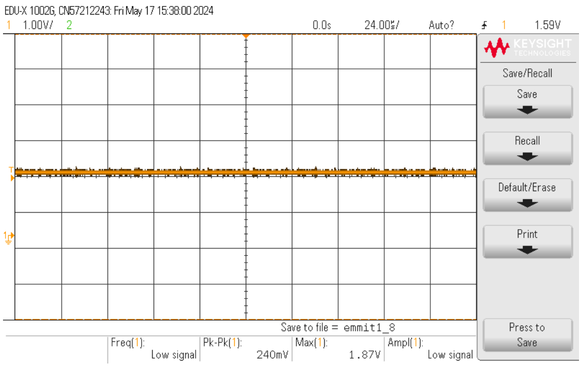

Figure 4.4: Output voltage at a 30-degree angle to the wall (distance of 6cm)

4.2.4 AT06

A voltage of 1.6V was detected after the emitter. An expected voltage drop of 1.6V was expected as per the data sheet of the component. This matches the tested results as we see only 1.7V detected after the emitter (0.1V off due to tolerances of components), which shows that there was a clear voltage drop over the component (3.3V-1.7V=1.6V).

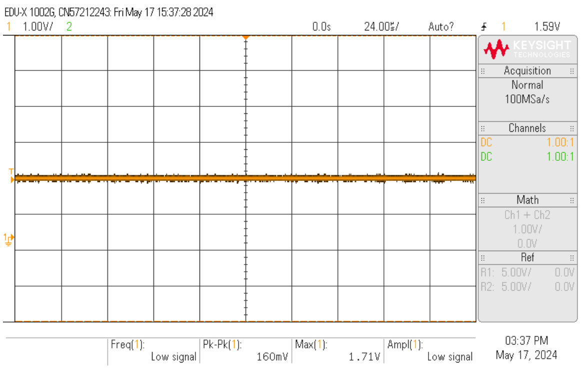

Figure 4.5: Voltage reading directly after the IR emitter

4.2.5 AT03

The output voltage for the left, right and front sensors remains at 200mV when not in the presence of a wall. This was as expected as the voltage is supposed to tend to 0V when not in the presence of a wall. On the other hand, when the system was placed into a box (i.e. walls present), the voltage jumped up to 2.29V respectively. This is also a desired result as the output was supposed to reach 2.625V. There was therefore some leakage voltage which may have been due to tolerances of components used in the PCB board. It must also be noted that the output resistors were increased during the process of testing and thus there should have been an even greater output voltage reached in the presence of a wall. Only after testing, a suitable resistor was chosen to maximise the difference in output voltage when there is or is not a wall present.

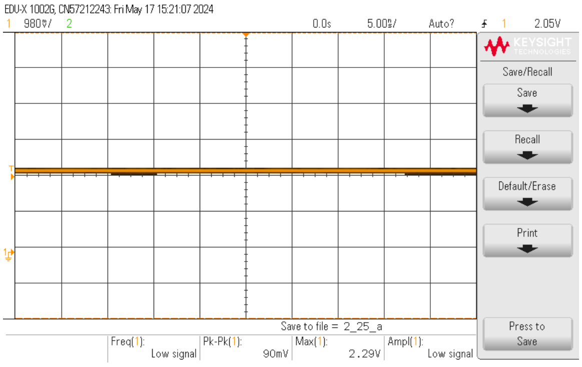

Figure 4.6: Output voltage when the system is placed in the center of the testing rig (walls surrounding system)

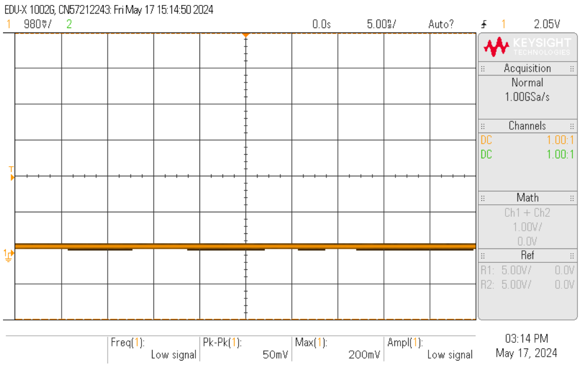

Figure 4.7: Output voltage when the system is placed in the center of the testing rig (no walls present)

Chapter 5

Conclusion

There are a few very important results which were observed during testing of the PCB board. These include the voltage directly after the IR emitter and the voltage directly after the photodiode (output). In addition to this was the voltage at the base of the transistor (for power saving).

Voltage at the base of transistor: A PWM was applied to the base of the transistor. Thus, turning it on and off on and off time was dependent on its duty cycle. A duty cycle of 80% was used. It was important to use a resistor that will keep the transistor in its linear mode. After testing, the voltage at the base of the transistor was 0.8V. This was in accordance with the calculated value and will allow the transistor to be in its linear mode. When the PWM is in its 0 state, the transistor will turn off and thus turning off the IR emitter, hence saving power. This PWM was configured using respective code which was included in the GitHub.

Voltage directly after the IR emitter: As stated earlier, the voltage directly after the IR emitter was measured to be 1.7V. Therefore, it can be calculated that a voltage drop of 1.6V was dropped over the IR emitter. This is 0.1V off the value stated on the datasheet. It was be concluded that this component is therefore on and working as expected.

Voltage directly after the photodiode (output): This is the most important value to measure as it tells us if the IR emitter and IR detector circuits are working together and producing an output as expected. After many alterations to the originally received PCB board, the output voltage showed expected results. When the system was in the presence of a wall, the output voltage was at a high (2.25V) and when not in the presence of a wall, this output voltage dropped to a low (200mV). Therefore, the photodiode is reverse biased as per the schematic, the output resistor is a suitable value to see a clear change in voltage when in front of a wall and not in front of a wall.

5.1 Recommendations

The optimisation of component values (resistors particularly) proved to be one of the most important factors in testing. Improving response time and sensitivity can be achieved by optimizing these component values. Time constraints for testing the system made it difficult to try out different combinations. Temperature and environmental testing could have been an interesting condition to test against. Again, time constraints prohibited this. Noise reduction techniques could have been incorporated into the photodiode circuit to reduce the effect of external noise and therefore improved signal clarity.