# Interim Design Report

Micromouse sensor Subsystem

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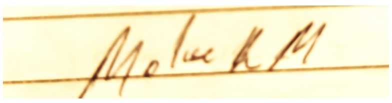

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# Contents

# Chapter 1

# Introduction

## 1.1 Problem Description

The aim of this project is to design and manufacture a sensor module for a micromouse. A micromouse is a small robot that can autonomously move through a maze to get to the centre.The sensor subsystem plays a crucial role of being the micromouse's eyes in order to accomplish the aforementioned. As

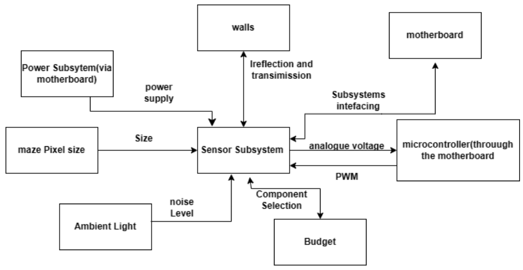



Figure 1.1: Context diagram for the sensor subsystem in the whole project

illustrated in the above figure, the sensor subsystem primarily detects obstacles in the environment of the micro-mouse specifically walls in front and on the side of the micromouse using transmission and reflection. Subsequently this allows the mouse to identify and avoid collisions with walls, adjusting its path accordingly to successfully reach the center. The microprocessor using its ADC examines analogue voltage outputs from the sensor to determine the presence of the wall.

## 1.2 Scope and Limitations

The project's focus is to design PCB boards for the sensor submodule and write code necessary for integration of the PCB with the microprocessor boards. The PCB must primarily offer effective and accurate wall detection in front and on the micro-mouse's right and left sides. The subsystem is to be designed to utilise switching techniques that enabling to have efficient battery use. Furthermore, testing procedures concentrate on the functionality of the sensor subsystem within the given requirements. However, this subsystem does not include the design or manufacture of the processor board and power subsystem . Testing is not conducted of the power subsystems and other subsystems. The manufacture of the two PCBs is limited to a maximum of $30. Additional restriction include no prototyping due to limited time before demonstration.

## 1.3 GitHub Link

repo link (contains datasheets and project versions references in the document)

# Chapter 2

# Requirements Analysis

## 2.1 Requirements

The requirements for a micromouse power module are described in Table 2.1.

Table 2.1: User and functional requirements of the Sensor subsystem.

| Requirement ID | Description |
|---|---|
| UR01 | It should have a switching mechanism |
| FR01 | It must detect walls in front and on the side of the micromouse |
| UR02 | It must be of the appropriate geometry for the maze pixels |
| UR03 | It must be cost-effective. Two PCBs cost at most $30 |
| UR04 | Its pin headers must connect to the motherboard at the right configuration for STM32L476 |
| UR05 | It should use only components available on JLCPCB excluding the pin headers |
| FR02 | the sensor output must be analogue |
| FR03 | It should reduce ambient light effects |
| FR04 | It should be power efficient and not drain the battery before completing the maze. |
| FR05 | should be capable of using LiPo 800mAh 3.7V power supply |
| FR06 | have written code that allows sensing board to detect walls in front, to the left and to the right of the micromouse. |

## 2.2 Specifications

The specifications, refined from the requirements in Table 2.1, for the micromouse 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 | Requirements ID | Description |
|---|---|---|
| SP01 | UR01 | IR LED switches on when microcontroller GPIO pins'PWM reaches 3.3V and is off below 2.5V |
| SP02 | FR01 | should have 3 sensors per PCB (one at the front and two on the sides) with detection range of 15cm |
| SP03 | FR01 | use 900-950nm Infrared LED and detector |
| SP04 | FR02 | the sensor output is analogue voltage in the range 0V to 2.8V |
| SP05 | FR03 | Photo-detector has daylight blocking filter with bandwidth matched with 900-950nm IR emitters |
| SP06 | FR04 | only 100mA when all 3 sensors are operational |
| SP07 | FR05 | the IR emitter and detector should work on the LiPo 800mAh 3.7V |
| SP08 | UR02 | must have maximum width of 30mm and length of 70mm |
| SP09 | UR03 | have a maximum of 4 low cost JLCPCB extended components |
| | UR05 | and the rest should be basic |
| SP10 | UR04 | 14x2 odd even standard pinheaders should be on sensor board |
| | | and matches the processor board connections thus the testing booad |
| SP11 | FR06 | Code must be compatible with the 2nd year STM32F0 devkit and toggle PB7 for left, PB6 For front and PB5 for right |

## 2.3 Testing Procedures

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

Table 2.3: acceptance tests summary

| Acceptance Test ID | Description |
|---|---|
| AT01 | short circuit test |
| AT02 | check if N mosfet low side switching works |
| AT03 | check if IR LEDs work |
| AT04 | check current consumption |
| AT05 | check if PWM switching mechanism works |
| AT06 | check if receiver circuit works |
| AT07 | check if walls can be detected |
| AT08 | check code used for integration works |
| AT09 | check if 14x2 pin headers can fit into the slots on processor board |
| AT09 | confirm board size |

## 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 | UR01 | SP01 | AT05,AT02 |
| 2 | FR01 | SP02, SP03 | AT04,AT07,AT08 |
| 3 | FR02 | SP04 | AT07 |
| 4 | FR03 | SP05 | AT06 |
| 5 | FR04 | SP06 | AT04 |
| 6 | FR05 | SP07 | AT01 |
| 7 | UR02 | SP08 | AT10 |
| 9 | FR06 | SP11 | AT07 |
| 10 | UR04 | SP10 | AT09 |

### 2.4.1 Traceability Analysis 1

UR01 is this from which SP01, use of PWM as swicthing means, can be derived. This is because the provided microcontroller offer PWM. To test this AT05 and AT02 are suggested because these test whether the mosfet used does switch or not.

From FR01, SP02 and SP03 can be derived because for the sensor subsystem to be functional in the task of sensing the walls on the side and front, all three sensor must use IR transmission and reflection to detect obstacle. These can be tested through AT07,AT08 and AT04 which tests if the emitter and transmitter are functional .This is because this tests require all three of the sensors to be operational

From FR02 , sP02 is derived because inorder for the sensor to have output that is analogue and can be used by the microcontroller ADC it is limited to 0-2.8V. Subsequently this means test AT07 confirms whether the voltage registered when an obstacle is present indeed falls with the 0-2.8V limit.

# Chapter 3

# Subsystem Design

## 3.1 Design Decisions

The detection of the wall, requires a wave that can be transmitted by the sensor subsystem and reflected by the wall back to the subsystem. Although there are various waves that can be used such as sound, this design will use Infrared as it is faster than sound moving at the speed of light. Thus this would give the micromouse a fast response. The 3.1 gives comparisons made between the most feasible emitters for the sensor subsystem.

Table 3.1: IR emitter component selection

| | forward current(typ) | forward current | Power Dissipation | Spectral range Sensitivity | Peak Wavelength | half angle(Deg) | Cost |
|---|---|---|---|---|---|---|---|
| TSAL6100 | 1.35V | 100mA | 160mW | 910-970nm | 940nm | 10 | $0.2147 |
| IR333C | 1.2V | 20mA | 150mW | 895-995nm | 940nm | 20 | $0.0339 |
| SFH4556 | 1.5V | 100mA | 150mW | 820-860nm | 840nm | 20 | $0.6120 |

Table 3.2: IR emitter component selection pros against cons comparison

| | TSAL6100 | SFH4556 | IR333C |
|---|---|---|---|
| pros | least expensive, meeting the UR03 requirement | 20 degrees half angle making it large enough for side wall detection(FR01) especially if the emitter needs to be placed at an angle on the PCB. | low current requirement for peak wavelength of 940nm, meeting SP05 Half angle same as SFH4556 making it also suitable for FR01 lowest voltage drop at peak walength current of 1.2V |
| cons | small wavelength spectral range make it less suitable for spectral range less than 900nm which could be generated if there slight changes current values | most expensive thus less likely if UR03 is to be met high current requirement of 100mA for peak wavelength the highest voltage drop of 1.5 V | lower maximum power dissipation of 150 compared to the other two. |

IR333C is selected given its advantages over the other components and although it has one the lower maximum power dissipation values,given it will not be driven to close to the max dissipation value it should be fine.

The use of pulse width modulation(PWM) requires the use of components that can switch on and off depending on whether the supply is high or low . Transistor are useful in this regard. Subsequently for low side switching which is easy to implement, a comparison between the NPN BJT ZTX652 and N channel mosfet MMBF170 on their effectiveness in this configuration is made .

MMBF170 provides faster and more stable switching at a lower cost than ZTX652. Although more difficult to hand solder than ZTX652, it can still be hand soldered meaning this does not negate the

Table 3.3: SWitching component selection pros against cons comparison

| | **MMBF170(N-channel Mosfet)** | **ZTX652(NPN BJT)** |
|---|---|---|
| pro | Idmax =0.5A meaning it can carry the 20mA required by IR333C<br><br>low voltage requirement of 0.13V at 250mA which means it can dissipate less power<br>It is an SMD thus is small can save space on the PCB subsequently helping in achieving UR02.<br>faster switching time as shown in table for both the switching on and off thus making it more suitaable for SP06 and SP05<br>As a mosfet it has a high current gain making more stable for changing drain currents and more stable than the ZTX652 | is THT thus is easier to solder by hand if revision are needed<br>Typically needs atleast +0.9V at the base thus can work at the 3.3V of the microcontroller. Thus making it more suitable for achieving SP06 and SP05. |
| cons | It is small making it hard to solder by hand if revisions are needed<br>Needs more voltage to be active which is greater or equal to Vgs threshold of 1.6V | since it is a BJT, it is slightly more affected by temperatures making it less stable in switching<br>costs more thus making it difficult to achieve UR03 |

MMBF170 use in the circuit. Thus MMBF170 was selected for this design.

Given the selection of the IR333C, the following receivers are selected as feasible components as they are sensitive to IR333C's peak wavelength of 940nm.

Table 3.4: IR receiver component selection

| | **forward voltage** | **daylight blocking** | **wavelength of max sensitivity** | **spectral range** | **half angle** | **unit cost** |
|---|---|---|---|---|---|---|
| BPV10NF | VR=0.85V at IR=50mA | present 850-950nm | 940 | 780-1050 | 20 | $0.4035 (extended) |
| TEFT4300 | VCE sat = 0.3 | Present 900-950nm | 925nm | 875-1000nm | 30 | $0.2147 (extended) |

Table 3.5: IR receiver component pros and cons

| | **BPV10NF** | **TEFT4300** |
|---|---|---|
| Pro | has a larger daylight-blocking filtering in the range 780-1050nm hence can filter more of the ambient light compared to TEFT4300.Thus making it very useful in achieving SP03<br>has a peak detection wavelength of 940nm which exactly matches IR333C's thus can operate at optimum detection level | has a daylight blocking filter range 875-1000nm so can still be used to meet SP03.<br>has a larger half angle of 30 degrees thus can be useful for detection at angles. Thus becomes very useful for FR01.<br>costs less at $0.2147 |
| cons | more expensive at $0.4035 | has a lower peak wavelength detection of 925nm compared to the transmitted one of IR333C of 940nm |

TEFT4300 is selected over BPV10NF because it costs less subsequently is effective in achieving UR03 and SP10. Even though it has a lower peak wavelength of 925nm while BPV10NF has a peak wavelength of 940nm which is exactly 940nm, the larger half angle is another reason it was choosen. This is because IR333C gives off a range of wavelengths 895-995nm thus 925nm is also radiated. Subsequently this means the wavelength disadvantage is overlooked and TEFT4300 was selected.

### 3.1.1 Final Design

The following design are inspired by ucla micromouse design however meticulous design decisions were made to the project's requirements and to ensure optimal performance and functionality. The IR333C and TEFT4300 are selected for their matching wavelength ranges, which enables fast response time. Given that as microcontroller STM32L476's GPIOs give out low currents, the IR333C emitter circuitand The receiver circuits are also supplied by the 3.7 V battery from the power subsystem. 47 ohm resistor is choosen to limit the current through the IR333C whilst ensuring it has current of 70mA which results in IR333C large radiant intensity. The 4.7 uF bypass capacitors across the LEDs ensures a clear signals when supplied by DC.

The 47k resistor connected to ground is placed at the gate of N channel mosfet to ensure the gate is zero when there is no voltage supplied. The gate of the MMBF170s is connected to the GPIO PE of the microcontroller for PWM since for the N channel mosfets current is not a requirement to switch on. MMBF170's gate to source threshold voltage is 1.6V thus 3.3V of the pins will switch the mosfets on. 100 ohm resistors at each of the MMBF170's gate is used for current limiting.
The unity voltage buffer is used in the circuit to protect the ADC from sudden spikes in voltage as a result of noise. The IC LM324 is then used because it reduces the space used thus achieving UR03. Voltage divider in the receiver circuit consisting of 470 and 1.5 k ohm resistors to ensure that the output is less than 3.3V of the inbuilt ADC of STM32L476.
A detail schematic with the above decisions is shown below.

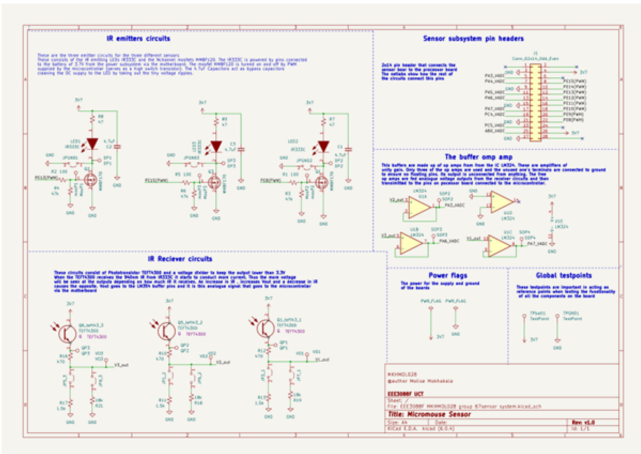
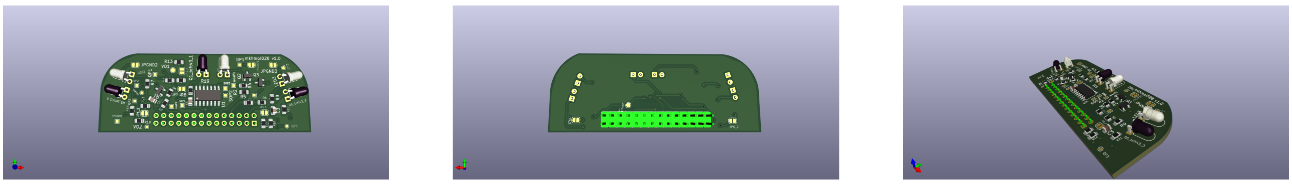



Figure 3.1: Schematic



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

Figure 3.2: PCB

## 3.2 Failure Management

Table 3.6: failure Precautions used in the PCB

| Name | Description |
|---|---|
| Test Points | Varies test points are placed all over the board across vital components to dectect specific component failures. The testpoints are named according the components they are to be used in testing for. Example DP3 is the test point for the IR333C giving out V3out in the Schematic The voltage across the components can be determined using the global tespoints TPbatt(battery testpoint)and TPGND1(ground testpoint). as references. |
| Though-hole emitters(IR333C) and receivers(TEFT4300) | Through holes are easy to desolder if polarity does not match the one specified in the PCB design due to some manufacture error. If in the wrong orientation ,the commonents can be resoldered in the right direction. in case replacement is necessay. |
| open Jumpers | The open jumpers connect various branches of circuits . Soldering them closes the circuit and desoldering opens it .The jumpers JP5_3 and JP9_3 connect to the two branches with 1.5k ohms and 18k ohms resistors respectively. If 1.5k ohms does not give the required 2.8V, the bigger resistor of 18k can be used for a larger voltage output. The jumpers are named after the sensor they are responsible for using (_number). JPGND1, JPGND2 and JPGND3 connect their respective emitters to 3.7V incase the switching machinism fails. |

## 3.3 System Integration and Interfacing

To integrate the subsystem with the rest of the systems ....

Table 3.7: Interfacing specifications

| Interface | Description | Pins/Output |
|---|---|---|
| 1001 | PWM from microcontroller for switching the sensor transmitter circuits on and off | PWM:Sensorboard Pin 12 to motherboard pin 26 to STM32L476 PE13(GPIO)<br>PWM: Pin 8 sensor board to pin 24 motherboard to STM32L476 PE15(GPIO)<br>PWM: Sensorboard Pin 22 to Motherboard pin 32 to STM32L476 PE8(GPIO) |
| 1002 | analogue voltage output to STM32L476's inbuilt ADC | Pin 5 of sensor board to Pin 43 of motherboard to STM32L476 PA3<br>Sensorboard Pin 13 to Motherboard Pin 40 to STM32L476 PA6<br>Sensorboard Pin 17 to Motherboard Pin 38 to STM32L476 PA7 |
| 1003 | battery voltage supply from power subsystem via the motherboard to the sensor subsystem. | Power: Pin7 of Power Subsystem to Pin 4 of Sensor subsystem(0-3.7V)<br>Power: Pin 26 of Power Subsystem to pin 8 of Sensor Subsystem(0-3.7)<br>GND: Pin 27 and Pin 15 of sensor subsystem to Pin 49 and 75 of motherboard to pin5 and 6 of power subsystem |

below is the interfacing diagram and table describing the interacting of the Sensor subsystem with other subsystems. These ignore unused pins by the sensor module.

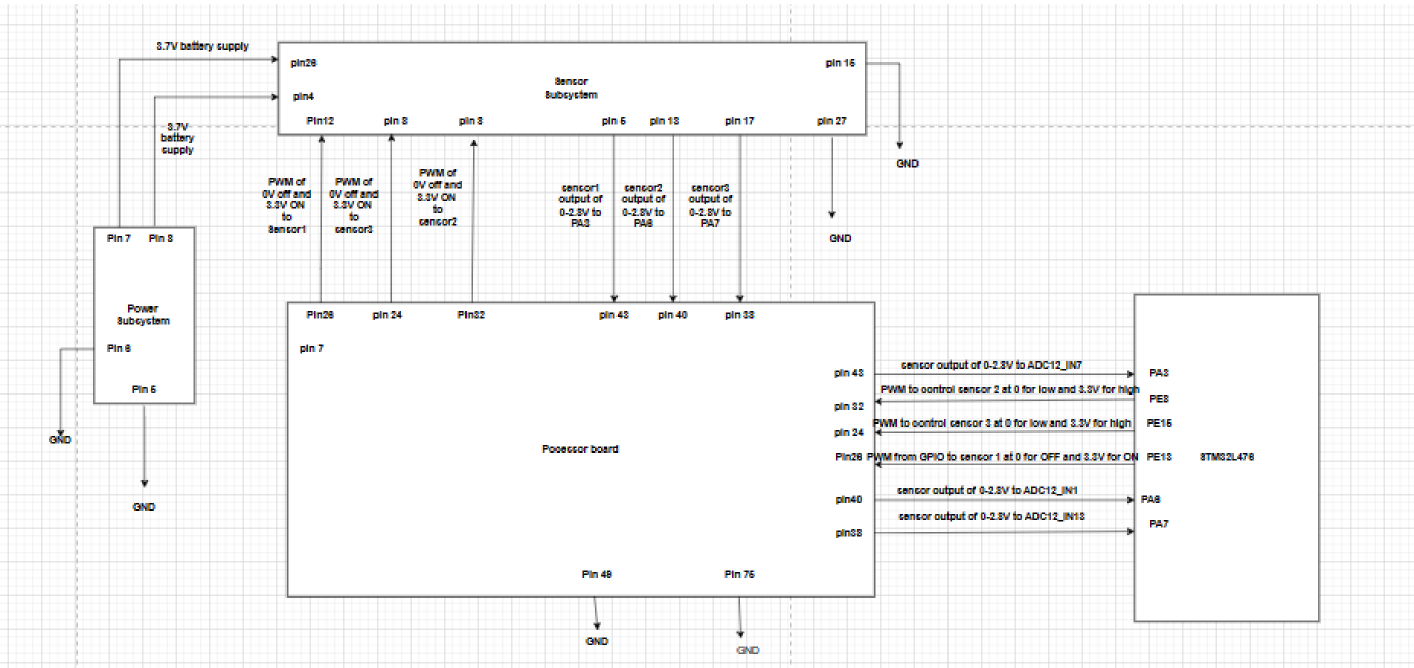



Figure 3.3: Interface diagram showing the interactions between all the subsystems in the context of the Sensor subsystem

# Chapter 4

# Acceptance Testing

## 4.1 Tests

Table 4.1: Subsystem acceptance tests

| Test ID | Description | Testing Procedure | Pass / Fail Criteria |
|---|---|---|---|
| AT01 | short circuit test. This is conducted to make sure that 3.7V supply supplied at pin 4 and pin 26 is not ground . Subsequently ensuring all the circuit SP08 is achieved | Set the lab desk multimeter to continuity test mode. Connect probes to the multimeter. Inserting a black test leads to COM and a red probe to the V jack . Place the black lead on the ground test point on the board(TPGND1) and place the red test lead on pin 26 and then pin 4 of the pin header. Listen for a beep from the multimeter when probe is at each pin | pass: No beep from multimeter when not on ground<br><br>Fail:beep |
| AT02 | Check if the Nchannel mosfet works to confirm to confirm if the sensors works when supplied by the 3.3V of the microcontroller GPIO. | Connect pins 4, and 26 of the pin header to a 3.7V lab DC supply and the supply's ground to pin 27 and 15 using some male-to-female jumper wires<br>Connect the females to the pins of the pinheader and their corresponding males to the supply accordingly.<br>Connect positive rail of the other DC supply set to 3.3V to pin 12,26 and 8 , connect the grounds together.<br>Set the multimeter to DC voltage mode<br>With the probes still connected to the multimeter as in AT01. Place the red probe on DP1 and the black probe on TPGND1. Read the voltage drop across the screen of the multimeter | pass: Voltage greater than 0V<br><br>Fail: Voltage reading= 0V |
| AT03 | Check if IR LEDs works using the multimeter polarity test. This is done to check if the IR333Cs are connected in the configuration subsequently whether they are on | Set the lab desk multimeter to diode polarity test mode . The connection of the leads to the multimeter is still unchanged. Connect the red test lead(positve lead ) to the side of the LED that is supposed to be the anode based on the schematic. And the COM lead on the other side. Look at the screen of the multimeter for voltage readings | pass: multimeter Voltage is greater or equal to 1V<br><br>fail: multimeter voltage reading = OV |
| AT04 | check the current consumption . Check if the expected current is drawn by the emitter circuit Subsequently this helps to check whether whether the all three circuits work. As it is expected that the three sensors will draw approximately 150mA when operational on 3.3 DC | Connect the females to the pins of the pinheader and their corresponding males to the supply<br><br>monitor the current on the screen of the power supply | pass: current drawn =150mA +/-20mA<br><br>fail : current drawn <130mA or current drawn >170mA |
| AT05 | Check if PWM switching mechanism works. This is to confirm that when the pin 22 , pin 12 and 8 are supplied with 3.3V square wave with 50% duty cycle , the IR333Cs are still on. Thus works on low current | Connect the pin 4, 26 to 3.7V DC supply and the grounds to pin 27 and 15 using the male to female jumper wires as in AT02. Using a wave generator , set the wave to square wave of 3.3v and frequency 1 kHz . Connect the pin 12, 26 and 8 to the positive terminal of the wave generator and the ground to the other the grounds.<br>Look at the supply current on the screen of the DC power supply | pass: supply current <100mA<br><br>fail: supply current >100mA |
| AT06 | Check if receiver circuit works . This is to confirm that the output of the sensors does change depending on the amount of IR with the condition the IR333Cs have been confirmed to be working , | Connect the pin 4, 26 to 3.7 V DC supply and the ground to pin 27 and 15 using the aforementioned male to female jumpers. Connect the 3.3 V DC supply to pin 12, 26 and 8 and connect its ground to the other grounds.<br>Use the multimeter leads in the same set up as AT02, place the COM lead to TPGND1 and the other lead on V01 (sensor 1 receiver output). Note the voltage as V1.<br>Place a cardboard piece at 5 cm in the front of sensor 1 and note the multimeter voltage reading as V2.<br>Do the same test for the other | pass: V2-V1>0.1<br><br>Fail: V2-V1= 0 or V2-V1<0.1 |
| AT07 | Check if walls can be detected. Check if the mazes walls can be detected from the center of the test maze pixel | Connect the pin 4, 26 to 3.7 V DC supply and the ground to pin 27 and 15 using the aforementioned male to female jumpers. Connect the 3.3 V DC supply to pin 12, 26 and 8 and connect its ground to the other grounds.<br>Use an oscilloscope to measure the DC voltage output. Place the ground of the probe at TPGND1 and the probe tip on S0P4 (sensor 1 receiver output). Note the voltage as V1.<br>Place the front wall and note the oscilloscope voltage reading as V2.<br>Do the same test for the other | Pass: Sensor 1 voltage >=1.5V sensor 2 and 3 >= 1<br><br>fail: Sensor 1 voltage <1.5 Sensor 2 and 3 voltage <1 |
| AT08 | Check if PB7, PB6 and PB5 on STM32FO devkit turn on based on the walls present. This test confirms that the code works and the sensor can be integrated with the STM32L476 | Place the sensor board at the centre of the test maze pixel<br>Connect the pin 4, 26 to 3.7 V DC supply and the ground to pin 27 and 15 using the aforementioned male to female jumpers. Connect the 3.3 V DC supply to pins 12, 26 and 8 and connect its ground to the other grounds.<br>connect pin17(PA7) of the sensor board to PA1 of devkit.<br>pin5 to PA0 of Devkit and pin 13 to PA2 of devkit.Place the front and look at the LEDS on the devkit<br>Do the same test for the other walls | Pass: PB7 on when left wall present<br>PB6 on when front wall present<br>PB5 on when right wall present<br><br>Fail: PB7, PB6 and PB5 on when corresponding walls are not present |
| AT09 | 14x2 pin headers have the needed configuration as the pins. This ensures that the sensor board can be integrated on the testing rig and motherboard | Fit the pins on to the processor board slot | pass: all pins fit into the slots places<br><br>fail: at least one pin does not fit slot configurations |
| AT010 | measure board size.<br>this is done to confirm that the size of the board is as needed for SP08 | use 10cm rule to measure the width and length | pass: length<=70mm and width<=30mm<br>fail: length>70mm or width>30mm configurations |

Table 4.2: Subsystem acceptance test results

| Test ID | Description | Result |
|---|---|---|
| AT03 | check if IR LEDs work | failed |
| AT04 | check current consumption | passed |
| AT05 | check if PWM switching mechanism works | passed |
| AT06 | check if receiver circuit works | passed |
| AT07 | check if walls can be detected | failed |
| AT08 | check code used for integration works | failed |
| AT09 | check if 14x2 pin headers can fit into the slots on the processor board | passed |
| AT09 | confirm board size | passed |
| AT02 | check if N MOSFET low side switching works | passed |
| AT01 | short circuit test | pass |

## 4.2 Critical Analysis of Testing

### 4.2.1 AT03

The left LED was oriented in the wrong direction thus when the expected anode was connect the V testing lead of the multimeter and the COM testing lead connected to the expected cathode 0V was registered on the display. And the reverse orientation resulted in a voltage drop of 1.2V was registered. Subsequently this meant the LED was placed the other way round. The fact that the though-hole IR333C was used became very useful, as this meant the LED could be easily desoldered. This was done and the LED leads were careful bend the other way round. And the LED was set right back into the holes and solder with the correct orientation. This could have happen because some of the silk mask for the LED was cut due to placing the LED right at the edge and this could have resulted in this manufacture error.To prevent this , it should also be made explicit on the manufacture BOM that specific components are in this orientation. Again silk masks should be used effectively as indication of the component orientation to prevent manufacture misplacement

### 4.2.2 AT04

The result was a pass because the current that was registered on the power supply was 150mA. By supply the gates of N channel with a known 3.3V DC supply which is larger than the gate to source threshold voltage of 1.6V, this ensures that MMBF170 is on. The test required the current to be non zero and above 130 mA as expected if all three sensors are operational.Given that 150 mA this means its very likely that all the sensors are operational. This result further suggests that the IR333Cs and TEFT4300 are soldered in the right orientation. This current drawn says that approximately each sensor draws 50mA in its operation. Subsequently, the power dissipated by each sensor is 0.050A*3.7V = 0.185 W and the total dissipated power by all three sensors is then 0.555W. This is high because the sensor consumes more than the 100mA specified in SP06. Subsequently this means the sensor should operated using PWM.As this could lower the consumed current.

### 4.2.3 AT05

This worked because the supply current registered was 69.6mA, This is certainly lower than the 100mA threshold set in the test and the 150mA in AT05. Given that the above test already establish that emitter circuits are operational, this means that the all three sensor are now operating at a lower power.

### 4.2.4 AT07

This was a fail because the front sensor could not have an output greater than 1.5V.This is because the receiver voltage divider was only made up of 470 ohm resistor and 1.5k resistor. This meant that if the current is low , the voltage drop across 1.5k resistor would be low. To correct this JP2_1 was desolder and JP7_1 was soldered instead this created the voltage divider with 470(R12) and 18k(R19). The sensor's output increased 2.3V when wall is present. Thus the jumper failure management became very useful in this regard. To make sure that there are even more options of resistors , resistors could be populated on the board even if they are not in use so that they can be desoldered and placed at a required place if the resistance is not enough

### 4.2.5 AT08

It is a failed because when either the left or right walls is removed with the other two walls present , all three LEDs are on , subsequently the sensor without wall registers wall. This due to putting the sensors at angles which means that the the reflections from the two walls still reach the sensor. Also the code did not implement PWM which could have been used to turn on the emitters at different times to prevent interference. Delays in the code of PWM at each pin can be chosen meticulously to allowed some time between the different sensor detections.

bibliography

UCLA, “Micromouse | IEEE at UCLA Project Docs,” projects.ieeebruins.com, 2024. https://projects.ieeebruins.com/micromouse/ (accessed Mar. 17, 2024).