Final Design Report

Micro-mouse Power Subsystem

Prepared by:
Luke Carter

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

May 17, 2024

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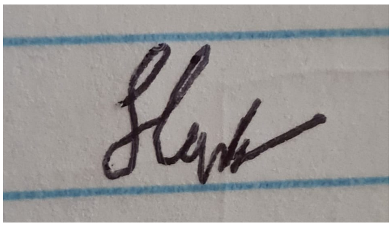

May 17, 2024

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Chapter 1

Introduction

1.1 Problem Description

This project aims at investigating and implementing a viable power system as a subsection to a micro-mouse system, capable of powering all necessary components of the system by utilizing a battery. The power subsection is part of a greater system under which two people are working towards creating a micro-mouse [1]. The micro-mouse is being created to complete a maze in the shortest time possible, where the mouse will first go through an entire maze recording the dimensions and paths of the maze, before calculating the fastest route through the maze and completing that journey, all within a 20-minute time limit, through the use of algorithms utilizing the physical components the students are designing. The other student will be working on the sensing subsystem, which will be used for the micro-mouse to detect walls for coordinated movement through the maze. Alongside these two subsystems, a processor and motherboard have been provided for integration purposes between the two subsystems allowing for control of the micro-mouse's movement at a later stage of development.

This report focuses on the development of the power subsystem to ensure power is given to the other subsystems and to the motors, which will be needed for the movement of the micro-mouse, and to be able to communicate important information to and from the processor to allow for coordinated movement and battery charge control.

1.2 Scope and Limitations

This project has a specific focus on the power subsection of the micro-mouse, with the focus for this subsection establishing a working power system capable of charging batteries needed to power the system once it is unplugged from the 5V power storage and then using the charged batteries to power the micro-controller, motors and other parts of the board. Although the sensing subsection will ultimately utilize power from the power system, it is not within the scope to provide the other subsection with a specific power as they will receive the power straight from the micro-controller itself.

Limitations in the project include budget, dimensions of the PCB, specifications of parts provided to the students and components available at JLCPCB, which all need to be considered when designing the board. Full freedom outside of this is given to students with regard to choosing components and board shapes.

1.3 GitHub Link

https://github.com/khnmuhaimin/EEE3088F-Group-64.git

Chapter 2

Requirements Analysis

2.1 Requirements

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

Table 2.1: Requirements of the power subsystem for the micro-mouse system.

Requirement ID	Description
R01	Use a battery as the method of power for the subsystem
R02	Operate two motors from available pins
R03	Provide an analogue connection to verify the battery state of charge
R04	Battery charged from the 5V pin
R05	The system needs an on/off switch for the battery
R06	The connector for the PCB needs to be in a tab off the board for a proper connection with the motherboard
R07	Make PCB as small as possible to minimize the distance from the centre of rotation
R08	Provide power to all subsections of the micro-mouse and components linked to the power sub-section e.g. the motors.

2.2 Specifications

The specifications, refined from the requirements in **??**, for the micro-mouse power module are described in Table 2.2.

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

Specification ID	Description
SP01	Battery is able to sustain a draw of 400mA at 4.2V
SP02	Two Motors capable of rotating clockwise and anti-clockwise, each drawing 200mA,

SPO3	3.3 maximum output voltage for BATT_ADC line
SPO4	Battery charged at 4.2V
SPO5	Switch must handle 1A in on state and less than 1mA in off state
SPO6	Tab height must be 18mm or greater and width height of no more than 35mm
SPO7	PCB on micro-mouse must not exceed the distance from center of rotation of 100mm
SPO8	Motors provided with 4.2V $\pm 5\%$

2.3 Testing Procedures

A summary of the testing procedures detailed in chapter 4 is given in Table 2.6.

Table 2.5: Acceptance Testing Proecdures

Acceptance Test ID	**Description**
AT01	Verify the battery is receiving 4.2V from the battery charger
AT02	Verify the battery charger is getting 5V input
AT03	Verify the switch is allowing 4.2V through when in On state
AT04	Verify the switch is not allowing voltage through when in Off state
AT05	Verify battery charger is outputting voltage, used to verify there is not a short between the battery connector and charger
AT06	Verify the motor 1 will spin clockwise when switch is on, Pin 14 is high and Pin 16 is low

Table 2.6: Acceptance Testing Proecdures

Acceptance Test ID	**Description**
AT07	Verify the motor 1 will spin anti-clockwise when switch is on, Pin 16 is high and Pin 14 is low
AT08	Verify the motor 2 will spin clockwise when switch is on, Pin 2 is high and Pin 4 is low
AT09	Verify the motor 2 will spin anti-clockwise when switch is on, Pin 4 is high and Pin 2 is low
AT10	Verify BATT_ADC is outputting voltage when switch is on
AT11	Verify BATT pin which will be connected to the microprocessor is outputting a voltage of 4.2V
AT12	Check resistors and capacitors in the circuit are not shorting

2.4 Traceability Analysis

The show how the requirements, specifications and testing procedures all link, Table 2.7 is provided.

Table 2.7: Requirements Traceability Matrix

#	Requirements	Specifications	Acceptance Test
1	R01	SP01	AT01
2	R02	SP02	AT06, AT07, AT08, AT09
3	R03	SP03	AT10
4	R04	SP04	AT01, AT03
5	R05	SP05	AT04, AT05
8	R08	SP05	AT11

R06, SP06, R07, SP07 are dimensions for the board that have been provided, no acceptance testing needs to be done for this, it just needs to be incorporated in the design section of the project AT12 are general tests that do not relate to the requirements or specifications of the project and are used to verify the board is operating correctly when it arrives

2.4.1 Traceability Analysis 1

R01 is the requirement that the system must be powered by a battery, with SP01 as the specification that it can sustain a draw of 400mA at 4.2V, which is verified using AT01 to check if the pins are producing that voltage

2.4.2 Traceability Analysis 2

R02 is the requirement that using available pins, two motors need to be operated, with SPO2 that they can rotate in multiple directions, each with a draw of 200mA. The motors will be spun based on a signal from the microcontroller, where there are 4 different signals, two for each motor, when one is high and another is low, it will spin in a certain direction. Using AT06, AT07, AT08 and AT09 we can verify for both batteries that they will spin in the correct direction based on the input from the microcontroller.

2.4.3 Traceability Analysis 3

R03 is the requirement that an analogue voltage connection is needed to verify the state of charge of the battery so the system can alert you if it is running low. SP03 indicates the max voltage on that line based on what the microcontroller can take, which will be tested using AT10 to test if the voltage is not exceeding that limit.

2.4.4 Traceability Analysis 4

R05 requires the battery to be charged from a 5V pin, with SP04 that the battery itself needs to be charged at 4.2V, meaning a battery charger is needed to supply 4.2V to the battery from the original 5V, which is tested using AT01 and AT03 to check correct voltages.

2.4.5 Traceability Analysis 5

R05 requires a working switch with SP05 that can handle 1A in on-state and 1mA in off-state. To verify the switch is working correctly AT04 and AT05 is used.

2.4.6 Traceability Analysis 6

R08 requires all subsystems are provided 4.2V with SP08 specifying the motors also be provided 4.2V, which is tested using AT11 which is connected to the system and motors.

Chapter 3

Subsystem Design

3.1 Design Decisions

3.1.1 Design Process

Within our system, different areas needed to be focused upon, each with its own challenges that needed to be solved. The three main areas of this design process were the battery charger, battery and switch system, and the motors. Within each area of the design process, several challenges need to be factored into how the final PCB was to be designed: the budget for this project was incredibly tight and certain components would therefore be out of our price range so that had to be accounted for:

- Budget - The budget for this project was incredibly tight, which made it harder when select parts as too many of certain parts would exceed the budget given, therefor considerations had to be made for each area to ensure that this project stayed below that range. The budget can be seen in the figure below:

Item	Student 1 (Sensing)	Student 2 (Power)
Starting Allowance	$30	$30
PCB Manufacture (5 units)	$4	$4
PCB Assembly (2 units)	$9.50	$9.50
Remaining Budget for components	30 – 13.5 = **$16.5 for 2 boards**	30 – 13.5 = **$16.5 for 2 boards**
OR alternatively	$8.25 per board	$8.25 per board

Figure 3.1: Budget

- Space - The PCB board had its own constraints, whereby a tab needed to be included in the design, and the dimensions of the board needed to take into consideration the turning circle of the micro-mouse such that the width and length of the PCB did not exceed the lengths. Measurements and calculations can be seen in the figure below:

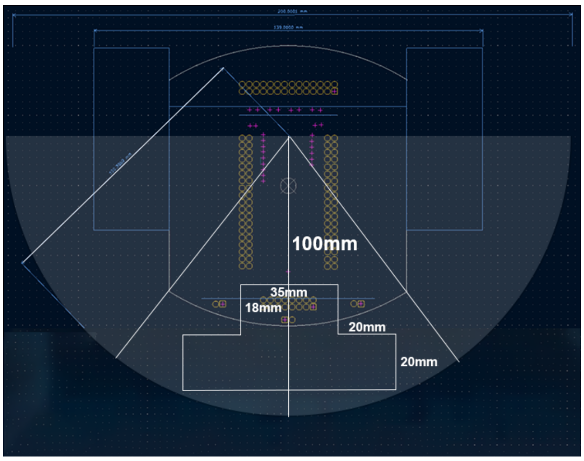


Figure 3.2: PCB Board Dimensions

- Battery - Although the system has a good sized battery, considerations do need to be made to ensure that the components we use do not over-deplete the battery as this project needs to be able to last for over 20 minutes while navigating a maze, and using too much current will deplete the battery faster.

With the above factors in mind, each section of the sub-system can be designed accordingly to ensure that the issues mentioned above are less likely to arise.

Battery Charger

The battery charger is an integral part of the design as it will be used to charge the battery for the whole system utilizing a 5V input from the microprocessor. A voltage divider circuit could be used to reduce the voltage to the correct voltage but lacked circuit protection, and an IC charger made more sense to ensure correct protection was integrated. A primary concern with the IC battery charger was the budget aspect, as through the website the PCBs would be ordered through, JLCPCB, and certain parts would have extended costs based on whether the part was in regular production or not, resulting in the extra cost of 3 dollars for extended parts. It became apparent that the parts needed for the other sections would need to be extended, so a basic part for the charger would reduce budget concerns. This was the first major design decision, as choosing a battery charger with no extended cost greatly decreased the budget concerns, and the battery charger TP4056-42-ESOP8 became the best choice over the other options as it had no additional costs.

Switch and Battery system

Switches were a problematic area of the design as there was only one basic part switch which was a push button, which would require extra circuitry like MOSFETs, transistors, resistors and capacitors to get it to work correctly, which added complication with verifying if the circuit would work correctly, with the added specification that the switch must be added to handle 1A in the on state. This was the second major design decision made, to utilize an extended part for the switch to allow for a better selection of switches based on the type of switch and current it could handle. Based on these decisions, it was decided to use a switch called MS-22D28-G020 with verifiable data sheets and footprints for easy integration into the system, capable of handling 1A at 6V.

Motor system

The subsection required two systems each capable of running a motor at 200mA at 4.2V. Originally, the design decision was made to create an H-bridge configuration utilizing various parts such as MOSFETs and transistors to create a switching system to allow for the rotation of the motors in different directions, however, it became complicated to select the parts and to verify that the H-bridge design would function correctly with the complications of shoot-through being present in the designs. Integrated Circuits (IC) available on JLC included shoot-through protection making it a more preferable option compared to building a circuit from scratch. The third major design decision was deciding to use an H-bridge driver DRV8837DSGT, which although had an extended cost, had shoot-through protection and was designed to function according to our needs.

3.1.2 Final Design

The following design integrates the decision decisions made above, utilizing the parts mentioned to create a system whereby a battery charger is used to charge the battery, the battery provides power to the circuit upon the switch being switched on, protected by a polarity protector. The battery will power two motors, the microprocessor and all things connected to that, and an ADC line in which the state of charge of the battery can be checked. Standard capacitors are used as a discharging method throughout, with resistors and LEDs for the TP4056 selected based on the datasheet for the component. The BATT_ADC line is protected by utilizing large resistors to protect the microprocessor.

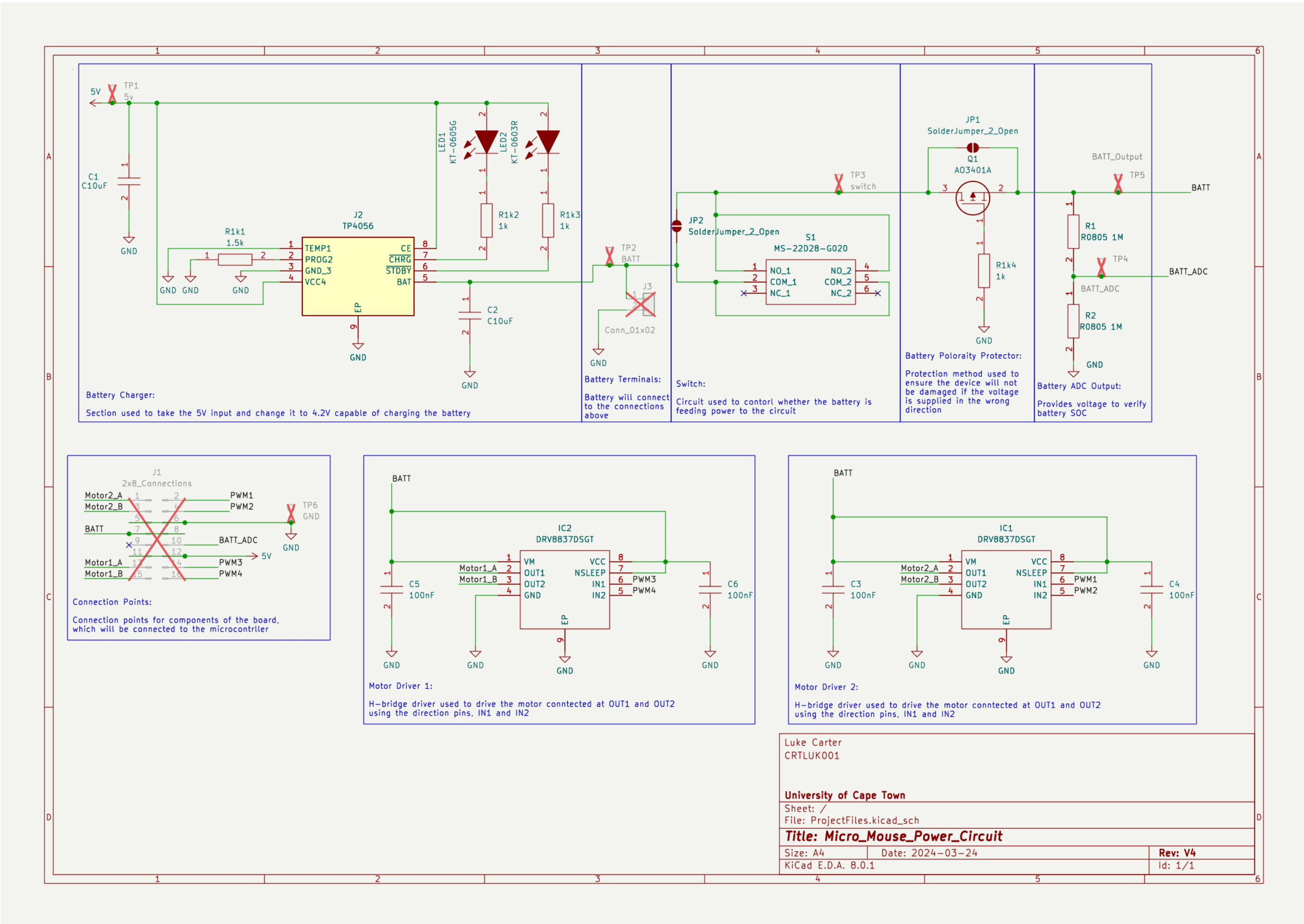
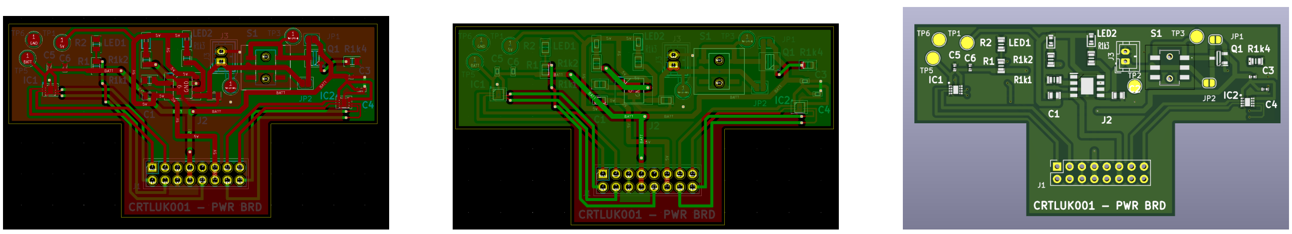


Figure 3.3: Schematic Drawing



(a) Front PCB

(b) Back PCB

(c) 3D PCB

3.2 Failure Management

Table 3.1: Failure Management

Name	Description
Switch Bypass	The switch is an area of concern because if the switch is incorrectly selected or implemented, there could be no power coming from the battery, so a solder jumper was added over the switch such that if a problem arose, the component could be bypassed completely.
Battery Polarity Bypass	Similar to the switch, a solder jumper was added to the battery polarity protector in the case the component was dysfunctional, it could be bypassed to ensure the circuit still worked.
Testing Points at critical points	Testing points are utilized to verify certain components on the board are operating as expected by checking for shorts and measuring voltage. The testing points on the design are used before and after the battery charger, after the switch, output battery voltage and the ADC voltage pin to verify at those points in the circuit the voltage is correct or that there are no shorts.

3.3 System Integration and Interfacing

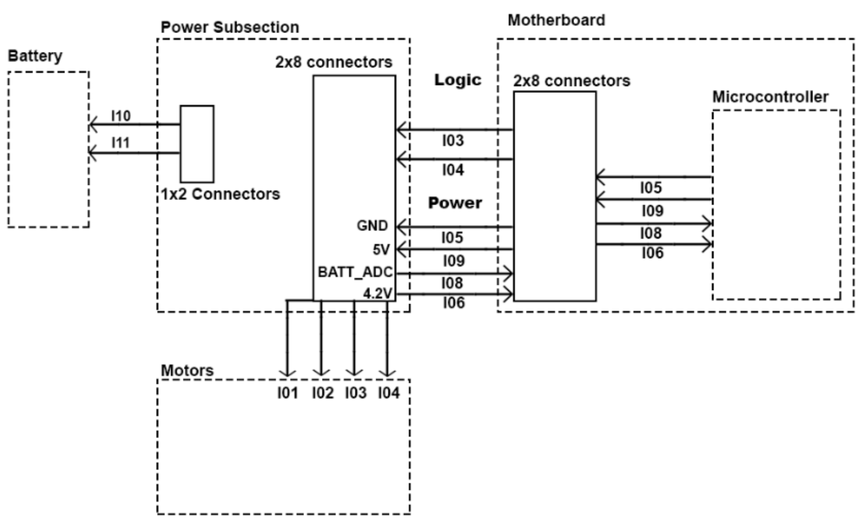


Figure 3.5: Interfacing Diagram

Table 3.2: Interfacing specifications

Interface	Description	Pins/Output
I01	Positive connector of motor	Pin 1, Pin 13
I02	Negative connector of motor	Pin 3, Pin 13
I03	Signal used to rotate motor in clockwise direction	Pin 2, Pin 14
I04	Signal used to rotate motor in anti-clockwise direction	Pin 4, Pin 16
I05	Ground pin to ground the power subsection using connection from microcontroller	Pin 5, Pin 6
I06	Battery Pin used to supply a voltage of 4.2V to the microcontroller and other parts of the system	Pin 7, Pin 8
I07	Pin which can be used for custom usage, in this case not utilized	Pin 9
I08	Battery ADC pin used to provide the microcontroller with an updated state of charge for the battery	Pin 10
I09	5V pin provided by the microcontroller to charge the battery	Pin 11, Pin 12
I10	Connection to positive battery terminal	Battery Connector Pin 1
I11	Connection to negative battery terminal	Battery Connector Pin 2

Chapter 4

Acceptance Testing

4.1 Tests

Table 4.1: Subsystem acceptance tests

Test ID	Description	Testing Procedure	Pass/Fail Criteria
AT01	Verify the battery is receiving 4.2V from the battery charger	• Plug a multi-meter in voltage mode across the connection points, postive to positive and negative to negative	Pass - 4.2V ± 0.2 V is measured on multi-meter
AT02	Verify the battery charger is getting 5V input	• Using the multi-meter in voltage mode, put the positive probe on the TP1 and negative probe on TP6	Pass - Multi-meter reads 5V
AT03	Verify the switch is allowing 4.2V through when in On state	• Put multi-meter in voltage mode with positive probe on TP3 and negative on TP6 • Put switch on	Pass - 4.2V ± 0.2 V is measured on multi-meter
AT04	Verify the switch is not allowing voltage through when in Off state	• Put multi-meter in voltage mode with positive probe on TP3 and negative on TP6 • Put switch on	Fail - Any voltage read on multi-meter
AT05	Verify battery charger is outputting voltage, used to verify there is not a short between the battery connector and charger	• Put multi-meter on voltage mode with positive probe on TP2 and negative on TP6	Pass - Multi-meter shows value of 4.2V ± 0.5 V

Table 4.2: Subsystem acceptance tests

Test ID	Description	Testing Procedure	Pass/Fail Criteria
AT06	Verify the motor 1 will spin clockwise when switch is on, Pin 14 is high and Pin 16 is low	• Put Multimeter in voltage mode with positive probe on Pin 13 and negative probe on Pin 15	Pass - 4.2V ±0.3 V is measured on multi-meter
AT07	Verify the motor 1 will spin anti-clockwise when switch is on, Pin 16 is high and Pin 14 is low	• Put Multimeter in voltage mode with positive probe on Pin 13 and negative probe on Pin 15	Pass - -4.2V ±0.3 V is measured on multi-meter
AT08	Verify the motor 2 will spin clockwise when switch is on, Pin 2 is high and Pin 4 is low	• Put Multimeter in voltage mode with positive probe on Pin 1 and negative probe on Pin 3	Pass - 4.2V ±0.3 V is measured on multi-meter
AT09	Verify the motor 2 will spin anti-clockwise when switch is on, Pin 4 is high and Pin 2 is low	• Put Multimeter in voltage mode with positive probe on Pin 1 and negative probe on Pin 3	Pass - -4.2V ±0.3 V is measured on multi-meter
AT10	Verify BATT_ADC is outputting voltage when switch is on	• Put multi-meter in voltage mode with positive probe on TP4 and negative on TP6	• Pass - Multi-meter records a value of less than 3.3V • Fail - Multi-meter has a reading of 0V or above 3.3V
AT11	Verify BATT pin which will be connected to the microprocessor is outputting a voltage of 4.2V	• Put multi-meter in voltage mode with positive probe on TP5 and negative on TP6	Pass - Multi-meter value records a voltage of 4.2V ±0.3 V
AT12	Check resistors and capacitors in the circuit are not shorting	• Put multimeter in continuity checker mode with probes across the postive and negative ends of the resistors and capacitors on the board to check for short circuit issues	• Pass - No noise is heard • Fail - Multi-meter starts beeping

4.2 Critical Analysis of Testing

Table 4.3: Subsystem acceptance test results

Test ID	Description	Result
AT01	Battery receives 4.2V	Pass
AT02	Battery charger receives 5V input	Pass
AT03	Switch is allowing 4.2V to pass through it	Pass
AT04	Switch is not allowing voltage through	Pass
AT05	Battery charger is outputting 4.2V	Pass
AT06	Motor 1 has the correct voltage to spin clockwise based on PWM signal	Pass
AT07	Motor 1 has the correct voltage to spin anti-clockwise based on PWM signal	Pass
AT08	Motor 2 has the correct voltage to spin clockwise based on PWM signal	Pass
AT09	Motor 2 has the correct voltage to spin anti-clockwise based on PWM signal	Pass
AT10	BATT_ADC outputting voltage between 0V and 3.3V	Pass
AT11	BATT pin is receiving 4.2V (in case AT01 fails due to short)	Pass
AT12	Resistors/Capacitors not shorting: • R1k1 • R1K2 • R1K2 • R1K3 • R1K4 • R1 • R2 • C1 • C2 • C3 • C4	• Pass • Pass • Pass • Pass • Pass • Pass • Pass • Pass • Pass • Pass • Pass

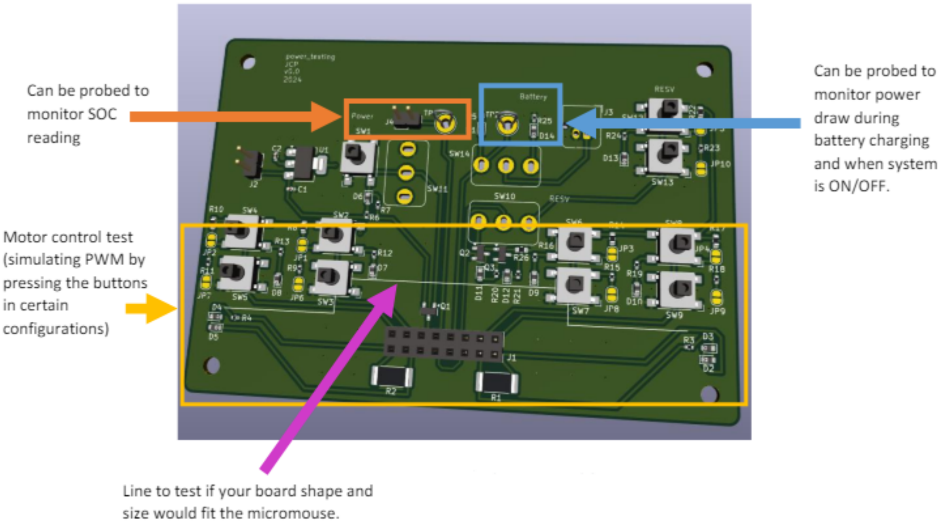


Figure 4.1: Testing Rig

4.2.1 AT01

AT01 was used to verify that the battery would be receiving 4.2V across the connector pins, from the battery charger which was provided with 5V. It was tested by powering the battery charger with 5V while the switch is off and then using a multi-meter in voltage mode with the probes connected across the 2mm pin battery connectors to verify the voltage that was being received was correct.

Testing

There were two phases of testing, the first done in a laboratory environment where the above testing procedure was followed, which resulted in a voltage ranging between 4.2V and 4.4V being recorded, which was in between the expected range, which meant it passed the acceptance test. The second phase of testing was done utilizing a testing rig seen above in the figure above, where by a battery was connected to the system to verify if the system as able to charge. When measured for a second time, a voltage of 3.9V was recorded, which although might be sufficient enough to charge the battery, was lower than expected and failed the acceptance test.

Analysis

The lower voltage recorded in the second phase of testing was 0.3V off what was expected, and after an investigation into the possible reasons why the lower voltage was recorded where the datasheet for the battery charger was investigated, it was determined that the subsequent reason that the voltage was capped at 3.9V is that when the battery becomes fully charged, the charger itself starts only outputting 3.9V to try and prevent battery overcharging which could result in long term battery efficiency issues. Once the system has utilized the power, the battery will charge at the correct voltage.

4.2.2 AT03

AT03 is testing whether the switch is operating correctly and will output 4.2V when the switch is in the on position. This test is done by putting a multi-meter in voltage mode from a testing point to ground to check that the voltage outputted is correct.

Testing

In the first phase of testing, the battery charger was connected to the 5V pin and the switch was turned on, and when the multi-meter was put across the testing points, the expected voltage of 4.2V was received on the other side of the switch. The second phase of testing had the same result in the on position which overall verified that the switch was working as expected when connected from the TP2 and ground on the testing rig and passed the acceptance test.

Analysis

The voltage received on the other side of the switch is 4.2V which is working as expected. However one flaw with the implementation of the switch as seen in Figure 3.3 was that the switch was implemented in what was deemed the wrong location. Although the switch operated as expected and outputted the correct voltage to the correct location, there was an issue with the actual placement of the switch as it was not placed in series with the battery terminals and instead placed after it which meant that rather than the whole circuit requiring being on when the battery charger was charging the battery, in this circuit it will only charge the battery. This might seem like a positive as none of the components will then be receiving voltage, however, there is a flaw with this as when the battery is not being used for long periods of time, it will discharge slowly over time as it is connected to ground through a capacitor after the battery charger, which means there will be an inefficiency long term, however, does not affect the overall outcome of the project, just means the battery will need to be charged before each use. This can be fixed in the design phase by moving the switch in series with the battery connectors.

4.2.3 AT06

AT06 is the same as AT07-AT09, just with slight modifications to what the probes are connected to and what PWM signal is provided. These acceptance tests work by measuring the voltage across the motor terminals and checking whether the voltage goes to positive 4.2V or negative 4.2V depending on what PWM signal is supplied. AT06 is checking whether Motor 1 will spin clockwise when provided with a high PWM signal in Pin 14.

Testing

In the first phase of testing, a button setup was utilized to simulate the PWM signals to Pin 14, with the multi-meter being used across the motor pins to check the voltage. Upon the button being pressed, the multi-meter read 3.99V which is within the acceptable range, and passes the acceptance test. The second phase of testing was done utilizing a testing rig, using the H-bridge setup seen in the image, where the PWM signal was given by pressing SW2 and SW5 which supplied Pin 14 with power resulting in the voltage going high across the pins, which recorded 4.2V which is within the acceptable range and passed the acceptance test.

Analysis

Both tests showed that the motor would perform as expected, with a slight difference in the second phase of testing's voltage reading as that system used an actual battery rather than the voltage supplied by a voltage supply from the first phase of testing which had inconsistent outputs as mentioned in AT01.

4.2.4 AT10

AT10 verifies if the output voltage signal is outputting a voltage that is below 3.3V to not exceed the voltage limit in the microcontroller board. It works by using a voltage divider to lower the 4.2V to a more suitable voltage to output to the system. The multi-meter is set up in voltage mode, measuring the voltage from the BATT_ADC pin to ground. Since it's a voltage divider utilizing two resistors of equal resistance as seen in Figure 3.3, it is expected that the voltage should be around 2.1V for a fully charged battery.

Testing

During the first phase of testing, when the multi-meter was put across those terminals, it recorded a voltage of 1.3V which was lower than expected, and although it scaled as the voltage of the voltage supply changed, it did not match the expected voltage. However, since the specifications for this ADC line was a voltage of less than 3.3V, it passed the acceptance test. The second phase of testing doing the same measurement with a multi-meter resulted in the same outcome, and the acceptance test remained passed.

Analysis

The output voltage met the specified requirements and specifications, however, outputted a lower voltage than expected based on calculations, which should have been 2.1V from a fully charged battery. The suspected reason the voltage was lower than expected was that two resistors of a too-big resistance were used, which might have resulted in a bigger voltage draw than expected in the one resistor, which resulted in a lower voltage. Since it passed the acceptance test, no immediate changes need to be made, but if the PCB were to be reordered, smaller resistors should be selected to ensure better accuracy during testing.

4.2.5 AT12

AT12 is testing certain components in the circuit to verify they are working as intended and that there are no shorts through those components. In most of the acceptance tests, if a component is not working or shorts, it will not make a noticeable difference, other than the voltage divider for AT10, but is important for verifying all features of the circuit will perform as expected and not with slight variations. In the battery charger section, there are several capacitors used for discharging, resistors for changing the output voltage and resistors for LED protection which are needed to ensure these components do not burn out. In the polarity protector section, another resistor is used at the gate of the MOSFET to prevent oscillations in the circuit, in the voltage divider, two resistors and in the two motor sections, two discharging capacitors that all need to be verified. They can be verified by using a multi-meter in continuity mode to check if they are shorting where if the multi-meter beeps, there is a short.

Testing

For this step, there is only one phase of testing, where each component is checked to see if there is a short. Upon testing each component, it was verified that none of them shorted the PCB and they all passed the acceptance test.

Analysis

Although it might seem unnecessary to verify if all components are working as expected, through the process of testing, it was important to ensure that no components were damaged in the testing process, or that the circuit had a fault in the design, or manufacturing process that could have resulted in a fault in the circuit.

Chapter 5

Conclusion

5.1 Conclusions from the project

The purpose of this project was to develop a power subsystem capable of powering its components, two motors and a system comprising of a microcontroller, motherboard and a sensing subsystem off the use of a battery. The micro-mouse would later be utilized to traverse a maze using its built-in power system to run the system and sensing system to traverse the maze using sensors. This report investigated the implementation of a power system in order to run the micro-mouse, and through a vigorous design and testing process, the power system has met the requirements in order to sufficiently power the micro-mouse to traverse the maze for the needed duration, as the battery is able to be charged and output the correct voltage which is utilized to power the motors which when provided with PWM signals, will traverse the maze as expected. Although the switch will result in a slow discharging of the battery when not in use, the micro-mouse itself will still work as expected. Overall the project resulted in a working power system meeting the requirements needed by the user to run the power aspect of a micro-mouse while coming in under the budget requirements and fitting in the necessary dimensions that were provided.

5.2 Recommendations

This project has a few areas in which it can be improved, the major one being a better switch implementation where the switch is placed in series with the battery instead of after the battery and charger. Another area for improvement is smaller resistor values chosen for the battery state of charge pin for better accuracy in the expected voltage when calculations need to be done in the algorithm coding phase. One minor issue was with the PCB design itself, which did not impact the outcome of the project, was where inconsistent trace widths were used as smaller trace widths were required for the motor driver ICs and the board itself although met the dimension requirements, could be optimized to be made smaller for efficiency of space.

Bibliography

[1] UKMARS, "Classic micromouse)," 2020. [Online]. Available: https://ukmars.org/contests/micromouse/