Interim Design Report

Micromouse Power Subsystem

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Contents

Chapter 1

Introduction

1.1 Problem Description

Holistically, the micro-mouse project is concerned with designing and integrating various hardware components, including specific subsystems that come together to create a maize-solving robot. Some of these hardware components are provided, like the microcontroller and processor subsystem, motors, wheels, etc. but some components have to be designed and interphase, namely, the power and sensing subsystems. The specific problem encompassing the power subsystem is sufficiently powering the motors of the robot and charging a battery that will provide power to the other subsystems. The board must complement the existing hardware. The connectors must fit into the pin headers of the motherboard, and be reasonably sized for the micro-mouse.

1.2 Scope and Limitations

The power subsystem is to drive two motors at a specified current. The subsystem is to provide an analog signal to provide information on the voltage level in the battery. The subsystem should have a battery charging circuit with various protection circuits. There should be an ON/OFF switch and connectors to interface with the other subsystems and connect to the battery.

The design of the power subsystem is limited by a maximum cost per breadboard. The voltage range the power subsystem can provide is limited to the voltage range the ISP1 cell can provide. The breadboard must be designed to complement the motherboard and may not be too large.

1.3 GitHub Link

Here is the link to the GitHub repo: https://github.com/NtsakoMahlaola/EEE3088F-GRP-34-.git

Chapter 2

Requirements Analysis

2.1 Requirements

The requirements for the power subsystem are detailed in Table 2.1.

Table 2.1: Functionality requirements for the Power subsystem.

Requirement ID	Description
RE01	The subsystem must provide a charging circuit for the battery
RE02	The subsystem must drive two motors at rated current
RE03	The subsystem must have a connector for the battery
RE04	The subsystem must have connectors to interface with the other subsystems
RE05	The subsystem must provide a signal to the motherboard to read the voltage level of the battery
RE06	The Subsystem must have an ON/OFF switch
RE07	The subsystem must be of an appropriate size

2.2 Specifications

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

2.3 Testing Procedures

A summary of the testing procedures detailed in chapter 4 is given in Table 3.2.

2.4 Traceability Analysis

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

2.4.1 Traceability Analysis 1

RE01 is to charge the battery, SP02, SP03, and SP04 are the conditions needed for the battery to charge. These are tested via AT02 and AT03 as these tests check for charging time, current, and voltage.

Table 2.2: Specifications for the Power subsystem Table 2.1.

Specification ID	Description
SP01	The motors must be able to draw 200 mA at the highest voltage of the ISP1 cell.
SP02	The subsystem must utilize the 5v USB input to charge the ISP1 battery at its maximum voltage
SP03	The battery must have 400mA max draw current
SP04	The battery must be charged at 0.5C
SP05	The design must adhere to the budget for each board, which is a total of 8.25 dollars for each breadboard.
SP06	Circut to draw no more than 500 uA when OFF and operate at maximum current when ON.
SP07	The JST PH 2mm pin pitch connector for the battery and the 2x8 (2.54mm pin pitch) pin header for interfacing with the motherboard PCB should be compatible with the specified requirements and provide secure and reliable connections.
SP08	The height of the connector tab must be greater than 18mm and must not have a width of greater than 35mm.
SP09	The subsystem must provide a 3.3v analogue connection
SP10	The subsystem must provide 3.7v Vbatt to the microcontroller.
SP11	The battery must be connected through a JST PH 2mm 02x01 connector

Table 2.3: CAPTION

Acceptance Test ID	Description
AT01	ON/OFF
AT02	Charging voltage
AT03	Charge at 0.5C
AT04	Analog connection
AT05	Unit testing
AT06	Motor current and voltage
AT07	Voltage and current to microcontroller

2.4.2 Traceability Analysis 2

RE02 is to drive two motors. SP01 is needed to meet this condition and is tested with AT06 to read the current through the motor terminals and the voltage.

2.4.3 Traceability Analysis 3

RE03 is to have a connector for the battery. SP11 is the specific connector. AT05 tests if this connector fits with the battery connector cable.

2.4.4 Traceability Analysis 4

REO4 is to have connectors for interfacing. SP07 specifies the connector to be used. AT05 tests if the connector tab complements the processor board.

2.4.5 Traceability Analysis 5

RE05 is to have an analog connection to the processor. SP10 specifies this voltage level and is tested on AT04 via TP3.

Table 2.4: Requirements Traceability Matrix

#	Requirements	Specifications	Acceptance Test
1	RE01	SP02, SP03,SP04,	AT02, AT03
2	RE02	SP01	AT06
3	RE03	SP11	AT05
4	RE04	SP07	AT05
5	RE05	SP10	AT04
6	RE06	SP06	AT01
7	RE07	SP08	AT05

2.4.6 Traceability Analysis 6

RE06 is to have a switch. SP06 specifies the current values for ON/OFF and these currents are tested in AT01.

2.4.7 Traceability Analysis 7

RE07 concerns the size of the board. SP08 specifies the dimensions and these are measured in AT05.

Chapter 3

Subsystem Design

3.1 Design Decisions

3.1.1 Final Design

The design chosen, as seen in Figure 1.1, came after design decisions were made on the four building blocks of the power subsystem. These building blocks are the battery charging circuit, the motor driver circuit, the analog connection circuit, and the switching circuit. In this section, the functionality of each block will be discussed and the design decisions made for these respective blocks will be provided.

Battery charging circuit

There were various battery-charging ICs to consider. Still, after seeing that most of them come with an extended fee, which would be out of budget, a voltage regulator circuit with necessary protection circuits was considered. It was then discovered that there are TP4056 charging circuits that fall under the 'preferred extended' category on JLCPCB. The TP4056 C725790 ESOP-8 battery management IC was chosen. The IC provides a variety of built-in protection circuits, including under-voltage lockout, voltage regulation, short circuit protection, and reverse charging current protection.

The circuit feeds a constant 4.2v to the battery, the maximum charging voltage for our ISP1 lithium battery. The battery has to be charged at 0.5C, which is 400 mA at max draw, and from full to fully discharged in 2 hours. To set this on the TP4056, the Rprog resistor (connected between Prog and GND ins), is set to 3000 Ohms. This is derived from the Rprog current settings table. The CHRG AND STDBY pins are connected to the LED's vial 1k current limiting resistors. The Chip Enable pin is set to normal operation by connecting it to Vcc. Decoupling capacitors are added to short out any high frequent voltage fluctuations and provide a more stable DC source.

With all considered, the TP4056 circuit makes a better charging circuit. The comparisons are tabulated below.

Motor driver circuit

The driver circuit is required to drive two motors at 200mA. This could be possible via the use of a MOSFET H-Bridge for each motor to allow each motor to rotate both clockwise and anti-clockwise. This would allow the micro-mouse to rotate with minimal space used. The first consideration was to build two H-Bridge drivers using MOSFETs as driver ICs were costly. This design works, and comes at an affordable price, but would come with complexities and the need for extensive failure management and testing.

Table 3.1: Voltage regulator with protection circuits vs TP4056

Comparison	Description
COST	Voltage regulators and protection circuitry, as well as the specific TP4056 chosen, do not come with an extended fee, making the cost a negligible factor the battery is charging at the highest voltage.
Simplicity	The TP4056 will offer a simpler solution compared to a voltage regulator.
Failure	The TP4066 will need less failure management since behavior is predictable and comes with built-in protection.
Testing	As compared to the voltage regulator, fewer test points will be needed with the TP4056.

Figure 3.1: DRV8833 QR Code

With the burden of an extended fee, motor driver ICs could be used for the driving circuit. For these, two options were the top selections. Firstly, two DRV8837 ICs could be used, but, the DRV8833PWP Dual H-bridge motor driver came out as the favorite option as it is simpler to use.

The DRV8833 comes with built-in Internal shutdown functions with a fault output pin provided for over-current protection, short-circuit protection, under-voltage lockout, and over-temperature. The driver IC is fairly simple to use, and meets the specifications needed for running the motors. The link to the data-sheet is attached below.

DRV8833 Dual H-Bridge Motor Driver Data sheet:

With all considered, the DRV8833PWP IC makes a better motor driver circuit. The comparisons are tabulated below.

Table 3.2: Voltage regulator with protection circuits vs TP4056

Comparison	Description
Cost	The DRV883x drivers come with a heavy extended fee whilst the H-bridge circuit would come at an affordable cost
Simplicity	Two H-bridge circuits come with high complexity consume more space and make a challenging design. The DRV338X drivers offer far more simplicity.
Failure	The H-bridge has a lot of possible failure points, and can barely provide the current needed on simulations, making the DRV338x easier to manage in terms of failure.
Testing	Testing the H-bridge would need several test points due to the several components included. The DRV338x wins.

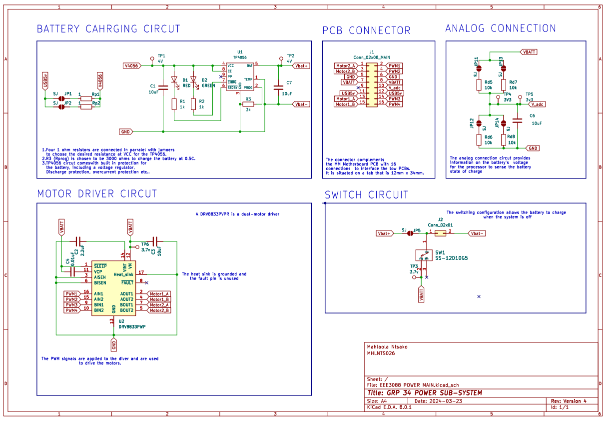


Figure 3.2: Enter Caption

Analogue connection circut

This block was fairly simple in design. The first design was to make a voltage divider from Vbat and add a non-inverting OP-Amp to offer high impedance at the output of the voltage divider. This was aimed at reducing the voltage going into the BATTADC pin of the STM32L476 microcontroller.

The OP-amp was then removed as it was noticed that the BATT-ADC pin comes with a high impedance. A capacitor was added to provide a smooth DC input to the pin. The voltage divider was configured with jumpers for different output voltage levels. This will be explained in detail in the failure management subsection. The resistance values are high to offer high impedance.

Switching circut

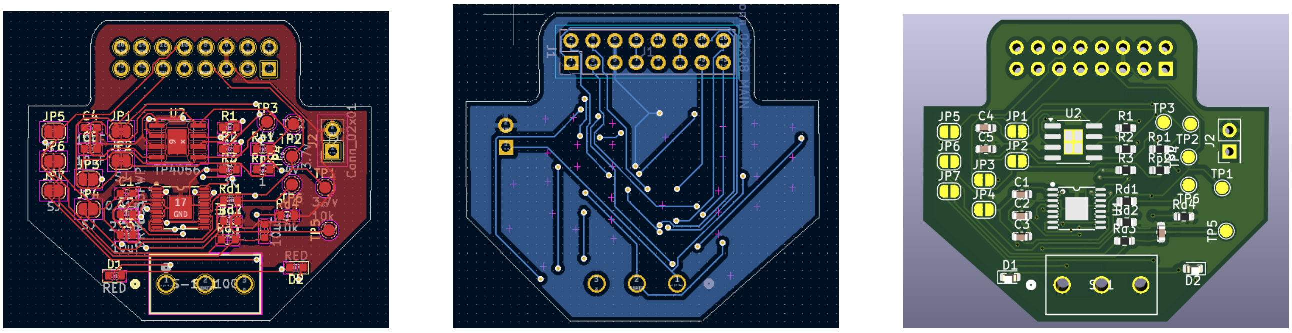
Once again, this circuit design was fairly simple in comparison. The challenge was finding a good switch. The circuit allows the battery to charge as the device is off. The configuration will be clear in the schematic. The switch chosen is the SS-12D10G5. This switch can handle 5A and up to 125V.

Figure 3.3: Schematic

3.2 Failure Management

3.3 System Integration and Interfacing

The power subsystem is integrated into the rest of the system through two connectors and is tabulated below.



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

Figure 3.4: PCB

Table 3.3: Failure management table

Name	Description
Jumpers	A total of seven jumpers were added to the circuit. Six of the jumpers are connected in series with resistors to allow utilization of the resistors if needed. The seventh jumper was connected from the Vbat+ to the switch to be able to use the circuit even if the switch fails
Parallel Resistors	Additional resistors were placed in parallel and connected to jumpers. This is done as the resistors are used to get a specific output/ input. In some cases, the precise voltage value was not known, thus is connected such as to allow different voltage readings depending on the connection chosen.

Table 3.4: Power Subsystem Interfacing

Interface	Description	Pins/Output
I001	PWM signals from processor subsystem to power subsystem for motor control	• PWM1: STM PC6 to PIN02 • PWM2: STM PC7 to PIN04 • PWM3: STM PC8 to PIN14 • PWM4: STM PC9 to PIN16
	Power subsystem ground connection to STM processor	• GND: PIN05 to STM GND • GND: PIN06 to STM GND
	USB connection from STM to power subsystem	• USB: STM 5V to PIN11 • USB: STM 5V to PIN12
	Analogue connection from battery to STM	• BATT-ADC: PIN10 to STM 3V3-ADC
	Reserved pin	• RESV: PIN09 to STM PD7
	Battery voltage from power subsystem to processor motherboard	• VBAT: PIN07 to STM VBAT • VBAT: PIN08 to STM VBAD
I002	Output power to motors	• Motor2-A: PINO1 to Motor2-A • Motor2-B: PIN03 to Motor2-B • Motor1-A: PIN13 to Motor1-A • Motor1-B: PIN15 to Motor1-B
I003	Voltage from power subsystem to ISP1 battery through 02x01 conn	• Vbatt+: PINO1 to Battery • Vbatt-: PIN02 to Battery

Chapter 4

Acceptance Testing

4.1 Tests

Table 4.1: Subsystem acceptance tests

Test ID	Description	Testing Procedure	Pass/Fail Criteria
AT01	ON/OFF	• Measure current across the motors, when the switch is off • Measure current across load when the switch is ON	Current measured must be 200mA when ON and <500uA when OFF
AT02	Charging voltage	• Measure voltage from TP2 • Measure voltage from TP3	TP2 must read slightly lower than 5V and TP3 must read 4.2V
AT03	Charge at 0.5C	• Measure charging time • Measure draw current	The battery must go from empty to fully charged in 2 hours at 400mA max draw
AT04	Analog connection	• Measure voltage at TP4 • Measure voltage at TP5	The voltage at both test points should read 3v3
AT05	Unit test	• Connect the 02x08 connector to the board and measure physical size • Connect the battery to the 02x01 Connector	The first connector should complement the processing board's connector and not be longer than 35mm in length and 39mm in width. The battery should start charging, indicated by the light from the white LED
AT06	Motor current and voltage	• Test the current through motor terminals • Measure voltage over motors	Current should be 200mA at maximum voltage
AT07	Voltage and current to microcontroller	• Test the current flowing to the microcontroller • Measure voltage flowing to the microcontroller via TP3	voltage when fully charged should be 3.7v

4.2 Critical Analysis of Testing

4.2.1 AT01

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

Table 4.2: Subsystem acceptance test results

Test ID	Description	Result
AT01	Powers on	

Chapter 5

Conclusion

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5.1 Recommendations

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Bibliography

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