SENIOR CAPSTONE FINAL REPORT – ET NAVSWARM ESC

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ECE 792
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2. Executive Summary:

a) The purpose of the executive summary is to provide key information up-front, such that while reading the report, a reader has expectations that are fulfilled on a continuous basis. The first sentence of any executive summary is important and must contain the most essential information that you wish to convey. The Executive Summary is usually written last.

b) The summary is to be written as a stand-alone document as if the reader is totally uninformed about your project and is not necessarily going to read the report itself. It must include a short synopsis of the project, the process, and the results.

c) The Executive Summary is to be one page or less with one figure maximum.

Table of Contents

Design Problem and Objectives

ET NavSwarm is an interdisciplinary group with the end goal of sending a swarm of small autonomous rovers to another planet to prospect for materials. The end goal is to use these materials to construct habitats for the eventual human colonists. The Computer Science group is tasked with implementing the particle swarm optimization (PSO) algorithm to the rovers. The PSO algorithm mainly includes two parts. One is a waypoint queue for each rover and the other is object avoidance with the help of a Lidar sensor array. Areas for improvements the group have identified include addressing hardware instabilities and promoting battery health. I took it upon myself to solve both objectives in a sleek and effective manner by designing a printed circuit board (PCB) designed for both functions. I also used this opportunity to teach myself how to design PCBs as that is not a topic or course offered at the University of New Hampshire. To design the PCB, I first chose to use Kicad a free and open-source EDA suite application. Due to its popularity, I was able to find many tutorials and guides on how to operate inside of it. To fabricate my design, I sent my Gerber, drill, and footprint files to JLCPCB.

Documentation

One of my original objectives was to create an electronic speed controller (ESC) with Insulated-Gate Bipolar Transistors (IGBTs) due to their inherent high-power specifications. I quickly learned why this was not feasible due to the great cost of IGBTs and the lack of consumer uses of IGBTs on similar devices. The previous hardware failures were due to a badly designed off-the-shelf ESC HW-039. The HW-039 would not sense its current correctly at times and burn itself out internally. A well-designed ESC with regular Metal Oxide Semiconductor Field Effect Transistors (MOSFETs) could complete the same objectives at a more competitive cost than IGBTs.

Some assumptions made during the design phase were choosing many central integrated circuits (ICs) to build around. The STM32F405 was chosen as the microcontroller for its popularity in the guides I found online. For my specific needs, this chip was more than capable. This helped me find clear descriptions for the need for decoupling capacitors, external oscillators, and boot switches along with recommended circuits for each.

The motivation for monitoring battery health also included a general desire to reduce environmental waste. A dead lithium battery is difficult to recycle and energy intense. I decided to monitor the battery health with two methods. The simpler of the two was simply measuring the pack voltage of the battery and cutting power if it fell below unhealthy limits. The other method was measuring the individual cell voltages of the battery by connecting to the balance leads of a typical lithium-Ion Polymer battery. This was not one of the original specifications but can better determine the condition of a battery. This is due to the internal resistances of each cell increasing at different rates over the life of the battery pack. All the voltages and system messages would be shown on an LCD for the user to view the status of the rover. The LCD is intended to be programmed over I^2C protocol to the microcontroller.

A minor addition to the original specification was to allow the rover's Raspberry Pi to be powered off the board. The circuitry for a 5V supply was already designed but had to be slightly altered for the increased power needs of a Raspberry Pi.

Five prototype boards were fabricated and partially assembled with components. This was due to a few chips in the design being out of stock by JLCPCB. The plan is to find these chips elsewhere and hand solder them to the boards. The prototypes were delivered on the first of May. The original goal was to have the first prototype delivered in March. This could not be met due to unaccounted for lengths time transferring the electrical schematic to a PCB layout.

The prototype boards were designed with two data planes, an internal ground plane, and an internal split voltage power plane. The processes used for fabrication were chosen to be as cost effective as possible to not exceed the allotted $100 from the Electrical and Computer Engineering Department. The first batch was slightly overbudget with a total cost of fabrication and assembly of $107.

Testing and Results

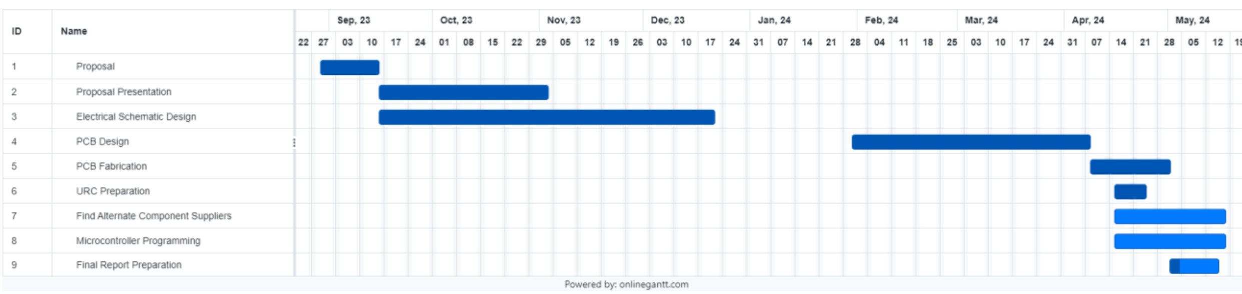
6. Laboratory test plans and results: Provide all portions of the system that were built and tested. Write a narrative description of test plan(s). Use tables, graphs, and graphics wherever possible to show your results. Also, include a description of how you tested the final system and subsystems designed. Indicate any features you included in the design to facilitate this testing.

(This section forms the written record of the performance of your design against the proposed Engineering Specifications.)

Bill of Materials

7. Bill of materials: Parts descriptions and costs. Include only those items used in the final design. A detailed bill of materials includes: the part manufacturer, part number, part description, supplier, quantity, and cost.

Gantt Chart



Ethical Consideration

The PCB prototype was fabricated with lead solder. This prevents the PCB from being used in medical settings or in RoHS compliance. Use in medical settings was not a specification at any time during development.

Safety

Safety was not a key consideration in the development of the prototype PCB. The design was completed on a computer. The safety conditions of the fabrication facility were not considered. Hand soldering the out-of-stock components has the risk of burning the user.

Standards Utilized

No specific standards were utilized in the development of the prototype PCB. This was because I chose not to for a prototype. Future iteration could include standards such as RoHS.

Contribution

Due to the nature of working on the PCB alone, all accomplishments and shortfalls are attributed to myself. Over the last two semesters completing this capstone I have taught myself a critical skill for all engineers by designing a PCB. I have also increased my knowledge of reading manufacturer documentation such as datasheets and application notes.

Conclusions

13. Conclusions: Provide a listing and description of only the most significant results for the project.

Future Efforts

There are many improvements that can be made for future iterations. These include a design that has all its components in stock at the same time, is RoHS compliant, has ESD protection, and can output increased power to both the motors and the 5V output. These were not considered for the prototype because of the designer's lack of experience with PCBs.

Acknowledgements

15. Acknowledgments: List individuals and/or companies that provided support in the way of equipment, advice, money, samples, etc.

References

16. References: Including books, technical journals, and patents. Use appropriate professional style and language in citing sources used in the design project. Suggested style guide for ECE is the IEEE Citation Reference Style

Appendix

17. Appendices: Appendices are meant for any supplementary materials that are required to make the report stand on its own merits as a complete document. It typically contains various types of information (examples follow):

a) Original project proposal

b) Interim report from ECE791

c) Schematic drawings, mechanical diagrams, etc.

d) Detailed computations and computer-generated data.

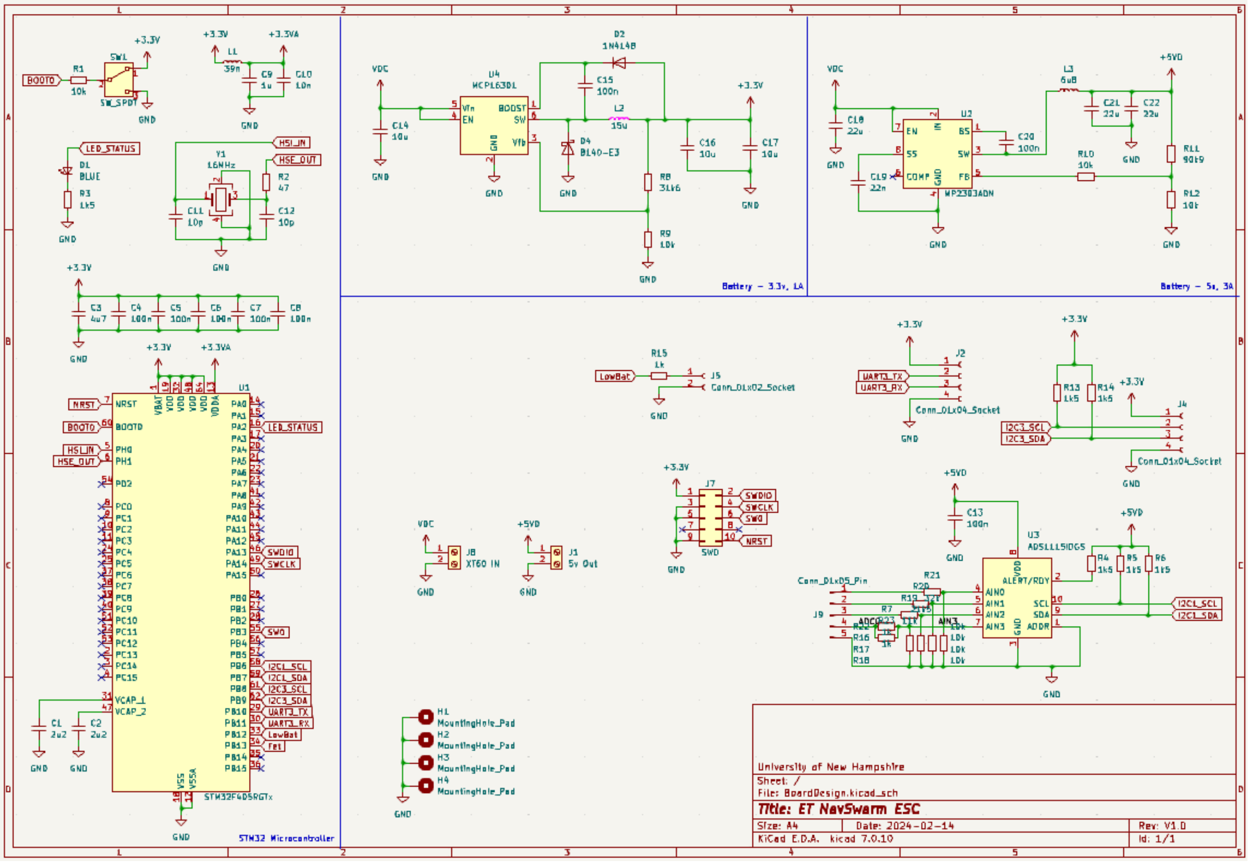
e) Original laboratory data obtained in testing

f) Manufacturers' specifications for components or assemblies used.

g) Product development plans

h) User’s Manual

Etc.


STM32 Microcontroller
Battery - 3.3v, 1A
Battery - 5v, 3A
University of New Hampshire
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File: BoardDesign.kicad_sch
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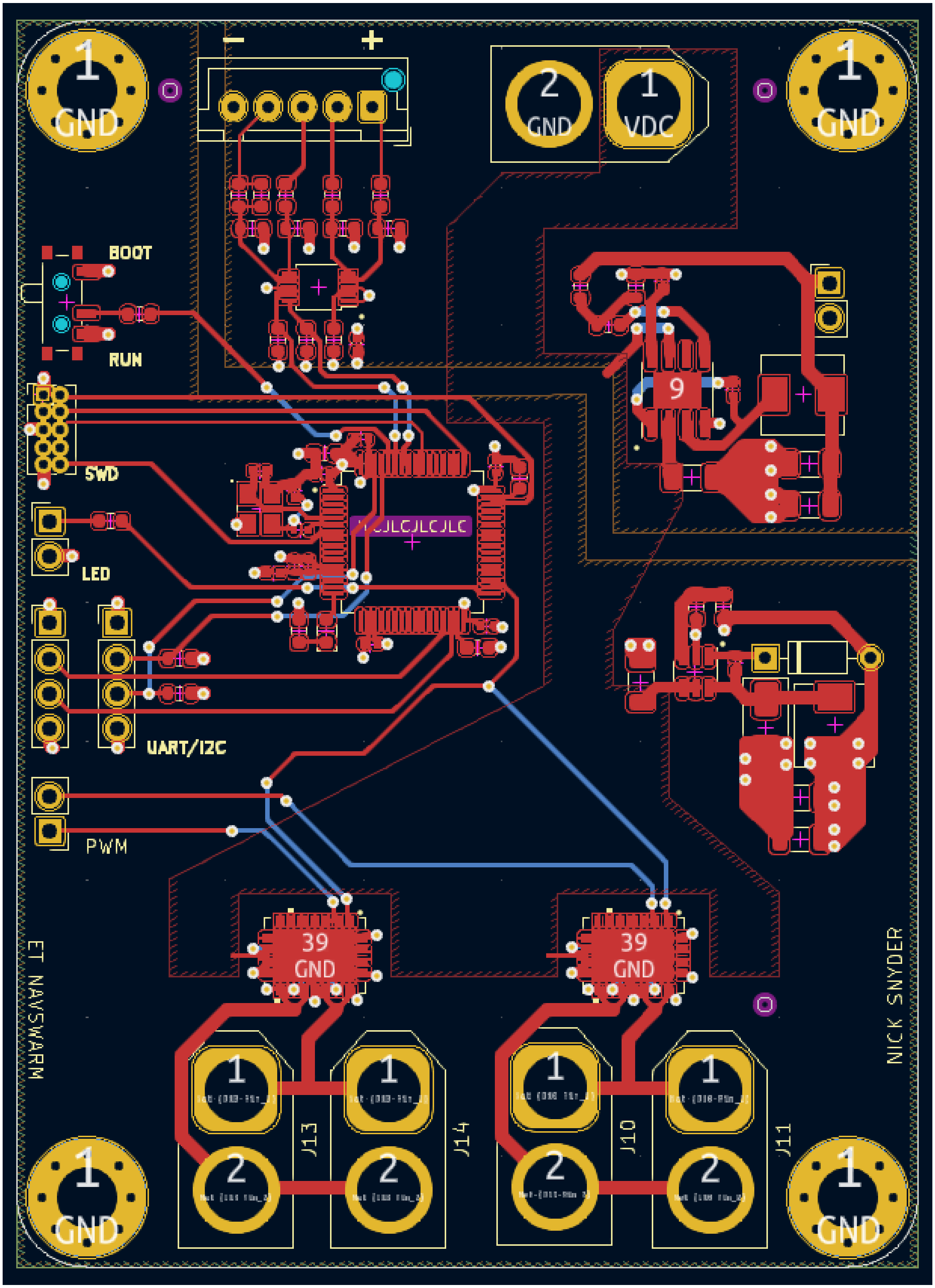
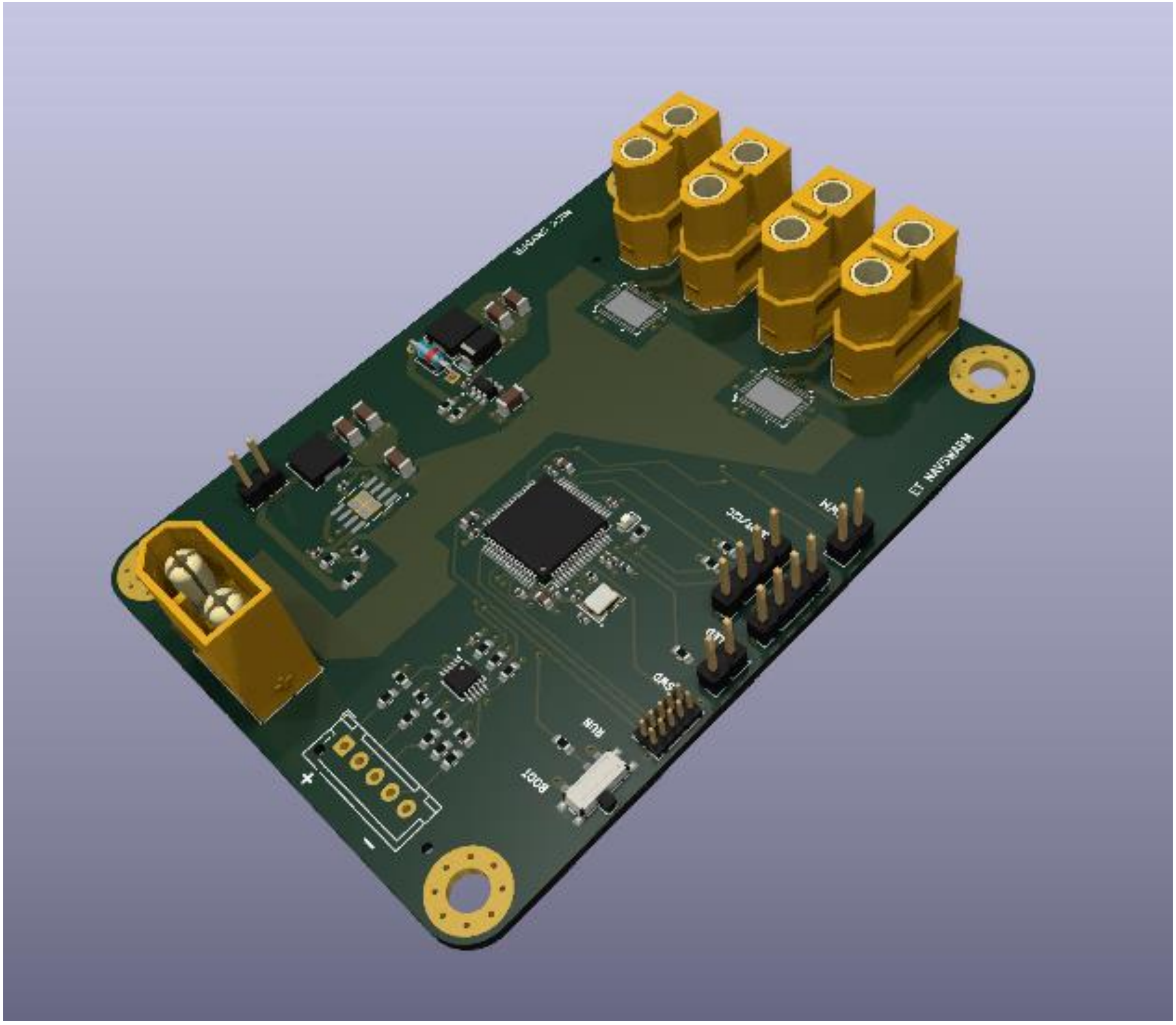
Size: A4
Date: 2024-02-14
Rev: V1.0
KiCad E.D.A. kicad 7.0.10
Id: 1/1



GND
VDC
BOOT
RUN
SWD
LED
UART/I2C
PWM
J13
J14
J10
J11
ET NAVSWARM
NICK SNYDER


ET NAVSWARM
SWD
RUN
BOOT
+
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