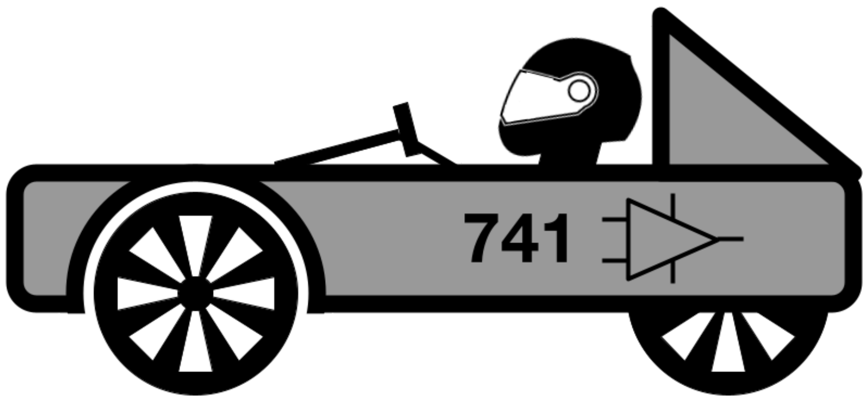
Group 27
EEL4914
9/8/2023

Initial Project Document

Rebuilt Electric Go-Kart



University of Central Florida
Department of Engineering and Computer Science

Dr. Lei Wei
Senior Design I

Group 27

Fouad Braimoh - Computer Engineering
Abdullah Arshad Choudhry - Electrical Engineering
Grace Tuomala - Computer Engineering
Julian Yerger - Electrical Engineering

Review Committee

UCF Professors - Dr. Zakia Abichar
- Dr. Chinwendu Enyioha
- Mark Maddox

Workshop Sponsor - Larry Wexler

Motivation and Background

Over the past several years, hybrid and electric vehicles (EVs) have been growing in popularity in an effort to reduce carbon emissions from gas-powered cars. A few years ago, a small group of friends at UCF sought to join this effort by forming the club Relectric. The club revolved around the design of electrical, software, and mechanical systems for electric vehicles. Two members of this senior design team, Julian and Grace, were primary contributors to Relectric's electrical team.

Inspired by other clubs building vehicles for racing, members of Relectric decided to build an electric go-kart. The idea led to the proposal of this senior design project: optimizing the electrical and software systems for an electric go-kart. The go-kart would be raced in the Electrathon - a competition for small electric vehicles that are optimized for efficiency. Current battery technology has much lower energy density than liquid fuels, so to achieve reasonable weight, cost, and range electric vehicles must be much more efficient than their gas powered predecessors. This focus on efficiency instead of power, downforce, or grip makes Electrathon more relevant to commercial electric vehicles than most racing leagues. Due to their small size, the cars are relatively cheap to build and modify, and due to their high efficiency, they have minimal wear on brakes and tires. Many teams race on the same set of tires for an entire season.

Electrathon races are held on a closed-loop track ¼ mile to 1 mile in length, and the goal is to complete as many laps as possible in 60 minutes while using less than 1000 Wh of energy. Electrathon is a nation-wide organization, and there is an active league in Tampa. Races are held throughout the year, typically hosted by high schools. Teams are scored in four separate classes based on education level - high school or "open" (which consists of college students and hobbyists) - and battery type - lead-acid or lithium-ion. Electrathon racing arrived in the United States in the 1990s and has historically used lead-acid batteries, but lithium-ion batteries are now standard in EVs, so the Advanced Battery class was created to accommodate them. We have chosen to race in this class because lithium-ion offers greater performance and is more relevant to future EVs. Besides the battery, other constraints and rules are given in the Electrathon Handbook [1].

The scope of this project does not include the mechanical frame, steering, or suspension; those have already been built. Rather, the project goal is to optimize the electrical system, and the team consists of two electrical engineering majors and two computer engineering majors. The most binding requirement is that rated capacity of all battery cells in the pack must be less than 1000 Wh, and every other electrical component on the vehicle should work towards maximizing the fraction of that energy that is delivered to the wheels. Batteries deliver peak energy under certain conditions, and motors reach peak efficiency under certain conditions, so a major part of the project is finding those optimal operating points. The rulebook dictates that Electrathon cars be controlled by a driver, and since the driver is responsible for keeping the car in an optimal state, the car must quickly present the driver with detailed and accurate information.

This project has three main components. First, a dynamometer will be constructed to measure the efficiency of different motors at different speeds and loads because the motors that are typically used in Electrathon come with very little documentation. Electric motors can act as generators if they are turned by an external force, and if the applied torque is measured with a lever arm and the RPM is measured with a speed sensor, the absorbed power can be found precisely. If this motor/generator is turned by another motor, the motor under test, and the input voltage and current is measured, the difference between input and output power can be used to find the efficiency. Varying the impedance connected to the generator varies the load on the test motor and allows the RPM to be controlled. These general principles will allow an inexpensive dynamometer to be constructed.

Off-the-shelf motor controllers in this power range are intended for Radio Control (RC) and electric bike applications where cost and weight are more important than efficiency. Thus, the second component of the project is building a custom motor controller that is optimized for higher efficiency. The third project component is building a Driver Information System that gathers data from sensors and presents it on a screen. The rulebook bans driver assistance features that would control the car directly, so this system will only present information and record it for later analysis. Specific goals and objectives for these systems are outlined in the next section.

Goals and Objectives

	Hardware	**Software**
Basic	Build custom DC-DC converters to supply power from battery pack to 15V, -15V, 5.5V, and 3.3V rails	In-car display including current and average speed, average power consumption, time left in race, and button to start/stop race
Advanced	Motor controller with greater efficiency than typical RC controller, finish at least one Electrathon race	Ability to send data to and from car, button for lap counting either in car or from pits with error checking in case a user misses a lap
Stretch	Win a Tampa Bay Electrathon race, Custom Battery Management System (BMS) to charge the battery more precisely	Automated lap counter to avoid errors if users miss counting a lap, real-time location tracking

At the basic level, the car must be able to complete an Electrathon race while meeting all of the requirements specified by the Electrathon handbook. The battery capacity must be under 1000Wh, but still close enough to maximize the energy available. The batteries need to last the entire race without being charged. This goal is largely dependent on the driver, who must budget energy to make the battery last throughout the race while also striving to complete as many laps as possible with that energy within the 60-minute time limit. Without any feedback on the car's status, the driver could greatly overestimate or underestimate how much battery life they have left. In the former case, the driver might be able to complete a lot of laps early on in the race by driving at the car's maximum speed, but risk having the car stop part way through the race when the battery runs out. Technically, the team would *not* be disqualified if this happened, and could theoretically even win the race if the car manages to complete more laps than any other team before it stops, despite not actually continuing for the entire race. Still, this is not an ideal strategy. In the latter case, the car could finish the race with a significant portion of their battery life remaining by driving slower than necessary, and consequently not complete as many laps as it would have if driven at a faster speed throughout the race.

To avoid these two cases while still complying with the Electrathon handbook (which does not allow autonomous driving), a display will be included in the car. At a minimum, this display will include how much time is left in the race, along with the current and average speed of the car and average power consumption. A start/stop button must also be part of the implemented design, because otherwise the race timer would start as soon as the power to the display is turned on.

If time and budget constraints permit, the next step will be further optimizing the car's motor controller and adding additional features to the display. One "advanced" goal is to send data to and from the car so that team members in the pits can view the same race information the driver sees. Additionally, a lap counter would be useful to help with energy budgeting. This could be implemented as a button pressed by either the driver or a spectating team member if they are able to connect remotely. As a stretch goal, it would be more ideal to design a method of automatically counting laps, and to be able to track the car's location in real time. On the hardware side, stretch goals include designing a custom battery management system for more precise charging, and winning a Tampa Bay Electrathon race.

Specifications

Powertrain	**Battery Capacity (0.1C)**	1000Wh, +/- 5%
	Battery Weight (cells)	< 15lbs
	Motor Controller Peak Efficiency	> 90%
	Speed Measurement Accuracy	+/- 10%

User Interface	**Current & Voltage Measurement Accuracy**	+/- 5%
	Display Response Time	1 second
Dynamometer	**Measurement Repeatability**	+/- 5%

Related Work

High School Electrathon Teams: Building an Electrathon car can be a valuable learning opportunity for high school students, especially those planning to major in mechanical or electrical engineering after they graduate. Middleton High School in Tampa is a STEM-focused school with multiple active Electrathon teams. Plant City High School also regularly participates in and hosts Electrathon races.

Electrathon cars built by high school teams are usually fairly simple in design - at this level it can be considered an accomplishment to get the car running at all. Examples of Tampa Bay Electrathon cars are featured on the Electrathon of Florida website: https://electrathonofflorida.org/.

Cliff: Consistently a local champion of Electrathon races, Cliff has a webpage dedicated to his award-winning vehicle: https://proev.com/P2Desc.htm. "ProEV", as it is titled, started from a Blue Sky Design Coupe and has been heavily modified to achieve maximum racing performance. Cliff's design is highly compact, with just enough space to fit himself. His battery pack consists of nine modules totaling 999Wh. He tests each module to get an ideal combination of stronger and weaker cells. During races, he uses voltage readers to alert him (via loud buzzers) when a cell is too low.

The ProEV's software includes an Arduino Mega 2560 and an OLED display. The display is attached to the vehicle's ceiling, just above the driver's line of sight between two rear-view mirrors. Similar to the goals of this project, it shows information such as speed, energy use, and time in the race. Many sensors are included in the car for enhancing the driver's ability to budget power throughout the race.

Heart Racer: In 2015, a senior design group of 3 electrical engineering majors built the "Heart Racer Go-Kart". The website for the project can be found at https://www.ece.ucf.edu/seniordesign/su2015fa2015/g19/. The Heart Racer was intended to improve the driving experience of a standard go-kart. Its design included lights, speakers, and a sensor that measured the driver's pulse in order to synchronize the changing colors of the lights to their heart rate. Since the Heart Racer was built for racing, performance was valued. However, contrary to the project proposed in this paper, it was clearly not optimized to reduce power consumption or cost.

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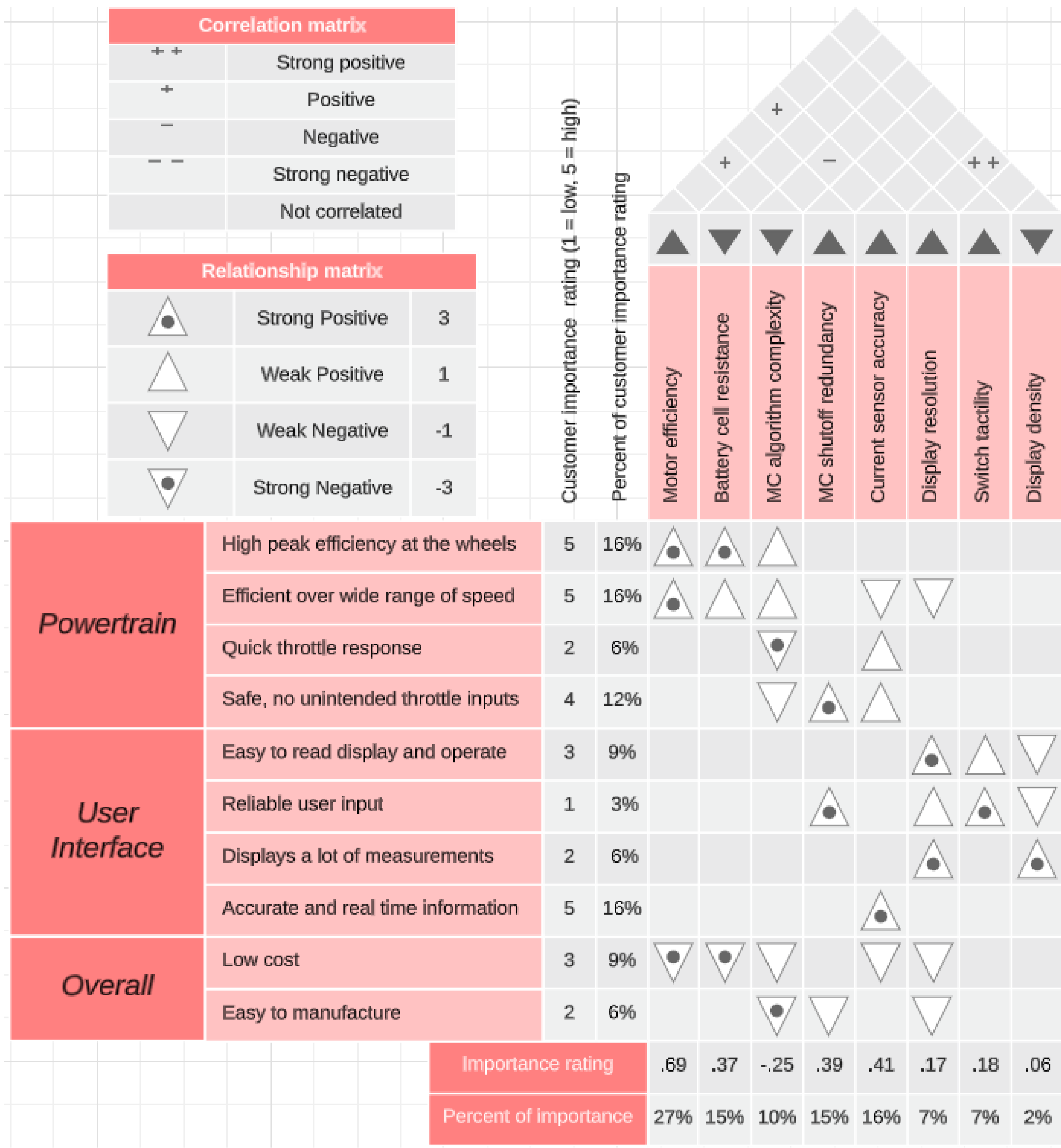
House of Quality



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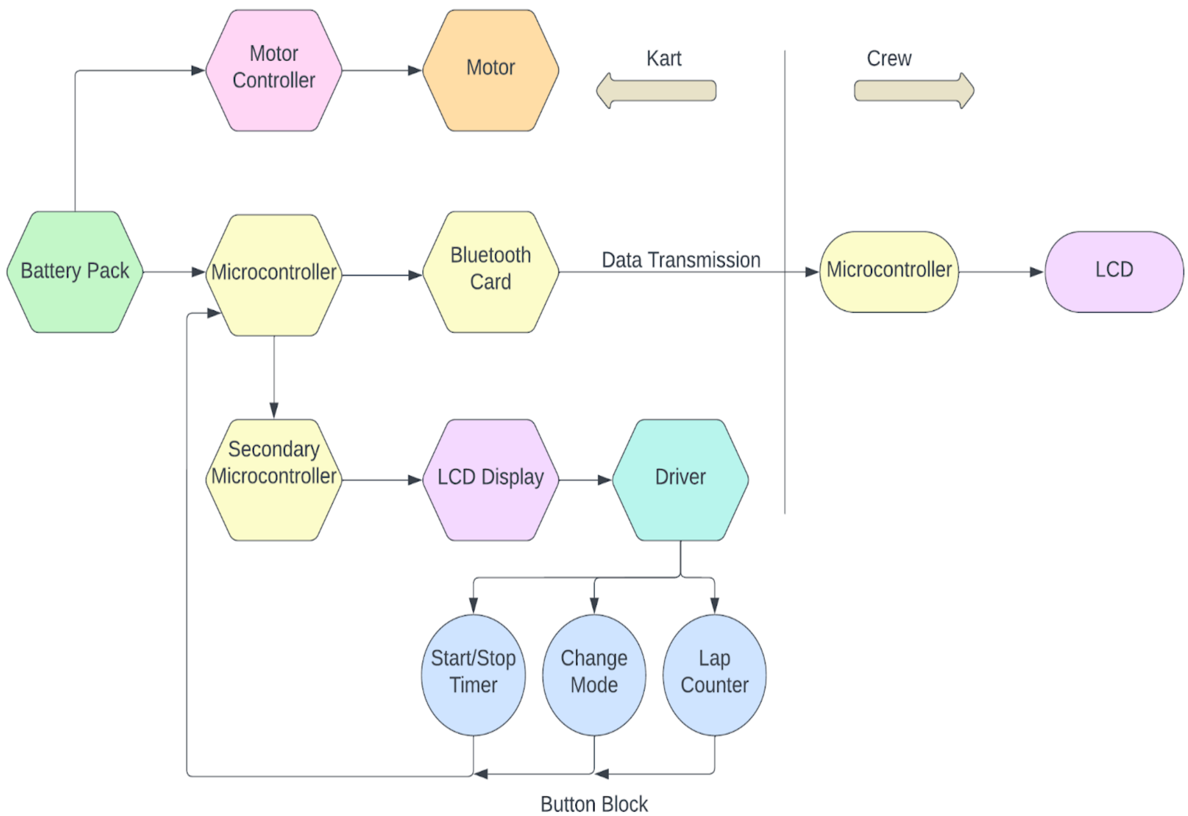
Hardware Block Diagram



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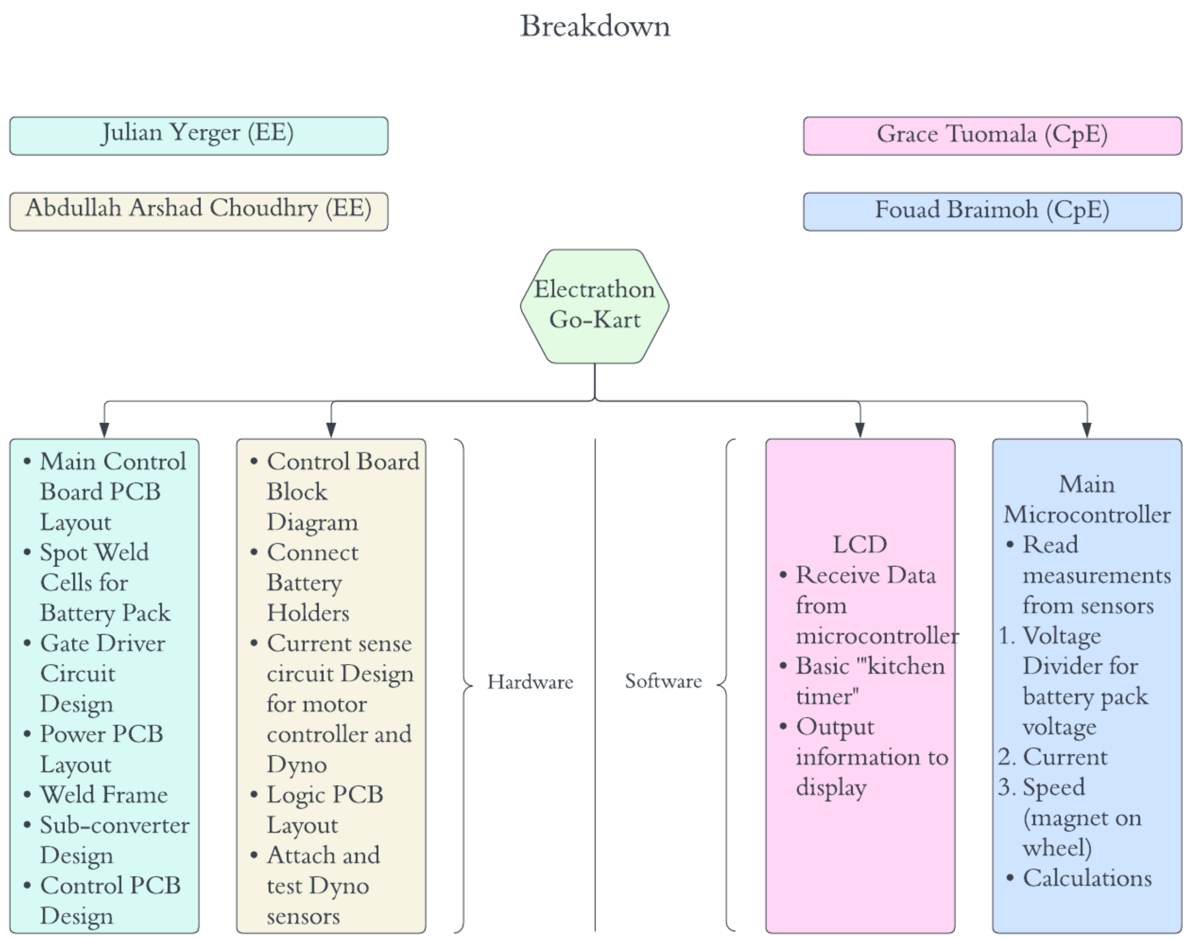
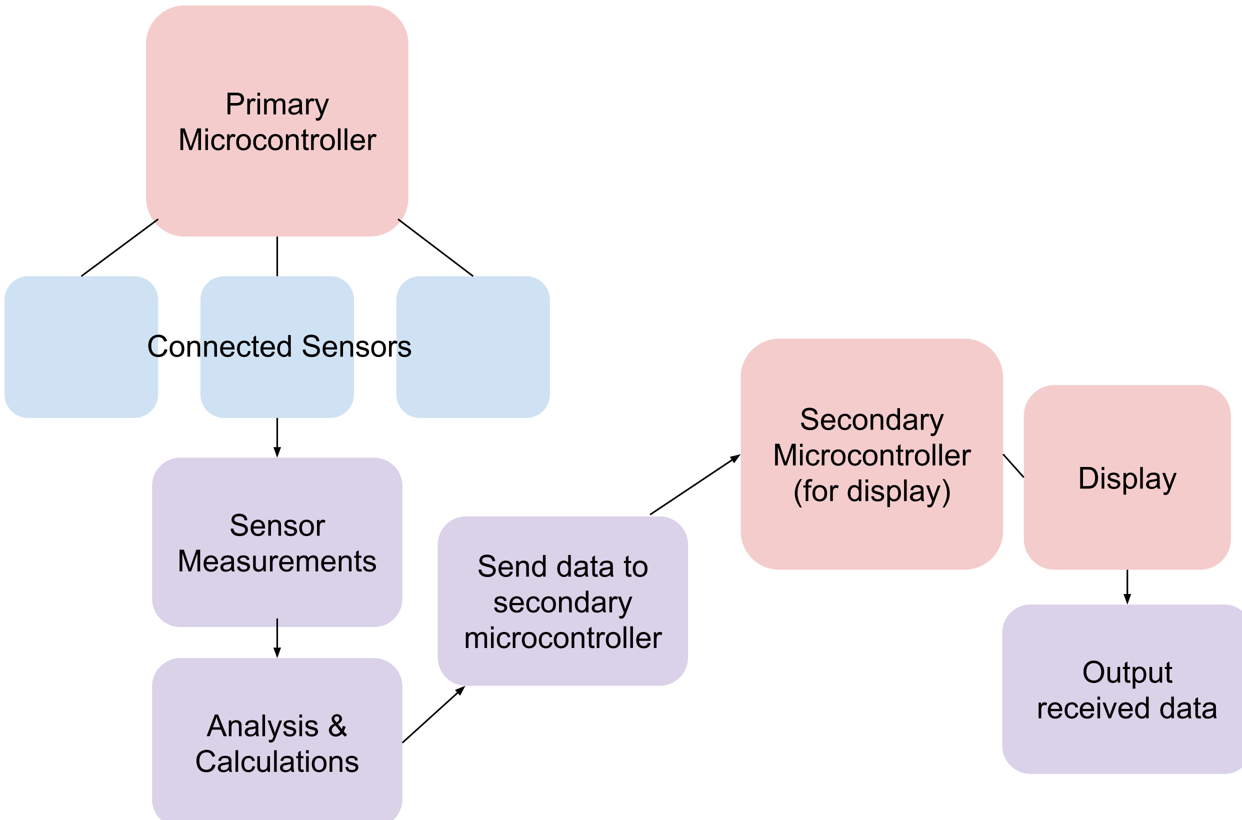
Work Breakdown



Software Flowchart

The group discussed that it would be most logical for Julian and Abdullah (electrical engineering majors) to work on the electrical components of the car, while Fouad and Grace (computer engineering majors) program the microcontroller and display.

An initial software design includes two microcontrollers: a “primary” microcontroller connected to various sensors, and a “secondary” microcontroller dedicated to the display. The primary microcontroller will read sensor data and perform any necessary calculations, then send the results to the secondary microcontroller, which will be responsible for outputting the data to the display.



Software Requirements

Microcontroller to run calculations:
We plan on using a microcontroller to calculate the values received from the sensors and return the values that are to be displayed to the drivers LCD display.

LCD display to display info to driver:
We plan on using an LCD instead of an LED display to conserve power and this will be used to display information from the sensors and relay to the driver.

Microcontroller to control LCD display:
We plan on using another microcontroller to control the LCD display and program what will be shown on the screen.

Bluetooth card to communicate between driver and pit crew:

We also plan on using a bluetooth card in the car with the driver and another one with the pit crew to have communications with the driver.

Motor sensors to read speed information:
We plan on using an embedded motor sensor to read the speed of the car through the motor.

Budget Estimate

Item	**Quantity**	**Price Estimate**
Samsung 20S battery cell	140	$700
Busbars and cell holders	200	$30
Active cell balancer	1	$150
Hacker A60-18L motor	1	$272
80V 90A motor controller	1	$300
Circuit breaker	1	$11
Wires and connectors	3	$32
Main microcontroller	1	$30
Parts for motor testing dyno	3	$253
Camlock 5-point harness	1	$52
Total		$1,830

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Project Milestones

Task	Planned Completion Week (SD1 and SD2)
Complete Divide and Conquer/Project description	**3-4**
Install a basic power system in car	4-6
Select microcontroller and display to use	4-6
Begin programming display	4-6
Request approval for on-campus demo of car	4-6
Have a drivable vehicle for baseline performance testing	5-7
Test performance of various motors	5-7
Design and build custom motor controller	8-10
Working display showing current and average speed, average power consumption and time left in race	8-10
Complete report chapters 3, 4, 5	10-12
Race car in Electrathon competitions	Throughout
End-of-semester demo	14-16
Make improvements to electrical system	Throughout
Add features to display	Throughout
Final Testing	28-30
Complete report chapters 6-11 and appendices	28-30

References

[1] "Home: America: The Official Electrathon America Site," Electrathon America https://www.electrathonamerica.org/_files/ugd/032d61_b585e3874fcd4bb6a51e92c2bfb3aa5b.pdf (accessed Sep. 7, 2023).