Solar Race Car Electronics Design and Implementation

Group members

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Team Leader

Curtis Duvall

Speciality Advisors

Dr. Cheng Zhang and Mr. Sam Russel

Course Instructor and Advisor

Dr. T Gilbar

Capstone Design I

EGN4950

Spring 2019

We certify that this assignment is the result of our own efforts.

Abstract: This senior design project is comprised of designing and implementing the electrical components of a solar race car while adhering to Formula Sun Grand Prix (FSGP) race guidelines. The electronic system of the car includes the rechargeable battery array, the motors and motor controllers, as well as standard street-legal vehicle lighting requirements. Further considerations include a drive chain system, battery fault system, and auxiliary batteries. Each component will be implemented on the University of West Florida's solar race car.

No more than 100 words for abstract. (79 current)

Notes on page numbering: The abstract is on a page of its own, following the title page (which has no page number(s)). It is page number ii. Roman numeral numbering should continue through the table on contents. Page 1 should be the first page of your report (the page with the introduction).

Table of Contents

1. Introduction:

Solar car racing was introduced in the mid 1980's and is a project undertaken by many universities to enhance the engineering skills of students. The first solar car race was the Tour de Sol in 1985. It was followed by other similar races across the US, Europe and Australia. The Formula Sun Grand Prix (FSGP) race is sponsored by the non-profit organization Innovators Educational Foundation (IEF) and began in 1990 in the US. The FSGP is a track competition designed to be a qualifying race for the American Solar Challenge (ASG) race.

For competition in either the FSGP or the ASG, a solar car must meet the race requirements for both the mechanical and electrical systems. These requirements are published by the IEF and scrutineering takes place at the race event prior to the car being allowed to take the track. For the electrical components, the standards cover the energy storage, protection circuitry, battery enclosures, fuses, cables, and control systems for the vehicle. Race vehicles must also meet lighting standards for added safety on the track.

The FSGP race itself is a three-day event with a winner declared based on the number of completed laps. The 2019 FSGP race requirements are being used for the technical specifications for this project and the completed car is expected to represent the University of West Florida in the 2020 FSGP race in Austin, TX.

2. Problem Definition

2.1 Problem/Need: This project will provide the battery, motor, monitoring, and control systems for a solar car following the FSGP guidelines for a race vehicle. The vehicle frame was completed by a mechanical engineering team and other teams will continue to complete the body and solar panel placement on the race car after completion of the electrical components.

2.2 Intended user(s) and use(s): The completed car will ultimately represent the University of West Florida in a Formula Sun Grand Prix (FSGP) race.

2.3 Assumptions and limitations: Because this project involves the work of prior teams and will rely on the work of later teams for completion, we must assume that the work already completed meets the specifications of the organization. We must also assume that future teams will continue forward with the project in the same manner. Some limitations exist because all we must ensure that all elements meet the specifications set forth in the regulations guide of the FSGP.

2.4 Design objectives: The project will require a battery system to hold the energy gathered from the solar panels that will be added to the car in a later project. The batteries will be used to run the motor of the car which will need to be designed in the most energy-efficient manner possible. We will also design a control system with sensors and a heads-up display for the driver. Further, standard electrical requirements of a vehicle (such as turn signals, emergency blinkers and a horn) must be operational.

3. Design Specifications:

A battery system capable of storing the solar-generated energy to power the vehicle (must meet specifications of chart shown below as figure 1). Supplemental battery power may be utilized to power auxiliary equipment such as fans or radios only. All batteries must have protection circuitry appropriate for the battery technology utilized. All batteries and main fuses must be fully contained in non-conductive enclosures that are electrically isolated from the solar car. (Since the frame has already been designed and built, we will have to also ensure that the enclosures fit well within the room allotted for the battery compartment.) Fuses must be placed in series with the batteries and all wiring off the main bus circuit must contain properly sized fuses. A main power switch to the vehicle must be located within the battery enclosure and the driver must have overriding control with the ability to turn off the main power at any time. An external power cut off switch must be readily accessible from the exterior of the vehicle in the event of an emergency. The accelerator mechanism must be free moving and must return to the zero position when released. Vehicle lighting must include headlights; front, side, and rear turn indicators that can also operate as emergency blinkers; rear brake lights; one high mounted brake light; and a BPS (bulk power system) fault warning indicator. While a later team will be responsible for the placement of the lighting components, our team maintains the responsibility for their operation.

Li-S	15.00 kg
Li-Ion	20.00 kg
Li-Polymer	20.00 kg
$LiFePo_4$	40.00 kg

Figure 1. Battery type and weight specifications.

4. End-Product Description:

The final product will be the complete battery and motor system as well as a functioning sensor feedback control system for a fully functioning FSGP solar-powered race vehicle. The finished product (along with the existing car frame) will be left for future teams to design and complete the body of the vehicle and to install solar cells. The battery system will be capable of safely powering the vehicle through the three-day Formula Sun Grand Prix race while the motor system will offer maximum energy efficiency.

5. Design Constraints:

5.1 Economical: While designing the components for this vehicle, extreme caution must be given to expenses. An initial budget has been offered between $1000-$1500 to obtain all batteries and components necessary for the build. While other teams racing in this competition have more expensive motors, we will have to design a system that can maximize the efficiency of a less expensive motor. We will also need to use extreme caution not to overcharge any batteries as there may not be adequate budget to replace them.

5.1.1 Environmental: Dealing with batteries immediately evokes an environmental concern. The batteries must be stored correctly and, if damaged, disposed of correctly.

5.1.3 Social and Political: There has been a new push by many in government to develop various forms of low/no emission energy sources. In the forefront of this push has emerged solar power which is fairly new and popular for both research and projects that will help fuel our automotive and utility industries.

5.1.3 Ethical: There are many safeguards in the FSGP regulations to attempt to stop teams from cheating. There will always be an opportunity to cheat, and our team must be sure that the work we create is fully in compliance with all race rules.

5.1.3 Health and Safety: Safety must be considered as the team works with volatile batteries and the electrical components. We must also consider the health and safety of the driver of our car and other riders on the track.

5.1.3 Manufacturability and Sustainability: Since the end-product is not designed to be reproduced, the manufacturability and sustainability categories do not apply to this project.

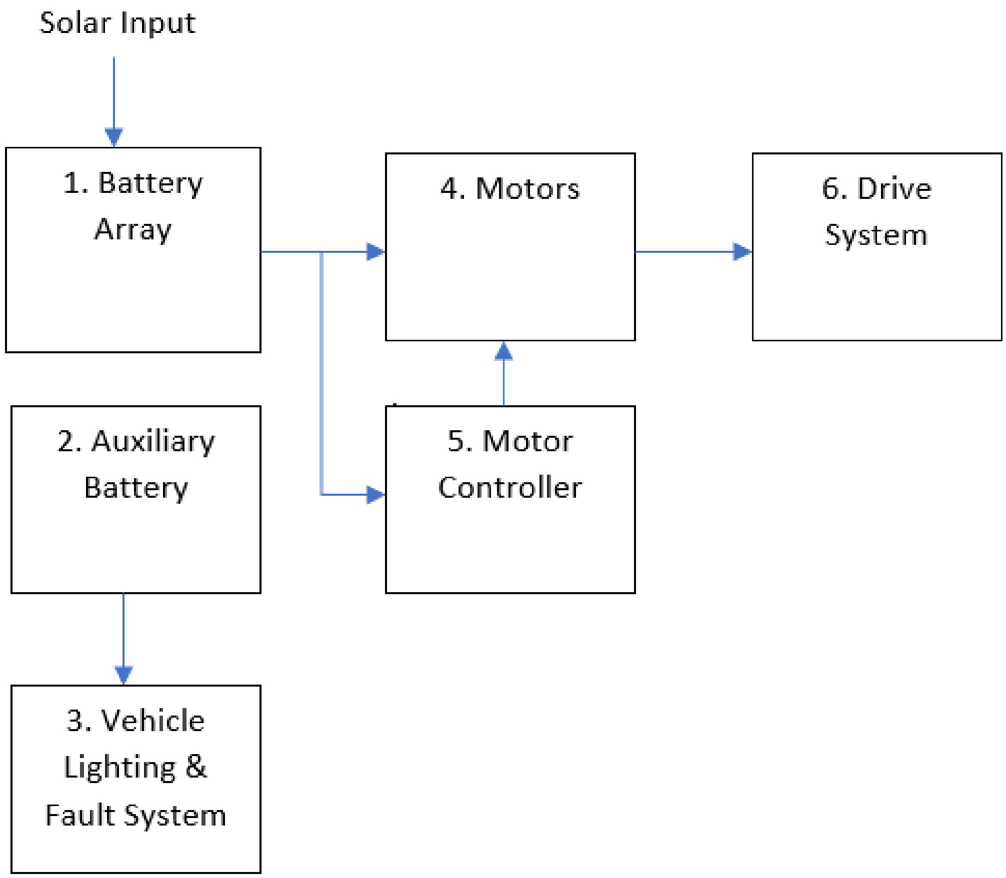
6. Engineering Standards:

ISO 18300:2016 has been applied to this project. The standard has specifications of lithium-ion battery systems that can be combined with lead acid battery or electric double layer capacitors to be used for automotive applications in class A systems. The standard only applies to combinations of such electric energy storages that are integrated in a common housing and specifies configurations, test procedures, and requirements for such combinations. While the batteries in our electrical system will not be housed in the same compartment, the standard was reviewed while selecting a lead acid auxiliary battery to be used alongside the rechargeable lithium batteries.

7. Technical Approach:

At the completion of Capstone 1, the block diagram shown below represents the anticipated approach for implementation of the electronics system. This block diagram will be revised as the actual project implementation begins during Capstone 2. Each block represents a component of the overall project and is described in detail in tables 1-6 below.

7.1 Functional Block diagrams.



7.2 Functional Requirements for Blocks

Table 1: Functional Requirements and Specifications of Block # 1, Battery Array

Requirements	**Specifications**
Functional Requirements	Must be able to store energy collected from the solar array (to be installed after completion of this project). Rechargeable batteries of a type allowed by FSGP regulations (see Figure 1).
Performance Requirements	Must be able to charge and discharge continuously throughout the duration of the race. Must not exceed the weight allowances set forth in FSGP regulations.
System Interaction	Interacts with the solar cell array through a multi-point power tracker for charging. Interacts with motors and controller to supply power.
Operator Interaction	Can be disconnected by the operator by a single switch in case of emergency.
Hardware/software interface	Interfaced to motors with 4/0 gauge welding cable

Table 2: Functional Requirements and Specifications of Block # 2, Auxiliary Battery

Requirements	Specifications
Functional Requirements	Able to power the vehicle lighting and safety components. Must be small enough to fit inside the area designated in the car frame (already constructed).
Performance Requirements	Able to be drawn upon for minimal load throughout time of race without depletion.
System Interaction	Interacts with the vehicle lighting components, horn, and main battery fault system.
Operator Interaction	No direct interaction with the operator.
Hardware/software interface	None

Table 3: Functional Requirements and Specifications of Block # 3, Lighting & Fault System

Requirements	Specifications
Functional Requirements	Standard vehicle lighting components to include: headlights, turn signals (front and rear), hazard lights, brake lights (low and high), and a horn. Fault system must be fully operational throughout duration of race and be able to immediately disconnect the main batteries.
Performance Requirements	Must remain functional throughout the duration of the race.
System Interaction	Power gained from auxiliary battery.
Operator Interaction	User can control the turn indicator signals, hazard signals and horn by switches inside the car. Battery fault override must be accessible to both the driver of the car and externally in case of emergency. Horn can be engaged by the driver of the vehicle.
Hardware/software interface	Equipment must interact with the control switches.

Table 4: Functional Requirements and Specifications of Block # 4, Motors

Requirements	Specifications
Functional Requirements	Must be capable of accurately maneuvering the vehicle.
Performance Requirements	Must be able to achieve minimum speed of 20mph. Cannot have excessive weight. Must be small enough to fit inside the area designated in the car frame (already constructed).
System Interaction	Interacts with the main battery array for power and the motor controller for programmed response.
Operator Interaction	Vehicle operator will indirectly interact with the motors through the steering, throttle, and brake mechanisms of the car.
Hardware/software interface	Interfaces with the motor controller, drive system, and the main

	battery array.

Table 5: Functional Requirements and Specifications of Block # 5, Motor Controller

Requirements	Specifications
Functional Requirements	Through coding techniques, must be able to control the motors to accurately drive the vehicle.
Performance Requirements	Should be an open source, dual controller option to support both motors.
System Interaction	Interacts with the main battery array for power and the motors.
Operator Interaction	No direct interaction with the operator.
Hardware/software interface	Direct interface to the motors.

Table 6: Functional Requirements and Specifications of Block # 6, Drive System

Requirements	Specifications
Functional Requirements	A chain drive system to propel the car.
Performance Requirements	Must be strong enough to withstand the weight of car and driver (combined estimated at 1000 lbs.).
System Interaction	Interacts with the motors.
Operator Interaction	No direct interaction with the operator.
Hardware/software interface	Direct interface with the motors.

7.3 Technical Details of Implementation

7.3.1 For the initial calculation of the motor size needed, a simplified calculation was performed to determine the energy needed to get up to speed assuming no friction or air resistance. This calculation is shown in Figure 7.3.1.1. Assumptions for this calculation were a mass of 500Kg.

$$Kinetic\ Energy = \frac{(Mass * Velocity^2)}{2}$$

	55mph	45mph	35mph
Energy(KJ)	151.17	101.2	61.15

Power (KW)	55mph	45mph	35mph
	Time to Speed (s)		
1	151	101	61
2	76	51	31
4	38	25	15
8	19	13	8
10	15	10	6

Figure 7.3.1.1

From this data, it was determined that the motors needed to product between 5 and 10 KW to be able to remain competitive, while keeping a low enough power consumption to complete the race. Ultimately two 3KW motors were chosen to give a total of 6KW.

The gearing ratio was calculated to determine what was needed to get to the target speed of 35-45MPH using the 21.3 inch diameter tires selected by the mechanical team. The calculations for this are shown in Figure

	RPM (Wheel) / Gear Ratio
55mph	[illegible]
45mph	[illegible]
35mph	[illegible]

7.3.1.2.

Figure 7.3.1.2.

The battery requirements were based partially around calculation, however the voltage chosen was set to 44.4V (12 cells in series) to improve safety, since a higher voltage could pose more of a danger for those working on the car prior to the initial race. However, the battery system was designed so that it can be reconfigured to any multiple of 22.2V by future teams if needed. The calculations for battery amperage capability are shown in Figure 7.3.1.3.

	Discharge Rating				
Amp Hour	**Amp Rating**	**12S1P**	**12S2P**	**12S3P**	**12S4P**
5AH	60C	300A	600A	900A	1200A
5AH	40C	200A	400A	600A	800A

	Charge Rating				
Amp Hour	**Amp Rating**	**12S1P**	**12S2P**	**12S3P**	**12S4P**
5AH	2C	10A	20A	30A	40A

Figure 7.3.1.3

7.3.2 Flow Charts

7.3.3 Schematics

7.3.4 Simulations

7.4 Our other approaches for the motor and motor controller system were many. Originally, the team chose to use smaller motors which, while they have the necessary characteristics are more likely to overheat. Additionally, these smaller motors had a much higher RPM and would need more of a gearing system to produce the necessary torque. The controllers for these motors are open source and if necessary, much easier to upgrade with fully open schematics. However, due to the heat limitations a physically larger motor with a higher torque and lower RPM was ultimately chosen.

Prior to choosing to move away from the smaller motors, the idea of utilizing a total of four motors (two per axle) was also considered to add additional torque. However, this would have increased the likelihood of a failure by a factor of two and so was abandoned. Additionally, this would have reduced our efficiency considerably by moving the motors outside of their efficient operation range.

In determining how to go about climbing hills on the course as needed, two solutions were proposed. The first was to implement an additional motor on one axle using a one way bearing, with the motor being much smaller than the others but with a large gear reduction. Ultimately the team chose to go in the direction of a two speed chain drive instead, likely sourced from bicycle components. This will reduce additional drive components and can also be used for initial acceleration to improve efficiency. Additionally this will allow a neutral mode to avoid losing power to running an the motors while they are not producing torque.

8. Part List and Budget:

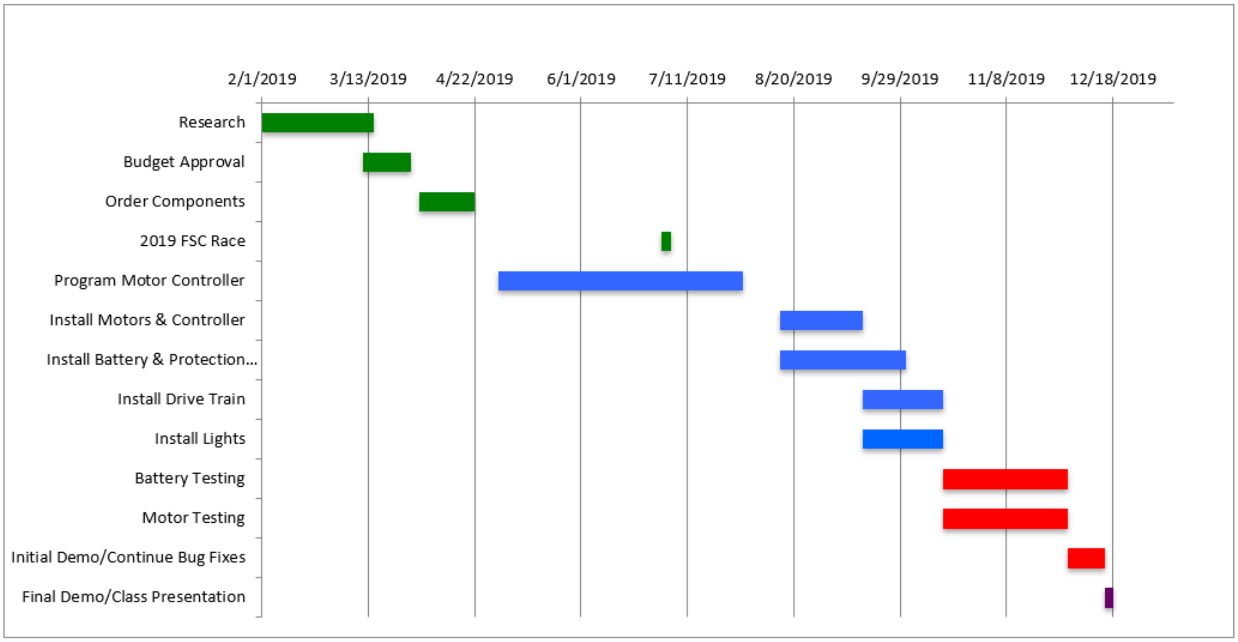
The part list and budget is accurate as of 4/11/19 and was submitted to mentors on 3/25/19 to begin ordering. On 4/8/19, an increased budget was offered to the team to enable us to purchase larger motors. At this time, we are revising the budget with new components and will have that submission to the team mentors prior to the end of the semester. As such, the budget shown below will not be valid after the revision.

Table 2: Part and Price Lists

Parts	Manufacturers	Quantity	Price Each	Total Cost
Motors	Flipsky	2	$89.00	$178.00
Dual Motor Controller	Flipsky	1	$269.00	$269.00
Primary Batteries	Turnigy	8	$74.25	$594.00
Battery Protection Box	Thermasheath	1	$22.00	$22.00
Fans - Primary Battery Box	Noctua	2	$15.00	$30.00
Auxiliary Battery	Apex	1	$30.00	$30.00
200A Relay	NVX	1	$45.00	$45.00
LED for Sensors	Dialight	4	$2.86	$11.44
Temp Sensors	Diymore	1	$14.00	$14.00
Digital Display Multimeter	DROK	1	$29.00	$29.00
Headlights	Online LED Store	1	$37.00	$37.00
Front Signals	King Show Star	1	$8.00	$8.00
Rear Signals	Purishion	1	$13.00	$13.00
3 Position Toggle Switch	Honeywell	1	$10.50	$10.50
Rocker Switches	Del City	2	$10.00	$20.00
Drivetrain Chain	Nieco	4	$4.20	$16.80
Drive Gear Wheel	J&P Cycles	1	$15.00	$15.00
Horn	Zoro	1	$20.00	$20.00
Horn Button	Zoro	1	$3.00	$3.00
Pedals	Blesiya	1	$20.00	$20.00
4/0 Welding Cable	EWCS	1	$164.80	$164.80
Signal Controller	Raspberry Pi	1	$5.00	$5.00
Pi Connector	Raspberry Pi	1	$2.25	$2.25
Micro SD Card	SanDisk	1	$5.79	$5.79
Micro Hub	Raspberry Pi	1	$14.95	$14.95
Controller	Can Bus	1	$26.95	$26.95
PCB Board	UXCell	1	$5.69	$5.69
XT Connectors 150A	Amass	3	$9.47	$28.41
16ga Wire	Infinit	40	$0.54	$21.60
Sensor Connectors	hexTronik	4	$2.42	$9.68
			TOTAL	$1670.86

9. Gantt Chart:

   The Gantt chart represents work and timelines prior to the budget increase offered on 4/8/19. The Gantt chart will be updated by the end of the semester once the mentors have made a final decision on the approved budget.



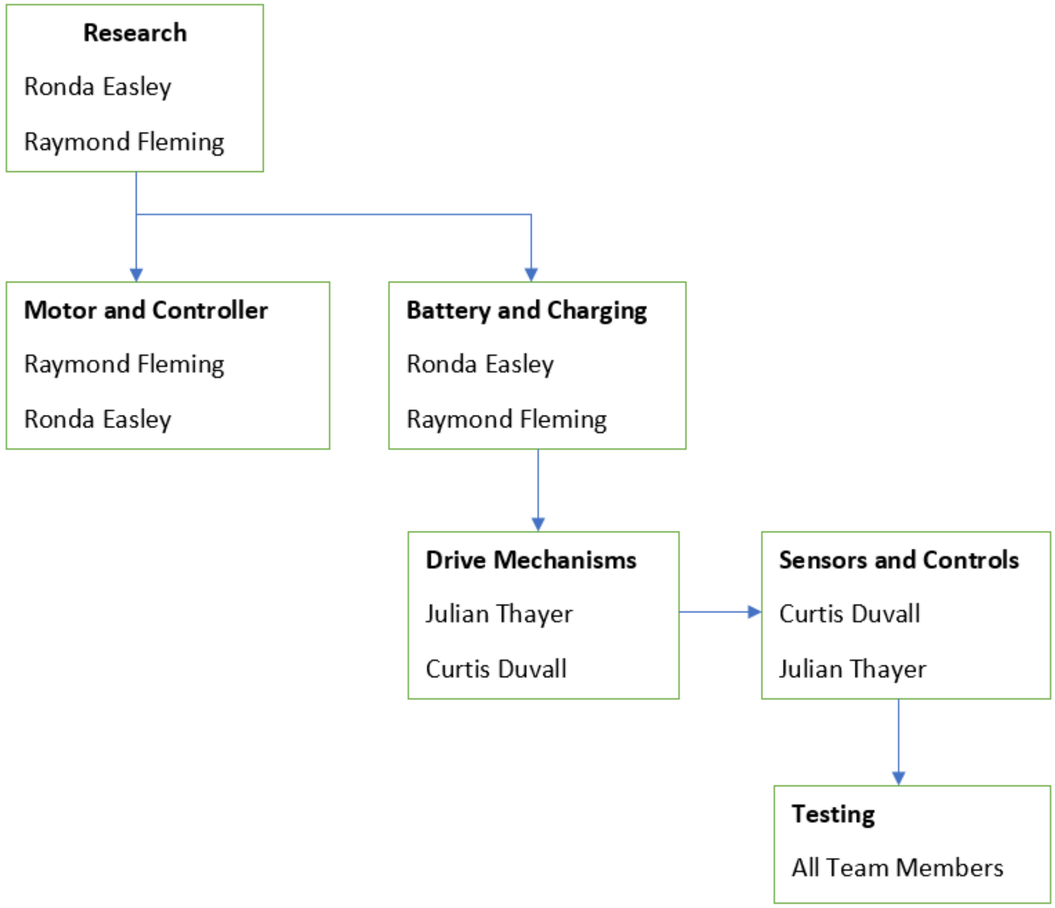
10. *Testing Approach:*

The testing for the project will be completed as each component is designed. The main battery system will be charged using a standard hobby battery charger and the voltage will be measured through a multimeter. The motors and controllers will be tested individually (one motor with one controller) through a bicycle trainer which can test a maximum of 750 watts. While this is not the full capability of our motors, it will allow us to verify that they are turning, controllable, and producing torque.

11. *Final Product/Project Results:*

At project conclusion, the solar race car will be able to store energy in the main battery system. The charge for the batteries will most likely still be gained through a standard battery charger as another team will be assigned later to work on the body of the car and the solar panel installation. The lights and safety systems will be operational. A second capstone team is currently working on the steering and suspension of the car. Assuming completion of their project, we will be able to demonstrate the success of the electronics system by actually driving the car.

12. *Flow Chart of Design Process*:



13. Conclusion:

In conclusion for Capstone 1, the semester has been a very good real-world example of an engineering project. Our team is working on a small portion of a larger project and therefore is interfacing with other team and mentors. It has provided practical experience in managing expectations within our team and from other teams. While researching the topic, we were able to speak to other teams across the US and learn from their experiences. We found that with an anticipated finished weight of 1000 pounds, our team's car was much heavier than that of other teams. We also learned that most of the other teams use commercial motors ranging in price from $10000 to $30000 per motor. At our initial budget of $1500 for all electrical components, we had to be very frugal in the selection of components for the project. There was no room for error or to replace a component if was damaged during testing. In the end, we were able to find a viable solution while remaining within 10% of the original budget. As we were ready for components to be ordered, we were offered an opportunity for an increased budget to be able to purchase larger motors. This resulted in the team returning to the "drawing board" to find other feasible options within the expanded budget. As the semester ends, we have submitted the new plan to the mentor team and are awaiting approval. While this has taken a month out of our schedule, it is well worth the delay to be able to offer a higher functioning end-product in December. One the final approval or denial is received, we are ready to order parts and to make up the lost time during the summer.

14. Assessment of Math, Science and Engineering Topics: The table below indicates by a numeric value (1-4, 1 meaning not at all, 4 meaning high usage) the amount of knowledge and skills used in the capstone project from the following courses.

Table 3: Assessment of Math, Science and Engineering Topics

Topics	Curtis Duvall	Ronda Easley	Raymond Fleming	Julian Thayer
CAD/modelling/simulations		**1**	**4**	
Chemistry courses		**1**	**2**	
Circuits		**4**	**4**	
Communications		**2**	**2**	
Computer Architecture		**1**	**1**	
Control Systems		**4**	**4**	
Digital Design		**4**	**1**	
Electromagnetic		**2**	**4**	
Electronics		**4**	**2**	
Engineering Software tools		**4**	**2**	
Fluid/Thermodynamic systems		**1**	**1**	
Image Processing		**1**	**1**	
Industrial/Manufacturing Engineering		**1**	**1**	
Material Science		**1**	**1**	
Math courses		**4**	**4**	
Mechanical Engineering		**3**	**3**	
Microprocessors/Interfacing/Embedded Systems		**3**	**3**	
PC Board		**1**	**1**	
Project Management		**4**	**2**	
Physics courses		**2**	**4**	
Power Engineering		**3**	**3**	
Programming		**3**	**2**	
Signal and Systems		**2**	**2**	
Soldering/welding		**4**	**4**	
Statics and Dynamics Course		**1**	**1**	
Statistics		**1**	**1**	
System integration		**4**	**4**	
Very Large Scale Integration (VLSI)		**1**	**1**	
Others: List				

15. Team Activity Report. The table below indicates with an "X" the sections where each team member has contributed to the project and/or the final report.

Table 4: Team Activity Report – Summary of Contributions by Team Members

	Team Members			
Sections	Curtis Duvall	Ronda	Raymond Fleming	Julian

		Easley		Thayer
Abstract		X		
1.0 Introduction		X		
2.0 Problem Definition		X		
2.1 Problem/Need		X		
2.2 Intended user(s) and use(s)		X		
2.3 Assumptions and limitations		X		
3.0 Design Objectives		X		
4.0 End-Product Description		X		
5.0 Design constraints		X		
5.1 Economical		X		
5.2 Environmental		X		
5.3 Social and Political		X		
5.4 Ethical		X		
5.5 Health and Safety		X		
5.6 Manufacturability and Sustainability		X		
6.0 Engineering Standards		X		
7.0 Technical Approach		X		
7.1 Functional Block diagrams		X		
7.2 Functional Requirements for Blocks		X		
7.3 Technical Details				
7.3.1 Theory and Calculations			X	
7.3.2 Flow Charts				
7.3.3 Schematics				
7.3.4 Simulations				
7.4 Other Approaches			X	
Change the list as appropriate for the project				
8 Part List and Budget		X		
9 Gantt Chart		X		
10. Testing Approach		X	X	
11. Final Product/Project Results		X		

12. Flow Chart of Design Process		X		
13. Conclusion		X		
References				

Appendix A – Team Member Resumes

**PLACEHOLDER FOR CURTIS

RONDA EASLEY

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(850)384-8898
120 Redbreast Ln • Pensacola, FL 32503

ACADEMIC BACKGROUND

Bachelor of Science: Electrical Engineering, December 2019
University of West Florida, *Pensacola, FL*
GPA: 3.66
Gulf Power Foundation Scholarship, May 2017
Drs. Muhammad and Fatema Rashid Female Engineer Scholarship, July 2018

Associate in Arts: Interdisciplinary Studies, May 1997.
Tyler Junior College, *Tyler, TX*
Presidential Scholarship recipient

WORK / LEADERSHIP HISTORY

Managing Partner, *Firearms Training Group, LLC*, Pensacola, FL, 2010-Present

- Supervise a team of six firearms instructors to organize and lead training seminars focused on safe and responsible gun ownership and handling.
- NRA certified instructor in multiple disciplines including advanced topics.
- Manage day-to-day business operations to including hiring and scheduling.

Account Executive, *Coventry Healthcare*, Sunrise, FL, 2005-2013

- Developed leads and tracked potential sales from development to close throughout a 400-mile territory.
- Conducted over 100 enrollment meetings for employer groups of various sizes.
- Effectively tracked and reported sales leads through verbal and written communications.

Credentials Coordinator, *MED3000*, Pensacola, FL, 2002-2005

- Verified credentials for over 1500 active medical providers in numerous states.
- Adhered to NCQA accreditation guidelines resulting in a perfect 100% audit score in 2004.
- Created training tools utilized for newly hired employees.

Accreditation Manager and Crime Analyst, *Tyler Texas Police Department*, Tyler, TX, 1998-2002

- Documented compliance of national accreditation standards and presented the department for onsite accreditation.
- Conducted over 50 presentations to department personnel, community leaders, and leadership personnel of outside agencies.

- Provided support to members of the department and community to provide for proactive policing.
- Reported crime statistics to both the state and federal governments.

Telecommunications, *Tyler Texas Police Department*, Tyler, TX, 1990-1998

- Supervised a shift of eight police telecommunicators to including hiring and training new personnel and completing personnel evaluations.
- Answered and directed both emergency and non-emergency calls for service.
- Dispatched both police and fire units in response to calls for service.

Licensure / Certifications

- State of Florida 215 Health, Life and Variable Annuity License #P00712, 10/25/2005 - 5/31/2020.
- NRA Instructor Certifications: Pistol, Shotgun, Rifle, Personal Protection Inside the Home, Personal Protection Outside the Home, Refuse to Be A Victim, and Chief Range Safety Officer #154320257, 4/2/2008 - 4/30/2020.

Professional Memberships

Eta Kappa Nu (HKN), 2016-Present
Honors society of IEEE

Society of Women Engineers (SWE), 2018-Present

Volunteer Experience

BEST Robotics Competition, 2016-Present
Escambia River Sportsman's Foundation, 2008-Present
Pensacola Junior League, 2006-2010
Pensacola Habitat for Humanity, 2005-2009

RAYMOND FLEMING

3205 E Olive Rd Apt 85 Pensacola, FL 32514
8502913018 rwf5@students.uwf.edu

PROFILE

Computer Engineer with 4 years of education in design and testing of electrical circuits and programs. Have received a BSCE degree, and possess a sound understanding of fundamental principles and trends in computer engineering. Eager to learn and adapt to new environments, products, and projects.

Product Development	Quality Control	Safety and Compliance
Technical Documentation	Schematic Design	Maintenance Standards

PROFESSIONAL EXPERIENCE

Best Buy Minneapolis, MN 2007 – Present
Best Buy is a very large retailer and service provider to consumers and businesses.
Desktop Support - Geek Squad
One of the largest Information Technology providers in the United States. The IT portion of the company has been part of Best Buy since 2004.

- Use troubleshooting theory to identify the source of a problem.
- Repair the problem using available tools, or part replacement when necessary.
- Documenting and posting found fixes for others to use through a company wide knowledge base.
- Contribute to editing and updating the knowledge base for fixes found by others.
- Instructing youth about technology yearly from 2016-2019 through Geek Squad Academy.
- Delivering meetings centered around difficult repair processes to between 20 and 150 employees.
- Training other employees to be effective technicians both in a remote and an office environment.
- Pilot employee for testing processes before expanding new processes company wide.

EDUCATION

University of West Florida 2007 - 2019
Bachelor of Science in Computer Engineering

- Best Robotics Volunteer 2017-2019.
- 2019 Member of the UWF Solar Car Project to race in the American Solar Car Challenge.

COMPUTER PROFICIENCIES

Autodesk Inventor	C++	VHDL
Linux	Windows	Mac OS
3D Printing	Motorola Assembly	MATLAB

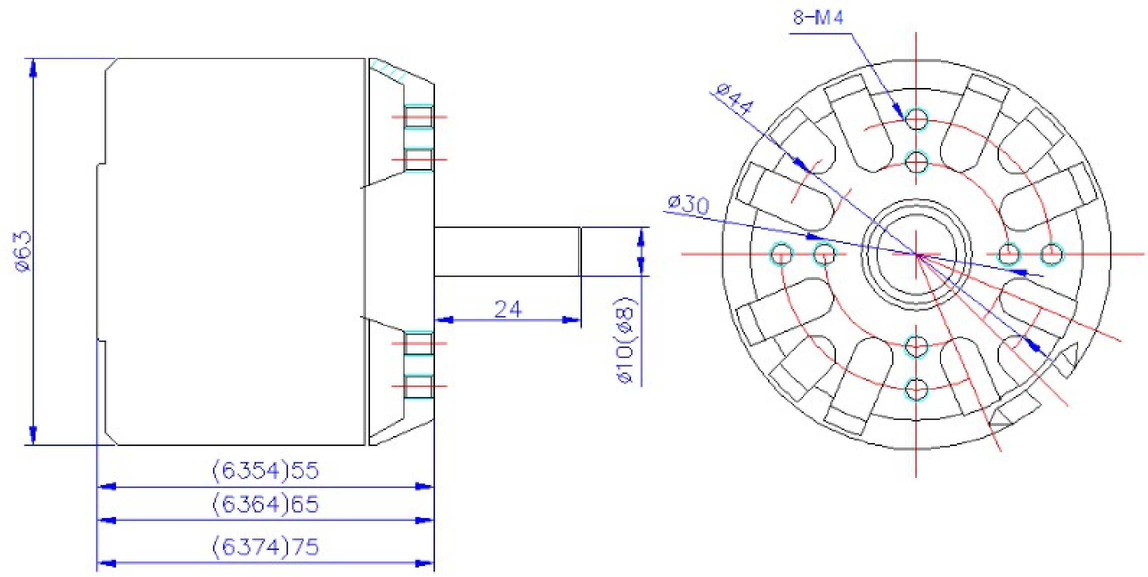
MEMBERSHIPS

Institute of Electrical and Electronics Engineers (IEEE) 2014 - Present

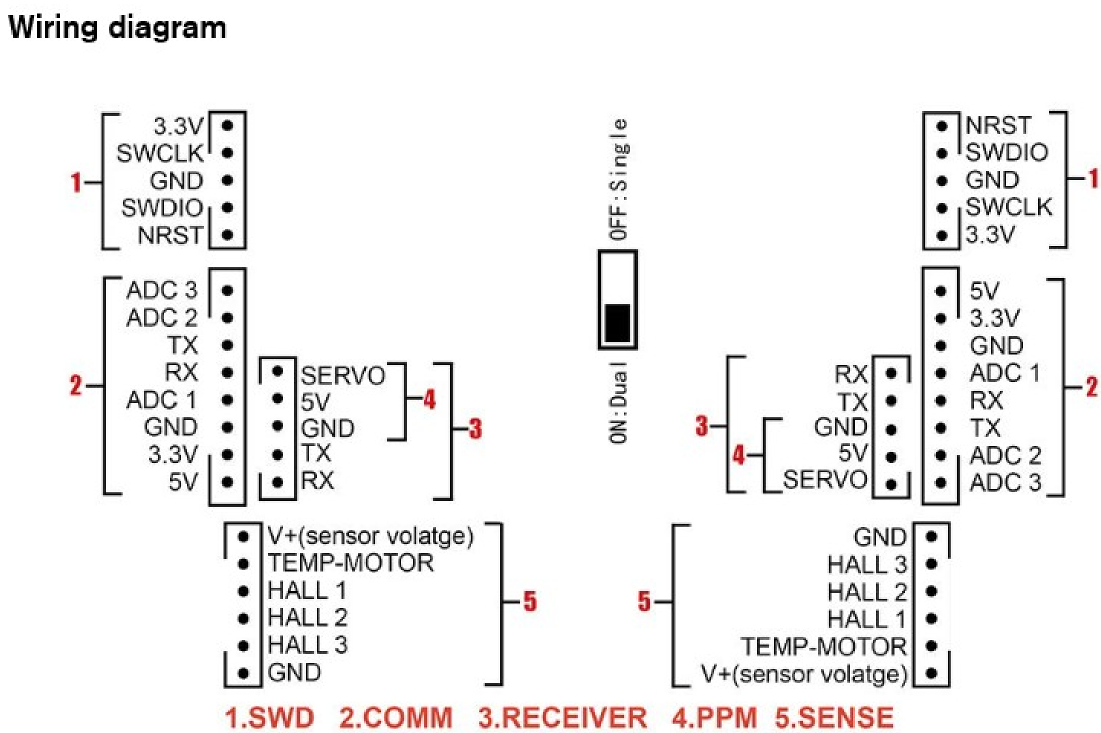
**PLACEHOLDER FOR JULIAN

Appendix B – Parts Diagrams

BLDC Belt Motor 6374 (190kV/3250W)



Dual FSESC6.6 Motor Controller



Golden Motor 3KW Performance Data

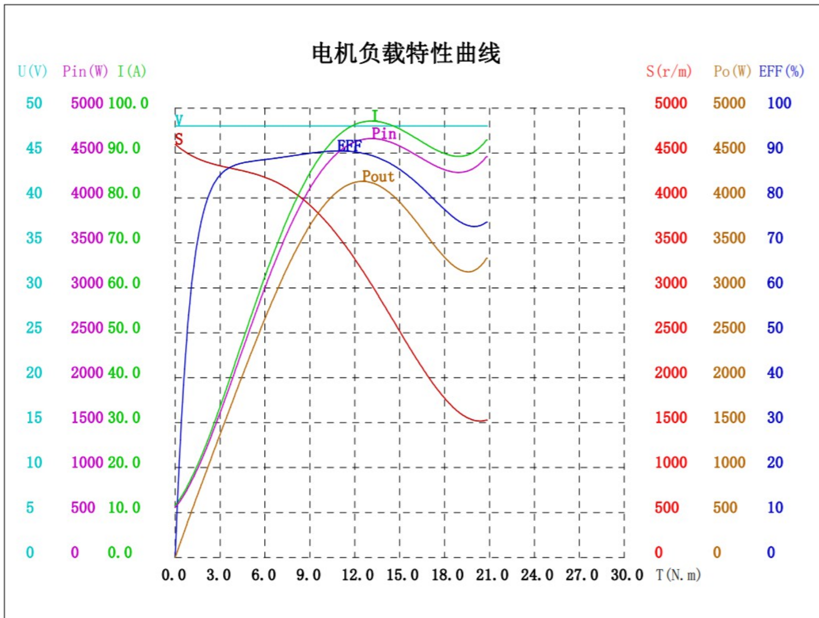
Golden Motor电机测试数据报表

电机型号	3KW			额定电压		48(V)	
单位名称	GOLDEN MOTOR			额定电流		85(A)	
测试人	1			额定功率		3000(W)	
测试日期	2014-12-31			额定转速		4000(r/m)	
No.	U(V)	I(A)	Pin(W)	T(N.m)	N(r/m)	Pout(W)	η(%)
001	48.0	14.87	715.3	0.7	4489	371.0	51.9
002	48.0	15.30	735.7	0.9	4487	433.0	58.9
003	48.0	16.07	773.0	0.9	4484	432.0	55.9
004	48.0	16.82	809.2	1.0	4480	494.0	61.0
005	48.0	18.10	870.5	1.1	4472	554.0	63.6
006	48.0	19.91	957.6	1.4	4461	676.0	70.6
007	48.0	22.67	1090	1.7	4445	796.0	73.0
008	48.0	26.16	1258	2.1	4421	975.0	77.5
009	48.0	30.02	1443	2.5	4396	1152	79.8
010	48.0	34.17	1643	3.0	4366	1384	84.2
011	48.0	38.39	1845	3.5	4339	1615	87.5
012	48.0	43.64	2097	4.0	4308	1841	87.8
013	48.0	49.07	2358	4.6	4267	2061	87.4
014	48.0	54.37	2613	5.2	4234	2338	89.5
015	48.0	59.81	2874	5.9	4200	2610	90.8
016	48.0	65.69	3157	6.5	4159	2866	90.8
017	48.0	71.96	3458	7.3	4119	3180	92.0
018	48.0	78.72	3783	8.0	4073	3425	90.5
019	48.0	87.20	4186	8.9	4017	3773	90.1
020	48.0	94.31	4527	10.0	3914	4098	90.5
021	48.0	94.55	4538	10.9	3578	4084	90.0
022	48.0	94.83	4551	12.2	3170	4050	90.0
023	48.0	94.60	4540	14.0	2632	3859	85.1
024	48.0	93.03	4465	16.8	2167	3812	85.4
025	48.0	92.81	4455	20.8	1508	3284	73.7

Golden Motor 3KW Performance Curves

Golden Motor电机测试报告

电机型号(Type)：	3KW	额定电压(Voltage)：	48(V)
单位名称(Company)：	GOLDEN MOTOR	额定电流(Current Rated)：	85(A)
测试人(Tester)：	1	额定功率(Power Rated)：	3000(W)
测试日期(Test Date):	2014-12-31	额定转速(Speed Rated)：	4000(r/m)



起始点(Start):0.7(N.m)
转速 = 4489 (r/m)
电流 = 14.87 (A)

最大转矩点(Max_Torque):
转矩 = 20.80 (N.m)
转速 = 1529 (r/m)
电流 = 92.93 (A)
输出功率 = 3329.3 (W)
效率 = 74.64 (%)

最大输出功率点(Max_Pout):4184.6 (W)
转矩 = 12.52 (N.m)
转速 = 3191 (r/m)
电流 = 96.89 (A)
效率 = 89.97 (%)

最高效率点(Max_Pout):90.47 (%)
转矩 = 11.06 (N.m)
转速 = 3539 (r/m)
电流 = 94.38 (A)
输出功率 = 4098.4 (W)