January 20, 2014

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, BC, V5A 1S6

Re: ENSC 440 Project Proposal for an Advanced Function Maximum Power Point Tracking Battery Charger for 12 Volt Lead-Acid and 16 Volt Ni-Cad Batteries

Dear Professor Rawicz:

The product outlined in the attached *Proposal for an Advanced Function Solar Power Batter Charger for 12 Volt Lead-Acid and 16 Volt Ni-Cad Batteries* is a project meant to fulfill our requirements for the course ENSC 440: Capstone Project and ENSC 305: Project Documentation at Simon Fraser University. Our goal is to design and implement a battery charger using a solar panel as a power source.

The purpose of the proposal is to outline the basic considerations of our product including cost, budget, project planning, research rationale, funding, and project organization. Furthermore, this proposal will outline the market for a commercial project and the market competitors.

Solar Solutions consists of five members and is receiving funding from Analytic Systems, which is North America's fastest growing power conversion company. You may contact me by phone at 604-761-4568 or by email at rhargrov@sfu.ca if you have any concerns or questions about our proposal.

Sincerely,

Richard Hargrove

Richard Hargrove
President and CEO
Solar Solutions

Enclosure: *Proposal of Advanced Function Maximum Power Point Tracking Battery Charger for 12 Volt Lead-Acid and 16 Volt Ni-Cad Batteries*

School of Engineering Science ▪ Simon Fraser University
8888 University Drive, Burnaby, BC ▪ (778) 321-7183

Proposal for an Advanced Function Maximum Power Point Tracking Battery Charger for 12 Volt Lead-Acid and 16 Volt Ni-Cad Batteries

ENSC 440: Capstone Project, ENSC 305: Project Documentation

Project Team: *Samuel Chow*
Richard Hargrove
Sulki Hong
Saman Hoshyar
Filip Zivkovic

Sponsors: *Analytic Systems, Delta*
(604) 946-9981

Proposal Date: *January 20th, 2014*

Panel: *Dr. Andrew Rawicz*
Steve Whitmore

Executive Summary

> **"Solar energy is a clean alternative energy source. It's clear, given the current energy crisis, that we need to embrace new sources of renewable energy that are good for our planet. I believe very strongly in using technology to provide affordable options that all consumers can put into practice [1]."**
> -Yang Yang, UCLA Engineering Professor

With energy becoming increasingly scarce, Yang's beliefs are becoming common around the globe. The need and demand for an alternative energy source has increased. Correspondingly, the needs for a product that uses and harvests these alternative energies have also increased. Some possible alternative energy sources that are available include nuclear, hydro, wind, geothermal, and solar energies.

For our project we decided to use solar energy as our source to charge a 12 Volt Lead-Acid or16 Volt Ni-Cad battery. Initially requested by BC Hydro in 2007, our product strives to replace the existing battery chargers that are in use across British Columbia. Solar panel battery chargers are especially required due to the remote locations in which they are deployed. Since it is a product that BC hydro requested, a market does exist for the product. However, the market is not our concern. The product will belong to Analytic Systems, ultimately making them our client. We undertook this project to gain valuable experience in hardware and embedded software skills required to create and control the prototype power supply.

Solar Solutions consist of five fourth year engineering science students with different backgrounds and different experiences. It is expected that our engineering cycle will include research, design and construction and testing of a prototype within the deadline of the due date of the project. Thus far, we have a budget of $2500 from Analytic Systems with the possibility of additional funding if required.

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Background of Maximum Power Point Tracking

The efficiency of solar panels is a hot topic in creating sustainable energy; however, the storage of the power itself is not a completely efficient because the input power is varying with changes in UV exposure. Maximum Power Point Tracking (MPPT) is required to choose an optimal voltage for power storage. Figure 1 shows the I-V curve for solar panel power sources with varying amounts of sunlight.

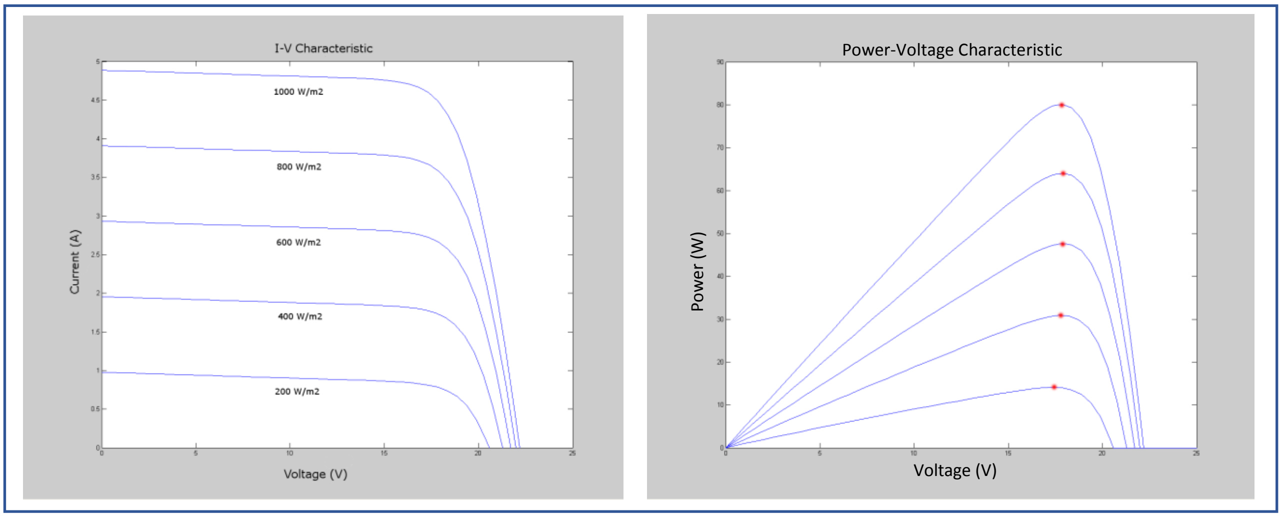


Figure 1: *The I-V and P-V Characteristic of Solar Panels [2].*

A strong market exists for the battery charger we are creating. One report from BC Hydro says they “would like to acquire a battery charger with advanced functions to replace its existing battery chargers at various sites throughout British Columbia [3]”. These chargers are placed in remote sites where other power sources are not available.

Figure one briefly elucidates the need for MPPT. In order to maximize power drawn from a solar cell, one needs to set the voltage across the solar cell such that it corresponds to the knee seen in the IV curves as shown on the left side of figure 1. In figure 1, the curves on the right represents the integral of the IV curves for the solar panel. Maximizing this integral will result in maximum power draw.

Introduction to Helios MK-I

The product name is Helios MK-I, and can be broken down to a few main components. The heart is the micro-controller (dsPIC33EP512MC806), which will take inputs from temperature sensors (LM50C), current sensors and additionally, voltage sensors if needed. The power conversion is implemented with a Non-Inverting Cascaded Buck-Boost Converter (NICBBC). The inductor of the NICBBC has already been designed at 48.4 micro-Farads, we have already selected the core, and wound five inductors with a 5% tolerance. We expect to have ordered 5 Printed Circuit Boards (PCB's) by February 10th, 2014, after which embedded software, control, testing, sampling of data and storage into FLASH memory with corresponding dates and times to be extracted using RS-232 serial communication. This data will be extracted using Visual Basic. Due to the difficulty of our project, we had begun planning many months ago. Table 1 outlines the key aspects of Helios MK-I.

Parameter	**Specification**
Input Voltage Range *Requirement*	8 Volts to 32 Volts
Target Input Voltage Range	6 Volts to 36 Volts
Maximum In/Out Current	20 Amps
Maximum Output Voltage	20 Volts
On Board Communication	
Micro-controller debugging during design is done via Pickit 3	
Communication from micro-controller to Flash memory	
RS-232 communication from Flash memory	
In circuit temperature readings must be read by micro-controller	
Serial-communication to chip using Visual Basic	
Components which will be Used	
Component Number	**Task**
LM50C	Temperature sensing
dsPIC33EP512MC806	Digital Control, memory storage
Hand-Wound Inductor	Main component of Buck-Boost
Software	
MPLAB® X, C 16 compiler, which is compatible with dsPIC, and free	
Power456 for buck-boost design and inductor core selection	
LTSpice and Altium for electronics design and simulation.	

Table 1: *The technical project description of Helios MK-I*

Scope of Helios MK-I Project

Summary of Challenges

Due to the nature of MPPT Battery Chargers, Helios MK-I's scope covers a wide range of fields. Both solar panels and lead-acid batteries need to be explored in some detail. To maximize solar panels efficiency one must implement an MPPT algorithm. This involves understanding of solar panel I-V curves and how they vary with differing amounts of sun exposure and temperature. With lead-acid batteries it is very important to ensure the batteries are charged correctly, or else explosions and fires can easily occur. This requires understating of lead-acid battery chemistry and make-up. In order to properly charge these batteries the Helios MK-I needs to work in both constant current and constant voltage modes.

On top of this, Helios MK-I also encompasses the field of switch mode power supply design. Within this discipline several different and widely ranging sub-disciplines are contained. The topology we have chosen to implement for the converter is called a non-inverting buck-boost topology. This topology offers several advantages such as the lack of a power transformer which reduces cost and simplifies control. However it also has its detractions such as the requirement for high side drive and difficulty in achieving high efficiencies. To reduce costs and keep more engineering options open, the Helios MK-I inductor is being wound in production, this requires understanding of magnetic materials, magnetic switching losses and requires a trial and error approach that is suitable for inductor design. Other things to be considered include the auxiliary power supply for the high side switch, and the 5/3.3V rails for op-amps, and microcontrollers.

Due to the high power density of this product, we must take into consideration the thermal aspect of the design. Proper heat sinking is critical to keep important and sensitive parts of the circuit cool. This is done by a combination of using a high efficiency design and interleaving PCB design and chassis design to maximize heat transfer to surroundings.

Summary of Risks

Alternative energy is a volatile field. Many who have rolled the dice and invested in alternative energy have left millionaires, and many have left with nothing. It is not uncommon to hear of giants such as Abound Solar crash spectacularly even after almost half a billion dollars of stimulus help from the government [4]. According to recent studies, the boom era of solar cell installation has come to end. Now the market is seeing more realistic growths [5]. The growth that was seen by the solar cell industry over the past few years can be credited to many different government policies enacted meant to increase solar cell usage in the early 2010s. This boom left the market saturated and severely reduced the price of solar panels in turn creating a slump which led to many companies leaving the solar cell sector. China has exasperated this problem by flooding the market with cheap solar panels [6].

The installation rate of solar cells in Europe dropped from 2011 to 2012 for the first time in 12 years; however global solar cell installation rate has remained constant. The future of the solar cell industry depends on many factors, most of them out of the hands of solar cell companies.

If governments no longer back solar energy and another global recession is encountered, it is likely that solar's share of the market would dwindle in lieu of conventional sources of power such as coal or nuclear.

One major risk Helios MK-I can suffer from is lack of efficiency. Failing to achieve a respectable efficiency would lead to an unsellable product. As our competition has a tremendous amount of experience, funding and time, they can afford to create products with 95%+ efficiency, It is unlikely we will reach such figures. To make Helios MK-I a success, we must keep design and manufacturing costs as low as possible. Given our lack of experience, this requirement of efficiency and low cost will be very taxing. We expect to hit several road blocks.

One threat to Helios MK-I comes from cheap replicated MPPT chargers which can sell at extremely low prices through being made by underpaid labor and a complete avoidance of any engineering safety factors or use of reliable electronic components.

Summary of Benefits

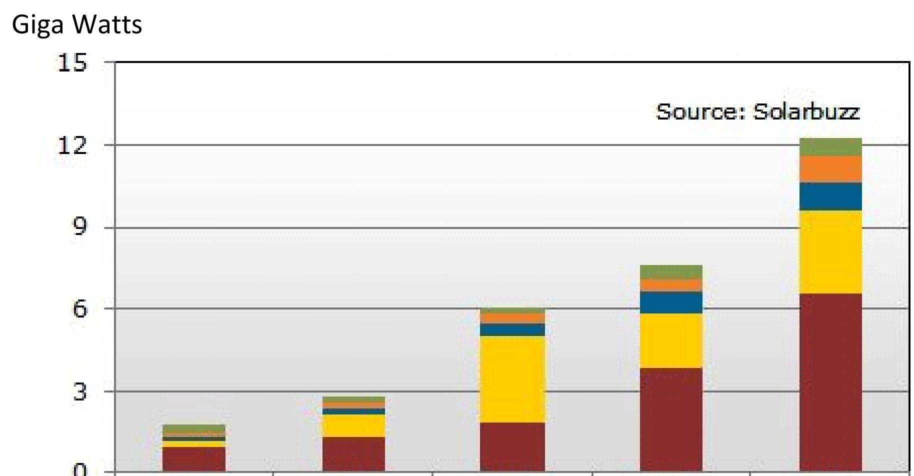
The tumultuousness of the Solar Energy sector aside, there is money to be made. Our product is not aimed at megawatt range installations, rather for smaller, isolated areas such as remote radio towers. For the vast majority, the most economical solution to powering these remote outposts is solar or wind. Since solar power has no moving parts, the maintenance is far less than that of wind power.

Beside the economic and momentary benefits that this product can bring, phrasing Dr. Jones of SFU, it is also a beautiful application of engineering for betterment of mankind. Solar Energy reduces the reliance on other fuels which can accelerate global warming. Further studies into MPPT solar cell schemes on larger scales can help make large scale solar panel installations more attractive options which can lead to a growth in alternative energy, helping the environment and reducing human's carbon footprint.

Commercial Overview of Helios MK-I

The Market of Helios MK-I

Much of our main energy sources are progressively becoming harder to extract; coal, oil and nuclear have their downfalls. One needs no better proof of this than the suffocating smog of Shanghai skyline or the desolation of Chernobyl's backdrop. Not only are such resources depleting, but as we can see, they are also harmful to our environment. There is much global awareness of pollution, leading to global actions and large markets in the field of alternative energy. Renewable energy is becoming the future, and Solar Energy is becoming increasingly demanded. This market has been growing in the past years, mainly in European countries and areas that receive sun for long periods of time throughout the year. According to Solar buzz (Solar Market research association) in 2009, the photovoltaic solar industry generated $38.5 billion in revenues globally, which includes the sale of solar modules and associated equipment, and the installation of solar systems [7]. Below is Figure 2, showing the amount of solar power used per each region, and it's respective increases from 2006 to 2010.



	2006	2007	2008	2009	2010
JPN	0.30	0.23	0.23	0.48	0.62
USA	0.14	0.22	0.36	0.49	0.97
ROW	0.15	0.22	0.50	0.81	1.02
ROE	0.18	0.82	3.13	1.94	3.01
GER	0.97	1.33	1.86	3.87	6.60

Figure 2: *PV Market Size Segmented by Region, Demonstrating Increases in Solar Demand per Region [7].*

Solar technology has improved so drastically that IKEA is planning on selling residential solar panels [8]. Each solar panel requires MPPT implementation. The evidence proves a growing market for Helios MK-1.

Market Competition with Helios MK-I

Many companies provide power solutions such as Xantrex, Go Power, Solio, and many more. The impact of the competition upon Helios MK-I profits relies on the similarity of the competitor's product to Helios MK-I, the release date of the competitors product and the performance of Helios MK-I in comparison to its competition.

Research Rationale of Helios MK-I

By no means are we trying to sweep the market with our design, as we have been allotted 13 weeks to finish this project. We will demonstrate an impressive prototype so as to excite the interest of investors. Though we may not get to the point of a selling model, our preliminary designs will show innovation as a product. Our first goal is to implement a design that is cheap, a cost efficient product that works well. The reason why solar energy is becoming more accessible is because of how inexpensive it is becoming. Next we want the product designed with digital controls; many battery chargers use analog controls. Digital control provides added versatility in different areas. An example is if the product malfunctions there are fewer parts to check for malfunction. If there is a better algorithm that can be used it is a matter of updating the firmware or replacing the microcontroller. The addition of the microcontroller will prove for a more robust and durable product.

The Background of Solar Solutions Founding Members

Helios MK-I Team Organization

To maintain the dynamics and communications amongst the members, we will hold meetings on Tuesday/Thursday at 1:30pm to delegate work and discuss progress. Further meetings are held on Wednesdays and over weekends at Analytic Systems. Every meeting will be limited in duration to ensure that time is used efficiently and communications between the members stay on topic. Meetings at Analytic Systems are usually intended to provide access to test equipment and components that are not available at SFU or our residences.

It is anticipated that tasks will be allocated based on the strength and weaknesses of the team members. However, due to the scope of work, sometimes it is inevitable to assign work to a particular member who is not familiar with the work. Moreover, it is expected that if a member struggles to complete a task within a deadline, other members make themselves available to help out. Because we believe that group dynamics and teamwork is important to successfully complete ENSC 440, we will ensure that we continue to support each team member with respect and teach each other the aspects which we learn.

Founding Member Profiles

Solar Solutions encompasses five creative, passionate and talented undergraduates as its founding members: Richard Hargrove, Saman Hoshyar, Sulki Hong, Samuel Chow and Filip Zikovic. With differing backgrounds and interests, each member will and has already contributed specific expertise to create Helios MK-I. Each member's expertise and title is outlined below.

Richard Hargrove, Chief Executive Officer

With my extensive experience in the alternative energy industry in production, test and design positions I am well equipped to be a team leader for every part of this project (software, firmware and hardware). I have designed several custom circuits, attended a workshop on power supply design, spent 8 months on Co-op working on batteries, implemented a Solar Panel simulator in Visual Basic, and wrote my own firmware for an Ammeter/Voltmeter. Aside from all the technical skills, I also have the vision and the understanding to ensure the project meets all of our goals.

Saman Hoshyar, Chief Technical Officer

I bring my passion of electronics and hardware with my extensive experience with both analog and digital circuitry design to Solar Solutions. I have experience designing power magnetic, transducer circuits, feedback networks and control circuits. I am experienced in optimizing high frequency high power circuits to achieve high efficiency and high reliability. I have gained experience in the power converter field through interning at a power supply company, extensive readings and experimentation on personal projects.

Samuel Chow, Chief Operations Officer (COO)

I will be bringing software skills to Solar Solutions that include coding embedded systems, ability in C++, VBA, LT Spice and familiarity of microcontrollers. Accompanying are my hardware skills that incorporates circuit analyzing and design. Aside from my education I have built pedals that include A/B line switching, and signal boosts. Working at AMEC in the transmission and distributions department has given familiarity with power systems, knowledge on the power grid and how our product will be able to be incorporated in real time.

Sulki Hong, Vice President of Software Engineering

I am a fourth year Systems Engineering student at Simon Fraser University with variety of different experiences gained from courses and co-op. I am familiar with basic electronic equipment such as oscilloscopes, power supplies, function generator and digital multimeters. Similarly, I am experienced with using LT Spice to simulate and build circuits. Furthermore, I am familiar with C++ programming as well as real time embedded systems. Last, but not the least, I have a very strong communication and team-work skills.

Filip Zikovic, Vice President of Firmware Engineering

My strongest assets are those covered in labs, such as digital and analog circuit analysis, CPU architecture, VHDL, and assembly programming. Furthermore, I completed a course beyond my curriculum, “Data Structures and Algorithms”, so as not to be limited by the scope of my degree. Through this course, and past employment, I have become proficient in C++ and Matlab. Firmware has been a hot topic in many courses, and is one of my best strengths as an engineer.

The Budget, Funding, and Schedule of Helios MK-I Prototype

The Budget and Funding of Helios MK-I Prototype

We have been contracted by Analytic Systems to design Helios MK-I 300W Maximum Power Point Tracking Battery Charger. This design requires a Printed Circuit Board and several expensive components.

Although funding for the project will be provided by Analytic Systems our goal is to keep component costs under $2500 while utilizing all of the resources provided by Analytic Systems that may exceed $2500 in value (chassis', components on site, wires, tools, production machines, etc.). A tentative budget is provided in Table 2 below.

Item	Cost
PCB Prototype #1	$500
Components Prototype #1	$500
PCB Prototype #2	$500
Components Prototype #2	$500
Total	$2000

Table 2: *Tentative budget for the design and verification of the Helios MK-I Prototype.*

The proposed budget allows for an additional $500 in materials and components and provides for a second revision of our circuit board. Furthermore, we will apply for funding from the Engineering Science Student Society at SFU, and utilize the $50 funding each group receives for their project.

The Schedule of Helios Mk-I Prototype

Our intended schedule is represented below in a Gantt chart. Only major tasks are highlighted and there are many aspects to each part of the project that need to be considered as well. To ensure we remain focused and on schedule we intend on having bi-weekly meetings to monitor each other's progress and assist with any problems, as outlined in the "Team Organization" section.

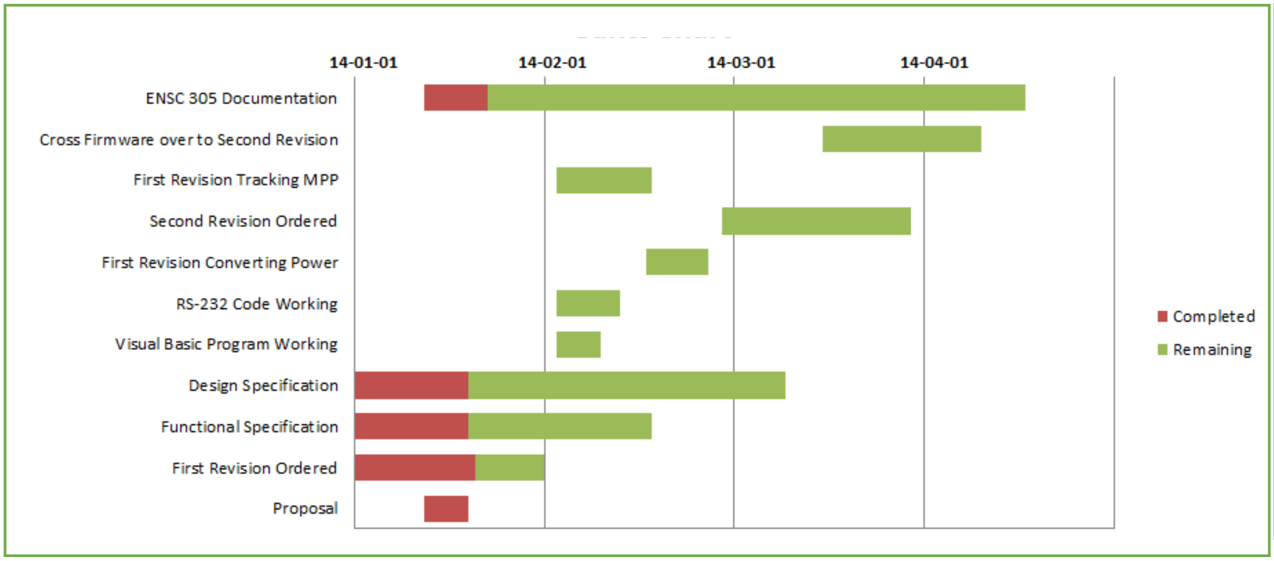


Figure 3: *Proposed Gantt Chart for the Development of Helios MK-I Prototype.*

Conclusion of Project Proposal

The high-tech team at Solar Solutions will create a physical prototype of an advanced function MPPT battery charger for 12 volt lead-acid and 16 volt Ni-Cad batteries as our capstone project.

Firstly, the members of the Solar Solutions team are well dedicated and motivated to the project. The following tasks have already been completed by each member.

- *Richard Hargrove* has already attended a power-supply design seminar held by Ray Ridley, one of the top power-electronics industry consultants. Richard brought back professional software and expertise, making the project possible.
- *Saman Hoshyar* has already began designing the high-side driving circuit for the power stage weeks ago, and has demonstrated working simulations which will likely reduce the requirement to order expensive parts, while sustaining the switching performance.
- *Filip Zivkovic* has already demonstrated understanding over the PIC microcontroller, setup the software, and understands how to program interrupts, timers, and the MPPT algorithms.
- *Sulki Hong* has already written code in Visual Basics that will use the serial port to extract data from Helios MK-I using the RS-232 protocol.
- *Samuel Chow* has designed and wound inductors within the 5% tolerance with various metal cores and wire thicknesses, so as to determine the optimal trade-off between material and heat dissipation. A bode plot was performed on each inductor.

The Helios MK-I product is contracted to Analytic Systems, who are covering the expenses, and providing both the funding and professional resources for the project. The main costs include the PCB's, chassis, power inductor, and the ordered electronics. The software used is available in free academic versions, and will be sufficient for the project.

The Solar Solutions Team is confident to propose Helios MK-I as our capstone project. Not only will we design and simulate the project, we are contracted to build a functioning prototype. Writing the firmware, testing for EMI, and collecting data of the prototype performance are all expected to be time consuming tasks. Therefore, a large amount of time has been designated for the completion of these tasks, and the team has already begun the project. Our next milestone is ordering a PCB by February 1st. The full schedule of our project has been outlined in a Gantt Chart, along with the organizational steps that will be taken to ensure each deadline is met.

References

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