Hybrid Solar/Battery for Electronic Derailleur

Design Document

sdmay22-01
Client and Advisor - Dr. Raj Raman
Team Members:
Aydin Bashich……..……………………..………..Circuit testing
Connor Davison……………………..…………..Circuit testing
Elba Estarellas…………..…Verification and Documentation
Mohamed Mohammed.…...Circuit testing and Verification
Seth Pierre……..…….Case Design and Battery Assembly
Rachel Vallier…………….Verification and Documentation
Jack Waskow………………Battery Assembly and Testing

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Development Standards and Practices Used

Development Standard 1:

1679.1-2017: Guide for the Characterization and Evaluation of Lithium-Based Batteries in Stationary Applications: https://ieeexplore.ieee.org/document/8262521

The article titled “Guide for the Characterization and Evaluation of Lithium-Based Batteries in Stationary Applications”, is a guide on how to take proper precautions while using a lithium battery. The project consisted of charging and discharging a lithium battery safely, so the guide assisted in understanding the proper precautions.

Development Standard 2:

1562-2021: IEEE Recommended Practice for Sizing Stand-Alone Photovoltaic (PV) Systems: https://standards.ieee.org/standard/1562-2021.htm

The article titled “IEEE Recommended Practice for Sizing Stand-Alone Photovoltaic (PV) Systems”, discusses the recommended sizes for photovoltaic systems. The project focused on determining the proper size for the PV cell in order to satisfy the client’s constraints and the electrical requirements.

Summary of Requirements

List of all requirements

- Solar cell must be approximately 2 x 2.5 inches
- Must output sufficient power to fully charge the battery within 6 hours
- Battery must be of sufficient size to last 10 hours in low light
- System must be mechanically robust and weather-resistant
- System must include charge controller to protect the battery
- Total cost not to exceed $500
- Battery and solar cell must be one unit

Applicable Courses from Iowa State University Curriculum

List of applicable courses

- EE 201: Electric Circuits
- EE 230: Electronic Circuits and Systems
- EE 285: Problem-Solving Methods and Tools for Electrical Engineering
- EE 330: Integrated Electronics
- EE 333: Electronic Systems Design
- EE 491: Senior Design Project 1 and Professionalism
- EE 492: Senior Design Project 2 and Professionalism
- ENGL 314: Technical Communications

New Skills and Knowledge acquired that was not taught in courses

List all-new skills and knowledge

- Understanding charge control and sizing for lithium polymer batteries
- Understanding how to use DC/DC converters
- Hands-on experience with perforated boards
- Prototyping beyond a breadboard
- Testing product for durability
- Better understanding of LTSpice and Arduino
- Designing and printing a case with 3D modeling

Table of Contents

1 Team

1.1 Team Members

Aydin Bashich, Connor Davison, Elba Estarellas, Mohamed Mohammad
Seth Pierre, Rachel Vallier, Jack Waskow

1.2 Required Skill Sets for Your Project

- Knowledge in circuit fabrication to design and model the system.
- Knowledge in mechanical fabrication to meet mechanical requirements.
- Understanding and application of C programming to program Arduino for testing purposes.
- 3D Modeling

1.3 Skill Sets covered by the Team

- Aydin Bashich - Coding and circuit design
- Connor Davison - Coding and mechanical fabrication
- Elba Estarellas - Simulation
- Mohamed Mohammed - Coding and mechanical fabrication
- Seth Pierre - 3D Modeling and circuit fabrication
- Rachel Vallier - Software and circuit fabrication
- Jack Waskow - Circuit fabrication and electrical components

1.4 Initial Project Management Roles

- Aydin Bashich - Technical Team
- Connor Davison - Technical Team
- Elba Estarellas - Documentation Team
- Mohamed Mohammed - Documentation Team
- Seth Pierre - Technical Team
- Rachel Vallier - Team Lead and Documentation Team
- Jack Waskow - Technical Team

2 Introduction

2.1 Problem Statement

The client requested a solar/hybrid battery to provide power to an electronic derailleur. The derailleur is currently powered by a battery that is charged through a wall outlet. The benefit of having the solar/hybrid battery is that the battery will never need to be taken off the derailleur to charge and, therefore, will hypothetically never die because the sun will be able to charge the battery since the bike is outside. For the project, the team determined the components needed to accomplish a set of criteria the client provided for the project. Key constraints include a dark-run time of 10 hours, a charge time of 6 hours in direct sunlight, a weather-proof system that adheres to IP58 standards, and a detachable and compact design.

Current solutions to charge the battery are expensive and require the user to remove the battery to charge it before a ride. The solution presented in this document solves those problems because it does not require an expensive external charger and charges the battery passively while riding.

2.2 Requirements and Constraints

List of all the requirements and constraints for the project

- Solar cell must charge the battery in 6 hours of direct sunlight
- Battery must have the capacity to run for 10 hours in low light
- System must include a charge control circuit to protect the battery and prevent overcharging
- Solar cell must be approximately 2 x 2.5 inches
- System must be mechanically robust
- Solar cell is compact and attached firmly
- Battery must use the existing battery's mechanism for attaching to the bike
- Circuits and batteries must be built to be weather-resistant
- Battery and the solar cell must be one unit
- The device must use the existing battery's mechanism and be detachable from the derailleur
- System must be sleek and compact
- Total cost for project limited to $500

2.3 Intended Users and Uses

The product was designed to the direct specifications of the client, Dr. Raman, an avid cyclist who rides a recumbent bicycle. The product works with all bicycles the original derailleur was compatible with. The price point of the standard derailleur likely excluded casual cyclists, so the focus was to deliver a high-quality product that appealed to the more serious and invested audience.

3 Project Plan

3.1 Project Management/Tracking Procedures

Here is an explanation of the management style that the team adopted for the project. The choices were agile, waterfall, or waterfall+agile.

The team used the waterfall+agile project management style. This suited the project because it allowed the team to pick the project management style that fits best for each step within the project.

The team communicated and collaborated throughout the project by conducting two weekly meetings to make progress on the project. Outside of meetings, the team communicated through email and discord to keep all members informed. Additionally, the team met once a week with the client, Dr. Raman to discuss the group's progress.

3.2 Task Decomposition

Big Tasks	Sub Task	Person(s)	Sub Task	Person(s)	Sub Task	Person(s)
Verification	Cross-checks	Mohamed				
Testing Circuit	Programming Arduino	Aydin	Building Arduino	Connor	Watching	Connor
Battery Assembly	Test Battery on breadboard	Jack	Electrical Assembly	Jack (Seth backup)		
Case Design	Model	Seth	Electical Connections (battery to derailleaur)	Mohamed	Weather Proofing	Seth
Documentation	Biweekly Report	Rachel and Elba	Correct/Update Design Document	Rachel and Elba	Update website	Seth

First Semester

- Assigned owners to design constraints
    - Discussed team members' preferences to assign constraints.
- Individual research was conducted for each constraint.
    - Each team member researched and informed the team of necessary steps or components based on their constraint.
- Parts were selected and ordered

    - The team ensured components theoretically would work together.
- Compiled design document
    - Completed first-semester design document to display progress on the project.

Second Semester

- Tested individual parts and components on breadboard
    - Ensured components worked as predicted.
- Design test board
    - Acquired a deeper understanding of how the components worked together to create a test board.
- Designed and printed attachment with 3D printer
    - Designed attachment for the product to connect the derailleur to the charge controller.
- Revisited design to implement changes and ordered new parts
    - Based on acquired data, the team had to alter the design to meet design requirements. Ordered additional components to implement the design.
- Designed and printed case with 3D printer
    - Designed outer case for the product to ensure weather protection.
- Designed and tested charge controller
    - Determined the original charge controller was not adequate for the design parameters. Therefore, the team designed a new charge controller.
- Tested full charge of electronic system
- Physical Construction
    - Took electronic system and used the 3D printed case to create final design
- Conducted environmental testing using IP58 standards
    - Environmental testing included dust, water, shock, and vibration

3.3 Other Resource Requirements

Below are the parts required for the project.

- 5V 250 mA PV Array
- 7.4V 300 mAh LiPo Battery
- SRAM Rival Etap Axs Rear Derailleur

- Charge Controller
- Arduino Uno
- 5-12 V DC/DC Converter
- 3D Printer
- Soldering Iron

4 Design

4.1 Design Context

4.1.1 Broader Context

Below is a description of the broader context for the design problem.

Area	Application to the project
Public health, safety, and welfare	The bike can be used as a piece of exercise equipment. The derailleur assists. Additionally, the derailleur is run by solar power, which is good for the environment.
Environmental	Increases the use of renewable energy, which decreases the need for nonrenewable energy.
Economic	Maintains a comparable price for a mid to high-end battery. Our target audience is enthusiasts who are willing to spend more on a quality product.

4.1.2 User Needs

The client requested a way to passively charge the battery for his derailleur because he did not want to charge the battery himself.
Electronic derailleurs are a product that largely appeals to avid/invested cyclists and appeals very little to the more casual crowd, so the group has chosen to focus on quality over the product's affordability.

4.1.3 Prior Work/Solutions

There are no known current products on the market like this. However, the client has done some high-level calculations to determine if the battery would be feasible, which he determined it would be.

4.1.4 Technical Complexity

The product consists of a photovoltaic array, a lipo battery, and a charge controller to protect the battery from overcharging. These components were combined into a final assembly that is waterproof, dustproof, and vibration resistant. Lithium-ion charge protection is a meaningfully complex circuit for the scope of this project.

4.2 Design Exploration

4.2.1 Design Decisions

Below is a list of key design decisions.

- Based on the client's requests for battery life and charge time, we have selected a battery of 7.4V and 300 mAh.
- We have decided on a panel with an epoxy dip to satisfy the client's request for a rigid outer coating.
- The solar panel will be mounted to the bike and a wire will be run down to the battery for optimal charging.
- A 3D modeled connection will be used to connect the charging port of the derailleur to the solar panel.

4.2.2 Ideation

Below is a description of one design decision for the project. For this design decision, the team included five options that were considered.

Decisions regarding the location of the solar panel:

- Mount it directly to the derailleur
- Mount it to a point higher on the bike and run a wire
- Mount it to a rear-wheel guard

- Mount it to the handle-bars/frame
- Make an attachment that would mount to the seat post

4.2.3 Decision-Making and Trade-Off

To decide the location of the solar panel, the team weighed the option between putting the solar cell where the client preferred against where the solar cell would perform the best. The length required for the possible wire was also considered, especially when moving parts like the handlebars. Also, the client wanted to have minimal wires if the cell was not directly mounted.

The team decided on mounting the solar panel to the seat post on the bike. The team decided that the solar panel was too large to put the solar cell directly into the derailleur. Additionally, it was determined that the solar cell would have a better performance which will allow the battery to charge in the time requirement of 6 hours.

4.3 Proposed Design

The design is intended to mount to the seat post of the bike and charge the derailleur battery during daytime riding while having the capacity to power long nighttime rides as well.

4.4 Technology Considerations

Here is a discussion of a design alternative.

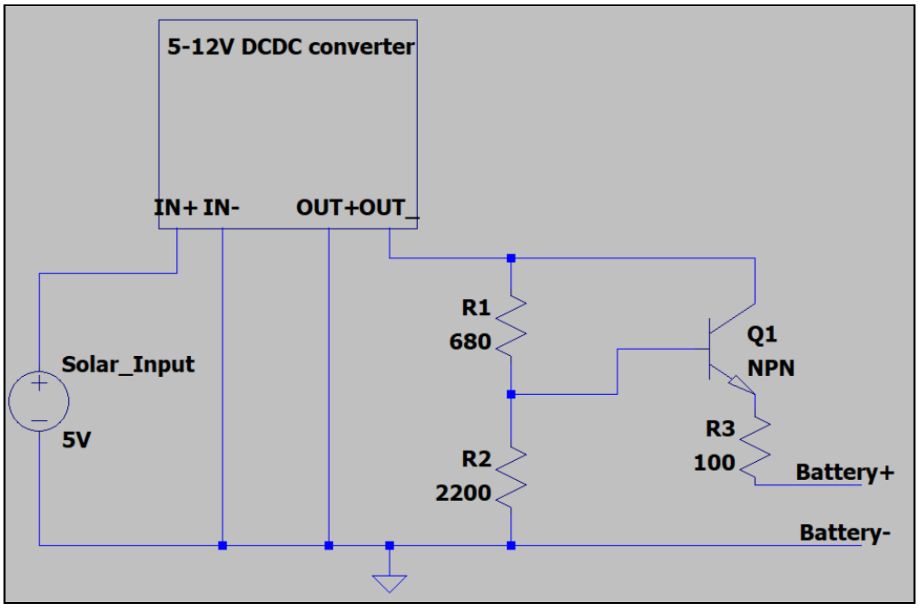
Opting for a small solar panel to fit the client's priority for a sleek design has limited possible power output for the circuit. Assuming roughly 60% efficiency the battery will still charge in the requested 6 hours, but that still assumes fairly ideal conditions that cannot be guaranteed. Using a larger panel in a better location would be ideal for functionality, but that design is something the client does not prefer.

4.5 Design Analysis

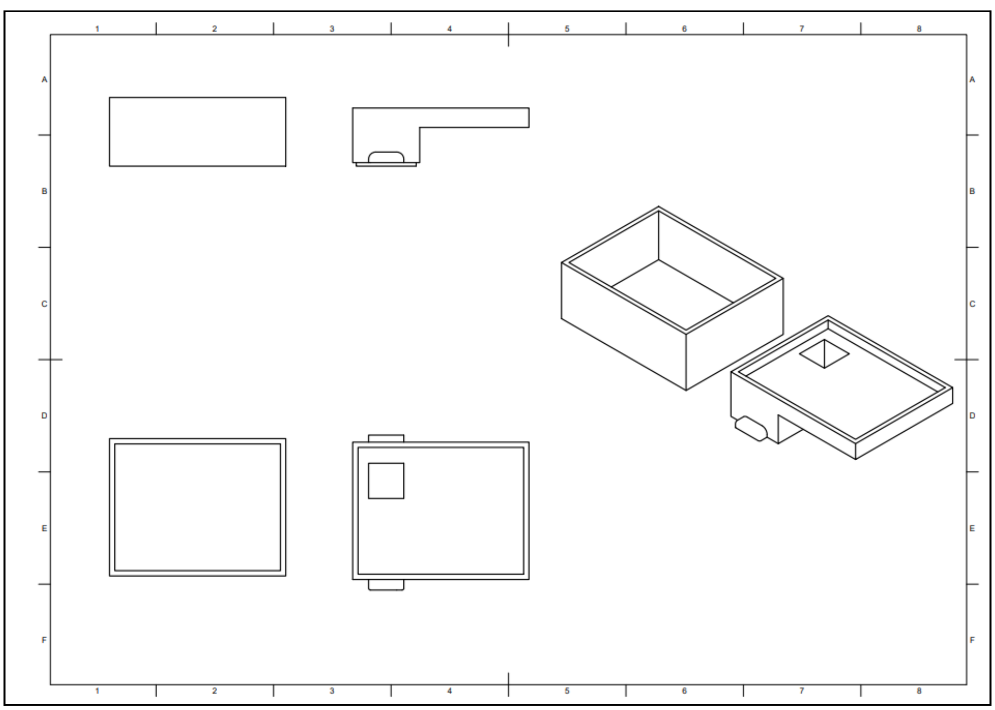
After initial testing and implementation, the team determined that this design alternative was necessary to accomplish the charging requirements. After discussing with the client the new proposed design, he agreed that the

modification was appropriate based on the desired charging time. The initial design can be found in *Appendix 3*.
There were three main design changes after the initial testing and implementation of the system.

- The client requested a size requirement of about 1.5 times the size of the original battery, which included the battery and PV array. After initial testing, the solar cells that were initially ordered received 6 times lower current than was required to charge the battery in the 6 hours time frame. Therefore, the team decided to increase the size of the solar cell from 2.36” x 2.16” to 4.33” x 2.75”. The solar cells used for the project had a current draw of 120 mA in direct sunlight when connected to the whole system. Although the change caused the size requirement to not be met, it was a necessary change in order to meet the charging time requirement.
- The increase in the size of the solar cell caused another change in the design from the initial plan. Initially, the team intended to mount the solar cell directly to the derailleur. However, the solar cell was too big to put safely onto the derailleur. Therefore, the team decided to mount the solar cell to the seat post and run a wire down to the battery. While this was not an ideal location for the client, it was determined it was beneficial because the location also allowed the solar cell to be in direct light for more time, which allowed the battery to charge faster.
- The final design change was the charge controller. Initially, the team ordered a charge controller online. However, after receiving the part, it was realized that the charge controller was not adequate for the system. The team opted to design and implement a charge controller. A picture of the charge controller can be found below. This change did not affect any of the initial requirements or other design aspects of the project.



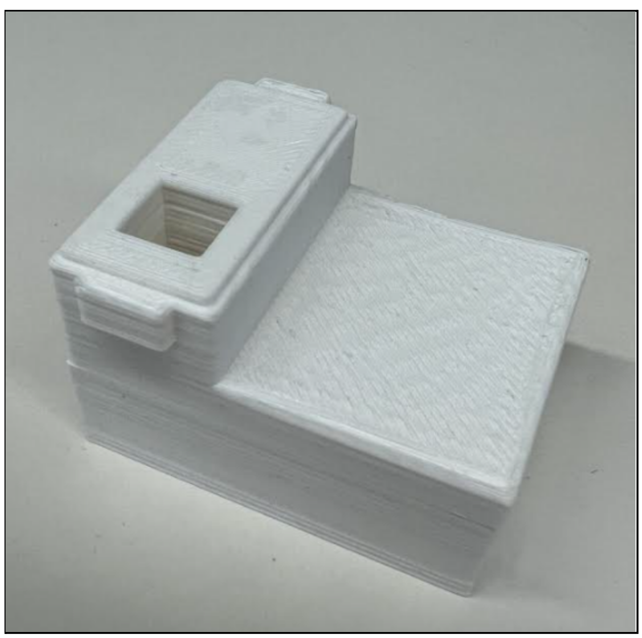
The team also designed a case that was modeled using AutoCAD Fusion 360 to keep the electronic components secured. A schematic of the 3D model can be found below. This case was also tested to be weatherproof. A discussion of the testing of this case can be found under the testing section of this document.



5 Implementation and Testing

5.1 Component Testing

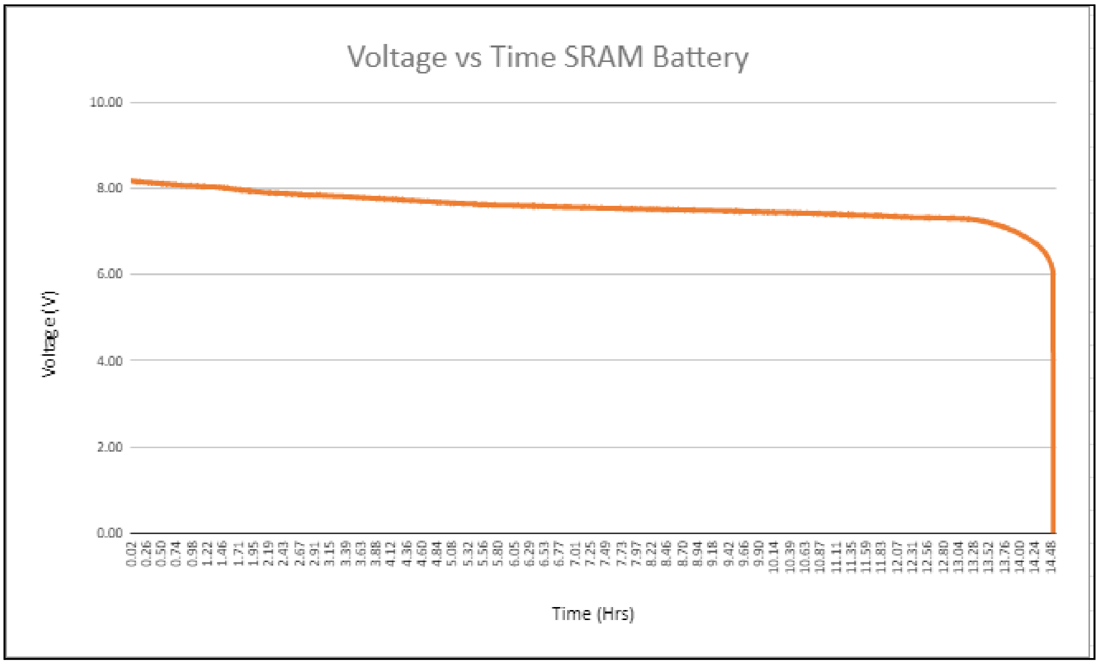
- DC/DC converter: As discussed in the design section, the initial DC/DC converter worked as anticipated.
- Initial Solar Cell: The initial solar cells outputted the expected voltage, which was 3 V. The maximum current was 28 mA but it should have been 120 mA. Due to this big discrepancy, the team determined bigger solar cells would be required for the project to meet the charge time.
- Implemented Solar Cells: The solar cells used in the project were measured to output 6 - 6.12 V and 100 - 190 mA in direct sunlight. When the solar cells were connected to the rest of the components the output was 6 - 6.12 V and 120 mA.
- Charge Controller: The team designed a charge controller which included the DC/DC converter. After testing the charge controller with the system, it was determined that it worked accordingly because the charge controller did not allow the voltage to go above 8.4 V.
- 3D Printed Case: The picture below shows the 3D case that held the circuit and was used to test in the tests conducted below.

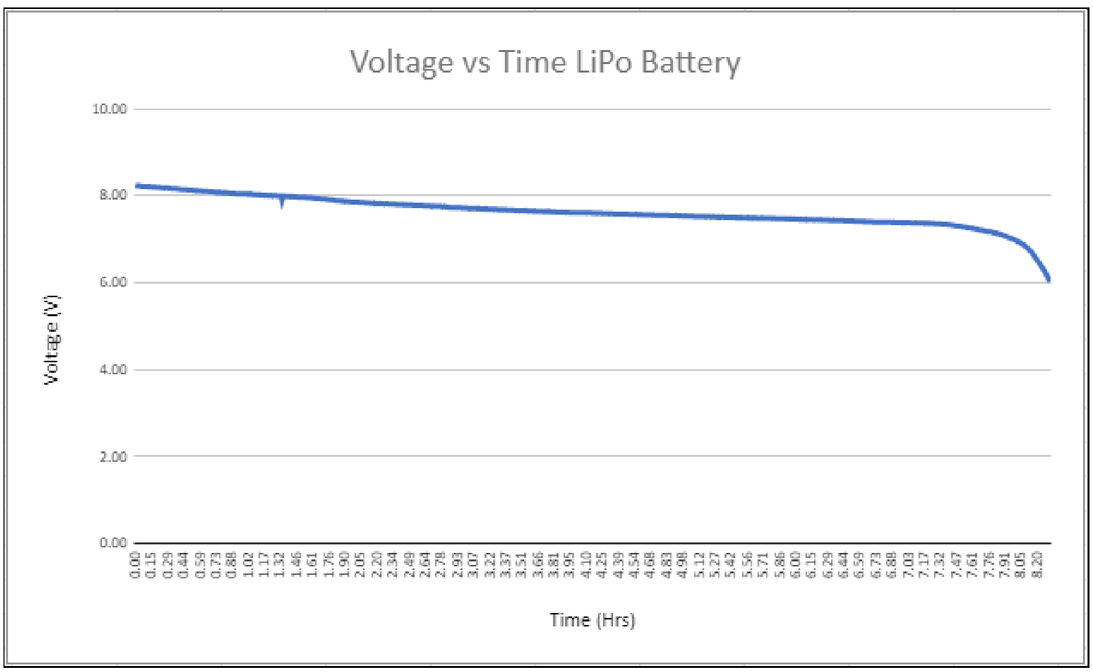


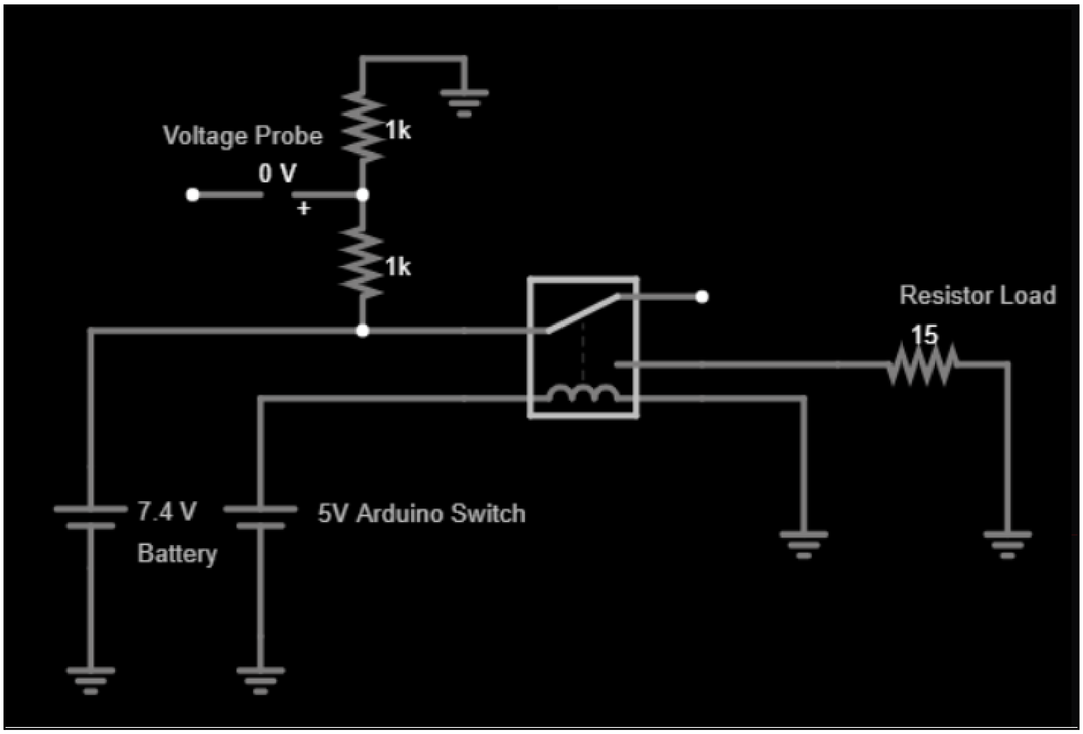
5.2 Battery Testing

Using an Arduino Uno, the team tested the time it took for the battery to discharge. To simulate a shift of the derailleur a current draw of 470 mA was conducted every 30 seconds. This simulated a shift occurring every 30 seconds. This time was chosen because, in a typical ride, fewer shifts would most likely occur, however, the team wanted to use a worst-case scenario to test the battery. The circuit that was used to simulate this with the Arduino Uno can be seen as the circuit below. The code that was used to simulate the shift can be seen in *Appendix 4* labeled as *Code 1*. Two tests were conducted, the first was with the battery that came with the derailleur and the second was with the LiPO battery that was implemented in the design. The first graph below shows the time it took the original derailleur battery to discharge. As seen on the graph it took approximately 13.76 hours. Around the 14-hour mark, the battery dropped from 6 V to 0 V, which was due to protection within the battery. The second graph below shows the time it took the LiPO battery used in the project to discharge. As seen on the graph, the LiPO battery has a run time of approximately 8 hours.

To conduct these tests, the team had to charge the batteries before simulating a shift. Therefore, these tests also verified that the battery was able to charge and was able to hold the appropriate amount of voltage. The LiPO battery was advertised to hold 7.4 V, and as seen on the graphs, the voltage was met. Overall, these tests met the requirements of the project even though the LiPO battery's run time was only 8 hours, instead of the 10 hours required. The test that the team conducted was very strenuous and extreme. On the derailleur's website, it stated that the original battery would have a run time of approximately 60 hours, however, with the team's harsher test, the run time was 13.76 hours. Taking this into consideration, it is appropriate to estimate that the run time for the LiPO battery is approximately 35 hours, which is more than enough to meet the requirement of a run time of 10 hours.


Voltage vs Time SRAM Battery
Voltage (V)
Time (Hrs)

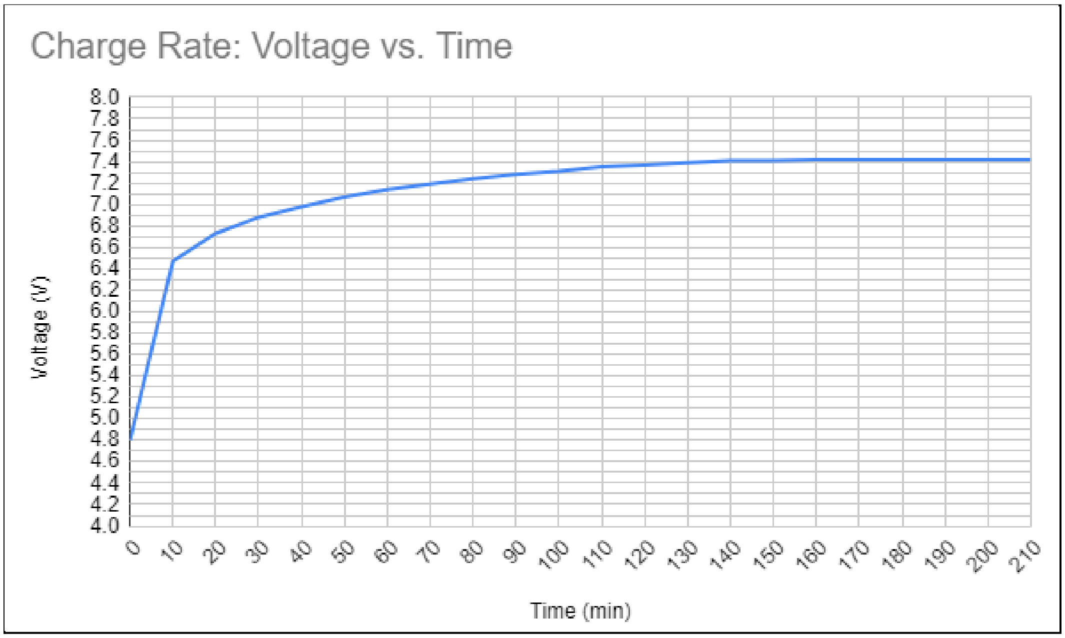

Voltage vs Time LiPo Battery
Voltage (V)
Time (Hrs)



To protect the battery from overcharging and being damaged by the current from the solar panel, the team needed a protective overcharge circuit. Originally, the team planned to use a prefabricated charge control board but decided to design a circuit to better fit the project's specifications. The group designed and tested the circuit in LTSpice and then assembled the circuit physically on perf board.

The circuit works by first stepping the 5 V input from the solar panel up to 12 V using a DC-DC converter IC. The 12 V output of the DC-DC converter is fed to the battery through an N channel BJT, which has its gate held at 9 V using a simple voltage divider. This gate voltage was chosen experimentally, after testing at a variety of different gate voltages, to throttle the current into the battery as the battery reaches roughly 7.4 V, a full charge per manufacturer specifications.

After conducting a short charge test in full sunlight to observe input power under ideal conditions, the team ran a dead-to-full charging test on the battery using a lab power supply. The charge test was conducted using an input power of 5 V and 180 mA, which is roughly 80% of the output power of the solar panel under ideal conditions. It was found that the battery was able to fully charge in 3.5 hours, well within the 6-hour charge time goal. Below is a graph to demonstrate the charge time.



5.3 Water Testing

For water testing, the team submerged the circuit that was encased in the 3D modeled case for 12 hours. After 12 hours, the case was dry inside which verified that the system met IP58 standards.

5.4 Dust Testing

To conduct dust testing, the team put sand on top of the case that held the circuit and agitated it to see if any dust was able to get into the case. After thoroughly testing, the team determined that the system was dustproof and met IP58 standards.

5.5 Vibration Testing

Vibration testing was conducted by applying a massage gun vibrating at 40 Hz to the system for an hour. After the test, the team ensured the battery was still appropriately attached to the derailleur and was working properly. This determined the system was resistant to vibration.

5.6 Shock Testing

The team attached the derailleur and battery to the bike and dropped the bike from various heights off the ground. After each drop, the team verified that the battery was still properly and firmly attached to the derailleur. Additionally, the group took the bike for a test ride over curbs and bumps, and the team verified that the battery was still properly attached. These tests ensured the system is shockproof.

6 Professionalism

This discussion is with respect to the paper titled “Contextualizing Professionalism in Capstone Projects Using the IDEALS Professional Responsibility Assessment”, International Journal of Engineering Education Vol. 28, No. 2, pp. 416–424, 2012

6.1 Areas of Responsibility

For this section the team chose to look at the IEEE Code of Ethics and the specific code of ethics that apply to each area of responsibility.

Area of responsibility	Society-specific code of ethics
Work Competence	IEEE Code 6 - This code focuses on undertaking tasks that match the professionals’ competence. Additionally, it emphasizes that the professional must maintain and gain new knowledge in the field.
Financial Responsibility	IEEE Code 3 - Honest and realistic communication is important to managing the finances of a project.
Communication Honesty	IEEE Code 3 - This code highlights being honest about the work done and communicating with everyone about your status.
Property Ownership	IEEE Code 9 - This code emphasizes the ethic that we have respect for property and the reputation of clients. Additionally, it focuses on not damaging the client property.

Health, Safety, Well-being	IEEE Code 9 - This code focuses on avoiding injuring others, their property, reputation, or employment.
Sustainability	IEEE Code 1 - This code focuses on striving to comply with ethical design and sustainable development practices.
Social Responsibility	IEEE Code 1 - This code is focused on considering public health and wellbeing in the design of products, which covers being socially responsible toward society and communities.

6.2 Project Specific Professional Responsibility Areas

For this section we explained how each area of responsibility applies to our project. If the area of responsibility did not apply, we also noted that.

Area of Responsibility	If / How it Applies
Work Competence	This area applies to the project because it encompasses a wide spectrum of ‘doing our job well. Work competence means understanding the technology, performing high-quality work, and being on time and professional with the client, all of which are important to any project.
Financial Responsibility	This area applies to the project because the team has been given a specific budget for the project that the client has required for the project.
Communication Honesty	This area applies to the project because the team has to maintain honest communication between each other. To have a more acquired knowledge of the progress the team is making and what needs to be finished.
Property Ownership	The team worked on modifying the device that belonged to the client, respecting that in the testing and building prototypes, and not treating the device carelessly.
Health, Safety, Well-being	This area does not apply to the project.

Sustainability	This area applies to the project because it uses the solar cell as a source to charge a battery.
Social Responsibility	This area does not apply to the project since the final product will only benefit one user.

6.3 Most Applicable Professional Responsibility Area

The area of professional responsibility that is important to the project and team is work competence. This is important because the responsibility focuses on working in a timely manner with integrity to deliver a high-quality product to the client. For the project specifically, the team has mapped out a timeline for the client with key deliverables and dates associated with the deliverables. This allows the team to stay within an appropriate timeframe and allows the client to have an understanding of when to expect key tasks to be accomplished.

7 References

[1] International Electrotechnical Commission (IEC), “International Standard.” IEC, Feb. 2008. Accessed on: Mar. 8, 2022. [Online]. Available: https://cloudflare-ipfs.com/ipfs/bafykbzacea2o53qv6fbdbexwfi5sbt346cwxlmtulhl3wgutnevqg5ozdzxwi?filename=IEC%20-%20IEC%2060068-2-27%20ed4%2C0%20Environmental%20testing%20-%20Part%202-27_%20Tests%20-%20Test%20Ea%20and%20guidance_%20Shock%20%282008%29.pdf.

8 Appendices

Appendix 1: Team Contract

Team Members:

Aydin Bashich, Connor Davison, Elba Estarellas, Mohamed Mohammad
Seth Pierre, Rachel Vallier, Jack Waskow

Team Procedures:

1. Team Meetings
    a. Monday at 1:10 with the client, Dr. Raman (over zoom).

    b. Monday at 2 with TA, Christopher (over Webex).
    c. Wednesday at 2:10 team meeting (over discord).
2. Communication
    a. The main form of communication between the team is discord and email.
    b. Communicate with the professor and TA over email.
3. Decision-making policy
    a. Mainly consensus if there are disagreements we will use majority vote.
4. Record keeping
    a. Keep a record of each meeting, what is discussed, and questions.
    b. A folder in google drive will store all the records.

Participation Expectations:

1. Individual expectations
    a. Arrive on time for meetings, if you will be late let others know.
    b. If unable to attend, let the group know before the meeting starts.
    c. Everyone can contribute ideas during meetings.
    d. If someone is not contributing/engaging we can talk to the individual.
2. Responsibilities
    a. Everyone should contribute accordingly to their specific task to accomplish their goal.
    b. Make sure each individual completes their task on time.
    c. If something comes up and a deadline can not be met let the team know.
3. Communication
    a. Let the group know at least a few hours before a meeting if unable to attend.
    b. Be honest with each other on the progress of the project.
4. Commitment
    a. We will work together to achieve the tasks.

Leadership:

1. Roles for team members
    a. 2 members will focus on meeting minutes, communication, and administrative tasks.
    b. 4 members will focus on the technical aspects of the project.
    c. 1 member will be a “floater” which will depend on the needs of that specific week.

    d. We intend to rotate through the roles throughout the project.
2. Supporting and guiding each other
    a. Keep an open mind and don't be afraid to ask questions.
    b. Be willing to ask for help.
3. Recognizing contributions
    a. When specific milestones are hit, acknowledge the member(s) that were responsible for that work.
    b. Give a "shoutout" within the team if someone does something above what is expected.

<u>Collaboration and Inclusion:</u>

1. Skills, expertise, and unique perspectives
    a. Mohamed Mohammad - Power systems
    b. Jack Waskow - Analogue & Digital electronics
    c. Seth Pierre - Communications & Signals and Systems, knowledge with soldering and bike parts/maintenance
    d. Aydin Bashich - Power and control systems
    e. Elba Estarellas - Semiconductors Materials and Circuits
    f. Connor Davison - Circuit Design and VLSI Design
    g. Rachel Vallier - Control Systems
2. Strategies for encouraging
    a. Have an open team environment.
    b. Make sure multiple ideas and perspectives are shared.
    c. Make sure everyone's voice is heard.
3. Resolve collaboration or inclusion issues
    a. If you are comfortable with speaking through the issue, share it during the team meeting on discord. If not, you can send an email or message to the team separately.
    b. If a team member is suddenly not engaged we can check in to make sure everything is okay.

<u>Goal-Setting, Planning, and Execution:</u>

1. Team goals for the semester
    a. Have the design for the project completed.
    b. Have a good understanding of how to communicate and work together as a team.
    c. Rotate roles to determine the best roles for each team member.
2. Strategies for planning and assigning individual and teamwork
    a. Determine individual strengths and assign tasks based on strengths.

    b. Discuss in team meetings to determine individual assignments.
3. Strategies for keeping on task
    a. At our weekly meetings on Wednesday, we will all discuss our accomplishments during that week.

<u>Consequences for not adhering to team contract:</u>

1. Handle infractions
    a. Initially handle the issue amongst ourselves, if it is a repeated issue then we can escalate the issue to the TA and then professors.
    b. If 2 individuals are having issues initially discussed amongst each other, but then escalate to the team setting if it becomes a bigger issue.
2. What if infractions continue
    a. Initially talk during the team meetings.
    b. After several attempts of working through the issue, we will then address the issue with the professors or TA.

****

a) I participated in formulating the standards, roles, and procedures as stated in this contract.
b) I understand that I am obligated to abide by these terms and conditions.
c) I understand that if I do not abide by these terms and conditions, I will suffer the
consequences as stated in this contract.

1) Rachel Vallier	DATE: 9/16/2021
2) Connor Davison	DATE: 9/16/2021
3) Seth Pierre	DATE: 9/16/2021
4) Elba Estarellas	DATE: 9/16/2021
5) Mohamed Mohammad	DATE: 9/16/2021
6) Jack Waskow	DATE: 9/16/2021
7) Aydin Bashich	DATE: 9/19/2021

Appendix 2: Operation Manual

To start using the hybrid solar/battery for the electronic derailleur, first attach the battery to the derailleur as seen in the figure below.

Once the battery is attached, add the solar cell to the bike and run the wire down to the battery, as seen in the figure below.

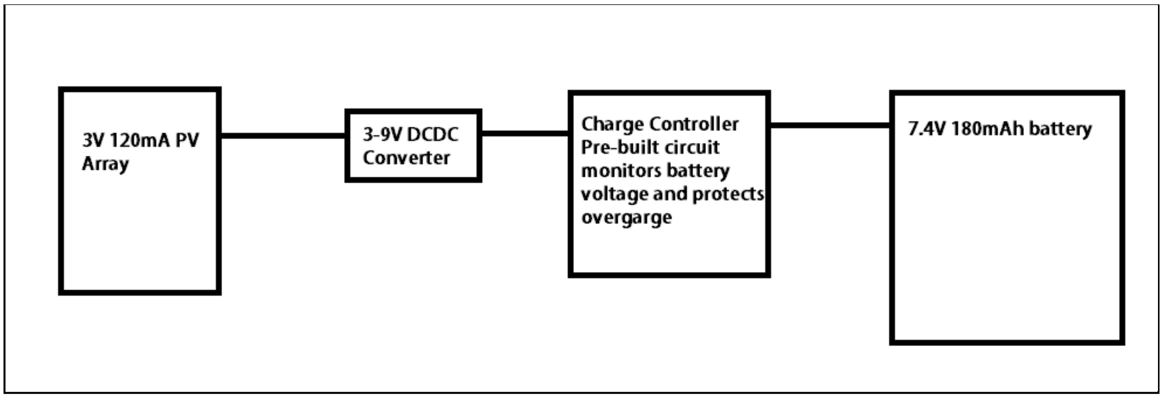
Next, you can turn the derailleur on by pressing the button on the top of the derailleur, as seen in the figure below. The button is located just above the light.

Once the derailleur is turned on, it is ready to be used on a ride as long as the battery is charged. If the battery is not charged, allow the solar cell to sit in the sun to charge before using the derailleur for a ride.

After the ride is over, leave the solar cell in the sun to recharge the battery to ensure there is enough charge for the next ride. Additionally, turn off the derailleur.

Appendix 3: Initial Design Version

Here is a visual description of the initial design. Additionally, there is an explanation of the design as well.



The initial design is a block diagram that helped guide the part selection and an idea of the physical construction of the project. Based on the client's requirements for charge time and battery capacity, there needed to be a minimum battery size of 100 mA and a solar cell that could charge the battery within 6 hours. Using a dc-dc converter to step up the PV voltage and a charge controller to protect the battery was achievable.

The main concern with the initial design was that the solar panel might not get enough sunlight to charge the battery within the time constraints the client requested. After testing the solar panel, the team determined that the initial size which was 2.36” x 2.16”, was too small to meet the charging requirements. Therefore, the team opted to use solar panels with dimensions 4.33” x 2.75”. Although these new dimensions of the solar cell were outside the initial size requested by the client, these new solar panels were able to meet the time requirement.

Appendix 4: Code

```
void setup() {
  pinMode(7,OUTPUT);
  pinMode(A0,INPUT);
  Serial.begin(9600);

}

void loop() {

  digitalWrite(7,HIGH); //turn supply on
  unsigned long CurrentTime = millis(); // Gets current time
  unsigned long TotalSeconds = CurrentTime/1000; // Calculates total time in hours
  int sensorValue = analogRead(A0); //get input information
  float voltage= 2 * sensorValue * (5.0 / 1023.0); //convert information to voltage values
  Serial.print(TotalSeconds); //print voltage values
  Serial.print(",");
  Serial.print(voltage); //print hours elapsed
  Serial.print(",");
  Serial.println();

  delay(1000); //wait 1 second

  digitalWrite(7,LOW); //turn supply off
  delay(30000); //wait 30 seconds

}
```

Code 1