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November 12, 2015

Dr. Andrew Rawicz
School of Engineering Science
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RE: ENSC 440 Capstone Project Design specification for D-charger Battery Pack

Dear Dr. Rawicz,

Attached below is the design specification document, for the Portable Re-charging Battery Pack, D-Charger.

The document will cover the mechanical and hardware portion to fulfill the proof-of-concept for the main 3 methods of self-generating electrical energy. Future additions of charging methods might be included, however would not be implemented at the current stage.

If there is any questions or concerns please contact me by email at dkao@sfu.ca.

Sincerely,

Davidson Kao
CEO
Discovery Technologies

Design Specifications For the D-Charger

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Executive Summary

Electricity has become one of the most important tools we use every day, almost every basic device requires electricity to perform its purpose. However, the availability of an AC source is not always present, preventing us from charge our electronic devices at anytime and anywhere. Therefore, our motivation for this project is to develop a portable self-generated electricity power source to support our daily use of electrical devices. D-Charger Battery pack is a helpful alternative for people, where steady electricity is not readily accessible.

The D-charger Battery pack uses three methods (hand cranking, pedaling and solar panel) to generate electricity. We will use a motor to transform kinetic energy (user input) into electricity (output). Additionally there is the use of solar panel, to absorb sunlight, in order to generate electricity passively. All of these were done to make the D-charger is able to transfer different energies into electricity. This design specification gives the specifics of how this design is achieved. The following details are given in this document:

- Mechanical design which is focused on gears connection and sketch up of our design.
- Electric Design outlining the AC-DC conversion circuitry design, energy storage circuitry design, and device charging circuitry design.
- Test plan that we have been test on our project so far.

Overall, this document shall serve as a set of guidelines for the device design, implementation and testing process. Our main goal at this stage is to outline the design specifications of our project based on the test plan we have.

Table of Contents

Glossary

AC	-	Alternating Current
DC	-	Direct Current
NiCd	-	Nickel-cadmium
NiMH	-	Nickel metal hydride
Li	-	Lithium

1. Introduction

The D-Charger battery pack is a self-generating electricity device which converts solar and kinetic energy (from generator) into electricity and provides people with a method of generating energy during emergencies and outdoor activities. This design specification contains the technical design requirements of the D-Charger.

1.1 Scope

This document outlines the design requirements that will be met by Discovery Technologies Inc. and how we aim to achieve our functional specifications ([Rn-I] and some [Rn-II]). In addition, this document describes the circuit design and mechanical design in detail.

1.2 Intended Audience

This design specification document is developed for the use of all members if of Discovery Technologies. The engineers will use this document as a guideline and reference in the design and integration of the D-Charger Battery Pack.

2. System Specification

D-Charger is a system that can charge a battery by 3 different ways which are hand cranking, feet petal, and solar panel. Meaning the battery pack is designed to be charged without using an AC outlet socket. The D-Charger will use the lithium ion batteries inside it to charge other electronic devices like cell phones, Ipad, etc. The D-Charger is designed for camping, hiking, emergencies, and military use where applicable.

D-Charger main components contains: a solar panel, hand crank, press pedal, brushless motor, gears, voltage step up circuit, AC to DC converter circuit, female USB port, and two lithium batteries. The hand crank module will contain the electrical circuit, motor, and batteries, making it a required component of the two other modules. Within the hand crank and feet pedal module, there will be an assortment of gears that will be used to turn the motor and producing the power. The electrical circuit will convert the AC current of the motor to a DC voltage and amplify all DC voltage (including the DC voltage from the solar panel) into the required voltage to charge the battery. Finally we use a female USB port to charge electronics devices of the user.

3. Overall System Design

In this section, the high-level overview of the entire designs including mechanical design, electrical design and safety design. Figure 1 displays a high level overview of our D-Charger's system.

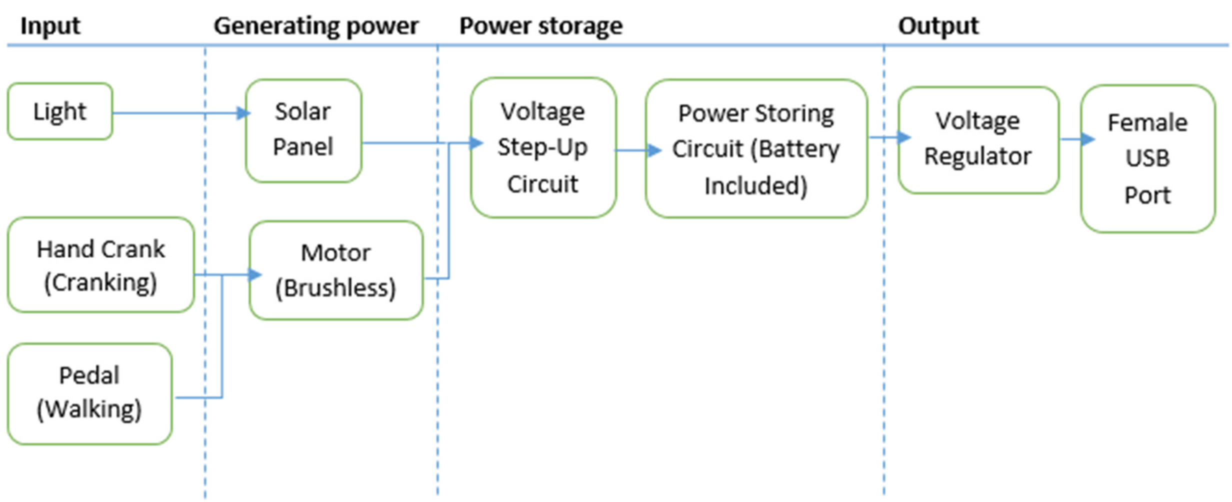

Figure 1: High level system overview.

3.1 Mechanical Design

3.1.1 Feet Pedal

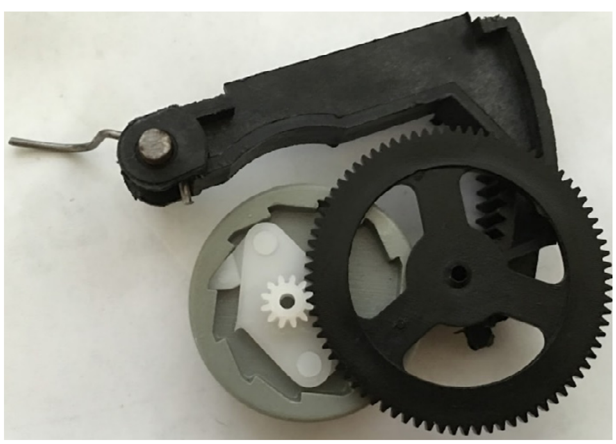

Figure 2: Displays the pedal, gears, and the ratchet.

The feet pedal module is a system that utilizes a pressing mechanism, making every step the user takes to generate electricity. D-Charger can be installed easily by using the strings on pedal module, to strap the module onto the shoes. The module uses a pedal to turn gears which turns the ratchet, as seen in Figure 2, which then turns the next gear but only in one direction. Thus allowing the pedal to return to its original position without applying a counter torque to the motor. The ratchet will turn a crank head, a pole like segment connected to the ratchet's gear, that will be shaped to fit the crank socket (refer to hand crank section). To generate energy the user must insert the hand crank head, on the pedal module, into the crank socket, as seen in Figure 3. If the user want to change it to feet pedal mode, he can unplug the hand crank and plug in the feet pedal part. There is a series of gears that linked the feet pedal with the gears that linked to the generator.

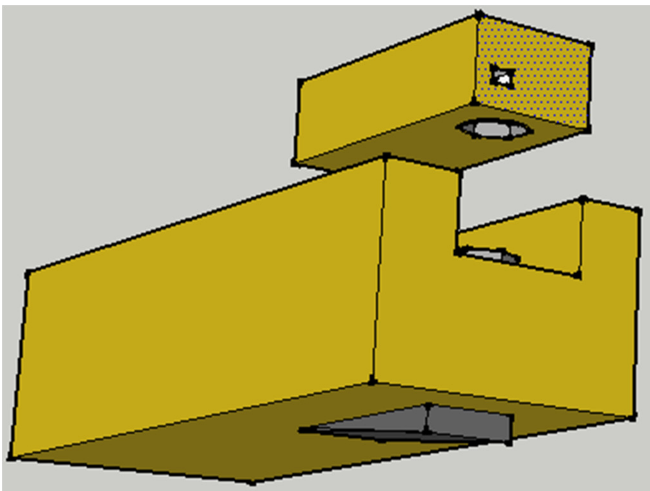

Figure 3: Feet pedal module with Hand crank module above showing how to connect the two modules.

3.1.2 Hand Crank

The Hand Crank Module will contain its own gears, motor, and the circuitry to generate, store, and export electric power. In order to generate the energy the user must insert the crank bar's head into the crank socket, as in Figure 4, to turn the gears that operate the motor.

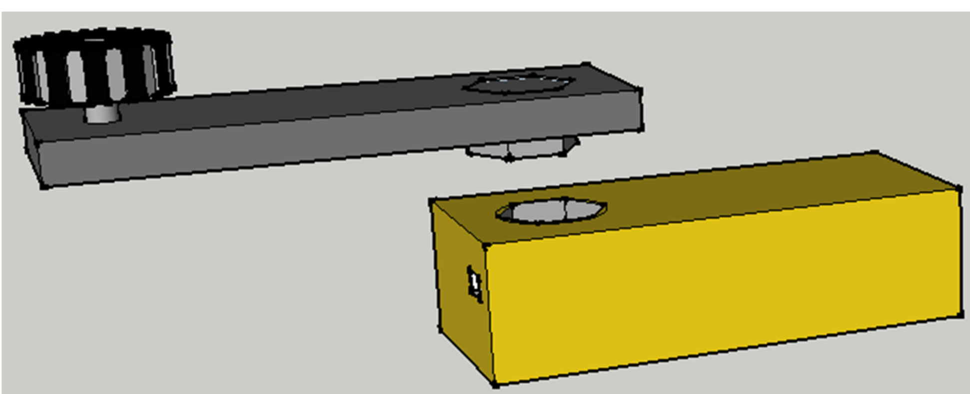

Figure 4: Hand Crank Module with Crank bar.

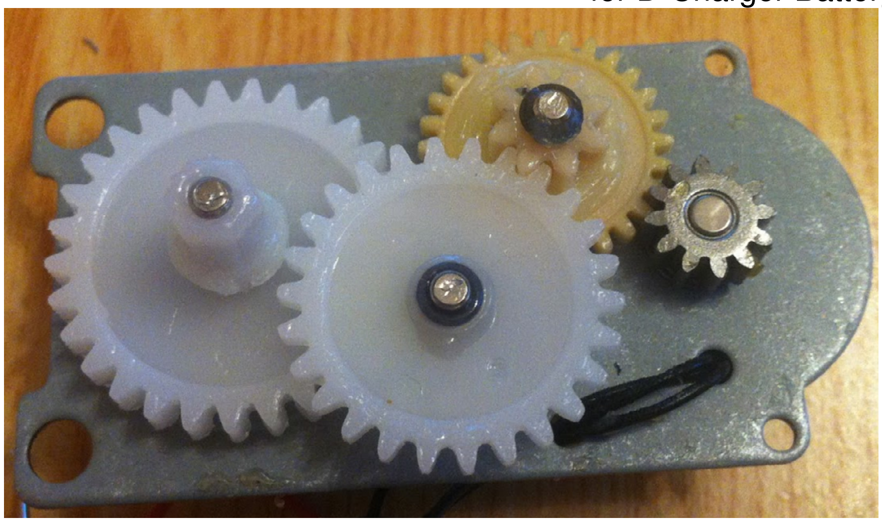

Figure 5: Multiple gears for increasing rotation speed.

The shape of the gears and arrangement, seen in Figure 5, is to increase the input rotational speed allowing the motor to produce enough energy. The energy generated will proceed through the circuit and be stored on the battery, which will be explained in the electrical design section. Lastly, this component will also have a port to connect to the solar panel component, and a USB port exporting the energy stored in the battery.

3.1.3 Solar Panel

Solar panel will be used as a passive way to generate energy from light. It will be designed to be able to connect to the hand crank module which contains the charging circuit. Also the panel's side and back will be wrapped in a non-conducting material with a pin, for preventing possible shock to the user and allowing the solar panel to be attached to the user's bag or clothes.

In order to meet the functional specification for portability and the electrical circuit requirement of a minimum 3V input, we have selected a solar panel of size 35*90mm (shown in Figure 6) that produces a 5.5V potential.

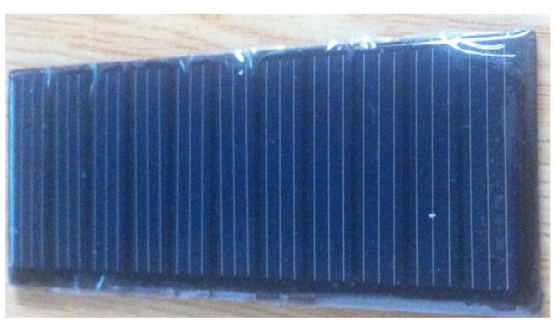

Figure 6: Solar Panel.

3.1.4 Brushless Motor Generator

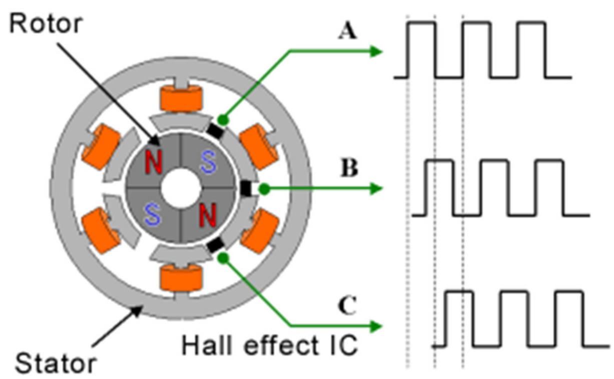

Figure 7: Brushless motor [1].

The brushless motor shown in Figure 7 is the type of motor we are using to generate the electricity from the feet pedal and hand crank module. According to Freddy's law, when we have a coiled loop of wire rotate in the magnetic field, an AC current will be generated [2]. The reason of this three phase brushless motor is used in our D-Charger is because of the complementary output. From the figure we can see that A, B and C three AC current, with a phase difference, will be generated as we rotate the motor. From the three out of phase currents are placed together, through a rectifier that is noted in the electrical design section, the output will resemble a DC output as seen in Figure 8.

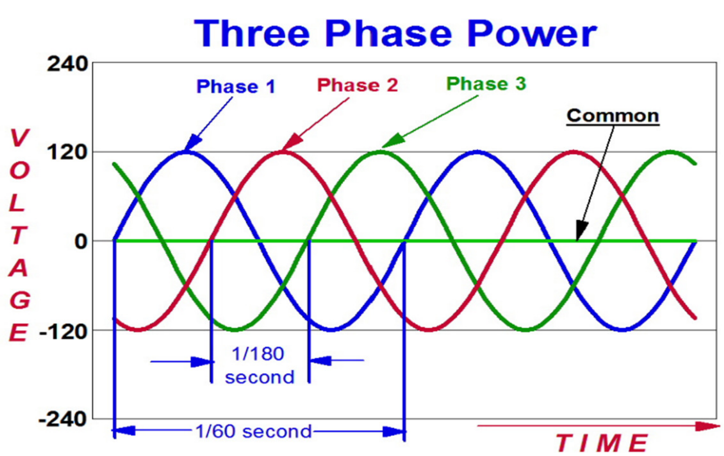

Figure 8: 3 phase power when overlapped can create a DC output [3].

3.2 Electrical Design

For our electrical design we developed a circuit which can be divided into two sub circuits, the energy storing circuit and the device charging circuit. The base of the energy storage circuit will convert the generated AC current, from a brushless generator, and convert it into a DC current which can be used for charging the batteries. Whereas the device charging circuit will be used the stored energy in the batteries to charge a device, through the female USB port. The two sub circuits will be explained in more detail below, additionally overall circuit can be viewed in Figure 9.

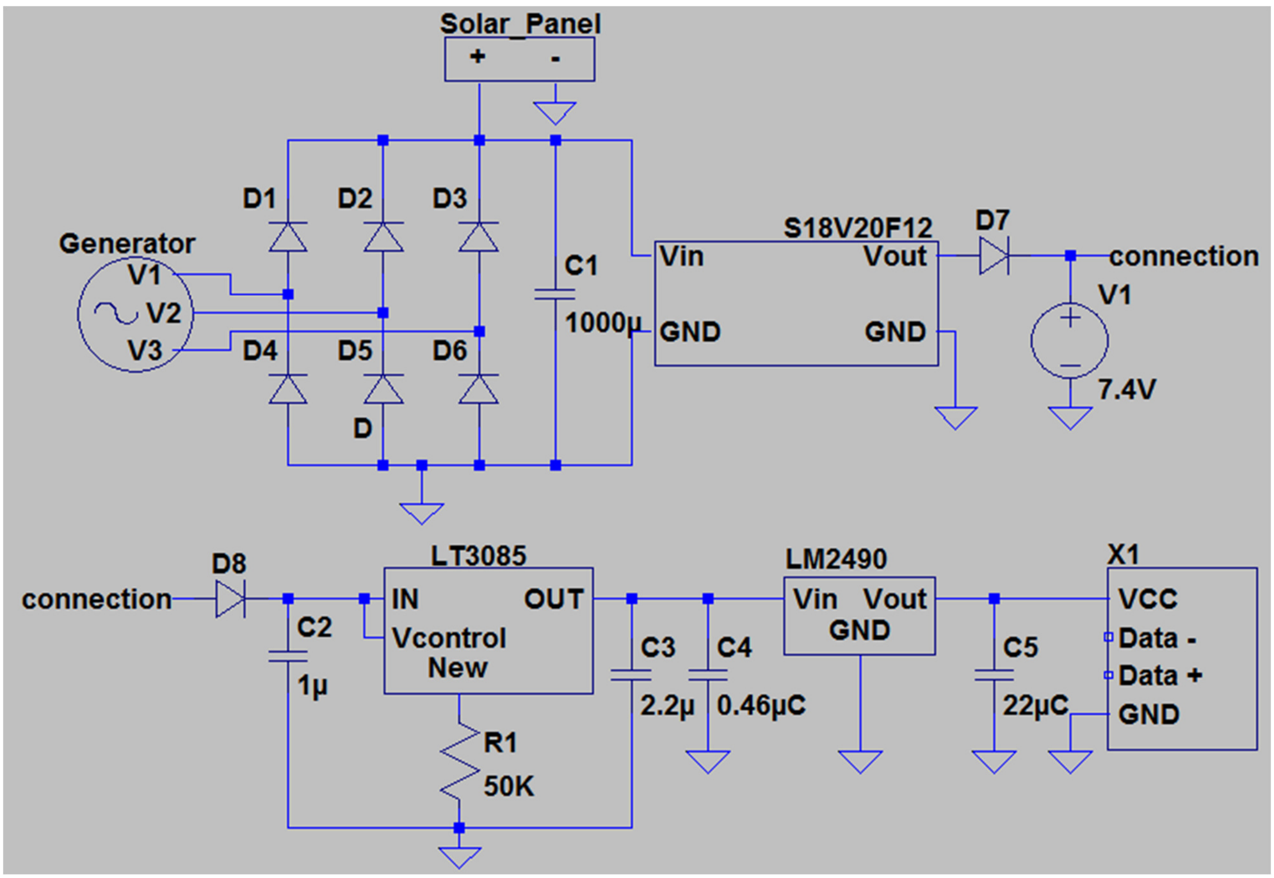

Figure 9: Entire Circuit Schematic.

3.2.1 Battery

We choose two 3.7 V LP803860 Lithium-ion (Li-ion) battery, manufactured by PKCELL, shown below in Figure 10. The main advantage of lithium-ion batteries is their high energy density. Also they have a long cycle life and do not suffer from the high self-discharge rate and memory effect of NiCd and NiMH batteries. In addition, Li-ion batteries chemical make is not toxic heavy, as other batteries [4].

Figure 10: LP803860 3.7V Li-ion battery.

For the purpose of our design we placed two batteries in series to increase the total voltage of the output. The length, width and height of a battery is 6 cm, 5 cm, and 0.5 cm respectively. From the dimensions of the battery, it would not be hard to place the battery inside the hand crank module.

3.2.2 Energy Storage Circuit

As explained in the motor generator section, the brushless motor produces three AC outputs with a phase difference. Where the frequency of the AC output depends on the rotations per minute (RPM). The circuit schematic in Figure 11, is designed in consideration of the motor's output characteristic to convert the AC current to a DC current. The diodes in the figure, D1 to D6, created a rectifier which allows the current to only proceed in one direction.

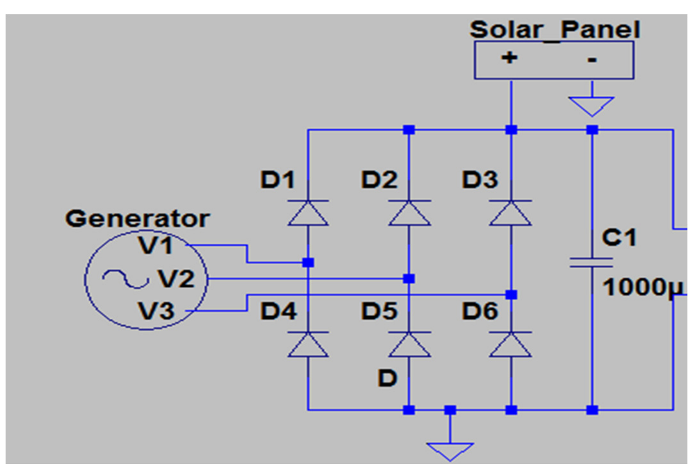

Figure 11: Generating Circuit.

Next part in the circuit takes the generated DC current, from either the motor or the solar panel, and step up the voltage using the S18V20F12. The S18V20F12, seen in Figure 12 and 13, will convert an input voltage ranging from 3V to 30V into a 12V output [5]. The reason we are using this pre-built circuit is because the batteries' charging requirement of 4.2V per battery, 8.4V if we put the individual batteries in series [6]. Note that diode D7 is present to only allow the current to flow into the batter, preventing the battery from discharging energy through backflow.

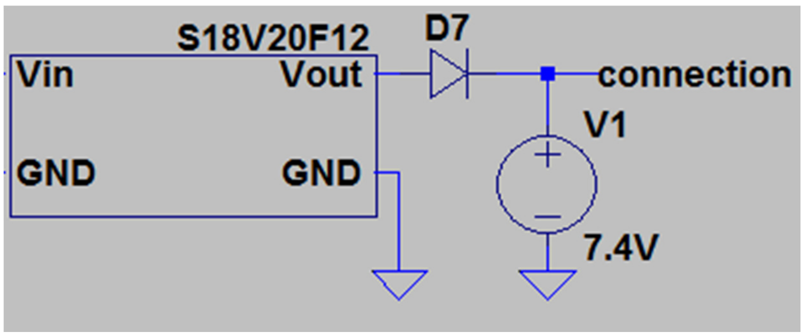

Figure 12: Schematics of storing electricity circuit.

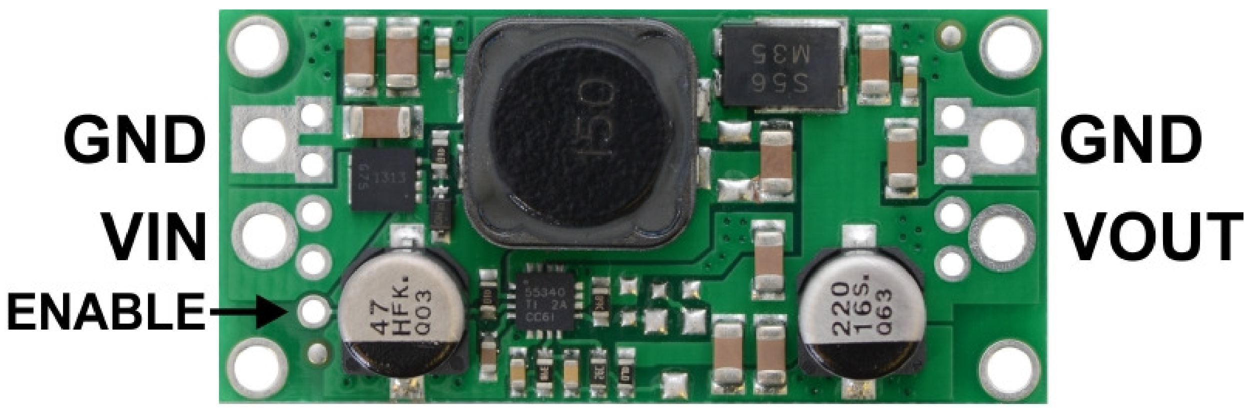

Figure 13: Step up/Step down Voltage Regulator S18V20F12 [5].

The S18V20F12 has two ground port a Vin and Vout port, and an enable port, as seen in Figure 13. For our circuit will not use the enable pin since by default the circuit is active, and applying a 0.7V in the enable pin will put the circuit in low-active mode [5].

3.2.3 Charging Circuit

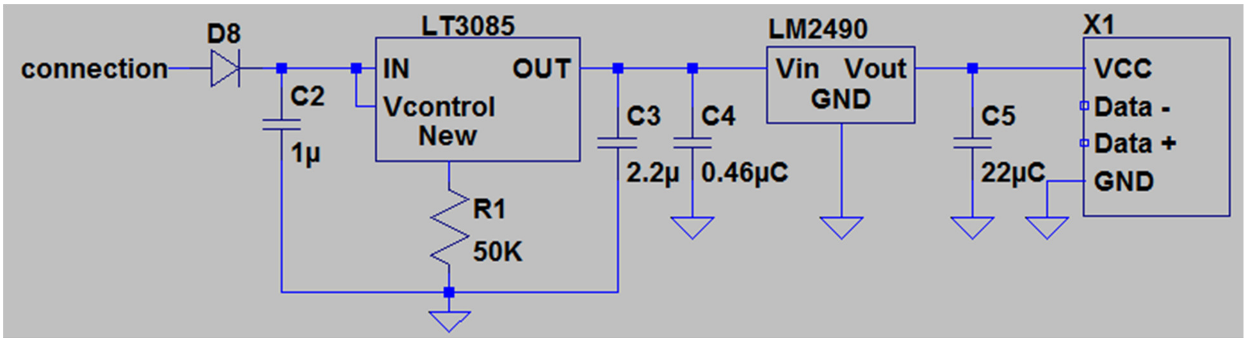

Figure 14: Charging portion of the Circuit.

The charging portion of the electrical circuit, shown above in Figure 14, consists of a diode, capacitors, a resistor, a voltage regulator (LM2490), a current regulator (LT3085), and a female USB port. The diode, D8, again is to prevent a backflow of the device's electrical energy into the battery. The choice of using the LM2490 is to drop the voltage that comes from the batteries to required voltage for the USB port, that being 5V [7, 8, 9, 10]. Whereas the LT3085 will regulate the current to a 0.5A output current to match with the USB protocol [8, 9, 10]. Also since our device is used to charge the user's device, we are not connecting or using the data transfer ports.

3.3 Safety Design

All the components are designed to put around human, so safety is important for the design and the following consideration are mentioned:

- Electrical shock
- Battery Exposure

In order to keep safety, we need to set the voltages to be under 25V [11]. The entire circuit will be tested via LTspice and then tested on breadboard to make sure whether it works.

4. Test Plan

The system can be divided into three modules which will initially be tested separately, before being integrated together as a whole.

4.1 Hardware

- Able to convert the AC input into a stable DC output that will be stored.
- Able to store the generated electrical energy into the battery.
- An LED should light up as the battery is charging.
- Able to convert the battery's voltage of 7.4V to 5.0V for the USB output.
- When USB port in connected the electrical energy will be transferred from the battery to the device through the USB port.

4.2 Hand Crank

- Must be durable enough to withstand cranking a total of 200000 times (revolutions)
  - 100000 revolutions from cranking by hand
  - 100000 revolutions when attached to the feet pedal module (assuming 100000 steps)

4.3 Feet Pedal

- Must be able to withstand the average weight of a man, about 80 Kg of mass, for 100,000 steps. (should withstand the weight for the demo when used for walking)
- The module must be able to connect to the hand crank module, and generate electricity using the hand crank module's motor.
- Module will have a mechanism for enlarging and shrinking, to a certain size, to accommodate different feet sizes.
- The Module will be able to attach to the shoe/runners of the user.

4.4 Solar Panel Module

- Able to connect to the Hand crank module, and store the generated energy.
- Can be attached to the clothing or bag of the user.
- The wire from the solar panel should not affect the user largely
- There should not be any electrical discharge from the solar panel's wire, shocking the user.

4.5 Test Cases

Test Case #1: Solar Panel Charging
Condition: Solar panel is placed in a position where it can easily receive light from a light source.

Expected Observation: The LED that symbolizes the battery is charging should light up, meaning that enough energy was generated by the solar panel to charge the battery. The LED will stay on until the energy produced by the solar panel stops being enough for charging the battery.

Test Case #2: Hand Crank Charging
User Input: The user will insert the hand crank rod into the cranking socket in the module. Then the user will provide a torque force by cranking using the rod to produce energy.

Condition: The hand crank rod will be inserted into the hand crank socket, and is ready for the user to crank.

Expected Observation: The LED that symbolizes that the battery is charging will light up, as long as the user is able to generate enough energy to charge the battery. When the LED's light extinguishes, it symbolizes the user did is not producing enough energy for charging.

Test Case #3: Feet Pedal Charging
User Input: The user is walking which pushes the pedal that leads to torque for turning gears which will turn the motor to generating electricity.

Condition: The pedal module will have a indention spot for placing the hand crank with a protruding part. Where the protruding part is used to insert into the hand crank socket to turn the gears like the hand crank rod. The user will be walking with the pedal module attached/ strapped to their shoe.

Expected Observation: The user should be able to walk relatively unaffected, while the module is attached to their shoe. In addition the module will be strong enough to withstand the weight of the user as they walk. Also the LED for charging will be lit indicating the storing of electrical energy in the battery. The LED will stay on until the energy produced becomes insufficient for charging the battery.

Test Case #4: Hand Crank and Solar Panel Charging (Simultaneously)
User Input: User will provide a torque input using the hand crank while the solar panel is attached and producing energy.

Condition: The hand crank module will have the crank rod inserted in the crank socket, and the solar panel will also be connected.

Expected Observation: The same result as Test #1 and #2 as simultaneously using both modules at will not necessary speed up the charging process. The LED will again light up until there is not enough energy to be able to store energy in the battery.

Test Case #5: Device Charging
User Input: User inserts a male USB connector into our female USB port on the hand crank module.
Condition: The USB port is used to connect a device to the battery pack, using a USB cable, without having any of the charging modules active.

Expected Observation: The user's device will display that it is charging, if it has the capabilities, and device will be charged as time passes.

Test Case #6: Charging a Device while Generating Energy
User Input: User can be providing a torque force by using the hand crank module, producing energy.

Condition: The USB port is connected to a device and the battery is currently charging the device. Additionally the user can be generating energy using the solar panel, hand crank, or both.

Expected Observation: The LED hoeing that the battery is being charged will light up until the charging stops or is not producing enough energy. Also we will see that the device is being charged, and its battery's charge is increasing, over time. Note that according to the circuit the energy generated is both charging the battery and the device simultaneously but at a slower rate.

5. Conclusion

The Design Specification in this document is proposed according to the requirements and standards in Functional Specification that will be held for D-charger. According to our current design, the D-charger is separated into 3 main charging methods being: solar panel, hand crank, and feet pedal modules. Each charging method is then subdivided to further allow better comprehension for the designing process. All the listed description in system specification will be implement on the D-charger while we are doing the development cycle. In the product test part, all the requirement and in the extreme situation will be test to make sure the functionality of D-charger will perform normally. The Design Document listed and clarified all the details for the development of D-charger.

6. Reference

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