Human-Powered Swing Generator

by

Danny Cai

Timothy Lai

Brandon Wong

Senior Project

ELECTRICAL ENGINEERING DEPARTMENT

California Polytechnic State University

San Luis Obispo

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Abstract

Many developing countries lack sufficient resources to provide enough electricity for every family to live with a satisfying level of comfort and convenience. Our project proposes a solution that provides families with an alternative access to electricity using a playground swing. This project addresses the design and construction of the Human-Powered Swing Generator, which converts mechanical energy to electrical energy for charging a battery. The charged battery serves as a source of DC energy for potential DC purposes, such as charging a cell phone.

I. Introduction

In today's society, energy has become an essential component in our daily lives. People consume vast amounts of energy every day, and unfortunately, Earth's limited resources are depleting because of this careless energy consumption. Consumers waste these resources without thinking of the consequences because they only look at the present moment and not the future. The burning of fossil fuels is also affecting the environment due to the pollution it creates. If this continues, the environment's resources will eventually be fully depleted.

Another problem is that access to electricity is not available to everyone in the world. Many developing countries lack funds for facilities or tools to provide energy access to families in rural areas. If we, as engineers, can provide a cost effective solution to energy, then we can provide these families with access to electricity and a means to comfort in living.

Fortunately, there is a solution to these problems. Alternative energy sources are well known in the community, but they are not being used to their full potential. Alternative energy sources such as solar, wind and hydro power have been a popular solution in recent years to try to solve these energy problems, but they have only been implemented on a small scale. However, if we were to implement all the alternative energy sources on a much larger scale, such as worldwide, it would generate a vast amount of energy. We would have a cleaner environment because it would lower the amount of pollution generated from burning fossil fuels. It would also help reduce the usage of Earth's natural resources. Although these alternative energy sources usually come with disadvantages such as cost and efficiency, technology is constantly improving over time, and these ideas are now becoming more plausible. Advances in technology are making these alternative energy sources more affordable and more efficient. With these advances, we have the opportunity to provide people who are not as fortunate as most of us with a means to electricity through alternative energy sources.

Another key solution that can be addressed for these isolated families in rural areas is the use of DC energy. AC systems are more favored in large areas such as cities because they can transfer high voltage efficiently over long distances to every individual home. In such large scale cases, systems running DC energy are much more expensive and inefficient. However, if families in rural areas are providing their own alternative source of power to their individual homes on a small scale, DC systems prove to be more efficient due to no AC transmission losses, and the energy does not require long travel or high amounts of voltage. DC systems can also be connected directly to low voltage storage devices such as batteries, so generated energy from these alternative sources can be stored for later use. Overall, the solution to providing power to families in need in rural areas is much easier to accomplish with DC rather than AC systems.

With these concepts in mind, the idea of a house running on generated electricity from natural or alternative sources can be fully achieved. Using these sources to generate DC power will prove to be an affordable and efficient solution in providing needed energy to these specific families and homes. In this project, we will build a Human-Powered Swing Generator that will take use the mechanical energy of a child on a swing and convert it into usable electrical DC energy, which is one of numerous projects in the overall DC House Project.

II. Background

The DC Swing's main purpose is to convert mechanical energy into electrical energy in order to help rural families that cannot afford or do not have access to electricity. This alternative energy form is accomplished through the use of a generator, rectifier, and DC to DC converters. When someone swings on the swing, it will power the generator, which outputs a certain voltage based on the rpm and torque of the swing [1]. The rectifier then converts the output to a DC voltage and using DC to DC converters, we will achieve our desired output voltage value for other uses such as charging batteries or powering a USB.

This is not the first attempt of creating the DC Swing. We are trying to improve the current model by building a completely new one since the current one is unstable and not presentable for both use and various weather conditions [2]. Factors such as cost, safety, efficiency, and appearances are all taken into consideration as an improvement. We are planning to use a different DC generator as the previous is too expensive and too powerful for our application. We will add a box to the swing to isolate all the electric components since the swing is primarily meant for kids to use and this will prevent any potential accidents that may occur. In addition to children safety, the box will protect the electric components from weather damages such as rain and wind. We will be using a different pulley system with an added wheel [3], which will generate more rpm and thus increase the efficiency of each swing since more rpm means more electricity being produced. Lastly, instead of a metal structure, we decided to use wood because it is a lot easier to handle and makes the swing look significantly more appealing. These improvements to the DC Swing will provide an adequate amount of electricity and a lot of fun.

Our project, the DC Swing, is only a small part of the DC House [4]. The ultimate goal of the DC house is to function purely on DC energy. The DC house mainly targets audiences who do not have access to electricity such as people in developing countries. The DC house is equipped with many other DC sources such as solar panels, smart wall plug, air ventilation, Merry Go Round, and more. These all serve the main purpose of converting renewable energy into electrical energy (DC). Like the DC swing, they all provide a clean source of energy with no emissions or use of diminishing resources. The DC swing generates energy through anyone swinging on it, thus making it human powered and very similar to that of a bicycle powered generator [5]. Other components of the DC House also use wind, solar, and hydro powered machines. The DC House tries to be versatile by providing many different ways to generate electricity, which allows it to be useful anywhere as we can find sunlight, water, wind and humans anywhere on Earth.

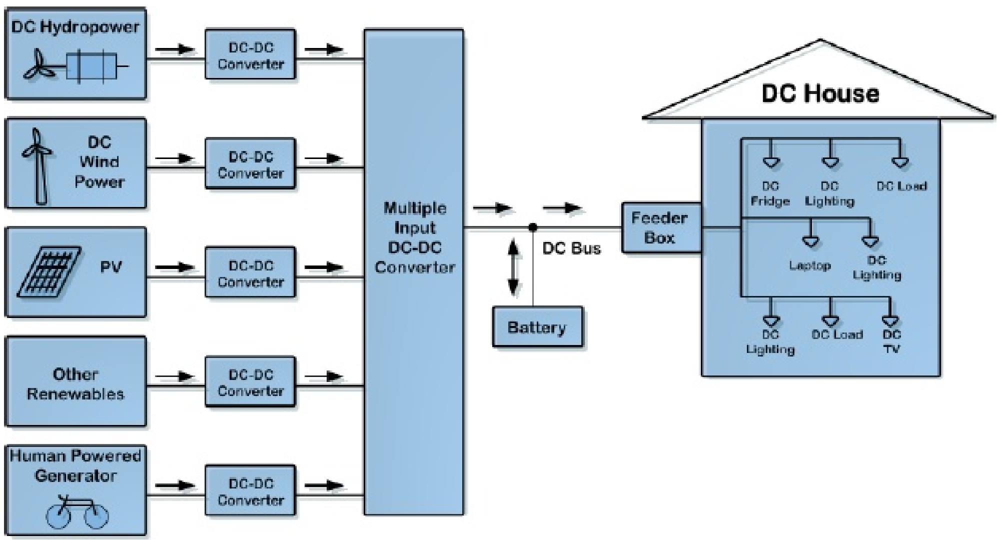

Figure 2-3: Schematic of the DC House Project

Imagine a family living in a developing country with their DC House. Normally, they would not have access to electricity or might have trouble affording it. But with the DC House, the children could play on the swing and help generate electricity for the family. The electricity stored in a battery could then be used for other applications such as powering an electric stove or powering the ceiling lights for the room. The children will help the family generate electricity while having fun doing so, which is the ultimate goal of the DC House. The family described is what the DC House hopes to provide, along with all the other less fortunate people.

III. Requirements and Specifications

The design of the Human-Powered Swing Generator consists of a pulley system that turns a DC generator on each swinging motion. The power generated from this system can then be used to charge a 12V lead acid battery, which will then be able to charge a load such as a cell phone through a USB connection. Since this product is targeted towards the families in rural areas that don't have easy access to electricity, the total cost of the whole system should be affordable.

The Human Powered Swing functions first through the mechanical energy from the swinging motions of the user. The rotational speed (rpm) from the swinging is then increased through a pulley system. The increased rpm turns the DC generator clockwise and counter clockwise due to the back and forth motion of the swing. This will cause the generated voltage to be AC, and since we desire a DC output to charge a battery and USB load, the voltage will be converted through a rectifier. The DC voltage we obtain through rectification will then be converted by boosting or bucking (depending on the generator's output) to 14V in order to charge the 12V battery [6]. The power stored in the battery will in turn be able to supply 5V to a USB charging station. A buck converter will be required to step down the 12V to 5V. The swing's structure will be built using sturdy 3" by 3" wooden pillars, and a rod and bearings on top will provide minimal friction for turning the pulley system.

Table 3-4: Human-Powered Swing Requirements and Specifications

Marketing Requirements	Engineering Specifications	Justification
1,2	The system converts mechanical energy to electrical DC energy.	DC energy provides a cheaper and more direct alternative compared to AC energy.
1	A full-bridge rectifier converts outputted AC voltage from the generator into DC voltage.	The DC generator produces AC energy due to the nature of the back and forth swing.
1,4	A DC to DC converter buck-boosts the rectified voltage to constant 14V to charge the 12V battery.	Based on the varying voltage that the generator produces, a buck-boost is required to step up or step down the voltage to the desired 14V charging level.
4	The system charges a 12V lead acid battery and supplies power to a 5V USB to charge a phone.	The lead acid battery acts as a storage device for the generated power and is much smaller in size and weight compared to a 12V car battery. The USB charger will provided as a visual demonstration when presenting the swing.
2,3,5	The swing consists of durable and cost efficient wood and covers all electrical components.	Durability ensures that numerous conditions do not affect the construction and stability of the swing. The covering of components eliminates exposure of potentially hazardous electrical wires to the user.
3	The swing supports a person who weighs up to 175 pounds.	Stability ensures the safety and support of the children playing on the swing.
2	Total cost should not exceed $1,000.	Low cost provides an affordable way to access energy.
Marketing Requirements 1. Produces human powered energy 2. Affordable cost for making in developing countries 3. Safe and stable for children 4. Collects and stores energy into a usable form 5. Withstands various weather conditions		

Table 3-1 shows the requirements and specifications for the project. Every marketing requirement backs up at least one engineering specification and vice versa. The justifications column explains why the group determined the given engineering requirements and specifications. DC energy ensures the cheapest and most affordable method of producing energy, and the swing's wood structure adds stability and safety for both the child and many weather conditions that may occur. An affordable lead acid battery will be used to collect and store the output energy from the generator and will serve as a source to charge a cell phone through a USB charger.

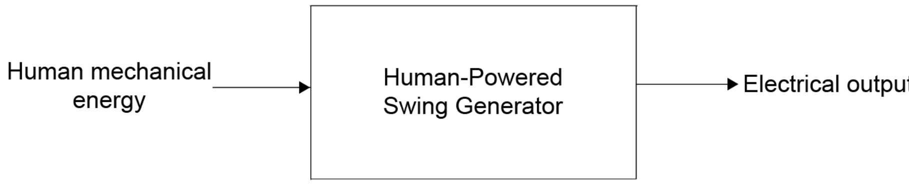

Figure 3-1: Level 0 block diagram of the Human-Powered Swing Generator

Table 3-2: Function Table for Level 0 block diagram of the Human-Powered Swing Generator

Module	Human-Powered Swing Generator
Inputs	- Human mechanical energy: User inputs mechanical energy into the system
Outputs	- Electrical output: 5V DC for charging via USB
Functionality	The system utilizes the user's mechanical energy and generates an output voltage suitable for charging a phone

Figure 3-1 shows the input and output of the Swing Human Powered Generator at the Level 0 design structure [5]. Table 3-2 describes the input, output, and functionality of the system. The system takes in the user's mechanical energy and outputs 5V DC suitable for charging an external phone.

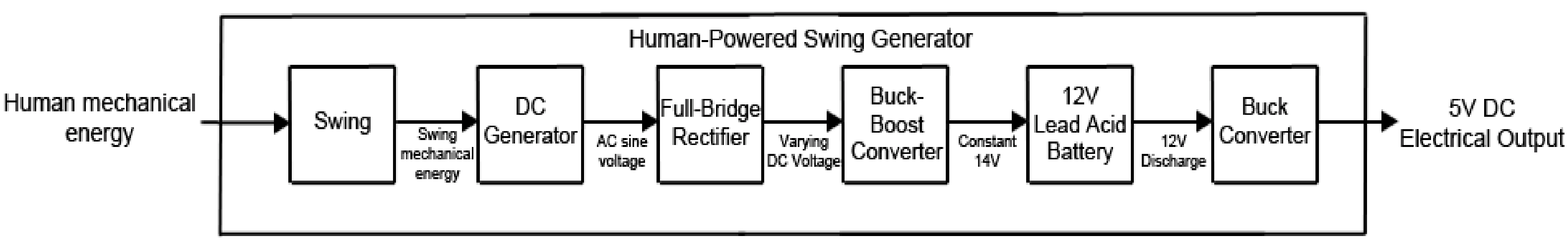

Figure 3-2: Level 1 block diagram of the Human-Powered Swing Generator

Table 3-3: Function Table for Module of the Swing

Module	Swing
Inputs	- Human mechanical energy: User inputs mechanical energy into the swing
Outputs	- Swing mechanical energy: Energy produced by the swing's torque
Functionality	The swing takes in the user's mechanical energy and outputs torque via the pulley system into the shaft of the DC generator.

Table 3-4: Function Table for Module of the DC Generator

Module	DC Generator
Inputs	- Swing mechanical energy: Energy produced by the swing's torque
Outputs	- Electrical output: AC sinusoidal voltage
Functionality	The DC generator utilizes the swing's torque and produces an AC voltage due to the back and forth motion of the swinging.

Table 3-5: Function Table for Module of the Full-Bridge Rectifier

Module	Full-Bridge Rectifier
Inputs	- Electrical input: AC sinusoidal voltage
Outputs	- Electrical output: Varying DC voltage
Functionality	The rectifier takes in the AC voltage and converts the negative swing positive in order to output a pure DC voltage.

Table 3-6: Function Table for Module of the Buck-Boost Converter

Module	Buck-Boost Converter
Inputs	- Electrical input: Varying DC voltage
Outputs	- Electrical output: Constant 14V
Functionality	The DC-DC buck-boost converter takes in the varying DC voltage and steps it up/down to constant 14V suitable for charging the 12V lead acid battery.

Table 3-7: Function Table for Module of the 12V Lead Acid Battery

Module	12V Lead Acid Battery
Inputs	- Electrical input: Constant 14V
Outputs	- Electrical output: 12V Discharge
Functionality	The 12V lead acid battery charges with the 14V input and discharges 12V into the buck converter when a load is connected.

Table 3-8: Function Table for Module of the Buck Converter

Module	Buck Converter
Inputs	- Electrical input: 12V Discharge
Outputs	- Electrical output: Constant 5V
Functionality	The DC-DC buck converter takes in the 12V discharging from the battery and steps it down to 5V suitable for charging the phone via USB connection.

Figure 3-2 shows the inputs and outputs of the individual modules of the Human Powered Swing Generator at the Level 1 design structure. Tables 3-3 through 3-8 describe the inputs, outputs, and functionalities of the modules in the system. The swing takes in the user's inputted mechanical energy and produces torque into the shaft of the DC generator through the use of a pulley system [7]. The DC generator utilizes the inputted torque and generates an AC sinusoidal voltage from the back and forth motion of the swing, with the amount of peak voltage dependent on the weight and acceleration of the user [1]. The AC voltage is converted to DC using the rectifier, when is then converted to a constant 14V by the buck-boost in order to charge the 12V lead acid battery[4]. The battery then stores the energy until a phone is connected at the output, where it then discharges 12V into the buck converter. The buck steps it down to constant 5V and charges the phone through the USB connection.

IV. Design

Swing Structure:

The previous year's senior project swing design was constructed using metal parts from a boat trailer. We decided that this required too much manual labor and time to build, so we chose to rebuild the swing using wood instead of metal and to improve on the structure of the swing. This method would only require sawing and drilling wood instead of having to cut and weld metal.

The swing structure utilizes five wooden posts with the dimensions of $3\frac{3}{8}in \times 3\frac{3}{8}in \times 8ft$ each. The type of wood should be heavy to ensure a sturdy structure. We used construction common wood to build our swing because it was the most cost effective wood that would be able to provide for a sturdy structure.

Each side of the swing is built using an A frame structure, which consists of two wooden posts forming an upside down V with an angle of 45 degrees at the top, base of 6 ft. 1 in., and height of 7 ft. 4 in. Both ends of each post are cut at a 22.5-degree angle. This ensures that the legs are flat and flush on the ground and that a right angle socket is formed at the top to hold the top beam post. A 4 ft. 8 in. crossbar, which is made of framing lumber and is wider yet flatter, completes the A formation and adds stability to the legs further down at the base. Towards the top of each side, a small construction common wood crossbar, which is 8 in. wide and 9 in. down from the top, is used to allow the bearings to rest on top of. Lastly, a 6 ft. 4 in. top beam is used to connect both A frames together and complete the structure. The wood was painted using the color redwood from Behr Premium Transparent Weather Proofing finish.

Figure 4-1: Side view of the swing structure with the A frame formation

Figure 4-2: Small crossbar supporting the bearing

Swing and Pulley System:

The bearings on top of each crossbar are used to allow the metal pole to rest in. The pole is 5 ft. 7 in. long and supports the actual swing. The bearings give the pole the ability to rotate as the swing swings back and forth. The actual swing uses a standard swing seat and is supported by chain links that are 4 ft. long on each side.

Figure 4-3: Completed design with the pole and swing

On the right side of the structure, a two-wheel pulley system is used to increase the amount of mechanical energy rotation being generated from the swing. The first wheel is connected at the end of the pole and is connected to the second wheel via a timing belt. The second wheel is stabilized by having it connected to a bearing placed on the inside of one of the swing posts. This wheel is then connected to the shaft of the generator with another timing belt**.** This pulley system allows increased shaft rotation for the generator compared to the minimal initial rotation produced by the swing and pole. Using the $\tau = F\ x\ L$ equation, the amount of torque can be calculated given the length of the swing and the weight and speed of the person on the swing.

Figure 4-4: Two-wheel pulley system

The initial swing structure did not provide enough lateral support at the connections of the top beam and the legs, therefore resulting in significant side-to-side wobble during swinging. We added flat metal plates and 90-degree angled metal supports at these connections to ensure stability and minimize the stress and wobble during use of the swing.

Figure 4-5: Metal plates added for stability at the top corners of the structure

Compartment Box:

The electrical components need to be protected from various weather conditions including extreme heat, strong wind, and rain. Therefore, a small compartment box was attached to the leg of the structure to encase all the components from exposure to the outside. The box has a door to open and close access to the circuit, as well as to attach the phone to the USB connection for charging.

Figure 4-6: Compartment box covering all the electrical components in the system

Electrical Circuit Design:

The first stage in the electrical circuit portion of the system is the generator. We used the Windzilla 12V DC Permanent Magnet Motor Generator, which is rated at producing 12V with 540RPM. We chose this particular generator because it was the most cost-effective unit on the market that provided high torque with low RPM. In addition, it provides bidirectional rotation of the shaft, which is required from the swing's nature, and it also included a foot mount for easy installation to the swing instead of a typical generator forcing to tie it down to a brace. Like mentioned in the previous section, the shaft of the generator is rotated by the pulley system. Since the swing swings back and forth, the output of the generator will be an AC sine waveform, with the positive portion produced from the forward swing and the negative portion from the backward swing.

Figure 4-7: Windzilla 12V DC Permanent Magnet Motor Generator

We want a DC output to use for the DC-DC converter, so a rectifier is used to convert the outputted AC sine waveform into a DC rectified waveform. We used the DF04M-ND full-wave bridge rectifier, which is rated at 400V and 1.5A. This converts the generated output into a fully positive waveform, inverting the negative portion from the backward swing to positive. At the output of the rectifier, we placed 3 capacitors in parallel to filter and smooth out the DC voltage.

Figure 4-8: DF04M-ND Full-Wave Bridge Rectifier

After rectification, the value of the voltage will still be lower than the 14V needed to charge the 12V battery, so we used a DC-DC buck-boost converter to step up/down the voltage to a constant 14V. The initial output from the generator will vary depending on the person, so the peak may be higher than 14V in some cases, producing a period of time where the input voltage is higher than the desired output. Therefore, a buck-boost converter is necessary to account for both periods of time where the input is either over or under the 14V output. After conversion, the output should be steady and stable to ensure proper charging to the battery load.

We chose the Auto DC Boost Buck Converter Solar Charge Regulator because it provides the ranges we want with 3-35V at the input and 1.25-30V at the output. The maximum output current rating is 2A, and the power rating is 12W. The maximum rated conversion efficiency is 92%, the switching frequency is 50kHz, and the output ripple is 40mV maximum.

Figure 4-9: Auto DC Buck-Boost Converter Solar Charge Regulator

With the 14V constant output from the buck-boost converter, the voltage is now ready to charge the 12V battery. We used a 12V lead acid battery since it is smaller in size compared to a standard 12V car battery. Its small size allows it to fit in the electrical compartment box. This battery acts as a storage device for the produced energy, something that was lacking in the previous design.

We chose the Werker WKA12-3.3F2 sealed non-spillable battery to store the generated energy. The battery specs are 12V and 3.3Ah, which are suitable for charging a phone at the output.

Figure 4-10: Werker 12V Lead Acid Battery

After the energy is stored in the battery, it can be used later for multiple application purposes. In our case, we are using the energy to charge a phone via USB connection, which requires a 5V output. Therefore, a DC-DC buck converter is needed to step down the 12V charged voltage from the battery to a constant 5V output.

We used the Auto DC Buck Converter Solar Charge Regulator to step down the voltage. The specs of the converter require a 3V to 40V DC input, and the input voltage must be higher than the output voltage by 1.5V or else it won't buck. The output requires 1.5V to 35V DC output, and it is continuously adjustable and has a high-efficiency maximum output current of 3A.

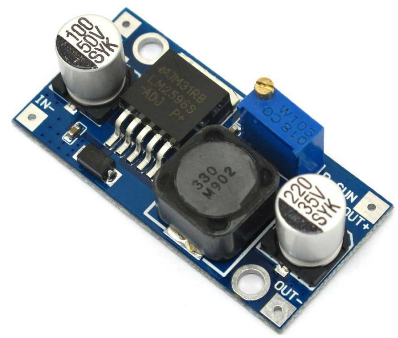

Figure 4-11: Auto DC Buck Converter Solar Charge Regulator

Now the outputted voltage from the buck converter can be used to charge a phone through USB. Overall, the varying voltage produced from the swing is stabilized and stored in an efficient manner useful for charging through the use of regulators and converters.

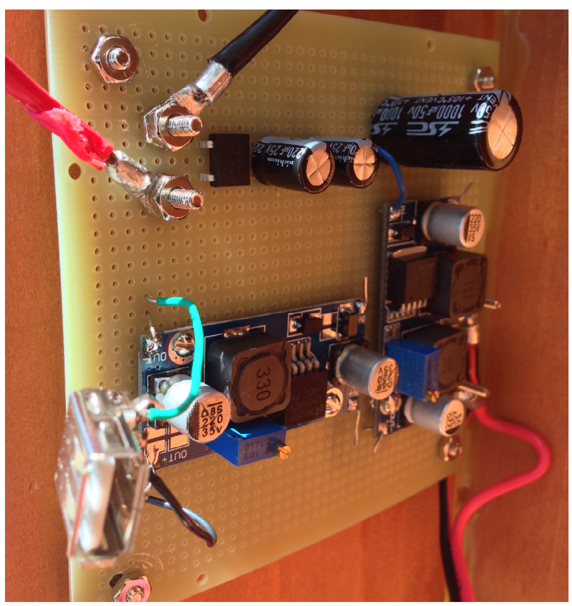

Figure 4-12: Completed hardware circuit on proto board

V. Testing and Data

Once the whole system was finished being constructed, we tested the output voltage at various stages of the circuit. The first stage was the voltage output that the generator was producing, which would also serve as the input to the rectifier. As expected, the generator outputs an AC sinusoidal waveform due to the back and forth swinging motion of the swing. For this test, the peak of the waveform is 16.7V with a period of 1.92s. This means that it takes almost 2 seconds to fully swing back and forth. Also, the 16.7V amplitude means that a buck-boost is necessary instead of just a normal boost since there will be small periods of time where the voltage is above the desired 14V output of the converter.

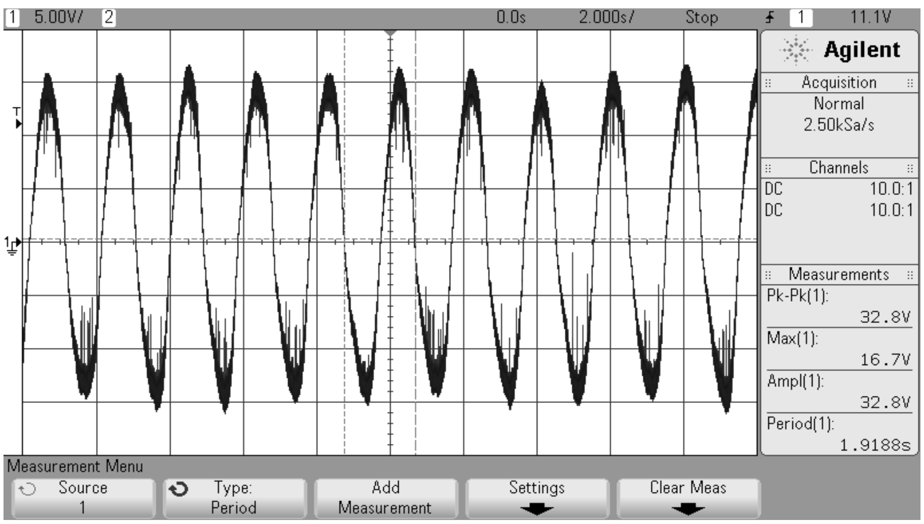

Figure 5-1: Voltage output of the generator and input to the rectifier

The next stage is the use of the full-bridge rectifier to convert the AC waveform to an all-positive DC waveform. The output of the rectifier, which is the input to the buck-boost converter, shows that the negative swing of the AC waveform has been converted into positive polarity. The amplitude in this case decreased slightly due to some loss in the rectifier, dropping to 13V.

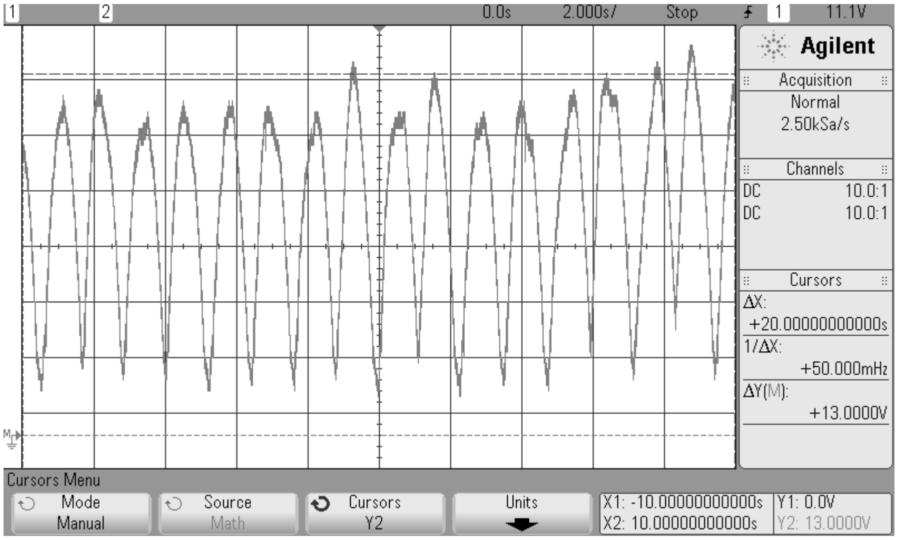

Figure 5-2: Voltage output of the rectifier and input to the buck-boost

After rectification, the buck-boost takes in the new DC voltage and converts it into a constant 14V output. Based on an isolated bench level testing of only the buck-boost converter powered by a DC supply, the required minimum input voltage needed to produce a constant 14V output was 2.9V, which essentially agrees with the 3V minimum input required by the converter. Also, on bench level testing with an ideal sine wave input from a function generator into the generator/rectifier/buck-boost circuit, the minimum peak to peak voltage required for producing 14V at the output was 8Vpp. Based on our tests from the swing, the generator produces peak to peak values greater than 8Vpp, so we are confident that output 14V from the generator should not be a problem when using the swing as the source.

The output voltage of the buck-boost was constant 14.5V, since we set the potentiometer on the converter to output slightly higher than 14V. This is suitable for charging the 12V battery. The waveform has minor dips due to some periods of time where the rectified output is dropping below the 3V minimum buck-boost input due to change of direction when swinging.

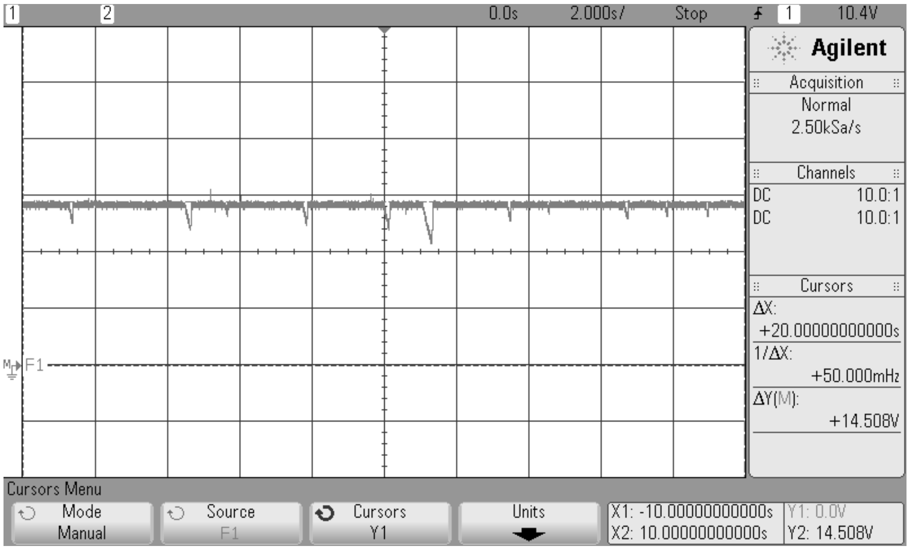

Figure 5-3: Voltage output of the buck-boost converter and input for charging the battery

We also connected a multimeter in series with the buck-boost and the battery to determine the amount of current going into the battery. We tested 24mA charging the battery, which is a relatively small value, but since we have enough voltage over 12V, the battery will still charge but will take longer due to the low amount of current. Based on the 3.3Ah specification of the battery, a 24mA current into it will take approximately 137.5 hours to fully charge the battery when started from empty.

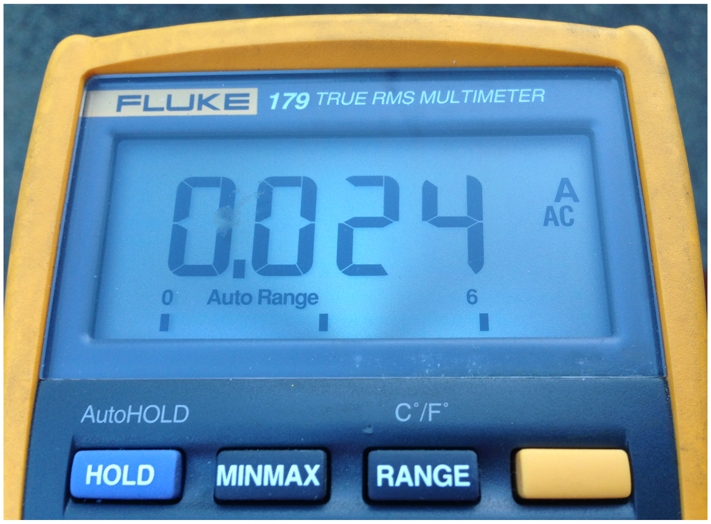

Figure 5-4: Current input into the charging of the battery

The constant 14V output from the buck-boost charges the 12V battery. The battery stores the charge until a load is connected. In this case, a cell phone is attached to the USB connection, and since it requires 5V, a buck converter is placed in-between to step down the voltage. The battery discharges 12V and acts as the input to the buck, and from testing, the output of the buck produced a smooth 5.14V output and charged the phone effortlessly.

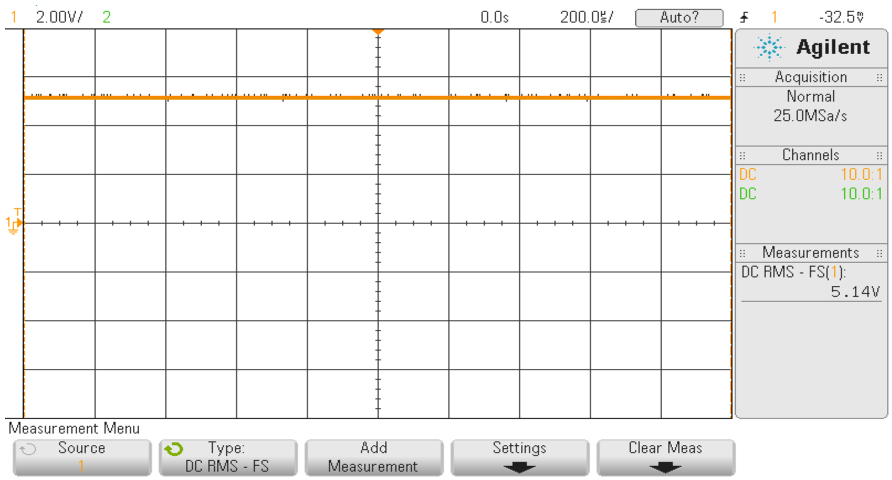

Figure 5-5: Voltage output of the buck converter and input to the USB connection

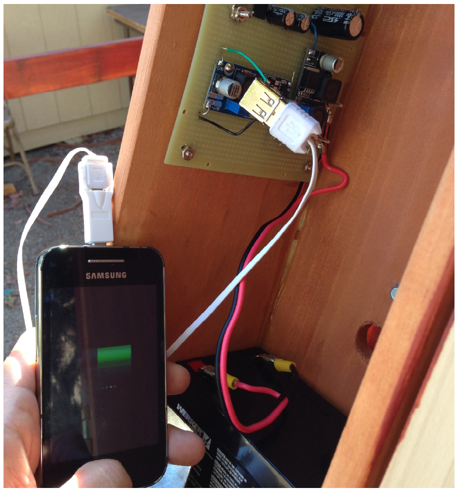

Figure 5-6: Picture showing a cell phone being charged via USB connection

VI. Conclusion and Future Recommendations

Conclusion:

The Human-Powered Swing Generator met all the goals that were required at the start of the project. Redoing the whole structure of the swing not only adds more stability and effectiveness compared to the previous design, but it also adds more appeal and attractiveness in order to make the project more presentable. The addition of the two-wheel pulley system gives more rpm to the shaft of the generator, and the choice of generator is both cheaper and more suitable towards the specifications that are needed in this project. The circuitry of the rectifier and converters are very cheap yet efficient, and the use of a non-spillable lead acid battery conserves space and is safer compared to a typical car battery. This allowed for all the electrical components to fit in a relatively small compartment box that added no significant extra space to the structure. Overall, the project does a great job of demonstrating that power to charge a device can be produced by human mechanical energy. This stage of the project aimed to charge a cell phone, while future iterations will aim towards powering the DC House.

Future Recommendations:

Although the overall project has been a tremendous success, there are still numerous issues that need to be addressed in the next stage by the following group. One main concern is the structure of the swing. The swing is more stable and durable than the previous design, but there are still uncertainties about it. The wood has some cracks in the legs of the swing, and while they don't seem to be a big issue at the moment, they may start to cause major problems as the structure sees more use over time. Also, there is a tremendous amount of stress throughout the whole swing, and it can be heard through the creeks and crackling of the design. The hollow metal pole that holds the swing also bends significantly when a user sits on the swing, so this may cause issues to both the durability and effectiveness of the project. In general, it is advised to have a mechanical engineer in the next group to address these issues since the current group consists of only electrical engineers.

The circuit portion of the project could also use some improvement as well. Although the system produces enough voltage to charge both the battery and a phone, the amount of current produced can be improved. As of now, it is unknown how much time it takes to charge the battery from empty to full, but the amount of current going into the battery suggests that it might take a relatively long time. However, the discharge from the battery charges a cell phone quickly, and it's about the same amount as if it was connected directly to a wall socket. Since later iterations of the project will use it to power the DC House, the circuit needs to be inspected and improved in order to produce enough power needed to supply larger appliances.

Lastly, the overall safety of the whole project needs to be improved as well. The pulley system adds potential dangerous exposure to children and needs to be covered up. In addition, the compartment box needs to be covered more to protect the internal circuitry from rain. More overall protection needs to be placed throughout all the moving and crucial parts of the system to ensure safety of both the user and the components. Therefore, given these recommendations, both mechanical and electrical engineers are highly suggested for the next group.

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[3] "Pulley Diameters and Speeds." *Pulley Diameters and Speeds*. The Engineering Toolbox, n.d. Web. Jan. 2014.

[4] Taufik. "The DC House Project." *The DC House Project*. Cal Poly SLO Electrical Engineering Dept., n.d. Web. Jan. 2014.

[5] S.C. Chen, T.C. Wu, S.C. Weng, and R.T. Chen, “Bicycle Generator,” U.S. Patent 5 874 792, Feb. 23, 1999.

[6] Taufik and D. Dolan, “Non-Isolated DC-DC Converters,” in *Introduction to Power Electronics*, 11th ed. San Luis Obispo, CA: Cal Poly, 2013, ch. 7, pp. 258-267.

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Appendix A – Senior Project Analysis

1. Summary of Functional Requirements

The system converts the swing’s inputted mechanical energy into an electrical output used for charging an external phone. The DC generator produces an AC sine voltage from the torque provided by the swing, and the rectifier converters it to DC voltage. A buck-boost converter steps up/down the voltage to constant 14V needed to charge the 12V lead acid battery. The battery collects and stores energy until a phone is connected at the load. The battery then discharges 12V into the buck converter, which steps down the voltage to 5V needed to charge the phone via USB connection.

2. Primary Constraints

The project targets developing nations, so designing and implementing a cost effective, yet safe and durable, swing system provides a significant challenge. The implementation of the buck and buck-boost converters also impacts the system's approach because of the group's current unfamiliarity at the start of the subject. The fact that the generated energy varies depending on the effectiveness of the user's mechanical energy provides a concern with the total efficiency and usefulness of the system.

3. Economic

The project affects the human capital of developing nations by providing knowledge and creativity in building a cost effective system that provides a form of energy to poor families. The project affects the financial capital of the companies who provide the equipment such as the generator, circuit components, and swing parts, as well as the developing nations' economy due to the imported goods from these exact companies. The project affects the manufactured or real capital due to the tools and machinery necessary to build the swing and the electrical system. The project affects the natural capital because it uses manufactured Earth resources such as the metal for the swing, as well as utilizing reusable parts like the external car battery. The costs and benefits accrue during the project's lifecycle when the system goes through its second iteration of designing and building since the reevaluation of the system provides changes that increase the cost effectiveness of the project. The required input project cost of parts and components limits at $1,000. The three group members split the cost equally, equating to $200 each, and the grant given to our advisor pays for the rest. The original estimated cost of component parts as of the start of the project amounts to around $600. The labor costs amount to around $1,700 total for all three members, as found in Appendix B. The additional equipment cost equates to zero if the project utilizes Cal Poly's equipment such as the soldering and welding tools. Poor families from developing nations profit the most from this project because they acquire energy through use of the children's playing rather than paying the bills. The products emerge after the completion of Dr. Taufik's DC House Project and continue to exist as long as families in these developing nations require the use and assistance of the project. The original estimated development time as of the start of the project equates to around 9 months.

4. If Manufactured on a Commercial Basis

Since the project focuses on designing a non-profit "how-to" guide for building the system in developing nations, the estimated number of devices sold per year equates to zero. The estimated manufacturing cost for producing each device limits at $700 for parts and components and $500 for labor costs. The estimated purchase price for each device and profit per year equates to zero since the group provides the design and earns no profit from it. The estimated cost for the user to operate the device equates to zero because the system requires only mechanical energy instead of a supplied electrical energy.

5. Environmental

The project impacts the environment by helping recycle and reuse parts such as the battery. The project directly uses the Earth's natural resources to build the swing. The project improves the ecosystem by not requiring the use of power plants or underground electrical lines to provide energy to families. With no external electrical plants or lines, other species no longer face the harm of injury or death from exposure of such dangerous systems.

6. Manufacturability

The families in developing nations face challenges in finding the appropriate parts suitable for building their systems. The costs of the components also affect the range of reliable parts that the families can afford. The labor costs play a role because the families desire cheaper labor costs, but that may signify unreliable build and durability of the system.

7. Sustainability

The wood of the swing provides an issue with maintaining the device since wood starts to crack over time. The project impacts the sustainable use of resources by reusing parts such as a battery, but this also provides another issue with the used battery's efficiency and reliability. Harsh weather conditions require the installment of protection for the system's electrical components, and upgrading this protection improves the design of the project but brings up the issue of added cost.

8. Ethical

Two ethical frameworks apply when designing and manufacturing the system. The Golden Rule and Platinum Rule both apply from our group towards the families whom the project targets. If we lived in their situation, we would want a way to find an affordable and cost effective way to generate electrical energy for daily use. The same applies for how the families would like us to treat them. Number 8 in the IEEE Code of Ethics also applies to this project since we plan on designing this project for any families in developing countries who need electricity, regardless of race, religion, or national origin.

9. Health and Safety

Since the project requires a child as the system user, health and safety maintains a crucial part of the design, manufacture, and use of the system. The existence of electrical components and durability of the swing's structure provide a major concern for the safety of the child. The swing's design and protection of exposure to electrical components remain a major impact towards the design and implementation of the project.

10. Social and Political

This project affects social and political issues with corporations in developing nations and impacts all parties involved in those countries. The stakeholders include Dr. Taufik and all the other members who worked on the DC House Project. Since the project requires no profit, it benefits the stakeholders by giving them the satisfaction of helping people in need. If ethical issues pertain to the project, it indirectly affects Cal Poly as an institution and directly affects the specific people involved in the DC House Project.

11. Development

We plan on completing the power electronics series of classes in order to help us choose the suitable DC-DC converters for the system. This project also helps us learn how to find the most efficient and cost effective methods for designing and implementing a system in order to help poor families looking for the cheapest alternatives.

Appendix B – Cost Estimates and Actual Cost

$$Cost = \frac{cost_a + 4cost_m + cost_b}{6}$$

$$where\ cost_a\ is\ the\ most\ optimistic, cost_m\ is\ the\ most\ likely, and\ cost_b\ is\ the\ most\ pessimistic$$

Table B-1: Cost Estimates of the Parts for the System

Parts	$cost_a$	$cost_m$	$cost_b$	Estimated Cost	Justification
Swing Set Equipment	$110	$130	$250	$147	$Cost_a$ plans on changing a minimal fraction of the previous swing, while using cheaper parts. $Cost_b$ plans on completely rebuilding the swing and using more durable parts.
Pulley System Equipment	$15	$25	$40	$26	$Cost_a$ plans on using a rope as the pulley, while $cost_b$ plans on using a chain connected to the generator through a bike crank.
DC Generator	$75	$150	$250	$154	$Cost_a$ plans on buying a cheaper generator that does not transfer torque as well, while $cost_b$ plans on buying an overly effective generator.
Enclosure Material	$25	$40	$70	$43	$Cost_a$ plans on enclosing the electrical components with weak material, while $cost_b$ plans on using thick and durable material.
Boost Converter Components	$15	$28	$40	$28	$Cost_a$ plans on using a simple and cheap configuration for the circuit, and $cost_b$ plans on using more efficient and durable components.
12V Car Battery	$20	$40	$60	$40	$Cost_a$ plans on buying a cheap battery that does not charge as efficiently, while $cost_b$ plans on buying a more durable and effective battery.
Labor Cost	$1,000	$1,700	$2,400	$1,700	The group plans on self-building the whole system, but the labor cost assumes the group earns pay for building the project.

Table B-2: Actual Cost of the Parts for the System

Parts	Cost	Justification
Wood	$115	The wood required for the structure of the swing included pillars for the legs and flat boards for the crossbars.
Pulley System	$170	The pulley system includes the two wheels, the timing belts, the metal pole to turn and support the swing, and the bearings.
Generator	$165	The generator used was much cheaper than the previous one and still met the requirements for the system.
Circuit	$20	The circuit includes the proto board, rectifier, buck and buck-boost converters, USB connection, and wires.
Battery	$30	The battery is affordable and maintains space and safety.
Compartment Box	$20	The compartment box is made of wood and has a door and lock to secure and access the items.
Chain and Swing	$20	The chain that holds the swing and the actual swing itself provide comfort and usability.
Screws and Bolts	$30	The numerous screws, bolts, and nuts that were used to hold everything together.

Appendix C – Gantt Chart

Task Name	Start	Finish	Duration
Project Planning	1-Sep	9-Dec	11 weeks
Abstract (Proposal) V1	1-Sep	23-Sep	22 days
Requirements and Specifications	23-Sep	7-Oct	14 days
Block Diagram	7-Oct	14-Oct	7 days
Literature Search	14-Oct	21-Oct	7 days
Gantt Chart	21-Oct	28-Oct	7 days
Cost Estimates	21-Oct	28-Oct	7 days
Sensitivity Analysis	21-Oct	31-Oct	10 days
ABET Sr. Project Analysis	28-Oct	4-Nov	7 days
Requirements and Specifications V2	4-Nov	11-Nov	7 days
Reverse Engineering	4-Nov	20-Nov	16 days
Report V1/Documentation	23-Sep	15-Nov	8 weeks
Report V2/Documentation	20-Nov	9-Dec	19 days

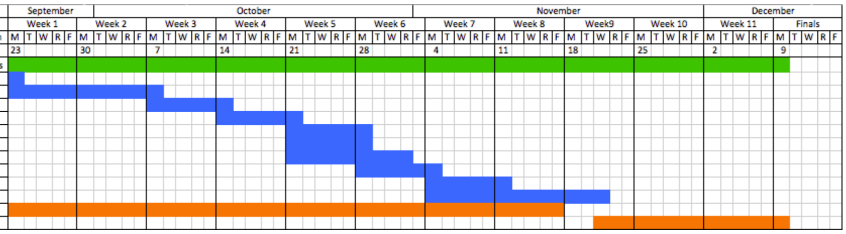

Figure C-1: Gantt Chart for Fall Quarter

Task Name	Start	Finish	Duration	Member
Swing Set				
Design Swing Set	6-Jan	15-Jan	9 days	Brandon
Purchase Swing Set Equipment	15-Jan	27-Jan	12 days	
Construct Swing Set	27-Jan	10-Feb	17 days	
Test Swing Set for Safety and Stability	10-Feb	19-Feb	9 days	
Document Swing Set	6-Jan	19-Feb	7 weeks	
Pulley System				
Design Pulley System for Generator	6-Jan	15-Jan	9 days	Danny
Purchase Pulley System Equipment	15-Jan	27-Jan	12 days	
Purchase DC Generator	15-Jan	27-Jan	12 days	
Build Pulley System	27-Jan	10-Feb	17 days	
Test Pulley System and Generator	10-Feb	19-Feb	9 days	
Document Pulley System and Generator	6-Jan	19-Feb	7 weeks	
Enclosure for Electrical Equipment				
Design Enclosure for Electrical Equipment	13-Jan	20-Jan	7 days	Brandon
Purchase Enclosure Material	20-Jan	3-Feb	14 days	
Build Enclosure	3-Feb	17-Feb	14 days	
Boost Converter Circuitry				
Design Boost Converter for 12V Car Battery	6-Jan	22-Jan	16 days	Tim
Purchase Circuitry Components	22-Jan	5-Feb	14 days	
Purchase 12V Car Battery	22-Jan	5-Feb	14 days	
Construct Boost Converter Circuitry	5-Feb	12-Feb	7 days	
Test Boost Converter Circuitry	12-Feb	19-Feb	7 days	
Document Boost Converter	6-Jan	19-Feb	7 weeks	
Design Review Activity	20-Feb	20-Feb	1 day	All
Integrate Whole System Together and Test	20-Feb	10-Mar	18 days	
Document Integration of Whole System	20-Feb	10-Mar	18 days	
End of 463 Report	20-Feb	14-Mar	22 days	

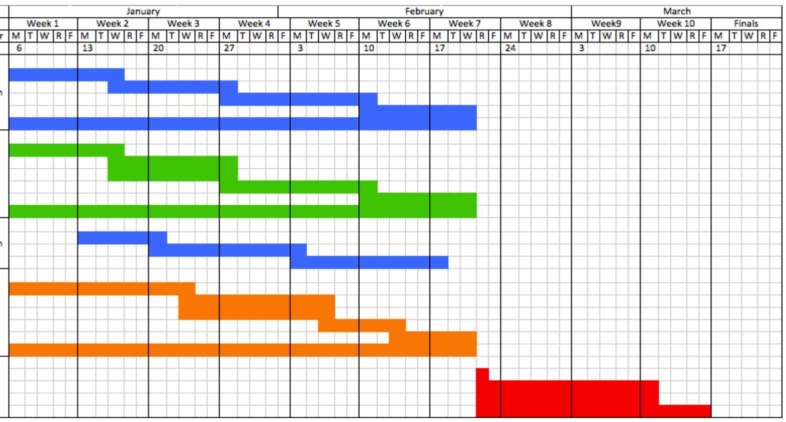

Figure C-2: Gantt Chart for Winter Quarter

Task Name	Start	Finish	Duration	Member
Swing Set				
Improve Swing Set Design	1-Apr	9-Apr	8 days	Brandon
Purchase Necessary Swing Set Equipment	9-Apr	21-Apr	12 days	
Implement/Reconstruct Improved Swing Set	21-Apr	30-Apr	9 days	
Test Improved Swing Set for Safety and Stability	30-Apr	7-May	7 days	
Document Improved Swing Set	1-Apr	7-May	6 weeks	
Pulley System				
Improve Pulley System Design for Generator	1-Apr	9-Apr	8 days	Danny
Purchase Necessary Pulley System/Generator Equipment	9-Apr	21-Apr	12 days	
Implement/Reconstruct Improved Pulley System	21-Apr	28-Apr	7 days	
Test Improved Pulley System and Generator	28-Apr	7-May	9 days	
Document Improved Pulley System and Generator	1-Apr	7-May	6 weeks	
Enclosure for Electrical Equipment				
Improve Enclosure Design for Electrical Equipment	7-Apr	14-Apr	7 days	Brandon
Purchase Necessary Enclosure Material	14-Apr	23-Apr	9 days	
Implement/Reconstruct Enclosure	23-Apr	7-May	14 days	
Boost Converter Circuitry				
Improve Boost Converter Design for 12V Car Battery	1-Apr	9-Apr	8 days	Tim
Purchase Necessary Circuitry Components	9-Apr	23-Apr	41 days	
Implement/Reconstruct Boost Converter Circuitry	23-Apr	30-Apr	7 days	
Test Improved Boost Converter Circuitry	30-Apr	7-May	8 days	
Document Improved Boost Converter	1-Apr	7-May	6 weeks	
Reintegrate Whole System Together and Retest	8-May	27-May	19 days	All
Document Integration of Whole System	8-May	27-May	19 days	
College of Engineering Show & Tell Expo Center	29-May	29-May	1 day	
End of 464 Report	8-May	6-Jun	4 weeks	

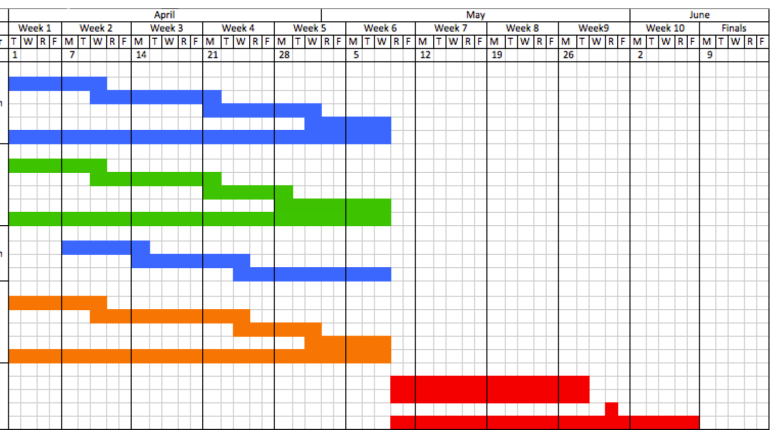

Figure C-3: Gantt Chart for Spring Quarter