Merry-Go-Round Human Powered Generator

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2013

Table of Contents

List of Tables and Figures

Tables

Figures

Abstract

This project entails the design and construction of a Merry-Go-Round Human Powered Generator for the DC House project. The Merry-Go-Round Human-Powered-Generator is a sustainable project focusing on utilizing renewable human mechanical energy. As young children play on the Merry-Go-Round, the generator converts the mechanical energy to electrical energy for the DC House. The Merry-Go-Round Generator boosts the generated voltage output to power a battery. This electrical energy then transfers from the battery to the DC House to provide power to it.

I. Introduction

With the spread of globalization, demand for inexpensive and renewable sources of electricity rises in many developing countries. Energy analysts at the IAEA expect demand for electricity in the next 20 years to increase to about $16 trillion, or $550 billion a year from 2010-2030 [2]. Additionally, analysts expect demand to increase more than the actual supply of electricity. Renewable and non-renewable sources need to develop and increase to mitigate the shortfall. With continued industrialization and development of less fortunate countries, people living in these countries need to have access to electricity.

Demand for renewable energy is expected to increase from two and a half to four times more from now until 2030 [3]. Analysts at Bloomberg New Energy Finance expect Hydro, geothermal, and biomass to become important sources of energy as well as solar and wind power. Many developed countries (such as the United States) began shifting their focus from fossil fuels into renewable sources.

New challenges arise where energy demand exists for those living off of the power grid. People living in poor, developing countries live too far from either the power grid or a city and need some form of renewable electricity. Of the many ways to accomplish this, one way utilizes clean and efficient renewable energy. Many renewable options for those living off the power grid include solar, wind, and mechanical conversion into usable electricity to help power homes.

The DC House aims to aid those who live too far from power supplies and systems. It allows them to gain access to electricity at a DC voltage instead of AC from typical power lines. The project started three years ago and previous students completed most of the internal parts of the DC House [1]. Voltage generation constitutes the current focus of the DC House. This development phase includes generating electricity from devices such as a swing, a merry-go-round, and a seesaw.

The DC Human-Powered-Generator device operates with one simple idea in mind: convert rotational mechanical energy from spinning a Merry-Go-Round to electrical energy that helps power a home. The Merry-Go-Round design aims to provide a safe and entertaining way for children to have fun while providing electrical benefits to homes. The Merry-Go-Round uses several power electronic circuit designs [4] that provide the means to power to the DC House with regulated DC voltage in accordance with the current DC House focus. The Human-Powered-Generator, part of a much larger DC House project, provides DC electricity to people in developing or impoverished areas [1].

The Merry-Go-Round utilizes a brushless AC generator [5] to provide an AC voltage source. The apparatus rectifies, filters, and steps up the voltage through a boost converter [6] to provide 12 volts for the DC House array. The custom made Merry-Go-Round design draws upon the aid of guides [7] and lightweight materials [8] to allow younger children to spin and play on the device without adult intervention.

II. Background

Many developing countries lack electrical power due to no access or great distance to power generated systems. Without a large capital system in place, there is little incentive for power generation or transmission companies to embark on multimillion dollar projects.

Other companies and colleges attempt to provide power generation to areas that lack it. For example, BYU students [11] and Empower Playgrounds (a non-profit company) [13] created human powered generators. They were responsible for creating voltage generation playground equipment sold and often donated to those living in many poor, rural areas. The students at BYU constructed a merry-go-round project (similar to this Merry-Go-Round project) for Empower Playgrounds and it helped power the classrooms of the children that play on it. Many attempts to power these impoverished areas will only increase as the demand for power in those areas continues to grow.

Overall, the DC House [1] aims to provide a cheap and renewable access to electricity for many inhabitants living below the poverty line. With the advancement in power electronic technology, more efficient methods to generate power without the use of large generators and transmission lines continue to develop. This project provides a method for DC power generation for the DC House. In particular, this project's objective is to design and construct a Merry-Go-Round human-powered generator to provide electrical power to the DC House. By using DC, the DC House can utilize the flexibility of non-concurrent power generation and power consumption. The DC House uses batteries, a component not ubiquitous to AC systems, to accomplish this task. For example, children in a village operate the merry-go-round during the morning hours to generate power and then use the stored power to light several rooms in their school during the afternoon hours.

III. Requirements and Specifications

Table 3-1 below lists requirements and specifications for the project. At least one marketing requirement backs up each engineering specification and vice versa. Justification for the specifications comes from Mark Cabaj's report [9] which laid down the groundwork for the reason why the array requires 12 volts from the output voltage. The IEEE code of ethics [10] informs the reason for protecting the users.

Table 3-1:
DC Merry-Go-Round Generator Requirements and Specifications

Marketing Requirements	Engineering Specifications	Justification
1, 2, 6	The Merry-Go-Round's base shall use plywood, along with wooden handrails [8]	Using a wooden base will be easier to spin for young children, cheaper than most metals, and survive most climates
1	Total cost of the generator, base, and any other materials used in this project must cost less than $1000	The Merry Go Round needs to provide an inexpensive option for those living in impoverished and developing areas
4, 7	The generator keeps any wiring used in a concealed yet accessible location	This prevents kids from touching the generator and allows repair by taking apart the enclosed section
2, 3	The 6ft diameter base handles 200lb at most (3 small children)	This length should be enough to house a generator beneath it and wide enough for children to play on the top
5, 6	The wiring for the generator will be insulated and output ≈ 12 V which leads to a battery [9]	The wiring from the generator allows the power generated to power a battery, which powers the DC House Array

Marketing Requirements

1. Affordable for those living in developing and impoverished countries.
2. Light enough to be spun by young kids ages 10 and up.
3. Big enough and able to support older, bigger kids.
4. Internal circuitry needs to be well hidden and unable to shock any of the users.
5. Generated power to needs to be sent to a battery array [9].
6. Able to operate under hot, cold, and humid climates [11].
7. Able to be maintained and repaired by those with little technical knowledge.

IV. Design

The Merry-Go-Round represents the Human Powered portion of the DC House and works with the other generators to provide renewable electricity to the home.

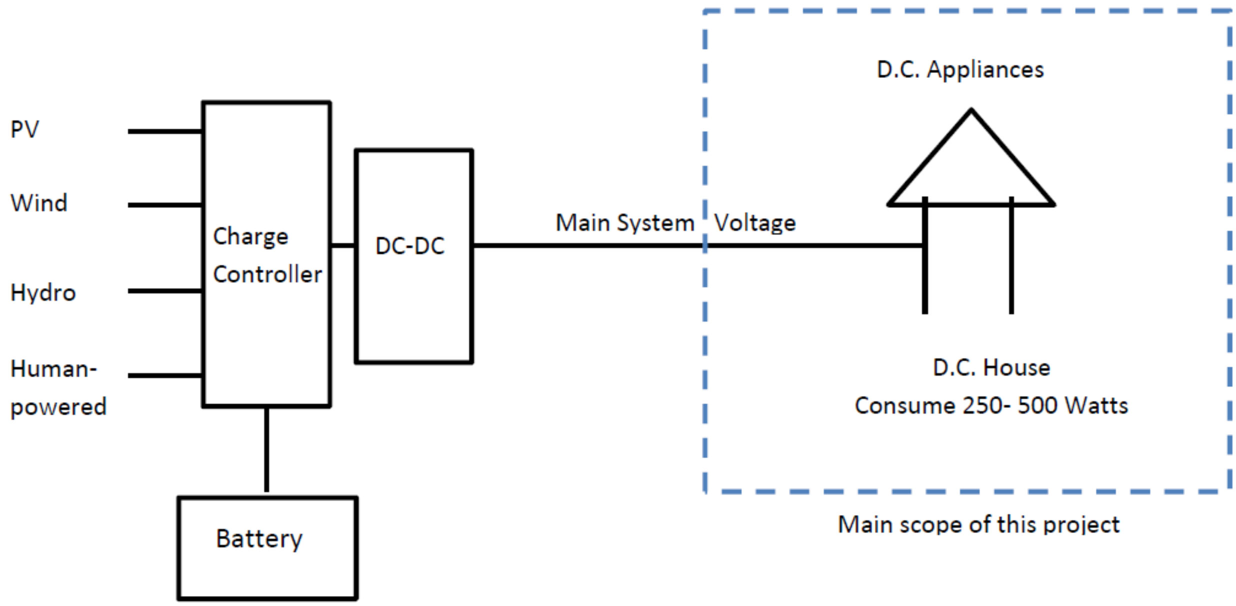

Figure 4-1:
DC House Overview

Figure 4-1 illustrates the large components that comprise the DC House project. The image was created for the DC House design and can be found on the DC House website. [1]

Level 0 Block Diagram

Figure 4-2 and Table 4-1 below represent a simplified view of the entire Human Powered generator, including details for each input and output.

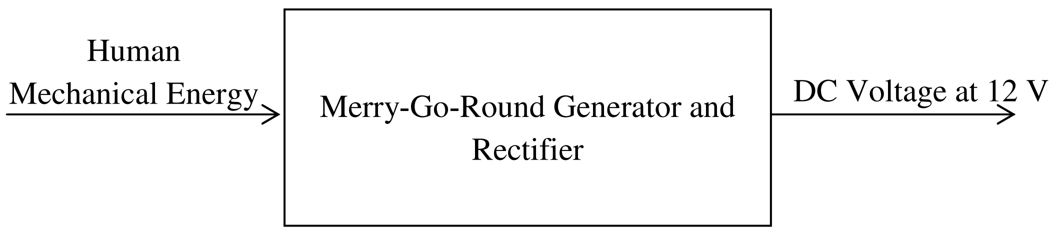

Figure 4-2:
Level 0 Block Diagram of DC Merry-Go-Round

Table 4-1:
Merry-Go-Round Generator and Rectifier (Level 0)

Module	Merry-Go-Round Generator and Rectifier
Inputs	Mechanical Energy: Rotational Energy from turning the Merry Go Round
Outputs	DC Voltage: 12 V to go into battery
Functionality	Spinning the Merry Go Round produces rectified and regulated electrical power connects to a DC battery array.

In this diagram, children apply rotational/mechanical energy to the Merry-Go-Round generator. Inside this level 0 box, the generator converts the generated AC voltage to 12 volts DC. This DC voltage charges a 12 volt battery which the DC House battery array uses as one of its inputs [9].

Level 1 Block Diagram

Figure 4-3 shows a more in-depth version of Figure 4-2. This block diagram includes an AC Coil Generator, an AC-DC Rectifier, and a boost Converter that converts Human Rotational-Mechanical Energy to a DC 12 volt output.

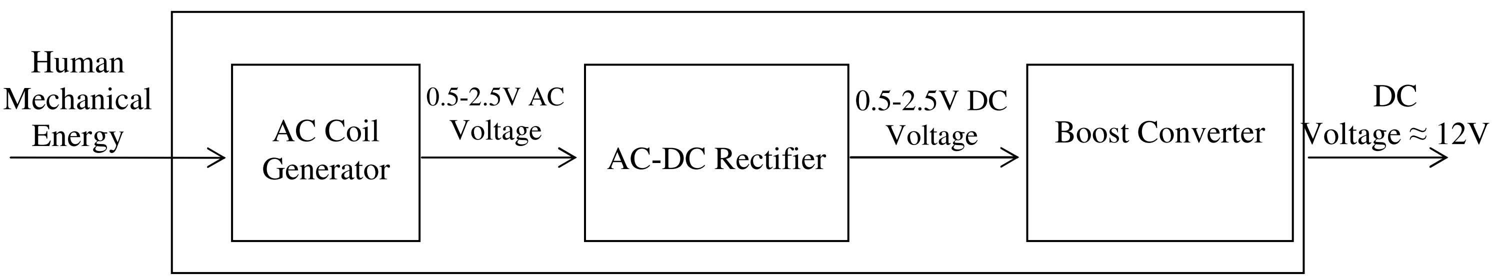

Figure 4-3:
Level 1 Block Diagram of Merry-Go-Round

Table 4-2:
AC Generator (Level 1)

Module	AC Generator
Inputs	Mechanical Energy from spinning the Human Powered Generator
Outputs	0.5-2.5 V AC Voltage
Functionality	The generator converts the rotational energy from spinning the Merry-Go-Round to an AC electrical voltage

Table 4-2 describes the AC Generator module. The AC Generator converts mechanical energy from rotating the wheel of the Merry-Go-Round to an AC voltage. Magnets passing over coils induce AC electrical voltages between 0.5-2.5 volts. The AC Generator follows the brushless design specified in Electric Machinery Fundamentals [5].

Table 4-3:
AC-DC Rectifier (Level 1)

Module	AC-DC Rectifier
Inputs	0.5-2.5 V AC Voltage
Outputs	DC Voltage ≈ 0.5-2.5 V DC
Functionality	The AC-DC Rectifier converts the AC voltage to a DC voltage with the same peak voltage from before

Table 4-3 describes the AC-DC Rectifier module. The rectifier converts the 0.5-2.5 AC voltage to a DC voltage equivalent with some AC ripple (See Figure 6-1). “Introduction to Power Electronics” course EE410 provides theory for the rectifier circuit [4].

Table 4-4:
Boost Converter (Level 1)

Module	Boost Converter
Inputs	DC Voltage ≈ 0.5-2.5 V DC
Outputs	DC Voltage ≈ 12 V DC
Functionality	The Boost Converter boosts the smaller DC Voltage to 12 V DC

Table 4-4 describes the Boost Converter section. The Boost Converter circuit receives the 0.5-2.5 DC voltage from the Rectifier and boosts it to 12 V DC. Linear Technology produces a chip which handles these voltage ranges and sells a test board which this project uses [6].

V. Construction

Construction of the mechanical segment of the Merry-Go-Round started from the ground and proceeded upward. It starts with the base supports followed by the base platform. The platform allows a flat surface for the Merry-Go-Round's top's wheels to roll on. The center of the base contains a metal pipe slightly larger than the top's drop-pipe so that the top pipe fits inside the lower pipe. This keeps the top of the Merry-Go-Round centered and from rolling off the base. The top, a 6 ft. diameter circle rotates on eight casters which bear the weight of the riders. Above the top, two crossing rails provide four posts for riders to use to push the Merry-Go-Round. Construction of the electrical part of the generator followed the mechanical part. 36 hand wound coils with 50 turns each reside in a 32" diameter ring around the center. Every three coils connect electrically to form a three-phase coil base with 12 coils per phase. The three phases produce six wire leads. These leads connect electrically in Y (wye) fashion to produce three phase voltages and a neutral common. Above the coil base and connected to the Merry-Go-Round top, 12 magnets alternate in polarity and pass over each coil during rotation.

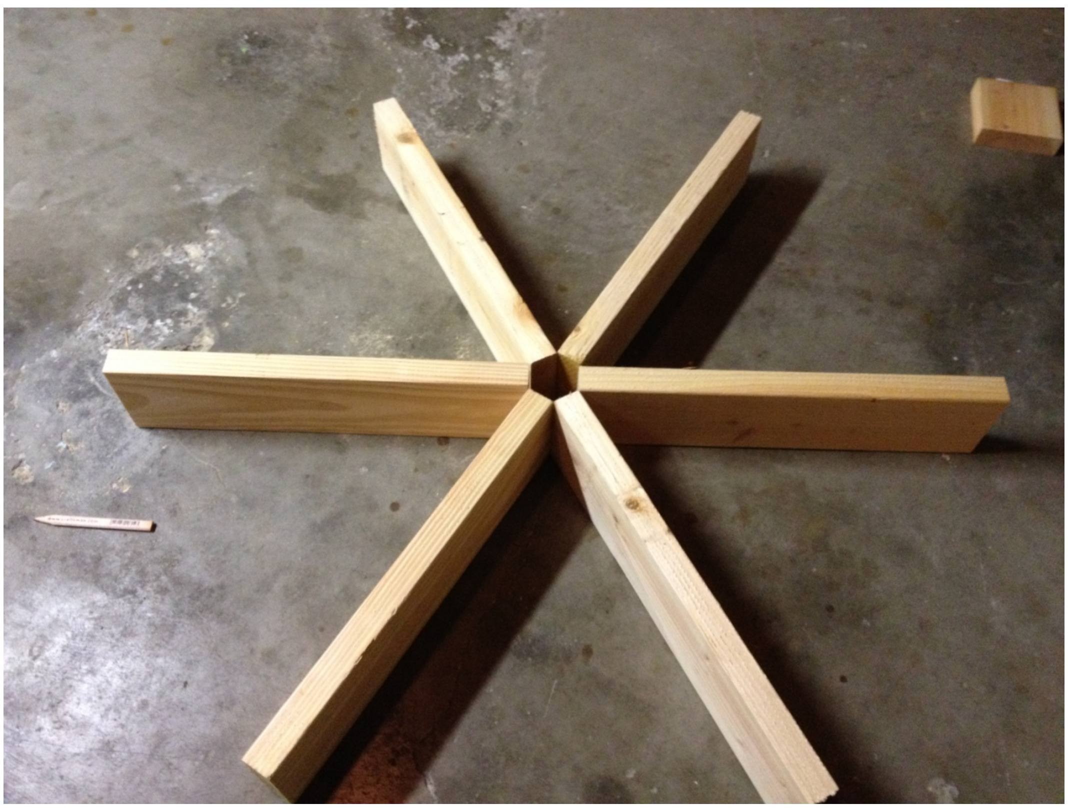

Figure 5-1:
Support boards organized into the pattern for base

Figure 5-1 illustrates the pattern for the support boards of the base. The length of any two cross-boards together measures 4 ft. The boards, 2"x6" stand on end to provide room for electrical components in one of the 60 degree sectors.

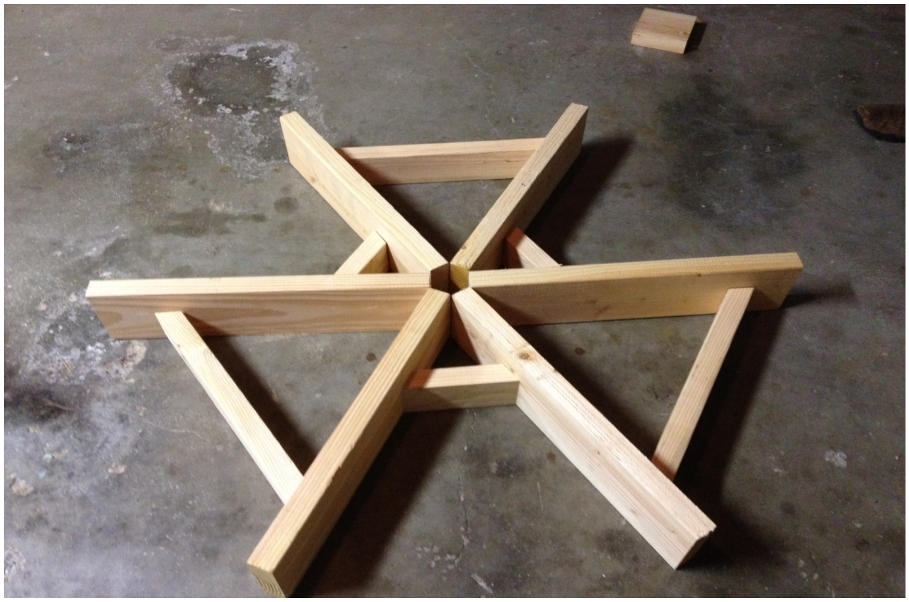

Figure 5-2:
Base with small support blocks

Figure 5-2 displays the small blocks between the six support boards. Each smaller block alternates in length to provide lateral support to the 2”x6” support boards to reduce the support boards’ ability to twist when loaded at a non-normal angle. Each smaller board’s ends use 60 degree cuts to fit snugly against the base support boards.

Figure 5-3:
4 ft diameter plywood circular platform on base

Figure 5-3 shows the ground perspective of the base. A 4 ft. diameter plywood circle attaches to the support boards to provide a base for the top’s casters to roll on.

Figure 5-4:
6 ft. diameter plywood circle as the Merry-Go-Round top

Figure 5-4 shows the top of the Merry-Go-Round next to the base. The top comprises two 6 ft. diameter semicircles attached to a 4 ft. diameter support. The plywood comes in 4’x8’ dimensions so a one piece 4 ft. diameter circle is possible but a one piece 6 ft. diameter circle is not.

Figure 5-5:
Base hole to keep stand and pipe in place

Figure 5-5 illustrates the centering pipe. Due to the support boards beneath, the flange must attach to the hexagonal board which attached to the base farther away from the center.

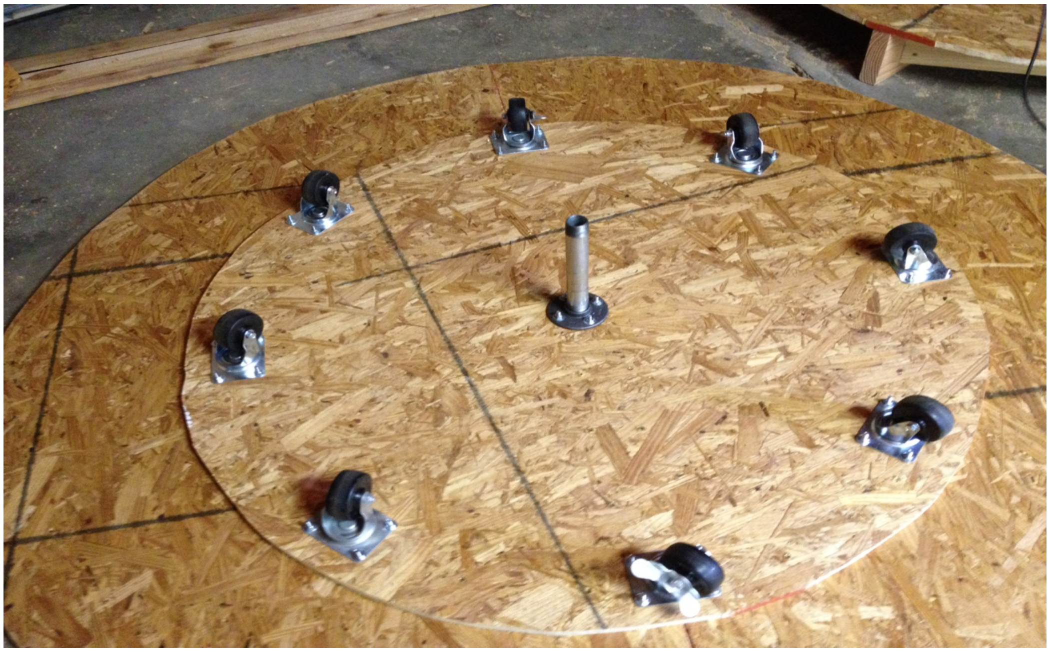

Figure 5-6:
Casters and centering pipe on bottom of top

Figure 5-6 shows two components attached to the top. In the center, a flange supports a pipe which fits inside the flange and pipe of the base to keep the top centered. Additionally, eight 3” casters attach to the top’s support equally spaced around the outside.

Figure 5-7:
Stand spinning on top of base

Figure 5-7 displays the top fitting on the base. The top spins in a circle on the base about the centering pipe. The top stands approximately 11 inches from the ground.

Figure 5-8:
Wooden Handrails

Figure 5-8 shows the wooden handrails bolted to the Merry-Go-Round top. Each 2”x4” cross board spans the 6 ft. diameter of the top. The 4”x4” posts stand approximately 2’6” tall with some deviation to accommodate the height of the cross board. The handrails attach and detach conveniently with a wrench.

Figure 5-9:
Example of wrapped coil

Figure 5-9 shows one 50 turn coil with approximately a 2.75 inch diameter.

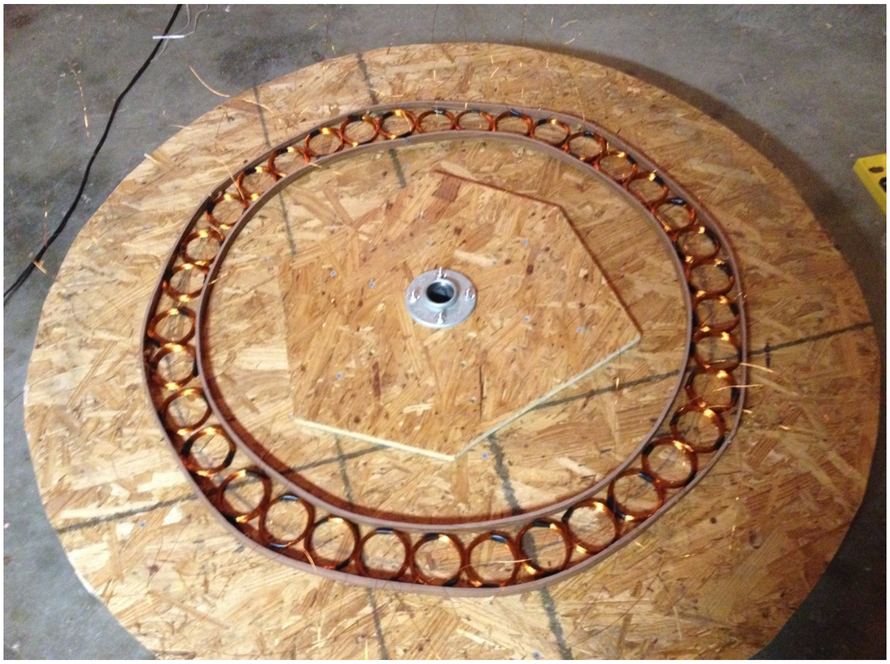

Figure 5-10:
Coils arranged in 3 phases

Figure 5-10 illustrates the arrangement of the 36 coils. The leads of each coil connect to every third coil to produce three phases. The center of the coils reside 16 inches away from the center between an inner and outer wall. The walls provide a volume for waterproof resin to fill to enclose the coils.

Figure 5-11:
Magnets arranged in North-South-North pattern

Figure 5-11 displays the arrangement of the magnets beneath the top. The polarities alternate North to South and the magnets in the blocks reside 16 inches away from the center and

equidistantly from each other. The blocks contain N48 neodymium magnets with 96 lb pull force. The blocks hang from the top by two bolts each. Turning the bolts clockwise raises the magnet blocks away from the coils while turning the bolts counterclockwise lowers the magnet blocks toward the coils.

Figure 5-12:
Finished Prototype of Merry-Go-Round Generator

Figure 5-12 shows the top resting on the base with handrails, coils, and magnets in place. The end leads from the coils drop down through a small hole in the base platform to connect to circuitry underneath the base.

VI. Testing

This section includes all the voltage testing for the Merry-Go-Round generator. The first few figures analyze the waveform shape obtained by the oscilloscope and compute rotational speed based on the waveforms. The next set of figures display the voltage output of the Merry-Go-Round spinning at different speeds. It includes no-load AC output as well as DC rectified and capacitor filtered waveforms. Finally, this section includes the 12 V DC output boosted from the rectified input.

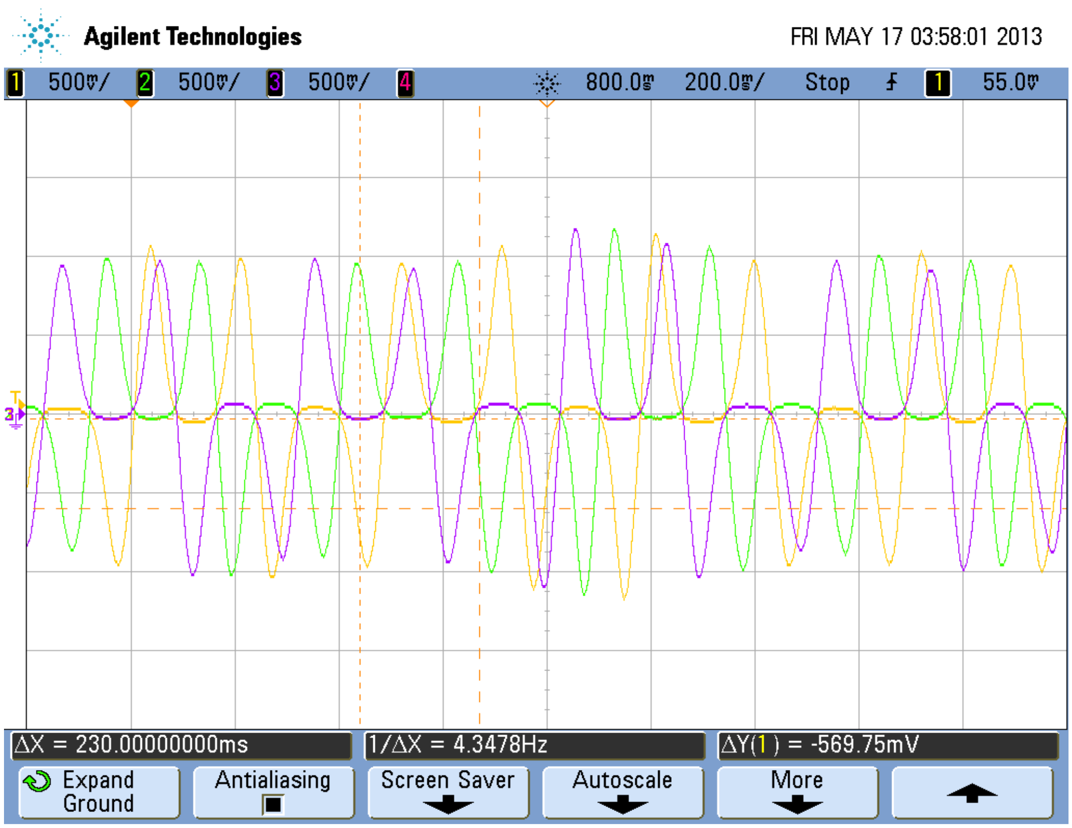

Figure 6-1:
Voltage Waveforms of 3 Phases

Figure 6-1 shows the voltage waveforms from the three generator phases. The oscilloscope measured the no-load voltages. The scope settings used 500 mV/div for each channel vertically and 200 ms/div horizontally. This test produced a 2 V peak to peak waveform for each phase. Each phase experiences a 2 V swing alternating in a positive and negative slope. These swings occur approximately 1.25 divisions apart indicating the magnets pass over a new coil for a given phase every 250 ms. With 12 coils per phase, the total period of revolution equals 3 seconds (12 coils/rev * 250 ms/coil) or 20 RPM. With an outermost wheel circumference of 18.85 ft, a person must run 6.283 ft/s (1.915 m/s) or 4.28 mph (6.89 km/h) to achieve this waveform.

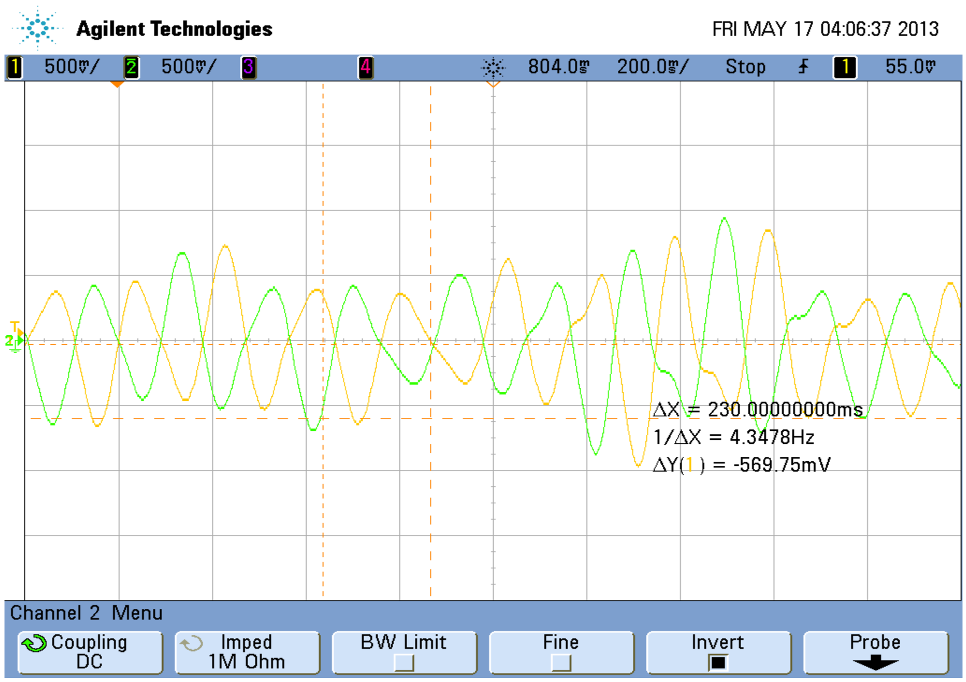

Figure 6-2:
Line-to-line voltages of the A phase and B phase

Figure 6-2 displays the line to line voltages across A-B and B-C at no-load and spinning the merry-go-round approximately 20 RPM. The line to line peak to peak voltages vary from 800 mV to 1.5 V at this speed.

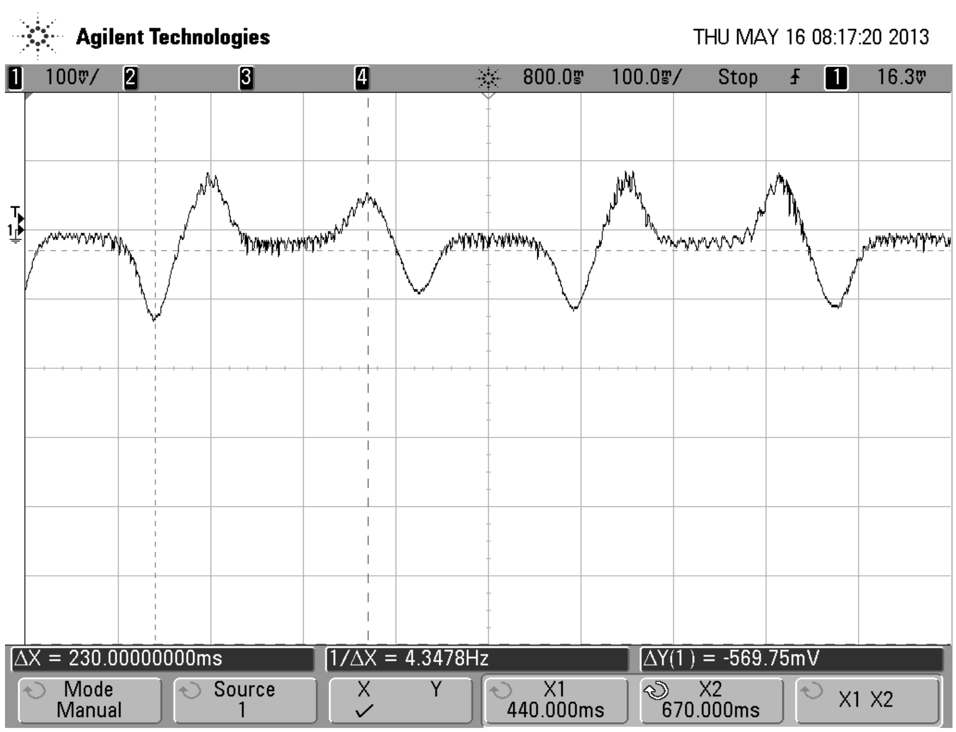

Figure 6-3:
Single phase voltage waveform

Figure 6-3 displays one phase of the generator at no load. The magnets pass over each coil for that phase every 230 ms which yields a 21.7 RPM rotational speed (60 s/min / (12 coils/rev * 0.230 s/coil)). The scope also displays a high frequency ripple during testing. This interference may originate from a local AM broadcast.

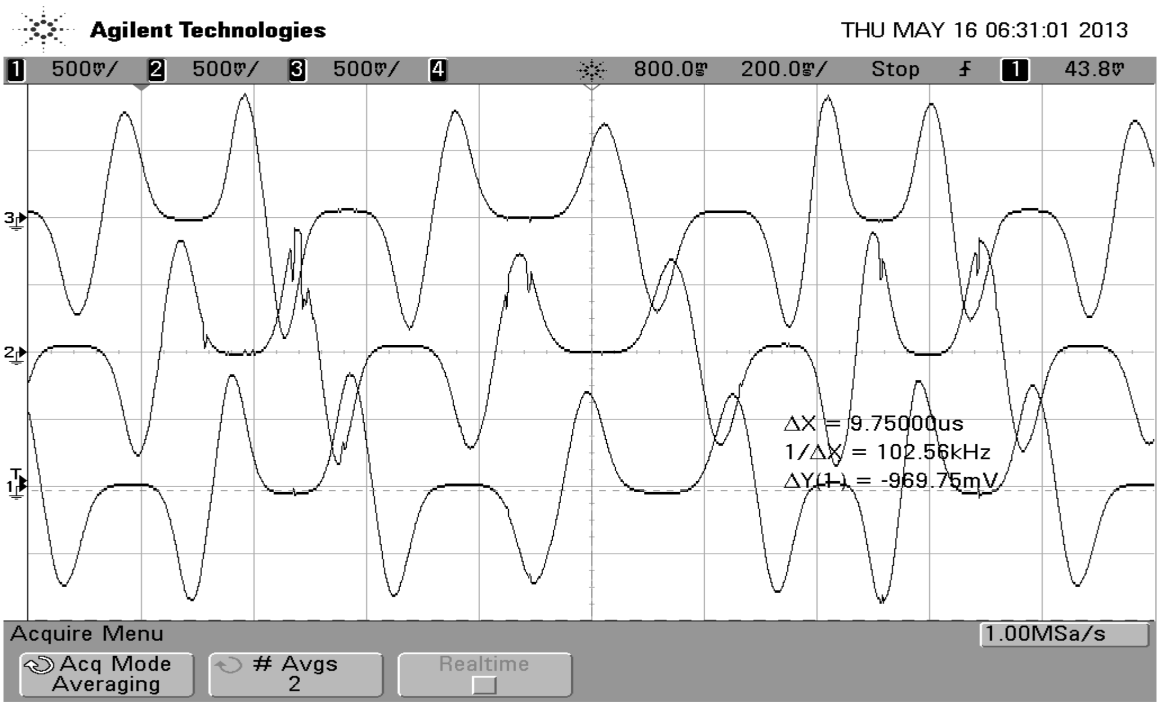

Figure 6-4:
Three phase voltages separated

Figure 6-4 displays the three phases separated on screen vertically to provide greater clarity for their shapes in comparison to each other (opposed to overlaid in Figure 6-1). Also, this screen capture uses two averages to null out the high frequency ripple seen in Figure 6-3.

Speed and Voltage Comparisons

Figures 6-5 through 6-10 show the AC voltage of the generator at no load ranging from 15 RPM to 33.75 RPM. Table 6-1 below summarizes the approximate peak to peak voltages with respect to rotational speed. The scope uses two averages to filter out high frequency noise so the table includes the peak value observed in case the two averaged waveforms occur out of phase with respect to each other.

Table 6-1

Generator Voltage vs Speed (V_{pp}, no load)

Speed (RPM)	V_{pp} (V)
15	1.25
18.75	1.75
22.5	2.0
26.25	2.5
30	2.75
33.75	2.5

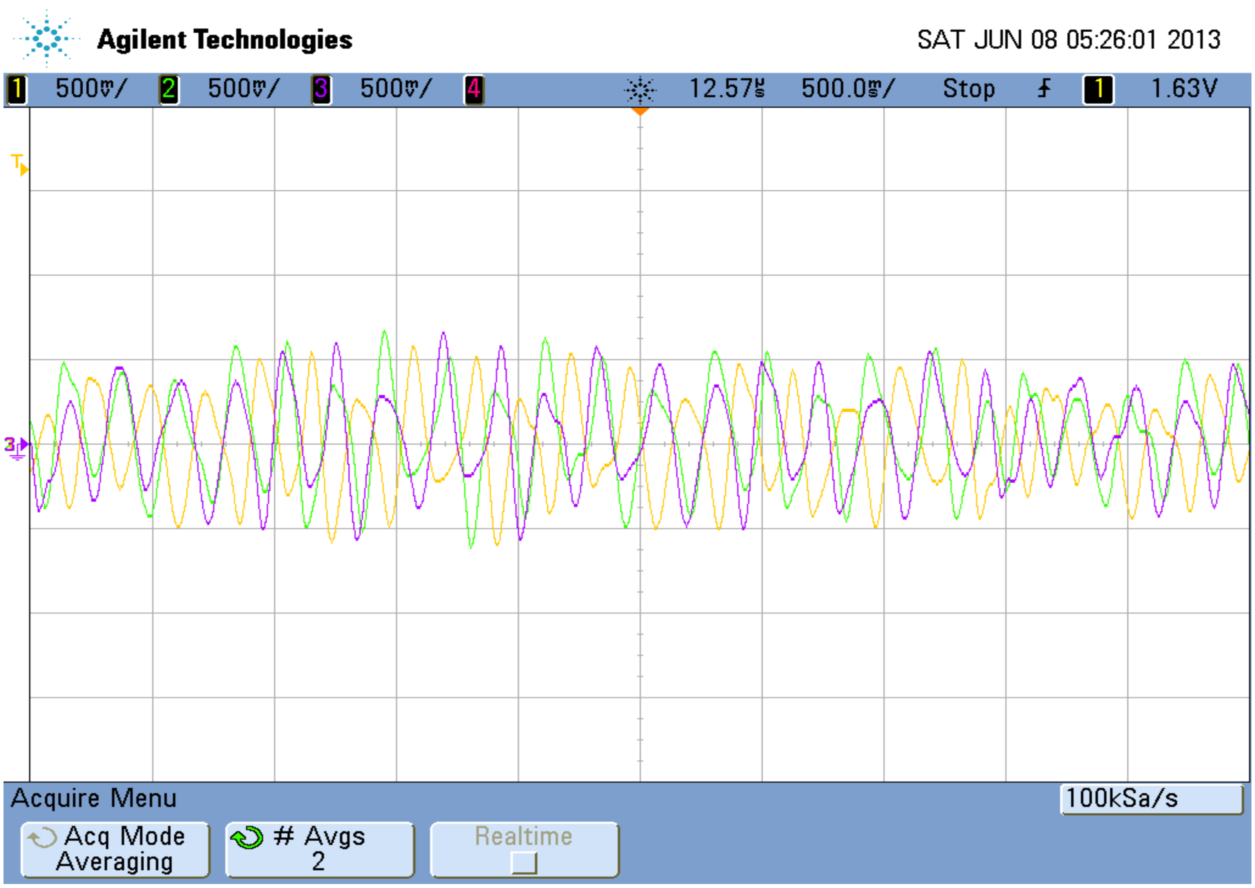

Figure 6-5:

No load voltage at 15 RPM

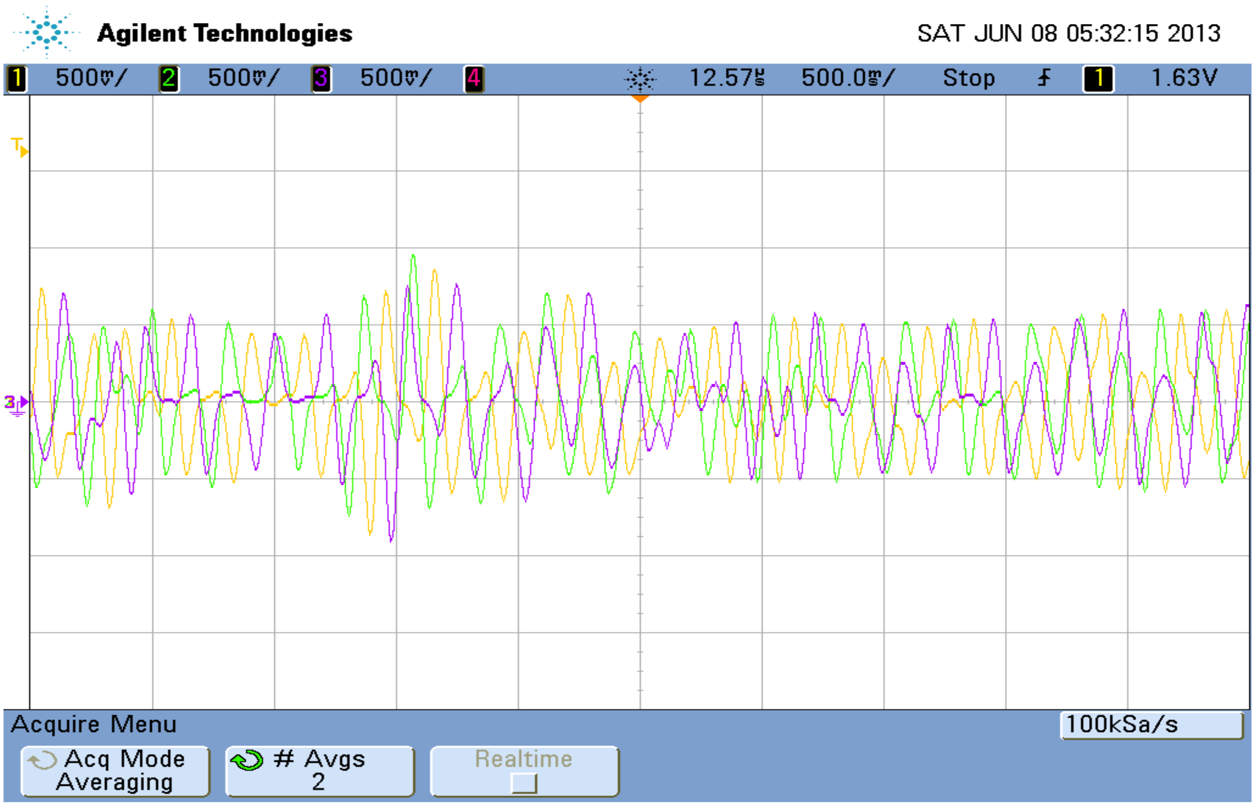

Figure 6-6:
No load voltage at 18.75 RPM

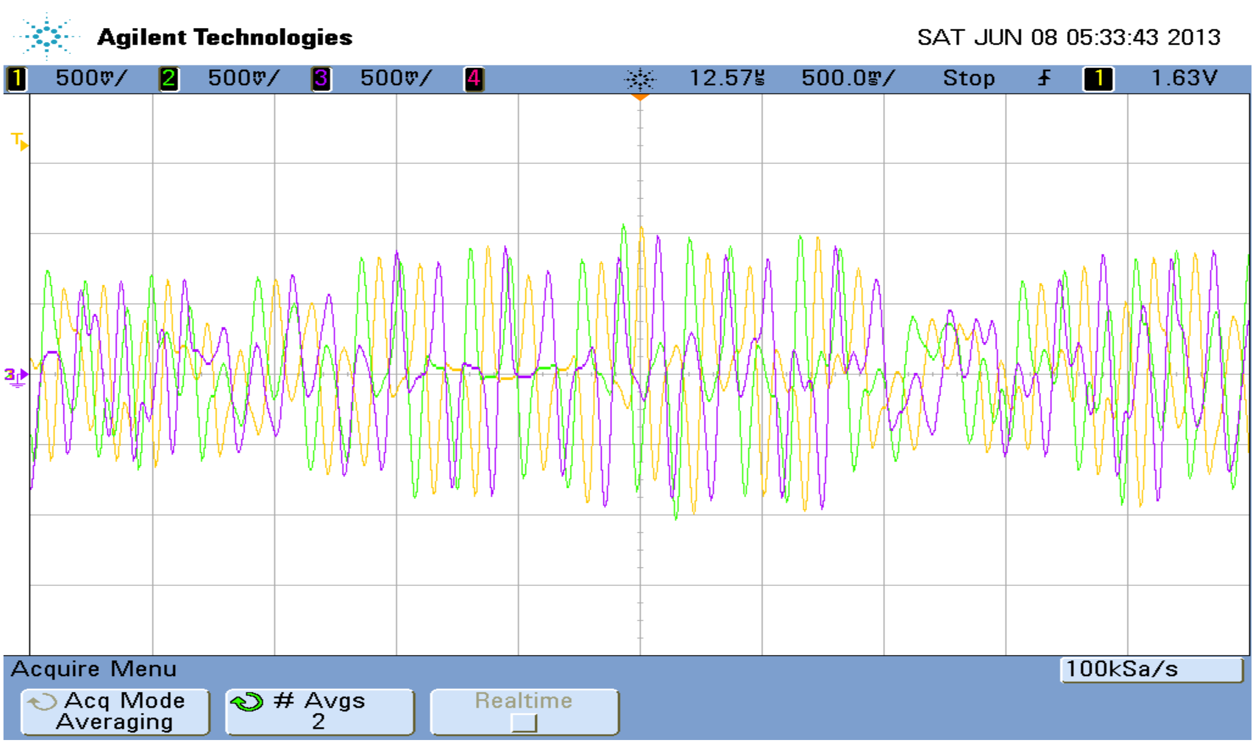

Figure 6-7:
No load voltage at 22.5 RPM

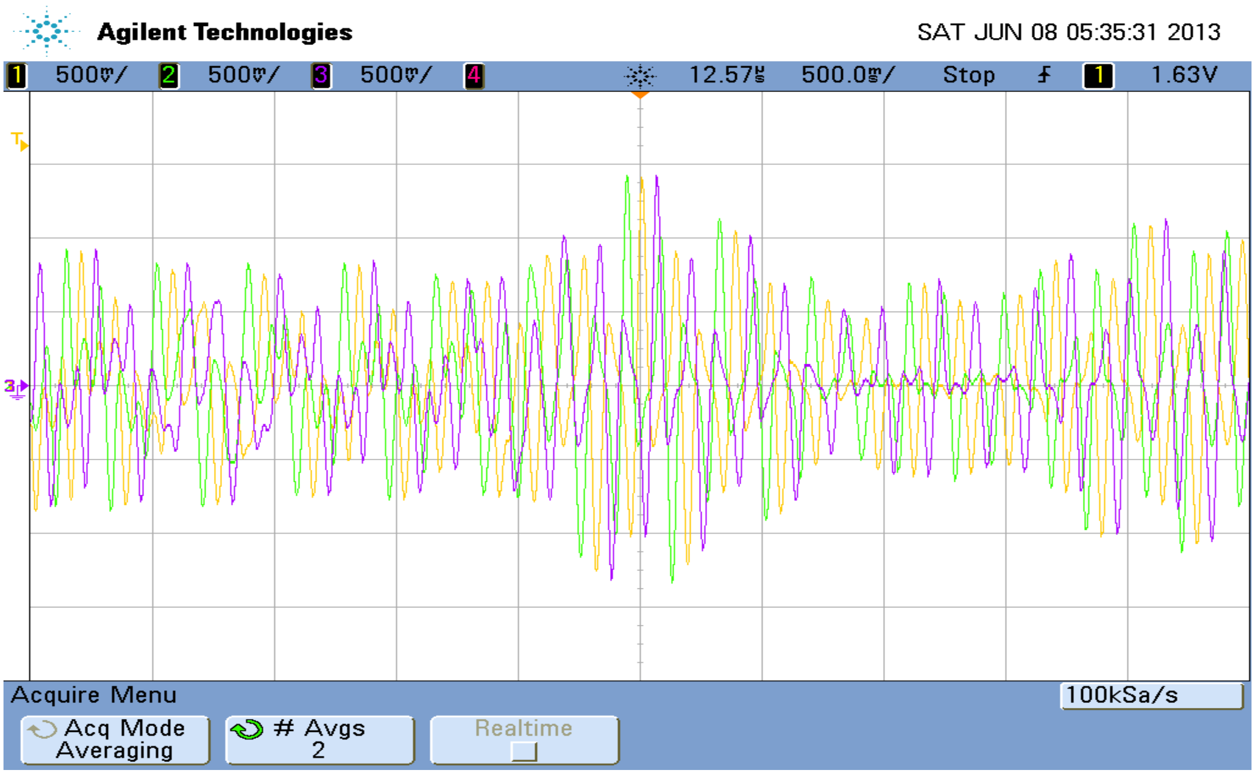

Figure 6-8:
No load voltage at 26.25 RPM

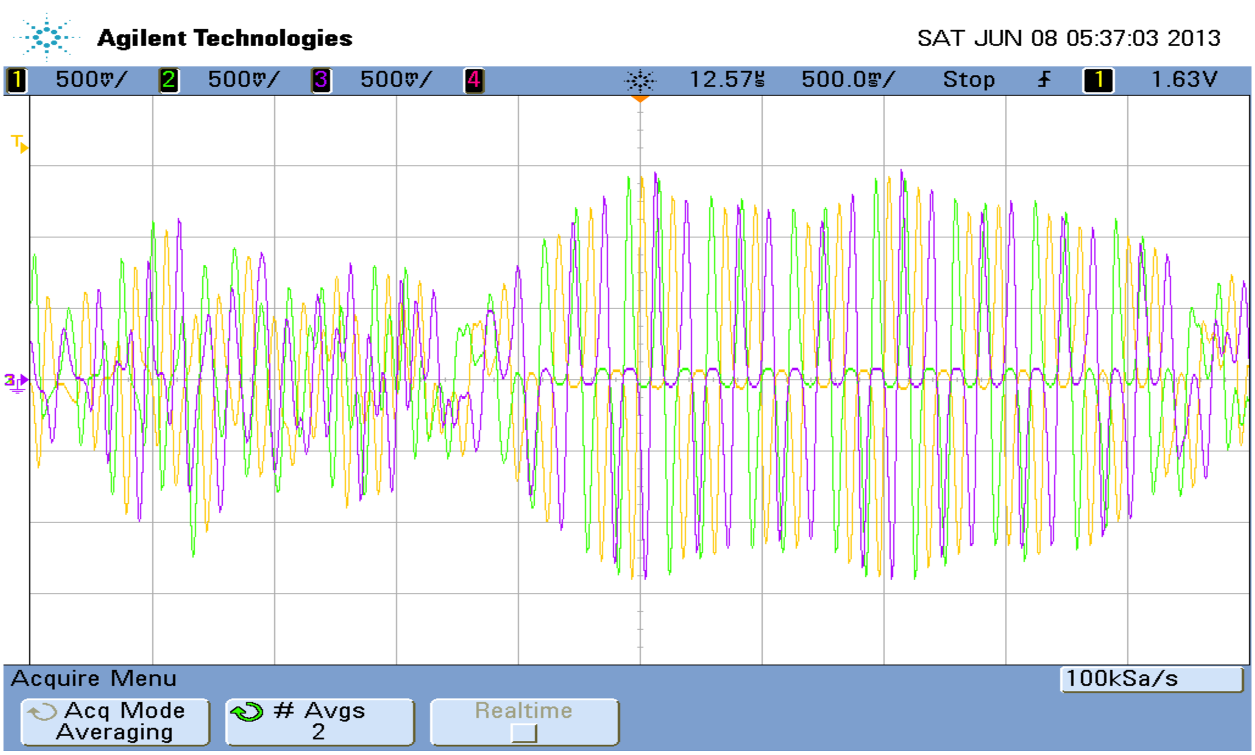

Figure 6-9:
No load voltage at 30 RPM

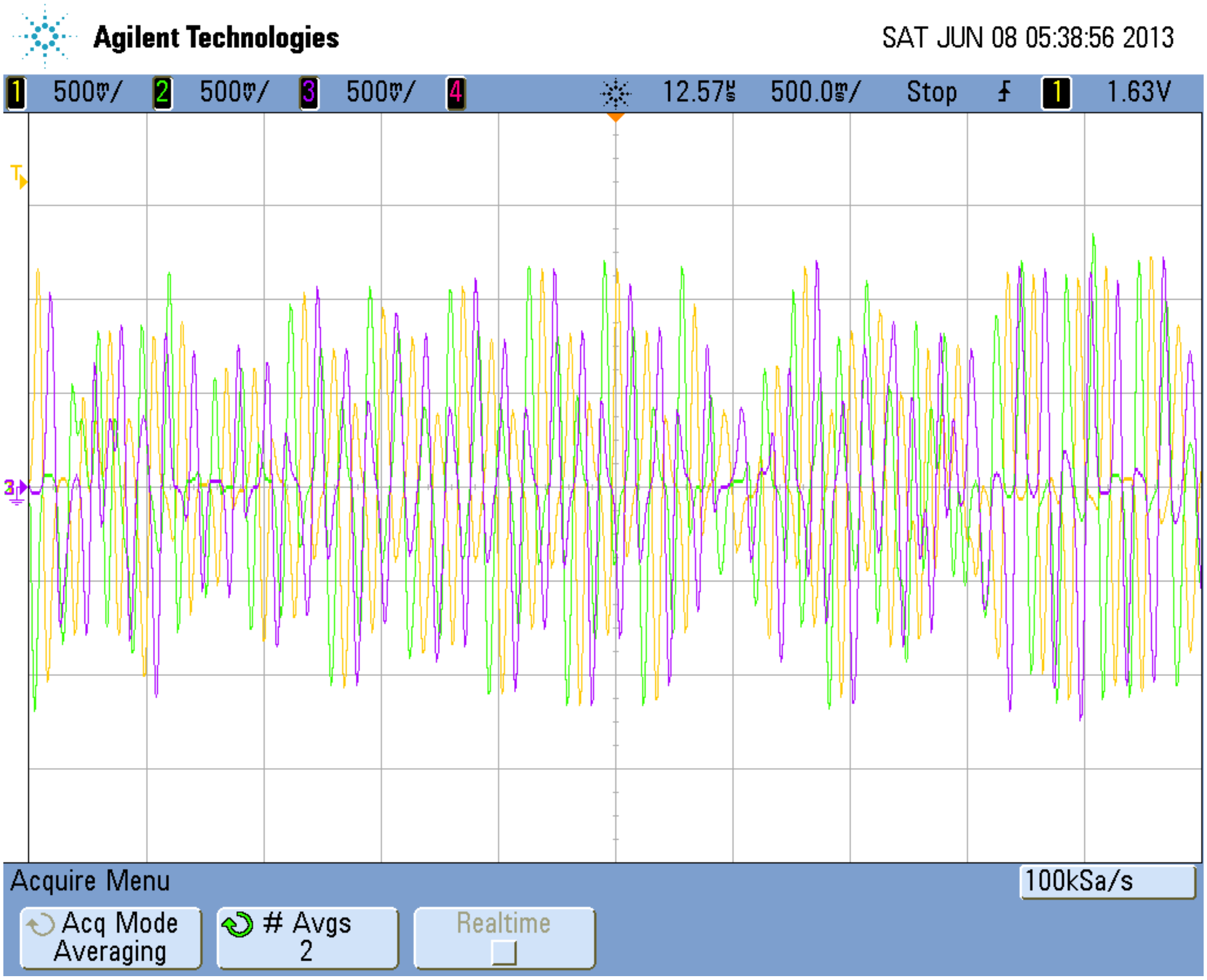

Figure 6-10:
No load voltage at 33.75 RPM

The next set of figures below display the rectified DC voltage of the generator vs speed. The scope measures the voltage across a 6.8 mF capacitor connected to the three-phase rectifier. Table 6-2 below summarizes the approximate average DC voltage for each speed.

Table 6-2
Generator Voltage vs Speed (V_{DC}, 6.8 mF capacitor load)

Speed (RPM)	**V_{DC} (V)**
15	1.25
18.75	1.6
22.5	1.8
26.25	2.0
30	2.13

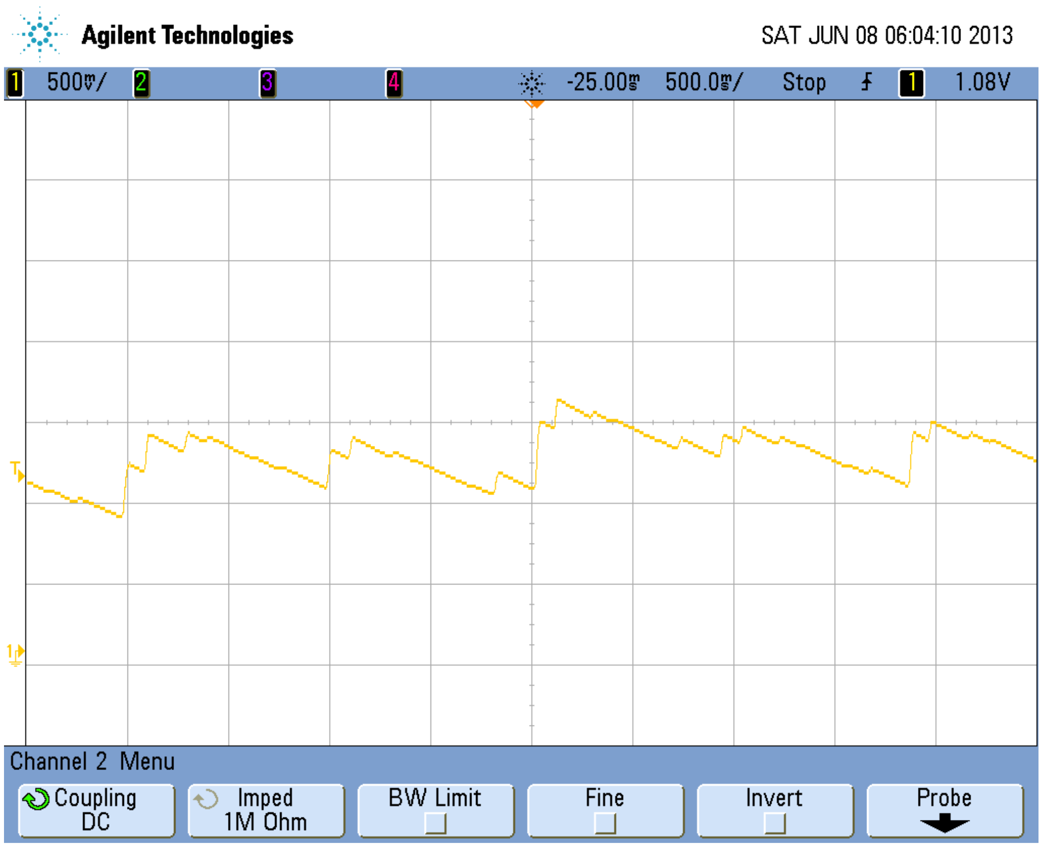

Figure 6-11:
Rectified capacitor load at 15 RPM

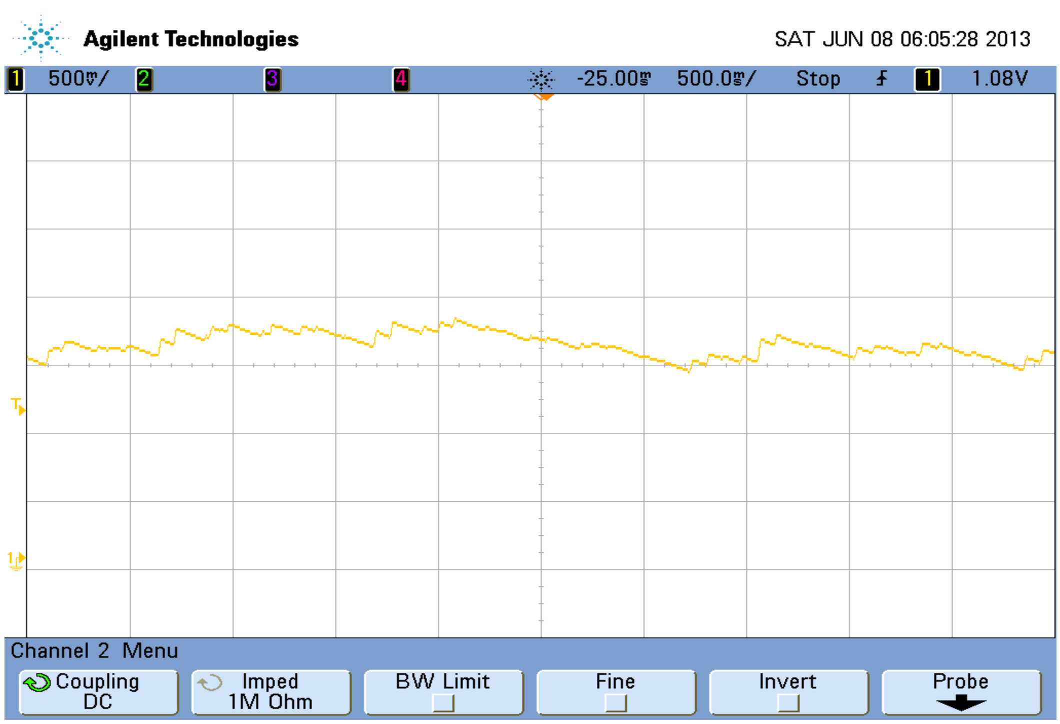

Figure 6-12:
Rectified capacitor load at 18.75 RPM

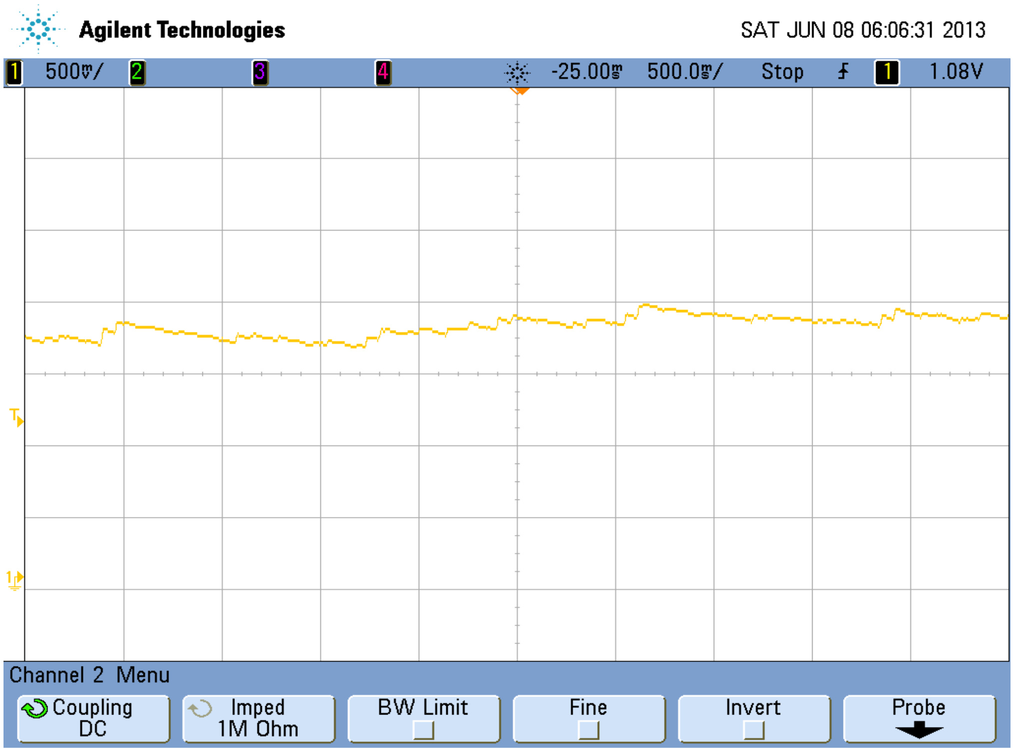

Figure 6-13:
Rectified capacitor load at 22.5 RPM

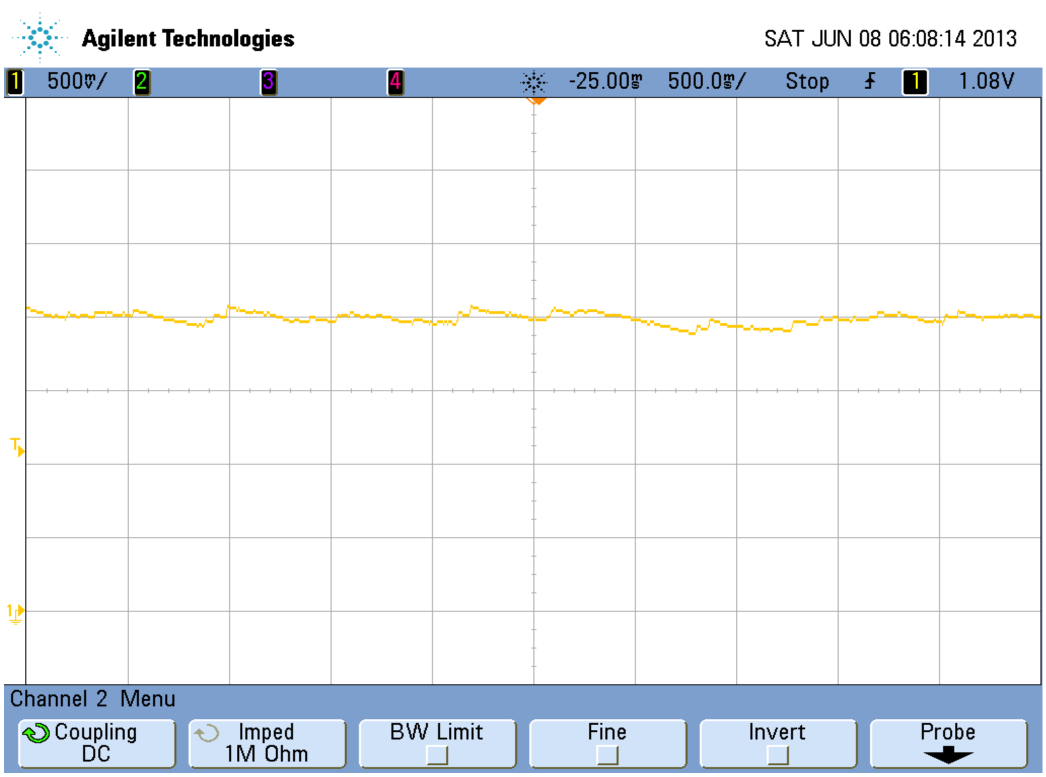

Figure 6-14:
Rectified capacitor load at 26.25 RPM

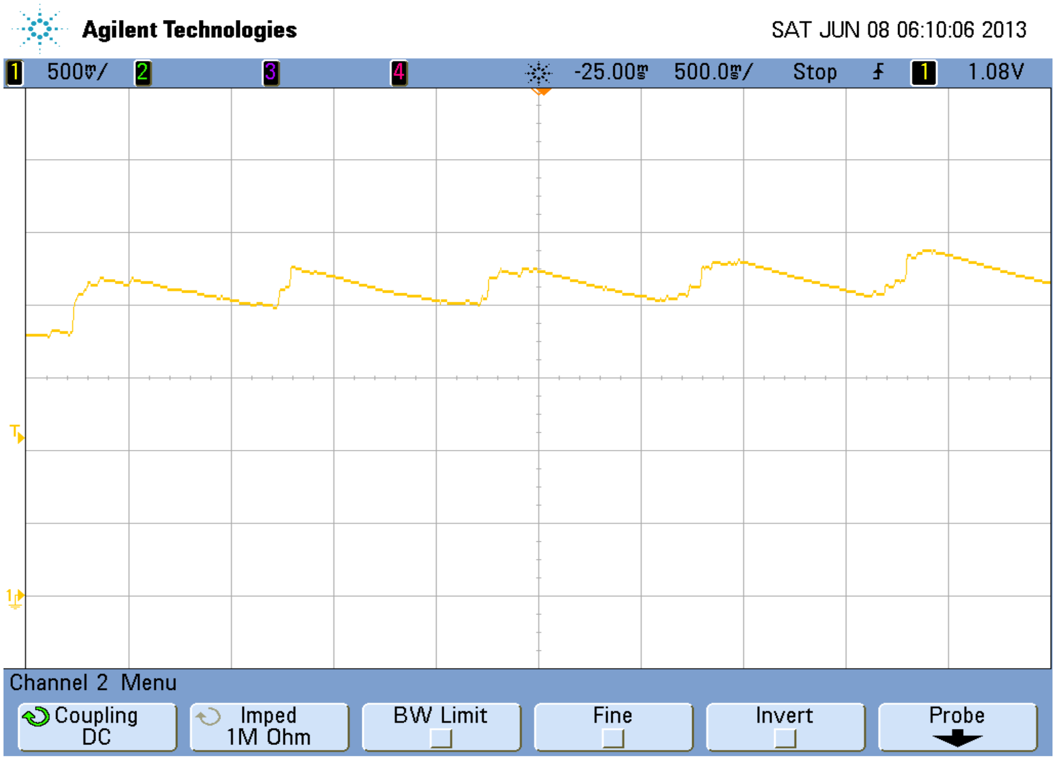

Figure 6-15:
Rectified capacitor load at 30 RPM

DC Boost Attempt

The next test observed the output of the DC boost circuit. The Merry-Go-Round spun for 20 seconds between 15 RPM and 20 RPM charging the 6.8 mF capacitor. After 20 seconds, the DC boost circuit was manually connected across the capacitor by toggling a switch.

Figure 6-16:
Boost Converter Input Voltage

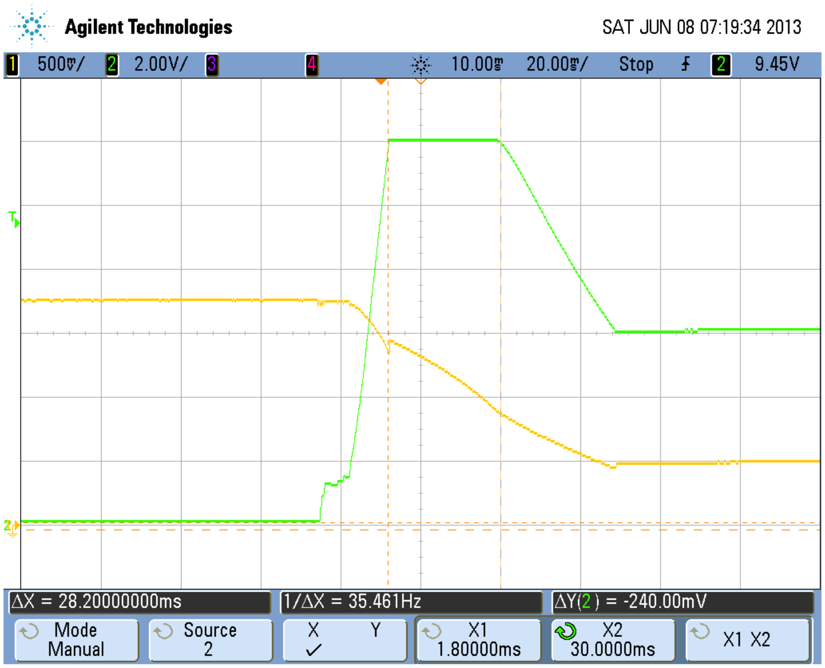

Figure 6-17:
Boost Converter Output Voltage

Figure 6-16 displays the characteristics of the input to the DC boost circuit (voltage of the capacitor). The voltage of the 6.8 mF capacitor reduced to 0.5 V from 1.75 V over 68 ms. Figure 6-17 displays the output voltage of the boost converter at no load. The voltage remained at 12 V for 28.2 ms before reducing to approximately 6 V as the input voltage reduced to 0.5 V.

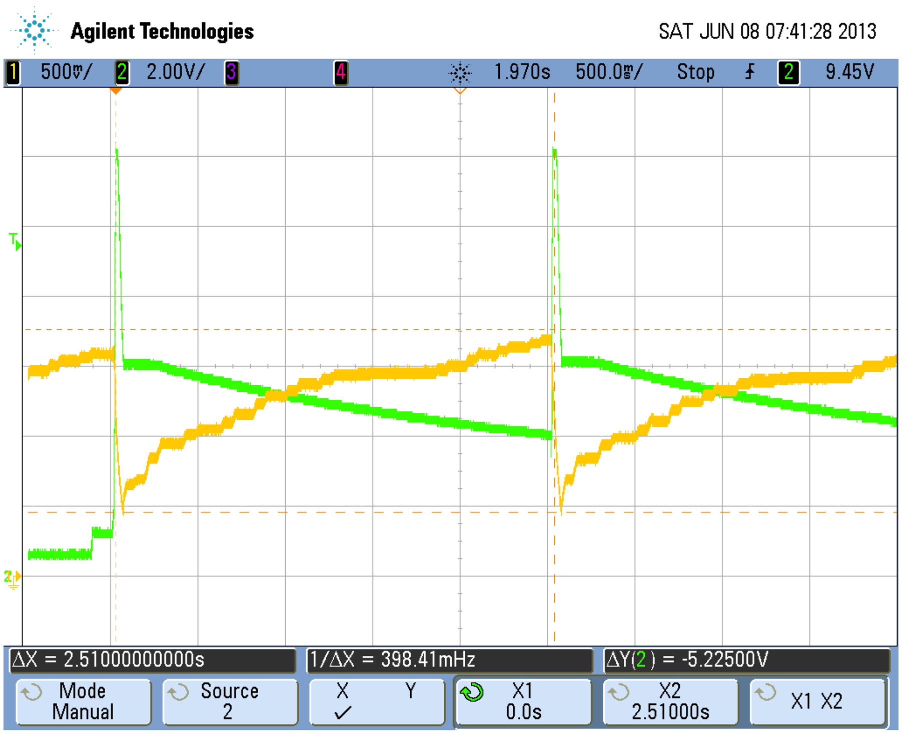

Figure 6-18:
Output Voltage spikes with no switch

Figure 6-18 displays the output of the boost converter with no load while continuously spinning the Merry-Go-Round between 15 RPM and 20 RPM. The switch was left closed so that the generator would charge the capacitor while the input voltage remained too low to turn the boost converter on, and supply direct current to the boost converter when the capacitor reached the boost converter's turn-on voltage. The boost converter produced brief 12 V ON times every 2.5 seconds.

VII. Conclusion and Recommendations

For this project, we set out with the objective to provide a means to clean, and renewable energy to those living in developing countries through the use of human power. We wanted to create a Merry-Go-Round and allow the conversion of spinning mechanical energy into usable electricity to power a home. We managed to keep our design relatively simple and renewable enough for constant and continued use. The design is large enough to support smaller children as well as a few large adults, and ensures that they will still be generating electricity while spinning. Although we were able to get our Merry-go-Round to output at 12 volts, it was only able to do so temporarily and a few reasons became apparent for why this was.

The design that we used was just a bunch of simple wrapped wires with an air core, and due to this, the voltage gain was not that much. Also because of this the current being outputted by the Merry-Go-Round was very low, not enough to allow the 1-2.5 volt output to be boosted to 12 volts. One thing we would recommend is to include iron cores in the coils for next time. We were only able to boost our voltage to 12 volts for about 30 milliseconds with another 2.5 seconds needed before the circuit can charge to 12 volts again. The use of a core in the center of each of our coils would probably help with voltage gain and allow a larger peak-to-peak voltage that would make it easier to either buck or boost down.

Another thing we would recommend in the future is to get someone with metal working and designing to aid in the construction of the physical Merry-Go-Round. We were able to build it out of wood, but there is much room for improvement in the overall design of the equipment. Proper bearings could have been used instead of wheels as they would have much less friction and would allow the Merry-Go-Round spin much faster. Also if the diameter of the Merry-Go-Round was increased along with the amount of coils used then a higher voltage could be generated especially once the speed of the Merry-Go-Round remained constant and it became easier to spin.

Overall, we were able to get the Merry-go-Round to generate a voltage that could be boosted to the required 12 volts, although the operation is not very practical. The DC House is an ongoing project that will end with another group improving the previous designs and finding ways to integrate them all together. Our hope is that now that we have been able to prove the concept of a clean and renewable electric source, someone else can find a way to improve our design and integrating it with the DC House.

VIII. References List

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IX. Appendix

A. Senior Project Analysis

Summary of Functional Requirements

The merry-go-round human powered generator primarily converts mechanical energy to electrical energy. The apparatus permits children to push one part of the merry-go-round in a circle to spin the wheel. The rotational motion turns a generator to produce electricity. The generated electricity charges a battery at the array [9] for later use.

Primary Constraints

The design of the wheel and its connection to the generator presents the most difficult challenge for this project. The mechanical nature of it requires knowledge of mechanical design [7]. The current project team members lack expertise in this field. Sizing an appropriate generator to factor in the characteristic rotational speed of the wheel and voltage output also present challenges. To mitigate the physical design challenges, the project may require consultation from a mechanical engineer. However, the cost for the consultation services increases the total project cost. Design costs contribute to the overhead cost which disperses among the total units produced. A greater overhead-to-units produced ratio reduces the flexibility for part selection and construction given the $1000 per unit requirement.

Economic

This project primarily benefits impoverished people in third-world villages. They receive an energy production source to power their homes. The costs of production aim to offset the costs of producing electricity at a power plant and delivering it to remote areas over the lifetime of the product. In acquiring the product, the buyer must exchange credit of some kind (i.e. bank notes, securities, stock, etc.) with the manufacturing company to receive it. The buyer must also pay a delivery company to transport the product from the manufacturer to the recipient. The financial capital exchanged by the recipient to the buyer remains outside the scope of this project. Realization of this project produces manufactured capital, such as the merry-go-round wheel, generator, and voltage converter. It requires real capital in the form of raw and refined materials for production, as well as electricity to power the tools to create it. Cost and benefit accrue over lifetime In the project's lifecycle, costs accrue in the form of labor needed to maintain the product. Each spin of the merry-go-round generates electricity that either offsets purchased electricity or that which never existed. The project requires a merry-go-round wheel, AC generator, AC-DC converter, boost converter, wiring, and insulation which collectively costs $576 (estimate from Table 7). It also requires various construction tools such as a drill, saw, wrench, level, and hammer. As a charitable item, the merry-go-round likely earns no profit for the donor. The recipients profit from the independent renewable power source. Table 7 indicates that the product requires approximately 46 days to complete. With proper usage and maintenance, the merry-go-round lifecycle should last at least 10 years. Figure 3 details the estimated time to complete each step in the project. When the project reaches completion, it joins the suite of other DC House projects [1].

If Manufactured on a Commercial Basis

The design costs for the project approximate $576 for parts and $7360 for labor (46 days at $160 per day). The estimate only analyzes the cost to produce one unit. Savings accrue when producing multiple units due to splitting the design cost among them and purchasing input materials in bulk (See [8] and [6] for sources of cost for project). In most cases, the purchasers of the merry-go-round do not enjoy direct benefits. The buyer unlikely sees any profit from purchasing the merry-go-round unless the buyer uses the device. The user of the product incurs an opportunity cost of doing anything else while operating it. Assuming a purchaser buys 100 units, the cost to produce each unit approaches the optimistic figures in Table 7, yielding a $757 cost per unit ($257 for parts and $500 for 25 days of labor at the same cost per day).

Environmental

Using this product generates no gaseous emissions. Therefore, the project offsets conventional sources of electricity such as burning coal as a fuel source. The merry-go-round occupies a 6' diameter circular footprint on flat ground and needs a 10' diameter circle for operating space. Optimal placement of the wheel displaces minimal vegetation outdoors. Conceivably, small animals may try to nest or burrow underneath the wheel for shelter. In producing the Merry-go-round Human Powered Generator, the manufacturing process requires wood, copper, aluminum, steel, and any other raw materials for manufacturing a circuit. Production of this project yields the greatest impact on the environment. When the product ultimately fails, the owner can salvage some of the parts such as metal fastenings, wires, generator, voltage converter circuitry, wood, etc. depending on what part fails.

Manufacturability

The Merry-go-round Human Powered Generator uses some pre-manufactured items such as fastenings, the generator, wires, encasings, and raw material for the wheel. Construction of the wheel itself and the power conversion circuit require custom manufacturing which poses the most challenging aspect in this regard. Also, the merry-go-round wheel should conceal all circuitry except for insulated wires that connect to the house. The rest of the manufacturing process requires joining or assembling modules together.

Sustainability

Given the dimensions of the wheel, future engineers may replace the wheel with a better design to attach to the generator. Likewise, they may also upgrade the generator to a better one that still fits the wheel. The electricity conversion module also remains replaceable. Mechanically, the bearing system most likely fails first since it encounters the most stress. A mechanical system that distributes the wheel's and riders' weight over a greater area while still permitting low-friction movement would benefit the design of this project. Electrically, the voltage converter system remains vulnerable to large voltage spikes. A voltage limiting or clamping intermediate circuit would also benefit the design of this project [4]. Environmentally, the source of power derives from human mechanical energy. The system as a whole remains separated from an electrical grid. Therefore, the system requires no prolonged natural resource consumption to function. Regarding maintenance, the owners may not possess the tools necessary to repair failed components. Perhaps the finished product could include a small, cheap aluminum wrench to aid disassembly. See the Environmental Analysis for a brief discussion on end-of-life consideration.

Ethical

The Merry-go-round Human Powered Generator relies on human energy to produce electricity. The product may be misused in the Utilitarian sense that a few people forced to operate the machine produces a source of 12V DC for the greater good (of those not forced to do the work). The next points address how the IEEE Code of Ethics [10] informs the ethical analysis.

1. This responsibility rests on the authors of this project. The Health and Safety and Environmental analyses address apparent dangers to manufacturers, users, and the environment.
2. No perceived conflicts of interest exist at this time.
3. Figure 3, Table 6, and Table 7 outline the various estimates for material cost and completion time.
4. A potential for bribery exists in the political arena. A manufacturer could bribe a politician to propose or pass a bill that orders Merry-go-round units constructed using public funds against the public's will.
5. While a project like this already exists, the concept remains novel. This project enhances the array of equipment that allow people to generate electricity through exercise and provides a base for product skews/variations.
6. Both authors of this project pursue a degree in Electrical Engineering at the time this was written. The authors seek guidance from the UL guidelines [12] to provide direction regarding safety.
7. This project receives technical peer review from fellow Electrical Engineering students Ryan Turner and Zachary Weiler as well as professors David Braun and Taufik.
8. This product does not discriminate against race, religion, gender, or national origin. However, it assumes that the people using it can see, walk, and push an object around a circle. It also assumes that only children operate the merry-go-round.
9. This project does not aim to injure any of its users, limiting their employability in turn. It also does not aim to interfere negatively with other interfacing systems.
10. Should any manufacturer produce the merry-go-round, this report informs them in multiple sections of some explicit pitfalls to avoid.

Health and Safety

This product contains large moving parts and electricity. The large moving part, the wheel, could potentially trap a human limb between itself and the ground since it rotates on a plane above the ground. The output of the system provides electricity to a battery array. Improper concealment of wiring poses an electrical safety hazard. This project will consider the guidelines established by Underwriters Laboratories (UL) [12]. Manufacturing the product requires proper precautions taken when using power tools and soldering irons.

Social and Political

The designers and manufacturers benefit monetarily from this project since it provides a source of work and payment. The users of this project also benefit from gaining a renewable source of electricity offsetting any recurring conventional sources of electricity. The donors of the Merry-go-round Human Powered Generator receive the psychic reward of charity and possibly good public relations [13]. However, given as a gift, this product may promote dependency by one group on another to the former's detriment, creating an unsustainable relationship or one which leaves a group indebted to another. On the other hand, the recipient may trade raw materials or inexpensive labor to receive the product.

Development

In the course of this project, we learned how to separate and enumerate marketing requirements and engineering specifications. We also gained an appreciation for Level 0, Level 1, Level 2, etc. block diagrams since they discretely define functionality and provide focus for the project. We anticipate that we need to learn how to draft physical objects in a program such as AutoCAD [14] if we cannot find a mechanical engineer to advise us on design.

B. Schematic

The 3-phase full wave voltage rectifier converts AC voltage to DC voltage. The capacitor on the DC side of the rectifier reduces the AC ripple that carries through the rectifier.

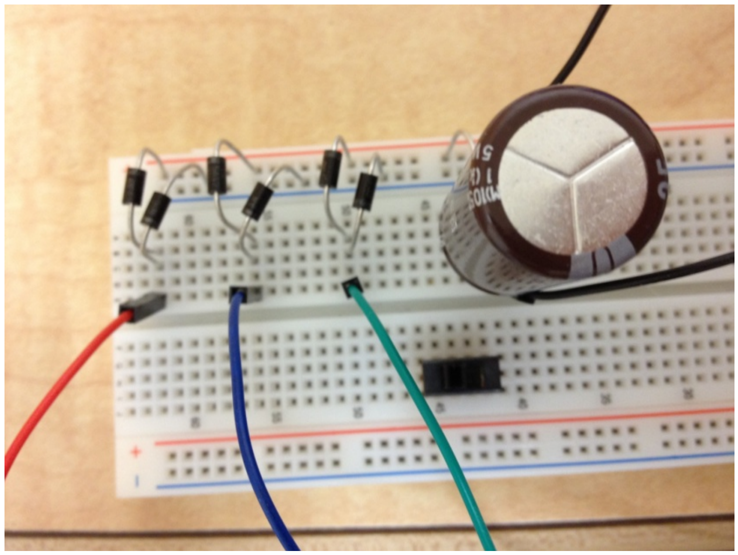

Figure 9-1:
3-phase full wave rectifier on a breadboard

Figure 9-1 above displays the full wave rectifier constructed using a 6800uF capacitor and 6 1N5817 Schottky diodes. The red, blue, and green wires correspond to phases A, B, and C from the generator.

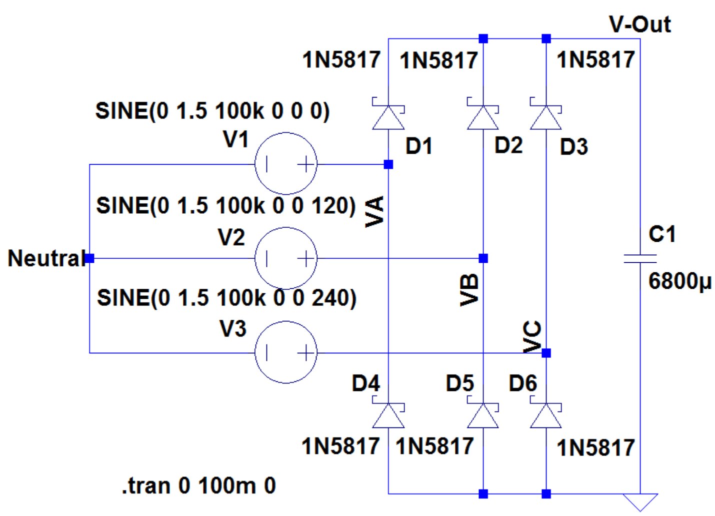

Figure 9-2:
3-phase rectifier schematic

Figure 9-2 displays the equivalent circuit for the generator, rectifier, and filter capacitor. The three phase voltages connect in Y (wye) fashion at the Neutral point. Each diode has a 0.32 V forward active voltage drop. The V-Out signal connects to the boost converter input.

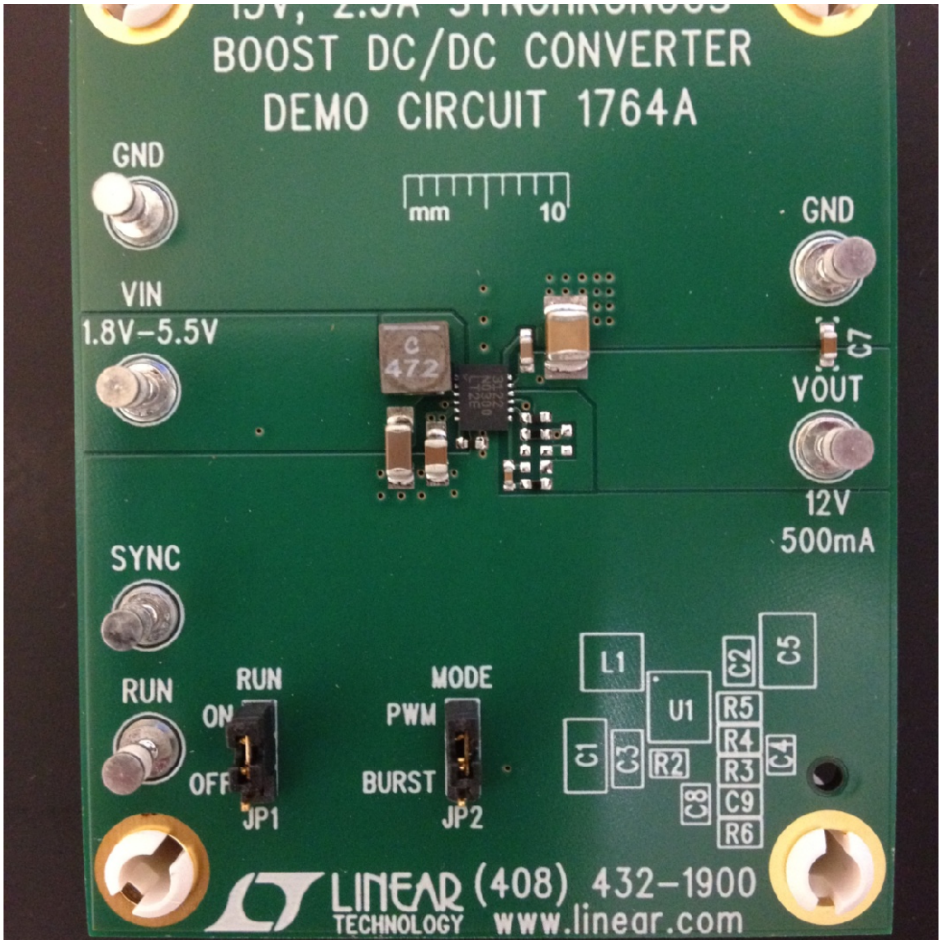

Figure 9-3:
12 Volt Boost Converter Demo Board

Figure 9-3 depicts the 12 volt boost converter. The input accepts 1.8 V to 5.5 V and outputs 12 V. The output of the boost converter ultimately connects to a rechargeable 12 V battery.

C. Parts List, Cost and Time Schedule Allocation

The Gantt chart in Figure 9-4 below details each actionable task and completion date to finish the project in a timely fashion. Four sections divide this chart (Table 9-1 contains more details):

I. Project planning and research
II. Design, purchasing, and construction
III. Integration of Systems
IV. Final Testing and Report

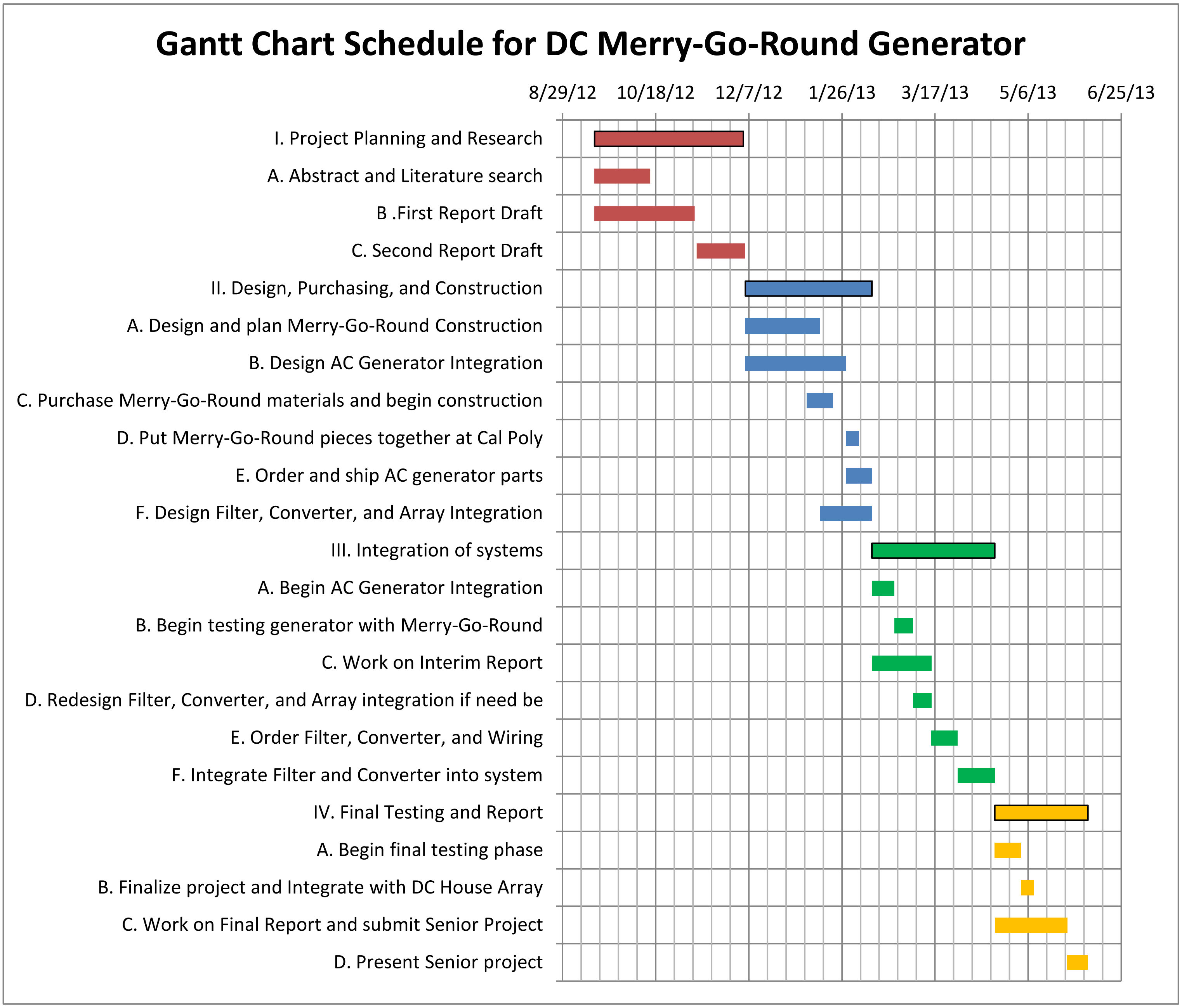

Figure 9-4:
Gantt chart schedule for Merry-Go-Round Project

In Table 9-1, a unique color represents each section as it appears in the Gantt chart and includes the finish date. Both partners work together on this project in every task. The project includes several design, build, and test iterations seen in sections 2 and 3 which ensure successful completion of the project.

Table 9-1:
Schedule for DC Merry-Go-Round Generator (refer to Figure 9-1)

Task Name	**Start**	**Duration (days)**	**Finish**
I. Project Planning and Research	9/15/12	80	12/5/12
A. Abstract and Literature search	9/15/12	30	10/15/12
B .First Report Draft	9/15/12	54	11/9/12
C. Second Report Draft	11/9/12	26	12/5/12
II. Design, Purchasing, and Construction	12/5/12	68	2/11/13
A. Design and plan Merry-Go-Round Construction	12/5/12	40	1/14/13
B. Design AC Generator Integration	12/5/12	54	1/28/13
C. Purchase Merry-Go-Round materials and begin construction	1/7/13	14	1/28/13
D. Put Merry-Go-Round pieces together at Cal Poly	1/28/13	7	2/4/13
E. Order and ship AC generator parts	1/28/13	14	2/11/13
F. Design Filter, Converter, and Array Integration	1/14/13	28	2/11/13
III. Integration of systems	2/11/13	66	4/18/13
A. Begin AC Generator Integration	2/11/13	12	2/23/13
B. Begin testing generator with Merry-Go-Round	2/23/13	10	3/5/13
C. Work on Interim Report	2/11/13	32	3/15/13
D. Redesign Filter, Converter, and Array integration if need be	3/5/13	10	3/15/13
E. Order Filter, Converter, and Wiring	3/15/13	14	3/29/13
F. Integrate Filter and Converter into system	3/29/13	20	4/18/13
IV. Final Testing and Report	4/18/13	50	6/7/13
A. Begin final testing phase	4/18/13	14	5/2/13
B. Finalize project and Integrate with DC House Array	5/2/13	7	5/9/13
C. Work on Final Report and submit Senior Project	4/18/13	39	5/27/13
D. Present Senior project	5/27/13	11	6/7/13

Table 9-2 defines the cost estimates for the project. Some component sections may come in under budget while some may come in over budget. The price of the parts for the AC generator may be quite expensive and time consuming to install. Proper sizing and efficient design presents the greatest challenge. Unlike the mechanical structure of the Merry-Go-Round, the AC-DC converter and boost converter should present less of a challenge to integrate in terms of installation and cost. [4].

Both of the converters should include a filtering mechanism to ensure the output remains as close as possible to a DC output with very little AC ripple output. According to the boost controller datasheet [6], it already includes a filter in the circuit to remove the AC ripple.

Table 9-2:
Merry-Go-Round Cost and Labor Chart

Material to be used in project	**Cost to Purchase**				**Time to integrate into system/setup**			
	Optimistic	Realistic	Pessimistic	Estimate	Optimistic	Realistic	Pessimistic	Estimate
Merry-Go-Round	$150	$300	$600	$325	4 days	7 days	14 days	8 days
AC Generator Parts	$50	$150	$300	$159	7 days	12 days	20 days	13 days
AC-DC Converter	$25	$30	$40	$31	5 days	8 days	12 days	9 days
Boost Converter	$2	$5	$10	$6	4 days	6 days	10 days	7 days
Wiring and Insulation	$30	$50	$100	$55	5 days	8 days	12 days	9 days
Total Predicted Cost and Time	**$257**	**$535**	**$1050**	**$576**	**25 days**	**41 days**	**68 days**	**46 days**
Actual Cost and Time	**$784.28**				**60 days**			

Table 9-2 above shows different outlooks for the cost of the Merry-Go-Round. Each cost estimate depends on an optimistic, pessimistic, and realistic price or completion time. This presents best-case, worst case and expected-case scenarios with the estimate case averaging all three cases. The bottom row displays the actual cost and time to complete the project.

Itemized List of Parts and Cost

The following chart in Table 9-3 includes a list of all parts and materials purchased to construct the Merry-Go-Round. A 5-6 month period covered all purchases in accordance with Table 9-1.

Table 9-3
Parts and Cost Itemized

Part	**Amount**	**Cost ($)**
Plywood 4'x8'	3	66.54
Screws 1-5/8”	32	8.47
Screws 2-1/2”	32	8.47
Protractor	1	5.97
Wood screws brass	32	13.41
2”x6” 8'	3	13.38
2”x4” 8'	1	2.94

bender board 14'	2	9.94
14 pc drill bit	1	25.99
hole saw 2”	1	13.99
hole saw bit	1	18.99
Grease	1	2.99
Pipe 1.25”x5.5”	1	3.99
pipe 1”x9”	1	4.49
flange 1.25”	1	10.99
flange 1”	1	5.49
3” caster w/ brake	2	17.98
3” caster	6	41.94
CA bag fee	1	0.1
Fasteners	32	7.36
Fasteners	32	2.88
Fasteners	32	2.88
Fasteners	32	2.88
Fasteners	4	0.92
Fasteners	4	0.8
Fasteners	16	1.44
Fasteners	8	0.72
16' edging	1	19.97
20' edging	1	24.97
2”x4” 12'	1	4.71
4”x4” 10'	1	9.06
frame anchor	8	25.2
hex nuts	16	1.92
carriage bolt 3/8”x2”	4	1.48
carriage bolt 3/8”x2-1/2”	4	1.84
hex bolt 3/8”x4-1/2”	4	2.52
carriage bolt 1/2”x4”	1	1.16
hex nut 1/2”	1	0.2
Washer 1/2”	2	0.4
Washer 3/8”	24	3.36
N48 neodymium magnet 1”x1”	13	116.35
magnet wire 24AWG 790'	2	60.74
magnet wire 24AWG 197.5'	1	8.76
wood glue	1 gallon	15.97
saw hole 1-1/4”	1	10.99
fiberglass resin	1 gallon	39.99
Fasteners	24	10.8
Fasteners	24	6.48
Fasteners	48	4.32
Fasteners	24	12
5qt pail	1	3.99
1oz cold weld	2	13.98

Tax total		43.38
Shipping Total		77.14
Discount		-33.34
Total Cost		**784.28**

The project did not require every single part. Some exclusions include extra wood, screws, nuts, bolts, washers, glue (only used in small quantities), and excess wire. While the unused material adds to inefficient component waste, it provides a safety time buffer to prevent extra shipping costs and time due to reworking mistakes.

D. Research Justifications

[1] This is Dr. Taufik's homepage for the DC House and details all the different projects other students completed for the DC House. It includes links to all the DC House senior projects. The fact that this is the homepage for the DC House and our project is directly part of the DC House makes it a credible source.

[2] This web article talks about the electricity output for the next 20 years and goes into detail about how much money will need to be invested into electricity. There is info about the split of what kind of electricity will come from oil and fossil fuels, as well as what kind of renewable sources will be used.

[3] This web article talks about how much of a part renewable energy will play in the next few decades and just what kind of sources will see an expanding market. There is also info about how many developed countries will have to start switching to a renewable source as the demand for fossil fuels begins to decrease.

[4] This book, written by Dr. Taufik and Dr. Dale Dolan at Cal Poly, goes into the basics of power electronics and design circuits such as AC-DC and DC-DC converters. Many of the circuit theory and ideas taught in this book will be directly applied to the design of the Human-Powered-Generator. Dr. Taufik is a professor of Cal Poly as well as an advisor for this project and head of the entire DC House project. He also actively encourages students interested in the DC House to take his power electronics class, which makes the learned information in the class directly relatable to constructing the DC House and related projects

[5] This patent details how to design an electronic system and we will use that design to implement a very similar system in our AC Generator. One of the authors of this patent also possesses patents to a few other devices as well as a PhD in EE.

[6] This datasheet details a 12 volt output Buck-Boost Converter that this project will use to convert the output voltage up or down to 12 volts depending on the input. This particular IC was created by Linear Technology and with the information from the datasheet, this becomes a credible reference.

[7] This links to an Instructables webpage for how to construct a Merry-Go-Round from a round table and a chair. Although out final design will be more complicated, this webpage gives valuable information regarding weight limits and size when constructing a Merry-Go-Round. Justification for this comes from the fact that this has already been constructed and verified by others on the site so the info here can be taken into account.

[8] This source is the home page for Home Depot and will be the primary store we will purchase materials from to construct the Merry-Go-Round. The plywood and PVC railing used in the Merry-Go-Round will be purchased from this store. Their source for prices gives them authority as a credible reference.

[9] This source talks about the basic design of the entire DC House and includes what voltage the generator will need to output to the DC House array. It has authority because it is an actual thesis that was written by someone who had approval from Taufik and the specification presented in that report will need to be implemented by any other DC house reports.

[10] This IEEE page details the IEEE code of ethics, ethics that this project is required to follow. The code also details the responsibilities that each engineer is required to take upon himself to ensure the wellbeing of the public. These codes are required to be met which is why they are included as a reference.

[11] This article mentions students from Brigham Young University that constructed a Merry-Go-Round generator that provided power for students living in an impoverished area of Ghana. The DC House has very similar goals to what these students did, as the DC House, too, will provide power and electricity to those living in impoverished areas. This article details much of the conditions and factors that the students had to account for when building the Merry-Go-Round, things that we too will have to look out for and prepare for when designing and constructing our Merry-Go-Round.

[12] According to their website, “UL certifies, validates tests, inspects, audits, and advises and trains.” They have been an authority on underwriting a diverse array of products for over one hundred years. Their ubiquitous logo appears on many products' labels indicating inspection. Compliance with their guidelines could help this project succeed in many countries where it intends to go (which also require UL listing).

[13] This article mentions Empower Playgrounds, which is a public charity organization that has developed electricity generating playground equipment that has been used in rural developing countries. One of the devices they have created is a Merry-Go-Round that generates electricity to power a battery, very similar to what this project intends to do. There are also mentions to other references as well the conditions and social issues the company ran into when installing and building these devices.

[14] AutoCAD is the industry standard tool for designing detailed 3-dimensional objects. Our project contains several critical moving parts and interfaces such as the wheel, bearing system, and generator. A CAD system allows not only a blue print for the physical system, but also deliverable to a consulting mechanical engineer to critique, modify, and enhance.

[15] This IEEE article talks about the main reasons for generation and causes of noise in DC-DC converters. Because the Merry-Go-Round will use a DC-DC converter when setting the output voltage to 12 volts, it will be important to eliminate as much noise as possible when sending the voltage out to the DC house array. The authors of this article have written several other articles featured on the IEEE website and also have PhDs in EE, so their credentials make them a credible source.