

# **Human Powered Generation – Seesaw**

a DC House Project

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## **Acknowledgements**

We would like to thank everyone who has assisted us in this project. Dr. Taufik, thank you for giving us the ability to branch out from our usual focus and try to prove the concept of playground equipment producing energy, and having a fun new way to tire out future generations of children. We'd also like to thank our parents for all of their help and support throughout the years. We would be much different people today without your influence. Thank you to all of our peers who have been curious about our seesaw, you gave us a perfect opportunity to share the knowledge we gained from this project.

## **Abstract**

This project is a proof of concept work, where playground equipment is implemented for power generation. In using a seesaw design, this project was able to show how a simple mechanical motion could be transformed in electrical power. A seesaw power generator was designed and constructed to demonstrate its feasibility. Results show that with some modification and improvement to the current design, the seesaw me indeed provide a viable method to produce electricity.

## **Introduction**

The use of fossil fuels and other non-reusable sources of energy must be reduced in order to keep emissions low and alleviate the use of diminishing resources. The idea of human powered generation has been implemented in many different situations. Some examples include hand-crank radios, shaking flashlights, and receiving power from gym equipment.

The DC House Project is a humanitarian effort that provides an enclosure with lighting and a power sources. Through the use of wind, solar, hydro, and human generated power, the system is provided with DC power. The goal of the human powered generator is to implement a seesaw in a playground where we can harness the energy of kids into real power.

The use of playground equipment for a clean source of energy would harness the seemingly endless energy of young children. It would provide them a means to exercise while unknowingly supplying power.

## Background

Using human powered generation gives a power source that is not directly derived from natural sources. An example is that a human powered generator can be operated if there is no sun for solar generation, no wind for wind generation, and no water for hydro generation. By using a seesaw specifically in a playground, a simple activity such as play time turns into an energy producing exercise.

There have been many versions of human powered generation applied towards electronics and electrical systems. An example of an early version of a crank radio is the Gibson Girl survival radio. This device allowed stranded sailors or pilots to power a radio that sent an SOS signal<sup>[1]</sup>. Other examples found now include flashlights, radios, and other small electronics.

Harnessing human energy on a larger scale and applying it to our current power system has been in development in recent years. One example that is very tempting is using exercise equipment to power gyms. By taking the energy that people pump into stationary bikes, rowing machines, and other equipment, a gym could become self-sustaining or even provide power to a power system. A lot of exercise equipment currently runs off the power that the person working out puts in, but if the extra power not used by the equipment could be input into the building, a lot of extra power could become available. This idea was attempted during the renovation of the Cal Poly Recreation Center as a thesis for a master's student<sup>[2]</sup>.

Another example of a seesaw being used as a generation source was developed by Fly Solar Generation. With their Kinectrics TeedleGen – See Saw Generator<sup>[3]</sup>, the idea is possible. This design consisted of a metal frame and a single direction generator with a ratcheting gear. In order to demonstrate the effectiveness of the seesaw with limited resources, the design chosen for the DC House is made of wood and has a simple bike gear ratio.

## Requirements

The final output of the system will be 24 V<sub>dc</sub> and must not exceed 150W max. The final output ties in as a source for the DC house. Two adults operating the oscillating motion of the seesaw serves as the prime mover for the system. The seesaw itself is to stand taller than the traditional playground design, and have a ground resting base instead of one sunken into the ground. The high torque, low speed motion is transformed through a multistage gear mechanism to a high speed, low torque motion acceptable for the generator. A full wave rectifier will transform the pseudo AC voltage from the generator to a DC voltage that will charge a car battery, during the period of the waveform. The car battery serves a dual purpose of energy storage and voltage support. From the terminals of the car battery a DC-DC converter is required to achieve final output characteristics. Additionally, a power inverter can be used to power standard 120 V<sub>ac</sub> appliances from the system, though this is not a documented requirement of the system.

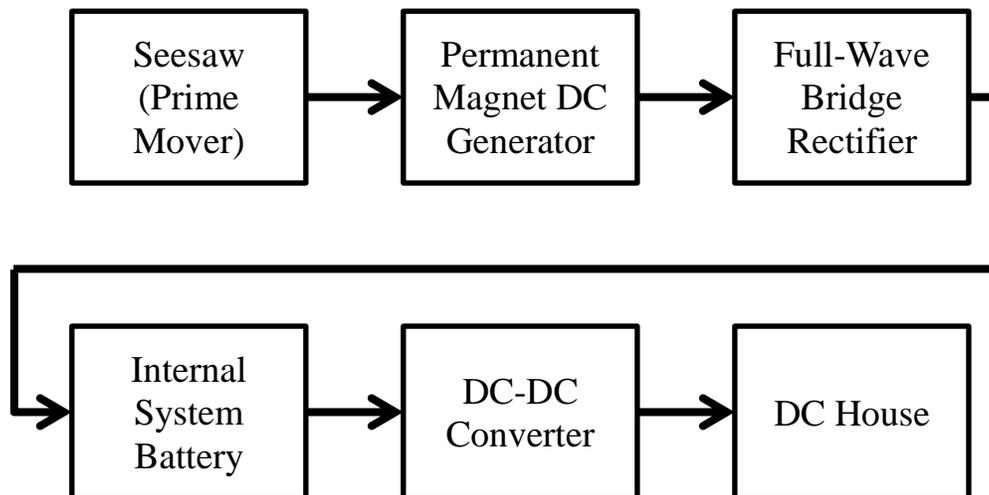
Given this project is proof of concept the primary goal is to build a system that may meet requirements with means of future improvement. General system design, construction, and baseline testing/modifications are the other key goals. Each block within the system may be improved by future groups if better materials, components, or means of design/constriction come about.

## System Design

The seesaw system is composed of the following parts:

- Seesaw/Gear Mechanism
- Permanent Magnet DC Generator
- Full-Wave Bridge Rectifier
- Internal System Battery
- DC-DC Converter

The block diagram below illustrates how the system is connected and how the flow of power gets to the DC House. Note that this block diagram only applies for proof of concept phase. In actual implementation the energy produced by the seesaw will go straight to the main DC bus of the DC House. Whenever there is excess of energy, the main central DC House battery will collect the energy.



**Figure 1 - Project Block Diagram**

The following sections describe each of the different components.

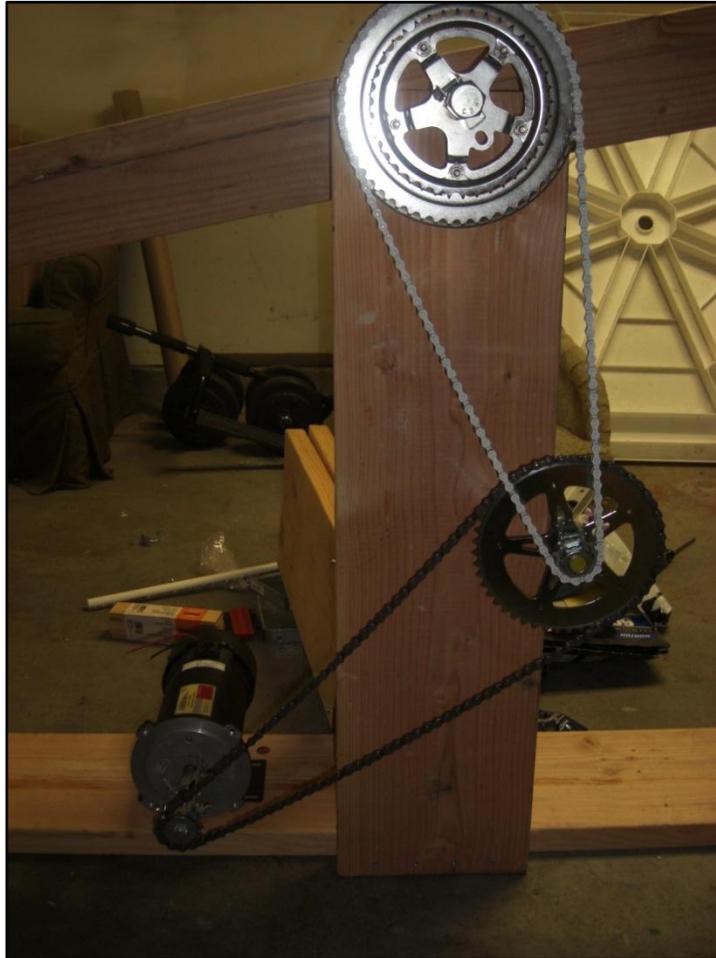
## Seesaw:



**Figure 2 - Seesaw**

The seesaw apparatus in this project has unique dimensions catered to its purpose of power generation. Significantly taller, from base to fulcrum, the device resembles a railroad pump cart more than a piece of playground equipment. The base height is 3 ft., 2 in., the saw length is 5 ft., 3 in., the operating swing arc length is 4 ft., 3 in., and the maximum swing apex height is 6 ft. It is still possible for two individuals to sit upon the device and operate it with their legs; however a standing operation is ideal. Handles at the ends of the saw provide the most efficient means to pump the lever up and down. For the sake of pumping speed and force, the two operators perform an alternating and abbreviated Olympic clean movement. Adults roughly six feet tall provide a swing distance from below the knees to the shoulders, totaling approximately 4.25 feet in one direction.

## Gear Mechanism:



**Figure 3 - Two Stage Gear Ratio**

Due to the lack of formal design schematics the gear mechanism is a piece by piece design the group specifically tailored to this project. The largest gear of 52 teeth is secured to a threaded hex bolt. The bolt is screwed and locked into a pipe adapter that fixes itself to the fulcrum shaft of the seesaw. The 104 link bicycle chain connects the 52 tooth gear to a 12 tooth gear; this connection serves as the first stage of the gear ratio. The 12 tooth gear is secured to a

threaded rod that runs parallel to the fulcrum shaft and is mounted to the upright supports of the seesaw. Additionally, fixed to the aforementioned rod is the 48 tooth gear. The 94 link bicycle chain connects the 48 tooth gear to another 12 tooth gear; this connection serves as the second stage of the gear ratio. The second 12 tooth gear is secured to a threaded rod that runs parallel to the fulcrum shaft and is mounted to the opposite side from the previous shaft on the upright supports of the seesaw. Additionally, fixed to the second aforementioned rod is the 53 tooth gear. The 116 link bicycle chain connects the 53 tooth gear to the 8 tooth gear; this connection serves as the third stage of the gear ratio. The 8 tooth gear is uniquely mounted to the generator shaft with a clamp-like adapter. Due to no standard milled shaft to bicycle gear connecting pieces, a clamping bracket secures the adapter to the shaft and a second clamp secures the gear to the connection bracket. The overall gear ratio from Seesaw to Generator is 114.83:1.

## Generator:



**Figure 4 - DC Generator**

The model 443902 permanent magnet DC generator was used in this design. Since the generator can handle output current of 7.5A, operating continuously, it can provide power of 96 to 118.5 W to charge the system battery. The previous power calculations are based on the range of the minimum terminal voltage needed at the generator based the car battery voltage and the rectifier's properties. There is a terminal voltage range 0 to 48 V based on shaft RPM and load conditions. The useful operating range is 600 to 1000 rpm for a terminal voltage of 12 to 24 V peak, with a projected power of 90 to 180W. Any time during operation, should the terminal voltage exceed 15.8V, it can pass current through the rectifier and charge the battery at its highest voltage. It is also noteworthy that the generator can output currents greater than 7.5 A for specified periods of time, while still maintaining its characteristics, specifically 8A for 85 min, 10 A for 43min, and 15 A for 21 min. Given this information reduced battery charging times are possible with possibilities of higher output current.

## Rectifier:



**Figure 5 - Full-Wave Bridge Rectifier**

The key properties of the rectifier are its 35A current limit and 0.7 V diode on-voltage. While current is being passed through the device there will be a theoretical 1.4V drop. This requires the generator voltage to be 1.4V high than that of the battery voltage, at any given time, for current to flow.

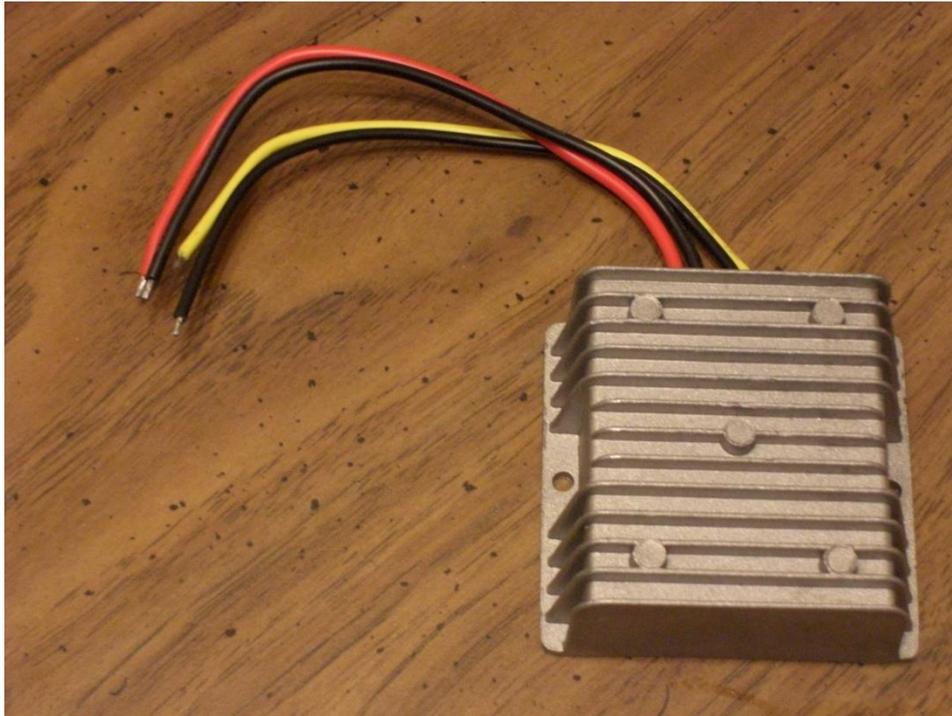
## Car Battery:



**Figure 6 - 12.6 V Car Batteries**

A standard car battery is used for its deep cycle charging characteristics, allowing for frequent and large inward and outward passages of charge. US standards have a nominal voltage of 12.6V yet range from 11.8 to 14.4V based on internal charge level. The typical amp-hours of a car battery are 40Ah. Under these conditions the system could draw maximum output power from the car battery alone for 4.2 hours. When not loaded and the generator operating at continuous duty maximum current it would take 5.3 hours to full charge a completely depleted battery.

## DC-DC Converter:



**Figure 7 - 12 V - 24 V DC-DC Converter**

The DC-DC converter required for this design is one with a voltage range encapsulating the battery voltage range with a 24V regulated output. Additionally, it must handle output power greater than 100W but not exceeding 150W. The Tobsun TBJ12DK120W receives a 12V input (8-18V range), 24V output with a max power of 120W. Also surge and overload protection is built into this model.

## **Testing & Troubleshooting**

### **Seesaw:**

Two primary locations for improvements, of the seesaw apparatus, became clear during testing. One was at the fulcrum, where the galvanized center shaft and seesaw base notches match up. This connection had far too much kinetic friction, rendering a loud squeaking noise and a slight resistance to movement. Given the materials used the solution was to sand out the notch just enough to allow for easy movement but without sacrificing structural stability. The second area for improvement was on the seesaw base where the base board and vertical supports are connected. Inward and outward wobble caused instability and inefficiency during operation. A cost effective solution was to anchor the inner sides of the base with shelving brackets.

### **Gear Mechanism:**

This portion of the project took the most time and thought for improvements and troubleshooting. Originally an externally mounted two stage gear ratio was the idea to be implemented. However, early in construction the usable bicycle parts available were extremely limited. Given these limitations the group decided to attempt a new gear mechanism configuration. This new set up, a hanging chain guide, provided the group with new challenges. Chain alignment and tension continuously cause problems. An additional free spinning gear, which fed the chain over/around the generator gear, solved the tension and alignment problem. But once again this intermediate design offered challenges. To insure the chain alignment and tension was maintained through the sawing motion, a reduced beat rate and length had to be used. This incidentally decreased the generator RPM by reducing the  $f_p$  and  $e_{swing}$  factors. Reduced RPMs meant reduced voltage and power. Once the group obtained more bike parts the

original design for the two stage gear ratio was constructed. Inherent to the set up alignment and tension were essentially running near ideal conditions upon set up. But, at the gear mounting locations on the rotating shafts' torque would cause the gears to slip, or the shafts to pitch upward, after extended use. A better bolt and lock washer configuration solved the gear slip issue and narrowing of the mounting brackets solved the shaft pitch issue. But at this stage of design, these were temporary fixes.

Due to the fact that the two stage gear system rendered a combined gear ratio of 26:1 (or 28.7:1 upon replacement of a 48 tooth gear with a 53) would spin the generator at an RPM that would charge the battery only when at 75% total charge or less, and for roughly 80% the waveform output of the generator. For improved characteristics and efficiency an increased gear ratio was needed. For this design it meant implementing a third stage. With ease, a near duplicate configuration to the second stage was constructed serving as the final stage. However, during extended use, torque seen by the second stage shaft and first stage hex bolt, caused significant shaft pitch and gear slip, respectively. Due to the need for ease of assembly and adjustment during testing and before frequent demonstration, the group decided not to make several of the gear ratio connections permanent (epoxied or welded) though it would have fixed the torquing of subsequent stages. But the design did provide proof that the concept is feasible, and works even in non-ideal conditions.

### **Generator through rectifier to battery subsystem:**

Critical beats per minute (BPM) to voltage points were the important data for this block of the project. Since all characteristics were dependent on load conditions, specific terminal voltage under conducting conditions would determine if the generator was delivering power at

that point.

As previously stated, a nearly depleted battery would have a voltage of 11.8V, and a nearly full charged one should have a voltage of 14.4V. Given the FWR would have a total conducting voltage of 1.4V, for the model in use, critical voltages for the generator would be 13.2 and 15.8V. Adding a slight contingency and attempting to conduct during most, if not all of the waveform, 16V is the most important terminal voltage.

It is to be noted that no feasibly stable beat rate on the seesaw could produce the necessary RPMs on the generator shaft to deliver a conducting voltage when implementing the chain guide design. The system only operated below 40 BPM but required over 130.

For the two stage gear mechanism, minimum conduction was achieved at 56 BPM but continuous maximum conduction required 89 BPM. Generation was achieved up to 75BPM, setting a limit to the mechanical stability of the system.

For the three stage gear mechanism, minimum conduction was achieved at 14BPM and continuous conduction was achieved at 28 BPM. However, due to the lack of mounting permanence (no epoxy or welding of the tension connections on the shafts of the gear mechanism), significant locking and or gear slip would occur after extended testing. The problem connections would be permanent in a future refined design.

#### **DC-DC converter:**

Given the connection of the input of the DC to DC converter to the terminals of the car battery, the chosen model would always provide regulated output voltage regardless of load condition. That is assuming the battery is not fully depleted, thus unable to provide power to the input of the converter. Additionally, the load cannot exceed 5A (thus 120W) on the output

because it would trigger the overload protection.

During characteristic verification testing the converter maintained transfer characteristics and regulations under various conditions. For no-load,  $V_{out}$  was always near 24V (+/- 0.25V) with an input range of 4 to 22V. Under 42% of maximum load (50W / 120W)  $V_{out}$  remained regulated around 24V (+/- 0.25V) for 7.2 to 18.9V. Under 83% of maximum load (100W / 120W)  $V_{out}$  remained regulated around 24V (+/- 0.25V) for 8.4 to 17.1V. The printed input range for the converter at maximum load was 8 to 18V, and test near maximum load verify those claims by the manufacturer.

No troubleshooting was necessary upon the arrival of the second copy of the chosen converter, due to the completely defective nature of the first one received. Through some testing, the group determined that the converter had a internal short from input to output and thus was rendered useless.

## Improvements

As the group progressed through this project, we encountered many obstacles. The most common problems we came across stemmed from the mechanical side of the project. Some areas that could be improved upon are the design, quality of construction and quality of materials.

The inspiration for the design of the seesaw was found on a do-it-yourself website from the DIY Network<sup>[4]</sup>. The group adjusted the idea of the children's seesaw that we discovered by increasing the dimensions and came out with the design we have today. This is where a first improvement can be noted. By increasing the dimensions, we made the seesaw too tall for anyone to ride safely. The upside to this design was that by having enough space to fully swing each side, we were able to greatly increase the output of the generator.

The next part that could be improved would be the materials and construction of the seesaw. Group members chose to use wood and other rudimentary parts to build the seesaw structure because they were less expensive and easier to work with. To improve upon this, many better materials come to mind. The strongest and most expensive option would be to design and weld a solid metal frame for the seesaw. This would provide stability and strength for those choosing to ride it. It would also give the opportunity to securely fasten the rest of the components, be it gears, the generator, etc, to a frame to insure precision between all of the parts. Another idea that comes to mind is the use of strong plastic piping. This would allow for strength while providing a lightweight, easy to transport seesaw. Another way to improve the quality of construction would be using power tools and other equipment to insure a stable configuration.

Some core ideas that could really improve the quality of future seesaws would be using machined parts, possibly having a different generator, and cooperating with a mechanical engineer. By using machined parts instead of jury-rigged pieces, the design becomes much more efficient and easier to construct. The down side to not using bike chains and gears is cost and ease of replacement. Bicycle equipment is quite common throughout the world, while machined parts are exactly that, machined in a factory to a specific size. The increase in stability and efficiency provided by machined parts is something to be considered when this project is attempted again. Another means to improve the seesaw would be to get a generator that would produce the same output characteristics as our current choice, but requiring a lower RPM. By utilizing a generator with a lower RPM, we would be able to use the two stage gear ratio with ease.

Some final suggestions when the next group begins to work on this project would be to include a specific budget and a diverse team. One of the key parts of the DC House project is trying to produce the desired results with minimal cost. If the group was provided a specific budget, we would be able to properly gauge the quality of construction and materials that we can use. Another recommendation would be to possibly pair an electrical engineering student with a mechanical engineering student. The ME would be able to greatly improve the design and strength of the seesaw and gear mechanism.

## Conclusion

In short, the project was a success in proving the concept that electrical energy can be harnessed from human power, specifically in the act of operating makeshift playground equipment. Moreover, members of the group increased their knowledge and understanding of engineering design concepts, mechanical/electrical systems, and project management. The group met design and construction goals for the project which included but were not limited to: seesaw sizing and assembly, gear mechanism design and construction, specification and selection of all electrical components. Additionally, the group met overall system goals of operation and basic generation upon final adjustments. Critical system specifications at the following points were met in the final adjustment: the minimum generator terminal voltage of 16V for continuous conduction through the rectifier to the battery, and a regulated/loaded output from the system ( $24V_{dc}$  up to 5A). With the work of future groups this proof of concept project will be significantly improved to become an effective and robust source for the DC house.

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## Appendix A: Photos



**Figure 8 - Demonstrating at the Senior Project Exhibition**



**Figure 9 - Senior Project Exhibition**

## Appendix B: Budget/Costs

<b>Item</b>	<b>Cost</b>
<b>Generator</b>	\$429.99
<b>Rectifier</b>	\$37.00
<b>DC Converter</b>	\$41.98
<b>Battery</b>	\$0.00
<b>Inverter</b>	\$0.00
<b>Gear Ratio</b>	\$59.37
<b>Seesaw Construction</b>	\$189.32
<b>Misc</b>	\$0.00
<b>Total</b>	<b>\$757.66</b>