GNG2101

Deliverable F – Prototype 2

Submitted by

Team 1.1

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ABSTRACT

The design, production, and testing of Prototype 2 of the human-powered lights project spanned the duration of several weeks, beginning from the completion of Prototype 1. Feedback was provided from the client, who was generally favorable of the developments to the overall design. When producing the prototype, several critical product assumptions were made to simplify calculations during the testing phase. Testing the electronic components by implementing rigorous test cases proved that they all worked individually and in tandem with each other, with comparable values from the target specifications deduced earlier.

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1 INTRODUCTION

This report will focus on the feedback received at the most recent client meeting. Based on that meeting prototype 2 is modified to best suit the client's wants and needs. Prior to creating the prototype, a critical list of assumptions is made. Next, Prototype 2 is made with a focus on the two main electrical subsystems. This prototype is an integration and milestone prototype. Prototype 2 is tested against target specifications to measure the progress made and evaluate areas to improve. This report covers progress on current prototype, guiding the group on improvements to be made for the final prototype.

2 CLIENT MEETING FINDINGS

We had our third meeting with our client on Monday 28 February 2022. The feedback that was provided from the second meeting was implemented into what is now Prototype 2. To accommodate the constraint of leaving the back wheel on the bicycle, the prototype was redesigned to have the flywheel of the bicycle trainer mate with the rear wheel and power the DC motor that way. The client also provided advice of searching for a converter that is already hooked onto the rechargeable battery to simplify calculations for power storage.

The meeting consisted of an update of the current prototype, supplemented by several slides and demonstrations of the electronic assembly as visual aids. This was followed by a bilateral question-and-answer period where the team and the client exchanged queries and responses in a natural manner.

The client is receptive to the flywheel adjustment, stating that it is a far better solution than having to remove the back wheel for the belt drive. When observing the grow light that was selected, the client remarked that it had to be clamped onto a flat surface, rather than having it stand upright on a flat surface. She believes that this is adaptable, for it may be able to be clamped on the pot that contains one of her plants. In terms of progress, the client remarked how this team is progressing at a faster rate than the team from last semester, as decision paralysis affected their progress.

For administrative purposes, the client stated that she can retrieve her bicycle “in a couple of days”, and that she would have us email her to arrange a time and place to pick it up.

3 CRITICAL PRODUCT ASSUMPTIONS

The critical assumptions we will make about this prototype are that the client will use the system for an adequate amount of time to power the lights. We are also assuming the client pedals at a constant cadence. While this isn’t necessarily biologically possible, we plan on testing a variable cadence by implementing additional systems in our next prototype (a bike and trainer will be used in lieu of a drill). This also includes the assumption that the additional systems will link to our current system properly.

All our materials have come in, so we will not have to deal with shipment or supply chain issues in the future. Lastly, our current battery bank does not have the full storage capacity we need to meet our target specifications, however it is the best battery bank that can be found with our budget. If we had a bigger budget, we plan on upgrading to a larger battery bank, such as the AIMTOM portable power station.

4 PROTOTYPE 2

4.1 Purpose of Prototype

This prototype consists of two smaller prototypes, the first is a battery charging circuit and the second is using the battery to power the grow light. The prototypes will be integration type. The electronic components are being combined and it can be observed how they will behave in the final prototype which allows for any potential bugs to be discovered now vs during the final prototype.

This prototype builds on Prototype 1. This milestone is a more detailed version of the proof-of-concept Prototype 1. The basic electronic components used on the bread board are now swapped for the more robust component which will be used in the final prototype. The milestone prototype should demonstrate that all components selected will work together. Overall, the goal is to test and ensure each component functions on its own and as well in the overall system, to ensure that we will not have to order a new component.

4.2 Assembled Prototype

The electronic components are connected and assembled. The electronic system is broken into 2 subsystems: the first is energy conversion and storage subsystem. A DC motor is connected in series to a diode, then a buck converter and finally the power bank. This setup is shown below in Figure 1.

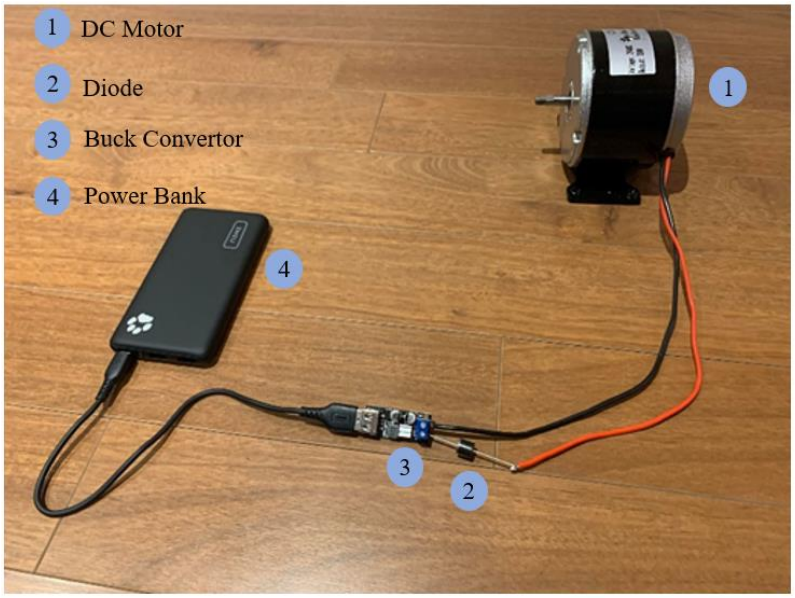

Figure 1: Energy Conversion and Storage Subsystems

The next prototype subsection of Prototype 2 is the energy storage and lighting system. This subsystem is composed of the battery which is connected to the LED grow lights. Figure 2 shows the connection of these two electronic components.

Figure 2: Energy Storage and Lighting System

Each of the components in the subsystems in Figure 1 and Figure 2 will be present in the final prototype. Figure 3 demonstrates the final prototype configuration, demonstrating the relative position that focused Prototype 2 will have in the overall design.

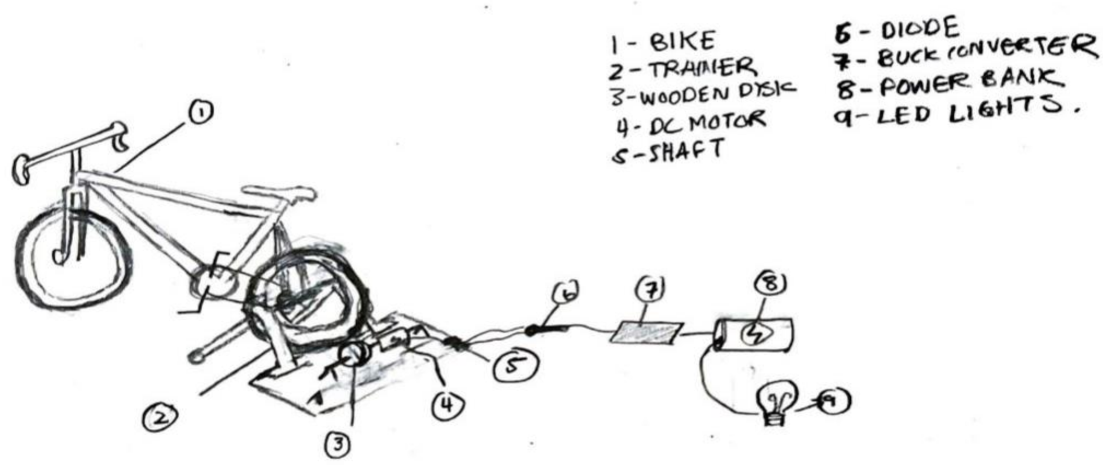

Figure 3: Sketch of Final Design

4.3 Future Directions for Prototypes

The next prototype will finally include a human component. The bike and bike trainer will be added to the system. This prototype used a drill but the goal going forward is to replace the drill with the bike and trainer to power the system. This will allow the measurement of how much energy can be output by the user compared to the calculations. Once this testing is completed formal efficiencies of the system can be tested.

5 TESTING

Prototype 1 displayed a proof of concept and verified certain assumptions regarding the electrical components of the system. In Prototype 2, the electrical components were assembled, along with the battery pack and the LED grow light. Focused testing was performed through the testing of the diode, energy conversion system, and battery pack capabilities. When testing the diode, the rotation of the motor had to spin in a specific direction (clockwise) to generate electrical power. This makes sense as the diode only allows for one-way current flow. This was verified using a multimeter. When the battery is connected to the overall system, the motor does not spin, further verifying the functionality of the diode in the circuit. In prototype one, the team used a small motor connected to a diode in series, this was rotated using a finger to power a little LED light. In the second prototype, the motor and diode used are the actual sizes that will be used in the system. The motor and diode are then connected to the buck converter. For the purpose of testing, the output of the buck converter is connected to a USB voltage and current measuring device which is then connected to the battery pack. The USB voltage and current measuring device is not part of the design, it is only used for testing purposes. A hand drill is used as a substitute for the human power input as the team does not have the client’s bike yet. The hand drill spins the motor, generating power and charging the battery. The figure below shows the successful operation of the energy conversion and storage subsystems during testing.

Figure 4: Testing of Power Generation and Energy Storage Subsystems

Finally, a test on if the battery pack can power grow lights was taken. This test confirmed that the battery pack was able to output the necessary voltage and current to power the LED grow lights. The figure below shows the successful operation of the battery pack powering the LED grow lights.

Figure 5: Testing of Output from Energy Storage System

Quantitative data was also taken during the testing process and compared with the target specifications stated in Deliverable B.

Table 1: Target Specifications Compared with Actual Results from Prototype 2

Metric description	Units	Target specifications	Actual results
Footprint (electronic components only)	Feet (ft^2)	16	268cm-> 0.28847ft^2
Light	Lumen (lm)	1000 lumen	1000 lumen
Speed	Revolutions per minute (RPM)	61	≈ 360
Time (lights)	Hours (Hr.)	8-14 (mimic natural daylight)	3.7

Time (power generation)	Minutes (min)	45	222
Cost	Canadian Dollar ($)	80	86.92
Weight (electronics only)	Kilograms (kg)	<30 kg	2 kg

5.1 Footprint:

The system's electronic components have a collapsible/compressibility, allowing the power bank and DC motor to be stacked on top of one another, resulting in more fluid flexibility. The largest footprint is taken by the DC motor (length = 20cm, width = 12.4cm), the power bank being smaller is placed on top of the motor resulting in 0.28847 square footage being taken up. The actual result is smaller than the target specification, although the bike has not been received from the client, there is a lot of square footage to work with. The compressibility of the electronic components helps respect the space requirements set by the client.

5.2 Light:

Because the battery pack was able to light up the LED grow light as seen in Figure 5, this means that the system was able to generate the 1000 lumen required as per the target specifications. If the LED light was not lit after connected to the battery pack, then the team would know that more power was needed to light the lights.

5.3 Speed:

In this prototype, the rotational speed of the hand drill was used to simulate the rotations of a foot to bike pedal. It should be stated that the RPM of the hand drill will be must faster than the RPM of an actual bike pedal rotation. Because the team did not have the client's bike, adjustments were made to further develop the prototype and verify project assumptions. The hand drill is a

Milwaukee brand, and from the specifications it states that it has a max RPM of 1800 [1]. The actual RPM of the drill was not measured, but assuming only 20% hand drill power, the calculated RPM of the hand drill was estimated to be 360 RPM. This speed value is much higher than the target specification value. However, this speed value is not totally indicative of the user's input speed as the bike will have various gear ratios. Prototype 3 will have a more accurate speed value when the client allows the team to perform tests on the bike.

5.4 Time (Lights):

The power bank being used has a rated capacity of 37 Wh [2]. The grow lights are rated to 10 W [3]. Dividing the capacity by the power consumption, the time value for running the lights is 3.7 hours. This value is much lower than the target specification of 8-14 hours. Due to budget constraints, the team was not able to feasibly purchase a power bank with a larger capacity. Furthermore, this is a low-fidelity prototype. To theoretically mitigate this issue, the user could use multiple identically sized power banks.

5.5 Time (Power Generation):

The team had not yet received the client's bike, estimated testing/calculations were performed to determine the approximate time the client would need to take to power the lights. During testing, the voltage and current measuring device showed that a peak of approximately 10 W could be achieved as input into the battery. Assuming that this 10 W can be maintained, the time it would take to charge the battery would be (37 Wh/10W) = 3.7 hours or 222 min. This is larger than the target specification of 45 min; however, this is still not with the bike and trainer, so it is not the final time value.

5.6 Cost:

The costs for all the materials were slightly above that of the target specifications, including tax. All materials purchased are in good condition and are currently working properly. The target specification of $80 for the budget allows the team to have some contingency money in case any parts are malfunctioning, or another piece is needed for the project. The team so far has spent $86.92.

5.7 Weight:

Given that the client has not given the team the bike yet, the weight of all the electronic components was measured for Prototype 2. The weight of the DC motor, wires, diode, buck converter, power bank all combined to approx. 2kg. This value is much smaller than the 30kg ceiling the team set in the target specifications.

6 CONCLUSION

In conclusion, Prototype 2 built upon assumptions and concepts that were investigated in Prototype 1. The main objectives were integrating all the electrical components, then checking if the electrical system was able to convert and store electrical power, and then checking if the power bank can power the grow lights. The team looks to continue power output tests with the client's actual bike for the final Prototype 3. Prototype 2 confirmed that the electrical subsystem that was envisioned will perform the task required of converting rotational energy to power LED lights.

7 References

[1] “MILWAUKEE COMPACT DRILL M18 BARE TOOL.” Grainger Canada. Accessed 6 Mar. 2022. https://www.grainger.ca/en/product/p/MTL2606-20

[2] INIU Portable Charger, USB C Slimmest Triple 3A High-Speed 10000mAh Phone Power Bank, Flashlight External Battery Pack Compatible with IPhone 13 12 11 X Samsung S20 Google LG IPad, Etc [2022 Version] : Amazon.ca: Electronics. https://www.amazon.ca/INIU-Portable-External-Powerbank-Compatible/dp/B07G34JZG2/. Accessed 6 Mar. 2022.

[3] 10W LED Grow Light for Indoor Plant, Full Spectrum Plant Grow Lights with Adjustable Neck, Auto ON & Off with 3/6/12H Timer 3 Lightness Dimmable Clip-On Grow Lamp for Veg&Flower Bloom : Amazon.ca: Patio, Lawn & Garden. https://www.amazon.ca/gp/product/B07WT2YQNX/. Accessed 6 Mar. 2022.