Phone Energizing Device and Lights Bike (PEDAL Bike)

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***Abstract* — The Phone Energizing Device and Lights (PEDAL) Bike aims to utilize renewable energy sources to charge a device through a bicycle's pedals and an attached solar panel. By pedaling a sidewall generator, the user can produce power while traveling and the solar panel covers times when the bike is stopped. Besides the small device the system can power an additional load. The sensor subsystem of the PEDAL Bike displays to the user environmental conditions for a more comfortable ride. This paper focuses on the process, functions, and purpose of this project.**

***Index Terms* — generator, embedded system, power generation, renewable energy sources, solar power**

I. Introduction

When going out on an expedition, whether it be far away or nearby, the most important possession on one's person is usually a cell phone. With this in mind, a discharged phone proves to be no more useful than a simple paper weight. Thus, the idea for the PEDAL Bike came into fruition. Although a phone can be charged nearly anywhere in the modern day and the average person may carry a charger, it can be difficult to do much when on the move. Even though the PEDAL Bike was made with phones in mind, it can apply to any device that uses a USB connection to charge. This one fact gives the bike many possibilities and can improve an outing considerably.

By being able to charge an electric lighter, portable speaker, portable charger, and of course a smartphone, the bike can suit any rider's lifestyle for the better, while also making a positive impact on the environment. Not only that, but with dependable solar panels that work for 20+ years, lithium ion batteries, chargers with heat and overcharge protection, and a generator that is waterproof and made to last, this system is very sustainable, not to mention extremely safe. The system aims to be usable in many different scenarios, as all bikes should be, so the necessary components will be protected against rain and other weather conditions. Along with all of the other useful features, the PEDAL Bike will be ready for daily bike usage even with all of the attachments involved.

II. System Components

The PEDAL Bike wouldn't be possible without the sidewall generator and solar panel attachments, but it's safe to say that there are several other important components that should be mentioned alongside them.

A. Sidewall Generator

Commonly mistaken as a dynamo, which produces DC energy, the sidewall generator (also known as a bottle generator) is one of the oldest but simplest generators able to be installed on a bicycle. Its ease of use is a key factor in the selection of this generator. Other generators exist on the market, but this type is one of the most common and one of the least expensive so these are easy to come by. These generators also have one of the least invasive installation processes, which makes installation easy to do ourselves.

Shown in Fig. 1 is the generator's internal structure.As the bike moves forward and the wheel rotates, the wheel at the end of the generator spins and generates AC power. Not much else is needed, but the pressure of the roller against the tire is important to maintain rotation.

The generator is most effective when installed at an angle such that a straight line could be drawn through the center of the generator to the axis of the wheel, aligning the generator with the wheel's dropout. Another useful feature is that sidewall generators can be disengaged at will, without having to dismantle the bicycle, unlike hub generators. Its low weight and decent specifications of 12V / 6W / 0.5A allow for a versatile component that fits the design very well.

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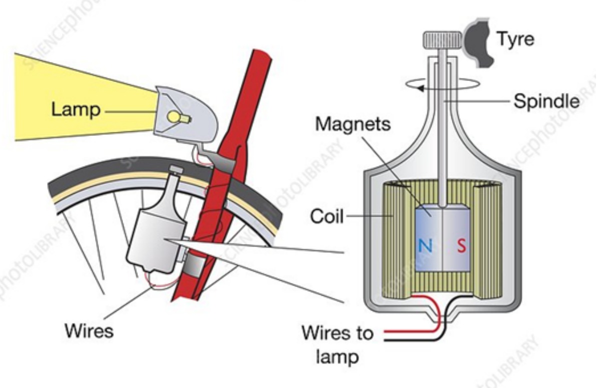

Fig. 1. Diagram of a Sidewall / Bottle Generator powering a lamp

B. Solar Panel

Out of the three main types of solar panels, the monocrystalline is the more efficient, more expensive type. Not only that, but it also usually has the longest lifespan and has been around the longest, making it more developed than the other types in the process. We chose a monocrystalline panel that has a rated conversion rate of 22%, and a max power output of 10W, this solar panel is well suited for anything the PEDAL Bike requires. This panel in particular has low weight and is water resistant with a rating of IP65, higher than our goal rating of IP34 ensuring that the rider can bike freely without worrying about some water damage.

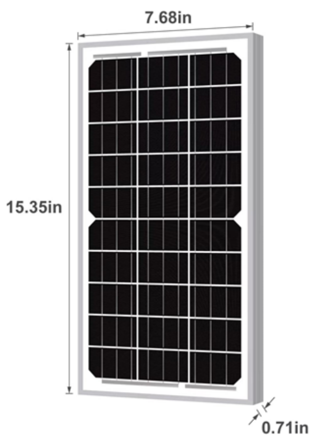

Fig. 2. Monocrystalline Panel

C. Sensors

In order to properly display temperature, speed, charge on the device, and voltage generated on the LCD, the system requires the three different sensors shown in the table below.

NEO-6M is a GPS chip that isn't as accurate as some other modules are when calculating speed, since it approximates speed based on where you are and how much movement there is, but its easily implemented components make it a suitable fit for the bike.

The Sensirion has the capability to show both temperature and humidity, and along with the INA219 and NEO-6M allows the rider to see a variety of useful features all while knowing how much charge they just gave their devices from a short and simple bike ride.

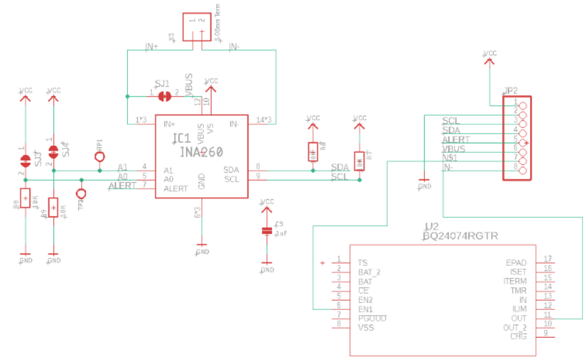

Fig. 3. Voltage Sensor schematic

Shown here is a look at the most involved of the sensors: the voltage and current sensor. This sensor needed to be connected to the microcontroller, the LCD, and a load to measure current, voltage, and power information.

Our plans for this sensor changed dramatically after we finished our Senior Design 1 documentation, which can be seen in how different this original schematic is from our final design. The chip shown in this schematic is the Adafruit INA260, which ended up going out of stock before it could be ordered. As an alternative, we used the Adafruit INA219, with the only difference between the two being that the INA219 could only measure high side DC current.

Our initial design also included a battery to store power coming in from the generator and solar panel, which can be seen in the schematic above. However, this design was reconsidered after our testing phase, and the battery as a middleman was cut out. As a result, our INA219 sensor now measures the voltage and power generated by the solar panel.

TABLE I
SUMMARY OF SENSORS

Sensor	Function
NEO-6M	GPS / Speed
Sensirion SHT40	Temperature
INA219	Voltage / Current / Power

D. Charger and Battery

In our original design we used the BQ25672 battery charger. This charger provides features that would have been very useful for the project, and some additional safety features. The BQ25672 supports 1-4 cell batteries and a wide range of voltages for the inputs, from 3.6V to 24V to be exact. Its innate feature that supports switching between sources is largely useful for the PEDAL Bike's use of both a generator and a solar panel. Not to mention that the charger is also compatible with USB output and photovoltaic panels, whether it be monocrystalline or polycrystalline. This charger has MPPT algorithm features that would have been ideal for our solar panel input and possibly even for our generator input as it also is variable. The MPPT would enable the charger to extract the maximum available power from the PV module under different conditions.

Its thermal shutdown and regulation qualities ensure that the battery doesn't pose a health hazard, along with a charging safety timer and input overvoltage protection that cover all the bases regarding safety and possible component malfunctions.

As for the battery, it was decided that a rechargeable lithium-ion battery suited the bike the best, since its lack of weight and high power density allow it to be both inconspicuous and long lasting. Thankfully, li-ion batteries also hold their charge the longest out of the batteries available on the market, giving the team another incentive to include it in the design.

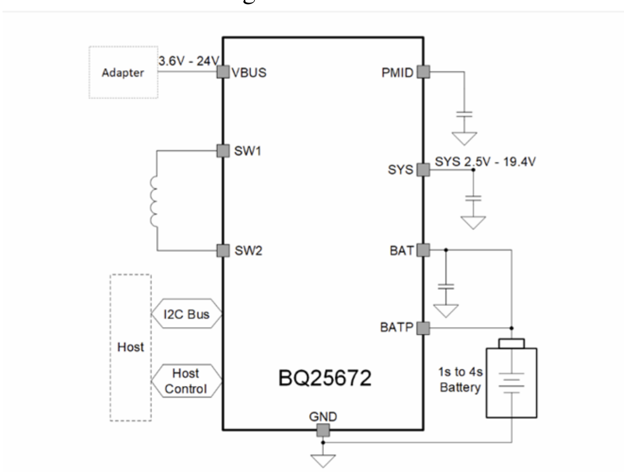

Fig. 3. BQ25672 Charger

E. Voltage regulators

In our original design we had three different voltage regulator circuits throughout the system, and four total. We used Ti WEBENCH® Power Designer to help with our design of these voltage regulators. One of the circuit designs was regulating voltage from each power source to the battery charger, with a DC input of 5V-20V and an output of 4.2A at 3A for the battery charger. The sources used separate voltage regulators but they used the same design, as the sources both fall within that input range and both were going to be connected to the battery charger. The next voltage regulators were regulating the input voltage of the loads. From the battery to the microcontroller the input accepted by the voltage regulator was a DC voltage of 2.3 V - 5.5 V, and the output of the voltage regulator was 3.6 V at 0.5 A. From the battery to the phone load the input range of the voltage regulator was a DC voltage of 2.5 V - 5.5 V and the output of that regulator was 3.3 V at 2 A.

These regulators ended up being a part of the reason that we had so many challenges with our initial PCB designs. When we filtered the voltage regulator options, we were looking for small footprints, low cost, an available schematic export, and an efficiency of over 80%. When we filtered for smaller footprints we didn't realize how much their size would affect our ability to work with them.

F. Microcontroller

Without any configurations, the Arduino Uno R3 offers a lot of perks due to its abundance and ability to use open source material. Although one drawback is the lack of pins available for use, many pins aren't necessary for its intended use. The microcontroller is at least quite fast, however, and it has a convenient USB plug-in that works both ways, since the microcontroller can connect to devices and can be connected to via USB-B. These attributes allow it to function properly as a critical piece of the bike's intended ease of use. Most importantly, the microcontroller is compact and powerful while also maintaining low power usage at all times, making it an important yet conservative segment of the current design.

At first, the original design used an MSP4330FR6989, but it was replaced due to it not functioning properly with the current design. This change was not a great inconvenience due to the bike now having more operating voltage and USB capabilities, albeit at the cost of many pins that were unplanned for use either way.

TABLE 2
SUMMARY OF MICROCONTROLLER FEATURES

	Arduino Uno R3	MSP430FR6989
Pins	14	83
Operating Voltage	7V - 12V	1.8 - 3.6V
Crystal Oscillator	16MHz	32kHz

Low Power Usage	Yes	Yes, with several modes
USB Connection	Connects to other devices and can be connected to with USB-B	Connects to other devices

G. LCD Display

In order to relay our sensor data back to the user, we chose to use an LCD attached to the bike. Originally, we opted to use the Sunfounder LCD 1602 that was included in the junior design kit as we knew how to use it and it was readily available. However, the row and column amounts proved to be somewhat restrictive, so an upgrade was made to the Sunfounder 2004 LCD, with double the rows and four additional characters in each. With this, the screen comfortably displays temperature, humidity, speed, voltage, power, and altitude.

III. New Power Generation Design

H. Need for Redesign

Unfortunately there were many factors that led to our initial design not working for us. Our main goal was to make the PCB as small as possible. To do this, we chose the smallest components we could find. For example, the battery charger component chosen was the BQ25672RQMR, which was only 4mm x 4mm. This battery charger was the largest component chosen for the entire design. This made our total footprint for the PCB the smallest possible. The issue started when the components were ordered and finally received. Attaching surface mount components that are small onto boards, even with a stencil, takes extreme precision for placement. Using the reflow oven also came with some unlucky downfalls. Components are known to shift while using the reflow oven to place them in their respective pads. Because the components that were chosen were smaller than 4mm x 4mm, the slightest movements can cause the pins on the components to short, or not place on its designated pad at all. Since the pins are so small, it was almost impossible to test each one with a standard voltmeter.

In trying to readjust components that shifted in the oven, it is possible for them to have been harmed under too much heat. Reordering components at that stage was not an option.

Ultimately we decided to go with a simpler design for the power subsystem. This was due to time constraints brought on from continuous debugging and unforeseen obstacles. The biggest obstacle was going with an original design that had extremely tiny components. Although a PCB with a smaller footprint would be ideal, it made it difficult to obtain any readings from any of the pins on the small components. Not being able to order a new PCB, we had to resort to soldering new components onto a perfboard and using that as the main power regulation.

The biggest set back was not being able to include a battery in the system. The battery would act as a steady DC source of energy to the loads. Instead, two voltage regulators, 7805T and 7812T were used for the sidewall mount generator and the solar panel respectively. The reason for using the 7812T regulator for the solar panel was that the solar panel had a larger voltage output than the sidewall mount generator. Since the solar panel, under a normal sunny day, would deliver more voltage than 12V, the regulator would always output a constant voltage. The same applied to the sidewall generator, where pedaling the bike generated more voltage than 5V, always allowing the 7805T regulator to output 5V. Being able to supply a steady voltage, even at the times the rider is not pedaling (because of the solar panel), allowed us to charge loads (cell phones) without having a battery as part of the system. Not having a battery as part of the system eliminated the need for the charging circuit. This turned out to be a positive since the battery charger that was initially ordered for the original design was a surface mount part and would be unusable on a perfboard, and parts to build a charging circuit from scratch was absent.

To have both outputs of the regulators be used for either of the two USB ports, both positive outputs of the 5V and 12V regulators were connected together and then connected to the positive terminal of the USB connector. This allowed for the generation source with the largest voltage output to supply the loads with power. Enough voltage was generated from the sidewall mount generator and solar panel that it enabled two cell phones to be charged simultaneously. This meant that it was possible to supply enough voltage to two loads

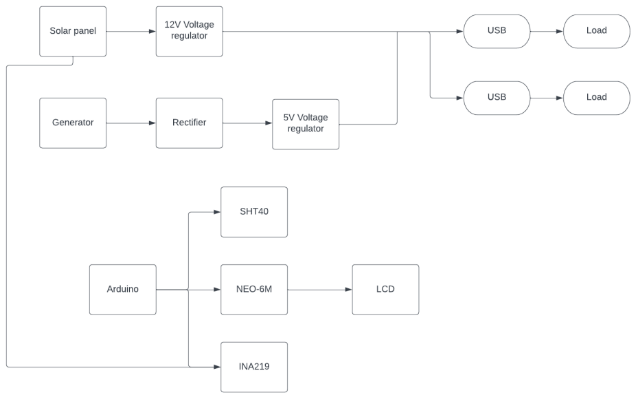

Fig. 4. Block diagram for new design

I. Prototyping

Before deciding on a new design we tested the design on solderless breadboards. We tried several iterations of designs similar to this: we tried different values of voltage regulator parts, different capacitor values, tried implementing the circuit with and without a battery, with and without a load, with and without two loads, with the power sources together and independently from each other. Eventually, after many trials, we landed on the design that we implemented.

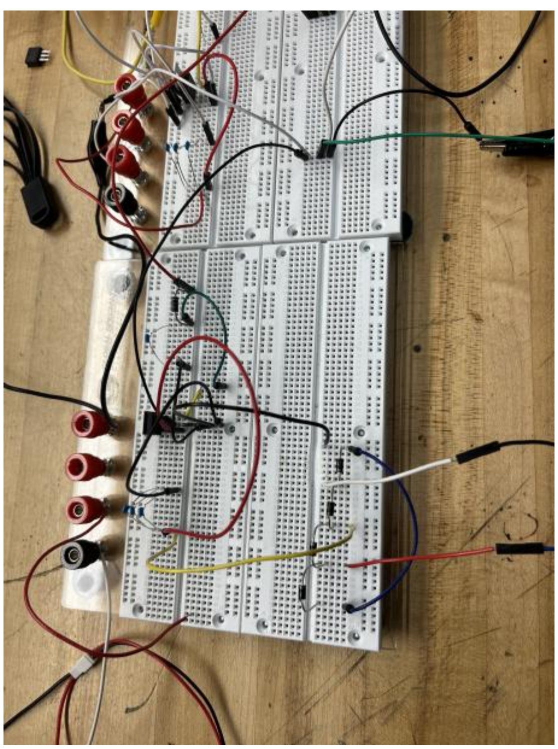

Fig. 5. Breadboard for testing new design

J. Rectifier

Due to the fact that most devices require a DC current to operate and that the sidewall generator used in the design produces AC current, rectifiers are needed to convert the AC power into DC power.

Between the options of the half-wave, full-wave center tapped, and bridge rectifiers, the bridge is both cost effective and allows for decent energy to be transferred to the battery, therefore serving more of a purpose here than the rest. This is because when compared to the other types, the bridge rectifier doesn't contain a center tap wire and a transformer, but rather just four diodes and a load resistor. This also results in a smaller size along with a voltage drop from the four diodes, which is an unfortunate downside. However, double the DC output than a half-wave and less complexity and cost than a full-wave make this rectifier suitable for the new power generation design.

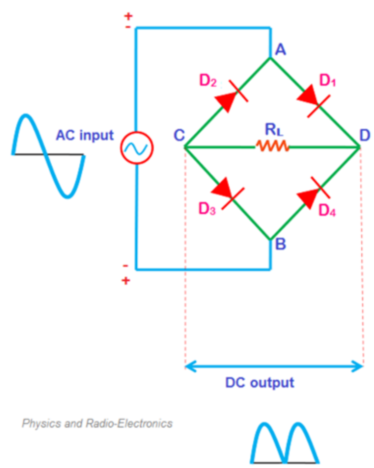

Fig. 6. Bridge Rectifier

K. Generator voltage regulator

After being rectified into DC voltage the power from the generator goes through voltage regulation. The voltage regulator circuit that we utilized for the sidewall generator uses the 7805t part. This is a 5 volt regulator. The design also includes a 0.33uF capacitor and a 0.1uF capacitor. In our design we used three 0.1uF capacitors in parallel to combine up the 0.33uF capacitor needed. In the original design, a surface mount rectifier was chosen. Since that option was no longer viable, a bridge rectifier was created using four 1N4006 diodes.

L. Solar voltage regulator

The voltage regulator circuit that we designed for the solar panel uses the 7812T part. This is a 12 volt regulator. Much like the voltage regulator for the generator, the voltage regulator circuit for the solar panel includes a 0.33uF capacitor and a 0.1uF capacitor, and we used 0.1uF capacitors in parallel to make the 0.33uF capacitor. The 12 voltage regulator allows us to take advantage of the solar panel's higher voltage rating of 17V when compared to the generator's 12V. Because the solar panel outputs DC voltage, there was no need to build a bridge rectifier for this part of the system.

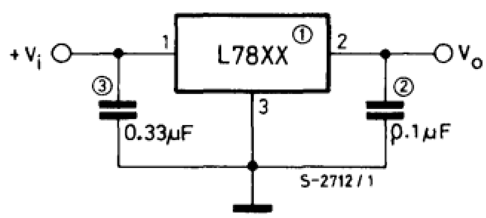

Fig. 7. Schematic for the 12V solar voltage regulator

M. Load distribution

The outputs of the voltage regulation circuits of both sources are combined onto two nodes in parallel, one node for the voltage lines and one for the ground lines. The two USB loads are then also connected to the same nodes effectively connecting the two sources and the two loads in parallel. Just before the nodes and after the voltage regulation each source line has a diode to make sure that they are only supplying power and not taking it from the loads. This is especially important for the solar panel as solar panels can take power from their loads at night or during other times of low light, when the solar panels are not producing any electricity.

IV. Software Design

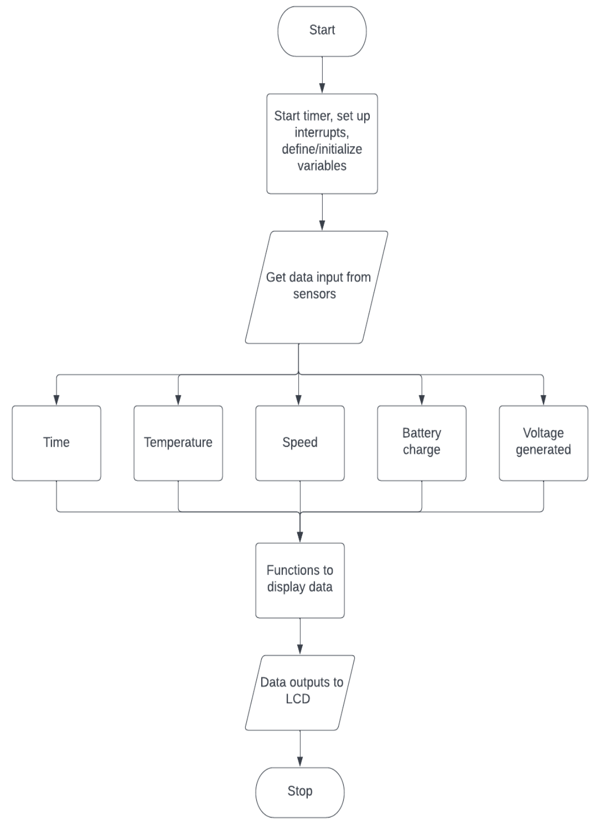

Fig. 8. Block diagram for software design

As can be seen in the diagram, our program will first begin with defining and initializing variables, which will be used later to store the information sent from the sensors. Then, data will be gathered from the sensors and sent through the microcontroller. These data include speed, power, voltage generated, temperature, humidity, and altitude. They will all be passed to functions written to display each different type of data. Finally, the functions will display the information to the LCD, and the program will continue going through the loop section of the Arduino code, updating the display with new information whenever it is received .

V. Printed Circuit Boards

Figures 10 and 11 show the new design implemented as a printed circuit board (PCB). Due to time constraints we were not able to assemble the PCBs but we built out the same design on a perf board and were able to get it working effectively. Figure 9 shows the manually soldered perf board with the functioning design.

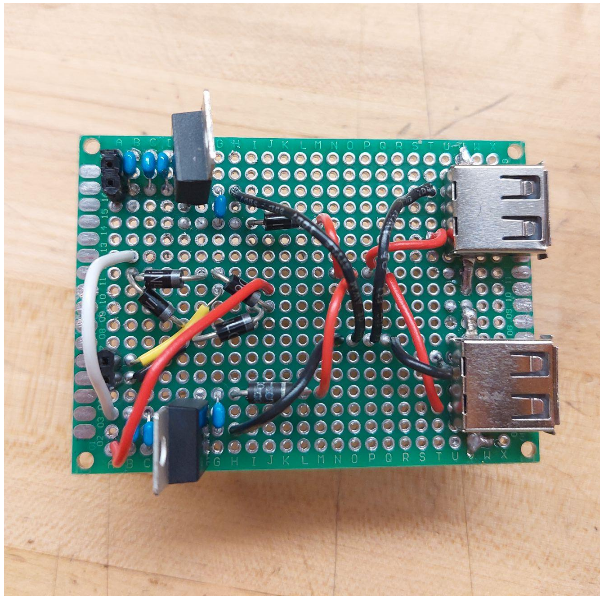

Fig. 9. Manually soldered power subsystem design

Biographies

Roxanna Cruz is a senior electrical engineering student at the University of Central Florida, with a focus on power and renewable energy, graduating in Spring 2023. She is especially interested in the sustainability and reliability of the power grid. For the past year she has been working as a teaching assistant for Computer Organization and has served as the president of UCF's Student branch chapter of IEEE PES. After graduation she plans on pursuing a career in the power field.

Elizabeth Curcio is a senior in the computer engineering comprehensive track at the University of Central Florida, graduating May 2023.

Dexter Mayorga is a senior electrical engineering student focusing on the power and renewable energy track. He will be graduating in Fall 2023, so in the meantime he will pursue internships and other opportunities while finishing his degree at the University of Central Florida. Afterwards, he will focus on the engineering foundation exam and plan to move upstate or out of the country with his degree in hand, aiming to work with renewable energy and eventually obtain a professional engineering license.

Melvin Vicente is currently a senior at the University of Central Florida studying electrical engineering and plans to graduate Spring 2023. For the past year, he has completed 3 Regulated Renewable Energy Co-op rotations with Duke Energy at the Hines Energy Complex where he has learned about power systems at a natural gas powered power plant. After graduation, he plans on either continuing to learn about power systems at a utility company or expand into a different sector of electrical engineering to widen his knowledge about the field.

Acknowledgement

The team would also like to thank the committee members, Dr. Qun Zhou Sun, Dr. Wei Sun and Dr. Mike Borowczak for taking the time to review the project. Thank you.

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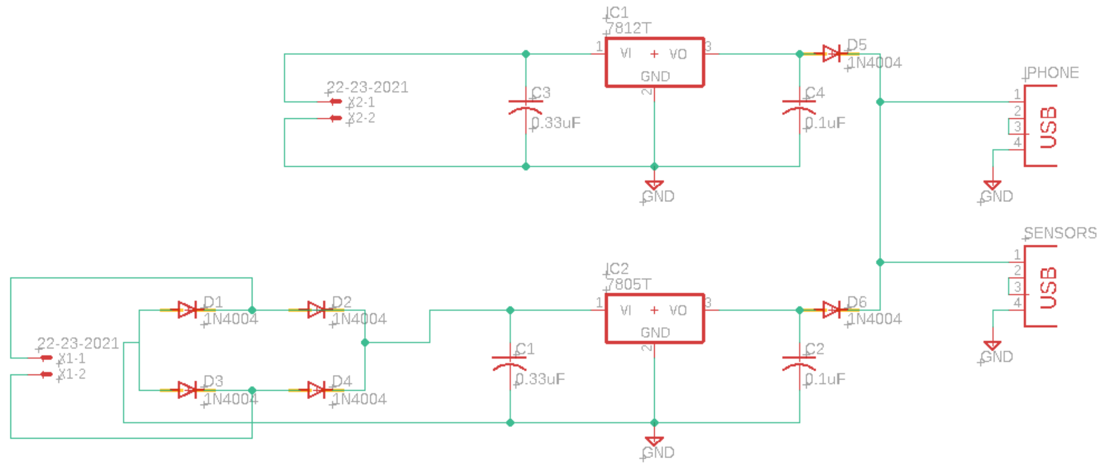

Fig. 10. Eagle schematic for new power subsystem board design

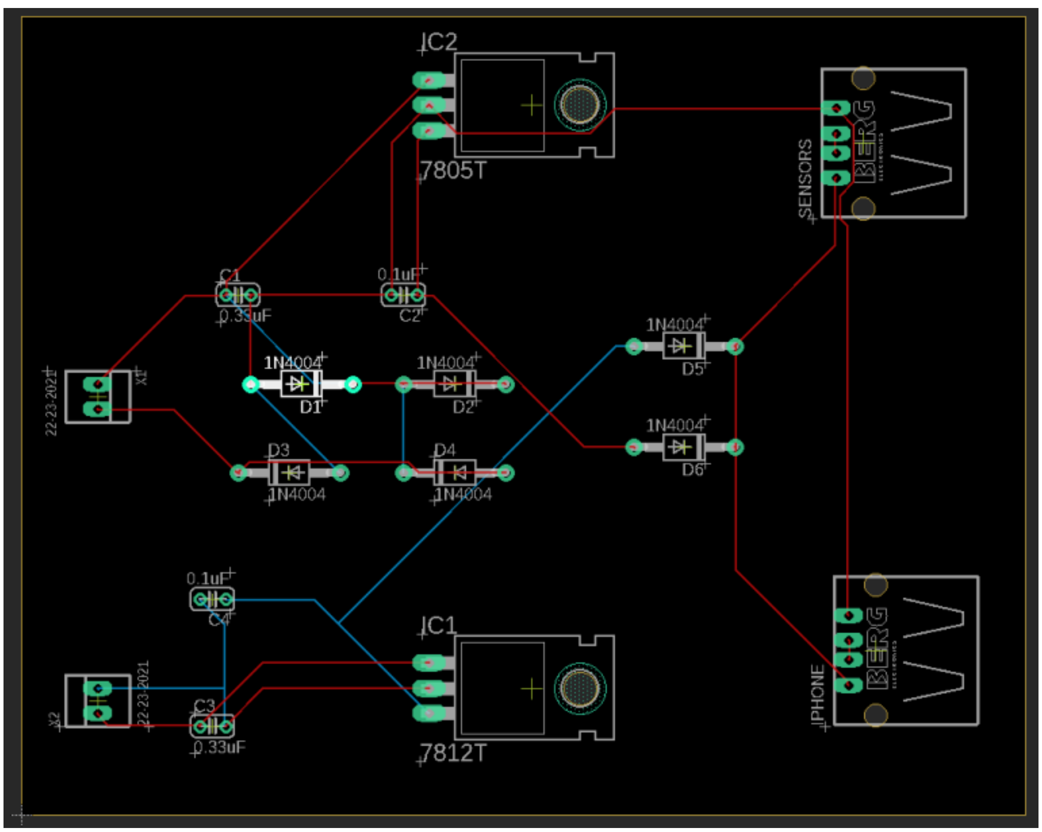

Fig. 11. Broad layout for new design