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PORTABLE HEARING AID SOLAR CHARGER

By

Lucien Tran

Student Number: 12878930

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Academic Advisor: Dylan Lu

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Abstract

PORTABLE HEARING AID SOLAR CHARGER

Lucien TRAN | AUTUMN 2021

With the growing percentage of the population suffering from hearing loss, an inclusive solution to an existing product was needed. Hearing aids running on batteries can run flat at any time without warning, leaving the user distressed and anxious that it could happen in undesirable situations. With the increasing use of renewable energy systems due to environmental reasons, disposable batteries can now be slowly discarded for rechargeable batteries. However, the change from disposable to rechargeable batteries in hearing aids is slow and often solutions are expensive. Thus, after extensive feasibility and product research, the implementation and development of a portable hearing aid solar charger was built successfully. The product can clip itself to hair, on a hat, or on any item of clothing. The research and implementation plan is discussed through the design of a printed circuit board as well as a 3D model. Applying previous knowledge to this project has brought significant experience and knowledge for both now and the future. A future where engineers can bring inclusive solutions for people living with a disability.

Acknowledgement

I would like to express my special thanks to my supervisor Dylan Lu who gave me valuable advice during the past year while undertaking my capstone project, pointed me in the right direction with suggestions for me to think for myself, and correcting me when I am wrong.

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Nomenclature

Term	Definition
MPPT	Maximum Power Point Theorem
PCB	Printed Circuit Board
PV	Photovoltaic
Li-ion	Lithium-ion
NiMH	Nickel-Metal Hydride
AgZn	Silver-Zinc
IC	Integrated Circuit

1 Introduction

With the current advancement in health technologies and the higher life expectancy of the population, a rise of people suffering from hearing losses is being noticed. Connect Hearing claims that “One in six Australians currently suffer from hearing loss. This number is expected to rise to one in four by 2050” (ConnectHearing, 2020). Furthermore, using disposable batteries to power those hearing aids must be stopped due to the detrimental effects it has on the environment, suffering enough as it is.

It was only in 2016 that rechargeable batteries have been introduced in hearing aids (Hearing Savers, 2018). However, users tend to choose disposable batteries because of the extended battery life and often inexpensive. This project has the aim to power hearing aids using solar energy. The solution must be portable as well as low cost as well as discreet. That solar-powered hearing aids charger can be attached to any item of clothing, such as hats, and can also be attached to the user’s hair thanks to the hair clip provided.

2 Literature Review

2.1 Feasibility Research

The literature review of the report determines the feasibility of the project. The technical research and implementation are further explored in the next sections.

Each aspect of the product: rechargeable batteries, solar panel technology, and its efficiency, is discussed below supported by scholarly articles. Those articles explore the engineering problems and propose a solution by supporting different hypothesis. They explain what can work and what cannot work.

Audiologist Tao Cui at ReSound claims that the use of rechargeable batteries for hearing aids is possible and has in fact been implemented by some companies. However, limitations are depending on each type of battery. In fact, batteries have different ratings: their capacity and their nominal voltage. Nominal voltage is based on the “electrochemistry of the battery” (Tao Cui, 2014) and not its size, thus smaller batteries of the same type have the same nominal voltage but generally smaller capacity. On the other hand, the capacity of a battery is “how much energy is stored in the battery” (Tao Cui, 2014) and is given in milli-ampere hour (mAh). The time it takes for the battery to run flat is found by dividing the current drain of the battery by its capacity. In this instance, a size 312 nickel-metal hydride battery (NiMH) has an average autonomy of 15 hours. Currently, hearings aids have a choice between three types of batteries to be implemented in their system: the previously mentioned nickel-metal hydride battery (NiMH), Silver-Zinc battery (AgZn), and lithium-ion battery (Li-ion). In 2016, the most common rechargeable battery found in hearing aids was the NiMH battery. However, the capacity and thus the autonomy of the NiMH battery is much lower than the other two choices. The rationale behind NiMH was that current hearing aids were only designed to withstand and “operate in the 1 to 1.6V range” (Tao Cui, 2014). On the other hand, The nominal voltages of both AgZn and Li-Ion are respectively 1.8 V and 3.7 V, which will thus damage the internal circuit of the device. At that point in time, replacing all existing hearing aids was not realistic and only a slow transition to newly designed hearing aids would be possible. The newly designed hearing aids will need to be able to operate in the range of Li-ion which has the most autonomy out of three choices of battery.

A major requirement needed for the project to succeed is the harvesting of solar energy. It is essential to power the hearing aids and for the charging of the product. A scholarly article about a “solar-powered mobile phone” discussed the feasibility of the project as well as the initial prototype with a small photovoltaic (PV) panel powering the phone. Hearing aids having a much smaller power consumption, it is assumed that the charging of a small PV panel is more than feasible and thus allowing the product to formalize.

Another aspect to consider before designing the product is the need to increase the effectiveness of solar charging. In fact, several methods can be used to improve the conversion rate: they are called the maximum power point theorem (MPPT). Several theorems can be implemented such as the Perturb and Observe (P&O) theorem, its variant (variable step), Hill Climbing Theorem, and Constant Voltage Theorem. While the perturb and observe and the hill-climbing theorems are adaptive to several uses of the system, the constant voltage theorem is more suitable for constant application where components do not need to change. Perturb and Observe Theorem consists of increasing and decreasing the duty cycle of the control signal to achieve the maximum power point. However, continuously changing the duty cycle brings instability as well as noise to the system. Checking how large the power feedback is and varying accordingly the increase and the decrease of the duty cycle will result in utilising the perturb and observe variable step. It is similar to the Hill-Climbing Theorem that relies on the same principle. Each theorem is supported by scholarly articles explaining their effectiveness, principles, and implementation. In conclusion, methods to improve the efficiency of solar charging are numerous and have unique characteristics that are suitable to each need.

2.2 Existing Solutions

As technology advances, new solar-powered hearing aids have come a long way from using NiMH batteries. In fact, several competitors offer charging docks for hearing aids to be charged at night or when needed.

2.2.1 Oticon

Oticon hearing aids allow the user to go out throughout the day without worrying about charging their hearing aids. The charging pad that comes with the purchase of the hearing aids allows the user to place them on and not worry about technical knowledge. It is very easy to use.

The Oticon model uses a Lithium-ion battery to power their device, thus having a long autonomy. However, the expense might discourage some buyers.

2.2.2 Phonak

Phonak also offers rechargeable batteries and boasts about its reliability as well as its fast charge. They claim that “They give you 1 day of hearing with a 2-hour charge. If you are in a rush, you can rely on a short 15-minute charge to give you up to 3 hours of full performance.”(Phonak, 2020). After extensive tests and using Lithium-Ion to power their hearing aids, they believe that the rechargeable batteries can last up to 6 years.

2.2.3 Powering hearing aids with alternate renewable energy

Other companies also propose rechargeable hearing aids solutions that have good autonomy and can be good alternatives to solar energy. Most of the businesses in that space have not implemented any kind of renewable energy systems such as solar and thermal powered. While it is advertised, the product was not available online.

The report from the competitors has shown high-cost and high-end renewable energy-powered hearing aids. In this case, no low cost and portable solutions have been explored and I strongly that the project was undertaken in this session will prove to be useful in the future.

3 Product Design and Considerations

3.1 Product Description

The solution proposed must satisfy several user stories:

- The product must be portable so that users can easily wear it without discomfort and can be stored in their pocket or their bag.
- The product must be able to charge the hearing aid using renewable energy.
- The product must be able to be attached to an item of clothing or the user’s hair.

Therefore, the portable hearing aid solar charger consists of a solar panel in a case that allows the user to plug their hearing aids and charge them. The case will be equipped with hairpins that will allow the user to attach it to their hair, their hat, and even their top.

For protection and ease of use, the product will come in a small case with the solar panel as its lid, a compartment for the battery as well as a female port to plug the charging cable into the hearing aids.

3.2 Maximum Power Point Theorem

Firstly, extended research in maximum power point theorems was needed to allow the system to reach the highest efficiency. As mentioned before, several theorems are available for us to use. The two choices that are considered are the Perturb & Observe (P&O) and the Constant Voltage Theorem.

The table below breaks down the advantages and the disadvantages of both theorems:

Theorem	Advantages	Disadvantages
Perturb & Observe	• Most used algorithm • Controlled according to environmental factors	• High settling time • Noise/vibrations due to fluctuating between two duty cycles at the maximum power point
Constant Voltage	• Simplest Implementation • One voltage reference to control the system.	• Not as accurate (radiation and temperature are disregarded)

Table 1 - Comparison of MPPT (P&O vs CV)

For a small system that is only operating on solar energy, it was decided to use the constant voltage theorem. To do so, the maximum power point must be determined.

3.3 Circuitry

The circuitry of the product is broken down into several modules to understand better what needs to be done and the different requirements of each part. Several features need to be implemented and that includes:

- Solar Charging
- Physical Interface
- Hearing Aids compatibility

3.3.1 Solar Harvesting and Charging

Several factors need to be considered to determine how the product will look like. First, the size of the solar panel should be as small as possible. However, it also needs to output enough power to charge the battery. In addition, the choice of type of battery is also essential to the project. Lithium-ion having a longer battery life than both NiMH and AgZn is the most suitable battery for the charger. The size of the battery also must be considered as it must fit in the designed compartment designed in the box above.

The first iteration of the components used in the system for solar harvesting and charging is as followed. A PV panel going to an IC that automates the charging and outputs power to the battery.

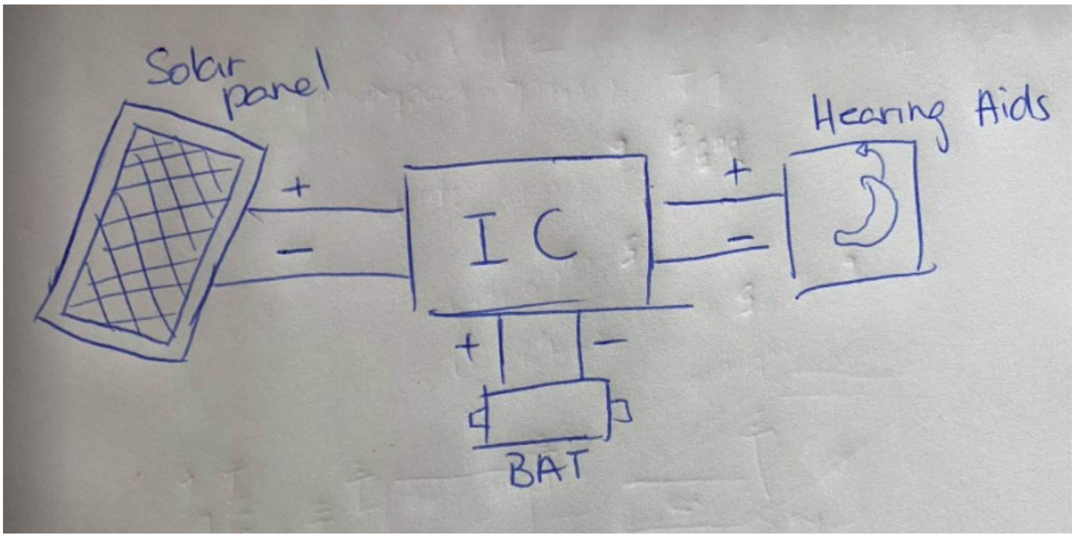

Figure 1 - Solar Charging component diagram

According to PowerElectronics, a hearing aid's power consumption is about 1 mA. In addition, the most common disposable battery used in hearing aids is a type 312 zinc-air battery and generally has a "useful life range from a week to 10 days" (PowerElectronics, 2011). However, the product being developed does not need as much autonomy: it is an alternative for the user to use when being out and realising that the hearing aids batteries might run flat.

Therefore, the smallest battery chosen to be charged by the solar panel available at CoreElectronics is a Polymer Lithium-Ion Battery (LiPo) with a rating of 3.7V and 120mAh. Following the logic that a hearing aid consumes about 1mA per hour, it means that being powered by the battery can last up to 120 hours. The following figure shows the photo of the LiPo battery and has the following dimension: 28x13x5mm.

Figure 2 - LiPo Battery 3.7V 120mAh (Source: CoreElectronics)

To satisfy the charging capability of the battery, a suitable PV panel must be chosen. For a 3.7V LiPo battery, the charging voltage must be about 4.2V as it is its ideal full charge voltage. Damage can be done if it is not charged with the adequate voltage. In this case, the choice of our Integrated Circuit (IC) will matter. The solar panel only needs a high enough voltage: a range of small-scale panels are available online. A 5V 0.15W solar panel was purchased from AutomationBros to be part of the system and has a dimension of 53x30mm.

Figure 3 - 5V 0.15W 53x30mm solar panel (Source: AutomationBros)

Finally, the choice of the IC is essential for the system to function as intended. Consonance Elec offers a range of IC specifically designed to charge a system using solar energy. The most suitable IC in the range is the CN3083 with the following characteristics: 6V 600mA. The maximum charge current the IC can handle is 600mA and the maximum voltage is 6V. Thus, the solar panel satisfies the chip requirements with 5V rated voltage.

The use of the CN3083 chip is common when charging using solar energy to a Li-ion or LiPo battery. Several factors have pushed me to choose this chip:

- It has a constant-current and a constant-voltage linear charging capability.
- Automatic adjustment of the charging current based on the input power capability using an 8-bit ADC.
- Thermal regulation to maximum charging.
- Low power sleep mode when the input supply voltage does not output enough.
- Precharge mode to revive discharged cells.
- Satisfies the system’s requirements.

A typical application circuit with a constant voltage level controlled by Rx is explained in the corresponding datasheet.

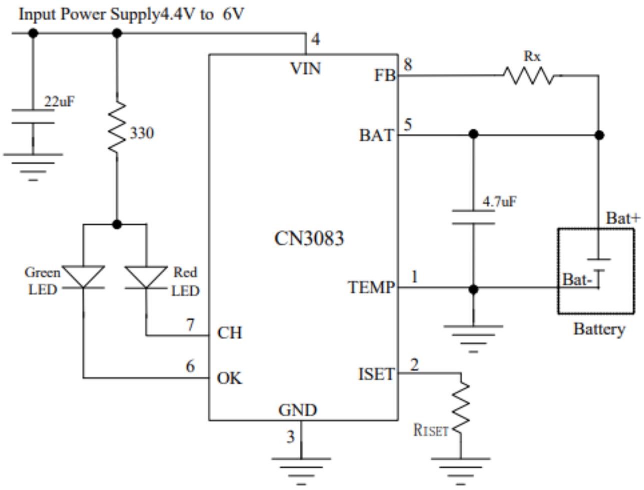

Figure 4 - Typical Application Circuit of CN3083 with variable Rx (Source: Consonance)

It is also explained the output voltage of the system that is charging the battery is constant and is controlled by Rx from the FB pin. The battery voltage can be found using the equation:

$$Vbat = 4.2 + 3.04 \times 10^{-6} \times Rx \text{ where Vbat is in volt and Rx is in ohm}$$

As mentioned before, the highest charging voltage for a Lithium-ion battery should be around 4.2V and thus no resistance Rx will be added to our product, as the charging voltage increases with Rx.

On the other hand, R_{ISET} from the ISET pin controls the charging current. The ISET pin in precharge mode has a regulated voltage of 0.2V and when in constant charge mode has a regulated voltage of 2V. To control the charging current I_{CH}, the following equation is used:

$$I_{CH} = \frac{V_{ISET}}{R_{ISET}} \times 900 \; where \; I_{CH} < 600mA$$

The charging current cannot exceed 600 mA as described in the datasheet. Thus, solving that equation, we have a I_{CH} of 500mA with a R_{ISET} of 3.6k Ω.

The rest of the typical application circuit can stay as such for our project. The green and red LED will allow the system to indicate the status of the charging, where red is charging, green is fully charged, and flashing red meaning no battery is attached.

The next step of the research is to understand how to implement the MPPT. For a small system that is only operating on solar energy, it was decided to use the constant voltage theorem. To do so, the maximum power point must be determined.

The components were purchased to test the typical application circuit of the CN3083. A variable resistance was then added to the output pins of the system to ascertain the maximum power point.

Resistance (Ω)	Voltage (V)	Current (A)	Power (W)
100	0.11	0.0011	0.000121
1000	1.11	0.00111	0.0012321
1800	1.89	0.00105	0.0019845
2200	1.96	0.000891	0.001746182
2300	1.96	0.000852	0.001670261
3900	2.88	0.000738	0.002126769
4700	3.05	0.000649	0.001979255
8200	3.47	0.000423	0.001468402
8600	3.43	0.000399	0.001368012
12100	3.53	0.000292	0.001029826
V_{MPP} (V)		2.88	
Condition		Inside, with a good amount of sun	

Table 2 - Maximum Power Point for 53x30mm PV Panel (Source: Lucien Tran)

From the experiment, we can find that the maximum power point is at 2.88V.

We can conclude that using the CN3083 chip in combination with the 5V 0.15W solar panel and the 120mAh 3.7V LiPo battery will satisfy the requirements of the project.

The battery will then output power to the hearing aids for charging.

3.3.2 Hearing Aids

As stated in the Literature Review, most hearing aids nowadays are still using disposable batteries. One of the most common batteries used are of type 312 zinc-air and have a nominal voltage of 1.45V. Therefore, most hearing aids are designed to operate in that region. The only rechargeable battery widely used with a similar nominal voltage is the Nickel-metal hydride (NiMH) battery (1.2V). The charging voltage of the battery always needs to be slightly higher, and it was found that the voltage that allows NiMH batteries to charge must be ranged between 1.4V to 1.6V. In this case, a solution needs to be found to step down the voltage from 3.7V to the charging voltage for NiMH batteries. To step down the voltage, a circuit consisting of a Zener diode placed in series was tested on LTSpice.

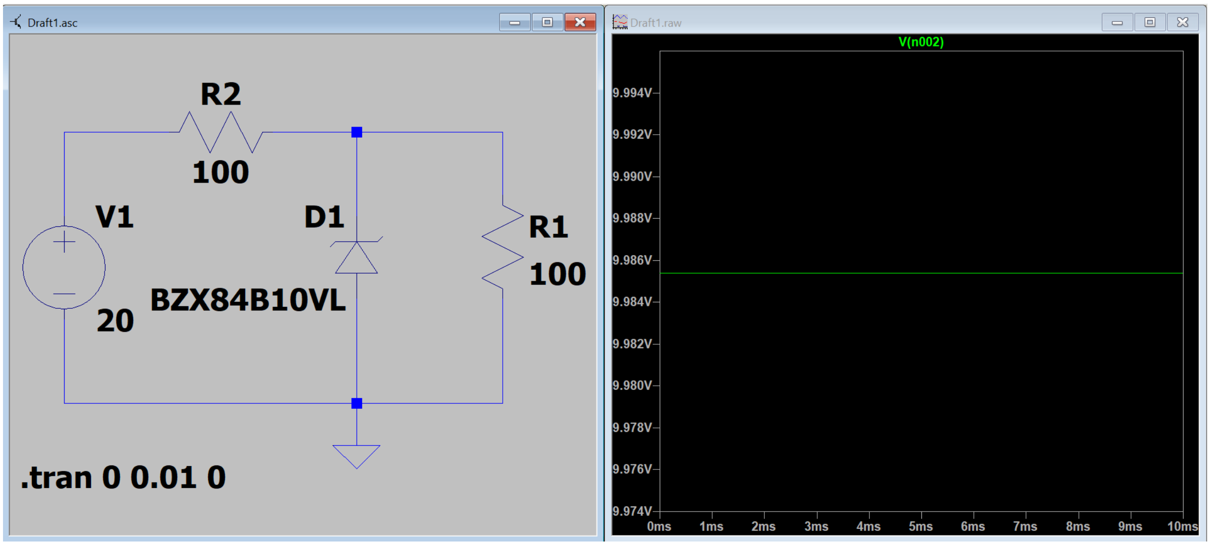

Figure 5 - Zener Diode Step down Circuit

In the figure above, a 10V Zener diode is added with the load parallel to the diode. As you can see, both resistances are equal (R1 and R2) and the output voltage thus equals the difference between the input voltage and the rated voltage of the Zener diode. R2 can be manipulated to control the voltage further: the higher R2 is, the higher the voltage drop, assuming that R1 remains constant.

Thus, a 1.5V Zener diode can be used in our system to drop down the circuit from 3.7V to 1.7V and then further stepped down by manipulating R2.

Available rechargeable hearing aids such as Oticon and Phonak range around AUD 1,600. The current budget did not allow such expenses and thus low-cost hearing aids were the most suitable for the system.

The first pair of rechargeable hearing aids found at a reasonable price was found on skfashionhub for AUD 89.97. It satisfied the requirements as it had a micro-USB port to allow charging with the following characteristics: the current drain of the product is around 4mA according to its datasheet with a rated voltage of 1.5V.

Figure 6 - Rechargeable Digital Hearing Aid (Source: skfashionhub)

However, the website was deemed to be unreliable with several reviews claiming that the clients never received their order. Therefore, cautiousness was chosen over risk.

Another pair that was considered was available on Amazon for a very low price and a relatively positive review. The hearing aids from MEDca use Lithium Polymer batteries which means that stepping down the voltage using the Zener diode will not be needed if it was to be used to produce a prototype. However, the charging port on the hearing amplifier is proprietary and thus the pin is not on sale online. The lack of information and the lack of datasheets available online has also pushed the decision to not order those hearing aids.

Figure 7 - Rechargeable Hearing Aids with docks (Source: MEDca)

Due to the unique pins required to charge the prototype that the project will not be using hearing aids. The lack of budget was also one of the catalysts that prompted the decision.

In conclusion, the use of hearing aids was essential to ensure the completion of the project. However, the lack of budget has changed the initial implementation plan. Several alternatives were thought and debated over such as using headphones, or a microphone to act as a hearing aid. The final decision is to purchase Bluetooth earphones that require charging.

Figure 8 - Testing Bluetooth Earphones(Source: JB-HIFI)

3.4 Physical Interface

The last module to design and research is the physical interface of the product. As mentioned above, several user stories are linked to the design of the product:

- The product must be portable.
- The product must be discreet.
- The product must be able to be attached to hair, a hat, or any item of clothing.

To fulfill all the requirements, numerous iterations and designs were drawn. The list of iterations can be found in Appendix A (Figure 27).

The final design of the product consists of a box with a lip. The interior of the box will include the printed circuit board (Printed Circuit Board) as well as the battery while the solar panel will sit on the lip and act as a lid. An opening is left for the charging cord to be inserted and thus allowing the charging to happen. In turn, the box will be attached to a twin hairpin that will permit the user to attach it to their item of clothing of their choosing.

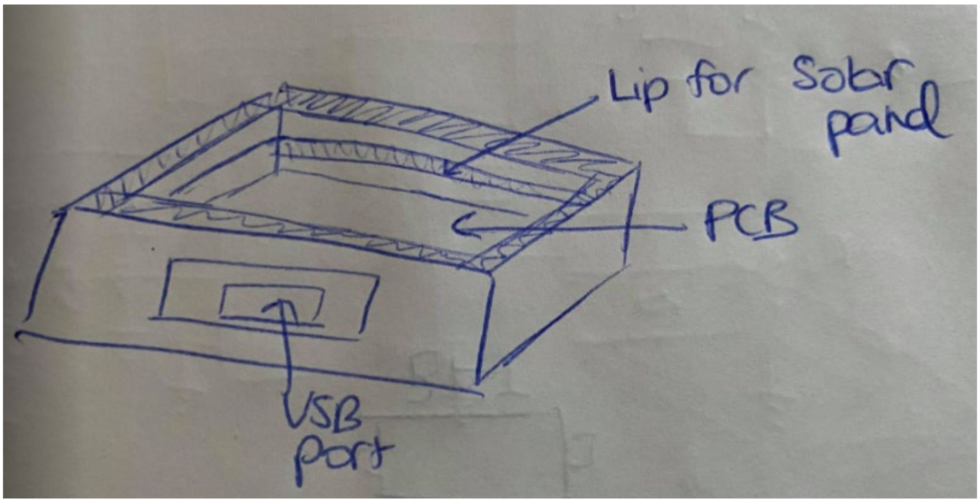

Figure 9 - Final design of the Prototype

In order to implement the design, a 3D version of the prototype must be designed using Fusion 360. Having no prior experience in 3D printing, research needed to be done. It was decided that the 3D printing will be developed using the free printing available at UTS ProtoSpace.

4 Product Implementation

The implementation plan consists of several sections: the technical design of the circuitry, the testing of the prototype, and finally the implementation of the physical interface.

4.1 Circuitry

Two segments contain two modules that encompass the electrical of the product as a whole. The solar charger circuit explained in the previous section of the report is followed by the development of the boost converter to allow charging the 5V earphones purchased for testing. The design of the PCB will be discussed for each electrical feature of the product.

4.1.1 Solar Charger

As mentioned in the previous section, the CN3083 chip will be the main controller of the charging system. The implementation of the typical circuit of the datasheet is used to charge a 3.7V LiPo battery at an output voltage of 4.2V. Using Altium Designer, the schematic of each component was drawn. Next, the schematic of the solar charging circuit was designed. The following figure shows the circuit with the solar panel as the input and the battery as the output.

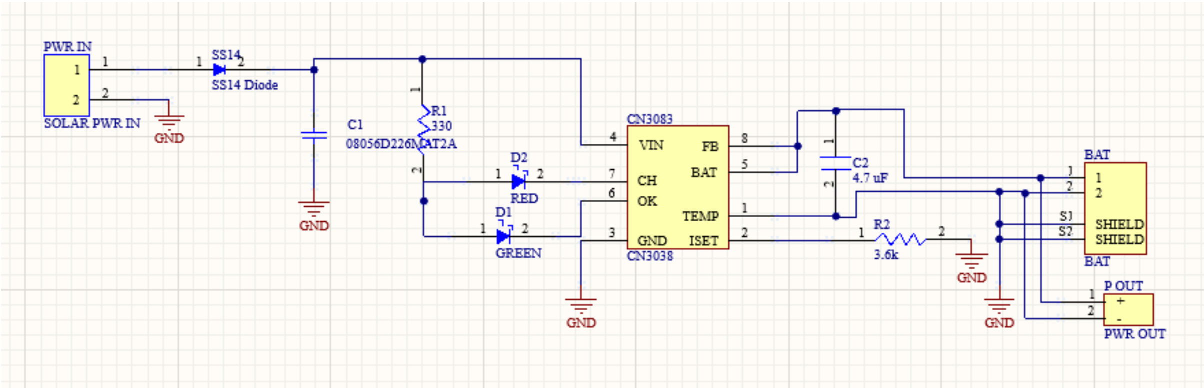

Figure 10 - Solar Charger Schematic

It was explained in the problem research section where the R2 of pin ISET controls the charging current of the system and the resistor at pin FB is non-existent to set the charging voltage to 4.2V and thus avoid damaging the LiPo battery, as:

$$V_{bat} = 4.2 + 3.04 \times 10^{-6} \times R_{FB}$$

In addition, I_{CH} cannot exceed 600mA due to the IC's capabilities. R2 is calculated using the equation found from the datasheet and replacing I_{CH} with the arbitrary value of 500mA.

$$R2 = V_{CH} \times \frac{900}{I_{CH}} = 2 \times \frac{900}{0.5} = 3600\ \Omega$$

A Schottky diode is added in series to the PV panel before branching to the typical application circuit. A Schottky diode is generally used to prevent reverse polarity issues by acting as a polarity protection device. Protecting the solar panel during the application and charging is essential to not damage any components.

After calculating all the values of all the components of the circuit, it was brought to attention that the 3.7V LiPo battery will not be able to charge the headphones that were purchased for testing purposes. Therefore, a boost converter stepping the voltage from 3.7V to 5V must be implemented for the prototype to function as intended.

4.1.2 Boost Converter

A boost converter is a DC-to-DC converter that has the purpose of stepping up the voltage while sacrificing current from the input to regulate the output voltage. The first step to implement the boost converter module is to find the adequate IC that satisfies the requirement of the circuit. The IC must be able to take 3.7V as an input and output a constant voltage of 5V. An excellent candidate to fulfill the role is the TPS61200 chip. It can adjust the output voltage with an input voltage ranging from 0.3V to 5.5V. The output voltage range of the IC can be from 1.8V to 5.5V. The following shows the integrated circuit available from Texas Instruments.

Figure 11 - TPS61200 Boost Converter (Source: Texas Instruments)

Again, the datasheet provides a typical application circuit to support the design of the product and particularly the design of the circuit of the boost converter. The

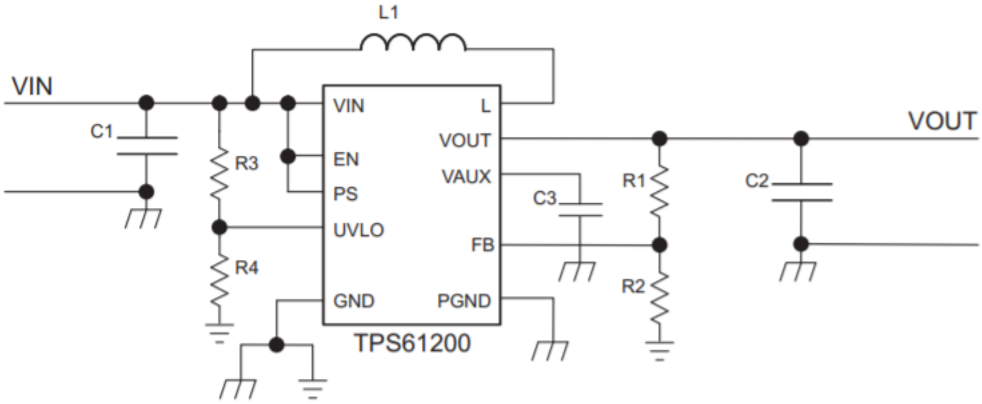

Figure 12 - Typical Application Circuit of TPS61200 Boost Converter (Source: Texas Instruments)

The equation to find resistors R1 and R2 is given by the datasheet depending on the output voltage wanted by the users.

$$R_1 = R_2 \times \left(\frac{V_{out}}{V_{FB}} - 1\right)$$

V_{FB} being the voltage at pin FB, the recommended resistance for R2 is to stay around 200kΩ. Furthermore, it was noted from the datasheet that V_{FB} is typically 500mV. The output voltage needed for our system is 5V to satisfy the charging requirements of the earphones. The values are then substituted in the equation above to find R1:

$$R_1 = 220 \times 10^3 \times \left(\frac{5}{0.5} - 1\right) = 1\ 980\ 000 \approx 2M\Omega$$

$$\therefore\ R_1 = 2M\Omega\,, R_2 = 220k\Omega$$

The next step of the design is to calculate the values of R3 and R4 of the circuit. It is stated that both resistances are used to program the UVLO threshold voltage.

$$R_3 = R_4 \times (\frac{V_{IN\ MIN}}{V_{UVLO}} - 1)$$

The typical end of discharge of a Lithium-ion or Lithium Polymer battery is around 2.8V-3V. In this case, the minimum input voltage is set at 2.8V. On the other hand, the datasheet expresses that the voltage at UVLO is generally around 250mV and that R4 should generally have a resistance of around 250kΩ. As 220kΩ was previously used for the resistance R2, the same resistance is used here.

$$R_3 = R_4 \times \left(\frac{V_{IN\ MIN}}{V_{UVLO}} - 1\right) = 220k \times \left(\frac{2.8}{0.25} - 1\right) = 2\ 244\ 000\ \approx 2M\Omega$$

$$\therefore\ R_3 = 2M\Omega\,, R_4 = 220k\Omega$$

The components used for R1 and R2 can thus be re-used for R3 and R4. Finally, the capacitors and inductors are discussed in the schematic below that is available on the TPS61200 datasheet.

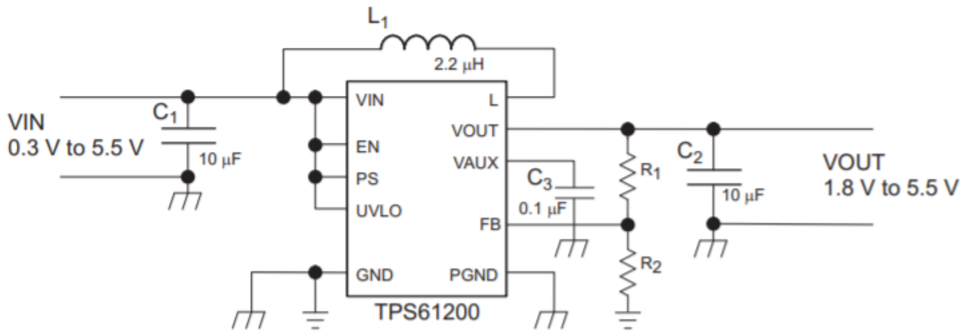

Figure 13 - Typical Application Circuit of TPS61200 with values (Source: Texas Instruments)

After computing the value of each component, the output type needs to be chosen. The first design implemented a micro-USB as an output but was later changed to a USB A as noted in the schematic below designed in Altium.

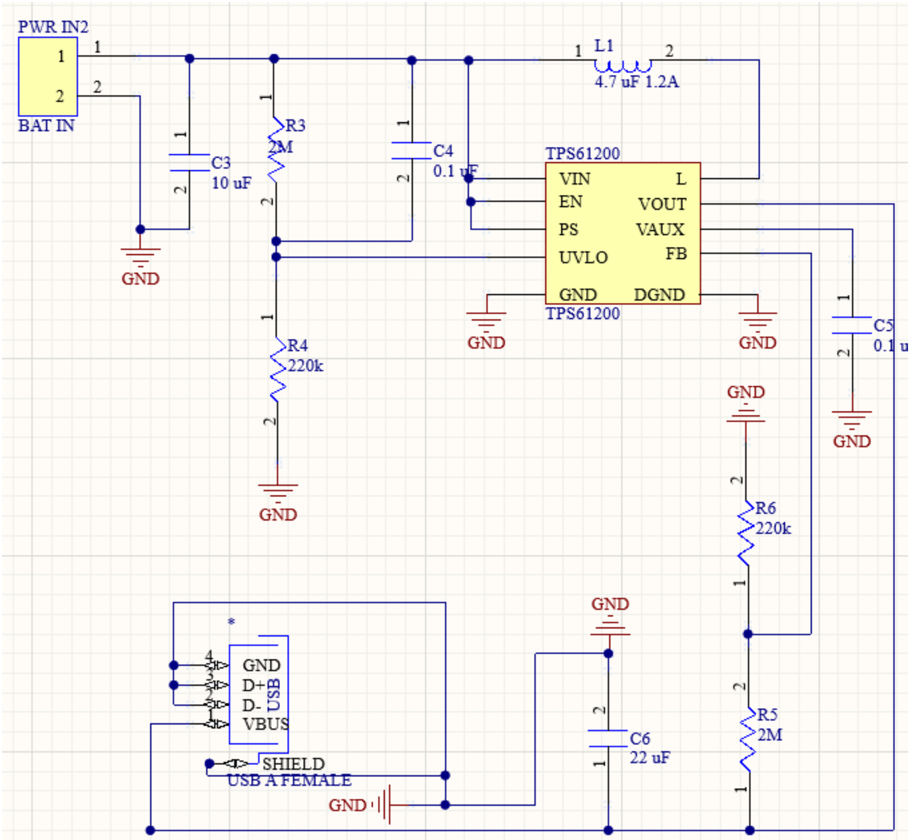

Figure 14 - Boost Converter to USB A schematic

The full schematic of both the boost converter and the solar charger can be found in Appendix B (Figure 29).

4.1.3 Choice of Materials and Routing

4.1.3.1 Choice of Components

The next step of the design of a PCB is adding the footprints of the elements created for the schematics. To do so, it was needed to choose the components needed and record them in a table. Most of the components have different packages and thus will have a different footprint. For the sake of saving time, the components were bought and during the time it took to be shipped, the footprints, as well as the routing, were implemented.

Due to electronic component shortage, components such as the IC CN3083 were unavailable in Australia and overseas shipment would have taken more than two months which would have marked the end of the project length. Fortunately, the 3.7V LiPo Charger (see Appendix B, Figure 28) found from CoreElectronics used the CN3083, and unsoldering it to use on the prototype was an option. In addition, one of the students of the Elctrical cohort was also designing a solar charger and allowed me to use his reserve of CN3083.

Another note that was stated by the datasheet was that the choice of the inductor in the TPS61200 chip was primordial for the IC to function the way it was intended. Knowing that the value of the inductor must be 2.2µF from the typical application circuit, the current rating must also be considered. A table listing the inductors that could be used in accordance with the TPS61200 was given by Texas Instruments:

VENDOR	INDUCTOR SERIES
Coilcraft	LPS3015
	LPS4012
Murata	LQH3NP
Tajo Yuden	NR3015
Wurth Elektronik	WE-TPC Typ S

Table 3 - List of Inductors compatible with TPS61200 (Source: Texas Instruments)

It was decided that the LPS3015 inductor from the vendor Coilcraft would be purchased for the implementation of the solar-powered hearing aids.

The packages of resistors were chosen to be between 0402 and 0806 with 0806 being bigger than 0402 packages. On the other hand, all capacitors chosen were ceramic capacitors with ratings X5R and X7R. The first letter of the capacitor rating is the letter code for the lowest temperature where it can operate while the second letter is the upper-temperature limit. Finally, the last letter points at the change of capacitance over the temperature range. A table explaining all the capacitor's ratings can be found in Appendix B in Figure 30.

Purchasing from different websites seemed to be costly due to shipping. Thankfully, all components were available from Element14 and were purchased. Similarly, the full list of components can be found in Appendix B (Figure 31).

Once purchased, adding footprints using either the datasheet dimensions or the files provided by the manufacturers was straightforward. To complete the 3D model, STEP files were added alongside footprint to allow the 3D view to show how each component is placed on the PCB.

4.1.3.2 Routing and PCB Order

The routing of the PCB is done by importing both the schematic file and the footprints of components. PCBs generally have two layers and the second layer usually being the ground plane. Thus, most tracing was done in the top layer. Some design recommendations were noted by the datasheet:

- Small ceramic capacitors and the inductor LPS3015 are to be placed as close as possible to the VOUT and PGND of the TPS61200.
- The ground pin of all ICs should be as close as possible to the ground.
- R_{ISET} should be placed as close as possible to the ISET pin of the CN3083 IC.
- The capacitors at VIN and BAT should also be placed as close as possible to the CN3083.

- The thermistor should be placed far enough from the CN3083 during charging.

Once it is considered, all the traces can be sketched using the interactive routing available in Altium.

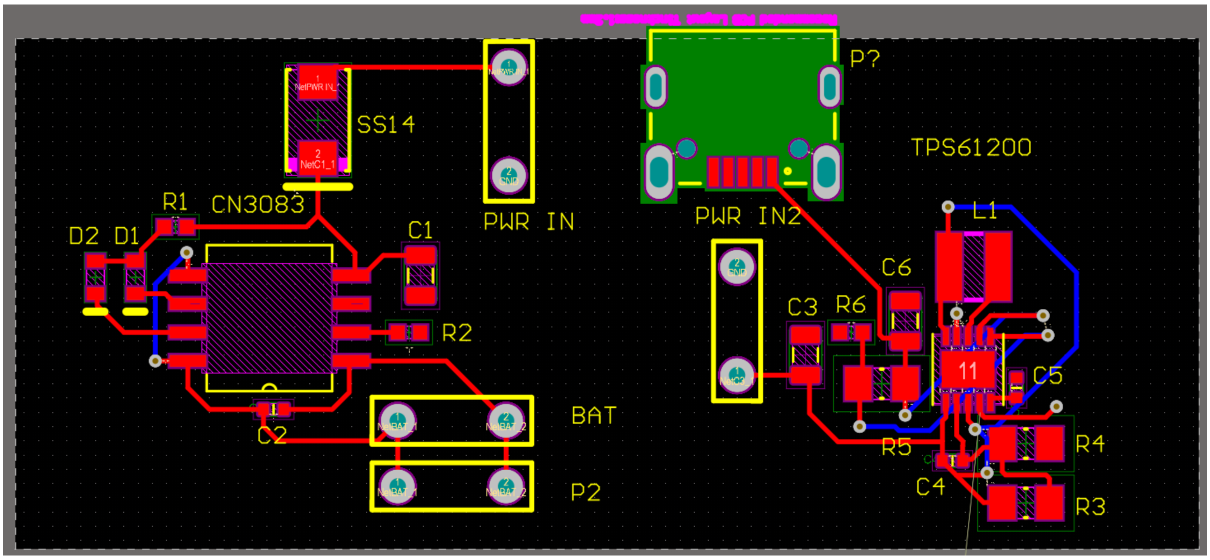

Figure 15 - Interactive Routing PCB

Note that none of the GND or GND pins are traced. The Polygon Pour feature will be used to fill the rest of the board to be the GND plane. Furthermore, adding stitching of 0.6mm vias was needed to tie the large area and connect both the ground from the first to the second layer. The vias have the following properties:

- 0.6mm diameter
- 0mm manual solder mask expansion from the hole edge
- Direct thermal relief

The following figure shows the result of using both the Polygon Pour feature and adding via stitching.

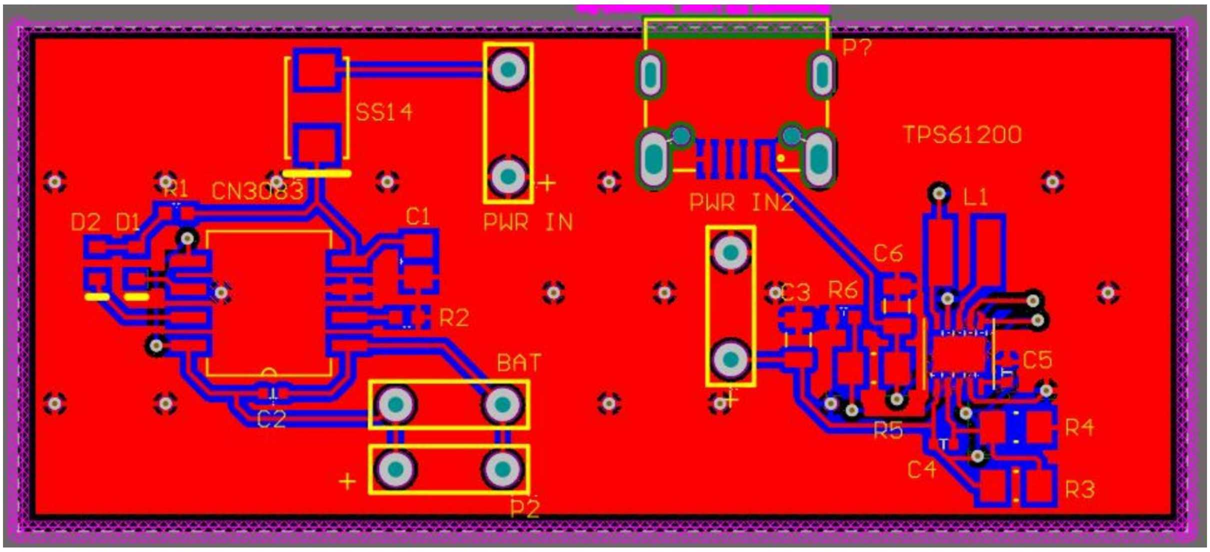

Figure 16 - First prototype PCB layout

Before ordering the PCB and mark it as complete, a 3D model is generated using STEP files of each component. It allows us to visualise how the components are sitting on the PCB but also if each footprint is correct.

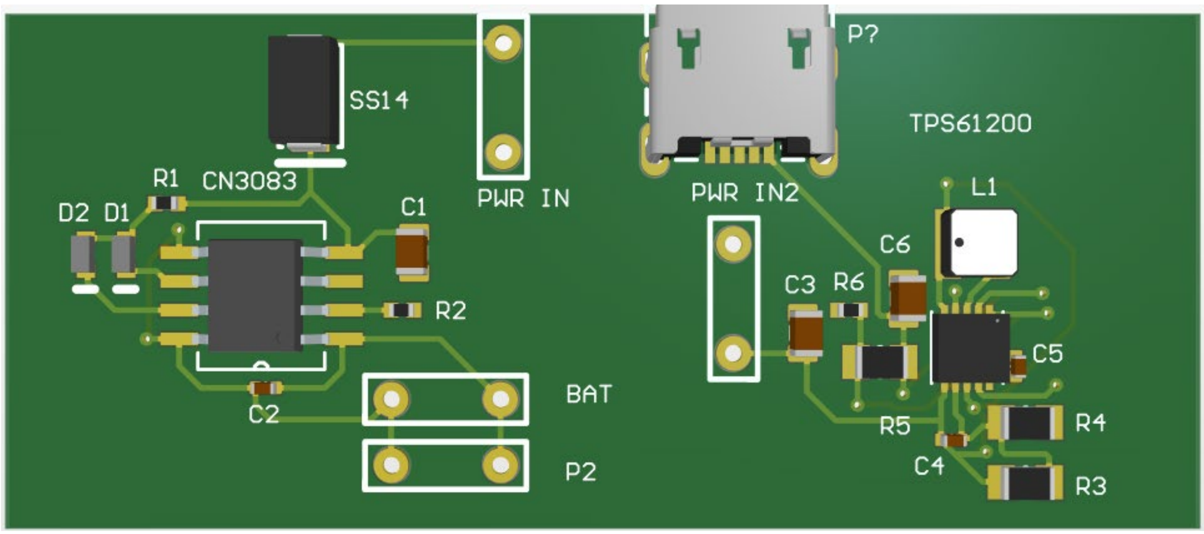

Figure 17 - 3D model of the first prototype

The next step in the design of the PCB is to check the design rules: whether it satisfies the PCB manufacturer. Rules can be imported on Altium and a check can be done the PCB is deemed to be satisfactory. It is noted that all manufacturers have different capabilities and thus different requirements. The PCB manufacturer chosen for this project is JLCPCB and the design check rules have allowed us to confirm that it met all the requirements necessary.

The last step is ordering the PCB. JLCPCB demands that the GERBER file must be exported from Altium, and a step-by-step tutorial was found on their website.

4.2 PCB Testing and Prototyping

During the length of the project, two PCBs have been designed for two iterations of the product. The first prototype was deemed to be unsatisfactory, and the flaws of the PCB are pointed out in the next section as well as how it was solved.

4.2.1 First Prototype

The PCB received is shown in the following figure.

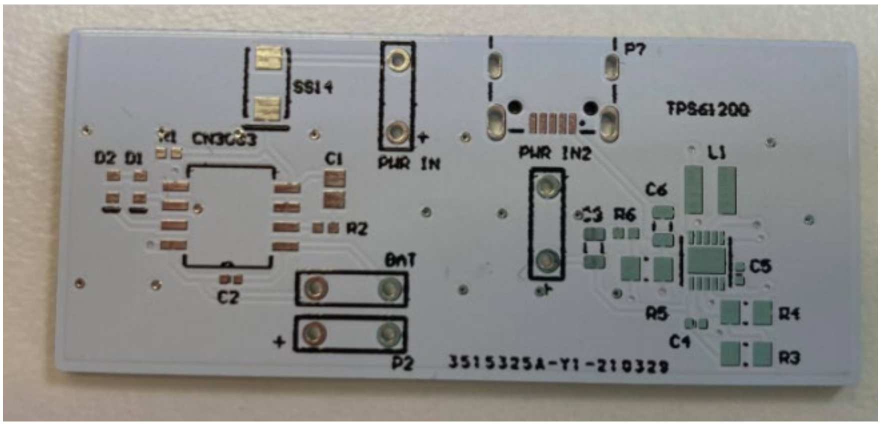

Figure 18 - First Prototype PCB received

All the pads and vias seemed to be printed correctly. The soldering is planned to be done using solder paste and placing the PCB on the hot plate using the junior circuit lab at UTS.

However, several reasons had pushed back the timing of the soldering of the PCB. One of the shipments was not sent by element14 and no tracking number was given. No notifications or notice was given either and the element14 support team decided to send another of the missing components.

Furthermore, the missing CN3083 with its unavailability has further slowed down the process and it was decided to start the soldering without it in the meantime. During the soldering, it was noted that R4 came in the wrong package. A 0402 was received rather than a 0805 package as designed (see figure 15). Fortunately, an extra 220kΩ resistor was later found in the reserve components from previous projects.

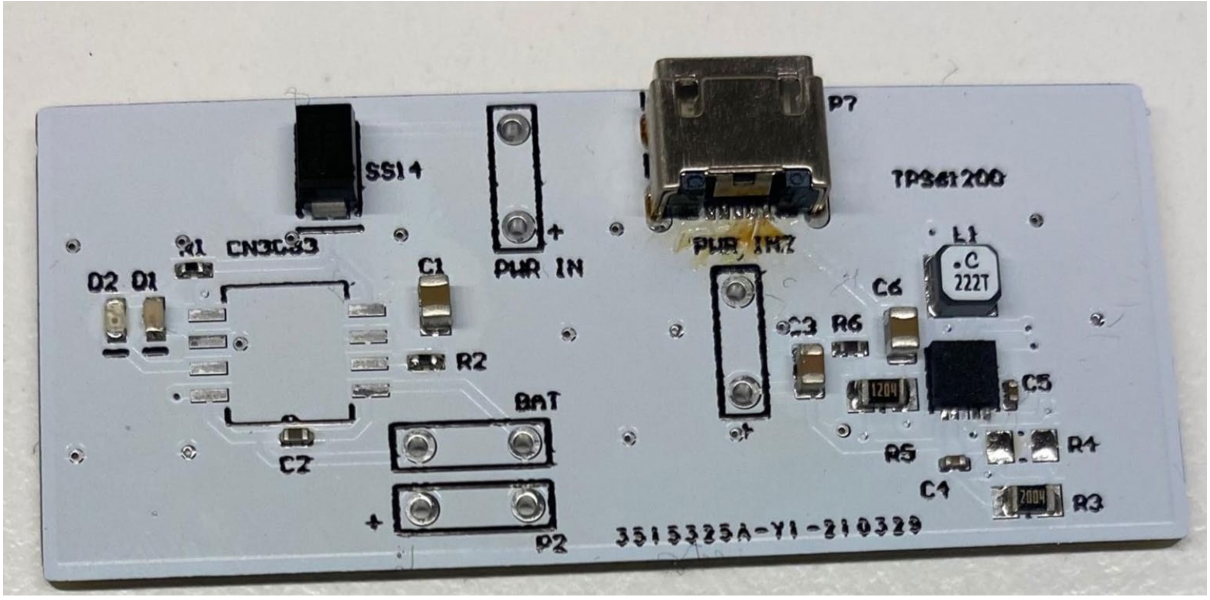

Figure 19 - PCB soldering result of First Prototype with missing CN3083

The photo above shows the missing resistor as well as the missing CN3083. Both solar charging and boost converter modules were also divided for easy debugging and less interference between modules.

One of the biggest obstacles during the soldering was adding the solder paste on the TPS61200 (IC placed on the bottom right of the PCB). The package used for this IC was the VSON|10 which was proven to be small and tricky to debug. Furthermore, purchasing 0402 packages turned out to be quite small. Ordering 0805 packages for all resistors as well as capacitors would have kept the design consistent as well as easier to solder.

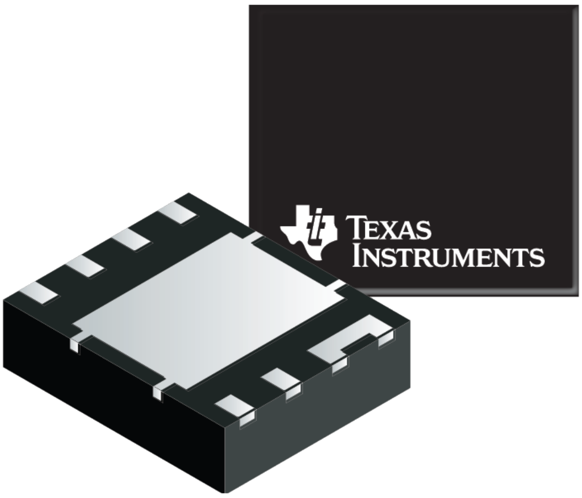

Figure 20 - TPS61200 VSON|10 package (Source: Texas Instruments)

After soldering the IC CN3083 and the missing resistor, the solar charger was first tested. The 53x33mm solar panel was attached to the input pins of the PCB and the voltage was recorded both at the input and the output pins. During the charging, the LED seemed to be working right where the red LED was on hinting that the battery was being charged.

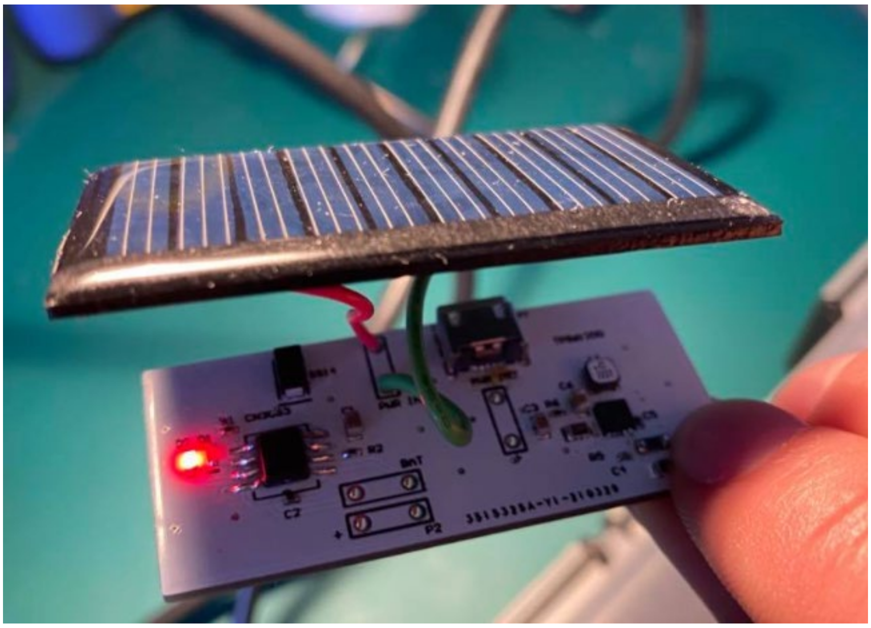

Figure 21 - Prototype 1 Charging phase

After testing the solar-powered charger, the boost converter needed to be tested. To do so, an Arduino outputting 3.3V was applied to the input ports of the boost converter circuit. The function of the boost converter is to step up the voltage and was designed to step it up to 5V. Thus, the voltage at the micro-USB should be 5V. However, it was found that the output voltage was only 3.3V. The Arduino code and the photo demonstrating the testing can be found in Appendix C (Figure 34).

After careful scrutinization, it was noted that the VAUX and VOUT of the TPS61200 were switched around. VOUT was traced to GND, and VAUX acted as an output which is incorrect. It was then it was decided to correct the mistake and create a second prototype.

Another issue was raised when to decrease the size of the prototype, a micro-USB to micro-USB was preferred. However, it is bad practice for host devices to use the same connectors as the slave devices. It is very uncommon to have such connector cords on sale as well. It could cause damage to the USB controller.

Several solutions were being debated after that realisation:

- To use a USB-A to micro-USB.
- To use a USB-C to USB-C (can be output and input).

However, the earphones purchased for testing have a micro-USB plug. For testing purposes, the second prototype will thus include a USB-A port that will then power the headphones.

In conclusion, a second prototype was needed at that point in time for the project to be successfully implemented. Several issues have been found during testing and will be corrected in the second iteration of the product:

- Micro-USB port changed to USB-A port.
- VAUX and VOUT pin corrected on the TPS61200 chip.
- Battery pads changed to JST 2-pin input.

4.2.2 Second Prototype

As stated earlier, several components were changed to first solve the previous issues but also improve the current product. The full list of components purchased for the second iteration of the project can be found in Appendix B (Figure 32).

In this section, the same steps are being repeated to design the PCB, from the interactive routing, to adding footprints, STEP files and checking the design rules. The following photos show the completed design of the PCB and the 3D model while the schematic can be found in Appendix C (Figure 35).

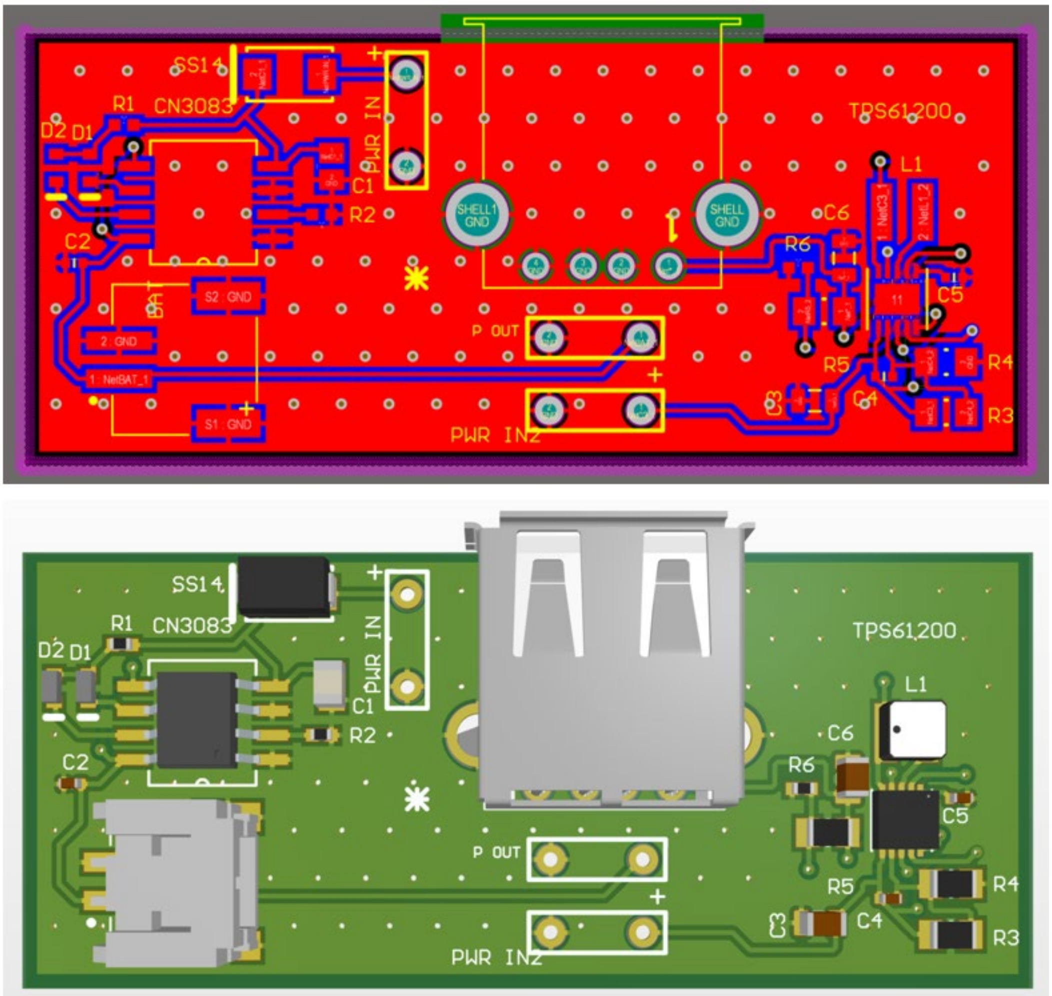

Figure 22 - Prototype 2 PCB design and 3D view

As noted in the figure above, the battery pads of the prototype have been replaced by a JST port for the battery to fit easily and ease of testing. Due to the big size of the USB-A, both modules also had to be moved around. The empty space on the PCB allows the battery to sit in it, providing enough space for it to fit in the case. Ultimately, it was although decided to keep both circuits separated again to test them individually. The larger size of the port will however affect the physical interface that is holding the PCB, the solar panel as well as the battery.

A slight delay in the shipping was noticed for the ordering of the second PCB. Five copies were finally received, and the assembly could start. Due to the lack of CN3083 on the market, unsoldering the IC from the first prototype using the hot plate was the best option at that point in time. Using solder paste and a hot plate, the soldering was done successfully. The process photo can be found in Appendix C (Figure 36) while the result of the PCB can be found below.

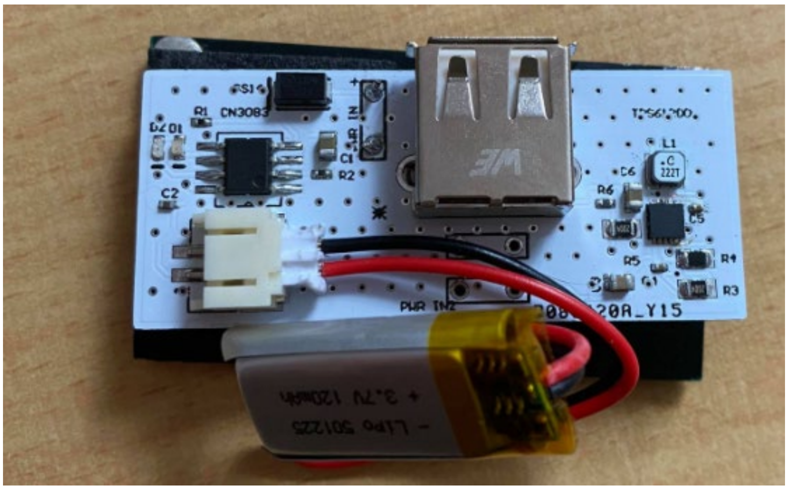

Figure 23 - PCB prototype 2

After doing so, the first phase of testing consisted of testing the solar charger circuit again. While the circuit was correct in the first iteration, incorrect soldering of components such as reversing the diode’s direction can happen. To ensure that the product is working as intended, the testing was done and the voltage was recorded. A photo of the testing involved is recorded in Appendix C (Figure 37). From that position, the output voltage and the battery voltages were calculated to be 4V.

The second phase of the testing includes the testing of the boost converter. Like it was done before, a 3.3V is inputted to the circuit using an Arduino Uno. It is then going through the boost converter circuit. The voltmeter is then added to the output pin of the USB-A in the photos in Appendix C (Figure 38). As you can see, when recording the input pin, the voltage is 3.3V. On the other hand, when recording the voltage of the output pin of the USB-A, it is clearly seen on the voltmeter that the voltage is of 4.99V, enough to power the headphones.

The last phase of the testing is the testing of the complete circuit. To do so, the solar charger circuit is connected to the boost converter circuit as intended in the design of the PCB. The output pads of the solar charger circuit are parallel to the input pads of the boost converter which makes it convenient for testing and attaching purposes.

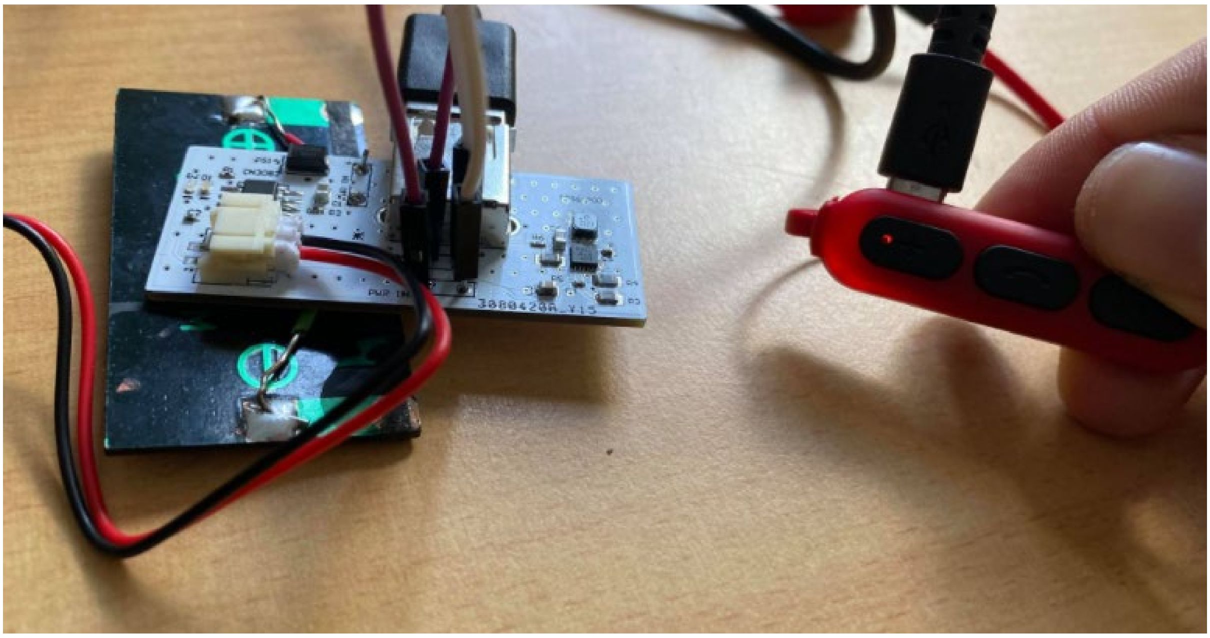

Figure 24- Prototype 2 Testing

The figure above shows the working circuit from the battery outputting voltage to the input ports of the boost converter. The earphones are then plugged into the USB-A port. The voltage of the output was once again measured to be 5V. Thus, the red LED of the earphone is on, showing that it is charging.

4.3 Physical Interface

As discussed in the research section of the project, the physical interface will be developed on Fusion 360. The final design of the box can be referred to in the earlier section. It will consist of a case with a wider surface at the top to accommodate the PV panel. On the longer side of the box, a port is made for the USB-A to be able to connect to the device.

The several iterations using Fusion 360 can be seen in Appendix D (Figure 40-43). To design in Fusion 360, a 2D plan first needs to be laid out in the appropriate plane, and only then do you need to extrude it.

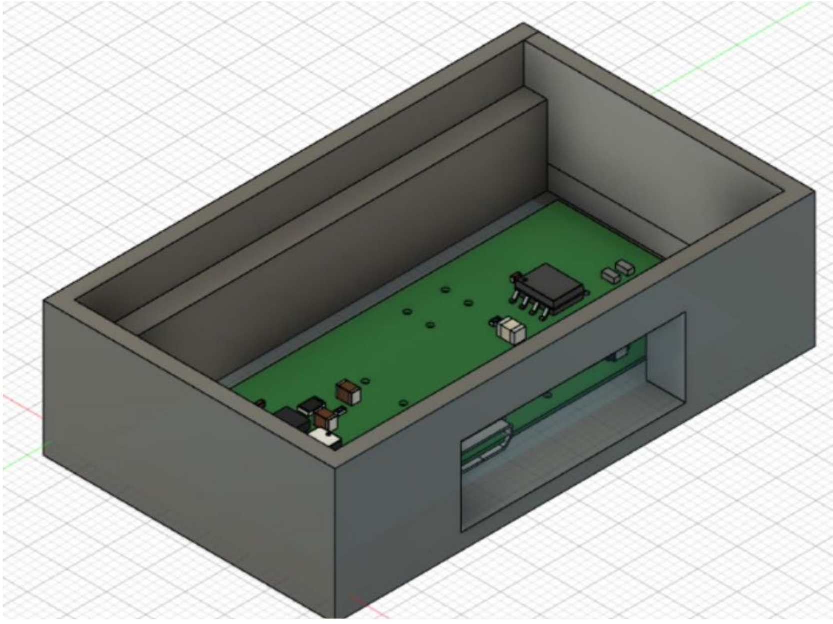

Figure 25 - Physical Interface with PCB

The figure shows the case with the PCB inside. A STEP file generated by Altium is needed to include the sketch in Fusion 360. While the model is quite high, it is because it must account for the USB-A port that is 1.1cm high as well as having space for the battery to be placed in it. The PV panel will sit on the lip of the box and act as its lid. The table of measurements can be found below:

Sides	Dimension
PCB	52.7x22.7mm
Solar Panel	53x30mm
Outside Box	60x40x20mm
Inside box (under the lip)	57x27mm
Inside (lip)	57x33mm

Table 4 - 3D view prototype dimensions

After exchanging emails with both my supervisor and UTS ProtoSpace, free 3D printing was available for the product to be developed. To do so the STL file of the 3D model from Fusion 360 needs to be exported. The next step is to download the Ultimaker Cura software which is used by the 3D printers at ProtoSpace to slice the 3D models. After slicing it, a 30% infill was chosen to make sure that the walls are durable enough, being only 1.5mm thick. The precision was then chosen to be engineering which has a 0.1mm accuracy. The last setting to change is the support: for the slot to be printed properly, the angle of change must not be too big. However, another method to counter it is to use support. It is a layer of print that is used to support the design and that can be snapped off the prototype once the printing is complete. The process will output a UFP file that is then uploaded to the 3D printer. The photo of the slicing settings is available in Appendix D (Figure 44).

On the 3D printer, a glass panel needs to be placed on the base of it. A layer of glue is applied to the glass panel before being placed. It was advised to check the first layer when the 3D printing commences. It is to make sure that it is printing correctly, the first layer being the foundation of the design. After waiting for four hours and letting the 3D printing cool down when finishing the print, the model is removed from the glass panel. The last step is to carefully remove the support without breaking the thin walls of the rest of the box. The figure below represents the finished print of the case.

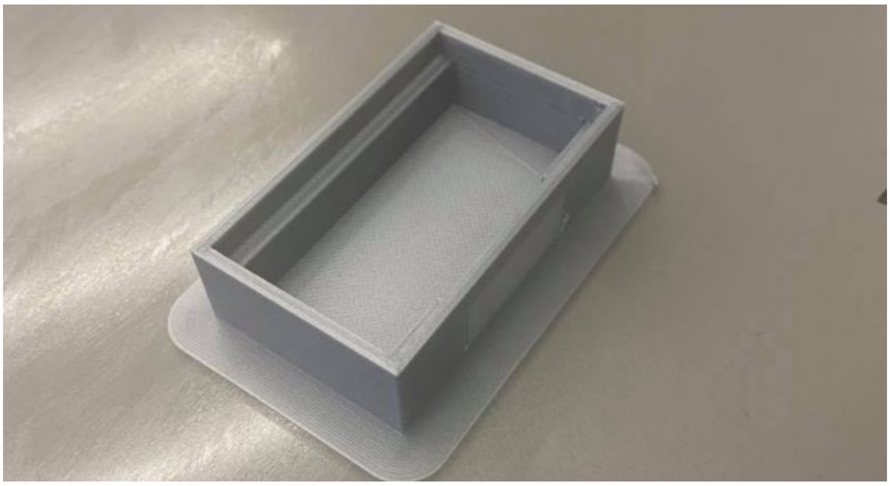

Figure 26 - 3D printed case

To complete the design, the PCB needs to be placed in the box alongside the PV panel. A clip is also glued to the bottom of the case to allow the user to attach it to their hat, hair, or any item of clothing.

Ultimately, the photos documenting the dimension of the PCB in the box, how the PV panel is fixed to the case, and how the case is attached to the user can be found in Appendix E.

Despite the bigger size of the prototype intended, the prototype is very light. During the testing of wearing, it attached to hair (Appendix E, Figure 51) and on a hat (Appendix E, Figure 52-53), it proved to be of little discomfort to none.

5 Conclusion

In conclusion, the development and implementation of the solar hearing aid charger was a success. Both modules, the solar charger, and the boost converter worked as intended and the user interface includes a USB-A output to charge the headphones purchased for testing purposes. It was a good learning opportunity to gain exposure to PCB design using Altium Designer as well as 3D printing and modelling using Fusion 360. Several issues slowed down the progress of the project including a missing shipment of components, a missing core component being the IC CN3083 as well as a lack of budget to purchase the hearing aids and this resulted in a change of plan in charging requirements. The earphones used for testing required 5V charging while standard hearing aids require 1.5V. Despite those difficulties, a critical thinking and problem-solving mindset allowed the project to continue with an end result prototype which was functional.

If a longer period of time was given to complete the project, several aspects of the product could be improved. These include:

- More effort spent on the interface – a more practical approach would be needed.
- More rigorous testing of the circuit such as letting the system run for some time.
- Use of better equipment such as current probes and thus better recording of results.
- If budget had permitted the purchase of hearing aids or USB-C earphones to decrease the size of the overall product.
- Smaller solar panel with a smaller PCB.

However, all those improvements are suggestions that could have increased the relevance of the project to the real world. It is encouraging that more assistive technologies are now being developed to promote inclusiveness in society and this project's aim was to achieve that.

6 References

Aston, B. (2019) *9 Of The Most Popular Project Management Methodologies Made Simple - The Digital Project Manager*, *The Digital Project Manager*. Available at: https://thedigitalprojectmanager.com/project-management-methodologies-made-simple/ (Accessed: 31 August 2020).

CHECKLIST, R. (2020) *RISK ASSESSMENT*, *Public-library.safetyculture.io*. Available at: https://public-library.safetyculture.io/products/risk-assessmentuztps (Accessed: 9 September 2020).

Hearingsavers.com.au. (2020) *Rechargeable Hearing Aids - Pros And Cons - HEARING SAVERS*. [online] Available at: <https://www.hearingsavers.com.au/rechargeable-hearing-aids/> [Accessed 18August 2020].

Signia Hearing Aids. (2020) *Seven Valuable Benefits Of Going Rechargeable With Hearing Aids*. [online] Available at: <https://www.signia-hearing.com.au/blog/going-rechargeable-with-hearing-aids/#:~:text=If%20you%20don't%20carry,security%20of%20a%20portable%20charger.> [Accessed 18 August 2020].

Audiology Online. (2020) *Can I Put A Rechargeable Battery In My Hearing Aid?*. [online] Available at: <https://www.audiologyonline.com/ask-the-experts/can-i-put-rechargeable-battery-12675#:~:text=Silver%2DZinc%20(AgZn)%20rechargeable,times%20as%20long%20as%20NiMH.> [Accessed 18 August 2020].

IEEEXplore. (2020) *Solar Powered Mobile Phone: An Innovative Experiment*. [online] Available at: <https://ieeexplore-ieee-org.ezproxy.lib.uts.edu.au/stamp/stamp.jsp?tp=&arnumber=7955594> [Accessed 18 August 2020].

Phonak. (2020) *Phonak | Life Is ON*. [online] Available at: <https://www.phonak.com/au/en/about- us/rechargeable-technology.html> [Accessed 18 August 2020].

Lucien Tran. (2020) *ERP Project Task 3.*

Oticon.com.au. (2020) *Rechargeable Hearing Aids | Oticon*. [online] Available at: <https://www.oticon.com.au/hearing-aid-users/hearing-aids/accessories/rechargeable-hearing-aids> [Accessed 18 August 2020].

ieeexplore. (2019) *Comparison Of Perturb & Observe And Hill Climbing MPPT Schemes For PV Plant Under Cloud Cover And Varying Load*. [online] Available at: <https://ieeexplore-ieee- org.ezproxy.lib.uts.edu.au/document/8754532> [Accessed 18 August 2020].

ieeexplore. (2016) *Improved Variable Step Size P&O MPPT Algorithm For PV Systems*. [online] Available at: <https://ieeexplore-ieee-org.ezproxy.lib.uts.edu.au/document/8114046> [Accessed 18August 2020].

ieeexplore. (2018) *Modeling Of A Photovoltaic System With Different MPPT Techniques UsingMATLAB/Simulink*. [online] Available at: <https://ieeexplore-ieee-org.ezproxy.lib.uts.edu.au/document/8398734> [Accessed 18 August 2020].

ieeexplore. (2019) *Comparison Of Three-Point P&O And Hill Climbing Methods For Maximum Power Point Tracking In PV Systems*. [online] Available at: <https://ieeexplore-ieee-org.ezproxy.lib.uts.edu.au/document/8697273> [Accessed 18 August 2020].

DAVIS, S. (2011) *Hearing Aid Balances Energy Efficiency and Performance, Power Electronics.* Available at: https://www.powerelectronics.com/markets/mobile/article/21857469/hearing-aid-balances-energy-efficiency-and-performance#:~:text=This%20hearing%20aid's%20power%20consumption,a%20week%20to%2010%20days.

Rechargeable Digital Hearing Aid Ear Care. 2021. Available at: https://skfashionhub.com/product/rechargeable-digital-hearing-aid/ (Accessed: 26 May 2021).

Pujar, R. (2017) *Difference between X7R, X5R, X8R, Z5U,Y5V, X7S, C0G Capacitor dielectrics - Embedded World, Embedded World*. Available at: https://www.raviyp.com/difference-between-x7r-x5r-x8r-z5u-y5v-x7s-c0g-capacitor-dielectrics/#:~:text=When%20manufacturer%20says%20that%20this,from%20its%20nominal%20value%20specified. (Accessed: 29 May 2021).

Texas Instruments. (2021) *TPS61200 datasheet*. Available at: https://www.sparkfun.com/datasheets/Prototyping/tps61200.pdf (Accessed: 30 May 2021).

Consonance. (2021) *Lithium Ion Battery Charger for Solar-Powered Systems CN3083*. Available at: https://www.robotshop.com/media/files/pdf2/datasheet-dfr-565.pdf (Accessed: 30 May 2021).

7 Appendices

7.1 Appendix A

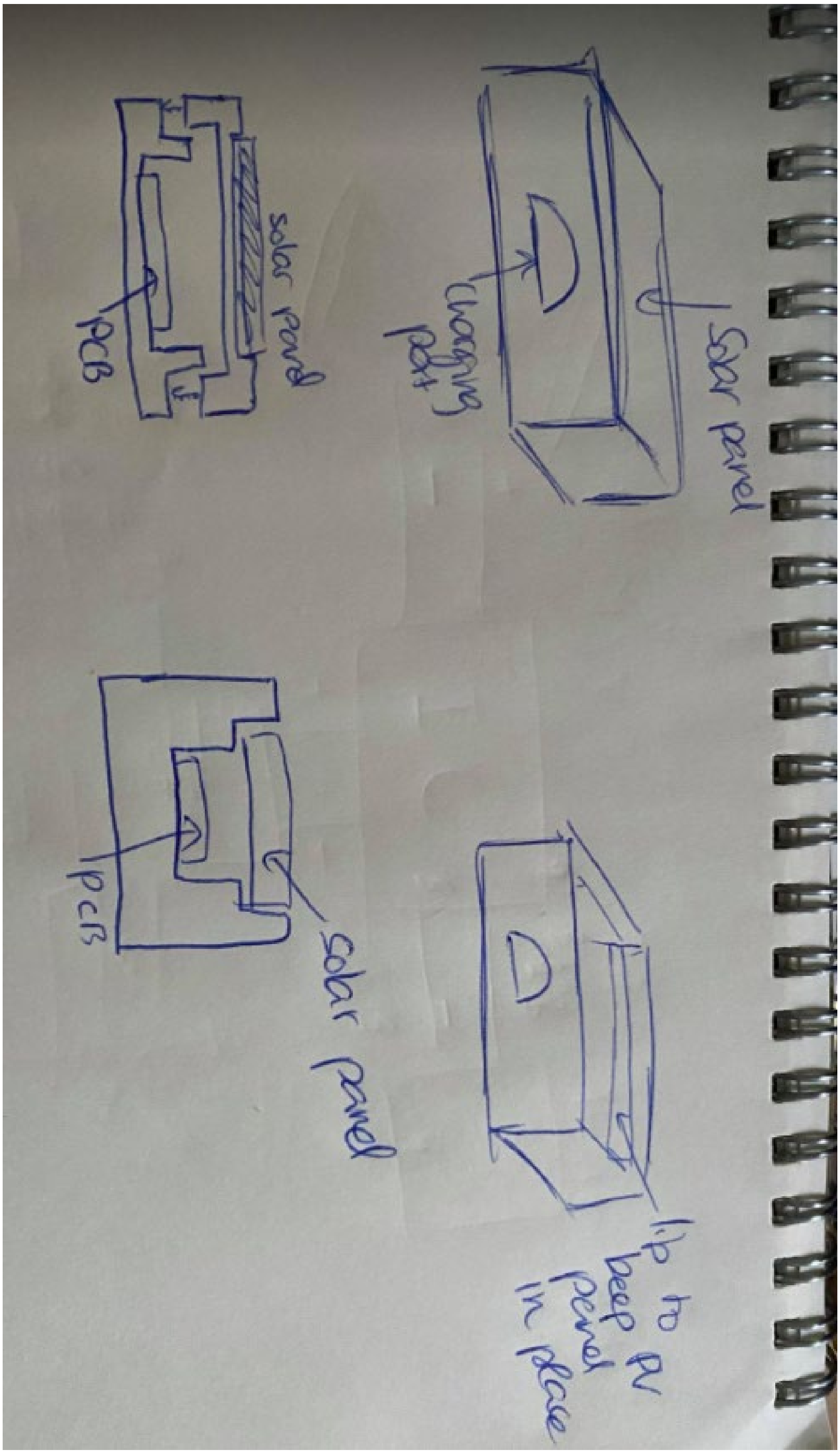

Figure 27 - Design draft of the case

7.2 Appendix B

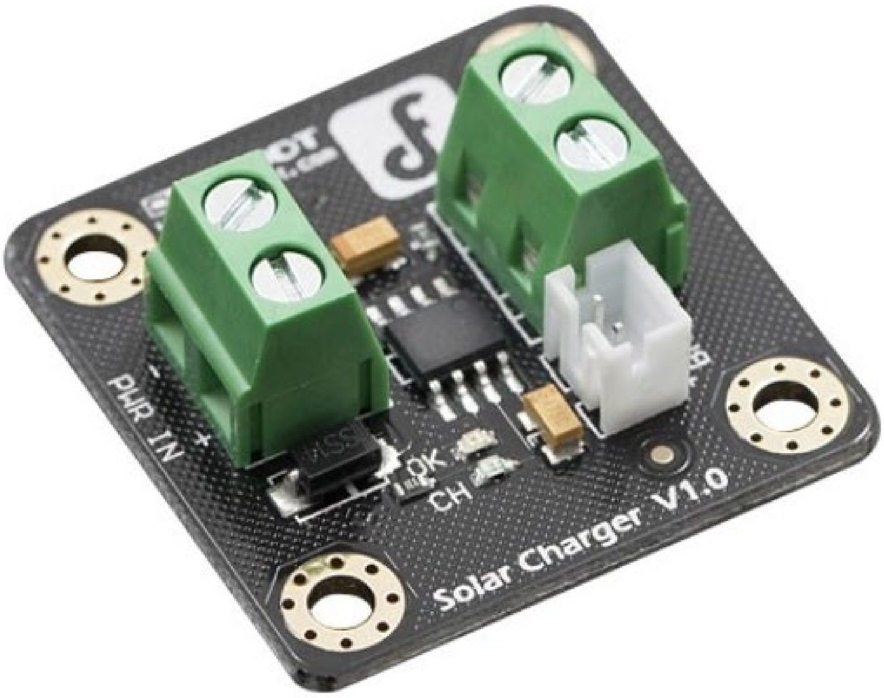

Figure 28 - 3.7V LiPo Solar Charger (Source: CoreElectronics)

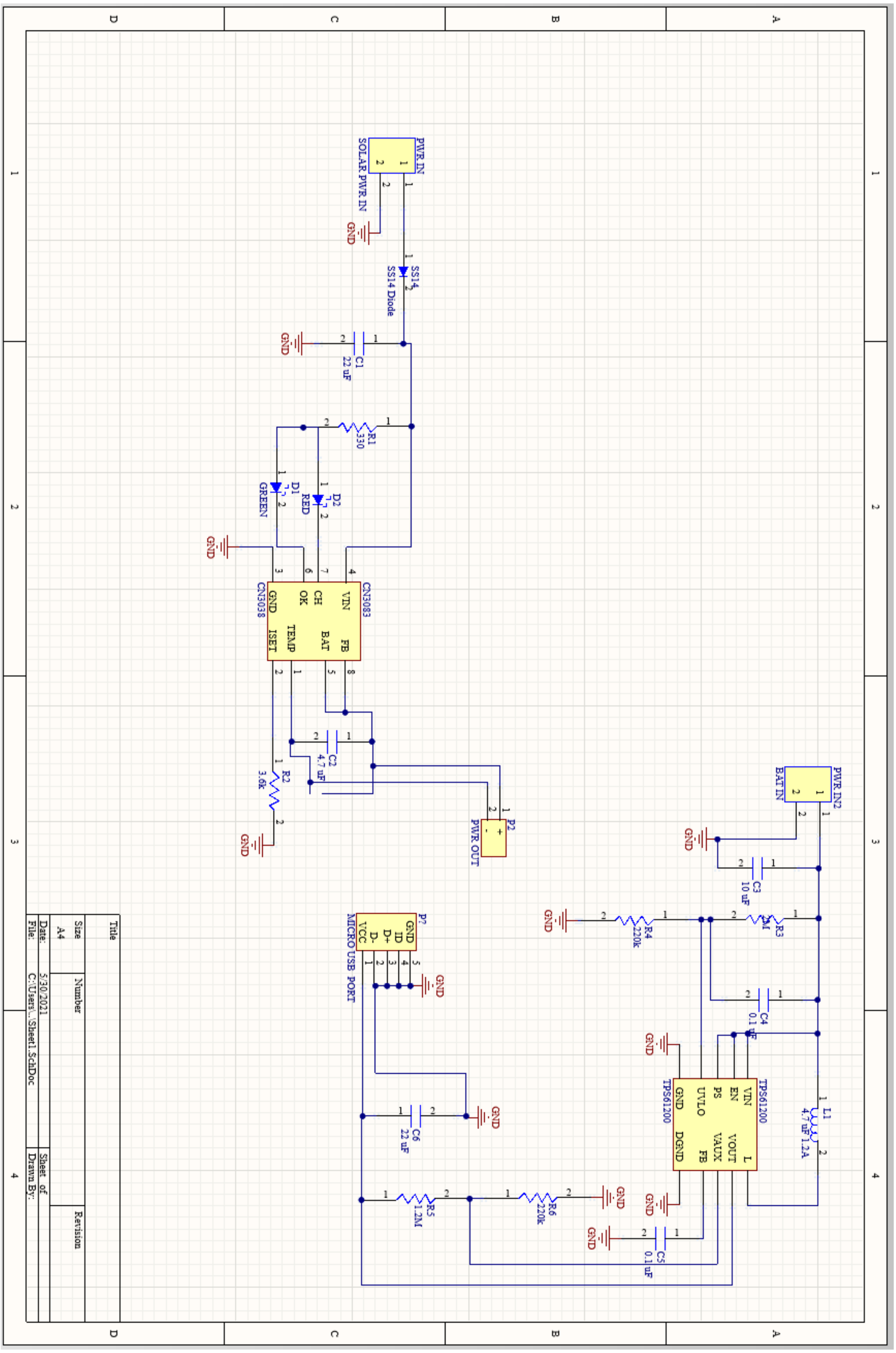

Figure 29 - Schematic First Prototype Solar Hearing Aid Charger

Class 2 ceramic capacitors
Code system regarding to EIA RS-198 for some temperature ranges and inherent change of capacitance

Letter code low temperature	Number code upper temperature	Letter code change of capacitance over the temperature range
X = −55 °C (−67 °F)	4 = +65 °C (+149 °F)	P = ±10%
Y = −30 °C (−22 °F)	5 = +85 °C (+185 °F)	R = ±15%
Z = +10 °C (+50 °F)	6 = +105 °C (+221 °F)	S = ±22%
	7 = +125 °C (+257 °F)	T = +22/−33%
	8 = +150 °C (+302 °F)	U = +22/−56%
	9 = +200 °C (+392 °F)	V = +22/−82%

Figure 30 - Capacitor Rating Table (Source: ravyip)

Order Code	Qty Ordered	Mftr. Part No	Your Part No	Manufacturer / Description
2470822	3	629105150521		WURTH ELEKTRONIK 629105150521 USB Connector, With Pegs, Micro USB Type B, USB 2.0, Receptacle, 5 Ways, Surface Mount, Right Angle Cut Tape
2408020	3	LPS3015-222MRB		COILCRAFT LPS3015-222MRB Power Inductor (SMD), 2.2 µH, 1.1 A, Shielded, 2 A, LPS3015 Series, 2.95mm x 2.95mm x 1.4mm
1467537	5	SS14		ON SEMICONDUCTOR SS14 Schottky Rectifier, 40 V, 1 A, Single, DO-214AC (SMA), 2 Pins, 500 mV Cut Tape
2497374	5	HSMG-C190		BROADCOM HSMG-C190 LED, Green, SMD, 0603, 20 mA, 2.2 V, 572 nm Cut Tape
1652080	5	ASMT-RR45-AQ902		BROADCOM ASMT-RR45-AQ902 LED, Red, SMD, 0603, 20 mA, 2 V, 622 nm Cut Tape
1867955	10	08056D226MAT2A		AVX 08056D226MAT2A SMD Multilayer Ceramic Capacitor, 22 µF, 6.3 V, 0805 [2012 Metric], ± 20%, X5R Cut Tape
2694603	10	MCWR04X3601FTL		MULTICOMP PRO MCWR04X3601FTL SMD Chip Resistor, 3.6 kohm, ± 1%, 62.5 mW, 0402 [1005 Metric], Thick Film, General Purpose Cut Tape
3121865	5	TPS61200DRCT		TEXAS INSTRUMENTS TPS61200DRCT DC-DC Switching Boost Step Up Regulator, Adjustable, 300mV-5.5Vin, 1.8V-5.5Vout, 1.2Aout, SON-10 Cut Tape
2992247	5	1-1614959-4		NEOHM - TE CONNECTIVITY 1-1614959-4 SMD Chip Resistor, 2 Mohm, ± 0.1%, 100 mW, 0805 [2012 Metric], Thin Film, Precision Low TCR Cut Tape
2992183	5	1614959-9		NEOHM - TE CONNECTIVITY 1614959-9 SMD Chip Resistor, 1.2 Mohm, ± 0.1%, 100 mW, 0805 [2012 Metric], Thin Film, Precision Low TCR Cut Tape
2861428	10	CRGCQ0402F220K		TE CONNECTIVITY CRGCQ0402F220K SMD Chip Resistor, 220 kohm, ± 1%, 62.5 mW, 0402 [1005 Metric], Thick Film, General Purpose Cut Tape
2680052	10	C0402C104K8RALTU		KEMET C0402C104K8RALTU CAP, MLCC, X7R, 0.1UF, 10V, 0402
3013457	5	CL21A106MQFNNNE		SAMSUNG ELECTRO-MECHANICS CL21A106MQFNNNE SMD Multilayer Ceramic Capacitor, 10 µF, 6.3 V, 0805 [2012 Metric], ± 20%, X5R, CL Series Re-reel
2112743	10	JMK105BBJ475MV-F		TAIYO YUDEN JMK105BBJ475MV-F SMD Multilayer Ceramic Capacitor, 4.7 µF, 6.3 V, 0402 [1005 Metric], ± 20%, X5R, M Series Cut Tape
2072931	10	MCMR04X331 JTL		MULTICOMP PRO MCMR04X331 JTL SMD Chip Resistor, Ceramic, 330 ohm, ± 5%, 62.5 mW, 0402 [1005 Metric], Thick Film Cut Tape

Figure 31 - List of Components (Prototype 1)

Order Code	Qty Ordered	Mftr. Part No	Your Part No	Manufacturer / Description
2617115	5	614004190021		WURTH ELEKTRONIK 614004190021 USB Connector, USB Type A, USB 2.0, Receptacle, 4 Ways, Through Hole Mount, Horizontal
9492615	5	S2B-PH-SM4-TB(LF)(SN)		JST (JAPAN SOLDERLESS TERMINALS) S2B-PH-SM4-TB(LF)(SN) Pin Header, Right Angle, Wire-to-Board, 2 mm, 1 Rows, 2 Contacts, Surface Mount Right Angle
9887121	1	309 99C 5C 1.2MM H 2M		MULTICORE (SOLDER) 309 99C 5C 1.2MM H 2M Solder Wire, Lead Free, 1.2mm Diameter, 227°C

Figure 32 - List of Components (Prototype 2)

7.3 Appendix C

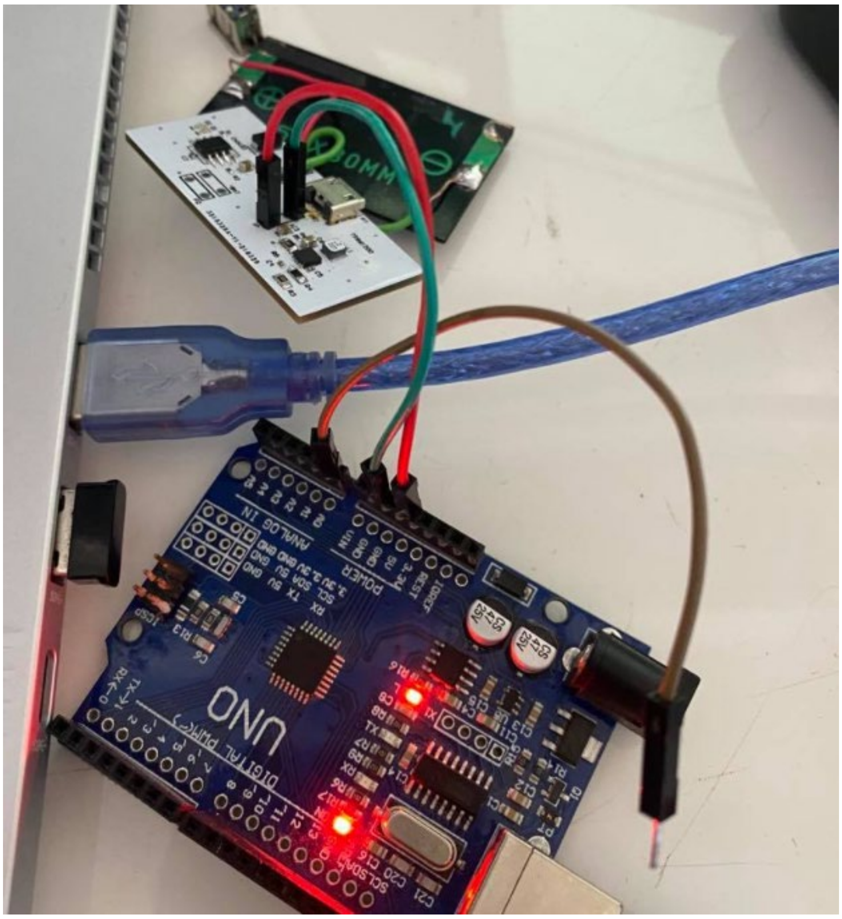

Figure 33 - Arduino Voltage Test

```
void setup() {
  Serial.begin(9600);
  pinMode(A0, INPUT);
}

void loop() {
  Serial.println(analogRead(A0)/1023.00*5.00);
  delay(1000);
}
```

Figure 34 - Arduino C code for Voltage Test

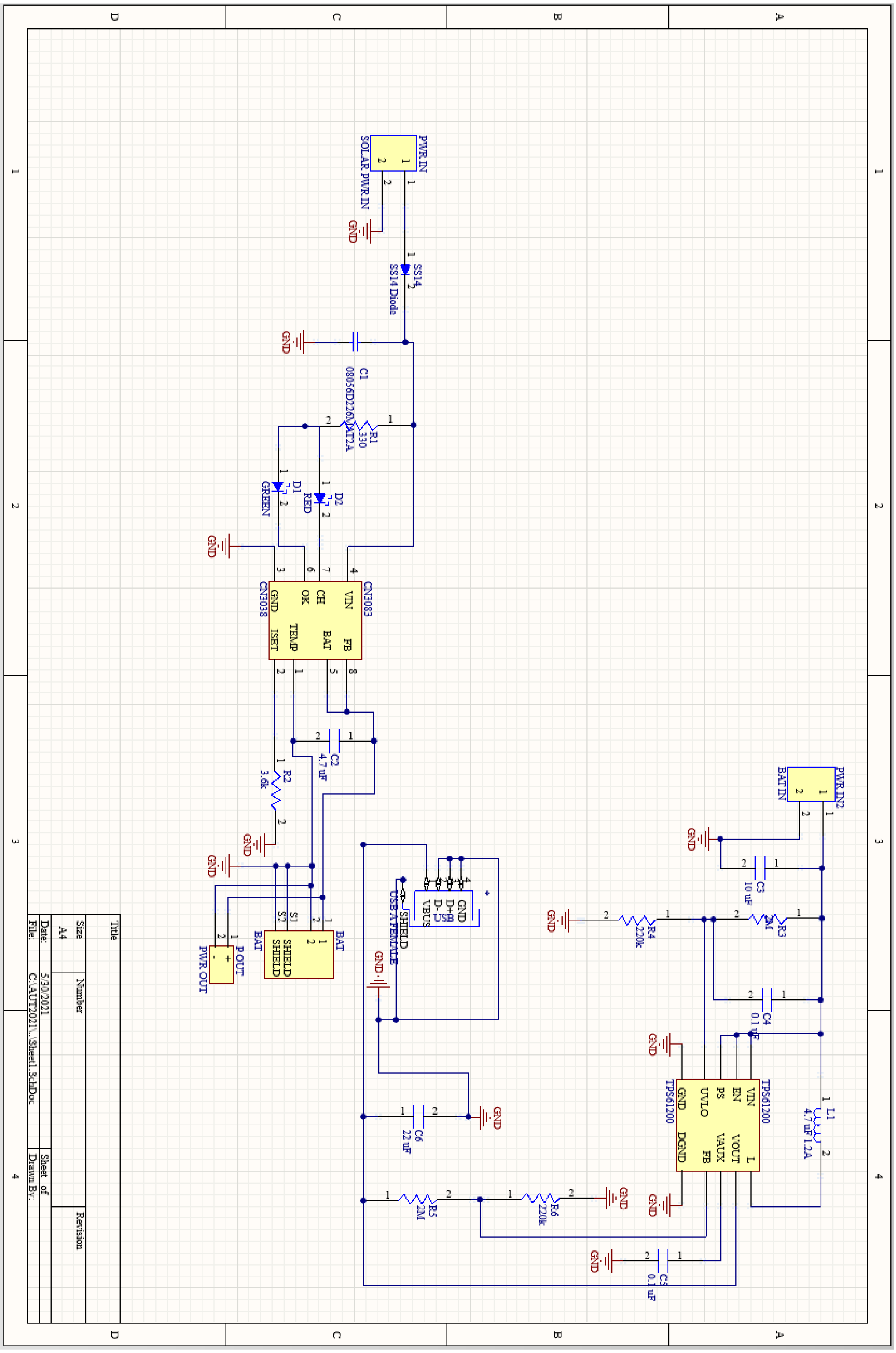

Figure 35 - Full Schematic Prototype 2

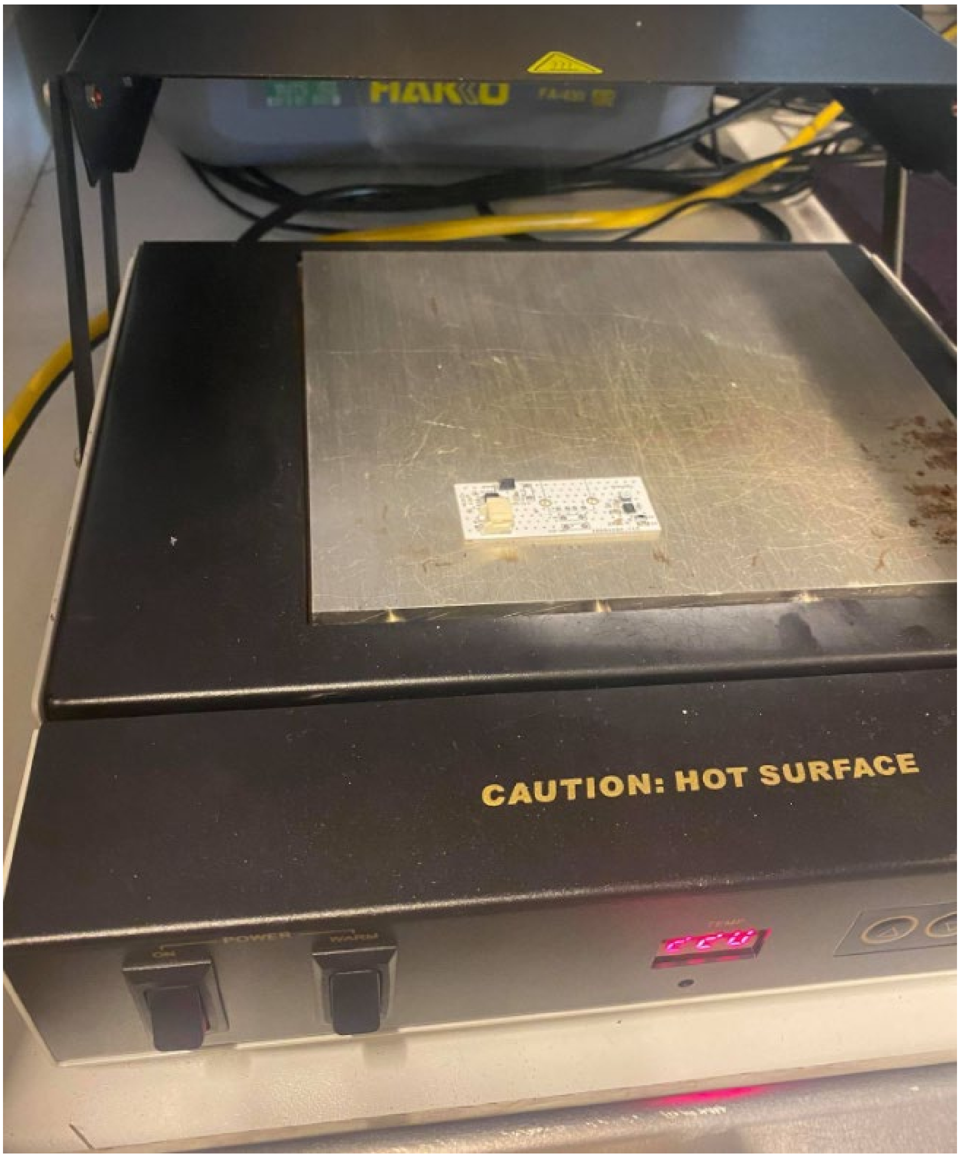

Figure 36 - Hot Plate Soldering Prototype 2

Figure 37 - Solar Charger Testing

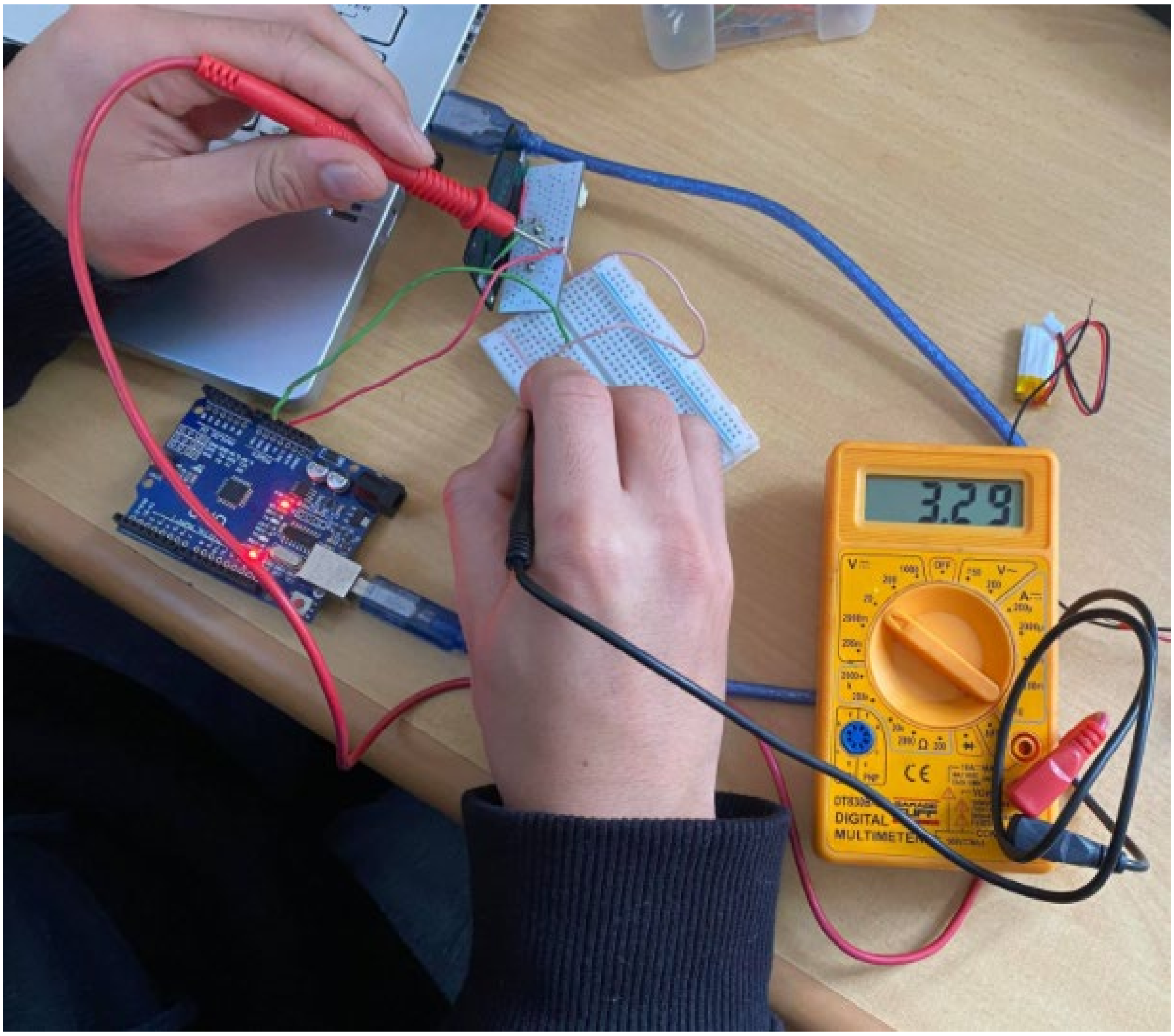

Figure 38 - Arduino Testing 3.3V input ports (Prototype 2)

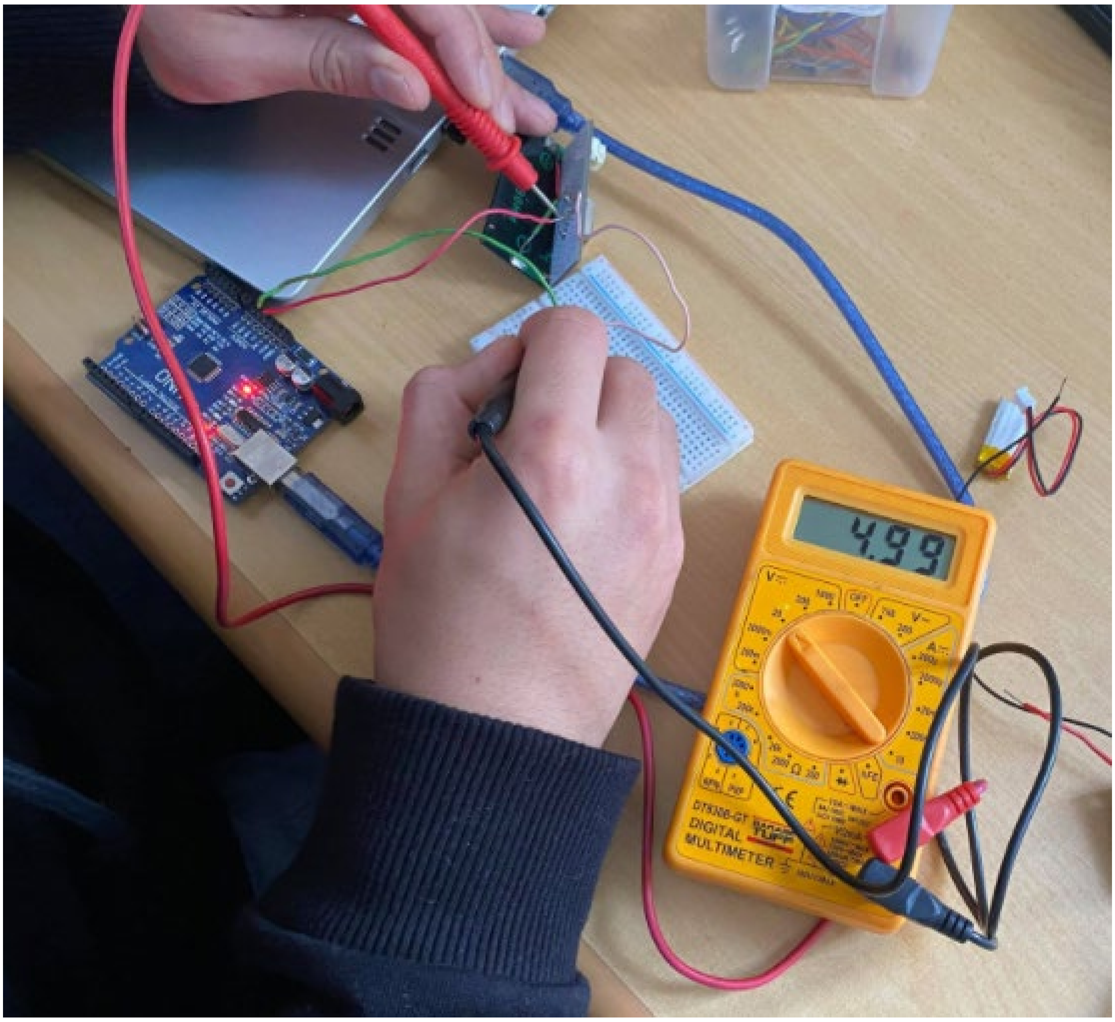

Figure 39 - Arduino Voltage Test output voltage (Prototype 2)

7.4 Appendix D

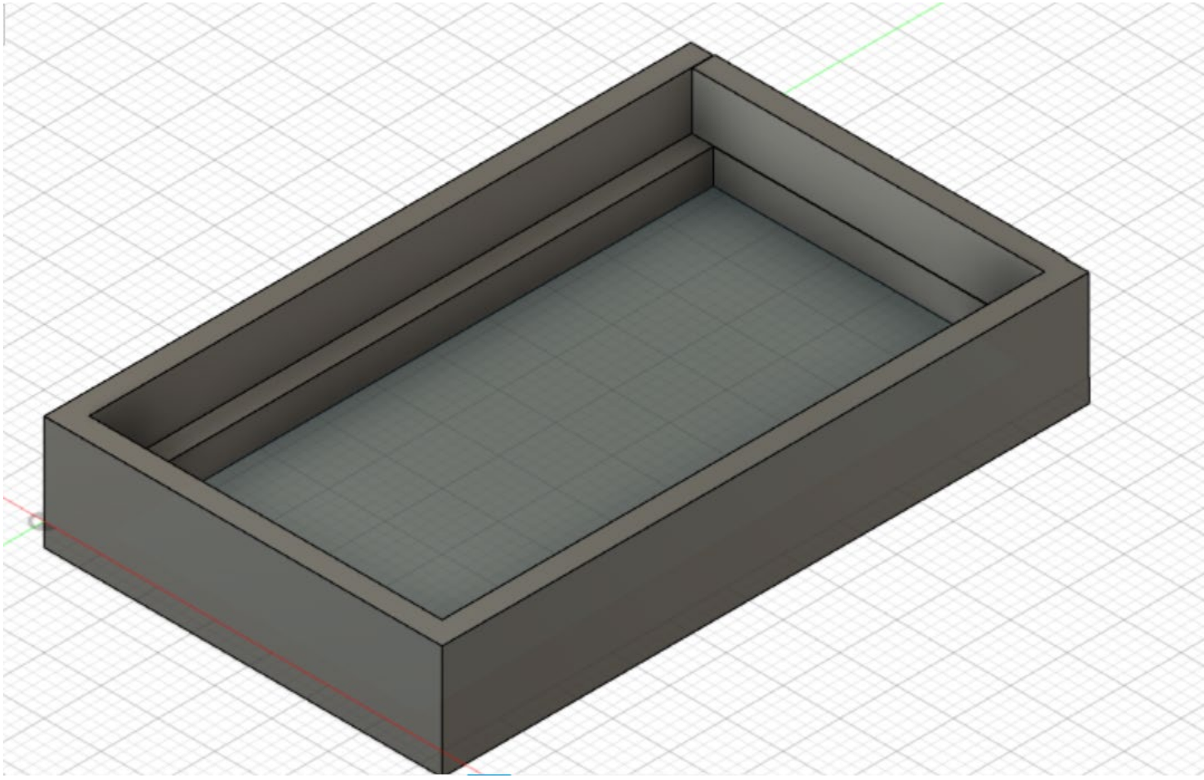

Figure 40 - Fusion 360 Case design (Iteration 1)

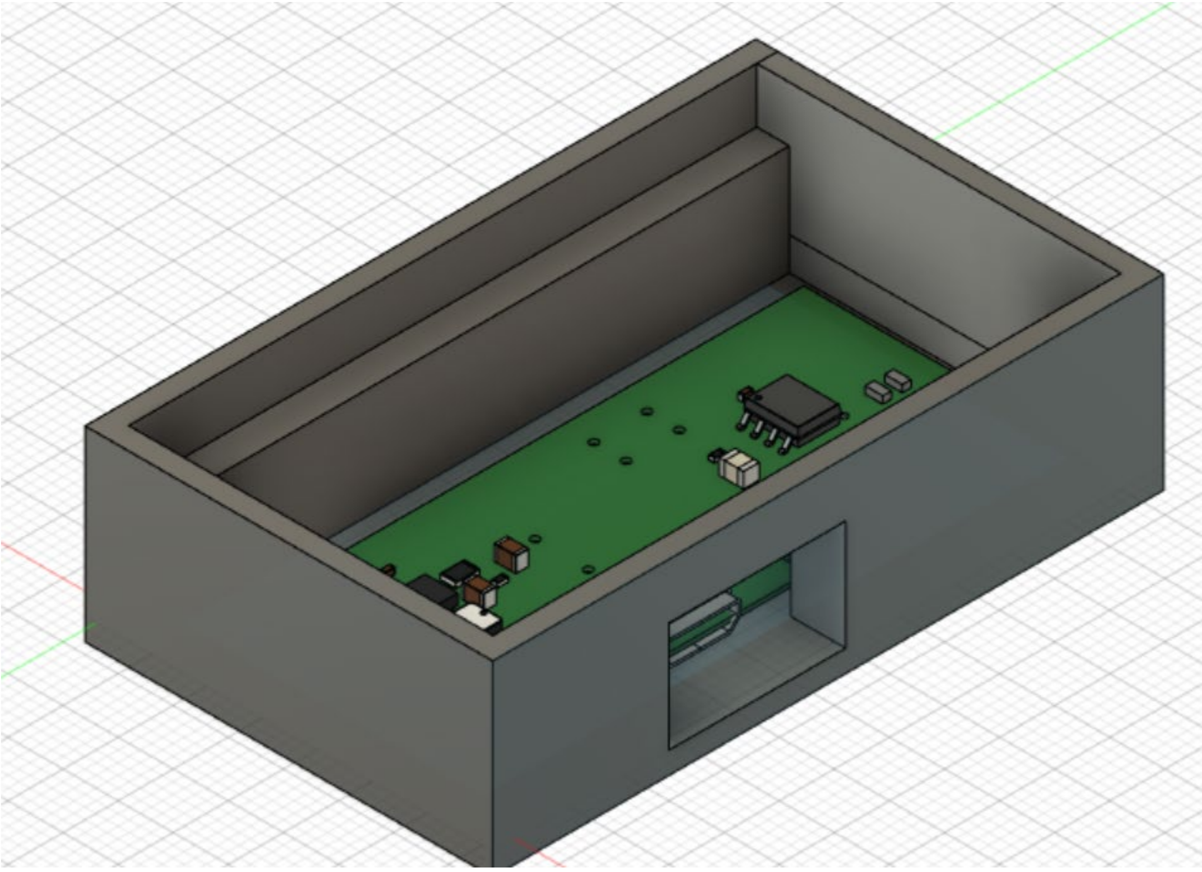

Figure 41 - PCB and Case Design for Prototype 1

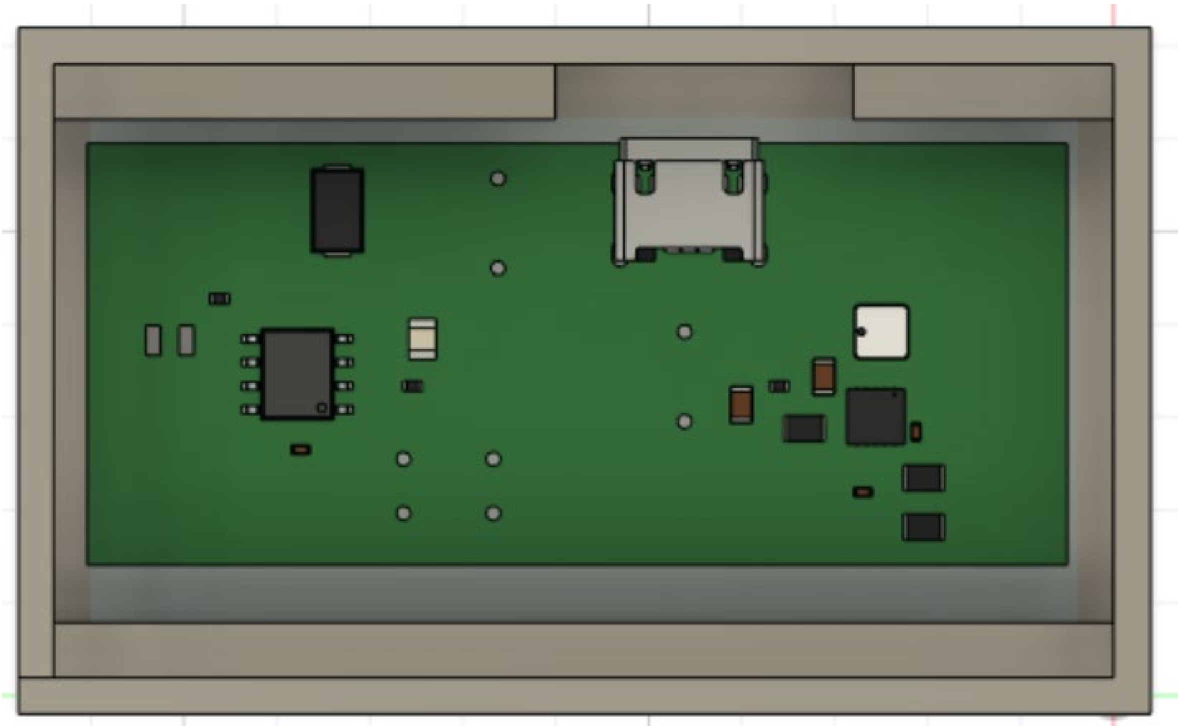

Figure 42 - Top view PCB and case design for Prototype 1

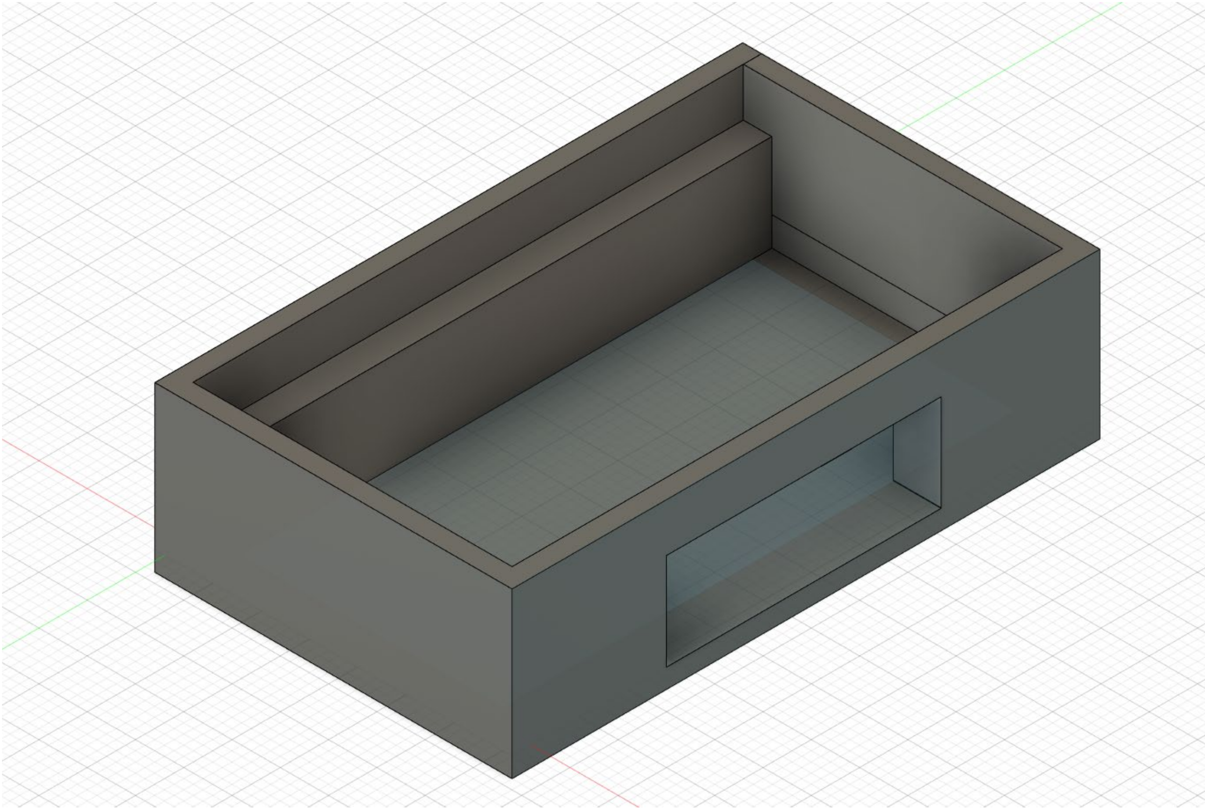

Figure 43 - Case design Prototype 2

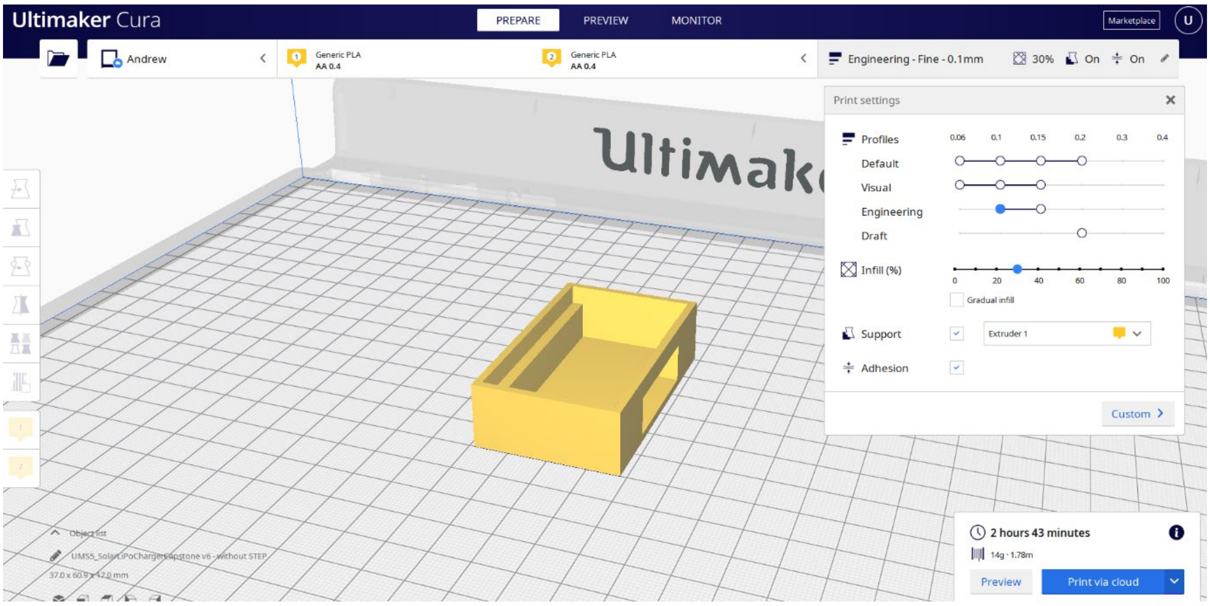

Figure 44 - Ultimaker Slicing preview

7.5 Appendix E

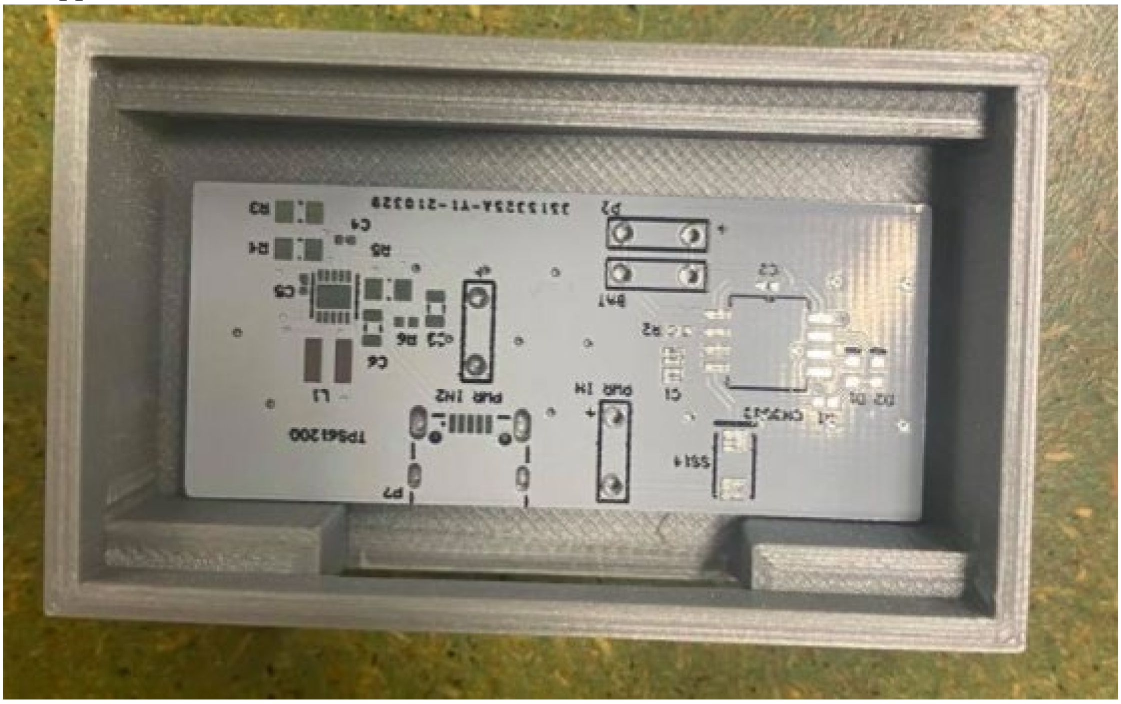

Figure 45 - Case and PCB dimension comparison

Figure 46 - Solar Panel and Case dimension comparison

Figure 47 - Clip attached to case BOTTOM/SIDE VIEW

Figure 48 - Case Attached to jumper

Figure 49 - Case and Clip SIDE VIEW

Figure 50 - Full Prototype 2 Side View

Figure 51 - Prototype 2 attached to the hair

Figure 52 - Prototype 2 attached to side hat

Figure 53 - Prototype 2 attached to the back of the hat

7.6 Communication Logs

Subject	Channel	Date	General Notes
Purchasing of potential hearing aids	MS Teams	02/01/2021	The first website suggested did not look trustworthy and thus was discarded
Purchasing of potential hearing aids part II	MS Teams	04/01/2021	A pair of hearing aids were available at a reasonable price but the charging port were proprietary
General meeting discussing advancement of the project	MS Teams/Zoom Meeting	27/01/2021	No hearing aids were bought and will be replaced by wireless/Bluetooth earphones
Boost Converter guidance	MS Teams	24/02/2021	Addition of Boost Converter to the circuit
Project Update and Advancements	MS Teams	17/03/2021	Ordering of PCB to proceed
Project Update and Advancements	MS Teams	13/04/2021	PCB received and reviewed, delivery of components missing, 3D print design to proceed
Soldering and Testing of PCB update	MS Teams	19/04/2021	Soldering of the PCB started, missing component due to shortage
Testing of PCB update	MS Teams	21/04/2021	Testing of solar charger and boost converter circuit
Completion of 3D print design and ordering of second PCB	MS Teams	26/04/2021	Review of the 3D print design on Fusion 360
Completion of the 3D print	MS Teams	23/05/2021	Successfully printed at ProtoSpace Testing of Prototype 2 successful.