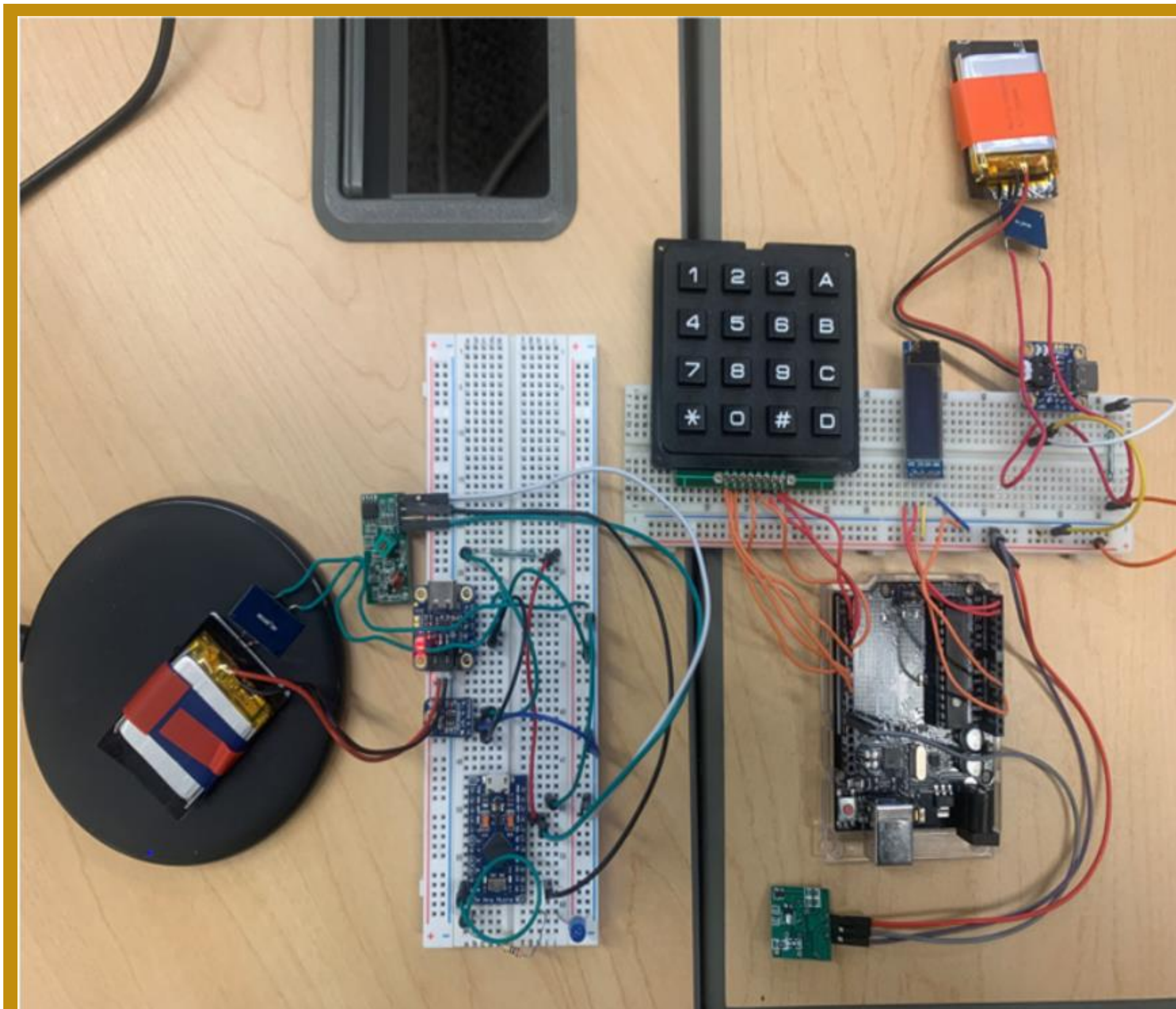


Keep the Tempo

DKC

EPICS

Mid-Semester Spring 2024

EPICS Design Document

CONTENTS

SECTION 1: PROJECT IDENTIFICATION

PROJECT OBJECTIVE STATEMENT

The Deaf Kids Code Tempo Trainer team (Keep The Tempo) is working to develop a training device for deaf and hard of hearing swimmers. Hearing swimmers often use a commercial Tempo Trainer to help them keep a steady stroke pace, or to work on developing a faster stroke pace. The device is worn under their swim cap and beeps at the pace set by the coach. Because the available Tempo Trainers rely on sound, this training technology is not readily available to deaf and hard of hearing swimmers, so they do not have same training opportunities as their counterparts. This fits into the mission of the team because the goal of the Deaf Kids Code is to improve the lives of the hard of hearing community.

DESCRIPTION OF THE COMMUNITY PARTNER

This project was originally created for Katie, a deaf high school swimmer. Katie was looking for a Tempo Trainer that could be used by a hard of hearing swimmer. A traditional Tempo Trainer is a device used to indicate pace for a swimmer through a beeping noise. The project is now being targeted towards swimmers who cannot use their cochlear implants to play tempo trainer beats through Bluetooth. Our goal is to have a solution that works for all members of the hard of hearing or Deaf community and this device will allow those without Bluetooth compatible cochlear implants to use a Tempo Trainer.

STAKEHOLDERS

One of the main stakeholders of this project is Shireen Hafeez, the founder of the Deaf Kids Code (DKC) program, whose mission is to bridge the severe economic and social gaps that exist between the deaf and the hard of hearing. This project is being created for deaf swimmers, specifically a high school swimmer named Katie. She is a family friend of Shireen Hafeez, who first brought her the idea for the project. A successful product could also be shared among other deaf swimmers around the world to help them train and improve. While the project was originally designed for Katie, Shireen keeps this goal in mind as well.

The second stakeholder is Rene Massengale, the Acting Director of USA Deaf Swimming, a National nonprofit organization supporting deaf and hard-of hearing swimmers and the national deaf swim team. As Acting Director, she is a member of the executive board and assists the organization with the support of the national team athletes who compete at national and international competitions such as the World Deaf Championships and Deaflympics.

Another stakeholder is Mark Cronk, who is one of the Board members of USA Deaf Swimming. Along with Rene, he is responsible for the promotion of competitive swimming among the deaf and hard of hearing community. His specific roles are treasurer, head of membership, fund raising, sponsorship and social media.

Our newest stakeholders for the Keep the Tempo team are the swimmers and the coaches of the Gallaudet swimming team. Gallaudet has a deaf swim team who has very generously offered to fill out surveys for our product and test it when it’s ready. Our primary contacts with Gallaudet are the head coach, Brian Bennett, and a volunteer coach, Larry Curran. Mr. Curran also has experience in developing accessible solutions for swimmers, specifically working with an LED start system for deaf and hard of hearing swimmers. Furthermore, he also has experience working with the exact microprocessor that we’ll be using for the Tempo Trainers.

PROJECT SCOPE

This project will result in a prototype for a new Tempo Trainer redesigned with hard of hearing swimmers in mind. This project group will focus on researching, ideating, designing, implementing, testing, and iterating upon a prototype for a deaf and hard of hearing accessible tempo trainer. After developing the product and creating a prototype that can be replicated and hopefully, this team plans to deliver a design that can be mass produced.

USER NEED LIST

Need #	Stakeholder	User Need
1	User	*Must be safe for the swimmer and others in the pool*
2	User	*Must allow swimmer or coach to change tempo while swimming*
3	User	*Must use a sense other than hearing*
4	User	*Must be waterproof*
5	User	*Must fit underneath a swim cap*
6	User	*Must last for an entire swim practice on one charge*
7	User	*Must not interfere with other swimmers' devices*

EXPECTED OVERALL PROJECT TIMELINE

Project Start Date: Fall 2018

Original Target Delivery Date: Spring 2019,
Updated Target Delivery Date: Spring 2025

Semester timeline:

January 2024:

- Onboard new members (Completed)
- Complete budget and order components (Completed)
- Create waterproof testing and waterproofing protocol documents (Completed)
- Implement power switch into Circuit Schematic and PCB (Completed)
- Research LED light pipe and related waterproofing (Completed)
- Iterate on Tempo Trainer CAD (Completed)

February 2024:

- Continue iterating on Tempo Trainer CAD and begin printing and testing (Started)
- Update software for new number pad circuit from Fall 2023 semester (Completed)
- Create PCB testing document

- Create software testing document
- Iterate on remote CAD (Started)
- Test remote PCB
- Begin Waterproof testing

March 2024:

- Finish testing remote PCB and order new design if needed
- Software testing
- Test Tempo Trainer PCB
- Continue waterproof testing

April 2024

- Full implementation testing (and respective iterating) with test users
- Wrap up semester work and documentation

SECTION 2: SPECIFICATION DEVELOPMENT

TUTORIALS

- Documentation: https://tinyurl.com/EpicsDesignProcessDocument
- Video Tutorial: https://tinyurl.com/EpicsSpecificationDevelopment

DESCRIPTION OF THE USE CONTEXT

This project is intended to be used as a training device for athletes, mainly swimmers, and provide an alternative option for members of the deaf community who cannot use a typical commercial tempo trainer. The project will need to interface with the user as well as potentially a coach or mentor.

The tempo trainer needs to be small – it should be small enough to fit in a swim cap – so probably no more than 2 in. by 2 in by 1 in.

The project shouldn't need to be maintained after use, as we intend (after iterations of the project) to have a "final" delivery of the product that would be a completely sealed version and should not need maintaining or updating, as the code set on the device will be final.

The device must be fully waterproof, as it will be submerged during use. However, it only needs to be able to be submerged deeply for a short amount of time – we will recommend this device only for swimming on the surface and not diving. If the user happens to drop the item in the pool however, we would like it to be waterproof for up to 2 days in deep water (~12 feet).

The main technological limits are the power consumption of the device and the size of the device. Since the device needs to last for a while on a battery with a small footprint, if the device draws too much power, it will not last at least an entire swim practice.

In addition to all of these technological limitations, we also need to make sure that this device is safe for use in the water. In addition to it being fully waterproof as to not break the components, we need to make sure that the device doesn't overheat, melt, or release any harmful chemicals or substances to the swimmer.

An important factor to consider is that this is intended to be a deaf adapted device. This project was born out of the need for a deaf adapted tempo trainer and keeping this goal in mind and its usability is key while designing the product.

BENCHMARKING

In the past, we had only found one solution for an existing tempo trainer, which is produced by Finis and does not have any deaf adapted products. The product is also expensive, retailing at about $60. We aim to provide this alternative that is not only accessible to deaf swimmers, but also cheaper than the alternative. We don't believe there are any deaf adapted tempo trainers out there.

In terms of intellectual property, we are looking at Finis' patent on their tempo trainer, which is located here:

https://patents.google.com/patent/US7081809B1/en

This patent is far different from the current design of the KTT tempo trainer. Finis' patent is a single device that emits audio and has onboard controls. The KTT solution is a two-device solution that emits a light instead of a sound. Additionally, the controls are on a second device (the remote) instead of on the tempo trainer. These large differences should pass the requirements of patent approval as these are novel changes.

During the Fall 2021 Semester, we had to change our user group focus. We have now found several different solutions for several different user groups.

The first user group is deaf swimmers with cochlear implants. One solution found that eliminates the need for any additional tempo trainer device is using the implant's Bluetooth. If the user's implants can connect to a device through Bluetooth, the implants can be used as a commercial tempo trainer. To do this, the user will connect their implants to their device and then use a metronome app to play beeps that they can hear. All the apps can be downloaded for free and by using them, the user has a working tempo trainer.

Another user group is deaf swimmers with cochlear implants that do not have Bluetooth. For this group, they have implants but are not able to connect their device to them. This group will be able to benefit from our product. The solution to this (as of Spring 2022) was to use a reed switch paired with magnets to turn the device on and off. However, because these magnets have the chance to interfere with the implants, it could pose a large threat to our device being unusable to these large user group. So, to allow this product to still be usable by cochlear implant wearers, we have decided to stray from using a reed switch. During Spring 2023, we have decided to use a button underneath a flexible waterproof layer instead of a reed switch and magnet.

The final group of users involve users without cochlear implants, users who use hearing aids, and users who do not use either cochlear implants or hearing aids. This group will be able to use our product as initially intended.

SPECIFICATION LIST

Need #	User Need	Spec #	Specification
1	*Must be safe for the swimmer and others in the pool*	1.1	The device must not cause any health hazards to the swimmer using the device or any other swimmer
2	*Must allow swimmer or coach to change tempo while swimming*	2.1	*Must have a changeable tempo*
		2.2	*Must have a UI to display current tempo*
3	*Must use a sense other than hearing*	3.1	*Must use a light or vibration to convey tempo*
4	*Must be waterproof*	4.1	*Must be able to withstand 2 days submerged in water*

		4.2	*Must withstand 12 ft depth for 30 minutes*
5	*Must fit underneath a swim cap or be able to latch on to the goggles*	5.1	*Must be less than 2 in by 2 in by 1 in*
6	*Must last a full practice*	6.1	*One charge must last at least 4 hours*
7	*Must not interfere with other swimmers' devices*	7.1	*Must be able to use multiple devices in the same pool/area*
		7.2	*Must not interfere with the other devices on the swimmer (ex. Cochlear Implants)*

SECTION 3: CONCEPTUAL DESIGN

CONCEPT GENERATION

In past semesters, the concept generation for the general design of the device was nearly complete. The concept was based around mounting a small LED on the swimmer's goggles that would allow them to see the tempo and rely on visual cues.

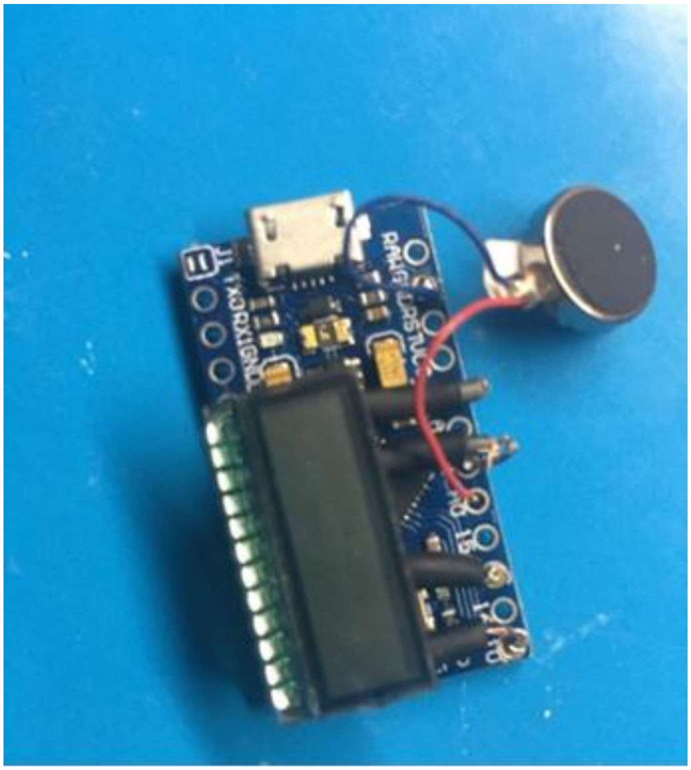
In order to communicate with the tempo trainer, the concept of a remote RF transmitter was utilized. The remote can change the frequency of the tempo trainer and send the RF signal to the swimmer's unit. This makes the waterproofing simpler since the swimmer's unit can be fully sealed without leaving places for buttons and a screen. The remote RF transmitter enables the remote to also send multiple RF signals to be received by multiple tempo trainers.
The previous team also planned for the components for the remote and receiver to be on a PCB and the battery that powers both receiver and remote to be charged by a wireless charger.

In the Spring 2023 semester, the concept for the tempo trainer and remote was modified. Instead of an RF transmitter and receiver, a Wi-Fi mesh will be utilized as an improved communication protocol. Additionally, wireless charging is currently going to be replaced by a charging cord. We also plan to have a detachable tempo trainer instead of permanently adhering it to the goggles.

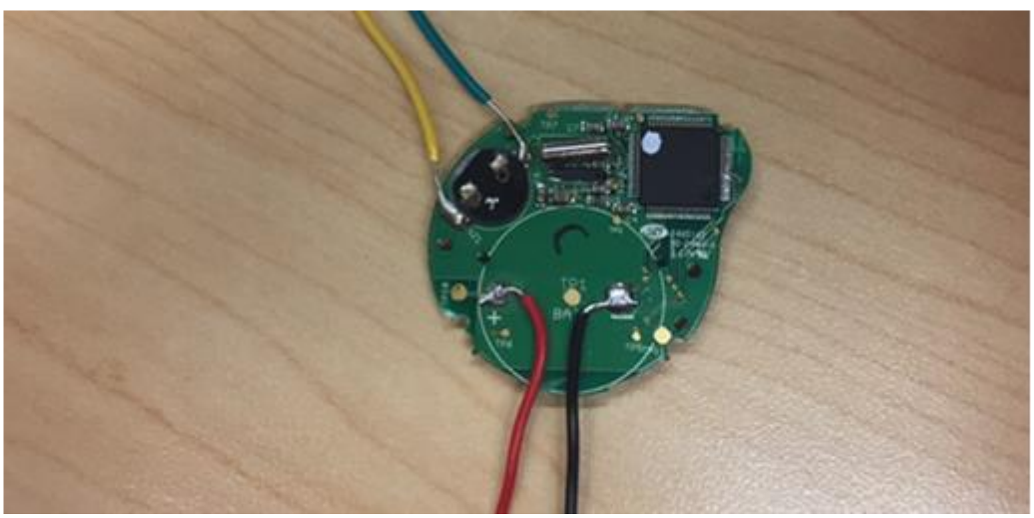
In the Fall 2023 semester, the concept for the LED on the tempo trainer was shifted. Our previous design used the LED mounted directly on the PCB, but we later realized that this wouldn't be applicable for the way we are using the LED, as the main stroke pace indicator. Past teams have toyed with using a copper cable going from the PCB out to the goggles, but we had some safety concerns with that application. Our final decision is to use an LED that's mounted on the PCB, but to also have an "LED Light Pipe" attached to it. This light pipe is an optic cable that will direct the light on the PCB out of the enclosure and closer to the user's eyes.

PROTOTYPING

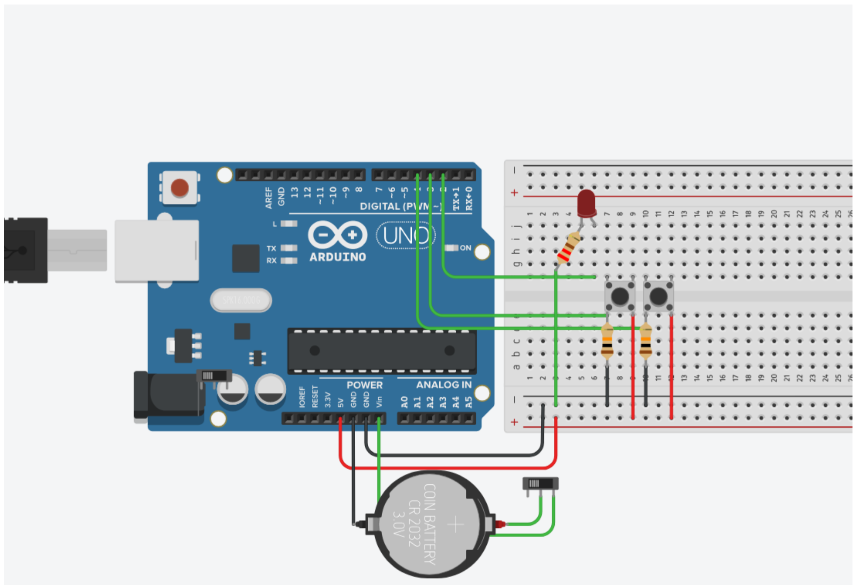
First Prototype: Fall 2018



This first prototype (Fall 2018) was a small device based around an Arduino Pro Micro. It contained a seven-segment LED screen that used almost all the available pins on the Arduino. There was also a small Haptic motor attached. Unfortunately, we chose to start over with the code base.

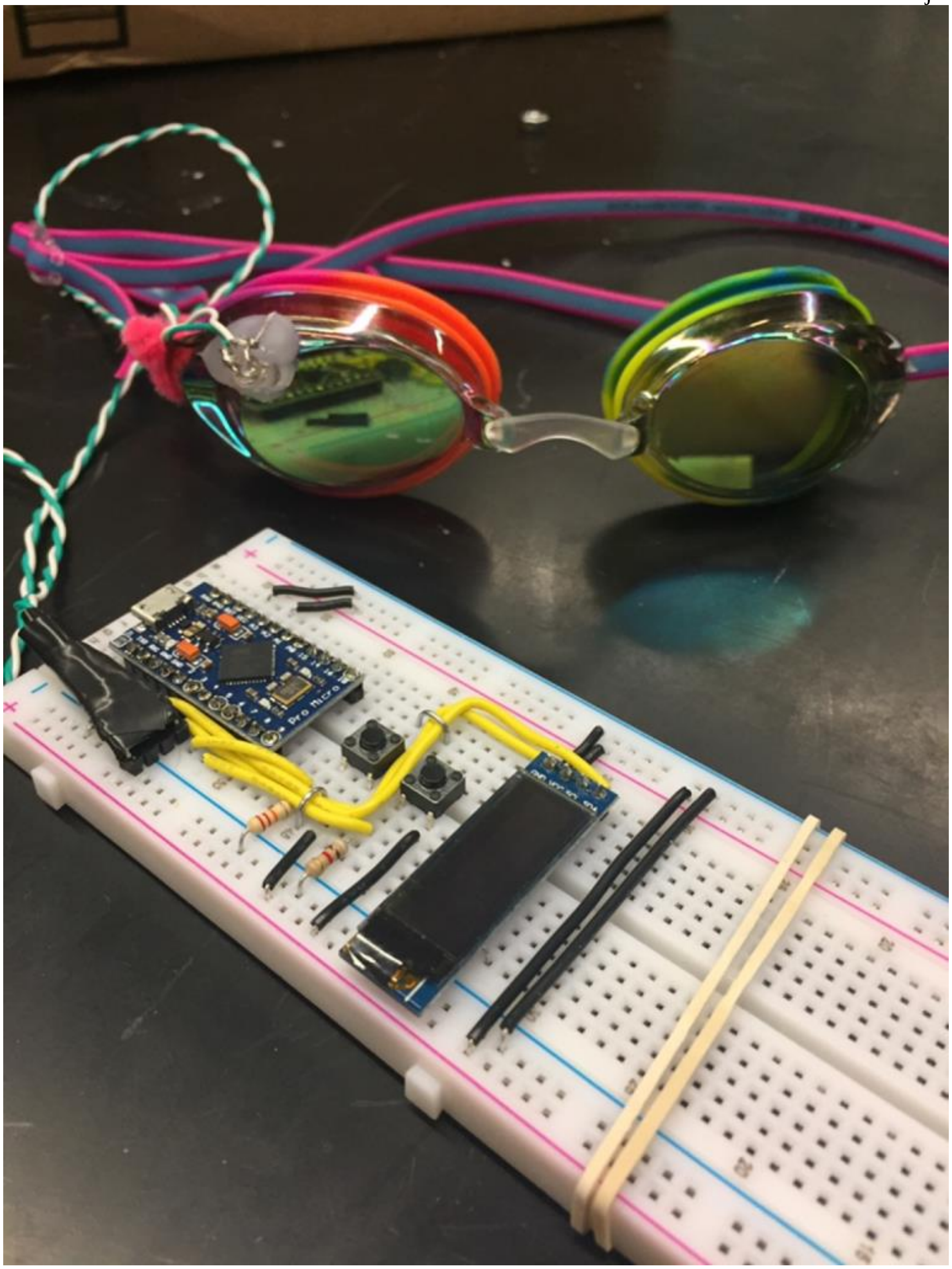


The second prototype (Spring 2019) was a smaller one where we tried to utilize the existing hardware on the current Tempo Trainer. We wanted to investigate how the tempo trainer that already exists works, and we found that it was mainly a microprocessor that attaches to a buzzer. At that time, we were planning on trying to just attach the haptic motor, but the output did not provide enough current, plus we would need to buy an entirely new tempo trainer every time we wanted to make one.



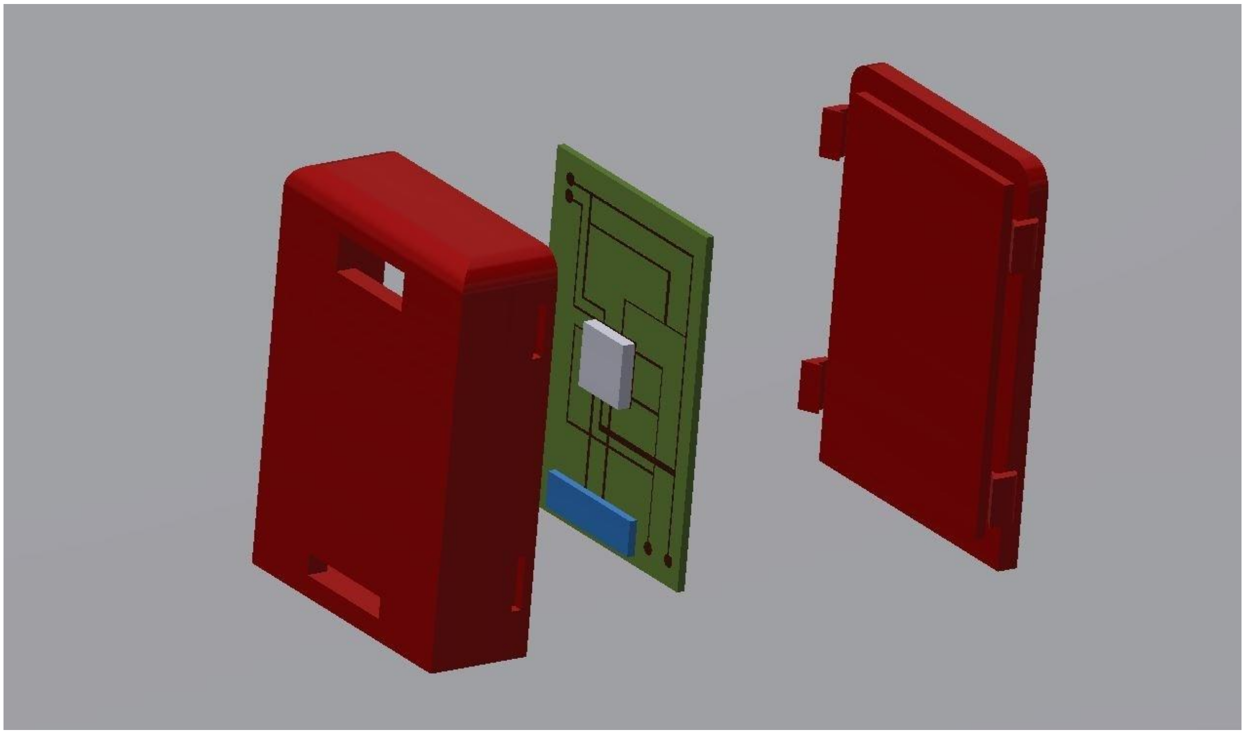
Components

The third prototype (Fall 2019) is the most promising basis for the design, as it is small and compact (only measuring a half inch by a quarter inch by an inch and a half) and contains a simple UI (buttons and a screen) This prototype is small, lightweight, and has a code set that will be flexible enough to undergo changes as necessary. The current light goggle design is a set of goggles with the LED hot glued onto the front of the goggles. The Arduino with the electronics is intended to be placed on the goggle strap. We chose a blue LED because it was the brightest and one of the resistor LEDs in the lab. The hot glue was used for its malleability and sturdiness. We made sure to buy many different goggle colors with many different tints to allow us to test for the ideal color that could work on any color tint of goggle. We also wanted to put the electronics towards the back of the goggle strap to allow the device to be out of the way and will allow it to stay on as the goggles are always on the swimmer's head. For now, we are keeping the electronics neatly on a breadboard which makes modifications and troubleshooting significantly easier. Once we solder the device to its prototyping board, it becomes virtually impossible to disassemble or fix. Most of these design decisions are very malleable, and as more testing data is acquired, these are most likely to change as most of the decisions and progress made this semester has been on the electronics side of the project.



The fourth prototype (Fall 2019) is an expanded version of the third one. The new prototype consists of the same screen and button methods of the third prototype. One of the key changes was changing the board from an Arduino Pro Micro to an Arduino Pro Mini. This new board runs on 3.3V and uses an 8 MHz clock, as opposed to the Pro Micro's 5V 16 MHz clock. There is now also a wireless charging circuit attached to the Arduino. This consists of a small Adafruit battery charging circuit, a 500 mAh LiPo battery, and a Qi compatible wireless charger. This was mainly chosen for the adherence to industry standard, as Qi chargers are very commonly used for cell phones.
This prototype has also now considered waterproofing methods. This prototype fits snugly in a small waterproof box and will contain a wire that comes out of the box and runs to the LED.

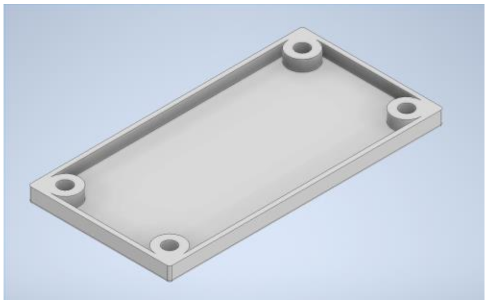
The fifth prototype (Spring 2020) utilized a remote configuration to control the tempo trainer. We moved the previously developed screen and button methods to a remote RF transmitter which would be kept away from the pool. The coach would adjust the frequency of the tempo trainer. In this way, we could keep the size and power of the swimmer's unit as small as possible to avoid potential safety concerns. This prototype which used a coin cell battery instead of LiPo battery had a lower risk of fire and explosion. In addition, this designed trainer only had the receiver and an Arduino Pro Mini in it which would be enclosed by our customized 3D printed box for extra waterproof. This 3D printed box also had a rubber seal custom 3D printed to ensure that the device is completely watertight.

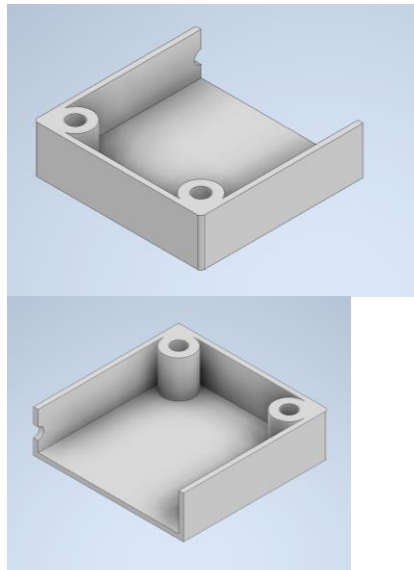


The sixth prototype (Spring 2022) had the same exact configuration as the fifth prototype, except it was able to send multiple RF signals to be received by multiple tempo trainers. Below are pictures of the circuit, for first the remote with the transmitter and second the tempo trainer with the receiver.

In Fall 2023, we worked on creating a 3D printed case for the tempo trainer. Currently, our team has two designs, consisting of three parts. For both designs, the first part is a tray for the PCB, so that the PCB does not have to be exposed after installation. This tray will then be screwed into the second part. The purpose of the second part will be to hold the battery. There will be a pipe coming off of the battery holder to allow for charging access. The final part is a lid that will be screwed into the battery holder. All of these parts will be screwed together using self-threading screws. The difference between the two designs is that one of the designs will be round, and one of the designs is rectangular. The purpose of this choice is to test which design is most comfortable for the user and if either of them provides a tighter waterproof seal than the other. So far, we have 3D printed tempo trainer cases for but have not tested them.

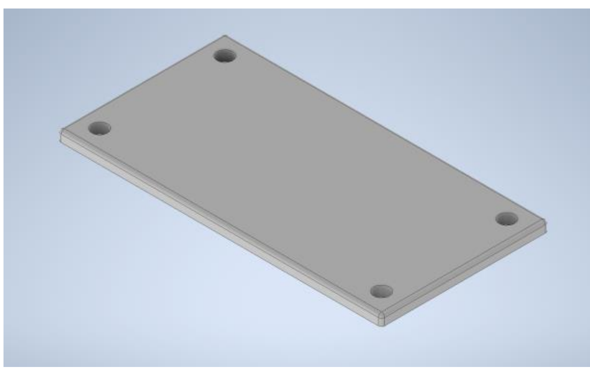
Rectangular Tempo Trainer Design Pictures:

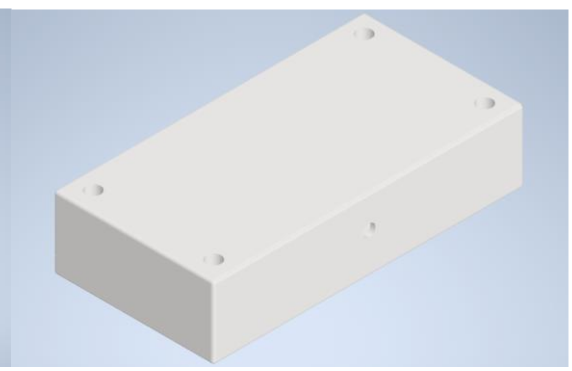




Current PCB Holder

Left and Right Sides of the Battery holder

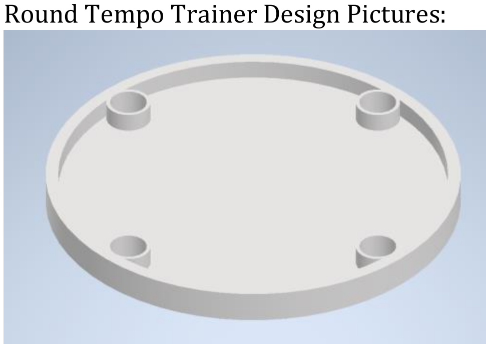


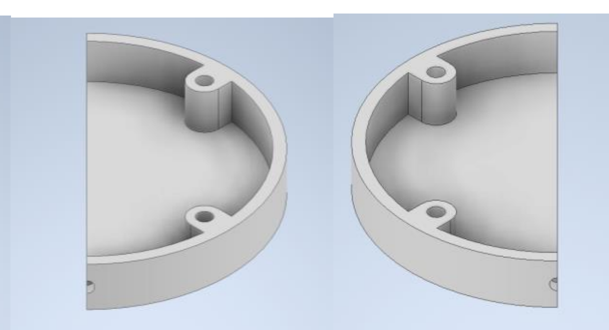


Lid to Rectangular Tempo Trainer

Rectangular Tempo Trainer Assembly

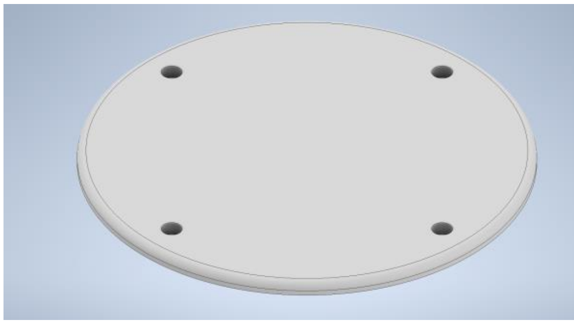
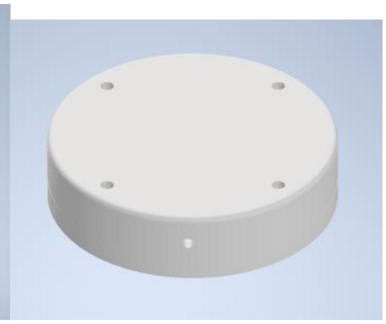
Round Tempo Trainer Design Pictures:





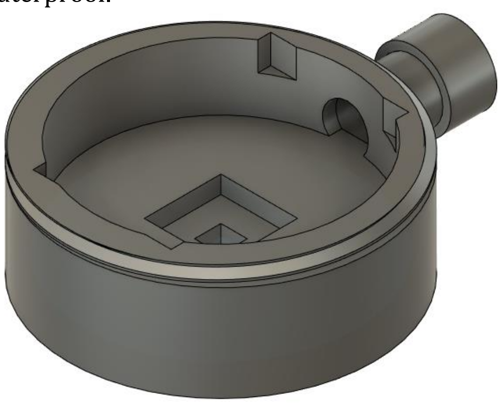
PCB Holder

Left and Right Battery Trays

Lid for Round Prototype Round Tempo Trainer Assembly

We have continued iterating on the round Tempo Trainer case for Spring 2024; we decided to move forward with the round tempo trainer design as it fits to the PCB and other components as tightly as possible. We also believe the round design will be more comfortable on swimmers' heads. The battery, PCB and power button will now sit together in the main compartment. The battery will sit on top of the PCB, and the power button will sit below the PCB. The power button will have a thin cover that allows it to be pressed through the Tempo Trainer case. There will be a pipe coming off the main compartment to allow for charging cable access. There are two caps to the Tempo Trainer. The cap on the bottom has a thin surface allowing it to be flexible so the power button can be pressed. This cap will be secured after manufacturing to ensure a waterproof seal and make sure it stays in place. The top cap will be removable if necessary to replace the battery and service the PCB. Moving away from the screws in previous iterations, the current iteration uses 3D printed caps for the top and bottom. We are in the process of printing and beginning to test the Tempo Trainer to ensure it is waterproof.

Main body for Battery, PCB and button Cap for Button with thin base

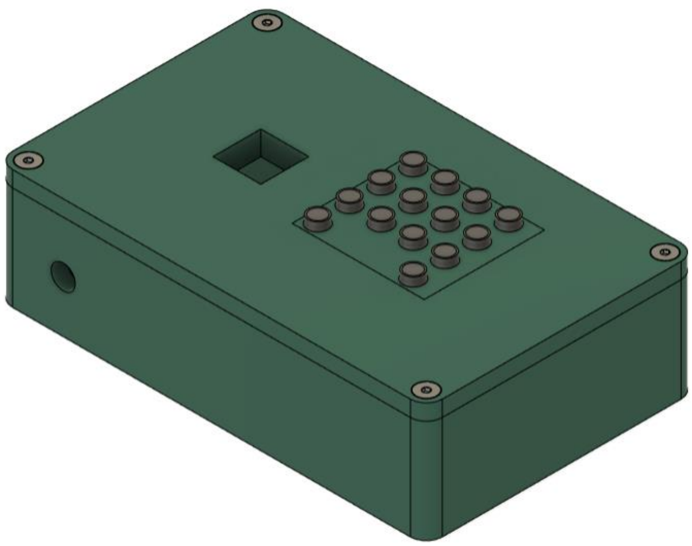
 

Main body cap Assembled Tempo Trainer Case

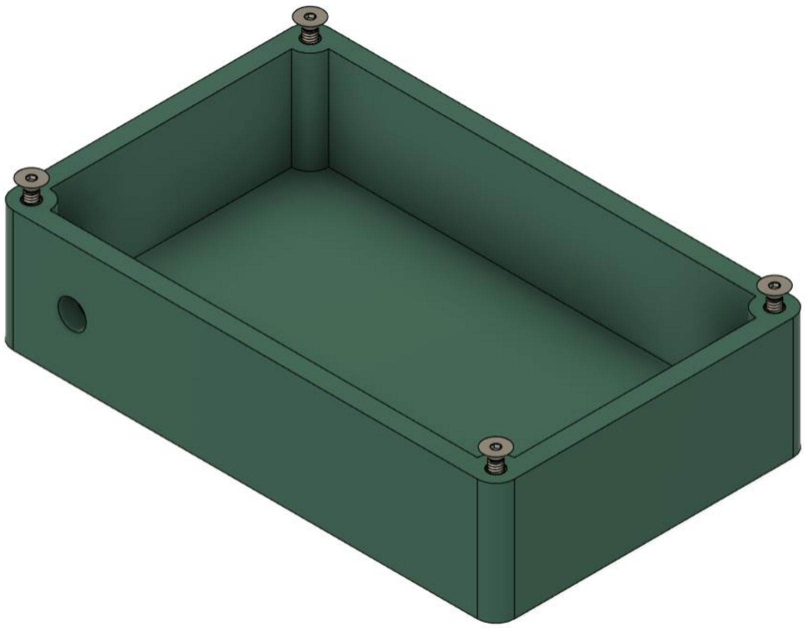
From Fall 2023, we have a prototype of the remote to control the tempo trainer. The current design is in two parts: a base and a lid. The lid is secured to the base using threaded inserts and screws. The threaded inserts can be added using a soldering iron to melt the plastic partially, and then inserted into the designated area. Then, screws are used to secure the lid tightly.

The case will be 3D printed using a flexible filament to allow for a number pad to be created. The buttons will be designed as part of the case, positioned above the number pad on the PCB. This will let users press the case's buttons, and the case will press down on the PCB buttons. The reason for this design is to allow the case to be waterproof, but still allow the number pad to be used. At this time, the number pad buttons are smooth on the top. One new development that we would like to add in the future would be to raise numbers and letters to indicate which button someone is pressing based on touch. This increases accessibility for the blind and low vision community.

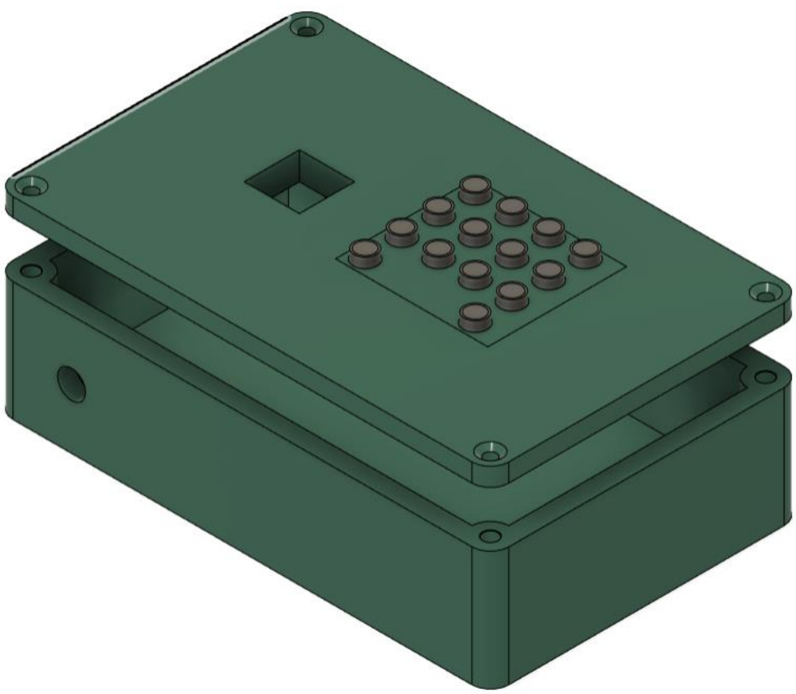
There is a viewing port cut out of the lid, which allows the users to see the OLED screen down below. The OLED screen is part of the PCB, meaning it must stay inside the waterproof case, but it is also important for the user to see, to confirm that they have input the correct information. The current idea is to have a clear piece of plastic adhered onto the top of the case.



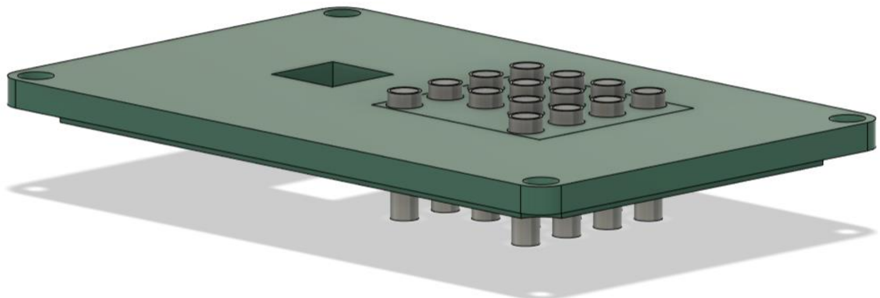
Complete Remote Case with lid attached using heat set inserts and screws



Base with Hardware attached



Base and Lid detached



Sideview of Lid with Numberpad

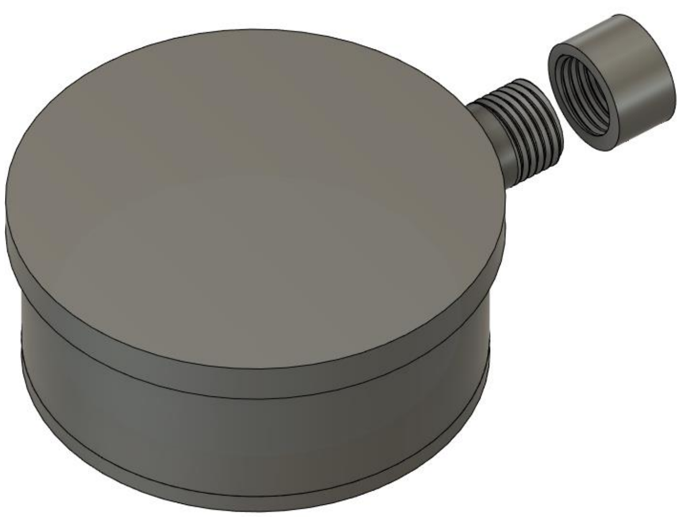
Numberpad

Charging Pipe Implementation

In Fall 2023, one issue our team faced was finding a way to ensure that the tempo trainer and remote could be charged, while still ensuring that the internal hardware remained waterproof. This required a way to allow a wire to be taken in and out of the tempo trainer and remote case. The solution that we came up with was to use a small PVC pipe slightly larger than the wire used for charging, thread the wire through the piece of PVC pipe, and secure the end with a threaded cap. PVC was chosen, as it is used frequently in water without any issues, such as deteriorating or chemical leaching. Ideally, only the end cap would be visible outside of the case. In future iterations, a female threaded cap would be ideal, as there would be less space outside of the case utilized. The current iteration will look like the picture below:

https://www.testriteoem.com/products/tube-ends-joiners-attachments/screw-on-end-caps

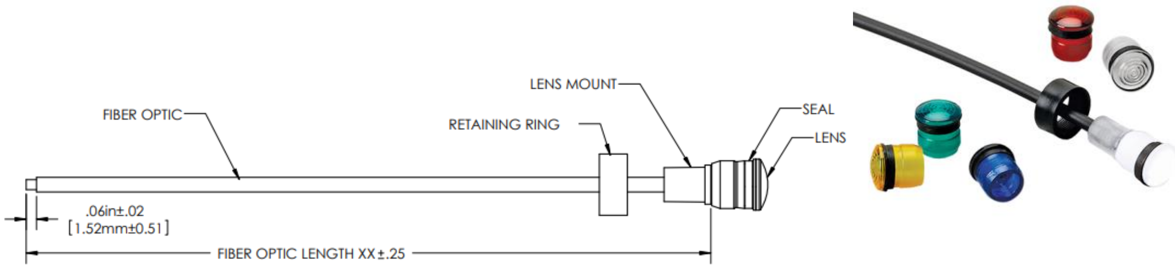
For the Spring 2024 revision of the Tempo Trainer and charging pipe, we have shifted to 3D printing the charging pipe and cap. When testing and researching the PVB pipe and cap from Fall 2023, we were having trouble finding an adhesive to secure and waterproof the charging pipe into the 3D printed Tempo Trainer. There were also concerns with the charging cable fitting into the charging pipe and fitting enough cable. To solve these problems, the Spring 2024 Tempo Trainer has a wider charging pipe integrated into the CAD design that will be 3D printed. This 3D printed charging pipe is threaded, and a 3D printed cap will be printed to go with the charging pipe.



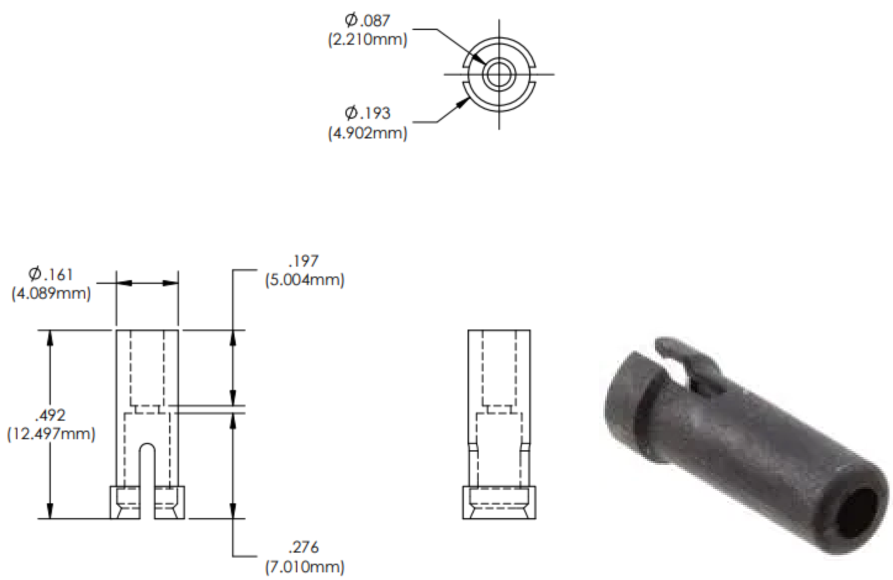
Tempo Trainer Case with Charging Pipe and Cap

LED Light Pipe Implementation:

In order to make the light emitted on the PCB visible to the user, we're planning to use an LED light pipe to transmit the light from the PCB to a position closer to the user's eyes. The light pipe is made of an optical grade plastic, and we plan to use a "flexible" light pipe so that we can modify the positioning to best fit the swimmer's comfortability. We're looking at the Flexible Moisture Sealed LED Light Pipe products from VCC, and we'll be placing the light pipe into a flexible PVC waterproof pipe. In addition to the light pipe, VCC also designs a product that holds the light pipe in place against the LED on the PCB, which we will use as well. Both of those are pictured below.



(above is a technical datasheet drawing of Flexible Moisture Sealed LED Light Pipe and an image of product)



(above is a technical datasheet drawing of LED Mounting Hardware Coupler and an image of product)

Waterproofing Research and Potential Solutions:

In the design phase of this portion of the product, we've looked at various different methods to waterproof the product. Below is a decision matrix regarding different options we investigated:

Criteria	Weight	3D Printing Combined with Acetone	Hot Glue	DIY Silicone Mold	Professional Silicone Mold	Flex Seal
Cost	2	5	5	4	0	4
Difficulty of Manufacturing	1	4	3	2	0	4
Accessibility	3	3	3	3	3	5
Durability	2	4	1	2	5	4
Effectiveness	3	5	2	3	5	5
Environmental Impact	10	5	3	2	4	0
Total Score		96	60	52	74	50

Reasoning		3D Printing combined with Acetone	Hot Glue	DIY Silicone Mold	Professional Silicone Mold	Flex Seal
Cost		The only cost would be the filament and acetone. The filament would already be paid for to create the product. Only a very small amount of acetone is required to waterproof the filament.	We probably already have all the materials necessary	The cost would be low, as all the materials are affordable. There are commercially available kits for around $20	Costs for manufacturing silicone molds are in the thousands at a minimum	Flex seal is relatively inexpensive
Difficulty of Manufacturing		The only required extra step beyond just printing the case is to just dunk the print in a container of acetone.	There is some skill involved in insuring that the glue covers all of the holes. A lot of testing would need to be done	Creating our own mold for silicone would be difficult to do correct enough to ensure waterproofing, since the main way to do this would be to create two pieces and seal them together, creating a seam	To produce a mold would require precise measuring and in-depth conversations with the manufacturer. This process would take months to years	All that is required is for the spray can to be sprayed onto the surface
Accessibility		The filament used may determine how slippery the product is.	The hot glue would most likely make the products harder to hold, since they would stick out of the intended design	silicone may become slippery when in water	silicone may become slippery when in water	More testing needs to be done, but we do not believe that there would be any issues with accessibility at this time

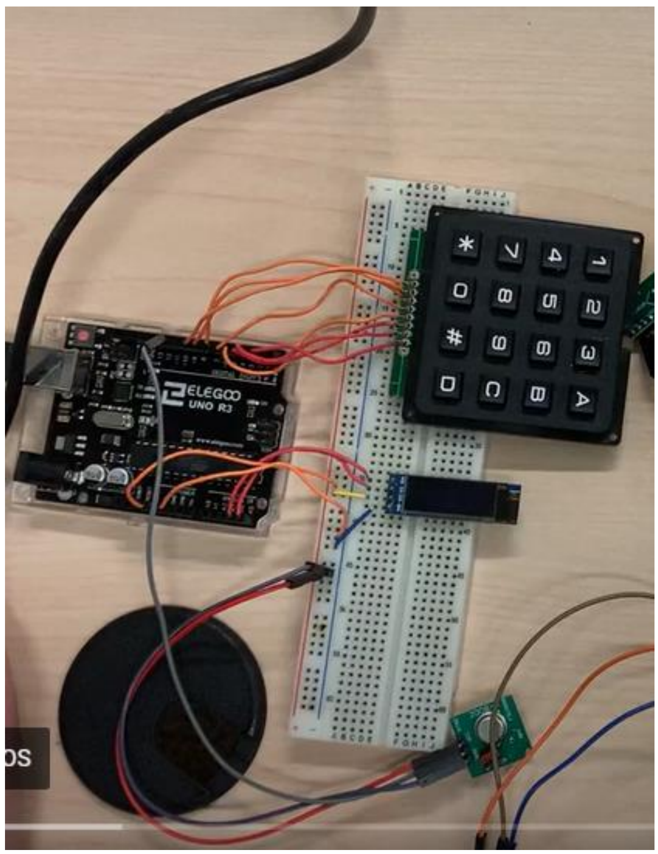
Durability		We do not foresee any difficulties with the durability of the filament. The specific filament we chose has been used in both chlorine and saltwater environments in the past with no issue. The addition of acetone has no added risks of durability loss.	There is a high chance that it would get knocked off frequently, meaning it would have to be reapplied	Since the silicone would be poured in a mold, we would have to make two pieces that attach. This seam would be a big breaking point for water	Since this would be a professional product, the silicone casing would be very durable.	Flex seal is intended to be used in water and in high traffic areas. We do not foresee any issues with durability
Effectiveness		The filament we have chosen is waterproof if combined with acetone.	Hot Glue is waterproof, but it would be nearly impossible to cover every hole in the design	Silicone would be very effective, but our own attempts would most likely not be very effective for waterproofing as it would be hard to make a perfect watertight mold, without creating a seam that would potentially be susceptible to leaks	Since this would be a professional product, silicone casing would be very effective.	Flex seal is intended to be used in water and in high traffic areas. We do not foresee any issues with effectiveness

Environmental Impact		3D printing combined with acetone would not add any impact to the environment. All of the acetone will be washed off of the container since the acetone is only used to modify the chemical bonds in the plastic. This design has been tested in both chlorine and salt water. It is safe for humans to be around, and there is no known chemical interaction to be aware of.	Hot Glue would be safe around humans, but it may break down when used in chlorine	Silicone can safely be used in salt water and chlorine; however, it may break down faster in chlorine.	Silicone can safely be used in salt water and chlorine; however, it may break down faster in chlorine.	Flex seal has chemicals that are harmful for both the environment and humans

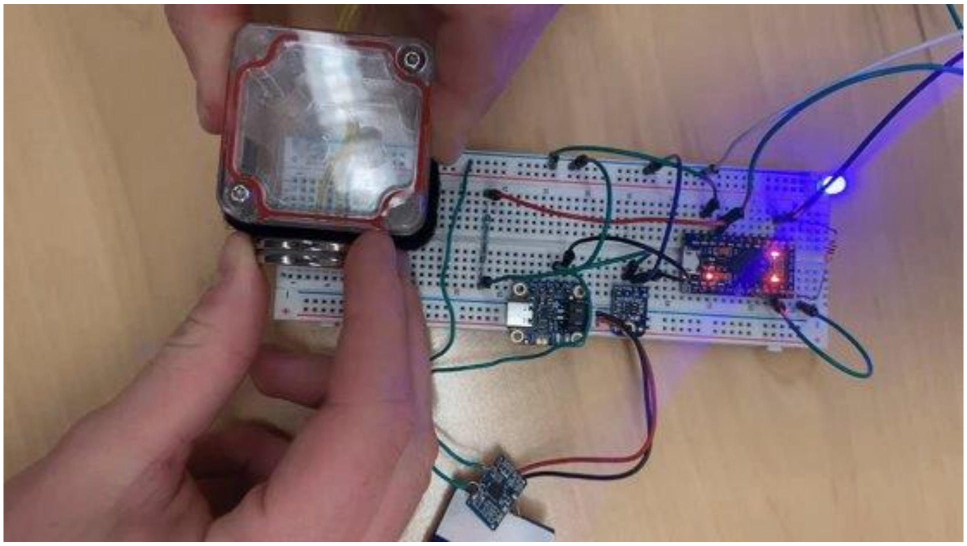
As can be seen above, based on the score of the decision matrix, we will be using the 3D printed filament specifically PETG along with acetone vapor smoothing to waterproof the tempo trainer and remote. The main reason for this decision comes from the fact that the 3D printed filament does not have any adverse environmental effects or effects on humans. More information, such as testing, will be discussed later on in this document.

The main issue with other ideas was that hot glue was too difficult to ensure waterproofing, a DIY silicone mold may have issues with production and ensuring waterproofing, a professional silicone mold is costly and time consuming, and Flex Seal contains dangerous chemicals.

<u>Circuit for Remote:</u>



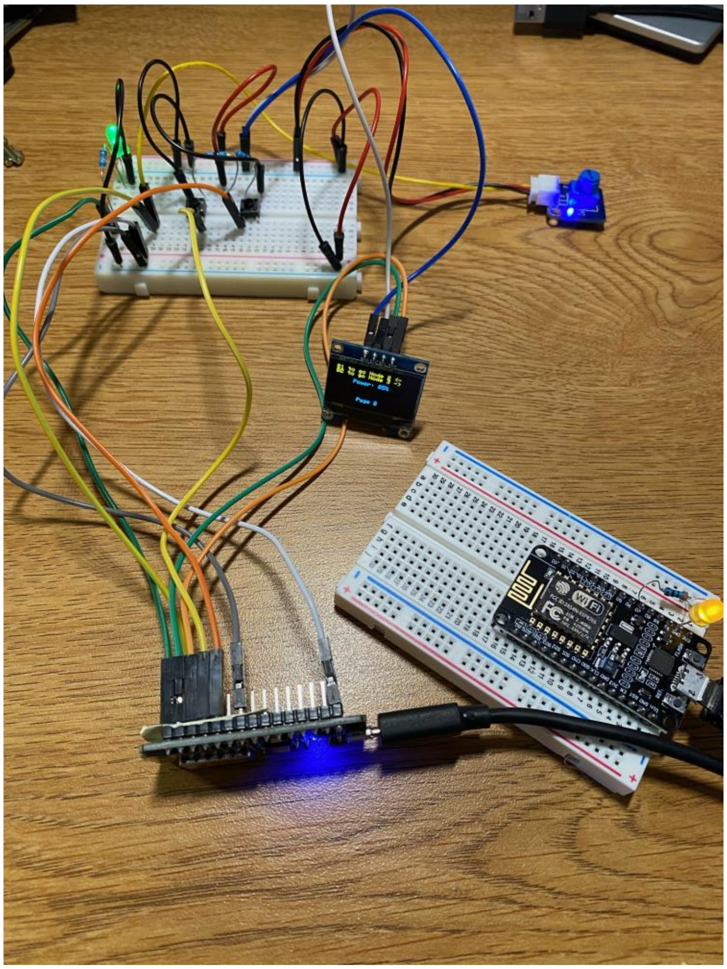
Circuit for Tempo Trainer:



The seventh prototype (Spring 2022) had the same exact configuration as the sixth but had the components of both the remote and receiver on a PCB design so that the circuit would be smaller and could fit within enclosures the user would use. We also incorporated a very easy way for the user to charge the battery that powers the remote and receiver using a wireless charger. The Tempo Trainer Circuit above shows the implemented charging circuit. The PCB designs were still being worked on at the time this prototype was made.

In the Spring 2023 semester, the eighth prototype was made. This protype included several revisions to the past prototype with improvements to the design of the tempo trainer and remote. The RF transmitter and receiver, along with the Arduino Pro Mini, were replaced with the ESP8266. The ESP8266 incorporates a configuration-free Wi-Fi mesh which is a big improvement from RF communication. In the image below you can see a prototype of the trainer and remote wirelessly communicating through a Wi-Fi mesh.

ESP8266 Prototype

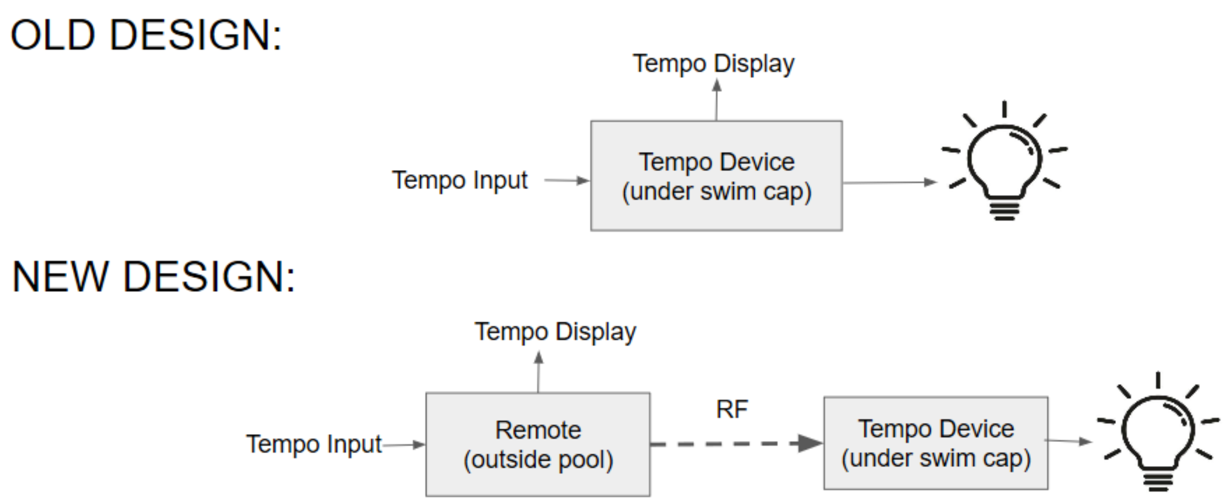


The team decided to use a specific ESP8266, the Feather Huzzah, which has an embedded charging circuit which could replace the previous charging circuit. The use of the Feather Huzzah also replaces the mode of charging from wireless charging to wired charging. Because of these large changes, the code being run on the microcontrollers also had to be updated to allow communication between trainer and remote to be efficient and effective. The team in Spring of 2023 also picked up where the past team left off and continued development of the PCB design.

CONCEPT CONVERGENCE

Over the course of the Spring 2019 semester, we tested the best way to communicate the tempo to the user. We wanted to test using a vibrational motor to see if we would be able to notice it. After attaching the device with a haptic motor to our arm, we were able to feel it. However, when moving, it was nearly impossible to notice the motor's vibrations, and we feel that a swimmer with their head and arm moving in and out of the water would not be able to feasibly feel this device.

During the Spring 2020 semester, the overall design of the tempo trainer was changed. We transitioned from one main device (Tempo Trainer) to two main devices (Tempo Trainer + Remote) as illustrated by the functional block diagram below.



Reasons for the Transition:

1. Design Want by Stakeholder

Our project partner wanted to have a separate remote, as very frequently her coach was the one changing the tempo.

2. No Need to Waterproof Buttons

On the previous design, buttons were placed on the Tempo Trainer so the user could change the frequency, and so the buttons needed to be waterproofed- which ended up being harder than initially first thought. With the current design, the buttons are placed on the Remote, which does not need to be waterproofed. Side Note: To turn on the Tempo Trainer, use the Low Power Mode Function.

3. Easier Waterproofing

With the current design, the waterproofing only needs to be completed on the Tempo Trainer box. The remote can be waterproofed to a lesser degree. It is assumed that the Remote would be used outside of the pool.

4. No Screen on Swimmer's Head

On the previous design, the screen to display the frequency was placed on the Tempo Trainer Device. Now, the screen and the electronics that goes with it, can be placed on the Remote.

5. Smaller Physical Design on Head

By no longer including the electronics for the buttons or the screen on the single Tempo Trainer Device, the size of the Tempo Trainer Device can be minimized.

Another design decision made in past semesters was the use of RF sensors for communication. There would be other options to communicate from the remote to the device, such as Bluetooth. Wowever, Bluetooth would be very difficult to set up with the connection to different devices. With the direct communication that RF uses, it involves no setup from the user, and our application is simple enough that using Bluetooth would not be necessary. Running Bluetooth modules is also much more current consuming than running an RF module. Past teams also decided to implement being able to send multiple RF signals in the code to go to multiple devices. Below are the Schematics of multiple RF signals being sent and the circuits.

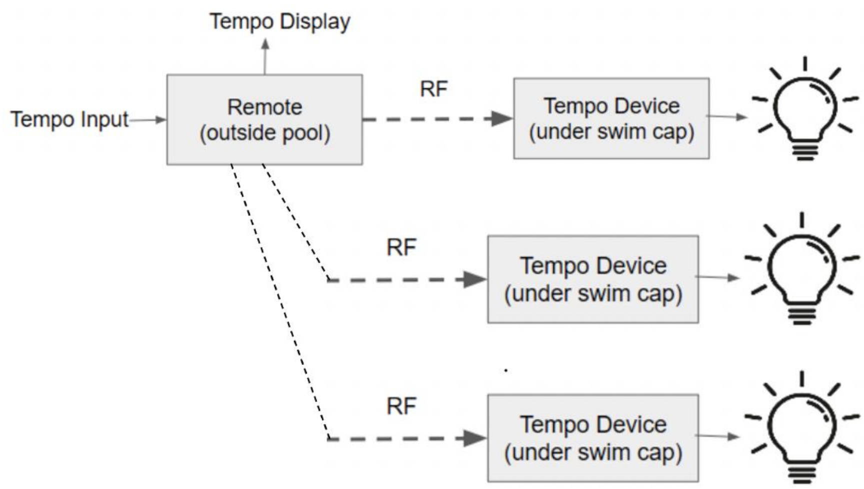
During the Fall 2020 Semester, KTT was able to implement the design of using a remote to send RF signals to the receiver which would then output the user tempo, as well as have the light flash signaling the stroke tempo to the swimmer.

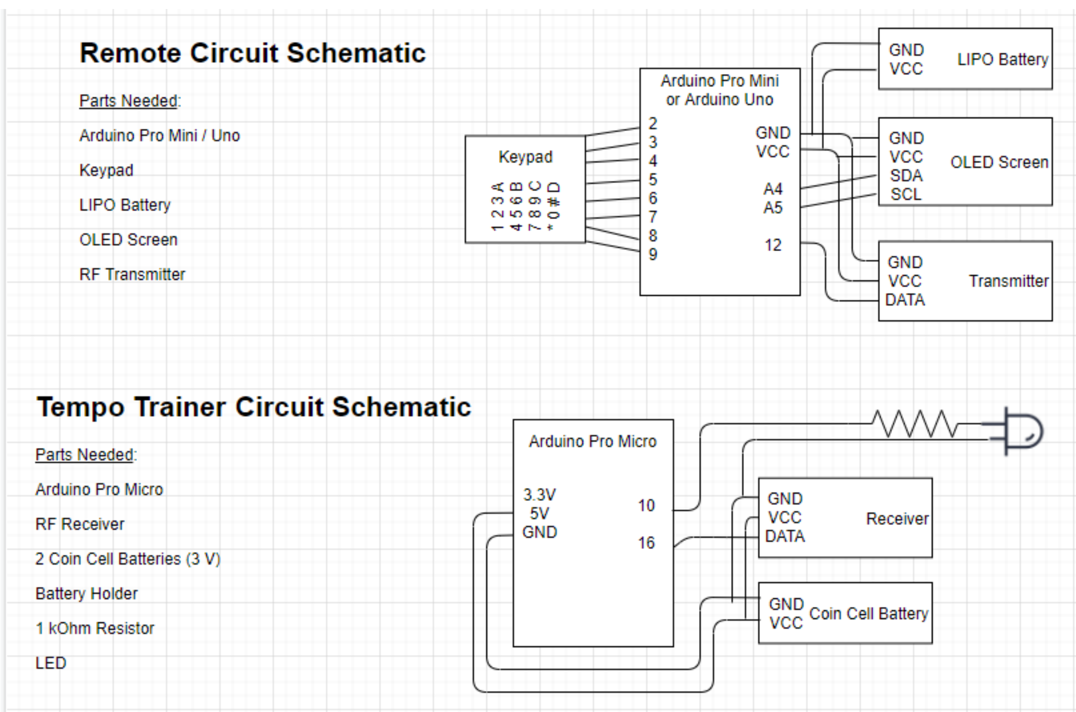
During the spring 2023 semester, after a deep dive into past technical notes, schematics, and pages upon pages of research, the team has decided to migrate from RF communication to a mesh Wi-Fi network. The reasoning for this includes:

- Wi-Fi has a much higher range of connection. A singular node-to-node communication can reach up to 500 meters. RF doesn't have the ability to even reach the end of an Olympic size pool (50 meters).
- Each tempo trainer would create its own personal Wi-Fi node which connects to every other tempo trainer and the remote via a mesh network.
- The mesh is much more flexible and programmable. It can detect what devices are connected and enable the user to be able to send a tempo to a single device, a tempo to several devices, or send a different tempo to several devices without having to input any sort of radio frequency or code.
- RF transmission is dependent on supplied power. The Arduino Micro supplies very little power which would further decrease the range of the RF communication. With an ESP8266 and Wi-Fi, the range is not limited by power.
- RF transmission with an Arduino requires external devices (RF receiver, RF transmitter) which leads to more production cost, production time, and more worries for waterproofing. However, the ESP8266 has built-in Wi-Fi modules.
- Data loss is inevitable due to RF transmission being a very faulty mode of communication. Wi-Fi is much more reliable.

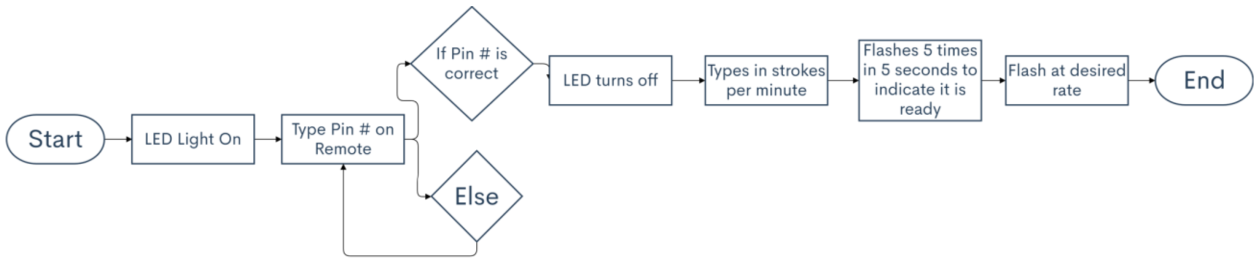
Updated schematics and flowcharts can be found below the 2020, 2021, and 2022 schematics in this section.

(2020)Schematic of RF Design:

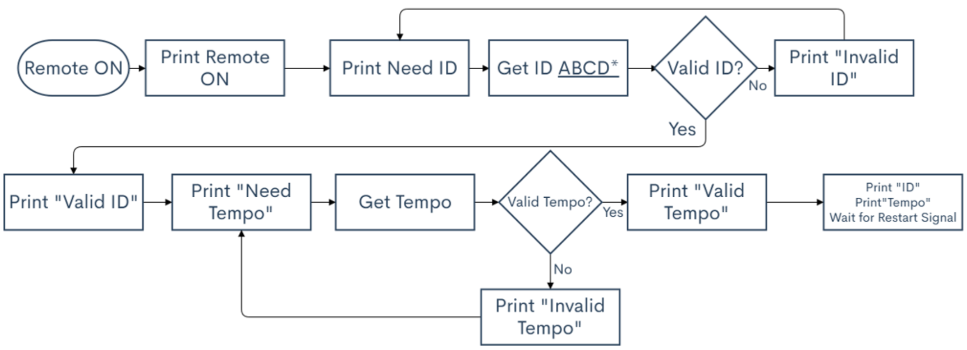




(2020)Flowchart for Tempo Trainer:



(2020)Flowchart for the Remote:



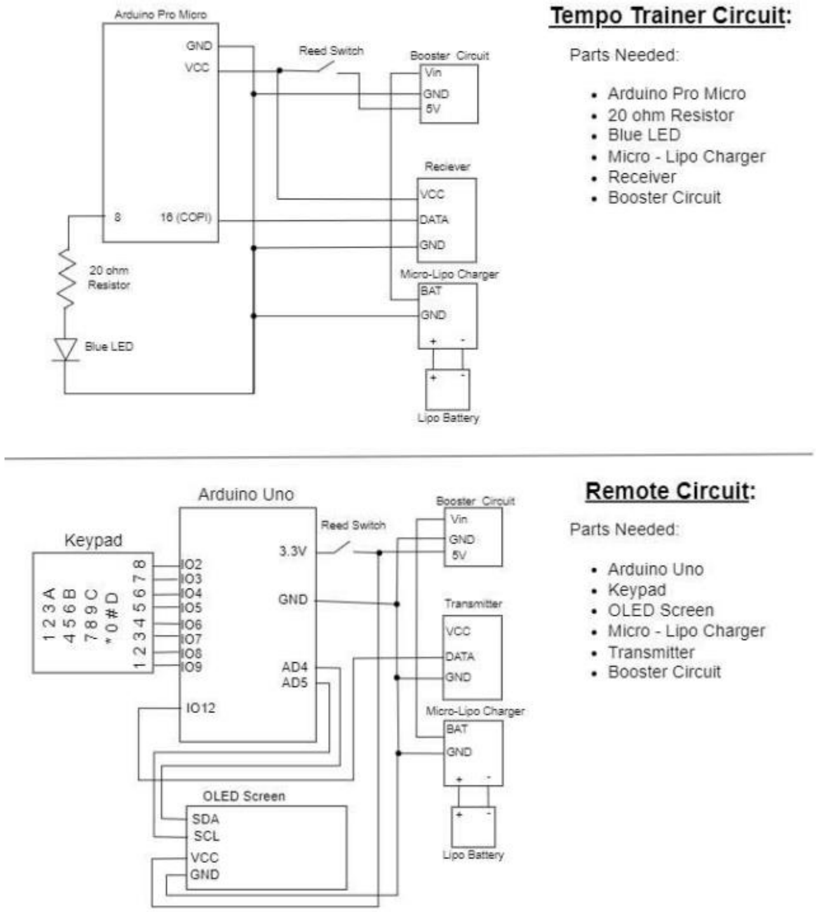
During the Spring 2021 Semester, it was decided to use a Wireless Charging Circuit to charge the batteries on the device. This was so the User would be familiar with the technology (like wireless charging a Phone) and so that the User would not be involved with the electronics inside either case.
Furthermore, it was decided that to turn on and off the devices, without opening or closing the electronic casings, we would use a Reed Switch and Magnet combination. When the magnet is placed on the device, the reed switch will close the circuit and the device will be on. When the magnet is not on the device, the device will not be powered on.

During the Fall 2021 Semester it was decided to add a feature to the code – a way to reset both devices from the Remote. This would be helpful when changing the tempo for a swimmer. Also, we decided to send all the codes (ID and Tempo) with the # button. We also decided that the Tempo Trainers IDs would be part of a list that we would give the user of the remote. We also decided to change the setting up flashes of the Tempo Trainer Circuit to only flash 3 times instead of 5 times.

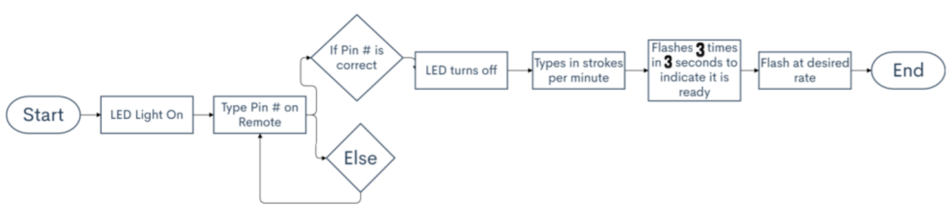
ID List = ABCD, ABCC, ABCB, ABCA, ABAB

Therefore, we changed the circuit schematics to add the connections to the charging circuits and the flowcharts to add the changes to the code as mentioned above.

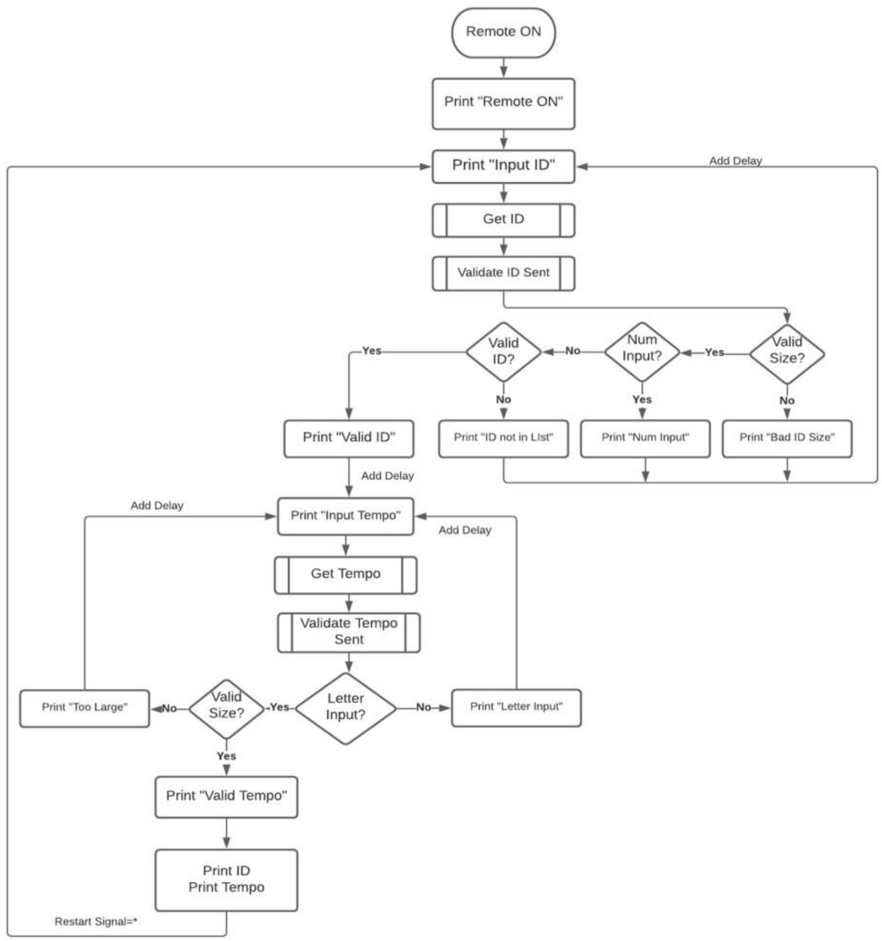
(2021)Schematic of Circuits:



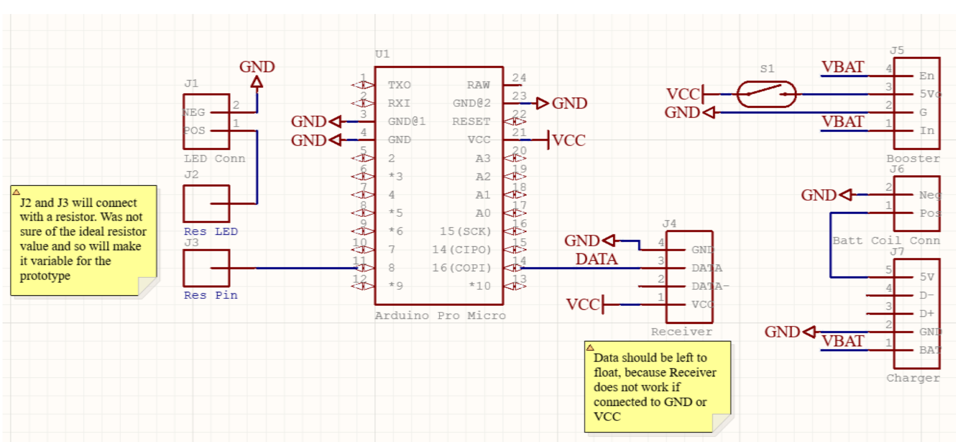
(2021)Flowchart for Tempo Trainer:



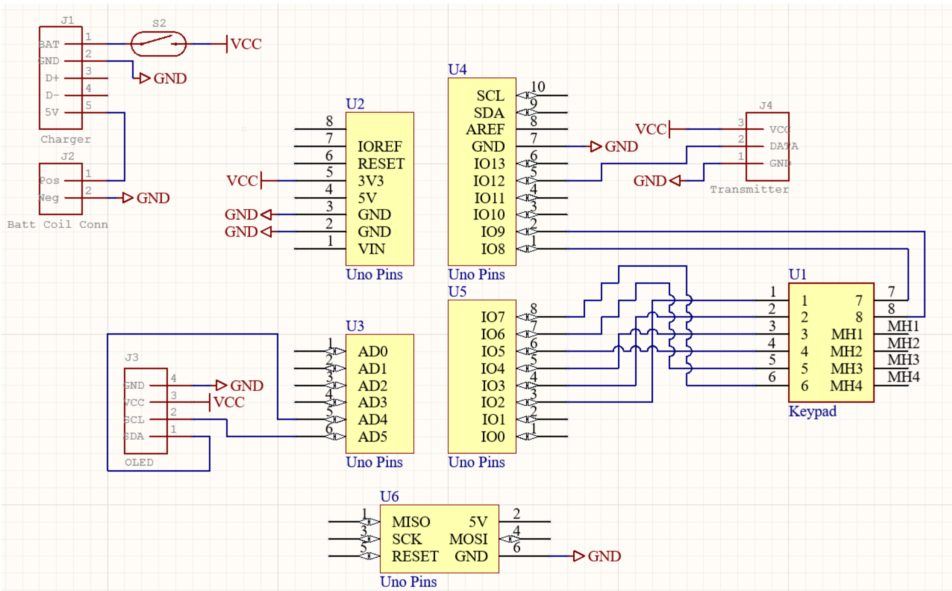
(2021)Flowchart for the Remote:



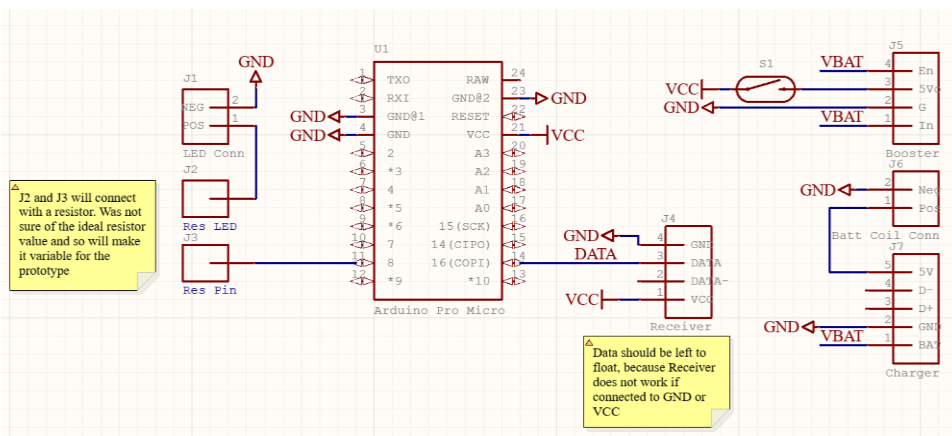
(2022)Schematic of Tempo Trainer Circuit:



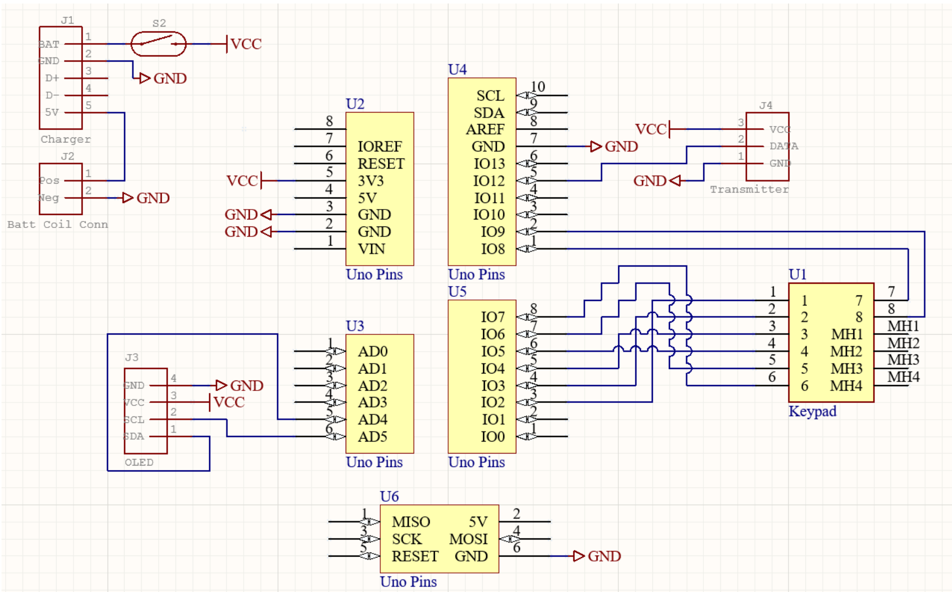
(2022)Schematic of Remote Circuit:



(2022)Schematic of Tempo Trainer Circuit:



(2022)Schematic of Remote Circuit:



For the Spring 2023 semester, it's been a year since KTT, the team, has been running, and with a new team, fresh perspectives, and varied skill levels, we've decided to reevaluate some of the design choices. This has led to many revisions and improvements to be made to the prior protype. The first of these changes is the communication protocol between the tempo trainers. We decided to switch from RF transmission to utilizing a Wi-Fi mesh; the reasoning for this change can be found in the table below.

(Spring 2023 Mid-Semester) RF to Wi-Fi Reasoning

RF	Wi-Fi
Low Range (~6 ft & less in water) * For past implementation	High Range (+1500 ft)
More expensive (~ $25)	Cheaper (~ $3)
External device needed	No external devices needed (less production cost/space/time)
Faulty – data loss	Connected theoretically forever
No built-in charging circuit	No setup, no need to connect to WiFi, programmable
Consumes less power (50 mAh)	Consumes more power (70-150 mAh)

As our team has seen in the technical notes and transition documents from Spring 2022, the current prototype doesn't have a functioning charging circuit component, and it doesn't produce the ideal amount of power. Because of this, the tempo trainer had a power boosting circuit. We've done some research on possible alternatives and found a new component that can push in the ideal amount of power and that should function as expected. The ESP8266 comes on many different board types with different features. The AdaFruit Feather Huzzah is an ESP8266 board that has an embedded charging circuit. With an embedded charging circuit, there will be no external circuit that could be faulty or broken. With the Feather Huzzah, no power booster is needed, and the only connection will be to a battery and to any components that need to be powered, such as the LED. For now, the current team wants to prioritize a working minimal viable product, so this will not include wireless charging. Instead, the charging will be wired, but wireless charging is a feature we would like to add back in the future.

(Spring 2023 Mid-Semester) AdaFruit Feather HUZZAH Reasoning

Reliability and Safety	Past charging circuit would overheat and was faulty. The HUZZAH allows us to ensure the battery will charge reliably and most importantly, safely, as it was pre-built to industry standards.
Cost	The cost of the microcontroller is significantly less than the previous semester's solution of Arduino Micro, radio, and battery charging module.

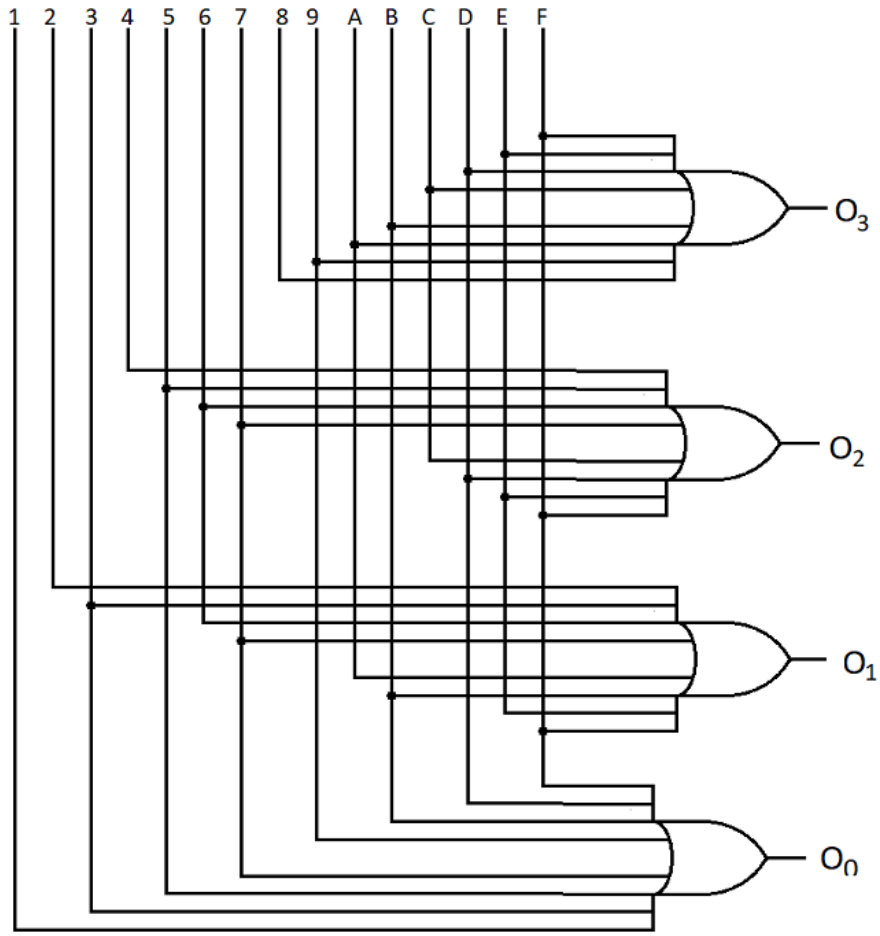
Compact	No external modules needed, unlike past design, so it all fits on one board.
Incorporates ESP8266	There is an ESP8266 embedded onto the HUZZAH.
No power booster needed	The HUZZAH outputs the correct amount of power, so no power booster circuit needs to be constructed.

We are also replacing the reed switch that powers the devices on and off to be more accessible and practical. The reed switch can interfere with cochlear implants due to the magnets which could possibly eliminate cochlear implant users from using the tempo trainer. Additionally, storing the magnet could also be logistically difficult; for example, when tempo trainers are being shipped the magnets would have to be stored separately from the devices, so they didn't turn on and drain batter. Because of these reasons, we will be replacing the reed switch with a different waterproof option. We have decided on using a flexible plastic or silicon that will cover an on/off button. This way, it is waterproof, intuitive, and does not have the same problems the reed switch had.

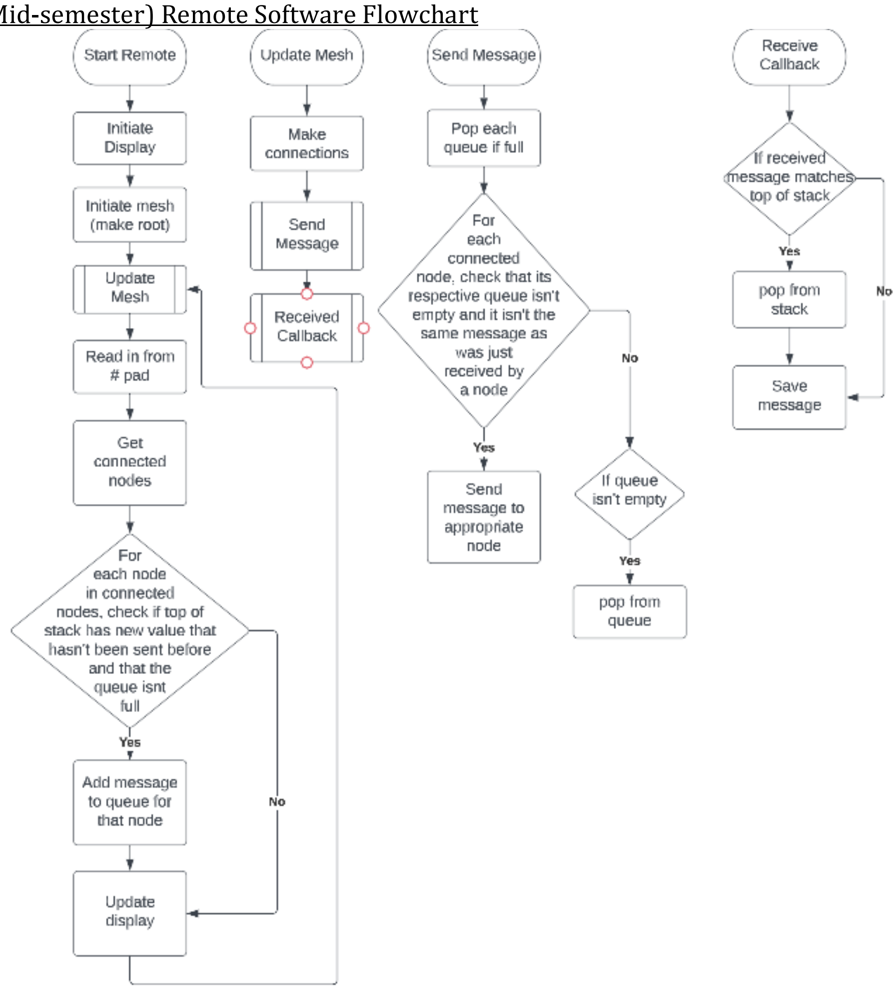
Lastly, the past prototypes had a very poor battery discharge time of an hour or less. Swim meets or practices can go for longer than an hour, so the current team decided to improve this by increasing the battery from a 500 mAh battery to a 2000 mAh. This should quadruple the battery discharge time and take up negligibly more space. Our updated schematics and flowcharts are presented below.

(Spring 2023 End-of-Semester) Number Pad Updates

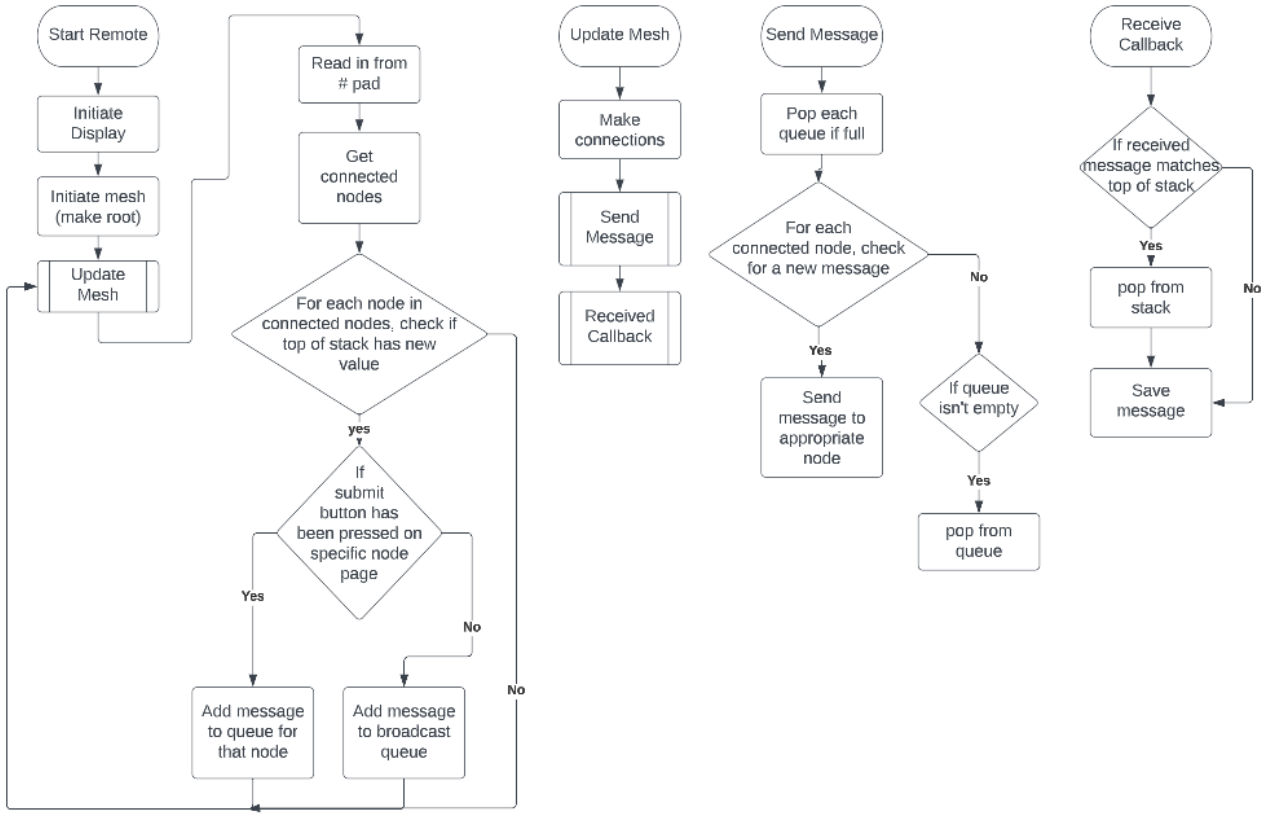
The previous design incorporated a pre-manufactured number pad to gather input data for the remote. This semester, this design will have to be modified. This is because the pre-manufactured number pad uses 8 pins and the HUZZAH only has 8 pins for GPIO purposes, and the OLED screen uses two of those. Additionally, we may want to add additional features in the future that use more pins. So, we needed to find a solution that utilized at most 6 pins. After testing a few different approaches, such as multiplexers, shift registers, and different encoders, we landed on using a 16:4 encoder. This solution fit every specification that we needed to hit. It only uses 4 pins, it allows for up to 16 input buttons (while we only need 14), and it costs less than a dollar to make while the original number-pad costs around 10 dollars. The schematic for the encoder can be seen below.



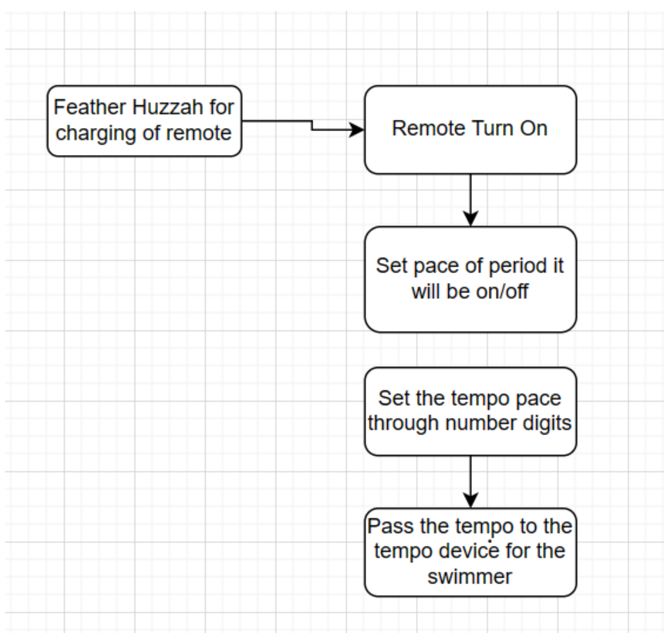
(Spring 2023 Mid-semester) Remote Software Flowchart



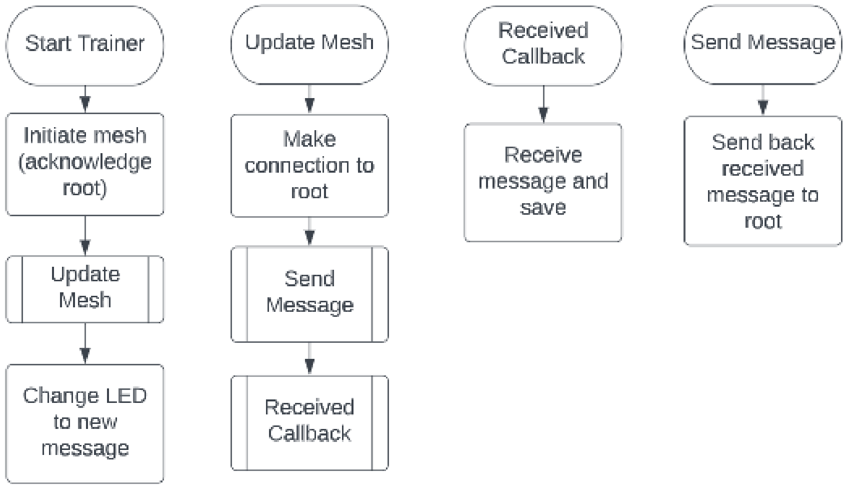
(Spring 2023 End-of-Semester) Updated Remote Software Flowchart



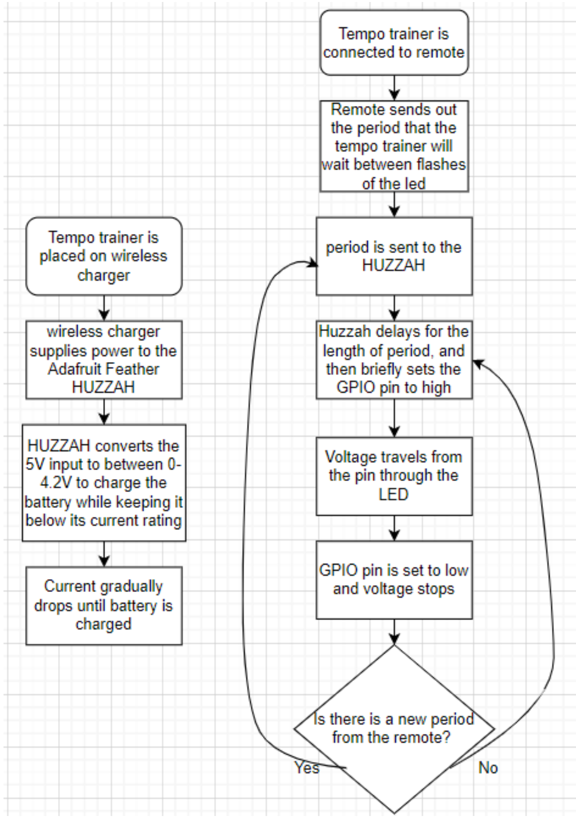
(Spring 2023) Remote Hardware Flowchart



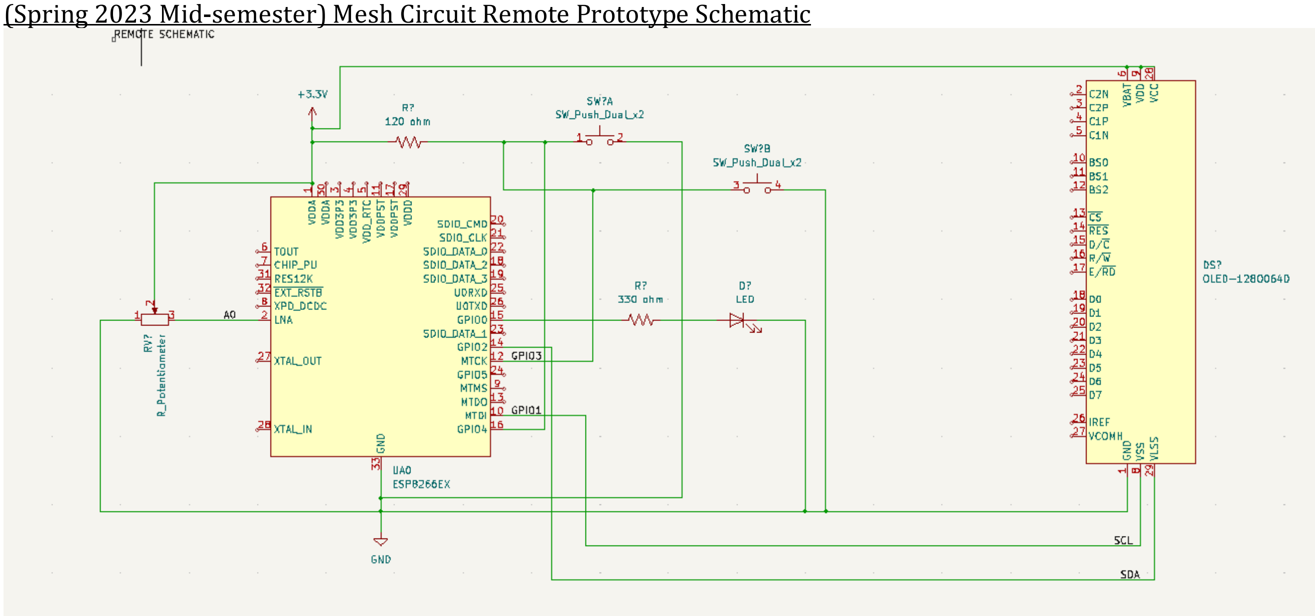
(Spring 2023) Tempo Trainer Software Flowchart



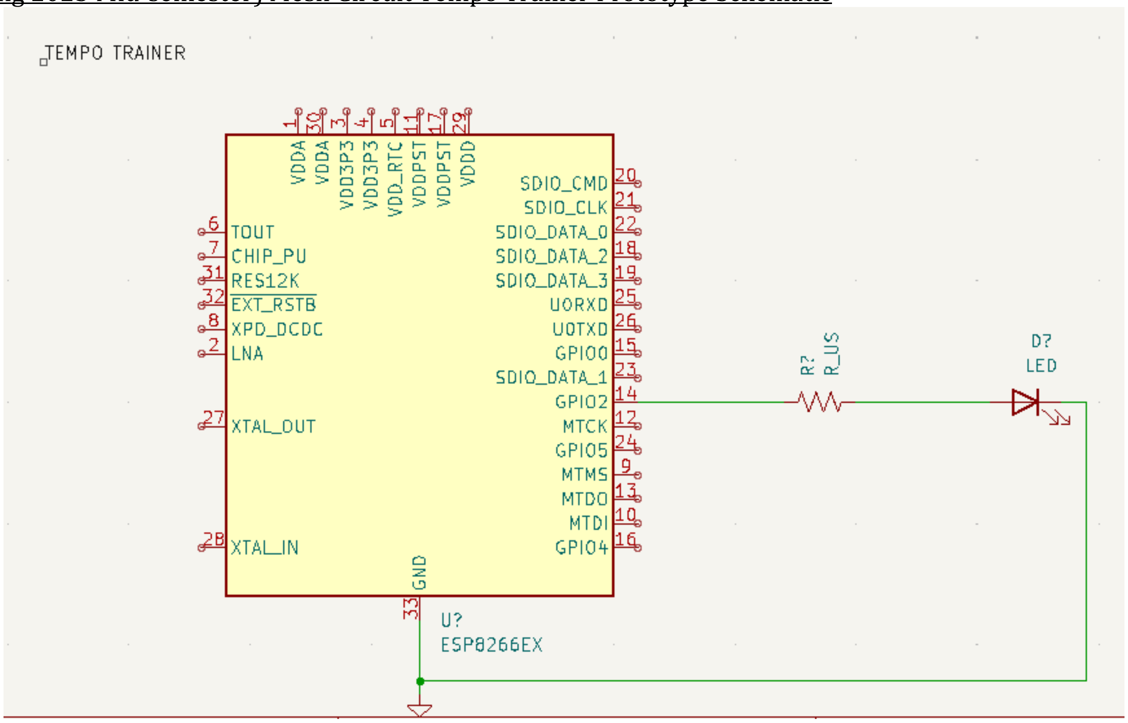
(Spring 2023) Tempo Trainer Hardware Flowchart



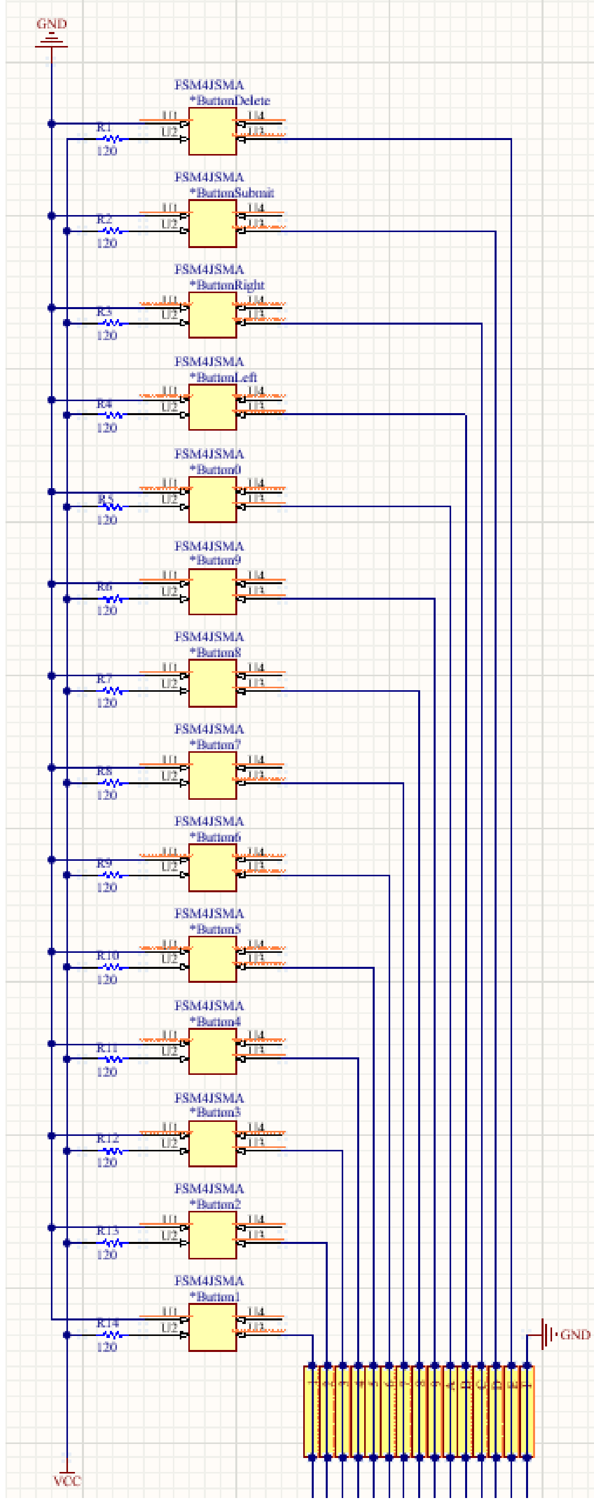
(Spring 2023 Mid-semester) Mesh Circuit Remote Prototype Schematic



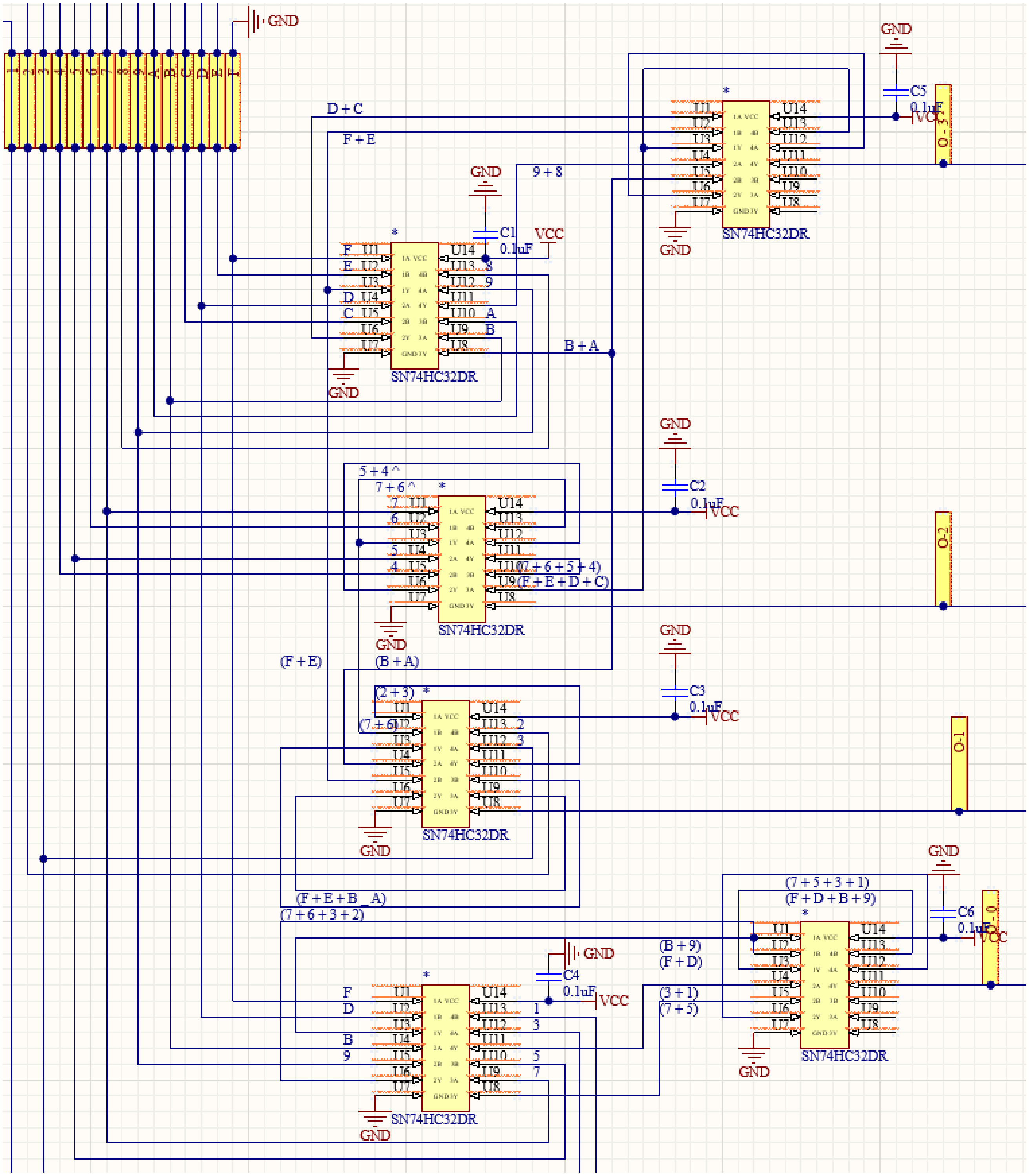
(Spring 2023 Mid-semester) Mesh Circuit Tempo Trainer Prototype Schematic



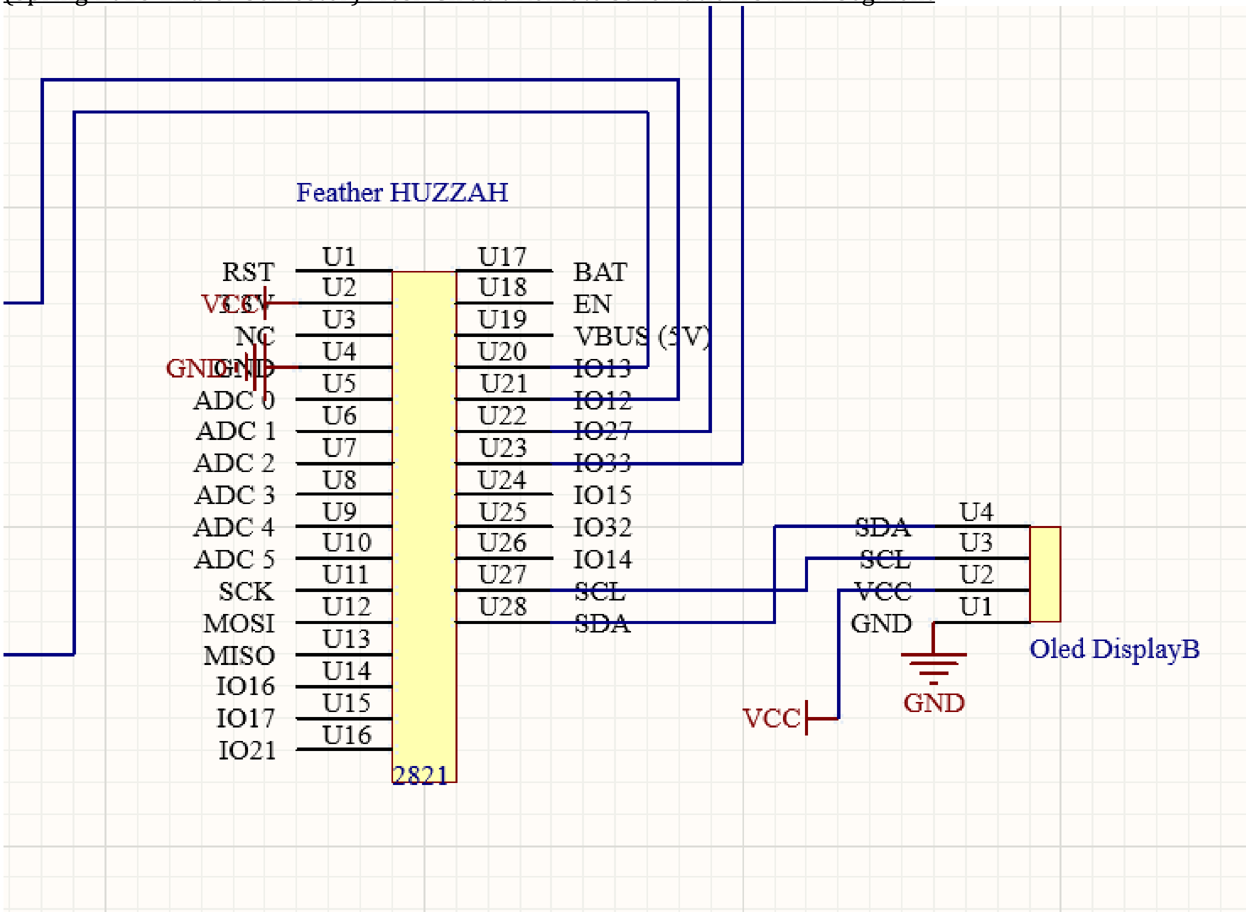
(Spring 2023 End-of-Semester) Mesh Circuit Remote Schematic Encoder Buttons Segment



(Spring 2023 End-of-Semester) Mesh Circuit Remote Schematic Encoder IC Segment

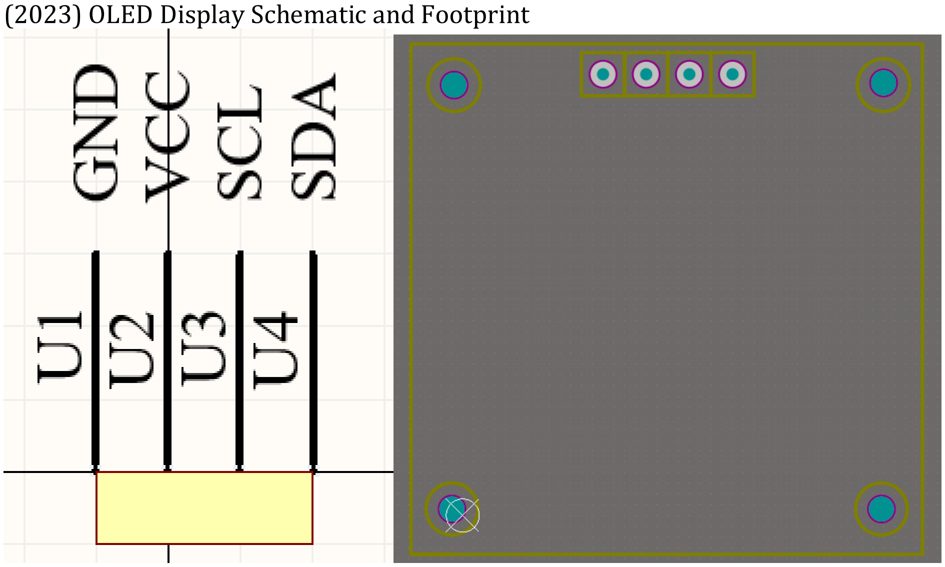


<u>(Spring 2023 End-of-Semester) Mesh Circuit Remote Schematic HUZZAH Segment</u>

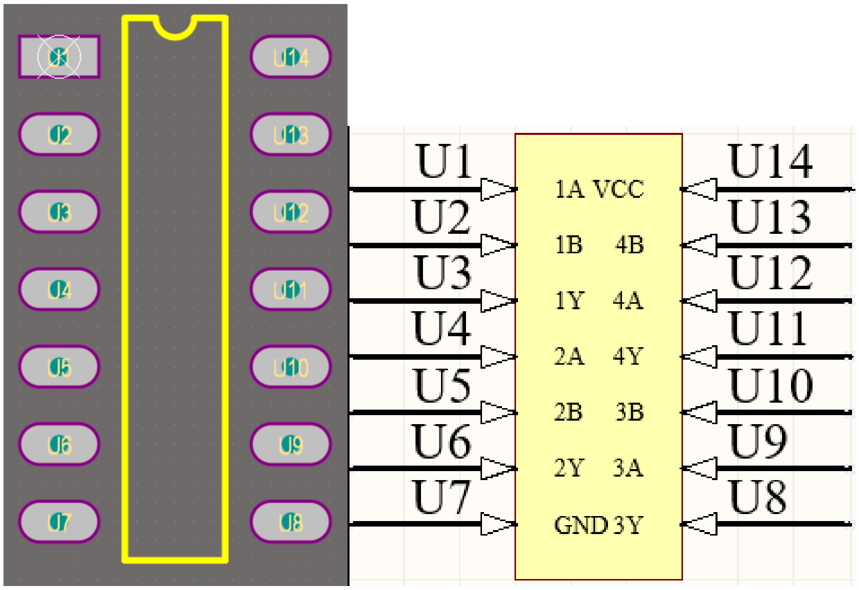


(2023) PCB files:

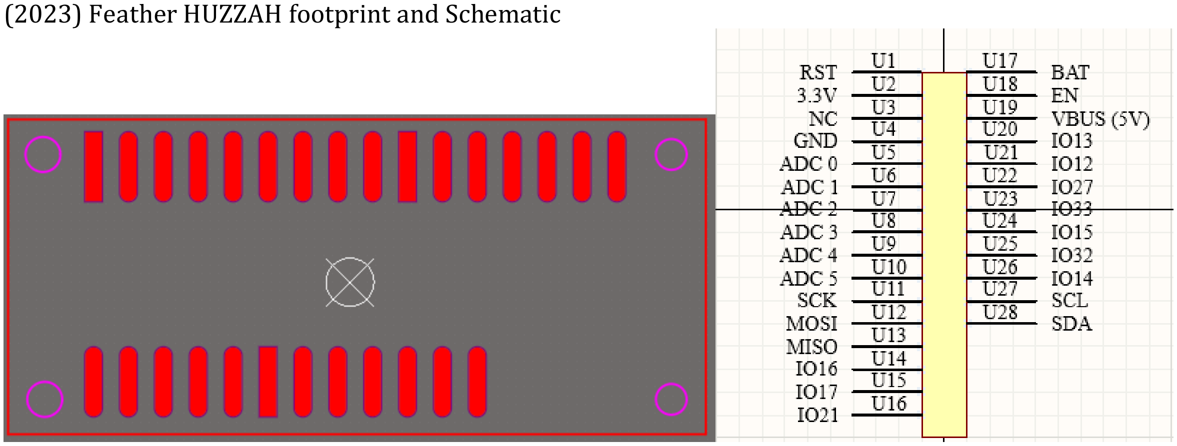
(2023) OLED Display Schematic and Footprint



(2023) OR-Gate footprint and Schematic

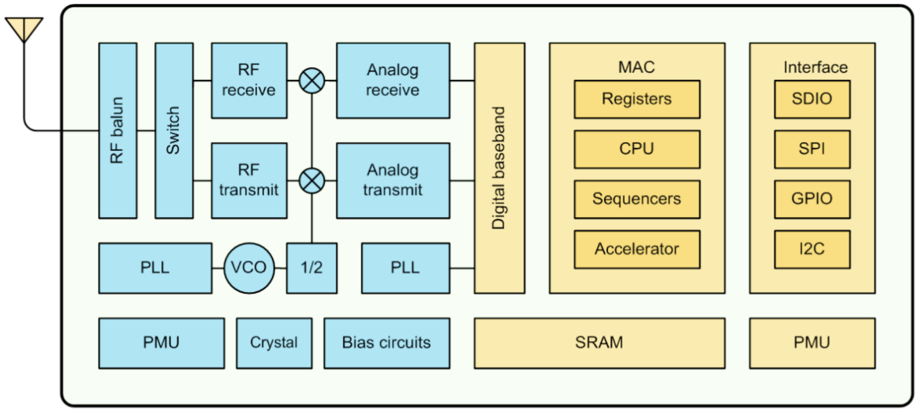


(2023) Feather HUZZAH footprint and Schematic



During the Spring 2022 Semester, the Schematics of the Circuits were altered (in terms of the charging circuit and some other connections) as shown below. The code was not altered.

(Spring 2023) ESP8266 Block Diagram



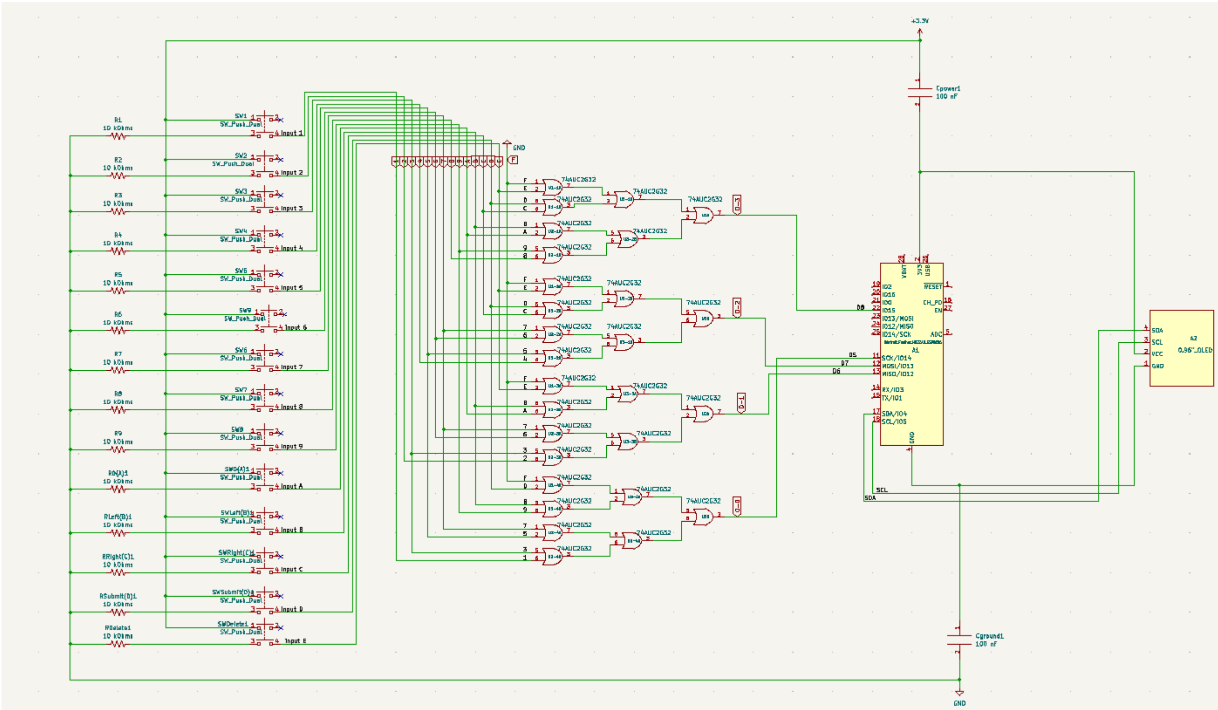
(Spring 2023) ESP8266 Power Consumption:

Parameters	Min	Typical	Max	Unit
Tx802.11b, CCK 11Mbps, P OUT=+17dBm		170		mA
Tx 802.11g, OFDM 54Mbps, P OUT =+15dBm		140		mA
Tx 802.11n, MCS7, P OUT =+13dBm		120		mA
Rx 802.11b, 1024 bytes packet length , -80dBm		50		mA
Rx 802.11g, 1024 bytes packet length, -70dBm		56		mA
Rx 802.11n, 1024 bytes packet length, -65dBm		56		mA
Modem-Sleep①		15		mA
Light-Sleep②		0.9		mA
Deep-Sleep③		10		uA
Power Off		0.5		uA

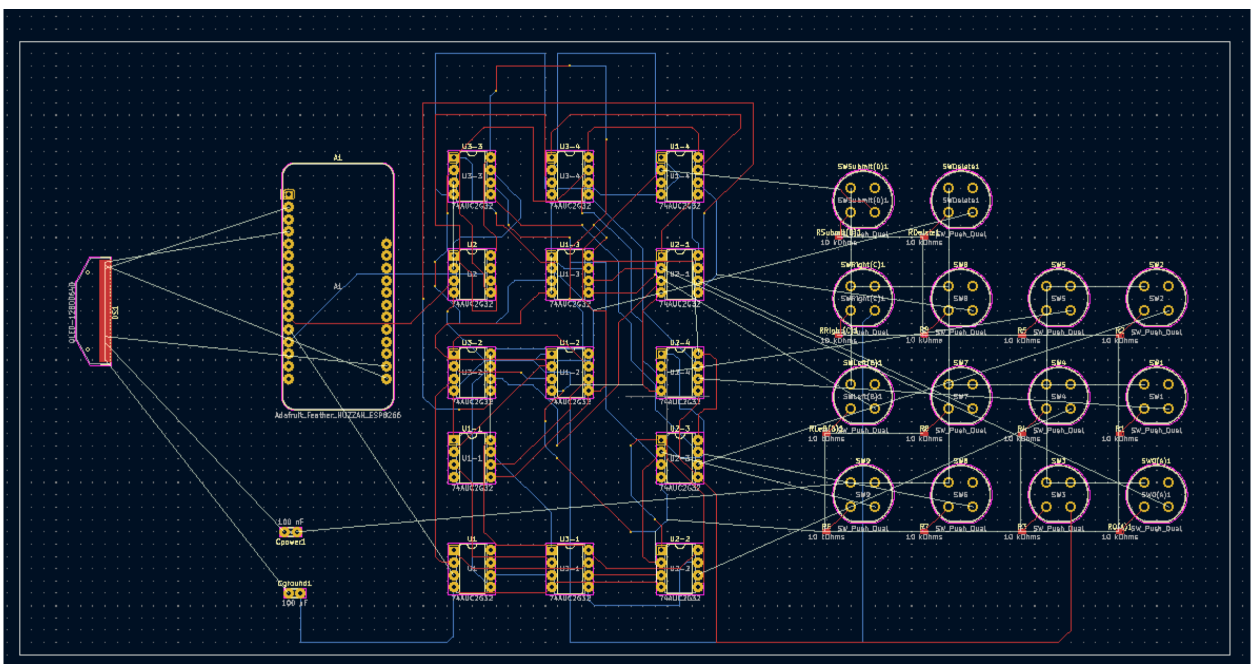
(Spring 2023) ESP8266 Wi-Fi, Hardware, and Software Parameters

Categories	Items	Values
WiFi Paramters	Certificates	FCC/CE/TELEC/SRRC
	WiFi Protocles	802.11 b/g/n
	Frequency Range	2.4G-2.5G (2400M-2483.5M)
	Tx Power	802.11 b: +20 dBm
		802.11 g: +17 dBm
		802.11 n: +14 dBm
	Rx Sensitivity	802.11 b: -91 dbm (11 Mbps)
		802.11 g: -75 dbm (54 Mbps)
		802.11 n: -72 dbm (MCS7)
	Types of Antenna	PCB Trace, External, IPEX Connector, Ceramic Chip
Hardware Paramaters	Peripheral Bus	UART/SDIO/SPI/I2C/I2S/IR Remote Control
		GPIO/PWM
	Operating Voltage	3.0~3.6V
	Operating Current	Average value: 80mA
	Operating Temperature Range	-40°~125°
	Ambient Temperature Range	Normal temperature
	Package Size	5x5mm
	External Interface	N/A
Software Parameters	WiFi mode	station/softAP/SoftAP+station
	Security	WPA/WPA2
	Encryption	WEP/TKIP/AES
	Firmware Upgrade	UART Download / OTA (via network)
	Ssoftware Development	Supports Cloud Server Development / SDK for custom firmware development
	Network Protocols	IPv4, TCP/UDP/HTTP/FTP

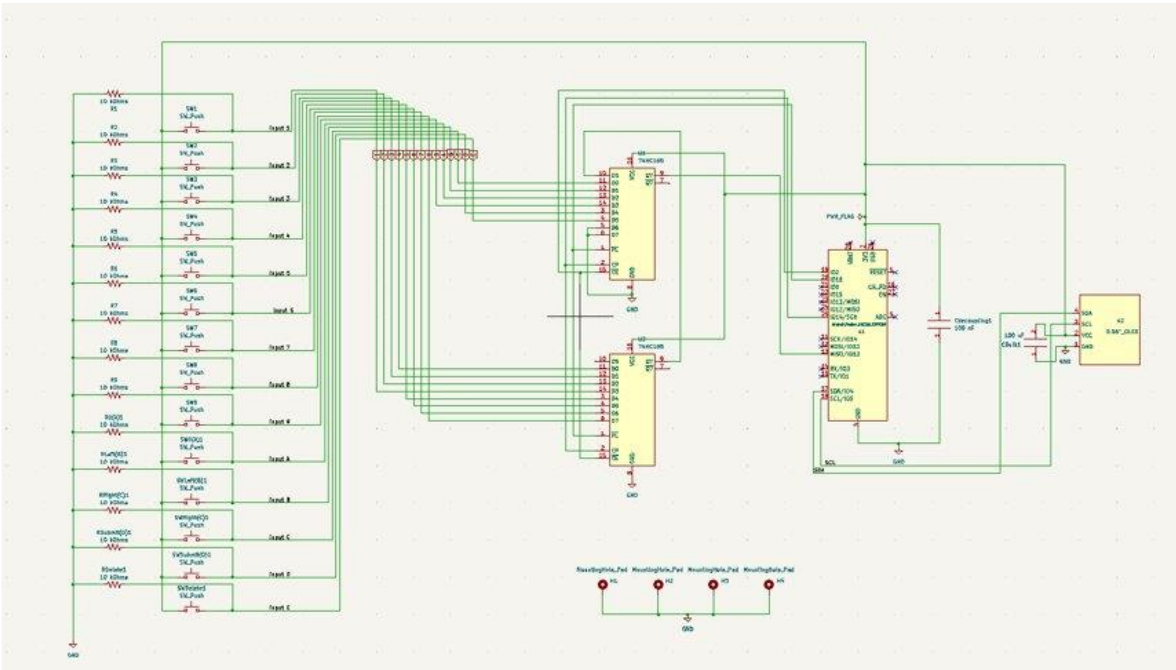
(Fall 2023) Remote Circuit Schematic at Midsemester



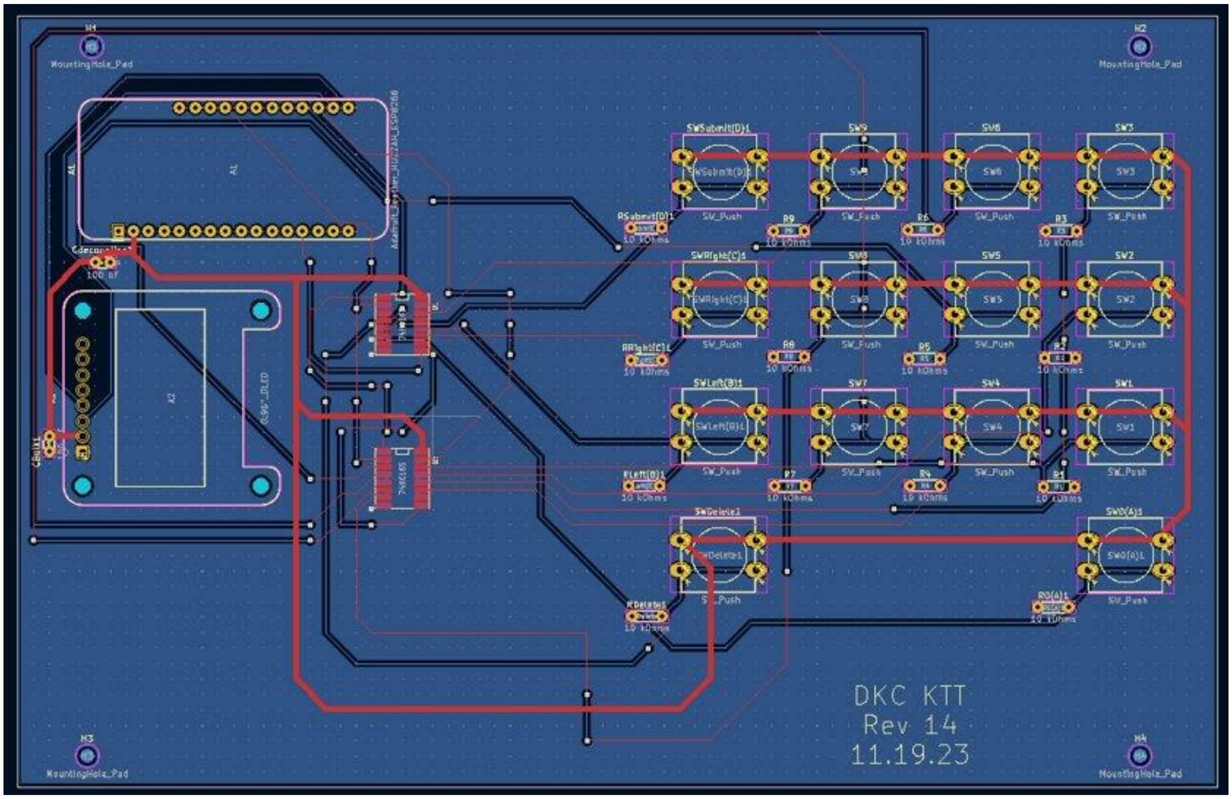
(Fall 2023) Remote PCB at Midsemester



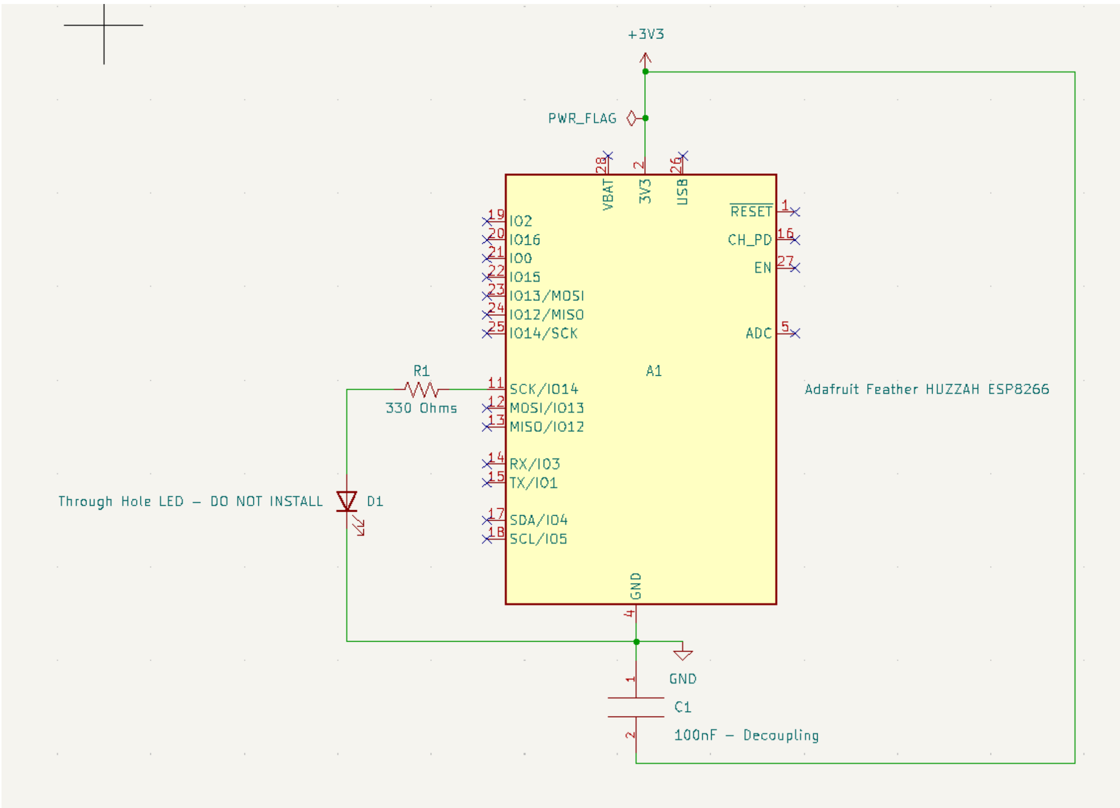
(Fall 2023) Remote Circuit Schematic at End of Semester: Pictured in this new schematic is our most recent circuit design component replaced the 15:4 encoder. The 15:4 encoder caused unnecessary complexity in the PCB design, and because of how complex it was, we were never able to fully test it via breadboard. The new solution that we've tested and know works well and efficiently is a shift register design that daisy chains two parallel in serial out 8-bit shift registers. It is also a cheaper solution too. This new design can be seen in the middle part of the schematic and PCB.



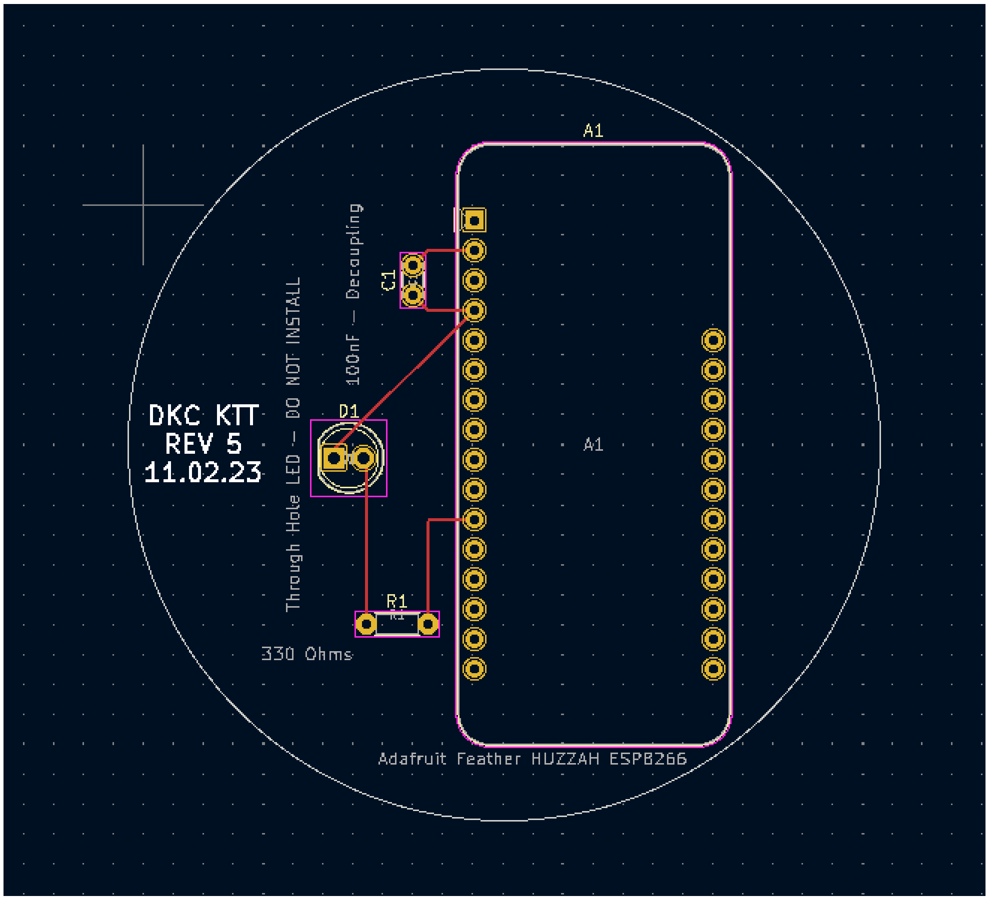
(Fall 2023) Remote PCB at End of Semester



(Fall 2023) Tempo Trainer Circuit Schematic at End of Semester

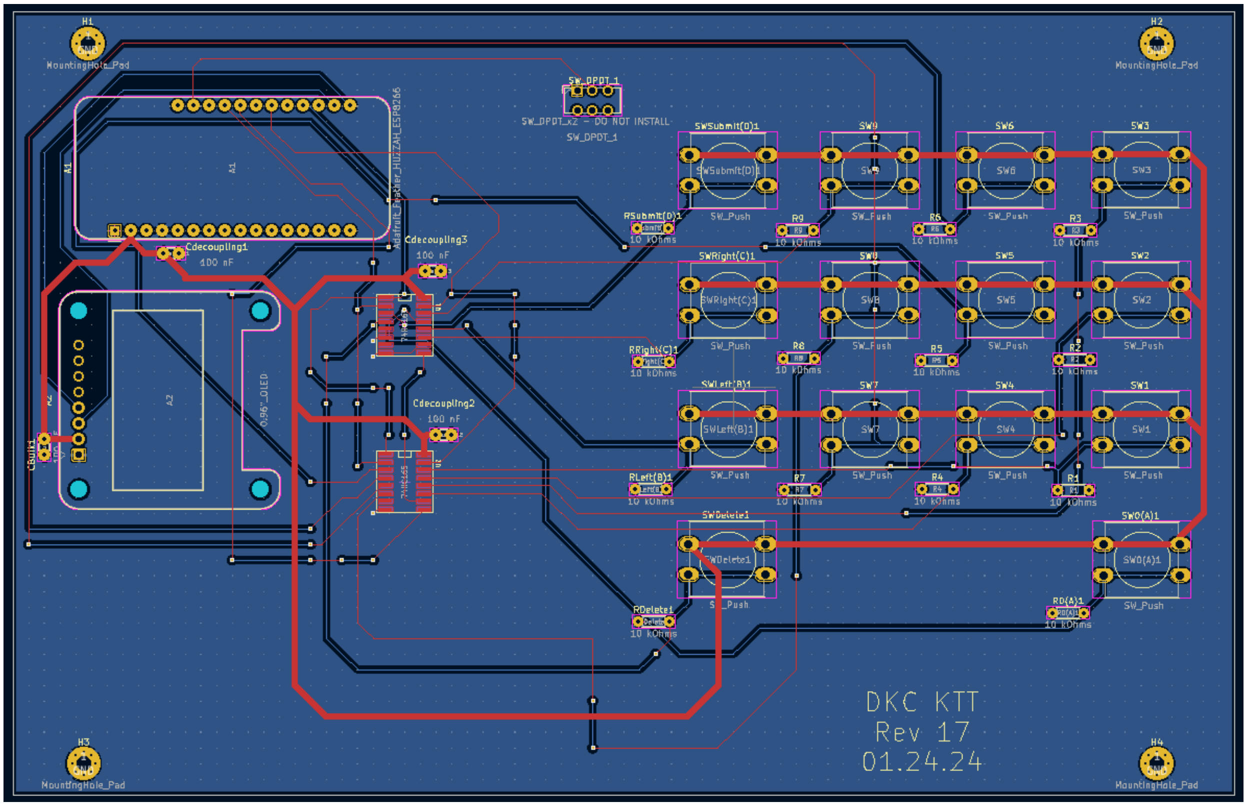


(Fall 2023) Tempo Trainer PCB at End of Semester



(Spring 2024) Remote PCB:

Several minor updates have been made to the remote schematic such as fixing the mounting holes, routing, adjusting decoupling capacitor placement, and also the addition of the power switch. The power switch will use a DPDT latched switch. This switch will not be soldered directly on the board and will instead be soldered on by wires to be placed off the board. The tempo trainer PCB is the same as last semester other than the addition of the same power switch.



OVERALL PROPOSED SOLUTION FOR KTT

The proposed solution is a small device, like a commercial tempo trainer, that utilizes an LED light pipe, made of an optical fiber, that will attach to the user's goggles. The device will have two main parts, the PCB sealed in an enclosure that should fit underneath a swim cap, and a flexible wire that goes from the PCB out of the enclosure that can be attached to the goggles or held in place near the swimmer's eyes. This product will also have a remote that allows a user outside of the water (e.g. the coach) to change the tempo of the device. It can be set poolside to allow the user to change it, so it will be waterproof as well. The remote will use a mesh Wi-Fi network to communicate the new tempos, which the small device on the swimmer's head will use the optical cable and LED to show the tempo. The remote will contain a keypad and a screen so that the user can type in the intended pace or frequency of the tempo trainer.

SECTION 4: DETAILED DESIGN

REFERENCES:

- Documentation: https://tinyurl.com/EpicsDesignProcessDocument
- Video Tutorial: https://tinyurl.com/EpicsDetailedDesign

BILL OF MATERIAL (B.O.M)

The below bill of materials includes general components necessary for the design. It does not give exact models as the "Detailed Design" phase of the design process is still occurring.

Currently Included:

Circuit Included	Name	Quantity
Both	LiPo Battery	2
	Adafruit Feather HUZZAH	2
	1.75mm TPU Flexible Filament for 3D printed cases	1kg Spool
	Resistors	15
	Gasket Material 12x12 inch	1
	Capacitors	4
	ICs	2
	Reusable Zip Ties	2
Tempo Trainer	LED	1
	Tempo Trainer PCB	1
	LED Light Pipe	1
	LED Light Pipe Mount	1
	Polyurethane PU Air Hose	1
Remote	0.96 Inch OLED Screen	1
	Remote PCB	1
	Push Buttons	14
	Heat set threaded inserts 4-40	4

	Stainless steel screws 4-40x5/8	4
Up to date as of 2/18/24		

PRINTS/SCHEMATICS/CODE

Code: https://github.com/mghera02/IoTMesh

Schematic: Shown Earlier in the Design Document.

MANUFACTURING AND ASSEMBLY PROCESSES

For the cases of our prototype, we plan on 3D printing. This will consist of modeling the cases in CAD. Next, the cases will be printed and tested to ensure that everything fits correctly. Finally, the models will be dunked into a container of acetone to finalize the waterproofing. We're currently working on developing our final plan for waterproofing and researching any potential implementations. We are also researching an epoxy-type material to waterproof the flexible LED light pipe. We're currently in contact with several industry members to find or design the ideal waterproofing material for our product.

For preliminary testing of the circuit schematic, a breadboard model was assembled using the traditional 'plug and push' methods. This model was tested extensively to ensure the theory behind the design is correct. The breadboard model is temporary. The manufacturing of the prototype will be implemented next.

To create our prototype, a printed circuit board (PCB) will have to be made. The current manufacturer that our team has decided on using is called JLCPCB. This manufacturer was chosen for multiple reasons. First, the manufacturer has an extensive library and warehouse of parts; JLCPCB has over 350,000 parts available that our team would be able to utilize. In comparison, other manufacturers considered had libraries around 300 parts. Another reason we chose JLCPCB is due to the customer service. There is a live chatroom available for any questions or issues we may have, and the website is incredibly detailed. Even our most difficult questions were answered in minutes. JLCPCB had comparable features to other considered companies as well, such as a program to consign parts. This allows us to send parts to them and have the manufacturer solder our components on the PCB.

The current estimate for production time is 24 hours, not including shipping. The minimum assembly is five PCBs, so we have opted to have five constructed for the initial prototype testing. Once the PCB has arrived, we will assemble the PCB, adding any finishing soldering or parts to the design. Finally, we will put the PCB inside the waterproof cases.

RISK ANALYSIS

Source	**Hazard**	**Parameters**	**Danger Zone**	**Mitigation**
LiPo batteries	Fire	Rate of charging	Near region of battery	Proper storage Use trusted and verified charging circuits Proper charging rate
LED	Seizure, headache or nausea	Flashing frequency	User's eyes	Setting a maximum flash frequency Keeping the brightness reasonably low
Water	Electronics damage and risk to swimmers	Quantity/depth of water, salt vs. Fresh vs. chlorinated	In pool	Proper waterproofing techniques Regular inspections of device
Device construction	Health impacts	Device material, amount of current, kind of battery	Next to user's head	Use proper padding around device Improve geometry of device
Improper Documentation	User error	Amount of device use explanation Type of explanation used	N/A	Proper documentation Test group Research

VERIFICATION

To be completed.

VALIDATION

To be completed.

SECTION 5: PROJECT DELIVERY

USER/SERVICE MANUAL

To be completed.

DELIVERY CHECKLIST

To be completed.

CUSTOMER SATISFACTION QUESTIONNAIRE

To be completed.

RECORD OF PROJECT DELIVERY

To be completed.

SECTION 6: CURRENT SEMESTER RECORD

POINT OF CONTACT FOR FUTURE TEAM MEMBERS (E.G DESIGN LEAD)

Bree Kalina – Project Manager of DKC (gkalina@purdue.edu) - SCHEMATICS DESIGN & LED LIGHT PIPE DESIGN
Matthew Ghera – Design Lead (mghera@purdue.edu) - SOFTWARE & SCHEMATICS & PCB DESIGN

Andrew Hall – Project Partner Liaison (hall657@purdue.edu) - PARTNER CONTACT & TEMPO TRAINER CAD DESIGN

Christopher Miotto – Financial Officer (cmiotto@purdue.edu) - MATERIALS & WATERPROOFING & REMOTE CAD DESIGN

POINT OF CONTACT AT THE COMMMUNITY PARTNER ORGANIZATION

Shireen Hafeez – Founder of Deaf Kids Code, contact@dkc.org , shireen@deafkidscode.org, 765-491-4434
Mark Cronk – Associate with USA Deaf Swimming markcronk@deafswim.org, 210-997-8748
Rene Massengale – Director USA Deaf Swimming, renemassengale@deafswim.org, 717-885-7777
Brian Bennett – Head Coach for Gallaudet Swimming, brian.bennett@gallaudet.edu
Larry Curran – Volunteer Coach for Gallaudet Swimming, larry.curran@gallaudet.edu

POINT OF CONTACT FOR VENDORS

Mario Rossetti – Technical Sales Engineer at VCC, mrossetti@vcclite.com , 480-385-8658
Alex Clark – Application Dev Specialist at Permabond, alex.clark@permabond.com , 732-868-1372 x209

CURRENT PROJECT STATUS

Last semester (Fall 2023), we made a lot of initial development and ideating progress with the CAD designs, circuit schematic and PCB design, and waterproofing. This semester (Spring 2024), we are very focused on continuing the development from last semester, implementing individual components into our prototype, and testing. So far, we have wrapped up the designs for our circuit schematic and PCBs for both the remote and tempo trainer. Additionally, we have ordered the remote PCB and plan to begin soldering components and testing within the next week. We have also made a lot of progress with the tempo trainer CAD design. We have continued to make several iterations from our design from last semester. We are approaching a finished prototype for the tempo trainer CAD design, and plan to begin waterproof testing within the next couple weeks. Speaking of waterproofing, we have also spent time writing protocol documents for how we plan to waterproof test along with how procedure for waterproofing our CAD design. Lastly, we have wrapped up our research and ideation on how we plan to waterproof the LED light pipe into our design. The rest of this semester will be spent on continuing iterating on the remote and tempo trainer CADs, testing our PCB along with our software, ordering any new designs for the PCB if needed, and testing our design for waterproofing capabilities. Our stretch goal is to begin testing with test users by the end of this semester.

CURRENT SEMESTER PROJECT TIMELINE

GANTT Chart for the Semester Timeline:

Section	Task	Assigned To:	Anticipated work weeks	Date Started	Date Finished	Percent complete
Onboarding	Onboard new members to design and files	All	weeks 1-2	1/12/2024	1/16/2024	100%
	Onboard new members to PCB and circuits	All	week 2	16-Jan	16-Jan	100
Specification Dev	Budget Chart	Chris	week 2-3	24-Jan	1-Feb	100
	Order Components	Chris	week 4	26-Jan		50%
	Gantt Chart	Matt	week 2	17-Jan	19-Jan	100
	Waterproofing Testing Procedure Doc	Chris	week 2	17-Jan	19-Jan	100
	PCB Testing Procedure Doc	Bree	week 5			
	Software Testing Procedure Doc	Matt	week 6			
Conceptual Design	Create prototype circuit with power switch	Matt	week 2	14-Jan	19-Jan	100
	Add power switch into circuit schematics	All	week 2	14-Jan	19-Jan	100
	Add power switch into PCBs	All	week 2	14-Jan	19-Jan	100
	Research for LED light pipe	Bree	weeks 2-3	14-Jan	31-Jan	100
	Review and modify first iteration of remote CAD	All	week 2			
	Review and modify first iteration of tempo trainer CAD	Andrew	week 2	14-Jan	24-Jan	100
	Modify remote CAD design first x iterations	ALL	weeks 4-9	24-Jan		30
	Modify tempo trainer CAD design first x iterations	Andrew	weeks 4-9			
	Modify circuit schematics/PCBs if needed after 1st iteration	All	week 8-11			
	Add in LED light pipe port to tempo trainer CAD	Andrew, Bree	weeks 3-4			
	Add in LED light pipe design into goggles	Bree	weeks 6-7			
	Design review	All	week 7			
	Research and select screws and heat threaded inserts	Andrew	week 2	14-Jan	19-Jan	100
Detailed Design	SR daisy chain with HUZZAH testing	Matt	week 2	14-Jan	19-Jan	100
	Print first iteration of remote CAD	Matt	week 3			
	Print first iteration of tempo trainer CAD	Matt	week 3	24-Jan	24-Jan	100
	Test first iteration of remote CAD	Chris	week 3			
	Test first iteration of tempo trainer CAD	Andrew, Chris	week 3			
	Print x iteration of remote CAD	Matt	weeks 5-9			
	Print x iteration of tempo trainer CAD	Matt	weeks 5-9	2/4/2024		
	Test x iteration of remote CAD	Chris	week 6-week 10			
	Test x iteration of tempo trainer CAD	Andrew, Chris	week 6-week 10			
	Test usability of charging port pipes and modify solution accordingly	Bree, Matt	weeks 5-9			
	Adam review final version of first iteration of circuit schematics/PCBs	All	week 3	25-Jan	25-Jan	100
	Adam review final version of second iteration of circuit schematics/PCBs	All	week 11			
	Test LED light pipe integration	Bree	weeks 9-11			
	Test software	Matt, Andrew	week 8-11			
	Order first iteration of PCB	Chris	week 4	26-Jan	26-Jan	100
	Order second iteration of PCB	Chris	week 12			
	Solder other components of PCB	All	week 6-7			
	Test first iteration of PCB	Bree	week 7-9			
	Test second iteration of PCB	Bree	weeks 13-15			
Delivery	Update all documentation	All	weeks 14-15			
	Create updated user guide	All	weeks 14-15			
	Create new transition document for the next semester	All	weeks 14-15			

PROJECT SEMESTER ACCOMPLISHMENTS

Spring 2024 Current Semester Record:

Week #	Team Member	Task Completed	Design Process
Week 3	Bree	compiled research on the VCC mount and light pipe, 3d print filament	Conceptual Design
Week 3	Bree	constructed emails for VCC and PermaBond sales people for pricing/product info	Conceptual Design
Week 3	Chris	designed protocol for vapor smoothing	Conceptual Design
Week 3	Chris	designed protocol for waterproof testing	Conceptual Design
Week 3	Andrew	found hardware for the tempo trainer case assembly	Detailed Design
Week 3	Andrew	updated the tempo trainer case - CAD modeling	Detailed Design
Week 3	Matt	finished updates to remote schematic and PCB	Detailed Design
Week 3	Matt	sent PCB and schematic to Adam, made all requested changes from Adam	Detailed Design
Week 4	Bree	researching vcc product pricing from different distributors / stock	Conceptual Design
Week 4	Bree	selecting base vcc products for budgeting	Budget
Week 4	Bree	researching waterproofing solutions (plastic adhesives, resin, tpu, petg, pvc pipes)	Conceptual Design
Week 4	Andrew	created 2 new iterations to the tempo trainer CAD design	Detailed Design
Week 4	Matt	fixed new shift register circuit with sofrware	Detailed Design
Week 4	Matt	fixed new shift register map to microcontroller functions	Detailed Design
Week 4	Chris	filled out order requests for everything currently needed	Budget
Week 4	Chris	met with design lead to onboard onto CAD	Onboarding
Week 5	Matt	made software overview doc	Design Review
Week 5	Matt	printed new iteration of tempo trainer and modified version	Detailed Design
Week 5	Matt	worked on design document	Design Review
Week 5	Andrew	created new iteration of tempo trainer with all threading integrated	Detailed Design
Week 5	Chris	filled our more purchase requests for the project	Budget
Week 5	Chris	began working on remote CAD design	Conceptual Design
Week 5	Bree	sent out design review invites to more colleagues	Design Review

APPENDIX A: PAST SEMESTER RECORDS

Fall 2018:
John Sommerfeld – Design Lead (sommerfj@purdue.edu)
Connor Desser – Project Partner Liaison (cdesser@purdue.edu)
Midori Kisanuki – Project Archivist (mkisanuk@purdue.edu)
Julia Katz – Team Member (katz12@purdue.edu)

At this point, KTT did research and designed conceptual products. The two final designs were a vibrational band and light goggles. With either of these devices, the main component is a microcontroller that could take user input, show the tempo on a display, and control the rate of the motor or flashing light. The team used an Arduino Pro micro because it was very small and easy to code. Most of the progress from this semester was identifying stakeholders and researching and designing the constraints of the project.

Spring 2019:
Midori Kisanuki – Design Lead (mkisanuk@purdue.edu)
Kaitlyn Bultemeier – Project Partner Liaison (bultemei@purdue.edu)
Shawn Prosky – Project Archivist (sprosky@purdue.edu)

This time KTT decided to ditch the previous team's prototype because it was very poorly soldered together and was rushed. We decided to take apart the commercially available tempo trainer to see how it worked. It was extremely difficult to take apart; we had to use a dremel, saw, and drill press, all while being careful to not damage the components. We soldered wires to the battery leads and the output leads where the beeper was. We hooked up an LED to the outputs and basically created what we wanted our prototype to emulate. We even considered making our entire project just modifying the tempo trainers with LEDs and reassembling them. There are several reasons why we decided to not pursue this—check out the design review presentation slides for more information on why we didn't just modify the existing tempo trainer as our project.

Currently, our we have 2 prototypes whose wiring is identical. One of them is permanently soldered and compact, the other is spread out on a breadboard for ease of changing it. Also, instead of soldering a switch to connect the battery to the board, we decided to use a low power mode which is what the actual tempo trainer uses and it's similar to an iclicker. In other words, this is when the board is always technically on and connected to the battery, but draws negligible current (microamps) from the battery. This way we can make the board "wake up" when it is to be used. This is a better option we decided because pushbuttons are already present in the design and they are much easier to waterproof using a membrane or heat shrink tubing which would go around the whole board. See the next section for information about the code we used to do this and some of the problems we had/have.

Fall 2019:
Kaitlyn Bultemeier – Design Lead (bultemei@purdue.edu)
Lauren Risany – Project Partner Liaison
Yousuf Abbas – Project Archivist

During the Fall 2019 Semester, the team was able to create the basic idea for the prototype, which is shown below. The main benefits kept from this prototype were the wireless charging circuit and the new box idea for the device. The wireless charging circuit contains an IC from Adafruit, a Qi wireless charging unit also from Adafruit, and a LiPo battery. The charger and the IC are both industry standard. Using the Qi wireless charger ensures that the device will work with a standard phone charger, and the IC will also make sure that the device is safe, as it prevents the device from overcharging. One flaw of this design was that there was a LiPo battery near the head of the user, which could be potentially dangerous in the wrong conditions. The store-bought box was clear and waterproof, which allowed the team to see the display screen and not have to focus on waterproofing techniques. However, the circuit components did not fit well into the box, and the box was expensive and bulky (and so it would not be mass produced easily). A key decision was also made to switch from an Arduino Pro Micro to an Arduino Pro Mini. The Pro Mini runs on 3.3V instead of 5V and has an 8 MHz clock instead of 16 MHz. This ensures that the device draws much less current, but still has the same functionality as the Pro Micro.

Spring 2020:
Kaitlyn Bultemeier – Design Lead and Project Partner Liaison (bultemei@purdue.edu)
Shangyin Tan – Project Archivist (tan279@purdue.edu)
Julia Taylor – Team Member (taylo773@purdue.edu)
Jonathan Miller – Team Member (mill2459@purdue.edu)
Emily Chen – Team Member (chen3227@purdue.edu)
Seyi Akinwumi – Team Member (oakinwum@purdue.edu)

This semester, the overall design of the tempo trainer was changed. We transitioned from one main device (Tempo Trainer) to two main devices (Tempo Trainer + Remote). The enclosure designs for the tempo trainer and wireless remote were changed due to the increased access of 3D Printing and the change in the overall design. The designs themselves will be expanded upon in the Current Prototype Section, along with the additional 3D Printing Document. For the Tempo Trainer and the Wireless Remote to communicate, RF was implemented between the two devices. The Code and Circuits Document explains how to run and test the communication lines. One goal of the semester was to make the prototypes more producible, so to do that, PCB Design was implemented into the Tempo Trainer Device, more information can be found in the PCB Design Document.

Fall 2020:
Julia Taylor – Design Lead (taylo773@purdue.edu)
Connor Truax – Project Archivist (truaxc@purdue.edu)
Gabe Weidman – Project Partner Liaison (gweidman@purdue.edu)
Declan Jackman – Team Member (jackmand@purdue.edu)
Austin Gray – Team Member (gray294@purdue.edu)

We focused on making sure the circuits worked, planned out the waterproofing, and figured out how we wanted to turn on and off the devices. We also got a decent amount of code completed.

Spring 2021:
Julia Taylor – Design Lead (taylo773@purdue.edu)
Connor Truax – Project Archivist (truaxc@purdue.edu)
Gabe Weidman – Team Member (gweidman@purdue.edu)
Declan Jackman – Project Partner Liaison (jackmand@purdue.edu)
Austin Gray – Team Member (gray294@purdue.edu)
William Havel – Team Member (whavel@purdue.edu)
This semester we planned to focus on creating PCB designs for the circuits, finishing the 3D models of the cases, and finishing the code.

However, this semester didn't really go as planned. We ran into some issues with our conceptual design and inexperience of the team hurt progress. The main problems of the semester are listed below:

1. Charging the devices had not been thought of during the previous semesters.
2. RF had only been consistent within 6ft, so we wanted to find a way to increase that distance with antennas, however circuits themselves were inconsistent.

3. Team was unexperienced in PCB Design and 3D Modeling, so we had to take some time to learn how to complete those tasks.
4. PCB Design itself took up more time than expected, decided to switch to physically prototyping the circuits first instead of designing them.
5. Had to debug the physical prototypes and found another error in the circuitry (we needed to order another small circuit to add).

Now I will list what we were able to complete despite the problems aforementioned:

1. Charging Circuits: We found out what circuit parts we needed so that we can wirelessly charge the two devices, this means that the user will not have to open the waterproof case (this will decrease the chance of the electronics being ruined). This charging circuits also have lights to tell the user when the battery is charging and when it is done charging.
2. Base 3D Design for the Remote: We will need to adjust the height of this design and add a hole next semester, but overall, it is a good base design. We had decided to not use 3D printed material for the Tempo Trainer.
3. Turning On / Off Devices: We finalized how the user will turn on and off the devices by correcting the circuitry with a reed switch and ordering the correct magnets. We also planned on how to keep the magnets attached to the Tempo Trainer.
4. Physical Prototype for Tempo Trainer: We built a physical prototype for the tempo trainer which mostly works – it works when the power is from the computer, we will need a small circuit added so that it can work off battery power.

Fall 2021:
Julia Taylor – Design Lead (taylo773@purdue.edu), PCB Sub-Team
Tessca Almeida – Project Partner Liaison (talmeida@purdue.edu), PCB Sub-Team
Kirby Rich - Project Archivist (kdrich@purdue.edu), Code Sub-Team
Liam Kauffman– Team Member (wkauffma@purdue.edu), Code Sub-Team
Nick Harp– Team Member (nharpen@purdue.edu), PCB Sub-Team
Joey Attardo – Team Member (jattardo@purdue.edu), Code Sub-Team

This semester, we focused on creating PCB designs for the circuits, finishing the 3D models of the cases, and completing the code.

However, this semester didn't really go as planned. We ran into some issues with our conceptual design and the inexperience of the team using Altium hurt our progress. The main problems of the semester are listed below:

1. Understanding the current market offerings was incomplete in past semesters.
2. Understanding the magnetic interactions between cochlear implants and our reed switch is incomplete and hard to generalize.
3. The team was unexperienced in PCB Design and 3D Modeling, so we had to take some time to learn how to complete those tasks.
4. The components used in the circuitry did not all have datasheets, which was hard to implement in Altium.

Now we were able to complete the tasks below despite the problems aforementioned:

1. PCB Design: We are currently in the process of completing the PCB design although it will not be completed, we have imported the libraries and have partially completed schematics.
2. Added ID List: We have created a feature to set the tempo for multiple devices.
3. Sending Signals with #: The # key will be used for sending signals.

4. Resetting the Remote with *: The * key will be used for resetting the remote.
5. Segment user groups: In order to understand who will be using our product we created a user group segmentation so we can design with the end user in mind.

This semester we also had to re-analyze how our project works with the various audiences within the deaf and hard of hearing community, which unfortunately hindered this semester's progress. It was concluded that our product will focus on users who do not have a cochlear implant. Fortunately, some of the cochlear implant audience has a viable alternative by using a Metronome App which can connect to their cochlear implant using Bluetooth. However, those without Bluetooth – capable cochlear implants currently are not able to use our Tempo Trainer prototype, at least without further safety investigation.

Spring 2022:

Julia Taylor – Design Lead (taylo773@purdue.edu)
Kirby Rich - Project Archivist (kdrich@purdue.edu)
Liam Kauffman– Project Partner Liaison (wkauffma@purdue.edu)

This semester, we focused on finishing the 3D models of the cases, completing the user guide, and finalizing the design of the PCB boards.

Although we didn't have any major issues as compared to last semester, we still had some minor delays. In regard to PCB design, we were forced to push back the schedule of completion, because of size constraints of the tempo trainer. Beyond PCB design, we were able to complete a model of the CAD remote case, but after a faulty 3D print, we were forced to push back the completion date.

Now we were able to complete the tasks below despite some of these obstacles:

1. Finalized Altium Schematics for tempo trainer and remote.
2. Partially completed PCB Board design for tempo trainer.
3. Partially completed user guide.
4. Sent out user surveys and received feedback from both Cochlear Implant and non-Cochlear Implant users and reviewed responses.
5. Redesigned the 3D model of remote case.

Currently, we are still working on the design of the physical prototype of the remote PCB and enclosure. We have completed the code using multiple Tempo Trainer devices. We have finished analyzing how to recharge the lithium-ion batteries that we use to power the receiver and remote using a coil that goes in between the battery and the wireless charger.
Semester Project Timeline:

Week 1: General Introductions – Assigned Students to Specific DKC Teams (KTT or DKO)
Week 2/3: Introduced current state of project and describe its design to new members, determine overall goal for the semester, Outline sub-goals for the semester
Week 4: Began user guide and CAD research
Week 5: Prepared and practiced for Design Review
Week 6: Design Review Presentation
Week 7: Designed base of remote, Design schematics boards in Altium, Outline User Guide, Battery Testing
Week 8 / 9: Continued schematic design, User Guide, and CAD
Week 10: Completed schematics in Altium and began work on PCB Board Design
Week 11: Continued work on all fronts
Week 12: Continued work on all fronts
Week 13: Completed CAD design and Printed case
Week 14: Prepare and practice for Design Review, End of semester documentation
Week 15: Final semester Design Review

Spring 2022 Project Semester Goals:
This semester the team has three returning members and can get right back into work. There are many goals for this semester. The biggest goal of this semester is to complete a full working prototype. There are many small parts that go into this.

1. The PCB schematics and Board Designs in Altium must be completed, ordered, and received.
2. A new remote case (designed alongside the finished PCB Board) must be completed.
3. The user guide must be completed to go along with the finalized models of the system.

Spring 2022 Project Semester Accomplishments:

1. New remote case designed and completed.
2. Altium schematics completed, and PCB design has been started.
3. User guide outline made and able to be completed when devices are finished.
4. Battery testing began.

Spring 2023:

Bree Kalina – Design Lead / Project Partner Liaison(gkalina@purdue.edu) - SCHEMATICS DESIGN
Matthew Ghera – Tech Lead (mghera@purdue.edu) - SOFTWARE DESIGN
Andrew Schlabach – Project Archivist/Financial Officer (aschlab@purdue.edu) - PCB DESIGN

In the Spring 2023 semester, KTT was restarted after a semester of not running, and was restarted with a completely new project team. Because of this, the team spent most of the first few weeks onboarding and researching past documentation and ideas for the KTT, in order to develop a plan for the future. Through this process, the team identified many potential issues that would need to be addressed, including the use of radio frequency communication and the failures noted from it, the dangers of the wireless charging circuit section overheating, the faulty microcontroller, and more.

Specific schematic and circuit element changes are listed below:

- Arduino Uno → Adafruit Feather Huzzah ESP8266
- Wireless Charging Circuit → Rechargeable LiPo Battery in Microcontroller (Huzzah)
- Power Booster Circuit → Included Module in Microcontroller (Huzzah)
- Radio Frequency Communication → Wi-Fi Mesh Network Communication
- Reed Switch On/Off Switch → Push Button On/Off Switch

Spring 2023 Semester Goals:

- Receive new circuit components and construct tempo trainer and remote prototypes
  - Assemble on breadboards to check components
- Test components and record data
  - If issues, problem solve
  - Possibly order more materials with the extra money
- Finish tempo trainer and remote code
- Begin designing the cases for the remote
- Begin designing a PCB for the tempo trainer and for the remote
- Begin designing cases for the tempo trainers
- Get PCB laid out the way we want it
- Begin routing between components
- Set up onboarding resources to begin next semester with a smooth transition
- Collect survey results
- Find a company to manufacture our PCBs for when they're done

Spring 2023 Semester Accomplishments:

- Onboarded new team members, after 1 full semester without project running

- Reconnected with project partners with USA deaf swimming
- Began working with Gallaudet swim team, and coaches
  - Intending to work with them for testing later on in the project
- Redesigned battery and charging circuit
- Chose a different microcontroller, Adafruit Feather Huzzah
- Updated code so that tempo trainers can receive individual messages from remote
- Updated code so users can send messages to different nodes
- Updated schematics, created on KiCAD Eeschema
- Chose to use a 15 to 4 encoder for the number pad
- Onboarded onto Altium, began PCB design
- Designed footprints for the Huzzah and OLED display in Altium

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Fall 2023:

Bree Kalina – Project Manager of DKC (gkalina@purdue.edu) - SCHEMATICS DESIGN & LED LIGHT PIPE DESIGN
Matthew Ghera – Design Lead (mghera@purdue.edu) - SOFTWARE & PCB DESIGN
Clare Little – Financial Officer (little55@purdue.edu) - PCB MANUFACTURING & REMOTE CAD DESIGN
Ceci Kane – Project Partner Liaison (kane100@purdue.edu) - TEMPO TRAINER CAD DESIGN & WATERPROOFING

This semester, we worked on implementing all the design decisions from Spring 2023. We made a lot of progress on both the circuit schematics and PCB designs for the tempo trainer and remote. The tempo trainer is nearly complete for both the circuit schematic and PCB design. After a final review, we will be able to manufacture the PCB. In addition, the remote circuit schematic and PCB design are also nearly complete. All that is left is to implement the new design for the reading in the signals from the keypad and then commence our final review before manufacturing. We also made a lot of progress on the CAD designs for the tempo trainer and remote. The tempo trainer CAD design is also nearly completed; all that is left to do is to review the final design and test it once waterproofed. Research and sketches have been made for the CAD design for the remote. We also did some research related to how we were going to get the LED adhered to the goggles and decided on using an LED light pipe. Additionally, we selected the LED light pipe product that we will use. Lastly, we have also spent a lot of time researching and brainstorming waterproofing methods. For the tempo trainer and remote, we will be using small plastic pipes and caps for the charging cable to be placed, allowing for easy access and a waterproof design. We also found a solution for waterproofing both the tempo trainer and remote via using a 3D printed filament, PETG, and dunking the prints into a container of acetone. We have done preliminary tests with this design, and it was successfully waterproof. With this current status, we expect to start testing our PCB designs, CAD designs, software, and other mechanics of our products within the first quarter of next semester.

Specific schematic and circuit element changes are listed below:

- Premade tempo trainer design → CAD tempo trainer design
- 16:4 encoder number pad → Daisy chain shift register number pad

Fall 2023 Semester Goals:

- Onboard new members
- Research PCB manufacturers
- CAD tempo trainer case
- Finalize remote circuit schematic
- Create remote PCB
- Review remote PCB
- Create trainer PCB

- Begin creating remote CAD
- Order remote PCB
- Finalize remote CAD
- Order trainer PCB
- Begin software and hardware testing
- Reorder improved remote PCB if needed
- Wrap up semester work and documentation

Fall 2023 Semester Accomplishments:

- Onboard new members
- Researched and selected PCB manufacturer
- Finished 2 CAD designs for tempo trainer case
- Nearly finalized remote circuit schematic (missing new SR circuit design & final review)
- Nearly finished remote PCB (missing SR circuit design)
- Nearly finished trainer circuit schematic (missing final review)
- Nearly finished trainer PCB (missing final review)
- Researched and sketched remote CAD design
- Chose LED light pipe solution
- Chose charging port pipe solution
- Designed a new shift register based solution to replace 15 to 4 encoder for keypad