ChargeForge: Gang Charging System for Physiological Sensors

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Problem Statement

Due to a number of factors such as rising temperatures at military training sites and decreasing fitness level among recruits[1], a need has developed for physiological monitoring to protect the safety of service members. Thus, a new wearable device, specifically designed for occupational safety in environments like heat stress and confined spaces, is currently being developed for use in the Marine Corps. While still in development, there is currently no way to consolidate, transport, charge, or protect the devices efficiently. These tasks are currently accomplished using a hard-shelled carrying case, which provides protection but lacks any way to organize the devices or connect them with charging cables. Thus, the team is tasked to design and fabricate a gang-charging system that allows neat organization of the devices in the case, charging for every device in the case, and an easy to use design.

Background Information

Background

- There has been an increased number of heat related illness in military. In 2021 488 cases of heat stroke in the US military[2].
- Physiological monitoring device can proactively prevent symptoms of heat related illness by analyzing skin temperature and heart rate variability.
- Once a certain threshold is met the device can send a warning alert to the users of the device.
- Primarily created for Marine Corps
- With around 360 recruits per training cycle in the marines[3], there will be large amounts of devices used at once

Figure 1: Image of device with arm band attached

Motivation

Motivation

- Need to consolidate large quantities of devices for transportation and protect them in rougher carrying conditions
- There is a lack of effective charging for the monitoring devices
  - There is no way to consistently connect device to charging pins for efficient charging
  - There is a lack of large scale charging in a singular device
- Tray should be straightforward to use

Figure 2: Concept for tray that client imagined for solving problem

Design Specifications

Client Requested Functions

- **The final tray design should:**
  - Withstand 100 uses/month for minimum 2 years
  - Use POGO pins that are 9.3mm tall and ~2mm in diameter
  - Must supply 5V at 2.4 amps via USB-C protocol
  - Function from -30° to 37° C as marines train in variety of conditions
  - The combined weight of the case and tray should be less than 30 lbs
  - Firm fit of devices inside tray
  - Secure connectivity of device to POGO pins
  - Remain safe and functional in humidity/dust
  - Intuitive to insert device into tray and remove it

Figure 3: Image of POGO pins and dimensions required[4]

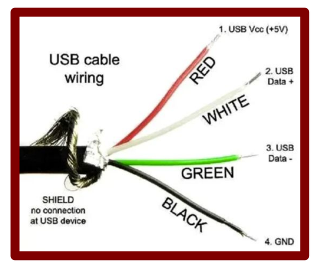


Figure 4: Inside of USB-C that is required to successfully connect to POGO pins[5]

*Information above as specified by client

Testing

- **Degradation Test:**
  - Simulated 1,200+ cycles of sensor insertion and removal to evaluate wear(approximately 1 year)
  - Measurements taken of dimensions of tooth every 200 uses using calipers to assess wearing
- **Security Test:**
  - Performed a drop test from 1 m to test if device stays in tray
    - Performed 10 trials in each slot for a total of 90 trials
  - Combined security and degradation by performing drop test in slot that simulated year of use
- **Electrical Performance Test:**
  - Measured voltage and current across pogo pins using a multimeter once wires were soldered to pins to ensure operation at 5V
- **Ease of Use Test:**
  - Conducted a usability survey with 100 participants using the System Usability Scale (SUS).
  - Timed each participate on how quickly they successfully inserted device into unit cell of tray

Figure 5: Dimensions of tooth that were measured for degradation test

Figure 6: Security Test

Prototyping Stages

Stage 1 - 3D Print Given Materials

Figure 7: Bottom of Current VigiLife Sensor Design

Figure 9: Top of Current VigiLife Sensor Design

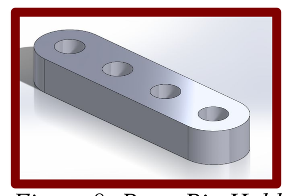


Figure 8: Pogo Pin Holder

Stage 2 - Preliminary Prototype

Figure 10: Unit Cell Design

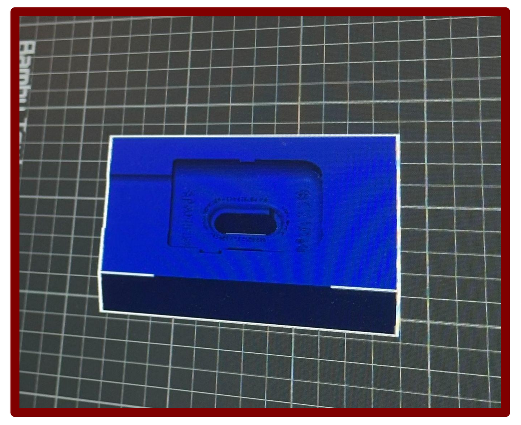


Figure 11: CAD Design of Unit Cell

Stage 3 Final Prototype

Figure 12: Closed Pelican Case

Figure 13: Half of Charging System

Figure 14: Charging System Within Pelican Case

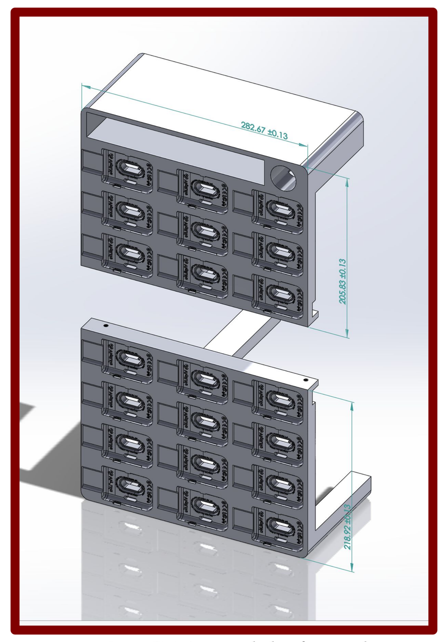


Figure 17: CAD Model of Final Tray Design

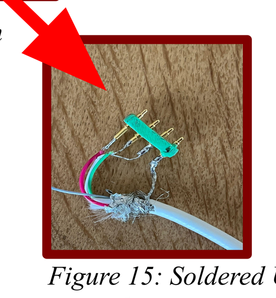


Figure 15: Soldered USB Into 3D Printed Pogo Pin Holder

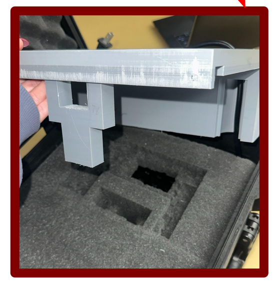


Figure 16: Padding Underneath the Tray

Figure 18: Mass USB-C Charging Port Within the Bottom of the Pelican Case

Results

- **Degradation Test:**
  - Original dimension 6.4mm x 1.03mm x 1.2mm
  - Width and height did not have a measurable change
  - The average wear-on length per use is 0.108 μm
- **Security Test:**
  - Device and pogo pins maintained connectivity in each unit for ten trials
  - After degradation, the test unit maintains connectivity for another 50 trials
- **Electrical Performance Test:**
  - Measured voltage was 5 to 5.21 V with vibrations and movement
  - Max capability of the current charging block allows for 8 devices to be charged at 5 V and 2.4 Amps
- **Ease of Use Test:**
  - 97/100 participants were able to insert the device within 30 seconds
  - The average time it took an individual to insert the device was 4.78 seconds

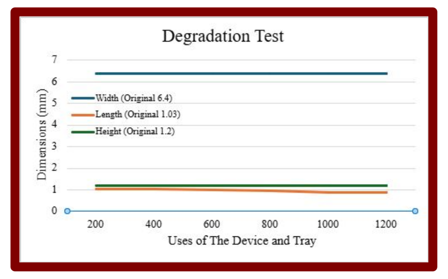


Figure 19: Degradation Test

Discussion

- **Design Limitations**
  - Device is currently in the prototype stage and is subject to change
  - Unable to test connectivity with the device
  - Large 3D prints are expensive, fail often, and less detailed
  - Injection molding is not available
- **PDS Criteria**
  - Final design was 5.17 kg < (10 kg)
  - Final prototype cost $287.64 < ($300)
  - Secure connection between device and tray
  - Delivered +5 V and 2.4 Amps for a single unit

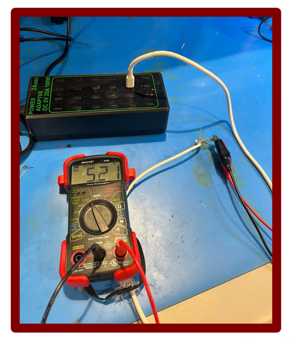
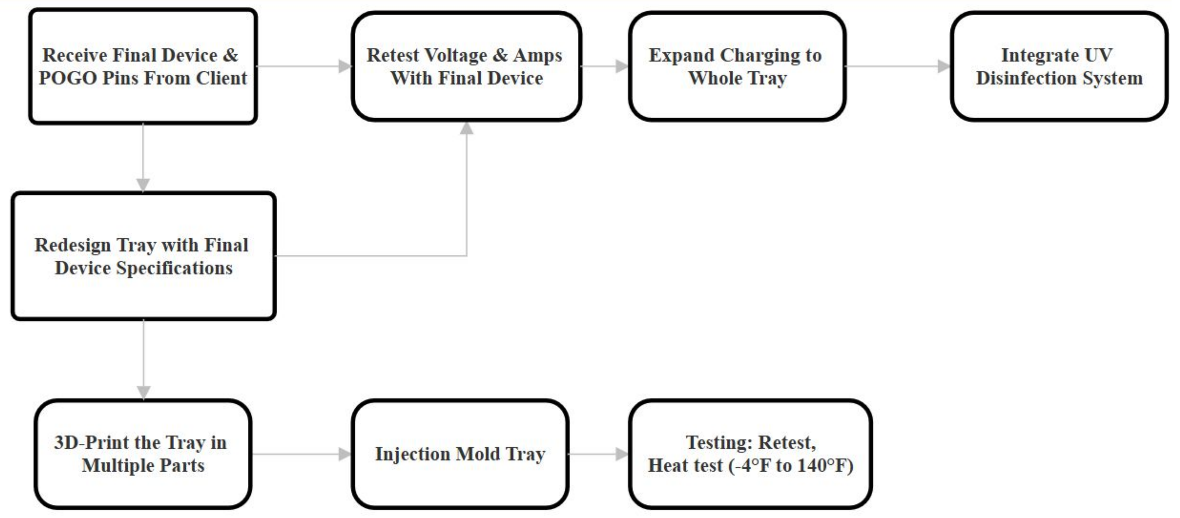


Figure 20: Measured Voltage

Figure 21: Print Failure of Final Tray Design

Future Work



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[1]C. Morrissey, “Heat Illness Prevention for Warfighters: MITHRIL’S Early Intervention System,” Aptima, Jul. 2024. https://www.aptima.com/mithril-phase-two-awarded/

[2] “Heat Illness, Active Component, U.S. Armed Forces, 2021,” Military Health System, Apr. 01, 2022. https://health.mil/News/Articles/2022/04/01/Update-Ht-MSMR (accessed Oct. 10, 2024).

[3]“One of Three Hundred,” 12th Marine Corps District, Oct. 13, 2022. https://www.12thmcd.marines.mil/News/Stories/Article/Article/3233876/one-of-three-hundred/ (accessed Dec. 05, 2024).

[4] Adam Tech, "PH-MVS-5370," *Digi-Key Electronics*. Available: https://www.digikey.com/en/products/detail/adam-tech/PH-MVS-5370/9831516

[5] “USB C Positive And Negative Wires Comprehensive Guide | Apphone,” Apphone, Jun. 2024, doi: https://doi.org/10855544045/WnaICMzV7O8ZEO3pqbgo.

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