TIRED TECHIES

Report 2 – Design Review

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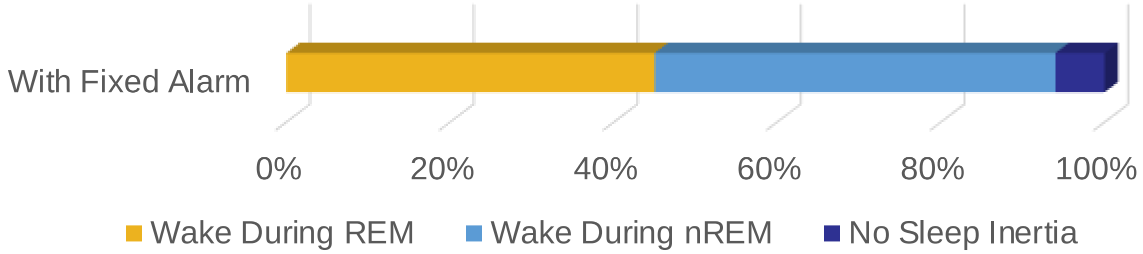
Problem

- Alarm clocks always wake users at a fixed time
- Being awakened during REM sleep can cause grogginess, formally known as "sleep inertia"

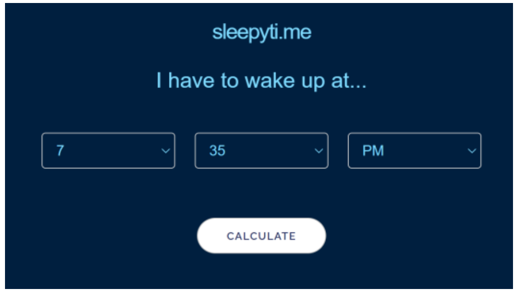


- Existing online "Sleep Calculators" that try to combat sleep inertia are very ineffective
- The problem is: when is the *healthiest* time for ***me*** to wake up?

Solution – Ready **E**very **M**orning Mask

- Current wearables:
  - ***Indirect*** method with heart rates, movement data, and machine learning
  - Estimation of sleep stages (~70% accurate)
- Our solution:
  - ***Direct*** method of measuring REM stages with eye movement during sleep; very accurate
  - <u>Goal:</u> wake users up on time, without compromising sleep quality
- We are unique in **TWO** key ways:
  - Can more accurately identify sleep stages, end of REM
  - Help users benefit from this data with "better" sleep!

Smart Watch



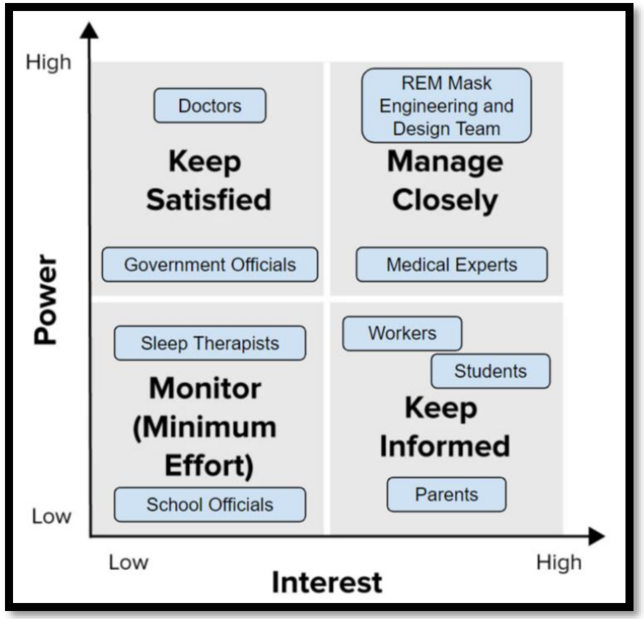
Sleepyti.me

Solution Description

- Product Overview:

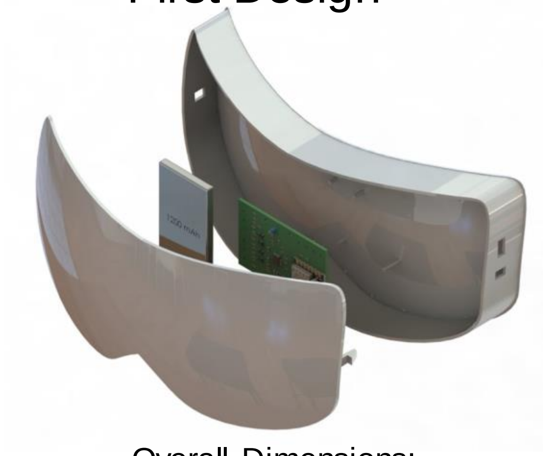
Mask gathers EOG sleep data → Data transmitted to mobile phone → Phone sounds the alarm

- Customer Requirements:
  - Fashionable, comfortable, affordable, reliable, intuitive
- Engineering Requirements:
  - Battery life at least 10 hours, max. charge time of 2 hours

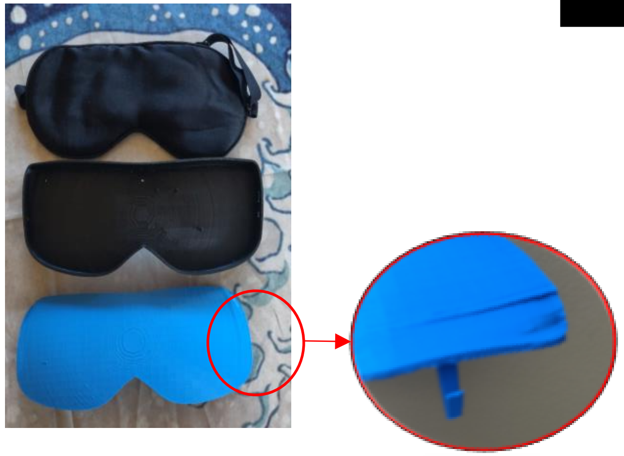


Prototype Design

First Design

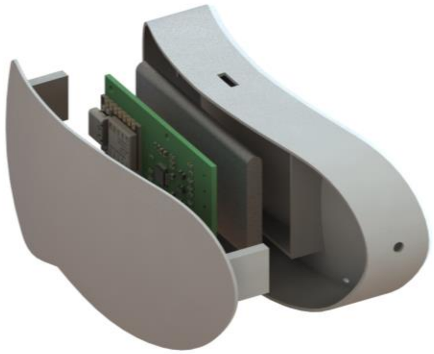


Overall Dimensions:
8.3in x 3.75in x 1.1*in



Side view

Second Design



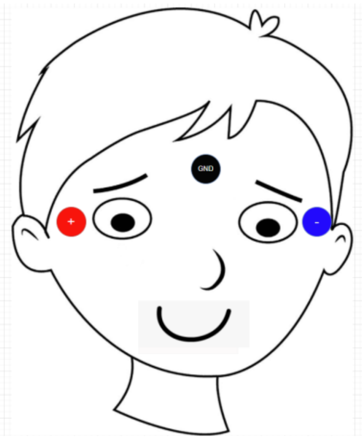
Overall Dimensions:
5in x 2.2in x 0.9*in

- As a prototype, designed to go over an existing sleeping mask.
- 2nd design is much more compact
- Weight of box is 35g. The entire assembly is 80.5g or ~0.2lb. Previously 161.5g.
- Due to curvature of the print, resin printing will be taken into considerations.
- Once second design assembled, a simple survey will be used to judge comfort and aesthetic.

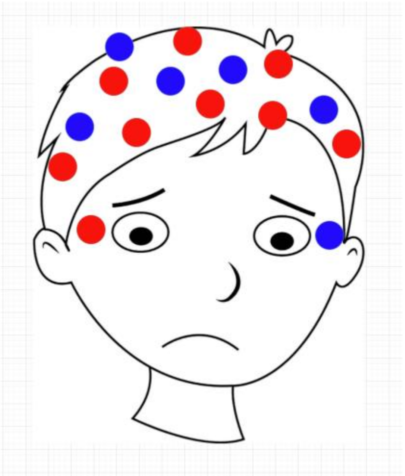
*Thickness

Hardware Design

- EOG
  - Minimally intrusive method of **direct** sleeping signal measurement
  - Detect eye movement—key feature of REM cycles
  - ADS1292 selected
    - Configurability for 2-channel if needed later (horizontal + vertical)
    - Right leg drive capability—noise rejection with "active" grounding
    - Integrated analog front-end solution for low-power sensing
    - Common interface: SPI
    - Manufacturability/availability
    - TI documentation

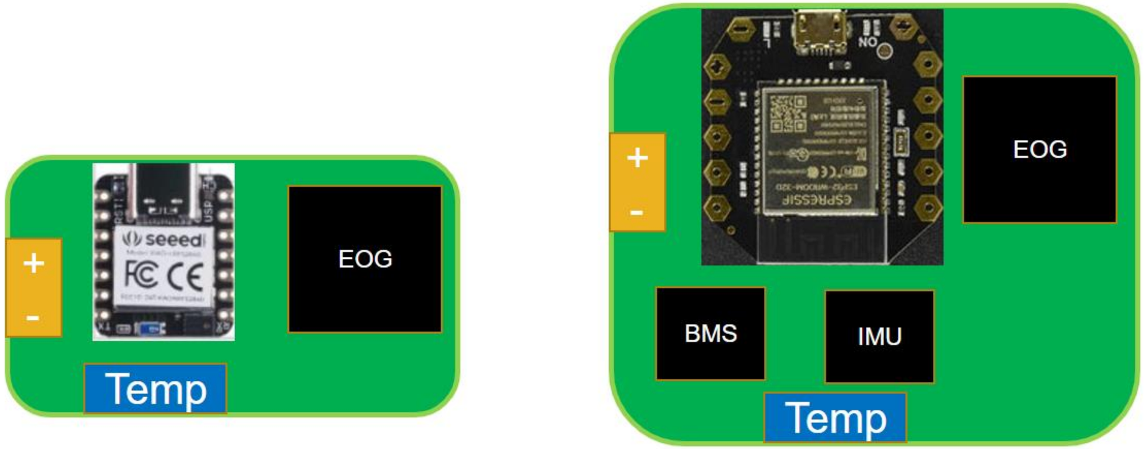


vs



Hardware Design

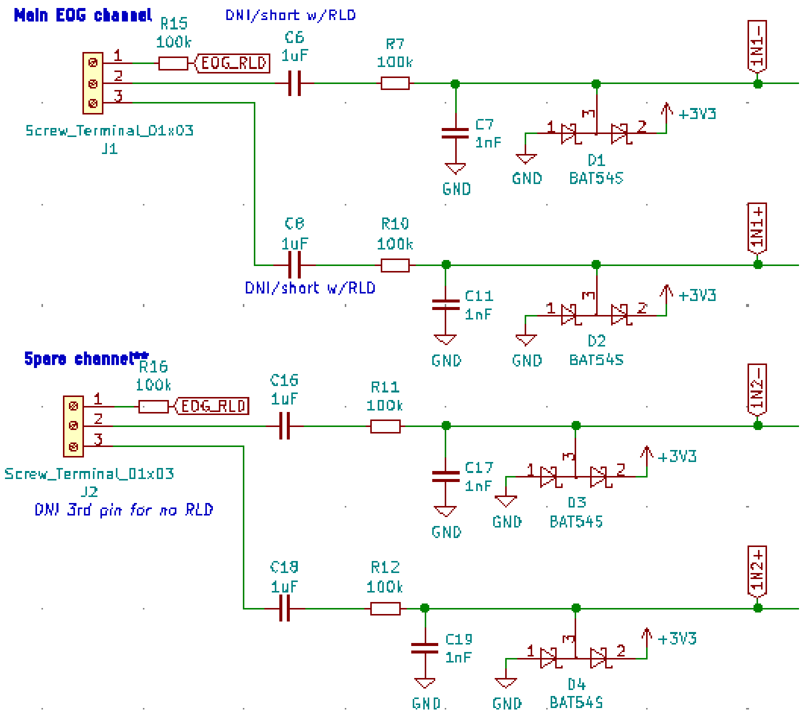
- MCU Selection
  - Toolchain familiarity for compressed timeline – Arduino
  - BLE capability with pre-certified module
  - Small form factor
  - Peripherals – SPI and I2C line
  - Integrated battery charge circuitry
  - Integrated IMU



XIAO Seeed vs. ESP32 board scale-accurate board estimate

Hardware Design

- Human body interface
  - Gel electrodes
    - Disposable
    - Better measurements for proof-of-concept
  - Standard protection circuitry (IEC 60601)
    - Diode ladder for transient voltage surges
    - Series resistor to body
    - DC blocking capacitors
    - Decoupling caps for high frequency noise/transience
- Lipo battery and charge circuit
  - Rechargeable
  - Compact form factor
- Temperature sensor
  - Contactless measurement over I2C
  - Comfort

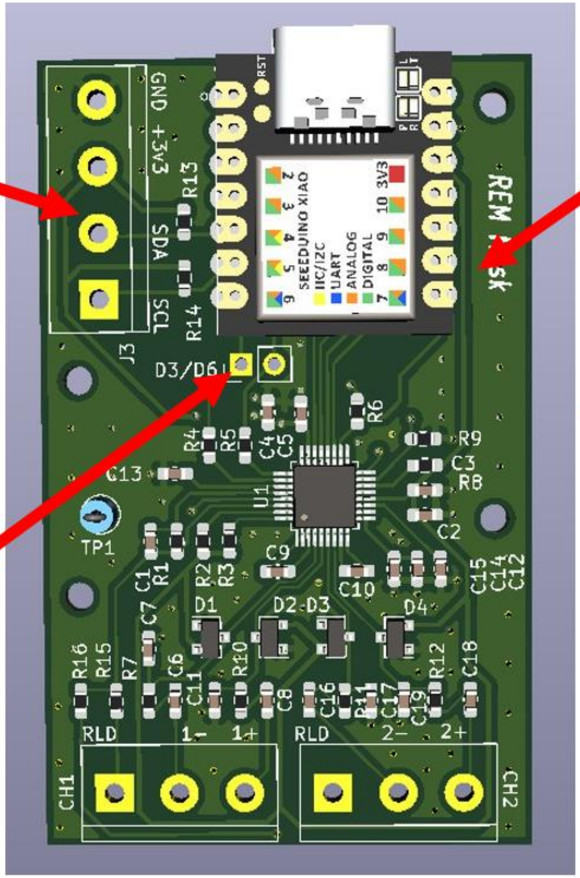


Hardware Design

- PCB Design

Footprint for screw terminals in case (1) take wires in and out (2) multiple I2C devices

GPIO access



3.8 cm x 6 cm

breakout SPI pins on this side--potential to add SD card separately or other SPI devices

Isolate analog and digital sections

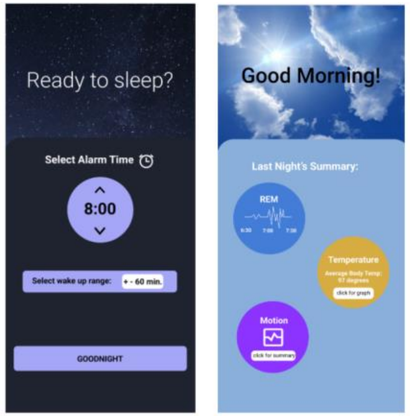
Clean ground plane under analog stuff

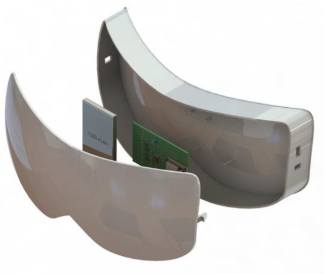
2-layer for quick build

Battery cutout

Application Design

Original Plan: Smartphone App

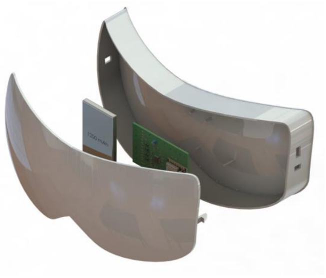




Problems:

- May take too long to create and design fully functional smartphone app
- But.. could be used for the project in the future!

Solution: Python GUI

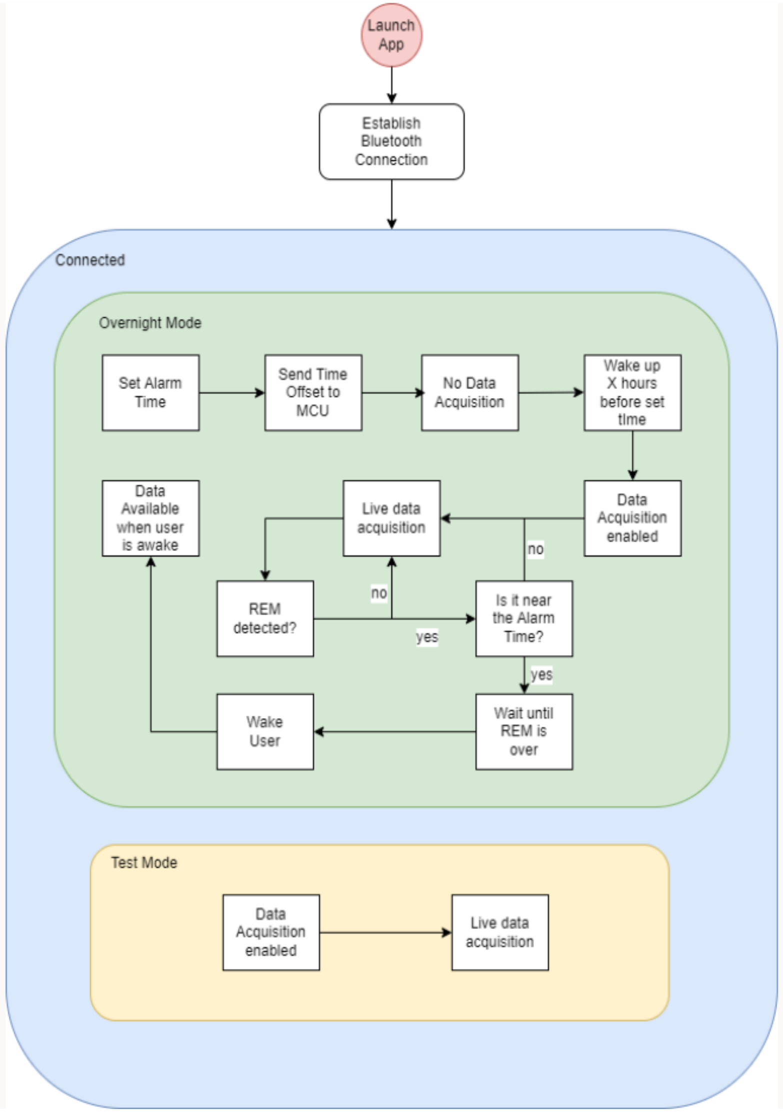


Solutions:

- Python libraries available for GUI design (Tkinter), plotting data (matplotlib), and BLE connection
- Easier to implement algorithm functionality and can be done in shorter period of time

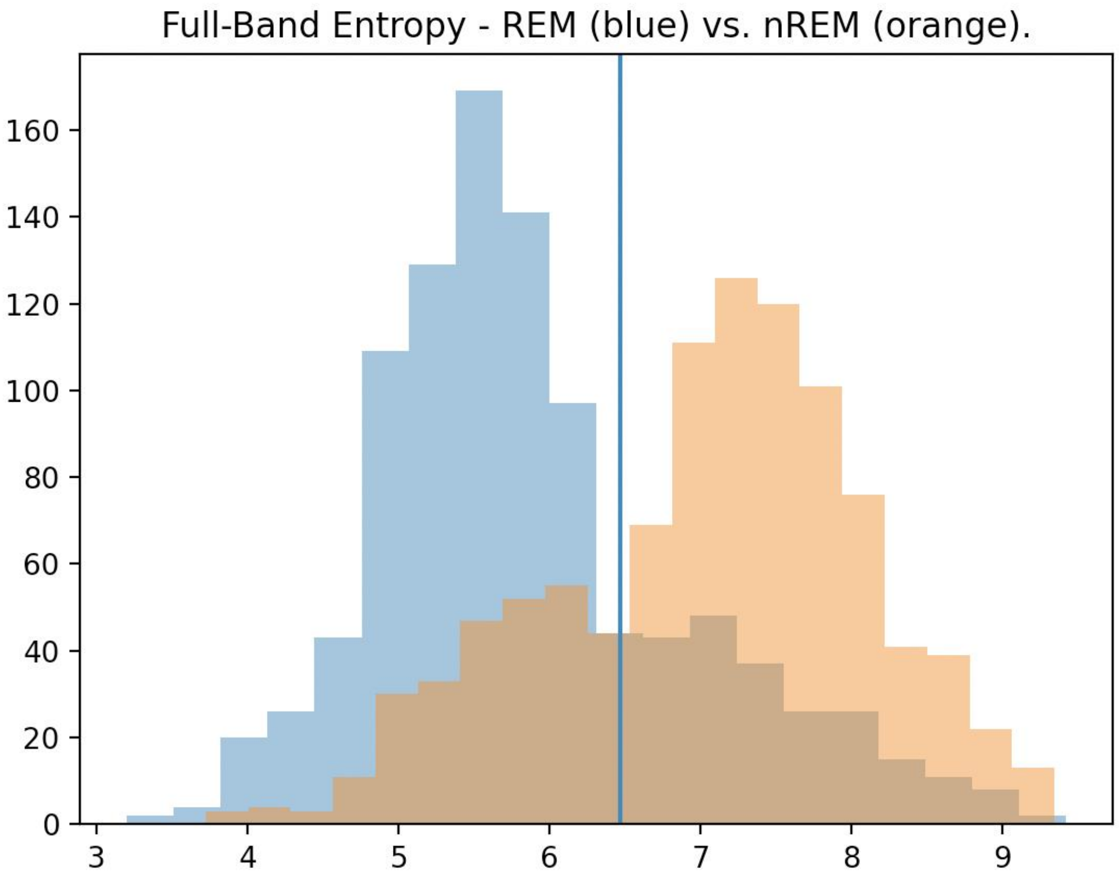
Application Design

- Application Design Decisions:
  - Allow user to specify "range" of times for alarm
    - Why? Another full sleep cycle lasts ~1.5 hours which could be "too late" for the user if previous sleep cycle ends right before user-specified time
    - Prioritizing waking up right after sleep cycle has ended over time spent asleep
  - Algorithm:
    - Continuous live data acquisition until REM is detected
    - Check if currently near the alarm time and predict whether next sleep cycle will fit in time range
      - If near alarm time, wake the user once REM is over
      - Otherwise, continue data acquisition
  - Test Mode:
    - Checks data acquisition over Bluetooth between device and application – serves as debugging tool



Sleep Classifier Design

- Feature vectors consist of subset:
  - Full-band spectral entropy
  - Multi-band spectral entropy
  - Statistical measures of raw data: mean, variance, kurtosis, skew
- Considered approaches: SVM, LDA, simple threshold
- Training on 98 nights of sleeping data
  - Observation: Training on a users' individual data yields higher accuracy.



Sleep Classifier Design, continued

- The progress on this part of the project has been substantial already
- Room for improvement:
  - Testing performance against various feature combinations and hyperparameter (i.e., STFT window size) tunings.
  - Construct a transition model of sleep using training data and attempt to implement an approach such as particle filter.
  - Pursue more advanced feature calculations, such as Refined Composite Multiscale Dispersion Entropy (RCMDE)

```
TEST COMPLETE!!! PRINTING METRICS...
CONFUSION MATRIX:
================================
[[17177  7218]
 [ 1310  5038]]
PERFORMANCE:
================================
0.722603519500374
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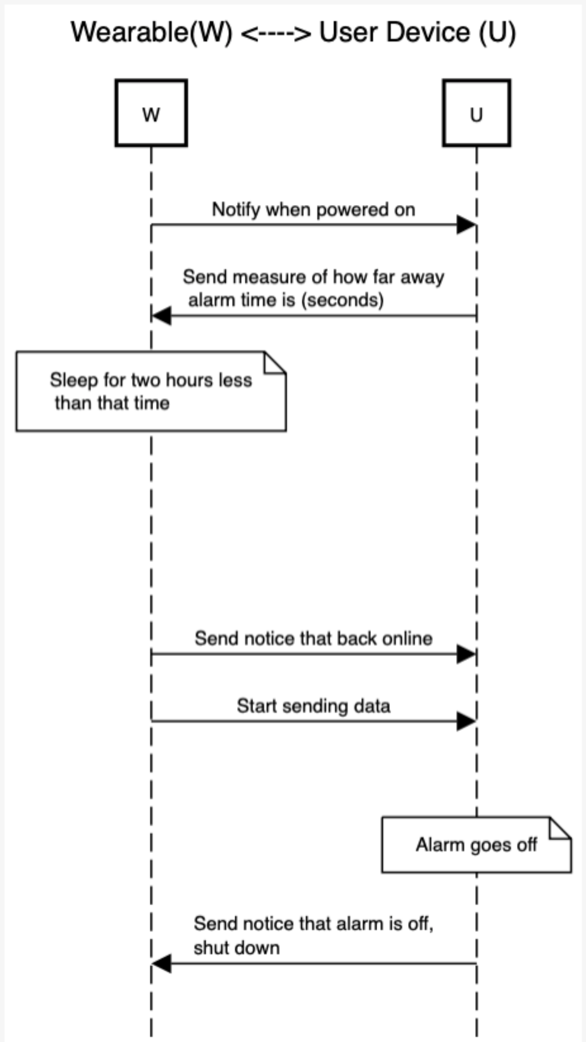
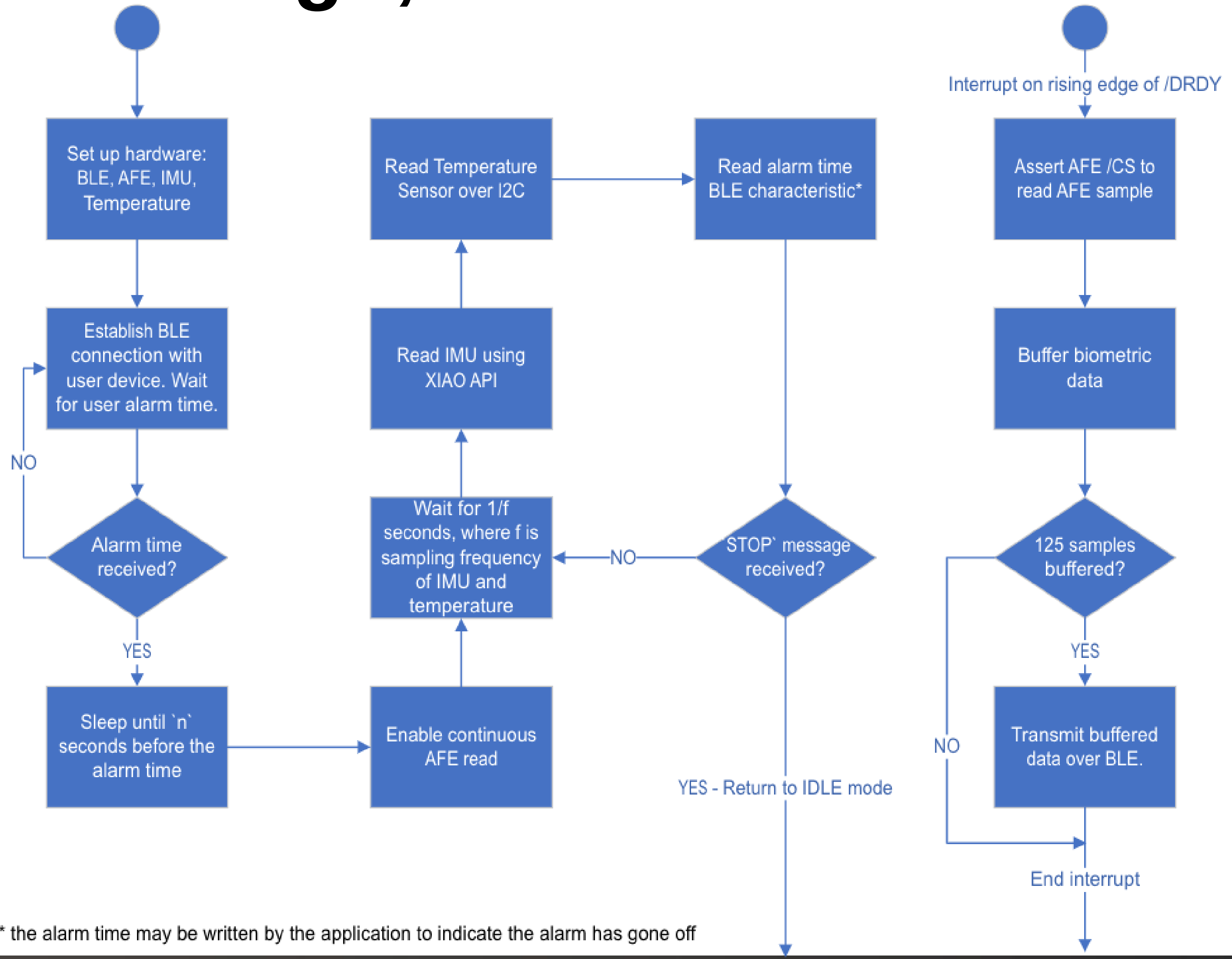
Firmware Design

- Low-power design: The MCU on the wearable device will be in deep sleep for most of the night.
- Bare-metal design favored over RTOS because most CPU activity will be driven by interrupts from the AFE.



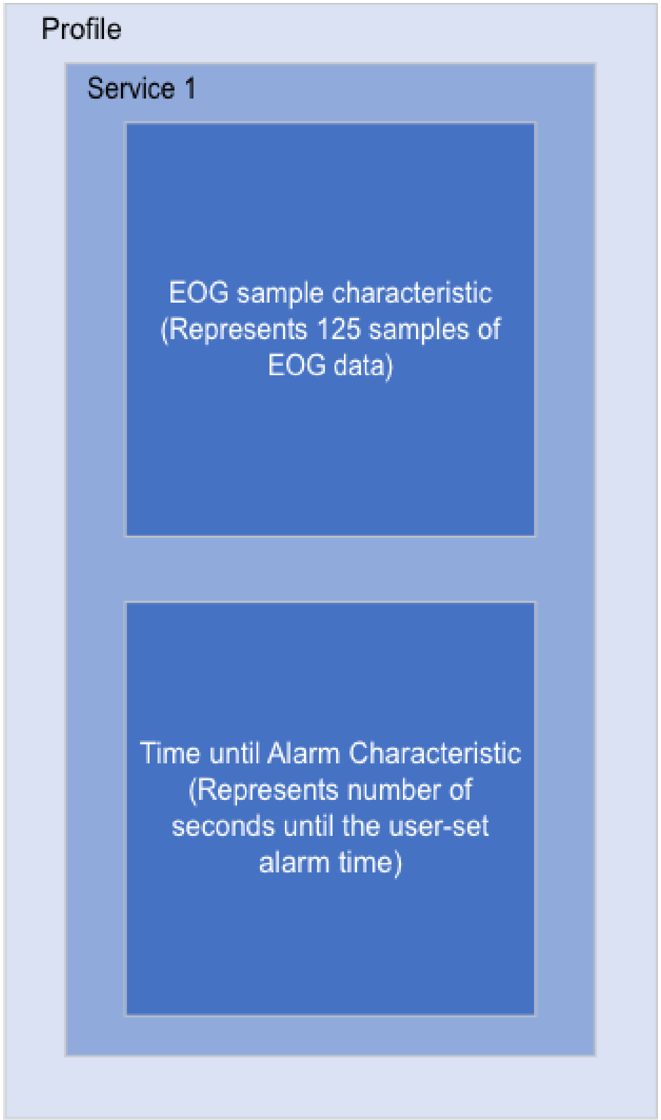
Firmware Design, continued



* the alarm time may be written by the application to indicate the alarm has gone off

Firmware Design, continued

- When the device wakes up, it writes a BLE characteristic once a second.
- Attributes can have a maximum size of 512 bytes.[1]
- 125 Hz sampling rate * 4 bytes / sample = 500 bytes / second.



[1] Source: Bluetooth Core Specification v5.3 Part F 3.2.9

Current Status

- Prototype: Printing second design (PLA + Resin)
- Hardware: Assembling PCB, tested serial communication with EOG IC
- Application: GUI still in progress – can input sleep alarm time but still need to implement overnight alarm logic. Also need to implement Bluetooth data acquisition.
- Classifier: >70% accuracy on overall data set using simple threshold. Will take more advanced approach to improve further
- Firmware: Design is complete, implementation has been delayed by shipping delays and is just beginning (high-priority).

Pivoting into the weekly report...

Last Week's Action Items

🚧 *In Progress*

- (Kai) 3D printing second design
- *(Andrew and Syed)* S11 - Mobile Application – Integrate algorithm and sleeping data with user interface
- *(Syed)* - Continue working on GUI
- *(Ananth)* - Read Bluetooth data on GUI
- *(Nabid)* - debugging SPI communication and finish PCB assembly

☑ *Completed*

- *(Kai)* Finish the 2nd Iteration CAD model
- *(Andrew)* S7.5 - Make the classification model loadable, not created every time the application is launched
- *(All)* - work on presentation/document for next week

Project Plan & Schedule

	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14	Week 15	Week 16
Task	w/e 1/15	w/e 1/22	w/e 1/29	w/e 2/5	w/e 2/12	w/e 2/19	w/e 2/26	w/e 3/5	w/e 3/12	w/e 3/19	w/e 3/26	w/e 4/2	w/e 4/9	w/e 4/16	w/e 4/23	w/e 4/30
Team Formation																
Project Bidding																
Problem Statement																
Project Summary																
Project Proposal																
Project Research																
System Decomposition																
Part Selection/BOM																
Electrical Design**																
Firmware Design**																
Software Design**																
Mechanical Design**																
Electrical Integration**																
Firmware Integration**																
Software Integration**																
Mechanical Integration**																
Redesign																
Electrical Test**																
Firmware Test**																
Software Test**																
Mechanical Test**																
Full System Integration**																
Full System Testing**																
Data Collection																
Data Analysis																
Poster Design																
Final Report																
Expo																

Current Status

- Website server up and running and can be edited! Check it out here: https://eceseniordesign2022spring.ece.gatech.edu/sd22p12/
- Printing issues with second in Invention Studio – queueing print in IDC
- Busy week due to exams and projects/labs being due – planning on catching up a bit over Spring Break

Tasks for upcoming week

- *(Kai)* 3D printing second design
- *(Andrew and Syed)* S11 - Mobile Application – Integrate algorithm and sleeping data with user interface
- *(Syed)* - Continue working on GUI
- *(Ananth)* - Read Bluetooth data on GUI
- *(Syed and Ananth)* - Integrate functional alarm algorithm in software
- *(Syed and Ananth)* - Use matplotlib to acquire live data waveform
- *(Nabid)* - debugging SPI communication and start PCB assembly
- *(Andrew and Nabid)* F2 - Read EOG data over SPI and buffer it