Sound Asleep

Electrical & Computer Engineering

Team 1

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Objective

- Slow Wave Sleep is an important factor in the quality of sleep
  - <1 Hz EEG Signal
- Shown to cause cardiovascular issues and mental health problems
- Often slow wave sleep can be too short, which causes feelings of tiredness when you wake up
- Pink noise stimulation during rise time of SWS causes amplitude and longevity enhancement
- Need full, closed-loop device for EEG readings and stimulation

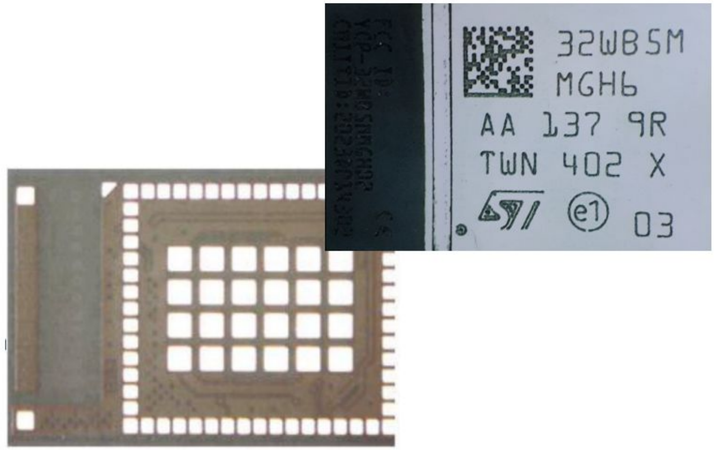
The Project

- Sound Asleep is a wearable headband based device designed to transmit EEG signals to a phone or laptop app
- App uses ML algorithms to analyze slow wave sleep and send pink noise stimulation
- User audio device enhances user sleep when paired with phone or laptop

Microcontroller

STM32WB5MMG

- Arm® Cortex®-M4 CPU based MCU
- Land Grid Array(LGA)
  - LGA 86 since 86 pin package
- Bluetooth® LE with inbuilt RF Antenna
  - No need for separate ESP32
- Ultra-low power modes for efficiency

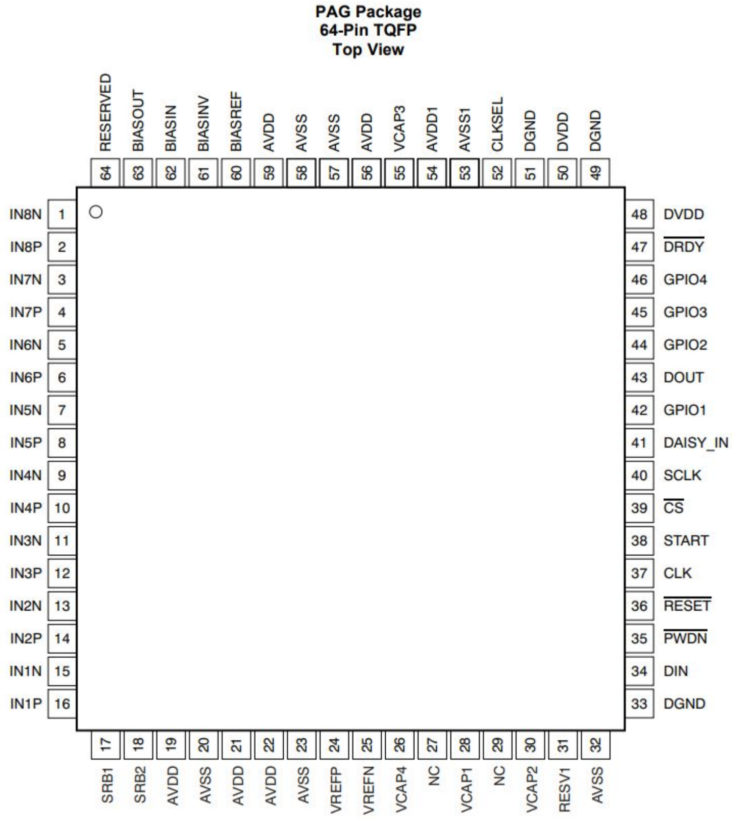


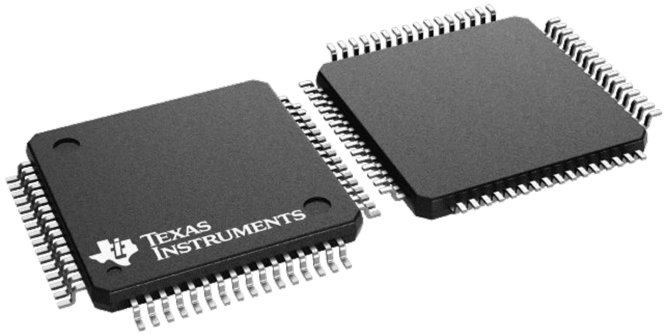
Datasheet: https://www.st.com/resource/en/datasheet/stm32wb5mmg.pdf

Analog to Digital Converter(ADC)

ADS1299IPAG

- 8-channel ADC
- 64-pin TQFP(Thin Quad Flat Pack)
- Designed for EEG/Biopotential Measurements
- Extreme Low Noise Performance
  - Very low input-referred noise (1 uV at 70-Hz bandwidth)
- High Resolution and Simultaneous Sampling
  - 24-bit resolution
  - 8 simultaneously sampling ADCs
  - Allows for synchronized capture of brainwave signals

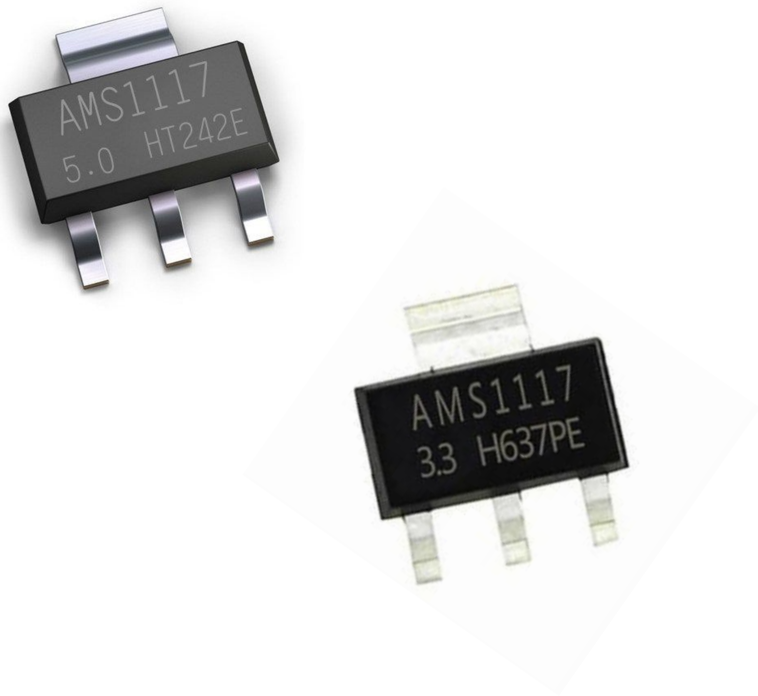




Datasheet: https://www.ti.com/lit/ds/symlink/ads1299.pdf

Power Regulation/Consumption of Components

Component	Supply Voltage Requirement	Current Draw (Typical)	Source / Note
STM32WB5MMG (MCU)	3.3 V	~8–12 mA	Radio: 5.2mA, CPU: 3.4mA
ADS1299 (ADC)	5.0 V	~5-6mA	Analog Supply
ADS1299 (ADC)	3.3 V	~0.7-1 mA	Digital Supply
LDO Regulators (Quiescent Current)	9.0 V	~10-20 mA	5-10mA per LDO (x2)
Load Current	5.0 V	~15-19mA	
Load Current	3.3 V	~1mA	
Total Current	**-**	**~40 mA**	**< 50mA Requirement Met**



Max Total Current ~ 40mA

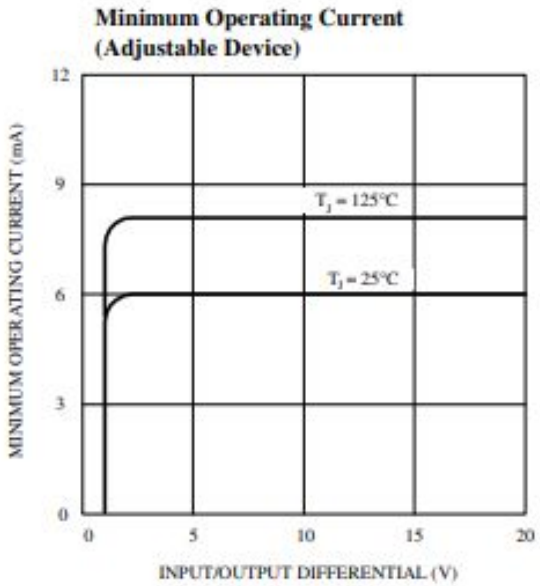
20mA + 20mA(max quiescent current)

Project Requirement <= 50mA

Datasheet: http://www.advanced-monolithic.com/pdf/ds1117.pdf

Power Supply and Heat Dissipation

- LDO Regulator dissipates heat due to linear nature
  - Acts as variable resistor which burns off excess voltage to maintain output
- Power Supplied ~ 9V * 40mA = 360mW
- Power Consumption ~ 261.7mW
  - 5V LDO ~ (9-5V) * 19mA + 9V * 10mA= 166mW
  - 3.3V LDO ~ (9-3.3V) * 1mA + 9V * 10mA= 95.7mW
- Power dissipated as Heat ~ 98.3mW (27.3%)



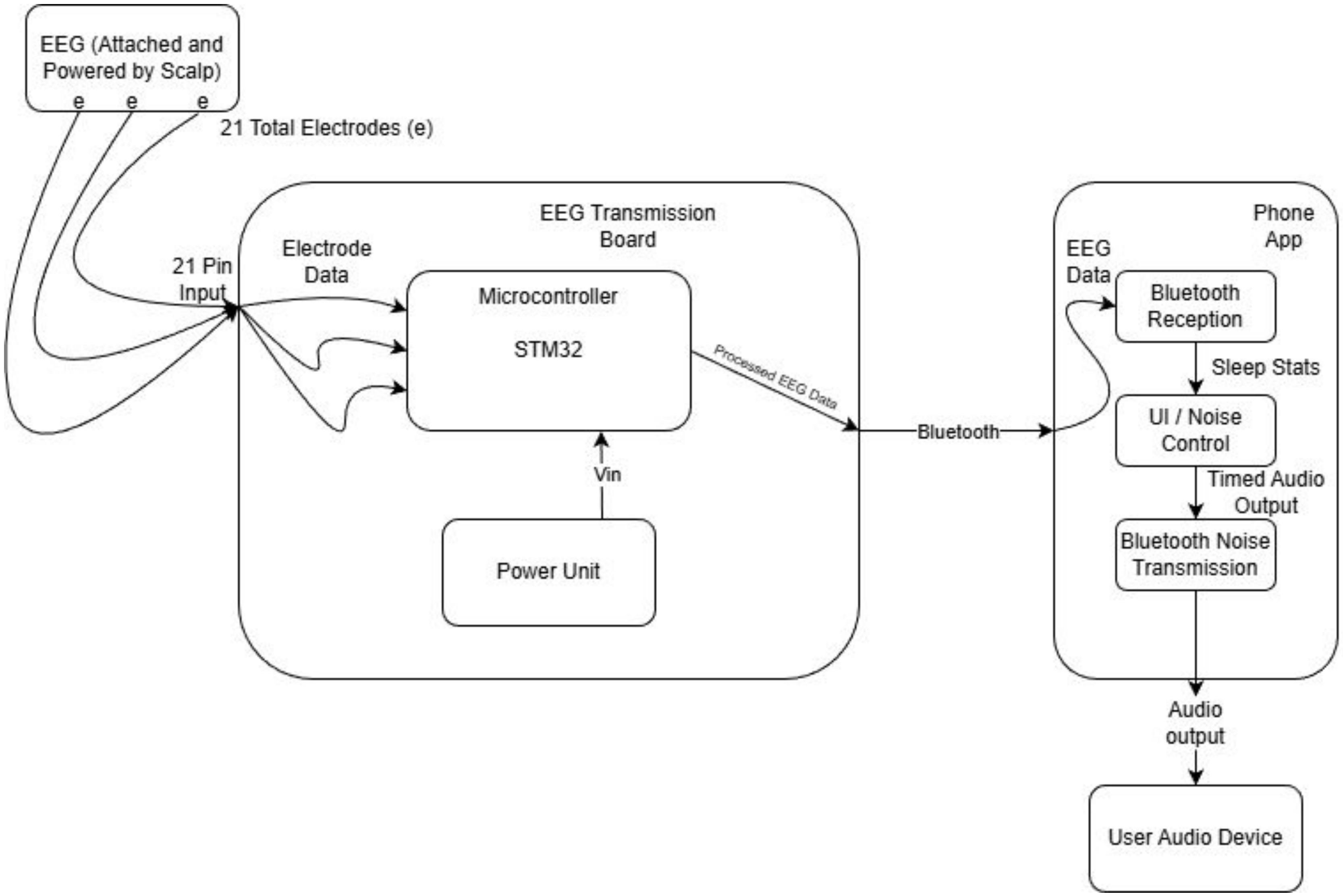
Datasheet: http://www.advanced-monolithic.com/pdf/ds1117.pdf

Standard 500mAh 9V Alkaline Battery

- Battery Life at full use ~ 580mAh/40mAh = 14.5 hours
  - Could be higher based on lower idle power consumption MCU and ADC + overestimated approximations
- Not tested due to PCB challenges
- Satisfies project requirement of 8 hr capacity
- Considerations made for rechargeable battery design
  - Micro-USB port placed on PCB
  - TP4056 Battery Charging IC
  - Not delivered in time

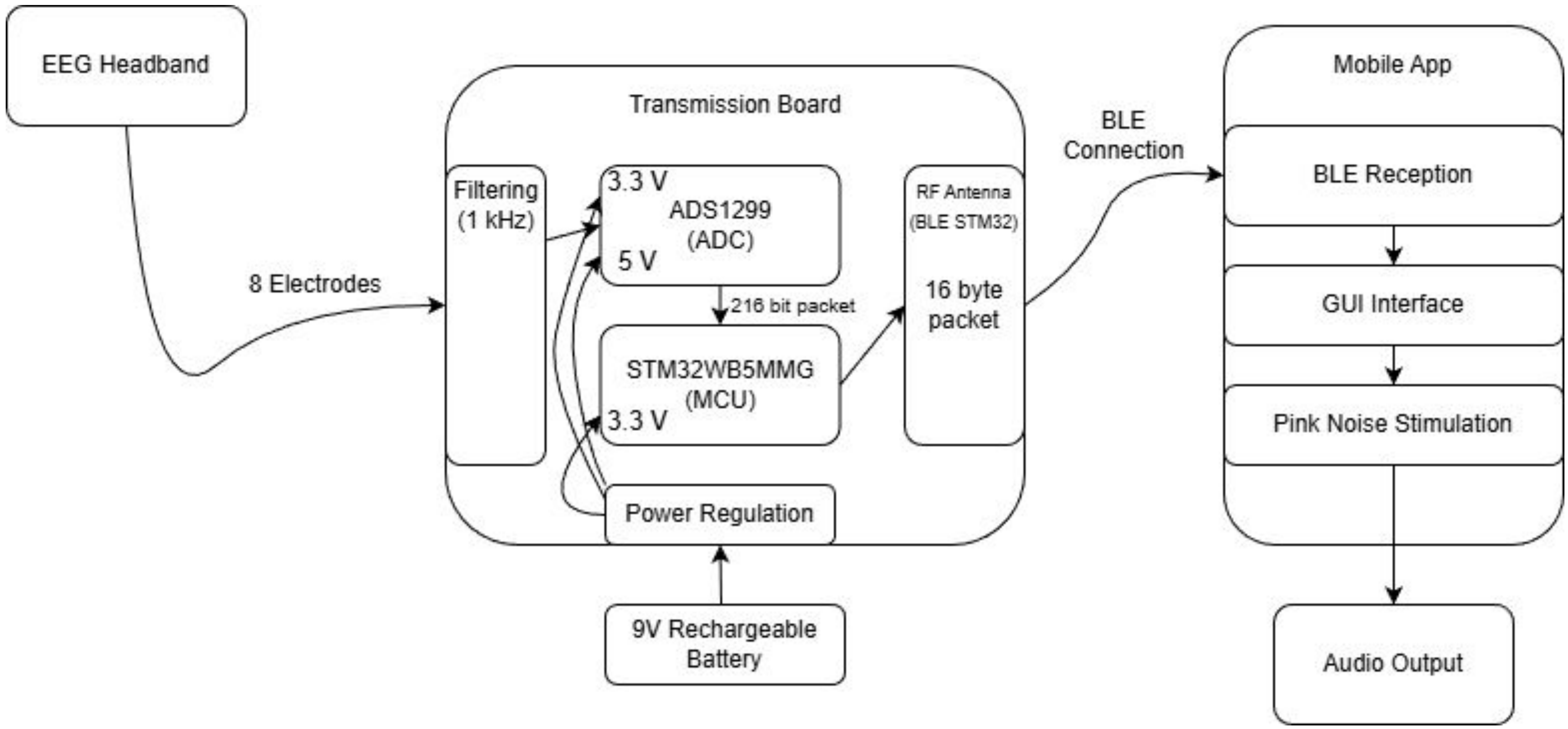
Original Block Diagram

Adam



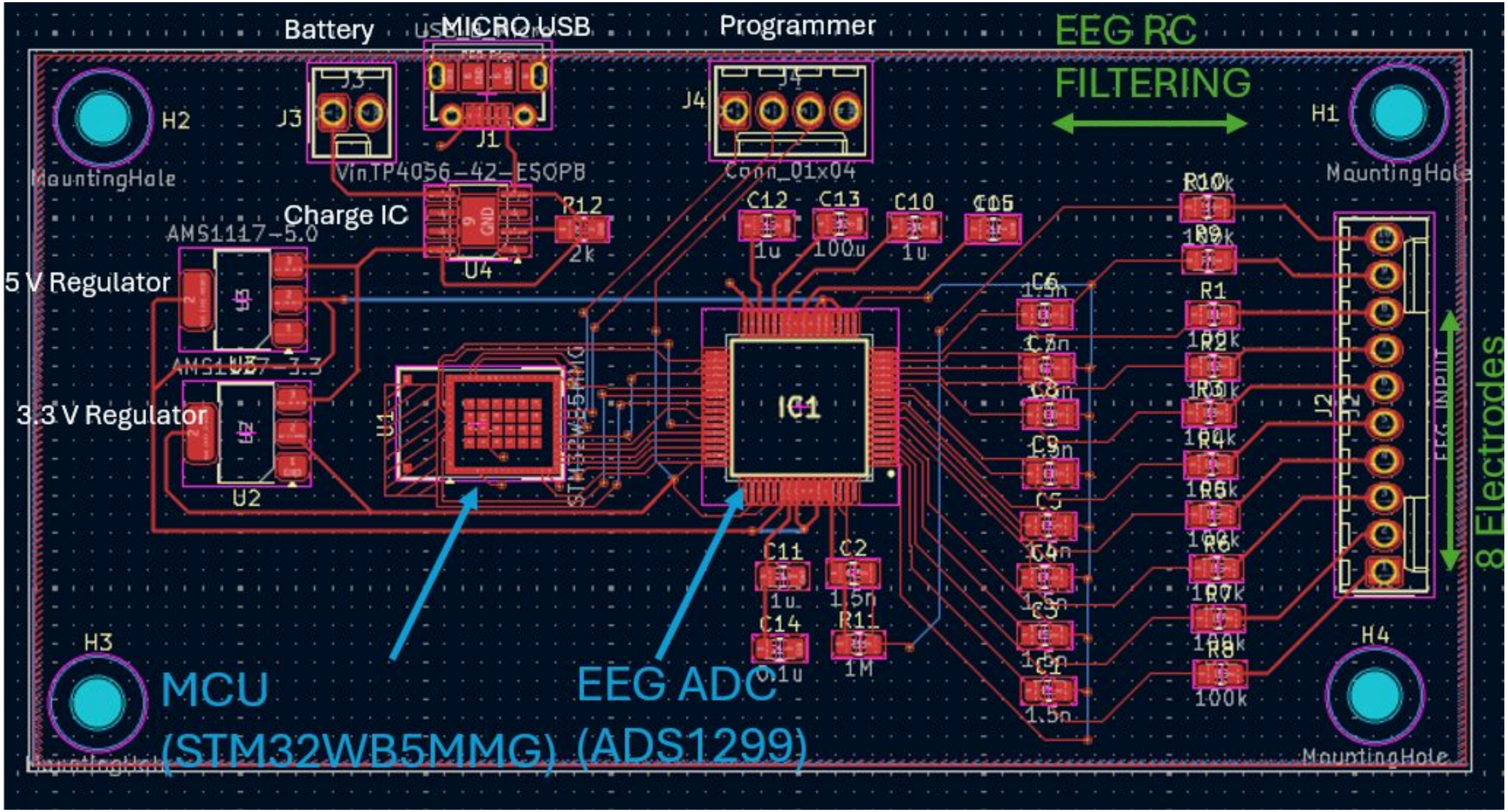
Updated Block Diagram

Adam

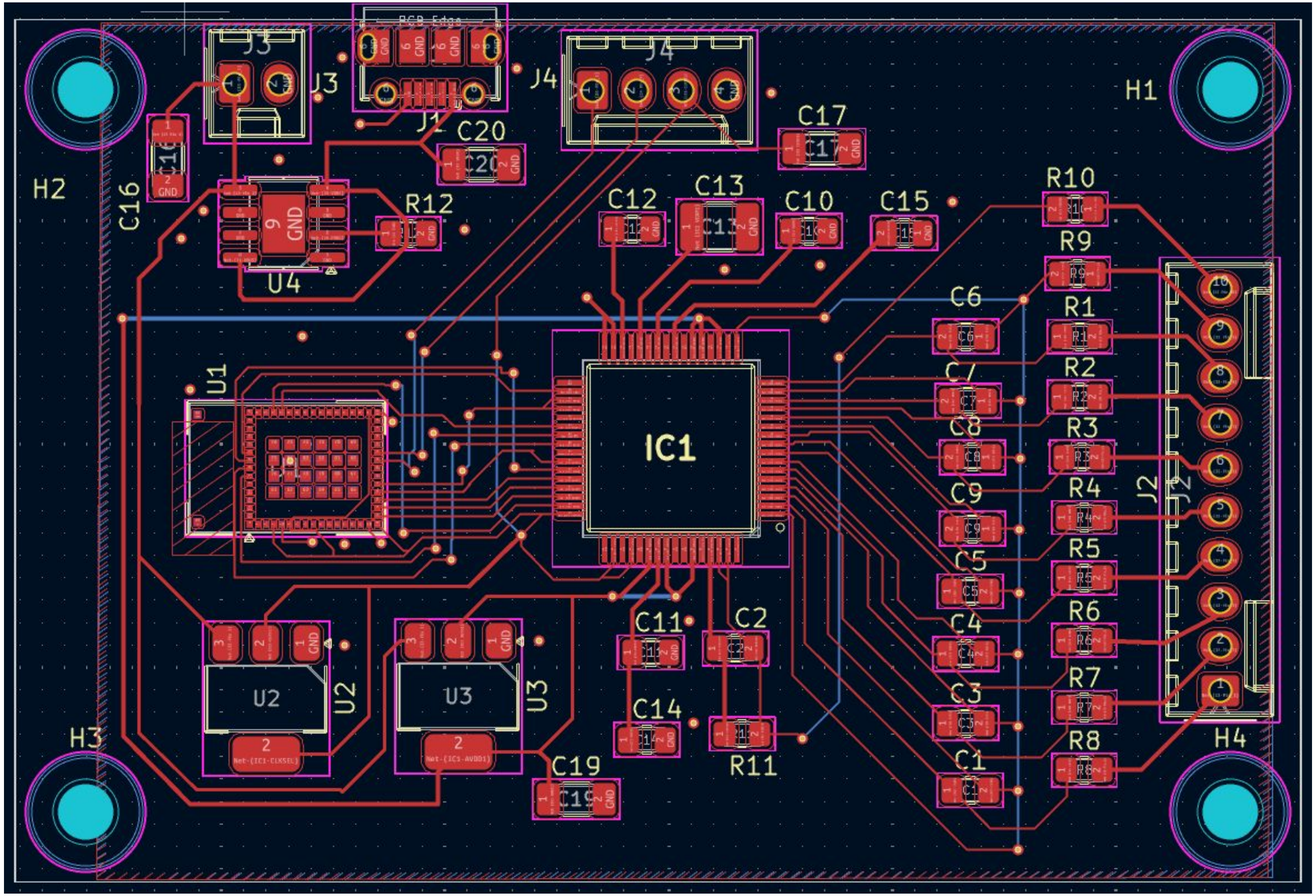


PCB Design (1st Draft)

Adam



PCB Design (Updated)

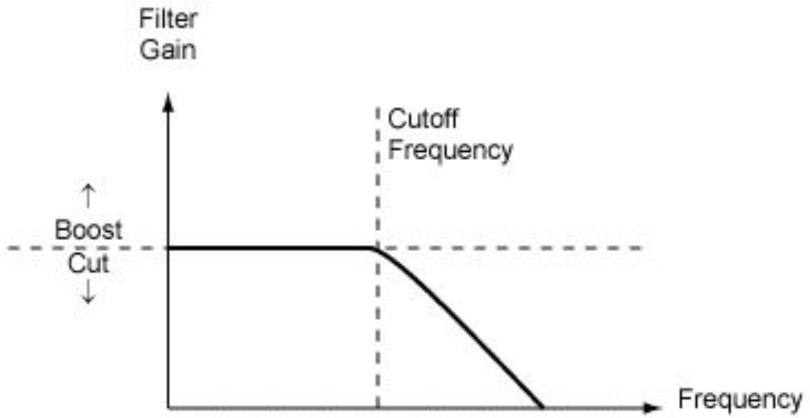


Filtering Choices

- 8 electrode filtering in order to reduce noise
  - Highest frequency EEG waves reach 500-2000 Hz
- Select 1000 Hz frequency cutoff to not attenuate frequency band and cut noise

$$F = \frac{1}{2\pi RC}$$

$$1062\ \mathrm{Hz} = \frac{1}{2\pi(100\ \mathrm{k})(1.5\ \mathrm{nF})}$$



- STM32WB5MMG
  - Supports Bluetooth Low Energy (BLE)
- ADS1299
  - EEG ADC
  - Communicates to MCU via SPI

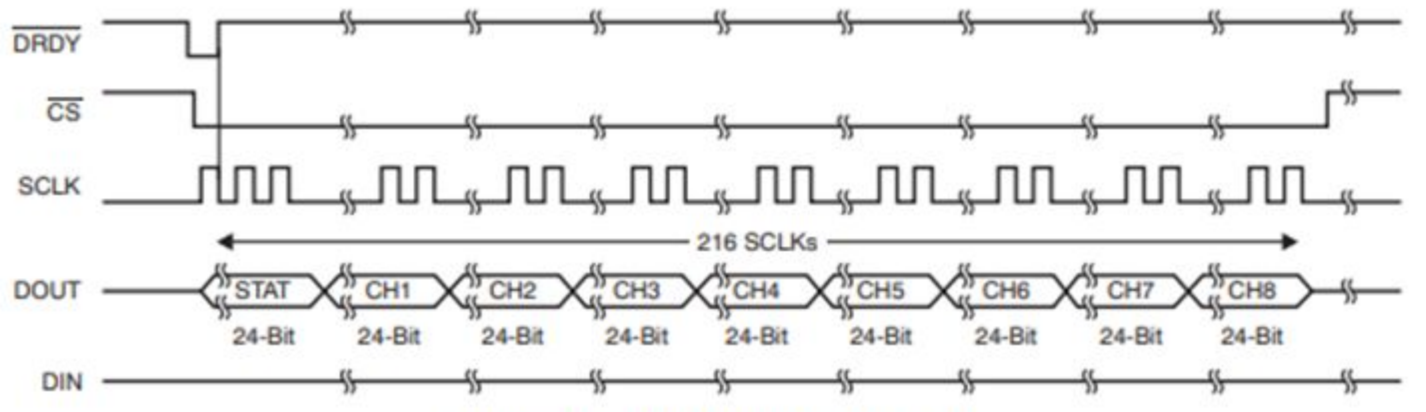
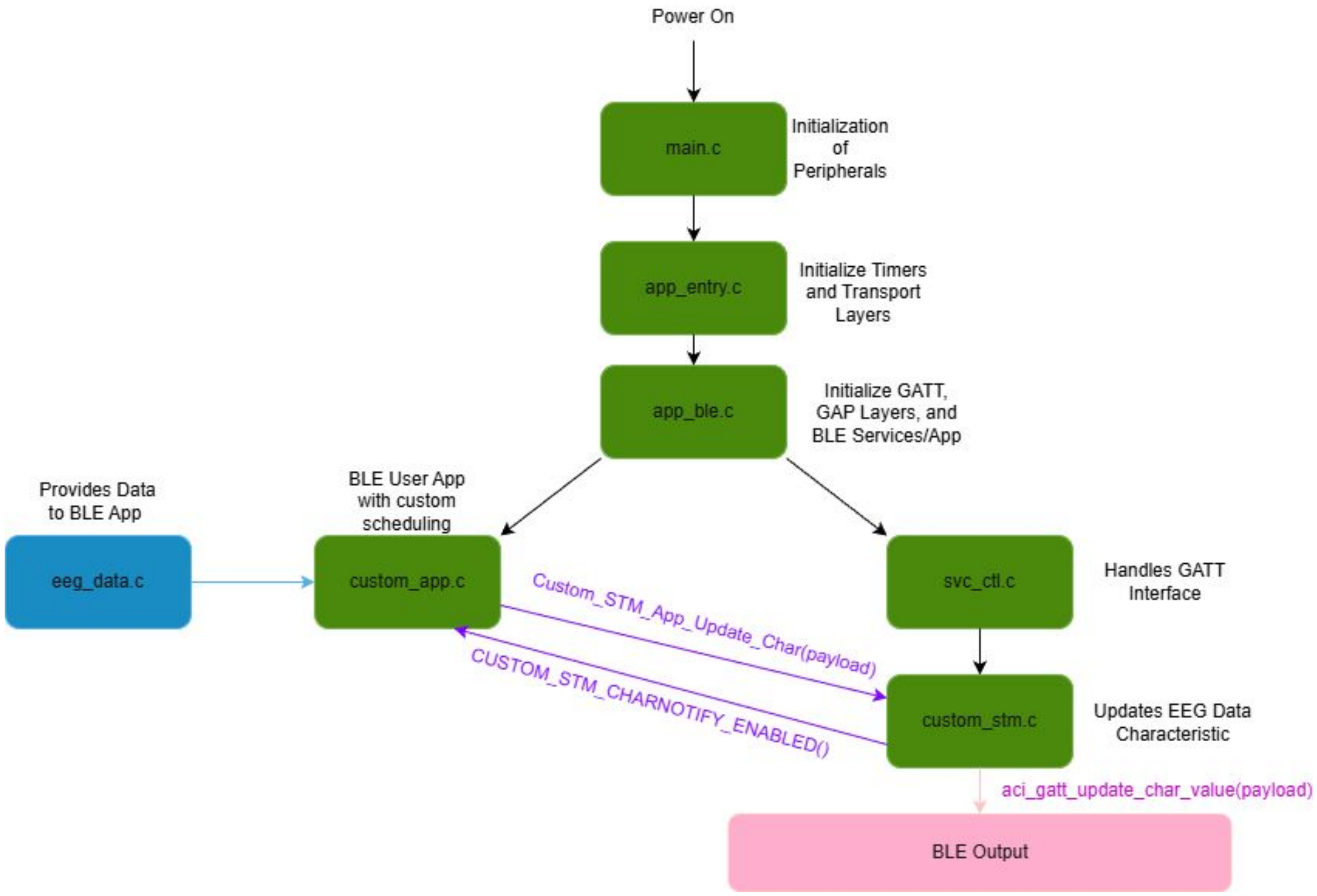
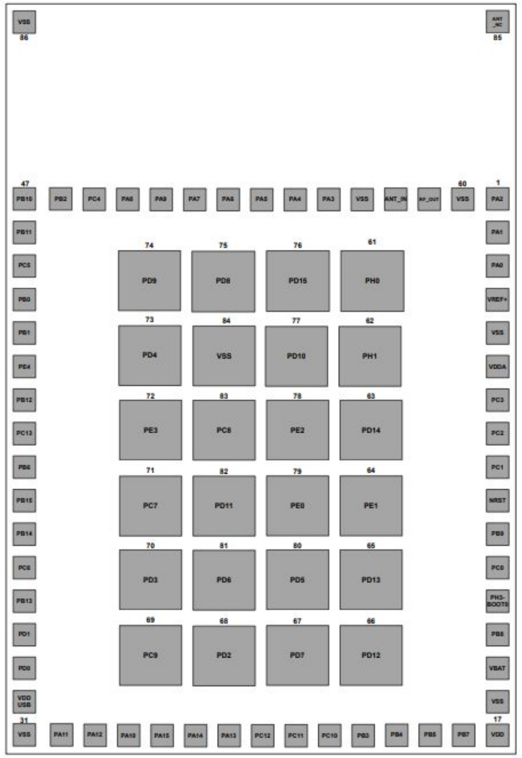


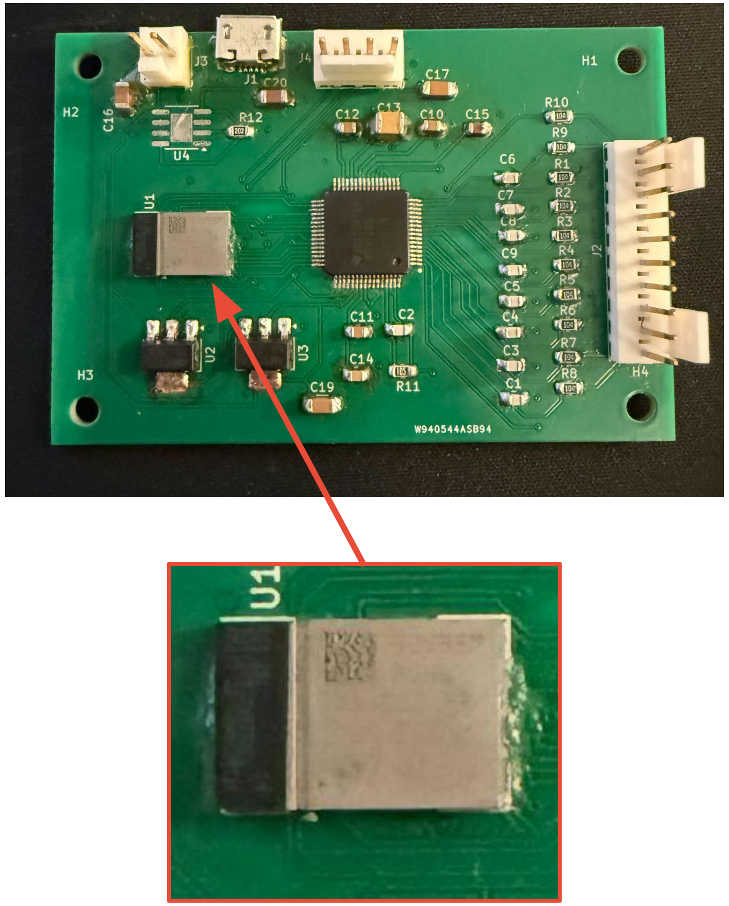
Figure 45. SPI Bus Data Output

- STM32WB5MM-DK Development Board Firmware Design



- MCU not functional
  - Stencil not sent (required for LGA packages)
- Recharge IC 4V limit
- ADS Testing Impossible
- 8 hour charging has not been tested





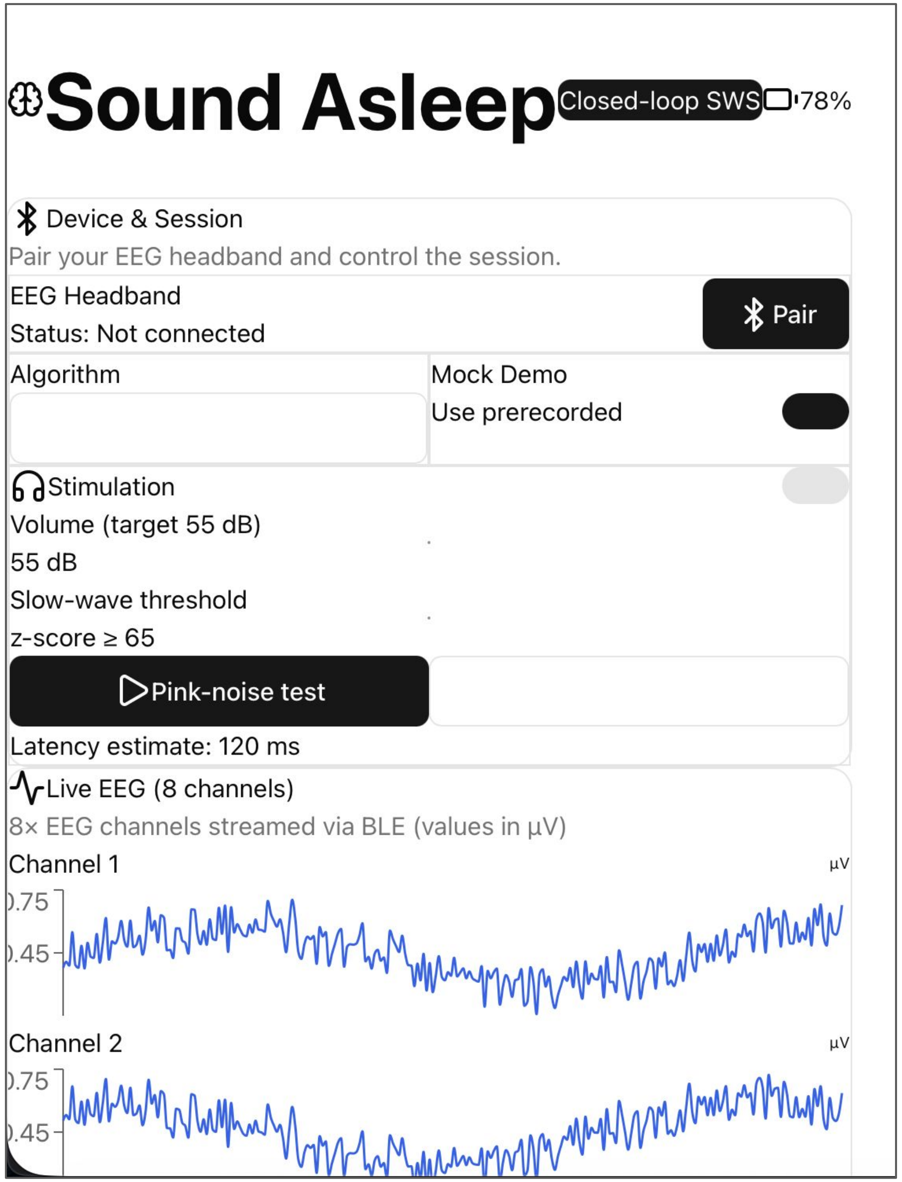
Transmission Board Positive Results

Adam

Requirement	Result
BLE Update Frequency of 250 Hz	Upsampled data resulted in equivalent response on app interface
Transmission Latency < 100 ms	Sent 10 Hz time stamped messages Received (5220 ms): 0001 D761 = 120,673 ms Received (5310 ms): 0001 D7C6 = 120,774 ms Time Difference: 5220 ms - 120,673 ms = -115,453 Latency: (5310 + 115453) - 120,774 = 11 ms
Transmission Latency +/- 10 ms	Same method, Calculated 3 more times Result 1: 18 ms Result 2: 7 ms Result 3: 14 ms
Current Draw of PCB < 50 mA	Set multimeter in series with battery and Vin Measured 13.3 mA when active

The Mobile App

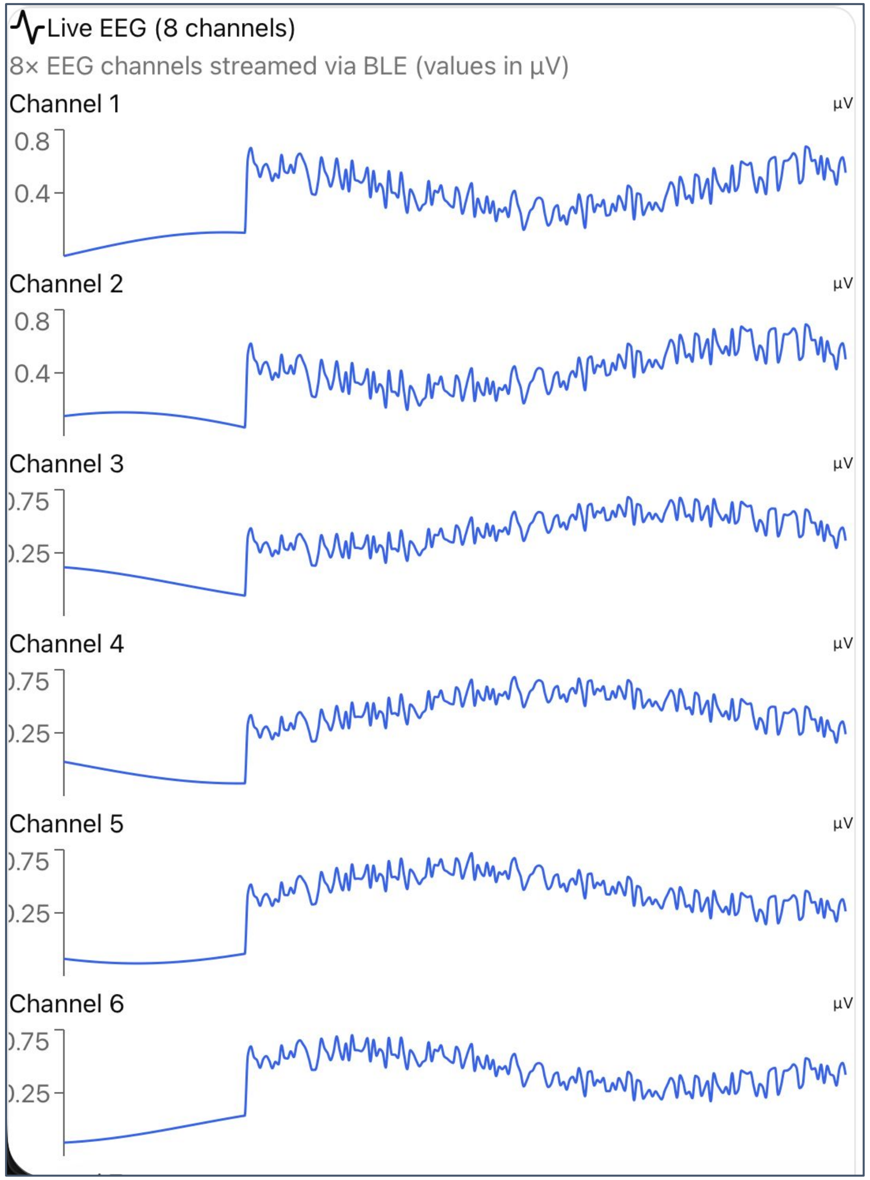
- App made in React, hosted online.
- Visualise the EEG data.
- Connect to the STM32 microcontroller via BLE.
- Play Pink-Noise on user audio device (headphones).
- Integrate YASA and CoSleep algorithm selections.
- Control the volume and duration of Pink-Noise sleep.
- Mock Demo mode and real-time EEG data.



EEG Graphs

Ambika

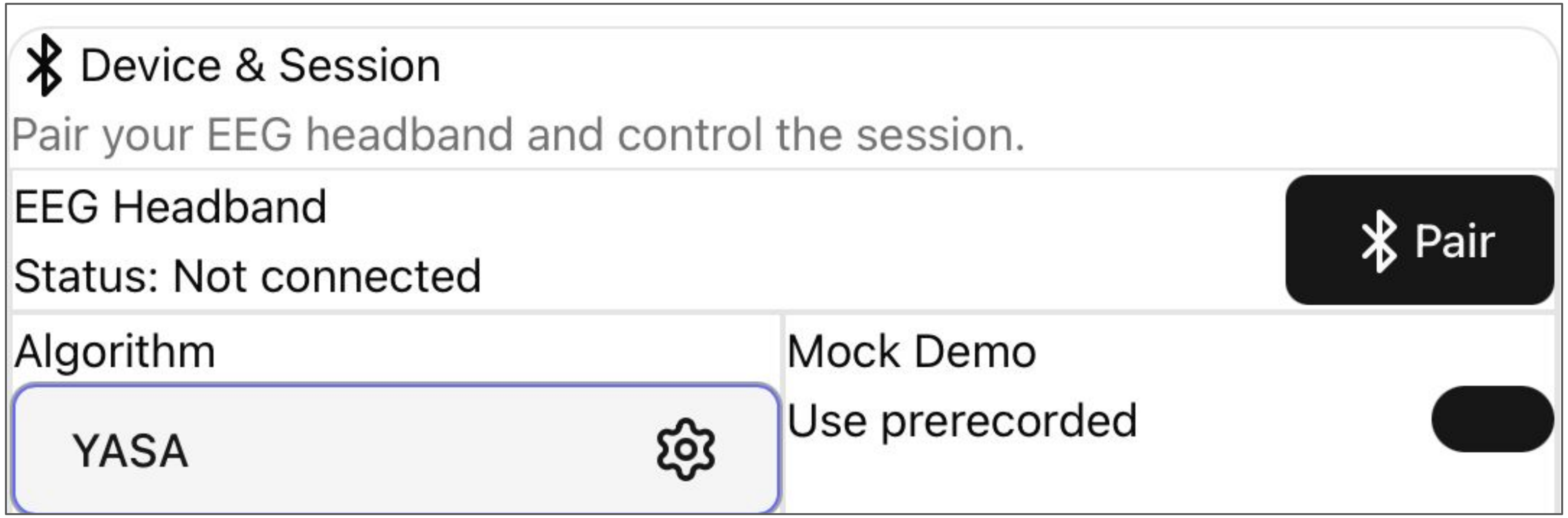
- Stream live **8 channel** EEG over BLE. The headband sends **16-byte** packets (**8× int16 values**) at **50 Hz**.
- The app decodes, scales to **µV**, and plots in real time with minimal delay.
- Each electrode updates as its own graph to verify the **ADS1299 + STM32** pipeline is functioning properly.
- Signal stability & artifact detection **-** The graphs help verify **<1 µV** rms noise during baseline.

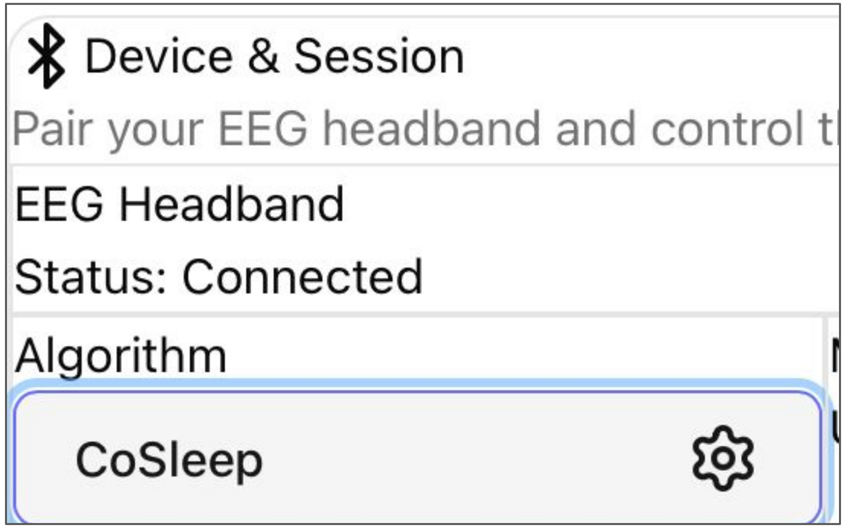


Sleep Stage Algorithms

Ambika

- Choose between **YASA** (Yet Another Sleep Algorithm) and **CoSleep** (uses Machine Learning).
- YASA is a **linear algorithm** which selects a standard Pink Noise test duration.
- CoSleep uses **PyTorch** to analyse sleep patterns and adapt the Pink Noise duration to user needs.





Sleep Stage Classification

Ambika

YASA

- Identifies SWS between **0.1 - 0.2 µV EEG voltage** and characteristic **< 1Hz oscillations.**
- Schedules **55 dB pink-noise bursts**, each lasting **10 seconds.**
- Repeats stimulation across a **1 hour training window** to enhance slow-wave sleep depth.

CoSleep

- Uses **deep learning models** (CNN style architectures) to evaluate **multi-channel EEG** patterns jointly.
- Captures **microarousals, asymmetric waves,** and **transient EEG features** that classical algorithms may miss.

Event Logs

Ambika

- Log events such as **STM32** and user audio device pairing, **Pink Noise test**.
- Also shows the peaks and troughs of the **8 EEG channels** from the **OpenBCI EEG**.
- Stores up to **32mB** of log data on the user device as part of the app storage.

Event Log

Most recent first.

- 5:36:15 PM Pink noise triggered.
- 5:36:15 PM Playing pink noise test...
- 5:35:58 PM Device paired + streaming.
- 5:35:58 PM Subscribed to EEG notifications (8× int16).
- 5:35:58 PM EEG characteristic acquired.
- 5:35:58 PM EEG service acquired.
- 5:35:56 PM GATT connected.
- 5:35:56 PM Selected device: SNDASLEEP
- 5:35:50 PM Requesting BLE EEG device...
- App initialized.
- Awaiting device pairing...

Conclusion

- Learnings:
  - EEG data collection and analysis of slow wave sleep
  - PCB soldering
  - MCU + App firmware design
- Possible Improvements for Board Design:
  - PCB Functionality with Stencil based resoldering
  - Alternate design without LGA based package
  - Additional sampling channels (Headband supports 16)
- Possible Improvements for Comfort and Modularity:
  - Electrode leads are not comfortable to wear while sleeping
  - Several long wires connected to the Transmission Board

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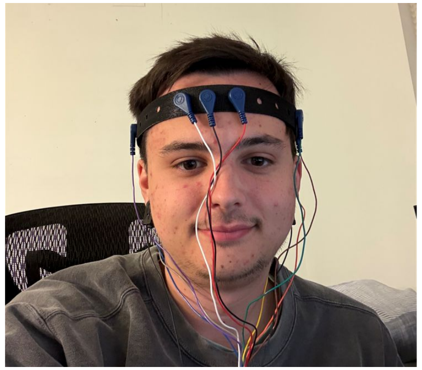
OpenBCI Headband Demo (Removed)

Adam



- Eye Blink Artifact
- 10 Hz Spike while eyes closed