Sound Asleep
ECE 445 Design Document - Fall 2025

Project #1

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1. Introduction

1.1 Problem

Sleep is one of the most vital components of human health, yet millions of people experience inadequate or poor-quality sleep. Insufficient slow-wave sleep (SWS) has been directly associated with reduced memory consolidation, weakened immune function, and increased risk of chronic illnesses such as diabetes and depression. Despite the availability of wearable sleep trackers, most commercial devices only monitor sleep rather than improving it. EEG-based devices that can detect sleep stages often suffer from discomfort during overnight use or lack the active intervention needed to enhance sleep quality.

Recent research demonstrates that auditory closed-loop stimulation which is the delivery of sound pulses precisely timed with brain slow waves. This can extend and amplify SWS leading to measurable improvements in cognitive performance and overall restfulness. However, existing prototypes are bulky and consumer options remain limited which often require proprietary hardware and offer limited flexibility for user comfort.

1.2 Solution

Sound Asleep addresses these limitations by introducing a comfortable, wireless, and real-time system designed to both detect and enhance slow-wave sleep. Our device consists of a lightweight EEG headband that records brain activity and transmits it via Bluetooth to a smartphone application. The mobile app analyzes EEG signals in real-time to detect SWS and delivers auditory stimuli i.e. pink noise bursts through the user’s chosen audio device at precise moments in the sleep cycle. Unlike traditional wearables, Sound Asleep prioritizes comfort and accessibility by allowing users to use their own headphones or speakers. By integrating closed-loop stimulation into a user-friendly system, this project bridges the gap between academic research and practical, consumer-ready sleep enhancement.

1.3 Visual Aid

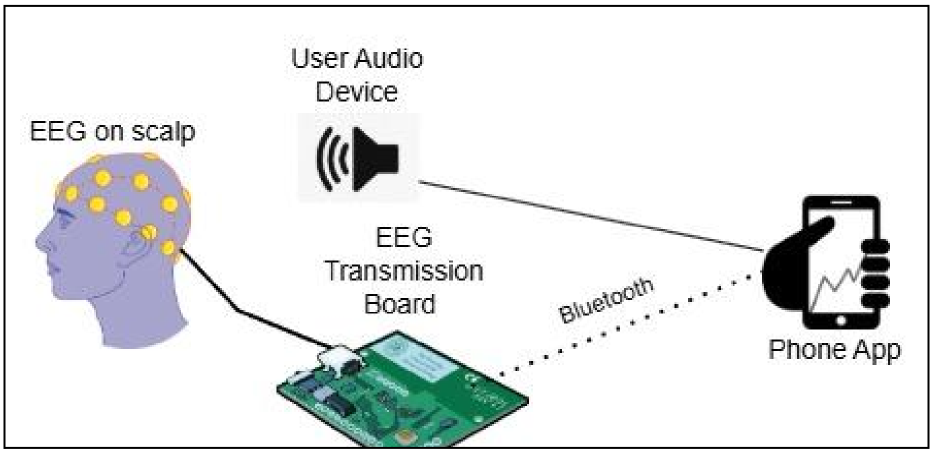

Figure 1. Visual representation of the Sound Asleep system.

Figure 2. OpenBCI EEG headband on user. Source: https://shop.openbci.com/products/openbci-eeg-headband-kit

EEG signals are captured through scalp electrodes integrated into a comfortable headband and transmitted via Bluetooth to a mobile phone app. The app processes these signals in real-time to detect slow-wave activity and triggers auditory stimulation through the user's chosen audio device (e.g., Bluetooth earbuds or speakers). This closed-loop design ensures synchronization between the brain's oscillations and sound delivery which enhances the depth and quality of slow-wave sleep.

1.4 High-Level Requirements

To ensure that Sound Asleep effectively detects and enhances slow-wave sleep, the following high-level requirements must be met:

- The wearable EEG headband must continuously record and transmit EEG signals overnight with sufficient signal fidelity to distinguish sleep stages, especially slow-wave sleep.
- The system must detect slow-wave oscillations in real-time with a maximum end-to-end latency of **200 ms** to properly synchronize auditory stimulation with brain activity.
- The mobile app must deliver auditory stimuli through a Bluetooth audio device with a timing accuracy of **±50 ms** relative to the detected slow-wave peak.
- The system must operate comfortably and safely for at least **8 hours** on a single charge, ensuring suitability for overnight use.

2. Design

2.1 Block Diagram

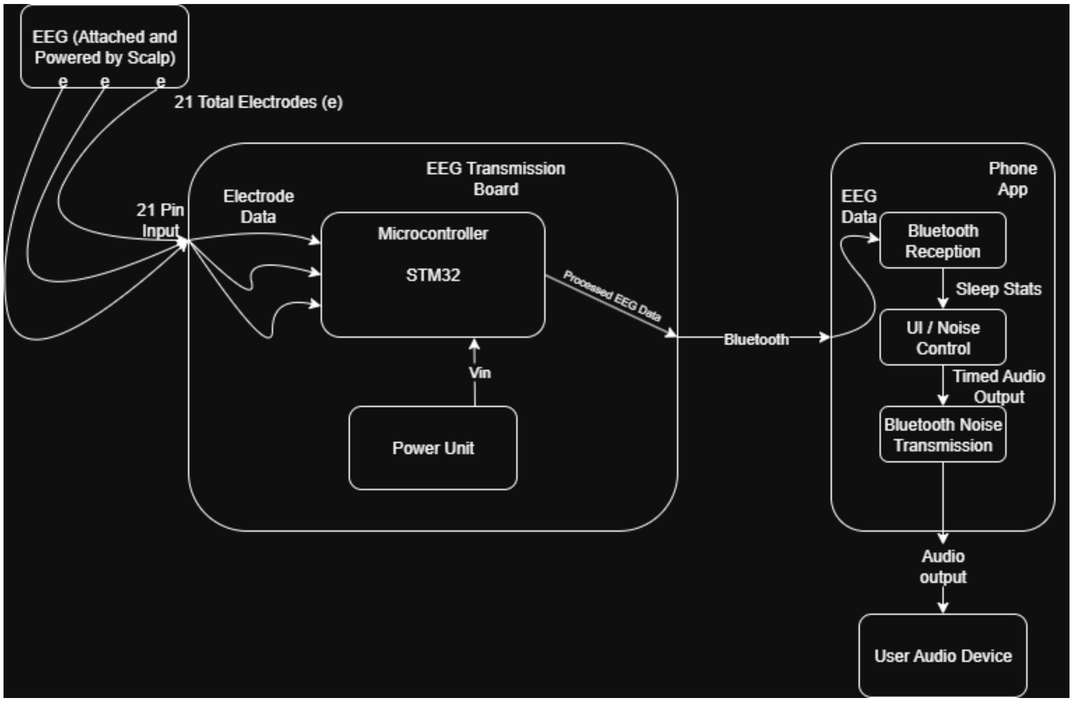

Figure 3. Block Diagram of Sound Asleep

The block diagram above illustrates the modular architecture of the *Sound Asleep* system, which consists of four main subsystems: the **EEG Module**, the **Wireless Transmission** and **Power Management Board**, the **Sleep Stage Processing Module**, and the **Auditory Stimulation Interface**.

The **EEG Acquisition Module** includes multiple scalp-attached electrodes integrated into a lightweight headband that record raw brain signals during sleep. These analog EEG signals are first amplified and filtered to remove noise, then passed into the **ADS1299**, a high-resolution, 24-bit, 8-channel analog-to-digital converter (ADC) specifically designed for biopotential measurements such as EEG. The ADS1299 plays a crucial role by digitizing the low-amplitude

EEG signals with exceptional precision and minimal noise, ensuring that even small variations in brain activity are accurately captured.

These digitized signals are then sent to the **STM32 microcontroller** on the Wireless Transmission Board, which manages data packaging, Bluetooth Low Energy (BLE) communication, and power regulation through the onboard battery management system (BMS). The **Mobile Application Interface** receives this EEG data and processes it in real-time using algorithms such as YASA and CoSleep to detect slow-wave sleep activity. When a slow-wave pattern is identified, the app activates the **Auditory Stimulation Subsystem**, which delivers pink noise bursts via the user's Bluetooth audio device.

This closed-loop interaction—starting from EEG acquisition through ADS1299-based digitization to auditory feedback—ensures that sound stimuli are precisely synchronized with the user's brain oscillations. As a result, Sound Asleep enhances the depth and quality of slow-wave sleep while prioritizing user comfort, safety, and overnight usability.

2.2 Subsystem 1: EEG Module

We adopt the **OpenBCI EEG Headband Kit** as the physical interface for scalp measurement. This kit includes **8 snap-comb Ag/AgCl electrodes** (plus ear clips) and a headband strap to maintain consistent contact. While the kit itself does not include the analog front-end or ADC (these are parts of the OpenBCI boards), in our design we pair it with our analog amplification/filtering stage and the ADS1299 as the core ADC. The electrodes interface via snap leads to the amplification/anti-aliasing stage; after conditioning, signals go into the

ADS1299 for digitization. The headband mechanical design (straps, lead routing, snap connectors) helps reduce motion artifacts and supports strain relief.

This subsystem must deliver low-noise, stable EEG signals during overnight use, maintain electrode contact impedance within acceptable limits, and interface cleanly to the downstream electronics (power, digital, mechanical). It supports the higher-level goals of reliable sleep staging (HLR-1) and long-duration usability (HLR-4).

We must clearly define how electrode contact is ensured, how motion artifacts are mitigated, how lead-off detection works, and what tolerances we accept on signal quality.

Table 1. Requirements and verification of EEG Module.

Requirement	Verification
R1. Electrode contact impedance. Each electrode must maintain impedance ≤ 50 kΩ (worst case) during stationary sleep and ≤ 100 kΩ during mild head motion (±20°) for 10 minutes.	**Equipment:** Impedance meter, resistor reference. **Procedure:** Attach headband on dummy head, measure impedance per electrode every 30 s over 10 min while simulating slight movement. **Result:** ≤ 50 kΩ static; ≤ 100 kΩ under motion.
R2. Lead-off detection & flagging. The system must detect electrode disconnection or impedance > 100 kΩ within ≤ 2 seconds and flag the channel.	**Equipment:** Resistor decade box. **Procedure:** Insert series resistor ramp (10 kΩ to 200 kΩ) and time detection by firmware. **Result:**Flag arises when impedance exceeds threshold ≤ 2 s.

R3. Noise floor with headband. With snap leads connected and no biological input, the conditioning + ADC chain (via headband) must exhibit ≤ 1.2 μV_rms noise (0.5–40 Hz).	**Equipment:** Shielded enclosure, shorted electrodes. **Procedure:** Short all inputs via headband wiring and log for 5 min; compute noise. **Result:** ≤ 1.2 μV_rms.
R4. Baseline drift & offset. DC offset drift (after initial settling) must be ≤ 50 μV over 5 min at 25 °C.	**Equipment:** Long-term recording setup. **Procedure:** Record a no-input channel over 5 min; compute offset drift. **Result:** ≤ ±50 μV drift.
R5. Artifact tolerance. During mild head movements (±20° yaw/pitch), the signal amplitude transient deflections should not exceed ±200 μV, and recovery time to baseline < 1 s.	**Equipment:** Motion rig, accelerometer, oscilloscope. **Procedure:**Apply controlled head rotations, measure voltage spikes and return. **Result:** Transients < ±200 μV, stabilization <1 s.
R6. Motion artifact dropouts. During normal overnight shifts (turning pillow, slight tossing), lead-off flags must occur < 1/min total across all channels.	**Equipment:** Human subject, logging environment. **Procedure:** Wear headband overnight in controlled environment; log lead-off events. **Result:** < 1 event per minute total.

2.3 Subsystem 2: Wireless Transmission and Power Management Board

The Wireless Transmission and Power Management Board serves as the central hardware system of Sound Asleep, bridging the EEG Acquisition Module and the Sleep Stage Processing Subsystem. It is responsible for ensuring reliable data acquisition and low-latency wireless communication for processing along with efficient power regulation and system-level synchronization to ensure real-time performance of the closed-loop auditory stimulation process.

At the heart of this subsystem is the STM32U5A5VJT6Q ultra-low-power microcontroller, selected for its integrated DSP instructions, multiple SPI interfaces, and efficient active/sleep power modes optimized for biomedical wearables. This STM32 variant will allow us to handle significant onboard processing of signals while also maintaining power efficiency. The STM32 communicates directly with the ADS1299 EEG analog front end via SPI, collecting 24-bit digitized EEG samples from the 8 channels of the headband at 250 Hz, and applies amplification/filters and real-time slow-wave detection algorithms such as bandpass filtering, envelope extraction and adaptive thresholding. These samples are packetized and transmitted over Bluetooth Low Energy (BLE) using an ESP32 module, which provides low-latency communication compatible with modern smartphones. Additionally, when the STM32 detects an event such as a slow-wave up-phase, it timestamps the event and forwards a compact event packet to the ESP32 over a low-latency interconnect.

Maintaining low end-to-end latency in this subsystem is crucial to meeting the system's 200 ms tolerance window for auditory stimulation synchronization. The STM32 firmware implements a lightweight buffering protocol with real-time timestamping to minimize transmission delay and jitter. On average, data acquisition and packaging contribute ~50 ms latency, and BLE transmission adds an additional 50–75 ms under standard conditions, resulting in a total subsystem delay well below the 100 ms target. This ensures that slow-wave detection and auditory feedback remain tightly phase-locked within the up-state window of the user's slow-wave sleep.

Power to our system is supplied as a 12V DC source. As part of our initial analysis of the components required, components such as the microcontroller and the ADC require an input limited between 2.7 to 3.3V. As such we are using a 12V to 3.3V high-efficiency low-dropout step-down voltage regulator that supplies the STM32 and ADS1299 a clean, noise-free power rail. The system supports continuous 8-hour operation, with typical current draw of ~45 mA during active data transmission and <100 µA in deep-sleep mode when idle.
The board integrates power monitoring via an I2C fuel gauge to report real-time battery levels to the mobile app and automatically initiates a low-power shutdown when the battery voltage drops below 3.0 V. Combined with proper EMI shielding, these design elements ensure stable performance, long operational life, and minimal interference with EEG signal acquisition.

This subsystem fulfills HLR-1 (high-fidelity EEG transmission), HLR-2 (low-latency, phase-locked operation), and HLR-4 (overnight power stability), providing the foundational link between sensing and stimulation within the closed-loop system.

Table 2. Requirements and verification of Wireless Transmission and Power Management Board

Requirement	**Verification**

R1. Wireless Throughput The BLE link shall transmit 8 channels of 24-bit EEG data sampled at 250 Hz (≈2 kB/s) continuously for 8 hours with <1% packet loss. mild head motion (±20°) for 10 minutes.	**Equipment:** Impedance meter, resistor reference. **Procedure:** Attach headband on dummy head, measure impedance per electrode every 30 s over 10 min while simulating slight movement. **Result:** ≤ 50 kΩ static; ≤ 100 kΩ under motion.
R2. Transmission Latency (Critical for Closed-Loop Timing) — The total delay from ADC sample acquisition to packet arrival at the processing subsystem shall not exceed 100 ms (mean ≤ 75 ms).	**Equipment:** Resistor decade box. **Procedure:** Insert series resistor ramp (10 kΩ to 200 kΩ) and time detection by firmware. **Result:**Flag arises when impedance exceeds threshold ≤ 2 s.
R3. Jitter Stability — Variability in transmission latency shall be ≤ ±10 ms over continuous 1-hour streaming.	**Equipment:** Shielded enclosure, shorted electrodes. **Procedure:** Short all inputs via headband wiring and log for 5 min; compute noise. **Result:** ≤ 1.2 µV_rms.
R4. Power Efficiency — The subsystem shall draw ≤ 50 mA during active transmission and ≤ 100 µA in deep-sleep mode.	**Equipment:** Long-term recording setup. **Procedure:** Record a no-input channel over 5 min; compute offset drift. **Result:** ≤ ±50 µV drift.

R5. Battery Life — The system shall operate continuously for ≥ 8 hours on a 1000 mAh Li-Ion cell.	**Equipment:** Motion rig, accelerometer, oscilloscope. **Procedure:**Apply controlled head rotations, measure voltage spikes and return. **Result:** Transients < ±200 µV, stabilization <1 s.
R6. Power Regulation Stability — 3.3 V regulated output shall remain within ±2% of nominal under 0–100 mA load.	**Equipment:** Human subject, logging environment. **Procedure:** Wear headband overnight in controlled environment; log lead-off events. **Result:** < 1 event per minute total.
R7. EMI Noise Isolation — Digital transmission noise coupled to the analog ground shall be <5 µV_rms (0.5–40 Hz).	**Equipment:** LCR meter. **Procedure:** Measure capacitance from snap-lead pair. **Result:** < 100 pF.

Table 2. Requirements and Verification of Wireless Transmission and Power Management Board

2.4 Subsystem 3: Sleep Stage Classification and Signal Processing

The **Sleep Stage Processing Subsystem** is a web-based application responsible for classifying EEG data into sleep stages, detecting slow-wave oscillations, and coordinating real-time auditory stimulation. It integrates two major open-source toolkits: **YASA (Yet Another Spindle Algorithm)** for automatic sleep staging and slow-wave/spindle detection, and **CoSleep**, which provides closed-loop stimulation capabilities and simulation/testing environments for OpenBCI-based EEG.

The app is implemented in **Python (Flask + YASA + MNE)** for backend data processing, and a **React web interface** for visualization, enabling remote operation via browser. The backend ingests Bluetooth-transmitted EEG data (24-bit, 250 Hz sampling) in EDF+ format, performs preprocessing (bandpass 0.1–40 Hz, artifact rejection, downsampling), and classifies each 30 s epoch into Wake, N1, N2, N3, or REM using YASA's trained feature set (spectral ratios, entropy, spindle density). Detected **slow-wave up-phases** trigger pink-noise playback commands with < 200 ms total latency to the auditory subsystem.

This subsystem directly fulfills high-level requirements HLR-1 (accurate sleep-stage detection), HLR-2 (real-time phase-locked stimulation), and HLR-3 (data logging and user feedback). It defines interfaces to:

- **Wireless Transmission Board** (input: EDF/BDF stream over BLE/Wi-Fi)
- **Auditory Stimulation Interface** (output: JSON socket event for noise trigger) and the **User Interface** (REST endpoint for visualization and manual override)

Table 3. Requirements and verification of Sleep Stage Classification and Signal Processing.

Requirements	Verification
R1. Classification Accuracy — The system shall achieve ≥ 80% epoch-level accuracy in automatic sleep staging compared to expert-scored PSG data.	**Equipment:** OpenBCI or PhysioNet dataset with labeled hypnogram. **Procedure:** Run YASA classifier; compare predicted vs.

	labeled epochs using Cohen's κ. **Result:** $\kappa \geq 0.75$, accuracy ≥ 80%.
R2. Detection Latency — From EEG event (slow-wave peak) to audio trigger, total closed-loop latency shall be ≤ 200 ms, with mean ≤ 150 ms.	**Equipment:** Oscilloscope, EEG simulator, timestamp logging. **Procedure:** Inject simulated slow wave, measure delay between EEG peak and output trigger. **Result:** ≤ 200 ms.
R3. Signal Throughput — The web app shall process and visualize 8 channels sampled at 250 Hz (2 kB/s) continuously for 8 hours without buffer overflow or > 1% data loss.	**Equipment:** BLE simulator, logging server. **Procedure:** Stream dummy EDF data overnight; monitor dropped packets and memory usage. **Result:** Data loss < 1%, no crash.
R4. Stimulation Timing Precision — Pink-noise burst shall be issued within ±50 ms of targeted slow-wave up-phase.	**Equipment:** EEG simulator + speaker latency logger. **Procedure:** Inject synthetic oscillations and trigger stimuli; measure temporal deviation. **Result:** ±50 ms tolerance met.

2.5 Subsystem 4: Auditory Stimulation Interface

The **Auditory Stimulation Interface** serves as the final stage in the closed-loop sleep enhancement system, responsible for **delivering precisely timed pink-noise bursts** that align with the user's slow-wave sleep cycle. It receives trigger commands from the **Sleep Stage Classification and Signal Processing Subsystem** and plays short (≈50 ms) pink-noise sounds through a Bluetooth-connected audio device or, by default, the smartphone speaker if no device is paired.

This subsystem is intentionally designed for **maximum flexibility and user comfort**, allowing the user to select any Bluetooth-compatible playback device, such as in-ear headphones, sleep earbuds, or bedside speakers. While in-ear devices are expected to provide the most effective stimulation due to improved acoustic coupling, broader compatibility ensures accessibility and personalization for different sleep environments.

Functionally, the subsystem must ensure **low-latency playback (< 200 ms total)** maintaining the effectiveness of closed-loop stimulation. Playback commands are handled using the smartphone's native audio APIs for deterministic timing, and each playback event returns an acknowledgment to the web-based processing system for synchronization and logging.

Although this subsystem requires no new hardware development, **performance testing across various Bluetooth devices** is critical to verify consistent timing, volume control (55 dB SPL), and reliability over extended use. In essence, the Auditory Stimulation Interface bridges advanced EEG analysis with a user-friendly auditory experience, completing the loop that enables real-time, phase-locked sleep modulation.

Table 4. Requirements and verification of Auditory Stimulation Interface.

Requirements	Verification
R1. Audio Latency — The system will playback audio within 200 ms of a pink noise burst being triggered.	**Equipment:** High Speed Audio Logger, Oscilloscope **Procedure:** Trigger multiple pink noise commands with sending timestamps. Record audio playback time with accurate timestamp. **Result:** Timestamp difference of less than 200 ms.
R2. Battery Life — The system will be responsive for at least 8 hours on a single charge	**Equipment:** Long duration playback test **Procedure:** Test a long duration of pink noise playback over 10 hours and record when the device lost connection with the app. **Result:** The device retains its battery over at least 8 hours.
R3. Device Activity — The device will be ready and active for at least 8 hours of charge. This will require the app to maintain device activity even when no noise is active.	**Equipment:** Inactive Audio Test **Procedure:** Pair the device with the phone and begin sleep. See if the device remains active over its full battery life period. **Result:** The device remains active with the same audio latency as R1.
R4. Acknowledgement Feedback — The device sends an acknowledgement that the	**Equipment:** Web app audio playback logger **Procedure:** Play pink noise stimulation to

pink noise was played within 100 ms of the start of playback.	audio device and wait for acknowledgement. **Result:** Receive an acknowledgement in less than 100 ms after audio playback is active.
R5. Audio Intensity — The device outputs audio at a loudness of approximately 55 dB SPL with diminishing intensity if the user appears to be exiting slow wave sleep.	**Equipment:** Sound Level Meter or in-ear microphone. **Procedure:** Play pink noise stimulation to audio device continuously while measuring loudness. After a short period, the app will direct the device to decrease in intensity and the loudness will again be measured. **Result:** Audio playback is measured to be within ±5 dB of 55 dB SPL with decreasing intensity when the app directs it to do so.

3. Tolerance Analysis

The most important tolerance within our closed loop system is our latency between the sensed EEG signal and the transmitted pink noise signal so that it occurs in phase with the slow wave sleep. Sources say that slow waves occur at a frequency of less than 1 Hz. We then would expect that we have 500 ms of up state slow wave sleep. The study from Hong Viet V. Ngo et al. suggest 50ms bursts of pink noise during this up state. Decreasing our latency allows more bursts within this up state which should increase the sleep enhancement. We must identify our latency between the up state of slow wave detection and the latency of audio playback from the pink noise trigger. We require a 200 ms latency between the detection of the up state and the audio playback of our first 50 ms pink noise burst. Decreasing this latency allows more bursts to be played during that up state and allows them to be more spaced from one another.

Requirement. End-to-end latency (EEG detection → audio onset at the ear) **≤ 200 ms**; timing precision ± **50 ms** relative to the SO up-state.

Latency contributors (typical / worst-case):

- ADS1299 group delay + decimation: ~4–8 ms
- STM32 packetization + SPI/BLE enqueue: 5–15 ms
- BLE link & phone receive : 15–35 ms
- App pre-processing (YASA/CoSleep): 10–25 ms

Nominal sum: ~**150 ms** (meets requirement).

Worst-case sum: ~**200–220 ms** (requires calibration and buffer tuning).

How latency affects stimulation opportunity :-

Assuming a 500 ms up-state and 50 ms bursts placed back-to-back (best-case), the **maximum number of bursts** available is:

$$N(L) \ = \lfloor \frac{500\ ms - L}{50\ ms} \rfloor, L \ = \text{first - burst latency.}$$

At **150 ms**, N=7 bursts remain; at the **200 ms** requirement, N=6

Design actions to stay under 200 ms:

- Use BLE 5.0 (2M PHY) and minimal connection interval (≈ 15–20 ms).
- Timestamp and calibrate audio device latency once; pre-schedule playback with offset.
- Keep app processing in fixed-size chunks (e.g., 128 samples @ 250 Hz ≈ 512 ms windows with overlap but compute every 64–128 ms).
- Prefer low-latency audio path (wired or LE Audio when available) during validation.

4. Cost Analysis

The total estimated cost for the Sound Asleep project, as shown in **Figure 18**, accounts for all essential hardware, microcontrollers, sensors, and supporting materials required for a fully functional EEG-based sleep enhancement prototype.

Each team member is expected to contribute approximately **60 hours** of development time at an estimated rate of **$40/hour**, totaling **$2,400 per member**. With three team members, the total labor cost amounts to **$7,200**.

The **OpenBCI EEG Headband Kit** and **ADS1299 analog front-end chip** represent the major hardware expenses as they provide research-grade signal quality and real-time data acquisition necessary for closed-loop sleep stimulation. All other important components are the **STM32 microcontroller**, **battery system**, **amplification/filtering circuits**, and **3D-printed enclosure**.

These are sourced using university lab inventory or purchased in small quantities to minimize cost.

Table 5. Itemized List of Components and Costs.

Description	Manufacturer	Quantity	Unit Price (USD)	Extended Price (USD)	Link / Notes
STM32U5A5VJT6Q Ultra-Low-Power Microcontroller	STMicroelectronics	1	$9.32	$9.32	ST Product Page
ADS1299-4PAGR 24-bit EEG Analog Front End	Texas Instruments	1	$32.50	$32.50	TI ADS1299 Datasheet
OpenBCI EEG Headband Kit	OpenBCI	1	$349.99	$349.99	OpenBCI Store
Bluetooth Low Energy Module (ESP32-WROOM-32E)	Espressif	1	$5.00	$5.00	DigiKey
Li-Ion Battery (3.7V 1000 mAh)	Adafruit	1	$9.00	$9.00	Adafruit
TP4056 Charger Module with Protection	SparkFun	1	$4.00	$4.00	SparkFun
EEG Lead Wires & Snap Connectors (Ag/AgCl)	OpenBCI	1	$20.00	$20.00	Accessory Pack
Low-Noise Amplifier and Filter PCB (Custom)	In-Lab Fabrication	1	$25.00	$25.00	Fabricated at ECE Lab
PLA Filament for 3D-Printed Housing	Hatchbox	1	$10.00	$10.00	Hatchbox
Misc. Hardware (wires, adhesives, connectors, heat-shrink)	—	—	—	$15.00	Estimated
USB-C Interface + Cables	SparkFun	1	$8.00	$8.00	SparkFun

Breadboard & Prototyping Components	UIUC ECE Inventory	—	—	$0.00	Provided by lab
Software Dependencies (YASA, CoSleep, Flask)	—	—	—	$0.00	Open-source
Labour costs	Team members	3	$2400	$7200	
Total Project Cost				**$7687.81**	
Funding Source	UIUC Carle Illinois School of Medicine			**$50,000.00**	Academic Research Grant

5. Schedule

Table 6. Timeline of the project.

Week	Task	Person(s)
September 29 – October 6	Finalize project architecture (EEG, STM32, ADS1299, BLE, mobile app). Order all components. Begin schematic design and component footprint mapping.	Everyone
October 6 – October 13	Complete first version of PCB schematic in KiCad/Altium. Breadboard test ADS1299 communication with STM32. Begin PCB layout.	Ambika & Shub
October 13 – October 20	Pass internal PCB audit and **submit first revision by Second Round PCBWay Order deadline (Oct 17)**. Finalize 3D printed housing for headband and STM32 board.	Ambika & Adam
October 20 – October 27	Continue breadboard prototyping for power system and Bluetooth module. Implement basic data transmission via BLE. Develop Python-based signal processing prototype using YASA.	Shub & Ambika

October 27 – November 3	**Breadboard Demo 2:** demonstrate working EEG acquisition and streaming to app. Begin firmware integration (ADC sampling, BLE data packets).	Everyone
November 3 – November 10	Test real-time EEG filtering and slow-wave event detection. Integrate auditory stimulation logic using CoSleep algorithm.	Shub & Adam
November 10 – November 17	Conduct pilot tests using OpenBCI EEG headband. Validate latency (<100 ms) and synchronization with auditory output.	Ambika & Shub
November 17 – November 24	Mock Demo: present partial closed-loop functionality to TAs. Collect feedback on signal accuracy and timing performance.	Everyone
November 24 – December 1	**Thanksgiving Break — no scheduled work.**	—
December 1 – December 8	**Final Demo:** present fully integrated closed-loop system with real-time EEG feedback and auditory stimulation. Evaluate power, latency, and comfort metrics.	Everyone
December 8 – December 15	**Final Presentation & Report Submission:** compile documentation, cost analysis, and experimental results.	Everyone

6. Ethics and Safety

Our project aims to improve sleep quality and neurological research accessibility by designing a non-invasive EEG-based wearable system that monitors and enhances slow-wave sleep through precisely timed auditory stimulation. This design directly aligns with IEEE's Code of Ethics Section I.1, which emphasizes the duty "to hold paramount the safety, health, and welfare of the public."

Because the Sound Asleep device operates in close contact with the user's head during sleep, safety and comfort are our foremost priorities. The system uses low-voltage circuits (<3.7 V) to ensure electrical isolation from the body. EEG electrodes are silver–chloride (Ag/AgCl) and medical-grade adhesive gel is used to minimize skin irritation. All analog front-end electronics, including the ADS1299 amplifier, are fully isolated from any external power supply via an onboard protection circuit.

We also acknowledge potential concerns regarding signal privacy and data integrity. Brainwave recordings may contain sensitive biometric information. Therefore, we commit to ensuring user privacy by performing all EEG processing locally on the embedded microcontroller or user's mobile device without cloud transmission. Any data logs are anonymized and encrypted in accordance with IEEE's Code of Ethics Section I.9, which promotes respect for privacy and protection of intellectual property.

In line with Section I.5 which calls for honesty and realism in stating claims based on available data, we will clearly communicate the intended functionality and limitations of the Sound Asleep system. While slow-wave stimulation has been shown in peer-reviewed studies to improve memory consolidation, our implementation is not a medical treatment and should not be marketed as such. All performance claims will be supported by quantitative test results, including latency measurements, synchronization accuracy, and EEG signal fidelity.

By adhering to these standards, this project upholds the ethical principles of transparency, user safety, and societal benefit as outlined in IEEE's Code of Ethics Section I.2, which emphasizes the responsibility "to improve the understanding by individuals and society of the capabilities and societal implications of conventional and emerging technologies, including intelligent systems."

7. Citations

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