UC San Diego

EEG Monitor for Detecting Neurological Disorders

By: Nikhita Sujan, Simran Bedi, Ly Nguyen, Sophia Lam, Louie Zhao

March 12, 2024

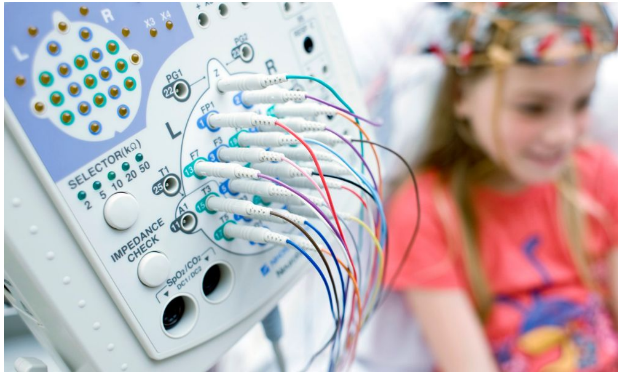
Motivation

Neurological Disorders

- A medical condition that affects the brain and nerves throughout the human body and spinal cord
- May stem from abnormalities in the brain, genetic disorders, brain or spinal cord injuries, malnutrition, psychiatric illnesses, etc.
- Symptoms include paralysis, abnormal movement, seizures, difficulty swallowing, and more

Using an EEG to Monitor Neurological Disorders

- An EEG (Electroencephalogram) is a non-invasive method that measures electrical activity in the brain
- Since brain cells communicate via electrical impulses, their activity can be recorded as EEG waveforms
- Analyzing abnormal patterns help clinicians diagnose various neurological conditions



Types of Neurological Disorders

1. Epilepsy
2. Alzheimer's Disease
3. Attention Deficit Hyperactivity Disorder (ADHD)
4. Anxiety Disorders
5. Parkinson's Disease

Methods

1. Setup the EEG

a. Place the headband with embedded electrodes on the respective locations of the scalp

2. **EEG Signal Processing**

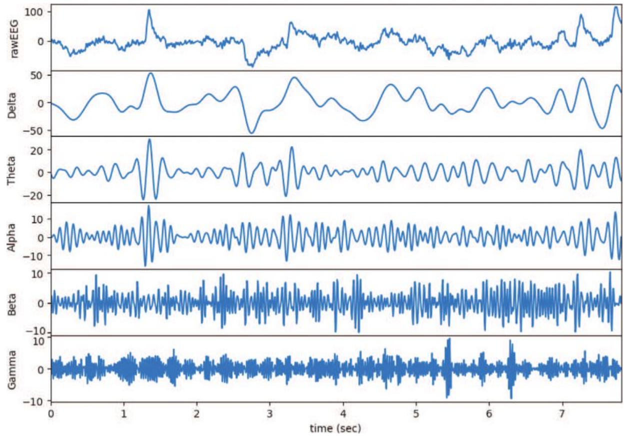
a. Motion artifacts & unwanted noise removal via an instrumentation amplifier and a high pass filter

b. Signal Processing: creation of alpha, beta, theta, and delta waveforms

3. EEG Signal Analysis

c. Visual Identification

d. Quantitative Analysis



Categorization of Waveforms

UC San Diego

Alpha Waves: observed when a person is awake but relaxed / eyes closed & a frequency of 8-12 Hz

- Reduced alpha wave activity or abnormalities, such as sharp peaks for 20-70 ms and amplitudes higher than 200 µv, detects conditions such as epilepsy, Alzheimer's disease / dementia, and ADHD

Beta Waves: observed when a person is fully awake / mentally concentrated & a frequency of 12 - 30 Hz

- Beta wave abnormalities, such as amplitudes lower than 5-10 µv, detects conditions such as anxiety disorders, dementia, and Parkinson's disease

Theta Waves: observed during light sleep or drowsiness or deep meditation & a frequency of 4-8 Hz

- Abnormalities, such as amplitudes outside the range of 5-10 µv, detects sleep disorders including insomnia, sleep apnea, or parasomnias

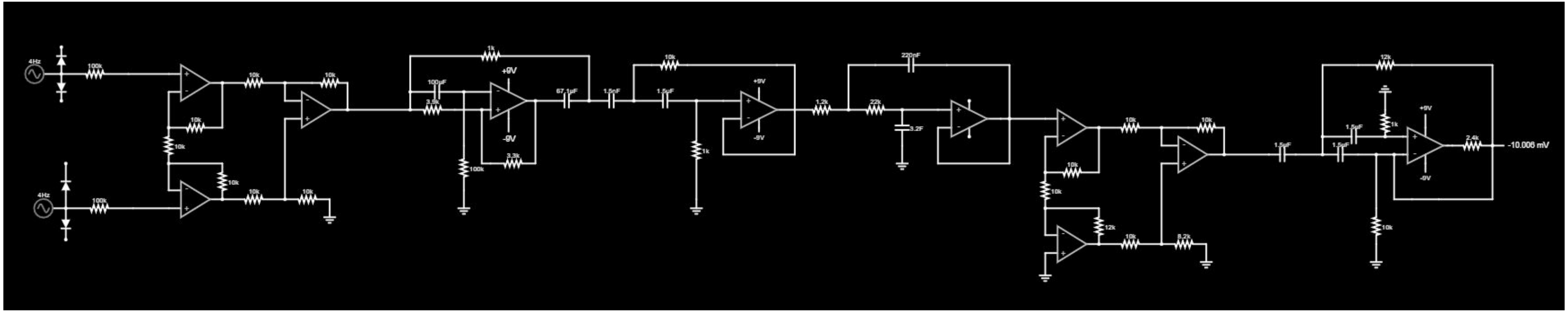
Delta Waves: observed during deep sleep & a frequency below 4 Hz

- Abnormalities classified detects neurological disorders from traumatic brain injuries and sleep disorders including insomnia and restless legs syndrome.

Assumptions

1. **Consistent User State:** the user's state remains relatively stable during EEG recording sessions, with variations occurring between distinguished neural states.
2. **Effective Frequency Filtering:** high pass, low pass, and notch filters designed to effectively remove unwanted frequency components outside the alpha wave range (8-12 Hz).
3. **Absence of Electrical Interference:** there is minimal interference from external electrical sources that could introduce noise into the EEG signal.
4. **Linear Amplification Response:** ideal amplification response of the instrumental amplifiers is linear within the desired frequency range of the alpha waves & gain remains constant across varying input voltages.
5. **Stable Electrode Contact:** there is consistent contact between the EEG electrodes and the user's scalp for reliable signal transmission.

Circuit Design



Main Components:

- Instrumental Amplifier
- Notch Filter
- High Pass Filter
- Low Pass Filter

Instrumentation Amplifier

Alpha wave signals are typically 15-50 uV, requiring lots of amplification for accurate signal detection.

Functionality

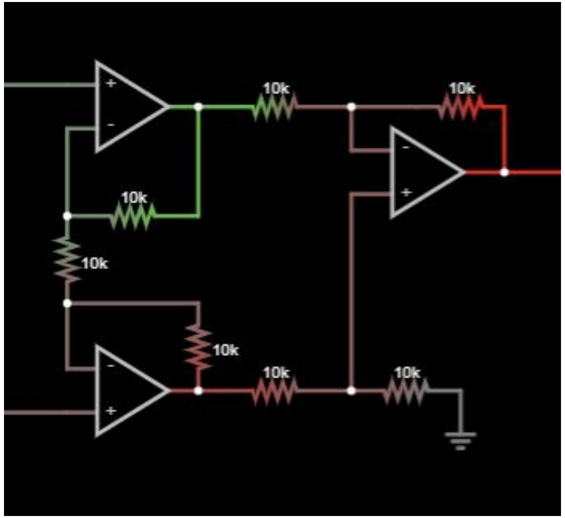
Utilizes two voltage inputs from active electrodes and outputs their difference multiplied by a gain factor of *G*.

$$G = 1 + (49.4k\ Ohm)/R_G$$

Common Mode Rejection Ratio (CMRR)

Indicates how effectively the amplifier ignores common offsets between input voltages (higher CMRR signifies better performance, resulting in an output closer to that of an ideal amplifier).

AD620



Notch Filter

The primary source of noise in EEG systems is often powerline interference (PLI), typically centered at 60 Hz.

Functionality

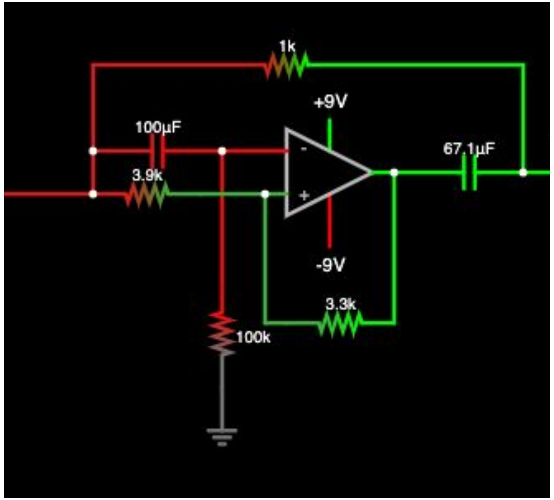
Designed to significantly reduce gain around a specific frequency, effectively filtering out interference.

1st Notch Filter

Filters out PLI before more gain can be applied to the circuit before amplification.

Frequency

f = 1/(2πRC)



High - Pass Filter

Functionality

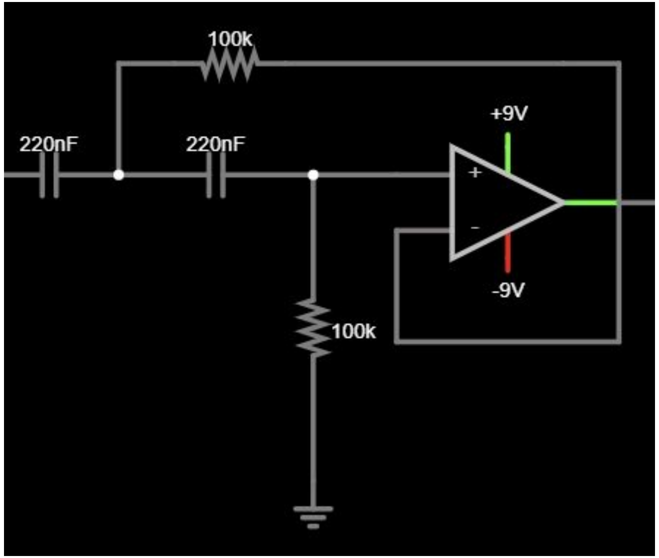
Filters noise from IA and the low frequencies that may occur from galvanic skin response. Also filters out most gamma/delta wave data leaving alpha/beta wave data

With the addition of the op-amp converts filter into an active high pass filter

Frequency

$$f = 1/2\pi RC$$

In this case, f = 7.2 Hz



Low - Pass Filter

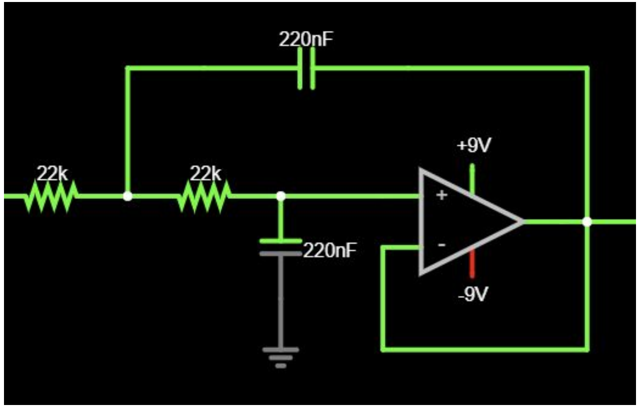
To refine EEG data, frequencies above those of interest must be filtered out. Beta waves, which ceases above 30 Hz, contributes noise beyond this range.

Functionality

This design ensures effective attenuation of frequencies above 30Hz while preserving alpha (8-12 Hz) and beta (12-30 Hz) waves of interest.

Frequency

$F_C = 32.9$ Hz



Instrumental Amplifier with Variable Gain

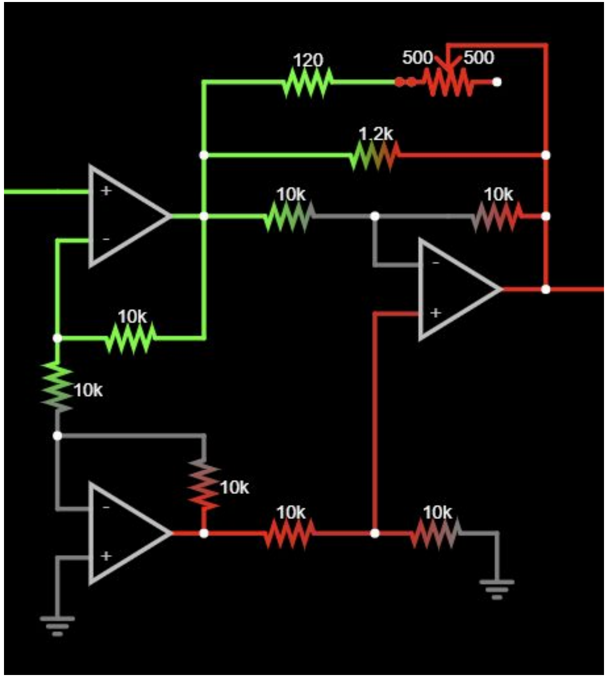
Weak neural signals recorded from scalp electrodes can be enhanced through amplification with variable gain based on the strength of the incoming EEG.

Functionality

By adjusting resistors, particularly through the potentiometer, the gain can be varied linearly between specific limits, effectively scaling up the magnitude of the EEG signal.

Gain

$G = 1 + R_{12}/(R_{13} + R_{14})$



Discussion

Analyzing and monitoring alpha wave patterns provide valuable insights on neurological disorders, aiding in early diagnosis, treatment planning, and evaluating the efficacy of therapeutic interventions.

How our device can be integrated:

1. Global RS alpha wave power was lower in people with Alzheimer's Disease
2. Children with ADHD observes high alpha wave activity

Limitations

UC San Diego

- **May pick up artifact signals that aren't related to the brain signals of interest**
    - May also capture signals from eye movements, facial expressions and heart movements.
- **Electrode placement**
    - Electrodes needs to be placed in specific areas to be able to record the signals
    - The skull of an individual will be different, you need to account where to place the electrodes to ensure accurate results
- **Analyzing different waves requires different setups**
    - Although capable of measuring different waveforms, each setup must be tailored to the waveform to ensure accurate and precise measurements.
- **Limited amount of electrodes**
    - To remove artifact signals that aren't of interest, there needs to be more components that filter out those signals, however to compensate for that there needs to be more electrodes

Improvements

UC San Diego

- **Utilize an independent component analysis (ICA) as it is more effective**
    - Eliminates motion artifacts
    - Propagation delays are negligible
    - Component time courses are independent
    - Number of components are equal or less than the number of channels
    - Mixing is linear at each electrode
    - Increases the number of electrodes
- **Identify ideal electrode placements**
    - As each person’s skull differs, electrode placement is crucial to achieve accurate results
    - Recognize universal areas where electrodes can be placed
- **Add component that filters out noise**
    - E.g. eye movement, heart movement and muscle contractions
    - May have to be accompanied by more electrodes

Conclusion

UC San Diego

- In this project we explored designing an EEG monitor that detects neurological disorders
- Our design included 4 main components: Instrumental Amplifier, Notch Filter, High Pass Filter, Low Pass Filter
- EEG processing was able to pick up and successfully filter out noise and we were able to achieve results for obtaining Alpha and Beta Waves
- With the obtained results, we were able to identify patterns in the brain that may be linked to neurological disorders
- Using this technology, we hope to identify and prevent these neurological disorders from happening by using EEG monitor, like this one we built to help millions worldwide who suffer from these issues.

References

- https://www.scirp.org/journal/paperinformation?paperid=112539#:~:text=Electroencephalogram%20(EEG)%20is%20a%20common,is%20a%20time%2Dconsuming%20task.
- https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7739973/
- https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3535182/
- https://www.instructables.com/DIY-EEG-and-ECG-Circuit/
- https://pubmed.ncbi.nlm.nih.gov/26812442/
- https://pubmed.ncbi.nlm.nih.gov/28759980/

Thank you!