402-20-Excellence-Neuroelectronics-Executive Summary Draft

Epilepsy is a brain disorder characterized by abnormal neuronal activity, leading to misfires in the brain and resulting in seizures. According to the World Health Organization, around 50 million people have epilepsy, nearly 80% of whom live in low- and middle-income countries. This poses a challenge to diagnosing the condition, as traditional diagnosis requires costly Electroencephalography (EEG) systems, which use scalp electrodes to record neurons and display abnormal activity. The cost ranges from $300 to $2500 for consumer EEG devices, with hospital-grade EEGs costing around $10,000 to $100,000. The World Health Organization estimates that up to 70% of people living with epilepsy could be seizure-free if they were properly diagnosed and treated. Thus, an affordable device that can be widely distributed for epilepsy detection is necessary to help patients. The entire project kit, including a headcap and circuitry, must cost under $100 to be affordable. The purpose of this device is to allow doctors in low and middle income countries an accessible option to understand the brainwaves of their patients and is not intended for diagnostic purposes within the U.S.The system must be able to acquire signals from ten different channels at a 1 kHz sampling rate with 12-bit resolution. Finally, the headcap design must fit between 50-64 cm, as these are the standard head sizes.

To tackle this problem, the design team developed an affordable, multi-channel EEG system capable of receiving and amplifying signals from ten independent channels while maintaining a projected cost under $100. The system comprises a printed circuit board (PCB), a custom-fabricated headcap for stable electrode placement, a 3D-printed ear clip to ensure proper grounding, and a graphic user interface for convenient visualization. The design process began by selecting a headcap and circuit design. For the headcap, we considered several options, including a fabric design, a 3D-printed cap, and a simple diagram of where to place the electrodes. The 3d-printed design upon testing fit very few subjects and was not easy to scale for users of other head sizes, the 10%-90% nasion to inion landmarks were on average about 6.5% off but some landmarks were as much as 40% away from where they should have been which would have lead to significant reading discrepancies. Thus, we decided to pursue a fabric headcap, due to greater mechanical flexibility and easier fabrication. The earclip was modeled after a chip clip. Various iterations of this design allowed for light, sustained contact with the ear while minimizing mechanical wear.

For the circuit, we decided on dedicated amplification stages placed in parallel and finished with a multiplexer. For this design, we calculated the signal to noise ratio (SNR) to be 71.5dB and the common-mode rejection ratio (CMRR) to be 8.5dB. These tests were conducted using a signal generator to apply appropriate signals to the circuit. A graphic user interface (GUI), coded with PyQtGraph, was created to display the signal from all ten channels, allowing the user to save the data in a CSV file for further analysis. The embedded system that interfaces with the GUI is further optimized for data streaming by employing dual recording buffers and batch processing to reduce computational overhead.

We were able to meet the requirements set forth by our client. These components cost less than $100, as outlined in the requirements. The circuit accommodated ten different channels while maintaining a 1 kHz sampling rate. This circuit is able to collect a signal and process it appropriately, then display the signal on the GUI interface. The fabric headcap could fit heads ranging from 50-64 cm in diameter. Throughout this process, TECH collaborators aided with the initial research for this project. Knowledge of not only epilepsy but the EEG system itself, including electrode placement, duration of the test, and ear clip grounding, was essential to developing the criteria used for a successful design.

This open-source system offers patients and enthusiasts in low- to mid-income countries access to this critical technology, facilitating Epilepsy diagnosis. Our achievements are bolstered by medical collaborators who helped the team to not only understand the pathology of Epilepsy, but also identify attributes that are critical to a diagnostic system. Further testing will assess reliability, noise characteristics, and consistency against established EEG benchmarks, with refinements focusing on optimizing electrode-skin contact and validating performance across different use cases. This accessible EEG solution could provide valuable neurophysiological monitoring capabilities for underserved communities, research institutions, and educational settings with limited resources. This could allow more people to be successfully diagnosed and treated, allowing them to live seizure-free lives.