Diagnostic EEG System for Viral-induced Epilepsy

October 4th, 2024

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Overview

- Problem Statement & Background
- Client Introduction
- Product Design Specifications
- Design Alternatives
- Design Matrices
- Final Design
- Future Works
- Reference & Acknowledgements

Problem Statement

- 50 million people are affected by Epilepsy worldwide
- Detection of Epilepsy using EEG is expensive
- Cost can range from $200 - $3000
- Affordable EEG technology
- Create the following components:
  - EEG cap
  - Effective electrode web
  - Amplification/filtering of signal
  - Graphic User Interface

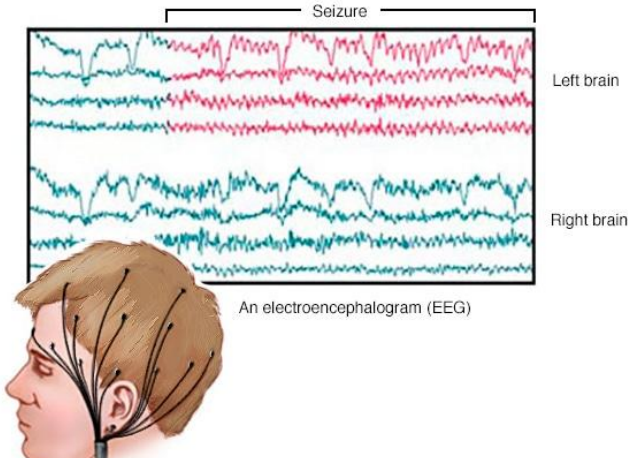

Figure 1: Sample EEG data [1]

Client Introduction

Dr. Brandon Coventry

- Wisconsin Institute for Translational Neuroengineering
- Post doctoral fellow in the department of Neurosurgery
- Neuromodulation within the thalamocortical circuits
    - Optical tools
    - Artificial intelligence

TECH Collaborators

- Jesse Montoure, M4
  - Neurology
- Tai le, M1
  - Undecided

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Product Design Specification

- Remain in operation for 3-4 years
- Head cap circumference between 50-64 cm
- Sample at 1kHz with 12-bit resolution
- Able to accommodate 10 different channels
- Cost of complete design under $100

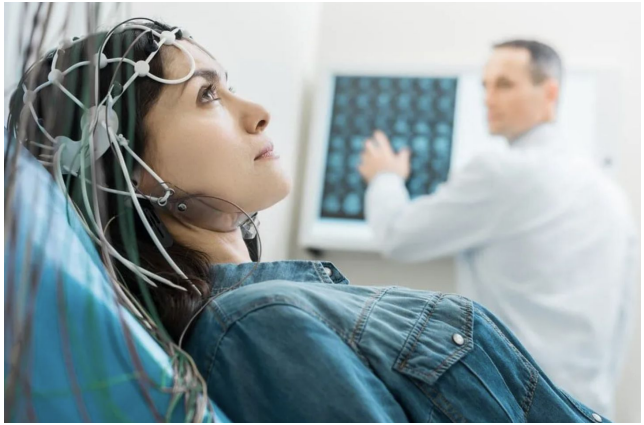

Figure 2: Example EEG Procedure [2]

Design Alternatives

Product	Channel Count	Sampling Rate (Hz)	Bit Depth	Wireless	Cost (USD)
Neurosky MindWave	1	512	12	Yes	130
Muse2	4	256	12	Yes	300
Emotiv MN8	2	128	14	Yes	400
Emotiv Insight	5	128	16	Yes	500
Emotiv EPOC X	14	256	14-16	Yes	1000
Emotiv Flex Saline	32	256	16	Yes	2000
Open BCI Complete Kit	16	125	24	No	2500
Open EEG	2-6	Up to 15.4k	10	No	200-400

Table 1: Summary of Existing Designs

Entire system $130-$2500

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Head Cap 1 - Store Bought

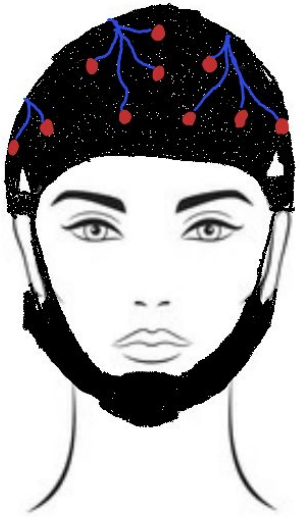

Figure 3: Store Bought EEG Head Cap

- Variety of Price
- Design for specific Electrodes
- Dependent on external supply chain, price, design

Figure 4: $500 OpenBCI Head Cap [3]

Figure 5: $16 Contec Head Cap [4]

Head Cap 2 - DIY

Figure 6: DIY Head Cap

- Requires Human Assembly
- Low adjustability
- Inconsistent Electrode Placement

Head Cap 3 - Naked Electrodes

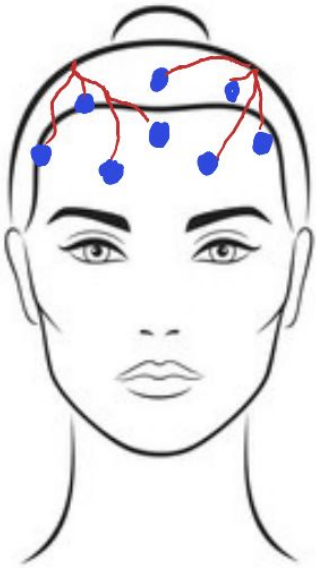

Figure 7: Naked Electrode Design

- Low cost
- Highly dependent on competence of user
- Human error
- Electrode stability

Head Cap 4 - 3D Printed

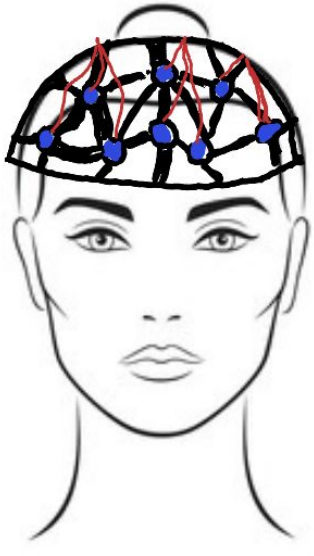

Figure 8: 3D-Printed Head Cap

- Variable Price
- Highly customizable
- Resources to create
- Open mesh

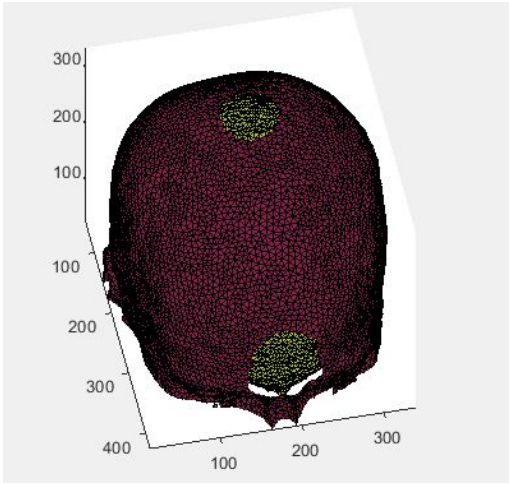

Figure 9: Head Cap Mesh [5]

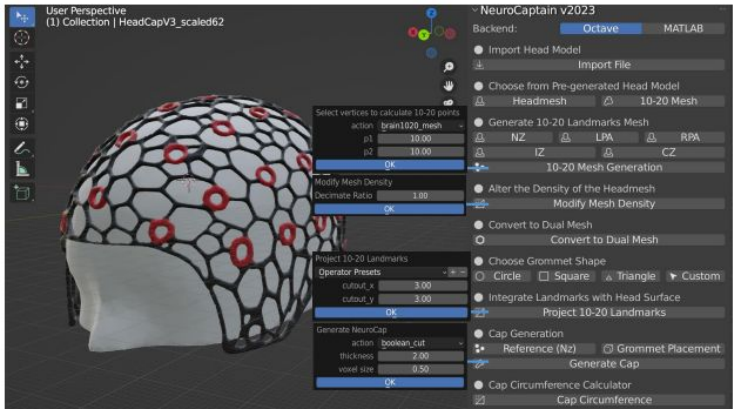

Figure 10: Blender View of the 3D-Printed Head Cap

Head Cap 4 - 3D Printed

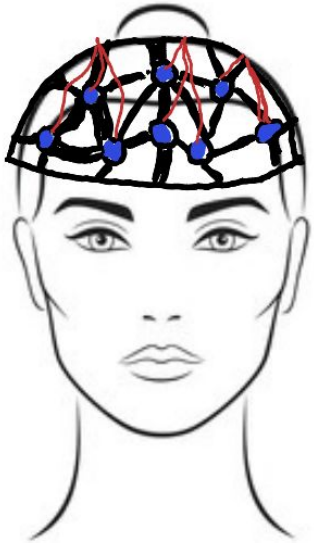

Figure 8: 3D-Printed Head Cap

Name (Flexible filament)	Cost/gram	Flexibility (Shore Hardness) Lower is more flexible	Printing Temp (deg C)
TPU	0.3-0.8	60A-77D	210-230
Soft PLA	0.12	92A	190-230
TPA	?	70A-95A	230-250
PEBA	0.16	75A-90A	240-260
TPC	0.052	95A	220-260
TPS	0.08	70A-90A	260-280

Table 2: Summary of Available Flexible Filament

~21g
+supports

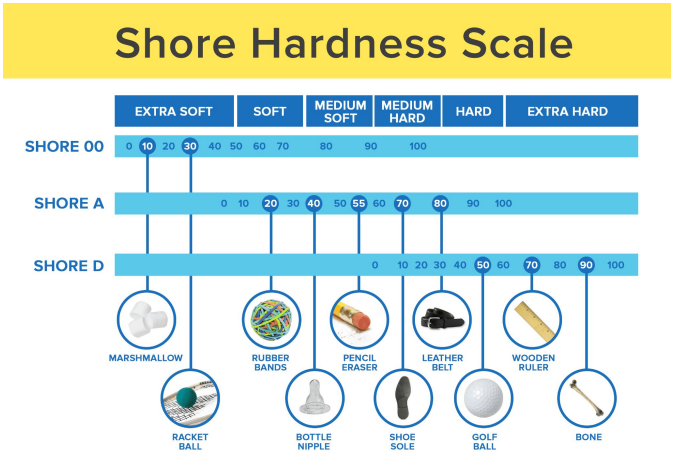

Figure 12: Hardness Scale

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Head Cap Design Matrix

		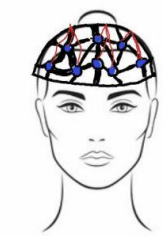	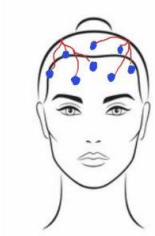	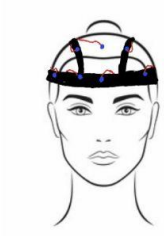	
	Store Bought	**3D Printed**	**No Head Cap**	**DIY**	**Weights**
Cost	0	16	20	16	20
Safety	15	12	9	9	15
Accuracy	14	11	3	6	14
Repeatibility	11	14	3	6	14
Ease of Use	13	10	5	5	13
Durability	12	7	10	5	12
Comfort	7	6	6	4	7
Ease of Fabrication	5	2	5	3	5
Total	**77**	**78**	**60**	**53**	100

Table 3: EEG Head Cap Design Matrix

Circuit 1 - Single-Channel Analog to Digital Converter (ADC) + MUX

- 10 channels in a MUX
- Instrumentation amp per electrode
- One bandpass filter and level shifter
- Directly connect to Microcontroller (MCU)

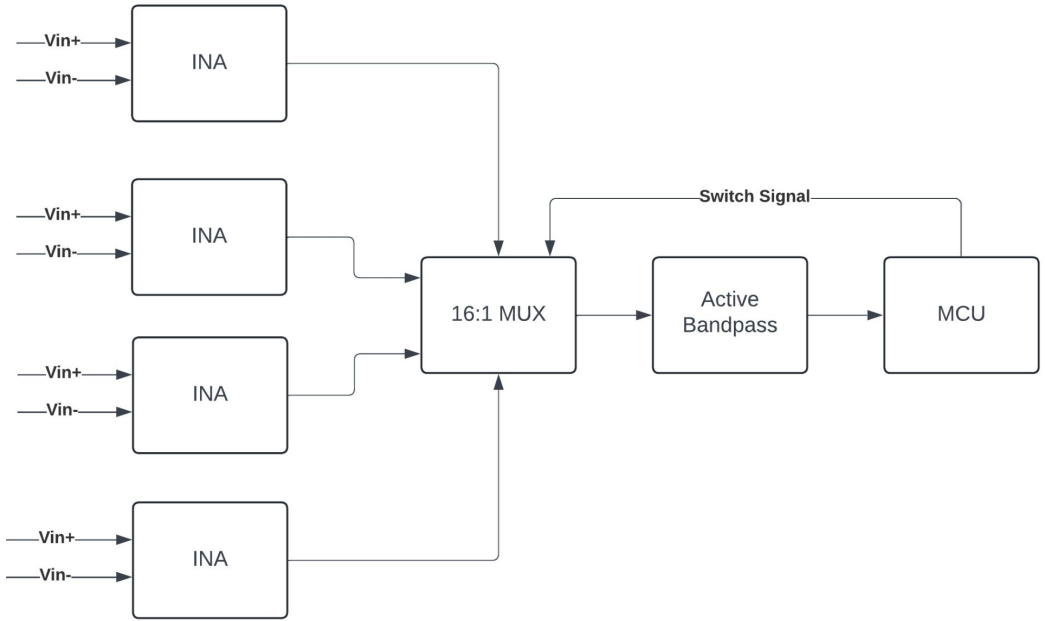

Figure 13: Single-channel ADC Analog Front End Block

Circuit 2 - Multi-Channel ADC

- 10 channels in a multi-channel ADC
- Instrumentation amp, bandpass filter, level shifter for each electrode
- Connect to ADC before MCU

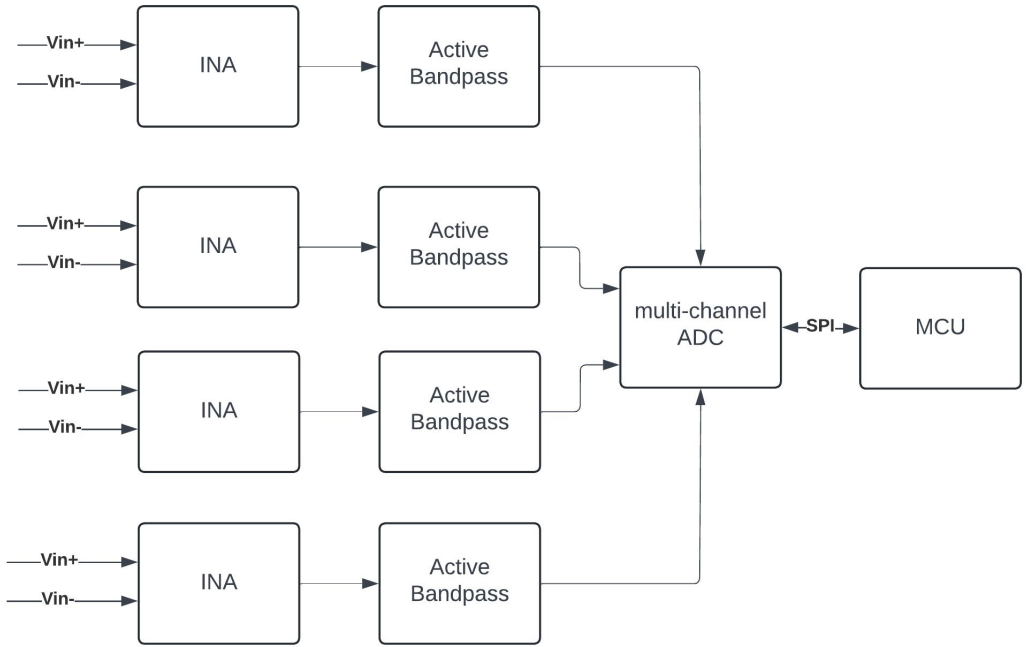

Figure 14: Multi-channel ADC Analog Front End Block Diagram

Analog Front End Design Matrix

	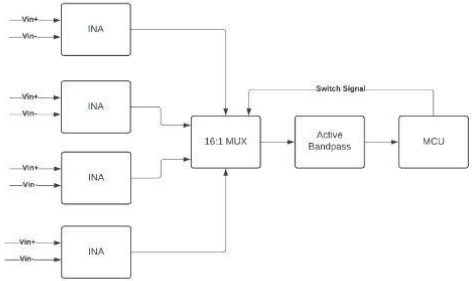	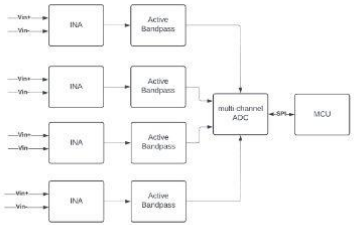	
	Single-channel ADC + MUX	**Multi-channel ADC**	**Weights**
Cost	26	16	26
Accuracy	16	21	26
Ease of fabrication	20	15	25
Firmware Complexity	5	3	5
Components Availability	14	10	17
Sum	**81**	**65**	100

Table 4: Analog Front End Design Matrix

Final Design

- Sampling rate: 1 kHz (50 kHz Max)
- Bandpass: 1-150 Hz
- Maximum Gain: 120 dB
- Electronics Subtotal: $ 30

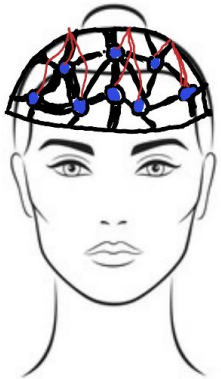

Figure 8: 3D-Printed Head Cap

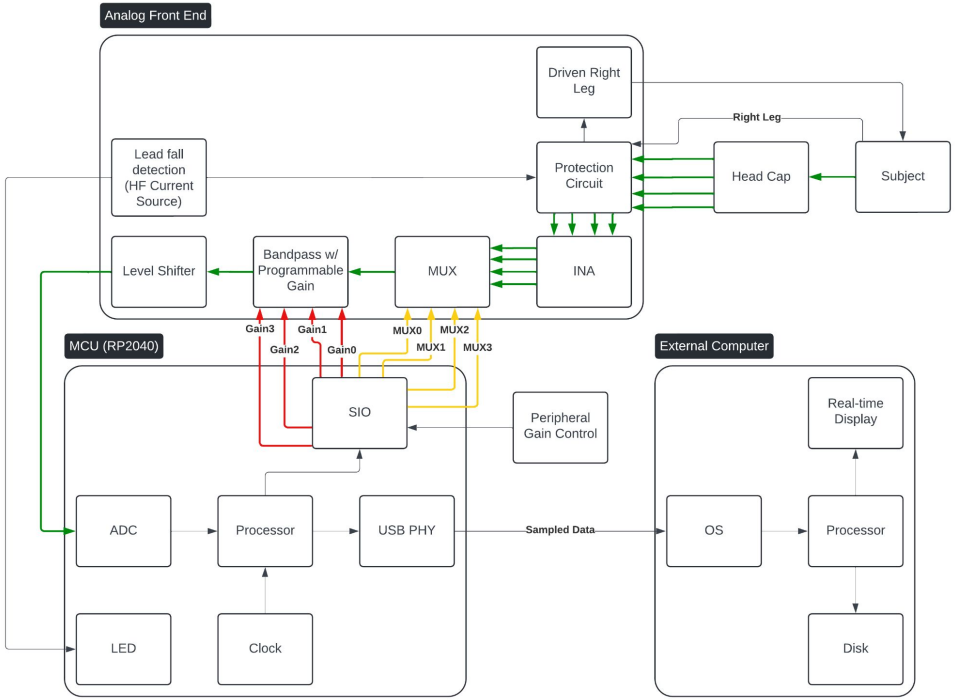

Figure 14: Block Diagram of the System

Future Work

- In progress
  - Create our first prototype - both EEG cap and circuit designs
- Semester Goal
  - Device testing protocol to evaluate the prototype
- Stretch Goal
  - Create a program to analyze results
  - Simplify the process of production

Acknowledgement

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Reference

[1] “Epilepsy,” Mayo Clinic, https://www.mayoclinic.org/diseases-conditions/epilepsy/diagnosis-treatment/drc-20350098 (accessed Oct. 3, 2024).

[2] “Can an EEG detect traumatic brain injury?,” Neurodiagnostics Medical P.C., https://neuroinjurycare.com/can-an-eeg-detect-traumatic-brain-injury/ (accessed Oct. 3, 2024).

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[4] Contec, “CONTEC NEW Standard Adjustable Rubber EEG cap For EEG machine KT88-3200,” CONTEC, 2019. https://contechealth.com/products/contec-new-standard-adjustable-rubber-eeg-cap-for-eeg-machine-kt88-3200?variant=43685387469029&currency=USD&utm_medium=product_sync&utm_source=google&utm_content=sag_organic&utm_campaign=sag_organic&srsltid=AfmBOoqbo0xTPKwmFi5n631cKRvb3jyqairhy1mGPAH7mP_eJKc-fyP1e_A (accessed Oct. 04, 2024).

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[6] “Durometer Shore Hardness Scale Explained | AeroMarine.” Aeromarine Products Inc., 30 July 2020, www.aeromarineproducts.com/durometer-shore-hardness-scale/.