Brain-Computer Interface

Signal Processing Board

Prepared for: Wenyao Xu,
Professor and Associate Depart Chair
University at Buffalo

Prepared by: Andrew Schaefer,
Undergraduate, Computer Engineering

Tianzhe Hu,
Undergraduate, Computer Engineering

Zihan Lin,
Undergraduate, Computer Engineering

Department of Computer Science & Engineering
University at Buffalo

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Requirements

The objective of this project is to create a PCB to acquire, process, and offload EEG and EOG signals by bluetooth using *RN-42*.

Features

- Powered with 6V rechargeable battery
- PIC32MX microprocessor
- ADS1194 Analog Front End
- EOG signal processing with digital output
- RN-42 Bluetooth Module
- Voltage Regulation (3.3V, +2.5V, -2.5V)
- Board Dimensions (L: 6 inch, W: 6 inch, H: 2 inch)

Compatibility

- 16-Channel EEG signal with 16-Bit Signed Data (e.g., 100Hz)
- 4-Channel EOG signal with 8-12 Bit Signed Data (e.g., 50Hz)
- EEG wave frequency = 100 Hz
- EOG wave frequency = 50 Hz

Background

The project is a Brain Computer Interface project of CSE450. This project requires creating PCB boards with a combination of EEG and EOG, so users can catch the signal from the brain and eye movement of people. The concept of this project is to use electrodes as nodes to distribute on people's head and eye, and the number of electrodes that is needed depends on how many channels the EEG and EOG are required. These electrodes will collect the signals from each node to transmit them to the converter and turn the signals into unified input data for the microprocessor to process.

EEG (electroencephalogram)

The EEG signal requires 16 channels and should output 16 bits ADC data, since the concept of the EEG board is not very clear, so a prototype EEG board with only 4 channels will be created on breadboard for testing how the EEG channels work. After the prototype EEG board can work, then a 16 channels EEG board will be built on PCB board based on the experience of creating the prototype EEG board.

EOG (electrooculogram)

EOG signal also requires 4 channels and outputs 8-12 bits ADC data. The EOG signal processing design is TBD.

Proposed Tasks / Plan of Work

Task 0: Background Study & Design

Study stage, the general knowledge learned on OpenBCI. All articles that are used for this project will be cited in the *References* section.

Task 1: Create Block Diagram and Schematic

The block diagram will define the system flow and functionality. The schematic will provide a technical foundation for the creation of the first prototype, and will eventually be used to design the PCB.

Task 2: Prototype BCI to Test Chips

Prototyping will be completed using a breadboard along with any components we decide to use within the schematic. This will allow us to better understand how the signals are processed and what we are looking for in microcontrollers and analog to digital converters.

Task 3: Program Microcontroller

Once we are sure that the microcontroller is receiving proper digital signals, we can begin writing code to offload these signals via the bluetooth unit. Once we are outputting the correct bluetooth signals, we can begin designing our PCB.

Task 4: Program Data Collection System

With bluetooth successfully implemented, we can begin developing our data collection system that will take place on an external computer. This will allow us to store the signals received from the BCI without needing to store anything on the physical unit, lowering the overall size of the device.

Task 5: PCB Development

PCB design will be done with Altium, using the schematic previously developed to layout the board. Our goal will be to fit all of the components in the smallest possible form factor without compromising the functionality of the system.

Task 6: Research Headsets

Once the PCB and software are complete, we can begin researching methods of how to efficiently gather signals from the user.

Schedule

Figure 1 is a schedule of tasks we would complete for this project. The range of the block is the day from the number below to the number of the next column.

Ex. The block above "17" means from Oct 17 to Oct 24.

Tasks	Date of Tasks (by Weeks)						
Background Study & Design							
Block Diagram & Schematic							
Prototype BCI to Test Chips							
Program Microcontroller							
Program Data Collection System							
PCB Development							
	Oct	Nov	Dec	Jan	Feb	Mar	Apr

Figure 1. Schedule of Project Tasks

Budget / Bill of Material

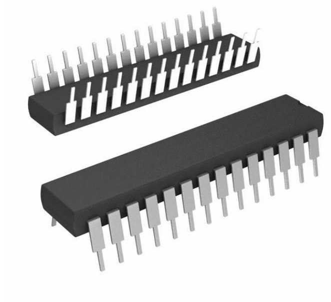
Below is an itemized budget for this project:

Item	Unit Price	Quantity	Cost
Microprocessor	$5.66/ea	1	$5.66
Analog Digital Converter (ADC)	$13.96/ea	4	$55.84
BlueTooth Module	$29.99/ea	1	$29.99
Microprocessor Programmer	$36.95/ea	1	$36.95
Voltage Regulator	$0.70/ea	1	$0.70
Lithium Ion Polymer Battery	$7.95/ea	1	$7.95
Capacitors	$TBD/ea	TBD	$TBD
Resistors	$TBD/ea	TBD	$TBD
PCB Board	$TBD/ea	1	$TBD
Conductive Paste	$19.99/ea	1	$19.99
Electrodes	$44.99/ea	2	$89.98
		Total:	**$247.06**[1]+

[1] *The price does not contain tax.*

Component Design

Microprocessor: PIC32MX250F128B has a 32 bit processor made by Microchip Technologies. It was chosen for its software compatibility, pin options, and its packaging.



Compatibility - The current OpenBCI board uses a similar microcontroller, allowing us to use their open source code without having to make extensive changes.

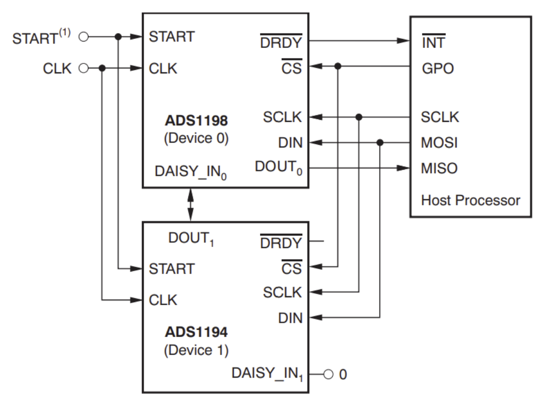
Pin Options - This chip has 19 I/O pins as well as two UART, SPI, and I2C ports each. This will allow our design to move in multiple directions without being limited by pins.

Packaging- This specific microcontroller is easily implemented into a prototype due to its through hole mounting type

ADC: For this application we chose ADS1194 as our analog to digital converter. This chip is manufactured by Texas Instruments. The low power used by this chip makes it ideal for collecting biometric data. It also communicates with SPI making it easy to implement into our microcontroller.

Resolution - ADS1194 has a resolution of 16 bits which was a set requirement for this project.

Daisy Chain - ADS1194 has daisy chain capabilities which allow multiple chips to be integrated into one system. 4 Chips will be daisy chained together to make up all 16-channels.



Example of daisy chain

Stock - ADS1194 was chosen over the 8-channel ADS1198 due to it being out of stock.

Main differences of ADS1198/4 devices:

Parameter	ADS1198	ADS1194
Sample Rate(max), ksps	8	8
Package Option	BGA or TQFP	BGQ or TQFP
Number of Channels	8	4
Min analog voltage, V	2.7	2.7
Max programmable gain	12	12
CMRR, dB	-105	-105

Bluetooth Module: RN-42 was chosen as our bluetooth module mounted on the 410-214-ND board to interface it with our prototype. The RN-42 chip is commonly used, therefore it has widespread support.

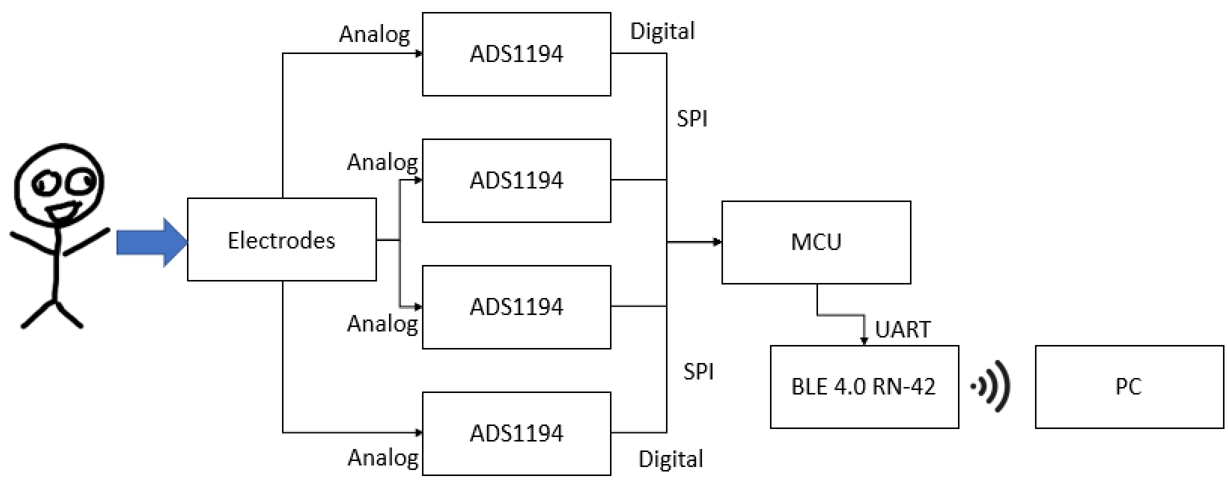
Power: To power this system we will be using a lithium ion rechargeable battery. This battery will provide rechargeable and portable power to our system.

Specs - This battery provides 3.7 volts and has a capacity of 500 mAh. This voltage is within spec for all of our chips, removing the need for any voltage dividers or amplifiers.

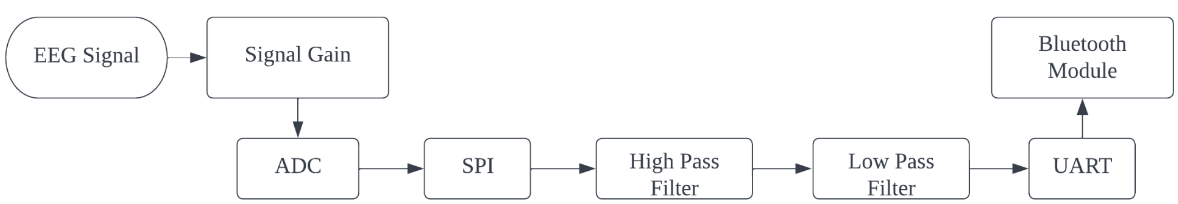
Other Parts:

- PICkit3 - Allows programming and debugging of PIC32MX microcontroller (for prototyping and building purposes only)
- Voltage Regulator - Receives power from battery and outputs a fixed voltage. (LP5907MFX-3.3)
- Electrodes and Paste - Provide access to EEG and EOG signals to be used for testing and debugging.

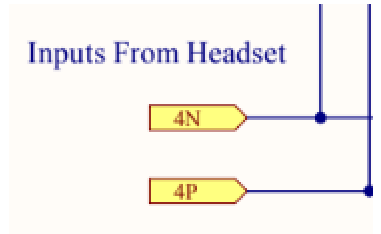
Electroencephalogram (EEG) system signal processing view:



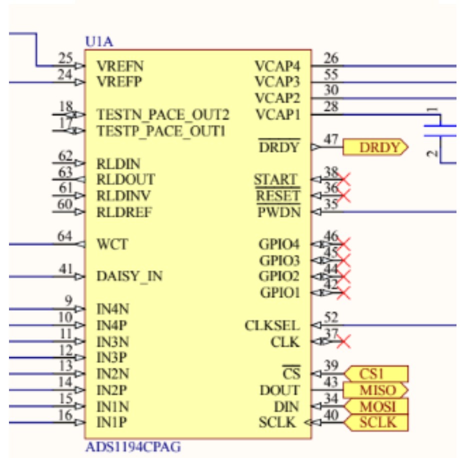
EEG signal processing flow chart:



Schematic Design

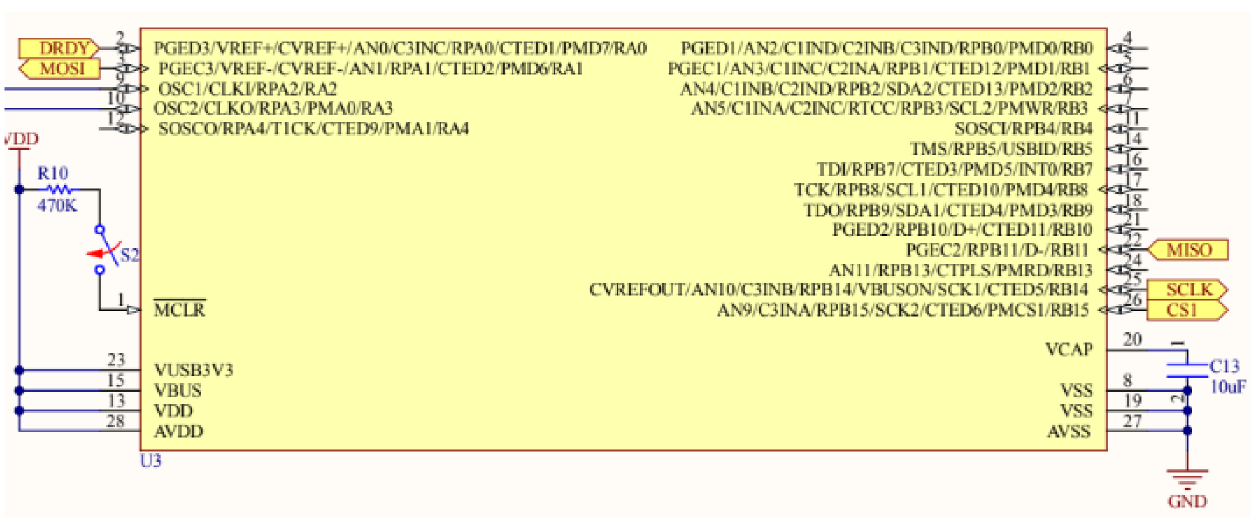


Input: The inputs are the signals from the brain that are collected by electrode. For the 4 channels prototype, there are 4 input signals with a positive and negative signal each for a total of 8 inputs.



ADC/Output: The analog digital converter will be used to convert the 8 inputs from electrodes. When the active low DRDY becomes 0, the conversion of the 16-Bit Signed Data result is completed and ready to be outputted by the DOUT pin, to meet the requirement from the client. Since one ADC can only convert the signals from 4 channels, the DAISY_IN pin will be used to cascade 3 more other ADCs for the 16 channels EEG board.

PIC32MX: The outputs (DRDY & MISO) from ADC will be the input for the Microprocessor, PIC32MX250F128B. When the program on the microprocessor senses that DRDY is active low(0), the microprocessor will start to process the data to identify the signals from the brainwave corresponding to. UART will then be used to transmit this data to the RN-42 bluetooth module.



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2. Myung B. R., & Yoo S. K. (2013). *Development of 16-channels Compact EEG System Using Real-time High-speed Wireless Transmission.* Retrieved from https://www.scirp.org/pdf/ENG_2013072910260384.pdf
3. Zou B., Zheng Y., Shen M., Luo Y., Li L., & Zhang L. (2017). *BEATS: An Open-Source, High-Precision, Multi-Channel EEG Acquisition Tool System.* Retrieved from https://arxiv.org/pdf/2203.02102.pdf