# Circuit design – Fixed challenge 2019

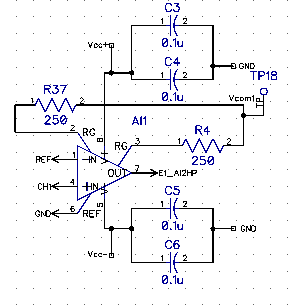
## Overview of the circuit

## Amplification

Electrical signals coming from the human body have weak amplitudes typically ranging from 1mV to 100mV. For the electroencephalogram (EEG), the voltage that can be measured at the surface of the brain is about 1-2mV whereas it decreases to microvolts (μV) when measured on the scalp with electrodes.[[1]](#footnote-1) Thus acquiring and visualizing EEG signals requires amplification of ~ 10 000. Such a gain allows the manipulation of the signals without saturating the operational amplifiers present in the circuit.

### Instrumentation Amplifier

The circuit to acquire EEG signals contain an operational amplifier placed directly after the electrodes to provide the signal with an initial gain before being filtered. The op amp used is Analog Devices’ AD8422, which is a high performance, low power, rail-to-rail precision amplifier. For the AD8422, the gain is determined by placing a single resistance RG across pin 2 and 3. PolyCortex decides the value of this resistance would be ###, therefore inducing a gain of ### (Gain = 1 + 19.8kΩ/RG). Furthermore, the datasheet suggests placing bypass capacitors as close as possible to each supply pins.



*Figure 1 : Schematic of the in-op AD8422*

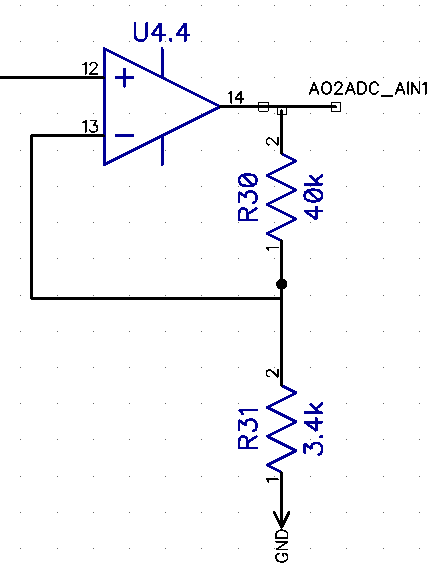
### Circuit amplification

To obtain the expected gain of ~10 000, the different filtering layers can also be used to introduce a gain. The filters used in this EEG circuit are second order Butterworth active filters where two resistors (Rf and Ri) can be connected to the output signal without affecting the cutoff frequency. Consequently, the gain of the high pass and low pass filter proportional to the ratio of these two resistors (Gain = 1 + Rf/Ri). During the design process, PolyCortex chose to introduce a gain of 8.9 in both filtering levels.



*Figure 2 : High pass filter with a gain (G = 1 + R18/R19) of 8.9*

After the signal has made its way through the in-op and the filtering levels, it is amplified a final time with a non-inverting operational amplifier. For this configuration, the gain is once more proportional to the ratio of the chosen resistors (Gain = 1 + Rf/Ri).



*Figure 3 : Final amplification level with a gain of 12.8 (G = 1 + R30/R31)*

The total gain produced by the cascading of the in-op, the high pass and low pass filter and the non-inverter is thereby the multiplication of each individual gain, producing a final gain of ###.

## Filters

Due to their week amplitudes, EEG signals are very susceptible to contamination

### High pass

### Low pass

### Notch

### RI

### Common mode chokes

## Right leg driver

## Simulation

## Components

### Power supply

### ADC

## Schematic, layout and routing

## Testing

1. [↑](#footnote-ref-1)