Design of active dry electrodes for wireless BCI system

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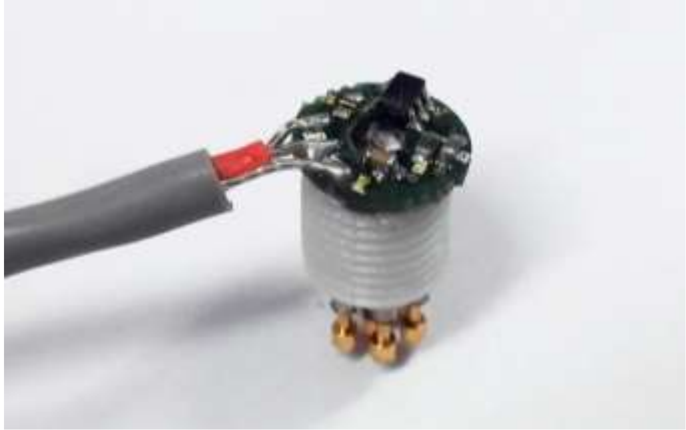
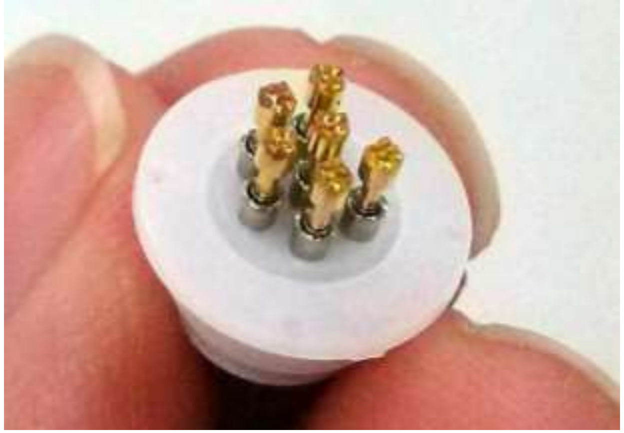
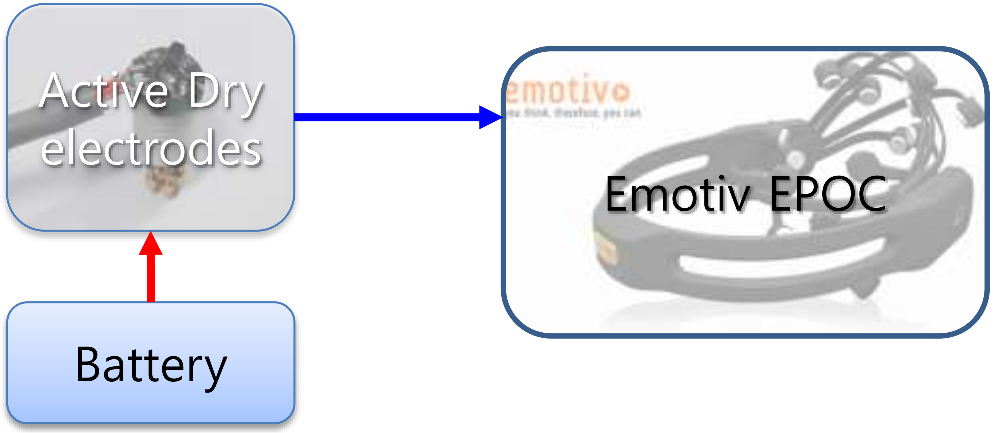
Introduction

- Development of active dry electrodes
  - For neuro-feedback applications, we are going to design a wireless BCI system.
  - We designed to equip with active dry electrodes for good signal quality and convenient installation.
  - I designed active dry electrodes with impedance converter(OPAMP buffer circuit) and low pass filter.
- Picture of active dry electrodes



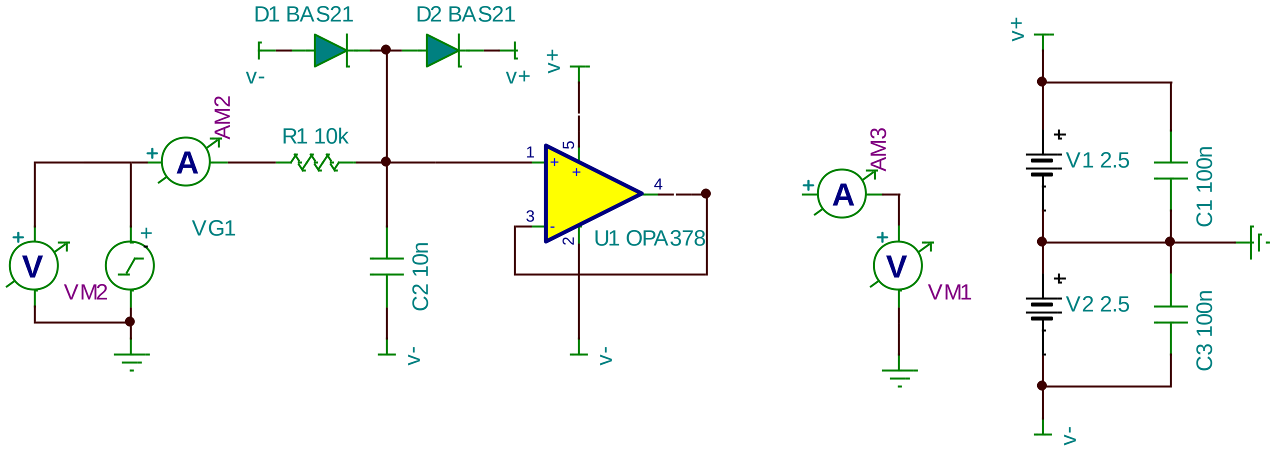


Electrodes test with Emotiv EPOC



- Test procedure
  - Connect a active dry electrode with Emotiv EPOC headset for measuring signal quality
  - The electrode received power supply from two AA batteries
  - Measure the signal quality using Emotiv test bench utility
- Test results
  - Comparing signal quality with wet electrodes equipped with EPOC headset, the signal quality of designed electrode is unstable and uncorrelated with wet electrodes signals.

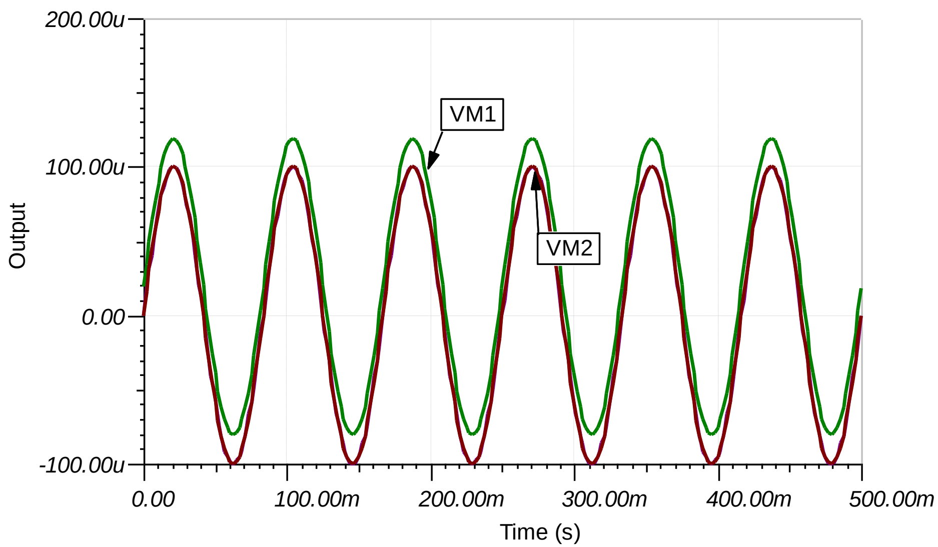
Redesign of electrode circuit



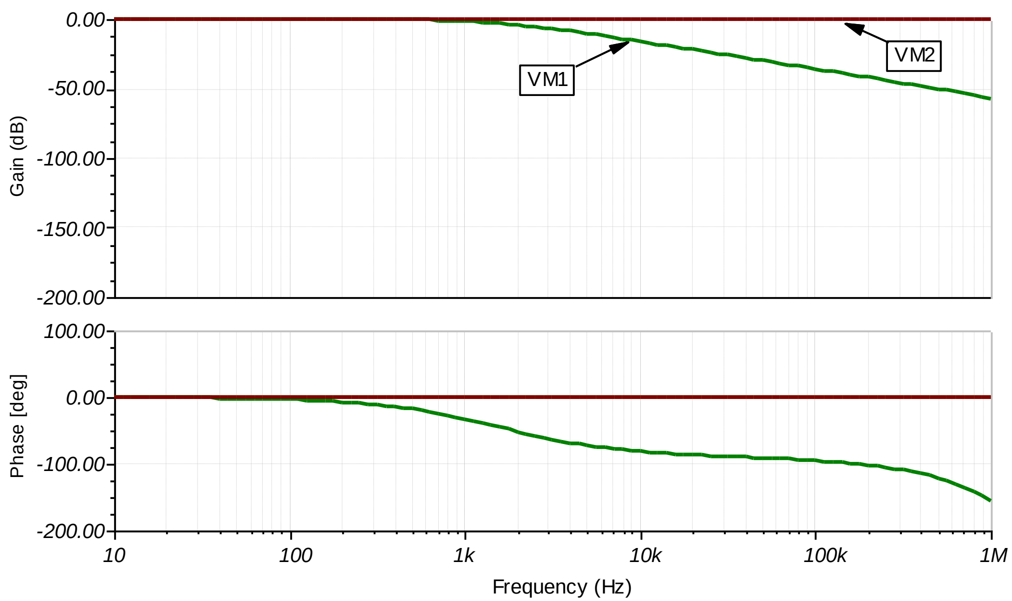
- Previous design of electrode circuit
  - Previous circuit was not working properly with Emotiv EPOC headset due to their unstable signal quality.
- Redesign of electrode circuit
  - RC low pass filter + OPAMP buffer + Protection circuit
  - Cutoff frequency of low pass filter = 1591Hz
  - Bipolar power supply ±2.5V

Redesign of electrode circuit

- Transient response

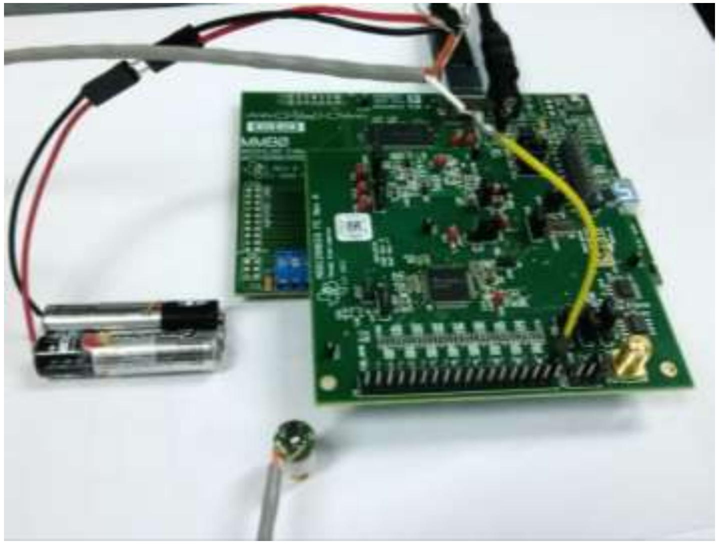


- Frequency response



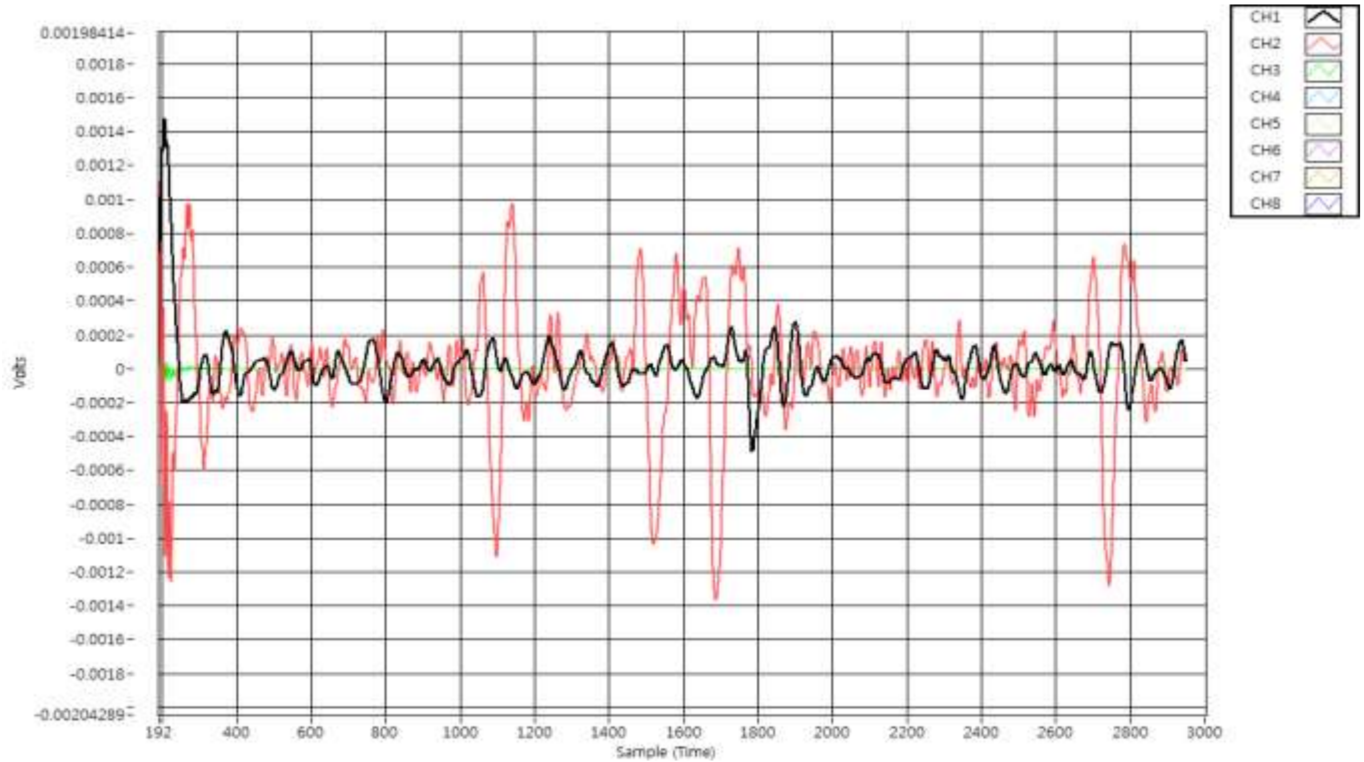
Electrodes test

- Test method
  - I measured the signal quality and electrodes impedance utilizing ADS1299 evaluation board.
    - The ADS1299 is a complete analog front end IC that including low-noise, multichannel, simultaneous-sampling, 24-bit ΔΣ ADC with a built-in programmable gain amplifier (PGA), internal reference, and an onboard oscillator for electroencephalogram (EEG) applications.
  - Connecting designed electrodes with evaluation board, I tested our active dry electrodes compared with conventional wet electrodes(Hurev stardisk) on my forehead.



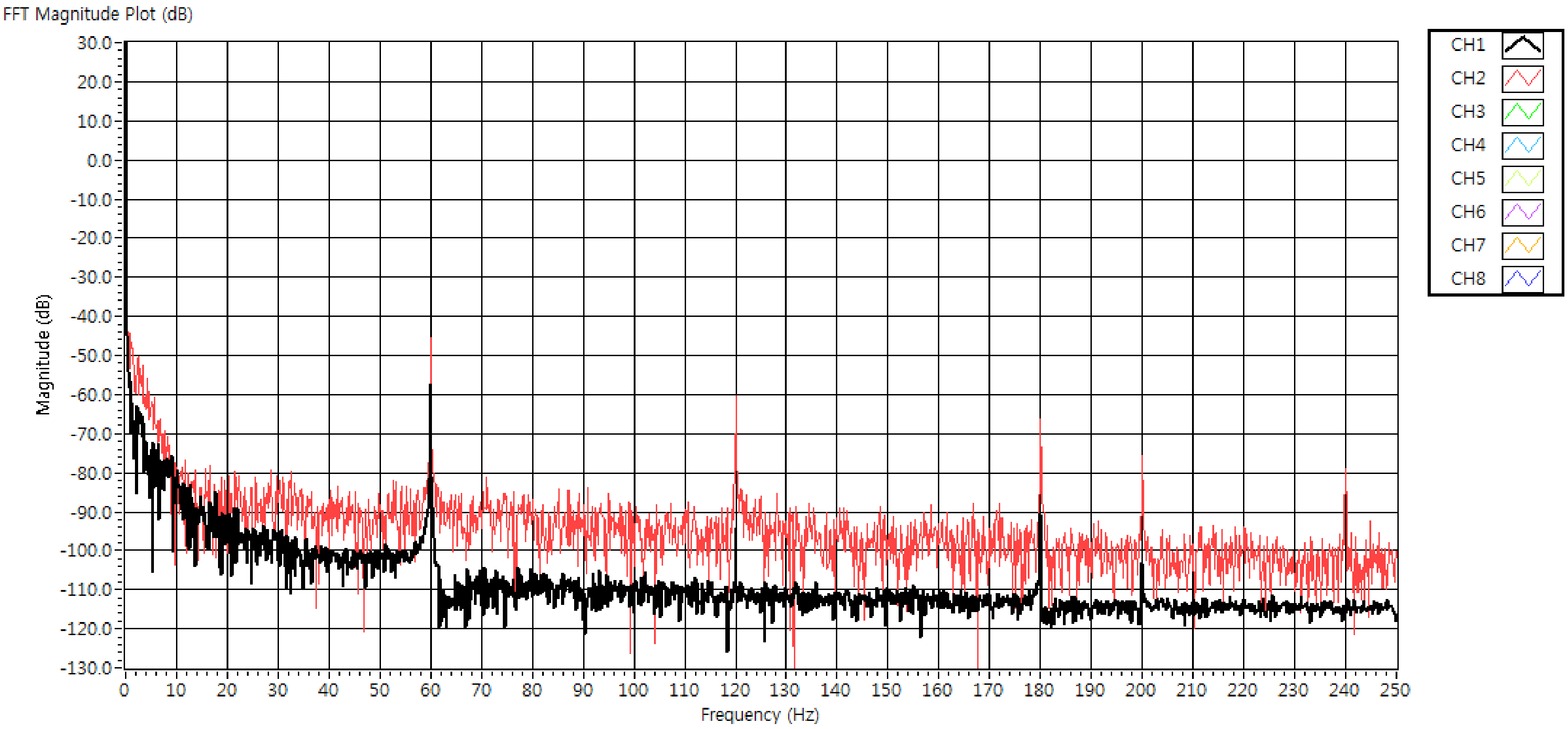
Electrodes test

- Measured waveforms
  - Sampling rate and time : 500 samples/sec, 6 seconds
  - Black line : designed active dry electrodes
    Red line : conventional wet electrodes
  - Measured EEG signals with designed electrodes looks like less noisy, but phase difference also observed between two measured signals.



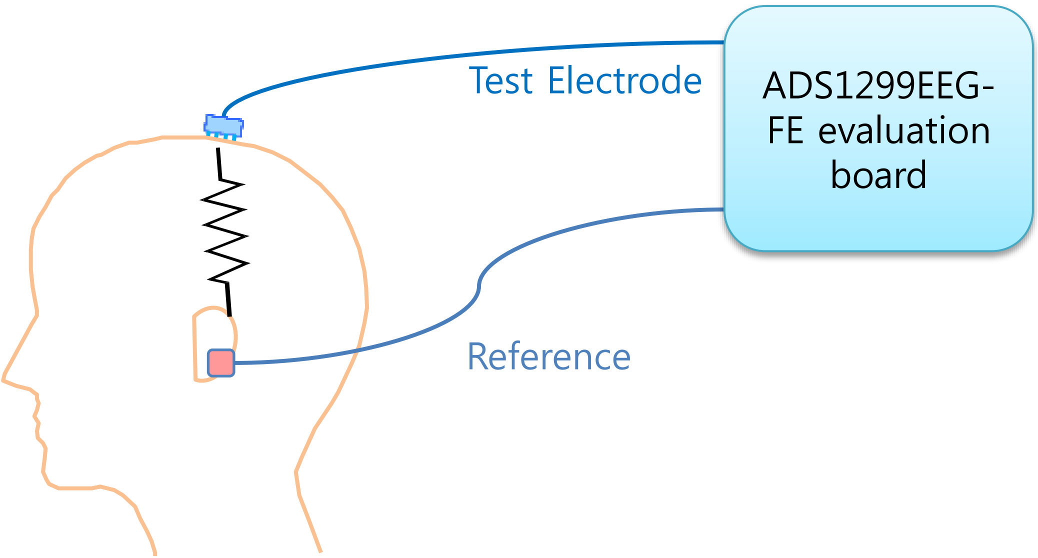
Electrodes test

- Frequency domain of measured waveforms



Electrodes test

- Electrode impedance
  - The impedance can be obtained by measuring the voltage difference between a reference electrode and a target electrode.
  - Lower impedance means a higher contact capability, and a better contact capability implies high quality EEG signal acquisition.
  - ADS1299 has special function for impedance measurement. Using function of AC lead-off detection with 31.25Hz frequency and 6uA current source, I measured electrodes impedance.

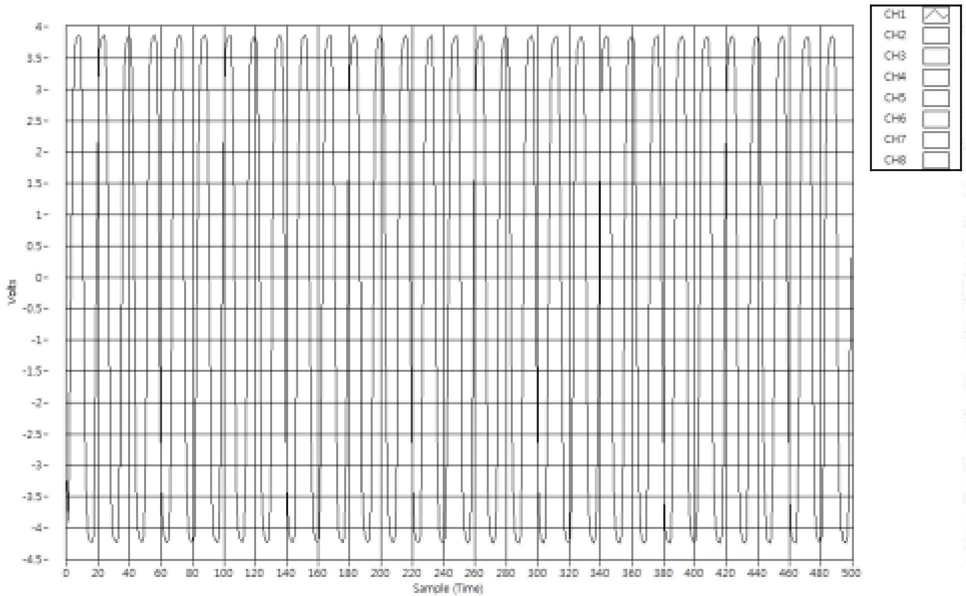


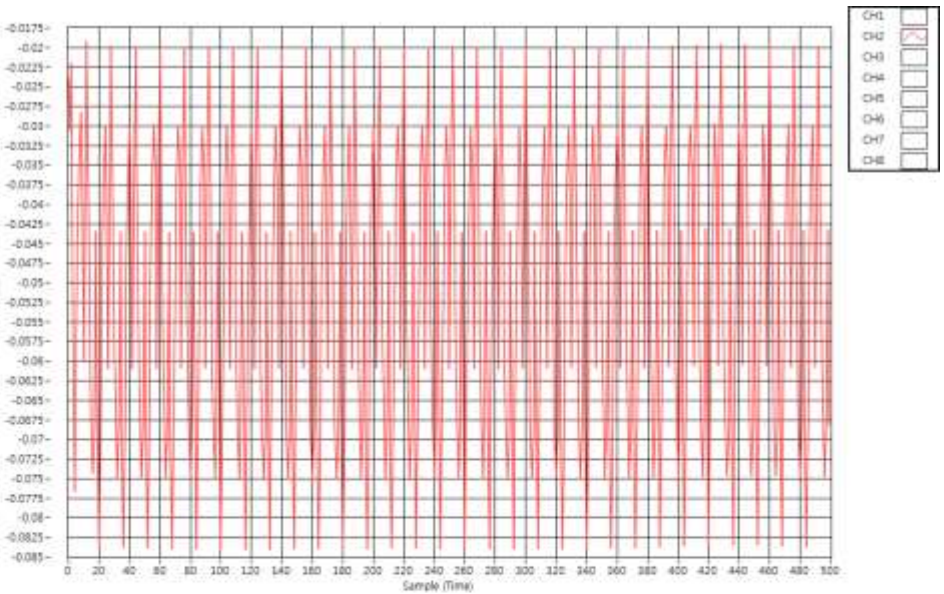
Electrodes test

- Impedance test method
  - Measuring peak-to-peak voltage, we can calculate electrodes impedance through Ohm’s law.
  - Measured peak-to peak voltage
    Ch1 : designed electrodes
    Ch2 : wet electrodes

	Channel 1	Channel 2
Mean (V)	-226.81E-3	-52.08E-3
Vrms	3.423019E+(	55.194730E-
Vpp	8.09E+0	64.86E-3

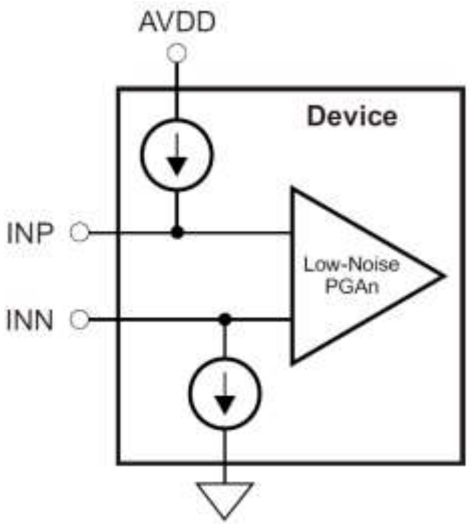
  - Impedance calculations
    - Designed electrodes = 8.09V/6uA = 1.348MΩ
    - Wet electrodes = 64.86mV/6uA = 10.81kΩ



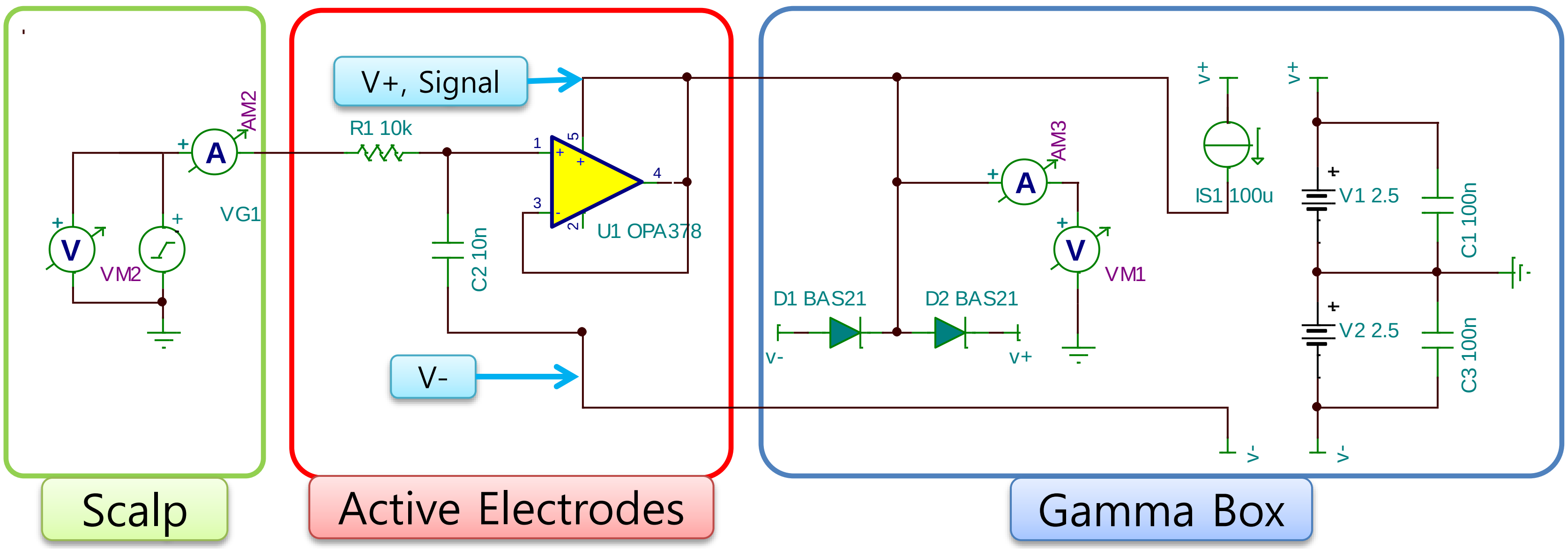


Electrodes test

- Discussion about designed electrode impedance
  - The impedance of designed electrodes reached 1.348MΩ.
  - This is because operational amplifier buffer on designed electrodes circuit.
  - Because OPAMP buffer blocks 6uA current flow from ADS1299, the measured voltages reached saturated voltage range.
  - So, for impedance measurement, we have to find another way.



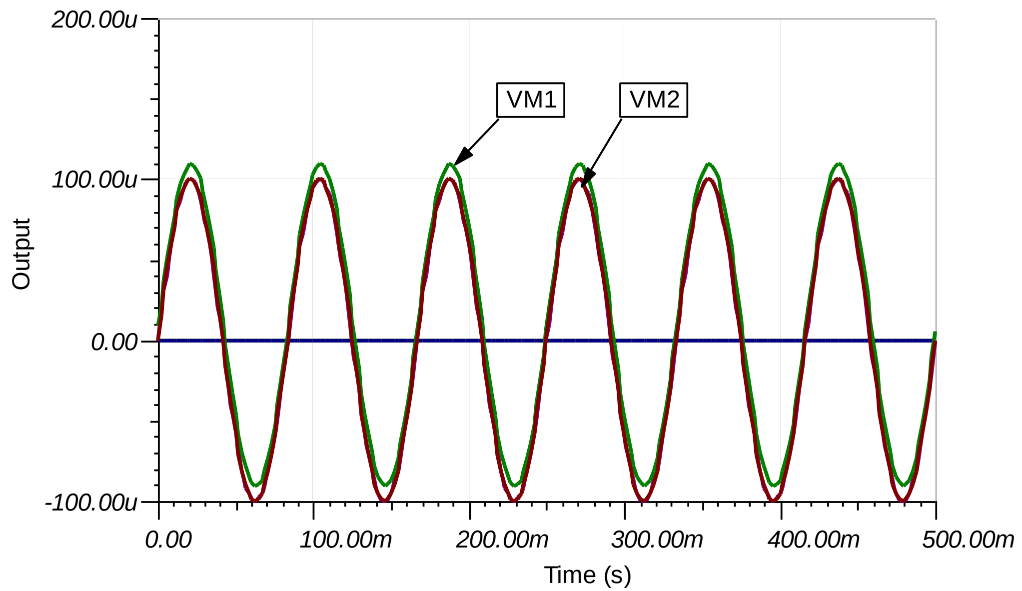
G.tec active electrodes circuit



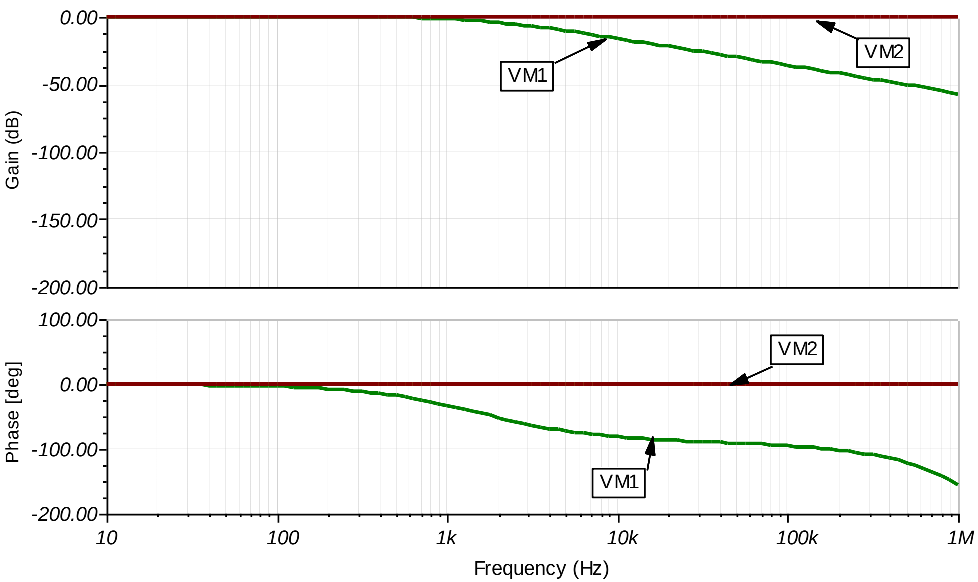
- Structure of g.tec active electrodes
  - Used only two wire for connection with Gamma box
    - 100uA current source for power supply instead of voltage source
    - Sharing power supply line and measured signal transmission line
  - RC low pass filter + OPAMP buffer

G.tec active electrodes circuit

- Transient response



- Frequency response



Wireless BCI system design

- Future work
  - Design of wireless BCI system based on ADS1299 and MSP430 microcontroller.
  - Measurement of impedance about active dry electrodes.
  - Test of g.tec active electrode circuit.