Two Channel Wireless EEG System

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***Abstract*— biomedical device is a more and more popular field nowadays. EEG is one of them that could test the brain wave. We can use EEG to extract our brain wave during different activity so that we can understand the brain better. In order to achieve the function that fetches the brain wave signal which is very small. We need a good amplifier to amplify the signal to the detectable magnitude. Moreover, in the amplifier circuit we need good filter to remove the noise to make sure we only get the signal we want. The brain wave is collect from the location above the eyebrow by electrode.**

I. Introduction

In this project, we are implementing fundamental principle and amplifier circuit use on medical field. We design a signal amplifier board with two-channel, as shown in Fig 1. In order to better understand the neurological devices, we try to design our own schematic. In the process, we need to understand the low-power amplifiers, filters, wireless power and the wireless telemetry. We test several parameters during simulation stage and adjust our design in order to get better design. After the simulation, we have our Printed circuit board be fabricated and do the real world testing in the lab session. We should learn the skill on solder the PCB board. The test instrument use method should also be learned. We will finally test the amplifier board with development kits and try to detect the "Blinking eyes" brain wave.

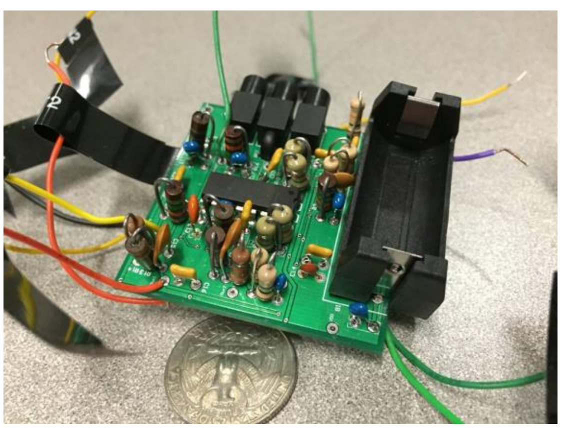

Fig 1. Two-channel amplifier PCB board. (5cm X 5cm)

II. Methods

We design a two-channel band-pass amplifier. The design detail is as followed.

A. Input Buffer

First, the input buffer offer high input impedance 10 T ohm. After buffer, we add a high pass filter to filter offset voltage, as shown in Fig 2.

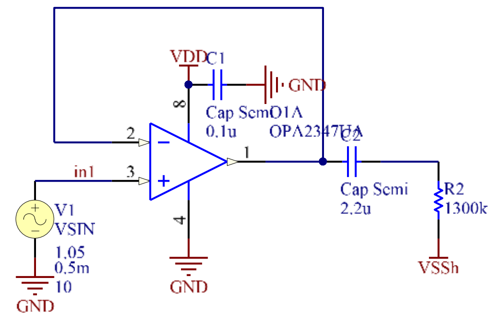

Fig 2. Ch1 input buffer

B. Instrument Amplifier

The instrument amplifier is the first stage amplifier, as shown in Fig 3. The gain should be 5+ (80/15) = 10.33.

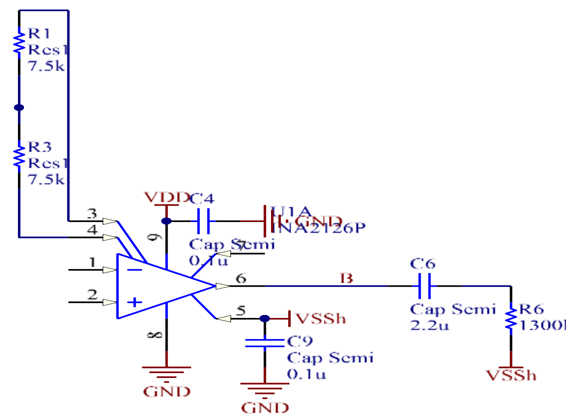

Fig 3. Ch1 instrument amplifier.

C. Band-pass Filter

The band-pass filter offer 0.1 Hz and 50 Hz -3dB points, as shown in Fig 4. It also is the second stage amplifier with gain= 1300/16= 81.25.

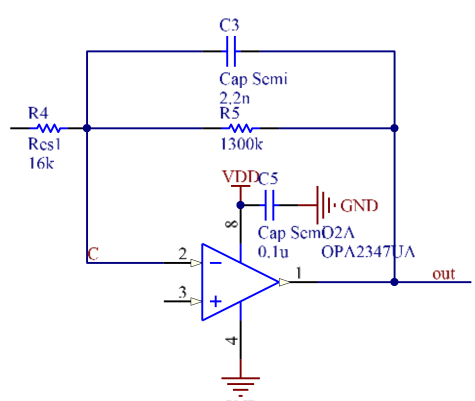

Fig 4. Band-pass amplifier.

D. *Right Leg Drive*

The right leg drive offer the human body voltage offset and it will connect to our body, as shown in Fig 5.

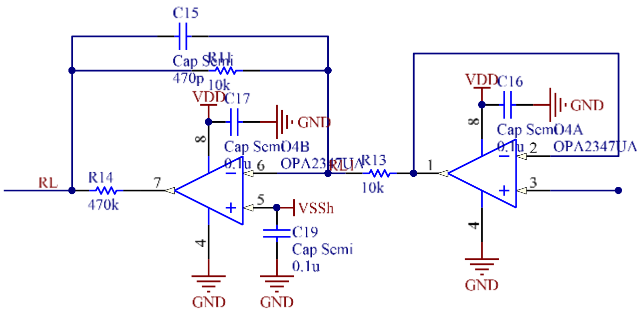

Fig 5. Right leg drive.

III. Results

We use Altium Designer to simulate our circuit and sketch out PCB board. And then, we order the PCB board and solder the parts. Finally, we connect this PCB board into wireless CC2541 Mini Development Kit. And we can see the eye blinkign EEG signal on diplay.

A. *Simulation Results*

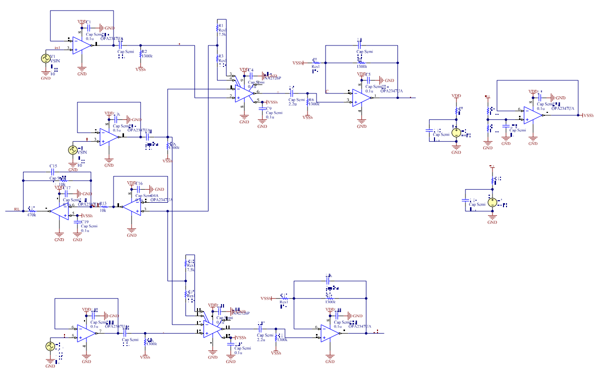

Fig 6. Full schematic diagram

Fig. 6 is our full schematic diagram. There are two channels, one share reference channel, and one right leg output.

Our simulation gain is 833, as shown in Fig 7.

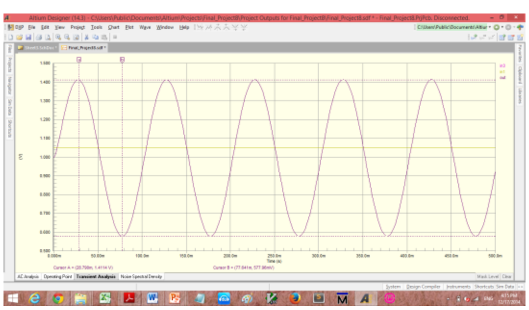

Fig 7. Output gain simulation.

The simulation noise is 0.198 uV rms, as shown in Fig. 9.

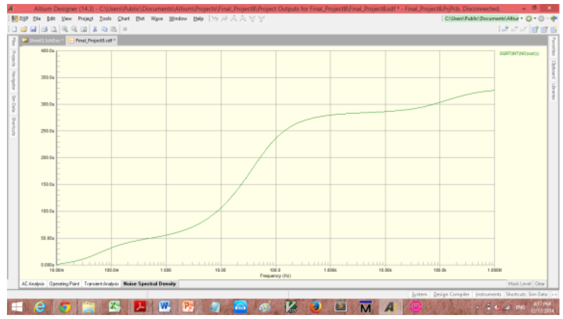

Fig 9. Output noise simulation.

The bandpass diagram is shown in Fig. 10.

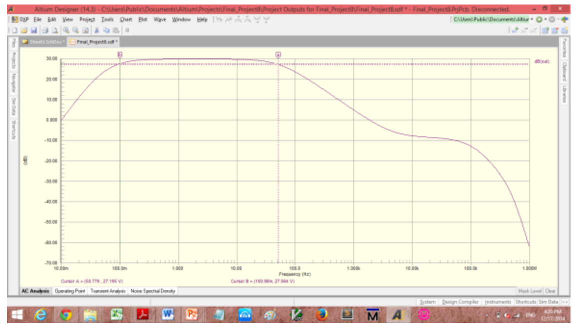

Fig 10. AC frequency response.

We series a resistor with power supply to calculate power consumption, as shown in Fig.11.

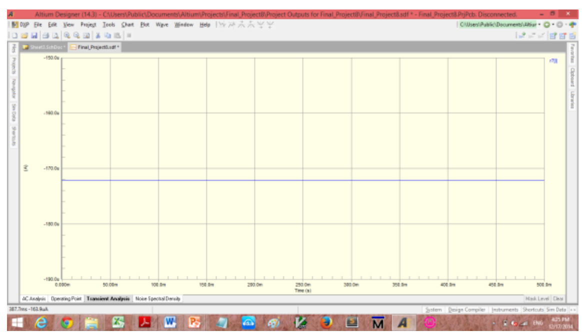

Fig 11. Power supply current

We calculate the common mode gain, as shown in Fig. 12 [1].

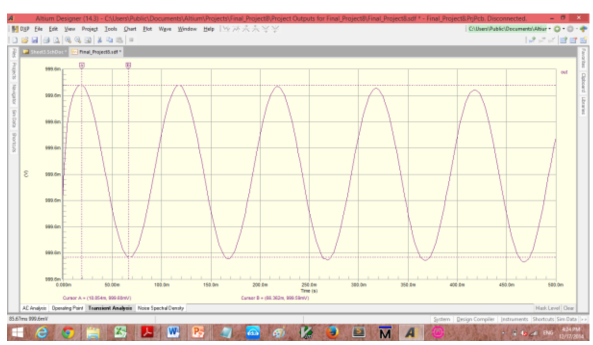

Fig 12. CMRR simulation

Fig. 13 is our PCB layout [2].

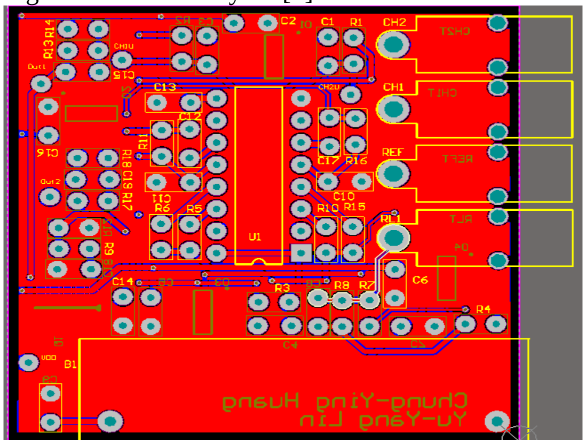

Fig 13. PCB layout

B. *Experiment Results*

The input voltage is 1mV pk-pk, and the output is shown in Fig 14. and Fig 15.

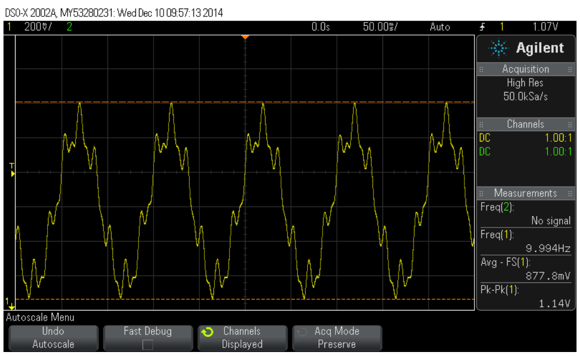

Fig 14. Ch1 output

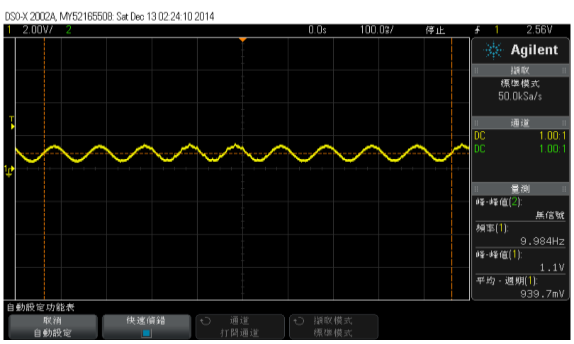

Fig 15. Ch2 output

The Noise is AC RMS/Gain= 71.8 uV, as shown in Fig 16 [3].

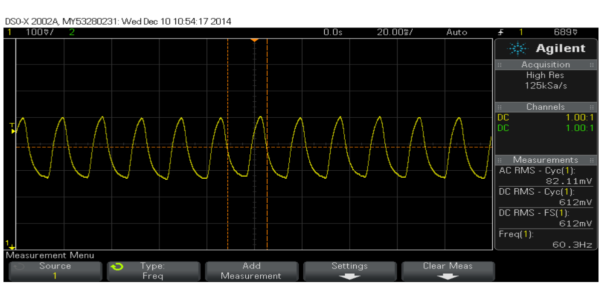

Fig 16. Noise output

The input voltage is 1 mV pk-pk, and frequency response is shown in Fig 17.

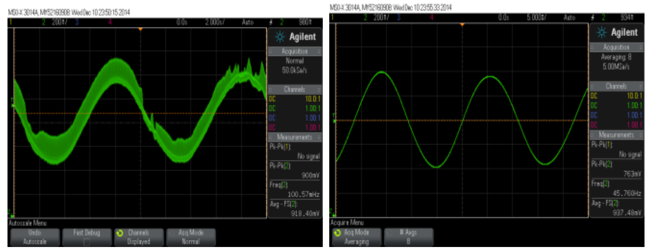

Fig 17. High pass and low pass -3dB points.

The input offset is 1.2 V and 1.8 V, and the input signal is 1 mV pk-pk, as shown in Fig 18.

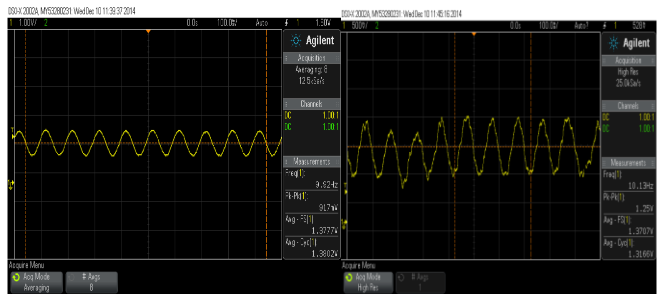

Fig 18. High pass and low pass -3dB points.

The input signal is 500 mV pk-pk. The Acm= 0.302 and Ad= 1140. So the CMRR is 71.54dB, as shown in Fig 19.

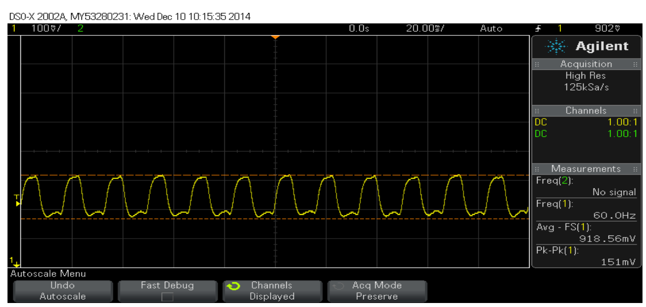

Fig 19. CMRR= 71.54 dB.

Finally, we connect our board to wireless board, as shown in Fig 20.

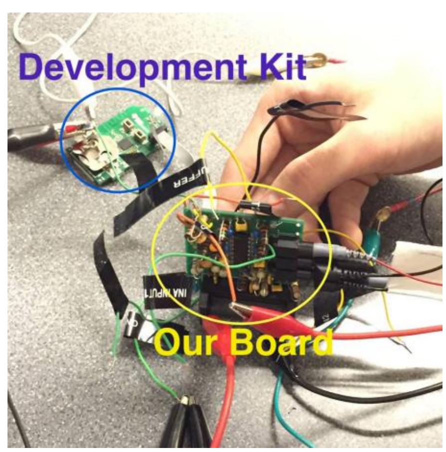

Fig 20. Amplifier Connects to CC2541 Mini Development Kit

We use signal generator generates 1mV pk-pk input, and the output transmit into wireless boards, shown on the laptop, as shown in Fig 21.

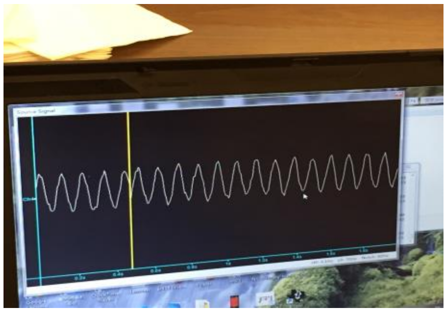

Fig 21. Wireless development kit output

Finally, we attach electrode on our brain, and the blinking eye signal is shown in Fig 22.

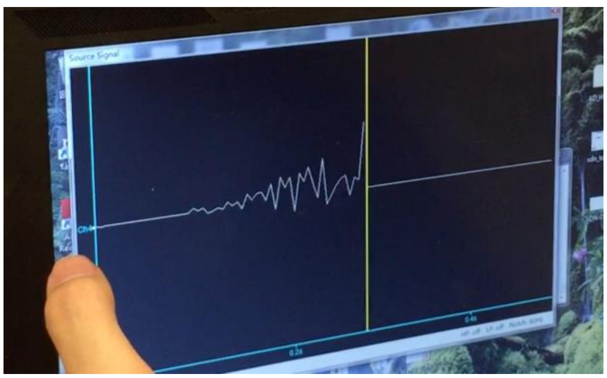

Fig 22. Eye blink EEG signal

IV. Discussion

What worked- All the function in our board is working correctly. We can test all the parameter out and see the correct output from our output stage. The board apply on the development kit system can work properly as well. We finally fetch the "Blinking eye" brain wave on the system. The only imperfect thing is that our signal is not very stable. The board may not work properly sometimes.

What not worked- The voltage divider cannot work properly. We cannot get the correct value after the voltage divider so that we provide the reference by power supply directly. This may cause by the buffer don't work properly.

What could you have improved in your design-The output signal is suffering visible noise interference. This may cause from the imperfect solder skill. There may some contact is not in good connection. The output signal is not stable, so that sometimes we cannot get output properly. We think we can improve this situation by having better solder skill to build solid connection on the board.

We compare the simulation and experiment on table 1, as shown in table 1.

Specification	Design Value	Simulation Result	Measured Result
Gain	1000	833	1140
Noise	0.143 µV rms from 0.1 to 50 Hz	0.198 µV rms	71.9 µV rms
Input voltage range	+/- 250 µV	+/- 500 µV	+/- 500 µV
High pass filter -3 dB	0.1 Hz	0.086 Hz	0.1 Hz
Low pass filter -3 dB	50 Hz	55.55 Hz	45.76 Hz
Input offset range	+/- 300 mV	+/- 300 mV	+/- 300 mV
Power consumption	0.765mW	1.026 mW	0.99 mW
CMRR (dB)	> 60 dB	91.26 dB	71.54 dB
Input Impedance	> 10 MΩ	10 TΩ	> 10 MΩ
BOM Cost ($)	< $50 / unit	N/A	$ 14.99

Tab 1. Simulation and experiment results

V. Conclusion

We successfully connect our PCB board into wireless development kit. And we can clearly see the blink signal on screen. In the future, we hope we can improve our output noise and power consumption.

VI. References

[1] John G. Webster "Medical Instrumentation Application and Design" 4th Ed. 1936 pp. 266-270

[2] Kraig Mitzner "Complete PCB Design Using OrCAD Capture and PCB Editor" 2009 ch1-ch2

[3] WIM van DRONGELEN "Signal Processing for Neuroscientists" 2007 ch3