Lab 10 Electronencephalography (EEG)

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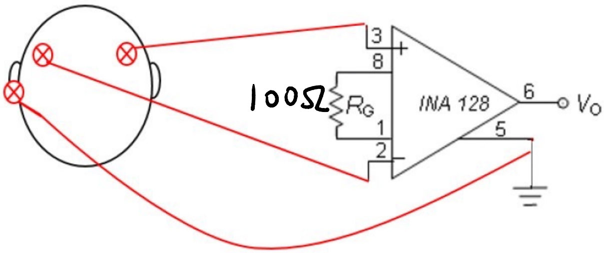
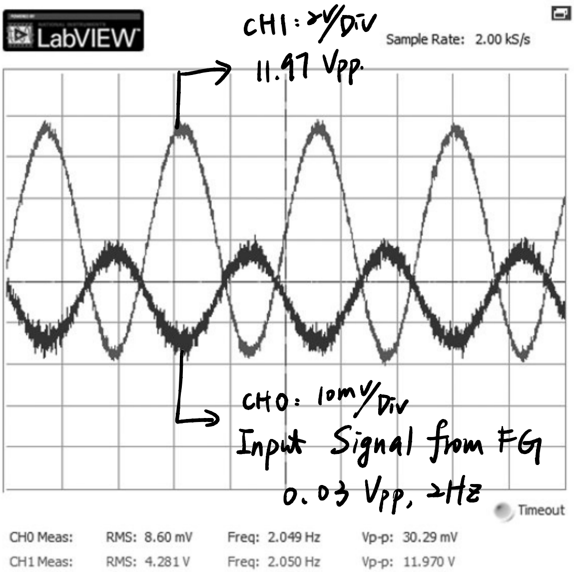
< Phase 1 >



$$R_g = 100\,\Omega$$

$$\Rightarrow G = 1 + \frac{50k\Omega}{100\Omega} = 501\ (V/V)$$



$$40\,dB = 10^{\frac{40}{20}} = 100\ (V/V)$$

$$G\Big|_{R_g=100\Omega} = \frac{RMS_{out}}{RMS_{in}} = \frac{4.281}{0.0086}$$

$$\approx 497\ (V/V) > 100\ (V/V)$$

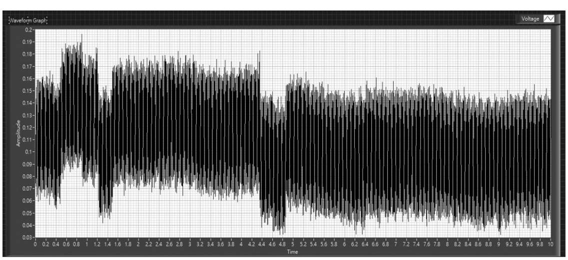


fig (1) stable.

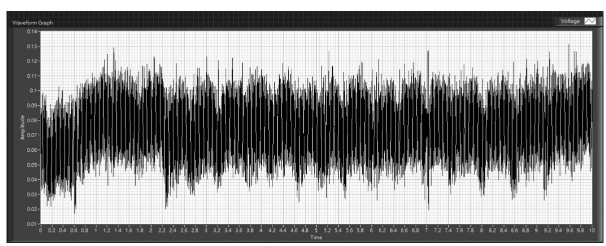


fig (2) rapidly blink eyes.

According to figure1 and figure2 on the last page, when the subject does nothing, the EEG signal has no pattern that can be recognized. However, if the subject blinks one's eyes rapidly, one can observe lumps two times per second on the waveform, which can be recognized as the signal that the subject is blinking one's eyes.

fig 3
stable
(no ear cable)

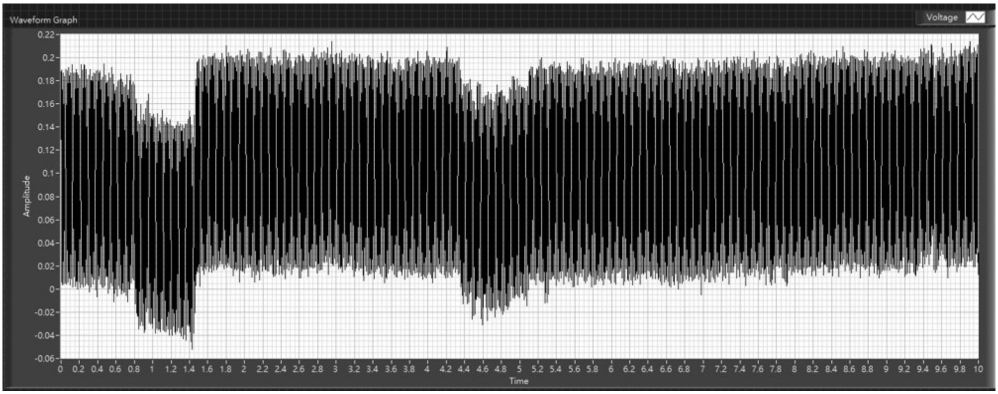
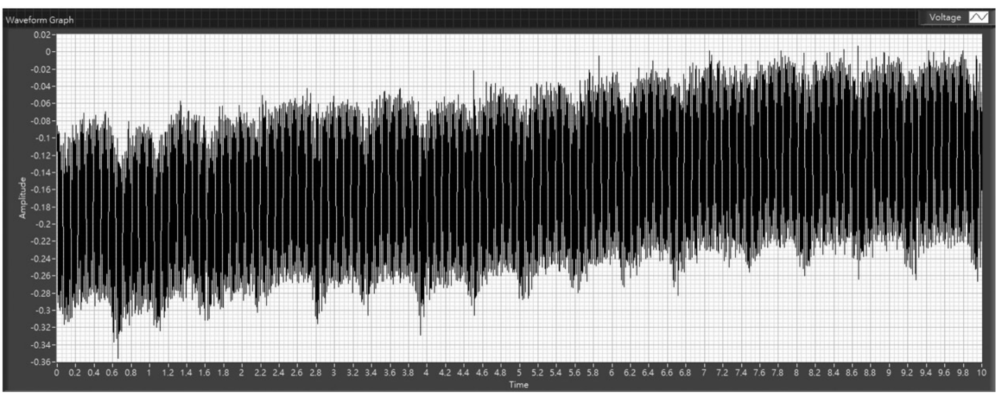
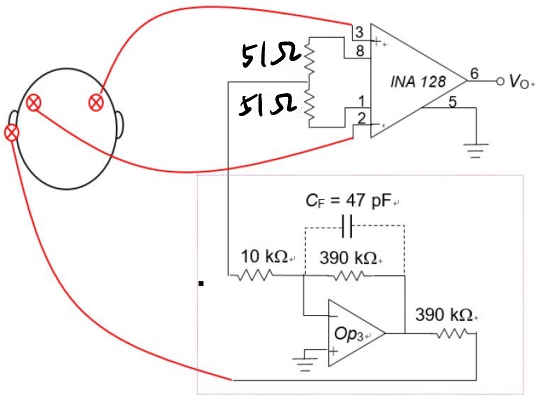


fig4
blink
(no ear cable)



If removing the cable on the ear, nothing special on the stable EEG signal in figure3. However, in figure4, one can find out the signal to noise ratio increases a little when the subject blink one's eyes.

<Phase 2>



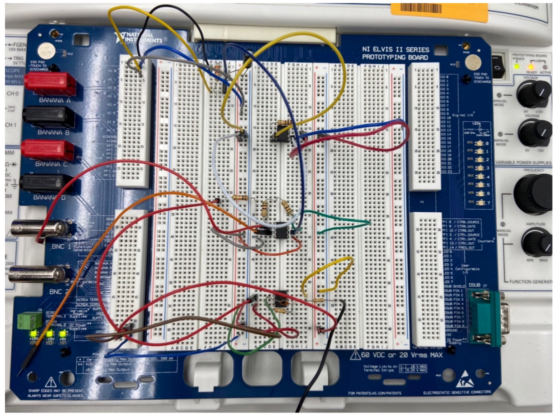


fig5
stable with
ref-drive
circuit

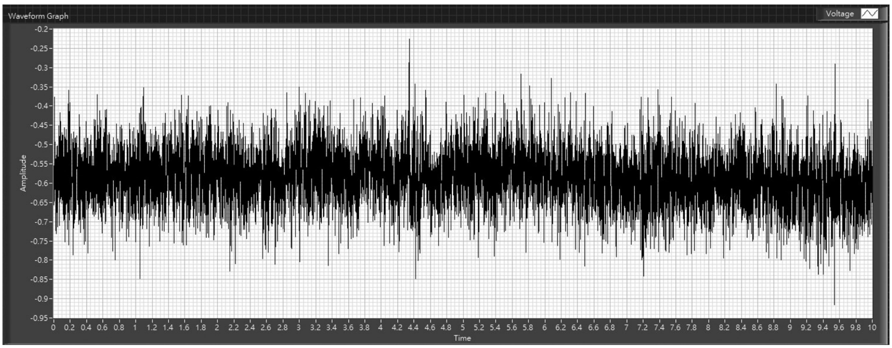
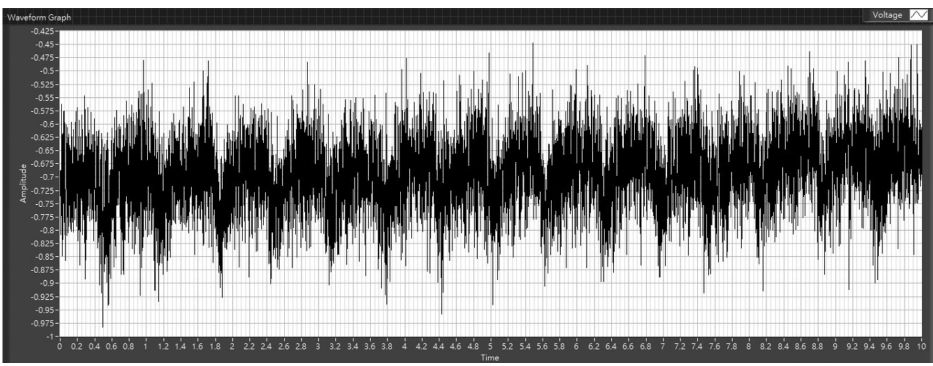


fig6
blink with
ref-drive
circuit



By adding a reference drive circuit to the original circuit, the noise component in figure5 decreases a lot. In figure6, when the subject blinks one's eyes, the signal can be observed more clearly compared to the output signal without a reference drive circuit.

fig 7

stable with 47pFC

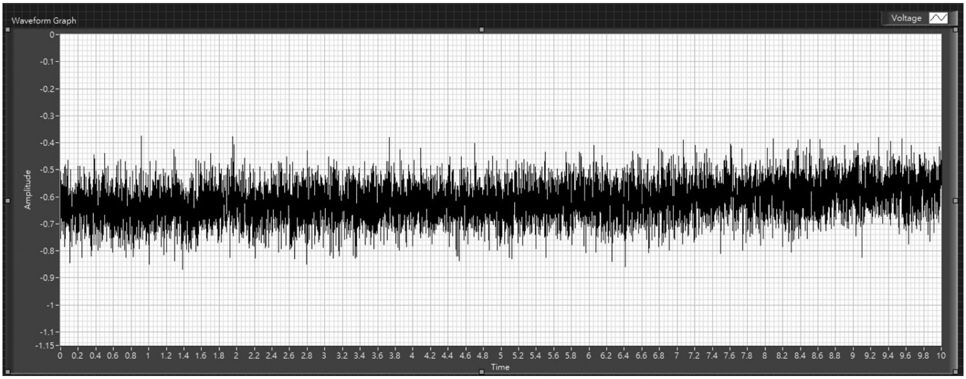


fig 8

stable without 47pFC

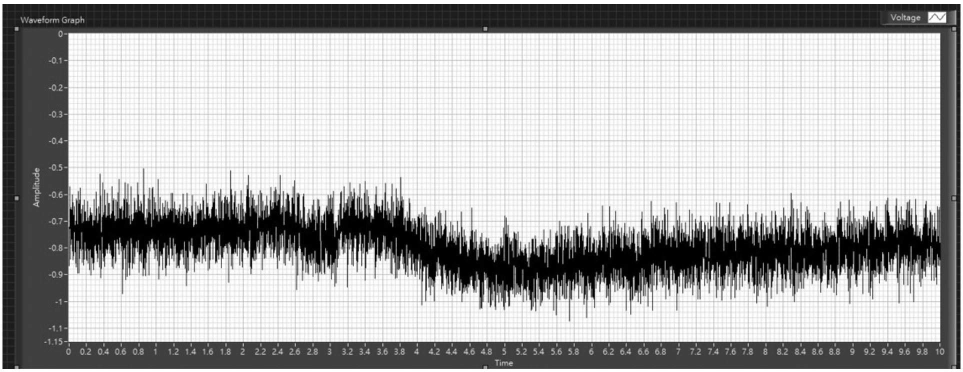
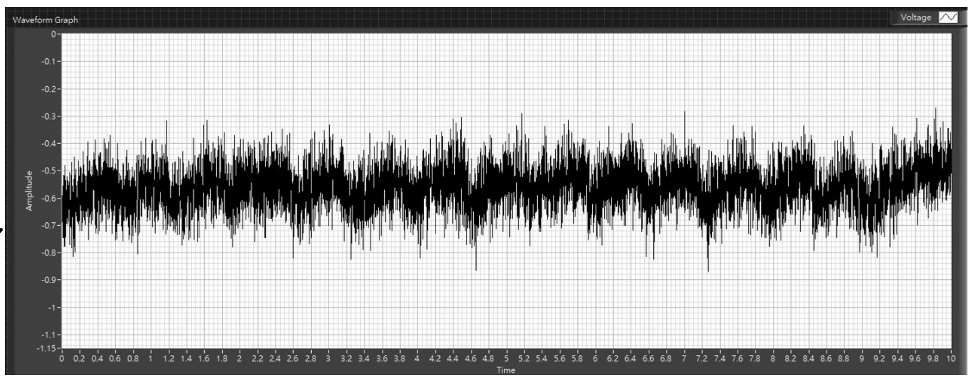


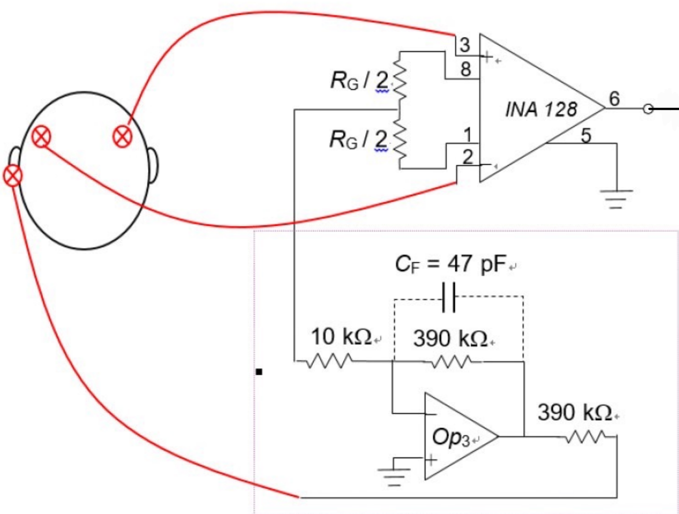
fig 9

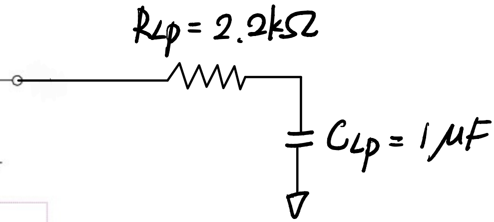
blink without 47pFC



There is nothing change with/without the 47pF capacitor in this experiment. The active inverting amplifier has a -3dB point at f = 1/(2piRC) ~= 9kHz, there is almost no effect on the EEG signal since the bandwidth of the EEG signal is typically from 0.1Hz to 50Hz.

<Phase 3>





$$f_{-3dB} = \frac{1}{2\pi \, 2200 \cdot 10^{-6}} \approx 72\,Hz$$

fig 10

stable

with LPF

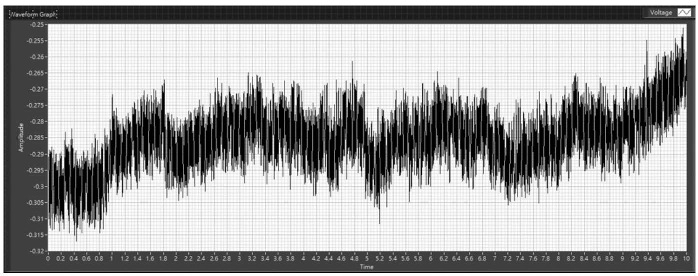


fig 11

reading

with LPF

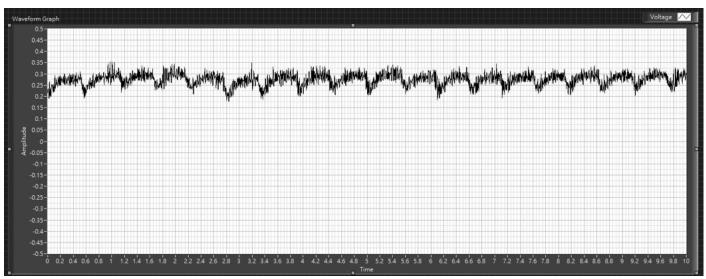
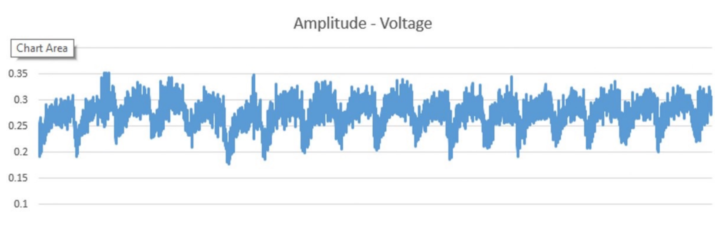
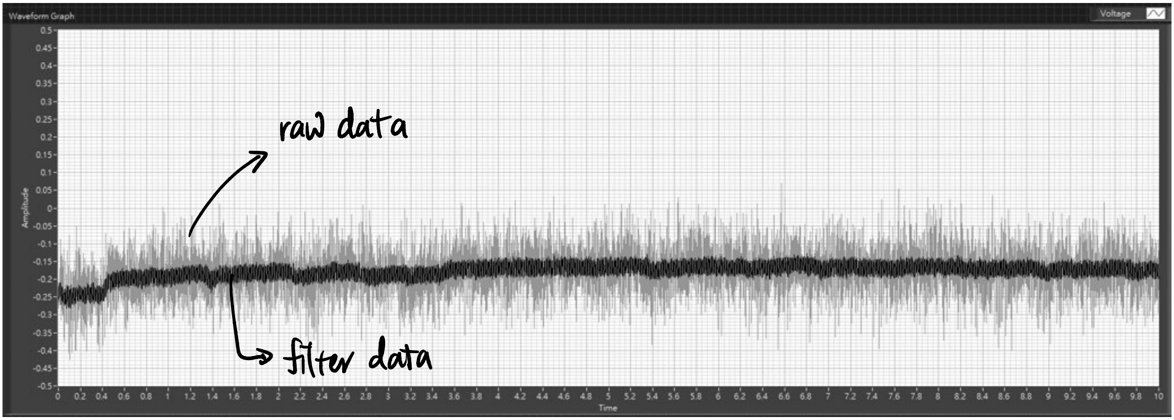


fig 12

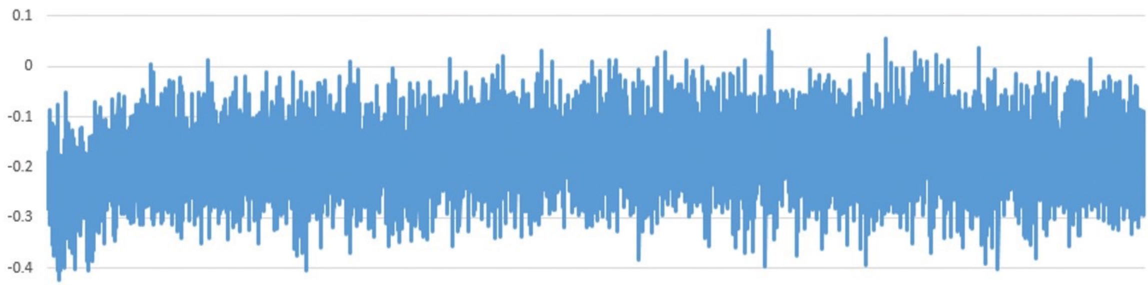
reading

export excel

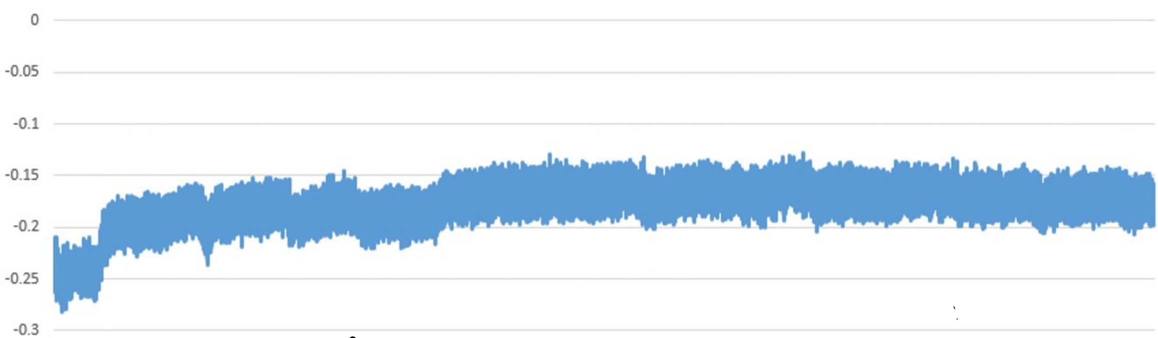




↑ fig 13, close eyes. (raw/filtered data)



↑ fig 14, close eyes (raw data)



↑ fig 15. close eyes (filtered data)

Figure 13 is the waveform of raw data and filtered data in one graph. According to the figure14, the raw data when the subject closes his eyes, there exists some stabs on the output EEG signal. However, the signal passing through the low pass filter in the figure15 has no more stabs.

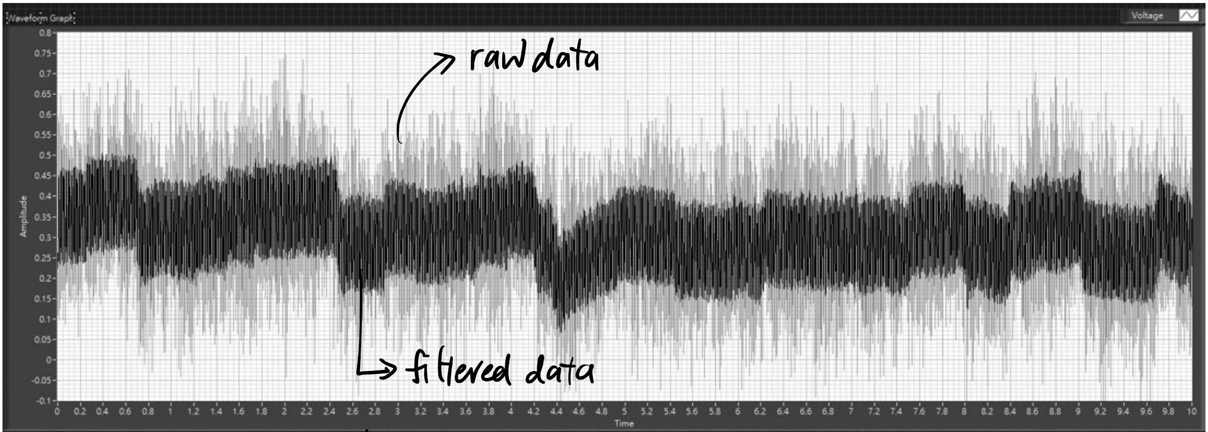


fig 16. reading (raw/filtered data)

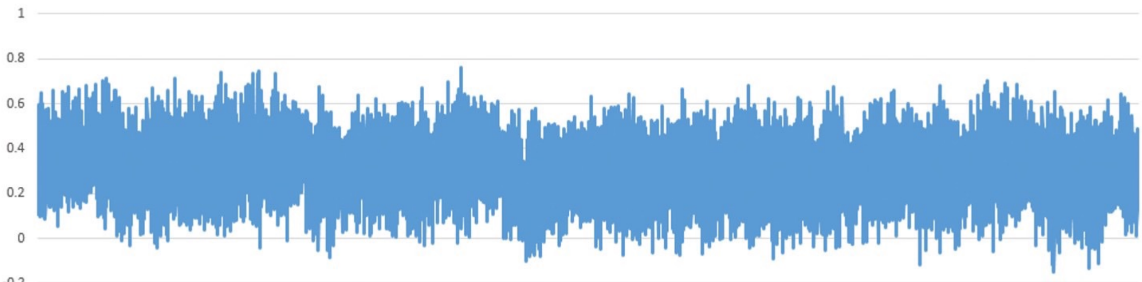


fig 17. reading raw data

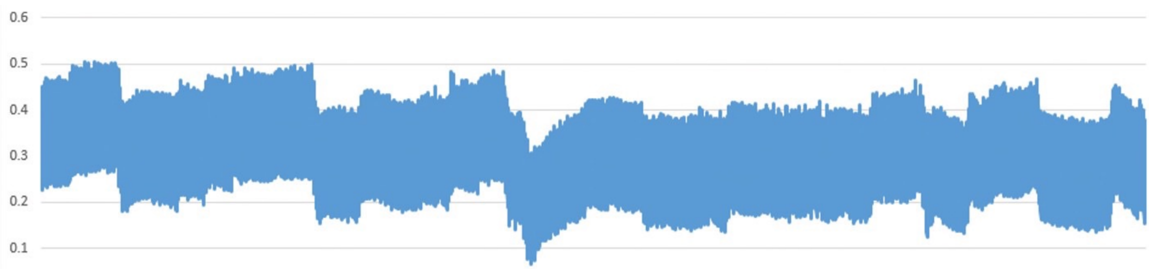


fig 18. reading filtered data

Figure 16 is the waveform of raw data and filtered data in one graph. According to the figure17, the raw data when the subject reads books, there exists some stabs on the output EEG signal. However, the signal passing through the low pass filter in the figure18 has no more stabs. The filtered signal is similar to the EOG signal in the last lab.

<Phase 4>

* close eyes

fig 19
close eyes
commercial
raw data

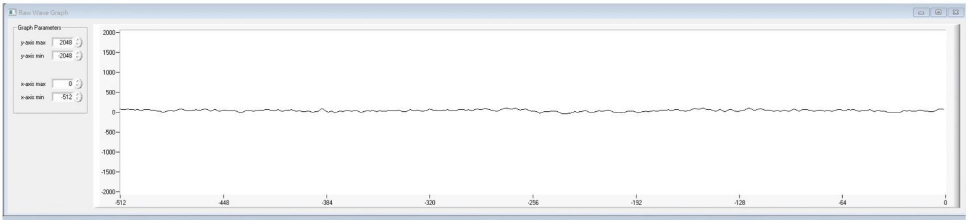


fig 20
close eyes
commercial
filtered data

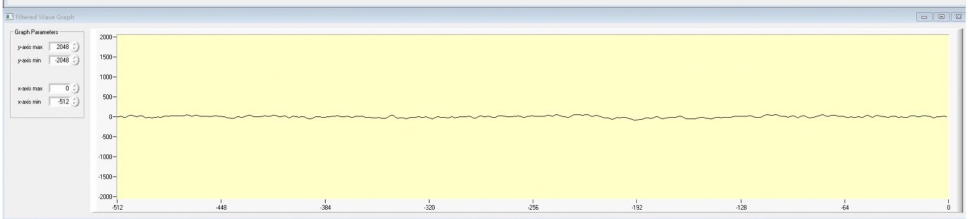


fig 21
close eyes
commercial
raw data
export

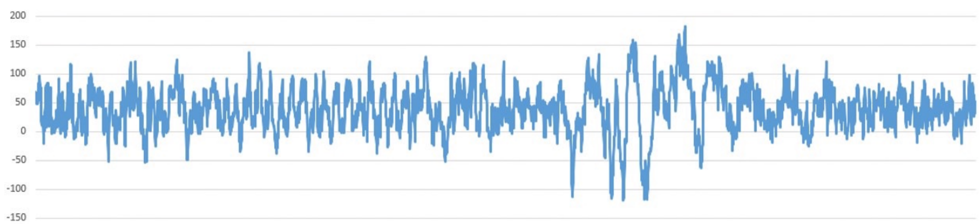
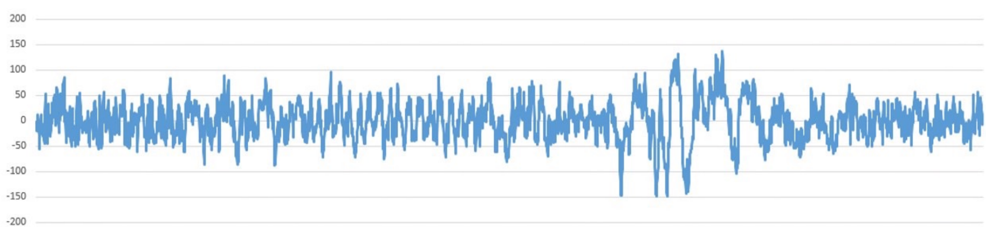


fig 22
close eyes
commercial
filtered data
export



The commercial EEG waveform has less high-frequency noise when the subject closes one's eyes. Besides, the RC delay can be observed by comparing with raw data and filtered data.

* reading

fig 3 reading commercial raw data

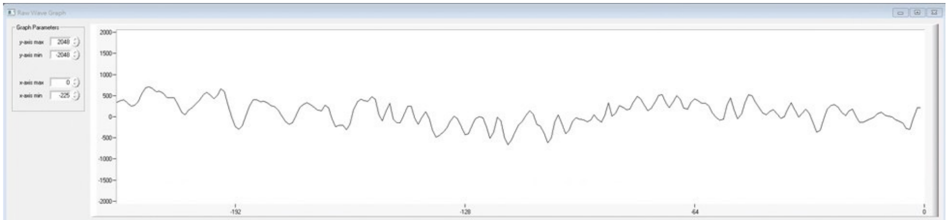


fig 4 reading commercial filtered data

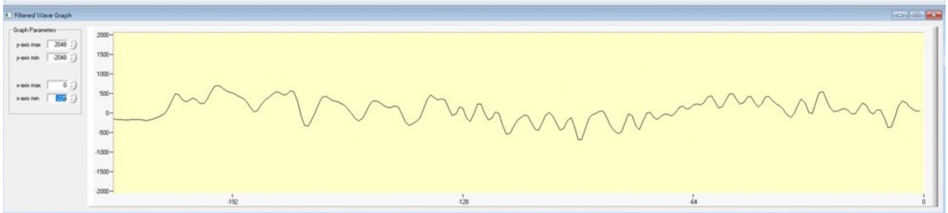


fig 5 reading commercial raw data

fig 6 reading commercial filtered data

When the subject is reading, there exists a pulse when one moves to the next line. The contrast of the pulse is more obvious than our result. Furthermore, the attenuation and RC delay can be observed by comparing with raw data and filtered data.

Question and Discussion

1. Is there noise (雜訊) associated with the EEG signal waveform measured in Step 1? If so, what is

Yes, there exists noise in the EEG signal waveform. The noise may come from physiological factors, such as Electrocardiogram (ECG), Electromyogram (EMG), and Electrooculogram (EOG). Also, the noise may come from the environment, such as AC power lines, electronic equipment, and so on.

2. In Figure 2 circuit, what is the functionality of reference drive circuit (驅動參考點電路)?

A reference drive circuit can be used to eliminate noise interference from the human body. The body will act as an antenna which induced radio-frequency interference and result in a large noise. With the reference drive circuit's help, one can actively eliminate the noise from the body.

3. The lab report must consist of the results outlined in Section G – Lab Reports.

1. Illustrate the *Vo* signal waveform graph obtained in Step 3 and record the signal waveform and circuit parameters.

Signal waveform & parameters	Circuit parameters
Peak-to-peak of V_O = 0.2 V (fig 3)	R_G = 100 Ω Voltage gain ≈ 500 V/V

2. Illustrate the *Vo* signal waveform graph obtained in Step 6 and record the signal waveform and circuit parameters.

Signal waveform & parameters	Circuit parameters
Peak-to-peak of V_O = 0.4 (fig 6)	R_G = 102 Ω Voltage gain ≃ 500 V/V

3. Illustrate the *Vo'* signal waveform graph obtained in Step 10 and record the signal waveform and circuit parameters

Signal waveform & parameters	Circuit parameters
Peak-to-peak of V_O' = 0.15 (fig 12)	R_G = 102 Ω Voltage gain ≃ 500 V/V R_{LP} = 220 Ω C_{LP} = 1 μF f_{-3dB} ≃ 72 Hz

4. How well does EEG signal waveform measured and the filtered wave from a Neurosky device agree with EEG signal waveform measured and filtered waveform using the device from phase III? Refer to Steps 15 and 16. Could we use the device from phase III to replace the Neurosky device in phase IV to measure EEG signal? Explain.

The waveform measured in the physical circuit with a low pass filter has a large difference from the commercial Neurosky device. The measured waveform still exists some noise. However, I believed inside the software of Neurosky, software must have performed some DSP technique on the signal, so that the output waveform becomes more readable.

Whether can we use the device from phase 3 to replace the Neuosky device depends on how much we want to observe. If we want to observe the readable waveform, we should use the Neurosky device. However, if one just wants to know whether the subject is stable or doing another thinking process the device in phase 3 is enough.

* Feedback

In practice, EEG measurements need more sensors to detect the signal generated from one's brain. To have these signals, scientists can give the subject some stimulation or let the subject watch some graphs to determine what's the function of a specific region of the human brain. It is quite interesting to try to measure the human EEG signal, it must be an important application in brain discovery.