Current design

Signal setting:

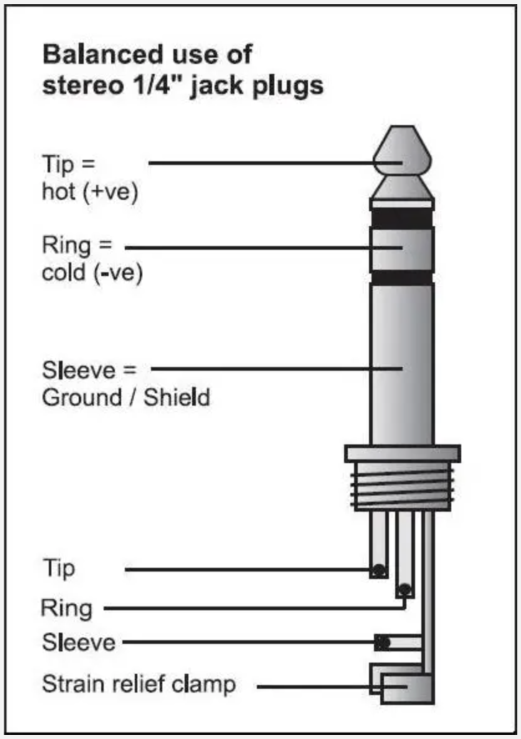
	Sig_1	Sig_2
Offset	1484mV	1356mV
Amplitude	3.5mV	10.8mV (200uV in wavegen)
Sampling frequency	83.34Hz	
Signal frequency(wavegen)	0.1Hz	

Mar 27, 2022

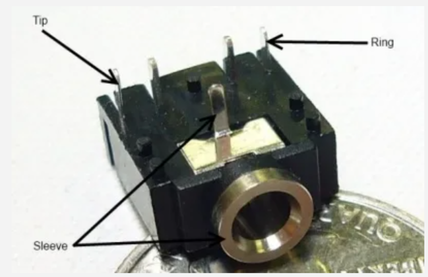
Today I tried out the eog sensor.
As shown in figure below, the pins of the jack correspond to the different regions of the plug.

Initially, I connected the pins directly to the analog discovery. However, no signal was obtained. I thought maybe it was simply too small, so I used the circuit from the last workshop(transistor) to create a simple amplifier, However, no signal was obtained either. Either I have not connected it correctly or the gain was not enough. From previous notes, the signal falls between 50uV to 3500 uV, so the gain needs to be around 500 to 1000 to get our operating voltage.

As a result, I think I'll return to this after I have studied more about the amplifiers. I should form a circuit that yields the desired gain first. I also wasn't able to find which pin corresponds to which eog cable too. I can only assume that the ring connects the red, tip the blue, and sleeve the ground.



Tip, Ring, Sleeve Diagram



3.5 mm Audio Jack Socket Pin Diagram

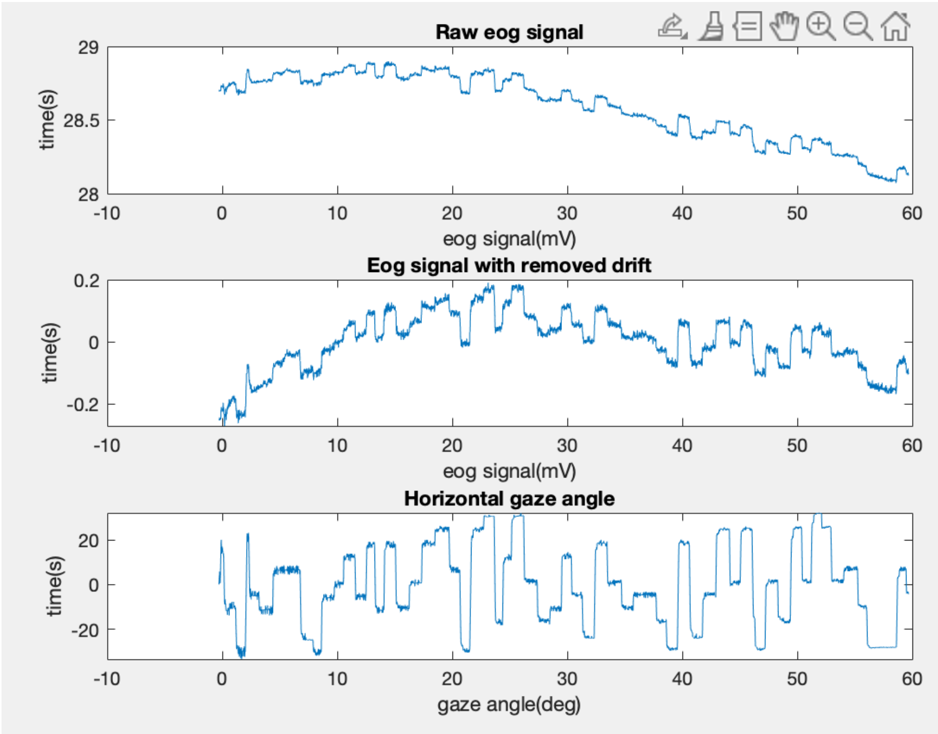
[Figure](#)

May 10, 2022

In case where I cannot get the sensor working, we will switch to using eog dataset as an alternative.
The eog data provided, though having the sampling frequency, does not indicate what the measuring units are, and no gaze angle was provided. Instead, I will use other datasets found from the internet, since I will have a larger sample size for validation, and the measurement units and equipment are known.

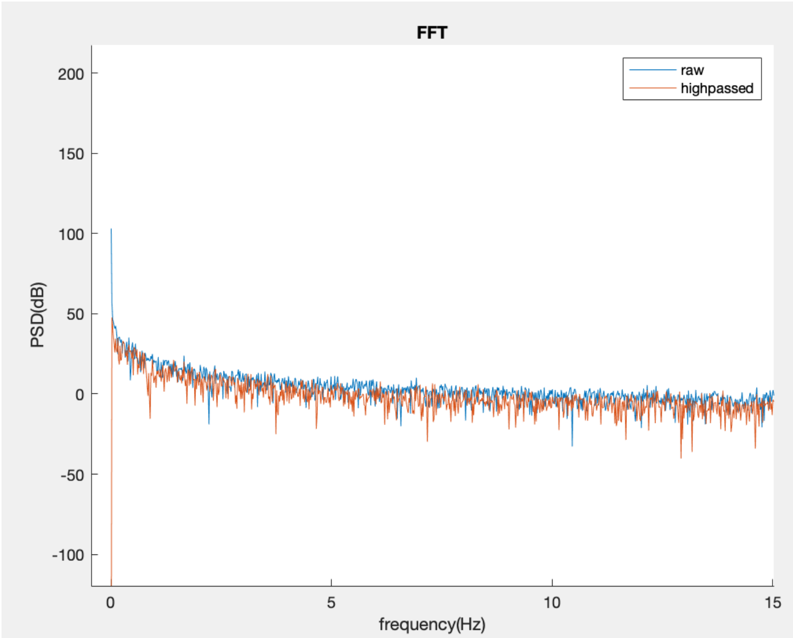
Measurements:
EOG : eog signal(mV) measured by conductive ear moulds
Since it is using a different equipment, the magnitude will not correspond to what we will get in our circuit
GAZE_INTERPOLATED : horizontal gaze angle(degrees)
TIME : time stamp(s)
Sampling frequency: 83.34 Hz.

An example of the data



From the fft results, we also need to reconsider what signal we put in to validate each block. Using sine waves may not be sufficient to capture the characteristics of the signal, since they do not contain any prominent spikes at any given frequency, but a mixture of low frequency signals.

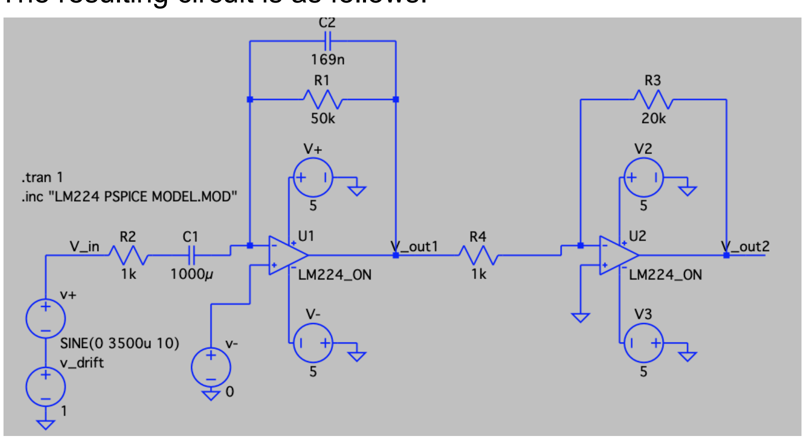
Powerline noise is not removed in the measurement, however, we do not see it in the psd. Since the sampling frequency is around 80Hz, a 50Hz noise will be aliased, which may be present at frequency around 10Hz, but we do not observe that. Maybe the magnitude of powerline noise is negligible in this measurement, we should be wary about its potential presence in our circuit.



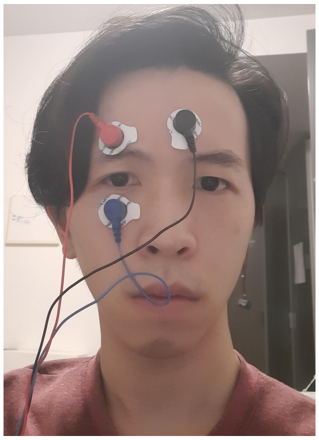
Dataset Publication

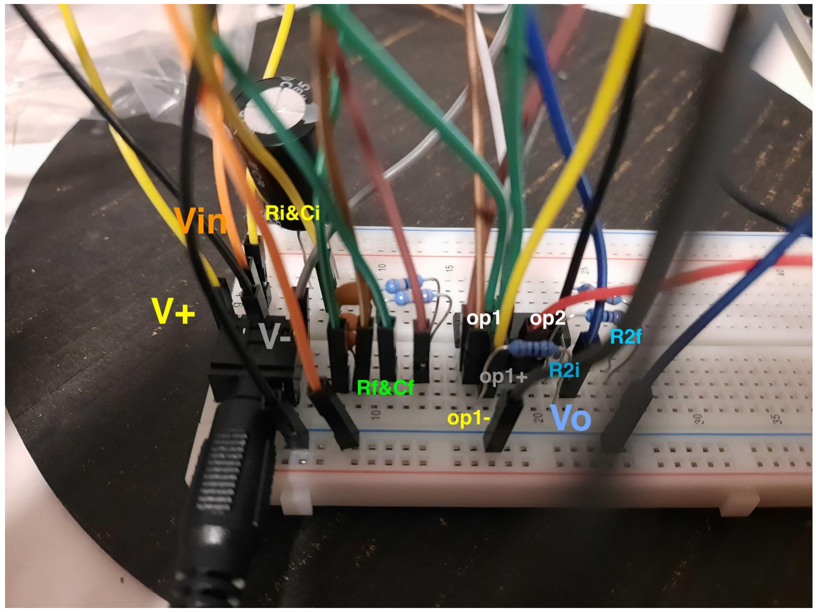
Reference
Hládek, Ľ., Porr, B., Brimijoin, W. O. (2018). Real-time estimation of horizontal gaze angle by saccade integration using in-ear electrooculography. PLOS ONE, 13(1), e0190420. doi:10.1371/journal.pone.01904

Test with difference amplifier
With the audio jack, I connected the middle pin(sleeve/ ground) to the ground, right most pin(tip/V+) to V_in, and left most pin (ring/ V-) to the + end of the first opamp.
The resulting circuit is as follows:



The result shows that there are no differences between Vi and the gaze angle. I may have not connected the audio jack correctly, or I may have not considered certain noises generated by the jack.





Vin
Ri&Ci
V+
V-
op1
op2
R2f
op1+
R2i
Rf&Cf
op1-
Vo

Gazing up

Welcome
Help
Scope 1
Supplies
File Control View Window
Export Rec. +XY +XYZ 3D +Zoom FFT Spectrogram Spectrogram 3D Histogram Persistence Data Measurements Logging Audio X Cursors Y Cursors
Single
Stop
Mode: Repeated Auto Source: Vo Condition: Rising Level: -630 uV Hyst.: Auto
Buffer: 10 Auto Set Type: Edge LCondition: Less Length: 100 ns HoldOff: 100 ns
Vo mV Trig'd Vi Vo 8192 samples at 10.639 kHz | 2022-05-10 16:08:40.968
X: 7.043 ms
Vi: -5.34 mV
Vo: 28.14 mV
350 300 250 200 150 100 50 0 -50 -100 -150
X -385 ms -308 ms -231 ms -154 ms -77 ms 0 ms 77 ms 154 ms 231 ms 308 ms 385 ms
Time
Position: 0 s
Base: 77 ms/div
Options
Add Channel
Vi (1±)
Offset: 100 mV
Range: 50 mV/div
Vo (2±)
Offset: -100 mV
Range: 50 mV/div

Gazing down

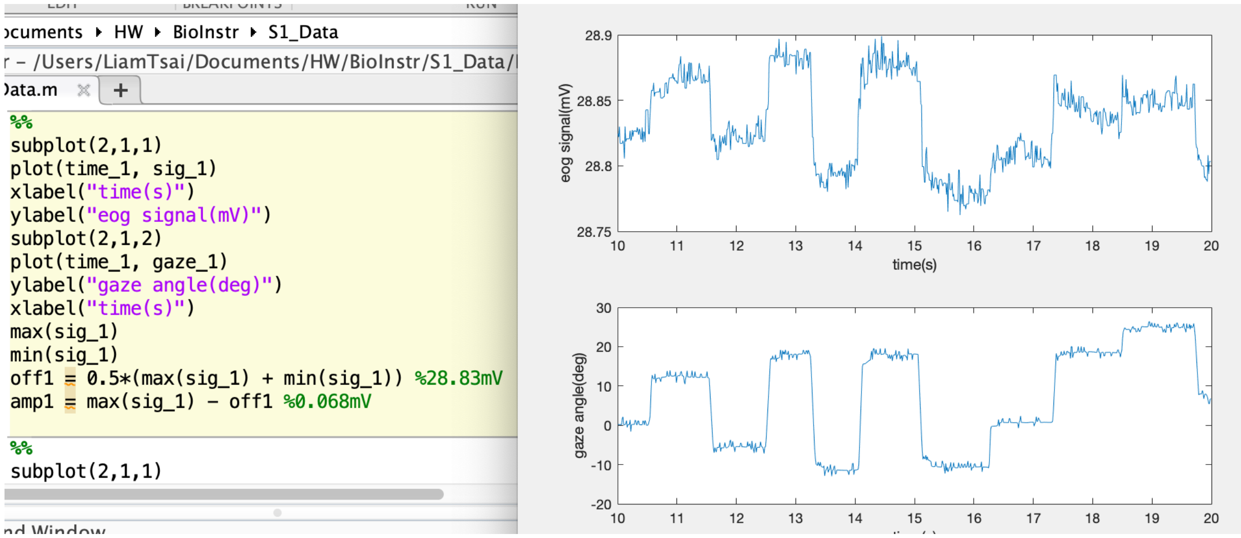
Gazing middle

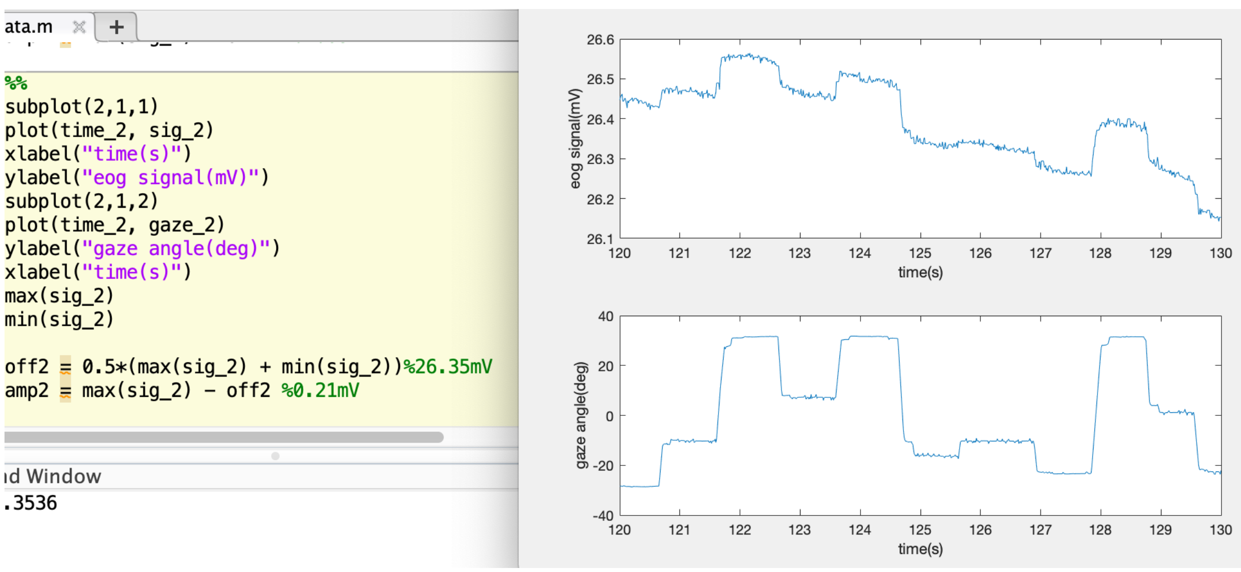
May 16, 2022

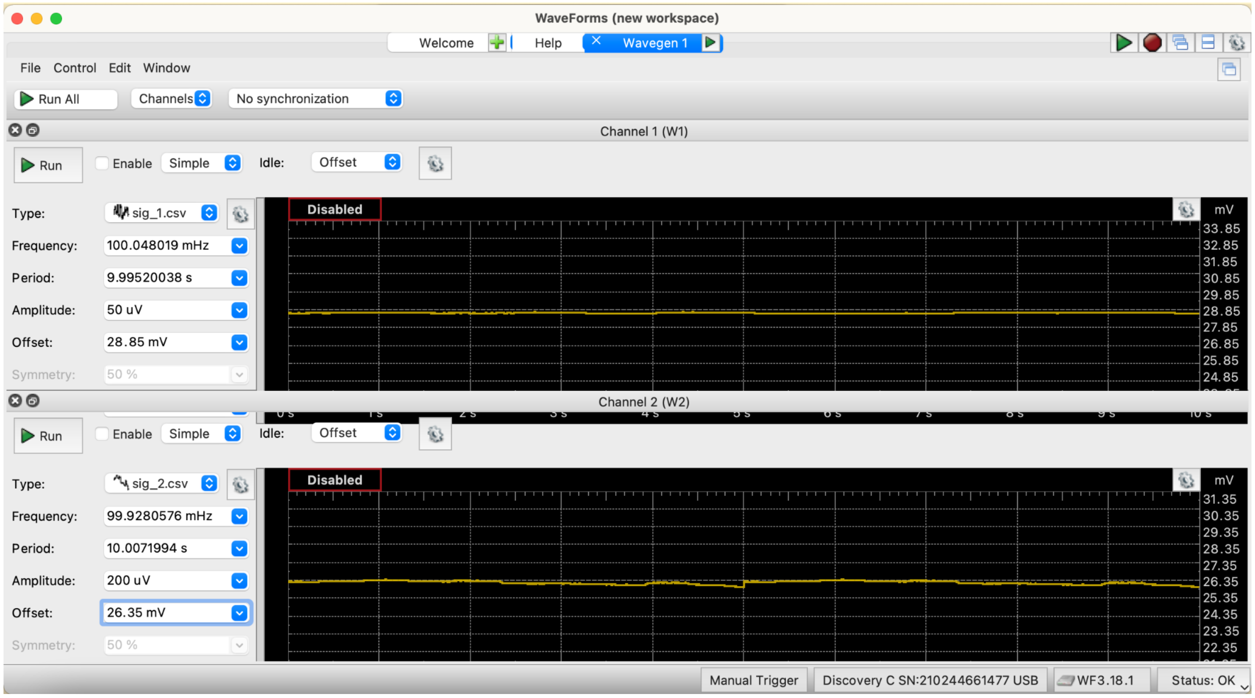
Two arbitrary sections were chosen from the signal as test signals.
Each lasts 10s.
The signals were exported as csv for waveform to read from.
The following table shows the parameters to be inserted into wavegen

	Sig_1	Sig_2
Offset	28.83mV	26.35mV
Amplitude	0.068mV	0.21mV

	(turns into 50uV in wavegen)	(200uV in wavegen)
Sampling frequency	83.34Hz	
Signal frequency(wavegen)	0.1Hz	







Testing results of the data on the amplifier & filters
From the results, we can see that the baseline of Vo sits at 0V in both signals, which shows that the drift is successfully removed. However, the amplitude of the signal is at 60mV for signal 1, and 80mV for signal 2. From the Vi shown in waveform, I am not sure whether our device is able to generate the required signal amplitude, since the graph looks more like a dc signal.

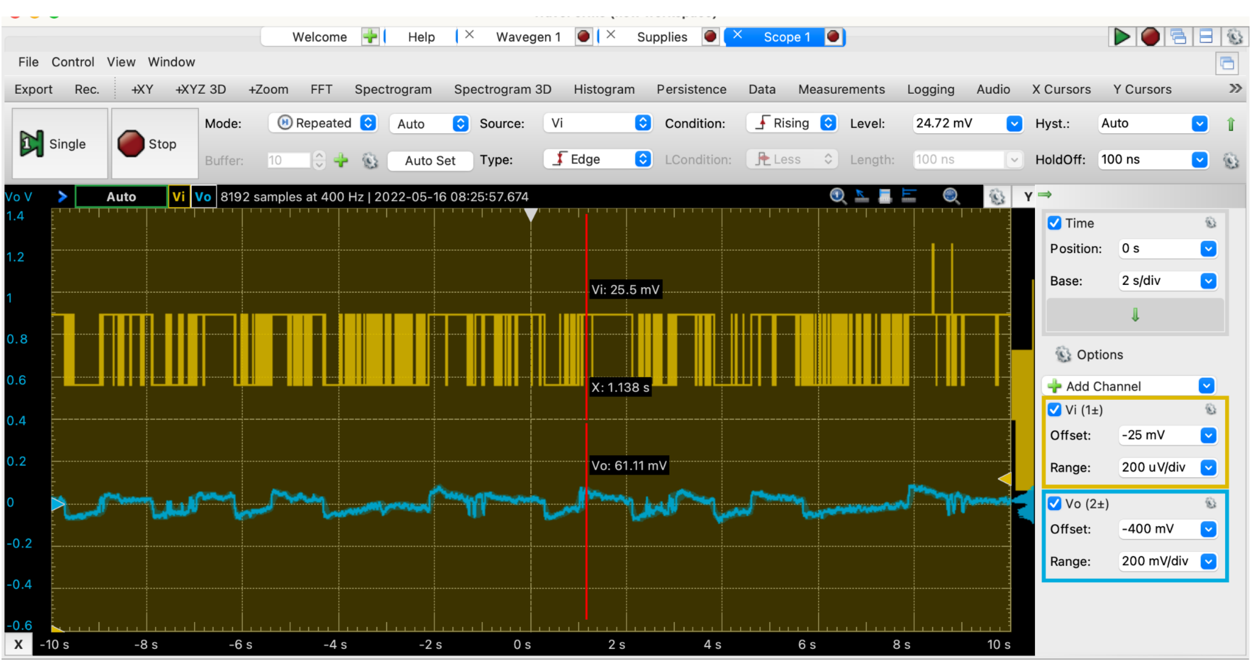


Figure : Results of signal 1

Figure : Results of signal 2

Assume that the offset from baseline is 0.068mV at 20 deg gaze angle, we will scale it to 3.5mV, as we have assumed in other sections of research, i.e. scaling all signals by 51.5. Thus, the new signals will be as follows:

	Sig_1	Sig_2
Offset	1484mV	1356mV
Amplitude	3.5mV	10.8mV (200uV in wavegen)
Sampling frequency	83.34Hz	
Signal frequency(wavegen)	0.1Hz	

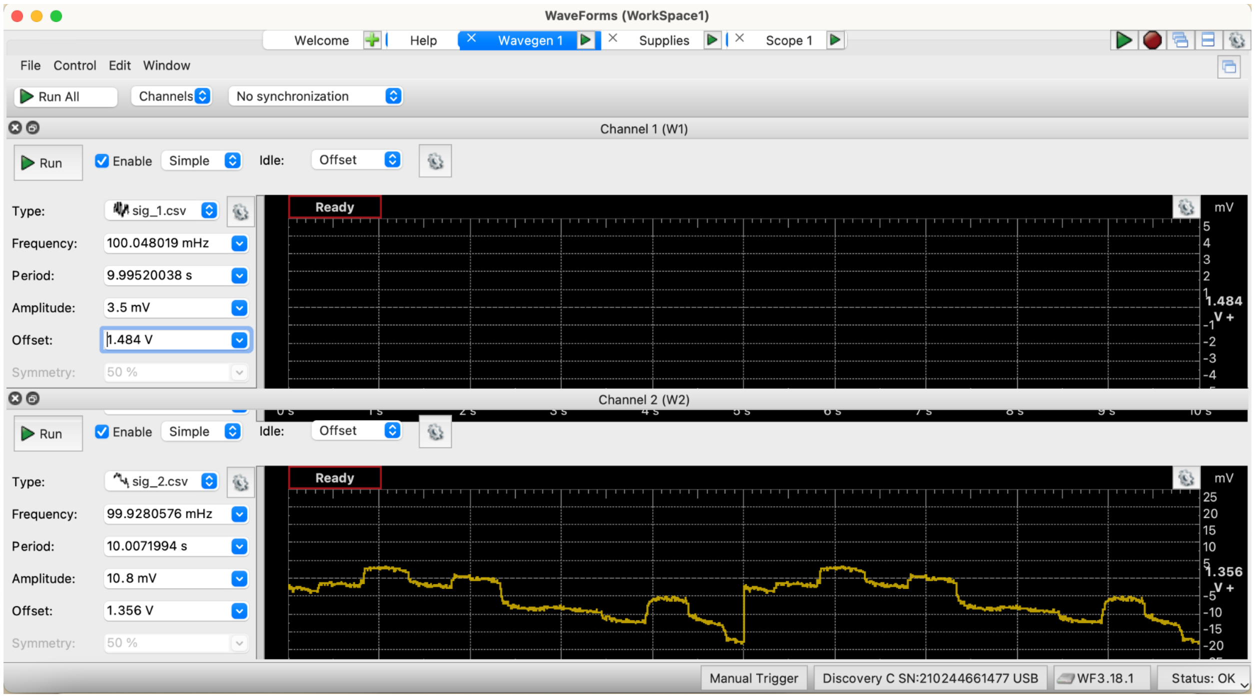
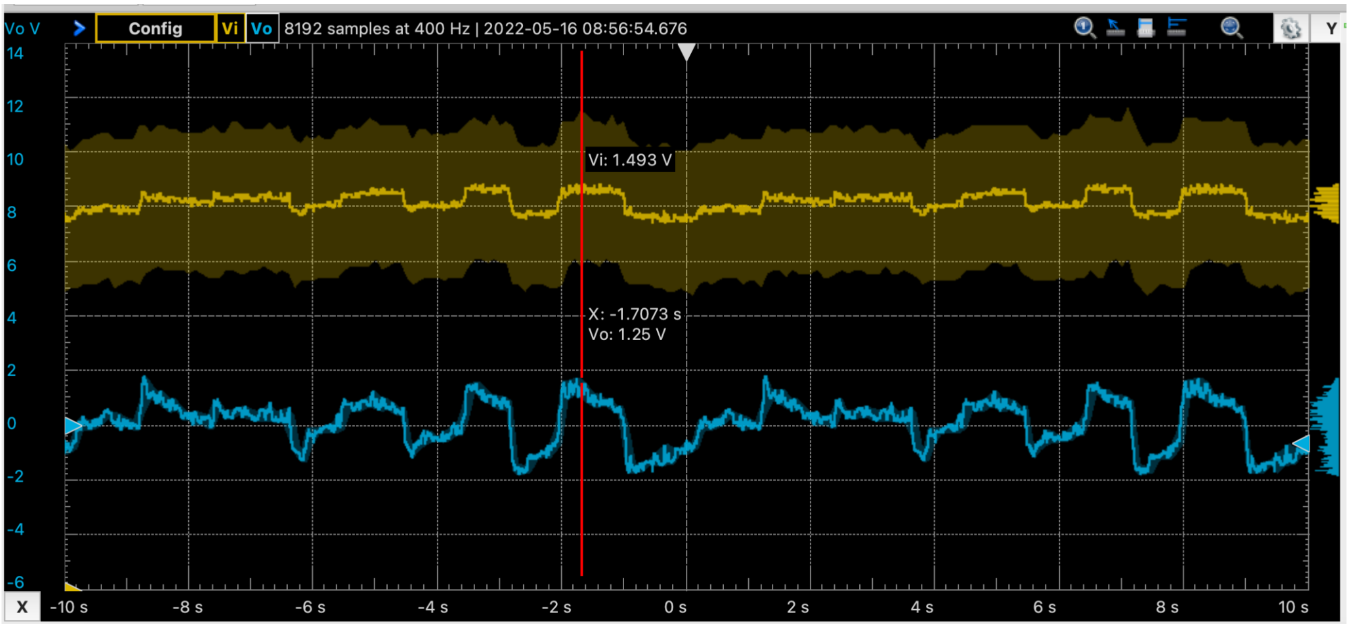


Figure : New signal

Results:

Now the results clearly show that the input is able to generate the waveform. For signal 1, the drift is successfully removed, and the amplitude is similar to the 1.5V we were getting from the testing of amp&filt. For signal 2, which has a higher drift,the amplitude from baseline remains at around 1.5V. However, the drift is not fully removed, as we can see that at the beginning of the signal, the output rises to 3.5V. This may be generated by the discontinuity in our signal, which may transform the low frequency drift into a composite of higher frequency waves. To mitigate that, we may need to mirror our testing signal, so that the beginning and the end of the signal lies on the same value.



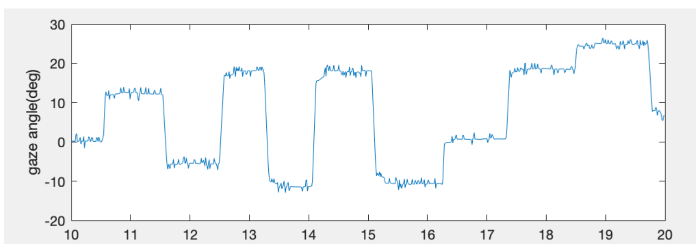
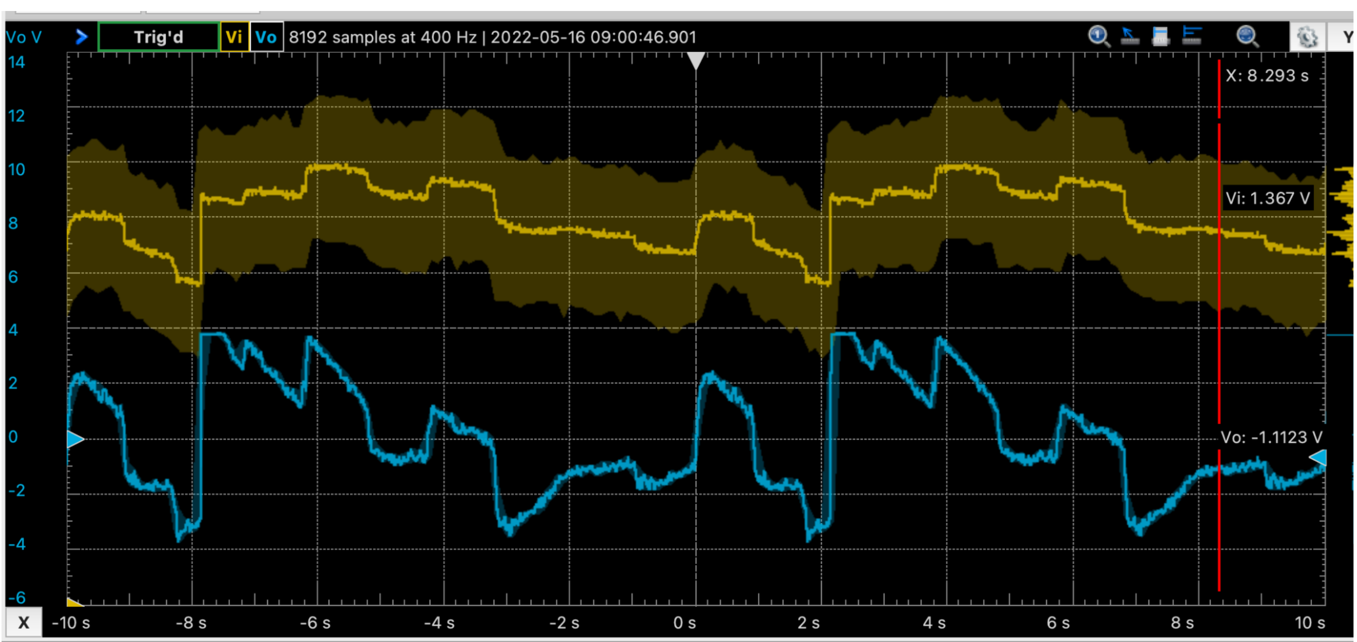


Figure : Signal 1



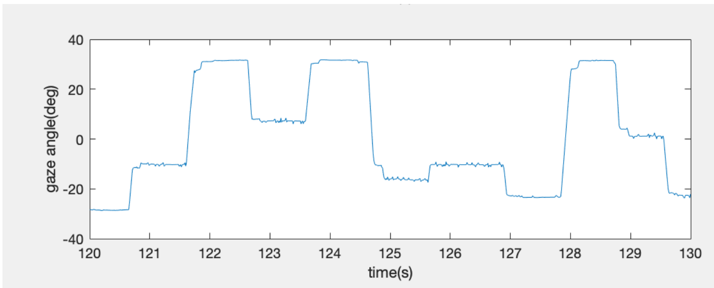


Figure : Signal 2

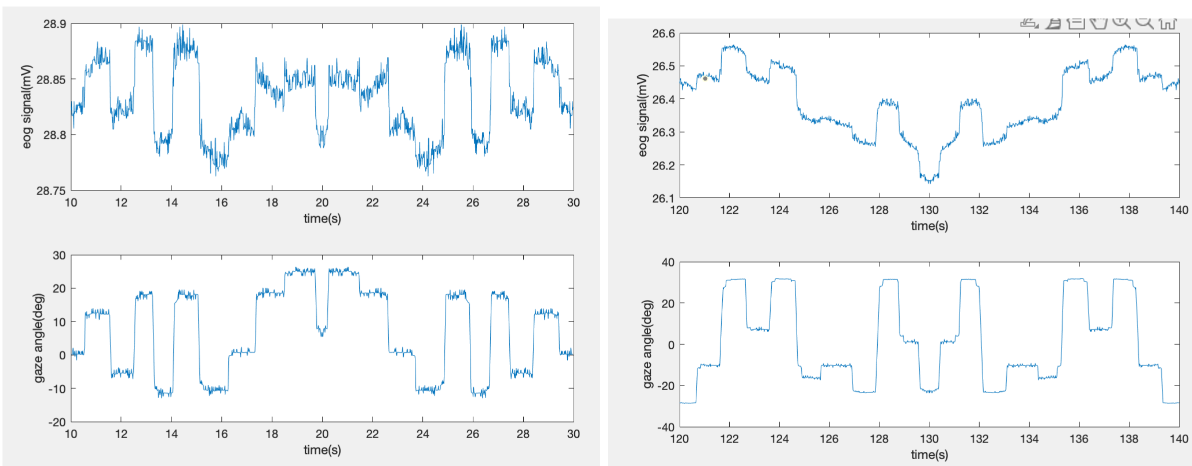
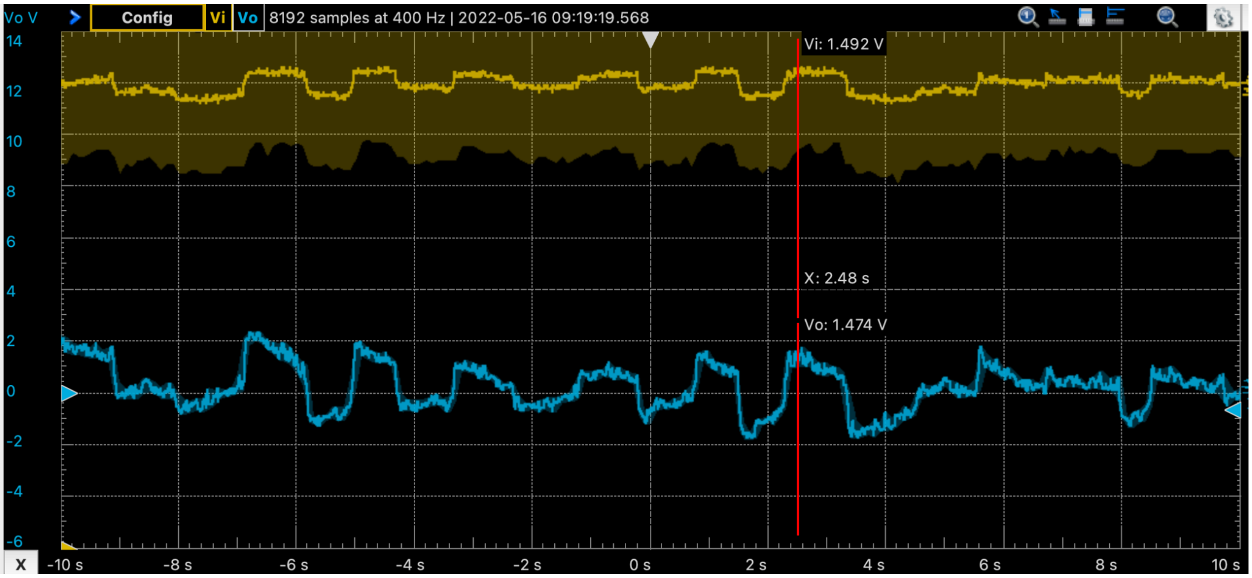
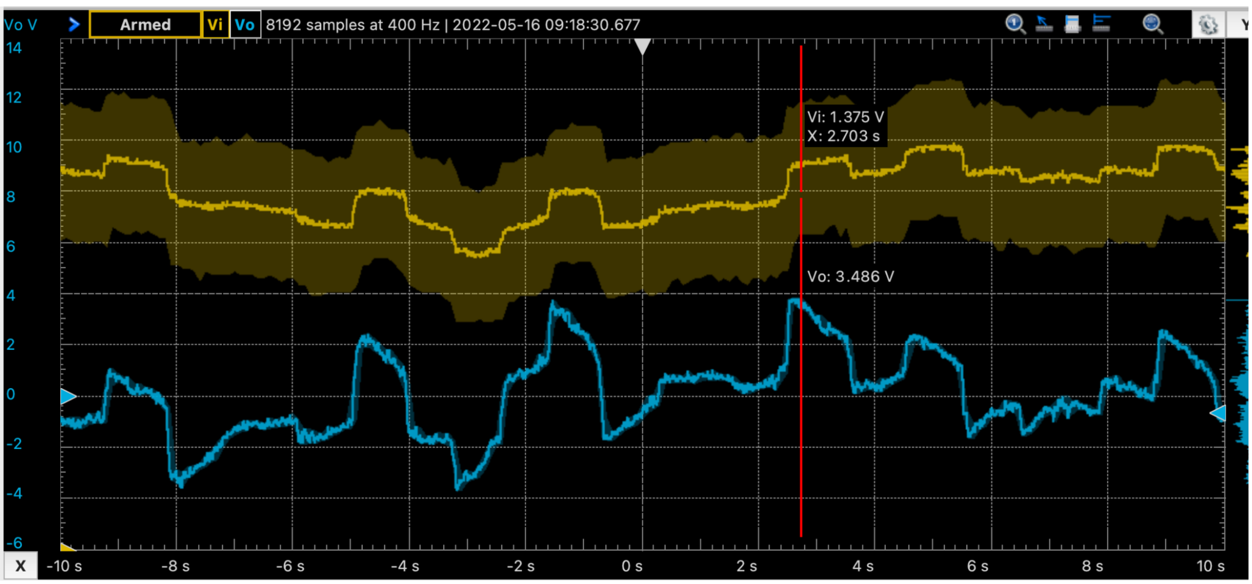


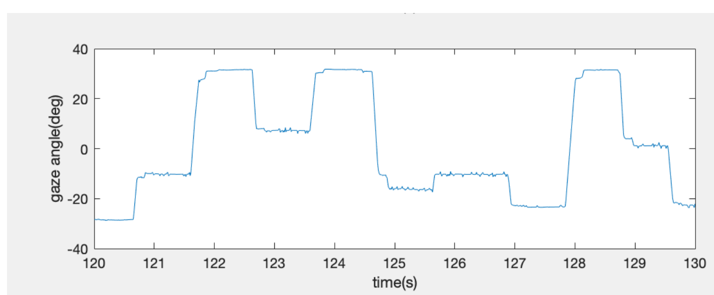
Figure : New signal (left) signal 1, (right) signal 2

Results:
The results in signal 2 looks a bit better now. Interestingly, the signals at 20 deg gaze shows a downward slope regardless of being mirrored or not. I think that is due to the high passing that tends to remove signals that persist at a fixed level. I.e., if the subject fixes his gaze angle for a certain time, that EOG voltage will be seen as the new baseline drift and thus removed. So in some sense, we can't really tell what direction someone is looking at, but instead the transient movement of eye gaze. Interpolating the slope, we may assume that gazes lasting over 2s will drop back to the baseline. We may need to rethink the purpose of our proposed design.

Nevertheless, this drift of the entire eog signal of subject1 is -2V. This may stem from the equipments they are using, e.g., that the contacts are loosening over time. I don't think the effect is bypassable merely by signal processing.


Vo V
Config
Vi
Vo
8192 samples at 400 Hz | 2022-05-16 09:19:19.568
Vi: 1.492 V
X: 2.48 s
Vo: 1.474 V
14
12
10
8
6
4
2
0
-2
-4
-6
X
-10 s
-8 s
-6 s
-4 s
-2 s
0 s
2 s
4 s
6 s
8 s
10 s


Vo V
Armed
Vi
Vo
8192 samples at 400 Hz | 2022-05-16 09:18:30.677
Vi: 1.375 V
X: 2.703 s
Vo: 3.486 V
14
12
10
8
6
4
2
0
-2
-4
-6
X
-10 s
-8 s
-6 s
-4 s
-2 s
0 s
2 s
4 s
6 s
8 s
10 s


gaze angle(deg)
40
20
0
-20
-40
120
121
122
123
124
125
126
127
128
129
130
time(s)