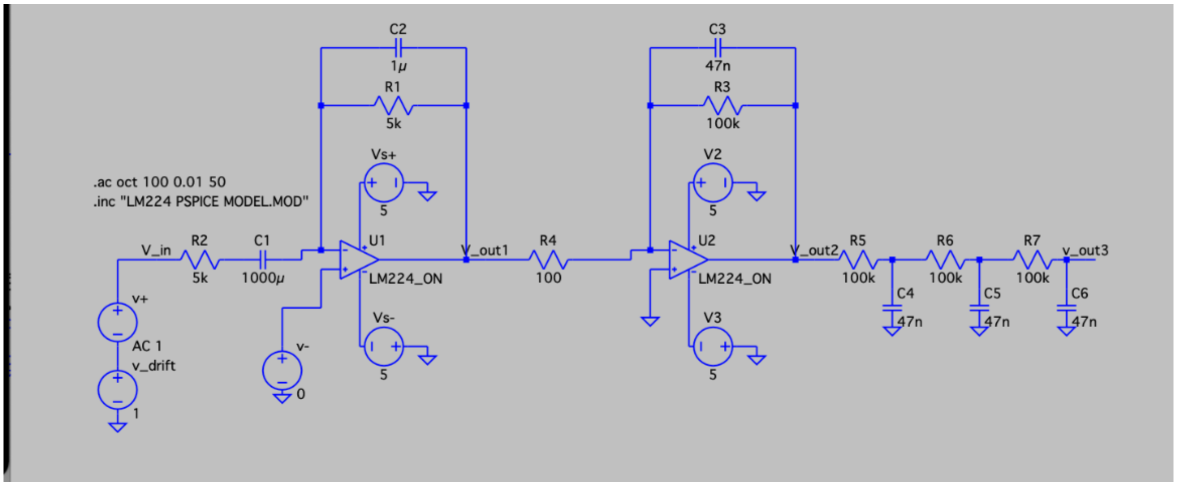
Filter + Amp

Current Design (May 18th)



BPF + amplifier + LPF
G1 = 1 = 0dB

$$F_L = \frac{1}{2\pi R_{IN} C_{IN}} = 0.0318Hz$$

$$F_H = \frac{1}{2\pi R_F C_F} = 33.86Hz$$

G2 = 1000 = 60dB
Total gain = 1000 = 60dB
V_i = 3500 uv
V_o = 3.5V (simulation) 1.5V (actual)
F_BP : 0.16 - 31.83Hz

Apr 5, 2022

- Actions

Verify whether I have the capacitors
Build and validate the circuit in real life

Detail

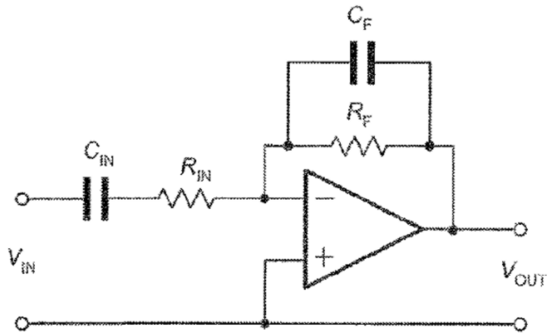


Figure 8.8 Adding capacitors to modify the frequency response of an inverting operational amplifier

(from perusal week 6 op amp)

Since only the frequency between 0.1 and 20Hz is related to eye movement, we will choose a bandpass between 0.1 to 25 Hz.

From ref[2], the typical signal is 50 to 3500 uV, and we want to amplify it to 0~1.5 V
So we need a gain of 428.6. If we choose $R_{IN} = 100\Omega$, $R_F = 42k\Omega$

Higher cutoff frequency :

$R_F = 42k\Omega$

$$F_H = \frac{1}{2\pi R_F C_F} = 25Hz$$,

$$C_F = \frac{1}{2\pi R_F F_H} = 152nF$$

For simpler circuit, we choose

$$C_F = \frac{1}{2\pi R_F F_H} = 150nF$$

$$F_H = \frac{1}{2\pi R_F C_F} = 25.26Hz$$

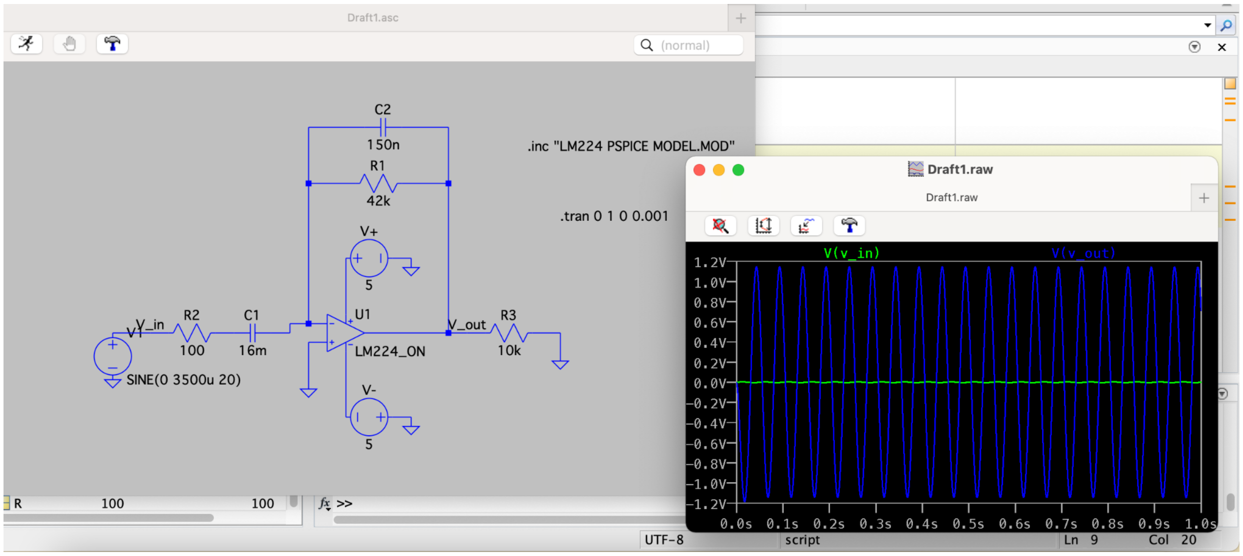
Lower cutoff frequency :

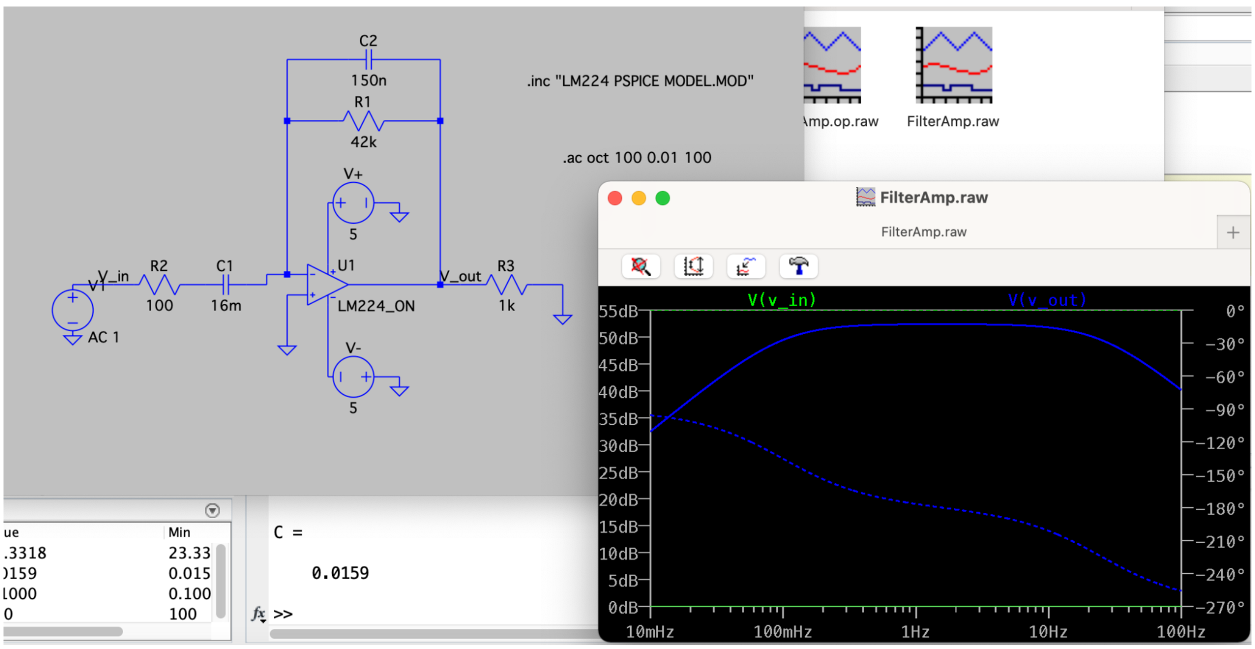
$R_{IN} = 100\Omega$

$$F_L = \frac{1}{2\pi R_{IN} C_{IN}} = 0.1Hz$$

$$C_{IN} = \frac{1}{2\pi R_{IN} F_L} = 16mF$$

By simulation, the result is pretty similar to what I expected





Ref

[2] - Deng, L. Y., Hsu, C.-L., Lin, T.-C., Tuan, J.-S., Chang, S.-M. (2010). EOG-based Human–Computer Interface system development. Expert Systems with Applications, 37(4), 3337–3343. doi:10.1016/j.eswa.2009.10.017

May 6, 2022

Issue 1 : The capacitance come in 1mF maximum

> R_in must be increased

Issue 2 : We need the output signal to be 5V instead of 1.5V

> Either change Rf or add another amplifier

New Gain : 5V/3500uV = 1428

If we use $R_{in} = 1k\Omega$

$$F_L = \frac{1}{2\pi R_{IN} C_{IN}} = 0.1Hz$$

$$C_{IN} = \frac{1}{2\pi R_{IN} F_L} = 1600uF$$

$$R_f = 1428k\Omega$$

$$C_F = \frac{1}{2\pi R_F F_H} = 4.581nF$$

This is a bit too small for our components, and 1.4MOhm may also induce large currents.

New Strategy: use two amplifiers with a same cutoff frequency

New Gain : $\sqrt{1428} = 37.78$ = 31.54dB

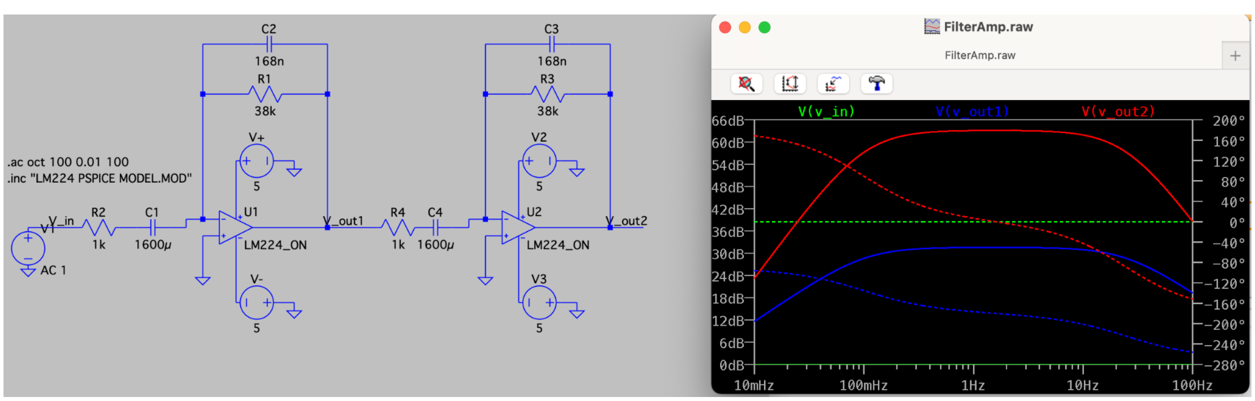
$$R_f = 37.78k\Omega$$

$$C_F = \frac{1}{2\pi R_F F_H} = 168.5nF$$

For simplicity,

Choose $R_f = 38k\Omega$, $C_F = 168nF$

New cut-off $F_H = 24.93Hz$



May 9, 2022

The full circuits were showing that the filt&amp are amplifying it to 3.5V instead of 5V. I noticed that I haven’t truly validated the circuit yet.

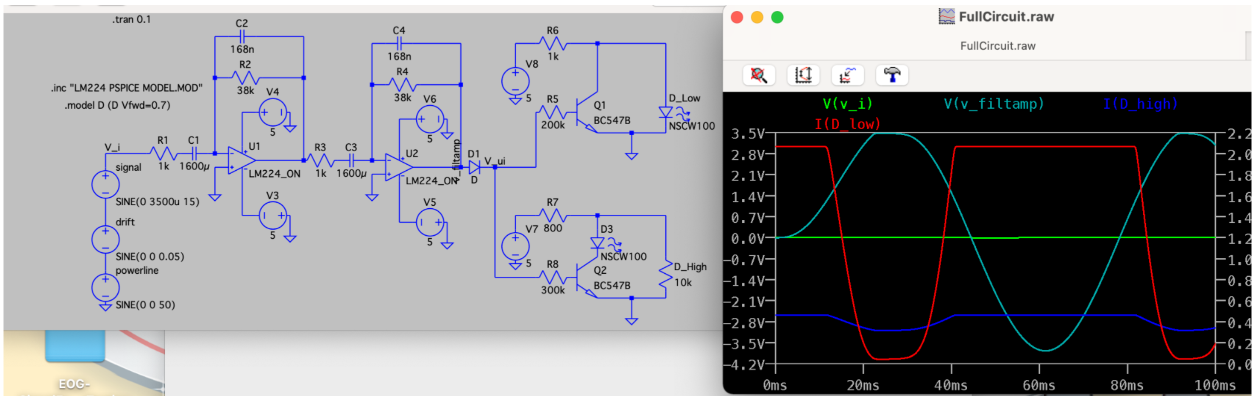
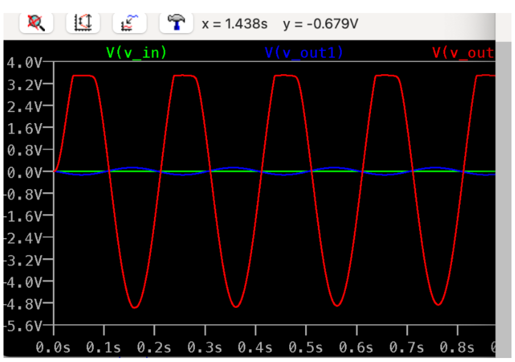
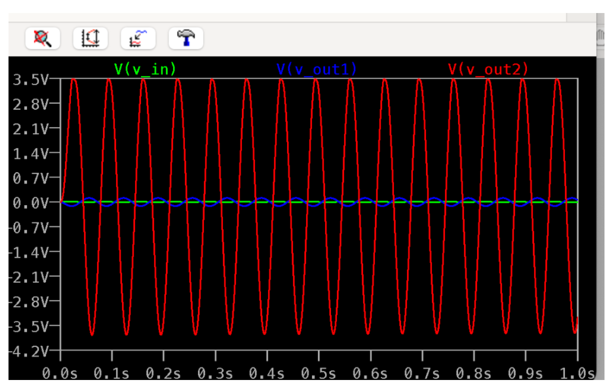
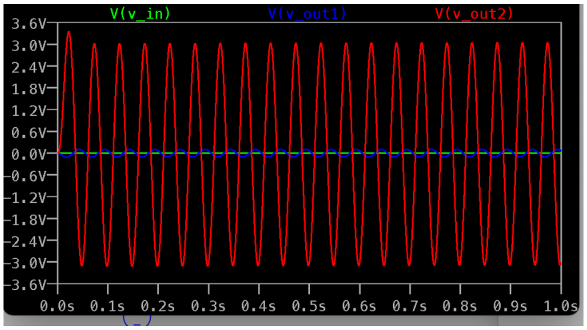
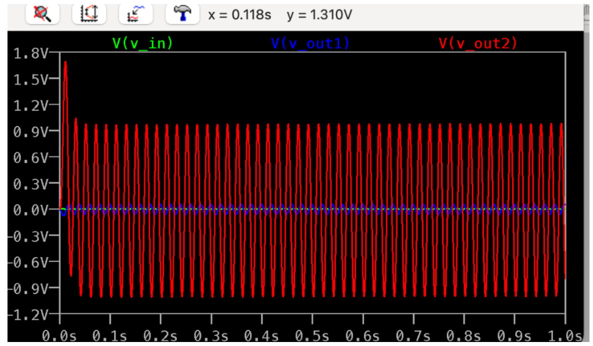


Figure : Result of the full circuit. The magnitude of the incoming signal to the ui was off, hence the threshold was not catered to that.

Testing the filt&amp circuit with sin wave of 3500uV magnitude, at 5 to 15 Hz, the output is consistent at around 3.5V. At 20 Hz, the output is starting to attenuate.
At a powerline frequency of 50 Hz, we can see that the output is lower than 1V, which I think is satisfactory for. If the actual magnitude is larger than the signal, we may need to redesign the filter again. Clearly, the calculations did not end up as I have anticipated, we will need a better understanding of the issue, probably bringing it up for consultation.

5Hz	15Hz
	
20Hz	50Hz





Future actions:

1. Reset the thresholds of the ui to suit this new gain.
2. May need a peak detector to capture the average signal value.

May 10, 2022

Building circuit

For ease of building, I have simplified some of the components, which altered the gain and cutoff frequencies in the first op amp. I have also removed the filtering in the second op amp, and instead make it do only amplifying. If the powerline noise do come in effect in the future, we may place it back.

Another thing I did not noticed in the past is that the upper limit of the amplified signal is not 5V, but 3.5V instead. So the 3.5V output I was seeing is generated by saturation of the component. I should have noticed that by the clipping in the peaks. Nevertheless, here are the new calculations:

G1 = 50 = 34dB

$$F_L = \frac{1}{2\pi R_{IN} C_{IN}} = 0.16Hz$$

$$F_H = \frac{1}{2\pi R_F C_F} = 18.83Hz$$

G2 = 20 = 26dB

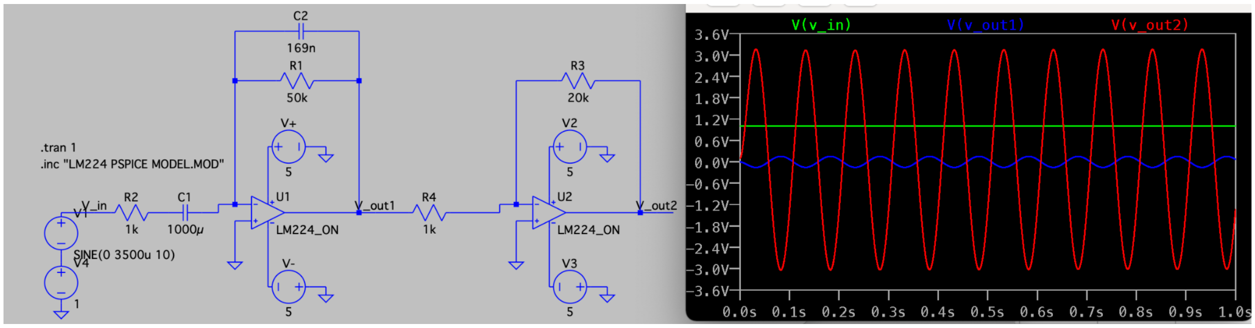
Total gain = 1000 = 60dB

V_i = 3500 uv

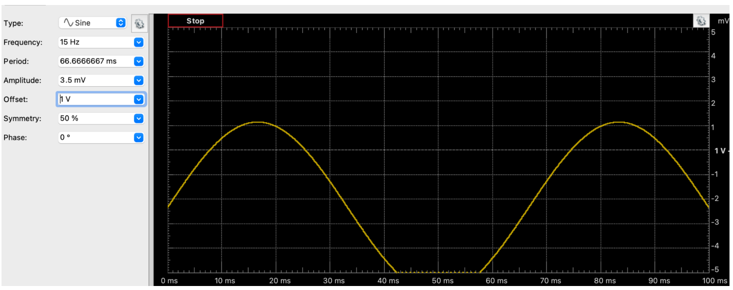
V_o = 3.5V (simulation) 1.5V (actual)

Interestingly, the actual voltage is way lower than simulation. I don't really know why. I may need to bring it up for consultation.

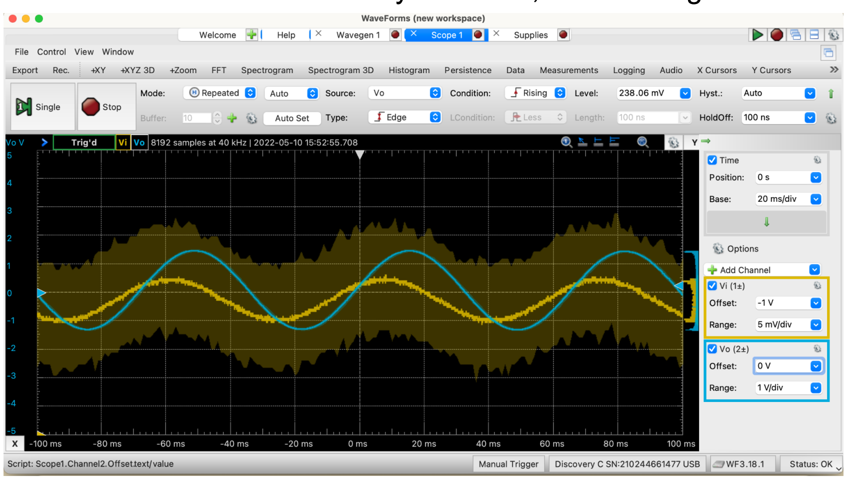
Simulation



Test signal : sine wave 15Hz, 3.5mV, offset(drift) of 1V

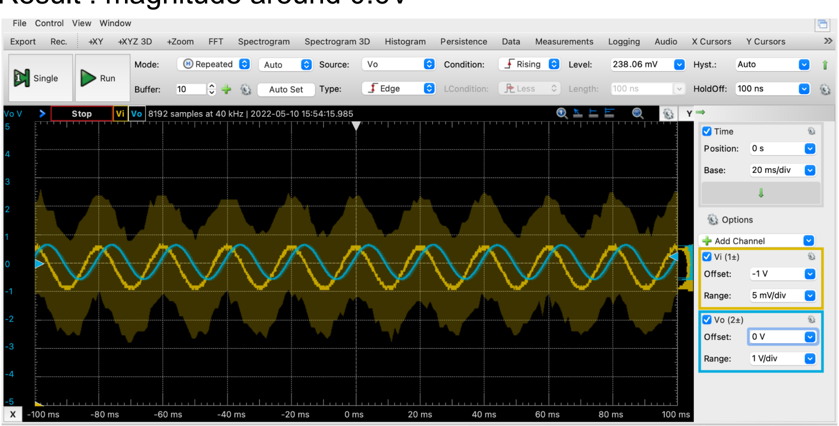


Result : The drift is successfully removed, but the magnitude is 1.5V instead

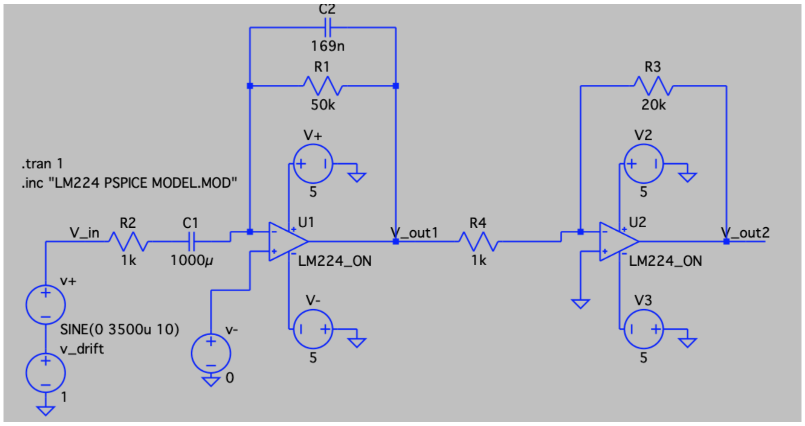


Test with 50Hz sine (powerline)

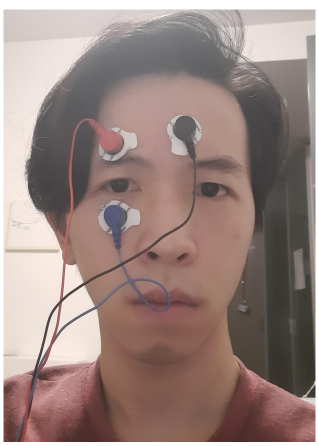
Result : magnitude around 0.6V

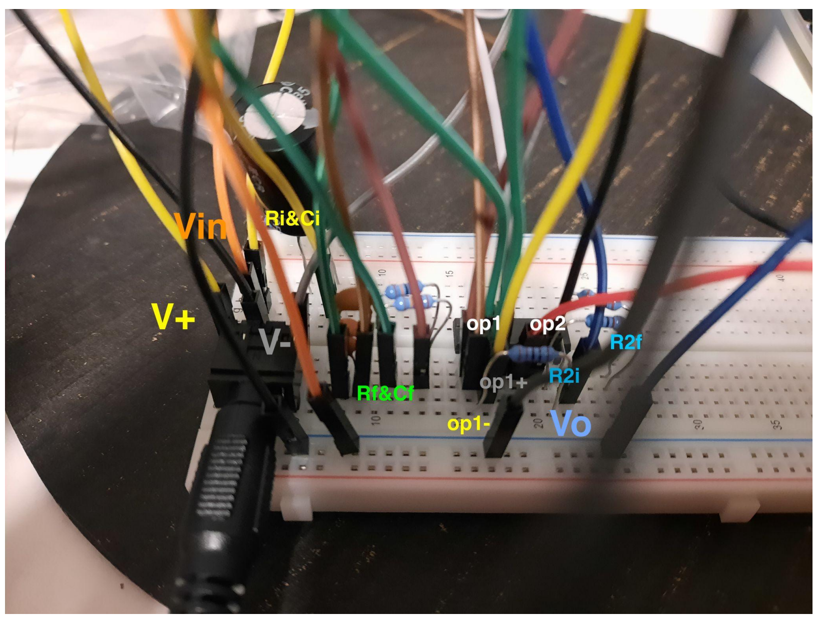


Testing with eog sensor
With the audio jack, I connected the middle pin(sleeve/ ground) to the ground, right most pin(tip/V+) to V_in, and left most pin (ring/ V-) to the + end of the first opamp.
The resulting circuit is as follows:



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.



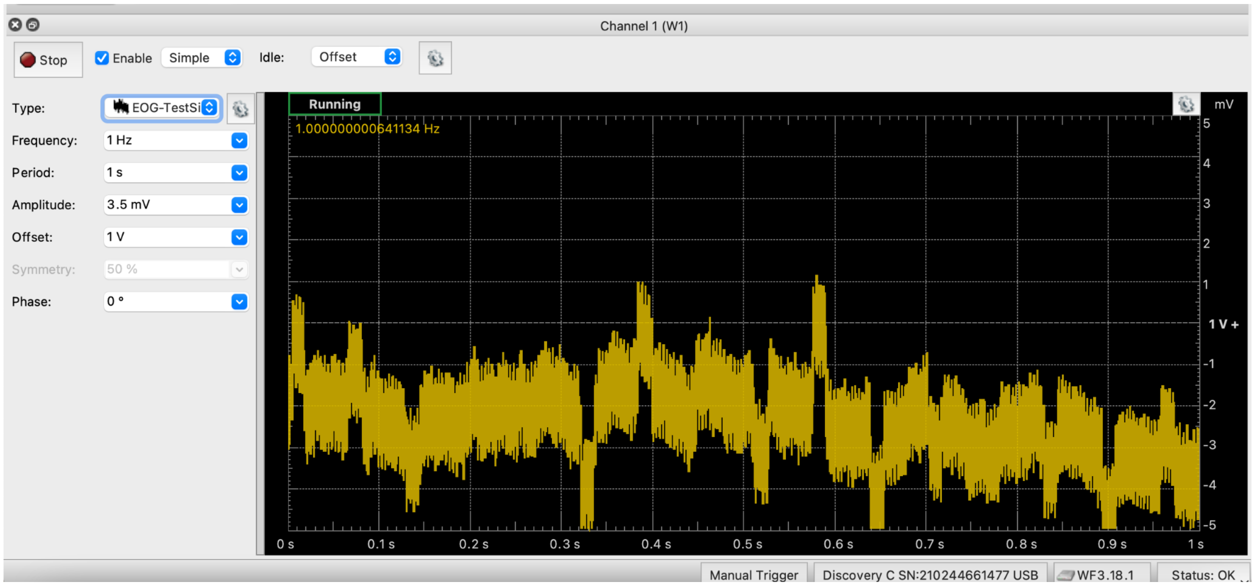


Gazing up

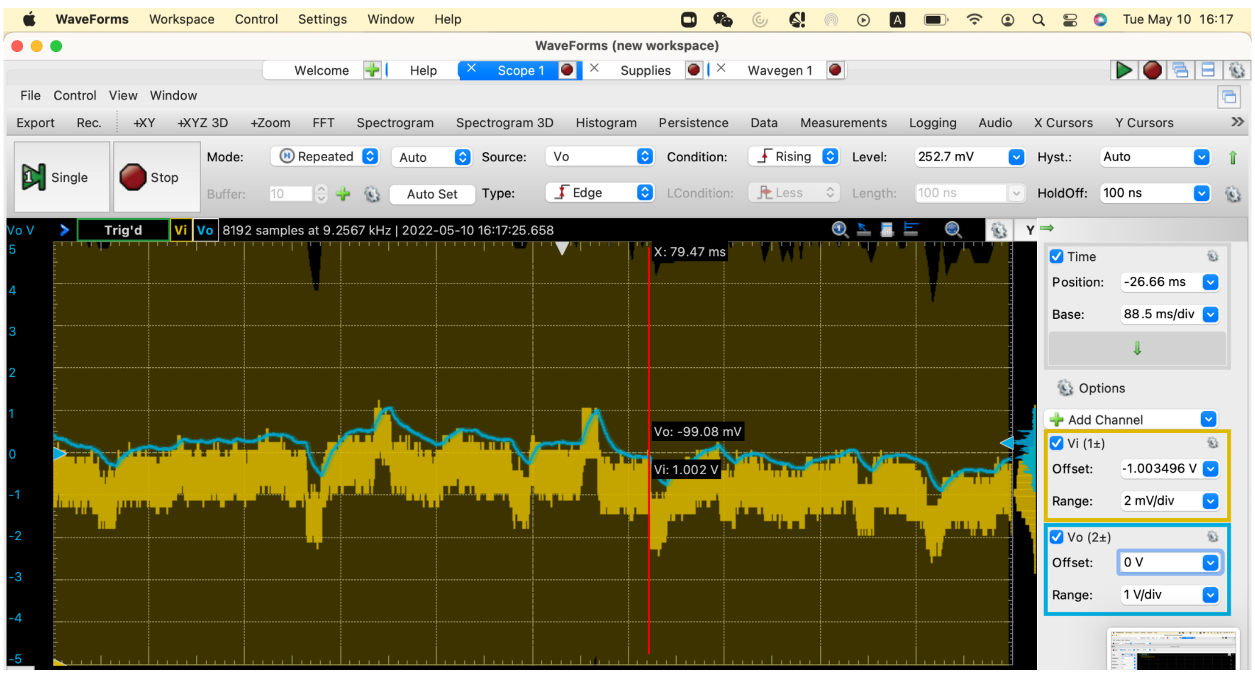
Gazing down

Gazing middle

Testing with workshop's dataset



Result: 1V drift successfully removed, signal amplified to 1V magnitude.



Future plans:

1. Book consult to understand why the gain is lower than expected
2. Consult on how to use eog sensor properly
3. Transform the data set found today(detail in "Sensor" document) to format easily imported by waveform

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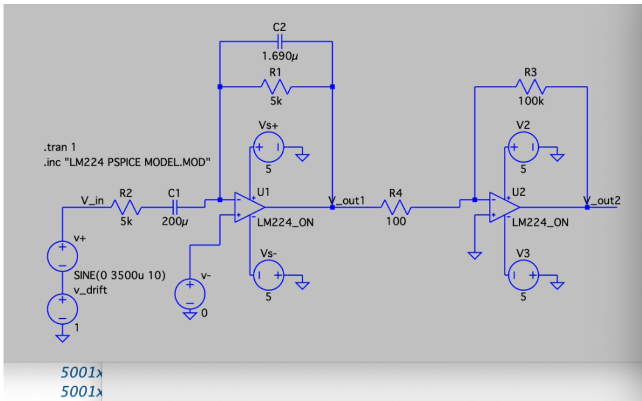
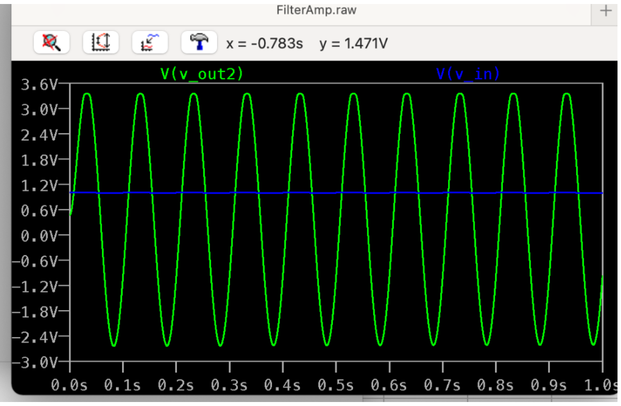
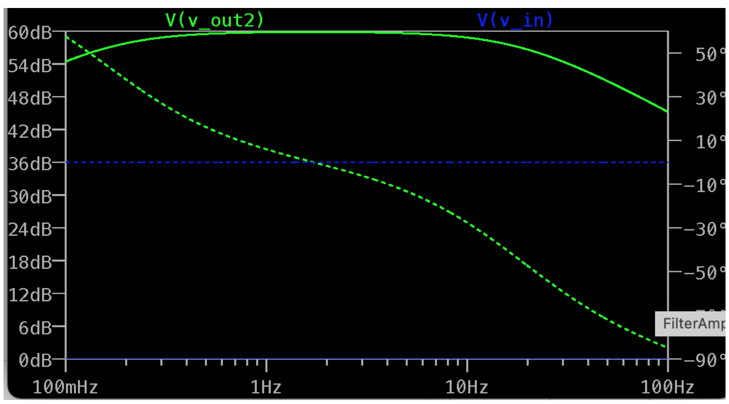
May 17, 2022

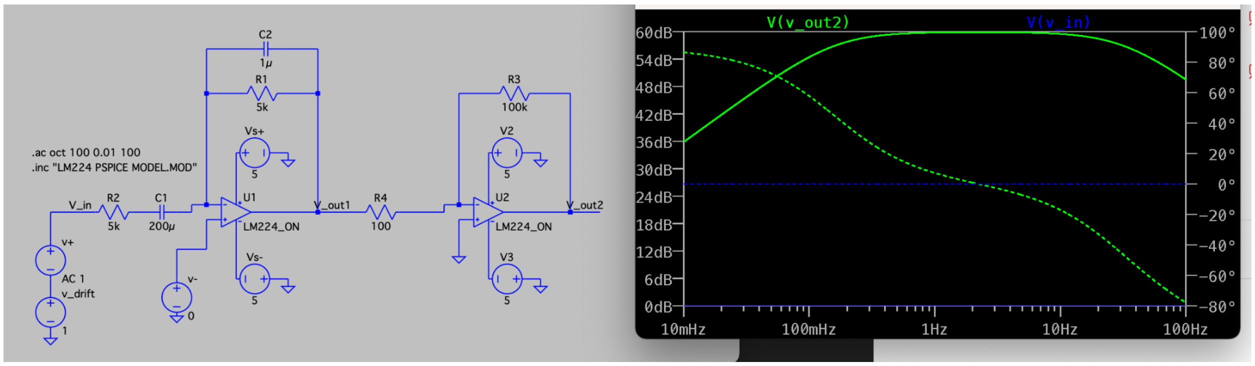
R1 Change to 50k, C1 to 20uF
Alter the BPF to unity gain. Maybe this will resolve the question that the amplification is less than expected.

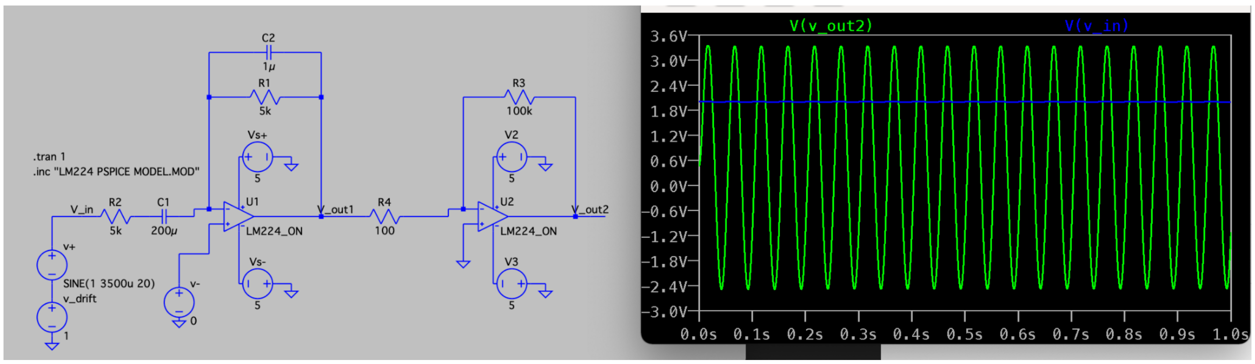






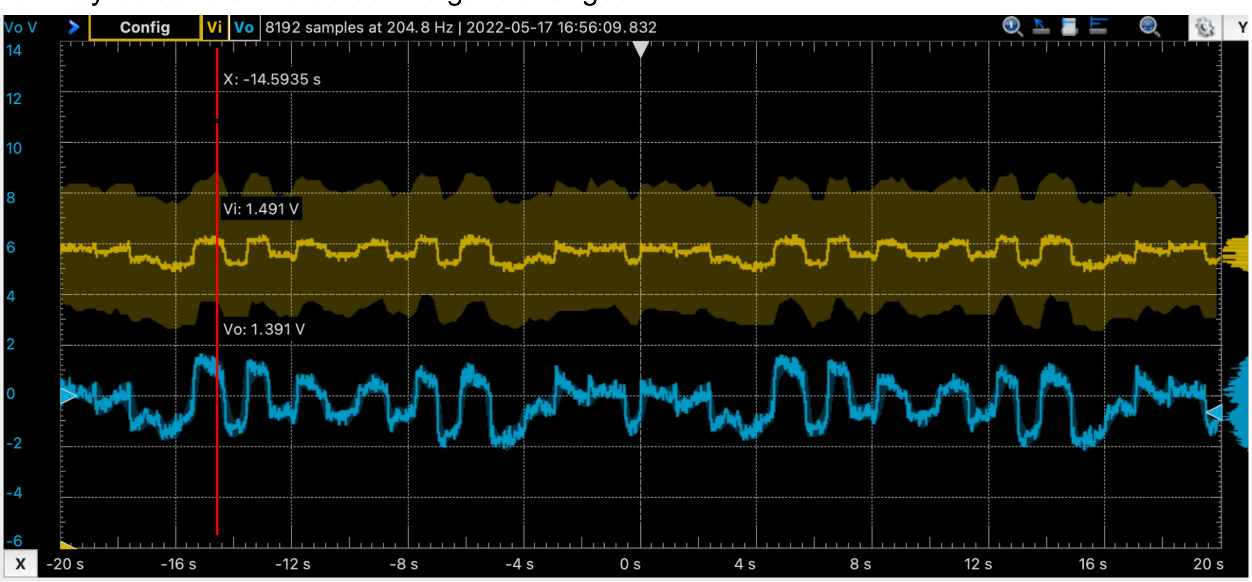
For ease of build, C2 is chosen as 1uF, then the new high cut-off frequency will be
Fh = 31.83Hz
Big revelation: I was mistaking 1k with 10k resistors in some components back then. Under a yellow warm light, brown stripes(10k) and the red stripes(1k) are faintly discernible. Note to self : always use a flashlight(white) when checking the circuit. Nevertheless, I don't want to return to the previous design right now. Not just that I'm lazy, it also prevents using a 1mF capacitor, which is a bit bulky, and not that ideal for applications.



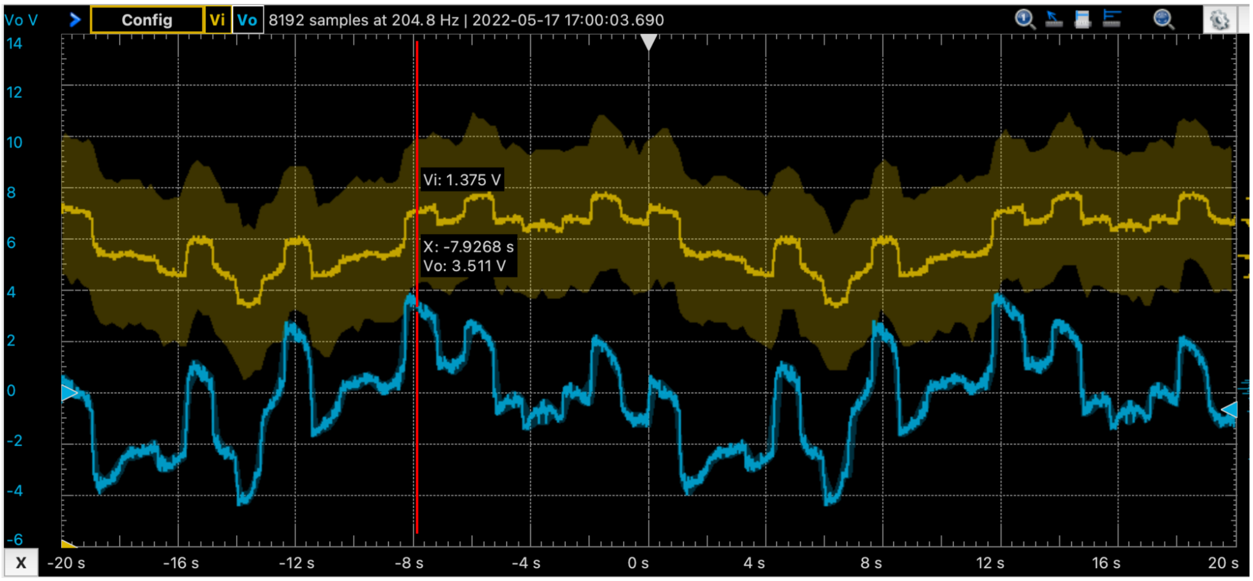


Testing results of the circuit:

The results are pretty much identical to the previous circuit (tested in Sensor May16th). So it shows that the unity gain at filtering isn't the affecting factor here. Nevertheless, a threshold of 1 volt may be sufficient to detect the gaze changes.



Signal 1



Signal 2

New Todos : Set the threshold of UI at 1 Volts

May 18, 2022

Since we were seeing large powerline noise, we need a low pass filter to remove the 50Hz noise (refer to Validation May 18th).
I added a capacitor to the amplifier to introduce low pass filtering.
The noise is reduced, but not fully removed. So I added sets of low pass filters downstream of the amplifiers. Since I have a voltage follower on the next block, I think I am free to add however many sets I want, but at the cost of reducing gain, and potential distortion.

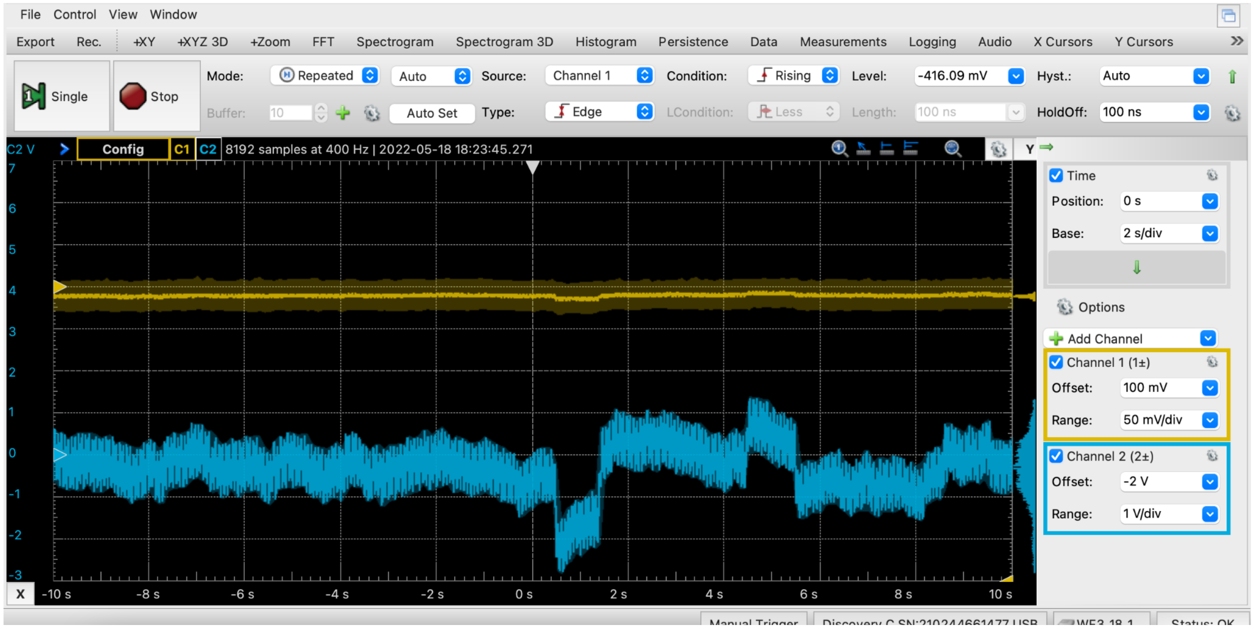


Figure : Output of noisy eog data, with LPF on the amplifier

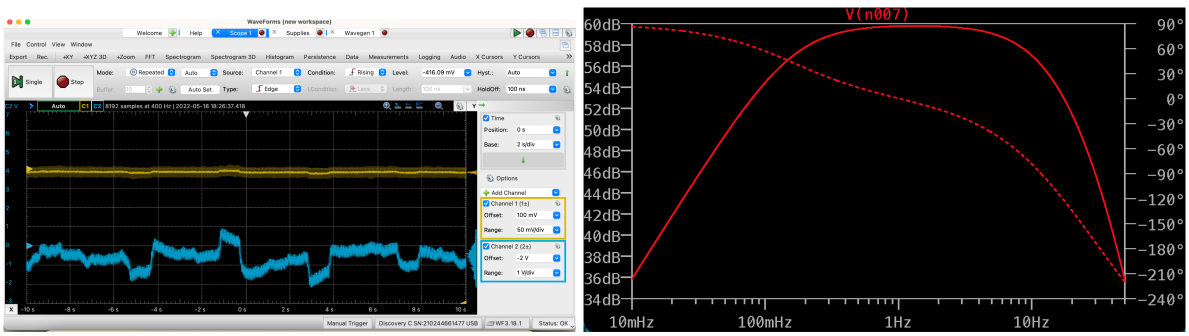


Figure : With 2nd order passive LPF

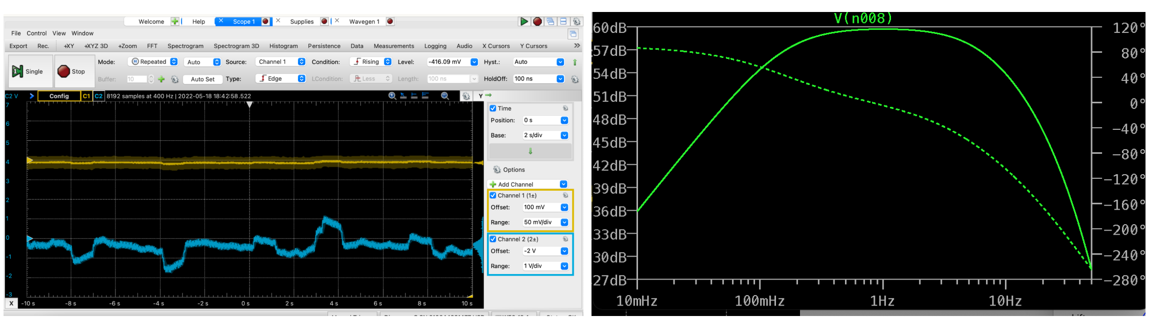
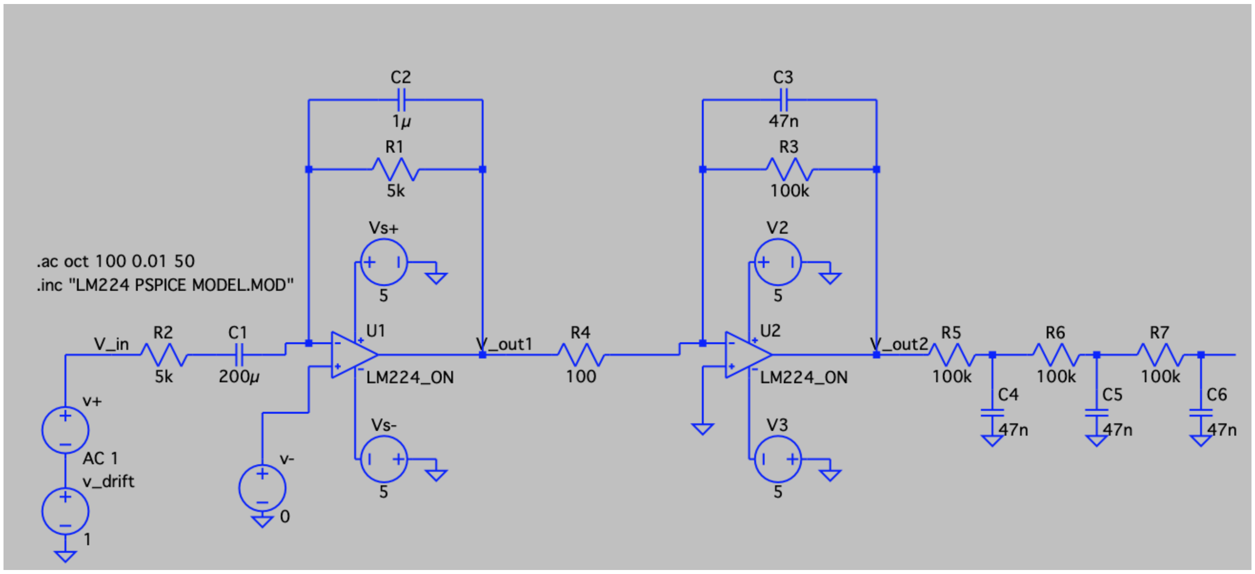


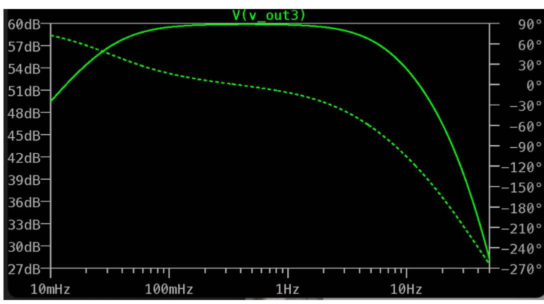
Figure : With 3rd order passive LPF

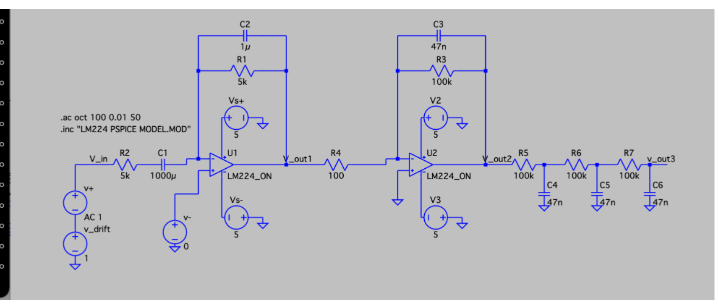
Now the powerline noise is mitigated. Although the leds are still flickering, we may increase the smoothing to compensate for that.



The input capacitance C1 was changed to 1mF, because I need the capacitor for UI (refer to LED_Interface May 18th). The capacitance was increased so that it does not increase the low cutoff frequency that may affect our signal, but the drift may be less attenuated, which we may need to validate with our dataset. I have tried to change the filter resistors from 5k to 50k, while keeping the cutoff frequencies intact, but the simulation results showed that the total gain drops to around 27dB, which clearly shows that some loading has taken effect, so I discarded the design.

After the adjustment, this is the resultant circuit





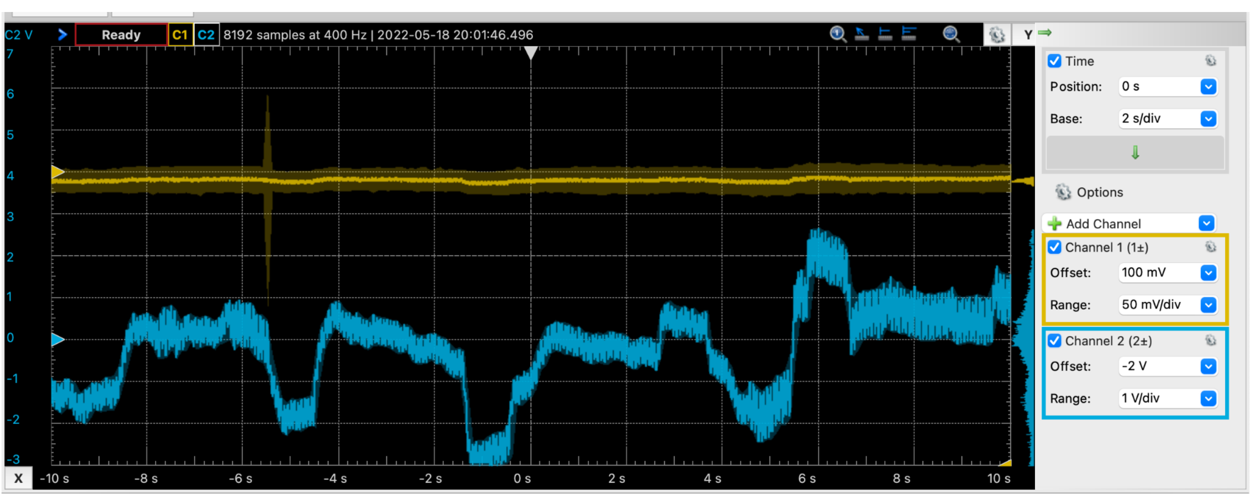


Figure : testing result of the noisy data