

Lab #5: Design of a Bioinstrumentation Amplifier for EOG

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Question 1. Plot the amplitude vs. angle of gaze

Table 1. Amplitude response for varying gaze angles collected by EOG.

Angle of Gaze (θ)	Voltage (V)
-30	3.8395
-25	3.5866
-20	2.6320
-15	1.7578
-10	1.0432
-5	0.3303
0	-0.0641
5	-0.1782
10	-0.8312
15	-1.2682
20	-2.5102
25	-3.1019
30	-4.1308

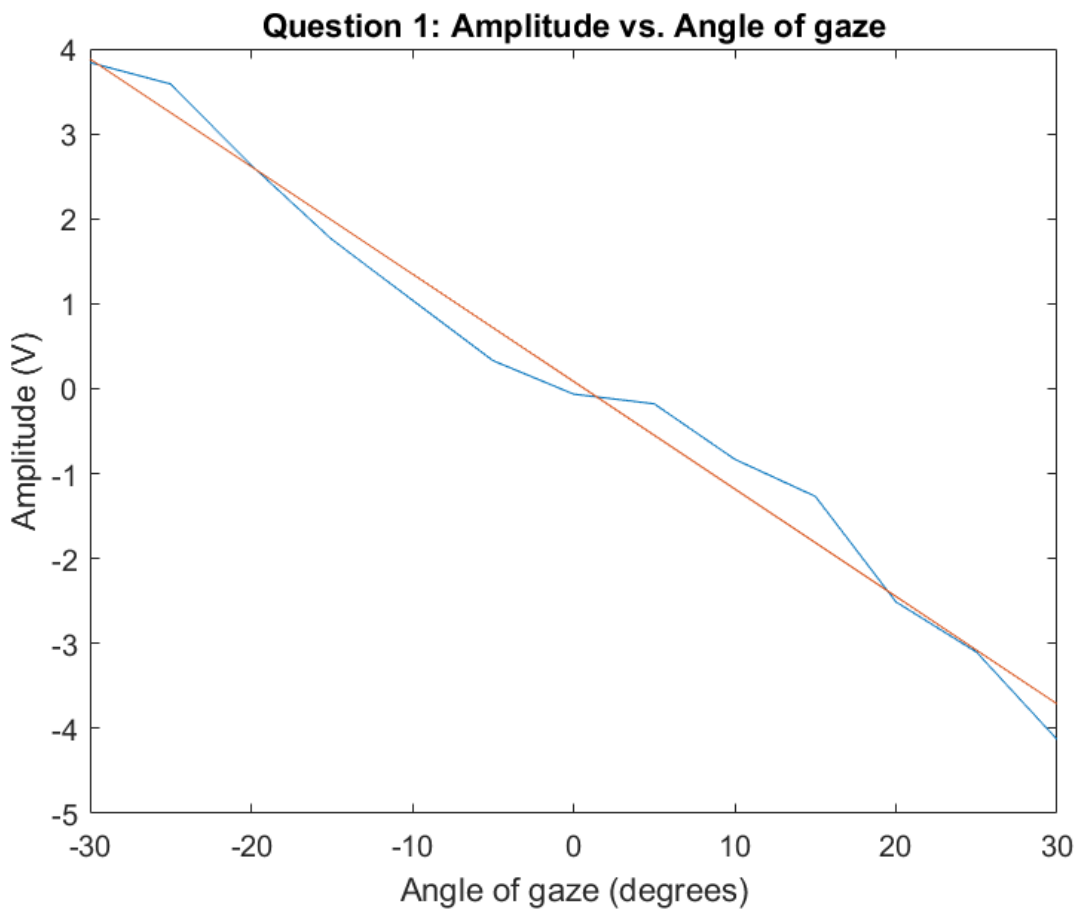


Figure 1. Amplitude response as a function of gaze angle (blue) and linear regression model (red).

Performing linear regression using MATLAB's *fitlm* function yields the following equation, where V is the amplitude in volts and θ is the angle in degrees :

$$V = (-0.12656)(\theta) + 0.084975$$

An R^2 value of 1 would indicate that the results are perfectly linear, which is the theoretical result. In our measured data, the R^2 value was 0.984, which shows that the data does not follow a linear trend exactly, but is similar. This can be further concluded from Figure 1, which shows the measured data and linear regression on the same axis. There are some deviances from the regression model, but overall there is a linear correlation between angle of gaze and voltage output. The deviation may be attributed to the slight drifting seen during the measurement. The voltage was not constant during this time, as seen in Figure 2. The line had a slight downwards drift. It could also be seen after 17 seconds that the measurement peaked at 4V, which means that the difference between -24° and -30° was low, which was also reflected in the low slope in Figure 1. There were also blinking artifacts, as seen in the large spike at around 5 seconds in the graph. Similar patterns could be seen in Figure 3.

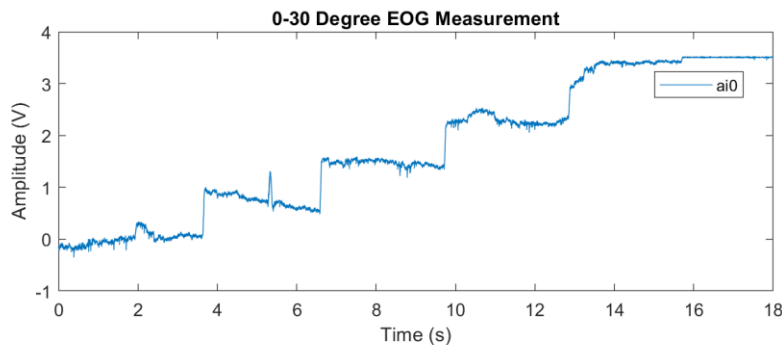


Figure 2: The measurement of 0 to -30° EOG in the time domain.

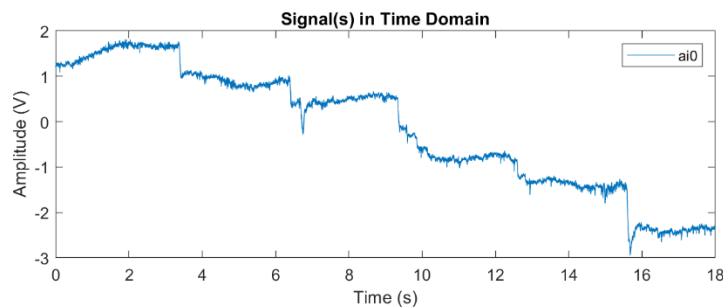


Figure 3: The EOG measurement of the eyes looking from 0° to 30° .

Question 2. Discuss the differences between the theoretical and actual EOG signal/data

Between the theoretical and actual EOG data, there were some differences that were found. First of all, the specified range should be between 3.5 to -3.5 volts, but it was found instead to be between -4 to 4 Volts. With perfect calibration, with the eyes perfectly centered, the y-intercept should be at zero. However, even as shown in Figure 3, drifting and the highly sensitive nature of the EOG data showed different voltage values for a centered eye at 0° . Additionally, since a ruler was used to ensure that the

eye would increment by 6° each time, the data should be perfectly linear. However, it was shown that it was not, due to what was explain in question 1 (eye drifting and artifacts). Additionally, the graphs in Figure 2 and 3 should also be symmetrical/mirrored as well, but they aren't which is again due to what was explained above.

Question 3. Plot the vertical and horizontal EOG signals with the blink artifacts. Describe the artifacts and compare them between the horizontal and vertical EOG signals.

Figures 4 and 5 show plots of the EOG signals with blinking artifacts at 2 second intervals for the horizontal and vertical signals, respectively.

In Figure 4 (the horizontal signal), the blinking artifacts are evident as spikes in the data corresponding to a voltage drop of $\sim 0.6-0.9V$ compared to the baseline (non-blinking) signal. Comparatively, in Figure 5 (the vertical signal), this voltage drop is much more pronounced ($\sim 4V$). These artifacts can be explained by the large difference in potential that exists between the cornea and retina; blinking causes shifts of the electric fields that propagate across the head corresponding to high-amplitude spikes that are detected by the electrodes placed on the face.

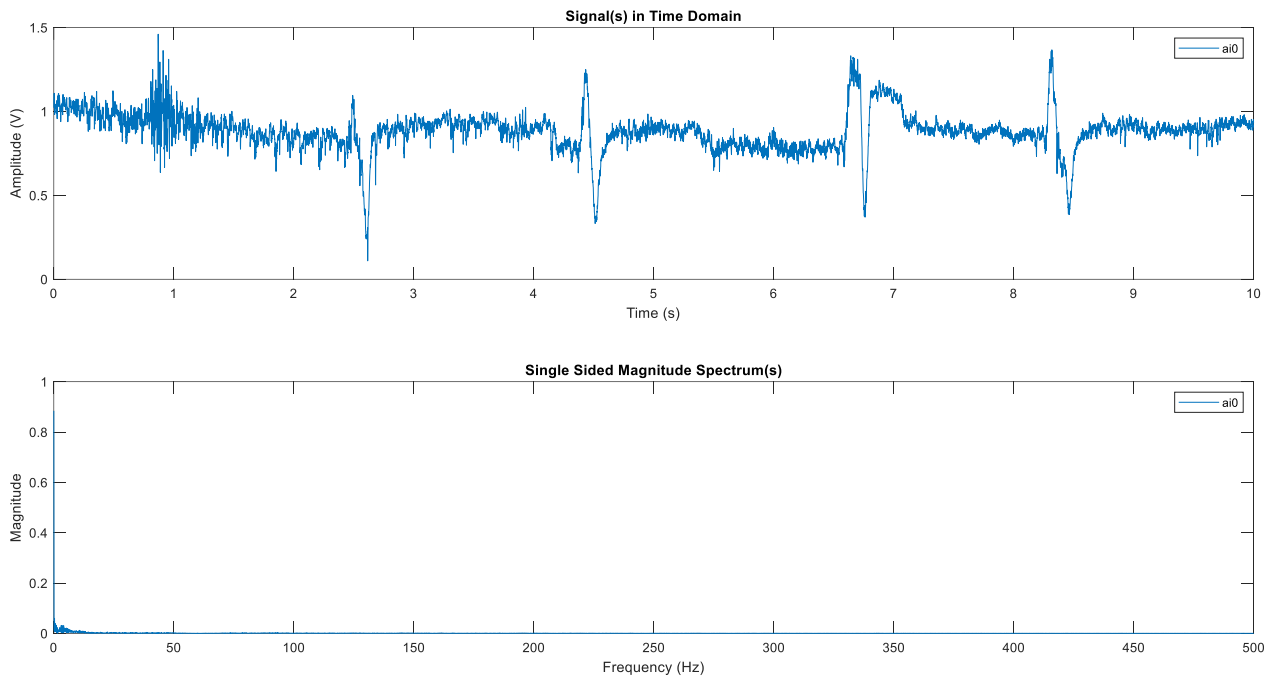


Figure 4. Horizontal EOG signal (including blinking artifacts separated by ~ 2 seconds).

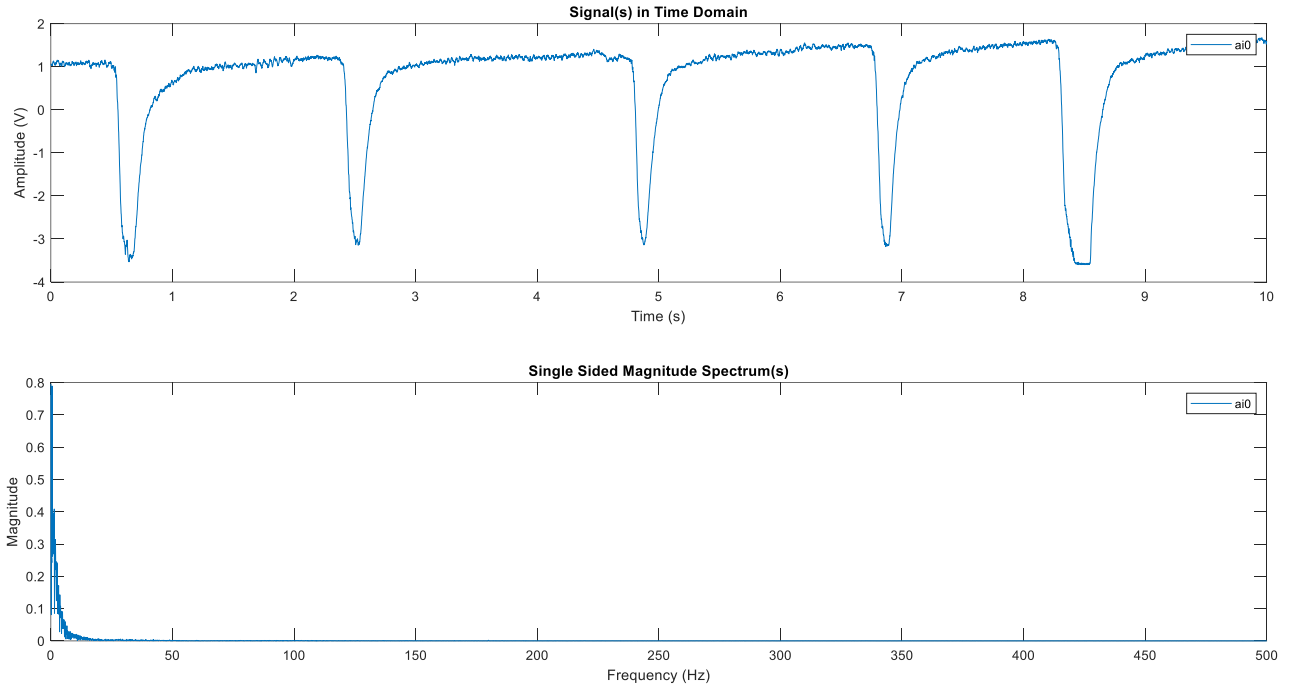


Figure 5. Vertical EOG signal (including blinking artifacts separated by ~2 seconds).

Bonus:

The mouse was controlled successfully, although it was a little too sensitive and there was drifting (the mouse would move slightly in one direction on its own if the eyes were still).

We were able to get the mouse to click, but there were occasional false negatives, as in a click would not be detected after a blink. Combined with a higher sensitivity (and a really large cursor), it was difficult to accurately click on the desired button. However, the video does show that both the mouse movement and the click was controlled by the eyes. The video first shows successful movement of the mouse in all four directions, and then an attempt was made to power off the computer.

<https://youtu.be/hVNdMLCwVgE>

Appendix

Code for Question 1

```
clear;
close all;

pos = load('0-30.mat');
neg = load('0--30.mat');
zero = load('0.mat');

duration = 18;
numinputs = length(pos.data);
time = (0:1/1000:duration-1/1000)';

pos_data_time = array2timestable(pos.data, 'SampleRate',1000);
neg_data_time = array2timestable(neg.data, 'SampleRate',1000);

data_neg_5 = mean(neg.data(1:3381)) + neg.data(2085);
data_neg_10 = mean(neg.data(3415:6401)) + neg.data(2085);
data_neg_15 = mean(neg.data(6421:9333)) + neg.data(2085);
data_neg_20 = mean(neg.data(9867:12593)) + neg.data(2085);
data_neg_25 = mean(neg.data(12617:15568)) + neg.data(2085);
data_neg_30 = mean(neg.data(15627:17999)) + neg.data(2085);

data_0 = mean(zero.data) - zero.data(1);

data_5 = mean(pos.data(1:3381)) - pos.data(1893);
data_10 = mean(pos.data(3415:6401)) - pos.data(1893);
data_15 = mean(pos.data(6421:9333)) - pos.data(1893);
data_20 = mean(pos.data(9867:12593)) - pos.data(1893);
data_25 = mean(pos.data(12617:15568)) - pos.data(1893);
data_30 = mean(pos.data(15627:17999)) - pos.data(1893);

degrees = -30:5:30;
avg_values = [data_neg_30 data_neg_25 data_neg_20 data_neg_15 data_neg_10
data_neg_5 data_0 data_5 data_10 data_15 data_20 data_25 data_30];

mdl = fitlm(degrees, avg_values);
Y = -0.12656*degrees + 0.084975;

figure
plot(degrees, avg_values)
hold on
plot(degrees, Y)
ylabel("Amplitude (V)")
xlabel("Angle of gaze (degrees)")
title("Question 1: Amplitude vs. Angle of gaze")
hold off
```

Code for Question 3 (taken from the DAQ given for this lab):

```
clear;
close all;

d = daq("ni"); %using NI USB-6216

d.Rate = 1000;

duration = 5;

addinput(d, "Dev6", "ai0", "Voltage");
numinputs = length(d.Channels);

data = read(d, seconds(duration), "OutputFormat", "Matrix");

Fs = d.Rate;
T = 1/Fs;
L = duration*Fs;
t = (0:L-1)*T;
f = Fs*(0:(L/2))/L;

time = (0:1/Fs:duration-1/Fs)';
FFTdata = zeros(L/2+1, numinputs);
for i = 1:numinputs

    Y = fft(data(:,i));
    P2 = abs(Y/L);
    P1 = P2(1:L/2+1);
    P1(2:end-1) = 2*P1(2:end-1);

    FFTdata(:,i) = P1;
end

figure
subplot(2,1,1)
for i=1:numinputs
    plot(time, data(:,i))
    hold on
end
hold off
ylabel("Amplitude (V)")
xlabel("Time (s)")
title("Signal(s) in Time Domain")
legend(d.Channels.ID)

subplot(2,1,2)
for i=1:numinputs
    plot(f, FFTdata(:,i))
    hold on
end
hold off
ylabel("Magnitude")
xlabel("Frequency (Hz)")
title("Single Sided Magnitude Spectrum(s)")
legend(d.Channels.ID)
clear d;
```