EoG circuit to facilitate late-stage ALS communication using Morse Code

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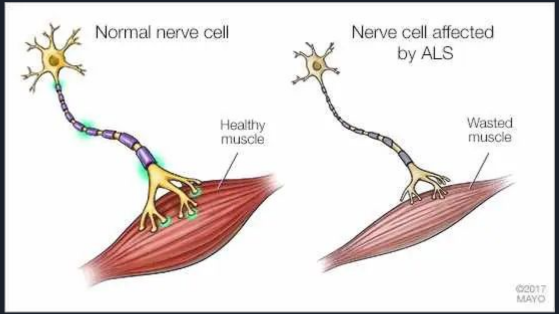
What is ALS?



-Amyotrophic lateral sclerosis

-neurodegenerative disease that progressively worsens over time

-degeneration of motor neurons leads to loss of voluntary muscle control

-There is currently no cure for ALS, current treatment methods focus on therapy (speech and physical), and overall improving comfort of life

-Each year, approximately 5000 new individuals are diagnosed with ALS in the United States

Symptoms

Early/Middle Stage

-increased difficulty speaking, breathing, swallowing

-fatigue and increased weakness

-weight loss

Late Stage

-muscle paralysis

-inability to speak

-cannot breathe without support

However...

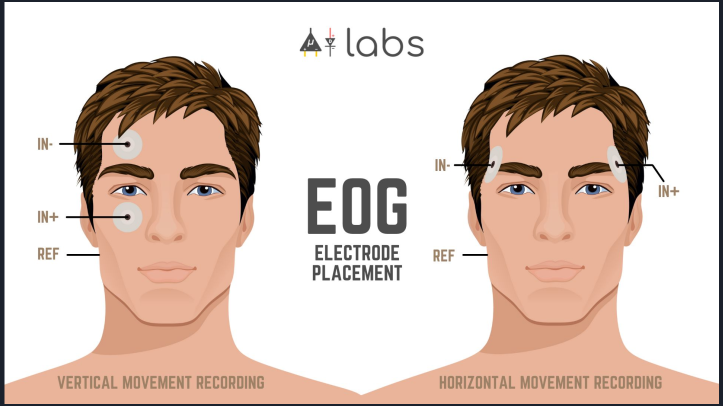
Eye muscle control is sustained the longest in comparison to other muscles- degeneration progresses slower

When patients' ability to move and talk go away, their ability to control their eyes and blink is still there- though eventually those will worsen as well

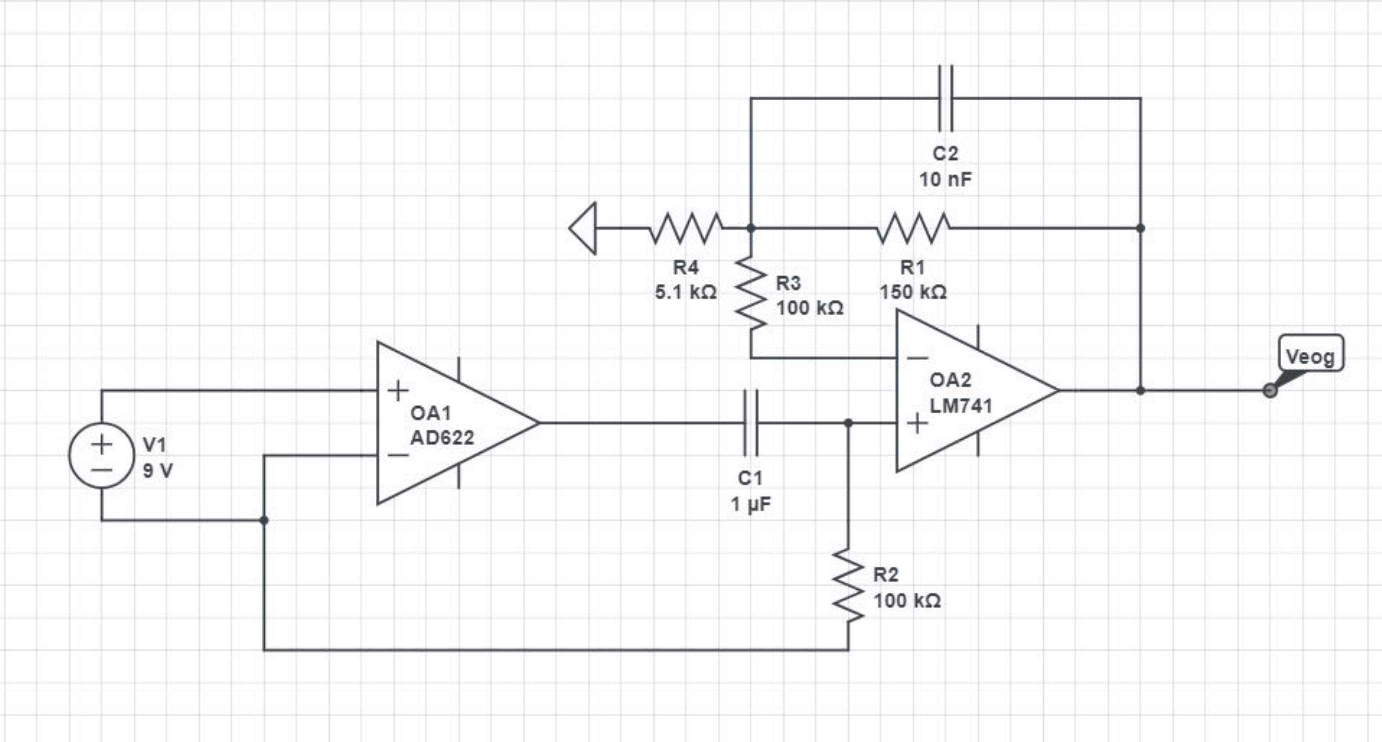
One application of EoG's is to track eye movement within the eye, such as looking to the left/right or looking up/down. However, we believe that eye movements with the eye open is more exhausting and less repeatable, which are not suitable qualities for ALS patients

EoG Signal Recording

- EoG signals record eye movements and deviations from rest
- EoG signal is recorded from sensors placed on the person's face
- The recorded signal then goes into a bio-potential amplifier where amplification and filtering of the signal occurs
- The signal is then processed and passed to a DAQ that passes the signal to MatLab where computations can be performed



Circuit Diagram (Biopotential Amplifier)

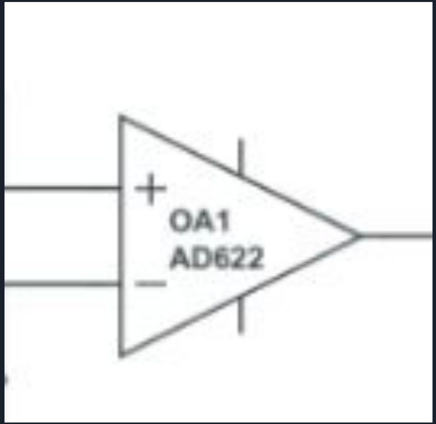


Circuit Components and Values

Goal: Sense, Amplify, and Filter Biopotentials from Muscles on your Face

Instrumentation Amplifier (In Amp)

- A differential amplifier amplifies the difference in voltage between two input signals
- Has high input impedance in order to preserve integrity of original signal
- Instrumentation Amplifier (AD622): buffers the input
- Used a gain of 26.25 by using a Rgain of 2 kOhms (Rgain = 50.5 kOhms/(Gain - 1))



PIN CONFIGURATION

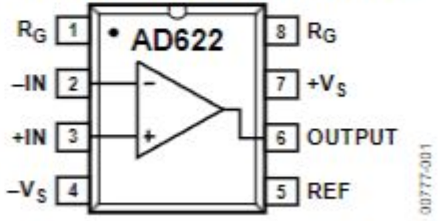
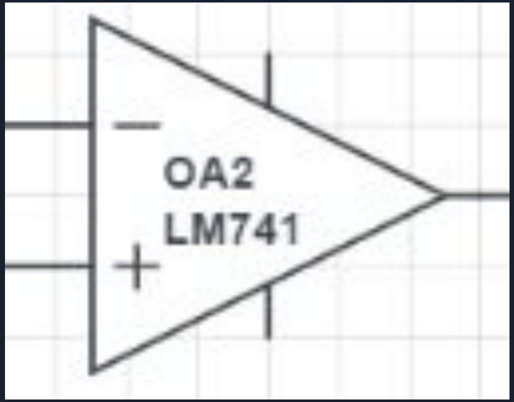
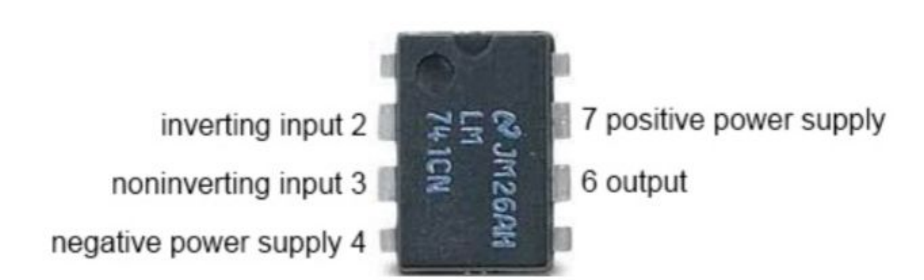


Figure 1. 8-Lead PDIP and 8-Lead SOIC_N (N and R Suffixes)

Operational Amplifier (Op Amp)

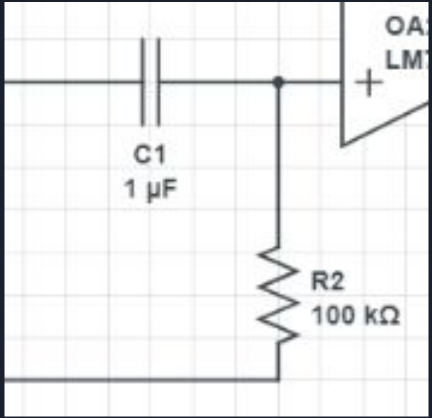
- Op Amps are used to acquire a signal of interest or to produce an analog output
- Op Amps are voltage amplifiers with very high gain and by using negative feedback, the gain can be set to a lower level or filter frequencies
- Operational Amplifier (LM741): a non-inverting amplifier
- Used a gain of 30.41 (1+(R1/R4))

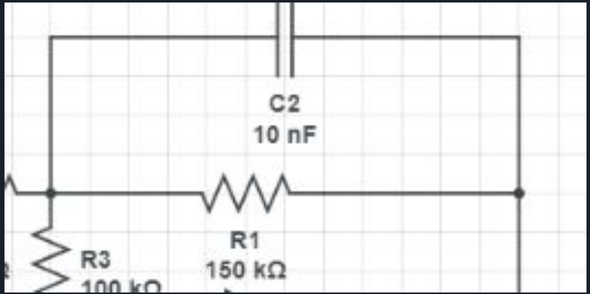




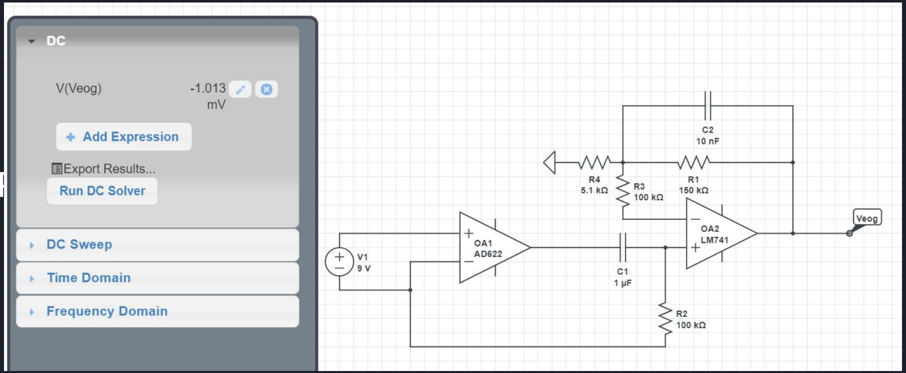
Filters

- R2 and C1 make a high pass filter with a cutoff of 1.6 Hz which is better for EMG signals and blocks DC drift
- R1 and C2 make a low pass filter with a time constant of 1.5 ms and a cutoff of 100 Hz (for low frequencies, the capacitor is open and is shorted for high frequencies)
- R3 matches R2 so bias currents are cancelled by the differential amplifier and eliminates the effect of bias currents while not affecting desired gain
- Connect 2 electrodes to circuit inputs and the third one to circuit ground

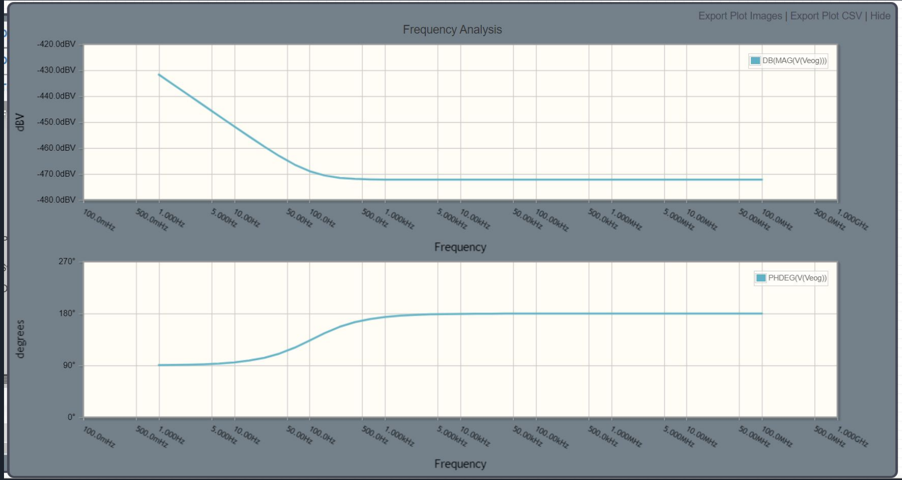




Simulation



DC Solver Simulation

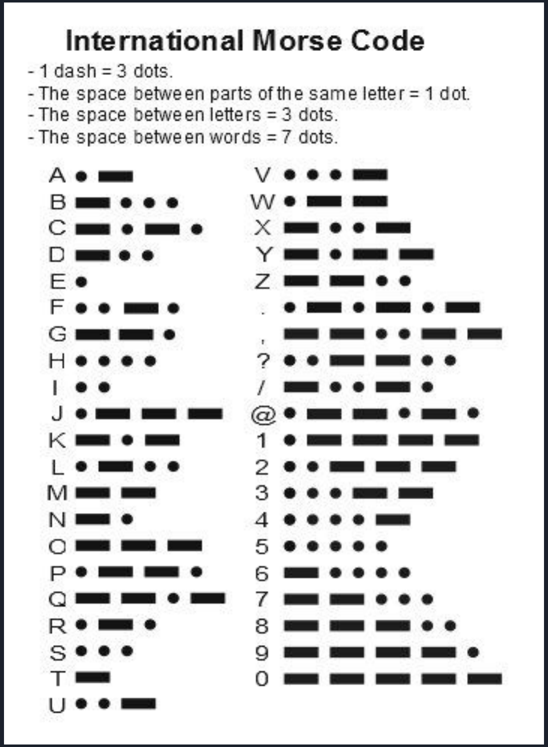


Frequency Analysis Simulation

MATLAB Code (Converting EoG Blinking Signal to Morse Code)

Conceptually:

- Input the EoG signal into MatLab through data acquisition (DAQ)
- Use Matlab to recognize the signal as an array or matrix that it can perform computations on
- Matlab code will assign dots or dashes to spike duration in the EoG signal that indicate short blinks or long blinks
- Dots will be assigned to short durations while dashes will be assigned to long durations
- Matlab will then recognize patterns of dots and dashes from the signal and assign a letter to the patterns from a list of morse code translation



MATLAB Code (Converting EoG Blinking Signal to Morse Code)

voltage_to_code_transducer.m

```
d = daqlist("ni");
dq = daq("ni");
dq.Rate = 50;
addinput(dq, "Dev1", "ai0", "Voltage");
tabledata = read(dq);
matrixdata = read(dq,"OutputFormat", "Matrix");
data = read(dq,minutes(3));
for n = 50:15000
    letter = zeros[4,1];
    A = data.Dev1_ai0(n:n-49);
    b = mean(A);
    c = zero(1)
    for k = 1
        for i = 1:length(A)
            if A(i) >= 0.5
                c(i) = 1;
            end
            if b >= 1
                d = sum(c);
                if d > 20
                    letter(k) = 2;
                elseif d <= 20
                    letter(k) = 1;
                end
            elseif b < 1
                letter(k) = 0;
            end
        end
    end
    for k = 2
        for i = 1:length(A)
            if A(i) >= 0.5
                c(i) = 1;
            end
            if b >= 1
                d = sum(c);
                if d > 20
                    letter(k) = 2;
                elseif d <= 20
                    letter(k) = 1;
                end
            end
            elseif b < 1
                letter(k) = 0;
            end
        end
    end
    for k = 3
        for i = 1:length(A)
            if A(i) >= 0.5
                c(i) = 1;
            end
            if b >= 1
                d = sum(c);
                if d > 20
                    letter(k) = 2;
                elseif d <= 20
                    letter(k) = 1;
                end
            end
            elseif b < 1
                letter(k) = 0;
            end
        end
    end
    z = sum(letter)
    if z >= 1
        if letter(1) == 2
            if letter(2) == 2
                if letter(3) == 2
                    if letter(4) == 2
                        disp("LETTER DOES NOT EXIST")
                    elseif letter(4) == 1
                        disp("LETTER DOES NOT EXIST")
                    elseif letter(4) == 0
                        disp("O")
                    end
                elseif letter(3) == 1
                    if letter(4) == 2
                        disp("Q")
                    elseif letter(4) == 1
                        disp("Z")
```

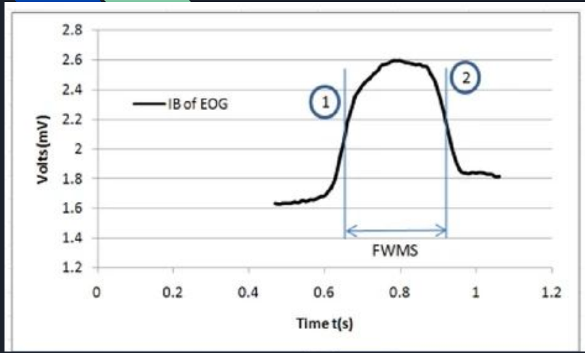
voltage_to_code_transducer.m

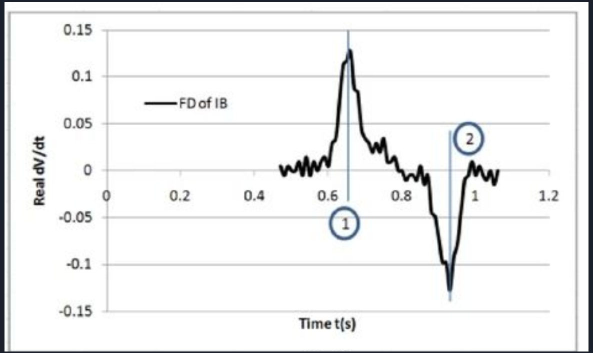
```
                        disp("Z")
                    elseif letter(4) == 0
                        disp("G")
                    end
                elseif letter(3) == 0
                    if letter (4) == 0
                        disp("M")
                    elseif letter(4) >= 1
                        disp("LETTER DOES NOT EXIST")
                    end
                end
            elseif letter(2) == 1
                if letter(3) == 2
                    if letter(4) == 2
                        disp("Y")
                    elseif letter(4) == 1
                        disp("C")
                    elseif letter(4) == 0
                        disp("K")
                    end
                elseif letter(3) == 1
                    if letter(4) == 2
                        disp("X")
                    elseif letter(4) == 1
                        disp("B")
                    elseif letter(4) == 0
                        disp("D")
                    end
                elseif letter(3) == 0
                    if letter(4) == 0
                        disp("N")
                    elseif letter(4) >= 1
                        disp("LETTER DOES NOT EXIST")
                    end
                end
            elseif letter(2) == 0
                if letter(3) == 0
                    if letter(4) == 0
                        disp("T")
                    elseif letter(4) >= 1
                        disp("LETTER DOES NOT EXIST")
                    end
                elseif letter(3) >= 1
                    disp("LETTER DOES NOT EXIST")
                end
        elseif letter(1) == 1
            if letter(2) == 2
                if letter(3) == 2
                    if letter(4) == 2
                        disp("J")
                    elseif letter(4) == 1
                        disp("P")
                    elseif letter(4) == 0
                        disp("W")
                elseif letter(3) == 1
                    if letter(4) == 2
                        disp("LETTER DOES NOT EXIST")
                    elseif letter(4) == 1
                        disp("L")
                    elseif letter(4) == 0
                        disp("R")
                elseif letter(3) == 0
                    if letter(4) == 2
                        disp("LETTER DOES NOT EXIST")
                    elseif letter(4) == 1
                        disp("LETTER DOES NOT EXIST")
                    elseif letter(4) == 0
                        disp("A")
                    end
                end
            elseif letter(2) == 1
                if letter(3) == 2
                    if letter(4) == 2
                        disp("LETTER DOES NOT EXIST")
                    elseif letter(4) == 1
                        disp("F")
                    elseif letter(4) == 0
                        disp("U")
                    end
                elseif letter(3) == 1
                    if letter(4) == 2
                        disp("V")
```

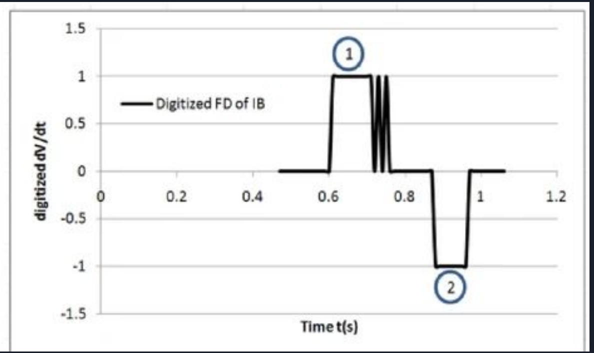
voltage_to_code_transducer.m

```
                if letter(3) == 2
                    if letter(4) == 2
                        disp("LETTER DOES NOT EXIST")
                    elseif letter(4) == 1
                        disp("F")
                    elseif letter(4) == 0
                        disp("U")
                    end
                elseif letter(3) == 1
                    if letter(4) == 2
                        disp("V")
                    elseif letter(4) == 1
                        disp("H")
                    elseif letter(4) == 0
                        disp("S")
                    end
                elseif letter(3) == 0
                    if letter(4) == 2
                        disp("LETTER DOES NOT EXIST")
                    elseif letter(4) == 1
                        disp("LETTER DOES NOT EXIST")
                    elseif letter(4) == 0
                        disp("I")
                    end
                end
            elseif letter(2) == 0
                if letter(3) == 0
                    if letter(4) == 0
                        disp("E")
                    elseif letter(4) >= 1
                        disp("LETTER DOES NOT EXIST")
                    end
                elseif letter(3) >= 1
                    disp("LETTER DOES NOT EXIST")
                end
            end
        elseif letter(1) == 0
            disp("ERROR DETERMINING MESSAGE")
        end
    end
end
```

Signal Processing







Stage 1:

Signal directly measured by EoG for a blink

FWMS: width of peak

Stage 2:

First derivative of the signal

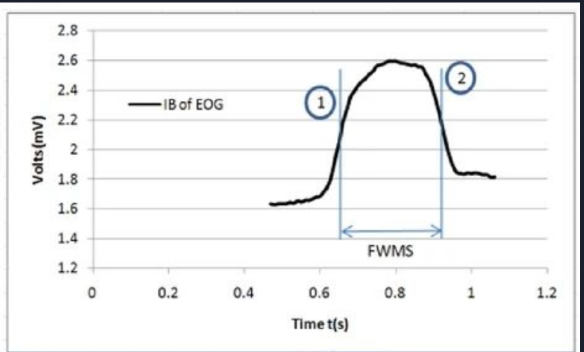
Stage 3:

Digitized first derivative for computer to recognize what peaks and troughs correspond to in terms of blinking

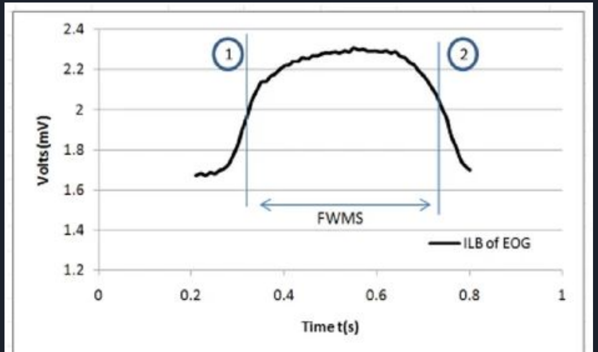
Differentiating Blinks

- Duration of blink and force of blink both affect the signal measured by the EoG
- Shorter blink ➡ Shorter FWMS
- Longer blink ➡ Longer FWMS
- Abnormal force blink ➡ more than one positive slope within FWMS

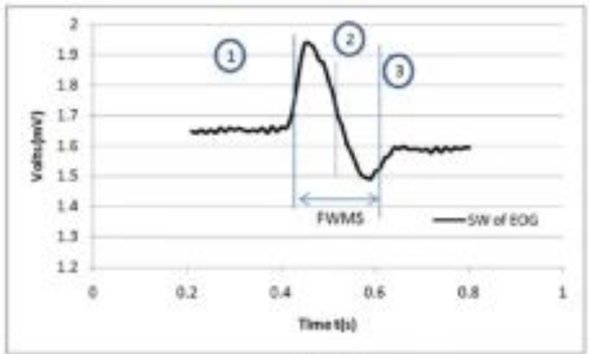
Short Blink



Long Blink



Blink with abnormal force



Limitations and Drawbacks

- Morse code isn't the most efficient way of communicating - longer messages contain many letters and spaces, which results in a large amount of blinking needed
- Our bioinstrument would require a baseline for calibration, as each individual's blinking differs - a short blink for one individual might register as a longer blink for another individual if the instrument wasn't uniquely calibrated
- Must isolate blinks-other eye movements that aren't blinks may cause unwanted signals-eye twitching for example
- Has to be able to differentiate between blinking and looking to the left/right and looking up/down
- Requires consistency with each blink, otherwise processing may be inaccurate

Many factors can cause unwanted signals that disrupt communication, so calibration has to be extremely precise

Future Applications and Significance

- This project will help give those with ALS an alternate form of communication after losing their ability to speak, sign language is also not an option due to muscle paralysis
- Grants ALS patients a form of independency, which is something that has been ripped away from them as a result of this disease
- Can be further implemented into text to speech technology allowing patients to speak out loud essentially in real time
- Eye movements can be an indicator of neurological disorders or neurodegenerative diseases- people Alzheimer’s disease have different eye movements
- Can be utilized in non-clinical forms: military environment, driving safety

Acknowledgements

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