

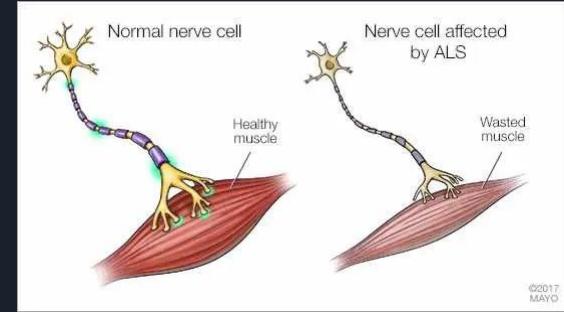


# EoG circuit to facilitate late-stage ALS communication using Morse Code

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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

## MOST COMMON SYMPTOMS OF ALS



Muscle  
weakness



Muscle cramps  
and spasms



Trouble  
breathing



Slow and  
slurred speech



Difficulty  
swallowing



Digestive  
issues



Anxiety and  
depression



Cognitive  
impairment



## However...

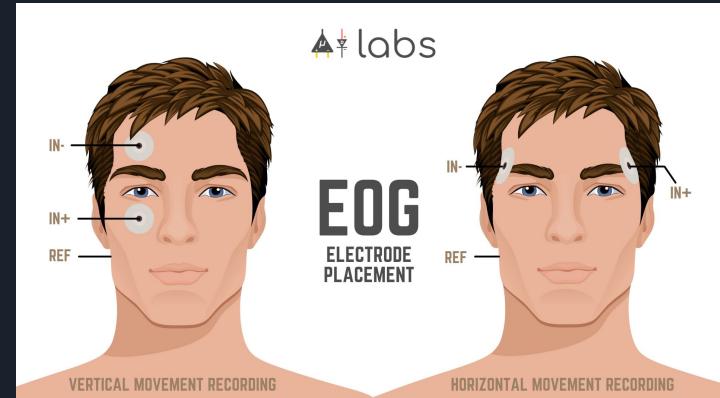
Eye muscle control is sustained the longest in comparison to other muscles- degeneration progresses slower

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

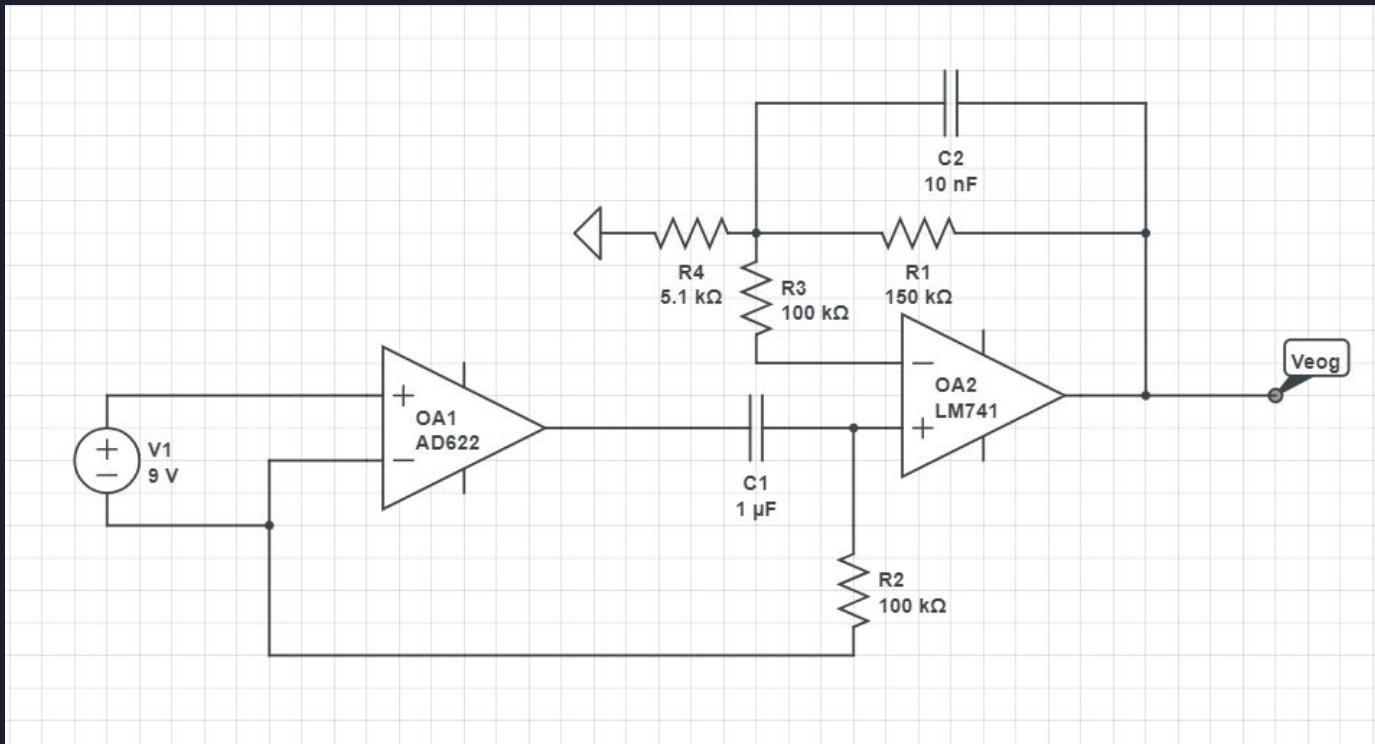
One application of EoG's is to track eye movement within the eye, such as looking to the left/right or looking up/down. However, we believe that eye movements with the eye open is more exhausting and less repeatable, which are not suitable qualities for ALS patients

# 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)



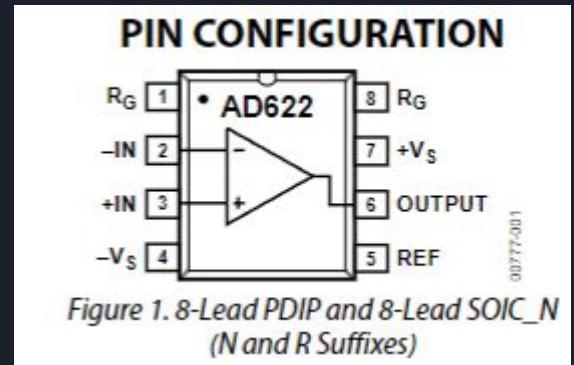
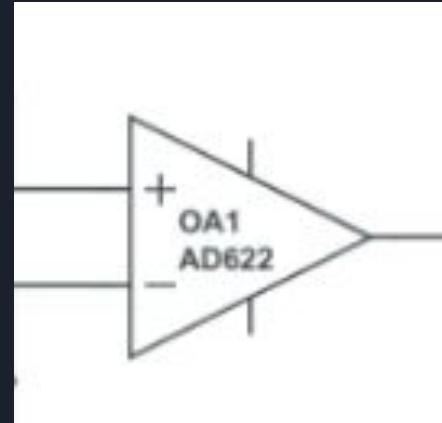


# Circuit Components and Values

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

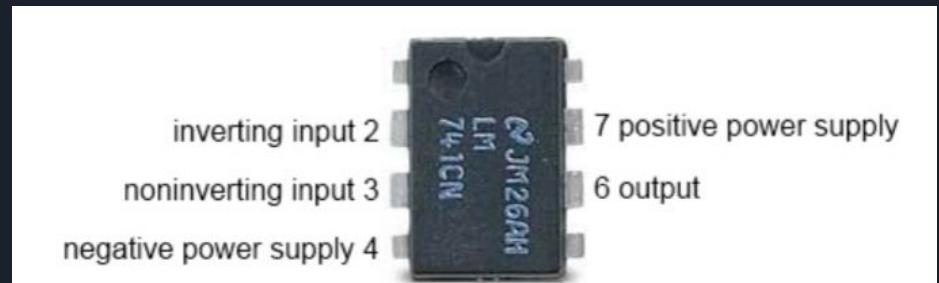
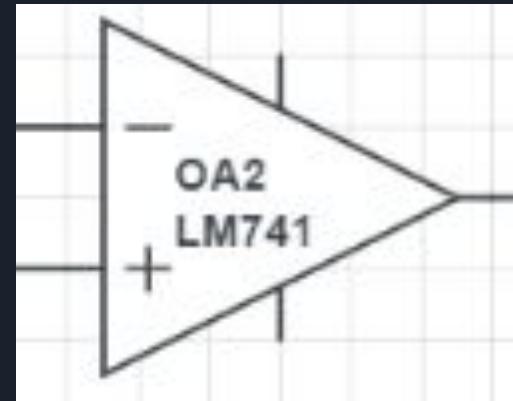
# Instrumentation Amplifier (In Amp)

- 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 ( $R_{gain} = 50.5 \text{ kOhms}/(Gain - 1)$ )



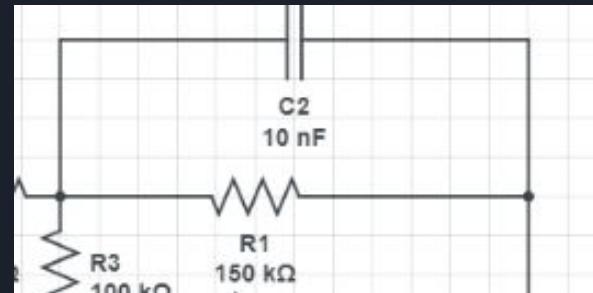
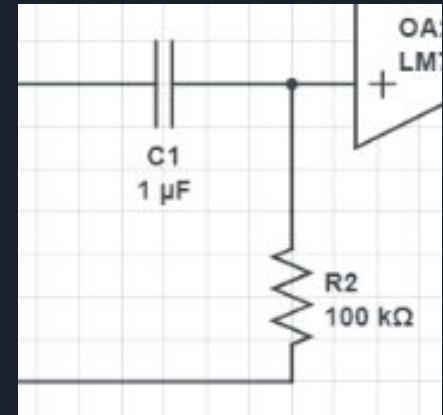
# Operational Amplifier (Op Amp)

- 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  $(1+(R1/R4))$

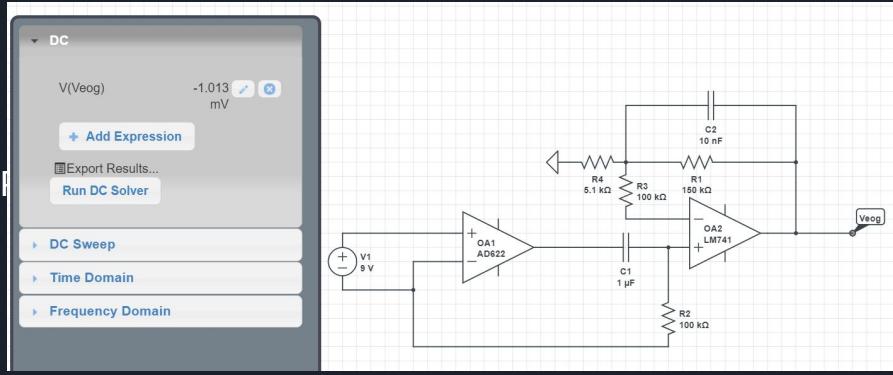


# Filters

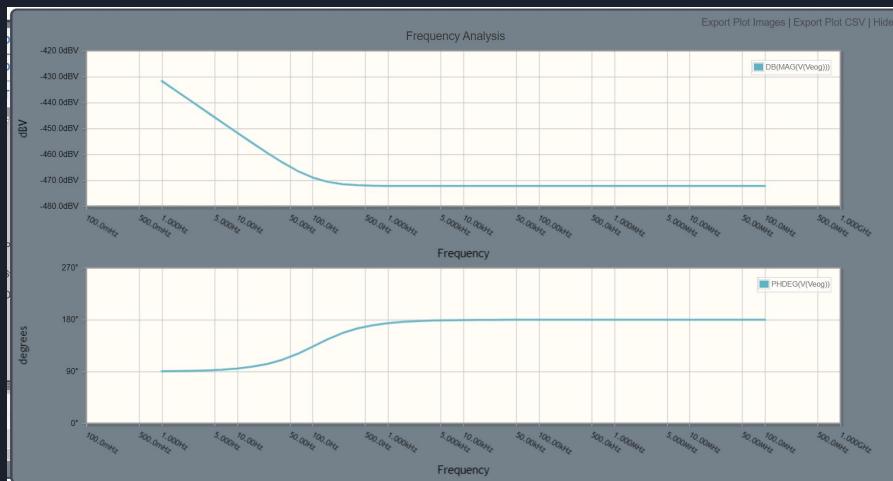
- R2 and C1 make a high pass filter with a cutoff of 1.6 Hz which is better for EMG signals and blocks DC drift
- R1 and C2 make a low pass filter with a time constant of 1.5 ms and a cutoff of 100 Hz (for low frequencies, the capacitor is open and is shorted for high frequencies)
- R3 matches R2 so 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

| <b>International Morse Code</b>                       |                                   |
|---|-----------------------------------|
| - 1 dash = 3 dots.                                    |                                   |
| - The space between parts of the same letter = 1 dot. |                                   |
| - The space between letters = 3 dots.                 |                                   |
| - The space between words = 7 dots.                   |                                   |
| A   | • - -                             |
| B   | - - - -                           |
| C   | - - . -                           |
| D   | - - - .                           |
| E   | •                                 |
| F   | • - - - .                         |
| G   | - - - - .                         |
| H   | • - - -                           |
| I   | • •                               |
| J   | • - - - -                         |
| K   | - - - - .                         |
| L   | - - - - -                         |
| M   | - - - -                           |
| N   | - - -                             |
| O   | - - - - -                         |
| P   | • - - - - .                       |
| Q   | - - - - - .                       |
| R   | • - - - .                         |
| S   | • - - -                           |
| T   | - - -                             |
| U   | • - - - -                         |
| V   | • • - -                           |
| W   | • - - - -                         |
| X   | - - - - -                         |
| Y   | - - - - - .                       |
| Z   | - - - - - - .                     |
| .   | - - - - - - -                     |
| ?   | • - - - - - -                     |
| /   | - - - - - - -                     |
| @   | - - - - - - - -                   |
| 1   | • - - - - - - -                   |
| 2   | • - - - - - - - -                 |
| 3   | • - - - - - - - - -               |
| 4   | • - - - - - - - - - -             |
| 5   | • - - - - - - - - - - -           |
| 6   | • - - - - - - - - - - - -         |
| 7   | • - - - - - - - - - - - - -       |
| 8   | • - - - - - - - - - - - - - -     |
| 9   | • - - - - - - - - - - - - - - -   |
| 0   | • - - - - - - - - - - - - - - - - |

# MATLAB Code (Converting EoG Blinking Signal to Morse Code)

```

|| voltage_to_code_transducer.m || +
1 d = deblk("m1");
2 dg = deblk("m2");
3 dg.Rate = 50;
4 dg.Format = "Raw";
5 dg.Channel = "Raw";
6 tabledata = readtable;
7 matrixdata = readtable("OutputFormat", "Matrix");
8 dg = deblk("m3");
9 dg.Rate = 50;
10 n = 50*1584;
11 letter = zeros(4,1);
12 A = zeros(1,n);
13 b = zeros(1,n);
14 c = zeros(1,n);
15 for i = 1:n
16     if i >= n-49;
17         c(i) = 0.5;
18     end
19     if b == 2;
20         d = sum(c);
21         letter(k) = 2;
22     elseif d <= 28;
23         letter(k) = 1;
24     end
25     elseif b < 1;
26         letter(k) = 0;
27     end
28 end
29 for k = 2
30     for i = 1:length(A)
31         if A(i) >= 0.5
32             c(i) = 1;
33         end
34         if b == 2;
35             d = sum(c);
36             if d >= 28;
37                 letter(k) = 2;
38             elseif d <= 28;
39                 letter(k) = 1;
40             end
41         end
42     end
43     elseif b < 1;
44         letter(k) = 0;
45     end
46 end
47 for k = 3
48     for i = 1:length(A)
49         if A(i) >= 0.5
50             c(i) = 1;
51         end
52         if b == 2;
53             d = sum(c);
54             if d >= 28;
55                 letter(k) = 2;
56             elseif d <= 28;
57                 letter(k) = 1;
58             end
59         end
60         elseif b < 1;
61             letter(k) = 0;
62         end
63     end
64     z = sum(letter)
65     if z >= 2;
66         if letter(1) == 2;
67             if letter(2) == 2;
68                 if letter(3) == 2;
69                     if letter(4) == 2;
70                         disp("LETTER DOES NOT EXIST")
71                     elseif letter(4) == 1;
72                         disp("LETTER DOES NOT EXIST")
73                     elseif letter(4) == 0;
74                         disp("LETTER DOES NOT EXIST")
75                     end
76                     disp("Z")
77                 end
78                 if letter(3) == 1;
79                     if letter(4) == 2;
80                         disp("Z")
81                     elseif letter(4) == 1;
82                         disp("Z")
83                     end
84                 end
85             end
86         end
87     end
88 end
89
```

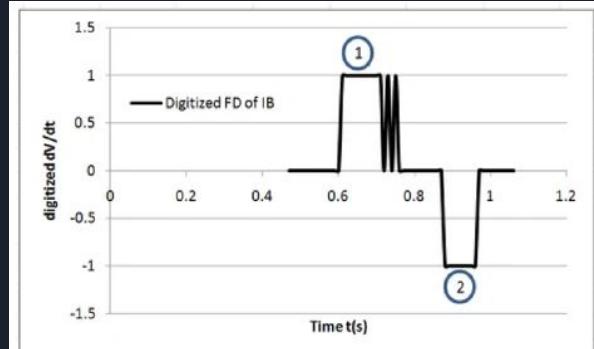
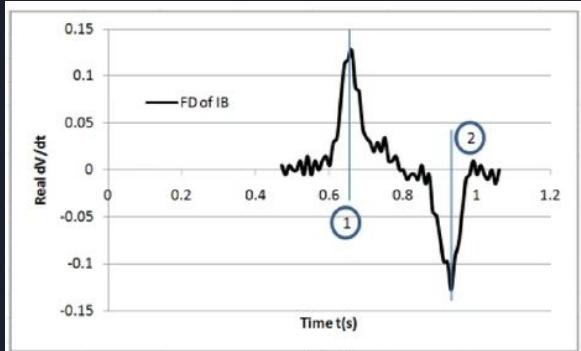
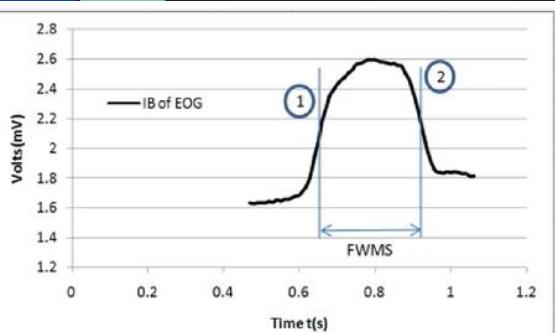
```

|| voltage_to_code_transducer.m || +
82
83         elseif letter(4) == 0;
84             disp("Z")
85         end
86         elseif letter(3) == 0;
87             if letter(4) == 0;
88                 disp("LETTER DOES NOT EXIST")
89             end
90         elseif letter(3) == 1;
91             if letter(4) == 1;
92                 b = mean(A);
93                 A = deblk("m1");
94                 c = zeros(1,n);
95                 for i = 1:length(A)
96                     if i >= n-49;
97                         c(i) = 1;
98                     end
99                 end
100                if b == 2;
101                    d = sum(c);
102                    letter(k) = 2;
103                elseif d <= 28;
104                    letter(k) = 1;
105                end
106                if letter(4) == 1;
107                    disp("Z")
108                    letter(k) = 0;
109                end
110                elseif letter(3) == 1;
111                    if letter(4) == 2;
112                        disp("Z")
113                    elseif letter(4) == 1;
114                        disp("Z")
115                    end
116                    if letter(4) == 0;
117                        disp("LETTER DOES NOT EXIST")
118                    end
119                elseif letter(3) == 2;
120                    if letter(4) == 2;
121                        disp("Z")
122                    elseif letter(4) == 1;
123                        disp("LETTER DOES NOT EXIST")
124                    end
125                elseif letter(3) == 0;
126                    disp("LETTER DOES NOT EXIST")
127                end
128                if letter(1) == 2;
129                    if letter(2) == 2;
130                        if letter(3) == 2;
131                            if letter(4) == 2;
132                                disp("Z")
133                            elseif letter(4) == 1;
134                                disp("Z")
135                            elseif letter(4) == 0;
136                                disp("Z")
137                            end
138                            if letter(3) == 1;
139                                if letter(4) == 2;
140                                    disp("LETTER DOES NOT EXIST")
141                                elseif letter(4) == 1;
142                                    disp("Z")
143                                elseif letter(4) == 0;
144                                    disp("Z")
145                                end
146                            end
147                            if letter(3) == 0;
148                                if letter(4) == 2;
149                                    disp("LETTER DOES NOT EXIST")
150                                elseif letter(4) == 1;
151                                    disp("LETTER DOES NOT EXIST")
152                                end
153                            end
154                            if letter(4) == 2;
155                                disp("LETTER DOES NOT EXIST")
156                            elseif letter(4) == 1;
157                                disp("Z")
158                            elseif letter(4) == 0;
159                                disp("Z")
160                            end
161                            if letter(3) == 1;
162                                if letter(4) == 2;
163                                disp("Z")
164                            end
165                            if letter(4) == 1;
166                                disp("Z")
167                            end
168                            if letter(3) == 0;
169                                disp("LETTER DOES NOT EXIST")
170                            end
171                            if letter(4) == 2;
172                                disp("LETTER DOES NOT EXIST")
173                            elseif letter(4) == 1;
174                                disp("LETTER DOES NOT EXIST")
175                            elseif letter(4) == 0;
176                                disp("LETTER DOES NOT EXIST")
177                            end
178                            if letter(3) == 1;
179                                if letter(4) == 2;
180                                    disp("Z")
181                                elseif letter(4) == 1;
182                                    disp("Z")
183                                elseif letter(4) == 0;
184                                    disp("Z")
185                                end
186                            end
187                            if letter(2) == 0;
188                                if letter(3) == 1;
189                                    if letter(4) == 2;
190                                        disp("Z")
191                                    elseif letter(4) == 1;
192                                        disp("LETTER DETERMINING MESSAGE")
193                                    end
194                            end
195                        end
196                    end
197                end
198            end
199        end
200    end
201
```

```

|| voltage_to_code_transducer.m || +
157
158        if letter(3) == 2;
159            if letter(4) == 2;
160                disp("LETTER DOES NOT EXIST")
161            elseif letter(4) == 1;
162                disp("Z")
163            elseif letter(4) == 0;
164                disp("Z")
165            end
166            if letter(3) == 1;
167                if letter(4) == 2;
168                    disp("LETTER DOES NOT EXIST")
169                elseif letter(4) == 1;
170                    disp("Z")
171                elseif letter(4) == 0;
172                    disp("Z")
173                end
174                if letter(3) == 2;
175                    if letter(4) == 2;
176                        disp("LETTER DOES NOT EXIST")
177                    elseif letter(4) == 1;
178                        disp("LETTER DOES NOT EXIST")
179                    elseif letter(4) == 0;
180                        disp("LETTER DOES NOT EXIST")
181                    end
182                end
183                if letter(2) == 0;
184                    if letter(3) == 1;
185                        if letter(4) == 2;
186                            disp("LETTER DOES NOT EXIST")
187                        elseif letter(4) == 1;
188                            disp("LETTER DOES NOT EXIST")
189                        elseif letter(4) == 0;
190                            disp("LETTER DOES NOT EXIST")
191                        end
192                    end
193                end
194            end
195        end
196    end
197
```

# Signal Processing



Stage 1:

Signal directly measured by EoG  
for a blink

FWMS: width of peak

Stage 2:

First derivative of the signal

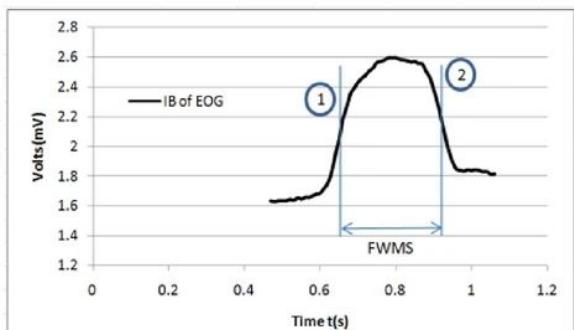
Stage 3:

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

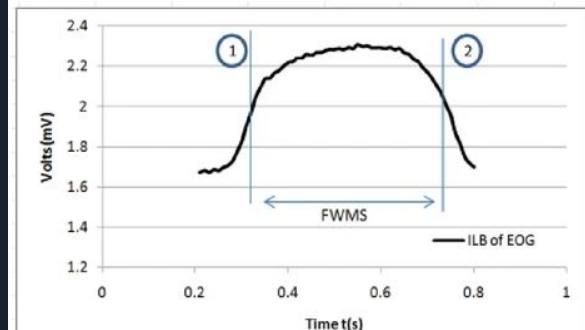
# Differentiating Blinks

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

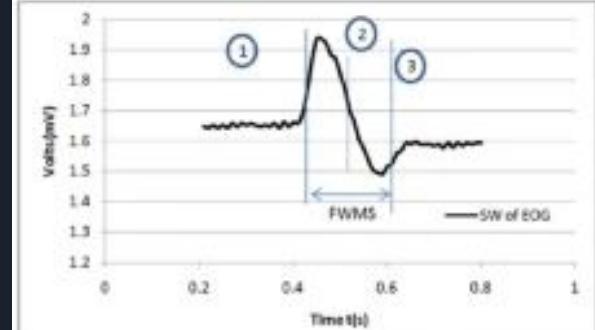
Short Blink



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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Cauwenberghs and the BENG  
186B TA's for instruction and  
support!

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*Output EOG Signal Showing Double, Short and Long Blinks. | Download ...*  
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