Bracelet to Prevent Dry-Eye Disease

Theonie Ho, Suraj Menon, Natalie Trakanrungsi, Amanda Whitley (University of Michigan-Ann Arbor)

***Abstract*-Dry Eye Disease is an inflammatory condition of the eye that affects millions of people throughout the United States and can cause severe health risks such as scarring or blindness [1] [2]. In this paper, we have developed a design that will alert a user when they have not blinked for an extended period of time to prevent the onset of DED by tracking time between blinks using a bracelet equipped with motor vibration. Our device was validated by analyzing the device's response to typical and abnormal blink rates on human subjects.**

***Index Terms*-Dry-Eye Disease(DED), Blink Detection, LabView, Arduino, Radio Frequency (RF) Transmitter, Electrooculogram (EOG), Microcontroller**

I. INTRODUCTION

Dry Eye Disease(DED) is an inflammatory condition characterized by inflammation of the ocular surface of the eye and increased osmolarity of the tear film in the eye. Blinking allows for distribution of tear fluid along the ocular surface and allows for meibomian gland secretion, both of which are significant in preventing DED [1]. Clinical studies have shown that healthy patients have a typical blink rate of about 13.21 blinks/minute, which corresponds with roughly 4.54 seconds in between blinks [3]. Tracking blink rate is significant in preventing the onset of DED, and there are no current, readily available methods to track it [4]. Considering DED affects 16.4 million people in the United States(US), there is a need for an at-home device that tracks blink rate in real time to alert a user when their blink rate has fallen below healthy physiological levels to prevent the onset of DED[1].

The objective of this project was to design a bracelet to monitor blink rate and alert an user when their blink rate falls below healthy, physiological levels.The proposed design described in this paper involves electrooculogram(EOG) electrodes to capture signals generated by eye muscles, a signal conditioning circuit, a LABVIEW VI to detect blinks in the filtered signal, Arduino code to specify what information is sent from our Arduino microcontroller to the Radio Frequency(RF) transmitter and receiver, and finally a MOSFET transistor to control voltage flow to the motor in the wearable bracelet.

II. EXPERIMENTAL SETUP

Our design involves 4 major systems: a circuit board for signal conditioning, LabVIEW for signal analysis, Arduino hardware for signal communication, and a motor circuit for conversion of electrical signals to motor vibration

Circuit. EOG electrodes were connected according to the schematic in Figure 1. The corresponding electric signals were then sent to a circuit board.

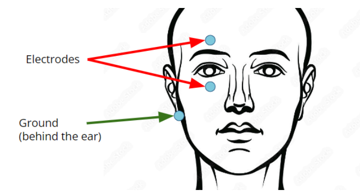

Figure 1. Locations of EOG attachments

The signal then was sent to a differential amplifier consisting of an AD620 operational amplifier (op-amp) and a 500 Ω resistor to get a total gain of 100, serving to increase the signal-to-noise ratio of the acquired signal. This output was sent to a bandpass filter consisting of an LM741 op-amp, 31.8E-8 Farad(F) and 3.97 nF capacitors, and 100 kΩ and 1 kΩ resistors. These capacitor and resistor values led to a circuit configuration with a total gain of 100, and a pass band of 5-40Hz. These cutoff frequencies represent the typical range of frequencies at which EOG signals are typically acquired, allowing us to filter out any noise outside of these frequencies. The gains of both amplifiers led to a total gain of 1000 in the circuit, which is needed to properly view EOG signals as they typically have amplitudes of only 0-150 µV [5]. The subsequent Bode Plot for this bandpass filter is shown below in Figure 2. Output from the bandpass filter was then sent to a DAQ channel on a DAQ assistant to allow for signal analysis.

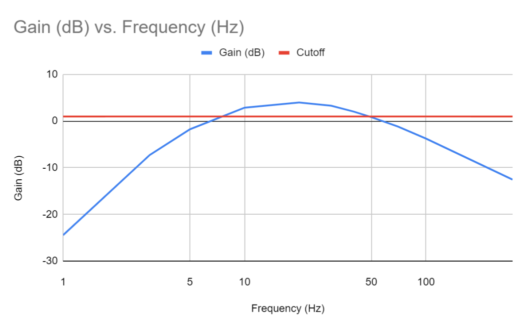

Figure 2. Bandpass filter Bode Plot

LabView VI. Signal analysis was performed using LabView VI software. The filtered signal from our conditioning circuit was sent to a DAQ Assistant VI in LabView. On this VI, controls for sampling rate and number of samples were created so we could control the rate at which sampling data was generated on LabView. Due to the 60 Hz power line noise that exists with EOG signals, a bandstop filter was created in LabView with a low cutoff frequency at 59 Hz and a high cutoff frequency at 61 Hz to filter out 60 Hz noise [5]. A graph indicator was created on this filter output to view the filtered signal on the front panel. A sample number of 1000 was used with a sample rate of 1000, limiting the time frame to one second. This filtered output was sent to a Peak Detector VI to detect peaks corresponding with blinks in the filtered signal. To determine peaks, we set the peak detector to detect rising peaks and the threshold to be about 0.06 V, as we determined this to be the threshold value that differentiated signal amplitudes corresponding with a blink from noise. The peak detector output was wired to a comparison VI to compare the output to 0, creating a boolean output that would be 1 if a blink was detected, and 0 if not. Additionally, an LED indicator was created to light up when this output was 1, or a blink was detected. This boolean output was then wired to a Digital Bool Output VI to output this result to our DAQ assistant, allowing for the boolean signal to be sent to an Arduino microcontroller for further signal processing.

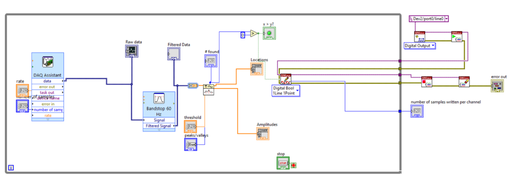

Figure 3. Block Diagram LabVIEW Schematic for Signal Analysis

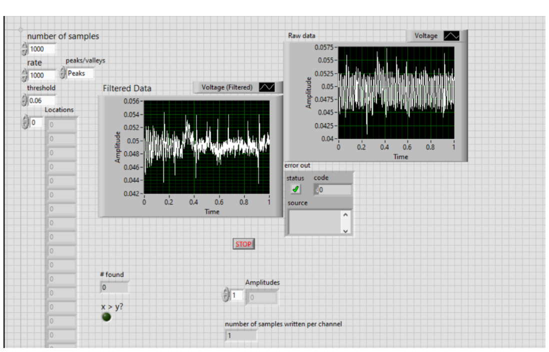

Figure 4. Front Panel LabVIEW Schematic for Signal Analysis

Arduino. An Arduino Uno microcontroller was wired to the DAQ assistant output by connecting a red wire between the PO 0.0 on the DAQ Assistant Terminal Block and AREF on the Arduino, and connecting a green wire between the D GND port on the DAQ Assistant Terminal Block and GND on the Arduino. The Arduino was then connected to the computer using a USB-USB-C cable from the Arduino Uno to the USB Comm port on the computer, to allow for microcontroller control of the RF transmitter in Arduino IDE. From here, wires were soldered from the Arduino Uno to a nRF24L01 according to the schematic shown in Figure 5, to allow for communication between the Arduino Uno microcontroller and transmitter.

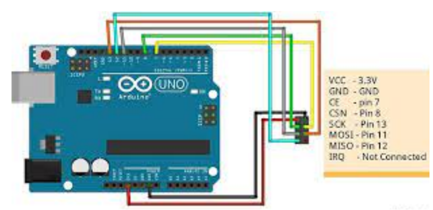

Figure 5. Schematic for Arduino Uno connection to nRF24Lo1 transmitter

Next, a XIAO, seeeduino, a microcontroller, was connected to an nRF24Lo1 receiver according to Figure 6.

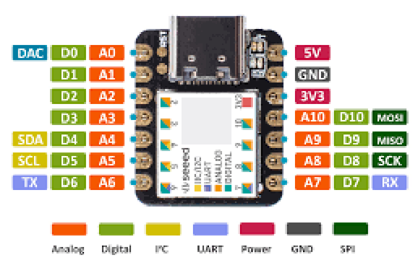

Figure 6. Schematic for XIAO microcontroller seeeduino connection to nRF24Lo1 receiver

This seeeduino was connected to a laptop via USB-C to USB-C cable for microcontroller control of the RF transmitter in Arduino IDE. We used Arduino IDE to control communication between the RF transmitter and receiver, and send signals to the RF transmitter to allow for control over motor vibration.

Motor Circuit. The seeeduino PWM and GND output were then wired to a circuit board, connected to 220 Ω and 10 kΩ resistors and a MOSFET according to the schematic shown below in Figure 7. The MOSFET was wired to our motor and a D3:1N5401/54 diode. The MOSFET prevented any power surges from the

The MOSFET prevented any power surges from the motor back to the seeeduino, and the diode drew any current from the motor when the motor was not active to prevent the motor from burning out over time. The seeeduino, according to the Arduino IDE, would send signals to the motor for vibration whenever the user had not blinked for more than 5 seconds as seen in signal analysis.

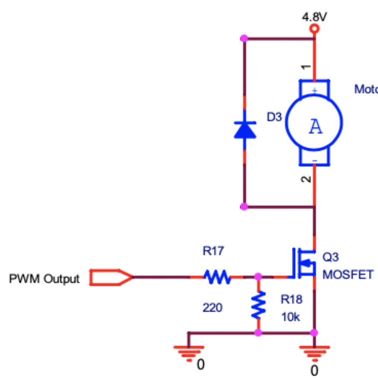

Figure 7. Motor Circuit Schematic setup

An overview of our overall setup can be seen in the block diagram in Figure 8.

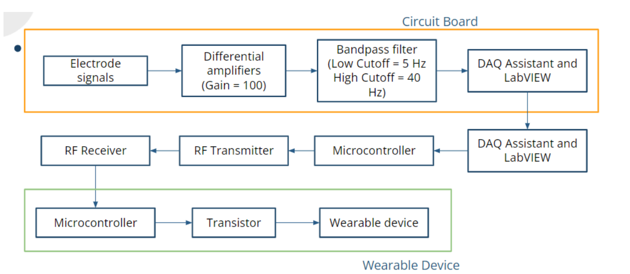

Figure 8. Experimental Setup Block Diagram

Software. Taking the boolean value from the DAQ input, which represents the user's blink, we used an Arduino function that takes the millisecond timestamp of the input. Whenever a blink was detected the timestamp was stored in a value we called t_0. Each input that the user does not blink we stored the timestamp into a constantly updating value called t_n. As t_n is continually updated with the DAQ input values, we continually compared the timestamps by taking the difference between them. When this difference was greater than the prescribed time which was 5000 ms, we set the RF value to 1. The RF value is also a boolean and is constantly being sent to the RF receiver. After opening the writing and reading pipes, we were able to write the RF value to the transmitter so that it can be sent to the receiver. On the receiver and motor side, the RF value that was sent corresponds when the motor should turn on. The second microcontroller that is connected to the RF receiver and motor takes the RF value and writes it to the motor, with a 1 turning the motor on and a 0 turning the motor off.

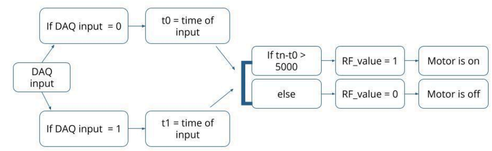

Figure 9. Software Logic Diagram

III. RESULTS

Acquiring Signal. EOG signal was successfully acquired and conditioned through hardware filtering as well as LabVIEW software. The EOG signals were obtained with distinct peaks of around 0.06 to 0.07 V. The signal-to-noise ratio was increased by the large gains of 100 in the differential and bandpass filters. The LabVIEW software was able to detect a peak in the EOG signal, therefore, indicating the presence of a blink within the one second time frame. Over 90% confidence was achieved with blink detection.

Data Analysis. The Arduino UNO successfully analyzed the data received from LabVIEW. The DAQ output 1 when a blink was detected and 0 when no blink was detected. When the user did not blink for over five seconds, and thus, no peaks were detected and the DAQ output zeros for five seconds, the Arduino successfully sent a signal that caused the motor to vibrate via the RF transmitter and receiver.

Treating DED. The subject successfully received a noticeable vibration from the motor. When the subject did not blink for more than five seconds, the motor would vibrate, alerting the subject and letting them know to blink.

IV. DISCUSSION AND CONCLUSION

Patients at risk for DED have lower blink rates, causing their eyes to dry and thus, putting them at risk for irritation and vision impairment.

In order to prevent the onset of DED and to treat those with DED, a blinking detection system was created. The blinking detection system acquired EOG signals via gel electrodes placed above and below the eye, with a reference electrode placed behind the ear. Through hardware and software conditioning, peaks in the EOG signal were able to be detected, thus, indicating the presence of blinks. The subject would experience a noticeable vibration from the motor if they did not blink within five seconds.

The project objectives were successfully met as blink rate was monitored and the user was alerted when their blink rate fell below healthy, physiological levels.

There were obstacles in learning the Arduino and RF transmitter and receiver hardware, as well as the Arduino code. However, these obstacles were overcome by analyzing hardware schematics and consulting online databases and forums. There was difficulty establishing a connection between LabVIEW and the original Arduino Leonardo that we attempted to use. The Leonardo was incapable of connecting, leading us to use an Arduino UNO instead. There was a recurring challenge with broken components, including an Arduino UNO, op-amps, and DAQ Assistant. The faulty components were resolved with simple replacements.

V. APPLICATIONS

Our current system requires manual calibration of the peak threshold every time a user replaces the EOG pads and from person-to-person. It would be beneficial to write a series of code that tells the user to not blink for a period of time, record the baseline noise, and do the same for continuous blinking so that the program can calculate the threshold for a peak. This would allow the user to calibrate the system without working with the code directly.

Second, our system requires the user to be physically attached to the EOG data collection system and motor circuit via cables. The next step in development is making a portable wearable device. To do so, EOG sensors would be placed on a eyewear to send data to a central device. Further, the motor circuit would be developed into a PCB with a rechargeable battery. These modifications make the device highly portable.

The system could lastly benefit from further testing around different eye movements. In our current experimentation, subjects looked at a specific object to minimize the presence of other eye movements on the monitor screen. By testing eye movements in the lab and further reducing noise, LabVIEW code could be developed to disregard peaks that are present, but are not characterized as blinks. Outside of our system, the eye movement characterizations could be used to develop a system that improves alertness when operating a motorized vehicle.

In addition, our device could be applied to similar biomedical applications such as nystagmus diagnosis [6]. Nystagmus is a condition characterized by small, repetitive movements. With small modifications to the code that tracks the time difference between distinct rapid eye movements, the patterns in uncontrollable eye movements could be detected, and therefore used as a measurable statistic in diagnosis.

VI. ACKNOWLEDGEMENT

The authors thank the University of Michigan - Ann Arbor's Department of Biomedical Engineering for the funding of this experiment, as well as Dr. Enrico Opri for his guidance in the project.

VII. REFERENCES

[1] Shtein, R. M. (2023, February 14). Dry Eye Disease. UpToDate. https://www.uptodate.com/contents/dry-eye-disease#:~:text=Prevalence%20—%20In%20epidemiological%20studies%20performed,diagnosed%20with%20DED%20%5B3%5D.

[2] Messmer E. M. (2015). The pathophysiology, diagnosis, and treatment of dry eye disease. Deutsches Arzteblatt international, 112(5), 71–82. https://doi.org/10.3238/arztebl.2015.0071.

[3] Ousler, G. W., 3rd, Abelson, M. B., Johnston, P. R., Rodriguez, J., Lane, K., & Smith, L. M. (2014). Blink patterns and lid-contact times in dry-eye and normal subjects. *Clinical ophthalmology* (Auckland, N.Z.), 8, 869–874. https://doi.org/10.2147/OPTH.S56783.G.

[4] Gisler, C., Ridi, A., Hennebert, J., Weinreb, R. N., & Mansouri, K. (2015). Automated Detection and Quantification of Circadian Eye Blinks Using a Contact Lens Sensor. Translational vision science & technology, 4(1), 4. https://doi.org/10.1167/tvst.4.1.4

[5] A. López, P. J. Arévalo, F. J. Ferrero, M. Valledor and J. C. Campo, "EOG-based system for mouse control," SENSORS, 2014 IEEE, Valencia, Spain, 2014, pp. 1264-1267, doi: 10.1109/ICSENS.2014.6985240.

[6] American Optometric Association, "Nystagmus," *www.aoa.org*. https://www.aoa.org/healthy-eyes/eye-and-vision-conditions/nystagmus?sso=y#:~:text=Nystagmus%20is%20a%20vision%20condition