Monitor for Repetitive Wrist Strain

Winter 2023 BENG 186B
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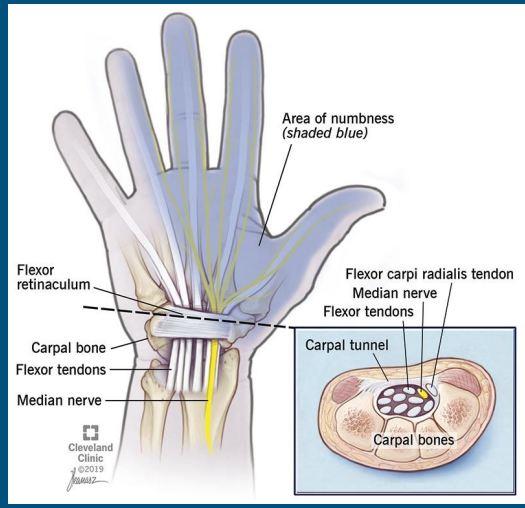
Introduction

Background:

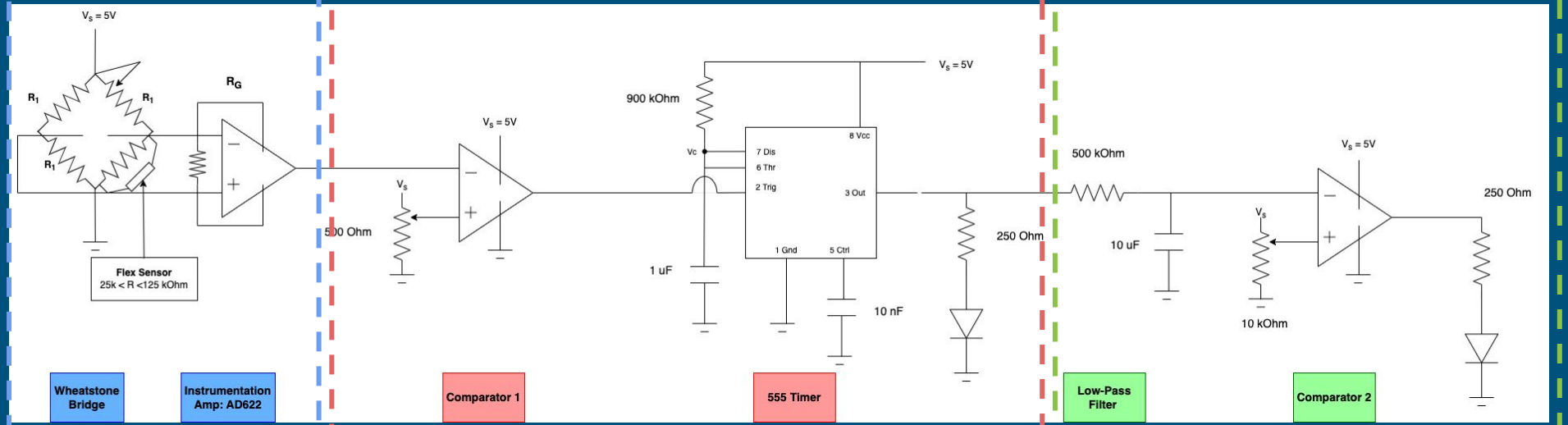
- A potential consequence of repeated strain is carpal tunnel, a common neurological condition that occurs when median nerve in the wrist becomes pressed
- Common symptoms: pain in hand and wrist, weakness, numbness
- Risk of carpal tunnel was shown to be increased with keyboard use greater than 20 hrs per week [5] due to frequent radial/ulnar deviations and changes in wrist flexion

Solution:

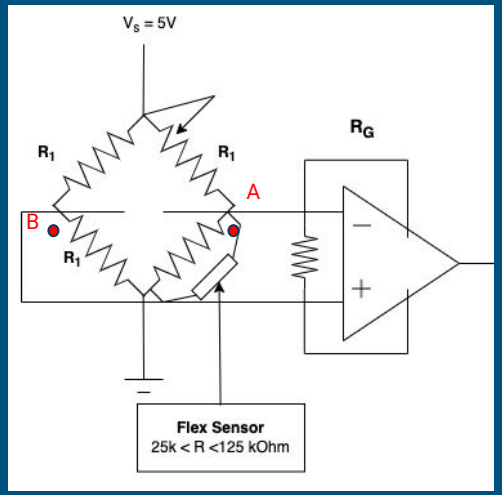
- Wearable glove/brace with flex sensors to monitor changes in radial or extension angles in everyday life
- Critical angles: +/- 30 Degrees for Wrist Flexion, +/- 15 Degrees for Radial/ulnar

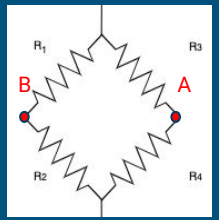


Circuit Diagram



Wheatstone Bridge + IA





Wheatstone bridge:

(1): $V_A - V_B = 0 = \frac{R_4}{R_3 + R_4} - \frac{R_2}{R_1 + R_2}$

(2): $\frac{R_3}{R_4} = \frac{R_1}{R_2} \rightarrow 1$

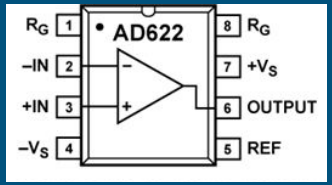
(2) into (1): $\frac{R_4}{R_3 + R_4} - \frac{1}{2} = 0$

(3) : $\frac{R_4(1+\Delta R)}{R_3 + R_4(1+\Delta R)} - \frac{1}{2} = 0 \rightarrow R_3 = R_4(1 + \Delta R)$

(4): $V_{out} \propto \Delta R$

- Want balanced W.B. so we get a positive voltage when threshold position is passed

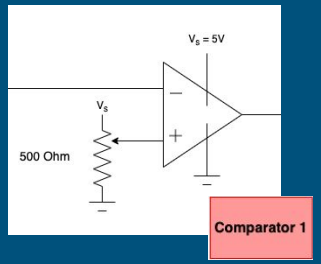
Instrumentation Amp:



$G = 1 + \frac{50.5k\Omega}{R_G}$

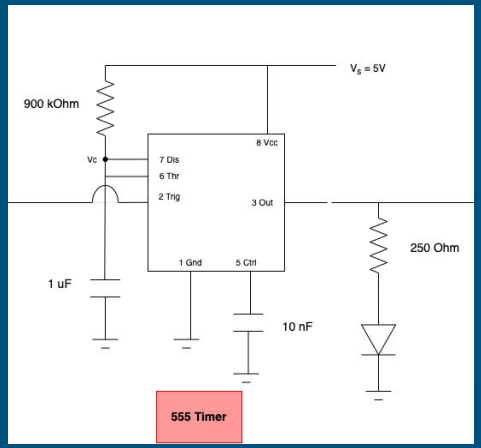
- AD622 IA
- Low sensitivity for flex sensor or if measuring small deviations

Comparator 1 and 555 Timer



Comparator:

- Compare voltage against threshold corresponding to bad hand posture, output voltage of low rail during this case
- Inverting comparator

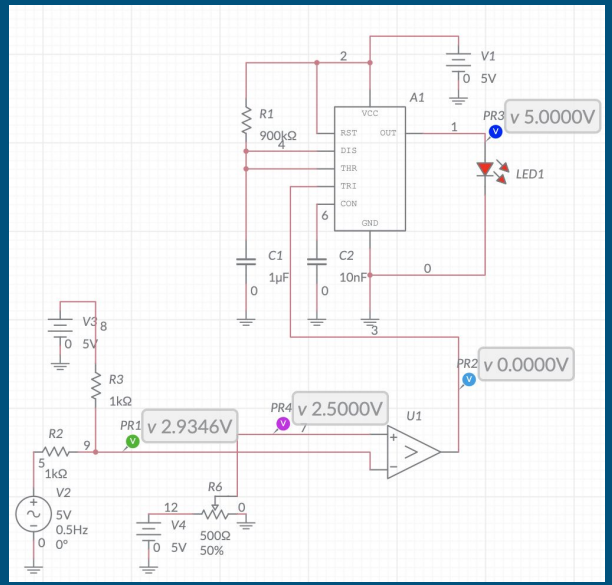


555 Timer:

- When the comparator output is low, trigger the LED to turn on
- LED duration controlled by RC value, about 0.9 seconds

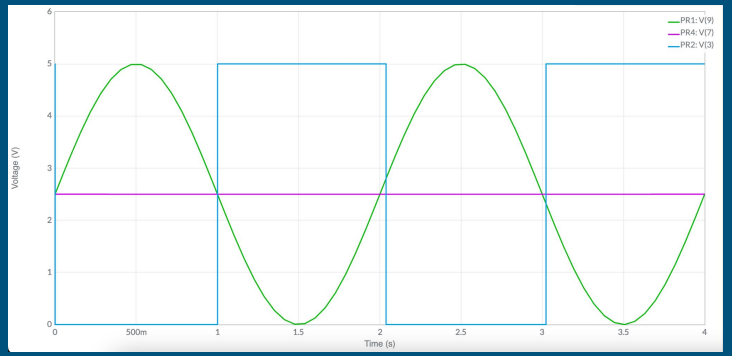
Simulation (first LED trigger)

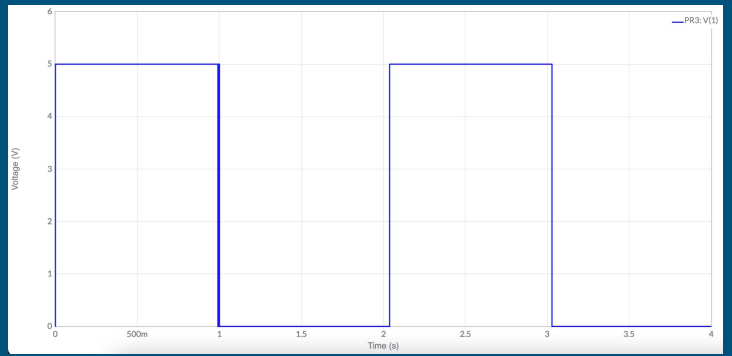
When the first LED is lit up, this corresponds to movement of the wrist beyond the critical angle.



- Simulated signal from flex sensor
- V_{REF} value manipulated with potentiometer
- Inverting comparator output

- 555 timer output:





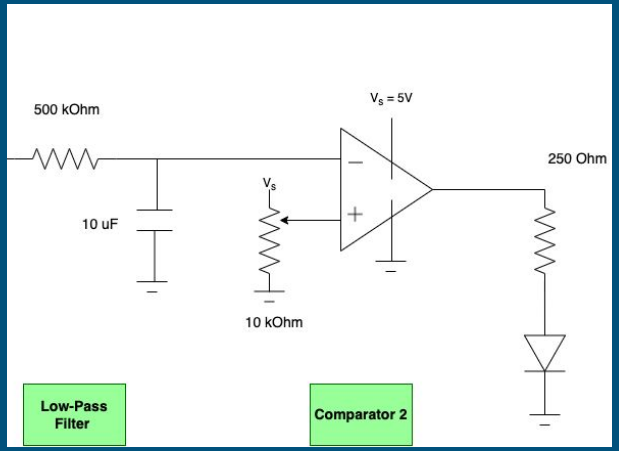
LPF and Comparator 2

Overview:

- Receives pulse output from the 555 timer when deviation from the critical angle is detected
- Capacitor charges more with each pulse that is passed to the LPF, sending a greater output voltage to the comparator each time, eventually causing the comparator to go high
- Detects the frequency of deviations

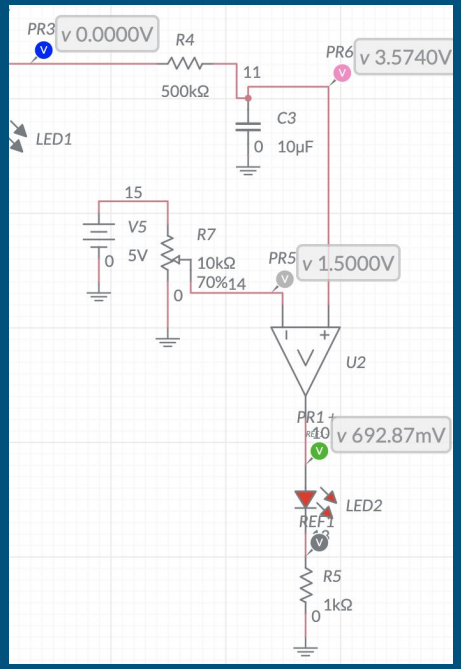
Considerations:

- Cutoff frequency: Determines the rate in which the capacitor charges
- Comparator threshold: Determines the point at which the LED lights up

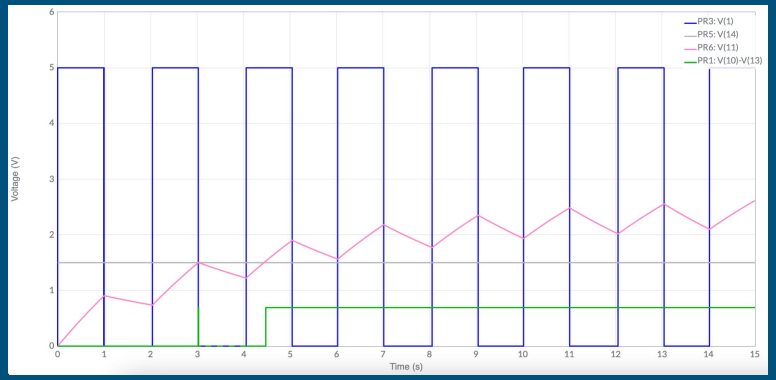


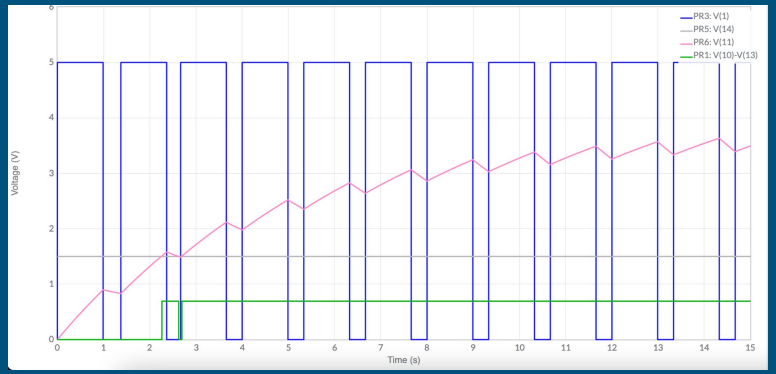
Simulation (second LED trigger)

When the second LED is lit up, this corresponds to a high frequency of repetitive strain movement.



- 555 timer output
- V_{REF} into non-inverting comparator
- Capacitor voltage
- LED voltage





- At higher frequency of movement, the capacitor charges faster.

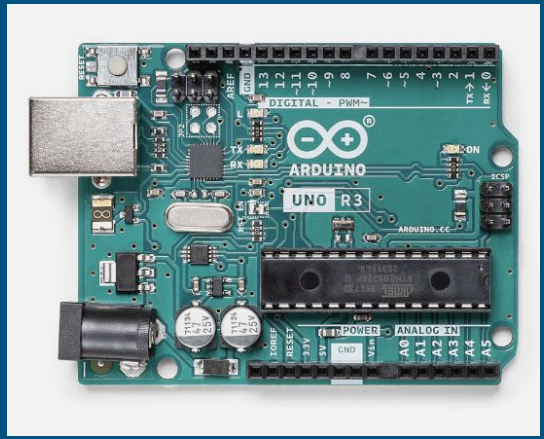
Discussion (Simulation improvements)

- Ideally, the input signal from the wheatstone bridge should be a waveform with irregular frequency
- Constraints:
  - Setting the V^+ and V^- values on the comparator (potential for hysteresis)
  - Simulation of discharging of the capacitor
  - Simulator assumes ideal components when in reality we would have to deal with real components (say inconsistency in time constants)

Next Steps

Improvements for the future:

- Fine-tune parameters after experimentation
- Improve design to alert in both directions of strain
- Design a window of angles that are considered in range of safe movement
  - Easier devised through Arduino and simple code
- Connect output to MATLAB
  - Generate a real-time plot of changes
  - Plot in terms of angle change instead of voltage



Conclusion

This project's main goal was to design a way of monitoring movements that induce wrist strain. For this project, once the user induces wrist strain, an alert is sent to the user of a repetitive strain injury around the wrist.

The real-world applications of this project is for helping people with carpal tunnel syndrome lessen the risk of further injury or reduce the risk for developing it. This system tackles this problem via the Wheatstone Bridge + Instrumentation Amp, Comparator 1 + 555 Timer, and LPF + Comparator 2.

Another clinical application is if an Arduino is used, it can collect data and track how much wrist straining is related to a higher risk of developing carpal tunnel.

Sources

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2. M. Mack and C. -H. Min, "Design of a Wearable Carpal Tunnel Syndrome Monitoring Device," *2019 IEEE 62nd International Midwest Symposium on Circuits and Systems (MWSCAS),* Dallas, TX, USA, 2019, pp. 1195-1198, doi: 10.1109/MWSCAS.2019.8884804.
3. How to Build a Flex Sensor Circuit with a Voltage Comparator [Online]. Available: http://www.learningaboutelectronics.com/Articles/Flex-sensor-circuit-with-a-voltage-comparator.php
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5. Wrist Posture and Carpal Tunnel Pressure when typing: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2649727/