ROBOTIC ARM USING ELECTROMYOGORAGHY

University of Brighton

Course: Electronics and Computer Engineering

Student: Eissa Elbashir

Supervisor: Dr Baha
Internal Examiner: Dr Gavin

Problem statement

- Every year in the UK, accidents and injuries gradually increase, and some are suffering from amputation due to fatal injuries, diseases, or infections. According to Diabetes UK data showed 27465 amputations from 2015 to 2018[1].
- Getting a prosthetic arm usually costs around 5500£ to 60000£ which is not affordable for everyone, especially for children who are growing up[2]. They would need to replace the prosthetic arm every few years.

Aim

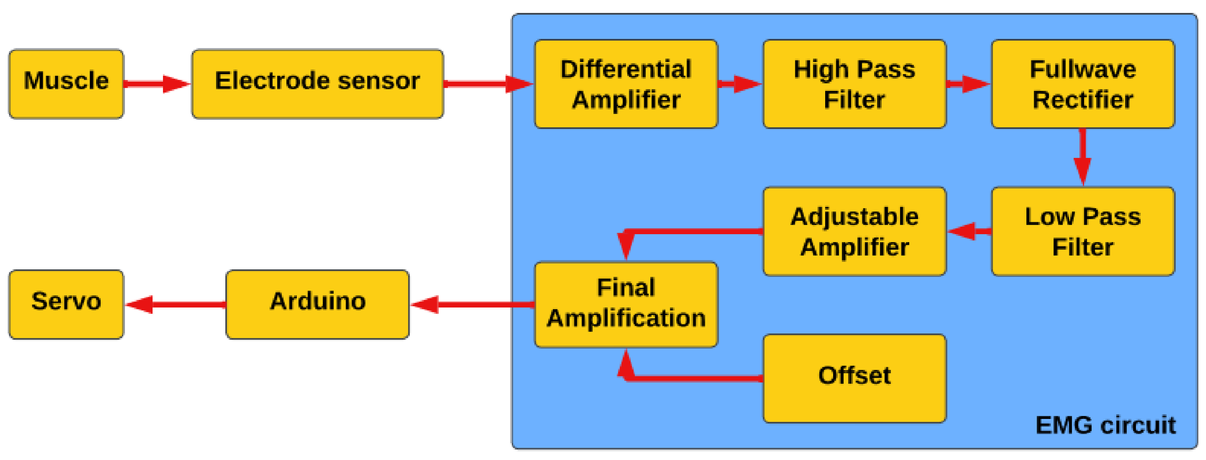
- The project aims to create a prosthetic arm using low-budget components like a 3D printer, servos and microcontroller that is affordable for everyone, easy to use for children and has a large range of freedom of movement.

Objective

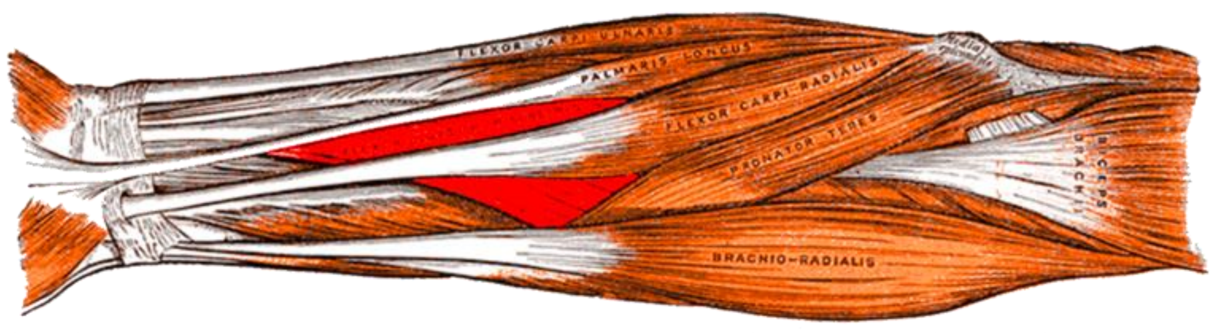
- Research into arm muscle anatomy and existing robotic arms.
- Simulating the circuit and calculating the value of the components.
- Building a prototype of the circuit and testing it.
- Translating the collected data into useful data using Arduino.
- Building and assembling all the parts.

Project diagram

- Hardware: it consists of an electrode sensor and EMG circuit to measure muscle contraction.
- Software: it contains an Arduino to convert the muscle contraction into servos movement.



Arm muscle anatomy



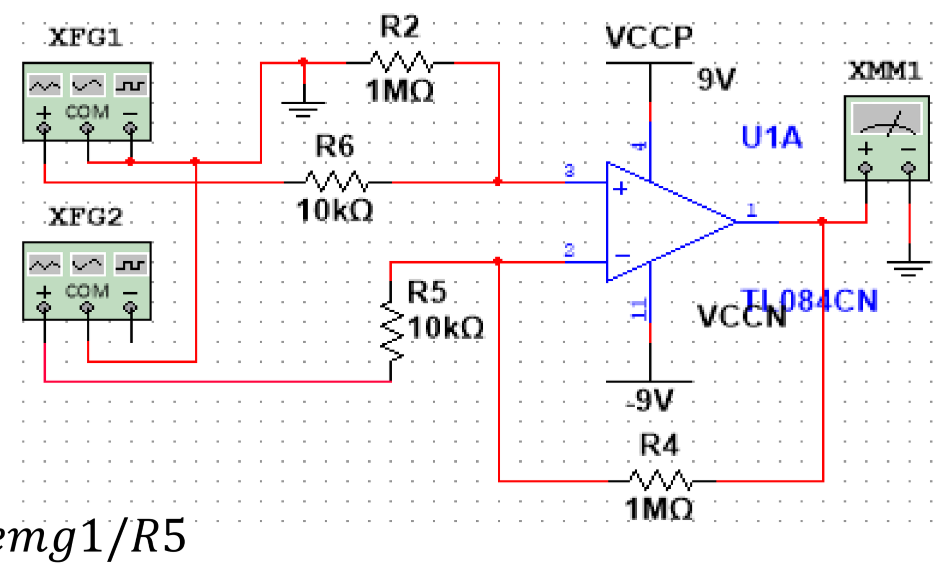
In the forearm, there is a muscle group responsible for the movements of the 4 fingers called flexor digitorum superficial.

The muscle contract when the brain sends a signal down via the spinal cord and then via motor neurons to the muscle this produces an action potential which is detectable by the electromyography sensor

Electromyography circuit

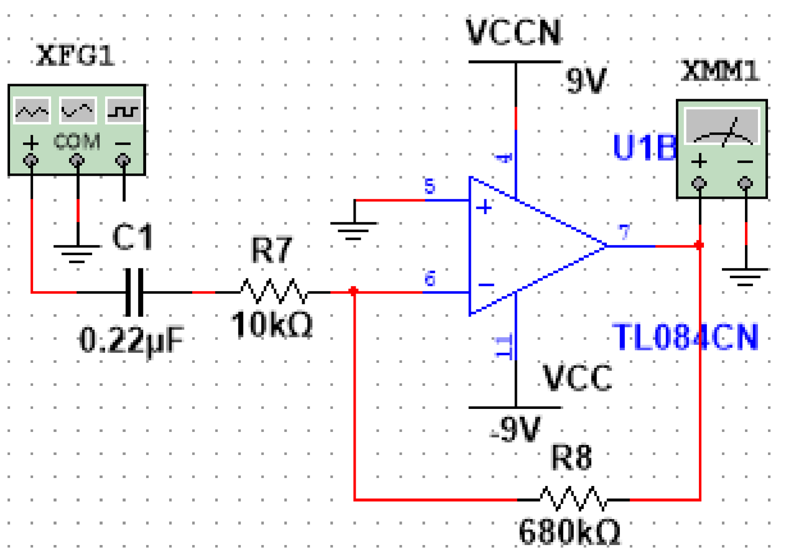
The EMG sensor consists of:

- Difference amplifier: it measures the difference of potential between two inputs coming from the surface electrodes, one of them is placed in the middle of the muscle and the other at the end of the muscle.
  We obtain the equation:



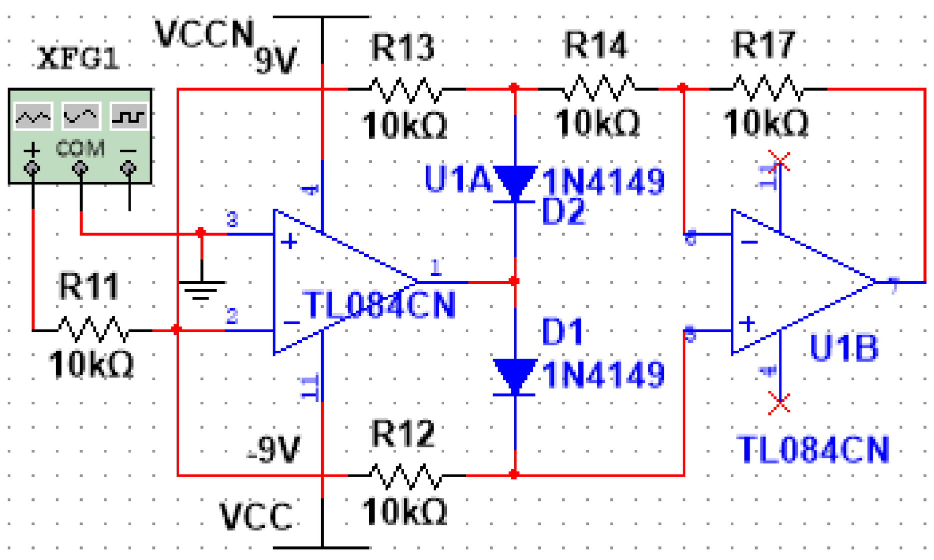
$$Vout = \frac{R2(R5+R4)Vemg1}{R5(R6+R2)} - R4\,Vemg1/R5$$

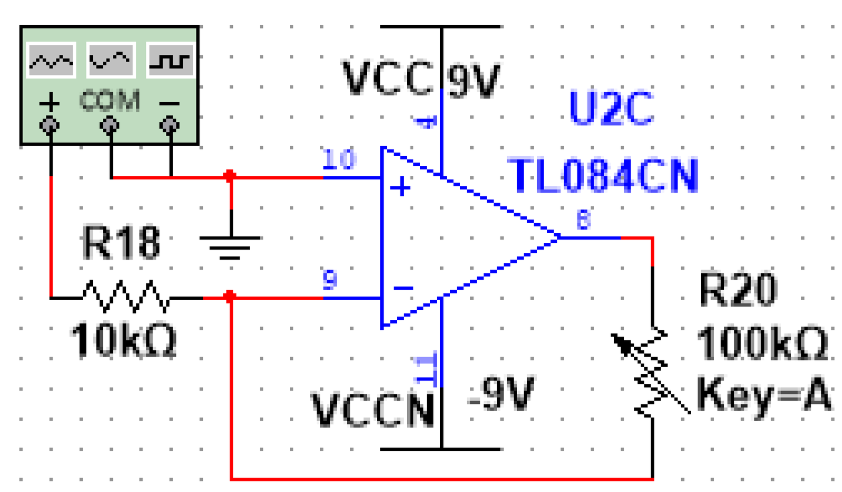
We can simplify the equation by making $R5 = R6 = 10k\Omega$ and $R2 = R4 = 1M\Omega$ Vout = R2(Vemg1 − Vemg2)/R6 we are going to multiply the difference by 100 $(R2/R6)$ because it is very small.



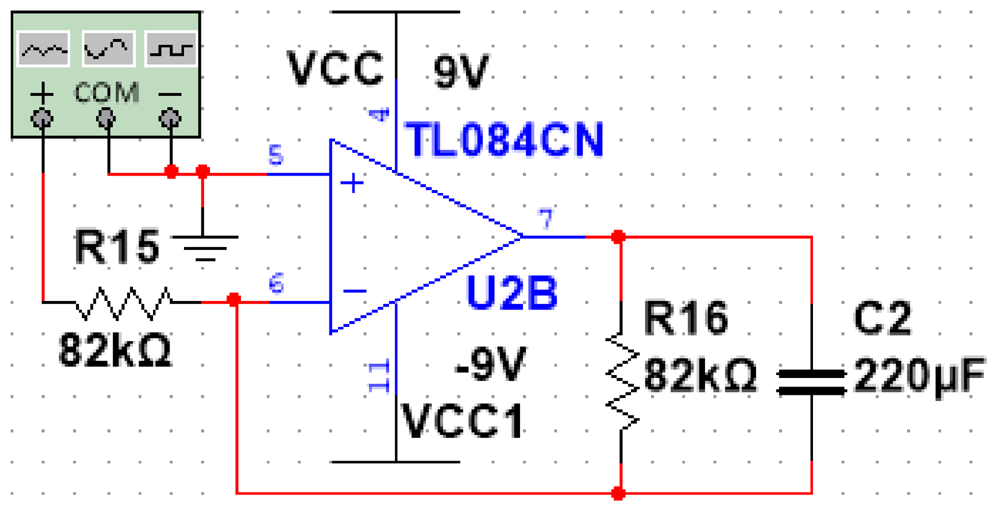
- High pass filter: at this point, we can't amplify the signal yet because it has a dc component due to a constant potential difference between the two points in the muscle.
  The maximum gain would be $\frac{R8}{R7} = 68$ and the cutoff frequency would be $\frac{1}{2\pi R8C1} = 2Hz$

- Precision full-wave rectifier: it converts the AC signal into a DC signal.
  Usually we use a bridge rectifier but in this case, the signal is still too weak to activate the diodes which have a 0.7V threshold.
  The circuit uses opamp to turn the diodes into super diodes which have no threshold and zero resistance.



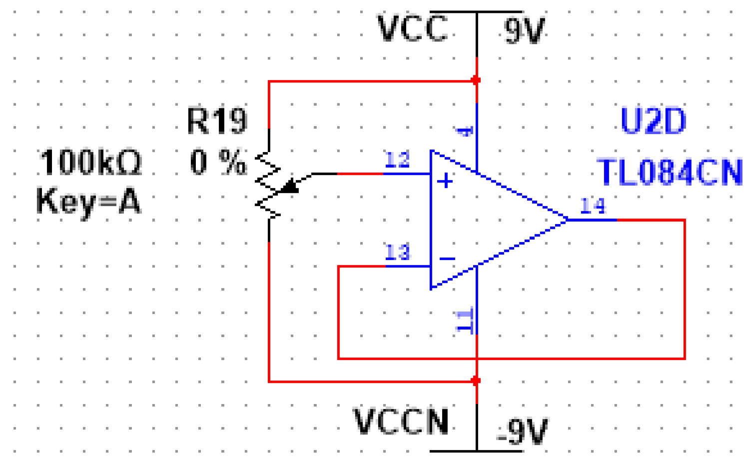


- Adjustable amplifier: $Vout = -\frac{R2}{R1}\,Vin$ it provides an adjustable gain up to 50.



- Low pass Filter: it smooths the output of the rectifier by removing high frequencies and making the signal suitable for Arduino.
  The maximum gain would be $\frac{R16}{R15} = 1$ and the cutoff frequency would be $\frac{1}{2\pi R16C2} = 10Hz$

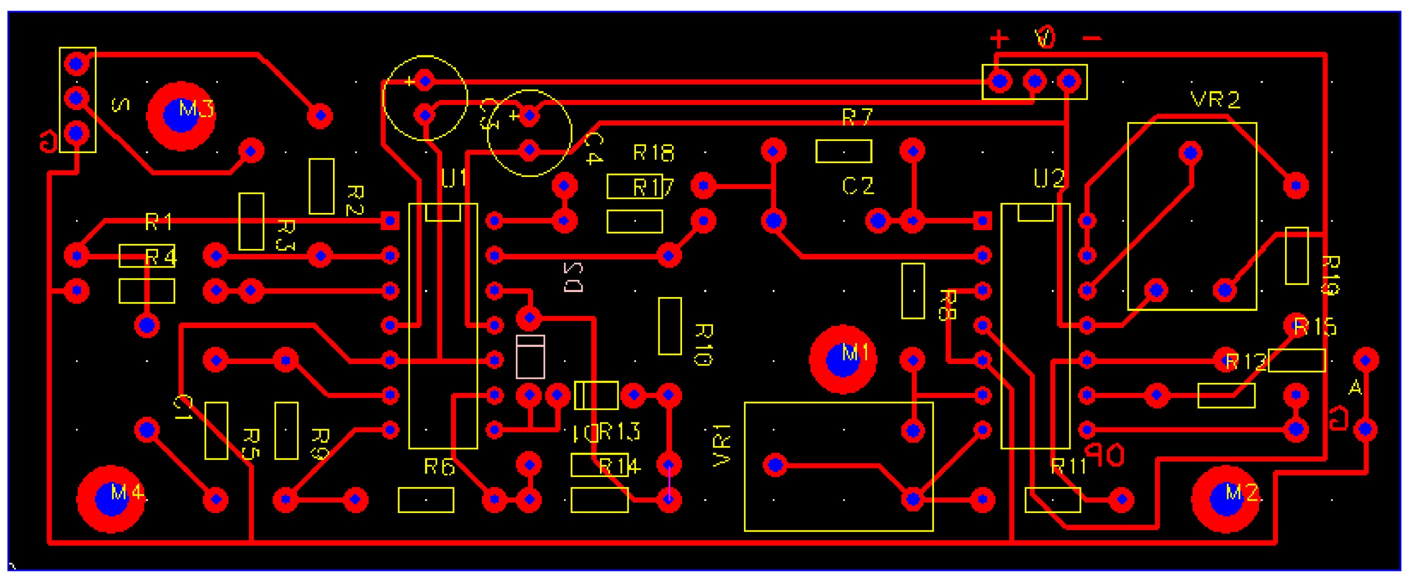
- Offset selector: output Vout is the voltage selected by the 100 kΩ potentiometer because it is a voltage follower.



Printed circuit board PCB

PCB component:

- Resistors
- Capacitors
- TL084 chip
- LM386 chip
- 1N4148 diode



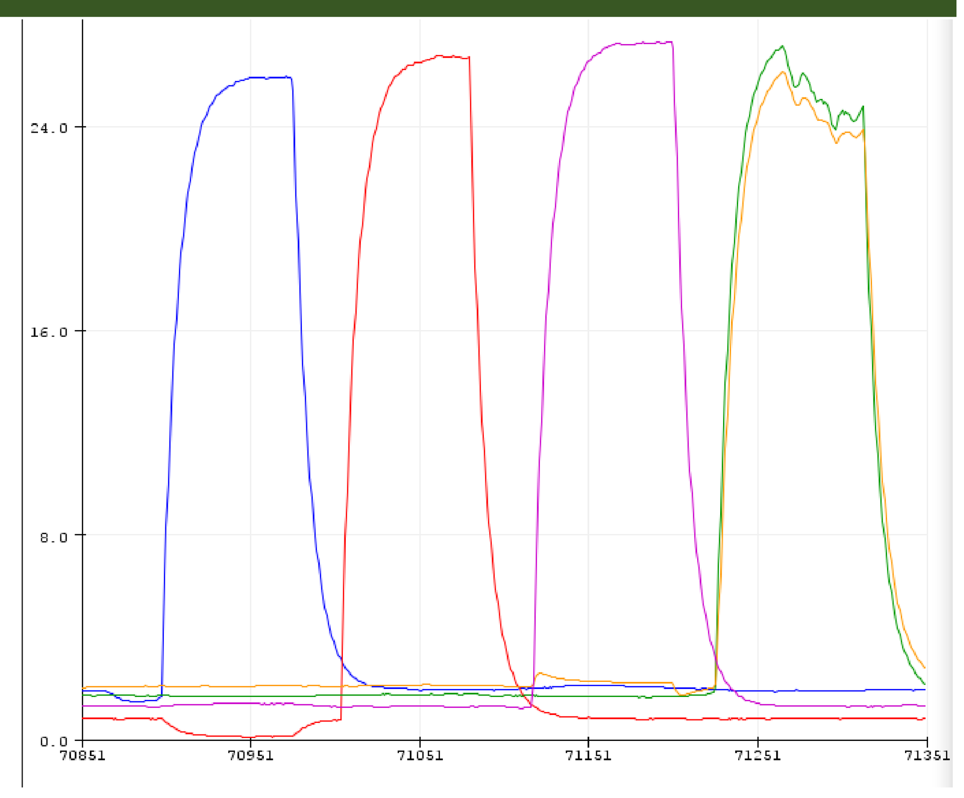
Code

Arduino code steps:

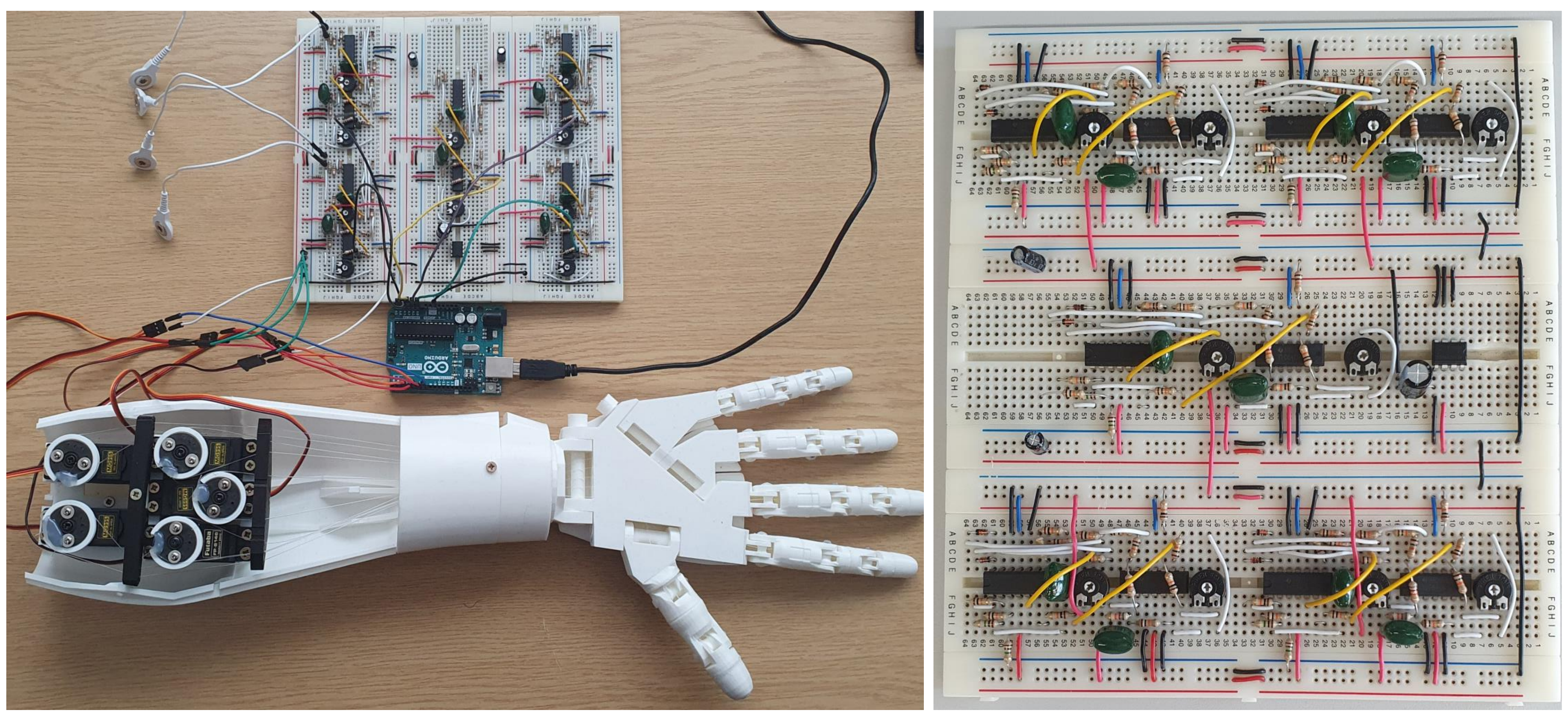
- Configuring all inputs and outputs for all five fingers using pinMode.
- Reading the voltage from the EMG circuit that measures muscle contraction.
- Convert the to 9v reading using *Voltage = (9. / 1023.) * Analogue reading*
- Using exponential moving average to smooth out the servo movement depending on the alpha value $current\ avg = (voltage\ * Alpha) + (last\ avg * (1 - Alpha))$
- Determining the servo positions that is equal to the signal using the slope of 2 points formula *(Angle1 – Angle2) = m (Voltage1 – Voltage2)*

Data

The graph represents real-time data on the muscle contraction of five fingers. Each colour represents a movement of a finger. The horizontal axis is time and the vertical axis measures the contraction power. The peak of each colour increases whenever the EMG circuit detects a movement.



Final design



Conclusion

The project aimed on the development of a prosthetic arm for amputees. The result has shown that the model was successfully able to detect the movement of each finger and translate it into data that was been processed by a microcontroller. However, there is still room for future improvement and further research, specifically in the accuracy of EMG circuits and signal processing.

Reference:

[1] the global diabetes community, "Rising number of diabetes-related amputations in England", February 27 2020.

[2] healthcare service, LUXMED. Available (online) February 9 2023: https://luxmedprotez.com/en/prosthetic-arm-price/

The robotic arm design form https://inmoov.fr/