

ELECTROMYOGRAPHY ROBOTIC HAND

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Abstract: The present work is to design an electromyography robotic hand that is controlled by sensing the muscular contractions in the arm of the user and to replicate the movements on the robotic hand. In the present paper we explain the neural interfaces between humans and machines so we thought an interesting and applicable project would be to control a robotic hand by just using nerve impulses. As a person's hand moves, the various muscles in the arm contract. We want to analyze the signals sent to muscles in the arm and replicate the hand's motions onto a robotic hand. Electrodes will be placed on multiple areas on the arm of the user and will sense the voltage differences of the muscles as they contract. The signal will be fed into a circuit which amplifies and filters the signal. The resulting signal will then be sent into the controller which will analyze the readings. An algorithm then decides which fingers should be moved and uses servos attached to each finger of the hand to move the fingers.

Keywords: Robotic hand, controller, biological signals, neural interface, Electrodes and surface electromyography (EMG).

1. INTRODUCTION

To read the muscle contractions in the arm, a surface electromyography (EMG) technique was used. Electrodes were placed on two areas on the underside of the arm to read the electrical signals. These places were chosen by pragmatic estimates as they produced the maximum muscle contractions when the fingers were pressed. Since the electrodes are placed on the surface of the skin, the signal strength is very weak and noisy.

To improve the signal an instrumentation amplifier is used, followed by a high pass filter, a differential amplifier and finally a low pass filter. The amplified and filtered signals were then fed into Analog to Digital Converters on the microcontroller. If certain conditions were met, a finger was determined to be pressed and servos would pull a string attached to a finger of the robotic hand to contract it [1]. The complete designing steps are provided below.

2. DESIGN STEPS

The complete construction details of Electromyography Robotic Hand is consisting the following steps.

1. Electrodes
2. Amplifier and Filter
3. Servos
4. ADC
5. Atmega 328P controller

2.1 ELECTRODES

We use two sets of electrodes in order to differentiate the signals between the different fingers on the forearm all referenced to the same ground. For both sets, the two electrodes were placed about a quarter to a half an inch apart and affixed to the arm of the user with tape or foam sticking pads.

When a muscle receives a signal from the nervous system, it triggers an action potential in the muscle cell fundamentally a voltage difference across the cell membrane. An attenuated version of these voltage differences can be measured on the surface of the skin, after passing through the dielectric medium of veins, body fat and skin. The action potentials occur at varying frequencies depending on the strength of contraction of the muscle.

The Silver Chloride (AgCl) electrode consists of a silver electrode. A conductive gel containing Chloride ions is applied to the electrodes before they are attached to the skin. When a muscle in the vicinity of an electrode fires an action potential, it can be detected as a current of chloride ions on the skin [2]. In order to get a good signal, the electrodes had to be placed over the belly of the muscle being read. If the electrodes are placed close to the tendons, the signal will be inconsistent and will not accurately reflect the activity of the muscle. Furthermore, there are several muscles in the forearm in close proximity to one another. This

makes it difficult to isolate a signal from only one muscle. In order to differentiate between the different inputs generated by different fingers, we measured the same group of muscles at two different locations. The variable activity between these two inputs allowed us to discriminate between the signals generated by the contraction of different fingers. The electrode is shown in below figure 1.1.



Figure 1.1: Electrodes

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2.2 AMPLIFIER AND FILTER

The signal detected on the surface of the skin is supposed to be around 2mV, but in practical it is around 10 uV. So an amplifier is designed in order to read this signal. The resistance of a human body is fairly high, on the order of Mega ohms, the input impedance of the amplifier needed to be significantly higher. The amplifier is characterized by extremely high input impedance, low noise, and high common mode rejection [3]. The amplifier we built contains two input op-amps along with a two stage differential amplifier. The gain of the first stage was 25, and the gain of the second stage was 214, for an overall gain of 5350. The amplifier contains high and low-pass filters, which are intended to reduce the signal, received to the frequency ranges that were relevant to us. The low-pass filter has a higher cutoff frequency of 1500Hz and the High-pass filter has a lower cutoff of 72Hz. This was aimed at eliminating 60Hz line noise. The circuit is shown in figure below.

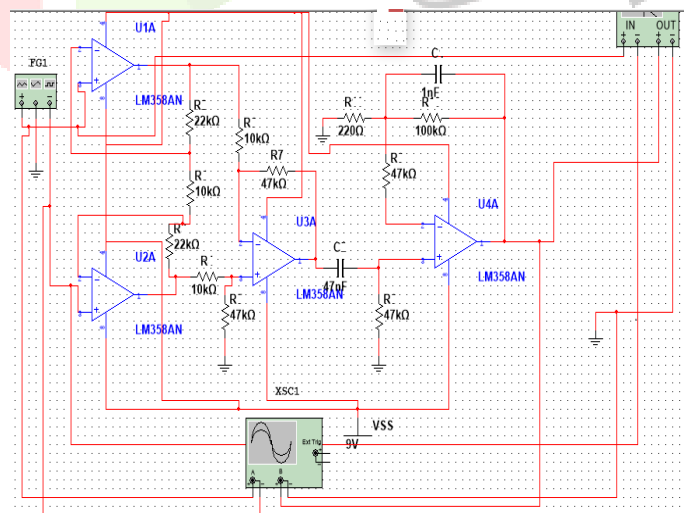


Figure 1.2: Amplifier and Filters

The final circuit contained two of these amplifiers, one for each of the two sets of electrodes. Running the circuit simulation, the oscilloscope output was seen to below figure 1.3.

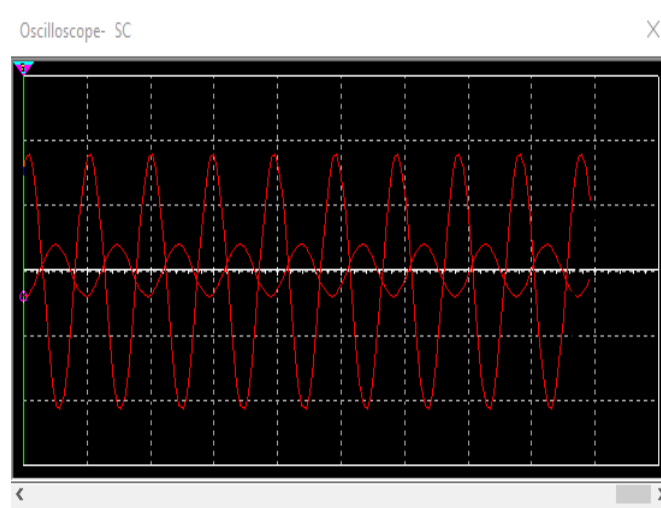


Figure 1.3: oscilloscope result of Amplifier

2.3 SERVOS

To control the fingers on the robotic hand servos attached to string manually pull the fingers down when the servos swing 180 degrees. To control the servos, PWM waves sent to the servo determine which angle the servo points to. For example, when the signal is high for 0.54 ms, the servo is at 0 degrees. When the signal is high for 2.5 ms, the servo points to 180 degrees.

The operating servos requires a 50 Hz PWM wave and the controller clock cycle is at 40 MHz, or 40×10^6 times per second, $40 \times 10^6 / 50 = 800,000$ times per period. Since 800,000 overloads the timer, a pre scalar of 16 was used. Therefore, $800,000/16 = 50,000$ times/period with a pre scalar of 16. It was found that to get the servos to point to 0 degrees, 1,350 of the 50,000 times need to be high. For the servos to point to 180 degrees, 6,250 times would need to be high out of the total 50,000. Loading the PWM function of the controller with the number of times that need to be high during one period allowed us to successfully output PWM waves and control the angle which the servos were pointing at.

Each servo has a finite time to rotate by 180 degrees. We empirically estimated this value to be 600 ms. We had to make sure that no other servo moved when another finger servo was moving, and make sure not to change the state of a particular finger unless 600 ms has passed. Both of these conditions were met by implementing a variable called `lock_motor`. Initially `lock_motor` is set to 0 when no finger servo is moving. If there is a change of state and if no other servo is moving, we set `lock_motor` to the current finger digit and make sure that no other finger moves unless this finger servo resets the `lock_motor` value back to 0. This is not done for at least 600 ms. Thus, by introducing this variable, we ensure that two finger servos do not move at the same time [4]. The complete photograph is shown in below figure 1.4.

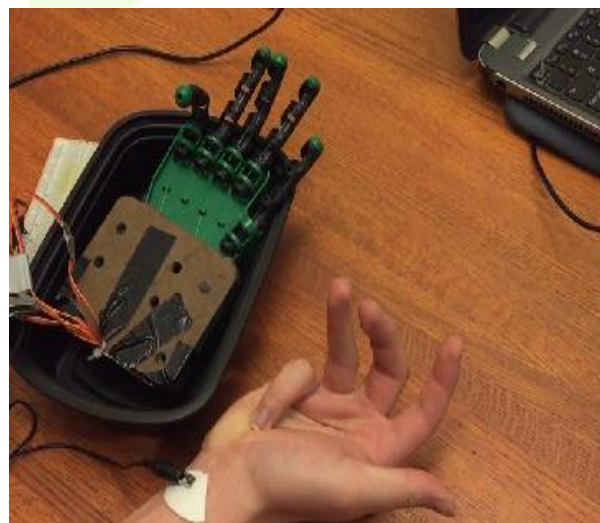


Figure 1.4: demonstration photograph

2.4 ADC

The ADC has two functions i.e sampling & conversion. The sampling rate for the ADC is set by using a clock divider and changing sample hold time for the ADC. All this is controlled in the initial configuration of the ADC. The ADC is configured to auto sample and convert. We also scan two analog input values (AN2 and AN3), from two different electrodes [5]. We use internal ADC of Atmega 328 p.

2.5 CONTROLLER

The ATmega328/P is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. By executing powerful instructions in a single clock cycle, the ATmega328/P achieves throughputs close to 1MIPS per MHz. This empowers system designed to optimize the device for power consumption versus processing speed. The internal ADC used to sample and conversion purpose. The converted values are programmed to control the servos.

3. CONCLUSION

The present design met our expectations and goals set at the beginning of the project. Our goal was to use only electrode inputs to impersonate on a robotic hand the movements of our own hand. At the end of the project, we were able to isolate the signals for each finger and move fingers independently of each other on the robotic hand. We are able to provide enough gain in the amplifier circuit for convert the signal from a few μV in amplitude to one that is a few volts large and readable by the ADC. We also successful in filtering out unwanted noise so that the signal we received was more accurate.

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