VOL. 11, NO. 5, MARCH 2016 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

RH-2000 ROBOTIC HAND CONTROL BASED ON LINEAR ENVELOPED ELECTROMYOGRAPHY SIGNAL FROM FOREARM MUSCLE

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ABSTRACT

Electromyography (EMG) can be used for many application, either in medical or industrial sectors. One of the famous application are prosthetic and exoskeleton devices. In order to use EMG signal efficiently, the signal must through signal processing method including preamplification, filtering, rectification and smoothing. After signal processing is done, the output of this signal will be used as input to control RH-2000 Robotic Hand. This paper explained a linear enveloped EMG circuit acquired from forearm muscle to control RH-2000 Robotic Hand. The data obtained from the experiment has been discussed and analyzed to determine a method to control prosthetic and exoskeleton devices can be achieved.

Keywords: EMG, robotic hand, signal processing, linear enveloped, preamplifier, band pass, rectifier, smoothing, microcontroller, forearm muscle.

INTRODUCTION

Electromyography (EMG) is a method used for recording the electrical activity on skeletal muscles. EMG signals can be acquired by using invasive electrodes or more commonly non-invasive electrodes. Surface electrodes are a non-invasive approach used to measure an electrical concentration that can be analyzed through signal processing. Recently, prosthetic devices available in market are based on EMG signal derived from voluntarily controlled muscles that are detected by electrode on the surface of the skin then amplified (typically in residual limbs). These signals act as ‘switches’ to control specific functions in prosthetic device.

In prosthesis research field, considerable efforts have been made to improve the performance of the prosthesis’s to be more naturally operated[1][2]. In [1], the researchers used the surface EMG signal to control the force of prosthetic hand for more dexterous operations. Another researchers [2] used surface EMG signal for controlling the movement of robotic hand to perform regular hand activities such as grasping and holding.

From previous conducted research [3]–[8], many reseachers consider four concepts for design and developing robotic or prosthesis hand. First concept is type of mechanism to actuate each fingers. Second is using at least two or three Degree of Freedom (DOF) for each finger to actuate. Third concept is selection of suitable actuator to generate good movement based on requirements. Fourth concept is selection of material that have criteria such as light, durable, easy to machining and low cost.

In this paper, one muscle namely Flexor Digitorum Superficialis (FDS) are selected to study the opening and closing of robotic hand based on human handgrip force. The location of FDS muscle can be seen on Figure-1. From [9], FDS muscle was chosen because it is the forearm muscle responsible for finger flexion and the clenching of fists [10]. Signals are collected from one healthy subject and processed then analyzed for control of the robotic hand. The robotic hand consisted of ten Degree of Freedom (DOF) for each fingers and one Degree of Freedom (DOF) for wrist movements. One male subject with right hand dominant are selected for data acquisition on forearm muscle. The subject will do several tasks like gripping the hand dynamometer at different force range with selected wrist angle.

This paper explained the integration of the developed circuit to produced linear enveloped EMG signal by using instrumentation method and the signal is used to control the robotic hand (RH-2000 Robotic Hand) in real time application, as well as future works and goals.

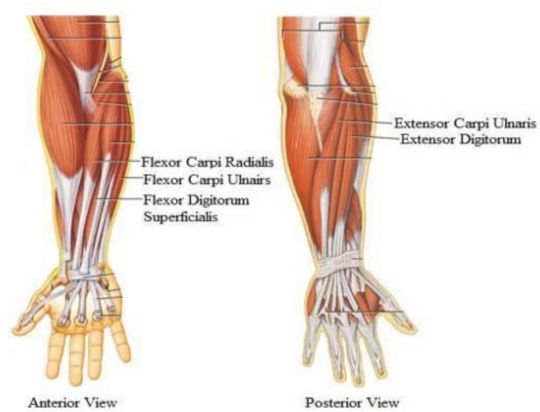

Figure-1. Forearm muscles [13].

METHODOLOGY

Figure-2 explain the overall stages involved in this section. At first, the signal is acquired at FDS muscle from one subject using surface electrodes and then amplified, filtered, rectified and smoothed using the linear enveloped EMG circuit. Microcontroller received the enveloped signal as input to control the linear motors for RH-2000.

VOL. 11, NO. 5, MARCH 2016 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

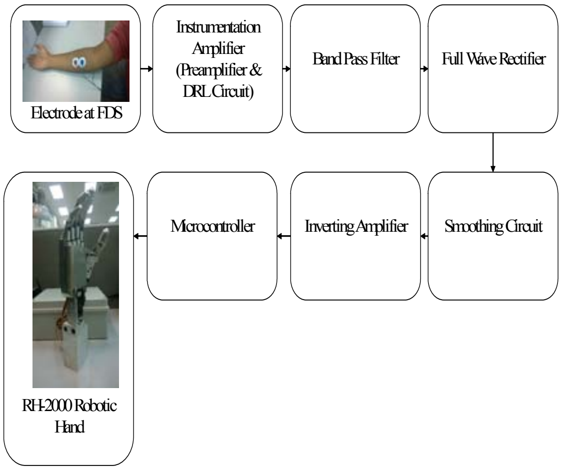

Figure-2. System overview.

a) Instrumentation amplifier

i. Preamplifier

The normal amplitude range of a surface EMG signal is from 50 uV to 30 mV. An amplifier is necessary to increase the EMG signal to a range of 20 mV to 2 V for analyzing process. From [9], high common mode rejection ration (CMMR) has the ability to subtract noise that appears as common mode signals to the instrumentation input. An instrumentation amplifier was designed using AD620 [11]. The gain of the instrumentation amplifier was set to 26 by placing a resistor between pin 1 and pin 8.

ii. The Driven Right Leg (DRL) circuit

To reduce the noise and increase the Signal-to-Noise ratio, Driven Right Leg concept is applied [12]. DRL is widely applied in the design of Electrocardiogram (ECG) circuits. From the DRL concept shown in Figure-3, the common mode noise signal is feedback to a 'bony' human part. Elbow is selected as the reference electrode.

b) The band pass filter

Creating a band pass filter consists of high pass and low pass filter was important to remove unwanted noise from the signal. A second-order Sallen-Key filter topology with Butterworth characteristics using OPA2604 operational amplifier shown in Figure-4 is chosen due to its ability to give flat response in the pass band [14]. A high pass filter [15] with cut-off frequency at 20Hz at -3dB is cascaded at the output of AD620 (pin 6). The low pass filter [16] used cut-off frequency of 500Hz to eliminate unwanted noise from high frequency signals caused by electronic equipment or radio waves.

c) Full wave rectifier

In full wave rectifier circuit, the first operational amplifier acts as the inverting amplifier while the other operational amplifier acts as non-inverting amplifier. The operational amplifier is called precision amplifier because its ability to rectify lower amplitude signal. From [17], after the signal is amplified, the signal is passed through a precision rectifier to get output of unidirectional positive phase signal. The rectifier constructed is shown in Figure-5.

d) EMG Smoothing circuit

According to [18], smoothing is done for the EMG signal to resemble muscle force exerted by the individual. This step is important for robotic hand application which the movement of the robotic hand is depends on human muscle activity. Smoothing is achieves by passing the output of the full wave rectifier through an active low pass filter with a very low cut-off frequency 1.95Hz. This frequency gives the smoothest signal however, it may depends on individual. Figure-6 show the smoothing cicuit builded with signal coming form full wave rectifier.

e) Inverting amplifier

From the signal processing (rectifier, filtering & smoothing), the signal acquired is in linear enveloped form. This linear enveloped EMG signal is suitable as the input to microcontroller [19]. The total gain of EMG circuit is 2600. In order to solve the problem which is different EMG signals amplitude with different people, variable resistor as seen in Figure-7 is placed to enable EMG circuit have variable gain value.

f) Microcontroller

The Arduino® Uno ATmega 328 is an 8-bit microcontroller and operates at operating voltage 5V. The microcontroller has a built-in A/D converter from defaults to a 10-bit resolution, giving a 0-1023 output range when the analog data is read in a digital environment. The microcontroller provide 6 Pulse-width modulation (PWM) in digital input/output pins. The microcontroller is used to acquire and process EMG signal from the EMG circuit. Only one analog input was utilized to receive signals from the circuit.

g) RH-2000 Robotic hand

RH-2000 Robotic Hand as shown in Figure-8 consists of ten Degree of Freedom (DOF) and has five linear DC motors that control each finger and thumb. Each motor has five different drivers each and operates at 5V with analog position feedback. Another one Degree of Freedom (DOF) is attached at the robotic hand wrist and it is for wrist movements. Several types of mechanism are applied based on previous work [20] done by other researchers to actuate the movement of Proximal Phalanx (PP), Middle Phalanx (MP) and Distal Phalanx.

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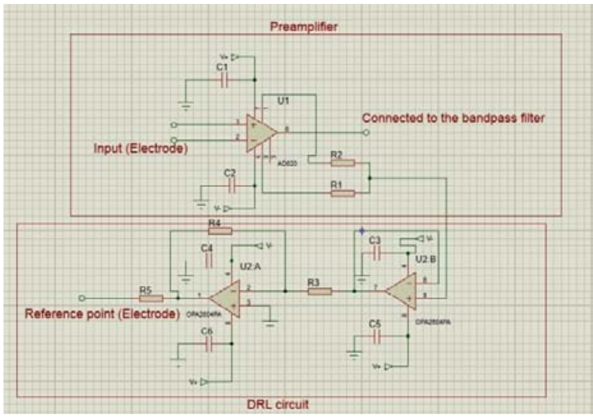

Figure-3. Preamplifier circuit with DRL concept.

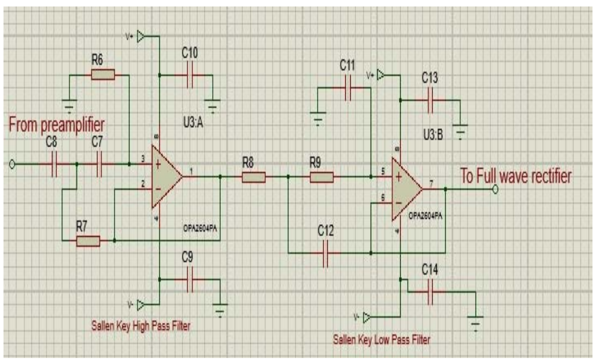

Figure-4. Sallen key band pass filter.

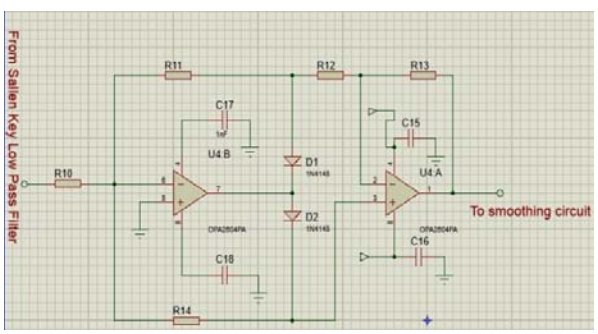

Figure-5. Full wave rectifier.

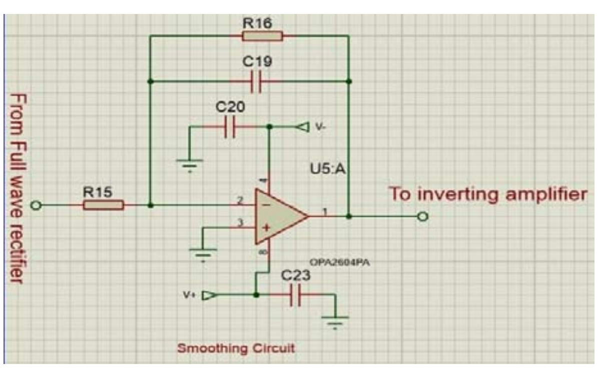

Figure-6. Smoothing circuit.

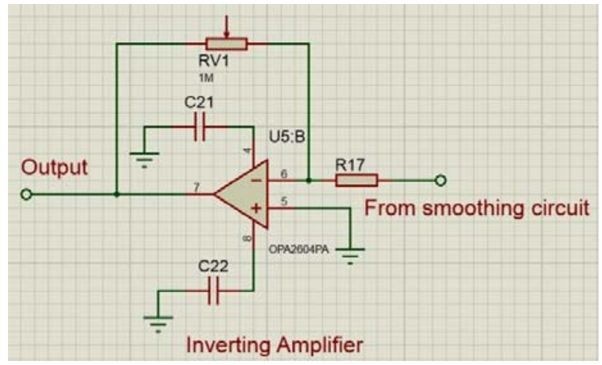

Figure-7. Inverting amplifier.

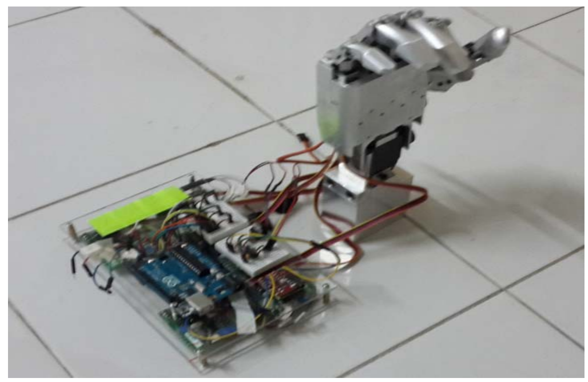
Figure-8. RH-2000 Robotic hand.

h) Arduino® to EMG circuit connection

The output from the complete EMG circuit as shown in Figure-9 is displayed in oscilloscope and saved in waveform. In the EMG waveform, the peak to peak value from one subject is analyzed into mean value and used as the input. The input will be processed by Arduino® to control the robotic hand by PWM.

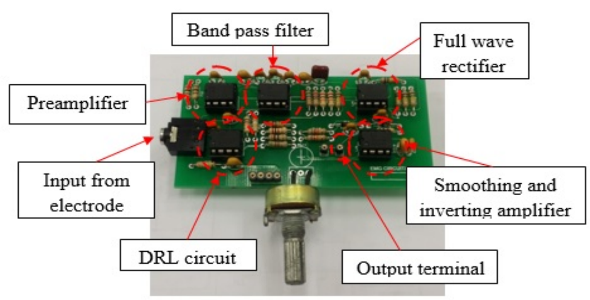

Figure-9. Finished PCB of EMG circuit.

EXPERIMENT DESCRIPTION

The experiment consists of using the developed EMG circuit to measure EMG signals from the FDS as shown in Figure-10. The EMG measurements are recorded using GW Instek GDS-3000 digital oscilloscope while the subject is gripping a hand dynamometer with force levels (120N±0.5) and different wrist angles (90°, 60° and 120°).

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After the signal is acquired, the data is tabulated and will be used as input for RH-2000 Robotic Hand.

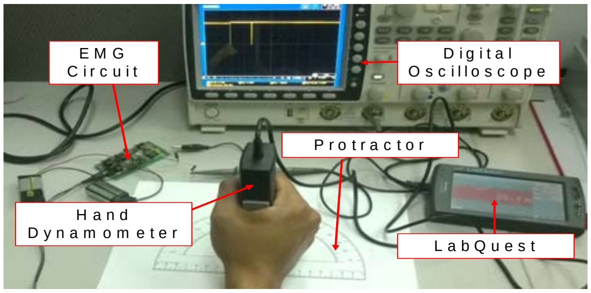

Figure-10. Experimental setup for EMG acquisition.

RESULTS AND DISCUSSION

The experiments were carried out as described in the previous section and oscilloscope displayed the resulting of EMG signals at force level 120N±0.5 with wrist angle 90°, 60° and 120° respectively. The results then saved in a waveform as shown in Figure-11 for 90°, Figure-12 for 60° and Figure-13 for 120°. From the waveform, the maximum and minimum value of the signal is tabulated in Table-1.

Table-1. Peak to peak from EMG signal at 120N±0.5 with wrist angle 90°, 60° and 120°.

Angle(°)	Maximum (V)	Minimum(V)
90	1.56	160m
60	1.12	0
120	2.72	440m

As shown in each figure, these results suggest that with different wrist angles the maximum and minimum value also change. Each maximum and minimum value from EMG signals increases with different wrist angles.

From the data collected, it will be used as input for controlling RH-2000 Robotic Hand. Figure-14 shows full setup of RH-2000 Robotic Hand with EMG circuit as sensor to generate PWM signals for the linear motors.

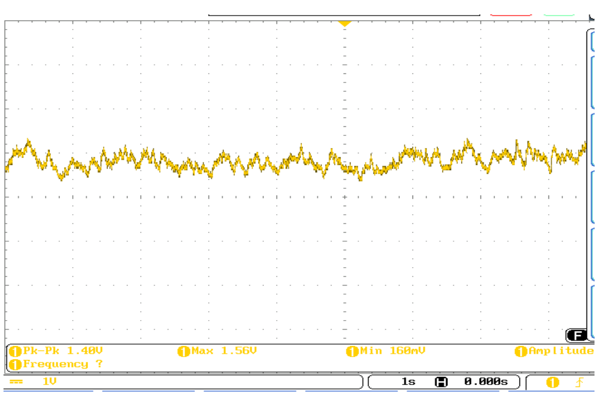

Figure-11. EMG signal for 120N±0.5 with wrist angle 90°.

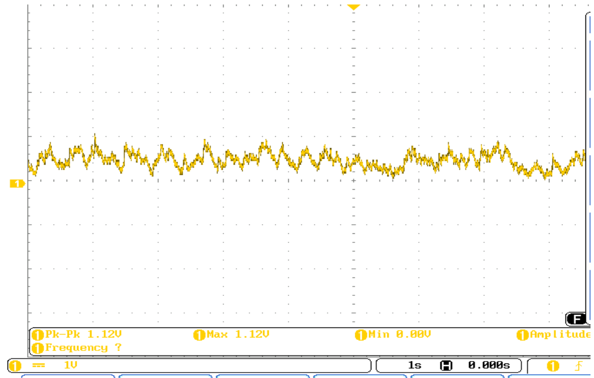

Figure-12. EMG signal for 120N±0.5 with wrist angle 60°.

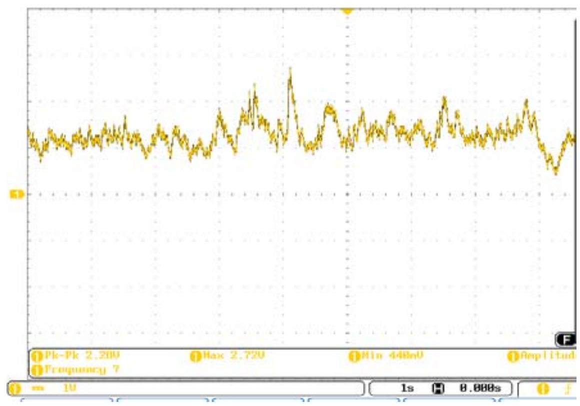

Figure-13. EMG signal for 120N±0.5 with wrist angle 120°.

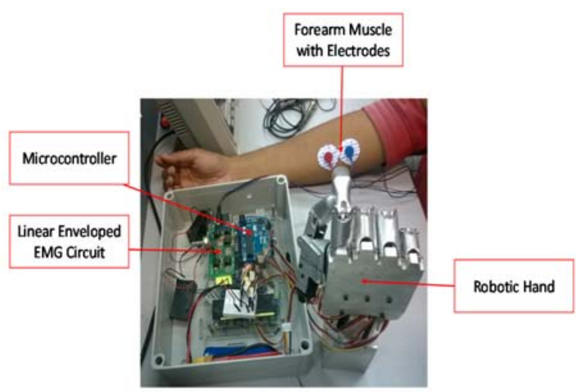

Figure-14. RH-2000 full setup.

Based on input from EMG circuit, RH-2000 Robotic Hand can perform normal human tasks such as opening and closing hand with gripping action. It means that FDS muscle can be used as input for controlling RH-2000 Robotic Hand. With correct method, we can control each fingers of RH-2000 Robotic Hand. This will be done in further application and future works. The works include control movements of each fingers and force control.

CONCLUSIONS

The circuit developed able to successful control of the RH-2000 Robotic Hand through signal processing in real time. The signal is processed by using instrumentation technique thus it will not require any signal processing software. For future research, the expectation is to control movement of each fingers and force control.

ACKNOWLEDGEMENTS

The authors would like to thank Malaysian Ministry of Education for the funding of this research RAGS2012/UTEM/TK02/1/B00008.

REFERENCES

[1] C. Castellini, P. van der Smagt, G. Sandini, and G. Hirzinger. 2008. Surface Emg for Force Control of Mechanical Hands. IEEE Int. Conf. Robot. Autom. pp. 725–730.

[2] A. Harada, T. Nakakuki, M. Hikita, and C. Ishii. 2010. Robot Finger Design for Myoelectric Prosthetic Hand and Recognition of Finger Motions via Surface Emg. IEEE Int. Conf. Autom. Logist. Ical. pp. 273–278.

[3] Jaffar, M. S. Bahari, C. Y. Low, and R. Jaafar. 2011. Design and Control of a Multifingered Anthropomorphic Robotic Hand. Int. J. Mech. Mech. Eng. 11(4): 26–33.

[4] W. Widhiada, S. Douglas, I. Jenkinson, and J. Gomm. 2012. Design and Control of Three Fingers Motion for Dexterous Assembly of Compliant Elements. Int. J. Eng. Sci. Technol. 3(6): 18–34.

[5] S. a Dalley, D. a Bennett, and M. Goldfarb. 2012. Preliminary Functional Assessment of a Multigrasp Myoelectric Prosthesis. Conf. Proc. IEEE Eng. Med. Biol. Soc. pp. 4172–4175.

[6] S. a. Dalley, T. E. Wiste, H. A. Varol, and M. Goldfarb. 2010. A Multigrasp Hand Prosthesis for Transradial Amputees. Annu. Int. Conf. IEEE Eng. Med. Biol. Soc. EMBC. pp. 5062–5065.

[7] P. L. Srinivasa, S. N. Nagananda, G. R. Kadambi, R. Hariharan, P. Shankpal, and S. R. Shankapal. 2013. Development of Two Degree of Freedom (Dof) Bionic Hand for Below Elbow Amputee. IEEE Int. Conf. Electron. Comput. Commun. Technol. CONECCT. pp. 1–6.

[8] L. Zollo, S. Roccella, E. Guglielmelli, M. C. Carrozza, and P. Dario. 2007. Biomechatronic Design and Control of an Anthropomorphic Artificial Hand for Prosthetic and Robotic Applications IEEE/ASME Trans. Mechatronics. 12(4): 418–429.

[9] J. H. Mohideen and S. N. Sidek. 2011. Development of EMG Circuit to Study the Relationship Between Flexor Digitorum Superficialis Muscle Activity and Hand Grip Strength. 4th Int. Conf. Mechatronicsno. pp. 1–7.

[10] K. Saladin. 2008. Human Anatomy. 1(5440): 10-60.

[11] A. Devices. 1999. AD620 Low Cost, Low Power Instrumentation Amplifier. www. datasheetcatalog. com. pp. 1–20.

[12] Z. Jamal, A. Waris, S. Nazir, S. Khan, J. Iqbal, A. Masood, and U. Shahbaz. 2011. Motor Drive Using Surface Electromyography for Flexion and Extension of Finger and Hand Muscles. Biomed. Eng. Informatics (BMEI). 4th Int. Conf. 3: 1287–1291

[13] Vol. 2002. EMG of Arm and Forearm Muscle Activities with Regard to Handgrip Force in Relation to Upper Limb Location. 4(2).

[14] M. H. Khan, A. Wajdan, M. Khan, H. Ali, J. Iqbal, U. Shahbaz, and N. Rashid. 2012. Design of Low Cost and Portable EMG Circuitry for Use in Active Prosthesis Applications. Int. Conf. Robot. Artif. Intell. ICRAI. pp. 204–207.

[15] Online Calculator: Sallen Key Highpass Filter. 2015.http://www.changpuak.ch/electronics/calc_09.php.

[16] Online Calculator. Sallen Key Lowpass Filter; 2015.http://www.changpuak.ch/electronics/calc_08.php.

[17] S. Das Gupta, S. Al Yusuf, J. Karim Ammar, and K. Hasan. 2012. An Analysis to Generate EMG Signal and its Perspective: A Panoramic Approach. Int. Conf. Adv. Power Convers. Energy Technol. APCET.

[18] Ahmad Jazlan and Shahrul Naim Sidek. 2014. Development of A Myoelectric Interface for Indirect Hand Grip Force and Wrist Angle Measurement/Analysis. Int. J. Biomechatronics Biomed. Robot. 3(1): 42–53.

[19] J. Sikula, J. Roell, and J. Desai. 2014. Human Forearm Myoelectric Signals used for Robotic Hand Control. 40th Annu. Northeast Bioeng. Conf. (NEBEC).

[20] S. Parasuraman. 2009. Bio-Mechanical Analysis of Human Hand. Int. Conf. Comput. Autom. Eng. pp. 93–97.