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The Impact of using Digital Filter and Analog Filter on EMG Signal

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ABSTRACT **Many accident cases result in humans having to going through a surgery to save them, then performing muscle therapy to help the patient's recovery after going through the post-surgery. The purpose of this therapy is to return the patient's body to its normal state. Exoskeleton is an additional clothing-like tool that aims to both protect and increase the wearer's abilities. Meanwhile, electromyography (EMG) is a technique to evaluate and record the electrical activity produced by skeletal muscles. The purpose of this study was to analyze the differences in using analog and digital filters on EMG, as well as the effect on the exoskeleton simulation. The method used in the main design consists of the myoware module, notch circuit, low pass filter, arduino uno, DAC module, teraterm software, and matlab. The intercepted signal was taken from the biceps using a disposable electrode (AG/AGCL.). The EMG signal tapped by the myoware module then is continued to another circuit, then was recorded on the Teraterm software, and analyzed in MATLAB. The voltage value on the analog filter is 1.541 Volt during relaxation and 2.086 Volt during contraction, while the digital filter that has passed through the DAC has a value of 41.8 mVolt during relaxation and 269.1 mVolt during contraction. The results of this study obtained that digital and analog filter values have an average difference of 5 to 30. The conclusion of this research is that the tool can detect changes in the use of analog and digital filters. Therefore, in the future research, development can be made to compare other types of digital filters along with replacement to wireless systems. The benefit or purpose of this research is as a simulation of exoskeleton skeletal motion and to see the difference between the use of digital and analog filters.**

INDEX TERMS EMG, Analog Filter, Digital Filter

I. INTRODUCTION

An exoskeleton is an additional outfit-like tool that aims to both protect and increase the wearer's abilities. Exoskeleton is a semi-active device with a small size and lightweight that is suitable to be mounted on the feet or hands [1]. Exoskeleton can be used to treat paralysis, muscle weakness, post-surgery, or muscle injury. Paralysis is a condition that causes the patient unable to move his leg muscles or hand muscles. Paralysis is caused by an injury to the central nervous system [2]. A person who experiences paralysis as a result of post-operative or joint injury to the hand, can use exoskeleton of the hand to treat the paralyzed part so that it can work normally again. In the application of exoskeleton, EMG can be used as a driving force for the framework. Furthermore, electromyography (EMG) is a technique to evaluate and record the electrical activity produced by the skeletal muscles. EMG is performed using a device called an Electromyography to produce a record called an electromyogram [3]. The application of an electromyography is done by tapping or recording the electrical signals in the muscles. Meanwhile, the recording is done by using electrodes connected to the circuit. The EMG sensor is a sensor that has a function to record the electrical activity generated by the muscles. The process of taking muscle signals is done by attaching EMG electrodes to the predetermined muscle points [4]. Muscle is a connective tissue in the body whose main job is for the muscle contraction.

Its function is to move the body parts and substances in the human body (heart, striated, and smooth). However, those that play a role in the movement of the human skeleton are striated (skeletal) muscles [5]. In Elbow CPM Control EMG Signal research done by Twoty Rahayu [6], researchers made therapy on the arm by using EMG as a CPM control which took part in moving the tool. The advantages of this tool is that it can be used as a therapy tool and CPM replacement on a stand, while the weakness of this tool is that it has not been converted to an exoskeleton so that it is not easy to carry or use daily. Furthermore, research on Fatigue Detection System Development for Car Drivers Based on Electromyography (EMG) Signals by Firdaus, S., et al [5] examined the EMG signal which discover information related to the condition of muscle activity, so that the recording can be an observable tool to evaluate the driver fatigue. This research used an HPF filter with a frequency of 20 Hz and an LPF of 500 Hz. The weakness of this research is that the tool has not been tested as a therapeutic tool. Further research is conducted on the Design and Implementation of Muscle Tension Measuring Instruments by Junaidi et al [7] in which the tracker used the measurement method on the surface of the body's muscles because it is more concise and less dangerous. The tracer also used a 9 volt battery, a BPF filter of order 2, and conducts this study when the patient or volunteer is in good health without any prior treatment. The weakness of this search is that it has not been applied to therapies that use exoskeletons. Another previous research conducted, entitled the Embedded System for Upper-limb Exoskeleton Based on Electromyography Control by Triwiyanto et al [8] was also carried out, where the researchers implemented elbow prediction on an embedded system to control the upper limb exoskeleton based on EMG signals. Researchers used servo motors to move the exoskeleton. The angle of the elbow joint was predicted based on the EMG signal generated by the biceps muscle. Researchers also used a sampling frequency of 2000 Hz and tried a digital filter order from two to eight to find the optimal location of the output signal. The weakness of this study is that there was no analysis or differences in the analog filters. The next previous research is the investigation of EMG Signal Processing as a Control Command for Electric Wheelchairs by da Silva et al [2], where the researcher used a high pass filer (HPF) to filter the intercepted signal. The researcher also used a band pass filter of 50 Hz and 500 Hz with three times of gain and a low pass filter (LPF) of 1 Hz. The researcher further used the Delphi display application to display the results of the intercepts that have entered the network. The tracer used the flexor carpi radialis muscle as the location of the electrode tapping. However, this study has weakness in the forms of that this has not been applied to hand therapy. Meanwhile, based on the study of Electromyograph (EMG) Signal Identification in Elbow Extension-Flexion Motion Using Convolution Methods and Artificial Neural Networks by Lenzi et al [9], the researcher described the results of research on the identification and classification of EMG signals in elbow Extension-Flexion motion (45^0, 90^0, and 135^0 motion) using the convolution method. The author used a sampling of 2000 points, a digital band pass filter (BPF) with a cut off frequency of 50Hz and 500Hz. In this filter section, the EMG signal convulsion process was carried out on the FIR impulse response. Furthermore, the final results obtained for an angle of 45^0 is 0.242mV amplitude on the motion signal, 90^0 obtained 0.253mV amplitude on the motion signal, and 135^0 obtained 0.372mV amplitude on the motion signal. However, this study has not been applied to exoskeleton therapy devices either. Literature study of Butterworth Filter for Subtracting Noise From Low Magnitude Surface Electromyogram by Maulana et al [10] further used a second order high pass filter (HPF) with a cut off frequency of 10 Hz and a gain of 2 times. The researcher used an order 8 low pass filter (LPF) with a cut off frequency of 400 Hz. Researchers received noise interference of 60 Hz from PLN grids, therefore researchers also used a notch filter circuit to reduce the interference. Researchers amplified the circuit for 5000 times. In this research, there was no analysis with analog filter. Furthermore, research on Filtering the Surface EMG signal: Movement Artifact and Baseline noise contamination by Mello et al [11], researchers argued that filters can reduce noise and keep the signal as expected. Researchers investigated the effects of mechanical noise and noise commonly encountered during EMG recording. In this case, the researchers used a butterworth filter with a frequency of 20 Hz. Researchers also assumed that the EMG signal has a range of 0-400 Hz depending on the distance between the electrodes and the amount of fat between the skin and muscle. Researchers used a low pass filter (LPF) and a high pass filter (HPF) of 20Hz. Researchers also used a sampling frequency of 5 Khz. The results of this study suggested that HPF 30 has succeeded in reducing noise. Meanwhile, results of Electromyography (EMG) Design and Analysis and Its Application in Detecting Muscle Signals by Purnomo et al [12] obtained that it was traceable using IC AD 620 AN in the instrument and got 10 times amplification. This research employed 50 Hz FC LPF filter, 0.28 Hz HPF filter, and Ag/AgCl tapping. The weaknesses of this study is that it has not been applied to the tool. Further research is concerning the Hybrid Impedance-Admite Control for Upper Limb Exoskeleton Using Electromyography by Putra et al [13]. In this study, it served to rehabilitate the upper limb using the biceps brachii for elbow flexion, then using the triceps muscle for elbow extension. This study did not mention the frequency with which the research was carried out. Meanwhile, in the research on Electromyography Signal Conditioning for Identification of Human Arm Movement by Rokhana et al [14], researchers used second-order and active-order LPF filters. Exponential filtering was performed in MATLAB. In this case, the researchers observed the amplitude generated by the signal which tapped the biceps and triceps. The weakness of this study is that there is no application to the exoskeleton. The next research reviewed is from the Intention-Based EMG Control for Powered Exoskeleton by Rozaqi et al. [15]. In this study, researchers used the biceps brachii and triceps muscles. Researchers also used a BPF of 10-500 hz, MATLAB, and gave 2000 digital filters. The weakness of this research is that there was no analysis with analog filters. Furthermore, the research on Design of Analog and Digital Filter of Electromyography by Secciani et al. [16] proved that the butterworth digital filter is better because it has a smooth transition. Researchers also wrote that artifacts in power will occur in the range below 20 Hz. In the cable, artifacts can occur from 1 to 50Hz, which depends on the raw material used. The last artifact is in PLN which can occur in the 50-60 Hz range depending on each country. Researchers used a BPF filter of 20-500Hz. The weakness of this research is that it has not been applied to the tool. A study from a novel application of a surface Electro-MyoGraphy-based control strategy for a hand exoskeleton system: A single-case study by Sitanaya et al [17] states that WHO recorded only 10% of people who can access the supporting technology due to limited costs. In this case, researchers used the servo HS-5495 BH. The weaknesses of this study is that the tool has not been applied to actual patients. Furthermore, research from Electromyography sensor-based control for a hand exoskeleton from Technical Papers [18] stated that in his research using a BPF filter type with a range of 20-450 Hz. In this study, it focuses on the palms or movements of the fingers. However, the weakness of this study is that no application done yet on the upper limb. The study of Digital filtering of EMG-SIGNALS by Triwiyanto et al [19] stated that even though the tapped skin was clean, sometimes artifacts could still be detected in the signal. This study used the Butterworth circuit which has good slopes and requires minimal computation. This literature study also stated that analog filters have the disadvantage of not being able to show the amount of interference in the signal to be used and artifacts in different signals. These artifacts may occur due to production of tolerances, tool ambient temperatures, and component characteristics. This literature study used a series of notch filters to help reduce artifacts. The weakness of this study is that it has not been applied to therapy. Research from Exoskeleton technology in rehabilitation: Towards an EMG-based orthosis system for upper limb neuromotor rehabilitation by Vaca Benitez et al [20] said that only 40% of stroke survivors can recover and return to normal work. One third are permanent depending on support and maintenance. Researchers stated that the advantages of using exoskeleton, is its stabilization during the direction of therapy, as well as the materials and mechanisms that can be adjusted to the patient's wishes, and can be used daily. Based on the results of the above discussion, the author will create an Upper Limb Exoskeleton Simulation tool with EMG control, where the output of the analog EMG filter will be compared to the output of the digital EMG filter. Researchers also made an exoskeleton as the output of signal processing. Then, the difference in the use of analog and digital filters on the load will be identified with the expectation of reducing noise and producing a smoother Electromyogram signal. With this tool, researchers hope to help patients in self-therapy.

Based on the description above, Part I explains the background of the problem where the exoskeleton is needed as a therapeutic tool for patients who experience paralysis or stroke. Then, Part II will provide a brief explanation of what is required. After that, Part III explains the tool system block diagram, tool flow diagram, and explains the mechanical design of the tool. Part IV describes the results of the study. Part V describes the discussion of the tools, and Part VI concludes the study.

The purpose of this research is to make Upper Limb Exoskeleton Simulation with EMG Control by using digital and analog filter, as well as to know the different signal of using analog and digital filter on EMG signal. After that, conclusion was made on which one is better, whether the analog or digital filter.

II. MATERIALS AND METHODS

A. EXPERIMENTAL SETUP

The difference between analog and digital filter signals can be seen in the Matlab which presents the results of recording all signals.

1) MATERIALS AND TOOL

This study used Disposable ECG (AG/AGCL) electrodes (OneMed, Jayamas Medical Industri, Indonesia). The electrode was placed on the right upper arm on the biceps and the ground around the elbow was pressed, in addition, the most prominent bone is flat. Arduino Uno microcontroller was used for EMG data acquisition which was then displayed on a serial plotter, then recorded with Tera Term software. Furthermore, the recording results are displayed in MATLAB version 2017a.

2) EXPERIMENT

After the design completed, the frequency response of this device was tested by looking at the serial plotter to see directly the difference in signals using analog and digital filters.

A. THE DIAGRAM BLOCK

In the case of contracting muscles of the patient, the electrodes was tapped and transferred to EMG module circuit, and amplified on the amplifier. Then, the analog filter was entered. In this case, the analog filters can be processed as FIGURE 1:

1. Directly entering the analog filter program. Then, the serial and exit was also entered, of which the output is in the forms of servo moving and was analyzed on MATLAB 2017a.
2. The second program was then started by entering the program that has a digital filter. The serial was further entered where the digital results were processed first using the DAC module and then the output is a moving motor and analyzed in matlab.

All servo motion of each filter was measured using a potentiometer to find out how much the angle difference when the servo moves.

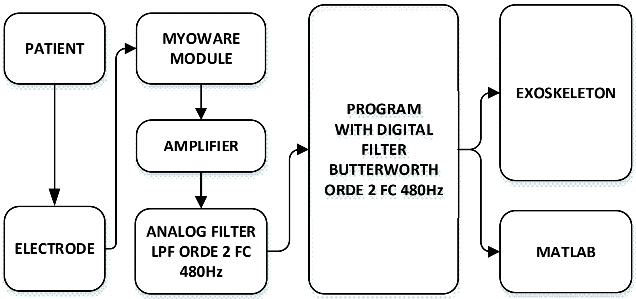

FIGURE 1. The Diagram Block

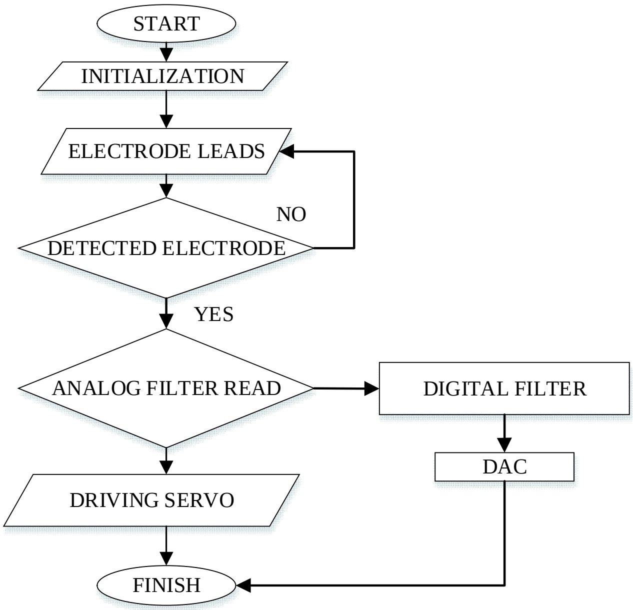

FIGURE 2. The Flowchart of the Arduino Program

B. THE FLOWCHART

The flow chart of FIGURE 2 begins with the initialization of the program. In this case, the electrode taps the EMG signal. If a lead is detected, it will proceed to the analog filter reading. After the analog filter reading is successful, the output will come out in the form of a moving servo. After that, on the other hand, there is a separate program which after reading the analog filter is successful, it will continue with reading the digital filter and then enter the DAC module. Then, the servo can move as a sign that the output occurs.

C. ANALOG CIRCUIT

1) NOTCH FILTER

The notch filter was used as a frequency reducer carried by PLN at 50 Hz. This circuit consists of a 47uF capacitor LM324 IC, and a 220 resistor. This circuit is a combination of a lowpass filter and a highpass filter.

2) THE ANALOG FILTER

This filter was used to limit the frequency of the incoming signal noise and is not the result of muscle activity. This filter consists of IC TL084, 3.3K resistor, and feedback resistor of 100K. The cut off frequency for this filter is 500 Hz. The output of this filter will be reprocessed on a digital filter to reduce noise. The following is the formula for the cut off frequency for the lowpass filter:

3) ENVELOPE CIRCUIT

This circuit was used as input for the servo so that the signal is more suppressed or only produces values of 1 and 0. The required circuit specifications are Using a diode, 0.1uf capacitor, and a resistor. The input of the analog filter circuit is connected to the envelope circuit.

III. RESULTS

In this study, EMG can be tested by looking at the serial plotter when the program is run. Recording was done by using the Tera Term software and the results are displayed in Matlab. The following is the result of the display on the EMG module on the analog output recorded by Tera Term and displayed in Matlab (FIGURE 3)

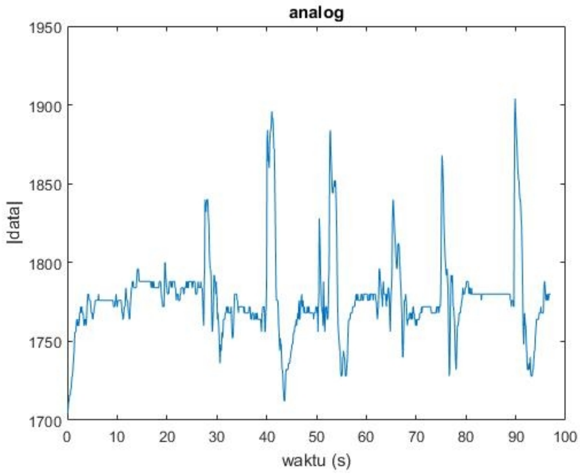

FIGURE 3. The Result of Analog Filter

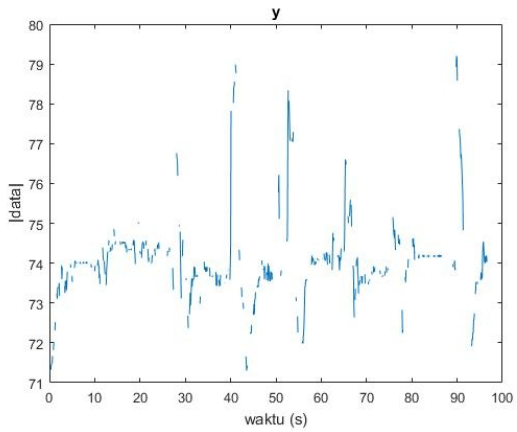

FIGURE 4. The Digital Signal

Based on FIGURE 4 it can be seen that at 40 to 60 seconds there is a peak at 1900 data as a sign that a contraction has occurred. Analog filter data in Fig 3. is raw data which is subjected to analog filtering only by using a 480Hz LLPF analog filter. Based on the figure Fig. 4. above, it can be seen that at 40 to 60 seconds, there is a peak at 79 data as a sign that a contraction has occurred. Fig. 5 is obtained after being given a digital filter on the Arduino program by using a 480Hz LPF digital filter. However, the result obtained are not perfect, even though the shadow form of the previous signal exists, the value obtained is lost data. The following is the result of the DAC signal EMG displayed in Matlab:

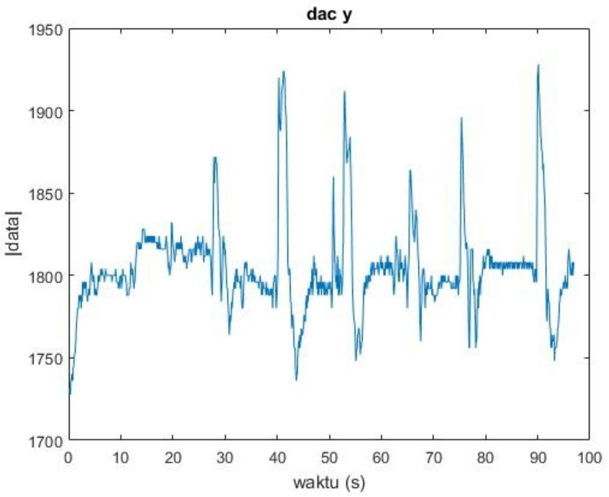

FIGURE 5. The DAC of Filter Digital

Based on the data results in FIGURE5., it can be seen that at 40 to 60 seconds, there is a peak at 1930 data as a sign that a contraction has occurred. The signal results obtained are clearer because it used a DAC module which functions to convert digital signals to analog so that they can be recorded and viewed.

IV. DISCUSSION

Based on this research, the researchers made a simulation of the upper limb exoskeleton with EMG control, where in its manufacture uses analog and digital filters as a comparison of the results of the two filters' signals. It is made of 8cm wide and about 20-30cm long when used on straight arms. This tool is run using myoware sensors when tapping the biceps muscle signal. The design has been tested with a 480Hz analog lowpass filter and a 480Hz Butterworth order 2 digital filter. Based on the results obtained, the digital filter signal on the Arduino program which is given a coefficient from MATLAB has data damage or is not recorded perfectly. Therefore, in order to bring out the signal from the digital filter, it clearly requires a module which is DAC as a converter of digital input to analog so that it can be used or fully record. Overall, the signal can be displayed directly on the serial plotter or serial monitor

This tool has been tested for 10 times. It also has a different signal on the two filter results. The difference is 5 to 30 data. In measuring the results, the angles made by the two filters have a difference of 0.5-1^0 and have a large angle difference when measured with a digital tilt gauge.

Based on the previous study conducted by Twenty Rahayu, CPM was made using EMG, where the tool has a large shape with an analog filter, but the tool does not yet have a digital filter.

This tool has limitations in lifting objects on the arm, because the torque power of the servo is limited to only 2 kg. This tool has noise due to the use of a DAC which results after the DAC is not filtered again and the DAC input is directly from the power supply.

V. CONCLUSION

The purpose of this study is to make an upper limb exoskeleton using EMG control, in which digital and analog filters can suppress the noise in the EMG signal. The results of suppression of signal noise have a difference of 5 to 30 data, depending on the patient's muscle tapped. Based on this study, analog filters tend to produce stable motion in the exoskeleton. Meanwhile, the digital filter has delay or noise in the movement of the exoskeleton. The use of the DAC module may be the cause of the noise or delay in the tool. The two filters can be seen directly on the Arduino serial monitor. However, the digital signals cannot be recorded directly using Tera Term if you do not use a DAC module. The digital signal also cannot drive the exoskeleton without the use of a DAC module. Suggestions for the development of the next tool can use wireless and compare the use of other types of digital filters.

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