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

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ABSTRACT Many cases of accidents which resulted in humans having to surgery to save them, then performend muscle therapy to help the patient's recovery after going through the post-surgery. This therapy has a purpose, so that the patient's body is expected to return to normal. An exoskeleton is a tool like an additional clothing that aims not only to protect, but also to increase the wearer's abilities. Electromyography (EMG) is a technique for evaluating and recording the electrical activity produced by skeletal muscles. The purpose of this study was to analyze the differences in the use of 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 is taken from the biceps using a disposable electrode (AG/AGCL.). The EMG signal tapped by the myoware module will continue to another circuit, then 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 tool can detect changes in the use of analog and digital filters, in the future research can be developed by comparing 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 can see the difference between the use of digital and analog filters

Keywords: EMG, Analog Filter, Digital Filter

I. INTRODUCTION

An exoskeleton is a tool like an additional outfit that aims not only to protect, but also to increase the wearer's abilities. The exoskeleton is a semi-active device with a small size and light weight that is suitable for mounting on the feet or hands [1]. The use of an exoskeleton can be used for the treatment of paralysis, muscle weakness, post-surgery, or muscle injury. Paralysis is a condition that causes the patient to be unable to move the 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 the exoskeleton of the hand to treat the paralyzed part so that it can work normally again. In the application of the exoskeleton, EMG can be used as a driving force for the framework. Electromyography (EMG) is a technique for evaluating and recording the electrical activity produced by the skeletal muscles. EMG is performed using a device called an Electromyograph, to produce a recording called an electromyogram [3]. In the application of an electromyograph, it is done by tapping or recording electrical signals in the muscles. Recording is done 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 predetermined muscle points [4]. Muscle is a connective tissue in the body whose main job is contraction. muscle contraction

functions to move / move body parts and substances in the human body (heart, striated, and smooth) but those that play a role in the movement of the human skeleton are striated (skeletal) muscles [5]. In Elbow CPM Control EMG Signal research by Twoty Rahayu [6]. Researchers make therapy on the arm by using EMG as a CPM control which takes part in moving the tool the advantages of this tool can be used as a therapy tool and CPM placement on a stand, the weakness of this tool is that it has not been converted to an exoskeleton so that it is easy to carry or use daily. Research on Fatigue Detection System Development for Car Drivers Based on Electromyography (EMG) Signals by Firdaus, S et al [5]. This study examines the EMG signal which has information related to the condition of muscle activity, so that the recording can be an observable tool to evaluate driver fatigue. This research uses an HPF filter with a frequency of 20Hz and an LPF of 500Hz. The weakness in this research is that the tool has not been tested as a therapeutic tool. Further traced from the Design and Implementation of Muscle Tension Measuring Instruments by Junaidi et al [7]. The tracker uses the measurement method on the surface of the body's muscles because it is more concise and less dangerous. The tracer also uses a 9 volt battery, a BPF filter of order 2, and the tracer conducts this study when the patient or volunteer is in good health without any prior treatment. The weakness in this search is that it has not been applied to therapies that use exoskeletons. Research results from the Embedded System for Upper-limb Exoskeleton Based on Electromyography Control by Triwiyanto et al [8]. 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 is predicted based on the EMG signal generated by the biceps muscle. Researchers used a sampling frequency of 2000Hz and tried a digital filter order from two to eight to find the optimal location of the output signal. The weakness in this study is that there is no analysis or difference with analog filters. The results of the next investigation of EMG Signal Processing as a Control Command for Electric Wheelchairs by da Silva et al [2]. The searcher uses a high pass filer (HPF) to filter the intercepted signal. The searcher also uses a band pass filter of 50Hz and 500Hz with three times the gain and a low pass filter (LPF) of 1Hz. The searcher uses the delphi display application to display the results of the intercepts that have entered the network. The tracer uses the flexor carpi radialis muscle as the location of the electrode tapping. Weaknesses in this study have not been applied to hand therapy From 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 describes the results of research on the identification and classification of EMG signals in elbow Extension-Flexion motion (45^o, 90^o, and 135^o motion) using the convolution method. The author uses a sampling of 2000 points. The author uses a digital band pass filter (BPF) with a cut off frequency of 50Hz and 500Hz. In this filter section, the EMG signal convulsion process is carried out on the FIR impulse response. In the final results obtained for an angle of 45^o 0.242mV amplitude on the motion signal, at 90^o obtained 0.253mV amplitude on the motion signal, and 0.372mV amplitude on the motion signal 135^o. In this study, it has not been applied to exoskeleton therapy devices. Literature study of Butterworth Filter For Subtracting Noise From Low Magnitude Surface Electromyogram by Maulana et al [10]. The researcher 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 400Hz. Researchers received noise interference of 60Hz from PLN grids, therefore researchers also used a notch filter circuit to reduce interference. Researchers amplify the circuit 5000 times. In this research, there is no analysis with analog filter. Research on Filtering the Surface EMG signal: Movement Artifact and Baseline noise contamination by Mello et al [11]. Researchers argue 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. Researchers used a butterworth filter with a frequency of 20Hz. Researchers assume that the EMG signal has a range of 0-400Hz depending on the distance between the electrodes and the amount of fat between the skin and muscle. Researchers used a low pass filter (LPF), a high pass filter (HPF) of 20Hz. Researchers also used a sampling frequency of 5Khz. The results of this study suggest that HPF 30 has succeeded in reducing noise. Results of Electromyography (EMG) Design and Analysis and Its Application in Detecting Muscle Signals by Purnomo et al [12]. In the results of this search, it was found that it was traceable using IC AD 620 AN in the instrument and got 10 times amplification. Using 50Hz FC LPF filter, 0.28Hz HPF filter, using Ag/AgCl tapping. Weaknesses in this study, have not been applied to the tool. Research on Hybrid Impedance-Admite Control For Upper Limb Exoskeleton Using Electromyography by Putra et al [13]. In this study, it serves to rehabilitate the upper limb using the biceps brachii for elbow flexion. Then use the triceps muscle for elbow extension. This study did not mention the frequency with which the research was carried out. Research on Electromyography Signal Conditioning for Identification of Human Arm Movement by Rokhana et al [14]. In this study, researchers used second-order and active-order LPF filters. Exponential filtering is performed in MATLAB. Researchers observed the amplitude generated by the signal. Which tapped the biceps and triceps. The weakness in this study is that there is no application to the exoskeleton. Research results 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 used a BPF of 10-500hz. Researchers used MATLAB. And the researchers gave 2000 digital filters. The weakness of this research is that there is no analysis with analog filters. Start here. Then the research on Design of Analog and Digital Filter of Electromyography by Secciani et al. [16] wrote that the researchers proved that the butterworth digital filter is better because it has a smooth transition. Researchers also write that artifacts in power will occur in the range below 20Hz. 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 50-60Hz range depending on each country. Researchers used a BPF filter of 20-500Hz. The weakness of this research, has not been applied to the tool. A study from A novel application of a surface ElectroMyoGraphy-based control strategy for a hand exoskeleton system: A single-case study by Sitanaya et al [17] states that WHO records only 10% of people who can access supporting or supporting technology due to limited costs. Researchers used the servo HS-5495 BH. Weaknesses in this study, the tool has not been applied to actual patients. 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 20-450Hz. In this study, it focuses on the palms or movements of the fingers. Weaknesses in this study have not been applied to 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 uses the Butterworth circuit which has good slopes and requires minimal computation. This literature study also says 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 tolerances, tool ambient temperatures, and component characteristics. This literature study uses a series of notch filters to help reduce artifacts. The weakness of this study 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] says that only 40% of stroke survivors can recover and return to normal work. One third are permanent depending on support and maintenance. Researchers stated the advantages of using exoskeeton, namely, stabilization during the direction of therapy, materials and mechanisms 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. Which is 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 see the difference in the use of analog and digital filters on the load. And see the difference between the use of analog and digital filters. With the hope of reducing noise and producing a smoother Electromyogram signal. With this tool, researchers hope to help patients in self-therapy.

From 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, as well as Part VI the conclusions of the study.

The purpose of this research is to make Upper Limb Exoskeleton Simulation With EMG Control. Also use digital and analog filter, then know the different signal of using analog and digital filter on EMG signal. After that make a conculsion about what is the better, using analog or digital filter.

II. MATERIALS AND METHODS

A. EXPERIMENTAL SETUP

To see the difference between analog and digital filter signals, you can look at Matlab from 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 is placed on the right upper arm on the biceps and the ground is pressed around the elbow, the most prominent bone is flat. Arduino Uno microcontroller is used for EMG data acquisition which is then displayed on a serial plotter, then recorded with Tera Term software, and the recording results are displayed in MATLAB version 2017a

2) EXPERIMENT

In this study, after the design was 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

From the contracting muscles of the patient, the electrodes will be tapped and then transferred to the EMG module circuit and amplified on the amplifier. Then enter the analog filter. From analog filters can be processed as FIGURE 1:

1. Directly enter the analog filter program then to serial and exit the output which becomes the servo moving and analyzed on. MATLAB 2017a.
2. Then the second program starts from entering the program that has a digital filter, then enters the serial where the digital results are processed first with the DAC module and then the output is a moving motor and analyzed in matlab.

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

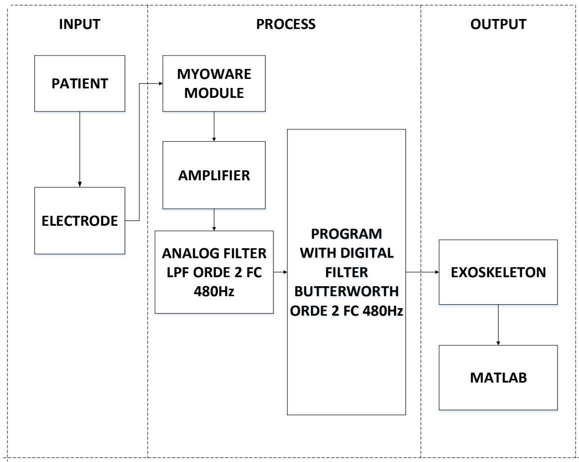

FIGURE 1. The Diagram Block

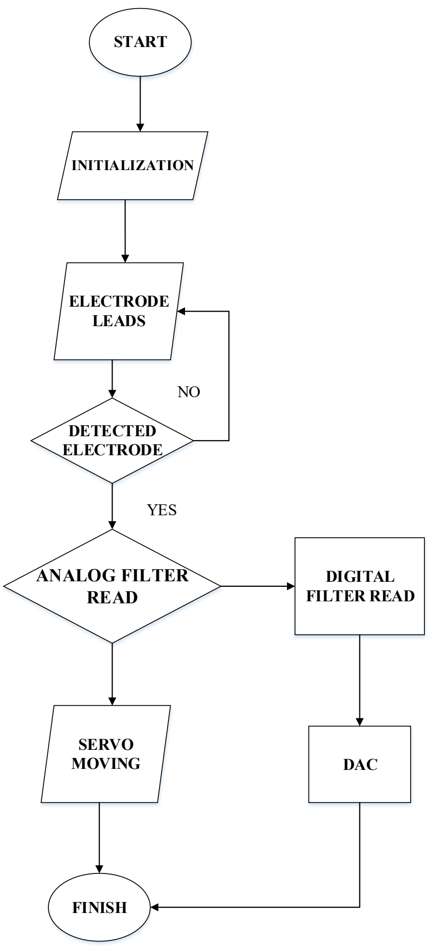

FIGURE 2. The Flowchart of the Arduino Program

B. The Flowchart

The flow chart FIGURE 2 begins with the initialization of the program. Where 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 circuit as shown in FIGURE 3 is used as a frequency reducer carried by PLN at 50Hz. 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.

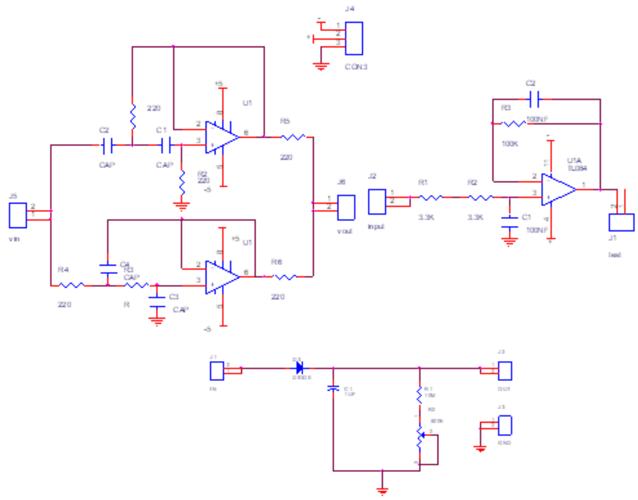

FIGURE 3. The Notch Filter Circuit

2) The Analog Filter

To limit the frequency of the incoming signal. Serves to reduce 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 500Hz. 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

The use of this circuit as input for the servo so that the signal is more suppressed or only produces values of 1 and 0. The use of this circuit 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:
1. Using a diode, 0.1uf capacitor, and a resistor.
2. The input of the analog filter circuit is connected to the envelope circuit.
3. Draw the circuit as follows

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III. RESULTS

In this study, EMG can be tested by looking at the serial plotter when the program is run. Recording using the Tera Term software and the results are displayed in Matlab.

1) RESULT FROM ANALOG FILTER RECORDING

The following is the result of the display on the EMG module on the analog output recorded by Tera Term and displayed in Matlab

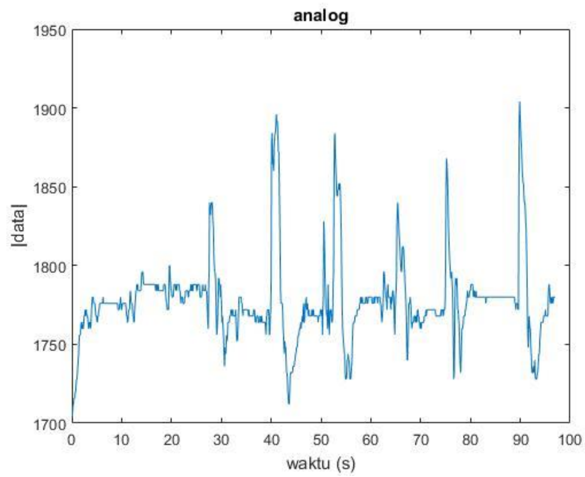

FIGURE 4. The Result of Analog Filter

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 Fig 9. Is raw data which is subjected to analog filtering only. By using a 480Hz LLPF analog filter.

TABLE I. EXAMPLE DATA OF CONTRACTION 0,5KG.

Nama	Nilai F. Analog	Nilai F. Digital DAC	Nilai F. Digital
P1	1885 data	1915 data	79 data
P2	1930 data	1940 data	78,8 data
P3	1925 data	1940 data	80,8 data
P4	1850 data	1885 data	77,2 data
P5	1810 data	1840 data	75,4 data
P6	1835 data	1845 data	76,4 data
P7	1880 data	1890 data	78,4 data
P8	1980 data	2000 data	78,5 data
P9	1827 data	1836 data	76,2 data
P10	1815 data	1820 data	74,9 data

TABLE I. is an example of the results of data collection for contraction at a weight of 0.5 kg. Which has an average of 77.56 data. And the following is the average of all the results of contraction and relaxation from a load of 0.5 kg to 1.5 kg.

TABLE II. THE AVERAGE OF CONTRACTION AND RELAXATION

Nama	The Result Average
Contraaction 0,5kg	77,56 data
Contraction 1kg	77,09 data
Contraction 1,5kg	77,4 data
Relaxation 0,5kg	73,19 data
Relaxation 1kg	73,21 data
Relaxation 1,5kg	73,9 data

The following is the result of the digital EMG filter signal displayed in Matlab:

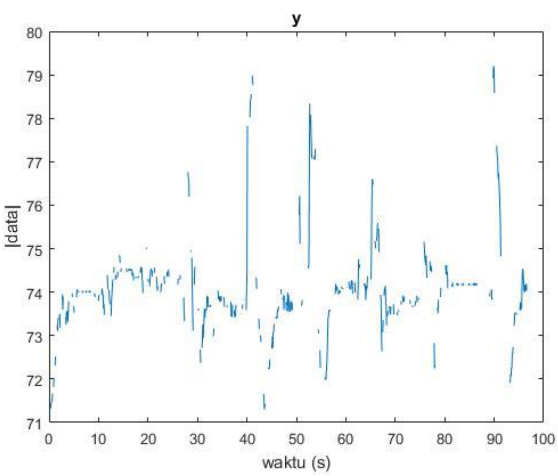

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FIGURE 5. The Digital Signal

The figure Fig. 10. 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 10. Obtained after being given a digital filter on the Arduino program. By using a 480Hz LPF digital filter. But 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:

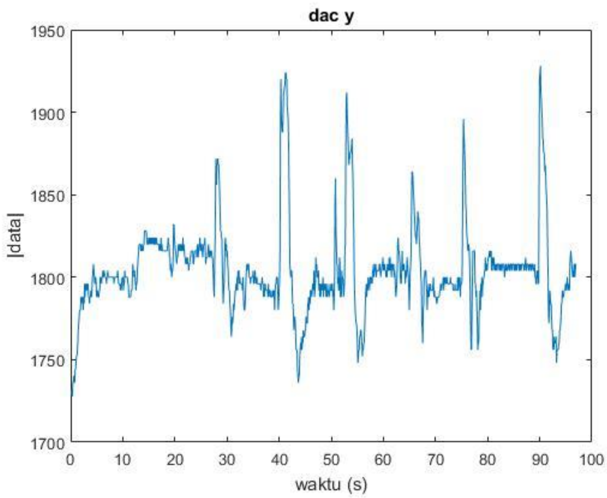

FIGURE 6. The DAC of Filter Digital

The data results in Fig 11. above, 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 uses a DAC module, which functions to convert digital signals to analog so that they can be recorded and viewed.

2) THE LISTING PROGRAM FOR ARDUINO EMG AND RECORD

In this paper, the software was divided into three sections which is for Analog filter record, Digital filter record, and DAC programming. The listing program for Analog filter record was shown in the Program 1.

Program 1.For record analog filter

```
#include <Servo.h>
Servo myservo;
Servo servo;
float EMGPIN = A0;
int pot=A2;
float sudutA;
int analog;


void setup()
{
pinMode(10, OUTPUT);
pinMode(pot,INPUT);
Serial.begin(9600);
}


void loop() {
int potensio = analogRead(A2) ; //Reads analog voltage from A1
int tegangan = (5/1023.0)* potensio
analog = analogRead(EMGPIN )*4; //Read Analog value from pin A0 and convert into digital (0-1023) multiply with 4 gives (0-4096)
sudutA=map(analog,0,4096.0,0,180);
if (sudutA>= 79) {
myservo.attach(10);
myservo.write(180);
delayMicroseconds(10);
}
if ( sudutA<= 78) {
myservo.write (0);
delayMicroseconds (10);
}
Serial.print(tegangan);
Serial.print(",");
Serial.println(analog);
delay(100);
}
```

3) THE DIGITAL RECORD

This program is for recording digital signal. It contain any something that make the result not perfect in recording. Program 2. For record digital filter

```
#include <Servo.h>
Servo myservo;
Servo servo;
float EMGPIN = A0;
const int digitalAnalog=A1;
int pot=A2;
float sudutD;
float digital;
int hasilPot;
int potensio;
int tegangan;
#define ts 0.001 //periode dari frekuensi sampling 1/1000
sampling T=1/fs
```

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```
int input;
//LOW  PAS IIR ORDE 4 FS 1000 FC 480
double b[5] = {0.84847529552435885,3.3939011820974354 ,5.090851773146154 ,3.3939011820974354,0.84847529552435885 };
double a[5] = {1,3.6717290891619347 ,5.0679983867341889 ,3.1159669252017448 ,0.7199103272918711 };
double
y,y10,y9,y8,y7,y6,y5,y4,y3,y2,y1,x,x10,x9,x8 ,x7,x6,x5,x4,x3,x2,x1,x0;//Variabel filter butterworth
void setup()
{
pinMode(10, OUTPUT);
pinMode(pot,INPUT);
communication
Serial.begin(9600);
}
void loop() {
int potensio = analogRead(A2) ; //Reads analog voltage from A1
int tegangan = (5/1023.0)* potensio;
dac = ((analog*y)/analog);    //hasil dari filter digital
float ipvolt = (5.0/4096.0)* analog;  //Finding
unsigned int digital = analogRead(A1)*4 ; //Reads analog voltage from A1
hasilPot=analogRead(A1)*4;
sudutD=map(hasilPot,0,4096.0,0,180);


y6=y5;
y5=y4;
y4=y3;
y3=y2;
y2=y1;
y1=y;
//
x6=x5;
x5=x4;
x4=x3;
x3=x2;
x2=x1;
x1=x0;
x0=analog;
y=b[0]*x0 + b[1]*x1 + b[2]*x2 + b[3]*x3 + b[4]*x4 + b[5]*x5 + b[6]*x6 - a[1]*y1 - a[2]*y2 - a[3]*y3 - a[4]*y4 - a[5]*y5 - a[6]*y6;
if (sudutD>= 80) {
myservo.attach(10);
myservo.write(180);
delayMicroseconds(10);
}
if ( sudutD<= 79) {
myservo.write (0);
delayMicroseconds (10);
}
Serial.print(tegangan);
Serial.print(",");
Serial.println(digital);
delay(100);
}
```

4) LISTING PROGRAM FOR DAC

This program to change the result of digital filter from Program 2. So the signal can full on recording.

Program 3. Program for DAC

```
#include<Wire.h>                    //Include Wire library for using I2C functions
#define MCP4725 0x60
const int digitalAnalog=A1;
unsigned int dac;
byte buffer[3];


void setup()
{
pinMode(10, OUTPUT);
pinMode(pot,INPUT);
Wire.begin();                       //Begins the I2C communication
Serial.begin(9600);  }
void loop() {
int potensio = analogRead(A2) ; //Reads analog voltage from A1
int tegangan = (5/1023.0)* potensio;
buffer[0] = 0b01000000;             //Sets the buffer0 with control byte (010-Sets in Write mode)
analog = analogRead(EMGPIN )*4;              //Read Analog value from pin A0 and convert into digital (0-1023) multiply with 4 gives (0-4096)
sudutA=map(analog,0,4096.0,0,180);
dac = ((analog*y)/analog);       //hasil dari filter digital
float ipvolt = (5.0/4096.0)* analog;    //Finding
```

```
voltage formula (A0)
buffer[1] = dac >> 4;  //Puts the most significant bit values
buffer[2] = dac << 4;  //Puts the Least significant bit values
Wire.beginTransmission(MCP4725);  //Joins I2C bus with MCP4725 with 0x61 address
Wire.write(buffer[0]);  //Sends the control byte to I2C
Wire.write(buffer[1]);  //Sends the MSB to I2C
Wire.write(buffer[2]);  //Sends the LSB to I2C
Wire.endTransmission();  //Ends the transmission
}
```

IV. DISCUSSION

From this research, the researchers made a simulation of the upper limb exoskeleton with emg control. Which 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. In running this tool 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. From 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, so to bring out the signal from the digital filter clearly requires a module. DAC as a converter of digital input to analog so that it can be used or recorded in full. Overall the signal can be displayed directly on the serial plotter or serial monitor

This tool has been tested 10 times. And 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^{o} and have a large angle difference when measured with a digital tilt gauge.

From a previous study belonging to Twenty Rahayu who made CPM with 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 2kg. 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 with EMG control. 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 being tapped. From this study, analog filters tend to produce stable motion in the exoskeleton. while 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. But digital signals cannot be recorded directly using TeraTerm if you don't 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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ATTACHMENT

If you need the program and example file matlab. You can visit this.
https://drive.google.com/drive/folders/1EzkA4vJw7I5lzimg_FWM71ezmqnu5jR8?usp=sharing