

RESEARCH PAPER

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Analysis of TENS Use in Muscle Fatigue with EMG Signal Monitoring (EMG Parameters)

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ABSTRACT Fatigue is defined as a decrease in the strength of the induced muscle contraction protocol. Muscle fatigue is a decrease in the ability to produce strength caused by exercise without rest. Abnormal fatigue can also be caused by restriction or disruption at various stages of muscle contraction. EMG is a technique for measuring the electrical activity of muscles. EMG signals are used to evaluate fatigue by monitoring changes in activity. Electrical signals produced by muscle fibers such as muscle weakness, numbness, certain types of pain, cramps, muscle disorders such as polymyositis or biomechanical movements of living things and can be used to determine the level of weakness and muscle strength for recovery purposes. The purpose of this study was to analyze the use of TENS in muscle fatigue by monitoring EMG signals (EMG parameters). The contribution of this study is to know the difference between pre-exercise, post exercise, and post Tens at the time of muscle fatigue. Tool design using Arduino Uno Microcontroller by processing analog signals with ADC data processed to FFT. The result of the EMG signal will be transferred to a PC (Laptop) device that serves to receive and process data whose results will be displayed in the form of EMG contingency signals. myoware muscle sensor serves to measure or monitor the work activity of listic muscles. Mpf data results in respondents with TENS therapy showed an average value in pre exercise + SD respondents of $0.9009 + 0.0973$, on average post exercise + SD of $1.4170 + 0.2153$, and in post TENS average + SD of $1.1040 + 0.1511$. The results showed that after testing the T-test of MPF post exercise and Post TENS data it can be known that there are significant differences in mpf values ($p\text{Value} < 0.05$) in post exercise and Post TENS. The results of this study can be implemented for muscle therapy at a time of muscle fatigue.

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myoware muscle sensor,
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I. INTRODUCTION

Exercise is basically a physical activity that can help optimize the development of the body through movements based on muscle movements. In the world of sports, an achievement and fitness can be achieved not only with talent or nutritional intake but the right training program. Athletes need good physical fitness so as not to experience fatigue during exercise. Strong and long muscle contractions result in a state known as muscle fatigue [1]. Fatigue is defined as a decrease in strength from the induced muscle contraction protocol. Muscle fatigue is a decrease in the ability to produce strength caused by exercise without rest. abnormal fatigue can also be caused by limitations or interference with different stages of muscle contraction. Muscle fatigue in general can be assessed based on the percentage of muscle strength decrease, muscle fatigue recovery time, as well as the time it takes until fatigue occurs.

Muscle fatigue will result in a decrease in the working efficiency of the muscles [2][3][4]. ATP is very important to prepare myosine to bind and provide energy for myosine [5][6]. EMG is a technique for measuring the electrical activity of muscles. EMG signals are used to evaluate fatigue by monitoring changes in activity. Electrical signals produced by muscle fibers such as muscle weakness, numbness, some types of pain, cramps, muscle disorders such as polymyositis or biomechanics of the movement of living things. and can be used to determine the level of weakness and muscle strength for recovery purposes [7][8][9][10][11][12][13]. TENS is a tool to stimulate the blood flow and muscles of human nerves [14]. TENS works by sending electricity to muscles that need therapy, causing muscles to train passively [15]. Long-term TENS is applied to

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the human body, can cause muscle fatigue and build-up of waste material, and serious muscle damage[16][17].

Some previous studies have introduced several muscle fatigue indexes that are processed from EMG signals in the frequency domain. Fast Fourier Transform is an algorithm used to represent signals in discrete time domains and frequency domains[18]. Fourier transformation is the most commonly used method for estimating the spectrum of EMG signals. They introduced the average frequency of the spectrum to determine differences before and after fatigue. D.yuliansyah research and W.yoon research have noted that frequency-based EMG variables are more sensitive to fatigue-related changes[19][2]. Cahyadi conducted research to detect muscle fatigue during arm movement using EMG signals [3]. F.khanam and M. Ahmad use the domain-frequency or domain-spectral feature commonly used to assess muscle fatigue and to convert EMG signals in domain-time to domain-frequency. Fourier transformation of emg signal autocorrelation function is used to provide power spectrum (PS) or power spectral density (PSD) [20]. In the previous research Triwiyanto in 2016, propose DWT analysis of EMG signals to infer which decomposition levels are most determined muscle fatigue in dynamic movement[16]. In 2017 Triwiyanto investigated the effects of muscle fatigue quantitatively on spectral parameters and the frequency of time from EMG signals using CWT. It was found that when the muscles are in a state of fatigue, then the spectrum parameters of the EMG signal change. The IMNF average decreased by 15.69% and the IMNP average increased by 84.14% [17].

Based on some of the literature that has been described, then some weaknesses in previous research, among others, no one discusses tens analysis, or analysis about before and after therapy by TENS. Based on the results of the identification of the above problems, the author intends to make a tool "Analysis of Tens Use In Muscle Fatigue With Emg Signal Monitoring (EMG Parameters)". The purpose of this study is to see the difference in muscle condition directly, so that the effectiveness of using TENS therapy on muscle fatigue can be known. The use of this design is more effective because it has advantages in terms of data collection on respondents, because by combining TENS and EMG the results of TENS therapy on muscle fatigue can be done directly using EMG so that the effect of using TENS therapy on muscle fatigue can be known. This article is composed of : Chapter I contains introduction, Chapter II contains Material and Methods, Chapter III contains Content, Chapter IV contains discussions and Chapter V contains conclusions.

II. MATERIALS AND METHODS

A. Experimental Setup

This study used 6 normal subject with age criteria 18-23 years. The subject was selected randomly. The data collection is taken through three steps with 5 times repetition. There are pre-exercise, post exercise and post TENS.

B. Materials and Tool

This study is used a myoware sensor as measurement or observe of the biceps muscle. The microcontroller is used Arduino Uno as data processing and serial communication used a Telemetry Viewer application. Telemetry viewer is application for record an ADC signal that connected with Arduino Uno who saved as .csv format. Matlab application is used for data processing that have been recorded with FFT method.

C. Experiment

After the design is completed, there are 3 steps to collect the data with 5 repetition. The 3 steps is pre-exercise, post exercise and post therapy by TENS then data will be recorded with telemetry viewer. Then, the data will be processed by matlab application from time domain to frequency domain. Firstly, pre-exercise is when the subject will be recorded without doing anything. Secondly, post exercise is when the subject was doing an exercise or given a dumbbell to make a biceps muscle fatigue. After that, the biceps muscle will be recorded by using myoware muscle sensor. And lastly, post TENS or after doing therapy by TENS, the subject have a therapy for 10 minutes by TENS and then recorded.

D. The Diagram Block

In Figure 1 shows that electrode is showing the biceps of subject. Then, the signal will be amplified and filtered analog on signal conditioning which is expected to reduce a noise in EMG signal. Furthermore, the analog signal is processed by microcontroller to digitized using ADC in Arduino Uno. Arduino Uno Microcontroller works with C language programming to process data, display the EMG signal and transfer it to PC by pairing it first. The baudrate of sending data is used for receive and process data which is displayed an EMG signal construction.

User attaches electrodes to subject for shows the muscle signal. After the module is turned on, it wil initialize and get an ADC data from EMG instrumentation. Then, it will process on microcontroller and sent to PC so that it can be monitored. And process with FFT method so it will be displayed on PC.

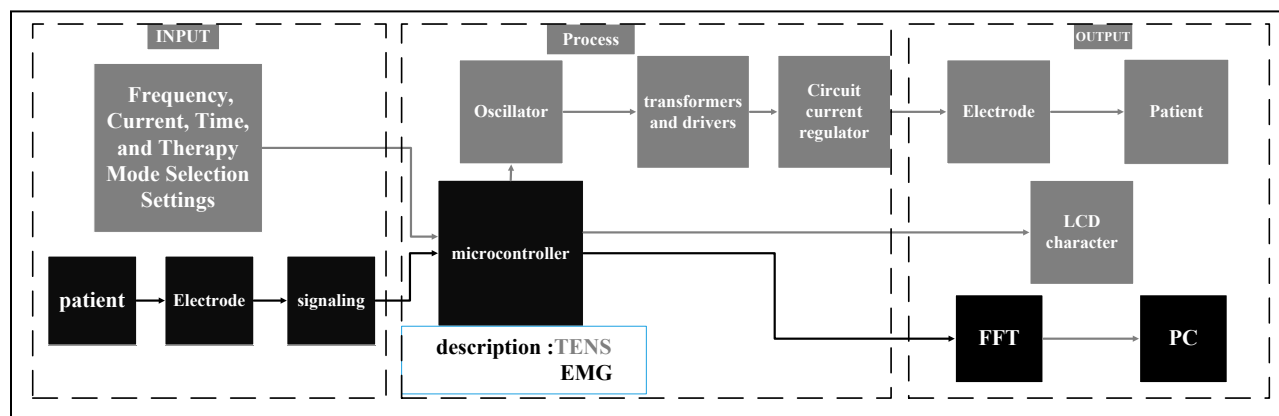


FIGURE 1. Block Diagram of the module TENS Use In Muscle Fatigue With EMG Signal Monitoring (EMG)

E. The Flowchart

In Figure 2 shows a flow chart on the processing of the program on the tool. When the device is turned on, the user attaches electrodes to the patient for tapping muscle signals. After the tool is turned on it will initialize, after that it will get ADC data from the EMG instrumentation leads which read muscle signals which will be processed on the microcontroller and sent to the PC so that it can be monitored.

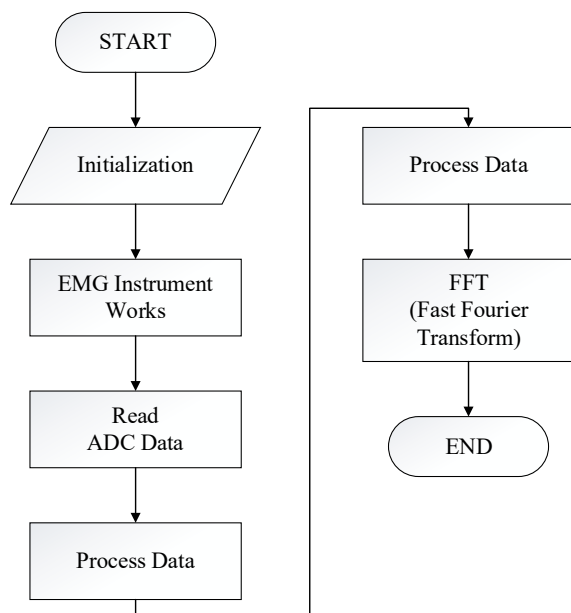


FIGURE 2. The Flowchart of TENS using EMG

III. RESULTS

In this study, the EMG module was tested with an Oscilloscope. The test results show that the output parameters are appropriate to proceed to the FFT processing

The photograph of the module design was shown in Figure 3. In (Figure 3), module was consists of Arduino, TENS, and EMG.



FIGURE 3. Microcontroller Design of EMG

A. The Listing Program

In this study, the software was divided into three sections which is for void library input and initialization, void setup, and for running command. When the required initialization is complete then the void Setup function can be executed. The listing program for void setup was shown in the Listing program for record a signal to telemetry application.

```

void setup() {
  Serial.begin(115200);}
void loop() {
  float function2 = (analogRead(A0));
  char function2_text[30];
  dtostrf(function2, 10, 10, function2_text);
  char text[32];
  snprintf(text, 32, "%s", function2_text);
  Serial.println(text);
}
  
```

We can see from the loop function that is to run the program repeatedly. Analog Read (A0) is used to input from

myoware modul. After record already finished, data will process on matlab application.

Y=Amplitude
(A)

myoware Sensor

Before the module was tested on the human, the myoware sensor was checked on the oscilloscope and telemetry viewer. In Figure 4 and Figure 5 show the output myoware using oscilloscope and Figure 5 show the output myoware using telemetry viewer. Both of them shows the output of myoware sensor while contraction and the maximum voltage is 2,84V.

X=Time(s)

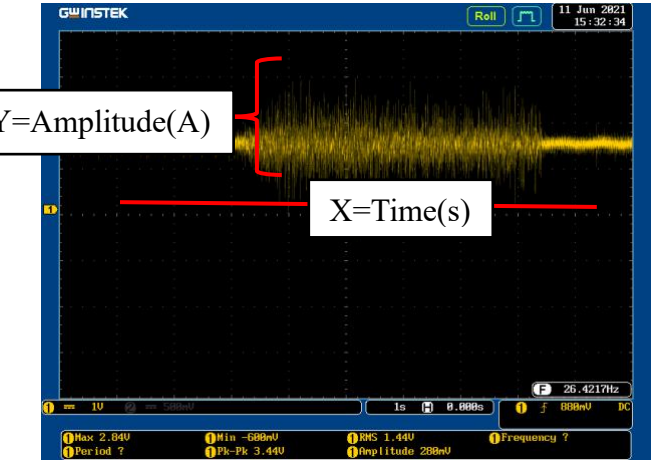


FIGURE 4. Output Sensor EMG (Myoware) on oscilloscope

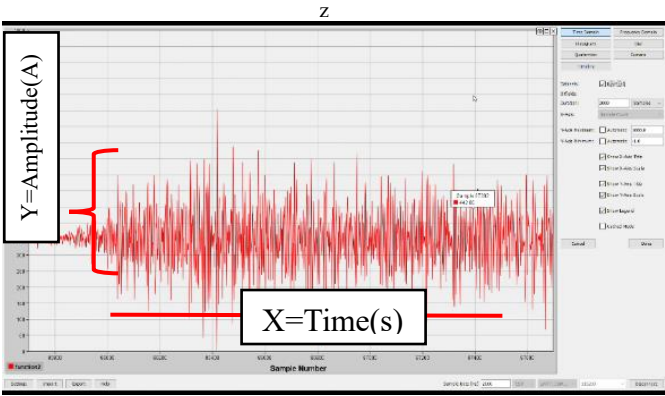


FIGURE 5. Output Sensor EMG (Myoware) on Telemetry Viewer

In Figure 6 shows the output of myoware sensor while relaxation of bicep muscles on normal subject. The amplitude value is 40mV.

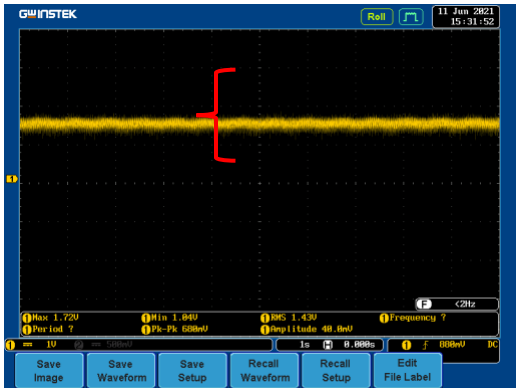


FIGURE 6. Output Sensor EMG (Myoware) on Oscilloscope

In Figure 7 shows the output of myoware sensor while contraction of bicep muscles on normal subject. The amplitude value is 200mV.

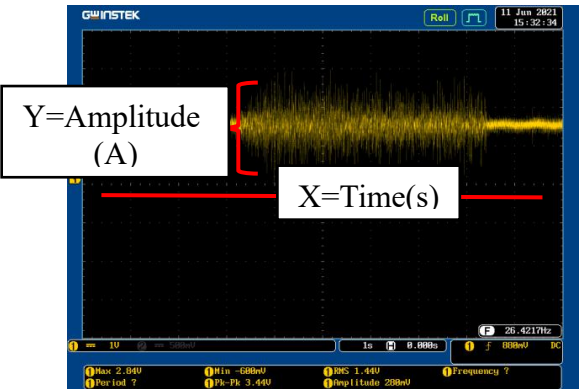


FIGURE 7. Output Sensor EMG (Myoware) on Oscilloscope

Fig. 1.

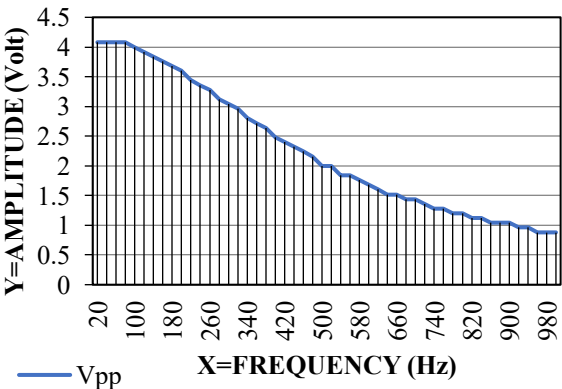


FIGURE 8. Graphic of Plotting Frequency

In Table I. shows the results of MPF data on subject while using TENS. The measurement is taken as 5 times with 3 steps, consist of pre-exercise that the subject was recorded before exercise, post exercise that the subject was recorded

after doing an exercise with 3kg of dumbbell, and post TENS that the subject was recorded while using TENS.

TABLE I. THE RESULTS OF MPF DATA ON SUBJECT USING TENS

SUBJECT	MPF(mV ² /Hz)		
	Pre-exercise	Post Exercise	Post TENS
	Range ± SD	Range± SD	Range ± SD
1	0.7000 ± 0.0950	0.8193 ± 0.1489	0.7223± 0.0942
2	0.9853 ± 0.2130	1.3319 ± 0.2007	1.1446± 0.1503
3	0.7985 ± 0.0639	0.8886 ± 0.1594	0.8150± 0.0660
4	1.0977 ± 0.0818	2.4234 ± 0.3982	1.5933± 0.2098
5	1.0657 ± 0.0966	1.7501 ± 0.2208	1.2821± 0.2133
6	0.7582 ± 0.0333	1.2886 ± 0.1638	1.0668± 0.1732
TOTAL	0.9009 ± 0.0973	1.4170 ± 0.2153	1.1040± 0.1511

In Table II. shows the results of MPF data on subject after TENS about 10 minutes.

Table II. THE RESULTS OF MPF DATA ON SUBJECT after REST 10 minutes

SUBJECT	MPF(mV ² /Hz)		
	Pre-exercise	Post Exercise	Post Rest
	Range ± SD	Range ± SD	Range ± SD
1	0.6321 ± 0.0340	1.4324 ± 0.1290	0.9719± 0.0875
2	0.7977 ± 0.1099	1.6301 ± 0.0832	0.8234± 0.0776
3	0.6099 ± 0.0456	0.9030 ± 0.0391	0.7075± 0.0313
4	1.6751 ± 0.2459	2.6733 ± 0.2647	1.9857± 0.1301
5	0.9566 ± 0.1420	1.4842 ± 0.1642	1.1225± 0.1164
6	0.7824 ± 0.0219	1.4094 ± 0.0504	0.9252± 0.0848

TOTAL	0.9090 ±	1.5887 ±	1.0894±
	0.0999	0.1217	0.0880

IV. DISCUSSION

In this study, the researches has made an analysis of tens use in muscle fatigue with emg signal monitoring. The EMG module used myoware sensor. Data collected by taken through 3 steps with 5 times repetition. There are pre exercise, post exercise and post TENS with 6 subjects. The average value of MPF data on subject with TENS therapy is 0.9009±0.0973 at pre exercise, 1.4170± 0.2153 at post exercise, and 1.1040 ± 0.1511 at post TENS.

The performance of this work is also compared with the work of others. Dhityo Yuliansyah etc. found that his works can cause muscle fatigue by using fest continuously [2]. But the research was carried out simultaneously with an EMG device and a stimulator so that it could not dampen the stimulated EMG signal. Maria Vromans and Faghri found that frequency affects strength and fatigue development and that there are differences between muscles of different composition and fiber size. also to reduce fatigue, FES treatment should not exceed 14-16 minutes for large and small muscle groups [9].

This study has a limitation. The module is not efficient and there is noise at myoware sensor output or bad on relaxation condition.

The benefit of this research is the combination of the TENS module and the EMG module allows to monitor changes in muscle condition so that the effect of TENS therapy on muscle fatigue can be known.

V. CONCLUSION

The purpose of this study is to investigated the effectiveness of TENS on muscle fatigue in the biceps muscle quantitatively. This data collected by 3 steps, there are pre exercise, post exercise, and post TENS. It can be known at post exercise and post TENS, there is a significant difference at MPF value (pValue < 0,05) that has been tested by T-test. This study shows that TENS therapy has effect on muscle fatigue. In the future works, this module can be developed by increasing the lead points to know which parts are experiencing muscle fatigue and add some method in data processing to determine the occurrence of muscle fatigue.

REFERENCES

[1] F. Rosyidah, T. B. Indarto, and M. P. A. T.P, "Monitoring Tetesan Infuse Pump dan Syringe Pump (Faizatul Rosyidah, Tri Bowo Indarto, Moch. Prastawa Assalim T.P) Jurusan Teknik Elektromedik Politeknik Kesehatan Surabaya Jln. Pucang Jajar Timur No. 10 Surabaya," 2018.

- [2] D. Yuliansyah, "Deteksi Kelelahan Otot Menggunakan Sinyal Emg Dan Detektor Gaya Pada Gerak Dasar Ekstensi Dan Fleksi Knee-Joint Untuk Evaluasi Penggunaan Functional Electrical Stimulation Pada Sistem Rehabilitasi Lower Limb," *Tugas Akhir*, p. 171, 2017.
- [3] B. N. Cahyadi *et al.*, "Muscle Fatigue Detections during Arm Movement using EMG Signal," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 557, no. 1, 2019, doi: 10.1088/1757-899X/557/1/012004.
- [4] Y. Utama, "Pengaruh Pemberian Kopi Terhadap Kelelahan Otot," *Skripsi*, pp. 15–19, 2010.
- [5] P. Mohana, "Muscle Fatigue Analysis Using EMG Obtained from IoT Based Neurorehabilitation Device," no. May, 2020, [Online]. Available: <http://search.proquest.com/openview/7709d9c0337f1c0efaf029b9abc560ed/1?pq-origsite=gscholar&cbl=18750&diss=y>.
- [6] Z. Lin and T. Yan, "Long-Term Effectiveness of Neuromuscular Electrical Stimulation for Promoting Motor Recovery of the Upper Extremity after Stroke," pp. 506–510, 2011, doi: 10.2340/16501977-0807.
- [7] J. S. R. Gaurav Raj, Neelam Rup Prakash, "IoT Based EMG Monitoring System," *Int. Res. J. Eng. Technol.*, pp. 355–361, 2017.
- [8] M. Vromans and P. Faghri, "Electrical Stimulation Frequency and Skeletal Muscle Characteristics: Effects on Force and Fatigue," *Eur. J. Transl. Myol.*, vol. 27, no. 4, pp. 239–245, 2017, doi: 10.4081/ejtm.2017.6816.
- [9] M. Vromans and P. D. Faghri, "Functional electrical stimulation-induced muscular fatigue: Effect of fiber composition and stimulation frequency on rate of fatigue development," *J. Electromyogr. Kinesiol.*, vol. 38, no. November 2017, pp. 67–72, 2018, doi: 10.1016/j.jelekin.2017.11.006.
- [10] A. Kumar, S. K. Pahuja, and A. Singh, "Real time monitoring of muscle fatigue and muscle disorder of biceps brachii using Surface Electromyography (sEMG)," *ICSCCC 2018 - 1st Int. Conf. Secur. Cyber Comput. Commun.*, pp. 401–405, 2018, doi: 10.1109/ICSCCC.2018.8703279.
- [11] B. Triwahyu, E. Yulianto, and T. Indrato, "Kursi Roda Dengan Kontrol Sinyal EMG Berbasis Wireless Dilengkapi Sensor Pengaman Benturan (Parameter EMG)," *Poltekkes Kemenkes Surabaya*, pp. 1–8, 2017.
- [12] G. Lattier, G. Y. Millet, A. Martin, and V. Martin, "Fatigue and recovery after high-intensity exercise. Part II: Recovery interventions," *Int. J. Sports Med.*, vol. 25, no. 7, pp. 509–515, 2004, doi: 10.1055/s-2004-820946.
- [13] Advancer Technologies, "Electromyography Sensor for Microcontroller Applications MyoWare™ Muscle Sensor (AT-04-001) Datasheet," p. 8, 2016.
- [14] Y. Setiawan, "Tens triangle and square wave microcontroller," pp. 1–8, 2016.
- [15] L. Mahmunim, "Transcutaneous Electrical Nerve Stimulation Outcomes," *Poltekkes Kemenkes Surabaya*, pp. 1–8, 2018.
- [16] Triwiyanto, O. Wahyunggoro, H. A. Nugroho, and H. Herianto, "DWT analysis of sEMG for muscle fatigue assessment of dynamic motion flexion-extension of elbow joint," *Proc. 2016 8th Int. Conf. Inf. Technol. Electr. Eng. Empower. Technol. Better Futur. ICITEE 2016*, 2017, doi: 10.1109/ICITEED.2016.7863300.
- [17] Triwiyanto, O. Wahyunggoro, H. Adi Nugroho, and Herianto, "Continuous wavelet transform analysis of surface electromyography for muscle fatigue assessment on the elbow joint motion," *Adv. Electr. Electron. Eng.*, vol. 15, no. 3, pp. 424–434, 2017, doi: 10.15598/aece.v15i3.2173.
- [18] A. B. Raharjo, B. Fatukhurrozi, and I. Nawawi, "Analisis sinyal electromyography (emg) pada otot biceps brachii untuk mendeteksi kelelahan otot dengan metode median frekuensi," *J. Electr. Eng. Comput. Inf. Technol.*, vol. 1, pp. 1–5, 2020.
- [19] W. Yoon, "Monitoring muscle fatigue following continuous load changes," *ULSAN Natl. INTITUTE Sci. Technol.*, pp. 1–53, 2020.
- [20] F. Khanam and M. Ahmad, "Frequency based EMG power spectrum analysis of Salat associated muscle contraction," *ICEEE 2015 - 1st Int. Conf. Electr. Electron. Eng.*, no. November, pp. 161–164, 2016, doi: 10.1109/CEEE.2015.7428245.

ATTACHMENT

- Schematic and Board :
<https://drive.google.com/drive/folders/1a6HZKetdCS-yFat5EXWghDr8shAHlfKp?usp=sharing>
- Listing Program :
<https://drive.google.com/drive/folders/1a6HZKetdCS-yFat5EXWghDr8shAHlfKp?usp=sharing>