

## RESEARCH PAPER

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# Palm and Foot Lead Electrocardiograph Signal Enhancement Using Digital Filter

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**ABSTRACT** Electrocardiograph (ECG) signal has proven to be a potential biometric to be used in the diagnosis of arrhythmias or pathologies in the human body. Generally, the location of the leads on the electrocardiograph are the hands and chest. The Purpose of this study, we design electrocardiograph with the lead is located on the palms of the hands and feet for sitting patient. Another purpose of this study to increase the signal which has too much noise that is not needed. This digital filter has the ability to improve its frequency response over time which is compatible for many biomedical signals. In this study using a digital filter type butterworth order 6 with a frequency limit of 0.5Hz to 50Hz. Comparing the results of the ECG signal from an analog filter and a digital filter using FFT. The results of this study can be concluded that from 3 types of digital filters, namely butterworth, chebyshev, and elliptic. By using order 6 the frequency limit is 0.5Hz to 50Hz. There is no significant difference in the results. It is advisable for future research to use other types of digital filters with different orders and frequency limits.

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## KEYWORDS

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## I. INTRODUCTION

Electrocardiogram (ECG) signal has proven to be a potential biometric to be used in the diagnosis of arrhythmias or pathologies in the human body [1] [2] [3] [4] [5]. The special interest in ECG analysis stems from its role as an efficient noninvasive investigative method [6]. Electrocardiogram (ECG) signals can provide a variety of significant properties to advocate for their use as biometrics, such as uniqueness, permanence, and ease of collection. ECG signals collected from fingers or palms contain more noise than signals collected from wrists and chest [7]. Work on ECG biometrics has made new advances, which make it easier to capture an ECG signal when performing it on the iris, fingerprint, palm, etc. [8] [9]. The clinical bandwidth of the ECG signal is 0.05 to 125 Hz, while the monitoring bandwidth is 0.5 to 50 Hz [10] [11]. Digital filters are used to reduce artifacts and interference from the ECG signal [12]. This digital filter has the ability to improve its frequency response over time which makes it compatible for many biomedical signal processing applications [11] [13] [14] [15].

An electrocardiogram (ECG) signal with a monitoring bandwidth of 0.5 to 50 Hz can take heart signal data not only on the wrist and chest but also on the iris, fingerprint, and palm. However, if you take ECG signal data that is placed on the iris, fingerprint, and palm, there will be more noise that will interfere with monitoring the ECG signal.

The design of the ECG machine has been carried out by several researchers in terms of process and data transmission. Rohadatul Aisy designed an ECG that can display the results

displayed on a personal computer [16]. However, the development carried out by Rohadatul Aisy is still not portable. Aziz developed using a portable form [17]. Yunarni did the development using an arduino-based system [18]. However, the development carried out by Yunarni still does not use a portable system. In general, the location of the leads on the electrocardiogram is on the wrist and chest, but Muhammad Syifaul Linnas developed a tapping method on the palms of the hands and feet, so that patients can be more relaxed because patients only put their palms and feet in a sitting position [19]. Rizki Aulia Rachman conducted research on a 6-lead electrocardiogram using Butterworth, Chebyshev I, Chebyshev II, and Elliptic filters. The author states that the Butterworth type digital filter with order 8 is ideal than Chebyshev I, Chebyshev II, and Elliptic [20].

This research was made because in previous research conducted by Muhammad Syifaul Linnas, there was noise when taking signals to humans. So this study will increase the signal using a digital filter in the hope of reducing unnecessary noise so that signal monitoring can be carried out clearly when viewed on the LCD.

The purpose of this study is to increase the signal which has too much noise that is not needed. We design electrocardiograph with the lead is located on the palms of the hands and feet for sitting patient.

## II. MATERIALS AND METHODS

### A. EXPERIMENTAL SETUP

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This study used ten normal subjects with the criteria the ages ranged between 20 and 23 years old. Subjects were sampled within 1 minute and 5000 data were generated in the form of numbers, then processed in a signal processing application.

1) MATERIALS AND TOOL

This study is used a reusable electrodes ECG (Electrodes Pad) and the ECG has been tested using an ECG phantom (Fluke MPS450). The Electordes were attached on palms (right hand and left hand) and soles (right leg and left hand) on the human. Intrumentation amplifier was built based on TL084 OP-AMP. The Arduino Uno microcontroller was used for ECG data acquisition.

2) EXPERIMENT

In this study, after the design is complete, calibration is carried out, the ECG is tested using an ECG simulator (phantom). Each setting, the output of the 3 Lead ECG of the ECG simulator (phantom) is compared with the human body.

B. THE DIAGRAM BLOCK

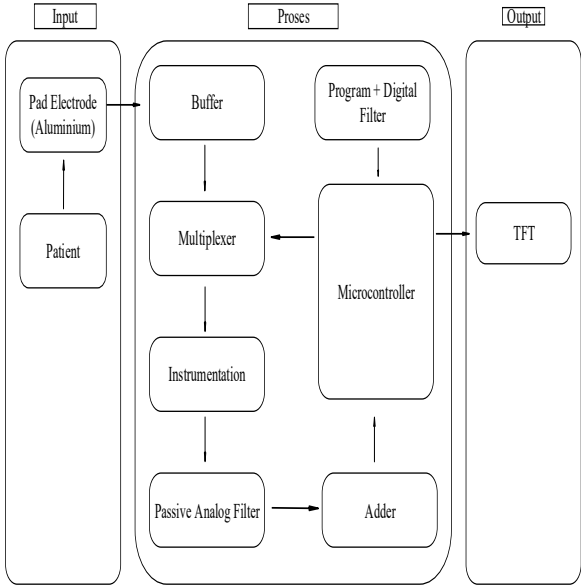


FIGURE 1. The diagram block of the ECG Monitor

In Figure 1 shows the diagram block of this study, heart signals in patients are detected using electrodes that are attached to the patient on the right palm, left palm, left foot, and right foot. In the process block, the signal buffer is carried out using a buffer circuit so that the detected signal is the actual signal. The signal will be selected alternately using a multiplexer to select the signal that has been tapped. The results of the weak heart signal are amplified in the instrumentation circuit. Furthermore, the signal is filtered using a passive analog filter circuit (HPF and LPF). The adder functions as an analog signal conditioner so that the microcontroller can read the voltage, then the signal is raised in reference to 0V to 5V DC. In the microcontroller there is

a digital filter that will reduce the electrocardiogram signal and send it to the TFT LCD.

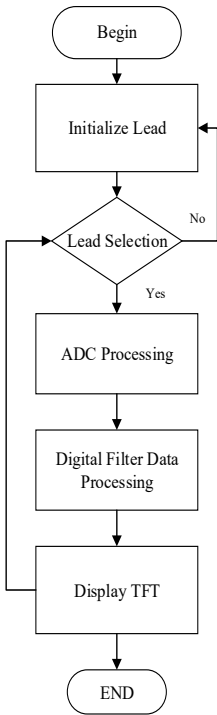


FIGURE 2. The flowchart

C. THE FLOWCHART

The Arduino program was built based on the flowchart as shown in Figure 2. After the initialization of the Arduino, lead selection using a multiplexer module and signals that have been tapped into the instrumentation and filter circuit. The analog signal is converted to digital on the ADC microcontroller and the data is processed using a digital filter program on the Arduino Uno. The processed signal is displayed on the TFT LCD. Lead selection is selected using the buttons on the TFT LCD.

III. RESULT

In this study, the ECG has been tested using an ECG phantom (Fluke MPS450) and ECG from the human body. The result shows that the recording is feasible to record the ECG signal from the human body. The proposed design is shown in Figure 3.

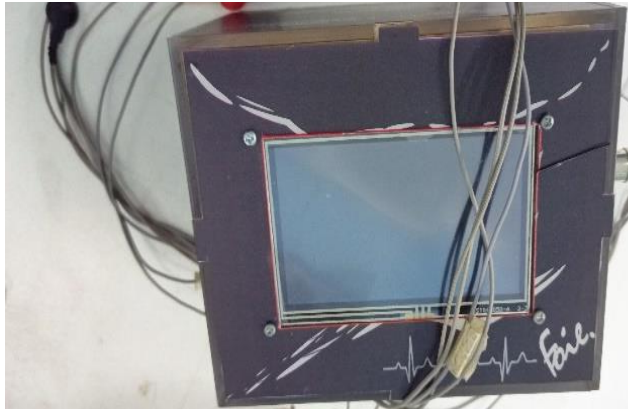


FIGURE 3. The result of the ECG design

### 1) ECG DESIGN

The analog part consists of 2 TL084 (OP-AMP) which each unit consists of four OP-AMP. There are also several variable resistors (10k multiturn) for gain and offset adjustments. The digital part consists of the Arduino UNO microcontroller which is the main board of the device.

### 2) Digital Filter Data Retrieval

Digital filter data retrieval program using. Double b is the numerator coefficient. While double a is the denominator coefficient. Both coefficients are obtained from the manufacture of filters using the Matlab application. x is a variable of the input signal or analog Read (A5). Then the delay Microseconds (3200) is the sampling frequency of the filter of 250Hz according to the manufacture of the filter in matlab. Furthermore, the signal will be processed with a formula and after being filtered (variable y) is displayed on the serial to retrieve data. For filter data retrieval, see **Pseudocode 1**.

**Pseudocode: 1.** Digital filter data retrieval program

```
double b[7] = {0.46892670664165964,0,-
1.406780119924979,0,1.406780119924979,0,-
0.46892670664165964};
double a[7] = {1,-1.3560291972940917,-
0.81831539285592891,0.85826308482086955,1.018107
0633939195,-0.55635346807596864,-
0.14565684413847868};
double
x,y10,y9,y8,y7,y6,y5,y4,y3,y2,y1,y,x10,x9,x8,x7,x6,x5,
x4,x3,x2,x1,x0;
void setup(){
y10=0;y9=0;y8=0;y7=0;y6=0;y5=0;y4=0;y3=0;y2=0;y1
=0;y=0;
x10=0;x9=0;x8=0;x7=0;x6=0;x5=0;x4=0;x3=0;x2=0;x1
=0;x0=0;
Serial.begin(115200);
```

```
}
void loop() {
int nilaiInput = analogRead(ecg);
delayMicroseconds (3200);
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=nilaiInput;
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;
Serial.println(y);
}
```

### 3) THE LISTING PROGRAM FOR TFT

This program is a program to send data to the TFT display. Variable Input value to display the original ECG signal or the signal before it is digitally filtered. Variable results to display the ECG signal after the digital filter is done. ECG with the input from ECG Simulator. For program TFT, see **Pseudocode 2**.

**Pseudocode: 2.** Program for TFT

```
int nilaiInput = analogRead(ecg);
nilaiInput = map(nilaiInput, 0, 1000, 0, 200);
Serial.print("add 2,0,");
Serial.print(nilaiInput);
Serial.write(0xff);
Serial.write(0xff);
Serial.write(0xff);

int hasil;
hasil = map(y,0,1000,0,200);
Serial.print("add 7,0,");
Serial.print(hasil);
Serial.write(0xff);
Serial.write(0xff);
Serial.write(0xff);
```

### 4) THE LISTING PROGRAM FOR SELECTED LEAD ECG

Lead selection based on the lead button on the TFT display. On the start page the logic sent by TFT is `CurrentPage == 0`. When TFT is pressed the START button then the page will change to 1 or `CurrentPage == 1`. The waveform has not shown the ECG until each LEAD button is pressed. When the LEAD 1 button is pressed, Arduino will provide HIGH, LOW, LOW, LOW, LOW logic on pins s0,s1,s2,s3, and E contained in the Multiplexer module so as to produce LEAD 1 configuration output. LEAD 2 button is pressed, Arduino will provide LOW, HIGH, LOW, LOW, LOW logic on pins s0,s1,s2,s3, and E contained in the Multiplexer module so as to produce LEAD 2 configuration

output. LEAD 3 is pressed, Arduino will provide HIGH, HIGH, LOW, LOW, LOW logic on pins s0,s1,s2,s3, and E contained in the Multiplexer module so as to produce LEAD 3 configuration output. For selecting Lead of The ECG Monitor, see **Pseudocode 3**.

### Pseudocode: 3. ECG Lead Selection

```
void pemilihan(){
  if (lead == 1) { //LEAD 1
    digitalWrite(s0, HIGH);
    digitalWrite(s1, LOW);
    digitalWrite(s2, LOW);
    digitalWrite(s3, LOW);
    digitalWrite(en, LOW);
  }
  if (lead == 2) { //LEAD 2
    digitalWrite(s0, LOW);
    digitalWrite(s1, HIGH);
    digitalWrite(s2, LOW);
    digitalWrite(s3, LOW);
    digitalWrite(en, LOW);
  }
  if (lead == 3) { //LEAD 3
    digitalWrite(s0, HIGH);
    digitalWrite(s1, HIGH);
    digitalWrite(s2, LOW);
    digitalWrite(s3, LOW);
    digitalWrite(en, LOW);
  }
}
```

## 5) RESULT USING PHANTOM ECG

Before the ECG was tested on the human, the device was calibrated using artificial ECG which generated from ECG Simulator. the ECG signal data processing using Matlab. Figure 4 show the ECG signal from simulator, Figure 5 show the ECG signal after using digital filter, Figure 6 show FFT of ECG signal, and Figure 7 FFT of ECG signal after using Digital Filter.

From Figure 8 (respondent's ECG signal) with Figure 4, the data from recording the ECG signal using a phantom ECG, the signal already looks different. The ECG signal generated by the ECG signal is more stable than the ECG signal from the body of each respondent and the noise from the phantom ECG is also less than the noise of the ECG signal from the body of each respondent.

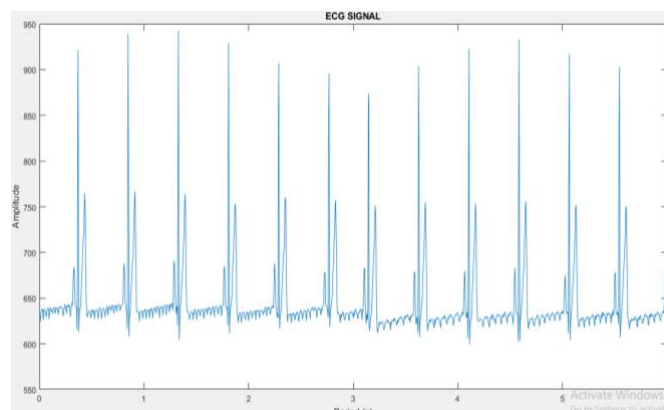


FIGURE 4. The recorded ECG signal from the ECG simulator

Figure 5 is the FFT result obtained from the data from Figure 4. The FFT results of the ECG signal from the phantom ECG, at a frequency point of 90Hz, are lower than the frequency of the ECG signal when using humans.

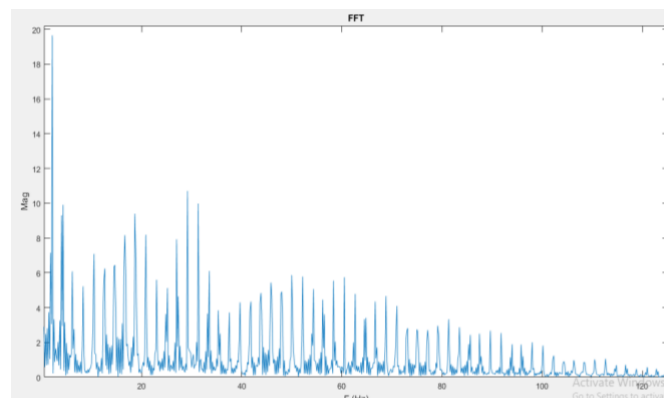
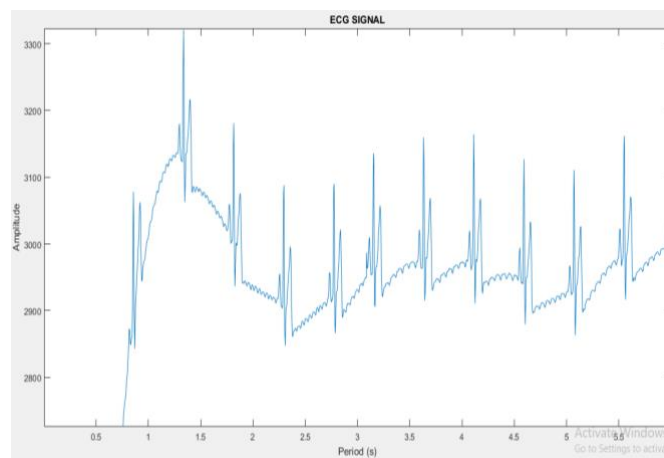


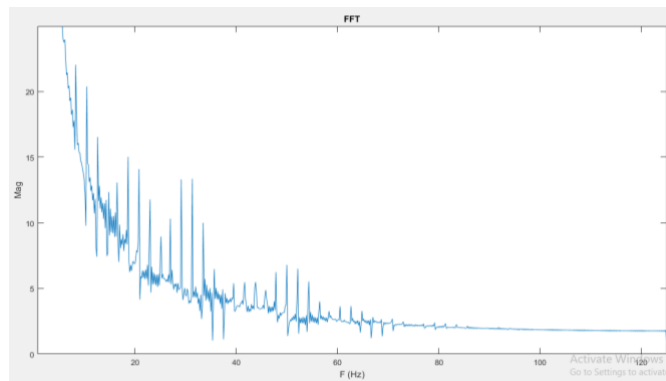
FIGURE 5. The recorded ECG signal from the ECG simulator after using Digital Filter

Figure 6 is the data recorded from the ECG signal from the phantom ECG after passing through the butterworth digital filter.



**FIGURE 6.** FFT of ECG signal

Figure 7 FFT results obtained from the data from Figure 6. From the FFT results that have been obtained, the digital butterworth filter is order 6 with a frequency limit of 0.5Hz to 50Hz. It can be seen the difference between Figure 4.33 and Figure 4.35, at the 50Hz frequency point there is already a frequency suppression although it is not too significant. Significant frequency suppression begins to occur at the 60Hz to 120Hz point.

**FIGURE 7.** FFT of ECG signal after using Digital Filter

#### 6) RESULT USING BUTTERWORTH DIGITAL FILTERS

Figure 8 is data from the respondent's ECG signal recording using only an analog filter. It can be seen from the picture that the results of the ECG signal are still disturbing noise.

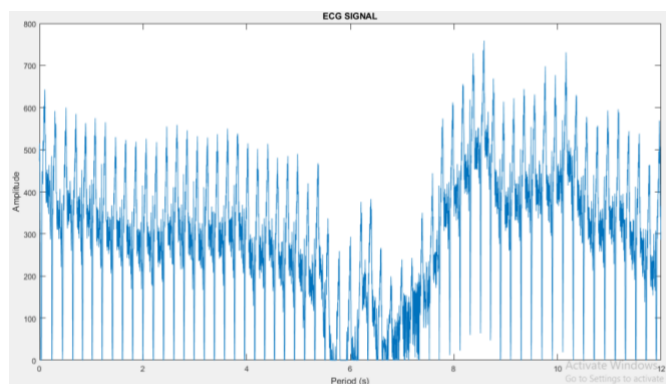
**FIGURE 8.** Respondent ECG Signal

Figure 9 takes the data from Figure 8 when the signal is in the period 7.9 to 8.9. In period 8.1 the height of the R signal is from 300 to 400.

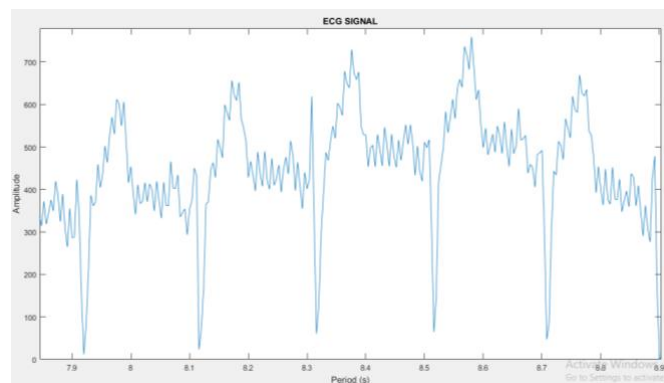
**FIGURE 9.** ECG Signal

Figure 10 is the FFT result obtained from the data from Figure 8. At a frequency of 0.5Hz to 120Hz there is still an incoming frequency so that it can interfere with signal monitoring.

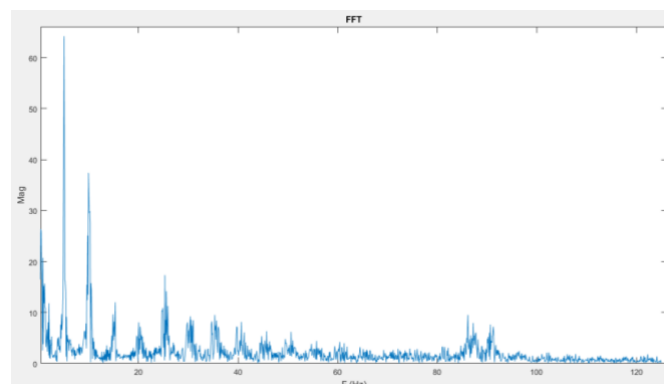
**FIGURE 10.** FFT ECG Signal from Respondent

Figure 11 is the data recorded by the respondent's ECG signal after passing through a butterworth digital filter. The bottom noise on the respondent's ECG signal is not much like Figure 8.

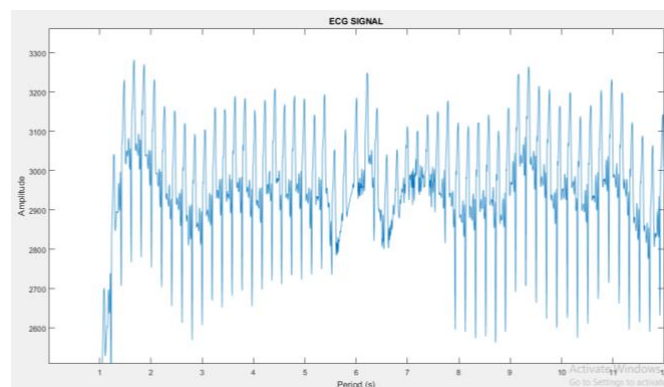
**FIGURE 11.** Respondent ECG Signal After using Digital Filter

Figure 12 takes data from Figure 11 when the signal is in the period 7.8 to 8.9. In the 8.1 period the R signal height is from 2850 to 2900.

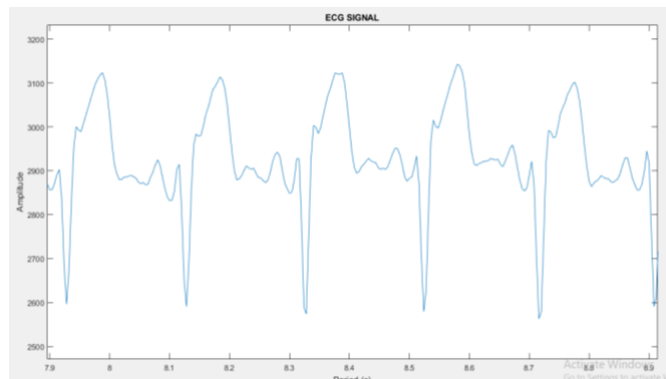


FIGURE 12. ECG Signal

Figure 13 FFT results obtained from the data from Figure 11. From the FFT results that have been obtained, the digital butterworth filter is order 6 with a frequency limit of 0.5Hz to 50Hz. It can be seen the difference between Figure 10 and Figure 13, at the 50Hz frequency point there is already a frequency suppression although it is not too significant. Significant frequency suppression begins to occur at the 60Hz to 120Hz point.

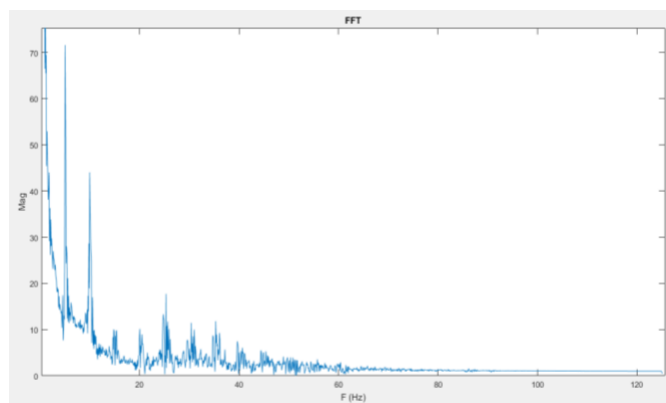


FIGURE 13. FFT Respondent ECG Signal After using Digital Filter

## 7) RESULT USING CHEBYSHEV DIGITAL FILTERS

Figure 14 is data from the respondent's ECG signal recording using only an analog filter. It can be seen from the picture that the results of the ECG signal are still disturbing noise.

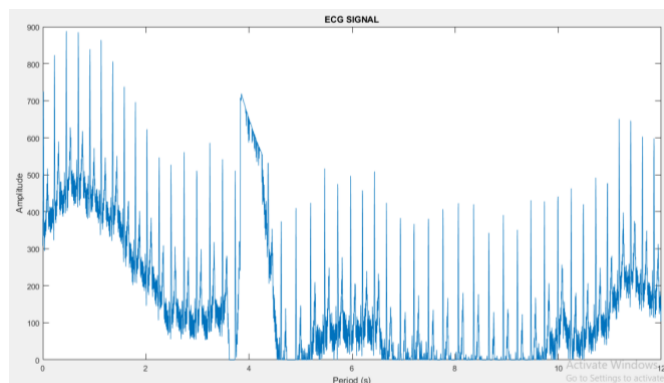


FIGURE 14. Respondent ECG Signal

Figure 15 takes the data from Figure 14 when the signal is in the period 5.1 to 6.8. In period 5.4 to 5.6 the height of the R signal is from 50 to 500.

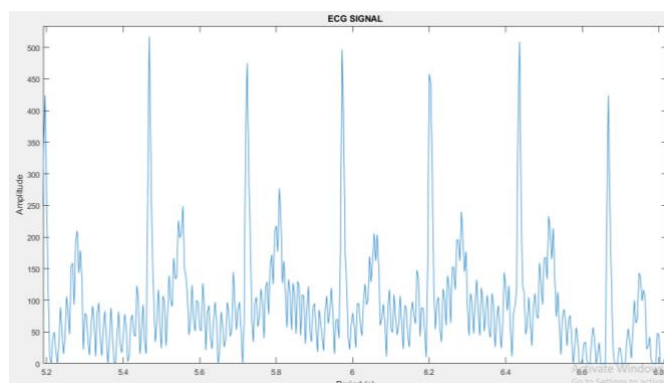


FIGURE 15. Respondent ECG Signal

Figure 16 is the FFT result obtained from the data from Figure 14. At a frequency of 0.5Hz to 120Hz there is still an incoming frequency so that it can interfere with signal monitoring.

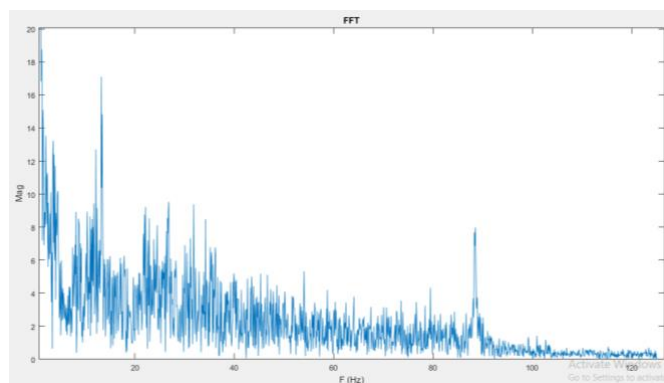


FIGURE 16. FFT Respondent ECG Signal Before using Digital Filter

Figure 17 is the data recorded by the respondent's ECG signal after passing through a chebyshev digital filter. The

bottom noise on the respondent's ECG signal is not much like Figure 14.

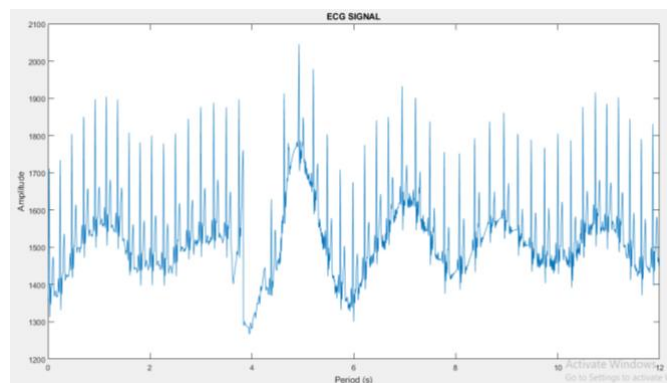


FIGURE 17. Respondent ECG Signal After Using Digital Filter

Figure 18 takes data from Figure 17 when the signal is in the period 5.1 to 6.8. In the 5.4 to 5.6 period the R signal height is from 1500 to 1800.

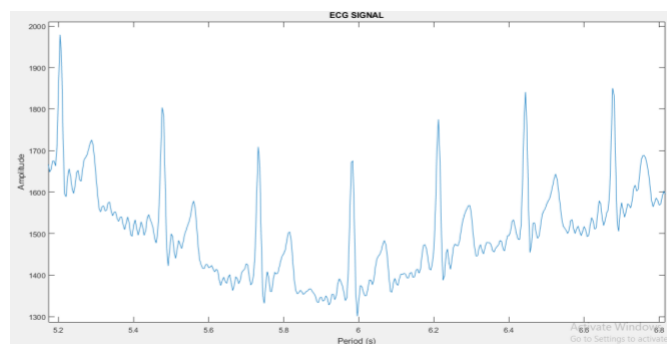


FIGURE 18. ECG Signal

Figure 19 FFT results obtained from the data from Figure 17. From the FFT results that have been obtained, the digital chebyshev filter is order 6 with a frequency limit of 0.5Hz to 50Hz. It can be seen the difference between Figure 19 and Figure 16, at the 50Hz frequency point there is already a frequency suppression although it is not too significant. Significant frequency suppression begins to occur at the 70Hz to 120Hz point.

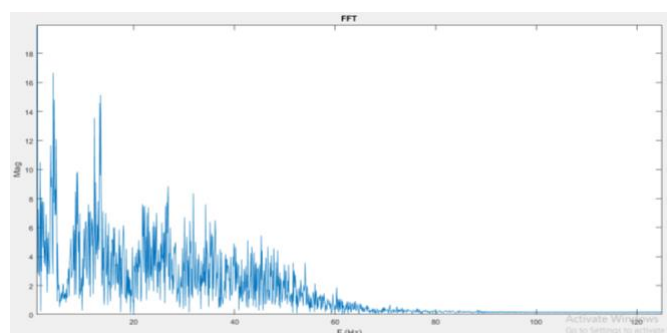


FIGURE 19. FFT Respondent ECG Signal After using Digital Filter

## 8) RESULT USING ELIPTIC DIGITAL FILTERS

Figure 20 is data from the respondent's ECG signal recording using only an analog filter. It can be seen from the picture that the results of the ECG signal are still disturbing noise.

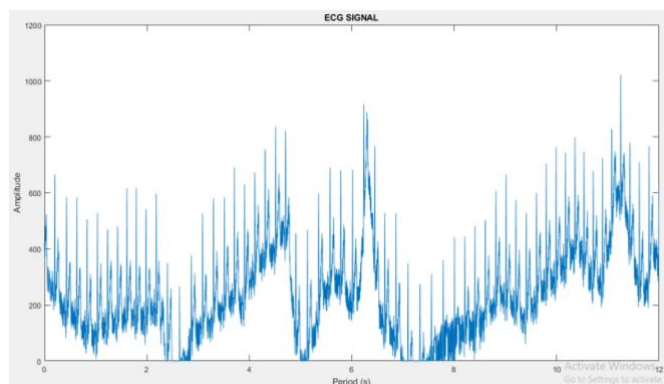


FIGURE 20. Respondent ECG Signal

Figure 21 takes the data from Figure 20 when the signal is in the period 0.1 to 2. In period 1.5 the height of the R signal is from 110 to 490.

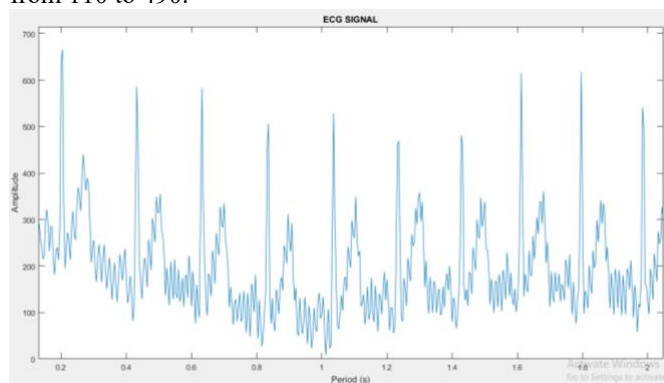


FIGURE 21. ECG Signal

Figure 22 is the FFT result obtained from the data from Figure 20. At a frequency of 0.5Hz to 120Hz there is still an incoming frequency so that it can interfere with signal monitoring.

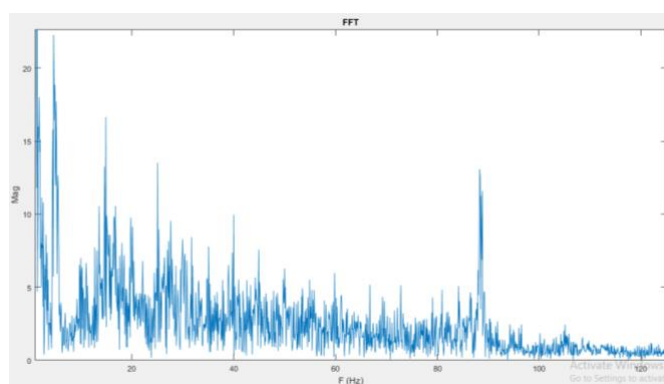


FIGURE 22. FFT Respondent ECG Signal Before using Digital Filter

Figure 23 is the data recorded by the respondent's ECG signal after passing through a elliptic digital filter. The bottom noise on the respondent's ECG signal is not much like Figure 20.

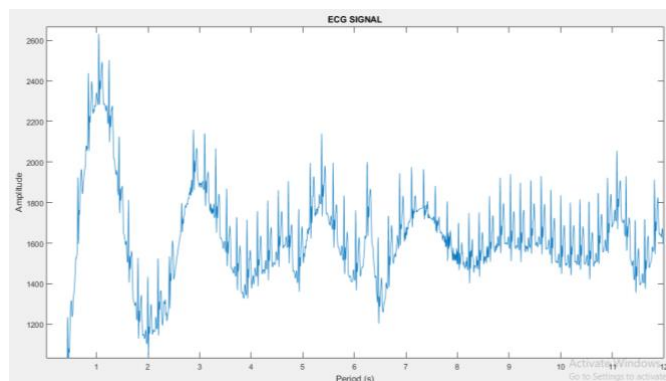


FIGURE 23. Respondent ECG Signal after Using Digital Filter

Figure 24 takes data from Figure 23 when the signal is in the period 0.8 to 1.8. In the 1.5 period the R signal height is from 1800 to 2100.

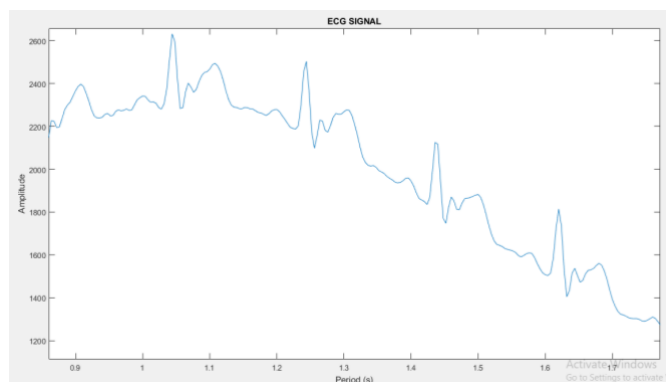


FIGURE 24. ECG Signal

Figure 25 FFT results obtained from the data from Figure 23. From the FFT results that have been obtained, the digital elliptic filter is order 6 with a frequency limit of 0.5Hz to 50Hz. It can be seen the difference between Figure 23 and Figure 21, at the 50Hz frequency point there is already a frequency suppression although it is not too significant. Significant frequency suppression begins to occur at the 70Hz to 120Hz point.

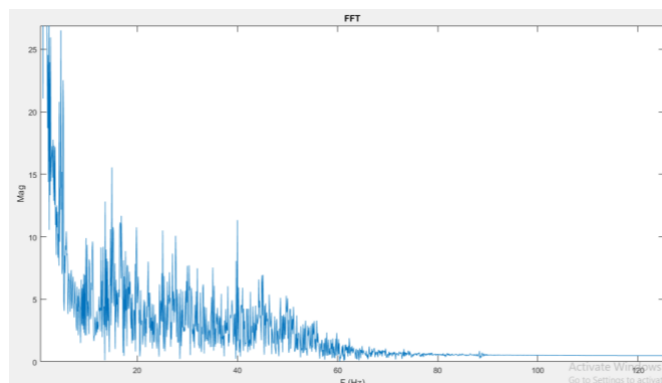


FIGURE 25. FFT Respondent ECG Signal After using Digital Filter

#### IV. DISCUSSION

In this study, 3 types of filters are used, order 6, and with a frequency limit of 0.5Hz to 50Hz. The filters used are butterworth, chebyshev, and elliptic. A digital filter with an order of 6 and with a frequency limit of 0.5Hz to 50Hz, at this frequency it is possible to monitor the ideal ECG signal, because if in order 8 the results of the tests that have been carried out are not showing the ECG signal and if using order 4 the results obtained are still less than the maximum, there is noise that can interfere with signal monitoring. The results of the FFT ECG signal before using a digital filter still contained a frequency of 0.5Hz to 120Hz and the form of the ECG signal obtained still contained noise. The results of the FFT ECG signal after going through the butterworth digital filter process. This filter is only capable of filtering frequencies from 90Hz to 120Hz. And then in this study, the tool has been tested using Phantom ECG. the result that has been obtained is that the digital filter will actually worsen the shape of the signal even though when it is displayed in the FFT there is a difference in the magnitude of the analog filter with the digital filter.

In previous research that has been done. the results that have been obtained previously, the signal still contains noise and this research noise that can interfere has been reduced. can be seen from the results of the FFT that has been used.

The benefit of this study is that the examination of a patient is only carried out in a relaxed sitting position in a chair, by placing both hands and both feet of the patient on the electrode pad that has been prepared.

The drawback of this study is that the signal that has been obtained from each respondent is not exactly at the predetermined baseline position. if using phantom ECG, the signal shape will be worse when using a digital filter. only uses one frequency bandwidth so it will be difficult to decide on the best filter.

#### V. CONCLUSION

The aim of this study is design electrocardiograph with the lead is located on the palms of the hands and feet for sitting patient and to increase the signal which has too much noise

that is not needed. Results from several respondents, this filter is only capable of filtering frequencies from 90Hz to 120Hz because this digital filter design uses Order 6 so the attenuation of the frequency does not match the design results. Butterworth type digital filter with order 6 and with a frequency limit of 0.5Hz to 50Hz, at this frequency an ideal ECG signal can be monitored, because if on order 8 the test results that have been carried out are not showing an ECG signal and if using order 4 the results are correct. obtained is still not optimal, there is noise that can interfere with signal monitoring. If using a phantom ECG. The increase that occurs in the ECG signal is not very obvious when viewed using a TFT LCD and serial monitor on an Arduino. The increase that occurs in the ECG signal will be clearly visible when processed using FFT.

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## ATTACHMENT

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