DOI: 10.35882/ijeeemi.v1i2.125 ISSN:2656-8624

Electrocardiogram 12 Lead in Transverse Plane Based on Computer

YB. Rischa Via Octantri, Her Gumiwang Ariswati and Syaifudin
Department of Electromedical Engineering Poltekkes Kemenkes Surabaya
Corresponding author : YB. Rischa Via Octantri (e-mail: ri2s.yb@gmail.com)

ABSTRACT An electrocardiogram (ECG) is a graph produced by an electrocardiograph to detect heart abnormalities by measuring the electrical activity produced by the heart. Heart disease currently represents 16% of total deaths from all causes. Based on data from the Basic Health Research (Riskesdas) in 2018, the incidence of heart disease is increasing from year to year. At least 15 out of 1000 people, or about 2,784,064 individuals in Indonesia suffer from heart disease. The purpose of this research is to make a 12 lead electrocardiogram (ECG) PC based with storage (transverse plane) to make it easier for users to see the condition of heart signals. The contribution of this research is that devices can display heart signals on a computer and the results can be saved in the form of images and excel. This study used a pre-experimental method. The ECG signal is obtained from the phantom which is connected using an ECG cable. The results of the leads are in the form of heart signals and BPM which will be processed on the microcontroller and then the results will be displayed on a computer and can be saved. Measurement of the BPM value using Phantom on V2 obtained an error value of 0.25% for 120 BPM, 0.125% for 240 BPM. The maximum limit in the BPM error tolerance is ±5%. The results showed that the system as a whole worked well. The shape of the V2 signal generated by the module is the same as the manufacturer's ECG.
Keywords: Electrocardiogram, Heart Signal, BPM, PC, Storage

I. INTRODUCTION

The heart is one of the organs of the body whose function is the most vital compared to other organs [1] [2]. The heart organ which is part of the cardiovascular system is responsible for pumping blood to all parts of the body continuously. Because of this very important function if there is a disturbance in the activity of the heart it can have an impact that can be fatal [3]. Heart disease has been the leading cause of death globally for the last 20 years. However, it is now killing more people than ever before. The number of deaths from heart disease has increased by more than 2 million since 2000, to nearly 9 million in 2019. Heart disease currently represents 16% of total deaths from all causes [4][5][6]. Based on data from Basic Health Research (Riskesdas) in 2018, the incidence of heart and blood vessel disease is increasing from year to year. At least 15 out of 1000 people, or about 2,784,064 individuals in Indonesia suffer from heart disease [7]. ECG or Electrocardiogram is the electrical picture of the human heart and an ECG equipment is needed to pick up and display these electrical signals from the body of a human subject [8][9][10]. An electrocardiogram (ECG) or is a graph produced by an electrocardiograph to detect heart abnormalities by measuring the electrical activity produced by the heart, as the heart contracts. ECG can help diagnose various heart health conditions [11]. Examination of the condition of the heart can be done using an electrocardiograph. Electrocardiogram (ECG) is a medical test to detect heart abnormalities by measuring the electrical activity produced by the heart, when the heart contracts. ECG can help diagnose various health conditions such as cardiac arrhythmias, enlargement of the heart, inflammation of the heart (pericarditis or myocarditis), and coronary heart disease [3].

Bambang Guruh Irianto made a 12-channel ECG device that utilizes the ATmega microcontroller technology, 64x12 LCD, which can interconnect with other devices. The program can be used to transform and run the program to the ECG machine to determine the number of heartbeats, the beep of each R wave of the ECG signal, displayed on the LCD graphic, computer, printed through the computer, and can be stored on the computer [12]. The disadvantages of this device are that there is no 1 mV calibration, paper speed settings, sensitivity and heart rate data collection is not real time. Agustiawan, et al made a device for the acquisition of ECG data. The acquisition design uses an ATMega16 microcontroller as the main controller, USB to serial RS232 as a computer interfacing communication medium [13]. The disadvantages of this device is that it does not use direct input from the human body and the data recording is not in real time. Yaya Suryana conducted research on heart rate monitoring systems. In this study, a heart rate monitoring system was carried out using three electrode sensors. Processing software applications used to display information generated from the module. The front-end hardware is the AD8232 Heart rate Monitor module, Arduino mini pro ATmega328 microcontroller, and electrodes [11]. The disadvantage of this system is that leads are limited to leads I, II and III. Sugondo Hadiyoso conducted research on ECG development and client-server applications. In this study, a 12 lead ECG device was designed with multiplexing technique. The combination of 12 lead ECG signal leads is controlled by multiplexer 4051 through a microcontroller in turn. Digital data results are sent serially to the server computer and can be viewed on the connected client computer. The results obtained indicate that analog devices have successfully acquired ECG signals from Lead I to Lead V6 [14]. The disadvantage of this device is that there is no data storage yet. Tatyana Dimitrova conducted research on high resolution front-end for ECG. This study consists of a 12 channel ECG amplifier built on the concept of body potential drive. The output of the amplifier is connected to 12 delta-sigma ADCs. All ADCs work synchronously and their output data is transferred to a computer via USB [15]. Li ning conducted research on ECG sinyal based on AVR. In tihi study introduces a kind of system which is based on the AVR to acquire the data of ECG. Such system using the A/D function of ATmega8 chip and the lattice graph LCD to design ECG heart acquisition. The disadvantages of this device is still use AVR and signal display in LCD [16]. Muhamad Wildan Gifari did a 12 lead ECG study with only 1 channel and used AD8232. This study presents the design of a single channel portable ECG device developed on the AD8232 chip platform. In order to improve the capabilities of the ECG portable device, the 12-lead ECG acquisition technique was also tested [17]. In this research there is no data storage for analysis data ECG. Alek Lichtman did a hardware and software design for one channel ECG measurement using MSP430 microcontroller. This work deals with hardware design of amplifier needed for a simple biosignal measurement (ECG) and software for processing these data using MSP430 microcontroller [18]. In this research for processing data, still use MSP430 microcontroller. Pallavi Patiil conducted a study on ECG use raspberry pi. The ECG signals are recorded from the patient via the AD8232 ECG module and then this data is digitized using serial ADC MCP3008 [19]. The disadvantages in this research is there is no storage for monitoring heart signal. Yan Lin conducted a study on the 12 lead ECG and monitoring system. In this study, the system consists of two parts, the pre-analog data acquisition section and the digital data processing section. In the analog initial data acquisition section, it consists of three line meter circuits and a main selector. In the digital data processing section, the microcontroller is programmed using C language. The USB interface is also used to transfer data to a computer. A 12 lead ECG system can be performed using a cable selector controlled by a microcontroller [20]. The researcher's suggestion for further research is to add a display for real-time analysis and a memory card for data storage.

Based on the description of the literature study that has been described, there are several things that need to be resolved through a study, including: 1) Monitoring of ECG 12-lead transverse including precordial unipolar leads. 2) Using multiplexer IC. 3) Using a 328 microcontroller IC. 4) Using the best filter to be applied to the module. 5) Using delphi as a display. Therefore, in this study will be designed a PC-based 12 lead ECG with storage.

The purpose of this study is to make a PC-based 12 lead (transverse plane) ECG equipped with storage. This device is made to make it easier for users to monitor ECG signals in precordial leads (V1, V2, V3, V4, V5 and V6). This design is more effective because it has the following advantages: 1) The signal displayed is 12 leads. 2) Displays BPM. 3) Equipped with storage (images and excel).

II. MATERIALS AND METHODS

A. EXPERIMENTAL SETUP

This study used a phantom ECG and two patients. The signal on the phantom ECG was tapped, with precordial unipolar leads (V1-V6) and data retrieval only on V2 was repeated 10 times. The patient's heart signal is tapped and data collection is done once per patient

1) MATERIALS AND TOOL

This study uses an ECG cable that is attached to the phantom ecg and the human body. Instrumentation amplifier using TL084. Arduino Mega microcontroller is used for data processing. Communication to the computer using serial. Delphi as a display that is used to display the ECG signal. A digital oscilloscope (Tetronix) is used to test analog circuits. Phantom ECG (fluke, MPS450 multiparameter simulator) was used to obtain cardiac signals.

2) EXPERIMENT

In this study, testing was carried out on the module and data collection using phantom ecg and the human body. Testing the module using phantom ecg with BPM settings (30, 60, 120 and 240) and sensitivity settings (0.5, 1, 2, 3, 4 and 5 mV) at V2. The results of the signal from the module will be displayed in the Delphi program. Then the results will be compared with the signal generated by the manufacturer's ecg.

B. THE DIAGRAM BLOCK

In this research, ECG recording was done by taking signals from the ECG as shown in FIGURE 1.The signal on the phantom ECG is detected using a cable connected to the transverse leads, namely V1, V2, V3, V4, V5 and V6. Signals will be selected alternately using a multiplexer to select signals. The instrumentation circuit is used to process body signals. The signal will be filtered using an HPF circuit with an fc of 0.05 Hz and an LPF with an fc of 100 Hz. Furthermore, the signal will enter the adder circuit to increase the signal reference from negative to positive. The adder circuit output is connected to the microcontroller ADC pin to be converted from an analog signal to a digital signal. The data will be processed on the microcontroller and will be displayed in the form of an ECG signal graph on delphi7 and stored in excel form.

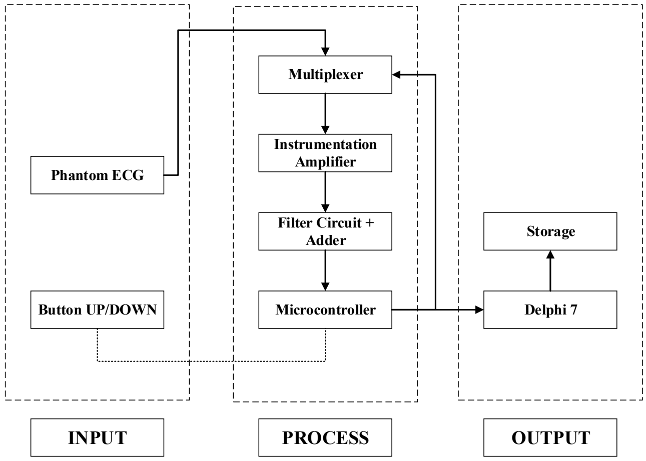


Figure 1. **The diagram block of ECG**

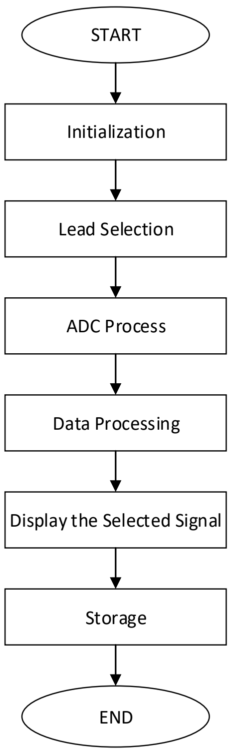


FIGURE 2. The Flowchart of the Arduino Program

C. THE FLOWCHART

The arduino program was built based on the flowchart as shown in FIGURE 2. Lead initialization is performed to pick up the signal on the phantom. Then the selection of leads using a multiplexer IC and tapped using a series of instrumentation and filters. The signal is converted from analog to digital on the ADC microcontroller and the data is processed and displayed on delphi7 and stored. Storage in the form of images (bmp.) and data will be processed and will be displayed in Excel (xls.). Lead selection using the buttons on the device.

D. ANALOG CIRCUIT

The important part of this research consists of: multiplexer circuit in FIGURE 3, instrumentation circuit in FIGURE 4, filter circuit in FIGURE 5 and FIGURE 6 and notch filter circuit in FIGURE 7.

1) MULTIPLEXER CIRCUIT

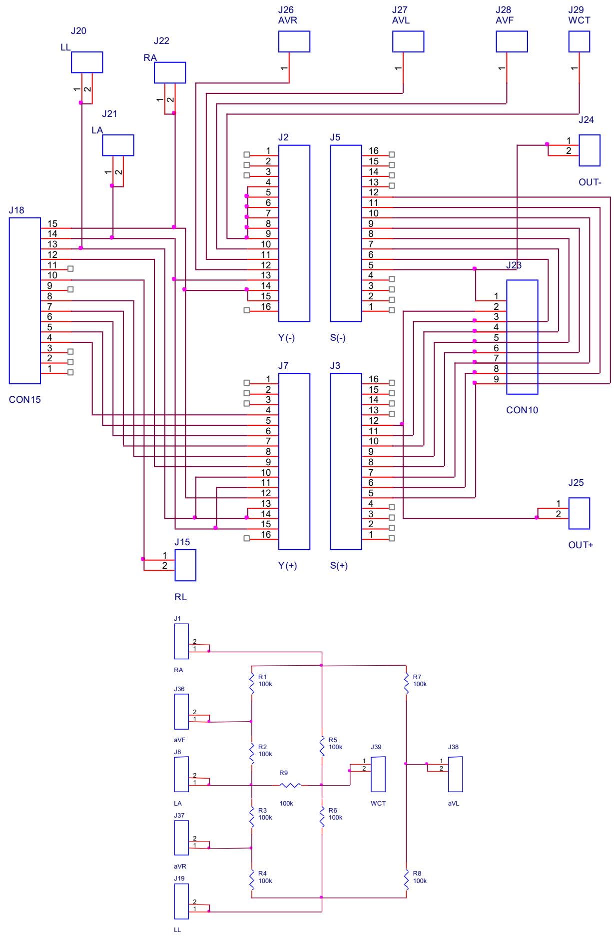


FIGURE 3. Multiplexer Circuit

The multiplexer circuit is shown in FIGURE 3. The CD74HC4067 multiplexer is an analog and digital multiplexer with low power consumption. In the 12 lead selection circuit, it is useful to change the ECG input signal that has been set in such a way that the output that comes out is in accordance with the settings. Requires wilson network circuit wilson central circuit. This terminal (WCT) is a circuit to obtain a reference voltage from taking at three different points of the body to produce an average voltage between the three points of the body. The three pick-up points are right arm (RA), left arm (RL) and left leg (LL).

2) INSTRUMENTATION AMPLIFIER CIRCUIT

IJEEMI, Vol. 1, No. 2, November 2019
DOI: 10.35882/ijeeemi.v1i2.125 ISSN:2656-8624

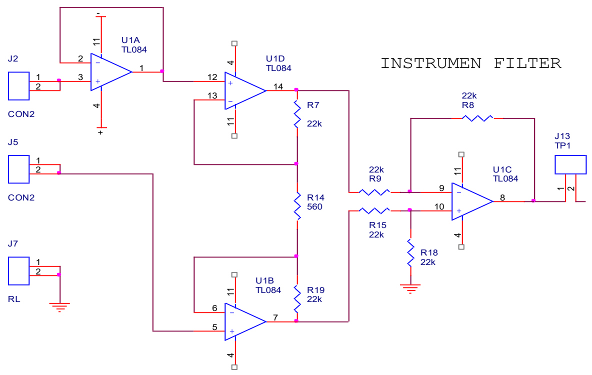
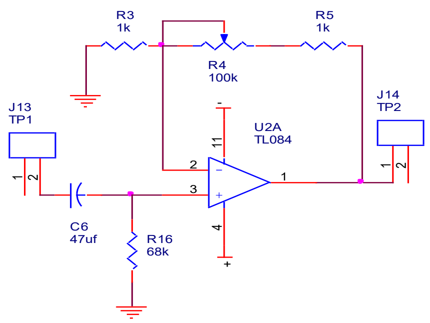


FIGURE. 4. Instrumentation Circuit

The instrument amplifier circuit shown in FIGURE 4. Instrument amplifier is composed of a differential amplifier circuit and a buffer amplifier. The instrument amplifier is useful for adjusting the desired gain by changing the value of Rg (resistor gain). This circuit serves to amplify the signal obtained from the Phantom ECG. At the output there is still a lot of noise (unwanted signal).

3) FILTER CIRCUIT



FiIGURE 5. High Pass Filter Circuit

High pass filter (HPF) in FIGURE 5 is a filter that functions to pass high frequencies and suppress low frequencies or those that are less than the cut off frequency. The HPF used is a passive

Cut-off Calculation :

Fc $= 1/2\pi RC$

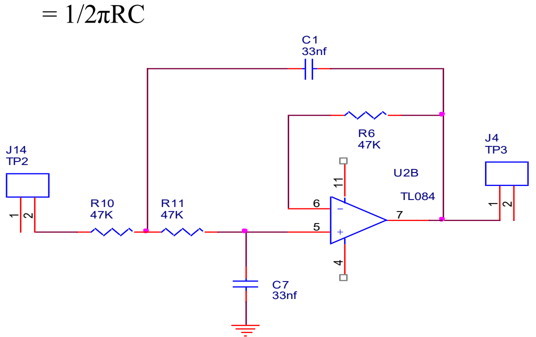


FIGURE 6. Low pass filter

Low pass filter (LPF) is shown at FIGURE 6. LPF is a filter that functions to pass low frequencies and suppress high frequencies or those that are more than the cut off frequency.

Cut-off Calculation :

Fc $= 1/(2\pi \sqrt{(R1 \times R2 \times C1 \times C2)})$

4) NOTCH FILTER CIRCUIT

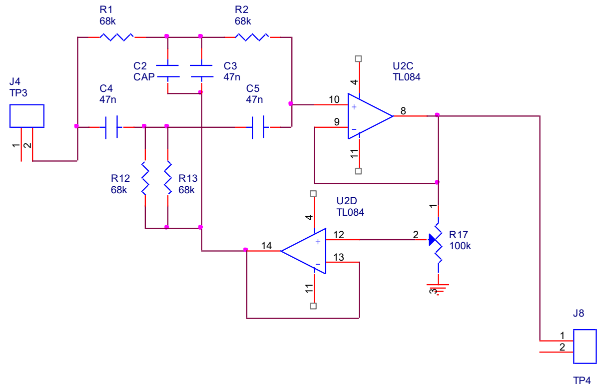


FIGURE 7. Notch Filter

The notch filter circuit is shown in FIGURE 7. This circuit serves to suppress signals that have the same frequency as the cut off frequency and will pass signals that have a frequency outside the cut off frequency, either less than or more than the cut off frequency.

III. RESULT

In this study, the ECG circuit was tested using a phantom ECG (Fluke, MPS450 multiparameter simulator) and an ECG of the human body. The recording results show that the recording is suitable for recording ECG signals. The design shown in FIGURE 8.

FIGURE 8. Design of ECG

1) THE LISTING PROGRAM FOR ARDUINO SELECTION LEAD

In this paper, the software is divided into two parts which are for arduino and delphi programming. The list of programs for arduino is shown in Pseudocode 1. It consists of a program for manual selection of leads.

Pseudocode: 1. Program for manual selection of leads

```
VOID LOOP (){
 IF (digitalRead(button1)==1){
   level
   mux();
   delay(100);
 IF (level>13){
   level=13; }}
 IF (digitalRead(button2)==1 {
   level=level-1;
   mux();
   delay(100);
 IF (level<1)
```

DOI: 10.35882/ijeeemi.v1i2.125 ISSN:2656-8624

```
   {level=1;}}
VOID MUX () {
 //y=1
 IF (level==1) {
   digitalWrite(pin_S0, LOW); //LEAD 1
   digitalWrite(pin_S1, HIGH);
   digitalWrite(pin_S2, HIGH);
   digitalWrite(pin_S3, HIGH);
   //digitalWrite(pin_EN, LOW);
   Serial.println ("LEAD 1");
   delay(1);
   lcd.clear();
   lcd.setCursor(0, 0);
   lcd.print ("Tampilkan");
   lcd.setCursor(5, 1);
   lcd.print ("LEAD 1");
   delay(100);}

 //y=2
 ELSE IF (level==2){
   digitalWrite(pin_S0, HIGH);
   digitalWrite(pin_S1, HIGH); //LEAD 2
   digitalWrite(pin_S2, LOW);
   digitalWrite(pin_S3, HIGH);
   digitalWrite(pin_EN, LOW);
   Serial.println ("LEAD 2");
   delay(1);
   lcd.clear();
   lcd.setCursor(0, 0);
   lcd.print ("Tampilkan");
   lcd.setCursor(5, 1);
   lcd.print ("LEAD 2");
   delay(100);}
```

3) THE LISTING PROGRAM FOR DISPLAY ECG SIGNAL AND BPM

Pseudocode: 2. Program for display the ECG signal and BPM

```
VOID Sinyal1(){
 //==========ECG==========//
  int ecg= analogRead(A1);
  Serial.print("a");
  Serial.print(ECG);
  Serial.print("b");
  delay(10);

 VOID Sinyal2 (){
   int ecg= analogRead(A3);
   //=========Auto ===========//
 IF (ref<=ecg){ref=ecg;}
 ELSE {ref=ref;hold=(ref*0.9);}
   //========end========//
   waktuawal=millis()-waktuBPM;
 IF (ecg>hold) {
   b=1; }
 IF (ecg<(hold*0.7)) {
  IF (b==1){
    BPMpalsu++
    hold=0;
     b=0
    ref=0; }
  IF (BPMpalsu==3) {
    BPMasli=(180000/waktuawal);
    BPMpalsu=0;
    //ref=0;
    waktuBPM=millis(); }}
    Serial.print("e");
    Serial.print(BPMasli);
    Serial.print("f");
```

4) THE LISTING PROGRAM FOR DELPHI ECG

In delphi programming, this program is grouped into several parts, namely : a program to display the ECG signal into a computer and a program to display BPM. Pseudocode 3. It consists of a program to display the ecg signal into the computer and a program to display BPM.

Psedocode 3. Program for display ECG signal and BPM to delphi.

```
//-------------OLAH SINYAL ECG----------//
 Procedure Tform1.ComDataPacket7Packet(Sender:
   TObject;const Str:String);
 Var
   E,dataadc:Integer;
   tegangan:Real;
   begin
 val(Str,dataadc,E);
 IF E <> 0 then exit;
 Tegangan:=dataadc*0.00788758532746823069403
    714565;
 Chart1.Series[0].AddXY(x,tegangan);
  x:=x+0.107;
 IF Chart1.Series[0].MaxXValue>
 Chart1.BottomAxis.Maximum then begin
 Chart1.Series[0].Clear;
    x:=0;
    memo1.lines.Add(str);
    end;
//-------------BPM---------------//
 Procedure Tform1.ComDataPacket1Packet(Sender:
   TObject; const str: String);
   begin
    Label4.Caption:=Str;
    Memo2.Lines.Add(str);
    end;
```

5) THE LISTING PROGRAM FOR SAVE DATA ECG

Delphi programming to save ECG signal and adc data from arduino and save to computer using Image9Click function. Furthermore, the ECG signal will then be saved into photos and excel data. Pseudocode 4. It consists of a delphi program to store the ECG signal.

Pseudocode 4. Program for saving ECG Signal and BPM.

```
//-----------------SAVE---------------//
 procedure Tform1.Image9Click(Sender:TObject);
  begin
 SaveDialog1.Execute;
   form1.Chart1.SaveToBitmapFile(SaveDialog1.
   FileName+'.bmp');
 memo1.LinesSaveToFile(SaveDialog1.FileName+
   '.xls');
 SaveDialog2.Execute;
 memo2.LinesSaveToFile(SaveDialog2.FileName+
   '.xls');
   memo1.Lines.Clear;
   memo2.Lines.Clear;
 Chart1.Series[0].Clear;
 if akandisimpan = false then begin
 Chart1.Series[0].Clear;
   memo1.Clear;
   memo2.Clear;
   akandisimpan:=True;
   end else begin
   akandisimpan:=False;
   end;
   end;
```

6) COMPARISON OF ECG SIGNAL AT SETTING BPM AND SENSITIVITY 1.00 MV

a) V1 Signal

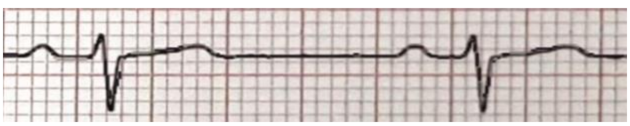


FIGURE 9. V1 Signal Comaprison Between Module and Manufacturer's ECG

FIGURE 9 shows a comparison of the V1 signal generated by the module with the manufacturer's ECG. It can be seen that the overall shape of the signal (wave P - wave T) is the same and there is no difference in the signal high.

b) V2 Signal

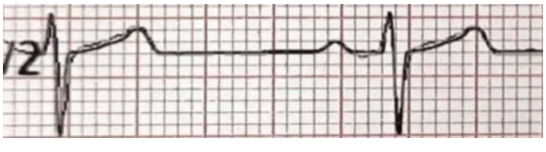


FIGURE 10. V2 Signal Comaprison Between Module and Manufacturer's ECG

FIGURE 10 shows a comparison of the V2 signal generated by the module with the manufacturer's ECG. It can be seen that the shape of the signal is slightly different in the ST segment. for the signal height there is no difference**.**

c) V3 Signal

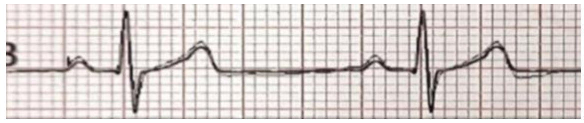


FIGURE 11. V3 Signal Comaprison Between Module and Manufacturer's

FIGURE 11 shows a comparison of the V3 signal generated by the module with the manufacturer's ECG. The thicker signal is the signal generated by the modul. It can be seen that there is a difference in the signal generated by the module. The P and T waves produced by the module are lower than the P and T waves from the manufacturer's ECG.

d) V4 Signal

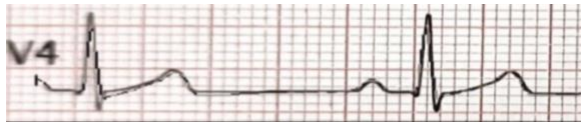


FIGURE 12. V4 Signal Comaprison Between Module and Manufacturer's

FIGURE 12 shows a comparison of the V4 signal generated by the module with manufacturer's ECG. The thicker signal is the signal generated by the module. It can be seen that there is a difference in the signal generated by the module. There are differences in the first wave. The R and S waves produced by the module are lower than the waves from the manufacturer's ECG.

e) V5 Signal

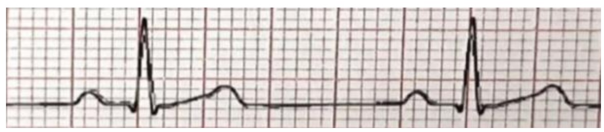


FIGURE 13. V5 Signal Comaprison Between Module and Manufacturer's

FIGURE 13 shows a comparison of the V1 signal generated by the module with the manufacturer's ECG. It can be seen that the overall shape of the signal (wave P - wave T) is the same and there is no difference in the signal high.

f) V6 Signal

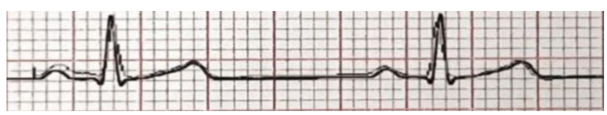


FIGURE 14. V6 Signal Comaprison Between Module and Manufacturer's

FIGURE 14 shows a comparison of the V6 signal generated by the module with manufacturer's ECG. A thicker signal is a signal from the manufacturer's ECG. It can be seen that there is a difference in the shape of the signal. The P-wave that the module produces is higher than the P-wave of the manufacturer's ECG. The S waves are not as sharp as the manufacturer's ECG.

7) THE RESULT OF PROCESSING MEASURING DATA

The BPM value on V2 of the module is obtained from the phantom ECG. The error was showed in Table I.

TABLE I. BPM MEASUREMENT RESULTS USING PHANTOM ON V2

NO	BPM	ERROR (%)
1	30	0
2	60	0
3	120	0.25
4	240	1.25

Table 1. shows the results of measuring BPM using phantom ECG. The results obtained from the module readings with several standard comparison values obtained from phantom. In the module test results using phantom. The calculation of the error value at setting 120 BPM is 0.25%. At 240 BPM, the error value is 0.125%.

IV. DISCUSSION

In this study, data collection using phantom ecg and carried out directly on 2 respondents in reading the ECG and BPM signals. After getting the results, comparing the module with the manufacturer's ECG. It is seen that there are different signal shapes on the PQRST wave. In FIGURE 9, FIGURE 10, FIGURE 11 and FIGURE 12, the results of the comparison of the signal between the module and the manufacturer's ECG show that the module signal results are good, but there is no slight difference in some signals. The results of the signal when reading directly to the respondent are appropriate, but in data collection there are obstacles. Constraints are caused by improper placement of the electrodes and the electrodes used are not good. Table 1 shows the result of measuring BPM using phantom ECG on V2. The calculation of the error value at setting 120 BPM is 0.25%. At 240 BPM, the error value is 0.125%.

Previous studies have dealt with a 12 lead ecg. The results of previous studies are that there is a 1mv button, the use of paper speed and sensitivity. However, there is no storage feature yet. So in this study, added storage features in the form of images and raw data in excel. Storage aims to make it easier for users to monitor heart signals.

The device made has several weaknesses, including there is no 1 mV calibration button, no paper speed and sensitivity settings, using a cable for data transmission (not effective), the resulting signal is slightly different from the manufacturer's ecg. The advantage of this tool is that there is a storage feature in the form of images and raw data in Excel.

The benefit of the device made is to help and facilitate the user in monitoring the ECG signal because there is a storage feature on the device.

V. CONCLUSION

The purpose of this research is to make a PC-based 12lLead ECG device equipped with storage (transverse plane) and can make it easier for users to monitor heart signals. In this study, making a 12-lead ECG (transverse plane, namely V1, V2, V3, V4, V5 and V6), displays the ECG signal and BPM value on a computer (delphi7 software), there is storage in the form of images (for ECG signals) and raw data in excel (for BPM values). The results obtained in this study are: the results of the signals taken from 2 respondents according to the manufacturer's ECG, but there are problems when collecting data. These constraints are caused by improper placement of the electrodes and the electrodes used are not good. In general, it can be concluded that the overall shape of the ECG signal is appropriate, but there are some signals whose shape is slightly different from the manufacturer's ECG signal. Suggestions for further research are using wireless such as wifi and bluetooth, adding sensitivity and paper speed selection features, making device with good grounding so that the ECG signal is not affected by the PLN voltage.

REFERENCES

[1] I. Tyas, *Rancang Bangun Elektrokardiograf (EKG)*, no. 071211533039. 2012.
[2] A. F. Putri and A. Widiantoro, "Monitoring Ekg (Elektrokardiograf) Berbasis Mikrokontroller Dan Pemrograman Delphi 7.0," *J. Tek. Elektro dan Komput. TRIAC*, vol. 7, no. 1, pp. 23–27, 2020, doi: 10.21107/triac.v7i1.7196.
[3] G. B. Adityaputra, T. Tasripan, and T. A. Sardjono, "Rancang Bangun Elektrokardiograf 12-Leads Untuk Sistem Pengawasan Kesehatan Jantung Jarak Jauh," *J. Tek. ITS*, vol. 8, no. 1, 2019, doi: 10.12962/j23373539.v8i1.38341.
[4] "WHO reveals leading causes of death and disability worldwide: 2000-2019." https://www.who.int/news/item/09-12-2020-who-reveals-leading-causes-of-death-and-disability-worldwide-2000-2019 (accessed Dec. 21, 2020).
[5] K. B. Jadhav and U. M. Chaskar, "Design and development of smart phone based ECG monitoring system," in *2017 2nd IEEE International Conference on Recent Trends in Electronics, Information & Communication Technology (RTEICT)*, 2017, pp. 1568–1572, doi: 10.1109/RTEICT.2017.8256862.
[6] L. Zeng, B. Liu, and C. Heng, "A Dual-Loop Eight-Channel ECG Recording System With Fast Settling Mode for 12-Lead Applications," *IEEE J. Solid-State Circuits*, vol. 54, no. 7, pp. 1895–1906, 2019, doi: 10.1109/JSSC.2019.2903471.
[7] *Press Release, World Heart Day PERKI 2019 - News & Event | Perhimpunan Dokter Spesialis Kardiovaskuler Indonesia (PERKI)*. 2019.
[8] A. Al-amin, A. K. M. Bodiuzzaman, A. I. Khan, and K. S. Rabbani, "Design and Development of a PC based ECG Equipment," *Bangladesh J. Med. Phys.*, vol. 6, no. 1, pp. 39–54, 2013.
[9] M. A. Burhanuddin *et al.*, "The Design of Low-Cost Patient Monitor Based on Computer," in *2019 International Seminar on Application for Technology of Information and Communication (iSemantic)*, 2019, pp. 405–410, doi: 10.1109/ISEMANTIC.2019.8884346.
[10] M. A. Agung and Basari, "3-lead acquisition using single channel ECG device developed on AD8232 analog front end for wireless ECG application," *AIP Conf. Proc.*, vol. 1817, no. 1, p. 40015, Feb. 2017, doi: 10.1063/1.4976800.
[11] Y. Suryana and R. Aziz, "Sistem Pemonitor Detak Jantung Portable Menggunakan Tiga Sensor Elektroda," *J. Al-AZHAR Indones. SERI SAINS DAN Teknol.*, vol. 4, no. 1, p. 14, 2018, doi: 10.36722/sst.v4i1.240.
[12] C. Science and B. G. Irianto, "Design of Electro Cardiograph Machine Based on ATmega Microcontroller," *Indones. J. Electr. Eng. Comput. Sci.*, vol. 2, no. 2, pp. 328–333, 2016, doi: 10.11591/ijeecs.v2.i2.pp328-333.
[13] A. Surtono and G. A. Pauzi, "Sistem Instrumentasi Akuisisi Data EKG 12 Lead Berbasis Komputer," *J. Teor. DAN Apl. Fis.*, vol. 04, no. 01, pp. 67–76, 2016.
[14] S. HADIYOSO, M. JULIAN, A. RIZAL, and S. AULIA, "Pengembangan Perangkat EKG 12 Lead dan Aplikasi Client-Server untuk Distribusi Data," *ELKOMIKA J. Tek. Energi Elektr. Tek. Telekomun. Tek. Elektron.*, vol. 3, no. 2, p. 91, 2015, doi: 10.26760/elkomika.v3i2.91.
[15] T. D. Neycheva and T. V. Stoyanov, "High Resolution Front End for ECG Signal Processing," *Electron. 2007*, pp. 61–66, 2007.
[16] L. Ning, Z. Ruilan, L. Jian, W. Xiaochen, C. Shuying, and L.

Zhuolin, “A ECG Signal Gathering and Displaying System Based on AVR,” *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 280, p. 12037, 2017, doi: 10.1088/1757-899x/280/1/012037.

[17] M. W. Gifari, H. Zakaria, and R. Mengko, “Design of ECG Homecare:12-lead ECG acquisition using single channel ECG device developed on AD8232 analog front end,” *Proc. - 5th Int. Conf. Electr. Eng. Informatics Bridg. Knowl. between Acad. Ind. Community, ICEEI 2015*, pp. 371–376, 2015, doi: 10.1109/ICEEI.2015.7352529.

[18] A. Lichtman and P. Fuchs, “Hardware and software design for one channel ECG measurement using MSP430 microcontroller,” in *2018 Cybernetics & Informatics (K&I)*, 2018, pp. 1–5, doi: 10.1109/CYBERI.2018.8337539.

[19] P. Patil and K. Bhole, “Real time ECG on internet using Raspberry Pi,” in *2018 International Conference on Communication, Computing and Internet of Things (IC3IoT)*, 2018, pp. 267–270, doi: 10.1109/IC3IoT.2018.8668157.

[20] Y. Lin and M. Sriyudthsak, “Design and Development of Standard 12-Lead ECG Data Acquisition and Monitoring System,” *Procedia - Procedia Comput. Sci.*, vol. 86, no. March, pp. 136–139, 2016, doi: 10.1016/j.procs.2016.05.034.