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A Simple Handheld Electrocardiogram Design

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ABSTRACT Chances of capturing arrhythmia signals become high when recorded using ECG 12lead. ECG 12lead provide traceability of 12 different heart electrical positions. Each lead intended to take electrical activity from different positions in the heart muscle, addition of Bluetooth is necessary so patient can always be monitored. Purpose of this research to develop ECG with more reading signals. Contribution of this study is makes ECG 12lead so that more heart signals can be diagnosed, by adding Bluetooth making ECG readings more portable for diagnosing so that it facilitates the work of nurses and signals can be monitored any time. From the above purpose, the idea is to make ECG 12lead 3channel display PC with Bluetooth as data transmission. This ECG circuit consists of circuit buffer, Multiplexer, Instrumentation Amplifier, High Pass Filter, Low Pass Filter, Notch Filter, Final amplifier and Adder, ECG signal obtained from the placement of electrodes on the patient's body, and Bluetooth to transmit data and then Delphi program as interface to PC. The results showed an average error value in the BPM reading is 1.04%, Signals matching result obtained an average error value is 2.67%, and this ECG can send signals up to a distance of 35m without obstructions and 12m with obstructions. The conclusion is ECG 12lead 3channel has been created with Bluetooth as data transmission. Results of this study can have implications on conventional ECG to improve signal reading and with the addition of Bluetooth can make it easier for nurses to monitor patients.

INDEX TERMS Heart, ECG, BPM, Bluetooth Module.

I. INTRODUCTION

One of the most important organs in the body is the heart. The heart functions to pump blood so that it can be distributed throughout the body and back to the heart [1]. The heart is a part of the body that has electrical (bioelectric) activity. This electrical activity of the heart can be recorded using an electrocardiogram machine [2]. Electrical events in the heart produce a signal, namely a bioelectric signal so that it can find out disturbances in the heart through an electrocardiogram [3]. According to the World Health Organization (WHO), Cardiovascular disease are the number one cause of death globally, with 17.9 million deaths every year, Cardiovascular disease is one of the leading causes of death in the UK, and a common cause of hospital admission [4]. Therefore, cardiovascular health care is very important, researchers develop skills and knowledge in relation to this issue if patients are to get the best care at the right time. One of the most important diagnostic tests is the 12 lead ECG [5][6]. An electrocardiogram (ECG) is a well-tolerated, non-invasive, and inexpensive test for overt electrical signs of cardiac pathology, including conduction disease, accessory pathways, and channelopathies; structural heart disease and previous ischaemic injury[7]. Experimental evidence has shown that many cardiovascular diseases can be better diagnosed, controlled, and prevented through continuous monitoring and analysis of signals from electrocardiograms [8]. Not only as a disease diagnosis tool, in its development ECG can be used as a daily activity [9], and also in sports activities [10], and even for certain special purposes [11][12][13]. An electrocardiograph is an electromedical instrument that serves to provide graphic data on the electrical potential generated by the heart when it contracts or an image formed as a result of the electrical activity of the heart [14]. Electrocardiograph should give results that are representative of the patient's heart condition [10]. To view the complete state of the heart, leads are needed inferior (leads II, III, aVF), lateral (leads I, aVL, V5, V6), septal (V1 and V2), anterior (V3, V4) and aVR [3][15]. Abnormalities of a person's heart function can be seen from the ECG signal record. The ECG signal can be damaged by various kinds of interference [16]. The clinical standard ECG technique method uses 10 electrodes attached to the body to produce 12 heart-leading signals. Each ECG signal has a different heart vector orientation. In general, leads are divided into 3: frontal leads, unipolar extremity leads, and precordial leads [2]. The signal can directly be displayed and be viewed on a computer [17].

In previous studies, ECG devices have been made by several researchers. One has been carried out by Agustiawan et al. (2015) who made research about Computer Based 12 Lead ECG Data Acquisition Instrumentation System. In 2021, Rizki Aulia Rachman conducted a study e made research about Development of a Low-Cost and Efficient ECG devices with IIR Digital Filter Design. In the study, researchers developed ECG 6 digital lead filter, the shortcomings in the research researchers haya make ECG with 6 Lead only[18]. And also Dwiky Wicaksono. (2015) made research about 12 Lead Electrocardiograph (ECG) Performed Computer (Frontal Field). In this research, the tool discusses 12-lead ECG which is then connected to a serial USB RS232 to display the results on a computer, but in this study, the ECG output display still uses 1 channel only [19][3]. In 2016, researchers named Yan lin and Mana Sriyudthsak made a 12 Lead ECG study entitled Design and Development of Standard 12-Lead ECG Data Acquisition and Monitoring System. This study discusses 12 lead ECG with 3 channel data transmission [20]. In 2012, Parin Dedhia et al. conducted an ECG study about low cost Solar ECG with Bluetooth transmitter. In this study, ECG data is sent via Bluetooth to be displayed on the LCD [21]. However, the drawback of this research is that the ECG still uses only 1 lead. In 2021 Jaehyo jung has also develop ECG using Bluetooth as signal transmitter [22][23]. Daniel E Lucani et al. (2006) conducted an ECG research about A portable ECG. Monitoring device with Bluetooth and Holter capabilities for telemedicine applications." In this study, researchers made a 3 lead 3 channel ECG with Bluetooth data transmission [24].

Based on the description of the literature study that has been described, in this research will be designed "Remote ECG with 3 Measurement Display on Computer via Bluetooth Communication (Limb Lead & Augmented Lead) the purpose of this study is to create an ECG tool with the aim of the ECG tool being able to read more signals by utilizing 12 Leads with 3 direct displays that can viewed on a computer. The lead selection is carried out by a switching system using a multiplexer, and data transmission is carried out via Bluetooth. with the aim of making 12 leads so more signals can be diagnosed, and by using Bluetooth we aim more portable diagnosis for the nurse and the signal can also be monitored at any time. The use of this design is more effective because it has advantages in terms of the number of signals that are read, the display can also be seen 3 at once directly on the Computer screen, the addition of Bluetooth also plays a role in facilitating the work of nurses because monitoring can be carried out within a certain distance. The purpose of this study is to develop ECG so that it can read more signals as much as 12 leads 3 channels, and with the addition of Bluetooth it functions to facilitate the work of nurses in monitoring patients.

This article consists of 5 parts, part II contains the materials and methods to be carried out, Part III, is the results obtained in this study, Part IV is a discussion of the findings, and Part V is the conclusion of this study.

II. MATERIAL AND METODS

A. EXPERIMENTAL SETUP

This study used ECG Phantom as signal source. the data taken is BPM data setting (30,60,120,240), then signal match data, and distance data. The data collection is repeated for 10 times

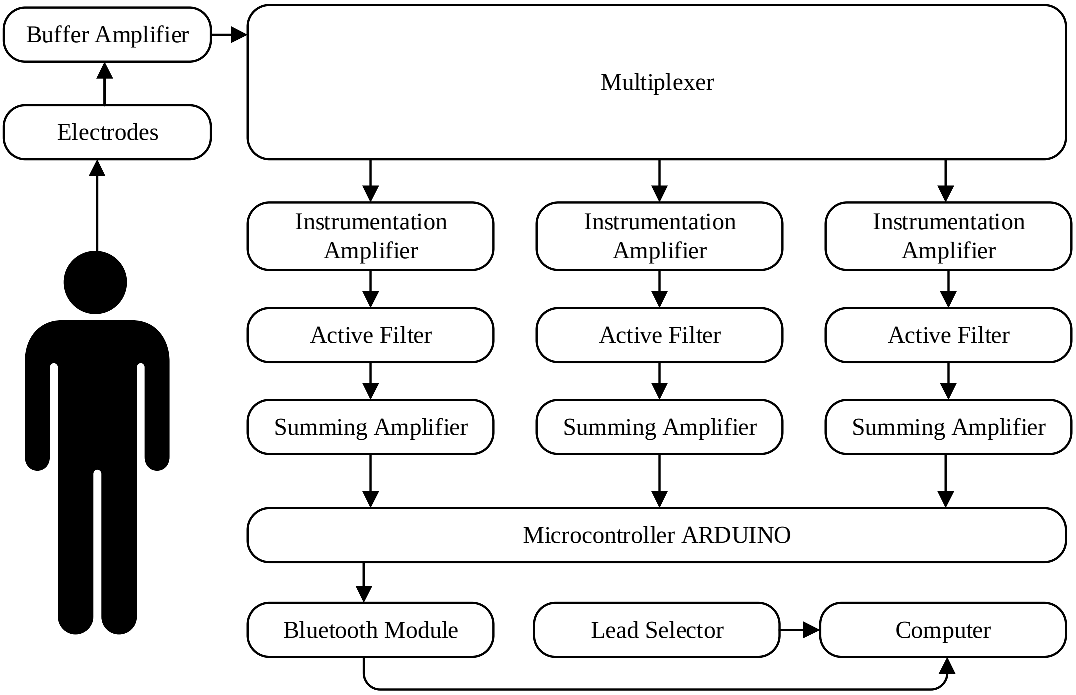


Figure 1. **The diagram block of the ECG Module**

for BPM data, 1 row for signal match and until bluetooth can't send signal anymore on distance data.

This study use fluke ECG Phantom (MPS450) as signal source, then connected to ECG electrode cable and then it will connect on ECG module, Lead Selector or Multiplexer use IC cd4051b as a signal processing, Instrumentation amplifier was built based on IC TL084 OP-AMP. The Arduino Uno microcontroller was used for ECG data acquisition and communication to the computer unit using Bluetooth module HC-05. A digital storage Oscilloscope (Textronic, DPO2012, Taiwan) was used to test the analogue circuit.

In this study, after the design was completed then the frequency response of this device was tested using a function generator according to the specification of the ECG signal. In the calibration stage, the ECG Module was tested using an ECG simulator (phantom) with all range (30, 60, 120, and 240 BPM). Each setting, the output of the was calculated to validate the result of this study. After that we also test signal match and the distance data.

B. THE DIAGRAM BLOCK

In the Figure 1 bellow, First, heart signals in the patient are detected using electrodes attached to the patient's body. Heart signals are detected using 3 instrumentation circuits, where Lead I, aVR, V1, V4 on the first instrumentation circuit, Lead II, aVL, V2, V5 on the second instrumentation circuit, Lead III, aVF, V3, V6 on the third instrumentation circuit. After that, the signal buffer is done by using a series of buffers so that the signal detected is the actual signal and no signal is lost. Furthermore, the signal will be selected alternately (switching) using multiplexer to select the signal to be tapped. The output of the Multiplexer will then go into the instrumentation of the amplifier, on the instrumentation circuit the ECG signal amplifier will be strengthened, the instrumentation output will be filtered using a passive filter with a frequency value according to the heart signal frequency value as well as strengthened by the amplifier. Furthermore, the output of the circuit will be adjusted to the reference value so that it can be read by the microcontroller. The data will be converted from analog to digital on the microcontroller before it is sent using a Bluetooth module. Data transmission using Bluetooth module which will then be received by the Computer and then will be displayed on Delphi software in the form of 3 channels of pre-selected signals that are useful as a signal display.

C. THE FLOWCHART

In the Figure. 2 bellow, when the tool is turned on, the ECG signal is passed on the lead selection block set using the IC multiplexer. This block serves to pass ECG signal tapping from the body controlled by microcontrollers, this block consists of multiplexer IC 4051 which is arranged in such a way as to be able to transmit signals from lead I to lead V6 alternately. IC 4051 has 8 signal input pins with 3 control pins to set the signal where it will be forwarded. The control is done by providing 000-111 logic. Instrument blocks consist of instrumentation amplifiers, filters, notches, final amplifiers, and adders, these blocks serve to process data obtained from the body so that the output data can be seen well, microcontrollers are programmed to control switch changes. to perform the reasoning of each lead then ADC performs signal conversion of each lead. ADC data reading occurs when receiving input from the lead selector, if it gets logic from multiplexer then notification / marker measurement will work so that it will be passed on the data processing that will later be sent using the Bluetooth transmitter module.

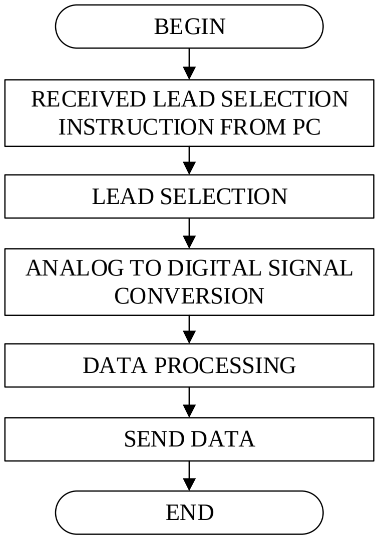


Figure 2. The Flowchart of the Arduino Program

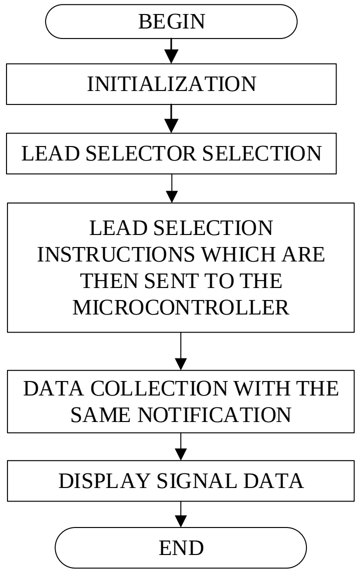


Figure 3. The Flowchart of the Delphi Program

The analog signal of the circuit will be received by Arduino. Then by Arduino the signal will be moved to the HC-05 bluetooth module to be sent to the receiver and will be displayed on the Computer screen through Delphi, when the Computer gets the command to move the lead, the bluetooth module will send the command to the microcontroller which will then make the multiplexer circuit send a signal that is in accordance with the command on the Computer so that the lead transfer process occurs. Graph programming is done using delphi applications, after HC-05 sends the data, the computer will receive the data, Delphi that has been connected to HC-05 will then be able to display a graph of signals that can be moved - move the signal display. In the Figure. 3 bellow, when the receiver diagram when starting on the Computer to call input data from the receiver by receiving a bluetooth signal from all measurements. Once connected to the Computer, it will be initialized on the software. The data received from the receiver is then displayed in the form of ECG signal that has been selected in the Lead Selector.

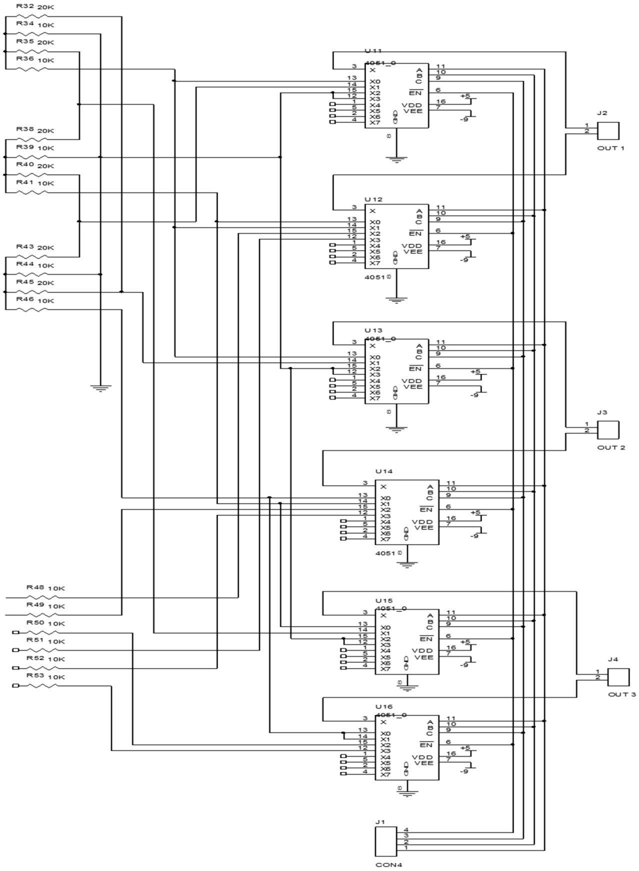


Figure 4. **Multiplexer**

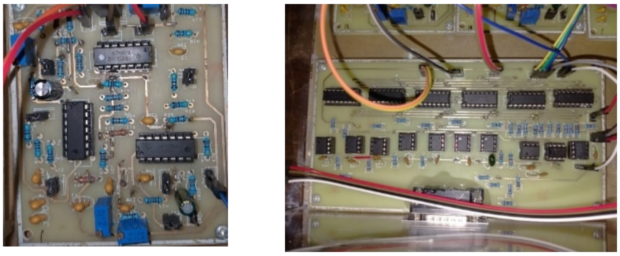
D. CIRCUIT

The buffer circuit serves as a current amplifier, which in this circuit does not change the output value. In other words, the resulting output value is equal to the input value. Multiplexer or Switching Lead circuit is a series that serves as a selection of leads, which will then be displayed on the computer, there are 6 Multiplexer IC (CD 4051) arranged in such a different way to be able to display 3 channels simultaneously. The CD4051 Multiplexer IC has 8 signal input pins with 3 control pins to set which signal to forward. The control is done by providing 000-111 logic. For example if given 000 control it will pass the signal from the input pin 0, if given logic 001 it will pass the signal from the input pin 1 onwards. From the arrangement of 6 pieces of this multiplexer IC, give 3 outer pins which are then passed on to the instrumentation amplifier circuit. An instrument amplifier is a closed loop amplifier. The amplifier instrument circuit is composed of a series of differential amplifiers and buffer amplifiers. An instrument amplifier is a closed loop amplifier. The amplifier instrument circuit is composed of a series of differential amplifiers and buffer amplifiers. Low Pass Filter (LPF) is one type of filter that serves to pass low frequencies and suppress frequencies higher than cut-off frequencies. ECG signal ranges from 0.05-110 Hz, after entering the HPF circuit block that passes the frequency above the cut-off frequency, then next in this LPF block, the signal with the frequency above the cut-off frequency will not be missed at all (Vo = 0 volts). High pass filter (HPF) is one type of filter that has the function of escaping high frequency and pressing low frequency or less than cut off frequency. The high pass filter used in this series is a passive high pass filter, a simple circuit consisting of one prisoner and one capacitor equipped with a series of amplifiers.

The notch filter circuit (band stop filter) serves to hold a signal that has a frequency corresponding to the cut-off frequency and will pass a signal that has a frequency beyond the cut-off frequency either less than or more than the cut-off frequency. In the notch filter circuit has a cut off frequency of 50 Hz. The final amplifier circuit is a series of non-inverting amplifier serves to strengthen the input does not reverse the phase in order to produce a higher output. Adder Circuit, this circuit serves to increase the reference to the ECG signal voltage, so that the negative voltage obtained from the ECG signal will be raised to the positive voltage value entirely.

III. RESULTS

In this study, the ECG Module has been tested using an ECG Phantom (fluke MPS450) as a signal source. The result shows that the recording is feasible to record the ECG signal from the human body. The proposed design is shown in Figure 6,. Figure 6(a) is the instrumentation block of this design, Figure 6 (b) is multiplexer part of this design, and Figure 7 is ECG module creation results.



(a) (b)

Figure 6. (a) **Instrumention Circuit, (b) Multiplexer Circuit**

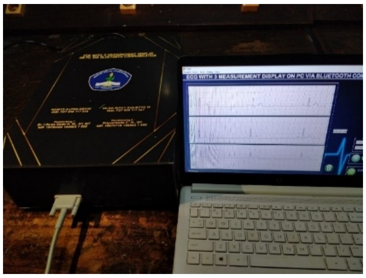


Figure 7. Result of ECG Module

The photograph of the analogue of the Holter ECG was shown in Fig. 8 and Fig. 9, respectively. The analogue part consisted of three of TL084 (OP-AMP) which each unit composed of four OP-AMP. There was also some variable resistor (multiturn 10k) for gain and offset adjustment. And then the multiplexer is using 6 IC CD4051 as the logic controller switching lead. The digital part consisted of the Arduino Uno microcontroller which is the main board of ECG module device, Bluetooth module (HC-05) which used to communicate the data between the microcontroller and computer unit. Precordial Lead signal merging test (V1, V2, V3, V4, V5, V6) This test intends to determine the signal accuracy on the ECG module, by combining the module's ECG signal with the standard ECG, signal pooling is performed using Corel Draw, this test is performed at a bpm setting of 60 and sensitivity of 1mV using phantom ECG as the signal source.

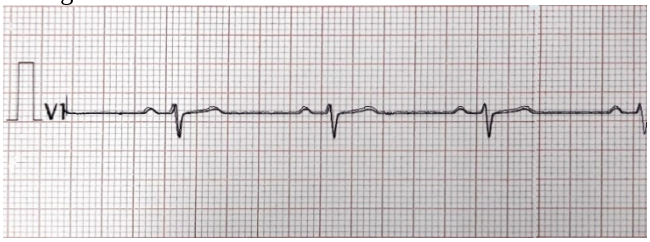


Figure 8. Signal V1 Comparation between ECG Module and Standard ECG

Figure.9 above is a comparison of the V1 signal between the module and the manufacturer's ECG at the BPM setting of 60 and the sensitivity of 1.00 mV. A thicker signal is a signal from the manufacturer's ECG. It can be seen that the overall signal shape (P wave – T wave) is the same only that the T wave in the ECG module is slightly higher than the Standard ECG. Obtained error value in the comparison above by 3,33 %.

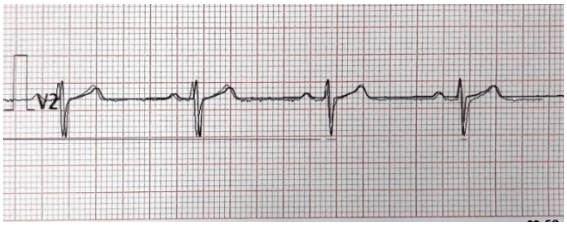


Figure 9. Signal V2 Comparation between ECG Module and Standard ECG

Figure.10 above is a comparison of the V2 signal between the module and the manufacturer's ECG at the BPM setting of 60 and the sensitivity of 1.00 mV. A thicker signal is a signal from the manufacturer's ECG. It can be seen that the overall signal shape (P wave – T wave) is the same only that the T wave in the ECG module is slightly higher than the Standard ECG. Obtained error value in the comparison above by 4,91%.

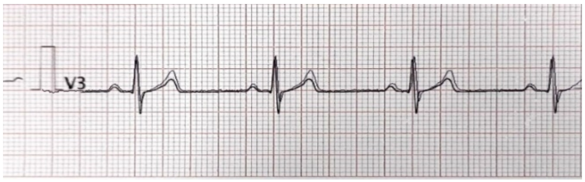


Figure 10. Signal V3 Comparation between ECG Module and Standard ECG

Figure.11 above is a comparison of the V3 signal between the module and the manufacturer's ECG at the BPM setting of 60 and the sensitivity of 1.00 mV. A thicker signal is a signal from the manufacturer's ECG. It can be seen that the overall signal shape (P wave – T wave) is the same only that the T wave in the ECG module is slightly higher than the Standard ECG. The error value in the comparison is above 3,98%.

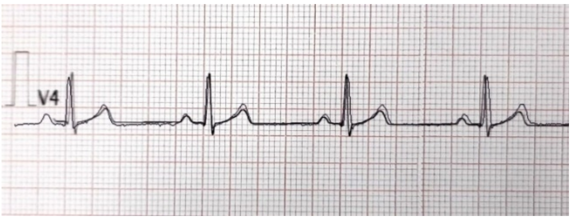


Figure 11. Signal V4 Comparation between ECG Module and Standard ECG

Figure.12 above is a comparison of the V4 signal between the module and the manufacturer's ECG at the

BPM setting of 60 and the sensitivity of 1.00 mV. A thicker signal is a signal from the manufacturer's ECG. It can be seen that the overall signal shape (P wave – T wave) is the same only P&T wave on the ECG module slightly higher than the Standard ECG. Obtained error value in the comparison above by 2,55%.

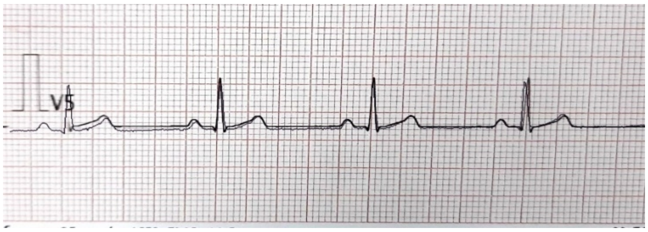


Figure 12. Signal V5 Comparation between ECG Module and Standard ECG

Figure.13 above is a comparison of the V5 signal between the module and the manufacturer's ECG at the BPM setting of 60 and the sensitivity of 1.00 mV. A thicker signal is a signal from the manufacturer's ECG. It can be seen that the overall signal shape (P wave – T wave) is the same. Obtained error value in the comparison above by 1,37%.

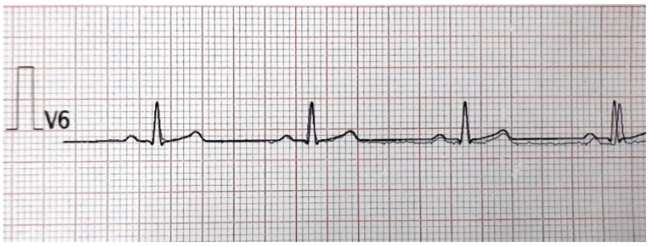


Figure 13. Signal V6 Comparation between ECG Module and Standard ECG

Figure.13 above is a comparison of the V6 signal between the module and the manufacturer's ECG at the BPM setting of 60 and the sensitivity of 1.00 mV. A thicker signal is a signal from the manufacturer's ECG. It can be seen that the overall signal shape (P wave – T wave) is the same. Error value obtained in the comparison above by 0,71%. Measurements were performed using *Phantom* ECG with Fluke MPS450 specification, Measurement was performed at the setting of 1mV sensitivity mode on phantom ECG 12 Lead.

TABLE 1
BPM Measurement Result

No	Parameter	Signal	BPM reading (BPM)			
			30	60	120	240
1	BPM	V1	30	60	120	250
2		V2	30	60	120	250
3		V3	30	60	120	250
4		V4	30	60	120	250
5		V5	30	60	120	250
6		V6	30	60	120	250
Mean			30	60	120	250
SD			0	0	0	0
Error (%)			0	0	0	4,17
Ketidakpastian (UA)			±0,00	±0,00	±0,00	±0,00

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 average value (mean), SD (standard deviation), error value and uncertainty in each BPM setting are obtained. The mean of setting 30 BPM is 30, setting 60 BPM is getting 60, setting 120 BPM is getting 120 and for setting 240 BPM, the result is 250. The standard deviation for setting BPM 30, 60, 120 is 0. Meanwhile, for setting 240 BPM, the result is 0.68. The calculation of the error value at setting 30 and 60 BPM is 0%, 0.25% for 120 BPM. At 240 BPM, the error value is 4,17 %. Uncertainty in setting BPM ±0,00. This test aims to find out how much the maximum distance of the Bluetooth HC-05 module to transmit ECG signals, the test is done using 2 methods, namely unhindered delivery and delivery with obstacles. The results of the distance test can be seen in table 2 below.

TABLE 2
Bluetooth Test Result

Distance (m)	No Obstacles	With Obstacles
5	Sent	Sent
10	Sent	Sent
13	Sent	Not Sent
15	Sent	Not Sent
20	Sent	Not Sent
25	Sent	Not Sent
30	Sent	Not Sent
35	Sent	Not Sent

IV. DISCUSSION

The ECG module design has been examined and test completely in this study. Based on the data, as we can see, in Figure 15, Figure 16, Figure 17, Figure 18, By comparing the output of the ECG Module and standard ECG, by using ECG Phantom as a Signal Source, It was shown that there is a no slight different pattern on PQRST waveform. Each ECG recording for each subject showed no big different amplitude. The obtained error value in the comparison is 3,33% for V1 Signal, 4,91% for V2 Signal, 3,98% for V3 Signal, 2,55% for V4 Signal, 1,37% for V5 Signal, and 0,71% for V6 Signal. the result of ECG signal when using the input from ECG simulator showed the right pattern of ECG signal which consisted of P, Q, R, S, and T waveform with the amplitude of 1 mV, for various BPM reading (30, 60, 120, and 240), with 1mV sensitivity, the error value of BPM reading between ECG Module and Standard ECG (with the input from ECG Phantom) showed the value of 0 % for BPM reading at 30, 60, 120 BPM, and 4,17% error reading for 240 BPM reading. This error value indicated that this ECG Module is feasible to be used as a medical device. While for the Bluetooth maximum range test, this Module can sent signal up to 35m without obstacle, and up to 12 m with obstacle.

The performance of this work was also compared to other works. In the previous studies by Agustiawan et al. (2015) made Computer Based 12 Lead ECG Data Acquisition Instrumentation System. and also research by Dwiky Wicaksono. (2015) who made research on 12 Lead Electrocardiograph (ECG) Performed Computer (Frontal Field) [19], [25]. In that research, the tool discusses 12-lead ECG which is then connected to a serial USB RS232 to display the results on a computer, and in that research, the ECG output display still uses 1 channel only. So in this study add more channel (3) and added Bluetooth communication for data signal transmission.

The disadvantages of ECG this module is the lack of clear signal waves on some waves such as S Wave on Lead 2 that should show negative deflection but on ECG This module does not look negative deflection is so significant, then at the time of the lead transfer process takes some time to stabilize the signal, and at the time of display on the Computer the display runs not very smooth.

V. CONCLUSION

The purpose of this research is to develop an ECG tool so that it can read more signals by utilizing 12 leads using 3 instrumentation circuits. The contribution of this research is making 12 lead so more signals can be diagnosed, and by using bluetooth we aim more portable diagnose for the nurse and the signal can also be monitored at any time. This research has found that you can make a 12 lead 3 channel ECG module with bluetooth delivery. In summary This ECG Module has and error for data comparation by 3,33% for V1 Signal, 4,91% for V2 Signal, 3,98% for V3 Signal, 2,55% for V4 Signal, 1,37% for V5 Signal, and 0,71% for V6 Signal. And for BPM reading has showed the value of 0 % for BPM reading at 30, 60, 120 BPM, and 4,17% error reading for 240 BPM reading. This error value indicated that this ECG Module is feasible to be used as a medical device. Further experimental investigation are needed to develop this module by displaying BPM values on Computer displays, Using high quality materials to produce better signals, Signal processing on Computer to stabilize signals up and down reference points, Making tools with good grounding systems so that ECG signals are not affected by 220 V, and the add more channel to the ECG

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APPENDIX

The Listing Program of Arduino and Delphi
In this paper, the software was divided into two sections which is for Arduino and Delphi programming. The listing program for Arduino was shown in the bellow. Which consisted of the program to send the data to the computer.

1. Listing Program on Arduino

a) Initialization Function

```
int p
int ecg,BPMpalsu,BPMasli
float hold,ref
unsigned long waktuBPM,waktuawal=0
unsigned long waktu, waktureset
unsigned long waktu1,reset=0

int p2
int ecg2,BPMpalsu2,BPMasli2
float hold2,ref2
unsigned long waktuBPM2,waktuawal2=0
unsigned long waktu2, waktureset2
unsigned long waktu12,reset2=0

int p3
int ecg3,BPMpalsu3,BPMasli3
float hold3,ref3
unsigned long waktuBPM3,waktuawal3=0
unsigned long waktu3, waktureset3
unsigned long waktu13,reset3=0
int level,val,val2,val3,daridelphi
SoftwareSerial MyBlue(10, 11) // RX |TX

void setup() {
pinMode(pin_A, OUTPUT);
pinMode(pin_B, OUTPUT);
pinMode(pin_C, OUTPUT);
pinMode (A1, INPUT);
pinMode (A2, INPUT);
pinMode (A3, INPUT);
Serial.begin(115200);
MyBlue.begin(115200);
}
```

The above program is used to enter initialization variables to provide baud rate commands and set the connection between input output Arduino to ECG module circuit.

b) Program Function

```
void loop() {
int sinyal1 = analogRead(A1);
int sinyal2 = analogRead(A2);
int sinyal3 = analogRead(A3);7

MyBlue.print("x");
MyBlue.print(sinyal1);
MyBlue.print("y");
delay(2.5);

MyBlue.print("c");
MyBlue.print(sinyal2);
MyBlue.print("d");
delay(2.5);

MyBlue.print("g");
MyBlue.print(sinyal3);
MyBlue.print("h");
delay(2.5);

 mux();   }
```

The program above is a delivery program which will then be received by Comport Delphi for the display process and the multiplexing process are carried out. Analog Pin will be connected by the instrumentation amplifier output which serves as a data source.

c) Multiplexing Program

```
void mux () {
while (MyBlue.available()){
daridelphi = MyBlue.read();

if (daridelphi=='1') {
 digitalWrite(pin_A, LOW);
 digitalWrite(pin_B, LOW);
 digitalWrite(pin_C, LOW);
 Serial.println ("coba 111");
 delay(50); }

if (daridelphi=='2') {
 digitalWrite(pin_A, HIGH);
 digitalWrite(pin_B, LOW);
 digitalWrite(pin_C, LOW);
 Serial.println ("coba 222");
 delay(50); }

if (daridelphi=='3'){
 digitalWrite(pin_A, LOW);
 digitalWrite(pin_B, HIGH);
 digitalWrite(pin_C, LOW);
 Serial.println ("coba 333");
 delay(50); }
if (daridelphi == '4'){
 digitalWrite(pin_A, HIGH);
 digitalWrite(pin_B, HIGH);
 digitalWrite(pin_C, LOW);
 Serial.println ("coba 444");
 delay(50); }
```

The above program is a multiplexing logic program for signal conversion process. In the multiplexing program, the pins will be connected to the digital pin as a logical process.

2. Listing Program on Delphi

a) Setting

```
//==============Connect===================
=
procedure TForm1.Connect1Click(Sender: TObject);
begin
 ComPort1.Open;
 Label4.Caption:='CONNECTED';
 Label4.Font.Color:=cllime;
 Beat:=0;
end;

//===============Pause====================
Procedure TForm1.Pause1Click(Sender: TObject);
begin
 ComPort1.Close;
 Label4.Caption:='PAUSED';
 label4.Font.Color:=clYellow;
end

//===============Reset====================
procedure TForm1.Reset1Click(Sender: TObject);
begin
 Chart1.Series[0].Clear; // sinyal ECG CH 1
 Chart2.Series[0].Clear; // sinyal ECG CH 2
 Chart3.Series[0].Clear; // sinyal ECG CH 3
Label4.Caption:='DISCONNECTED';
label4.Font.Color:=clRed;
end;

//===============Exit====================
procedure TForm1.Close1Click(Sender: TObject);
begin
close();
end;
```

Setting is a program on Delphi that serves to give basic commands on Delphi views such as Connect, Pause, Reset, Exit. Connect program works when Label Connect is pressed, Comport1.open means Comport1 will start the interaction process which means Delphi port has been connected. Pause is a program that serves to stop the running of the program, by means of close ComPort. The reset program serves to redo the chart, by removing the signal on the chart. Program Exit serves to stop the program.

b) Data Processing Program

```
//--------------CHANNEL 1--------------
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*0.0041875855327468230694037145
65;
Chart1.Series[0].AddXY(x,tegangan);
x:=x+0.089;
if chart1.Series[0].MaxXValue >
Chart1.BottomAxis.Maximum then begin
 Chart1.Series[0].Clear;
 x:=0;
end;
 end;

//--------------CHANNEL 2--------------
procedure TForm1.ComDataPacket1Packet(Sender:
TObject;
const Str: String);
Var
 E1,dataadc1: Integer;
 tegangan1, teganganbaru: Real;
begin
Val(Str,dataadc1,E1);
if E1 <> 0 then Exit;
tegangan1:=dataadc1*0.0040875855327468230694037 1
4565;
Chart2.Series[0].AddXY(x1,tegangan1);
x1:=x1+0.089;
if chart2.Series[0].MaxXValue >
Chart2.BottomAxis.Maximum then begin
 Chart2.Series[0].Clear;
 x1:=0;
end;
 end;
//--------------CHANNEL 3--------------
procedure TForm1.ComDataPacket2Packet(Sender:
TObject;
const Str: String);
Var
E3,dataadc3: Integer;
tegangan3: Real;
begin
Val(Str,dataadc3,E3);
if E3 <> 0 then Exit;
tegangan3:=dataadc3*0.0049875855327468230694037 1
4565;
Chart3.Series[0].AddXY(x3,tegangan3);
x3:=x3+0.089;
if chart3.Series[0].MaxXValue >
Chart3.BottomAxis.Maximum then
begin
Chart3.Series[0].Clear;
x3:=0;
end;
end;
```

The above program is an amplifier instrumentation data processing program that has been processed by a microcontroller and sent by HC-05.

c) Multiplexing Program

```
procedure TForm1.Button1Click(Sender: TObject);
begin
if ComPort1.Connected then
 begin
 ComPort1.WriteStr('1');
 Label7.Caption:='L1-L2-L3';
 end;
end;
procedure TForm1.Button2Click(Sender: TObject);
begin
if ComPort1.Connected then
 begin
 ComPort1.WriteStr('2');
 Label7.Caption:='AVR-AVL-AVF';
 end;
end;
procedure TForm1.Button3Click(Sender: TObject);
begin
if ComPort1.Connected then
 begin
 ComPort1.WriteStr('3');
 Label7.Caption:='V1-V2-V3';
 end;
end;
procedure TForm1.Button4Click(Sender: TObject);
begin
if ComPort1.Connected then
 begin
 ComPort1.WriteStr('4');
 Label7.Caption:='V4-V5-V6';
 end;
end;
```

This Multiplexing program is a program that receives programs from Arduino, serving as a logic changer that aims to change the signal displayed.

ATTACHMENT

- Schematic and Board: https://drive.google.com/drive/folders/1Mo8_9nwkTHW6cZEocAjfAp_xdsQyTlfU?usp=sharing

- Listing Program: https://drive.google.com/drive/folders/164smYN-fDd6XVK23E3hZWGbp0OmcG1hK?usp=sharing