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An Advanced Holter Monitor Using AD8232 and MEGA 2560

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ABSTRACT Monitoring of heart signals carried out for twenty hours will help doctors to diagnose heart disease. The aim of this research is to develop a portable and inexpensive ECG monitoring system such as the so-called Holter monitor. The type of method used in the manufacture of this module uses the after only design method. The main design consists of the AD8232 ECG module, DS3231 RTC module, Arduino microcontroller, and SD card memory. ECG signals are collected from the body based on standard LEAD II measurements. To record the raw data of the ECG signal, the SD card memory is used to store the data for further data analysis. Calibration is performed using a phantom ECG. The average result of measuring the BPM module parameter is 11 times. The data taken has a minimum error value of 0%, the largest error value is 0.74%, and the average error value is 0.35%. In measuring the parameters of the ECG chart with a comparison, measurements were made 6 times. The data taken has a minimum error value of 166.66%, has the largest error value of 700%, and the average error value is 319.67%. From the results obtained, the Holter Monitor tool can be made with a PC interface and storage on an SD card. The purpose of this research is to make a portable ECG that does not restrict the patient's movement, is easy to use, and can be produced at an affordable price.

INDEX TERMS ECG, Holter Monitor, AD8232, RTC DS3231, SD Card.

I. INTRODUCTION

The heart is one of the vital organs for the body whose main function is to circulate blood throughout the body. The heart consists of right and left parts which are divided into atria at the top of the heart and ventricles at the bottom of the heart. Blood from each atrium is sent to the ventricle. Blood from the right ventricle is pumped into the lungs and blood from the left ventricle is pumped throughout the body. The heart can contract, which is known as cardiac rhythm from this mechanism.

In the heart there are muscles that contract automatically until an electric current is generated in the form of an action potential or cardiac conduction and the heart rhythm can be controlled. The direction of cardiac conduction is from the Sinotrial (SA) node to the Atriventricular (AV) node then to the bundle of His and branching in the Purkinje fibers which lead to the left and right ventricles, respectively. The condition of the heart is related to the number of heart rates (heart beats) per minute. Heart rate is used as an indication of abnormalities in the heart. Normal heart rate is 60-100 beats/minute.

The heart as one of the vital organs of the body is very susceptible to disease. Heart examination is usually done with an EKG (electrocardiogram). The results displayed on the ECG are PQRST signals with a certain meaning. The P wave represents atrial depolarization, the QRS complex represents ventricular depolarization, and the T wave represents ventricular repolarization. Based on the resulting signal can be analyzed by the doctor about the disease in suffering.

Holter Monitor (often called "Holter" or sometimes also called "Ambulatory Electrocardiography Device") is a portable device that is used to monitor various electrical activity of the cardiovascular system continuously for at least 24 hours. The working principle of this tool is by attaching an electrode cable to the patient's chest. This tool works with battery power as a recording device that can be pocketed or carried anywhere with a belt or shoulder strap. The heart signal can be directly displayed on the TFT so that the medical team can more easily diagnose the heart signal and it has been recorded.

In a previous study, Rio Yulian Dwi Putra holter, the monitor appeared on a PC 2016, but data cannot be sent directly to a Personal Computer (PC) automatically. Then developed by Ananta Faxia Kusuma Wardani holter monitor 2017 which can be sent directly to a PC via the HC-05 bluetooth module, but the storage power is still 2 hours and there is still noise when the patient moves or touches the ground.

Based on the identification of these problems, the authors plan to develop a holter monitor that can function as a portable electrocardiograph (ECG) monitoring tool that focuses on lead II that can store up to a minimum of 6 hours of recording and eliminate noise from patient movements. The purpose of this research is to make a portable ECG that does not restrict the patient's movement, is easy to use, and can be produced at an affordable price

II. MATERIALS AND METHOD

The focus of this research is the graphic data of the ECG signal and beat per minute (BPM) parameters. The ECG signal from the patient will go through amplification and filtering on the AD8232 ECG module so that later the data will be processed and read by the microcontroller. Step retrieval of data on the subject of this research is focused by tapping leads 2 that uses the placement of sensors at three points, namely RA, RL, LL. Analysts data used in this study using the method of measuring the value of the mean error and standard deviation of the data captured.

A) TRIAL SETTING

This study used ten normal subjects with criteria for age between 18 and 22 years and weight between 40 and 60 kg. Subjects were randomly sampled and data collection was repeated 5 times.

B) MATERIALS AND TOOLS

This study used disposable ECG electrodes (OneMed, Jayamas Medical Industri, Indonesia). Electrodes are mounted on the human right hand, left hand and right leg. The AD8232 module as an ECG sensor has the advantages of filter, instrumentation, and amplifier in one module. Arduino Mega 2560 microcontroller is used for ECG data acquisition. SD Card memory with 16 Mbyte is used to store ECG data in real-time. A phantom ECG (Fluke, PS320, USA) was used to calibrate the analog circuit.

C) EXPERIMENT

In this study, after the design was completed, the frequency response of this device was tested using an ECG (phantom) simulator with all ranges (30, 60, 120, 180, and 240 BPM). For each setting, Holter outputs were calculated to validate the results of this study. Then Holter was tested on the human body.

D) BLOCK DIAGRAM

The electrodes that have been attached will detect the heart's electrical signals. When the power button is pressed, all circuits (AD8232, RTC DS3231, TFT LCD, SD card module) will receive voltage. And the 8232 ECG Module will read the heart rate signal. The output of the AD8232 ECG module is still in analog form and will be converted into a digital signal through programming on the Arduino. Arduino will convert the ADC signal into data bits. The data will be stored on the SD Card. The RTC module functions as a real time timer while the ecg module records the heartbeat signal. Furthermore, the data is then processed to be displayed through the TFT display.

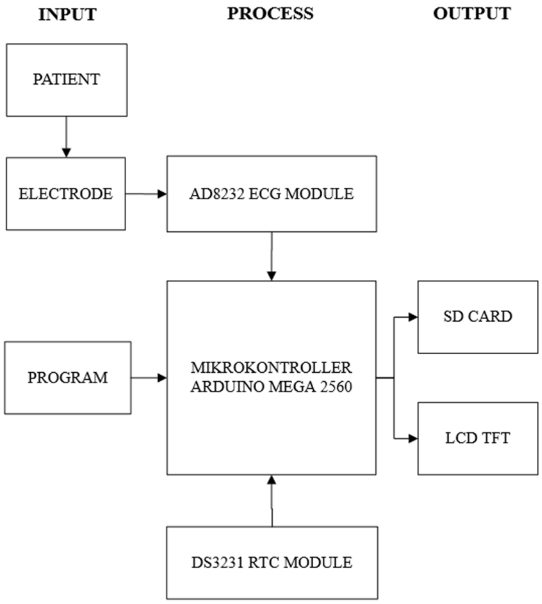

FIGURE 1. Holter Monitor Block Diagram

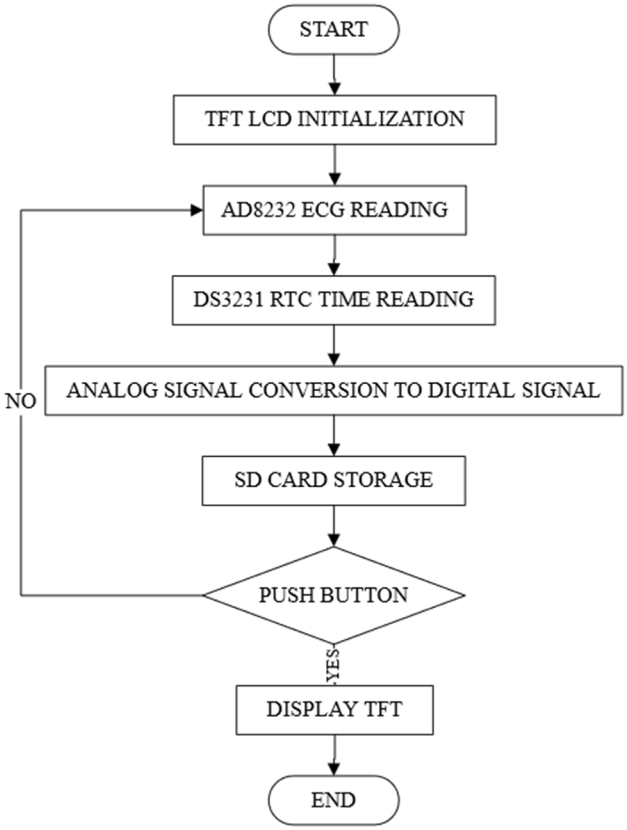

FIGURE 2. Flowchart

E) FLOWCHART

When conditions start working ecg module will perform the reading of analog output values using the programming will be processed by a microcontroller ATMega2560. By going through settings and settings on the microcontroller programming it will produce leads that suit.

AD3231 RTC module will serve as a reading record retrieval time of AD8232 are working together. Through the initialization TFT will display a graph of the ECG signal that has been processed into a digital output via the micro programming. At the same SD Card module will store the output of the AD8232 sensor.

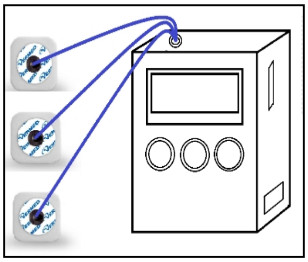

FIGURE 3. Diagram Mechanical Holter Monitor

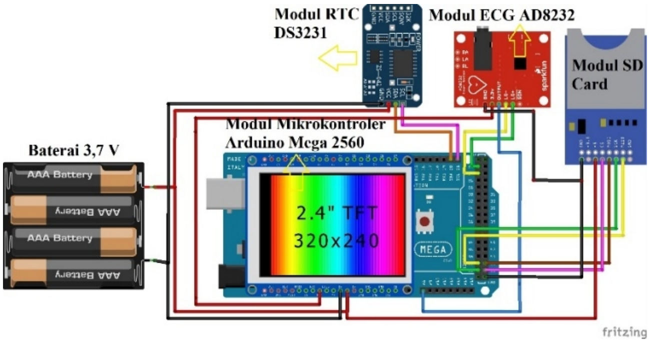

FIGURE 4. Section Digital Holter Monitor

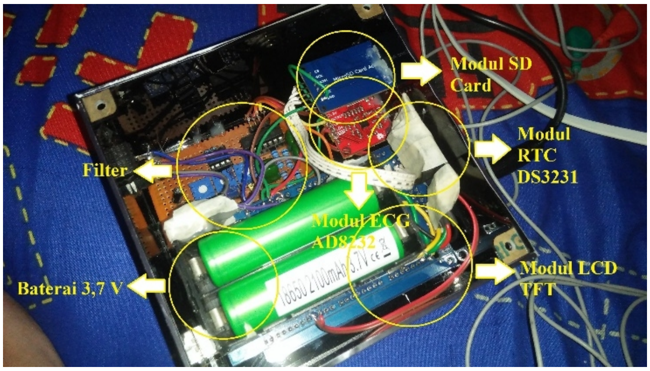

FIGURE 5. Holter Monitor Circuit

FIGURE 6. Box Holter Monitor

F) ANALOG CIRCUIT

An important part of this development is that the analog circuit described in the AD8232 ECG Module is used to process the ECG signal, the DS3231 RTC Module as a real time timer, and the SD Card Module as storage. Therefore it will be ready for digital processing using Arduino.

1) AD8232 ECG MODULE

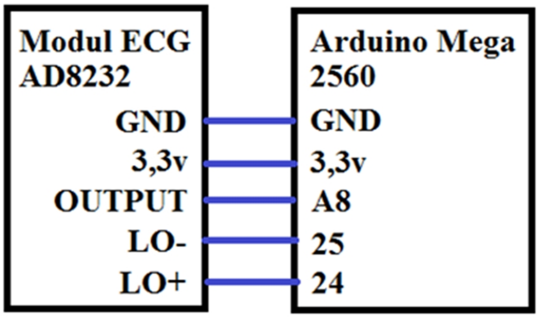

FIGURE 7. ECG AD8232 Module Connection

AD8232 is a sensor ECG / EKG or electrocardiogram. The electrocardiogram (ECG) is a graphic produced by an electrocardiograph, which records the electrical activity of the heart over time. This test records the electrical activity through the waves, which appeared in the paper tracker. The results will be interpreted, either by a trained technician or a cardiologist. Normal heart rate is 60-100 per minute. Furthermore, the wave (high and low) should be equal or consistent. Any deviation can be an indication of potential cardiac problems.

2) DS3231 RTC MODULE

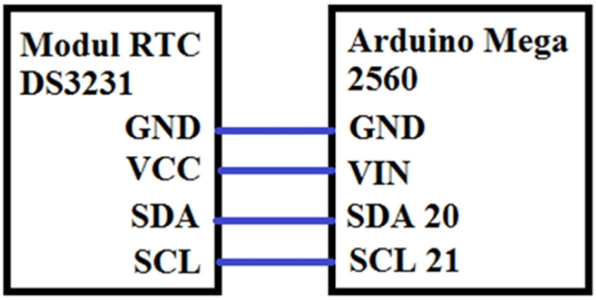

FIGURE 8. DS3231 RTC Module Connection

RTC stands for Real Time Clock. In simple terms, the RTC module is a Time and Date reminder system that uses a battery as a power supply to keep this module running. This module updates the Date and Time regularly, so that we can receive the correct Date and Time

3) SD CARD MODULE

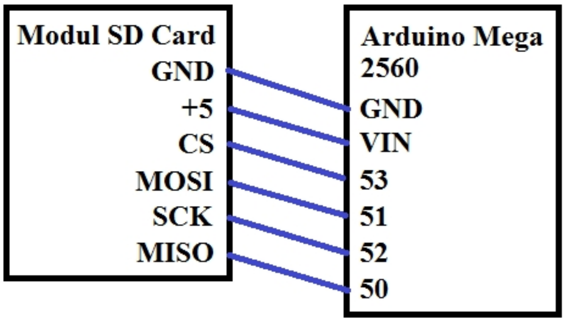

FIGURE 9. SD Card Module Connection

The SD Card module is a module that functions to read and write data to/from the SD Card. This module interfacing using SPI communication. The working voltage of this module can use voltage level is 3.3 V DC or 5V DC, which can be one of them. accurate than RTC module whenever we need. This module ccocok used to make devices that require a non-volatile storage (data will remain stored even if not getting supply voltage) with a large capacity, up to Gigabyte. This module is widely used for the manufacture of medical recording, the recording and playback of music, data logger and also for building a database.

4) ARDUINO MEGA 2560

Board Arduino Mega 2560 is an Arduino board that uses a microcontroller ATmega 2560.Board ic has pin I / O are relatively large, 54 digital input / output, 15 pieces of which can be used as PWM outputs, 16 pieces of analog input, 4 UARTs . Arduino Mega 2560 is equipped MHz crystal 16. To use relatively simple to stay connect the power from the USB to a PC / Laptop or through Jack DC adapter use 7-12 V DC

HOLTER ECG DESIGN

The analog part consists of the AD8232 ECG Module. The digital part consists of the Arduino Mega 2560 microcontroller which is the main board of the Holter device, the RTC module, and the SD card memory module to store ECG data in real - time.
PROGRAM LISTING FOR ARDUINO HOLTER MONITOR

Program to initialize ECG reading, real time timer and save data to SD card memory which can be selected in initial program.

PROGRAM LISTING FOR ARDUINO HOLTER MONITOR

Program to initialize ECG reading, real time timer and save data to SD card memory which can be selected in initial program.

PROGRAM LISTING 2. DS3231 RTC MODULE READING PROGRAM INPUT

```
RTC_DS3231 rtc;
char dataHari[7][12] = {"Minggu", "Senin", "Selasa", "Rabu", "Kamis", "Jumat", "Sabtu"};
String hari;
int tanggal, bulan, tahun, jam, menit, detik;
if (! rtc.begin()) {
Serial.println("RTC Tidak Ditemukan");
Serial.flush();
abort(); }  //Atur Waktu
rtc.adjust(DateTime(F(__DATE__), F(__TIME__))); //
rtc.adjust(DateTime(2014, 1, 21, 3, 0, 0)); }
void loop() {
DateTime now = rtc.now();
hari   = dataHari[now.dayOfTheWeek()];
tanggal = now.day(), DEC;
bulan   = now.month(), DEC;
tahun   = now.year(), DEC;
jam     = now.hour(), DEC;
menit   = now.minute(), DEC;
detik   = now.second(), DEC;
delay(1000);
```

PROGRAM LISTING 3. SD CARD MODULE READING PROGRAM INPUT

```
File myFile;
void setup() {
Serial.begin(1000000);  // baud komunikasi serial
Serial.println("Buka file di kartu microSD");
if (!SD.begin(53)) { //tergantung di pin chipselect yang digunakan
Serial.println("Gagal baca microSD!");
return; }
Serial.println("Sukses baca kartu microSD!");
Serial.println("SELESAI!");
```

```
myFile = SD.open("BPM.txt", FILE_WRITE); //menulis File ECG.txt // jika file sudah berhasil dibuka maka tulis data dimulai
if (myFile) {
Serial.println(String() + hari + ", " + tanggal + "-" + bulan + "-" + tahun);
Serial.println(String() + jam + ":" + menit + ":" + detik);
Serial.println("Nilai Jantung :");
val = analogRead(analogPin);
Serial.println(val);
Serial.println();
myFile.println(String() + hari + ", " + tanggal + "-" + bulan + "-" + tahun);
myFile.println(String() + jam + ":" + menit + ":" + detik);
myFile.print(bpm);
myFile.print("");
myFile.close();
Serial.println(bpm); }
else {
Serial.println("Failed open BPM.txt"); // jika gagal print error }
delay(2000); } //}  }   }
```

Arduino programming receives ECG data from the output of the ECG module and saves it to the SD Card. Furthermore, the ECG signal will then be displayed in graphic form on the TFT LCD Display.

In order for Holter to store the recorded ECG signal while the subject is doing any activity, an SD card is used to store the ECG signal.

The respective programs are used to save and open the recorded ECG signal. The recorded ECG signal is in a txt file.

LISTING PROGRAM 4. INPUT PROGRAM PEMBACAAN MODUL ECG AD8232

```
int analogPin = A7;
int val = 0;
pinMode(A7,INPUT);
```

LISTING PROGRAM 5. PROGRAM OUTPUT DISPLAY LCD TFT

```
if (millis() - previousmillis > 0.1) {
previousmillis = millis();
dataadcSinyal = analogRead(A7);
if (dataadcSinyal <= 10) {
myGLCD.setColor(0, 255, 0);
myGLCD.drawLine(0, 40, 319, 40);  }
y1 = dataadcSinyal / 2;
myGLCD.setColor(0, 0, 0);
myGLCD.fillRect(x1, 0, x1 + 5, 169);
myGLCD.setColor(0, 255, 0);
myGLCD.drawLine(x1 - 1, 500 - ybef, x1 - 1, 500 - y1);
ybef = y1;
```

LISTING PROGRAM 6. LISTING PROGRAM SETTING BPM

BPM is used to calculate the rate of the recorded ECG signal. BPM is calculated based detector R with putting the threshold value into the ECG signal.

```
{ sensor = analogRead (A7);
sensor = sensor / 10 ;
if (ref < sensor) {
ref = sensor; }
else {
ref = ref;
hold = (ref * 0.9); }
waktu = millis() - waktureset;
if (sensor > hold) {
beat = 1; }
if (sensor < hold) {
if (beat == 1) {
beat2++;
//hold = 0;
beat = 0; } }
if (beat2 == 2) {
bpm = 120000 / waktu;
beat2 = 0;
waktureset = millis(); }
//Serial.println(bpm); }
```

III. RESULT

In this study, Holter was tested using a phantom ECG (Fluke, SP2002, USA) and an ECG of the human body. The recording results show that the recording is feasible to record ECG signals from the human body.

ECG Holter with input from ECG Simulator

Before the Holter ECG is tested on humans, the device is calibrated using an artificial ECG generated from the ECG Simulator.

FIGURE 10. ECG graph on the TFT Module and on the Comparison ECG with phantom leads with a setting of 30 BPM

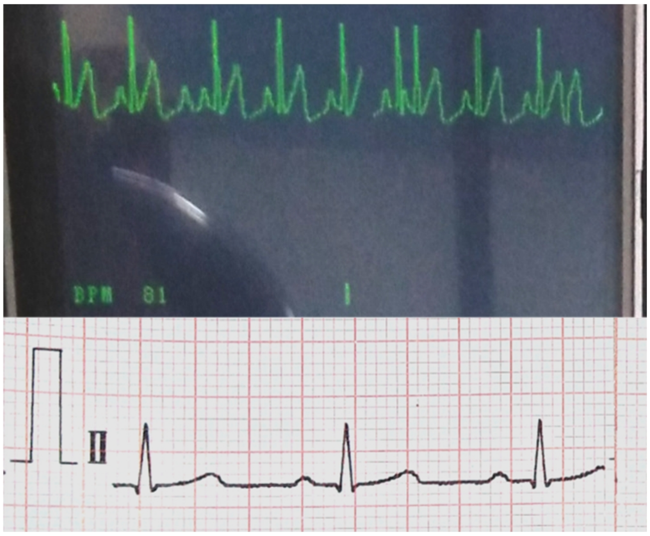

FIGURE 11. **ECG graph on the TFT Module and on the Comparison ECG with phantom leads with a setting of 80 BPM**

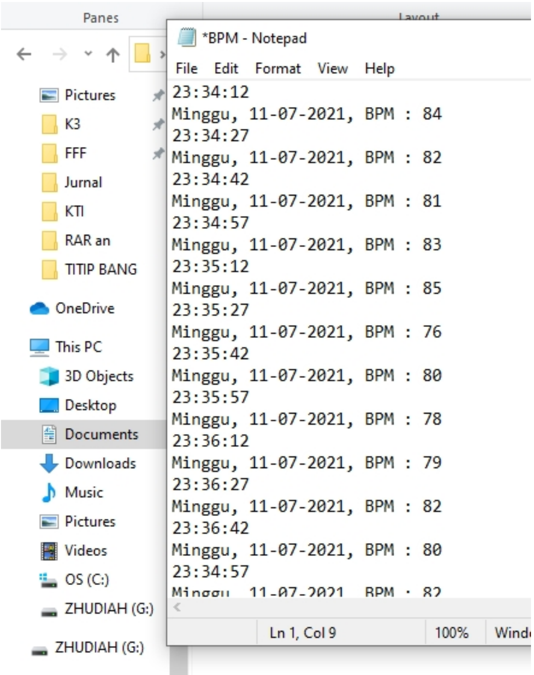

FIGURE 16. **ECG Module Output Storage Results to SD Card**

TABLE I
THE ERROR OF MEASUREMENT FOR BPM PARAMETER BETWEEN THE DESIGN AND CALIBRATOR.

BPM	Standard Deviation	Error(%)
30	0	0 %
80	0,3	0,0125 %
90	0	0 %
120	0	0 %
150	0,3	0,66 %
180	0,3	0,55 %
210	-0.3	0,47 %
240	0,3	0,41 %
270	0,42	0,74 %
300	0,42	0,66 %
320	0	0 %
Mean		0,31%

TABLE II
COMPARISON OF THE NUMBER OF SIGNAL WAVES FROM THE COMPARISON ECG AND THE DESIGN HOLTER MONITOR

Value BPM	Standard Deviation	Error (%)
30	2,85	700 %
80	2,03	166,66 %
120	4,08	250 %
180	6,12	250 %
240	8,17	262,5 %
300	11,02	288,88 %
Mean		319,67 %

IV. DISCUSSION

The measurement results indicate an error value, this is due to many factors, such as grounding, excessive patient movement and how to install the electrodes will affect the reading results. The measurement of BPM parameters with comparison was carried out 11 times. The data taken has a minimum error value of 0%, the largest error value is 0.74%, and the average error value is 0.35%.

The module works according to the program that has been given. When the ON button is pressed or in a ready state, all circuits get voltage and are processed in the Arduino circuit. TFT LCD will start initialization, and initial display appears, along with RTC, and SD Card Module working.

From the results of the measurements made on the comparison of the ECG results on the module with the Comparative ECG, it was found that there was a difference in frequency (the distance between one pqrst wave to the next ECG wave in one BPM input). The data taken has a minimum error value of 166.66%, has the largest error value of 700%, and the average error value is 319.67%.

The purpose of this research is to make a portable ECG that does not restrict the patient's movement, is easy to use, and can be produced at an affordable price. Disadvantages module that box tool is still too large, the results of the reading of the heartbeat on an SD storage card do need to remove the SD Card, limited storage in accordance with the capacity of the SD Card, still using the module Arduino, and there were frequent noise cable that could arise from patient movement.

V. CONCLUSION

This research has demonstrated the development of Holter based on Arduino Mega 2560 microcontroller to monitor ECG signal using ECG module AD8232 of a subject in real time using RTC DS3231 module and data recording can be read from SD card memory. The measurement of BPM parameters with comparison was carried out 11 times. The data taken has a minimum error value of 0%, the largest error value is 0.74%, and the average error value is 0.35%. In measuring the parameters of the ECG chart with a comparison, measurements were made 6 times. The data taken has a minimum error value of 166.66%, has the largest error value of 700%, and the average error value is 319.67%.

Developments in this research can be carried out on: Using an ECG module that has better specifications Using a minimum microcontroller system in order to reduce the size of the module. Eliminate noise on the electrode sensor jack cable, niose the rx tx cable on the nextion lcd tft output pin connection with the arduino rx tx. Eliminates power supply noise, as well as the influence of grounding and patient movement on leads. Using electrodes with maximum sticking results, clean the patient's body parts first using an alcohol swab.

REFERENCE

[1] A. Caretta, L. A. Leo, V. L. Paiocchi, S. Schlossbauer, F. F. Faletra, and T. Moccetti, “Correlation between EKG abnormalities and CMR-late gadolinium enhancement in acute myocarditis,” Eur. Hear. J. - Cardiovasc. Imaging, vol. 20, no. Supplement_2, p. 2019, 2019, doi: 10.1093/ehjci/jez117.043.

[2] A. Faxia et al., “HOLTER MONITOR,” Draft Semin. Poltekkes Surabaya, p. 7, 2017, [Online]. Available: http://digilib.poltekkesdepkes-sby.ac.id/view.php?id=1520#info-tab.

[3] 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.

[4] A. Katheria et al., “A pilot randomized controlled trial of EKG for neonatal resuscitation,” PLoS One, vol. 12, no. 11, pp. 1–8, 2017, doi: 10.1371/journal.pone.0187730.

[5] A. N. Fauzi, I. D. G. H. W, S. Si, and J. T. Elektromedik, “Modifikasi Treadmill Dengan Kontrol Kecepatan Motor Dilengkapi Monitoring EKG Portable Secara Wireless Melalui PC (Kontrol Kecepatan Motor) Abstrak yang dapat menyebabkan abnormalitas kardiovaskuler yang tidak ditemukan pada saat pemantauan Elektrokardi,” Politek. Kesehat. KEMENTRIAN Kesehat. SURABAYA, pp. 1–11, 2014.

[6] C. Meisel and K. A. Bailey, “Identifying signal-dependent information about the preictal state: A comparison across ECoG, EEG and EKG using deep learning,” EBioMedicine, vol. 45, pp. 422–431, 2019, doi: 10.1016/j.ebiom.2019.07.001.

[7] D. Chandra et al., “Assessment of coronary artery calcium by chest CT compared with EKG-gated cardiac CT in the multicenter AIDS cohort study,” PLoS One, vol. 12, no. 4, pp. 1–12, 2017, doi: 10.1371/journal.pone.0176557.

[8] F. C. S. Tyas Istiqomah, Welina Ratnayanti, “Pengembangan Elektrokardiografi (EKG) Portable Sebagai Wujud Teknologi Tepat Guna,” Unair, vol. 335, pp. 93–96, 2007.

[9] H. Heruyanto, “Sistem Pengukuran Denyut Jantung Berbasis Mikrokontroler ATMEGA8535,” J. Progr. Stud. Fis. FMIPA Univ. Hasanuddin, no. September, pp. 1–10, 2014, [Online]. Available: http://repository.unhas.ac.id/handle/123456789/10869.

[10] M. Melanie Lyons et al., “Screening for obstructive sleep apnea in commercial drivers using EKG-derived respiratory power index,” J. Clin. Sleep Med., vol. 15, no. 1, pp. 23–32, 2019, doi: 10.5664/jcsm.7562.

[11] N. J. N. N. P. S. Daniel E Shumer, “Helmet Sign on EKG: A Rare Indicator of Poor Prognosis in Critically Ill Patients,” Physiol. Behav., vol. 176, no. 12, pp. 139–148, 2017, doi: 10.12691/ajmcr-7-10-9.Helmet.

[12] R. Aisuwarya, “Rancang Bangun Instrumentasi Elektrokardiograf (EKG) dan Klasifikasi Kenormalan Jantung Pada Pola Sinyal EKG Menggunakan Learning Vector Quantization (LVQ),” J. Inf. Technol. Comput. Eng., vol. 2, no. 01, pp. 19–26, 2018, doi: 10.25077/jitce.2.01.19-26.2018.

[13] R. AMITA PUTRI, J. Yuda Mindara, and S. Suryaningsih, “Rancang Bangun Wireless Elektrokardiogram (Ekg),” J. Ilmu dan Inov. Fis., vol. 1, no. 1, pp. 58–64, 2017, doi: 10.24198/jiif.v1n1.8.

[14] R. N. Aldebaran, “Modifikasi Treadmill Dengan Kontrol Kecepatan Motor Dilengkapi Monitoring EKG Portable Secara Wireless Melalui PC (Monitoring EKG),” Teknokes, vol. 10, p. 2, 2015.

[15] Rio Yulian Dwi Putra, “Laporan Tugas Akhir Holter Monitor,” J. Tek. Elektromedik Poltekkes Kemenkes Surabaya, p. 32, 2016, [Online]. Available: http://digilib.poltekkesdepkes-sby.ac.id/view.php?id=748#file-tab.

[16] S. Alam et al., “Rancang Bangun Sistem Monitoring Detak Jantung Menggunakan,” J. Teknol. Terap., vol. 5, no. September, pp. 47–55, 2019.

[17] S. M. ee C. Bedy, K. B. Goddard, J. A. W. Stilley, and C. S. Sampson, “Western Journal of Emergency Medicine: Integrating emergency care with population health,” West. J. Emerg. Med., vol. 20, no. 2, pp. 357–362, 2019, doi: 10.5811/westjem.2018.10.37958.

[18] W. P. Burns, N. D. Hartman, P. L. Weygandt, S. C. Jones, H. Caretta-Weyer, and K. G. Moore, “Critical Electrocardiogram Curriculum: Setting the Standard for Flipped-Classroom EKG Instruction,” West. J. Emerg. Med., vol. 21, no. 1, pp. 52–57, 2019, doi: 10.5811/westjem.2019.11.44509.

[19] Y. Shen, C. Qiu, Y. Li, W. Shi, and X. Rui, “An analytical solution for two-dimensional vacuum preloading combined with electro-osmosis consolidation using EKG electrodes,” PLoS One, vol. 12, no. 8, pp. 1–15, 2017, doi: 10.1371/journal.pone.0180974.

[20] 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.v4i1.2