Telemedicine-equipped android interface-based heart rate monitoring

Hanifah Rahmi Fajrin[1], Bayu Satrio Adi[2], Heri Purwoko[3], Irma Permata Sari[4]
[1,2]Department of Medical Electronics Technology, Universitas Muhammadiyah Yogyakarta, Indonesia
[3]Wirosaban Public Hospital, Yogyakarta, Indonesia
[4]Department of System and Information Technology, Jakarta State University, Indonesia

Article Info	ABSTRACT
	This research aimed to design a device that can monitor heart rate and help nurses or doctors when they need to monitor and retrieve data of patients. By utilizing Android as a displayer makes it easier for nurses to minimize data retrieval time. The principle of the tool is to record the heart rate data received by the ear clip sensor to be processed by the Atmega328 microcontroller, then displayed on the Oled LCD and sent to Android phones via HC-05 Bluetooth for display. If the heart rate data is beyond the normal range, the Android application will post a notification in the form of an SMS to the recipient's cellphone. In testing the tool, it uses a comparison device (pulse oximetry) to determine its accuracy. Based on the testing, the heart rate monitoring device had a small error value of 0.32% and had the most substantial error value of 0.81%. The application of the monitoring system in android data can be sent well at a maximum distance of 13 meters, as well as the implementation of telemedicine in the form of a warning (SMS) can work properly.

Corresponding Author:

Hanifah Rahmi Fajrin
Department of Medical Electronics Technology
Universitas Muhammadiyah Yogyakarta
Jalan Brawijaya, Taman Tirto, Kasihan, Bantul, Indonesia 55183.
Email: hanifah.fajrin@vokasi.umy.ac.id

1. INTRODUCTION

Heart rate is a beat released by the heart due to blood flows through the heart, and one of the crucial parameters and vital signs to be monitored routinely by paramedics [1]. Also, the heart rate is used by paramedics to find out the physical condition and mental state of a person [2]. If a person's heart rate is abnormal, then further efforts need to be made to avoid undesirable things [3]. Any person can experience heart problems or suffer from heart disease [4].

Based on data from the World Heart Federation, deaths caused by heart disease range from 17.1 million people (19% of total deaths) per year [5]. This number is four times the population of Singapore. In Indonesia, based on the records of the Indonesian Heart Foundation, the prevalence is 7-12% per year. That is, at least 16.8 million out of 240 million people in Indonesia suffer from heart disease. Of this number, those in 30-50 years old (productive age) are 50% of the total number [6].

There are still many people who do not realize that they suffer heart disease and eventually find out after being severely affected [7]. The lack of awareness of the public about the importance of the heart as the primary life support makes the death rate caused by heart disease increases every year [8]. Although coupled with medical equipment to monitor or check the heart rate condition, the stethoscope is less effective for

nurses and doctors [9], because it still takes time to reach the patient's room when monitoring and retrieving the patient's heart rate data. When the patient's condition suddenly worsens, there will be time wasted looking for or calling on nurses and doctors [1, 7]. So we need a smart health device that is able to immediately display patient's data without having to go to the patient's room [10]. With the existence of these devices/tools, nurses and doctors can shorten the time in taking data, monitoring patients, or taking immediate action in the event undesirable things on the patient's heart [11, 12]. Based on data from Asymco analyst - Horace Dediu, Indonesia is now the fifth-ranked country with the most smartphone users in the world, with 1 billion users [13].

In previous research [14] a smartphone accessory was designed to determine the heart rate, especially for cardiac patients who need to monitor their heart rate. It became an essential indicator for prognosis and diagnosis to share with their physician anytime to seek medical advice when needed. The first step is the explanation of how to extract the ECG signal from the patient. After that, the presentation about the methods to filter the signal, to calculate the heart rate, and the last is to send the heart rate to the patient's smartphone. There are three sections to clarify the function of each block in building the smartphone accessory. A design for a mobile heart rate monitor device includes both software and hardware that can provide patients with a portable heart rate monitor in the form of a smartphone accessory connected via USB to the phone. It continuously tracks the medical condition and alerts of any possible life-threatening heart complications, in addition to share the resulted heart rate with their physician by sending an SMS to seek medical help and supervision with a press of a single button. However, the device only provides connection via USB, so it is not portable.

Hasmah Mansor et al. [15] designed a health monitoring system equipped with heart rate and body temperature wireless sensors. The main components involved in this project were pulse sensor, microcontroller (Arduino with Ethernet shield), and wireless communication device (Xbee). Results showed that the real-time heart rate reading successfully monitored locally (at home) and remotely (at doctor's computer). The performance and efficiency of the device can be further improved in future especially in terms of connection in other platforms besides computer. Possibly, the heart rate sensor can be designed to be worn at the ear lobe so that it will not interrupt patient's activities.

Similar to the previous one, [16] the researcher developed a working prototype of an assistive wireless device for bedridden patients. The device continuously monitors the heart rate of the patient. The device communicates with a mobile in which a customizable application will enable the alert mechanism. The communication between the device and the mobile is via GSM Module. The major parts of this project are Heart Beat Sensor, Arduino Uno, and LCD & GSM Module. In this project, the highest error value reached 6.49 % which is high for diagnostic devices. Less sensitive sensor readings may affect it because the sensor is fitted at the fingertips.

The description of the problem stated hereinabove encourages the author to design a device that can be used in a hospital to help nurses or doctors in monitoring and retrieving data on patients' heart rate conditions by using android [17] as a data displayer and health information technology (Telemedicine) by sending short messages or texting information data on the status of the patient when reaching abnormal heart rate range to the doctor or nurse [18-20]. The sensor is an ear clip sensor which is more effective and accurate [21].

2.   RESEARCH METHOD
Several stages of work include hardware design, software design, testing device/tool, and data collection to achieve the expected purpose.

2.1. Block diagram
Based on Figure 1, it can be seen that the patient whose heartbeats are monitored, his earlobe is clamped with the ear clip sensor. Inside the sensor there is an infrared light that will illuminate the earlobe and there is also a photodiode sensitive to light intensity [22]. Every time blood flows, there is a difference in light intensity, which will then be received by the photodiode. The analog signal from the photodiode is processed in a signal conditioning circuit, which consists of a filter where the results of signal capture from the sensor are filtered to reduce noise from the signal [23]. Then the analog data are amplified by a signal conditioning circuit because the received signal is minimal. The signal that has been filtered and amplified is processed in the microcontroller to calculate the patient's BPM value. The output signal enters the ADC on the microcontroller. The microcontroller reads the time interval between signals in every ten pulses of heart blood flow. The obtained data will be converted to a BPM value and displayed on the LCD. The analog signal output from the signal conditioning amplifying is also compared to the reference in the comparator circuit [24]. The output of the comparator is in the form of a high or low signal and triggers the transistor as

an indicator of a slow heart rate. The BPM value is then transferred to Bluetooth to be sent to the Android application [25]. If the BPM value is below 60 or above 100, the Android app will send an SMS to the operator to find out the patient's condition and provide immediate medical action to the patient [26].
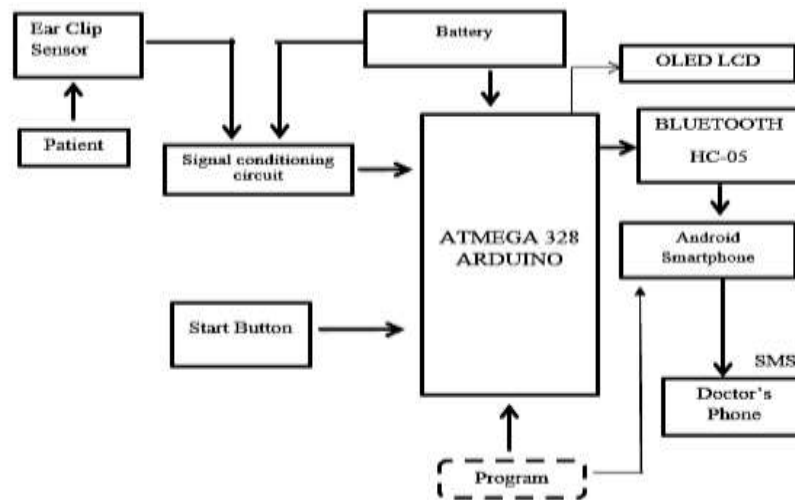

Figure 1. Block diagram

2.2. Hardware design

At the hardware design stage, making a circuit block consists of making an Ear Clip sensor circuit block, signal conditioning circuit, and a microcontroller circuit of the ATMega328p system.

2.2.1. Ear clip sensor circuit

The Circuit of Ear Clip Sensor is in Figure 2. This Ear Clip sensor circuit consists of two resistors with a value of 220 ohms for the infrared led and 100k ohm for the photodiode [27]. This series of Ear Clip Sensor function is to calculate the number of heartbeats in units of BPM (beat per minute) when infrared emits light passes through the earlobe, and the photodiode captures the light. Because of the influence of blood flow, signals arise [28, 29].
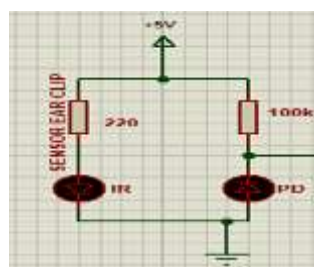

Figure 2. Ear clip sensor circuit

2.2.2. Signal conditioning circuit

Component specifications used in the signal conditioning circuit is in Figure 3. It consists of:
a. High pass filter (HPF), non-inverting amplifier, and comparator.
b. 100k ohm variable resistor for comparator reference controllers.
c. There is an input signal indicator, namely the red led.
d. LM 35, NE 555 ICs, and 2n222 transistor.

This signal conditioning circuit receives a signal from the ear clip sensor which is then filtered to reduce noise and will be amplified using the LM358 IC which has two op-amps [30], where the first op-amp is for non-inverting amplifier [31], and the second op-amp is to buffer so that the resulting amplifying is

stable. The amplified voltage is compared by a comparator (LM393 IC) where the reference voltage of the comparator is +5V. The output of the comparator will trigger the 2n222 transistor where in turn will become an indicator that the signal from the sensor has been received and then give output to forward to the ATMega 328 microcontroller system.
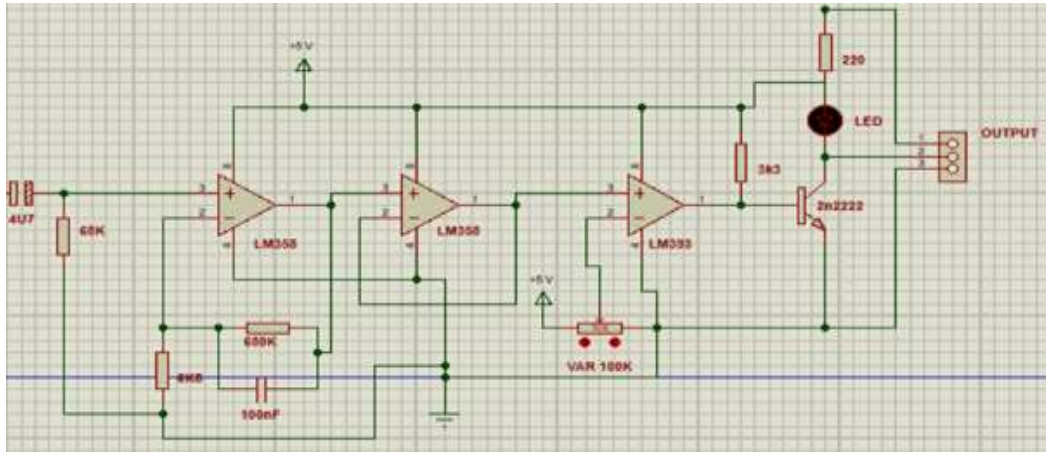

Figure 3. Signal conditioning circuit

2.2.3.   ATMega328p microcontroller
Figure 4 shows that the component specifications used in the Microcontroller of the ATMega328p are:
a.   ATMega328p.
b.   Crystal.
c.   Operating voltage of +5V, and GND.
d.   Push button resistor 10kΩ, 4k7Ω, and 100nF, 22 pF capacitor.
ATMega328p acts as a controller of the system as a data displayer and data processor, as data sender from tool to the android application. The microcontroller consists of ATMega328p, crystal, and reset button [32].
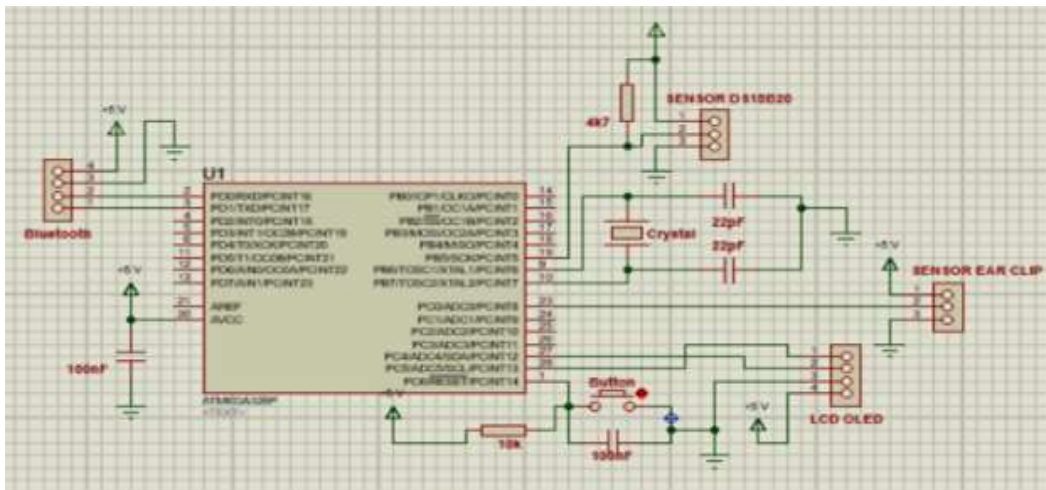

Figure 4. ATMega328p microcontroller

2.3. Software design
The software is designed to control the workings of a telemedicine-equipped android interaction-based heart rate monitoring tools. The software needed for making the device is Arduino software and MIT App Inventor.

2.3.1. Ardunio software

Arduino software platform can be seen in Figure 5. This Arduino software is used as access to the hardware that has been made [33]. All the desired commands can be embedded in the controller system later, such as the command data, to forward the displayed data to Android [5].

Figure 5. Arduino software

2.3.2. MIT app *inventor*

Figure 6 is a platform of MIT App Inventor. It is a website that provides facilities to create an android application [34]. The designed application can receive data, save data and send SMS to the predetermined number.

Figure 6. MIT app inventor

3. RESULTS AND DISCUSSION

In this study, the authors conducted a tool test by measuring heart rate (BPM) with pulse oximetry, measuring the maximum distance of sending data from the hardware/tool to android, and sending messages (SMS) to the number entered.

3.1   Results of measurement on respondents

The following data in Table 1 is the heart rate data obtained from the measurement of 10 respondents in three different times. In the process of collecting heart rate data, a comparator (Pulse Oximeter) was mounted on the finger, and the tool was mounted on the earlobe. Then respondents were then conditioned to relax.

Based on the results of measurements and comparisons using pulse oximeter [17], different results were obtained with a different value in each respondent. The smallest error value was 0.32%, and the highest was 0.81%. The error value existed because there were other factors such as the location of the sensor module with different comparisons. Besides, the measurement time on the tool was slightly longer than the comparator that measured continuously.

3.2   Results of distance measurement

The distance measurement between tool and android was conducted with the existence and non-existence of obstacles. Based on the results of distance measurement between the tool and android application in Table 2, the data could be sent at a maximum distance of 13 meters. At the distance of 14-15 meters, the connection started to be unstable and disturbed. The transmitted data was difficult to read by the android application. At the range of 16-20 meters and further, data could not be read, and the connection between the module's Bluetooth and smartphone's Bluetooth had been disconnected [25], as seen in Figure 7.

Table 1. The results of measurement on respondents

Respondent	Device	Measurement (BPM)			Error (%)
		1	2	3	
1	Pulse Oximeter	84	85	86	0.4
	Tool	82	85	87	
2	Pulse Oximeter	103	104	105	0.32
	Tool	102	103	106	
3	Pulse Oximeter	86	83	83	0.79
	Tool	85	84	81	
4	Pulse Oximeter	83	82	82	0.81
	Tool	82	81	82	
5	Pulse Oximeter	90	92	93	0.37
	Tool	90	94	92	
6	Pulse Oximeter	94	94	95	0.34
	Tool	93	93	96	
7	Pulse Oximeter	90	90	91	0.34
	Tool	91	89	93	
8	Pulse Oximeter	92	91	92	0.72
	Tool	92	91	90	
9	Pulse Oximeter	97	96	98	0.69
	Tool	97	95	97	
10	Pulse Oximeter	78	76	77	0.44
	Tool	77	75	78	

Figure 7. Data received by android

Table 2. Distance measurement

Distance (m)	Data	Bluetooth Connection
1	Sent	Stable
2	Sent	Stable
3	Sent	Stable
4	Sent	Stable
5	Sent	Stable
6	Sent	Stable
7	Sent	Stable
8	Sent	Stable
9	Sent	Stable
10	Sent	Stable
11	Sent	Stable
12	Sent	Stable
13	Sent	Stable
14	Sent	Unstable
15	Sent	Unstable
16	Not Sent	Disconnected
17	Not Sent	Disconnected
18	Not Sent	Disconnected
19	Not Sent	Disconnected
20	Not Sent	Disconnected

3.3   The results of message (SMS) delivery monitoring

The results of this monitoring were conducted by waiting for the condition of the heart rate to be abnormal or exceeds the range of 60-100. Based on the results of data transmission (SMS) monitoring in Table 3, the results obtained were as desired. If the detected data were less than or more than the standard BPM value (<60 or >100), the application would display a warning sign and send an SMS to the doctor/nurse/operator that the BPM value of the patient/respondent was not good or abnormal. Then if the value on the data were detected normally (60-100 BPM), the application would not display a warning sign nor send an SMS to the doctor/nurse/operator, as illustrated in Figure 8.

Table 3. Message (SMS) monitoring

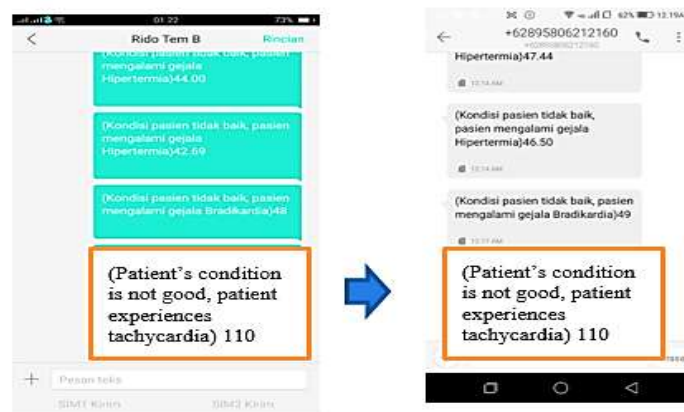| BPM Data	SMS Status	SMS Description
< 60 BPM	Sent	Bad condition
60-100 BPM	Not Sent	-
< 100 BPM	Sent	Bad condition

Figure 8. Patient's data sent

4.   CONCLUSION

After conducting the process of creation and planning literature study, device testing, as well as data collection, the heart rate monitoring device based on android could work well. The obtained error value after performing measurement and calculation were the lowest of 0.23% and the highest of 0.81%. The android

application connected to the tool also worked well to display data at a maximum distance of 13 meters. The app also saved data as well as send SMS to doctor/nurse/operator when the heartbeat condition is <60 or >100 BPM.

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