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Body temperature monitoring based on telemedicine

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Abstract. In general, medical equipment at the Hospital to monitor body temperature such as a thermometer is less effective for nurses and doctors because it takes time to come to the patient's room to retrieve body temperature data. Then, when the patient's condition suddenly worsens, it still takes time for the treatment process. Therefore, the authors intend to make a tool that can help nurses monitor the patient's body temperature through an Android smartphone in real time and equipped with telemedicine that can send notifications in the form of SMS when the patient's body temperature is outside the normal limit. The working principle of this tool is that the body temperature data received by the DS18B20 sensor that will be processed by the Atmega328 microcontroller, then displayed on the OLED LCD and sent to an Android smartphone via Bluetooth HC-05. If body temperature data is outside the normal range, the Android application will send an SMS to another recipient's smartphone. Based on the results of the tool testing, the highest data error results is 0.829% and the lowest is 0%. For the process of sending data using Bluetooth HC-05 by taking measurements every 1 meter, the maximum distance obtained is 13 meters with a hitch. In the application of telemedicine in the form of automatic SMS sending successfully sends body temperature to other recipient's cellphone.

1. Introduction

Examination of vital signs is a measurement of the most basic functions of the body to find out clinical signs and is useful to strengthen the diagnosis of a disease and in determining appropriate medical action planning [1]. Vital signs of human health can be identified from body temperature, heart rate, respiratory, and blood pressure. From these vital signs, body temperature is a sign that needs most attention. Body temperature is the difference between the amount of heat produced by body processes and the amount of heat lost to the outside environment. Normal temperatures in adults range from 36.5 °C - 37.5 °C [2]. If the body temperature is below 36 °C, a hypothermia is indicated, but if the body temperature is above 37 °C, it is indicated that one suffers from hyperthermia.

Body temperature is an equally important parameter in checking body condition. Unhealthy physical



conditions are reflected in poor body temperature. Many people are not aware of the importance of keeping body temperature normal. Any changes in environmental temperature will cause changes in one's body temperature[3].

The importance of checking body temperature causes everyone to be aware of their body condition. However, medical equipment used in hospitals to monitor or check body temperature is a thermometer that is less effective for nurses and doctors because it takes time to reach the patient's room to collect the body temperature data. Then, when the patient's condition suddenly deteriorates, it also still needs time to process it, so that a device that can immediately display patient's data without having to go to the patient's room is needed [4].

Based on the data from Asymco analyst - Horace Dediu, Indonesia is the fifth ranked country with the most smartphone users in the world and the world most Android users with 1 billion users [5]. Utilization of Android technology today can be used as a means to support health information technology (Telemedicine), as well as monitoring or examination technology from Android to determine heart health and body temperature.

From the problems stated hereinabove, the author intends to design a device that can be used to help nurses or doctors when they monitor or retrieve patient's data who are being treated by utilizing Android as the displayer making it easier for nurses for data retrieval process. And this device also uses a Telemedicine system that is sending short messages or SMS about the information of the patient's condition data that beyond the normal body temperature to the doctor or nurse.

2. Related Work

Mansor et.al. conducted a project to design and develop body temperature measurement device that can be observed by the doctor in real time as well as history data via internet with an alarm/indication in case of abnormalities. That project was only focus on body temperature wireless monitoring system. The temperature sensors will send the readings to a microcontroller using Xbee wireless communication. To send the real-time data to health monitoring database, wireless local area network (WLAN) has been used. Arduino with Ethernet shield based on IEEE 802.11 standard has been used for this purpose [6]. Test results from a group of voluntary shows the real-time temperature reading successfully monitored locally (at home) and remotely (at doctor's computer) and the readings are comparable to commercial thermometer. Yet, this system needs to be developed using portable basis. For example: using smartphone as an interface. Therefore, it is easy to carry everywhere.

A wireless wearable device for monitoring internal temperature a few centimeters deep in the body is presented by Will Haines et.al [7]. A radiometer operating in the 1.4-1.427 GHz quiet band is used with a circular patch probe to measure the thermal radiation emitted by the body. The output is digitized and transmitted over Bluetooth by a TI CC2541. The wearable device is powered by a 3.7V Li-Ion battery, through three buck-conversion circuits. The sensor design trades performance (continuous calibration) for simplicity to reduce size and power consumption. Validated measurement data of water temperature inside the cheek demonstrates the feasibility of radiometric internal temperature measurement in a wearable platform. However this tool does not provide Telemedicine system that can send patient's body temperature to paramedic.

Previous research has been developed by [8] who designed "Heart Rate Measurement and Body Temperature with Data Storage". From the results of measurements of data taken from 20 people with 5 measurements and compared with a comparison device. The error value obtained still meets the standard because it is still below the maximum error of 5%. The disadvantage of this tool is that it still used LCD Character displays to display temperature results.

Muhlis et.al. developed a tool entitled "Implementation of a System for Monitoring the Heartbeat and Temperature of the Human Body Wirelessly". This tool takes data from 10 people and compared with a comparison tool, and the results of the errors obtained still meet the standard because it is still below the maximum error of 5%. The device has also used the NRF24L01 wireless system as the sender of data to a personal computer [1]. However, this tool is still not practical because it only displays data on personal computers only and has not been equipped with Telemedicine.

So the author designed and made a body temperature monitoring device using the DS18B20 waterproof sensor so that when the measurements of human body temperature that are usually affixed to the armpit make the sensor's performance uninterrupted. The tool that is made can also display data on the Android display with the help of Bluetooth and also equipped with telemedicine in the form of SMS with a system of sending information on patient condition data if at any time the patient experiences

an increase or decrease in body temperature.

3. Research Method

3.1 Hardware Design

Hardware design uses a number of circuit modules including the controller system circuit and DS18B20 temperature sensor circuit.

3.1.1 Controller Circuit. It can be seen from Figure 1 that working principle of controller circuit is utilizing the ATmega328 IC to make orders to other circuits such as the temperature sensor and OLED LCD. This circuit requires an input voltage of +5V and ground to work. The Program Input Connector is useful for downloading Arduino program to be installed into microcontroller. OLED LCD connectors are useful for connecting LCD with microcontrollers to display body temperature data output. Bluetooth connector is used to connect the HC-05 Bluetooth module with TX and RX pins on the microcontroller for the process of sending body temperature data to android. DS18B20 sensor connector is used for connecting body temperature sensors with microcontroller which output from the sensor will enter the PB5 pin. The reset circuit in which a reset button exists is useful to repeat the program work. LED is useful as indicator that voltage has entered the minimum system circuit and the system works.

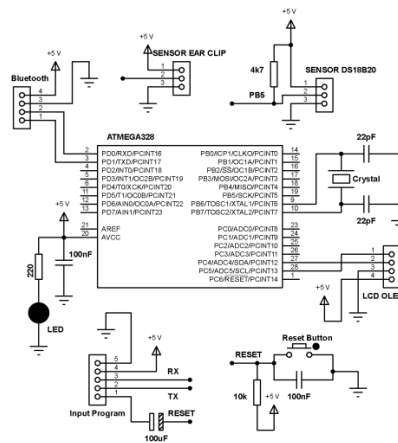


Figure 1. Minimum system circuit

3.1.2 DS18B20 Sensor Circuit. Figure 2 shows the working principle of DS18B20 sensor, there are 3 pins such as Vcc pin, ground, and data output. The voltage needed by this sensor to work is +5 V. Data output from the sensor will enter the digital microcontroller pin, namely PB5 pin.

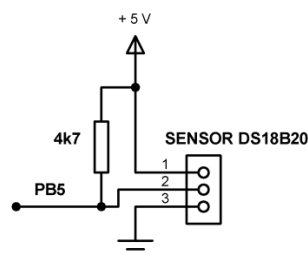


Figure 2. DS18B20 sensor circuit

3.2 Software design

The software used is Arduino programming software as a tool for data processing and MIT Inventor app as a data processor in the Android application.

3.2.1 Block diagram. The patient will be fitted with a DS18B20 temperature sensor placed in the patient's armpit. Afterwards, the sensor will measure the patient's body temperature and the results will be sent directly to the microcontroller. After entering the microcontroller, the results will be processed and displayed on the LCD. The results that have entered the microcontroller will also be sent to the Android application via Bluetooth and will appear on the Android application interface. If the results of the body temperature show results below 35°C or above 37.5°C, the Android application will send an SMS to other

cellphone users (doctors, nurses, or patient families) to determine the patient's condition and to take medical action quickly. Block diagram is as follows in Figure 3.

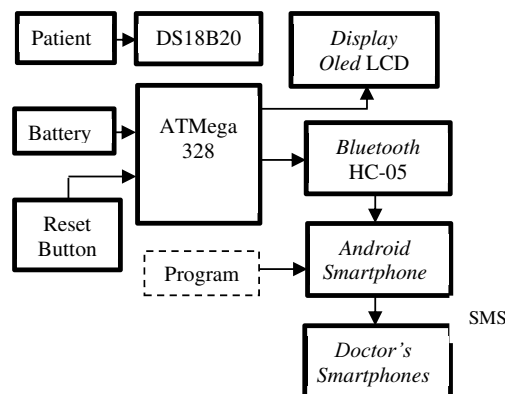


Figure 3. System's block diagram

3.2.2 Flowchart. In Figure 4, the working process of the device starting from taking body temperature data by the sensor and displayed on the OLED LCD, then sending temperature data to the android application for display and sending SMS.

When the device is switched on firsthand, it will initialize the data. Then, the temperature sensor will work to read the body temperature of the patient. Afterwards, the microcontroller will perform data calculations to calculate data retrieved from the patient and will be displayed on the OLED LCD display on the tool. Data will also be inputted into Bluetooth circuit to be sent to the Android application and will be displayed on the application.

When the Android application is activated, the application will perform a data initialization process. When the application has initialized and is connected to the device by Bluetooth, the application automatically receives data and displays the data. The process of connecting between the sender and receiver of data is by using and pairing the sender's Bluetooth ID. If the Bluetooth ID of the sender has been found on Android, then the recipient can choose the Bluetooth ID and once connected, the data can be approved. If the temperature is below 35°C or above 37.5°C, the application will immediately send an SMS to the destination number. For the process of sending abnormal data by SMS, you must request the contact number of the receiver beforehand in the column on the android application.

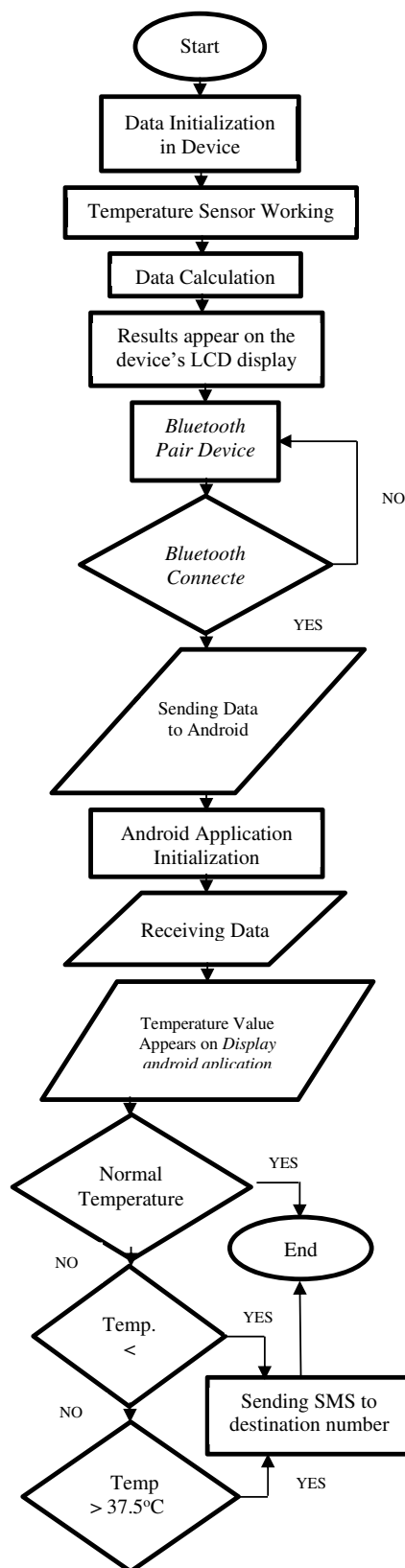


Figure 4. Tool's Flowchart

4. Research Results And Discussion

4.1 Body Temperature Measurement

The following data in Table 1 are measured data taken from 10 respondents by measuring body temperature in the armpit area for 1 minute and comparing it with a digital thermometer.

Table 1. Body Temperature Measurement

No.	Equipment	Measurement Result (°C)			Average	Error (%)
		1	2	3		
1	Thermo	36.3	36.3	36.3	36.3	0.367
	Module	36.1	36.2	36.2	36.17	
2	Thermo	35.5	35.8	35.9	35.73	0.653
	Module	35.3	35.6	35.6	35.5	
3	Thermo	36.1	36.1	36	36.07	0.462
	Module	35.9	35.9	35.9	35.9	
4	Thermo	36.2	36.2	36.2	36.2	0.829
	Module	35.9	35.9	35.9	35.9	
5	Thermo	34.8	34.8	34.8	34.8	0.67
	Module	35	35.1	35	35.03	
6	Thermo	36.5	36.5	36.5	36.5	0.548
	Module	36.2	36.3	36.4	36.3	
7	Thermo	36.9	36.9	36.9	36.9	0
	Module	36.9	36.9	36.9	36.9	
8	Thermo	36.7	36.7	36.7	36.7	0
	Module	36.7	36.7	36.7	36.7	
9	Thermo	36	36	36	36	0.556
	Module	36.2	36.2	36.2	36.2	
10	Thermo	36.2	36.2	36.2	36.2	0.276
	Module	36.1	36.1	36.1	36.1	

From the results of the tool measurement with a comparison, it shows that the change in temperature value on the tool is close to the temperature value displayed by the comparison device. Based on the measurement results between the module and thermometer (comparator), the data results of the device error is 0.829% as the largest and 0% as the smallest. The amount of uncertainty obtained is due to several factors such as less precise sensor placement and ambient temperature influence.

4.2 The Measurement of Bluetooth Performance

The process of sending data from the device module to Android via Bluetooth is by setting the position of the Android smartphone that has been connected to the Bluetooth connection and moving it every 1 meter. The specific testing results are as follows in Table 2.

Table 2. The Measurement Result of Data Transmission via Bluetooth

Distance (m)	Data Result	Description
1	Sent	Succeed
2	Sent	Succeed
3	Sent	Succeed
4	Sent	Succeed
5	Sent	Succeed
6	Sent	Succeed
7	Sent	Succeed
8	Sent	Succeed
9	Sent	Succeed
10	Sent	Succeed
11	Sent	Succeed
12	Sent	Succeed

13	Sent	Succeed
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



Figure 5. Android Display when Connected

Based on the measurement results of the above data transmission it is known that HC-05 Bluetooth can only send data with a distance of 1 m to 13 m stably, whereas at a distance of 14 m to 15 m the connection will be disrupted or unstable and at a distance of 16 m to 20 m, it is disconnected. This can be due to the distance limit of the Bluetooth module and the presence of signal blockers such as walls. Figure 5 is a Telemedicine application which content some features and can display the data when the system is active.

4.3 The Measurement of SMS Delivery Performance

Based on the measurement results of the Telemedicine data in Table 3, it is known that the data will be successfully sent if the temperature is below 35 °C and above 37.5 °C. This happens because it has been set in the Telemedicine application program to send messages in the form of SMS when the temperature is beyond normal. Figure 6 shows the SMS sent to a phone which the phone number has been saved.

Table 3. The Measurement Results of SMS Delivery Performance or Telemedicine

Temperature (°C)	Data Process	Description
43.69	Sent	Succeed
47.44	Sent	Succeed
46.50	Sent	Succeed

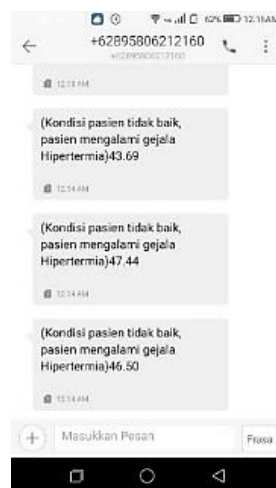


Figure 6. SMS Notification to Receiver

5. Conclusion

Based on the device testing and data collection on 10 respondents then compares it to digital thermometer, the highest error value obtained is 0.829%. The device module uses Bluetooth that is able to send data from module to android application. The process of data retrieval and transmission is by putting the android smartphone that has been connected to the device and moving it every 1 meter. The data transmission distance has maximum limit of 13 meters with wall as obstacle. Android application can display measurement data from the module as long as Bluetooth stays connected and saves the temporary recent data. And there is also column for cell phone number as Telemedicine operation that is useful for sending SMS to the smartphone user automatically when the patient's body temperature is below or above the normal range. The application of Telemedicine can send notification in form of SMS to the receiver's number or other smartphone regarding the illness suffered by the patient and when the temperature data is below 35 °C or above 37.5 °C. Overall, the tool that author design can work well based on the minimum error value obtained from tool testing.

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