Jurnal Teknokes
International: Rapid Review: Open Access Journal Vol. 15, No. 2, June 2022, pp. 96-102 ISSN: 2407-896

RESEARCH ARTICLE OPEN ACCESS

Manuscript received June 13, 2022; Revised June 17, 2022; accepted June 19, 2022; date of publication June 30, 2022
Digital Object Identifier (DOI): https://doi.org/10.35882/teknokes.v15i2.245

How to cite Moch Prastawa Assalim Tetra Putra, Levana Forra Wakidi, Anita Nurliana, Tri Bowo Indrato, Ram Gopal, "Non-Body Contact Thermometer with Voice Output Via Wireless Communication", Jurnal Teknokes, vol. 15, no. 2, pp. 96–102, June. 2022.

Non-Body Contact Thermometer with Voice Output Via Wireless Communication

Moch Prastawa Assalim Tetra Putra[1], Levana Forra Wakidi[1], Anita Nurliana[1], Tri Bowo Indrato[1], Ram Gopal[2]

[1] Departement of Electromedical Engineering Poltekkes Kemenkes, Surabaya
[2] Department of Electronics & Communication Engineering, Institute of Technology & Management, Gorakhpur, India (email: ramgopal.iitbhu@gmail.com)

Corresponding author: Levana Forra Wakidi (e-mail: lep.forra@poltekkesdepkes-sby.ac.id).

ABSTRACT Currently, thermometer has been widely used by the public. In general, thermometers are designed for people who have normal physical conditions, especially in the ability to see. Disabled people, especially blind people, will find it difficult to use the existing thermometer, especially with the current pandemic situation, which is likely to spread COVID-19 quickly. In connection with this problem, non-contact body temperature measurement is needed with sound output and a wireless system so that there is less possibility of exposure to disease. Therefore, this study describes a non-body contact thermometer with sound output via wireless. The purpose of this study concludes that Non-Body Contact Thermometers can be made with Voice Output Via Wireless to determine normal or hyper and hypo human body temperatures. Thus, this thermometer make it easier for those who have limitations to see and reduce exposure to covid-19 between patients and users. The method in this study employed MLX90614 as a sensor whose output is in the form of digital data, HC-SR04 as a trigger on the MLX90614 sensor, and DF player as a reader on data that have been recorded via Google and stored on the SD card, and XBEE module as transceivers of data to pc. Temperature testing was further conducted by comparing the module with a standard tool, that is a digital thermometer. The error obtained from the module at normal temperature is 0.98%, while the smallest error is 0.1%. Furthermore, in terms of the hypo temperature, the largest error is 1.80%, while the smallest error is 0.42%. Last, at hyper temperature, the largest error is 1.75%, while the smallest error is 0.10%.

INDEX TERMS Thermometer, Non-Contact, Temperature, HC SR-04, MLX90614, DF Player Mini, XBEES2C, covid-19, blind

I. INTRODUCTION

Temperature is an indicator of the body's interior energy which is a universal characteristic [1]. Currently, all equipment showing indicators of physical quantity was manufactured and intended for normal humans. This means that all these devices can only be used in normal physical conditions. What about humans who have abnormal body conditions, such as being blind, or disabled? Their current body temperature will be certainly not seen [2][3][4][5], particularly with the presence of the Coronavirus disease, which is a disease that spreads quickly between humans. COVID-19 is a virus that infects the respiratory system. A question raised is whether an interchangeably contact thermometer can be used when checking body temperature, particularly a thermometer based on the excitation current. In this case, contact will certainly accelerate the occurrence of Covid-19 exposure [6][7][8][9]. In addition, this method is also still far from being accurate [10].

Temperature is a measure of the average energy of molecules motion in a substance. Temperature does not depend on the size or type of object or the hot or cold an object feel through touching. However, the sense of touch is not a temperature measuring device because it cannot determine the value of an object with certain units. In this case, non-contact thermometer is the best choice as a solution for measuring temperature of moving targets [11]. Several researchers have been developing such thermometer in terms of its process and technology. In 2016, Jescon Steven et al conducted research

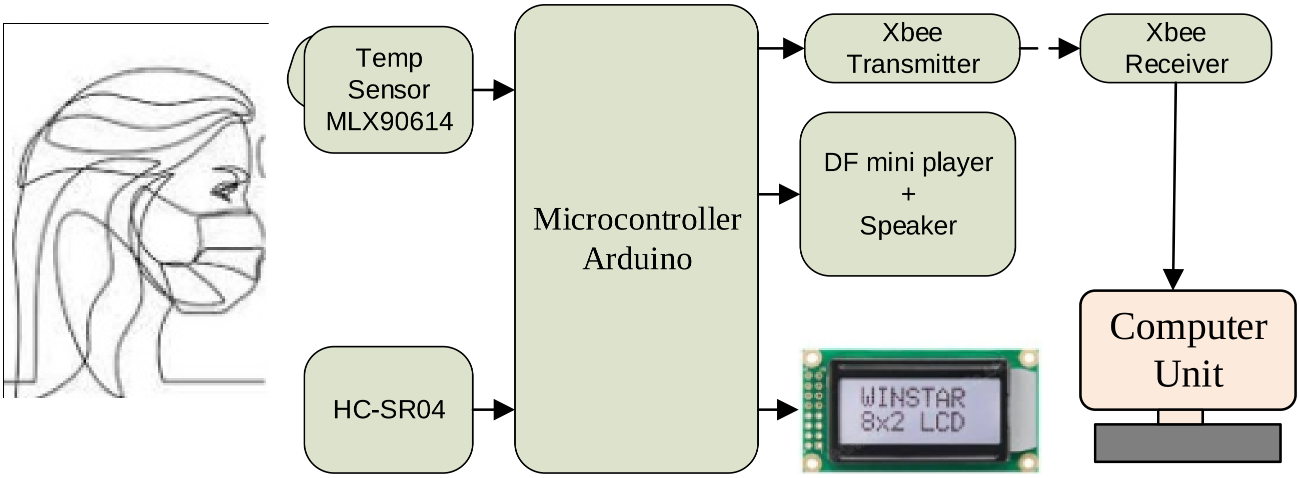

FIGURE 1. Patients are 2-5 cm away from the device and data are further provided on the proximity sensor to give commands to the temperature sensor to detect the patient's temperature. The temperature data are processed by the microcontroller to be sent to 3 outputs, directly to the LCD, the mini dfplayer will make a sound on the speaker, and send the data wirelessly to the PC to be displayed in the program.

on the design of a touchless digital thermometer, particularly on body temperature measurements [12]. Another research project was also conducted on body thermometer with a sound output based on the MCS51 microcontroller that has a drawback in the form of unclear sound output, the use of ic isd2590, and an infrared sensor mlx90614 with low reliability [13]. In order to compare the accuracy of the data, another study was conducted on a body temperature thermometer with ATmega8 microcontroller-based voice output for blind patients. However, in this study, the temperature sensor is not fast in detecting the patient's body temperature and there has been no diagnosis of hypothermia and hyperthermia temperatures [14]. Furthermore, a study was also carried out on a non-body contact thermometer with the sound output but it does not have a wireless system [15].

Based on the description of the literatures described, several problems need to be solved in this research. The first problem is about the sensor, where in the case of this study, we used the MLX0614 sensor which can be used to measure temperature linearly [16][2][9][17]. The second problem is changing the circuit and sensor design so that the sound output sounds clearer [18][19]. The third problem is that no previous studies which have ever used a wireless system. Therefore, this problem must be resolved so that there is no contact at all between the user and the patient [7][20][21][22]. Furthermore, based on the identification of the problems above, there was no thermometer stand either, yet this device can be used to reduce disease transmission between users and patients. Therefore, the current researchers developed a wireltss non-body contact thermometer with sound output in this study. This aims so that Non-Body Contact Thermometers can be made with Voice Output via Wireless to determine normal or hyper and hypo human body temperatures. This design is considered more effective because it has the advantage of fast measurement results without contact [23]. In addition, the sound can be changed to the desired language [24]. In this case, Xbee is a wireless network with a data transmission distance of up to 16 meters [25].

This device provides voice and wireless outputs to make it easier for people with disabilities to see and reduce COVID-19 exposure between patients and users. Thermometers designed are those that can be used to detect body temperature without having contact with the patient. In addition, the device that the author made has a voice output feature for blind patients. Furthermore, in order to reduce exposure to the coronavirus, this thermometer does not need to be held directly by the operator. However, since it uses a wireless system, the operators can read the measured data even at a certain distance from the patient. It is expected that the thermometer can be used for all patients, make it easier for blind people to know their body temperature, and reduce exposure of covid-19 between patients and users.

II. MATERIALS AND METHODS

A. *EXPERIMENTAL SETUP*

The thermometer is designed with sound output and having a wireless transfer system. In order that this device achieves accuracy, an experiment was conducted to measure the temperature of 10 female and male respondents. Data from each respondent was recorded for 5 times.

1) MATERIAL AND TOOL

Human body temperature varies due to metabolism rate; the higher the metabolic rate, the higher the normal body temperature, and the slower the metabolic rate, the lower the normal body temperature [24]. This research employed the infrared sensor MLX90614 to detect human body temperature. In addition, researchers also used ATMega328 for the process of displaying data on an 8x2 LCD, a mini DFPlayer and speaker to process the sound output, and

XBEE S2C for transferring the data from the device to a PC. Furthermore, the standard device employed is in the form of an infrared thermometer with JPD FR 202 brand and a measurement range of -32 to 350ºC and a resolution of 0.2ºC.

2) EXPERIMENT

After the design was completed, the device was tested for its accuracy. To test the level of accuracy, the designed device and the selected standard device were used to measure 2 types of subjects. The first subject are 10 adults where the measurements were made on the subject's forehead almost simultaneously between the designed device and the standard device. In this case, each subject was measured 5 times. The second subject is the subject of an object that is set to have a high temperature and a temperature below 35. In this subject, measurements were also carried out 10 times using designed device and standard device with small time differences. The results of the data collection were processed and compared between the measurement results using the designed device and standard device. The results of the comparative analysis further show the level of accuracy.

B. THE DIAGRAM BLOCK

The thermometer designed has a block diagram shown in FIGURE 1 consisting of 3 sides, input, process, and output. On the input side, there are two sensors; the first sensor is the HC-SR 04 Ultrasonic sensor which detects the presence of a patient by detecting the presence of an object at a distance of 2-5cm. Data on the presence of the object will further provide input to the microcontroller. The second sensor is the MLX90614 infrared sensor, which will detect body temperature.

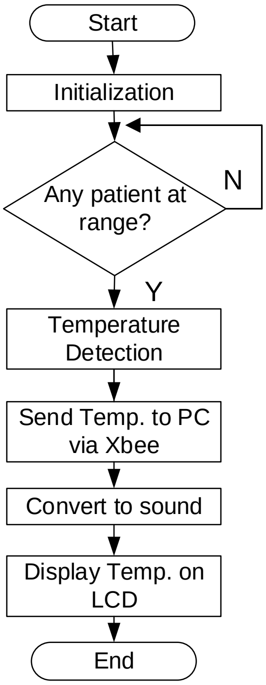

FIGURE 2. The picture above shows a simple tool workflow, patient detection, temperature detection, by data, send to PC, convert data to voice, display to LCD.

This second sensor will work when the first sensor detects an object. The data processing side uses ATMega328p. The results of temperature detection carried out by the second sensor are further processed by the microcontroller. The data are then processed by the microcontroller into 3 output data. The output side consists of 3 outputs. The first temperature data will be directly displayed on the LCD. Second, the temperature data are processed into an address that give a command to the mini DFplayer to give a sound signal to the speaker. The third is the wireless device, the Xbee module that sends this data to a PC that has been connected wirelessly. The PC that has the program installed displays the temperature data sent by the microcontroller.

C. THE FLOWCHART

The program flow diagram shown in FIGURE 2 describes the workflow of this device. When started, all sides will do initialization. After the initialization, the proximity sensor detects the presence of the patient within certain distance. When there is no patient, it will continue to detect the presence of the patient. If there is a patient, the temperature sensor will work to detect the temperature. The temperature data are processed and sent to a PC via Xbee, converted into sound, and displayed directly to the LCD. This will be repeated continuously until the system turns off. The MLX90614 sensor reads body temperature which will produce digital data. The data are processed by the microcontroller which will be input from the mini DFPlayer and then managed back into the sound output on the speakers. The process will repeat until the device is tuned OFF. In the transmitter and receiver data block, once the device is turned on, it will initialize. The data that have been detected by the MLX90614 infrared sensor are then input into the Analog pin. Then, the data are processed by the microcontroller and sent through the transmitter. Furthermore, the user connects and starts calling the input data from the transmitter. The data received by the recipient are then processed on the PC using the Visual Studio application. The data are then be displayed on a digital number display on the PC and stored.

III. RESULT

A. THE CIRCUIT

FIGURE 3 shows the electronic circuit of thermometers carried out by design. In the initial state, the circuit did circuit a voltage supply. When the power button was pressed, the entire circuit obtained voltage from the battery. Ultrasonic Sensor HC-SR04 further triggered the MLX90614 sensor to start processing and displaying body temperature, then the output issued the digital data. The minimum system of ATMega328 processed data issued by the MLX90614 sensor. The MLX90614 sensor was connected to the ATMega328 via pin 27 (SDA) and pin 28 (SCL). In this case, the SDA was used to transfer data, while the SCL pin was used to transfer data clocks. Furthermore, ATMega328 processed I2C as a driver of the LCD pin 27 and pin 28 (SCL) and processed the DF Player mini via pin 4 (RX) and pin 5 (TX). RX was used to receive data, while TX was used to send data/output data. Then ATMega328 processed XBEE as wireless data which were sent to the PC.

FIGURE 3. shows the results of a very simple design, containing only a few components.

In the data program, the sensor read and record the temperature every 1 second and produce voice output in the form of mp3 which was then stored on the SD card and then read by the mini df player. The temperature data obtained are further multiplied by 10 and subtracted by 309 to get the position of the data that corresponds to the voice data stored on the SD card. When the temperature sensor reading is more than 32 and less than 37.5, then the sound output is in accordance with the data appears on the LCD, and when the temperature sensor reading is more than 37.5 then the sound output will sound 1 "Your temperature is high" by mentioning the temperature data obtained. The program used to display data automatically lists the data and deletes the data when new data are inputted. The program is used for data storage in excel. The data that appear in the list box are stored automatically. When there are new data, the previous data will be deleted automatically but the deleted data are stored in excel.

B. DATA PROCESSING

After the data collection, the data were divided into 3 categories. Data were taken on 10 male and female subjects. The first data are data on human body temperature within the normal range. Body temperature data were collected from ten subjects involved. Furthermore, data collection was carried out at the measurement point, namely the forehead of the research subject. Data retrieval was carried out using two devices, modules and standard device, almost simultaneously. Data collection was carried out five times for each subject. After the data were collected, the mean value of each subject was calculated. The results were shown in FIGURE 4, indicating the distribution of the data between the two data. It can be seen that there was a difference between the two data being compared, but the difference was very small. Each data collection result was compared between the module measurement results and standard device to get the error value. Then, the average error value was calculated for each subject. These results can be seen in TABLE 1, which shows the comparison results between data collection using the design module and standard device. The error value was further taken from the difference between the two data. The lowest error is 0.1%, while the highest is 0.98%.

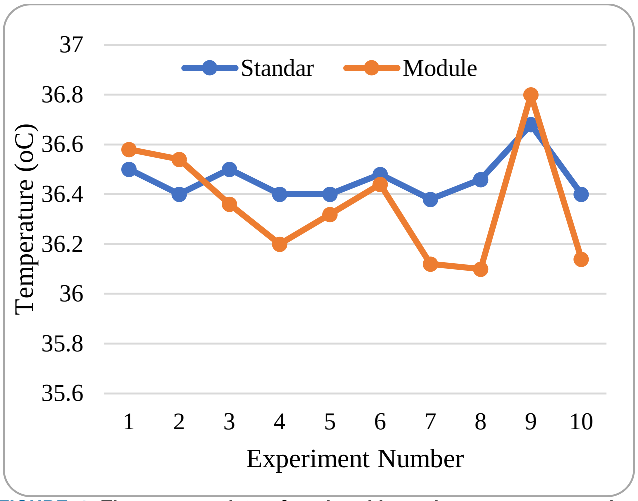

FIGURE 4. The average data of each subject whose temperature data were taken. There is a slight discrepancy in the data.

TABLE 1
The average error data for each subject whose temperature data were taken using a module compared to data using standard device. The maximum error shown did not reach 1%

Subject Name (initial)	Error
NPA	0.21%
AN	0.38%
UAR	0.60%
DSRS	0.54%
NM	0.21%
RR	0.1%
DKW	0.71%
STPB	0.98%
MRF	0.32%
MKJ	0.71%

The second data are data taken by simulating a low temperature of around 32-34 Celsius. The designed modules and standard device were used to perform data retrieval together. Data were collected in 10 conditions, and each step was taken 10 times. Each data collection result were then compared between the module measurement results and standard device to get the error value. Furthermore, the average error value was calculated for each subject. These results are presented in TABLE 2. That shows the average error in the comparison of the two data for each data collection. Based on the table, it was seen that the smallest error is 0.42%, while the largest is 1.8%.

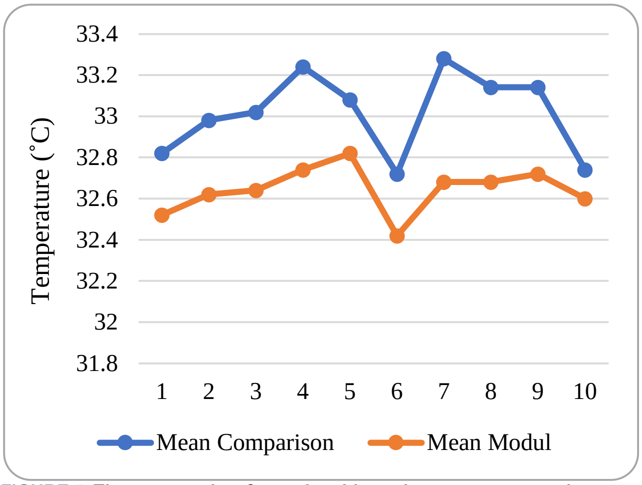

FIGURE 5. **The average data for each subject whose temperature data were taken. There is both small difference and similarity in the curve**

Data collection was carried out ten times for each step. After the data were collected, the mean value of each subject was calculated. The results are shown in FIGURE 5, showing the data difference curve between the data at the time of data collection using designed modules and standard device. As seen in the figure, the biggest difference is around 1 celsius. However, some data are also very close.

TABLE 2

Average Result of Hypo Temperature Overall

Subject	Error
1	0.91%
2	1.09%
3	1.15%
4	1.50%
5	0.78%
6	0.91%
7	1.80%
8	1.38%
9	1.26%
10	0.42%

The third data were data taken by simulating a high temperature of around 38-40 Celsius. The designed modules and standard devices were used to perform data retrieval together. Data were collected in 10 conditions and each step was taken 5 times. Each data collection result was further compared between the measurement results of the module and the standard device to get the error value. Then, the average error value was calculated for each subject. These results can be seen in TABLE 3, that shows the average error in the comparison of the two data for each data collection. It was seen that the smallest error is 0.1%, while the largest is 1.24 %

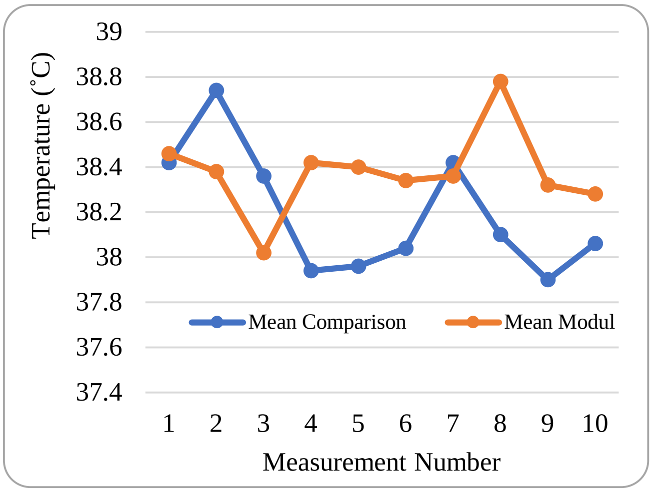

FIGURE 6. **Graph of Average Overall Hyper Temperature**

Data collection was carried out five times for each subject. After the data were collected, the mean value of each subject was calculated. The results are shown in FIGURE 6, showing the data difference curve between the data at the time of data collection using the designed modules and standard device. As presented, the biggest difference is around 1 celsius. However, some data are very close.

TABLE 3

Average Result of Hyper Temperature Overall

Subject	Error %
1	0.10%
2	0.92%
3	0.88%
4	1.24%
5	1.14%
6	0.78%
7	0.15%
8	1.75%
9	1.09%

The data were taken from the comparison display and then compared with the values listed on the module display. Data collection was carried out 5 times. The data taken has a minimum error value of 0.1% and a maximum error value of 0.98%. Furthermore, the error obtained at the hypo temperature is 1.80%, while the smallest error is 0.42%. Meanwhile, in terms of the hyper temperature, the obtained error is 1% and the smallest error of 0.10%.

IV. DISCUSSION

The non-contact body thermometer module has been fully examined and tested in this study. Based on temperature measurements using the thermometer, it produced output according to sensor specifications by collecting data 10 times each at normal, hypo, and hyper temperatures.

Furthermore, the data collected are in the forms of human body temperature. During the data collection, the measurement was carried out at normal, hypo, and hyper temperature. In this case, 10 patients' temperature were examined using the designed module and standard device in a closed room. The largest error value generated by the designed module is 0.98%, while the smallest error is 0.1%. Furthermore, the error obtained at hypo temperature is 1.80%, with smallest error is 0.42%. In terms of hyper temperature, the error obtained is 1.75%, while the smallest error is 0.10%. Based on the results obtained, both devices employed have almost similar error value as the device in the previous study. However, the advantage of this research is that the designed device can determine the hypo, normal or hyper body temperature without having to touch the device, in addition to the assistance of sound output for patients to reduce exposure to covid-19 and the wireless system.

In this study, the mlx90614 sensor was used as a temperature sensor. This sensor was placed ±2 cm from the patient's forehead and the result data appear on the 8X2 LCD. Then, the data that appears read by DFPlayer mini as processor voice data and produce sound output. In this study, there was a 0.1 temperature difference that appears on the display and the sound output temperature because the mini dfplayer cannot read the previous temperature due to unstable temperature. Then the data will be sent to the PC and read by the user. On the data transceiver, there was a transmission distance of 10-16 meters for the data to be read. If the distance exceeds 16 meters, the data will not be read.

The implication of the results of this study is a thermometer that makes it easier for patients of all ages without exception to know their respective body temperatures by displaying temperature data through 2 outputs; written on LCD display and sound output for those visually impaired. Then, from a mechanical point of view, the device that has been designed was in the form of a stand to avoid physical contact between the user and the patient that can cause disease transmission. Users can also see the measurement results directly obtained from wireless transmission from the module to the PC.

The weakness of this research is the use of measurement subjects using humans and simulators that cannot be stabilized. In this case, it will greatly affect the analysis of the accuracy value generated on the designed device. The second weakness is the mechanical design which has not been validated so that the capabilities of this device cannot be ascertained.

V. CONCLUSION

The purpose of this study concludes that Non-Body Contact Thermometers can be made with Voice Output via Wireless to determine normal or hyper and hypo human body temperatures. This device is equipped with voice and wireless outputs to make it easier for people with disabilities to see and reduce COVID-19 exposure between patients and users. From this research, it can be seen that the error result of the instrument is influenced by the placement of the sensor of the device that is too far away for the temperature data collection on the patient so that it gets a larger error. The result will be stable when the sensor is placed 2-5 cm from the patient's forehead. Furthermore, some suggestions regarding the current research are that the device needs to use a more sensitive temperature sensor so that the error value can be suppressed, adding a camera for face detection with a mask, and adding a mechanical part to provide a gap in the pole for hand sanitizer.

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