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Integrated Digital Sphygmomanometer for Simultaneous Blood Pressure and Body Temperature Monitoring

Farahun Nisa Aulia[1], Andjar Pudji[1], Sumber[1]

[1] Department of Medical Electronics Technology, Poltekkes Kemenkes Surabaya, Surabaya, Indonesia

Corresponding author: Andjar Pudji (e-mail: andjar@poltekkesdepkes-sby.ac.id).

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ABSTRACT Hypertension is a condition when the blood pressure against the artery walls is too high. High blood pressure can occur because of the patient's temperature, because the higher the patient's body temperature the higher the blood pressure. Therefore, body temperature must be detected before measuring blood pressure in patients. These Digital Tension and Body Temperature parameters are usually still used separately. Because of that, we had the idea to make these two parameters into one unit to facilitate health monitoring. The design of this tool uses the MPX5050GP sensor as a blood pressure detector, the MLX90614 sensor as a body temperature detector and the two sensors are connected directly to the Arduino UNO microcontroller to be processed and later displayed on the Nextion LCD later. The measurement results with the MPX5050GP and MLX9061 showed that the largest systolic error was 2.23% and the smallest was 0.53%. The biggest diastole error was 4.69% and the smallest was 1.79%. The biggest body temperature error is 1.65% and the smallest is 0.45%.

INDEX TERMS Digital Blood Pressure, Body Temperature, Hypertension , MPX5050GP, MLX90614, Arduino Uno.

I. INTRODUCTION

Blood pressure is the pressure of the blood pumped by the heart against the walls of the arteries [1][2][3]. In general, blood pressure conditions are divided into 2, namely systolic blood pressure and diastolic blood pressure. Systole is the result of blood pressure which is usually depicted in the first number which indicates a person's blood pressure that occurs when the heart is working. While the second number is called the diastole which shows a person's blood pressure when the heart is resting. In general, the blood pressure of a normal and healthy person is 120/80 mmHg. The number 120 is the systolic pressure and the number 80 is the diastolic pressure[4][5]. Several human diseases are directly related to abnormal blood pressure conditions, including high blood pressure (hypertension) and low blood pressure (hypotension). Hypertension is a disease that is very common in society. Hypertension is a dangerous disease because it can lead to other complications such as heart problems and strokes[6]. Therefore, the blood pressure of hypertensive patients must be monitored regularly [7][8]. It is said to have high blood pressure if while sitting the systolic pressure reaches 140 mmHg or more, or the diastolic pressure reaches 90 mmHg or more, or both [9]. In the body there are 2 kinds of temperature, namely core temperature and skin temperature. Core temperature is the temperature of the internal body and is kept constant, around ±1ºF (±0.6ºC) from day to day, unless a person has a fever. Body temperature is defined as a vital sign that describes a person's health status [10]. Normal body temperature is 35.8°C – 37.5°C. In the morning the temperature will be close to 35.5°C, while in the evening it will be close to 37.7°C [11]. Excessive heat exposure in the work environment is also associated with dyslipidemia, cardiovascular and digestive diseases, and can even cause death. In addition, these conditions cause vasoconstriction of deep blood vessels so that cardiac output and oxygen demand increase and blood pressure increases [12][13]. The digital sphygmomanometer is the latest development among the three sphygmomanometers [14][15]. Measurements using this analog sphygmomanometer do not use electronic technology so that the results are not perfect and precise, there are still frequent scale reading errors. According to research, even though the mercury sphygmomanometer has good accuracy, there are many deficiencies, for example the tube is dirty or the mercury is not at zero which will affect the blood pressure reading[16]. When it comes to maintenance, mercury is also a little dangerous because even if mercury is exposed to the skin too often it can cause irritation, itching and burning of the skin and also allergies [8].

In 2008 Irwan Hamzah conducted research entitled **"Digital Tension Meter Using Atmega8535 Equipped with Voice Processor"** using the MPX2050 pressure sensor, which later data will enter the microcontroller and display on the display screen. But this sensor has too large a pressure reading [17]. In 2010 Sugiyarto made a tool based on the results of his research entitled **"Digital Blood Pressure Meter (Tensimeter) Based on Micro Atmega8535 Digital Blood Pressure Meter (Digital Tensimeter) Based on Micro Atmega8535"** with a digital tensimeter system that will be made using the ATMega8535 microcontroller. The ATMega 8535 microcontroller is a generation of AVR (Alf and Vegard's Risc processor) which has very advanced capabilities, with minimal economic costs. ATMega8535 is used because this microcontroller is easy to obtain and cheap in terms of costs incurred. In addition, the ATMega8535 has complete facilities that can support the author in making a digital tensimeter based on the micro ATMega8535. However, the lack of reinforcement from the circuit so that the pressure value is not perfect[18]. In 2013 N. Yazid and A. Harjoko made a tool with the title **"Digital Blood Pressure Monitor Based on Pressure Sensor MPX2050GP"** where this tool uses a digital blood pressure monitoring system using the MPX2050GP pressure sensor as a pulse detector and uses an ATMega 32 microcontroller as a data processor. . However, the resulting reading of the pressure value still has too large an error [19]. Then in 2022 J. Alunsari conducted research with the title **"DIGITAL TENSIMETER PERFORMING ANDROID".** The design of this tool consists of the Wemos D1 Mini microcontroller and the MAX30100 sensor module. The sensor is connected directly to the microcontroller as a voltage source and the sensor work controller which will then be displayed on the character LCD and also the Blynk application. However, the systo-diastolic pressure value is still inaccurate and diastolic detection is still difficult [8].

Based on the background of the problem above, there are still many error problems in the systo-diastolic pressure detection section and there is also no digital tensimeter equipped with body temperature with an LCD Nextion display. In previous studies there were also weaknesses in the discovery of diastolic values and imperfect appearance on the LCD. The sensor used also still has a small accuracy value and data processing still uses ATMega 32, but there is also a microcontroller that already uses Wemos D1 Mini where the module will display results on Android. Sensors that already have good accuracy values are also used but still have difficulty detecting the diastolic value of blood pressure.

Therefore the author had the idea to make a tool "Digital Sphygmomanometer Detects Diastolic Systolic Display (Body Temperature)" which aims to facilitate medical personnel in measuring blood pressure in a better way, as well as measuring 2 parameters in one single operation. . Making this digital blood pressure is also intended for ordinary people to make it easier to use, bearing in mind that aneroid blood pressure and mercury blood pressure require expertise in their detection. The display on the tool is bigger and clearer using the Nextion 3.2 inch LCD to make it easier to read blood pressure results. The design of this tool uses the MPX5050GP sensor as a blood pressure detector, the MLX90614 sensor as a body temperature detector and the two sensors are connected directly to the Arduino Uno microcontroller to be processed and later displayed on the Nextion LCD later.

II. METHOD

This research was conducted at the Surabaya Ministry of Health Health Polytechnic in the Electromedical Technology department using a Digital Tensimeter brand Omciron and Thermogun brand Conec which were used for comparison of the results of module measurements. Measurement data collection was carried out on 10 respondents with 10 repetitions for each respondent. Data collection for each respondent was given a distance of 5 minutes for each repetition, so that the resulting measurement results or data are good and correct.

The independent variables in this study are where there is pressure pumped into the cuff using a DC motor and there is body temperature detection on the module. The dependent variable is the value of blood pressure measurement results using the MPX5050GP and body temperature measurements using the MLX90614 which will later be processed on the Arduino Uno microcontroller and displayed on the Nextion LCD.

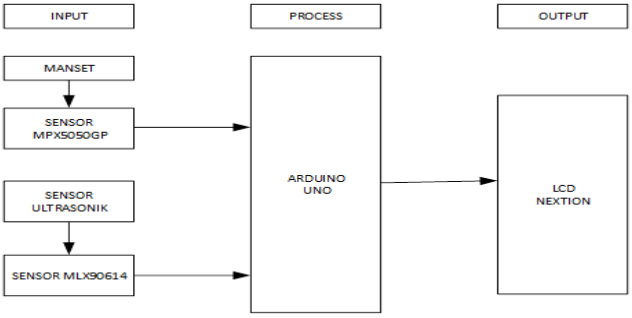

FIGURE 1. Block Diagram of the Systole Diastolic Sphygmomanometer Detector Module Displays (Body Temperature)

This study uses the MPX5050GP sensor where this sensor is used as a blood pressure detector, the MLX90614 sensor is used as a body temperature detector, then all data will be forwarded or processed on the Arduino Uno microcontroller, so that all data measurement results that have been processed will be displayed on the Nextion LCD. For a more detailed explanation can be seen in **FIGURE 1** which contains 3 parts of the block, namely input, process and output. At the input there are cuffs and ultrasonic sensors as a starting point for applying pressure to the arm and object distance, there are also MPX5050GP sensors and MLX90614 sensors for detecting blood pressure along with body temperature. In the process section there is an Arduino Uno microcontroller, after the data is received, the microcontroller will process the data and it will be ready to be sent later. Finally, at the output there is a Nextion LCD which will display the measurement results of the 2 parameters that have been processed on the microcontroller.

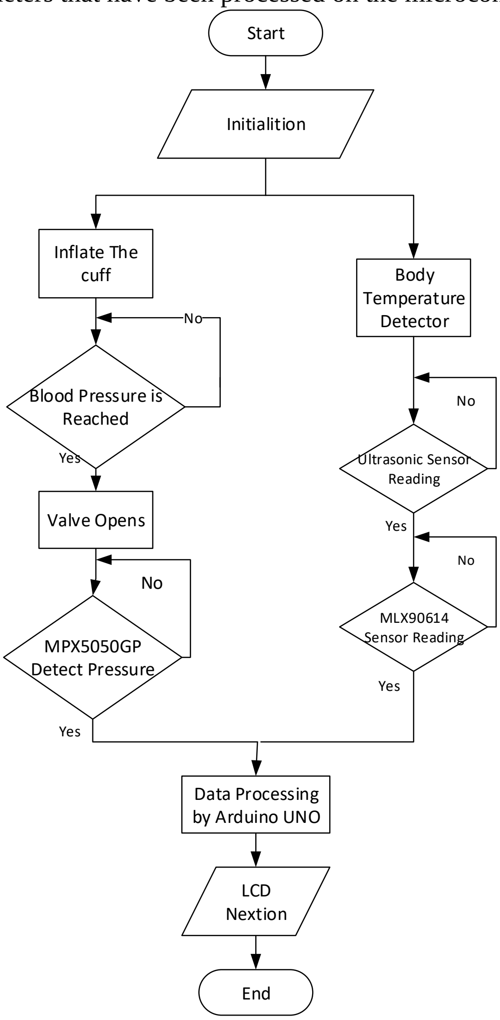

FIGURE 2. Flowchart on the Sphygmomanometer Detector Module for Systole Diastolic Display (Body Temperature)

In **FIGURE 2** you can see how the process is modul in detecting blood pressure along with body temperature until the final result. When the module is on or in an active state, there are two measurements that can be taken alternately. To measure blood pressure, there is a push button that must be pressed so that the motor turns on and the valve is closed so that the cuff will pump up to a certain pressure, after the pressure is reached the valve will open and the MPX5050GP sensor will read the systolic/diastolic pressure while at body temperature when the object is brought close to the Ultrasonic sensor then the MLX90614 sensor will be active and then body temperature will be detected and a temperature reading will be taken. All data will be processed on Arduino uno and will be displayed on the Nextion LCD.

How to collect data is done with the position of the respondent sitting and in a relaxed state [20]. Before taking measurements it was suggested to respondents to rest for approximately 5 minutes [11][21]. This aims to keep blood pressure in a stable state. For measurements taken on the left arm with a distance of 2-3 fingers above the elbow [22][23]. Placement on the left hand because it is closer to the heart which aims to get more accurate results. In addition, the size of the cuff used must be appropriate, namely the size of an adult cuff with a size of 27-44 cm. The measurement process from the start until the sensor detects pressure takes 3 to 5 minutes[24][25]. To measure body temperature by placing the palm of the hand on the ultrasonic sensor as a distance detector and the MLX90614 sensor to detect temperature with a distance of 3-5cm. The detection results will be processed by the microcontroller and will appear on the LCD display.

A. DATA ANALYSIS

Systolic, diastolic and body temperature measurements were repeated 10 times for each respondent with a total of 10 respondents. The mean value of the measurements is obtained by using the mean or average by applying equation (1).

$$\bar{x} = \frac{x1+x2 ... +x}{n}$$

Where denotes the mean (average) value for n-measurements, x1 denotes the first measurement, x2 denotes the second measurement, and xn denotes the nth measurement. The standard deviation is a value that indicates the level (degree) of variation in a group of data or a measure of the standard deviation from the mean. The standard deviation formula (SD) can be shown in equation (2):

$$SD = \sqrt{\frac{\Sigma(x - \bar{x})^2}{(n-1)}}$$

Where UA denotes the uncertainty value of the total measurement, SD denotes the resulting standard deviation, and n denotes the number of measurements. %error indicates a system error. The lower error value is the average difference of each data. Errors may indicate deviations between a standard and a design or model. The error formula is shown in equation (3).

$$\%ERROR = \frac{(x_n - x)}{x_n} \times 100\%$$

Where xn is the measured value of the comparator. X is the measured value of the design.

III. RESULT

In this study, the module was tested using a calibrator, namely DPM (Digital Pressure Meter) with a value range of 60/30 mmHg, 120/80 mmHg, and 150/100 mmHg. An example of calibration results is shown in FIGURE 3. It can be seen in the figure that the comparison between the calibration tool and the module is less than 5 mmHg. Calibration value measurements were carried out 6 times for each range of values measured, calibration measurement data can be seen in TABLE 1 .

FIGURE 3 . Calibration Using DPM

Arrangement (mmHg)	Measurement Results (mmHg)				
	x1	x2	x3	x4	x5
60/30	57/33	61/33	54/33	58/32	61/33
120/80	121/80	119/77	117/79	123/74	18/77
150/100	153/93	157/95	155/93	157/96	153/97

TABLE 1 . Calibration value results

FIGURE 4 and FIGURE 5 are the overall circuit or circuit in this research module. This module uses the Arduino UNO microcontroller as the main data processing component. The program stored on the Arduino UNO includes the detection of systolic, diastolic and body temperature values. In addition, the stored program functions to display results on the Nextion LCD. This module also has a circuit, namely a motor driver circuit and a solenoid valve driver circuit. Inside the circuit there is a transistor that functions as a switch, the purpose here is to start and stop the circuit.

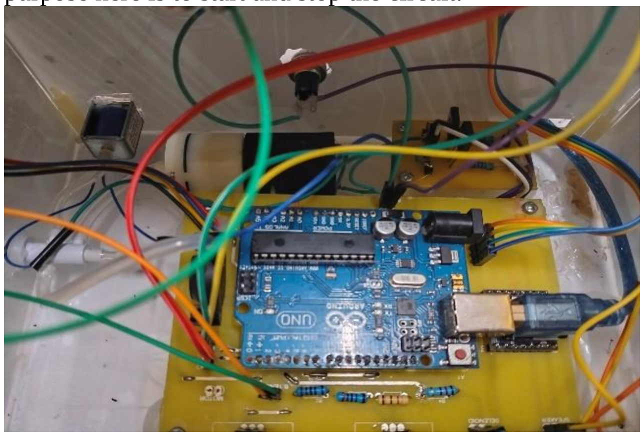

FIGURE 4. Overall circuit design

FIGURE 5. Circuit Design of the Overall Circuit

Tests were also carried out on the MLX90614 sensor to find out how stable body temperature measurements are at predetermined distances. The distance range for temperature detection starts from 1 cm–5 cm. To find out the stable range of body temperature measurements can be seen in TABLE 2.

Distance (cm)	Tool Measurement (°C)	Comparison (°C)
1 cm	37,88	36,5
2 cm	37,87	36,6
3 cm	36,57	36,4
4 cm	36,55	36,4
5 cm	36,53	36,4

TABLE 2 . MLX90614 Sensor Test Results

In this study, the parameters of blood pressure and body temperature were compared with digital blood pressure devices from the Omicron brand and the thermogun from the Conec brand by measuring 10 respondents and repeating 10 times for each respondent. Error value is the difference between the value on the comparison tool and the value of the module results in units of mmHg (Millimeters of Mercury (Hydrargyrum)) and ºC. In TABLE 3 are the results of the recapitulation of 10 respondents with repetition of 10 times per respondent on the results of measuring systolic blood pressure. By looking at the table it can be seen that the average value, standard deviation, and also the error value have been compared with the Omicron digital tensimeter. From these data the largest error value of this blood pressure module measurement in systole is the largest is 3.13% and the smallest is 0.53%. In addition, the standard deviation obtained from systole measurements can still be said to be in a good range, because the results do not exceed the average systolic blood pressure measurement.

Resp	Module (Digital Sphygmomanometer)		Comparison (Digital Sphygmomanometer)		Error
	Mean	STDEV	Mean	STDEV	
1	109,7	4,77	112,2	4,72	2,23%
2	111,9	3,33	113,1	5,12	1,06%
3	111	2,64	113,2	3,78	1,94%
4	113,5	2,45	114,1	4,25	0,53%
5	111,2	2,89	113,5	2,5	2,03%
6	119,3	4,33	118,6	3,9	0,59%
7	113,8	4,58	115,2	2,63	1,22%
8	108,2	4,82	111,7	4,12	3,13%
9	112,9	3,41	114,1	2,84	1,05%
10	109,4	3,74	111,3	4,36	1,71%

TABLE 3 . **Recapitulation of Systolic Blood Pressure Measurement Results**

Resp	Module (Digital Sphygmomanometer)		Comparison (Digital Sphygmomanometer)		Error
	Mean	STDEV	Mean	STDEV	
1	70,8	2,78	74	2,79	4,32%
2	73,6	2,57	75,6	2,87	2,65%
3	71,2	2,67	74,7	2,41	4,69%
4	72,8	2,71	74,3	3,1	2,02%
5	72,3	2,75	74,8	2,92	3,34%
6	75	2,48	76,5	1,68	1,96%
7	72	2,64	75,1	2,46	4,13%
8	72,4	2,83	74,1	2,84	2,29%
9	73,4	2,37	75,7	1,84	2,02%
10	71,5	2,5	72,8	3,54	1,79%

TABLE 4 . **Recapitulation of Diastolic Blood Pressure Measurement Results**

TABLE 4 is a table recapitulation of systolic blood pressure measurements. By looking at the table it can be seen that the average value, standard deviation, and also the error value have been compared with the Omicron digital tensimeter. From these data the largest error value of this blood pressure module measurement at diastole is the largest 4.69%, while the smallest error value is 1.79%. In addition, the standard deviation obtained from measurements at diastole can still be said to be in a good range, because the results do not exceed the average value of diastolic blood pressure measurements.

Resp	Module (Body Temperature)		Comparison (Body Temperature)		Error
	Mean	STDEV	Mean	STDEV	
1	35,72	0,578	36,38	0,188	1,58%
2	35,70	0,435	36,3	0,184	1,65%
3	36,06	0,388	36,23	0,223	0,45%
4	35,65	0,466	35,95	0,229	0,82%
5	36,015	0,370	36,43	0,232	1,14%
6	35,80	0,405	35,98	0,116	0,49%
7	35,974	0,503	36,2	0,219	0,62%
8	35,76	0,477	36,3	0,340	1,49%
9	35,861	0,510	36,37	0,19	1,40%
10	35,846	0,513	36,23	0,195	1,06%

TABLE 5. **Body temperature measurement results recapitulation**

TABLE 5 is a table recapitulation of measurements of body temperature. By looking at the table it can be seen the value of the average, standard deviation, and also the error value that has been compared with the conec brand thermogun. From these data the largest error value of the body temperature module measurement is 1.65% and the smallest error is 0.45%. In addition, the standard deviation obtained from measurements at body temperature can still be said to be in a good range, because the resulting value does not exceed the average value. - Average body temperature measurement.

IV. DISCUSSION

After data collection and measurement of the digital sphygmomanometer module for the detection of systolic diastolic displays (body temperature), data collection and analysis of the results were carried out to determine the stability and accuracy of the module manufacture. From this study, the results obtained were measurements of blood pressure in adults and body temperature with the condition of the respondents relaxed. Measurements were taken at the Health Polytechnic of the Ministry of Health in Surabaya on the Electromedical Technology campus with 10 measurements taken on 10 respondents.

After the first respondent was measured 10 times, the error value obtained at systole was 2.23% and the error value for diastolic measurement was 4.32%. Measurements were made on the second respondent, the error value for the systolic measurement was 1.06% and for the diastolic error value was 2.65%. Measurements were made on the third respondent, the systolic error value was 1.94% and the error value for the diastole measurement was 4.69%. Measurements were taken on the fourth respondent, the systolic error value was 0.53% and the error value for the diastolic measurement was 2.02%. Measurements were taken on the fifth respondent, the systolic error value was 2.03% and the error value for the diastole measurement was 3.34%. Measurements were taken on the sixth respondent, the systolic error value was 0.59% and the error value for the diastole measurement was 1.96%. Measurements were taken on the seventh respondent, the systolic error value was 1.22% and the error value for the diastolic measurement was 4.13%. Measurements were taken on the eighth respondent, an error value of 3.13% was obtained and for the error value on the diastole measurement, it was 2.29%. Measurements were made on the ninth respondent, the systolic error value was 1.05% and the error value for the diastolic measurement was 2.02%. Measurements were made on the tenth respondent, the systolic error value was 1.71% and the error value for the diastolic measurement was 1.79%. There is also an error value in measuring body temperature, namely 1.58% for the first respondent, 1.65% for the second respondent, 0.45% for the third respondent, 0.82% for the fourth respondent , measurements taken on the fifth respondent 1.14%, measurements taken on the sixth respondent 0.49%, measurements taken on the seventh respondent 0.62%, measurements taken on the eighth respondent 1.49%, measurements made on the respondent ninth 1.40%, measurements made on the tenth respondent 1.06%. The results of the error are obtained from several factors such as the patient's condition that is not relaxed, the measurement distance between one and the next has a distance that is too fast, the patient's condition when the measurement is carried out a lot, the placement of the cuff that is still not quite right, and also the ambient temperature which makes the patient's body temperature changed. In this study apart from the error value, the results of the measurements are the average and standard deviation. The average values for systolic, diastole and body temperature measurements when compared with digital tensimeters and thermoguns have values that are not much different. The biggest difference from the average measurement is 3.5 and for the smallest value is 0.6. Then for the results of the standard deviation obtained, all of them get good results, which do not exceed the average value.

Penelitian ini merupakan pengembangan dari previous research. From existing research, there is a similarity in the method used, namely the oscillometric method. However, there are differences in the sensors used that give different accuracy results. If the previous study required an amplifier because the output from the sensor was small, in this study the MPX5050GP sensor was used, which has a larger output. Thus, minimizing the existence of additional circuits such as the amplifier. In addition, the LCD display used in the previous study used a character LCD which was small in size and also lacked screen illumination, so this research will develop an LCD that makes it easier to read. In previous studies, there was also no increase in body temperature in the modules that were made.

Due to various factors, the modules made by the author are still far from perfect, both in terms of planning, manufacturing, and how the module works. So that there are several shortcomings that have been analyzed from the tool that the author made. The first is the supply used. This module uses a power bank as a supply for the device, so the room size becomes larger. Then the error values obtained in several measurements are high, although they still do not exceed the tolerance limit of calibration, which is 5%. And the last drawback of this module is that there is no indicator on body temperature to find out whether the temperature has been detected or not. However, the temperature results shown are good and the range from the comparator is not too far away.

Making this module has advantages and also benefits for the community besides non-medical members. With a portable device design, it is very suitable for everyday use for monitoring blood pressure, especially for someone who suffers from high blood pressure (hypertension). In addition, with the addition of body temperature measurements, it can make it easier for medical personnel to take measurements at once in one device, considering that every blood pressure check is the first step taken, namely checking the body temperature of respondents or patients. In addition, the tool can be used for ordinary people who do not can use a blood pressure detector in general, so that it can be used independently by someone. The principle of the module is also very easy, namely just attaching the cuff to the arm and then pressing the existing push button. and placing your palms on the temperature sensor, then the results will come out in 2 ways, namely on the LCD.

IV. CONCLUSION

The purpose of this research is to make it easier for medical personnel and ordinary people to measure blood pressure and body temperature in one tool in an easy-to-understand way. From the measurement experiment of 10 respondents with the results of a comparison using a Digital Tensimeter and Thermogun and 10 repetitions for each respondent, the largest systolic error value was 2.23% and the smallest was 0.53%. The biggest diastole error was 4.69% and the smallest was 1.79%. The biggest body temperature error is 1.65% and the smallest is 0.45%. The creation of a digital tensimeter with body temperature serves to measure blood pressure as well as body temperature in one device with the MPX5050GP sensor as a pressure detector and the

MLX90614 sensor as a detector. The manufacture of this tool is the development of the original digital tensimeter which is modified by adding body temperature parameters and displayed on Nextion. The measurement results from the digital tensimeter tool module are equipped with body temperature compared to the digital tensimeter brand Omicron and the thermogun brand Contec. From the results of the blood pressure measurement device test with a comparison tool, namely a digital tensimeter which was carried out on 10 respondents, there was the largest systolic error of 2.23%. The biggest diastole error is 4.69%. The biggest body temperature error is 1.65%. There are several deficiencies or things that can be added for further research, namely the addition of indicators to find out that the temperature has been detected.

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