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Iot-Based Blood Pressure and Body Temperature Monitoring System

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ABSTRACT

Health is an essential element that humans must consider. Examination of vital signs has two critical parameters in the diagnosis: blood pressure and body temperature. Blood pressure is a critical factor for the circulatory system. There are two types of blood pressure, namely systolic and diastolic. Body temperature is a measured body temperature expressed in degrees Celsius (°C). We developed an IoT-based blood pressure and body temperature monitoring device using MPX5100DP & DS18B20 sensors. The measurement carried out by comparing pressure and temperature data with standard tool, it was found that the percentage level of accuracy of the average pressure of 96.26% and temperature of 98.61%. Accuracy data were obtained for pressure measurement is 93.01% and for temperature measurement is 99.91%. The error on the device are found to be 2.96% systolic pressure, 3.29% diastolic pressure, and 0.63% body temperature. According to that, developed blood pressure and body temperature monitoring tool can work satisfiedly.

Keywords : Blood Pressure, Body Temperature, DS18B20, Internet of Things (IoT), MPX5100DP.

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I. INTRODUCTION

Body health is an important thing that must be considered in human life. The diagnosis require information about the disease, followed by an examination of the general condition, vital signs, and organ system analysis. Examination of vital signs includes blood pressure check, respiratory rate, and body temperature. Among the parameters for examining vital signs, two essential parameters are often used to determine health: blood pressure and body temperature. Doctors use the examination results to diagnose [1]. Blood pressure is essential to the circulatory system [2]. There are two types of blood pressure: systolic and diastolic. Systolic pressure occurs when the ventricles contract and eject blood into the arteries, while diastolic pressure occurs when the ventricles relax and fill with blood from the atria [3]. Temperature is a substance's hot or cold state; body temperature is the difference in the amount of heat produced by the body and the amount of heat lost to the environment. The average body temperature for adults ranges from 36°C-38°C [4]. In the medical field, blood pressure is measured using a Tensimeter, and body temperature is measured by a Sphygmomanometer [5]. However, measurements made with these tools are generally still local because the measurement system can only monitor the patient's location [6].

Previous [7], an IoT-based blood pressure monitoring tool has been designed. The microcontroller used in this study are Arduino and NodeMCU ESP8266. However, using two microcontrollers simultaneously is less effective because it wasting cost & has complicated algorithm in microntroller. In addition, another drawback in this study is the absence of a body temperature measurement function. Internet of Things (IoT) is a term where objects in life are connected to the internet [8]. Monitoring of blood pressure and body temperature is processed using an Arduino microcontroller. Arduino is a microcontroller hardware using an Atmel AVR processor [9] Arduino programming language use C language through Arduino IDE software [10]. ESP-01 WiFi modulee as IoT communication to send data from blood pressure and body temperature measurements to the ThingSpeak web server which is connected to an application made in App Inventor. App Inventor is an application maker tool for android [11], while ThingSpeak is a service used for IoT applications [12].

In measuring blood pressure, the MPX5100DP sensor is used. MPX5100DP is a pressure sensor sensitive to low pressure, and blowing it can affect the resulting voltage [13]. For measuring body temperature, the DS18B20 sensor is used. DS18B20 is a temperature sensor with one interface cable installation [14]. The blood pressure and body temperature results are displayed on a 16x2 LCD. The 16x2 LCD is connected to the I2C port, so it is easy to use because it only uses four cables connected to the Arduino's SDA and SCL ports. At the same time, the other two cables are connected to +5 Volt and GND [15]. After the results of blood pressure and body temperature measurements are displayed on a 16x2 LCD, the measurement data is sent to ThingSpeak to be monitored via a smartphone through an application created in the App Inventor. The power supply for the microcontroller is a 9 Volt adapter, and the battery is used as a power supply for the pump and solenoid.

II. METHOD

This research will produce an IoT-based blood pressure and body temperature monitoring device. The data in this study is obtained from blood pressure and body temperature measurements, blood pressure data obtained from the MPX5100DP pressure sensor, and body temperature data obtained from the DS18B20 temperature sensor. The analysis results from the MPX5100DP and DS18B20 sensors will be sent to the microcontroller for processing so they can be displayed on the LCD screen. Accuracy data is obtained by comparing pressure and temperature from standard tools with developed tools. While the precision data is obtained by measurement the pressure and temperature repeatedly ten times under the same conditions. The block diagram of IoT-based blood pressure and body temperature monitor consists of an MPX5100DP sensor, DS18B20 sensor, push button, power supply, Arduino, ESP-01, relay, 16x2 LCD, air pump and solenoid. The block diagram for monitoring blood pressure and body temperature can be seen in Figure 1.

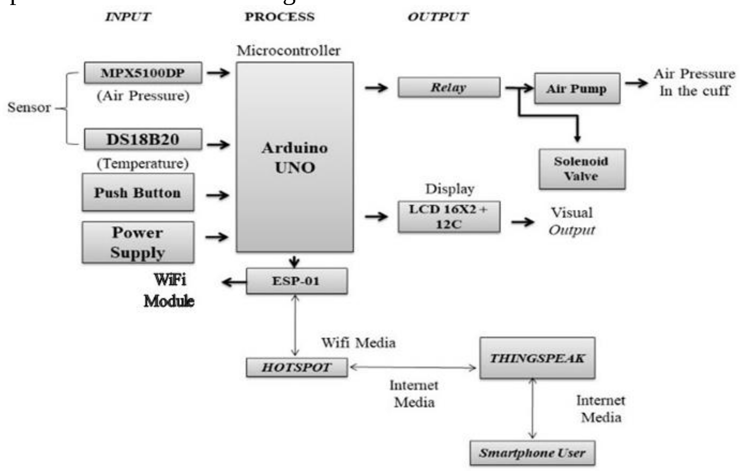


Fig 1. Diagram block of blood pressure and body temperature monitoring tools

Figure 1 explains that the power supply is connected to the microcontroller to activate the Arduino. The MPX5100DP sensor, DS18B20 sensor, and push button are inputs for Arduino in processing blood pressure and body temperature measurement data displayed on the LCD screen, followed by data transmission on ThingSpeak so that it can be monitored via a smartphone. After several circuits are connected a circuit is obtained for an IoT-based blood pressure and body temperature monitoring device as shown in Figure 2 below.

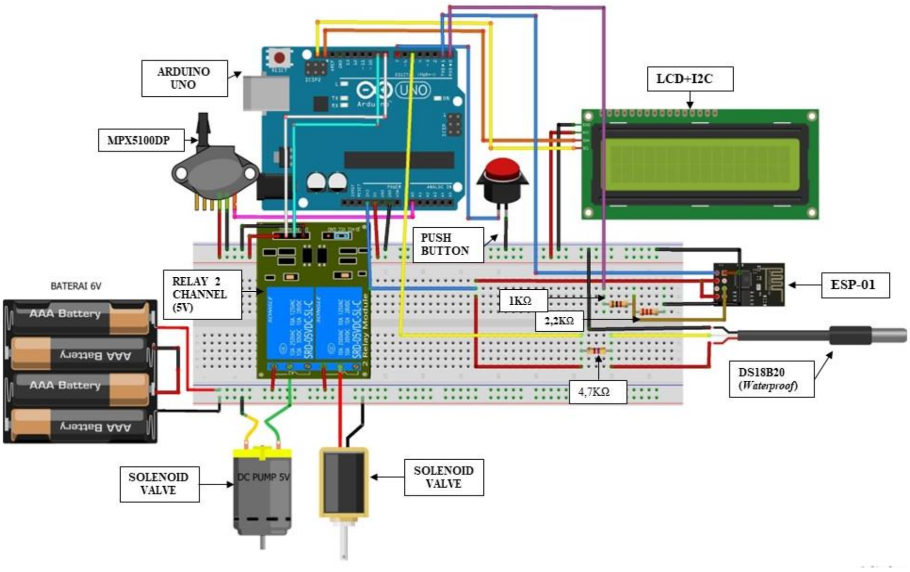


Fig 2. A series of IoT-based blood pressure and body temperature monitoring tools.

Figure 2 shows a series of IoT-based blood pressure and body temperature monitoring devices with the main sensors used, the MPX5100DP sensor for measuring pressure and the DS18B20 sensor for measuring temperature. The circuit will be able to work after the power supply is connected to the circuit. Measurement Setup could be seen in Figure 3 as following.

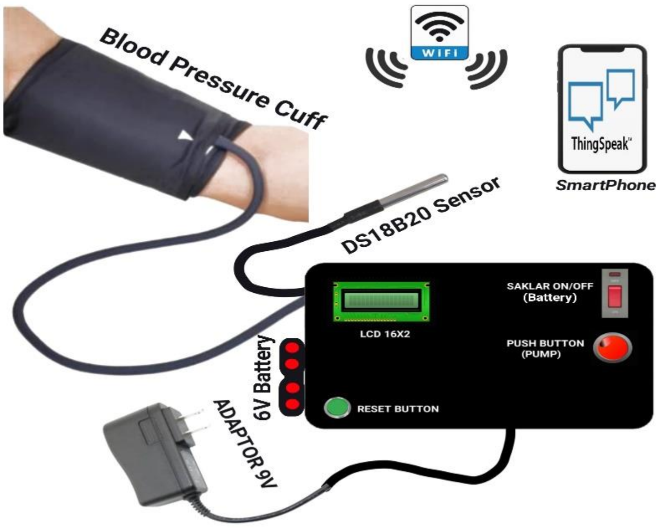


Fig 3. The development design of blood pressure and body temperature monitoring.

III. RESULTS AND DISCUSSION

A. Hardware Systems.

The first results of this study is the design specifications of IoT-based blood pressure and body temperature monitoring devices, consist of several designs in determining the performance of the system so that it can work properly. The first design is the MPX5100DP sensor circuit and the DS18B20 sensor can be seen in Figure 4.

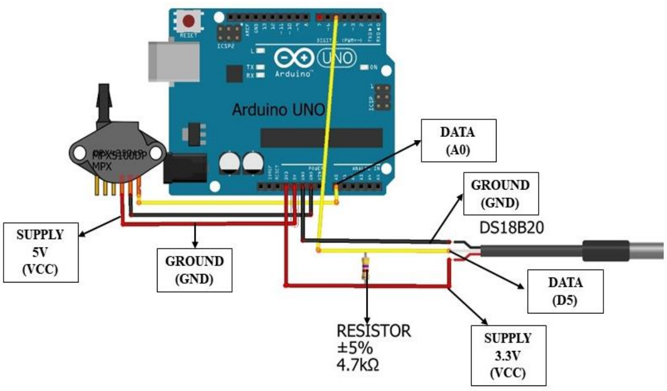


Fig 4. MPX5100DP circuit and DS18B20 sensor.

The MPX5100DP sensor circuit has three connected pins. The first pin is the Vcc pin as a positive voltage source on the +5 V sensor, the second pin is ground, and the third is Vout (output voltage) as the sender of analog data from the sensor to the microcontroller. Vcc is connected to a voltage source, the Vout pin is connected to pin A0 on the Arduino and the ground pin is connected to the ground on the Arduino. The DS18B20 sensor has three pins, the first is Vcc as a positive voltage source of +3.3 V, the second is ground, and the third is the data pin as a digital output. Vcc is connected to a voltage source, the ground pin is connected to the ground on the Arduino, and the sensor data pin is connected to the digital pin (D5) via a 4.7 kΩ resistor as a pull-up from the data line to ensure the digital data transfer process continues to run well and stable. Then the LCD+I2C circuit and the WiFi modulee are connected to the Arduino as a data sender from the microcontroller to ThingSpeak and the smartphone can be seen in Figure 5.

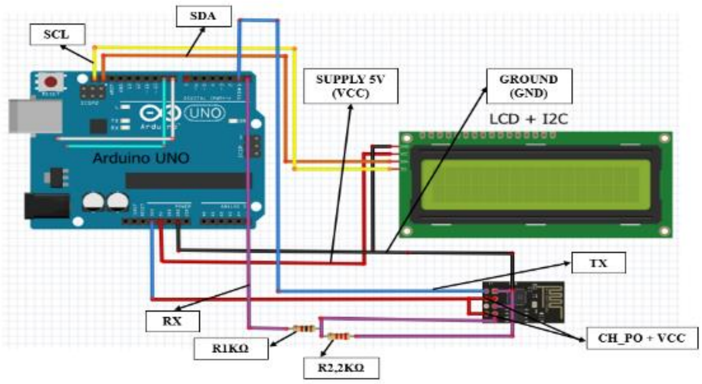


Fig 5. LCD I2C circuit and ESP-01 WiFi module

The LCD+I2C has four pins, first Vcc as a positive voltage source of +5 Volts, second GND or ground pins, third SDA and SCL pins as Serial Data and Serial Clock for LCD. The Vcc pin is connected to a voltage source on the Arduino, the ground pin is connected to the GND pin on the Arduino, and the SDA/SCL pin is connected to the SDA and SCL pins on the Arduino. The WiFi modulee circuit can be seen in Figure 6.

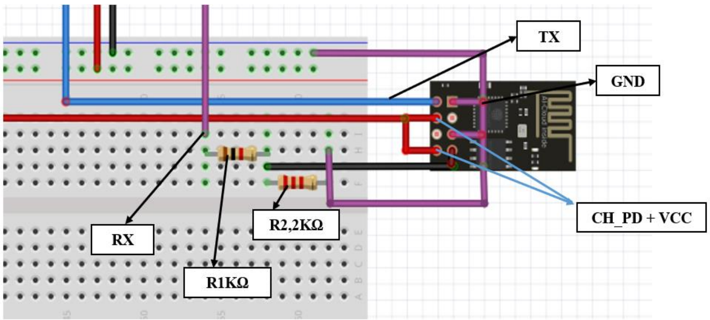


Fig 6. ESP-01 module circuit

The ESP-01 modulee has four pins connected, the first pin Vcc + CH_PD (power down chip) as a positive voltage source of +3.3 Volts, the second pin +GPIO1 ground, the third pin TX as a transmitter for the UART serial protocol, and the fourth pin RX as a receiver for the UART serial protocol which is used for serial communication or serial port of peripheral devices. Furthermore, to turn on the pump and solenoid, a battery circuit is needed as a power supply for the pump and solenoid, as shown in Figure 7.

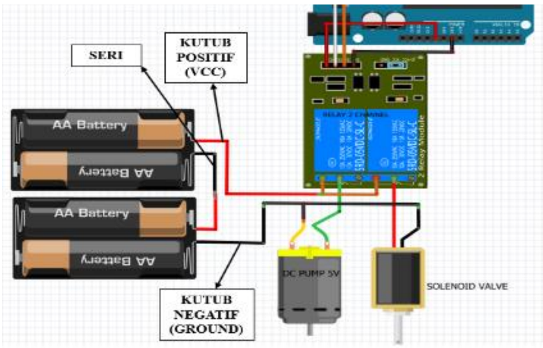
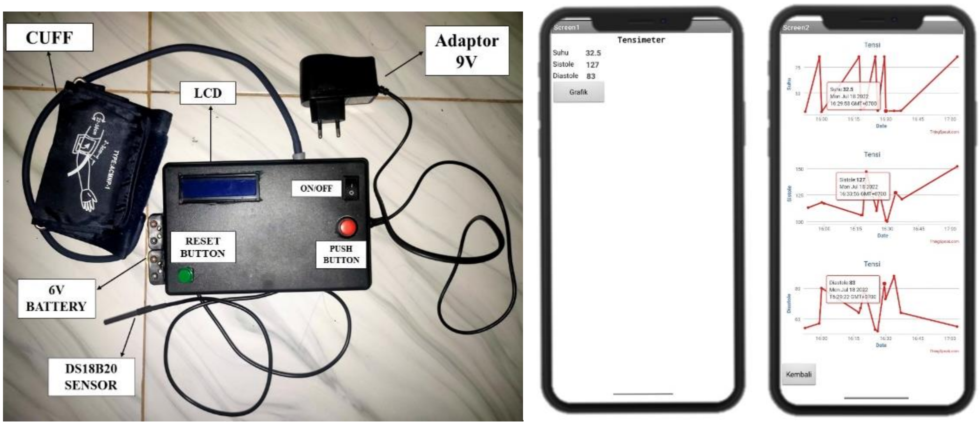


Fig 7. Pump and solenoid power supply circuit

The 6 Volt battery consists of 2 pins. The first pin is the positive pole pin (Vcc) and the negative pole pin (ground). The pump and solenoid each consist of 2 pins. The first pin is the Vcc pin and the second is the ground pin. The Vcc on the battery is connected to the two pins of the relay. The Vcc pin of the pump and the solenoid are connected to the relay then the pump and solenoid ground pins are connected to the battery ground.

The series of blood pressure and body temperature monitoring tools will turn on after the 9-volt adapter is connected to electric source/electricity and the battery is already connected to the relay, so the button to turn on the pump can work. The blood pressure and body temperature monitoring tools are arranged in a toolbox as shown in Figure 8.



(a) (b)

Fig 8. (a) The developed blood pressure and body temperature monitoring.
(b) Display of measurement results on the smartphone.

The designed tool contains components for monitoring blood pressure and body temperature. The red push button functions as a start button to activate the sensor and turn on the pump so that it presses the cuff to measure blood pressure and body temperature. The reset button has a function to reset the tool to return to its original state, besides that the reset button also plays an important role when the tool experiences an error or doesn't work normally. The on/off switch on the device functions to turn on or stop the current and voltage flowing from the battery to the circuit. then the results of the measurements will be displayed on the smartphone through an application that has been made on the App Inventor.

B. Performance Specifications.

To check/to measure the performance specifications of the developed tool, the MPX5100DP pressure sensor is tested to see the results of the sensor output voltage and pressure, correlation of the sensor output voltage and pressure data can be seen in Figure 9.

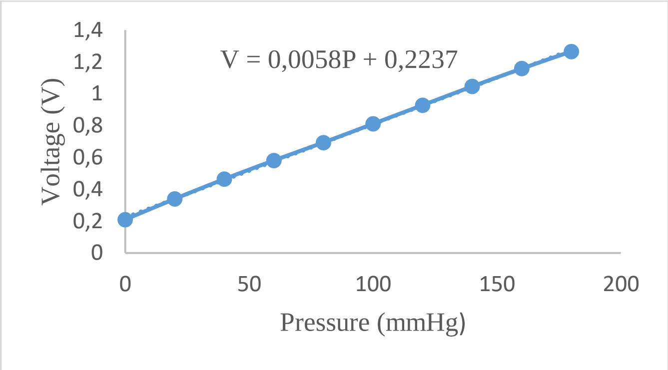


Fig 9. Graph of MPX5100DP sensor test results

Based on Figure 9, it can be seen the graph of the MPX5100DP sensor test results with Equation (1).

$$V = 0{,}0058P + 0{,}2237 \quad (1)$$

From Figure 8 and Equation 1 it can be seen that the pressure is directly proportional to the sensor output voltage, it is obtained that the greater the pressure applied, the sensor output voltage will also increase and vice versa.

Table 1. MPX5100DP sensor accuracy data

Experiment Order-	MPX5100DP Sensor (mmHg)	Pressure Gauge (mmHg)	%Accuracy
1	112,2	110	98,01
2	100,15	100	99,85
3	89,37	90	99,31
4	81,5	80	98,12
5	73,01	70	95,71
6	62,02	60	96,66
7	52,01	50	96,01
8	43,14	40	92,15
9	32,21	30	92,63
10	21,15	20	94,25
	Average		**96,26**

Table 1 shows the pressure value of the designed tool using the MPX5100DP sensor compare to standard pressure gauge. The measurement was carried out by experimenting with 10 variations of pressure measurement. It can be seen that the pressure value obtained on the standard pressure gauge is not much different from the designed tool using the MPX5100DP sensor. The average of accuracy, percentage is 96,26%. The minimum accuracy percentage is 92,15%, and maximum accuracy obtained is 99,85%. This show that the developed system have an excellent accuracy in mostly all data point of pressure.

Table 2. MPX5100DP sensor precision data

Measurement order-	Pressure (mmHg)	%Precision
1	26,45	85,29
2	30,49	98,32
3	29,65	95,61
4	32,17	96,25
5	31,33	98,96
6	27,13	87,48
7	30,49	98,32
8	35,53	85,42
9	32,17	96,25
10	34,69	88,13
Average	**31,01**	**93,01**

Table 2 shows that the data on the accuracy of the pressure measurement of the designed tool using the MPX5100DP sensor that was obtained by measuring the pressure repeatedly ten times simultaneously 3 seconds. The average of precision, percentage is 93,01%. The minimum precision percentage is 85,29%, the reason for the measurement percentage below 90% is due to the possibility of measurement errors and time calculation errors, then maximum precision obtained is 98,96%. This show that the developed system have an very good precision in mostly all data point of pressure.

Table 3. DS18B20 sensor accuracy data

Experiment order-	Sensor DS18B20 (℃)	Thermometer (℃)	% Accuracy
1	75,12	75	99,8
2	70,66	70	99,1
3	65,56	65	99,1
4	60,06	60	99,9
5	55,81	55	98,5
6	50,75	50	98,5
7	45,69	45	98,4
8	40,75	40	98,1
9	35,88	35	97,4
10	30,87	30	97,1
	Average		**98,61**

Table 3 is the data on the accuracy of temperature measurements on the designed tool obtained by comparing the temperature obtained by developed systems using DS18B20 sensor and standard Thermometer. The average of accuracy, percentage is 98,61%. The minimum accuracy percentage is 97,1%, and maximum accuracy obtained is 99,8%. This show that the developed system have an excellent accuracy in mostly all data point of pressure.

Table 4. DS18B20 sensor precision data

Measurement order-	DS18B20 (°C)	Precision (%)
1	30,81	99,86
2	30,75	99,94
3	30,75	99,94
4	30,81	99,86
5	30,75	99,94
6	30,75	99,94
7	30,81	99,86
8	30,75	99,94
9	30,75	99,94
10	30,75	99,94
Average	**30,77**	**99,91**

Table 4 shows the data on the accuracy of the temperature measuring instrument using the DS18B20 sensor obtained by measuring the temperature repeatedly ten times in the water with an average temperature of 30℃. Measurements made on the accuracy of the DS18B20 sensor were carried out with repeated measurements ten times in the same position. The average of precision, percentage is 99,91%, the precision of the DS18B20 sensor is almost towards perfect accuracy because the sensor is a digital sensor which already has a percentage of sensor default error is 0,5%, and minimum precision percentage is 99,86%, then the maximum precision obtained is 99,94%. This show that the developed system have an very good precision in mostly all data point of pressure.

The data on measuring blood pressure and body temperature using the MPX5100DP sensor and the DS18B20 sensor can be seen in Table 5.

Table 5. Data on the results of blood pressure measurements using the MPX5100DP sensor

Responden	Gender	Design Tool (mmHg)		Tensimeter digital Omicron B869 (mmHg)		Error (%)	
		Sistole	Diastole	Sistole	Diastole	Sistole	Diastole
1	P	117	83	116	82	0,87	1,22
2	L	121	80	128	80	5,47	0
3	L	144	89	141	86	2,13	3,48
4	L	126	69	127	71	0,78	2,81
5	L	153	80	139	83	10,07	3,61
6	L	137	86	141	86	2,83	0
7	L	142	89	139	83	2,15	7,22
8	L	128	84	125	80	2,4	5
9	L	142	89	139	84	2,15	5,95
10	L	133	86	132	83	0,75	3,61
		Average				**2,96**	**3,29**

Table 5 is blood pressure measurement data using a blood pressure device designed and standardized, data collection was carried out 10 times. The average result of the percentage of error, systolic is 2,96% and diastolic is 3,29%, the minimum percentage of errors from the systolic value is 0,75% and the maximum percentage of systolic errors is 10,07%. the minimum percentage of error from the diastolic value is 0% and the maximum percentage of diastolic error is 7,22%, the high maximum error in systolic and diastolic is caused by errors from measurements and also relative errors that occur in the MPX5100DP analog sensor in the measurement process.

[16] Systolic blood pressure is higher because it is the force generated by the heart muscle in the left chamber thick ones are useful for pushing blood towards whole body. While the heart muscle in the left porch not as thick as the left chamber because it only pumps blood between chambers in the heart so that the force is generated nor is it big. From the results that have been obtained from the percentage of errors, it can be concluded that the developed tool has a low percentage and can be used properly. The data on the results of body temperature measurements can be seen in Table 6.

Table 6. Data on body temperature measurements

Responden	Gender	Developed Tools (°C)	Thermometer (°C)	Error (%)
1	P	36,2	36	0,55
2	L	35,1	35	0,28
3	L	34,8	35	0,57
4	L	36,2	36	0,55
5	L	36,7	37	0,81
6	L	37,2	37	0,54
7	L	35,7	36	0,83
8	L	36,1	36	0,27
9	L	37,9	38	0,26
10	L	36,6	36	1,66
Average				**0,63**

Table 6 shows that blood pressure and body temperature data were measured on 2018 class physics students. Using designed tools and standard blood pressure and body temperature data were collected from 10 students who measured blood pressure and body temperature measuring devices. The average result of the percentage of error, percentage is 0,63%. The advantage of developing a body temperature measuring device compared to a thermometer is that the tool developed can display accurate results and is also more thorough compared to the results displayed from ordinary thermometers, this show that the developed system have an very good precision in mostly all data point of pressure.

The IoT-based blood pressure and body temperature monitoring device consisting of a series of MPX5100DP sensors and DS18B20 sensors, a series of LCD+I2C and WiFi modulees, a battery circuit as a pump and solenoid power supply, a series of IoT-based blood pressure and body temperature monitoring tools, making data storage, and making data display on smartphones. The results obtained from the design specifications that the performance of the tool can work excellently.

The results of the performance specifications of the first IoT-based blood pressure and body temperature monitoring tool are data on the effect of pressure on the sensor output voltage. A linear or proportional relationship is obtained from the sensor output voltage measurement data, where the more significant the pressure applied, the greater the output voltage on the sensor. The second data is the accuracy and precision of the MPX5100DP sensor and the DS18B20 sensor. The accuracy data is done by comparing the measurement results from the standard tool with the designed tool, so the accuracy for the MPX5100DP sensor is 96.26% and for the DS18B20 sensor is 98.61%. Furthermore, the precision data for the MPX5100DP sensor and the DS18B20 sensor are obtained from repeated measurements 10 times with the same position and circumstances so that the precision for the MPX5100DP sensor is 93.01% and the DS18B20 sensor is 99.91%. The following data is the measurement data of the accuracy of blood pressure and body temperature measuring devices. In the measurement of blood pressure and body temperature, which was carried out on 10 physics students, the measurement was carried out with two measurements, namely using a design tool and measuring using a standard tool, the percentage of error in the measurement of systolic blood pressure was 2.96%, diastolic blood pressure was 2.96%. 3.29%, and for the measurement of body temperature, the error percentage is 0.63%.

IV. CONCLUSION

Based on the results of the design of the IoT-based blood pressure and body temperature monitoring tool, it can be concluded that the results of the device design specifications consist of a series of MPX5100DP and DS18B20 sensors, a series of LCD+I2C and WiFi modulees, a battery circuit as a pump and solenoid power supply, a series of monitoring tools IoT-based blood pressure and body temperature creation of storage on ThingSpeak, and Making displays on smartphones/androids. The results of the performance specifications of the IoT-based blood pressure and body temperature monitoring tool consisting of the data for the accuracy of MPX5100DP and DS18B20 was 96.26% and 98.61%, respectively. The MPX5100DP and DS18B20 pressure sensor accuracy data obtained are 93.01% and 99.91%, respectively. Using a design tool with a Sphygmomanometer and Thermometer, the measurement data obtained a percentage of error, namely 2.96% systolic pressure, 3.29% diastole and 0.63% temperature. From the data obtained, it can be concluded that the tool can work well, referring to the standard error of blood pressure measurement, which is 3 mmHg.

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